Ravenswood Pond Restoration
Surface Elevation Tables-Marker Horizon Monitoring

Summary Report 2023-2025

January 13, 2026

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Background

USGS Western Ecological Research Center manages a decadal network of surface elevation table-marker horizon (SET-MH) plots throughout California, including San Francisco Bay. These plots provide data on elevation change and accretion in wetlands, which can be utilized to assess vulnerability to sea-level rise, restoration evolution, and manage for endangered species.

New sites are regularly added to the network, spanning different land-uses and habitat types, from established older marshes to modern restorations. In 2023, SET-MH plots were installed at Ravenswood Pond R4 prior to its breach to tidal waters to monitor the restoring wetland elevation and accretion change. This report summarizes the installations and subsequent SET-MH readings between December 2023 and December 2025, two years post-breach.

Methods

Surface elevation tables (SETs) are stable benchmarks that can measure change over time (Figure 1). SET plots consist of deep steel rods driven into the substrate until they reach a stable layer (i.e. bedrock). The rods are cemented in place and fitted with a receiver, to which the SET reader arm is mounted during measurements. The SET arm is read in four pre-set directions (typically cardinal directions) within each plot and has nine fiberglass pins that are lowered to the sediment surface. The distance from the top of the SET reader arm to the top of the pin is recorded in millimeters, then the data are averaged across all directions and pins for each SET. Over time, an increase in this measurement indicates positive elevation gain and a decrease can indicate erosion, compaction or subsidence. Cumulative change and average rate of change are calculated using these measurements. At each SET, feldspar marker horizon (MH) plots are installed to measure accretion. Feldspar is laid out in 50 cm x 50 cm plots at three corners of the SET, creating a marker horizon in the soil, on which sediment accumulates. Each time SETs are read, small cores are taken using a knife within the feldspar plots, and the distance from the feldspar layer to the top of the soil is recorded for each side of the core at each corner of the SET and averaged to estimate cumulative surface accretion. A summary of the SET-MH protocol was published by Lynch et al. (2015) and our methodology follows standardized methods set by

Cahoon et al. (2002) and Webb at al. (2013).

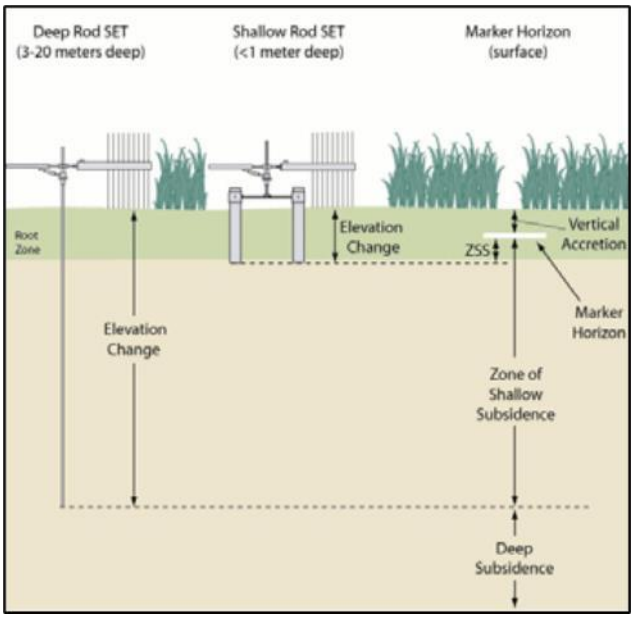

Figure 1. Conceptual diagram of the sampling approach for deep rod Surface Elevation Table – Marker Horizons (SET-MH). From Cahoon and Lynch 2002.

In early December 2023, we installed deep SET-MH plots (n=4) to quantify the relative contributions of surface and subsurface processes to vertical accretion and elevation change at four distinct locations within Ravenwood (Figure 2), prior to the pond being breached to bay waters on 12/13/2023. The plot locations were selected to achieve spatial coverage of the site. Prior to breach, the soil surface was covered by a thick salt crust and was unvegetated (Figure 3). Plots were surveyed for initial elevation using a Leica Viva Real Time Kinematic (RTK) Global Positioning System (GPS) rover with real-time corrections (SmartNet North America, accuracy ±1 cm x, y; ±2 cm z; Leica Geosystems Inc., Norcross, GA, Table 1). Plots will continue to be surveyed for elevation annually. A Solinst Levellogger 5 LTC was installed in the channel between RWNE and RWSE to collect time series data on water level, temperature and salinity for one year. Vegetation development is monitored at each SET-MH measurement. During readings, percent cover and average height of vegetation is recorded at the plot level and in three additional 1 m^2 quadrats.

