ENVIRONMENTAL PROTECTION BRANCH
ENVIRONMENTAL PROTECTION SERVICE
PACIFIC REGION

A PERFORMANCE EVALUATION OF THE VILLAGE OF LAKE COWICHAN SEWAGE TREATMENT LAGOONS

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ABSTRACT

An evaluation of the Village of Lake Cowichan sewage treatment lagoon system was conducted by personnel of the Environmental Protection Branch, Environmental Protection Service (Pacific Region) from February 20 to 24, 1978. Sampling for bacteriological, chemical, and toxicity analyses, as well as a dye study of the dechlorination basin were conducted.

Chemical and bacteriological analyses results indicated that the lagoon treatment system performed well, producing an effluent of typical quality for this type of system.

Results of a 48 hour total residual chlorine (TRC) survey revealed high chlorinated and dechlorinated effluent TRC concentrations. A dye test indicated that the dechlorination basin functioned as designed.

Although bioassay results indicated that a non-toxic final dechlorinated effluent was produced by the treatment system, certain chemical agents were present at concentrations reported to be toxic to fish.

RÉSUMÉ

Du 20 au 24 février 1978, la Direction de la protection de l'environnement (région du Pacifique) du Service du méme nom a étudié la système de bassins de l'usine d'épuration du village de lake Cowichan. Elle a prélevé des échantillons pour effectuer des analyses bactériologiques, chimiques et toxicologiques de méme qu'une étude à la teinture du bassin de déchloration.

Le résultat des analyses chimiques et bacteriologiques indiquait que le système de bassins d'épuration fonctionnait bein et que l'effluent qui en sortait était d'une qualité normale pour ce type de traitement.

Une épreuve de 48 heures de chlore résiduel total (CRT) en a révéle de fortes concentrations dans l'effluent tant chloré que déchloré. L'épreuve à la teinture a montré que le bassin de déchloration fonctionnait selon les normes prévues.

Le résultat des essais biologiques indiquait que le système d'épuration produisait un effluent de sortie déchloré, non toxique. Cependant, on a noté la présence de certains agents chimiques atteignant des concentrations susceptibles d'avoir un effet toxique sur le poisson.

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LIST OF ABBREVIATIONS

BOD_5	5 day biochemical oxygen demand
COD	chemical oxygen demand
DO	dissolved oxygen
EPS	Environmental Protection Service
FMS	Fisheries and Marine Service
FR	filterable residue
kg	kilograms
m^3/day	cubic meters per day
MF	membrane filtration
ml	milliliters
mg/l	milligrams per liter
NFR	non-filterable residue
PCB	Pollution Control Branch
ppb	parts per billion
ppm	parts per million
TAlk	total alkalinity
TFR	total fixed residue
TOC	total organic carbon
TPO_4	total phosphate
TR	total residue
TRC	total residual chlorine
TVR	total volatile residue
USGPD	US gallons per day

CONCLUSIONS AND OBSERVATIONS

1. In terms of fecal coliform indicator organism reduction, the Village of Lake Cowichan's aerated lagoon sewage treatment system performed effectively. The sewage aeration lagoons effected a three log reduction in fecal coliforms, while chlorination was responsible for a further three log reduction.

2. Chemical analyses results indicated that the lagoons produced a typical quality effluent for this type of system. Reduction efficiencies for BOD_5, TOC, and NFR were greater than 92, 98, and 88% respectively.

3. The 48 hour total residual chlorine survey and dechlorination basin dye test showed that:
   a) The chlorine demand of the lagoon treated effluent is low (about 0.4 mg/l) and the present chlorine dosage rate of 0.9 kg/day (2 lb/day) could be reduced, possibly to 0.23 kg/day (0.5 lb/day), and still meet Pollution Control Branch (PCB) permit requirements.
   b) If the chlorinated effluent TRC concentration was reduced to 0.1 mg/l, and assuming the dechlorination system operated with the 51% reduction efficiency noted during this study, then the final dechlorinated effluent TRC concentration would meet the PCB permit requirement of 0.05 mg/l.
   c) Conversion of the complete mix dechlorination system to a plug flow configuration using curtains or baffles would improve the TRC reduction efficiency. However, it is doubtful if this system could reduce the chlorinated TRC levels noted during this survey to the desired dechlorinated level.
   d) The discrepancy between the TRC data gathered by EPS personnel during this survey using the more accurate

amperometric technique, and daily results obtained by the Village of Lake Cowichan operator using the Orthotolidine method, suggests that the latter method is not providing accurate results (for this sampling interval).

4. Final dechlorinated effluent bioassay results indicated a non-toxic effluent. Yet, final effluent TRC and un-ionized NH_3 concentrations were at levels that have been reported to be toxic to fish.

5. If there was no chlorination of the lagoon treated effluent, then, the Cowichan River low flow since 1958 of 4.42 m^3/sec would provide sufficient dilution to produce a 6 fecal coliforms/100 ml count in the River. Whether or not chlorination is necessary would depend upon the downstream water uses.

1 INTRODUCTION

The Village of Lake Cowichan is situated about 27 km west of the City of Duncan on the shore of Cowichan Lake. Forestry is the principle industry in the area and directly or indirectly provides employment for most of the residents.

Prior to 1975, sewage from about 100 homes in the Village of Lake Cowichan was collected in a large septic tank and discharged to Cowichan Lake. In 1975, an aerated lagoon sewage treatment system was constructed and treated sewage is now discharged to the Cowichan River. The characteristics of the lagoon system are summarized in Table 1 and Figure 1.

Sewage is collected within the Village and pumped from a pump station located at the foot of Pine Street to the sewage lagoons. The sewage is subjected to serial aeration through basins No. 1 and No. 2, chlorinated, and dechlorinated prior to discharge.

The Cowichan River supports a valuable commercial and sports fishery. As such, any deleterious effects of sewage discharged to the River is of concern.

The function of the Lake Cowichan dechlorination basin is to reduce the chlorinated effluent total residual chlorine concentration. Martens and Servizi (1) have observed that the toxicity of primary treated sewage to sockeye salmon was significantly increased 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-situ bioassay techniques.

An evaluation of the performance of the Lake Cowichan dechlorination basin was conducted by personnel from the Environmental Protection Service from October 18 to 20, 1976 (3). Samples were

TABLE 1 DESIGN CHARACTERISTICS OF THE VILLAGE OF LAKE COWICHAN SEWAGE TREATMENT SYSTEM (2)

Equivalent Contributing Population	2600
Average Daily Sewage Flow (m^3/day)	980 (260 000 USGPD)
Minimum Daily Sewage Flow (m^3/day)	450 (120 000 USGPD)
Maximum Daily Sewage Flow (m^3/day)	7400 (1.95 MUSGPD)
Aerated Basin No. 1	
Water Surface Area (m^2)	2630 (0.65 acres)
Water Depth (m)	3.1 (10 ft)
Detention Time at Average Flows	7.7 days
Total Aerator Power (Watts)	9700 (13 H.P.)
Aerated Basin No. 2	
Water Surface Area (m^2)	7490 (1.85 acres)
Water Depth (m)	3.1 (10 ft)
Detention Time at Average Flows	23 days
Total Aerator Power (Watts)	9700 (13 H.P.)
Chlorination	
No. of Chlorinators	1
Chlorine Feed Rate at 10 ppm (kg/day)	9.8 (21.6 lb/day)
Chlorine Contact Tank Detention Time	1.53 hours
Dechlorination Basin	
Water Surface Area (m^2)	1820 (0.45 acres)
Water Depths (m)	1.2 (4 ft)
Detention Time at Average Flows	1.53 days

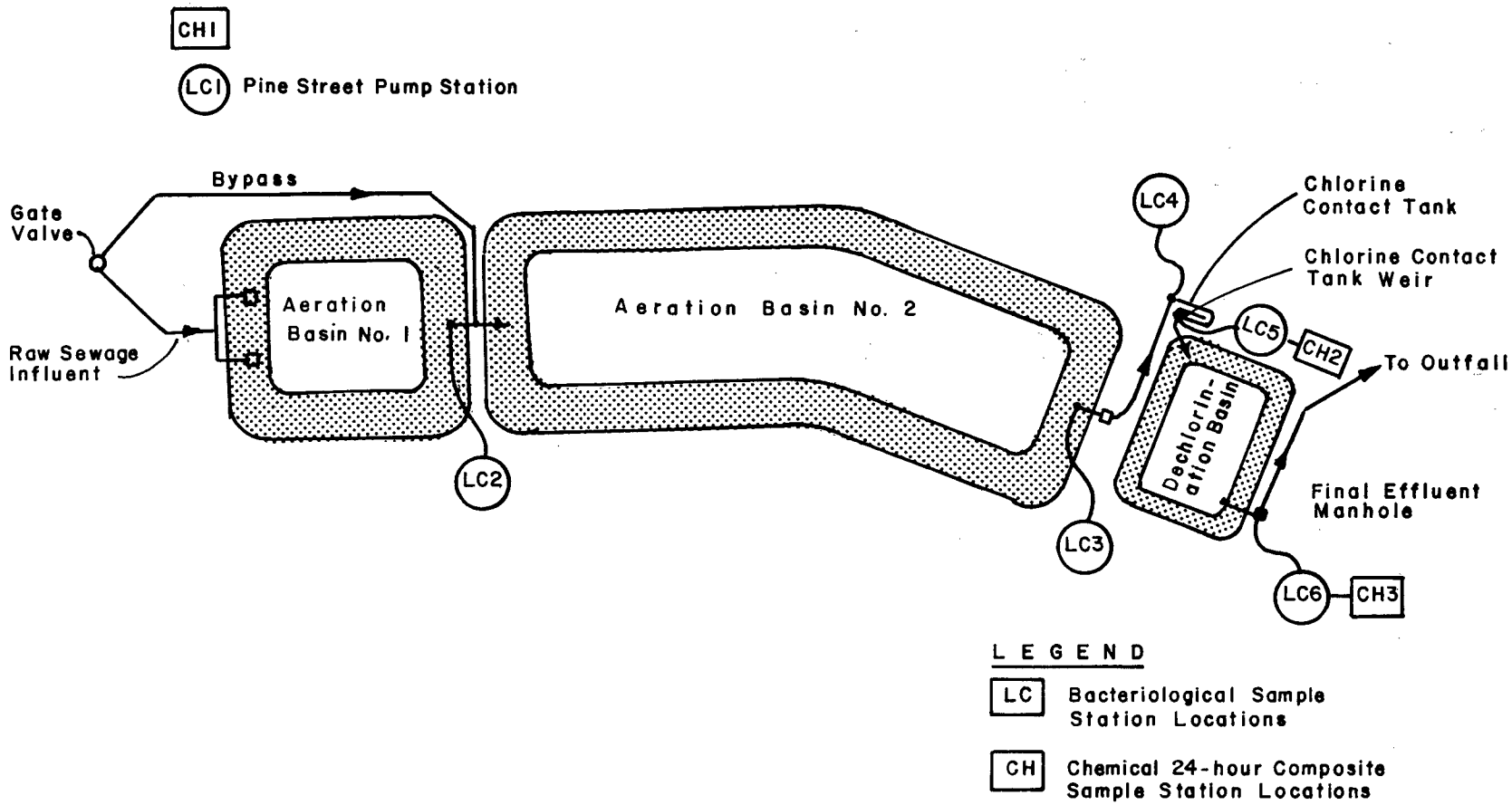

FIGURE I VILLAGE OF LAKE COWICHAN SEWAGE TREATMENT SYSTEM BACTERIOLOGICAL AND CHEMICAL SAMPLE STATION LOCATIONS

collected hourly for a 48 hour period at the chlorine contact tank weir and the point of discharge from the dechlorination lagoon. These samples were analysed for total residual chlorine using the amperometric titration method. The results of that study showed that the arithmetic mean total residual chlorine concentration was reduced by approximately 90% (3.91 to 0.39 mg/l) by the dechlorination lagoon. However, two major changes in the chlorine addition rate (by the treatment system operator), and a lack of specific information on the residence time in the dechlorination cell, made it difficult to accurately determine the residual chlorine percentage reduction. The residual chlorine concentration of all final effluent samples was found to be greater than 0.02 mg/l. Due the to fluctuating chlorine addition rate noted and the knowledge of an impending proposed increase in sewage to the collection system, it was recommended that a further study be made.

