Draft Science Plan
Tijuana Estuary Sediment Fate and Transport Demonstration Project
Coastal and Marine Geology Program
U.S. Geological Survey
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Background

Fine-grained sediment is a natural part of the California nearshore coastal waters, and recent work suggests that approximately 34 million tonnes (Mt) – or roughly 30,000,000 cubic yards – of fine-grained sediment enters California coastal waters each year from coastal watersheds (Farnsworth and Warrick, 2007). Fine-grained sediment may also enter California coastal waters from human activities, including opportunistic use of sediment for beach nourishment, that are subject to a precautionary rule of thumb that sediment with greater than 20% fines (silt and clay) is not appropriate for placement in the nearshore unless additional information exists to show that such placement won't result in environmental degradation. This so-called 80-20 (coarse-to-fine sediment) "rule of thumb" was originally used as a threshold for determining whether pollutants were attached to the fines in sufficient quantity to be of concern. The rule of thumb is also consistently applied to clean sediment as well, with extensive/long-lasting turbidity and burial of species/habitat typically cited as the reasons for concern.

Unfortunately, much of the available sediment suitable for opportunistic use does not meet the 80-20 standard and must be transported inland to landfills at significantly higher cost than beneficially reused at nearby coastal locations (for example, beach restoration). In order to reevaluate whether this rule of thumb is appropriately protective or overly conservative, a small demonstration project is proposed to provide the physical and biological data needed to assess the extent and duration of both turbidity and sedimentation when sediment with greater that 20% fines is used for opportunistic reuse. Below we present a draft science plan that is designed to provide answers to pending questions about fine-grained sediment in California nearshore waters: (1) What are the transport pathways and fate of fine-grained sediment introduced at the coastal shoreline? (2) How do environmental and project variables, such as sediment placement volume, percent fines, waves, currents, and shelf setting, influence the rates and modes of transport and eventual fate?

Study Site

The proposed study site for the demonstration project is the South Beach of the Tijuana River National Estuarine Research Reserve of southern California (Figure 1), where there has been extensive wetlands loss over the past few decades due to sedimentation resulting from large volumes of sediment discharge from urbanizing tributaries. To help alleviate this problem, a debris basin was built at the mouth of the largest contributing tributary, Goat Canyon (Figure 1B), that annually traps greater than 40,000 yd^3 of sediment. This sediment is expensive for the State Parks to remove and dispose and could provide beneficial reuse as a supply for beach nourishment. The opportunistic sediment available at the Tijuana Estuary contains a relatively high percentage of fine-grained sediment, and therefore would normally not be considered as suitable for beach nourishment based on the 80-20 rule of thumb. Beneficial reuse could provide an ideal opportunity to investigate how fine sediment moves in such a coastal setting, thus providing valuable information for future management activities.

It is important to compare the proposed placement with natural rates of fine-grained sediment input to the ocean for the region. Based on 46 years of historical data, Farnsworth and Warrick (in press) calculated that the Tijuana River annually discharges approximately 120,000 yd^3 of suspended sediment to the Pacific Ocean through the river mouth, roughly 90,000 yd^3 – or 77% – of this river sediment is fine-grained. Thus, the proposed sediment placement discussed below would be equivalent to 27% of the average annual fine-grained sediment discharged annually from the Tijuana River to the Pacific Ocean. The actual annual discharge of sediment from the Tijuana River is highly variable, however, ranging from 0 to ~2,000,000 yd^3 over the historical record. Tijuana River sediment represents roughly 18% of the total fine-grained sediment inputs from the Peninsular Range (San Diego County to southern Orange County), from which 64% is estimated to be from river discharge and 36% from coastal bluff and cliff erosion.

