**Title**

Post-project appraisals of constructed vernal pools in Solano County, California



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# Post-project appraisals of constructed vernal pools

# in Solano County, California

**Term Project for Restoration of Rivers and Streams – LD ARCH 227**

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**ABSTRACT**

We conducted post project appraisals for two vernal pool restoration projects in Solano County within the Elsie Gridley Mitigation Bank and the Montezuma Wetlands. We collected and analyzed field data, including surveyed cross sections, soils information and general observations. We also analyzed existing hydrologic, soil, floral and faunal monitoring data provided by project managers and local monitoring stations. The two projects vary in terms of successes and challenges, which can be traced to specific design, implementation, and management techniques. Both projects are vernal pool construction projects and both use similar monitoring parameters including branchiopod, flora, water depth and water duration monitoring. The projects vary in timing, size, quantities of monitoring data, project goal and criteria clarity, design (pool density, soils and topography), and implementation methods (inoculation and planting/seeding). Data showed that pools between sites were gently sloping ranging from 9:1 to 63:1 and that pools varied in terms of location in the landscape, pool depths (5.3 to 15.3 inches), pool inundation, and floral and faunal conditions. In general, Montezuma Wetlands has design concerns that may inhibit the establishment of vernal pool hydrology in some created pools, in turn affecting other vernal pool functions. Elsie Gridley Mitigation Bank, requires more data to determine whether the project is trending towards success, and has various management concerns that should be addressed. Both projects will require further monitoring in order to determine whether success is being met.

**Post-project appraisals of constructed vernal pools in Solano County, California**

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## INTRODUCTION

Vernal pools are gently-sloping, shallow, depressional pools characterized by annual wet and dry seasons and varying in size, shape, depth, hydroperiod and micro-topography (Barbour et al May 2007). The complexity and extremes provided by the described conditions yield a beautifully intricate ecosystem supporting a unique assemblage of plants, invertebrates and wildlife. There are many definitions for the term "vernal pool" based on many different parameters (Zedler 2003). One definition based on hydrology, soils, flora, and temperature defines vernal pools as "precipitation-filled seasonal wetlands inundated during a period when temperature is sufficient for plant growth, followed by a brief waterlogged terrestrial stage and culminating in extreme desiccating soil conditions of extended duration (Zedler 2003)." While definitions may vary, it is important to understand that the characteristic structure and function of vernal pools are a result of interactions between spatially and temporally varying processes and conditions: such as climate, landscape, pool topography, soils, hydrology, isolation and connectedness (Zedler 2003).

Vernal pools exist in various regions throughout the world, often in Mediterranean climates like the California climate (Keeley and Zedler 1998). Vernal pools typically exist in level to gently sloping landscapes, often within mima mound topography. Mima mounds are small mounds commonly reaching heights of two meters and diameters of 20 meters (Cox and Hunt 1990). Vernal pools vary in size, have gently sloping sides, and often exhibit micro-topography along the pool bottom (Holland 1981). Vernal pools occur in soils containing an impermeable layer such as a claypan, cemented hardpan or rock (Barbour et al 2007). Typically California vernal pools begin to fill during November and remain wet through the winter and spring. During the wet season water depths typically range from saturated soils to less than 19.7 inches (50 cm) (Barbour et al 2007). As temperature rises and precipitation decreases during the summer, the pools dry up, and remain desiccated until the rainy season returns the following winter (Barbour et al 2007).

There are approximately 100 plant taxa commonly found in vernal pools (Barbour et al 2007). In addition, there is an unquantifiable number of rare species found in vernal pools (Barbour et al 2007). These rare taxa may not provide a large percent cover, but perform various crucial vernal pool functions and are often unique to single pools or groups of pools (Barbour 2007). When vegetation flowers in the spring, regular and irregular rings reflect the interaction between the vegetation and the topography, water level and various other pool conditions (Barbour 2007). Vernal pool fauna typically include invertebrates, insects and amphibians, many of which are federally listed species, such as vernal pool tadpole shrimp (*Lepidurus packardi)- endangered* and Delta green ground beetle (*Elaphrus viridus)- endangered* (Barbour et al 2007). Vernal pool flora and fauna have adapted to extreme conditions in water level, soil pH and salinity; therefore, a unique group of species survive in the pools, excluding upland and aquatic species (Zedler 2003 and Baskin1994). There is a high level of endemism in species likely due to the extreme conditions and varying degrees of isolation and connectedness of pools (Zedler 2003 and Baskin 1994).

The complexity of vernal pools makes performing successful vernal pool restorations difficult. Background research indicates that vernal pool restoration efforts are largely implemented and monitored in an inconsistent and insufficient manner and that certain restoration approaches simply do not work (De Weese 1998). Vernal pool experts express that there are many details that must be addressed in performing vernal pool restorations, that restoration takes a long time, and that success cannot be achieved quickly or without detailed planning (Barbour 2007; Witham 2007). Some of the key issues in restoration design include proper site selection, careful implementation techniques, and appropriate management (Barbour 2007). Site selection should be based on soils, topography, and hydrologic conditions, and should be pool specific (Barbour 2007). It is also important to address design and implementation issues such as invasive and exotic species, adjacent land uses, historical context, construction techniques which reduce soil compaction and plant trampling, and seeding and inoculation (the transfer of a small section of surface soils from a functioning vernal pool to a constructed vernal pool) to increase the establishment of vernal pool flora and fauna (Barbour 2007). After construction, management techniques such as grazing and burning are useful to control nuisance and exotic species. Lastly, although it is not always prioritized or proposed, it is necessary to perform post project appraisal for each project.

A post project appraisal should include a combination of monitoring data collection, monitoring data analysis and adaptive management (Downs & Kondolf 2002; Kondolf & Micheli 1995). Often, while monitoring data may be collected, it may not be appropriate or sufficient, and analysis may not be conducted correctly or at all (De Weese 1998). One common issue in vernal pool monitoring is the taxonomic abilities of the person monitoring the pools (Barbour 2007). Vernal pools have many common, and even rarer species, which are important in terms of understanding the structure and function of a pool (Barbour 2007). Therefore, depending upon the appropriateness or sufficiency of monitoring data, the project status and success may not be clearly understood. Data should be collected and analyzed appropriately, so that the proper measures can be taken to correct design issues or improve management practices to reach success (Downs & Kondolf 2002; Kondolf & Micheli 1995). Post project appraisal and adaptive management is important not only in recognizing project successes, but also in learning how to correct project failures and learn from our mistakes. Table 1 provides the basic information we determined necessary to review a vernal pool restoration project and lists general information the consultants provided. Table 3 lists literature values for typical vernal pool characteristics on which we based success criteria. Our success criteria and recommended vernal pool restoration and maintenance techniques are listed in Appendix B (Table B3 and B4).

We performed post project appraisals for a subset of created vernal pools within two completed restoration projects entitled Elsie Gridley Mitigation Bank and Montezuma Wetlands. Our objectives were:

1) To determine whether these restoration projects have clear goals and objectives

2) To determine whether these restoration projects are meeting our success criteria (Appendix B)

3) To determine whether they are ultimately successful through additional data collection and analysis.

We focused our appraisals on the vernal pool restoration components of the restoration projects and specifically collected data from one preserved and three constructed vernal pools within each project.

Our post project appraisals provide additional information towards determining whether vernal pool restoration is a viable option for mitigation, an issue highly pertinent to the larger issue of vernal pool restoration in California. Considering the large number of vernal pool restoration projects proposed as mitigation in California for vernal pool impacts and the uncertainty of restoration success, it is critical to determine whether or not impacts to vernal pools are truly being mitigated. While this concern has been expressed by experts, consultants, and regulators, we hope to further stress the uncertainty involved in vernal pool restorations and provide further data to understand the state of vernal pool restoration.

## METHODS

*Project and Site Description: Meyer Cookware Goldfield's Preserve*

The Meyer Cookware project site is located off Highway 12 in the town of Fairfield in Solano County, California. The purpose of this project was to provide mitigation for the loss of wetland habitat from construction of the Meyer Cookware factory and parking lots. We decided not to use this project for a thorough PPA because the created habitats were not vernal pools per se but a combination of wetlands (swales and pools), some with vernal pool characteristics. We also rejected this project for inclusion in our PPA because the objectives changed in the course of the project making it more difficult for us to evaluate and reach conclusions, and current monitoring data/reports were available for this project as for the other two projects (Table 4).

*Project and Site Description: Elsie-Gridley Mitigation Bank*

The Elsie Gridley Mitigation Area is in eastern Solano County, south of Dixon and adjacent to Solano Land Trust's Jepson Prairie Preserve. The site is 1,814 acres and consists of native and non-native grasslands, eucalyptus groves, Ulatis Creek, Alamo Creek, Barker Slough, an historic railroad, and wetlands (perennial marshes, vernal marshes, alkali mesic grasslands, alkali playa pools, and vernal pools). Natural vernal pool and associated habitats exist on 1,100 acres, while degraded vernal pool habitat, pasture and agriculture land existed on the remaining 700 acres, prior to the beginning of this project. Site elevations range between 5 and 15 feet, with generally level mima mound topography.

The purpose of the bank is to provide offsite mitigation opportunities for future projects involving impacts to vernal pool, grassland and riparian habitats, as well as associated rare, threatened, and endangered species. Restoration includes 1,100 acres of natural vernal pool habitat restoration, 300 acres of pasture/ agricultural production, and 376 acres of restoration, including the restoration of approximately 100 acre of former vernal pool habitat. Vernal pool restoration goals included biological enhancement, weed reduction and native plant promotion, native plant and animal diversity enhancement, special-status species habitat protection and restoration, and management plan efficiency (D-1).

The design rationale is clearly stated in the reports and is based on the restoration site conditions and design approach. Vernal pool restoration areas were specifically proposed in pastures that formerly supported vernal pool habitat, that contained typical vernal pool soils and micro-topography, and that were located adjacent to existing vernal pool habitat. The design approach is based on mimicking the existing onsite vernal pools (reference pools) in terms of typical pool/swale size (varies), typical pool depths (4.8-9.6 inches), typical pool slopes (10:1-17:1) and uplands side slopes (7:1-50:1), typical mound heights (1-2 feet), typical pool density (39-41%), general topography (mima mound), hydrology, vegetation and wildlife (D-2). The typical ranges were adapted from reference pool surveys and observations (D-2 and D5). In addition, inoculation and seeding were proposed to enhance species establishment.

A 10 year monitoring plan includes vegetative monitoring (quantitative sampling, percent cover, diagnostic species recognition), hydrologic monitoring (pool depth and duration), and wildlife monitoring (aquatic invertebrates and vernal pool associated species) proposed at various years throughout the monitoring period (D-1 and D-2). Monitoring activities are lowest priority in terms of funding (D-1). Vernal pool maintenance activities include the restoration plan, grazing prescriptions, exotic plant control, fire/fuel breaks, native grasses management, no rodent control, and limited hunting (D-1). We focused our study on Phase I, as more monitoring data was available (Appendix B). Phase I construction was completed by December 2005, and the first year as-built report was completed by January 10, 2007.

*Project and Site Description: Montezuma Wetlands*

The Montezuma Wetlands project site is located in southeastern Solano County, California, just northeast of the confluence of the Montezuma Slough and the Sacramento/San Joaquin River (Figure 1). The upland site that serves as the vernal pool preserve (~160 acres), including the creation area for the new vernal pools, is a mixed native and non-native grassland with gently undulating topography (Figure 3). There are a total of thirty pools on the Montezuma site: 9 "preserved" pools (i.e., natural vernal pools that are monitored to obtain mitigation credits), 13 "avoided" pools (i.e., pools that have had human impacts and are not currently monitored), and eight newly created pools (i.e., constructed by Vollmar Consulting in October 2003 and monitored to obtain mitigation credits). The northern section of the site (where created pools C1-5 are located) is sheep grazed, while the southern portion (where created pools C6-8 are located) is cow grazed (Figure 3).

The purpose of the larger Montezuma Wetland project is to restore a tidal wetland by depositing dredged bay muds into diked historic baylands. However, the marsh restoration will impact vernal pools within the project site that support listed branchiopod species. Therefore, the other goals of the project are to preserve 3.7 acres of existing vernal pools and to construct five acres of new vernal pools as compensatory habitat for the loss of 0.98 acres. For the construction of new vernal pools, the goal is to create pools that mimic the high-quality natural pools already on site, especially by providing habitat for four species of listed branchiopods: vernal pool fairy shrimp, Conservancy fairy shrimp, vernal pool tadpole shrimp, and California fairy shrimp (D-10).

The design for the created vernal pools was based on the features of the natural vernal pools on the site obtained from baseline surveys, conducted one wet season before construction (D-10). The design included the following specifications: spillway elevations on average one inch higher than OHWMs; slopes (from pool edge to pool bottom) between 12:1 and 20:1, with the steeper slope usually located at the southeastern side of the pool; and pool depths at an average maximum of seven inches, with larger pools at an average maximum of ten inches (D-10). The design was very site specific: the consultant said that they had picked the best areas to be pool sites and had designed the pools to fit the landscape (Vollmar 2007). However, site selection for pools on the northern section had been done by a different methodology by a previous consultant, and could not be re-done by Vollmar Consulting due to project budget constraints (Vollmar 2007). The methodology for the northern section was to use soil surveys for Solano County (USGS) to select the location of the created pools based on slopes (2-9%) and soils with appropriate subsoil and claypan necessary to trap water in pool basins (Pescadero clay loams or Solano loams) (Vollmar 2007).

Post-project monitoring is required on an annual basis for a minimum of seven years in a ten-year period to assess the changes in performance in the created pools and any impacts to the preserved pools. Monitoring by consultants has now been performed for three years out of the ten-year period (2004, 2005, and 2006) and has included: hydrology, water quality, aquatic invertebrates and amphibians at three annual visits (early, mid, and late season inundation); and floristics at one annual visit (peak spring bloom).

*Document Review:*

Initially, we conducted a cursory review of three completed restoration projects (Montezuma Wetlands, Elsie Gridley Mitigation Bank, and Meyer Cookware Gold Fields Preserve), and then selected two projects for a thorough post-project appraisal or PPA (Downs & Kondolf 2002; Kondolf & Micheli

1995). For the selected projects, we reviewed as many of the project documents as could be retained (Table 4). We use the citation code listed in Table 4 throughout the rest of this manuscript to reference specific project documents. Based on the documents we retained, we then determined what information was missing and attempted to obtain this information through a combination of literature review, interviews, and field work.

*Interviews:*

We conducted interviews with project consultants and people we considered experts in vernal pool restoration. Two project consultants, John Vollmar of Vollmar Consulting and Steve Foreman of LSA, were interviewed and generously shared project documents for the three restoration projects we reviewed. Experts, Carol Witham (California Native Plant Society) and Michael Barbour (UC Davis), were interviewed to provide further background information concerning the status of vernal pool restoration work. The details of these four interviews are contained in the Literature Cited section and we refer to them by their short in-text citation throughout the paper. In addition, we conducted a literature review.

*Field Visits:*

We conducted three field visits all of which involved photography and observations of the selected vernal pools on October 18, November 1, and November 12, 2007. The first visit was to all three project sites and helped us to determine which two we would use for our final PPA. During this first visit some of the pools on the Montezuma site held water which allowed us to conduct dip net surveys, and pool depth and area measurements, in addition to general site observations. On our second field visit (11/1/07) we used standard hydrology survey methods (Dunne and Leopold 1978) to conduct cross section surveys on the Montezuma site of one preserved natural vernal pool and three created pools. Similarly, on our third field visit (11/12/07) we conducted cross section surveys on the Elsie Gridley site of one preserved natural vernal pool and three created pools. Also during our third field visit, we made observations of pool conditions, mima mound heights and densities at nearby Jepson Prairie Preserve to obtain reference conditions for the Elsie-Gridley pools.

During both survey visits, our benchmark for each pool was a rebar stake with flagging that we pounded into the ground. Project documents provided the known elevations for the each site and we used the average of these as the benchmark elevation. We set up the level along one axis in each pool, taking note of top of bank, bottom of bank, ordinary high water marks (OHWMs), slope changes, vegetation and substrate conditions along the entire cross section. We then measured several transects perpendicular to the surveyed axis to determine the complete morphology and area of each pool. We also paced the OHWMs around each pool to calculate a perimeter in feet. We sketched facies maps for each pool, again noting vegetation and substrate. We plotted pool morphology as cross section profiles and pool facies maps, and annotated the plots with vegetation data. We also calculated slopes from the edge of the pools to their deepest point (i.e., OHWM to deepest point), noting these values on the cross section plots (Appendix A).

*Precipitation measurements:*

We used precipitation data from nearby rain gauge stations listed on the California Data Exchange Center website (http://cdec.water.ca.gov), managed by the California Department of Water Resources. We analyzed historical rain trends using data from the Davis station (DVS). Located in Yolo County, approximately 31 miles north of the Montezuma site and 17 miles north of the Elsie Gridley site (Figure 1), it is the closest gauge with long-term monthly precipitation data. We downloaded monthly rainfall accumulation for the period of record from January 1905 to September 2007. However, the monthly data between 10/1/2003 and 9/1/2006, were missing; therefore, we used data from the second closest gauging station covering the same period of record at Woodland (WDL), 10.5 miles north of Davis (Figure 1).

To analyze our historical precipitation data, we determined the total rainfall accumulation for each water year during the period of record (January 1905 to September 2007) by summing the monthly values, and plotting water year accumulation (Figure 10). We then calculated the mean, maximum, and minimum total rainfall of the water years for the period of record and compared data from our project sites with these results.

*Soil Surveys:*

We used Solano County Soil Survey data from United States Department of Agriculture surveys to verify the soil information provided by each of the project documents (USDA 1977). Because soil information served as a basis for pool site selection, we found it necessary to examine how these determinations had been made from the surveys available.

*Analyses:*

Upon completion of project document review, interviews, literature review, precipitation and soil data collection, and field visits, we analyzed all the data to determine the current state of each of the restoration projects. We summarized the overall findings for the two projects based on common PPA criteria (Downs & Kondolf 2002) in Table 1. For each of the projects, we compared the hydrology and pool morphology information obtained from our field surveys, and the general site conditions obtained from our photographs and field notes with baseline (or literature values if baseline data was not available), as-built, and monitoring data. We compared data for the created pools to the preserved pools on each site, and then we compared the results from each site to each other and to information obtained from the literature for pristine, ecologically functioning vernal pools. The gathered information and secondary analysis will provide the basis for answering our research questions about vernal pool restoration process, evaluation, and success.

## RESULTS AND DISCUSSION

The following case studies include our analysis and discussion of data we obtained from the consultant, and data we collected in the field.

### *CASE STUDY: ELSIE GRIDLEY MITIGATION BANK*

*Consultant Secondary Analysis:*

The consultant performed a basic secondary analysis as the first year success criteria are limited to general vegetation establishment and hydrologic ponding over 18 consecutive days.

