Fisheries and Environment Canada
Pêches et Environnement Canada

Environmental Protection Service
Service de la protection de l'environnement

# A Study of Municipal Wastewater Toxicity, Village of Clinton Sewage Treatment Lagoons and the Town of Williams Lake Sewage Treatment Lagoons, August, 1976

Manuscript Report
77-10

Pacific Region
December, 1977

# A STUDY OF MUNICIPAL WASTEWATER TOXICITY, VILLAGE OF CLINTON SEWAGE TREATMENT LAGOONS AND THE TOWN OF WILLIAMS LAKE SEWAGE TREATMENT LAGOONS, AUGUST 1976

by

T.W. Higgs, P.Eng.
Sigma Resource Consultants Ltd.

for the

Environmental Protection Branch
Environmental Protection Service
Pacific Region

Manuscript Report 77-10
December, 1977

## ABSTRACT

Wastewater toxicity studies of the Village of Clinton, Sewage Treatment Lagoons and the Town of Williams Lake, Sewage Treatment Lagoons were conducted by personnel from the Environmental Protection Service, Pacific Region.

The objectives of the surveys carried out at Clinton and Williams Lake were as follows:

1. to determine the extent of toxicity removal achieved by lagoon sewage treatment systems,
2. to determine the effect of chlorination on the toxicity of the effluent (Williams Lake),
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.

These studies also included the collection of information concerning such factors as system design, actual loadings and chlorine dosages. 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 different treatment lagoon locations.

## TABLE OF CONTENTS

## LIST OF FIGURES



## LIST OF TABLES

## LIST OF ABBREVIATIONS

| | |
|---|---|
| ft | feet |
| GLC | gas liquid chromatography |
| hr | hour(s) |
| Imp GPD | imperial gallons per day |
| l | liter(s) |
| LAS | linear alkylate sulfonate |
| $LC_{50}$ | 50th percentile lethal concentration |
| mg/l | milligrams per liter |
| NFR | non filterable residue (formerly SS) |
| PCB | polychlorinated biphenyls |
| ppb | parts per billion |
| ppm | parts per million |
| Tc | toxicity concentration |
| TRC | total residual chlorine |
| TU | toxic units |
| µg/l | micrograms per liter |

## CONCLUSIONS

Based on data collected at the Clinton Sewage Treatment Lagoons from August 3 to August 5, 1976 the following conclusions can be made:

1. The treatment lagoons were responsible for complete removal of the toxicity associated with the raw sewage samples ($T_c$ = 2.21). This was attributable to the reduction of surfactant and un-ionized ammonia concentrations accomplished by biological treatment in the lagoons.

2. The average raw sewage PCB concentration was 0.031 ppb. The treatment system reduced PCB levels an average of 52%. All PCB concentrations encountered were significantly low.

Based on data collected at the Williams Lake Sewage Treatment Lagoons from August 10 to August 12, 1976, the following conclusions can be made.

1. The treatment lagoons were responsible for complete removal of the toxicity associated with the raw sewage samples ($T_C$ = 2.06). This was attributable to the reduction of the surfactant and un-ionized ammonia concentrations accomplished by biological treatment in the lagoons.

2. Chlorination of the final effluent was not responsible for any change in toxicity. However, as discussed in Section 3.6 the chlorine residuals maintained in the effluent would be insufficient to result in any increase in toxicity.

3. The average raw sewage PCB concentration was 0.052 ppb. The treatment system reduced PCB levels an average of 89%. All PCB concentrations encountered were significantly low.

## 1. INTRODUCTION

The Village of Clinton, located in the Cariboo area of British Columbia, had an estimated population of 800 in 1976(1). All sewage from the village is collected and treated by the Clinton Sewage Treatment Lagoons. The sanitary and storm sewers are completely separate. Economic activity is mainly associated with service to the agricultural resources in the area plus tourism in the summer months. There are no industrial discharges to the sewer system.

The Town of Williams Lake, located in the Cariboo area of British Columbia, had an estimated population of 6,199 in 1976(1). All sewage from the town is collected and treated by the Williams Lake Treatment Lagoons. The sanitary and storm sewers are completely separate. Economic activity is associated with lumber, agriculture and service industries. There are no industrial discharges to the sewer system.

The objectives of the surveys carried out at Clinton and Williams Lake were as follows:

1) to determine the extent of toxicity removal achieved by lagoon sewage treatment systems,
2) to determine the effect of chlorination on the toxicity of the effluent (Williams Lake),
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 surveys consisted of the following programs:

1) a 2 day composite sampling program,
2) a 12 hour grab sampling program,
3) a lagoon contents grab sampling program,
4) a 24 hour chlorine residual monitoring program (Williams Lake only), and
5) general operating data collection.

The Clinton Sewage treatment lagoon survey was carried out from August 3 to 5, 1976; the Williams Lake sewage treatment lagoon survey was carried out from August 10 to 12, 1976.

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 in each case.

## 1.1 Clinton Sewage Treatment Lagoons, Description

The Clinton Sewage Treatment Lagoons consist of two anaerobic primary lagoons, which operate alternately, a facultative secondary lagoon and a final aerobic lagoon. A flow diagram showing sample point locations is presented in Figure 1. At the design flowrate of 100,000 Imp GPD, the anaerobic lagoon has a retention time of approximately 10 days, the facultative lagoon has a retention of 43 days and the final aerobic lagoon has a retention time of 84 days, for a total of 137 days. The final aerobic lagoon and the facultative lagoon have operating depths of 5 ft while the anaerobic lagoon or primary lagoon has an operating depth of 10 ft. The final effluent discharges through a Parshall flume for flow measurement. The flowrate measurement and recording device was not operating either prior to, or during the survey. The lagoon effluent is discharged to Clinton Creek as shown in Figure 1.

## 1.2 Williams Lake Sewage Treatment Lagoons, Description

The Williams Lake Sewage Treatment Lagoons consist of two anaerobic primary lagoons, which operate alternately, an aerated lagoon, a final settling lagoon and chlorine addition. The outfall is used to provide chlorine contact. A flow diagram showing sample point locations is presented in Figure 2. At the average daily flowrate during July, 1976 of 280,000 Imp GPD the anaerobic lagoon had a retention time of approximately 13 days, the aerated lagoon had a retention of 61 days and the final settling lagoon had a retention time of 31 days, for a total of 105 days. All the lagoons have operating depths of 15 ft. Chlorine addition takes

