Change everywhere to three years and separate out what we can/not pay for with current money

Three Creeks Parkway Restoration Project Adaptive Management and Monitoring Plan

A Project With American Rivers and Contra Costa County Flood Control and Water Conservation District

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Acronyms and Abbreviations

AMMP	Adaptive Management and Monitoring Plan
BACI	Before/after, control/impact
BASMAA	Bay Area Storm Water Management Agencies Association
BMI	Benthic macroinvertebrate
BMPs	Best Management Practices
BOD	Biochemical Oxygen Demand
CASQA	California Association of Stormwater Agencies
CCCWP	Contra Costa Clean Water Program
CCCFCD Or "District"	Contra Costa County Flood Control and Water Conservation District
CDFW	California Department of Fish and Wildlife
CEDEN	California Environmental Data Exchange Network
CNDDB	California Natural Diversity Database
COC	Chain of Custody
CRAM	California Rapid Assessment Method
CVRWQCB	Central Valley Regional Water Quality Control Board
DO	Dissolved oxygen
DRERIP	Delta Regional Ecosystem Restoration Implementation Plan
DWR	California Department of Water Resources
EBRPD	East Bay Regional Park District
ECCCHC	East Contra Costa County Habitat Conservancy
ECCID	East Contra Costa Irrigation District
EPT	Ephemeroptera, Plecoptera, and Trichoptera
FOMCW	Friends of Marsh Creek Watershed
HCP	East Contra Costa County Habitat Conservation Plan
IBI	Contra Costa Index of Biological Integrity
MRP	Municipal Regional Permit
NCCP	Natural Community Conservation Plan
NHI	Natural Heritage Institute
NPDES	National Pollutant Discharge Elimination System
OHWM	Ordinary high water mark
PAHs	Polycyclic aromatic hydrocarbons
PBDEs	Polybrominated diphenyl ethers
PCBs	Polychlorinated biphenyls
QAPP	Quality Assurance Project Plan
RMP	San Francisco Bay Regional Monitoring Program
SES	Stellar Environmental Solutions, Inc.
SFBRWQCB	San Francisco Bay Regional Water Quality Control Board
SJCDWQC	San Joaquin County Delta Water Quality Coalition
SOPs	Standard operating procedures
SSID	Stressor/Source Identification

STLS	Small Tributaries Loading Strategy
SWAMP	Surface Water Ambient Monitoring Program
TDS	Total dissolved solids
TKN	Total Kjeldahl nitrogen
TMDL	Total Maximum Daily Load
TSS	Total suspended solids
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
WRAMP	Wetland and Riparian Area Monitoring Program
WSEL	Water surface elevation level
WWTP	Brentwood Wastewater Treatment Plant
WY	Water year

1.0 INTRODUCTION AND PURPOSE

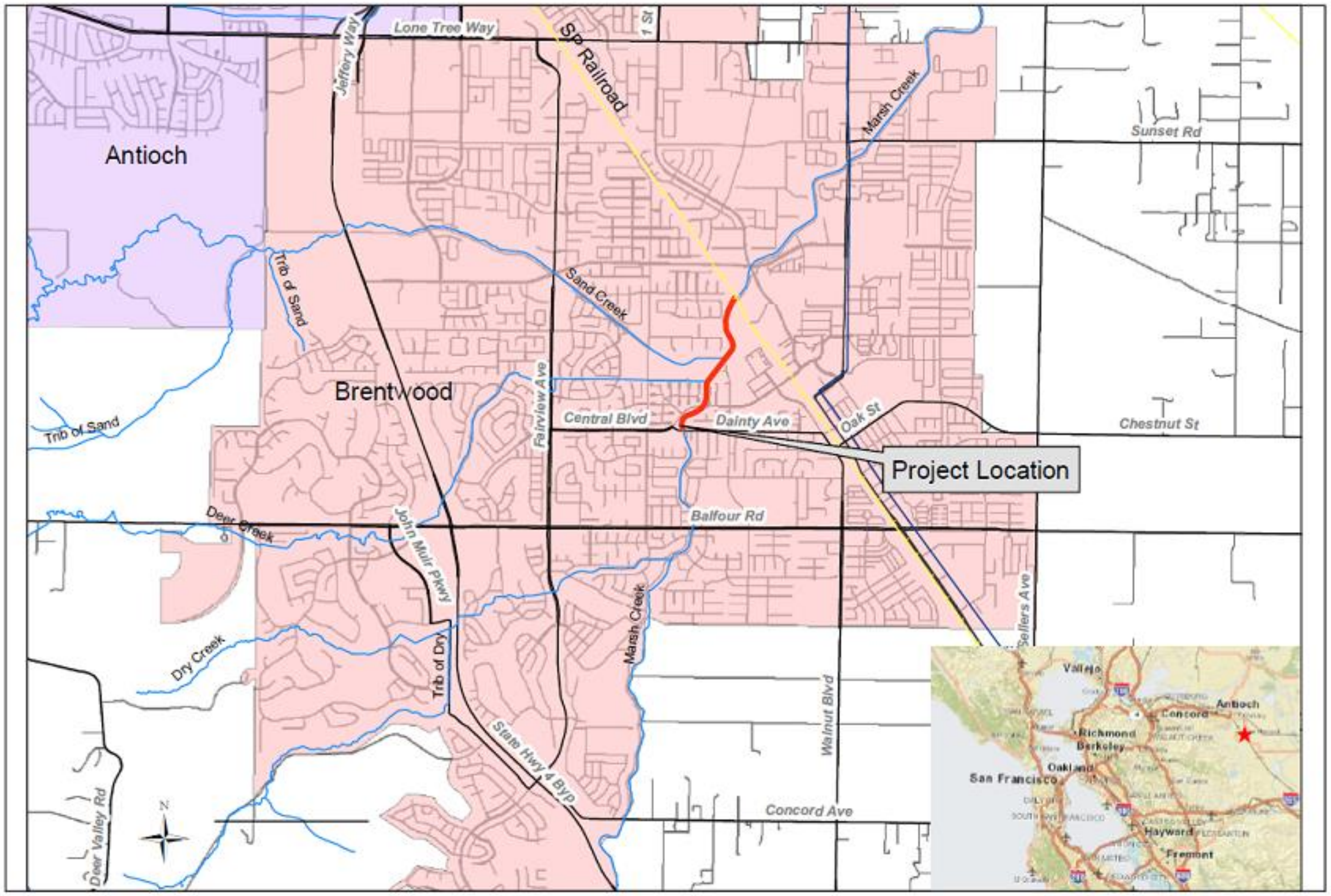
1.1 Project Background and Location

The Three Creeks Parkway Restoration project is a multi-benefit flood control and creek restoration project proposed by the Contra Costa County Flood Control and Water Conservation District (CCCFCD or "District") and American Rivers, a national non-profit organization that protects wild rivers, restores damaged rivers and conserves clean water for people and nature. It proposes to improve flood conveyance capacity and restore native vegetation along an approximately 4,000 linear feet section of Marsh Creek located in Brentwood by widening the channel with a floodplain (or sections where more constrained, floodplain benches) and planting with native vegetation. When implementation is complete, the project site will include 2.14 acres of frequently inundated floodplain (seasonal wetland), and 4.42 acres of upland habitat (grasslands and oak woodland). The project will also enhance habitat and recreation within the watershed.

In addition to the CCCFCD and American Rivers, other project partners include the City of Brentwood, the Friends of Marsh Creek Watershed (FOMCW), East Contra Costa County Habitat Conservancy (ECCCHC), and East Bay Regional Park District (EBRPD).

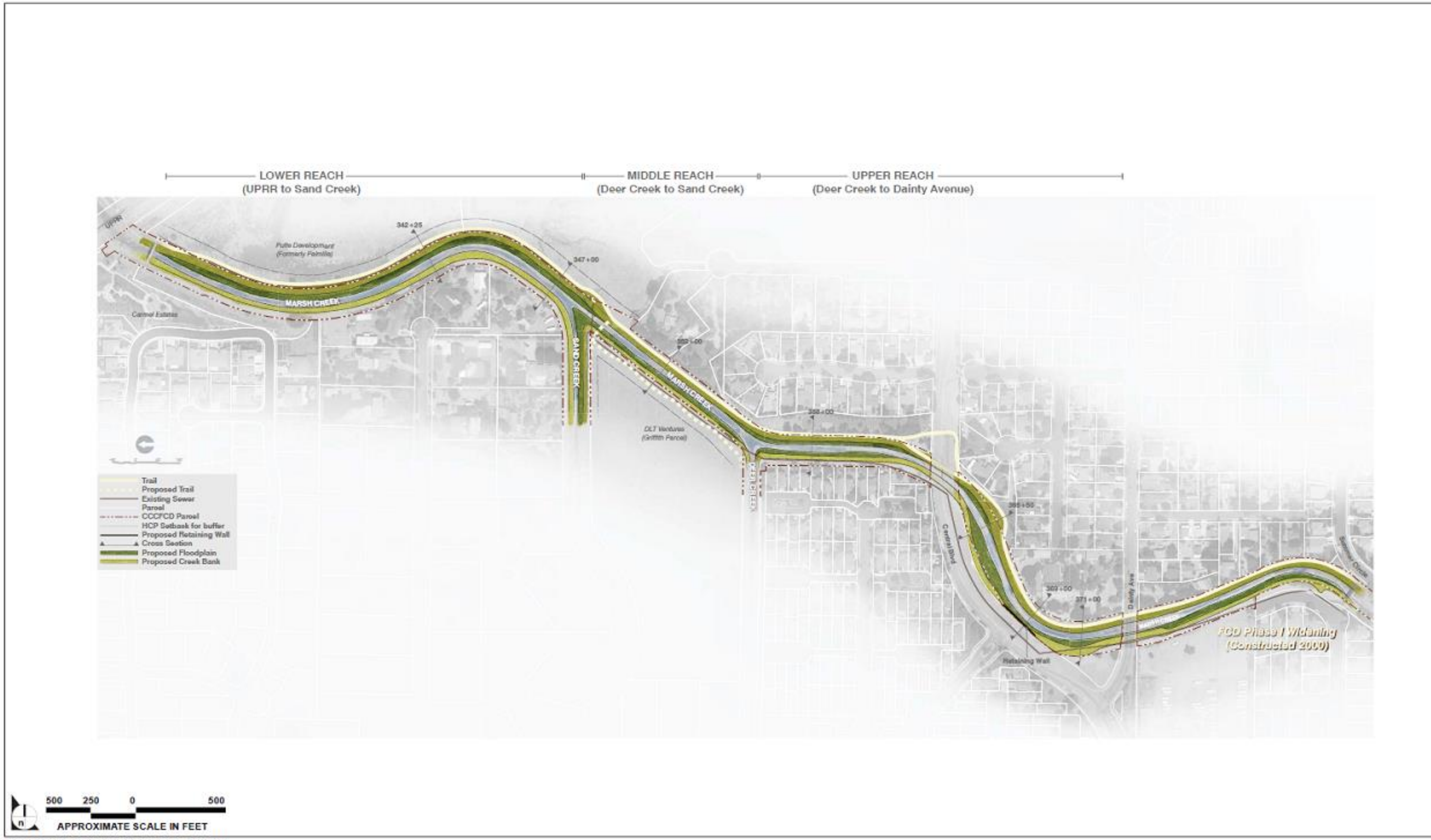
Marsh Creek watershed, located about 35 miles east of San Francisco, is uniquely situated between the Bay-Delta and the Diablo Range, providing an important ecological corridor in a burgeoning urban area. Marsh Creek flows 30 river miles from the eastern slope of Mount Diablo State Park in central Contra Costa County to the San Joaquin Delta at Big Break in Oakley. Major tributaries to Marsh Creek include Dry, Deer, and Sand Creeks. Through the existing EBRPD park facilities and trails, Marsh Creek also provides a cultural and physical connection to the Delta, allowing East County residents to walk and bike from Big Break and its aquatic recreation facilities, through Oakley to downtown Brentwood. Thus, Marsh Creek provides one of the longest, non-motorized pathways in Contra Costa County.
The project site is located along Marsh Creek in the City of Brentwood (**Figure 1)**.

The upper/southern limit of the project is just north of Dainty Avenue Bridge while the lower/northern limit is the pedestrian bridge across Marsh Creek about 175 feet south of the Union Pacific Railroad (UPRR) tracks. Marsh Creek trail, a regional trail owned by EBRPD is located on the east bank of Marsh Creek within the project area. As shown in **Figure 2**, the project is divided into three reaches.



SOURCE: Restoration Design Group, Inc. 2016

Figure 1. Project Location



SOURCE: Restoration Design Group, Inc. 2016

Figure 2. Project Site Plan

1.2 Project Goals and Objectives

During the 1960s and early 1970s, approximately 7.9 miles of Marsh Creek from the mouth of the creek near Big Break on San Joaquin Delta in Oakley to the Dry Creek confluence in Brentwood were channelized into earthen and armored trapezoidal flood control channels. To provide conveyance capacity, the flood control channel was designed with steep banks, all riparian vegetation along the channel was removed, and the earthen channel was vegetated with non-native grasses. The channel was designed for a 50-year flood event in an agricultural setting.

Since the flood control channel was constructed, the upper watershed has remained mostly protected parklands and open space, but the lower watershed has urbanized rapidly. Over the last 25 years, the population of the Marsh Creek watershed has increased six-fold. This development has transformed the watershed into a dense residential and commercial area, covering open space with impervious surfaces, substantially increasing runoff volume and degrading water quality. The District has constructed detention basins on each of Marsh Creek's three tributaries (Dry, Deer, and Sand Creeks) to accommodate increased run-off associated with urban development and impervious surfaces; however, urban and agricultural runoff remain issues.

An Engineer's Report prepared by the CCCFCD in January 1990 identified the need to widen 7,000 feet of Marsh Creek to reduce flooding in the lower portion of the watershed. Based on the report, the District prepared a plan to widen the creek in three phases, with Phase I involving creek widening from Summer Circle to near Dainty Avenue Bridge, Phase II (" Upper Reach") involving widening from near Dainty Avenue Bridge to Deer Creek confluence, and Phase III ("Middle Reach") widening the creek between Deer Creek and Sand Creek. In March 1990 the "Draft Environmental Impact Report for the Marsh Creek Watershed, Regional Drainage Plan" was published and a Final EIR was subsequently approved. Following this approval, Phase I was completed in 2000, which included the installation of a new concrete culvert at Dainty Avenue and creek widening that was almost entirely on the east bank. Downstream of Phase I, Marsh Creek does not meet the District's standards for flood protection, exposing adjacent homes and businesses to flood risk. When looking at the capacity within the channel the District requirement for containment is controlled by the 50-year water surface elevation level (WSEL) plus freeboard or the 100-year WSEL, whichever one is higher. District analysis indicates that for the channel downstream of Phase I project, the 50-year WSEL plus freeboard will be greater than the 100-year WSEL and dictates the channel design.

The project will widen the downstream sections of the creek so that the 100-year storm water surface elevation level and the 50-year storm plus WSEL would be contained within the creek channel.

Both the channelization that was implemented in the 1960s and early 1970s and the removal of riparian vegetation for flood management have limited the ecological functions of the creek. These factors have severely limited habitat complexity, structure, shade, riparian inputs, and floodplain wetlands. High velocities during annual peak flow events, which are exacerbated by increased peak run-off from newly urbanized surfaces, presumably flush most of the egg and larval stages of aquatic species downstream. Poor water quality from urban run-off is made worse by the lack of wetlands, shade, and microbial activity. Relatively high temperatures combined with low dissolved oxygen levels have likely contributed to multiple fish kills on Marsh Creek in recent years. The combination of fish kills and poor habitat complexity limits the productivity, diversity, and resilience of the creek ecosystem. The Integrated

Monitoring Report prepared by the Contra Costa Clean Water Program (CCCWP) for 2012-2013 (CCCWP 2014) summarizes some of the causes of DO, pH and temperature problems in Marsh Creek:

> "Previous observation of Marsh Creek and Walnut Creek have shown that slow currents, warm water temperatures, and a high degree of channel exposure to solar radiation result in extensive growth of filamentous algae in the wetted creek channel. When this large amount of algae biomass is living, it begins to produce dissolved oxygen by photosynthesis once the sun rises, particularly as it shines on the water. If there is minimal current and wind rippling the stream channel waters, super saturation of dissolved oxygen is common. During the night, the algae revert to respiration and consume dissolved oxygen, dropping the stream's dissolved oxygen level to its minimum by dawn. Carbon dioxide produced by the algae during the evening's respiration is the major natural factor holding down the pH of the water. When excessive dissolved oxygen is produced in the stream water because of a large volume of living algae or aquatic plant biomass responding to the sunlight, the carbon dioxide in the water is greatly reduced and pH rises. So even long before decomposition of the dying filamentous algae in the fall increases the stream's Biochemical Oxygen Demand (BOD) and lowers levels of dissolved oxygen, the natural cycle of algae photosynthesis during the day and respiration during the night causes large shifts in dissolved oxygen and pH on a diurnal basis."

The project is expected to help alleviate these severe water quality problems by restoring floodplain that will provide shade, lower water temperatures, and moderate algae production and nutrients. The project proposes to improve the ecological functions of the creek by reducing flow velocities, creating wetlands, and restoring riparian habitat. Although much of the watershed has been constrained by urbanization, the Three Creeks Parkway Restoration project site is the longest remaining stretch of undeveloped land along the creek where there is still an opportunity to widen the channel and provide a more natural creek system that is connected to the historic floodplain.

The project would also improve recreational amenities. Currently the Marsh Creek Trail located along the east bank of Marsh Creek passes through a primarily treeless stretch of land. With the restoration of riparian vegetation along the creek banks, the project would provide areas where trail users can stop in the shade and enjoy the beauty of the creek which will improve the experience of the trail users.

The primary goal of the project is to improve habitat along Marsh Creek by restoring riparian and floodplain habitat along the Marsh Creek flood control channel. The project will advance this goal by expanding the channel enough to allow for the growth of riparian vegetation while minimizing the need for future long-term vegetation management and satisfying the Flood Control District's flood capacity requirement.

The specific objectives of this project are to:

1. Restore floodplain and native vegetation along 4,000 linear feet of Marsh Creek between Dainty Avenue and the Union Pacific Railroad.
2. Dramatically improve habitat by restoring 13.5 weedy, ruderal and treeless acres including planting native vegetation to enhance the creek's ecosystem, such as frequently inundated floodplain (seasonal wetland), woody riparian vegetation, grasslands and native scrub that will provide habitat for several species covered by the East Contra Costa County Habitat Conservation Plan/Natural Community Conservation Plan (HCP/NCCP).

3. Help alleviate water quality problems in Marsh Creek by providing vegetation and canopy which is expected to reduce water temperature, help limit algal growth, and assist in nutrient removal.
4. Create an attractive parkway environment that provides ample shade along the Marsh Creek Trail.
5. Implement a successful multi-benefit flood management project that can serve as a catalyst for other projects along Marsh Creek and throughout the Delta watershed.

The project will increase floodplain area and native vegetation by excavating a floodplain along the banks of approximately 4,000 linear feet of the Marsh Creek flood control channel. The project will improve riparian habitat by reestablishing native vegetation within the flood control channel.

1.3 Project Components

This project is an innovative non-structural approach to flood management and habitat restoration. Instead of trying to control the creek in a narrow zone with levees and floodwalls, it focuses on giving the creek more room to safely convey flood waters while also providing habitat for aquatic and terrestrial species. **Table 1** below presents basic information about the project. Details of the project components follow the table.

Table 1. Project Data

Element	Upper Reach	Middle Reach	Lower Reach
Length	1,600 feet	800 feet	1,600 feet
Total Area Disturbed	2.1 acres	1.0 acre	4.25 acres
Soil Excavation	10,500 cu yards	2,500 cu yards	13,000 cu yards
Floodplain or bench width Bench slopes to top of bank	3-15 feet 2:1 or 3:1	3-15 feet 2:1 or 3:1	10-30 feet 3:1 or less typical, 2:1 max.
Temporary Staging/Access Areas[1]	Within creek parcels (017-17C-004, 017-20C-XXX) or adjacent City-owned parcel (017-210-004, 017-201-038, 017-260-080, 017-280-113)[2]	Within creek parcel (017-17C-004) or adjacent parcel (017-110-011)	Within creek parcels (017-17C-004) or adjacent private parcels (017-170-008, 017-170-007)
Permanent Access/Maintenance Easements[1]	017-260-080 017-280-113 017-201-038 017-210-029	017-110-011	017-170-007 017-170-008

[1] Some or all of the non-County-owned parcels would potentially require a temporary construction easement for access and staging and/or permanent easement for access and/or maintenance.

Channel Widening

The main function of expanding the channel is to create enough conveyance capacity to allow for the planting of woody riparian vegetation (trees) while also safely conveying large flood flows. The project will increase the cross-sectional area of the stream channel by excavating 24,000 cubic yards (5,500 for upper, 3,500 for middle, and 15,000 for lower reach,) of earth along approximately 4,000 linear feet of both banks of Marsh Creek to create new floodplain.

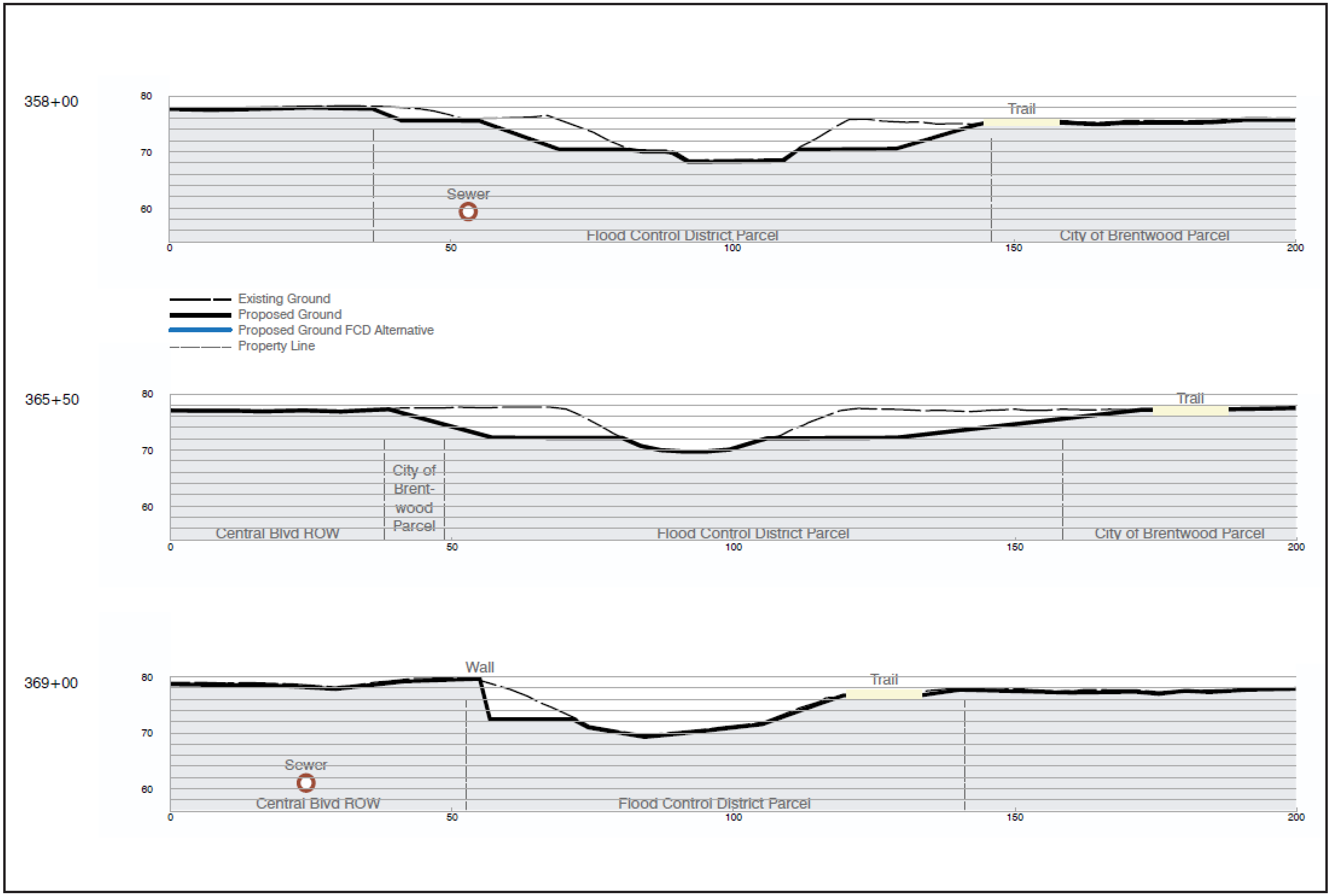
Upper Reach

As noted earlier, the Upper Reach is approximately 1,600 feet of the channel between just north of Dainty Avenue bridge and the Deer Creek confluence. The reach is constrained by development on both sides and channel widening in this section will include excavation of both banks to construct a number of floodplain benches on both sides of the creek of varying widths with slopes ranging from 2:1 to 3:1 (**Figure 3**). The benches will be located above the ordinary high water mark (OHWM). The construction of the floodplain benches would satisfy the District's freeboard requirements for an earthen channel. **Figure 4** presents existing and modified creek cross-sections for this reach. Once the benches are constructed, permanent slope protection such as erosion control matting or other biotechnical methods would be installed on all benches and slopes for slope stabilization and to prevent long-term effects of erosion. The selected erosion control material would provide soil stabilization and promote vegetation growth.