Figure 2. SET-MH plot locations in Ravenswood Pond R4 restoration. The site was breached to bay tidal waters in the northeast corner.

Name	Northing	Easting	Initial elevation (m, NAVD88)	Estimated benchmark depth (m)	Measurements completed
RWNW	4150174	573828	1.431	11	4
RWNE	4150242	574641	1.405	12	4
RWSW	4149780	573773	1.362	13.5	4
RWSE	4149993	574511	1.384	9.75	4

Table 1. Details for all SET-MH including **i**nitial elevations prior to breach and estimated depth of installed benchmarks based on the number of steel rods installed.

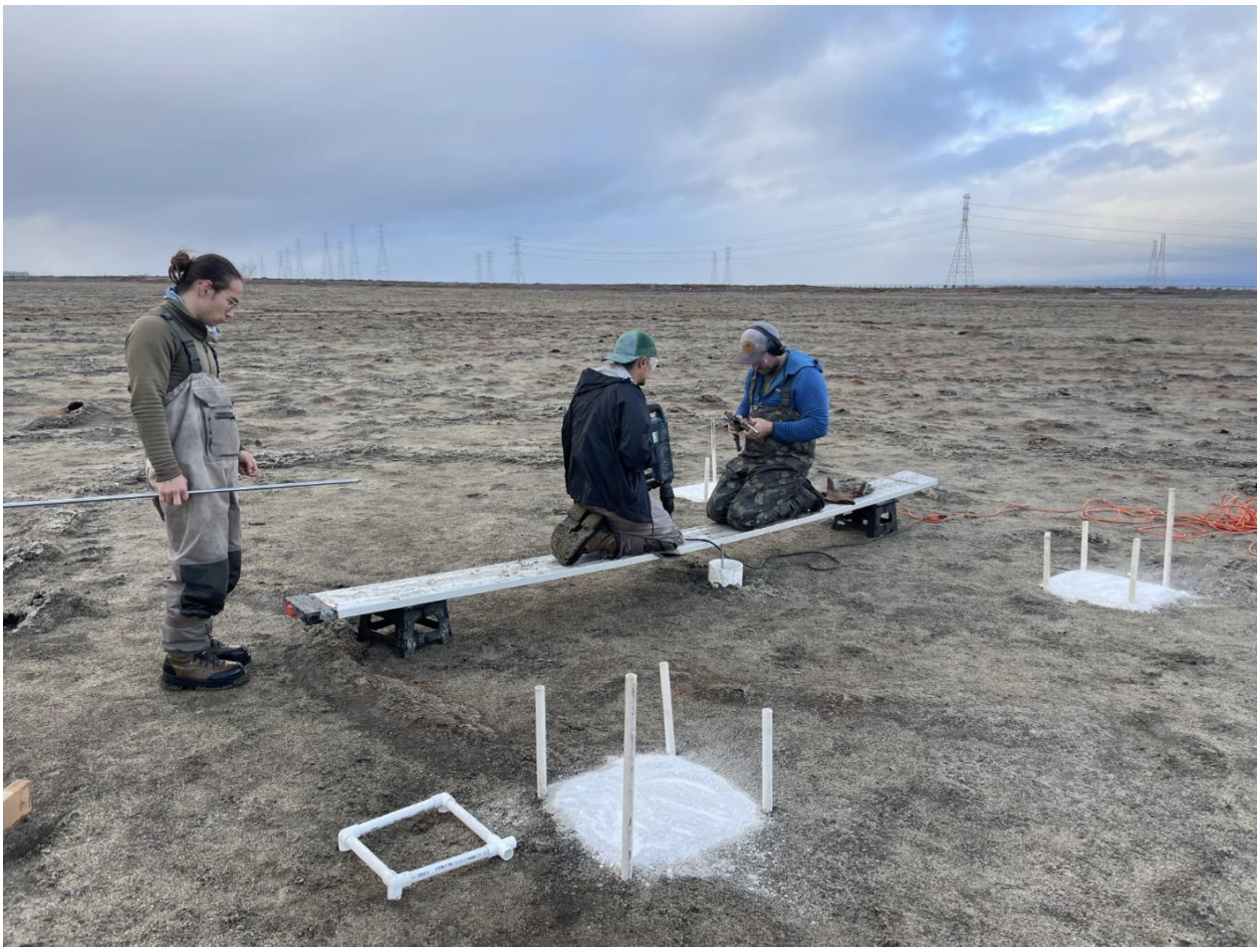

Figure 3. Installation of SET-MH plots prior to site breach to bay waters in December 2023. Image shows the center monument benchmark being installed by field staff and felspar marker horizon plots in the corners of the SET-MH.