Study Applicability

The Science Plan has been developed with the intention of providing results that will be applicable and may be generalized to other coastal settings. For example, the project is designed to have multiple placements with different placement volumes, which will result in a range of environmental (wave and current) and project variables to evaluate. Multiple observation techniques are also proposed, which will allow for result and trend confirmation. Combined, these observations will be compared to environmental conditions during the project, and these results – in turn – will be compared to the existing body of sediment transport theory and observations. Emphasis will be directed toward comparisons with general sediment transport theory and developing new insights for how fine sediment moves in continental shelf settings under the sediment loading proposed.

We fully expect to obtain results that are applicable to open-coast, dissipative beaches with somewhat broad continental shelves, settings that are similar to numerous sites in California where future sediment management might be practiced. Application of the results to other coastal sites will be possible with comparisons of site physical settings and appropriate scaling of the results to the site in question.

Placement Design

A detailed description of the placement design is provided in the Project Description Report, here we provide an abbreviated synthesis of this plan to inform the reader of the general techniques planned. Sediment will be acquired from the Goat Canyon sediment basin processing pad, screened to remove trash, and would contain a grain size distribution of approximately 40% fines:60% sand based on prior inventories of this sediment. The material will be transported from the processing pad to the beach during the 2008-‘09 winter and staged on the upper beach, above highest high water (Figure 1). From there material will be bulldozed down to the exposed lower beach during times of low tides (Figure 2). There will be three placements, timed four weeks apart and coinciding with spring tides (Figure 3). Multiple placements will allow for the evaluation of how environmental conditions (waves, currents, and placement volume) affect sediment pathways and fate.

Placement 1: 10,000 yd^3 (~4,000 yd^3 of fines)
Placement 2: 10,000 yd^3 (~4,000 yd^3 of fines)
Placement 3: 40,000 yd^3 (~16,000 yd^3 of fines)

Total Placement Volume = 60,000 yd^3

The material will be placed in a flat-topped berm stretching along the beach and with a height of approximately 2 yd (Figure 2). Using historical topographic information from the beach, it appears that a 20 yd wide berm could be constructed within the important intertidal portion of the beach (Figure 2). This placement geometry (2 yd thick, 20 yd wide) would result in alongshore placement lengths of 250 yd for the first two placements and 1000 yd for the last placement.

Science Plan Methods

We propose the following integrated science plan to examine the dispersal and fate of sediment placed in the nearshore for the demonstration project. This study is intended to serve as a model for the dispersal and fate of mixed sediment from opportunistic beach nourishment for the Tijuana Estuary beaches and other coastal settings along California. We plan to use a variety of placement volumes and study the resulting water-column turbidity and sedimentation on the seabed. This work is expected to provide scientific documentation to aid in the development of protocols for fine-grained sediment placement.

The transport and fate of fine-grained sediment introduced into the nearshore of the South Beach of the Tijuana River National Estuarine Research Reserve will be investigated an extensive field study and analyses of these results. The main questions that will be addressed include:

1. What are the residence times and mechanisms of water turbidity due to the introduced fine sediment?
2. What are the residence times and mechanisms of sedimentation on the seabed due to the introduced fine sediment?
3. What are the sediment transport pathways that lead to the final sink for the fine sediment introduced into the nearshore?
4. How does project implementation (volume and rate of placement) influence ocean sediment transport and fate?
5. Will the coarser fraction of sediment added to the nearshore benefit the beach profile?

Field Study

Any sediment placed in the nearshore will be reworked and possibly transported prior to eventual deposition on the seafloor. Both waves and currents act on the sediment to transport it along- as well as across-shore. Field observations are essential for describing sediment movement and deposition, thus we will describe and quantify sediment transport along the Tijuana Estuary coastline with a combination of existing oceanographic data, seafloor mapping, tripod deployments, and water and seafloor sampling.

The field study will begin several months before the demonstration project and continue until at least several months after the project (Figure 3). We expect that this work will be conducted by a research team that will include the USGS and other academic, state, federal, and private industry partnerships. This program is divided into five tasks, as detailed below.

