DEPARTMENT OF ENVIRONMENT
ENVIRONMENTAL PROTECTION SERVICE
PACIFIC REGION

CACHE CREEK
SEWAGE TREATMENT PLANT
EVALUATION
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By

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ABSTRACT

The operation and performance of the Cache Creek Sewage Treatment Plant was evaluated over a 4 day period. Plant influent and effluent was sampled daily and analyzed for numerous parameters including BOD_5 and non-filterable residue, as well as metals. Several locations in the plant and in the receiving waters were sampled daily and analyzed for indicator bacteria. A continuous fish bioassay was run on the final effluent but was not entirely successful due to equipment malfunctions. Other parameters measured included total residual chlorine, aeration tank dissolved oxygen, and mixed liquor settleability. The chlorine contact chamber was evaluated using dye tracer techniques. Recommendations are made to improve plant performance and reliability.

RÉSUMÉ

Le mode d'opération et le rendement de l'usine d'épuration de Cache Creek ont fait l'objet d'une évaluation étalée sur quatre jours. On a prélevé quotidiennement des échantillons à l'entrée et à la sortie de l'usine afin d'en faire l'analyse à partir de nombreux paramètres dont le DBO_5, les résidus non filtrables et les métaux. On a prélevé quotidiennement des échantillons à divers endroits de l'usine ainsi que dans les eaux réceptrices afin de déterminer de la présence bactéries indicatrices. On a effectué un dosage biologique continu dans l'effluent final, à l'aide de poissons, mais les résultats n'ont pas été entièrement concluants, du fait d'un fonctionnement défectueux du matériel. Parmi les autres paramètres étudiés, il faut citer le chlore résiduel total, l'oxygène dissous du bassin d'aération et la décantabilité de la solution mixte. Le bassin de contact de chlore a fait l'objet d'un examen basé sur des techniques de détection par les colorants. Des recommendations suivent afin d'améliover le rendement et la fiabilité de l'usine.

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RECOMMENDATIONS AND CONCLUSIONS

Plant Operation

1. Use only one side of the parallel treatment system.

With this mode of operation the plant would operate more within the recommended design constraints for the activated sludge process at the present flow rates. This would simplify process control and minimize maintenance requirements, as well as provide a backup system.

2. Maintain aeration tank dissolved oxygen between 2 and 4 mg/L.

Too much dissolved oxygen (D.O.) may result in overagitation and destruction of the biomass floc, and is a waste of energy; a D.O. of less than 2 mg/L may result in anaerobic conditions in the clarifier and possibily in the aeration tank. Also, D.O. levels outside the 2-4 mg/L range, particularly low levels, may promote the growth of filamentous bacteria. The D.O. will tend to change according to organic loading and, ideally, should be continuously monitored and adjusted by appropriate instrumentation and controls. In the absence of automatic equipment the D.O. should be checked at least once per day and adjusted accordingly.

3. Control sludge wasting to maintain an F:M ratio of 0.3 to 0.4.

Once the approximate influent BOD_5 is known (it should not vary too much on a day to day basis at Cache Creek) then the MLVSS can be controlled at the required level by varying the rate of sludge wasting. This F:M range will minimize bulking sludge due to a high or, particularly, low (an F:M ratio of less than 0.2 has been identified as the cause of sludge bulking in several studies) organic loading.

4. Skim clarifier floatables.

The floating solids on the clarifier should be skimmed continuously, or manually at least once per day. This will permit monitoring of the clarified effluent for pin-point floc or rising sludge on a daily basis; otherwise it is impossible to tell whether the floating sludge is recent.

5. Reinstitute aerobic digestion.

Aerobic digestion of the sludge and subsequent thickening will reduce the quantity of sludge discharged to the drying beds and thereby increase drying capacity, as well as eliminate odours now generated at the drying beds by the non-digested sludge. (The cause of digester odours during previous attempts to digest the sludge are unknown, but should be minimal provided adequate oxygen is supplied).

6. Disinfect sludge return as required to control filamentous bacteria.

If filamentous bacteria are not eliminated by a higher F:M ratio and maintenance of appropriate D.O. levels in the aeration tank and it is determined that the filamentous growth is adversely affecting the effluent, then the <u>continuous</u> injection of chlorine into the return sludge should be considered to remedy the situation.

7. Minimize influent surges.

Adjustments and/or revisions to the raw sewage lift station should be considered, such as smaller capacity pumps or trimming of impellers on existing pumps, in order to produce as constant a flow as possible to the plant.

Plant Modifications

1. Install influent screen.

Consideration should be given to replacing the existing barminutor (perhaps retain for backup) with a relatively fine screen for the removal of plastics, rags, and other nondegradable suspended solids. Removing, rather than reducing the size of, these solids will reduce diffuser plugging thereby minimizing diffuser maintenance as well as ensuring uniform mixing and oxygen supply to the entire aeration tank. Screening will also minimize floatables in the aeration tank and clarifier, and produce a cleaner sludge.

2. Provide reliable flow measurement.

In order to properly control the treatment process it is essential that accurate flow information is provided. The existing flow measuring equipment must be modified or replaced. The existing rectangular weir is not acceptable due to its width and the consequent small change in head produced for a large change in flow. A V-notch weir, or perhaps a flume, will provide more accurate flow measurement. Also, if a weir is used the point of head measurement should be removed from any surface agitation, unlike the present situation where the float is affected by turbulence generated by the influent to the weir box. The flow rate should be recorded and the flow volume totalized.

3. Modify the chlorination facilities.

Two minor modifications to the chlorination facilities should significantly improve chlorination efficiency: 1) the chlorine should be injected through a sparger pipe below the water surface at the point of maximum agitation which in this case is directly below the waterfall from the weir and, 2) installation of an underflow baffle about 1 metre downstream from the point of chlorine injection.

These modifications will provide more efficient chlorine use (higher bacteria kill per unit of chlorine applied) and reduce short circuiting. Mechanical mixing at the point of chlorine addition and additional overflow and underflow baffles through the chamber would further enhance chlorination efficiency, but at the present low flows may not be warranted.

Regular measurement of the chlorine residual and effluent bacteria levels should be made in order to optimize chlorine and sulfite usage.

4. Installation of permanent dechlorination equipment.

Permanent facilities should be installed for the storage and application of sodium sulfite, particularly a variable speed metering pump for positive dosage control.

5. Investigate land disposal alternatives.

The Cache Creek climate (hot and dry) is ideal for the land disposal of treated sewage. All land disposal options should be considered including spray irrigation and rapid infiltration. The sandy/gravelly soil of the region appears to be particularly suited to such treatment (an appropriate study should be carried out to determine land availablity and soil suitability).

1 INTRODUCTION

In November, 1981 the Environmental Protection Service undertook an evaluation of the Cache Creek Sewage Treatment Plant (STP) in order to assess the effluent impact on the Bonaparte River.

Influent and effluent samples were taken each day from November 7 to 10, 1981, preserved, and couriered to the EPS laboratory in West Vancouver for analyses. Each composite sample consisted of 4 two litre grab samples taken 1 hour apart during the period 0800 to 1200. Bacteriological analyses were carried out on site in a mobile laboratory on samples taken at several locations through the plant and from the Bonaparte River. Also, a continuous fish bioassay was carried out on the final effluent but for various reasons was not entirely successful. Other on- site measurements included aeration tank dissolved oxygen, mixed liquor settleability, and total residual chlorine. As well, microscopic examinations of the mixed liquor were carried out.

A dye tracer study of the chlorine contact chamber was carried out to determine the degree of short-circuiting and longitudinal dispersion.

2 PLANT DESCRIPTION

The Cache Creek STP services the Village of Cache Creek which has a population of about 1000.

Figure 1 is a flow schematic of the treatment process. Raw sewage is lifted by pumps to the plant where it passes through a barminutor with a bar screen bypass. The flow then splits and passes through parallel biological treatment systems; the aeration tank design most resembles that of complete-mix activated sludge. Settled sludge from the secondary clarifiers is returned to several points in the aeration tank by air-lift pumps. Some of the return sludge is continuously wasted, presently directly to the sludge drying beds as the aerobic digesters are not being used. The combined overflow from the clarifiers passes through a rectangular weir box where the flow is automatically measured. The weir overflow discharges to the chlorine contact chamber where the chlorine solution is added to the effluent surface. The Cl_2 application rate is manually controlled and the usage is generally in the 1.1 to 2.3 kg/d (2.5 to 5.0 lb/day) range. Dechlorination is accomplished by the addition of a sodium sulfite solution at the discharge end of the contact chamber. The sulfite solution is gravity fed and manually controlled. The effluent discharges from the chamber through a standpipe and buried line to a submerged outfall in the Bonaparte River.

The residence times of the major plant components at the present daily flow rate for both parallel and single system operation are compared to the approximate design residence times in Table 1. The present parallel operation provides more than adequate residence time in the aeration tanks and chlorine contact chamber, and too much time in the secondary clarifiers. The more than 10 hour residence time in the clarifiers may produce anaerobic conditions resulting in denitrification and therefore resuspension of the settled sludge by nitrogen gas. Use of only one side of the system would yield an appropriate clarifier residence time and probably adequate aeration time.

