Publication No. WI-2010-06

The Watershed Institute

Division of Science and Environmental Policy

California State University Monterey Bay
http://watershed.csumb.edu
100 Campus Center, Seaside, CA, 93955

Central Coast Watershed Studies

CCoWS

Spatio-temporal dynamics of salinity in the Old Salinas River and Tembladero Slough Castroville, California

FALL 2010

CSUMB Class ENVS660:

Colin Nicol
William Brandt
Sandy Clifton
David Nishijima
Maria Osiadacz
Emily Paddock
Violetta Pristel
Fred Watson (Instructor)

Acknowledgements

Thanks to:

- Pam Krone-Davis for salinity profiles at TEM-MOL and ion concentrations time-series
- CCoWS Access database managers
- Thor Anderson and Fred Watson for field instruments and equipment
- Brent Buche from the Monterey County Water Resources Agency
- Mike Scattini from Luis Scattini and Sons, Castroville, CA

Disclaimer:

This report primarily represents student work completed within the constraints of a fixed-duration (four week), limited-verification college class setting.

This report may be cited as:

CSUMB Class ENVS 660: Nicol. C., Brandt, W., Clifton, S., Nishijima, D., Osiadacz, M., Paddock, E., Pristel, V., & Watson F. 2010. Tembladero Slough salinity patterns and dynamics: Fall 2010. The Watershed Institute, California State Monterey Bay, Publication No. WI-2010-06, pp. 43.

Executive Summary

This report describes the research conducted as part of a class project by students in the Advanced Watershed Science and Policy (ENVS 660) course at California State University Monterey Bay. The project focused on describing the spatial patterns and temporal dynamics of salinity in the Old Salinas River Channel and Tembladero Slough (approximately between the tide gates at Potrero Road and Highway 1). The goals of our project were to 1) review the importance of understanding the extent of saline influence in inshore surface waters and 2) measure salinity (throughout the vertical and longitudinal profile) within the study area to determine the extent of saline influence. We postulated that longitudinal and vertical patterns in salinity exist within the study area, longitudinal and vertical patterns in salinity vary over time, and temporal and spatial variations in salinity patterns are controlled by tidal variations.

To characterize spatial variations, we measured salinity longitudinally along the channel from a boat on two separate days. One survey was conducted on a rising tide near high tide, and revealed a layer of relatively saline water extending along the bottom of most of the study area. Maximum salinity in the profile was approximately 20 ppt just upstream of the tide gates, and reduced with distance from the tide gates until we found salinity under 1 ppt in Tembladero Slough, approximately 1.5 km upstream of the Molera Road bridge. On a separate survey on a falling tide closer to low tide, with the exception of directly upstream of the tide gates (~25 ppt), we found no salinity levels above 3 ppt.

To characterize temporal variations in the slough, we took multiple salinity measurements and corresponding staff plate measurements throughout the study period from stationary sampling locations: the Potrero Road tide gates and Molera Road bridge. In general, we found on high tides there is an increase in stage and salinity, while on low tides there is a decrease in both stage and salinity. It should be noted, however, that at both sampling sites salinity varied between 0 and ~25 ppt, with some of the extreme conditions not matching a low or high tide.

We concluded that in general during our study period, longitudinal and vertical patterns in salinity exist and these patterns vary over time. Given our data it is likely that tidal fluctuations influence the observed salinity patterns. Despite the predominantly one-way action of the tide gates, saline water from Moss Landing Harbor entered the slough on each high tide. On each low tide the flow reversed at the tide gates and the saline water was flushed from the system. It is possible other external factors exist that influence the observed salinity patterns. Future work should focus on long term continuous salinity monitoring, which would ideally capture salinity over a full month tide cycle. Future studies should also create and approximate hydrologic budget to estimate volumes and sources of water upstream of the tide gates.

Table of Contents

Acknowledgements ii
Executive Summary iii
Table of Contents iv
List of Definitions v
1.0 Introduction 1
1.1 Background 1
1.2 Goals and Postulates 2
1.3 Study Area 2
2.0 Methods 4
2.1 Longitudinal Salinity Profile 4
2.2 Temporal Salinity Profile 5
2.3 Correction of Elevations 5
3.0 Results 6
3.1 Longitudinal Salinity Characterizations 6
3.2 Temporal Salinity Variations 10
4.0 Discussions and Conclusions 14
5.0 References 16
Appendices 18
Appendix A. Annotated Bibliography 18
Appendix B. Scope of Work 34

List of Definitions

Electrical conductivity (EC): or specific conductance is a measure of a material's ability to conduct an electric current (NRMED 2010). EC measures the charge carrying ability of liquid in a measuring cell of specific dimensions.

Neap tide: Either of the two tides that occur at the first or last quarter of the moon when the tide-generating forces of the sun and moon oppose each other and produce the smallest rise and fall in tidal level.

Salinity: is the total quantity of dissolved salt in water and is commonly measured in parts per thousand (ppt). For example, a typical 1000 gram sample of seawater (35 ppt) is made up of 35 grams of salt and 965 grams of water. Dissolved salts (ions) conduct electricity therefore salinity measurements can be made directly with an electrical probe. Salinity measurements are based on conductivity and temperature of a sample, relative to the conductivity of a standard potassium chloride solution at 15℃ (Sverdrup and Armbrust 2008).

Salinity definitions: freshwater, < 3000 mg L^{-1} (3 ppt); brackish water, 3000 – 35000 mg L^{-1} (3-35 ppt); seawater, 35000 mg L^{-1} (35 ppt) (Nielsen et al. 2003).

Salt tolerance: Plant salt tolerance is the inherent ability of the plant to withstand the effects of high salts in the root zone or on the plant's leaves without a significant adverse effect (GAARD 2001).

Spring tide: Either of the two tides that occur at or just after new moon and full moon when the tide-generating force of the sun acts in the same direction as that of the moon, reinforcing it and causing the greatest rise and fall in tidal level.

Tidal prism: is the volume of water that flows between a bay and the ocean over a tidal cycle. (Broenkow and Breaker 2005).

1.0 Introduction

1.1Background

Salinity variations impact freshwater and brackish environments. A salt gradient (halocline) established from density stratification can reduce mixing and solute transport within aquatic systems, which has implications for nutrient and carbon cycling and dissolved oxygen levels (Nielsen et al. 2003). Anoxia will result if a halocline becomes a significant barrier to the movement of oxygen from the water surface to the bottom and has been reported in rivers where intrusions of saline water occur (Nielsen et al. 2003). If salinity increases above 1000 mg L^{-1} (1 ppt) in fresh water systems, species richness and abundance decreases (Brock et al 2005). Sudden increases in salinity can impact treatment wetlands because denitrification is significantly reduced (Marks 2005). Salt-induced aggregation and flocculation of suspended matter removes particles, trace elements and nutrients from the water column, making them less readily available to pelagic organisms (Nielsen et al. 2003). Increased water clarity, as a consequence of saline groundwater intrusions has been implicated in the formation of cyanobacteria blooms (Nielsen et al. 2003). There is a lack of data on the salt sensitivities of freshwater biota and their various life stages over long periods of time (Hart et al. 1991). Aquatic organisms and plants are most sensitive to salinity at early stages in their development, and saline waters released in pulses are thought to have the largest negative effect on aquatic biota (Hart et al. 1991). Salinity variations may have terrestrial impacts because salinity in irrigation water may significantly decrease agricultural yield, although some crops such as artichokes are moderately salt-tolerant (Katerji et al. 1999; Shannon and Grieve 1999).

External factors that may influence salinity in freshwater and brackish systems include tide, river discharge, wind, seasonality, and anthropogenic effects such as tide gates and brackish inputs from agricultural tailwater. Changes in salinity patterns may also indicate climate change and sea level rise (Anderson et al. 2008). Residual soil salinity flushed by irrigation, seawater intrusion and natural tidal fluctuations increase salinity levels and may impact freshwater marshes and wetlands (CAW CWP 2009).

Tides may have a large impact on salinity in coastal systems. Tidal cycles affect vertical mixing of the water column and influence the salinity stratification (Schoellhamer 2001). Spring/neap tidal cycle has a large impact on vertical mixing, with spring tides causing the greatest vertical mixing. During neap tides, vertical mixing is reduced which allows density stratification to occur (Schoellhamer 2001). In Monterey County, CA, Tembladero Slough and Elkhorn Slough became open to tidal influence after Moss Landing Harbor was built in 1946 (Broenkow and Breaker 2005). Elkhorn Slough was historically dominated by fresh and brackish water, but after the creation of the harbor, Elkhorn Slough became a salt water dominated environment (Broenkow and Breaker 2005). Tembladero Slough and Elkhorn Slough share the same ocean inlet at Moss Landing Harbor. Although no formal studies have been published, Tembladero

Slough might have undergone the same salinity change as was observed in the Elkhorn Slough. After the creation of the harbor, tide gates were installed at the mouth of the Old Salinas River Channel leading up to the Tembladero Slough, changing the tidal effects and potentially the salinity.

Developing an understanding of temporal and spatial variations in salinity is important because of potential ecological implications. If the tide gates malfunction, salt water could enter the channel. Salinity in Tembladero Slough potentially impacts the functioning of systems reliant on freshwater upstream of the tide gates. Potential biological, environmental and agricultural implications include biological functioning of treatment wetlands, habitat for coastal fish species (e.g. tidewater goby), potential for oxygen crashes and fish kills, or effects on shallow groundwater within rooting zone of nearby crops. The objective of the study was to characterize the temporal and spatial extent of salinity upstream of the tide gates at Potrero Road.

1.2 Goals and Postulates

The goals of our study were to:

Goal 1: Review the importance of understanding the extent of saline influence in inshore surface waters

Goal 2: Measure salinity (throughout the vertical and longitudinal profile) within the study area to determine the extent of saline influence

Based on our goals, we postulated that:

Postulate 1: Longitudinal and vertical patterns in salinity exist in the Tembladero Slough

Postulate 2: Longitudinal and vertical patterns in salinity of the Tembladero Slough vary over time

Postulate 3: Temporal and spatial variations in salinity patterns are controlled by tidal variations

1.3 Study Area

The study channel (Channel) for this project started at the Potrero Road Bridge tide gates (OLS-POT) (Figure 1), continued upstream of the Old Salinas River (OLS) and into the Tembladero Slough (TS) to the extent of brackish water (when $x < 3$ ppt). Other points of reference include the confluence of TS and OLS (TEM-MOL), and the staff plate in OLS (OLS-MON). TS exists mainly as a channelized drainage ditch within the Gabilan Watershed system of Central California. It flows northwest, about 5.5 kilometers, through the Castroville region of Monterey County (Figure 2).

Merritt Creek and the Reclamation Ditch - the latter used to be the lower portion of Gabilan Creek - drain into TS just past the Highway 183 Bridge located 7.4 kilometers southeast of Moss Landing Harbor. TS flows into the Old Salinas River (at the site of the constructed Molera

Wetland), and the Old Salinas River discharges into Moss Landing Harbor in Monterey Bay (CALAM CWP 2009; Casagrande and Watson 2006; CCA#40 2006; CMRPP 2004).

Figure 1. (a) Water flowing through the smaller section of three tide gates on the right bank of Potrero Road Bridge facing downstream (lower tide gates). (b) Downstream side of the main tide gates at low tide (November 5, 2010).

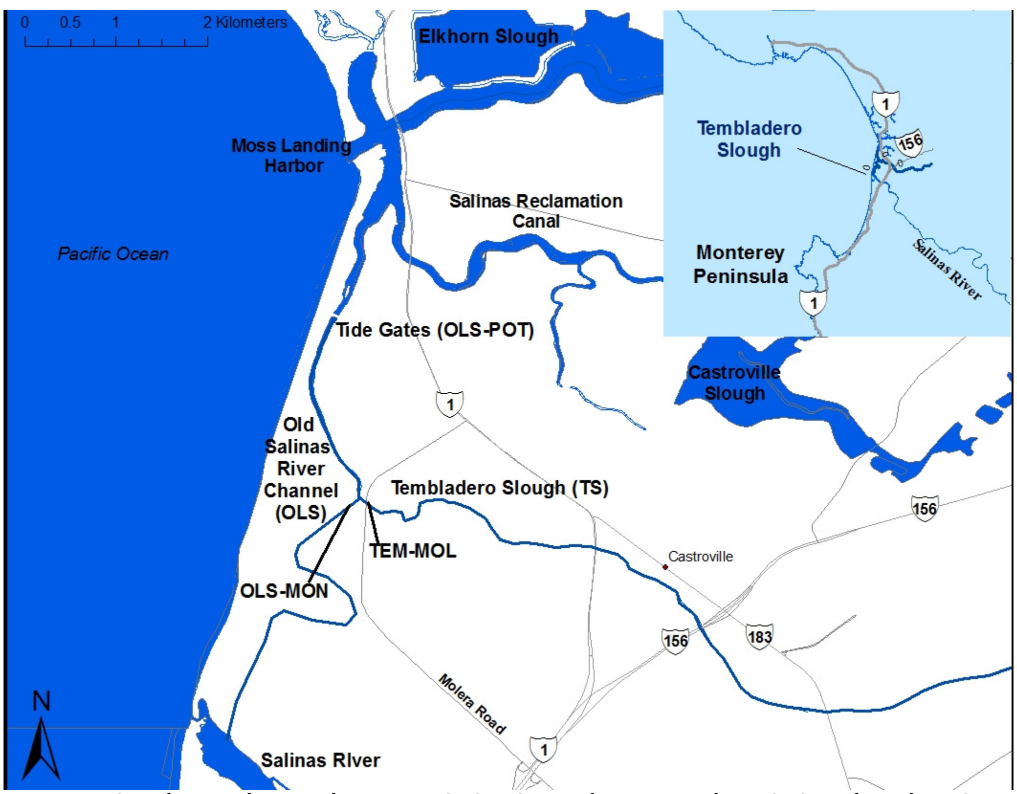


Figure 2. The study area began at OLS-POT and continued up OLS and to the TS.

