Progress Report for

Coastal Water Quality: The Role of Wetlands in Mitigating the Effects of Urban and Rural Runoff

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1. Introduction

Tidal salt water marshes are located at the outlets of many urban watersheds along the southern California coastline. Because of their location at the interface between urban watersheds and the ocean, these wetlands are uniquely situated to mitigate the impacts of land runoff on coastal pollution. Beginning July 1, 2002, a team of researchers from UCI, UCSD, and UCLA were funded by the UC Marine Council Coastal Environmental Quality Initiative (UCMC-CEQI) to investigate the role that saltwater marshes play in modulating (either positively or negatively) the input of fecal indicator bacteria (FIB) into southern California's coastal ocean. FIB are the focus of this study because they may indicate the presence of fecal pollution from point and non-point sources of sewage, their presence in coastal waters is correlated with increased marine recreational health risk, and they are widely used as a water quality index by state and local officials for making decisions regarding the posting and closure of recreational ocean beaches.

This report describes fieldwork, data analysis, and numerical modeling efforts conducted by the research team over the eleven months since the UCMC-CEQI project was funded. The document is a short synopsis of the research team's main accomplishments; more details are available in a series of appendices covering various project components.

2. Group-Wide Field Study: The Breach of San Dieguito Lagoon

The UCMC-CEQI project has supported a spectrum of activities, ranging from single-investigator driven research to a large multidisciplinary field study involving all team members. The first year's primary group-wide field effort grew out of an opportunity created when the City of Del Mar decided to excavate the outlet of the San Dieguito Lagoon, a regionally important tidal saltwater marsh in San Diego County. The lagoon outlet was blocked with sand during a large wave storm in November 2001, and over the following year water quality inside the lagoon steadily worsened, as evidenced by declining dissolved oxygen concentrations, declining salinity, and increasingly frequent fish kills. The deterioration in water quality was presumably caused by the absence of tidal flushing, coupled with the accumulation of nutrient-laden runoff from the surrounding area, which includes the Del Mar Race Track and Fair Grounds, several horse stables, and a large residential community in the San Dieguito watershed. The excavation was planned such that tidal flushing to the lagoon was restored at the bottom of an ebb tide at noon on October 4, 2002.

Recognizing that the breach of San Dieguito Lagoon represented a unique opportunity to study how this particular management strategy affects both wetland ecology and coastal water quality, the study team carried out a set of complementary research projects designed to: (1) Characterize water circulation in the lagoon and in the inshore region of the ocean (led by C. Winant). (2) Follow the temporal evolution of FIB in the lagoon, in the surf zone, and offshore (led by S. Grant). (3) Measure the spatial distribution of FIB in the lagoon sediments, the relationships between FIB-laden sediment and landscape features, and the ecological response of the wetland to the breach event (led by R. Ambrose and L. Levin). (4) Identify linkages between FIB occurrence patterns and within-wetland circulation as revealed by hydrodynamic modeling studies (led by B. Sanders). The offshore component of this particular field experiment was supported with

matching funds from Southern California Edison, which is leading a long-term effort to restore San Dieguito Lagoon. The matching funds, which totaled $75,000 in cash and approximately $25,000 of in-kind support, paid for the construction and deployment of six semi-autonomous sampling stations offshore of the lagoon outlet, the rental and installation of three current meters (an acoustic Doppler current profiler (ADCP) offshore and two S4 current meters within the lagoon), and a portion of the cost associated with collecting, transporting, and testing approximately 2000 water samples. Preliminary results are described in a series of appendices, including circulation measurements (Appendix 1), FIB water column measurements (Appendix 2), the FIB sediment measurements and wetland ecology studies (Appendix 3), and hydrodynamic wetland circulation studies (Appendix 4). A brief synopsis of the main results is presented below.

The breach took place on a day characterized by unusually small waves, and weak littoral and inshore currents. Consequently, the surf zone was very thin, and relatively little of the lagoon effluent was directly entrained in the surf zone. Instead, as the outlet was breached, water flowed out of the lagoon, down the beach, crossed the surf zone, and spread out in a more-or-less symmetrical pattern offshore. Drogues released near the outlet were taken offshore initially, and many returned back to the shoreline within 1 km of their point of release. From an analysis of drogue tracks and inshore ADCP records, it appears that contaminants associated with the lagoon effluent would have been taken offshore initially, and some fraction may have been recycled back into the surf zone by shoreward directed currents.

