JOHN SPELLMAN
Governor

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STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
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MEMORANDUM
April 22, 1981

To: Carl Nuechterlein, Eastern Regional Office

From: Joseph Joy, Water and Wastewater Monitoring

Subject: Dragoon Creek Receiving Water Study/Deer Park STP

INTRODUCTION

A Class II inspection and receiving water study was requested by your office to determine the condition of the Deer Park sewage treatment plant (STP) and its receiving water, Dragoon Creek (waterway segment 24-55-02). It is the understanding of this office that the system serving Deer Park is under a stop hook-up order imposed by the local health department. Increased residential growth in the area has health officials concerned about possible STP inefficiencies and the resultant deterioration of water quality of Dragoon Creek. Total hook-ups are expected to increase 10 percent in the near future (Nuechterlein, 1980).

This report concentrates on the receiving water study portion of a total investigation performed November 18-19, 1980. The Class II inspection portion has been written under a separate cover (Abercrombie, 1981).

Site Description

Deer Park is a community of about 2,100 people located approximately 30 km north of Spokane. It lies near river mile (RM) 15 of Dragoon Creek, a tributary to the Little Spokane River.

The creek meanders through pastures and fields to the west of town (Figure 1). The STP lies on an acre abutting the creek which is surrounded by pasture and residential dwellings. Sludge beds are within 7.5 m (25 feet) of the channel and dug into unsealed, loose fill built up to 1.5 m (5 feet) above the level of the creek bed. The STP outfall is located 450 m (1,475 feet) downstream from the plant, about 37 m (120 feet) beyond the Highway 395 bridge on the right (north) bank. The outfall pipe crosses the creek bed under the Crawford Street bridge.

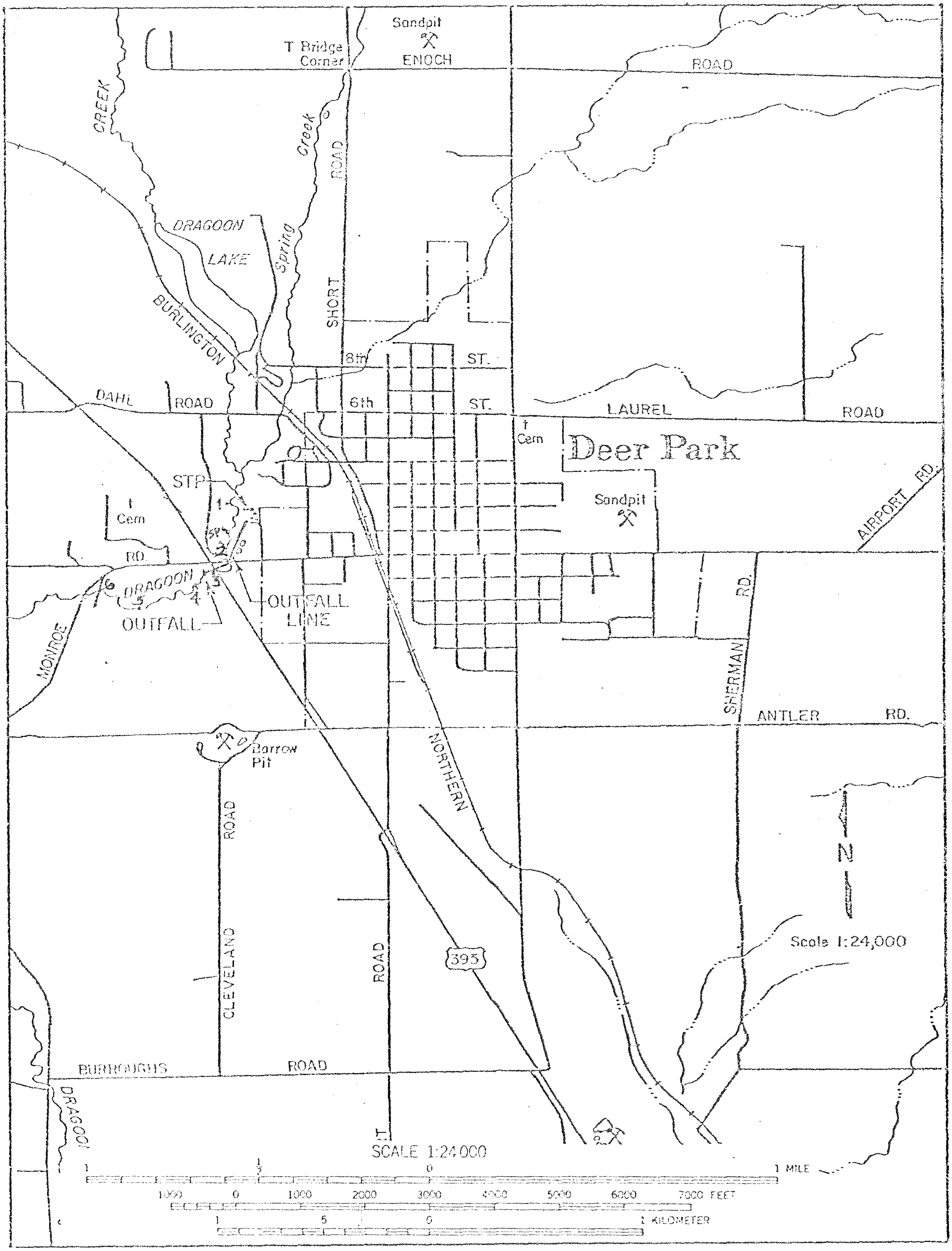


Figure I. DRAGOON CREEK – DEER PARK AND VICINITY.

The study area included 1.4 km (0.9 mile) of creek from 100 m (325 feet) above the STP to the old Monroe Road bridge 700 m (2,500 feet) downstream from the outfall (Figure 1). Adjacent lands are used for grazing small herds of livestock and operating small farms. Only one small irrigation withdrawal was seen; its location 475 m (2,000 feet) downstream from the outfall.

Within the study area, Dragoon Creek is relatively uniform. The channel is less than 3.5 m (11 feet) wide with steep, under-cut banks except where livestock have made accesses and bridges cross. The streambed is predominantly clay and silt except where bridge construction has left rubble. These factors produce a channel that is nearly all pools and runs with few riffles; 60 percent, 40 percent, and 2 percent, respectively (Kittle, 1977). Dragoon Creek's drainage area at RM 15 is approximately 155 km^2 (60 $miles^2$) of similar pasture and agricultural lands to the north and west.

The only tributary noted within the study area was a small spring entering on the right bank, 150 m (500 feet) downstream from the STP. It is assumed that the downstream discharge within the study area is increased by groundwater and subsurface flow.

Dragoon Creek is designated a Class A stream under WAC 173-201-070(6) and WAC 173-201-080(a5). Established Class A water quality standards are listed in Table 1 along with beneficial uses attributed to such waters.

Historical Data

There is a paucity of historical water quality and water resource data for Dragoon Creek, especially within the Deer Park vicinity. The USGS had operated a partial record discharge station at RM 0.1 in 1948 and 1960-1970. Calculated low flows for the creek are given in Table 2 (Chung, 1975).

A direct ratio of discharge to drainage area would give an approximate 7-day average, 20-year low flow of 4.5 cfs at RM 15. A low water discharge of 2.9 cfs was measured above the STP outfall in August of 1977 (Kittle, 1977). The dilution ratio at the outfall was approximately 13:1 during that study.

No record has been kept of Dragoon Creek biota by the Washington State Department of Game (WDG), Spokane Office, but a resident population of trout is known to provide good fishing between RM 15 and RM 4.1 (Peck, 1981). In 1977, Kittle sampled two fish index areas, one above and one below the outfall, which yielded two species of game fish along with several species of non-game fish. The largest groups of fish were suckers (f. Catostomidae) and minnows (f. Cyprinidae). The rainbow trout (*Salmo gairdneri*) and brook trout (*Salvelinus fontinalis*), both game fish species, were found to be in equal numbers above and below the outfall.