This follow-up study of the Lake Cowichan treatment system, as well as the receiving waters of the Cowichan River, was conducted from September 6-8, 1977 (4). Bacteriological, toxicity, and TRC analyses were performed on samples collected from the treatment system. Unfortunately, accurate TRC results were not obtained due to malfunction in the amperometric titrator. Bacteriological analyses results indicated that the two aeration basins were responsible for almost a four log reduction in fecal coliform concentrations, and chlorination did not effect a further reduction. All samples collected for bioassay purposes were non-toxic.

Results of bacteriological and chemical analyses of samples collected from the Cowichan River during the survey did not indicate that the lagoon discharge degraded river water quality. The sampling was conducted during relatively dry weather. In wet weather, increased flows through the lagoon system due to inflow and infiltration into the collection system, could result in reduced bacteriological and chemical quality of the effluent.

A bacteriological, bioassay and chemical sampling program of the Lake Cowichan sewage treatment system was conducted from February 20-24, 1978. The purpose of this program was:

1) To determine the reduction in fecal coliform indicator bacteria effected by the Lake Cowichan aerated lagoons in order to assess the need for chlorination of the sewage treatment plant effluent, and to compare the results to the September 1977 study.
2) To determine the reduction in TRC effected by the dechlorination lagoon in order to assess its performance under normal operating conditions.
3) To determine the flow characteristics and mean retention time of the dechlorination lagoon in order to compare design parameters to actual operating conditions.
4) To evaluate the overall performance of the treatment system. Data gathered during a limited study of the City of Duncan and Municipality of North Cowichan sewage treatment lagoons is also presented in this report for comparison purposes. Both these systems, and the Lake Cowichan system, utilize two aerated lagoons in series followed by chlorination. Neither the Duncan nor North Cowichan systems have dechlorination facilities.

The Duncan and North Cowichan treatment systems are located side by side on the Cowichan Indian Reserve No. 1 and discharge treated effluent to the Cowichan River. Presently, a pipe connects the two systems and up to 50% of the sewage which passes through the first aeration lagoon in the Duncan system flows into the North Cowichan first aerated lagoon. A new sewage treatment scheme is in the planning stages and it is intended that the two existing systems will be replaced by one aerated lagoon system.

2 PROCEDURES AND METHODS

2.1 Bacteriological Sampling

Samples for bacteriological analyses were collected in sterile 170 cc widemouth bottles from selected stages of the sewage treatment system and analyzed for fecal coliforms using the Membrane Filtration Technique as described in Part 909 of the 14th edition of Standard Methods for the Examination of Water and Wastewater(5).

Samples were collected three times daily for three days of the raw sewage (LC1), effluent after lagoon No. 1 (LC2), polishing lagoon effluent (LC3), effluent immediately following chlorination (LC4), at the end of the chlorine contact chamber (LC5) and final effluent following dechlorination (LC6) (Figure 1).

Total heterotroph determinations using the pour plate techniques as described in Section 3.2 of Methods of Microbiological Analyses of Waters, Wastewaters and Sediments (6) were performed on stations LC1 and LC6. All samples for bacteriological analysis were analyzed within 30 minutes of collection in the mobile microbiology laboratory located at the site.

2.2 Chemical Sampling

Commencing 0800 February 20 and continuing to 0800 February 22, grab samples were obtained every hour and analyzed for total residual chlorine. Each hour, one chlorinated effluent sample was collected at the chlorine contact tank weir and one final dechlorinated effluent sample from the manhole immediately following the dechlorination basin as shown in Figure 1.

Following collection, samples were immediately analyzed using a Fischer and Porter Co. Amperometric Titrator Model 17T1010. The

procedure used is a Back Titration method which involves 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 this method yields the concentration of compounds in the wastewater containing active chlorine which include monochloramines, dichloramines, and hypochlorous acid.

Commencing 0800 February 20 and continuing to 0800 February 21, approximate 6 l grab samples were obtained hourly of the chlorinated effluent and dechlorinated effluent at the same locations as the TRC samples. Twenty-four hour composite samples were obtained by combining and mixing these hourly grab samples in a plastic lined 45 gallon drum.

A 24 hour raw sewage composite sample was obtained from the Pine Street pump station wet well at the same time. Approximate 250 ml samples were taken every 2.5 minutes using a Markland Model 2101-Spec. Duckbill sampler.

Grab samples for oil and grease analysis were collected of the raw sewage, chlorinated effluent, dechlorinated final effluent every four hours for the 24 hour period.

Composite samples were split into sample bottles and preserved as outlined in the Environment Canada Pollution Sampling Handbook (7). Samples were delivered to the Department of Fisheries and Environment (EPS-FMS) Laboratory in West Vancovuer for chemical analyses within four hours of the completion of the 24 hour sampling period. All chemical parameters were determined at this laboratory with the exception of Kjeldahl Nitrogen (Organic Nitrogen plus NH_3) which was analyzed by the Can Test Limited Laboratory in Vancouver.

2.3 Bioassay Sampling

Five-5 gallon capacity plastic jerry cans were filled with the raw sewage composite sample, and four cans each, with chlorinated effluent and dechlorinated effluent. Sampling locations and methods were as described for the chemical analyses samples. The three samples were transferred to the Environmental Protection Service Aquatic Toxicity Laboratory in North Vancouver within four hours of the completion of the sampling period. A bioassay determination was performed on each sample and a 96 hour LC_{50} value obtained.

The 96 hour LC_{50} is defined as the concentration of measurable lethal agent (in this case wastewater) required to kill the 50th percentile in a group of test organisms over a 96 hour period. In the test, a series of 30 l glass vessels containing different sample dilutions with five rainbow trout (Salmo gairdneri) per test vessel were placed in a controlled environment room with a maintained temperature of 15.0 $\pm$ 1°C. The photo period was limited to 16 hours per 24 hours. Samples with a pH value below 6.0 or above 8.0 are neutralized to a pH of 7; however, pH adjustment was not required for any of the samples collected.

For this survey, a bioassay procedure was used whereby the sample was pre-aerated at 150 to 200 ml/minute with air for two hours if the initial dissolved oxygen level (D.O.) was found to be below 5 ppm; and pre-aerated for 30 minutes if the D.O. was greater than 5 ppm. This procedure was followed in order that D.O. would not be a factor in sample toxicity while air stripping of the sample's chemical constituents would be minimized. All samples had an initial D.O. concentration above 7.0 ppm and were therefore pre-aerated for only 30 minutes.

The bioassays began about eight hours after the completion of the 24 hour sampling period due to the travel time from Lake Cowichan to the Aquatic Toxicity Laboratory in North Vancouver. The amount of sample

detoxification which occurred during this period is not known. Moreover, since in this survey, time constraints necessitated that only one sample at each location could be submitted for bioassay analysis, the results obtained must be viewed as an indication only of the sample toxicity.

2.4 Dye Study

In an attempt to determine the flow characteristics and mean retention time of the Lake Cowichan dechlorination lagoon, about 200 ml of a 20% solution of Rhodamine WT dye was added as a slug at the mid-point of the chlorination contact tank at 0930 February 23rd. Rhodamine WT is the most suitable dye for this purpose since:

a) unlike Fluorescein dye it has a low photo-chemical decay rate and,

b) unlike standard Rhodamine it is not appreciably adsorbed onto soil particles. Since the Lake Cowichan dechlorination basin is soil lined and designed for a 1.5 day detention time, neither standard Rhodamine nor Fluoroscein dye would have been suitable.

Grab samples of dyed effluent entering the dechlorination basin were collected at the chlorine contact tank weir every five minutes from the dye addition time of 0930 till 1020, at 1030, then every 15 minutes from 1030 till 1330, and finally, every 30 minutes from 1330 till 1630. Samples were collected using a bucket on a rope.

Discrete samples of the dechlorinated effluent were collected from the final effluent manhole using a Sigmamoter sequential automatic sampler. Samples were collected every 15 minutes from 1015 till 1630 February 23, and every 30 minutes from 1630 February 23 till 1300 February 24.

The concentration of dye was to be measured using a Turner Model 110 Fluorometer. However, due to high background interference (probably caused by algae), a Nessler tube method was used. Standards of 0.1, 0.2, 0.4, 0.6, 0.8, 1.0, 2.0, 4.0, 6.0, 8.0, 10.0, 20.0, and 40.0 ppb Rhodamine WT dye were prepared by the EPS-FMS laboratory using a sample of the dechlorinated final effluent as "make-up" water. The concentration of dye in an unknown sample was determined by visually comparing the colour of the unknown to two known standards. Using this method, the estimated error in the 0.1 to 1.0 ppb range is $\pm$ 0.05 ppb; in the 1.0 to 10 ppb range it is $\pm$ 0.5 ppb; and in the 10 to 40 ppb range it is $\pm$ 5 ppb.

Flow data was obtained from the Lake Cowichan flow recorder which measures the height of water in the chlorine contact tank.

3 RESULTS

Sampling Conditions

Little precipitation was noted during this study. As measured at Duncan (8), rain fell on February 19 (2.0 mm) and February 20 (1.5 mm) only.

