B. APPENDIX B  VEGETATION AND HABITAT MANAGEMENT PLAN
Bahia Wetland Restoration Project
Vegetation MONITORING PLAN
DRAFT

(Early stages of succession and zonation of brackish tidal marsh shoreline, Lower Petaluma River reference site (Carl’s Marsh), 1996)

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1.0 INTRODUCTION: Bahia Wetland Restoration Project

Marin Audubon Society’s Bahia Wetland Restoration Project will restore a subsided diked bayland to a major contiguous block of brackish tidal wetlands (over 300 acres) in the southwestern Petaluma Marsh, Marin County, south of Black John Slough. The project site is adjacent to the Bahia-Toy (Greenpoint) Marshes, one of the only major breeding North Bay populations of California clapper rails (*Rallus longirostris obsoletus*) that have persisted through the 1990s to the present.

A primary goal of the Bahia Wetland Restoration Project is to rapidly generate abundant suitable brackish tidal marsh vegetation suitable as breeding habitat for clapper rails, to support rapid, major expansion of breeding clapper rail populations from adjacent tidal marshes. The tidal restoration site is contiguous with some intact terrestrial habitats, including mature oak woodlands, seasonal freshwater streams and marsh, and grassland. The site location affords an exceptional opportunity to link restoration of a complex tidal marsh directly linked to established native terrestrial plant communities.

The restoration planning team for the project is led by Philip Williams and Associates (PWA) under the guidance of the California Department of Fish and Game (CDFG) and Marin Audubon Society (MAS). The Point Reyes Bird Observatory (PRBO) is the lead consultant for wildlife biology. Vegetation management and restoration is planned by Peter Baye. This vegetation monitoring plan provides the technical specifications and background information for the plant community and vegetation aspects of the overall monitoring plan.

2.0 SUMMARY OF BAHIA VEGETATION OBJECTIVES

The vegetation objectives for the Bahia Wetland Restoration Project are provided in detail in the vegetation management plan for the project (Baye 2005). They provide the background and underlying purpose for vegetation monitoring. The primary vegetation and habitat goals for Central Bahia and Mahoney Spur are to promote rapid establishment of brackish tidal marsh vegetation favorable for colonization by clapper rails. The local vegetation model of young, suitable clapper rail habitat consists of mixtures of tall alkali-bulrush and Pacific cordgrass vegetation in large patches near dense, sinuous tidal creeks, in proximity to tall subshrubby vegetation of high marsh. This based in part on the recent vegetation succession at the adjacent former Bahia lagoon mudflats (now marsh), where clapper rails have rapidly colonized young marsh.

**Restoration of limited areas high pickleweed marsh with ample emergent high tide cover** is also a near-term vegetation/habitat goal for portions of the project. Black John Slough tidal marshes are presumed to support a substantial resident population of the salt
marsh harvest mouse (SMHM). Deep, prolonged (winter-spring) and complete submergence of all Mahoney Spur vegetation in 2004-2005 has probably reduced the resident SMHM population and habitat quality. Depending on accelerated rates of sea-level rise, extensive development of marsh plains supporting pickleweed-dominated marsh with well-distributed high marsh, suitable as habitat for the salt marsh harvest mouse, may be a viable long-term objective.

Near-term vegetation objectives for the more deeply subsided West Bahia include slower spread of alkali-bulrush marsh and cordgrass marsh into lower intertidal mudflat and subtidal shallows. Tidal range and sedimentation are expected to be subdued relative to Central Bahia. Restoration objectives for West Bahia in the near-term emphasize development of fringing tidal brackish marsh and terrestrial ecotones along the terrestrial (south) shoreline.

Objectives for conserved seasonal wetlands (derelict dredge disposal site) include increased abundance and diversity of native wetland vegetation, improved management flexibility to reduce mosquito production, and improved wetland habitat for wading birds, waterfowl, and amphibians.

3.0 CONCEPTUAL MODEL OF EARLY SUCCESSION BRACKISH TIDAL MARSH

The development of appropriate vegetation monitoring methods for the project will depend in part on project objectives, the planned lifespan and resources available for the monitoring program, and the conceptual model of vegetation succession. The expected patterns, processes, and pace of tidal marsh succession should indicate what data would be most informative and efficient for measuring the vegetation trends and results of tidal marsh restoration.

The local general conceptual model for early stages of succession from tidal mudflat to brackish tidal marsh is based in part on the recent vegetation succession at the adjacent former Bahia channel and lagoon mudflats (now marsh), where clapper rails have rapidly colonized young marsh. Since the late 1990s, this vegetation has developed into of abundant mixtures of tall alkali-bulrush and Pacific cordgrass vegetation in large patches near dense, sinuous tidal creeks. Dominance patterns vary from year to year, influenced by climate-driven fluctuations in salinity, and rapid marsh sediment accretion. Pioneer colonization occurred in two patterns: prograding fringing marsh, and coalescence of roughly circular clonal patches of alkali-bulrush and Pacific cordgrass. Coalescing colonies and fringing marsh merged into effectively continuous marsh by 2002. Notably, clapper rails began breeding in the local vegetation before marsh cover became closed, and before tall semi-evergreen subshrubby vegetation of high marsh (gumplant, pickleweed) developed significantly. The recent marsh vegetation of the Bahia lagoon and channel are shown in Figure 1.

This conceptual model for early brackish marsh succession is modified by vegetation and topography designs for of the Bahia Wetland Restoration Project, particularly the East Unit
(Central Bahia and Mahoney Spur). The topography and vegetation of the site will be engineered to accelerate the early successional processes after tidal restoration. The conceptual vegetation designs for these patterns are illustrated in Figure 2. Topographic high mid- to upper intertidal areas are proposed to be “pre-vegetated” during a phase of non-tidal water management, so that tidal restoration will begin with substantial established alkali-bulrush and pickleweed-dominated vegetation. Key vegetation elements include localized high marsh along creekbank ridges (emulating natural levee patterns in mature tidal marshes, and scattered “nuclei” or founder colonies of alkali-bulrush scattered over mid-intertidal mounds. Graded wide platforms approaching Mean High Water would be partially vegetated with picklweed and alkali-bulrush at the onset of tidal restoration.

The successional model for West Bahia marsh vegetation forecasts slow expansion of alkali-bulrush marsh and cordgrass into mudflat and shallows, where tidal range and sedimentation are expected to be subdued relative to Central Bahia. Very little marsh development is expected within the first five years after tidal restoration. Mudflats and shallow lagoon conditions are expected to persist at much of West Bahia, where tidal range and sedimentation are likely to be subdued for a period of time that is difficult to predict, but is likely to be prolonged well beyond the early stages of marsh succession at the East Unit. Most brackish marsh in the first decade of West Bahia tidal restoration is expected to occur as fringing brackish marsh and high marsh transition zones along the south shore, where tides will again contact the native terrestrial vegetation of hillslopes and sloping valleys.

Vegetation management actions proposed also include some localized planting and seeding of native perennial grassland at some terrestrial edges; limited planting or inoculation of vernal marsh propagules in seasonal wetlands, and source reduction of wetland weed populations, such as perennial pepperweed. Disturbance of seasonal wetland vegetation normally results in at least several years of highly unstable patterns of patchy species abundance, and rapid species turnover or shifts in dominance. Generally, perennials like creeping wildrye and common spikerush can gradually outcompete and replace non-native seasonal wetland vegetation if they can establish initially, and are free from disturbance by excessive grazing, cattle trampling, or severe intermittent drought. Mature vernal marshes and alluvial grasslands at Sears Point support extensive turfs dominated by spikerush, rushes, and creeping wildrye. Successional undisturbed seasonal wetlands (released from grazing and excessive drainage) adjacent to eastern Olive Avenue (Novato) exhibit strong dominance by spreading patches of these species as well. These bayland examples may be treated as models for mature restored seasonal wetland vegetation at Bahia.

The spatial pattern and scale of vegetation sampling, and vegetation monitoring methods, must be adapted to the patterns and rates of marsh vegetation development associated with early marsh succession described in these conceptual models of the Bahia Wetland Restoration units. Without fitting sampling strategy and methodology to the types, patterns, and dynamics of vegetation observed in the time-frame of monitoring, vegetation monitoring would provide only data with weak interpretive or predictive value.

4.0 VEGETATION MONITORING OBJECTIVES
The recommended overall goals of the vegetation monitoring plan for the Bahia Wetland Restoration Project are:

1. to provide objective data on the rate, pattern, and dynamic composition of vegetation at least during early stages of ecological succession following restoration actions;

2. to provide some basic relevant data on vegetation’s structural characteristics relevant to wildlife habitat; and

3. to provide essential or practical data for adaptive management of the site’s vegetation.

Specific objectives for monitoring are described in relation to the distinctive vegetation management units of the project, following the vegetation management plan, as discussed below. No specific regulatory criteria, formats, or performance criteria are assumed for the vegetation monitoring plan, based on pre-proposal discussion with MAS.

MAS has recommended that the vegetation monitoring focus on the first five years of the project, owing to limited project resources and commitments for monitoring. The first five years of tidal marsh succession will probably result in some significant changes, the first five years represents only the earliest stages of marsh succession, even in the most rapidly advancing marsh-mudflat transitions. Monitoring data limited to this period would not be able to test whether project objectives are met, or are likely to be met. The monitoring methods proposed in this plan are intended to be basic enough so that it may be feasible to continue monitoring with at least irregular intervals for long after the first five official monitoring years. Most information about the long-term tidal marsh vegetation dynamics will not be evident until at least 10 to 20 years after tidal restoration. Most marsh formation will probably occur in the East Unit in 5 to 15 years after restoration, and well after than in West Bahia. Long-term continuity of vegetation monitoring, rather than intensity of data collection and analysis, is most valuable for understanding tidal marsh restoration.

**Specific vegetation monitoring objectives for the main units** of the Bahia Wetland Restoration Project are described below. They are divided into near-term vegetation monitoring objectives (to 5 years) and optional long-term monitoring objectives, based on estimates of vegetation conditions within stages of succession realistically expected within this time-frame.

**East Unit (Mahoney Spur and Central Bahia).** Key objectives for monitoring vegetation of the East Unit are

- Measuring the cumulative cover of marsh vegetation, and its rate of (clonal) spread
- Measuring coarse-scale colonization (density and distribution of new colonies as patches detected in aerial photographs)
- Measuring patch size of continuous vegetation cover
- Measuring vegetation height of alkali-bulrush and high marsh, as wildlife habitat
• Documenting changes in species richness (number of plant species) and their relative abundance.

West Bahia

• Measuring linear extent and width of fringing tidal marsh
• Measuring the cumulative cover of marsh vegetation, and its rate of spread
• Documenting changes in species richness (number of plant species) and their relative abundance, particularly in terrestrial ecotones of high marsh.

Seasonal Wetlands

• Measuring cover of native and non-native seasonal wetland plant species

5.0 VEGETATION SAMPLING STRATEGY AND METHODS

The recommended vegetation sampling strategy applies a combination of aerial photographic data collection, GIS analysis, and ground-based sampling methods. The combination of these two data collection approaches is the most cost-effective way of providing accurate, comprehensive, site-wide monitoring of vegetation dynamics. The descriptive, interpretive and predictive value of purely ground-based vegetation sampling methods (e.g. sampling small numbers of labor-intensive transects or permanent plots to measure cover) is very limited. Aerial photography interpreted without adequate ground-based surveys can be subjective and prone to inaccuracy, limiting its value for measuring long-term change. (“Ground-based” and “terrestrial” methods are synonymous, but “ground-based” is used here to avoid confusion between “wetland” and “terrestrial” vegetation, which are both treated with “terrestrial” sampling methods.)

Aerial photography and GIS. Aerial photographic interpretation and measurement is the only practical approach for providing meaningful data about the distribution and abundance of sparse, irregularly distributed patches of tidal marsh vegetation in early stages of colonization and spread, particularly for large sites. Analysis of aerial photography can be used to measure overall rates of marsh vegetation spread over large areas, and document significant changes in pattern, such as coalescence of discrete small pioneer colonies to consolidated stands of marsh.

The ability to derive meaningful quantitative vegetation data from aerial photography depends on high-resolution, low-altitude orthophotos using either color or false-color infrared film, or digital color photography, during optimal seasonal stages of vegetation development. False-color infrared film is preferable for distinguishing vegetation types and small vegetation patches over predominantly mineral substrate backgrounds (like mudflats or graded soils), but true color aerial photography can be equally useful if it is interpreted with thorough ground surveys. Black and white photography provides very limited ability to delineate and classify vegetation types, even with ample ground survey data. Aerial photographs provide the raw data for delineation of classified vegetation patches using GIS.
The number of discrete patches (colonies) of marsh vegetation, and their areas, are readily quantified in GIS. Analysis of delineated vegetation patches provides accurate estimates of the variability and parameters for the cumulative marsh vegetation cover, marsh vegetation spread, and frequency distribution of size-classes of marsh colonies. These are among the most ecologically significant variables that are direct expressions of basic ecological processes driving marsh succession. GIS analysis of accurately interpreted aerial photography generates accurate and easily-understood static vegetation maps, and maps of dynamic vegetation change. Such maps are very useful for monitoring reports used by the general public, resource agencies, and scientists.

**Ground-based vegetation methods.** Ground-based vegetation surveys are essential for accurate interpretation of aerial photography, and delineation of distinct types of vegetation. Ground-based survey methods are also essential for useful information about the location of invasive wetland weed populations at early stages of spread, when they are not detectible from aerial photographs. In early stages of tidal mudflat-marsh succession, physical access to most vegetation for terrestrial vegetation measurement techniques is infeasible or extremely inefficient and hazardous. Terrestrial vegetation methods in early tidal marsh succession are practically focused on the upper end of the fringing marsh shoreline (high marsh, upper middle marsh zone).

Because terrestrial vegetation sampling is labor-intensive, it has a poor track record for continuity in long-term vegetation monitoring of wetland restoration sites. Relatively few wetland restoration projects have maintained consistent levels of effort necessary to establish periodic transects with adequate sampling intensity to quantify and interpret long-term change.

Ground-based methods include:

1. **Fixed perspective photography.** Fixed-perspective wide-angle photography from permanently marked plots or points provides useful qualitative interpretive data on many vegetation characteristics. Over time, repeated fixed-perspective photographs of vegetation provide a very important and cost-effective method for tracking and demonstrating subtle long-term vegetation changes, and supplementing the value of aerial photography and quantitative terrestrial vegetation measurement methods. Because it is infeasible to measure all relevant vegetation variables, a long-term visual record of vegetation change can significantly improve the accuracy of interpretation from data and analysis. Photomonitoring stations should always record **descriptive notes about vegetation within view** (effectively “releves”, species lists with rank abundance for boundless plots, supplemental narrative comments; Bonham 1989) at each photo recording date.

2. **GPS mapping of plot/transect locations and rare plant populations.** GPS (global positioning survey) provides relatively accurate geographic point-data for recovering positions of sampling locations (plots, transects) and occurrences of plant populations of interest to management, such as rare native plants or discrete colonies of invasive weeds. GPS data are incorporated in GIS maps of vegetation as layers.
Vegetation Monitoring Plan

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(3) **Wandering transects and searches for targeted species.** Intensive spatial sampling of small areas within large sites generally fails to provide useful data about infrequent species that may be very important to vegetation objectives and adaptive management, such as detection of small or inconspicuous founder populations of invasive weeds, or rare native species. Comprehensive surveys (systematic visual inspection of all vegetation with a study area) are usually infeasible because of time and cost constraints. As an intermediate approach, wandering transects are meandering, are semi-random (haphazard) “foraging” surveys for targeted searches of species occurrences within potential habitats. They are located within stratified (pre-classified) blocks of relatively homogeneous vegetation. Wandering transects are used to sample the following types of data useful for monitoring of young marsh restoration sites:

- relatively complete plant species lists,
- rank abundance and frequency of widespread species,
- frequency and location (GPS) of rare native plants, and
- frequency and location (GPS) of locally rare (founder) populations of invasive plants.

At the Bahia site, wandering transects would be applicable to the dredge disposal site’s seasonal wetlands, and wide high tidal marsh-terrestrial ecotones.

