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Developing Adaptive Management Tools for the Carmel River Floodplain Restoration and Environmental Enhancement Project

Publication No. WI-2016-12
12 December 2016

The Watershed Institute

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Acknowledgements

We are grateful for the assistance and collaboration of:

- Big Sur Land Trust (BSLT): Sarah Hardgrave, Jeff Powers, Patrick Riparetti, Rachel Saunders
- Monterey Peninsula Water Management District (MPWMD): Thomas Christensen

This report primarily represents graduate student work completed within the constraints of a fixed-duration (five-week), limited-verification college class setting.

Cite this report as:

CSUMB Class ENVS 660: Chow K, Fields J, Flores S, Hart K, Kleven A, Luna L, MacCarter L, and Burton R. 2016. Developing Adaptive Management Tools for the Carmel River Floodplain Restoration and Environmental Enhancement Project. The Watershed Institute, California State University Monterey Bay, Publication No. WI-2016-12, 58 pp.

Executive Summary

This report was a class project conducted by students in the Advanced Watershed Science and Policy (ENVS 660) course at California State University Monterey Bay (CSUMB). ENVS 660 partnered with the Big Sur Land Trust (BSLT) to plan for long term planting and management of the Tier 2 restoration of the Carmel River Floodplain Restoration and Environmental Enhancement (FREE) project, located within the lower Carmel River Watershed in Monterey County, California.

The main goals of the Carmel River FREE project are flood prevention and restoration of 92 acres of native floodplain and riparian habitat. The Carmel River FREE project will restore connectivity between the Carmel River main channel, the southern floodplain, and the Carmel River Lagoon by notching the levee in five locations, constructing a causeway under State Route 1 (SR 1), and grading the floodplain to promote flow to the south arm of the Carmel River Lagoon. Levee breaks will provide flood protection for residents living within the 100-year flood zone.

Tier 2 of the Carmel River FREE project involves restoring 77 acres east of SR 1 to native habitat and establishing a 23-acre agricultural preserve. Our goal was to create adaptive management tools that will enable BSLT to model depth to groundwater (DTGW) for the Tier 2 project site, determine planting zones, and design a planting and irrigation schedule. We also provide recommendations of monitoring protocols that will enable BSLT to monitor changes in the site over time and evaluate effectiveness or their restoration strategies.

In developing a suitable model for estimating DTGW we used water surface elevation (WSE) data from groundwater monitoring wells to approximate depth to groundwater across the project site. Data from the groundwater monitoring wells was spatially and temporally limited, which constrained the DTGW model. The data available for the three wells within the project boundary were collected from 2014-2016, during which the maximum water right (124 acre-feet per year (afy)) was pumped from the property (West Yost Assoc. 2013). We encourage BSLT to continue to expand local groundwater monitoring to improve estimates of DTGW for adaptive management purposes.

To calculate DTGW we interpolated WSE across the proposed planting area using a Kriging model and subtracted WSE from the grading plan elevations. Estimated WSE was stable during wet months and variable during dry months. DTGW during the wet season (Jan – Mar) had the greatest area of shallow groundwater compared to the dry season (Oct – Dec). Most change in DTGW between seasons occurred in the eastern section of the project site where the ground surface elevation was greatest for all seasons.

We designed multiple planting plans based on depth to groundwater for the driest groundwater conditions on record, average dry season conditions, and wet conditions. Planting zones included willow and cottonwood riparian forest, mixed riparian forest, upland habitat, maintained flood conveyance areas (MFCAs: native grasses, sedges, rushes), and an agricultural preserve. The perimeters of each zone will likely shift as additional groundwater data become available.

We calculated the evapotranspiration (ET) for each plant community to determine the minimum amount of water required for irrigation. We used the U.S Department of Food and Agriculture standard equation for estimating ET and calculated the monthly average reference ET from available local meteorological data. We determined factors that affect the rate of transpiration for each plant community and derived zone specific ET factors. Riparian zones have the highest evapotranspirative loss at 40 in (3.4 afy/ac). Grasslands have the lowest ET loss at 12.3 in (1.2 afy/ac). The volume of loss from ET is a function of species composition and planting zone area. We used ET to determine the monthly Estimated Total Water Use (ETWU) for each planting zone using the Model Water Efficient Landscape Ordinance (Cal code of regs. 2009).

Supplemental irrigation is needed when effective precipitation is lower than the estimated total water use (ETWU); consequently irrigation is not necessarily needed during winter months (Oct- Feb), assuming normal rainfall. We determined the monthly and annual volume of supplemental irrigation required for each planting zone for low, average, and high precipitation years. The first three years of irrigation are the most critical for riparian communities to allow time for their roots to reach the groundwater table. Irrigation can be tapered off after three to five years depending on specific plant needs. In general, total irrigation time will vary depending on depth to groundwater, precipitation, soil types, and species-specific root growth rates.

We also created the Adaptive Management Irrigation Schedule Tool (AMIST) in Excel to inform the development of planting schedules based upon water needs for each planting zone. AMIST incorporates the water requirements for each planting zone and annual effective precipitation to determine the total irrigation required for each planting phase. We developed a tentative planting schedule that adheres to the current water allocation of 28 afy. The implementation plan to restore 77 acres would take approximately 15 years for planting zones based on below average estimated depth to groundwater and average annual precipitation.

We recommended strategies for monitoring planting zones, exotic species and invasive weeds, and natural recruitment. These strategies can be adapted as the restoration proceeds to identify changes in species abundance, cover, and richness over time.

Recommended monitoring methods include: the California Rapid Assessment Method (CRAM), point intercept transects, relevé plots, and photo monitoring. We proved recommended locations for test plots that can be monitored to determine optimal plant densities, species compositions, growth rates, survivorship, and irrigation schedules for each planting zone. This paired plot system will also allow for manipulation of experimental plots alongside paired control plots; which can be used to identify factors that exert the greatest influence on restoration success. Annual monitoring data can be used to evaluate progress and inform adaptive management for future plant phasing and irrigation strategies.

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1 Introduction

1.1 Background

1.1.1 Carmel River Floodplain Restoration and Environmental Enhancement Project

The Big Sur Land Trust (BSLT) partnered with the Advanced Watershed Science Class (ENVS 660) at California State University Monterey Bay to plan for long term management of the habitat restoration component of the Carmel River Floodplain Restoration and Environmental Enhancement (FREE) project. Specifically, BSLT requested assistance with developing tools to analyze groundwater data, create a planting plan, develop an irrigation schedule based on evapotranspirative loss, and monitor progress for Tier 2 of the project.

The Carmel River FREE project has multiple benefits. The project will provide flood protection for Monterey Community Service Area 50 (CSA-50) and restore connectivity between the Carmel River main channel, the southern floodplain, and the Carmel River Lagoon. The Carmel River FREE project will achieve this in part by removing sections of the levee, by constructing a causeway under State Route 1 (SR 1), and contour grading of the floodplain area to facilitate flows sufficient to dissipate 5 year or greater storm events across the floodplain (Balance Hydrologics, Inc 2015). The primary driving factors for the Carmel River FREE project are flood prevention and restoration of 92 acres of native floodplain and riparian habitat.

1.1.2 Project Area

The Carmel River FREE project is located within the lower Carmel River Watershed in Monterey County, California (Fig. 1). The project area to the west and east of SR 1 are referred to as Odello West and Odello East, respectively. This study focused on the Odello East property, which is bounded to the north and south by the Carmel River and Palo Corona Regional Park, respectively. Soils within the project site are predominantly coarse with moderate infiltration, characterized by hydrologic soil type B (Fig. 2, SSURGO). Pre-project land cover conditions were an open mosaic of exotic plants and annual grasslands, stocked with cattle for the last three years (Fig. 3).

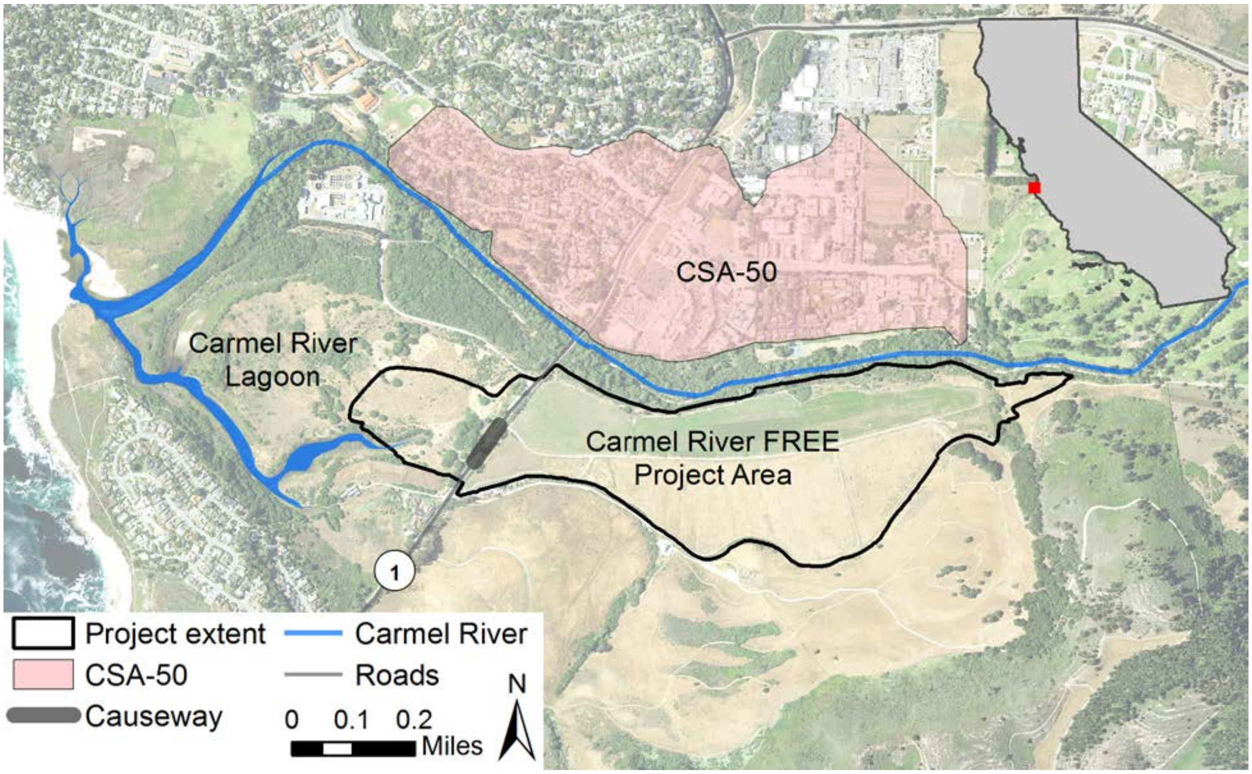

Figure 1. Carmel River FREE project area, Monterey County, California. CSA-50 businesses and residents will benefit from improved flood conveyance.

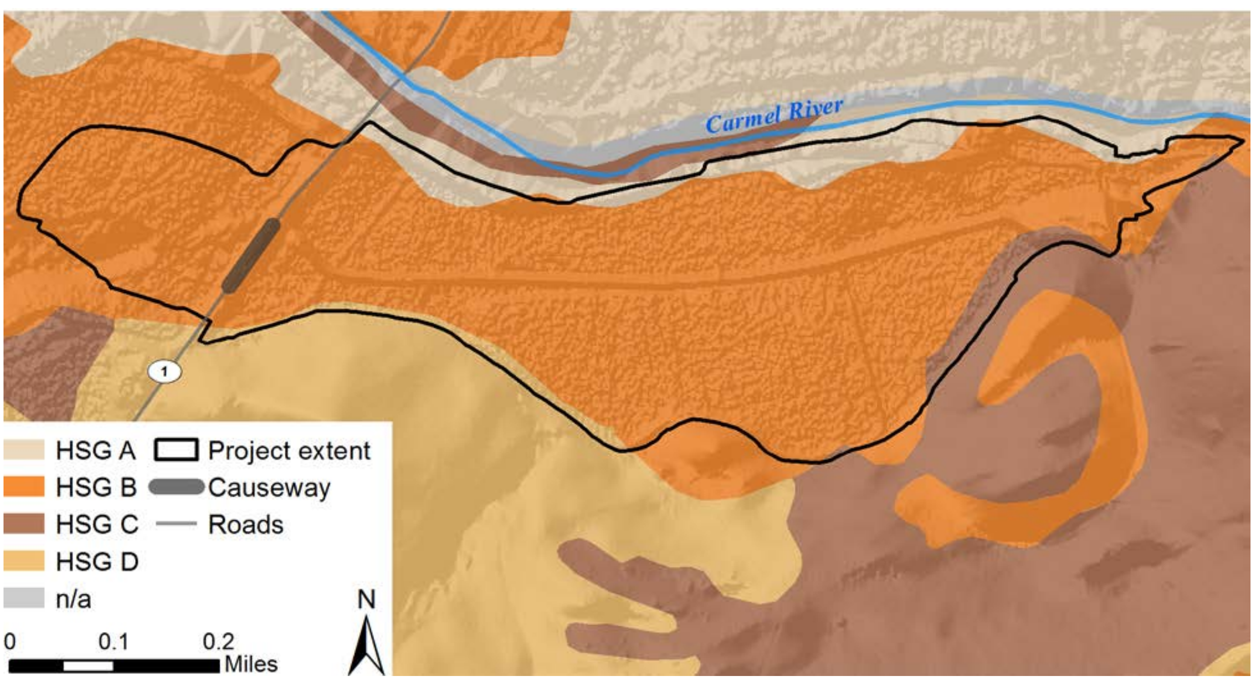

Figure 2. Hydrologic soil groups for the Carmel River FREE project (CCRWQCB 2016).

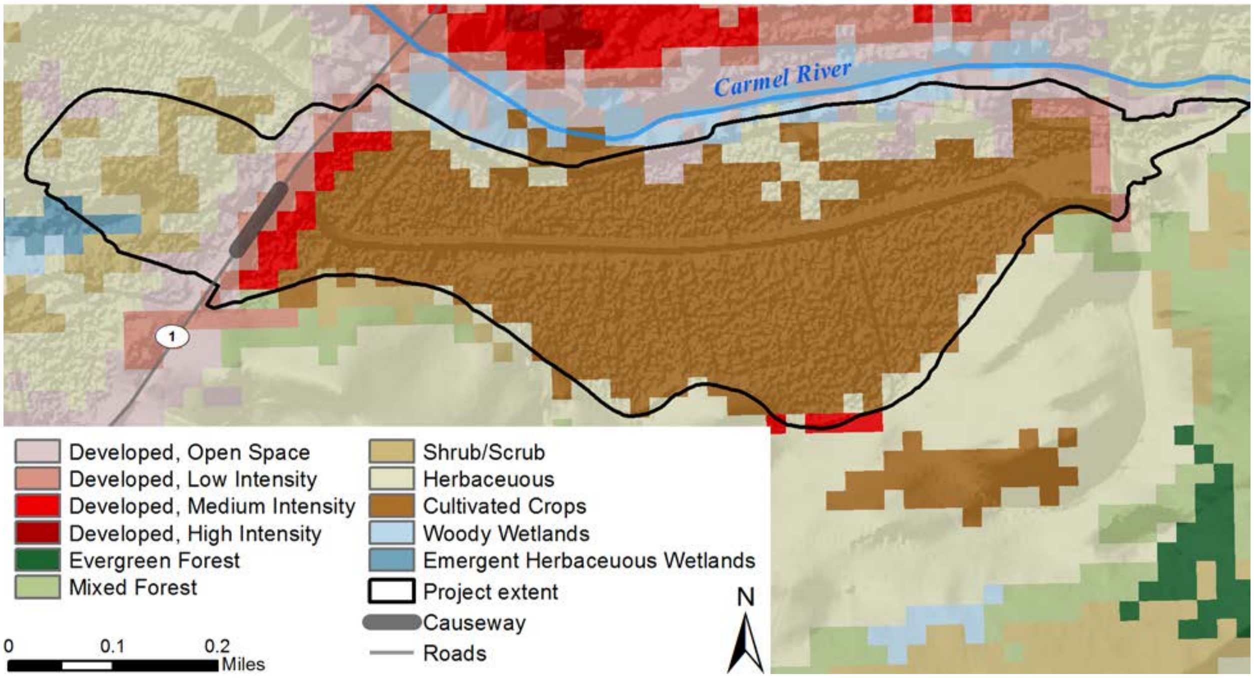

Figure 3. Land use and land cover for the Carmel River FREE project (USGS 2011).