The breach event caused significant changes in the spatial distribution of FIB in the lagoon, along the shoreline, and offshore. Before the breach, FIB concentrations inside the lagoon increased along an inland-to-coastal gradient; i.e., the highest concentrations were observed at the site closest to the tidal outlet. FIB pollution near the outlet was associated with low salinity water, and hence probably originated in nuisance surface water runoff (e.g., from the nearby horse stables) or leaks from the local sewer collection system. The FIB gradient reversed several days after the breach, where after FIB concentrations increased with increasing distance inland. The effects of the breach on surf zone water quality also took several days to develop. Several days post breach a nearly Gaussian distribution of FIB developed in the surf zone around the lagoon outlet. Perhaps most surprisingly, within 24 hours of the breach event, FIB from the lagoon had contaminated a >4 km^2 area offshore, stretching at least 4 kilometers along shore and 1.2 km offshore. The FIB plume was most concentrated directly offshore of the tidal outlet, consistent with the relatively weak long-shore currents observed during the circulation studies (see above). After the breach, chlorophyll and turbidity were elevated around the tidal outlet in the surf zone; however, the breach did not measurably affect the concentration of chlorophyll or turbidity at the offshore sites.

Before the breach, FIB were concentrated in the shallow subtidal sediments of the lagoon. The concentration of FIB in the subtidal sediments decreased after the breach, but only after the outlet had been open to tidal flushing for about one month. FIB concentrations were very low at all of the lower marsh transects and showed no apparent response to breaching. Intriguingly, high concentrations of FIB were associated with

algae, which experienced reduced abundance at the sampled sites after breaching. Vegetation cover may also enhance the survival of FIB in sediment, for example by shielding the organisms from harmful UV radiation. These data indicate that tidal saltwater marshes may harbor many microenvironments conducive to the regrowth of FIB.

Possible links between residence time distributions (both pre- and post-breach) and the observed spatial distribution of FIB in the water column and sediment, are currently being explored with a three-dimensional hydrodynamic modeling system specifically designed for shallow tidal wetlands like San Dieguito. The California Tidal Wetland Modeling System (CalTWiMS), which will serve as a common platform for circulation and mixing analyses at all of the UCMC-CEQI sites, outputs spatial maps of residence time distributions, shear stress distributions, inundation frequencies and durations, and salinity variations.

3. Group-Wide Field Study: Planned Activities for Year 2

During the second year of the UCMC-CEQI project, we will write up and submit for publication the results of the San Dieguito Breach Study, and we will conduct several additional group-wide field investigations. The San Dieguito study will be written up as two complementary manuscripts: one focusing on the observations of inshore circulation patterns (i.e., the drogue and ADCP data) and FIB distributions in the lagoon, surf zone, and offshore pre and post breach, and another that explores the linkage between within wetland circulation patterns (e.g., residence time distributions, residual circulation, bed stress distributions), and the changes in water quality gradients, both in the sediment and water column, induced by the breach event.

Group-wide activities in Year 2 are still being planned, and will likely include: 1) Follow up studies at the upstream and downstream margins of San Dieguito lagoon to determine whether the wetland is producing, or consuming, FIB; 2) Measurements of the export rate of FIB from a small constructed wetland in Mission Bay, San Diego County, planned for June 2003; 3) Another breach study at Malibu Lagoon, Surfrider Beach, in LA County; and 4) Field studies of within wetland circulation at the Santa Ana River Sloughs.

3. Focused Investigations Funded by UCMC-CEQI

As a complement to large multi-campus studies (like the one at San Dieguito Lagoon), more focused investigations, involving one or more of the team members, have also been carried out during the review period. These more focused studies are described below.

