

NATIONAL WETLANDS INVENTORY MAPPING FOR  
SAN FRANCISCO BAY/DELTA AREA, CALIFORNIA

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ABSTRACT

The U.S. Fish and Wildlife Service's National Wetlands Inventory Project (NWI) completed wetland mapping in 1982-83 for the San Francisco Bay/Delta area of California using mid-1970's summer, high level color infrared aerial photography and in 1986-87 using 1985, color infrared, aerial photography. In addition, mid-1950's aerial photography was used to produce 1950's era wetland maps for the south San Francisco Bay area. The 1976 aerial photos and corresponding wetland maps and mid-1950's interpreted aerial photos were reviewed and compared to the 1985 aeriels to minimize possible interpretation errors on these earlier photos. For south San Francisco Bay eighteen NWI wetland maps are published for each of the three years - 1985, 1976 and mid-1950's; for the north bay area 24 NWI wetland maps are published for each of two years - 1985 and 1976; and 62 NWI 1985 wetland maps are published for the Sacramento/San Joaquin Delta and areas adjacent to San Francisco Bay. Wetland information is entered into a computerized geographical information system providing a digital data base from which wetland maps and acreage data showing historical wetland changes can be generated.

INTRODUCTION

Wetlands of the United States have experienced significant losses and changes. Tiner (1984) provides an excellent discussion of these wetland losses. Briefly, of the approximately 215 million acres of wetlands in the lower 48 at the time of the nation's settlement, only 99 million acres (46% of the original acreage) remained in the mid-1970's. Between the mid-1950's and the mid-1970's there was a net loss of 9 million acres; an average annual net loss of 458,000 acres of wetland. Agricultural development was responsible for 87% of recent national wetland losses and urban and other developments for 13%. For the western part of the United States area-specific wetland change data are almost nonexistent.

San Francisco Bay, the largest estuary on the West Coast of the United States, is known as an "urbanized estuary" reflecting both the five million residents in the area and the many present features of the bay which are the results of people's activities (Davis, 1982). This urbanization and development of San Francisco Bay and the Sacramento/San Joaquin Delta has led to destruction of 95% of the original tidal marshes (Josselyn, 1983).

In 1984 the Environmental Protection Agency (EPA) funded the U.S. Fish Wildlife Service (USFWS) to update NWI wetland maps in the San Francisco Bay and the Sacramento/San Joaquin Delta areas of California. The objectives of this Bay/Delta wetland mapping project,

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were to produce a time-series of wetland maps, to digitize the wetland habitat information, to load it into a geographical information system, and to generate wetland change information (Cotter, et al., 1985). The wetland change information is not from original to present conditions, but rather from the mid-50's, to the mid-70's, to the mid-80's.

The study was jointly conducted by the USFWS's National Wetlands Inventory (NWI) and National Wetlands Research Center (NWRC). The NWI was responsible for the production of wetland maps and NWRC for digitization and data analysis. The focus of this paper is a discussion of the wetland mapping procedures. Initial results of the study were the subject of a paper at Coastal Zone 87 (Handley and Quammen, in prep.).

#### STUDY AREA

The study area, encompassing over 5,000 square miles, covers San Francisco Bay, the Sacramento/San Joaquin Delta, and extensive portions of the surrounding area (Fig. 1). The study area boundary corresponds to existing USGS quadrangle maps and is bounded roughly by the cities of San Jose to the south, Stockton to the east, Sacramento and Napa to the north, and the coastline to the west. This study area is divided into three work areas as discussed below and shown on Figure 1:

A. South San Francisco Bay - Defined by 18 USGS quadrangle maps extending from about the cities of Sausalito and Berkeley south to the areas of the cities of Milpitas and Mountain View and west to the coastline.

B. North San Francisco Bay and Suisun Marsh - Defined by 24 USGS quadrangle maps covering San Pablo Bay; Napa, Petaluma and Suisun Marshes; and the Jersey Island and city of Rio Vista areas of the Sacramento/San Joaquin Delta.

C. Delta and Outlying Areas - Defined by 62 USGS quadrangle maps covering the Sacramento/San Joaquin Delta and outlying areas adjacent to work areas A and B. The outlying portion includes such areas as Tomales Bay, Bodega Head, Drakes Bay, Yolo by-pass, and the cities of Sacramento and Livermore areas.