Widening the channel cross-section is expected to decrease velocities and erosion potential. However, detailed hydraulic modeling that will be completed to inform the final design may indicate that some bank armoring is necessary where the expanded channel will taper down to the existing channel at the downstream project boundary. In one location along the Upper Reach, the project will require a retaining wall along approximately 250 feet on the left (west) bank due to the presence of Central Boulevard in Brentwood that will extend approximately 5 feet above ground. The retaining wall will rise from the back of the floodplain and would not touch the low flow channel. The project also includes replacement and repair of grouted rock at the Deer Creek confluence.

SOURCE: Restoration Design Group, Inc. 2016

Figure 3. Upper Reach Improvements



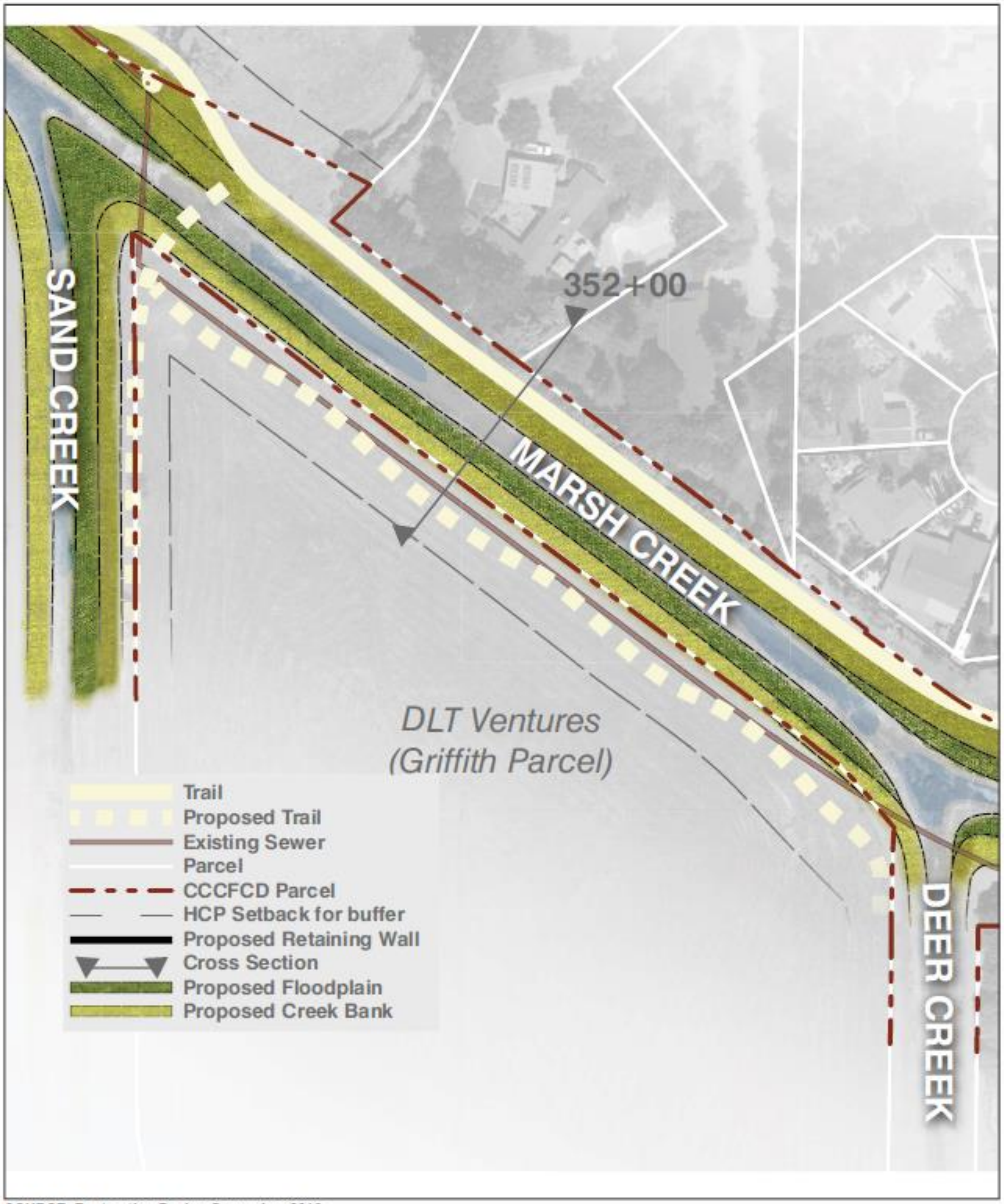
SOURCE: Restoration Design Group, Inc. 2016

Figure 4. Upper Reach Cross Sections

Middle Reach

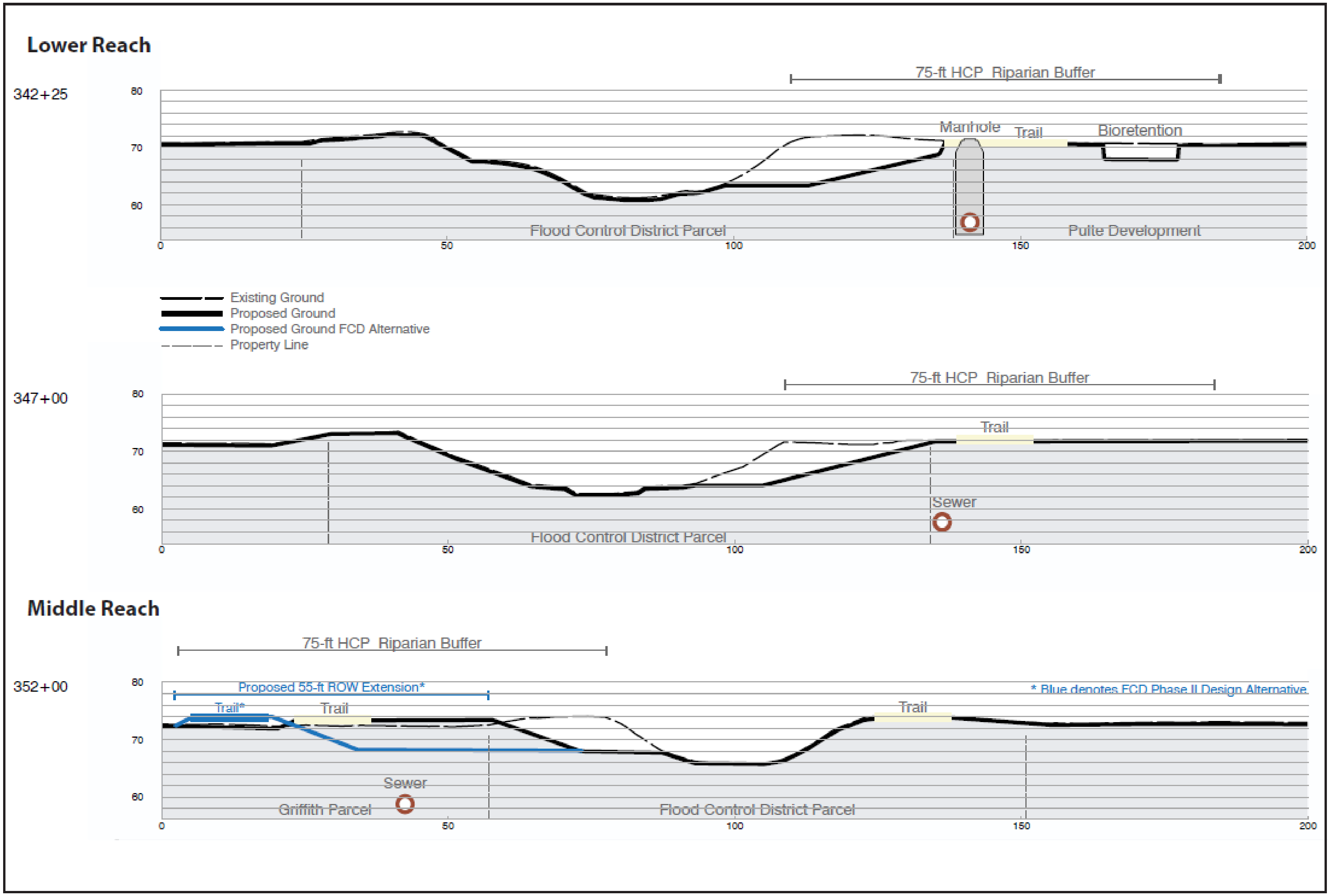
The Middle Reach, which is about 800 feet in length, will be widened along the west bank as part of the proposed project. As the Middle Reach is also constrained, channel widening will involve excavation of both banks to construct a number of floodplain benches of varying widths as shown in **Figure 5**, with slopes ranging from 2:1 to 3:1. The benches will be located above the OHWM. The construction of the floodplain benches will satisfy the District's freeboard requirements for an earthen channel. **Figure 6** presents existing and modified creek cross-sections for this reach.

The Griffith parcel (also known as DLT Ventures or the Hancock parcel) is a 10.2 acre undeveloped property located between Sand and Deer Creeks adjacent to the west side of the middle reach of Marsh Creek (017-110-011) **(Figure 6)**. The Griffith parcel is bounded on the north, south, and east by channelized creek and to the west by private residential property. These lands are strictly uplands and are located above the top of bank of all three creeks. The vacant Griffith parcel will be used as a staging area and the placement of excavated material (26,000 cubic yards) for the updated project. The excavated material would be spread across the parcel to elevate the ground surface (**Figure 7**).



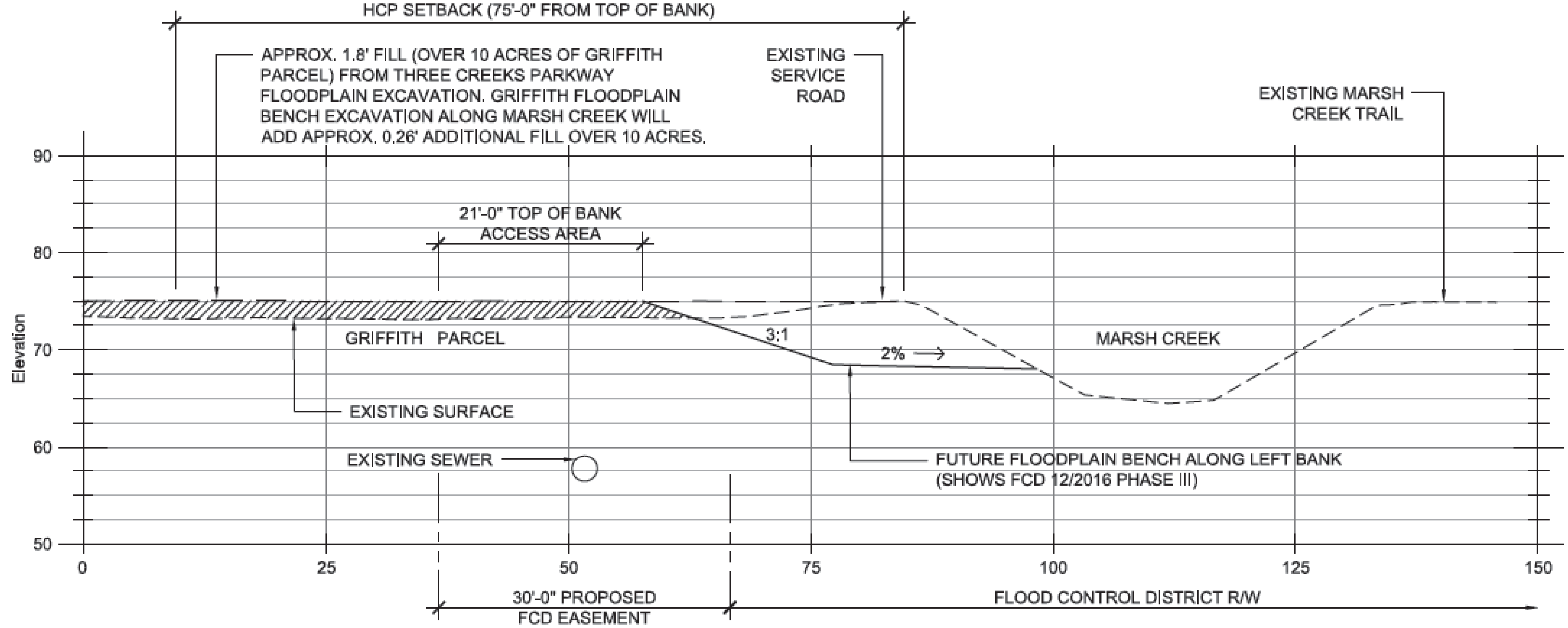
SOURCE: Restoration Design Group, Inc. 2016

Figure 5. Middle Reach Improvements



SOURCE: Restoration Design Group, Inc. 2016

Figure 6. Middle and Lower Reach Cross Sections



SOURCE: Restoration Design Group, Inc. 2017

Figure 7. Griffith Parcel Section

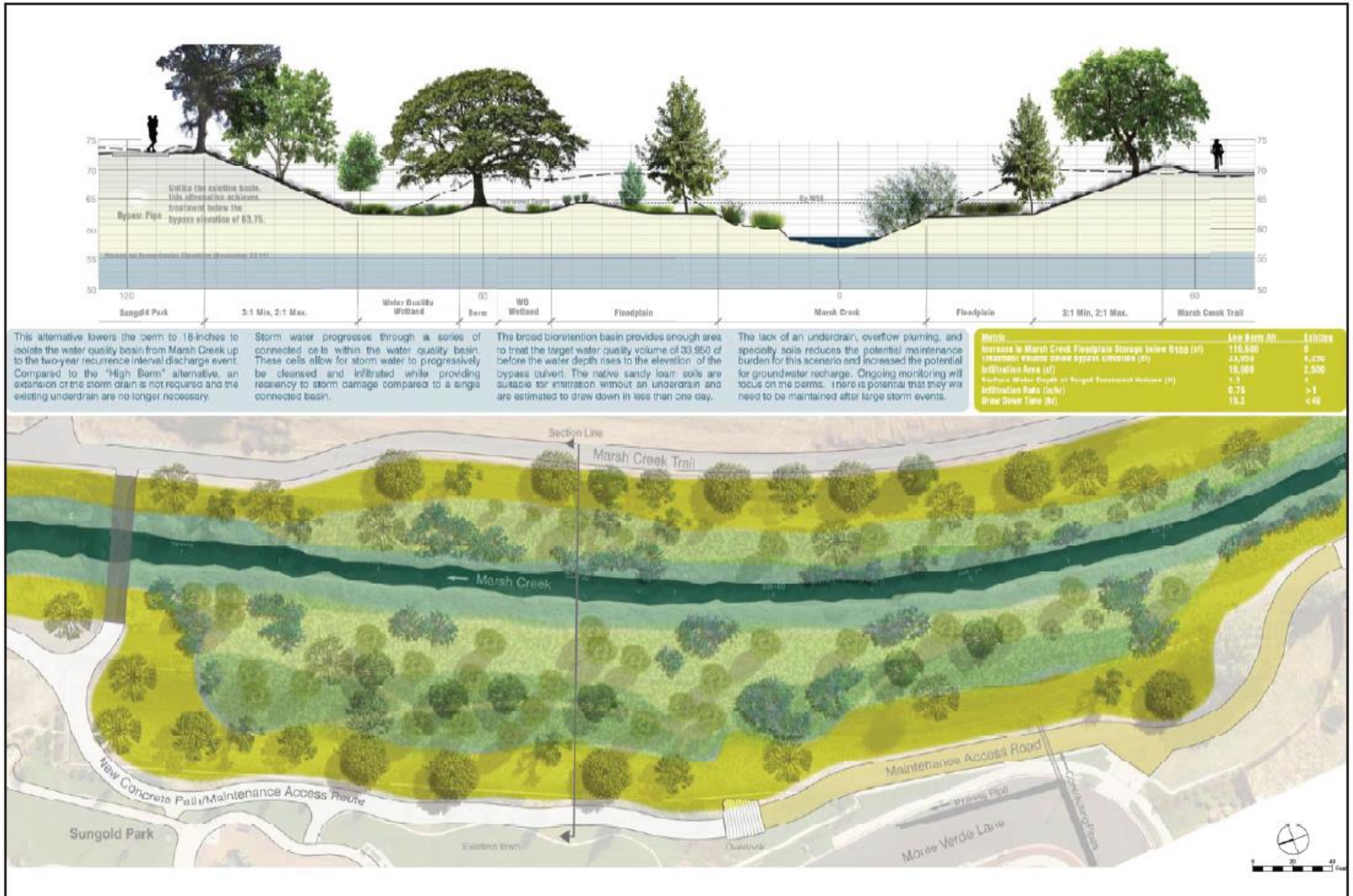
Lower Reach
The Lower Reach, which is about 1,600 feet in length, is less constrained, and more substantial widening of the channel is planned for this area. The project will excavate the east bank of the creek down to the OHWM to create a 10 to 40-foot wide floodplain with slopes typically 3:1 or less, but never more than 2:1 (**Figure 8**). **Figure 6** presents existing and modified creek cross-sections for this reach. If bank protection is necessary at some locations, the project would use biotechnical methods or large rocks to create an aesthetically pleasing bank.

Although erosion is currently not a problem, the project will reduce the potential for erosion by lowering water stage, reducing the velocity by widening the cross-sectional velocity of the channel, and establishing native riparian vegetation where compatible with the flood management objectives. To prevent weathering and erosion of slopes, permanent slope protection in the form of erosion control matting, armor, biotechnical methods, or appropriate ground cover would be installed, and the material would provide soil stabilization and promote vegetation growth.

There is an existing 0.7-acre linear water quality/detention basin (Assessor Parcel 017-670-040) located between Carmel Estates/Sungold Park and Marsh Creek to detain runoff from the Carmel Estates residential development for treatment before discharge into Marsh Creek (**Figure 7)**. The detention basin is enclosed on all sides by a fence. This basin would be incorporated into the project by adding native vegetation including trees and shrubs, creating a creekside mulch path, removing the fences, and lowering the eastern berm of the basin and western bank of the creek (**Figure 8**). This would allow flood waters from the creek to spill into the basin as needed. The western fence may be reinstalled along the western length of the basin. In addition, a new trail, which would also serve as a District maintenance access road, would be added to the adjacent City of Brentwood Sungold Park (017-670-039, 017-450-065). Other improvements, such as landscaping and a creek overlook with seating and an interpretive area, would be added to showcase the environmental benefits of the project (**Figure 9**). The total area of improvements would be approximately 3.25 acres.

SOURCE: Restoration Design Group, Inc. 2016

Figure 8. Lower Reach Improvements



SOURCE: Restoration Design Group, Inc. 2017

Figure 9. Incorporation of Water Quality Basin and Improvements to Sungold Park

Low-Flow Channel
The existing low-flow channel within project limits is engineered with rock grade control structures and banks. The existing, engineered channel has proven stable over the last 40 years and the rock grade control structures create a sequence of pools and riffles that provide some habitat for aquatic species. The excavation for floodplain widening typically will not touch the low-flow channel below the OHWM. The new floodplain will be graded to inundate during the storm events with the low-flow channel continuing to function much as it does today. Some work in the low-flow channel may be performed and would include creation of instream habitat in the low-flow channel by placing boulders and large woody debris, and the placement of rock slope protection in some portions of the low-flow channel in the Upper and Middle Reaches.

Sewer Line
A 33" City of Brentwood sewer main is located on the west side of the Upper Reach (as shown in **Figures 3 and 4**). For most of the length, the sewer is within the Central Boulevard right of way. However, a portion of this sewer is located within one of the District's parcels where flood control improvements would be constructed. The sewer line is over 15 feet deep, at least 4 feet below the flow line of the creek. As the sewer line is below the maximum depth of excavation, it would not be relocated.

Near Sand Creek confluence in the Middle and Lower Reach, the sewer main crosses under the creek and continues north along the east bank of the Lower Reach. In the Lower Reach, the sewer line is located within the area that would be excavated to create the right (east) bank floodplain. The sewer line will not be relocated to the east on the Pulte residential subdivision project site. The City of Brentwood has requested that the floodplain widening be stopped short of the existing sewer alignment so it does not need to be relocated. Throughout the project reach, minor modifications to sewer manholes may be required to accommodate changes in ground elevation. In all cases, grading will be performed around manholes so that potential spills from manholes would initially drain away from Marsh Creek.

Establishment of Wetlands
The newly created flood benches and floodplain would be inundated when flows in the creek rise during typical storm events that recur nearly annually. The floodplain and benches would be expected to be inundated frequently enough that they will support wetlands. The project will create approximately 2.14 acres of frequently inundated floodplain (seasonal wetland). However, to minimize mosquito breeding in the aquatic environment, floodplain and benches will be sloped at two percent to drain flood flows back to the creek and prevent ponding that would allow mosquitos to breed.