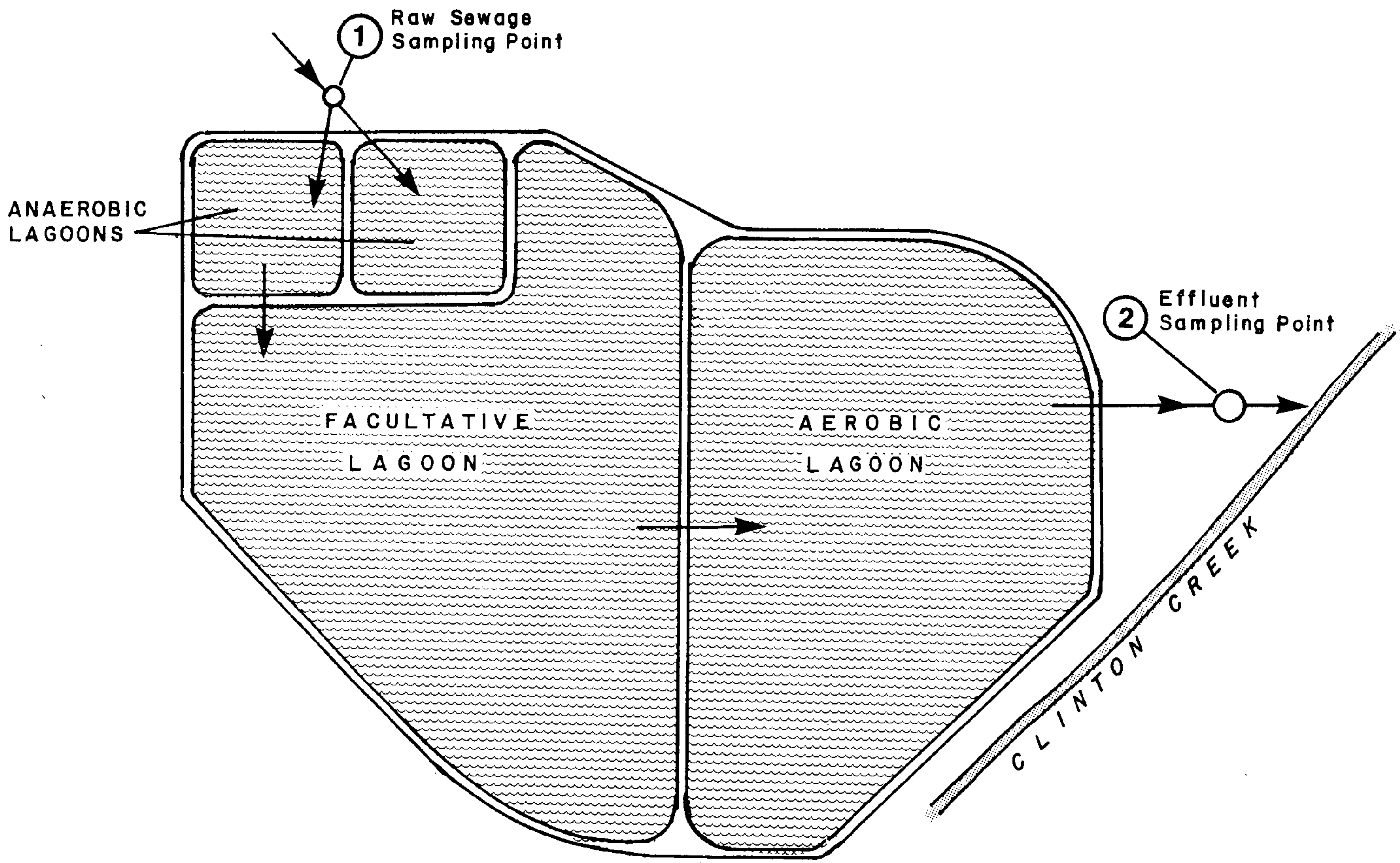



FIGURE I VILLAGE OF CLINTON - SEWAGE TREATMENT LAGOONS, FLOW DIAGRAM AND SAMPLE POINT LOCATIONS

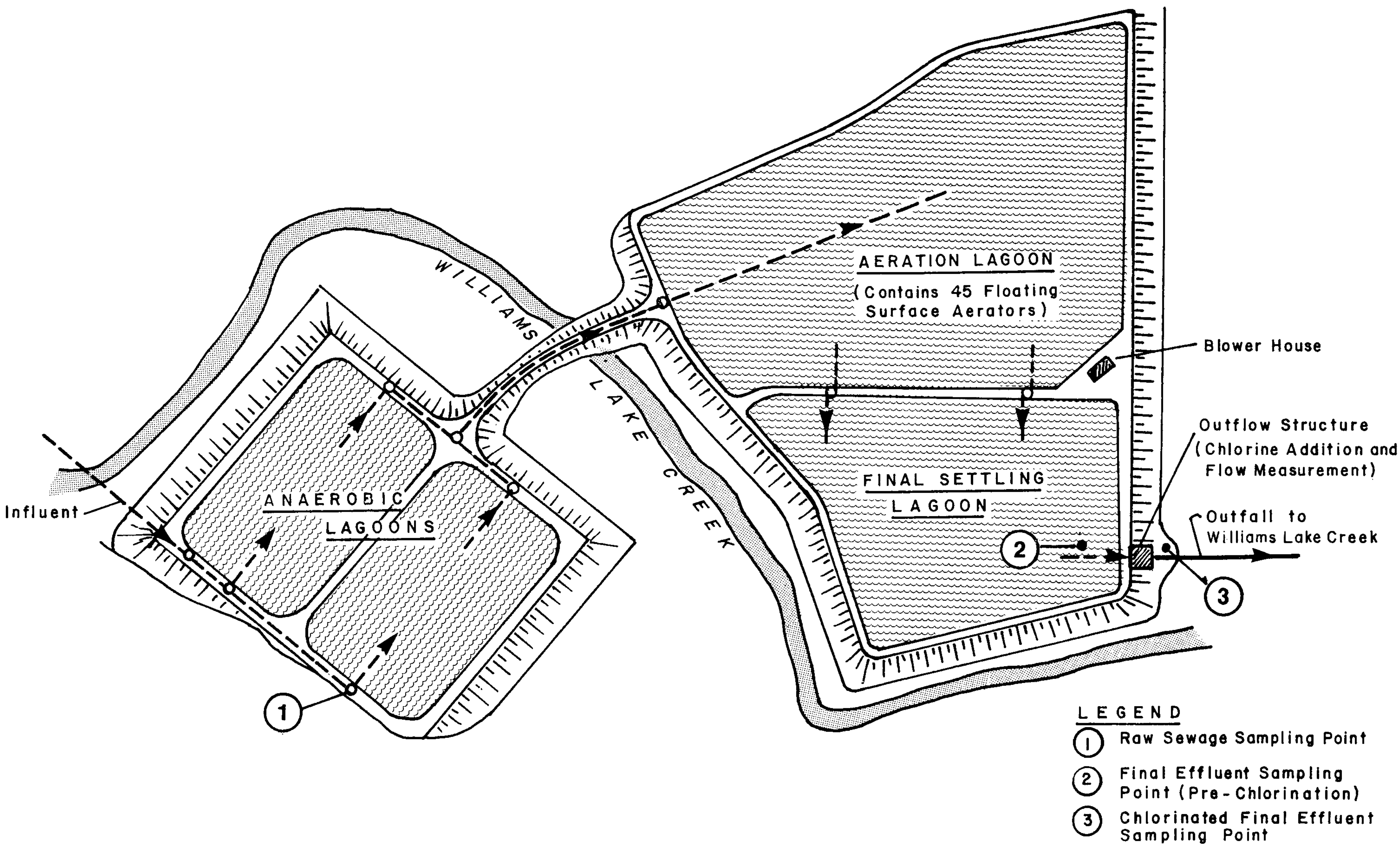



FIGURE 2 WILLIAMS LAKE-SEWAGE TREATMENT LAGOONS, FLOW DIAGRAM AND SAMPLE POINT LOCATIONS

place in the outflow structure just prior to discharge to the outfall. The outflow structure also contains a V notch weir and floating flow measurement device, which is connected to a flow recorder in the blower house. A signal from the flow recorder paces the chlorine metering equipment. The final chlorinated effluent discharges to Williams Lake Creek.

## 2. PROCEDURES AND METHODS

### 2.1 Sampling Program - Clinton Sewage Treatment Lagoons

The time proportional 24 hour composite samples were collected at two locations:

1) The raw sewage sample was taken from a manhole, as shown in Figure 1, situated between the sewer line and the primary lagoons. Approximate 1.1 l samples were taken every ten minutes, using a timer assembly and a submersible pump.

2) The final effluent sample was taken from a manhole, as shown in Figure 1, situated between the final lagoon and the discharge point. Approximate 250 ml samples were taken every 2.5 minutes using a Markland Model 2101- Special Duckbill sampler.

The composite sample aliquots were collected in 45 gallon polyethylene barrels. The composite sampling program commenced at 0600 hr August 3 and ended at 0600 hr August 5.

The raw sewage grab samples, taken from the same location as the composite, were collected every 2 hr on August 4 from 0600 hr to 1800 hr.

In addition, the contents of each lagoon were grab sampled on August 4 and 5 using a small boat. This was done to determine the level of treatment accomplished by each lagoon.

### 2.2 Sampling Program - Williams Lake Sewage Treatment Lagoons

The time proportional 24 hr composite samples were collected at three locations as follows.

1) The raw sewage sample was taken from the inlet structure, as shown in Figure 2, situated between the sewer line and the anaerobic lagoon, which was in operation during the survey. Approximate 250 ml samples were taken every 2.5 minutes using a Markland Model 2101 - Special Duckbill sampler.

2) The final effluent sample (pre-chlorination) was taken from the final settling lagoon directly adjacent to the outlet to the outflow structure. A submersible pump was suspended from a raft anchored to the berm and controlled by a timer assembly. Approximate 1.1 l samples were taken every 10 minutes.

3) The chlorinated effluent sample was taken from the outflow structure adjacent to the overflow weir. Approximate 1.1 l samples were taken every 10 minutes using a submersible pump and a timer assembly.

The composite sample aliquots were collected in 45 gal. polyethylene barrels. The composite sampling program commenced at 0800 hr August 10 and ended at 0800 hr August 12.

Grab samples of the influent and final chlorinated effluent were collected every two hours on August 11 from 0600 hr to 1800 hr. The contents of each lagoon were grab sampled on August 10 using a small boat.

## 2.3 Analyses

Table 1 lists the analytical parameters for the 24 hour composite sampling program. Table 2 lists the analytical parameters for the grab sampling program.

The contents of the composite sample barrels were blended prior to sample division. The samples for chemical analysis including metals were divided into sample bottles and preserved as outlined in the Environment Canada Pollution Sampling Handbook. Samples for bioassay analysis were placed in 4 - 5 gallon jerry cans. All samples were delivered within 6 hours to the respective Environment Canada laboratory facility. Sample analysis for all parameters except metals commenced within 7 hours of collection.

Grab samples collected on August 4 (Clinton) and August 11 (Williams Lake) were separated into the proper container, preserved as required and stored at $4^{\circ}C$ before being shipped the following day with the 24 hour composite samples.

TABLE 1 ANALYTICAL PARAMETERS - 24 HOUR COMPOSITE 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 |
| Total Alkalinity | - | mg/l $CaCO_3$ |
| 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 |
| Aluminum, Total & Dissolved | Al | mg/l |
| Cadmium, Total & Dissolved | Cd | mg/l |
| Manganese, Total & Dissolved | Mn | mg/l |
| Chromium, Total & Dissolved | Cr | mg/l |

TABLE 2 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 |

2.3.1 Chemical Analyses

The chemical parameters, including metals as listed in Tables 1 and 2, were analyzed as described in the Environment Canada Pacific Region Laboratory Manual.

2.3.2 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 involved acetone- hexane extraction, filtration, purification and electron capture GLC analysis. The detection limit for a one gallon sample is approximately 0.005 ppb.

2.3.3 Bioassay Determination (96 hr $LC_{50}$). The static fish bioassay test gives an approximate numerical value to the biological toxicity of 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 $15.0 \pm 1.0^{o}$ 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 continuously, 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 0.5 g/l. The percent mortality and percent dilution were plotted on semi log paper to establish an $LC_{50}$ value.

2.4 Chlorine Residual Monitoring (Williams Lake)

The chlorine residual monitoring program consisted of grab sampling the chlorinated final effluent (Sample Point No.3) every hour for 24 hours from 0600 hr August 11 to 0600 hr August 12 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 (phenylarsine oxide solution) of known strength, in the presence of potassium iodide.

Total residual chlorine as determined by the amperometric Back Titration method determines the concentration of compounds in the waste-water containing active chlorine (which consist of monochloramines, dichloramines and hypochlorous acid).

# 3. RESULTS

## 3.1 Bioassay Results

The static fish bioassay results obtained from the 24 hour composite samples are included in Table 4 (Page 23). The results are expressed as both a 96 hour $LC_{50}$ as defined earlier and a toxicity concentration Tc. The toxicity concentration, Tc can be expressed in toxic unit, TU, as follows:

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

This value becomes important when considering wastewater that produces less than 50 per cent mortality at the 100% concentration in the bioassay test. The Tc value in this case is determined by plotting the per cent mortality of test fish versus the Tc values for the various test dilutions.