Flows through the Lake Cowichan sewage treatment system as measured at the chlorine contact tank for February 20 to February 24 are shown in Figure 2. Minimum flows through the contact tank occurred at 0800 hours while maximums were noted at 2200 hours. Sewage flows were well below the average daily design flow of 980 m^3/day as the greatest peak flow recorded for the period (2200 hours February 21) was equivalent to only 900 m^3/day and the average daily flow for the study period was about 700 m^3/day.

3.1 Bacteriological Analyses Results

Sewage effluent samples after various stages of treatment were obtained and fecal coliform MF plate counts determined. Sample station locations are shown in Figure 1 and location descriptions are given in Appendix I. The results of the bacteriological analyses are summarized in Table 2, while a complete account is given in Appendix I.

The Lake Cowichan raw sewage exhibited a mean fecal coliform (FC) count of 3.8×10^6, about the same as for Duncan and North Cowichan (Appendix III). Aerated basin No. 1 was responsible for about a one log reduction in fecal coliforms, while the first lagoons at Duncan and North Cowichan effected almost a two log reduction. Treated effluent discharged from Lake Cowichan aerated basin No. 2 showed a three log reduction in fecal coliforms compared to the raw sewage.

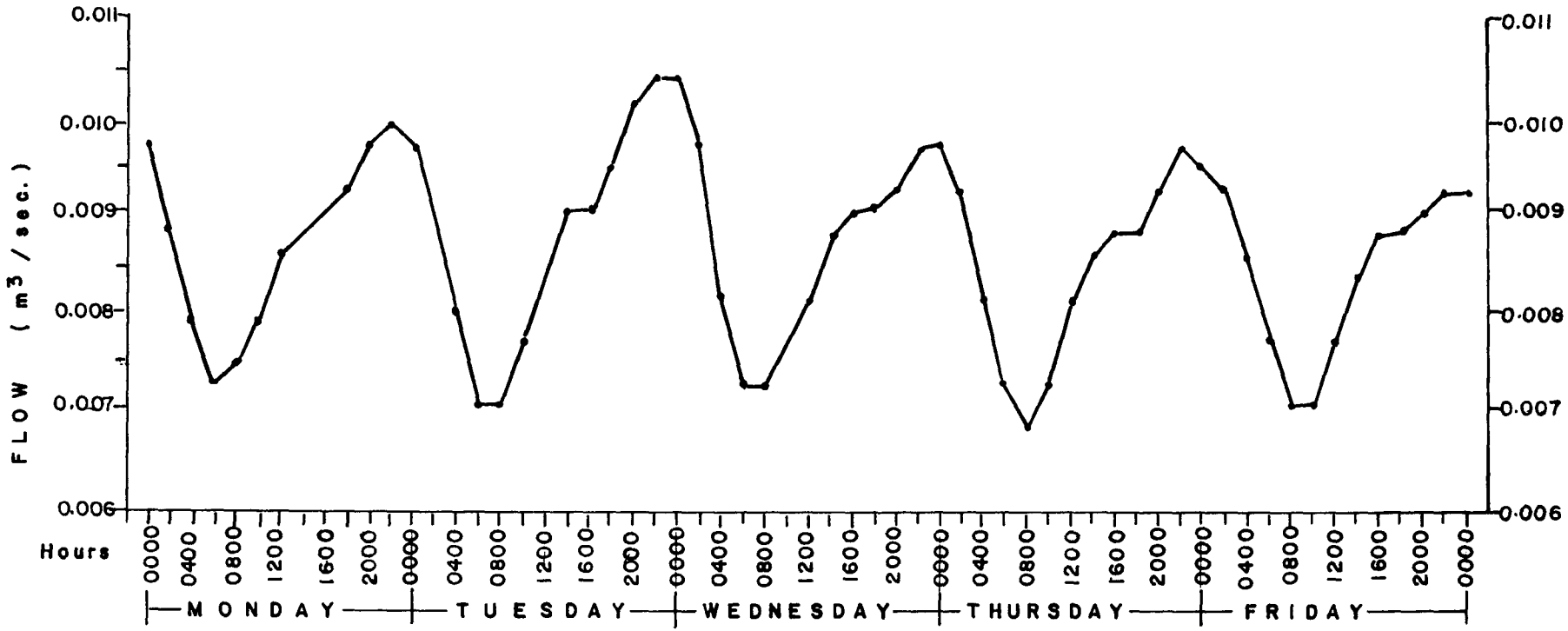

FIGURE 2 FLOW THROUGH THE LAKE COWICHAN SEWAGE TREATMENT LAGOONS
February 20 to February 24, 1978

TABLE 2 SUMMARY OF BACTERIOLOGICAL ANALYSES RESULTS

Station	Mean Bacteria Counts		Percent Reduction in Fecal Coliforms*	
	Fecal Coliforms (MF counts/100 ml)	Heterotrophic Bacteria (counts/ml)	This Survey	1977 Survey
LC1	3.8×10^6 (8)	1.1×10^8 (2)		
LC2	1.4×10^5 (9)		96.32	99.43 (4)
LC3	2.8×10^3 (9)		99.93	99.989 (4)
LC4	1.7×10^2 (9)		99.995	99.993 (5)
LC5	<10 (8) and 380 (1)		>99.997	99.976 (5)
LC6	<10 (8) and 80 (1)	1.1×10^4 (3)	>99.9997	99.997 (5)

() - denotes number of samples

* - reduction from mean raw sewage fecal coliform count

Chlorination was responsible for almost a three log reduction in fecal coliform bacteria, producing a final effluent FC count of less than 10/100 ml. The Municipality of North Cowichan chlorination system was as effective as Lake Cowichan's, but, the City of Duncan's average final effluent FC count (300/100 ml) was only reduced by about one log by chlorination.

The fecal coliform reduction achieved by the two Lake Cowichan lagoons (99.93% at LC3) was not as great as that recorded in the September 1977 survey where a reduction of 99.989 was noted. The increased efficiency of the lagooning systems to reduce fecal coliform densities during the September survey, was due in part, to increased biological activity in the lagoons with a concurrent rise in competitors and predators to the coliform organisms. The cooler weather during which this survey was conducted probably prevented as high a level of biological activity.

Total heterotroph counts obtained from the raw sewage and the final effluent at all three systems indicate the Lake Cowichan system was the most efficient (99.99%) in reducing the total number of bacteria in the system. The significance of these results is not altogether clear since this method does not differentiate between the kinds of bacteria present nor record changes in the bacterial populations across the system.

3.2 Chemical Analyses Results and Dye Study Results

Results of chemical analyses performed on Lake Cowichan composite raw sewage, treated effluent following aerated basin No. 2, and dechlorinated final effluent samples are shown in Table 3. Results indicate that the treatment system works well under the conditions encountered during the survey. The aerated lagoons and dechlorination lagoon system was found to reduce the TOC concentration by 82% (102.0 to 18.0 mg/l), NFR by 88% (95 to 11 mg/l), BOD_5 by 96% (117 to 5 mg/l),

TABLE 3 CHEMICAL ANALYSES RESULTS

Parameter	Raw Sewage	Chlorinated Effluent		Dechlorinated Effluent		
		mg/l	(% reduction)*	mg/l	(% reduction)*	(% reduction)**
pH (pH units)	7.3	7.7		7.8		
TOC	102.0	12.0	(88)	18.0	(82)	(+50)
TAlK	132	99.0	(25)	94.6	(28)	(5)
TPO_4	5.50	3.17	(43)	3.05	(45)	(4)
NO_2	0.0065	0.0332	(+410)	0.0514	(+690)	(+55)
NO_3	<0.010	0.240	(>+2300)	0.230	(>+2200)	(4)
NH_3	17.0	15.9	(7)	14.8	(13)	(7)
Organic N	18.4	1.8	(90)	7.4	(60)	(+310)
FR	223	137	(39)	136	(39)	(0)
NFR	95	16	(83)	11	(88)	(31)
TR	318	153	(52)	147	(54)	(4)
TVR	148	37	(75)	38	(74)	(+3)
TFR	170	116	(32)	109	(36)	(6)
BOD_5	117	17	(85)	5	(96)	(70)
COD	338	78	(77)	52	(85)	(33)
Surfactants	2.9	0.18	(94)	0.23	(92)	(+27)
Oils and Greases	54	<5	(>91)	<5	(>91)	(0)
Cu	0.087	0.021	(76)	<0.020	(>77)	(>1)
Fe	1.93	0.807	(58)	0.752	(61)	(7)
Pb	<0.10	<0.10		<0.10		
Zn	0.143	0.062	(57)	0.040	(72)	(42)
Cd	<0.010	<0.010		<0.010		
Ni	<0.20	<0.20		<0.20		
Hg	<0.00020	<0.00020		<0.00020		
Ca	13.0	10.7	(18)	10.9	(16)	(+2)
Mg	2.08	1.76	(15)	1.76	(15)	(0)
Na	31.6	20.1	(36)	20.2	(36)	(0)
Ba	0.0554	0.0076	(86)	0.0068	(87)	(10)
Cr	0.135	0.034	(75)	<0.020	(>85)	(>41)
Sn	0.27	0.13	(52)	<0.10	(>62)	(>23)
Sr	0.0442	0.0377	(15)	0.0377	(15)	(0)
Mn	0.388	0.328	(15)	0.317	(18)	(3)

* percent reduction from raw sewage
** percent reduction from chlorinated effluent

and oils and greases by greater than 91% (54 to 5 mg/l). Final dechlorinated lagoon effluent BOD_5 and NFR concentrations are well below the Pollution Control Branch permit requirements of 45 mg/l and 60 mg/l respectively.

The treatment system is designed for the following BOD_5 reduction efficiency, assuming a raw sewage BOD_5 of 205 mg/l.

BOD_5 reduction at average flow
@ 4 °C - 93.0%
@ 13°C - 94.9%
@ 20°C - 96%

Effluent BOD_5 at average flow
@ 4 °C - 14.3 mg/l
@ 13°C - 10.4 mg/l
@ 20°C - 8.2 mg/l

As noted above, the raw sewage BOD_5 was only 117 mg/l, however, the system still achieved a 96% reduction efficiency, producing a final effluent BOD_5 of only 5 mg/l.

Generally, the Lake Cowichan raw sewage may be classified as weak, as shown in Table 4. Only organic nitrogen and total alkalinity concentrations are above typical weak sewage levels.

All final effluent total metal concentrations are relatively low. The treatment system exhibited high removal efficiencies for Cu (77%), Fe (61%), Zn (72%), Ba (87%), and Sn (62%).

