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M E M O R A N D U M
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To: Tom Eaton

From: Lynn Singleton and Gary Bailey

Subject: Receiving Water Survey of Gig Harbor, Washington

INTRODUCTION

The Gig Harbor wastewater treatment plant (WTP), which was completed in 1975, is currently operating at a flow of .29 MGD and demand for the remaining permitted treatment capacity (to .45 MGD) is high (Monahan, 1982). Consequently, a Class II inspection of the treatment plant (Clark, 1983) and a receiving water survey were requested by the Washington State Department of Ecology (WDOE) Southwest Regional Office (SWRO) to determine if problems are occurring at present flow or may occur at the maximum permitted flow. The primary objective of the receiving water survey, with which this report deals, was to determine if the present treatment plant discharge impacts water quality in the harbor. Secondary objectives were to determine the presence and impact of raw sewage discharges to the harbor from unsewered homes, the flushing characteristics of the harbor, and to compare current water quality data with earlier data collected by Anderson (1978).

METHODS

On July 20, 1983 water samples were collected and field measurements were made at stations 1 through 5 in Gig Harbor (Figure 1) and at control stations 6 and 7 in the Narrows (Figure 2). The parameters measured and depths sampled are given in Table 1. Chemical and biological analyses of the water samples were performed by the WDOE Olympia Environmental Laboratory as per U.S. EPA methods (1979). Flow in Crescent Creek (station 10) was measured at the time of sampling by measuring velocity (Marsh-McBernie meter) and cross-sectional area. Flow in North Creek (station 9) was estimated by measuring depth and velocity in a culvert, and flow in an unnamed creek (station 8) was estimated by visual observation.

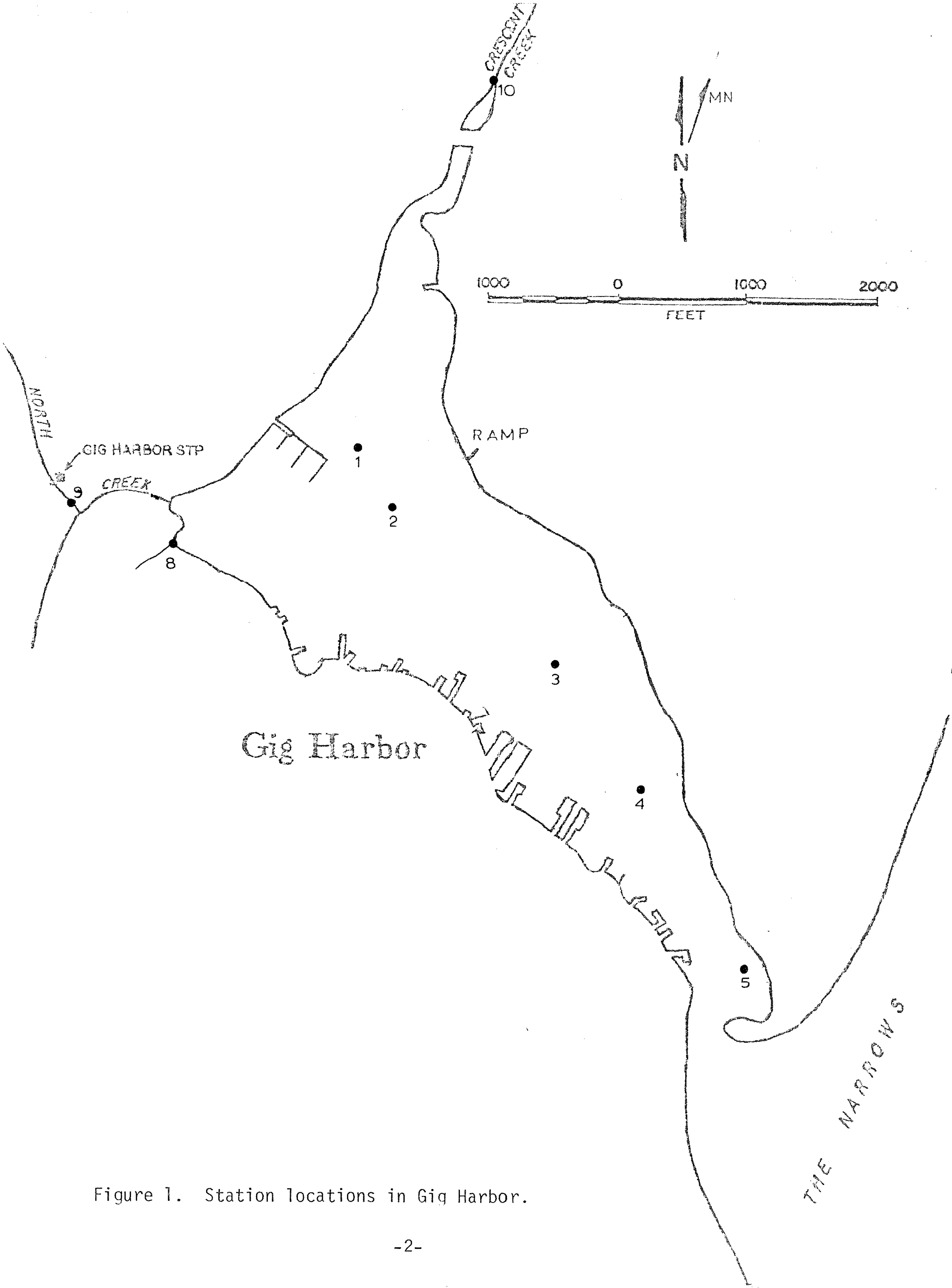

Figure 1. Station locations in Gig Harbor.

