Cruise Ship Plume Tracking Survey

Survey Date: August 10-13, 2001

1. General

Project title	*Cruise Ship Sampling*
Survey title	Cruise Ship Plume Tracking Survey
Survey vessel	OSV *Peter W. Anderson*
Vessel requested by	Kennard Potts/David Redford
Organization	EPA Oceans and Coastal Protection Division
EPA Work Assignment Manager	Kennard Potts
EPA Chief Scientist	David Redford
Organization	EPA Oceans and Coastal Protection Division
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Work Assignment Leader	Wayne Trulli
Organization	Battelle
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EPA Contract Number	Contract No. 68-C-00-121 Work Assignment 1-23

2. Schedule of operations

Mobilization Date	August 8 and 9, 2001
Location	United States Coast Guard Base 100 MacArthur Causeway Miami, Florida 33139 (cruise ship docks to be determined)
Departure Date	August 10, 2001
Planned Survey Duration (Days)	4
Allowable Weather Days	None
Maximum Duration (Days)	4 (excluding mobilization and demobilization)
Demobilization Date	August 14, 2001
Location	USCG Base, Miami, Florida
Comments	None

3. Background Information

On March 17, 2000, the Administrator of the United Stated Environmental Protection Agency (EPA) received a petition from the Bluewater Network on behalf of 53 organizations suggesting that gaps in regulations pertaining to cruise-ship water pollution result in potential risk to the environment (Bluewater Network, 2000). The petition requests that EPA assess cruise ship discharges and delineate options for regulations or programs to address the industry's waste-management practices. EPA's Office of Water responded to the petition by forming an interoffice working group to gather information and seek public comment on pollution from cruise ships.

A key aspect of EPA's response is a report (in preparation) that will assess the characteristics, amounts, and impacts of water discharges from cruise ships. While developing this report, EPA determined that a field study was necessary to more completely characterize cruise-ship discharges into receiving waters.

4. Survey justification and rationale

This plume tracking survey is designed to provide information on the cruise-ship-discharge (effluent) plume characteristics in offshore waters, and provide preliminary information on whether or not cruise ship blackwater or graywater discharge-plumes behave as predicted by a model developed for Alaska waters (Colonell *et al.*, 2000). During the August 2001 survey, Rhodamine dye concentrations in the effluent plumes are projected to decrease to less than 10 µg/L, based on calculations of secondary dilution caused through mixing by the cruise ship propellers. However, the model (Colonell *et al.*, 2000) derived for cruise ships in Alaska predicts that this secondary dilution will be minimal, and concentrations of Rhodamine dye greater than 10 µg/L may be detected. This survey is designed to provide field data to compare against modeled dilutions.

5. Objectives

The project objectives are to (1) determine the effluent dilution characteristics in the wake of the cruise ship; (2) track the longer-term location and mixing dynamics of the effluent plume; (3) provide preliminary information on whether discharge plumes behave as predicted by the model; and (4) assess the utility and feasibility of monitoring fecal coliforms (tracers of sewage) in the wake of the cruise ship. To accomplish these objectives, a tracer dye, Rhodamine WT, will be added to holding tanks in the cruise-ship effluent-discharge system. A suite of sensors will be towed through the receiving waters offshore Miami, providing high-resolution, *in-situ* measurements of the Rhodamine WT dye concentrations, salinity, temperature, density (calculated), turbidity, dissolved oxygen, and chlorophyll fluorescence in the water.

This Survey Plan is written in support of the August 2001 plume-tracking survey offshore Miami, FL. The objectives of this Survey Plan are to

- describe the dye addition, monitoring, and sampling protocols that will take place aboard the cruise ships;
- describe the monitoring and sampling protocols that will take place during the offshore plume tracking survey; and
- establish communication systems between all involved parties.

6. Environmental management questions asked by project/survey

The project is designed to characterize the dilution and dispersion performance of cruise-ship effluent by describing the plumes created by four cruise ships operating out of Miami, Florida.

7. Survey/Sampling Methodologies

The persistence, dilution characteristics, and transport of each cruise-ship discharge will be characterized by using *in situ* hydrographic measurements and a tracer dye, Rhodamine WT, in the plume created by cruise ship effluent (either blackwater or graywater) and in the receiving waters. Data collected during the plume tracking survey will be used to determine the location of the discharge plume as it exits each targeted ship and mixes with the receiving waters. Measurements of dye concentration, as well as hydrographic measurements, will continue as the plume disperses and until the dye plume is no longer detectable or for an amount of time to be determined by the EPA Chief Scientist. Cruise-ship plume tracking will be conducted using the Battelle Ocean Sampling System (BOSS) deployed from EPA's ocean survey vessel (OSV) *Peter W. Anderson.*

7.1. August 8 Pre-Survey Meeting

A pre-survey kickoff meeting will be held on August 8 (or August 9, if necessary) prior to commencing any activities aboard the cruise ships. The meeting participants will include the EPA Chief Scientist and the Second Scientist, survey technical staff, the captain and designated *Anderson* crew, and representatives of the participating cruise lines (Royal Caribbean and Carnival). The purpose of the meeting is to ensure that all participating organizations understand the study objectives and design, as well as their respective roles and responsibilities and those of the other participants.