1.1.3 Carmel River FREE Project Objectives

The main objectives of the Carmel River FREE Project Restoration and Management Plan (HT Harvey & Assoc. 2015) are to:

- Recover natural functions that were historically present along the floodplain prior to engineered modification of the river channel through hydraulic reconnection of the southern floodplain to the main channel of the Carmel River.
- Establish vegetation typical of river corridor environments and centered around a dense, diverse riparian habitat.
- Restore approximately 92 acres of riparian and upland area within the historic floodplain to provide habitat for sensitive species, including the federally listed California red-legged frog (*Rana draytonii*).
- Establish and sustain Maintained Flow Conveyance Areas (MFCAs) between the main channel and southern floodplain to reduce flooding hazards in developed areas north of the Carmel River.
- Increase flow conveyance and habitat connectivity between the project site and the south arm of the Carmel River Lagoon (CRL), benefiting the federally listed Central California Coast Steelhead (*Oncorhynchus mykiss*).
- Promote groundwater storage and recharge beneath the restored floodplain.

1.1.4 Carmel River FREE Project Components

The Carmel River FREE project is divided into two components, Tier 1 and Tier 2 (Fig. 4). Tier 1 involves construction of a causeway under SR 1 and implementation of compensatory mitigation for 16 acres. Tier 1 is largely located within the CRL area immediately west of SR 1, with a smaller section located within the western portion of the Odello East property. H.T. Harvey & Associates developed a Restoration and Management Plan that described Tier 1 in detail (HT Harvey & Assoc. 2015). Tier 2 involves restoration of 77.1 acres, west of SR 1, to native habitat and establishment of a 23-acre agricultural preserve. The focus of this planning effort was to develop tools to model depth to groundwater for the project site, in order to inform planting plan design for Tier 2 that reflects variations in groundwater depth across the project site.

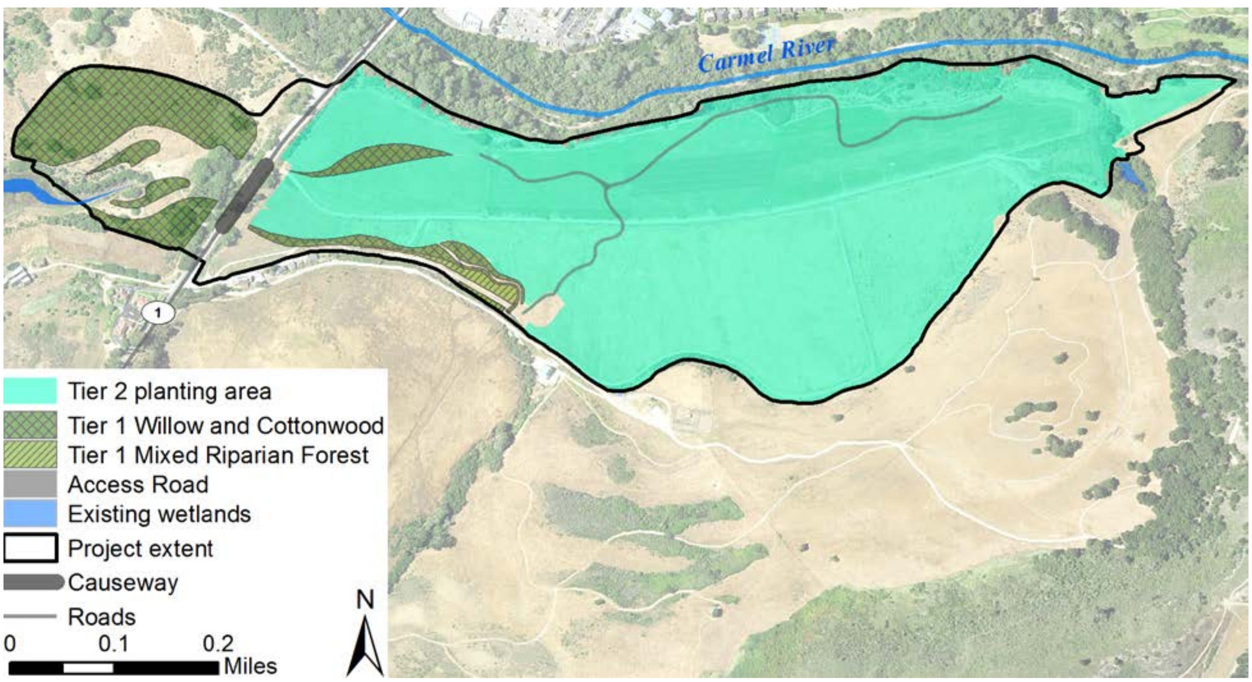

Figure 4. Tier 1 and Tier 2 project areas for the Carmel River FREE project, Monterey County, CA.

1.2 Lower Carmel River History

1.2.1 History of Local Water Rights

Water is an extremely valuable and contested resource throughout California and the western United States. California water law recognizes the oldest rights with the most generous allotment of water. The laws dictate who can divert water, what the water is used for, how much can be used, and under what terms.

Water is an important topic in the Carmel River Watershed because it is a limited resource with high demand and a large number of stakeholders. Water diversions affect the stability of critical habitats for several special status species that live in the Carmel River Watershed (Carmel River Watershed Conservancy 2004, NMFS 2013). The California American Water Company (Cal-Am) currently diverts water from the Carmel River to provide water for residents on the Monterey Peninsula. Cal-Am's legal right to pump water from the Carmel River is 3,376 acre-feet per year (afy); however, they pumped 11,285 afy in 1997 and will likely continue to pump around 8,310 afy until 2021 when the State Water Resource's Cease and Desist Order takes effect (SWRCB 2015).

The water use regime in the lower Carmel River watershed may change in the near future. The Rancho Canada Golf Course was located immediately upstream of the Carmel River FREE project. The property was sold in 2016 with the expectation to repurpose the area as a natural park and permanently allocate 175 -190 afy of the property's water right to the Carmel River. In addition, the Trust for Public Lands secured an interim water use forbearance of 300 afy through 2009 (Sutton 2016). Reallocation of water use has the potential to alter groundwater and Carmel River flow conditions.

The first water rights on record for the Carmel River FREE project area were claimed for Rancho Los Laureles in 1876 (MPWMD). The Odello brothers diverted water from the Carmel River to irrigate their 175-acre artichoke farm. Later, the Eastwoods held a water right to 124 afy for the Odello East property (West Yost Assoc. 2013). The BLST currently has a consumptive water use allowance of 28 afy for the project site. Subsequently water for restoration will be a limiting factor for the Carmel River FREE project. Creating an adaptive and detailed water budget will be a useful tool to ensure that the BSLT does not exceed their water allowance.

1.2.2 Land Use History

The Odello family owned the Carmel River FREE project site, "Odello East," from the 1920s to 1994 and primarily used the land to farm artichokes. The property was protected from Carmel River flood events by a south bank levee. Following the 1995 flood, a small notch was put in the south bank levee by Monterey County Resource Management Agency to alleviate flooding of north bank commercial and residential areas (Odello Brothers vs. County of Monterey 1998). As a result, less damage occurred in CSA-50 during the 1998 flood event.

Clinton and Margaret Eastwood purchased 134 acres of the former Odello agriculture fields in 1995 and have since donated the land to the BSLT for long-term management. The property was transferred in two transactions: the first took place in 1997 and included 49 acres; the second transfer was completed in 2016 for the remaining 79 acres (Conrad 2016). The project area is currently owned by three entities: BSLT, California Department of Parks and Recreation (CDPR), and Monterey Peninsula Regional Park District (MPRPD).

The Carmel River Steelhead Association completed the Carmel River Lagoon Enhancement (CRLE) Plan in 1992 (Philip Williams and Assoc. 1992). CDPR implemented the first phase of the CRLE project in 2004. Phase 1 included extending and deepening the Carmel River Lagoon South Arm and restoring wetland habitat west of SR 1. The Carmel River FREE project will initiate the second phase of a larger effort by reconnecting the east and west areas of the floodplain under SR 1.

1.2.3 Hydrologic History in the Lower Carmel River

The lower Carmel River has a history of flooding due to the relatively low and flat topography of the surrounding area. The typical 100-year flood for the lower Carmel River was estimated to be 29,100 cfs, 28,160 cfs, and 22,700 cfs in 1991, 2002, and 2009 respectively (Balance Hydrologics, Inc 2014). However, extensive damage to businesses and residences can occur at much lower discharges.

In 1995, the Carmel River reached a peak flow of 16,000 cfs and the lower watershed flooded. Most damage occurred in CSA-50, north of the Carmel River FREE project site. CSA-50 is located within the Carmel River 100-year floodplain and includes Mission Fields, Crossroads, Arroyo Carmel, and Riverwood properties. The 1995 flood event damaged the SR 1 bridge near Carmel to the extent that the bridge was immediately closed and rebuilt. This flood event also damaged 220 residences, and forced evacuation of residents in the Mission Fields area (Balance Hydrologics, Inc 2014).

Changes in topography and land cover affect the hydrology of the lower Carmel River and could result in increased or decreased flooding hazard. Development of open areas in the lower Carmel River has created impervious areas, which further increase flood risk (Konrad 2003). One such instance within the Carmel River Watershed is the area near Schulte Bridge. Around 1950, the riverbanks were relatively stable and floodplains developed. By the 1960s, groundwater extraction and drought destabilized the streambanks and degraded the surrounding riparian vegetation resulting in devastating floods a decade later that put habitat, residences, and native species at risk (MPWMD 2015).

The Monterey Peninsula Water Management District (MPWMD) responded to the eminent flood risk with the Schulte Restoration Project, which involved grading the channel topography to a stable geometry, stabilizing the area with riparian species, and enhancing aquatic habitat (MPWMD 2015). The significance of this project is that they successfully stabilized the banks with riparian vegetation, rather than armoring with fabric or boulders, providing habitat to native species. This highlights the importance of riparian floodplain restoration projects in the Carmel River Watershed that reestablish riparian corridors and enable flow across historic floodplains to reduce the risk of flooding (CREP n.d.).

1.3 Riparian Restoration

1.3.1 Importance of Riparian Habitat and Diversity

Riparian corridors improve habitat for aquatic species such as the federally threatened south central coast steelhead; they increase food availability, raise primary production, improve water quality, and provide shade that moderates water temperatures (Knight and Bottorff 1981). Riparian plants also enhance soil fertility and local biomass (Reich *et al.* 2012).

Riparian habitat in central California is composed mainly of trees such as willows and cottonwoods. However, herbaceous understories also benefit the local ecosystem by providing bank stability, nutrient processing, and wildlife habitat. Understory vegetation complexity also contributes to biodiversity, thus increasing community resilience and adaptability to disturbances (Viers *et al.* 2011). The extent of riparian habitats has been significantly reduced throughout the central coast and California in general because of anthropogenic encroachment into floodplains and adjacent river areas, and modification of natural river flow patterns. More recent understanding of the ecological and hydrological value of riparian habitats and the number of species recognized as threatened or endangered due to the alteration of riparian habitats emphasizes the urgent need for riparian restoration projects (NAP 2002).

1.3.2 Local Riparian Restoration Strategies

We investigated techniques and strategies for the Carmel River FREE project's goals that were implemented in other riparian restoration projects. We evaluated five projects near the coast, ranging from Big Sur to Watsonville, California (Table 1). Three restoration projects were located in the Carmel River watershed (CRW) and two additional sites were in the Big Sur and Carneros Creek watersheds.

The active phase of the Big Sur River Riparian Restoration Project occurred between 1995 – 1998. Restoration included planting trees and shrubs in Creamery Meadows in

Table 1. Central California coast riparian restoration strategies.

Project	Location	Timeline	Acres	Planting density	Years irrigated	Source
Creamery Meadows	Andrew Molera State Park, Big Sur, CA	1995-1998	69	~83 trees & shrubs/ acre, in a ratio of 70:30	1 to 3	Shihadeh & Founds 2008
ALBA, Carneros Creek floodplain	Watsonville, CA	Completed 2013	40	1250 grasses & rushes/ acre	None	ECI 2016
Schulte Road Songbird Preserve	Carmel River Watershed	1987-present	25	1000's of willow and cottonwood cuttings	Ongoing	MPWMD 2015
CalTrans CRB, Carmel River Lagoon	Carmel River State Beach, Carmel, CA	1996-1998	43	Unknown	Ongoing	USDoT 1998
CRLEP, Carmel River Lagoon	Carmel River State Beach, Carmel, CA	2004-2007	100	Riparian: 824 plants/ acre; Upland: 1428	3	CDPR 2009

Andrew Molera State Park. The 69-acre restoration site was irrigated for the first three years of the restoration effort to encourage root growth and establishment (Shihadeh and Founds 2008).

The Carneros Creek riparian corridor was restored as a component of the larger Agriculture and Land Based Training Association (ALBA) Wetlands Restoration Project. Forty acres of Triple M Ranch farmland located in the historic floodplain of Carneros Creek were planted with grasses and rushes, and seeded to rehabilitate wetland and riparian habitats. The site was left to naturally reestablish once active restoration efforts were completed in March 2013 (ECI 2016). This project differed from others mentioned since most of the plantings were herbaceous species; the Carneros Creek floodplain is a good example of how to plant MFCAs in the Carmel River FREE project.

The Schulte Road Restoration Project was one of the initial riparian restoration projects to occur in the CRW. Work began on the 25-acre site, known as the BSLT's Songbird Preserve, in 1987 by MPWMD. Prior to restoration, the site had been denuded of most riparian-associated vegetation, resulting in an open, unshaded river channel. Restoration involved willow cutting installations, native plantings, and drip irrigation (MPWMD 2015).

The California Department of Transportation (CalTrans) Carmel River Mitigation Bank (CRB) is a 43-acre restoration project in the Carmel River Lagoon led and funded by CalTrans in partnership with CDPR. Efforts to restore the historic floodplain began in 1996, following a 1995 bridge failure, and included levee removal, planting riparian and wetland species, invasive plant and animal abatement, and routine irrigation (USDOT 1998).

The Carmel River Lagoon Enhancement Project (CRLE) is a 100-acre restoration site located south of the CRMB property. CRLE continued conversion of historic lower Carmel River agriculture lands to wetland and riparian habitats. Restoration began in 2005 and included planting native wetland, upland, and riparian species as well as weed abatement. The site was irrigated for a minimum of three years beginning in 2006 (CDPR 2009). Components of these restorations were selected and adapted to the specific goals of the Carmel River FREE project.

2 Project Goals

The goal of this report was to provide a toolset, which resource managers can use to develop a water budget and planting plan, based on groundwater levels, and to determine irrigation needs for the Tier 2 restoration area of the Carmel River FREE Project. These tools can be used for adaptive management as the project develops. We accomplished this by:

- Estimating depth to groundwater for the project area (Section 4).
- Recommending planting zones based on water needs and depth to groundwater (Section 5).
- Determining irrigation requirements for each planting zone (Section 6).
- Recommending a strategy for implementation and management of the planting zones (Section 7).
- Recommending monitoring strategies that will inform adaptive management and quantify restoration success rates (Section 8).

This report will assist BSLT in determining plant community type and spatial distribution of planting phases. We created the Adaptive Management Irrigation Scheduling Tool (AMIST) to help resource managers explore irrigation needs based on plant community type and water availability. The tool will assist BSLT with future planning once water rights and budgets are finalized.

3 Available Data

3.1 Spatial Data

We obtained spatial data from:

- Big Sur Land Trust:
  - Restoration and Management Plan project design Geographic Information System (GIS) shapefiles (HT Harvey & Assoc. 2015)
  - Project GIS shapefiles including: well locations, causeway, existing habitats, and proposed trails (DD&A 2016).
- Balance Hydrologics, Inc/ Whitson Engineers:
  - CRFREE 1m grading contours, NAD 1983 State Plane California IV FIPS 0404 feet, NAVD 88
- USDA: NRCS Geospatial Data Gateway (NRCS 2016a):
  - USDA-FSA-APFO 2014 NAIP MrSID Mosaic, 1m: aerial imagery raster for Monterey County, USDA/FSA - Aerial Photography Field Office
  - Monterey County land cover raster, 30m, US Geological Survey National Land Cover Database (USGS 2011)
- Central Coast Post-Construction Stormwater Requirements from the Central Coast Regional Water Quality Control Board (CCRWQCB 2016):
  - SSURGO data mosaic for the California Central Coast, Hydrologic Soil Groups (HSG) vector
- United States Geological Survey National Elevation Database (USGS 2016):
  - 2012 National Elevation Dataset, 3m, 1/9 arc-second tiles

3.2 Hydrologic Data

We obtained Daily Mean Water Surface Elevations (ft) in NAVD 88 from Balance Hydrologics for 14 monitoring wells in the vicinity of the Carmel River FREE Project (Table 2). WSE records for wells on the Carmel River FREE project site were markedly limited. The data were temporally limited, ranging from 2012-06-28 to 2016-11-02. The data were also spatially limited; most monitoring wells were concentrated west of SR 1. Monitoring wells located within the Tier 2 project boundary (OE-inactive, MW-A, MW-B) only had a short record of WSE.