**Permanent plots.** Permanent plots (Bonham 1989) are used to take repeated measurements of vegetation at fixed locations. They be used to track vegetation change over long periods of time. Plots are marked with stakes where substrates are stable; where substrates are unstable, GPS points may be substituted. Permanent plots may be sampled directly as single replicates for vegetation variables (**permanent quadrats**), or they may be used to define larger plots for internal “nested” sampling using smaller, randomized, non-permanent replicate quadrats within them. Randomized multiple quadrats can be used for inferential statistical analysis of vegetation data. Permanent plots would be useful at the Bahia project for recording both short-term and long-term changes. Because large numbers of replicated permanent plots require labor-intensive data collection, and because most of the restoration area will consist of unstable substrate, only a few representative permanent plots are recommended at the upper edges of the restored tidal marsh.

Permanent plots can also be used to make direct measurements of clonal plant patches, generating simple, important data that can be used to estimate rates of spread, and time to achieve dominance.

**Permanent transects.** Transects are useful for quantifying change in vegetation across environmental gradients, such as marsh elevation gradients at the upper landward shoreline, or along the edges of channels. Permanent transects allow for detection of long-term change in vegetation along environmental gradients. They are not unbiased or efficient as sampling units to estimate means of area-wide vegetation variables, and they should not be used instead of stratified random sampling of quadrats to estimate parameters such as vegetation cover, height, or density. For short-term vegetation change in early tidal marsh succession, a few permanent transects would demonstrate dynamic zonation of the upper marsh edge.
This would not be essential for large-scale interpretation of the site vegetation, but would be useful for documenting the development of critical sub-habitats, such as high marsh used as high tide escape cover for wildlife. A small number of permanent transects would achieve this along the accessible southern shorelines of West Bahia and Central Bahia. Transect locations should be selected to represent relatively homogeneous areas, because only a small number of transects would be allowed by monitoring budgets; randomized multiple transects may not be feasible.

**Sampling techniques and variables.** Cover, a measure of vegetation abundance, is the most widely used vegetation variable. The most efficient *objective quantitative* technique for vegetation cover data in tidal marshes is the *line-intercept* method (Bonham 1989). *Subjective* (ocular) estimates of *cover-classes* of vegetation can be used to describe vegetation for purposes of classification (typing), but it is invalid to use them for inferential statistical analysis about vegetation change. Consistency of cover-class ranks varies significantly between observers, and even with individual observers in different types of vegetation. Line-intercept technique is recommended for repeated randomized samples used for data analysis. Cover-class estimation is recommended for vegetation descriptions of large or boundless plots covering large areas (releves). For vegetation mapping, cover-class estimates in large plots would be useful. For transects or stratified random plots, line-intercept sampling should be used.

**Plant height** is another potentially important variable to measure in certain sub-habitats of tidal marshes because it is ecologically significant for wildlife habitat. Measurements of cover and plant height are recommended for wildlife habitat assessments of tidal marsh vegetation in permanent transects. **Density** is (number of individuals or modules of plants per unit area) is not recommended as a variable for Bahia because it is extremely labor-intensive to measure, and would not provide significantly more information than cover.

### 6.0 MONITORING PROGRAM FOR BAHIA RESTORATION UNITS

**6.0 Whole-site aerial and ground photography.** Color or false-color infrared aerial photography should be flown at low altitude in the first growing season after tidal restoration. Permanent fixed-perspective ground photo stations should be distributed along all accessible shoreline areas along West Bahia and Central Bahia, and at least three fixed-perspective photo stations should be included for Mahoney Spur and northern shores of West Bahia. Precise locations of photo stations should be *selected* after tidal restoration is initiated, to capture significant areas of regenerating vegetation and also include representative unvegetated mudflats or subtidal shallows. Intervals between photo stations should minimize gaps, and cover the entire accessible shoreline length. Wide-angle photographs are recommended. Vertical close-up photos of ground vegetation adjacent to photo stations is also recommended. Narrative descriptive vegetation accounts for photo stations is recommended.

If project budget allows, whole-site aerial photography should be included for the second and fifth year at minimum. Faster vegetation change is expected for Mahoney Spur and Central Bahia, so annual aerial photography (either project-specific or coordinated with
other aerial photo surveys) is highly recommended. Minimizing gaps between color aerial photo survey years after year 5 (maximum 2 to 3 year gaps) facilitates accurate interpretation of low-resolution/high altitude images from other sources in non-survey years.

Analysis of aerial photography in GIS should include classification of all marsh in terms of dominant plant species. During early succession, fringing marsh continuous with the shoreline should be sampled separately from isolated mudflats colonies of vegetation. Photo interpretation should be verified by reference to ground photo monitoring stations, descriptive notes, and wandering transects. All marsh vegetation patches should be delineated and classified in GIS.

6.1. East Unit (Central Bahia, Mahoney Spur)

The East Unit will consist of a mix of new mudflat and regenerating pre-established brackish marsh vegetation during the first year of tidal restoration. Monitoring of vegetation should include the following sampling methods:

- **Delineation of vegetation types (GIS).** Vegetation in aerial photos should be classified by dominant species of each patch (interpreted from ground surveys, photos). Vegetation associated with constructed marsh features (marsh nuclei, creekbank ridges, marsh platforms) should be identified with subordinate classifications as GIS layers.

- **Wandering transects.** The entire shoreline of the East unit should be surveyed on foot, segmented to a series of wandering transects for maximum coverage. Plant species frequency should be estimated from transects. GPS locations of invasive plant populations and uncommon to rare native plants should be recorded. Where sharp discontinuities in vegetation occur within transects, releves (Bonham 1989; see also fixed-perspective photomonitoring) are recommended to provide semi-quantitative descriptions of unique stands or large areas of relatively homogeneous, distinct, vegetation.

- **Fixed-perspective photomonitoring stations.** These stations would be selected in the first growing season after tidal restoration, to maximize coverage of the shoreline and representation of vegetation. Photography should be taken in the same week during April (early emergence) and August each year. In drought years, an additional photo series is recommended to document dieback of alkali-bulrush between April and July, before foliage is completely dead. Descriptive notes for releves should be recorded at each photomonitoring station.

- **Permanent transects** (Optional). Two or three permanent transects should be established, extending from lowered levees, across new high marsh gradients, to the lower edge of marsh vegetation. Where the gradient includes terrestrial vegetation, terrestrial vegetation of the highest elevation point should be included in the transect. The edge between mudflat and vegetation should be marked with a permanent stake at the end of each transect each sample year. Transects should be
sampled at least in years 1, 2 or 3, and 5, but preferably each year until year 5. Line-intercept samples should be made at intervals of 1 to 2 meters or more, depending on the steepness of the gradient. Preliminary sampling should determine appropriate sampling intervals. **Porewater soil salinity** should be measured for intertidal marsh zones with saturated or flooded substrate.

6.2. West Bahia

Vegetation monitoring for West Bahia would differ from the East Unit mostly in terms of the proportional monitoring effort for shoreline vegetation compared with open mudflat or open water areas. Little or no GIS/aerial photo analysis of vegetation would be expected for the majority of West Bahia within the first 5 years at least, unless subtidal stands of *Ruppia maritima* are detectible in low-turbidity conditions. Aerial photo interpretation of restored marsh during the first 5 years would very probably focus on development of narrow fringing marsh along the terrestrial (south) shoreline, and development of terrestrial ecotones with marsh. Lower effort needed for aerial photo interpretation and vegetation mapping may be compensated by slightly increased effort in ground-based surveys along the marsh edge.

The emphasis on ground-based vegetation monitoring would be on permanent transects and wandering transects. **Wandering transects** should cover the entire shoreline (entire fringing marsh band up to and including lower edge of terrestrial vegetation) for at least 3 of the first 5 years, for detection and recording GPS locations of infrequent species (rare/uncommon native plants, invasive species), and recording of relevés to describe distinct, homogeneous blocks of vegetation (with GPS locations), to aid in aerial photo interpretation. Annual wandering transects are recommended. Optional **permanent transects** should be located to represent at least two examples of transitions between steep oak woodland/grassland and tidal marsh, and two examples of transitions between seasonal wetland or mesic vegetation patches where valleys and ephemeral stream mouths contact tidal marsh. Line-intercept measurements should be sampled at intervals along transects. **Soil porewater salinity** (and surface water salinity) should be sampled at each interval.

6.3. Seasonal wetlands

Monitoring of seasonal wetland vegetation at the dredge disposal site will not rely primarily on aerial photo interpretation of vegetation because of fine-scale, heterogeneous vegetation patterns (small and variable patch size) and relatively high plant diversity. Permanent **photomonitoring stations** should include the edges of the site, and edges of the seasonal pools. **Permanent large plots** within pool areas and grassland areas should be established and staked. The precise plot size and number appropriate for the site should be determined through preliminary sampling, so that relatively homogeneous blocks of vegetation are represented in single large or multiple small plots (stratified sampling). Rank cover-abundance classes of all plant species should be recorded at two times each sample year, during late aquatic phase (spring-flooded pools), and during late drawdown phase when plants are either fruiting or flowering. If budget allows, stratified random sampling of line-intercept “quadrats” within permanent plots is recommended. Again, sampling intensity should be adjusted by preliminary sampling to assess variability of the vegetation: if
vegetation is relatively homogeneous within plots, smaller numbers of line-intercept “quadrats” may be employed. Single seasonal samples will not be sufficient to identify species present and record significant changes in relative abundance between early and late spring. April and June are recommended months for sampling. Sampling should be at least conducted in the first year after grading/inoculation or planting, in year 2 or 3, and in year 5. Annual sampling is recommended.

7.0 Data analysis, presentation, and reporting

Most comprehensive information about the project’s vegetation will be analyzed and presented through GIS vegetation maps. GIS vegetation maps based on aerial photography should display polygons representing all detectable occurrences of:

- Each terrestrial or wetland vegetation type based on dominant species (modified Keeler-Wolf and Sawyer 1995), adapted for site-specific assemblages or significant density-classes of vegetation types (subjective estimates).
- Cover-classes of mudflat, channel, shallow open water
- Patches of invasive non-native plants
- Patches (or points) of rare or uncommon native plants
- Constructed marsh restoration features (non-vegetation data layer)

GIS maps after the initial year of data collection should be accompanied by analysis of data on changes between years of vegetation mapping. The GIS analysis should include:

- Measurement of radial (lateral) spread of vegetation edges of fringing tidal marsh, marsh nuclei
- Change in the density (number/area) of pioneer mudflat colonies of tidal vegetation (marsh nuclei and spontaneous colonies)
- Cumulative vegetation cover by type, and total tidal marsh vegetation cover

Additional analysis, if feasible for monitoring budgets, should include quantification of variation in tidal marsh zone width over time, size-class distribution of marsh patches (measurement of shifts between colonization and coalescence/consolidation of marsh), and tracking the fate of marsh nuclei (survivorship, coalescence). Analysis of marsh growth rates in “treated” (nucleated) and “untreated” (open mudflat) areas of equivalent average initial elevation would be useful for testing hypotheses about the ability to accelerate marsh succession with minor, local topographic modifications.

Data from permanent transects along tidal marsh gradients (variation in plant cover and vegetation height along tidal marsh elevation gradients) should be presented graphically, with emphasis on change in horizontal position of vegetation types (dominance classes) within zones. Height variation of vegetation (canopy height) along the gradient should also be included as average absolute height above ground surface, and relative height in relation to tidal datums. Permanent plot data from seasonal wetland pools and grassland should be summarized as a table representing ranges (not means) of cover-class values, or means and
standard deviations of quantitative cover values of each species. Soil salinity data should be presented with transect data.

Data analysis on tidal marsh species diversity is not necessary for the earliest, unstable stages of tidal marsh succession in this region (including the first 5 years), when a only a few dominant species compose the vegetation. Similarly, species diversity measurements in the unstable plant assemblages of the young high marsh zone would have little predictive value. Species diversity measurements would be potentially useful after the vegetation stabilizes physically and in dominance (past year 5). Species richness (wandering transect data) and mapping of uncommon plants should provide sufficient information about species changes in the earliest stages of marsh succession.

Monitoring reports should include narrative descriptive accounts of the current status of vegetation, variation within vegetation types, and significant changes in vegetation since the previous monitoring report. Significant events (storms erosion or deposition events, droughts, floods, etc.) should be incorporated in vegetation accounts. Ecologically significant and unanticipated changes in vegetation that are not adequately represented by established data collection protocols should be noted in reports, and recommendations should be made to adapt monitoring (sampling locations, intensity, intervals, methods, etc.) to ensure that significant ecological changes are documented.

Draft monitoring reports should be submitted to the lead agency (either Marin Audubon Society or a delegated representative agency, such as the California Department of Fish and Game) by October 15 of each monitoring year, to be subject to discretionary scientific peer review, agency comments, and revisions. Final monitoring reports should be submitted to the lead agency by December 31 of each monitoring year.
LITERATURE CITED


Bahia Wetland Restoration Project

Vegetation and Habitat Management Plan

DRAFT

(Recent brackish tidal marsh and channels, alkali-bulrush dominant, with local patches of cordgrass; breeding clapper rails present. Silted Bahia "lagoon", marsh habitat reference site for restoration. June 2005)

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Appendix 7: Native seasonal wetland plants, Northwestern San Pablo Bay
Executive Summary

The Bahia Wetland Restoration Project will restore a subsided diked bayland to a major contiguous block of brackish tidal marsh (over 300 acres) in the southwestern Petaluma Marsh, Marin County, south of Black John Slough. The project site is adjacent to the Bahia-Toy (Greenpoint) Marshes, one of the only major breeding North Bay populations of California clapper rails (\textit{Rallus longirostris obsoletus}) that have persisted through the 1990s to the present. A primary goal of the project is to generate abundant suitable brackish tidal marsh vegetation with suitable structure to serve as complete habitat for clapper rails, and support rapid, major expansion of breeding clapper rail populations from south of the site.

The project site is contiguous with some intact terrestrial habitats, including mature oak woodlands, seasonal freshwater streams and marsh, and patches of grassland. The site location affords an exceptional opportunity to link restoration of a complex tidal marsh directly linked to established native terrestrial plant communities.

The existing diked baylands at the project site consist of brackish alkali-bulrush/saltgrass marsh and shallow perennial ponds (West Bahia unit), and a mix of seasonal pickleweed marsh, annual and perennial non-native grassland, and brackish seasonal saline flats and ponds (Central Bahia and Mahoney Spur units). The project site is adjacent to the mature, wide, fringing high tidal brackish marsh along Black John Slough, the Petaluma River. It also lies adjacent to young (1990s) brackish tidal marsh dominated by dense, tall alkali-bulrush that supports a growing local clapper rail population (Bahia Lagoon Marsh). The site also contains a derelict dredge disposal site supporting seasonal non-tidal marsh, with a mix of native and non-native vegetation.

The primary vegetation and habitat goals for Central Bahia and Mahoney Spur are to promote rapid establishment marsh favorable for colonization by clapper rails. The local vegetation model of young, suitable clapper rail habitat consists of mixtures of tall alkali-bulrush and Pacific cordgrass vegetation in large patches near dense, sinuous tidal creeks, in proximity to tall subshrubby vegetation of high marsh. This based in part on the recent vegetation succession at the adjacent former Bahia lagoon mudflats (now marsh), where clapper rails have rapidly colonized young marsh.

Restoration of high pickleweed marsh with ample emergent high tide cover is also a vegetation/habitat goal for portions of the project. Mahoney Spur was presumed to support a substantial resident population of the salt marsh harvest mouse (SMHM) in its former nontidal pickleweed vegetation. Deep, prolonged (winter-spring) and complete submergence of all Mahoney Spur vegetation in 2004-2005 has probably reduced the resident SMHM population and habitat quality.
Near-term vegetation objectives for West Bahia include slower expansion of alkali-bulrush marsh and cordgrass into mudflat and shallows, where tidal range and sedimentation are expected to be subdued relative to Central Bahia. Objectives for conserved seasonal wetlands (dredge disposal areas) include increased abundance and diversity of native vegetation, improved management flexibility to reduce mosquito production, and improved habitat for wading birds, waterfowl, and amphibians.