1. Finalize communication logistics between the bridge of each cruise ship, the *Anderson* bridge, the plume tracking technical staff aboard the *Anderson*, and the cruise ship engineers managing the holding tanks.
2. Determine final volumes of wastewater and dye stock solution in the wastewater tanks and the discharge rate from each tank discharged for the study.
3. Coordinate the plume tracking schedule and activities.
4. Finalize positioning for the study.
5. Review and discuss the shakedown survey.

In addition to the pre-survey meeting, on the morning of each plume tracking event (August 10-13) the survey party will meet with the cruise-ship participants to review the plan as it applies to the ship participating in the study that day.

7.2. Selecting the Cruise Ships and Wastewater Stream to be Monitored

During this survey, the discharge plumes from four cruise ships operated by two major cruise lines out of Miami will be monitored – Royal Caribbean Cruise Lines' *Majesty* and *Explorer* and

Carnival Cruise Lines' *Fascination* and *Paradise.* Each vessel is configured differently in terms of propeller type and graywater/blackwater treatment and discharge systems, but the ship configuration was not a major consideration when selecting the ships to participate in the study. The wastewater stream (graywater/blackwater) from each individual ship was selected based the three criteria:

- accessibility to and size of the holding tank where the dye (stock) solution will be added;
- ease with which pre-discharge samples can be collected after mixing of the dye and wastewater; and
- volume of wastewater that can be discharged within 20 minutes in order to achieve a (secondary) dilution of <10 µg/L at the stern of the cruise ship. **NOTE: The final volume of dye and wastewater added to each tank and the exact discharge rate from each tank will be determined during the August 8 pre-survey meeting between the cruise ship and the EPA survey teams.**

Majesty (Royal Caribbean Cruise Lines)

The Rhodamine dye will be added to the graywater system of the *Majesty*. The tank to be used in this study is more accessible than other wastewater tanks. Also, the graywater tank that will be used during the study can be pumped down to a volume of approximately 3 m^3 prior to dye addition, and, once the dye is added, refilled to a volume that can be entirely discharged in 20 minutes. In preparation for plume tracking, the following steps will be followed.

1. One of the 277-m^3 capacity graywater tanks will be pumped almost dry.
2. 16 gal of dye stock solution will be added to the tank.
3. A sampling port will be provided on the discharge side of the wastewater-overboard pipe.
4. Graywater will be added to the tank to the appropriate volume in order to achieve a (secondary) dilution of <10 µg/L at the stern of the cruise ship.

Explorer (Royal Caribbean Cruise LIne)

The Rhodamine dye will be added to the blackwater system of the *Explorer*. The treatment tank is small (25 m^3) compared to the other holding tanks aboard the ship and is easily accessible for dye addition. The tank can be pumped dry prior to dye addition, and then refilled to a volume that can be entirely discharged in 20 minutes. In preparation for plume tracking, the following steps will be followed.

1. The 25-m^3 blackwater treatment tank will be pumped dry,
2. 16 gal of dye stock solution will be added to the tank
3. A sampling port will be provided on the discharge side of the wastewater overboard pipe.
4. Blackwater water will be added to the tank to the appropriate volume in order to achieve a (secondary) dilution of <10 µg/L at the stern of the cruise ship.

Paradise and *Fascination* (Carnival Cruise Lines)

The Rhodamine-dye stock solution will be added to the laundry graywater systems of the *Paradise* and *Fascination* because the holding tanks are more accessible than other wastewater tanks aboard the ships. The tanks are approximately 26-m^3 capacity. In preparation for plume tracking, the following steps will be followed.

1. The 26-m^3 laundry graywater treatment tank will be pumped dry. Because the inflow cannot be isolated, the tanks will be emptied to the extent possible.
2. At least 16 gal of dye stock solution will be added to the tank. Because the tanks are smaller capacity and the inflow cannot be isolated as for the tanks aboard the Royal Caribbean ships, more than 16 gal of dye stock solution may be required.
3. A sampling port will be provided on the discharge side of the wastewater overboard pipe.
4. Graywater will be added to the tank to the appropriate volume in order to achieve a (secondary) dilution of <10 µg/L at the stern of the cruise ship. The crews on each Carnival ship will mix the dye and laundry-water solution by using a bellows pump (provided by the cruise ship engineers) to recirculate the solution for several hours before arriving on station.

7.3. Activities Aboard the Cruise Ships

Dye Addition

The targeted wastewater tanks aboard the selected cruise ships will be emptied as much as possible prior to addition of the dye. On the morning of each plume tracking study, and once the wastewater tank is empty, a measured amount (approximately 16 gal) of Rhodamine WT dye stock solution[1] will be added to the wastewater tank by a Battelle technician. Subsequently the cruise ship engineers will begin filling the tank to a volume that can be discharged entirely over a 20-min period. Mixing of the dye into the wastewater will occur during the addition of the wastewater into the holding tank.

Assuming that the plume undergoes initial dilution followed by secondary dilution by the propellers, the required volume of stock dye solution that must be added to the wastewater tank can be calculated by the following equation.

$$\text{Desired Dye Conc (µg/L) at the stern} = \text{TVD(kg)} * 0.2/(L_t \times W_s \times D_s) * 10^9$$

where TVD = Total volume of dye discharged into the receiving water
L_t = Total length traveled in meters over a 20-min period at an average speed of 17 kn
W_s = Width of the stern of the vessel in meters
D_s = Depth of the propellers in meters
0.2 represents 20% wt/vol dye concentration in the stock solution

[1] Concentration of 8.3 lb dye per gal, or approximately 20% wt/vol. Purchased from Keystone Aniline Corporation.