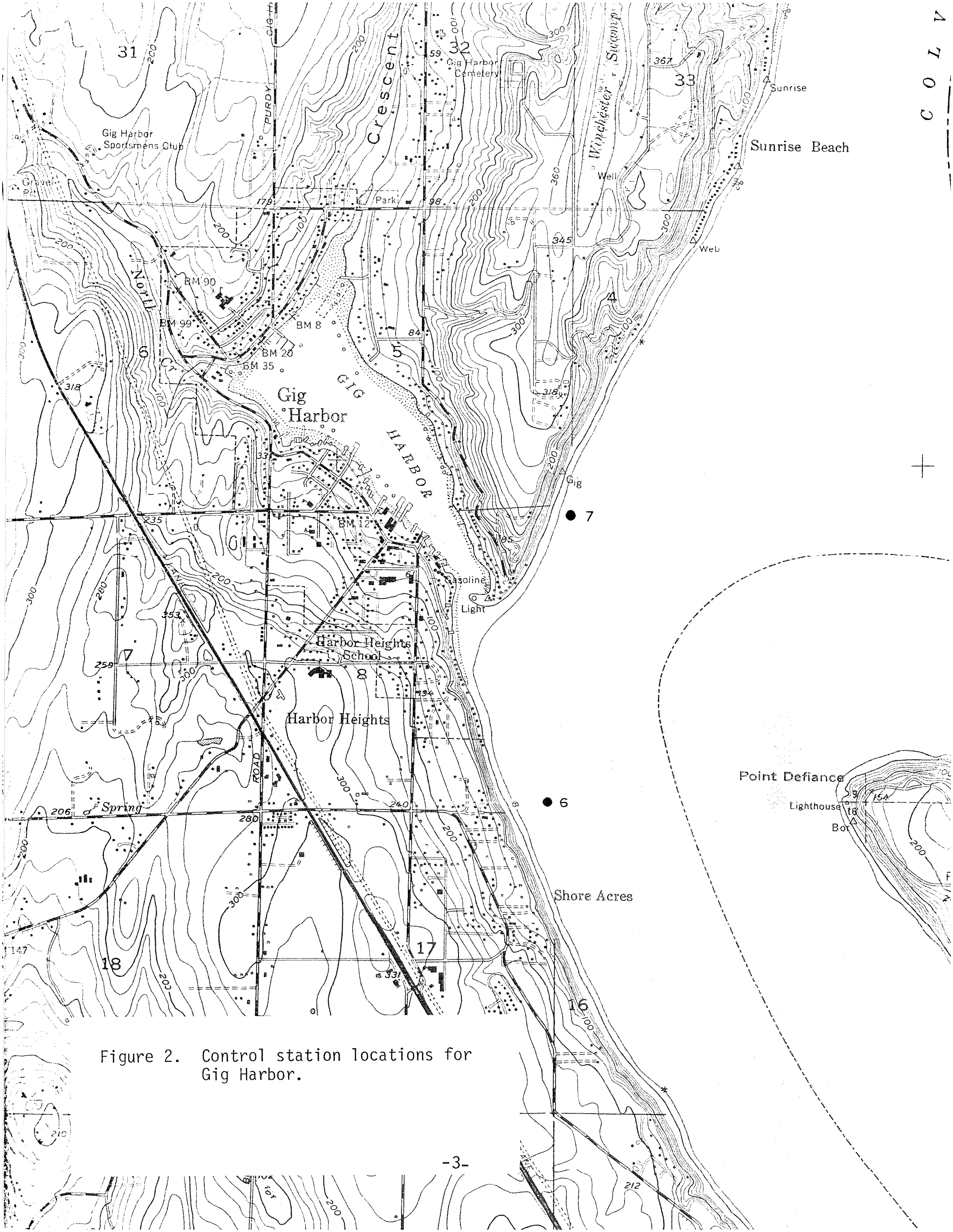

Figure 2. Control station locations for Gig Harbor.

Table 1. Parametric sampling and analysis of Gig Harbor, WA on July 20, 1983.

Parameters	Stations	Depths Sampled	Tide When Sampled[1/]
Laboratory Analyses			
pH, Spec. cond., salinity, NO_3-N, NH_3-N, O-PO_4-P, and total P	1-5	3m intervals to bottom	H, L
	6, 7	3m intervals to 12m	L
	8, 9, 10	surface	L
Fecal coliform	1-6, 9, 10	surface	H, L
	7, 8	surface	L
COD	8, 9, 10	surface	L
Field Analyses			
Dissolved oxygen	1-3	3m intervals to bottom	H, L
	4, 5	3m intervals to bottom	L
	6, 7	3m intervals to 12m	L
	8, 9, 10	Surface	L
Secchi disk	1-6	--	H, L
	7	--	L
Spec. cond., salinity, temperature	1, 2, 3, 5	2m intervals to bottom	H, L
	4	2m intervals to bottom	L
	6, 7	2m intervals to 20m	L

1/ H = high tide
L = low tide

Two drogue surveys, using the methods of Determan (1981), were conducted in July to estimate harbor flushing on a falling tide. The tides on the dates chosen for the drogue surveys represented a high exchange (July 12) and a low exchange (July 29) (Table 2). Tidal height at times between high and low slack were calculated by methods given in NOAA (1983). On July 12, two drogues suspended at one and four meters, respectively, were placed at the effluent discharge site at 0635 hours. The tidal levels on July 12 were from +11.5 feet at 0549 hours to -3.3 feet at 1313 hours (14.8 feet exchange in seven hours, 24 minutes). Drogue locations were determined by triangulation with reference points (compass) and distance measurements (rangefinder). Salinity, specific conductance, and temperature profiles (not reported) were taken at one-hour intervals concurrent with the drogue tracking, at points on a line midway between the location of the two drogues. The second drogue survey using the same design was conducted on July 29. Three drogues, two set at a depth of one meter and one at a depth of four meters, were placed at the effluent discharge at 0835 hours. The tidal levels on this date were from 9.4 feet at 0755 hours to 0.7 foot at 1435 hours (8.7 feet exchange).