Table 1. Class A (Excellent) Water Quality Standards (WAC 173-201-045) and Characteristic Uses.

Characteristic Uses:	Water supply; wildlife habitat; livestock watering; general recreation and aesthetic enjoyment; commerce and navigation; fish reproduction, rearing, and harvesting.
<u>Water Quality Criteria</u>	
Fecal Coliform:	Median not to exceed 100 organisms/100 mls with not more than 10 percent of samples exceeding 200 organisms/100 mls.
Dissolved Oxygen:	Shall exceed 8 mg/L.
Total Dissolved Gas:	Shall not exceed 110 percent saturation.
Temperature:	Shall not exceed 18°C due to human activity. Increases shall not, at any time, exceed t = 28/(T+7); or where temperature exceeds 18°C naturally, no increase greater than 0.3°C. t = temperature in dilution zone, and T = highest temperature outside the dilution zone increases from non-point sources shall not exceed 2.8°C.
pH:	Shall be within the range of 6.5 to 8.5, with man-caused variation within a range of less than 0.5 units.
Toxic, Radioactive, or Deleterious Materials:	Shall be below concentrations of public health significance, or which may cause acute or chronic toxic conditions to the aquatic biota, or which may adversely affect any water use.
Aesthetic Values:	Shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste.

Table 2. Dragoon Creek Calculated Low Flows.

Dragoon Creek: 177 square miles (458 km^2) drainage area at RM 0.1

7-day average, 2-year low flow	19.5 cfs
7-day average, 20-year low flow	12.2 cfs

Water quality data from Kittle's August 1977 study are presented in Table 3. In-stream problems noted were high nutrient levels, especially ammonia. Corrected values for effluent and stream mixing shown indicate possibly un-ionized ammonia and chlorine toxicity problems. The study stated that no algal growth or change in bottom sediments was seen below the outfall.

Table 3. Mean Values from "Deer Park STP/Dragoon Creek Drought Monitoring Survey (August 22-25, 1977)" and unpublished notes data, Kittle, 1977.

Sampling Site	Flow cfs	Temp. °C	pH	NH_3-N (mg/L)	Un-ionized NH_3-N (mg/L)	NO_3-N (mg/L)	Total P (mg/L)	Total Residual Cl_2 (mg/L)
Upstream	2.90	22.0	7.2	0.01	--	2.10	0.07	--
Effluent	0.22	21.6	7.2	18.93	0.210	1.33	9.77	1.75 1.75 0.70
Downstream 20 feet from Outfall	3.12	22.0	7.3	0.49	0.007	2.03	0.43	N.D.
Theoretical Mixing Values	--	22.0	7.2	1.34	0.015	2.05	0.75	0.05

METHODS

Water quality samples were taken on two separate occasions at eight stations within the study area (Figure 1). Grab samples were taken at three sites above the outfall (Stations 1 through 3), at the spring (SP), the outfall (Eff.), and three sites below the outfall (Stations 4 through 6). In additon, 24-hour composite samples were taken at Stations 1 and 4 with Manning[R] field compositors set to collect 250 mls every 30 minutes.

Field analyses of the following parameters were performed at each station: temperature (°C); dissolved oxygen (D.O.) using the Winkler method; total residual chlorine (TRC) using DPD ferrous titrametric method; specific conductivity; and pH by field meters. In addition, water quality samples were collected, packed in ice, and transported to arrive at the Tumwater DOE analytical laboratory within 24 hours. The following analyses were performed on those samples:

- pH (S.U.)
- Specific Conductivity (umhos/cm)
- Chemical Oxygen Demand (mg/L)
- Biochemical Oxygen Demand (mg/L)
- Nitrate-N (mg/L)
- Nitrite-N (mg/L)
- Ammonia-N (mg/L)
- Orthophosphate-P (mg/L)
- Total Phosphate-P (mg/L)
- Total Solids (mg/L)
- Total Non-volatile Solids (mg/L)
- Total Suspended Solids (mg/L)
- Total Non-volatile Suspended Solids (mg/L)
- Total Coliform (organisms/100 ml)
- Fecal Coliform (organisms/100 ml)

All laboratory analyses were performed according to procedures stated in *Methods for Chemical Analysis of Water and Wastes* (U.S. EPA, 1979). Un-ionized ammonia fractions of total ammonia were calculated using field temperature and pH values (Thurston, Russo, and Emerson, 1979).

Stream discharge was calculated at Stations 1, 6, and the spring. A Marsh-McBernie® Magnetic Flow Meter and stream dimension measurements every six inches were used for each cross-sectional calculation. The STP outfall discharge was calculated from influent flow measured by a Manning® Dipper Flow Meter over a 24-hour period. Plant effluent discharge was rounded to 0.2 cfs instead of using the daily average of 0.187 cfs calculated from the recording chart (Abercrombie, 1981).

Benthic macroinvertebrate samples were taken at four sites. These sites were located at Stations 2, 6, 13.1 m (43 feet) upstream from Station 3, and 5 m (16 feet) downstream from Station 5. Rubble substrate at these sites provided the best chance of obtaining macroinvertebrates, although this substrate was not typical of the study area. Velocity appeared uniform across the channel at all sites.

Three rocks of approximately 500 cc were selected at each site. Rocks were taken at the head of a riffle, one each from the left, center, and right channel areas. Each rock was placed in a separate plastic bag, rinsed with a 70 percent ethanol solution, and inspected to see that all macroinvertebrates had been removed. Rocks were then measured and returned to the stream bed. The contents of each bag were rinsed through a #45 standard mesh sieve at the laboratory and the retained organisms then keyed to the lowest taxonomic level possible.

RESULTS AND DISCUSSION

The water quality analytical results are shown in Table 4. Included are grab samples and composite sample results for both days of collection. The mean value for most parameters at each station also has been calculated from these two grab sample results (Table 4a).

Values for Station 4 were considered to be higher than complete mixing of effluent and stream water would warrant. Calculation of conservative constituents indicated that mixing was only 55 percent complete, based on the estimated 0.2 cfs outfall and 5.9 cfs upstream discharges (30:1). Therefore, the values calculated at complete mixing also are shown in Table 4a.

Physical and Chemical

Temperature, pH, and specific conductivity values show only slight perturbations within the study area; values of Station 6 approach those of Station 1. Warmer spring water and STP effluent raised temperatures slightly at downstream stations before being cooled by ambient conditions. The slightly lower and constant pH of the spring water sample is

Table 4. Results of Water Quality Sampling at Dragoon Creek near Deer Park, November 18-19, 1980.[1/]

