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Sampling Episode Report Princess Cruise Lines Island Princess Sampling Episode 6505

Chapter 2 Wastewater System and Sampling Points

March 2006

2.0 WASTEWATER SYSTEM AND SAMPLING POINTS

This section describes graywater and sewage generation, collection, and treatment on the Island, as well as the sample collection points and flow meter locations and installation points used in this sampling episode.

2.1 Wastewater Generation and Collection

The ship's collection, holding, and transfer system (CHT) collects and transfers graywater and sewage generated onboard to the ship's Hamworthy treatment system or to overboard discharge. For the purpose of this report, graywater refers to non-sewage wastewaters that are collected by the CHT system. The CHT system is composed of five subsystems, referred to by the ship's crew as the galley, food pulper, accommodations, laundry, and sewage systems. Figure 2-1 is a simplified diagram of the Island's graywater and sewage CHT system. Wastewater sources collected by each of the five subsystems are described in Table 2-1. The Hamworthy treatment system treats only accommodations wastewater and sewage. The other wastewaters are stored in double-bottom holding tanks untreated and discharged overboard outside of 12 nautical miles (nm).

Potable water is used as source water for all ship operations that generate graywater and sewage (e.g., laundry, galley, food pulper, sinks, showers, and toilets). Potable water is produced onboard and bunkered while in port, with produced water providing approximately two-thirds of freshwater requirements and bunkered water providing approximately one-third of fresh water requirements.

2.2 Wastewater Treatment

The Island is outfitted with a Hamworthy treatment system, an advanced treatment system that uses aerobic biological treatment followed by ultrafiltration and ultraviolet (UV) disinfection. Figure 2-2 provides a simplified diagram of the Hamworthy treatment system. This system treats only accommodations wastewater and sewage onboard the Island.

Wastewater from the accommodations CHT system culminates in two holding tanks, which are pumped to two wastewater buffer tanks, the first component of the Hamworthy treatment system. Air is added via blowers to aerate the buffer tanks. The sewage CHT system culminates in four sewage collection tanks. Accommodations wastewater from the buffer tanks and sewage from the storage collection tanks mixes in a common line and then splits for treatment through two parallel treatment trains. The first unit of the treatment trains are self-cleaning screen presses (mesh size 400 μm) to remove paper and other coarse solids. Next, the wastewater is pumped to the first stage aerated bioreactors, then to interstage bag filters (mesh size 200 μm) and filtrate tanks, and finally to the second stage aerated bioreactors. Mixed liquor (wastewater containing organic matter and biological floc) overflows from the second stage bioreactors back to the first stage bioreactors. Bioreactor aeration is provided by fine bubble diffusers at the bottoms of the bioreactors.

From the second stage bioreactors, the wastewater is pumped through the membrane filters (ultrafiltration, pore size 40 nm) and collects into permeate tanks. The membrane filters use cross flow design (wastewater flows parallel to membrane surface) to minimize fouling. Membrane concentrate, consisting of particulate matter and mixed liquor, is returned to the second stage bioreactors. Approximately once every two weeks, the treatment trains are taken offline for approximately 1.5 hours to disinfect the membrane filters using sodium hypochlorite; the sodium hypochlorite solution remains in the system. (When one treatment train is being disinfected, all wastewater is diverted to the second, parallel treatment train.) In the final stage of treatment, the combined wastewater from the two permeate tanks undergoes UV disinfection. The hydraulic residence time of the treatment system (i.e., the amount of time the wastewater stays in the treatment system) is less than one day.

According to the ship's crew, the Hamworthy system can treat 600 m^3 (159,000 gallons) per day of sewage and accommodations wastewater generated onboard, well in excess of its typical daily load, approximately 450 m^3 (119,000 gallons) as determined by interviews with the ship's crew and measured flows collected during the sampling episode.

The Hamworthy treatment system operates continuously, regardless of the ship's location (e.g., in port, at sea within Alaska waters, at sea outside Alaska waters). The vessel typically continuously discharges treated wastewater from this system overboard. Where overboard discharge is prohibited, such as in Glacier Bay National Park, treated wastewater is diverted to storage in double-bottom holding tanks and held for eventual discharge overboard outside 12 nautical miles (nm) from shore.