The target dye concentration is between 0 and 10 µg/L at the stern of the cruise ship. At a speed of 17 kn the average distance a ship can travel in 20 min is 9599 m. The average depth of a cruise ship is approximately 8 m from the waterline to the bottom of the propellers, and the average beam width at the water line is 32 m. The Rhodamine WT dye solution is 20% w/v as active ingredient. For planning purposes, each plume tracking event has been estimated to need a volume of 16 L dye stock solution. The exact volume will be determined at the August 8 pre-survey meeting. No additional dye or wastewater will be added to the wastewater holding tank once the tank is filled to the appropriate volume.

After departing the Port of Miami, the cruise ships will be in continuous contact by radio with the *Anderson.* The EPA vessel will be conducting background-sampling activities at the appointed discharge (rendezvous) location, approximately 25°53.8′ N latitude and 079°52.8′W longitude. The cruise ship will approach the *Anderson* on a course of 054° at speeds ranging from 16-to-18 kn. When the cruise ship is approximately 0.5 miles from the rendezvous with the *Anderson*, the EPA Chief Scientist (aboard the *Anderson*) will notify the cruise ship bridge to begin discharging the dye-dosed wastewater. At this point, the cruise ship engineering staff will begin discharging the tank and a crewman on the stern of the cruise ship simultaneously will deploy overboard the first of five (5) weighted and drogued buoys to mark the beginning of the plume. To mark the cruise-ship-plume track, the crewman at the stern will continue to deploy one drogued buoy at two-minute intervals for 10 min., until all five buoys have been deployed. Because the cruise ship will travel nearly 10 km during the 20-min discharge period, a buoy marking completion of the discharge will not be deployed. The buoys will be retrieved once the tracking of a plume is completed.

Discrete Sampling from the Wastewater Discharge Lines

Immediately after the cruise ship begins discharging, one of the cruise-ship engineering staff will collect samples of the dye-laden wastewater at a designated sampling port located at the furthest possible point downstream in the discharge system. Samples will be collected at 5-min intervals beginning at Time=0 (T=0) and thereafter until the 20-min discharge has been completed (total of 5 samples: T=0 through T=4) (Table 1). After the survey, these samples will be analyzed for dye concentration to determine if the dye was homogeneously mixed throughout the entire discharge period. Samples collected by the cruise ship engineers will be sent to the following address:

Lynda Short
Battelle Duxbury Operations
397 Washington Street
Duxbury, MA 02332
(781) 952-5295

The following supplies will be provided to the cruise ships for use during the survey.

Drogued buoys with radar reflectors and lights
Rhodamine dye
Coolers (ice not provided but must be added when storing samples)
Prelabeled sample jars

Sample custody forms
Tank and discharge information forms
Shipping labels

Table 1. Discrete samples to be collected from the wastewater stream of each cruise ship.

Parameter	Number of samples	Sample Volume (Target) (mL)[a]	Sample Containers	On-site Processing/ Preservation[c]	Maximum Holding Time to Analysis
Rhodamine WT	1 sample per 5-min interval (5 total)	200	16oz HDPE wide mouth jars	Store at 4°C	28 days

Safe Handling of Wastewater Samples

The collection and handling of wastewater samples will be discussed in detail by the survey microbiologist at the pre-survey meeting. Sample storage conditions are shown in Table 1.

7.4. Offshore Field Sampling Procedures

Plume tracking will be conducted using the Battelle Ocean Sampling System (BOSS) deployed from the OSV *Peter W. Anderson*. The BOSS *in situ* sensor package includes the following instruments: two Rhodamine Seapoint fluorometers (one set to a range of 0-5µg/L and the other set to a range of 0-50µg/L), a chlorophyll fluorometer (WET Labs WETStar), an Ocean Sensors CTD [which measures temperature, conductivity (for salinity), sigma-t, and pressure (for depth)], and a Sea Tech transmissometer (light transmission) (Table 2). A winch and vessel speed will be used to control the depth of the towed sensor package. The BOSS sensor package can be raised or lowered using the winch at a rate of 0- to 1.0-m/sec.

Table 2. Instruments deployed for the offshore plume sampling.

Parameter	Lab	Units	Instrument	Reference[a]
Rhodamine fluorescence	Battelle	µg/L	Seapoint RWT Fluorometer	Seapoint manual (2000)
Conductivity	Battelle	Mmhos/cm	OS200 CTD	Ocean Sensors CTD manual (1999)
Temperature	Battelle	C	OS200 CTD	Ocean Sensors CTD manual (1999)
Pressure	Battelle	m	OS200 CTD	Ocean Sensors CTD manual (1999)
Transmissometry	Battelle	m-1	Seatech 20-cm (660nm)	Seatech manual (1998)
Bottom depth	*Anderson*	m	Unknown	Unknown
Navigational position	*Anderson*	degrees	Unknown	Unknown
Ocean current velocity	Battelle	cm/sec	RD Instruments ADCP WHM600-I-UG6	RD Instrument manual (2000)
Sigma-T	Battelle	No units	OS200 CTD	Fofonoff and Millard (1983)
Chlorophyll	Battelle	Mg/L	WETLabs WETStar fluorometer	WETStar manual
Salinity	Battelle	PSU	OS200 CTD	Fofonoff and Millard (1983)

[a]SOPs are listed in the QAPP (Battelle, 2001).

