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On July 10, 2001, members of the Cruise Ship Wastewater Science Advisory Panel, meeting in Juneau, Alaska, conducted a study of opportunity to observe currents and turbulence in the wake of two cruise ships. The study used drogues to follow a parcel of water behind each ship and a fathometer to identify the extent of the water column experiencing turbulence from their passage. The objective of the study was to evaluate how drogues, or fathometer observations, or a combination of the two could be used to identify, follow and describe the parcel of water where effluent discharged from a cruise ship would mix with the ambient water. Observations were made from the *Princeton Hall* and two smaller speedboats.

Study location, predicted tides and currents and observed winds.

The study was performed in Gastineau Channel, about 5 nautical miles southeast from downtown Juneau, Alaska. The channel runs northwest to southeast, and cruise ships exiting Juneau steered to the southeast, paralleling the channel. The channel in the vicinity of the study was 15 to 22 fathoms (27 to 40 meters) deep and about 4,500 feet (1,400 meters) wide. The study took place between 1730 and 2130. A high tide of 14.2 feet (4.3 meters) occurred at 1727 and a low tide of 4.0 feet (1.2 meters) occurred at 2312. The NOAA current tables predicted slack water to occur at 1739 and a maximum ebb current of 0.56 knots at 2118 with an ebb current direction to the southeast (144). Winds were nil to light during the study, but the common direction of wind during the day was from the southeast.

Study design

The study design called for placing 2 columns of drift objects (drogues) in the wake of a passing cruise ship. Two vessels were utilized for the drogue deployments. One column of drogues was to be deployed approximately in line with the port side of the ship and the other in line with the starboard side. The drogues were of windowshade design, approximately 1 square meter, set to depth by the length of line attached to a low lying 2'x2' surface float of insulating styrofoam. The depths to the centers of the drogues were 1 m, 2 m, 4 m, 6 m and 8 m. These depths were selected to sample the currents in the upper 8 m of the water column. 8 m was selected as that is the hull depth of the typical large cruise ship. The two columns of drogues would bracket the sides of the rectangle in which the Science Advisory Panel has estimated initial mixing of discharged effluent would occur.

In addition to the two columns of drogues, a line of surface drifters consisting of 2'x2' squares of plywood was deployed across the wake and two additional drogues, one at 4 m and one at 8 m, were deployed in line with the center of the wake.

Prior to the arrival of the cruise ships, a practice run was made, deploying one column of drogues, tracking them briefly and then recovering them. This deployment from 1731 to 1751, occurred close to the predicted slack water and documented weak currents yet significant shear in the upper 8 meters without influence from a cruise ship passage. Speeds and general directions for this launch were.

Surface 0.32 knots to the NW
1 meter 0.15 knots to the NW
2 meters 0.25 knots to the E
4 meters 0.11 knots to the E
6 meters 0.11 knots to the SE
8 meters 0.18 knots to the ENE

Following the launching of the drogues behind the first cruise ship, the *Princeton Hall* moved to the southeast of the drogues and began to move back and forth, perpendicular to the cruise ship wake, to observe the width and depth of the zone of turbulence from the passage of the cruise ship with its fathometer. This part of the study evolved rapidly as it was occurring. The fathometer observation was initially tried just to see what, if any, information it might produce. It was quickly apparent that the fathometer clearly delineated the extent of the wake turbulence. The Science Advisory Panel collectively began to improvise methods to better quantify the dimensions of the areas of turbulence and to track the changing shapes and sizes after passage of the cruise ships. As all this was happening, one member of the Science Advisory Panel documented the events using a digital video camera. This allowed for later analysis and it proved to be a very useful method for data recording as it captured verbal discussions which included numerous relevant facts such as radar ranges to the cruise ship, the speed of *Princeton Hall* as it crossed the wake, etc.

The drogues were followed by the small boats for approximately one hour with locations obtained by hand-held GPS systems. After an hour, the drogues in the first launch were retrieved for deployment behind the next cruise ship. An hour after the second launch the drogues were retrieved to get out of the way of a third cruise ship. The drogue separations that occurred over time illustrated vertical shear in the water column, as well as probable surface effects of wind. Drogue positions in latitude and longitude were plotted and evaluated.

Observations behind the cruise ship *Ryndam*

Drogues

The first drogue deployment was made close behind the cruise ship *Ryndam* and essentially followed the above study design. The *Ryndam* was in the middle of Gastineau Channel and moving to the southeast at a reported speed of 10 knots. The two columns of drogues were launched at 1847 and 1849 and followed until 2000. The period of observation was midway between the predicted slack tidal current and the maximum ebb tidal current. Additional surface drifters and drogues were launched a little later. The raw fix data for the drogues were sorted to chronological observations for each drogue and entered into a spreadsheet. Positions were plotted and speeds and directions between fixes determined. The fix data, speeds and directions as well as plots are provided in Attachment A.

The recorded initial launch points for the columns of drogues plot in line with the cruise ship track as opposed to perpendicular to it. The Port and Starboard launches were actually made perpendicular to the track, but a single fix for each group was made following the launch, and the time delay between the launching and the fixing, coupled with the direction of the currents, could explain the appearance of a launch in line with, instead of perpendicular to the track. The actual launch for the starboard column probably began a minute or two earlier than the fix and to the west.

The drogues showed they were useful to track the parcel of water behind the cruise ship. The movement of the parcel was complex. Considerable shear existed within the water column and in the early stages of the deployment much of the shear was perpendicular to the track of the cruise ship. The following is a brief description of the behavior of the two columns of drogues. The labels "S" and "P" signify the starboard and port launches and the numbers signify the depth in meters.

- Surface. Both surface drifters moved to the north, curving to the northwest. The average speed for each surface drifter was about 0.2 knot.
- 1 meter. Both moved initially to the east and then curved to the southeast. The average speed was about 0.15 knot.
- 2 meters. Drogue P2 moved to the east curving to the southeast much like the 1 meter drogues. The average speed was about 0.2 knot. Drogue S2 was deployed shallower than 2 meters. For this reason it was not plotted.
- 4 meters. Drogue P4 moved northeast at 0.15 knot, then curved to the southeast and increased speed to 0.25 knot. Drogue S4 moved east at about 0.2 knot then curved to the east southeast, maintaining speed of 0.2 knot. Each of the 4 meter drogues traveled further to the northeast than drogues at other depths.
- 6 meters. Drogue P6 moved east at about 0.2 knot then curved clockwise to the south southeast and increased speed to 0.25 knot. Drogue S6 did not deploy to depth properly. For this reason it was not plotted. 8 meters. The 8 meter drogues behaved somewhat like the 6 meter drogues.
- 8 meters. The 8 meter drogues behaved somewhat like the 6 meter drogues. Drogue P8 moved initially to the northwest at 0.2 knot then curved clockwise to the southeast at about 0.15 knot. Drogue S8 moved initially to the northwest at about 0.2 knot and then curved counterclockwise to the south at about 0.2 knot

The line of surface drifters that was spread across the track all behaved like the two surface drifters in the port and starboard column launches. They all moved together to the north and then to the northwest and were ultimately retrieved close together. They are not individually plotted nor described further in this report. Their fix locations are included in the tables in Attachment A.

