Vegetation Mapping of
Suisun Marsh, Solano County California

A Report to the California Department of Water Resources

Prepared by
Wildlife and Habitat Data Analysis Branch
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Executive Summary

This document summarizes the methods and results of the vegetation mapping of Suisun Marsh conducted by the Wildlife and Habitat Data Analysis Branch of the California Department of Fish and Game. This effort involves different methodologies from those undertaken in prior habitat monitoring and assessment of the Suisun Marsh. Therefore, it discusses them in some detail and includes recommendations based on the authors' experience with this project.

The mapping project blends ground-based classification, aerial photo interpretation, and GIS editing and processing. The method is based on the development of a quantitative vegetation classification, which is used to describe the vegetation map units of the marsh. The classification is defined to meet the specifications of the National and State standards for vegetation classification, but is related through a cross-walking table to other standard classifications in use locally or statewide. The reporting of this information is broken into sections on field and lab- based methods, results and conclusions. In some cases it has been necessary to describe the processes involved from the standpoint of the vegetation classifier, delineator, and mapper. Thus, there is some inherent redundancy in the report, but this we trust will be appreciated by the various specialists who may be interested in the product and the processes involved.

The mapping area as defined in the contract is bounded by the 10-foot elevation contour surrounding the marsh on the west, north, and east and extends into the open water beyond the tidal flats and marsh vegetation in the Suisun Bay to the south. It excludes the Potrero Hills (see Figure 1). In total 69,323 acres were mapped. Within this area 198 vegetation samples were collected, 271 reconnaissance plots and 271 accuracy assessment plots were taken, and 39,460 polygons were delineated and attributed. A total of 121 mapping units were used to depict the vegetation.

Introduction

Vegetation mapping has been an important step in the development of a resource management plan for any natural or semi-natural area. A vegetation map has been shown to be valuable as a means of displaying the full array of biological diversity of any area, thus providing an efficient context in which to conduct natural resource planning. Although habitat mapping has been standard practice for the planning process for Suisun Marsh ever since an inter-agency agreement for co-management of the Suisun Marsh's rare and unique natural resources (The Suisun Marsh Preservation Act) was signed in 1977, for several reasons the philosophy and methodology of this mapping effort differs from the previous efforts.

Background:
The Suisun Marsh is one of the largest contiguous brackish marshes remaining in the United States covering over 69,000 acres of tidal and seasonally managed wetland. This marsh is a key wintering area for waterfowl and supports a number of sensitive plants and animals. In 1977 the Suisun Marsh Preservation Act was legislated and required that the Suisun Marsh be managed for its wildlife resources. Consequently, the Plan of Protection for the Suisun Marsh (Plan of Protection) was developed. In 1981 the U.S. Fish and Wildlife Service (USFWS) produced a Section 7 Biological Opinion (BO) for the Plan of Protection. Their BO accepted the monitoring program in the Plan of Protection and added specific conservation measures to protect salt marsh harvest mouse (SMHM) habitat.

As part of the monitoring program in the Plan of Protection, a Triennial Vegetation Survey was developed to document the overall vegetation composition of the marsh and to monitor SMHM habitat by the use of aerial photography in combination with ground verification. Prior to the final Plan of Protection, an initial vegetation survey was conducted in 1981 to provide a baseline for the future Triennial survey. However, since completion of the Suisun Marsh Salinity Control Gates as described in the Plan of Protection was delayed until 1988, the 1988 survey was the closest to the start of facility operation. However, the 1981 survey can be used for a pre-gate operation base line. The Triennial Vegetation Survey was carried out in the Suisun Marsh in 1981, 1988, 1991, and 1994 to document any changes in vegetation composition over time.

There were some concerns about the methodology used and the lack of useful maps from the 1988, 1991, and 1994 surveys. These concerns have led to the proposed change in methodology. Additional criticism of the past methodology included not using a habitat classification system such as that used in the California Wildlife Habitat Relationship System, and using inappropriate methods for calculating the acreages of each habitat type. In 1996, an interagency technical committee was convened to review the current survey methodology and recommended a more detailed monitoring system for vegetation changes within the marsh. Consequently, in July 1997 the committee agreed to implement a new survey methodology for the 1998 vegetation survey.

This new methodology is based on work by the Department of Fish and Game, Wildlife and Habitat Data Analysis Branch. It has been conducted at Anza-Borrego Desert State Park, Point Reyes National Seashore, Yosemite National Park, Sequoia-Kings Canyon National Park, Joshua Tree National Park, and the Mojave Desert. The survey methodology is designed to meet the goal of documenting changes in preferred habitat for the Salt Marsh Harvest Mouse, as well as gather the vegetation information in such a way that it can be used for a variety of other purposes. These may include: correlating management activities with vegetation changes; gathering data to support the use of a GIS format that will allow queries and overlaying of additional information such as soil type, ownership, and hydrology; and creation of a base map for future studies.

The Project:

The Suisun Marsh Triennial Vegetation Survey was originally intended to answer specific questions required by permits and the Suisun Marsh Preservation Agreement (SMPA). With new technology it is now possible to meet the original intentions of the vegetation survey and fulfill additional data needs. By incorporating Triennial Vegetation data into a geographic information system (GIS) database it is possible to create a single vegetation map for the Suisun Marsh that provides an accurate representation of vegetation types and acreages of each. This vegetation map and database will allow easy access to vegetation data, change detection and determination of underlying influences of vegetation. It will also afford systematic updating of the map.

Concepts and Standards:

The methods and philosophy of this product reflects the protocol for "Field Methods for Vegetation Mapping" supported by the National Park Service and Biological Resources Division of the United States Geological Survey. This methodology (USGS 1997a) is the standard for all new vegetation mapping efforts for U.S. National Parks. The rational for this protocol stresses the importance of a standardized vegetation classification for the United States - the National Vegetation Classification or "NVC" (USGS 1997b). All National Park mapping efforts will be tied to a single classification system. This evolving classification treats the vegetation of the country as a multi-resolution hierarchy, enabling description of vegetation from the local stand level all the way up to ecoregional-scale groupings. Thus, all areas mapped in this manner will include detailed data supporting the map and will simultaneously amass additional information for the growing NVC.

To amass classification information and provide useful mapping units, that national classification relies on quantitative vegetation sampling data collected in the field. This data-driven principle is the same as the classification of California vegetation described in Manual of California Vegetation ("MCV", Sawyer and Keeler-Wolf, 1995). The classification in the MCV was developed in conjunction with the standards for the National Vegetation Classification and the basic floristic elements of both classifications are equivalent in scale and meaning.

Basing Map Units on Locally Derived Samples:

A typical vegetation map uses a predetermined classification. The vegetation polygons are labeled with these classification units prior to any extensive field verification (for example see the Holland 1986 classification). The methodology used in this mapping effort requires a quantitative sample-based classification. Because the quantitative vegetation classification efforts have not been systematic in California, many areas of the State lack data-driven descriptions of vegetation units. The Suisun Marsh was one of those regions. Thus, a vegetation classification had to be defined before the map could be labeled.

In comparison with existing classifications for the State, the MCV is complex. The number of vegetation alliances and associations (see definition of words in classification section) already described outnumber the other existing detailed classifications such as Holland (1986) or CALVEG (Parker and Matayas 1979). The basic vegetation units of MCV (henceforth called alliances) are based on dominant and characteristic species, not on general habitat considerations, for example, the Holland (1986) category "Coastal and valley freshwater marsh" contains several MCV alliances such as *Typha* spp. (cattail), *Juncus balticus, Scirpus californicus (S. acutus), Scirpus americanus,* and *Potemogeton pectinatus*. Therefore, the level of investigation to define floristic classification vegetation units in this map was substantial. An intensive data collection and development phase preceded the labeling phase.

Delineating Vegetation in the Marsh:

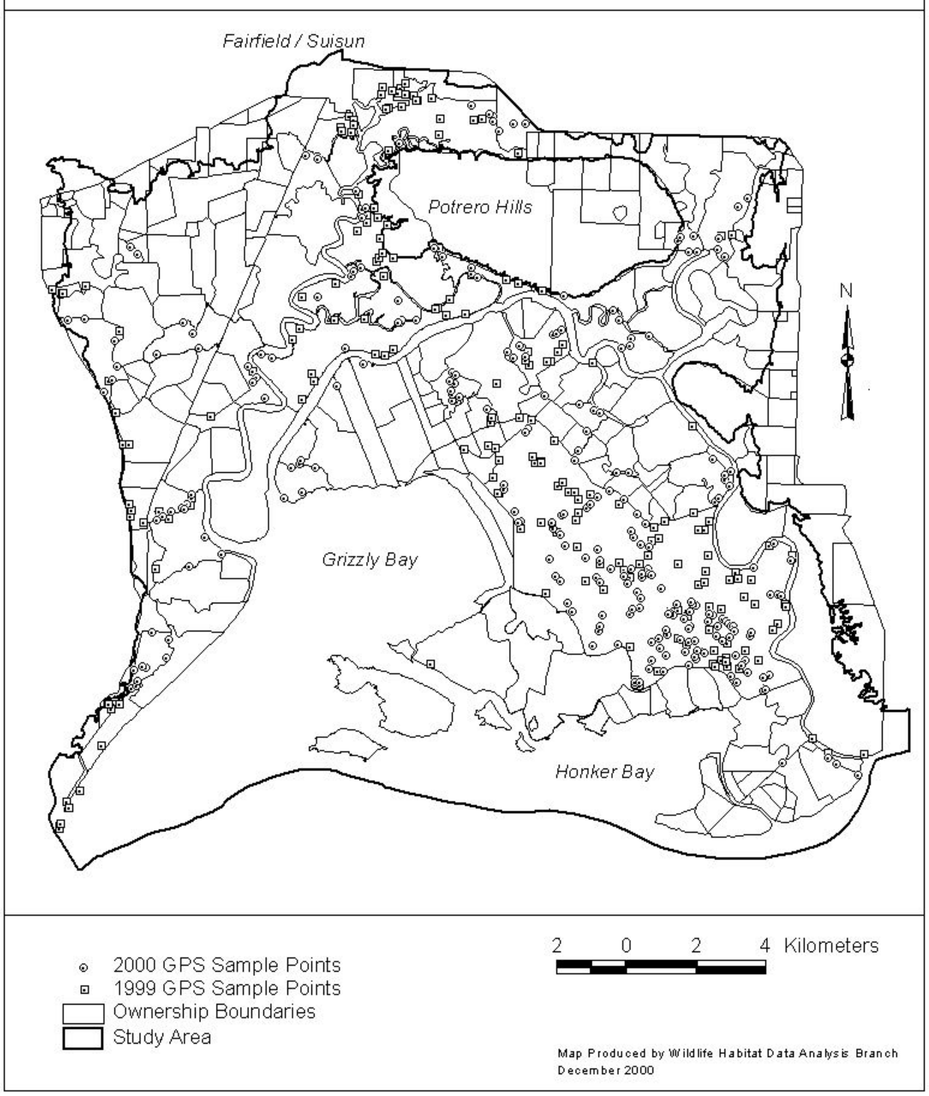
Although it was impossible to pre-label the vegetation polygons for this map, it was necessary to define polygons, or "delineate," to complete the map in a timely fashion. Delineation of the fine grained matrix of vegetation stands in marsh habitats requires an ability to use surrogates for transitions from one vegetation type to the next. This may be necessary because many of these transitions are invisible even on relatively large scale aerial photographs, or they may appear differently at different times of year based on flooding and drying cycles and concomitant responses by plant species. Our delineation team spent a large amount of the time in the marsh visiting numerous localities and noting the correlation between various environmental effects such as landform, season, and moisture upon the patterns of vegetation. This information was used to extrapolate vegetation patterns. In some cases visual patterns observed from aerial photographs proved to be relatively minor variations in vegetation when visited on the ground. The substantial field verification and sampling used in this method of mapping allows for correction of both over-delineation and under-delineation.

Value of the Approach:

Both precise vegetation maps and detailed classifications of vegetation are needed for ecosystem-level resource assessment. A quantitative hierarchical vegetation classification is useful to describe the full range of variation for ecological management from the species population level to the bioregional level. A map that is capable of matching this classification has the advantage of displaying the spatial distribution of these vegetation types so systematic planning can occur across the entire mapping area. By basing the map classification on extensive field data it is also possible to support a value-added approach, delivering more than just a distribution of vegetation types. For example, in this product we provide information relating to on-the-ground impacts. We did this by categorically noting impact (any non-natural effect on stands of native vegetation), and threat intensity for each of the polygons. These data are provided with the map coverage and can provide a picture of which types of vegetation have certain types of threats associated with them. As a result of the ownership boundaries provided within this product we can determine which parcels are supporting certain vegetation and this information can be related to management practices by each landowner.

Figure 1

Distribution of Sample Points in Suisun Marsh



Methods for Vegetation Sampling and Classification

For this project, the primary basis for attributing the vegetation map stems from the collection and analysis of vegetation samples. Therefore, substantial thought and effort was put into the development of a field sampling protocol and allocation of samples throughout the marsh.

Sampling Protocol:

The foundation for the vegetation sampling field form used in this project was the California Native Plant Society (CNPS) Vegetation Sampling Protocol (see Sawyer and Keeler-Wolf 1995). This methodology was developed for simple quantitative vegetation sampling repeatable in many vegetation types throughout California. However, several modifications were made to the CNPS protocol based on the specific needs of this project. These are described below:

1. Because the area to be mapped was extensive and time for repeated sampling was limited, the 50 m line intercept described in the CNPS protocol was replaced with an ocular estimating procedure. This took less time on average than the transect method and allowed an estimate of cover for all species enumerated over a larger area.

2. The samples taken had to be representative of the entire delineated map polygon with as few replications as possible. Thus, the size and shape of the sample was increased from the standard CNPS 5 x 50 m (250 m sq.) rectangle to a larger, but variable-size plot based on the physiognomy of the vegetation. Sites dominated by vegetation taller than 5 m were sampled in 1000 m sq plots. All other vegetation, including graminoids, shrubs and herbs, was sampled in 400 m sq plots. Plots were typically square but other shapes were used depending on the general dimensions of the vegetation to be sampled (e.g., long riparian corridors were typically sampled as long strips that totaled 1000 m sq). Plot size and shape were recorded on each field form. The variable size and shape of the plot based on the physiognomy of the vegetation and the fact that we collected estimates of cover for species rather than exact measurements exemplify characteristics of a phytosociological relevé (see Barbour et al 1992) rather than a fixed plot or point-intercept sample.

3. Global positioning systems were used to record the sample plots and additional information regarding GPS file name and duration of data collection were added to the field form.

4. Record keeping was based on the assignment of plots to a particular vegetation polygon number. First, a preliminary number was given to the sample based on the aerial photo covering the area of the sample and individual numbers of polygons within that photo. The polygon numbers were re-assigned following entry of all polygons into the GIS system.

5. Estimates of percent cover were required for all species greater than or equal to 1% cover. Additional fields for total vegetation cover, and total tall, medium and low cover were added. These were thought to be important for such polygons attributes as total cover estimates.

6. A separate entry for non-natives was added to help with assessing impacts of invasive species.

7. Cover estimates for <u>seven</u> height classes were assigned based on a six-point scale (see example datasheet). The dominant species for each height class was also recorded.

8. As with plant species, the cover values for open water (bedrock, gravel, cobble, stone, litter) were estimated in cover classes and percent throughout the plot.

Sample Allocation:

The Geographical Information System (GIS) was implemented as a tool to develop random sample points in the marsh. Several GIS tools exist to help with the design process.

In this study the Suisun Resource Conservation District boundary coordinates, and areas below 10' mean sea level define the sample area.

To sample all vegetated habitats, a stratification of the sampling frame was desired. Typically, environmental conditions such as elevation, slope, soil moisture, soil type, salinity, and flood duration are used as spatial strata in stratified random sampling procedures, such as gradient-directed sampling (Gillison and Brewer, 1985). However, such spatial layers were not available, or only available at a coarse resolution. As a surrogate to having detailed environmental data, the vegetation itself was used to create strata.

A SPOT satellite image of the marsh, acquired June 23, 1999, measured reflected visible and infrared light and provided a fast but coarse level stratification for random sampling. Vegetation types, structures, and densities reflect visible and infrared light differently, providing a method to measure preliminary levels of vegetation variability. Soil moisture and surface water also are parameters affecting light reflectance. Digital processing to produce non-overlapping spatial strata, and randomly selected points allocated to these strata were performed in a matter of hours. A more detailed stratification could be made using interpreted aerial photos, however, these interpretations were not available in digital format for the entire marsh before the sampling was to begin.

SPOT multi-spectral imagery, bands 1-4 and a vegetation index (band 3 near infrared / band 2 red) were segmented into a target number of 40 classes. The vegetation index was helpful in making statistically separable clusters. The image was clustered using an iterative self-organizing clustering routine, which finds natural groupings of spectral features in the image, and which does not require user knowledge of the landscape. An evaluation was performed on the clusters to check for statistical exclusiveness. It is important to remember that the satellite signatures are a surrogate measure of vegetation. Each satellite derived habitat class may be comprised of several vegetation alliances.

In the best of all possible statistical designs, sampling would occur throughout the marsh. The marsh itself is composed of public and private land holdings. Permission to gain access to private lands varies. The initial sampling allocation (60%) was limited to public lands in the marsh where field access is assured. The remaining portion was allocated to private land holdings. Public lands included DFG Wildlife areas, and Rush Ranch Open Space Area. The sample space was restricted to within 100 meters of a road or levee, which provides access. This criterion improves the efficiency of traveling to the sample spot, and may provide a level of safety for field personnel, but assumes no sampling bias is introduced due to a distribution of vegetation influenced by the existence of the road itself.

As a test of this assumption, histograms of spectral classes developed from the satellite image, and occurring on public lands was compared with histogram of spectral classes on public lands, but limited to within a 100-meter buffer. The proportions of each these satellite signatures did not change significantly when comparing the entire area with only the buffer. These results suggest that a sampling bias would not be introduced by locating samples in a 100-meter buffer. The road source was 1:100,000 roads coverage from Teale Data Center. The levees were obtained from the CALFED program. There may have been roads not represented in this existing digital layer.

Two hundred forty sample locations were requested. One hundred forty three random samples were generated in areas of public lands; ninety-two random samples were generated on parcels of private lands, where access would be likely (See Figure 1). Permission was requested before entering private lands for sampling. The allocation of points was proportional based on area represented within a satellite spectral class. A minimum of five points was defined for each class type, with three occurring on public lands, regardless of area proportion. The size of the sampling units was 3 pixels on a side, or 60 meters. A selection algorithm checks to make sure the entire 60 x 60 meter sample block was created. Large format maps were printed and used to guide field crews to the sample locations.

Classification Field Work:

Sampling forays were planned on a daily basis with the objective of completing as many plots as possible. Routes were determined based on accessibility and printouts of the allocated samples overlaid on topographic maps. The single two-person field crew navigated to these points using undelineated aerial photos and the allocation printouts. Once on site, the vegetation was assessed to determine its suitability for sampling. If the vegetation was consistent over at least a half acre then a representative area was chosen. Plot boundaries were determined using two 20 m tapes laid at right angles to each other.

Sampling began in July 1999 utilizing the allocated points for sample selection. Although an extensive network of roads and levees provides great vehicular access throughout Suisun Marsh, much of the land is privately owned. Randomly allocated sample points fell on forty-six private lands. Letters asking permission for access were sent to these landowners; a liability waiver was included. Permission was granted on twenty-two properties, which accounted for twenty-eight sample plots. When the initial allocated points had been exhausted, a directed search for vegetation types commenced. Vegetation communities known to be common in the study area but poorly represented by the spectral analysis were sampled. Further, vegetation communities that were only sampled once or twice were sought out to provide more complete data for the future analysis. A boat was used to sample vegetation along sloughs and intertidal areas. At the end of the 1999 field season 198 vegetation samples were collected.