Revegetation Activities
Where possible, existing trees along the creek would be protected and retained. Following the construction of channel widening activities, depending on location, the project area will be planted with native wetland forbs, grasses, shrubs, and trees. Riparian trees will be planted along the banks and will include valley oak, sycamore, live oak, buckeye, cottonwood, and willow.
Slopes and banks will be planted with grassland and scrub species, which would include creeping wild rye (*Elymus triticoides*), California brome (*Bromus carinatus*), purple needlegrass (*Stipa pulchra, deawned*), silver lupine (*Lupinus albifrons)*, mugwort (*Artemisia douglasiana*), common yarrow (*Achillea millefolium*), narrow-leaved milkweed (*Asclepias fascicularis*)), reduced wild buckwheat (*Eriogonum nudum*) and California poppy (*Eschscholzia californica*). Areas of the floodplain will be planted with seasonal wetland species that will include, but not be limited to, seep monkey flower (*Erythranthe guttata*), Baltic rush (*Juncus balticus*), and Santa Barbara sedge (*Carex barbarae*).

In 2000, the District completed Phase I widening of Marsh Creek from Dainty Avenue upstream to approximately Summer Circle (**Figure 2**). While additional widening of this segment is not proposed for this project due to constraints from the adjacent subdivisions, native shrubs and trees may be planted to provide a continuous riparian corridor with the existing riparian vegetation upstream of this segment and the proposed restoration of the project.

Recreational Improvements
The project will enhance opportunities for strolling, hiking, and biking along Marsh Creek. Marsh Creek trail will be relocated to the new top of the eastern bank along Upper and Middle Reach as part of the proposed project. The relocated trail section within the Upper Reach would be routed to pass under the Central Avenue road bridge. The trail section along the eastern bank of the Lower Reach will be relocated by the Pulte developer and this trail relocation is not within the scope of this project. However, the project will reduce the gradient of the steep slope between the creek and the trail and would provide a new unpaved foot trail within the created floodplain. Pervious pavement is being considered for use on the relocated trail. The City of Brentwood Parks, Trails, and Recreation Master Plan (2002) shows a future pedestrian bridge connecting the current Marsh Creek Regional Trail to the Griffith (DLT Ventures) property in the Middle Reach that would allow people to safely access and cross the creek as well as access possible future trails along Sand Creek and/or Deer Creek. These components are not part of this project. The City of Brentwood will be updating its Master Plan and the location of these features may be adjusted appropriately.

The lower 1,600 feet of the project will be integrated into a new linear city park, which will provide passive recreation amenities and native landscaping consistent with creek restoration. Consistent with the standards of the East Contra Costa County Habitat Conservation Plan (HCP), native trees will be planted within a 60-linear foot band of two city parks, along the west side of Pulte development within the HCP/NCCP required setback to provide a natural buffer adjacent to the creek. The project will also include interpretive signs along Marsh Creek.

Temporary Creek Crossings
The project anticipates up to six temporary creek crossings to facilitate construction access between the excavation areas on the east side of Marsh Creek and the Griffith parcel on the west side of Marsh Creek. Temporary creek crossings would occur across Marsh Creek near the water quality basin in the lower reach, and across Sand, Marsh and Deer creeks to the Griffith parcel on the west bank (**Figure 2**). While Figure 2 shows four crossings locations, the actual number, locations, and design will be determined by the project contractor. The creek crossings would be installed by placing a temporary culvert in the channel and then placing fill (i.e., clean gravel) that is wrapped in geotextile fabric over the culvert. The fabric would keep the fill separated from the creek environment and would make the removal clean and quick, as the fill would be kept separate from the creek bed materials. The fill material utilized would be free of silt or other contaminants. Each culvert could be up to 60 feet in length. Total area of each crossing would be approximately 2,500 square feet and each crossing would require approximately 600 cubic yards of fill material. The culverts would extend below the ordinary high water mark (OHWM) but fill would be expected to remain mostly above.
The creek crossings would be in place only during the grading operations. Upon completion of grading, the earthen fill, fabric, and pipe would be removed and the original channel conditions restored. Any surface flows in these channels at the time of installation would be uninterrupted and Best Management Practices (BMPs) would be in place to ensure there is no release of sediment

downstream. However, at least one creek crossing is proposed to remain in place through restoration planting to connect the Griffith parcel on the west side of Marsh Creek with the east side of the creek.

Operations and Maintenance

American Rivers and the Contra Costa County Flood Control and Water Conservation District will prepare an Operations and Maintenance Plan for this project. This plan will specify how the project site will be managed after implementation of the Three Creeks Restoration Project, including compliance with any permit requirements.

1.4 Monitoring objectives

Project monitoring will be conducted for multiple purposes, including:

- Compliance with permits and other regulatory requirements;
- Quantitative evaluation of project performance;
- Evaluation of project benefits and long-term trends;
- Education, outreach, and community engagement; and
- Information collection for adaptive management.

Each of the above monitoring objectives is described in the following subsections.

1.4.1 Compliance Monitoring

Regulatory permits obtained for constructing the Project have associated conservation and mitigation measures that require specific monitoring actions to satisfy compliance. These monitoring elements focus on permitting requirements and mitigation measures under the United States Army Corps of Engineers (USACE), CVRWQCB), and California Department of Fish and Wildlife (CDFW) permits, and Section 7 consultations with the USFWS. Monitoring requirements will be documented in the Operations and Maintenance Plan once the final permits have been issued.

1.4.2 Performance Monitoring

Project performance monitoring will focus on evaluating achievement of specific project objectives that are within the control of the project, are expected to be achieved within the first few years and are not expected to be heavily influenced by factors that can't be controlled by or are not part of the project. To evaluate success in meeting overall project goals, the Project Sponsor (Contra Costa County Flood Control and Water Conservation District and American Rivers) or representative will conduct monitoring. Specific details about who will be responsible for conducting monitoring immediately following project implementation, during the establishment period, and in the long-term, will be documented in the Operations and Maintenance Plan. Monitoring will be conducted in the following areas:

- Vegetation. Monitor restoration vegetation to assess the success of riparian habitat.
- Floodplain Morphology and Deposition. Monitor topographic changes on the floodplain surface alongside the Marsh Creek flood control channel. Not all changes to floodplain morphology or vegetation are detrimental. Considerable reconfiguration of physical features may be expected. As long as changes do not adversely affect flood conveyance, bank stability, structural integrity, or habitat quality, intervention may not be required.

1.4.3 Monitoring of Project Benefits and Long Term Trends

The project is also expected to result in benefits in other areas such as water quality and ecosystem communities including fish, aquatic invertebrates, birds, and wildlife. However, these are affected by many factors outside of the project and may fluctuate from year to year for multiple reasons, making them impractical for use as indicators of project performance. For example, water quality is heavily impacted by agricultural, residential, and industrial runoff upstream of the project site. Although floodplain restoration is expected to help mitigate certain water quality problems, conditions will be driven primarily by upstream runoff and it will not be practical to use water quality monitoring to try to quantify the success of the project. It will be useful to include water quality in the overall monitoring program so that additional measures outside of the project can be considered for future implementation to enhance the aquatic ecosystem of the Marsh Creek watershed. Therefore, in addition to project performance monitoring, some types of monitoring will be conducted for purposes of evaluating project benefits in conjunction with long term trends, identifying potential additional actions, engaging community groups, and providing data for future adaptive management both for this project and for the Marsh Creek watershed in general.

Monitoring in this category will include the following and will be coordinated with community volunteer groups:

- Water Quality: Measure water quality parameters in Marsh Creek and tributaries near the project site.
- Fish: Conduct fish counts during the salmon migration season.
- Aquatic Ecology: Conduct benthic macroinvertebrate bioassessment to evaluate the success of stream ecosystem improvements.
- Birds, amphibians, reptiles, and other wildlife: Conduct periodic monitoring with volunteers to identify species using the project site.
- Recreation: Conduct surveys to evaluate public opinion regarding the value of the restoration project.

1.4.4 Adaptive Management

Monitoring for the Project will follow an adaptive management approach. Adaptive management is a framework allowing for a flexible decision-making process for ongoing knowledge acquisition, monitoring, and evaluation, leading to continuous improvements in management and implementation of a project to achieve specified objectives (Delta Reform Act, Water Code Section 85052). In addition to project-specific adaptive management, information gained can be used to help guide future restoration planning and design efforts. Additional details on the adaptive management approach can be found in Sections 5.4 and 7.0 of this document.

2.0 CONCEPTUAL MODEL

Per the guidelines of the Delta Plan, we used the best available science to identify conceptual models and guide the planning and design for this project, and we will continue to use best available science in the adaptive management process. The criteria for best available science from the Delta Plan are laid out in Table 2.

Table 2. Criteria for Best Available Science (from Delta Plan)

Criteria	Description
Relevance	Scientific information used should be germane to the Delta ecosystem and/or biological and physical components (and/or process) affected by the proposed decisions. Analogous information from a different region but applicable to the Delta ecosystem and/or biological and physical components may be the most relevant when Delta-specific scientific information is nonexistent or insufficient. The quality and relevance of the data and information used shall be clearly addressed.
Inclusiveness	Scientific information used shall incorporate a thorough review of relevant information and analyses across relevant disciplines. Many analysis tools are available to the scientific community (e.g., search engines and citation indices).
Objectivity	Data collection and analyses considered shall meet the standards of the scientific method and be void of nonscientific influences and considerations.
Transparency and openness	The sources and methods used for analyzing the science (including scientific and engineering models) used shall be clearly identified. The opportunity for public comment on the use of science in proposed covered actions is recommended. Limitations of research used shall be clearly identified and explained. If a range of uncertainty is associated with the data and information used, a mechanism for communicating uncertainty shall be employed.
Timeliness	Timeliness has two main elements: (1) data collection shall occur in a manner sufficient for adequate analyses before a management decision is needed, and (2) scientific information used shall be applicable to current situations. Timeliness also means that results from scientific studies and monitoring may be brought forward before the study is complete to address management needs. In these instances, it is necessary that the uncertainties, limitations, and risks associated with preliminary results are clearly documented.
Peer review	The quality of the science used will be measured by the extent and quality of the review process. Independent external scientific review of the science is most important because it ensures scientific objectivity and validity. The following criteria represent a desirable peer review process. Coordination of Peer Review. Independent peer review shall be coordinated by entities and/or individuals that (1) are not a member of the independent external review team/panel and (2) have had no direct involvement in the particular actions under review. Independent External Reviewers. A qualified independent external reviewer embodies the following qualities: (1) has no conflict of interest with the outcome of the decision being made, (2) can perform the review free of persuasion by others, (3) has demonstrable competence in the subject as evidenced by formal training or experience, (4) is willing to utilize his or her scientific expertise to reach objective conclusions that may be incongruent with his or her personal biases, and (5) is willing to identify the costs and benefits of ecological and social alternative decisions.

When to Conduct Peer Review. Independent scientific peer review shall be applied formally to proposed projects and initial draft plans, in writing after official draft plans or policies are released to the public, and to final released plans. Formal peer review should also be applied to outcomes and products of projects as appropriate.

Because the primary ecological goal of this project is to increase floodplain and riparian habitat, we utilized the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) conceptual models for floodplains and riparian vegetation. Representative schematics of these models are presented in Figures 10 and 11 below.

Figure 10. MODEL ONE – Creating the template (from DRERIP)

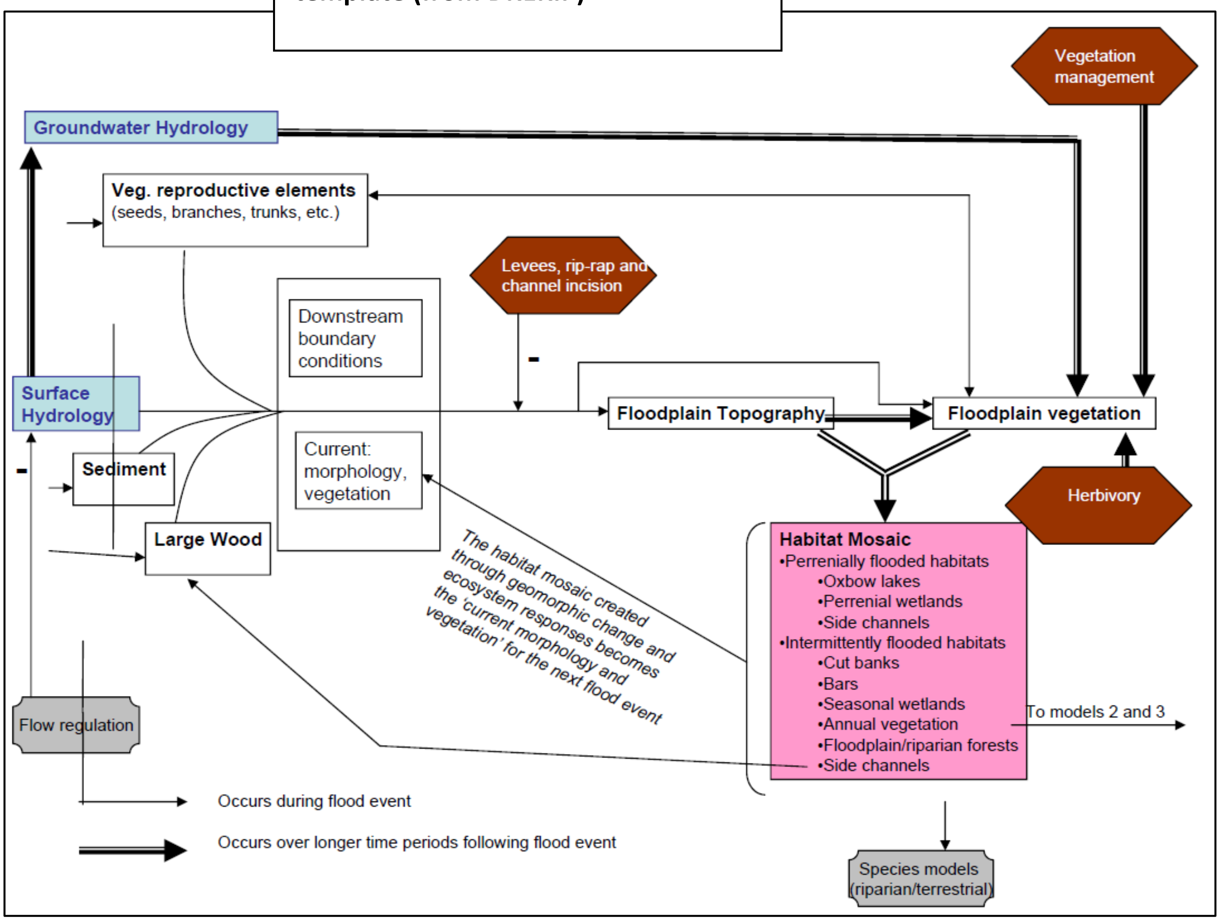
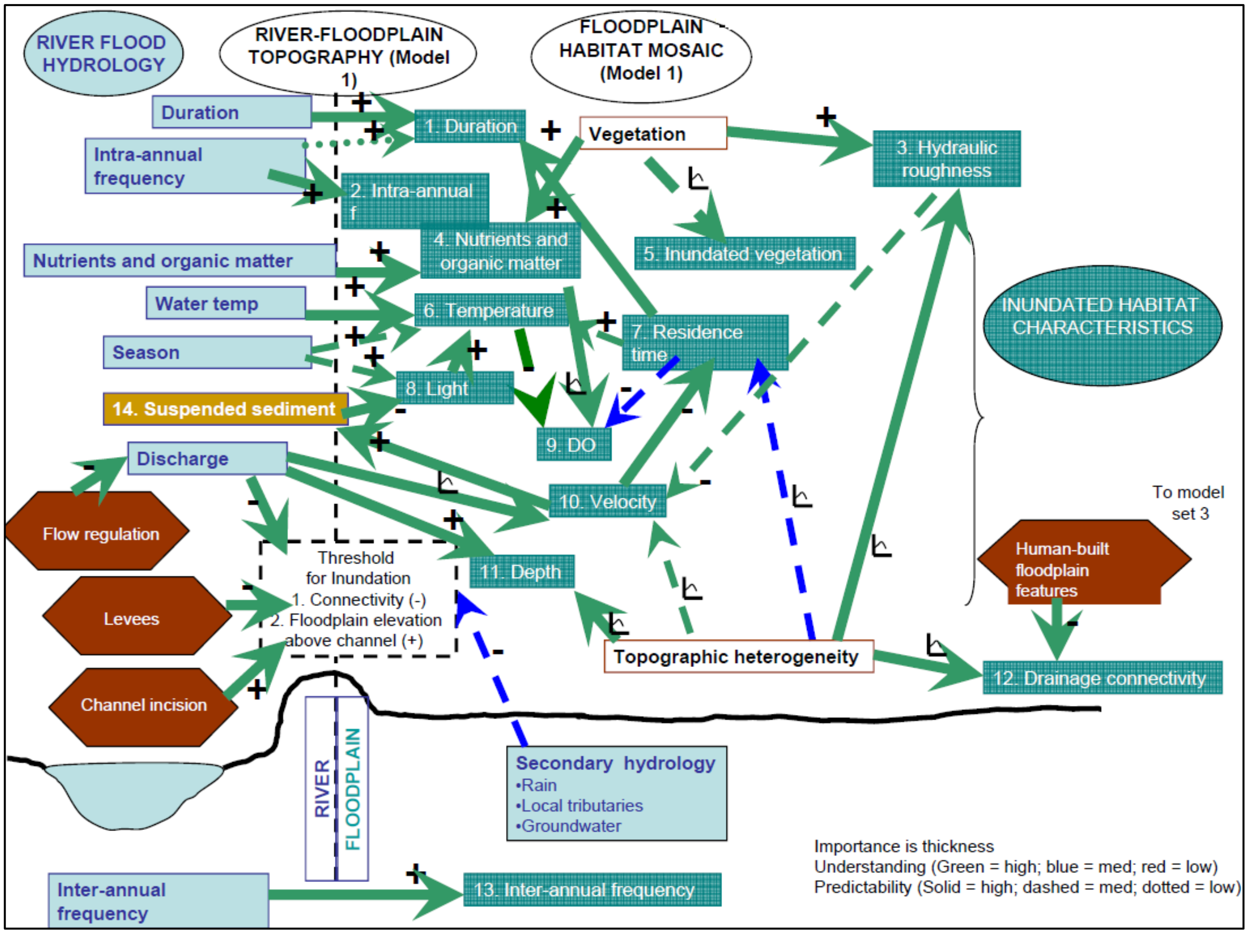


Figure 11. MODEL TWO – Inundating the template (from DRERIP)



The prerequisite for an ecologically functional floodplain (i.e., that which can produce the benefits considered here) is hydrological connectivity between the river and floodplain (Amoros, 1991; Tockner and Stanford, 2002). Floodplains can potentially export biologically available carbon to downstream food webs (Junk *et al.*, 1989; Benke, 2001). Central Valley floodplains can produce high levels of phytoplankton and other algae, particularly during long-duration flooding that occurs in the spring (Schemel *et al.*, 2004; Sommer *et al.*, 2004; Ahearn *et al.*, 2006). Algae provide the most important food source for zooplankton in the Delta (Muller-Solger *et al.*, 2002) and these zooplankton are a primary food source for numerous Delta fish species. Consequently, a potential benefit of floodplain restoration is an increase in the productivity of food webs that support Delta fish species (Ahearn *et al.* 2006).

Juvenile Chinook salmon (*Oncorhynchus tshawytscha*) have faster growth rates on floodplains than in mainstem river channels (Sommer *et al.*, 2001b; Jeffres *et al.*, 2008). Juvenile Chinook can enter and rear on floodplains during their downstream migrations in the winter and early to mid-spring. The juveniles have access to a diverse and dense prey base on floodplains—zooplankton density can be 10-100 times greater in a floodplain compared to the river (Grosholz and Gallo, 2006)—along with generally more favorable habitat conditions (warmer, slower water, fewer predators). These conditions translate to faster growth compared to juveniles rearing in rivers. Faster growth has been documented in the upper Sacramento (Limm and Marchetti, 2009), the Yolo Bypass (Sommer *et al.*, 2001b), and the Cosumnes River (Jeffres *et al.* 2008). Faster growth rates allow juveniles to attain larger sizes when they enter the estuary and ocean, and body size has been found to be positively associated with survival to adulthood for salmonids (Unwin, 1997, Bond *et al.* 2008).

In general, floodplain benefits for juvenile Chinook should increase with increasing duration of flooding, as longer time on the floodplain provides more opportunities for feeding within a more productive environment than river channels. However, even relatively short periods of access may provide benefits as fish reared in enclosures on floodplain habitats showed rapid growth in a two-week interval on the Cosumnes River floodplain (Jeffres *et al*., 2008). Salmon population benefits will increase with increasing interannual frequency of flooding. Several pulses (and associated high residence time draining periods) within a year may be associated with greater productivity, and so, several pulses may also benefit salmon growth rates. Several pulses may also give salmon the opportunity to exit the floodplain, although stranding does not appear to be a major problem for native fish (Sommer *et al.*, 2004).

Recruitment of Sacramento splittail, known to congregate at the mouth of Marsh Creek, is also strongly correlated with the duration of inundation in the Yolo Bypass; inundation of at least a month appears to be necessary for a strong year class of splittail (Sommer *et al.*, 1997). Splittail benefit from inundated floodplain in numerous ways. Flooded annual vegetation is the preferred spawning substrate, and floodplains may provide abundant food resources for adults prior to spawning and for larva after hatching. Flooded areas may also reduce predation on both eggs and larval fish. Extensive spawning of splittail has also been observed in the Cosumnes River Preserve; splittail rearing in these floodplain habitats generally had higher condition factors than fish rearing in the river or ditch habitats (Ribeiro *et al*., 2004).

Floodplain connectivity (i.e., the magnitude, frequency, duration, and timing of a natural or artificial hydraulic connection between a river channel and its floodplain) is a critical element of a healthy river ecosystem (Bayley, 1995). The ability of a river channel to overflow its banks and inundate its adjacent floodplain is essential to maintaining channel complexity and habitat. Reduced floodplain connectivity results in increased velocities and scour, which ultimately lead to reduced hydraulic and habitat diversity (Schiemer *et al*., 1999). For example, channel confinement by levees increases bed shear stresses and velocities of high flows, thereby increasing the frequency of channel bed mobilization and bank erosion and reducing complexity of the river channel.

Floodplain and channel complexity can influence water temperature dynamics in several ways. Riparian vegetation shading reduces rates of water temperature warming while inundation of complex channel and floodplain features increases hyporheic exchange (Tompkins, 2006; Arrigoni *et al*., 2008). High inflows drive hyporheic exchange directly by forcing water into alluvial features such as side channels and sand bars, and indirectly facilitate hyporheic exchange by creating and maintaining complex channel and floodplain morphology.

During low-flow conditions that occur along with high ambient air temperature, hyporheic exchange can have significant cooling effects**. Figure 12** is a plot of one day of water temperature data from downwelling and upwelling hyporheic exchange sites in lower Deer Creek, a tributary to the Sacramento River near Vina, CA. The figure illustrates the potential influence of hyporheic exchange on river water temperature. Peak temperature reduction is the difference between the daily peaks of the downwelling and upwelling water temperatures. Amplitude reduction is the difference between the downwelling amplitude of water temperature fluctuation (i.e., daily peak minus daily minimum) and the upwelling amplitude of water temperature fluctuation. Lag time is the difference between the time of the upwelling daily peak temperature and the downwelling peak temperature.