*Site Observations:*

During our field visits, we walked Phase II of the project, observed pools in Jepson Preserve, and observed and collected data from the onsite preserved vernal pools and the constructed pools in Phase II of the project. When we walked Phase II, most of the small pools were dry, had bare ground, and cracking soils (Figure 8A-B). The large pools along the northeast side of Phase II held water and exhibited low plant cover and cracking soils. Pool turbidity was variable and burrowing species were using the mima mounds. When we observed the natural vernal pools at the Jepson Preserve, the larger pools held water, the pool water was predominately turbid, the pool bottoms had established vegetation and cracking soils, and the margins were distinct (Figures 8C). The surrounding terrain includes gently sloping mima mound topography (Figure 8D), with mounds varying in height from approximately 2-4 feet. Burrowing species were using the mima mounds. We then observed the preserved pools within Elsie Gridley Mitigation Bank and collected data from one of the preserved pools (Figure 8E). The preserved pools were dry and the surrounding terrain included gently sloping mima mound topography. Mima mound topography was similar to the Jepson Preserve.

Finally we observed and collected data from the constructed pools for Phase I. These pools were dry (Figures 8F-H), although some did have slightly wet soils at the surface. We noticed that, in Phase II, the mima mounds are taller than in Phase I, and that the pool density in Phase I and II appeared higher than the preserved pool density and the pool density on Jepson Prairie. We also noticed that many of the pools in Phase I were covered by thatch, such as Pool 52 (Figure 8G). The consultant informed us that he was required by permitting agencies to provide more mima mound topography in Phase II, and that grazing was proposed to the control the thatch overgrowth in the Phase I (Foreman 2007).

*Cross-section surveys:*

During the November 2007 field visit, we surveyed cross-sections in one preserved pool and three created pools for Phase I (Figures 2, 4A-D, and 5A-D). We obtained pool areas, ordinary high water marks, maximum depths, sites of maximum depths (Table 2A). The cross section data shows that the Phase I constructed pools are more gently sloping than the typical preserved (reference) pools onsite and more gently sloping than the reference pool that we surveyed. The constructed pool maximum depths were within the range of the reference pools. The constructed pool perimeters (based on paces) ranged from 174 to 428 feet, which is smaller than the preserved pool perimeter of 800 feet. Ponding areas varied from 0.06 to 0.31 acres for the constructed pools. The reference pool surveyed was 0.5 acres. The constructed pools were smaller than the preserved pool; however, there were smaller preserved pools located onsite as well.

*Soils:*

The majority of Phase I restoration area is located in Solano-Pescadero complex soils and a small portion of the site is located in San Ysidro sandy loam. Both soils have very low permeability rates. Both are formed from alluvium from sedimentary rock as the parent material, and are older alluvium, although not considered old in geologic terms, that have formed argillic horizons having had sufficient time to form fine textured horizons from the translocation of silicate clays (USDA 1977). The soil surface in the restoration areas had historically been altered by tillage and leveling; however, narratives provided by the consultant state that the soil chemistry and impermeable layer are still intact. The reports include soil chemistry data, but do not include information pertaining to the impermeable layer condition. Water is holding in the pools; however, further monitoring data, including soils information, is required to determine whether the impermeable layer condition will affect the vernal pool hydrology.

*Monitoring Data:*

We looked at monthly and annual precipitation for the area for the entire period of record (water years 1906 to 2007, partial) (Figure 10). The average yearly total precipitation was 17.25 inches, the maximum precipitation occurred in 1983 at 37.16 inches, and the minimum precipitation occurred in 1976 at 6.78 inches. When we compared the baseline and monitoring data years to the period of record we found: the baseline data year 2006 was 6th wettest in the period of record with 28.61 inches. Precipitation data for part of year 2007was available (from October 2006-July 2007), at which point precipitation totaled 10.13 inches. Overall hydrologic monitoring data shows that in water year 2006 pools held water at depths ranging from 1 inch in the beginning and end of the wet season to as high as 21 inches during the wettest point of the season, which is a higher than typical depth for vernal pools (<19.7 inches). In the second year (2007) pool were drier holding 0-10 inches of water. All Phase I pool depths and durations lie within the limits of the success criteria and within typical vernal pools depth range and durations (< 19.7 inches, and duration of 10-65 days). Data for the specific pools we surveyed lie within these ranges as well, and followed a similar decrease in hydrology for the second year. Data shows that the pools are holding water, however further monitoring data will be necessary to determine whether the water depths will remain sufficient to support vernal pool flora and fauna with the climate variations.

Vegetation has not been monitored for Phase I yet, however initial establishment of vegetation and the presence of special status species particularly Alkali milkvetch (*Astragalus tener* var. *tener*) were noted in the as-builts (Appendix B). Vegetative monitoring is proposed for these pools. We were not able to take vegetative data during our site visits for our specific pools as the site was too dry. Some of the pools, such as Pool 43 and 51 (Figures 8F and 8H), have low vegetation establishment; however, other pools, including Pool 52 (Figure 8G), were overgrown with thatch, which is a problem that needs to be addressed. Overgrowth of thatch prevents high diversity and produces higher levels of organic matter decomposition inhibiting vernal pool establishment of floral and faunal species (King 1998). The consultant informed us that grazing was proposed on the site to control the cover in the pools.

Brachiopod monitoring was conducted for the Phase I pools, during the first year as-builts. All three constructed pools contained brachiopods: California fairy shrimp (*Linderiella occidentalis*), a species of concern, in pool 43, and vernal pool tadpole shrimp (*Lepidurus packardi*), an endangered species, in 51 and 52. And 70% of the total pools contained typical vernal pool brachiopods. The success of recruitment could be due to the inoculation (Appendix B).

***CASE STUDY: MONTEZUMA WETLANDS***

*Consultant Secondary Analyses*

The consultants analyzed their monitoring data annually (2004-2006) and performed a comparison of their monitoring data across all four years (2003-2006, including the baseline data for preserved pools on the site). From the comparison across all four years, they found that conditions within the created pools fluctuated greatly over the three years post-construction, whereas the natural pools were fairly consistent over those same years despite interannual differences in precipitation. Doing this comparison over the three to four year period allowed them to see positive trends in increasing vernal pool species and negative trends in decreasing ponding depths for certain pools (C1, C3, and C6). For example, animal diversity increased but was still much lower than the preserved pool numbers, whereas plant diversity decreased but stayed within the range of preserved pool numbers (Appendix B).

Another key finding was the presence of vernal pool tadpole shrimp in one of the created pools (C5) for the first time in 2006. The consultants viewed this appearance of tadpole shrimp and an increase in other vernal pool indicator taxa in other created pools as an indication that the pools are moving toward natural, functional vernal pool ecosystems. The consultants expect the created pools to support the remaining three branchiopods found in neighboring preserved pools on site within the next few years (by common dispersal mechanisms such as live stock and high winds present on site). While it is indeed the hope that the created pools will meet their success criteria and provide habitat for the four listed branchiopods, there is no level of confidence given for these predictions and they are not based on any other studies or literature values.

To address the finding that three created pools that did not attain minimum ponding depths (C1, C3, and C6), the consultants proposed to "closely monitor" them next year. However, they do not specify what corrective actions will be taken if pools continue to not meet success criteria such as ponding depths and duration, and presence of listed branchiopods. There is no adaptive management plan for correcting design flaws or other non-compliance issues.

Two of the metrics used by the consultants in their analyses are of questionable validity. First, "ponding duration" is assigned as the date and water level found on the third monitoring visit regardless of whether the pools have dried out or not (i.e., ponding duration = date of third visit – date of first or second visit, whichever held water) (Vollmar 2007). Second, four groups of invertebrates were assigned by the consultants as "vernal pool indicator (VPI) taxa" without any recognized agreement or utilization of this metric in the vernal pool restoration field or the biomonitoring literature. The consultant used both "ponding duration" and the "VPI" metrics in their latest 2006 report to show positive trends in created pools (D-13) , but trends based on these metrics are spurious because the metrics themselves have not been shown to be valid.

*Site observations*

During our reconnaissance field visit to Montezuma on Oct 18, 2007, we were able to walk almost the entire site (preserved pool 9 was not visited) and observe several differences between preserved and created pools. First, the northern pools (C1-5) clearly stuck out as "created" in their shape (many are more elongated and larger than the preserved pools), their location on the landscape (on convex slopes and upland areas), and their lack of characteristic pool bottoms both in terms of vegetation types and cover, and pool slopes. Several are filled with encroaching upland vegetation without pronounced slopes separating them from the landscape (Figure 9A & B). Others lacked vegetation--possibly because they are still early in their development as vernal pools and do not have the same floristic community richness as the preserved pools (Figure 9C & D). When we looked for the southern pools (C6-8), it was difficult to distinguish them from the nearby preserved and avoided pools and we had to consult our map to tell which ones were which. This was clearly a good sign that they were designed to mimic the natural pools on the site as the consultants claimed and that they have developed a similar ecology (soil, hydrology, and floristic community) since their construction.

Second, three (P3, P5, and P6) of the nine preserved pools we visited were holding water (2-3 inches) (Figure 9E &F), whereas none of the created pools had water, possibly due to less hydrological function in the created pools. We conducted dip net surveys of the aquatic organisms in the preserved pools that were holding water and found at least five groups (Table 5A). There was also ample evidence of other animal uses of the preserved pools but no such evidence in the created pools (probably because the preserved pools were holding water earlier in the season than the created pools) (Table 5B) (Figure 9G).

*Cross-section surveys*

By conducting cross section surveys of one preserved and three created pools on the Montezuma site we obtained: pool areas, ordinary high water marks (OHWMs), maximum depths, sites of maximum depths (Table 2B). Previous monitoring found that slightly less area ponded than was targeted in the design the first wet season, but max depths were all in the design range (7-11 inches for pools C1 and C3 and 11 inches for C5). From our cross sections we found that all the created pools were much larger than the natural pool (P6) in ponding area, but were close in acreage to the targeted ponding areas. This meant they did not mimic the natural pool very well in size (at least this one natural pool we surveyed) and they had lower ponding areas than their design criteria. Pools C1 and C3 had much shallower slopes and lower max depths than their design criteria, and lower than reported in the as-built report (D-10). The consultants also reported this trend of Pools C1, C3, and C6 having decreasing max depths over time. Pool C5 met its targeted max depth and but had variable slopes that were either much larger than 12:1 on one side (had a much steeper side than design criteria would allow) and less than 20:1 on the other side. The natural pool we used for comparison had everything approximately within the targeted design criteria: slopes within targeted range for created pools of 12:1 to 20:1, and max depth within targeted range of 7-11 inches (Table 2B).

*Soils*

We consulted the same Solano County Soil Survey and found that several of the created vernal pools may not have been on Pescadero clay loams as targeted in the design, resulting in construction problems that may then impair their hydrological function (i.e., holding water and meeting water depth criteria). By matching the location of vernal pools on the site to the soil survey map (using 1970 aerial photographs), we could see that some of the pools seem to be on Diablo-Ayar clays and not the Pescadero clay loam that was the targeted soil series for pool creation. This difference in soils was noted to have caused significant problems during the construction of the pools: "Some pools have small areas (no greater than 10X10') along the pool basin that are deeper than design specifications. This was a result of the unintentional removal of large clumps of clay from the pool basin, which would periodically happen over the course of excavation" (D-10).

*Precipitation*

We looked at annual precipitation for the area for the entire period of record (water years 1906 to 2007, partial) (Figure 10). The average yearly total precipitation was 17.25 inches, the maximum precipitation occurred in 1983 at 37.16 inches, and the minimum precipitation occurred in 1976 at 6.78 inches. When we compared the baseline and monitoring data years to the period of record we found: the baseline data year 2003 was higher than average with 21.98 inches; two of the monitoring years were slightly wetter than average with 18.6 inches in 2004 and 18.4 inches in 2005; and the third monitoring year was the 6$^{th}$ wettest in the period of record with 28.61 inches. While these fluctuations possibly explain some of the interannual variation in monitoring data, all years were wetter than average, indicating we do not yet know how the pools will perform in a spate of drier than average years. Also, some of the trends, such as a lack of ponding in pools, are clearly not the result of less water because they were designed around pool levels on a wet year (2003) but have experienced three wet years including one incredibly wet year (2006) where they failed to meet their ponding area and max depth success criteria. Also because 3 out of the 10 years have been wet, extended monitoring beyond 10 years should be considered to capture the stochastic variation in pool response due to climate.

***CASE STUDY COMPARISON***

Our evaluations of the Elsie Gridley Mitigation Bank and Montezuma Wetlands reflect that the projects have similarities and differences which have lead to various successes, failures, and challenges. Some of the successes and failures are quite clear, while others are very unclear.

The two projects are similar in that both are vernal pool construction projects and both use similar monitoring parameters such as brachiopod, floral, water depth and water duration monitoring. Specifically, the project appraisals showed that for both projects constructed vernal pool slopes are gentler than natural vernal pools slopes, constructed pool depths fall within the typical range for natural vernal pools, and floral establishment is still in the beginning stages of recruitment.

The projects differ in level of clarity of goals and success criteria. Elsie Gridley Mitigation Bank has listed goals and success criteria; however, goals such as biological success and enhancement of species habitat are not clearly defined. In addition, success criteria are measurable in some cases and in other cases simply observable estimations, such as initial plant establishment. However, plant establishment is not well defined. Unlike Montezuma, Elsie Gridley Mitigation Bank does not provide pool specific criteria. Montezuma provides pool specific criteria (e.g. acreages, slopes, ponding depths), but does not provide clear project goals or success criteria.

The projects differ in timing and available monitoring data. Montezuma has been in place since 2003 and Elsie Gridley since 2005. Therefore, there is less monitoring data available for Elsie Gridley. Available monitoring data and analysis indicate that pools in Montezuma and Elsie Gridley are not meeting all their success criteria. More monitoring information is required to determine whether success criteria will be met in the future.

The projects were similar in their design rationale in that both utilized the baseline study data almost exclusively as reference data. The Montezuma design rationale never made the intellectual link to anything known from other study sites or the literature on pool requirements (i.e., shape, size, ponding depth, etc.) for the four species of listed branchiopods. While Elsie Gridley Mitigation did not reference literature values, they did gather baseline data from several surrounding sites. The fact that they did not use any existing written standards for their design could be interpreted as positive in that a template or formulaic approach was avoided, or as a negative in that information from the literature was not incorporated into the design. Both design rationales reference that site conditions were used for determining the constructed pool locations.

The projects differ in size, pool density and pool location in the landscape. Both projects are located on large tracts of land (~1000 acres). However, in Elsie Gridley mitigation bank the constructed pools are all densely packed within a smaller area in the southern portion of the site, while in Montezuma the pools are spread in a much lower density across the landscape. It is also notable that the mima-mound density in Phase II of Elsie Gridley appears more exaggerated than the natural areas. The Elsie Gridley Mitigation Bank consultant states that the constructed pool and mima-mound density is based on natural densities; however, in both Phase I and Phase II pools appear to be denser than the natural areas. Further data would be necessary to verify this observation.

The topography and soils also vary between the two projects. Both are located on relatively level low elevations; however, while pools in Elsie Gridley are constructed within mima mound topography, Montezuma pools are spread out on topography that has larger-scale undulations. Pools C-1 and C-3 in the Montezuma are located on convex slopes. Soils were appropriately chosen for Elsie Gridley Mitigation Bank Phase II, but they may have been incorrectly chosen for some of the Montezuma pools. This may be reflected in the hydrology: several of the Montezuma pools were not holding sufficient water in the last year. This could be a combination of the incorrect choice of soils, topography, or other construction problems such as not achieving the desired slope ratios.

The projects differ in hydrologic, vegetative and fauna success as well, summarized in Appendix B. Elsie Gridley Mitigation vernal pool hydrology is generally present in all pools, hydrology is variable and hydrologic similarity to onsite natural pools is not yet known. The pool-swale design of the mitigation bank is atypical of natural vernal pool systems. The depths and durations are somewhat variable, although this variability may or may not be a negative aspect as it may provide habitat diversity. The hydrology of the pools while still in the range of typical vernal pools did decrease from year one to year two. This could likely be due to decrease precipitation, however, further monitoring is recommended in order to determine whether water holding capacity of the pools is sufficient to support vernal pool species in the long-term. Plant establishment is unclear as we were not able to collect data due to the season and monitoring data is not yet available, however observations in as-builts describe the presence of typical and rare vernal pool species. Brachiopod data indicates that the majority of the pools are supporting species, likely introduced by inoculation. Elsie Gridley used two methods to enhance floral and faunal recruitment including seeding of the soils and inoculation. While sufficient data has not been provided concerning floral success, brachiopod success has been high-70% of the constructed pools.

Montezuma vernal pool hydrology is also variable in the constructed pools. We found that some of the southern created pools are almost indistinguishable visually from the natural pools, and their overall trend has been an increase in plant community but pool C6 among them is not meeting its hydrological success criteria. The other created pools on the northern part of the site look far less "natural" with odd shapes, convex landscape positions, encroaching vegetation (some basins are full of upland grasses) or sparser vegetation; and both their monitoring data and our cross section surveys indicate that at least two out of these five (C1 and C3) are not performing hydrologically. After three years of monitoring post-construction, only one of the created pools has just one of the targeted listed branchiopods that are the most critical part of their success criteria. Montezuma did not inoculate or use seeding. The plant establishment is similar to preserved pools in diversity but much lower in vegetative cover, and the pools have had lower use by invertebrates.

One issue more prevalent in the Elsie Gridley Mitigation Bank, thatch was overgrown in various pools. Grazing has not been used yet, but the consultant did state in the field that it was proposed as a means for controlling thatch overgrowth. In addition, no success criteria were required for wildlife which may hinder the understanding of success if monitoring is not provided; however, reference pool data could be applied in establishing criteria for fauna.

Overall, Elsie Gridley Mitigation Bank has both individual successes and challenges. It seems to be trending towards supporting vernal pool functions. However, further monitoring and clearer definitions of success are necessary to determine whether it will be truly successful. Montezuma also has both individual successes and challenges. Some pools are functioning similarly to preserved pools, while others are functioning as uplands. The pools that are functioning as uplands may have design flaws in terms of soils and topography that will require modifying the pools. Further monitoring data is required.

## CONCLUSION

**"Nature doesn't make vernal pools perfectly and neither do people"** (D-10).

This quote from the Montezuma as-built report captures our findings perfectly for both the Montezuma and the Elsie-Gridley Mitigation Projects. The consultants wrote this quote to explain problems in the construction of the created pools on the site, but it has held true for our post-project assessment results of both projects.

Our findings, literature reviews, and interviews solidify that while singular successes are possible, such as the recruitment of fauna in some pools or the vegetative success in another, there are many interacting forces which lead to fully functioning vernal pools. Therefore, a detailed design with consideration of appropriate and site specific methods is required to create vernal pool function. Returning to the quote, considering the intricate relationship involved in vernal pool function, it is impossible that every detail can be addressed. With this in mind, the product of a restoration design will reflect the care taken to such details.