The BOSS will be towed off the port side of the *Anderson* using the crane and boom deployed perpendicular to the ship's axis. The deployment position ensures that the BOSS will operate out of the ship's wake.

Depending on the sampling platform's speed and winch operation, the BOSS can operate in three different modes: vertical profile, constant-depth towing, or towyo. In vertical profiling mode, data is acquired as a function of depth while the sampling platform remains stationary. During constant-depth towing mode, the BOSS is towed at a constant depth while the platform is underway. During towyo mode, the BOSS is operated in a vertically undulating (ascent and descent) pattern to obtain data continuously at different depths while the platform is underway. The plume tracking survey may utilize BOSS in all three modes.

Discrete Sample Collection. During operations, discrete water samples will be collected for fecal coliform analysis and dye fluorescence using a water pumping system integrated with the BOSS towfish/cable assembly. This assembly consists of an instrument package and pump, which is towed and powered by an electrical-mechanical cable (200 ft long) with a Teflon tube down the middle of the cable to provide synoptic sampling capabilities. The maximum operational depths versus vessel speed are listed in Table 3.

Table 3. BOSS modes and vessel speeds.

Vessel speed (& mode)	Maximum depth (m) when pumping
0 knots (vertical profile)	45
2 knots (towyo)	40
4 knots (towyo)	25

Current Velocities and Density Profiles. In support of the plume tracking studies, current velocities and density profiles within the study area will be measured. The density profiles will be collected using the BOSS CTD. A downward-looking RD Instruments acoustic doppler current profiler (ADCP) will be deployed to collect real-time current measurements at 0.5-m or 1.0-m vertical increments through the water column, and in the surface 10 m in particular. The ADCP measurements will document the ambient currents (particularly tidal and wind-driven) that will affect the dilution and trajectory of the plume. Also, the ADCP will provide relative backscatter amplitude through the whole water column at the same resolution, which will be used to assess the effectiveness of backscatter as a plume-monitoring tool.

Shipboard Fecal Coliform Analysis. Discrete samples will be analyzed for fecal coliforms, a bacterial indicator or sewage. Water samples will be analyzed for fecal coliforms using the membrane filtration technique according to Standard Method 9222D: *Fecal Coliform Membrane Filtration Procedure* (APHA, 1995)[2]. A dilution water blank (100 mL) will be processed with each

[2] APHA. 1995. Standard methods for the evaluation of water and wastewater. 19th ed. American Public Health Association. Washington DC. Standard Method 9222D. Fecal Coliform Membrane Filter Method (APHA 1995).

series of samples. The sample duplicates will be processed with the original sample. General microbiological sterile techniques are defined in SOP 5-302-01.

Three sample aliquots (100 mL, 10 mL, and 1 mL) will be removed from each field sample using "S" class graduated, pre-sterilized, plastic pipettes and filtered for plating. Samples will be filtered through sterile, 47-mm gridded cellulose nitrate membrane filters with a pore size of 0.45 or 0.70 µm. and placed on commercially prepared mFC agar plates and incubated within 6 hours of sample collection. Incubation conditions are:

Time:	24 ± 2 hours
Temperature:	44.5 ± 0.2°C
Agar:	mFC

After the 24 ± 2 hour incubation period, all blue colonies are counted and recorded as fecal coliform colonies. Colonies should be counted using the filter grid.

7.5. Shakedown, Background, and Plume Tracking Surveys

This plume tracking exercise will include three distinct survey types 1) a shakedown survey, 2) four background characterization surveys, and 3) four nearfield/transect surveys. Over the course of the offshore surveys, both *in situ* and discrete samples will be collected. A brief description of each survey is given below.

Shakedown Survey

Objective: To carefully discharge dye from the OSV Anderson and practice tracking the plume according to survey design.

On the second day of mobilization (August 9) or the morning of the first day of the cruise ship survey (August 10), the scientific team aboard the *Anderson* will conduct a shakedown survey. The *Anderson* will transit to a location offshore to conduct the 1-day shakedown survey. When on station, dye will be slowly released into the wake of the *Anderson* by siphoning the dye from a carboy (by using 30-ft of tubing) while the ship is underway at cruising speed (10-12 kn). (Drogued buoys may or may not be deployed for this exercise). After a sufficiently long trail of dye has been released over a 10-min period, the BOSS towfish will be deployed and towed through the plume. Transects perpendicular to and along the centerline of the plume will be conducted in the shakedown plume to determine the feasibility of accomplishing the study design and the quickest manner in which to achieve the necessary vessel maneuvers. The survey design outlined in this survey plan may be modified based on the results of the shakedown survey. All modifications will be documented by the EPA Chief Scientist or his designate.

Throughout the shakedown survey the ADCP will be deployed to collect current shear and backscatter data.

Background Surveys

Objective: To obtain measurements of background fluorescence in the environment prior to dye release from the cruise ships and to obtain discrete background water samples from locations in ambient water around the area where the discharge will occur.