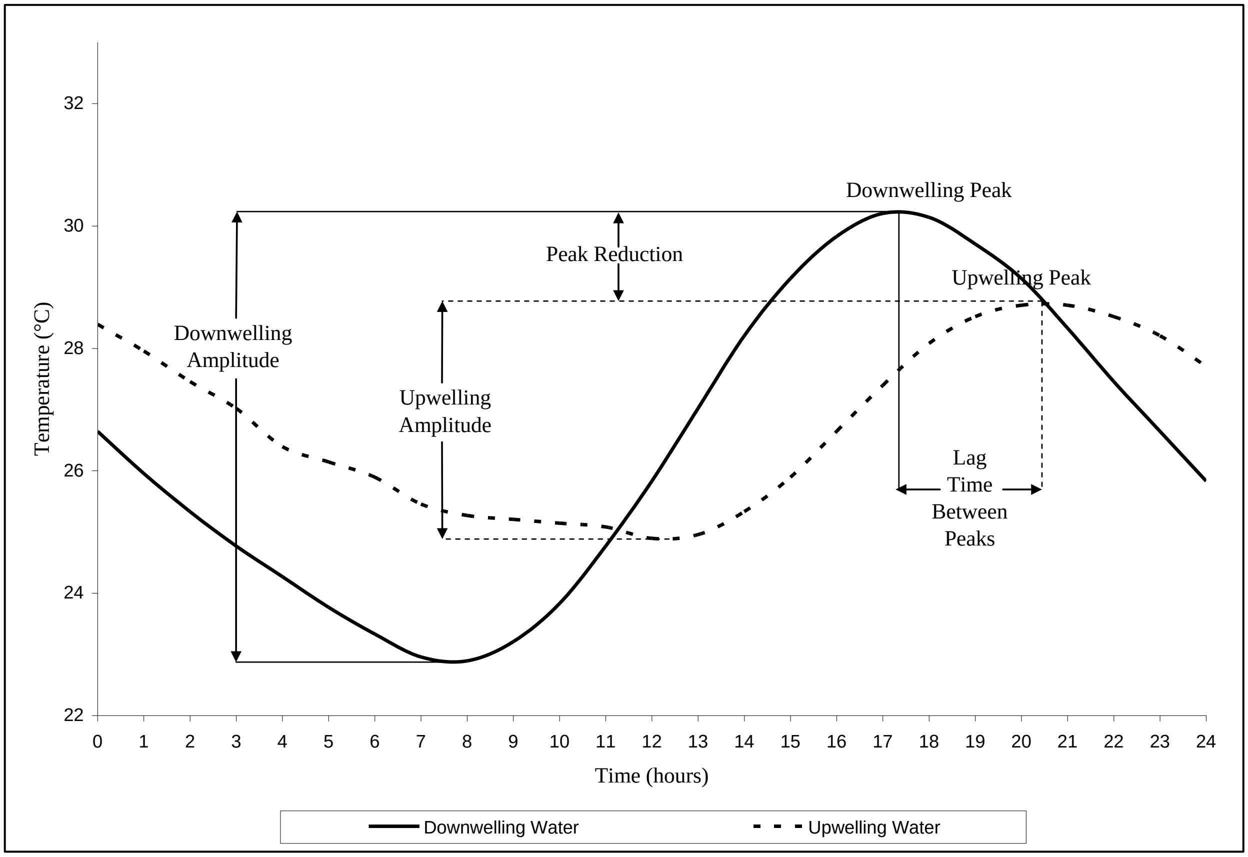


Figure 12: Temperature impacts of hyporheic exchange from Tompkins (2006).

Arrigoni *et al.* (2008) observed that upwelling hyporheic water cooled relative to downwelling surface water by up to 1.1 °C, and the magnitude of fluctuations of upwelling hyporheic water were reduced relative to downwelling surface water by up to 2.7°C. In Deer Creek, significant peak temperature reduction (1.55 – 3.47 °C) and amplitude reduction (3.5 – 7.2 °C) were documented at hyporheic exchange sites in the lower 11 miles of the river. These studies were conducted between July and October, a period when average surface water temperatures in the lower river are typically unsuitable for salmonids.

While peak daily temperature and amplitude reductions may only affect water temperature in the immediate vicinity of upwelling hyporheic sites and may not significantly cool receiving surface water, in some locations hyporheic exchange could provide local "micro-refugia" for aquatic organisms, especially benthic macroinvertebrates that can live in the interstitial spaces of the hyporheic zone. More extensive channel complexity driving more widespread hyporheic could extend the period during which suitable temperatures are accessible to salmonids and other aquatic species. Observations of salmonid smolts in the upwelling zone of a hyporheic exchange site in lower Deer Creek in July when surrounding surface water temperatures were as high as 86°F (30°C) indicates that this occurs, and if properly analyzed and incorporated into management of Delta inflows, could help maximize the value of flows delivered to the Delta for ecological purposes.

3.0 PERFORMANCE CRITERIA

Performance measures are derived from the goals and objectives and help to address the status and trends of progress toward achieving them. The conceptual model described in Section 2.0 was used to develop performance measures and performance metrics that will help to evaluate the success of the restoration project. Table 3 identifies the performance measures and metrics linked to each project objective, and Sections 3.1 and 3.2 describe performance criteria and adaptive management triggers. Section 4 describes existing data and Section 5 describes the overall monitoring and adaptive management approach. Methods for collecting data on performance metrics are described in Section 6.0 and methods for incorporating these findings into adaptive management actions, reporting and communicating findings are discussed in Sections 7, 8, and 9.

Performance metrics selected for this project are based primarily on establishment of vegetation, because most of the project objectives are tied to outcomes that rely on restoration of riparian vegetation. For example, the conceptual model presented in Section 2.0 shows how vegetative shade is important for lowering water temperatures and improving water quality. A tree canopy that provides shade has also been identified as very important for recreational users of the trail. Although monitoring results for water quality, biology/ecology, and public response will not be used to evaluate project performance for reasons discussed in Section 1.4.3 and thus no performance measures were established for these parameters, the monitoring program is designed to allow for evaluation of project benefits and long term trends in these areas. This type of monitoring design includes comparison to pre-project baseline conditions, as well as data collection at reference sites within the watershed in addition to monitoring the project site. Reference site data will allow for evaluation of the influence of factors outside the control of the project, such as climatic events, pollution from upstream runoff, etc. The baseline data set will include existing data described in Section 4, as well as new data collected prior to construction. When possible, planned monitoring locations coincide with previous monitoring locations, and methods are designed to be consistent with previously used methods for better comparability. Because one of the objectives of monitoring includes engaging the community, this category of monitoring will be coordinated with student and volunteer groups, and when appropriate will use protocols they have already established.

Table 3. Project Objectives, Performance Measures, and Performance Metrics

Project Objectives	Performance Metrics	Action Thresholds	Actions
• Restore floodplain and native vegetation along 4,000 linear feet of Marsh Creek between Dainty Avenue and the Union Pacific Railroad. • Create frequently inundated floodplains • Create as wide floodplains as feasible • Active channel banks may move while the broader river corridor banks are stable	Directly following implementation: • Number and species of plants installed • Floodplain relative elevation * Floodplain width	Directly following implementation: • Number and species are within 5% of plans • Floodplain relative elevation averages within 10% of plans • Floodplain width from bankfull to top of bank is within 10% of plans	Directly following implementation: • Install additional or remove extra plants as appropriate to attain target • Recontour floodplain surface to within 10% of plans • Recontour floodplain width to within 10% of plans
	5 years after restoration: • Absolute percent cover native plant species per CNPS • Floodplain relative elevation • Floodplain width • Bank stability	5 years after restoration: • Percent cover native plant species >60% • Floodplain relative elevation averages within 20% of plans • Floodplain width from bankfull to top of bank is within 20% of plans • Bank stability rated moderately to completely unstable along >20 ft river length	5 years after restoration: • Review native and non-native species composition and address invasives while supporting or propagating successful natives to attain threshold • Review hydrology and geomorphology of channel to identify source of change • Assess best next steps in close consultation with professional fluvial geomorphologist and flood district engineer • Assess best next steps in close consultation with professional fluvial geomorphologist and flood district engineer

Project Objectives	Performance Metrics	Action Thresholds	Actions
1. Restore 13.5 weedy, ruderal and treeless acres with native vegetation to enhance the creek's ecosystem, including frequently inundated floodplain (seasonal wetland), woody riparian vegetation, grasslands and native scrub.	Absolute percent cover of: • invasive plant species[1] • bare mineral soil[2] • native plant species • tree canopy cover for trees >6 ft in height	5 years after restoration: • >10% invasive plant species • >15% bare mineral soil • <60% cover native species • <15% tree canopy cover for trees >6 ft in height	5 years after restoration: • Review and revise weed management plan; implement until threshold is attained • Review reasons for high cover of bare mineral soil; treat soil and replant as appropriate to attain threshold • Install successful native species based on monitoring results to achieve threshold • Review tree health to identify source of limitation and treat existing trees and/or replant with revised methods
2. Help alleviate water quality problems in Marsh Creek by providing vegetation and canopy which is expected to reduce water temperature, help limit algal growth, and assist in nutrient removal.	• Percent canopy cover over channel	5 years after restoration: <12% canopy cover over channel	5 years after restoration: • Install successful native shade species based on monitoring results to achieve threshold
3. Create an attractive parkway environment that provides ample shade along the Marsh Creek Trail.	• Tree density within 20 ft of trail in Project Area	5 years after restoration: • < 1 live ≥6 ft tall tree per every 40 ft of trail OR < 2 live > 4ft tall trees within project	5 years after restoration: • Install successful native shade species based on

[1] Invasive species include all species rated Moderate or High by Cal-IPC.

[2] Bare mineral soil specifically does not include mulch placed by the project to protect installed plants.

Project Objectives	Performance Metrics	Action Thresholds	Actions
		area and within 20 ft buffer of trail	monitoring results to achieve threshold
5. Implement a successful multi-benefit flood management project that can serve as a catalyst for other projects along Marsh Creek and throughout the Delta watershed.	Number of additional projects to protect and restore the Marsh Creek ecosystem initiated.	• At least one project initiated.	• Interview associated local groups to understand lack of project initiation and revise approach accordingly.

3.1 Vegetation

The intent of vegetative restoration is to achieve floodplain of diverse riparian species, floodplain woodlands that support wildlife, and a stream side riparian corridor which functions with the stream channel to provide shade, bank stability, instream habitat, and a food source for aquatic organisms and contributes to in channel sediment sorting. **Table 4** shows the specific objectives for vegetative cover. Three years after civil construction is complete and planting begins, a comprehensive evaluation of the riparian vegetation will be conducted to ensure the overall desired mixture and percent cover of native species, shade over the channel and tree density along the trail is being achieved.

Table 4. Vegetation Performance Criteria

	2021	Year 2024	Year 2026
Total vegetation cover (absolute)	>5%	>20%	>30%
% Native Plant Cover (relative)	>20%	>40%	>60%
% Highly Invasive Species (relative)	<15%	<10%	<5%
% Moderately Invasive Species (relative)	<20%	<15%	<10%
% Bare Ground (absolute)	<20%	<15%	<15%
% Canopy Cover (absolute; creek at low flow)	>1%	>5%	>12%
Tree density along trail (# live trees, height [ft] of trees per 40 ft of stream side trail)	2, 2	2, 3	2, 3 or 1, 4

3.2 Channel and Bank Stability and Morphology

The primary geomorphic performance criterion for bank stability and morphology is whether or not the riparian corridor (rather than the active channel) banks are stable. Henshaw and Booth (2000) developed and tested a field metric for classifying bank stability into four broad but reliable categories: stable, slightly unstable, moderately unstable, and completely unstable. Clear and common site characteristics are used to distinguish among the four categories, making the classification repeatable and reliable among sites and among field assessors. Bank lengths showing indications of moderate to high ("complete") instability will be surveyed and remedial actions brought under consideration from County engineers.

4.0 EXISTING MONITORING DATA

This section summarizes existing monitoring data for the Marsh Creek watershed. These data will be used in conjunction with additional baseline data and post-project data to evaluate long term trends in the watershed and the project site, and to document the benefits of the project over time.

4.1 Previous and Existing Marsh Creek Monitoring Programs

This section describes existing and historical monitoring programs that have collected environmental data in Marsh Creek over the last couple of decades. Sampling locations for each program are shown in Figure 14. Because multiple programs sampled locations that were very close to each other with no obvious discharge or tributary confluence between them, these sites were considered essentially one location and were pooled and assigned new Site IDs as shown in **Table 5 and Figure 14**.

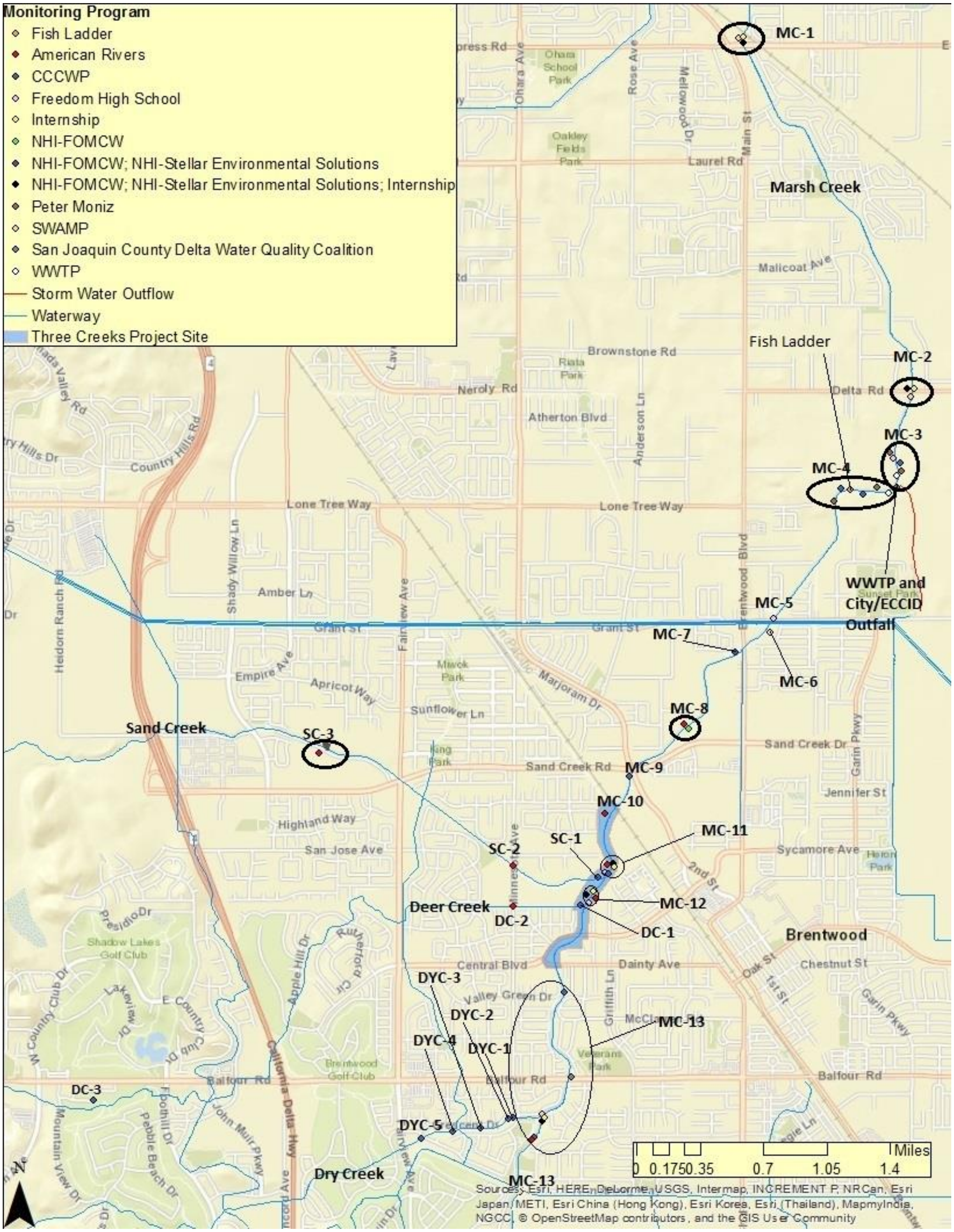


Figure 14. Historical Monitoring Locations

Table 5. New Site IDs for Historical Monitoring Locations

Description	Monitoring Program	Report Site ID	AR Site ID	Latitude	Longitude
Cypress Rd	SWAMP, FOMCW, Internship	541MERECY	MC-1	37.99100	-121.69600
Delta Rd	SWAMP, Internship	541MERDEL	MC-2	37.96900	-121.68300
DS WWTP	CCCWP, Freedom HS, CCCWP	M1, ST1, R3	MC-3	37.96389	-121.6839
US WWTP	CCCWP, UC Berkeley	M2, 544MRC400, R1	MC-4	37.9625	-121.685
Sunset Rd./ Trail bridge	Freedom HS	None	MC-5	37.95452	-121.69373
Marsh Creek 30m Southwest of Brentwood Boulevard/ Sunset	Freedom HS, SWAMP, CCCWP	544R00281; 541MERSUN	MC-6	37.95238	-121.6968
Brentwood Blvd	CCCWP	544R00281	MC-7	37.95238	-121.69678
Tech Center	FOMCW, AR	MSH-030	MC-8	37.94800	-121.70100
Sand Creek Rd.	CCCWP	544R01305	MC-9	37.94454	-121.70527
Sungold Park	None	None	MC-10	37.942099	-121.706833
Central	FOMCW, CCCWP, Freedom HS, Internship, AR	CF-2, MSH-045	MC-11	37.93600	-121.70900
Central2	FOMCW, CCCWP, Freedom HS, Internship, AR	CF-1, MSH-050	MC-12	37.93800	-121.70700
Balfour Road Creekside Park	SJCDWQC, Internship, AR	544XMCACA	MC-13	37.92300	-121.71200
Concord Ave	SJCDWQC	544XMCABA	MC-14	37.9039	-121.716
Sand Creek US of Marsh Creek confluence	CCCWP	M3	SC-1	37.93815	-121.708
Sand Creek at Minnesota Ave	AR	None	SC-2	37.93891	-121.715
Sand Creek	FOMCW, AR	None	SC-3	37.946	-121.73
Deer Creek US of Marsh Creek confluence	CCCWP	M4	DC-1	37.93641	-121.70916
Deer Creek at Minnesota Ave	AR	None	DC-2	37.93638	-121.715
Deer Creek US of Marsh Creek confluence	CCCWP	543R00137	DC-3	37.92408	-121.748

Description	Monitoring Program	Report Site ID	AR Site ID	Latitude	Longitude
Dry Creek US of Marsh creek confluence	CCCWP	544R00025DS/544MSH062	DYC-1	37.92303	-121.715
Dry Creek	CCCWP	M5	DYC-2	37.92294	-121.715
Dry Creek	CCCWP	543R00137	DYC-3	37.922	-121.717
Dry Creek	CCCWP	544R01049	DYC-4	37.92213	-121.719
Dry Creek	CCCWP	544R00025US/544MSH065	DYC-5	37.92172	-121.722

4.1.1 Friends of Marsh Creek Watershed

From 2001 to 2016 FOMCW volunteers and staff collected water quality at seven sites along lower Marsh Creek (**Figure 14**), with five of these sites monitored for the duration and 2 more sites added in recent years. During this time, parameters consistently sampled included water temperature, dissolved oxygen (DO), pH, conductivity and turbidity. Consistent weekly sampling was conducted June 2014 – December 2016, with lower frequency prior to that time. Water quality data collected between 2012-2013 are not included in this data evaluation because they appear to be missing.

In partnership with the United States Environmental Protection Agency (USEPA) and the Central Valley Regional Water Quality Control Board (CVRWQCB), FOMCW developed a Quality Assurance Project Plan (QAPP) (FOMCW, 2013). A QAPP describes the activities of an environmental data operations project involved with the acquisition of environmental information whether generated from direct measurements activities, collected from other sources, or compiled from computerized databases and information systems. The QAPP documents the results of a project's technical planning process, providing in one place a clear, concise, and complete plan for the environmental data operation and its quality objectives and identifying key project personnel.

FOMCW has worked with regulatory agencies (including CDFW and the CVRWQCB) to try to determine the cause of regularly occurring fish kills on Marsh Creek. FOMCW worked collaboratively with the CVRWQCB to develop a Surface Water Ambient Monitoring Program (SWAMP) -compliant water quality monitoring program as an effort to provide ongoing weekly field monitoring during the two months of concern, May and September. Between approximately 2012 and 2016, FOMCW served as the immediate local response team by taking SWAMP-compliant water samples and fish carcasses in the event of a fish kill and supplying those samples to CVRWQCB's Irrigated Lands Regulatory Program for analysis.

FOMCW has also been active in monitoring the arrival and number of fall run Chinook salmon in Marsh Creek, and have been conducting adult spawner surveys between 2011 and 2017. Most of the salmon are likely strays from the fall run on the San Joaquin River. Salmon education and monitoring walks with the communities of Oakley and Brentwood are organized during the months of October through

December. The cities of Oakley and Brentwood, and CCCFCD has partnered with FOMCW volunteers and staff to conduct trash assessments of Marsh Creek. Sites covered the lower watershed of Marsh Creek.

4.1.2 High School Programs

Oakley's Freedom High School environmental science and chemistry students monitored water quality at five sites between 2001 and 2007 on Marsh Creek (**Figure 14**). Two sites were below the fish ladder and three sites were above the fish ladder between Creekside Park in Brentwood and the confluence of Marsh Creek and Sand Creek. In addition to water temperature, DO, pH, conductivity and turbidity, the students collected data on nitrate and ammonia using field test kits that provide rough estimates of concentration ranges. Periodic samples of benthic invertebrates were also collected, with identification to order or family level.

4.1.3 Marsh Creek Restoration Studies

In water year (WY) 2006 – 2007, five sampling events were conducted on Marsh Creek sediment and water quality (Nov 2006, January, February, May, August 2008). This baseline study was conducted by Stellar Environmental Solutions, Inc., retained by Natural Heritage Institute (NHI) to inform restoration planning and design efforts. The study was targeted on the proposed diversion of Marsh Creek to the Emmerson Parcel, where Marsh Creek enters the Delta. Five sampling locations were established in lower Marsh Creek from Creekside Park in Brentwood to downstream in Oakley, an approximately 5.5-mile section of the Creek (**Figure 14**). Water and sediment samples were collected along with information regarding creek flow, DO, temperature, salinity, conductivity, pH and turbidity. Samples were analyzed for ammonia (as nitrogen), chloride, DOC, and total organic carbon, bromide, total mercury, dissolved mercury and methylmercury, nitrate, and total Kjeldahl nitrogen (TKN), total dissolved solids (TDS) and total suspended solids (TSS), total coliform, fecal coliform and e.coli, priority 13 metals (zinc, arsenic, copper, cadmium, chromium, lead, nickel, selenium), iron, aluminum, manganese, total phosphate, and orthophosphate.

HydroFocus, Inc. is a consulting firm contracted by the California Department of Water Resources (DWR) to conduct hydrologic and water-quality investigations on the Dutch Slough Restoration Project, an 1,166-acre tidal marsh restoration project at the mouth of Marsh Creek. Marsh Creek will be re-routed to restore the creek delta, providing seasonal freshwater flows to cue out-migrating salmon into the restored marsh. HydroFocus will be monitoring water quality once a month at the mouth of Marsh Creek and collects samples for determining an array of inorganic and organic constituents. The primary objective of the sampling is to assess possible water quality issues associated with the re-routing of Marsh Creek waters onto the Dutch Slough Restoration area. No surface water quality data has been collected yet under this program.