We recommend that the monitoring period be extended on both of these projects to capture the stochastic effects of climate and other variables and to see the full successional processes as the vernal pool flora and fauna become established. Usually post-project monitoring for river restoration would be conducted until new geomorphological equilibrium conditions are met, which if applied to vernal pools which are ancient systems that have taken hundreds to tens of thousands of years to develop, may not be feasible. In a Mediterranean climate with fluctuating and unpredictable cycles of wet and dry years, it may take more than ten years to reach an equilibrium or for ecological function to become established. Also, because of the paucity of vernal pool creation examples, a commitment to long-term monitoring would provide a very valuable data source to enhance knowledge in the field of vernal pool restoration.

Additional studies are recommended for these two sites including the installation of rain gauges in order to obtain more accurate precipitation data and the verification of the soil types underlying the constructed pools. In addition, more studies of other vernal pool restoration projects, particularly those with a vernal pool creation component, need to be done to capture the best practices and lessons learned for this nascent restoration field.

The good news regarding the difficulty of creating ecologically functioning vernal pools is that the USFWS has developed a blanket ban on vernal pool creation as a means of achieving mitigation (Vollmar 2007). Instead they only want to see restoration. One consultant we interviewed generally supports this, but thinks some value exists in creating large vernal pools that certain vernal pool endemic species rely on, because natural large vernal pools have mostly been destroyed (Vollmar 2007). Both the consultant and vernal pool experts we spoke with feel strongly that value should be placed on preservation of natural, intact vernal pool sites. Currently, existing vernal pool landscapes have low mitigation value and ¾ of the sales at mitigation banks are of created or restored vernal pools (due to their high mitigation value) (Vollmar 2007). However, if the ratio for preservation were changed by the agencies then potentially all vernal pool landscapes could be preserved, saving an incredibly valuable, unique and almost extinct ecosystem (Baskin 1994).

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## LIST OF TABLES

**Table 1. Summary of information contained in three vernal pool restoration project documents**

| Project | Elsie Gridley (LSA) | Meyer Cookware (Vollmar Consulting) | Montezuma Wetlands (Vollmar Consulting) |
|---|---|---|---|
| PRE-PROJECT DATA | | | |
| Purpose and Goals | To create a mitigation bank including vernal pool restoration and preservation, and riparian restoration. Biological goals clearly stated. | To create 0.360 ac. vernal pool mitigation to compensate for loss of habitat | To create 5 acres of new vernal pools to mitigate for 0.98 acres of habitat loss from wetland/slough restoration project on site. Detailed goals not provided. |
| Success criteria | General: Criteria provided but all goals are not addressed by criteria. Some criteria are observable and measureable others are not. | Monitoring goals are provided concerning hydrology and vegetation. | General: Created vernal pools should mimic high-quality natural pools already on site including vegetation and hydrology, and esp. by providing habitat for four species of listed Branchiopods. |
| Baseline surveys | Narratives provided describing preliminary and as-built conditions (based on survey data). Floral and faunal surveys provided. Restoration pre-condition information not obtained. | Plant species list, descriptive narratives | Surveys by consultants of existing preserve site pools one wet season (2003) before pool construction: hydrology, water quality, aquatic organisms, floristics. Surveys in summer 2003 of preserve pools for created pool design: spillway elevations, OHW marks, slopes, pool depths. Also used topographic mapping, soil surveys, and soil sampling (but none of this data included in documents we obtained) |
| Design rationale | Based on natural onsite pools and conditions of restoration area including soils and micro-topography. | Based on site conditions: soils, hydrology and existing wetlands onsite. | Design based on natural vernal pools on the site and modified based on consultants past experience creating vernal pools. |
| Design drawings | Typical drawing provided including cross sections and overviews. | Two overviews provided. No detailed drawings. | One schematic cross-section drawing based on desired pool features (slopes, OHWMs, etc.) from natural pools |
| As-builts | Provided and includes cross-sections and narratives. | Some as-built information: Narrative and OHWL info, no cross-sections provided. | Written report (Feb 2004) following construction in Oct 2003. Also Memo (6/30/04) regarding ponding acreages for created pools achieved in 2004 wet season. |

**Table 1. Continued**

| Project | Elsie Gridley (LSA) | | Montezuma Wetlands (Vollmar Consulting) |
|---|---|---|---|
| FOLLOW-UP INFORMATION | | | |
| Periodic or event-driven monitoring | Periodic monitoring proposed, including floral, faunal, hydrologic monitoring. Some data from the first year has been provided including descriptive narratives and floral, faunal and hydrologic survey data. | Five year plan: Hydrology & Vegetation First and third year monitoring reports & a seven year update provided. Consultants conducted a goldfields habitat use study onsite. | Hydrology, water quality, aquatic invertebrates & amphibians monitored over 3 visits yearly and (2004-2006): early, mid, late season inundation. Floristics monitored at peak spring bloom yearly (2004-2006). Represents 3 years out of 10 of required monitoring. |
| Use of supplementary historical data | Soils information used for site selection. | | Used soil surveys to chose location of created vernal pools. |
| Secondary analysis* | Not performed by consultant as year 1 has not been reached. Comparison to reference pools proposed as analysis method. | Analysis provided for each monitoring event. | Created pool performance compared to that of other vernal pools on site. Section of report (2006) compares data across 4 monitoring years = a pre- and post-project assessment by consultant. |

*The objective of our PPA is to provide critical secondary analyses: compare across several projects, and compare pre- and post-project data sets (esp. data we collected such as cross-sections, observations, and photographs).

**Table 2A: Elsie Gridley Mitigation Bank - Phase I: Comparison of as-built to current pool measurements**

**As-built cross sections (January 10, 2007) and Reference Pool Data**

| Pool # | Ponding Area (Acres) | *Measured OHWM Ponding Area (Acres) | Max. Depth (inches) | Slope to deep end | Deep End Locations |
|---|---|---|---|---|---|
| Created Pool 43 | NA | NA | 8.4 | 32:1 - 42:1 | East Center |
| Created Pool 51 | NA | NA | NA | NA | NA |
| Created Pool 52 | NA | NA | 9.6 | 26:1 - 33:1 | NA |
| Reference Pool (Typical) | NA | NA | 4.8-9.6 | 10:1-17:1 | NA |

**PPA cross sections (Nov 13, 2007)**

| Pool # | CAD Ponding Area (Acres) | Perimeter Ponding Distance (ft) | Max. Depth (inches) | Slope to deep end (from OHWL) | Deep End Locations |
|---|---|---|---|---|---|
| Created Pool 43 | 0.19 | 72.5 paces = 372 | 6.00 | 52:1 - 63:1 | East Center |
| Created Pool 51 | 0.06 | 34 paces = 174 | 7.02 | 37:1 - 40:1 | Center |
| Created Pool 52 | 0.31 | 83.5 paces = 428 | 7.50 | 26:1 - 32:1 | North Center |
| Reference Pool (Specific) | 0.50 | 156 paces = 800 | 15.30 | 24:1 - 34:1 | East Center |

**Table 2B: Montezuma Cross Sections: Comparison of As-built to current pool measurements**

**As-built cross sections (Feb 2004 Report or *6/30/04 Memo)**

| Pool # | Ponding Area (Acres) | *Measured OHWM Ponding Area (Acres) | Max. Depth (inches) | Slope to deep end | Deep End Locations |
|---|---|---|---|---|---|
| C-1 | 0.48 | 0.45 | 9 | 15:1 to 20:1 | northeast area |
| C-3 | 0.39 | 0.37 | 9 | 12:1 to 20:1 | northern area |
| C-5 | 0.95 | 0.94 | 11 | 12:1 to 20:1 | eastern area |
| P-6 | not available | not available | not available | not available | not available |

**PPA cross sections (Nov 1, 2007)**

| Pool # | CAD Ponding Area (Acres) | Perimeter Ponding Area (ft) | Max. Depth (inches) | Slope to deep end | Deep End Locations |
|---|---|---|---|---|---|
| C-1 | 20,390 ft2 = .47 | 120. 5 paces = 618 | 5.3 | <20:1 (some convex) | northeast area |
| C-3 | 17,963 ft2 = .41 | 88 paces = 451 | 6.6 | ≤20:1 (some convex) | northern area |
| C-5 | 45,437 ft2 = 1.0 | 167 paces = 857 | 11.2 | 9:1 to <20:1 | eastern area |
| P-6 | 8,131 ft2 = .19 | ? paces = x | 8.3 | >5:1 to <20:1 | northwest area |

**Table 3: Literature Values: Typical Vernal Pool Characteristics**

**adapted from *Barbour et al 2007***

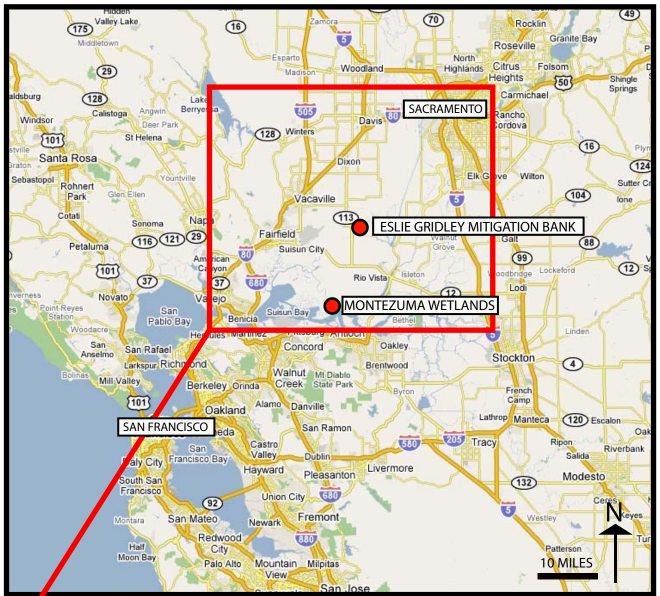
| Ponding Acreage | Typical Maximum Water Depth | Period of Inundation | Typical Soil Characteristics | Typical Flora | Typical Fauna |
|---|---|---|---|---|---|
| Variable | <19.7 inches (50 cm) | 10-65 days | | | |
| **Associated Slopes** | **Wet Season** | **Dry Season** | | | |
| Gentle side slopes, located on gently sloping topography | Pool begin to fill in November and remain moist through April | As temperatures rise and precipition decreases, a period of dessication occurs until following winter rains | Claypan, cemented hardpan, or rock creates impermeable layer, and characteristic pH and salinity for different types of pools | Common Species Examples: *Downingia bicornuta* and *Lasthenia fremontii* Diagnostic species and rare taxa: many species, lower cover | Hydroperiod too short/variable for the survival of aquatic species, too long enough for survival of upland species; includes species such as amphibians and invertebrates |

**Table 4: Documents retained for each project**

| Citation code | Name of Document | Document Date | Type of Document |
|---|---|---|---|
| *Meyer Cookware Goldfield's Preserve* | | | |
| NA | Proposal to Develop a Contra Costa Goldfields "Pre-Mitigation" Site on the Meyer Cookware Industries Property in Fairfiled, CA | 1/9/1998 | Project proposal |
| NA | Wetland Mitigation Monitoring Report for the Meyer Cookware Manufacturing Facility. Fairfield, CA.Year-1. | 12/28/1998 | Baseline monitoring |
| NA | Additional Information Requested by USFWS to Initiate Formal Section 7 Consultation on Issuance of Department of the Army Permit for Meyer Cookware Industries Inc Solano County, CA. | 5/15/1999 | Permitting document |
| NA | Wetland and Contra Costa Goldfields Mitigation and Monitoring Plan for the Meyer Business Campus Development Project. | 5/18/1999 | Project and monitoring proposal |
| NA | 2000 Wetland Mitigation Monitoring Report for the Meyer Cookware Manufacturing Facility, Fairfield, CA. Year-3. | 12/15/2000 | Monitoring data/report |
| NA | Status Report on Created Wetlands in Contra Costa Goldfields Monitoring on Meyer Cookware Fairfields Property. | 5/18/2002 | Monitoring data/report |
| NA | Hydrology Check for Created Wetlands on Meyer Cookware Site. | 3/27/2003 | Monitoring data/report |
| *Elsie Gridley Mitigation Bank* | | | |
| D-1 | Management Plan | 9/20/2005 | Management details, project goals, budget and funding |
| D-2 | Habitat Restoration and Monitoring Plan | 9/27/2005 | Baseline data, success criteria, construction and monitoring details |
| D-3 | Phase I—As-built Report | Jan 2007 | As-built report and data |
| D-4 | Phase II—As-built Report | 10/18/2007 | As-built report and data |
| D-5 | 2006 Branchiopod Survey | June 2006 | Baseline data |
| D-6 | 2007 Hydrologic Data | Jan. – March 2007 | Monitoring data |
| D-7 | 2007 Branchiopod Survey | 2007 | Monitoring data |
| *Montezuma Wetlands* | | | |
| D-8 | Memorandum: Scope and budget for oversight of vernal pool construction at the Montezuma Wetlands Project site. | 8/27/2003 | Construction scope and budget |
| D-9 | Memorandum: Scope and Budget for Montezuma Wetlands Vernal Pool Design and Construction Report. | 1/15/2004 | Scope and budget |
| D-10 | 2003 Vernal Pool Construction Report Includes: Vicinity Map, Preserve site map with present newly constructed vernal pools, Design Specs, References. | Feb 2004 | As-built report, maps, design specs |
| D-11 | Memorandum: Acreages of created vernal pools at Montezuma. | 6/30/2004 | As-built data |
| D-12 | Memorandum: Preliminary cost estimate for 2006 Montezuma Wetlands vernal pool construction. | 3/22/2006 | Cost estimate |

| | | | |
|---|---|---|---|
| D-13 | Montezuma Wetlands Project Vernal Pool Preserve and Avoidance Sites 2006 Ecological Monitoring Report. | May 2007 | Monitoring data/report |

| **Table 5A: List of Aquatic Organisms found in Montezuma preserved pools (by dip net surveys)** | |
|---|---|
| ***Common name*** | ***Order or family name*** |
| Predaceous diving beetles (adult & larva) | Dytiscidae |
| Water boatmen | Notonectidae |
| Snails | Lymnaeidae |
| Amphibian egg masses | NA |
| Insect egg masses | NA |
| **Table 5B: List of other animal uses observed for Montezuma preserved pools** | |
| ***Description of animal evidence*** | |
| Adult damselflies (Zygoptera) mating & possibly ovipositing | |
| Racoon paw prints | |
| Coyote tracks | |
| Fresh rabbit droppings | |
| Birds foraging | |



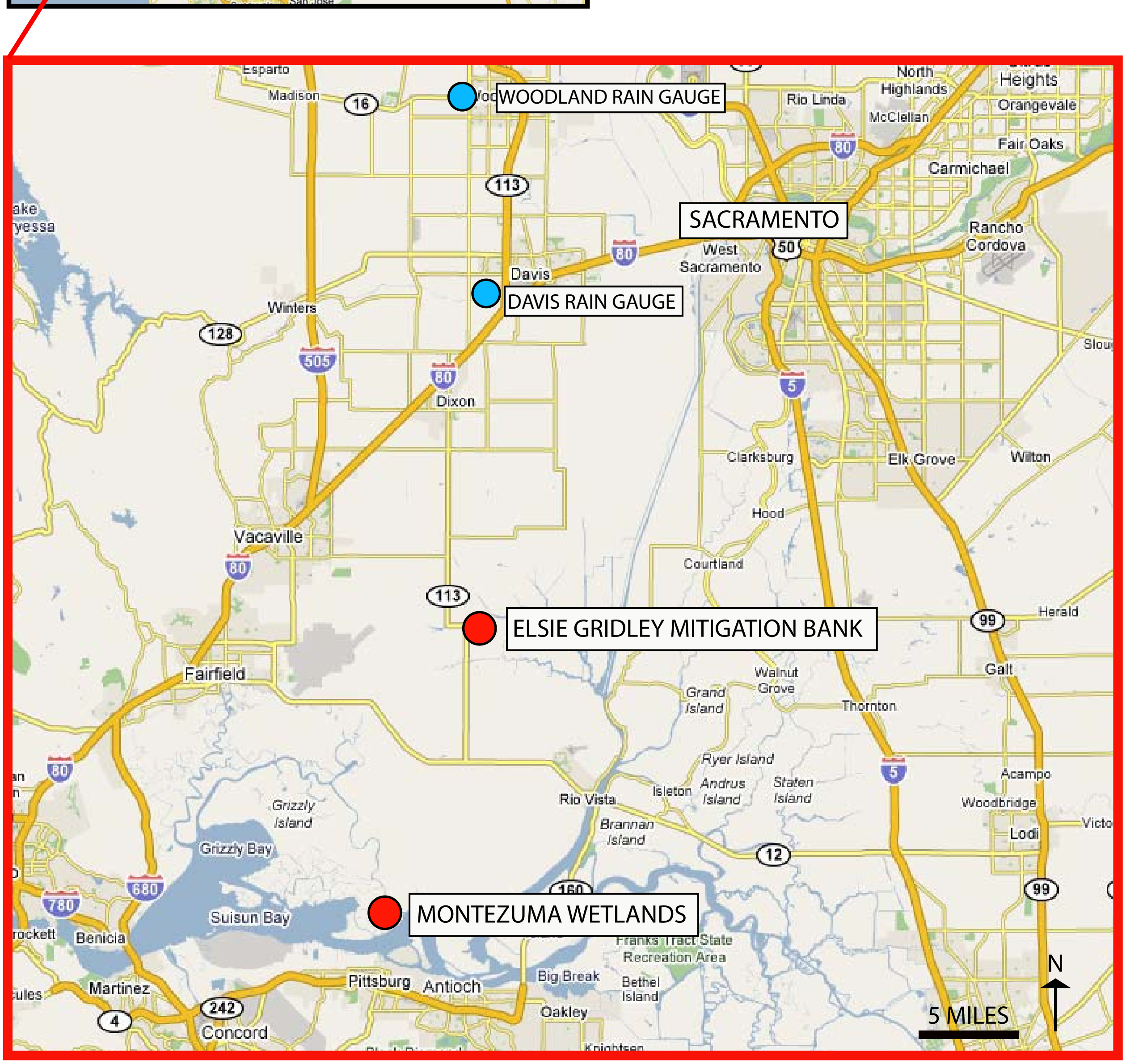




FIGURE-1 Project locations with location of rain gauges; the Davis rain gauge is 17 miles away from Elsie Gridley Mitigation Bank and 27.5 miles away from Montezuma Wetlands.

FIGURE- 2 Elsie Gridley Mitigation Bank: location of studied pools.