The average Tc values listed in Table 4 represent the average of the Tc values obtained with each bioassay determination and not the Tc which could be calculated using the average $LC_{50}$ value.

## 3.2 Chemical Analyses Results - Clinton

The chemical analyses (non-metal and metal) results from the 24 hr composite sampling program are listed in Appendix I.

A comparison between influent and effluent using these results is illustrated in Figure 3a and b. The values plotted in this comparison represent the mean values from two 24-hour composite samples. The results of the 12 hour raw sewage grab sampling program, for metals and non-metals, are listed in Appendix II.

## 3.3 Chemical Analyses Results - Williams Lake

The chemical analyses non-metal and metal results from the 24 hour composite sampling program are listed in Appendix I. A comparison between influent and effluent using these results is illustrated in Figure 4a and b. The values plotted represent the mean values from two

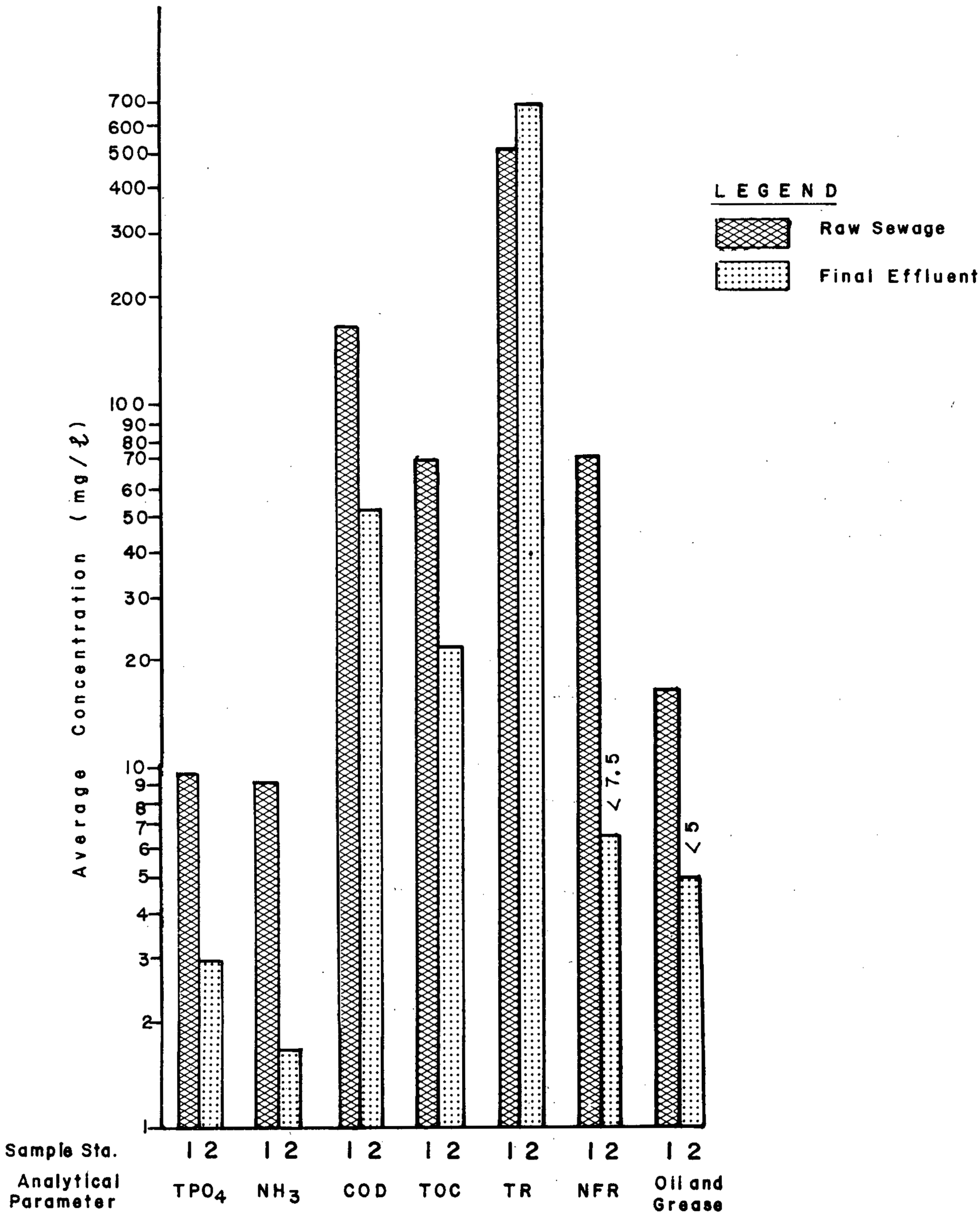



FIGURE 3a COMPARISON OF INFLUENT AND EFFLUENT ANALYTICAL RESULTS - CLINTON LAGOONS

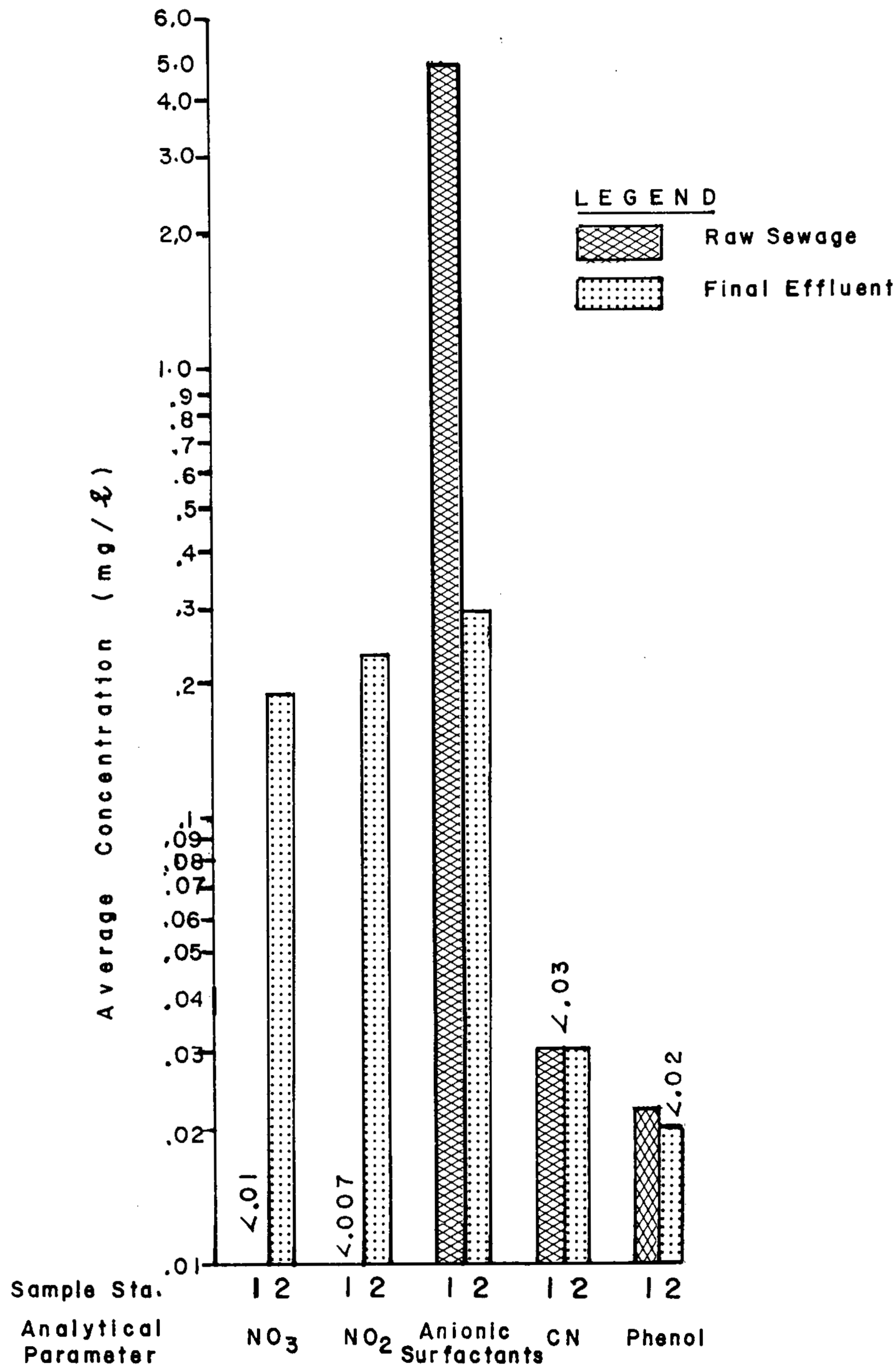



FIGURE 3b COMPARISON OF INFLUENT AND EFFLUENT ANALYTICAL RESULTS - CLINTON LAGOONS

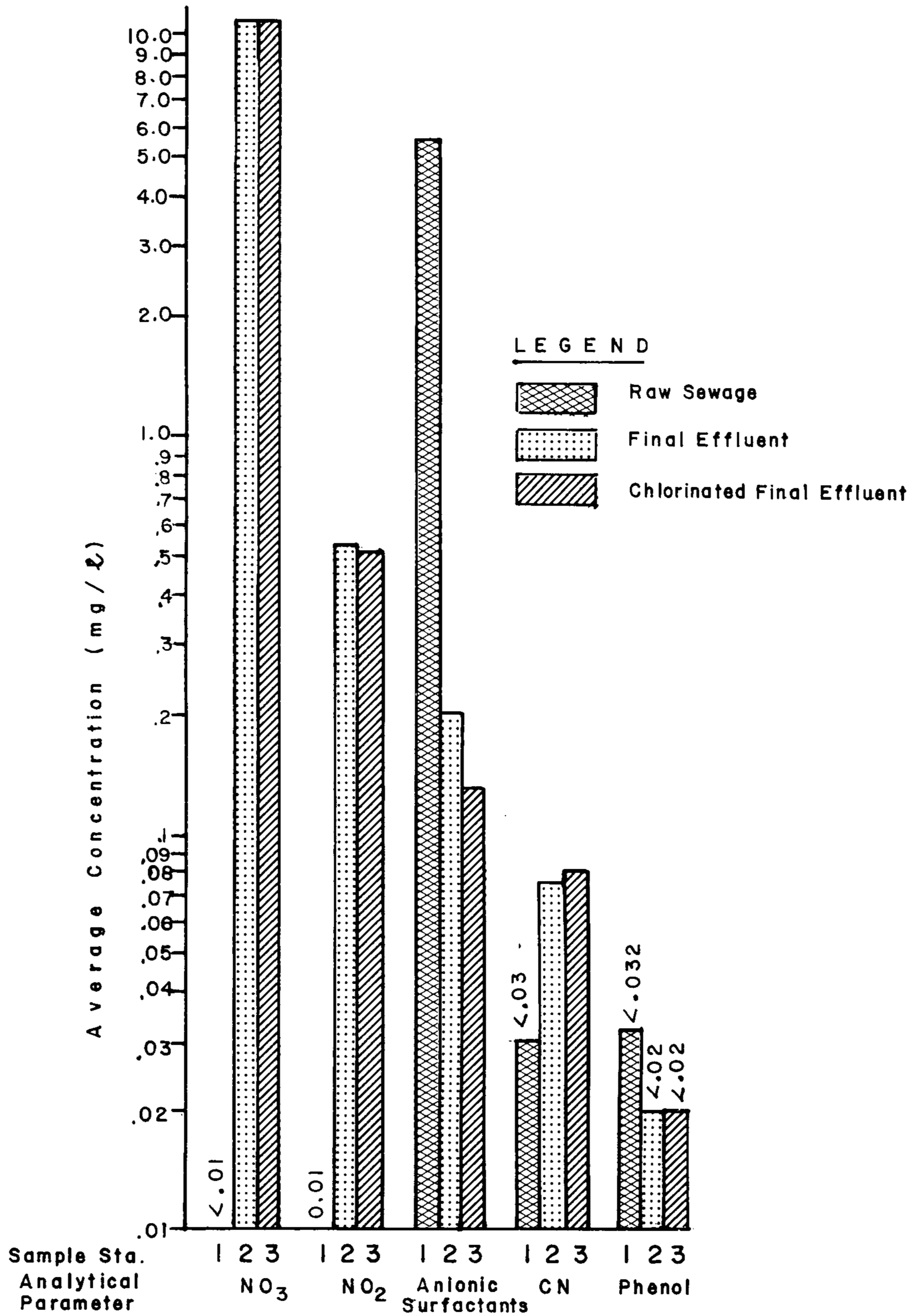



FIGURE 4a COMPARISON OF ANALYTICAL RESULTS - WILLIAMS LAKE LAGOONS

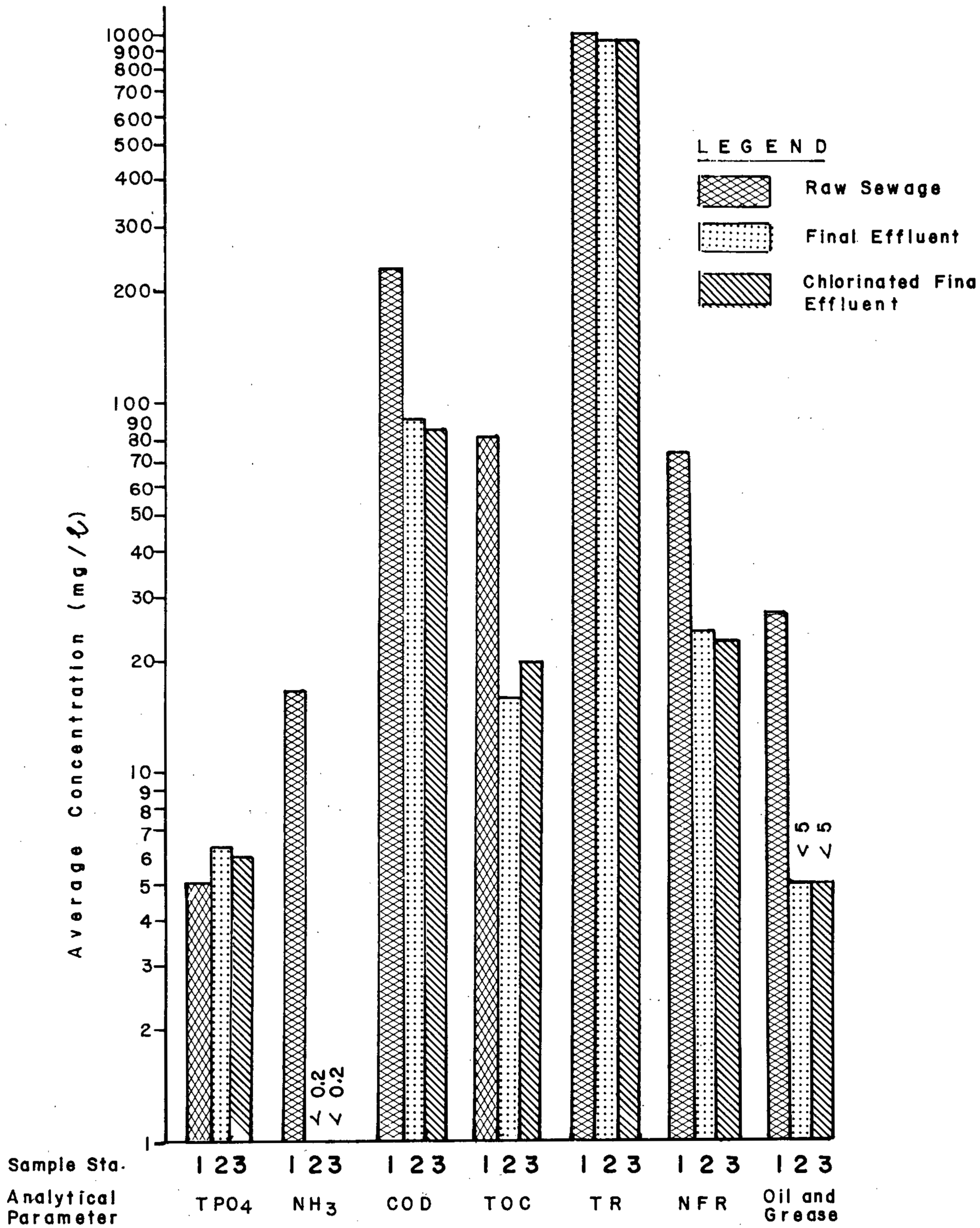



FIGURE 4b COMPARISON OF ANALYTICAL RESULTS - WILLIAMS LAKE LAGOONS

24-hour composite samples. The results of the 12 hour grab sampling program are listed in Appendix II.

