Clean Beaches Initiative (CBI) 2012 – Fate and Transport Plume Tracking and Near-Shore Models Coupled with Enhanced Monitoring to Improve Public Health Protection

I. Background

Protecting water quality of Southern California's beaches is a vital objective undertaken by regional and state municipalities due to the recreational and economic importance of area beaches to the region. Impaired beach water quality remains a persistent problem that leads to significant beach closures annually due to microbial contamination from urban runoff and dry weather pollution sources. For example, a 2000 report from the Southern California Coastal Water Research Project (SCCWRP) indicated ~60% of the beaches in the 1,100 km from Point Conception (Santa Barbara County) to Punta Bandera, Mexico, were found to exceed water quality health standards after rain events of an inch or more and that number increased to ~90% for beaches close to rivers, creeks, and freshwater outlets (Brooks, et al., 2005). Fate and transport models of pollutants (from wet and dry sources) are essential in effectively and efficiently assessing beach exposure, thus providing a pivotal resource for determining beach closures. The objective of the proposed work outlined by this document is to improve predictive models and procedures currently used to monitor and predict microbial contamination at beaches near the mouth of the Tijuana River Estuary.

Imperial Beach, just north of the mouth of the Tijuana River Estuary, is a prominent example of a region affected by pollution from both wet and dry sources. During dry weather conditions, there are three main potential sources of bacteria associated with human fecal matter that have the potential to impact area beaches: rogue flows from the Tijuana River Estuary, surfacing events from the South Bay Ocean Outfall (SBOO), and northward flow from the San Antonio del los Buenos Wastewater Treatment Plant (SABWT). Additional sources include sediment basins and nonpoint sources. Some of the sources contain partially treated or raw sewage, therefore, the potential impacts to human health are of high priority.

Potential sources of microbial pollution in the area include:

A. Tijuana River Estuary

Over 75% of the Tijuana River Watershed lies on the Mexican side of the border. Over the last several decades, extensive work has been performed to minimize the impact of sewage flows from Mexico that reach the Tijuana River Estuary and area beaches through dry weather diversions and treatment facilities. However, dry weather flows containing sewage originating from Mexico have been periodically detected flowing across the border. These rogue flows discharge to the Tijuana River Estuary and may reach area beaches.

During wet weather (storm events) flows in the Tijuana River (which originate primarily from the Mexico side of the U.S./Mexico border [border]) overwhelm the Tijuana River Estuary and

often cause large plumes of highly contaminated discharge from the mouth of the estuary that impact area beaches.

B. The South Bay Ocean Outfall (SBOO)

This ocean outfall receives sewage flows from the South Bay International Wastewater Treatment Plant (SBIWTP). The SBIWTP treats approximately 25 mgd of Tijuana sewage that discharges to the SBOO, approximately 4.5 km off the coast of Imperial Beach. During a 2007 - 2008 SBOO discharge monitoring project, the plume was found to surface approximately 20 - 25% of the time in a 12 month period. According to the final report prepared for the International Boundary and Water Commission (Terrill 2009), "The analysis suggests that it may be possible for beaches near the U.S.-Mexico border to be exposed to the SBOO plume during a transition from southward to northward flow." Unfortunately, fluctuations in ocean conditions which result in plume surfacing are too dynamic to be captured by monthly boat surveys – e.g. present sampling pursuant to the NPDES permit is too coarse in time for identifying periods when the outfall plume is surfacing. Likewise, the NPDES permit has no sampling requirements for knowing the ocean currents into which the discharge takes place.

C. The San Antonio de los Buenos Wastewater Treatment Plant (SABWT)

This sewage treatment plant, located in the City of Tijuana, has a pumping capacity of 64 mgd and an average daily operational capacity of 48 mgd (approximately 25 mgd goes through secondary treatment). It discharges to the surf zone off the Mexican coast at Punta Bandera, approximately 5.6 miles south of the international border. ***The plant is scheduled for an upgrade, but during construction it will be off-line and pumping untreated sewage into the surfzone.*** Northward flows can carry the Punta Bandera discharge plume along beaches in Mexico and into the US; therefore, a***ccurate tracking of this plume is an increasing priority.***

D. Sediment Basins

To protect and preserve the rare and sensitive marsh lands of the estuary (which includes a National Estuarine Research Reserve), sediments flowing from Mexico are trapped in sediment basins. These fill quickly with substantial yearly maintenance costs (on the order of $1M). Possible management strategies including releasing the sediments during storm events or using them for beach re-nourishment. However, the sediments can have high bacteria and possibly pathogen loads, and this must be accessed and understood before such management strategies can be considered.