**Marsh vegetation restoration and management methods** to achieve these habitat goals include:

1. **interim nontidal water management** to promote early establishment and spread of alkali-bulrush and pickleweed marsh vegetation over modified topography at Central Bahia and Mahoney Spur, prior to tidal breaching;

2. limited **supplemental manual planting** of topographic highs (soil mounds between Mean Tide Line to Mean High Water) to act as nuclei of expanding tidal marsh in open mudflats; and

3. limited supplemental manual **planting of high marsh on constructed banks** adjacent to channels, to act as high tide flood refugia for resident wildlife;

4. **grading of existing weedy artificial upland fills** to provide channelized platforms for brackish marsh and transition zones.

Vegetation management actions proposed also include some localized planting and seeding of native perennial grassland at some terrestrial edges; limited planting of vernal marsh propagules in seasonal wetlands, and source reduction of wetland weed populations, such as perennial pepperweed.
1.0 Scope and Purpose of Vegetation Management Plan

The purpose of this vegetation management plan (VMP) is to develop practical, low-cost, effective methods of establishing suitable tidal brackish marsh vegetation, and seasonal (nontidal) marsh, consistent with the wildlife habitat objectives for the Bahia Wetland Restoration Project (PWA 200_), Novato, Marin County, California (Figure 1). The VMP emphasizes design strategies to develop suitable habitat for the federally endangered California clapper rail at the southeast end of the project site, next to existing clapper rail populations at the Bahia Homeowner’s Association Channel and Lagoon, which may be threatened by dredging. The vegetation strategies were developed in coordination with the preliminary draft conceptual engineering and habitat restoration designs for the project, in collaboration with Philip Williams and Associates (Bob Battalio, Don Danmeier, Mark Lindley) and Point Reyes Bird Observatory (Nadav Nur). The Vegetation Management Plan [draft] has been prepared in advance of a final grading and engineering plan, and therefore includes only approximately estimated specifications for acreages and numeric values of planting units.

2.0 Biogeographic setting of the Bahia Wetland Restoration Project

The project site is a diked bayland, historic tidal marsh reclaimed for agriculture around the beginning of the 20th century, as were most of the tidal marshes of northern San Pablo Bay (Goals Project 1999). The project site lies near the southern end of the Petaluma Marsh, the largest unreclaimed prehistoric tidal marsh complex in the San Francisco Estuary (Goals Project 1999; Atwater et al. 1979).

The Petaluma Marsh is brackish (oligohaline to mesohaline), strongly influenced by freshwater discharges of the Petaluma River that reduce salinity of tidal waters along a gradient upstream of the river’s mouth at San Pablo Bay. At the upstream end of the Petaluma River, dominant brackish marsh vegetation corresponds to that of the northern Napa Marsh, or western Suisun Marsh. Near the Petaluma River mouth, tidal marshes approach the composition of northern San Pablo Bay salt marsh vegetation. Tidal marshes between these ends of the salinity gradient vary subtly with position, but vary profoundly with short-term climate fluctuations.

Marsh salinities of Petaluma Marsh can fluctuate significantly among years, depending on the amount and timing of rainfall. Between-year variation in marsh salinity patterns can cause the the dominant marsh vegetation and species diversity to vary significantly between “dry” high-salinity years, and “wet” low-salinity years. Alkali-bulrush (Bolboschoenus maritimus; syn. Scirpus maritimus) is one of the dominant species of the marsh...
plain in “wet” years, but it can die back early in the growing season, or fail to emerge altogether, in “dry” years. Pickleweed (Sarcocornia perennis; syn. Salicornia virginica) and saltgrass (Distichlis spicata) persist in the vegetation throughout climate cycles, but dominate throughout the marsh plain in higher salinity years. The typical brackish marsh plain vegetation of Petaluma Marsh, therefore, is dynamic and unstable, within a natural range of variation. Alkali-bulrush and Pacific cordgrass (Spartina foliosa) also vary in relative abundance in the low brackish marsh zone along channels of Petaluma River marshes, with S. foliosa most abundant in more saline conditions, or after rapid pulses of mud accretion.

The Bahia Wetland Restoration Project site’s geographic position within the Petaluma Marsh is significant in terms of potential restored tidal marsh vegetation, and habitat potential. These are strongly influenced by the sites’ position along variable salinity and sedimentation gradients, and adjacent land uses and vegetation types (section 3.1).

Although the Petaluma Marsh still contains extensive plains of prehistoric brackish tidal marsh, almost all of the modern adjacent terrestrial ecotones (transitions to uplands along marsh edges) are either separated from tidal marsh by dikes, or they are agriculturally modified for cattle grazing or viticulture. The majority of the eastern Petaluma Marsh edge consists of gently sloping alluvial plains, fans and deltas associated with Petaluma Formation sediments. These supported historic grasslands, later converted to livestock pasture and more recently, vineyards. In contrast, the western Petaluma Marsh borders steep Franciscan bedrock, supporting hillslopes with natural mixed evergreen forest dominated by oak and bay, as at the Bahia project site. The Baylands Ecosystem Habitat Goals Report (Goals Project 1999) noted that this subregion provides rare opportunities to restore natural tidal marsh/upland transitions near extensive brackish marshes, particularly oak woodlands.

3.0 Existing vegetation and habitats: status and trends

Project site and adjacent landscape units. The Bahia Wetland Restoration Project site is a 333 acre subsided diked bayland, reclaimed from brackish tidal marshes south of Black John Slough, Petaluma Marsh (PWA 2004). It is bordered on its southern, landward side by intact terrestrial soils of hillslopes dominated by oak woodland vegetation, with coast live oak (Quercus agrifolia) and California bay (Umbellularia californica) prevalent near sea level, often with overhanging tree canopy at the diked marsh shoreline (Appendices 1, 2). Ephemeral to seasonal streams and wetlands swales with shrub thickets, rush and sedge marsh (Juncus balticus, Carex obnupta or C. barbarae) drain to the diked marsh in valleys within the oak woodland. The site borders relatively mature historic fringing tidal brackish marsh along Black John Slough, formed over former undiked mudflats during the 20th century.

The diked baylands of the site itself are generally subsided below modern sea level (PWA 2003), and support variable types of brackish non-tidal marsh vegetation (section 3.2). The diked wetlands have undergone major recent changes from predominantly seasonal pickleweed marsh, to extensive perennial brackish to saline marsh (saltgrass, pickleweed, alkali-bulrush) and ponds with highly variable flooding regimes, and dynamic vegetation conditions (submerged wigeon-grass, brass-button flats and pans; Appendices 1, 2).
The diked bayland directly contacts terrestrial soils along its southern limits, except at the southwest end, where a steep bay mud dike, and a derelict dredge disposal pond separates the subsided bayland and the hillslopes.

The XX acre derelict dredge disposal site at the supports a mixture of weedy non-native grassland (ryegrass and annual grasses, bull thistle) mixed with pickleweed, and freshwater seasonal wetlands. Bordering the southeast end of site is a levee along an artificial navigation channel to Bahia Lagoon. The Bahia Homeowners former “lagoon” and its navigation channel have mostly infilled with fine sediment and brackish marsh. (Appendices 1, 2)

Potential restored tidal marsh vegetation: reference conditions. The recent primary succession of mudflat to tidal marsh at the Bahia Homeowners’ channel and lagoon (silted docks) indicates the patterns and processes of ecological succession are likely to prevail in the first decade after tidal restoration, once upper intertidal elevations are achieved. Alkali-bulrush expanded rapidly over the Bahia lagoon mudflats in the mid-1990s, forming dense, tall emergent canopies exceeding the height of local high marsh vegetation (gumplant/pickleweed) by 2000, and continuous bulrush marsh by 2004. Cordgrass formed a minor component of the vegetation, restricted to lower channel banks. Pickleweed developed as a sub-canopy of alkali-bulrush, dominant only during summer dieback of alkali-bulrush in some dry years. Annual pickleweed (Salicornia europaea) was also a minor component of the vegetation.

In contrast, the old (ca. 100 yr) fringing marshes of Black John Slough represent the potential “mature” local condition of tidal marsh, formed by long-term accumulation of brackish marsh peat under favorably gradual rates of sea level rise. Because of uncertainties about the rate of accelerated sea level rise in the next 50 to 100 years, it is not possible to predict whether this mature, relatively stable condition would be reached by the restored tidal marshes of the project site.

At the Bahia site, extensive but often steep terrestrial ecotones with tidal marsh are available for immediate “restoration”: the mature native terrestrial vegetation already exists, and restoration of tidal flows would regenerate the ecotone to new tidal marsh. In fact, much of the potential “ecotone’ is an abrupt edge, consisting woody tree and shrub canopy (mixed evergreen forest and oak-savannah with limited grassland) overhanging wetlands from north-facing terrestrial hillslopes. The broad alkaline/subsaline alluvial grassland associated with eastern and northwest Petaluma Marsh does not occur at Bahia. Some gently sloping wetland swales (rush-sedge wetlands), streams, and semi-open grasslands and scrub would become ecotonal with tidal wetlands at the eastern end of West Bahia.

Potential vegetation-habitat relationships at the site. The existing site is bordered by levees, and the eastern half of the site (Central Bahia and Mahoney Spur) dry by late summer, so that the site is surrounded by, and internalizes, erratic “upland” terrestrial habitat, extending close to Black John Slough. The terrestrial components of the site provide efficient tidal marsh access to terrestrial predators such as raccoon and red fox, as well as coyote, indicated by frequent scat and tracks in dry mud, and on levees (P. Baye, unpublished data). Tidal restoration can eliminate the unfavorable, unnatural interspersion

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of uplands in tidal marshes, and regenerate deep, extensive, insular marshes with habitats remote from intensive terrestrial predation.

Vegetation and land use at the terrestrial edge of the restored marsh may also be significant for long-term habitat quality of restored tidal marsh, and recovery of endangered or rare resident marsh wildlife. High-order mammalian predators, such as coyotes, may be active in the mix of evergreen hardwood forest, grassland/savannah, with abundant prey (hare and juvenile deer), and absence of ranching activities that requiring eradication of coyotes. This potential “refuge” for coyotes may help discourage future activity of red fox in restored tidal marshes, which would otherwise pose challenges for recovery of rare resident marsh wildlife, such as clapper rails.

The eastern end of Bahia wetland restoration site (Central Bahia, Mahoney Spur) is directly adjacent to the largest contemporary breeding populations of California clapper rails in San Pablo Bay, in the brackish marshes along the southwestern Petaluma River to Bahia/Toy Marsh, including the relatively new Bahia channel/lagoon marsh (Evens 2004). These adjacent tidal marshes may supply a proximate source population for dispersal of clapper rails to suitably restored brackish marsh at the project site. The eastern end of the site is also relatively close to tidal sources of suspended sediment and salinity, near the mouth of Black John Slough/Petaluma River (and Bahia navigation channel). The eastern end of the site (especially Mahoney Spur) also includes some of the highest initial elevations of the site to act as a substrate for intertidal mudflat and marsh. These factors together indicate high potential for restoration of clapper rail habitat at the eastern end of the site, and suggest priorities for restoration designs regarding the structure and distribution of restored brackish marsh and channels.

4.0. Vegetation and habitat objectives for Bahia Wetland Restoration

Vegetation objectives for Bahia Wetland Restoration Project are specific to each of its three component units, Mahoney Spur, Central Bahia, West Bahia, and the derelict dredge disposal site. Broadly, vegetation objectives for Mahoney Spur and Central Bahia are similar enough to treat them together as an Eastern Unit (not to be confused with “East Bahia” peninsulas and lagoon, distinct from West Bahia. The seasonal wetlands of the dredge disposal site comprise a distinct unit.

The VMP assumes that the ultimate ecological aims of vegetation objectives are:

- to support **habitat for rare or endangered** resident tidal marsh wildlife **species** (California clapper rail, California black rail, salt marsh harvest mouse, salt marsh common yellowthroat, San Pablo song sparrow;
- to **replicate natural ecosystem functions of successional tidal brackish marsh** (trophic structure, productivity, geomorphic processes, biogeochemical processes)
- to **support native species diversity** of plant, invertebrate, bird, fish, and mammal communities.
There are also subordinate, instrumental objectives for vegetation as physical tools to facilitate marsh-building processes and address engineering issues with tidal restoration. Brackish marsh vegetation should be used to stabilize substrate, facilitate sediment trapping and accretion of suspended marsh sediments, contribute directly to organic accretion of marsh soils, and damp excessive wave energy. These practical objectives for vegetation apply to near-term, early stages of succession conditions (mudflat-marsh transition).

4.1. Eastern Unit vegetation/habitat objectives

The vegetation and habitat objectives of the Eastern Unit (Figure 1; Central Bahia and Mahoney Spur) follow directly from the description of potential vegetation-habitat relationships described in section 3.1. Objectives for this unit are related to key inherent features of its position and site characteristics: (1) proximity to existing clapper rail populations; (2) relatively large areas with intertidal substrate elevations; and (3) close proximity to tidal sources of sediment and salinity from the Petaluma River. The overall model for the Eastern Unit is the young brackish marsh supporting breeding clapper rails at the Bahia “Lagoon” (Appendix 3; section 4), which exhibited very rapid succession from mudflat to dense alkali-bulrush dominated brackish marsh.

Thus, the overall ecological goal for vegetation in the Eastern Unit is to establish rapid primary brackish marsh succession, and achieve vegetation structure and abundance suitable for rapid colonization by clapper rails from Bahia Homeowners Channel and “Lagoon” marshes, and from lower Black John Slough. The proximate vegetation objectives are to establish extensive alkali-bulrush stands with sufficient density and height to enable rails to utilize them as cover during high tides, and as nesting habitat, in only a few years after tidal restoration. Timing is an important aspect of vegetation objectives for the Eastern Unit: very rapid spread of tall alkali-bulrush stands, similar to (or faster than) the pace observed at Bahia Homeowner’s Lagoon, is desirable.

Expected or “typical” clapper rail habitat features such as cordgrass-dominated channels, dense gumplant canopies above highest tide levels (flood escape habitat), and thick pickleweed, have not yet developed at the Bahia Lagoon, but clapper rails have established nonetheless in early stages of marsh succession. The youthful marsh habitat in tall, dense alkali-bulrush there has evidently been sufficient for nesting and maintaining territories, despite the scarcity of tall high marsh vegetation (gumplant, tall-form pickleweed, which here is generally shorter and less dense than the dominant alkali-bulrush of the marsh plain). Therefore, the proximate vegetation criteria are aimed at Bahia Lagoon marshes as a primary reference site. To increase the likelihood that vegetation structure would be supportive of clapper rails, some additional vegetation objectives focus on emulating natural patterns and structure of high marsh vegetation (erect, subshrubby gumplant-pickleweed) in relation to tidal channels, to a limited extent.

Essential structural vegetation objectives for clapper rail habitat are:
(1) close proximity between productive **foraging habitat** (extensive mudflat/bulrush-cordgrass marsh edges, channel bank/bulrush-cordgrass edges), and **escape cover** (high-density, tall alkali-bulrush for normal tides; tall gumplant/pickleweed for extreme high tides);

(2) **Wide dispersion of high marsh** suitable for **nesting habitat** and extreme high tide **escape cover** throughout banks of the new **channel system** (creekbank high marsh), not just near peripheral levees;

The vegetation objective for **wide distribution of small amounts of tall, dense high marsh vegetation** along **tidal creekbanks** is essential to wildlife habitat quality. High marsh lags behind development other brackish tidal marsh habitat types because it requires much longer for accretion of mineral and organic sediments to build them naturally. Thus, high marsh often becomes a limiting factor for habitat suitability of rails (and other resident marsh wildlife) during “youthful” stages of tidal wetland restoration. High marsh is otherwise limited for many years to scarce relict fills associated with peripheral levees, leaving many potential rail territories without escape or nesting cover. Because rails tend to key territories to tidal channel systems, and because high marsh is naturally associated with local drainage and overbank deposition of sediment at channel edges, high marsh vegetation should be distributed along channel banks. Placing high marsh used as escape cover far from creek-aligned territories (e.g., only at peripheral levees) may cause force rails to leave safe travel corridors and cross exposed marsh to reach escape cover during extreme flood events, increasing their risk of mortality from predation. Insufficient internal creekbank high marsh may limit the “saturation” of otherwise suitable marsh habitat with rail territories, or may result in lower survivorship or nest success of rails.