3.4 Polychlorinated Biphenyls Results (PCB)

The results of the PCB analyses for the 24-hour composite samples for Clinton and Williams Lake are listed in Appendix I. All levels encountered are significantly low. The Clinton Sewage Treatment Lagoons were responsible for a 52% reduction in PCB levels while the Williams Lake Sewage Treatment Lagoons were responsible for a 89% reduction.

3.5 Lagoon Contents Grab Sampling Results

Clinton. The results of the lagoon contents grab sampling program are listed in Appendix III. The results indicate significant reductions take place in $NH_3$, $TPO_4$ and NFR levels with corresponding increases is $NO_3$, $NO_2$ and DO levels from the primary to the final lagoon.

Williams Lake. The results of the lagoon contents grab sampling program are listed in Appendix III. The results indicate a reduction of $NH_3$ and subsequent conversion to $NO_3$ and $NO_2$ from the anaerobic lagoon to the final settling lagoon.

3.6 Chlorine Residual Monitoring Results - Williams Lake

The results of the 24-hour chlorine residual monitoring program are illustrated in Figure 5. The TRC concentration had a mean of 0.034 mg/l and a range of 0.26 to non-detectable. The TRC was non-detectable for 14 samples out of 25. These chlorine residuals would be insufficient to produce a significant reduction of fecal coliform levels in the effluent. In addition, it can be assumed that the chlorination practiced by the plant would not result in an increase in toxicity (in this case).