The additional 4 meter and 8 meter drogues that were launched are also not plotted or evaluated. The intent was to launch them along the center of the wake, between the starboard and port columns, after the starboard and port columns had been deployed. The study design was overly ambitious. The time delay before these were launched is

such that it is hard to compare them to an initial launch position of the center of the wake. The fix locations for these drogues are in the tables in Attachment A.

Fathometer

On the first pass over the wake the fathometer showed that it was capable of picking up a strong return signal from the wake turbulence. The Science Advisory Panel began efforts to quantify the dimensions over time and determined the following:

Cruise Ship Distance	**Wake Turbulence Description**			
	Time	**Depth**	**Width**	**Area**
1.39 km	2 min.	12 m	?	?
2.78 km	6 min.	7.5 m	125 m	940 sq m
5.55 km	12 min	6 m	155 m	930 sq m

The wake turbulence on the fathometer was observed to become asymmetrical over time. A photo of the fathometer trace showing this asymmetry is presented in Attachment A. The wake turbulence was well pronounced from the surface down to depth on the northeast side of the transect while on the southwest side it was evident at depth but not the surface. The current shear evident from the drogues is probably the reason for the asymmetrical wake turbulence pattern.

The radar ranges and the time difference from when the ship passed indicated that the ship was doing about 15 knots within 6 minutes after passing. Consequently, the *Ryndam* must have been accelerating as it went by. Perhaps this increase in thrust would produce a greater area of wake turbulence than if the ship was maintaining a constant speed of 10 knots.

Observations behind the cruise ship *Dawn Princess*.

Drogues

The second drogue deployment was made close behind the cruise ship *Dawn Princess*. It differed from the above study design in that it was simplified to just include two columns each consisting of a surface drifter and drogues at 1 m, 2 m, 4 m, 6 m and 8 m. The Dawn Princess was located approximately in the middle of Gastineau Channel and moving to the southeast at a reported speed of 12 knots. The drogues were launched at 2025 and followed until 2120. The period of observation was close to the predicted maximum ebb tidal current. The raw fix data for the drogues were sorted to chronological observations for each drogue and entered into a spreadsheet. Positions were plotted and speeds and directions between fixes determined. The fix data, speeds and directions as well as plots are provided in Attachment B.

The video footage showed that the area of the initial launches of drogues was very turbulent and the distance to the cruise ship rapidly increased while the drogues were being launched. The Dawn Princess was about 1,000 feet (about 300 meters) away by the time all the drogues were deployed.

The drogues showed they were useful to track the parcel of water behind the cruise ship. Considerable shear existed within the water column in the same direction as the ship's track. Speeds, general direction and behavior for the Port and Starboard launches were similar to each other.

- Surface. 0.2 to 0.3 knots to SE, then reversed counter clockwise and moved to the NW at 0.2 knots
- 1 meter. 0.4 knots to the SE
- 2 meters. 0.45 knots to the SE
- 4 meters. 0.3 to 0.39 knots to the SE
- 6 meters. 0.1 knots to the SE. Drogue S6 essentially stopped after about 20 minutes
- 8 meters. Weak and variable. Drogue S8 moved to the SE then turned counterclockwise to the SW. Drogue P8 moved a short distance to the SE. After run times of 45 to 50 minutes, both 8 meter drogues were still within 100 meters of the launch point.

Probably because of the stronger tidal currents, the drogues did not spread out as much across Gastineau Channel as they did for the earlier launch behind the *Ryndam*.

Fathometer

While the drogue study was simplified for the second cruise ship, the fathometer observations became more detailed. Observations included the time when entering the wake, the seconds needed to pass through the wake, the speed range of the *Princeton Hall* as it passed through the wake, the depth range of the turbulence and the distance range to the cruise ship for each crossing of the wake. The *Dawn Princess* passed the *Princeton Hall* at 2021 and 30 seconds. With the times reported as the time following passage of the *Dawn Princess*, the fathometer illustrated the following:

Cruise Ship Distance	**Wake Turbulence Description**			
	Time	**Depth**	**Width**	**Area**
.93 km	1.5 min	18.3 m	?	?
1.85 km	2.6 min	12.2 m	76-79 m	928-968 sq m
3.2-3.7 km	6.0 min	6.1 m	103-104 m	627-635 sq m
3.9-4.2 km	9.0 min	5.5-6.1 m	124-129 m	682-787 sq m
5.3 km	11.7 min	4.6-6.1 m	131 m	600-800 sq m
na	14.6 min	3.0-4.6 m	126-131 m	385-600 sq m
na	16.5 min	2.4-3.0 m	125-130 m	305-396 sq m

Several photos of the fathometer are presented in **Attachment B**.

Probably because of the stronger tidal currents in the same direction as the ship's track, the width of the wake turbulence was not as great as was observed behind the *Ryndam*.

Observations behind the cruise ship *Regal Princess* (Photos of the fathometer readings can be found in **Appendix C**)

Fathometer

While the *Princeton Hall* returned to port, the Science Advisory Panel conducted additional fathometer observations behind the cruise ship *Regal Princess*. These showed that the wake turbulence weakened and thinned as the time following the ships' passage increased. The wake turbulence observed by fathometer was nearly gone at a distance of about 3 nautical miles (5.5 km) behind the cruise ship. The speed of the *Regal Princess* when it transited this distance was not noted, but it probably was traveling slower than the other two ships when they were observed.

Conclusions

The fathometer observations were very useful to describe the depth and width of the water column experiencing turbulence from the passage of the cruise ships. The turbulence initially extended down to well below 8 m. The width of the turbulence rapidly spread to greater than 100 m wide within about 5 minutes after the cruise ship passed by. The wake turbulence gradually grew wider and shallower over time. The wake turbulence could be observed with the fathometer for up to 17 minutes. The time during which the wake turbulence can be observed is probably proportional to the speed and size of the cruise ship. The width of wake turbulence was greater behind the *Ryndam* than behind the *Dawn Princess*. The drogues behind the *Ryndam* also dispersed more across Gastineau Channel than they did behind the *Dawn Princess*. Both of these observations might be explained by the different strength of the tidal currents. The tidal currents were stronger during the *Dawn Princess* observations.