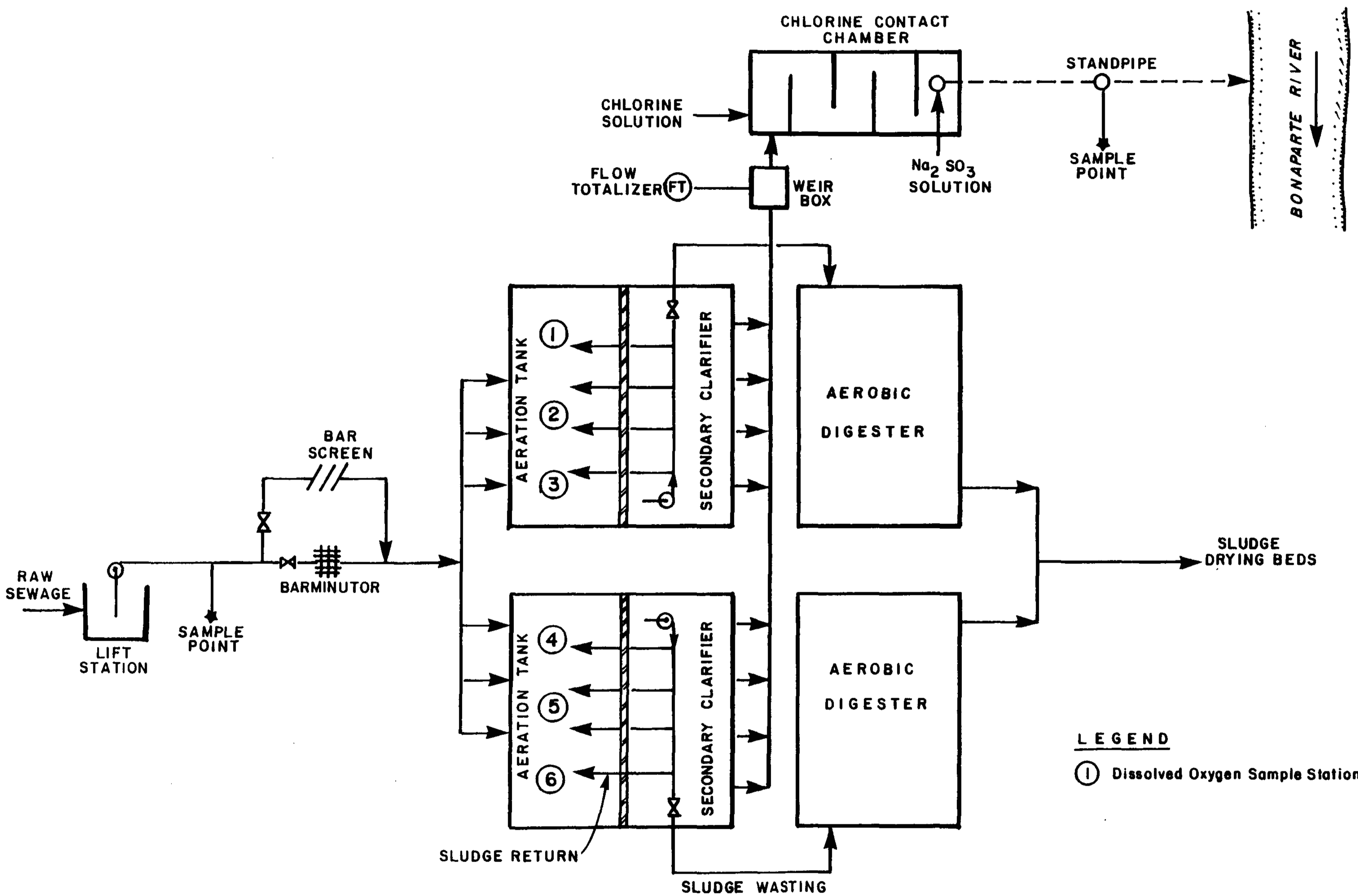


FIGURE 1 CACHE CREEK SEWAGE TREATMENT PLANT - SCHEMATIC PROCESS FLOW DIAGRAM

TABLE 1. MAJOR COMPONENT RESIDENCE TIMES

Component	Approximate Operating Volume (m^3)	THEORETICAL RESIDENCE TIME (h)[1] Present Flow Rate[2] Parallel	Single	Design[3]
Aeration Tanks	224	9.5	4.7	3.0
Clarifiers	252	10.7	5.3	3.3
Cl_2 Contact Chamber	68	2.9	2.9	0.9

1 Not including sludge recirculation

2 Assuming average daily flow rate = 567 m^3/day (150,000 USGPD)

3 1818 m^3/day (400,000 IGPD)

3 DISCUSSION OF RESULTS

3.1 Influent and Effluent Samples

The analytical results from the daily composite grab samples are presented in Table 2. As the results indicate the reduction in BOD_5 and suspended solids (non-filterable residue) across the plant was excellent at the time of sampling. This is surprising considering the quantity of floating sludge in the clarifiers. However, the underflow/overflow weir arrangement at the clarifier outlet apparently prevents this floating sludge from discharging with the effluent. Historical (Waste Management Branch permit monitoring) data presented in Table 3 indicates that effluent quality, with respect to BOD_5 and NFR, is not always as good as that experienced during this study.

The ammonia and nitrite/nitrate results (and alkalinity reduction) show that considerable nitrification is occurring in the treatment process, indicating that the residence time of the sewage in the process, the sludge age, and the oxygen supply to the biomass are sufficient to oxidize essentially all the carbonaceous matter as well as most of the ammonia.

The extractable metal results are presented in Table 4. There are no particularly unusual metal levels except for high concentrations of magnesium and calcium, and therefore high hardness (see Table 1), due to Cache Creek's hard water supply.

3.2 Process Parameters

Several process parameters were measured during the 4 day study including mixed liquor total and volatile suspended solids, mixed liquor settleability, and aeration tank dissolved oxygen. The results were used to determine the sludge volume index (SVI) and F:M (food to microorganism) ratio in order to evaluate process status.

TABLE 2. CACHE CREEK STP ANALYTICAL RESULTS[1]

PARAMETER	NOV 7		NOV 8		NOV 9		NOV 10		MEAN		%
	IN[2]	OUT[3]	IN	OUT	IN	OUT	IN	OUT	IN	OUT	REDUCTION
BOD_5	90	3	155	5	150	3	170	13	141	6	96
COD	235	40	410	35	405	55	430	55			
TOC	-	-	110	12	130	12	122	12			
TR	710	630	850	640	880	660	900	640			
TVR	250	150	350	150	340	160	350	160			
NFR	120	9	190	12	200	9	230	11	185	10	95
OIL & GREASE	26	18	83	4	45	39	71	14			
SURFACTANTS	1.7	0.15	2.8	0.15	5.5	0.15	4.4	0.13			
PHENOLS	-	-	< 0.015	< 0.015	< 0.015	< 0.015	0.03	< 0.015			
CYANIDE (CN)	-	-	< 0.04	0.04	< 0.02	0.04	< 0.02	0.04			
NH_3 (N)	24.0	2.8	33.8	1.7	30.0	2.3	27.6	1.3	29	2	93
NITRITE (N)	< 0.005	0.54	0.0064	0.319	0.0080	0.397	0.0080	0.480			
NITRATE (N)	< 0.010	12.5	< 0.010	12.4	< 0.010	11.6	< 0.010	11.1			
TOTAL PO_4 (P)	4.30	4.50	4.90	4.90	7.83	4.40	9.08	4.30			
TOTAL ALKALINITY ($CaCO_3$)	365	246	410	255	415	260	400	260			
HARDNESS	322.0	292.0	308.0	305.0	311.0	309.0	319.0	304.0			
pH	7.9	7.8	7.7	7.7	7.7	7.7	7.9	7.7			

1 All values in mg/L except pH

2 Raw sewage upstream of barminutor (See Figure 1)

3 Final effluent after chlorination/dechlorination (See Figure 1)

TABLE 3. CACHE CREEK STP EFFLUENT HISTORICAL DATA SUMMARY[1]

PARAMETER	NO. OF SAMPLES	MAX.	MIN.	MEAN	50 Percentile
pH	54	8.3	7.0	7.75	7.7
NFR (mg/L)	66	100	5	23.8	20
BOD_5 (mg/L)	55	103	10	35.7	28
Temp. (C°)	35	23	6.5	14.6	15
Total Residual Chlorine (mg/L)	99	0.9	0	0.32	0.3
Total Alkalinity (mg/L)	15	353	234	305	317
Ammonia (mg/L)	37	29	0.04	10.8	12.8
NO_2/NO_3 (mg/L)	33	20.5	0.02	7.7	5.8
COD (mg/L)	11	134	40.3	86.9	86.2
Total PO_4 (mg/L)	76	12.2	2.4	6.1	5.8
Fecal Coliform (MPN/100mL)	41	350,000	80	26,470	2,000
Total Coliform (MPN/100mL)	28	$> 2.4 \times 10^6$	500	243,340	54,000

1 Data since 1976, provided by the Waste Management Branch.

TABLE 4. CACHE CREEK STP EXTRACTABLE METALS RESULTS (mg/L)

PARAMETER	NOV 7		NOV 8		NOV 9		NOV 10	
	IN	OUT	IN	OUT	IN	OUT	IN	OUT
As	<0.075	<0.075	<0.075	<0.075	< 0.075	< 0.075	< 0.075	< 0.075
Ba	0.104	0.0412	0.0931	0.0442	0.0623	0.0443	0.0644	0.0436
Be	<0.001	<0.001	<0.001	<0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cd	<0.004	<0.004	<0.004	<0.004	< 0.004	< 0.004	< 0.004	< 0.004
Co	<0.0075	<0.0075	<0.0075	<0.0075	< 0.0075	< 0.0075	< 0.0075	< 0.0075
Cr	<0.0075	<0.0075	<0.0075	<0.0075	< 0.0075	< 0.0075	< 0.0075	< 0.0075
Cu	0.341	0.0378	0.438	0.0423	0.436	0.0866	0.487	0.0522
Hg	<0.05	<0.05	<0.05	<0.05	< 0.05	< 0.05	< 0.05	< 0.05
Mn	0.0131	0.0045	0.0177	0.001	0.0192	0.001	0.0193	0.001
Mo	<0.015	<0.015	<0.015	<0.015	< 0.015	< 0.015	< 0.015	< 0.015
Ni	<0.04	<0.04	<0.04	<0.04	< 0.04	< 0.04	< 0.04	< 0.04
P	5.08	4.55	8.63	4.77	8.93	5.18	10.0	4.8
Pb	<0.04	<0.04	<0.04	<0.04	< 0.04	< 0.04	< 0.04	< 0.04
Sb	<0.04	<0.04	<0.04	<0.04	< 0.04	< 0.04	< 0.04	< 0.04
Se	<0.075	<0.075	<0.075	<0.075	< 0.075	< 0.075	< 0.075	< 0.075
Sn	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Sr	0.333	0.297	0.320	0.313	0.320	0.318	0.332	0.312
Ti	<0.004	<0.004	<0.004	<0.004	< 0.004	< 0.004	< 0.004	< 0.004
V	<0.02	<0.02	<0.02	<0.02	< 0.02	< 0.02	< 0.02	< 0.02
Zn	0.0646	0.023	0.0853	0.0203	0.0958	0.0163	0.0945	0.0144
Al	0.127	<0.05	0.328	<0.05	0.341	< 0.05	0.255	< 0.05
Fe	0.144	0.0608	0.227	0.0412	0.249	0.0304	0.232	0.0337
Si	8.7	8.64	9.07	9.11	10.1	9.29	9.86	9.01
Mg	37.2	33.8	35.5	35.5	35.8	36.0	36.6	35.2
Na	49.5	55.5	58.1	58.7	75.5	64.8	90.1	61.0
Ca	67.6	61.3	64.8	63.8	65.6	64.4	67.3	63.8