Decontamination: Prior to conducting background sampling activities on each survey day, the BOSS water sampling system will be decontaminated to rid the system of potentially contaminating bacteria from previous plume-tracking studies. This will be accomplished by pumping 2 L of 95% alcohol through the entire system followed by a rinse with 15 L of deionized (DI) water.

Background Plume Tracking: Measurements of background hydrographic data and fluorescence, using the BOSS system in constant-depth towing mode, will be conducted along a track line regularly used by cruise ship departing the Port of Miami, and where these ships normally begin discharging wastewater. This track line will begin at the predetermined location for rendezvous with the cruise ship - 25°53.8′ N latitude and 079°52.8′W longitude - and will follow the projected cruise-ship trackline at 054ºT.

During this background survey, a subset of discrete water samples for dye fluorescence and fecal coliform bacteria will be collected using the BOSS water pumping system. The survey vessel will transit along the projected cruise ship track line described above, and the samples will be collected at five locations along this track line at a depth of approximately 4 m below the surface. The 4-m sampling depth for these background samples was selected because it is at the midpoint of the expected mixing zone (0 to 8 m). The exact location of the discrete sampling points will be determined during the survey in relation to real-time measurements of beam attenuation, temperature, and salinity. These background measurements will be used to correct values of parameters used as wastewater tracers.

A set of two discrete samples, one fecal coliform sample and one dye-fluorescence sample, will be collected at the discretion of the EPA Chief Scientist and based on field observations of *in situ* data. Each location will be logged as an event in the BOSS system. Table 4 lists number and type of samples to be collected offshore.

Throughout the background survey the ADCP will be deployed to collect current shear and backscatter data.

Table 4. Discrete water samples to be collected during each of the four background and the four discharge surveys.

Parameter	Background Survey Samples/Day	Discharge Survey Samples/Day	Total # Samples /Survey	Sample Volume (Target) (mL)[a]	Sample Containers	On-site Processing/ Preservation[c]	Holding Time
Rhodamine WT	5 samples	6 samples	44	200	16oz HDPE wide mouth jars	Store at 4°C	28 days
Fecal coliform	5 samples	6 samples	44	200	250 mL sterile polyethylene	Store at 1-4°C.	6 hours

Nearfield/Transect Surveys

Objective: To determine plume structure and behavior in the nearfield following cruise ship discharge by examining the influence of the propellers and the ship's wake on the plume's vertical and horizontal distribution.

After background sampling has been completed and the cruise ship approaches the rendezvous location, the OSV *Anderson* will contact the cruise ship and inform them to begin discharging. The *Anderson* with the towfish deployed near the surface (1 m deep), will make a perpendicular transect through the wake of the cruise ship to determine breadth of the plume at the surface at time T=0. When the greatest concentration of dye is detected during this first transect, the first set of discrete fecal coliform and dye-fluorescence samples will be collected. After completing the first transect, the *Anderson* will deploy the BOSS towfish to a depth of 5 m and make a second transect 10 to 100 m up-plume (toward the cruise ship and the next buoy) from the first transect, so that the *Anderson* is out of the mixing area created by its own wake. During this second transect, the second set of fecal coliform and dye-fluorescence samples will be collected in the highest concentration of dye. After completing the second transect, the *Anderson* will deploy the BOSS towfish to a depth of 8 m and conduct a third transect 10 to 100 m up-plume from the previous transect. During this transect, a third set of fecal coliform and dye-fluorescence samples will be collected in the highest concentration of dye. Each transect will end and the *Anderson* will make a 180-debree turn as soon as no dye is detected by the BOSS sensors. Figures 1 and 2 show a schematic diagram of the buoy deployment and the trackline between the buoys.

Immediately after completing the perpendicular transects through the plume, the *Anderson* will conduct a towyo transect up the center of the plume to better define the vertical extent of the plume (i.e., define the bottom of the plume). The drogued buoys deployed by the cruise ship will be used to mark the axis of the transect. Beginning at the surface in the most concentrated area of the plume, the tow fish will be lowered until a set of data extending from the ocean surface to the deepest detectable boundary of the plume are obtained. At three depths (at the surface, a mid-depth, and at the bottom of the plume), a single set of samples for fecal coliform and dye fluorescence analysis will be collected (total of three per plume centerline transect).

Figure 1. Schematic diagram of the plume-tracking trackline showing five buoys deployed.

