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STATE OF
WASHINGTON

Dixy Lee Ray
Governor

DEPARTMENT OF ECOLOG
7272 Cleanwater Lane, Olympia, Washington 98504

MEMORANDUM

October 14, 1980

To: Dick Cunningham

From: Tim Determan TD

Subject: Review of Proposals for Discharge of Treated STP Effluent into Sinclair Inlet

INTRODUCTION

At your request, I have reviewed several proposals for discharge of treated effluent into Sinclair Inlet. These proposals, as we understand them, are as follows:

> Proposal I - Combine sewage from Bremerton and Manette and treat at Charleston; use primary treatment and discharge at 10 MGD through existing outfall. Combine sewage from Port Orchard and Retsil, secondary treatment and discharge of 2 MGD at Retsil.
>
> Proposal II - Combine sewage from Bremerton, Manette, Port Orchard, and Retsil and treat at Charleston; primary treatment and discharge of 12 MGD.

Except for the level of sewage treatment, these proposals are similar to those proposed in EPA, 1978 (Figure 1).

The purpose of our review was to predict the probable environmental impact of these proposals on the receiving waters of Sinclair Inlet The review process consisted of examination of DOE-generated water quality data and Class II inspection reports from Charleston and Retsil STP's and review of facilities plans and environmental impact statements for those plans. Original research was limited to application of the Puget Sound physical model located at the Department of Oceanography, University of Washington. We undertook no field efforts due to severe time restraints.

SUMMARY AND RECOMMENDATIONS

Two wastewater treatment and disposal proposals for communities situated along Sinclair Inlet were Evaluated. Proposal I (Bremerton and Manette diverted to Charleston; Port Orchard diverted to Retsil) calls for 10 MGD and 2 MGD to be discharged at two sites. Proposal II calls for diverting wastes from all five existing sites (12 MGD) to Charleston. The two siting possibilities appear to be about the same in terms of water quality in Sinclair Inlet. There are dilution, flushing, and dispersion problems either way.

Since both proposals are about equal in terms of expected impacts, and are the only two options available, the main question is the degree of treatment required. EPA (1978) characterized the Charleston site as only fair for disposal of even secondarily-treated wastes due to poor flushing and disperson characteristics of the inlet. Our limited assessment agrees with this finding. Proposals I and II both call for primary treatment which would permit significantly larger loadings of BOD_5, suspended solids, and fecal coliform than desired. These levels will probably cause localized violations of water quality standards and seasonal oxygen demand problems. In addition, the larger amounts of chlorine needed to disinfect the primarily-treated wastewaters could pose toxic problems. Dissolved nutrients in the effluents of secondary and primary STP's are not significantly different. Therefore, considering the evidence, secondary treatment as a minimum should be required of any discharge into Sinclair Inlet.

ENVIRONMENTAL SETTING (EPA, 1978)

Sinclair Inlet is a shallow bay approximately 1.2 km (0.75 mile) wide and 8 km (5 miles) long. Mean lower low water (MLLW) depth varies from 6 to 7.6 m (20 to 25 feet) at the west end to over 15.2 m (50 feet) at the east end of the inlet.

In order to study water quality and mixing characteristics, two models have been used - a mathematical ecological model applied by EPA and the University of Washington Puget Sound physical model. Both models have certain limitations that require appropriate allowances in use of results.

The currents in Sinclair inlet were studied in the Puget Sound physical model and verified by field data to test model accuracy. Currents were shown to be weak (0.2 to 0.3 knot) with a slow oscillating bi-directional flow giving a net transport to the east. A drogue study was performed in July 1975 (CH_2M-HILL, 1976b). The drogues, which were suspended at different depths, remained relatively stationary, although each drogue moved in a different direction (see Figure 2). An average speed of 0.08 knot was determined. The divergent flows with depth suggested water column stratification. Further evidence of stratification can be seen in temperature profiles recorded by the University of Washington during late summer (URS 1976). Stratification limits considerably the potential for assimilating waste discharges.

In order to quantitatively evaluate the effects of the Charleston discharge on Sinclair Inlet, we conducted a study using the Puget Sound model at the University of Washington Department of Oceanography. We were assisted by Senior Oceanographer, John Lincoln, who designed and built the model. Dye was continuously injected into Sinclair Inlet waters at Charleston at model rates of 3 MGD and 10 MGD in two experiments. Tides were simulated for the period of August 15 through August 31. Photographs were taken at higher high waters (HHW) of each tide cycle. An additional 3 MGD continuous discharge was injected at the Retsil site and photographs were taken. Despite inaccuracies inherent in such a model application, review of the photographs clearly demonstrate the lack of flushing in Sinclair Inlet. After each two-week interval, dye could be observed dispersed throughout all of Sinclair Inlet. Minor losses of dye were observed after the first week at the eastern edge of the dye cloud. The dye cloud at Retsil was dispersed coastwise with dye-loss occurring along the northerly edge. The data suggested the effluents from both facilities would eventually mix in an area of Sinclair Inlet seaward of Port Orchard.

The weak tidal currents suggest a low rate of tidal exchange in the upper reaches of Sinclair Inlet. Quantitative data on the hydrodynamics of Sinclair Inlet are limited but comparisons were made with the San Francisco Bay system which has been extensively studied. Tidal inflow into lower Port Orchard and Sinclair Inlet is mainly through Rich Passage. It was assumed that at the southern tip of Bainbridge Island, tidal exchange is 25 percent. (Tidal exchange is defined as the percentage of water volume brought in with the tide that is new water. The remainder of the water is returned from previous tidal cycles.) At Charleston (Figure 3), tidal exchange is estimated at 2.5 percent. Since there are two tide cycles per day, five percent of the water is exchanged each day. If Sinclair Inlet averages 12 m (40 feet) in depth and the average change in tide height is 2.4 m (8 feet), the change in volume between high and low tides would be about 20 percent of the low-tide inlet volume. Thus the volume of water exchanged each day in Sinclair Inlet is (5% x 20%) or one percent of the volume of Sinclair Inlet.

It should be borne in mind that these are estimates only, based on application of models. Effects due to field factors such as wind and built-in errors in modelling could cause errors in prediction. Nevertheless, these estimates are felt to be a reasonable idea of what to expect in terms of dilution and flushing in the inlet.

Discharges into any water body are undoubtedly affected by wind in addition to current and tide. Rainfall may affect surface runoff, stream flow, and characteristics of the sewage if significant infiltration into the sewer system occurs. Figure 4 shows wind data for Sinclair Inlet. Figure 5 shows annual rainfall. In general, southwesterly winds prevail in fall and winter, while summer and autumn months are characterized by northwesterly winds.

BIOLOGICAL FEATURES AND LAND USE

Biological data are meager on conditions specifically in Sinclair Inlet. No extensive inventories have been made in the vicinity of the currently functioning outfalls. Table 1 shows a summary of probable marine organisms and known usages prepared by URS (1976). In waters of Sinclair Inlet less than 10 m (30 ft) deep, the Washington clam, the small clams (Axinopsis serricatus) and Psephidia lordi are found. Some aquaculture resources are located along the southern shore of Sinclair Inlet (Figure 6). Tables 2 and 3 identify habitat types and vertical zonation within the study area. Water Resources Engineers (1975) applied an ecologic model in order to estimate phytoplankton production in Sinclair Inlet and nearby areas. Sinclair Inlet shows high biomass values in spring during the annual bloom. Summer values are lower due to grazing by zooplankton. Bloom biomass levels are higher in the upper reaches of Sinclair and Dyes inlets relative to other areas due to correspondingly higher levels of nutrients available year-round. As in other areas of Puget Sound, phytoplankton production is light-limited during the winter, while it is nitrogen-limited during bloom periods (Figure 7).

Current land-use patterns are shown on Figure 8. There are Conservancy zones located within the Gorst Estuary and one mile west of Port Orchard. Urban, semi-rural, and rural uses share the shoreline at Sinclair Inlet.

WATER QUALITY

EPA (1978) characterizes the water quality in Sinclair Inlet as showing seasonally high coliform and nutrient and low dissolved oxygen levels. During the spring bloom, nutrient levels drop. Dissolved oxygen levels rise during the spring and summer to saturation levels. However, during periods of algal die-off, decomposers consume dissolved oxygen, resulting in oxygen depletion. During these periods, discharge of additional organic materials such as primarily treated or untreated sewage becomes a risk for marine systems of limited circulation since anoxic conditions could result and cause the suffocation of benthic organisms and territorial fish.

Sinclair Inlet currently carries two Water Quality Standards classifications. Waters west of 122°37'W (Retsil) are classified as A waters (DOE, 1980). Waters to the east are classified as AA waters. Table 4 shows total coliform levels in nearshore waters of Sinclair Inlet. Those locations followed by asterisks are isolated from known STP discharges. The median values at these stations appear to be above the current water quality standard. Table 5 summarizes data from DOE ambient station SIN001 located in mid-inlet south of the Puget Sound Naval Shipyard (PSNS). The values are contrasted with water quality standards requirements. The data show that at mid-bay, water quality standards are being met. We have no long-term values for nearshore areas, however.

CURRENT STP LOADS

The Charleston STP presently discharges an average of 3 MGD of primarily-treated sewage into lower Sinclair Inlet. The outfall lies at 10 m depth. Sewage is dispersed through 20 diffuser ports spaced 2 m apart. The discharge is located east of PSNS. The Port Orchard STP discharges about 0.5 MGD primary effluent into Sinclair Inlet immediately north of the Port Orchard marina in about 15 m of water. The Retsil (KCSD No. 5) facility discharges about 1 MGD primary effluent into Sinclair Inlet. The point of discharge lies 1800 feet north of the Retsil shoreline.