Treated wastewater is recycled back to the treatment system when effluent total suspended solids concentrations exceed 27 mg/L (determined based on a correlation to measured effluent turbidity) to ensure that inadequately treated wastewater is not discharged.

The Hamworthy system generates three types of residual waste: screening solids (from the screen presses), spent bag filters (from the interstage bag filters), and waste biosludge (excess biological mass from the second stage bioreactors). The screening solids (50 kilograms/day) drop from the dry waste outlets of the screen presses and collect into plastic bags. The bag filters are replaced every 200 hours of operation. The plastic bags containing both screening solids and spent bag filters are manually fed to the onboard incinerator via a small chute. Incinerator ash is disposed of on shore as a non-hazardous waste.

Approximately 10 metric tons of waste biosludge are removed from the second stage bioreactors each week to maintain bioreactor total suspended solids (mixed liquor suspended solids (MLSS)) concentrations at approximately 20,000 mg/L. The biosludge is not dewatered and is immediately discharged overboard (i.e., it is not discharged to holding tanks); therefore, biosludge is wasted only when the vessel is greater than 12 nm from shore.

The Hamworthy treatment system includes a total of 48 membrane modules, arranged in four groups of four sets of three. At any given time, only two of the three membrane modules in each set are operated; the third membrane module in each set is a backup module. One membrane module is cleaned each day, so the membrane cleaning cycle repeats every 48 days. The cleaning process uses "Membrane Cleaner Part 1" and "Membrane Cleaner Part 2"

and clean water, and requires a total of eight hours. The nonhazardous wash wastewater is collected in a double-bottom holding tank and discharged at sea outside of 12 nm.

Wastewater flow through the treatment system is controlled by the accommodations wastewater and sewage pumps. However, during periods of reduced treatment capacity (e.g., maintenance), seven double-bottom holding tanks provide a holding capacity of 822 m³. The contents of these holding tanks can either be pumped to the wastewater treatment system or held for discharge without treatment outside 12 nm from shore.

2.3 Wastewater and Residual Sample Collection Points

Samples were taken from the graywater sources (galley, laundry, and accommodations); influent to the treatment system (combined accommodations wastewater and sewage); influent to the UV disinfection portion of the treatment system; effluent from the treatment system; source water (water from the ship's potable water system); wastewater treatment residuals; and incinerator ash. Table 2-1 describes the wastewaters sampled, their sampling point locations, their flow meter locations (if applicable), and the number of days they were sampled. Table 2-2 provides the same information for the treatment residuals and incinerator ash sampled. In general, food pulper and wastewater treatment residual samples were taken for one 24-hour period, while samples of accommodations, galley, and laundry wastewater and the influent to and effluent from the treatment system were taken for five 24-hour periods. See Section 3.2 and Table 3-2 for information on the analytes tested. Note that samples were also collected of galley, laundry, and food pulper wastewaters as they were discharged untreated from a double-bottom holding tank.

Samples were collected from the ship's potable water system (source water) to determine if any of the target analytes were present as background contamination. One trip blank was prepared and analyzed for volatile organics to evaluate possible contamination during shipment and handling of samples. Finally, an equipment blank was prepared and analyzed to evaluate possible contamination caused by the sampling equipment.

Samples were not taken directly from the sewage CHT system. In addition, samples could not be collected of wastewater held in double-bottom holding tanks for discharge outside 12 nm from shore (i.e., treated effluent diverted to storage while the ship cruised Glacier Bay) because (1) double-bottom holding tanks cannot be accessed directly due to safety considerations, and (2) sampling from the holding tank discharge manifold would characterize combined holding tank discharges and not discharges specific to the holding tanks of interest.