#### PROCEDURES

The Bay/Delta wetland mapping project used standard NWI procedures and mapping conventions (Wilens, 1980; NWI 1981; NWI, 1985). Wetlands were identified through the use of high altitude aerial photography and were classified according to "Classification of Wetlands and Deepwater Habitats of the United States" (Cowardin, et al. 1979). Air photointerpretation was supplemented by the use of existing collateral data, ground checking, and discussions with individuals familiar with the local wetland resources.

To the extent possible through air photointerpretation, an attempt was made to identify and classify all wetlands regardless of location, size, type, or ownership. As with any mapping project, the level of detail on the Bay/Delta wetland mapping final products was dependent on the scale of final products and its data (aerial photography). At 1:24,000 scale, the wetland maps allow for relatively complete wetland

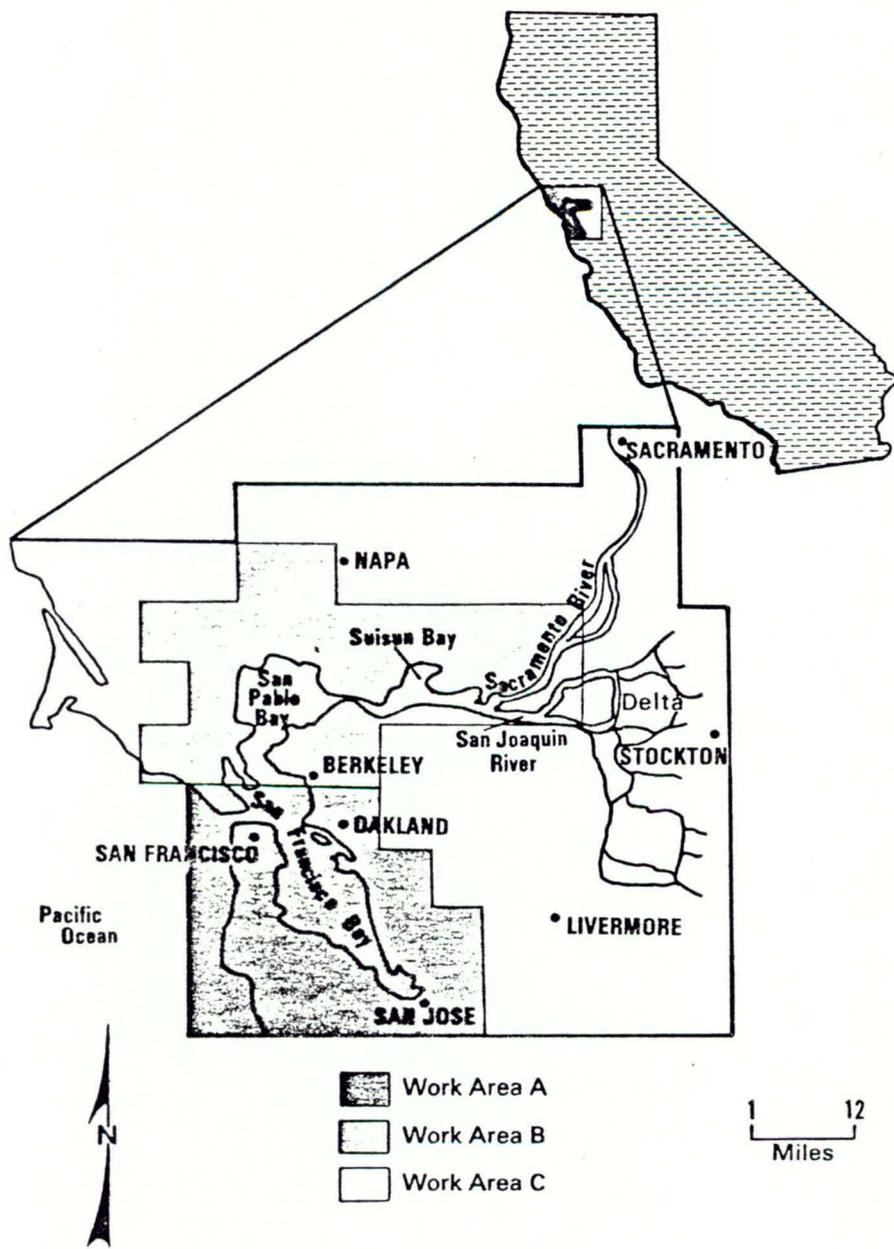


Figure 1. San Francisco Bay/Delta wetland mapping study area.

data, but the smaller scale aerials (1:65,000 scale) limited the practical information that could be interpreted and mapped. Though no minimum mapping unit was established, delineations were made with an understanding of the aerial photography limitations. Detailed wetland classification within a given expanse of wetlands may not have occurred and inclusion or omission of small wetlands was dependent on surrounding areas and contrasting signatures on the aerials.