3.7 Daily Flowrates, Chlorine Dosages and Precipitation

Daily flowrates and chlorine dosages for Williams Lake for a one year period from August 1, 1975 to July 31, 1976 have been plotted in Appendix IV. In addition total daily precipitation data has been provided. This data would tend to indicate the absence of an infiltration/inflow

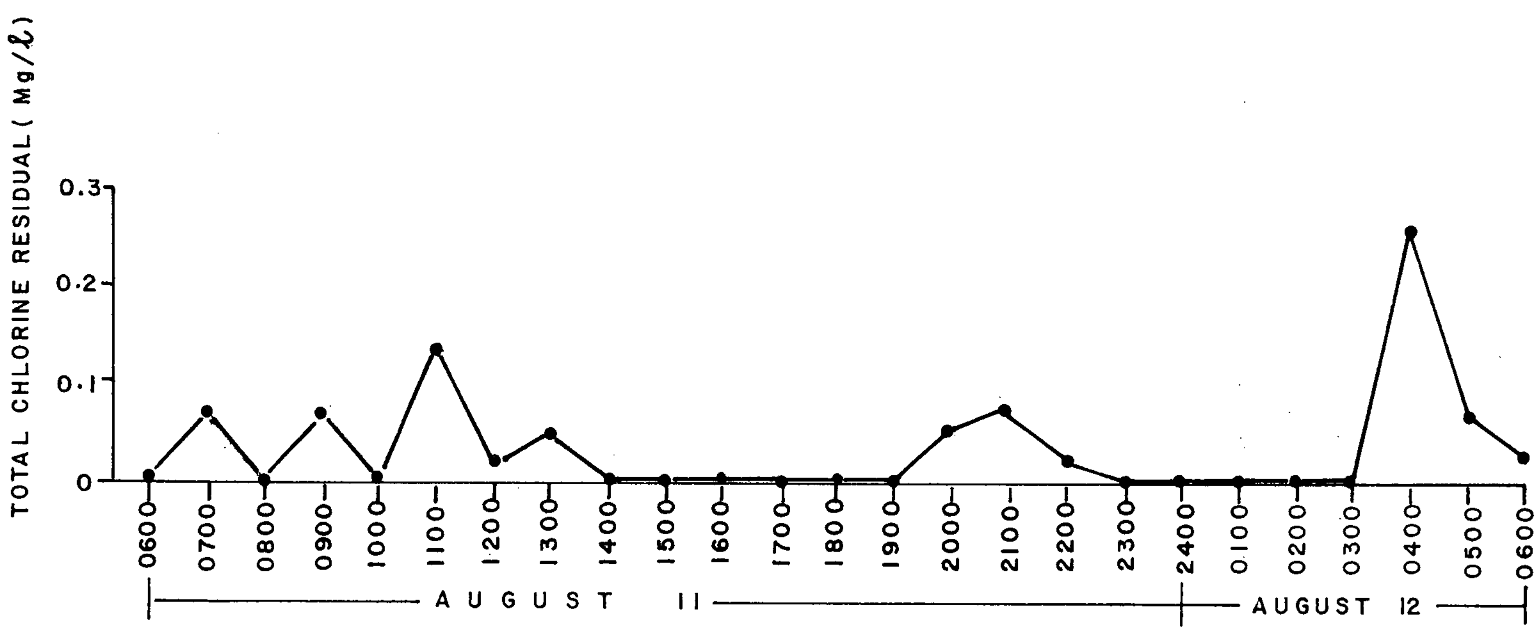



FIGURE 5 24-HOUR CHLORINE RESIDUAL MONITORING PROGRAM - WILLIAMS LAKE LAGOONS - August 11-12, 1976 problem in the sewer system. However, in reference to the months of May and June, 1976, flowrates tended to increase during periods of heavy rainfall and decrease during dry periods.

3.8 Metal Analyses Summary

A summary of metal analyses results from Clinton Sewage Treatment Lagoons and the Williams Lake Sewage Treatment Lagoons is presented in Table 3. Municipal water supply metal analyses have been included to provide background information.

TABLE 3 METAL ANALYSES SUMMARY

| Metal | Clinton | | | Williams Lake | | |
|---|---|---|---|---|---|---|
| (Total) | Influent* mg/l | Effluent* mg/l | Water** Supply mg/l | Influent* mg/l | Effluent* mg/l | Water** Supply mg/l |
| Cu | 0.06 | 0.015 | 0.07 | 0.07 | 0.01 | 0.12 |
| Fe | 0.32 | <0.30 | 0.03 | 0.61 | 0.09 | 0.14 |
| Ni | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Pb | <0.02 | <0.02 | <0.02 | 0.02 | <0.02 | <0.02 |
| Zn | 0.10 | 0.10 | 0.07 | 0.18 | 0.06 | 0.09 |
| Al | <0.3 | <0.3 | <0.3 | 0.4 | <0.3 | <0.3 |
| Cd | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Mn | 0.08 | 0.03 | <0.03 | 0.15 | <0.03 | 0.15 |
| Cr | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 |
| Hg*** | <0.20 | <0.20 | <0.20 | 0.20 | <0.20 | 0.25 |

*Average of two 24-hour composite samples

**Results from one grab sample

***µg/l

# 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 affect 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 4. 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 in Salmo gairdneri in 96 hours.

The raw sewage samples from both the Clinton and Williams Lake Sewage Lagoons exhibited un-ionized $NH_3$ levels that could be expected to exert some toxicity. However, the levels encountered in the final effluent samples are near the threshold level and as indicated did not exert a toxic effect. Esvelt, Kaufman and Selleck (6) point out that factors in addition to un-ionized ammonia, in this case high alkalinity, may tend to modify ammonia toxicity.

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 4 would be expected to contribute significantly to wastewater toxicity. In addition, the surfactant toxicity in both cases would tend to increase with the alkalinity of the wastewater (assuming a relationship between hardness and alkalinity).

TABLE 4

COMPARISON OF ANALYTICAL AND BIOASSAY RESULTS

| | Sample Points | Date | $LC_{50}$ | $T_c$ | $NH_3$ | [1]Un-Ionized $NH_3$ | Anionic Surfactants | Total Alkalinity | pH | Pre-test Aeration |
|---|---|---|---|---|---|---|---|---|---|---|
| | | August | % | TU | mg/l N | mg/l N | mg/l LAS | mg/l $CaCO_3$ | | hr. |
| Clinton Sewage Treatment Lagoons | Raw Sewage | 4 | 60.5 | 1.65 | 9.7 | 0.13 | 3.5 | 330 | 7.7 | 18 |
| | | 5 | 36.0 | 2.78 | 8.5 | 0.12 | 6.4 | 326 | 7.7 | 21.5 |
| | Final Effluent | 4 | [2]NT | - | 1.5 | 0.05 | 0.42 | 510 | 8.1 | 18 |
| | | 5 | NT | - | 1.8 | 0.07 | 0.16 | 514 | 8.2 | 21.5 |
| Williams Lake Sewage Treatment Lagoons | Raw Sewage | 10 | 48 | 2.08 | 14.0 | 0.22 | 4.6 | 500 | 7.9 | - |
| | | 11 | 49 | 2.04 | 19.0 | 0.15 | 6.4 | 500 | 7.6 | - |
| | Final Effluent | 10 | NT | - | 0.12 | 0.007 | 0.10 | 390 | 8.5 | - |
| | | 11 | NT | - | 0.20 | 0.008 | 0.30 | 400 | 8.3 | - |
| | Chlorinated Final Effluent | 10 | NT | - | 0.12 | 0.007 | 0.11 | 390 | 8.5 | - |
| | | 11 | NT | - | 0.17 | 0.007 | 0.15 | 390 | 8.3 | - |

[1] According to Emmerson et al (2)

[2] NT Non toxic (no mortalities at 100% concentration)

## 4.2 Bioassay Summary

4.2.1 Clinton Bioassay Summary. The raw sewage exhibited 96 hr $LC_{50}$ values of 60.5 and 36.0% (Tc = 1.65 and 2.78). Most of this toxicity would be attributable to the anionic surfactant concentration. The un-ionized ammonia content would also be expected to exert some toxicity.

The final effluent was non-toxic at the 100% concentration for both 24 hour composite samples indicating that treatment is responsible for the removal of the raw sewage toxicity.

4.2.2 Williams Lake Bioassay. The raw sewage exhibited 96 hr $LC_{50}$ values of 48 and 49% (Tc = 2.08 and 2.04). This toxicity would be attributable to the un-ionized ammonia and surfactant concentrations, with surfactant toxicity being influenced by the alkalinity of the wastewater.

The final effluent was non-toxic at the 100% concentration for both 24 hour composite samples, indicating that treatment is responsible for the removal of the toxicity associated with the raw sewage samples.

The chlorinated final effluent was also non-toxic at the 100% concentration for both 24 hour composite samples. However, as pointed out in Section 3.6, the TRC was maintained at either a very low or non-detectable level during the chlorine residual monitoring program. Chlorination, in this case, would not be expected to influence toxicity.

# REFERENCES


1. Statistics Canada, Personal Correpsondence.

2. Emmerson, K., Russo, R.C., Lund, R.E., Thurston, R.V. "Aqueous Ammonia Equilibrium Calculations: Effects of pH and Temperature", J. Fish Res. Board Can. 32, (1975).

3. Mayo, R.D., Liao, P.B., and Williams, W.G., "A Study for Development of Fish Hatchery Water Treatment Systems", U.S. Bureau of Sport Fisheries and Wildlife, Seattle, (1972).

4. Notes on Water Pollution No.63, Department of the Environment, U.K., H.M.S.O., (1973).

5. Lloyd, R. and L.D. Orr, "The Diuretic Response by Rainbow Trout to Sublethal Concentrations of $NH_3$", Water Research 3(5), (1969).

6. Esvelt, L.A., W.J. Kaufman and R.E. Selleck, "Toxicity Removal from Municipal Wastewater", SERL Rept. No. 71-7 San. Eng. Res. Lab., Univ. of California, Berkely, (1971).

7. Water Quality Criteria. A report of the Committee on Water Quality Criteria, Environmental Protection Agency, Washington, D.C., 1972.

8. Thatcher, T.O. and J.F. Santner, "Acute Toxicity of LAS to Various Fish Species", Purdue Univ. Eng. Bull. Ext. Ser. 121, (1966).

9. Dolan, J.M. and A.C. Hendricks, "The Lethality of an Intact & Degraded LAS Mixture to Bluegill Sunfish & a Snail", J. Water Pollut. Contr. Fed. 48(11), (1976).

## ACKNOWLEDGEMENTS

The author wishes to acknowledge the assistance of the following:

G. Trasolini, Technical Officer, Surveillance Unit, Technical Services, Environmental Protection Service for planning and directing the study.

G. Thompson, Project Technologist, Surveillance Unit, Technical Services, Environmental Protection Service, for co-ordinating the field activities and for collecting and organizing data for this report.

The Chemistry and Bioassay Laboratory Services staff, Environmental Protection Service, for conducting analyses.

The Analytical Services of the Environmental Management Service for carrying out the polychlorinated biphenyls analyses.

T. Newton, Sewage Treatment Lagoon Operator, Village of Clinton for assistance in carrying out the survey and providing operating information.