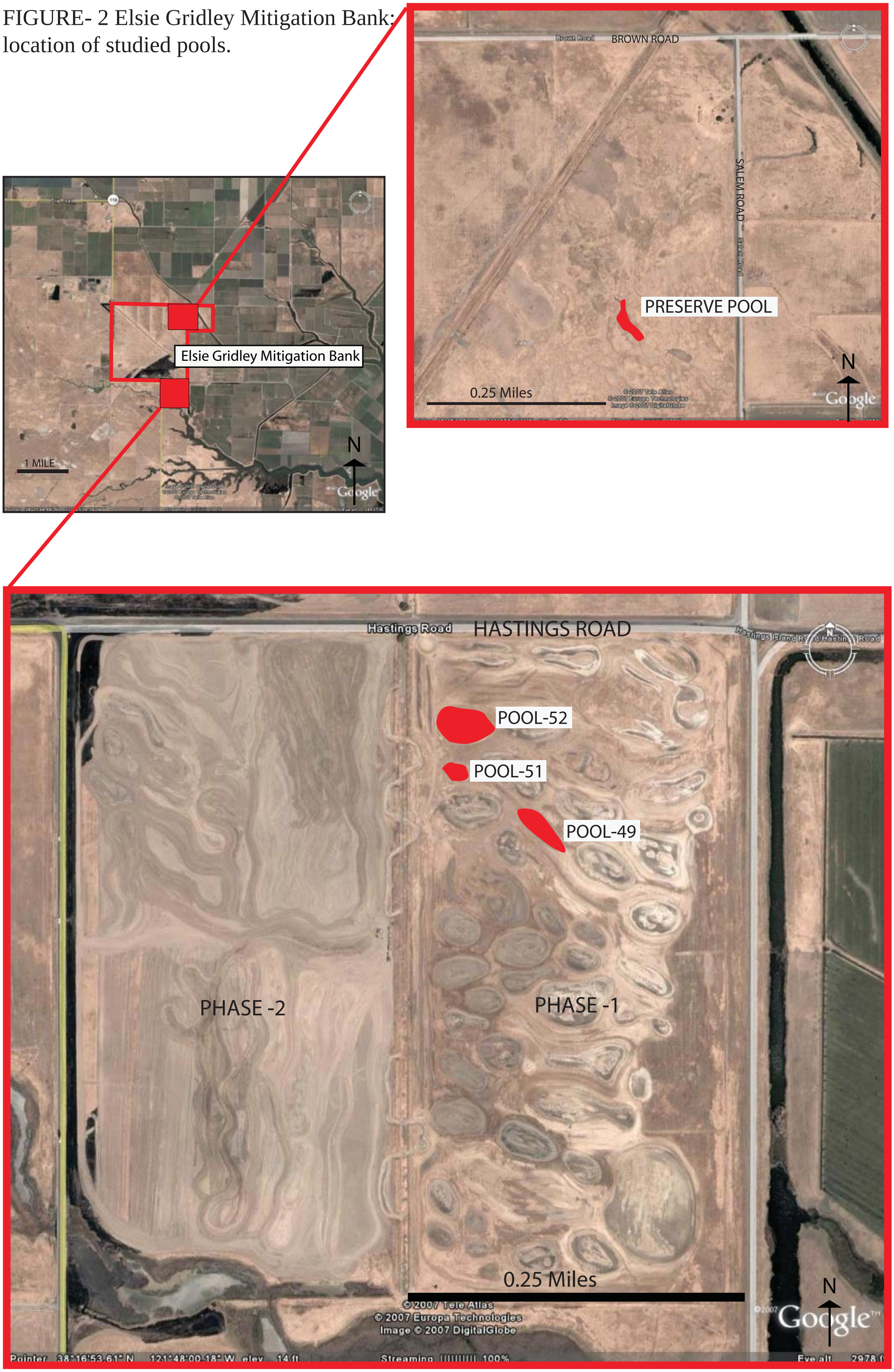



FIGURE- 3 Montezuma Wetlands; location of studied pools and fence dividing the site into northern and southern sections.

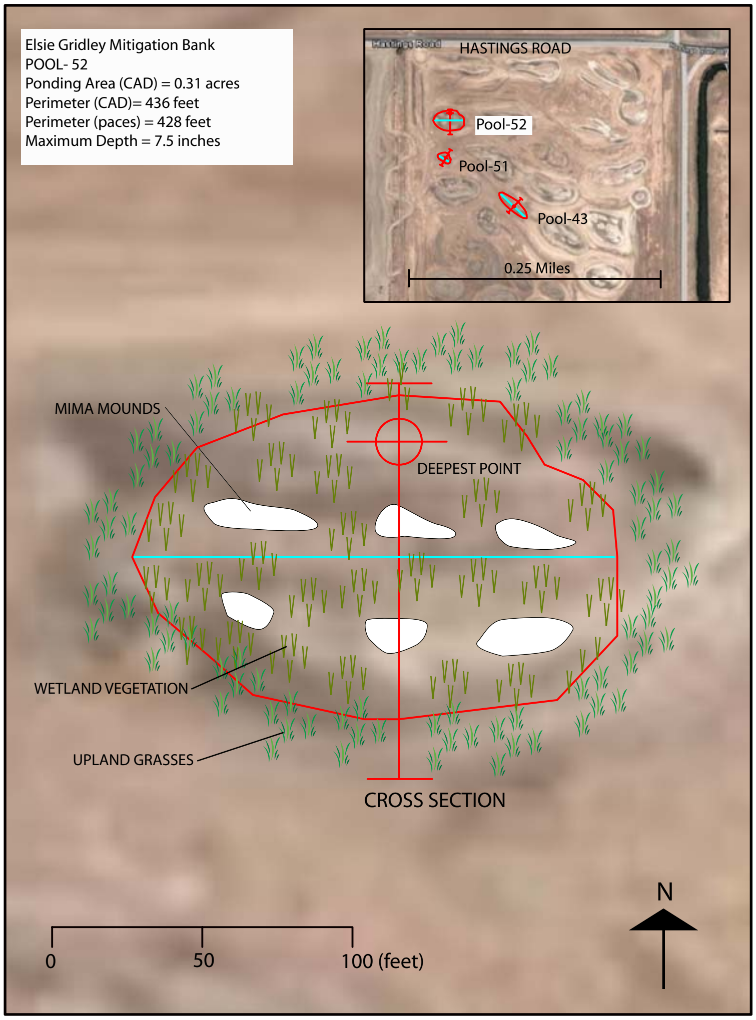



FIGURE- 4a Pool dominated by wetland vegetation; difficult to establish pool boundary due to gradual transition of pool edge from upland grasses to wetland vegetation; low visibility of Ordinary High Water Mark.

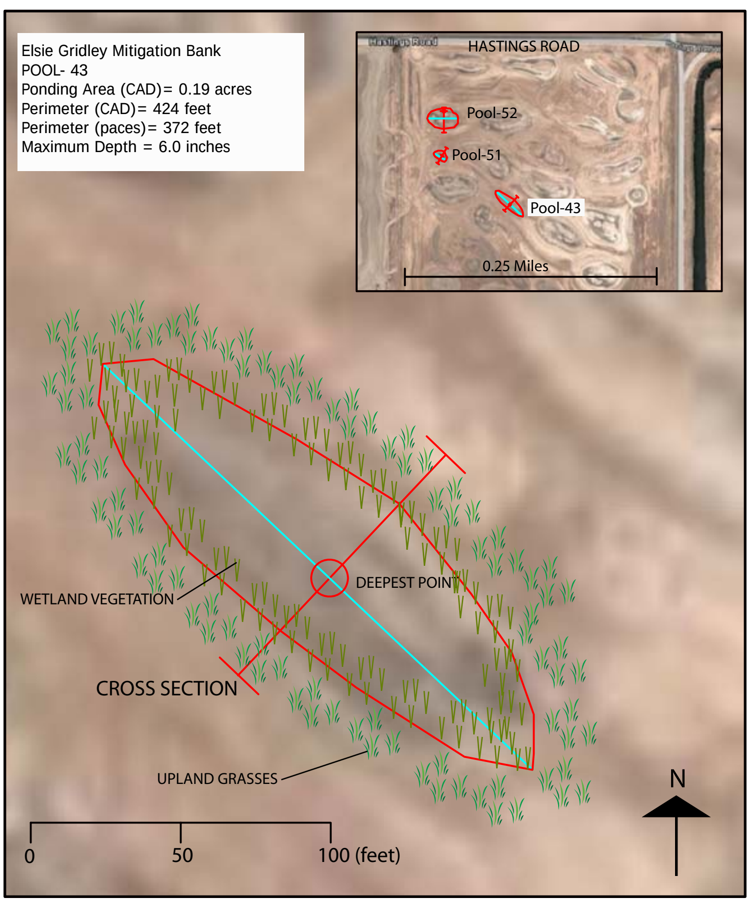



FIGURE- 4b Wetland vegetation encroaching on pool edges.

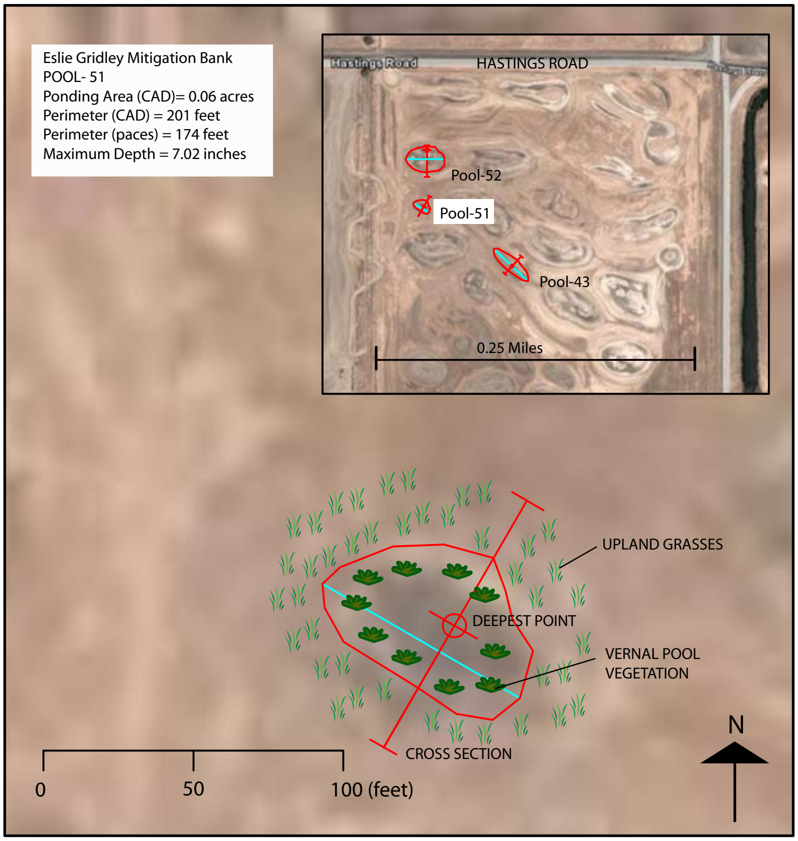



FIGURE- 4c Clear pool boundary; Ordinary High Water Mark clearly visible;pool populated by vernal pool vegetation; no encroaching vegetation.

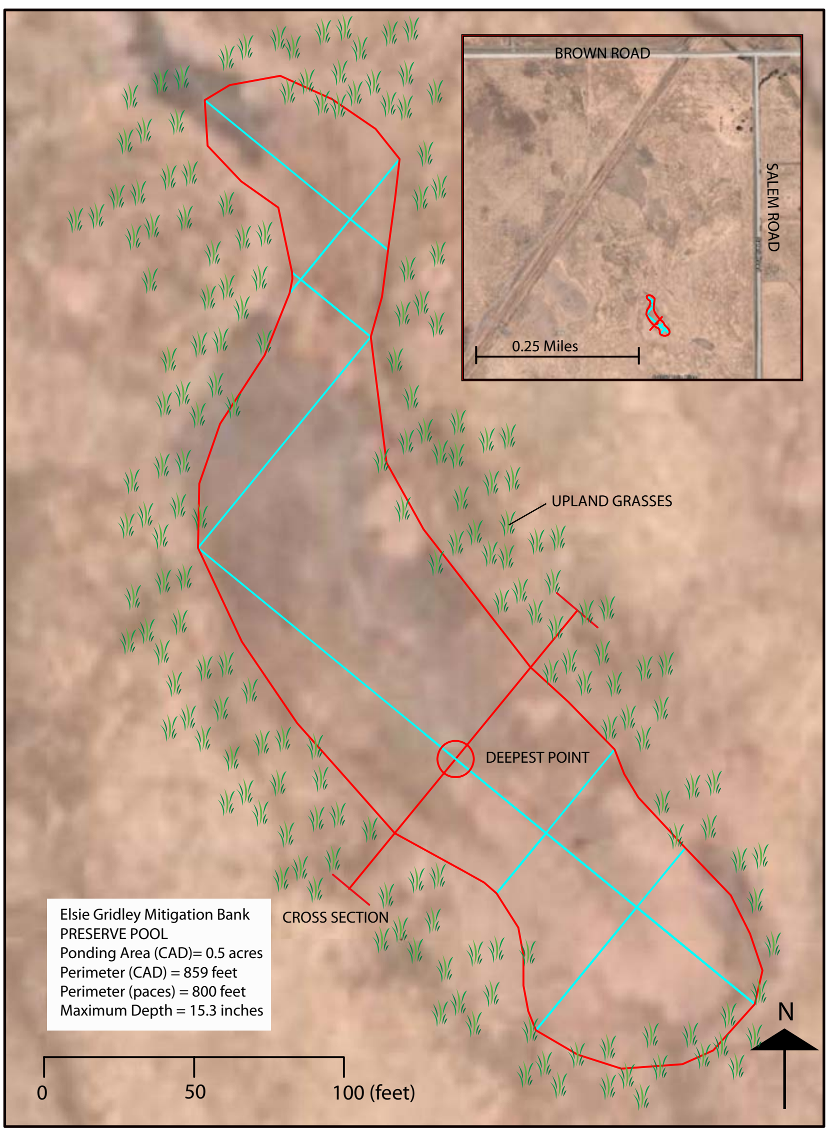



FIGURE- 4d Clear pool boundary; Ordinary High Water Mark visible; some encroaching vegetation.

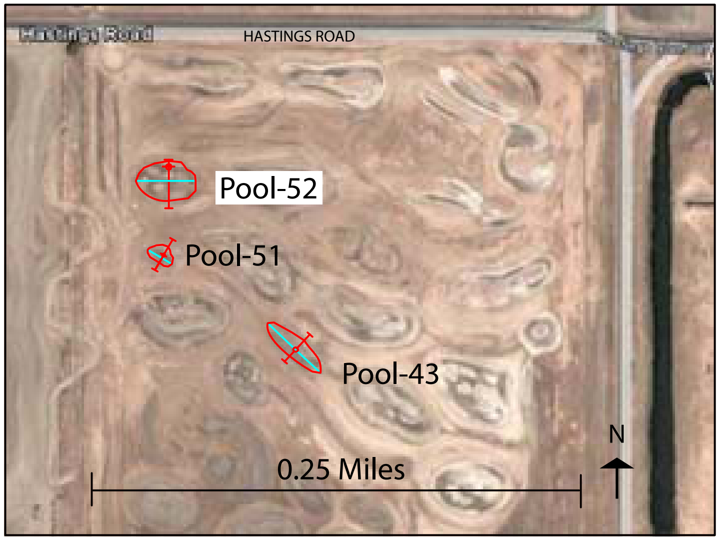
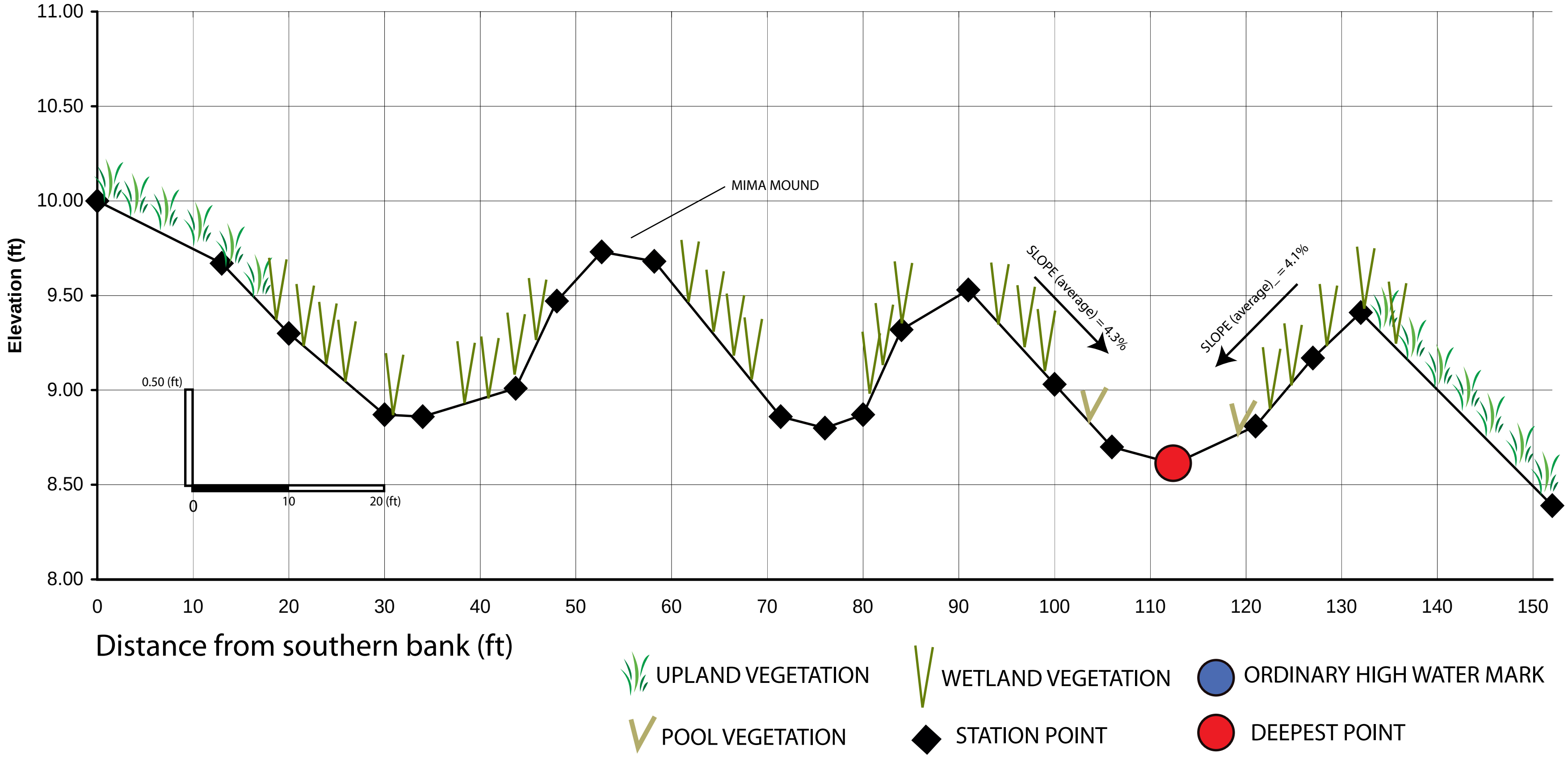