The surrounding coastal landscape consists of dunes with elevations ranging between 1 and 15 meters. Holocene age alluvial deposits lie underneath the study area. Unconsolidated sediments of interbedded sands, silts and clays have been deposited along the lower Gabilan watershed. The floodplains are relatively flat and poorly drained (CALAM CWP 2009; Casagrande and Watson 2006; CCA#40 2006; CMRPP 2004).

Historically, the low-lying areas in this region supported natural wetlands, but today a large extent is cultivated land with row crop agriculture consisting mostly of artichoke fields; there is very little riparian vegetation and wetland habitat along the reach of the slough. To facilitate cultivation, grazing and maintain flood/tidal control, the natural hydrology of the area has been significantly changed. TS has been channelized over time to accommodate agricultural runoff from the surrounding fields, but runoff from the hills directly north along with urban runoff from the nearby cities of Castroville and Prunedale also drain into the slough (CALAM CWP 2009; Casagrande and Watson 2006).

2.0 Methods

We measured salinity spatially and temporally in November 2010. Salinity was measured spatially from a boat on a single day and temporally from OLS-POT and TEM-MOL on multiple days. Water stage height was also recorded throughout the sampling period at OLS-POT, TEM-MOL and on the Old Salinas River channel at Monterey Dunes Colony Road (OLS-MON). The tide height data during the sampling period were collected (MBARI 2010).

2.1 Longitudinal Salinity Profile

The extent of salty and brackish water was measured via salinity (ppt) depth (m) profiles along the length of the channel. To establish the effects of tides, measurements were taken during a spring high tide and a neap low tide. Salinity and depth were measured from a boat approximately every 200 m using a YSI 556 Handheld Multiparameter Instrument at quarter meter increments below water surface and a Speedtech Instruments Portable Depth Sounder (Figure 3). All measurement locations were recorded using a Trimble GPS GeoXM unit. The first measurements were taken at the tide gates and subsequent measurements were taken up the channel until salinity dropped below 2.0 ppt throughout the water column.

Figure 3. Longitudinal boat survey beginning at the tide gates at OLS-POT.

2.2 Temporal Salinity Profile

The temporal variation in salinity was measured using a YSI 556 Handheld Multiparameter Instrument. Data were recorded downstream of the TEM-MOL Bridge (Figure 4) and upstream of OLS-POT. Salinity was measured starting at the surface and at 25 cm increments to the bottom of the water column.

Figure 4. Salinity testing at the TEM-MOL.

2.3 Correction of Elevations

We corrected our measurements and staff plate readings into the North American Vertical Datum (NAVD 88) framework, which uses mean lower low water of the ocean surface as its datum. Using a Topcon RL-60B rotating laser we surveyed from the staff plate just upstream of the tide gates to the middle of Potrero Road at the tide gates. Using the same instrument we also surveyed from the staff plate in the Old Salinas River Channel to the middle of Dunes Colony Road.

We used a 1 m digital elevation model derived from a circa 2004 LiDAR survey (Naval Postgraduate School, unpublished data) to find the NAVD 88 elevations of the roads. Elevation data in the LiDAR were in the North American Datum (NAD 83) ellipsoid framework, and were converted to the NAVD 88 framework using the Geoid 09 (NGS NOAA 2009) model. We then used the NAD83-NAVD88 correction for the coordinates of the tide gates, and applied the single correction to the LiDAR data covering our study area. Once our LiDAR data were corrected to NAVD 88, we extracted elevation values for the Potrero Road tide gates and Dunes Colony Road. We adjusted our staff plate data into the NAVD 88 framework

3.0 Results

Salinity measurements were taken periodically from November 5 through November 21, 2010. Water surface elevation (WSE) was calculated from staff plate readings taken when salinity measurements were conducted (Figure 5). Discharge data was also collected during the study period from OLS and the Reclamation Ditch USGS gage (11152650). On average, the discharge into the Old Salinas River Channel through the slide gates from the Salinas Lagoon was estimated to have been 7 cfs, in a northward direction (B. Buche, MCWRA, pers. comm.) and the Reclamation Ditch discharged between 0.7 and 3.0 cfs (Figure 6). Discharge from the Reclamation Ditch during the sampling period also had two flood events during the study period on November 8 (~80 cfs) and November 20 and 21 (~30 cfs).

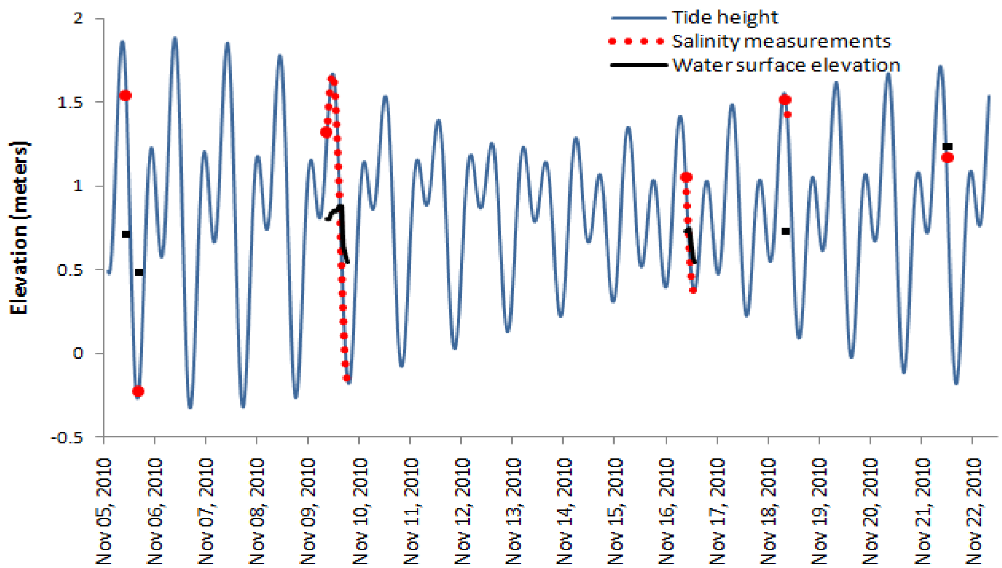


Figure 5: Tidal heights for Moss Landing Harbor between November 5, 2010 and November 19, 2010 (Data from Monterey Bay Aquarium Research Institute, 2010). Sampling occurred on November 5, 2010 at 10:37 and 16:34 (high tide 1.859 m at 8:46 and low tide -0.271 m at 15:52), November 9, 2010 from 9:00 to 19:00 (high tide 1.667 m at 11:33 and low tide -0.182 m at 19:08), November 16, 2010 from 9:30 to 14:00 (high tide 1.413 m at 6:56 and low tide 0.366 m at 13:31 pm) and November 18, 2010 from 8:22 to 8:59 (high tide 1.551 m at 7:47 and low tide 0.897 m at 14:40). WSE shown on the figure was read from the staff plate at OLS-POT.

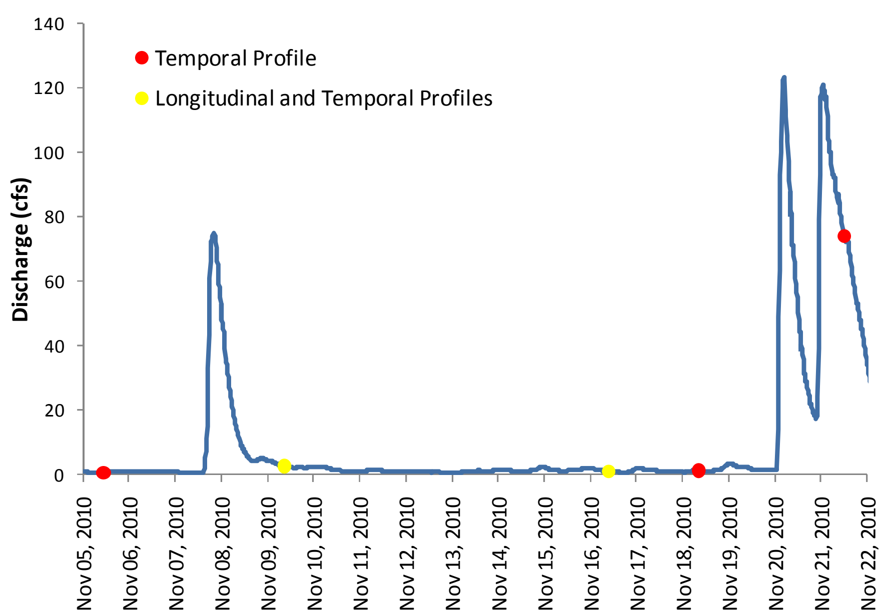


Figure 6. Discharge data from the USGS Reclamation Ditch near Salinas gage (11152650). The discharge (cfs) at the start of each data collection day is denoted.

3.1 Longitudinal Salinity Characterization

On November 9 and 16 longitudinal salinity measurements were taken from the Potrero Road tide gates up the channel to establish the extent of brackish and salty water during high and low tide events (Figures 7 and 8). The limit of the survey was determined by the extent of the salt water wedge.

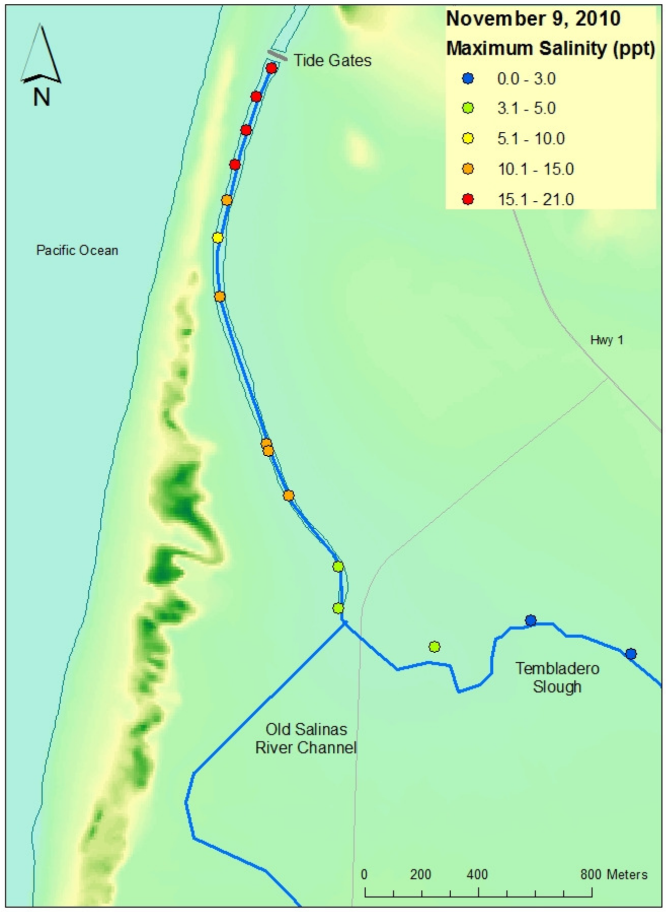
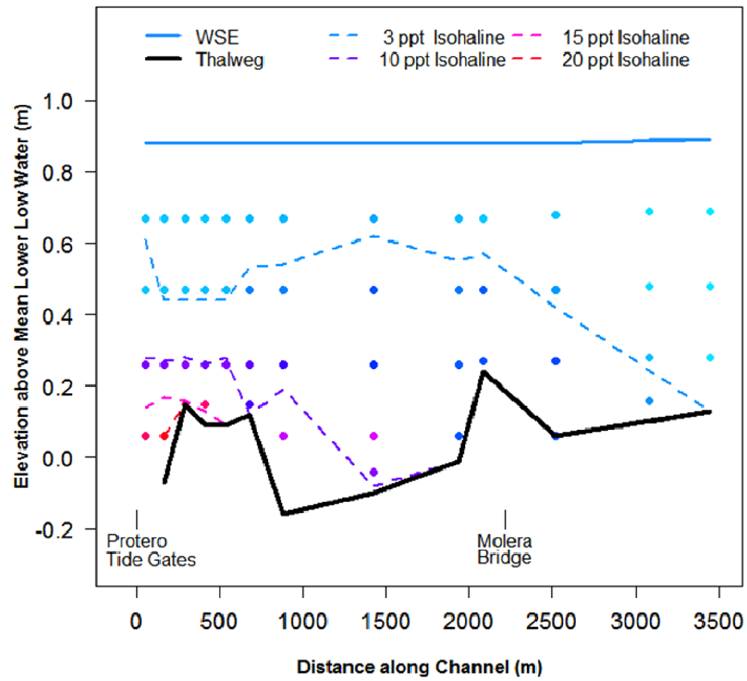


Figure 7. The November 9 boat survey showing a brackish wedge of water extending up the Channel (3.5 km) during a high tide (1.67 m). In general, it was found that salinities decreased with increasing distances away from OLS-POT.

Figure 8: Boat survey data on November 16 during a low tide (0.38 m) revealed a homogeneous water column (~3 ppt) that extended 2.5 km upstream of OLS-POT. Note one measurement of salinity at taken at OLS-POT showed high salinity (~22.1). This measurement is further discussed in the Temporal Salinity Variations Section.