Map Verification:

The second sampling season began in June 2000. In the first phase of the field season, we conducted "verification plots", the purpose of which was to increase both confidence and accuracy of our ongoing photo interpretation efforts. This involved systematic drive and/or walk-through surveys of both public and permitted private areas within the marsh. Samples were taken at stands of those vegetation types that proved challenging on photo interpretation. Information gathered during these informal plots consisted of a GPS reading, approximate stand size, classification label, five associated species, and a confidence estimate (see **Appendix 1**). A total of 271 verification plot samples were collected.

The second phase of the 2000 field season was for assessing the accuracy of the map. The accuracy assessment phase began in September 2000. Team members were provided with Global Positioning System waypoint numbers and a map highlighting the polygon destinations. Trimble GPS units were downloaded with the waypoint numbers, and were then used to locate polygons on the ground. Once on location, accuracy assessment data forms were completed (see **Appendix 1**). A total of 271 vegetation polygons were visited during this effort.

Review of the Actual Sample Allocation:

At the end of this project we can see the distribution of all samples with GPS points taken (see Figure 1). Eighty-one percent of the sample plots were collected on 14,700 acres of California Department of Fish & Game lands. Samples are concentrated on the Hill Slough, Joice Island, Grizzly Island and Crescent Units of the Grizzly Island Wildlife Area. These areas have well maintained levees and unlimited access. Over the two field seasons we accessed sixty-four private parcels totaling 22,000 acres and accounting for nineteen percent of the sample plots. Approximately 39,000 acres (fifty percent) of the study area were never visited.

Suisun Marsh is comprised of unleveed wetlands and leveed wetlands. Rush Ranch, administered by the Solano County Open Space Foundation, offered unlimited access to the largest aggregation of unleveed areas in the marsh. Twenty-seven samples were collected over approximately 2,800 acres of unleveed wetlands, thirteen of these at Rush Ranch and nine on the southeast portion of Hill Slough. Four hundred forty-two samples were collected on leveed wetlands, totaling approximately 74,700 acres, or ninety-six percent of the study area.

Photographic and Field Data Archives:

When collecting field data, photographs of the relevés were taken for documentary reference. The compass direction in which each photo was taken was recorded on the field forms. The prints were marked with date, polygon number and direction the photo was taken and placed in print archival pages. These archives are stored with the field data forms. Prints proved to be useful in making decisions about polygon labeling and assigning certain transitional vegetation samples to a vegetation series or association.

Data forms used to collect information in the field were stored in alphanumerical order by aerial photo. Prints of the field plots were stored with the data forms.

Data Entry:

Data from the field forms from the first field season was entered into a pc computer using the California Vegetation Information System (CVIS), a Paradox System database. Fields were designed to mirror entries on the relevé field form (see **Appendix 1**). Data from a total of 198 field forms was entered. This information has been archived at the Department of Fish and Game, Wildlife and Habitat Data Analysis Branch.

Methods for Classification of Vegetation of the Suisun Marsh Mapping Project:

The development of a quantitative, data-driven vegetation classification for the Suisun Marsh mapping project is a necessary first phase prior to the final labeling of the vegetation map polygons. In addition, the vegetation classification is intended to be a stand-alone product that can be used with or without reference to the map (see key, page 27). The National Vegetation Classification System (NVCS) (Grossman et al. 1998) is the standard classification throughout this project. The NVCS is a hierarchical vegetation classification, which can provide a framework for a number of different ecological assessments. The Manual of California Vegetation (Sawyer and Keeler-Wolf 1995) is the California view of the national classification, based on the same quantitative classification ideology. The floristically-based, fine scale of the classification (the association level) may be used at the local scale to address specific projects, while the physiognomically-based upper levels of the classification such as the formation or group may be used as a basis of broad regional or national assessments. The fine-resolution floristically-based **association level** of the classification used as the basis for this project is appropriate for this fine-resolution mapping effort. Table 1 provides an example of the different resolutions of the National Vegetation Classification from the broadest class level to the floristically based alliance and association levels. A full break-down of the Suisun Marsh vegetation samples as seen in terms of the national classification may been seen in **Appendix 3**.

Quantitative classification of vegetation for the Suisun Marsh has never been attempted prior to this effort. Prior to Sawyer and Keeler-Wolf (1995) all previous classification efforts for wetlands in California have been based either on anecdotal and/or habitat-based descriptions of vegetation types (Holland 1986, WHR 1988) or a hydrogeomorphic and non-floristic hierarchy (Ferren et al 1995). Sawyer and Keeler-Wolf (1995) attempted to glean all published and written analyses of wetland vegetation. However, their first iteration classification was in many cases speculative, without quantitative data for a number of the series (= alliances) they describe, although the second edition (in preparation) will include all new data (including information from this report).

The process of developing a standardized, quantitative classification of the Suisun Marsh has involved several major steps. In the following paragraphs a detailed description of the processes and methods involved are described. In brief, the phases can be summarized as follows:

1. accumulate existing literature and combine into preliminary classification
2. use current field sampling to capture all bio-environments in the study area and fill in the gaps in the existing classification
3. analysis of new plots to develop quantitative classification rules
4. Bring the classification into accordance with the standardized National Vegetation Classification System
5. develop keys and descriptions to all the alliances of the mapping area
6. translate classification into mapping units..

Table 1: Classification Hierarchy in the National Vegetation Classification, examples occurring within the mapping area. Hierarchy becomes finer in resolution from left to right. For complete hierarchy see appendix 6.

Class	Sub-class	Group	Formation	Alliance	Association
III. Shrubland. Shrubs or trees usually 0.5 to 5 m tall with individuals or clumps not touching to interlocking (generally forming >25% canopy cover).	*III.A. EVERGREEN SHRUBLAND. EVERGREEN SPECIES GENERALLY CONTRIBUTE >75% OF THE TOTAL SHRUB AND/OR TREE COVER.*	**III.A.2 temperate microphyllous evergreen shrubland**	*III.A.2.N.h . microphyllous evergreen shrubland*	**III.A.2.N.h.2 Baccharis pilularis** *shrubland alliance*	**Baccharis/Annual Grass *association 603***
V. Herbaceous vegetation. Graminoids and/or forbs (including ferns) generally forming >10% cover with woody cover usually <10%.	*V.A. PERENNIAL GRAMINOID VEGETATION. GRAMINOIDS OVER 1 M TALL WHEN INFLORESCENCES ARE FULLY DEVELOPED, GENERALLY CONTRIBUTING TO >50% OF TOTAL HERBACEOUS COVER*	**V.A.5. temperate or subpolar grassland**	*V.A.5.N.d . permanently flooded tall temperate or subpolar grassland*	**V.A.5.N.d.3 Typha (latifolia, angustifolia)** *herbaceous alliance*	*Typha angustifolia-latifolia-domingensis /Distichlis* association 126
V. Herbaceous vegetation. Graminoids and/or forbs (including ferns) generally forming >10% cover with woody cover usually <10%.	*V.A. PERENNIAL GRAMINOID VEGETATION. GRAMINOIDS OVER 1 M TALL WHEN INFLORESCENCES ARE FULLY DEVELOPED, GENERALLY CONTRIBUTING TO >50% OF TOTAL HERBACEOUS COVER*	**V.A.5. Temperate or sub-polar grassland**	*V.A.5.N.k . Seasonally flooded temperate or subpolar grassland*	**V.A.5.N.k.13 Juncus balticus seasonally flooded herbaceous alliance**	**Juncus balticus/Potentilla anserina** *association 135*

Existing Literature Review:

Beginning in the spring of 1999 a literature search was made for existing information on vegetation classification of the Suisun Marsh. Information from Sawyer and Keeler-Wolf (1995), Reid et al. (1999) and personal communication with TNC Regional Ecologist (M. Reid, pers. comm.) was compiled to obtain the most current view of the National Vegetation Classification (NVC) for the mapping area.

This information was developed into a preliminary classification for the marsh at the alliance and association level. Because the spatial resolution of the association units of vegetation classification is highly variable, notes were also made on the "mappability" of each of the alliances thought to occur in the area. These included discernability based on visual distinctiveness as well as size of stand. The initial inventory suggested that about 70 associations existed in the mapping area.

TWINSPAN and Cluster Analysis:

The analysis of data collected in 1999 was undertaken using the PC-Ord softeware suite of ordination and classification tools (McCune 1997). PC-Ord allows disparate types of data to be fed directly into classification programs such as TWINSPAN (Hill 1979, Gauch 1982) or Cluster Analysis (McCune 1997), whether entered in various spreadsheet, database, or condensed formats.

Following the 1999 sampling effort by the field crew using the stratified random design described in the sampling methodology section, 198 vegetation plots were available for analysis. The classification analysis for all sampling data followed a standard process. First, all sample-by-species information was subjected to two basic TWINSPAN runs. The first was based on presence/absence of species with no additional cover data considered. This provided a general impression of the relationships between all the groups based solely on species membership. The second was based on the standard default run where cover values are converted to 5 different classes including:

Class I	merely present - 2%
Class II	>2 – 5%
Class III	>5-10%
Class IV	>10-20%
Class V	>20% cover.

These cover values have been tested for classification of many vegetation types (Hill 1979) and are reasonable for most wetland vegetation. The first three cover classes compose the majority of the species values. This second run demonstrated the modifications cover values can make on the group memberships. Depending on the size of the data set the default runs were modified to show from 6 to 12 divisions (the largest data sets were subdivided more than the smaller data sets.) A minimum group size of three was specified for all runs. The intent was to display the natural divisions at the finest level of classification (the association) rather than the alliance level.

Following each of these runs, consistent groupings were identified and compared. Following the identification of natural groups in TWINSPAN, Cluster Analysis using Ward's scaling method and Euclidean Distance (McCune 1997) measure was employed for an agglomerative view of grouping as opposed to the divisive grouping in the TWINSPAN algorithm. The congruence of groupings between TWINSPAN and Cluster Analysis was generally close. Disparities were resolved by reviewing the species composition of individual samples. Most of these uncertain plots either represented transitional forms of vegetation that could be though of as borderline mis-classified plots, or outliers with no similar samples in the data set.

1. Because of the size of the data set initial TWINSPAN runs were made to help break the data into further finer levels which were in-turn re-analyzed using TWINSPAN and Cluster Analysis - this process is known as progressive fragmentation (Bridgewater 1989). The full data set was first analyzed together, then broken into distinct subsets, and those individually analyzed. Subsets included plots with tall graminoid wetland vegetation (*Typha, Scirpus,* etc.), plots with *Salicornia virginica* and plots with upland herbs (e.g.,*Centaurea, Bromus* spp.).
2. Following Cluster Analysis and TWINSPAN analysis of all subsets of the primary new data set each plot was re-visited within the context of the cluster it had been assigned to in order to quantitatively define the membership rules for each alliance. These membership rules were defined by species constancy and species cover values and were translated into a first-order plot-based classification.
3. The first-order classification was tested in the field during the accuracy assessment of Fall 2000 and was refined into the key presented in this report.

This set of data collected throughout the mapping area was to be used as the principal means of defining the association composition of the sample area. As a result careful scrutiny of the membership of each grouping defined had to be employed to establish membership rules for all existing plot data and set the standard for the definition of the associations defined as one of the products of this report (Table 2).

The process of analysis followed these steps:

a. Run outlier analysis on data, including sub-sets, to determine most distantly related plots
b. Run presence-absence TWINSPAN to determine general arrangement of species along the gradient of axis 1 of DCA (both Recriprocal Averaging techniques of species-by-sample scores)
c. Run different permutations of TWINSPAN to see the general variation in arrangement of samples. Samples generally held together well and main gradient did not vary
d. Settle on the final representative TWINSPAN run to use in the preliminary labeling
e. Preliminary label alliance and association for each of the samples
f. Identify major break points (main divisions) in TWINSPAN of full data set and subject major subsets of data to individual TWINSPAN runs
g. Run Cluster Analysis (Ward's method) to test congruence with the subsetted TWINSPAN groupings
h. Develop decision rules for each association and alliance based on most conservative group membership possibilities based on review of species cover on a plot-by-plot basis
i. Re-label final alliance labels for each sample and arrange in spreadsheet with locational data for each plot.
j. Use decision rules developed in the new data to assign alliance names to all existing data and all data collected in the 2000 field season (verification and accuracy plots).

Despite the strong influence of outlier plots (plots that did not fit neatly into analysis groupings) on the arrangement of the main body of vegetation data we chose not to remove them from the analysis. Although outliers were typically removed from additional analysis to clarify the main groupings of samples, they were considered as valid samples in the final enumeration and description of types. Because the sampling scheme tended to under-represent the rare types, based on their rare bio-environments, these relatively unique samples were considered important. They were often the only representatives of rare alliances defined from areas beyond the boundary of the study. In some cases they represented unusual species groupings here-to-fore un-described, and were viewed as affording perspective into unusual vegetation types that would deserve further sampling at some future date.

Table 2: An example of the cluster analysis showing the arrangement and relationship of plots in the clustering diagram and their preliminary and final names is shown in the following figure. Each differently colored group indicates clusters of plots that have been grouped together as associations or alliances.

<table>
<tr><th>sui plot name</th><th>final class</th><th></th><th>Diagram (splits closest to the left are ecologically more closely related than splits to the right)</th></tr>
<tr><td>Sui041</td><td>J. balticus/Lepidium</td><td>134</td><td>-----| | |</td></tr>
<tr><td>Sui060</td><td>Lepidium/Distichlis</td><td>323</td><td>|--| |----------------------| | |-|</td></tr>
<tr><td>Sui137</td><td>Lepidium/Distichlis</td><td>323</td><td>| |-| | | | |</td></tr>
<tr><td>Sui099</td><td>Lepidium/Distichlis</td><td>323</td><td>---| |------| | |</td></tr>
<tr><td>Sui146</td><td>J. balticus/Conium</td><td>133</td><td>|| | | |</td></tr>
<tr><td>Sui177</td><td>J. balticus/Conium</td><td>133</td><td>||--------------------------| | |</td></tr>
<tr><td>Sui194</td><td>Juncus balticus</td><td>132</td><td>-| | |-|</td></tr>
<tr><td>Sui028</td><td>Distichlis/Lotus</td><td>147</td><td>|------------------------------------| | |</td></tr>
<tr><td>Sui081</td><td>Distichlis/Lotus</td><td>147</td><td>| | |</td></tr>
<tr><td>Sui126</td><td>Lotus corniculatus</td><td>344</td><td>| | |</td></tr>
<tr><td>Sui127</td><td>Lotus corniculatus</td><td>344</td><td>| | |</td></tr>
<tr><td>Sui013</td><td>Centaurea (generic)</td><td>413</td><td>|----| | |</td></tr>
<tr><td>Sui030</td><td>Centaurea (generic)</td><td>413</td><td>| |---------------------------------| |--|</td></tr>
<tr><td>Sui198</td><td>Centaurea (generic)</td><td>413</td><td>| | | |</td></tr>
<tr><td>Sui155</td><td>Centaurea (generic)</td><td>413</td><td>-----| | |</td></tr>
<tr><td>Sui025</td><td>Lolium (generic)</td><td>218</td><td>|--| | |</td></tr>
<tr><td>Sui122</td><td>Lolium (generic)</td><td>218</td><td>| || | |</td></tr>
<tr><td>Sui093</td><td>Lolium (generic)</td><td>218</td><td>---||--| | |</td></tr>
<tr><td>Sui147</td><td>Lolium (generic)</td><td>218</td><td>----| |---------------------------------| |-|</td></tr>
<tr><td>Sui120</td><td>Lolium/Lepidium</td><td>220</td><td>--|----| | |</td></tr>
<tr><td>Sui125</td><td>Lolium (generic)</td><td>218</td><td>|-| | |</td></tr>
<tr><td>Sui148</td><td>Lolium (generic)</td><td>218</td><td>| | |</td></tr>
<tr><td>Sui017</td><td>Leymus (generic)</td><td>215</td><td>| | |---|</td></tr>
<tr><td>Sui062</td><td>Leymus (generic)</td><td>215</td><td>| | | |</td></tr>
<tr><td>Sui128</td><td>Leymus (generic)</td><td>215</td><td>|---| | |</td></tr>
<tr><td>Sui065</td><td>Leymus (generic)</td><td>215</td><td>| | |</td></tr>
<tr><td>Sui131</td><td>Cotula coronopifolia</td><td>342</td><td>|----------| | |</td></tr>
<tr><td>Sui132</td><td>Cotula coronopifolia</td><td>342</td><td>| |----------------------------------| |----|</td></tr>
<tr><td>Sui173</td><td>Cotula coronopifolia</td><td>342</td><td>| | | |</td></tr>
<tr><td>Sui150</td><td>Xanthium/Polypogon</td><td>332</td><td>-----------| | |</td></tr>
<tr><td>Sui050</td><td>Sesuvium verrucosum</td><td>357</td><td>| | |</td></tr>
<tr><td>Sui130</td><td>Sesuvium verrucosum</td><td>357</td><td>|-----| | |</td></tr>
<tr><td>Sui172</td><td>Sesuvium verrucosum</td><td>357</td><td>| | | |</td></tr>
<tr><td>Sui179</td><td>Sesuvium verrucosum</td><td>357</td><td>| |---| |</td></tr>
<tr><td>Sui105</td><td>Sesuvium/Distichlis</td><td>358</td><td>|| | |</td></tr>
<tr><td>Sui129</td><td>Sesuvium verrucosum</td><td>357</td><td>||----| |</td></tr>
<tr><td>Sui166</td><td>Sesuvium/Cotula</td><td>362</td><td>|| |</td></tr>
<tr><td>Sui187</td><td>Sesuvium/Lolium</td><td>359</td><td>-| |</td></tr>
</table>

Bringing the Suisun Classification into the National Vegetation Classification Framework:

Quantitative floristic data derived from field plots are the building blocks of the NVC. However, as a result of the abrupt shift from the floristic units of the association and alliance to the physiognomic units of formation, group, and class (see Table 1) additional groupings in the classification must be made to accommodate significant physical differences in the vegetation. These may not strictly reflect the floristic affinities of the plots. The higher order divisions in the key (see results) are based on physiognomic characteristics related to life-form and general habitat (wetland, upland) in keeping with the formation and group levels of the NVC.

The Difference Between a Mapping Legend and a Vegetation Classification:

Maps of vegetation based on photography or other remotely sensed imagery are always compromises between what can be visibly discerned through that imagery and what is actually defined on the ground via vegetation sampling and classification. Although the 1:9600 scale photography was very effective in determining the precise type of vegetation that actually occurred, vagaries in the dominant or indicator species' phenology and in photo quality sometimes made it impossible for the photo interpreters to decide upon the precise vegetation type. In some cases this had to do with the difficulty of determining what proved to be an important ecological distinction indicated by a shift in species composition. For example, it proved difficult to distinguish between *Salicornia/Atriplex triangularis* and *Salicornia /Distichlis* stands. Thus, in some cases a *Salicornia* generic category was used.

In other cases the issue was less of discernability, and more one of uncertainty of the classification for certain types. Additional plot data will be needed to determine whether some of the mapping units, discerned by the photo interpreters, are actually vegetation associations. None-the-less, these mapping units are shown in the mapping classification and defined in the key based on their superficial species composition (not solidified yet by detailed sampling). They are indicated in the key as "mapping units or stands" as opposed to " associations". Associations are defined only when we have sufficient samples and repeated observations, which substantiate their validity as units of vegetation.

A mapping unit as defined in the following key can either be an aggregated unit as described above, or an as-yet poorly defined unit with insufficient quantitative data. Aggregated units are termed generic in the classification, while ill-defined units are termed "stands" (Table 3).

With further vegetation sampling augmenting the 198 plots taken in 1999, it will be possible to develop an association level classification for all vegetation in the marsh.

Table 3: All mapping units that are not defined by quantitative analysis: They are broken into 33 generic and 28 stand categories as defined above.

