Bathymetric Time Series Analysis of Tidal Scour Rates in Elkhorn Slough 1993- 2009

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Introduction

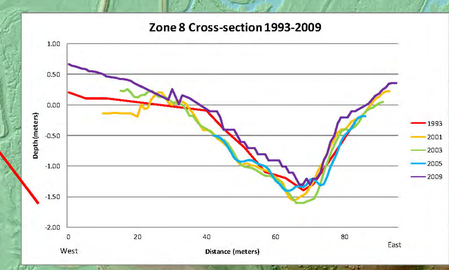
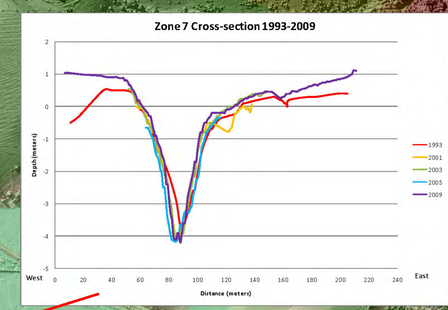
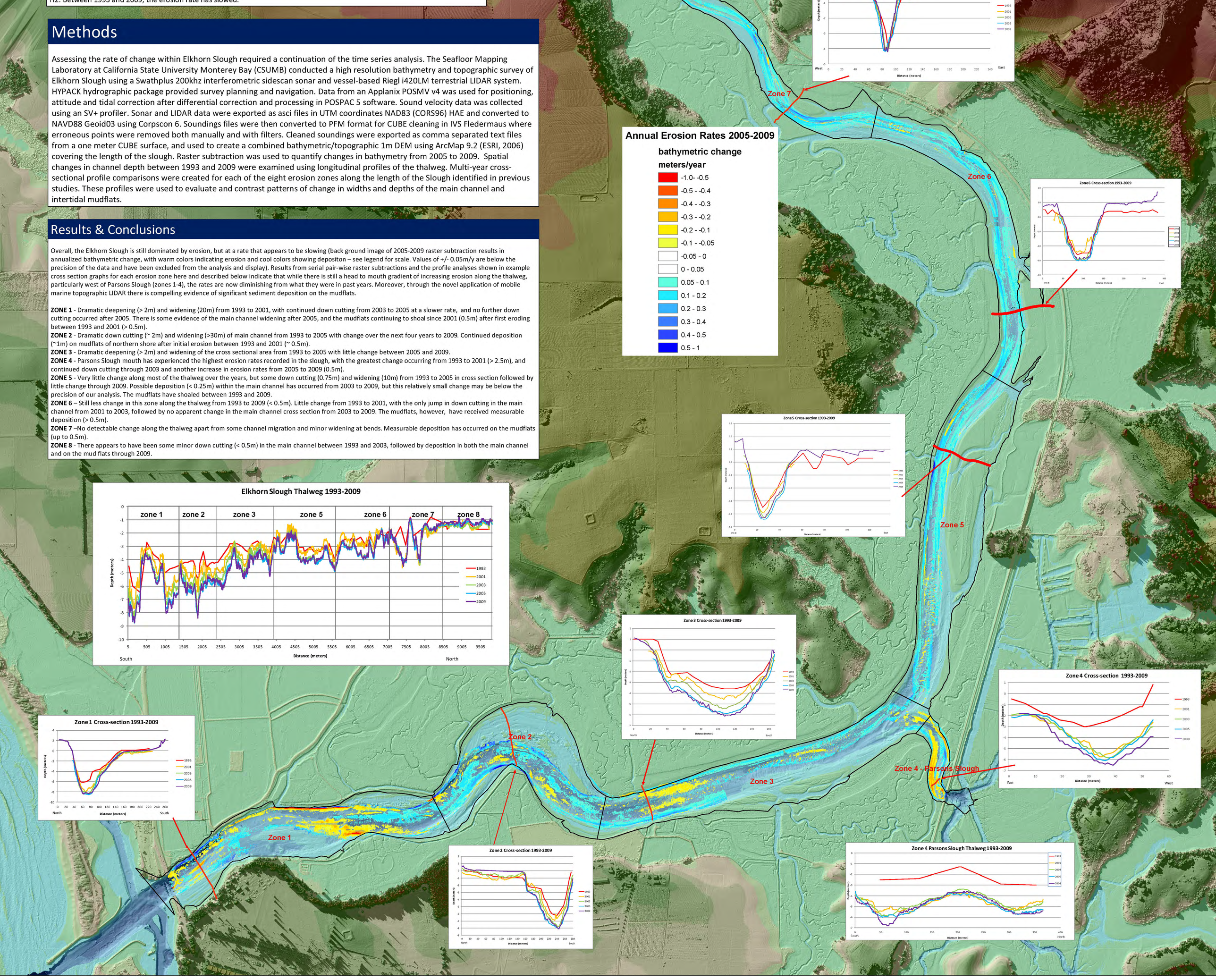
Over the past 100 years 90% of California's wetlands have been destroyed (Buchsbaum 2000). Wetlands are ecologically important ecosystems that provide a wide array of services that we take advantage of on a daily basis. In California, urban spread and agriculture have caused the vast majority of our wetlands to disappear. Elkhorn Slough, one of the last remaining coastal wetlands in California, has been experiencing rapid habitat loss since the opening of the Moss Landing Harbor mouth in 1946, which increased tidal flux from seasonal to daily. Previous studies have documented rapid and accelerating rates of tidal flow, erosion and habitat loss along the main channel, and a variety of management actions are now being considered by the Elkhorn Slough National Estuarine Research Reserve (ESNERR) (Broenkow and Breaker 2005 and Bildstein et. al. 2001). Malzone (1999) compared bathymetric data from 1988 to 1993, which indicated a sediment loss of 8x104 m3/yr. Two follow up studies, conducted by Sampey (2005) and Dean (2003) concluded that between 2001 and 2003 the Slough continued to erode at 1.5 times the annual rate calculated by Malzone. Each of these studies documented an overall deepening of the central channel with the highest rates of erosion occurring in the seaward half of the slough west of the Parsons Slough mouth (zones 1-4), with significant but lower rates found in the mid slough (zones 5-6) and low to no erosion occurring towards the head (zones 7-8). ESNERR initiated the Elkhorn Slough Tidal Wetlands Project (ESTWP) to recommend management solutions to halt or reverse these processes (Caffrey et. al. 2002). The goal of the present study is to determine whether the spatial pattern and rates of tidal scour and erosion have changed since the 2003 survey.