Station Description No.	Station Location	River Mile	Flow ft^3/sec.	Temperature (°C)	pH (Standard Units)	Field Sp. Conductivity (µmhos/cm)	Dissolved Oxygen (mg/L)	% Saturated Dissolved Oxygen	Total Residual Chlorine (mg/L)	BOD_5 (mg/L)	COD (mg/L)	Total NH_3-N (mg/L)	Un-ionized NH_3-N (mg/L)	NO_2-N (mg/L)	NO_3-N (mg/L)	Orthophosphate PO_4-P (mg/L)	Total PO_4-P (mg/L)	Total Solids (mg/L)	Total Non-volatile Solids (mg/L)
1	100 m above STP Works	15.32	3.8	4.8	7.70	200	11.0	91.9	--	<4	25	0.02	--	0.01	1.4	0.02	0.06	180	130
			4.2	5.3	7.40	272	10.8	91.0	--	<4	19	0.05	--	<0.01	1.3	0.02	0.05	180	130
	Upstream 24-hr. Comp.	15.32	--	--	7.7[4/]	268[4/]	--	--	--	<4	17	0.03	--	0.01	1.5	0.03	0.06	200	160
SP	150 m below STP - Rt. Bank	15.19	0.5[2/]	8.8	7.35	265	6.5	60.0	--	<4	13	<0.01	--	<0.01	5.2	0.01	0.03	170	120
				8.9	7.30	253	6.6	60.6	--	<4	8	0.02	--	<0.01	5.3	0.04	0.04	190	120
2	Upstream of Crawford St. Bridge	15.09	5.4[2/]	5.0	7.80	270	10.9	91.6	--	<4	25	0.02	--	0.01	2.0	0.04	0.05	170	120
				5.6	7.70	276	10.5	89.5	--	<4	21	0.04	--	<0.01	1.8	0.02	0.05	170	120
3	Downstream of Hwy. 395 Bridge	15.00	5.6[2/]	5.0	7.80	270	10.9	92.0	--	<4	17	0.02	--	0.01	1.9	0.03	0.04	190	150
				5.5	7.90	283	10.5	89.3	--	<4	21	0.04	--	<0.01	1.9	0.03	0.05	190	120
STP	36 m below Hwy. 395 Bridge	14.98	0.2	12.6	7.75	550	5.1	51.3	1.35	85	220	31.0	0.480	<0.02	0.4	8.4	9.8	450	280
				12.5	7.50	700	4.9	49.2	0.45	77	210	31.0	0.270	0.10	0.4	7.5	9.4	430	260
4	92 m below Outfall	14.92	6.1[2/]	5.4	7.75	290	10.0	84.9	0.04	6	29	3.0	0.026	0.03	1.9	0.56	0.67	210	150
				5.8	7.60	300	9.4	80.6	0.01	7	34	2.0	0.013	0.04	1.8	0.26	0.61	210	120
	Downstream 24-hr. Comp.	14.92	--	--	7.7[4/]	282[4/]	--	--	--	6	25	1.8	0.014	0.02	1.9	0.46	0.55	210	160
5	518 m below Outfall	14.66	6.6[2/]	5.0	7.65	220	8.1	68.0	<0.01	5	25	1.1	0.007	0.06	2.2	0.48	0.52	200	150
				5.4	7.50	288	8.0	68.3	<0.01	7	17	0.70	0.003	0.04	2.0	0.16	0.34	210	150
6	Upstream of Old Monroe Rd. Br.	14.51	--	4.8	7.65	210	7.8	65.6	N.D.[5/]	4	19	0.57	0.003	0.04	2.2	0.32	0.38	190	150
			7.1	5.3	7.50	280	7.8	65.6	N.D.[5/]	<4	21	0.36	0.002	0.04	2.1	0.14	0.26	200	130

[1/] Each station other than composites includes data collected once during each day

[2/] Estimated Flow

[3/] Estimated number based on non-ideal plate counts

[4/] Lab Measurement

[5/] None detected

Table 4a. Mean values from Two Samplings: November 18 and November 19, 1980, Dragoon Creek, WA.

Station	Temp. (°C)	pH (S.U.)	Sp. Cond. (μmhos/cm)	D.O. (mg/L)	D.O. Saturation (%)	BOD_5 (mg/L)	COD (mg/L)	NH_3-N (mg/L)	NO_3-N (mg/L)	NO_2-N (mg/L)	Total P. (mg/L)	O-PO_4-P (mg/L)
1*	5.0	7.6	240	10.9	91.4	<4	20	0.03	1.40	0.01	0.06	0.02
SP	8.8	7.3	259	6.5	60.3	<4	10	0.01	5.25	0.01	0.04	0.02
2	5.3	7.8	273	10.7	91.0	<4	23	0.03	1.90	0.01	0.05	0.03
3	5.2	7.8	276	10.7	91.0	<4	19	0.03	1.90	0.01	0.04	0.03
STP	12.6	7.6	600	5.0	50.0	81	215	31.00	0.40	0.06	9.60	8.00
4*	5.6	7.7	295	9.7	83.0	6	29	2.30	1.87	0.03	0.61	0.43
Complete Mixing Values	5.4	7.8	290	10.5	89.1	--	--	1.05	1.85	0.01	0.40	0.30
5	5.2	7.6	250	8.1	68.2	6	21	0.90	2.10	0.05	0.40	0.30
6	5.0	7.6	240	7.8	65.6	4	20	0.50	2.15	0.04	0.32	0.30

*24-hour compositor results included in mean values typical of groundwater sources in the area (Cline, 1969). The spring water seemed to have no effect on the main channel pH that ranged from 7.4 at Station 1 on the 19th to 7.8 at Stations 2 and 3 on the 18th. The pH tended to rise at Station 2 and 3, then drop at stations downstream from the outfall. Chemical reactions between effluent constituents are the most likely cause of this drop. These reactions will be explained in greater detail below. Conductivity generally rose between Stations 1 and 2 and between Stations 3 and 4, then dropped between Stations 4 and 6. The spring and outfall conductivity levels are thought to cause these slight increases, while incoming near-surface and ground waters decreased levels farther downstream.

Dissolved Oxygen

D.O. concentrations were generally lower below the outfall than above. The low D.O. spring water had no effect on the creek. Results of a single factor analysis of variance (ANOVA) and Newman-Keuls statisticals tests at $\alpha = 0.05$ were used to compare the mean levels of D.O. found during the survey period with the following results:

$$\text{Sta. } 1 = \text{Sta. } 2 = \text{Sta. } 3 \neq \text{Sta. } 4 \neq \text{Sta. } 5 = \text{Sta. } 6$$

All stations upstream of the outfall (1-3) had the same D.O. level. A significant drop from incoming low D.O. effluent is recorded at Station 4. Dissolved oxygen levels at Stations 5 and 6 are essentially the same but significantly lower than Station 4.

Values found at Station 6 are slightly below the 8.0 mg/L Class A standard. Stations 1, 2, and 3 were well above this standard and indicate that during the survey period, no drop in D.O. levels occurred from the possible impacts of livestock, sludge beds, ground waters, and road runoff (Figure 2).