Table 2. Groundwater monitoring wells (MW) for which water surface elevation (WSE) data were available including date ranges and well locations (data source: Balance Hydrologics, Inc).

Well	WSE Date Range	Latitude	Longitude
MW-1	6/28/12 - 11/2/16	N 36° 32' 08.9496"	W 121° 54' 59.8427"
MW-2	6/28/12 - 11/2/16	N 36° 32' 07.2148"	W 121° 55' 14.9058"
MW-3a	6/28/12 - 11/2/16	N 36° 32' 12.7380"	W 121° 55' 12.3800"
MW-3b	6/28/12 - 11/2/16	N 36° 32' 12.6730"	W 121° 55' 12.2059"
MW-3c	6/28/12 - 5/24/14 2/6/15 - 11/2/16	N 36° 32' 12.5969"	W 121° 55' 12.0805"
MW-4	6/28/12 - 11/2/16	N 36° 32' 13.0566"	W 121° 55' 15.9229"
MW-A	3/18/15 - 11/2/16	N 36° 31' 58.4800"	W 121° 54' 42.2300"
MW-B	1/20/14 - 3/12/15 3/18/15 - 11/2/16	N 36° 31' 55.1300"	W 121° 54' 14.6900"
OE-inactive	2/5/15 - 11/8/15	N 36° 32' 8.5400"	W 121° 54' 05.7500"
Rio Rd	2/5/15 - 11/2/16	N 36° 32' 18.2200"	W 121°54' 11.7500'
State Parks	2/5/15 - 11/2/16	N 36° 32' 18.6400"	W 121° 55' 01.9300"
CAWD Dewater	4/3/15 - 11/2/16	N 36° 32' 24.0000"	W 121° 55' 07.4000"
CR Lagoon	6/28/12 - 10/20/16		

4 Groundwater Analysis

4.1 Ground Surface Elevation

We interpreted the Carmel River FREE project topography to determine the depth to groundwater subsequent to future grading. We predicted ground surface elevation (GSE) across the project site using grading contours produced by Whitson Engineers. In ArcGIS, we converted contours from polylines to raster, then generated random points within the raster and extracted surface elevations (ESRI 2016). We used a Kriging model to interpolate those points with surface elevation. Kriging is a geostatistical modeling tool available for use in ESRI ArcGIS software that uses statistical models to estimate values between points to create a continuous surface. A greater number of points for the Kriging tool results in better performing models that more accurately depict reality. Figure 5 shows the output of the Kriging model that predicted ground surface elevation throughout the project site. The model did a sufficient job estimating future topography of the project site, which we then used to determine depth to groundwater (DTGW).

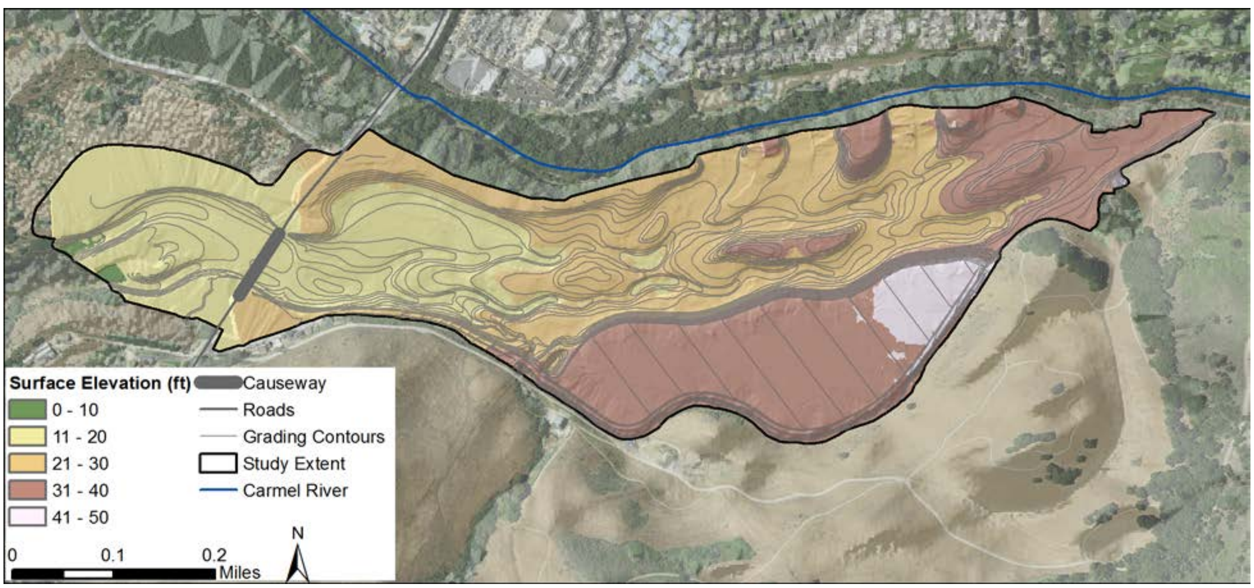

Figure 5. Future ground surface elevation (ft) for the Carmel River FREE project site based on anticipated grading contours (data source: Whitson Engineers).

4.2 Water Surface Elevation

We used water surface elevation (WSE) data to approximate DTGW. We estimated WSE in proposed planting areas via Kriging of WSE measurements from 13 wells in the vicinity of the Carmel River FREE project site that were provided by Balance Hydrologics, Inc (Fig. 6). We analyzed groundwater depth to determine WSE for seasonal averages and the best and worst conditions from recent records. To obtain seasonal WSE, we took the average of specific months for all years when monitoring well data overlapped (Table 3). We compensated for limited spatial extent of well data by creating a synthetic point in the eastern section of the project site, which allowed the WSE model to cover the entire proposed planting area. We assigned the artificial point a WSE value based on interpretation of our initial Kriging model, then modified the model to include the artificial point. Estimated WSE was stable during wet months and variable during dry months (Fig. 7).

We calculated WSE with data that was recorded when maximum pumping (124 afy) was occurring at the project site (West Yost Assoc. 2013). It is expected that future WSE will be higher with the cessation of maximum extraction of the former property water right and as ground water responds to reduced upstream pumping by Cal-Am.

Table 3. Ground surface elevation (GSE) and average seasonal water surface elevation (WSE) for 13 wells in the vicinity of the Carmel River FREE project site (all values are feet NAVD88; data source: Balance Hydrologics, Inc).

Well	GSE (ft)		Bedrock Elevation (ft)	WSE (ft)					
	Current	After Grading		Summer Avg. (July – Sept)	Fall Avg. (Oct – Dec)	Winter Avg. (Jan – Mar)	Spring Avg. (Apr – June)	"Extreme Dry Conditions" (11/2/2014)	"Extreme Wet Conditions" (3/1/2016)
MW-1	16.7		-72.3	7.3	7.6	9.2	9.0	6.7	9.0
MW-2	13.2		-140.8	6.5	7.5	8.6	8.6	6.9	7.9
MW-3a	13.4			6.7	7.6	8.9	8.5	6.9	8.2
MW-3b	13.3			6.7	7.5	8.9	8.7	6.6	8.4
MW-3c	13.6			7.0	7.8	8.9	9.0		8.4
MW-4	12.9			6.5	7.5	8.7	8.5	6.7	8.1
MW-A	23.7	24	7.2	11.1	10.8	12.9	11.9		12.1
MW-B	30.7	39	3.2	10.3	9.4	11.4	11.4	6.6	13.2
OE-inactive	31.7	31	-93.3	15.3	7.3	16.6	15.7		
Rio Rd	28.6		-130.4	15.6	14.5	16.5	16.7		17.0
State Parks	17.8		-112.2	8.7	9.3	10.1	10.2		9.5
CAWD Dewater	17.9			7.0	8.3	9.3	9.2		8.0
CR Lagoon	8.2			6.2	7.3	8.0	8.2	7.1	5.8

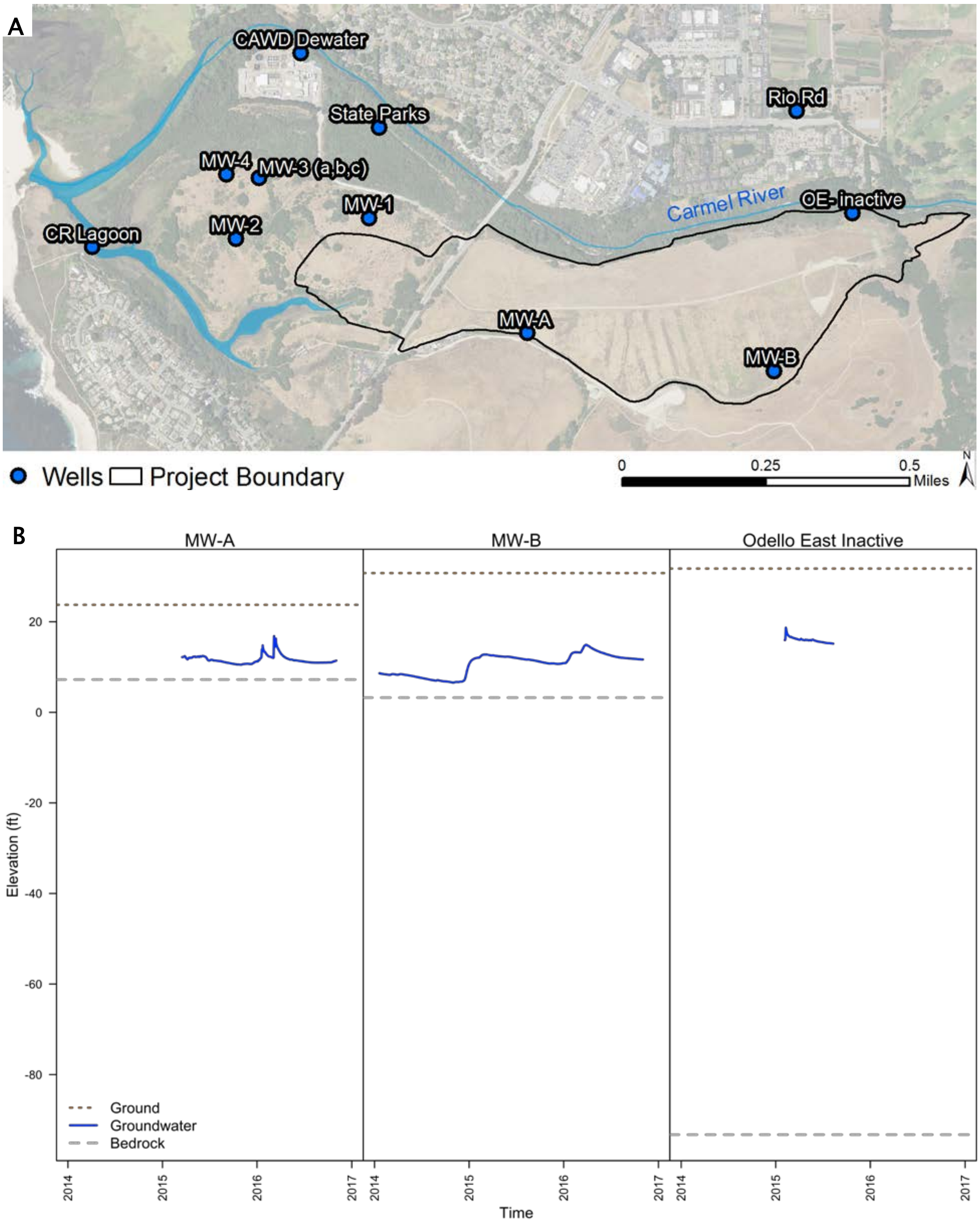

Figure 6. (A) locations of groundwater monitoring wells in the Carmel River FREE project vicinity and (B) available ground surface, water surface, and bedrock elevation data (ft) for wells located within the project boundary (NAVD88; data source: Balance Hydrologics, Inc).

4.3 Depth to Groundwater

We estimated DTGW in order to design a planting plan suitable for seasonal water table conditions. We subtracted WSE from GSE to determine future DTGW across the project site for every season as well as the best and worst conditions recorded for water surface elevation (Fig. 7).

There were noticeable changes in DTGW spatially and temporally. DTGW during the wet months (Jan – Mar) had the greatest area of shallow groundwater compared to the dry months (Oct – Dec). Most of the variation in DTGW between seasons occurred in the eastern section of the project site where GSE elevation was greatest. Overall the general trend of DTGW was that as conditions become dryer, shallow groundwater begins to recede west, leaving areas of deeper groundwater in the eastern extent of the site.

A limitation on our analysis resulted from the sparse number of wells in the project site and insufficient data from the inactive Odello East well. The accuracy of the DTGW model would be expected to increase with the future inclusion of data from additional monitoring wells on the property. Additionally, the lack of historical data from all wells, particularly the inactive Odello East well, limited the accuracy of estimates of the true driest conditions for each well.

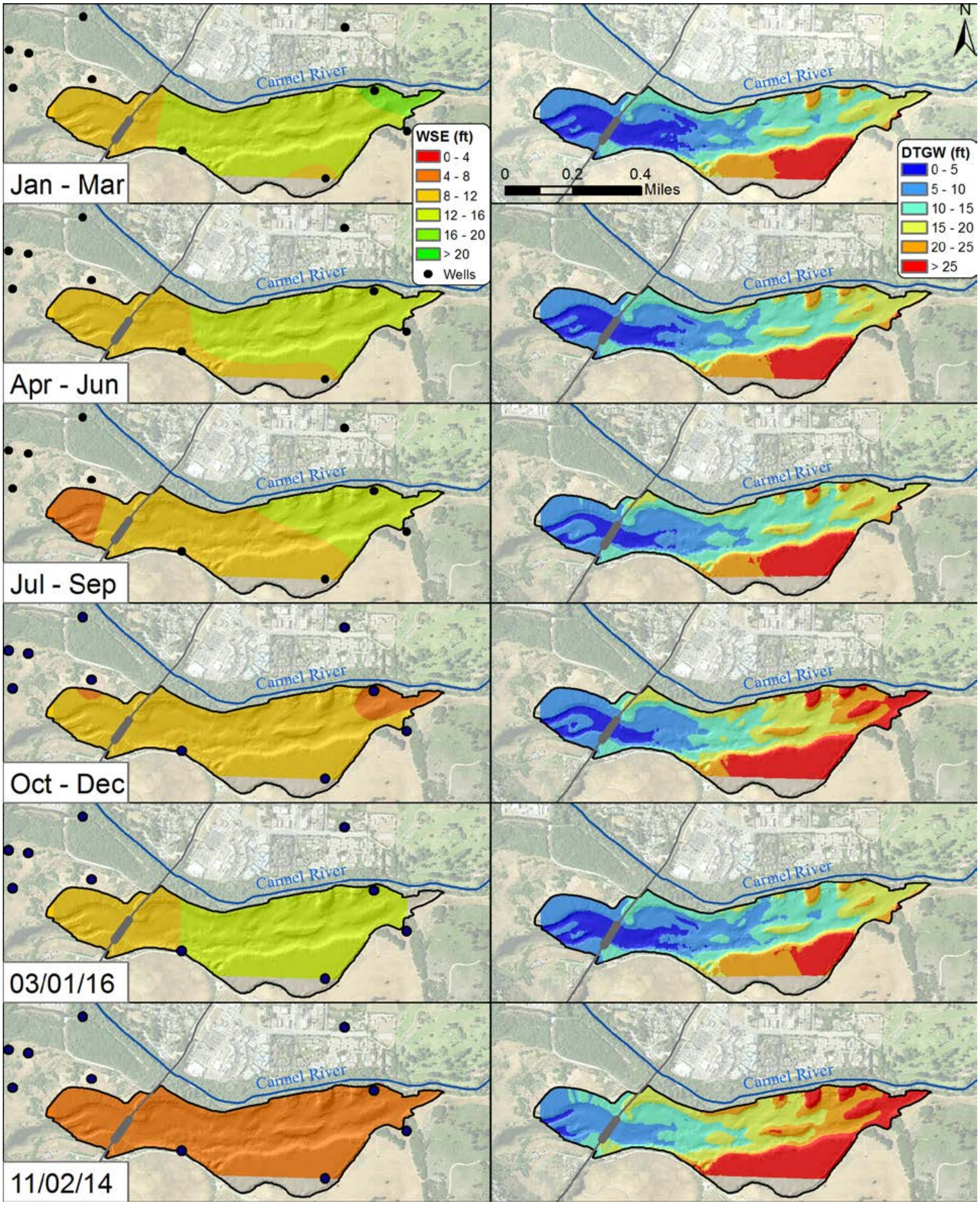

Figure 7. Future depth to groundwater (DTGW) for the Carmel River FREE project site based on interpolated water surface elevation (WSE) and grading contours. Seasonal WSE was averaged from wells with variable time frames ranging from 2012-2016.