A. With funding from the CEQI grant, C. Winant has concentrated on three different aspects of the circulation and exchange between coastal lagoons and the adjacent ocean[1,2,3] These efforts are directly relevant to the central goal of the CEQI

[1] Winant, C.D. and G. Gutierrez de Velasco, 2003: Tidal dynamics and residual circulation in a well-mixed inverse estuary. *J. Phys. Ocean*., Vol. 33 (7).
[2] Winant, C.D., 2003: Three-dimensional wind-driven flow in a linear, constant density basin, submitted *J. Phys. Ocean*.

project, because they illuminate how mass (including contaminants such as FIB) is exchanged between wetlands and the coastal zone. Two of the three papers are collaborations with Guillermo Gutierrez de Velasco, a Mexican colleague from CICESE, and are based on observations in a Mexican lagoon, taken before the CEQI funding became available.

B. With CEQI funding, S. Grant and his students have submitted several manuscripts for possible publication. The first of these papers[4] shows that current methods for issuing coastal water quality health advisories (based on routine fecal pollution monitoring data) are highly prone to error, in some cases exceeding 50% (a coin toss). The manuscript presents a stochastic model for predicting health advisory error rates, and describes how physical transport processes (e.g., long-shore advection of pollutants by wave-driven currents) influence whether monitoring data are stochastic or deterministic in nature. The second paper[5] describes a mass budget analysis of high frequency (i.e., f~1/h) surf zone monitoring data that can be used to pinpoint the location of, and quantify the timing and magnitude of, sources of surf zone pollution.

C. With CEQI funding, S. Grant and B. Sanders are currently analyzing FIB data collected (before the CEQI grant was awarded) from several tidal saltwater marshes in Orange County, including Upper Newport Bay and sloughs located along the levy of the Santa Ana River. The goal of these studies is to quantify the export rate of FIB from tidal saltwater marshes and to examine how export rates are affected by physical features of the wetland (SAR slough studies) and to explore how the spatial distributions of FIB within a wetland are influenced by residence time distributions and external forcing (e.g., storms, Newport Bay studies).

D. R. Ambrose and his student (M. Evanson) are using CEQI funds to conduct longitudinal studies of FIB in sediments from San Dieguito Lagoon and the Santa Ana River Sloughs. In particular, the focus of this investigation is on how storm events affect the spatial distribution and magnitude of FIB concentrations in wetland sediments.

E. The CEQI grant is also funding R. Ambrose and L. Levin, and their students, to investigate the linkage between landscape ecology and FIB concentrations in within wetland sediments. Initial sampling has been conducted at San Dieguito

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[3] Guttierez de Velasco, G. and C.D. Winant, 2003. Wind and density-driven circulation in a well-mixed inverse estuary. Submitted, *J. Phys. Ocean*.

[4] Kim, J., Ensari, S., McGee, C., and Grant, S. 2003: Public mis-notification of coastal water quality, Submitted, *Environ. Sci. Technol*.

[5] Kim, J., Sanders, B.F., McGee, C., Largier, J., Grant, S. 2003: Tidal dynamics and mass budgets of fecal pollution in the surf zone: case study at Huntington State Beach, California, to be submitted shortly to *Environ. Sci. Technol*.

Lagoon and the Santa Ana River sloughs, with future sampling to include Mugu Lagoon, Newport Bay, and other sites.

5. Project Organization, Student Involvement, and Outreach

A central objective of this study is to foster the development of new insights into the functioning of tidal saltwater marshes, and their relationship to coastal water quality, by stimulating collaborative activities between researchers with diverse backgrounds. Mechanisms put in place to facilitate across-campus collaboration include (1) approximately once per month phone conferences and face-to-face meetings between the principle investigators and their students/post-docs, (2) a one day conference (held at UCI on January 24, 2003) to present and discuss research progress, (3) the creation of an ftp site to facilitate the sharing of large data sets between researchers, and (4) the ongoing development of a public web site that will, when finished, describe the general goals of the research effort, and provide non-technical descriptions of the primary findings (the site is planned to go live in the next couple of days).

Tangible examples of public outreach during the first year of the project include the involvement of local stakeholders in the January 2003 research meeting, the inclusion of volunteers from the San Dieguito Wetland Conservancy in the October 2002 field experiment, and press coverage of the field study at San Dieguito Lagoon (copies of newspaper articles available upon request). Approximately seven graduate students and two post-doctoral researchers have so far received support under this project, and approximately 60 undergraduate and graduate students were hired as temporary workers during the large field study at San Dieguito Lagoon.