1. Seafloor Mapping

Seafloor mapping will be used to develop local baselines of bathymetry and seabed sediment type, which will then be used for change detection following the demonstration project. Two mapping cruises are planned for the field study, the first for May-June 2008 for a total of three weeks (Figure 3A), two weeks will be spent on obtaining high resolution swath sonar maps of ~50 km^2 of the study area (Figure 4) and one week will be spent collecting underwater video and seafloor grain-size measurements for ground-truth of the sonar. This mapping will be an important product for project planning and to evaluate changes in the seafloor following the experiment. The second sonar-mapping cruise will reoccupy the same nearshore areas, using identical techniques, and will be conducted after the demonstration project and during the same portion of the calendar year of the first mapping cruise (May-June 2009; Figure 3A). The primary purpose of the second mapping cruise is a comparison with pre-demonstration project bathymetry and seafloor substrate.

2. Plume Mapping – Nearshore Tripods

A series of tripods will be placed in the nearshore of the study area (Figure 4) and will include acoustic and optical instruments to characterize the evolution of suspended sediment, water, and seafloor properties during the demonstration project (Figure 3B). The purpose of this task is to provide high-resolution time series of oceanographic properties at a series of locations in the study area to track the dispersal characteristics of sediment during the demonstration project. Six tripods will be deployed by the USGS both along- and across-shore of the sediment placement location, for a period of approximately 4 months (Figures 3 and 4). Instruments on the tripods will include optical and acoustic sensors to evaluate suspended sediment and water velocity conditions in the water column with emphasis on the lowest 2 meters above the seabed, where much of the sediment is expected to transport. Because optical sensors will provide important measurements of the characteristics of suspended sediment, and because these sensors can foul from biologic growth, divers will be utilized in between each sediment placement to clean these sensors. We will also deploy a bottom-mounted acoustic Doppler current profiler (ADCP) with directional wave capabilities to provide detailed information about the incoming wave conditions (Figure 4). Combined, these measurements will be used to identify whether or not the sediment placements can be tracked as clear pulses of suspended and (or) deposited sediment in the nearshore.

3. Plume Mapping – Boat

Seafloor grain size and water column properties will be surveyed before, during, and after the demonstration project sediment placements by boat sampling. Seafloor grain size will be sampled with the an underwater bed camera developed by the USGS as detailed by Rubin and others (2006), the water column will be sampled with a conductivity, temperature, depth (CTD) sensor combined with optical turbidity and grain size sensors (transmissometer, optical backscatterance sensor – OBS, and a laser diffraction particle size analyzer – LISST). The boat surveys will be used in conjunction with the other sampling to track the movement of sediment offshore of the surf zone. An adaptive sampling strategy will be used for the boat sampling to provide samples that follow the plume location and focus on the days of maximum sediment movement.

4. Plume Mapping – Surf Zone and Sediment Sampling

The surf zone will be the initial zone of sediment suspension and movement and will direct the initial fate of the sediment. Surf-zone sampling will be important to track the initial sediment movement and the topographic and grain size responses of the beach to sediment placements. Surf-zone sampling will include both topographic surveys of the beach surrounding the region and water sampling by both physical sampling and, perhaps, moored instrumentation. If seabed armoring in the surf zone is identified to be an important process, then significant amounts of fine grained material will be trapped beneath a thick layer of coarser material, and there will be a need to continue portions of the study for significantly longer periods than shown in the project timeline (Figure 3). We are currently in discussions with academic partner(s) to provide the sampling and analysis of this task.

5. Plume Mapping – Aerial Remote Sensing

Aerial remote sensing will be used to collect multi-spectral imagery of the study area to evaluate sediment dispersal pathways. Remote sensing will be provided by airplane overflights by Ocean Imaging, a private remote sensing company, which has been collecting multi-spectral imagery of the study area for approximately 4 years in a partnership with the City of San Diego. The imagery has a ground resolution of approximately 2 meters, which is adequate to track suspended sediment in both the surf zone and the nearshore. Two subtasks will be completed. First, historical imagery of the study area from Ocean Imaging will be organized, processed and synthesized to describe the turbidity and physical properties (for example, rip currents and river plumes) of the study area. This first subtask is ongoing in a partnership between the USGS, Ocean Imaging and Dr. Katie Farnsworth of the Indiana University of Pennsylvania. Secondly, 20 new overflights are proposed for the demonstration project, to be conducted daily during and immediately following placements, as weather permits.