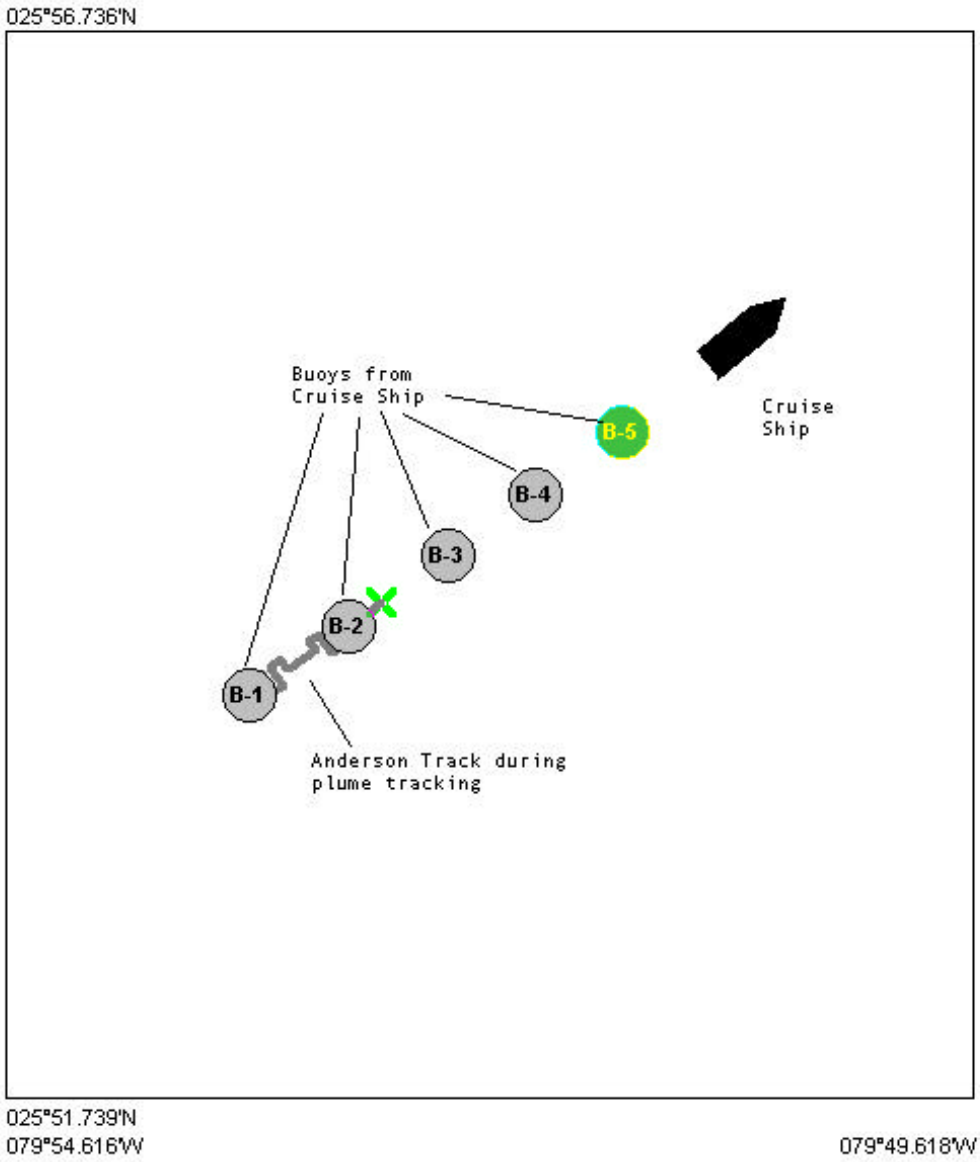
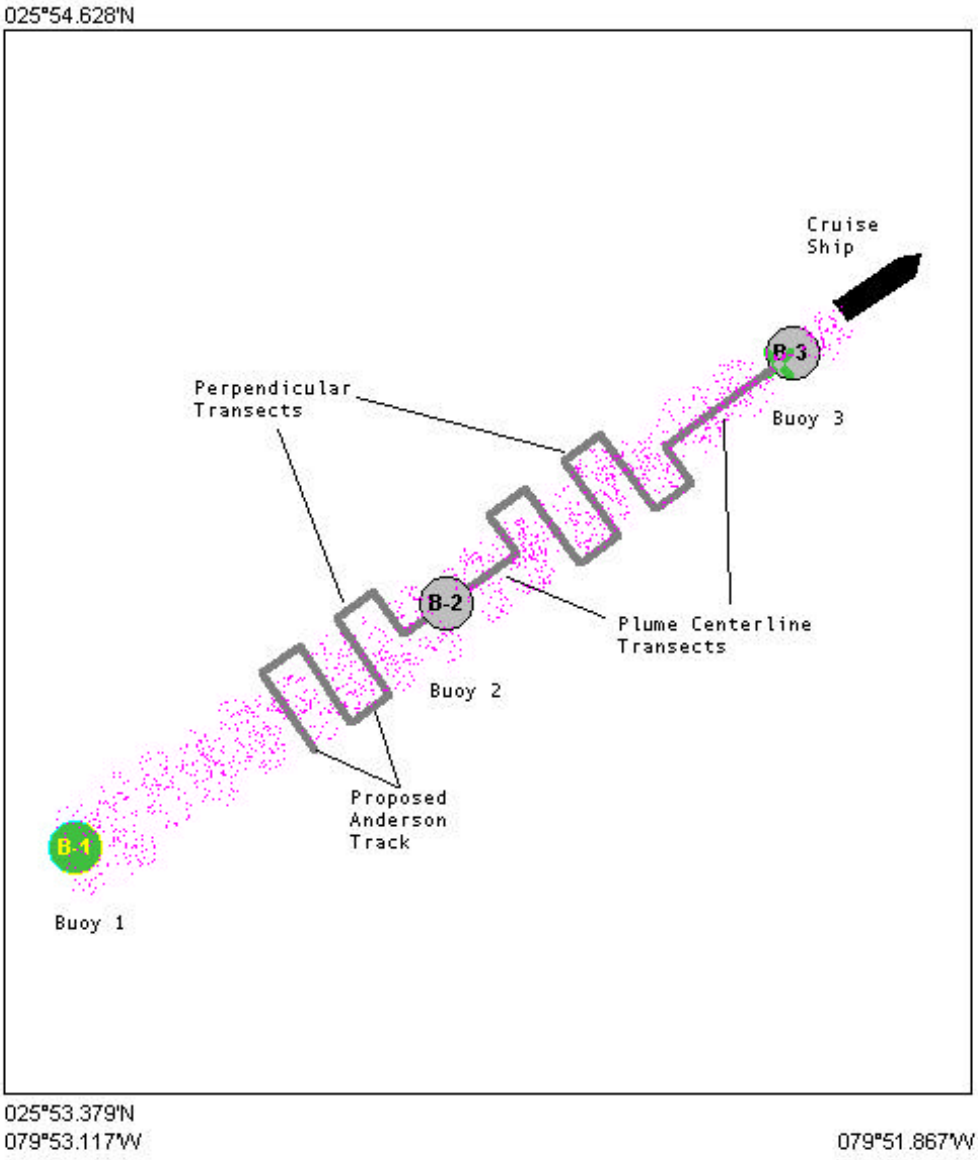