5 Planting Plan

5.1 Riparian Vegetation Objectives

The BSLT identified the following objectives for Tier 2 floodplain restoration of the Carmel River FREE Project site:

- Retained levees will function as "topographic islands"; vegetation on retained levees must provide refuge for wildlife and erosion control during flood events (Balance Hydrologics, Inc 2015).
- Plantings must provide a dense, diverse riparian habitat (HT Harvey & Assoc. 2015).

The main project constraint was that levee breaks and floodplain channel MFCAs must be planted with grasses that do not impact the roughness coefficient and maintained to allow direct river access through the floodplain during storm events (Balance Hydrologics, Inc 2015).

5.2 Planting Plan Methodology

5.2.1 Determining Plant Palettes

We referenced planting methodology from the Carmel River FREE Restoration and Management Report, the Carmel River Lagoon Enhancement Project, and the Carmel River Watershed Stewardship Manual to compile a list of suitable plants for palustrine riparian restoration at the Carmel River FREE project site (HT Harvey & Assoc. 2015, Hubert *et al.* 2003, RCDMC 2013). We researched species-specific growth requirements such as soil moisture tolerance, soil type, maximum root depth, and summer water needs (Stone and Kalisz 1991). We then grouped species with similar resource requirements into willow and cottonwood riparian forest, mixed riparian forest, upland habitat, and MFCA (native grasses, sedges, rushes) plant communities.

The following sources were utilized to identify species-specific requirements:

- California Native Plant Society - Calscape (CNPS 2016).
- USDA National Resource Conservation Service - PLANTS database (NRCS 2016b).
- USDA - Forest Service Fire Effects Information System (FEIS) Species Reviews (USDA 2016).
- Forest Ecology and Management - On the maximum extent of tree roots (Stone and Kalisz 1991).

We developed a list of species we expect would establish if planted and others that may naturally recruit (Table 4). We recommend planting as diverse a plant palette as possible to develop the native seed bank and to increase resilience in the event of unpredicted changes in climate, DTGW, and irrigation.

Table 4. Plants suitable for riparian restoration in the Lower Carmel River Watershed. An asterisk (*) indicates that the species was listed in the Restoration and Management Plan (HT Harvey & Assoc. 2015).

Type	Common name	Scientific name	Type	Common name	Scientific name
Grass	CA brome*	*Bromus carinatus*	Shrub	California sagebrush	*Artemisia californica*
Grass	California oatgrass	*Danthonia californica*	Shrub	Coyote brush*	*Baccharis pilularis*
Grass	Blue wild rye*	*Elymus glaucus*	Shrub	Mulefat*	*Baccharis salicifolia*
Grass	Small fescue*	*Festuca microstachys*	Shrub	Blue blossom*	*Ceanothus thyrsiflorus*
Grass	Meadow barley*	*Hordeum brachyantherum*	Shrub	Coffeeberry*	*Frangula californica*
Grass	Creeping wildrye	*Elymus tritichoides*	Shrub	Toyon*	*Heteromeles arbutifolia*
Rush	Dune rush	*Juncus lescurii*	Shrub	Coast twinberry	*Lonicera involucrata*
Rush	Common rush*	*Juncus patens*	Shrub	Flowering currant	*Ribes sanguineum*
Sedge	Valley sedge	*Carex barbareae*	Shrub	California rose	*Rosa californica*
Herb	Deerweed	*Acmispon glaber*	Shrub	California blackberry	*Rubus ursinus*
Herb	Mugwort*	*Artemisia douglasiana*	Shrub	Creeping snowberry	*Symphoricarpos mollis*
Herb	Salt marsh baccharis	*Baccharis glutinosa*	Tree	Box elder*	*Acer negundo*
Herb	Creek clematis	*Clematis ligusticifolia*	Tree	California buckeye*	*Aesculus californica*
Herb	Gumplant	*Grindelia stricta*	Tree	White alder*	*Alnus rhombifolia*
Herb	Iris leaved rush	*Juncus xiphioides*	Tree	Creek dogwood*	*Cornus sericea*
Herb	California man-root	*Marah fabacea*	Tree	CA sycamore*	*Platanus racemosa*
Herb	Water parsley	*Oenanthe sarmentosa*	Tree	Black cottonwood*	*Populus trichocarpa*
Herb	Silverweed cinquefoil	*Potentilla anserina*	Tree	Coast live oak*	*Quercus agrifolia*
Herb	Panicled bulrush	*Scirpus microcarpus*	Tree	Narrowleaf willow	*Salix exigua*
Herb	Checkerbloom	*Sidalcea malviflora*	Tree	Red willow*	*Salix laevigata*
Herb	Blue-eyed grass	*Sisyrinchium bellum*	Tree	Arroyo willow*	*Salix lasiolepis*
Herb	California hedgenettle	*Stachys bullata*	Tree	Blue elderberry*	*Sambucus nigra spp. caerulea*
Herb	California aster	*Symphyoctrichum chilense*			
Herb	Creek clover*	*Trifolium obtusiflorum*			
Herb	Stinging nettle	*Urtica dioica*			

5.2.2 Delineating Plant Communities Based on Depth to Groundwater

We delineated planting zones for the Carmel River FREE project Tier 2 floodplain based on available depth to groundwater data and plant community water use requirements. We used the following dry-season DTGW ranges for plant communities based on soil moisture preferences so that they will not need irrigation once established (FISRWG 1998; Griggs 2009):

- Willow and cottonwood riparian forest: 0-15 ft
- Mixed riparian forest: 10-20 ft
- Upland: greater than 15 ft
- MFCAs: designated as grassland regardless of DTGW

In ArcGIS, we overlaid the Tier 2 design plan shapefile from the Restoration and Management Plan (HT Harvey & Assoc. 2015) on to DTGW raster images for the average dry-season (October to December) and the driest conditions on record (11/4/2014). We then determined appropriate plant community boundaries for each scenario (Fig. 8).

If the dry-season water table rises due to changes in water management in the Carmel River Watershed and DTGW is reduced, then it may be feasible to shift some of the lower-elevation areas to willow and cottonwood riparian forest and mixed riparian forest. We created planting zones, based on the average wet season (January to March), to approximate a hypothetical increase in DTGW (Fig. 9).

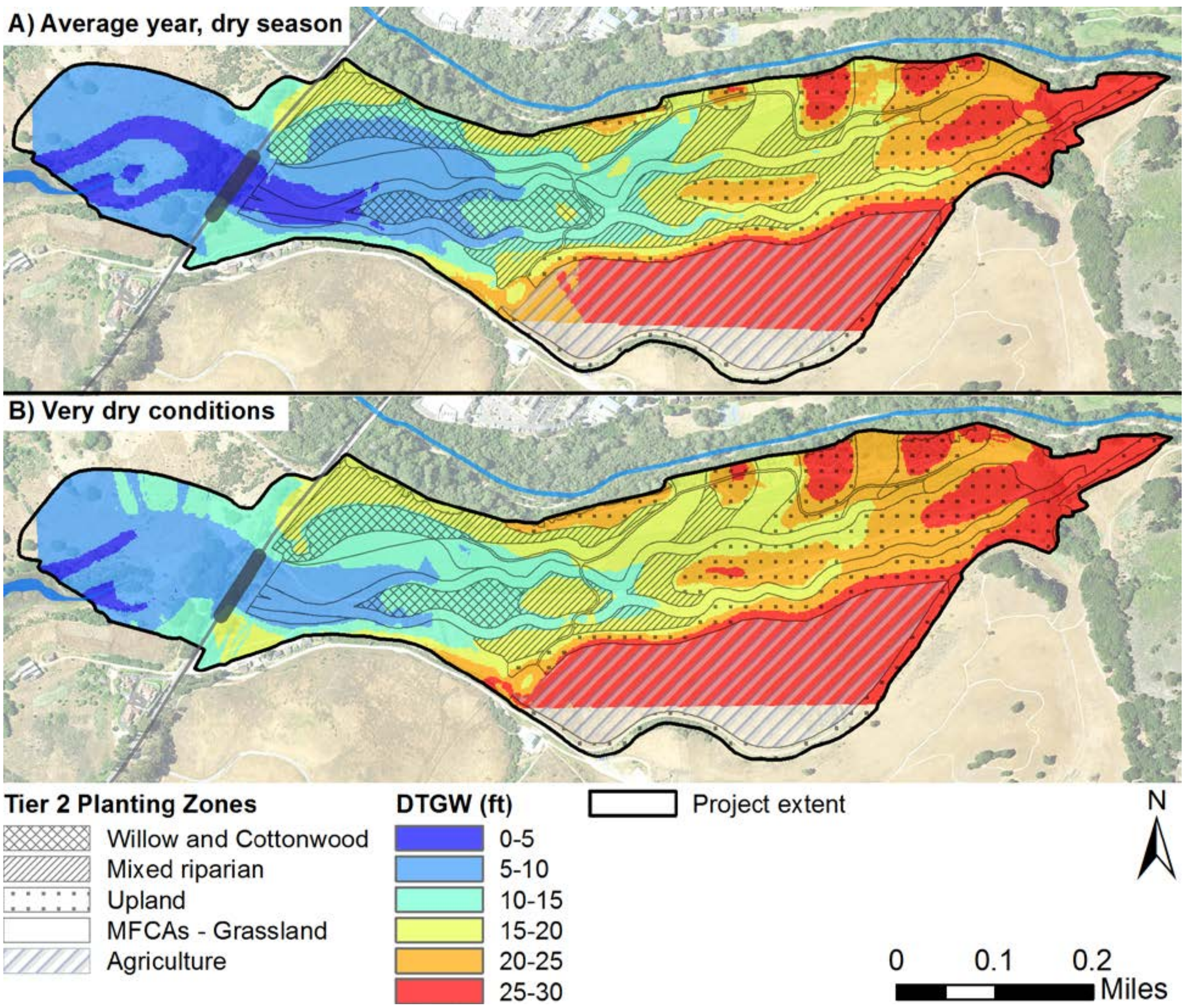

Figure 8. Potential Tier 2 planting zones based on depth to groundwater (DTGW) for (A) average end of dry season conditions for October to December and (B) the driest conditions on record (11/4/2014).

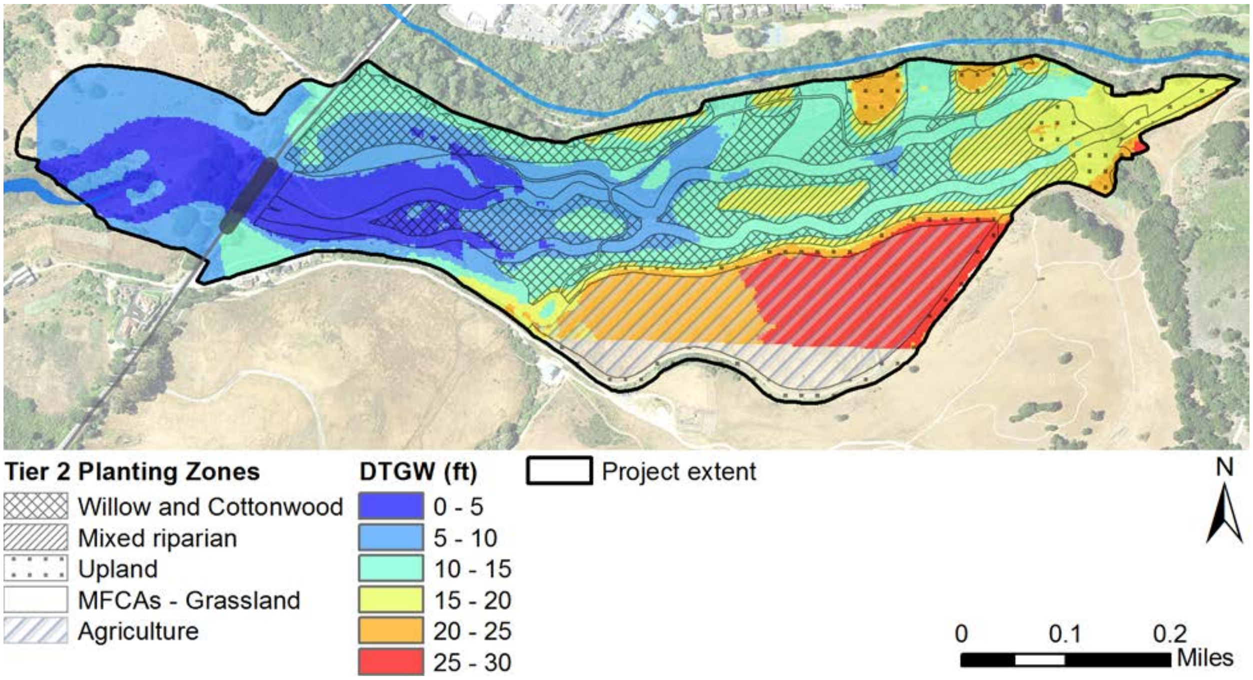

Figure 9. Hypothetical Tier 2 planting zones based on an increase in water table elevation. Depth to groundwater (DTGW) is the average of available groundwater data for January to March from 2012-2016.

5.3 Planting Zones

We developed suggested planting zones based on a compromise between seasonal DTGW and the driest conditions on record (Fig. 10, Table 5). Planting zones should be re-evaluated if future groundwater monitoring provides additional insight into groundwater conditions.

Under current DTGW conditions, the eastern half of the site was better suited for drought tolerant grasses and upland species and the western half was suited for riparian communities. Grassland MFCAs were predetermined in the Restoration and Management Plan, to occupy levee breaks and floodplain channels and must be planted with low-lying vegetation to allow for rapid flow of floodwaters across the site. The location of the agricultural preserve was also specified in the Restoration and Management Plan and may be farmed once restoration is complete.

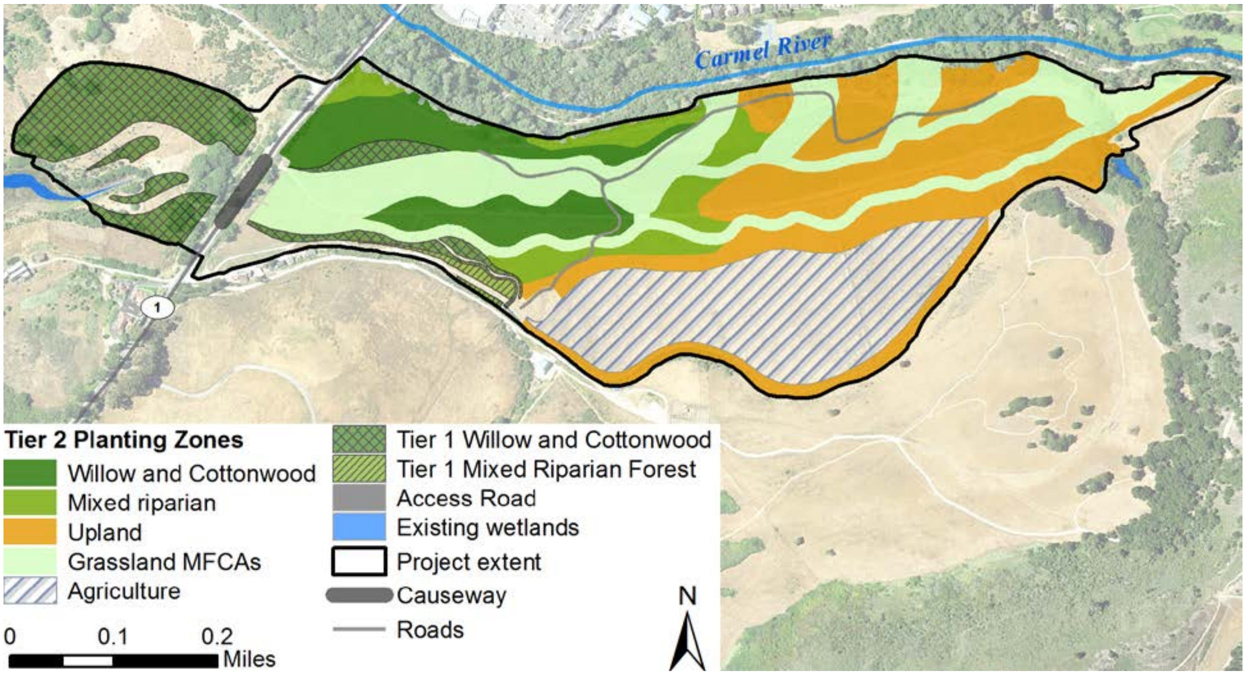

Figure 10. Carmel River FREE project Tier 2 recommended planting zones based on below average dry season depth to groundwater.