The high tide on November 9 (1.67 m at 11:33) produced a brackish wedge that extended 3.5 km upstream of the tide gates at Potrero Road (Figure 9a). Salinity measurements at roughly 25 cm increments below the water surface elevation (WSE) were interpolated to establish the depth of the 3 ppt, 10 ppt, 15 ppt, and 20 ppt isohalines along the channel. The 3 ppt isohaline extended the farthest upstream from the tide gates at Potrero Road (3.5 km). The 10 ppt isohaline however only extended 1.5 km and the 15 and 20 ppt isohalines only extended 500 m. The 15 ppt and 20 ppt isohalines may have been impeded from moving further upstream by relatively sharp increases in the channel bed elevation. Water surface elevation at the tide gates remained relatively constant during the survey. During the low tide event (0.37 m at 13:31) on November 16 we observed a relatively homogeneous water column (~3 ppt) that extended 2.5 km upstream (Figure 9b). The halocline was irrespective of the thalweg bathymetry and for the most part traced the water surface elevation through time.

a.



b.

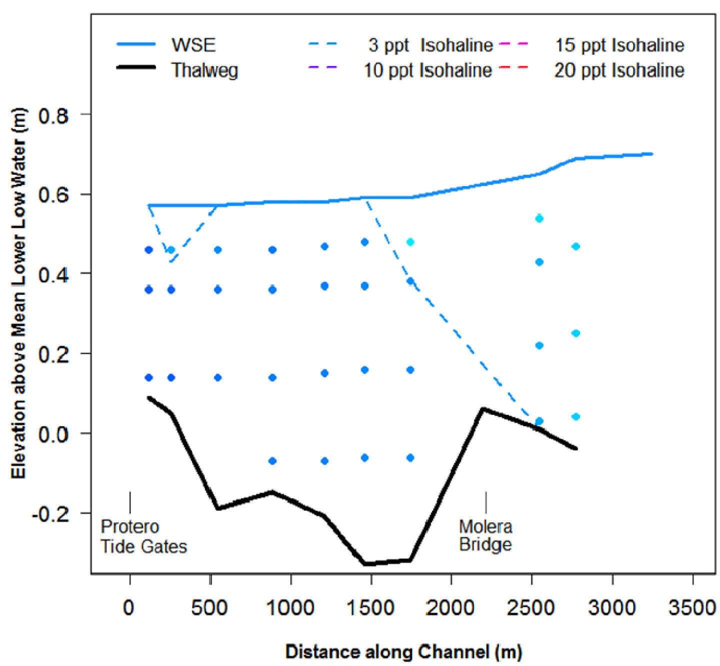


Figure 9. Longitudinal cross sections of salinity in the channel on November 9 during a high tide (a) and on November 16 during a low tide (b). Isohalines in both figures are denoted by dashed lines. Blue dots represent salinity measurements taken at various depths below the surface with darker colors depicting higher salinities. Water Surface Elevation (WSE) changed through time as a result of head pressure on the tide gates. During a high tide, it was found that a brackish wedge extended 3.5 km upstream of the tide gates. The apparent difference between the thalwegs in 9a and 9b was due to boat movements during depth surveys that created noise, and subsequently, irregularities in the bathymetry data.

3.2 Temporal Salinity Variations

Temporal variations in salinity were observed from the upstream side of the tide gates and downstream side of the Molera Bridge. Hourly salinity and WSE measurments were taken from the Potrero Bridge. Sporadic samples were also taken during the study period at both locations.

On November 9 measurements were taken between 09:00 and 19:00, starting just before the high tide (1.67 m at 11:33) and ending after low tide (-0.18 m at 19:08). We observed a halocline at the Potrero tide gates during high tide, which dissipated with the ebbing tide (Figure 10). Salinity levels on the surface were <3 ppt (fresh water) and increased with depth to >15 ppt (brackish). As the tide receded the water column became relatively homogeneous (between 3 to 6 ppt). WSE elevation slightly increased with the rising tide, and quickly decreased with the lowering tide.

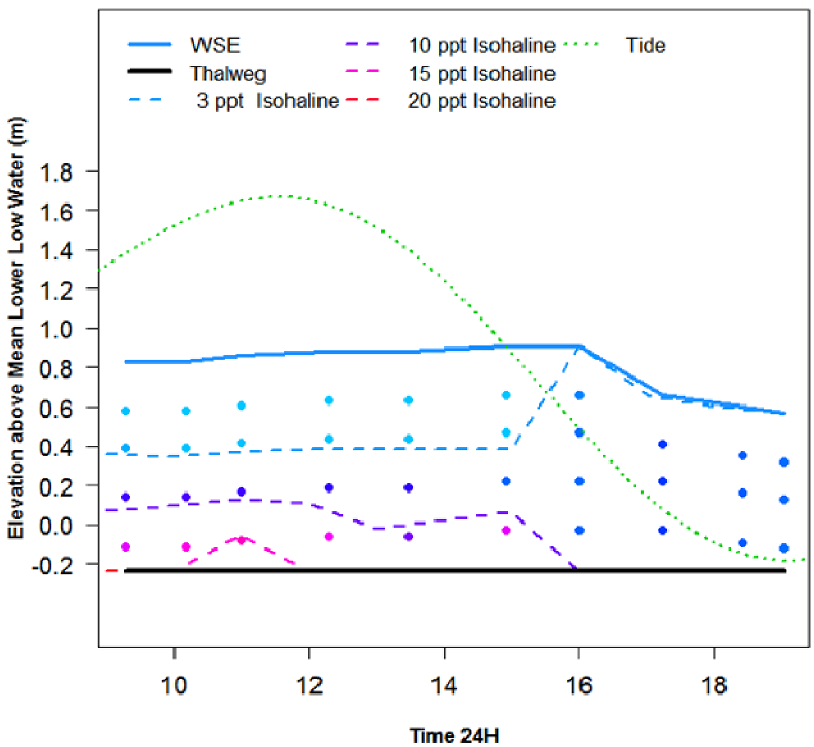


Figure 10. November 9 salinity measurements upstream of OLS-POT during high tide. A distinct halocline was present at high tide and dissipated with the ebbing tide as the water column became relatively homogeneous.

On November 16 measurements were taken between 09:30 and 14:00, starting just before the high tide (1.41 m at 06:56) and ending after low tide (0.37 m at 13:31). We observed a halocline both at the higher tide and the lower tides (Figure 11). Salinity levels on the surface were <3 ppt (fresh water) and increased with depth to >20 ppt (brackish). WSE elevation slightly decreased with the lowering tide.

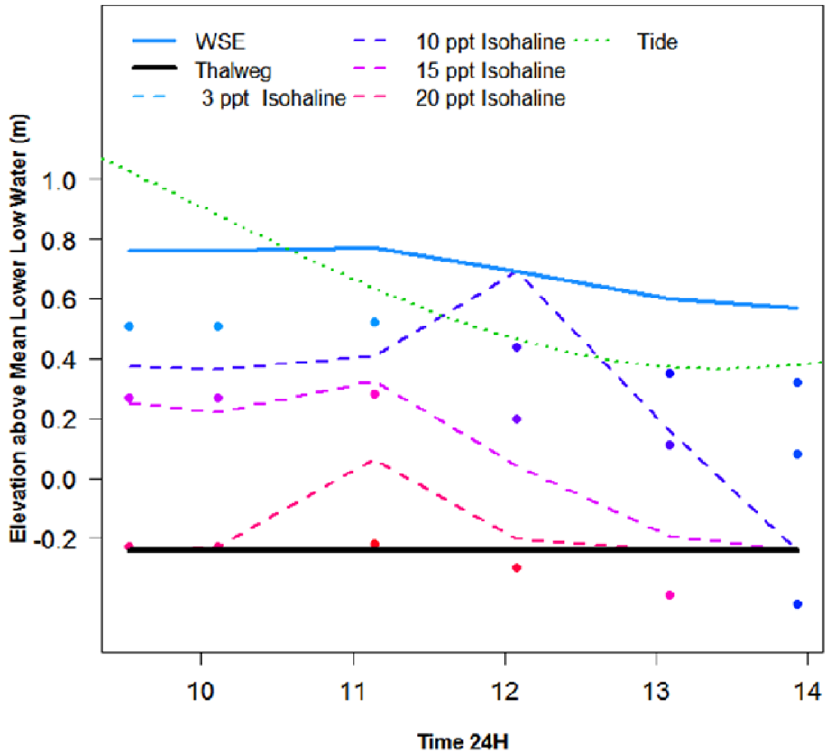


Figure 11. November 16 salinity measurements upstream of OLS-POT. A halocline was present throughout the day, with the water column mixing near the end of the day following low tide. We observed high salinities for the majority of the day.

At TEM-MOL, approximately 2 km upstream from the tide gates, salinity was measured over a similar time period (Figure 12). The salinity at TEM-MOL varied temporally with tide height. Salinity variations revealed tidal influence via the presence or absence of a halocline with higher tides producing a stronger halocline. Corresponding staff plate readings showed that tides do not have the same degree of influence at OLS-MON as OLS-POT (Figure 13).

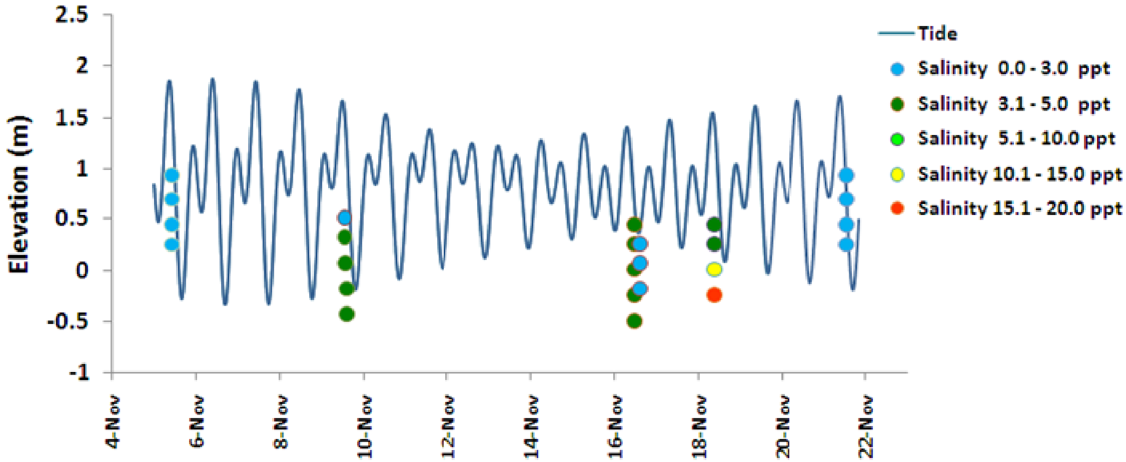


Figure 12. Tide height and salinity measurements through the water column at TEM-MOL. Salinity measurements show temporal variations throughout the study period. Salinity measurement were usually well mixed and between 0-5 ppt, however on one day there was a halocline and the two deepest measurements were above 10 ppt. Looking at tide data, the relationship between tides and salinity is not clear.

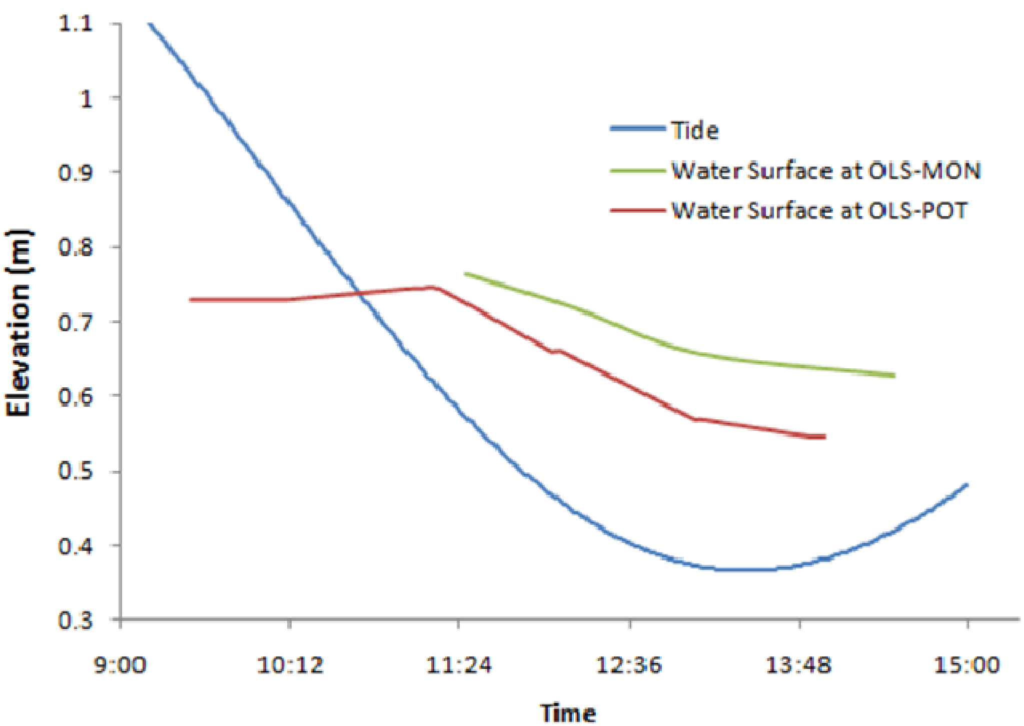


Figure 13. Corresponding staff plate elevations on the Old Salinas River channel on November 16, 2010 showed there was a smaller tidal influence at the site near the Tembladero confluence. The tidal signal is lagged and dampened with distance from the Moss Landing Harbor.

