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A Study of Municipal Wastewater Toxicity, Village of Cache Creek Sewage Treatment Plant, September, 1976

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A STUDY OF MUNICIPAL WASTEWATER TOXICITY, VILLAGE OF CACHE CREEK SEWAGE TREATMENT PLANT, SEPTEMBER, 1976

by

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ABSTRACT

A wastewater toxicity study of the Cache Creek Sewage Treatment Plant was conducted by personnel of the Environmental Protection Service, Pacific Region.

The objectives of this study, conducted from August 30 - September 3, 1976, were as follows:

1. to determine the extent of toxicity removal achieved by the sewage treatment plant,
2. to determine the effect of chlorination on the toxicity of the effluent,
3. to relate the toxicity of the influent and effluent to the concentrations of certain known toxic substances, and
4. to determine the incidence and the extent of removal of polychlorinated biphenyls.

The study also included the collection of information concerning such factors as plant design and actual loading, chlorine dosage and the extent of sewer line infiltration. This information was collected to assist in interpreting data gathered for the objectives listed above.

This report contains the results of bioassay determinations and chemical analyses of samples collected during the survey at various treatment plant locations.

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LIST OF ABBREVIATIONS

BOD_5	5 day biochemical oxygen demand
Cl_2	Chlorine
Cu. ft.	Cubic feet
DO	Dissolved Oxygen
Ft.	Feet
GLC	Gas Liquid Chromatography
g/ℓ	Grams per Liter
hr	Hour(s)
Imp GPD	Imperial Gallons per Day
ℓ	Liter(s)
LAS	Linear Alkylate Sulfonate
mg/ℓ	Milligrams per Liter
Min.	Minute(s)
ml	Milliliters
MLSS	Mixed Liquor Suspended Solids
ppm	Parts per Million
ppb	Parts per Billion
STP	Sewage Treatment Plant
Tc	Toxicity Concentration
TRC	Total Residual Chlorine
TU	Toxic Units
μg/ℓ	Micrograms per Liter

CONCLUSIONS

Based on data collected at the Cache Creek Sewage Treatment Plant from August 30 - September 3, 1976, the following conclusions can be made:

1. Activated sludge sewage treatment was responsible for a reduction in the average toxicity concentration from 2.55 toxic units in the raw sewage to 1.58 toxic units in the secondary effluent.

2. Chlorination resulted in no significant increase in effluent toxicity. A discussion of the factors involved is presented in section 4.1.3.

3. The wastewater constituents which were examined and deemed responsible in part for the bioassay results were:

   (i) un-ionized ammonia and
   (ii) anionic surfactants.

4. The polychlorinated biphenyls concentrations, as reported in Appendix I, were all significantly low. The treatment plant was responsible for a 31% reduction of the raw sewage PCB level.

1. INTRODUCTION

The Village of Cache Creek had an estimated population of 1041 in 1976 (1). All sewage from the village is treated by the Cache Creek Sewage Treatment Plant. The sanitary and storm sewer systems are completely separate. Economic activity is mainly associated with transportation and service to the agricultural resources in the area. There are no major industrial discharges to the sewer system.

Village of Cache Creek officials have estimated water consumption as follows (13).

1. Domestic 65%
2. Commercial 30%
3. Industrial 3% and
4. Institutional 2%

The objectives of this study, conducted from August 30 - September 3, 1976 were as follows:

1. to determine the extent of toxicity removal achieved by the sewage treatment plant;
2. to determine the effect of chlorination on the toxicity of the effluent;
3. to relate the toxicity of the influent and the effluent to the concentrations of certain known toxic substances,
4. to determine the incidence and the extent of removal of polychlorinated biphenyls.

The survey consisted of the following programs:

1. a 4 day composite sampling program
2. a 12 hour grab sampling program
3. a 24 hour chlorine residual monitoring program and
4. general plant operation data collection.

Additional municipal wastewater toxicity studies were conducted at other locations in the Pacific Region during 1976. These surveys were conducted to collect information regarding the ability of various types of sewage treatment systems to remove or reduce wastewater toxicity and to establish the toxicity concentrations involved with each case.

1.1 Cache Creek Sewage Treatment Plant Description

The Cache Creek STP is an activated sludge plant consisting of two parallel treatment modules which include an aeration tank, a clarifier and an aerobic sludge digester. The treatment components also include a barminutor, a flow measurement device, a chlorine contact tank and sludge drying beds. A flow diagram showing sample point locations is presented in Figure 1. Oxygen and mixing are supplied by submerged air diffusers. Activated sludge is transferred from the clarifier to the aeration tank by means of an airlift reciprocating collector. Waste activated sludge is gravity fed from the airlift system to the aerobic sludge digesters. In turn the final digested sludge is wasted to the sludge drying beds manually.

The aerobic sludge digesters contain decanting chambers for supernatant return, however this system has proven inoperative due to poor sludge settling characteristics. Supernatant is presently returned to the aeration tank from the digester by shutting off the air diffusers, allowing the heavy solids to settle, and finally using a decanting pipe and a portable pump. A separate sludge handling facility, including a sludge thickening and decanting chamber and a sludge storage lagoon, is presently under construction. The operational characteristics of the Cache Creek STP are listed in Table I. At the design flow-rate of $4X10^5$ Imp GPD the aeration tanks have a hydraulic retention time of 3.0 hr. A discussion of plant performance is presented in section 4.3.

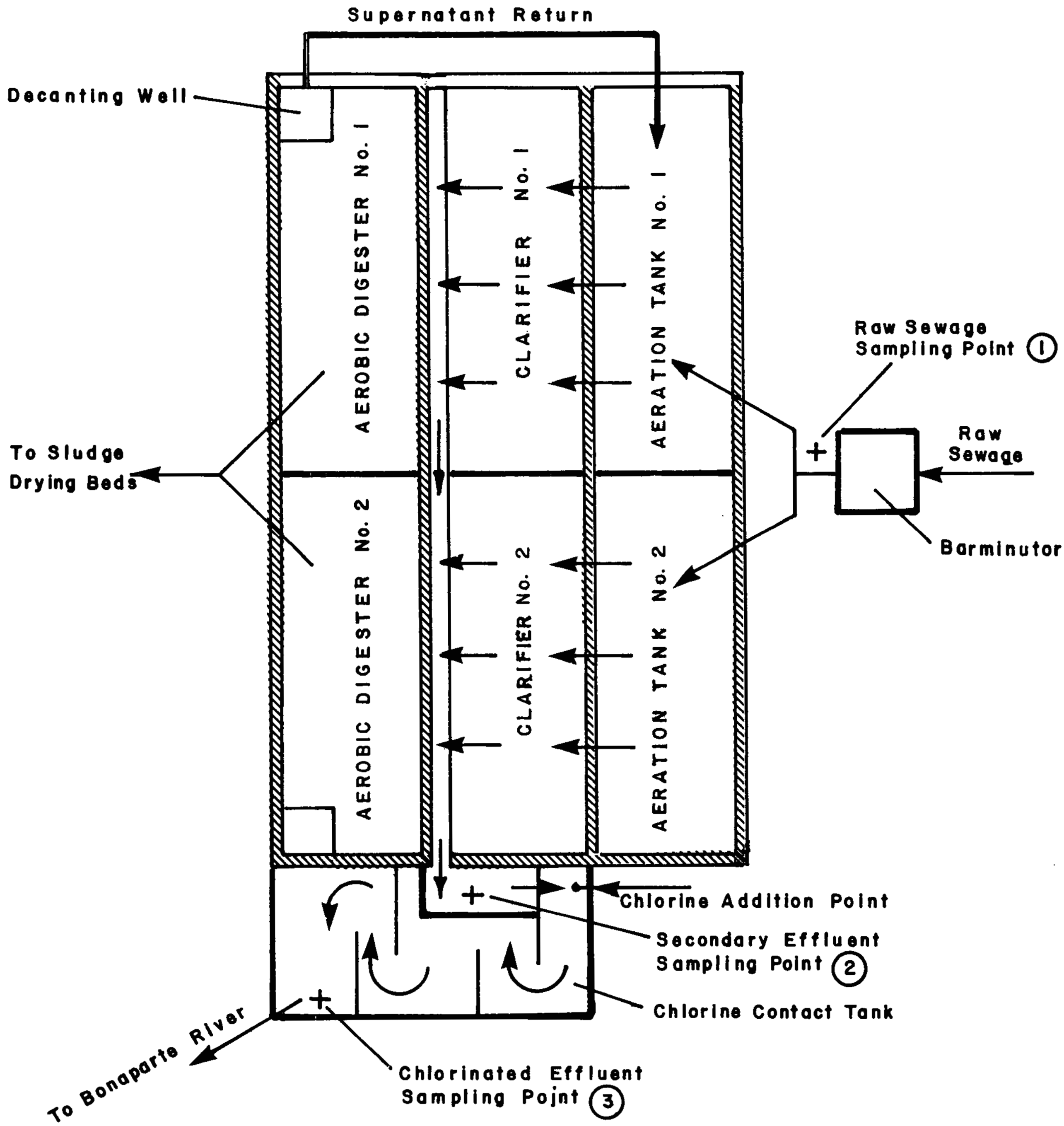

FIGURE I CACHE CREEK SEWAGE TREATMENT PLANT FLOW DIAGRAM AND SAMPLE POINT LOCATIONS

TABLE 1 OPERATIONAL CHARACTERISTICS OF THE CACHE CREEK STP

Type of Treatment:	Activated sludge
Treatment Components:	1. Raw Sewage Pump 2. Barminutor 3. Aeration Tanks 2 Parallel 4. Clarifiers 2 Parallel 5. Chlorine Contact Tank
Design Flow	= 400,000 Imp GPD
Average Flow (July 75 - Aug. 76)	= 146,000 Imp GPD
Average Flow Aug. 76	= 158,900 Imp GPD
Clarifier Design Overflow Rate	= 400 gal/ft^2/day
Design Hydraulic Retention Time	= 3.0 hr (50% recycle)
Design Chlorine Contact Retention	= 20 min.
Aerobic Digesters Capacity	= 12,128 cu. ft.
Chlorinator	- Manually adjusted checked daily
Point of Discharge	- Bonaparte River

2. PROCEDURES AND METHODS

2.1 Sampling Program

The time proportional 24 hour composite samples were collected at three treatment plant locations as follows:

1. The raw sewage sample was taken from the influent channel after the barminutor near the overflow to the aeration tanks. Approximate 250 ml samples were taken every 2.5 minutes using a Markland Model 2101-Spec. Duckbill sampler.