During the extreme low tide on July 12, the beach areas were inspected for indications of raw sewage and/or greywater discharges.

An inspection of the discharge pipe and the bottom around the outfall was conducted on October 26 by SCUBA.

RESULTS

The most striking differences between the control stations in the Tacoma Narrows (stations 6 and 7) and the Gig Harbor stations were the reduced water clarity (measured as Secchi disk depth) and stratification (temperature, dissolved oxygen, salinity, nitrate-nitrogen) at the harbor stations.

Secchi disk measurements at the Narrows stations were 7.2 to 7.6 m compared to measurements at the harbor stations of about 2.5 m (Table 3). The influx and mixing of channel water on the rising tide was apparent at the outermost harbor station 5 by the increase in Secchi disk from 4.7 to 7.2 m. Stations farther inside the harbor showed little or no increase in Secchi disk measurements on the rising tide.

The stratification of temperature, dissolved oxygen, salinity, and nitrate-nitrogen occurred in the harbor stations at about two to three meters. The zero- to three-meter strata was of lower salinity, higher temperature, lower nitrate-nitrogen concentration and was supersaturated in dissolved oxygen. Salinity and temperature demonstrated a slightly higher stratification (lower salinity and higher temperature at the surface) at high tide than at low tide. The higher temperature was

Table 2. Tidal exchanges in Gig Harbor during two drogue surveys (7/12/83; 7/29/83) and during water quality sampling (7/20/83).

7/12/83

high tide at 0549 at 11.5 feet
low tide at 1313 at -3.3 feet
1m and 4m drogues placed at 0635 at 11.1 feet
duration of tidal fall = 7 hours 24 minutes
range of tidal fall = 14.8 feet
tide height at 1228 - -2.9 feet
tidal exchange at 1101 (1m drogue left harbor) = 11.3 feet
tidal exchange at 1228 (4m drogue left harbor) = 14 feet

7/29/83

high tide at 0755 at 9.4 feet
low tide at 1435 at 0.7 foot
three drogues placed at 0835 at 9.2 feet
duration of tidal fall = 6 hours 40 minutes
range of tidal fall = 8.7 feet

7/20/83

high tide at 1625 at 10.6 feet
low tide at 0857 at 0.2 foot
range of tidal rise = 10.4 feet

Mean annual tidal range = 8.2 feet (NOAA, 1983)

Mean 24-hour maximum tidal range for June - September 1983 = 10.8 feet

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Table 3. Field analysis for specific conductance, salinity, temperature, and dissolved oxygen in Gig Harbor (7/20/83) during low tide. Time and other values in parentheses are for high tide.

Depth (meters)	Conductance (mmhos/cm)	Salinity (ppt)	Temperature (°C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen Percent Saturation
			Station 1 1058(1625)		
0	35.5(36.3)	27.2(26.9)	15.6(17.7)	12.5(12.0)	146(146)
2	34.2(34.8)	28.2(28.7)	12.6(12.8)		
3				7.5(10.2)	84(116)
4	33.9(34.4)	28.3(29.0)	11.9(11.8)		
5.5	33.9	28.4	11.7(11.8)	7.6	83
6	(34.5)	(29.1)		(8.7)	(97)
8	(34.4)	(29.1)	(11.8)	(8.6)	(96)
	Low tide Secchi disk = 7.5 ft. = 2.3 m				
	High tide Secchi disk = 8.0 ft. = 2.4 m				
			Station 2 1035(1605)		
0	35.3(37.4)	27.3(28.2)	15.5(16.7)	12.4(12.9)	145(157)
2	34.1(35.4)	28.4(29.0)	12.2(12.8)		
3				8.9(9.8)	98(110)
4	33.9(34.8)	28.4(29.3)	11.7(12.2)		
6	33.9(34.7)	28.6(29.1)	11.7(11.8)	7.9(8.7)	87(96)
7.5	33.9	28.5	11.6	7.2	79
8	(34.6)	(29.3)	(11.8)		
9				(8.0)	(88)
10	(34.6)	(29.3)	(11.7)		
	Low tide Secchi disk = 8.0 ft. = 2.4 m				
	High tide Secchi disk = 8.5 ft. = 2.6 m				
			Station 3 1014(1643)		
0	35.4(36.0)	27.3(27.0)	15.5(16.8)	12.3(13.0)	144(159)
2	33.9(34.9)	28.2(28.8)	12.2(12.5)		
3				10.0(10.0)	111(111)
4	33.8(34.6)	28.4(29.0)	11.8(11.9)		
6	33.8(34.5)	28.5(28.8)	11.6(12.2)	8.0(8.5)	87(94)
8	33.8(34.5)	28.5(29.2)	11.6(11.8)		
9				8.2(8.5)	89(95)
10	33.8(34.5)	28.5(29.0)	11.6(11.9)		
12	(34.5)	(29.2)	(11.6)	(8.1)	(89)
	Low tide Secchi disk = 9.5 ft. = 2.9 m				
	High tide Secchi disk = 9.0 ft. = 2.7 m				
			Station 4 0954(1700)		
0	35.4	27.8	14.9	12.1	140
2	34.3	28.5	12.2		
3				10.7	118
4	34.2	28.5	12.1		
6	34.2	28.6	11.8	8.4	93
8	34.0	28.6	11.6		
	Low tide Secchi disk = 9.5 ft. = 2.9 m				
	High tide Secchi disk = 14.0 ft. = 4.3 m				

Table 3 - Continued.