Supporting Data

The science plan will benefit from data collected in the study area region, including:

1. San Diego Coastal Ocean Observing System (SDCOOS) high-frequency (HF) radar observations of surface currents, which will provide valuable near real-time

information about the regional ocean circulation, and the Tijuana River plume.

2. National Oceanic and Atmospheric Administration (NOAA) NDBC meteorologic buoys, especially buoy 46086 (San Clemente Basin), which provides near real-time wind and wave information at a location ~70 km offshore of the demonstration project.

3. There may be an opportunity to collaborate with the Scripps Institute of Oceanography (SIO) Coastal Data Information Program (CDIP) wave buoy program to provide highly accurate, and near real-time, directional wave information for the study area region.

4. Tijuana Estuary Demonstration Project Sampling and Analysis Plan (SAP). The SAP is designed to provide the environmental monitoring (including biologic monitoring) necessary for the permitting of the demonstration project. Data collected in the SAP will be essential for evaluating biology response to the demonstration project.

5. Historic water quality data collected offshore of the demonstration project by the City of San Diego in coordination with the operation of the South Bay Outfall.

Project Synthesis

The results of the demonstration project science plan will be analyzed, interpreted and synthesized in peer-reviewed USGS reports and journal articles, which will be made available to the public. An executive summary of the experiment will be developed into a two-page USGS Fact Sheet, which will available to distribute to interested parties.

Cited References:

Farnsworth, K.L. and J.A. Warrick, 2007. Sources, dispersal, and fate of fine-grained sediment supplied to Coastal California: U.S. Geological Survey Scientific Investigation 2007-133, in press.

Rubin, D,M. H. Chezar, J.N. Harney, D.J. Topping, T.S. Melis, C.R. Sherwood, 2006. Underwater microscope for measuring spatial and temporal changes in bed-sediment grain size: U.S. Geological Survey Open-File Report 2006-1360, 15 p.