Members of the Science Advisory Panel pondered the question of just what the fathometer was measuring when the screen appeared to illuminate the wake turbulence. One theory is that it is reflecting off bubbles entrained in the wake. If this is the case, then there may be additional turbulence below the depth shown in the fathometer, where there is turbulence but no bubbles entrained from the surface.

One would assume that the wake turbulence seen in the fathometer observations provides an upper bound on the area involved in the initial mixing of the effluent compared to the more conservative estimate of mixing provided by the Science Advisory Panel's earlier report on effluent dispersion. That report assumed the mixing in the first 15 minutes occurred in an area equal to the width times the hull depth of the cruise vessel (typically 32 m by 8 m). The wake turbulence observations quickly attained cross sectional areas more than 3 times the area defined by the depth and width of a cruise ship.

The drogue observations showed considerable variability in current direction over the water column, indicative of shear effects. Similar shear effects were also evident in a test launch of drogues before the passage of any cruise ships. The surface drifters appeared to be influenced by a wind driven surface drift, even though the wind was slight. In the observations behind the *Dawn Princess*, the wake turbulence initially broke the stratification and the surface drifters moved in the same direction as the deeper drogues, but the shallow wind driven surface drift was quickly restored and the surface drifters moved in the opposite direction.

The shear evident from the drogues behind the *Dawn Princess* will not have had much effect on the shape of the wake turbulence since most of the shear was oriented in the same direction as the cruise ship track. A parcel of water represented by the drogue launch would have been stretched out considerably, but in line with the cruise ship track. The shear evident from the drogues behind the *Ryndam* had more of a cross track component, such that the shallower water, (surface to 4 meters) moved to the left of the ships track, while some of the deeper drogues (6 and 8 meters) from the starboard launch lingered near the track line and then moved to the right of the track line. The video taped observations of the *Ryndam's* wake turbulence showed a skew developing over time in which the turbulence on the southwest side was evident at depth but not at the surface, while on the northeast side it was evident up to the surface.

Consider the effects of current shear if a cruise ship was on a track perpendicular to the currents and the shear. The shape of the wake turbulence (and the area where initial effluent mixing would occur) would be expected to respond accordingly (shallow on the leading edge and deeper on the trailing edge). This was the case with the *Ryndam*, but not with the *Dawn Princess*. Shear effects on wake turbulence would also impact the distribution of any discharged effluent, and should be looked for in any future dye studies. Where shear is in the same direction as a cruise track it will probably not have much effect on the dilution, but where shear is not oriented parallel to a cruise track it will probably enhance mixing, and its effects would be strongest when the shear was perpendicular to the cruise track.

Recommendations

There are several key recommendations relevant to the August, 2001 cruise ship dye study that develop from this study of opportunity.

1. The wake turbulence provides an initial measure of the maximum extent in which initial mixing is expected to occur. Dye studies should evaluate how the dye distribution occurs within and a little beyond the wake turbulence area. Wake turbulence remains evident with the fathometer for 15 to 20 minutes.
2. Drogues may be useful for identifying a parcel of the wake turbulence area that should be sampled at selected intervals in the dye study. A vessel transiting the wake should place drogues at a few depths just outside of the port and starboard edges of the wake turbulence area as determined from the fathometer, not from visual observations of the surface. The drogues should be placed within the first 5 to 10 minutes following the passage of the cruise ship. We suggest 1 m, 3 m and 6 m as depths for drogue placement. The drogues will also assist in describing current shear effects.
3. The dye study should evaluate the changing concentrations of the dye over time between the port and starboard drogue launches. This will provide a record of how the dilution in the parcel of water proceeds over time. The drogue positions will allow the dye study to continue to follow the same parcel of water after the wake turbulence has dissipated. Shear effects may be correlated between the drogues, the early wake turbulence and the dye distribution.
4. Many cruise ships discharge along the side of the hull, and not along the bottom. If a cruise ship involved in the dye study has a side discharge arrangement, it should discharge only from one side during the dye study, in order to identify what parts of the wake turbulence are, or are not involved in the mixing from a side discharge.

Attachments:

A. *Ryndam* observations
   drogue location, speed and direction data
   drogue plots
   fathometer photos showing wake turbulence

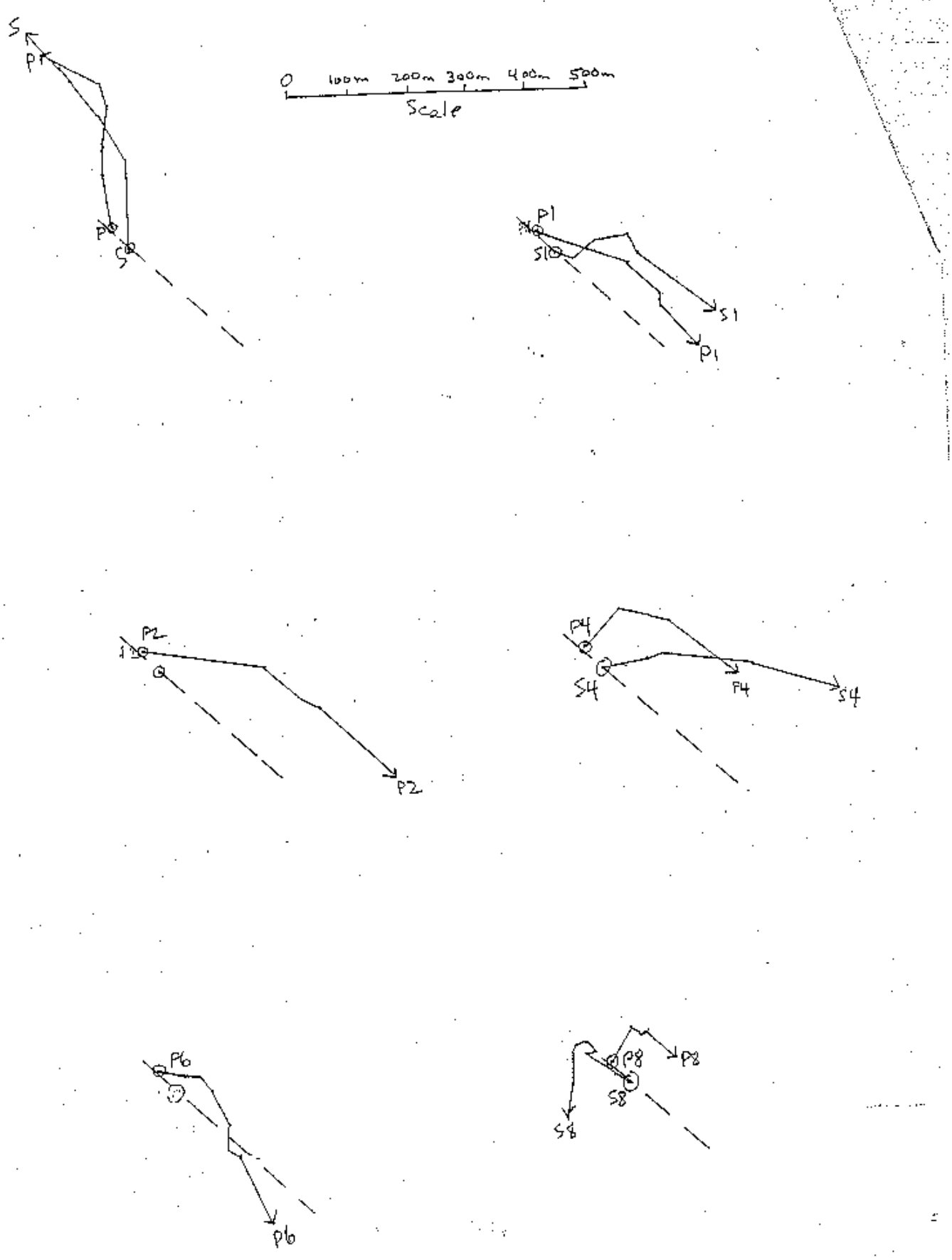
B. *Dawn Princess* observations
   drogue location, speed and direction data
   drogue plots