E. Nonpoint sources

In addition to the point sources described above, high counts of fecal indicating bacteria can be found in areas with high wildlife abundance, such as estuaries. Elevated nutrient conditions also can contribute to high numbers of bacteria in water and sediments. Such nonpoint sources of bacteria complicate TMDL and Best Management Practice formulations; the information gained in the research outlined below will be value added for those applications.

II. Research Goals

A. Predictive Model Enhancement

Improve existing predictive models with surfzone current models to increase understanding of FIB fate and transport and to trigger enhanced monitoring to better protect public health.

The Coastal Observing Research and Development Center (CORDC), a partner of Southern California Coastal Ocean Observing System (SCCOOS), has developed a near real-time model for tracking plumes derived from the Tijuana River discharge and statistical plume exposure maps for the SBOO and SABWT. The Tijuana River plume tracking model has been used operationally by the San Diego County Department of Health (DEH) for decision making and guidance in the postings of beach advisories (Clifton et al., 2007) and culture techniques for fecal indicating bacteria (FIB) – enterococci, E. coli, fecal coliforms. The model was developed using surface current observations provided by a network of HF radar stations operated as part of SCCOOS. The model calculates surface vector current fields from radial velocity measurements using an optimal interpolation (OI) method, eliminating the need for multiple mapping steps (common in traditional least-squares fitting methods) and optimally filling intermittent coverage gap (Kim et al. 2009). A random walk model uses the OI derived surface currents to determine the trajectory of the forward particle through Lagrangian time integration. Plume tracking accuracy was assessed by comparing outputs with water quality sampling of shoreline bacteria indicator, and the skill of an alarm for low water quality was evaluated using the receiver (or relative) operating characteristic (ROC) analysis. Four years of surface current data were examined, and the accuracy of the particle tracking model during several rain events was estimated at approximately 70% (Kim et al 2009).

The onshore boundary of HF radar derived surface currents is approximately 1 km from shore - i.e., far-field observations. Currently, the model uses a simple interpolation scheme to predict currents from the 1 km boundary to the shoreline. However, surfzone (near-field -- within a few 100 m of the shoreline) currents can be quite different than currents farther offshore. Shelf flows are driven by winds, buoyancy and tides. In contrast, surfzone currents are driven by wave-breaking (e.g., summertime south swell drives northward currents) and are typically much stronger (up to 1 m/s) than currents just a few 100 m offshore, providing a significant conduit for pollution transport (Grant et al. JGR 2005). We propose to improve the current near-shore trajectory estimates of the plume tracker model by coupling with a high accuracy near-shore transport model driven by waves developed by F. Feddersen (Scripps Institute of Oceanography, SIO) for the area of Imperial Beach.

The original surfzone current model was developed in collaboration with the Coastal Data Integration Project (CDIP) for the Huntington Beach State Park region as part of a 2006 SCCOOS project. The CDIP wave model provided predictions of wave height, period, and angle seaward of the surfzone (6 m depth) at a variety of alongshore locations. This information provided a boundary condition for a surfzone wave and current model. This model has been previously validated at beaches on the US East Coast and Europe. Using 1.5 months of in situ observations collected at Huntington Beach State Park, the model accurately predicted the surfzone breaker height and the mean alongshore current. This model provided real-time nearshore alongshore transport predictions for the Huntington Beach (HB) region from the Santa

Ana river mouth to north of the HB pier from 2006-2010 that were used by the Orange County Sanitation District.

Alongshore current projections from the CDIP wave model will be combined with observed offshore HF radar surface currents to form a single current vector field. The plume tracker model will process this "complete" dataset to determine Tijuana River plume trajectories. Successful coupling of the SCCOOS operational model with the proposed surfzone transport model is expected to provide significant improvements to alongshore plume tracking . Locally, it should greatly increase the accuracy of both dry- and wet-weather predictions. Furthermore, we propose to couple the predictive models with enhanced monitoring (see below) to allow for timely notification of potential health risks.

B. SBOO Monitoring Buoy Installation

Complement predictive models for the area and track the SBOO through installation of a monitoring buoy.