Agrostis avenacea stands 228

Ailanthus altissima stands 911

Annual Grasses (generic) 231

Annual Grasses/Weeds (generic) 227

Apocynum/Scirpus *stands* 302

Atriplex/Annual Grasses stands 337

Atriplex triangularis (generic) 339

Atriplex lentiformis (generic) 514

Baccharis/Annual Grasses stands 603

Brassica nigra (generic) 406

Conium maculatum (genric) 402

Cultivated Annual Graminoid (generic) 225

Cynodon dactylon stands 161

Distichlis spicata (generic) *156*

Elytrigia pontica stands 211

Eucalyptus 800 (generic)

Eucalyptus globulus (generic) 801

Floating-leaved Wetland Herbs (generic) 370

Foeniculum vulgare stands 403

Frankenia (generic) 320

Fraxinus latifolia stands 912

Frankenia/Agrostis stands 317

Grindelia stricta var. *stricta* stands 321

Landscape Trees (generic) 910

Lepidium/Distichlis stands 323

Leymus triticoides alliance (generic) 215

Lolium (generic) 218

Medium Upland Herbs (generic) 410

Medium Upland Graminoids (generic) 210

Medium Wetland Graminoids [generic] 130

Medium Wetland Herbs (Generic) 310

Medium Wetland Shrubs (Generic) 510

Oaks (Generic) 900

Perennial Grass (generic) 226

Phalaris aquatica stands 223

Polypogon monspeliensis (generic) 238

Potentilla anserina stands (generic) 338

Raphanus sativus (generic) 405

Rumex (generic) 336

Salicornia (generic) 361

Salicornia/Annual Grasses stands 347

Salicornia/Atriplex stands 348

Salicornia/Cotula stands 365

Salicornia/Echinocloa-Polygonum-Xanthium stands 364

Salicornia/Sesuvium stands 356

Salix lasiolepis/Quercus agrifolia Stands 705

Scirpus (californicus and/or *acutus*)/Wetland Herbs stands 158

Scirpus (*californicus* or *acutus*)/*Rosa califorinca* stands 162

Scirpus americanus/S. californicus-S. acutus stands 113

Scirpus americanus (generic) 114

Sesuvium/Lolium stands 359

Short Upland Graminoids (generic) 230

Short Upland Herbs (generic) 420

Spergularia/Cotula stands 360

Tall Wetland Graminoids (generic) 101

Tall Wetland Shrubs (generic) 501

Tall Upland Herbs (generic) 401

Tall Upland Graminoids (generic) 201

Typha angustifolia-latifolia-domingensis /Phragmites australis stands 129

Typha angustifolia-latifolia-domingensis /Echinocloa-Polygonum-Xanthium stands 120

Typha angustifolia-latifolia-domingensis /S. americanus stands 121

Typha species (generic) 123

Vulpia/Euthamia stands 235

Further sampling and subsequent analysis of the stands would determine how many of these could be considered formal associations. We suspect that approximately 90 additional samples focused on these types (about 3 per type) would afford a complete quantitative classification of the marsh.

Delineation and Labeling Methods

Delineation:

The map produced by this project is based on interpretation of aerial photographs combined with field investigation. The Department of Fish and Game borrowed aerial photographs and corresponding diapositives from the Department of Water Resources. The 341 photos taken on June 16, 1999 at a scale of 1:9600 cover the entire study area. These true color photographs were provided as 9 X 9 inch prints and 9 X 9 inch diapositives.

The term "delineation" as used in this project refers to the process of drawing the outlines of the vegetation as interpreted from the aerial photographs. Based on much reconnaissance work in Suisun Marsh during the spring of 1999, project staff delineated the irregular shapes of differing photographic signatures (polygons) that appeared to represent vegetative units. Using light tables, delineations were drawn with a .2 mm water-soluble pen (Uniball Microroller) directly on mylar sheets taped to the diapositives. Due to the sixty percent overlap of adjacent photos, the center of every other photo was delineated. Sam Hayashi and Craig Bailey were responsible for the majority of the delineations. Craig Turner also delineated portions of the marsh.

The minimum mapping unit for this project was 0.5 acre. Delineation was done without attempting to classify the signatures; all visibly different signatures were delineated. A small number of the resulting polygons were below the general 0.5 acre minimum; these were drawn because they had distinctive photo signatures. Our general philosophy was to delineate what we could see distinctly and allow further knowledge based on field sampling and verification to refine delineations in the editing process.

Because the delineations were drawn directly on the aerial photographs the resulting shapes were not corrected for spherical distortion. The subsequent steps of scanning and use of computer algorithms corrected this distortion.

Labeling Polygons:

As used here, an "attribute" is a characteristic that describes the vegetation polygons appearing on the map. Mehrey Vaghti, Karen Converse and Cynthia Graves assigned attributes for each of the polygons delineated to represent the vegetation of the marsh. A total of 39,600 polygons received attributes.

The following attributes were assigned for each polygon:

- **POLYNUM**: a unique number for the individual digitized polygon, assigned by computer. Primary key used to link the database with the GIS coverage.
- **PHOTO**: the aerial photo number associated with the polygon.
- **VEGCODE F**: the vegetation association as defined through sampling and analysis.
- **HTCODE**: the height of the dominant vegetation. Seven classes of height were recognized: 1(<.5m), 2(.5-1m), 3(1-2m), 4(2-5m), 5(5-10m), 6(>10m), 7(N/A).
- **COVCODE**: the total cover of vegetation within the polygon. This included cover by the association defining dominant plus all under story vegetation. Seven classes of total cover were recognized; Unvegetated (<2%), Sparse (2-10%), Open (10-25%), Intermittent (25-50%), Moderate (50-75%), Dense (>75%), Not applicable
- **.DIST**: the level of disturbance from management activites. Five disturbance levels were recognized; Not

evident (1), Low (2), Medium (3), High (4), Not applicable (5).

- **ID**: the method used to determine the vegetation attributes; Sample (S), Reconnaissance ®, or Photo interpretation (P).
- **WHO**: which of the project team members assigned the attributes; Karen Converse (KC), Cynthia Graves (CG), Mehrey Vaghti (MV).
- **QC WHO**: who completed quality control of attributes for the polygon; Karen Converse (KC), Todd Keeler-Wolf (TKW), Mehrey Vaghti (MV).

During the one-month training period in January-February 2000, team members reviewed all the sampled vegetation plot data collected during the classification field season. Considerable time was spent gaining familiarity with the photo signatures and vegetation distributions of those polygons sampled. Additionally, several reconnaissance visits to Suisun Marsh were made to verify initial attribution efforts and collect information on unusual photo signatures.

For each photograph, team members examined all sample data and reconnaissance information. Species composition, and photographs of the samples were of particular importance. Sample and reconnaissance polygons were assigned attributes. Similarity of photographic signatures, tidal influence, soil saturation, the position of the vegetation in the landscape, management information, and field experience were used to attribute polygons that had not been visited. Vegetation was labeled at the association level except when the photo interpreter could not make such a determination due to an unidentifiable photo signature. Thus some polygons were labeled with their alliance or mapping unit designation (see Methods for Classification section for further explanation).

The attribute information was entered directly by the photo interpreters into a Microsoft Access database to be later merged with the GIS vegetation layer. Attributes for each photo were entered into a table labeled by photo number. At the completion of the attribution phase, all the tables were merged into one and combined with the GIS vegetation layer.

Geographic Information System (GIS) Materials and Methods

Overview of GIS Methods:

The GIS methods section of this report describes the process by which source data - aerial photography, its interpretations, and field observations - becomes a final spatial data layer, viewable on computer screens, printable as a map, and capable of various types of summary reports, and analysis.

One of the first steps in the planning process was decide among myriad techniques, and multiple paths to accomplish the end goal. Five main options were considered :

1. digitizing vegetation delineations directly from aerial photos,
2. transferring vegetation delineations to DOQQ, then digitizing from these,
3. registration of digital aerial photos and heads up digitizing,
4. digital classification,
5. scanning the vegetation delineation, followed by raster to vector line following conversion (Arc/Scan).

Various options were ruled out based on what was perceived to be the most efficient, accurate, and utilitarian approach. Digitizing from aerial photos is relatively quick, but sometimes insufficiently corrects for the inherent distortion within an aerial photo. Transferring line-work to Digital ortho-photo quarter quadrangles (DOQQ's) allows an effective registration since the DOQQ's are planimetric, but the transfer process relies on multiple stepwise adjustments between an overlay, and the DOQQ, since creating a DOQQ at exactly the same scale as an aerial photo would be impossible. Given a 6 year interval between the date of the DOQQ and the vegetation study, spatial control may be difficult to identify. Digitial classification sounded interesting and fast, but hue and brightness variation between flights and within a single frame could have posed edge matching issues and created even more spurious delineations that related more to phenology and less to true vegetation differences. At large-scale displays, the stairstep edge artifact of raster conversion can be detracting. Scanning the linework had been tested before in earlier mapping projects such as in the Anza-Borrego Desert State Park vegetation map (Keeler-Wolf et al. 1998) and found to require much time consuming post-process editing. Editing and edge matching issues are considered costs that counter the speed of digital conversion.

Option 3) was chosen for this project. The benefit of image registration of aerial photos is a data product that can be shared with various agencies, and reused in the future, or for different purposes. This process was considered to be efficient because the digitizing would be done in a single, seamless coverage, which avoids the cost of stitching together photo-based coverages, and edge-matching the line-work, and attributes.

Georeferencing:

1) Photos were scanned at 300 dots / inch on a HP 6300 scanner, saved in compressed jpeg format, using "excellent" quality. Jpeg compression can cause degradation if this parameter is set to maximum compression. Output file size per frame is ~ 5 Megabytes. Fiducial marks were not included in the scan, or used in the process of registration. Note: to speed processing every other photo was skipped. Adjacent photos had a 60% overlap, which is perfect for stereo interpretation, and orthoregistration. Skipping every other photo resulted in photos with about a 20% overlap.

2) Image to map registration. ERDAS Imagine was used to transform the scanned aerial photography to map projection. Source control points were selected from 1993 USGS Digital Ortho Quarter Quads at 1-meter resolution, and a real world positional accuracy of a 1:12,000 scale map. The cell sampling rate (or resolution) on the registered aerial photos is 1 meter on the ground (See Figure 2).

For this project, the 2nd order polynomial transformation was used. A second order polynomial fits the typical scale changes in an aerial photograph of flat terrain very well.

Photo-scale changes due to terrain effects were not important because the project area is in very flat terrain, so orthorectification was not performed. The residuals (how far each measured point deviates from its mathematically predicted location), which are reported as Root Mean Square Error (RMSE), may be interpreted as how well the image matches the map projection. However a caveat exists: the mean spatial error in the image may be higher than the residuals imply. Solutions for the polynomial Root Mean Square Error (RMSE) values were targeted for less than 1 meter, or equivalently, one pixel. For some frames, the RMSE averaged slightly greater than one. The anecdotal test for goodness of fit was to overlay the registered photos with the orthophoto quad, and to compare the fit between adjacent quads.

Digitizing:

Digitizing is the process by which lines on a map are captured in an electronic format. Lines are represented by a series of x, y coordinate pairs representing the locations of line start and end points, and the positions of line direction changes. This process can be achieve with special electronically sensitive tracing boards or by capturing on-screen mouse movements.

Aerial photos with their delineations were used as a backdrop on the screen in an Arc/Info environment. ArcEdit was used to trace polygons. An Arc Macro Language (aml) menu was written to handle the basic editing functions: Add an image to the backdrop, set editing scale, set the feature type, file save, etc. The scale set during digitizing was typically 1:4800, but often a larger scale was set to digitize finer detail.

Editing of polygons was undertaken to utilize built-in routines in Arc/Edit to build polygon topology, and to automatically add label points.

Display response tended to slow down as polygons were digitized, thus the study area was digitized in nine separate coverages, then merged when the process was complete. To facilitate the merging process, the edge polygons of the completed coverage were copied into the new coverage. Digitizing would continue, building onto the row of copied polygons. At the completion of digitizing, the polygons copied from the adjacent coverage were deleted, so they would not be redundant entries when the separate coverages were joined back together.

At the completion of a digitizing session, the topology of polygons was rebuilt, adding label points to newly digitized polygons, etc. Another check performed was to list label errors. This would list any illegally formed polygons, such as those not containing a label point, or containing two label points with different id numbers.

Random Selection for Accuracy Assessment:

An accuracy assessment of the photo interpretation by field visit was desired (see Map Accuracy Assessment section for further information). Since all of the polygons could not be field checked due to time and budget constraints, a random selection was desired, so that the results of the sample selected could be an indicator for map accuracy. The sample selection was constrained to public properties, and selected private properties for which access was granted. Due to limited time to perform field studies, only certain classes of vegetation were assessed. The number of polygons was selected for each class based on estimated variance of proportion correct, and a bounding variable (Table 4).

The selection process proceeded as follows:

1) select all polygons in the sample frame of properties accessible.

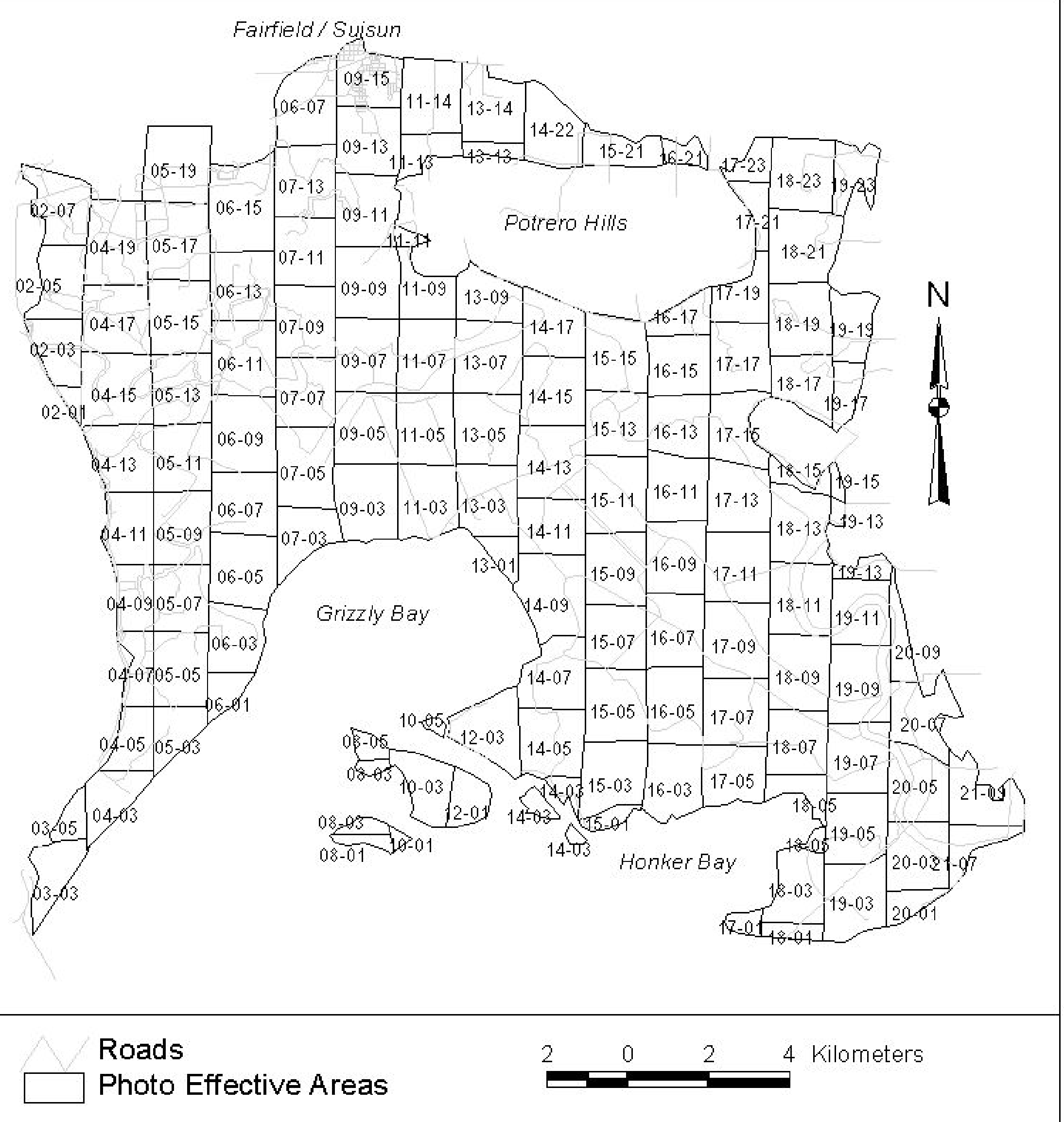
2) remove as candidates for selection any polygon that had been visited in the field.

3) for each class to be assessed, use a random number generation to select n polygons. A standard ArcView script is included to do this, it was modified to select a certain number, rather than percent. The random selection process is based on records, giving equal probability to both small and large polygons.

4) centroids for polygons were downloaded into a GPS unit, and maps of selected polygon boundaries, and centroids were plotted over aerial photos to provide field crews a means to reconnoiter to the polygon which was checked.

Figure 2

Effective Mapping Areas of Suisun Marsh



Map Produced by Wildlife Habitat Data Analysis Branch
December 2000

Table 4: Vegetation classes assessed for accuracy, the estimated variance (proportion correct), and number of samples needed. See the discussion of accuracy assessment in the results for further detail on the methodology.

Final Vegetation Code	Classification Name	Estimated Percent Correct	Number of Samples
103	Phragmites australis	95	5
116	S. califoricus/S. Acutus	80	16
123	Typha species (generic)	80	16
137	Scirpus maritimus	75	19
141	Distichlis spicata	90	9
142	Distichlis / annual Grasses	90	9
157	Scirpus (ca or acutus)-Typha sp.	80	16
159	Echinocloa-Polygonum-Xanthium	90	9
160	Distichlis-Juncus-Triglochin-Glaux	90	9
162	Sc. ca-Sc. ac/ Rosa	90	9
227	Annual Grasses/Weeds	90	9
231	Annual Grasses (generic)	95	5
311	Atriplex trangularis	75	19
316*	Atriplex/Sesuvium	75	19
324	Lepidium (generic)	95	5
342	Cotula coronopifolia	95	5
344	Lotus corniculatus	95	5
346	Salicornia virginica	95	5
347	Salicornia / Annual Grasses	95	5
348	Salicornia / Atriplex	80	16
356	Salicornia / Sesuvium	95	5
357	Sesuvium verrucosum	90	9
402	Conium maculatum	95	5
413	Centaurea (generic)	90	9
514	A. lentiformis (generic)	95	5
604	Rosa californica	90	9

Labeling:

At the completion of digitizing, but before joining adjacent coverages, unique identification numbers were assigned to each polygon. The first coverage had on the order of five to six thousand polygons. This was assumed to be typical of each of the following coverages as well. It was necessary to devise a numbering system that would provide a unique number for every vegetation polygon in the project area. Using a sequential numbering process in ARC/INFO, polygons were assigned numbers beginning with 1 and ending with a number greater than 1 by the total number of polygons in each coverage. For example, if the mapping area in Coverage 2 had 7485 polygons, the polygon numbers would start at 1 and end with 7486. Prior to transferring the data into ArcView GIS, polygon numbers were increased by a multiple of 10,000 which corresponded with the Coverage number to yield unique polygon numbers. In this example, Coverage 2 would contain polygons 20001 through 27486. Polygons were numbered this way to provide a consistent number of characters for effortless transfer of attribute data into the GIS.

Once the sequential numbering was complete, printouts of the polygons and polygon numbers were plotted for each photograph. Due to the small polygon size printouts were made at a scale of 1:7250 or larger. The photo interpreters used these printouts to record vegetation attributes prior to entering them into the Access database.