The mixed liquor total and volatile suspended solids results are presented in Table 5. The total suspended solids along with the 30 minute settling results for the mixed liquor are used to calculate the SVI (Table 6). The SVI is an index of the volume of settled solids per weight of settled solids and is, therfore, an indication of mixed liquor settle-ability. Generally, values over 150 indicate poor settleability and those below 100 good settleability. As the SVI results in Table 6 indicate, at the time of this study the Cache Creek STP mixed liquor demonstrated very poor settling characteristics. Microscopic examination of the mixed liquor confirmed the presence of filamentous bacteria which prevent the biomass from properly flocculating for good settleability. Despite the poor mixed liquor settling characteristics the effluent had remarkably low suspended solids levels because although the mixed liquor settled slowly the supernatant was quite clear. Time constraints did not permit determination of the exact cause of the filamentous growth, however, it may be due to a low F:M ratio. In other words the organic loading (influent BOD_5) is too low for the quantity of biomass in the aeration tanks. Four estimates of Cache Creek's F:M varied from 0.15 to 0.26 day^{-1} (Table 7) which is on the border of the reported allowable minimum of 0.2 day^{-1} needed to prevent filamentous growth; the recommended F:M ratio for complete-mix activated sludge design is 0.3 to 0.4 day^{-1} to produce a well-flocculated and settleable sludge. Many different causes of bulking sludge have been identified besides a low F:M ratio, including a high influent temperature and a change in influent temperature, either of which may explain seasonal excesses of filamentous bacteria growth at Cache Creek.

Daily measurements of the aeration tanks' dissolved oxygen concentrations were made (Table 8) and were considerably higher in the east tank (ranging from 3.7 to 6.8 mg/L) than in the west tank (ranging from 1.4 to 2.3 mg/L), indicating that the west tank was receiving less air and/or a higher organic load. This inequity demonstrates one problem of manually controlling a parallel system.

TABLE 5. MIXED LIQUOR RESULTS[1]

DATE	EAST TANK NFR (mg/L)[2]	EAST TANK NFVR (mg/L)[3]	EAST TANK % Volatile	WEST TANK NFR (mg/L)	WEST TANK NFVR (mg/L)	WEST TANK % Volatile
Nov. 7	1560	1280	82	1990	1700	85
Nov. 8	1820	1520	84	1990	1690	85
Nov. 9	1650	1370	83	1800	1550	86
Nov. 10	1730	1460	84	2070	1790	86

1 All samples were grabs taken between 0900 and 1130h

2 Non-filterable residue (MLSS)

3 Non-filterable volatile residue (MLVSS)

TABLE 6. SLUDGE VOLUME INDEX

DATE	EAST TANK			WEST TANK		
	SETTLING (mL/L)[1]	NFR (mg/L)	SVI	SETTLING (mL/L)	NFR (mg/L)	SVI
Nov. 7	490	1560	314	510	1990	256
Nov. 8	810	1820	445	790	1990	397
Nov. 9	610	1650	370	630	1800	350

1 Settled volume of 1 litre of mixed liquor in a 1 litre graduated cylinder after 30 minutes.

TABLE 7. FOOD: MICROORGANISM RATIOS

DATE	MEAN[1] NFVR (mg/L)	TOTAL BIOMASS [M](kg)[2]	INFLUENT BOD_5 (mg/L)	BOD_5 LOAD [F](kg/day)[3]	F:M
Nov. 7	1490	334	90	51	0.15
Nov. 8	1605	360	155	88	0.24
Nov. 9	1460	327	150	85	0.26
Nov. 10	1625	364	170	96	0.26

1 mean of the 2 aeration tanks
2 biomass in aeration tanks only, not including biomass in clarifier
3 assumes daily flow of 567 m^3/day

TABLE 8. AERATION TANK DISSOLVED OXYGEN RESULTS (mg/L)[1]

	EAST TANK			WEST TANK		
DATE / SAMPLE STATION[2]:	1	2	3	4	5	6
Nov. 7	6.8	5.9	4.8	2.2	2.3	2.1
Nov. 8	5.4	4.8	3.7	1.9	1.5	1.5
Nov. 9	5.5	4.5	3.9	1.9	1.7	1.4

1 all samples were at 15.0°C

2 see Figure 1 for sample station locations

The Cache Creek STP physical design does not strictly meet any of the most common activated sludge variations but is closest to that of the complete-mix, as previously mentioned. However, a comparison of process design parameters presented in Table 9 shows that the Cache Creek STP is significantly underloaded both organically and volumetrically. Operating in the parallel mode, the plant also has considerable excess hydraulic capacity (Table 1). As pointed out in Section 2 the long residence time in the secondary clarifiers may result in resuspension of the settled sludge due to denitrification and explain why there was so much floating sludge on the clarifiers at the time of the study. Also, the clarifier overflow rate of 4 to 8 $m^3/day/m^2$ (100 to 200 USGPD/ft^2) is substantially less than typical design of about 30 $m^3/day/m^2$ (740 USGPD/ft^2) for activated sludge clarifiers. These data suggest that the plant would operate closer to typical design values if only one side of the parallel system was utilized. This mode of operation should provide easier control of the process, and result in less maintenance.

3.3 Flow Measurement

A record of instantaneous and daily flows, and the method of measurement during the study are presented in Table 10.

The existing rectangular weir is not appropriate for the low flows experienced at the Cache Creek plant. The weir edge is too long (0.66m) resulting in a head of only about 0.1 feet (0.03m). A V-notch weir will provide more accurate flow measurement at the present flow rates and even at the design rate of 1800 m^3/day. (V-notch weirs are recommended for flows less than 2450 m^3/day [450 USGPM]). Also, the weir box should be longer and/or baffled to reduce water surface turbulence at the point of head measurement. A check of the weir on November 7 by measuring the rate of change in the chlorine contact chamber volume, revealed the difficulty in obtaining a reliable flow rate with the weir. The existing flow instrument should be refurbished or replaced with a new instrument to

TABLE 9. COMPARISON OF SOME TYPICAL DESIGN PARAMETERS WITH CACHE CREEK STP

PARAMETER	CACHE CREEK STP	TYPICAL COMPLETE MIX DESIGN[1]
F:M (organic loading)	0.15 - 0.26	0.2 - 0.6
Volumetric loading (lb BOD_5/day/1000 ft^3)	25	50 - 120
MLSS (mg/L)	1500 - 2000	3000 - 6000

1 Metcalf and Eddy Inc. "Wastewater Engineering: Collection, Treatment, Disposal". McGraw-Hill Inc. 1972

TABLE 10. FLOW MEASUREMENT RESULTS

DATE	TIME	FLOW (m^3/day) INSTANTANEOUS	FLOW (m^3/day) DAILY	METHOD
Nov. 7/81	1500	783	-	Volume change in Cl_2 contact chamber
	1530	621	-	Weir
Nov. 8/81	0900	-	420	Flow totalizer
	1400	801	-	Weir
Nov. 9/81	1055	-	550	Flow totalizer
	0800	711	-	Weir
	0950	849	-	Weir
	1155	802	-	Weir
	1350	667	-	Weir
Nov. 10/81	0835	-	432	Flow totalizer
	1410	667	-	Weir

provide reliable flow recording and totalizing. A graduated stick should be permanently installed in the weir box as a manual check of the head and therefore the flow instrument, and as backup to the instrument when it is out of service.

3.4 Bacteriology

Samples were taken for bacteriological analyses at several stations through the plant and upstream and downstream of the outfall in the Bonaparte River. The complete results are presented in Appendix 1. A summary of the fecal coliform and fecal streptococci results across the plant is presented in Table 11.

The mean influent fecal coliform levels of 5.0×10^6 counts/ 100mL is typical for raw sewage, as is the order of magnitude reduction across both aeration and secondary clarification. Human feces are reported (1) to have a FC:FS ratio of 4.4, while other warm-blooded animals a FC:FS ratio of less than 0.7. The raw influent FC:FS ratio at Cache Creek ranged from 1.3 to 3.4 with a mean of 2.3, suggesting that there may be some animal sources in the sewage collection system.

The fecal coliform and fecal streptococci results for the Bonaparte River samples are summarized in Table 12. The results indicate a marginal increase in fecal coliform bacteria levels downstream of the STP discharge. The Bonaparte River winds through considerable pastureland immediately north of the Village where grazing animals appeared to have direct access to the River and most certainly are at least partially responsible for the elevated background bacteria levels. These levels probably increase substantially at times of precipitation due to the resultant landwash effect, and likely produce larger numbers of bacteria to the River than the STP effluent.

TABLE 11. CACHE CREEK STP BACTERIOLOGICAL SUMMARY

LOCATION	FECAL COLIFORM MEAN NO. OF SAMPLES	FECAL COLIFORM MEAN counts/100 mL	FECAL STREPTOCOCCI MEAN NO. OF SAMPLES	FECAL STREPTOCOCCI MEAN counts/100 mL	MEAN FC:FS
Raw Influent	5	5.0×10^6	5	2.1×10^6	2.3
Aeration Tanks	16	3.9×10^5	15	2.8×10^6	-
Clarifier Effluent	15	4.8×10^4	15	4.9×10^4	-
Final Effluent	12	3.6×10^2	12	8.3×10^2	-

TABLE 12. BONAPARTE RIVER BACTERIOLOGICAL SUMMARY

LOCATION	FECAL COLIFORM MEAN NO. OF SAMPLES	FECAL COLIFORM MEAN counts/100 mL	FECAL STREPTOCOCCI MEAN NO. OF SAMPLES	FECAL STREPTOCOCCI MEAN counts/100 mL
Upstream of STP Discharge	8	22	7	51
Downstream of STP Discharge	8	32	8	46

3.5 Chlorination/Dechlorination

Total residual chlorine analyses were performed several times a day on the final effluent. These results along with the chlorine and sodium sulfite usage, and the effluent fecal coliform levels are presented in Table 13.