Organic (Kjeldahl), nitrate, nitrite, and ammonia nitrogen analyses were performed on samples of the raw sewage, chlorinated effluent, and final dechlorinated effluent in order to obtain a nitrogen balance (Figure 3). The raw sewage nitrogen is primarily in the organic

TABLE 4 RAW SEWAGE STRENGTH

Parameter	Typical Composition (9) Strong	Medium	Weak	Lake Cowichan
	mg/l			
TR	1200	700	350	318
NFR	350	200	100	95
FR	600	350	175	223
TVR	600	350	175	148
TFR	850	500	250	170
BOD_5	300	200	100	117
TOC	300	200	100	102.0
COD	1000	500	250	338
Organic N	35	15	8	18.4
NH_3	50	25	12	17.0
NO_3	0	0	0	<0.010
NO_2	0	0	0	0.0065
TPO_4	20	10	6	5.50
TAlk	200	100	50	132
Grease	150	100	50	54

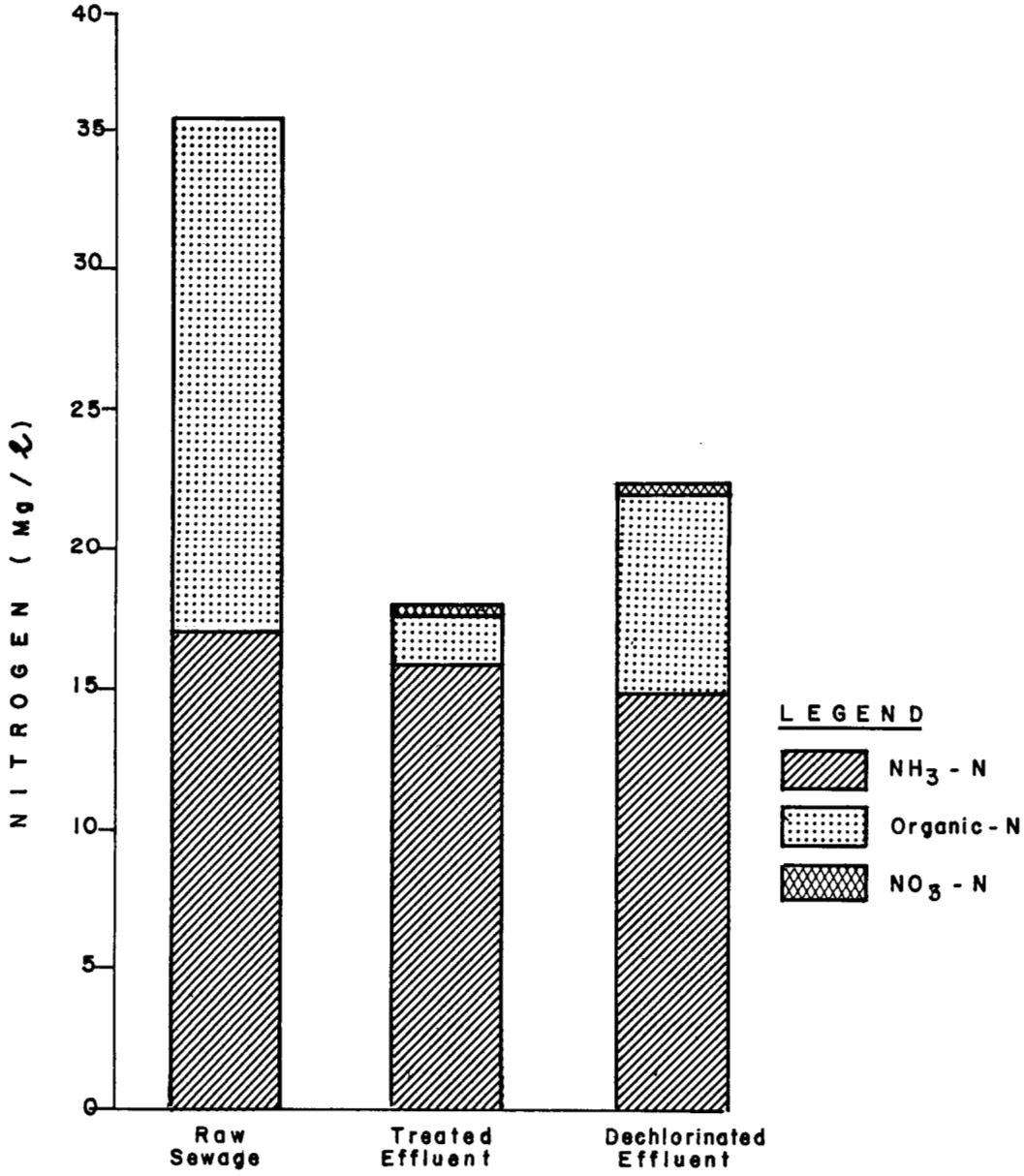

FIGURE 3 LAKE COWICHAN SEWAGE TREATMENT LAGOONS NITROGEN BALANCE

and ammonia form. The organic fraction may be protein, amino acids, or urea, while ammonia may be formed by hydrolysis of urea, and decomposition of protein and amino acids. Household cleaning agents may also contribute ammonia nitrogen to the sewage collection system.

The organic nitrogen concentration decreased from a value of 18.4 mg/l in the raw sewage to 1.8 mg/l in the chlorinated effluent due to the breakdown of urea, protein, and amino acids. The ammonia concentration decreased slightly from 17.0 to 15.4 mg/l. Little nitrification occurred as shown by a small increase in nitrite and nitrate from 0.0065 to 0.0332 mg/l for nitrite and from 0.010 to 0.240 mg/l for nitrate. The decrease in total nitrogen could be due to ammonia volatilization.

The organic nitrogen concentration increased significantly from the chlorinated to dechlorinated effluent sample while the ammonia concentration decreased. This organic nitrogen increase could be due to the formation of blue-green (Cyanophyta) algae which can utilize atmospheric nitrogen in cell synthesis.

Chlorination and Dechlorination Systems

The Lake Cowichan sewage treatment system was designed and constructed to have flow proportional gaseous chlorine addition. The sewage collection system is reported to be subject to excessive groundwater infiltration and stormwater inflow such that wet weather daily flow rates can be greater than four times the average dry weather flows. The normal chlorine addition rate was found to be excessive when the flow proportional addition system was used with a low chlorine demand diluted sewage, and high residuals remained in the dechlorinated final effluent. In the summer of 1977, the flow proportional chlorine addition system was disconnected and chlorine is now added by manually setting the dosage.

The quantity of chlorine used from February 19 to February 24, 1978 is shown in Table 5. The theoretical TRC concentrations assuming a chlorine gas-liquid transfer ratio of 1.0, for the design daily flow and actual daily flow are also shown.

Results of the 48 hour TRC survey are shown in Table 6 and Figure 4. The theoretical TRC concentrations for February 20, 21, and 22 (1.20, 1.80, and 2.39 mg/l) were close to the actual average TRC concentration of the chlorinated effluent (1.32, 1.42, and 1.51 mg/l). The data for February 20 and 22 is for only a 16 and 8 hour period respectively. The average theoretical TRC concentration for the three days is 1.80 mg/l close to the average actual TRC for the period 0800 February 20 to 0800 February 22 of 1.40 mg/l. These observations indicate that:

1. The actual TRC chlorine gas-liquid transfer ratio is close to 1.0.
2. The aerated lagoons effluent had very little chlorine demand (about 0.4 mg/l).
3. The consultants' recommended theoretical TRC dosage concentration of 10 ppm is too high (2).

The dechlorination lagoon was responsible for a 51% reduction in total chlorine residual. However, the average dechlorinated effluent residual concentration of 0.71 mg/l is well above the 0.02 mg/l chlorine residual concentration for acute toxicity reported by Servizi and Martens. Moreover, this average concentration is also above the Pollution Control Branch permit requirement of 0.05 mg/l.

The PCB permit requires that the operator "maintain a chlorine residual between 0.1 and 1.0 mg/l at all times at an acceptable point in the system and provide not less than one hour's contact time at average flow rates". Only 3 of the 50 chlorinated effluent TRC analyses results obtained during this study are within this permitted range. Results of tests performed by the Village personnel using the Orthotolidine (Hach

TABLE 5 CHLORINE USED AND THEORETICAL TRC

Date	Chlorine Used		Flow		Theoretical TRC at Actual Flow
	kg	(lbs)	m^3/day	(USGPD x 10^3)	mg/l
Feb. 19	1.4	(3)	760	(200)	1.80
20	0.9	(2)	760	(200)	1.20
21	1.4	(3)	760	(200)	1.80
22	1.8	(4)	760	(200)	2.39
23	1.4	(3)	740	(195)	1.84
24	1.1	(2)	720	(190)	1.57

TABLE 6 LAKE COWICHAN 48 HOUR RESIDUAL CHLORINE SURVEY RESULTS
February 20-22 0800-0800

	Chlorinated mg/l	Dechlorinated mg/l
Monday		
0800	1.79	0.90
0900	1.82	0.90
1000	1.85	0.40
1100	1.30	0.74
1200	1.63	0.60
1300	0.41	0.60
1400	0.24	0.66
1500	1.02	0.65
1600	1.14	0.74
1700	1.42	0.79
1800	1.60	0.79
1900	1.47	0.60
2000	1.47	0.67
2100	1.23	0.74
2200	1.35	0.48
2300	1.30	0.72
2400	1.30	0.69
Day Average	1.32	0.69
Tuesday		
0100	1.40	0.67
0200	1.35	0.60
0300	1.30	0.53
0400	1.51	0.72
0500	1.42	0.55
0600	1.49	0.76
0700	1.68	0.72
0800	1.49	0.65
0900	1.86	0.76
1000	.72	0.79
1100	1.68	0.74
1200	1.23	0.87
1300	1.51	0.79
1400	1.30	0.72
1500	1.42	0.32
1600	1.40	0.65
1700	1.37	0.69
1800	1.32	0.81
2000	1.37	0.76
2100	1.23	0.74
2200	1.21	0.69
2300	1.14	0.60
2400	1.43	0.60
Day Average	1.42	0.69

TABLE 6 LAKE COWICHAN 48 HOUR RESIDUAL CHLORINE SURVEY RESULTS
February 20-22 0800-0800 (continued)

	Chlorinated mg/l	Dechlorinated mg/l
Wednesday		
0100	1.33	0.79
0200	1.23	0.76
0300	1.28	0.69
0400	1.44	0.72
0500	1.68	0.88
0600	1.75	0.83
0700	1.53	0.95
0800	1.84	0.93
Day Average	1.51	0.82
48 Hour Average	1.40	0.71

