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# Wetlands Analysis

## Monitoring Change in South San Francisco Bay


Satellite imagery has proved to be a cost-effective tool for studying marsh vegetation over a large area.

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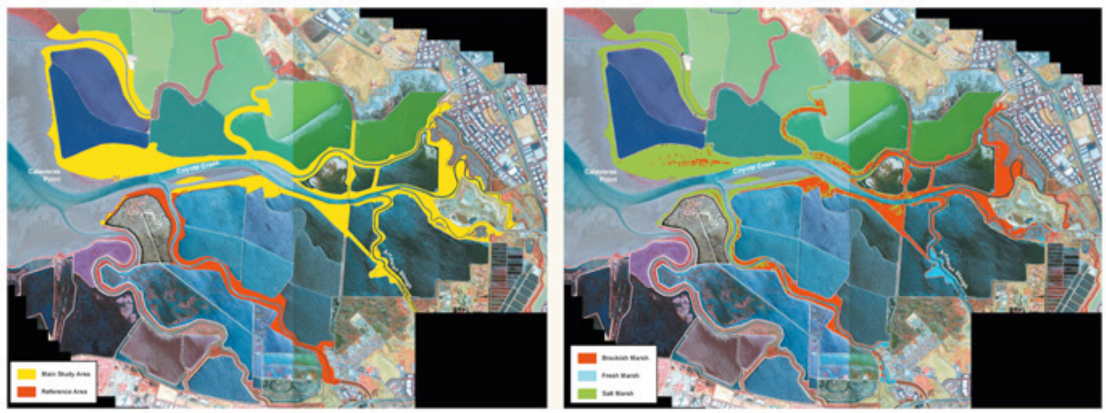
Human development during the last century has brought profound changes to South San Francisco Bay's estuary and marshes, fueling concern about the fate of the remaining marshlands.

A monitoring program mandated by the San Francisco Bay Regional Water Quality Control Board requires the city of San José, Calif., to annually assess the marshes potentially affected by freshwater discharge from the San José-Santa Clara Water Pollution Control Plant (WPCP). The studies use IKONOS 1-meter satellite imagery from GeoEye Inc. (www.geoeye.com) to document annual changes to plant species in the study area, thereby determining the distribution and aerial extent of salt, brackish and freshwater marsh.

**Assessing the Study Area**

The area's first large-scale plant community changes were observed in the 1970s and confirmed by additional studies in 1984. As part of the Water Quality Control Board's monitoring program, the city of San José contracted with H.T. Harvey & Associates to conduct more detailed studies of the marshes in 1989, 1991, 1994 and annually thereafter.

The data help researchers better understand the relative influences of environmental and anthropogenic factors affecting changes in marsh type. In addition, the information will help assess how long-term changes in marsh composition could potentially affect two endangered salt marsh wildlife species (see "Monitoring Surveys Protect Endangered Species," below). The data also serve as an important baseline for the 15,000-acre South Bay Salt Pond Restoration Project, the largest wetlands restoration project on the U.S. West Coast.




**The total marsh study area is approximately 2,000 acres. The Reference Area was included to provide a baseline of marsh information from which to judge whether changes in marsh vegetation in the Main Study Area were a result of WPCP discharge (left). By monitoring annual changes to plant species in the study area, researchers can determine the distribution and aerial extent of brackish, freshwater and salt marsh (right).**

The pan-sharpened, multispectral (red, green, blue and near-infrared bands) satellite imagery has been used for plant association mapping since 2004. Color-infrared (CIR) aerial photography was used to monitor the study area for years, but in 2003 it was determined that 1-meter satellite imagery could significantly reduce costs and still provide needed resolution (see "Satellite Imagery Provides a Cost-Effective Solution," below).

The total marsh study area is approximately 2,000 acres. As detailed in the upper-left figure, the area is divided into the Main Study Area, a portion of the South San Francisco Bay near and directly downstream of San José/Santa Clara WPCP discharge, and a Reference Area located on Alviso Slough, which forms the mouth of the Guadalupe River.