H. Wilkinson, Sewage Treatment Lagoon Operator, Town of Williams Lake for assistance in carrying out the survey and for providing operating information.

P. J. Shand, Stanley Associates Engineering Ltd., for providing design drawings and operating data for both Clinton and Williams Lake lagoons.

# APPENDIX I

## COMPOSITE SAMPLING PROGRAM

## ANALYTICAL RESULTS

APPENDIX I

## CLINTON SEWAGE TREATMENT LAGOONS
## COMPOSITE SAMPLE ANALYTICAL RESULTS - NON-METALS

| Sampling Point | Number |
|---|---|
| Raw Sewage | 1 |
| Final Effluent | 2 |

| Analytical Parameter | Sampling Point | Date: August 4 | Date: August 5 |
|---|---|---|---|
| $TPO_4$ mg/l | 1 | 3.5 | 16 |
| | 2 | 2.4 | 3.5 |
| $NH_3$ mg/l N | 1 | 9.7 | 8.5 |
| | 2 | 1.5 | 1.8 |
| $NO_3$ mg/l N | 1 | <0.01 | <0.01 |
| | 2 | 0.27 | 0.11 |
| $NO_2$ mg/l N | 1 | <0.005 | 0.008 |
| | 2 | 0.16 | 0.30 |
| Alkalinity mg/l $CaCO_3$ | 1 | 330 | 325 |
| | 2 | 510 | 514 |
| COD mg/l | 1 | 160 | 170 |
| | 2 | 59 | 45 |
| TOC mg/l | 1 | 87 | 56 |
| | 2 | 26 | 18 |
| pH | 1 | 7.7 | 7.7 |
| | 2 | 8.1 | 8.2 |
| NFR mg/l | 1 | 76 | 69 |
| | 2 | <5 | <10 |
| Anionic Surfactants mg/l LAS | 1 | 3.5 | 6.4 |
| | 2 | 0.42 | 0.16 |
| TR mg/l | 1 | 530 | 500 |
| | 2 | 730 | 650 |
| CN mg/l | 1 | <0.03 | <0.03 |
| | 2 | <0.03 | - |
| Phenol mg/l | 1 | 0.25 | 0.02 |
| | 2 | <0.02 | <0.02 |
| Oil & Grease mg/l | 1 | 16 | 17 |
| | 2 | <5 | <5 |
| PCB ppb | 1 | 0.043 | 0.035 |
| | 2 | 0.018 | 0.019 |

APPENDIX I CLINTON SEWAGE TREATMENT LAGOONS

COMPOSITE SAMPLE ANALYTICAL RESULTS - METALS

| Sampling Point | Number |
|---|---|
| Raw Sewage | 1 |
| Final Effluent | 2 |

| Analytical Parameter | | Units | Sampling Point | Date: August 4 | Date: August 5 |
|---|---|---|---|---|---|
| Hg | Total | µg/l | 1 | <0.2 | <0.2 |
| | | | 2 | <0.2 | <0.2 |
| Cu | Total | mg/l | 1 | 0.05 | 0.06 |
| | | | 2 | <0.01 | 0.02 |
| Cu | Dissolved | mg/l | 1 | 0.01 | 0.02 |
| | | | 2 | <0.01 | 0.01 |
| Fe | Total | mg/l | 1 | 0.27 | 0.37 |
| | | | 2 | 0.48 | 0.12 |
| Fe | Dissolved | mg/l | 1 | 0.04 | 0.09 |
| | | | 2 | 0.08 | 0.04 |
| Ni | Total | mg/l | 1 | <0.05 | <0.05 |
| | | | 2 | <0.05 | <0.05 |
| Ni | Dissolved | mg/l | 1 | <0.05 | <0.05 |
| | | | 2 | <0.05 | <0.05 |
| Pb | Total | mg/l | 1 | <0.02 | <0.02 |
| | | | 2 | <0.02 | <0.02 |
| Pb | Dissolved | mg/l | 1 | <0.02 | <0.02 |
| | | | 2 | <0.02 | <0.02 |
| Zn | Total | mg/l | 1 | 0.10 | 0.10 |
| | | | 2 | 0.19 | 0.03 |
| Zn | Dissolved | mg/l | 1 | <0.01 | 0.10 |
| | | | 2 | 0.06 | 0.03 |
| Al | Total | mg/l | 1 | <0.3 | 0.3 |
| | | | 2 | <0.3 | <0.3 |
| Al | Dissolved | mg/l | 1 | <0.3 | 0.3 |
| | | | 2 | <0.3 | <0.3 |
| Cd | Total | mg/l | 1 | <0.01 | <0.01 |
| | | | 2 | <0.01 | <0.01 |
| Cd | Dissolved | mg/l | 1 | <0.01 | <0.01 |
| | | | 2 | <0.01 | <0.01 |
| Cr | Total | mg/l | 1 | <0.02 | <0.02 |
| | | | 2 | <0.02 | <0.02 |
| Cr | Dissolved | mg/l | 1 | <0.02 | <0.02 |
| | | | 2 | <0.02 | <0.02 |
| Mn | Total | mg/l | 1 | 0.13 | 0.03 |
| | | | 2 | <0.03 | 0.04 |
| Mn | Dissolved | mg/l | 1 | 0.10 | 0.03 |
| | | | 2 | <0.03 | 0.03 |

APPENDIX I WILLIAMS LAKE SEWAGE TREATMENT LAGOONS

COMPOSITE SAMPLE ANALYTICAL RESULTS - NON-METALS

| Sampling Point | Number | |
|---|---|---|
| Raw Sewage | 1 | |
| Final Effluent | 2 | (Pre-chlorination) |
| Chlorinated Final Effluent | 3 | |

| Analytical Parameter | | Sampling Point | Date | |
|---|---|---|---|---|
| | | | August 11 | August 12 |
| $TPO_4$ | mg/l P | 1 | 5.7 | 6.5 |
| | | 2 | 5.6 | 7.0 |
| | | 3 | 5.4 | 6.3 |
| $NH_3$ | mg/l N | 1 | 14.0 | 19.0 |
| | | 2 | 0.12 | 0.20 |
| | | 3 | 0.12 | 0.17 |
| $NO_3$ | mg/l N | 1 | <0.01 | - |
| | | 2 | 11.0 | 11.0 |
| | | 3 | 11.0 | 11.0 |
| $NO_2$ | mg/l N | 1 | 0.01 | 0.01 |
| | | 2 | 0.58 | 0.47 |
| | | 3 | 0.56 | 0.45 |
| Alkalinity | mg/l $CaCO_3$ | 1 | 500 | 500 |
| | | 2 | 390 | 400 |
| | | 3 | 390 | 390 |
| COD | mg/l | 1 | 270 | 200 |
| | | 2 | 86 | 96 |
| | | 3 | 88 | 82 |
| TOC | mg/l | 1 | - | 81 |
| | | 2 | - | 16 |
| | | 3 | - | 20 |
| pH | | 1 | 7.8 | 7.8 |
| | | 2 | 8.6 | 8.6 |
| | | 3 | 8.6 | 8.6 |
| NFR | mg/l | 1 | 95 | 56 |
| | | 2 | 27 | 21 |
| | | 3 | 23 | 22 |
| Anionic Surfactants | mg/l LAS | 1 | 4.6 | 6.4 |
| | | 2 | 0.10 | 0.30 |
| | | 3 | 0.11 | 0.15 |

APPENDIX I (Cont'd.)

WILLIAMS LAKE SEWAGE TREATMENT LAGOONS
COMPOSITE SAMPLE ANALYTICAL RESULTS - NON-METALS

| Sampling Point | Number | |
|---|---|---|
| Raw Sewage | 1 | |
| Final Effluent | 2 | (Pre-chlorination) |
| Chlorinated Final Effluent | 3 | |

| Analytical Parameter | | Sampling Point | Date | |
|---|---|---|---|---|
| | | | August 11 | August 12 |
| TR | mg/l | 1 | 1000 | 1000 |
| | | 2 | 970 | 930 |
| | | 3 | 940 | 940 |
| CN | mg/l | 1 | <0.03 | <0.03 |
| | | 2 | 0.08 | 0.07 |
| | | 3 | 0.08 | 0.08 |
| Phenol | mg/l | 1 | <0.02 | 0.044 |
| | | 2 | <0.02 | <0.02 |
| | | 3 | <0.02 | <0.02 |
| Oil & Grease | mg/l | 1 | 27 | 27 |
| | | 2 | <5 | <5 |
| | | 3 | <5 | <5 |
| PCB | ppb | 1 | 0.059 | 0.044 |
| | | 2 | 0.007 | <0.005 |
| | | 3 | 0.006 | <0.005 |

APPENDIX 1 WILLIAMS LAKE SEWAGE TREATMENT LAGOONS
COMPOSITE SAMPLE ANALYTICAL RESULTS - METALS

| Sampling Point | Number | |
|---|---|---|
| Raw Sewage | 1 | |
| Final Effluent | 2 | (Pre-chlorination) |
| Chlorinated Final Effluent | 3 | |

| Analytical Parameter | | Units | Sampling Point | Date August 11 | Date August 12 |
|---|---|---|---|---|---|
| Hg | Total | µg/l | 1 | 0.20 | <0.20 |
| | | | 2 | <0.20 | <0.20 |
| | | | 3 | <0.20 | <0.20 |
| Cu | Total | mg/l | 1 | 0.08 | 0.06 |
| | | | 2 | 0.02 | 0.04 |
| | | | 3 | 0.01 | 0.01 |
| Cu | Dissolved | mg/l | 1 | 0.02 | 0.02 |
| | | | 2 | 0.02 | 0.03 |
| | | | 3 | 0.02 | 0.02 |
| Fe | Total | mg/l | 1 | 0.74 | 0.48 |
| | | | 2 | 0.09 | 0.14 |
| | | | 3 | 0.11 | 0.06 |
| Fe | Dissolved | mg/l | 1 | 0.10 | 0.09 |
| | | | 2 | 0.04 | <0.03 |
| | | | 3 | 0.05 | 0.08 |
| Ni | Total | mg/l | 1 | <0.05 | <0.05 |
| | | | 2 | <0.05 | <0.05 |
| | | | 3 | <0.05 | <0.05 |
| Ni | Dissolved | mg/l | 1 | <0.05 | <0.05 |
| | | | 2 | <0.05 | <0.05 |
| | | | 3 | <0.05 | <0.05 |
| Pb | Total | mg/l | 1 | 0.02 | 0.02 |
| | | | 2 | <0.02 | <0.02 |
| | | | 3 | <0.02 | <0.02 |
| Pb | Dissolved | mg/l | 1 | <0.02 | <0.02 |
| | | | 2 | <0.02 | <0.02 |
| | | | 3 | <0.02 | <0.02 |
| Zn | Total | mg/l | 1 | 0.19 | 0.16 |
| | | | 2 | 0.04 | 0.10 |
| | | | 3 | 0.07 | 0.04 |
| Zn | Dissolved | mg/l | 1 | 0.23 | + |
| | | | 2 | 0.12 | + |
| | | | 3 | 0.10 | + |