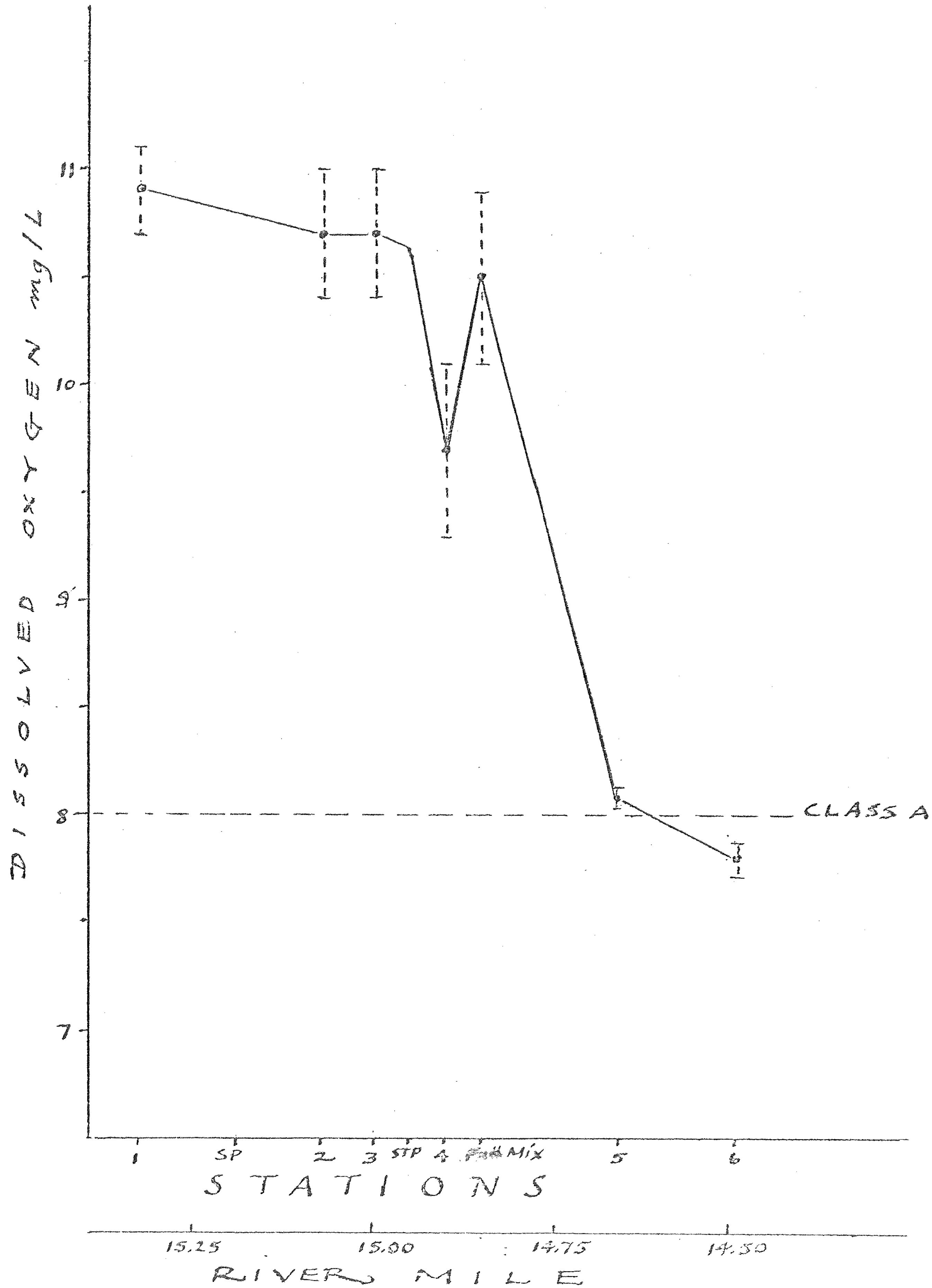
The channel configuration and substrate of Dragoon Creek described earlier are not conducive to reaeration processes. Reaeration and the D.O. sag at Stations 5 and 6 will be discussed later in this report.

Nutrients

Nitrogen and phosphorus levels were found to be elevated along the course of the creek (Table 4). In most cases, the levels found may not have been harmful to the balance of the creek during the period of the study, but pose the potential to cause the creek problems under different conditions.

Samples from Stations 1, 2, and 3 indicate that the stream is enriched with nitrate, ammonia, and orthophosphate before effluent enters from the STP outfall. These levels exceed the threshold values considered necessary for algal blooms in lakes: 0.01 mg/L orthophosphate-phosphorus, 0.2 mg/L ammonia-nitrogen, and 0.3 mg/L nitrate-nitrogen (Klein, 1959).

Figure 2. Mean dissolved oxygen concentrations with standard deviations found Nov. 18-19, 1981 on Dragoon Cr.



These nutrients may emanate from surface runoff of agricultural lands upstream, decomposition of organic materials in the stream, or are contained in groundwater. Reported nitrate levels in wells in the Deer Park area are as high as 5.7 mg/L (Cline, 1969). The spring samples contained higher levels of nitrates than the creek, but comparable levels of nitrite, total phosphate, and orthophosphate. Levels of stream nutrients correspond very well to estimated levels based upon a 50 percent agricultural basin usage (Zison, Kendall, and Mills, 1977), but again, the spring nitrate-to-phosphate or orthophosphate ratios are not the same as those found in the creek. Whether the source of nitrates in the spring is of agricultural or geologic origin remains uncertain.

Table 5. Nutrient Loads at Stations Along Dragoon Creek.

Station	Lbs. NO_3-N / Day	Lbs. NO_2-N / Day	Lbs. NH_3-N / Day	Lbs. Total Inorg. N. / Day	Lbs. Total P. / Day	Lbs. O-PO_4-P / Day
1	31.7	0.2	0.7	32.6	1.4	0.5
Below Spring*	46.9	0.3	1.0	48.2	1.6	0.5
2	55.3	0.3	0.9	56.5	1.5	0.9
3	57.3	0.3	0.9	58.5	1.2	0.9
Below Outfall*	60.8	0.3	34.5	95.6	11.5	9.5
5	74.7	1.8	32.0	108.5	14.2	10.7
6	82.3	1.5	19.1	102.9	12.2	11.4

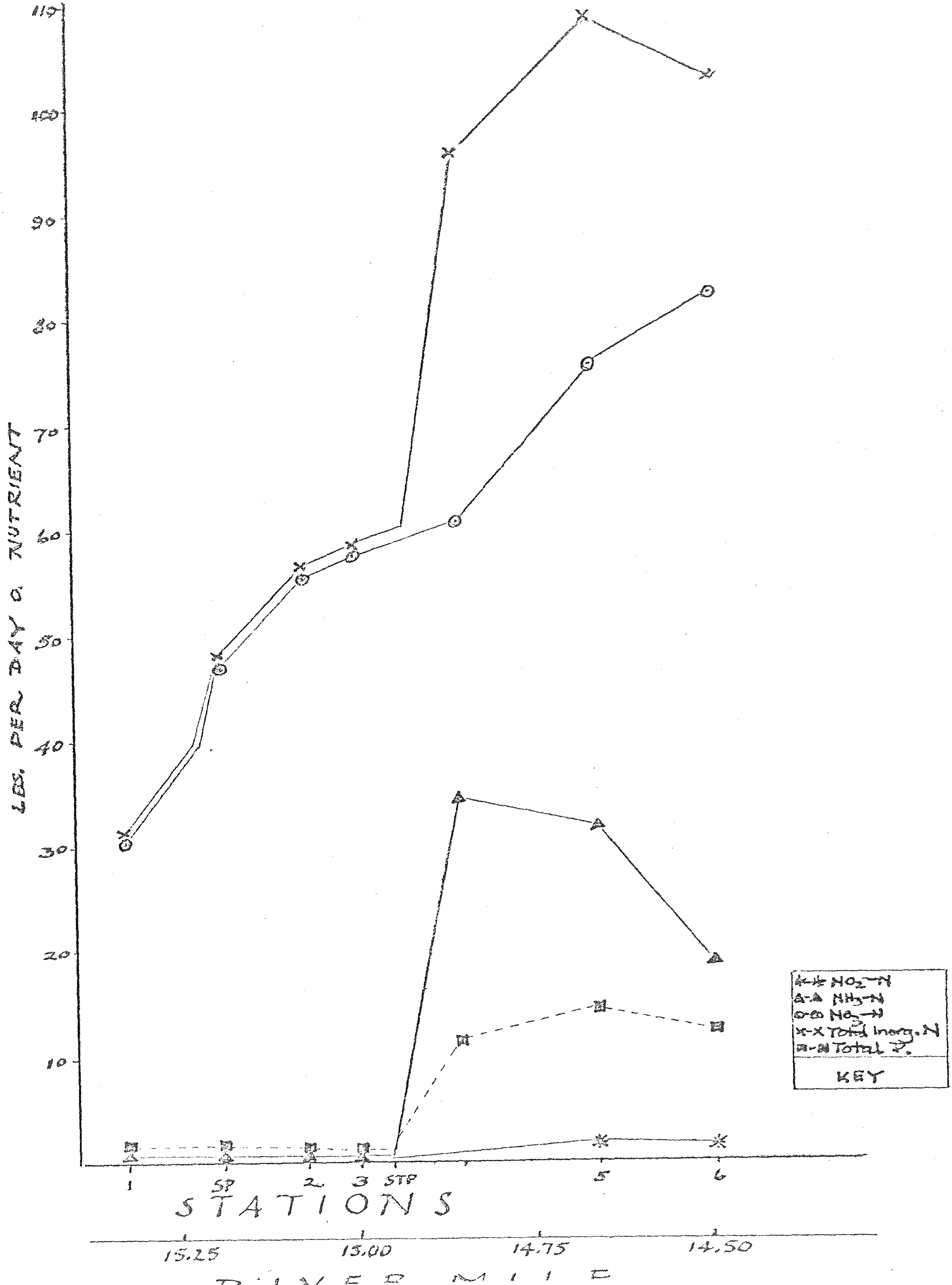
*Theoretical total mixing values

Below the outfall, the stream nutrient load increased appreciably except in the case of nitrates and nitrites (Figure 3). Ammonia loading was 37 times greater; orthophosphate and total phosphate loading each were about 10 times greater; total inorganic nitrogen levels increased by 60 percent.