C. *Regal Princess* observations
fathometer photos showing wake turbulence

Cruise Ship____***Ryndam***					Course SE		Speed 10 kts		
Date 10 Jul 01_	Time__1847_____				Wind speed _weak		Wind direction_from SE		
	__Time__			__Latitude____			__Longitude____		
Drogue	hr	min	sec	deg	min	sec	deg	min	sec	Speed (knots)	Dir
P	18	47	50	58	14	22.3	134	18	14.3		
P	19	5	52	58	14	25.0	134	18	14.6	0.16	N
P	19	12	34	58	14	26.5	134	18	15	0.25	N
P	19	24	7	58	14	28.8	134	18	14.1	0.25	N
P	19	33	45	58	14	29.6	134	18	14.6	0.14	N
P	19	44	35	58	14	31.5	134	18	20.2	0.33	NW
	Surface moved to the north then curved to the northwest										
S	18	49	5	58	14	20.9	134	18	12.4		
S	19	6	26	58	14	26.1	134	18	13.1	0.29	N
S	19	14	30	58	14	28.3	134	18	15.1	0.39	NNW
S	19	23	5	58	14	29.9	134	18	17.7	0.25	NNW
S	19	36	0	58	14	30.9	134	18	18.8	0.06	NNW
S	19	42	5	58	14	32.5	134	18	22.1	0.48	NNW
	Surface moved to the north then curved to the northnorthwest										
C	19	5	52	58	14	25	134	18	14.6	not plotted	
C	19	8	3	58	14	25.6	134	18	14.6		
C	19	12	34	58	14	26.5	134	18	15		
C	19	23	24	58	14	29	134	18	14.6		
C	19	34	58	58	14	30.3	134	18	16.4		
C	19	43	7	58	14	32.3	134	18	20.2		
	Not plotted, but moved north with surface drifters P and $										
L	19	6	15	58	14	25.7	134	18	13.5	not plotted	
L	19	13	33	58	14	27	134	18	13		
L	19	23	34	58	14	29.6	134	18	15.2		
L	19	35	15	58	14	30.8	134	18	16.7		
L	19	42	40	58	14	32.4	134	18	20.7		
	Not plotted, but moved north with surface drifters P and $										
A	19	7	18	58	14	27.2	134	18	15.3	not plotted	
A	19	15	27	58	14	27.8	134	18	15.8		
A	19	25	57	58	14	28.7	134	18	14.8		
A	19	33	13	58	14	29.5	134	18	13.9		
A	19	45	55	58	14	31.3	134	18	19.1		
	Not plotted, but moved north with surface drifters P and $										
X	19	8	3	58	14	25.6	134	18	14.6	not plotted	
X	19	12	34	58	14	26.5	134	18	15		
X	19	24	7	58	14	28.8	134	18	14.1		
X	19	34	25	58	14	30	134	18	13.9		
X	19	45	17	58	14	31.3	134	18	20.2		
	Not plotted, but moved north with surface drifters P and $										
K	19	6	59	58	14	27.6	134	18	13.8	not plotted	
K	19	15	44	58	14	29.4	134	18	17.5		
K	19	22	12	58	14	30.6	134	18	18.5		
K	19	36	40	58	14	31.7	134	18	20.9		
K	19	41	22	58	14	32.6	134	18	22.9		
	Not plotted, but moved north with surface drifters P and $										
O	19	8	45	58	14	24.9	134	18	10.8	not plotted	

Cruise Ship____***Ryndam***							Course SE			Speed 10 kts						
Date 10 Jul 01_		Time__1847_____					Wind speed _weak			Wind direction_from SE						
O		19	24	21		58	14	28.4		134	18	13.5				
O		19	32	45		58	14	29.8		134	18	13.4				
O		19	44	0		58	14	31.8		134	18	19.8				
		Not plotted, but moved north with surface drifters P and $														
P1		18	47	50		58	14	22.3		134	18	14.3				
P1		19	13	0		58	14	20.3		134	18	4.9		0.2		ESE
P1		19	29	40		58	14	19.4		134	18	3.4		0.07		SE
P1		19	35	17		58	14	18.8		134	18	2.3		0.21		SE
P1		19	37	24		58	14	18.6		134	18	2.1		0.24		SE
P1		19	55	30		58	14	16.4		134	17	58.7		0.15		SE
		1 meter moved eastsoutheast then to the southeast														
S1		18	49	5		58	14	20.9		134	18	12.4				
S1		18	58	49		58	14	20.8		134	18	11		0.1		E
S1		19	11	31		58	14	21.8		134	18	8.8		0.11		NE
S1		19	27	30		58	14	22		134	18	5		0.13		E
S1		19	31	4		58	14	21.6		134	18	4.5		0.3		SE
S1		19	54	25		58	14	18.2		134	17	56.7		0.2		SE
		1 meter moved to eastnortheast then to the southeast														
P2		18	47	50		58	14	22.3		134	18	14.3				
P2		19	12	45		58	14	20.7		134	18	2		0.28		E
P2		19	30	50		58	14	19.6		134	17	58.6		0.15		SE
P2		19	36	42		58	14	19		134	17	57.2		0.15		SE
P2		20	0	19		58	14	15.2		134	17	49.1		0.22		SE
		2 meters moved to east then to southeast														
S2		18	49	5		58	14	20.9		134	18	12.4		not plotted		
S2		18	59	24		58	14	21		134	18	9.4				
S2		19	2	48		58	14	21.2		134	18	8.6				
S2		19	12	2		58	14	21.3		134	18	6.8				
S2		19	26	0		58	14	21.8		134	18	6.3				
S2		19	31	18		58	14	21		134	18	5.4				
S2		19	58	15		58	14	15.1		134	17	56.2				
at 1926 it was noted that S2 only deployed to 1 meter.																
P4		18	47	50		58	14	22.3		134	18	14.3				
P4		19	9	11		58	14	24.1		134	18	11		0.15		NE
P4		19	25	0		58	14	23.8		134	18	7.5		0.13		ESE
P4		19	30	22		58	14	23.6		134	18	5.4		0.25		ESE
P4		19	50	56		58	14	20		134	17	59.2		0.27		SE
4 meters started out to the northeast but curved around to the southeast																
C4		19	0	8		58	14	21.7		134	18	9.1		not plotted		
C4		19	11	55		58	14	21.1		134	18	7.3				
C4		19	30	5		58	14	19.8		134	18	2.9				
C4		19	35	44		58	14	20		134	18	0.2				
C4		20	1	47		58	14	16.1		134	17	46.2				
S4		18	49	5		58	14	20.9		134	18	12.4				
S4		19	2	48		58	14	21.2		134	18	8.6		0.18		E
S4		19	12	15		58	14	21.4		134	18	6		0.12		E
S4		19	36	6		58	14	20.6		134	17	57.9		0.21		E
S4		19	59	30		58	14	14.2		134	17	48.7		0.21		ESE
on recovery, noted drogue deployed to depth, but tangled. Plotted anway.																
4 meters moved to the east																