2. The secondary effluent sample was taken from the clarifier overflow channel just prior to the flow measurement device. Approximate 1.1 ℓ samples were taken every 10 minutes using an Eagle Signal timer assembly and a submersible pump.

3. The chlorinated effluent sample was taken from the chlorine contact tank near the overflow pipe. Approximate 1.1 ℓ samples, were taken every 10 minutes using an Eagle Signal timer assembly and a submersible pump.

The composite samples were collected in 45 gallon polyethylene barrels. The 24 hour composite sampling program commenced at 0700 hours August 30 and ended at 0700 hours September 3, 1976.

The raw sewage and final effluent grab samples were taken from the same locations as the composites. The grab samples were collected every 2 hours on September 1 from 0700 hr to 1900 hr. Sample point locations are illustrated in Figure 1.

2.2 Analyses

Table 2 lists the analytical parameters for the 24 hour composite sampling program. Table 3 lists the analytical parameters for the grab sampling program.

The contents of each composite sample barrel were well mixed prior to sample division. The samples for chemical analysis(including metals) were divided into sample bottles and preserved as outlined in the

TABLE 2 ANALYTICAL PARAMETERS - 24 HOUR COMPOSITE SAMPLING PROGRAM

Parameter	Abbreviation	Unit
Total Phosphate	TPO_4	mg/ℓ P
Ammonia	NH_3	mg/ℓ N
Nitrate	NO_3	mg/ℓ N
Nitrite	NO_2	mg/ℓ N
Total Alkalinity	-	mg/ℓ Ca CO_3
Chemical Oxygen Demand	COD	mg/ℓ
Total Organic Carbon	TOC	mg/ℓ C
pH	-	0-14 pH units
Non Filterable Residue	NFR	mg/ℓ
Anionic Surfactants	-	mg/ℓ LAS
Total Residue	TR	mg/ℓ
Cyanide	CN	mg/ℓ
Phenol	-	mg/ℓ
Oil & Grease	-	mg/ℓ
Polychlorinated Biphenyls	PCB	ppb
Bioassay	LC_{50}	%
<u>Metals</u>		
Total Mercury	Hg	µg/ℓ
Copper, Total & Dissolved	Cu	mg/ℓ
Iron, Total & Dissolved	Fe	mg/ℓ
Nickel, Total & Dissolved	Ni	mg/ℓ
Lead, Total & Dissolved	Pb	mg/ℓ
Zinc, Total & Dissolved	Zn	mg/ℓ
Aluminium, Total & Dissolved	Al	mg/ℓ
Cadmium, Total & Dissolved	Cd	mg/ℓ
Manganese, Total & Dissolved	Mn	mg/ℓ
Chromium, Total & Dissolved	Cr	mg/ℓ

TABLE 3 ANALYTICAL PARAMETERS - GRAB SAMPLING PROGRAM

Parameter	Abbreviation	Units
Total Phosphate	TPO_4	mg/ℓ P
Ammonia	NH_3	mg/ℓ N
Nitrate	NO_3	mg/ℓ N
Nitrite	NO_2	mg/ℓ N
Non Filterable Residue	NFR	mg/ℓ
Chemical Oxygen Demand	COD	mg/ℓ
Anionic Surfactants	-	mg/ℓ LAS
Total Residue	TR	mg/ℓ
Total Organic Carbon	TOC	mg/ℓ C

Environment Canada Pollution Sampling Handbook. Samples for bioassay analysis were placed in four 5 gal. plastic jerry cans. All samples were shipped by air within 2 hours of the completion of each sampling period to Environment Canada laboratory facilities. Sample analysis for all parameters except metals and PCB's commenced within 6 hours of completion of each sampling day. Grab samples collected on Sept. 1 were separated into the proper containers, preserved as required and stored at 4^{o}C before being shipped on Sept. 2 at 0830 hr. with the 24 hour composite samples.

2.2.1 Chemical Analyses. The chemical parameters including metals, as listed in Tables 2 and 3, were analyzed as described in the Environment Canada Pacific Region Laboratory Manual.

2.2.2 Polychlorinated Biphenyls Analysis (PCB). Samples for PCB were collected in one gallon amber glass bottles containing 50 ml hexane as a preservative. Basically the analysis involves acetone: hexane extraction, filtration, purification and electron capture GLC analysis. The detection limit for a one gallon sample is approximately 0.005 ppb.

2.2.3 Bioassay Determination (96 hour LC_{50}). The static fish bioassay test gives an approximate numerical value to the biological toxicity of a wastewater. It is defined as the concentration of a measurable lethal agent (in this case wastewater) required to kill the 50th percentile in a group of test organisms over a period of 96 hours.

The static bioassay test consists of a series of 30 ℓ glass vessels containing different sample dilutions with 6-9 Rainbow Trout (*Salmo gairdneri*) per test vessel. The test vessels were placed in a controlled environment room with the temperature maintained at 14.25 ± 1.0^{o}C and a photo period limited to 16 hours per 24 hours. The bioassay test procedure calls for samples with pH values below 6.0 or above 8.0 to be neutralized to a pH of 7; however, pH adjustment was not required for any of the samples collected. All samples were aerated prior to the test and continously for the 96 hour period. Pre-test aeration times are listed with the test results in Table 4. The fish loading density in each vessel was 0.73 g/l. The percent mortality and percent dilution were plotted on semi log paper to establish an LC_{50} value.

2.3 Chlorine Residual Monitoring

The chlorine residual monitoring program consisted of grab sampling the chlorinated effluent every hour for 24 hours from 0800 hr August 30 to 0800 hr August 31 and determining the total residual chlorine concentration (TRC).

The determination of TRC was done using a Wallace & Tiernan Amperometric Titrator series A-790013. The fundamental procedure used is a Back Titration method involving the neutralization of an oxidizing agent (free iodine) with a reducing agent (phenylarsene oxide solution) of known strength, in the presence of potassium iodide.

The total residual chlorine analysis determines the concentration of compounds in the wastewater containing active chlorine which includes monochloramines, dichloramines and hypochlorous acid.

3. RESULTS

3.1 Bioassay

The static bioassay test results obtained from the 24 hour composite samples are outlined in Table 4. The results are expressed as both a 96 hour LC_{50} as defined earlier and a toxicity concentration, Tc. The toxicity concentration, Tc, expressed in toxic units, TU can be derived as follows:

$$Tc = \frac{100\%}{96\text{ hr } LC_{50}\ (\%)}$$

A Tc value can also be calculated when considering wastewater that produces less than 50 percent mortality at the 100% concentration. The actual Tc value in this case is determined by plotting the percent mortality of test fish versus the Tc values for the various test dilutions of wastewater in which the undiluted wastewater has a Tc value less than 1.

3.2 Chemical Analyses Non Metals

The chemical analyses non-metal results obtained from the 24 hour composite samples are listed in Appendix I. A comparison of these results and the treatment level involved with each sample is illustrated in Figure 2a and 2b. The values plotted in this comparison represent the mean value from the four 24 hour composite samples. The chemical analysis non-metal results obtained from the grab sampling program are outlined in Appendix II.

3.3 Chemical Analyses Metals

The results of the metal analyses, including total and dissolved for the 24 hour composite sampling program, are presented in Appendix I.

3.4 Chlorine Residual Monitoring Results

The results of the 24 hour chlorine residual monitoring program are illustrated in Figure 3. The TRC had a range of 0-2.14 mg/ℓ and a mean of 0.22 mg/ℓ.