Table 5. Carmel River FREE project Tier 2 recommended planting zone areas based on below average dry season depth to groundwater.

Zone	Type	Area (acres)	Percent of restoration area
0	Access road	1.1	-
1	MFCA- grasses, sedges, rushes	28.2	36.6%
2	Willow and cottonwood riparian	11.9	15.5%
3	Mixed riparian	7.3	9.5%
4	Upland	29.7	38.5%
5	Agricultural preserve	24.0	-
	Total	102.2	
	Total acres of restored habitat	**77.1**	100%

We developed a recommended planting list for each zone (Table 6). While these species are commonly used for riparian restoration, the final project site planting list will also depend on which species are available for seed collection and propagation.

Table 6. Recommended plant species by zone. Preferred soil moisture key: Extremely low is below average moisture; Very Low is average moisture; Low is above average moisture; Moderate-High is moist year-round.

Zone	Type	Common name	Scientific name	Preferred soil moisture	Max root depth (ft)	Root growth
Initial Erosion Control	Grass	Small fescue*	*Festuca microstachys*	Very low	-	-
	Herb	Creek clover*	*Trifolium obtusiflorum*	Moderate-high	-	-
MFCA	Grass	California brome*	*Bromus carinatus*	Low	3	Fast
	Grass	Blue wild rye*	*Elymus glaucus*	Low to high	-	Fast
	Grass	Meadow barley*	*Hordeum brachyantherum*	Low	-	-
	Grass	Creeping wildrye	*Elymus tritichoides*	Moderate-high	-	Fast
	Rush	Common rush*	*Juncus patens*	Low	-	Moderate
	Sedge	Valley sedge	*Carex barbareae*	Moderate-high	-	Fast
Willow & Cottonwood Riparian Forest	Shrub	California blackberry*	*Rubus ursinus*	Moderate-high	-	Fast
	Tree	White alder*	*Alnus rhombifolia*	Moderate-high	1.5	Fast
	Tree	Creek dogwood*	*Cornus sericea*	Moderate-high	-	Fast
	Tree	California sycamore*	*Platanus racemosa*	Moderate-high	6	Fast
	Tree	Black cottonwood*	*Populus trichocarpa*	Moderate-high	3 to 9	1-3 cm/day
	Tree	Red willow*	*Salix laevigata*	Moderate-high	15 to 18	1-3 cm/day
	Tree	Arroyo willow*	*Salix lasiolepis*	High	15 to 18	1-3 cm/day
Mixed Riparian Forest	Herb	Mugwort*	*Artemisia douglasiana*	Low to moderate	-	Fast
	Herb	Gumplant	*Grindelia stricta*	Low	-	Moderate
	Herb	California hedgenettle	*Stachys bullata*	Moderate-high	-	Moderate
	Shrub	Coyote brush*	*Baccharis pilularis*	Very low	10.5	Fast
	Shrub	Mulefat*	*Baccharis salicifolia*	Low	-	Fast
	Shrub	Blue blossom*	*Ceanothus thyrsiflorus*	Low	-	Moderate
	Shrub	Coffeeberry*	*Frangula californica*	Very low	-	Moderate
	Shrub	California blackberry*	*Rubus ursinus*	Moderate-high	-	Fast
	Tree	Box elder*	*Acer negundo*	Low	12	Fast
	Tree	California buckeye*	*Aesculus californica*	Very low	-	Fast
	Tree	Creek dogwood*	*Cornus sericea*	Moderate-high	-	Fast
	Tree	California sycamore*	*Platanus racemosa*	Moderate-high	6	Fast
	Tree	Black cottonwood*	*Populus trichocarpa*	Moderate-high	3 to 9	1-3 cm/day
	Tree	Coast live oak*	*Quercus agrifolia*	Very low	27	Moderate
	Tree	Red willow*	*Salix laevigata*	Moderate-high	15 to 18	1-3 cm/day
	Tree	Arroyo willow*	*Salix lasiolepis*	High	15 to 18	1-3 cm/day
	Tree	Blue elderberry*	*Sambucus nigra spp. caerulea*	Low	-	Fast
Upland	Herb	Deerweed	*Acmispon glaber*	Very low	-	Fast
	Herb	Checkerbloom	*Sidalcea malviflora*	Low	-	Fast
	Herb	California aster	*Symphyoctrichum chilense*	Low	-	Fast
	Shrub	California sagebrush*	*Artemisia californica*	Extremely low	-	Fast
	Shrub	Coyote brush*	*Baccharis pilularis*	Very low	10.5	Fast
	Shrub	Blue blossom*	*Ceanothus thyrsiflorus*	Low	-	Moderate
	Shrub	Coffeeberry*	*Frangula californica*	Very low	-	Moderate
	Shrub	Toyon*	*Heteromeles arbutifolia*	Very low	-	Moderate
	Shrub	Flowering currant	*Ribes sanguineum*	Low	-	Fast
	Shrub	California rose	*Rosa californica*	Low	-	Moderate
	Shrub	Creeping snowberry	*Symphoricarpos mollis*	Low	-	Moderate
	Tree	California buckeye*	*Aesculus californica*	Very low	-	Fast
	Tree	Coast live oak*	*Quercus agrifolia*	Very low	27	Moderate
	Tree	Blue elderberry*	*Sambucus nigra spp. caerulea*	Low	-	Fast

6 Water Budget

The Carmel River FREE project has a water allowance of 28.1 afy for irrigation. We estimated water requirements per acre for each proposed planting zone in order to use the allotment most efficiently and to ensure the allotment is not exceeded.

6.1 Evapotranspiration

Evapotranspiration (ET) is the amount of water lost to the atmosphere from plants and soil. The minimum amount of water required for irrigation is calculated by estimating water loss to the environment and adding the amount of water each plant species requires to offset this loss. There are a variety of methods for estimating ET. Typical workflows initially estimate potential ET (ET_0) for the local area and subsequently incorporate species specific factors (Allen *et al.* 1994).

The Food and Agriculture's standard equation for calculating reference ET is the Penman-Monteith equation (Allen *et al.* 1994). We calculated average, monthly reference ET from 2008 to 2016 for the Carmel River FREE project area using the following equation:

$$ET_0 = \frac{\Delta (R_n - G) + \rho_a c_p (\delta e) g_a}{(\Delta + \gamma (1 + \frac{g_a}{g_s})) L_v}$$

where ET_0 is the reference ET, Δ is the slope of the saturation vapor pressure temperature relationship, R_n is net radiation, G is soil heat flux, ρ_a is the mean air density at constant pressure, c_p is the specific heat of the air, δ_e is specific humidity, g_a is atmospheric conductance, Υ is the psychrometric constant, g_a is the conductivity of air, g_s is the surface conductance of stoma, and L_v is the volumetric latent heat of vaporization. We incorporated meteorological data obtained from the CIMIS station (210) located in Carmel.

We derived zone specific ET factors for each plant community by integrating parameters that affect the rate of transpiration. Parameters included drought tolerance and typical sun exposure from leaf area. We combined the monthly reference ET and monthly vegetation coefficients *(*K_v*)* to calculate the average annual, planting zone specific ET (Table 7) with the following equation:

$$ET = ET_0 \times K_V$$

where ET_0 is the reference ET (in) and K_V is a unitless vegetation coefficient. Mixed riparian refers to the combination of riparian and upland species, in which case specific species factors were derived by averaging values for the two groups for each month. An averaged legume vegetation coefficient was used for the agricultural preserve as a proxy number from Allen *et al.* (1994). This should be further refined once a specific legume species is selected. Approximate volume of water loss through ET was calculated by multiplying the planting zone area by ET.

Our calculated ET estimates assume the entire area is planted. Thus, the volume of loss from ET is a function of the species composition (K_V) and the planting zone area (Table 7). Riparian zones have the highest evapotranspirative loss at 40 in (3.4 afy/ac) because they are not resistant to drought and have the largest planting area. Grasslands appear to have the lowest ET loss at 12.3 in (1.2 afy/ac).

Table 7. Summary of reference evapotranspiration (ET_0) values (in), vegetation coefficients (K_v), and estimated ET for each plant zone by month. Average ET is also calculated for each planting zone in inches and afy/ ac. Vegetation coefficients were summarized by Howes *et al.* (2015) and Allen *et al.* (1994).

	avg ET_0	Willow & Cottonwood		Mixed Riparian		Upland		MFCA		Agricultural		
Month	**(in)**	**K_v**	**ET**	**K_v**	**ET**	**K_v**	**ET**	**K_v**	**ET**	**K_v**	**ET**	
January	1.8	0.8	1.5	0.7	1.2	0.5	1.0	0.7	1.2	0.6	1.0	
February	2.4	0.8	1.9	0.6	1.4	0.4	0.9	0.6	1.5	0.6	1.3	
March	3.3	0.8	2.7	0.6	2.2	0.5	1.6	0.7	2.3	0.6	1.8	
April	4.4	0.8	3.5	0.7	3.0	0.6	2.6	0.6	2.8	0.4	1.7	
May	4.5	0.9	4.0	0.7	3.2	0.6	2.5	0.3	1.5	0.4	1.8	
June	4.9	1.0	4.9	0.7	3.2	0.3	1.5	0.1	0.5	0.4	2.0	
July	4.6	1.1	5.1	0.6	3.0	0.2	0.8	0.0	0.1	0.4	1.8	
August	4.2	1.2	5.1	0.7	2.8	0.1	0.5	0.0	0.1	1.2	4.9	
September	4.0	1.2	4.8	0.6	2.5	0.1	0.3	0.0	0.0	1.2	4.6	
October	3.1	1.2	3.6	0.6	1.9	0.0	0.1	0.0	0.0	1.2	3.6	
November	2.0	1.0	2.0	0.7	1.4	0.4	0.7	0.4	0.9	1.2	2.3	
December	1.5	0.9	1.2	1.0	1.4	1.1	1.6	0.9	1.3	0.6	0.8	
Annual	**40.8**	**40.3**		**27.2**		**14.1**		**12.3**		**27.7**		**in**
		3.4		**2.3**		**1.2**		**1.0**		**2.3**		**afy/ac**

6.2 Estimated Total Water Use

The California Constitution states that water rights are limited to the amount reasonably required for the specified beneficial use. Excess or unreasonable use of water is not permitted. The Model Water Efficient Landscape Ordinance provides a standardized way to calculate Estimated Total Water Use (ETWU, Cal code of regs. 2009). This ordinance was created to establish a structure for planning and maintaining water efficient landscapes in new construction and rehabilitated projects. Monthly ETWU for each plant zone was calculated with the following equation:

$$ETWU = (ET)(0.62)\left(\frac{K_v \times PZ}{IE}\right)$$

where *ET* is evapotranspiration, *Kv* is the same plant factor described above, *PZ* is the planting zone area in square feet, and *IE* is irrigation efficiency. We used the common IE value, 0.71 (Cal code of regs. 2009). Further details on each variable can be found in the California Code of Regulations, Title 23, Division 2, Chapter 2.7 (2009). Monthly ETWU and effective precipitation can then be used to determine timing and magnitude of irrigation.

6.3 Irrigation

Supplemental irrigation is needed when effective precipitation is lower than the ETWU. Effective precipitation is defined as the volume of precipitation, which is not lost through deep percolation and runoff, and is subsequently stored in the root zone and thereby available to the plant (Brauwer and Heibloem 1986). Brauwer and Heibloem (1986) related total monthly precipitation to monthly effective precipitation. We have utilized the data to develop the following equation relating total precipitation to effective precipitation.

$$P_e = 0.0004P^2 + 0.6502P - 13.386$$

where P_e represents effective rainfall (mm) and P is total rainfall (mm).

To determine the monthly and annual volume of supplemental irrigation needed for each planting zone, effective precipitation in various local climate conditions was subtracted from the ETWU and then normalized by area resulting in total irrigation needed in acre-feet per acre for years with low, average, and high precipitation (ac-ft/acre, Fig. 11).

Irrigation is not needed during the winter months (Oct – Feb), assuming normal rainfall levels occur, and should be ceased during precipitation events. Appendix A summarizes the monthly water needs for each planting zone given low, average, and high annual precipitation scenarios. Generally, irrigation will not be necessary beyond three years after planting as vegetation becomes established (Griggs 2009, Shihadeh and Founds 2008).

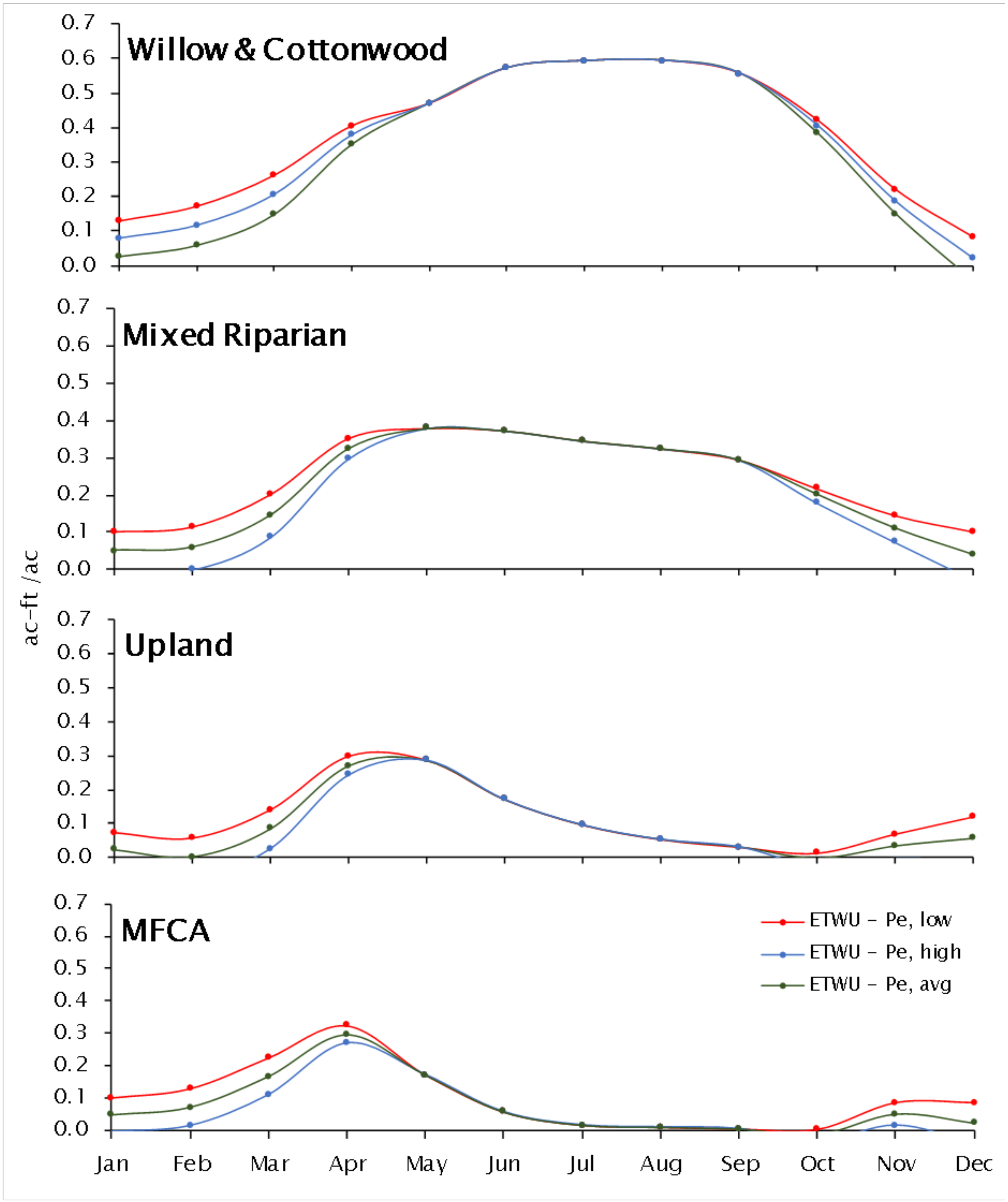

Figure 11. Monthly ETWU for each planting zone in acre-feet/ acre. Red, green, and blue represent a year of extreme dry, average, and wet conditions (9.7 in, 15.5 in, and 21.2 in), respectively. Values below or at zero represent months where effective precipitation can provide the zone's water needs and supplemental irrigation is not required.