Cruise Ship____***Ryndam***							Course SE			Speed 10 kts			
Date 10 Jul 01_	Time__1847_____						Wind speed _weak			Wind direction_from SE			
P6	18	47	50	58	14		22.3	134	18	14.3			
P6	19	1	45	58	14		22.1	134	18	10.4		0.18	E
P6	19	13	53	58	14		20.9	134	18	8.7		0.11	SE
P6	19	28	45	58	14		19.3	134	18	7.5		0.13	SSE
P6	19	34	40	58	14		18.1	134	18	6.5		0.24	S
P6	19	38	5	58	14		17.5	134	18	6.3		0.27	SE
P6	19	56	30	58	14		13.8	134	18	3.9		0.2	SSE
6 meters moved to the east then turned clockwise to the southeast													
S6	18	49	5	58	14		20.9	134	18	12.4			
S6	18	56	34	58	14		20.9	134	18	14.6		0.17	W
S6	19	4	20	58	14		21.2	134	18	15.3		0.08	NW
S6	19	10	19	58	14		20.9	134	18	15.6		0.09	SW
S6	19	14	55	58	14		20.6	134	18	16.2		0.12	SW
S6	19	23	16	58	14		19.8	134	18	16		0.16	SE
S6	19	33	15	58	14		19.1	134	18	14.3		0.16	SSE
S6	19	39	2	58	14		18.7	134	18	11.8		0.32	ESE
S6	19	45	2	58	14		18.3	134	18	9.3		0.25	SE
on recovery, noted did not deploy properly, line wrapped. Plotted anyway.													
6 meters moved to the west then turned counterclockwise to the southeast													
P8	18	47	50	58	14		22.3	134	18	14.3			
P8	19	9	45	58	14		23.8	134	18	12.8		0.1	NE
P8	19	24	20	58	14		23.6	134	18	11.8		0.04	SSE
P8	19	29	33	58	14		23.6	134	18	11		0.05	E
P8	19	42	21	58	14		22.5	134	18	7.6		0.17	SE
8 meters moved to the northeast then turned clockwise to the southeast													
C8	19	11	9	58	14		22.7	134	18	9.8		not plotted	
C8	19	25	35	58	14		22.1	134	18	8.2			
C8	19	46	46	58	14		19.9	134	18	6.7			
S8	18	49	5	58	14		20.9	134	18	12.4			
S8	18	55	54	58	14		21.8	134	18	14.5		0.15	NW
S8	19	5	5	58	14		22.9	134	18	16.3		0.22	NW
S8	19	11	11	58	14		22.9	134	18	15.9		0.14	E
S8	19	16	2	58	14		23.6	134	18	17.3		0.21	NW
S8	19	22	30	58	14		23.5	134	18	17.7		0.09	W
S8	19	28	32	58	14		22.6	134	18	17.8		0.15	SW
S8	19	40	1	58	14		20.6	134	18	18.3		0.17	SW
S8	19	46	34	58	14		19.1	134	18	18.6		0.31	SW
8 meters moved to the northwest then turned clockwise to the southwest													



Drogue trajectories from wake of the Ryndam passage in Gastineau Channel on July 10, 2001. Ryndam course (dashed line) was to the southeast. Predicted ebb tidal currents were to the southeast. North is to the top of the page. Designations of "S" & "P" are for starboard and port side launches. Numbers following designation are for the depth of the drogue in meters. Those with no number, but just a "P" or "S" are surface drifters. See