2.4 **Flow Meter Locations**

Strap-on flow meters (Controlotron Model 1010) were installed at four sampling locations to collect flow data and to control automatic composite sample machines (by triggering sample collection after a defined amount of flow passed through the pipe). The first flow meter location was on the outlet pipe from the crew galley wastewater collection tank (galley wastewater, SP-1; see Table 2-1 for a description of wastewaters and Figure 2-1 for a simplified graywater and sewage CHT system diagram showing sampling points and flow meter locations). The second location was on the outlet pipe from one of the eleven accommodations collection tanks (accommodations wastewater, SP-3; see Table 2-1 and Figure 2-1). The third location was at the influent to the wastewater treatment system on the combined wastewater inlet pipe to the screen presses (SP-4; see Table 2-1 and Figure 2-2). The final location was at the effluent from the treatment system (on the overboard discharge line for the treated effluent, SP-6/7; see Table 2-1 and Figure 2-2).

The sampling point for laundry wastewater was located on piping that would not support installation of a strap-on flow meter (see Table 2-1), precluding collection of flow data and flow-weighted composite samples at this sampling point. Time-weighted composite samples were collected at the laundry wastewater sampling point (see Table 3-1 for a description of the sample collection method). Flow estimates for the food pulper wastewater were provided by the ship's crew.

Table 2-1

Wastewater, Sampling Point, and Flow Meter Descriptions, Island Princess

Descriptions of wastewaters sampled, sampling point locations, flow meter locations, and number of days sampled for the Island sampling episode (August 28 through September 4, 2004).

Wastewater Name	Wastewater Description(a)	Sampling Point # (a) (b)	Sampling Point Description(b)	Flow Meter Description(b)	# of Days Sampled
Galley	Wastewater from dishwashers, food preparation, galley sinks and floor drains, and sinks in restaurants, bars, and cafes. Galley wastewater drains to three collection tanks and eight holding tanks located throughout the ship (see Figure 2-1). Galley wastewater from these holding tanks is discharged at sea without treatment. One-time grab samples were also taken of galley wastewater as it was discharged from the holding tanks (see SP-8).	SP-1	Sample tap was installed on the outlet pipe from the crew galley collection tank. According to the ship's crew, all collection and holding tanks receive similar wastewater; therefore, the specific collection tank sampled was selected based on accessibility.	Strap-on flow meter was installed on the outlet pipe from the crew galley wastewater collection tank (the same outlet pipe as the installed sample tap).	5
Laundry	Wastewater from the main laundry, crew laundry, passenger laundrettes, and small items laundries. All laundry wastewater drains to three holding tanks and is discharged at sea without treatment. One-time grab samples were also taken of laundry wastewater as it was discharged from the holding tanks (see SP-9).	SP-2	Sample tap was installed on the inlet pipe to one of the laundry wastewater holding tanks. According to the ship's crew, all three holding tanks receive similar wastewater; therefore, the specific collection tank samples was selected based on accessibility.	Flow data for laundry wastewater were not obtained. Strap-on flow meter set up and calibration procedures were unsuccessful at the inlet pipe to the laundry wastewater holding tank, most likely due to poor pipe flow conditions such as pipe scaling or extreme aeration. Pipe configurations precluded all other potential flow meter locations.	5

(a) List of wastewaters may not be comprehensive.

(b) See Figures 2-1 and 2-2 for simplified diagrams of the Island graywater and sewage CHT and treatment systems indicating the sampling point and flow meter locations.

(c) Two sampling point numbers indicate duplicate samples taken at this point for certain analytes. See Section 5.2.3 and Tables 5-3 and 5-4 for details on duplicate sampling.

(d) Graywater overboard discharge are typically discharged simultaneously through a common overboard discharge line. A single sample tap was installed on the overboard discharge line, but for the purposes of sampling the individual graywater overboard sources, ship personnel discharged each graywater source in series, so each source could be sampled separately.

Table 2-1 (Continued)