Several Class II inspections have been made at the Charleston STP during the last several years. One Class II inspection has been made at Retsil in conjunction with a receiving water study. Table 6 summarizes the data. The receiving water study at Retsil concluded that although 95 percent of the fecal coliform counts exceeded Class AA standards (14 colonies/100 ml), the excess did not constitute a serious violation.

CH_2M-HILL (1976a) summarized performance values on the existing facilities discharging into Sinclair Inlet. These are included in Table 7. The data in their report do not conflict markedly ~~from~~ with DOE data. The limited FC data that are available are questionable. The low values that have been reported may have been due to the use of bacteriological sampling bottles that had not had tho added to neutralize Cl_2.

thiosulfate

CURRENT PROPOSALS

The present proposals follow the 1978 facilities plan discussed in EPA (1978) closely with the exception that the Charleston STP is not to be upgraded from primary to secondary. The effects of discharge on the receiving system can be evaluated in terms of the quality of the discharge, the dilution it receives in the receiving water, and the nature of the receiving water. The dilution of a discharge is a function of the design of the diffuser and the rate of transport of clean dilution water across the site. Inadequate dilution and subsequent downstream dispersal of wastewater discharge can lead to short-term stress in localized areas and long-term degradation of water quality and cumulative effects upon the marine environment.

EPA (1978) analyzed these issues for the dischage of secondarily-treated waste into marine waters. They initially compared applicable water quality standards with effluent from a secondary STP at 100:1 dilution, 10:1 dilution and undiluted sewage using a continuity equation method. Table 8 summarizes their data as adapted. I have also included BOD_5 and total suspended solids values. All were corrected against background values obtained from SIN001 (Table 5). Efficiently designed and operated primary systems should remove from 50 to 65 percent of the suspended solids, and from 25 to 40 percent of the BOD_5 (Metcalf and Eddy, 1972). I applied the lower efficiency values to expected influent characteristics (John Stetson, DPE, personal communication) in order to obtain a worst-case estimate of impact. Table 8 indicates that fecal coliform water quality standards would be met if dilution ratios of 100:1 existed at all times. However, this is not the case in Sinclair Inlet. On the average, this ideal dilution ratio occurs only 25 percent of the time with values considerably less than this. DOE has performed no receiving water studies at the Charleston discharge site. However, Kramer, Chin and Mayo (1974) performed a dye study that indicated poor dispersal with effluent concentrations near the diffuser. Dilution ratios at the surface ranged from 1.3:1 to 2140:1 depending on sample location. Subsurface samples indicated an average dilution ratio of 5.5:1. After consideration of these data, EPA (1978) characterized the suitability of the Charleston site for discharge of secondarily-treated wastes as only fair. Due to the poor circulation, diluted effluent would be receiving water for more effluent. Under these conditions, local build-up of bacteria, suspended solids, and biological oxygen demand would occur. Toxic levels of ammonia could also occur. Nutrients that are pooled locally could promote large intertidal algal blooms that could out compete benthic intertidal organisms for space at least initially, until populations of grazers such as limpets rebound. In any case, large solids and organic loads coupled with high BOD_5 could create oxygen problems when benthic algae die-off occurs during late summer minus tides. In addition to threatening local benthic community structure, these conditions may produce aesthetic problems such as obnoxious odors.

The use of chlorine for disinfection of wastes should be of special concern. In order to meet water quality standards in primary STP's the past attitude has been to use elevated chlorine levels since much of the chlorine is consumed by other organic materials in the waste. However, this procedure has been shown to produce complex tocic chlorinated organic compounds though halogenation of household organic solvents (Allinger, et al., 1971). EPA (1978) recognized this problem in their reply to comments submitted by CH_2M-HILL in response to the draft Sinclair Inlet EIS. These comments are as follows:

> "The prime concern regarding the discharge of secondary treated effluent in Sinclair Inlet is not in meeting the coliform standards *per se*. This can be achieved successfully by disinfection. The real concern arises from the discharge of other constituents, whose importance, although not recognized by the class A description, is becoming increasingly apparent. Starting in the early seventies, studies showed that chlorine reacts with sewage constituents generating a number of potentially toxic elements (chloramines, trihalomethanes, etc.).
>
> "The issue is not just chlorine concentrations for disinfection, chlorine residuals or ammonia levels, but the complexes formed from these chemicals and other wastewater constituents that can be toxic to aquatic life (see response no. 1). While studies have been performed on levels of toxicity and avoidance of chlorine and ammonia, research is still continuing on synergistic effects of these compounds and newly-discovered complexes."

We should note that the EPA response is made toward the impact of chlorinating secondarily-treated effluents with less organic and bacteria loads than primary discharges. Since the chlorinated compounds have been shown to be toxic and persistent, the effects of their continued discharge into an inlet such as Sinclair should be carefully evaluated.

In addition to initial dilution, dispersal throughout the inlet should be considered. EPA (1978) calculated the total tidal exchange volume to be one percent of the total. The facilities plan (CH_2M-HILL, 1976a) estimated the inlet volume to be 1600 times the designed effluent discharge flow. Thus the dilution of effluent into the total volume of the inlet is 16:1 at dynamic equilibrium, neglecting localized pooling around the Charleston discharge. The long-term effects of primary discharge inlet-wide are difficult to evaluate. Nutrient loads from secondary plants are the same as primary. Since background nutrient levels in Sinclair Inlet are high, the amount of initial elevation due to either treatment level would be the same in either proposal and relatively unimportant in terms of this decision. However, the organics load suspended material and potential for oxygen demand from a primary facility could be of importance during certain times of the year relative to a secondary plant. During winter months, oxygen obtained from primary production would be minimal since the system is light-limited. Under these conditions, the added organic load and BOD_5 could promote a risk of oxygen depression below WQS levels. This risk is significantly greater than that produced under present discharge conditions because the ultimate design discharge of the current proposals will be about three fold the present flow. During the algal die-off during the late summer, the discharge of primary wastes produces the risk of oxygen depression due to the decomposition of the algae and loss of primary productive capacity.

In choosing between either of the two proposals, several types of environmental impacts were considered; the long-term impacts of the discharge themselves and the short-term impacts of construction. In terms of discharge impacts, Proposal II (the addition of 20 percent more flow at Charleston and the cessation of flow at Retsil) would probably not produce any greater degree of risk than already imposed by Proposal I. However, the short-term impacts of pipeline construction to Sinclair Inlet shorelines are of some importance. EPA (1978) summarized the adverse impacts of the alternatives they considered (Table 9). Their Alternative 2 (similar to Proposal I, above) and Alternative 3 (similar to our Proposal II) have identical scores. The higher municipal service costs under Alternative 2 are balanced by higher erosion and stability hazards under Alternative 3. Of course, the original proposals called for secondary treatment while the current proposals call for primary only. We therefore would expect lowered water quality, fisheries and marine biota scores under the present proposals, but the scores would change equally for each proposal.

TAD:cp

Attachments

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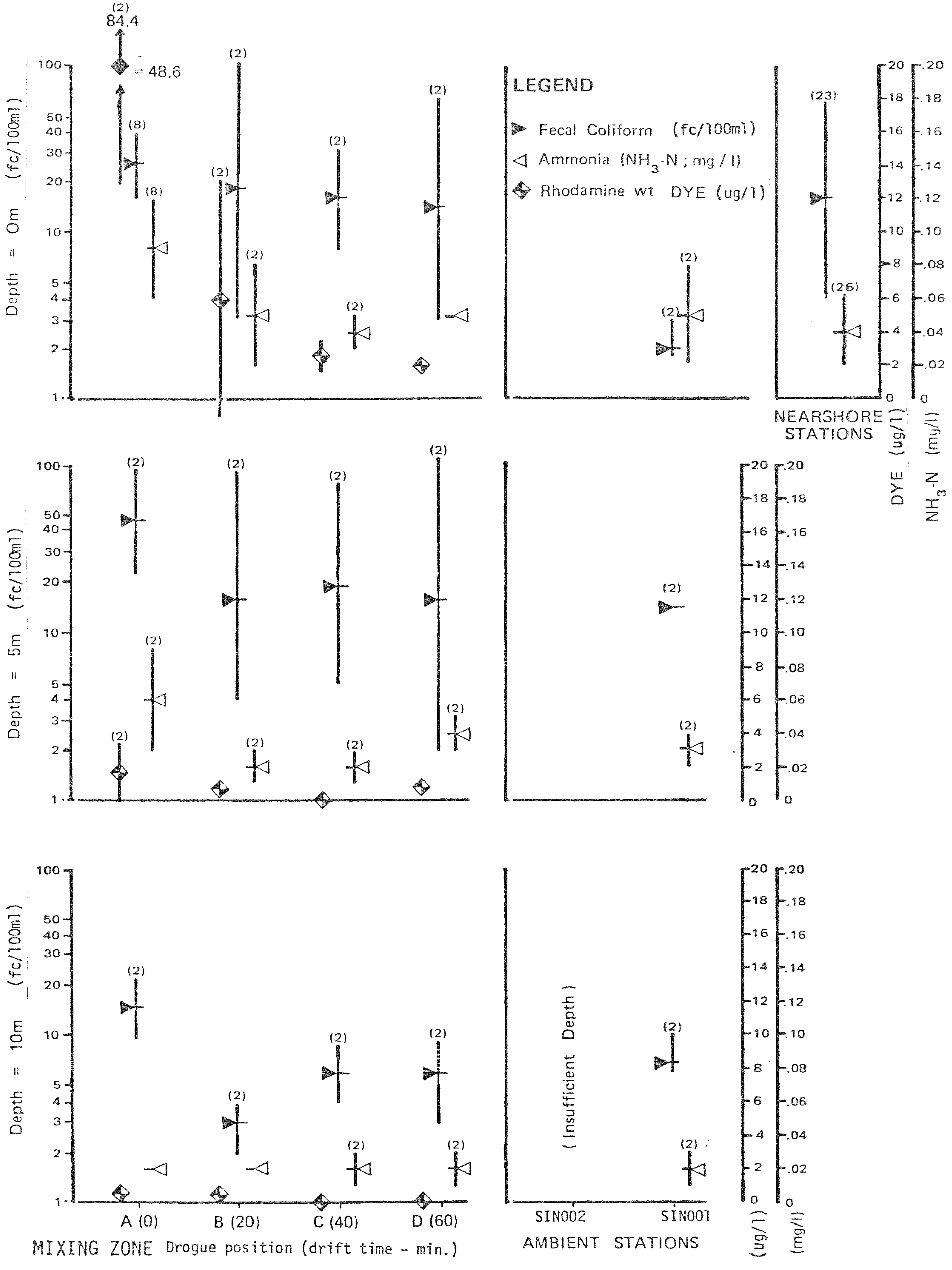