The TRC was non detectable for 19 hr during the monitoring

TABLE 4 CACHE CREEK STP COMPOSITE SAMPLE BIOASSAY RESULTS

Sample Point	Parameter	Unit	Date				Average
			Aug. 31	Sept. 1	Sept. 2	Sept. 3	
Raw Sewage	Pre-test Aeration	hr	5	-	17	24	
	LC_{50}	%	32	46	42.5	39.5	40
	Tc	TU	3.13	2.17	2.35	2.53	2.55
Secondary Effluent	Pre-test Aeration	hr	4.5	-	17	24	
	LC_{50}	%	65	74	65	52.5	64.1
	Tc	TU	1.54	1.35	1.54	1.90	1.58
Chlorinated Effluent	Pre-test Aeration	hr	4.5	-	17	24	
	LC_{50}	%	61	87	65	52.5	66.4
	Tc	TU	1.64	1.15	1.54	1.90	1.56

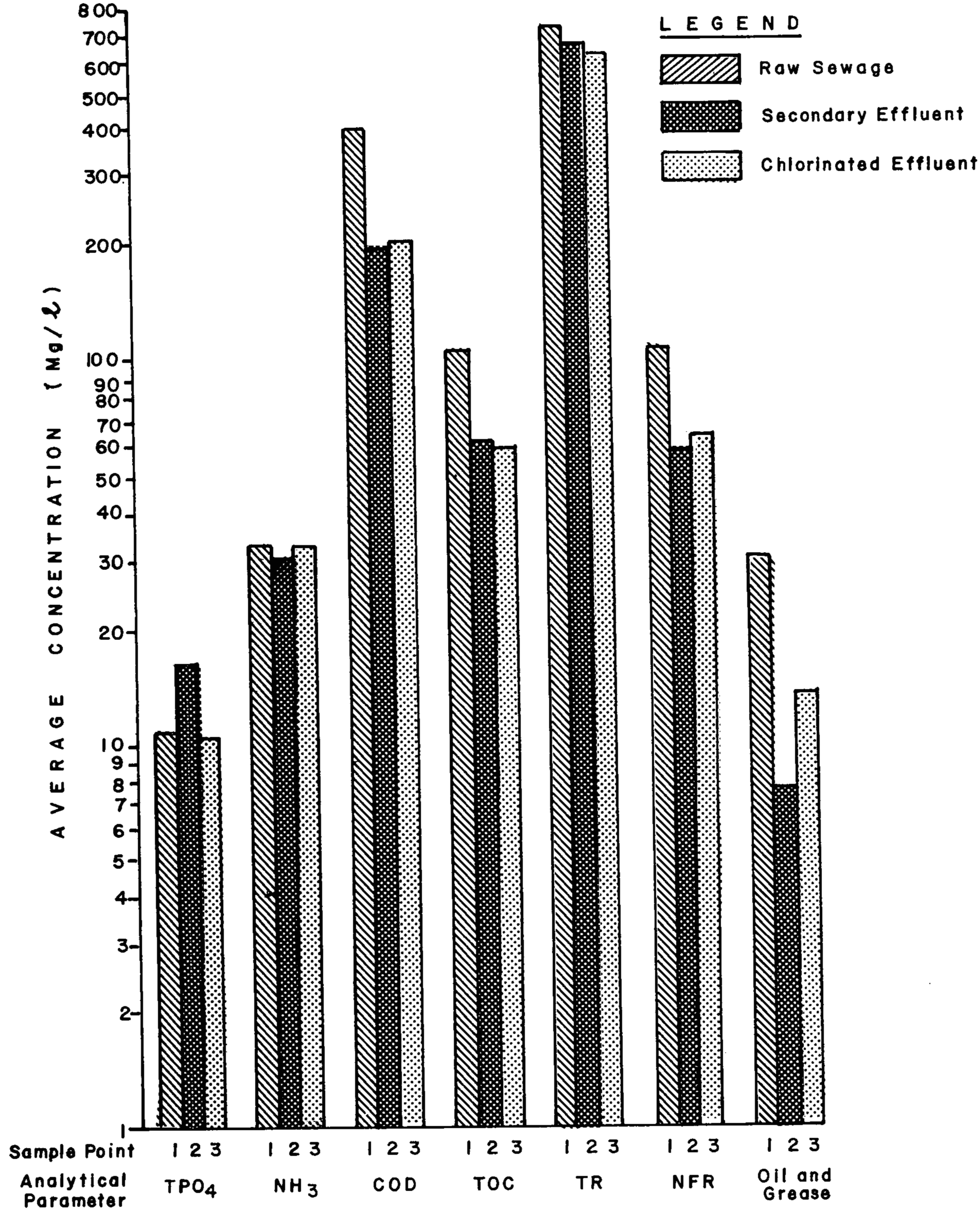

FIGURE 2a. COMPARISON OF ANALYTICAL RESULTS AND TREATMENT LEVELS

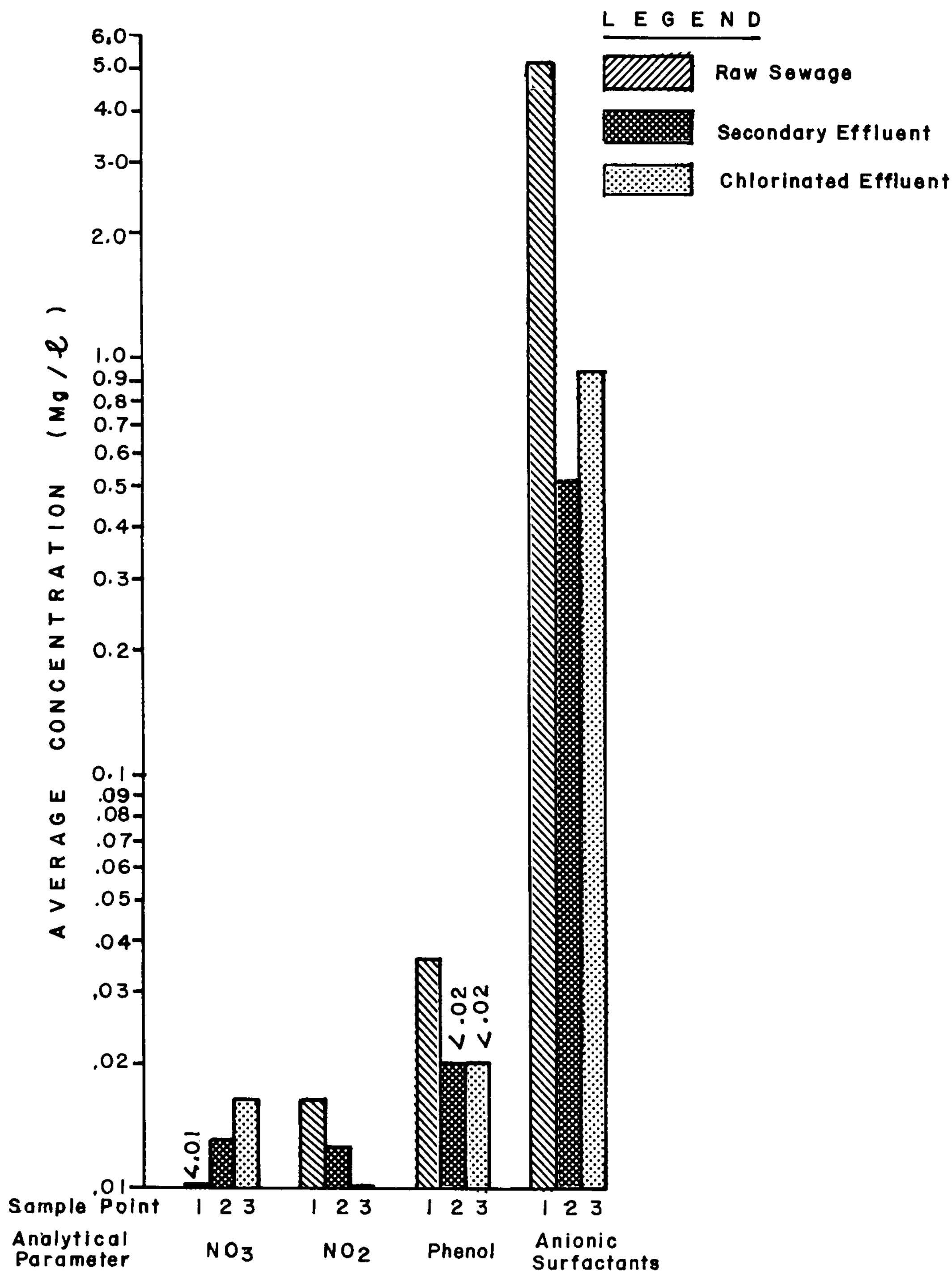

FIGURE 2b. COMPARISON OF ANALYTICAL RESULTS AND TREATMENT LEVELS

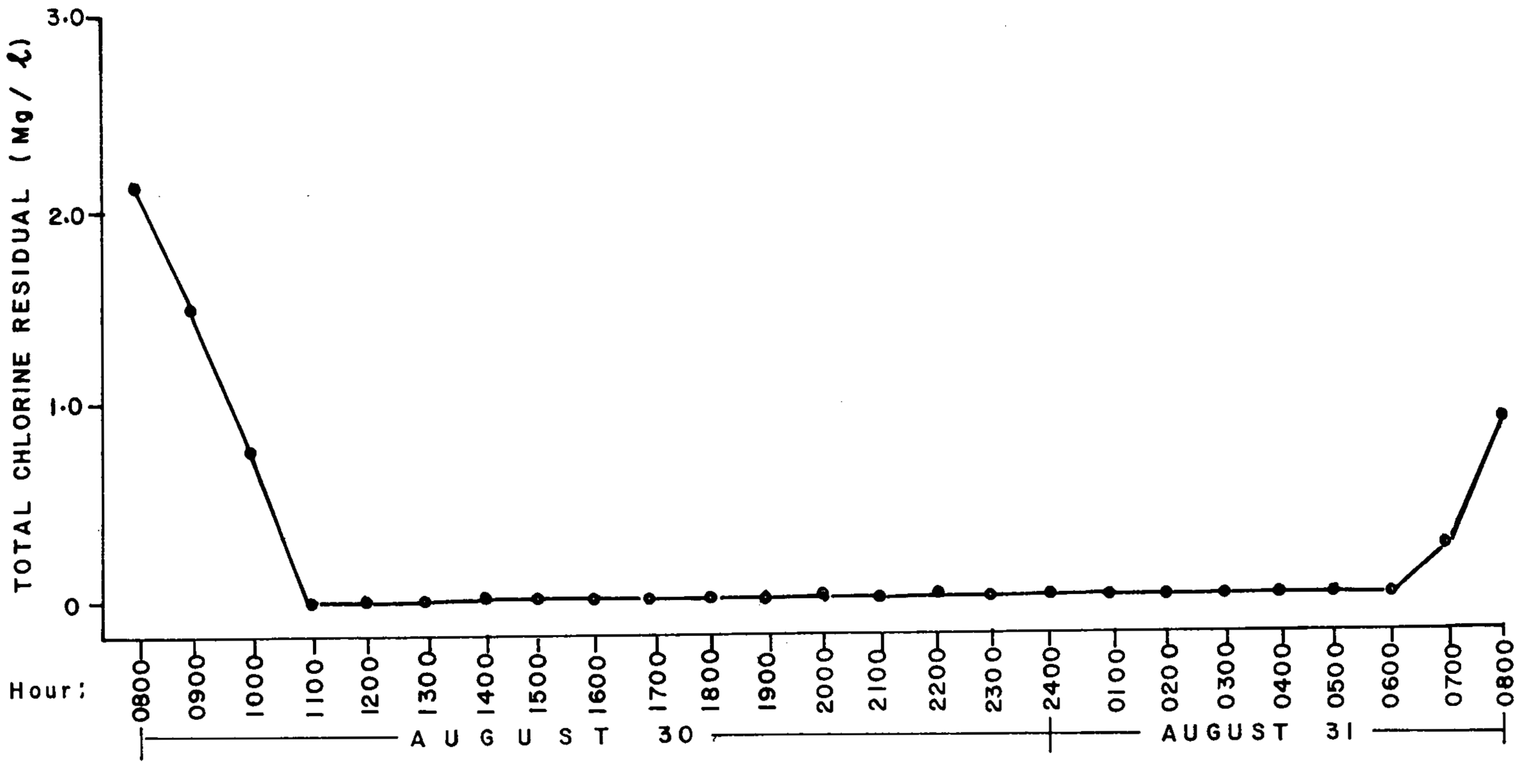

FIGURE 3 24 HOUR CHLORINE RESIDUAL MONITORING PROGRAM
August 30 - 31, 1976

program, from 1100 hr August 30 to 0600 hr August 31.

3.5 Polychlorinated Biphenyls Results

The results of the PCB analysis for the 24 hour composite sampling program are listed in Appendix I. All levels encountered are significantly low. The treatment plant is responsible for a 31% reduction in PCB levels from influent to effluent.

3.6 Daily Flowrates, Chlorine Dosages and Precipitation

Daily flowrates and chlorine dosages for a one year period, Sept. 1, 1975 to Aug. 31, 1976, for the Cache Creek STP have been plotted in Appendix III. In addition total daily precipitation data has been provided. This data would tend to indicate the absence of an infiltration/inflow problem in the sewer system. Daily flows increased slightly during the month of August, 1976, due to the excessive rainfall received in the area during that period.

The mean annual precipitation (1941-1970) for Cache Creek is 212.6 mm. Figure 4 illustrates the actual flow readings taken approximately every 2 hours for the period from 0800 hr Aug. 30 to 0800 hr Sept. 3, 1976. This shows a typical diurnal pattern with peaks of $1.7X10^5$ Imp GPD and lows of $0.8X10^5$ Imp GPD.

3.7 Metal Analyses Summary

In addition to the metal analyses conducted during the survey on the composite samples, metal determinations were also carried out on samples from:

1. aerobic digesters 1 and 2, and
2. the municipal water supply.

The results of these analyses plus the average values for influent and effluent composite samples are presented in Table 5. The results indicate a reduction of copper, iron, zinc and aluminium levels from influent to effluent and a subsequent accumulation of metals in the digester sludges. The municipal water supply sample was provided for background information.

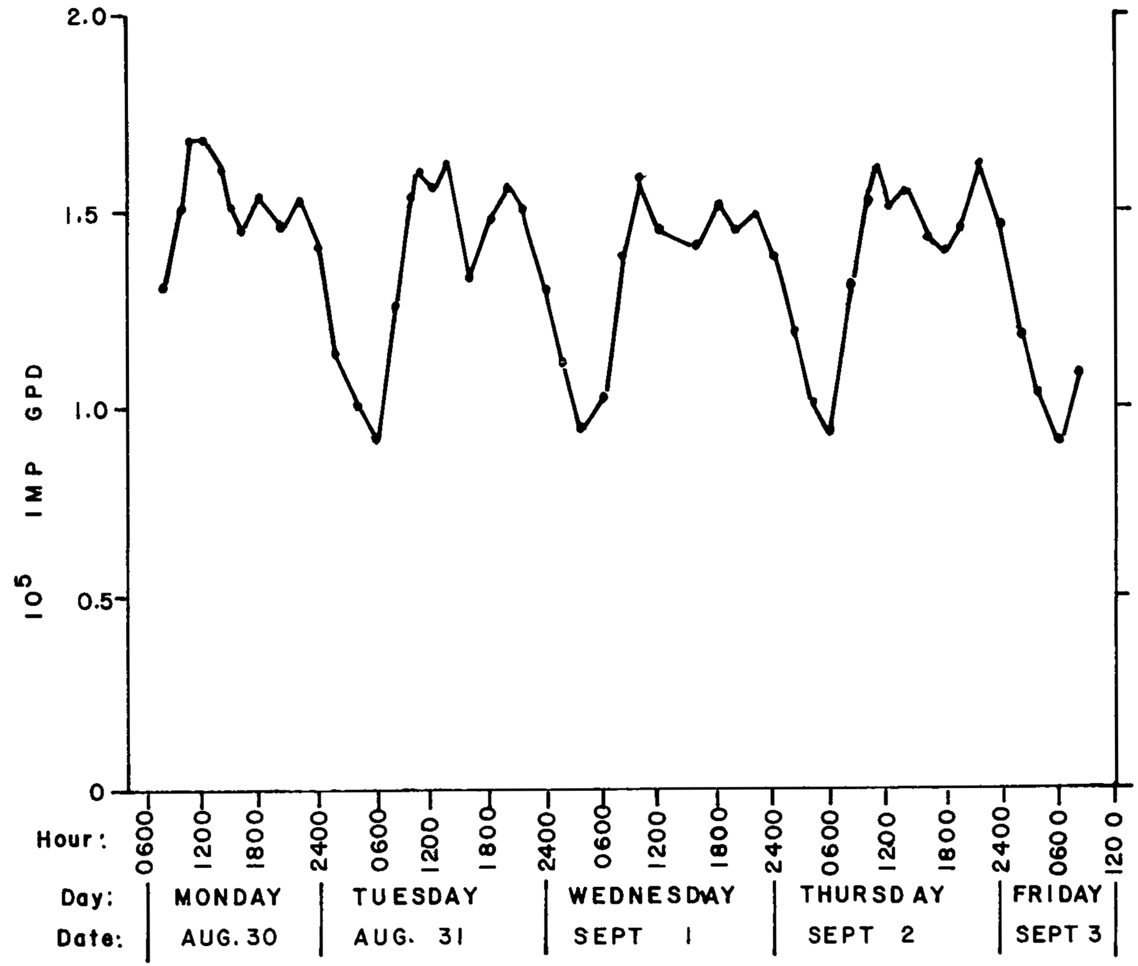

FIGURE 4 CACHE CREEK STP - FLOW READINGS - Aug. 30 - Sept. 3, 1976

TABLE 5 METAL ANALYSIS SUMMARY

Sample Points

Metal	Units	Raw[1] Sewage	Final[1] Effluent	Digester[2] Sludge #1[3]	Digester[2] Sludge #2[3]	Municipal[2] Water Supply
Cu	mg/ℓ	0.23	0.1	13	15	0.19
Fe	mg/ℓ	0.62	0.46	93	120	<0.03
Ni	mg/ℓ	0.05	<0.05			<0.05
Pb	mg/ℓ	<0.02	<0.02	0.93	1.4	<0.02
Zn	mg/ℓ	0.2	0.07	6.3	9.5	0.04
Al	mg/ℓ	0.42	<0.35	15	140	<0.3
Cd	mg/ℓ	<0.01	<0.01	<0.07	<0.1	<0.01
Mn	mg/ℓ	0.04	0.04	2.0	2.1	<0.03
Cr	mg/ℓ	<0.02	<0.02	0.61	1.2	<0.02
Hg	μg/ℓ	<0.2	<0.2	0.69	0.76	<0.2

[1] Average of four 24 hr composite samples

[2] Results of one grab sample only

[3] Denotes separate digesters

4. DISCUSSION

4.1 Bioassay Evaluation

Municipal wastewaters in general contain a wide variety of chemical constituents readily known to be toxic to fish. The most common constituents exerting toxicity include ammonia, cyanide, sulfides, chlorine and chloramine, phenols, surfactants and several heavy metals which include copper, zinc, chromium and nickel. Other factors such as temperature, pH, hardness, alkalinity and dissolved oxygen tend to modify the toxicity produced by various chemical constituents. However, as outlined earlier, the bioassay test conditions are controlled so that pH, temperature and dissolved oxygen do not themselves exert toxicity. The chemical analyses results for the individual composite samples were examined with reference to the literature to determine those factors responsible for toxicity. Following is a discussion of those factors deemed responsible for the bioassay results encountered in the survey.