Wastewater Name	Wastewater Description(a)	Sampling Point # (a) (b)	Sampling Point Description(b)	Flow Meter Description(b)	# of Days Sampled
Accommodations	Wastewater from sinks, tubs, and showers in guest and crew rooms, pantry areas, medical floor drains and sinks, most interior deck drains, and non-engine room shop sinks. Accommodations wastewater drains to 11 collection tanks located throughout the ship and then is pumped into two holding tanks equal in size.	SP-3	Sample tap was installed on the inlet pipe to one of the accommodations wastewater collection tanks. According to the ship's crew, all collection tanks receive similar wastewater; therefore, the specific collection tank sampled was selected based on accessibility.	Strap-on flow meter was installed on the inlet pipe to one of the accommodations wastewater collection tanks (the same inlet pipe as the installed sample tap).	5
Influent to Hamworthy Treatment System	Combined wastewaters from the accommodations and sewage collection, holding, and transfer (CHT) systems. Does not include galley, laundry, and food pulper wastewaters, which are discharged at sea without treatment. A vacuum CHT system conveys sewage from passenger and crew toilets and urinals. Accommodations CHT system culminates in two holding tanks which are pumped to two wastewater buffer tanks, the first component of the Hamworthy treatment system. The sewage CHT system culminates in four sewage collection tanks. Wastewater from the buffer tanks and sewage collection tanks mixes in a common line as it flows to the screen press component of the Hamworthy treatment system.	SP-4	Sample tap was installed on the combined wastewater inlet pipe to the screen presses.	Strap-on flow meter was installed on the inlet pipe to the screen presses (the same pipe as the installed sample tap).	5

(a) List of wastewaters may not be comprehensive.

(b) See Figures 2-1 and 2-2 for simplified diagrams of the Island graywater and sewage CHT and treatment systems indicating the sampling point and flow meter locations.

(c) Two sampling point numbers indicate duplicate samples taken at this point for certain analytes. See Section 5.2.3 and Tables 5-3 and 5-4 for details on duplicate sampling.

(d) Graywater overboard discharge sources are typically discharged simultaneously through a common overboard discharge line. A single sample tap was installed on the overboard discharge line, but for the purposes of sampling the individual graywater overboard sources, ship personnel discharged each graywater source in series, so each source could be sampled separately.

Table 2-1 (Continued)

Wastewater Name	Wastewater Description(a)	Sampling Point # (a) (b)	Sampling Point Description(b)	Flow Meter Description(b)	# of Days Sampled
Influent to UV Disinfection Part of Hamworthy Treatment System	Wastewater following treatment by biological oxidation but ultrafiltration but prior to ultraviolet (UV) disinfection.	SP-5	Sample tap was installed on the inlet pipe to the UV disinfection unit.	Flow measurements not required.	5
Effluent from Hamworthy Treatment System	Final treated wastewater effluent from the Hamworthy wastewater treatment system. Effluent is typically continuously discharged overboard. Where discharge is prohibited (e.g., Glacier Bay), wastewater is diverted to storage in double-bottom holding tanks for discharge overboard outside 12 nm from shore.	SP-6/7	Sample tap was installed on the overboard discharge pipe for the treated effluent about 1 meter upstream of the discharge port (i.e., on the effluent pipe from the UV disinfection unit, downstream of the diversion valve that directs wastewater to either overboard discharge or to storage in double-bottom holding tanks).	Strap-on flow meter was installed on the overboard discharge pipe for the treated effluent about 1 meter upstream of the discharge port (i.e., on the effluent pipe from the UV disinfection unit, downstream of the diversion valve that directs wastewater to either overboard discharge or to storage in double-bottom holding tanks) (the same pipe as the installed sample tap).	5
Galley Overboard Discharge	Galley wastewater from the 8 holding tanks is discharged untreated outside of 12 nm from shore. Galley wastewater from each of these tanks is combined in a common line for overboard discharge.	SP-8	Sample tap was installed on the overboard discharge line. (d)	Flow measurements not required. Approximately 250 m ³ of galley wastewater is generated per day, according to the ship's crew.	1 (August 26, 2005, prior to sampling episode; see Table 3-5)
Laundry Overboard Discharge	Laundry wastewater from the three holding tanks is discharged untreated outside of 12 nm from shore. Laundry wastewater from the holding tanks is combined in a common line for overboard discharge.	SP-9	Sample tap was installed on the overboard discharge line. (d)	Flow measurements not required. Approximately 160 m ³ of laundry wastewater is generated per day, according to the ship's crew.	1 (August 26, 2005, prior to sampling episode; see Table 3-5)

(a) List of wastewaters may not be comprehensive.

(b) See Figures 2-1 and 2-2 for simplified diagrams of the Island graywater and sewage CHT and treatment systems indicating the sampling point and flow meter locations.