During the first two days, the amount of sodium sulfite added was not sufficient to reduce the chlorine, and consequently a chlorine residual existed in the final effluent and fish died in the bioassay (bioassay results are in Appendix 2). A subsequent adjustment by the operator to the rate of chlorine and sulfite addition on November 9 resulted in little or no chlorine residual and no dead or apparently dying fish in the bioassay. Effluent fecal coliform levels increased on November 10 but were about the same as the counts on November 8, and therefore cannot necessarily be attributed to the reduced chlorine usage.

Improved chlorine application and contact chamber design will provide more efficient chlorine contact and allow relatively less chlorine usage (see Section 3.6).

3.6 Chlorine Contact Chamber Dye Study

A residence time investigation of the chlorine contact chamber (Figure 2) using fluorescent dye was carried out to determine the degree of short circuiting and longitudinal dispersion (backmixing).

A slug dose of Rhodamine WT dye, equivalent to about 10 ug/L if the dye were completely mixed with the entire contact chamber volume, was added to the contact chamber below the weir at the point of sewage inflow. The contact chamber effluent dye concentration was continuously monitored using a Turner fluorometer with flow-through appurtenances and a recorder. The results are plotted in Figure 3. Fluorescent measurements were ceased after 190 minutes due to darkness, and the curve beyond this time is extrapolated.

TABLE 13. CHLORINATION/DECHLORINATION RESULTS

DATE	TIME	Cl_2 USAGE (lb/day)	SULFITE USAGE (lb/day)[1]	EFFLUENT TRC[2]	EFFLUENT FC/100 mL
Nov. 7	0800	4.75	1.73	N.D.[3]	10
	1100	"	"	N.D.	10
	1300	"	"	0.1	160
Nov. 8	0800	"	"	0.46, 0.42	390
	1100	"	"	N.D.	1400
	1300	"	"	0.15	230
Nov. 9	0800	"	"	N.D.	10
	0915	"	"	1.15	N.D.
	1100	"	2.73	0.44	20
	1300	2.50	"	0.06	190
	1630	"	"	0.04	N.D.
Nov. 10	0800	"	"	0.04	60
	0900	"	"	0.04	N.D.
	1100	"	"	N.D.	510
	1300	"	"	N.D.	1300

1 Assumes 9.5 lb Na_2SO_3 added to 200 L of water (operator information)
2 total residual chlorine by DPD colourimetric method using Hach Model CN-70
3 Not Determined

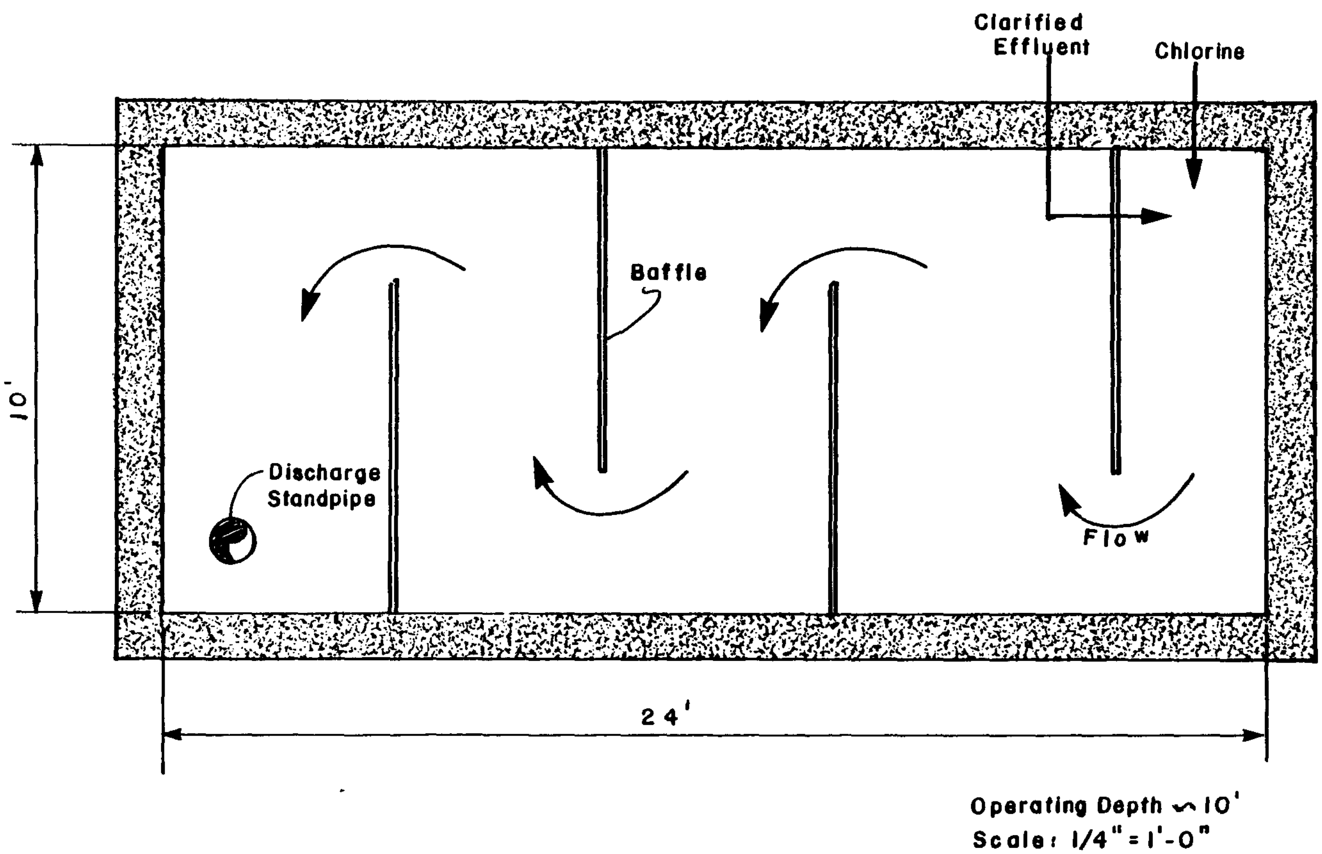
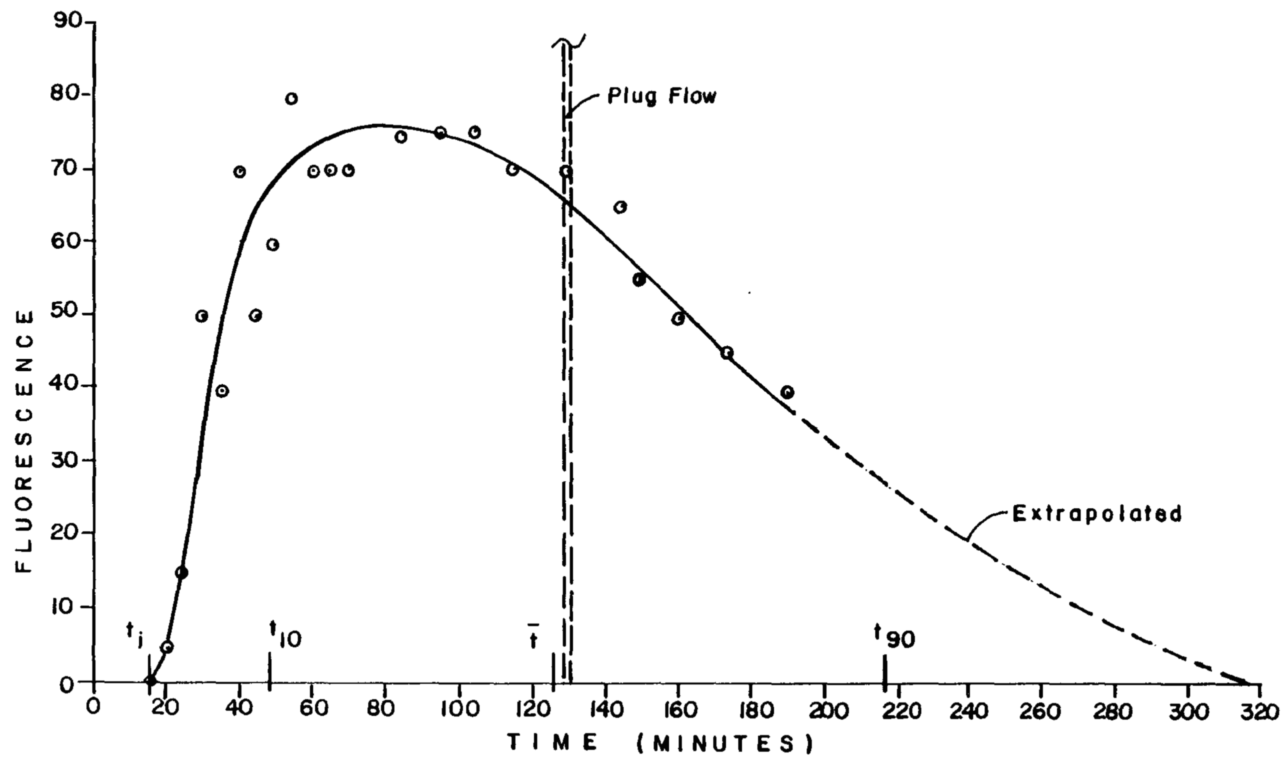


FIGURE 2 CACHE CREEK CHLORINE CONTACT CHAMBER



LEGEND

$T = \frac{V}{Q} = 129$ Minutes★ - Theoretical Residence Time

$\bar{t}$ = 126 Min. - Mean Residence Time

t_i = 16 Min. - Time to First Dye passing Tank Outlet

t_{10} = 49 Min. - Time to 10% of Dye passing Tank Outlet

t_{90} = 217 Min. - Time to 90% of Dye passing Tank Outlet

t_{90}/t_{10} = 4.4 - Morrill Index

Dispersion Number ~ 5

★ - assumes a Flow Rate of 757 m^3/d (200,000 USGPD)

FIGURE 3 CHLORINE CONTACT CHAMBER DYE TRACER RESULTS

The theoretical residence time of 129 minutes is based on an estimated flow rate at the time of the dye test of 757 m^3/day (200,000 USGPD); flow measurement problems at this site are discussed in Section 3.6. This means that if the contact chamber provided the ideal, i.e. plug flow, then all the dye would reach the chamber outlet 129 minutes after injection. The ideal never occurs in such a system due to short circuiting and dispersion and the result is a distribution of dye in the effluent. However, in Cache Creek's case the curve is much more spread out than it should be indicating extreme dispersion (Figure 3).