Irrigation schedules should be optimized for downward root growth. The first year of irrigation is the most critical as roots are not typically established until the second or third year of planting (Griggs 2009). Once plants become established, typically after three to five years depending on specific plot needs, irrigation levels can be reduced or ceased altogether. Total irrigation time will however depend on depth to groundwater, precipitation rates, and species-specific root growth rates (Cerny *et at.* 2002).

The Willow and Cottonwood and mixed riparian planting zones will become established once their roots reach groundwater. At approximately 1-3 cm of root growth per day, their roots can grow 12-36 feet per year (Table 6). Therefore, with suitable climate and irrigation conditions, riparian zones may become established within two years of planting. Upland planting zones have moderately slower root growth rates and are not expected to ever reach groundwater, although these species are typically adapted to survive these conditions. Irrigation in the upland planting zones would be expected to cease after two years with favorable climate conditions.

Soil moisture must be considered when deciding the duration and quantity of water required for irrigation. A majority of the Carmel River FREE project site consists of hydrologic soil type B, typically 10-20% clay and 50-90% sand. B soil types have moderately low runoff potential and high infiltration rates (USDA 2009). Sandy soils have the fastest absorption rate (2 inches per hour) followed by loam soils (¾ inches per hour). Over-saturated soils can reduce available levels of soil oxygen and stress plants. Cottonwood roots grow eight times as fast at 20% soil saturation compared to 50% soil saturation (Taylor 2000). Long, infrequent irrigation in soils comprised predominately of sand will promote root growth in trees and shrubs, which have more extensive root systems and will mitigate risk of oversaturation.

Drip irrigation delivers water directly to the root zone of the plant and is an efficient way to water shrubs and smaller trees. We recommend a drip irrigation system with a flow rate of 1 gallon per hour. During months with minimal precipitation (March-September) drip irrigation should be applied for eight hours approximately two to three times a month depending on specific monthly ETWU (Fig. 10). During years 2-3 irrigation rates can be decreased to once a month, however plants should be monitored for potential drought stress after reduction in irrigation frequency schedules. In general, irrigation schedules for each planting zone should reflect the ETWU per acre per month.

7 Implementation Strategy

We developed an Adaptive Management Irrigation Scheduling Tool (AMIST), which can be used to develop planting schedules. This tool will enable managers to adaptively change the progression of restoration, based upon precipitation and irrigation requirements. The tool calculates water needs for each planting zone for low, average, and high precipitation years. AMIST incorporates effective rainfall in each condition and determines total irrigation needs for each planting phase. Restoration managers can use AMIST to determine the supplemental irrigation (afy) needed for each planting phase by adjusting the planting acreage.

We recommend given the current water allotment of 28 ac-ft, that managers plan for each phase to become established before planting and irrigating new areas. This strategy would result in planting phases occurring in three-year cycles until the restoration is complete.

We developed a tentative planting schedule, which adheres to the current water allocation of 28 afy and is based on ETWU and supplemental irrigation necessary for each planting zone to become established. It is important to note that this tentative schedule is only an example of methods that could be used in future management and not a prescribed plan. This example implementation plan would require approximately 15 years to complete restoration of 77.1 acres of the Tier 2 project area (Table 8). This proposed plan incorporates planting and irrigating the agriculture field after year 16, following establishment of the floodplain restoration phase of the project.

Spatial distribution was also taken into consideration when designing this phased planting approach (Fig. 12). The tentative phasing was designed to proceed from west to east based upon spatial density of high priority planting zones, location of irrigation sources, and visual effect. We assumed grasslands to be highest priority for erosion control during future overbank flooding events. Willow and cottonwoods were assumed to be the next highest priority, as these species require more time to establish and promote succession of the understory. We then selected areas near the access road for ease of maintenance. Upland vegetation and the 24 acres of agricultural land would be planted following completion of the riparian core restoration.

This tentative implementation strategy is just one example of how AMIST can be used to manage restoration within the constraints of the 28 ac-ft water right allotment. Implementation budgets, water allotment, annual precipitation, and results from monitoring test plots are expected to change over time and as these parameters become more precisely defined AMIST can be used to adjust planting strategies.

Table 8. Proposed planting phases in acres, ETWU (afy), Effective Precipitation (afy) and Supplemental Irrigation (afy) needed for each planting zone.

Planting Zones	Phase Year and Areas (acres)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
MFCA	28.20															
Willow/ cottonwood	0.05			6.46			5.46									
Mixed riparian	0.05			0.05			1.50			5.68						
Upland	0.05			0.05			0.24			11.32			21.10			
Ag																10.35
Total	28.3			6.6			7.2			17.0			21.1			10.4
ETWU (ac-ft)	40.9	40.9	40.9	30.7	30.7	30.7	30.8	30.8	30.8	36.6	36.6	36.6	34.6	34.6	34.6	33.5
Effective Rainfall (ac-ft)	14.9	14.9	14.9	3.4	3.4	3.4	3.8	3.8	3.8	8.9	8.9	8.9	11.1	11.1	11.1	5.4
Irrigation needs (ac-ft)	26.0	26.0	26.0	27.2	27.2	27.2	27.1	27.1	27.1	27.7	27.7	27.7	23.6	23.6	23.6	28.1

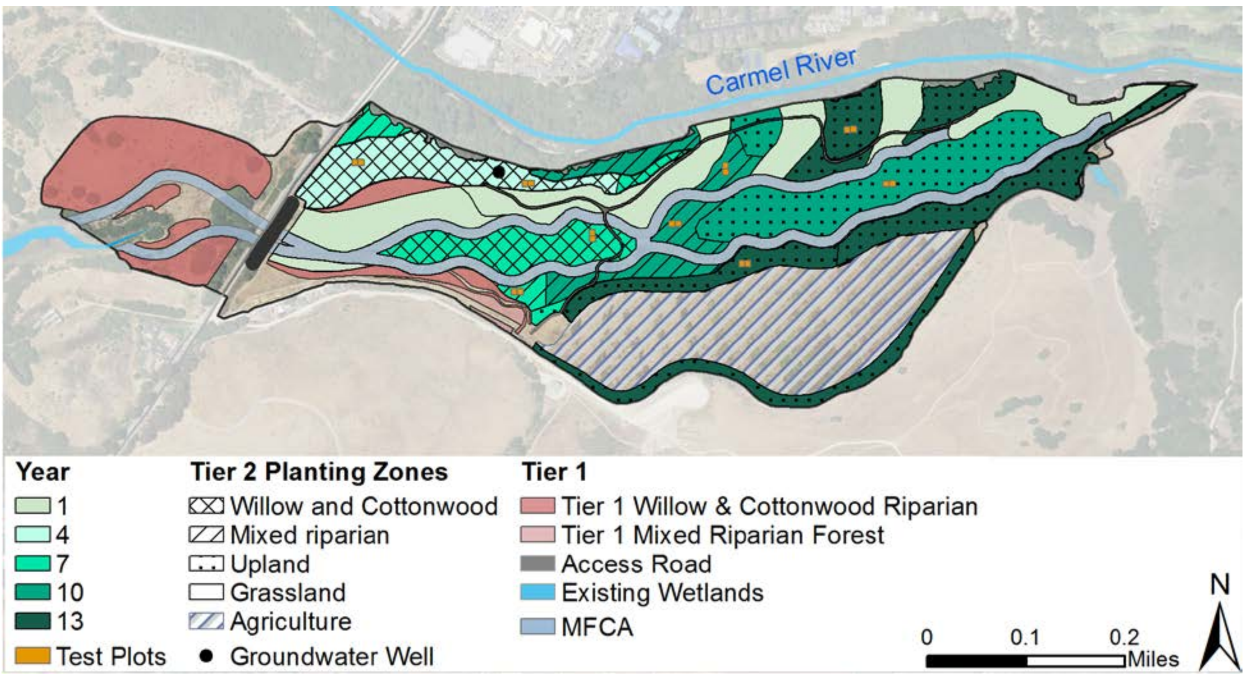

Figure 12. A proposed 16-year phased restoration. Restoration phasing was determined based upon priority planting zones and west to east progression. Grasslands were determined highest priority and selected for year 1. Willows and Cottonwoods were the next highest priority for years 1 and 4. Test plots were included in year 1 phasing.

8 Monitoring

8.1 Monitoring Strategies

Monitoring can ascertain progress of a project following initiation of active restoration (USFS 2004). We recommend various strategies for monitoring planting zones and natural recruitment to evaluate riparian restoration success criteria and implement adaptive management. Proposed monitoring strategies are rapid, thorough, repeatable, and provide adequate detail to statistically evaluate successes and setbacks on an annual basis.

Many methods have been used to evaluate riparian restoration and track progress. One qualitative method commonly used in California is the California Rapid Assessment Method (CRAM). BSLT contracted Central Coast Wetlands Group to conduct CRAM surveys prior to project implementation and provide a baseline of vegetative structure and cover (CCWG 2015). CRAM surveys are quick, standardized, and cost-effect monitoring strategies. However, they do not generate sufficient detail to identify small-scale changes in species abundance and cover that is necessary to inform and adapt future plantings.

Quantitative and qualitative monitoring methodologies are commonly used concurrently to assess plant health and habitat development through analysis of vegetative vigor, cover, density and diversity (Elzinga *et al.* 2000, Meek n.d.). Point intercept and photo monitoring techniques were used in the adjacent Carmel River Lagoon Enhancement restoration project to monitor succession of native and non-native species, and to identify dominant species (Hubert *et al*. 2003, CDPR 2009). Paired-plot techniques were used to monitor grasslands in Palo Corona Regional Park and inform adaptive management programs (Fields 2016). More recently, aerial imagery and spatial analysis software has been used to monitor expansion of the riparian canopy at the Schulte Road restoration site (Christensen and Geisler 2009, Dufour *et al.* 2013). We provide a subset of qualitative and quantitative monitoring strategies that could be implemented at the Carmel River FREE project site, including test plots, point intercept transects, relevé surveys, and photo monitoring stations (Elzinga *et al.* 2000).

8.2 Success Criteria

Annual monitoring strategies implemented at the Camel River FREE project site should allow for adaptive management to ensure that Tier 2 restoration areas meet the success criteria outlined by funding agencies and the project goals (HT Harvey & Assoc. 2015). The progression and success of similar local restoration sites provides an idea of what to expect for the Carmel River FREE project.

Two reference sites in the Carmel River Watershed are the Schulte Road riparian restoration project and Garland Park restoration. Garland Park is an example of a passive restoration approach, which required approximately 30 years to achieve the current level of maturity and species composition. This site experienced substantial growth following overbank flooding events which deposited nutrient rich soils and fresh seeds onto the floodplain. The Schulte Road restoration was an active restoration project, which included regular plant installations, irrigation, and weed management. In 1987, 3.3 acres of riparian trees existed on the floodplain. By 2007, the riparian habitat had expanded to 16.93 acres, resulting in an average increase of 1.36 acres/year (Christensen and Geisler 2009).

The Creamery Meadows restoration in Andrew Molera State Park is also an informative reference of potential recovery rates. Similar to the Odello West floodplain, Creamery Meadow is coastal and adjacent to a perennial river. The site was actively restored and irrigated for four years. Ventana Wildlife Society planted 5,377 riparian trees and shrubs, between 1995-1998. In 2007, plant survivorship was 18.6% or 768 plants (Shihadeh and Founds 2008). The plant survivorship and expansion of riparian vegetation documented in these sites provide a model of success against which the Carmel FREE project success criteria can be developed.

8.3 Initial Test Plots

The Restoration Management Plan for the project recommended establishing test plots within the Tier 2 project area (HT Harvey & Assoc. 2015). We propose establishing and monitoring test plots throughout the Tier 2 project area to evaluate the suitability of planting zone boundaries. We suggest establishing nine paired plots, such that each 100 m^2 plot (plots A and B) is one half of a 200 m^2 monitoring unit (Fig. 13). A 100 m^2 plot should be sufficient to describe trends in establishment of both planted or naturally recruited species (Kent and Paddy 2011). We positioned the test plots in locations where DTGW differed within a subset of each planting zones. Test plots established in locations where DTGW differs would be expected to provide a more complete picture of which plant communities will thrive in locations with similar DTGW levels.

Test plots can be monitored to provide insight into growth rates, presence and extent of invasive species, and refining of irrigation needs (HT Harvey & Assoc. 2015). We highly recommend test plots be established as soon as possible, preferably at the same time Tier 1 is implemented in order to maximize the collection of monitoring data. Test plots could be planted with a variety of species to test performance under differing conditions. Each plant installation could be flagged at the time of planting to conduct a quantitative assessment of plant survivorship (Roni and Quimby 2005). Following the first growing

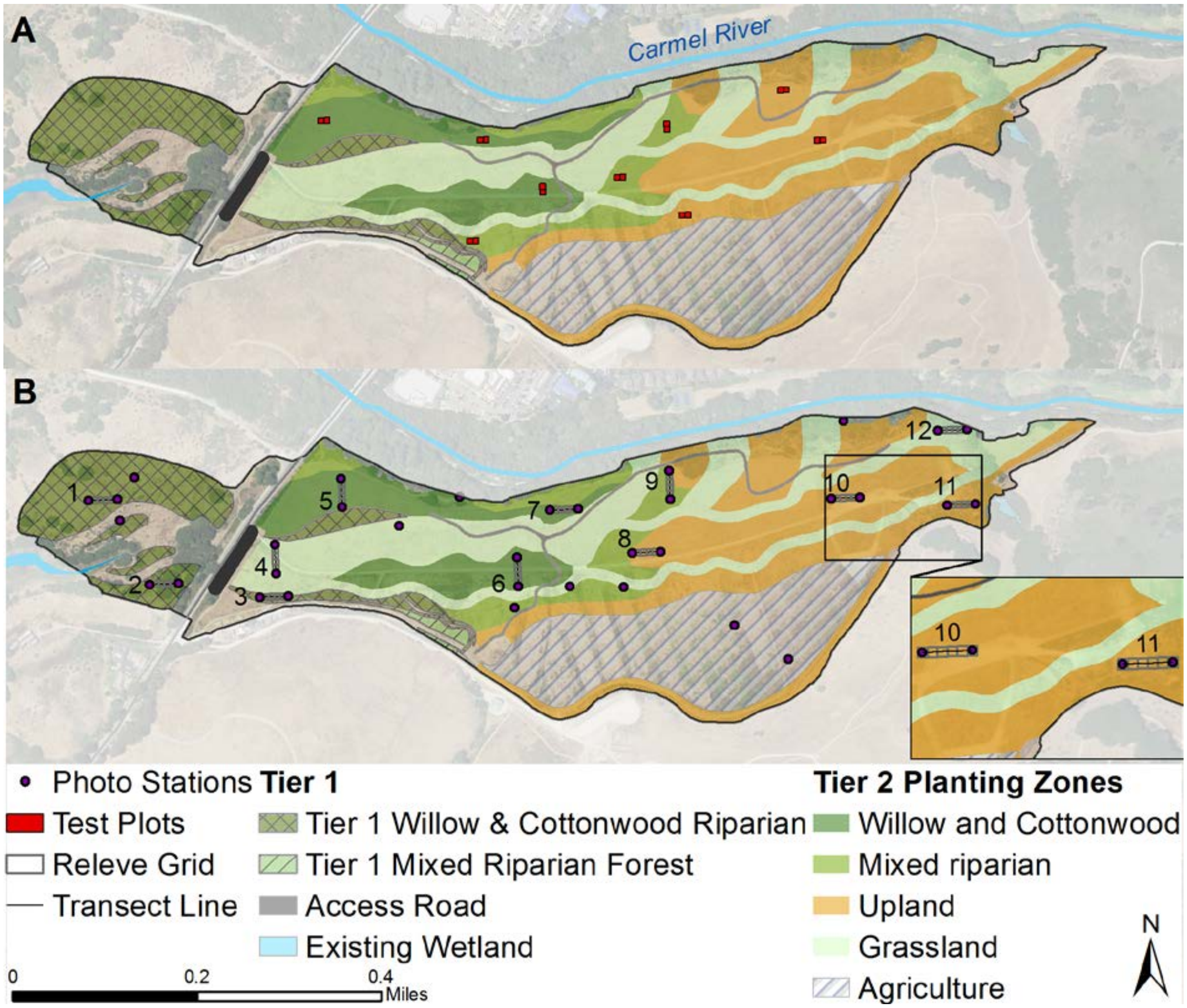

Figure 13. Suggested (A) test plot locations and (B) transect lines and photo monitoring stations for the Carmel River FREE project.

season, we recommend surveying test plots for percent survivorship by removing and counting flags next to dead plants. Then dominant surviving species could be documented, and planted in higher densities across the associated planting zone to improve survivorship in the future. In addition, we suggest a visual assessment of percent cover of non-native species be used to develop removal strategies.