A time series analysis was continued along the thalweg to determine if the rate of change in Elkhorn Slough is increasing, decreasing, or reaching an equilibrium state. Using bathymetric data collected in 1993, 2001, 2003, 2005, and 2009, cross-sections were compared in the eight zones of the slough to test the following hypotheses:
H1: Between 1993 and 2009, the erosion rate has increased.
H2: Between 1993 and 2009, the erosion rate has slowed.

Methods

Assessing the rate of change within Elkhorn Slough required a continuation of the time series analysis. The Seafloor Mapping Laboratory at California State University Monterey Bay (CSUMB) conducted a high resolution bathymetry and topographic survey of Elkhorn Slough using a Swathplus 200khz interferometric sidescan sonar and vessel-based Riegl i420LM terrestrial LIDAR system. HYPACK hydrographic package provided survey planning and navigation. Data from an Applanix POSMV v4 was used for positioning, attitude and tidal correction after differential correction and processing in POSPAC 5 software. Sound velocity data was collected using an SV+ profiler. Sonar and LIDAR data were exported as asci files in UTM coordinates NAD83 (CORS96) HAE and converted to NAVD88 Geoid03 using Corpscon 6. Soundings files were then converted to PFM format for CUBE cleaning in IVS Fledermaus where erroneous points were removed both manually and with filters. Cleaned soundings were exported as comma separated text files from a one meter CUBE surface, and used to create a combined bathymetric/topographic 1m DEM using ArcMap 9.2 (ESRI, 2006) covering the length of the slough. Raster subtraction was used to quantify changes in bathymetry from 2005 to 2009. Spatial changes in channel depth between 1993 and 2009 were examined using longitudinal profiles of the thalweg. Multi-year cross-sectional profile comparisons were created for each of the eight erosion zones along the length of the Slough identified in previous studies. These profiles were used to evaluate and contrast patterns of change in widths and depths of the main channel and intertidal mudflats.

Results & Conclusions

Overall, the Elkhorn Slough is still dominated by erosion, but at a rate that appears to be slowing (back ground image of 2005-2009 raster subtraction results in annualized bathymetric change, with warm colors indicating erosion and cool colors showing depositon – see legend for scale. Values of +/- 0.05m/y are below the precision of the data and have been excluded from the analysis and display). Results from serial pair-wise raster subtractions and the profile analyses shown in example cross section graphs for each erosion zone here and described below indicate that while there is still a head to mouth gradient of increasing erosion along the thalweg, particularly west of Parsons Slough (zones 1-4), the rates are now diminishing from what they were in past years. Moreover, through the novel application of mobile marine topographic LIDAR there is compelling evidence of significant sediment deposition on the mudflats.

ZONE 1 - Dramatic deepening (> 2m) and widening (20m) from 1993 to 2001, with continued down cutting from 2003 to 2005 at a slower rate, and no further down cutting occurred after 2005. There is some evidence of the main channel widening after 2005, and the mudflats continuing to shoal since 2001 (0.5m) after first eroding between 1993 and 2001 (> 0.5m).
ZONE 2 - Dramatic down cutting (~ 2m) and widening (>30m) of main channel from 1993 to 2005 with change over the next four years to 2009. Continued deposition (~1m) on mudflats of northern shore after initial erosion between 1993 and 2001 (~ 0.5m).
ZONE 3 - Dramatic deepening (> 2m) and widening of the cross sectional area from 1993 to 2005 with little change between 2005 and 2009.
ZONE 4 - Parsons Slough mouth has experienced the highest erosion rates recorded in the slough, with the greatest change occurring from 1993 to 2001 (> 2.5m), and continued down cutting through 2003 and another increase in erosion rates from 2005 to 2009 (0.5m).
ZONE 5 - Very little change along most of the thalweg over the years, but some down cutting (0.75m) and widening (10m) from 1993 to 2005 in cross section followed by little change through 2009. Possible deposition (< 0.25m) within the main channel has occurred from 2003 to 2009, but this relatively small change may be below the precision of our analysis. The mudflats have shoaled between 1993 and 2009.
ZONE 6 – Still less change in this zone along the thalweg from 1993 to 2009 (< 0.5m). Little change from 1993 to 2001, with the only jump in down cutting in the main channel from 2001 to 2003, followed by no apparent change in the main channel cross section from 2003 to 2009. The mudflats, however, have received measurable deposition (> 0.5m).
ZONE 7 –No detectable change along the thalweg apart from some channel migration and minor widening at bends. Measurable deposition has occurred on the mudflats (up to 0.5m).
ZONE 8 - There appears to have been some minor down cutting (< 0.5m) in the main channel between 1993 and 2003, followed by deposition in both the main channel and on the mud flats through 2009.