(c) Two sampling point numbers indicate duplicate samples taken at this point for certain analytes. See Section 5.2.3 and Tables 5-3 and 5-4 for details on duplicate sampling.

(d) Graywater overboard discharge sources are typically discharged simultaneously through a common overboard discharge line. A single sample tap was installed on the overboard discharge line, but for the purposes of sampling the individual graywater overboard sources, ship personnel discharged each graywater source in series, so each source could be sampled separately.

Table 2-1 (Continued)

Wastewater Name	Wastewater Description(a)	Sampling Point # (a) (b)	Sampling Point Description(b)	Flow Meter Description(b)	# of Days Sampled
Food Pulper Overboard Discharge	Wastewater from the Somat food pulper system. Food waste is mixed with water and processed into a slurry. The food slurry is then separated into semi-dry food solids and wastewater (food pulper wastewater). Food pulper wastewater is routed to a food pulper wastewater holding tank for recirculation back to the Somat system; Gamazyme Boe is added to the recirculated wastewater as a bio odor eliminator. Every few days, the food pulper wastewater is drained from the holding tank to a storage tank and replaced with fresh water. Both food pulper wastewater and dewatered food waste are stored for discharge untreated outside of 12 nm from shore.	SP-10	Sample tap was installed on the overboard discharge line. (d)	Flow measurements not required. Approximately 31 m³ of food pulper wastewater is generated per day, according to the ship's crew.	1 (August 26, 2005, prior to sampling episode; see Table 3-5)
Source Water	Potable water used as source water for all systems that generate wastewater that is treated by the Hamworthy treatment system.	SP-14	Samples collected from a water fountain located near the sample staging area.	Flow measurements not required.	1 (Day 2)

(a) List of wastewaters may not be comprehensive.

(b) See Figures 2-1 and 2-2 for simplified diagrams of the Island graywater and sewage CHT and treatment systems indicating the sampling point and flow meter locations.

(c) Two sampling point numbers indicate duplicate samples taken at this point for certain analytes. See Section 5.2.3 and Tables 5-3 and 5-4 for details on duplicate sampling.

(d) Graywater overboard discharge sources are typically discharged simultaneously through a common overboard discharge line. A single sample tap was installed on the overboard discharge line, but for the purposes of sampling the individual graywater overboard sources, ship personnel discharged each graywater source in series, so each source could be sampled separately.

Table 2-2

Treatment Residuals and Incinerator Ash Descriptions, Island Princess

Descriptions of treatment residuals and incinerator ash sampled, sampling point locations, flow meter locations, and number of days sampled for the Island sampling episode (August 28 through September 4, 2004).

Treatment Residual Name	Treatment Residual Description	Sampling Point # (a)	Sampling Point Description	Flow Meter Description	# of Days Sampled
Screening Solids	Solids generated by the screen presses of the Hamworthy treatment system. Screening solids are collected from the screen presses' dry waste discharge lines and put into bags. Screening solids bags are incinerated onboard.	SP-11	Samples were collected directly from the solids collection bags.	Flow measurements not required. Approximately 50 kg of screening solids are generated per day, according to the ship's crew.	1 (Day 3)
Waste Biosludge	Each week when the ship is outside 12nm from shore, waste biosludge is removed from the bioreactors of the Hamworthy wastewater treatment system and immediately discharged overboard (i.e., it is not stored in double-bottom holding tanks).	SP-12	Sample tap was installed on the waste biosludge overboard discharge pipe.	Flow measurements not required. Approximately 10 metric tons of waste sludge are removed from the second stage bioreactors each week, according to the ship's crew.	1 (Day 1)
Incinerator Ash	Ash generated from the incineration of trash (e.g., cardboard, paper, plastic), screening solids, and spent bag filters. Incinerator ash is collected in incinerator ash storage hoppers for disposal onshore.	SP-13	Samples were collected directly from an incinerator ash storage hopper.	Flow measurements not required.	1 (Day 3)

(a) See Figures 2-1 and 2-2 for simplified diagrams of the Island's graywater and sewage CHT and treatment systems indicating the sampling point and flow meter locations.