+ - Data Unreliable

APPENDIX 1 (Cont'd.) WILLIAMS LAKE SEWAGE TREATMENT LAGOONS
COMPOSITE SAMPLE ANALYTICAL RESULTS - METALS

| Sampling Point | Number |
|---|---|
| Raw Sewage | 1 |
| Final Effluent | 2 (Pre-chlorination) |
| Chlorinated Final Effluent | 3 |

| Analytical Parameter | | Units | Sampling Point | Date August 11 | Date August 12 |
|---|---|---|---|---|---|
| Al | Total | mg/l | 1 | 0.5 | <0.3 |
| | | | 2 | <0.3 | <0.3 |
| | | | 3 | <0.3 | <0.3 |
| Al | Dissolved | mg/l | 1 | <0.3 | <0.3 |
| | | | 2 | <0.3 | <0.3 |
| | | | 3 | <0.3 | <0.3 |
| Cd | Total | mg/l | 1 | <0.01 | 0.01 |
| | | | 2 | <0.01 | <0.01 |
| | | | 3 | <0.01 | <0.01 |
| Cd | Dissolved | mg/l | 1 | <0.01 | <0.01 |
| | | | 2 | <0.01 | <0.01 |
| | | | 3 | <0.01 | <0.01 |
| Cr | Total | mg/l | 1 | <0.02 | <0.02 |
| | | | 2 | <0.02 | <0.02 |
| | | | 3 | <0.02 | <0.02 |
| Cr | Dissolved | mg/l | 1 | <0.02 | <0.02 |
| | | | 2 | <0.02 | <0.02 |
| | | | 3 | <0.02 | <0.02 |
| Mn | Total | mg/l | 1 | 0.15 | 0.14 |
| | | | 2 | <0.03 | <0.03 |
| | | | 3 | <0.03 | <0.03 |
| Mn | Dissolved | mg/l | 1 | 0.14 | 0.10 |
| | | | 2 | <0.03 | <0.03 |
| | | | 3 | <0.03 | <0.03 |

# APPENDIX II

## 12 HOUR GRAB SAMPLING PROGRAM

## ANALYTICAL RESULTS

APPENDIX II CLINTON SEWAGE TREATMENT LAGOON 12 HOUR GRAB SAMPLING ANALYTICAL RESULTS - RAW SEWAGE

| Analytical Parameter | Units | Time (hr) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 0600 | 0800 | 1000 | 1200 | 1400 | 1600 | 1800 |
| $TPO_4$ | mg/l P | 4.0 | 5.0 | 6.7 | 6.4 | 6.5 | 6.8 | 6.5 |
| $NH_3$ | mg/l N | 5.6 | 7.0 | 18 | 9.8 | 5.0 | 11.0 | 9.8 |
| $NO_3$ | mg/l N | 0.84 | 0.65 | 0.55 | 0.40 | 0.41 | 0.44 | 0.53 |
| $NO_2$ | mg/l N | 0.025 | 0.059 | 0.078 | 0.098 | 0.024 | 0.060 | 0.074 |
| NFR | mg/l | 49 | 36 | 67 | 90 | + | 100 | 88 |
| COD | mg/l | 69 | 130 | 200 | 260 | 190 | 280 | 290 |
| Anionic Surfactants | mg/l LAS | 2.1 | + | 2.0 | 6.25 | 10.8 | 13.3 | 13 |
| TR | mg/l | 530 | 450 | 490 | 540 | 490 | 660 | 650 |
| TOC | mg/l C | 30 | 70 | 49 | 70 | 68 | 108 | 86 |

+ - Data unreliable

APPENDIX II WILLIAMS LAKE SEWAGE TREATMENT LAGOONS
GRAB SAMPLING ANALYTICAL RESULTS, AUGUST 11, 1976

| Sampling Point | Number |
|---|---|
| Raw Sewage | 1 |
| Final Chlorinated Effluent | 3 |

| Analytical Parameter | Sampling Point | Time (hr) 0600 | 0800 | 1000 | 1200 | 1400 | 1600 | 1800 |
|---|---|---|---|---|---|---|---|---|
| $TPO_4$ mg/l P | 1 | 1.60 | 3.80 | 9.25 | 10.8 | 11.8 | 10.0 | 8.50 |
| | 3 | 7.50 | 7.00 | 6.75 | 6.50 | 6.50 | 6.75 | 6.75 |
| $NH_3$ mg/l N | 1 | 11.0 | 22.0 | 30.0 | 17.0 | 18.0 | 21.0 | 17.0 |
| | 3 | 0.46 | + | + | + | + | + | + |
| $NO_3$ mg/l N | 1 | + | + | + | + | + | + | + |
| | 3 | 10.0 | 11.0 | 11.0 | 12.0 | 12.0 | 12.0 | 12.0 |
| $NO_2$ mg/l N | 1 | 0.16 | 0.35 | 0.011 | 0.014 | 0.011 | 0.016 | 0.012 |
| | 3 | 0.42 | 0.46 | 0.46 | 0.32 | 0.46 | 0.46 | 0.40 |
| NFR mg/l | 1 | 24 | 53 | 155 | 150 | 120 | 130 | 120 |
| | 3 | 24 | 26 | 35 | 18 | 17 | 10 | 15 |
| COD mg/l | 1 | 96 | 140 | 370 | 410 | 340 | 390 | 330 |
| | 3 | 120 | 96 | 100 | 130 | 92 | 110 | 360 |
| Anionic Surfactants mg/l LAS | 1 | 1.2 | 1.0 | 2.5 | 9.0 | 11.8 | 15.3 | 10.3 |
| | 3 | 0.15 | 0.13 | 0.11 | 0.19 | 0.18 | 0.19 | +1 |
| TR mg/l | 1 | 1200 | 1200 | 1100 | 1200 | 980 | 1200 | 980 |
| | 3 | 910 | 930 | 930 | 800 | 900 | 910 | 940 |
| TOC mg/l C | 1 | 12 | 32 | 96 | 106 | 114 | 104 | 104 |
| | 3 | 18 | 17 | 22 | 17 | 18 | 17 | 16 |

+ Results obtained deemed unreliable due to interference

# APPENDIX III

## LAGOON CONTENTS GRAB SAMPLING RESULTS

APPENDIX III CLINTON SEWAGE TREATMENT LAGOONS

RESULTS OF LAGOON CONTENTS GRAB SAMPLING

| | Date | TR mg/l | NFR mg/l | pH | $TPO_4$ mg/l P | $NH_3$ mg/l N | $NO_3$ mg/l N | $NO_2$ mg/l N | DO mg/l $O_2$ |
|---|---|---|---|---|---|---|---|---|---|
| Primary Lagoon | Aug.4 | 520 | 110 | 7.1 | 6.6 | 5.0 | <.01 | .011 | 0.0 |
| (Anaerobic) | Aug.5 | 490 | 79 | | 4.3 | 5.4 | <.01 | .020 | |
| Seconday Lagoon | Aug.4 | 460 | 35 | 7.4 | 3.4 | 2.2 | .033 | .067 | 3.4 |
| (Facultative) | Aug.5 | 510 | 29 | | 3.5 | 1.6 | .023 | .066 | |
| Final Lagoon | Aug.4 | 560 | - | 6.8 | 4.2 | 0.7 | .41 | .49 | 9.4 |
| (Aerobic) | Aug.5 | 740 | <10 | | 2.5 | 0.8 | .25 | .65 | |

APPENDIX III

WILLIAMS LAKE SEWAGE TREATMENT LAGOONS
RESULTS OF LAGOON CONTENTS GRAB SAMPLING
AUGUST 11, 1976

| | TR mg/l | TVR mg/l | NFR mg/l | $NH_3$ mg/l N | $NO_3$ mg/l N | $NO_2$ mg/l N | $TPO_4$ mg/l P |
|---|---|---|---|---|---|---|---|
| Primary Lagoon (Anaerobic) | 996 | 360 | 42 | 17 | <.01 | .024 | 8.5 |
| Secondary Lagoon (Aerated) | 966 | 320 | 29 | 0.07 | 13 | 0.76 | 8.6 |
| Final Lagoon (Settling) | 940 | 310 | 40* | 0.33 | 9.3 | 0.72 | 10.0 |