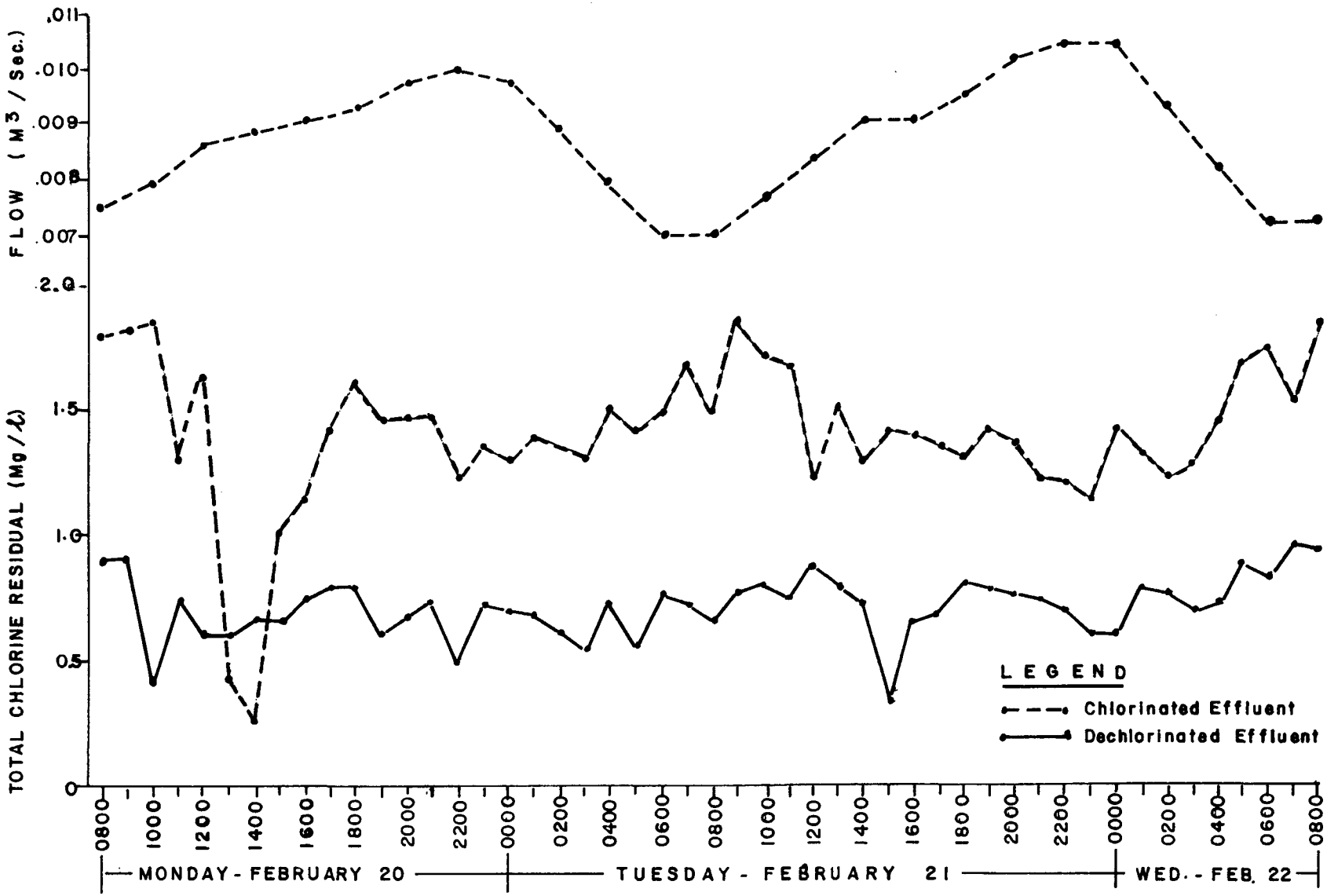

FIGURE 4 48 HOUR LAKE COWICHAN TRC STUDY RESULTS

Chemical Co.) method were 0.6, 0.8, and 1.0 mg/l for February 20, 21, and 22 respectively. The amperometric titration method is recognized as a more accurate method of measuring TRC.

The results of the dechlorination basin dye study are shown in Figures 5, 6, and 7. Following dye addition at 0930 February 23, the dye moved towards the chlorine contact tank weir, but, did not enter the dechlorination basin as a "slug". Undercurrents in the chlorine contact tank carried much of the dye opposite to the direction of surface flow, resulting in the entire chlorine contact tank contents being dyed. The concentration of dye in the chlorinated effluent as it entered the dechlorination basin is shown in Figure 6.

The dyed chlorinated effluent entered the dechlorination basin through a 30.5 mm (12") diameter submerged A.C. pipe set at - 10% grade. This influent pipe is located at the northwest corner of the basin and directs the chlorinated effluent towards the southeast corner (Figure 5). The dyed effluent plume initially occupied the northeast side of the basin only and the leading edge reached the 30.5 mm diameter A.C. dechlorination basin drain at 1115. The first measurable dye concentration was noted at that time as shown in Figure 6. The dye plume swirled around the southeast corner of the basin and began to move up the easterly side. By 1200 hours the visibly dyed effluent occupied about 60% of the basin and significant dye concentrations were measured at the final effluent manhole. The concentration of dye in the final dechlorinated effluent reached a peak of 0.5 ppb at 1530 hours. The concentration began to decrease from that time, reaching 0.2 ppb at 13 hours on February 24, and samples taken from the four corners of the dechlorination basin, and east and west sides, showed the dye to be uniformally distributed throughout the lagoon at a concentration of 0.2 ppb.

The flow characteristics of the dechlorination basin more closely resemble a "complete mix" rather than a "plug flow" system (Figure 6). In plug flow (10):