4.1.4 Contra Costa Clean Water Program

The CCCWP serves and is governed by unincorporated Contra Costa County, the CCCFCD, and 19 incorporated cities and towns (including Brentwood, Antioch and Oakley), which are collectively called the "Permittees". The mission of the CCCWP is to coordinate and assist Permittees' efforts to reduce and/or eliminate pollutant discharges into and from their municipal storm drain systems in compliance with their National Pollutant Discharge Elimination System (NPDES) municipal stormwater permits.

Stormwater discharges in the eastern portion of the County, which drains to the Delta and includes portions of unincorporated Contra Costa County, CCCFCD, and the cities of Antioch, Brentwood, and Oakley, is covered under an NPDES stormwater permit issued by the Central Valley Regional Water Board (Region 5). This stormwater permit is commonly known as the Municipal Regional Permit or MRP. The NPDES stormwater permits implement load reduction requirements for pollutants with established Total Maximum Daily Loads (TMDLs). The East Contra Costa stormwater permit largely matches the requirements of the MRP, and hereafter use of MRP refers collectively to both permits.

CCCWP conducted a study of stressor/source identification on Dry Creek and Grayson Creek in WY 2014. Dry Creek is a tributary to Marsh Creek in Brentwood, Grayson Creek is a tributary of Walnut Creek. The study was prompted by data from March 2012, and April 2013 that demonstrated a toxic response to the freshwater amphipod *Hyalella azteca*, with associated elevated levels of pyrethroids. For WY 2014, Dry Creek wet weather events were sampled 2/6/14 and 2/28/14, with dry weather sampling on 7/22/14. Two sites (upstream (DYC-5) and downstream (DYC-1)) on Dry Creek (**Figure 14**) were analyzed for water chemistry and toxicity and at the same two sites samples were collected for sediment chemistry and toxicity. Water quality measurements performed included water temperature, pH, DO, and specific conductance. Chemistry analysis of water samples included pyrethroid pesticides, fipronil and degradates, organochlorine pesticides, total organic carbon and suspended sediment concentration. Sediment samples were collected for bioassessment and chronic toxicity testing was conducted with the freshwater amphipod, *H. azteca*.

The CCCWP implemented a Methylmercury Control Study from 2012 to 2015. The Methylmercury Control Study Progress Report includes samples from Dry Creek (directly upstream of confluence with Marsh Creek (DYC-2)), Deer Creek (directly upstream of confluence with Marsh Creek (DC-1)), Sand Creek (directly upstream of confluence with Marsh Creek (SC-1)) and Marsh Creek (upstream (MC-4) and downstream (MC-3) of the City of Brentwood Wastewater Treatment Plant (WWTP)) (**Figure 14**). Samples were collected during “wet weather” and “dry weather” in November through June during 2012 to 2015 (CCCWP 2015).

As a provision of the MRP, a regional collaboration known as Bay Area Storm Water Management Agencies Association (BASMAA) provided a framework for implementing monitoring programs in compliance with MRP and Central Valley Permit. The association monitored nutrients and water quality for the 2014-2015 year on Marsh Creek upstream of Sand Creek Rd. (MC-9).

Between 2002 and 2009, FOMCW sampled benthic macroinvertebrate communities in coordination with CCCWP at 17 sites on upper and lower Marsh Creek (some locations were sampled in multiple years while others were sampled only once). Between 2012 and 2015, CCCWP continued to sample benthic macroinvertebrates. In WY 2012 and 2013, CCCWP sampled benthic macroinvertebrate communities on Marsh Creek (two upstream sites and one at the intersection of Brentwood Blvd), Dry Creek (300m west of Claremont Dr.) and Deer Creek (300m west of Foothill Dr.). In WY 2015, CCCWP sampled benthic macroinvertebrate communities at the intersection of Marsh Creek and Sand Creek Rd. and Dry Creek 350m west of Creekside Park.

4.1.5 Mercury Methylation and Bioaccumulation Studies

For three years, 1995 – 1997, Slotton, *et. al.* (2008), conducted a baseline mercury assessment in the Marsh Creek watershed. The project focused on the mercury occurring in the upper Marsh Creek watershed, for evaluation of mitigation work at the Mt. Diablo Mercury Mine.

Invertebrates (mayflies, stoneflies, and hellgrammites), small or juvenile fish (juvenile salmon, juvenile largemouth bass, juvenile bluegill, mosquito fish, stickleback and California Roach) and sediment samples were analyzed for total mercury. Samples were collected in significant tributaries of the upper Marsh Creek watershed, the Marsh Creek reservoir and two sites downstream of the reservoir.
As part of the CalFed Fish Mercury Project, Marsh Creek at Big Break, Big Break and Emerson Slough were sampled in November and December of 2005 in a separate small fish biosentinal mercury study (Slotton *et al.,* 2007). Stellar Environmental Solutions, Inc. (SES) was retained by the Natural Heritage Institute in 2006 and 2007 to sample for mercury and methylmercury in lower Marsh Creek. In March and August of 2008, small fish biosentinal mercury monitoring was conducted in tidal Marsh Creek at sites in and adjacent to the Dutch Slough wetland. Five sites were sampled in Marsh Creek (above tidal influence at Delta Rd [MC-2]), Emerson Slough, Little Dutch Slough and Big Break in both March and August (Slotton, 2008).

4.1.6 San Joaquin County Delta Water Quality Coalition (SJCDWQC)

In 2004 the SJCDWQC formed under the lead agency, San Joaquin County Resource Conservation District, working in cooperation with the Central Valley Regional Water Quality Control Board to comply with implementation of the Irrigated Land Regulatory Program (ILRP). Marsh Creek and Sand Creek are on the western edge of the Coalition boundary, Contra Costa Zone 6. **S**ampling sites in the Marsh Creek watershed included Marsh Creek at Balfour Ave., (2005 -2006), Marsh Creek at Concord Ave., (2005 – 2008) and Sand Creek at Highway 4 Bypass (SC-3) (2007 – 2008 and 2011 – 2016) (**Figure 14**). Sand Creek at Highway 4 Bypass will continue to be monitored by the Coalition under the Management Plan.

Monitoring included general physical parameters (DO, pH, temperature, turbidity, conductivity) and flow. In addition, samples were taken for nutrient analysis, pathogens, pesticides, metals and photo monitoring. Water toxicity tests (Fresh water algae, *Selenastrum capricornutum*, the water flea, *Ceriodaphnia dubia*, and Fathead minnow, *Pimephales promelas*) were conducted with each sampling event and twice a year sediment was sampled for toxicity testing (*Hyallea azteca*) (CEDEN 2017).

4.1.7 Surface Water Ambient Monitoring Program

SWAMP is a program under the State Water Resources Control Board. SWAMP is tasked with assessing water quality in all of California's surface waters. The program conducts monitoring directly and through collaborative partnerships, and provides numerous information products, all designed to support water resource management in California. SWAMP was created in 2000 and fulfills the state mandate of Assembly bill 982 to unify programs addressing regional water quality concerns. Two basic questions are addressed through SWAMP, the first: Is it safe to eat the fish? And second: Are ecosystems protected in freshwater streams, rivers and lakes? SWAMP includes statewide and regional monitoring programs that are designed to address one or more of the following assessment questions for defined water body types and beneficial uses:

- Status: What is the overall quality of California's surface waters?
- Trends: What is the pace and direction of change in surface water quality over time?
- Problem Identification: Which water bodies have water quality problems and which areas are at risk?
- Diagnostic: What are the causes of water quality problems and where are the sources of those stressors?
- Evaluation: How effective are clean water projects and programs?

Between 2001 and 2008, the Contra Costa County Community Development Department and the Contra Costa Clean Water Program collaborated to form the Contra Costa County Volunteer Creek Monitoring Program (Volunteer Monitoring Program) in coordination with SWAMP. The Volunteer Monitoring Program worked with local creek groups, including the FOMCW, to collect BMI and GPS data. GPS data included 50-foot intervals: water flow, substrate, shade cover, bank slope, undercut bank, substrate composition; constructed features: bank composition, debris jams, bridges, outfalls, severe erosion, dumping areas; vegetation: vegetation cover, type of bank cover, type of in-stream cover, % cover of each vegetation type, number of trees, invasive plants (Ivy, Pampas Grass, Tamarix, Giant Thistle, Star Thistle, Tree of Heaven, Vinca).

Four sites on Marsh Creek have been sampled by the CCCWP under the SWAMP program (MC-1, MC-2, MC-6, MC-13) (Table 14). From 2010-2015, samples collected at three sites downstream of the project area were tested for toxicity on various dates, and basic water quality parameters and ammonia were measured at these sites, as well as once at and another site upstream of the project area in 2006.

4.1.8 Brentwood Wastewater Treatment Plant

The WWTP treats sewage from City of Brentwood residents and discharges treated water into Marsh Creek between Delta Road and Sand Creek Road. As a point source, the WWTP has a National Pollutant Discharge Elimination System (NPDES) permit and must comply with Total Maximum Daily Load (TMDL) requirements for water quality parameters. The WWTP monitors water quality upstream (MC-4) and downstream of the WWTP outfall (MC-3) on Marsh Creek on a weekly basis, with parameters including conductivity, DO, hardness, pH, turbidity, chloride, sulfate, and alkalinity. In 2016, additional data were collected on priority pollutants.

4.1.9 UC Berkeley Students

The City of Brentwood and the Natural Heritage Institute engaged the Department of Landscape Architecture and Environmental Planning at the University of California, Berkeley to complete a study of the creeks' conditions and their potential to shape and guide the future development of Brentwood. A group of UC Berkeley led by Professors Louise Mozingo, Joe McBride, and G. Mathais Kondolf conducted the study in Fall 2001. The work consisted of three parts: as an initial step, an inventory and analysis that documents and assesses existing creek conditions; next, the formulation of alternative master plans that delineate how future development can incorporate the creeks and enhance the overall environment of the city landscape; and last, the design of specific sites that illustrate what creek conscious building could look like (UC Berkeley, 2001).

Additional studies have been conducted by UC Berkeley students. In 2003, two UC Berkeley students prepared a design to modify Marsh Creek Dam to allow Chinook salmon passage upstream to access spawning habitat (McNulty and Wickland, 2003). Subsequently, two more UC Berkeley students assessed the quality of potential spawning habitat in a 1.2- mile reach of lower Marsh Creek and found that suitable habitat was present (Levine and Stewart, 2004). A study conducted in September 2012 by UC Berkeley student Peter Moniz compared benthic macroinvertebrate communities at five sites: two sites upstream of Brentwood's WWTP, (both designated as MC-4 on **Figure 14**), and three sites downstream of Brentwood's WWTP (all designated as MC-3 on **Figure 14**).

4.1.10 East Bay Regional Park District

EBRPD has partnered with FOMCW and American Rivers staff to conduct salmon monitoring along Marsh Creek. EBRPD leads public walks along Marsh Creek, including bird watching, and conducts water quality sampling at the Big Break Regional Shoreline.

4.1.11 The Watershed Project

The Watershed Project trains and leads teams of interested volunteers in conducting monitoring projects in urban creeks across Contra Costa County. The Watershed Project is working with the Contra Costa Watershed Forum to lead a collaboration between community groups and agencies to establish a standardized water quality monitoring system that will be used throughout Contra Costa County. They have obtained grant funding for an intern to conduct monthly water quality monitoring throughout the county, including 5 sites in Marsh Creek Watershed (sites designated as “Internship” on Figure 14) that have also been monitored by FOMCW. Field measurements include DO, conductivity, pH, and temperature. Nitrates and phosphates concentrations will be estimated using colorimeters, and total mercury will be sampled once during the first stormwater flush. The group is hoping to obtain funding to continue monitoring past August 2018.

4.1.12 Bay Area Stormwater Management Association

Bay Area Stormwater Programs, represented by the Bay Area Stormwater Management Agencies Association (BASMAA), collaborated with the San Francisco Bay Regional Monitoring Program (RMP) to develop the Small Tributaries Loading Strategy (STLS) to address four key management questions:

- MQ1. Which Bay tributaries (including stormwater conveyances) contribute most to Bay impairment from POCs;
- MQ2. What are the annual loads or concentrations of POCs from tributaries to the Bay;
- MQ3. What are the decadal-scale loading or concentration trends of POCs from small tributaries to the Bay; and,
- MQ4. What are the projected impacts of management actions (including control measures) on tributaries and where should these management actions be implemented to have the greatest beneficial impact.

This program collected data from small Bay Area tributaries, including data for Marsh Creek in WY’s 2011, 2012, 2013, and 2014. The monitoring design focused on winter season storms between October 1 and April 30 of each water year. Measurement of continuous stage and turbidity at time intervals of 15 min or less was the basis of the monitoring design. Grab samples were collected and analyzed for suspended sediment, polychlorinated biphenyls (PCBs), total mercury and methylmercury, nutrients, copper, selenium, polycyclic aromatic hydrocarbons (PAHs), polybrominated diphenyl ethers (PBDEs), and several pesticides.

4.2 Available data

Although many programs collected various types of monitoring data in Marsh Creek and its tributaries, much of the data collection was sporadic and at a limited number of sites. For some water quality parameters (dissolved oxygen, temperature, turbidity, and conductivity), there is sufficient historical data available to look at trends spatially and seasonally. For each of these parameters, all available data from multiple programs were pooled into one data set. When multiple sites sampled locations that were very close to each other with no obvious discharge or tributary confluence between them, these sites were considered essentially one location and were pooled and assigned new Site IDs as shown in Table 5 and Figure 15. For each sample, concentrations were compared to relevant water quality objectives or to other thresholds based on the designated aquatic life beneficial uses of Marsh Creek (warm freshwater habitat, wildlife habitat, and rare, threatened or endangered species habitat, as designated by the Water Quality Control Plan (CVRWQCB, 2016). At each location with sufficient data (**Figure 15**), data from all years were combined and summarized on a quarterly basis in **Table 6**, and this information was used to identify problematic locations and times of the year. The analysis does not include data recently obtained by the Watershed Project (starting August 2017) or the new baseline data collected for this project (starting October 2017).

Table 6. Quarterly Data Summaries for DO, Temperature, Conductivity, pH, and Turbidity (2001-2016)

Location and Data type		DO (ppm)			
		1 (January-March)	2 (April-June)	3 (July-September)	4 (October-December)
MC-1	Max	12.5	15.4	13.3	8.8
	Avg	9.5	10.7	9.5	7.1
	Min	6.3	7.4	6.1	5.9
	# Samples exceeding threshold	2 (15.4%) ; 0 (0%)	0 (0.0%) ; 0 (0.0%)	2 (10.5%) ; 0 (0.0%)	6 (54.5%) ; 0 (0.0%)
	n	13	33	19	11
MC-2	Max		13.8		
	Avg		10.3		
	Min		7.1		
	# Samples exceeding threshold		0 (0%) ; 0 (0%)		
	n		25		
MC-3	Max	11.8	14.3	13.1	12.0
	Avg	8.9	8.2	6.9	7.2
	Min	5.8	4.6	4.3	4.1
	# Samples exceeding threshold	22 (8.3%) ; 0 (0%)	58 (21.2%) ; 2 (.73%)	153 (54.1%) ; 16 (5.7%)	112 (41.3%) ; 9 (3.3%)
	n	265	274	283	271
MC-4	Max	15.2	16.4	11.5	14.4
	Avg	10.0	8.3	4.7	7.2
	Min	4.5	0.7	0.0	0.5
	# Samples exceeding threshold	27 (10.3%) ; 7 (2.7%)	91 (34.9%) ; 30 (11.5%)	229 (83.9%) ; 149 (54.6%)	126 (46.7%) ; 48 (17.8%)
	n	263	261	273	270
MC-8	Max		18.5	12.6	
	Avg		11.4	8.3	
	Min		5.6	4.8	
	# Samples exceeding threshold		1 (3.3%) ; 0 (0%)	3 (25%) ; 1 (8.3%)	
	n		30	12	
MC-11	Max	15.1	16.4	13.5	
	Avg	10.1	10.1	7.8	
	Min	3.4	5.8	6.2	

Location and Data type		DO (ppm)			
		1 (January-March)	2 (April-June)	3 (July-September)	4 (October-December)
	# Samples exceeding threshold*	2 (14.3%) ; 1 (7.1%)	4 (15.4%) ; 0 (0%)	4 (30.8%) ; 0 (0%)	
	n	14	26	13	
MC-12	Max	18.2	18.5	13.1	
	Avg	10.4	11.4	9.2	
	Min	1.3	7.2	5.9	
	# Samples exceeding threshold	2 (14.3 %) ; 1 (7.1%)	0 (0%) ; 0 (0%)	2 (13.3%) ; 0 (0%)	
	n	14	34	15	
MC-13	Max			11.9	9.0
	Avg			8.2	8.0
	Min			6.8	6.8
	# Samples exceeding threshold*			5 (16.1%)	2 (6.9%)
	n			31	29
SC-3	Max			9.5	8.8
	Avg			8.4	8.2
	Min			7.2	7.8
	# Samples exceeding threshold			7 (31.8%)	3 (14.3%)
	n			22	21

Location and Data type		pH			
		1 (January-March)	2 (April-June)	3 (July-September)	4 (October-December)
MC-1	Max	9.2	9.0	8.5	9.3
	Avg	8.3	8.2	8.1	8.0
	Min	7.3	7.1	7.8	6.8

Location and Data type		pH			
		1 (January-March)	2 (April-June)	3 (July-September)	4 (October-December)
	# Samples exceeding threshold	10 (37.0%)	8 (22.2%)	0 (0.0%)	1 (4.5%)
	n	27	36	20	22
MC-2	Max	9.0	8.4		9.3
	Avg	8.1	7.8		7.9
	Min	7.0	7.2		7.5
	# Samples exceeding threshold	3 (11.5%)	0 (0.0%)		1 (5.3%)
	n	26	26		19
MC-3	Max	8.4	8.7	8.3	8.3
	Avg	7.9	7.9	7.7	7.7
	Min	7.5	7.3	7.2	7.0
	# Samples exceeding threshold	0 (0%)	1 (0.4%)	0 (0.0%)	0 (0.0%)
	n	265	273	284	271
MC-4	Max	8.7	8.5	8.4	8.2
	Avg	8.0	7.9	7.6	7.7
	Min	7.3	7.2	6.8	7.1
	# Samples exceeding threshold	3 (1.1%)	3 (1.2%)	0 (0.0%)	0 (0.0%)
	n	262	261	274	270

Location and Data type		pH			
		1 (January-March)	2 (April-June)	3 (July-September)	4 (October-December)
MC-8	Max	9.8	8.9	8.4	8.4
	Avg	8.3	8.2	7.8	7.8
	Min	7.3	7.1	7.0	7.2
	# Samples exceeding threshold	8 (36.4%)	10 (30.3%)	0 (0%)	0 (0%)
	n	22	33	13	9
MC-11	Max	9.7	10.0	8.6	9.2
	Avg	8.3	8.3	7.8	8.0
	Min	7.5	7.2	7.4	7.4
	# Samples exceeding threshold*	6 (26.1%)	8 (30.8%)	1 (7.1%)	1 (6.3%)
	n	23	26	14	16
MC-12	Max	10.0	9.8	8.4	8.6
	Avg	8.5	8.4	7.9	8.1
	Min	7.4	7.1	7.6	7.6
	# Samples exceeding threshold	9 (32.1%)	15 (42.9%)	0 (0.0%)	4 (23.5%)
	n	28	35	16	17
MC-13	Max	8.9	8.8	19.2	26.0
	Avg	8.1	8.0	12.0	18.3
	Min	6.7	7.0	5.9	12.2

Location and Data type		**pH**			
		1 (January-March)	2 (April-June)	3 (July-September)	4 (October-December)
	# Samples exceeding threshold*	3 (18.8%)	3 (15.0%)	9 (37.5%) ; 0 (0.0%)	23 (95.8%) ; 3 (12.5%)
	n	16	20	24	24
SC-3	Max		8.7	20.0	29.8
	Avg		8.4	13.2	24.0
	Min		7.9	5.6	15.6
	# Samples exceeding threshold		3 (30.0%)	13 (61.9%) ; 0 (0.0%)	21 (100.0%) ; 15 (71.4%)
	n		10	21	21

Location and Data type		Temperature (C)			
		1 (January-March)	2 (April-June)	3 (July-September)	4 (October-December)
MC-1	Max	22.2	26.2	30.3	22.1
	Avg	15.7	21.8	24.3	17.5
	Min	10.5	16.0	20.7	12.0
	# Samples exceeding threshold	20 (74.1%) ; 1 (3.7%)	36 (100.0%) ; 21 (58.3%)	27 (100.0%) ; 26 (96.3%)	27 (90.0%) ; 3 (10.0%)
	n	27	36	27	30
MC-2	Max	20.5	25.9	26.2	24.0
	Avg	16.0	22.3	24.2	19.4
	Min	9.4	17.8	22.2	12.9
	# Samples exceeding threshold	20 (83.3%) ; 0 (0.0%)	26 (100.0%) ; 15 (57.7%)	18 (100.0%) ; 18 (100.0%)	26 (92.9%) ; 6 (21.4%)
	n	24	26	18	28
MC-3	Max	21.1	25.0	28.7	25.0
	Avg	16.1	21.2	24.1	19.8
	Min	8.5	13.3	20.7	10.2
	# Samples exceeding threshold	0 (0.0%)	272 (99.6%) ; 159 (58.2%)	284 (100.0%) ; 279 (98.2%)	268 (98.5%) ; 88 (32.4%)
	n	265	273	284	272
MC-4	Max	21.1	26.3	27.3	25.6
	Avg	13.2	20.5	23.0	15.8
	Min	6.1	12.7	18.3	6.7
	# Samples exceeding threshold	126 (46.7%); 0 (0.0%)	258 (98.9%) ; 112 (42.9%)	274 (100.0%) ; 218 (79.6%)	191 (70.0%) ; 22 (8.1%)
	n	270	261	274	270
MC-8	Max	21.1	28.4	28.2	24.7
	Avg	12.7	22.0	25.4	16.1
	Min	6.3	16.3	19.3	9.5
	# Samples exceeding threshold	8 (40.0%) ; 0 (0%)	33 (100.0%) ; 18 (54.5%)	15 (100.0%) ; 14 (93.3%)	6 (60.0%) ; 2 (20.0%)
	n	20	33	15	10
MC-11	Max	19.3	27.9	30.9	19.7
	Avg	12.9	19.0	23.6	14.3
	Min	5.1	7.8	17.0	6.4
	# Samples exceeding threshold*	11 (45.8%) ; 0 (0.0%)	25 (96.2%) ; 6 (23.1%)	19 (100.0%) ; 14 (73.7%)	10 (55.6%) ; 0 (0.0%)
	n	24	26	19	18