Test plots also provide an opportunity to experiment with restoration treatments and to document response to differing conditions, such as shallower or deeper DTGW or soil conditions (Wright and Chambers 2002). The paired-plot design we suggest also enables manipulations of an experimental plot adjacent to a control plot that can be used to identify factors that benefit or reduce recovery rates.

Irrigation is likely to have the greatest influence on growth rates and species establishment within the project site (CDPR 2009, Shihadeh and Founds 2008). We recommend utilizing these paired-plots to examine the effect of modified irrigation schedules on plant survivorship. In riparian areas, irrigation can be slowly retracted to determine if the roots have reached groundwater after three to five years. For example, managers can reduce irrigation in Plot A at regular intervals and continue irrigation in Plot B. These test plots could then be monitored weekly for evidence of plant withering or yellowing to determine the degree to which plantings are dependent on irrigation.

8.4 Point Intercept Monitoring

Point intercept surveys are considered the least biased and most objective assessment of diversity and cover (Elzinga *et al.* 2000). Surveys are conducted by recording plants intercepted by a monitoring dowel along a predetermined transect line.

There are both in-depth and generalized techniques for conducting point intercept surveys. An in-depth technique documents each specific species intercepted by the monitoring dowel (Fields 2016). This method requires more time and knowledge, but improves information about species richness, natural recruitment, and invasive species across a site. A more rapid and general survey records the intercepted species according to height classes of herb (<0.4 m), tall herb or shrub (0.4- 2.5 m), and tree (>2.5 m) (CDPR 2009). An individual with limited knowledge of plant taxonomy is able to conduct these surveys. The most specific data possible should be collected given the available time and knowledge of plant taxonomy.

We identified twelve permanent 50m transects for monitoring vegetative cover and species richness across the Carmel River FREE project area (Fig. 13). The start and end locations of each transect line should be marked in the field so that the same line is monitored each year. Transect locations were determined subjectively based upon proximity to the Carmel River, planting zones, and DTGW elevations in late summer and fall. Transect lines were distributed in both Tier 1 and Tier 2 zones to representation of the entire site.

We suggest implementing point intercept surveys as follows:

- Extend a 50 m transect tape between the two permanent transect points.
- Generate a random number between zero and 50 cm to indicate the first intercept point.

- Use a measuring dowel to record the species code for tallest species touching the rod at each survey point and indicate if the species is alive (A), yellowing (Y), or dead (D). Record the species height in cm.
- Imagine a vertical extension of the dowel and record the overhead species and its approximate height in cm. This step will document canopy complexity at each survey point and will become important as plant communities establish.
- Record point data in a well-organized data sheet (Table 9).
- Repeat this process every 0.5 m.
- Following point intercept surveys, scan a 5 m^2 buffer around the transect line and record all species not found during point surveys.
- At the start and end of each transect take two photos of the project site. These photos should be duplicated each year using previous photos as reference.

We suggest recording species every 0.5 m to document a total of 1200 survey points for the site. A qualified team of two could complete this survey in approximately three days. As vegetation diversifies and becomes denser, survey time is likely to increase. Species would be easiest to identify during the peak growing season in late spring.

Table 9. Sample data sheet for point intercept surveys to assess plant abundance and coverage of planted, naturally recruited, and non-native species. The status of the plants should be documented as alive (A), yellowing (Y), or dead (D).

Transect ID	Point	Sp. Code	Status (A/Y/D)	Height (cm)	Canopy Sp.	Photo Station	Photo Number
1	0.5	BRANIG	A	45	N/A	1A	1
1	1.0	RUBURS	A	35	SALLAS	N/A	
1	1.5	BACPIL	Y	53	N/A	N/A	
1	2.0	QUEAGR	D	65	N/A	N/A	

8.5 Relevé Monitoring

Relevé monitoring is a visual assessment of species cover and abundance used to quickly obtain information for a specified area (Mueller-Dombois and Ellenberg 1974). Vegetation can be grouped by type such as grasses, herbs, shrubs, trees, and weeds or by the specific species present in a plot depending on the level of detail necessary and the time available.

Relevé surveys could be conducted in 10 m^2 plots at 10 m intervals along each permanent transect line (Fig. 13). Using a general plant classification method, 72 relevé plots could be surveyed in approximately two days with a single observer.

We suggest using a modified Braun-Blanquet scale with seven cover classes to document the mean abundance of each plant species and bare ground within the survey boundary (Table 10; Mueller-Dombois and Ellenberg 1974). Using a broad category classification scale improves accuracy between multiple observers. This system has gained popularity in North America and was recently used to monitor maritime chaparral within Monterey County (TNC 1994, Van dyke and Holl 2001, Van dyke and Holl 2003). The procedure for conducting a relevé is as follows:

- The observer stands at the start of the transect line and visualizes a 10 m^2 plot.
- The observer visually assesses the percent cover of plants and bare ground in the 10 m^2 plot and records a score for species present following the modified Braun-Blanquet scale (Table 10, Appendix B).
- The observer repeats this process every 10 m for the length of the 50 m transects.

The relevé method could be used in addition to the point intercept method to provide a quick, semi-quantitative survey of abundance and cover. The average abundance of each species or plant type can be compared across years. Analysis can be completed within transects, planting zones or across the entire site. Although the two methods describe

Table 10. A modified Braun-Blanquet scale for measuring abundance and percent cover of native and non-native vegetation within the restoration area.

Braun-Blanquet Score	Abundance	Percent Cover
0.1	Rare/ Solitary	small cover
0.5	Few	small cover
1	Numerous	< 5%
2	Any number	5-25 %
3	Any number	25-50 %
4	Any number	50-75%
5	Any number	75 -100%

similar metrics, the relevé method has a higher observer influence than point intercept surveys and lacks the resolution needed to detect small changes in species cover over shorter periods of time (Elzinga *et al.* 2000). However, this method could be performed in years where funding or resources are limited. For these reasons, we suggest conducting both techniques.

8.6 Photo Monitoring

We identified 34 photo-monitoring stations to qualitatively assess restoration success over time (Fig. 13, Appendix B: Table 3). Photos should also be taken at the start and end of each permanent point intercept transect. We generated 10 random photo-monitoring stations within the project boundary. A digital photo should be taken at each station within the same two-week period in spring and fall each year. A compass bearing should be recorded after the first photo is taken and used to align future photos. Photo monitoring allows for qualitative documentation of plant succession and growth during the wet and dry seasons.

9 Adaptive Management

BSLT has committed to restoring the Odello East floodplain to a more natural state with a diverse assemblage of plant species. The final composition of the restoration site is likely to change with shifts in environmental conditions such as DTGW levels, precipitation patterns, floodplain microtopography, and natural recruitment. The irrigation, planting, maintenance and monitoring strategies provided are subject to change and should be adapted as new data becomes available.

9.1 Data limitations

Groundwater data were especially limited for the Carmel River FREE project site. The accuracy of our water management analysis was restricted by the number of groundwater monitoring wells and short duration of data captured within existing wells. Areas of interest for riparian, upland, and agriculture plantings, which fell outside a 100-m radius of existing wells, were considered to have poor WSE data availability. To address this data gap we created a 200-m buffer around existing wells to identify potential locations for future monitoring wells, should funding allow (Fig. 14). Increasing the number and distribution of groundwater monitoring wells would greatly improve the accuracy of future planting efforts.

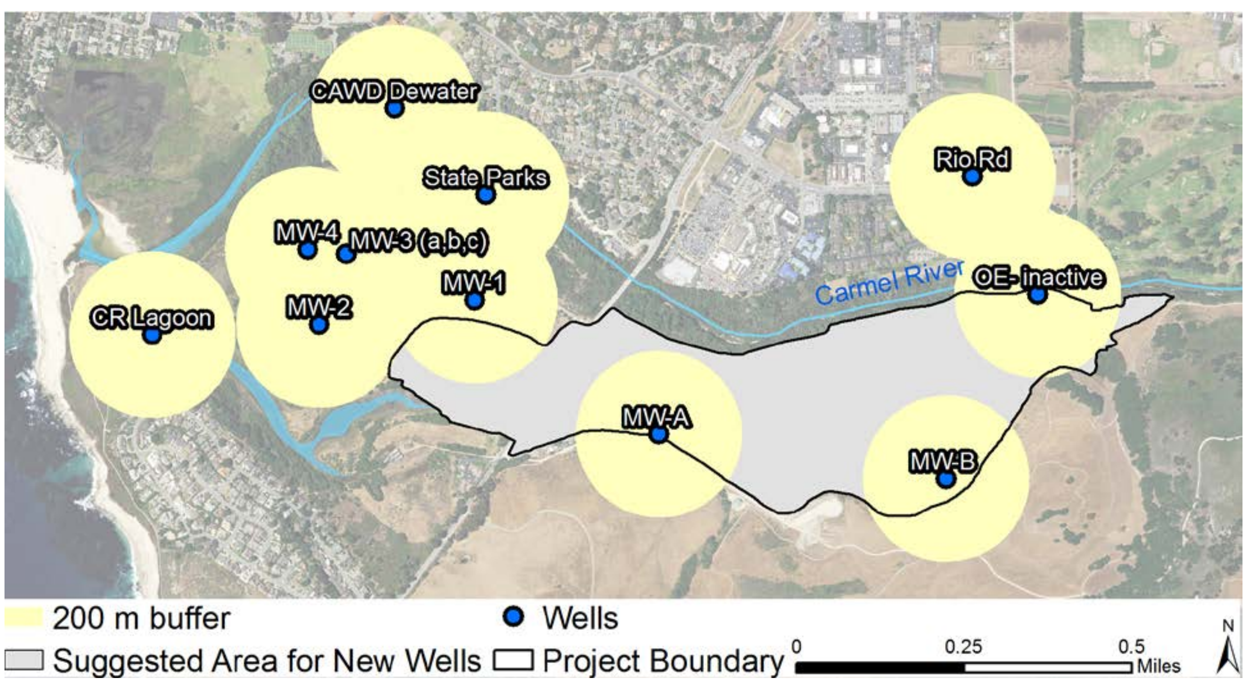

Figure 14. Suggested area for additional monitoring wells on the Carmel River FREE project site based on 200-m buffer from existing monitoring wells.

In addition, WSE data were collected during a period of below-average rainfall conditions and maximum pumping at the project site (124 afy, West Yost Assoc. 2013). Phasing, irrigation, and planting recommendations in this document should be reevaluated as new data becomes available, especially if groundwater extraction in the Carmel River Watershed decreases significantly.

9.2 Tools for Success

The Carmel River FREE project is a long-term effort that will require adaptive management to meet project goals. We have provided tools to monitor fluctuations in DTGW over time, reassess planting zone locations, irrigate efficiently, refine the planting timeline, and monitor to evaluate progress. BSLT restoration managers and project planning committees can use these tools to implement adaptive management to meet restoration success criteria and goals (HT Harvey & Assoc. 2015, USFS 2004).

10 References

Allen RG, Rereira LS, Raes D, Smith M. 1994. FAO irrigation and drainage paper, Crop evapotranspiration, Guidelines for computing crop water requirements. Food and Agriculture Organization, Water Resources. Project No. 56.

Balance Hydrologics, Inc: Ballman ED, Nazarov A, Chartrand S. 2015. Carmel River floodplain restoration and environmental enhancement project 35% design basis report. Prepared for the Big Sur Land Trust. Project No. 214044.

Balance Hydrologics, Inc: Ballman ED, Riedner E, Rianda A, Fisher GR, Liang C, Nazarov A. Weber R, Milam N, Harwayne J. 2014. California Service Area 50 final lower Carmel River stormwater management and flood control report. Prepared for the Monterey County Resource Management Agency. Project No. 212028.

Brouwer C and Heibloem M. 1986. Irrigation Water Management: Irrigation Water Needs, Training manual no.3. Food and Agriculture Organization of the United Nations.

Carmel River Watershed Conservancy. 2004. Watershed assessment and action plan of the Carmel River Watershed California. Final Document.

Cal. Code Regs. tit. 23, § 490 (2009)

[CCWG] Central Coast Wetlands Group. 2015. Carmel River Floodplain Monitoring and Assessment. Prepared for the Big Sur Land Trust.

[CCRWQCB] Central Coast Regional Water Quality Control Board. 2016. Central Coast Post-Construction Stormwater Requirements. CA.gov. [accessed 2016 Feb 20]. http://www.waterboards.ca.gov/centralcoast/water_issues/programs/stormwater/docs/lid/lid_hydromod_charette_index.shtml

[CDPR] California Department of Parks and Recreation. 2009. 2009 Carmel River Lagoon enhancement project report. 29 pp.

Cerny TA, Kopp K, and Johnson. M. 2002. Efficient Irrigation of Trees and Shrubs. *CWEL Extension Fact Sheets*. Paper 6.

Christensen T, Geisler E. 2009. Monterey Peninsula Water Management District Schulte Road restoration project. Poster.

[CIMIS 210] California Irrigation Management Systems. Station 210. Department of Water Resources, California. [Accessed 2016 November 13]. Available from: http://wwwcimis.water.ca.gov/Default.aspx

[CNPS] California Native Plant Society. 2016. Calscape. [Internet]. [cited 2016 November 20]. Available from: http://calscape.org/

Conrad C. 2016. Clint, Maggie Eastwood donate 79 acres to Big Sur Land Trust. [Internet]. [cited 2016 December 9]. Available from: http://www.ksbw.com/article/clint-maggie-eastwood-donate-79-acres-to-big-sur-land-trust/1297516

[CREP] Conservation Reserve Enhancement Program. Functions of riparian areas for flood control. Prepared for Department of Fisheries, Wildlife and Environmental Law Enforcement. Available from: http://www.nys- soilandwater.org/crep/forms/FactSheet2.pdf

Dufour S, Bernez I, Betbeder J, Corgne S, Hubert-Moy L, Nabucet J, Rapinel S, Sawtschuk J, Trolle C. 2013. Monitoring restored riparian vegetation: how can recent development in remote sensing science help?. Knowledge and Management of Aquatic Ecosystems 410(10):15 pp.

[ECI] Ecological Concerns Incorporated. 2016. Alba Triple M Ranch Wetland Restoration, Watsonville, CA. [Internet]. [Cited 2016 Nov. 15]. Available from: http://www.ecologicalconcerns.com/alba-triple-m/

Elzinga CL, Salzer DW, Willoughby JW. 1998. Measuring and Monitoring Plant Populations. Bureau of Land Management. TR 1730-1.

[ESRI] Environmental Systems Research Institute. 2016. ArcGIS Desktop: Release 10.4. Redlands, CA.

[FISRWG] The Federal Interagency Stream Restoration Working Group. 1998. Stream corridor restoration: principles, processes, and practices. GPO Item No. 0120-A. SuDocs No. A 57.6/2:EN 3/PT.653. ISBN-0-934213-59-3.

Field J. 2016. 2016 Grassland monitoring report. Prepared for the Palo Corona Regional Park. 36 pp.

Griggs FT. 2009. California riparian habitat restoration handbook, 2nd edition.

Howes DJ, Fox P, Hutton PH. 2015. Evapotranspiration from natural vegetation in the central valley of California: Monthly grass reference-based vegetation coefficients and the dual crop coefficient approach. Journal of Hydrologic Engineering.