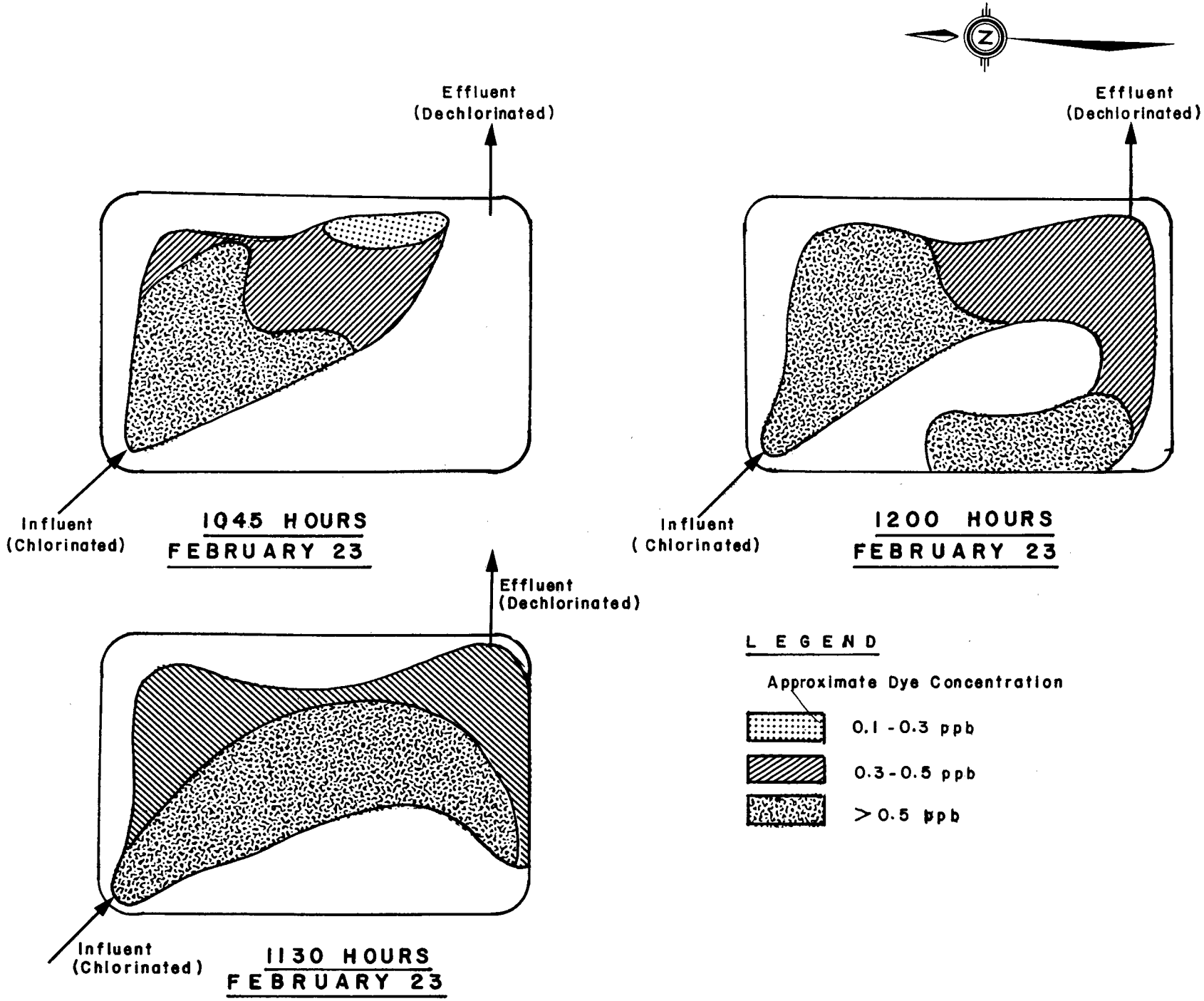

FIGURE 5 MOVEMENT OF RHODAMINE WT DYE IN LAKE COWICHAN DECHLORINATION BASIN

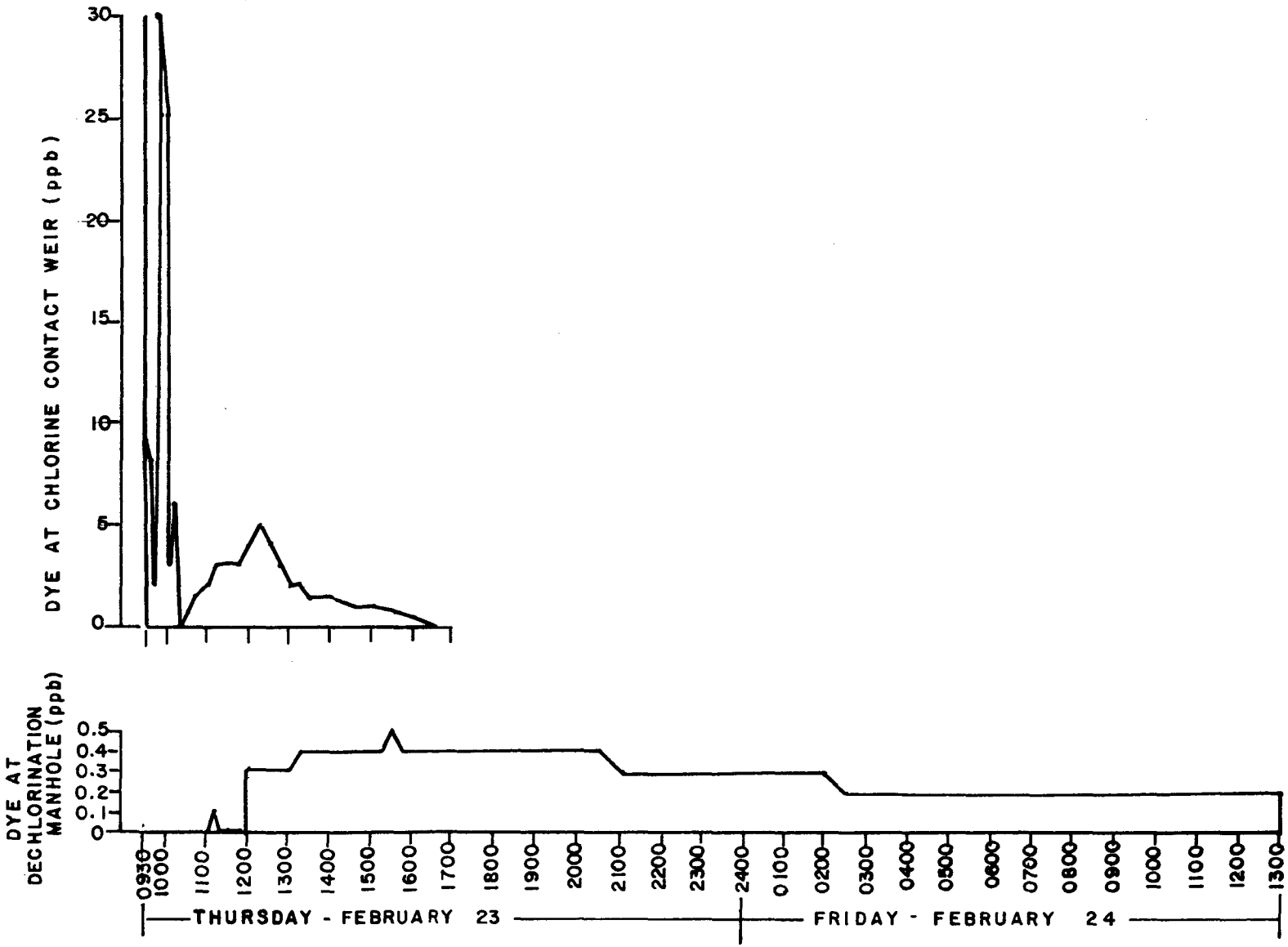

FIGURE 6 LAKE COWICHAN DECHLORINATION BASIN DYE STUDY RESULTS

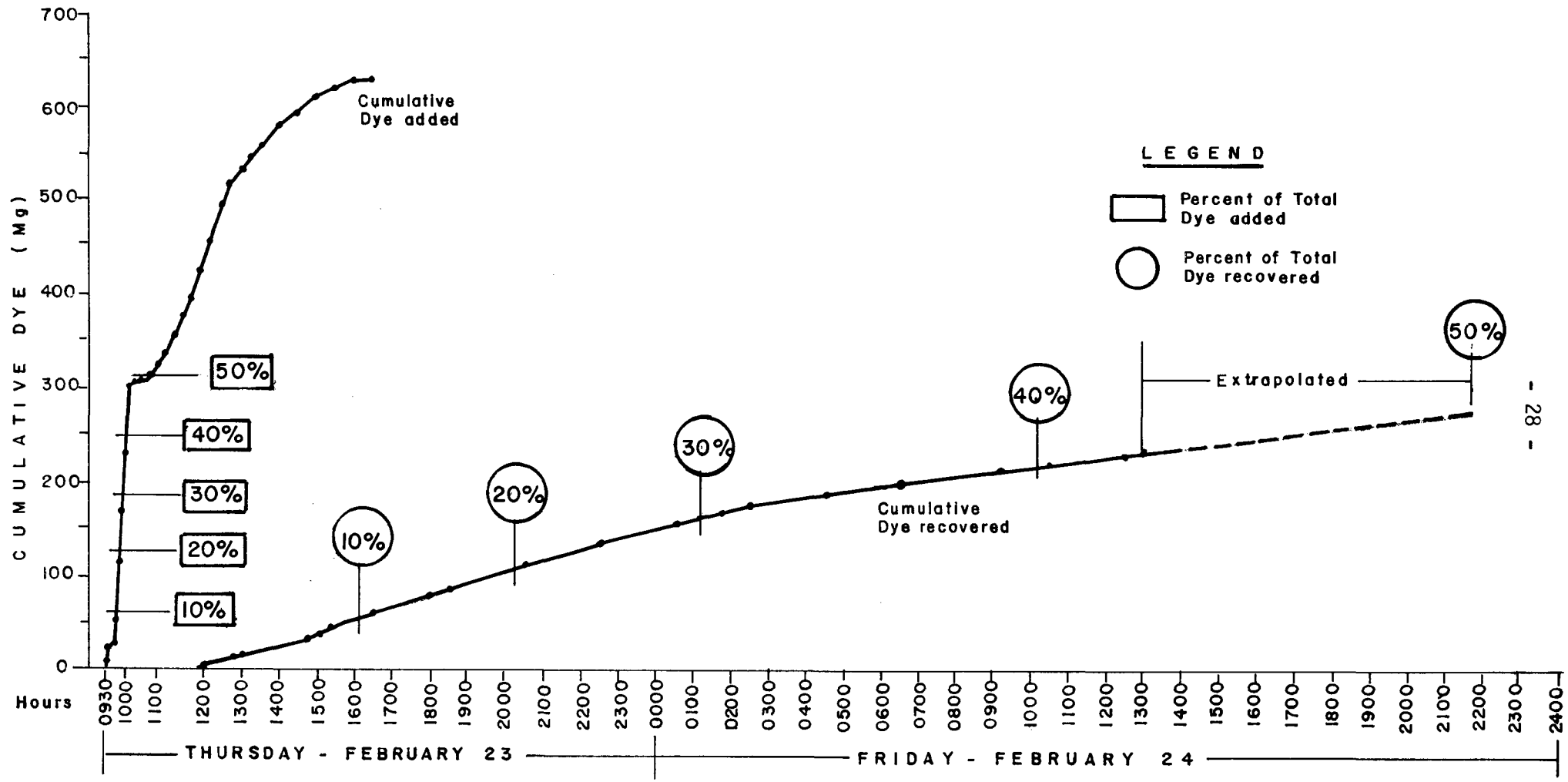

FIGURE 7 CUMULATIVE DYE ADDITION AND RECOVERY - LAKE COWICHAN DECHLORINATION BASIN DYE STUDY

"... fluid particles pass through the tank and are discharged in the same sequence in which they enter. The particles retain their identity and remain in the tank for a time equal to the theoretical detention time."

In complete mix (10):

"... the particles entering the tank are immediately dispersed throughout the tank. The particles leave the tank in proportion to their statistical population."

In this case, if the Lake Cowichan dechlorination basin had plug flow characteristics, the dechlorinated effluent dye curve shown in Figure 6 would have resembled the dye addition curve.

The cumulative weight of dye, added and recovered was calculated (Figure 7) using the dye concentration and relevant flow data.

	Weight	%
Total Dye Added	629 mg	100
Total Dye Recovered		
- at manhole (to 1300 hours February 24)	229 mg	36
- left in lagoon (after 1300 hours)	301 mg	48
Total Recoverable	530 mg	84
Unaccounted For	99 mg	16

The unaccounted for dye could have been lost through soil adsorption or photo-chemical decay.

Dechlorination basin effluent residence times were calculated using Figure 7 and are shown in Table 7. The actual mean residence time of 1.55 days is very close to the design time of 1.5 days. However, due to the complete mix characteristic of the system, significant quantities of effluent have residence times considerably less than 1.5 days. As

TABLE 7 FLOW CHARACTERISTICS OF THE LAKE COWICHAN DECHLORINATION BASIN AS DETERMINED BY A DYE STUDY

General Description - most closely resembles a complete mix system

Residence Times	
minimum residence time	2 hours
10% of the effluent has a residence time less than	6.0 hours
20%	10.75 hours
30%	15.5 hours
40%	24.75 hours
Effluent mean residence time	1.55 days

such, this chlorination basin would produce final effluent with a higher TRC than would a 1.5 day designed plug flow lagoon. However, it is doubtful if such a plug flow lagoon could reduce the high chlorinated effluent TRC levels noted during this survey to the Pollution Control Branch permit required dechlorinated effluent level of 0.05 mg/l.

3.3 Bioassay Results

A summary of the results of the 96 hour LC_{50} bioassay test may be found in Table 8.

A study of municipal wastewater toxicity of eight sewage treatment plants was conducted by personnel of the Environmental Protection Service during 1976 and the results appear in EPS published reports by T.W. Higgs (11). In that study, three chemical parameters were regularly noted to be responsible for acute toxicity to the test fish. These were anionic surfactants, un-ionized NH_3, and TRC.

TABLE 8 SUMMARY OF 96 HOUR LC_{50} BIOASSAY RESULTS AND SELECTED CHEMICAL ANALYSES RESULTS

Sample Location	Type of Sample	96 hour LC_{50}	Un-ionized NH_3* (mg/l)	anionic surfactants (mg/l)	Average TRC (mg/l)
Lake Cowichan					
Raw sewage	24 hour composite	39%	0.106	2.9	
Chlorinated effluent	24 hour composite	non-toxic	0.251	0.18	1.40
Final effluent	24 hour composite	non-toxic	0.287	0.23	0.71
Duncan					
Raw sewage	Grab	41%	0.097	0.95	
Final effluent	Grab	non-toxic	0.026	1.5	
North Cowichan					
Raw sewage	Grab	40%	0.152	2.3	
Final effluent	Grab	32%	0.195	0.11	

*Un-ionized NH_3 concentrations were calculated using NH_3 concentration, pH, temperature data, and tables prepared by Emerson, et al (12).

Critical concentrations of these parameters reported in the literature are shown in Table 9. A detailed discussion of the subject is beyond the scope of this report and the reader is referred to the appropriate references listed.

During the September 6-8, 1977 EPS study of the Lake Cowichan sewage lagoons, samples were collected of the chlorinated and dechlorinated effluent. One set of three hour composite samples were collected on each of the first two days of the study and a grab set collected on the last day - for a total of three chlorinated and three dechlorinated samples. Samples were analyzed in the Environmental Protection Service Aquatic Toxicity Laboratory. All samples were found to be non-toxic. No chemical data is available to relate the bioassay results to chemical parameter concentrations.

Generally, it is difficult to correlate toxicity data with chemical results obtained during this 1978 study. With the exception of the Duncan final effluent, all un-ionized NH_3 concentrations noted are capable of exerting significant toxicity. The apparent increase of un-ionized NH_3 concentration from raw sewage to final effluent at Lake Cowichan and North Cowichan is due to an increase in pH. In the case of Lake Cowichan, the increase in pH from raw sewage, to chlorinated effluent, to final effluent was 7.3 to 7.7 to 7.8 respectively. However, the results of bioassay analyses of the Lake Cowichan chlorinated and final effluent indicated that they were non-toxic. The North Cowichan final effluent, for comparison, had a 96 hour LC_{50} value lower than that of the raw sewage; perhaps in response to the un-ionized NH_3 concentration increase.