The East Unit vegetation objectives for clapper rails are likely to be consistent with those of the **salt marsh common yellowthroat** and the **San Pablo song sparrow**, particularly the objectives for creekbank high marsh vegetation. Habitat values for these species would be expected to increase as the marsh plain matures, and more extensive creekbank high marsh develops. Similarly, the East Unit vegetation objectives should be consistent with some general habitat requirements of the **California black rail**, but relatively higher salinity marsh vegetation at the East Unit, compared with West Bahia, would be expected to favor relatively higher abundance of clapper rails (viz. Bahia Homeowners Channel and Lagoon marsh).

There are no corresponding goals in the East Unit for **rapid** development of extensive habitat for the **salt marsh harvest mouse**, which consists of high-intertidal pickleweed-dominated marsh with well-dispersed patches of tall high marsh vegetation and other associated halophytes (salt-tolerant plants). Vegetation objectives consistent with the habitat requirements of the salt marsh harvest mouse are limited to peripheral gradients with high marsh zones (primarily along the east end of the unit). Cost and fill constraints preclude construction of extensive artificial high marsh platforms. There is also higher priority for grading fill to initiate naturally spreading, rapidly maturing low marsh in areas that would otherwise be low intertidal mudflat. Long-term vegetation/habitat objectives are to establish extensive, mature brackish marsh plains suitable for salt marsh harvest mouse habitat. This
long-term objective may be limited by expected accelerated sea level rise, which may maintain pickleweed/alkali-bulrush marshes that flood too deeply and frequently to sustain viable populations of the salt marsh harvest mouse.

Short-term stabilization objectives for vegetation in the Eastern Unit are to consolidated perennial vegetation cover along the projected high tide shoreline, develop extensive tall, fibrous or subshrubby (persistent) perennial marsh cover over most of the bed of the Central Bahia unit, and maintain dense, tall perennial marsh cover in Mahoney Spur, prior to tidal breaching, in managed non-tidal or microtidal water regimes, similar to some types of Suisun Marsh management. The purposes of developing antecedent brackish marsh vegetation in nontidal, pre-breach conditions are:

(1) to “prime” the site for immediate initiation of tidal marsh succession with vigorous, extensive clones of perennial, pioneer tidal marsh plants that can directly stabilize and colonize tidally restored substrates (within suitable intertidal elevation range);

(2) To establish vegetative (clonal) populations of pioneer marsh species at intertidal elevations that would initially be too low (or too unstable) for seedling establishment;

(3) To establish “sacrificial” persistent standing plant litter at tidal elevations too low to allow survivorship, to provide bed and shoreline stabilization and roughness, increasing sediment trapping and frictional drag on wave propagation (reducing wave energy) in shallow water;

(4) To establish discrete nuclei of radially expanding, accreting, coalescing marsh colonies throughout new mudflats, eliminating dependency on the high-risk seedling establishment stage;

(5) To restrict fetch and efficiency of internal wind-wave generation.

The principle plant species that would be able to act as efficient primary (pioneer) colonizers of both nontidal and tidal brackish marsh, and achieve these geomorphic/engineering functions, are perennial pickleweed and alkali-bulrush. Both are readily recruited passively from naturally dispersed seed in fall, transported by bay water.

Long-term vegetation objectives for the Eastern Unit are to achieve marsh vegetation composition, diversity, and structure similar to the more mature Black John Slough marshes, but without an accelerated schedule. The pace of long-term marsh succession (after achieving proximate objectives) will depend on expected accelerated rates of sea-level rise that cannot be predicted with precision or confidence. If mature marsh conditions are able to stabilize, and complex, dense tidal creek systems evolve, the long-term habitat objective for wildlife is to provide extensive, high-quality, stable habitat supporting populations of California clapper rail, California black rail, San Pablo song sparrow, salt marsh common yellowthroat, and the salt marsh harvest mouse, as well as more
common waterfowl, wading birds, invertebrates, and native estuarine fish. Population densities of these species should be within the ranges found in lower Petaluma Marsh.

**Objectives for native wetland plant species diversity** in the near-term are largely associated with the upper edge of the restored tidal marsh at Central Bahia, and primarily along terrestrial hillslopes. The marsh plain is expected to remain too low (well below mean higher high water) to support the potentially higher diversity of brackish marsh plant species that are associated with mature tidal marsh topography. Therefore, it would be premature to assign plant diversity objectives to the marsh plain until it develops mature microtopography and drainage, and thus becomes receptive to colonization by additional species.

The upper edge of the restored marsh (**high marsh - terrestrial ecotone**), flooded by brackish water infrequently and irregularly during extreme astronomic tides and storm surges, can support either relatively species-poor native vegetation (dominated by creeping wildrye, *Leymus triticoides*, saltgrass, and meadow barley, *Hordeum brachyantherum*), or species-rich vegetation (brackish-freshwater marsh, alkali grassland with relatively low dominance by component species). Natural **terrestrial or alluvial soils** (originating from uplands) affected by tidal salinity are likely to provide the highest native species diversity. Only a short segment of the Central Bahia shoreline contacts terrestrial soils, so objectives for high plant species diversity are limited, compared with West Bahia, which supports an extensive terrestrial/bay edge. Reworked bay mud fills along the high tide line (such as old levees) are likely to support a rich weed flora, and are better suited to high-dominance native species like creeping wildrye in terrestrial ecotones, or gumplant-pickleweed vegetation along lowered levee crests.

### 4.2. West Bahia vegetation/habitat objectives

West Bahia vegetation objectives reflect this largest unit’s lower substrate elevations (predominantly lower intertidal to subtidal), relative remoteness of tidal sources of suspended sediment and salinity, and greater constraints on tidal flows. They also reflect the extensive natural terrestrial edge along oak woodlands and small freshwater swales and ephemeral or seasonal streams. The overall goals for West Bahia are to establish a slow, gradual succession from shallow open water lagoon with interspersed marsh islets, to a matrix of brackish low marsh, higher pickleweed-saltgrass marsh patches, and **enclosed large tidal ponds**. West Bahia may also exhibit relatively **damped tidal range** because of tidal choking by the high fringing marshes of Black John Slough. One example of this type of brackish tidal marsh and pond complex, including damped tidal range, is Lower Tubbs Island (at lower Tolay Creek), in the San Pablo Bay National Wildlife Refuge. Until recent failure of culverts (enabling increased tidal range), Lower Tubbs Island supported the largest population of California black rails in the San Francisco Bay National Wildlife Refuge Complex, and also supported large numbers of migratory waterfowl (Giselle Downard and Louise Vicencio, pers. comm.).

Given the expected slow pace of marsh accretion at West Bahia, persistent high proportion of low marsh, and the high ratio of open water or pond area to marsh, **wildlife objectives** for West Bahia **emphasize value to waterfowl, shorebirds, wading birds, and estuarine...**
fish. Only limited and gradual colonization of West Bahia by rails and passerine birds is expected, possibly only after several decades, if at all. The vegetation indicators of lower salinity observed within West Bahia in recent years (relative to the East Unit), indicate relatively more favorable long-term tidal marsh conditions for the California black rail. Therefore, habitat objectives for this species should be emphasized at shallow edges of West Bahia’s embayed shorelines where high tide cover will occur in natural terrestrial ecotones.

Because West Bahia’s nontidal brackish wetlands have already spontaneously established “marsh islets” (discrete colonies of creeping alkali-bulrush) to act as nuclei of marsh expansion, the objective for this function is to retain existing alkali-bulrush colonies, and if feasible, initiate additional ones.

**Long-term objectives for plant diversity at West Bahia** are limited to the terrestrial/high marsh ecotone, at the toe of the hillslopes where large gaps in the oak/bay tree canopy occur. (Most coast live oaks and bay trees near sea level are expected to survive tidal restoration). Because of the steep slope prevalent along hillslopes, limited areas of high-diversity high marsh ecotone are expected to develop. Moist swales, ephemeral streams, and freshwater wetlands in narrow valleys are most amenable to development of high native plant species diversity at the edge of tidal influence. The intertidal marsh plain is expected to develop low plant species diversity for at least two decades, and probably longer.

### 4.3. Derelict dredge disposal site: seasonal wetland vegetation and habitat objectives

The general ecological objectives for the seasonal wetlands of the derelict dredge disposal site are to modify them to more closely resemble and function like certain types of natural seasonal wetlands historically present at the edges of Marin County tidal marshes, particularly where freshwater drainages, marshes or riparian woodland grade into brackish seasonal marshes and pools near the upper limits of tidal influence. Examples of relatively natural (spontaneously regenerated) seasonal wetlands at edges of tidal marshes, both historic and contemporary, exist at a few locations at China Camp, and at a diked seasonal marsh north of Olive Avenue (Novato). These and other examples may serve as reference sites for reintroducing native plant species at the Bahia seasonal wetlands. Historic herbarium collections also indicate a number of species that were very likely components of tidal-edge seasonal wetlands. **Native species** of rush, sedge, spike-rush, and some vernal pool plants (e.g., semaphore-grass, rayless goldfields, aquatic buttercup) compose natural seasonal wetland vegetation (Appendix 7). Some of these species already occur in portions of the deeply flooded dredge disposal site. It would be highly desirable to alter the hydrology of the dredge disposal site, and the seed/bud banks in the soil, to promote prolonged **submergence of short native seasonal wetland vegetation**, followed by relatively **rapid drawdown and desiccation in spring**, similar to natural vernal pools and swales.

The small dredge **decant pond** has established almost complete cover of broadleaf cattails, typical perennial freshwater marsh vegetation formed under seasonal wetlands conditions with very long hydroperiod (summer drawdown, effectively a perennial fresh-brackish marsh). Objectives for this late-flooded, perennial-dominated “seasonal” wetland subunit...
are to conserve essentially freshwater cattail marsh vegetation, and improve the ratio of open water (bare pond bottom) to cattail marsh, to increase habitat values for wading birds and waterfowl. This subunit should be protected against conversion to brackish perennial marsh (bulrush) to conserve overall community diversity at the site.

Specific objectives for the dredge disposal site’s seasonal wetlands are:

1. to minimize the extent of non-native weedy seasonal wetland vegetation;
2. to improve management of mosquito production;
3. to retain and expand native seasonal wetland vegetation, and increase diversity of native wetland plant species (based on reference sites and historic botanical documentation (Appendix 7);
4. to improve habitat for invertebrates, amphibians, reptiles, wading birds, shorebirds, and dabbling ducks;
5. to conserve local perennial freshwater marsh.

Summary of Vegetation Objectives
Bahia Wetland Restoration Project

<table>
<thead>
<tr>
<th>Unit</th>
<th>Proximate objectives (near-term)</th>
<th>ultimate objectives (long-term)</th>
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| Eastern Unit (Mahoney Spur and Central Bahia) (tidal wetlands) | - “prime” early tidal marsh succession with pre-established perennial, pioneer brackish marsh vegetation
- pre-establish pioneer marsh vegetation at intertidal elevations that would initially preclude natural seedling colonization
- establish “sacrificial” vegetation (drowned marsh with persistent litter) for bed stabilization and roughness
- establish “nuclei” (marsh islets) of radially expanding, coalescing marsh colonies throughout new mudflats
- To restrict fetch and wind-wave generation
- rapidly establish extensive alkali-bulrush stands with sufficient density and height to enable clapper rails to colonize early in succession | - achieve marsh vegetation composition, diversity, and structure similar to the more mature Black John Slough marshes
- provide extensive, stable high-quality mature brackish marsh habitat supporting clapper rails, black rails, song sparrow, yellowthroat, salt marsh harvest mouse, and common fish and wildlife species of Petaluma Marsh |
| West Bahia (tidal wetlands) | - establish a slow, gradual succession of shallow open water lagoon with interspersed marsh islets
- retain existing alkali-bulrush colonies, and if feasible, initiate | - develop a matrix of brackish low marsh, higher pickleweed-saltgrass marsh patches, and enclosed large tidal ponds |
These objectives for seasonal wetland management are mutually compatible. Shifting the vegetation from seasonally saturated, weedy ryegrass meadow (high mosquito potential) to seasonal ponds (vernal pool vegetation, rapid drawdown) should improve both native species and habitat diversity, and mosquito control.

5.0 Management of tidal marsh succession: East Unit

The management of primary vegetation succession at Central Bahia and Mahoney spur addresses both pattern and process in vegetation dynamics. **Pattern** concerns the spatial distribution of vegetation types related to natural geomorphic patterns of natural tidal brackish marshes, and wildlife habitat requirements. **Process**, during early tidal marsh succession, addresses the basic interactions between vegetation establishment by seed and clonal expansion, vegetation growth, and sediment transport. Vegetation designs for pattern and process focus on their relation to topography and drainage during early stages of marsh succession.

5.1. Conceptual design elements of vegetation – East Unit

The generalized layout of conceptual design elements for early-succession vegetation and habitat at the East Unit are shown in plan view in Figure 2, representing idealized, full expression of the recommended vegetation concept designs. The basic vegetation design elements are flexible enough to be incorporated in the final grading plan, adjusted in scale and distribution according to available construction budget. The essential conceptual design elements include:

1. Development of large, continuous blocks of **alkali-bulrush and cordgrass** on **upper intertidal marsh terrace** (graded platform elevations between local Mean Sea Level to near mean High Water) dissected by **high densities of irregular, sinuous small channels**, located at the east end of Central Bahia and Mahoney Spur (Figures 2, 3);
(2) Wide dispersion of multiple centers (nuclei) of pioneer clonal (creeping, rhizomatous) brackish marsh vegetation (alkali-bulrush and cordgrass) on areas near, but below, Mean Sea Level elevations (Figures 2, 4, 5) in Central Bahia. At Mahoney Spur (elevations commonly above Mean Sea Level, able to support pioneer vegetation), marsh nuclei are not recommended.

(3) Concentration of high marsh vegetation (gumplant/tall-form pickleweed) in narrow strips along crests of ridges at well-drained, sinuous tidal creek banks (Figures 4, 6);

(4) Gently sloping gradients (1:10 or flatter) creating transitions between low (cordgrass), middle (alkali-bulrush/pickleweed dominants) and high (gumplant/pickleweed dominant) brackish marsh along modified perimeter levees, (depending on cost and availability of substrate) (Figure 4). This includes some replacement of upland vegetation on compacted substrates of supratidal levee crests with periodically flooded high marsh vegetation on loosened (low bulk density) upper intertidal bay mud substrate.

(5) For the entire unit, the graded site should be thoroughly vegetated with brackish marsh prior to tidal restoration, by applying established brackish water management schedules (seasonal flood/drain cycles or muted tidal flows, based on Suisun Marsh regimes) to promote rapid natural spread and extensive cover of graded substrates by pickleweed, saltgrass, and alkali-bulrush. (Appendix 4). This process has partially occurred spontaneously, prior to site grading, because of pump failure and overtopping of levees. It can be augmented by transplanting of alkali-bulrush.

There is a significant time-lag between levee breaching and extensive vegetation establishment on new mudflats in nearly all traditional levee-breath diked baylands (“tabula rasa” or blank slate templates of denuded, graded, dry bay mud), ranging between 5 to 15 years or more, depending on initial bed elevations. The combination of a pre-vegetated brackish marsh “primer”, marsh nuclei, creekbank high marsh ridges, and constructed alkali-bulrush marsh, would significantly reduce or eliminate this lag time, and would instead initiate the tidal marsh restoration with an advanced rate of vegetation spread.