Ryndam – photographs of fathometer recordings of wake profile

Setting drogues

Gastineau channel

First pass across the plume/path of Ryndam Distance 1.39 km 2 min 12 m depth

Second pass

Third pass

Fourth pass 2.78 km 6 min 7.5 m deep 125 m wide 940 sq m area

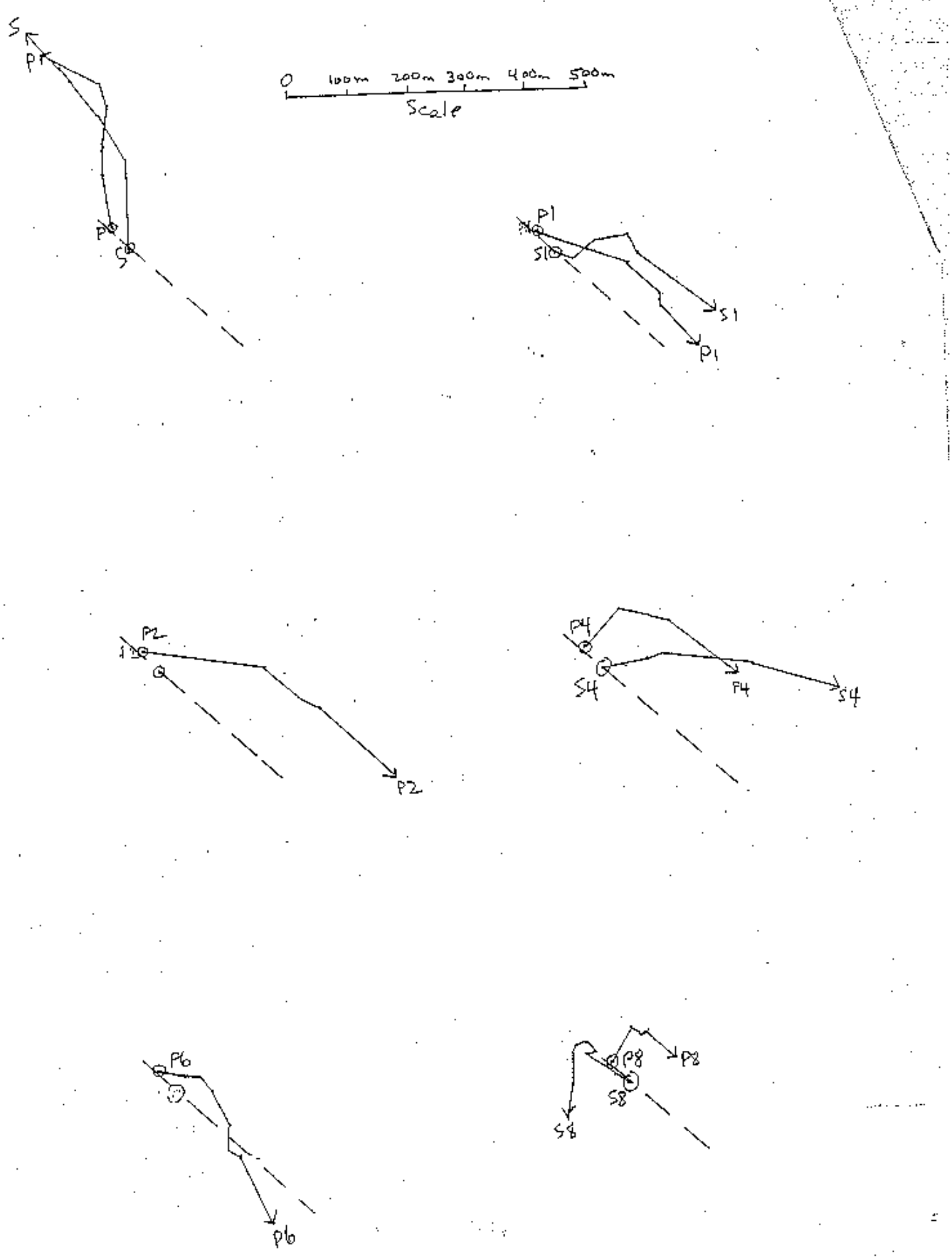
Fifth pass

Sixth pass 5.55 km 12 min 6 m deep 155 m wide 930 sq m area

Seventh pass

Cruise Ship_***Dawn Princess***				Course SE			Speed 12 kts				
Date 10 Jul 01___	Time__2025_____			Wind speed _weak			Wind direction_from SE				
	__Time__			__Latitude____			__Longitude____			Speed	Dir
Drogue	hr	min	sec	deg	min	sec	deg	min	sec	(knots)	
S	20	25	0	58	14	12.5	134	17	51.4		
S	20	37	25	58	14	9.9	134	17	48.8	0.24	SE
S	20	42	46	58	14	9.2	134	17	50.2	0.26	SW
S	20	48	48	58	14	9	134	17	49.8	0.11	SE
S	20	57	16	58	14	9.7	134	17	52.7	0.20	NW
S	21	22	50	58	14	11.8	134	18	0.8	0.20	NW
	Surface started out to SE, then reversed counterclockwise to northwest										
P	20	27	0	58	14	13.3	134	17	49.1		
P	20	36	42	58	14	8.7	134	17	46.1	0.48	SE
P	20	42	22	58	14	8.7	134	17	47.5	0.22	W
P	20	51	42	58	14	8.3	134	17	48.2	0.06	SW
P	20	56	45	58	14	8.2	134	17	50.1	0.17	W
P	21	21	30	58	14	9.6	134	18	0.2	0.23	WNW
	Surface started out to SE, then reversed counterclockwise to northwest										
S1	20	25	0	58	14	12.5	134	17	51.4		
S1	20	41	30	58	14	6.7	134	17	43.5	0.44	SE
S1	20	47	0	58	14	4.4	134	17	40.0	0.54	SE
S1	20	53	45	58	14	3.2	134	17	38.7	0.17	SE
S1	21	11	40	58	13	58.6	134	17	30.4	0.39	SE
	1 meter moved to southeast at about 0.4 knots										
P1	20	27	0	58	14	13.3	134	17	49.1		
P1	20	36	0	58	14	8.3	134	17	43.9	0.58	SE
P1	20	40	40	58	14	6.3	134	17	42.2	0.45	SSE
P1	20	46	0	58	14	4.8	134	17	40.8	0.38	SSE
P1	20	55	25	58	14	2.1	134	17	34.5	0.33	SE
P1	21	1	50	58	13	59.1	134	17	26.2	0.90	SE
	1 meter moved to southeast at about 0.5 knots										
S2	20	25	0	58	14	12.5	134	17	51.4		
S2	20	34	50	58	14	8	134	17	44.5	0.59	SE
S2	20	40	56	58	14	5.9	134	17	40.6	0.51	SE
S2	20	46	20	58	14	3.9	134	17	39.1	0.44	SSE
S2	20	55	7	58	14	1.7	134	17	33.4	0.43	SE
S2	21	9	29	58	13	56.9	134	17	24.0	0.45	SE
	2 meters moved to southeast at about 0.5 knots										
P2	20	27	0	58	14	13.3	134	17	49.1		
P2	20	40	0	58	14	9	134	17	41.7	0.40	SE
P2	20	45	25	58	14	7.2	134	17	40.3	0.42	SSE
P2	20	54	25	58	14	3.5	134	17	33.8	0.56	SE
P2	21	5	45	58	13	59.7	134	17	26.6	0.43	SSE
	2 meters moved southeast at about 0.4 knots										
S4	20	25	0	58	14	12.5	134	17	51.4		
S4	20	34	0	58	14	8	134	17	46.0	0.57	SE
S4	20	40	20	58	14	7.5	134	17	42.2	0.39	ESE
S4	20	45	42	58	14	6.1	134	17	40.7	0.35	SE
S4	20	54	25	58	14	3.5	134	17	33.8	0.49	SE
S4	21	3	40	58	14	1.6	134	17	29.1	0.26	SSE
	4 meters moved southeast at about 0.4 knots										
P4	20	27	0	58	14	13.3	134	17	49.1		