Phosphorus levels stayed relatively stable at the downstream stations, but nitrogen species tended to show change. Between the mixing zone and Station 5 nitrites began to appear. Nitrates increased at a faster rate than between the spring confluence and Station 3, while ammonia began to drop. Total inorganic nitrogen continued to increase.

The changes in nitrogenous species indicate that the nitrification reactions explained in the oxygen sag analysis below were taking place. This nitrification process is biologically mediated by *Nitrosomonas* and *Nitrobacter* micro-organisms:

Fig. 3. Nutrient loads along Dragoon Creek, Nov. 18-19, 1981.



$$NH_4^+ + 1\text{-}1/2\ O_2 \xrightleftharpoons{\textit{Nitrosomonas}} 2H^+ + NO_2^- + H_2O$$

$$NO_2^- + 1\text{-}1/2\ O_2 \xrightleftharpoons{\textit{Nitrobacter}} NO_3^-$$

The nitrification process uses about 4.3 mg of dissolved oxygen for each milligram ammonium-N converted to nitrate (Hines, McKenzie, Rickert, and Rinella, 1977). Also, evolution of H^+ during nitrification tends to lower pH levels.

Nitrification seems to continue between Stations 5 and 6. The ammonia load is nearly half of initial values at the outfall; nitrites still are present, and nitrates are continuing to increase. When initial total inorganic nitrogen levels below the outfall are compared to Station 6 levels (Table 5), there is a 7 lbs/day credit at Station 6 attributed to NO_3-N. This could be an addition from high nitrate subsurface or ground waters, or an error from using estimated values.

Un-ionized ammonia levels were calculated (Table 4) and found to be within the 0.016 mg/L NH_3-N standard suggested for protection of aquatic life (U.S. EPA, 1976; Thurston, Russo, Fetterolf, et al., 1979). Other studies indicate possible stress at lower un-ionized ammonia levels at temperatures around 5°C (Willingham, 1976). Since the percentage of un-ionized ammonia varies with temperature, pH, and alkalinity, ammonia levels found in the STP effluent could cause serious toxicity problems under slightly different circumstances. A recalculation of data from Kittle's 1977 study yields a mean un-ionized level of 0.015 mg/L NH_3-N (0.013 to 0.017 range) with effluent total concentrations at 18.93 mg/L NH_3-N (16.8 to 20.8 range). Although effluent concentrations were lower, higher temperatures and lower stream discharge produced higher un-ionized ammonia levels than during this study.

If the low water discharge and temperature data found during Kittle's 1977 study is used, and an estimate for the projected 10 percent increase over current NH_3-N loading can be made, the resultant in-stream total ammonia concentration for a low flow, summer season would be estimated as follows:

31 mg/L NH_3-N from outfall	0.02 mg/L NH_3-N upstream at 2.9 cfs
+ 3 mg/L NH_3-N increase	
34 mg/L NH_3-N at 0.22 cfs	

$$\text{Downstream } NH_3\text{-N} = (34 \times 0.22) + (2.9 \times 0.02)/3.12$$

$$= 2.42 \text{ mg/L } NH_3\text{-N}$$

The un-ionized fraction of 2.42 mg/L NH_3-N at a temperature of 22.2°C and a pH of 7.3 is 0.027 mg/L NH_3-N (Thurston, Russo, and Emerson, 1979). In-stream temperatures of 25°C and 30°C would result in un-ionized concentrations of 0.04 and 0.05 mg/L NH_3-N, respectively. All of these concentrations exceed the un-ionized 0.016 mg/L NH_3-N guideline. They would also continue at toxic concentrations for a distance downstream since incoming dilution water would be at a minimum.

Total Residual Chlorine

Total residual chlorine may be in concentrations toxic to aquatic life for 0.32 mile downstream of the STP outfall. Samples tested from Station 4 for total residual chlorine far exceed the 2 µg/L TRC criteria for salmonids (U.S. EPA, 1976) as well as the 3 to 5 µg/L TRC criteria for all aquatic life (Thurston, Russo, Fetterolf, et al., 1979). Calculated complete mixing values for both days also violate these standards (Table 4a). Levels of TRC at Station 5 were just at the 10 µg/L detection limit of the method, but indicate a continued violation of these standards.

The 1.35 mg/L TRC (1350 µg/L) in the effluent on the 18th clearly violated the NPDES waste discharge permit level of 0.5 mg/L TRC established for Deer Park STP (Abercrombie, 1981). Adjustments to 0.45 mg/L TRC on the 19th decreased levels in the creek. Samples taken at Station 5 on that day were below technique detection limits. Under low-flow conditions (2.9 cfs), an in-stream concentration of 0.03 mg/L TRC (30 µg/L) would be present at an effluent concentration of 0.45 mg/L TRC (450 µg/L). Higher temperatures would dissipate chlorine rapidly, but enough residual may remain instream to exceed guidelines.

Solids

Solids data are presented in Table 6 and Figure 4 in units of lbs/day.

Table 6. Mean Value Solids Data for Dragoon Creek in lbs/day.

Station	Total Solids	Total Non-Vol. Solids	Total Susp. Sol.	Non.-Vol. Susp. Sol.	Volatile Susp. Sol.	Total Dissolved Solids*
1	4,300	3,200	140	68	72	4,160
2	4,900	3,500	87	58	29	4,810
3	5,700	4,200	270	180	90	5,430
Below Outfall	6,500	4,700	360	200	160	6,140
5	7,300	5,300	360	210	150	6,940
6	7,500	5,400	150	77	73	7,350

*Calculated by difference: Total solids - total suspended solids = Total Dissolved Solids