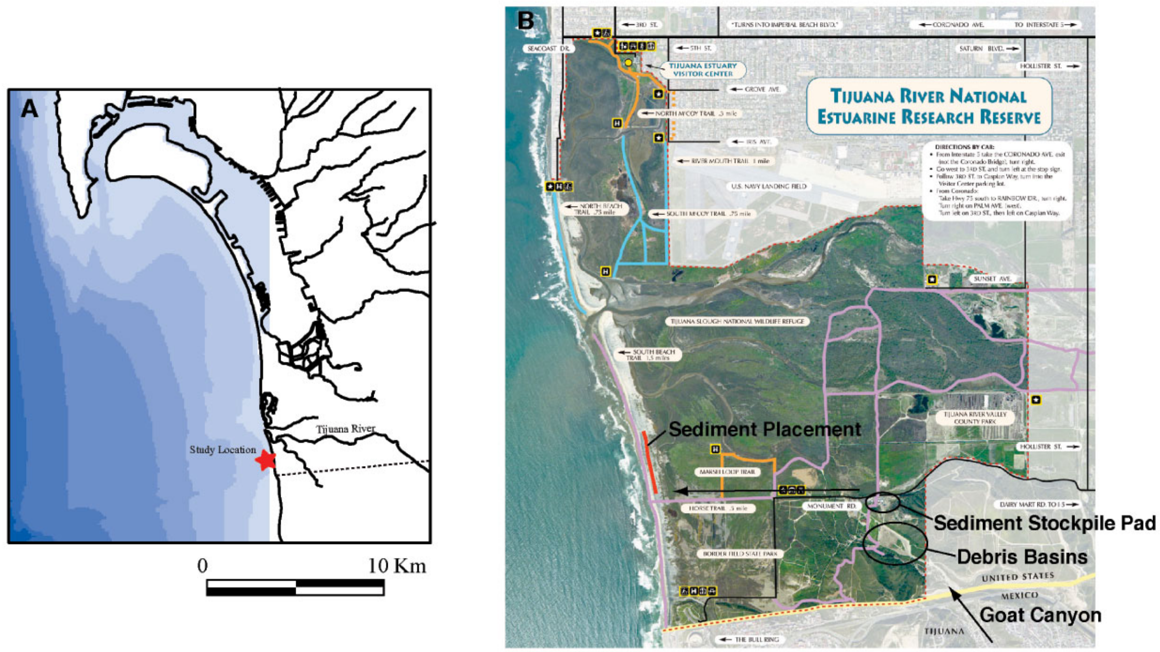

Figure 1: (A) Location of Tijuana River Estuary and proposed demostration project location. (B) Map of the demonstration project area with project locations highlighted (after the Tijuana River National Estuarine Research Reserve trail map).