#### 1985 Mapping

Using 1985 aerial photography (NASA 1:65,000 scale, color infrared April 30, 1985) wetland mapping was completed for 104 1:24,000 scale maps (USGS 7.5' quadrangle sheets) for the entire study area.

National High Altitude Photography (NHAP) 1982-84 aerials (CIR, 1:58,000 scale) were used as collateral information. While new aerials were flown for this particular project, it is generally not necessary for such mapping efforts as existing aerial photography may be adequate. Important factors to evaluate are time of year, quality, emulsion, cloud cover, wetness/dryness, and scales of existing aerials in meeting objectives of resource mapping projects.

Wetlands were classified as to system, subsystem, class, water regime modifier, and special modifiers of the Service's wetland classification system (Cowardin, et al. 1979). Water chemistry modifiers were applied where collateral data were available; for the Bay/Delta wetland mapping, this was generally limited to salt ponds and associated units.

Copies of draft and preliminary final wetland maps were provided to over 70 potential users/reviewers. Reviewers included, in part, Federal agencies such as Corps of Engineers, EPA, Soil Conservation Service, and Coast Guard; State agencies such as Department of Fish & Game, Department of Transportation, Department of Water Resources, Department of Conservation, Bay Conservation & Development Commission, and Regional Water Quality Control Boards; local county and city planning departments; private organizations such as Bay Planning Coalition, Save San Francisco Bay Association, Bay Institute of San Francisco, Port of Oakland, Leslie Salt Company, California Chamber of Commerce; and several consulting and legal corporations.

#### 1976 Mapping

NWI wetland mapping was initially completed for the San Francisco Bay area in 1982-83 using NASA high altitude, summer 1972-77, color infrared aerial photography at 1:120,000 and 1:130,000 scales and some black and white coverage at 1:80,000 scale. Wetlands were classified to system, subsystem, class, a "lumped" water regime modifier, and special modifiers (NWI, 1981). "Lumped" water regimes are groupings of the seven non-tidal water regime modifiers into three groups which facilitated wetland classification using the small scale aerials.

As part of the Bay/Delta wetland mapping, 42 of the original 1976 NWI wetland maps and aerial photos were reviewed and revised using the 1985 wetland maps as important collateral data.

#### Mid-1950's Mapping

NWI wetland mapping for the mid-1950's covered only work area A and was completed using black and white 1:20,000 and 1:31,000 scale aerial photography taken in May, June and September 1956 and July 1958 and minor amounts of 1:80,000 black and white from July and September

1954. Wetlands were classified to system, subsystem, and class with farmed and diked/impounded special modifiers. Photointerpretation was initiated after completion of photointerpretation of the 1985 aeriels. Eighteen NWI wetland maps based on mid-1950's aeriels were produced.

#### DISCUSSION

The Bay/Delta wetland mapping project involved three work areas, three time periods of aerial photography, and three sets of wetland maps (Table 1). Work area A had three tasks - wetland mapping from 1985 aerial photography (A85), revision of 1976 NWI wetland maps (A76), and wetland mapping from mid-50's aerial photos (A50). Work area B, had two tasks - B85 and B76; and work area C had one task - C85.

It was necessary to ensure that the three sets of interpreted aerial photos and resulting wetland maps were comparable and that, within the limitations of widely differing aerial photography, wetland differences were the result of wetland changes and not air photointerpretation problems. Since work area A, south San Francisco Bay, involved the widest variety of tasks, aerial photos, time periods and products, it will be used to discuss how the wetland maps from the three time periods were related to each other.