Phase II Editing:

During the attribution phase, any errors found in the original vegetation polygon coverages were corrected on the printouts used for attributing. Mehrey Vaghti used the printouts to perform edits to the polygon coverage in ArcView. Polygons were added, deleted or redrawn as necessary.

Attributing the GIS Vegetation Coverage:

Before vegetation attributes were assigned to the GIS vegetation coverage from the database (.mdb) files created in Access, quality control of the database files was performed. Duplicate and missing polygon numbers were referred to attributers for correction. All records in the vegetation database files were reviewed and invalid codes were corrected.

Following completion of the quality control process, the one hundred fifteen vegetation tables were placed into a single table using Access software. The single large database file was used with the JOIN command in ArcView to assign attributes to the GIS vegetation coverage. Following the completion of manual labeling of the polygons, additional database files containing vegetation crosswalk information to WHR and Holland classifications were linked with the main database. The result is a single GIS coverage depicting the location and extent of vegetation in the project area. Detailed technical information about the Suisun Marsh digital vegetation map can be found in the Metadata (**Appendix 4**).

Global Positioning Systems (GPS):

A Global Positioning System (GPS) is a computerized instrument which uses satellite signals to determine its geographic position on the earth. GPS units were used during the 1999 field data collection phase of the project to record locations where vegetation sampling occurred. Satellite signals used by the GPS were altered by the Department of Defense, preventing immediate, precise location of geographic position. Therefore, in order to accurately determine the position of a unit on the ground during a given time period, a base station must be functional during the time period when GPS units were used. A base station is a GPS unit located at a fixed location which collects satellite data. Using locational data collected in the field along with data from the base station collected from the same time period, and GPS software, it is possible to correct the altered positions of field points to yield accurate information on their geographic position. This process is commonly known as differential correction.

GPS readings were collected at each vegetation sampling point by acquiring a 3 minute stationary reading at one second intervals, using a PDOP mask of 6, and a signal to noise ratio of 5. In some cases, parameters were relaxed to allow acquisition of a signal. These readings were differentially corrected, and then averaged to provide a single location for each site where field vegetation sampling occurred, accurate to within 5 meters. Using the GPS software, these points were projected into the UTM Zone 11 projection to yield a GIS coverage of the locations in which vegetation sampling occurred.

In May 2000 the Department of Defense stopped altering satellite GPS signals. GPS readings collected during the map verification phase were differentially corrected to improve accuracy. During the data collection phase of accuracy assessment, GPS units were programmed with the centroids of polygons to be visited and used to facilitate navigation to these points.

Hardware / Software Configuration:

A variety of personal computers, and laptop computers were used to accomplish the GIS processing, and attribution. Registration of aerial photos, and mosaicking of photos was accomplished with Erdas Imagine version 8.3 on computers with a processor speed of 333 Mhz, and 128 MB ram. Most of the digitizing was accomplished with Arc/Info, version 7.2. Additional edits have been performed in the ArcView environment with ArcView version 3.x. The attribute database was developed in Access 2000 on a laptop computer. Links between the polygons and Access are performed dynamically by connecting through an Open Data Base Connection (ODBC), then joining the Access virtual table to the shapefile by the Unique-id key field. Data backups have been written to Jazz diskettes, and written to CD's.

Field sample locations were documented using a Trimble GeoExplorer II Global Positioning System (GPS) receiver. Stationary positions were read for approximately 3 minutes to collect 180 readings, which were differentially corrected in Trimble Pathfinder Office from base station files collected from the US Forest Service Community Base Station in Sacramento, CA.

Data Sets:

The following data sets were created during the 1999 Suisun Marsh vegetation mapping process

- Vegetation coverage interpreted from aerial photography. Access database of attributes for each polygon.
- Vegetation Classification tables, and crosswalks to other classification schemes.
- Registered natural color aerial photographs at one meter resolution. Photomosaics of aerial photos by 7 ½ minute quad sheet areas, and within the Suisun Marsh Study Area.
- Satellite image classification for sample stratification.
- Stratified random samples for field data collection.
- Field sample GPS locations.
- Field data on species, and relative composition. Data stored in California Vegetation Information System (CVIS).
- Additional field verification locations.
- Accuracy assessment locations.
- Suisun Marsh Study Area, defined by a combination of boundaries and limited by the 10 foot contour line.
- Property boundaries for selected owners, but without owner information.

The following data sets were acquired for the project:

- SPOT satellite image, both 20 meter multispectral, and 10 meter panchromatic, June 1999. This data set is licensed by SPOT Image Corp., which limits redistribution rights.
- Digital Orthophoto Quarter Quads at one-meter resolution, produced by USGS.

The following existing data sets were used, and maybe redistributed:

- USGS 7 ½ minute topographic quads, in digital format.

- 1:100,000 scale roads, levees.
- Dept. of Fish and Game Lands, and Rush Ranch Open Space Preserve, Solano County.
- Hydrology at 1:24,000.

Producing the Hard Copy Maps:

Prior to production of large scale maps, a new field was created in the attribute table in ArcView and calculated as a string of the fields vegcode f, htcode, covcode, and dist. This field was utilized with the Geoprocessing Wizard to dissolve boundaries between adjacent polygons with identical attributes.

A hard copy map of the entire project area was produced at a scale of 1: 30,000 using the layout feature of ArcView GIS software. This map represents all of the 121 vegetation units described within the mapping area as represented by a total of 31156 vegetation polygons

Results

Classification and Field Guide to the Vegetation Types and Mapping Units:

This guide should be sufficient to identify all mappable vegetation types detected in the fieldwork for this project. Identification is by means of a key. The key is not a traditional dichotomous one, but is habitat-based, offering up general choices of different environments based on wetland/upland position and physiognomy of the vegetation. This approach was chosen: 1) to reduce the length and redundancy common to dichotomous keys, and 2) because such a guide can be easily mastered by non-botanists/plant ecologists. Our expectation is that this can be a stand-alone product that will allow anyone with some basic ecology background and knowledge of the main characteristic plant species of the marsh to identify its vegetation. Our hope is that this guide will afford further refinement to the understanding of vegetation in the marsh, both from the standpoint of the classification and in refining the accuracy of the existing vegetation map.

In most cases the vegetation types are based on quantitative sampling and analysis using TWINSPAN and cluster analysis (McCune 1997). However, other mappable types that were not sampled are included. Some of these unnamed types are un-vegetated (slough, mudflat, bare soil) and are defined by their physical characteristics. Others (mixed wetland herbs) are vegetated, but either botanically complex and too difficult to determine characteristic species from aerial photos, or are unnatural (e.g., iceplant) and do not warrant further classification in a vegetation map of natural vegetation.

The key is first broken into major units based on dominant plant life form: trees, shrubs and herbs. Within these groups it is further divided by wetland/upland distinctions, by graminoid or forb distinctions if herbaceous and also by height categories (e.g., tall, short, or medium height herbs). Since the vast majority of vegetation in the mapping area is herbaceous, this portion of the key is the most complicated and detailed.

The associations defined are based on quantitative analysis (see classification analysis section). Other categories in the keys such as "mapping units" or "stands" are either not floristically defined, or not represented by sufficient vegetation samples to warrant association status. A mapping unit is designated if we have a distinctive air photo signature for the type, but we don't have sufficient quantitative information to give it a formal name, or if the photo signature of the type is indistinct and thus represents an agglomeration of two to several distinctive vegetation types.

Within each group, vegetation types are listed by their alliance and association. An alliance is a floristically defined unit of vegetation characterized by one or more dominant species. An association is a sub-floristic unit of an alliance defined by characteristic species (not necessarily dominant), restricted to an environmental subset of the range of an alliance. Both alliances and the associations within them are defined quantitatively via vegetation sampling. (See Sawyer and Keeler-Wolf 1995, or Grossman et al. 1998 for further description of these classification units). In some cases associations are not defined for an alliance and just the alliance name is listed (see classification section for discussion). Often a particular vegetation alliance or association may occur in multiple groups. Each major group within the physiognomic groups should include all possible types identified within it. Descriptions are brief and restricted to salient individuating features. Complete descriptions of associated species and ecological settings will be published as separate findings and will be included in the next edition of the Manual of California Vegetation. A mapping classification hierarchy is presented in Table 5. This classification is based on the mapping hierarchy of vegetation used for air photo interpretation. Thus, it includes generic mapping units and undersampled stands as well as formally defined associations with sufficient field samples. This hierarchy is somewhat different than the formal National Vegetation Classification Hierarchy, which only classifies vegetation that has been sampled and analyzed through quantitative classification. An outline of how the 198 vegetation sample plots falls into the National Vegetation Classification is presented in **Appendix 3.**

In using the following key as a field guide it should be kept in mind that this is a key to vegetation mapping polygons, not necessarily to vegetation types. It was devised with the map in mind. The general question of whether an area meets the criteria should be assessed using the entire polygon. In some cases polygons have some substantial internal variation, thus an averaging approach, estimating the modal vegetation within a polygon should be invoked. Some polygons are unvegetated types, which are given codes based on their physiognomy. To assign polygons to a vegetation type run through appropriate general category, then choose the most appropriate category listed. If no association is listed go with the closest alliance or mapping unit type.

To use this guide without reference to the vegetation map, one should keep in mind the constraints of minimum mapping unit (mmu). In general, vegetation stands of upland types were not delineated below 0.5 acres in size (please see delineation section for further details). In some cases dominance must be averaged over the entire polygon and in all cases nominate species for a series must be evenly distributed over a stand to assign it to the nominate species series. For example, in a tall wetland herbaceous stand there may be a concentration of *Typha* (cattail) in a 1/4 acre area where the cover is; *Typha* 15% over a under story of *Distichlis spicata* (saltgrass) at 10%. However, over the majority of the surrounding 0. 5 acre polygon the cover is; *Distichlis* 55% and Typha 2%. Because the *Typha* area of dominance is below the minimum mapping unit, the whole area would be properly considered a *Distichlis* alliance map polygon. In this same vein there are many small wetland stands that have not been seen to reach mappable size in the study area. Thus, these fine-scale types are not included in the guide and are absorbed by the larger adjacent stands in the map. The key provides multiple avenues for arriving at the same answer for confusing groups, thus many of the confusing types are listed more than once and can be found in different parts of the key.

Table 5:

Field and Photo-Interpretation Key to the Vegetation Alliances and Defined Associations from The Suisun Marsh

Key to Main Vegetation Divisions:

I. Vegetation dominated by non-woody herbaceous species including grasses, graminoids, and broad-leaved herbaceous species. Tall shrub species, if present, of lower cover than herbs (<15%). Subshrubs, if present, may form significant cover (up to 30%), but never taller than dominant herbaceous vegetation. Trees, if present, compose <10% cover: **= <u>Division A, Herbaceous Vegetation</u>**

II. Vegetation dominated by woody shrubs or sub-shrubs. Trees, if present, generally less than 10% cover in stand, herbaceous species may total higher cover than shrubs, but are shorter in stature. Shrubs are always at least 10% cover = **<u>Division B, Shrub Vegetation</u>**

III. Vegetation dominated by trees (at least 5 m tall). Tree canopy may be as low as 12% over denser sub-canopies of shrub and herbaceous species = **<u>Division C, Tree Vegetation</u>**

<u>Division A Herbaceous Vegetation:</u>

<u>Group 1</u>: Vegetation Dominated by Grasses or Grass-like species**: = I**

IA. Upland grasslands generally not associated with saturated soil or tidal influence throughout the growing season, shrubs generally less than 10% cover or if more, sub-shrubs over-topped by the dominant grass species:

A1. Grasslands dominated by annual grass species with no more than 15% relative cover of native perennial species present in any stand . Dominant species include *Hordeum murinum*, *Bromus* spp.*, Lolium multiflorum* , and *Avena* spp.

a. Vegetation dominated by the annual non-native Italian ryegrass (*Lolium multiflorum*), although other non-native annual grasses (*Bromus hordaceous, Hordeum* spp.) may be present in lower cover. A common alliance of disked fields and managed uplands in the marsh, generally considered upland, but stands may be flooded or saturated for short periods in the winter and early spring = ***Lolium multiflorum*** **alliance**

1. *Lolium multiflorum* co-occurs in stands with significant amounts (>1-<50% cover) of *Lepidium latifolium* = ***Lolium/Lepidium*** **association 220**
2. *Lolium* occurs with significant portion of *Rumex crispus* or other *Rumex* species, does not have significant *Lepidium latifolium* = ***Lolium/Rumex*** **association 222**
3. *Lolium* is dominant, associatiated species may occur, but remain undifferentiated. Generally a mapping unit used when *Lepidium ,Rumex* and other associated species are not discernable **= *Lolium* (generic) 218**

b. Stands dominated by annual non-native *Bromus* spp (mainly *B. hordaceus*) and *Hordeum* (Including

H. marinum and *H. murinum*) generally occur in more upland settings than *Lolium* alliance **= *Bromus* spp./*Hordeum* spp. association 232**

c. Stands dominated by either *Hordeum murinum* or *H. marinum* but with a significant (> 10 %) mixture of *Lolium multiflorum.* = ***Hordeum/Lolium* association 234**

d. Stands dominated by rabbit's foot grass (*Polypogon monspeliensis)* usually in vernally wet areas in borders between wetland and upland vegetation but may occur in areas with saturated ground through the early summer months. This classification unit includes all stands of *Polypogon* . May have various subordinate species of herbs and grasses, but *Polypogon* is > 50% relative cover **= *Polypogon monspeliensis* stands (generic) 238**

e. stands dominated by annual species of *Vulpia* (typically *V. myuros*, rattail fescue) intermixed with a taller scattered emergent overstory of western goldenrod (*Euthamia occidentalis*) =***Vulpia* sp. /*Euthamia occidentalis* association 235**

f. Grasslands dominated by annual species with no single species discernable or predominant. Generally a mapping unit and not used as an on the ground classification. Dominant species include *Hordeum murinum*, *Bromus* spp., *Lolium spp* , *Polypogon monspeliensis*, and *Avena* spp.**= Annual Grasses generic 231**

g. A mapping unit distinguished by grasslands dominated by annual species with a significant component (usually 10%-30% absolute cover) of taller non-native forbs such as *Sonchus oleracea. Lactuca seriola*., *Picris* , etc**. = Annual Grasses/Weeds 227**

h. Annual grass-dominated mapping unit distinguished by heavily managed site history. Species various, but planted, mowed and/or cultivated regularly **= Cultivated Annual Graminoid 225**

i. An association with annual grasses such as *Hordeum* spp. *Lolium multiflorum*, and *Polypogon monspeliensis* associated with saltgrass (*Distichlis spicata*). Either saltgrass or annual grasses may be dominant. **= *Distichlis spicata*/Annual Grasses association 142**

j. A mapping unit with tallest vegetation layer dominated by *Salicornia* and a dense layer of annual grasses (*Polypogon*, *Hordeum*, *Lolium, Bromus* spp.) beneath. Stands that key here have high grass and relatively low *Salicornia* cover (down to 15% relative cover of *Salicornia*) = ***Salicornia*/Annual Grasses 347**

A2. Grasslands and stands of graminoids (grass-like species) with at least 50% relative cover of perennial species.

a. Upland perennial grassland stands averaging between 0.5 and 1 m in height

1. Stands dominated (>50% relative cover) by the native creeping ryegrass (*Leymus triticoides*). Stands are generally narrow bands of wetland-upland borders including natural ecotones

between *Distichlis spicata* alliance and *Lolium multiflorum* alliance, *Bromus-Hordeum* association , or other annual grass stands. Also occurs along levee tops and margins of marsh adjacent to vegetation of intermittent flooding zone= ***Leymus triticoides* alliance (generic) 215**

2. Stands dominated (> 50% relative cover) by the introduced perennial bunchgrass *Agrostis avenacea*. Scattered throughout the marsh usually in small stands in open disturbed areas usually associated with other non-native annual species **= *Agrostis avenacea* stands 228**
3. a mapping unit defined by stands of unknown composition of mostly medium height graminoids of uplands = **Medium Upland Graminoids 210 (generic)**
4. a mapping unit defined by perennial grass/graminoid dominance of unknown composition **= Perennial Grass 226**

b. Upland grassland stands dominated by tall perennial grasses generally > 1 m in height.

1. stands dominated by the very large, tall non-native pampas grass (*Cortaderia selloana*). Stands are generally small, but conspicuous, and occur in moist areas in ecotone between wetlands and uplands.. Some stands occur in wetlands **= *Cortaderia selloana* alliance 202**
2. Stands dominated strongly by the large non-native tall wheatgrass (*Elytrigia pontica*), typically planted in upland or intermittently flooded alkaline fields within the marsh; as at Grizzly Island **= *Elytrigia pontica* stands 211**
3. Stands dominated by the tall bunch grass Canary Grass (*Phalaris aquatica*). Usually small stands along levees, but may occur in larger upland stands adjacent to the marsh (e.g, Rush Ranch). **= *Phalaris aquatica* stands 223**
4. A mapping unit dominated by unspecified upland grasses including *Cortaderia, Elytrigia pontica,* and/or *Phaleris aquatica* **= Tall Upland Graminoids 201 (generic)**
5. a mapping unit defined by perennial grass/graminoid dominance of unknown composition **= Perennial Grass 226**

c. a mapping unit defined by short (<0.5 m) perennial grass/graminoid dominance of unknown composition = **Short Upland Graminoids 230 (generic)**

IB. Wetland grasslands and stands dominated or co-dominated by graminoids (*Juncus* spp., *Carex* spp., *Scirpus* spp., *Typha* spp.). Occurs in conditions where substrate is intermittently, temporarily or permanently saturated or flooded throughout the growing season. Some stands have a significant broad-leaf herbaceous component, but all have near equal or greater proportion of total vegetative cover composed of grasses/graminoids.