4.1.1 Ammonia Toxicity. The common sources of ammonia in wastewater are:

1. Urine, which contains urea (H_2NCOH_2N) which in turn readily hydrolyzes to ammonia,
2. Organic matter containing protein and amino acids which decomposes under bacterial action yielding ammonia,
3. Chemical plants and cleaning establishments which release ammonia to the sewer system, and
4. Household cleaning agents.

The toxicity of ammonia and ammonium salts to fish is directly related to the amount of un-ionized ammonia in solution. Ammonia establishes a pH dependent equilibrium in solution as follows:

$$NH_3 + nH_2O \rightleftharpoons NH_3 \cdot nH_2O \rightleftharpoons NH^+_4 + OH + (n-1)\ H_2O$$

Emmerson, et al (2) have outlined a set of equilibrium calculations for determining the un-ionized ammonia in solution under varying conditions of pH and temperature. The un-ionized ammonia concentrations for the 24 hour composite samples have been calculated according to this set of equations and are reported in Table 6. In addition, this table lists the bioassay results and the major toxic constituents involved for each composite sample.

Mayo, et al (3) state that 0.006 mg/ℓ N un-ionized ammonia may be considered to be the desirable upper level for extended fish exposure. A level of 0.025 mg/ℓ un-ionized ammonia has been stated as the maximum that fish can tolerate (4). Lloyd and Orr (5) reported that 0.44 mg/ℓ un-ionized ammonia caused 100% mortality of Salmo gairdneri in 96 hours.

The un-ionized ammonia levels reported in Table 6 fall within, and in some cases exceed, the 0.025 - 0.44 mg/ℓ range and would be expected to contribute a significant amount of toxicity to the influent and effluent. However as pointed out by Esvelt, Kaufman and Selleck (6), factors in addition to un-ionized ammonia may be associated with the toxicity of ammonia. A full discussion of these factors is beyond the scope of this report.

4.1.2 Surfactant Toxicity. Detergents are a common component of sewage and industrial effluents, derived largely from household cleaning agents. Surfactants can be divided as being either anionic, cationic or non-ionic. In current detergent formulas, the primary toxic active agent is LAS (Linear alkylate sulfonates), an anionic surfactant. The surfactant analysis conducted during this survey was carried out specifically for LAS.

The toxicity of LAS tends to increase in hard water, and increase as the carbon chain length increases (6). Thatcher and Santner (8) found 96 Hr LC_{50} values for LAS of 3.3-6.4 mg/ℓ for five species of fish. Dolan and Hendricks determined an LC_{50} of 5.9 mg/ℓ LAS for bluegill sunfish (9). The anionic surfactant concentrations for the raw sewage samples as outlined in Table 6 would be expected to contribute to wastewater toxicity.

4.1.3 Chlorine Toxicity. The toxicity of chlorine and other

TABLE 6 COMPARISON OF ANALYTICAL AND BIOASSAY RESULTS

Sample Points	Date	LC_{50}	Tc	NH_3	*Un-ionized NH_3	Anionic Surfactants	Alkalinity	pH
		%	TU	mg/ℓ N	mg/ℓ N	mg/ℓ LAS	mg/ℓ Ca CO_3	
Raw Sewage	Aug. 31	32	3.13	33	0.48	4.5	350	7.8
	Sept. 1	46	2.17	26	0.48	5.2	320	7.9
	" 2	42.5	2.35	31	0.12	6.3	282	7.2
	" 3	39.5	2.53	45	0.42	5.1	330	7.6
Secondary Effluent	Aug. 31	65	1.54	31	0.57	0.56	270	7.9
	Sept. 1	74	1.35	30	0.35	0.53	350	7.7
	" 2	65	1.54	27	0.16	0.75	315	7.4
	" 3	52.5	1.90	36	0.33	0.18	350	7.6
Chlorinated Effluent	Aug. 31	61	1.64	34	0.62	0.58	340	7.9
	Sept. 1	87	1.15	36	0.42	0.64	320	7.7
	" 2	65	1.54	26	0.24	0.59	317	7.6
	" 3	52.5	1.90	37	0.34	2.0	360	7.6

* According to Emerson, et al (2)

chlorinated compounds such as chloramines and chlorinated hydrocarbons has been thoroughly documented in the literature. Martens and Servizi (10) observed that the toxicity of primary treated sewage to sockeye salmon was increased several fold whenever chlorine residuals were detected in the effluent. In field studies, residual chlorine levels above 0.02 mg/ℓ were found likely to be toxic to rainbow trout and sockeye salmon using in-stream bioassay techniques (10).

The toxicity of chlorinated wastewater does not depend directly on the amount of chlorine added but on the concentration of residual chlorine remaining (11). Residual chlorine is commonly understood to mean the total concentration of compounds containing active chlorine which remain after free chlorine addition. These compounds consist of monochloramines, dichloramines and hypochlorous acid. In addition chlorine may combine with a variety of compounds in wastewater including cyanide, phenols and alkyl sulfonates, which are not detectable by the amperometric technique.

During the 24 hour chlorine residual monitoring program carried out during the Cache Creek study, the TRC averaged 0.22 mg/ℓ and had a range of 0-2.14 mg/ℓ.

Due to the low chlorine dosage being applied and the high chlorine demand of the effluent, there was no detectable chlorine residual for 19 hours during the monitoring program. In addition the chlorine residuals of the composite samples were non-detectable. Chlorination of the effluent did not result in an increase in toxicity in this case, but it would be expected that an increase in toxicity would occur if the chlorine dosage had been high enough to yield a consistently detectable residual. The chlorine dosage averaged 4.3 ppm during the survey.

4.2 Bioassay Summary

A comparison of the toxicity concentrations, Tc, of the 24 hour composite samples obtained from the three treatment plant locations appears in Figure 5.

The raw sewage exhibited a mean 96 hr LC_{50} of 40% (Tc = 2.54).

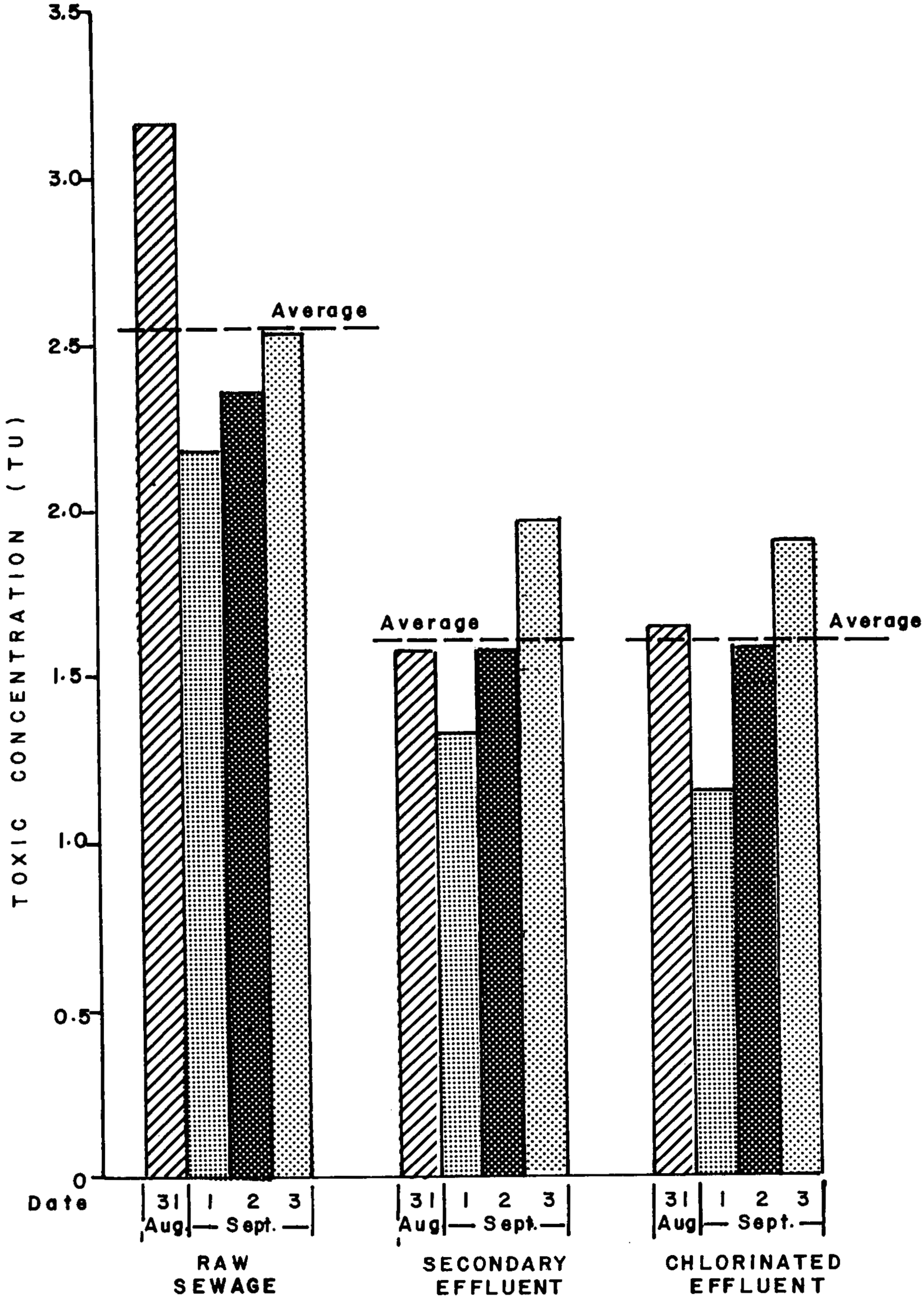

FIGURE 5 CACHE CREEK STP BIOASSAY RESULTS
TOXICITY CONCENTRATIONS - Aug. 31 - Sept. 3, 1976

Most of the toxicity associated with the raw sewage would be attributable to the un-ionized ammonia content (a mean of 0.375 mg/l N) and to the anionic surfactant concentration (a mean of 5.275 mg/l LAS). In addition the raw sewage total alkalinity would tend to increase surfactant toxicity. (Assuming a close relationship exists between hardness and alkalinity).