Figure 2. Schematic diagram showing detail of trackline between buoys.



These transect sets (three perpendicular and one along the centerline) will be repeated until the plume is no longer detectable, or for an amount of time to be determined by the EPA Chief Scientist. Additional fecal coliform and dye-fluorescence samples may be taken at the discretion of the EPA Chief Scientist.

Depending on time and longevity of the dye plume, the EPA Chief Scientist may decide to conduct vertical profiles (using the BOSS towfish in the vertical mode) at specified locations along the plume centerline. These profiles will be used to further define the vertical extent of the plume. The Chief Scientist and Second Scientist will make the decision on methods and sampling depths as the *in situ* data is observed.

Throughout the nearfield/transect survey the ADCP will be deployed to collect current shear and backscatter data.

The discrete samples to be analyzed for fecal coliform (bacterial indicators) and dye fluorescence (for verifying BOSS sensor measurements) will be collected using the submersible pumping subsystem of the BOSS. The internal gear pump is located on the towed body. The pump provides a flow rate of approximately 14 Lpm (will be verified on each survey day), which translates into a 28-second transit time for the water to go from the pump inlet to the outlet onboard the sampling platform. This lag time will be verified using an onboard flow-through transmissometer. The NAVSAM© software will be used to record the hydrographic data at the selected location of the discrete samples. The NAVSAM© software will also printout corresponding labels for the collection bottles and sample log form once the exact location is selected. The software will calculate the hose-transit lag time that is required before collection of the actual water sample on deck. With 10-20 seconds left on the countdown, the sampling technician will be instructed to rinse the suite of bottles to be used for that sampling event. When the countdown is finished the sampling technician will be instructed to collect water. Table 4 lists number and type of samples to be collected. Fecal coliform and dye fluorescence samples will be collected at the depth of maximum dye concentration.

Diving on Survey

Not applicable.

8. Sequence of Survey Task/Events

Date/Time (24-h clock)		Team	Task
August 7/1700		Battelle	Survey team arrivals in Miami, FL
August 8/0800		Battelle	Begin mobilization efforts; mount BOSS winch, set up microbiology lab, meet with Nancy Wheatly, Willem Peetom, and Jim Walsh of the cruise lines to discuss access to the cruise ships and survey logistics.
August 9/0800		Battelle	Continue mobilization. Conduct a test dye-tracking survey before monitoring the cruise ships.
August 10/0800	Event 1 – *Majesty*	Battelle	Brandy and Tim board the *Majesty* to add 16 gal dye to graywater tank. Cruise ship crew adds enough gray water to allow discharge within 20 min.
August 10/1400		Battelle	OSV *Anderson* departs dock to conduct background survey
August 10/1700		Royal Caribbean	*Majesty* departs dock.
August 10/1800		Royal Caribbean	*Majesty* arrives rendezvous location, begins discharge, and collects samples.
August 10/1800		Battelle	OSV *Anderson* begins plume-tracking operations.
August 10/2000		Battelle	OSV *Anderson* ends plume-tracking operations.
August 10/2130		Battelle	OSV *Anderson* arrives at dock.
August 11/0800	Event 2 - *Explorer*	Battelle	Brandy and Tim board the *Explorer* to add 16 gal dye to graywater tank. Cruise ship crew adds enough graywater to allow discharge within 20 min.
August 11/1400		Battelle	OSV *Anderson* departs dock to conduct background
August 11/1700		Royal Caribbean	*Explorer* departs dock.
August 11/1800		Royal Caribbean	*Explorer* arrives rendezvous location, begins discharge, and collects samples.
August 11/1800		Battelle	OSV *Anderson* begins plume-tracking operations.
August 11/2000		Battelle	OSV *Anderson* ends plume-tracking operations.
August 11/2130		Battelle	OSV *Anderson* arrives at dock.
August 12/0800	Event 3 - *Paradise*	Battelle	Brandy and Tim board the *Paradise* to add 16 gal dye to laundry-water tank. Cruise ship crew adds enough laundry water to allow discharge within 20 min.
August 12/1400		Battelle	OSV *Anderson* departs dock to conduct background
August 12/1700		Carnival	*Paradise* departs dock.
August 12/1800		Carnival	*Paradise* arrives rendezvous location, begins discharge, and collects samples.
August 12/1800		Battelle	OSV *Anderson* begins plume-tracking operations.
August 12/2000		Battelle	OSV *Anderson* ends plume-tracking operations.
August 12/2130		Battelle	OSV *Anderson* arrives at dock.
August 13/0800	Event 4 - *Fascination*	Battelle	Brandy and Tim board the *Fascination* to add 16 gal. dye to laundry-water tank. Cruise ship crew adds enough laundry water to allow discharge within 20 min.
August 13/1400		Battelle	OSV *Anderson* departs dock to conduct background
August 13/1700		Carnival	*Fascination* departs dock.
August 13/1800		Carnival	*Fascination* arrives rendezvous location, begins discharge, and collects samples.
August 13/1800		Battelle	OSV *Anderson* begins plume-tracking operations.
August 13/2000		Battelle	OSV *Anderson* ends plume-tracking operations.
August 13/2130		Battelle	OSV *Anderson* arrives at dock.
August 14/0800		Battelle	Demobilization and team departs.