Depth (meters)	Conductance (mmhos/cm)	Salinity (ppt)	Temperature (°C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen Percent Saturation
			Station 5 0939(1710)		
0	34.5(34.6)	27.8(28.5)	13.5(12.9)	10.4	118
2	33.7(34.7)	28.4(28.9)	11.7(12.3)		
3				8.0	88
4	33.7(34.5)	28.5(29.0)	11.6(11.9)		
5.5	33.8	28.5	11.6	7.9	87
6	(34.5)	(29.0)	(11.8)		
8	(34.6)	(29.2)	(11.8)		
	Low tide Secchi disk = 15.5 ft. = 4.7 m				
	High tide Secchi disk = 23.5 ft. = 7.2 m				
			Station 6 0919		
0	33.4	28.2	11.5	7.6	82
2	33.5	28.5	11.5		
3				7.5	81
4	33.5	28.3	11.5		
6	33.6	28.4	11.5	7.5	81
8	33.5	28.4	11.4		
9				7.5	
10	33.6	28.5	11.4		
12	33.7	28.6	11.4	7.5	
14	33.7	28.6	11.4		
16	33.7	28.6	11.4		
18	33.7	28.5	11.4		
20	33.7	28.5	11.4		
	Low tide Secchi disk = 25.0 ft. = 7.6 m				
	High tide Secchi disk = 25.0 ft. = 7.6 m				
			Station 7 0841		
0	34.0	28.7	11.6	7.7	85
2	34.1	28.8	11.6		
3				7.7	85
4	34.1	28.9	11.5		
6	34.0	28.7	11.6		
8	33.9	28.7	11.6		
9				7.6	84
10	33.8	28.7	11.5		
12	33.8	28.6	11.5	7.6	83
14	33.8	28.6	11.7		
16	33.8	28.6	11.4		
18	33.8	28.7	11.5		
20	33.8	28.7	11.5		
	Low tide Secchi disk = 23.5 ft. = 7.2 m				

probably normal warming as the day progressed. At depths greater than three meters, chemical and physical measurements at all harbor stations were similar to those in the Narrows, the source of any exchange water in the harbor.

There were no measurable increases in nutrients (N and P) attributable to the WTP discharge because the apparent high primary production was causing nutrient (NO_3-N) depletion in the surface water. The high primary (algal) production in the harbor water was evidenced by the low Secchi disk and the dissolved oxygen supersaturation at the harbor stations (Table 3).

Fecal coliform numbers at all harbor stations were low (<1 to 4) and no difference in counts was observed between high and low tides (Table 4). The stream stations had higher coliform numbers than the harbor stations. The coliform counts on Crescent Creek (220-250 col/100 mL) exceeded Class A standards, probably due to cattle which have access to the stream near the sampling station.

No raw sewage discharges to Gig Harbor were found during the -3.3 foot tide. Three pipes were found on the northeast shore that may have at some time conveyed sewage, but now appear inactive and are filled with sand or are broken. A possible discharge site on the town (southeast) side of the harbor was located for us by the Gig Harbor WTP operator. The reported discharge was not observed; however, it is supposed to be located on the bank under a dense growth of blackberry bushes. An extremely small flow was noted (≃ 100 mL/sec) emerging from the blackberries, but no typical smell or evidence of tissue was observed. No flow was noted on several subsequent visits to the site.

Drogue Surveys

During the high tidal exchange on July 12 (see Table 2 for a summary of tides at the three sampling dates), the one-meter drogue passed the harbor mouth 4 hours 21 minutes from the time of placement and after 11.3 feet of tidal fall. The path of the one-meter drogue tended toward the northeasterly shore while the four-meter drogue tended to move down the center of the harbor (Figure 3). The average velocity of the one-meter drogue was 19 ft/min inside the harbor and 132 ft/min after passing the harbor mouth. The four-meter drogue became grounded after 5 hours 35 minutes of travel (13.4 ft/min) and the depth of the drogue was changed to two meters. The drogue became grounded again 18 minutes later at the harbor mouth and was retrieved.

On July 29 during the low exchange, one of the one-meter drogues traveled 1000 feet toward the harbor mouth in 6 hours and 8.7 feet of tidal fall. The other one-meter drogue traveled 1000 feet to the docks on the southwest shore and was retrieved after 3 hours 58 minutes. The four-meter

Table 4. Laboratory-determined water quality data for Gig Harbor, Washington, at low and high tide (July 20, 1983). High tide values are given in parentheses. Station locations are given in Figures 1 and 2. Nitrite-nitrogen concentrations were below detectable limits (0.01 mg/L) at all stations.