5.1.1. Constructed alkali-bulrush marsh. The constructed alkali-bulrush marsh terrace (southeast corner of Central Bahia; Figures 2, 3) is designed to provide “instant” tidal marsh at the time of tidal breaching, close to a condition suitable as habitat for clapper rails found at the Bahia Lagoon. The rationale for emphasizing alkali-bulrush vegetation is:

(a) In terms of efficient initial marsh yield from limited volumes of fill (yield of suitable potential clapper rail habitat per unit volume of fill and grading effort), maximizing alkali-bulrush at intermediate middle-low initial marsh elevations (MSL to MHW) would provide more extensive suitable rail habitat than equivalent volumes graded to provide immediate platforms for high pickleweed marsh (MHHW), and much sooner in the project life;
(b) Alkali-bulrush is the **overwhelming dominant vegetation in the Bahia Homeowners Lagoon and channel**, and it supported clapper rail nesting almost as soon as it developed there;

(c) **Alkali-bulrush** vegetation can **establish more extensively**, and **grow more rapidly and larger** under low-energy, sheltered, brackish **nontidal conditions than in newly restored brackish tidal marsh**, allowing precocious and more extensive initial tidal marsh habitat development with minimal revegetation effort. Robust alkali-bulrush **clones** can **vegetatively regenerate at lower intertidal elevations than its seedlings**, effectively lowering the tidal elevation threshold for pioneer colonization of new mudflats.

(d) Alkali-bulrush marsh can **undergo fairly rapid succession to pickleweed/saltgrass marsh** under favorable conditions of sediment supply, transport, and marsh productivity (organogenic sediment). **Sheltering of adjacent mudflats** by alkali-bulrush marsh may also promote accretion and establishment of spontaneous **cordgrass marsh**. Thus, precocious alkali-bulrush marsh can catalyze general primary brackish marsh succession.

The constructed alkali-bulrush marsh would consist of redistributed “upland” fills (bay mud from the RV park site, levees, and scraped from the weedy drier portions of the dredge disposal site), spread to a wide, gently sloping platform between local Mean High Water and Mean Sea Level, with rough grading. Rough grading facilitates surface microtopography that promotes seed deposition, ‘safe sites’ for seedling emergence, and seedling establishment.

If graded fills are **compacted** by grading equipment, they should be **disced** when dry or drained, after final earthwork is completed, to reduce soil bulk density and improve root penetration potential. **Low soil bulk density** and high root penetration would promote vigorous, tall alkali-bulrush growth favorable for clapper rail habitat. Compacted fill would restrict root penetration and risk “dwarfing” the vegetation, resulting in vegetation height unsuitable for clapper rail cover.

The alkali-bulrush marsh should be dissected with a **high density of excavated sinous tidal channels** with beds at or below Mean Low Water, to promote tidal drainage, increase local bulrush height near channel banks, and provide travel corridors and foraging habitat for rails. Rail densities correspond roughly with channel densities in marsh with tall, thick vegetation cover.

The alkali-bulrush marsh terrace should be located mostly in the **southeast corner of Central Bahia**, between the northern edge of the dredge disposal site, and the levee along the Bahia Homeowners channel (centered on the former RV park site). When this levee is lowered to form high marsh connections between the restored East Unit marsh and the Bahia Homeowners channel marsh, clapper rails may potentially move directly to the new alkali-bulrush marsh, so that the new and old marshes become one large, consolidated rail habitat.

5.1.2. Marsh nuclei. Marsh nuclei should be constructed as loose, unengineered **soil mounds** (scraped into piles, or cut/fill from local borrow areas) with broad, irregular, rough
crests between Mean Sea Level and Mean High Water, to support points of vegetation spread early in marsh-mudflat succession (Figures 4, 5). Marsh nuclei would be located where elevations slightly lower than Mean Sea Level. Mounds would locally raise local topography so that the tops would be able to support alkali-bulrush and cordgrass very early in marsh succession, creating “islets” of marsh progradation. Marsh nuclei are analogous with creekbank high marsh ridges, but they would be located on the open plain at variable variable density between channels. Mounds would become vegetated in pre-breach managed non-tidal water regimes.

Soil mounds for marsh nuclei should be placed mostly in the Central Bahia area, because much of the Mahoney Spur elevations are already at upper intertidal elevations capable of supporting pickleweed and alkali-bulrush in full tidal conditions. Mounds are not necessary where existing elevations lie between MSL and MHW, or higher. Lower limits of tidal elevations tolerated by alkali-bulrush depend on tidal range: higher tidal range shifts its distribution towards MHW, and lower tidal range expands it towards MSL. Rapid sediment accretion can allow initially unstable low-elevation plantings to survive and grow vigorously.

The marsh nuclei may optionally be sprigged with dormant alkali-bulrush tubers (locally harvested and redistributed from existing vigorous borrow source stands on site), but most of their alkali-bulrush and pickleweed vegetation is expected to develop directly from seed under non-tidal water management regimes (Appendix 4), prior to tidal breaching. Developing alkali-bulrush marsh vegetation on mounds in managed non-tidal conditions (Appendix 5), similar to pre-project conditions, would be highly advantageous and relatively efficient. Mounds may also be vegetated by direct transplanting of dormant alkali-bulrush tubers immediately prior to tidal restoration, but this would result in higher risk of mortality (especially following storms occurring at early stages of establishment) and potentially slower growth (especially during years of high summer salinity that cause early dieback); therefore it is not recommended unless nontidal marsh management is precluded. Cordgrass cannot be established in non-tidal managed marsh mounds.

If soil mounds are not pre-vegetated when exposed to higher-energy tidal conditions, brackish marsh plant seedling colonization may occur, but even more slowly and less reliably. Alkali-bulrush growth and spread are usually more significantly more vigorous and faster under nontidal brackish marsh conditions than under full tidal conditions in the lower Petaluma Marsh. Like the constructed alkali-bulrush marsh, the soils of the mounds must be low in bulk density, uncompacted, for adequate root penetration and plant vigor.

The pre-vegetated marsh nuclei would become “instant” patches of stabilized tidal marsh after levee breaching. Creeping rhizomes would radiate from their edges, spreading the zone of sediment-trapping edge vegetation laterally into adjacent mudflats. After surrounding mudflats accrete above Mean Sea Level, clusters of radiating marsh nuclei should begin to coalesce into large alkali-bulrush marsh patches, even before mudflats accrete to elevations at which cordgrass and alkali-bulrush seedlings would be able to establish frequently. Otherwise, significant alkali-bulrush and cordgrass seedling establishment would not be expected to occur on mudflats deposited by purely physical processes until they reach approximately Mean High Water.
5.1.3. Creekbank high marsh ridges. Similar to marsh nuclei, the East Unit model features discontinuous slender strips of high marsh along constructed channels, developed on unengineered side-cast ridges or berms (Figures 4, 6), immediately adjacent to main excavated channels. They are designed to emulate the form and function of natural levee microtopography associated with tidal channels of mature marsh plains. They differ from the marsh nuclei designs in position (flanking channels), shape (linear), and elevation (near Mean Higher High Water) and function (wildlife habitat rather than marsh growth).

High marsh vegetation would also partially develop on creekbank ridges under non-tidal water management, which is likely to promote growth of pickleweed and saltgrass on topographic highs of saline soils. Planting is not necessary for these high marsh strips, as long as they are stabilized by vegetation at the time of tidal breaching. Otherwise, unstabilized ridges or berms may erode slightly and develop only as marshplain vegetation. Gumplant would be expected to colonize the side-cast ridges gradually during tidal restoration, as mudflats accrete around them and merge to form a gradient between local high marsh and patchy cordgrass/alkali-bulrush marsh of the adjacent young marsh plain (5.1.2). Like the constructed alkali-bulrush marsh, the soils of the ridges must be low in bulk density, uncompacted, for adequate root penetration and plant vigor.

5.1.4. Perimeter levee: high marsh conversion. Most perimeter levees will act as upland habitat extensions deep into tidal marsh and after tidal restoration. Existing levees of Mahoney Spur support some dense cover of coyote-brush and have value as escape cover for endemic resident tidal marsh wildlife during extreme high tide flooding of the marsh. Upland levee habitats also attract terrestrial mammalian prey (hares, ground squirrels, voles, mice, rats) of avian and terrestrial predators. The levee supports noxious weeds such as Italian thistle (*Carduus pycnocephalus*) and yellow start-thistle (*Centaurea solstitialis*). The bare levee road/trail along the Bahia Homeowners Channel exhibits sign of raccoon, fox, and ground squirrels. It also supports a two vigorous, old, but dwarfish native oaks (canyon oak or hybrid coast live oak). The channel road levee provides upland habitat connection to the outer Mahoney Spur levee. The former dredge disposal levees are steep and weedy terrestrial habitats with no flood control function.

High tidal marsh with vigorous gumplant vegetation can provide ample high tide escape cover, without providing attractive habitat for terrestrial predators, or artificially enhancing the prey base for avian predator foraging activity. **Spreading levee crest material over wider areas to high marsh elevations** (upper intertidal, a few centimeters above MHHW) therefore may increase overall escape cover habitat, while reducing long-term artificial predation risks to resident endemic tidal marsh wildlife (Figure 4).

Grading the Bahia channel (road) levee to high marsh elevations should be the highest priority. The few dwarfed old oaks on the east levee may provide locally important cover for marsh wildlife, and if severed from upland corridors, they are unlikely to provide a nuisance value; thus, they could be retained with a 20 foot buffer. The dredge disposal levee is also of greater value regraded to a slope that supports a wide high marsh transition to marsh plain (constructed alkali-bulrush marsh).
Reggraded, revegetated perimeter levees should form **gently sloped gradients** (1:10 if possible, but at least 1:7 to minimize potential for wave-cut scarps in the first few years after tides are restored). Gentle slopes will allow for marsh zonation and greater diversity of vegetation and habitats.

Newly graded high marsh is at some risk of rapid invasion by perennial pepperweed (*Lepidium latifolium*) if there are nearby seed sources. Local source reduction of pepperweed is recommended for the growing season prior to levee grading. Subsequent to levee grading, inspection and early (juvenile/seedling) control of initial pepperweed colonies is recommended because control of clonal (vegetative root-spreading) colonies is extremely difficult, requiring herbicides. (Appendix 5)

### 5.1.5. Managed interim non-tidal brackish marsh: tidal marsh vegetation “primer”.

When the Bahia site was acquired, the vegetation was predominantly non-tidal seasonal salt marsh dominated by pickleweed and saltgrass, with some non-native grasslands. Since approximately 2002, the site has effectively become an impounded perennial marsh and pond complex, significantly and progressively wetter (more prolonged flooding, marsh emergence later in the growing season, and deeper flooding) than its pickleweed marsh antecedents. Unmanaged flooding (drainage failure) at the Bahia site is already approximating optimal artificial water management regimes for brackish marsh, by impounding water from winter overtopping of levees, hillslope runoff and ephemeral streams, and rainwater, with gradual evaporational drawdown in late spring and summer. This unplanned, unmanaged conversion to brackish marsh has demonstrated the extent and speed with which highly vigorous alkali-bulrush colonies can grow and spread on the site, especially at West Bahia. With relatively low-level planting efforts (transplanting dormant tubers in fall) to initiate widespread clones of alkali-bulrush, marsh dispersion could be significantly increased over much of the site.

The practical restoration advantages of pre-establishing or “priming” a tidal marsh restoration site with perennial alkali-bulrush marsh are summarized in section 4.1. Alkali-bulrush and pickleweed are primary colonizers of brackish marsh in both tidal and non-tidal wetlands. In low-energy, sheltered conditions of shallow-flooded diked baylands, natural seedling colonization can occur over a wider elevation range, and faster, than in fully tidal hydrology on bare substrates. When tidal restoration begins, pre-established vegetative colonies can already occupy the full potential tidal elevational range for alkali-bulrush (well below seedling elevation tolerances), and tidally “drowned” vegetation can provide persistent bed surface roughness and stabilization.

The flooding and drainage schedules (water management regimes) for passively “cultivating” alkali-bulrush and pickleweed marshes in brackish non-tidal baylands have been developed in Suisun Marsh by the California Department of Fish and Game, and the Suisun Resource Conservation District (as well as marsh managers from other U.S. regions) for well over half a century (Mall 1969, Kantrud 1996, Suisun Resource Conservation District 1998).
Appendix 5 outlines the optimal water management practices for establishing alkali-bulrush marsh. Timing of initial water intake is aimed at starting flooding with low salinity water, and flooding to drown out competing vegetation in fall and winter. A brief drawdown to shallow water and mud (partial drainage to 3 to 8 cm depth, then mud, for 2 to 3 weeks) is made in spring to help stimulate seedling germination and emergence of bulrush and pickleweed. Re-flooding with bay water at low salinity then suppresses competing vegetation and stimulates alkali-bulrush growth. Moderate soil porewater salinity (7 to 10 ppt optimal; growth up to about 20 ppt) enables vegetative growth of alkali-bulrush, but suppresses competition by cattails. A fluctuating water level around 10 to 20 cm can be optimal for alkali-bulrush, but deeper flooding (as at West Bahia) also support its vigorous growth and spread. A non-fluctuating, single seasonal drawdown can also yield significant growth, but proportionally more pickleweed and saltgrass. Low-amplitude tidal range from circulating flows choked by tidegates can also be used to maintain a full growing season of alkali-bulrush, but only if tidal source water salinities are low in summer.

Construction of interior site features (channels, ditch blocks, engineered or unengineered fills) will require dewatering of the site for earthwork, and much of the existing non-tidal marsh vegetation will be destroyed by grading. Directly restoring tides to the devegetated surface will result in the maximum delay in the onset of marsh vegetation re-establishment, and the slowest progress. A range of marsh revegetation options are available after earthwork is completed:

(a) **No revegetation.** Direct tidal reflooding of barren, unstable graded substrates immediately after construction. High mortality of remnant interior marsh vegetation after dewatering for construction. Tidal marsh succession must initiate on unsheltered open mudflats. Marsh seedling colonization of full tidal wetland is largely restricted to a narrow shoreline zone, and crests of placed/engineered fills (mounds, ridges, terraces/platforms). Approximately 4 to 5 years after breaching to establish pioneer marsh that is mostly limited to initial raised surfaces. Most potential marsh elevations (above MSL) are colonized within about 10 - 15 years.

(b) **Direct planting of placed/engineered fills.** Extensive direct planting of vegetative propagules of alkali-bulrush, Pacific cordgrass, over available substrate surfaces above Mean Sea Level. Moderate survivorship may be expected. Approximately 3 to 4 years after breaching to establish blocks of bulrush/cordgrass marsh within planted areas. Most potential marsh elevations (above MSL) are colonized within about 10 - 15 years.

(c) **Passive nontidal impoundment:** Breaching is delayed 2 growing seasons; levee overtopping, flooding resumes, with gradual summer drawdown, to re-establish brackish marsh. Limited alkali-bulrush seedling colonies establish because of a lack of spring drawdown, but some regeneration of remnant tubers occurs, with patchy establishment. Mounds, ridges may become mostly pickleweed/saltgrass vegetation, less suitable for tidal conversion than alkali-bulrush. Alkali-bulrush establishes mostly in ponds/depressions as in 2003-5, mostly lower intertidal after breaching (minimal survival). Approximately 2 to 4 years after breaching to establish blocks of
bulrush/cordgrass marsh in filled areas above Mean Sea Level. Total time after construction (2 season delay of breaching) 3 to 5 years, but up to 4 to 6 years depending on season when interior construction is complete. Most potential marsh elevations (above MSL) are colonized within about 10 - 15 years.

(d) **Managed flooding with low-density planting of alkali-bulrush (recommended).** Breaching is delayed 2 growing seasons. Alkali-bulrush tubers are planted sparsely on areas above Mean Sea Level elevations. Levee overtopping, flooding resumes, but water elevations are managed (operation of tidegates) to allow for spring drawdown to recruit alkali-bulrush and pickleweed seedlings, and to maintain shallow flooding (10 to 20 cm, up to 30 cm) of fills above Mean Sea Level to Mean High Water elevations. Alkali-bulrush develops mostly at future intertidal elevations; wigeongrass colonizes beds; pickleweed colonizes shorelines. After 2 growing seasons, extensive brackish marsh is established over most of the surface. At time of breach (two years after completion of interior construction), most upper intertidal surfaces are already partially vegetated, and continue growth the following year. Within 1 year after breaching, extensive blocks of bulrush/cordgrass marsh establish. Within 2 to 3 years after breaching (total 4 to 5 years after completion of interior construction), most potential marsh elevations above MSL are vegetated.