Location and Data type		Temperature (C)			
		1 (January-March)	2 (April-June)	3 (July-September)	4 (October-December)
MC-12	Max	17.8	26.0	29.8	19.8
	Avg	12.4	20.0	24.6	14.6
	Min	5.6	9.0	17.4	7.9
	# Samples exceeding threshold	13 (48.1%) ; 0 (0.0%)	34 (94.4%) ; 16 (44.4%)	19 (100.0%) ; 16 (84.2%)	10 (52.6%) ; 0 (0.0%)
	n	27	36	19	19
MC-13	Max		18.9	928.0	130.0
	Avg		13.5	68.6	22.7
	Min		8.0	2.1	1.7
	# Samples exceeding threshold*		7 (50.0%) ; 0 (0.0%)	5 (16.7%)	4 (18.2%)
	n		14	30	22
SC-3	Max		21.2	264.0	108.3
	Avg		14.6	34.8	39.3
	Min		8.4	1.1	6.4
	# Samples exceeding threshold		7 (58.3%) ; 0 (0.0%)	4 (18.2%)	12 (57.1%)
	n		12	22	21
		Turbidity (NTU)			
		1 (January-March)	2 (April-June)	3 (July-September)	4 (October-December)
MC-1	Max	856.0	25.5	18.0	265.9
	Avg	54.7	5.6	5.7	25.4
	Min	0.6	0.0	1.0	0.5
	# Samples exceeding threshold	3 (12.5%)	0 (0.0%)	0 (0.0%)	5 (17.9%)
	n	24	28	20	28
MC-2	Max	1520.0	27.2	16.4	460.0
	Avg	71.9	8.1	6.6	31.1
	Min	0.2	1.5	1.3	1.0
	# Samples exceeding threshold	3 (11.5%)	1 (3.7%)	0 (0.0%)	3 (10.7%)
	n	26	27	18	28
MC-3	Max	990.0	414.0	390.0	817.0
	Avg	48.7	15.5	13.0	11.9
	Min	1.0	0.0	1.0	1.0

Location and Data type		Temperature (C)			
		1 (January-March)	2 (April-June)	3 (July-September)	4 (October-December)
	# Samples exceeding threshold	37 (14.18%)	30 (11.4%)	23 (8.4%)	17 (6.3%)
	n	261	263	273	269
MC-4	Max	1000.0	598.0	519.0	1540.0
	Avg	81.1	24.3	30.7	39.0
	Min	1.0	0.6	1.0	0.0
	# Samples exceeding threshold	92 (35.38%)	33 (12.7%)	46 (17.0%)	73 (27.3%)
	n	260	259	271	267
MC-8	Max	880.0	38.3		841.4
	Avg	58.7	17.4		201.0
	Min	1.4	1.6		2.7
	# Samples exceeding threshold	3 (13.0%)	7 (25.9%)		5 (50.0%)
	n	23	27		10
MC-11	Max	840.0	74.0		64.0
	Avg	65.3	16.2		19.8
	Min	1.3	1.2		1.3
	# Samples exceeding threshold*	2 (10.5%)	5 (29.4%)		4 (26.7%)
	n	19	17		15
MC-12	Max	944.0	107.4	571.6	284.0
	Avg	59.4	18.8	76.8	35.1
	Min	1.1	0.2	2.7	3.2
	# Samples exceeding threshold	4 (16.7%)	6 (22.2%)	4 (36.4%)	2 (12.5%)
	n	24	27	11	16
MC-13	Max	69.3	643.6	4381.0	4305.0
	Avg	19.4	65.5	1537.2	1978.5
	Min	1.1	1.6	11.0	460.0
	# Samples exceeding threshold*	2 (20.0%)	3 (21.4%)	8 (28.6%)	14 (53.8%)
	n	10	14	28	26
SC-3	Max	131.0	192.6	2571.0	2381.0
	Avg	40.7	34.0	1366.2	999.5
	Min	8.4	1.3	481.0	368.0

Location and Data type		Temperature (C)			
		1 (January-March)	2 (April-June)	3 (July-September)	4 (October-December)
	# Samples exceeding threshold	4 (40.0%)	4 (33.3%)	7 (38.9%)	3 (14.3%)
	n	10	12	18	21
		Conductivity (uS/cm)			
		1 (January-March)	2 (April-June)	3 (July-September)	4 (October-December)
MC-1	Max	2242.0	2700.0	6600.0	2320.0
	Avg	1456.3	1839.8	2450.8	1774.7
	Min	395.0	880.0	1582.0	511.0
	# Samples exceeding threshold	8 (36.4%)	18 (62.1%)	18 (78.3%)	6 (23.1%)
	n	22	27	23	26
MC-2	Max	2211.0	2638.0	2538.0	2364.0
	Avg	1456.4	1748.2	2046.0	1799.4
	Min	399.0	1009.0	1552.0	541.0
	# Samples exceeding threshold	9 (40.9%)	17 (63.0%)	15 (88.2%)	9 (36.0%)
	n	22	27	17	25
MC-3	Max	2290.0	2820.0	6120.0	2380.0
	Avg	1511.4	1551.9	1692.9	1733.2
	Min	324.0	462.0	465.0	309.0
	# Samples exceeding threshold	97 (36.6%)	116 (43.6%)	103 (36.8%)	72 (26.5%)
	n	265	266	280	272
MC-4	Max	2070.0	2190.0	2110.0	2430.0
	Avg	1171.5	1163.0	1404.7	1383.7
	Min	294.0	344.0	428.0	239.0
	# Samples exceeding threshold	21 (8.01%)	26 (10.0%)	56 (20.4%)	8 (3.0%)
	n	262	260	274	269
MC-8	Max	2798.0	2120.0		
	Avg	1230.2	1217.1		
	Min	370.0	582.0		
	# Samples exceeding threshold	4 (21.1%)	5 (18.5%)		
	n	19	27		
MC-11	Max	2805.0	1976.0	5760.0	2290.0

Location and Data type		Temperature (C)			
		1 (January-March)	2 (April-June)	3 (July-September)	4 (October-December)
	Avg	1378.1	1186.5	2284.5	1391.6
	Min	343.0	702.0	1350.0	367.0
	# Samples exceeding threshold*	7 (31.8%)	4 (20.0%)	6 (54.5%)	1 (7.7%)
	n	22	20	11	13
MC-12	Max	2806.0	2307.0	6050.0	2370.0
	Avg	1360.3	1349.8	2090.9	1504.4
	Min	349.0	588.0	526.0	460.0
	# Samples exceeding threshold	6 (26.1%)	10 (34.5%)	5 (38.5%)	5 (29.4%)
	n	23	29	13	17
MC-13	Max	2900.0	3620.0	2900.0	3620
	Avg	1587.5	2162.7	1587.5	2162.727273
	Min	552.0	775.0	552.0	775
	# Samples exceeding threshold*	4 (40.0%)	7 (63.6%)	4 (40.0%)	7 (63.6%)
	n	10	11	10	11
SC-3	Max		2193.0		2193
	Avg		1358.2		1358.2
	Min		326.0		326
	# Samples exceeding threshold		4 (40.0%)		4 (40%)
	n		10		10

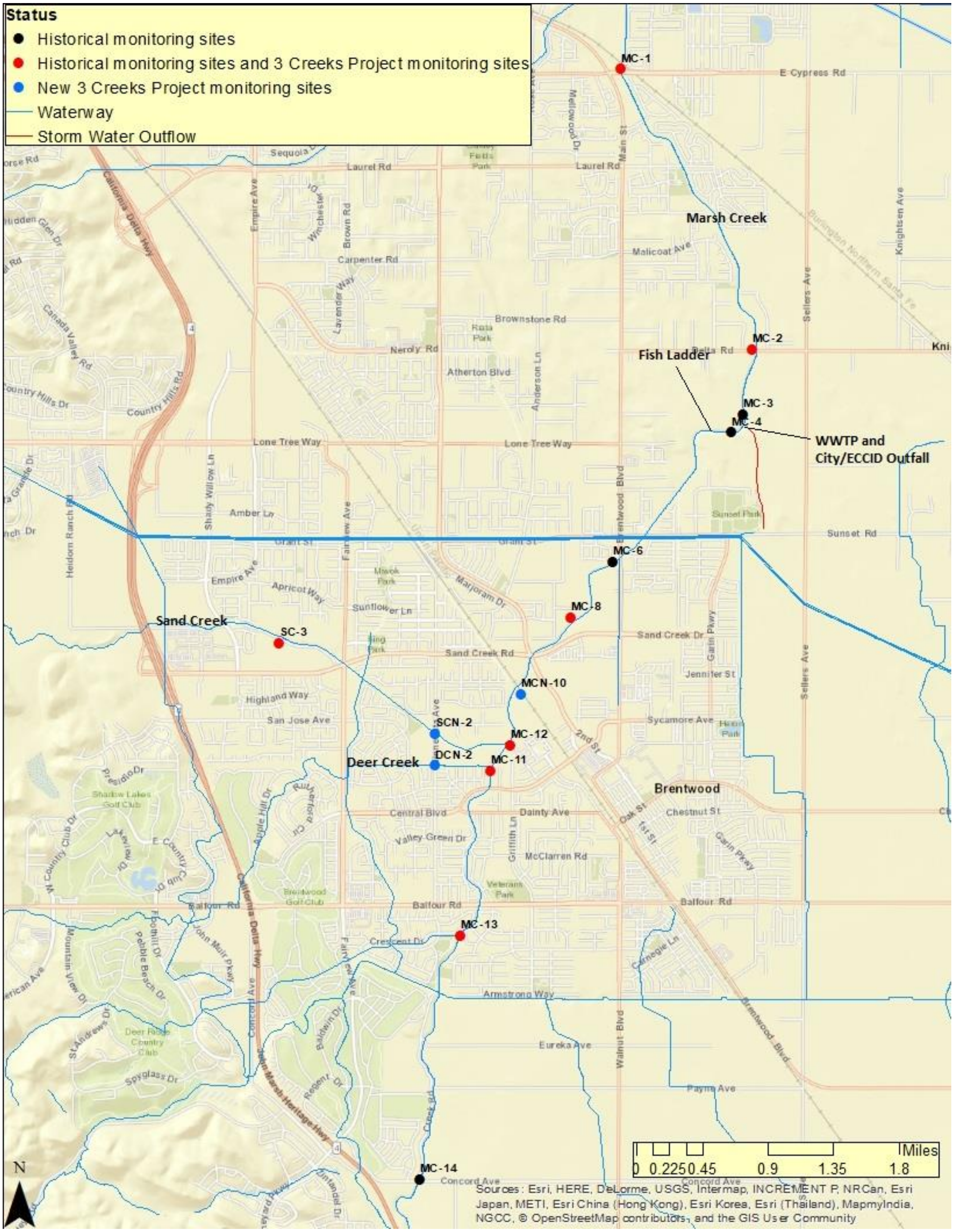


Figure 15. Existing and New Monitoring Locations.

For other types of monitoring data collected in Marsh Creek, a more qualitative evaluation of existing data is provided because data are generally insufficient to evaluate spatial or temporal trends. The objective of this evaluation is to identify parameters that may impact the health of the aquatic ecosystem in the watershed, based on the limited data available, and use this information to plan future monitoring efforts. This section presents summaries of available data on parameters for which at least a few samples were collected, but does not include parameters that were measured only sporadically.

4.2.1 Temperature

Similar to DO, temperature values were compared to two thresholds. Based on its beneficial use designations, the water quality objective of <20.5C for warm freshwater bodies is the regulatory water quality objective for temperature for Marsh Creek (CVRWQCB, 2016). However, this objective is not considered protective of salmonids, which attempt to spawn in Marsh Creek in fall months. Therefore, we also compared temperature to a threshold of 13.3C, which is the lowest of the daily average thresholds of detrimental conditions for Chinook salmon adult migration, spawning, and egg incubation (Anchor QEA, 2016).

Water temperature regularly exceeds the water quality objective of <20.5C during spring, summer and fall at almost all sites monitored. Not surprisingly, exceedances of this objective were highest in summer, with 73.7% to 100% exceeding the 20.5C objective at all sites with sufficient data to evaluate (at least 10 samples per quarter). In winter, temperatures exceeded this objective only occasionally at MC-8 and MC-1 (**Table 6**).

During both the fall and winter quarters when salmon attempt to migrate up Marsh Creek to spawn, temperatures frequently exceed the protective threshold of 13.3C. This consistently occurs at all sites, with frequency of exceedance generally around 50% or more (**Table 6**).

4.2.2 Dissolved Oxygen

Dissolved oxygen (DO) concentrations were compared to two thresholds. Based on its beneficial use designations, the water quality objective of 5.0 mg/L for warm freshwater bodies is the regulatory water quality objective for DO for Marsh Creek (CVRWQCB 2016). However, this objective is not considered protective of salmonids, which attempt to spawn in Marsh Creek in fall months. Therefore, we also compared DO concentrations to a value of 7.0 mg/L, which is the water quality objective set for designated spawning habitat, and is generally considered protective of salmonids.

Dissolved oxygen appears to consistently be problematic in Marsh Creek, which is not surprising given the obvious eutrophication and algal growth combined with high temperatures and lack of shade especially during summer months. However, very low DO concentrations have been measured at some locations even in winter months.

Low DO concentrations occur more frequently at locations upstream of the wastewater treatment plant, which is located between sites MC-4 and MC-3 (**Figure 15**). Of the three sites downstream of the treatment plant, concentrations below 5 mg/L were measured at only one site just downstream (MC-3) , and these concentrations occurred in only 5.7% of samples collected in summer and 3.3% of samples collected in fall (Table 6). In contrast, concentrations below 5 mg/L were measured much more frequently at some locations upstream of the treatment plant; for example 54.7% of samples collected in summer at MC-4 just upstream of the treatment plant.

At almost all locations and during all seasons, DO concentrations below 7.0 mg/L were measured.

Very limited data on DO are available for Sand Creek (SC-3), and none on Deer Creek. At sites within the project area (MC-11 and MC-12), DO concentrations were rarely below 5.0 mg/L, but often below 7.0 mg/L in the summer at MC-11 (Table 6).

4.2.3 pH

The water quality objective for pH for Marsh Creek is 6.5 - 8.5 (CVRWQCB, 2016). While pH was never measured below 6.5, it was often above 8.5, both upstream and downstream of the treatment plant. These exceedances occurred most often in the winter and spring quarters (30.8% in spring at MC-11; 37.0% in winter at MC-1; and 31.8% in winter at SC-3) (**Table 6**).

4.2.4 Conductivity

No specific water quality objective for conductivity has been established for Marsh Creek by regulatory agencies. Therefore, for each quarter the 75th percentile value for data from all sites was calculated. This value was used for comparison to identify sites with unusually high conductivity measurements.

Conductivity values ranged widely between 11 – 6600 uS/cm. Values above 3000 uS/cm were measured only during the summer and only at three sites: MC-12, MC-1, and MC-3. While values ranged widely, the average values for each site were fairly similar, ranging from 1150.4 to 1537.2 uS/cm in winter, and 1136.8 to 2450.8 uS/cm in summer. Sites with high percentage of values exceeding the 75th percentile value included MC-13 (63.6% in fall), MC-2 (88.2% in summer), and MC-1 (78.3% in summer) (**Table 6**).

4.2.5 Turbidity

No specific water quality objective for turbidity has been established for Marsh Creek by regulatory agencies. Therefore, for each quarter the 75th percentile value for data from all sites was calculated. This value was used for comparison to identify sites with unusually high turbidity measurements.

Maximum and average turbidity values tended to be highest during the fall and winter (**Table 6**), which is typical in California as turbidity often peaks during precipitation events. At all sites and during all quarters, minimum values were very low (< 10 NTU), indicating that water in Marsh Creek is generally very clear. High turbidity values are likely to be triggered by precipitation runoff events, irrigation runoff, or some other kind of discharge, erosion, or disturbance. At some sites, unusually high turbidity values did occur in summer (571.6 NTU at MC-12; 519.0 at MC-4; 390 NTU at MC-3. However, these sites did not have an unusually large percentage of measurements above the 75th percentile value for summer. Available data does not indicate that specific sites are problematic with respect to turbidity, and the data set appears to follow typical temporal trends for the region.

4.2.6 Nutrients

Nutrients are elements or compounds essential for animal and plant growth. They exist naturally in the environment and are also in fertilizers for lawn and garden care and crop production. Common nutrients in fertilizer include nitrogen, phosphorus, and potassium, which can all exist in various forms in water. Nitrates are highly mobile in water and may reach groundwater from point sources such as sewage disposal systems and livestock facilities, non-point sources such as fertilized cropland, parks, golf courses, lawns and gardens, or from natural occurring sources of nitrogen. Elevated nitrogen and phosphorus concentrations in surface water can trigger eutrophication, resulting in excessive, often unsightly, growth of algae and other nuisance aquatic plants. Marsh Creek has an excessive growth of algae in the wetted creek channel. FOMCW monitoring between 2001 and 2011 with nutrient test kits found elevated levels of nitrates in Marsh Creek downstream of the WWTP (MC-3) and at Cypress Road (MC-1) (**Figure 15**) (FOMCW and NHI, 2011); however, the nutrient test kits provide only rough estimates of nutrient concentrations.

As part of SWAMP monitoring program, CCCWP sampled for ammonia and nitrates at the confluence of Sand Creek and Marsh Creek (MC-11), the confluence of Deer Creek and Marsh Creek (MC-12), Marsh Creek at Brentwood Tech Center (MC-8), Marsh Creek at Cypress road (MC-1), and Marsh Creek downstream of the WWTP (MC-3) (Figure 14). Samples were collected September of 2010 and September and October of 2011. Samples collected in 2010 all scored below the nitrate threshold (10mg/L for municipal use, which doesn't apply to Marsh Creek or its tributaries) and contained 0.1-0.2 mg/L of ammonia. Samples collected in September 2011 also scored below the nitrate threshold, and contained 0.4-7.3 mg/L of ammonia. Samples collected in October 2011 also included the East Contra Costa Irrigation District (ECCID) and WWTP outfalls (MC-3). Samples from the ECCID and WWTP outfalls both exceeded the threshold, and ammonia content ranged from nondetect to 0.7 mg/L (California Environmental Data Exchange Network (CEDEN 2017).

CCCWP monitoring in WY 2012 and 2013 applied thresholds for nutrients delineated in the San Francisco Basin Water Quality Control Plan. CCCWP observed nitrate levels below the 10 mg/L threshold and ammonia levels below the 0.025 mg/L threshold they identified. However, this threshold from the San Francisco Bay Basin Plan (SFBRWQCB 2017) is not meant to apply to freshwater. The USEPA recommended chronic criterion for protection of freshwater organisms is 1.9 mg/L total ammonia nitrogen (USEPA 2013), but this number should be adjusted for temperature and pH conditions. Samples were obtained from Marsh Creek at Brentwood Blvd (MC-7) and Dry Creek at Claremont Dr. (DYC-1) (Figure 14) (CCCWP 2014).

CCCWP monitoring in WY 2015 applied the same criterion and observed similar results at the intersection of Marsh Creek and Sand Creek Road and Dry Creek 350m west of Creekside Park (Figure 14) (CCCWP 2016).

CCCWP monitoring in WY 2015 applied the same criterion and observed similar results from Marsh Creek at Sand Creek Road (MC-9) and Dry Creek 350m west of Creekside Park (DYC-3) (Figure 14) (CCCWP 2016).

As part of BASMAA monitoring in April of 2015, CCCWP collected nutrient samples from upstream of Sand Creek Rd [MC-9]. Nitrates fell below the municipal use threshold of 10 mg/L., and ammonia thresholds were exceeded (BASMAA). FOMCW SWAMP monitoring was conducted in the same month 0.3 mi above Highway 4 and at Brentwood Tech Center [MC-8]) (Figure 14). The sites exceeded ammonia thresholds. Phosphorus ranged from 0.03-0.045 mg/L in the three sites.

4.2.7 Mercury

The abandoned Mount Diablo Mercury Mine site is located on Dunn Creek, a tributary to Marsh Creek in the upper watershed. Although mining activities took place from 1875 to 1939, mercury-rich waste rocks or tailing sites thrown into nearby creeks remain a major contributor to mercury in Marsh Creek today (Cain *et al.,* 2004). Eighty-five percent of fish sampled between the Dunn Creek inflow and the Marsh Creek Reservoir in 1997 contained mercury concentrations above the California Department of Health consumption guideline levels (Slotton *et al.,* 1998). Mercury-laden sediments originating from the mine have been deposited and accumulated in the slack water of the Marsh Creek Reservoir. In the Reservoir sediments, anaerobic conditions and naturally occurring microbial populations transform, or methylate, less toxic forms of mercury into highly toxic and bioavailable methylmercury (Cain *et al*., 2004). Marsh Creek Reservoir has been closed to fishing since the mid-1980's.

As part of the CalFed Fish Mercury Project, Marsh Creek at Big Break, Big Break and Emerson Slough were sampled in November and December of 2005 in a separate small fish biosentinal mercury study (Slotton *et al*., 2007). 2008 concentrations were lower along the Marsh Creek sites. At Emerson and Big Break, August 2008 levels were lower and March 2008 levels were slightly elevated.

In March and August of 2008, small fish biosentinal mercury monitoring was conducted in tidal Marsh Creek at sites in and adjacent to the Dutch Slough wetland. Five sites were sampled in Marsh Creek (above tidal influence at Delta Rd [MC-2]), Emerson Slough, Little Dutch Slough and Big Break in both March and August. Predatory fish, such as juvenile largemouth bass and prickly sculpin, were found to contain higher mercury concentration than those lower on lower trophic levels, such as bluegill, sunfish and shiners. Mercury concentrations declined, especially in largemouth bass, from March to August. Highest mercury concentrations were found in Big Break and Emerson Slough, and the lowest concentrations were found at the most upstream site at Delta Rd. (MC-2) (Slotton, 2008).

The TMDL goal for methylmercury for the Sacramento-San Joaquin River Delta is 0.06 nanograms per liter (ng/L) (CCCWP, 2014). Maximum methylmercury concentrations observed in lower Marsh Creek by MRP permittees were 0.407 ng/L during WY 2012 and 1.2 ng/L during WY 2013, both greater than the proposed goal (Gilbreath, et al. 2014).

SES was retained by the NHI in 2006 and 2007 to sample for mercury and methylmercury in lower Marsh Creek. The highest concentration of methylmercury observed by SES in Marsh Creek was 1.41 ng/L, during a November sampling event at Creekside Park in Brentwood (MC-13). Methylmercury concentrations in Marsh Creek surface water were observed to exceed TMDL concentrations (0.06ng/L) at all five sampling locations during all five sampling events in 2006-07 (**Figure 14**).

SES only detected total mercury during the August 2007 sediment plume downstream of Sand Creek. SES concluded that the majority of methylmercury found in the Marsh Creek sampling area is traveling from the Marsh Creek Reservoir, or from further upstream in a dissolved state. The same trend was observed in methylmercury and total mercury concentrations in soil, with methylmercury concentrations being almost double that of total mercury concentrations.

MRP permittees found Marsh Creek monitoring is lacking information on high intensity upper watershed rain events where sediment mobilization from the historic mercury mining area could occur. Thus, the CCCWP implemented a Methylmercury Control Study from 2012 to 2015, and samples were collected during "wet weather" and "dry weather" in November through June during 2012 to 2015 (CCCWP, 2015). Only one sample was obtained from upper Marsh Creek due to dry conditions. All samples exceeded the 0.06 ng/mL threshold, except for the samples on Sand Creek (SC-1), Deer Creek (DC-1) and Dry Creek (DYC-1) in dry weather in January and February of 2015.

4.2.8 Pesticides

The San Francisco Bay Regional Water Quality Control Board (SFBRWQCB) has adopted a TMDL for pesticides in urban creeks (SFBRWQCB 2005). The CVRWQCB also has adopted a TMDL for diazanon and chlorpyrifos for Delta creeks, and a separate TMDL for pyrethroid pesticides (CVRWQCB, 2017). Toxicity to the benthic amphipod *Hyalella azteca* was observed in Marsh and Dry Creek during storm events in WY 2012 and WY 2013. The MRP requires that a Stressor/Source ID (SSID) Study be completed if a measurement exceeds triggers in the permit. A SSID was done on Dry Creek, a tributary that enters Marsh Creek near Creekside Park in the City of Brentwood.