Depth (m)	pH (units)	Spec. Cond. (mmhos/cm)	Salinity (ppt)	NO_3-N (mg/L)	NH_3-N (mg/L)	O-PO_4-P (mg/L)	Tot. P (mg/L)	Fecal Coli. (col/100 mL)	COD (mg/L)
				Station 1					
0	8.3(8.4)	38.1(38.6)	28.2(27.4)	<0.01(<0.01)	0.01(0.09)	0.02(0.02)	0.04(0.04)	≈1(≈1)	
3	7.9(8.0)	39.9(42.1)	29.5(29.5)	0.08(0.10)	0.04(0.02)	0.05(0.03)	0.06(0.05)		
6	7.9(8.0)	39.3(40.9)	29.6(29.6)	0.16(0.16)	0.02(0.01)	0.04(0.04)	0.06(0.05)		
9	(8.0)	(40.8)	(29.6)	(0.17)	(0.02)	(0.04)	(0.05)		
				Station 2					
0	8.2(8.4)	38.7(39.2)	28.7(28.4)	0.01(<0.01)	0.02(0.01)	0.02(0.02)	0.06(0.04)	≈2(<1)	
3	8.0(8.0)	39.5(40.5)	28.5(29.5)	0.14(0.11)	0.02(0.01)	0.03(0.03)	0.06(0.05)		
6	7.9(8.0)	39.9(40.8)	29.6(29.6)	0.20(0.14)	0.02(0.01)	0.04(0.03)	0.06(0.06)		
9	7.9(7.9)	40.2(41.2)	29.6(29.6)	0.19(0.18)	0.04(0.02)	0.04(0.04)	0.06(0.06)		
				Station 3					
0	8.3(8.4)	39.7(39.5)	29.5(27.8)	<0.01(<0.01)	0.01(0.08)	0.02(0.03)	0.06(0.06)	<1(≈4)	
3	8.0(8.0)	40.4(41.2)	29.6(29.5)	0.12(0.10)	0.01(0.01)	0.04(0.04)	0.06(0.05)		
6	7.9(7.9)	41.9(42.5)	28.5(29.6)	0.17(0.17)	0.02(0.01)	0.04(0.03)	0.06(0.05)		
9	7.9(8.0)	41.4(41.4)	29.6(29.6)	0.18(0.18)	0.02(0.02)	0.04(0.03)	0.07(0.06)		
12				(0.18)	(0.02)	(0.04)	(0.06)		
				Station 4					
0	8.2	39.1	29.5	<0.01	0.02	0.02	0.05	<1(≈1)	
3	8.1	40.3	29.6	0.08	0.01	0.03	0.07		
6	8.0	39.8	28.9	0.14	0.02	0.04	0.06		
				Station 5					
0	8.1	39.8	29.6	0.04	0.02	0.02	0.06	≈1(<1)	
3	8.0	39.6	29.5	0.18	0.02	0.04	0.06		
6	7.9	39.8	29.3	0.16	0.02	0.03	0.06		
				Station 6					
0	7.8	40.4	28.6	0.09	0.03	0.06	0.06	<1(<1)	
3	7.9	40.1	29.6	0.20	0.02	0.04	0.06		
6	7.9	41.1	29.6	0.18	0.02	0.03	0.06		
9	7.9	42.4	29.6	0.20	0.02	0.04	0.06		
12	7.9	41.6	29.6	0.20	0.02	0.04	0.06		
				Station 7					
0	7.9	40.5	29.6	0.20	0.03	0.04	0.06	<1	
3	7.9	40.5	29.6	0.18	0.02	0.04	0.06		
6	7.9	40.3	29.6	0.18	0.02	0.04	0.06		
9	7.9	40.2	29.6	0.20	0.02	0.04	0.06		
12	7.9	40.4	29.6	0.20	0.02	0.04	0.04		
				Station 8 Flow ≈ .02cfs D.O. = 9.6					
--	7.5	0.198	0.4	0.17	0.18	0.04	0.04	21	24
				Station 9 Flow ≈ .65 cfs D.O. = 11.1					
--	7.9	0.118	0.1	0.26	0.01	0.05	0.06	≈14(24)	14
				Station 10 Flow ≈ 3.7 cfs D.O. = 10.6					
--	7.7	0.115	0.1	0.32	0.02	0.02	0.04	220(250)	24