If weather delays are experienced, the survey schedule will be altered based on a joint decision between the Captain of the OSV *Anderson*, the Battelle Chief Scientist, and the EPA Chief Scientist. The captain of the vessel has final authority over all vessel operations.

9. Communication Plan

The logistics of this plume-tracking program are complex. Efficient and explicit communications will be essential to the success of the surveys. The critical communication channels will be between the cruise-ship bridge, the dye addition team, the OSV *Anderson* bridge, and the plume-tracking team aboard the OSV *Anderson.* Ultimately, the EPA Chief Scientist is responsible for maintaining the communication bridges throughout the study. The logistics of these communications, including the designation of those persons responsible aboard each vessel, will be finalized during the August 8 pre-survey meeting. In addition to the "on survey" communications, important notifications and communications will take place in the days and hours leading up to the survey.

The EPA Chief Scientist and the Second Scientist will assess weather conditions and determine survey feasibility well in advance. The EPA Chief Scientist will directly inform the dye addition team and the cruise ship and OSV *Anderson* bridges about the decision to initiate dye addition. Each tracking event is expected to last up to 2 hours if the plumes disperse as expected. A collaborative decision among the EPA Chief Scientist and the Battelle Second Scientist to continue tracking a non-dispersive plume will be made on site

10. Navigation and Positioning Control

Navigation of the *Anderson* will be accomplished through the OSV *Anderson* differential GPS. The dGPS will be interfaced with the BOSS during sampling. The BOSS dGPS will be available as a backup.

11. Vessel, Equipment, and Supplies

The 167–ft OSV *Anderson* will be used as the sampling platform during these survey operations.

Equipment from vessel

Crane with forward guy wire to support BOSS towing operations, electrical (110V and 220V) and hydraulic power and hose connection to mate with the BOSS winch, microbiology lab space, incubator, navigation output to Battelle computer, welder to mount deck plates for winch and ADCP mounts, steel cable for boom support during towing

Equipment from Battelle

BOSS *in situ* sensor package, barcode printer, navigation equipment (as a back-up), computer equipment, NAVSAM™ data acquisition software, filtration systems, water bath, ADCP, BOSS winch and hydraulic hoses

Expendable supplies from vessel

None

Expendable supplies from Battelle

Rhodamine WT dye, sample bottles, sterile fecal coliform sample containers, dye fluorescence sample (provided to cruise ships as well as for use on the *Anderson*), media, test tubes, alcohol for sterilization, foil pouches, filters, computer discs, printer paper, and barcoded sample labels, drogued buoys, discharge tank information logs, sample custody forms, coolers, shipping labels

12. QA/QC Procedures

Refer to Combined work/quality assurance project plan (W/QAPjP) for plume tracking (Battelle, 2001).

13. Survey Crew

	Name	Survey Responsibility	Survey Day	Organization
1	Dave Redford	Chief Scientist	Sept. 7 – 14	EPA
2	Kennard Potts	Work Assignment Manager	Sept. 7 – 14	EPA
3	Wayne Trulli	Second Scientist	Sept. 7 – 14	Battelle
4	Bob Mandeville	BOSS Operator	Sept. 7 – 14	Battelle
5	Stacy Abramson	Microbiologist	Sept. 7 – 14	Battelle
6	Tim Kaufman	Winch Operator	Sept. 7 – 14	Battelle
7	Brandy Curtis	Sampling Tech	Sept. 7 – 14	Battelle
8	Kenwyn George	Observer	Sept. 7 – 14	Alaska DEC

14. Reporting requirements

Debriefing Telephone Call NA

Survey report due date Four weeks after completion of survey (Approximately September 7, 2001)

15. References

Battelle. 2001. Work/Quality Assurance Project Plan for Cruise Ship Sampling. Prepared for U.S. Environmental Protection Agency Oceans and Coastal Protection Division, Washington, DC. Contract NO. 68-C-00-121, Work Assignment 1-23.

Bluewater Network. 2000. Letter to Carol Browner, EPA Administrator. March 17, 2000.

Colonell, JM, SV Smith, and RB Spies. 2000. Cruise Ship Wastewater Discharge into Alaskan Coastal Waters. Alaska SeaLife Center Technical Report Number 2000-01. 48pp.