Results

In the two years since Ravenwood Pond R4 was breached and restored to tidal regimes, elevation change has varied spatially across the site (Figure 4). The eastern SET-MHs have shown no elevation gain (RWNE, RWSE), and in fact, the SET-MH closest to the breach (RWNE) has shown significant elevation loss (RWNE: -82.47 mm/year, $t = 15.78$, $p < 0.05$; RWSE: -19.92 mm/year, $t = 16.94$, $p = 0.325$, Figure 5), whereas the western SET-MHs (RWNW, RWSW) have both increased in elevation (RWSW: 39.83 mm/year, $t = 3.816$, $p < 0.01$; RWNW: 55.25 mm/year, $t = 12.377$, $p < 0.01$). Cumulative total elevation change was negative at the eastern SET-MHs and positive at the western SET-MHs (RWNE: -154.92 ± 5.88 mm; RWSE: -50.17 ± 16.33 mm; RWNW: 111 ± 10.72 mm; RWSW: 84.53 ± 2.39 mm; Figure 5).

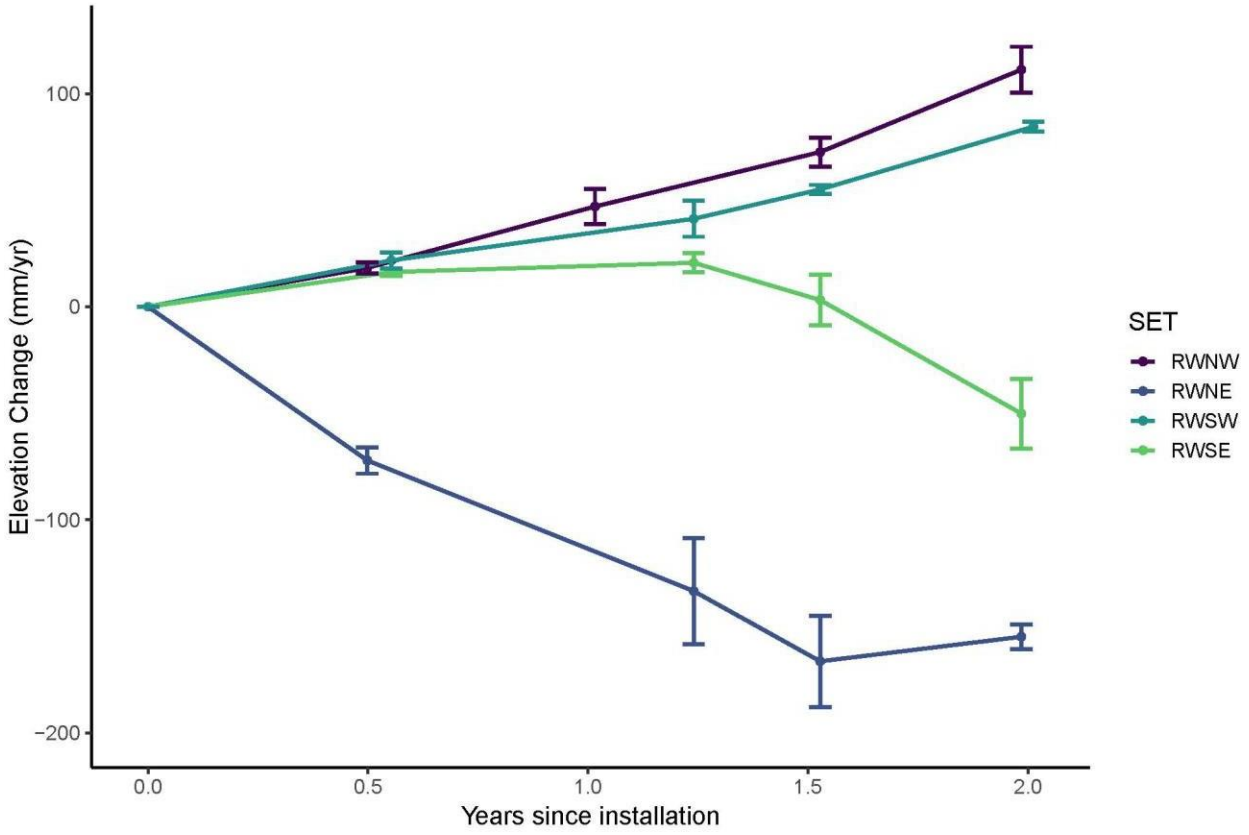

Figure 4. Elevation change over time (mm/year) at each SET-MH plot in Ravenswood/R4 since breach.