FIGURE 4. Levels of fecal coliform, ammonia and Rhodamine wt dye within the mixing zone of Port Orchard STP during high slack tide on Dec. 15, 1980 and Jan. 28, 1981. Values at other station catagories are also shown. Vertical bars demark ± 1 standard deviation and parenthasized values indicate number of data

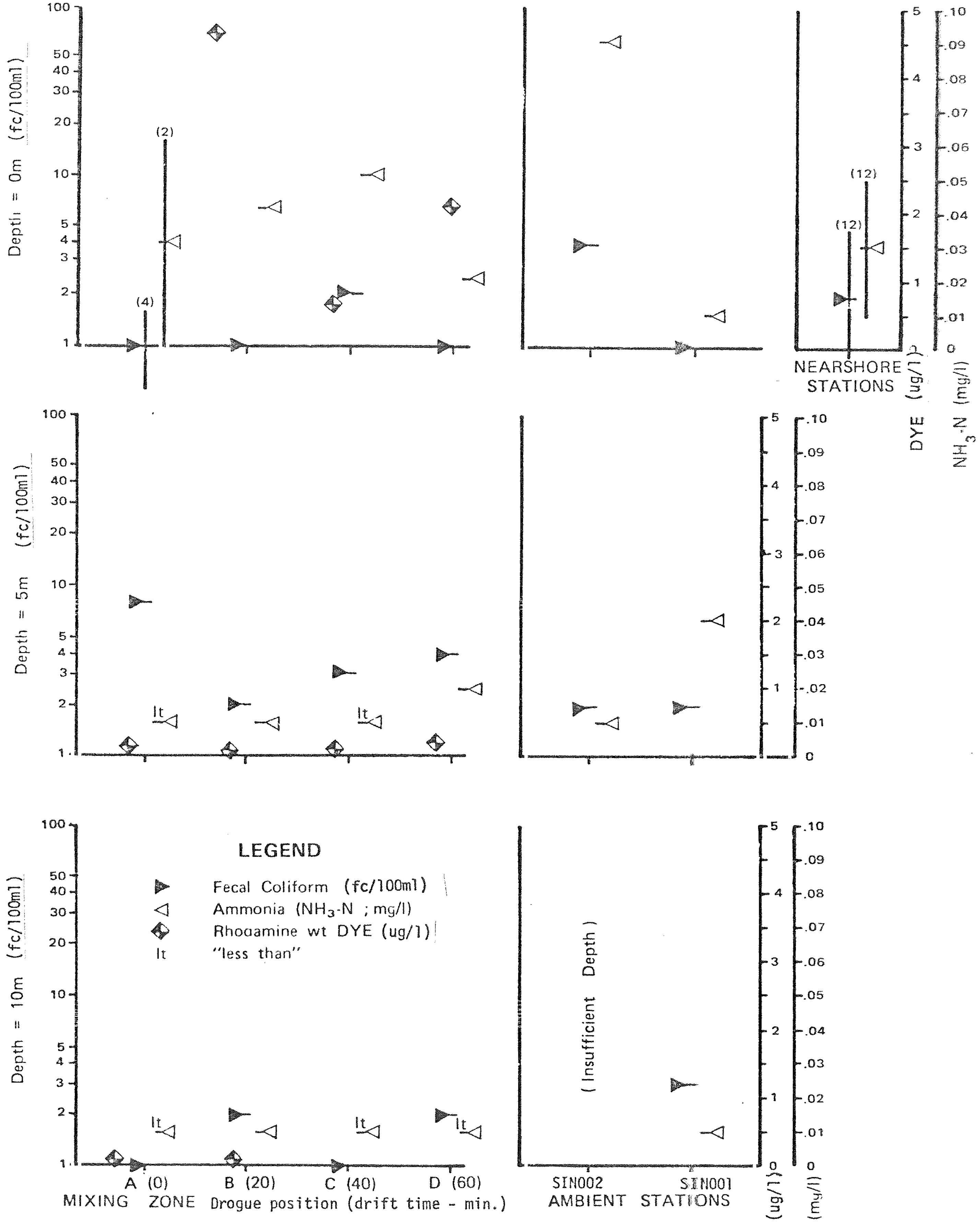


FIGURE 5. Levels of fecal coliform, ammonia, and Rhodamine wt dye within the mixing zone of Port Orchard STP during low slack tide on March 25, 1981. Values at other station catagories are also shown. Vertical bars demark ± 1 standard deviation and parenthasized values indicate number of data.

The low slack case (Figure 5) demonstrated few significant fecal coliform levels anywhere. The nearshore fixed stations showed lower values than in December and January, possibly due to seasonal reduction in runoff. Surface dye and ammonia levels were elevated within the mixing zone. No discernible downstream dilution picture emerged. Ammonia levels were similar among all stations.

Total residual chlorine measurements were taken from the effluent and at the surface above the point of discharge. Effluent leaving the plant averaged 5.0 mg/L. Chlorine levels over the outfall were less than 0.1 mg/L which is the limit of sensitivity of the field method employed. Due to the sensitivity limitations of the field method, we did not gain an accurate value for chlorine in the surface waters. We, therefore, cannot determine the effects of the chlorine on the marine ecosystem. However, the concentrations in the effluent leaving the plant suggests that excessive amounts of chlorine are being used; perhaps more than is necessary for purposes of disinfection.

Considerable interest has been expressed during recent years concerning halogenated organic compounds which form in chlorinated effluents. That issue was beyond the scope of this study.

On December 30, 1980 prior to departure from the Port Orchard public boat ramp for work off Bremerton STP No. 2 (Charleston), the survey crew noted a substantial boil located about 25 m (75 feet) west of the end of the ramp service dock (Station 7., Figure 1). The boil was sampled for fecal coliform densities which were 1,500 per 100 ml. There was insufficient time to locate the source.

Overall, Port Orchard STP wastewater had little discernible effect on receiving waters during this study. Although a number of samples from within the mixing zone were slightly above the water quality standard for fecal coliform in Class A waters (Table 1), the violations were not excessive and did not appear to be substantially higher than nearshore waters. There were no violations of the oxygen standard (less than 6.0 mg/L), temperature standard (no greater than 18°C), pH standard (within 7.0 to 8.5). A few violations of the turbidity standard occurred, but as in the case of fecal coliform, these were not significantly different from the neashore stations.

Bremerton STP No. 2 (Charleston)

Surveys were conducted off Charleston during high slack tide on December 30, 1980 and January 26, 1981. Low slack conditions were evaluated on March 23, 1981. The latter survey coincided with a Class II inspection performed by DOE's Northwest Regional office. Dave Wright (DOE N.W. Region) reported that a bypass was occurring during the survey. A sewage bypass also occurred on January 26. Weather conditions during each survey were typically marginal with cloudy skies, cold temperatures, and light to moderate rainfall. Winds were southwesterly from calm to moderate breeze (Beaufort Scale 4; Bowditch, 1966).

The dyed wastewater appeared in the surface waters above the diffuser 14 minutes after injection on January 26, 1981. This elapsed time was about the same during other surveys. Unlike the Port Orchard case, the dye did not appear all at once but emerged above the first diffuser nozzle, then progressively outward. We placed our reference buoy approximately at the center of the elongated dye patch.