B1. Stands dominated or co-dominated by grasses and graminoids generally between 0.5-1 m tall. (Includes all Medium Wetland Graminoids, a mapping unit with unspecified dominance = Medium Wetland Graminoids 130 [generic])

a. Vegetation of regularly disturbed winter and vernally wet ponds and fields usually on fine-grained clay rich soils . May be dominated by any of the three following species, but typically has *Polygonum* *lapathifolium* and *Echinocloa crus-gallii* as the two main species, occasionally *Xanthium strumarium* (cocklebur) may be rare or even absent = ***Echinocloa-Polygonum-Xanthium strumarium* Association of the *Polygonum lapathifolium-Echinocloea crus-galii* Alliance 159**

b. Vegetation dominated by the stoloniferous (clonal) rush *Juncus balticus* (including some individuals more closely resembling *Juncus mexicanus*), often associated with other taller or shorter herbaceous species. Usually of temporarily saturated wetlands not inundated for extensive periods = ***Juncus balticus* alliance**

Includes four different associations:

1. Stands strongly dominated by *J. balticus* with low cover of other species = ***Juncus balticus* association 132**

2. *Conium maculatum* (Poison hemlock) forms an overstory of varying cover (sometimes approaching cover of the underlying *Juncus*) generally in disturbed fields and wetland borders **= *Juncus balticus/Conium maculatum* association 133**

3. *Juncus balticus* forms the principal ground layer with the often somewhat taller nonnative *Lepidium latifolium* (perennial pepperweed) as a principal associate, found in both managed and unmanaged sites, uncommon **= *Juncus balticus/Lepidium* association 134**

4. Stands with a taller graminoid layer of *Juncus balticus* with a sparse to dense short herbaceous understory characterized by *Potentilla anserina* (may include several other native herbs) **= *Juncus balticus/Potentilla anserina* association 135**

c. Vegetation of seasonally wet flats and pond bottoms, dominated (>50% relative cover) by *Scirpus maritimus* (Alkali bulrush) in the taller herb/graminoid layer. May include short herbs or grasses with near equal or higher cover than the taller *S. maritimus*. Some stands also include the similar species, *Scirpus robustus* or hybrids between the two = ***Scirpus maritimus* alliance 137** (includes pure stands and the generic category)

also differentiated into the following associations:

1. Vegetation with an overstory of *Scirpus maritimus* and/or *S. robustus* with a shorter higher or lower cover of *Salicornia virginica.* If both *Sesuvium* and *Salicornia* present in near equal cover, then *Salicornia* is considered the indicator species = ***Scirpus maritimus/Salicornia virginica* association (138)**
2. Vegetation with an overstory of *Scirpus maritimus* and or *S. robustus* with a shorter and +-equal or lower cover of *Sesuvium verrucosum* (sea purslane) If both *Salicornia* and *Sesuvium* present then *Sesuvium* must greatly exceed *Salicornia* for it to be the indicator species . = ***Scirpus maritimus/Sesuvium verrucosum* association (139)**

d. Vegetation of tidally inundated mudflats, dominated by the native cordgrass *Spartina foliosa*, localized at the SW edge of Suisun Marsh **= *Spartina foliosa* alliance and association (136)**

B2. Stands dominated by annual or perennial grasses less than 0.5 m tall. May include taller overstory grass or herbaceous species, but these are not the dominant species = Short Wetland Graminoids 140 (generic)(<0.5 m)

Includes the following types:

a. Short annual grass-dominated stands dominated by the low annual swamp timothy (*Crypsis schoenoides*). Found in winter and vernally flooded flats and pools. Vegetation generally scattered with interveining small to large openings of dry, cracked mud during summer **=*Crypsis schoenoides* alliance and association 155**

b. Vegetation dominated by perennial sod-forming grasses although other grass or herb species in stand may be taller:

1.Stands usually dominated (> 50% relative cover) by saltgrass (*Distichlis spicata*), or if not dominant, saltgrass has higher cover than any other single species = ***Distichlis spicata* alliance**

Includes the following types:

i. stands strongly dominated by saltgrass with no other species greater than 5% cover = ***Distichlis spicata* association 141**

ii. stands with an overstory of *A. triangularis* covering at least 40% relative cover and an understory of *Distichlis spicata* (saltgrass) which may approach or even exceed *A. triangularis* in total cover. **= *Atriplex/Distichlis* association 312**

iii. stands of saltgrass with the annual *Cotula coronopifolia* (brass-buttons) as a subordinate species **= *Distichlis/Cotula* association 153**

iv stands of saltgrass with *Juncus balticus* (or *mexicanus*) principal subordinate species (> 5% relative cover) = ***Distichlis/Juncus* association 145**

v stands of saltgrass with *Lotus corniculatus* (bird's foot trefoil) as major sub ordinate species = ***Distichlis/Lotus* association 147**

vi. stands of saltgrass with pickleweed (*Salicornia virginica*) as major subordinate species, *Salicornia* may be from 1/3 to almost equal cover of *Distichlis* **=*Distichlis/Salicornia* association 148**

vii. saltgrass is major low grass species with emergent taller *Scirpus americanus* (three square) conspicuous, but less than 40% cover **= *Distichlis/Scirpus americanus* association 149**

viii Saltgrass is major short ground cover with a sparse to intermittent overstory of cattails (typically *Typha angustifolia*, but may include *T. latifolia* and/or *T. dominigensis*) = ***Distichlis/Typha* species association 126**

ix. Saltgrass is major ground cover, associated with a variety of native tidal marsh species including *Triglochin maritima*, *Glaux maritima*, *Jaumaea carnnosa*, and *Limonium californicum* = ***Distichlis-Juncus-Triglochin-Glaux* association 160**

x. Stands composed of a mixture of saltgrass and non-native annual grasses. *Distichlis* may be dominant or share dominance (as low as 40% relative cover) with annual grass species (primarily *Polypogon. Lolium*, and/or *Hordeum* spp.) generally annuals cover at least 10% **= *Distichlis*/Annual Grasses association 142**

xi. a mapping unit characterized by a dominance of *Distichlis spicata* with or without undifferentiated associated species **= *Distichlis spicata* (generic) *156***

2. Stands dominated by the low introduced Bermuda grass (*Cynodon dactylon*). Generally associated with human structures or disturbed levee tops, occasional throughout the marsh = ***Cynodon dactylon* stands 161**

B3. Stands dominated (at least 10% cover over a sometimes greater cover of shorter herbs and graminoids) by tall (generally > 1 m) wetland grasses and graminoids including *Typha* sp. (cattails), *Scirpus* sp. (tules and bulrushes), and reeds (*Arundo donax* and *Phragmites australis*).

a.Vegetation dominated by California Bulrush (*Scirpus californicus*) and/or the ecologically and morphologically similar giant bulrush *Scirpus acutus.* Locally *S. californicus* appears to be more abundant that *S. acutus*, but both appear frequently in the same stands. Occasionally *Typha* spp. may occur in equal or higher cover than the *Scirpus* spp., but *Scirpus californicus* or *S. acutus* always at least 10% relative cover**= Tall Bulrush (*Scirpus californicus- Scirpus acutus*) Alliance**

may be further differentiated into the following types:

1. Stands dominated by *S. acutus* and or *S. californicus* with little (<20% relative cover) or no other species present - ***Scirpus californicus/S. acutus* association 116**

2. Stands dominated in the overstory by *Scirpus californicus* and/or *S. acutus* with a lower (down to 2%) to somewhat higher cover of *Typha angustifolia, T. latifolia*, and/or *T. dominigensis*, may have up to 50% cover of wetland herbs (*Polygonum, Epilobium, Euthamia*, etc.) **= *Scirpus* (*californicus* and/or *acutus*)-*Typha* sp. association 157**

3. Stands dominated by *Scirpus californicus* and or *S. acutus* with an understory of > 12% that is a varying mixture of mostly native perennial herbs such as *Euthamia occidentalis, Aster lentus, A. subulatus, Artemisia douglasiana, Baccharis douglasiana*, *Achillea millefolium,* and *Stachys adjugoides.* May also include *Lepidium* **= *Scirpus (californicus* and/or *acutus*)/Wetland Herbs 158**

4. *Rosa californica* present (as low as 5% cover) with *Scirpus californicus* and/or *S. acutus*. Usually along levees bordering sloughs and channels **= *Scirpus* (*californicus* or *acutus*)/*Rosa* 162**

b. stands dominated by cattail species including *Typha angustifolia, T. latifolia,* and *T. domingensis*. The distinguishing features of these three species are often blurred in the marsh and there is frequently evidence of hybridization. *Typha* species are often found in the same stand and are considered ecologically equivalent. Throughout most of the marsh, narrow-leaved forms (*T. angustifolia/domigensis*) predominate **= *Typha angustifolia-latifolia-domingensis* alliance**

may be further subdivided into the following groups:

1. *Typha* sp dominate over a short understory of saltgrass (*Distichlis spicata*). Generally occurs in managed wetands where fields and ponds have had an combination of flooding and mechanical disturbance = ***Typha angustifolia-latifolia-domingensis* /*Distichlis* association 126**

2. Stands dominated by *Typha* with lesser cover of the common reed (*Phragmites australis*) = ***Typha angustifolia-latifolia-domingensis /Phragmites australis* 129**

3. Stands dominated by *Typha* sp. with a mixture of *Echinochloea crus-galii, Polygonum lapathifolium,* and/or *Xanthium strumarium*. Usually occurs in managed wetland ponds that have heald water late into the growing season = ***Typha angustifolia-latifolia-domingensis /Echinocloa-Polygonum-Xanthium* 120**

4. *Typha* sp. dominate with three-square (*Scirpus americanus*) as a common component. *S. americanus* may equal cover of *Typha* or be as low as 10% relative cover if no other tall graminoids present. Edges of tidal sloughs and ditches = ***Typha angustifolia-latifolia-domingensis /S. americanus* 121**

5. *Typha* species are strongly dominant or *Typha* sp. occur as a mapping unit without clear identification of any other associated species **= *Typha* species (generic) 123**

c.stands dominated (> 50% relative cover) by the American bulrush (three-square), *Scirpus americanus*, generally occupies portions of the marsh that are saturated, but not permanently flooded, often along the upper reaches of tidally influenced sloughs, creeks, and ditches = ***Scirpus americanus* alliance**

may be further subdivided into the following associations:

1. *Scirpus americanus* dominant overstory with significant understory of *Lepidium latifolium*, which may approach *S. americanus* in total cover. Tends to replace native associations such as *S. americanus/Potentilla anserina* along small tidal creeks and channels **= *Scirpus americanus/Lepidium latifolium* association 127**
2. *Scirpus americanus* dominant overstory with native *Potentilla anserina* as principal understory species, occurs along small tidal creeks, ditches in non-managed portions of the marsh **= *Scirpus americanus/Potentilla anserina* association 112**
3. *Scirpus americanus* may dominate or be co-dominant with *Scirpus californicus* and/or *S. acutus*, usually along deeper or wider sloughs and channels than previous two associations = ***Scirpus americanus/S. californicus-S. acutus* 113**
4. A mapping unit distinguished by dominance of *S. americanus* without associated species identified **= *Scirpus americanus* (generic) 114**

d. Common reed (*Phragmites australis*) is the principal dominant species (> 50% relative cover). Generally forming close-ranked clonal stands, the largest and most widespread occur in managed portions of the marsh = ***Phragmites australis* alliance**

may be further subdivided into the following associations:

1. *Phragmites* dominates (>50% relative cover) in association with *Scirpus acutus* and/or *S. californicus* generally along slough and larger channel banks throughout marsh **=*Phragmites/Scirpus* association 104**
2. Stands strongly dominated by *Phragmites* without significant cover of any other species **= *Phragmites australis* association 103**
3. Stands of *Phragmites* mixed with *Xanthium strumarium* (Cocklebur). Usually in managed wetland ponds and seasonally flooded flats **= *Phragmites/Xanthium* association 105**

e. Clonal dense stands of *Arundo donax* (Giant reed), generally small and locally distributed near settlements and roads in marsh **= *Arundo donax* alliance and association 102**

f. Mapping unit distinguished by tall wetland graminoids of undetermined species **=Tall Wetland Graminoids 101 (generic)**

Group II : Vegetation dominated by Annual or Perennial Forbs = II

IIA. Vegetation dominated by tall (>1 m) non-native annual forbs of uplands including species such as *Raphanus sativa, Brassica nigra* and *Conium maculatum* . May have an understory of annual grasses with equal or higher cover (overstory needs to be at least 10% cover evenly distributed over polygon). Disturbed fields, levees, railroad sidings.

a, A mapping unit or a mixed association with either undifferentiated species or a more-or-less even mix of two or more species. **= Tall Upland Herbs 401 (generic)** (>1m)

b. stands dominated by *Brassica nigra* (black mustard) **= *Brassica nigra* (generic) 406**

c.stands dominated by *Conium maculatum (*poison hemlock) **= *Conium maculatum* 402**

d. stands dominated by *Foeniculum vulgare* (fennel) **= *Foeniculum vulgare* 403**

e. stands dominated by wild radish = ***Raphanus sativus* (generic) 405**

IIB. Vegetation dominated by short herbs (< 0.5 m tall) found in upland portions of the mapping area

a. Stands of undifferentiated short upland herbs; a mapping unit = **Short Upland Herbs 420 (generic)** (<0.5 m)

b. Vegetation dominated (> 50% relative cover) by perennial non-native Iceplant (*Carpobrotus edulus*), generally local in marsh area on levees and areas adjacent to buildings = **Iceplant (*Carpobrotus edulus*) Alliance 421**

II C. Vegetation dominated by medium (0.5-1 m tall) upland herbs.

a. a general mapping unit defined by medium height herbaceous species (non-grass or graminoid) of uplands = **Medium Upland Herbs 410 (generic)**

b. stands dominated (at least in summer) by yellow star thistle (*Centaurea solstitialis*). Occurs in narrow upland belts as on levee tops or broad expanses in uplands adjacent to the marsh as in Garibaldi unit or Rush Ranch. Some stands occur within drier managed areas (Grizzly Island Wildlife Area, Montezuma Wetlands, private clubs) = ***Centaurea solstitialis* alliance (generic) 413**

IID. Vegetation co-dominated by a combination of tall bulrush (*Scirpus californicus* and/or *S. acutus* and medium to tall wetland herbs

a. Indian hemp (*Apocynum cannibinum*) and tall bulrush (*Scirpus californicus* and/or *S. acutus)* co-occur in stands. Occasional on levees and channel edges **= *Apocynum/Scirpus* 302**
b. Stands co-dominated by *Scirpus californicus* and/ or *S. acutus* and an herbaceous component that is a varying mixture of mostly native perennial herbs such as *Euthamia occidentalis, Aster lentus, A. subulatus, Artemisia douglasiana, Baccharis douglasiana, Achillea millefolium,* and Stachys *adjugoides*. May also include *Lepidium* **= *Scirpus* (*californicus* and/or *acutus*)/Wetland Herbs 158**

IIE. Vegetation dominated (> 50% relative cover in tallest layer) by medium height (0.5-1m) herbaceous species of wetlands. If taller layer is present and is 10% or greater cover, then go to IIA or IB.

a. a generic mapping unit of undifferentiated medium height wetland herbs **= Medium Wetland Herbs 310 (generic)**
b. Stands dominated or characterized by *Atriplex triangularis* (Fat hen). Generally of managed temporarily or intermittently flooded saline or slightly saline wetlands. This is a late season species that is generally ephemeral and may wax and wane from year to year **= *Atriplex triangularis* alliance**

May be further differentiated into the following associations:

1. stands strongly dominated by *Atriplex triangularis* with few other species (none greater than 5% cover) **= *Atriplex triangularis* association 311**

2. stands with an overstory of *A. triangularis* covering at least 40% relative cover and an understory of *Distichlis spicata* (saltgrass) which may approach or even exceed *A. triangularis* in total cover. **= *Atriplex/Distichlis* association 312**

3. stands with an overstory of *A. triangularis* and an understory of annual non native grasses including *Polypogon* , *Hordeum* sp., *Lolium* sp. and *Bromus* sp. Annual grasses are > 10% absolute cover = ***Atriplex*/Annual Grasses stands 337**

4. stands characterized by a mixture of *A. triangularis* and *Scirpus maritimus* (alkali bulrush) **= *Atriplex/S. maritimus* association 315**

5. stands characterized by a mixture of *Atriplex triangularis* with a low understory of *Sesuvium verrucosum* = ***Atriplex/Sesuvium* association 316**

6. a mapping unit defined by dominance of *A triangularis* with or without unspecified associated species = ***Atriplex triangularis* (generic) 339**

c. The subshrub *Frankenia salina* (alkali heath) dominant or important, may have equal or somewhat higher cover of *Distichlis* or annual grasses. Generally of seasonally moist or intermittently flooded clayey saline soils = ***Frankenia salina* Alliance**

May be further differentiated into the following types:

1. *Frankenia salina* dominant with conspicuous tufts of *Agrostis arenacea* = ***Frankenia/Agrostis* stands 317**

2. *Frankenia* important with lower to slightly higher cover of *Distichlis* = ***Frankenia/Distichlis* association 318**

3. A mapping unit characterized by *Frankenia* either as sole dominant or with undetermined associated subordinate species = ***Frankenia* (generic) 320**

d. Stands dominated by the diffuse perennial herb or subshrub *Grindelia stricta* var. *stricta* (gum plant). May contain a variety of subordinate species some weedy, some native. Typically of edges of wetlands on slightly elevated or drier ground than adjacent vegetation (natural or constructed levees, road margins, etc.) = ***Grindelia stricta* var. *stricta* stands 321**

e..Stands dominated by the invasive *Lepidium latifolium* (perennial pepperweed) may occur in temporarily flooded, intermittently flood and saturated wetlands, typically in at least slightly saline soils. Appears to be expanding in marsh and is particularly threatening to native tidal marsh vegetation such as *Scirpus americanus, Juncus balticus,* and *Distichlis spicata* alliance stands (as at Rush Ranch). **= *Lepidium latifolium* alliance**

May be further subdivided into:

1. Stands with *Lepidium latifolium* as dominant with an understory of saltgrass = ***Lepidium/Distichlis* stands 323**

2. a mapping unit distinguished by dominance of *Lepidium latifolium* with or without additional species such as *Scirpus* sp.,*Typha* sp., *Potentilla anserina, Oenanthe samentosa, Aster lentus, Cirsium hydrophyllum, Achillea millefolium, Baccharis douglasiana*, etc. Insufficient samples to determine further association level differences.= ***Lepidium* (generic) 324**

f. Stands dominated by *Potentilla anserina* (silverweed) . A relatively localized type of non-managed tidal marsh, often with a sparse overstory (1-15%) of *Juncus balticus* and/or *Scirpus americanus* = ***Potentilla anserina* stands (generic) 338**

g. Stands dominated by *Rumex* species (*Rumex crispus, R. pulcher, R. conglomeratus* are most common) Generally of winter flooded and/or saturated fields and flats, often with near equivalent cover of annual grasses in understory = ***Rumex* (generic)   336**

h. Vegetation dominated or co-dominated by *Euthamia occidentalis* and *Vulpia* sp. Stands that key here will have near equivalent cover of both species. Stands that have more *Vulpia* cover can be keyed in the annual upland grass section. = ***Vulpia/Euthamia*   stands 235**

IIF. Stands of wetland vegetation characterized by the dominance of short (<0.5 m) herbaceous species = Short Wetland Herbs   340 (generic)

a. stands dominated or co-dominated by the non-native annual *Cotula coronopifolia* (brass buttons) and/or the native *Sesuvium verrucosum* (sea purslane). Usually of saline temporarily flooded, often managed wetlands.