The time to initial trace of dye in the effluent, t_i, is only 16 minutes which demonstrates severe short circuiting. The main reason for this is probably the fact that both the inlet and the outlet are at the surface, and that there are no underflow baffles to force the flow down to the bottom of the chamber.

The Morrill Index and dispersion number are indicators of longitudinal dispersion (backmixing). A Morrill Index of 1.0 represents plug flow and the higher the value is above 1.0 the greater the dispersion, and therefore the more spread out the curve. Index values greater than 3.0 represent "a large amount of dispersion" (2). The Morrill Index at Cache Creek was 4.4.

The dispersion number, which equals 0 for plug flow and infinity for completely mixed flow, was calculated after Levenspiel (3). According to Levenspiel a value of 0.2 represents a large amount of dispersion. In this study the dispersion number is approximately 5 and like the Morrill Index indicates much dispersion is occurring.

There are probably several reasons for the short circuiting and dispersion including:

i) both inlet and outlet are at the surface

ii) there is no underflow/overflow baffling

iii) the low length-to-width ratio of approximately 12

iv) the high height to width ratio which ranges from 2 to 3

The first two items were discussed previously and installation of 3 or 5 alternating underflow/overflow baffles would significantly reduce short circuiting. The length-to-width ratio of 12 is quite low and should be in excess of 20 in order to achieve any degree of plug flow. Also, the more turns (in this case 4) in the chamber the greater the number of dead spaces resulting in increased short circuiting. A better design for this chamber would be to have 2 lengthwise baffles rather than 4 widthwise baffles, thereby reducing the number of turns to 2 and increasing the L:W ratio to about 24. With regard to the height (water depth): width ratio, one study (4) concluded that this value should be less than 1.0 in order to minimize the effects of density currents and sidewall drag on the liquid, thereby reducing dispersion.

Apart from plug flow the efficiency of disinfection by chlorination is very dependent on initial mixing. Rapid mixing using an hydraulic pump or mechanical mixer immediately downstream of chlorine injection provides efficient use of the chlorine by maximizing free chlorine/bacteria contact before the chlorine is converted to chloramines and other less effective disinfectants.

The combination of rapid initial mixing and plug flow results in more efficient use of chlorine and therefore less chlorine usage for the same degree of disinfection.

The efficiency of this contact tank could be significantly improved with 2 minor modifications:

1) inject the Cl_2 solution under pressure through a sparger pipe below the water surface underneath the influent waterfall.
2) install an underflow baffle immediately downstream of the inlet mixing zone. This will separate the agitation caused by the mixing from the plug flow region of the chamber as well as force the influent to the bottom of the tank and increase distribution through the entire tank cross section.

Further modifications including mechanical mixing and/or additional alternating overflow/underflow baffles could be added at a later date if deemed necessary.

Chlorine usage could be minimized by removing chlorine demanding settled solids from the chamber on a regular basis. Less Cl_2 usage reduces sodium sulfite requirements and therefore the costs associated with both.

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NOMENCLATURE

L	litre
mL	millilitre
kg	kilogram
mg	milligram
h	hour
d	day
m	metre
lb	pound
USGPD	United States gallons per day
IGPD	Imperial gallons per day
D.O.	dissolved oxygen
STP	sewage treatment plant
F:M	food to microorganism ratio
SVI	sludge volume index
MLSS	mixed liquor suspended solids
MLVSS	mixed liquor volatile suspended solids
BOD_5	biochemical oxygen demand
COD	chemical oxygen demand
TOC	total organic carbon
TR	total residue
TVR	total volatile residue
NFR	non-filterable residue

APPENDIX 1

BACTERIOLOGICAL RESULTS

By

B.H. Kay

Introduction

Samples for bacteriological analysis were collected from the raw influent (CC01), each of the two aeration tanks (CC02, CC02A), each of the two clarifiers (CC03, CC03A), through the chlorine contact chamber (CC04A, CC04B, CC04C, CC04), and from the final dechlorinated effluent (CC05). Sampling at CC03 and CC03A was discontinued after the 0800 samples on Nov. 9 and replaced with CC03C, a sample of the combined clarifier effluents. The bacteriological results are summarized in Table 1a and presented graphically in Figures 1a-6a. The daily bacteriological results are presented in Table 4a. Sample station locations are shown in Figure 7a.

Total Coliforms

Total coliform measurements were made on the raw influent and final effluent samples. Due to difficulties with culture media quality and/or interferences from other organisms, there is very little total coliform data. The data that was obtained showed a 99.921% reduction in total coliform densities between the influent and final effluent samples.

Fecal Coliforms

Fecal coliform (FC) analyses were conducted two or three times daily at all treatment plant sample points. Figure 1a illustrates the decrease in FC levels through the plant. Approximately a 1 $\log_{10}$ unit decrease in FC densities occurs after each treatment stage with a 2 $\log_{10}$ drop occurring due to chlorination.

Percent reduction of fecal coliforms after each treatment stage is presented in Table 2a. The cause of the apparent increase in FC between chlorinated and final effluent samples (CC04 and CC05, respectively) is unknown. Additional sulfite was added to the sampling bottles for CC04 and CC05 following the 0800 h sampling on Nov. 11 to ensure that disinfection was halted in the sample bottles during storage prior to analysis. A comparison of results for the two treatments is presented below:

	Fecal Coliforms (counts/100 mL)	
	Station CC04	Station CC05
	< 10	< 10
Without additional	10	390
Sulfite	< 10	10
	90	< 10
	40	1400
		160
		230
Mean FC/100 mL	(<)38	(<)316
	20	20
With additional	790	510
Sulfite	< 10	190
	500	4300
Mean FC/100 mL	(<)218	1255

The data shows that FC levels in the final effluent were higher regardless of the addition of extra sulfite to the sample bottles.

Levels of FC through the plant remained fairly constant at all sampling times (Figure 3a) with slightly higher levels occurring at the 1100 h and 1300 h sampling times compared to the 0800 h samples.

Samples collected through the chlorine contact chamber were analyzed for FC and the results are shown in Figure 5a. Considerable variation was noted in the FC levels, particularly at stations CC04C and CC04. This presumably was the result of changes in chlorine addition rates as well as mixing and influent (to chlorine contact chamber) quality.

Fecal Streptococci

All samples analyzed for FC were also analyzed for fecal streptococci (FS). Unlike FC, the FS densities increased after aeration but then dropped to levels similar to FC after clarification (Figure 2a). Final effluent levels were in the same range as FC although were somewhat more variable.

FS levels through the plant were relatively constant at all sampling times as illustrated in Figure 4a.

The decrease in FS through the chlorine contact chamber is similar to that observed for FC (Figure 6a), with FC levels being slightly higher.

Calculation of the FC:FS ratio presents some interesting results. The raw influent for example has an FC:FS ratio of 2.3 (Table 3). This value does not agree with literature values for municipal sewage which state that such effluents have FC:FS ratios in excess of 4.4. The reason for this discrepancy is unknown. The variation in ratios through the plant reflect the differential die-off rates for fecal coliforms and fecal streptococci.

Standard Plate Count

Limited sampling for this parameter was undertaken with the exception of the influent and final effluent sampling points. The treatment and disinfection of the sewage resulted in a 99.585% reduction in bacterial numbers.

Bonaparte River

Samples collected 40 m upstream (BR01A & BR01B) and 60 m downstream (BR02A & BR02B) of the effluent discharge did not differ significantly for TC, FC, FS or SPC measurements. During this study, the discharge of sewage from the Cache Creek STP did not result in elevated levels of indicator bacteria in the river.

