situ. Such measurements may exhibit specific optical characteristics associated with sewage plumes, which could be used as optical tracers of sewage. To take advantage of this new generation of instruments, the optical characteristics of wastewater must be known.

Only a few studies on the absorption and fluorescence of both raw and treated sewage have appeared in the peer-reviewed literature [*Ahmad et al.*, 1993; *Ahmad and Reynolds*, 1995; *Reynolds and Ahmad*, 1995]. Absorption spectra of raw sewage exhibit a local maximum at 280 nm, which is absent in absorption of secondary-treated wastewater [*Ahmad et al.*, 1993]. Raw sewage fluorescence varies in magnitude from sample to sample but exhibits an approximately constant spectral shape [*Ahmad et al.*, 1993]. *Ahmad et al.* [1993] found that two chromophoric groups are excited at 248 nm in raw sewage (one with an emission maximum around 340 nm, the other around 370 nm). *Ahmad and Reynolds* [1995] attributed such peaks to biodegradable aromatic hydrocarbon constituents, present in both raw and secondary-treated sewage samples. They asserted that since the peak positions were highly reproducible in samples from different locations and times, such a technique could potentially be used for estimating concentrations of biodegradable constituents and suspended solids in wastewaters.

Mamala Bay, the southern bay of Oahu, Hawaii, displays a complex oceanographic environment into which anthropogenic particle fields are introduced. Municipal wastewater is discharged, after primary treatment, through the Sand Island Treatment Plant (SITP) sewage outfall located 4 km offshore at the top of the continental slope, where flushing with offshore waters is expected. Pollution problems occurring throughout the year on the eastern beaches of Mamala Bay prompted a general study of all potential point and nonpoint sources of pollution in the bay [*Colwell et al.*, 1995]. Data for the present study were collected as part of the component of the Mamala Bay project focusing on the SITP sewage plume.

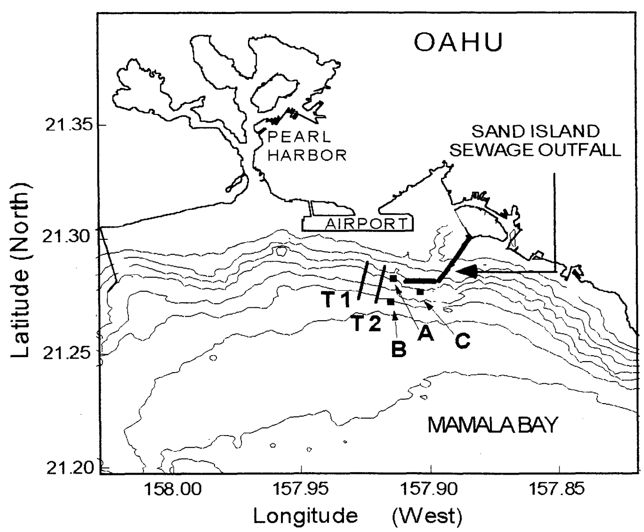

Figure 1. Map of the eastern part of Mamala Bay. Casts 9, 13, and 19 were collected at station A; cast 12 at station B; and cast 15 at station C. Towyo 30 was collected along T1, and towyo 32 along T2. Isobaths correspond to depths of 15, 25, 50, 100, 200, 300, 400, and 500 m.

Table 1. Subset of Data Selected for the Study

Casts/Towyo	Location in Figure 1	Date	Time (UT)
Cast 9	station A	Sept. 29	1700
Cast 12	station B	Sept. 29	1900
Cast 13	station A	Sept. 30	0930
Cast 15	station C	Sept. 30	1330
Towyo 30	T1	Oct. 01	1010-1025
Towyo 32	T2	Oct. 01	1115-1130
Cast 19	station A	Oct. 01	1300

The primary goal of this study was to determine the effects of the SITP sewage plume on the biology, optical characteristics, and particle size distributions using a natural tracer technique, state-of-the-art in situ instruments (ac-9, SAFire, and particle size analyzer), and bottle sample analyses. The secondary goal was to evaluate the potential of new in situ real-time techniques for detecting effluent-affected waters.

2. Methods

The present field study took place aboard the R/V *Kila* from September 25 to October 1, 1994. The sampling region was approximately 6 km along-shore and 3 km cross-shelf centered on the Sand Island outfall diffuser (Figure 1). In situ measurements were obtained from an instrumented towyo platform executing either vertical profiles (referred to as casts) or towyos. Details on the casts and towyos corresponding to the subset of data used in this study are given in Table 1. Data were time-stamped (for postcruise merging of the data) and recorded simultaneously via the modular ocean data acquisition power system (MODAPS, WETLabs, Inc.). Following vertical profiling with the towyo instrument package, discrete water samples were obtained with 5-L Niskin bottles at selected depths based on features apparent in the vertical profiles. Undiluted, treated sewage samples were directly collected at the SITP, in the open basin leading to the underwater outfall, on three occasions (September 29, 0745 UT; September 30, 1640 UT; and October 5, 0930 UT). The various parameters derived from data, measured either in situ or in the laboratory, are described below.

2.1. Physical Data

Conductivity, temperature (°C), and pressure (dbar), were measured with a conductivity-temperature-depth (CTD) instrument (Sea-Bird Electronics model SBE 9/11+), and were used to derive salinity (practical salinity units, psu).

2.2. Inherent Optical Properties

Some inherent optical properties (IOPs) were measured in situ as continuous profiles or at discrete depths from bottle samples.

2.2.1. In situ IOPs. The in situ instruments included a 0.25 m path length transmissometer at 660 nm wavelength (Sea Tech, Inc.), providing the beam attenuation coefficient at 660 nm (c660 in m^{-1}; which includes pure water attenuation), and a nine-wavelength absorption-attenuation meter (ac-9, WETLabs, Inc.), providing absorption and beam attenuation coefficients (a_{meas} and c; pure water subtracted). The ac-9