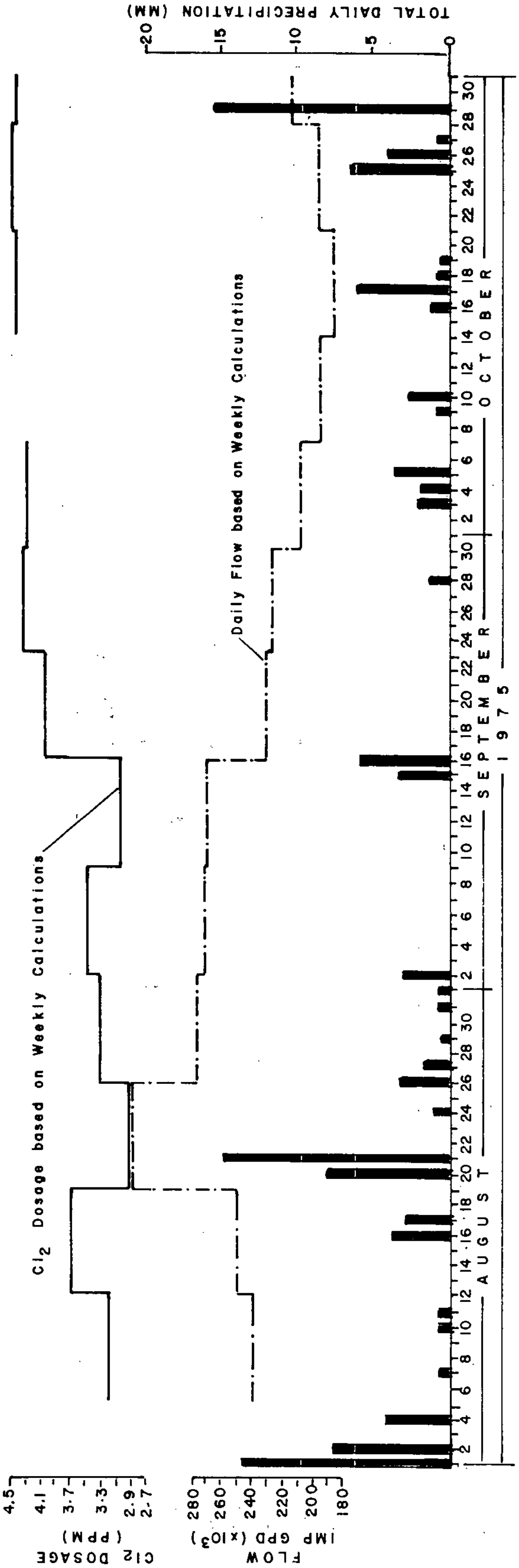
*High algal concentration

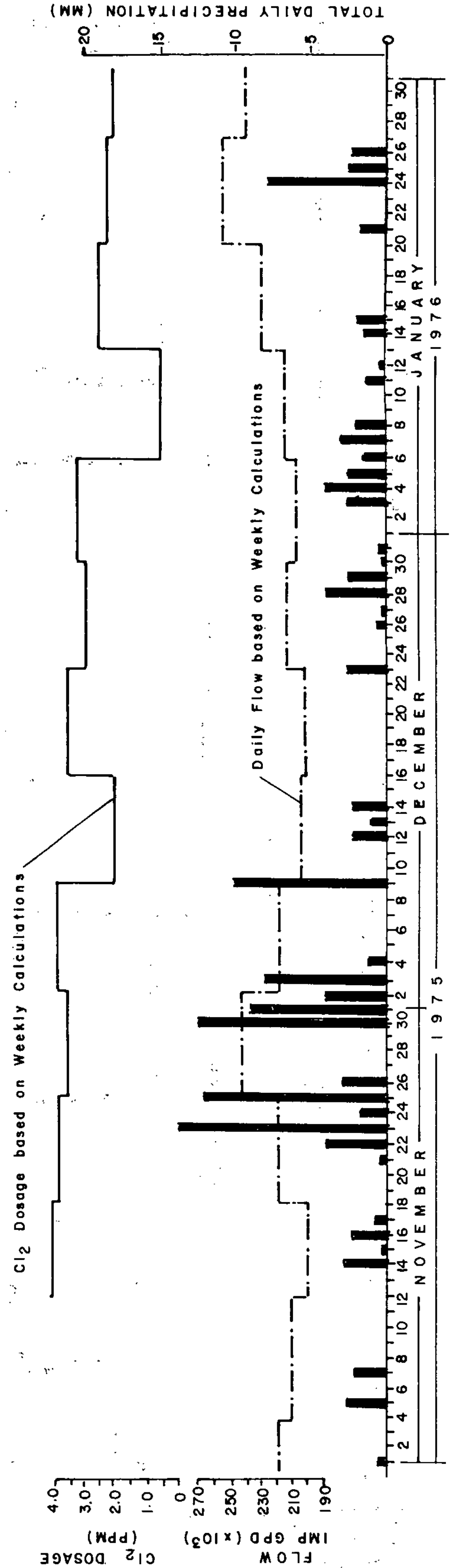
# APPENDIX IV

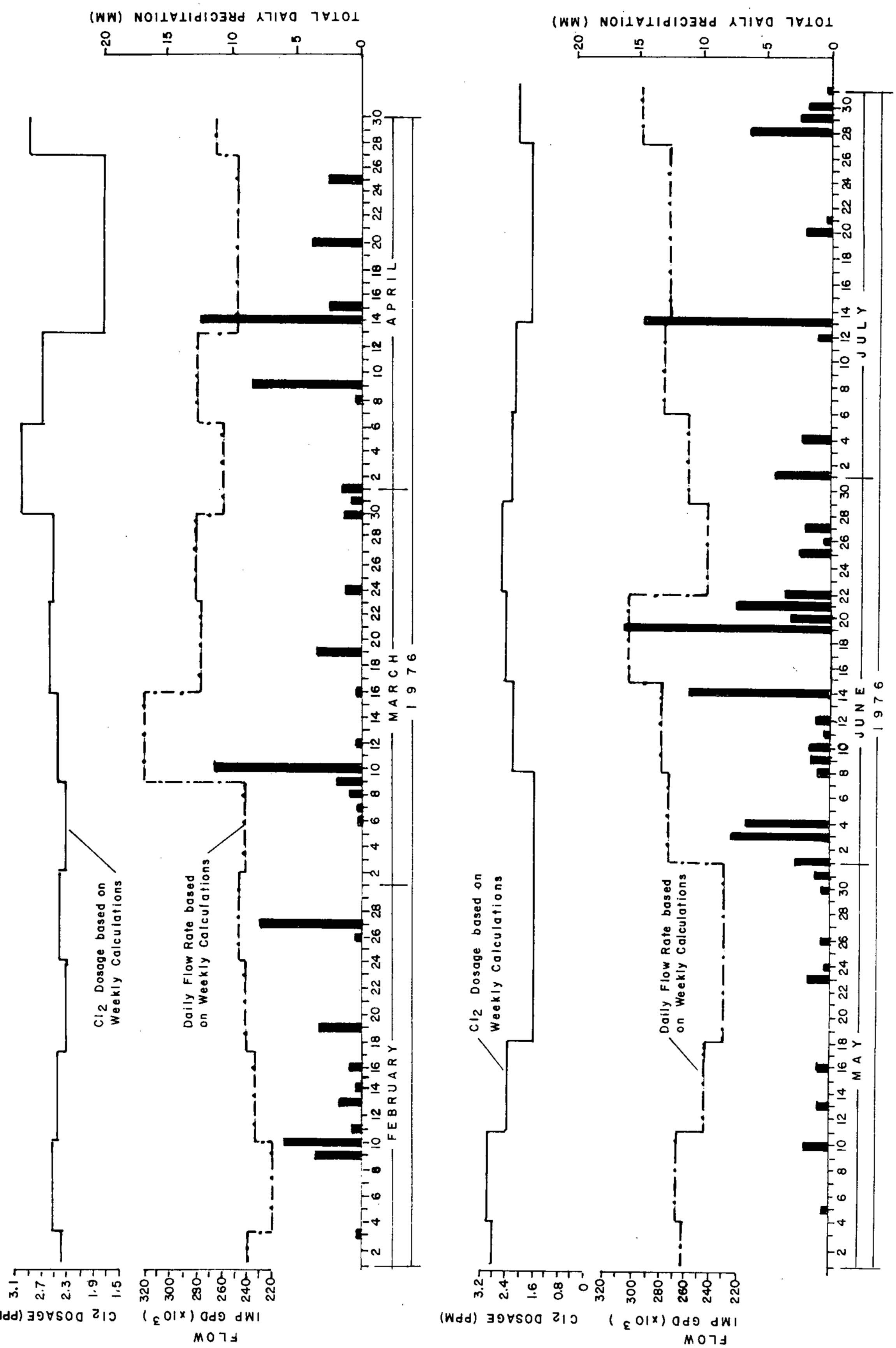
## WILLIAMS LAKE SEWAGE TREATMENT LAGOONS

## DAILY FLOWS, CHLORINE DOSAGES AND PRECIPITATION

August 1, 1975 to July 31, 1976


TOTAL DAILY PRECIPITATION (MM)
Daily Flow based on Weekly Calculations
Cl2 Dosage based on Weekly Calculations
A U G U S T
S E P T E M B E R
O C T O B E R
1 9 7 5
FLOW
IMP GPD (x10³)
Cl2 DOSAGE
(PPM)


TOTAL DAILY PRECIPITATION (MM)
Daily Flow based on Weekly Calculations
Cl2 Dosage based on Weekly Calculations
N O V E M B E R
D E C E M B E R
1 9 7 5
J A N U A R Y
1 9 7 6
FLOW
IMP GPD (x10³)
Cl2 DOSAGE
(PPM)


TOTAL DAILY PRECIPITATION (MM)
Cl2 Dosage based on Weekly Calculations
Daily Flow Rate based on Weekly Calculations
FEBRUARY
MARCH
APRIL
1976
Cl2 DOSAGE (PPM)
FLOW
IMP GPD (x10³)
TOTAL DAILY PRECIPITATION (MM)
Cl2 Dosage based on Weekly Calculations
Daily Flow Rate based on Weekly Calculations
MAY
JUNE
JULY
1976
Cl2 DOSAGE (PPM)
FLOW
IMP GPD (x10³)