4.0 Discussion and Conclusions

Salinity levels were measured in the Old Salinas River channel and Tembladero Slough during November, 2010, and relevant literature was reviewed. We completed our primary analytical goal to measure salinity (throughout the vertical and longitudinal profile) within the study area to determine the extent of saline occurrence. At the outset of the study, we postulated that: 1) longitudinal and vertical patterns of salinity exist; 2) these patterns vary over time; and 3) the fluctuations are controlled by tidal variations. We confirmed the existence of longitudinal and vertical salinity patterns, and these patterns vary over time. It is likely that tidal fluctuations control the observed salinity patterns.

From our longitudinal data, we found salinity typically decreased with distance from the tide gates, increased with depth in the water column, rising tides and corresponding stage height at OLS-POT and OLS-MON. From our temporal data, we found that when ocean WSE (i.e. downstream of OLS-POT) was greater than Channel WSE, the tide gates were nominally closed, leading to an increasing stage height. The rise in stage was likely from freshwater inputs from both the Old Salinas River Channel and Tembladero Slough. During this time we observed saline water (>10 ppt) upstream of OLS-POT. When ocean WSE is less than Channel WSE the tide gates are open which leads to a decreasing stage height and water flowing into Moss Landing Harbor. Freshwater was observed throughout the water column after 1-2 hrs of the tide gates being open.

We speculate temporal and spatial variations of salinity in the Channel are a result of the timing and magnitude of the tides in combination with other factors. The tide gates work by utilizing the difference in ocean and slough head pressures. As the tide rises, the water on the ocean side of the tide gates rises above the WSE of the slough, forcing the gates to close. When the tide recedes, WSE in the slough is greater than the ocean surface, allowing the tide gates to open and slough water to flow into Moss Landing harbor. During our study when WSE on the downstream side of the Potrero road tide gates was above upstream WSE, salty water made its way through the gates and up the Channel. During the low tide however, water leaving the slough caused mixing which increased the uniformity and decreased the spatial extent of the brackish water wedge upstream. Our data indicate this is a cyclical pattern directed by the head pressure difference at the tide gates; salt water is continuously being "pushed" upstream by tidal head pressure and/or "pushed" downstream by freshwater discharge.

Not all of the variations in salinity can be explained by daily tide variations. It is possible spring and neap tide cycles affect salinity. Longitudinal and vertical measurements during a spring high tide (November 9) showed a distinct halocline closer to the tide gates, with salinity gradient decreasing with distance upstream of the tide gates. However, during a neap low tide (November 16) a halocline was present directly upstream of the tide gates, with salinities varying from 3 to 20 ppt. The rest of the channel was relatively homogeneous, characterized by salinities between 3 and 5 ppt. On this particular day it was also noted that WSE was below the main set of tide gates, and no flow was passing through them. Instead, all water was passing through the smaller set of tide gates, which are positioned lower and adjacent to the main set of gates (Figure 1). We speculate that denser high salinity water may have become trapped between the main tide gates and the adjacent lower tide gates. As the day progressed, mixing eventually lowered the salinity at OLS-POT to between 3 and 10 ppt—which is still notably higher than anything observed in the Channel.

On November 18 we measured a salinity of 20 ppt at TEM-MOL, which was five times higher than what was observed during a spring high tide on November 9. It is possible that during neap low tide the ocean WSE elevation never recedes enough to allow channel WSE to force the tide gates open.

Future studies need to focus on long term continuous salinity monitoring at both OLS-POT and TEM-MOL. Further investigation of monthly spring/neap tide cycles should be examined to develop an understanding of tide cycles on salinity. Other factors influencing salinity patterns may include precipitation, river discharge, wind, and agriculture. Developing a hydrologic budget for the study area to determine the approximate volumes and origins of water in the Channel could be revealing.

The salinity levels we found in the Channel are potentially a concern for freshwater aquatic biota. The salinity in the channel appears to occur in pulses, which creates an environment which is stressful for both brackish and fresh water biota (Brock et al 2005). If treatment wetlands are proposed to utilize water from the Channel, they should be designed to tolerate pulses of salinity or placed far enough upstream to avoid brackish inputs.

In conclusion, salinity in the OLS and TS channel is influenced by tidal fluctuations. But there are other influences to consider such as the combination of tide heights and types of tides, river discharge, wind and agricultural runoff. All these factors would, and probably do, directly influence the strength of the halocline as well as its spatial and temporal extents in the channel. Future studies should explore how the full tidal cycle affects salinity at OLS-POT and TEM-MOL. Time series data at both locations with continuously collected data at depth and WSE would help elucidate the relationship between tide height and salinity in the channel.

5.0 References

Anderson J, Chung F, Anderson M, Brekke L, Easton D, Ejeta M, Peterson R, Snyder R. 2008. Progress on incorporating climate change into management of California's water resources. Climatic Change 87 (S1):S91-S108.

Brock MA, Nielsen DL, Crossle K. 2005. Changes in biotic communities developing from freshwater wetland sediments under experimental salinity and water regimes. Freshwater Biology 50:1376-1390.

Broenkow WW, Breaker LC. November 2005. A 30-Year History of Tide and Current Measurements in Elkhorn Slough, California. Moss Landing Marine Laboratories. Available from: http://aquacomm.fcla.edu/3128/1/broenkow_and_breaker_30_year_history_of_tide.pdf

[CALAM CWP] California American Water Coastal Water Project. January 2009. Chapter 4: Environmental setting, impacts and mitigation measures: Moss Landing and North Marina Project. Draft Environmental Impacts Report, ESA/205335. Available from: http://www.cwp-eir.com/downloads/Vol1_CalAm%20DEIR/4-1_to_4-6-setting_impacts_mitigations.pdf

Casagrande J, Watson F. 2006. Reclamation Ditch Watershed Assessment and Management Plan: Part A - Watershed Assessment. Monterey County Water Resources Agency and the Watershed Institute, California State University Monterey Bay, 283 pp. Available from: http://www.mcwra.co.monterey.ca.us/Agency_data/RecDitchFinal/RecDitchFinal.htm

[CAW CWP] California American Water Coastal Water Project. January 2009. Chapter 4: Environmental setting, impacts and mitigation measures: Moss Landing and North Marina Project. Draft Environmental Impacts Report, ESA/205335. Available from: http://www.cwp-eir.com/downloads/Vol1_CalAm%20DEIR/4-1_to_4-6-setting_impacts_mitigations.pdf

[CCA #40] California's Critical Coastal Areas Report. June 2, 2006. Old Salinas River Estuary (electronic source). California Coastal Commission. Available from: http://www.coastal.ca.gov/nps/Web/cca_pdf/centcoastpdf/CCA40OldSalinasRiver.pdf

[CMRPP] County of Monterey Resource Protection Program. December 1, 2004. Castroville Community Plan. [Internet]. [cited 2010 November 9]. Available from: http://www.co.monterey.ca.us/housing/pdfs/castrov_proj/ResourceEnhance.pdf

[GAARD] Government of Alberta Agriculture and Rural Development. 2001. Salt tolerance of plants. [Internet]. Available from: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex3303

Hart BT, Bailey P, Edwards R, Hortle K, James K, McMahon A, Meredith C, Swadling K. 1991. A review of the salt sensitivity of the Australian freshwater biota. Hydrobiologia 210(105):105-144.

Katerji N, van Hoorn JW, Hamdy A, Mastrorilli M. 1999. Salt tolerance classification of crops according to soil salinity and to water stress day index. Agricultural Water Management 43:99-109.

Marks BW. May 2010. The effects of salinity on nitrogen cycling in wetland soils and sediments of the Breton Sound Estuary, LA [DPhil thesis]. Baton Rouge (LA): Louisiana State University. 107 p. Available from: http://etd.lsu.edu/docs/available/etd-04262010-140636/unrestricted/marks_thesis.pdf

[MBARI] Monterey Bay Aquarium Research Institute. 2010. Tide process and display for Elkhorn Slough and Moss Landing, CA. [internet]. [cited November 20, 2010]. Available from: http://www2.mbari-org/~coletti/cgi-bin/pagetide.cgi

[NGS NOAA] National Geodetic Survey, NOAA. 2009. Computation of GEOID09 GEOID Height. [Internet]. Available from: http://www.ngs.noaa.gov/cgi-bin/GEOID_STUFF/geoid09_prompt1.prl

Nielsen DL, Brock MA, Rees GN, Baldwin DS. 2003. Effects of increasing salinity on freshwater ecosystems in Australia. Australian Journal of Botany 51:655-665.

[NRMED] Natural Resources Management and Environment Department. Guidelines: land evaluation for irrigated agriculture. [Internet] Available from: http://www.fao.org/docrep/x5648e/x5648e0m.htm

[RAMC] Redevelopment Agency of Monterey County. Castroville Community Plan. 2010. The Castroville Focus: Monterey County Redevelopment News. Available from: http://www.co.monterey.ca.us/housing/pdfs/castrov_proj/RDA%20News%20Castroville.PDF

Schoellhamer DH. 2001. Influence of salinity, bottom topography, and tides on locations of estuarine turbidity maxima in northern San Francisco Bay. McAnally, W.H. and Mehta, A.J., ed., Coastal and Estuarine Fine Sediment Transport Processes: Elsevier Science B.V., p. 343-357. Available from: http://sfbay.wr.usgs.gov/sediment/elsevier0102.pdf

Shannon MC, Grieve CM. 1999. Tolerance of vegetable crops to salinity. Scientia Horticulturae 78:5-38

Sverdrup KA, Armbrust VE. An introduction to the world's oceans. 9th ed. New York: McGraw-Hill; 2008. 521p.

Appendices

Appendix A
Annotated bibliography of relevant literature

Anderson J, Chung F, Anderson M, Brekke L, Easton D, Ejeta M, Peterson R, Snyder R. 2008. Progress on incorporating climate change into management of California's water resources. Climatic Change 87 (S1):S91-S108.

Annotation: The Department of Water Resources staff co-authored this paper on how it has integrated climate change into water resource management practices in California. Climate change could affect air temperature, precipitation, runoff and sea level rise. At the Golden Gate Bridge in San Francisco sea level has risen 0.23 meters in the past 100 years (Figure 7.1). The Intergovernmental Panel for Climate Change (2001) stated that future climate change could result in sea-level rise from 0.09 to 0.88 meters by the end of the century. Sea level rise would cause an increase of salt water in the Sacramento-San Joaquin Delta. To maintain the appropriate salinity in the Delta, an increased volume of water would need to be released from reservoirs upstream or fresh water use from the Delta would have to be decreased. The Delta Simulation Model 2 was used to study how different State Water Project and Central Valley Project management strategies would affect the Delta.

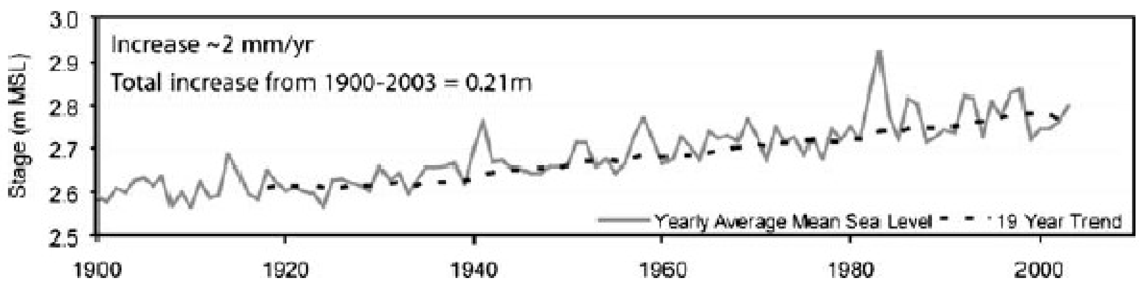


Fig. 5 Historical annual mean sea level at Golden Gate, 1900–2003

Figure 7.1: At the Golden Gate Bridge in San Francisco sea level has risen 0.23 meters in the past 100 years (Reproduced from Anderson et al. 2008).

Brock MA, Nielsen DL, Crossle K. 2005. Changes in biotic communities developing from freshwater wetland sediments under experimental salinity and water regimes. Freshwater Biology 50:1376-1390.

Annotation: Salinity increases have been attributed to reductions in biota diversities within freshwater habitats in Australia. However, little is known about the effects of salinity and water regimes on aquatic biodiversity. Therefore, the effect of salinity and water regimens on germinating aquatic plant seeds and the emergence of zooplankton eggs was tested in sediments from 7 wetlands in south-eastern Australia. Salinity levels of 300, 1000, 2000, and 5000 mg L^{-1} and water regimes of damp (or water logged) and submerged were tested. It was found that as salinity increased above 1000 mg L^{-1} species richness and abundance decreased in 4 of the wetlands. Salinity had a particularly strong effect in the damp (waterlogged) samples versus the submerged experiments. As a result it was concluded that salinity affects on species richness are a product of the water regimes. For aquatic plants the reduction will be more severe for germinating plants at the bank edges rather than in submerged conditions.

Broenkow W, Breaker L. 2005. A 30-Year history of tide and current measurements in Elkhorn Slough, California. Moss Landing Marine Laboratories. Available from: http://aquacomm.fcla.edu/3128/1/broenkow_and_breaker_30_year_history_of_tide.pdf

Annotation: William Broenkow and Laurence Breaker are physical oceanographers at Moss Landing Marine Labs. The report was cited in the National Marine Sanctuaries Condition Report and the intended audience was policy makers and scientists interested in long term changes and patterns in Elkhorn Slough. Moss Landing Harbor was constructed in 1946 exposing the inland estuaries and sloughs to an altered tidal influence. Tidal studies have been conducted in Elkhorn Slough since the 1970's. Elkhorn Slough is north of Tembladero Slough and the Old Salinas River Channel, but the tidal effects will be similar because they share the same ocean inlet. The tides in Monterey Bay are mixed with a form ratio of 0.96. There are semidiurnal tides of mixed strengths. Elkhorn Slough is an ebb-dominated estuary which means the lower low water always follows the higher high water and the rise and fall of tides is asymmetric. The flood tide lasts approximately twice as long as the ebb tide. The tidal asymmetry causes high tides to propagate more slowly than lower tides through the Slough (ebb current speeds exceed flood current speeds). The mean range of a semidiurnal tide is 1.2 meters. The spring tide range is approximately 2.5 meters and the neap tide range is approximately 0.9 meters.