The Bay/Delta wetland mapping involved three very different sets of aerial photography relative to dates, scales, and emulsions. In order to generate as accurate as possible wetland change information, these differing data sources needed to be standardized. The commonality in all tasks was use of standard NWI mapping procedures and the USFWS's wetland classification system, although to differing levels of detail (Table 1). Considering date, quality, scale, and emulsion the 1985 NASA coverage was the best set of aeriels used and became the principle data sources for this wetland mapping.

Field checking was designed to check signatures on the aerial photos with on-the-ground situations. While published soil surveys (SCS,1981; SCS, 1977; SCS,1961) and the USFWS's list of wetland plant species (FWS, 1985) were used, neither site-specific soil probes nor detailed vegetative surveys were conducted. It is important to note that the Bay/Delta wetland mapping was an air photointerpretation project rather than a field mapping effort.

The 1985 wetland maps, with the incorporation of review comments received on draft and preliminary final maps, are considered the most recent and comprehensive NWI wetland maps for the Bay/Delta wetland mapping. These wetland maps became important collateral data for review of the 1976 delineated aerial photos and the original NWI wetland maps and for the mid-1950's air photointerpretation.

For each quadrangle map within work area A, clear overlays of the wetland delineations and classifications were prepared for each of the three time periods. Clear copies of the 1976 wetland maps were directly overlaid on the 1985 wetland maps. Wetland delineations were compared for linework and classification coding and any variations were highlighted on the 1976 wetland map overlays. Because of the previously noted variations in aerial photography, the highlighted areas were not unconditionally accepted as wetland changes. The 1976 aerial photos were carefully reviewed with special emphasis toward those areas differing from the 1985 wetland delineations. If wetland changes had occurred, the 1976 wetland maps were not modified; if air

Table 1: Work areas, products, aerial photography and classification detail for the Bay/Delta Wetland Mapping.

Work Areas	Products	Photography			Classification Detail <sup>1</sup>				
		Date	Scale	Emulsion	System	Subsystem	Class	Water Regime	Special Modifiers
South Bay	1985 NWI maps	1985 82-84	1:65K 1:58K	CIR <sup>2</sup> CIR	yes	yes	yes	yes	yes
	1976 Revised NWI maps	1972 to 1977	1:120K 1:130K & 1:80K	CIR CIR B&W <sup>3</sup>	yes	yes	yes	lumped	yes
	1950's NWI maps	1956 & 1958	1:20K & 1:31K	B&W	yes	yes	yes	no	farmed, diked
North Bay	1985 NWI maps	1985 82-84	1:65K 1:58K	CIR CIR	yes	yes	yes	yes	yes
	1976 Revised NWI maps	1972 to 1977	1:120K 1:130K & 1:80K	CIR CIR B&W	yes	yes	yes	lumped	yes
	1950's None								
Delta & other areas	1985 NWI maps	1985 82-84	1:65K 1:58K	CIR CIR	yes	yes	yes	yes	yes
	1976 NWI maps not revised								
	1950's None								

1. Classification of Wetlands and Deepwater Habitats of the United States, (Cowardin, 1979)

2. Color infrared aerial photos

3. Black & white aerial photos

photointerpretation caused the variation, necessary wetland delineations and classifications were changed on the 1976 maps.

The clear copies of initial mid-1950's wetland maps were subjected to the same comparative procedures, using both the 1985 and revised 1976 data. Any differences between the mid-1950's drafts and either of the two earlier time frames were annotated on the drafts and necessary corrections made.

A similar process was used for work area B for preparation of 1985 and revised 1976 original wetland maps, and for work area C for production of 1985 wetland maps.

While each set of NWI wetland maps and corresponding aerial photography were carefully compared and related, air photointerpretation and resultant wetland maps are intended to "stand alone" reflecting wetland conditions at the time of photography. The original NWI 1976 wetland maps were prepared using less than the most desirable aerial photography considering time of year (summer) and scales (1:80,000 to 1:130,000). Several areas of possible photointerpretation and/or mapping problems had been noted in field use of the NWI 1976 wetland maps. Of particular concern were seasonal wetlands which had been extremely difficult to see on the 1976 small scale summer aerials. As expected, larger scale, better quality, and time of year of the 1985 aerials allowed for greater mapping detail. Size, shape and numbers of small wetland maps were more evident and reflected in more detailed wetland maps compared to the mid-70's maps.