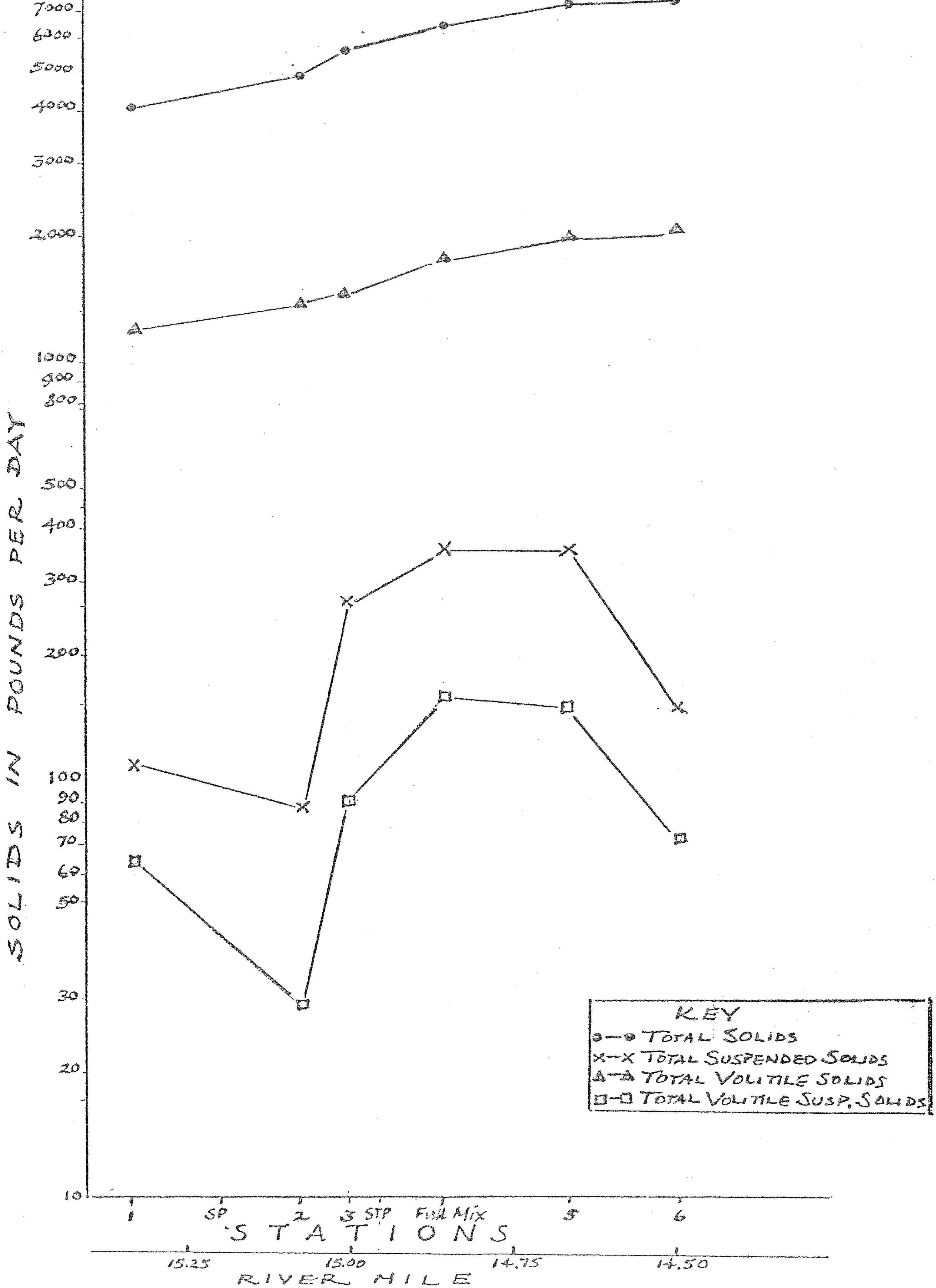


Fig. 4. Solids load along Dragoon Cr., Nov. 18-19, 1981.

Total solids, primarily as dissolved solids (96 percent) increased steadily downstream within the study area. The suspended load portion was appreciably smaller and went through more perturbations. The non-volatile portion of total solids stayed about 72 percent while the non-volatile portion of the suspended load varied from 59 percent to 33 percent. The total suspended load doubled after the creek passed under the two bridges between Stations 2 and 3; either blown sediments from the road or channel change to that of riffles is suspected to cause the sudden increase in loading. Total suspended solids, especially the volatile portion, increased again at the outfall, then dropped between Stations 5 and 6.

The sudden decrease between Stations 5 and 6 coincides with the drop in ammonia, dissolved oxygen, and total phosphorus levels. Electrostatic interaction between suspended fine sediments or organic detritus and these constituents may result in their precipitation. The affinity of ammonia for clay particles is well known (Manahan, 1975). After these particles precipitate, they continue to react in various ways including oxidation processes which deplete oxygen from overlying water. A likelihood here.

Dissolved Oxygen Sag

The lack of evident reaeration in Dragoon Creek between the outfall and Station 6, coupled with high BOD and NH_3-N levels in the effluent favor an oxygen depletion situation at Stations 5 and 6. The complete equation is calculated in Appendix I. Highlights of the calculations and corresponding assessment of the D.O. regime in the creek relative to Deer Park STP follow:

The prime source of oxygen enrichment for a stream is reaeration. The reaeration rate is a function of depth, velocity, slope, channel configuration, and temperature. Dragoon Creek, in the vicinity of the outfall, tends to be deep, slow, and with little surface turbulence. Low temperatures at the time of study decreased rates of oxygen diffusion so that the reaeration rate was low, at 0.23 day^{-1} (base e).

Elevated concentrations of BOD and ammonia and other nutrients were not dispersed easily in this reach of the creek. As mentioned, at 91 m (300 feet) downstream, only 55 percent mixing had occurred at a 30:1 dilution ratio. Such slow velocities and dispersion increase sludge accumulation rates until winter and spring freshets can scour and displace accumulated sludge. Until such times, the sludge exerts a demand on overlying water. This benthal demand was estimated conservatively at 1.5 gms O_2/m^2/day at 20°C, but its contribution to the oxygen deficit at Station 6 was 0.08 mg/L O_2 of the total 4.08 mg/L O_2.

The rates of carbonaceous biochemical oxygen demand (CBOD) and nitrogenous oxygen demand (NOD) could only be estimated from five-day BOD values and the ammonia concentrations found at downstream stations. The reactions to breakdown carbonaceous effluent constituents and convert ammonia to nitrite and nitrate are bacterially mediated and require oxygen. The reaction rates are dependent upon bacterial populations and temperature.

Since true CBOD rates are difficult to determine without special tests and extensive sampling, a value of 0.1 day^{-1} at 20°C was considered the best estimate available. Temperature compensation and conversion to natural logarithms changed this value to 0.12 day^{-1}. The 0.1 day^{-1} value is commonly used for streams moderately polluted with municipal waste effluent, although it is rarely found when intensive BOD analyses are done (APHA, 1976).

The ultimate CBOD calculation has a similar weakness as it is a gross estimate. Using these values resulted in a 0.32 mg/L contribution to the oxygen deficit at Station 6. Not unexpected since the rate is slow and dilution of effluent CBOD is 30:1.

The rate of NOD was calculated for the reach using ammonia concentrations at the outfall, Station 5, and Station 6. Ammonia concentrations diminished quite rapidly so that most of the oxygen depletion at Stations 5 and 6 is thought to be of NOD origin. The rate of 4.82 day^{-1} is incredibly rapid and could be taking into account ammonia that has precipitated with clay particles and has been converted to nitrate over a longer time. The benthal demand was calculated conservatively and therefore the NOD rate may include some of this demand. The conversion of ammonia to nitrate accounted for the largest portion (2.42 mg/L O_2) of the oxygen deficit at Station 6.

The upstream oxygen deficit at Station 3 and addition of effluent water of low D.O. concentration had a contribution of 1.26 mg/L O_2 to the Station 6 deficit. The deficit was carried on downstream because of poor reaeration in the stream.

Addition of oxygen from algal and periphyton photosynthesis and depletion from their respiration were ignored because of the season. During spring and summer these two factors could play a large role in the D.O. balance.

Additions of NOD and BOD from non-point sources were also not included. Livestock and agricultural uses may be adding nutrients to CBOD loads at a rate that affects oxygen concentrations appreciably at other times of the year. The small differences between oxygen saturation levels and D.O. levels found at Stations 1 through 3 may be a result of this loading.

Serious problems may occur with higher temperatures and a dilution ratio lower than 20:1, as was found in 1977. The equation here is too rough to estimate downstream oxygen depletion adequately under such conditions. With the many pools between the outfall and Station 6, the time of travel could be quite different. Temperature would increase BOD and NOD rates and also reaeration; how much of an increase would be difficult to estimate since the roles are very roughly calculated now.

A hypothetical problem to reveal the seriousness of this situation is as follows:

> Using 22.2°C, upstream D.O. of 7.9 mg/L, upstream flow of 2.9 cfs, mean depth of 2 feet, and mean velocity of 0.19 ft/sec, a downstream discharge of 3.4 cfs, and 0.15 days to Station 6; while keeping upstream and outfall loading at current levels, an estimated 5.8 mg/L O_2 would be found at Station 6 without any NOD contribution. No oxygen would be present at Station 6 if the NOD rate is temperature compensated from current rates and added to the calculation.

Given the above possible conditions, oxygen conditions in this reach at times could become critical to the survival of fish and other aquatic organisms.