The tidal prism is the volume of water that flows between a bay and the ocean over a tidal cycle. In a mixed tide system, the tidal prism is the difference in volume of water between a mean higher high water and the lower low water unless there are other sources of water entering the system. Based upon the time series of data gathered the researchers estimate that the tidal prism extends for almost five kilometers inland from the mouth of Elkhorn Slough. They also found that there is an approximately thirty minute lag time for tide to travel from the mouth of the slough to the northernmost extent of the north arm. A tidal prism and continuity model is also presented in the paper. The researchers conclude that while tidal prism seems to have increased linearly over time this may be the result of anthropogenic changes, such as the opening of the harbor entrance and marsh restoration, rather than a true linear trend. In the Elkhorn Slough, a source of fresh water is from the Old Salinas River Channel. The fresh water forms a thin layer on the surface, but is usually pumped out by the PG&E power plant so its influence usually does not extend beyond the harbor. Temperature and salinity variations were found to vary with tidal height amplitudes at 12 and 24 hours. The salinity of the water in Moss Landing Harbor is controlled by hypersaline water from the Elkhorn Slough, seawater from the Monterey Bay, and fresh water from contributing rivers and agricultural irrigation.

[CAW CWP] California American Water Coastal Water Project. January 2009. Chapter 4: Environmental setting, impacts and mitigation measures: Moss Landing and North

Marina Project. Draft Environmental Impacts Report, ESA/205335. Available from: http://www.cwp-eir.com/downloads/Vol1_CalAm%20DEIR/4-1_to_4-6-setting_impacts_mitigations.pdf

Annotation: Over the last six decades, groundwater pumping from the Salinas Valley Groundwater Basin (SVGB) has led to a serious seawater intrusion problem in the 140 mi^2 coastal zone defined by the Monterey County Water Resources Agency (MCWRA) as the *Pressure Subarea*. There are three primary aquifers in this subarea that have serviced industrial, commercial, residential and agricultural water needs for communities in Monterey County: the 180 acre-foot aquifer (upper), the 400 acre-foot aquifer (beneath the upper), and the 900 acre feet (deep) aquifer. Due to overdrafting from the 180 and 400 foot aquifers, saltwater has contaminated the groundwater supply rendering these two aquifers unusable. Almost 90% of the water is consumed for crop irrigation and growers that cultivate land near the coast, including land surrounding the lower Gabilan watershed, rely on the use of recycled water obtained from the Monterey Regional Water Pollution Control Agency. Plans to reverse the saltwater intrusion are under development; however, continued overdrafting may result in increased salinity levels in the aquifers as well as surface water bodies. Residual soil salinity and seawater intrusion increase salinity levels and contaminate freshwater marshes and wetlands that provide habitat for a wide variety of plant and animal species.

Chapin TP, Caffrey JM, Jannasch HW, Coletti LJ, Haskins JC, Johnson KS. 2004. Nitrate sources and sinks in Elkhorn Slough, California: Results from long-term continuous in situ nitrate analyzers. Esturaries 27(5): 882-894.

Annotation: The authors examine how short-term and long-term changes in nitrate concentrations reflect tidal cycling, biological processes, and runoff from agricultural fields in Elkhorn Slough, an estuary in Monterey Bay. They identified 3 primary water masses at the Main Channel during each tidal cycle: surface Monterey Bay water with low nitrate and low temperature observed during high tide; Upper Elkhorn Slough water with higher salinity, higher temperature, and low to medium nitrate observed during low tide; and a high nitrate water mass observed during the rising tide. The properties of the high nitrate water mass were not consistent with surface Monterey Bay waters, Upper Elkhorn Slough waters, or Salinas River water (heavily impacted by agricultural nutrient inputs). The propagation of an internal wave carrying water up the Monterey Submarine Canyon and into the lower section of Elkhorn Slough on every rising tide was found to be a major source of nitrate, accounting for 80-90% of the nitrogen load during the dry summer period. Tidal cycling was the dominant forcing, often changing nitrate concentrations by 5-fold or more within a few hours. These results suggested the waters of Elkhorn Slough were not a major source of nitrate to Monterey Bay but actually a nitrate sink during the dry season. The limited winter data at the Main Channel site suggest that nitrate was exported from Elkhorn Slough during the wet season.

Frank, D. 2006. Pollutant estimates in the Tembladero Slough during the Winter of 2005-06 [Capstone Report]. Seaside, CA: CSUMB. 31 p.

Annotation: David Frank wrote this report on the Tembladero Slough as his capstone thesis for CSUMB. The Tembladero Slough was listed as a 303(d) impacted waterway. To improve the water quality a treatment wetland was constructed. The goal of the capstone was to quantify the pollutant load in the Slough during the winter and summer of 2005-06, to better understand the mitigation capabilities of the wetland. Discharge was measured where Tembladero Slough passes under Highway 156 (approximately 4.7 km from the tide gates). Stage was influenced by the tides, so discharge calculations were corrected to account for tidal influence (Figure 7.2).

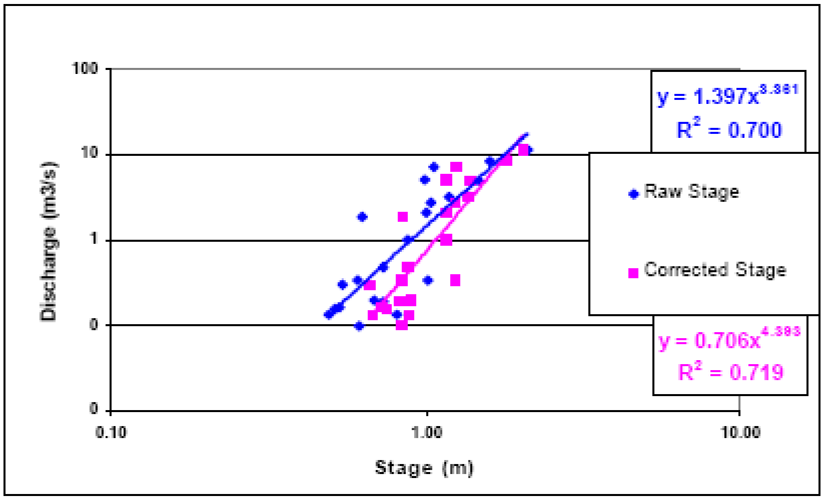


Figure 3.2.2. Tidally corrected verse raw stage data.

Figure 7.2: The data corrected for tidal influence had a higher R^2 value (Reproduced from Frank 2006).

Frank found that increased discharges were more strongly or equally influenced by tides as ambient discharges. The tide gates potentially block the direct effect of tides during lower discharges because the gates are mostly closed. As discharge increases, the gates are opened and the tides have a greater influence up the slough (Figure 7.3).

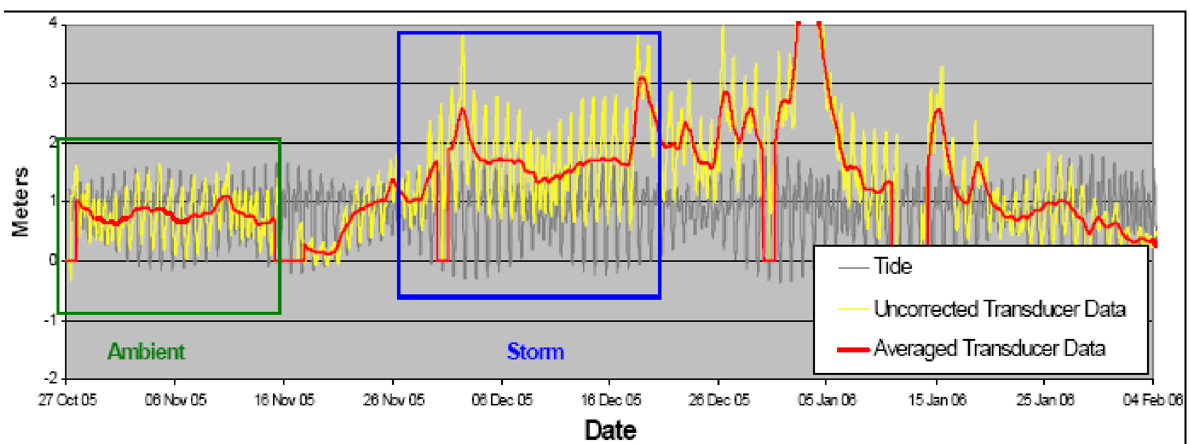


Figure 7.3: Tidal influence on pressure transducer data showed tide height fluctuations reflected in the pressure at the gage above the tide gates (Reproduced from Frank 2006).

[GOA] Government of Alberta. 1988. Salt Tolerance of Plants. [Internet]. Available from: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex3303

Table 7.1: Salinity rating and electrical conductivity value (Reproduced from GOA 1988)

Soil Depth	Non-Saline	Weakly Saline	Moderately Saline	Strongly Saline	Very Strongly Saline
0-60 cm (0-2 ft)	<2 ds/m*	2-4 ds/m	4-8 ds/m	8-16 ds/m	>16 ds/m
60-120 cm(2-4 ft)	<4 ds/m	4-8 ds/m	8-16 ds/m	16-24 ds/m	>24 ds/m

* ds/m = decisiemens per metre.

Salt Tolerance of various vegetables:

Very high:	none of those tested
High	none of those tested
Moderate to High:	beets, asparagus, spinach
Moderate:	tomatoes, broccoli
Moderate to Low:	corn, potatoes
Low:	carrots, onions, strawberries, peas, beans+

As a general rule, plants that have a low drought tolerance will have a low salinity tolerance.

Greene HG. 1970. Geology of southern Monterey Bay and its relationship to the ground water basin and salt water intrusion: U.S. Geological Survey Open-File Report 1465 [now Open-File Report 70-141]. Available from: http://pubs.er.usgs.gov/pubs/ofr/ofr70141

Annotation: This USGS Open file Report offers an historical account of seawater intrusion on the central coast. Saltwater was first discovered in wells along the shores of Monterey Bay 1931. An understanding of the distribution of geologic units (surface and subsurface) along the coastal zone is an important part of understanding the dynamics of saltwater intrusion in this region. Continuous heavy groundwater pumping has caused a depression reversing the natural hydraulic gradient and allowing the saltwater to enter through the subsurface beneath the Monterey Bay. This has occurred mainly where the Monterey Submarine Canyon has been cut into the alluvium deposited by the Salinas River and nearby streams, where gravelly outcrops exist in the canyon walls. The submarine canyon and tributary canyons are believed to be the source of saltwater intrusion. The objective of this survey was to delineate the groundwater basin offshore and determine the location and extent of the aquifers (areas where aquifers outcrop) to identify where saltwater enters into the basin.

Hart BT, Bailey P, Edwards R, Hortle K, James K, McMahon A, Meredith C, Swadling K. 1991. A review of the salt sensitivity of the Australian freshwater biota. Hydrobiologia 210(105):105-144.

Annotation: The paper is a review of salt tolerances of microbes, macrophytes, micro-algae, riparian vegetation, invertebrates, fish, amphibians, reptiles, mammals and birds. Salinization is a natural process, but human caused salinity is rapidly increasing salt concentrations within freshwater ecosystems. Data suggests that adverse effects to organisms begin to occur around 1,000 mg L^{-1}. However, the review highlights a significant lack of data on the salt sensitivities of freshwater biota and their various life stages over long periods of time. The authors found that small changes in the salinity were found to have little effect on basic microbial processes. However, as salinity is increased water column stratification can have subsequently larger and larger negative impacts on microbial activities. Many aquatic macrophytes are salt sensitive with salinities becoming lethal between 1,000 and 2,000 mg L^{-1}. Riparian plants are also salt sensitive with observable negative changes occurring above 2,000 mg L^{-1}. Invertebrates appear to be the most sensitive by salts with adverse affects occurring as low as 1,000 mg L^{-1}. Some species of insects and mollusks were also found to have similar sensitivities. Fish however were tolerant of salinities in some cases greater than 10,000 mg L^{-1}, but larval stages and eggs were found to be far less tolerant. Salinity tolerance of water fowl appeared to vary greatly. Some species can forage in saline water bodies, but require fresh water supplies for drinking (i.e. below 3,000 mg L^{-1}). Finally it was determined that saline waters released in pulses would have the largest negative effects on aquatic biota than continuous releases, which would allow for adaptations or avoidance tactics.

Katerji N, van Hoorn JW, Hamdy A, Mastrorilli M. 1999. Salt tolerance classification of crops according to soil salinity and to water stress day index. Agricultural Water Management 43:99-109.

Annotation: Due to the increasing water requirements for irrigation and the competing water uses there has been an increase in interest in the use of saline water for irrigation. This paper is a comparison of crop tolerance to saline water irrigation and salt tolerance classifications determined by Maas and Hoffman using soil salinity. This study evaluated sugarbeet, wheat, broadbean, maize, potato, sunflower and tomato under two soil types (loam and clay) and three water qualities, fresh (EC 0.9 d Sm^{-1}), saline (EC 2.3 and 3.6 dS m^{-1}). Increases in salinity caused significant decreases in yield, evapotranspiration, pre-dawn leaf water potential and stomatal conductance. The authors found the salt tolerance of the eight crops grown in the experiment corresponds well with the classification of Maas and Hoffman except soybean which may be due to varietal differences. In addition, weather conditions had a considerable effect on salt tolerance for broadbeans. Sugar beet and wheat are classified as salt tolerant, broadbean, maize, potato, sunflower and tomato as moderately salt sensitive.