The secondary effluent prior to chlorination exhibited a mean 96 hr LC_{50} of 64.1% (Tc = 1.58). This represents a 37.8% reduction of the initial raw sewage toxicity. Secondary treatment was responsible for reducing the average anionic surfactant level to 0.51 mg/l LAS which results in a decrease in toxicity. Secondary treatment was responsible for only a slight decrease in the un-ionized ammonia concentration.

The chlorinated effluent exhibited a mean 96 hr LC_{50} of 66.4% (Tc = 1.56). Chlorination in this case did not result in an increase in toxicity, however, as pointed out in section 3.4, the TRC during the residual chlorine monitoring program was at a non-detectable level (i.e., below 0.02 mg/l) for 19 of the 25 samples. An increase in chlorine dosage sufficient to yield a consistently measureable residual could be expected to cause an increase in toxicity. The chlorine dosage averaged 4.3 mg/l during the survey.

4.3 General Plant Performance

Based on data collected during the survey, the treatment plant reduced raw sewage COD, TOC and NFR levels by 49%, 44% and 46% respectively. The average effluent NFR was 63 mg/l which is slightly in excess of the Pollution Control Branch permit requirement for this plant of a maximum of 60 mg/l. Assuming that, generally for municipal wastewater, BOD_5 is 60% of the COD value, the average effluent BOD_5 would be 120 mg/l (a 49% reduction), also in excess of permit requirements. Conventional activated sludge treatment plants are generally capable of reducing BOD_5 levels by 88-93% (12). The low treatment efficiencies were due to the high MLSS levels maintained in the aeration tanks (MLSS; #1 = 7500 mg/l, #2 = 4700 mg/l). This in turn results in a high mean cell residence time and an activated sludge with poor settling characteristics. To increase overall efficiency would require a reduction in the MLSS levels and consequently an increase in the sludge wastage rate. However, due to the problems associated with supernatant separation in the digesters, as mentioned in section 1.1, and solids handling problems in general, significant increases in overall plant efficiency cannot be accomplished until the separate sludge handling facilities have been completed.

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APPENDIX I

CACHE CREEK STP COMPOSITE SAMPLE

ANALYTICAL RESULTS

a. Non Metals

b. Metals

APPENDIX I CACHE CREEK STP COMPOSITE SAMPLE ANALYTICAL RESULTS
a. Non Metals

Sampling Point	Number
Raw Sewage	1
Secondary Effluent	2
Chlorinated Effluent	3

Analytical Parameter	Sampling Point	Date			
		Aug. 31	Sept. 1	Sept. 2	Sept. 3
TPO_4	1	11.5	13.5	10	9
	2	12.2	13	11	30
mg/ℓ P	3	12.2	12.3	10	9
NH_3	1	33	26	31	45
	2	31	30	27	36
mg/ℓ N	3	34	36	26	37
NO_3	1	<0.01	<0.01	<0.01	<0.01
	2	0.023	<0.01	<0.01	<0.01
mg/ℓ N	3	0.036	<0.01	<0.01	<0.01
NO_2	1	0.011	0.014	0.011	0.03
	2	0.015	0.01	0.011	0.014
mg/ℓ N	3	0.012	0.012	0.01	0.007
Alkalinity	1	350	320	282	330
mg/ℓ Ca CO_3	2	270	350	315	350
	3	340	320	317	360
COD	1	400	410	350	400
mg/ℓ	2	190	180	190	210
	3	170	250	180	200
TOC	1	124	108	112	114
mg/ℓ	2	46	64	67	70
	3	54	64	56	61
pH	1	7.8	7.9	7.2	7.6
	2	7.9	7.7	7.4	7.6
	3	7.9	7.7	7.6	7.6
NFR	1	120	130	94	120
mg/ℓ	2	47	39	64	78
	3	45	69	66	71
Anionic Surfactants	1	4.5	5.2	6.3	5.1
	2	0.56	0.53	0.75	0.18
mg/ℓ LAS	3	0.58	0.64	0.59	2.0
TR	1	700	730	700	710
mg/ℓ	2	626	650	660	660
	3	610	640	640	640
CN	1	<0.03	<0.03	<0.03	<0.03
mg/ℓ	2	<0.03	<0.03	<0.03	<0.03
	3	<0.03	<0.03	<0.03	<0.03
Phenol	1	0.05	0.04	0.04	0.014
mg/ℓ	2	0.02	<0.02	0.03	0.005
	3	<0.02	<0.02	0.02	0.004
Oil & Grease	1	36	37	39	11.2
mg/ℓ	2	5.2	-	9	8.8
	3	6.2	26	11	10.8
PCB	1	0.057	0.062	0.052	0.037
ppb	2	0.043	0.048	0.041	0.049
	3	0.037	0.031	0.032	0.044

APPENDIX I CACHE CREEK STP COMPOSITE SAMPLE ANALYTICAL RESULTS
b. Metals

Sampling Point	Number
Raw Sewage	1
Secondary Effluent	2
Chlorinated Effluent	3

Analytical	Parameter	Sampling Point	Date			
			Aug. 31	Sept. 1	Sept. 2	Sept. 3
Hg	Total	1	<0.2	<0.2	<0.2	<0.2
μg/ℓ		2	0.4	1.3	0.2	0.63
		3	<0.2	<0.2	<0.2	<0.2
Cu	Total	1	0.23	0.23	0.23	0.23
mg/ℓ		2	0.08	0.1	0.12	0.12
		3	0.08	0.08	0.12	0.12
Cu	Dissolved	1	0.01	0.01	0.03	0.04
		2	<0.01	<0.01	<0.01	0.01
		3	0.07	<0.01	<0.01	0.01
Fe	Total	1	0.84	9.65	0.58	0.44
		2	0.47	0.45	0.44	0.44
		3	0.45	0.45	0.5	0.45
Fe	Dissolved	1	0.23	0.11	0.09	0.08
		2	0.19	0.16	0.15	0.14
		3	0.21	0.16	0.14	0.12
Ni	Total	1	<0.05	<0.05	<0.05	<0.05
		2	<0.05	<0.05	<0.05	<0.05
		3	<0.05	<0.05	<0.05	<0.05
Ni	Dissolved	1	<0.05	<0.05	<0.05	<0.05
		2	<0.05	<0.05	<0.05	<0.05
		3	<0.05	<0.05	<0.05	<0.05
Pb	Total	1	<0.02	<0.02	<0.02	<0.02
		2	<0.02	<0.02	<0.02	<0.02
		3	<0.02	<0.02	<0.02	<0.02
Pb	Dissolved	1	<0.02	<0.02	<0.02	<0.02
		2	<0.02	<0.02	<0.02	<0.02
		3	<0.02	<0.02	<0.02	<0.02
Zn	Total	1	0.19	0.22	0.12	0.28
		2	0.15	0.13	0.09	0.08
		3	0.07	0.07	0.07	0.07
Zn	Dissolved	1	0.18	0.03	0.04	0.06
		2	0.28	0.04	0.05	0.02
		3	0.14	0.06	0.02	0.04
Al	Total	1	0.4	0.4	0.5	0.4
		2	<0.3	0.5	0.3	0.4
		3	<0.3	0.4	<0.3	0.4
Al	Dissolved	1	<0.3	<0.3	<0.3	<0.3
		2	<0.3	<0.3	<0.3	<0.3
		3	<0.3	<0.3	<0.3	<0.3
Cd	Total	1	<0.01	<0.01	<0.01	<0.01
		2	<0.01	<0.01	<0.01	<0.01
		3	<0.01	<0.01	<0.01	<0.01
Cd	Dissolved	1	<0.01	<0.01	<0.01	<0.01
		2	<0.01	<0.01	<0.01	<0.01
		3	<0.01	<0.01	<0.01	<0.01
Mn	Total	1	0.05	0.06	0.05	0.04
		2	0.06	0.06	0.06	0.05
		3	0.06	0.05	0.05	0.05
Mn	Dissolved	1	0.05	0.04	0.04	0.03
		2	0.05	0.05	0.04	0.05
		3	0.04	0.04	0.04	0.04
Cr	Total	1	<0.02	<0.02	<0.02	<0.02
		2	<0.02	<0.02	<0.02	<0.02
		3	<0.02	<0.02	<0.02	<0.02
Cr	Dissolved	1	<0.02	<0.02	<0.02	<0.02
		2	<0.02	<0.02	<0.02	<0.02
		3	<0.02	<0.02	<0.02	<0.02