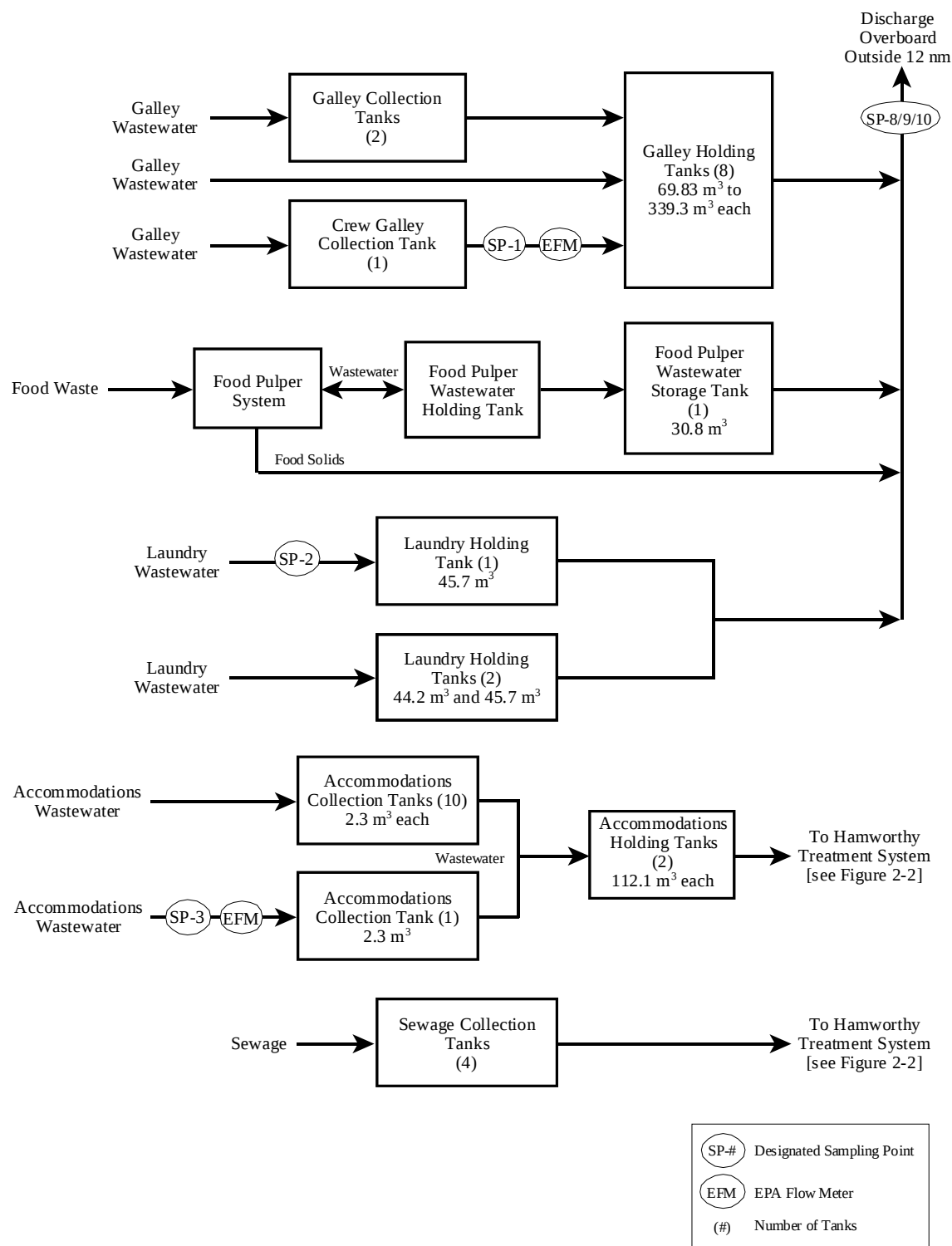


Figure 2-1. Graywater and Sewage Collection, Holding, and Transfer System, Island Princess

Simplified diagram of the Island Princess graywater and sewage CHT system. See Table 2-1 for a list of streams in each wastewater source.



Simplified diagram of the Island Princess Hamworthy treatment system. See Table 2-1 for a list of wastewater streams in each wastewater source, and Figure 2-1 for their collection and conveyance to the treatment system.