TABLE 1a. SUMMARY OF BACTERIOLOGICAL DATA

Sample Station	Total Coliform/100 mL # of Samples	Total Coliform/100 mL Range	Total Coliform/100 mL Mean	Fecal Coliform/100 mL # of Samples	Fecal Coliform/100 mL Range	Fecal Coliform/100 mL Mean	Fecal Streptococci/100 mL # of Samples	Fecal Streptococci/100 mL Range	Fecal Streptococci/100 mL Mean	Standard Plate Count/mL # of Samples	Standard Plate Count/mL Range	Standard Plate Count/mL Mean
CC01 (0800)	--	--	--	2	$1.0 \times 10^6 - 1.1 \times 10^7$	6.0×10^6	2	$3.0 \times 10^5 - 5.0 \times 10^6$	2.9×10^6	3	$1.9 \times 10^6 - 4.4 \times 10^6$	3.0×10^6
CC01 (1100)	--	--	--	2	$1.6 \times 10^6 - 5.5 \times 10^6$	3.6×10^6	2	$6.0 \times 10^5 - 2.8 \times 10^6$	1.7×10^6	3	$2.9 \times 10^6 - 7.1 \times 10^6$	5.2×10^6
CC01 (1300)	1	--	3.8×10^6	1		6.1×10^6			1.7×10^6	1	--	4.0×10^6
CC01 (All)	1	--	3.8×10^6	5	$1.0 \times 10^6 - 1.1 \times 10^7$	5.0×10^6	5	$3.0 \times 10^5 - 5.0 \times 10^6$	2.1×10^6	7	$1.9 \times 10^6 - 7.1 \times 10^6$	4.1×10^6
CC02 (0800)	--	--	--	3	$1.9 \times 10^5 - 5.8 \times 10^5$	3.6×10^5	3	$6.1 \times 10^5 - 7.3 \times 10^6$	3.3×10^6	1	--	1.3×10^6
CC02 (1100)	--	--	--	3	$2.8 \times 10^5 - 9.2 \times 10^5$	5.3×10^5	2	$1.8 \times 10^6 - 1.9 \times 10^6$	1.9×10^6	--	--	--
CC02 (1300)	--	--	--	2	$3.2 \times 10^5 - 5.7 \times 10^5$	4.5×10^5	2	$2.1 \times 10^6 - 5.4 \times 10^6$	7.8×10^6	--	--	--
CC02 (All)	--	--	--	8	$1.9 \times 10^5 - 9.2 \times 10^5$	4.5×10^5	7	$6.1 \times 10^5 - 7.3 \times 10^6$	3.0×10^6	1	--	1.3×10^6
CC02A (0800)	--	--	--	3	$3.1 \times 10^5 - 3.9 \times 10^5$	3.6×10^5	3	$2.5 \times 10^6 - 3.5 \times 10^6$	3.1×10^6	1	--	1.2×10^5
CC02A (1100)	--	--	--	3	$2.6 \times 10^5 - 4.9 \times 10^5$	3.7×10^5	3	$1.6 \times 10^6 - 2.8 \times 10^6$	2.0×10^6	--	--	--
CC02A (1300)	--	--	--	2	$1.8 \times 10^5 - 3.7 \times 10^5$	2.8×10^5	2	$2.0 \times 10^6 - 3.5 \times 10^6$	2.8×10^6	--	--	--
CC02A (All)	--	--	--	8	$2.6 \times 10^5 - 5.7 \times 10^5$	3.4×10^5	8	$1.6 \times 10^6 - 5.4 \times 10^6$	2.6×10^6	1	--	1.2×10^5
CC02/CC02A (All)	--	--	--	16	$1.9 \times 10^5 - 9.2 \times 10^5$	3.9×10^5	15	$6.1 \times 10^5 - 7.3 \times 10^6$	2.8×10^6	2	--	7.1×10^5
CC03 (0800)	--	--	--	3	$2.1 \times 10^4 - 4.0 \times 10^4$	3.1×10^4	3	$3.2 \times 10^4 - 8.0 \times 10^4$	5.0×10^4	1	--	1.1×10^5
CC03 (1100)	--	--	--	2	$6.5 \times 10^4 - 1.3 \times 10^5$	9.8×10^4	2	$1.3 \times 10^5 - 1.5 \times 10^5$	1.4×10^5	--	--	--
CC03 (All)	--	--	--	5	$2.1 \times 10^4 - 1.3 \times 10^5$	5.8×10^4	5	$3.2 \times 10^4 - 1.5 \times 10^5$	8.6×10^4	1	--	1.1×10^5
CC03A (0800)	--	--	--	3	$9.0 \times 10^3 - 3.3 \times 10^4$	1.9×10^4	3	$8.0 \times 10^3 - 8.0 \times 10^4$	3.3×10^4	1	--	1.5×10^5
CC03A (1100)	--	--	--	2	$6.2 \times 10^4 - 7.0 \times 10^4$	6.6×10^4	2	$2.2 \times 10^4 - 5.0 \times 10^4$	3.6×10^4	--	--	--
CC03A (All)	--	--	--	5	$9.0 \times 10^3 - 7.0 \times 10^4$	3.8×10^4	5	$8.0 \times 10^3 - 8.0 \times 10^4$	3.4×10^4	1	--	1.5×10^5
CC03C (0800)	--	--	--	1	--	2.2×10^4	1	--	3.2×10^4	--	--	--
CC03C (1100)	--	--	--	2	$4.3 \times 10^4 - 6.0 \times 10^4$	5.2×10^4	2	$2.6 \times 10^4 - 2.7 \times 10^4$	2.7×10^4	--	--	--
CC03C (1300)	--	--	--	2	$5.3 \times 10^4 - 6.3 \times 10^4$	5.8×10^4	2	$1.5 \times 10^4 - 3.5 \times 10^4$	2.5×10^4	--	--	--
CC03/CC03A/ CC03C (All)	--	--	--	15	$9.0 \times 10^3 - 1.3 \times 10^5$	4.8×10^4	15	$8.0 \times 10^3 - 1.5 \times 10^5$	4.9×10^4	2	$1.1 \times 10^5 - 1.5 \times 10^5$	1.3×10^5
CC04 (0800)	--	--	--	4	< 10 - 90	30	4	10 - 320	1.7×10^2	1	--	320
CC04 (1100)	--	--	--	4	20 - 790	2.4×10^2	4	20 - 460	1.6×10^2	--	--	--
CC04 (1300)	--	--	--	2	< 10 - 500	2.6×10^2	2	$50 - 1.6 \times 10^3$	8.3×10^2	--	--	--
CC04 (All)	--	--	--	10	< 10 - 790	1.6×10^2	10	$10 - 1.6 \times 10^3$	3.0×10^2	1	--	320
CC04 A	--	--	--	2	$6.9 \times 10^3 - 1.5 \times 10^4$	1.1×10^4	2	$2.8 \times 10^3 - 6.4 \times 10^3$	4.6×10^3	--	--	--
CC04 B	--	--	--	3	$1.4 \times 10^3 - 5.9 \times 10^3$	3.1×10^3	2	$1.2 \times 10^3 - 1.6 \times 10^3$	1.6×10^3	--	--	--
CC04 C	--	--	--	3	$10 - 2.9 \times 10^3$	1.1×10^3	2	290 - 600	4.5×10^2	--	--	--
CC05 (0800)	3	10 - 800	2.7×10^2	4	< 10 - 390	1.2×10^2	4	< 10 - 490	2.4×10^2	3	$1.0 \times 10^3 - 1.4 \times 10^4$	6.6×10^3
CC05 (1100)	2	500 - 2700	1.6×10^3	4	$< 10 - 1.4 \times 10^3$	4.9×10^2	4	$40 - 2.4 \times 10^3$	8.9×10^2	3	$6.2 \times 10^3 - 2.6 \times 10^4$	1.4×10^4
CC05 (1300)	2	$< 10 - 1.7 \times 10^4$	8.5×10^3	4	$160 - 1.3 \times 10^3$	4.7×10^2	4	$90 - 4.3 \times 10^3$	1.5×10^3	3	$1.6 \times 10^4 - 4.7 \times 10^4$	3.2×10^4
CC05 (All)	7	$< 10 - 1.7 \times 10^4$	3.0×10^2	12	$< 10 - 1.4 \times 10^3$	3.6×10^2	12	$< 10 - 4.3 \times 10^3$	8.3×10^2	9	$1.0 \times 10^3 - 4.7 \times 10^4$	1.7×10^4
River:												
BR01 A	4	6 - 66	39	4	12 - 50	25	3	28 - 130	64	3	$1.5 \times 10^2 - 4.9 \times 10^2$	2.7×10^2
BR01 B	4	8 - 52	23	4	4 - 30	18	4	32 - 150	68	3	$1.6 \times 10^2 - 3.5 \times 10^2$	2.4×10^2
BR02 A	4	10 - 158	71	4	12 - 82	41	4	24 - 64	44	3	$2.3 \times 10^2 - 3.4 \times 10^2$	2.8×10^2
BR02 B	4	10 - 148	66	4	8 - 42	23	4	24 - 66	49	3	$1.6 \times 10^2 - 3.0 \times 10^2$	2.3×10^2

Table 2a. PERCENT REDUCTION OF BACTERIA LEVELS AT VARIOUS TREATMENT STAGES

Parameter	% Reduction From Influent			
	Post-Aeration	Post-Clarification	Post-Chlorination	Final Effluent
Fecal Coliform	92.2	99.04	99.997	99.993
Fecal Streptococci	(33.3)	97.66	99.986	99.960
Total Coliform	--	--	--	99.921
Standard Plate Count	82.63	96.83	99.992	99.585

Table 3a. FC:FS RATIOS AT VARIOUS TREATMENT STAGES

Treatment Stage	FC:FS Ratio
Influent	2.3
Post-Aeration	0.14
Post-Clarification	0.98
Post-Chlorination	0.53
Final Effluent	0.43