5.1.6. **Optional native plant reintroductions.** No re-introductions of uncommon or rare native tidal marsh species are recommended in the early stages of marsh restoration, because plant communities are unstable and subject to strong fluctuations of dominance. Most of the restored marsh in the first 5 to 10 years, in all revegetation scenarios, would consist of middle to low marsh zones dominated exclusively by widespread, common species (alkali-bulrush, annual pickleweed, Pacific cordgrass). Most native species diversity in tidal marshes is naturally concentrated in the high marsh and terrestrial ecotone. Only a few uncommon plants that are native to high marsh ecotones in the Petaluma Marsh have strong colonizing ability in open, bare substrates.

After the high marsh and transition zone of the tidally restored marsh becomes stabilized by dominant perennial marsh vegetation, it may become more feasible to re-introduce some uncommon to rare native plants. Artificial re-introduction is justified for uncommon tidal marsh plants, because (a) seed source populations are often small and remote (or extirpated in the subregion) because of historic marsh reclamation; (b) seed dispersal occurs mostly very close to parent plants; long-distance dispersal events occur, but they are very rare; and (c) the probability of seedling recruitment depends on the seed density in suitable habitats. can be introduced (seeded, transplanted) into artificial gaps (denuded areas). The most feasible subjects for re-introduction in the high marsh zone would be clonal perennial plants, such as creeping wildrye (*Leymus triticoides*), salt marsh baccharis (*Baccharis douglasii*), western goldenrod (*Euthamia occidentalis*). Creeping wildrye is recommended for transplanting in areas with gradients containing elevations above Extreme High Water (supratidal areas) in the East Unit, such as the dredge disposal site levee. Creeping wildrye gradually forms closed, dense sods and cover, and dense stands of it can out-compete many noxious weeds that otherwise rapidly dominate graded bay muds in uplands, such as radish, fennel, and star-thistle.
Re-introduction of other native tidal marsh plants should be deferred to later stages of marsh succession, when relatively stable marsh plains dominated by pickleweed, saltgrass, and jaumea have established. This could occur as soon as 5 to 10 years after tidal restoration in areas with engineered high marsh gradients. Candidate regionally rare species for re-introduction may include smooth goldfields (*Lasthenia glabrata* ssp. *glabrata*), salt-marsh owl’s-clover (*Castilleja ambigua* ssp. *ambigua*, salt marsh populations), northern salt marsh bird’s-beak (*Cordylanthus maritimus* ssp. *maritimus*) and soft bird’s-beak (*Cordylanthus mollis* ssp. *mollis*). Of these, *C. maritimus* and *L. glabrata* have local Petaluma/North Bay source populations in Marin County. All are potentially established by seeding directly into sparsely vegetated high brackish marsh along tidal channel banks or upper shorelines. Artificial propagation of seed stock from local populations is recommended to ensure very high initial seeding densities. Re-introduction experiments should be designed and monitored in cooperation with the California Department of Fish and Game, and the U.S. Fish and Wildlife Service. A detailed re-introduction plan for each species.

In addition, the regionally rare dwarf spikerush (*Eleocharis parvula*) should be salvaged from the site (Central Bahia) prior to construction, by collecting abundant seed. It may also be re-introduced opportunistically by seeding into potentially receptive habitats, such as poorly drained tidal marsh or shallow pans that remain flooded into spring.

### 6.0 Management of tidal marsh vegetation succession: West Bahia

West Bahia is too large, too deeply subsided, and too likely to be affected by prolonged tidal damping to justify a comparable effort for rapid initiation of marsh revegetation in tidal mudflats. A revegetation/topographic strategy similar to that of the East Unit (marsh nuclei, creekbank ridges, constructed marsh platforms) would probably be effective at West Bahia as well, but costs for implementing it on the more deeply subsided site would be much greater, and much of their purpose (to accelerate marsh succession) would be defeated by expected tidal damping and slower sedimentation.

West Bahia does now contain large stands of alkali-bulrush that will likely continue to spread. Most of them occur in deeply subsided areas that would become lower intertidal or subtidal after tidal restoration, and would result in complete mortality. As dead persistent litter, the very tall (over 1.5 m) and dense alkali-bulrush stands would still be effective at stabilizing the bed, and trapping sediment, however slowly. An alternative re-use of the abundant alkali-bulrush stands would be to redistribute them in bulk to the mid-intertidal edges of the site, where they could rapidly initiate brackish marsh. Selected borrow stands of alkali-bulrush could be scraped from the dewatered site in fall, during construction. Marsh soil with rhizome fragments and tubers could be spread along the shoreline near MHW elevation and either disced into the soil, or shallowly buried.

The perimeter levee of West Bahia is also highly subsided, and is scarcely above the elevation of the adjacent tidal marsh plain in many reaches. Re-grading the perimeter levee here to convert it to high marsh is a relatively lower priority than at the eastern East Unit, where there is a high priority for expanding the existing, adjacent clapper rail breeding habitat.
The upland edge of West Bahia is extensive, and exists in a relatively natural state. No additional planting of oaks, native shrubs, or grasses is recommended, because there is no indication that there is any deficiency in native vegetation caused by human impacts. Restoration of native terrestrial grasslands by reducing non-native annual grasses is beyond the scope of this vegetation management plan, and it is unlikely that any cost-effective methods to do so would apply here; controlled burns are not likely to be compatible with conservation of the mixed evergreen forest and oak woodland. High marsh ecotones should be allowed to form spontaneously on existing terrestrial soils affected by estuarine flooding and salinity. Special attention may be given to the freshwater seeps and seasonal streams that discharge to the restored tidal wetland edge. Freshwater ecotones may re-establish gradually here. As they do, they should be carefully re-assessed for potential re-introduction of uncommon fresh-brackish marsh plant species. Because such communities are variable and cannot be predicted, specific recommendations for reintroductions should be deferred until after assessments of local marsh ecotones are made, probably 5 to 10 years after tidal restoration, at the earliest.

7.0 Management of seasonal wetlands: former dredge disposal site

The seasonal wetlands of the dredge disposal site with relatively high habitat values for egrets, dabbling ducks, some shorebirds, and amphibians (mostly tree-frogs) are confined to relatively small areas of low depressions with relatively deep, wide pools, with aquatic habitat persisting into late spring most years. These seasonal ponds are transitional to perennial-dominated vernal marsh, particularly in wet years. They support some native vernal marsh plants such as semaphore-grass (*Pleuropogon californica*). The remainder of the seasonal wetlands is grassland dominated by non-native ryegrass, non-native thistles, and relict stands of sparse pickleweed with minimal residual soil salinity. These ryegrass-dominated plains are seldom submerged, produce few or no amphibians or waterfowl foods, and produce abundant mosquitoes.

Therefore, the basic vegetation management actions recommended for the dredge disposal site, integrated with restoration objectives and methods for the tidal restoration of the East Unit, are as follows:

1. **Reduce seasonally saturated/shallow-flooded ryegrass meadow** area;

2. **Increase the number and areal extent of seasonal ponds** capable of supporting vernal marsh, amphibians, waterfowl and wading bird habitat;

3. **Convert remaining non-native ryegrass-dominated wetlands to native perennial creeping wildrye/barley meadow** (*Leymus triticoides/Hordeum brachyantherum*) grassland, well-adapted to seasonally saturated bay mud;

4. **Revegetate newly scraped/excavated seasonal pond depressions** with **suitable native vegetative propagules and seed** salvaged or translocated in bulk from donor sites. The propagule mix should include species naturally dominant or
abundant in native seasonal wetlands of northwestern San Pablo Bay (Appendix 7), with common spikerush, panicled brown-headed rush, and semaphore grass expected to dominate at least initial conditions.

The borrowing of fill for construction of tidal marsh platforms for alkali-bulrush marsh adjacent to the dredge disposal site may be integrated with enhancement of seasonal wetland habitat. The surface soils containing seed and buds of ryegrass are responsible for overwhelming dominance of ryegrass at the site. Scraping the ryegrass-dominated surface soils away, “scraping” down to buried mineral clay, and disposing of them in the areas designated for tidal alkali-bulrush marsh, will co-generate a “blank slate” for native species revegetation of seasonal wetlands, and a platform for tidal marsh (Figure 7). In effect, seasonal wetland enhancement can ‘subsidize’ tidal marsh restoration, to the extent that limited project budget for earthwork allows.

Additional scraping or excavation to generate about 20 to 50 cm deep depressions in broad (minimum 20 meters diameter) areas would provide additional seasonal pool habitat to an extent determined by project construction budgets. Because most valuable seasonal wetland habitats in dredge disposal sites and derelict farm fields in diked baylands are not engineered, it is recommended that seasonal wetland depressions be constructed through non-engineered, on-site “improvisational grading”, to minimize planning costs. Grading can be guided to some extent by on-site supervision by project hydrologists or biologists.

Because of mosquito abatement concerns, it would be desirable to include internal drainage ditches to connect new seasonal pools or ponds with existing pools, and provide some simple drainage outlet control (Figure 6; assume weir/flashboard) to provide management flexibility for the Marin-Sonoma Mosquito Abatement District to “flash-drain” the seasonal pond system if flood mosquito production is excessive. This would require leaving at least a low berm impoundment in place near the outer edge of the dredge disposal site, to replace the existing steep-sided, weed-dominated berm. Otherwise, the seasonal wetland hydrology should be controlled by unmanaged variable direct precipitation and hillslope runoff. If the average grade of the seasonal wetlands and perimeter berm elevation were low enough to be slightly overtopped by extreme high winter tides as sea level rises, the seasonal wetlands would have the additional restoration benefit of becoming a potential marsh transgression platform, and a new high marsh ecotone.

The seasonal wetland grassland would be revegetated by low-density vegetative plantings (divisions of dormant shoots and rhizomes) of creeping wildrye from local (Sears Point, MAS Petaluma Marsh Enhancement Project) populations. Planting densities recommended would be approximately 2 to 3 meter nearest-neighbor distances, subjectively estimated by planting crews. Meadow barley propagated from local source populations in saline soils should be seeded in patches within the scraped area. Gradually (7-10 yr), creeping wildrye would be expected to dominate the seasonal wetland grassland in the long term, even if ryegrass temporarily regenerates in abundance. Excessive early abundance of ryegrass, however, may retard spread of young creeping wildrye clones. Scraped surfaces should be revegetated in the late fall/early winter season after soils are wetted by rains. If creeping wildrye canopy density and height becomes a concern for mosquito abatement after

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it dominates the site, the sward can be either mowed, hayed, or occasionally grazed without harm, from late spring to fall, to minimize cover. Mowing/haying may stimulate creeping wildrye stand vigor.

New seasonal ponds should be at least minimally inoculated with propagules harvested from donor wetlands (Appendix 7). The Marin Audubon marsh at Olive-Atherton is recommended as one primary source for spring-summer seed harvesting (semaphore-grass) and dormant vegetative propagules (rush, sedge). Additional vernal pool plant propagules may be available from abundant sources at Sonoma Land Trust parcels at North Parcel and Sears Point, particularly areas proposed for tidal restoration. Propagule sources should be selected to avoid mass seeding of curley dock (*Rumex crispus*), which is not harmful to wildlife, but is a nuisance for native plant community restoration. Manual planting of dormant vegetative propagules in randomly scattered patches in scraped pools is recommended to achieve optimum long-term results with minimum initial revegetation costs and maximum volunteer labor. Planting intensity can be adjusted for the level of volunteer work available, or revegetation specifications can be developed from commercial revegetation contractors. Habitat value for wildlife in seasonal ponds does not depend on rapid revegetation with natives, so a slow, long-term, low-cost method should be acceptable if project budget is constrained.

The small cattail marsh in the former “decant pond” is currently breached to be open to flooding and drainage of the Central Bahia site. To prevent this marsh pocket from becoming salinized after tidal restoration, the breach in the perimeter levee should be plugged, and potentially replaced by a simple water control structure to allow water management options for mosquito control and waterbird habitat. The levee of the cattail marsh can either be left, or graded down (fill salvage and re-used as borrow material for tidal marsh restoration fills) to a low, wide berm to impound rainwater and prevent tidal overtopping, maintaining the freshwater marsh hydrology. It would be advisable to excavate irregular depressions (about 30-40% of bed) within the cattail marsh while the Central Bahia site is dewatered and under construction. This will increase open-water area to a more favorable ratio for waterfowl use, and will extend the seasonal duration of open shallow water habitat, increasing internal habitat diversity. It will also prolong the duration of shallow open-water habitat and slow complete encroachment by cattails by at least a few years.

### 8.0 Conceptual model of vegetation dynamics after tidal restoration

Long-term ecological succession of restored tidal marsh is subject to unpredictable and uncontrolled physical variables that drive ecological processes, primarily (a) rate of sea level rise; (b) long-term seasonal and interannual salinity trends; and (c) sediment supply. As a baseline for a conceptual model of vegetation change at the site, it would be practical to outline a developmental sequence of marsh vegetation dynamics based on projection of recent past conditions into the future trends, even though this assumption is not justified as an actual prediction. The conceptual model of vegetation dynamics presented below are based on the proposed vegetation management recommendations and their assumptions stated in Section 5. The timing of actual ecological threshold conditions (e.g. conversion of
mudflat to marsh, shift from low to middle marsh vegetation zones, etc.) would depend on external physical variables such as sea level rise.

8.1 East Unit: Central Bahia and Mahoney Spur

The pre-vegetated surfaces at elevations above Mean Sea Level would consolidate to continuous marsh rapidly, in the first two years after tidal restoration. Most of Mahoney Spur would be a mosaic of marsh and mudflats within the first two years of tidal restoration, with rapid expansion of tidal brackish marsh (alkali-bulrush/pickleweed in wet years, cordgrass/bulrush in drought years).

In Central Bahia, some mortality of alkali-bulrush may occur at the lower elevation range (near MSL), but alkali-bulrush would grow extensively in non-drought years, so lateral vegetative spread (marsh progradation) of alkali-bulrush would soon compensate for mortality at lower tidal elevations. Alkali-bulrush growth could be interrupted by drought conditions that impose high salinity (over approximately 20 ppt channel water) in late spring/early summer. Pickleweed and cordgrass would dominate in drought years, but cordgrass establishment by seedlings is erratic and variable among years.

Mudflat areas sheltered by multiple extensive alkali-bulrush marsh would undergo more rapid accretion to near Mean High Water, the elevation threshold for very rapid seedling colonization. Seedling colonization (mostly cordgrass or alkali-bulrush, depending on seasonal salinity patterns) would be most frequent in sheltered areas in mudflats between established marsh patches. Marsh nuclei would consolidate to large, irregular marsh patches within approximately 3 to 5 non-drought years after tidal restoration, unless tidal flows or sedimentation are constrained. Similarly, marsh platforms (above MSL) would consolidate rapidly to alkali-bulrush/pickleweed marsh within about two years or less after tidal restoration. Clapper rails may spread into the new channelized bulrush marshes about this time.

High marsh strips along creekbank ridges should recruit gumplants within 1-2 years after tidal restoration even without planting, but dense growth of flowering mature gumplant is not expected until about 3 years after tidal restoration. Constructed high marsh areas will remain subject to invasion by perennial pepperweed until high marsh vegetation develops dense, closed cover, which may take up to 4 to 5 years.

The site overall would become mostly vegetated brackish marsh, similar to Toy Marsh, Carl’s Marsh, and Bahia Lagoon Marsh in about 10 – 20 years after tidal restoration. The potential marsh succession delay caused by the greater area and internal wave energy of the subsided Central Bahia subunit, compared with these reference sites, would be somewhat offset by the pre-vegetation of the site and placement of precocious marsh nuclei, platforms, and creekbank high marsh ridges.
8.2. West Bahia

Most marsh restoration at West Bahia within the first two decades after tidal breaching is expected to be confined mostly to the shoreline along the hillslopes at the south end of the site. Shallow lagoon conditions, potentially dominated by submerged wigeongrass (*Ruppia maritima*) in backwater, low-turbidity, low-energy areas, are likely to remain extensive during the tidal choking/tidal damping phase, however long it persists. Tidal damping is likely to amplify annual variations in salinity at the West Bahia lagoon, establishing more fresh-brackish conditions in wet years relative to fully tidal marshes, and creating more hypersaline conditions in drought years. Habitat use of West Bahia by wading birds, waterfowl, and estuarine fish use is likely to increase compared with pre-project nontidal lagoon conditions, but habitat distribution of waterbirds may shift towards the edges of the site. A sparse mosaic of low brackish marsh at most is expected within 20 to 30 years, with shallow lagoon and mudflats persisting even as tidal damping is reduced. Species-rich high marsh transition habitats and fringing brackish marsh are expected to develop along the south shore within 10 years after tidal breaching, even with significant tidal damping.