**Figure-5a Cross Section of Created Pool 52**
**Elsie Gridley, Solano County, CA**
Taken on November 12, 2007



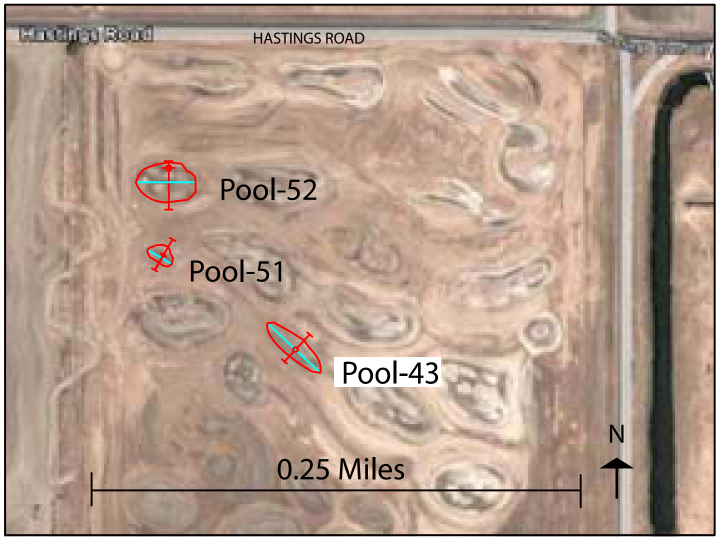
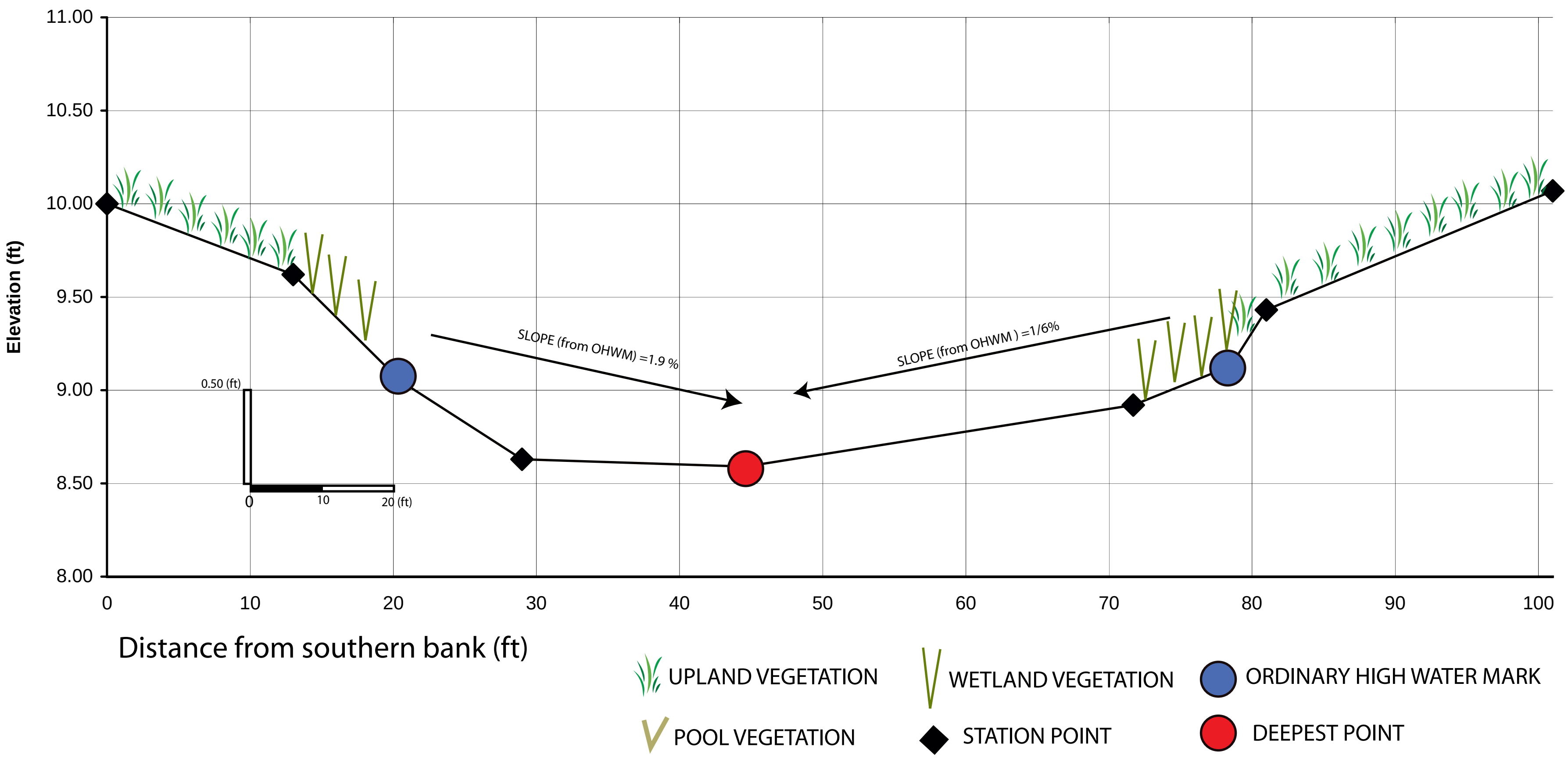



**Figure-5b Cross Section of Created Pool 43**
**Elsie Gridley, Solano County, CA**
Taken on November 12



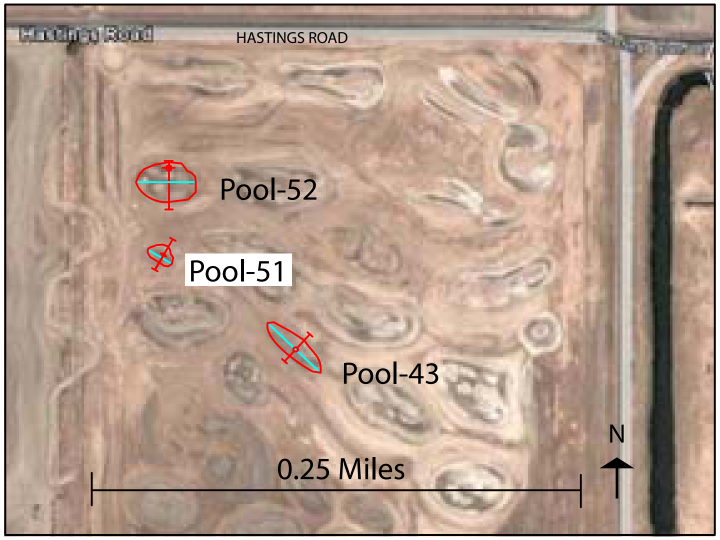



**Figure-5c Cross Section of Created Pool 51**
**Elsie Gridley, Solano County, CA**
Taken on November 12, 2007

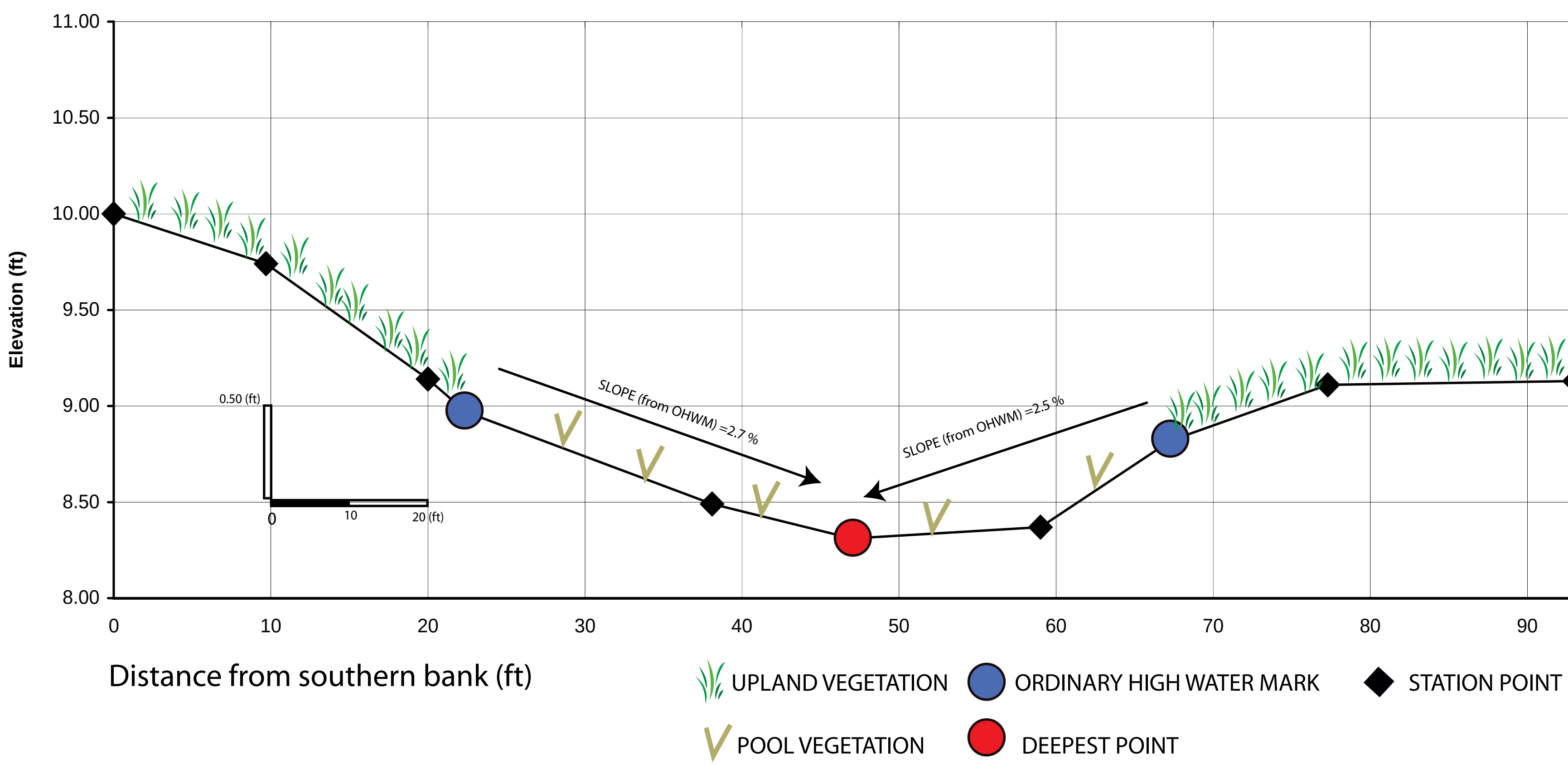
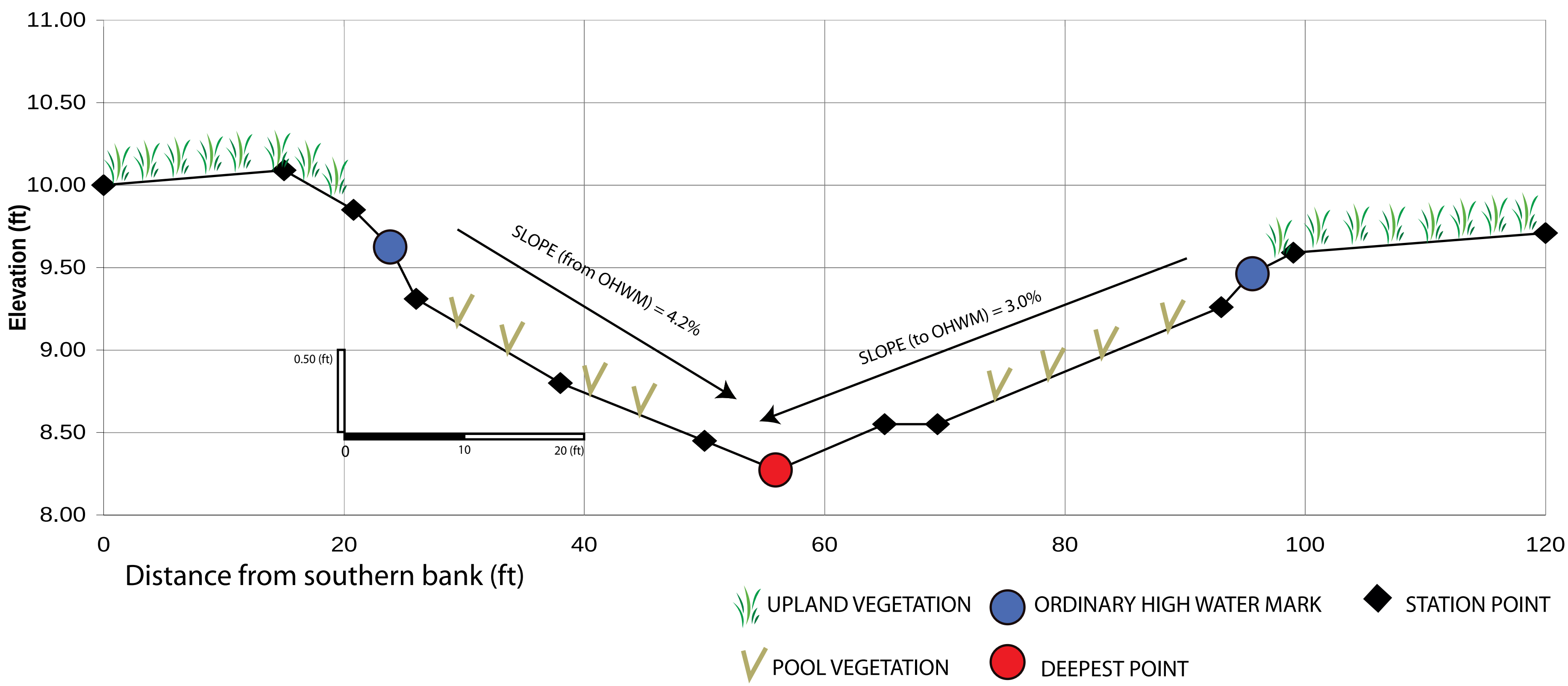



**Figure -5d Cross Section of Preserve Pool**
**Elsie Gridley, Solano County, CA**
Taken on November 12



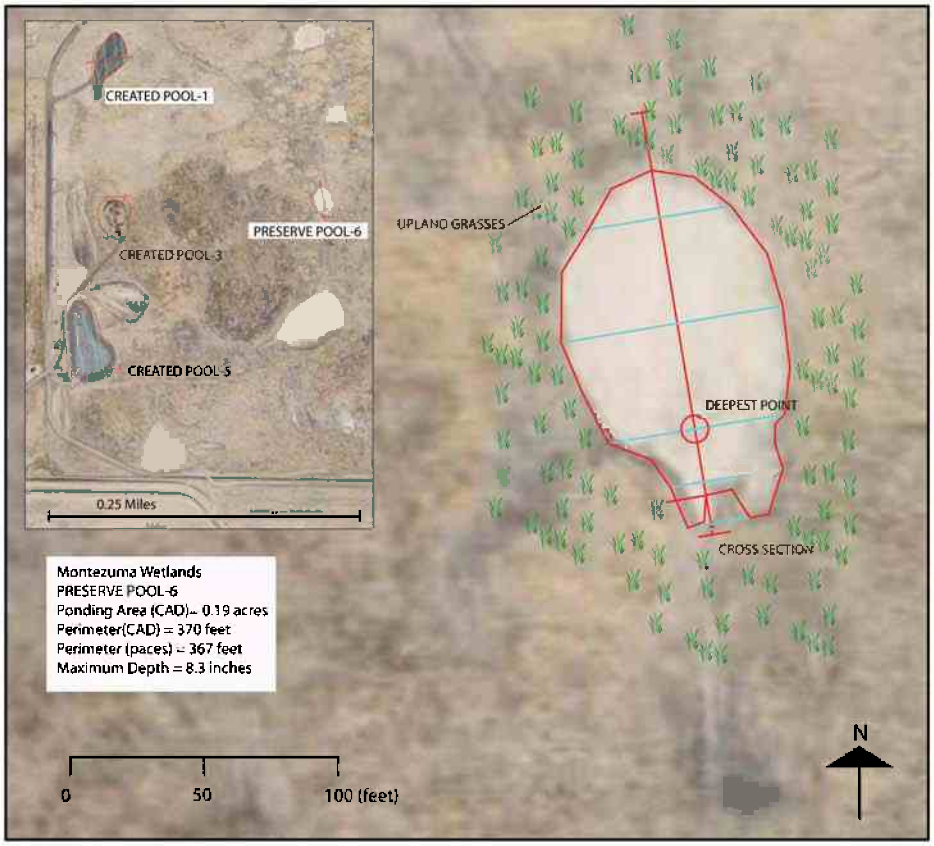



FIGURE- 6a Clear pool boundary; Ordinary High Water Mark clearly visible; no encroaching vegetation.

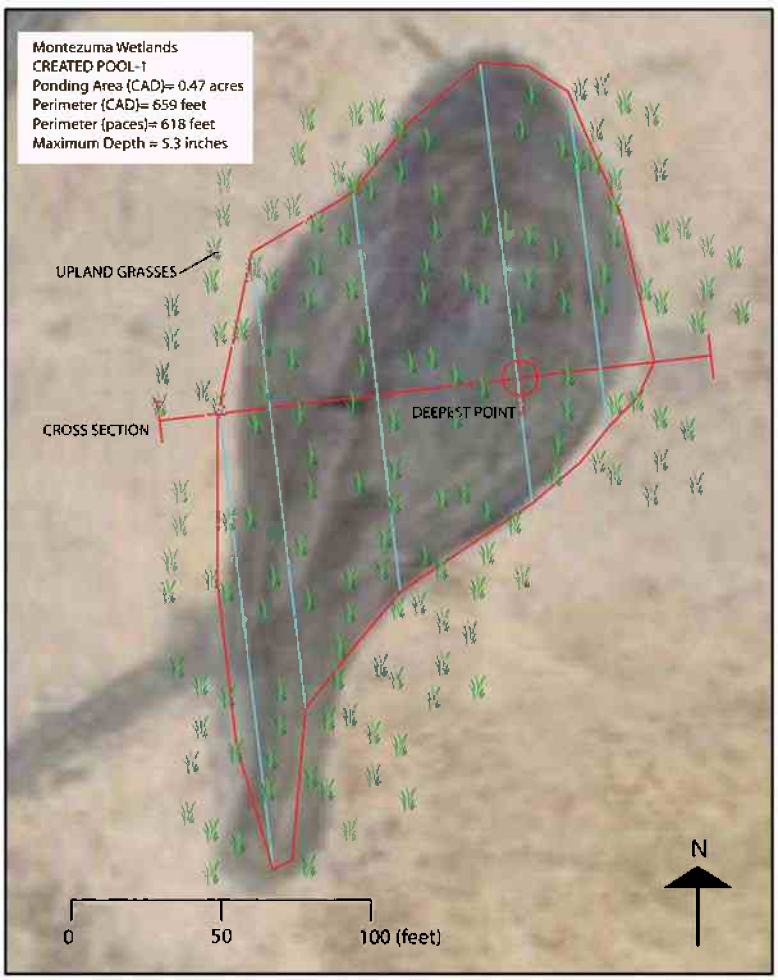



FIGURE- 6b No clear pool boundary; upland grasses encroaching on entire pool.