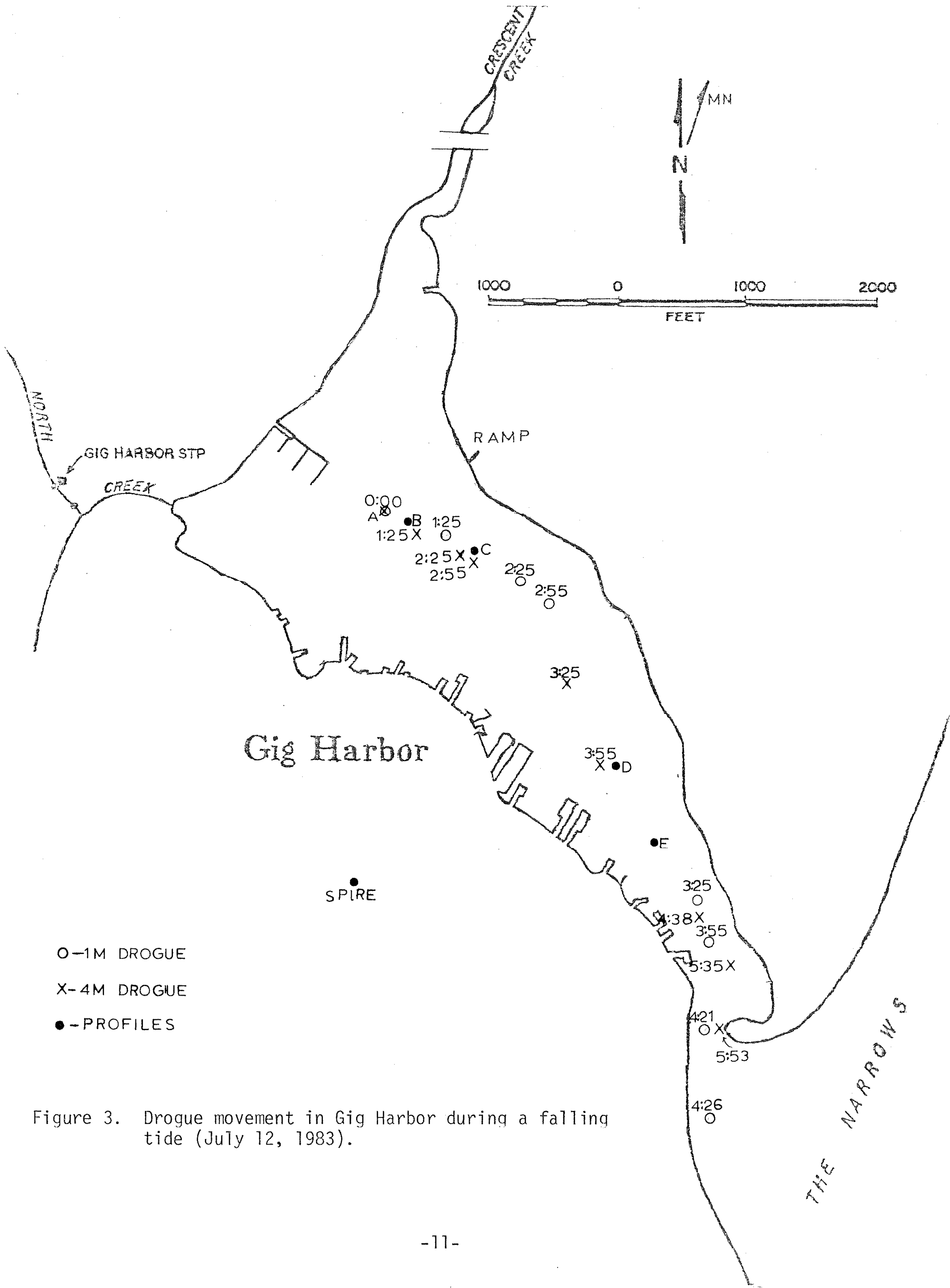

Figure 3. Drogue movement in Gig Harbor during a falling tide (July 12, 1983).

drogue traveled in a circular route and reached a maximum distance of 370 feet from the discharge point after 5 hours 30 minutes (Figure 4).

The drogue studies indicated that about 11.3 feet of tidal fall are required for complete flushing of the surface waters out of Gig Harbor. An examination of the tidal record (NOAA, 1983) for June through September, the time of highest algal growth, indicates that an 11.3-foot or greater tidal exchange occurs on 48 of 122 days or 39 percent of the days. The tidal record also indicates that an 8.7-foot tidal fall or less occurs on 12 percent of the summer days. The drogue studies indicated on these days there is very poor flushing of the harbor. Tidal heights are periodic such that high and low exchanges occur for three to six consecutive days.

Although the harbor appears enriched by the treatment plant discharge, there is no measurable increase of nutrients. High primary production in the summer is common in sheltered harbors of the Puget Sound area even where nutrient input is minimal (Yake, 1983), so it is difficult to determine the amount of primary production attributable to the treatment plant discharge.

One criterion suggested for determining if estuarine waters are eutrophic is the concentration of phosphorus in the waters. Concentrations of inorganic phosphorus above 0.08 mg/L in the winter and 0.05 mg/L in the summer are an indication of eutrophic conditions (Ketchum, 1969). Gig Harbor waters contain inorganic phosphorus concentrations of 0.14 mg/L in the winter (Anderson, 1978) and 0.03 mg/L in the summer. The relation between phosphorus concentration in estuarine waters and eutrophic conditions may be a valid observation but it implies that phosphorus is the limiting nutrient. In Gig Harbor and apparently most temperate marine waters, the limiting nutrient is nitrogen (Ryther and Dunstan, 1971; Webb, *et al.*, 1979). In freshwater, nitrogen rarely becomes a limiting factor to primary production because of the ability of cyanophytes (blue-green algae) to fix atmospheric and dissolved nitrogen. In temperate marine waters, however, cyanophytes do not comprise a significant portion of the planktonic algae (Fogg, 1973). If kept in perspective, the phosphorus relationship is an indicator for consideration.

The analytical technique discussed by the U.S. EPA (1973) for predicting nutrient overloading in marine waters is to determine the loading which causes oxygen depletion in the bottom waters. This technique utilizes the elemental ratios of living marine populations (plant and animal) and the changes caused by the growth of these populations. These ratios by weight are:

$$\frac{\Delta O}{138} : \frac{\Delta C}{40} : \frac{\Delta N}{7.25} : \frac{\Delta P}{1}$$ (Redfield, *et al.*, 1963).