8.3. Seasonal Wetlands

Inoculated or planted seasonal wetland pools would become sparsely vegetated by common spikerush, rushes, semaphore-grass, and sedges to form patchy vernal marsh within 5 years, assuming non-drought conditions. Seasonal ponds would develop a prevalence of native vegetation and become mostly vegetated after seasonal emergence within 10 years. Seasonal wetland grassland would be initially slow to develop creeping wildrye cover in the first 3 to 4 years after planting. Meadow barley cover would depend on initial seeding intensity, and cannot be predicted without estimation of the area sown and seed density. Clonal spread and local dominance should increase significantly around years 4 to 5, and should achieve dominance over most of the wet grasslands within 10 years. Creeping wildrye may invade pool edges or beds in drought years.

The cattail marsh would undergo an immediate increase in open-water area after pits or depressions are excavated. Exclusion of tidal and non-tidal flooding should increase cattail growth and vigor (height, density, spread), but steep-sided depressions may retard rapid re-encroachment of open water areas. Open water areas may require regeneration by either excavation in the dry, or herbicide application, or hard mowing, within 10 to 15 years after restoration.

9.0 Selected preventive and corrective actions for vegetation management

Relatively few corrective actions are feasible for large-scale tidal marsh restoration projects in mudflat-marsh succession stages, other than control of non-native wetland plant invasions at early stages of colonization. Mudflats are highly inaccessible and hazardous for any manual manipulations of vegetation. Most corrective manipulations are therefore practically confined to the shoreline and high marsh.
The highest **priority and need for corrective actions in vegetation management** would be early detection and control of perennial pepperweed (*Lepidium latifolium*), Mediterranean saltwort (*Salsola soda*), giant wheatgrass (*Elytrigia pontica ssp. pontica*), and especially hybrid smooth cordgrass (*Spartina foliosa x alterniflora*) in tidal marsh restoration areas. In seasonal wetlands, vigilance for early detection and eradication of Australian bentgrass (*Agrostis avenacea*), which colonized the Central Bahia pans in 2004, is a very high priority. MAS should coordinate with the Invasive Spartina Project for technical consultation regarding early survey and detection of hybrid cordgrass seedlings, and the most recent locations of hybrid cordgrass colonies in San Pablo Bay.

The highest **priority for preventive actions in vegetation management** would be detection and suppression (or elimination) of noxious potential weeds during project construction phases. Construction activities may spread noxious wildland weeds, or they may be guided to beneficially reduce them. Prior to project construction, the site should be comprehensively surveyed for locations of noxious weed populations, primarily perennial pepperweed (*Lepidium latifolium*), Mediterranean saltwort (*Salsola soda*), giant wheatgrass (*Elytrigia pontica ssp. pontica*), hybrid smooth cordgrass (*Spartina foliosa x alterniflora*), non-native thistles and starthistle (*Cirsium vulgare, Carduus pycnocephala, Centaurea solstitialis*), fennel (*Foeniculum vulgare*), poison-hemlock (*Conium maculatum*) and Australian bentgrass (*Agrostis avenacea*).

To the extent feasible, grading and excavation work should be aligned with weed management, so that propagule source populations are either deeply buried, or at least not spread to receptive habitats. In addition, post-construction and pre-breach phases should incorporate spot-treatments (herbicide, mowing, manual removal) of mapped or field-flagged local populations of weeds on or near the site that are not affected by construction activities. Pre-emptive treatment of adjacent perennial pepperweed populations in tidal marshes is recommended. Currently, pepperweed abundance in the immediate site vicinity is relatively low compared with most of the Petaluma Marsh.

Small-scale supplemental planting of dormant vegetative divisions alkali-bulrush or Pacific cordgrass may be warranted if local areas at suitable tidal elevations are lagging in seedling colonization 3 to 4 years after tidal restoration. This may occur, for example, after a series of drought years or episodes of excessive storm wave energy. Planting on tidal mudflat surfaces may be based on culturing weighed propagules (rooted plants in soil plugs with stone “anchors”) pressed into soft mud from low-draft inflatable boats during brief stages of tidal cycles when target mudflat areas are shallowly submerged, but within arm’s reach. Weighted or anchored plugs or rhizome/tuber propagules can be pressed into mud after being dropped from the side craft, but this method is feasible only for spot-treatments and founder colony establishment, not large-scale revegetation.

If graded uplands with bay mud soils become heavily invaded by typical levee weeds such as radish, fennel, or poison-hemlock, mowing during early flowering is recommended as an initial method for reducing abundance. Application of relatively low-toxicity herbicides and surfactants approved for use in wildlands and adjacent to wetlands (mostly glyphosate formulations) may be required after mowing. Creeping wildrye plantings are recommended.
as a long-term “smother crop” to inhibit re-establishment of weed dominance; native shrubs and trees can be planted into creeping wildrye on graded bay mud.
LITERATURE CITED


Rollins, G.L. 1981. A guide to waterfowl habitat management in the Suisun Marsh. California Department of Fish and Game, Sacramento, California
Figure 1. Young tidal brackish marsh in former mudflats (ca. 1997-1998), Bahia Homeowners Channel and former lagoon, adjacent to project site. Reference site/model for early-succession monitoring of Bahia Wetland Restoration Project.

Figure 1(a) Alkali-bulrush vegetation is dominant in fringing marsh of channel and portion of silted lagoon. Note internal tidal channels with patches of cordgrass (lighter gray-green due to silt deposits)

Figure 1(b) Small tidal channel (blue arrow) with Pacific cordgrass and annual pickleweed is obscured by dense, tall growth of alkali-bulrush, flowering in low-salinity conditions. Patchy perennial pickleweed sub-canopy layer is also obscured. June 2005.
**Figure 1 (c). Bahia Lagoon marsh vegetation patterns.** Marsh is dominated by a heterogeneous stand of alkali-bulrush, showing traces of minor tidal channels (red arrows) branching from the main tidal channel. Marsh vegetation patterns suggest potential patterns of sampling using ground-based methods: stratified random placement of replicated permanent quadrats (red squares), placement of few transects located at selected representative locations across elevation gradients between marsh edge and main tidal channel (red line). Discrete patches of cordgrass (blue arrow) occur along channel edges.
Figure 2. Conceptual design of Central Bahia brackish tidal marsh vegetation features for accelerated development of alkali-bulrush marsh (marsh nuclei clusters, marsh platform, creekbank high marsh ridges), showing relationship to potential sampling patterns. Red lines: selected non-random locations of representative transects across high marsh-mudflat wetland gradients. Squares: permanent quadrats.
**APPENDIX 3**

**Implementation Schedule Outline for Vegetation Management Actions (other than grading substrate)**

<table>
<thead>
<tr>
<th>Bahia unit</th>
<th>Phase 1 Site preparation, pre-grading</th>
<th>Phase 2 Post-grading</th>
<th>Phase 3 Pre-breach</th>
<th>Phase 4 Post-breach</th>
</tr>
</thead>
<tbody>
<tr>
<td>EAST UNIT</td>
<td>- Native seed and propagule collection (dwarf spikerush, alkali-bulrush seed, corms), summer-fall.</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>- alkali-bulrush fall planting mounds, creekbank ridges, terrace/platforms</td>
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<tr>
<td></td>
<td>- creeping wildrye fall planting, edge of dredge disposal site</td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>- initial fall flood-up post-planting, spring drawdown, flood-up for growing season</td>
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<td></td>
<td></td>
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<tr>
<td></td>
<td>- maintain managed brackish marsh 2 growing seasons, brackish marsh vegetation 'primer'.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- end of pre-breach: Cordgrass salvage at breaches; transplant cordgrass to marsh nuclei</td>
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<tr>
<td></td>
<td>- perform preliminary sampling of vegetation, placement of transects, permanent quadrats, photomonitoring stations.</td>
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<td></td>
</tr>
<tr>
<td>WEST BAHIA</td>
<td>- Native seed and propagule collection (alkali-bulrush seed), summer-fall.</td>
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<td></td>
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<tr>
<td></td>
<td>- manage water regime for fringing brackish marsh at future high tide line</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>(no action)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DREDGE DISPOSAL SITE</td>
<td>- Native seed and propagule salvage, summer.</td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>- creeping wildrye planting and spikerush transplants, meadow barley &amp; vernal pool plant seeding</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>- rapid drawdown after deep impoundment in spring, manage mosquitoes.</td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>- (MSMAD maintenance)rapid drawdown after deep impoundment in spring, manage mosquitoes.</td>
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</tbody>
</table>
APPENDIX 5

WATER MANAGEMENT FOR NONTIDAL BRACKISH MARSH PHASE:
BRACKISH TIDAL MARSH “PRIMER” VEGETATION

The following brackish nontidal water management regimes are adapted from Mall’s (1969) studies in Suisun Marsh, national data on managed alkali-bulrush marshes (Kantrud 1996), and local observations from the Bahia site since 2003. The objective for nontidal water management at Bahia is to establish abundant alkali-bulrush and pickleweed marsh at elevations corresponding to those of intertidal marsh after restoration, but during non-tidal conditions with lower salinity and lower wave energy.

Pickleweed would establish along the upper edges of marshes managed for alkali-bulrush in the Petaluma Marsh. It would require no special management because on-site seed sources, adjacent seed sources, and soil salinities are already highly favorable.

General target conditions for alkali-bulrush marsh hydrology during the spring-summer growing season (MARCH-SEPTEMBER) are:

SOIL POREWATER SALINITY: below 16 – 20 ppt (upper limits of tolerance for active growth); optimal below 10 ppt. Flooding with low-salinity water (below 10 ppt) in spring is desirable to avoid hypersalinity of floodwater during the growing season. Soil porewater salinity may lag behind floodwater salinity in undrained conditions.

WATER DEPTH: fluctuation between 10 to 20 cm at upper end of alkali-bulrush zone; maximum depth 50 cm at lower end of alkali-bulrush zone.

DURATION OF SOIL SATURATION/SUBMERGENCE: Summer drawdown (surface emergence) no earlier than mid-June; preferable to maintain saturated brackish soils, shallow flooding through September. Pickleweed and other seasonal wetland plants dominate with earlier drawdown. Growth of alkali-bulrush ceases after soils begin to drain. Optimal duration of flooding for alkali-bulrush is estimated to be 7 to 8 months per year where competition with cattail at low salinity (less than 5 ppt) may occur. Shorter flood durations reduce production and cover.

FLOOD/DRAINAGE SCHEDULE OPTIONS

Alkali-bulrush marshes may be recruited from planted corms, seeds, or both. A combination of both is recommended because corms result in reliable regeneration but high effort, while seedling establishment can be unpredictable, but more extensive, and requires minimal or no planting effort. Planting hedges uncertainties about seedling recruitment. The flood/drainage regime requirements for seedlings are more specific. If significant and widespread recruitment from seed is desirable, the seedling recruitment regime is recommended. If project constraints (mosquito abatement, water management costs or infrastructure) prohibit seedling water regimes, the vegetative corm regime may be selected instead, with less widespread recruitment and more planting effort.
1. Seedling recruitment regime.

1.1. **Fall flood-up.** Deeply flood bayland in fall with bay water intake; seed dispersal from brackish marsh occurs.
1.2. **Winter circulation.** Maintain circulating flooded conditions to target elevations from October to mid-January, low-salinity conditions.
1.3. **Spring germination drawdown cycle.** Draw down to expose mud (‘moist soil conditions’) over target elevation range desired for alkali-bulrush. Briefly reflood and draw down in late February/March if mosquito production is problematic. Maintain approximately 2-3 weeks drawdown in alkali-bulrush target zone while salinities are low and temperatures encourage seed germination. Inspect for seed germination.
1.4. **Spring seedling flood-up.** While bay intake channel salinities are still low (below 10 ppt), gradually reflood alkali-bulrush zone to target depth range of 10-30 cm. Circulate (damped tidal fluctuation) if possible while intake salinities are below 10 ppt.

2. Vegetative (corm) recruitment regime

2.1. **Fall drawdown.** Maintain or achieve drained site conditions for fall planting of corms.
2.2. **Late fall/early winter flood-up.** Submerge target alkali-bulrush elevation zone to suppress competing wetland plants.
2.3. **Optional spring drawdown.** The site may be drained in late winter/early spring for mosquito control if desired.
2.4. **Growing depth fluctuation circulation.** Maintain water depths as close to 10-30 cm depth over alkali-bulrush zone, with as much circulation (damped tidal fluctuation) if possible. Recruitment of planted bulrush is expected to depths up to 50 cm, with maximum growth between average 10-30 cm depth. Cease intake after channel salinities exceed 10 ppt – 12 ppt.

3. Spring-summer growing season.

Maintain water depths and circulation between 10-20 cm over widest area possible within target elevation range (equivalent to intertidal marsh), while intake water salinity remains below 10 ppt. Fluctuation of water levels is preferable over continuous evaporative drawdown. Discontinue intake after intake channel salinities reach 10-12 ppt. in spring. If channel intake salinities remain near 10 ppt by June, continue circulation. Allow passive evaporative drawdown after mid-June. If mosquito production on moist soils is excessive in early summer, reflood with bay water and actively flush by rapidly draining down.

3. **Fall water management for established marsh.**
Once dormant in late summer, alkali-bulrush may be maintained dry, or may be reflooded, depending on wildlife management and mosquito abatement preferences.
APPENDIX 6

MANAGEMENT OF NON-NATIVE INVASIVE VEGETATION at the
BAHIA WETLAND RESTORATION PROJECT SITE

Non-native invasive vegetation (weeds of wetlands and uplands) at the Bahia Wetland Restoration Site may expand opportunistically after grading and other disturbances associated with restoration activities. Earthmoving activities disperse seeds and create receptive, open seedling habitats for pioneer species, and reduce or eliminate competition with established vegetation. If weeds establish early and in abundance in primary succession (new colonization of bare substrate), they can quickly achieve dominance, and become difficult, expensive, and slow, to control. Once weeds become widespread in restored habitats, and regenerate from large, established seed banks or below-ground “bud banks” of vegetative perennial structures, such as rhizomes or roots, populations become highly resistant to management.

Therefore, the emphasis on wildland weed control at Bahia is on (a) early detection and source reduction of highly invasive weeds prior to site construction; (b) early detection and eradication/control of invasive weeds at early stages of their invasion, and at early stages of primary succession, while weed populations occur as small, discrete founder populations. The goal of the weed control strategy at Bahia is to suppress early expansion of invasive non-native vegetation long enough for native vegetation to “pre-empt” available open space, establishing relatively closed native vegetation cover. If native vegetation dominates the site first, and weed invasion pressure is reduced by low initial population size, the potential for costly long-term weed management should be minimized to low-level detection and maintenance in the long term.

Some weed seed sources already occur on the project site or adjacent to it. Sources of local weed seeds can be reduced prior to earthmoving to reduce invasion pressures on restored wetland areas. Some weed seed sources can be reduced by guiding grading activities themselves. Widely dispersed weed seed sources cannot readily be mitigated, but the site’s receptivity to their colonization can be reduced by encouraging the rapid development of closed vegetation cover by native species. After major restoration activities have been completed, controlling invasions of discrete, isolated weed populations is a matter of early detection and control when populations remain localized, small, and while they have not yet produced viable seed.

Not all non-native plant species that may occur at the site are likely to behave as invasive or noxious weeds. The focus of weed control should be on non-native species that rapidly achieve and maintain dominance within their plant assemblages, and tend to spread rapidly. The ecological focus is also on the wetlands and their transition zones (particularly terrestrial edges of the high marsh zone). The principal weed threats to the restoration site, based on long-term observations of invasive plants in San Pablo Bay, in descending order of immediate threat, are listed below. Each of these species is known to
produce dominant or monotypic stands that degrade or completely displace native plants in seasonal wetlands, tidal wetlands, or their terrestrial edges.