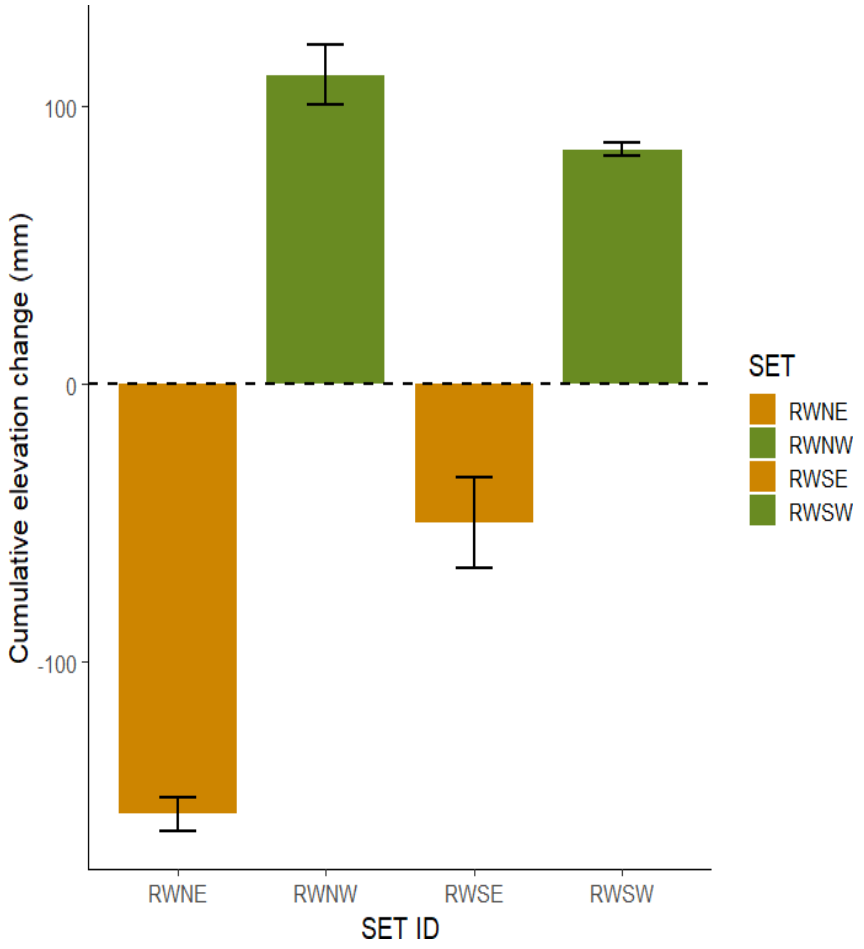

Figure 5. Cumulative elevation change (mm) at each SET-MH plot in Ravenswood/R4 since breach.

Feldspar plots at all SET-MHs have not been located since breach, possibly eroded from high water velocities. Two years post-breach, the topsoil layer is no longer a salt crust, and the site is now covered in a thin mud layer (Figure 6).

Water level data show the site is restored to tidal regimes with seasonal patterns of salinity (Figure 7). The SET-MHs and immediate surrounding area remain unvegetated, but cyanobacterial mats, which assist in soil priming, occur at all plots. Field staff have noted *Spartina spp.* and *Salicornia pacifica* in other areas of the restoration.