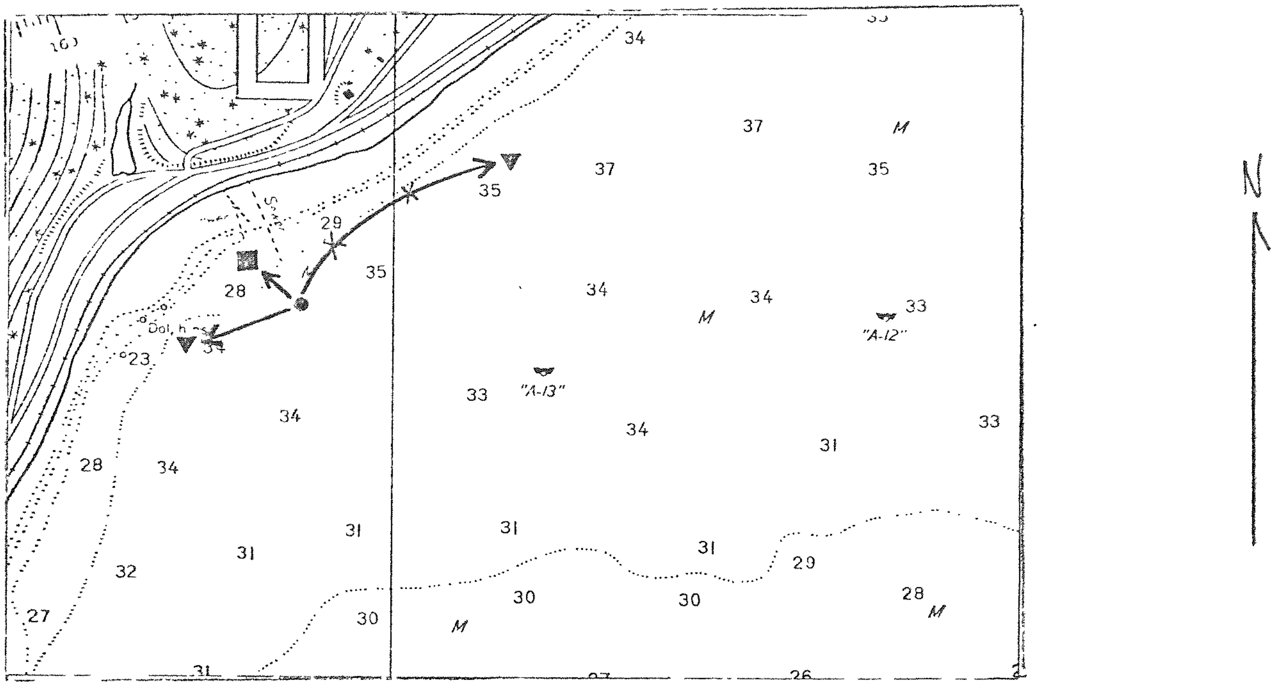
Drogue track lines for January 26 and March 23, 1981 are shown in Figure 6. Unlike the Port Orchard case, the 1 m drogues diverged considerably after deployment over the outfall. During high slack tide on January 26, 1981, one 1 m drogue travelled coastwise to the ENE and the other was displaced into shallow waters in the opposite direction. The 5 m drogue drifted directly shoreward. Sampling was conducted in association with the ENE 1 m drogue. During low slack tide on March 25, 1 m drogue divergence was less extreme. Both drogues were displaced shoreward into water of less than 10 m depth. The motion of the 5 m drogue paralleled that of the sampled 1 m drogue.

The drogue motion suggests, given the present location of the diffuser, that during slack water conditions, the shoreward part of the plume tends to be trapped nearshore while the outer part of the plume becomes entrained in coastwise offshore flow.

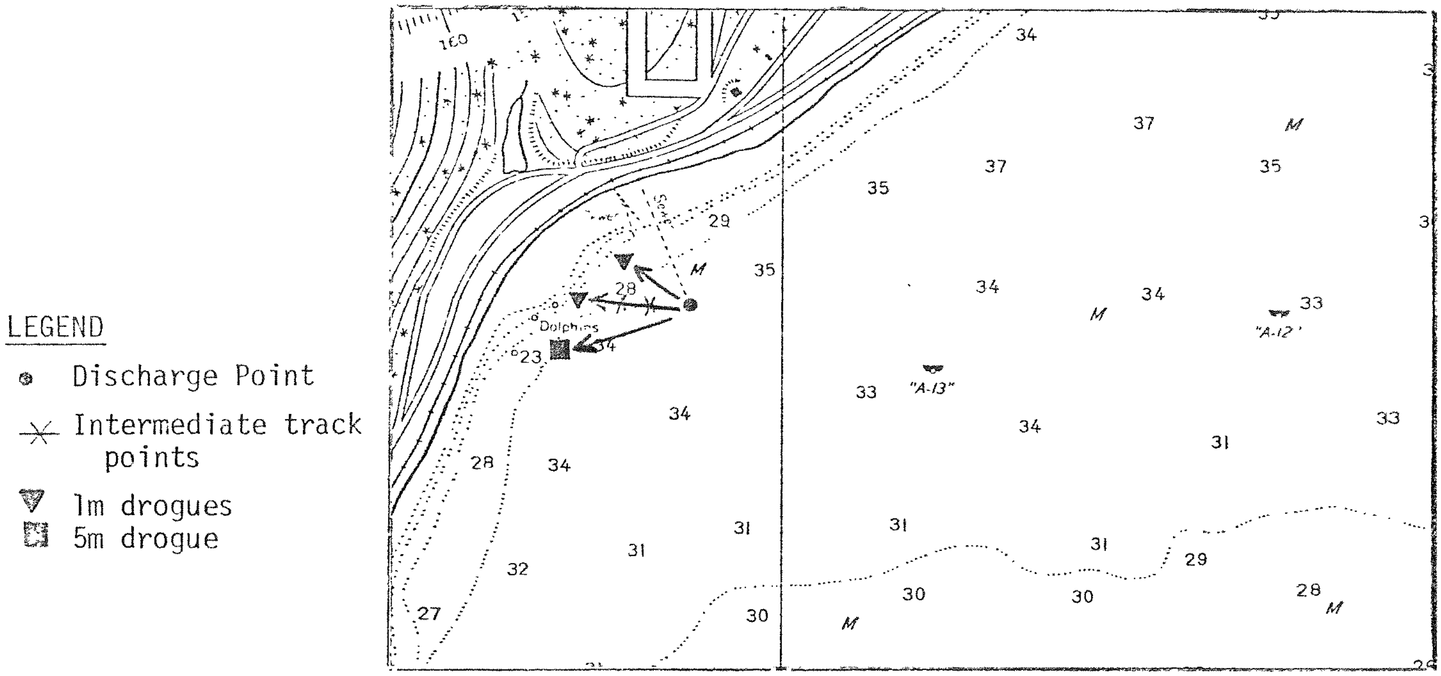
Water quality data for all surveys, stations, and depths off Charleston STP are shown in Tables 4 and 5. Figures 7 and 8 present fecal coliform densities, ammonia (NH_3-N), and Rhodamine wt dye concentrations from the data. The plotted data serve to compare station categories. Estimation of downstream mixing rates were not possible given data variability.

The pooled high slack data (Table 4) show few parameters within the discharge zone significantly different from the nearshore fixed stations or ambient stations SIN001 and SIN002. However, several parameters appear to be different. Dissolved oxygen levels within the discharge zone are significantly higher than the nearshore fixed stations although all values meet water quality standards. Fecal coliform values for the mixing zone are lower than the ambient or the fixed nearshore stations. Mixing zone ammonia levels, however, average nearly twice as high as the nearshore stations and over four times greater than found in mid-inlet. Figure 7 suggests that high ammonia values within the mixing zone may be explained by the levels at the surface and 5 m.

Low slack data obtained in March were somewhat different. Oxygen levels were higher at all stations. Oxygen levels within the discharge zone were significantly lower than the other categories. Nitrate and ammonia were lower overall in March than in December and January. The relatively high oxygen and low inorganic nitrogen levels beyond the mixing zone may be a seasonal phenomenon as increasing light and temperature lead to uptake of nutrients by plants. Ammonia levels are again higher within the mixing zone than the ambient stations and slightly higher than nearshore waters.



January 26, 1981 (high slack)



March 25, 1981 (low slack)

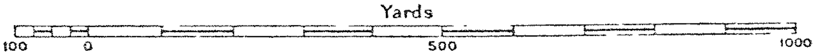


Figure 6. Drogue tracks for high and low slack tidal current states offshore from Bremerton STP No. 2 (Charleston) after 1-hour drift periods (taken from NOAA Nautical Chart No. 18542).

Table 4. Summary of water quality data collected at Sinclair Inlet and within the mixing zone of the Bremerton STP No. 2 (Charleston) during high slack tide conditions (December 30, 1980 and January 26, 1981).[1]

Stn. No.	Depth (m)	Temp. (°C)[2] $\bar{X}$ ± s (n)	Salinity (in situ, o/oo)[2] $\bar{X}$ ± s (n)	Sigma-t[2] $\bar{X}$ ± s (n)	Secchi Depth (m)[2] $\bar{X}$ ± s (n)	Dye (ug/L)[2] $\bar{X}$ ± s (n)	FC (org per 100 ml) G.M. (n)	D.O. (mg/L)[2] $\bar{X}$ ± s (n)	D.O. (% sat.)[2] $\bar{X}$ ± s (n)
STP							2×10^7 (1)		
MIXING ZONE									
A	0	8.37 ± .16 (4)	28.62 ± .04 (4)	22.25 ± .02 (4)	2.1 ± .9 (3)	11.6 ± 5.5 (2)	32 (7)	7.14 ± .05 (4)	73.2 ± .5 (4)
	5	8.25 (1)	28.82 (1)	22.42 (1)		0 (2)	12 (1)	7.40 (1)	76 (1)
	10	8.25 (1)	29.02 (1)	22.58 (1)		0 (2)	17 (1)	7.10 (1)	73 (1)
B	0	8.25 (1)	28.68 (1)	22.31 (1)	3.6 (1)	.8 ± .6 (2)	4 (1)	7.22 (1)	74 (1)
	5	8.31 (1)	28.73 (1)	22.35 (1)		.8 ± 1.1 (2)	12 (2)	7.23 (1)	74 (1)
	10	8.46 (1)	29.02 (1)	22.56 (1)		0 (1)	12 (2)	7.13 (1)	74 (1)
C	0	8.25 (1)	28.72 (1)	22.34 (1)	3.6 (1)	.8 ± .6 (2)	17 (1)	7.30 (1)	75 (1)
	5	8.35 (1)	28.80 (1)	22.39 (1)		1.0 ± 1.4 (2)	21 (2)	7.33 (1)	75 (1)
	10	8.35 (1)	29.03 (1)	22.57 (1)		.5 (1)	8 (1)	7.19 (1)	74 (1)
D	0	8.22 (1)	28.71 (1)	22.34 (1)	4.5 (1)	3.4 ± 4.3 (2)	13 (1)	7.25 (1)	74 (1)
	5	8.50 (1)	28.79 (1)	22.36 (1)		.2 ± .3 (2)	20 (2)	7.22 (1)	74 (1)
	10	8.29 (1)	29.04 (1)	22.51 (1)		0 (1)	4 (1)	7.24 (1)	74 (1)
OVERALL		8.33 ± .11 (15)	28.79 ± .16 (15)	22.38 ± .12 (15)			17 (22)	7.21 ± .09 (15)	74.0 ± .9 (15)
DOE AMBIENT STATIONS									
SIN002	0	8.02 (1)	27.99 (1)	21.82 (1)	3.9 (1)	0 (2)	30 (2)	7.30 (1)	74 (1)
	5	8.15 (1)	28.90 (1)	22.50 (1)		0 (2)	17 (2)	7.05 (1)	72 (1)
SIN001	0	7.60 (1)	28.15 (1)	21.99 (1)		0 (2)	50 (2)	7.58 (1)	76 (1)
	5	8.00 (1)	28.77 (1)	22.43 (1)		0 (2)	39 (2)	7.51 (1)	76 (1)
	10	8.25 (1)	29.06	22.61 (1)		.3 ± .4 (2)	14 (2)	7.28 (1)	75 (1)
OVERALL		8.00 ± .25 (5)	28.57 ± .47 (5)	22.27 ± .34 (5)			26 (10)	7.34 ± .21 (5)	74.6 ± 1.7 (5)
NEARSHORE FIXED SURFACE STATIONS									
B1		7.75 (1)	28.54				98 (2)	7.25 (1)	73 (1)
B2		8.24 (1)	26.69				65 (2)	7.19 (1)	72 (1)
B3		8.25 (1)	28.58				148 (2)	7.02 (1)	72 (1)
B4		8.19 (1)	.80				93 (2)	7.00 (1)	60 (1)
B5		8.16 (1)	28.50				42 (2)	7.22 (1)	72 (1)
OVERALL		8.12 ± .21 (5)	22.62 ± 12.23(5)				81 (10)	7.14 ± .12 (5)	69.8 ± 5.5 (5)

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[1] Data are shown for all variables (except FC) as mean ($\bar{X}$) ± 1 standard deviation (s). Numbers of data are shown in parentheses (n). Geometric means (G.M.) for FC data are shown. If there is only one value, this value is shown with n equal to 1.

[2] January 26 values only.

Table 4. - Continued[1]

Stn. No.	Depth (m)	NO_3-N (mg/L) $\bar{X}$ ± s (n)	NO_2-N (mg/L) $\bar{X}$ ± s (n)	NH_3-N (mg/L) $\bar{X}$ ± s (n)	O-PO_4-P (mg/L) $\bar{X}$ ± s (n)	T-PO_4-P (mg/L) $\bar{X}$ ± s (n)	pH (units) $\bar{X}$ ± s (n)	Turb. (NTU) $\bar{X}$ ± s (n)	TSS (mg/L) $\bar{X}$ ± s (n)
STP		.20 (1)	<.2 (1)	15.0 (1)	3.2 (1)	5.4 (1)	7.4 (1)	21 (1)	390 (1)
MIXING ZONE									
A	0	.43 ± .02 (8)	<.01 (8)	.17 ± .07 (8)	.08 ± .02 (2)	.12 ± .03 (8)	7.65 ± .11 (8)	5 ± 1 (1)	9 ± 3 (8)
	5	.43 ± .04 (2)	<.01 (2)	.03 ± .03 (2)	.07 ± .01 (2)	.10 ± .01 (2)	7.70 ± .14 (2)	2 ± 2 (2)	6 ± 1 (2)
	10	.42 ± .03 (2)	<.01 (2)	.02 ± .01 (2)	.07 ± .01 (2)	.10 ± .01 (2)	7.70 ± .00 (2)	5 ± 0 (2)	8 ± 6 (2)
B	0	.42 ± .03 (2)	<.01 (2)	.10 ± .02 (2)	.08 ± .01 (2)	.11 ± .01 (2)	7.75 ± .07 (2)	4 ± 1 (2)	8 ± 2 (2)
	5	.43 ± .04 (2)	<.01 (2)	.06 ± .01 (2)	.07 ± .01 (2)	.10 ± .01 (2)	7.70 ± .00 (2)	4 ± 2 (2)	6 ± 3 (2)
	10	.46 (1)	<.01 (1)	<.01 (1)	.07 (1)	.09 (1)	7.8 (1)	3 (1)	5 (1)
C	0	.44 ± .02 (2)	<.01 (2)	.09 ± .02 (2)	.08 ± .01 (2)	.10 ± .00 (2)	7.75 ± .07 (2)	5 ± 3 (2)	7 ± 1 (2)
	5	.43 ± .02 (2)	<.01 (2)	.03 ± .00 (2)	.07 ± .00 (2)	.09 ± .00 (2)	7.70 ± .00 (2)	3 ± 1 (2)	6 ± 4 (2)
	10	.44 (1)	<.01 (1)	<.01 (1)	.08 (1)	.09 (1)	7.70 (1)	5 (1)	6 (1)
D	0	.43 ± .04 (2)	<.01 (1)	.08 ± .01 (2)	.08 ± .01 (2)	.10 ± .00 (2)	7.70 ± .14 (2)	4 ± 5 (2)	8 ± 4 (2)
	5	.43 ± .03 (2)	<.01 (1)	.05 ± .04 (2)	.07 ± .00 (2)	.10 ± .00 (2)	7.70 ± .14 (2)	3 ± 3 (2)	5 ± 1 (2)
	10	.46 (1)	<.01 (1)	.01 (1)	.07 (1)	.09 (1)	7.6 (1)	1 (1)	5 (1)
OVERALL		.43 ± .02 (27)	<.01 (27)	.09 ± .07 (27)	.08 ± .01 (27)	.10 ± .02 (27)	7.69 ± .09 (27)	4 ± 2 (27)	7 ± 3 (27)
DOE AMBIENT STATIONS									
SIN002	0	.43 ± .03 (2)	<.01 (2)	.03 ± .01 (2)	.07 ± .01 (2)	.09 ± .01 (2)	7.70 ± .00 (2)	4 ± 1 (2)	6 ± 0 (2)
	5	.42 ± .03 (2)	<.01 (2)	.02 ± .01 (2)	.07 ± .01 (2)	.09 ± .01 (2)	7.70 ± .00 (2)	2 ± 1 (2)	7 ± 1 (2)
SIN001	0	.42 ± .03 (2)	<.01 (2)	.03 ± .01 (2)	.07 ± .01 (2)	.09 ± .01 (2)	7.70 ± .14 (2)	4 ± 2 (2)	8 ± 4 (2)
	5	.43 ± .04 (2)	<.01 (2)	.02 ± .01 (2)	.07 ± .01 (2)	.09 ± .01 (2)	7.75 ± .07 (2)	4 ± 4 (2)	6 ± 0 (2)
	10	.44 ± .05 (2)	<.01 (2)	.02 ± .01 (2)	.07 ± .01 (2)	.09 ± .01 (2)	7.70 ± .00 (2)	3 ± 1 (2)	6 ± 5 (2)
OVERALL		.43 ± .03 (10)	<.01 (10)	.02 ± .01 (10)	.07 ± .01 (10)	.09 ± .01 (2)	7.71 ± .06 (10)	4 ± 2 (2)	7 ± 2 (10)
NEARSHORE FIXED SURFACE STATIONS									
B1		.42 ± .04 (2)	<.01 (2)	.04 ± .00 (2)	.08 ± .01 (2)	.09 ± .01 (2)	7.70 ± .00 (2)	4 ± 1 (2)	9 ± 1 (2)
B2		.42 ± .02 (2)	<.01 (2)	.08 ± .02 (2)	.07 ± .01 (2)	.10 ± .01 (2)	7.65 ± .07 (2)	4 ± 2 (2)	9 ± 3 (2)
B3		.47 ± .08 (2)	<.01 (2)	.05 ± .04 (2)	.07 ± .01 (2)	.11 ± .04 (2)	7.60 ± .00 (2)	6 ± 3 (2)	8 ± 4 (2)
B4		.49 ± .05 (2)	<.01 (2)	.04 ± .01 (2)	.06 ± .00 (2)	.11 ± .04 (2)	7.85 ± .21 (2)	6 ± 1 (2)	7 ± 4 (2)
B5		.47 ± .01 (2)	<.01 (2)	.04 ± .03 (2)	.07 ± .01 (2)	.11 ± .02 (2)	7.75 ± .06 (2)	4 ± 3 (2)	8 ± 0 (2)
OVERALL		.45 ± .05 (10)	<.01 (10)	.05 ± .02 (10)	.07 ± .01 (10)	.10 ± .02 (10)	7.71 ± .12 (10)	5 ± 2 (10)	8 ± 2 (10)

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[1] Data are shown for all variables (except FC) as mean ($\bar{X}$) ± 1 standard deviation (s). Numbers of data are shown in parentheses (n). Geometric means (G.M.) for FC data are shown. If there is only one value, this value is shown with n equal to 1.

[2] January 26 values only.

Table 5. Summary of water quality data collected at Sinclair Inlet and within the mixing zone of the Bremerton STP No. 2 (Charleston) during low slack tide conditions, March 23, 1981.[1]

Stn. No.	Depth (m)	Temp. (°C) X̄ ± s (n)	Salinity (in situ, o/oo) X̄ ± s (n)	Sigma-t X̄ ± s (n)	Secchi Depth (m) X̄ ± s (n)	Dye (ug/L)	FC (org per 100 ml) G.M. (n)	D.O. (mg/L) X̄ ± s (n)	D.O. (% sat.) X̄ ± s (n)
STP							6.1×10^6(1)		
MIXING ZONE									
A	0	9.9 ± .1 (4)	28.25 ± .04 (3)	21.75 ± .04 (3)	.8 ± .2 (4)	20.58 (1)	23 (3)	9.06 ± .18 (2)	95.5 ± 2.1 (2)
	5	10.0 (1)	28.62 (1)	22.01 (1)		.12 (1)	10 (1)	9.00 (1)	96 (1)
	10	10.0 (1)	28.59 (1)	21.99 (1)		.24 (1)	<1 (1)	8.74 (1)	93 (1)
B	0	9.9 (1)	28.32 (1)	21.79 (1)	.7 (1)	12.12 (1)	14 (1)	9.00 (1)	95 (1)
	5	9.8 (1)	28.61 (1)	22.03 (1)		.25 (1)	1 (1)	8.74 (1)	93 (1)
	10	9.8 (1)	28.64 (1)	22.05 (1)		.12 (1)	<1 (1)	8.52 (1)	90 (1)
C	0	9.8 (1)	28.26 (1)	21.76 (1)	.9 (1)	13.40 (1)	9 (1)	8.79 (1)	93 (1)
	5	9.8 (1)	28.60 (1)	22.02 (1)		.24 (1)	1 (1)	8.82 (1)	94 (1)
	10	--	--	--		--	--	--	--
D	0	9.8 (1)	28.33 (1)	21.81 (1)	.9 (1)	2.69 (1)	5 (1)	9.15 (1)	97 (1)
	5	9.8 (1)	28.59 (1)	22.02 (1)		.24 (1)	7 (1)	8.94 (1)	95 (1)
	10	--	--	--		--	--	--	--
OVERALL		9.9 ± .1 (13)	28.44 ± .17 (12)	21.89 ± .14 (12)			6 (12)	8.89 ± .19(11)	94 ± 2 (11)
DOE AMBIENT STATIONS									
SIN002	0	9.9 (1)	28.18 (1)	21.68 (1)	.8 (1)		7 (1)	10.36 (1)	107 (1)
	5	9.7 (1)	28.16 (1)	21.69 (1)			7 (1)	9.58 (1)	101 (1)
SIN001	0	9.8 (1)	28.60 (1)	21.81 (1)	1.4 (1)		1 (1)	9.24 (1)	98 (1)
	5	9.8 (1)	28.46 (1)	21.91 (1)			2 (1)	10.12 (1)	107 (1)
	10	9.7 (1)	28.31 (1)	22.02 (1)			<1 (1)	10.13 (1)	107 (1)
OVERALL		9.8 ± .1 (5)	28.34 ± .19 (5)	21.82 ± .15 (5)			3 (5)	9.89 ± .46 (5)	104 ± 4 (5)
NEARSHORE FIXED SURFACE STATIONS									
B1		10.0 (1)	24.34 (1)	--			64 (1)	10.05 (1)	105 (1)
B2		9.8 (1)	25.97 (1)	--			140 (1)	9.75 (1)	102 (1)
B3		9.8 (1)	28.19 (1)	--			90 (1)	8.87 (1)	94 (1)
B4		--	--	--			--	--	--
B5		9.8 (1)	27.77 (1)	--			6 (1)	8.89 (1)	104 (1)
OVERALL		9.8 ± .1 (4)	26.57 ± 1.77 (4)				47 (4)	9.39 ± .60 (4)	101 ± 5 (4)

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[1] Data are shown for all variables (except F.C.) as mean (X̄) ± 1 standard deviation (s). Number of data are shown in parentheses (n). Geometric means (G.M.) are shown for fecal coliform (F.C.) data. If there is only one value, this value is shown with (n) equal to 1.

Table 5. - Continued[1/]

Stn. No.	Depth (m)	NO_3-N (mg/L) $\overline{X}$ ± s	(n)	NO_2-N (mg/L) $\overline{X}$ ± s	(n)	NH_3-N (mg/L) $\overline{X}$ ± s	(n)	O-PO_4-P (mg/L) $\overline{X}$ ± s	(n)	T-PO_4-P (mg/L) $\overline{X}$ ± s	(n)	pH (units) $\overline{X}$ ± s	(n)	Turb. (NTU) $\overline{X}$ ± s	(n)	TSS (mg/L) $\overline{X}$ ± s	(n)
STP		<.10	(1)	<.10	(1)	11	(1)	2.4	(1)			7.2	(1)	64	(1)	84	(1)
MIXING ZONE																	
A	0	.36 ± .01	(3)	<.01	(3)	.14 ± .02	(3)	.08 ± .01	(3)			7.8 ± .00	(3)	5 ± 2	(3)	16.3 ± 4.2	(3)
	5	.38	(1)	<.01	(1)	.02	(1)	.05	(1)			7.7	(1)	3	(1)	19	(1)
	10	.37	(1)	<.01	(1)	.01	(1)	.06	(1)			7.8	(1)	1	(1)	14	(1)
B	0	.37	(1)	<.01	(1)	.11	(1)	.08	(1)			7.8	(1)	2	(1)	30	(1)
	5	.36	(1)	<.01	(1)	.01	(1)	.07	(1)			7.8	(1)	4	(1)	36	(1)
	10	.36	(1)	<.01	(1)	.01	(1)	.07	(1)			7.8	(1)	2	(1)	27	(1)
C	0	.36	(1)	<.01	(1)	.13	(1)	.08	(1)			7.8	(1)	5	(1)	30	(1)
	5	.36	(1)	<.01	(1)	.01	(1)	.07	(1)			7.8	(1)	2	(1)	26	(1)
	10	--		--		--		--				--		--		--	
D	0	.36	(1)	<.01	(1)	.08	(1)	.07	(1)			7.8	(1)	3	(1)	20	(1)
	5	.36	(1)	<.01	(1)	.01	(1)	.06	(1)			7.8	(1)	4	(1)	22	(1)
	10	--		--		--		--				--		--		--	
OVERALL		.36 ± .01	(12)	<.01	(12)	.07 ± .06	(12)	.07 ± .01	(12)			7.8 ± .0	(12)	3 ± 2	(12)	23 ± 7	(12)
DOE AMBIENT STATIONS																	
SIN002	0	.30	(1)	<.01	(1)	.01	(1)	.06	(1)			7.9	(1)	2	(1)	38	(1)
	5	.29	(1)	<.01	(1)	<.01	(1)	.06	(1)			7.9	(1)	3	(1)	34	(1)
SIN001	0	.35	(1)	<.01	(1)	.01	(1)	.06	(1)			7.9	(1)	2	(1)	34	(1)
	5	.34	(1)	<.01	(1)	.01	(1)	.06	(1)			7.9	(1)	2	(1)	20	(1)
	10	.31	(1)	<.01	(1)	.01	(1)	.06	(1)			7.9	(1)	4	(1)	21	(1)
OVERALL		.32 ± .03	(5)	<.01	(5)	.01 ± .00	(5)	.06 ± .0	(5)			7.9 ± .0	(5)	3 ± 1	(5)	29 ± 8	(5)
NEARSHORE FIXED SURFACE STATIONS																	
B1		.30	(1)	<.01	(1)	.05	(1)	.09	(1)			7.6	(1)	4	(1)	27	(1)
B2		.29	(1)	<.01	(1)	.07	(1)	.07	(1)			7.8	(1)	2	(1)	54	(1)
B3		.34	(1)	<.01	(1)	.05	(1)	.07	(1)			7.8	(1)	3	(1)	44	(1)
B4		--		--		--		--				--		--		--	
B5		.34	(1)	<.01	(1)	.02	(1)	.07	(1)			7.8	(1)	5	(1)	47	(1)
OVERALL		.32 ± .03	(4)	<.01	(4)	.05 ± .02	(4)	.08 ± .01	(4)			7.8 ± .1	(4)	4 ± 1	(4)	43 ± 11	(4)

[1/] Data are shown for all variables (except F.C.) as mean ($\overline{X}$) ± 1 standard deviation (s). Number of data are shown in parantheses (n). Geometric means (G.M.) are shown for fecal coliform (F.C.) data. If there is only one value, this value is shown with (n) equal to 1.

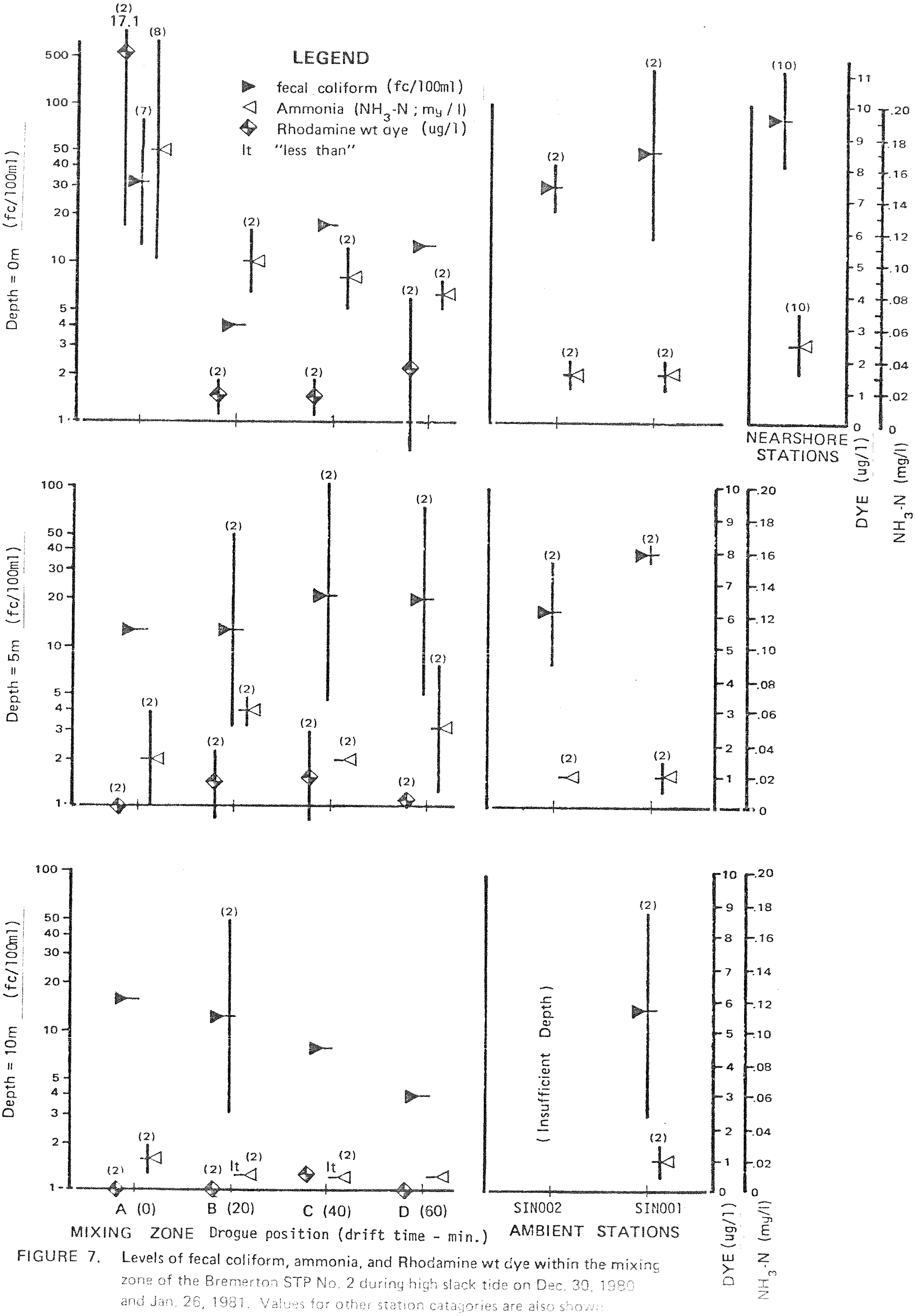

FIGURE 7. Levels of fecal coliform, ammonia, and Rhodamine wt dye within the mixing zone of the Bremerton STP No. 2 during high slack tide on Dec. 30, 1980 and Jan. 26, 1981. Values for other station catagories are also shown. Vertical bars demark ±1 standard deviation and parenthasized values indicate number of data.

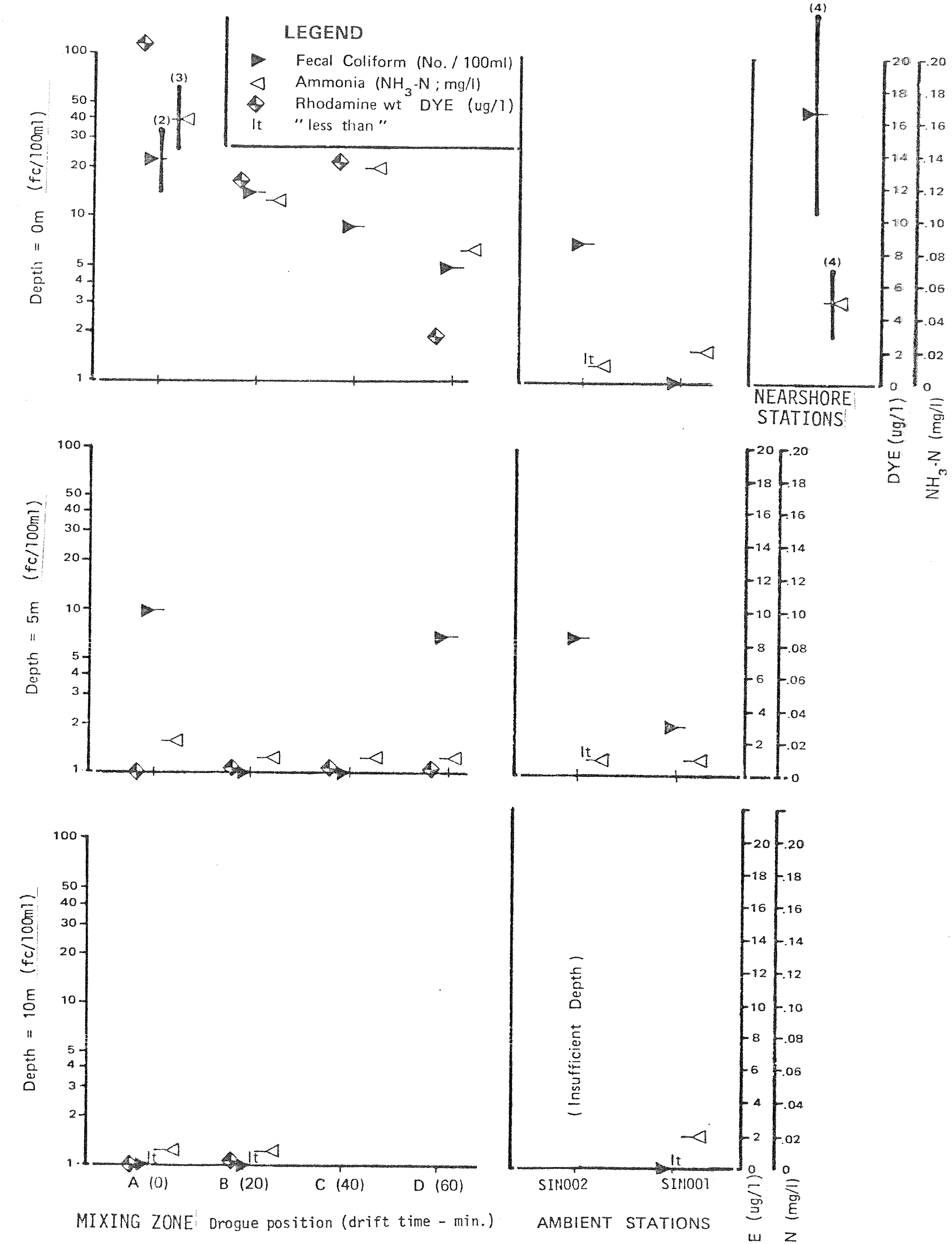

FIGURE 8. Levels of fecal coliform, ammonia, and Rhodamine wt dye within the mixing zone of the Bremerton STP No. 2., during low slack tide on March 26, 1981. Values for other station catagories are also shown. Vertical bars demark ±1 standard deviation and parenthasized values indicate number of data.

Fecal coliform levels within the mixing zone were higher than the ambient stations. Ambient values averaged less than 11 percent as high as the December and January surveys. Nearshore values were also substantially lower, although they were higher than those within the mixing zone.

Figure 8 shows that water quality violations for fecal coliform (greater than 14 fecal coliform per 100 ml) within the mixing zone occurred at the surface stations nearest the diffuser and among the nearshore surface stations. According to the effluent discharge zone guidelines (WDOE, 1980a), surface waters shallower than 1.0 foot deep are excluded from dilution zones. The high ammonia concentrations followed the same pattern. Values at depth within the mixing zone are not greatly different than those at the ambient stations. On the other hand, nearshore ammonia values appear to be slightly higher. This may be due to localized ammonia buildup as effluent approaches the beach during slack tide periods. However, the shoreside ammonia levels (although higher than elsewhere) are not excessive.

Total residual chlorine in the plant effluent averaged 2.5 to 3.0 mg/L. Average residuals at the surface above the outfall on all occasions were below 0.1 mg/L, the limit of equipment sensitivity.

In general, marine receiving waters showed the effects of the Bremerton STP discharge to a greater degree than Port Orchard. Ammonia, in particular, showed elevated levels in surface waters. One factor may be the six-fold higher flow rate at Bremerton. Another factor may be less active current activity at slack tide within the discharge zone. However, under present operating conditions and loads, the elevations did not appear to be excessive.

The data also suggested that shore values may be degraded by the unnamed creek near the discharge (Station B2, Figure 1). The small creek forms an estuary on the landward side of the highway which drains through an box culvert into Sinclair Inlet during tidal drops.

DISCUSSION

Dilution and Dispersion

Generally, the application of Rhodamine wt dye to estimate downstream mixing rates was less than successful. The correlation of dye concentrations with other parameters appeared weak. During high slack at Port Orchard, ammonia levels correlate roughly with dye concentrations but fecal coliform do not (Figure 4). There was no apparent correlation at all during low slack at Port Orchard (Figure 5) or high slack at Charleston (Figure 7). However, fairly strong correlation among all three parameters occurred during low slack at Charleston (Figure 8).

An additional means of evaluating the effluent distribution is to determine the density field within the vicinity of the outfall. The density or specific gravity of seawater depends primarily on temperature (t) and salinity (S o/oo) of the water sample and sea pressure since water is slightly compressible. However, in shallow waters, pressure effects are negligable. Freshwater is slightly less dense than sea water because of dissolved salts and should therefore be found at the surface in zones of freshwater discharge. In open ocean, the average density of surface water is about 1.025 gm per cm^{-3} (Newmann and Pierson, 1966). In estuaries, the salinity may be anywhere between this value and 1.00 gm per cm^{-3} (pure water). It has become customary to abbreviate density values because fresh water and oceanic values differ only at the third or fourth significant figure. This abbreviation is known as sigma-t (Dietrich, 1957; Neumann and Pierson, 1966).

$$\text{sigma-t} = (D_{s,t} - 1.000) \times 10^3$$

where $D_{s,t}$ is the density and is a function of salinity and temperature. Sigma-t values for this work as a function of salinity and temperature were determined by the methods of Bialek (1966) and are shown on Tables 2 through 5. These data show that in January surface waters at both ambient and mixing zone stations are slightly less dense than waters at depth. Since temperatures among depths at each station are relatively uniform, the differences are due to varying salinity. Thus, during midwinter a slight vertical stratification appears to exist due to dilution of Sinclair Inlet surface waters by rivers and stormwater runoff. Surprisingly, surface waters over the discharges actually appear to be higher than surface waters in mid-inlet. The STP discharge did not appear to decrease surface salinities to a greater degree than surface runoff. We would also expect surface density to increase downstream from the discharge as the seawater further dilutes the freshwater discharge. However, the downstream change in values were too slight to identify this process.

During March, surface water densities were lower than in mid-winter probably due to elevated surface water temperatures in addition to reduced salinity. Vertical stratification appeared to be increased. As before, surface water directly over both discharges were slightly more dense than those at mid-inlet due to higher salinities. Thus, the March case is similar to the earlier period in that both discharges seem to undergo a level of initial dilution such that freshwater accumulation at the surface is not apparent. Downstream mixing processes do not appear to be important.

It appears that neither discharge is of sufficient volume at present to significantly alter the existing salt balance or density field within the vicinity of the discharge. Prediction of the outcome of increasing STP flows is beyond the scope of this work.

Loading Characteristics

Table 6 contains calculated loads of materials which were discharged into Sinclair Inlet from a number of rivers and the discharges during the study. These loads are derived from river flow data obtained during March and from the STP Class II studies (Abercrombie and Yake, 1980; Wright, personal communication). River and stream flows were probably lower than those typical of mid-winter high runoff periods. The total load from all river sources are lower than actual values because time constraints prevented obtaining samples and flow measurements from all streams and storm drains entering Sinclair Inlet. Load calculations on materials discharged from the STPs are subject to uncertainty because the STP samples were taken at the beginning of each outfall line, not at the discharge end. Fecal coliform loads were impossible to determine exactly because of the extended period of contact time in the outfall pipe prior to discharge.

An estimated fc value may be obtained by taking a sample of chlorinated effluent and dechlorinating it with sodium thiosulfate after a time equal to the outfall travel time. Abercrombie and Yake (1980) dechlorinated a sample after 36 minutes at Port Orchard STP. Total chlorine residual was 6.0-9.0 mg/L. On March 23, 1981, travel time and total chlorine residual was comparable. Their data was used to calculate the Port Orchard STP fecal coliform load. They did not perform this procedure at Bremerton STP No. 1. Therefore, no fecal loads were estimated.

CONCLUSIONS

Generally, the Port Orchard STP and the Bremerton STP No. 2 produced few noteworthy impacts on their respective receiving waters. This is due in part to initial dilution of the relatively small-volume discharges, and the relatively high levels of fecal coliform and ammonia in samples taken at nearshore stations in the vicinity. Although a number of water quality violations occurred, these were borderline and not substantially different than values at adjacent nearshore stations. The loads of materials attributable to the STPs appeared to be absorbed without excessive buildup of concentrations attributable to them. This is not to say that this case is the same during other seasons of the year. EPA (1978) identified a critical period during algal die-off in which oxygen levels would drop due to resultant decomposition processes. The critical period would likely occur during late summer or early fall. Added STP organic loads may create oxygen problems. Further study may be indicated.

Despite the lack of evidence of materials buildup in the receiving waters, proper concern should be paid to the effects of accumulation of materials that are stable over several weeks. This particularly true at Bremerton STP No. 2 where the possibility of nearshore encroachment is high. The University of Washington physical model of Puget Sound was used to qualitatively analyze Sinclair Inlet circulation (Determan, 1980). Ink was injected at the site of the Bremerton facility during a model two-week

Table 6. Summary of loading characteristics of selected Sinclair Inlet streams, Bremerton STP No. 2 and Port Orchard STP sampled during March 23 through March 26, 1981.

Location	Date Sampled	Flow (MGD)	Fecal Coliform[1]	Total Inorganic Nitrogen	$O\text{-}PO_4\text{-}P$	Total Suspended Solids	BOD_5[2]
Bremerton STP No. 2[3]	3/23/81	4.21					
Concentration[4]				11	2.4	84	82
Load[5]				387.1	84.5	2,956.4	2,886.0
(Relative load; %)		(9.0)		(63)	(74.3)	(43.4)	(77.2)
Unnamed Creek (B-2)	3/24/81	0.14					
Concentration			180	0.96	0.05	50	--
Load			9.6×10^8	1.12	0.1	58.5	--
(Relative load; %)		(0.3)	--	(0.2)	(0.1)	(0.8)	--
Unnamed Creek (B-4)	3/24/81	1.42					
Concentration			4 (est)	0.58	<0.01	5	--
Load			2.2×10^8	6.89	<0.1	59.3	--
(Relative load; %)		(3.0)	--	(1.0)	(<0.1)	(0.9)	--
Ghorst Creek	3/24/81	22.52					
Concentration			5,000	0.48	0.03	13	--
Load			4.3×10^{12}	90.37	5.6	2,458.6	--
(Relative load; %)		(48.1)	--	(15)	(4.9)	(36.1)	--
Port Orchard STP	3/25/81	0.68					
Concentration			260	12	3.5	54	150
Load			6.7×10^9	68.22	19.9	307.0	852.7
(Relative load; %)		(1.45)	--	(11)	(17.5)	(4.5)	(22.8)
Blackjack Creek (B-2)	3/24/81	12.41					
Concentration			22	0.42	0.02	5	--
Load			10.4×10^9	43.47	2.1	520.4	--
(Relative load; %)		(26.5)	--	(7)	(1.8)	(7.6)	--
Ross Creek	3/24/81	5.40					
Concentration			170	0.38	0.03	10	--
Load			3.5×10^{10}	17.15	1.4	451.4	--
(Relative load; %)		(11.5)	--	(3)	(1.2)	(6.6)	--
Total STP Load		4.89	--	455.32	104.4	3,263	3,738
(Relative load; %)		(9.6)	--	(74)	(92)	(48)	(100)
Total River Load		41.89	4.3×10^{12}	159.00	9.3	3,548	--
(Relative load; %)		(90.4)	--	(26)	(8)	(52)	--
Total Load All Sources		46.78	--	614.32	113.7	6,811	--
(Relative load; %)		(100)	--	(100)	(100)	(100)	--

1/ Final unchlorinated effluent.

2/ Final chlorinated effluent.

3/ Wright (1981).

4/ Concentration units; fecal coliform:Fc/100 ml; others: mg/L.

5/ Load units; fecal coliform:Fc/day (x 10^9); others: pounds/day.

6/ Abercrombie and Yake (1981); sample dechlorinated after 36 minutes.

period of tidal flow. Analysis of a time-series of photographys showed that the limited circulation caused ink concentrations to build up uniform~~i~~ly inlet wide. A well-defined boundary exists between Retsil and the southwest corner of Puget Sound Naval Shipyard. Ink appeared to escape to the east near Port Orchard. The study suggested that a steady state existed after two weeks.

Although the purpose of this study was largely confined to descriptions of the water quality at present discharge flows, there has been some interest in the prediction of the effects of increased discharge from the two facilities (Determan, 1980) on Sinclair Inlet receiving waters. This is beyond the scope of this work. However, EPA Region X has used PLUME, a computer model to estimate the effects of ocean discharges. The model can be calibrated by applying the concentration of a conservative (nonreactive) parameter obtained within the surface waters over the discharge (John Yearsley, personal communication). It is hoped that the data obtained in this study may be useful in this regard.

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