Kirst GO. 1989. Salinity tolerance of eukaryotic marine algae. Annual Review Plant Physiology Plant Molecular Biology 40:21-53.

Annotation: This paper reviews the physiological effects of salinity on marine algae. It is particularly relevant as it discusses physiological processes which can be applied to freshwater organisms encountering salt gradients. Changes in salinity effect organism in 3 ways: osmotic stress (water movement into or out of a cell); ion (salt) stress caused by the uptake or loss of specific ions; and changing of the cellular ion ratios due to ion uptake or loss. General responses to changes in salinity are then discussed followed by the process of osmotic acclimation and finally sea ice algae and their adaptations to a constantly changing environment.

Langevin CD, Swain ED, Wolfert MA. 2004. Simulation of integrated surface-water/ground water and salinity for a coastal wetland and adjacent estuary. U.S Geological Survey Greater Everglades Priority Ecosystem Science Program 2004-1097.

Annotation: A model of freshwater flow and salinity was created for Taylor Slough, which drains into Florida Bay. The model of the slough predicted salinity levels peak (30-35 practical salinity units) in the summer time when there are high rates of evaporation and little freshwater input from rains. On an annual timescale, the model showed an increase in salinity until the first major rains, when the salinity quickly gets flushed out of the system and is replaced by fresher water (4-7 psu).

Malzone C, Marcus J, Pauly T. 2009. Modeling the multidimensional and fiscal impacts of storm surge and sea level rise: A compelling view through a powerful interactive 4D data integration, analysis and visualization tool. Oceans 2009, MTS/IEEE Biloxi- Marine Technology for Our Future: Global and Local Challenges: 1-7.

Annotation: The Intergovernmental Panel for Climate Change (2007) found that the climate is unequivocally warming and the global mean sea level is rising. Coastal resources and their relationship to changes in the climate need to be understood so they can be effectively managed. Eonfusion is a GIS visualization software package that allows the spatial analysis of sea level elevation changes over time. Elkhorn Slough was used as a case study application for Eonfusion. A DEM, created from LiDar and multibeam bathymetry data, was used for the analysis. Eonfusion rendered the DEM into a 3D surface and the data was divided into bands representing their susceptibility for erosion. Three different sea level rise scenarios were modeled. The visualization showed there was an increase in the hydraulic head and changes in the salt-marsh area, the area demarcated as the most susceptible to erosion. The visualization showed complete loss of the salt marsh region in approximately 130 years because of sea level rise. To further explain the driving processes, erosion rates were inputted into the model using site measurements and bathymetric surveys. Land use data and sub-tidal substrate and sediment data was also incorporated. A measured erosion rate of 20 cm/year in Parson's Slough was used in the model. Eonfusion showed a widening of the channel and a subsequent larger hydraulic head which resulted in increased tidal scour. The visualization showed a 50% loss in intertidal habitat after 40 years of sea level rise (Figure 7.4). The tide gates at the mouth of the Old Salinas River Channel and the Tembladero Slough will alter the effects of sea level rise.

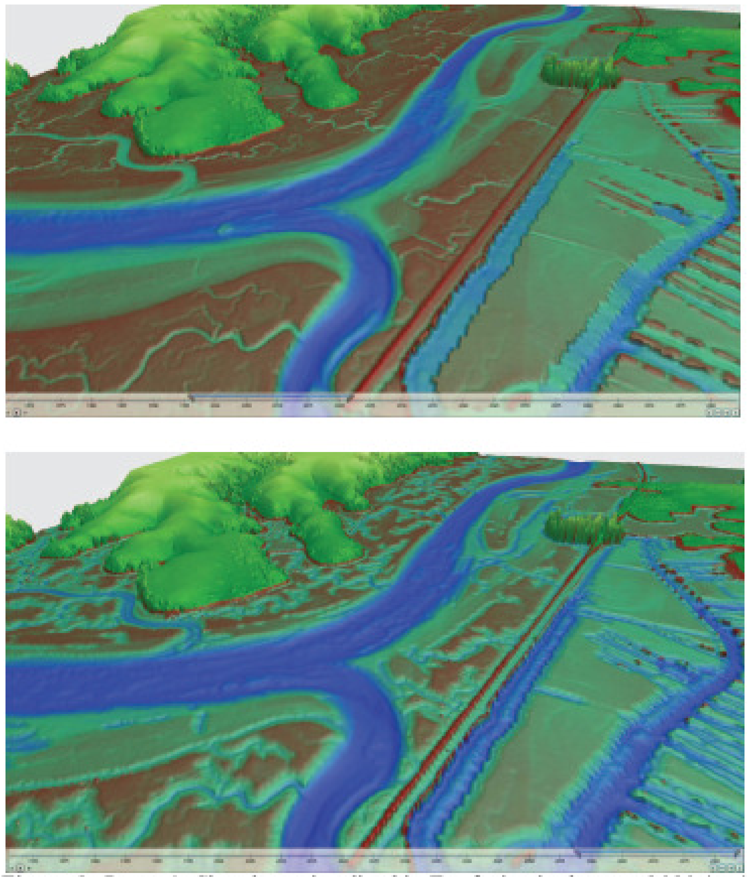


Figure 6. Parson's Slough as visualized in Eonfusion in the year 2020 (top) and then the year 2090 (bottom). The achieve this, measured data is directly incorporated into the visual dataflow model, fused with land use data, sediment type and DEM information . DEM information is then dynamically linked to the time slider and modified to provide a realistic visualization of habitat loss in Elkhorn Slough

Figure 7.4: Eonfusion visualization of salt marsh habitat loss as a result of sea level rise. The influence of sea level rise may potentially be mitigated by the tide gates at the mouth of the Old Salinas River channel and the Tembladero Slough.(Reproduced from Malzone et al. 2009).

Marks BW. May 2010. The effects of salinity on nitrogen cycling in wetland soils and sediments of the Breton Sound Estuary, LA [DPhil thesis]. Baton Rouge (LA): Louisiana State University. 107 p. Available from: http://etd.lsu.edu/docs/available/etd-04262010-140636/unrestricted/marks_thesis.pdf

Annotation: The paper reported the effect of salinity changes on two nitrogen cycling processes, potential denitrification and N-mineralization, in fresh and salt marsh soils/sediments in the Breton Sound estuary, Louisiana. At 0 ppt potential denitrification in fresh and salt marsh soils reached 373 ± 22.2 and 9.18 ± 3.27 mg N_2O-N kg^{-1} d^{-1}, respectively. At 35 ppt, the rates were 615 ± 182 in salt marsh and 99.7 ± 21.1 mg N_2O-N kg^{-1} d^{-1} in fresh marsh soils. N mineralization rates in each fresh and saline marsh soil/sediment at three salinity treatments did not significantly differ from one another. The author concluded

sudden fluxes in salinity had only short-term effects on N mineralization, while denitrification showed significant effects with sudden salinity changes in wetlands soils.

Mizrahi Y, Pasternak D. 1985. Effect of salinity on quality of various agricultural crops. Plant and Soil 89:301-307.

Annotation: This study reports the effect of saline irrigation water on quality of several crops. Processing tomatoes, melons, lettuce, peanuts, iceberg lettuce and Chinese cabbage were grown and evaluated at the Ben-Gurion University in Israel. The control treatment had an electrical conductivity (EC_i) of 1.2 dS m^{-1} with three saline treatments of 1.2, 4.5, 7.5 and 10.0 dS m^{-1}. Taste testers were employees of the university and scored for taste and preference of all crops in the study. In addition yield, total soluble solids (TSS), acidity and acidity were evaluated at harvest for tomatoes. Yield and tip burn were evaluated at harvest for Chinese cabbage. Salinity was shown to have a positive effect on taste and higher values for total soluble solids for melons and tomatoes although the yield was reduced. There was no difference in taste for lettuce and peanuts and a potential loss in yield. A decrease in quality was seen in Chinese cabbage due to an increase in tipburn with no difference in taste.

[MCWRA] Monterey County Water Resources Agency. August 26, 2009. Historic Seawater Intrusion Map, 180-ft Aquifer. Available from: http://www.mcwra.co.monterey.ca.us/SVWP/01swi180.pdf

[MCWRA] Monterey County Water Resources Agency. August 26, 2009. Historic Seawater Intrusion Map, 400-ft Aquifer. Available from: http://www.mcwra.co.monterey.ca.us/SVWP/01swi400.pdf

Annotation: The historic seawater intrusion map shown (Fig. 7.5) for the 180-foot aquifer indicates that seawater has intruded about five miles inland between 1944 and 2007. For the 400-foot aquifer, seawater has intruded about two miles inland between 1959 and 2007. Both contained chloride concentrations greater than 500 mg/L and exceeded established standards for safe drinking water (250mg/L according to the California Safe Drinking Water Act). This is primarily due to extensive groundwater production in the Salinas Valley. Water supplies have been degraded and many wells (urban and agricultural) have been abandoned. Because the Salinas Valley Groundwater Basin is directly connected (hydrologically) to the ocean, there is constant seawater recharge, especially during overdrafting conditions. Additionally, elevations at and below sea level along the coast and directly inland have developed a landward groundwater gradient further inducing seawater intrusion.

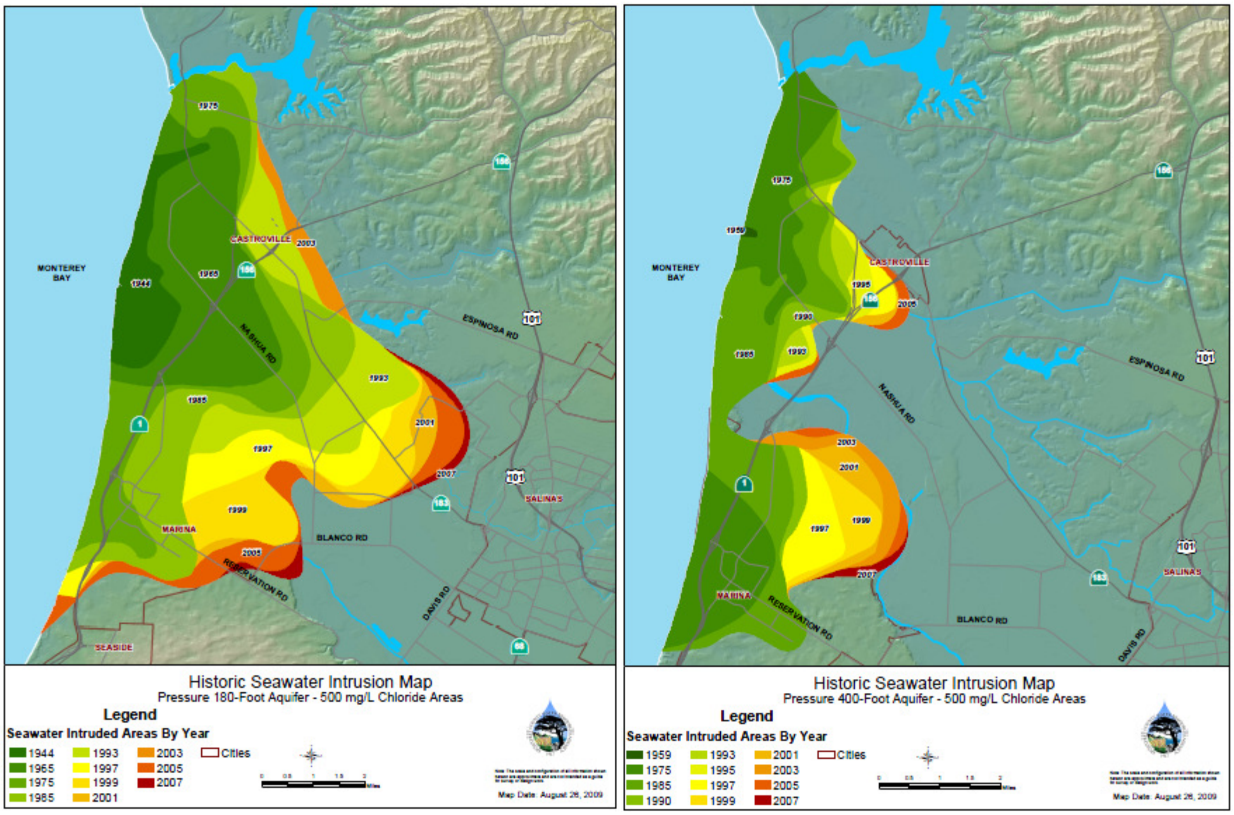


Figure 7.5: Seawater intrusion in the 180 ft aquifer and 400 ft aquifer over time (Reproduced from MCWRA 2009).

[MRWPCA] Monterey Regional Water Pollution Control Agency. 2010. Recycled Water – Agronomic Chemical Analysis. [Internet]. Available from: http://www.mrwpca.org/recycling/chem2010.php

Annotation: Monthly water testing in 2010 of recycled water distributed via purple pipes in to 4,900 hectares of prime farmland in Monterey County shows conductivity was stable ranging from 1.5-1.7 dSm^{-1}.

Moyle PB, Lund JR, Bennett WA, Fleenor WE. 2010. Habitat variability and complexity in the upper San Francisco estuary. San Francisco Estuary and Watershed Science, John Muir Institute of in the Environment, UC Davis: http://escholarship.org/uc/item/0kf0d32x.