Cruise Ship_***Dawn Princess***						Course SE			Speed 12 kts				
Date 10 Jul 01___		Time__2025_____				Wind speed _weak			Wind direction_from SE				
P4		20	39	35		58	14	10.2		134	17	43.6	0.32	SE
P4		20	40	52		58	14	9.4		134	17	42.9	0.62	SSE
P4		20	52	50		58	14	8.2		134	17	37.5	0.25	ESE
P4		21	1	25		58	14	7.1		134	17	33.2	0.30	ESE
		4 meters moved southeast at about 0.3 knots												
S6		20	25	0		58	14	12.5		134	17	51.4		
S6		20	33	0		58	14	11		134	17	51.7	0.16	SE
S6		20	37	25		58	14	9.9		134	17	48.8	0.33	SE
S6		20	48	14		58	14	8.7		134	17	46.1	0.18	SE
S6		20	51	20		58	14	9		134	17	45.7	0.13	NE
S6		20	59	37		58	14	8.5		134	17	46.0	0.05	SW
S6		21	16	0		58	14	8.6		134	17	44.5	0.06	E
		6 meters moved southeast at less than 0.2 knots for 15 minutes												
		then became weak and variable												
P6		20	27	0		58	14	13.3		134	17	49.1		
P6		20	39	0		58	14	12.1		134	17	47.2	0.13	ESE
P6		20	44	0		58	14	11.8		134	17	46.9	0.12	S
P6		20	50	54		58	14	10.5		134	17	45.4	0.20	SE
P6		20	59	16		58	14	10.1		134	17	46.3	0.06	SW
P6		21	14	10		58	14	8.5		134	17	42.9	0.18	SE
		6 meters moved southeast at less than 0.2 knots for 25 minutes												
		then became weak and variable												
S8		20	25	0		58	14	12.5		134	17	51.4		
S8		20	32	0		58	14	11.9		134	17	51.4	nil	SE
S8		20	38	0		58	14	10.7		134	17	50.5	0.31	SE
S8		20	43	7		58	14	10.9		134	17	50.9	nil	NW
S8		20	49	37		58	14	10.1		134	17	51.7	0.08	SW
S8		20	58	10		58	14	10.5		134	17	53.5	0.13	NW
S8		21	19	55		58	14	10.1		134	17	54.1	0.06	WSW
		8 meters barely moved, but did rotate counterclockwise and												
		wound up a short distance to the southwest of the launch point												
P8		20	27	0		58	14	13.3		134	17	49.1		
P8		20	38	35		58	14	12.8		134	17	48.4	0.09	SE
P8		20	43	40		58	14	12.7		134	17	48.2	nil	..
P8		20	50	29		58	14	11.3		134	17	47.6	0.15	SE
P8		20	58	45		58	14	11.9		134	17	48.4	0.15	NW
P8		21	17	50		58	14	9.1		134	17	45.7	0.15	SE
		8 meters showed little movement and wound up a short distance to												
		the southeast of the launch point.												

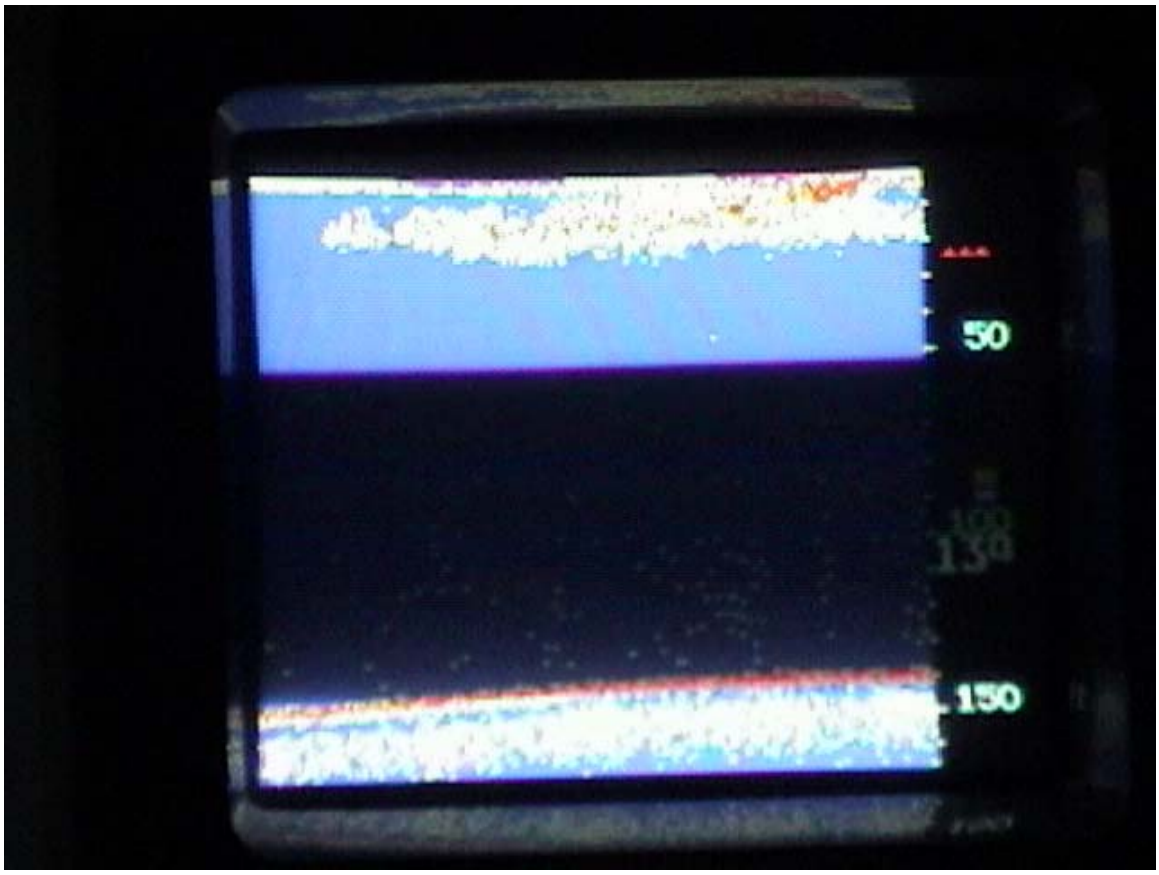


Drogue trajectories from wake of the Ryndam passage in Gastineau Channel on July 10, 2001. Ryndam course (dashed line) was to the southeast. Predicted ebb tidal currents were to the southeast. North is to the top of the page. Designations of "S" & "P" are for starboard and port side launches. Numbers following designation are for the depth of the drogue in meters. Those with no number, but just a "P" or "S" are surface drifters. See