1. stands strongly dominated by *Cotula* with little or no significant cover from other species **= *Cotula coronopifolia*   alliance (generic) 342**

2**.** Stands dominated or co-dominated by the native annual herb *Sesuvium verrucosum* (sea purslane)

May be further subdivided into the following categories:

i. *Sesuvium* dominant with *Cotula* from 1-20% cover- **= *Sesuvium/Cotula* association 362**

ii**.** *Sesuvium* dominant with light to near equal cover of saltgrass (*Distichlis spicata*) = ***Sesuvium/Distichlis*   association 358**

iii. *Sesuvium* dominant or important . Other herbs (non-grass) such as *Cotula coronopifolia* and *Spergularia marina* may form near equal cover**= *Sesuvium verrucosum* association   357**

iv. *Sesuvium* occurs with the annual grass *Lolium multiflorum* = ***Sesuvium/Lolium* stands 359**

b. Stands dominated or co-dominated by the non-native yellow-flowered *Lotus corniculatus* (bird's foot, trefoil); often at edges of intermittently flooded wetlands may occur with an equally or slightly higher cover e.g., up to 60% grass and 40% *Lotus*) of annual grasses such as *Lolium multiflorum* **= *Lotus corniculatus* alliance 344**

c. stands dominated by *Spergularia marina* (salt marsh sand spurry) with *Cotula* as an associate = ***Spergularia/Cotula*   360**

IIG. Vegetation growing in standing water and supported by water (non-emergent)

a. includes a general mapping category for all undifferentiated floating leaved hydrophytes **= Floating-leaved Wetland Herbs   370 (generic)**

b. floating in open ponds as floating masses strongly dominated by *Potamogeton pectinatus* (narrow-leaved pondweed) = ***Potamogeton pectinatus* association 371**

IIH. Vegetation dominated (at least 10% cover over a sometimes higher cover of short annual or perennial grasses) by the native perennial salt marsh sub-shrubby or herbaceous Pickleweed (*Salicornia virginica*) = *Salicornia virginica* Alliance

represented locally by several associations differentiated by their character species:

a. vegetation dominated solely by *Salicornia virginica*, more than twice as much cover by than any other combination of species in stand **=** ***Salicornia virginica*** **association 346**

b. vegetation dominated by *Salicornia* with a variable amount of *Atriplex triangularis.* May include other species such as *Scirpus maritimus, Bassia,* but these usually in lower total cover than *A. triangularis.* A common type of managed wetlands = ***Salicornia/Atriplex*** **association 348**

c. Vegetation dominated by *Salicornia* with an ephemeral annual component of *Cotula* (Brass buttons *Salicornia*), which may cover enough ground to co-dominate in the early growing season = ***Salicornia/Cotula*** **365**

d. Vegetation dominated by *Salicornia* mixed with a short intermittent layer of *Crypsis* (swamp timothy) **=** ***Salicornia/Crypsis*** **350**

e. vegetation may be co-dominated by *Salicornia* and *Distichlis* either species may be > or = 30% relative cover = ***Distichlis/Salicornia*** **association 148**

f. Vegetation dominated by *Salicornia* but with a mixture of relatively tall non-native and native herbs and graminoids including *Echinocloa crus-galli*, *Polygonum lapathifolium*, and *Xanthium strumarium.* Typically of managed wetlands = ***Salicornia/Echinocloa-Polygonum-Xanthium*** **association 364**

g. Tallest vegetation layer dominated by *Salicornia* with a sparse to dense mixture of annual grasses (*Polypogon, Hordeum, Lolium, Bromus* spp.) beneath = ***Salicornia*****/Annual Grasses 347**

h. Vegetation dominated or co-dominated by *Salicornia* with *Sesuvium* (sea purslane) as a main subordinate species (at least 20% relative cover), may also include relatively high cover of *Cotula* **=** ***Salicornia/Sesuvium*** **356**

i. A mapping unit defined by the dominance of *Salicornia* with or without associated species = ***Salicornia*** **(generic) 361**

Division B Shrub-Dominated Vegetation:

Group I. Scrub dominated by tall (>3m) broad-leaved winter deciduous wetland species

1A. narrow-leaf willow (*Salix exigua*) is dominant, typically narrow stringers of upper marsh along fresh water creeks and seeps = *Salix exigua* alliance 502

1B. A generalized mapping unit for undifferentiated tall wetalnd shrubs =

Tall Wetland Shrubs 501 (generic)

Group II. Scrub dominated by medium height (1- 3 m) species

IIA. Generalized mapping category for all undifferentiated wetland shrubs = Medium Wetland Shrubs 510 (generic)

IIB. Scrub dominated by the medium-to-large-sized grayish shrub (up to 4 m in height), *Atriplex lentiformis* (quailbush). Generally occurs in small stands at borders of managed fields and intermittently flooded wetlands, usually associated with annual grasses and non-native herbs =*Atriplex lentiformis* (generic) 514

IIC. A generalized mapping category for undifferentiated upland shrubs 1-3 m tall = Medium Upland Shrubs

601 (generic)

IID. Vegetation characterized by the presence of *Rosa californica* (California wild rose) in the shrub strata, may or may not be the dominant

1. *Rosa californica* dominant and conspicuous, often forming narrow briar patches along levees and roads, occasionally in lower lying portions of marsh). Includes stands strongly dominated by *Rosa* **= *Rosa californica* alliance 604**
2. *Rosa* and *Baccharis* pilularis co-occur in stand, either species may be dominant, but both over 5% cover. **= *Rosa/Baccharis* association 605**
3. *Rosa* present with *Scirpus californicus* and/or *S. acutus*. Usually along levees bordering sloughs and channels (including intertidal zone) **= *Scirpus* (*californicus* or *acutus*)/*Rosa* 162**

IIE. *Baccharis pilularis* (coyotebush) is dominant although other shrubs (other than *Rosa californica*) may co-occur (e.g., *Atriplex lentiformis*). Understory is typically dominated by annual grasses (*Hordeum, Lolium, Bromus* spp.) = *Baccharis*/Annual Grasses 603

IIF. Vegetation dominated by the introduced *Rubus discolor* (Himalayan berry), often in narrow briar patches along levees and roads in marsh = *Rubus discolor* alliance 606

Division C Tree Dominated Vegetation:

Group I. woodland or forest dominated by tree-sized wetland (> 5 m) willows =

Willow Trees 700 (generic)

IA. Willows include a mix of Red willow (*S. laevigata*) and Arroyo willow (*S. lasiolepis*) Generally at edges of marsh along freshwater creeks = *Salix laevigata/S. lasiolepis* association 702

IB. Arroyo willow (*S. lasiolepis)* mixed with coast live oak (*Quercus agrifolia*) = *Salix lasiolepis/Quercus agrifolia* 705

Group II. Woodland or forest dominated by species of *Quercus* (oaks) = Oaks 900 (Generic mapping unit for undifferentiated oak stands)

May be further subdivided into:

IIA. Oak stands dominated by *Quercus agrifolia* (coast live oak). Typically bordering freshwater creeks at upper reaches of marsh only = *Quercus agrifolia* alliance 901

IIB. Oak stands dominated by *Quercus lobata* (valley oak) occasionally along edges of creeks at upper edges of marsh = *Quercus lobata* alliance 903

Group III. Woodland or forest stands dominated by introduced *Eucalyptus* sp. =

IIIA. generic mapping unit composed of undifferentiated eucalyptus species = *Eucalyptus* 800 (generic)

IIIB Planted stands dominated by Eucalyptus globulus (blue gum) . the most common species of eucalyptus in the marsh. = *Eucalyptus globulus* 801

<u>Group IV.</u> Woodland or forest stands dominated by trees other than above species:

IV A. Usually planted trees without spreading or self-perpetuating stands =Landscape Trees 910

Includes the following groups:

***Ailanthus altissima* stands 911**

***Fraxinus latifolia* stands 912**

Cross-walking to Other Classifications:

The term “cross-walking” is commonly used in vegetation mapping and classification. It refers to the development of relationships between classification systems. The need for cross-walking arises when, as in this project, there is more than one classification system in use for a given area. In this project the contract calls for relating the principle MCV classification (Sawyer and Keeler-Wolf 1995) to the Wildlife Habitat Relationships (Mayer and Laudenslayer 1988),and Holland (1986) classifications.

In a vegetation map cross-walking is never precise. Assuming classifications arise independently, the meaning of one classification unit may not always encompass, or be nested within, the other classification unit(s) to which it’s being related. Choices always have to be made about those classification units that are partially included within two or more types of another classification system. For labeling a vegetation map one, only one choice can be made for each relationship drawn. Thus, typically a “modal” expression of the vegetation unit in question is chosen. For example, the Holland (1986) classification unit Coast and Valley Brackish Marsh actually includes many vegetation alliances (see Table 6). Likewise the National Vegetation Classification alliance *Typha* spp.- *Scirpus acutus* can be partly in Holland’s Valley and Coastal Freshwater Marsh and Valley and Coastal Brackish Marsh. However, as most of the Suisun Marsh expression of *Typha* spp.- *Scirpus acutus* alliance is encompassed by Holland’s Valley and Coastal Brackish Marsh, we chose it as the single type to be related to the *Typha* spp. – *Scirpus acutus* alliance.

The complexity and uncertainty of such relationships arise not only from independent evolution of classifications, but also from their imprecise definitions, without quantitative rules for proper interpretation. The best crosswalks are those that have been developed with a good understanding of the meaning and definitions of each classification system.

Table 6: Cross-walk of Classifications between NVC Quantitative, Holland (1986), and WHR (Mayer and Laudenslayer 1988)

Formation Category	Suisun Classification Name	Suisun number	Holland code	Holland name	WHR code	WHRname
	Bare Ground 001	1		none	none	
	Fallow Disced Field 002	2		none	CRP	cropland
	Parking Lot 003	3		none	URB	urban
	Road 004	4		none	URB	urban
	Structure 005	5		none	URB	urban
	Slough 006	6		none	EST	esturine
	Tidal Mudflat 007	7		none	EST	esturine
	Railroad Track 008	8		none	URB	urban
	Ditch 009	9		none	EST	esturine
	Trail 010	10		none	URB	urban
	Flooded Managed Wetland 011	11		none	LAC	lacustrine
	Freshwater Drainage 012	12		none	RIV	riverine
	Water Treatment Pond 013	13		none	LAC	lacustrine
	Urban Area 014	14		none	URB	urban
Tall Wetland Graminoids	101 (generic) (>1 m)	101	52200	coastal brackish marsh	SEW	saline emergent wetland
	Arundo donax 102	102	52410	coastal and valley freshwater marsh	FEW	fresh emergent wetland
	Phragmites australis 103	103	52200	coastal brackish marsh	SEW	saline emergent wetland
	Phragmites/Scirpus 104	104	52200	coastal brackish marsh	SEW	saline emergent wetland
	Phragmites/Xanthium 105	105	52200	coastal brackish marsh	SEW	saline emergent wetland
	Scirpus americanus/Lepidium 127	127	52200	coastal brackish marsh	SEW	saline emergent wetland
	Scirpus americanus/Potentilla 112	112	52200	coastal brackish marsh	SEW	saline emergent wetland
	Scirpus americanus/S. Californicus-S. acutus 113	113	52200	coastal brackish marsh	SEW	saline emergent wetland
	Scirpus americanus (generic) 114	114	52200	coastal brackish marsh	SEW	saline emergent wetland
	Scirpus californicus/S. acutus 116	116	52200	coastal brackish marsh	SEW	saline emergent wetland
	Scirpus (californicus or acutus)/Rosa 162	162	52200	coastal brackish marsh	SEW	saline emergent wetland
	Scirpus (californicus or acutus)-Typha sp. 157	157	52200	coastal brackish marsh	SEW	saline emergent wetland
	Scirpus (californicus or acutus)/Wetland Herbs 158	158	52200	coastal brackish marsh	SEW	saline emergent wetland
	Typha angustifolia (dead stalks) 125	125	52410	coastal and valley freshwater marsh	FEW	fresh emergent wetland
	Typha angustifolia/Distichlis 126	126	52200	coastal brackish marsh	SEW	saline emergent wetland
	Typha angustifolia/Phragmites 129	129	52200	coastal brackish marsh	SEW	saline emergent wetland

Formation Category	Suisun Classification Name	Suisun number	Holland code	Holland name	WHR code	WHRname
	Typha angustifolia/Polygonum-Xanthium-Echinochloa 120	120	52410	coastal and valley freshwater marsh	FEW	fresh emergent wetland
	Typha angustifolia/S. americanus 121	121	52200	coastal brackish marsh	SEW	saline emergent wetland
	Typha species (generic) 123	123	52410	coastal and valley freshwater marsh	FEW	fresh emergent wetland
Medium Wetland Graminoids (0.5-1 m)	130 (generic)	130	52200	coastal brackish marsh	SEW	saline emergent wetland
	Juncus balticus/Conium 133	133	52200	coastal brackish marsh	SEW	saline emergent wetland
	Juncus balticus/Lepidium 134	134	52200	coastal brackish marsh	SEW	saline emergent wetland
	Juncus balticus/Potentilla 135	135	52200	coastal brackish marsh	SEW	saline emergent wetland
	Scirpus maritimus 137	137	52200	coastal brackish marsh	SEW	saline emergent wetland
	Scirpus maritimus/Salicornia 138	138	52200	coastal brackish marsh	SEW	saline emergent wetland
	Scirpus maritimus/Sesuvium 139	139	52200	coastal brackish marsh	SEW	saline emergent wetland
	Spartina foliosa 136	136	52110	Northern coastal salt marsh	SEW	saline emergent wetland
Short Wetland Graminoids (generic)(<0.5 m)	140	140	52200	coastal brackish marsh	SEW	saline emergent wetland
	Crypsis schoenoides 155	155	52200	coastal brackish marsh	SEW	saline emergent wetland
	Distichlis spicata 141	141	52200	Northern coastal salt marsh	SEW	saline emergent wetland
	Distichlis/Annual Grasses 142	142	52200	coastal brackish marsh	SEW	saline emergent wetland
	Distichlis/Cotula 153	153	52200	coastal brackish marsh	SEW	saline emergent wetland
	Distichlis/Juncus 145	145	52200	coastal brackish marsh	SEW	saline emergent wetland
	Distichlis-Juncus-Triglochin-Glaux 160	160	52110	Northern coastal salt marsh	SEW	saline emergent wetland
	Distichlis/Lotus 147	147	52200	coastal brackish marsh	SEW	saline emergent wetland
	Distichlis/Salicornia 148	148	52110	Northern coastal salt marsh	SEW	saline emergent wetland
	Distichlis/S. americanus 149	149	52200	coastal brackish marsh	SEW	saline emergent wetland
	Distichlis (generic) 156	156	52200	coastal brackish marsh	SEW	saline emergent wetland
	Cynodon dactylon 161	161	52200	coastal brackish marsh	SEW	saline emergent wetland
Tall Upland Graminoids (>1 m)	201 (generic)	201	52410	coastal and valley freshwater marsh	FEW	fresh emergent wetland
	Cortaderia selloana 202	202	52410	coastal and valley freshwater marsh	FEW	fresh emergent wetland
Medium Upland Graminoids (0.5-1 m)	210 (generic)	210	42200	Non-native grassland	PGS	perennial grassland
	Agrostis avenacea 228	228	42200	Non-native grassland	PGS	perennial grassland
	Annual Grasses/Weeds 227	227	42200	Non-native grassland	AGS	annual grassland
	Cultivated Annual Graminoid 225	225	42200	Non-native grassland	AGS	annual grassland
	Elytrigia pontica 211	211	42200	Non-native grassland	PGS	perennial grassland
	Leymus (generic) 215	215	42140	valley wildrye grassland	PGS	perennial grassland

Formation Category	Suisun Classification Name	Suisun number	Holland code	Hollandname	WHR code	WHRname
	Lolium/Lepidium 220	220	42200	non-native grassland	AGS	annual grassland
	Lolium/Rumex 222	222	42200	non-native grassland	AGS	annual grassland
	Lolium (generic) 218	218	42200	non-native grassland	AGS	annual grassland
	Perennial Grass 226	226	42200	non-native grassland	PGS	perennial grassland
	Phalaris aquatica 223	223	42200	non-native grassland	PGS	perennial grassland
Short Upland Graminoids 230 (generic) (<0.5 m)		230	42200	non-native grassland	AGS	annual grassland
	Annual Grasses generic 231	231	42200	non-native grassland	AGS	annual grassland
	Bromus spp/Hordeum 232	232	42200	non-native grassland	AGS	annual grassland
	Hordeum/Lolium 234	234	42200	non-native grassland	AGS	annual grassland
	Polypogon monspeliensis (generic) 238	238	42200	non-native grassland	AGS	annual grassland
	Vulpia/Euthamia 235	235	42200	non-native grassland	AGS	annual grassland
Tall Wetland Herbs 301 (generic) (>1m)		301	52200	coastal brackish marsh	SEW	saline emergent wetland
	Apocynum/Scirpus 302	302	52200	coastal brackish marsh	SEW	saline emergent wetland
Medium Wetland Herbs 310 (generic) (0.5-1m)		310	52200	coastal brackish marsh	SEW	saline emergent wetland
	Atriplex triangularis 311	311	52200	coastal brackish marsh	SEW	saline emergent wetland
	Atriplex/Annual Grasses 337	337	52200	coastal brackish marsh	SEW	saline emergent wetland
	Atriplex/Distichlis 312	312	52200	coastal brackish marsh	SEW	saline emergent wetland
	Atriplex/S. maritimus 315	315	52200	coastal brackish marsh	SEW	saline emergent wetland
	Atriplex/Sesuvium 316	316	52200	coastal brackish marsh	SEW	saline emergent wetland
	Atriplex triangularis(generic) 339	339	52200	coastal brackish marsh	SEW	saline emergent wetland
	Frankenia/Agrostis 317	317	52200	coastal brackish marsh	SEW	saline emergent wetland
	Frankenia/Distichlis 318	318	52200	coastal brackish marsh	SEW	saline emergent wetland
	Frankenia (generic) 320	320	52200	coastal brackish marsh	SEW	saline emergent wetland
	Grindelia stricta var stricta 321	321	52200	coastal brackish marsh	SEW	saline emergent wetland
	Lepidium/Distichlis 323	323	52200	coastal brackish marsh	SEW	saline emergent wetland
	Lepidium (generic) 324	324	52200	coastal brackish marsh	SEW	saline emergent wetland
	Polygonum-Xanthium-Echinochloa 329	329	52410	coastal and valley freshwater marsh	FEW	fresh emergent wetland
	Potentilla anserina (generic) 338	338	52200	coastal brackish marsh	SEW	saline emergent wetland
	Rumex (generic) 336	336	42200	non-native grassland	AGS	annual grassland
Short Wetland Herbs 340 (generic)(<0.5 m)		340	52200	coastal brackish marsh	SEW	saline emergent wetland
	Cotula coronopifolia 342	342	52200	coastal brackish marsh	SEW	saline emergent wetland
	Lotus corniculatus 344	344	42200	non-native grassland	AGS	annual grassland
	Salicornia virginica 346	346	52110	Northern coastal salt marsh	SEW	saline emergent wetland
	Salicornia/Annual Grasses 347	347	52200	coastal brackish marsh	SEW	saline emergent wetland
	Salicornia/Atriplex 348	348	52110	Northern coastal salt marsh	SEW	saline emergent wetland

Formation Category	Suisun Classification Name	Suisun number	Holland code	Hollandname	WHR code	WHRname
	Salicornia/Cotula 365	365	52110	Northern coastal salt marsh	SEW	saline emergent wetland
	Salicornia/Crypsis 350	350	52110	Northern coastal salt marsh	SEW	saline emergent wetland
	Salicornia/Polygonum-Xanthium-Echinochloa 364	364	52200	coastal brackish marsh	SEW	saline emergent wetland
	Salicornia/Sesuvium 356	356	52200	coastal brackish marsh	SEW	saline emergent wetland
	Salicornia (generic) 361	361	52200	coastal brackish marsh	SEW	saline emergent wetland
	Sesuvium verrucosum 357	357	52200	coastal brackish marsh	SEW	saline emergent wetland
	Sesuvium/Distichlis 358	358	52200	coastal brackish marsh	SEW	saline emergent wetland
	Sesuvium/Lolium 359	359	52200	coastal brackish marsh	SEW	saline emergent wetland
Floating-leaved Wetland Herbs 370 (generic)		370	52410	coastal and valley freshwater marsh	FEW	fresh emergent wetland
	Potamogeton pectinatus 371	371	52410	coastal and valley freshwater marsh	FEW	fresh emergent wetland
Tall Upland Herbs 401 (generic) (>1m)		401	42200	non-native grassland	AGS	annual grassand
	Brassica nigra (generic) 406	406	42200	non-native grassland	AGS	annual grassand
	Conium maculatum 402	402	42200	non-native grassland	AGS	annual grassand
	Foeniculum vulgare 403	403	42200	non-native grassland	AGS	annual grassand
	Raphanus sativus (generic) 405	405	42200	non-native grassland	AGS	annual grassand
Medium Upland Herbs 410 (generic) (0.5-1 m)		410	42200	non-native grassland	AGS	annual grassland
	Centaurea (generic) 413	413	42200	non-native grassland	AGS	annual grassland
Short Upland Herbs 420 (generic) (<0.5 m)		420	52200	coastal brackish marsh	SEW	saline emergent wetland
	Carpobrotus edulis 421	421	52200	coastal brackish marsh	SEW	saline emergent wetland
Tall Wetland Shrubs 501 (generic) (>1m)		501	63410	Great Valley willow scrub	VRI	valley foothill riparian
	Salix exigua 502	502	63410	Great Valley willow scrub	VRI	valley foothill riparian
Medium Wetland Shrubs 510 (generic) (>1m)		501	36220	valley saltbush scrub	ASC	alkali desert scrub
	Atriplex lentiformis (generic) 514	514	36220	valley saltbush scrub	ASC	alkali desert scrub
Medium Upland Shrubs 601 (generic) (0.5-1 m)		601	32100	northern coastal scrub	CSC	coastal scrub
	Baccharis/Annual Grasses 603	603	32110	northern coyote brush scrub	CSC	coastal scrub
	Rosa californica 604	604	63400	Great Valley riparian scrub	CSC	coastal scrub
	Rosa/Baccharis 605	605	32100	northern coastal scrub	CSC	coastal scrub
	Rubus discolor 606	606	63400	Great Valley riparian scrub	CSC	coastal scrub
Willow Trees 700 (generic)		700	61230	Central coast arroyo willow riparian forest	VRI	valley foothill riparian
	Salix laevigata/S. lasiolepis 702	702	61230	Central coast arroyo willow riparian forest	VRI	valley foothill riparian
	Salix lasiolepis/Quercus agrifolia 705	705	61230	Central coast arroyo willow riparian forest	VRI	valley foothill riparian