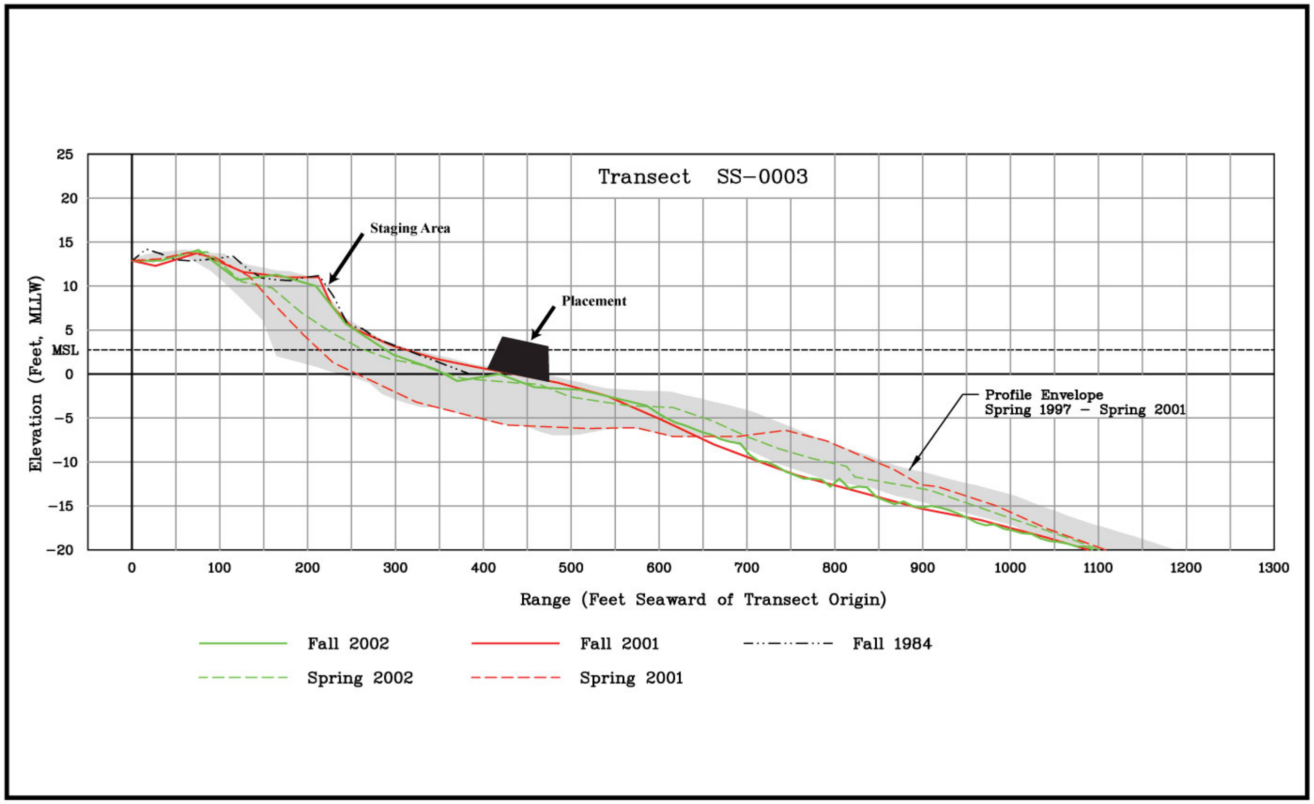

Figure 2: Beach profile along transect SS-0003, farthest south SANDAG beach profile, with locations of staging and placment indicated. (Adapted from profile in the appendices of the SANDAG, 2002 Regional Beach Monitoring Program Annual Report).