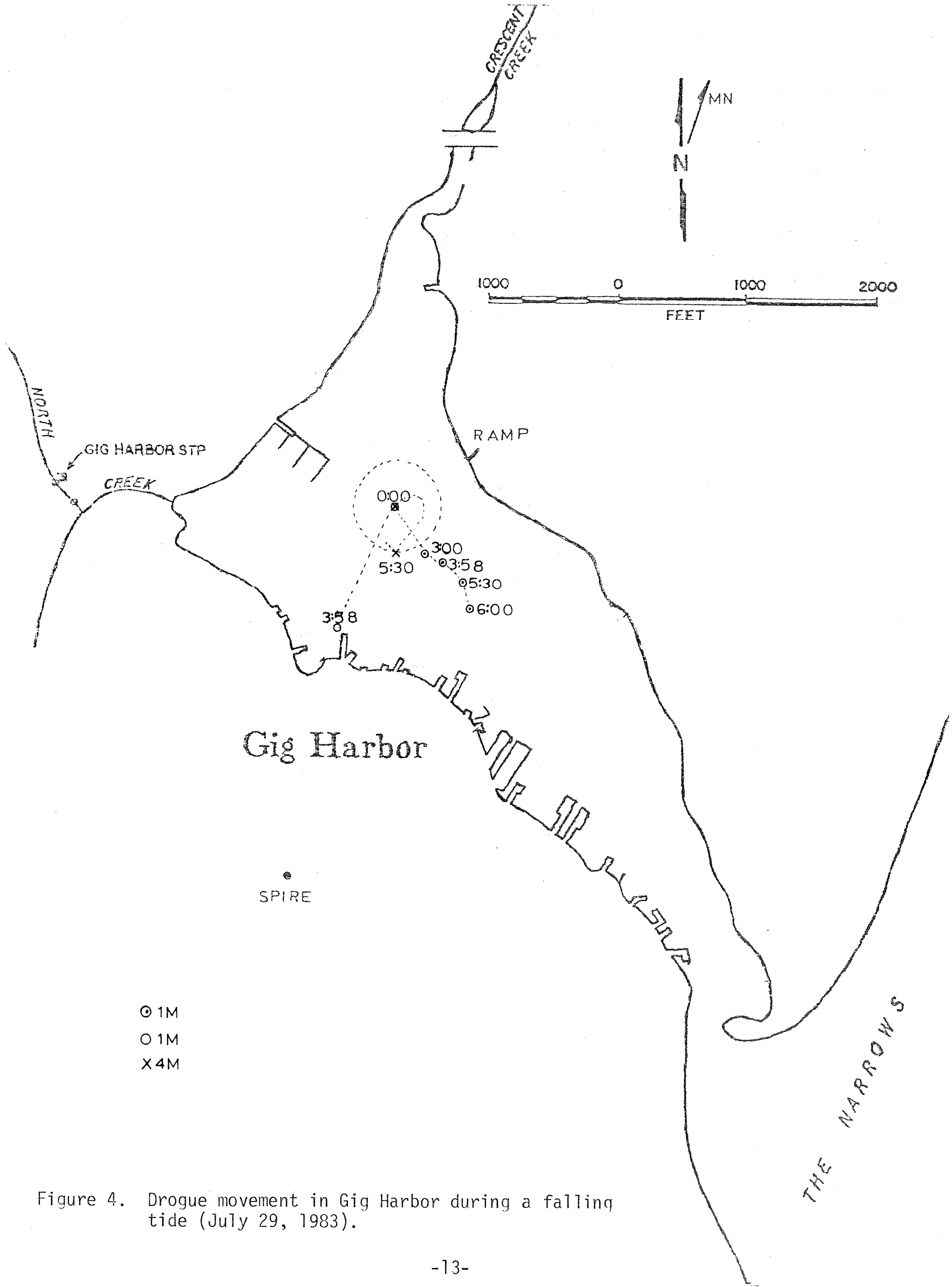

Figure 4. Drogue movement in Gig Harbor during a falling tide (July 29, 1983).

According to these ratios, the addition of one part P (by weight) requires 138 parts O to be assimilated (if other elements are not limiting). In a simple, closed system, the addition of 50 µg/L P and 362.5 µg/L N would require 6.9 mg/L oxygen for assimilation. In a real system such as Gig Harbor, tidal flushing carries away part of the organic matter produced, a portion of the organic matter produced (algae) also produces oxygen during the day, nutrients are present in the inflowing water, oxygen may be replenished by atmospheric exchange or inflowing water, and the nutrient inflow is accompanied by an oxygen demand (BOD).

The nutrient loading to Gig Harbor from the wastewater treatment plant (data from Clark, 1983) and inflowing creeks (low flow) is 6.2 kg P and 19.0 kg N per day. The wastewater treatment plant discharge forms the major portion of this loading (5.9 kg P; 15.5 kg N). The 6.2 kg P/day requires 45 kg N and 856 kg O per day. The nitrogen inflow is less than required for complete assimilation of the phosphorus indicating that N would be the limiting nutrient if replenishment from tidal exchange water is ignored. The oxygen requirement for assimilation of the nitrogen loading is 362 kg/day.

The total nutrient loading to Gig Harbor can be approximated by determining the amount of water exchanged. The mean annual tidal cycle in Gig Harbor is 8.2 feet (NOAA, 1983). The approximate volume of Gig Harbor from 0.0 to 8.2 feet is 2.23×10^6 m^3 (area estimate from USGS topographical map and assuming vertical banks between 0.0 and 8.2 feet). The average daily exchange volume is $(2.23 \times 10^6\ m^3) \times 2 = 4.47 \times 10^6\ m^3$. The daily freshwater inflow from the sewage effluent and creeks during the summer is 11,733 m^3 or about .3 percent of the daily exchange volume; thus, the majority of the inflowing water is from the Narrows. The phosphorus and nitrogen loading from the exchange water is 179 kg P and 983 kg N based on the July 20 data. The loading from the effluent is about 3 percent of the total phosphorus loading and 2 percent of the total N loading.

This type of loading estimate assumes complete horizontal and vertical mixing in the harbor and if it were so, water quality in the harbor would be very similar to that in the Narrows. The freshwater inflows, including the WTP effluent, because they are less dense tend to rise to the surface where algae growth is the highest. In addition, complete vertical mixing occurs only near the harbor mouth as evident from the data collected on July 20.