As wetland change data for the Bay/Delta wetland mapping are more completely analyzed and graphically presented, possible photointerpretation "problems" surface. Some of these are: seasonal wetlands on the 1985 aerials are not seen on the mid-70's because of wetland size, dryness (drought conditions existed), and/or agricultural practices; linear wetland delineations on the mid-70's aerials are delineated as polygons on the 1985 aerials (scale related); and several wetland classifications on the mid-70's do not include the diked special modifier as applied in 1985. The large scale of the mid-50's aerial photography offset the limitations of black and white emulsion. Further review and comparison of the mid-70's and 1985 photointerpretation and wetland delineations are being initiated.

#### SUMMARY

The U.S. Fish and Wildlife Service has prepared a series of wetland maps for the San Francisco Bay, Sacramento/San Joaquin Delta and surrounding areas. The most recent set of NWI wetland maps consist of 104 maps based on 1985 aerial photography; a second set is 42 revised NWI wetland maps based on mid-1970's aerials for the San Francisco Bay area; and a third set is 18 wetland maps based on mid-1950's aerials for the south San Francisco Bay area.

For the 18 wetland maps covering work area A (south bay), wetlands and deepwater habitats (excluding the open ocean and subtidal open water portion of South San Francisco Bay) cover about 14% of the area. Between the mid-50's and mid-70's wetlands and deepwater habitats decreased by about 7% and from the mid-70's to mid-80's by about 2%. Diked estuarine emergent wetlands showed drastic changes: mid-50's to mid-70's about a 92% loss and mid-70's to mid-80's about a 50% loss; non-diked estuarine emergent wetlands showed a 13% decline mid-50's to

mid-70's and less than 1% decline mid-70's to mid-80's. Non-estuarine wetlands, excluding farmed and forested wetlands, decreased by about 35% (50's to 70's) and increased by about 18% mid-70's to mid-80's. For detailed information see Handley and Quammen (in prep).

The Bay/Delta wetland mapping project included standard NWI wetland mapping. However, the project had several additional aspects and associated costs. These included flying of specific aerial photography, purchase and photointerpretation of 1950's era aerials, detailed review of original (1976) NWI wetland maps and aerial photography, and map production of revised 1976 and initial 1950's era wetland maps. Cost for the wetland mapping covering three time periods was about 2.5 to 3 times greater than standard NWI wetland mapping. Air photo acquisition, photointerpretation, and map production required about 40% of the total funding of the Bay/Delta wetland mapping. The remaining funds were used for digitizing the wetland data into a computerized geographical information system and report production. Digitization of the data is necessary for easy and complete analysis of the wetland data and future monitoring of the wetland resources.

Wetland change/trend data should continue to be gathered throughout various parts of the United States. Tiner (1984) discusses both causes and locations of wetland losses which is useful in developing priority areas for change/trend work. Within Region 1 of the U.S. Fish and Wildlife Service (ID, WA, OR, NV, CA and the Pacific Islands) wetland change/trend information would be important for such areas as the California central valley and south coast, Grays Harbor and Puget Sound in Washington, Klamath and Malheur Basins in Oregon, the Hawaiian Islands, and continuing monitoring of the San Francisco Bay and Sacramento/San Joaquin Delta wetlands. Using the USFWS's wetland classification system and NWI wetland maps and mapping procedures would allow for monitoring of wetland changes and current conditions from consistent base information.

Additional wetland change/trend data would offer the best way to assess cumulative impacts and would provide data for development of future wetland loss models. Wetland change information covering time periods before and after full and active implementation of various federal, state and/or local permit programs and active public awareness of the importance of wetlands is an excellent means to truly evaluate the effectiveness of wetland protection.

As refined wetland change/trend information is gathered, resource agencies at all levels and the public should be challenged to answer:

- Will and are wetland losses continuing?
- What has been the effect of these losses?
- For what reasons was and is it acceptable to suffer wetland losses?
- How much additional loss is too much?
- What is the quality of the wetlands that remain?
- How have wetland losses affected waterfowl?
- Do we need more refuges?
- Are the refuges still strategically located?

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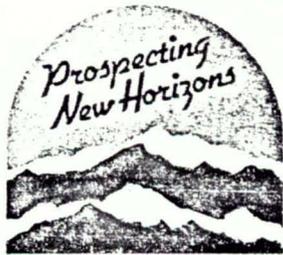
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