The Lake Cowichan and North Cowichan raw sewage anionic surfactant levels would be expected to exert some toxicity while final effluent levels would not. The Duncan final effluent anionic surfactant concentration is anomalously high (1.5 mg/l) although visible foaming at the outfall was noted during the survey.

TABLE 9 CRITICAL CONCENTRATIONS OF ANIONIC SURFACTANTS, UN-IONIZED NH_3, AND TRC REPORTED TO BE TOXIC TO FISH

Parameter	Concentration (mg/l)	Significance	Reference
un-ionized NH_3	0.006	desirable upper limit	(13)
	0.025	maximum tolerated	(14)
	0.44	100% mortality after 96 hours	(15)
Anionic surfactants	3.3-6.4	96 hour LC_{50}	(16)
	5.9	LC_{50}	(17)
TRC	0.02	likely toxic	(1)

As previously noted, both chlorinated and dechlorinated Lake Cowichan final effluent TRC levels are well above critical toxicity concentrations. Residual chlorine is known to decrease significantly with time as it reacts with substances in sewage (18). Since both samples were 24-hour composites, aliquots collected early in the sampling period had relatively long storage times. Some detoxification would be expected during this period.

The synergistic effects of many compounds may reduce the toxic effects predicted from chemical analyses results. Modifying conditions for bioassays include effects of temperature, water hardness, alkalinity, pH, dissolved oxygen, among others (19). Any one of these factors may be responsible for the apparent poor correlation between the chemical and bioassay results of this study.

3.4 Minimum Dilution in the Cowichan River

The minimum dilution of Lake Cowichan sewage effluent in the Cowichan River may be calculated using annual 7-day average low flows as shown in Appendix II (20). The minimum flow for the period of record occured in 1944 - 0.473 m^3/sec (16.7 cfs). However, in 1958 a weir was installed at the outlet of Cowichan Lake and since then, the flow in the Cowichan River has been controlled. The weir was installed in order to maintain a minimum flow in the river for the fishery resource and the use of the BCFP Crofton Pulp Mill (21). In the period from 1958 to 1971, the minimum annual 7-day average low flow occurred on August 20, 1961 - 4.42 m^3/sec (156 cfs). Using this value and an average sewage effluent flow of 0.0114 m^3/sec (260 000 USGPD), the minimum dilution in the Cowichan River is:

$$\frac{4.42\ m^3/sec}{0.0114\ m^3/sec} = 389$$

Assuming an average final effluent chlorine residual of 0.71 mg/l, the TRC in the Cowichan River would be 0.0018 mg/l - well below the critical toxic TRC concentration discussed previously. This assumes even distribution of the effluent across the River and complete mixing. Since neither of these assumption are true, a somewhat higher TRC concentration than calculated here would be expected in the immediate area of the outfall and within a downstream zone of mixing.

If there was no chlorination of the aerated lagoon treated effluent, then the average fecal coliform count in the Cowichan River at 4.42 m^3/sec flow conditions noted above would be:

$$\frac{2.8 \times 10^3\ MF\ counts/100\ ml}{389} = 6\ counts/100\ ml$$

This is below the Canadian Drinking Water Standards objective for raw water fecal coliform standards (22):

> "At least 95% of the samples in any consecutive 30-day period should have a faecal (sic) coliform density of less than 10 per 100 ml."

Treatment by chlorination of this water would be necessary if it is to be used for drinking purposes. This calculation does not take into account either fecal coliform colony growth or die-off (various authors have reported an apparent growth of coliform colonies in receiving waters following the discharge of chlorinated wastewaters (23).

The acceptability of a six fecal coliform/100 ml count in the Cowichan River would depend upon the downstream water uses.

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APPENDIX I

BACTERIOLOGICAL ANALYSES RESULTS AND SAMPLE STATION LOCATIONS

APPENDIX I BACTERIOLOGICAL ANALYSES RESULTS AND SAMPLE STATION LOCATIONS

Sample Station Location	Sampling Time	Sampling Date	Bacteriological Analysis Results MF Count per 100 ml Fecal Coliform	Total Heterotrophs
			Village of Lake Cowichan	
LC1	0930	Feb. 20	2.3×10^6	
	1400	20	2.5×10^6	4.1×10^6
	0930	21	7.6×10^6	
	1300	21	5.0×10^5	3.1×10^8
	1500	21	1.7×10^6	
	0930	22	4.6×10^6	
	1300	22	6.6×10^6	1.01×10^7
	1500	22	4.8×10^6	
LC2	0930	20	62 000	
	1100	20	64 000	
	1400	20	140 000	
	0930	21	62 000	
	1300	21	130 000	
	1500	21	160 000	
	0980	22	68 000	
	1300	22	160 000	
	1500	22	380 000	
LC3	0930	20	3400	
	1100	20	2400	
	1400	20	2200	
	0930	21	3200	
	1300	21	1500	
	1500	21	2600	
	0930	22	1100	
	1300	22	1500	
	1500	22	7800	
LC4	0930	20	530	
	1100	20	80	
	1400	20	140	
	0930	21	90	
	1300	21	100	
	1500	21	240	
	0930	22	100	
	1300	22	74	
	1500	22	172	

APPENDIX I BACTERIOLOGICAL ANALYSES RESULTS AND SAMPLE STATION LOCATIONS (Continued)

Sample Station Location	Sampling Time	Sampling Date	Bacteriological Analysis Results MF Count per 100 ml: Fecal Coliform	Total Heterotrophs
		Village of Lake Cowichan		
LC5	0930	Feb. 20	10	
	1100	20	10	
	1400	20	380	
	0930	21	10	
	1300	21	10	
	1500	21	10	
	0930	22	10	
	1300	22	10	
	1500	22	10	
LC6	0930	20	10	
	1100	20	10	
	1400	20	10	2.3×10^3
	0930	21	80	
	1300	21	10	3.9×10^3
	1500	21	10	
	0930	22	10	
	1300	22	10	2.7×10^4
	1500	22	10	

Bacteriological Sample Station Location and Descriptions

Village of Lake Cowichan

LC1 Raw sewage at Pine Street Pump Station
LC2 Effluent after aeration basin #1
LC3 Effluent after aeration basin #2
LC4 Effluent at start of chlorine contact tank
LC5 Effluent at end of chlorine contact tank
LC6 Final Effluent after dechlorination basin

APPENDIX II

ANNUAL 7-DAY AVERAGE LOW FLOWS FOR THE COWICHAN RIVER (20)

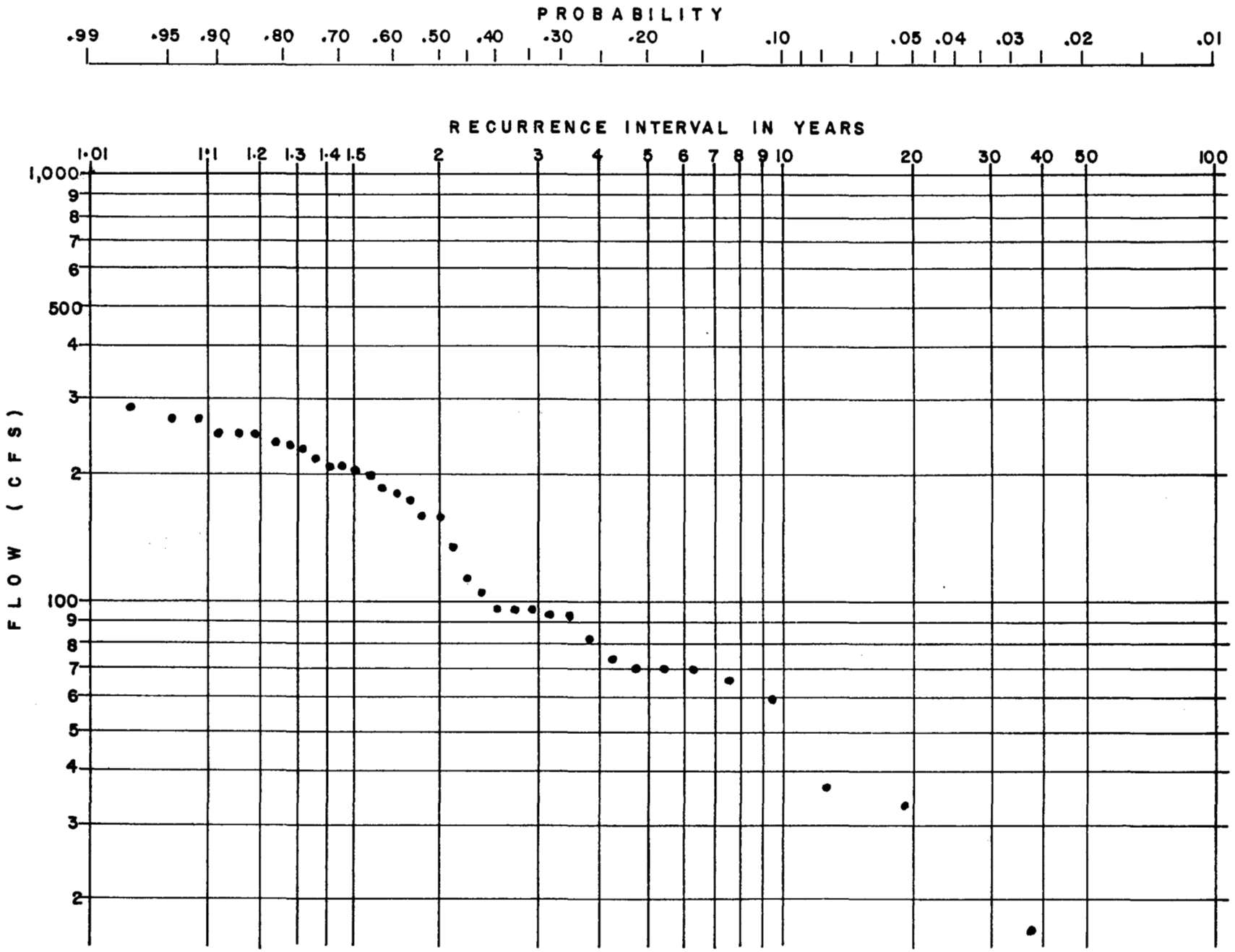
APPENDIX II

ANNUAL 7-DAY AVERAGE LOW FLOWS
Station No. 08HA002
Cowichan River at Lake Cowichan