**A GIS-Based Approach**

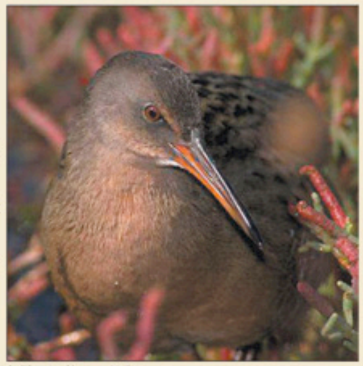
Complete ground-truthing of the preliminary mapping work was conducted during site visits to the project area during August and September 2005. Marsh vegetation was observed primarily from areas directly adjacent to the marshes to maintain consistency with the methods employed in previous years, as well as to follow U.S. Fish and Wildlife Service (USFWS) guidelines and regulations.

# Monitoring Surveys Protect Endangered Species

In 1989, as part of a monitoring program required by the San Francisco Bay Regional Water Quality Control Board, the city of San José, Calif., commissioned a survey for two federal endangered species within the South San Francisco Bay Estuary: California clapper rail (Rallus longirostris obsoletus), a shy, elusive bird, and the salt marsh harvest mouse (Reithrodontomys raviventris). The first surveys were completed in 1990.

## Preferred Habitats

California clapper rails once lived in coastal marshes throughout central and northern California, but today can only be found along San Francisco Bay. Optimal clapper rail habitat comprises tidal salt marsh in the bay with direct tidal circulation, an intricate network of tidal sloughs, pickleweed with cordgrass, gumplant, and other high-marsh plants, as well as abundant and dense high-marsh vegetation for cover during high tides. Brackish marshes generally aren't considered to be suitable habitat. The 1990 surveys found that clapper rail densities were highest in marshes with a transitional vegetation type between salt and brackish marsh, while densities were lowest in brackish marshes. In 1990, 23 clapper rails were found.



*California Clapper Rail*

*Salt Marsh Harvest Mouse*

The preferred habitat of the salt marsh harvest mouse is the middle and high zones of tidal salt marshes, which are predominantly pickleweed. The mouse depends on dense perennial salt marsh vegetation for food and cover. In 1990, 95 salt marsh harvest mice were identified.

## Future Surveys

The next clapper rail and salt marsh harvest mouse surveys are due to be completed by late 2006. One objective is to determine the degree of suitable habitat that brackish marsh vegetation may provide for the mouse. The use of IKONOS satellite imagery for the 2006 surveys will result in clearer delineations of species habitat—i.e., salt, brackish and fresh—using the same methodology as the marsh studies commissioned by the city of San José. This will help field biologists better locate areas to observe these species and meet survey objectives.

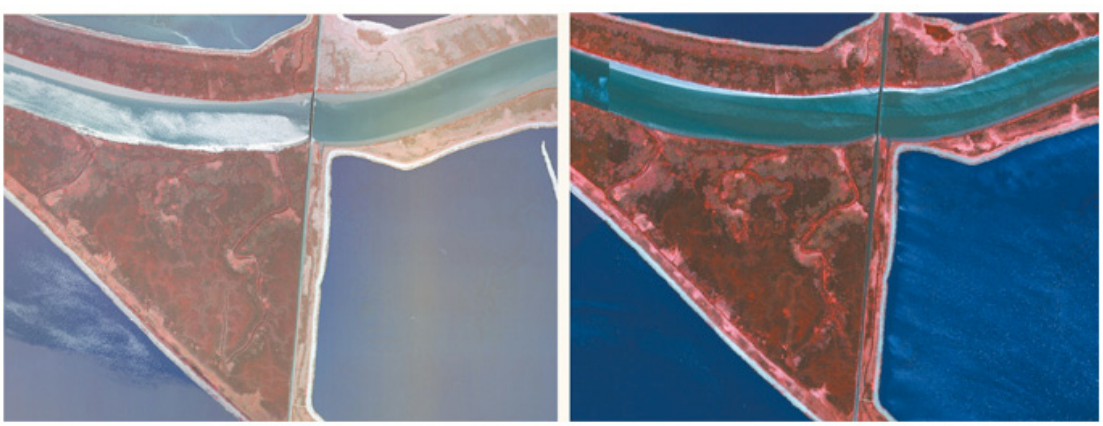
Acreage -calculations by plant -associations, dominant species and habitat type maps, as well as acreage tables, were produced in ArcGIS geographic information system (GIS) software from ESRI (www.esri.com). The GIS database was downloaded and backed-up weekly. Digitized boundaries of habitat areas were reviewed for consistency and quality, and plant association acreages and color-coded figures for the entire study area were generated. Comparisons were made between 2005 maps and those created in previous years.