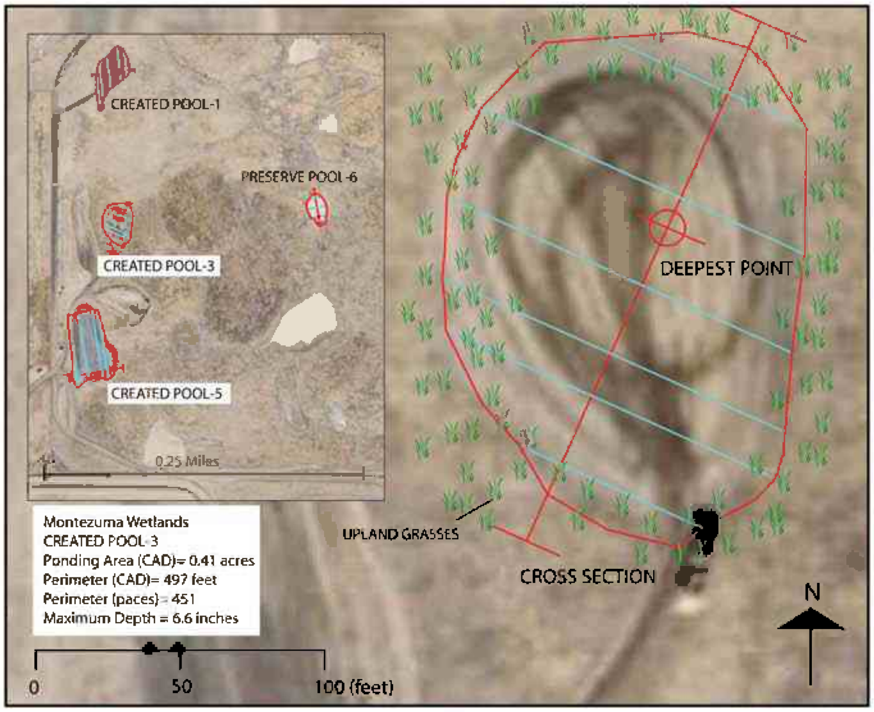



FIGURE-6c Upland grasses encroaching on pool edges.

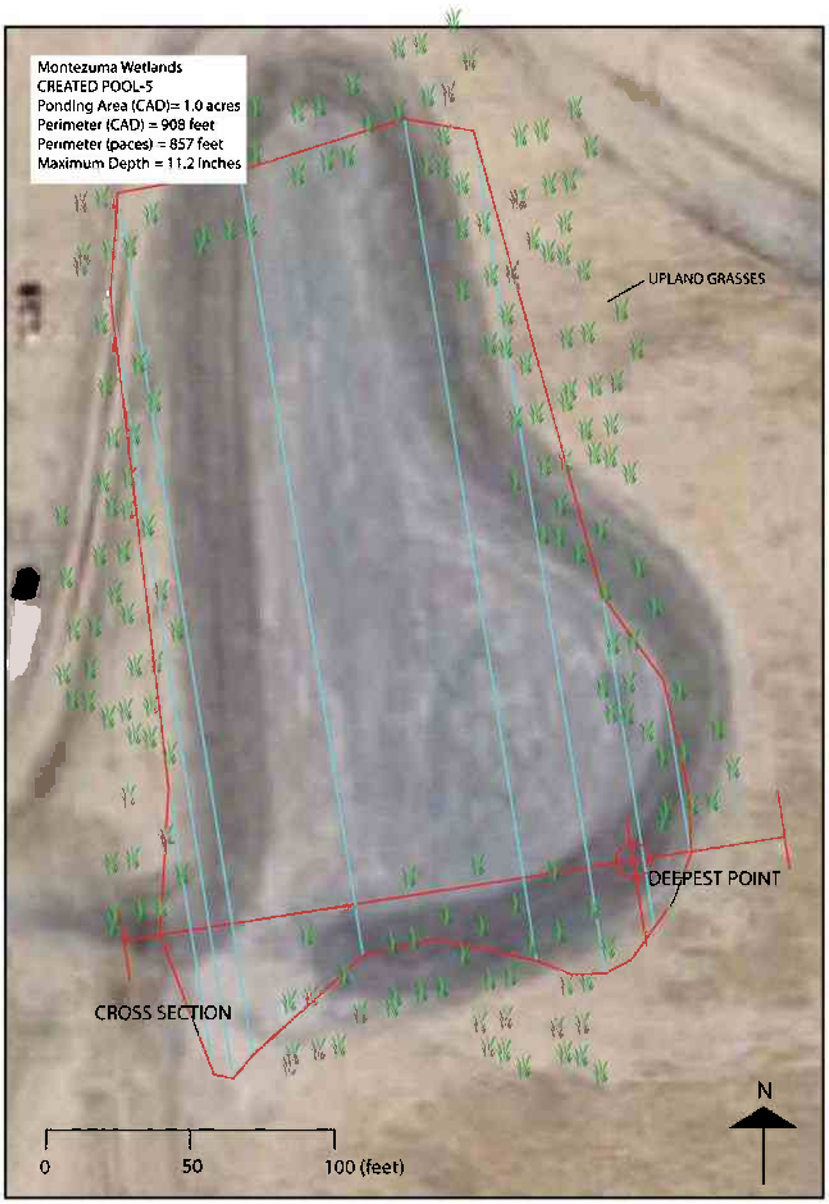



FIGURE-6d Upland grasses encroaching on pool edges.

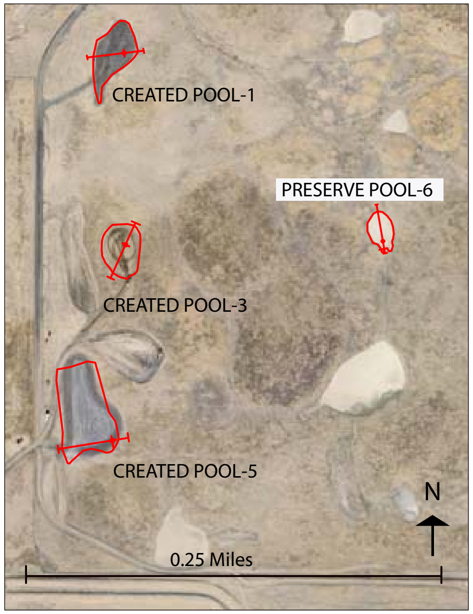
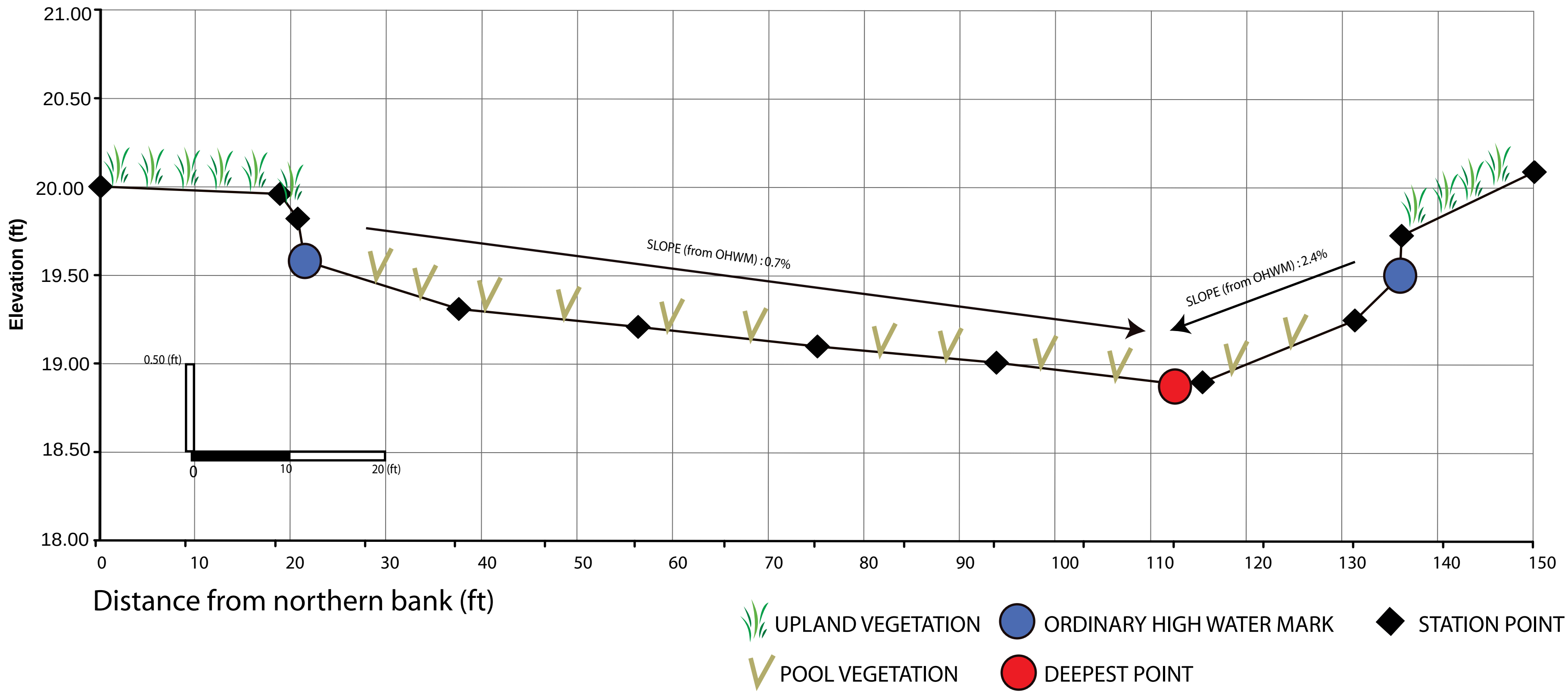



**Figure-7a Cross Section of Preserve Pool 6**
**Montezuma, Solano County, CA**
Taken on November 1, 2007



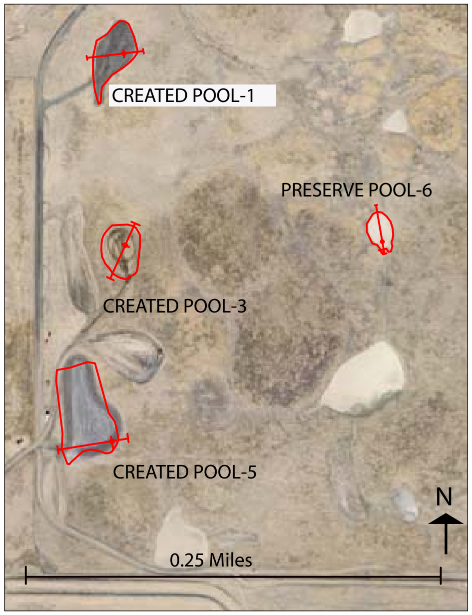
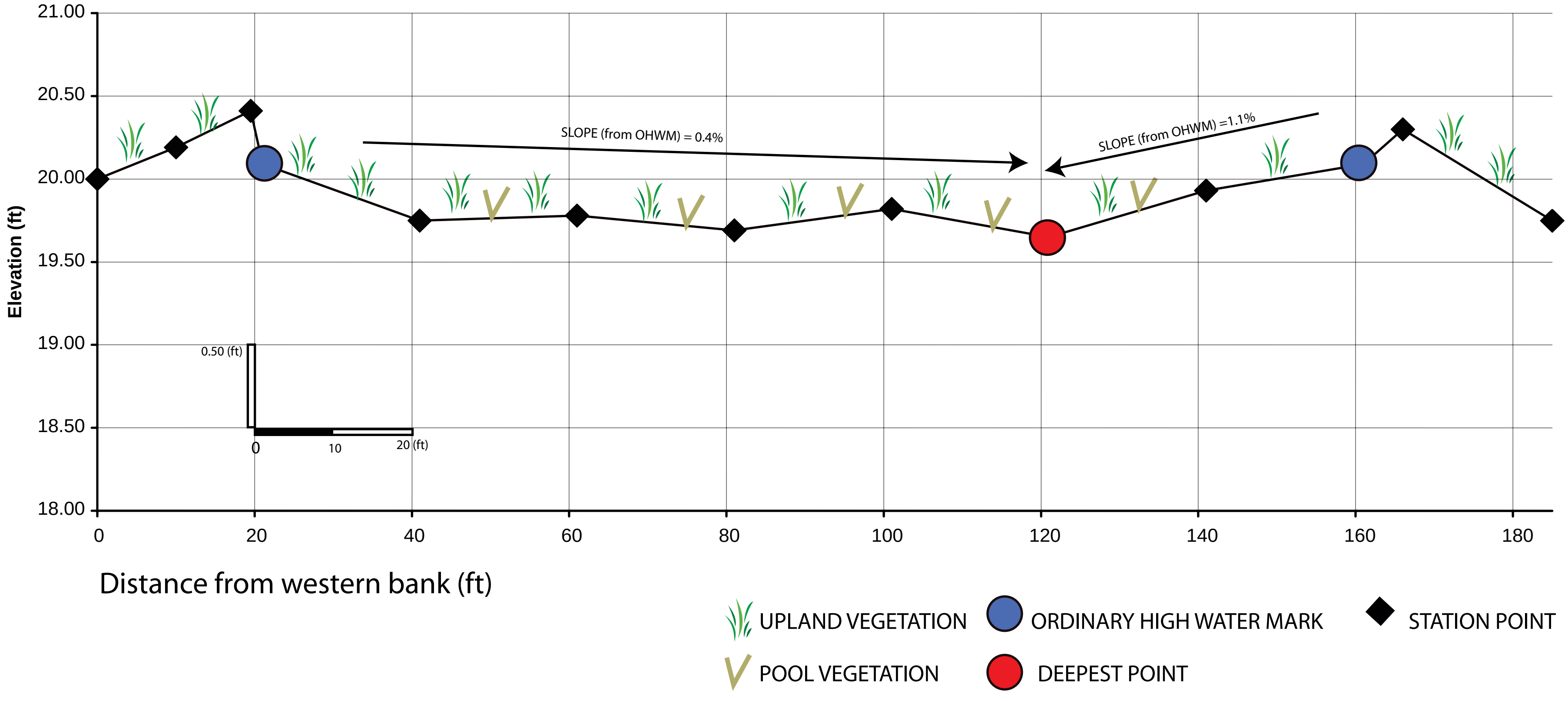



**Figure-7b Cross Section of Created Pool 1**
**Montezuma, Solano County, CA**
Taken on November 1, 2007



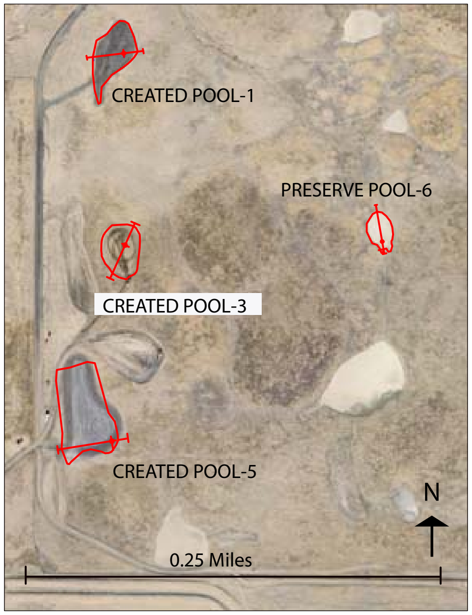
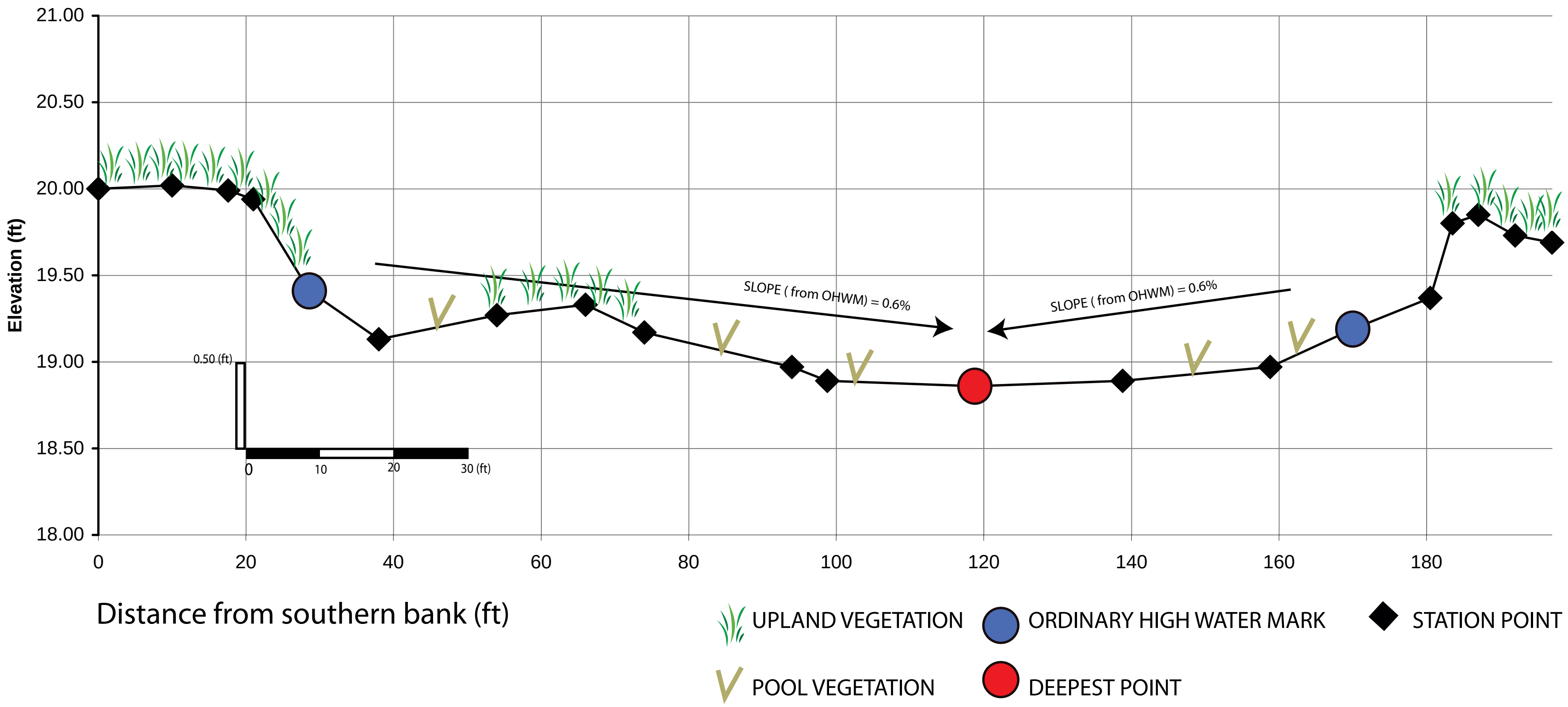