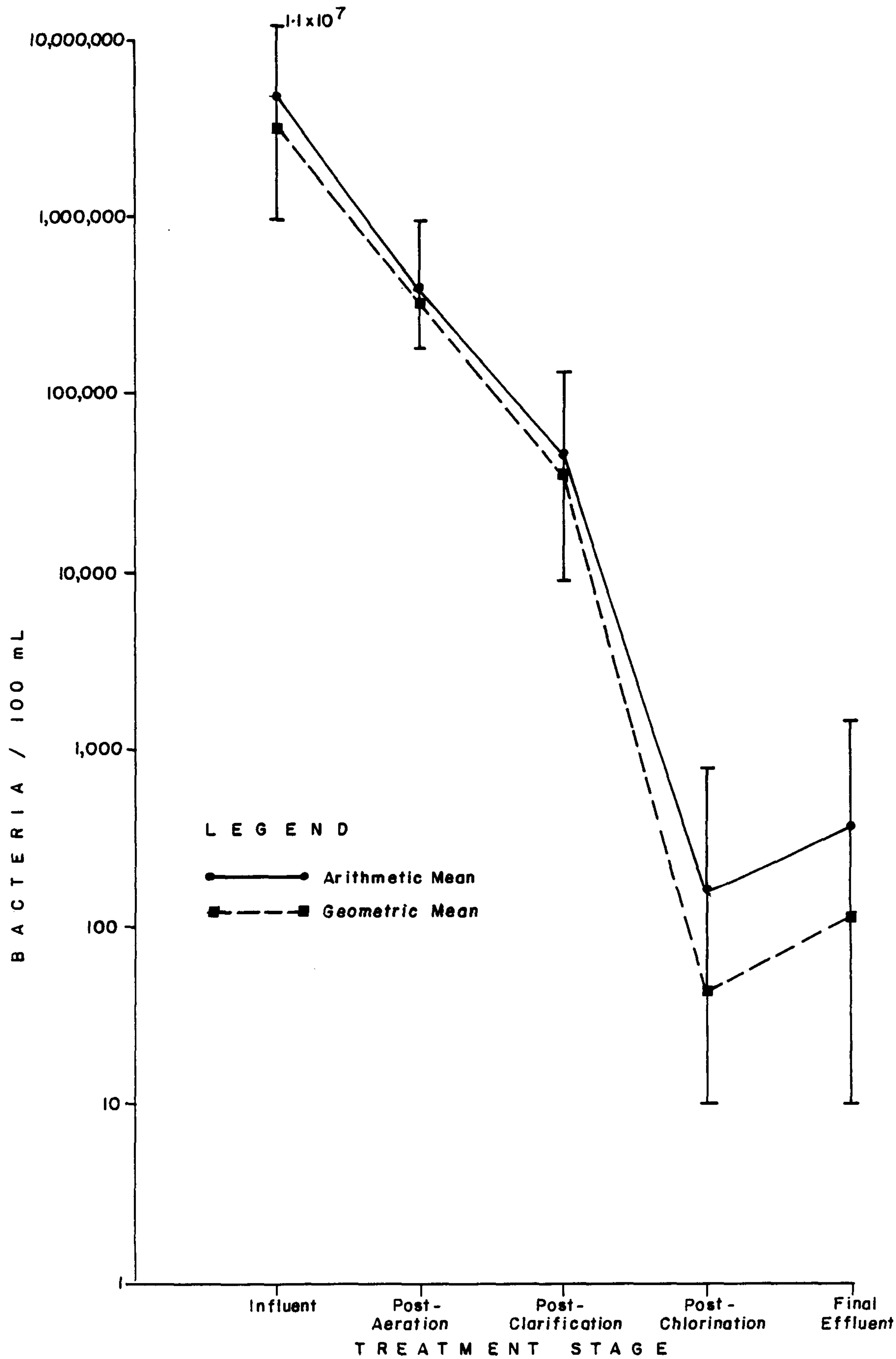

FIGURE 1a MEAN FECAL COLIFORM LEVELS AT VARIOUS TREATMENT STAGES

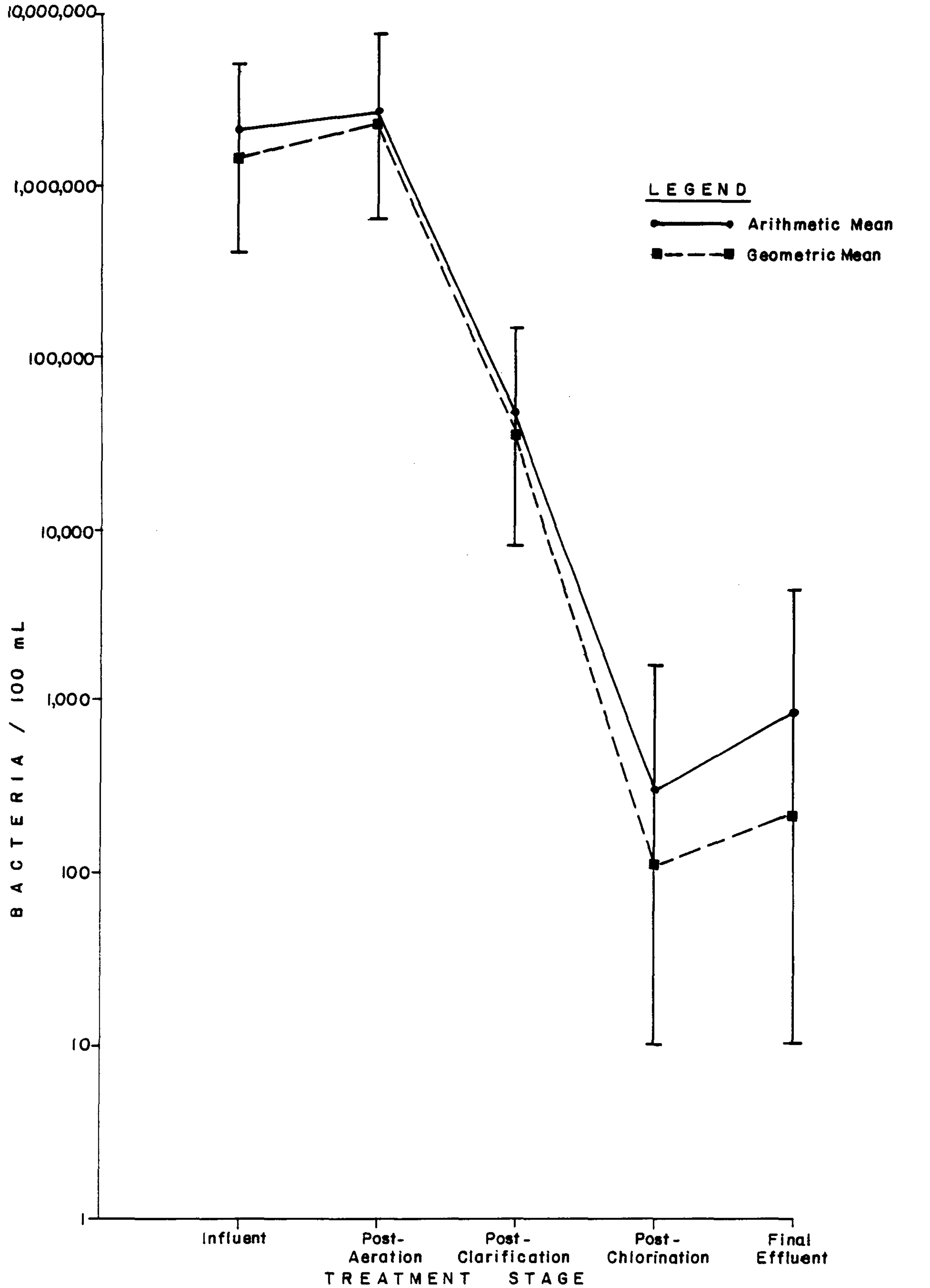

FIGURE 2a MEAN FECAL STREPTOCOCCI LEVELS AT VARIOUS TREATMENT STAGES

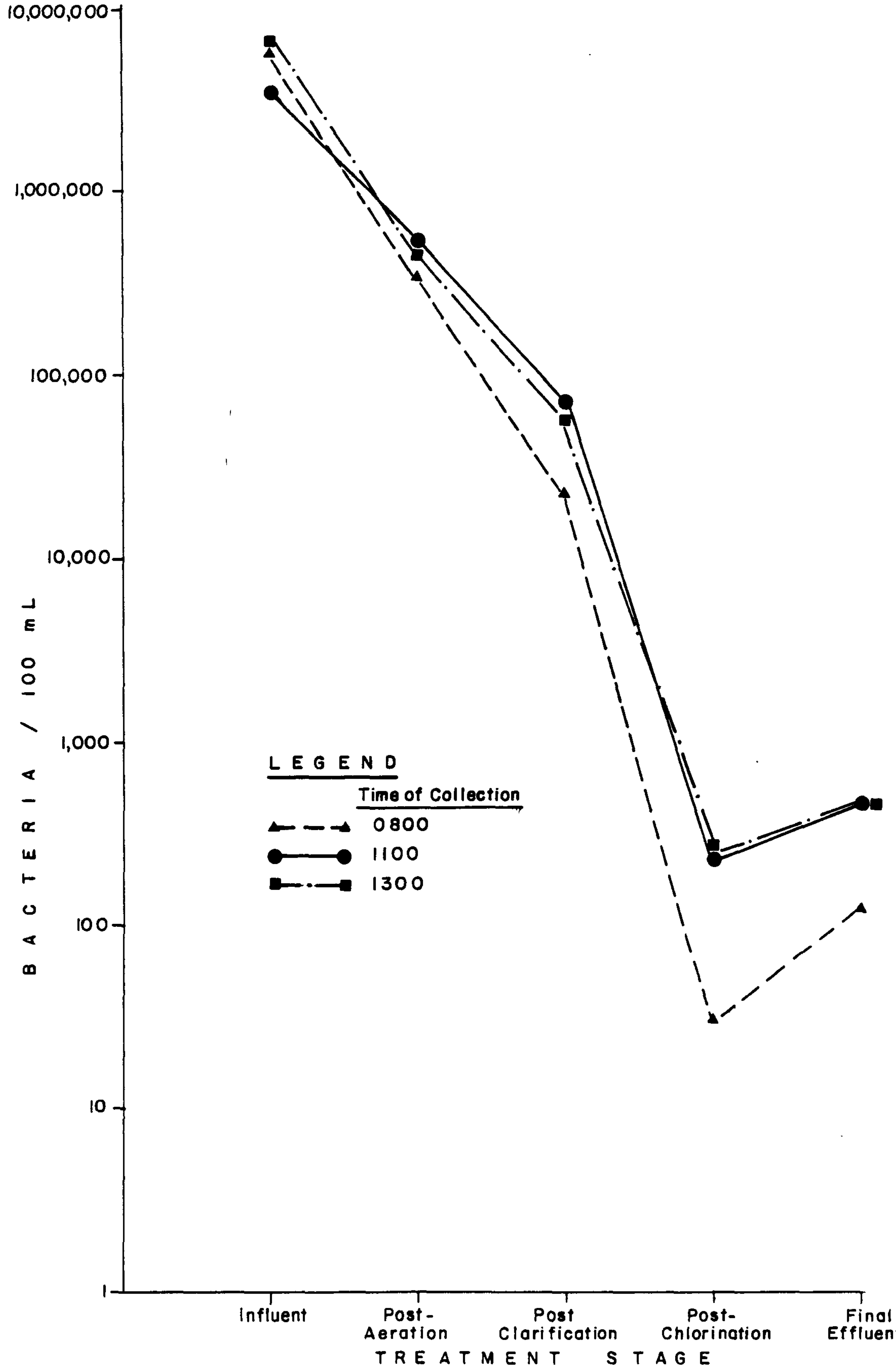

FIGURE 3a TEMPORAL CHANGES IN MEAN FECAL COLIFORM LEVELS AT VARIOUS TREATMENT STAGES

