Surf zone entrainment, along-shore transport, and human health implications of pollution from tidal outlets

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[1] Field experiments and modeling studies were carried out to characterize the surf zone entrainment and along-shore transport of pollution from two tidal outlets that drain into Huntington Beach and Newport Beach, popular public beaches in southern California. The surf zone entrainment and near-shore transport of pollutants from these tidal outlets appears to be controlled by prevailing wave conditions and coastal currents, and fine-scale features of the flow field around the outlets. An analysis of data from dye experiments and fecal indicator bacteria monitoring studies reveals that the along-shore flux of surf zone water is at least 50 to 300 times larger than the cross-shore flux of surf zone water. As a result, pollutants entrained in the surf zone hug the shore, where they travel significant distances parallel to the beach before diluting to extinction. Under the assumption that all surf zone pollution at Huntington Beach originates from two tidal outlets, the Santa Ana River and Talbert Marsh outlets, models of mass and momentum transport in the surf zone approximately capture the observed tidal phasing and magnitude of certain fecal indicator bacteria groups (total coliform) but not others (*Escherichia coli* and enterococci), implying the existence of multiple sources of, and/or multiple transport pathways for, fecal pollution at this site. The intersection of human recreation and near-shore pollution pathways implies that, from a human health perspective, special care should be taken to reduce the discharge of harmful pollutants from land-side sources of surface water runoff, such as tidal outlets and storm drains.

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1. Introduction

[2] Oceans adjacent to large urban communities, or "urban oceans," are the final repositories of human waste from a myriad of sources [*Culliton*, 1998]. Historically, pollutant loading to the urban ocean was dominated by point sources of untreated or partially treated sewage [e.g., *Murray et al.*, 2002]. Improvements in sewage treatment and disposal technology, together with better source controls, have progressed to the point that, nowadays, pollutant loading rates to the urban ocean are often dominated by non-point sources of pollution, typically in the form of dry and wet weather surface water runoff [*Schiff et al.*, 2000]. Unlike sewage, which is typically discharged far offshore through long submarine outfalls [*Koh and Brooks*, 1975], runoff flows into the ocean at the surfline where dilution is minimal and the likelihood of human contact is greatest [*Inman and Brush*, 1973]. In southern California, contamination of the surf zone by dry weather runoff apparently increases the risk that marine recreational bathers will contract diarrhea and other acute illnesses [*Haile et al.*, 1999; *Dwight et al.*, 2004]. In turn, illnesses caused by recreating in contaminated ocean waters have annual economic impacts ranging into the millions of dollars locally [*Dwight et al.*, 2005] and into the billions of dollars globally [*Shuval*, 2003]. Dry and wet weather runoff from urban areas contains both human viruses [*Jiang and Chu*, 2004; *Ahn et al.*, 2005; *Jiang et al.*, 2001; C. Surbeck et al., Transport of suspended particles and fecal pollution in storm water runoff from an urban watershed in southern California, submitted to *Environmental Science and Technology*, 2005] and elevated concentrations of fecal indicator bacteria, the organisms tested for in most marine bathing water quality monitoring programs [*Reeves et al.*, 2004]. Consequently, surface water runoff is a leading cause of beach health advisories and beach closures [*Boehm et al.*, 2002a; *Dwight et al.*, 2002; *Kim and Grant*, 2004; *Kim et al.*, 2004].

[3] The focus of this paper is the dry weather contamination of shoreline bathing waters with fecal indicator

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