The data collected during this study show no clear evidence of oxygen consumption in the bottom waters. Bottom waters at station 2 (outfall site) at low tide were 79 percent saturation compared to 81 to 85 percent for control stations (Table 3), but other harbor stations were of equal or slightly higher saturation than control stations. If it is assumed that Gig Harbor waters are in dynamic equilibrium with the current nutrient input and BOD, but that no excess capacity exists, then the additional nutrient loading to remain within the regulatory limit for 0.2 mg/L oxygen man-caused degradation can be calculated as:

$$0.2 \text{ mg/L O} \div 19 = .01 \text{ mg/L N}$$

where 19 is $\Delta O \div \Delta N$

$$.01 \text{ mg/L N/day} \times 5.855 \times 10^5 \text{ m}^3 = 5.85 \text{ kg N/day}$$

where 5.855×10^5 m^3 = volume of water in Gig Harbor of 18 feet or deeper

This assumes that the nutrient loading and BOD from the WTP goes to the upper 8.2 feet, the BOD causes no oxygen deficit because of the oxygen supersaturation, the nutrients cause algae growth which then decays in the bottom waters, and that the bottom waters are flushed uniformly and daily. The tidal record for the summer, however, indicates that there are sequences of three consecutive low-exchange days. The 5.85 kg N/day is divided by three to arrive at 2.0 kg N/day. This 2.0 kg N/day represents a 13 percent increase over the current WTP loading, but is smaller than the loading expected if the plant was operating at the permit limit of .45 MGD.

A comparison of current and 1978 data (Table 5) shows little change except for those parameters that would normally be expected to vary by season. The numbers of fecal coliform bacteria continue to be low at all harbor stations and high in Crescent Creek. We did not observe an increase in coliform numbers at high tide as noted by Anderson (1978). Nutrients (N and P) would be expected to be lower in July than in March and higher algal production causes supersaturation of oxygen in the surface water at the inner stations.

SCUBA inspection revealed that the effluent diffuser is a T with two six-inch orifices on a north-south orientation. The ports are about six feet apart and about three feet from the bottom. There is a concrete ledge projecting about two feet above the bottom and about two feet east of the diffuser. The effluent line to the diffuser was not visible. There were no apparent sludge deposits near the diffuser and the quantity and type of biota near the diffuser appeared no different than the biota 1000 feet away from the diffuser.

CONCLUSIONS

There is no clear evidence of significant water quality impact from the current Gig Harbor WTP discharge; however, the poor flushing characteristics at low exchange and the high primary production in the summer signal a potential problem if nutrient loadings increase. One criterion of eutrophication, based on phosphorus concentrations, indicates Gig Harbor is borderline.

Table 5. A comparison of some water quality data at equivalent stations (surface only) in Gig Harbor for 1978 and 1983. Values are for low tide and (high tide).

Station Number		F. Coli. (col/100 mL)		NO_3-N (mg/L)		Total P (mg/L)		Dissolved Oxygen Percent Saturation	
3/01/78	7/20/83	3/01/78	7/20/83	3/01/78	7/20/83	3/01/78	7/20/83	3/01/78	7/20/83
6	1	1(≈26)*	≈1(≈1)	.38(.38)	<.01(<.01)	.09(.08)	.04(.04)	84(86)	146(146)
9	2	1(≈2)	≈2(<1)	.39(.39)	.01(<.01)	.07(.26)	.06(.04)	86(89)	145(157)
12	3	1(≈7)	<1(≈4)	.39(.39)	<.01(<.01)	.07(.10)	.06(.06)	86(85)	144(159)
14	4	1(≈15)	<1(≈1)	.39(.39)	<.01	.07(.08)	.05	89(87)	140
16	5	<2(≈42)	≈1(<1)	.39(.39)	.04	.09(.07)	.06	89(87)	118
18	6	(40)	<1(<1)	.40(.39)	.09	.07(.07)	.06	88(88)	82
19	10	(400)	220(250)	(.59)	.32	(.04)	.04	--	--
20	9	(≈7)	≈14(24)	(.51)	.26	(.04)	.04	--	--

*The approximation sign (≈) indicates the plate counts were too high or too low for good statistical accuracy.

It is very difficult to predict the nutrient loading that will cause a significant oxygen reduction in the bottom waters. If it is assumed that Gig Harbor is at the boundary of assimilative capacity, based on the phosphorus criterion, then an increased nutrient loading of 13 percent may cause a 0.2 mg/L reduction of dissolved oxygen in the bottom waters. A 0.2 mg/L reduction of dissolved oxygen is barely perceptible given the precision of the analysis, temporal, and spatial variation and is probably of no biological significance, but <u>does</u> signal the point at which the assimilative capacity is reached.

RECOMMENDATIONS

It is recommended that additional water quality surveys be conducted when the WTP reaches flows of .33, .39, and .45 MGD, assuming that nutrient concentrations remain relatively constant with increasing discharge. These surveys should be conducted in July or August on the third day of a series of low tidal exchange days. The surveys should include Secchi disk, surface chlorophyll *a*, and measurements at 2- or 3-meter intervals of temperature, dissolved oxygen, pH, salinity, nitrate-nitrogen, nitrite-nitrogen, ammonia-nitrogen, total phosphorus, and orthophosphorus. Measurements should be made at the outfall (station 2 of this study) and at a Narrows (control) station. When a measurable dissolved oxygen reduction is detected, a more precise analysis of the assimilative capacity of Gig Harbor should be conducted.

LRS:GB:cp

Attachment (references)

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