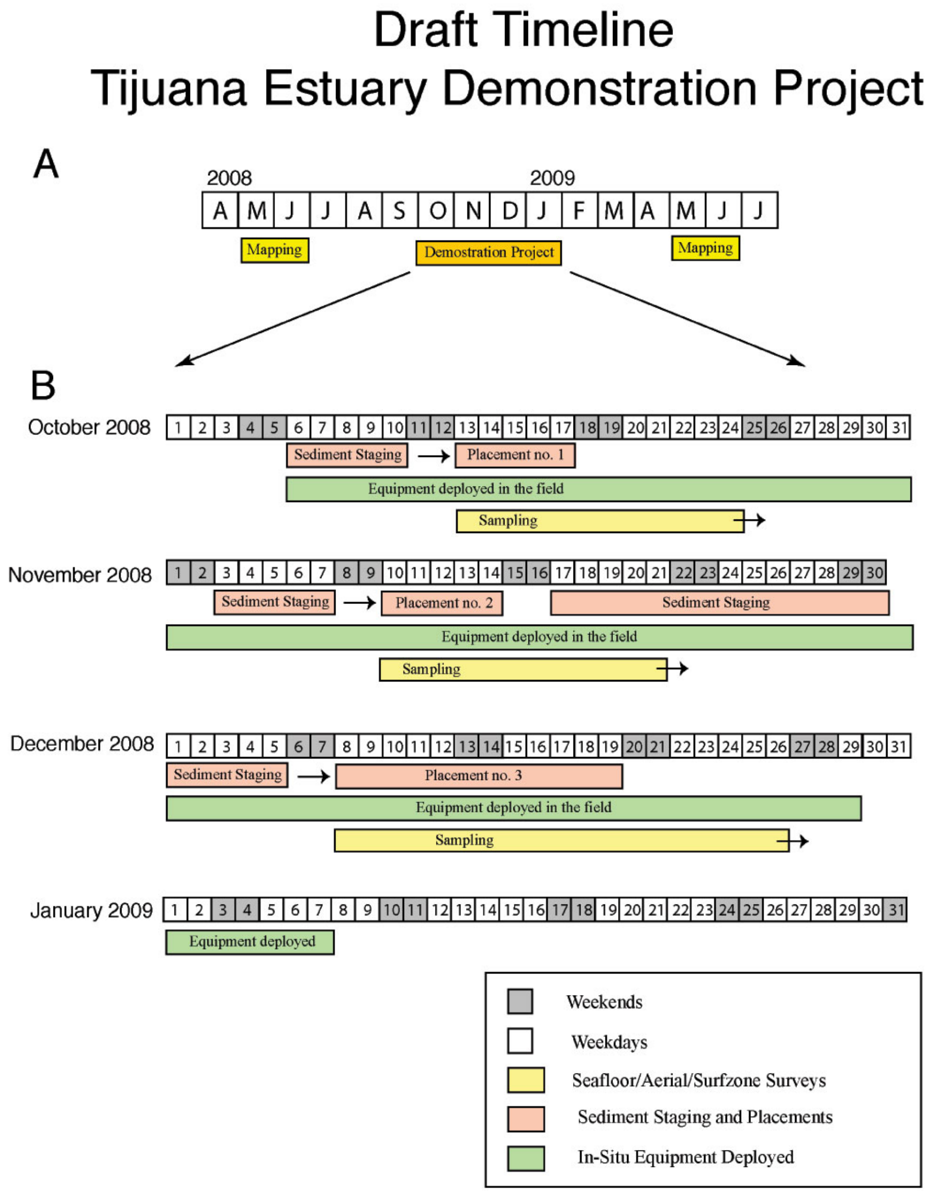

Figure 3: Preliminary timeline of Tijuana River Fate and Transport Project. Dates for placement were determined by times of highest high and lowest low tides. Exact timing of repeat measurements during project have yet to be determined.

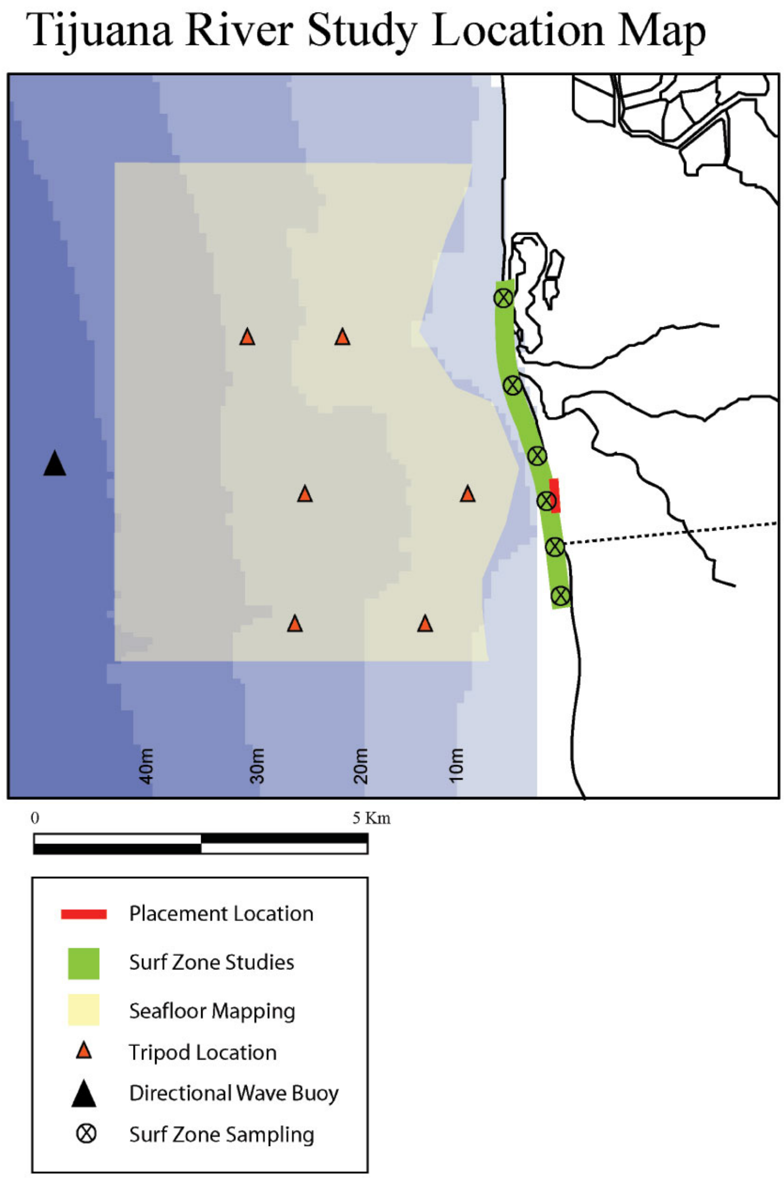

Figure 4: Map showing study area and in-situ equipment locations.