Annotation: The upper San Francisco Estuary was once a highly productive habitat for native flora and fauna. This was mainly a result of shifting environmental conditions both in space and time. Current conditions discourage the native biota which provides some rationale for restoring the estuary to a state that at least partly reflects past conditions. To do this 10 suggestions were made which briefly include: 1) establish internal delta flows that create a tidally mixed gradient; 2) create a network of natural sloughs; 3) increase flows from the Sacramento and San Joaquin rivers; 4) increase marsh habitat; 5) create and allow low salinity (1-4 ppt) habitat within the delta; 6) create salinity variability within the upper estuary to discourage alien invasions; 7) reduce non-natives; 8) establish floodplain habitat; 9) reduce agricultural and urban pollutant loads; and 10) maintain temperatures below 20°C. The paper provides a good summary of estuarine environments and their importance in ecology as well as the importance of disturbances in maintaining healthy ecosystems. The paper has interesting implications for Tembladero Slough, especially if efforts are made to restore biota to the slough.

Nielsen DL, Brock MA, Rees GN, Baldwin DS. 2003. Effects of increasing salinity on freshwater ecosystems in Australia. Australian Journal of Botany 51:655-665.

Annotation: Salts are often a natural component of Australia's rivers and wetlands to which flora and fauna have adapted. Under very low flow conditions salt concentrations increase and build over time. Organisms survive these salinity increases by either avoidance or tolerance. However, because of an increase in water usage these freshwater ecosystems are now under threat as a result of rising saline groundwater, a reduction of flushing events and therefore rising salt concentrations. Data suggest that if salinity exceeds 1000 mg L^{-1} aquatic biota will be severely affected. The upper limit of salinity tolerated by most freshwater aquatic plant appears to be 4000 mg L^{-1}. However, little is known about how salinization will affect the physical and biological environment. The paper reviews current information on how salinity affects aquatic biota and the physical components of aquatic ecosystems. The authors' stress that aquatic organisms and plants are the most sensitive to salinity at early stages in their development.

Salinization of a freshwater body can potentially change both the light climate and the mixing properties, which in turn have an impact on the cycling of energy and nutrients. Salt-induced aggregation and flocculation of suspended matter is a major factor in the removal of particles from the water column, resulting in an increase in light penetration and may increase photosynthesis. Flocculation of sediment may also remove trace elements and nutrients, making them less readily available to pelagic organisms. Increased water clarity, as a consequence of saline groundwater intrusions, has been implicated in the formation of cyanobacteria blooms. Freshwater cyanobacteria appear to be inhibited by variations in salinity but have been found to acclimatize to gradual salinity increases. Establishment of a salt gradient can reduce mixing and solute transport within aquatic systems. A halocline is a barrier to the transport of materials between the surface and bottom strata, which has implications for nutrient and carbon cycling. Anoxia of bottom waters has been reported in rivers where intrusions of saline water occur. Anoxia will result if a halocline becomes a barrier to the movement of oxygen from the water surface to the bottom, ultimately leading to death of benthic organisms and altering cycling of nutrients mediated by microbes. However, there appears to be no difference in the rate of nitrogen fixation by benthic communities with different levels of salinity.

[RAMC] Redevelopment Agency of Monterey County. Castroville Community Plan. The Castroville Focus: Monterey County Redevelopment News. Available from: http://www.co.monterey.ca.us/housing/pdfs/castrov_proj/RDA%20News%20Castroville.PDF

Annotation: The report defines Tembladero Slough as a drainage ditch which empties into the Salinas river that is "currently extremely degraded with limited habitat values and high levels of contaminates". The report states Tembladero Slough is a key resource such that its enhancement and protection is a critical portion of the Castroville redevelopment plan. The literature goes on to describe the various enhancement strategies planned for the slough which include "flood protection and storm water drainage facilities with water quality enhancement, riparian habitat restoration and mitigation of impacts to resources that may result from the development." The improvements also call for planting of native vegetation, creating a riparian corridor that will serve as flood protection and scenic area in which walking trails will be created. In addition, a water quality treatment wetland will be utilized to treat runoff from the recreational park area before it is discharged into the slough.

Rosenfeld, L. 2008. Combined effluent dilution calculations for Moss Landing Power Plant. Final Environmental Impact Report for the California American Water Coastal Water Project. [Internet]. Available from: http://www.cwp-eir.com/downloads/Vol3_FEIR/appendix-c_calam_feir.pdf.

Annotation: Rosenfeld wrote this report as part of an Environmental Impact Report for the construction and use of a desalination plant at the location of the power plant in Moss Landing Harbor. The purpose of the report was to calculate the salinity over time at the potential intake and discharge location. The flow rates necessary to maintain specific salinities in the harbor were also calculated. To determine what the intake water would be at the desalination plant, Rosenfeld used a proxy data set at the Moss Landing Marine Labs boat dock. A study of the salinity near Moss Landing Marine Labs (MLML) was completed in 2008. The salinity of the water in Moss Landing Harbor is controlled by hypersaline water from the Elkhorn Slough, seawater from the Monterey Bay, and fresh water from contributing rivers and agricultural irrigation. The salinity near the MLML is a proxy for the salinity at the tide gate approximately 1,600 meters away. The salinity fluctuated throughout the year, decreasing from large precipitation events (Figure 7.6).

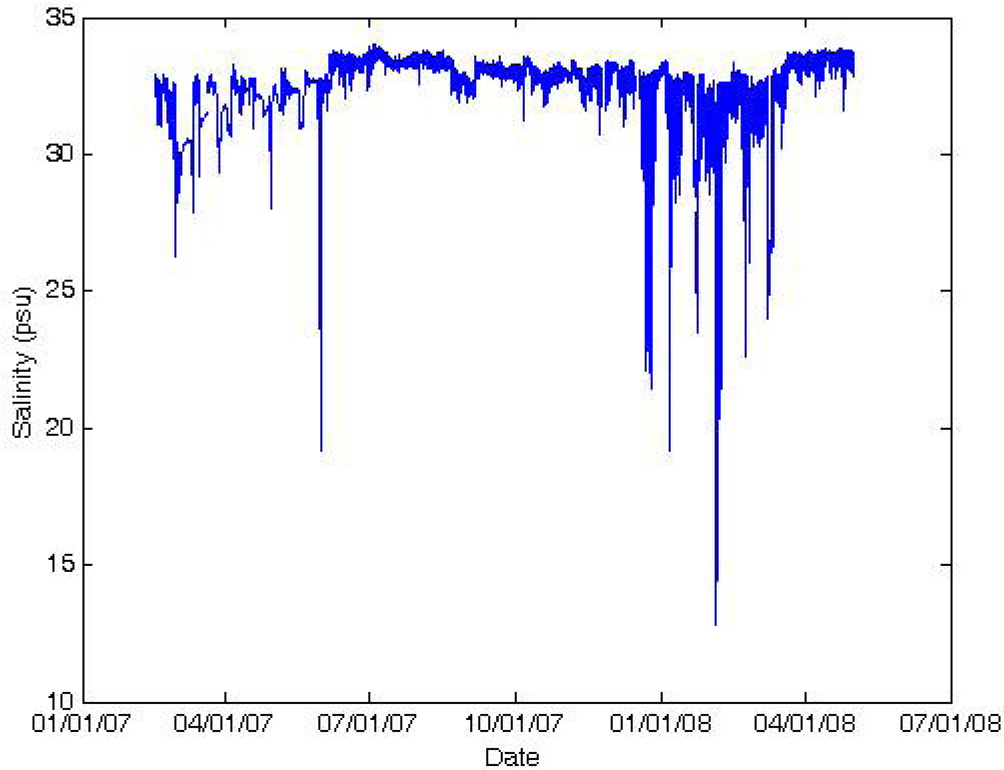


Figure 7.6: Hourly salinity measured at Moss Landing Marine Lab from a small boat dock (Reproduced from Rosenfeld 2008). A salinity study was completed over a year near the Moss Landing Marine Labs (MLML). Salinity measurements were taken in the harbor, approximately 1,600 meters from the tide gate. Although there are different influences at the MLML location, the data set is a proxy for the salinity levels at the tide gates.

Scattini M. 2010. Personal communication.

Annotation: Personal conversation with a grower farming land adjacent to Tembladero Slough confirmed most farms surrounding Tembladero Slough are irrigated with recycled water as many of the wells in the area have high salinity due to salt water intrusion.

Schoellhamer DH. 2001. Influence of salinity, bottom topography, and tides on locations of estuarine turbidity maxima in northern San Francisco Bay. In McAnally, W.H. and Mehta, A.J., ed.,Coastal and Estuarine Fine Sediment Transport Processes: Elsevier Science B.V., p. 343-357. Available at :http://ca.water.usgs.gov/abstract/sfbay/elsevier0102.pdf

Annotation: Paper presents a time series of salinity and suspended-solids concentration measured at four locations in addition to vertical profiles of salinity and suspended-solid concentrations measured during water-quality cruises across a four year time-span between 1993 and 1997. Data analysis describes the influence of salinity, bottom topography and tides on locations of estuarine turbidity maxima in northern San Francisco Bay, California. Researchers found estuarine turbidity forms a maxima when salinity is present, but this maxima cannot be attributed to a singular source of salinity. Bottom channel topography was also found to impact salinity stratification, gravitational circulation and location of estuarine turbidity formation. The spring/neap tidal cycle had a large influence on vertical mixing as well, with spring tides causing the greatest vertical mixing and suspended solid concentrations across multiple locations. However, salinity stratification is greatest during neap tides, which reduces vertical mixing and increases deposition.

Shannon MC, Grieve CM. 1999. Tolerance of vegetable crops to salinity. Scientia Horticulturae 78:5-38.

Annotation: Although salt tolerance information exists for over 130 crop species, there are many vegetable crops which lack data. The salt tolerance of vegetables is important because they generally have a higher cash value than field crops. Generally, salinity is measured in units of electrical conductivity of a saturated soil paste extract taken from the root zone of the plant and averaged over time and depth. The soluble salt concentration of a soil extract is roughly one half as concentrated as the soil water for most soils. Plant salt tolerance is the inherent ability of the plant to withstand the effects of high salts in the root zone on the plant's leaves without a significant adverse effect. Salt tolerance may vary according to the growth stage and often affects the timing of development. Adverse effects of salinity may appear on the marketable portion of the crop reducing the value. Salt tolerance responses of various crops often depend on soil type and other environmental factors. This paper compiles known salt tolerance information for a variety of vegetables, particularly commonly grown crops for Monterey County. Artichokes, mustard greens, turnip greens, arugula, beets, and cauliflower have been rated as moderately salt-tolerant. Broccoli, cabbage, Brussels sprout, kohlrabi, Chinese cabbage, radish and spinach are moderately salt sensitive.

Skaggs RW, Breve MA, Gilliam JW. 1994. Hydrologic and water quality impacts of agricultural drainage. Critical Reviews in Environmental Science and Technology 24(1):1-32.

Annotation: Agriculture drainage is increasingly perceived as a major contributor to unfavorable off-site environmental impacts. The mechanisms influencing the hydrology and loss of pollutants from artificially drained soils are complex and vary with conditions prior to drainage improvements and other factors such as land use, management practices, soils, site conditions, and climate. This paper reviews research on the hydrologic and water quality effects of agricultural drainage and discusses design and management strategies that reduce negative environmental impacts. Increasing drainage intensity on land in agricultural production may have positive or negative impact on hydrology and water quality. Increasing subsurface drainage is found to reduce loss of phosphorus and organic nitrogen and increase loss of nitrate-nitrogen and soluble salts. Whereas, increasing surface drainage increases phosphorus loss and reduces nitrate-nitrogen outflows. In irrigated arid lands, improving drainage prevents the rise of the water table, water-logging, and salinity buildup in the soil. Salt accumulation in receiving waters is the most prevalent problem affecting downstream users. The authors suggest identifying a reliable drainage outlet prior to construction of irrigation projects to reduce the detrimental effects on the environment of increased agricultural drainage.

Smith R. 1973. The Hydrography of Elkhorn Slough. Moss Landing Marine Laboratories No. 42 Technical Publication 73-2.

Annotation: During the time of this report (before the tide gate was installed), large horizontal salinity gradients could be found in Moss Landing Harbor. This is because of the freshwater inputs from the Tembladero Slough. The largest gradients could be found at low tide, and the smallest at high tide. Presumably this is because at low tide fresh water flows to the harbor before it mixes with ocean water.

Snyder RI, Platts BE, Cahn MD, Holden RB, Malanka MG. 2004. Effects of Recycled Water on Soil Salinity Levels for Cool Season Vegetables. Acta Horticulture 664. Proceedings of the Fourth International Symposium on Irrigation of Horticultural Crops.[Internet]. Available from: http://www.mrwpca.org/dwnloads/wr/4th_intl_ihc.pdf

Annotation: Although the average SAR of 4.6 and EC of 1.6 of the recycled water is considered safe for long-term irrigation, ESP (exchangeable sodium percentage) values collected by growers indicated significant increases in the soil exchangeable sodium percentage which may decrease soil permeability and water retention, which had become a challenge to growers. In addition there was concern that increases in salinity would result in decreased yields of the cool season vegetable crops grown in the area. This study looks at the long term use of recycled water for irrigation in agriculture. Two treatments, one with recycled water and one with well water from out of the area with a lower salt content on four test sites were included in the study and data was collected of soil sampling, water quality testing, crop quality for 2000, 2001 and 2002. The results of the study showed recycled water with higher salt content increased levels of soil salinity in comparison to soils receiving the lower salt well water. The differences were not found to be increasing over the three year study period and the higher values were acceptable for cool season vegetable production with no yield losses reported by growers.