Bacteriological

Coliform results indicate some contamination upstream from the outfall, probably from livestock on adjacent farms. The heavy chlorination in the effluent on the 18th dramatically suppressed fecal coliform levels downstream from the outfall. Total coliform levels show an increase at 4 and 5, then a return to upstream values by Station 6.

Less drastic reduction in fecal and total coliform levels was seen on the 19th after the effluent chlorine residual had been adjusted to meet permit limits. Laboratory results for coliform counts were conflicting for nearly identical samples from the effluent on this day. Receiving water coliform counts stayed low downstream from the outfall. A sample taken at the outfall by Carl Nuechterlein of the Eastern Regional Office on December 2, 1980 was determined to have 460 organisms/100 ml at a TRC of 0.5 mg/L.

Biological

Results of benthic invertebrate sampling are presented in Table 7. The Brillouin Diversity Index (BDI) (Archibald, 1972) and Brinkhurst Trophic (BTI) Index (Brinkhurst, 1968) values are included with organism enumeration at each station. The trophic rating used for the Brinkhurst calculation follows each organism.

The BDI was used rather than the more common Shannon Diversity Index because the BDI is more accurate when the number of organisms in a sample is less than 500 (Stephens, 1978). Both indicate the health of a benthic community, with a more diverse community being healthier than one with only one type of organism. A modified t-test (Zar, 1974) was used to compare the BDI at Station 2 with the BDI at Station 5. No significant difference in diversity was found at $\alpha = 0.05$ ($0.10 < P < 0.20$). Stations 2 and 5 had greater diversity than Stations 3 and 6.

Table 7. Results of benthic organism sampling at four sites along Dragoon Creek, November 19, 1980.

	Trophic[1/] Rating	Number of Individuals Found Station[2/] 2	Station 3	Station 5	Station 6
Annelida - Segmented Worms					
Helobdella stagnalis (leech)	T	--	--	13	1
Turbellaria - Flatworms					
Neohabdocoela	F	5	--	--	--
Hydracarnia - Water mites	I	7	7	2	2
Plecoptera - Stoneflies					
Perlodidae (*Isoperla?*)	I	5	--	--	--
Ephemeroptera - May flies					
Leptophelbinae (*Paraleptophebia*)	F	1	1	--	--
Ephemerellidae (*Ephemerella*)	F	144	19	79	2
Baetidae (*Baetis*)	F	6	--	--	1
Trichoptera - Caddis flies					
Hydropsychidae (*Hydropsyche, Cheumatopsyche*)	F	31	--	1	--
Hydroptilidae (*Neotrichia?*)	I	6	7	--	--
Glossosmatidae (*Glossosoma*)	F	2	--	--	--
Coleoptera - Beetles					
Elmidae	F	2	--	--	--
Diptera - True flies					
Empididae	F	1	1	23	--
Tipulidae (*Dicranota, Antocha*)	I	4	1	--	--
Simulidae (*Cnephia?*)	F	1	1	1	134
Chironomidae	F	265	428	255	964
Gastropoda - Snails					
Planorbidae (*Gyraulus?*)	F	1	--	--	--
Physidae (*Physa* sp.)	F	4	--	1	1
Lymnaeidae	F	--	1	--	--
Ancylidae (*Ferrissia* sp.)	F	3	--	23	6
Pelecypoda - Clams					
Sphaeriidae	F	2	--	--	--
Total Number of Organisms		490	466	398	1,111
Brinkhurst Trophic Index		0.955	0.968	1.03	0.999
Brillouin Diversity Index		1.88	0.54	1.56	0.63

1/ = Trophic rating given by Weber, 1973

2/ = Station number refers to nearby water quality sampling stations.

T = Tolerant

F = Facultative

I = Intolerant

The BTI gives an idea of a community's tolerance to organic wastes. Individual organisms found in a community are rated according to their tolerance as: tolerant; facultative; or intolerant. The rating is based upon research done on the organisms by several workers, compiled and rated by Weber (1973). The following formula is then used to calculate a station's BTI:

$$BTI = \frac{N_1 + 2N_2}{No + N_1 + N_2}$$

where No = number of intolerant species
N_1 = number of facultative species
and N_2 = number of tolerant species

The larger the index number the more tolerant the community to perturbations from organic wastes.

The appearance of the leech, *Helobdella stagnalis*, a tolerant organism, and the simultaneous disappearance of intolerant stoneflies (*Isoperla* sp.), micro-caddis flies (*Neotricha* sp.), and tipulid flies (*Dicranota, Antocha* sp.) from the two sites downstream from the outfall were reflected in the index scores. The mean index score of the two upstream stations is statistically different from the mean score of the downstream stations at $\alpha = 0.1$ using a two-tailed t-test. This indicates a change in community structure due to impacts of the outfall.

Further cluster analysis of community structure using Jaccard's coefficient of similarity (Sokal and Sneath, 1963) show an even closer relationship between Stations 5 and 6. Jaccard's equation measures occurrence of similar organisms in two communities:

$$Sj = \frac{a}{a+b+c}$$

where, a = number of species occurring at both stations
b = number at one but not the other
c = number at other but not the first

Similarity between communities increases as the index value approaches 1.0. A matrix and cluster diagram of station-to-station comparison is presented in Figure 5. Stations 5 and 6 show a good similarity (0.78) while Stations 2 and 3 show only some similarity (0.42). These two clusters show the least amount of similarity (0.37).

So, although the diversity indices may lead one to conclude that there was no change after the outfall, closer evaluation shows that effluents have forced a change in the type of organisms in-stream. This tolerant community shows further stress shown as lower diversity at Station 6, as far downstream as was monitored.

STATION	6	5	3	2
2	0.40	0.40	0.42	1.00
3	0.31	0.38	1.00	
5	0.78	1.00		
6	1.00			

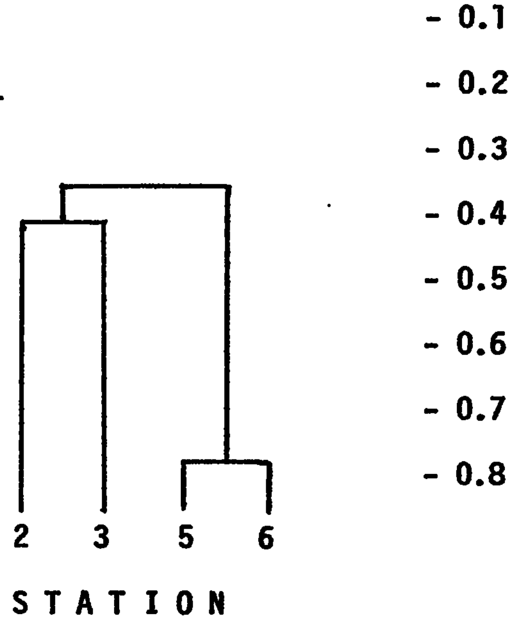


Figure 5. Matrix of Jaccard's Coefficient of Similarity for Pairwise Comparisions by Stations and Cluster Dendrogram of the Results.

The low diversity at Station 3 could be sample variance, but further investigation might show impacts from road runoff or sedimentation affecting habitat and lowering diversity. The presence of intolerant organisms does indicates that the community is not under the same sort of stress as found below the outfall.

SUMMARY

The Deer Park STP has been shown to be exerting a negative influence on Dragoon Creek under normal loading and stream discharge conditions. Specific influences include: (1) Elevated ammonia and BOD levels, causing Class A D.O. standard violations; (2) probable toxic residual chlorine levels, greater than 0.002 mg/L TRC; and (3) aggravation of nutrient loading problems already existing in-stream. These problems are present for at least the 0.5 mile below the outfall investigated, and may be present beyond the studied area.