Habitat mapping was completed at a scale of 1:2,400 using IKONOS imagery acquired between May and June of each study year during low tide as a base layer prior to the start of fieldwork. The spectral signatures obtained from the IKONOS imagery identified known and tentative habitat classifications. Two laptop computers equipped with ArcGIS, along with the IKONOS imagery, were used to assist in habitat field verification mapping.

**Overall Results**

The entire study area has become less saline since 1989. Newly forming freshwater marsh habitat in both the Reference Area and the Main Study Area indicates that freshwater influences are affecting all local marshes.

Between 1989 and 1999, there was greater change in habitat types in the Reference Area compared to the Main Study Area. However, there was also a higher rate of new marsh formation in the Main Study Area. This indicates that the conversion of salt marsh habitats within the South San Francisco Bay Estuary was likely driven by large-scale influences affecting the entire system. The overall gains in salt marsh habitat from 2001 to 2005 highlight the multiple factors affecting changes in marsh vegetation types in South San Francisco Bay.



**Although CIR aerial photography was used to monitor the study area for years (left), in 2003 it was determined that 1-meter satellite imagery (right) could significantly reduce costs and still provide needed resolution.**

Freshwater discharges from the WPCP clearly influence plant species distribution within the south portion of the Artesian Slough. However, the volume of WPCP discharge has been relatively constant since 1990. During that same period salt marsh conversion further downstream has fluctuated. Therefore, it’s likely that much of the interannual variation in habitats within the South Bay marshes is due to the ongoing resizing of the channels from sedimentation and reductions in tidal prism, as well as large-scale environmental factors, such as changes in annual rainfall, changes in bay salinity due to delta outflows, and local land subsidence or increases in mean sea level.

**Satellite Imagery Benefits**
IKONOS satellite imagery has proved to be a reliable, cost-effective tool for studying marsh vegetation over a large area. Aerial photography provides higher resolution, but at a greater cost and with significant limitations to flexibility: aerial overflights have to be specifically planned and contracted, whereas IKONOS images can be purchased from archives. Despite a slight reduction in resolution, the multispectral quality of IKONOS imagery provides an indication of plant types that is as good or better than that provided by aerial photographs.

**Publisher's note:** For further information on the marsh studies performed by the city of San José, visit the Marsh Studies Web site at www.sanjoseca.gov/esd/marsh-studies.htm.

# Satellite Imagery Provides a Cost-Effective Solution

Although color-infrared (CIR) aerial photography has a spatial resolution of 6 inches, and IKONOS imagery has a pan-sharpened spatial resolution of 1 meter, researchers determined that 1-meter satellite imagery could significantly reduce costs and still provide adequate resolution. Additionally, IKONOS imagery has higher spectral resolution. By being able to manipulate the different spectral signatures associated with the vegetation, certain distinctions in the vegetation types that weren't visible on the CIR aerial photos now can be seen clearly. This advantage allows more consistent mapping of vegetation types.

It should be noted that the spectral resolution of vegetation types using IKONOS imagery differs from that provided by aerial photos in previous years, blurring the line between habitat types. This necessitated a higher degree of reliance on field observations during the initial transition between using CIR aerial photos and CIR IKONOS imagery. Factoring in these one-time field-survey costs, however, still produced a first-year cost savings.

Shown at right are the cost savings for the first three years of using IKONOS imagery vs. CIR aerial photos. First-year net savings was approximately $1,500 or 13 percent. During the second and third years, the cost savings was 65 percent. Approximately $16,500 was saved in three years by switching to IKONOS imagery.

## Three-Year Cost Savings

### First Year Cost Savings (2003)

| Item | Cost |
|---|---|
| CIR Aerial Photos | $11,500 |
| IKONOS Imagery | $3,500 |
| Additional Field Work* | $3,000 |
| Image Analysis for ArcGIS Software* | $3,500 |
| Net Savings | $1,500 |

### Second Year Cost Savings (2004)

| Item | Cost |
|---|---|
| CIR Aerial Photos | $11,500 |
| IKONOS Imagery | $3,500 |
| Image Analysis for ArcGIS Software** | $500 |
| Net Savings | $7,500 |

### Third Year Cost Savings (2005)

| Item | Cost |
|---|---|
| CIR Aerial Photos | $11,500 |
| IKONOS Imagery | $3,500 |
| Image Analysis for ArcGIS Software** | $500 |
| Net Savings | $7,500 |

* one-time cost for 2003 "transition to IKONOS" study year

** annual maintenance

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