APPENDIX II

CACHE CREEK GRAB SAMPLE

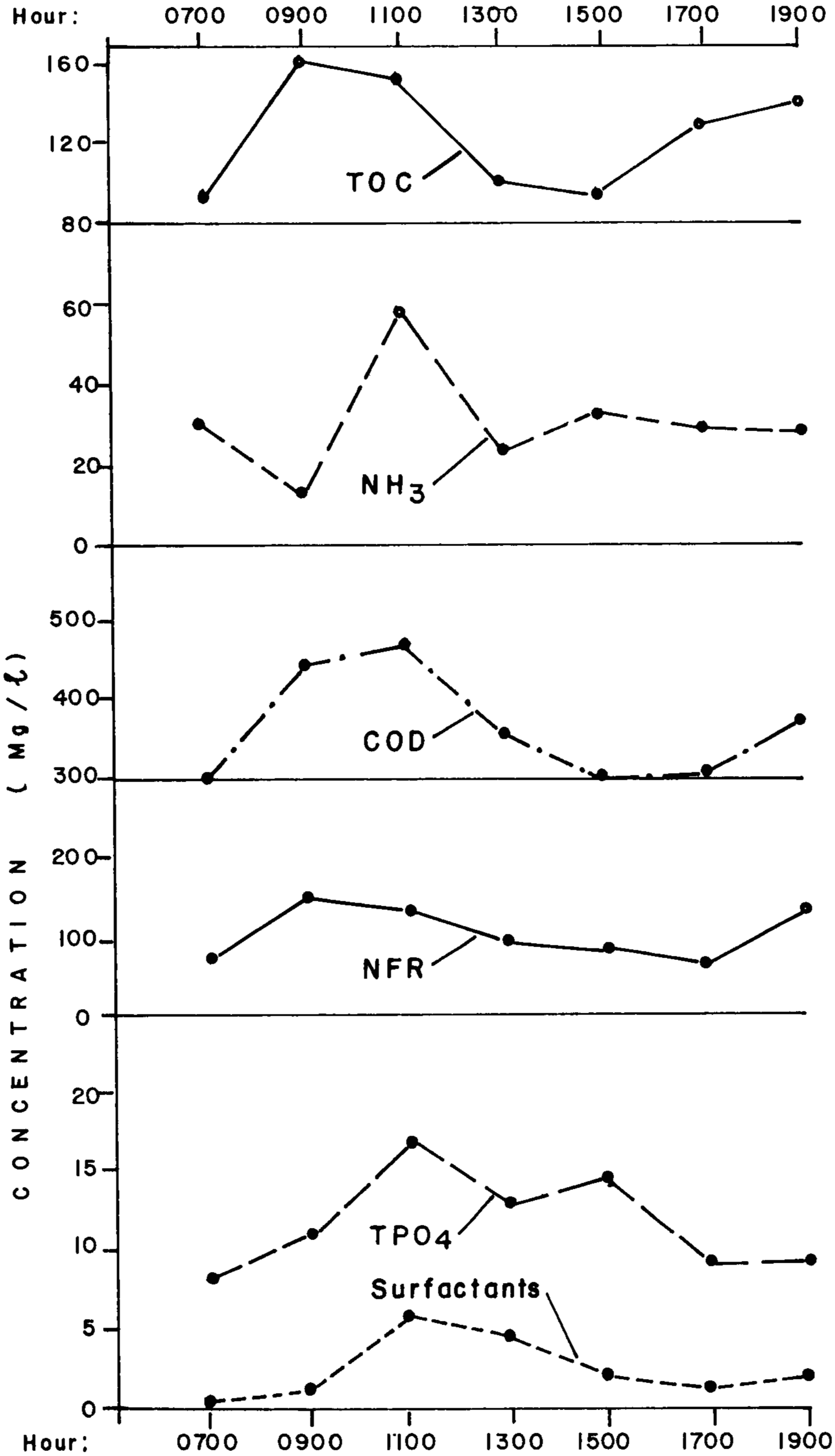
ANALYTICAL RESULTS

APPENDIX II CACHE CREEK STP GRAB SAMPLE ANALYTICAL RESULTS

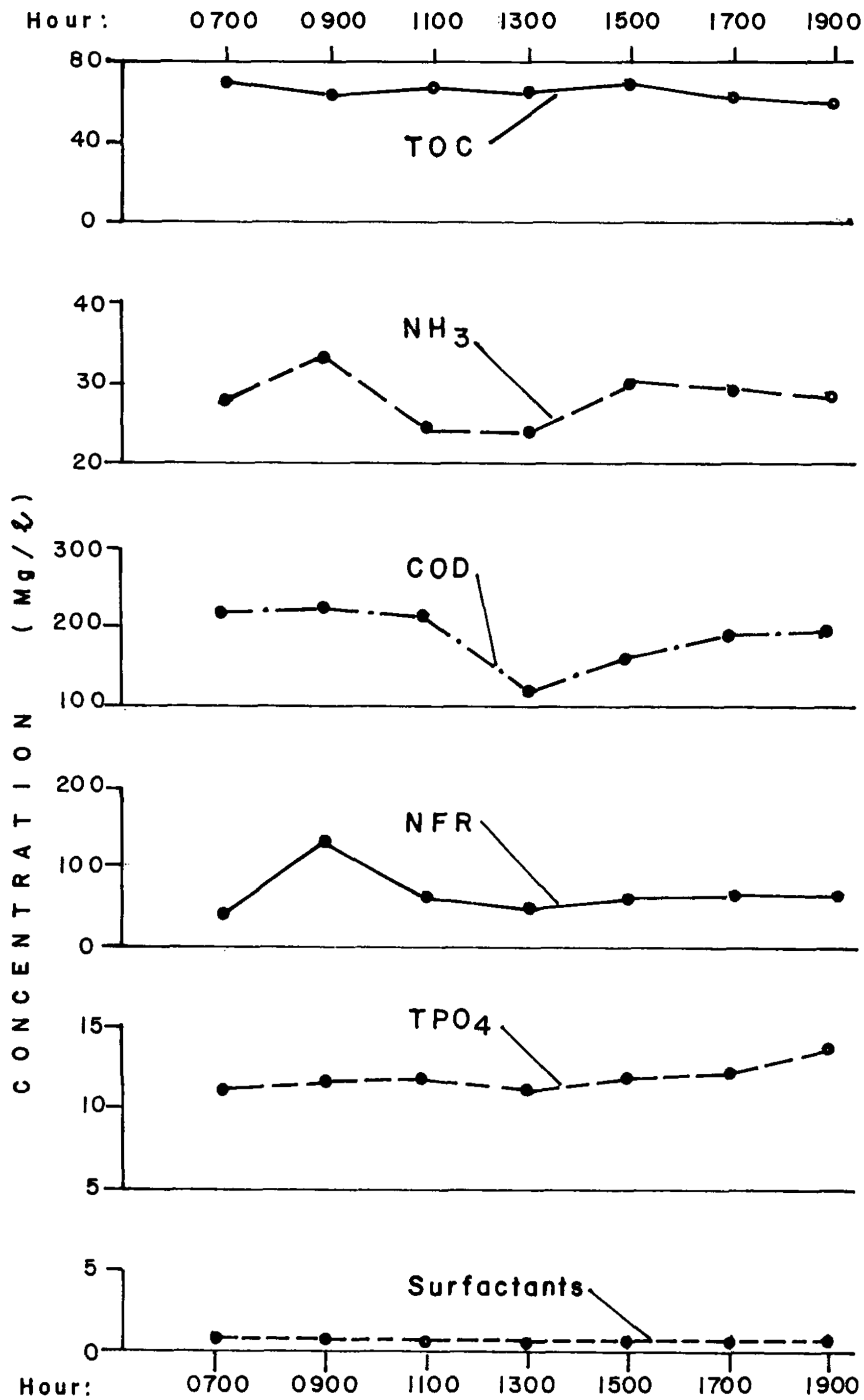
NON METALS

Sampling Point	Number
Raw Sewage	1
Chlorinated Effluent	3

Analytical Parameter	Sampling Point	Time						
		0700	0900	1100	1300	1500	1700	1900
TPO_4	1	8	11	17	13	14	9	9
mg/ℓ	3	11	12	12	11	12	12	13
NH_3	1	30	13	58	25	32	29	28
mg/ℓ N	3	28	33	24	24	30	29	35
NO_3	1	<.01	<.01	<.01	<.01	<.01	<.01	3.5
mg/ℓ N	3	<.01	<.01	<.01	<.01	<.01	<.01	<.01
NO_2	1	.011	.02	.021	.016	.014	.011	.012
mg/ℓ N	3	.014	.014	.014	.011	.011	.012	.012
NFR	1	74	150	130	98	81	71	130
mg/ℓ	3	45	130	62	46	51	63	63
COD	1	300	440	470	350	300	300	370
mg/ℓ	3	210	220	210	120	160	190	190
Anionic Surfactants	1	0.2	1.4	6.0	4.5	2.4	1.9	2.4
mg/ℓ LAS	3	0.2	0.3	0.26	0.1	0.22	0.16	0.5
TR	1	630	780	810	670	690	590	660
mg/ℓ	3	600	700	610	610	610	650	610
TOC	1	96	162	154	100	94	128	140
mg/ℓ C	3	68	64	66	64	66	62	60