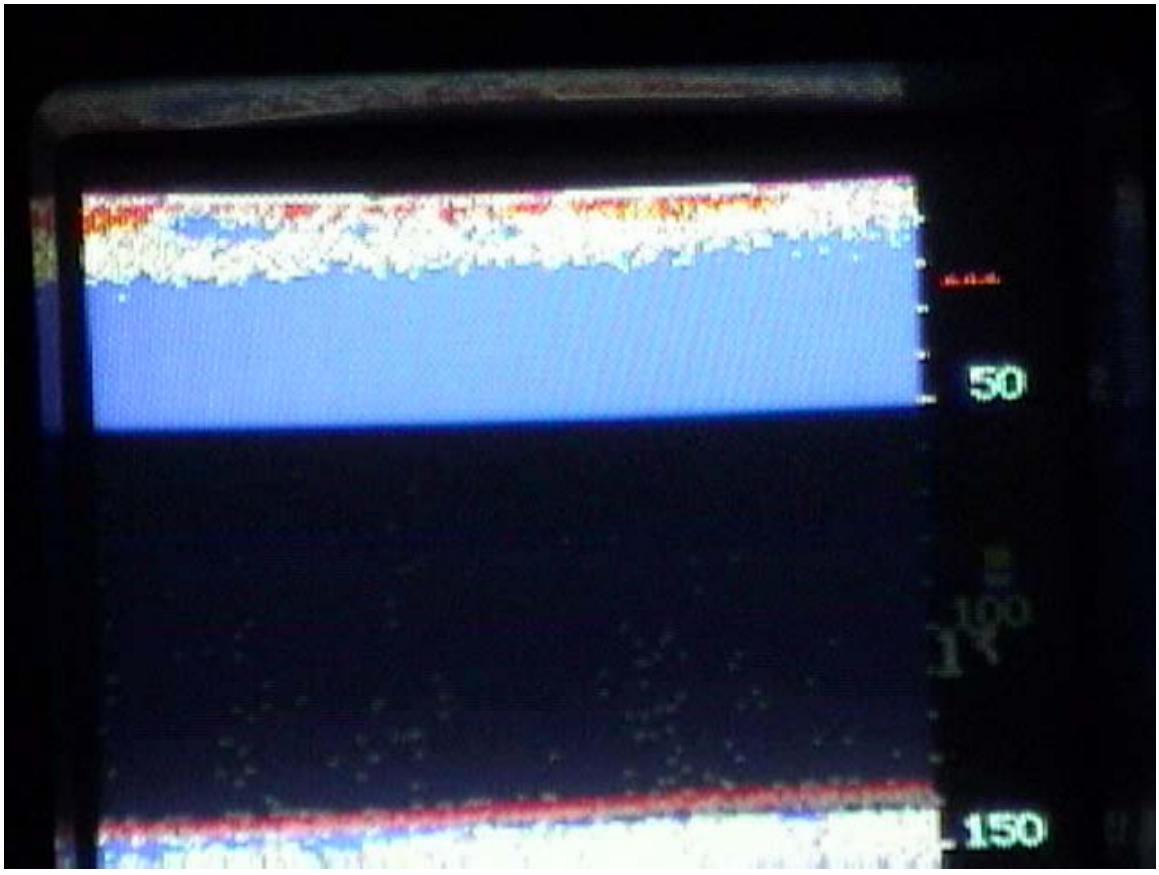
Regal Princess – **photographs of fathometer recordings of wake profile**

Approaching vessel

Bow wave

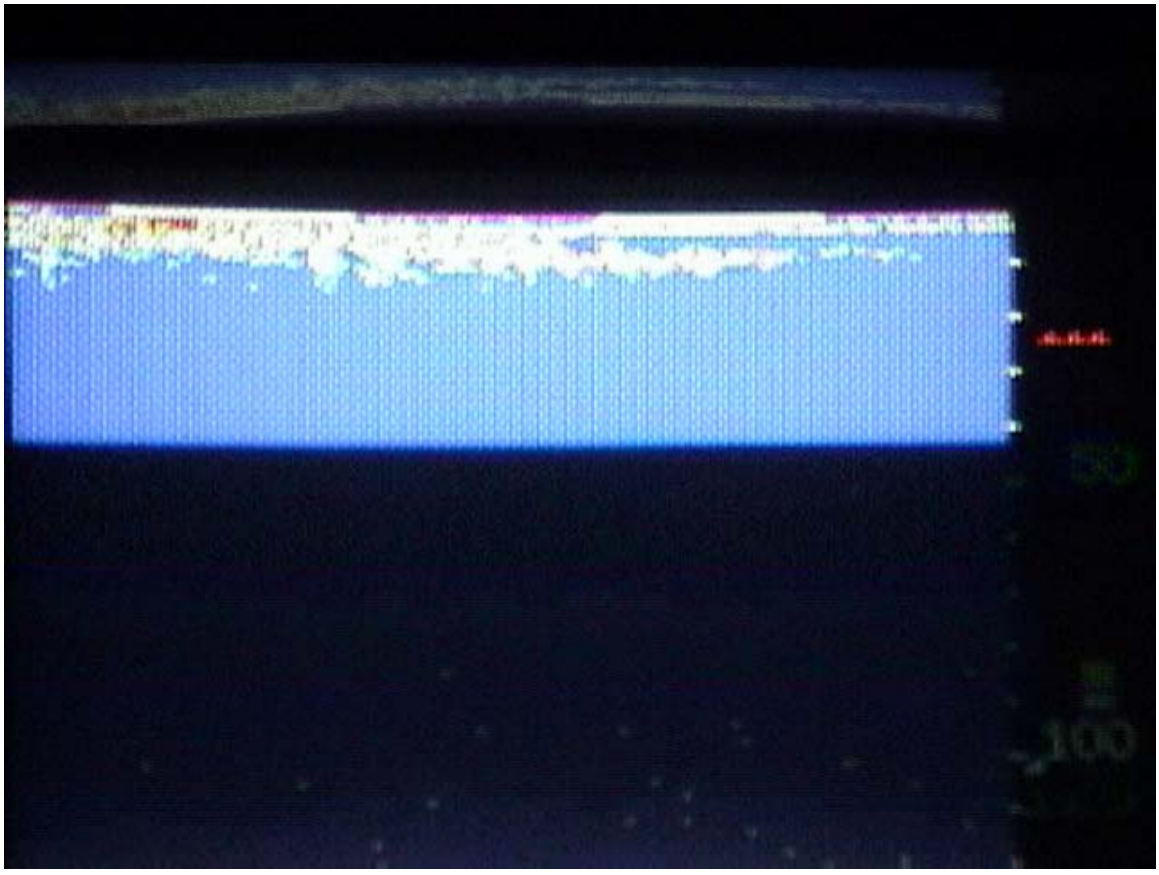


First picture



Second picture

Third picture



Fourth picture