The SBOO was previously equipped with a monitoring buoy, allowing predictive modeling of the discharge plume. We propose to reinstate the monitoring buoy to measure full-water column stratification and subsurface currents at no less than hourly intervals at the SBOO discharge site. An Iridium Satellite modem will report to shore on a near real-time basis so that the discharge plume behavior can be assessed on a regular basis. Trajectory estimates representing the bulk transport of the water for the entire water column will be computed for 48 hours of data and updated on an automated basis with the receipt of the next hour of data. When the plume is submerged, the subsurface velocity measurements will be critical for a) improving estimates of the plume's location so that it can be effectively sampled and b) assessing the annual behavior of the plume to understand it spatial distribution. Data monitored with the mooring also can be used within a plume rise height model to estimate the vertical extent of SBOO water as a function of time. Estimates of the fate of the plume in the nearshore will be improved using surfzone models, as described above.

C. Beach Monitoring

Advances in molecular biology may benefit monitoring and notification programs. To test this theory, enhanced monitoring (qPCR for enterococci and fecal source identification) will be triggered by the following:

- predictive models (described above) predicting oceanographic conditions with high risk to bring discharge plumes to the beach (SBOO on-shore transport transport from the SABWT, as predicted by models)
- Tijuana (TJ) River storm events and dry weather sampling
- beach water quality exceedance (via the current monitoring program), including sewage spills
- lifeguard input regarding suspicious conditions (e.g. "smelly" water)

Seawater samples will be collected up to five times per year from the following six sites: Two (2) sites south of the TJ River, two (2) sites north of the TJ River, at the TJ River mouth, and an upstream site (to calculate loads into the TJ estuary).

Once enhanced monitoring is triggered, sites along Imperial Beach will be tested by quantitative polymerase chain reaction (qPCR) techniques. In all cases, ***samples will be analyzed by qPCR for enterococci and compared to culture, and the effect on closure decisions compared to the current monitoring program will be assessed, both from the perspective of using rapid indicators to make closure decisions (including beach re-opening) and from the perspective of fate and transport models (see above)***. In addition to enterococci by qPCR and culture, all samples also will be analyzed for human fecal sources by qPCR (based on recommendation form the Source Identification Pilot Project, SIPP, recommendations) in order to confirm human fecal sources predicted by model (e.g., versus natural sources). In addition, molecular source tracking (MST) analysis for bird fecal sources by qPCR would be implemented because this is expected to be a significant non-point source of pollution. Depending on the trigger, (e.g., Tijuana River plume and wet weather), additional quantitative fecal source identification methods could be tested, including dog, and horse sources in order to understand the magnitude of these sources to receiving waters.

D. Sediment Analysis

Assess FIB and pathogen loads in sediments stored in sediment basins to evaluate the potential health risks of certain disposal practices (e.g. release into the river, beach re-nourishment).

Sediments would be tested for the following EPA reference pathogens: *Campylobacter, Salmonella, Cryptosporidium*, and adenovirus. In addition *Staphylococcus aureus* would be investigated because risk calculations for this pathogen in sand are available.

E. Integration of Model and Beach Monitoring Analysis

Assess the impact of using rapid indicators and source tracking markers coupled with predictive models on beach monitoring. Within this integrated assessment, the following hypothesis will be tested:

- Predictive models coupled with enhanced monitoring can improve the effectiveness of beach monitoring programs with regard to predicting exposure to contaminated water.
- Rapid methods coupled with predictive models can reduce the number of beach closure days by more rapidly showing when contamination events have cleared.
- In the course of research using rapid methods in response to storm events, we will gain a more accurate understanding of how long the beach stays contaminated after a storm event (including dependencies on storm size).

III. Summary

The Tijuana River plume tracker model has been used by the DEH as a key decision aid in determination of beach closures in the San Diego region since approximately 2005. The SBOO model has been used to determine plume rise height, surfacing, and exposure to area beaches. The goal of the proposed work is to improve the operational predictive models and procedures used to monitor coastal areas affected by the Tijuana River discharge and SBOO. The work will significantly improve the assessment of nearshore fate and transport of pollutants dispersed from the Tijuana River discharge and SBOO and will also aim to capture the San Antonio de los

Buenos surfzone discharge impact on beaches. The improved models coupled with rapid assessment methods will (1) create an online near real-time decision support tool for public health and safety (2) limit local economic losses due to false positive beach closures in the areas affected by the Tijuana River discharge (3) serve as a benchmark pollutant plume tracking procedure that can be implemented in other high risk coastal areas.

References

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