Dry Creek flows through a culvert from the Brentwood Golf Club west of Arlington Way (upstream sampling site), approximately 350 meters along Crescent Drive (south of Balfour Drive), in a grassed flood control channel. It then enters another culvert just downstream of the downstream sampling location, and flows under Creekside Park to its confluence at Marsh Creek. This reach receives runoff from the neighboring urban development as well as from the golf course (CCCWP, 2014).

The SSID study concluded that pyrethroid pesticides in water and sediment samples were likely to be the principal cause of the toxicity to *Hyalella Azteca*. Pyrethroid pesticides have replaced diazinon and chlorpyrifos as the most commonly applied urban pesticides. Four DDT breakdown products were detected in upstream and downstream sediment samples (CCCWP SSID Studies, Part A, 2014). Reports indicate that when diazanon and chlopyrifos were re-registered to restrict use to registered professional applicators, acute toxicity was eliminated. CCCWP is planning to work with BASMAA and members of the California Association of Stormwater Agencies (CASQA) to lobby for re-registration of pyrethroid pesticides.

As part of CCCWP's SWAMP monitoring, pyrethroid pesticides were sampled in Marsh Creek at Cypress Rd. (MC-1). Eight different pyrethroids were detected in Marsh Creek at Cypress Rd. (MC-1) from 2010-2015, ranging from 0.69-159 ng/g DW. As part of the Irrigated Lands Regulatory Program, the SJCDWQC sampled Balfour Rd. (MC-13), downstream of Sand Creek Rd (MC-6), and Concord Ave (MC-14)(**Figure 14**) from 2006 to 2008. No pyrethroids were detected in Marsh Creek at Concord Ave (MC-14). Three different pyrethroids, ranging from 0.015-0.049 ng/g DW were detected in Marsh creek at Balfour Ave (MC-13) in 2005. No pyrethroids were detected downstream of Sand Creek Rd. (MC-6) in 2007 (CEDEN 2017).

4.2.9 Benthic Macroinvertebrates

Between 2002 and 2009, FOMCW sampled benthic macroinvertebrate communities in coordination with CCCWP at 17 sites on upper and lower Marsh Creek (some locations were sampled in multiple years while others were sampled only once). The lower Marsh Creek sites (downstream of the reservoir) scores were generally marginal, while the upper Marsh Creek sites scored higher on the Contra Costa Index of Biological Integrity (IBI) (FOMCW and NHI, 2011).

In WY 2012 and 2013, CCCWP sampled benthic macroinvertebrate communities on Marsh Creek (two upstream sites and one at the intersection of Brentwood Boulevard [MC-7]), Dry Creek (300m west of Claremont Drive [DYC-3]) and Deer Creek (300m west of Foothill Drive [DC-3]). In 2012, the Deer Creek and Dry Creek sites scored marginal, while the two upstream Marsh Creek sites scored very good on the

Contra Costa Benthic Index of Biological Integrity (Contra Costa B-IBI). For 2013, the Marsh Creek/Brentwood Boulevard site scored fair on the Contra Costa IBI (CCCWP, 2014).

In WY 2015, CCCWP sampled benthic macroinvertebrate communities at the intersection of Marsh Creek and Sand Creek Rd. (MC-9) and Dry Creek 350m west of Creekside Park (DYC-3). Both locations scored marginal condition on the Contra Costa IBI (CCCWP, 2016).

A study conducted in September 2012 by a UC Berkeley student compared benthic macroinvertebrate communities at five sites: two sites upstream of Brentwood's WWTP (MC-2) and three downstream of Brentwood's WWTP (MC-3). A general increase in relative abundance of sensitive taxa (% ephemeroptera, plecoptera, and trichoptera (EPT)) and decrease in family biotic index was detected in the downstream sites, suggesting better water quality downstream of the WWTP (Moniz, 2013).

4.2.10 Habitat Quality

Based on surveys conducted for project CEQA documentation (Impact Sciences 2016 and Wood Biological Consulting, 2017), no natural, unaltered plant communities are present onsite or in the project vicinity. Although native plant species are present, none of the habitats present are considered indigenous and natural; each is characterized as a product of post-disturbance recolonization. The predominant vegetation type is ruderal. Anthropogenic habitat, consisting of plantings, is present along the Marsh Creek Regional Trail and on adjacent properties. A narrow band of ruderal freshwater marsh habitat is present along the base of each channel bank. No federally or State-listed plant species or California Rare Plant Rank 1A, 1B and 2 species were detected within the study area and none is expected to occur within the project disturbance areas due to level of historical disturbance and lack of appropriate habitat.

Based on the availability of suitable habitat, there is potential for nine special-status wildlife species to occur on site. These include silvery legless lizard, California red-legged frog, Pacific pond turtle, Chinook salmon, steelhead (Central Valley distinct population segment), burrowing owl, white-tailed kite, loggerhead shrike, and Swainson's hawk. Of the nine species, two of these species were observed on site during surveys: burrowing owl was observed nesting within the study area and Swainson's hawk was observed foraging over the site. Populations of California red-legged frog, Pacific (Western) pond turtle, and silvery legless lizard have been recorded from the project region, but the occurrence of these species on the project site is considered unlikely (Impact Sciences, 2016 and Wood Biological Consulting, 2017).

Although there are no records for steelhead or Chinook salmon occurring in Marsh Creek in the 2015 California Natural Diversity Database (CNDDB) and occurrence on site for both species is considered unlikely, recent sightings of fall-run Chinook have been reported within Marsh Creek, and within the project site, and suitable habitat for steelhead is present in the project area. Populations of listed salmonids have not been regularly observed in Marsh Creek; any present would be considered stray migrants. Listed salmonids have the greatest potential to occur within the project area between November and June based on the timing of adult and juvenile migrations in and through the waterways of the Sacramento/San Joaquin Delta (Impact Sciences, 2016).

The project site trees, shrubs, vines, and grasslands provide suitable nesting habitat for four special-status bird species (Swainson's hawk, white-tailed kite, burrowing owl, and loggerhead shrike) as well as many other migratory bird species (Impact Sciences, 2016 and Wood Biological Consulting, 2017).

CCCWP conducted assessments of physical stream habitat at the locations and dates of macroinvertebrate sample collection. Physical habitat condition was assessed on a preliminary basis using PHab scores, computed from three physical habitat attributes (epifaunal substrate/cover, sediment deposition, and channel alteration) measured in the field. The composite mini-PHab score has a possible range from 0 to 60, with each of the contributing factors scored on a range of 0–20 points. Higher PHab scores reflect higher-quality habitat. The California Rapid Assessment Method (CRAM) was also used in 2015 to evaluate habitat. The CRAM methodology includes an assessment of the following four attributes within a defined riparian assessment area: 1) buffer and landscape context; 2) hydrology; 3) physical structure; and 4) biotic structure.

In 2013, the Dry Creek site received a score of 18, the Deer Creek site received a score of 38, and the Marsh Creek site received a composite PHab score of 26 out of 60. In 2015, the Dry Creek site received a composite PHab score of 19, and a CRAM score of 39 (poor) (CCCWP, 2014). The Marsh Creek site received a composite PHab score of 14, and a CRAM score of 53 (fair). For both metrics, these were among the lowest scores compared to other creeks monitored by CCCWP (CCCWP, 2016).

4.2.11 Fish Monitoring

FOMCW and other volunteer groups have been tracking occurrence of adult salmon migrating upstream in Marsh Creek since 2001. Salmon were observed to occur each year from 2001-2009. No salmon were observed from fall 2008 to spring 2010; however, salmon may have been present but not observed, as surveys were qualitative in nature and level of effort, timing, and locations covered varied. Salmon were again observed in fall of 2011, 2016, and 2017. All salmon are assumed to be stray Chinook salmon.

Multiple fish kills on Marsh Creek have occurred at least since 2005, generally with unidentified causes. In recent years fish kills have become more frequent, occurring every year since 2014. All but one of them occurred in an area just downstream of the WWTP outfall and a discharge drain from the ECCID, and a storm water drain pipe (MC-3 on **Figure 14**). In 2011, FOMCW developed a plan for monitoring in the event of fish kills, and FOMCW were trained by CVRWQCB staff. However, fish kills have continued to occur with no additional information on causes. In 2016, a Marsh Creek Fish Kill Committee was formed by CDFW, and includes AR staff and consultants, Flood Control, City of Brentwood and other interested parties.

In April 2002, Erica Cleugh, a CDFW employee, identified 13 juvenile Chinook salmon between 60 and 80mm downstream of the drop structure. Darell Slotton found five juvenile salmon below the drop structure between Oakley and Brentwood in 1995, when he sampled for mercury concentrations in 1995, 1996 and 1997 during the spring following the major rainfall and runoff of the year (approximately between March and May). The fish length ranged from 60-80 mm (Slotton, 1998).

5.0 MONITORING AND ADAPTIVE MANAGEMENT APPROACH

5.1 Permit Compliance Monitoring

Monitoring will be done to comply with all permit requirements as specified in the final project permits. Permit compliance monitoring may overlap with other types of monitoring discussed in the following sections, but additional monitoring may be required. When appropriate, permit compliance monitoring will be integrated into monitoring efforts that are already planned, which may result in some alteration of the monitoring plan in order to comply with permit requirements. It is likely that permits will require preconstruction biological surveys, and information from these surveys will be used to inform future surveys of fish, herps, and wildlife that are conducted in coordination with community volunteer groups.

5.2 Performance Monitoring

Project performance monitoring will focus on evaluating performance metrics for vegetation (quantitative measurements) and floodplain morphology (qualitative evaluation) on an annual basis. Because the performance metrics established are independent of influences outside the control of the project (such as weather, predation, etc.), monitoring will be conducted at locations within the project site only, and no pre-project baseline monitoring or monitoring of reference sites elsewhere in the watershed is planned.

5.3 Monitoring of Project Benefits and Long Term Trends

Although monitoring results for water quality, biology/ecology, and public response will not be used to evaluate project performance for reasons discussed in Section 1.4.3, the monitoring program is designed to allow for evaluation of project benefits and long term trends in these areas. This type of monitoring design includes comparison to pre-project baseline conditions, as well as data collection at reference sites within the watershed in addition to monitoring the project site. Reference site data will allow for evaluation of the influence of factors outside the control of the project, such as climatic events, pollution from upstream runoff, etc. The baseline data set will include existing data described in Section 4, as well as new data collected in 2018 prior to construction. When possible, planned monitoring locations coincide with previous monitoring locations, and methods are designed to be consistent with previously used methods for better comparability. Because one of the objectives of monitoring includes engaging the community, this category of monitoring will be coordinated with student and volunteer groups, and when appropriate will use protocols they have already established.

5.4 Adaptive Management

The adaptive management and monitoring approach for this project has been designed to be consistent with the nine-step adaptive management framework presented in the Delta Plan (Figure 13). This adaptive management monitoring plan (AMMP) lays out the planning phase: Steps 1 and 2 are addressed in the Introduction, Step 3 in Section 2 (Conceptual Model), Step 4 in Section 3 (Performance Metrics). This AMMP also specifies how the action phase will be implemented (Step 5 is described in the Project Background, and Step 6 in the entire document), and how the evaluate and respond phase will be conducted (Step 7 and 8 in Data Analysis and Reporting, and Step 9 in Adaptive Management).

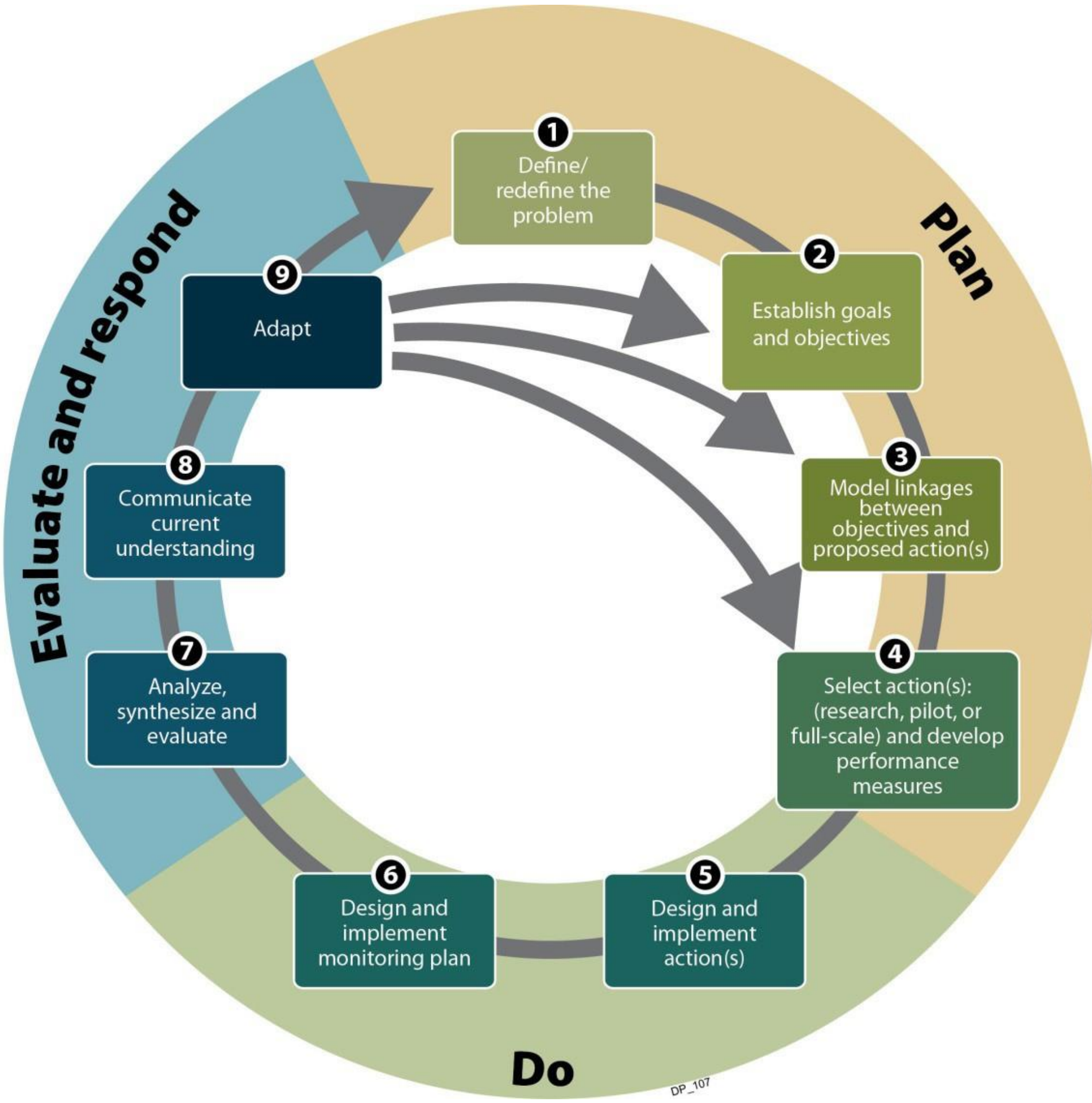


Figure 13: A Nine-step Adaptive Management Framework (from Delta Plan)
The shading represents the three broad phases of adaptive management (Plan, Do, and Evaluate and Respond), and the boxes represent the nine steps within the adaptive management framework. The circular arrow represents the general sequence of steps. The additional arrows indicate possible next steps for adapting (for example, revising the selected action based on what has been learned).

6.0 MONITORING METHODS, SCHEDULE AND LOCATIONS

6.1 Schedule

The project construction is expected to occur in late summer and fall 2020. Additional baseline monitoring for this project began in fall 2017 and will continue until the project is constructed. Post restoration monitoring will continue at least 2 years after completion of the project and is expected to continue for at least 5-10 years pending funding.

Baseline and post-project data monitoring will be collected on the following schedule:

- Basic water quality – monthly
- Nutrients in water – quarterly
- Macroinvertebrate bioassessment and habitat assessment – annually in late spring
- Fish counts – after rain events from Oct 1 – Feb 28
- Herp surveys – annually
- Wildlife surveys – annually
- Avian surveys – annually

6.2 Vegetation Monitoring

The initial three-year planting and establishment period will involve intensive efforts to establish native plantings so that they can out-compete undesirable invasive plants[3]. To ensure that this is occurring, the Project Sponsor or representative will monitor percent cover of native and undesirable invasive plants, and percent bare ground in plots and along four to six representative transects.

The monitoring will report percent tree canopy cover (including stakes and poles) over the channel along creek lengths that extend 40 feet upstream and downstream of six established transects. The monitoring will also report percent bare ground and percent weed cover, as well as the number, species and height of live trees within 20 ft of the trail in the project area, measured along randomly selected increments of trail.

Monitoring will be conducted annually for three years at the same time of year each year so that the data are comparable across sampling dates.

Field Methods

Measurements will be collected in plots and along four to six transects within the Project Area that include all four Maintenance Cover Types (Figure K-1). Annual field surveys will be conducted starting in 2021 and ending in 2026, during which information will be collected using the following methods, briefly summarized below.

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[3] Undesirable invasive plants are defined as Cal-IPC defined at a minimum to include all species with a “Moderate” or “High” rating (https://www.cal-ipc.org/plants/inventory/).

Absolute Cover by Line Intercept

Permanent transects, running from Project Area boundary on River Left to the Project Area boundary on River Right will be established. A tape measure is run along a straight line (with the ground contour) from river right to river left project boundaries along each transect. Starting at River Left, field crew record the beginning and end distance and each shrub canopy or tree intersected at 3 ft above ground. Scientific plant species names of each canopy or tree bole intersection are recorded along with transect distances.

Absolute cover for all plants and by species is calculated as (Total Length with Vegetation / Total Transect Length)*100. More detail on this protocol can be found in Coulloudon et al. 1999.

Absolute and Relative Cover by Releve'

Three 100 m2 plots are randomly located within each Maintenance Cover Type, totaling twelve 100 m2 plots for the Project Area. Plot shapes can vary to fit well within the vegetation type boundaries. We will use a modified version of the CNPS releve' methodology (CNPS 2019). More detail on this protocol can be found in CNPS 2019.

Absolute percent cover all vascular vegetation: The percent of the plot area covered, considering a bird's eye view, by vascular vegetation is recorded , considering 'porosity' of the cover and disregarding overlap of different vegetation layers (so that if a tree canopy shades a shrub, only the area of the tree canopy is counted unless the shrub canopy shades area outside of the tree canopy).

Absolute percent cover by species: percent cover of each species is recorded, disregarding overlap and considering porosity.

Relative percent cover of native species: Species are then identified as native or non-native species and then the sum of native species cover is compared to the absolute percent cover of all vascular vegetation: (sum of native species cover/ percent cover all vascular vegetation) *100. Relative percent covers of highly invasive and moderately invasive weed species are calculated in a similar manner.

Absolute percent cover bare ground: Within the 100 m2 plot, record the percent of mineral soil (not litter or cobbles or larger substrate) visible below the shrub and tree canopies.

Percent Canopy Cover over Channel

A densiometer measurement is made at three points upstream, downstream and at the intersection of the channel and each transect (Lemmon 1956). The densiometer is placed in the center of the channel and canopy cover recorded at each of the three locations per transect. Average canopy cover values are reported per transect.

Tree Stem/Height Density

Record the species, number and height of trees within 20 ft of the trail (measured perpendicular to the trail) that extends 80 ft upstream and 80 ft downstream of each transect. Thus, 160 ft of trail that straddles Transect 1 will be walked by the field crew. The height and species of each tree within 20 ft of that length of trail will be recorded. This same process will be repeated for the section of Marsh Creek trail bisected by each transect. The total number of trees, by height category are then divided by the total number of feet of trail included in the census; these numbers are then reported.

6.3 Morphology and Stability Monitoring

Floodplain morphology and stability will be evaluated by a review of topographic survey data (when determined necessary) and visual inspection.

Visual Inspections

The channel and project area will be inspected annually for three years for any problems and areas of excessive erosion or deposition with additional focus on areas adjacent to key structural components such as bridges. The inspections will be visual but will also include examination of aerial photos and topographic surveys in order to determine any trends. Banks will be surveyed and for streambank stability class, as described in Henshaw and Booth 2000. Bank lengths of 20+ ft with moderately to completely unstable banks will be flagged and assessed for restorative actions by project sponsor engineer or other qualified personnel.

Photopoints

The Project Sponsor or representative will conduct photographic surveys for the first three years at nine fixed photo-monitoring stations (one each at the two vehicular bridges, one pedestrian bridge, and the right bank benchmark of each cross section) to observe changes over time.

6.4 Water Quality Monitoring

Water quality monitoring parameters were selected based on known water quality issues identified in previous monitoring results and field observations (Section 4.0). As discussed in Section 4.0, parameters such as DO, temperature, and pH frequently exceed recommended thresholds for protection of aquatic life. Limited data have been collected on nutrient concentrations, but data suggests significant nutrient pollution, which likely contributes to eutrophication and low DO concentrations. Water quality field measurements will be collected monthly, and nutrient sampling will be done quarterly. All water quality monitoring and laboratory analysis will follow SWAMP standard operating procedures (SOPs) (DFW, 2014) and quality assurance practices.

Mercury mining upstream has resulted in elevated concentrations of mercury in the Marsh Creek watershed, and mercury methylation and bioaccumulation may increase with floodplain restoration (Alpers et al. 2008). The project team considered including mercury monitoring because there is known to be elevated mercury in the upper portion of the Marsh Creek watershed. However, available data have not indicated mercury to be problematic in the lower watershed where the project site is located. Data indicate that most of the mercury is trapped in the reservoir upstream, which only releases water when it overflows, and CCCWP is conducting additional monitoring to confirm this. In addition, even if elevated levels of mercury did occur in the project area, it is unlikely that collection of grab samples collected once per year would provide sufficient data to quantitatively evaluate the effect of the project on mercury methylation.

A total of 10 sites will be monitored for water quality, including: four sites upstream of the project area on Marsh Creek, Sand Creek, and Deer Creek; three sites within the project area; and three sites downstream of the project area (**Figure 15 and Table 7**). The monitoring program is designed to allow for evaluation of project benefits as well as long term trends in water quality. The design includes comparison to pre-project baseline conditions, as well as data collection at reference sites within the watershed upstream of the project site, in addition to monitoring the project site and downstream locations. Reference site data will allow for evaluation of the influence of factors outside the control of the project, such as climatic events, pollution from upstream runoff, etc. The baseline data set will include existing data described in Section 4.0, as well as new data collected prior to construction. Seven of the planned monitoring locations coincide with previous monitoring locations, and methods are designed to be consistent with previously used methods for better comparability. Three new monitoring locations were identified to ensure good coverage of each of the tributaries discharging into Marsh Creek at the project, and of Marsh Creek within the project site. This design will facilitate identification of sources of pollution that impact ecosystem health of the project site and the watershed in general, including potential causes of fish kills that have been occurring frequently downstream of the project site.

Because one of the objectives of monitoring includes engaging the community, water quality monitoring will be coordinated with student and volunteer groups. A consultant under contract with American Rivers will be leading the water quality monitoring program, and at this time two community volunteers are assisting every month. In addition, Los Medanos Community College students will likely assist with monitoring.