Formation Category	Suisun Classification Name	Suisun number	Holland code	Hollandname	WHR code	WHRname
Eucalyptus	800 (generic)			none	EUC	Eucalyptus
	Eucalyptus globulus 801	801		none	EUC	Eucalyptus
Oaks	900 (generic)	900	71100	oak woodland	VOW	valley oak woodland
	Quercus agrifolia 901	901	61220	central coast live oak riparian forest	VRI	valley foothill riparian
	Quercus lobata 903	903	61430	Great Valley valley oak riparian forest	VRI	valley foothill riparian
Other						
	Landscape Trees 910	910		none	URB	urban
	Ailanthus altissima 911	911		none	URB	urban
	Fraxinus latifolia 912	912	61200	Central coast riparian forest	VRI	valley foothill riparian

Acreage Information:

Information about the number of acres of each vegetation type within the Suisun Marsh Vegetation mapping area is provided in **Table 7** below:

LEGEND		Sum Of ACRES	Polygon Count
001	Bare Ground	2191.7	912
002	Fallow Disced Field	171.48	13
003	Parking Lot	263.39	47
004	Road	1059.91	168
005	Structure	214.09	93
006	Slough	4196.08	127
007	Tidal Mudflat	375.1	59
008	Railroad Track	105.73	7
009	Ditch	1576.2	511
010	Trail	5.21	4
011	Flooded Managed Wetland	3774.48	664
012	Freshwater Drainage	35.96	9
013	Water Treatment Pond	4.37	2
014	Urban Area	341.27	8
101	Tall Wetland Graminoids	30.79	15
102	Arundo donax	4.73	8
103	Phragmites australis	549.43	432
104	Phragmites/Scirpus	134.12	75
105	Phragmites/Xanthium	9.57	5
112	Scirpus americanus/Potentilla	266.97	118
113	Scirpus americanus/S. Californicus-S. acutus	154.65	70
114	Scirpus americanus (generic)	704.01	358
116	Scirpus californicus/S. acutus	2026.04	960
120	Typha angustifolia/Polygonum-Xanthium-Echino	433.51	250
121	Typha angustifolia/S. americanus	1134.55	381
123	Typha species (generic)	4167.09	1935
125	Typha angustifolia (dead stalks)	116.09	89
126	Typha angustifolia/Distichlis	970.56	614
127	Scirpus americanus/Lepidium	41.41	44
129	Typha angustifolia/Phragmites	172.81	124
130	Medium Wetland Graminoids	1.09	2

LEGEND	Sum Of ACRES	Polygon Count

132	Juncus balticus	337.88	247
133	Juncus balticus/Conium	62.77	40
134	Juncus balticus/Lepidium	16.03	13
135	Juncus balticus/Potentilla	11.1	5
137	Scirpus maritimus	1734.87	1017
138	Scirpus maritimus/Salicornia	537.05	265
139	Scirpus maritimus/Sesuvium	233.78	108
141	Distichlis spicata	2890.37	1612
142	Distichlis/Annual Grasses	1988.12	1177
145	Distichlis/Juncus	390.17	251
147	Distichlis/Lotus	190.98	126
148	Distichlis/Salicornia	2416.57	1408
149	Distichlis/S. americanus	485.88	253
153	Distichlis/Cotula	180.08	139
154	Distichlis/S. maritimus	368.15	191
155	Crypsis schoenoides	92.5	49
156	Distichlis (generic)	791.27	397
157	Scirpus (californicus or acutus)-Typha sp.	2069.32	794
158	Scirpus (californicus or acutus)/Wetland Her	414.58	215
160	Distichlis-Juncus-Triglochin-Glaux	346.06	141
161	Cynodon dactylon	16.24	6
162	Scirpus (californicus or acutus)/Rosa	368.9	178
202	Cortaderia selloana	9.78	6
210	Medium Upland Graminoids	141.74	40
211	Elytrigia pontica	90.23	21
215	Leymus (generic)	21.53	23
218	Lolium (generic)	247.4	95
220	Lolium/Lepidium	55.24	26
222	Lolium/Rumex	13.44	3
223	Phalaris aquatica	24.89	13
225	Cultivated Annual Graminoid	540.96	50
226	Perennial Grass	444.33	126
227	Annual Grasses/Weeds	1582.5	637
228	Agrostis avenacea	34.99	29
230	Short Upland Graminoids	3.28	4
231	Annual Grasses generic	7574.25	2773
	LEGEND	**Sum Of ACRES**	**Polygon Count**

232	Bromus spp/Hordeum	8.04	5
234	Hordeum/Lolium	1.71	2
235	Vulpia/Euthamia	1.33	1
238	Polypogon monspeliensis (generic)	54.36	22
300	Wetland Herbs	46.96	25
301	Tall Wetland Herbs	8.06	10
310	Medium Wetland Herbs	301.22	193
311	Atriplex triangularis	604.54	356
312	Atriplex/Distichlis	406.8	205
315	Atriplex/S. maritimus	64.78	49
316	Atriplex/Sesuvium	9.49	6
317	Frankenia/Agrostis	2.07	4
318	Frankenia/Distichlis	53.16	32
320	Frankenia (generic)	114.07	70
321	Grindelia stricta var stricta	2.03	2
323	Lepidium/Distichlis	198.82	150
324	Lepidium (generic)	646.43	430
329	Polygonum-Xanthium-Echinochloa	1208.47	642
336	Rumex (generic)	20.17	13
337	Atriplex/Annual Grasses	330.22	224
338	Potentilla anserina (generic)	60.48	41
339	Atriplex triangularis(generic)	100.49	61
340	Short Wetland Herbs	65.33	35
342	Cotula coronopifolia	393.75	341
344	Lotus corniculatus	250.35	169
346	Salicornia virginica	6132.05	3560
347	Salicornia/Annual Grasses	2306.33	1574
348	Salicornia/Atriplex	664.85	347
350	Salicornia/Crypsis	2.12	1
356	Salicornia/Sesuvium	122.76	74
357	Sesuvium verrucosum	408.63	205
358	Sesuvium/Distichlis	28.73	17
359	Sesuvium/Lolium	15.68	6
360	Spergularia/Cotula	5.44	3
361	Salicornia (generic)	556.49	328
364	Salicornia/Polygonum-Xanthium-Echinochloa	109.15	79

LEGEND		Sum Of ACRES	Polygon Count
365	Salicornia/Cotula	264.26	195
371	Potamogeton pectinatus	32.5	6
401	Upland Herbs	188.8	104
402	Conium maculatum	247.44	172
403	Foeniculum vulgare	140.93	95
405	Raphanus sativus (generic)	294.77	186
406	Brassica nigra (generic)	31.91	23
410	Medium Upland Herbs	40.65	28
413	Centaurea (generic)	76.91	32
421	Carpobrotus edulis	7.03	7
502	Salix exigua	1.53	1
514	Atriplex lentiformis (generic)	31.37	20
601	Medium Upland Shrubs	7.1	6
603	Baccharis/Annual Grasses	85.78	66
604	Rosa californica	146.33	84
605	Rosa/Baccharis	62.46	32
606	Rubus discolor	119.16	70
700	Willow Trees	11.33	4
702	Salix laevigata/S. lasiolepis	4.92	5
705	Salix lasiolepis/Quercus agrifolia	3.42	1
800	Eucalyptus	5.13	5
801	Eucalyptus globulus	204.67	118
900	Oaks	2.99	3
901	Quercus agrifolia	10.95	4
903	Quercus lobata	1.35	1
910	Landscape Trees	10.21	8
911	Ailanthus altissima	0.75	1
912	Fraxinus latifolia	2.91	2
Totals		**69323**	**31156**

Map Accuracy Assessment:

Reporting the accuracy of a vegetation map is critical in the understanding of its usefulness and limitations. Formal accuracy assessments however, are often not undertaken because they are extremely labor-intensive and expensive. In this mapping effort we were constrained by the above limitations, but felt it necessary to attempt a partial accuracy assessment and to develop a methodology for others to continue these efforts beyond the scope of this project. We present here the methods and results of a partial accuracy assessment conducted in September and October 2000, and suggestions for further accuracy assessment.

General Methodology: Formal accuracy assessment entails two perspectives: 1) Accuracy from the standpoint of the producer, where one determines what percentage of a certain type of mapped vegetation is actually that type (this view assesses errors of omission), and 2) user's accuracy (this view assesses errors of commission). From a resource manager's standpoint the latter measurement is far more important because it gets at the reliability of the map. In other words, how likely is it that a particular mapping unit labeled as vegetation type "x" will actually be type "x" when it is visited on the ground?

The simplest way of depicting the summary statistics of an accuracy assessment is via a contingency table where the number of accurately determined vegetation types, based on field checking, is compared with the number of vegetation types labeled from the remote sensing effort (Story and Congalton 1986, Congalton 1991). For simple vegetation maps with just a few categories this process is very straightforward. However, in detailed complex vegetation maps with many categories, some being rare and some being abundant it is often not statistically relevant to report accuracy of all mapping units. Unless a significant sample of all vegetation types mapped is assessed, then a complete contingency table cannot be produced.

This problem arises from basic statistical considerations of the analysis. When we go out to collect field data to test the accuracy of a map, we must already assume something about the variability in our ability to accurately represent the different types of vegetation. These assumptions are important because they can lead to the most appropriate degree of effort in field checking (avoiding too many or too few samples). Thus, an easily distinguishable (distinctive signature from an aerial photo) vegetation type would be given a higher likelihood of being correctly identified than an amorphous, poorly distinguishable type. The number of samples we take should be based on the certainty of distinguishibility.

Specific Considerations for Suisun Marsh: Most accuracy assessment sample allocation is based on the binomial distribution (Congalton 1991). If we are to do a thorough accuracy assessment and to meet assumptions of the binomial distribution, it is necessary to have an adequate sample size of every mapping unit. At Suisun Marsh this is not possible for several reasons. There are numerous vegetation types that are rare, with fewer than 10 mapped stands in our GIS database. Many of these are difficult to distinguish from certain similar vegetation types, thus our level of confidence around them is not particularly high. The only way to have confidence that these types are mapped correctly is to visit each of them. On the other hand, there are numerous vegetation mapping types that are represented by hundreds of individual polygons and based on our assessment of their reliability we can devise field sampling regimes to collect a statistically valid sample size from these types and check their accuracy. Another serious constraint for this mapping project is the accessibility of much of the privately managed land. Even with advanced notice and a coordinated solicitation of permission to access lands, only about 50% of the landowners afforded our field crews access. For types that are already rare and localized, reduced access made it difficult to fulfill statistical requirements for sufficient sample sizes.

Undeniably, the most critical constraint in the accuracy assessment of the Suisun Marsh vegetation was the seasonal and year-to-year variance in vegetation. Due to intensive management of much of the marsh, vegetation stands could be one type in 1999 when the photos were taken and could have been significantly modified by burning, plowing, disking, flooding, re-planting, or other means by the summer of 2000. Also, because much of the vegetation in the marsh is subject to high variation due to natural climatic change from year to year (e.g., annual grasses, annual wetland herbs), the vegetation depicted in the photographs of 1999 may have a different set of dominants or a different phenology (natural progression of flowering, leaf production, and plant development) than the summer of 2000 when the accuracy assessment was done.

Methods for the Partial Accuracy Assessment: Immediately following the completion of the final classification, derived from the analysis of the vegetation samples (see vegetation description section), we conducted the accuracy assessment. We realized that there would not be enough time to spend more than a month of field time and were thus constrained by the amount of area we could cover and the number of samples we could collect. Fortunately, accuracy assessment sampling is not as labor-intensive as complete vegetation sampling. A simple field form was developed (see **Appendix 1** for an example) and field crews were trained in its proper use prior to the data collection. We emphasized rapid assessment and expected field crews to spend no more than 10 minutes describing an individual polygon.

A general assessment of which vegetation types would be amenable to assessment was made prior to the visit. We knew that at our most efficient, we couldn't expect to collect more than 10 samples per day per team. We calculated that we could collect about 250 samples during the period. From this total we selected a set of vegetation types that could be easily sampled based on their expected sample size needed using the normal approximation of the binomial distribution (Cochran 1977), but would also be representative of the full range of variation of vegetation known to occur throughout the marsh. Thus, types were selected to represent upland and wetland herbaceous vegetation, as well as shrub-dominated vegetation. We also made a special effort to select types that had management significance. In all, 25 types were selected for accuracy assessment (which represents about 20% of the total number of mappable types).

The formula for sample size is based on Cochran (1977, <u>Sampling Techniques, 3rd Edition</u> (p. 75):

$n = (t^2pq)/d^2$

n = number of samples

t = abscissa of a normal curve that cuts off an area of a (alpha)

p = estimated variance, proportion correct

q = 1- p

d = discrepancy.

For this sampling exercise, the following parameter were set for all classes: alpha = .05, t = 1.96, d = .2, p is estimated for each class in the table below, under the column Estimated Proportion correct.

For the first class, the number of samples, n, is calculated by:

$n = (1.96^2 * .95 * .05) / .2^2$

$n = (3.8416 * 0.0475) / .04$

n = 4.5, or rounded up, 5 samples

In brief, the two primary considerations for selecting sample size are 1) the "p" level, a guess of how accurately we labeled a particular vegetation type in the mapping effort and 2) the "d," or margin of error in the estimate of how well we guessed the accuracy of a given vegetation type to be between the actual accuracy of the vegetation type (known as upper case "P") and the estimated accuracy (lower case "p" as described above). In general, as your certainty in the "p" value increases, the number of samples required for accuracy assessment goes down. As the allowable discrepancy ("d") between the actual accuracy ("P") of a mapping type and its predicted accuracy ("p") increases (e.g., you are more lenient about the margin of error) the fewer the samples required. These concepts are further discussed in texts such as Cochran (1977).

Due to the high probability of year to year variation of vegetation and the high physical similarity of many vegetation types within the mapping area, we suspected that a simple yes or no for accuracy would yield disappointing and unrealistic results. Many of the vegetation types are so physically similar that it takes a detailed field-based estimate of cover of the component species to determine if a type is a member of one association or another. Many of these associations and alliances are ecologically similar as well. Thus, the photo-identification of these look-alike and act-alike vegetation types would be expected to be relatively imprecise.

A common accuracy assessment procedure compares the label assigned to a polygon in the map (map label) with the label assigned to the same polygon using 'ground truthing' (evaluation sites). Using a traditional method, only one possible answer (considered to be the best answer by an 'expert' in the field) is compared to the map label. However, vegetation map classes do not always lend themselves to unambiguous measurements. While a map label of *Typha* spp. may be considered absolutely correct for a particular site, a user might consider acceptable a map label of *Scirpus californicus-acutus-Typha* spp. An alternative method for evaluating map accuracy, and the one chosen for use in this assessment, is based on the use of fuzzy sets, first developed by Gopal and Woodcock (1994). The use of fuzzy sets to evaluate vegetation maps has now occurred on vegetation maps of the Stanislaus National Forest, (Woodcock and Gopal, 1992) the Modoc and Lassen National Forests (Milliken, et al 1997) and the four southern California National Forests, (Franklin, et al, 1999). With the fuzzy logic method of accuracy assessment, for each evaluation site, all map classes including the map label are assigned a ranking based on a linguistic scale as to their degree of match with the ground data. The linguistic scale, and corresponding numeric score, used in this assessment is shown below:

Fuzzy Logic Rules for Suisun Accuracy Assessment:

0= completely wrong life form and very low ecological similarity

1 = same life-form (e.g, shrub, tree, or herb-grass), not ecologically related in cluster analysis

2 = same sub lifeform (e.g, tall wetland herb, short annual grass), but not necessarily ecologically related in cluster analysis) or could be diff life form, but share diagnostic spp or somewhat ecologically related (same super cluster)

3 = same alliance or similar alliance within same meso- cluster, but diagnostic species not shared for association

4. = same alliance or similar alliance within same meso-cluster and diagnostic species shared, but doesn’t meet key definitions

5 = perfect, meets key definitions for the vegetation type or mapping unit

Using the ground-collected data with a set of decision rules (described below), a ranking of 0 to 5 was assigned to all map classes at each evaluation site. These rankings were then used to measure: a) how frequently the map label was the best choice for the site; b) how frequently the map label was acceptable.

In Table 8 below the 25 types assessed are reported giving their total score of percent correct based on the 0 to 5 point scale. A fraction reported with each represents the total number of points possible as the denominator with the numerator as the number of points received. The column “meet predicted accuracy standards” reports on the ability of our photo interpreters to accurately predict the actual accuracy of the mapping unit and thus lends credence to the predictions of accuracy to the rest of the vegetation types that were not formally assessed but are reported in Table 9.

Table 8: Fuzzy Logic Accuracy Assessment for Year 2000 accuracy assessment of 25 Vegetation types in Suisun Marsh.

Vegetation Type **(* = < 80% accuracy)**	**Ratio of attained points over total possible points using 0 to 5 fuzzy scale**	**Percent accuracy using fuzzy logic rules**	**Sample size (* = not significant at accepted p and d values)**	**Predicted accuracy standards**	**Percent totally correct using yes/no logic**
Phragmites australis	45/50	90%	n=10	Predicted 95%	70%
Scirpus californicus/S. acutus	70/80	87.5%	n=16	Predicted 80%	56%
Typha	65/80	81.3%	n=16	Predicted 80%	25%
**Scirpus maritimus*	69/90	77%	n=18	Predicted 75%	16%
Distichlis spicata	43/50	86%	n=10	Predicted 90%	60%
Distichlis/annual grass	40/45	89%	n= 9	Predicted 90%	55%
Scirpus californica-acutus-Typha spp	96/110	87.3%	n=22	Predicted 80%	41%
Echinocloa-Polygonum-Xanthium	34/40	85%	n=8	Predicted 90%	63%
Distichlis-Juncus-Triglochin-Glaux	29/35	83%	n=7	Predicted 90%	14%
Scirpus californicus-acutus/Rosa californica	38/45	84%	n=9	Predicted 90%	44%
Annual Grasses/Weeds	37/45	82.2%	n=9	Predicted 90%	22%
Annual grasses (generic)	38/40	95%	n=8	Predicted 95%	50%
**Atriplex triangularis*	57/80	71.3%	n=16	Predicted 75%	6%
Lepidium generic	15/15	100%	n=3*	Predicted 95%	100%

Vegetation Type (* = < 80% accuracy)	Ratio of attained points over total possible points using 0 to 5 fuzzy scale	Percent accuracy using fuzzy logic rules	Sample size (* = not significant at accepted p and d values)	Predicted accuracy standards	Percent totally correct using yes/no logic
Cotula	20/25	80%	n=5*	Predicted 95%	25%
Lotus corniculatus	24/30	80%	n=6*	Predicted 95%	33%
Salicornia virginica	36/40	90%	n=8	Predicted 95%	63%
Salicornia/annual grasses	44/45	98%	n=9	Predicted 95%	80%
**Salicornia/Atriplex*	65/105	62%	n= 21	Predicted 80%	0%
**Salicornia/Sesuvium*	15/20	75%	n=4*	Predicted 95%	0%
**Sesuvium verricosum*	22/30	73%	n=6*	Predicted 90%	0%
Conium maculatum	35/40	87.5%	n=8	Predicted 95%	75%
Centaurea	24/30	80%	n=6*	Predicted 90%	16%
Atriplex lentiformis	25/25	100%	n=5	Predicted 95%	100%
Rosa californica	12/15	80%	n=3*	Predicted 90%	0%

Note that 15 out of 25 types were predicted to have higher map accuracies than were actually shown by the assessment, while 5 were found to have actually higher than predicted and 5 were within one percent of the assessed value. Appendix 5 lists the full results of the accuracy assessment for all 260 plots assessed in September-October 2000 with interpretive notes on each plot.