Date	7-day avg. low flow in cfs	Rank	Recurrence interval in years	7-day avg. low flow in cfs	Year
August 29, 1913	243	1	38.0	16.7	1944
September 4,1914	96.3	2	19.0	33.4	1915
September 28, 1915	33.4	3	12.7	36.9	1951
October 24, 1916	95.3	4	9.5	58.3	1942
September 22, 1917	177	5	7.6	64.7	1956
October 1, 1918	92.7	6	6.3	68.3	1943
August 29, 1941	106	7	5.4	68.9	1950
September 27, 1942	58.3	8	4.75	69.7	1947
September 21, 1943	68.3	9	4.22	71.7	1958
September 11, 1944	16.7	10	3.80	82.0	1953
August 31, 1945	95.1	11	3.45	92.7	1918
October 16, 1946	113	12	3.17	92.7	1952
September 26, 1947	69.7	13	2.92	95.1	1945
August 23, 1948	173	14	2.71	95.3	1916
September 13, 1949	133	15	2.53	96.3	1914
September 22, 1950	68.9	16	2.37	106	1941
September 19, 1951	36.9	17	2.24	113	1946
October 21, 1952	92.7	18	2.11	133	1949
September 18, 1953	82.0	19	2.00	156	1961
September 7, 1954	231	20	1.90	159	1955
October 3, 1955	159	21	1.81	173	1948
September 17, 1956	64.7	22	1.73	177	1917
September 2, 1957	208	23	1.65	182	1963
September 6, 1958	71.7	24	1.58	198	1965
September 6, 1959	233	25	1.52	201	1960
August 5, 1960	201	26	1.46	208	1957
August 20, 1961	156	27	1.41	208	1970
July 31, 1962	228	28	1.36	214	1967
October 9, 1963	182	29	1.31	228	1962
August 29, 1964	243	30	1.27	231	1954
October 1, 1965	198	31	1.23	233	1959
August 27, 1966	249	32	1.187	243	1913
September 27, 1967	214	33	1.152	243	1964
August 4, 1968	269	34	1.118	249	1966
August 23, 1969	262	35	1.086	262	1969
August 3, 1970	208	36	1.056	269	1968
August 11, 1971	284	37	1.027	284	1971

Mean flow: 149 cfs
Standard deviation: 77.9 cfs
Remarks: Flow regulated since 1958

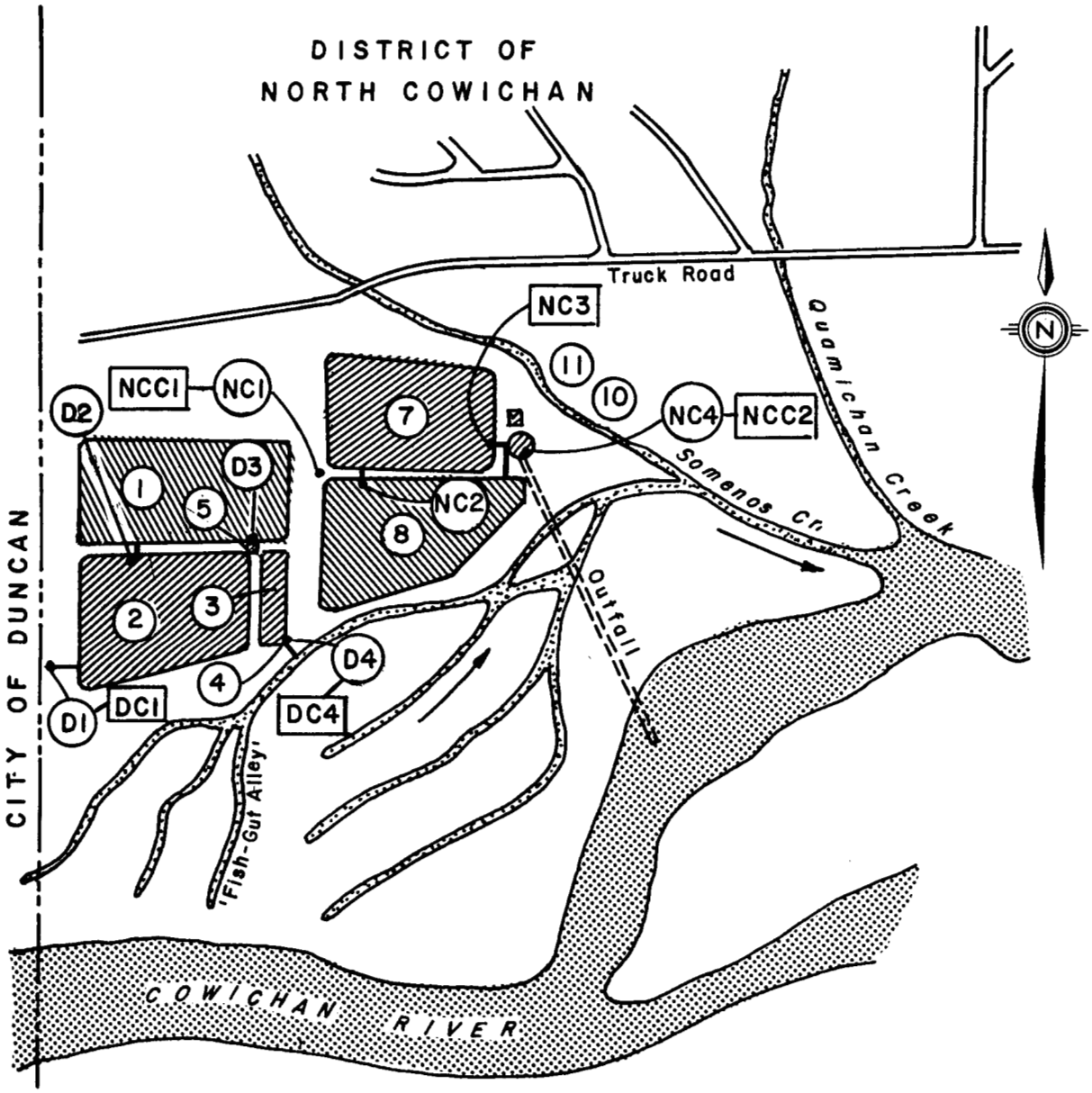
Drainage area: 235 sq. mi.



APPENDIX II RECURRENCE INTERVAL OF ANNUAL 7-DAY AVERAGE LOW FLOWS (20)

APPENDIX III

BACTERIOLOGICAL AND CHEMICAL ANALYSES RESULTS - CITY OF DUNCAN AND MUNICIPALITY OF NORTH COWICHAN SEWAGE TREATMENT LAGOONS



LEGEND

Treatment System Components

DUNCAN

1. Polishing Cell
2. Aerated Lagoon
3. Chlorination Cell
4. Outfall to Ditch
5. Chlorinator

NORTH COWICHAN

7. Aerated Lagoon A
8. Aerated Lagoon B
9. Chlorine Contact Pond
10. Chlorinator

Sampling Locations

DUNCAN

(D) Bacteriological Sample Station Locations

[DG] Chemical Grab Sample Station Locations

NORTH COWICHAN

(NC) Bacteriological Sample Station Locations

[NCC] Chemical Grab Sample Station Locations

APPENDIX III SAMPLING SITES AT THE NORTH COWICHAN AND DUNCAN SEWAGE LAGOONS

APPENDIX III SUMMARY OF BACTERIOLOGICAL ANALYSES RESULTS

Station	Mean Bacteria Counts		Percent Reduction in Fecal Coliforms from Raw Sewage
	Fecal Coliforms (MF counts/100 ml)	Heterotrophs	
	(counts/ml)		
	City of Duncan		
D1	2.5×10^6 (3)	4.7×10^6 (3)	
D2	3.1×10^4 (3)		98.76
D3	7.6×10^3 (3)		99.70
D4	3.0×10^2 (3)	2.1×10^6 (2)	99.988
	Municipality of North Cowichan		
NC1	3.8×10^6 (3)	2.6×10^7 (3)	
NC2	6.6×10^4 (3)		98.26
NC3	1.4×10^3 (2)		99.96
NC4	<10 (3)	5.0×10^4 (3)	>99.9997

() - denotes number of samples

APPENDIX III CHEMICAL ANALYSES RESULTS - CITY OF DUNCAN
(Grab Samples)

Parameter	Raw Sewage (D1) mg/l	Final Effluent (D2) mg/l	Reduction (%) from raw sewage
pH (pH units)	7.1	6.9	
TOC	375.0	17.0	95
TAlk	161	78.4	51
TPO_4	7.95	2.65	67
NO_2	0.0095	0.0160	+68
NO_3	0.010	0.0205	+105
NH_3	24.9	11.0	56
Organic N	37.4	8.2	78
FR	323	132	59
NFR	647	15	98
TR	920	147	84
TVR	427	38	91
TFR	493	109	78
BOD_5	239	18	92
COD	370	26	93
Surfactants	0.95	1.5	+58
Oils and Greases	690	<5	>99
Cu	0.288	0.052	82
Fe	1.46	0.471	68
Pb	<0.10	<0.10	
Zn	0.175	0.037	79
Cd	<0.010	<0.010	
Ni	<0.20	<0.20	
Hg	<0.00020	<0.00020	
Ca	25.7	14.1	45
Mg	3.41	1.82	47
Na	30.1	17.6	42
Ba	0.481	0.0224	95
Cr	0.038	0.062	+63
Sn	<0.10	<0.10	
Sr	0.0738	0.0451	39
Mn	0.0894	0.0368	59

APPENDIX III CHEMICAL ANALYSES RESULTS - MUNICIPALITY OF NORTH COWICHAN (Grab Samples)

Parameter	Raw Sewage (NCC1) mg/l	Final Effluent (NCC2) mg/l	Reduction (%) from raw sewage
pH (pH units)	7.3	7.6	
TOC	185.0	15.0	92
TAlk	152.0	103	32
TPO_4	6.93	2.83	59
NO_2	0.0085	0.0460	+440
NO_3	<0.010	0.265	>2550
NH_3	24.4	16.0	34
Organic N	30.8	8.0	74
FR	240	172	28
NFR	167	13.9	92
TR	417	186	55
TVR	220	48.6	78
TFR	197	138	30
BOD_5	225	9	96
COD	195	26	87
Surfactants	2.3	0.11	95
Oils and Greases	45	<5	89
Cu	0.315	0.021	93
Fe	1.14	0.977	14
Pb	<0.10	<0.10	
Zn	0.154	0.034	78
Cd	<0.010	<0.010	
Ni	<0.20	<0.20	
Hg	<0.00020	<0.00020	
Ca	20.6	17.3	16
Mg	2.81	2.64	6
Na	33.7	21.9	35
Ba	0.0537	0.0267	50
Cr	<0.020	<0.020	
Sn	<0.10	<0.10	
Sr	0.0697	0.0622	11
Mn	0.0825	0.0947	+15