Table 7. List of site locations and GPS coordinates (shown on Figure 15).

Site Locations	Site ID	GPS coordinates (Lat., Long.)
Creekside Park in Brentwood, downstream of pedestrian bridge	MC-13	37.923, -121.712
Central #1, Marsh Ck. above Deer Ck	MC-11	37.936, -121.709
Central #2, Marsh Ck. above Sand Ck	MC-12	37.938, -121.707
Deer Creek downstream of Minnesota Ave.	DCN-2	37.936, -121.714
Sand Creek upstream of Minnesota Ave.	SCN-2	37.938, -121.714
Sungold Park downstream of pedestrian bridge	MCN-10	37.942, -121.706
Sand Creek	SC-3	37.946, -121.730
Marsh Ck @ Tech Center	MC-8	37.948, -121.701
Marsh Ck upstream of Delta Road bridge	MC-2	37.969, -121.683
Marsh Ck downstream of Cypress Road bridge	MC-1	37.991, -121.696

At each site, water samples for turbidity and nutrient analysis will always be collected before in situ physical measurements are taken, and in situ physical measurements will always be conducted before any other monitoring activity that might disturb the streambed, such as collection of macroinvertebrate samples.

All field measurements will be recorded using a standardized SWAMP field data sheet (Appendix A), which will be completed for each site even the site is dry and no measurements can be taken. Monthly field sampling will be conducted with field measurements of DO, pH, temperature, and conductivity with a multiparameter probe (YSI Pro) on long term loan from the Contra Costa Resource Conservation District. Water samples will be collected for turbidity measurements to be measured by the field technician in the laboratory of either The Watershed Project or the EBRPD Big Break Shoreline

Interpretive Center using a HACH 2100 portable turbidity meter, which complies with USEPA Method 180.1.

Immediately before use (same day), pH, dissolve oxygen, conductivity and turbidity instruments will be calibrated against standards. A calibration check will be performed on field equipment after the last site has been monitored. Field measurement equipment will be checked monthly for operation in accordance with the manufacture's specifications. This includes necessary equipment recertification, battery checks, routine replacement of membranes, and cleaning of conductivity electrodes.

When possible, water samples will be collected at a location in the stream where the stream appears to be completely mixed. Grab samples for turbidity and nutrients will be taken at approximately 0.1 m and multi-probe measurements will be taken at approximately 0.2 m, or less if water is shallow or access is difficult. If water depth is less than 0.1 m, grab samples will be collected at the surface. Depth will be noted on the field data sheet.

For each sampling event, one site will be selected randomly for collection of field duplicates for all samples collected for laboratory analysis. In addition, one field travel blank sample will be conducted for nutrient analysis for each sampling event. Additional laboratory QA samples, including laboratory blanks, laboratory spikes, and duplicates will be conducted by the laboratory per SWAMP requirements.

Nutrient sample containers will be supplied by contracted analytical laboratories (Table 8). Each sample container will be labeled with the station ID, analysis type, date and time of collection. After sampling, the label will be secured around the bottle with clear packaging tape. Samples will be maintained at 4^{o}C until delivery to the analytical laboratory. Care will be taken at all times during sampling collection, handling and transport to prevent exposure of the sample to direct sunlight. When collecting water samples, disposable polyethylene gloves will be worn to prevent contamination of the sample and to protect the sampler from environmental hazards. Staff will train all volunteers in appropriate field collection methods. Every batch of samples delivered to the laboratory will include a complete Chain of Custody (COC) that lists all samples collected and the analyses to be performed on these samples. Photos will be taken of the COC and of all sample bottle labels.

Table 8. Analytical Methods, Container, Preservation and Hold times for Nutrient Analysis

Analysis	Method	Container	Preservation	Max. Holding Time
Ammonium as N	E350.1	500mL Amber Glass jar	H_2SO_4, pH<2, cool 4^{o}C	28 Days
Nitrate/Nitrite (Inorganic Anions)	E300.1	125mL HDPE bottle	Cool, 4^{o}C	48 hours
Total Kjeldahl Nitrogen (TKN)	E351.2	500mL Amber Glass jar	H_2SO_4, pH<2, cool 4^{o}C	28 Days
Dissolved Phosphorous	E365.1	500mL Amber Glass jar	Cool, 4^{o}C	48 hours

Total Phosphorous as P	E365.1	500mL Amber Glass jar	H_2SO_4, pH<2, cool 4ºC	28 Days

6.5 Fish Monitoring

Salmon Spawner Surveys will be conducted using the *Daily Salmon Spawning Stock Survey Field Form* (Appendix B), which is based on guidance from CDFW's *Salmonid Stream Habitat Restoration Manual* (CDFW, 1998) and the existing method used by FOMCW in previous years, in coordination with volunteer groups. This method is qualitative in nature and its purpose is to document the presence of salmon attempting to migrate and spawn in Marsh Creek. The salmon surveys also serve as outreach and education tools and help to get the community involved in protection of Marsh Creek. Although observed fish are counted, the method is not considered quantitative because counts are not standardized by level of effort, thus data are not comparable temporally or spatially. In addition, surveys do not always cover all of the same locations. Surveys are conducted during the spawning season between October and February, generally at least several times a month after precipitation events.

Salmon spawner surveys are stream bank or above water surveys. The qualitative information gathered will determine if adults are returning to and spawning within a stream and identify preferred spawning habitat area. The method for conducting spawner surveys is to walk along the stream bank counting and entering all salmon carcasses, redds, and live fish observed. All information is recorded, along with weather conditions, time/date and section of Marsh Creek, Sand Creek or Deer Creek surveyed. Salmon have been observed October through December in Marsh Creek. Once salmon have been sighted, surveys are most useful after storm events to monitor salmon traveling further upstream beyond the fish ladder.

Surveys will be conducted with volunteer groups led by trained staff of AR, FOMCW, and EBRPD. The surveys generally cover from Creekside Park in Oakley upstream to Creekside Park in Brentwood. AR will attempt to coordinate with CDFW to collect carcasses and submit coded wire tags to determine hatchery origin.

6.6 Avian Monitoring

Bird surveys of the project site as well as upstream and downstream areas will be conducted at least once per year to document presence of avian species using visual surveys. They will be conducted by experienced ornithologists and trained citizen observers in collaboration with EBRPD's Big Break Regional Shoreline staff. Appendix B of the *Friends of Marsh Creek Watershed Salmon Monitoring Training Manual* contains descriptions of birds found at Marsh Creek. Additional birds will be added based on biological surveys done for CEQA (Impact Sciences, 2016), as well as any preconstruction surveys done in advance of project implementation. Similar to salmon surveys, avian surveys will be qualitative in nature, with the primary purposes being community education and outreach, and to document bird species presence over time.

6.7 Herp Monitoring

Reptile and amphibian surveys of the project site as well as upstream and downstream areas will be conducted at least once per year to document presence of avian species using visual surveys. They will be conducted by experienced biologists and trained citizen observers in collaboration with groups that may include: EBRPD, Save Mount Diablo, and Los Medanos College. Surveys will be designed based on potential species identified in biological surveys done for CEQA (Impact Sciences, 2016), as well as any preconstruction surveys done in advance of project implementation. Herp surveys will be qualitative in nature, with the primary purposes being community education and outreach, and to document species presence over time.

6.8 Mammalian Wildlife Monitoring

Mammalian wildlife surveys of the project site as well as upstream and downstream areas will be conducted at least once per year to document presence of avian species using visual surveys. They will be conducted by experienced biologists and trained citizen observers in collaboration with groups that may include: EBRPD, Save Mount Diablo, and Los Medanos College. Surveys will be designed based on potential species identified in biological surveys done for CEQA (Impact Sciences, 2016), as well as any preconstruction surveys done in advance of project implementation. Mammalian wildlife surveys will be qualitative in nature, with the primary purposes being community education and outreach, and to document species presence over time.

6.9 Additional Optional Monitoring and Studies

In collaboration with other entities conducting monitoring in the region, the project team will attempt to obtain funding and/or coordinate volunteer teams to implement a number of additional monitoring components and studies. For example, beginning in summer 2018, CCCWP will implement an SSID study to investigate the causes of fish kills that occur in Marsh Creek, and has requested collaboration with the Three Creeks project team and other community groups. In addition, it would be highly beneficial to install continuous water quality monitoring stations within and/or downstream of the project site, that would provide much more complete data sets than monthly grab samples. Continuous monitoring data would be invaluable both for evaluating the benefits of the restoration project on water quality, and for identifying temporal variability in factors such as low DO and high pH, providing information that could help to identify sources of pollutants.

Potential additional monitoring and studies include the following:

- **Collection of benthic macroinvertebrate (BMI) assemblages** may be conducted at the same ten sites that are sampled for water quality (**Figure 15**). If funding is available, duplicate samples will be collected at 10% of study sites (one site per year). Procedures will follow SWAMP guidance (Ode *et al*., 2016) Biotic sampling will be conducted during late April or early May, with the criterion that sampling be carried out at least two and preferable three, weeks after any storm event that has generated enough stream power to move cobbles and sand/silt capable of scouring stream beds. The stream reach will not be sampled for bioassessment shortly after a scour event that has mobilized materials and potentially disrupted benthic communities. All water quality samples will be collected before any BMI samples are taken, and water quality measurements will be recorded following the procedures outlined in Section 6.4 of this document.

Proper field hygiene will be practiced avoiding transferring invasive organisms or pathogens. Equipment such as footwear and D-frame net for collecting BMI samples will be decontaminated after the entire site/reach is sampled.

The geographic coordinates of the downstream end (Transect A) will be recorded with a GPS receiver. The length of the reach depends upon the average "wetted width "of the stream reach. If the average wetted width is greater than or equal to 10m a reach of 150m will be delineated. If the average wetted width >10m, a 250m reach will be delineated.

Wire-stemmed flags will be used to indicated location of transects. Standard sampling layout consists of 11 "main" transects (A-K), all of which are arranged perpendicularly to the stream flow. The first flag is installed at the water's edge on one bank at the downstream limit of the sampling reach to indicate the first main transect "A". The positions of the remaining transects are then established heading upstream and measured segment of 7.5m (if sampling reach is 150m) or 12.5m (if it is 250m).

Starting with the downstream transect (Transect A) identify a point that is 25% of the stream width from the left bank (looking downstream). Once the sampling spot is identified the 500 micron D-frame net is placed in the water 1m downstream of the target transect. The net is positioned perpendicular to, and facing into, the flow of water. A sampling plot $1ft^2$ will be sampled adjacent to the net opening. Once the coarser substrates have been removed and all rocks larger than a golf ball have been cleaned, allowing attached organisms to wash downstream into the sampling net, dig to a depth of about 10cm where gravels and finer particles are dominant. The net is carefully lifted from the water and the next transect will be subsampled in the same manner. The sampling position with each transect is alternated between the left (25%), center, right (25%) positions along the same order, while moving upstream from transect to transect.

Once all of the 11 subsamples have been collected and composited, the composite will be transferred to one or more 500ml wide mouth plastic sample jars. To insure proper preservation jars will not be filled more than half with sample material. A date/locality label, filled out in pencil, placed inside the jar and the jar will be completely filled with 95% ethanol. A second waterproof label will be placed on the outside of the jar and secured with clear tape. All samples will have both internal and external labels. Preserved BMI samples will then be shipped directly to the CDFW Aquatic Bioassessment Laboratory, where samples will be processed, identified and analyzed per SWAMP guidelines.

- **Install continuous monitoring stations** within and/or just downstream of the project site to monitor parameters such as temperature, turbidity, dissolved oxygen, and pH. The project is expected to lower the temperature of the creek water by providing shade, which will in turn help to mitigate low DO and high pH levels. Our current plan of monitoring monthly will help to track these changes, but all of these variables vary considerably on a daily cycle, and it will be difficult to determine changes with only monthly grab samples. Although there is no continuous baseline data, the available data indicates that all three of these parameters are frequently outside of ranges that are protective of aquatic life. We expect the restoration to result in a shaded canopy that will eventually cover most of the creek in the project reach, and it will take years for the canopy to fill in, so we expect to see increasing benefits to water quality over time. In conjunction with the Contra Costa Clean Water Program (CCCWP) and others, we will attempt to obtain funding to install continuous monitoring stations immediately after project implementation, so that we can start monitoring at time zero and evaluate benefits as time progresses.

- **Add an annual survey of canopy cover over the entire stream length within the project site**, to be conducted by volunteers. This would be in addition to vegetation performance monitoring done annually and would use the same methods as that used during the SWAMP bioassessment habitat survey at each of the 10 monitoring sites, or alternatively may be done with a drone survey. This information would be evaluated in conjunction with water and air temperature data to evaluate effectiveness of increased canopy cover in improving water quality.

- **Monitor biochemical oxygen demand (BOD), total suspended solids (TSS), and sulfides** once a month or quarterly at all 10 monitoring sites. While we are already measuring dissolved oxygen (DO) and turbidity in the field, DO levels vary considerably during the daily cycle and from day to day, and these parameters will help determine whether nutrients and low dissolved oxygen likely contributes to fish kills. This work would be done in collaboration with CCCWP and with the City of Brentwood WWTP, with volunteers collecting samples during monthly monitoring and dropping them off at the WWTP for analysis.

- **Collaborate with the CCCWP to identify the sources of flow spikes that may be sources of pollutants.** The CCCWP has determined that regular flow spikes occur about once every two weeks in Marsh Creek during summer months. The flow spikes are often associated with turbidity spikes. Starting in summer 2018, CCCWP will be monitoring water levels and turbidity continuously, with telemetry and alerts to monitoring staff when flow or turbidity spikes occur. We will help them by organizing volunteers to respond when flow alerts occur by walking the creek to attempt to identify the sources of flow spikes.

- **Conduct surveys** annually after project implementation in order to gather information on public opinion and perceptions of the restored site. Surveys will be distributed to residents that live near the creek or use the trail. Surveys may include questions in the following categories:
    - Perceived value of the restoration project
    - Level of knowledge of the restoration project
    - Level of knowledge of the creek ecosystem and species presence
    - Personal use and perception of the project area before and after restoration
    - Usefulness of signage and other interpretative materials
    - Participation and interest in biological surveys
    - Participation and interest in other education and outreach activities

6.10 Quality Assurance/Quality Control Procedures

Once the project permits are finalized, a QAPP will be developed for all project monitoring activities. Existing QAPPs prepared by FOMCW and other groups will be updated as necessary and incorporated into the QAPP for this project. Quality assurance/quality control procedures will meet SWAMP requirements and will follow all permit requirements.

7.0 ADAPTIVE MANAGEMENT

7.1 Vegetation

Based upon the monitoring results, the project vegetation specialist may determine that modifications to the original revegetation plans are in order due to different or changing conditions. For example, there may be natural native plant colonization that is different from what is prescribed by the planting plan or there might be areas subject to frequent scour or too dry to support the intended vegetation cover. The vegetation specialist should propose a modified cover that complies with hydraulic objectives, the project goals, and other requirements set by the regulatory agencies. Plants will be replaced as necessary in order to achieve success in meeting performance criteria and will be thinned when and where needed in order to meet flood conveyance objectives. In both cases, plant replacement and plant thinning, actions and the rationale behind them will be documented and included in annual monitoring reports.

7.2 Morphology and Stability

Where appropriate, project related channel and riparian corridor bank changes will be compared by a geomorphologist against previous data in order to assess changes and extents of moderately or highly unstable riparian corridor banks. If action thresholds are exceeded, as outlined in Table 3 and further specified for each project in its tailored AMMP, a professional engineer will be enlisted to provide recommendations for remedial actions, if necessary, in consultation with the project geomorphologist, project sponsor and appropriate agencies. If surveys or visual inspections indicate that there may be excessive erosion adjacent to critical structures, then measures will be implemented accordingly to repair the eroded area. Depending on the extent and severity of the erosion, a registered geotechnical engineer may be retained.

7.3 Other

Other types of monitoring will be used for ongoing adaptive management of the project site, as well as to identify and plan future actions to help achieve long term goals in the Marsh Creek watershed. Project proponents are involved in multiple efforts to protect the watershed, and data collected under this project will be shared with community groups to assist ongoing efforts in various ways. Some examples include:

- Biological survey data will be used to track species that are utilizing the project site and surrounding areas, and this may inform the way the site is managed (such as additional protection of nesting areas for sensitive species).
- Water quality data will be used to help identify upstream pollutant sources, determine potential ecosystem impacts, and aid in future control actions. Although funding is not currently available for these types of actions, additional funding may be sought by project proponents and/or other groups.
- Fish count and fish kill data will be evaluated in conjunction with water quality data to determine patterns and identify potential causes. Data will be shared with the Marsh Creek Fish Kill Committee, which was recently formed by CDFW due to the occurrence of repeated fish kills. Although funding is not currently available for these types of actions, additional funding may be sought by project proponents and/or other groups.

In addition, the data obtained under this project will help in planning of future restoration projects by providing information on the benefits and limitations of floodplain restoration on urban creeks. Some examples include:

- Water quality data upstream of, within, and downstream of the project site be provide information on benefits of floodplain restoration in reducing nutrient concentrations.
- Invertebrate community data will be compared to baseline conditions and reference site data to evaluate changes in community metrics over time, which will help to predict how fast these communities can recover after restoration is implemented.

To facilitate future utilization of “lessons learned” from monitoring of this project, monitoring data and reports will be made publicly available as described in Section 8.0, and the results may also be presented at scientific conferences and/or published.

8.0 DATA ANALYSIS AND REPORTING

Monitoring data will be managed, stored, and disseminated by American Rivers. Relevant project monitoring data will be uploaded to EcoAtlas annually. Consistent with the Wetland and Riparian Area Monitoring Program (WRAMP) guidance and CDFW requirements, water quality monitoring data will be submitted annually to the California Environmental Data Exchange Network (CEDEN) in a format that meets SWAMP requirements.

Data will be reviewed for consistency with quality control guidelines, and data not meeting guidelines will be flagged and treated appropriately when analyzing data sets. For performance monitoring of vegetation and geomorphology, data analysis will primarily include comparison to performance metrics. For water quality and biological monitoring, data analysis will include evaluation of spatial and temporal trends. Water quality data will be used to help identify potential pollutant sources that may lead to eutrophication, fish kills, or other adverse effects on ecosystem health. In addition, when possible a before/after, control/impact (BACI) approach will be used to evaluate project effects with regard to water quality and macroinvertebrate communities. Most biological data (fish, herps, birds, wildlife) will be more qualitative in nature (presence/absence), and data analysis will primarily consist of evaluating changes in species use over time and space.

Monitoring reports will be prepared annually on a schedule that will meet permit requirements, to be determined when permits are issued. Submittals to the US Army Corps of Engineers will include the Corp's Mitigation Monitoring Form.

9.0 COMMUNICATIONS PLAN

Community engagement and education is an integral part of this restoration project. By involving community members as volunteers in restoration monitoring efforts, we hope to raise awareness of the benefits of creek protection and ecosystem restoration. Educational signage will also promote creek conservation and inform recreational users about freshwater aquatic habitat, ecosystems, and species using the restored area. The project team will make monitoring reports and other informational documents easily accessible to community members and other interested parties. In addition, the project team will actively engage with community groups and local educational institutions.

Efforts will be made to inform community members and groups of specific findings when appropriate. For example, if special status species are found in the vicinity of the restored site, the project team may engage others to collaborate in limiting disturbance to the species. If water quality monitoring results indicate that pollutants are coming from particular locations, volunteers and community groups will be engages to help determine specific sources and educate landowners and community members to reduce pollutants.

The following groups and organizations will be actively engaged in volunteer and educational activities:

- FOMCW
- The Watershed Project
- EBRPD
- Save Mount Diablo

- Los Medanos College
- Freedom High School
- Earth Team

Monitoring reports and other relevant documents will be sent the following local groups and organizations for distribution:

- FOMCW
- CCCWP
- The Watershed Project
- EBRPD

In addition, monitoring reports and other relevant documents will be posted and publicly accessible on at least one website, which will likely include a website of a local group such as FOMCW, The Watershed Project, or CCCWP.

To facilitate future utilization of "lessons learned" from monitoring of this project, the results may also be presented at scientific conferences and/or published. This may include regional conferences such as State of the Estuary and the Bay-Delta Science Conference, as well as national or international conferences.

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Appendix A

DQM Field Data Sheet for Water Quality Monitoring

Date ________ Page _________

of _____ _______

Waterbody Name: ____________________________________

Project Name and/or ID: _______________________________

Station ID: ________________________

Group/Organization name and/or ID: _____________________

Station Name: _________________________

Team Name: ____

Station Habitat (*circle one*: Pool, Run, Riffle)

Trip ID ________ Station Visit ID _________

Leader (name &

Members:

(list additional names on back)

Date of last rain

Observations: *Circle one underlined option:*

Observations Time: ____________________

Cloud cover	no clouds; partly cloudy; cloudy sky
Precipitation	none ; misty; foggy; drizzle; rain;
Wind	calm; breezy; windy;
Water Murkiness	clear water; cloudy water (>4" visibility), murky (<4" visibility). *[this pertains to the water itself, not to scum]*
Flow conditions	dry creekbed; isolated pools; trickle (< 0.25 gal/sec); < 5 gal/sec; > 5 gal/sec; full waterway no observed flow
Sample color	none; amber; yellow; green; brown; gray; other:
Sample odor	none; fresh algae smell; chlorine; rotten eggs; sewage; other
Other (presence:)	algae or water plants; oily sheen; foam or suds; litter; trash; other

Measurements

Instrument ID	Parameter	Unit	Result	Repeated Measurement Result	Bracket/ Resolution	Measurement Time	Measurement Depth*	Comments
	Total Depth (at Station) or Staff Gage readout	cm					not applicable	
	Specific conductivity	uS/cm						
	Dissolved oxygen (DO)	mg/l (ppm)						
	Temperature, water	°C						
	pH .	pH						
	Transparency	cm						

***Measurement Depth**: *(Select)* surface; mid-column; near-bottom; (*or provide measured number and unit*)

Sampling Device: *(for observations, measurements, and Samples)*: none; pole&beaker; bucket& rope; Kemmerer; other:

Sample ID *(for offsite analyses)*	Collection Time	Collection Depth	Sample Containers

Appendix B

DAILY SALMON SPAWNING STOCK SURVEY FIELD FORM

Stream: ______________________________ **T** _______ **R** _______ **S** _______
Lat: ____________________ **Long:** ________________ **Quad:** ____________________
Drainage: ______________________________ **County:** ________________
Starting location: ______________________ **Lat:** ____________ **Long:** ____________
Ending location: ______________________ **Lat:** ____________ **Long:** ____________
Feet/miles surveyed: ______________
Date of survey: ____/____/____ **Weather:** clear ________ overcast ________ rain ________
Water clarity: 0-2 ft. __________ 2-4 ft. __________ >4 ft. __________
Water temp: ______________ **Air temp:** ______________ **Time:** ________________
Crew: ____

Number of live fish observed: Chinook adults__________ Chinook grilse__________ Coho _________
Steelhead ______________ Unknown ______________

Number carcasses examined:

Chinook Male (FL)	Chinook Female (FL)	Coho Male (FL)	Coho Female (FL)

Tag number of adipose clipped fish and snout recoveries:

Other fin clips observed: ____
____

Number of skeletons observed:
Chinook ______________ Coho ______________ Steelhead ______________ Unknown ______________

Number of redds observed: ______________________

Comments: