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CHAMBERS CREEK WASTEWATER TREATMENT PLANT RECEIVING WATER STUDY

by

Timothy A. Determan

Washington State Department of Ecology
Water Quality Investigations Section
Olympia, Washington 98504-6811

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ABSTRACT

The Chambers Creek Wastewater Treatment Plant is currently at half its design capacity. Its dilution zone generally complies with dilution zone guidelines. The effluent plume may surface during slack current, but its effects are minimal and temporary. There are no water quality violations attributable to the effluent.

INTRODUCTION

The Chambers Creek Wastewater Treatment Plant (WTP) is about three years old. The plant has a design flow of 12 million gallons per day (MGD). The present flow is about half the design capacity. A study of the effect of the WTP on the receiving waters was requested by Darrel Anderson of the Southwest Regional Office (SWRO) of the Department of Ecology. The objectives of the survey were as follows:

1. To locate the dilution zone accurately as defined in Chapter 25 of Criteria for Sewage Works Design (Ecology, 1985).

2. To determine whether the effluent reaches 100:1 dilution within the dilution zone.

The study was performed by the Water Quality Investigations Section (WQIS) on February 17 and 18, 1987. The author was assisted in the field by Will Kendra. The study was performed in conjunction with a Class II inspection of the WTP by Donald Reif of the same section (Reif, 1987).

SETTING

The WTP discharges into southern Puget Sound immediately north of the mouth of Chambers Creek and about two miles north of Steilacoom (Figure 1). The area is classified as AA in the state Water Quality Standards (Ecology, 1982). The criteria applicable to the standards are in Appendix 1.

Effluent from the WTP is discharged through a diffuser which is 112 feet long and lies 100 to 120 feet below mean lower low water at a minimum distance of 700 feet from shore (Figure 2). The diffuser has eight cylindrical risers spaced 16 feet apart. The risers are about six feet above the bottom (Sunchasers, Inc., 1985). Each riser has a single discharge port oriented perpendicular to the axis of the diffuser line. Alternate ports face opposite directions.

The dimensions of a dilution zone in an estuary are governed by Ecology (1985). This document was used to define the dimensions of the dilution zone for the Chambers Creek discharge. This is discussed in Appendix 2.

Three other permitted point sources discharge into nearshore waters in the vicinity. Steilacoom WTP, located about one mile to the south, is a primary WTP with a permit flow ranging from 1.2 MGD in dry weather to

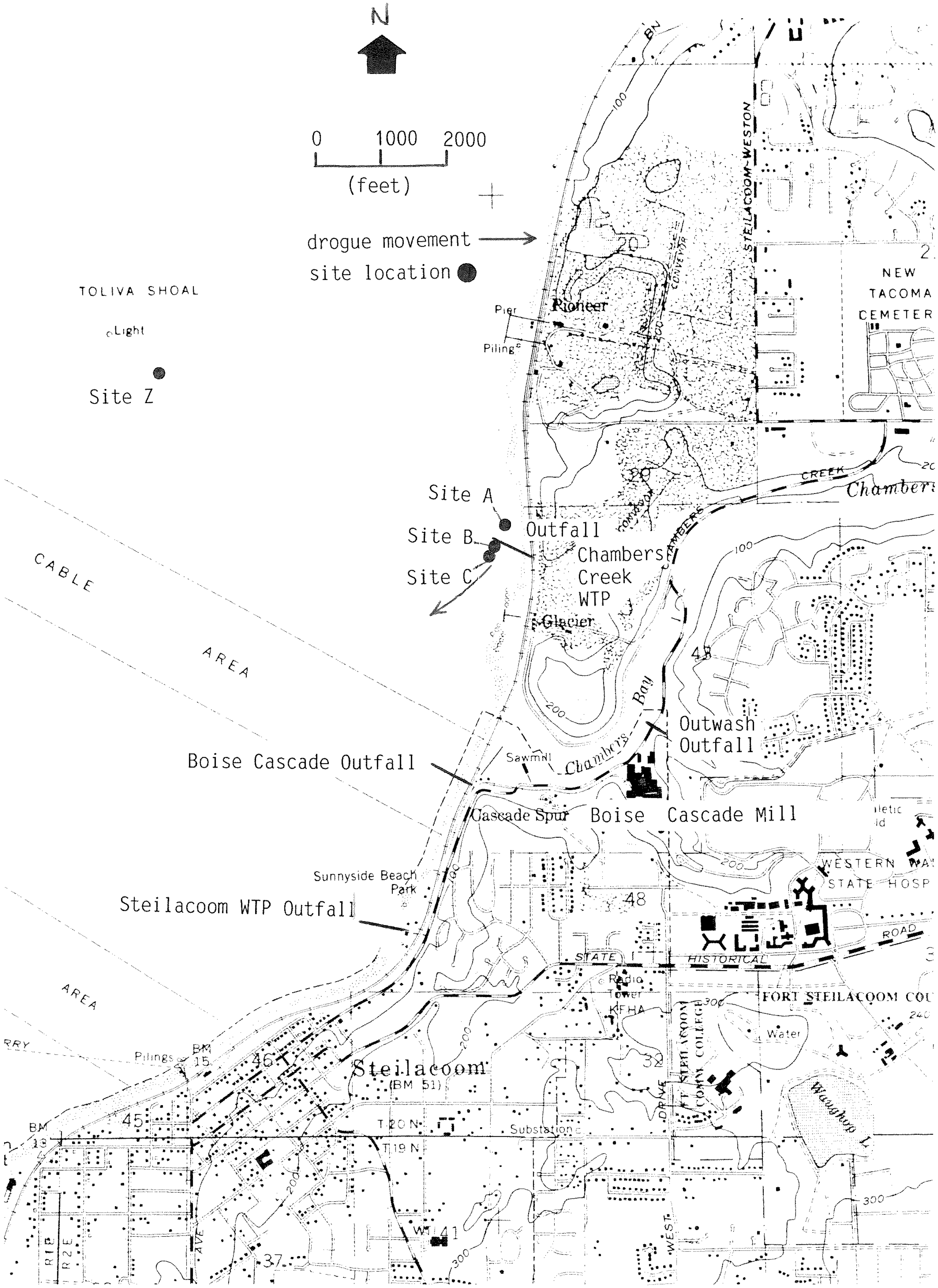

Figure 1. Chambers Creek WTP dilution zone and sampling sites during a receiving water study on February 17-18, 1987.

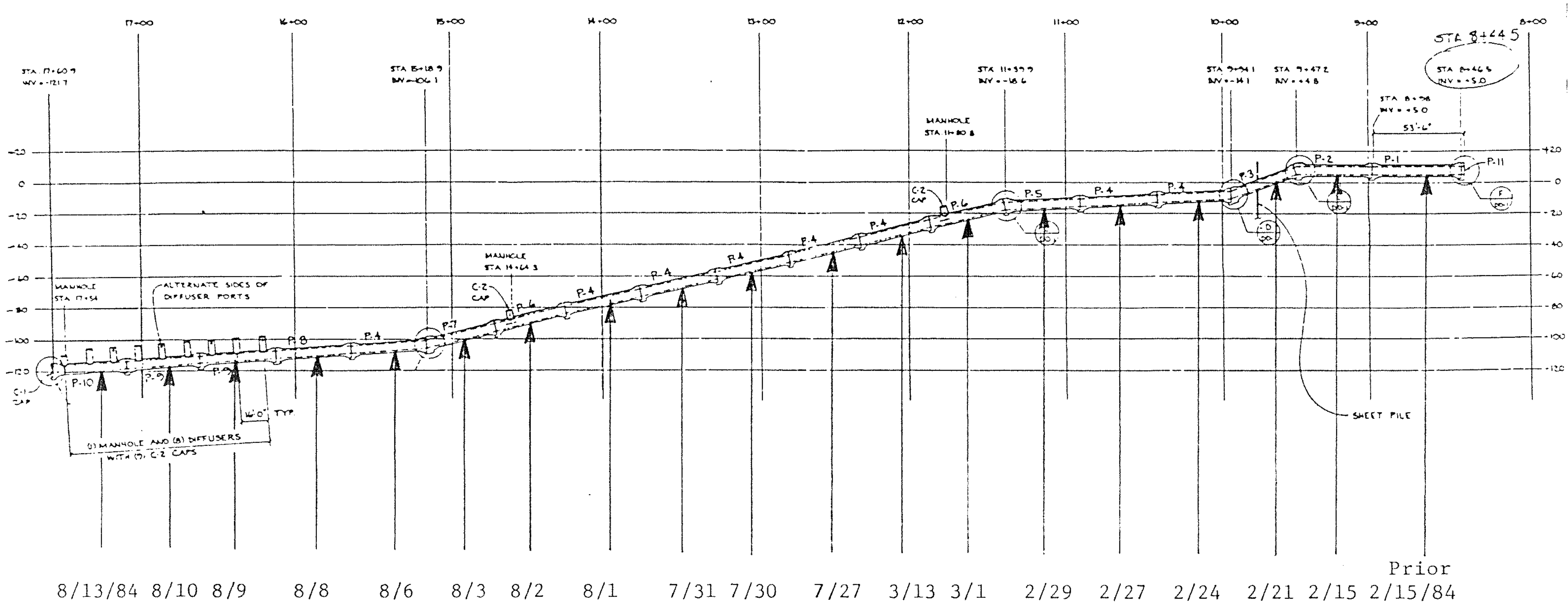

Figure 2. Profile of completed Outfall line serving Chambers Creek WTP.

1.9 MGD in wet. Its capacity has recently been expanded and the depth of the outfall increased. The plant will be phased out and the sewage diverted to the Chambers Creek facility in two years (D. Anderson, personal communication).

Two outfalls serve the Boise Cascade Paper Company pulping plant south of Chambers Creek. One outfall carries backwash from a process water filtration plant to Chambers Creek. Flow is intermittent. A second outfall discharges secondarily treated effluent into Puget Sound via a 96-foot (30-meter) diffuser lying about 400 feet (120 meters) offshore. A review of NPDES discharge monitoring reports shows an average wet-weather flow of 4.4 MGD.

Two quarry companies occupy much of the shoreline between Chambers Creek and Sunset Beach to the north. Routine operations include washing of sand and gravel. However, there does not appear to be any seaward discharge of washwater. Additional shoreline use in this area is precluded by the Burlington Northern Railroad right-of-way.

Currents in the area were described by McGary and Lincoln (1977) based on a physical model of Puget Sound. During flood tide, several gyres form among nearby islands and shoals. Smaller gyres are associated with bights along the shoreline. These gyres break down during ebb tide when a unidirectional regional flow moves northward toward the Tacoma Narrows.

During most of the tide cycle, a clockwise gyre exists at the mouth of Chambers Creek. This may sweep creek water into the center of the channel and away from the WTP diffuser. This gyre breaks down during ebb tide. River flow may then pass directly over the diffuser.

METHODS

The discharge line was located with a Sitex-Honda Model HE-356 recording depth sounder. The seaward end was located when the outfall pipe was no longer visible on the recorder. At that point, an anchor attached to a line was deployed. The other end of the line was weighted with a 3-pound downrigger weight. A surface float was attached so that it could slide freely on the line. In this way, the line continually adjusted for changing tide height. Next, a measuring line and the image on the depth sounder were used to locate the landward end of the diffuser. At that point, another line/float was deployed.

Two drift drogues (0.25 square meter) were launched at the beginning of the sampling on February 17 to estimate the current velocity. The drogues were launched at the diffuser about 15 minutes before slack water was predicted to occur at mid-channel off Gibson Point to the north (NOAA, 1987a). This was 22 minutes after the predicted lower low tide at the Tacoma Narrows (NOAA, 1987b). Current direction at the diffuser was southwesterly. The current direction minimized the direct effects of the sources discussed earlier. Each drogue was suspended at a depth of 1 meter by a surface float. Bearings were taken periodically with a hand-bearing compass and plotted. Velocity was calculated by dividing the displaced distance by the elapsed time.

Three sampling sites were located in the vicinity of the diffuser. Site A was about 300 feet (90 meters) northeast of the diffuser beyond the up-current boundary of the dilution zone. Depth at this point was relative shallow--66 feet (20 meters). Site B was 100 feet (33 meters) down-current of the diffuser. Water depth averaged 120 feet (35 meters). Site C was about 300 feet (90 meters) down-current of the diffuser at or just beyond the dilution zone. The depth here was just under 100 feet (30 meters). Positions down-current from the diffuser were estimated by reference to marked surface lines clipped to the floats marking the diffuser. Site Z, the control site, was located near the Toliva Shoal navigational buoy, about one nautical mile NNW of the diffuser.

Salinity, temperature, dissolved oxygen (D.O.), were recorded with a Hydrolab Surveyor II. Readings were made at each site, generally at depths of 0, 1, 5, 10, 20, 30, and 40 meters. Deviations from this format are shown on the appropriate tables and figures. Average values were calculated from several readings at each site and depth in order to evaluate field variation.

Water samples were taken at each site with a Kemmerer water sampling bottle. Inorganic nutrients (nitrate+nitrite, ammonia, total phosphorus), turbidity, and total suspended solids were sampled at 0, 1, 5, and 10 meters depth. Total Kjeldahl nitrogen was sampled at 0 and 10 meters. Fecal coliform samples were taken at the surface using sterilized bottles containing sodium thiosulfate to arrest disinfection of FC in case chlorine residual was present in the dilution zone. All samples were collected according to procedures in Huntamer (1986) and sent to Ecology's environmental laboratory at Manchester for analysis according to APHA (1985) and EPA (1979).

In order to directly evaluate mixing processes within the dilution zone, flourescent dye was injected into the discharge line and attempts made to measure dye concentrations in the receiving waters. None was detected. Upon further reflection, it appears likely that the dye was injected for an insufficient length of time and therefore was missed in the receiving water.

Data were analyzed and plotted using a SMART spreadsheet (Innovative Software, Inc., 1986) and STATGRAPHICS (STSC, Inc., 1986).

RESULTS AND DISCUSSION

Current movement in the dilution zone during both days of the survey was southwesterly. (This was in accord with the study design which called for sampling during rising tide following lower low water.) Initially, the drogues moved toward Steilacoom for about 50 minutes and then turned westward toward the center of the Sound. This agreed with McGary and Lincoln (1966) who described a clockwise gyre associated with the mouth of Chambers Creek. Total displacement of the drogues was 360 meters in 91 minutes. The velocity was 0.07 m/sec.

Figures 3 through 6(a and b) and Table 1 show data collected on February 17. The figures show maximum gradient in depths shallower than 5 meters and relatively little change deeper.

Temperature was similar at all sites and most depths (Figure 3). Surface waters (0 and 1m) at Site A (up-current of the discharge) were cooler than all other sites. The plot shows no evidence of effluent at depth.

Salinity is shown in Figure 4. The pattern of a surfacing discharge plume cannot be discerned from these data. The salinity dipped slightly at 10 meters at Site B. This might be expected if a trapping layer from a plume were present at that depth. But salinity both up-current (Site A) and down-current (Site C) of the diffuser were generally lower than Site B, which would be expected to be more affected by a rising plume.

Salinity at Site Z (Toliva Shoal) at most depths is slightly greater than sites near the discharge zone. This suggests that freshwater from numerous sources (e.g., Chambers Creek) has resulted in lower salinities nearshore. In such a system, localized sources may be difficult to distinguish from others.

Density is a function of both temperature and salinity and it more directly depicts the buoyant behavior of freshwater effluent in saltwater than either of those independent variables alone. (Density is also a function of pressure. However in shallow water, pressure effects are negligible.) Density was calculated as sigma-t units using the methods of Bialek (1966):

$$\text{sigma-t} = (\text{Density} - 1.000) * 1000 \qquad (2)$$

The data are plotted in Figure 5. The sigma-t data (like salinity) suggest that the water column up-current from the diffuser was less dense than at Site B which was immediately down-current of the diffuser. This is unlikely and indicates that the data are probably not statistically different within the same depth. Thus the effluent plume is not discernible in this case, either.

All sites showed similar vertical patterns of oxygen, both as concentrations and as percent saturation (Figures 6a and b). Oxygen met the water quality criteria everywhere. Again, there was no evidence of a plume. Oxygen levels appeared to be lower at the control site than in the vicinity of the dilution zone. On the other hand, there is evidence that D.O. fell slightly moving down-current through the dilution zone.

Table 1 shows results of laboratory analysis. These results are contrasted with results obtained from both 24-hour composite and grab samples of the WTP effluent obtained during the Class II inspection (Reif, 1987, in preparation). The plant complied with all NPDES permit requirements.

Ammonia at the surface just down-current from the diffuser (Site B) was greater than at depth or farther down-current (Site C) or up-current of the diffuser (Site A). This may be evidence of a surfacing plume. If we assume the ammonia at this point was from the WTP, the fraction of

Table 1. Summary of in-situ measurements and laboratory results for sites in the vicinity of the Chambers Creek WTP dilution zone and control site. Results from the WTP effluent (Reif, 1987) are included for comparison.

Site Number	Site Description	Depth (meters)	Salinity (ppt)	Temp. (°C)	Density* (sigma-T)	pH (S.U.)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% sat.)	Nitrate+ Nitrite (mg/L)	Ammonia (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Total Phos. (mg/L)	Turb. (NTU)	Total Susp. Solids (mg/L)	Fecal Coliform (#/100 mL)
WTP	Effluent		NT	14	NT	7.20	14(1)	NT	6.6	17	NT	NT	4	11	60(2)
A	100 meters	0	27.20	8.37	21.2	**	8.49	85.7	0.23	0.08	0.31	0.09	1	3	15
	upflow	1	27.20	8.40	21.2	**	8.38	84.7	0.25	0.06	*	0.09	1	1	*
	from WTP	5	27.90	8.24	21.7	**	8.13	82.3	0.24	0.03	*	0.08	1	1	*
	diffuser	10	27.90	8.24	21.7	**	8.07	81.7	0.26	0.05	0.23	0.08	1	2	*
		20	28.19	8.23	21.9	**	7.97	80.8	*	*	*	*	*	*	*
B	33 meters	0	27.30	8.33	21.2	**	8.60	86.8	0.24	0.14	0.29	0.08	1	2	7
	downflow	1	27.53	8.24	21.4	**	8.25	83.3	0.23	0.09	*	0.08	1	4	*
	of the	5	28.05	8.23	21.8	**	8.10	82.0	0.25	0.07	*	0.08	1	2	*
	diffuser	10	27.95	8.21	21.8	**	8.00	80.9	0.23	0.08	0.23	0.08	1	1	*
		20	28.20	8.22	22.0	**	7.92	80.3	*	*	*	*	*	*	*
		35	28.58	8.23	22.2	**	7.77	79.0	*	*	*	*	*	*	*
C	100 meters	0	27.50	8.30	21.4	**	8.37	84.6	0.24	0.08	0.27	0.08	1	1	13
	downflow	1	27.70	8.26	21.6	**	8.25	83.4	0.23	0.05	*	0.08	1	3	*
	from WTP	5	27.80	8.22	21.6	**	7.98	80.7	0.25	0.06	*	0.08	1	1	*
	diffuser	10	*	*	*	**	*	*	0.23	0.04	0.19	0.08	1	3	*
	diffuser	20	27.99	8.22	21.8	**	7.88	79.7	*	*	*	*	*	*	*
		30	28.03	8.23	21.8	**	7.81	79.1	*	*	*	*	*	*	*
Z	Control	0	27.86	8.30	21.7	**	8.57	86.9	0.25	0.04	**	0.08	1	11	1
	site	1	27.90	8.30	21.7	**	8.35	84.6	0.29	0.05	*	0.08	1	1	*
	(Toliva	5	28.07	8.26	21.8	**	8.22	83.3	0.27	0.09	*	0.08	1	1	*
	Shoals)	10	28.08	8.24	21.8	**	8.13	82.4	0.22	**	0.31	0.08	1	2	*
		20	28.20	8.23	22.0	**	7.95	80.6	*	*	*	*	*	*	*
		40	28.11	8.24	21.9	**	7.91	80.2	*	*	*	*	*	*	*

NT = Not taken or not performed.
(1) = 5-day BOD
(2) = Geometric mean of two grab samples.
* = Sample not taken at this depth.
** = Data not included due to field aberration or analytical error.

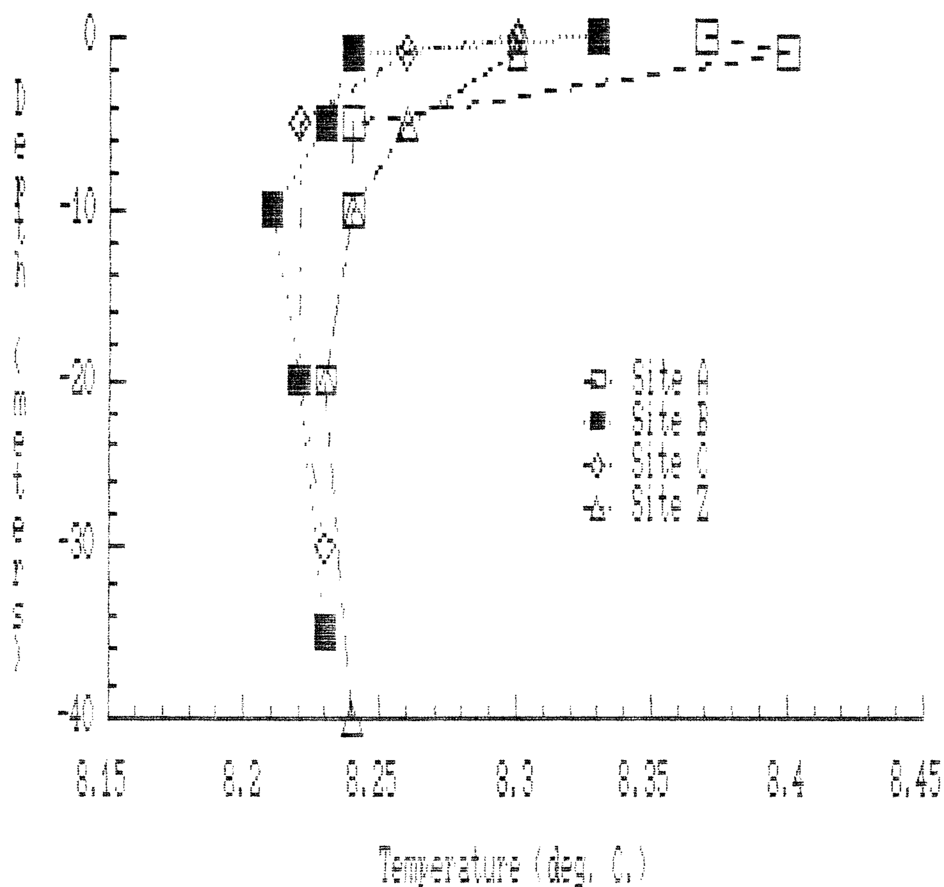

Figure 3. Vertical distribution of temperature with depth from data collected during the Chambers Creek WTP receiving water study on February 17, 1987.

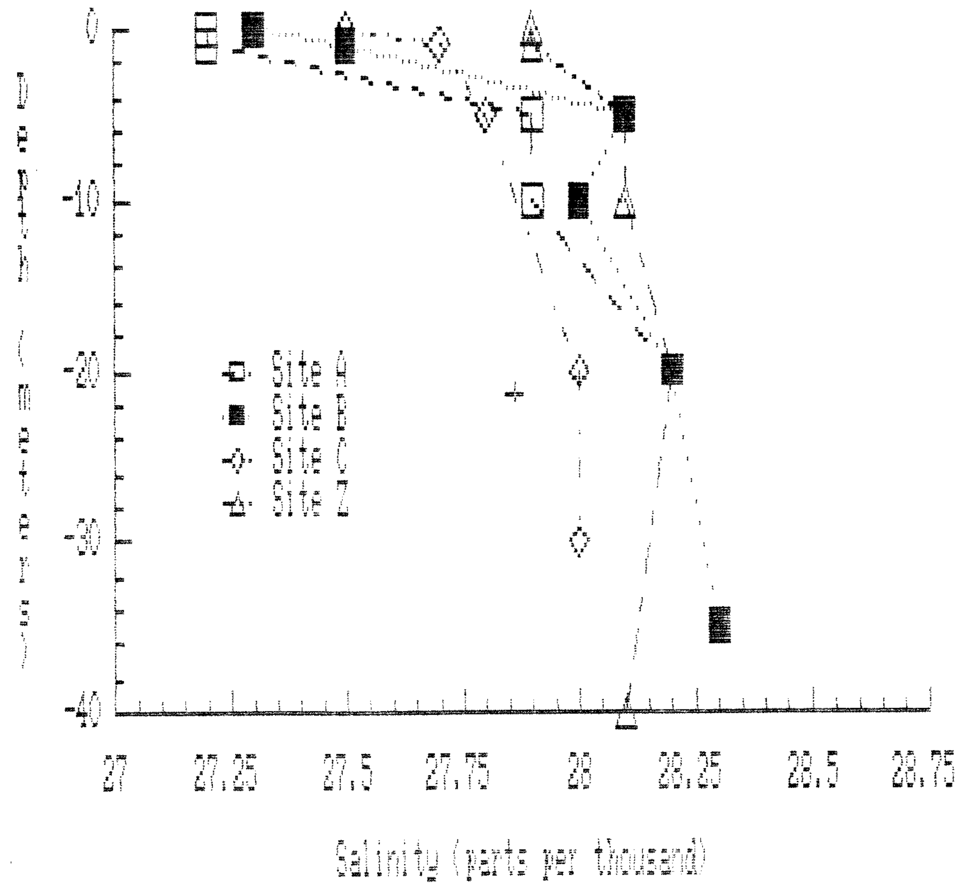

Figure 4. Vertical distribution of salinity with depth from data collected during the Chambers Creek WTP receiving water study on February 17, 1987.

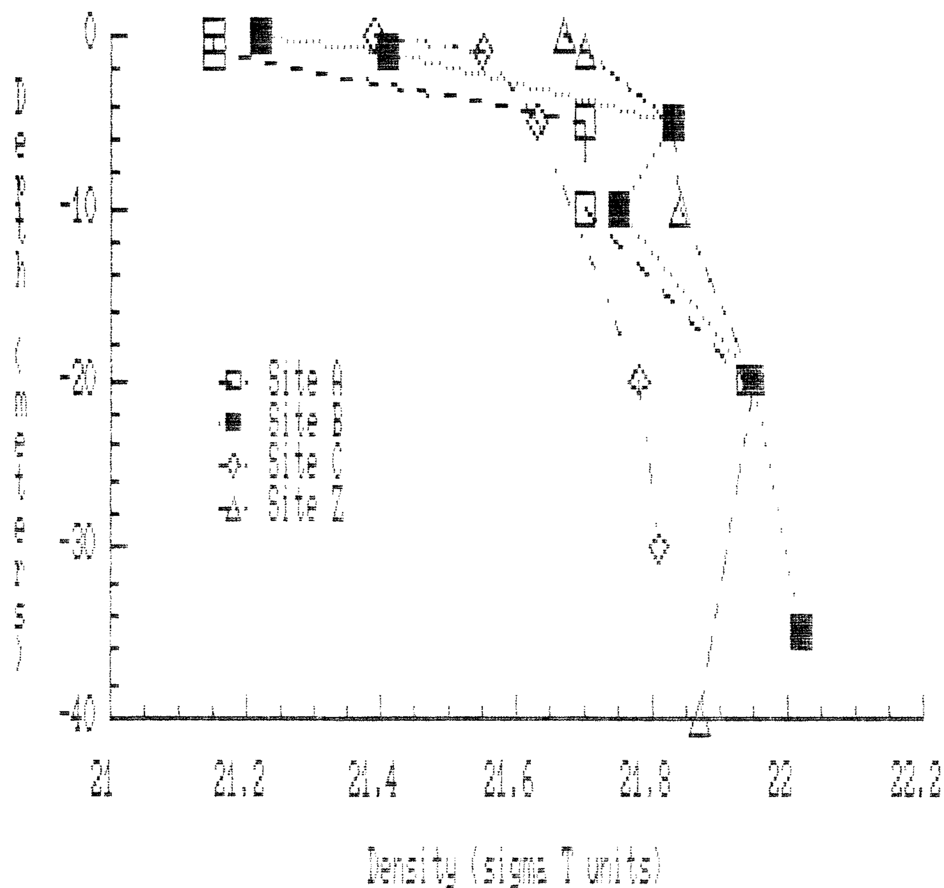

Figure 5. Vertical distribution of water density (sigma-t) with depth from data collected during the Chambers Creek WTP receiving water study on February 17, 1987.

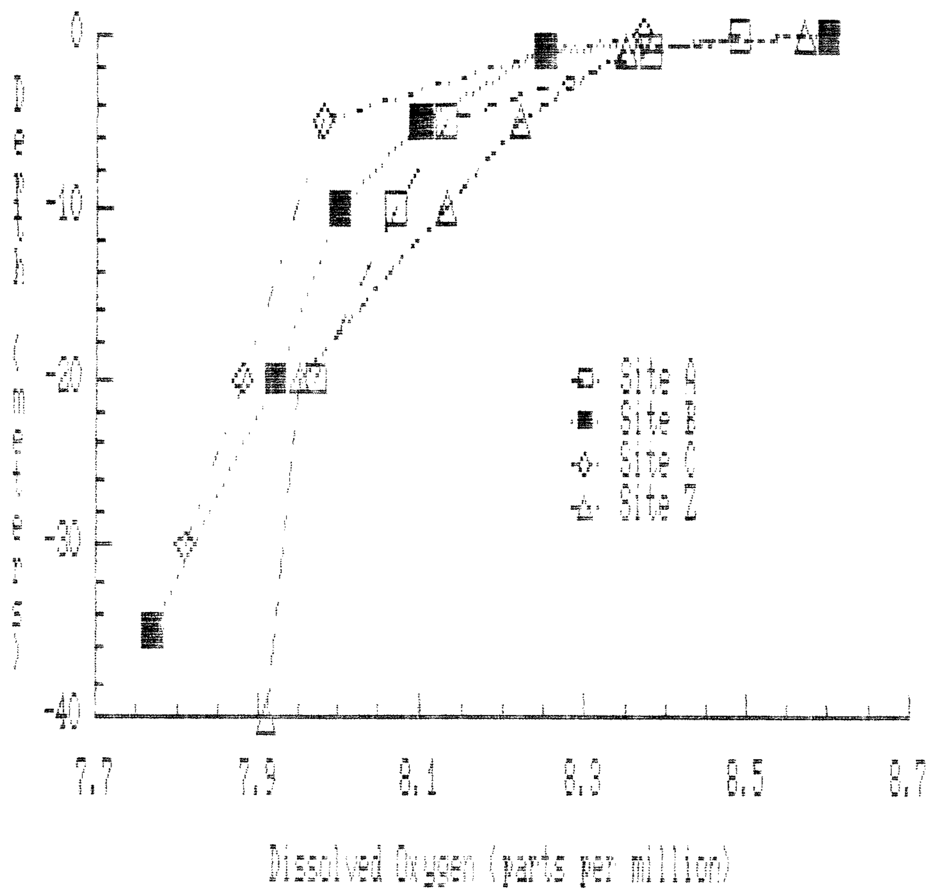

Figure 6a. Vertical distribution of dissolved oxygen concentrations with depth from data collected during the Chambers Creek WTP receiving water study on February 17, 1987.

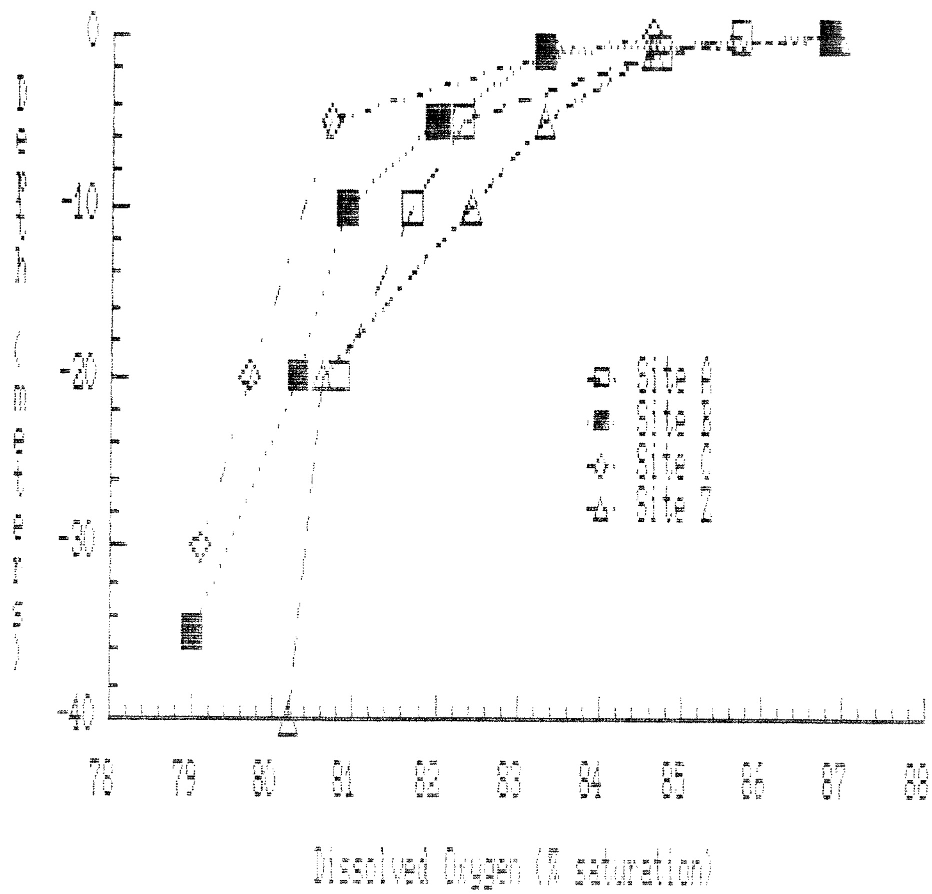

Figure 6b. Vertical distribution of dissolved oxygen (percent saturation) with depth from data collected during the Chambers Creek WTP receiving water study on February 17, 1987.

effluent would be 0.14/17 or slightly less than one percent. This suggests conformance with the dilution ratio of 100:1 specified by Ecology (1985).

The remaining data on Table 1 do not show corresponding evidence of a surfacing plume. Fecal coliforms in the vicinity of the dilution zone were much greater than the level at Toliva Shoal (Site Z), but were within or very close to the water quality standard (see Appendix 1).

The dilution zone guidelines (Ecology, 1985) require a dilution ratio of 100:1. The concentration of effluent after dilution would be about one percent of the initial effluent concentration. We can evaluate the dilution characteristics of the Chambers Creek WTP in terms of the fraction of freshwater found within the dilution zone. It was assumed that all the freshwater found within the dilution zone (particularly at depth) came from the effluent and thus was a conservative tracer for the effluent. The fraction of freshwater (or effluent) was estimated using Mills, et al. (1982):

$$f = (S - S') / S \qquad (3)$$

where f = the fraction of freshwater at each point and depth in the dilution zone;
S = the salinity (ppt) at the corresponding depth at Toliva Shoals;
S' = the salinity at a point in the dilution zone.

The fraction of freshwater was determined for each sampling point (Table 2). Each value was calculated with the Toliva Shoal salinity from the corresponding depth. Toliva Shoal was assumed to have minimum freshwater given its relative isolation from the shoreline.

The results show only trace amounts of freshwater in the dilution zone. The highest percentages were near-surface at and up-current of the diffuser (2 to 3 percent). This may be evidence of a plume that surfaced during the previous period of slack current. But the feature was temporary. After sampling was completed on February 17, a surface slick was noticed about 10 meters up-current from the marked location of the diffuser. A series of salinity readings was made on February 17 at 1 meter deep inside and outside the slick to determine the amount of effluent (if any) present. The results from both locations were identical (27.9 ppt). The fraction of freshwater present (relative to the surface at Toliva Shoals) was 0.0. This indicated that the slick was likely a boundary between local currents rather than a surfacing plume.

The fraction of freshwater at all other points below 1 meter and at the down-current boundary of the dilution zone (Site C) did not exceed 1 percent. Thus the Chambers Creek discharge generally conforms to the dilution ratio specified in the dilution zone guidelines (Ecology, 1985).

Table 2. The fraction of freshwater at various sites and depths in the vicinity of Chambers Creek WTP dilution zone.

DEPTHS (meters)	SITE A (100 meters upcurrent of diffuser)	SITE B (33 meters downcurrent of diffuser)	SITE C (100 meters downcurrent of diffuser)
0	0.02	0.02	0.01
1	0.03	0.01	0.01
5	0.00	0.00	0.01
10	0.01	0.01	*
20	0.00	0.00	0.01
30	*	*	0.00
35	*	0.00	*
40	*	*	*

*Sample not taken at this depth.

CONCLUSIONS

1. The dilution zone under the present WTP flow regime appeared to comply fully with the dilution zone guidelines in Ecology (1985).

2. There was a suggestion that the plume surfaced during slack current. But its effects appeared to be minimal and temporary.

3. There were no violations of the water quality standards attributable to the WTP effluent.

RECOMMENDATIONS

The results of this study serve as a baseline. The study should be repeated after the Chambers Creek WTP reaches its design flow.

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Appendix 1. Parametric coverage, rationale, and associated water quality standards (WDOE, 1982) for Puget Sound in the vicinity of Chambers Creek WTP discharge.

Parameter	Method	Reason for Sampling	Water Quality Standard (Class AA)
Fecal Coliform Bacteria (FC/100 mL)	APHA (1985)	Indicator of presence of intestinal wastes from humans and other animals.	Not to exceed a geometric mean of 14 FC per 100 mL, with not more than 10 percent of samples to ex- samples to exceed 43 FC/ 100 mL.
Temperature (^{o}C)	Temperature function on Hydrolab Surveyor II	Used with salinity to determine water density (sigma-t) and with oxygen to determine percent saturation. Temperature also affects gas solubility and rates of biological processes.	Not to exceed 13.0^{o}C due to human activities. When natural conditions exceed 13.0^{o}C (seawater), no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3^{o}C.
Salinity (o/oo)	Salinity function on Hydrolab Surveyor II	Used to trace passage of freshwater through marine waters. Also affects mixing rates and density distribution in water column and solubility of dissolved oxygen.	In brackish waters of estuaries, where fresh and marine water quality criteria differ within the same classification, the criteria shall be interpolated on the basis of salinity; except that the marine water quality criteria shall apply for dissolved oxygen when the salinity is one part per thousand or greater and for fecal coliform organisms when the salinity is ten parts per thousand or greater.
Dissolved Oxygen (mg/L)	Oxygen function on Hydrolab Surveyor II	Elevated, relatively constant oxygen levels are essential for stable aquatic communities. Highly variable levels downflow from a source may be indicative of an organic load in excess of the system to assimilate it.	Shall exceed 7.0 mg/L; when natural conditions (e.g., upwelling) depress D.O. near or below 7.0 mg/L, natural D.O. levels can be degraded by up to 0.2 mg/L by man-caused activities.

Appendix 1 - continued.

Parameter	Method	Reason for Sampling	Water Quality Standard (Class AA)
Nutrients (mg/L) NO_3-N; NO_2-N; NH_3-N; O-PO_4-P; T-PO_4-P	EPA (1979); APHA (1985)	Inorganic nutrients are readily available for assimilation by algae and other aquatic plants. Excessive levels with abundant light may lead to massive algae production at the expense of other plants and animals. Ammonia (NH_3-N) is an immediate by-product of the breakdown of urine and therefore may be useful to trace animal wastes in water.	State numerical standard for ammonia under development. Toxicity standard contained in EPA (1986) based on temperature and pH.
pH (S.U.)	pH function on Hydrolab Surveyor II	pH affects the carbonic acid-carbon dioxide balance in water. pH also affects the activity of un-ionized ammonia, sulfide, and metals.	Shall be within the range 7.0 to 8.5 with man-caused variation within a range of less than 0.2 unit.
Total Suspended Solids (mg/L)	EPA (1979); APHA (1985)	Measures water column transparency and light availability, and is an estimate of suspended material in water column.	No numerical standard. Sufficient light is essential to aquatic plant growth. Excessive suspended material may stress plants and animals by light reduction or smothering.
Turbidity (NTU)	Hach Turbidimeter	Measures water column transparency and light availability, and is an estimate of suspended material in water column. Turbidity is a function of the quantity and light-scattering characteristics of the suspended material.	Not to exceed 5 NTU over background if background is 50 NTU or less, or have more than a 10 percent increase in turbidity when background turbidity is more than 50 NTU. Sufficient light is essential to aquatic plant growth. Excessive suspended material may stress plants and animals by light reduction or smothering.

Appendix 2

The depth, width, and length of the Chambers Creek WTP dilution zone is as follows:

1. The limits in depth are one foot below the surface to one foot above the bottom.

2. The length with respect to the center line of the diffuser is 150 feet (45 meters) plus the water depth. Water depth at the time of the survey was about 110 feet (33 meters). Thus the length of the dilution zone was about 250 feet (75 meters) on either side of the diffuser.

3. The width shall be the length of the diffuser (112 feet or 34 meters) plus 100 feet (30 meters) plus the water depth (110 feet or 33 meters) for a total of 320 feet (96 meters). The shoreward and seaward boundary of the dilution zone lie 105 feet (32 meters) beyond the ends of the diffuser.

General requirements for dilution zones are included as follows:

1. The quality of water outside the dilution zone is to be maintained at the existing water quality or shall satisfy established water quality standards, whichever is greater.

2. The effluent from a dilution zone is not to effect beneficial uses in any way.

3. The overlapping of several dilution zones is not to be permitted.

4. The ratio of receiving water flow to effluent in a dilution zone is to be at least 100:1.