**Figure-7c Cross Section of Created Pool 3**
**Montezuma, Solano County, CA**
Taken on November 1, 2007



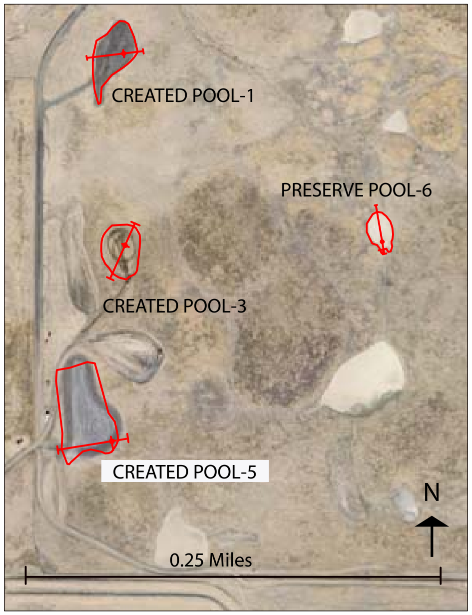



**Figure-7d Cross Section of Created Pool 5**
**Montezuma, Solano County, CA**
Taken on November 1, 2007

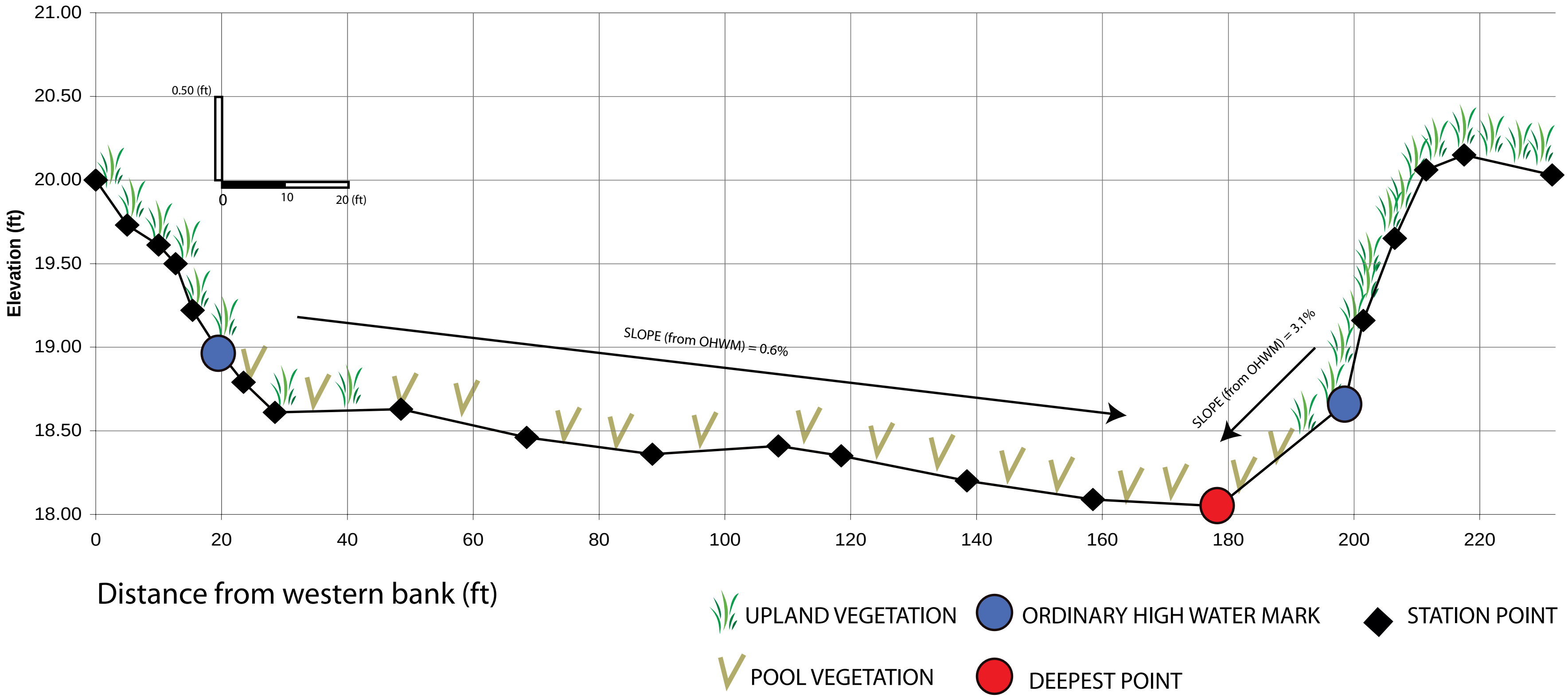


**FIGURE 8: ELSIE GRIDLEY MITIGATION BANK**

Figure 8A: Phase II general site conditions: The pools are shown by the bare soils, and the uplands are dominated by thick grasses. The majority of the smaller pools were not holding water.

Figure 8B: Most pools in Phase II had bare soils with sparsely scattered plants. Soils exhibited cracks indicating shrinking clay

Figure 8C: Large pools at Jepson Prairie Preserve were partially filled with water.

Figure 8D: Mima mound topography at Jepson Prairie Preserve

Figure 8E: The preserve pool that we surveyed on Elsie Gridley Mitigation Bank. The preserve pool margins were relatively distinct. Vegetation was established in the pool.

Figure 8F: Pool 51 was dry, has some vegetation established, distinct margins.

Figure 8G: The mima mounds in Pool 52 are covered by less vegetation than the pool as the pool is full of thatch.

Figure 8H: Pool 43, wetted soils, distinct margins, and some vegetation establishment

# FIGURE 9: MONTEZUMA WETLANDS FIGURES

Figure 9A: Preserved pool 8. Pool edge is very distinct. 1)Upland grasses do not encroach into pool as in the created pools; and 2) characteristic suite of pool bottom vegetation is well-established, but is very sparse and not well-established in created pools.

Figure 9B: Created pool 3. Edges are not easy to distinguish because slopes are shallow and upland vegetation fills the entire pool basin.

Figure 9C: Created pool 5. Vegetation on pool bottom is sparse and not as well-established as preserved pools.

Figure 9D: Preserved pool 8. Vegetation on pool bottom has higher richness and is very well-established as compared to created pools.

Figure 9E: Preserved pool 6 holding water on Oct 18, 2007 visit. Three (P3, P5 & P6) of nine preserved pools visited held water; whereas none of the created pools did.

Figure 9F: Preserved pool 6 had max depth of 3 inches on Oct 18, 2007. Found adult predaceous diving beetle (Dytiscidae), water boatmen (Notonectidae), amphibian egg masses, and insect egg masses (by dip net survey).

Figure 9G: Preserved pool 5. Evidence of animal uses of the preserved pools from raccoon tracks in fresh mud on pool bottom. Other animal signs included: rabbit droppings, coyote tracks, adult damselflies mating and possibly ovipositing, and birds foraging.

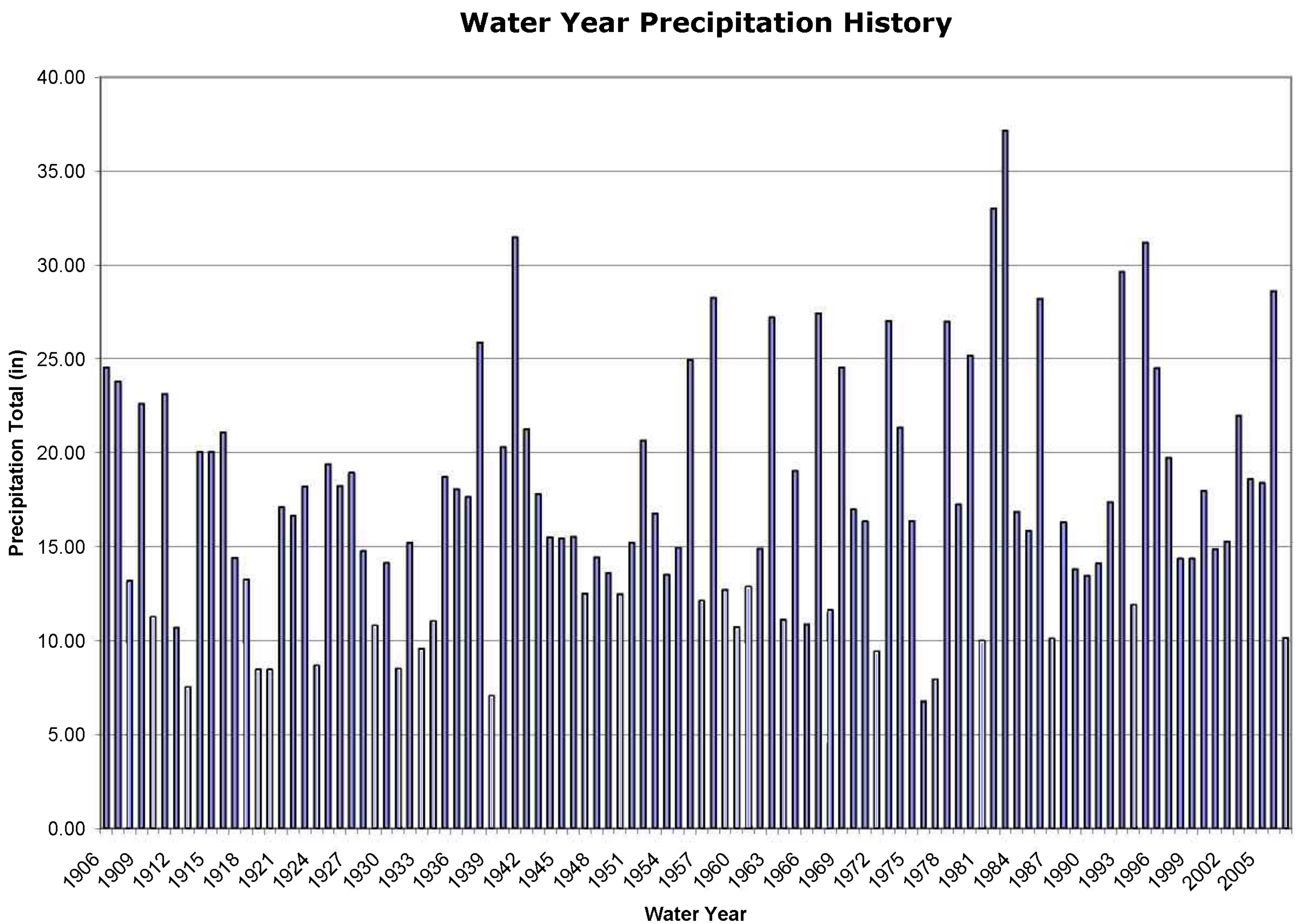



Figure 10. Water year precipitation accumulation (in inches) from 1906 to 2007 at the Davis Station is shown. Data from nearby Woodland Station was used when Davis Station records were missing data from 2003-2006. The average water year rainfall accumulation was 17.25 in., the maximum was 37.16 in (in 1983), and the minimum was 6.78 in (in 1976).

## APPENDIX A: CALCULATIONS

### I. Example slope calculation:

For Montezuma Wetlands Pool P6, north side

Slope from OHWM to deepest point

Slope = rise/run

Using survey elevation data for rise divided by survey station data for run (both in feet)

(19.5-18.89)/(145-120) = 0.0244 = **2.4%** (41:1)

This slope is <20:1 ratio used in the consultant design specs

### II. Example perimeter calculation:

For Montezuma Wetlands Pool C5

Using paces measured by Wendy Renz: **5.13 feet/pace**

Pace is defined as right step to right step

167 paces * 5.13 feet/pace = **857 feet**

# APPENDIX B: MONITORING DATA

**Table B1: Elsie Gridley Mitigation Bank - Phase I: Hydrologic Monitoring Data Summary**

| Pool # | Pool Water Depths - As-builts: 12/15/05 | 1/8/06 | 1/27/06 | 2/15/06 | 3/17/06 | 5/9/06 | Pool Inundation Notes |
|---|---|---|---|---|---|---|---|
| Created Pool 43 | 1 | 10 | 9.5 | 8 | 10 | 3 | mid-December to mid-March |
| Created Pool 51 | 1 | 12.5 | 12 | 10 | 13 | 3 | mid-December to mid-March |
| Created Pool 52 | 1 | 8 | 8 | 7 | 9 | 4 | mid-December to mid-March |
| Reference Pool (Typical) | Not Obtained | | | | | | Not Obtained |

| Pool # | Pool Water Depths - Winter 2007 Monitoring: 1/13/07 | 2/15/07 | 3/2/07 | 3/29/07 |
|---|---|---|---|---|
| Created Pool 43 | 0 | 4 | 6 | 3 |
| Created Pool 51 | 0 | s | 5 | 2 |
| Created Pool 52 | 0 | 1 | 1 | 0 |
| Reference Pool (Typical) | Not Provided | | | |
| | s = saturated | | | |

**Table B2: Elsie Gridley Mitigation Bank - Phase I: Floral and Faunal Monitoring Information**

| Pool # | Crustaceans and Fauna Present 2006 | Vegetation: as-built and preliminary evaluation summaries - Jan. 2007 | Crustaceans and Fauna: as-built and preliminary evaluation summaries - Jan. 2007 | Crustaceans Present 2007 Monitoring | Vegetation During Nov. 2007 Field Visit | Crustaceans Present During Field Day |
|---|---|---|---|---|---|---|
| Created Pool 43 | NA | NOT POOL SPECIFIC: As-built narrative states that constructed pools exhibited good initial establishment including common vernal pool species such as *Layia* spp., *Downingia* spp., *Lepidium nitidium,Lasthenia californica, Plagiogthrus* spp., and *Callitriche* spp.; Special status species include *Astragalus tener* | NOT POOL SPECIFIC: 70% of the constructed pools contained tadpole shrimp (FWS threatened), Pacific Tree frogs found breeding in many of the constructed pools | California lindereilla (Linderiella occidentalis) - Species of concern | Too dry to identify species, mostly bare ground | None observed, conditions too dry |
| Created Pool 51 | NA | | | Vernal pool tadpole shrimp (*Lepidurus packardi*)- endangered | Too dry to identify species, mostly bare ground | |
| Created Pool 52 | NA | | | Vernal pool tadpole shrimp (*Lepidurus packardi*)- endangered | Contained a lot of unidentified grasses, very little bare ground | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Reference Pool | California Tiger Salamander (Larvae), Vernal Pool Tadpole Shrimp, and potential predators (Fish and/or crayfish) | TYPICAL REFERENCE POOLS: Pools support common species such *Ranunculus bonariensis, Pogogyne* spp., *Deschampsia danthonoioides, Downingia* spp., *Aloprciris saccatus,* and *Wleocharis acicularis;* Pools support special status species such as *Astragalus tener, Navarretia leucocephala, Altriplex depressa, Atriplex cordulata, Psilocarphus brevissimus* and *Downingia pusilla* | TYPICAL REFERENCE POOLS: Special status animals found in pools include vernal pool tadpole shrimp (*Lepidurus packardi)*-endangered, conservancey fairy shrimp (*Branchniecta conservatio)* - endangered, vernal pool fairy shrimp (*Branchniecta lynchi)*- threatened, California lindereilla (*Linderiella occidentalis*) - Species of concern, and Delta green ground beetle (*Elaphrus viridus)*- Threatened | NA | Too dry to identify species, mostly bare ground | |

**Table B3-a: Elsie Gridley Mitigation Bank - Phase I: Vernal Pool Success Criteria**

| Success Criteria | Criteria Met | Notes: |
|---|---|---|
| Acreage | NA | Proposed acreage was met, but vernal pool impacts have not occurred, so not an immediate issue as a mitigation bank. |
| Hydrophytic Plant Species Cover | YES | YR 1 objective (exhibit initial establishment of vegetation) All pools have exhibited establishment of vegetation. YR 3 objective (be statistically similar to reference pools) - NA |
| Invasive Exotic Plant Species | NA | Not monitored as of yet. |
| Species Diversity similar to reference pools | NA | Not Monitored as of yet. |
| Listed Branchiopod Species | NA | All pools supported listed brachiopods, however specific success criteria not provided as a part of this project. |
| Soil Saturation and Ponding (Hydrology) | YES | YR 1 objective (greater than 18 consecutive days) All pools met this criteria. YR 3 objective (be stastically similar to reference pool) - NA |

**Table B3-b: Elsie Gridley Mitigation Bank - Phase I: Various Vernal Pool Restoration and Maintenance Techniques suggested by interviewed vernal pool experts**

| Technique | Employed | Notes: |
|---|---|---|
| Innoculation | YES | Establishment of vegetation and crustaceans in under one year |
| Seeding/Planting | YES | Establishment of vegetation in under one year |
| Grazing | NO | Grasses are overgrown along inner edge Pool 52, grazing is proposed |
| Controlled Burns | NO | |

**Table B4-a: Montezuma Wetlands Project: Vernal Pool Success Criteria**

| Success Criteria | Criteria Met | Notes: |
|---|---|---|
| Acreage | NO | Year 1 (2004), pools met ponding acreage requirements. Year 3 (2006) three pools did not meet requirements because held less water than design specs. |
| Hydrophytic Plant Species Cover | YES | Was not a project success criteria but has occurred. |
| Invasive Exotic Plant Species | NA | Was not a project success criteria and was not monitored specifically. |
| Species Diversity similar to reference pools | YES-plants<br>NO-inverts | The plant species diversity of created pools is similar to preserve pools (but no statistical tests done). Vegetative cover is much lower for created pools. Invertebrate diversity is much lower than reference pools; therefore not similar. |
| Listed Branchiopod Species | NO | Only one created pool supported tadpole shrimp in 2006 for first time. |
| Soil Saturation and Ponding (Hydrology) | NO | Three pools did not hold sufficient water during inundation period in 2006, even though wetter year than 2005. |