Stewart PK, Price R. 2002. Origin of Salinity Variations in Florida Bay. Limnology and Oceanography 47(4): 1234-1241.

Annotation: The authors of this paper use isotopes in water to trace the origins of fresh water in a salt water bay in Florida. The data used in the study was collected from the surface waters of the bay on an approximately monthly basis. The results suggest the major source of fresh water causing a decrease in salinity in the bay was rain, not runoff from the everglades.

[SWRCB] California State Water Resources Control Board. *Regional Board 3, Central Coast Region*. Category 5 303(d) list of water quality limited segments. Draft 2008 California 305(b)/303(d) Integrated Report. Available from: http://www.swrcb.ca.gov/centralcoast/water_issues/programs/tmdl/303d/appendix_e.shtml

Annotation: The slough is highly contaminated and the surrounding habitat degraded. The Central Coast Regional Water Quality Control Board placed TS on the Category 5 Section 305(b)/303(d) list of the Clean Water Act as a quality limited segment. Table 7.2 identifies a list of pollutants that exceed maximum contaminants levels with a scheduled TMDL completion

requirement by 2013. The staff has identified the potential sources for these pollutants to include: agriculture return flows, storm runoff and irrigation tailwater; irrigated crop production; grazing; removal of riparian vegetation; urban runoff and storm sewer drainage; natural sources; nonpoint sources (SWRCB 2008).

Table 7.2: List of pollutants in Tembladero Slough, within a 5.5 mi^2 assessed area (Reproduced from SWRCB 2008).

Pollutant	First year listed	Pollutant	First year listed
Chlorophyll-a	2008	Nutrients	1996
Chlorpyrifos	2008	Pesticides	1996
Diazinon	2008	Sediment Toxicity	2008
Enterococcus	2008	Total Coliform	2008
Escherichia coli (E. Coli)	2008	Turbidity	2008
Fecal Coliform	2002	Unknown Toxicity	2008
Nitrate	2008	pH	2008

[UCCE] University of California Cooperative Extension. 2007. Monterey County Ag Census. [Internet]. Available from: http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/County_Profiles/California/cp06053.pdf

Annotation: With 1200 farms and 1.3 million acres in agricultural production, Monterey County ranked #1 in the state for vegetables and #1 in acreage for lettuce, broccoli and cauliflower grown in the state. The market value in crops for 2007 was $2.1 billion.

Appendix B
Scope of Work

Spatio-temporal dynamics of salinity in Tembladero Slough, Castroville, California – Fall 2010

A CSUMB ENVS 660 class project

Issued by: Fred Watson, PhD, Assistant Professor, CSUMB

2nd November 2010

1 Summary

Class will complete a report in the CCoWS report series describing the spatial patterns and temporal dynamics of salinity in Tembladero Slough and Old Salinas River Channel extending between the downstream and upstream limits of the presence of brackish water (approximately between Moss Landing Harbor and Highway 168). Required elements include a review of the importance of understanding the extent of saline influence in inshore surface waters, sampling data during the project period (2 Nov 2010 to 7 Dec 2010), vertical (1D) profiles, longitudinal-vertical (2D) profiles, and maps of salinity at the extremes of the range of variation exhibited during the sampling period, measurements of stage, discharge, and wind at locations spanning the project area, and an attempt to characterize the influence of these on salinity.

2 Background

Knowledge of spatial patterns and temporal dynamics of salinity is thought to be important for the following reasons:

- Salinity of surface waters impacts suitability of nearby land for farming and/or habitat
- Salinity of surface waters causes density stratification, which potentially reduces the residence time of flowing water by altering the effective cross-sectional area of flowing water.
- Salinity of surface waters potentially influences transport, settling, resuspension, transformation, and degradation rates of pollutants such as nutrients, pesticides, and bacterial and protozoan pathogens in the inland coastal zone between watershed sources and coastal and ocean destinations, by potentially altering processes and properties such as adsorption, flocculation, settling, dissolved oxygen concentration, pH, and others.
- Salinity of surface waters potentially impacts the functioning of treatment wetlands that are intended to receive water from upstream sources and reduce the concentration of pollutants in water discharging downstream.
- Observed changes in salinity patterns of surface waters are a consequence and indicator of climate change and/or global sea level rise, with potential implications for all of the above.

3 Project period and project area definition

- 2 Nov 2010 to 7 Dec 2010

- Definition: Extent of brackish water (salinity between 2 ppt and 30 ppt) in Temladero Slough (TS) no further upstream than San Jon Road, the TS reach of Moss Landing Harbor, and the Old Salinas River Channel.

4 Tasks

Task 1 – Executive Summary

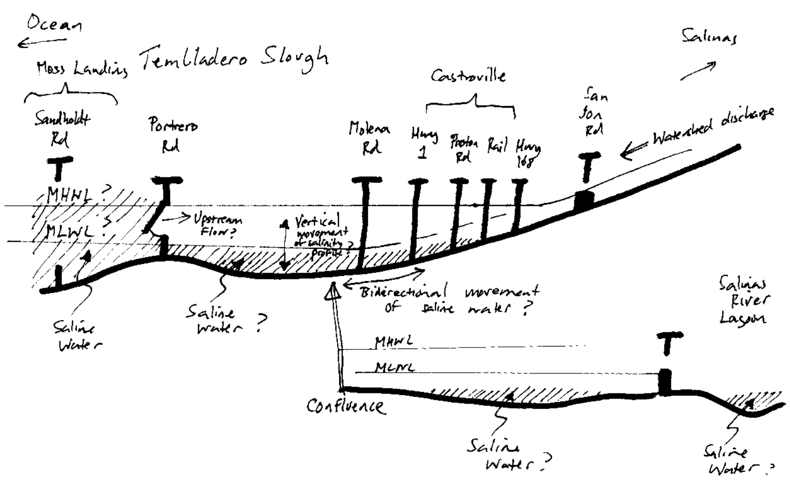
- To be included near the start of the final report, not exceeding two pages, summarizing all goals, results, and conclusions.

Task 2 – Review

- Explain why salinity patterns are important to understand, with reference to the ideas suggested in 'Background' above, and fully referencing the pertinent literature
    - Note: 'Literature' here includes any publicly accessible document.
- Provide annotated bibliography of general hydrological literature and pre-existing data pertaining to Tembladero Slough or otherwise relevant to project. Suggested sources include:
    - Any documents to do with Castroville Redevelopment Plan, incorporating restoration, floodway alteration, bike paths etc at Tembladero Slough as it passes by Castroville.
    - CCoWS / MCWRA. Approx. 2006. Report on Reclamation Ditch Watershed Assessment.
    - Harris et al. 2007. CCoWS report on Molera Wetland for Prop 13.
    - Various CCoWS reports on Salinas Lagoon. Early 2000s. Note: longitudinal profile graphics.
    - Stage-discharge relationships at various bridges over Tembladero Slough developed by CCoWS in the early to mid 2000s
    - Stage-discharge relationship for TEM-MOL developed in CSUMB undergraduate thesis by D. Frank (also reproduced in Harris et al. report)
    - Salinity profiles at TEM-MOL by CSUMB staff and more recently by CSUMB MS thesis students M. Daniels and P. Krone-Davis
    - Observations over time of salinity and Chloride ion concentration at Molera Rd Treatment Wetland inlet by P. Krone-Davis
    - Miller et al. Peer-reviewed journal literature on protozoan pathogen occurrence in Central Coast region; cross-referenced against possible literature on influence of salinity on pathogen transport.
    - ENVS 660 Class Report for Carmel Lagoon in Fall 2009, which has good examples of solid color longitudinal plots.
    - Seawater intrusion maps produced by MCWRA (for groundwater).
    - Various documents relating to projected sea-level in the Central Coast and San Francisco Bay regions.
    - Various proposals involving MCWRA, USACE, and NMFS to modify the tide gates at Potrero Rd and to modify the slide-gate structure at the southern end of the Old Salinas River channel with fish screens.
    - Any relevant documents by the Habitat Restoration Group at MLML.

Task 3 – Postulates and/or Goals

- The postulates and/or goals of the work should be stated.
- The following postulates are suggested, but may be refined by the class. Their truth or falsehood is considered to be unknown at the outset of the project.
    - P1: Tembladero Slough exhibits spatial patterns in salinity
        - P1A: In parts of Tembladero Slough, vertical variation occurs as a density stratification between fresher water at the surface and more saline bottom water
        - P1B: Longitudinal variation occurs, such that the presence and thickness of a saline layer varies along the channel
    - P2: Longitudinal-vertical patterns changes over time
        - P2A: The vertical salinity profile at selected stations moves up and down over time
        - P2B: The longitudinal extent of a saline layer moves upstream and downstream over time
    - P3: Temporal variations are driven by external influences such as tide, discharge, and wind.
    - P4: Tidal influence extends upstream of the tide gates at Potrero Rd, through mechanisms such as:
        - Tidal head controlling downstream discharge through the tide gates
        - Some upstream discharge 'leaking' through the tide gates
        - Some saline water entering Tembladero Slough upstream through the tide gates
    - P5: Tidal influence occurs via water entering Tembladero Slough from the Salinas River Lagoon. e.g. saline water may reach TS from the ocean via SRL.
    - P6: Brackish inputs occur through irrigation tailwater discharges to Tembladero Slough and its tributary channels and drains (this irrigation water having originally been pumped from groundwater subject to seawater intrusion).
- Conceptual illustration of some of the above postulates:



- Definition of terms

    - Define for the scope of the project terms such as: saline, brackish, fresh, salinity, etc.

Task 4 – Study area description

- Describe definition and location of project area
- Include map with aerial photography.

Task 5 – Basic data

- Spatial data
    - Provide thalweg profile and representative cross-sections
- Temporal data
    - List locations and data sources relevant to the project area for information on:
        - Tides (at Moss Landing Harbor)
        - Discharge (e.g. Reclamation Canal at San Jon Rd, Salinas River at Spreckels)
        - Stage (e.g. CCoWS staff plates at various bridges over TS, MCWRA stage recorders in TS at Dunes Colony Rd, and in Salinas River Lagoon)
        - Wind speed and direction at any nearby recording stations (possibly including CSUMB, Monterey Airport, locations in Castroville or Moss Landing)
    - Graphically summarize data from above data sources, probably as time-series plots with matched time axes.
- Sources
    - List potential sources of brackish or saline water (SRL, MLH, Tailwater...)

Task 6 – Salinity data

- 2D Longitudinal-vertical profiles should be produced with elevation on the Y-Axis, distance along channel on the X-Axis, and either solid color or contours depicting salinity and/or isohalines. Separate profiles should be produced that reflect the extremes of variation observed during the project period (e.g. when saline water is generally farthest downstream and reduced, and when saline water is more prevalent and extending farthest upstream, as well as typical conditions. Profiles should include thalweg, water surface elevation (WSE), and locations of bridges.
- 1D vertical profiles should be produced for selected stations with elevation on the Y-axis, salinity on the X-Axis, and separate lines for representative dates. Selected stations should include TEM-MOL, since this is the inlet location for the Molera Rd Treatment Wetland. Profiles should include thalweg and WSE.
- 2D Temporal-vertical profiles should be produced for selected stations with elevation on the Y-Axis, time on the X-Axis and either solid color or contours depicting salinity and/or isohalines. Profiles should include thalweg and WSE.
- Lateral-vertical profiles of salinity should be produced for selected locations representing the greatest thickness of the saline layer, with elevation on the Y-axis, across-channel distance on the X-Axis, and either solid color or contours depicting salinity and/or isohalines. In conjunction with the longitudinal-vertical profiles, these

profiles should permit a rough estimate of the total volume of saline water in Tembladero Slough. Profiles should include channel-bottom and WSE.

Task 7 – Salinity analysis

- Analyses should be included that attempt to relate the studied variables to each other, exploring for example:
  - Synchrony of tides and longitudinal movements of saline layer
  - Flushing of saline layers in the downstream direction by higher discharges arising from the watershed
  - 'Smearing' of saline layers in the upstream direction by tidally driven 'upstream' (negative) discharges.
  - Discharge driven by tidal variation in the lower portions of Tembladero Slough

Task 8 – Final report

- Final report should include results of all the above tasks.
- Final report should include this Scope of Work as an Appendix.
- Final report to be prepared using MS Word in established style of CCoWS report series (See examples at: http://ccows.csumb.edu/pubs/)
- Final report to be delivered in PDF format, with MS Word files and all supporting files included for archival.
- Final report to be posted by instructor, and pending instructor approval, at: http://ccows.csumb.edu/pubs/ .

Task 9 – Administrative reporting

- November 9th – Skeleton report (headings only) and personnel workload assignments due by email to instructor at 8 PM, in MS Word format.
- November 16th – Incomplete draft report (including some example content for every task) due by email to instructor at 8 PM, in MS Word format.
- November 30th – Complete draft report (including all data, with exception of final samples of data sets that are already include in the report in near entirety) due by email to instructor at 8 PM, in MS Word and PDF format.
- December 7th – Final report ready for public web posting due by email to instructor at 8 PM.

Contingencies

It is recognized by the instructor at the outset that weather, resource limitations, equipment malfunctions etc may limit the extent to which this SOW is fully realized. The priority in such cases is to meet the deadlines with **completed work**, even if this means possibly reducing the overall scope of the work.

5 Resources

- Class will be provided with field instrumentation such as salinity meters and flow meters.
- Class will be provided with access to computers and software (e.g. MS Office, R, Photoshop, ArcMap) for analysis and report preparation.
- Class will be provided with access to canoe and kayaks.

6 Budget

No cash funds are available, but instructor will remunerate class in the form of an A grade pending the completion of all tasks on time.