During periods of low discharge and high temperatures, additional problems of toxic un-ionized ammonia concentrations and algal/periphyton blooms may exist; the resultant algal die-off depressing downstream D.O. concentrations to still lower levels, thereby endangering resident aquatic life. Less groundwater for dilution downstream could cause toxic un-ionized ammonia concentrations to be present for several hundred feet downstream from the outfall. Algal bloom and die-off could occur in pooling areas within 0.5 mile or several miles downstream.

Further investigation would be necessary to establish if in-stream fecal coliform levels could be kept below permit limits without an excessive and toxic in-stream total residual chlorine concentration.

Finally, the problems seem to occur frequently enough to have had an effect on the benthic community. The change in benthic community structure 0.36 mile below the outfall and that community's lack of diversity 0.15 mile farther downstream is a good indication of deteriorating water quality.

JJ:cp

Attachments

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APPENDIX I

The following primary equation is taken from Zison, et al., 1977 in their discussion of D.O. - BOD interactions in streams.

Other equations not from Zison are referenced where presented.

Oxygen depletion is found at any point t within a reach containing a point source (t = 0) as follows:

$$(1)\quad Dt = Do\ \exp(-k_2t) + \frac{Lok_1}{k_2-k_1}\left[\exp(-k_1t) - \exp(-k_2t)\right] + \frac{Nokn}{k_2-k_n}$$

$$\left[\exp(-k_nt)-\exp(-k_2t)\right] + \frac{Sb}{k_2}\ \left[1-\exp(-k_2t)\right]$$

where Dt = oxygen deficit at time (t) - mg/L
k_1 = CBOD decay coefficient
Lo = Initial CBOD deficit upstream, ultimate BOD
k_2 = reaeration rate
t = time of travel (days)
Do - initial oxygen deficit
kn = Nitrogeneous oxygen demand rate
No = initial nitrogeneous oxygen demand deficit
Sb = benthal oxygen uptake rate.

Oxygen deficit or addition due to algal production and respiration was considered to be negligible at this time of year.

k_1 was selected to be 0.1, a typical value for polluted streams at 20°C (Nemerow, 1974). To adjust for the 5.2°C, the following formula was used:

$$(2)\quad K_{1,T} = K_{1,20}\Theta^{(T-20)} \qquad K_{1,5.2} = 0.1(1.047)^{(5.2-20)}$$

Θ = 1.047 conversion unit $\qquad = 0.1\ (0.507)$
T = 5.2°C $\qquad = 0.051\ \text{day}^{-1}$
$K_{1,20} = 0.1 \qquad 10^{-0.051} = \exp(0.23)$

k_2 was calculated from Isaacs' formula as follows (Nemerow, 1974):

(3) $k_2(20°C) = C(V/H^{1.5})$

where C = roughness coefficient (2.9281 for a square channel)
V = mean velocity of reach (ft/sec)
H = mean depth of flow (ft)

Field observations between the outfall and Station 6 yielded the following:

Mean depth = 3 feet   length = 2,500 feet
Mean width = 9 feet   mean disch. = 6.6 ft^3/sec.

So that mean velocity would be:

V = mean discharge/(mean width x mean depth)
6.6 ft^3/sec/(3 ft. x 9 ft.)
= 0.24 ft./sec.

Returning to formula 3: $k_2\ (20°C) = (2.9281)\ \frac{0.24}{3^{1.5}}$

$= (2.9281)(0.046) = 0.14\ day^{-1}$

To adjust k_2 (20°C) to k_2 (5.2°C) a similar conversion is needed as was done for k_1, above:

(4) $k_{2,T} = K_{2,2°C}(1.0238)^{(T-20)}$

$5.2°C = 0.099\ day^{-1} = e^{.23}$

To calculate time of travel between the outfall and Station 6, the mean values from field observations were used (Velz, 1970):

(5) t(sec.) = (9 ft. x 3 ft x 2500 ft.)/6.6 ft^3/sec. =
62910 ft^3/6.6 $ft.^3$/sec. = 10227.3 sec. = 0.12 day

Lo, the ultimate BOD, can be estimated from the 5-day BOD:

(6) $CBOD_5/0.68$
81/0.68 = 119 mg/L

(7) Lo = (Lu x Qu + W)/(Qu + Qw)
[2(5.9) + (119 x 0.2 x 5.39)]/6.1
22.9 mg/L O_2 CBOD

where, Lu = upstream CBOD, mg/L
Qu = upstream discharge, cfs
Qw = outfall discharge, cfs
W = lbs./day CBOD from outfall

Do, the initial oxygen deficit can be calculated using data from Station 3 and the outfall:

(8) $Do = Cs-[(CwQw + CuQu)/(Qw + Qu)]$
$11.84-[(5.0 \times 0.2 + 10.74 \times 5.9)/(6.1)]$
$11.84-10.55 = 1.3$ mg/L O_2

where, Cs = O_2 saturation at 5.2°C and at 2000' altitude.
Cw and Cu = D.O. in effluent and D.O. in upstream water, respectively.

Kn, the rate of nitrogeneous oxygen demand (NOD) is roughly calculated from data in the following table of values found during the time of study and using 4.3 mg O_2 potential depletion in NH_4 to NO_3 conversion.

Station Number	t (day)	NH_3-N mg/L	NH_4^+-N mg/L	lbs. O_2/ lb NH_4^+	ln (lbs. O_2/ lb NH_3-N
Outfall	0.000	1.05	1.35	191	5.25227
5	0.08	0.9	1.16	177	5.17615
6	0.12	0.465	0.60	99	4.59512

A slope of 4.8 day^{-1} (r = 0.82), is found by regression analysis of t vs. ln (lbs. O_2/lbs. NH_3-N) which will be used as kn.

No, the initial NOD, is found by substituting No for Lo in Formula 6 and converting first to NH_4, then to mg/L O_2 at 4.3 mg O_2/mg NH_4 converted

$No = ([0.03(5.9) + 31(.2)(5.39)][18/14][4.3])/(6.1(5.39)) = 5.65$ mg/L O_2

Finally, Sb, the average benthal demand for aged municipal sewage sludge has been given as 1.5 gms O_2/m^2-day at 20°C.

Temperature effects are approximated using:

$$Sb_T = Sb_{20} (1.065)^{(T-20)}$$

$$Sb_{5.2} = 1.5 (1.065)^{(5.2-20)} = 0.59 \text{ gms } O_2/m^2 \text{ day}^{-1}$$

and to fit this value into the main formula, it must be divided by the mean depth of the reach expressed in meters:

$$Sb = 0.59/0.914 = 0.65 \text{ mg/L } O_2 \text{ day}^{-1}$$

Inserting all values into Formula 1 for Station 6, t = 0.12, the following oxygen deficit is found:

$$D_{(0.12)} = 1.3\exp(-0.23 \times 0.12) + \frac{22.9 \times 0.12}{0.23 - 0.12}[\exp(-0.12 \times 0.12) - \exp(-0.23 \times 0.12)] + \frac{5.65 \times 4.8}{0.23 - 4.8}[\exp(-4.8 \times 0.12) - \exp(-0.23 \times 0.12)] + \frac{0.65}{0.23}[1 - \exp(-0.23 \times 0.12)]$$

$$= 1.3(0.973) + 25(0.986 - 0.973) + -5.9(0.562 - 0.973) + 2.82\ (1 - 0.973)$$

$$= 1.26 + 0.32 + 2.42 + 0.08$$

$$= 4.08 \text{ mg/L } O_2 \text{ deficit at Station 6}$$

The oxygen concentration at Station 6 can be found as follows:

$$Cs - D_{0.12} = C_{0.12}$$

$$11.89 - 4.08 = 7.81 \text{ mg/L } O_2 \text{ at Station 6.}$$

This value is very near the 7.8 mg/L O_2 found during the study at Station 6.

If the equation is run for Station 5, t = 0.08, a deficit of 3.31 mg/L O_2 is found, or 8.58 mg/L O_2 would remain. Concentrations of D.O. at Station 5 during this study were 8.1 and 8.0 (Table 4).