CACHE CREEK STP GRAB SAMPLING PROGRAM - RAW SEWAGE - September 1, 1976

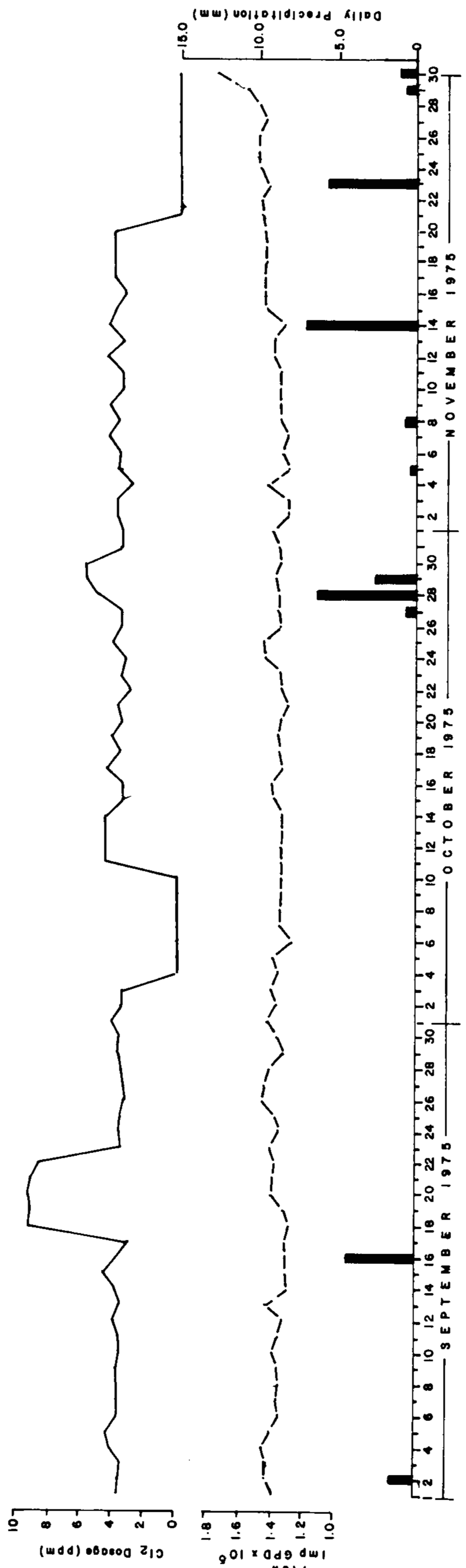


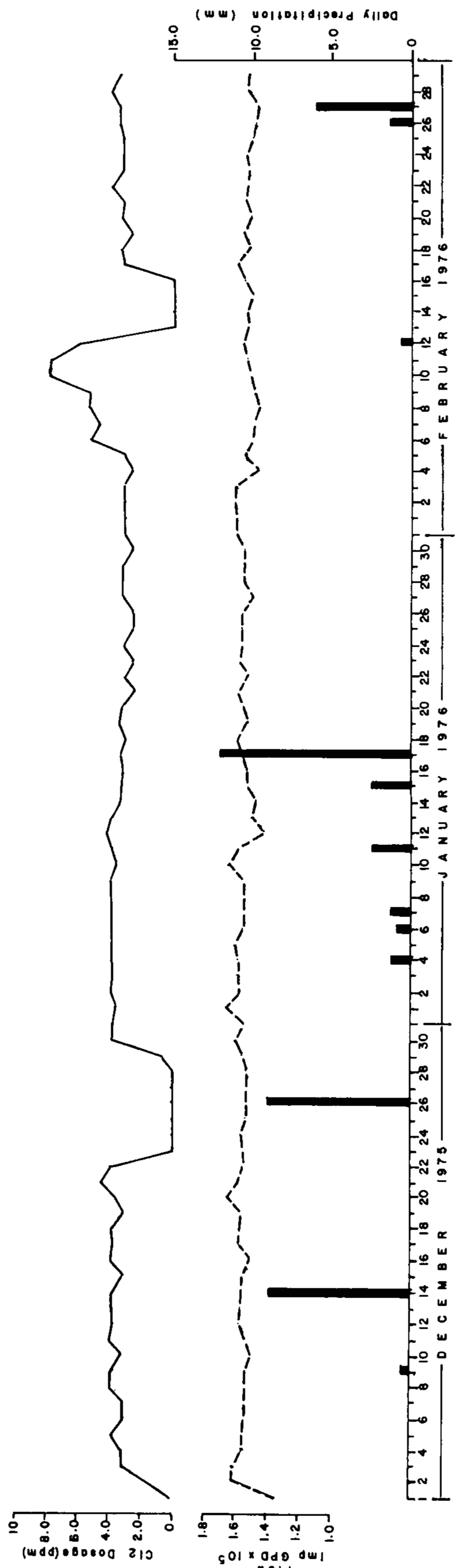
CACHE CREEK STP GRAB SAMPLING PROGRAM - CHLORINATED EFFLUENT - September 1, 1976

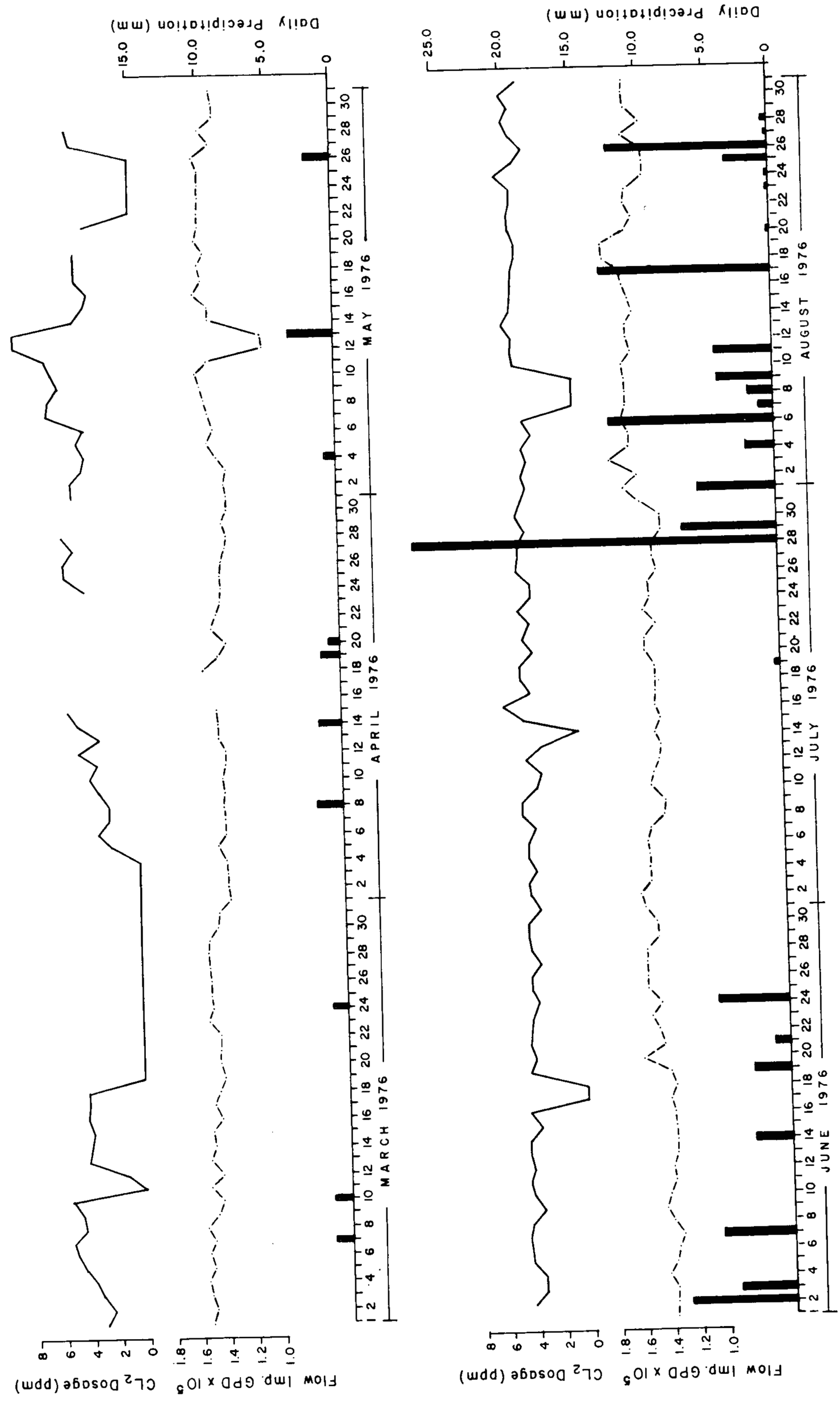
APPENDIX III

CACHE CREEK STP DAILY FLOWS, CHLORINE DOSAGES AND PRECIPITATION

SEPT. 1, 1975 TO AUG. 31, 1976


Daily Precipitation (mm)
15.0
10.0
5.0
0
SEPTEMBER 1975
OCTOBER 1975
NOVEMBER 1975
Cl2 Dosage (ppm)
Flow
Imp GPD x 10^6


Daily Precipitation (mm)
15.0
10.0
5.0
0
DECEMBER 1975
JANUARY 1976
FEBRUARY 1976
Cl2 Dosage (ppm)
Flow
Imp GPD x 10^5


Daily Precipitation (mm)
CL2 Dosage (ppm)
Flow Imp. GPD x 10^5
MARCH 1976
APRIL 1976
MAY 1976
Daily Precipitation (mm)
CL2 Dosage (ppm)
Flow Imp. GPD x 10^5
JUNE 1976
JULY 1976
AUGUST 1976