Table 8 shows the predicted accuracy of all types judged by the photo-interpreters with the associated number of accuracy assessment plots needed based on these estimates of accuracy. Note this is predicted and not actual accuracy. It can be assumed by the trends evident in Table 7 that actual accuracy will be somewhat lower (between 5 and 10% on average) for most of these types.

Table 9: Complete predicted accuracy for all mapping units. The X under aa types show the types selected for formal accuracy assessment. The Confidence (p) column indicates predicted % accuracy for each type. The AA plots column indicates the number of plots statistically required for accepting a d of 20% difference between actual and predicted percent accuracy

Physiognomic Group	Mapping Unit/Classification Unit	Vegcode	AA_Types	Confidence (p)	AA_Plots
Unvegetated Mapping Units					
	Bare Ground 001	001		95	5
	Fallow Disced Field 002	002		95	5
	Parking Lot 003	003		95	5
	Road 004	004		95	5
	Structure 005	005		95	5
	Slough 006	006		95	5
	Tidal Mudflat 007	007		95	5
	Railroad Track 008	008		95	5
	Ditch 009	009		95	5
	Trail 010	010		95	5
	Flooded Managed Wetland 011	011		95	5
	Freshwater Drainage 012	012		95	5
	Water Treatment Pond 013	013		95	5
	Urban Area 014	014		95	5
Tall Wetland Graminoids 101 (generic) (>1 m)		101		95	5
	Arundo donax 102	102		95	5
	Phragmites australis 103	103	X	95	5
	Phragmites/Scirpus 104	104		95	5
	Phragmites/Xanthium 105	105		95	5
	Scirpus americanus/Potentilla 112	112		80	16
	Scirpus americanus/S. Californicus-S. acutus 113	113		75	19
	Scirpus americanus (generic) 114	114		75	19
	Scirpus californicus/S. acutus 116	116	X	80	16
	Typha angustifolia/Echinocloa-Polygonum-Xanthium 120	120		85	13
	Typha angustifolia/S. americanus 121	121		75	19
	Typha species (generic) 123	123	X	80	16
	Typha angustifolia (dead stalks) 125	125		85	13
	Typha angustifolia/Distichlis 126	126		80	16
	Scirpus americanus/Lepidium 127	127		80	16
	Typha angustifolia/Phragmites 129	129		85	13

Physiognomic Group	Mapping Unit/Classification Unit	Vegcode	AA_Types	Confidence (p)	AA_Plots
Medium Wetland Graminoids 130 (generic) (0.5-1 m)		130		90	9
	Juncus balticus 132	132		75	19
	Juncus balticus/Conium 133	133		80	16
	Juncus balticus/Lepidium 134	134		80	16
	Juncus balticus/Potentilla 135	135		85	13
	Spartina foliosa 136	136		90	9
	Scirpus maritimus 137	137	X	75	19
	Scirpus maritimus/Salicornia 138	138		75	19
	Scirpus maritimus/Sesuvium 139	139		75	19
Short Wetland Graminoids 140 (generic)(<0.5 m)		140		90	9
	Distichlis spicata 141	141	X	90	9
	Distichlis/Annual Grasses 142	142	X	90	9
	Distichlis/Juncus 145	145		90	9
	Distichlis/Lotus 147	147		90	9
	Distichlis/Salicornia 148	148		90	9
	Distichlis/Salicornia 148	149		85	13
	Distichlis/T. Angustifolia 152	152		85	13
	Distichlis/Cotula 153	153		90	9
	Crypsis schoenoides 155	155		80	16
	Distichlis (generic) 156	156		90	9
	Scirpus (californicus or acutus)-Typha sp. 157	157	X	80	16
	Scirpus (californicus or acutus)/Wetland Herbs 158	158		90	9
	Echinocloa-Polygonum-Xanthium 159	159	X	90	9
	Distichlis-Juncus-Triglochin-Glaux 160	160	X	90	9
	Cynodon dactylon 161	161		90	9
	Scirpus (californicus or acutus)/Rosa 162	162	X	90	9
Tall Upland Graminoids 201 (generic) (>1 m)		201		90	9
	Cortaderia selloana 202	202		95	5
Medium Upland Graminoids 210 (generic) (0.5-1 m)		210		90	9
	Elytrigia pontica 211	211		95	5
	Leymus (generic) 215	215		85	13
	Lolium (generic) 218	218		95	5
	Lolium/Lepidium 220	220		90	9

Physiognomic Group	Mapping Unit/Classification Unit	Vegcode	AA_Types	Confidence (p)	AA_Plots
	Lolium/Rumex 222	222		90	9
	Phalaris aquatica 223	223		90	9
	Cultivated Annual Graminoid 225	225		90	9
	Perennial Grass 226	226		95	5
	Annual Grasses/Weeds 227	227	X	90	9
	Agrostis avenacea 228	228		95	5
Short Upland Graminoids 230 (generic) (<0.5 m)		230		90	9
	Annual Grasses generic 231	231	X	95	5
	Bromus spp/Hordeum 232	232		95	5
	Hordeum/Lolium 234	234		95	5
	Vulpia/Euthamia 235	235		95	5
	Polypogon monspeliensis (generic) 238	238		95	5
Tall Wetland Herbs 301 (generic) (>1m)		301		90	9
	Apocynum/Scirpus 302	302		95	5
Medium Wetland Herbs 310 (generic) (0.5-1m)		310		90	9
	Atriplex triangularis 311	311	X	75	19
	Atriplex/Distichlis 312	312		80	16
	Atriplex/S. maritimus 315	315		70	21
	Atriplex/Sesuvium 316	316	X	75	19
	Frankenia/Agrostis 317	317		90	9
	Frankenia/Distichlis 318	318		90	9
	Frankenia (generic) 320	320		90	9
	Grindelia stricta var stricta 321	321		85	13
	Lepidium/Distichlis 323	323		95	5
	Lepidium (generic) 324	324	X	95	5
	Rumex (generic) 336	336		90	9
	Atriplex/Annual Grasses 337	337		75	19
	Potentilla anserina (generic) 338	338		95	5
	Atriplex triangularis(generic) 339	339		80	16
Short Wetland Herbs 340 (generic)(<0.5 m)		340		90	9
	Cotula coronopifolia 342	342	X	95	5
	Lotus corniculatus 344	344	X	95	5
	Salicornia virginica 346	346	X	95	5

Physiognomic Group	Mapping Unit/Classification Unit	Vegcode	AA_Types	Confidence (p)	AA_Plots
	Salicornia/Annual Grasses 347	347	X	95	5
	Salicornia/Atriplex 348	348	X	80	16
	Salicornia/Crypsis 350	350		85	13
	Salicornia/Sesuvium 356	356	X	95	5
	Sesuvium verrucosum 357	357	X	90	9
	Sesuvium/Distichlis 358	358		95	5
	Sesuvium/Lolium 359	359		90	9
	Salicornia (generic) 361	361		90	9
	Sesuvium/Cotula 362	362		95	5
	Salicornia/Echinocloa-Polygonum-Xanthium 364	364		95	5
	Salicornia/Cotula 365	365		95	5
Floating-leaved Wetland Herbs 370 (generic)		370		95	5
	Potamogeton pectinatus 371	371		90	9
Tall Upland Herbs 401 (generic) (>1m)		401		95	5
	Conium maculatum 402	402		90	9
	Foeniculum vulgare 403	403	X	95	5
	Raphanus sativus (generic) 405	405		90	9
	Brassica nigra (generic) 406	406		95	5
Medium Upland Herbs 410 (generic) (0.5-1 m)		410		90	9
	Centaurea (generic) 413	413		90	9
Short Upland Herbs 420 (generic) (<0.5 m)		420	X	90	9
	Carpobrotus edulis 421	421		90	9
Tall Wetland Shrubs 501 (generic) (>1m)		501		95	5
	Salix exigua 502	502		90	9
Medium Wetland Shrubs 510 (generic) (>1m)		510		80	16
	Atriplex lentiformis (generic) 514	514		90	9
Medium Upland Shrubs 601 (generic) (0.5-1 m)		601	X	95	5
	Baccharis/Annual Grasses 603	603		90	9
	Rosa californica 604	604	X	90	9
	Rosa/Baccharis 605	605	X	90	9
	Rubus discolor 606	606		90	9
Willow Trees 700 (generic)		700		95	5
	Salix laevigata/S. lasiolepis 702	702		90	9

Physiognomic Group	Mapping Unit/Classification Unit	Vegcode	AA_Types	Confidence (p)	AA_Plots
	Salix lasiolepis/Quercus agrifolia 705	705		85	13
Eucalyptus (generic)	800	800		85	13
	Eucalyptus globulus 801	801		95	5
Oaks 900 (generic)		900		95	5
	Quercus agrifolia 901	901		90	9
	Quercus lobata 903	903		85	13
	Landscape Trees 910	910		85	13
	Ailanthus altissima 911	911		90	9
	Fraxinus latifolia 912	912		90	9

We do not recommend complete accuracy assessment of the 1999 map because of the rapid rate of change of the vegetation in the Suisun Marsh. This is particularly true of the managed portions. See recommendations and conclusions for further comments.

Discussion of Map Updating Process

Because of the continuing interest in the management of the marsh for endangered species habitat, and for a balanced management of waterfowl and other wildlife, we are providing an overview of the most likely scenario for long-term revision of this map.

Now that the GIS vegetation layer is complete, the map can be continually updated with relatively little additional effort. Our mapping team has reviewed several potential methods of updating the map. We have settled upon a method that we will implement for the first time in the winter of 2001. In this effort we will compare the June 16, 1999 air photos used to build the existing vegetation map with photos taken approximately one year later, July 5, 2000.

Proposed Methodology:

As part of the product package for this current vegetation map we have created polygon line work of the study area (see CD readme.txt file). These ortho-rectified polygons, as delineated from the 1999 photos, can be plotted on acetate or mylar. Using the line work as a backdrop, the new July 2000 photos can be positioned under the previous year's lines delineating the vegetation polygons and each of the new photos can be individually compared with the existing vegetation layer. Because the GIS layer is scaleable, we can match the scale of the new 2000 photography. Vegetation composition changes will be identified by comparing the two year's photos with each other.

We expect to proceed photo-by-photo and identify all significant changes in shape and in composition of the polygons beginning in the winter of 2001. We propose to annually update the map using this method. The meaning of "significant" in this case deserves further explanation. The following changes are considered significant and will be updated:

- A greater than 20% change in acreage of an exiting small polygon (small is from < 0.5 acre to 1 acre)
- A greater than 10% change in acreage of a mid-sized polygon (mid-sized is defined as from 1-5 acres)
- A greater than 5% change in a large polygon (large polygons are > 5 acres)
- A type conversion of a vegetation polygon dominated by perennial species. (type conversion as defined here, occurs when a previously mapped vegetation type dominated by perennial species has changed based on the decision rules set forth in the vegetation an mapping unit key defined in this report, or when an annual species dominated vegetation type is converted to a perennial vegetation type.
- A persistent physical change has altered any vegetation polygon and partially or entirely replaced it with a non-vegetated area (non-vegetated areas include buildings, dredged ditches, new levees, roads, or other human engineered structures).
- A change in management style, which includes a conversion or restoration from an actively managed situation including annual burning, disking, plowing, flooding, or other management practice which annually disturbs the vegetation

Non-significant changes include the following and will not be assessed:

- Annual to annual type conversion is not considered because of the vagaries of climate on annual vegetation
- Polygons that are regularly heavily managed by annual burning, disking, flooding, or other means will not be considered. These changes unless they show some direction (eg., from passive management to active, or vice versa) are considered regular management perturbations and maintain the same general vegetation pattern through regular disturbance.

Table 10 indicates all annual vegetation types that will not be considered a "change" if one is found to change to another.

Table 10: The following is a list of annual dominated vegetation types provided to give an indication of what types would not be assessed if one changed to another.

Crypsis schoenoides 155

Distichlis/Annual Grasses 142

Distichlis/Cotula 153

Annual Grasses/Weeds 227

Cultivated Annual Graminoid 225

Lolium/Lepidium 220

Lolium/Rumex 222

Lolium (generic) 218

Short Upland Graminoids 230 (generic) (<0.5 m)

Annual Grasses generic 231

Bromus spp/Hordeum 232

Hordeum/Lolium 234

Polypogon monspeliensis (generic) 238

Vulpia/Euthamia 235

Atriplex triangularis 311

Atriplex/Annual Grasses 337

Atriplex/Distichlis 312

Atriplex/S. maritimus 315

Atriplex/Sesuvium 316

Atriplex triangularis(generic) 339

Polygonum-Xanthium-Echinochloa 329

Rumex (generic) 336

Cotula coronopifolia 342

Sesuvium verrucosum 357

Sesuvium/Distichlis 358

Sesuvium/Lolium 359

Brassica nigra (generic) 406

Raphanus sativus (generic) 405

Centaurea (generic) 413

Updating will involve creating a new Access database table with fields for unique id, spatial change, and vegetation type conversion. Each year a new table will be created. These tables can be joined, individually or successively, to the existing ArcView attribute table based on unique id. For example if a polygon changes several times over the course of years, there will be a record of what change occurred in each year. In addition to the vegetation code, the cover, disturbance level and height class will be recorded for each year there was a change. Indication of whether a polygon has been split based on a partial change, or has changed in shape will also be noted.

Using this methodology we can identify the types of changes that occur annually and will be able to track significant changes over the course of the monitoring program for vegetation. Thus, particularly strong or weak years of change can be identified and types of changes summarized, leading to a comprehensive understanding of trends over time and appropriate management.

Discussion of Retrospective Mapping:

Retrospective mapping is using historic information to develop maps of an area, as it existed when the information was first obtained. Because aerial photography has been flown for the Triennial Marsh Surveys since 1979 we have the opportunity to learn much of the long-term trends in marsh vegetation through natural and management-induced conditions by comparing maps of the vegetation in the "early years" of this study to present-day conditions.

Although the methods for monitoring the vegetation prior to this current effort are not comparable either with each other or with this effort, we have the opportunity to use the standardized classification and GIS mapping methodology established for this project to travel back in time to re-map from the existing aerial photography taken in the past.

Assuming that the classification developed for this project is sufficient to encompass all vegetation types that existed in the marsh over the past 20 years, we should be able to use vegetation signatures we identified and verified for the 1999-2000 project to extrapolate back to previous years.

We have made an overview of the series of aerial photography accumulated for the years 1981, 1985, 1988, 1991, 1994 and 1998 by the Bay-Delta Division of DFG. Unfortunately, most of the older photographs are of insufficient quality to match the level of resolution and clarity of the 1999 photography used for the current map. However, the 1985 photography is relatively high quality and could be used as base imagery for conducting an assessment of marsh vegetation as it existed on July 5, 1985. If we used a set of 1985 photos to re-map the marsh we would have a sense of how much change and how significant that change was over a 15-year period.

Based on a rapid overview of the 1985 aerial photos, we have determined that significant change has occurred over much of the marsh such that the use of the current map polygons developed from the 1999 photographs would not provide us with any savings of time. Thus a completely new map would have to be delineated and attributed. As much has been learned of photo signatures and classification, the time spent to delineate and attribute the historic set of photos would take a team of two approximately 8 months to accomplish.

Conclusions and Recommendations

Technical Needs and Considerations:

1. Prior to the classification field season permission forms and liability waivers were sent to landowners, whose property contained sample sites selected during the allocation process. Based on the low percent return of permission forms, prior to the verification field season permission was asked of **all** the private landowners of the Suisun Marsh. Management questionnaires were sent to all landowners where plot sampling actually occurred which provided valuable information on disturbance levels. Overall, correspondence was returned at an approximate rate of fifty-two percent.

2. At the outset, on-screen digitizing of delineated vegetation proved to be troublesome. Comparing the patterns delineated on the photo and replicating those patterns while digitizing required a lot of visual referencing of two separate sources, which was a very time consuming process. The process was originally visualized to only use the patterns in the digital version, without requiring a match to delineations drawn on photos. To improve the process, a test was performed to see if modification of our technique could increase efficiency. A sample photo was scanned with the delineations, then registered. This combined photo was then used as a backdrop. Personnel performing the digitizing reported that they could capture the delineations many times faster, and were more assured that they were following the delineation more precisely. As a result of this test, all of the photos were re-scanned with the mylar overlay showing the delineations.

Validation of Vegetation Signatures:

The map verification phase was extremely effective for increasing familiarity with photo signatures. Data was collected throughout the marsh either by driving levee roads or walking areas inaccessible to vehicles. The photo interpreters participated in this work and were able to conduct sampling according to their needs. Efforts were directed toward vegetation types with little or no data from the first field season and toward unfamiliar photo signatures. Further, all time spent in the field led to greater familiarity with vegetation patterns and management practices.

Final Polygon Attribution:

Experience dictates that manual attribution and data entry is the most effective method for generating an accurate vegetation map at such a fine level of detail. Among the most time-consuming parts of the project was the manual labeling of the 39,600+ initial polygons. Using three different people this process took about 9 months to complete. Manual entry of information was necessary for all primary attributes (see Labeling Polygons section) although default values could be used for several (PHOTO, ID, WHO). Automated procedures were developed for entry of the cross-walk, color scheme and other attributes.

Quality Control:

The main flaw in the quality control process for this project occurred in the digitization phase. It is recommended that the digitized coverage be rigorously checked and double checked in ARC/INFO for gaps and overlap before any polygon numbers are assigned. The majority of errors occurred along boundaries where the preliminary coverages were merged together. Such errors are more easily rectified early on and save time repeatedly in the attribution and editing phases. Using printouts of the delineations was an invaluable quality control tool. During attribution every inch of the coverage was examined and all delineation errors and gaps could be highlighted on the printouts.

Microsoft Access proved useful in assuring quality control of the attribute data entry. Input masks, look up tables, default values, and establishment of a primary key greatly reduced keystroke errors. Queries were used to identify any codes that were incorrectly entered. A formal quality control process was established to assure correct interpretation of photo signatures. Due to time constraints very few polygons were actually reviewed.

Further Classification:

As discussed in the classification section, additional samples should be taken in different vegetation within the marsh to assure a full data-driven classification. The value of a full classification goes beyond the ability to map in more detail at some future date. It will enable the field biologists to quantitatively identify any stand of natural vegetation in the marsh and to make field-based decisions on the quality and value of particular sites within the marsh. We recommend further sampling to consolidate and validate the classification based on the 198 plots analyzed for this project. This may entail approximately 90 more samples. With a field team of two and an estimated data entry and analysis time of 2 months a complete classification can be predicted to take four months.

Value-Added Information:

In addition to the map and classification of vegetation we have also included in the CD package a recently digitized ownership layer, the five Salt Marsh Harvest Mouse Management Areas, and several other public GIS layers that will facilitate analysis by the users (see page 25 and complete metadata in CD). The ownership layer includes all ownership boundaries with the Suisun Marsh Resource Conservation District. The intersection of ownership information and vegetation information should prove useful for understanding the overall management direction in the marsh. Management practices and their influence on vegetation can be plainly seen with this type of analysis.

Another form of investigation may involve intersecting the known locations and densities of special status plants and animals with vegetation in the marsh. Such analysis may show strong correlations between certain types and densities of vegetation and the location and densities of species of concern. Such correlations may enable predictive modeling for location of additional habitat for the species and for planning for conservation management strategies in the marsh.

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