Figure 6. Photo of a SET-MH plot in Pond R4 approximately one-year post-breach. Feldspar plots have not been located at any SET-MH location. All SET-MH plots remain unvegetated, but algal mats have been observed

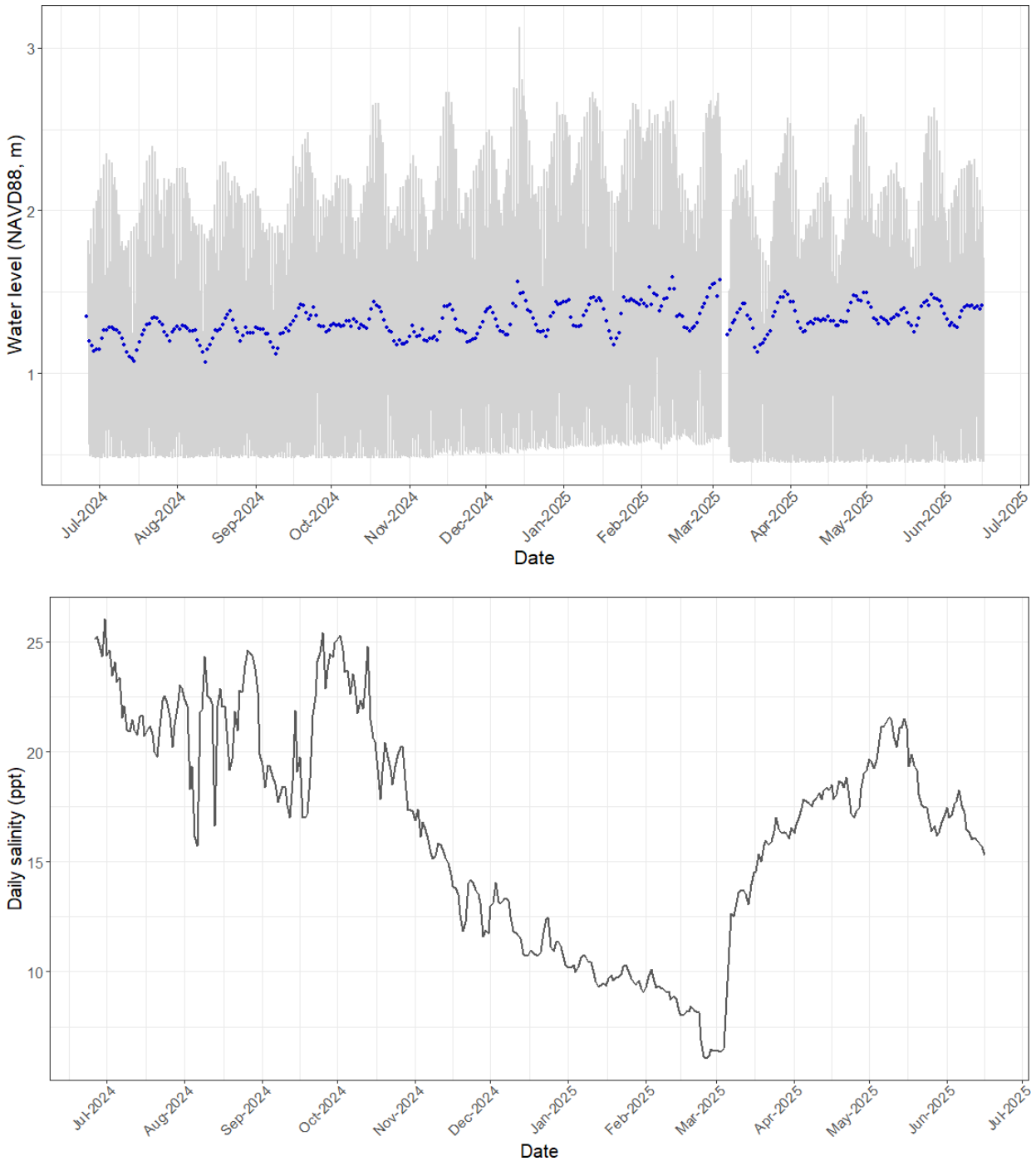

Figure 7. Sub-hourly (light grey) and daily average (blue) water level data (top) and average daily salinity values (bottom) at Ravenswood/R4 restoration from June 2024 to June 2025.

Summary

- Visible and measurable change has occurred at Ravenswood Pond R4 since the site was breached to tidal waters. Elevation change across the site shows positive elevation gains in the western area of the site, and elevation loss near the breach, potentially caused by water velocites during breach or thereafter.
- The restoration has a seasonal patterns of water salinity and tidal cycles.
- Wetland vegetation is not present at SET-MH plots, but cyanobacteria have begun to colonize and is an indicator of succession and is an early colonizer for vegetation establishment.
- USGS plans to re-install marker horizons and employ alternative methods if necessary in fall 2026.