- Lepidium latifolium, BROADLEAF PEPPERWEED
- Agrostis avenacea, AUSTRALIAN BENTGRASS
- Spartina alterniflora x foliosa, HYBRID SMOOTH CORDGRASS
- Salsola soda, MEDITERRANEAN SALTWORT
- Genista monspessulana, FRENCH BROOM
- Raphanus sativa, WILD RADISH

Other invasive species of high marsh edges and seasonal wetlands in San Pablo Bay should be targeted for surveys. These include giant wheatgrass (Elytrigia pontica ssp. pontica), Italian thistle and starthistle (Carduus pycneophala, Centaurea solstitialis), fennel (Foeniculum vulgare), poison-hemlock (Conium maculatum). Small founder populations of these species should be removed manually during early flowering stages.

In contrast, some non-native wetland plants may be assumed to provide relatively brief or localized dominance during tidal marsh succession, and have low potential to permanently reduce diversity of native tidal marsh vegetation. Examples include Cotula coronopifolia (brass-buttons), and Polypogon monspeliensis (rabbit’sfoot grass). These species may be tolerated rather than controlled in tidal marshes. In seasonal wetlands, it would be desirable to keep initial abundance of these “tolerable” wetland weeds low, but they are unlikely to warrant long-term control or management.

A6-1.0. General weed management actions prior to restoration activities

Before construction activities are begun, the site should be surveyed for the distribution of high-priority weeds, particularly those with localized populations on site. Populations that appear to be in early stages of rapid spread should be treated prior to grading of the site. Populations that appear to be locally dominant but only slowly spreading can be treated during site grading. Weed populations to be controlled prior or during site construction should be flagged and staked in the field to prevent accidental dispersal. Of the known species present, Agrostis avenacea is most likely to warrant pre-emptive treatment prior to site grading, because of its abundant wind-dispersed seedheads capable of rapid long-distance transport, and its recent history of rapid invasion along the Highway 37 corridor to Novato.

A6-2.0. Weed management actions during site grading. If grading of the site is properly guided, it can reduce or eliminate weed populations rather than spread them. In seasonal wetlands, scraping the top 10 to 20 cm of soil to expose mineral soil below will generally remove most of the seeds and vegetative buds and expose underlying soils. Stockpiling weed-infested topsoil, and disposing of it in areas where restored tidal hydrology will be lethal to the target weed species, will minimize regeneration of both noxious weeds and lower-priority weeds alike. For example, during cut/fill activities to transfer fill from borrow sites to wetland restoration areas, topsoils laden with ryegrass (a dominant but not noxious weedy grass) can be stripped and placed at bottom layers of
restored intertidal wetlands. Similarly, during levee lowering, weeds along high marsh edges at uplands (e.g. French broom, radish, and other upland-edge weeds can be scraped and displaced to lower intertidal wetland fills. A qualified on-site biologist should coordinate with equipment operators to develop feasible patterns for removal and placement of stripped soils, consistent with operation needs.

**A6-3.0. General weed management after restoration.** After earthwork is complete, and primary vegetation succession is underway, weed management must focus on early detection and local control of weed populations prior to seed reproduction or clonal spread. Annual weeds in small patches can be controlled manually (pulling, hoeing, mattocks), or with weighted black plastic. Perennial weeds, particularly clonal species with high capacity for regeneration (such as perennial pepperweed) may require treatment with herbicides registered for use in or adjacent to wetlands. Approved herbicides likely to be available during the project life would be aquatic formulations of glyphosate (Aquamaster, Rodeo), and probably formulations of imazapyr without added surfactants. A licensed herbicide applicator may be needed for spot-treatments of early detected populations. Weed survey times should be keyed to the optimal season for detection. Early May is an appropriate time to detect pepperweed while it is in flower, but before seed set, and it is within the potential flowering season of early-flowering weeds such as radish.

Hybrid smooth cordgrass is more difficult to detect visually because of its establishment in inaccessible mudflats, and its resemblance to native cordgrass before it matures and flowers. In addition to general weed surveys, the project should coordinate with the regional Spartina Control Project (of the Invasive Spartina Project, California Coastal Conservancy) to be included in regional surveys to detect new colonies.

**A6-4.0. Specific wildland weed species management**

4.1. *Lepidium latifolium*, BROADLEAF PEPPERWEED.

Perennial pepperweed is a clonal forb that establishes in the high marsh and terrestrial ecotone of brackish marshes. It also establishes in middle marsh zones where salinities are near the tolerance limits of unspecialized non-halophytes. It is one of the dominant species of Petaluma Marsh, but is most aggressive in disturbed, well-drained soils of high marshes, side-cast berms along ditches, and along edges of levees. If the first “crop” of flowering/seeding shoots is damaged, a second pulse of flowering may occur later in summer.

Detection efforts for perennial pepperweed should focus on the edges of levees, and near the high tide line (drift-line) zone of the restored tidal marsh.

Perennial pepperweed spreads by seed (long-distance dispersal) and by clonal growth from thick rhizome-like roots near the soil surface that develop shoot buds. Manual removal results in fragmentation of the clonal root system and facilitates sprouting. Root fragments are resistant to physiological stress and may remain viable after long periods of
drying, darkness, soaking, etc. Manual removal may be effective for seedlings and juvenile plants that have not yet established spreading clonal roots. Seedlings form low-growing rosettes that are difficult to detect until they “bolt” (elongate to pre-flowering shoots). Imazapyr is expected to be registered for use in California wetlands by the time of project construction. As long as imazapyr is used in early stages of tidal marsh succession, when no uncommon or sensitive plants are present, and when only small treatment areas are indicated, it would probably be the most effective herbicide to eradicate small, local populations of pepperweed after one or two treatments. Glyphosate, in contrast, tends to result in partial regeneration of treated pepperweed clones, and may require multiple treatments over years to eliminate local clonal populations.

4.2 Agrostis avenacea, AUSTRALIAN BENTGRASS

Australian bentgrass is a perennial bunchgrass with short stolons (above-ground horizontal shoots capable of rooting and clonal spread over short distances). It is amphibious, able to grow floating leaves in submerged (pond) conditions, and terrestrial leaves after it emerges. It is tolerant of brackish soil conditions, and rapidly becomes abundant in bayland ditches, seasonal pond beds, pans, and seasonal wetlands. It spreads with exceptional speed because it develops massive quantities of detached lightweight, seed-bearing panicles that act as wind-transported “tumbleweeds”. Its flowering period extends from April or May to fall, depending on time of drawdown. It can rapidly dominate seasonal wetlands.

There is little information on control of Australian bentgrass. Prevention of seed production is the highest priority, and establishment of dense, competing vegetation cover is an important means of reducing seeding colonization. Aquatic-habitat herbicides (glyphosate, imazapyr formulations without surfactants) are likely to be the only effective control techniques for reducing local infestations, and these will probably be effective only if plants are treated before seed set.

Detection efforts for Australian bentgrass should be focused on the first 4 to 6 weeks in spring after drawdown of seasonal ponds/vernal pools, or mid-May, whichever is earlier. Australian bentgrass may also occur in the high tide line of brackish marshes, where vegetation cover is sparse.

4.3. Spartina alterniflora × foliosa, HYBRID SMOOTH CORDGRASS

Hybrid smooth cordgrass can rapidly dominate early stages of mudflat-marsh succession in the San Francisco Estuary. It spreads by seed, by clonal spread (rhizome growth), and also by highly fertile hybrid pollen that may generate hybrid seed from native cordgrass populations. Most of the invasion pressure at the time of the project is likely to remain in Central and South San Francisco Bay, but outlier populations have established at the Loch Lomond Marina in San Rafael. Long-distance dispersal events from San Francisco Bay should be expected.
Visual detection of hybrid smooth cordgrass is difficult in most seasons, especially when plants are juvenile. Hybrids are variable in size, form, and pigmentation. Most hybrids remain mostly green in mid-October, when native cordgrass has senesced seasonally. Many hybrids have stiff, erect leaves in dense clones, and are usually much taller than native cordgrass clones. These traits are useful in screening candidate hybrids.

The restored Bahia mudflats should be annually surveyed in early October to detect tall, green cordgrass plants, using binoculars from the shoreline. If candidate hybrid plants are detected, tissue samples should be obtained using low-draft inflatable boats on a rising tide. Tissue samples should be sent to U.C. Davis (Debra Ayres), in coordination with the Invasive Spartina Project (ISP; www.spartina.org; Katy Zaremba). Control should be coordinated with the ISP.

The less common *Spartina densiflora* (Chilean cordgrass) is unlikely to occur at Bahia, but it should be considered as a “watch” species during surveys for broadleaf pepperweed, which occupies a similar vegetation zone in the tidal marsh.

### 4.4. Salsola soda, MEDITERRANEAN SALTWORT, SALSOLA

*Salsola soda* is a succulent annual forb that produces buoyant fruits (seeds) capable of long-distance dispersal in water, concentrating deposition in drift-lines at the high tide line (the high marsh zone). It is also spread in dredge disposal sites by grading and diskling. Most infestations, however, are related to intensive local seed production and dispersal around parent plants. Once local seed production is established, Salsola is difficult to control. Control efforts should be based on detection of pioneer plants and removal prior to seed set. Seed set may occur as early as mid-summer in dry soils. Salsola is readily detected visually. Plants can be removed by manual pulling as long as seed have not formed. Succulent plants may survive for many days after uprooting, so if removal occurs near seed set, plants should be bagged and removed.

### 4.5. Genista monspessulana  FRENCH BROOM

French broom is a shrub that produces fragrant flowers and abundant long-lived seed. It is seldom a weed of tidal marsh edges, but a vigorous population is established at the edge of the Bahia bayland levees, and appears to have potential for spread if soils are disturbed, moved, and if heavy equipment disperses seed. Once seed are deposited, seedlings may be recruited for many years after flowering populations have been eliminated. French broom should be eliminated during early flowering (late spring/early summer) using either manual methods (mattocks cutting stems below the soil surface; weed wrenches) or herbicide (glyphosate). Alternatively, broom-infested soils can be excavated and deposited into tidal wetland restoration areas during site grading.

### 4.6. Raphanus sativa  WILD RADISH

Wild radish is a coarse annual forb that can rapidly invade disturbed, drained bay mud and develop pure stands that strongly inhibit establishment of other species. For this
reason, all high marsh zones (particularly levees above spring tide elevations) should be kept free of radish. Large radish stands can be treated in the seedling stage during the rainy season by applying saline water to the soil; soil salinization favors high marsh species, and continues to suppress germination and survival of radish through the rest of the growing season. Manual removal (hoeing) is effective before bolting; manual removal of hard, fibrous stems and taproots is inefficient. Weighted black plastic mulches can likewise be applied to populations in juvenile (pre-bolt or early bolt) stages of development. Over time, clonal growth of creeping wildrye (*Leymus triticoides*) can significantly reduce density of established radish populations, and can prevent its invasion.
Appendix 7

Native Seasonal Wetland Plant Species
Northwestern San Pablo Bay

The following list of native seasonal wetland plants is a composite of surveys from the following reference sites: (1) Olive-Atherton diked marshes at Novato, Marin County (Atherton Avenue, near Bahia); (2) Sears Point baylands and vernal pools, Sonoma County (North Point Joint Venture and Dickson Brothers parcels, Sonoma Land Trust); China Camp, San Rafael. Each site occurs at or adjacent to the margins of estuarine wetlands (including diked baylands) of northwestern San Pablo Bay. The list is supplemented by historic botanical data (herbarium, local flora) describing seasonal wetlands of baylands (Howell 1949; CALFLORA, SMASCH databases). The list provides a preliminary model for vegetation objectives and management of seasonal wetlands marginal to restored tidal marshes from Gallinas Creek to Tolay Creek. Local remnant populations are available for propagation unless otherwise noted.

1. Dominant species: terrestrial ecotone

   Hordeum brachyantherum  MEADOW BARLEY
   Leymus triticoides     CREEPING WILDRYE

2. Freshwater seeps and swales at terrestrial ecotones

   Dominant

   Carex barbarae      SANTA BARBARA SEDGE, WHITEROOT
   Carex obnupta       SLOUGH SEDGE
   Juncus balticus     BALTIC RUSH

   Locally dominant or abundant

   Carex praegracilis  SEDGE
   Salix laevigata     ARROYO WILLOW
   Typha latifolia     BROADLEAF CATTAIL
   Typha angustifolia  NARROWLEAF CATTAIL

3. Vernal marsh and pool (alkaline to fresh-brackish)

   Dominant

   Eleocharis macrostachya  COMMON SPIKERUSH
   Juncus phaeocephalus var. paniculatus  BROWN-HEADED RUSH
   Juncus xiphioides     IRIS-LEAF RUSH
   Pleurospogon californica  SEMAPHORE-GRASS
Locally dominant or abundant

*Castilleja ambigua* ssp. *ambigua*  JOHNNY-NIP  
*Eryngium aristulatum*  COYOTE-THISTLE  
*Lasthenia glaberrima*  RAYLESS GOLDFIELDS  
*Lasthenia glabrata* ssp. *glabrata*  SMOOTH GOLDFIELDS  
*Layia platyglossa, L. chrysanthemoides*  TIDYTIPS  
*Lilaea scilloides* (FLOWERING QUILLWORT)  
*Plagiobothrys bracteatus*  BRACKETED POPCORNFLOWER  
*Ranunculus aquatica*  AQUATIC BUTTERCUP  
*Triphysaria floribunda* ssp. *versicolor*  BUTTER-AND-EGGS  
*Trifolium depauperatum* ssp. *depauperatum*  SAC-CLOVER  
*Trifolium depauperatum* ssp. *hydrophilum*  WATER SAC-CLOVER
Figure 1. Project site location in Petaluma Marsh area, Marin County, California
Figure 2. Schematic representation of conceptual design elements for early-succession vegetation and habitat at the East Unit, plan view. MS = Mahoney Spur. CB = Central Bahia.
Figure 4. Marsh nuclei and creekbank high marsh ridges in relation to mudflats and channel. Schematic representation, not to scale. Marsh nuclei may be established on topographic highs raised to elevations above Mean Sea Level, or existing topography above Mean Sea Level. Vegetation is partially established prior to tidal restoration. Perimeter levees are graded down to gradients between intertidal marsh and high marsh, with priority for bare or weedy levees near adjacent, exterior tidal marshes with clapper rail populations.
Figure 3. Alkali-bulrush and cordgrass marsh on constructed upper intertidal marsh terrace. Schematic representation, not to scale. Small, sinuous channels (constructed ditches) provide potential clapper rail habitat within the marsh. Vegetation is partially established prior to tidal restoration. Note continuity with high marsh creekbank ridges and main tidal channel.
Figure 5. Marsh nuclei: schematic cross-section. Existing and constructed topographic high areas between MSL and MHW support some alkali-bulrush vegetation at the time of tidal restoration, initiating radial spread (marsh progradation) and sediment accretion.
Figure 6. Constructed creekbank high marsh ridges. Functional and structural equivalents of natural creekbank levees in mature tidal marsh plains, these are located at intervals along bends of channels. Crests reach or slightly exceed local Mean Higher High Water, rough microtopography from discharge or grading. Unengineered fill consists of side-cast spoils from channel excavation. Initial vegetation zonation approximately 3 years after tidal restoration is shown. Ridges act as high tide escape cover, potential nest sites, and centers of marsh progradation; physically, vegetation-stabilized emergent intertidal islets reduce fetch, wave energy. Schematic; no scale.
Figure 7. Seasonal wetlands, derelict dredge disposal site. Existing ryegrass-dominated seasonal wetland vegetation and surface soils are scraped away and deposited in the Central Bahia lowlands to fill the platform for alkali-bulrush marsh and the high marsh gradient. Exposed soil is sparsely replanted with native creeping wildrye and meadow barley. Scraped or excavated depressions provide additional borrow material, and are inoculated or planted with native seasonal marsh plant propagules. New ditches connect to weir or outlet structure for Mosquito Abatement management flexibility to rapidly drain the pools. Cattail marsh/pond is conserved, partially excavated to improve ratio of open water area; breach in its perimeter levee is blocked or replaced with weir. Levees are graded down to low, wide berms, continuous with high tidal marsh.