**Table B4-b: Montezuma Wetlands Project: Various Vernal Pool Restoration and Maintenance Techniques suggested by interviewed vernal pool experts**

| Technique | Employed | Notes: |
|---|---|---|
| Innoculation | NO | Establishment of vegetation to some degree in all pools in three years; establishment of one out of four species of listed Branchiopods in only one pool in three years. |
| Seeding/Planting | NO | Establishment of vegetation to some degree in all pools in three years. |
| Grazing | YES | Grasses are prevented from overgrowing by cow grazing on northern section and sheep grazing on southern section. |
| Controlled Burns | NO | Not performed on this site. |

Table B5a- Comparison of 2003-2006 mean values for number and abundance of invertabrates within pools sampled at the Montezuma Wetlands Project Site , Solano County, CA. (Prepared by Vollmar Consulting)

| Pool Group | Year | # Invert Taxa/125 liters | #Listed Large Branchiopod Species/125 liters | # VPI Taxa/125 liters | % VPI Taxa/125 liters | Invert. Abundance/125 liters | VPI Invert. Abundance/125 liters | % VPI Invert. Abundance/125 liters |
|---|---|---|---|---|---|---|---|---|
| Railroad Site Avoided Pools | 2003 | 3.8 | 0.4 | 1.2 | 17 | 49.0 | 17.0 | 15 |
| | 2004 | 3.3 | 0.1 | 0.9 | 19 | 56.0 | 15.9 | 25 |
| | 2005 | 3.6 | 0.2 | 0.9 | 21 | 115.7 | 43.2 | 28 |
| | 2006 | 4.8 | 0.3 | 2.1 | 45 | 114.1 | 71.6 | 51 |
| Preserve Site Preserved Pools | 2003 | 7.2 | 1.2 | 3.3 | 43 | 105.0 | 85.0 | 71 |
| | 2004 | 5.8. | 1.0 | 2.8 | 51 | 140.0 | 94.4 | 67 |
| | 2005 | 5.2 | 0.8 | 2.2 | 41 | 177.8 | 94.5 | 55 |
| | 2006 | 5.1 | 0.4 | 2.5 | 49 | 119.3 | 86.0 | 67 |
| Preserve Site Created Pools[1] | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| | 2004 | 1.5 | 0.0 | 0.2 | 11 | 47.0 | 13.4 | 12 |
| | 2005 | 2.7 | 0.0 | 0.7 | 25 | 86.4 | 40.9 | 32 |
| | 2006 | 4.2 | 0.1 | 2.0 | 50 | 104.5 | 75.9 | 70 |
| Preserve Site Avoided Pools[2] | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| | 2005 | 3.8 | 0.3 | 0.9 | 26 | 123.3 | 32.4 | 18 |
| | 2006 | 3.7 | 0.1 | 1.4 | 39 | 88.8 | 43.2 | 43 |

1. No data were collected for the Preserve Site created pools during the 2003 field season because the pools were not yet created.
2. The Preserve Site avoided pools were discovered during the 2004 field season, at which time only large branchiopod occurrence data were recorded.

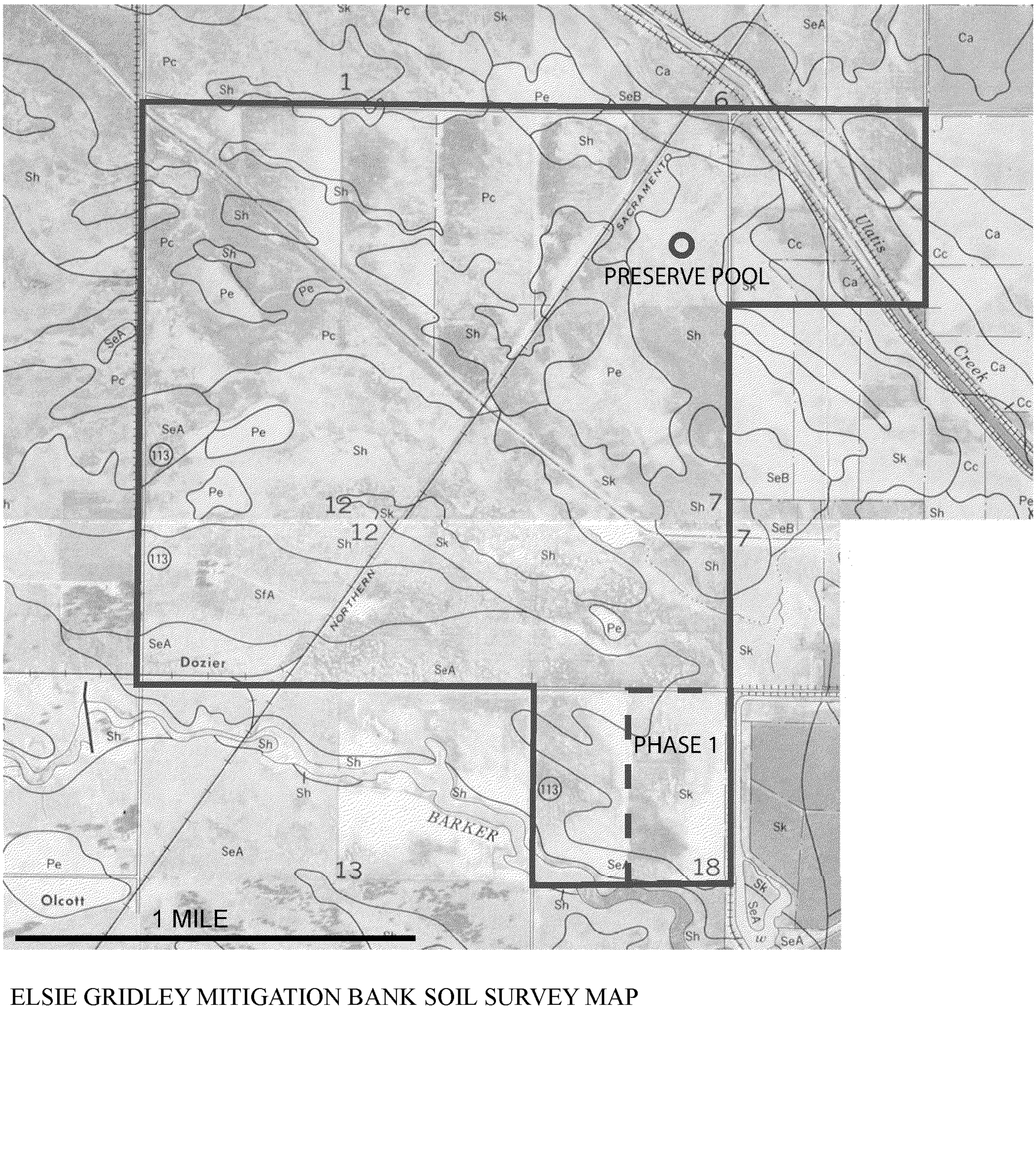
Table B5b- Comparison of 2003-2006 mean values for number and absolute percent cover of native and vernal pool indicator (VPI) plant species by pool group at the Montezuma Wetlands Project Site, Solano County, CA. (Prepared by Vollmar Consulting)

| Pool Group | Year | Total # Species | Total # Native Species | % Native Species | Total # VPI Species | % VPI Species | Mean % Cover of Native Species[3] | Mean % Cover of VPI Species[3] |
|---|---|---|---|---|---|---|---|---|
| Railroad Site Avoided Pools | 2003 | 41 | 19 | 46 | 8 | 20 | N/A | N/A |
| | 2004 | 28 | 17 | 61 | 12 | 43 | 36 | 34 |
| | 2005 | 27 | 17 | 63 | 9 | 33 | 51 | 44 |
| | 2006 | 31 | 15 | 48 | 7 | 23 | 28 | 20 |
| Preserve Site Preserved Pools | 2003 | 39 | 28 | 72 | 19 | 49 | N/A | N/A |
| | 2004 | 30 | 21 | 70 | 15 | 50 | 79 | 63 |
| | 2005 | 31 | 24 | 77 | 19 | 61 | 77 | 54 |
| | 2006 | 35 | 24 | 69 | 18 | 51 | 42 | 33 |
| Preserve Site Created Pools[1] | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| | 2004 | 35 | 15 | 43 | 8 | 23 | 9 | 4 |
| | 2005 | 55 | 36 | 65 | 20 | 36 | 18 | 16 |
| | 2006 | 43 | 26 | 60 | 17 | 40 | 18 | 26 |
| Preserve Site Avoided Pools[2] | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| | 2005 | 25 | 17 | 68 | 15 | 60 | 19 | 17 |
| | 2006 | 40 | 22 | 55 | 12 | 30 | 27 | 20 |

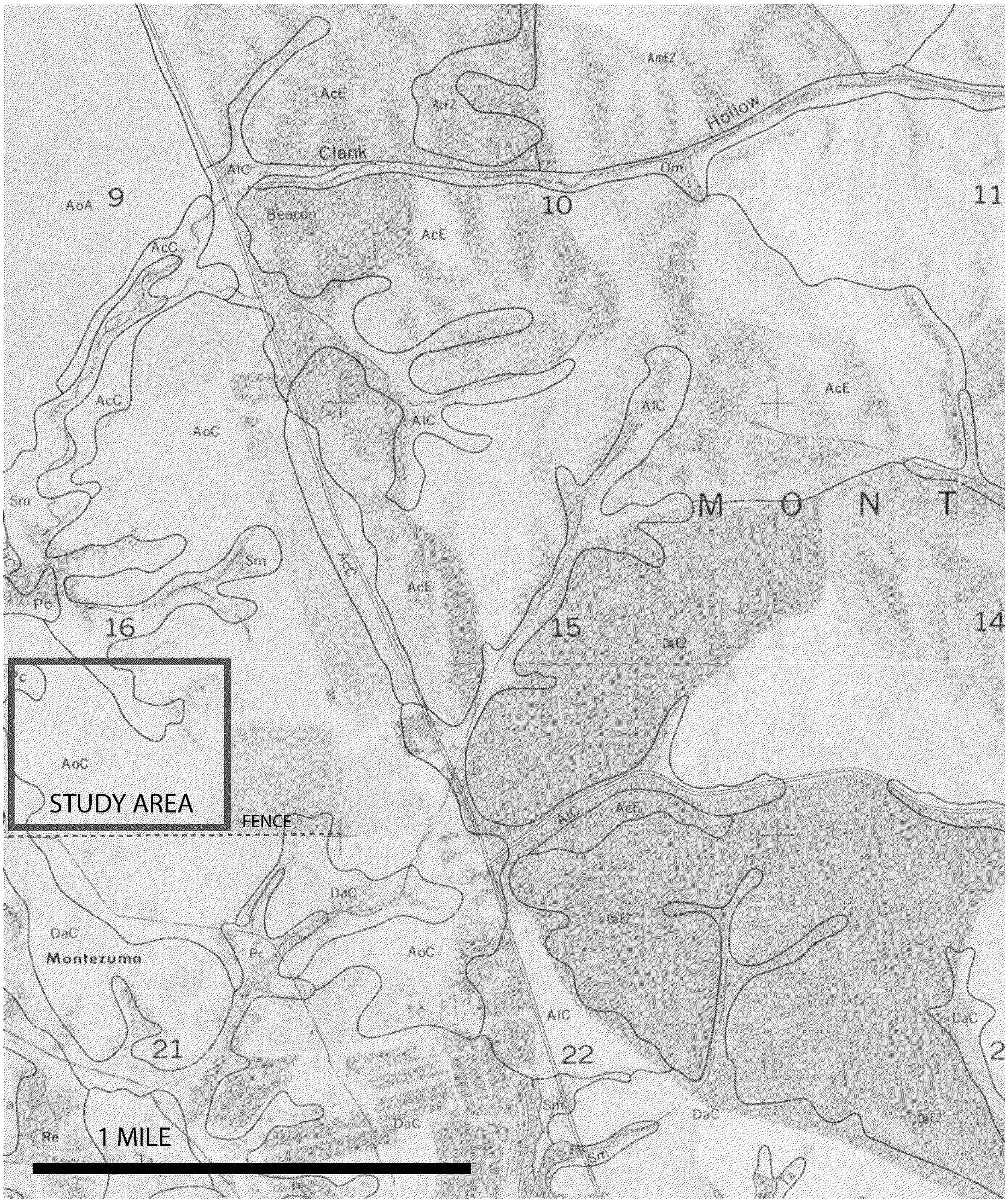
1. No data were collected for the Preserve Site created pools during the 2003 field season because the pools were not yet created.
2. The Preserve Site avoided pools were discovered during the 2004 field season, at which time only large branchiopod occurrence data were recorded.
3. The method for determining % cover (abundance) was inconsistent in 2003, therefore data for % cover of native and VPI plant species collected in 2004 will be used as baseline data.

# APPENDIX C: 1977 USDA SONOMA COUNTY SOILS SURVEYS

## APPENDIX C: 1977 USDA SONOMA COUNTY SOILS SURVEYS




ELSIE GRIDLEY MITIGATION BANK SOIL SURVEY MAP




MONTEZUMA WETLANDS SOIL SURVEY MAP

## SOIL LEGEND

Each symbol consists of letters or a combination of letters and numbers. The first capital letter is the initial one of the soil name. A second capital letter, if used, shows the class of slope. Symbols without a slope letter are for nearly level soils. A final number, 2 or 3, in a symbol shows that the soil is named as eroded or severely eroded.

| SYMBOL | NAME |
|---|---|
| AcC | Altamont clay, 2 to 9 percent slopes |
| AcE | Altamont clay, 9 to 30 percent slopes |
| AcF2 | Altamont clay, 30 to 50 percent slopes, eroded |
| AIC | Altamont-San Ysidro-San Benito complex, 2 to 9 percent slopes |
| AIE | Altamont-San Ysidro-San Benito complex, 9 to 30 percent slopes |
| AmC | Altamont-Diablo clays, 2 to 9 percent slopes |
| AmE2 | Altamont-Diablo clays, 9 to 30 percent slopes, eroded |
| An | Alviso silty clay loam |
| AoA | Antioch-San Ysidro complex, 0 to 2 percent slopes |
| AoC | Antioch-San Ysidro complex, 2 to 9 percent slopes |
| AsA | Antioch-San Ysidro complex, thick surface, 0 to 2 percent slopes |
| AsC | Antioch-San Ysidro complex, thick surface, 2 to 9 percent slopes |
| BrA | Brentwood clay loam, 0 to 2 percent slopes |
| BrC | Brentwood clay loam, 2 to 9 percent slopes |
| Ca | Capay silty clay loam |
| Cc | Capay clay |
| CeA | Clear Lake clay, 0 to 2 percent slopes |
| CeB | Clear Lake clay, 2 to 5 percent slopes |
| ClA | Clear Lake clay, saline, 0 to 2 percent slopes |
| Cm | Columbia fine sandy loam |
| Cn | Conejo loam |
| Co | Conejo gravelly loam |
| Cr | Conejo clay loam |
| Cs | Conejo soils, wet |
| CvD2 | Corning gravelly loam, 2 to 15 percent slopes, eroded |
| CvE2 | Corning gravelly loam, 15 to 30 percent slopes, eroded |
| DaC | Diablo-Ayar clays, 2 to 9 percent slopes |
| DaE2 | Diablo-Ayar clays, 9 to 30 percent slopes, eroded |
| DbC | Dibble-Los Osos loams, 2 to 9 percent slopes |
| DbE | Dibble-Los Osos loams, 9 to 30 percent slopes |
| DbF2 | Dibble-Los Osos loams, 30 to 50 percent slopes, eroded |
| DIC | Dibble-Los Osos clay loams, 2 to 9 percent slopes |
| DIE | Dibble-Los Osos clay loams, 9 to 30 percent slopes |
| DIF2 | Dibble-Los Osos clay loams, 30 to 50 percent slopes, eroded |
| Eb | Egbert silty clay loam |
| Ec | Egbert silty clay loam, occasionally flooded |
| GaG2 | Gaviota sandy loam, 30 to 75 percent slopes, eroded |
| GIE | Gilroy loam, 9 to 30 percent slopes |
| HaF | Hambright loam, 15 to 40 percent slopes |
| HtE | Hambright-Toomes stony loams, 9 to 30 percent slopes |
| Ja | Joice muck |
| Jb | Joice muck, clay subsoil variant |
| Ma | Made land |
| MeG3 | Maymen-Los Gatos loams, 15 to 75 percent slopes, severely eroded |
| MkA | Millsap sandy loam, 0 to 2 percent slopes |
| MIC | Millsap-Los Osos complex, 2 to 9 percent slopes |
| MmE | Millsholm loam, 15 to 30 percent slopes |
| MmG2 | Millsholm loam, 30 to 75 percent slopes, eroded |
| MnC | Millsholm loam, moderately deep variant, 2 to 9 percent slopes |
| MnE | Millsholm loam, moderately deep variant, 9 to 30 percent slopes |
| Om | Omni clay loam |
| On | Omni silty clay |
| Pc | Pescadero clay loam |
| Pe | Pescadero clay |
| Ra | Reiff fine sandy loam |
| Rd | Reyes silty clay loam, drained |
| Re | Reyes silty clay |
| RnC | Rincon loam, 2 to 9 percent slopes |
| RoA | Rincon clay loam, 0 to 2 percent slopes |
| RoC | Rincon clay loam, 2 to 9 percent slopes |
| Rw | Riverwash |
| Ry | Ryde clay loam |
| Sa | Sacramento silty clay loam |
| Sc | Sacramento silty clay loam, occasionally flooded |
| Sd | Sacramento clay |
| SeA | San Ysidro sandy loam, 0 to 2 percent slopes |
| SeB | San Ysidro sandy loam, 2 to 5 percent slopes |
| SfA | San Ysidro sandy loam, thick surface, 0 to 2 percent slopes |
| Sh | Solano loam |
| Sk | Solano-Pescadero complex |
| Sm | Solano loam, dark surface variant |
| Sp | Suisun peaty muck |
| Sr | Sycamore silty clay loam |
| Ss | Sycamore silty clay loam, drained |
| St | Sycamore silty clay loam, saline |
| Su | Sycamore complex, occasionally flooded |
| Ta | Tamba mucky clay |
| Td | Tidal marsh |
| ToG2 | Toomes stony loam, 30 to 75 percent slopes, eroded |
| TrE | Trimmer loam, 9 to 30 percent slopes |
| TsF2 | Trimmer cobbly clay loam, shallow variant, 15 to 50 percent slopes, eroded |
| Tu | Tujunga fine sand |
| Va | Valdez silt loam, drained |
| Vc | Valdez silty clay loam |
| Vd | Valdez silty clay loam, wet |
| Ve | Valdez silty clay loam, clay substratum |
| Wc | Willows clay |
| Yo | Yolo loam |
| Yr | Yolo loam, clay substratum |
| Ys | Yolo silty clay loam |