Hubert E, Palkovic A, Dellavalle Sanvictores M. 2003. Revegetation, mitigation, and monitoring plan: Carmel River Lagoon enhancement project, Carmel River State Beach. California Department of Parks and Recreation.

Kent M, Paddy C. 2011. Vegetation description and data analysis: A practical approach.

Knight AW, Bottorff RL. 1981. The importance of riparian vegetation to stream ecosystems. University of California, Davis. California Riparian Systems Conference [Sept 17-19, 1981]. Available from: http://publishing.cdlib.org/ucpressebooks/view?docId=ft1c6003wp&chunk.id=d0e23728&toc.depth=1&toc.id=d0e23728&brand=ucpress

Konrad, CP. 2003. Effects of urban development on floods, Fact Sheet 076-03. United States Geological Survey. Available from: http://pubs.usgs.gov/fs/fs07603/

Meek J. Restoration and Monitoring of Riparian Habitat Corridors Along the Lower Mokelumne River. San Joaquin Resource Conservation District.

[MPWMD] Chronology of significant water events for the Monterey peninsula.

[MPWMD] Monterey Peninsula Water Management District. 2015. Schulte road restoration project. [Internet]. [cited 2016 November 11]. Available from: http://www.mpwmd.net/wp-content/uploads/2015/04/Schulte-Restoration-Project.pdf

Mueller-Dombois D, Ellenberg H. 1974. Aims and methods of vegetation ecology. New York: John Wiley & Sons.

National Academic Press. 2002. Riparian areas: function and strategies for management. Prepared by the Committee on Riparian Zone Functioning and Strategies for Management.

[NMFS] National Marine Fisheries Service. 2013. South-central California coast steelhead recovery plan. West Coast Region, California coastal area office, Long Beach, California.

[NRC] National Research Council. Riparian areas: functions and strategies for management. National Academy Press, Washington D.C. Available from: https://www.nap.edu/read/10327/chapter/1

[NRCS] National Resource Conservation Service, U.S. Department of Agriculture. 2016a. Geospatial Data Gateway. Usda.gov. [accessed 2016 Feb 20]. https://gdg.sc.egov.usda.gov/

[NRCS] National Resource Conservation Service, U.S. Department of Agriculture. 2016b. PLANTS database. [Internet]. [cited 2016 November 20]. Available from: http://plants.usda.gov/java/

Odello Brothers v. County of Monterey. 1998. H017028. Sixth Dist.

Philip Williams and Associates and California Coastal Conservancy. 1992. Carmel River Lagoon enhancement plan. Prepared for Carmel River Steelhead Association.

[RCDMC] Resource Conservation District of Monterey County. 2013. Carmel River Watershed stewardship manual; a user's guide for landowners and residents. Available from: http://www.rcdmonterey.org/Downloads/PDFs.html

Reich PB, Tilman D, Isbell F, Mueller K, Hobbie SE, Flynn DFB, Eisenhauer N. 2012. Impacts of biodiversity loss escalate through time as redundancy fades. Science, 336 (6081):589–592.

Roni P, Quimby E. 2005. Monitoring stream and watershed restoration. American Fisheries Society. 350 pp.

Shihadeh K, Founds D. 2008. Creamery Meadows post-restoration vegetation inventory. Prepared for the California Department of Parks and Recreation by the Ventana Wildlife Society.

[SSURGO] Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic Database. [accessed 2016 Feb 20] Available from: http://sdmdataaccess.nrcs.usda.gov/.

Stone EL, Kalisz PJ. 1991. On the maximum extent of tree roots. Forest Ecology and Management 46:59–102.

Sutton D. 2016. Preliminary Staff Recommendation to Modify Cease & Desist Order WR 2009-0060. Prepared on behalf of the Trust for Public Lands. [cited: Dec 2016] Available from: http://www.swrcb.ca.gov/waterrights/water_issues/projects/california_american_water_company/docs/tpl070716.pdf

[SWRCB] State Water Resources Control Board. 2015. Decision canceling protests, revoking a water right, and issuing water rights. Available from: http://www.swrcb.ca.gov/waterrights/water_issues/programs/applications/division_decisions/2015/DD2015_0001.pdf

[H.T. Harvey & Associates] Stephens D, Rottenborn S, Quinn M, Spangler W, Strusis-Timmer M, Ballman E, Nazarov A, Chartrand S. 2015. Restoration and management plan for the Carmel River floodplain restoration and environmental enhancement project. Prepared for the Big Sur Land Trust. Project No. 3420-03.

Taylor JL. 2000. *Populus fremontii*. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available from: http://www.fs.fed.us/database/feis/ [2016, December 1].

[TNC] The Nature Conservancy and Environmental Systems Research Institute. 1994. NBS/NPS vegetation mapping program: Final draft, standardized national vegetation classification system.

[USDOT] United States Department of Transportation Federal Highway Administration. 1998. Draft Supplemental environmental impact report/ statement for the Highway 1 improvement project.

[USDA] U.S. Department of Agriculture. Jan 2009. Hydrology National Engineering Handbook, Chapter 7: Hydrologic Soil Groups. [accessed 1 December 2016] Available from: http://www.wcc.nrcs.usda.gov/ftpref/wntsc/H&H/NEHhydrology/ch7.pdf

[USDA] U.S. Department of Agriculture Forest Service. 2016. Fire effects information system (FEIS). [Internet]. [cited 2016 November 20]. Available from: http://www.feis-crs.org/feis/

[USFS] United States Department of Agriculture Forest Service. 2004. Riparian restoration. San Dimas, CA.

[USGS] U.S. Geological Survey. 2011. 20140331, NLCD 2011 Land Cover (2011 Edition), U.S. Geological Survey, Sioux Falls, SD.

[USGS] U.S. Geological Survey. 2016. The National Map, 2016, 3DEP products and services: The National Map, 3D Elevation Program Web page, accessed 2016 October 06. Available from: http://nationalmap.gov/3DEP/3dep_prodserv.html

Viers JH, Fremer AK, Hutchinson RA, Quinn JF, Thorne JH, Vaghti MG. 2011. Multiscale patterns of riparian plant diversity and implications for restoration. Restoration Ecology, 20 (2): 160-169.

Watson F. 1993. Altitudinal distribution of vegetation in the headwaters of the Wongungarra River, Victoria. University of Melbourne. 86 pp.

West Yost Associates. 2013. Groundwater and surface water evaluation report Eastwood/Odello water right change petition project. Prepared for Macaulay Water Resources and Barkiewics, Kronick, and Shanahan. 131 pp.

Wright JM, Chambers JC. 2002. Restoring riparian meadows currently dominated by Artemisa using alternative state concepts- above ground vegetative response. Applied Vegetation Science. 5:237-246.

Van Dyke E, Holl KD. 2003. Mapping the distribution of maritime chaparral species in the Monterey Bay area. Prepared for the U.S. Fish and Wildlife Service. 22pp

Van Dyke E, Holl KD. 2001. Maritime chaparral community restoration in the absence of fire. Department of Environmental Studies. University of California Santa Cruz.

11 Appendix A: ETWU and Supplemental Irrigation

Table 1. Monthly and annual ETWU and Supplemental Irrigation needed for each planting zone given low (9.7 in), average (15.5 in) and high (21.2 in) annual precipitation (P_e). Greyed out cells represent months in which supplemental irrigation is not required.

		ETWU (af/a)					ETWU – $P_{e, low}$				
Year	Month	MFCA	Willow & Cottonwood	Mixed Riparian	Upland	Ag	MFCA	Willow & Cottonwood	Mixed Riparian	Upland	Ag
1	Jan	0.143	0.173	0.145	0.117	0.119	0.101	0.131	0.103	0.075	0.077
	Feb	0.178	0.223	0.166	0.109	0.153	0.129	0.174	0.117	0.059	0.104
	Mar	0.273	0.312	0.252	0.191	0.215	0.224	0.263	0.203	0.142	0.166
	Apr	0.326	0.407	0.354	0.300	0.204	0.325	0.406	0.353	0.299	0.202
	May	0.173	0.471	0.379	0.288	0.209	0.173	0.471	0.379	0.288	0.209
	Jun	0.057	0.573	0.373	0.172	0.229	0.057	0.573	0.373	0.172	0.229
	Jul	0.016	0.593	0.345	0.097	0.216	0.016	0.593	0.345	0.097	0.216
	Aug	0.010	0.595	0.325	0.055	0.570	0.010	0.595	0.325	0.055	0.570
	Sep	0.005	0.557	0.295	0.032	0.534	0.005	0.557	0.295	0.032	0.534
	Oct	0.004	0.421	0.218	0.015	0.421	0.004	0.421	0.218	0.015	0.421
	Nov	0.102	0.237	0.161	0.085	0.273	0.087	0.222	0.146	0.070	0.258
	Dec	0.147	0.145	0.163	0.181	0.094	0.087	0.085	0.103	0.121	0.034
	Annual	1.433	4.708	3.175	1.642	3.237	1.217	4.492	2.959	1.426	3.021
		ETWU – $P_{e, avg}$					ETWU – $P_{e, high}$				
Year	Month	MFCA	Willow & Cottonwood	Mixed Riparian	Upland	Ag	MFCA	Willow & Cottonwood	Mixed Riparian	Upland	Ag
1	Jan	0.049	0.079	0.051	0.023	0.025	−0.004	0.026	−0.002	−0.030	−0.028
	Feb	0.072	0.117	0.060	0.003	0.047	0.014	0.058	0.001	−0.056	−0.011
	Mar	0.168	0.207	0.146	0.086	0.109	0.109	0.148	0.088	0.027	0.051
	Apr	0.297	0.379	0.325	0.272	0.175	0.270	0.351	0.298	0.244	0.148
	May	0.173	0.471	0.379	0.288	0.209	0.173	0.471	0.379	0.288	0.209
	Jun	0.057	0.573	0.373	0.172	0.229	0.057	0.573	0.373	0.172	0.229
	Jul	0.016	0.593	0.345	0.097	0.216	0.016	0.593	0.345	0.097	0.216
	Aug	0.010	0.595	0.325	0.055	0.570	0.010	0.595	0.325	0.055	0.570
	Sep	0.005	0.557	0.295	0.032	0.534	0.005	0.557	0.295	0.032	0.534
	Oct	−0.012	0.406	0.202	−0.001	0.406	−0.035	0.383	0.180	−0.024	0.383
	Nov	0.051	0.187	0.111	0.035	0.222	0.015	0.151	0.075	−0.001	0.186
	Dec	0.023	0.021	0.039	0.057	−0.030	−0.043	−0.044	−0.026	−0.009	−0.096
	Annual	0.921	4.184	2.651	1.119	2.743	0.669	3.906	2.357	0.915	2.525

12 Appendix B: Sample Data Monitoring Data Sheets

Table 1. Sample data sheet for conducting generalized relevés using the Braun-Blanquet scale. A more in-depth relevé can be conducted by identify specic species cover in each plantig zone. Table 6 identifies the vegetative species and type which may be planted or recruited in each plant zone.

Surveyor:____________________ Date: _______________

Plant zone: ____________________ Transect: __________________

		Braun-Blanquet cover/abundance scores							
Transect ID	Point ID	Water	Soil	Shrub	Tree	Grass	Herb	Weed	Note

Braun-Blanquet Scores
0.1 = Rare / Solitary, with small cover
0.5 = Few, with small cover
1 = Numerous, but cover < 5%
2 = Any number, cover 5-25%
3 = Any number, cover 25-50%
4 = Any number, cover 50-75%
5 = Any number, cover 75-100%

Table 2. Sample data sheet for compiling point intercept surveys to document percent cover and status. Asterisk (*) indicates species that were listed in the Restoration and Management Plan (HT Harvey & Assoc. 2015). Not bolded species are non-native, potentially invasive species.

			Number of Counts			Counts		
Common Name	Scientific Name	Species Co	Native	Non- Native	% Cover	A	Y	D
Arroyo willow*	***Salix lasiolepis***	SALLAS						
Black cottonwood*	***Populus trichocarpa***	POPTRI						
Black mustard	*Brassica Nigra*	BRANIG						
Blue blossom*	***Ceanothus thyrsiflorus***	CEATHY						
Blue elderberry*	***Sambucus nigra***	SAMNIG						
Blue wild rye*	***Elymus glaucus***	ELYGLA						
Blue-eyed grass	***Sisyrinchium bellum***	SISBEL						
Box elder*	***Acer negundo***	ACENEG						
CA brome*	***Bromus carinatus***	BROCAR						
CA sycamore*	***Platanus racemosa***	PLARAC						
California aster	***Symphyoctrichum chilense***	SYMCHI						
California blackberry*	***Rubus ursinus***	RUBURS						
California buckeye*	***Aesculus californica***	AESCAL						
California hedgenettle	***Stachys bullata***	STABUL						
California man-root	***Marah fabacea***	MARFAB						
California oatgrass	***Danthonia californica***	DANCAL						
California rose	***Rosa californica***	ROSCAL						
California sagebrush*	***Artemisia californica***	ARTCAL						
Checkerbloom	***Sidalcea malviflora***	SIDMAL						
Coast live oak*	***Quercus agrifolia***	QUEAGR						
Coast twinberry	***Lonicera involucrata***	LONINV						
Coffeeberry*	***Frangula californica***	FRACAL						
Common rush*	***Juncus patens***	JUNPAT						
Coyote brush*	***Baccharis pilularis***	BACPIL						
Creek clematis	***Clematis ligusticifolia***	CLELIG						
Creek clover*	***Trifolium obtusiflorum***	TRIOBT						
Creek dogwood*	***Cornus sericea***	CORSER						
Creeping snowberry	***Symphoricarpos mollis***	SYMMOL						
Creeping wildrye	***Elymus tritichoides***	ELYTRI						
Deerweed	***Acmispon glaber***	ACMGLA						
Dune rush	***Juncus lescurii***	JUNLES						
Flowering currant	***Ribes sanguineum***	RIBSAN						
French broom	*genista monplessulana*	GENMON						
Gumplant	***Grindelia stricta***	GRISTR						
Himilayan Blackberry	*Rubus armeniascus*	RUBARM						
Iris leaved rush	***Juncus xiphioides***	JUNXIP						
Meadow barley*	***Hordeum brachyantherum***	HORBRA						
Mugwort*	***Artemisia douglasiana***	ARTDOU						
Mulefat*	***Baccharis salicifolia***	BACSAL						
Narrowleaf willow	***Salix exigua***	SALEXI						
Panicled bulrush	***Scirpus microcarpus***	SCIMIC						
Poinson hemlock	*conium maculatum*	CONMAC						
Red willow*	***Salix laevigata***	SALLAE						
Salt marsh baccharis	***Baccharis glutinosa***	BACGLU						
Silverweed cinquefoil	***Potentilla anserina***	POTANS						
Small fescue*	***Festuca microstachys***	FESMIC						
Stinging nettle	***Urtica dioica***	URTDIO						
Toyon*	***Heteromeles arbutifolia***	HETARB						
Valley sedge	***Carex barbareae***	CARBAR						
Water parsley	***Oenanthe sarmentosa***	OENSAR						
White alder*	***Alnus rhombifolia***	ALNRHO						

Table 3. Coordinates for transect lines and photo monitoring stations. (WGS 1984 UTM Zone 10)

TransectID	StationID	X	Y
	1A	597052.03	4043654.18
1	1B	597001.79	4043652.09
	1A	596945.28	4043800.71
2	1B	596895.04	4043798.62
	3A	597338.39	4043786.89
3	3B	597336.29	4043837.13
	4A	597244.19	4043631.99
4	4B	597193.95	4043629.90
	5A	597220.33	4043721.58
5	5B	597222.42	4043671.35
	6A	597646.09	4043648.73
6	6B	597643.99	4043698.97
	7A	597700.93	4043781.86
7	7B	597751.17	4043783.95
	8A	597844.94	4043707.34
8	8B	597895.18	4043709.43
	9A	597911.51	4043800.69
9	9B	597909.42	4043850.93
	10A	598243.49	4043804.46
10	10B	598193.26	4043802.36
	11A	598445.28	4043792.73
11	11B	598395.04	4043790.64
	12A	598379.55	4043920.84
12	12B	598429.79	4043922.93
	13	596974.34	4043839.29
	14	596948.08	4043764.41
	15	597436.71	4043754.60
	16	597541.90	4043805.51
	17	597638.84	4043612.03
	18	597735.00	4043649.16
	19	597829.06	4043647.79
	20	598023.06	4043581.20
	21	598116.99	4043521.91
	22	598212.89	4043937.95