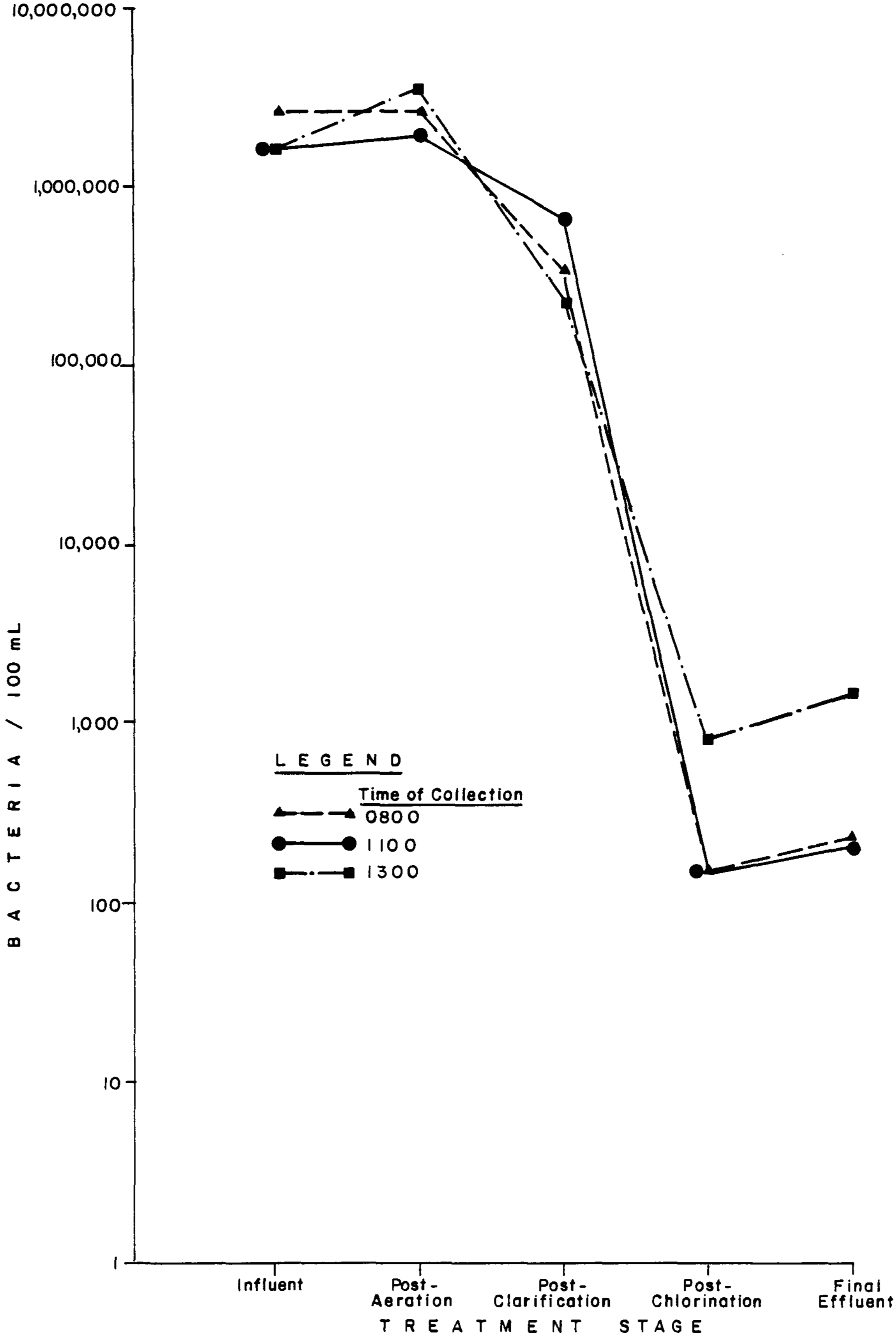

FIGURE 4a TEMPORAL CHANGES IN MEAN FECAL STREPTOCOCCI LEVELS AT VARIOUS TREATMENT STAGES

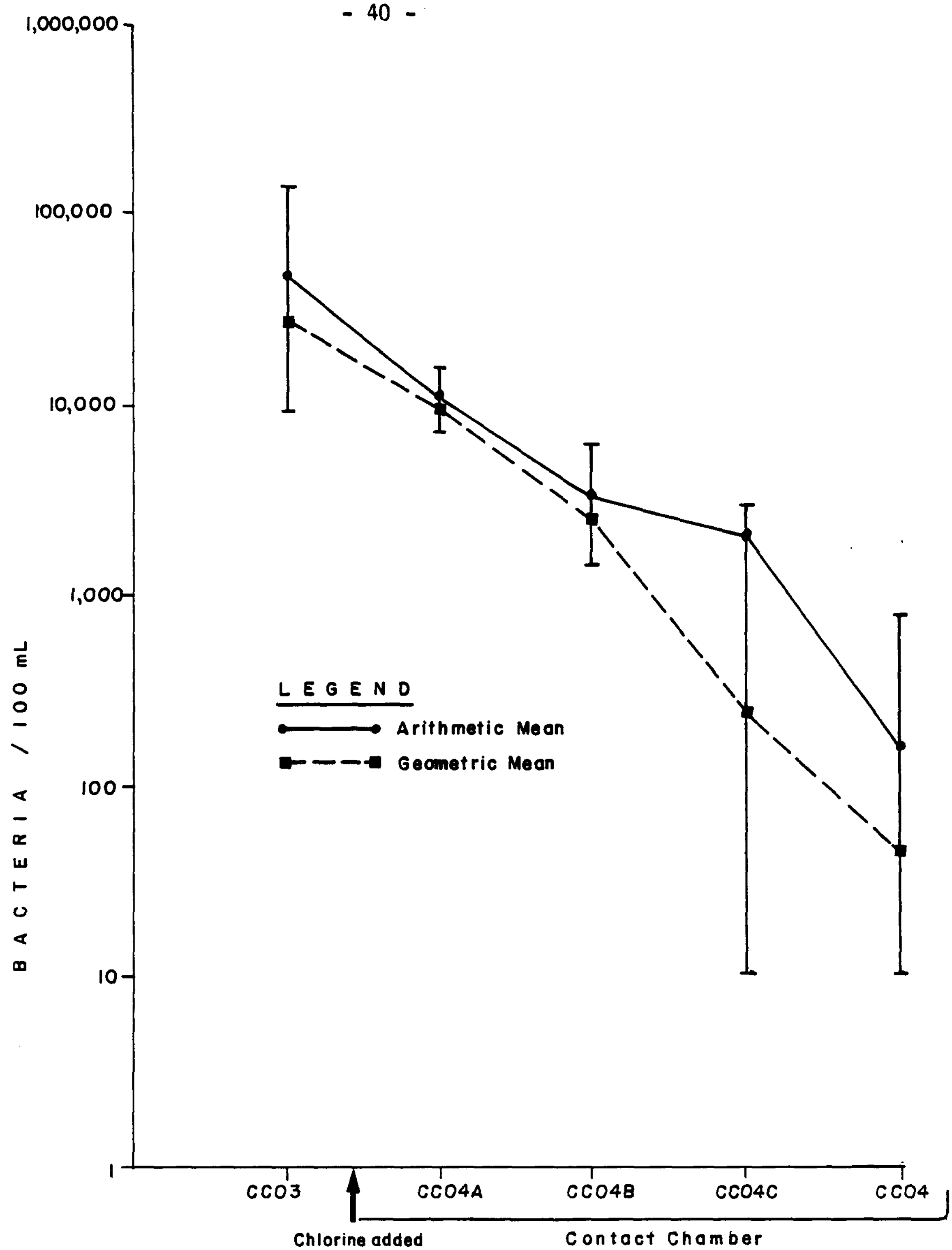

FIGURE 5a CHANGES IN MEAN FECAL COLIFORM LEVELS THROUGH CHLORINE CONTACT CHAMBER

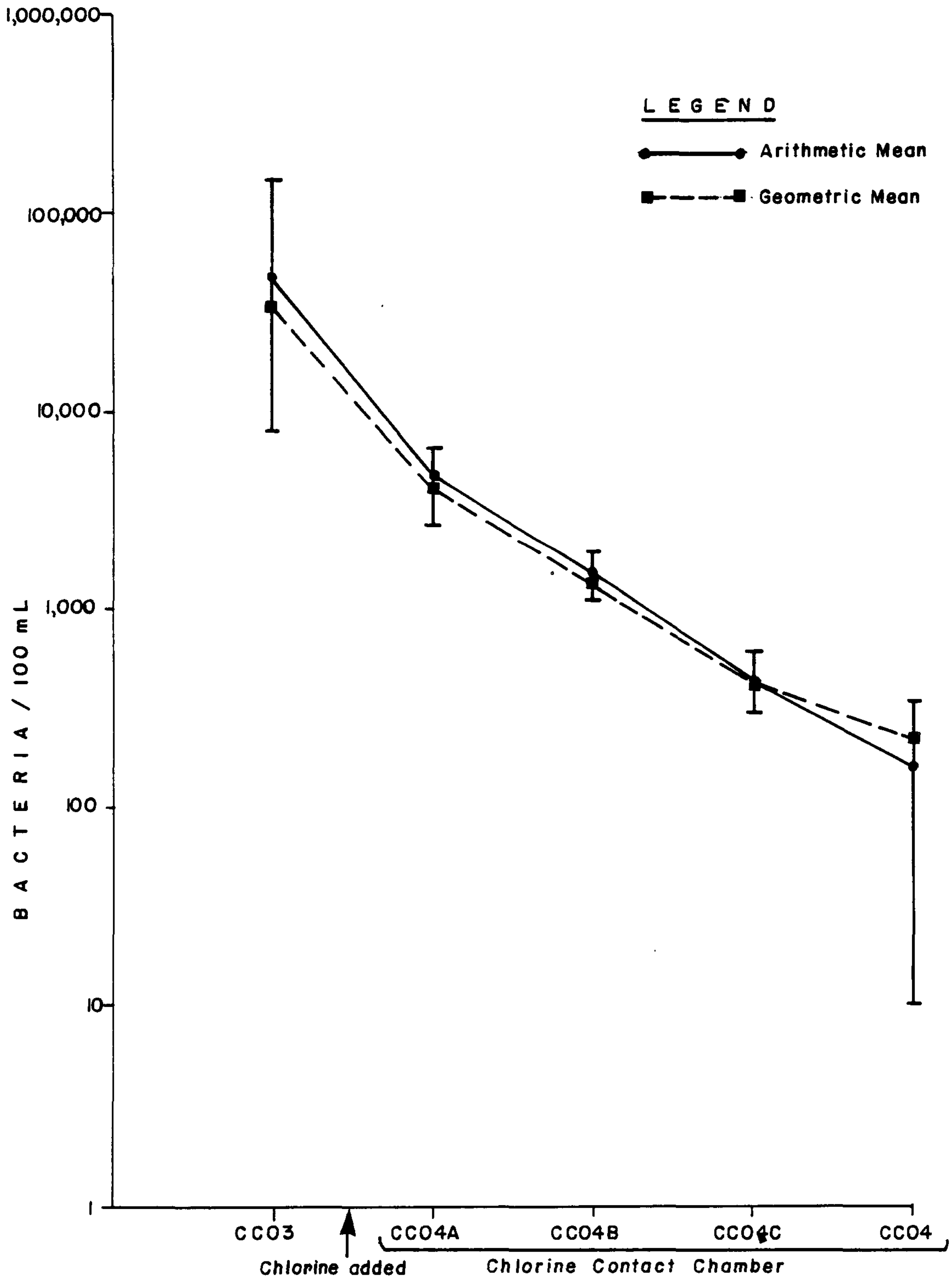

FIGURE 6a CHANGES IN MEAN FECAL STREPTOCOCCI LEVELS THROUGH CHLORINE CONTACT CHAMBER

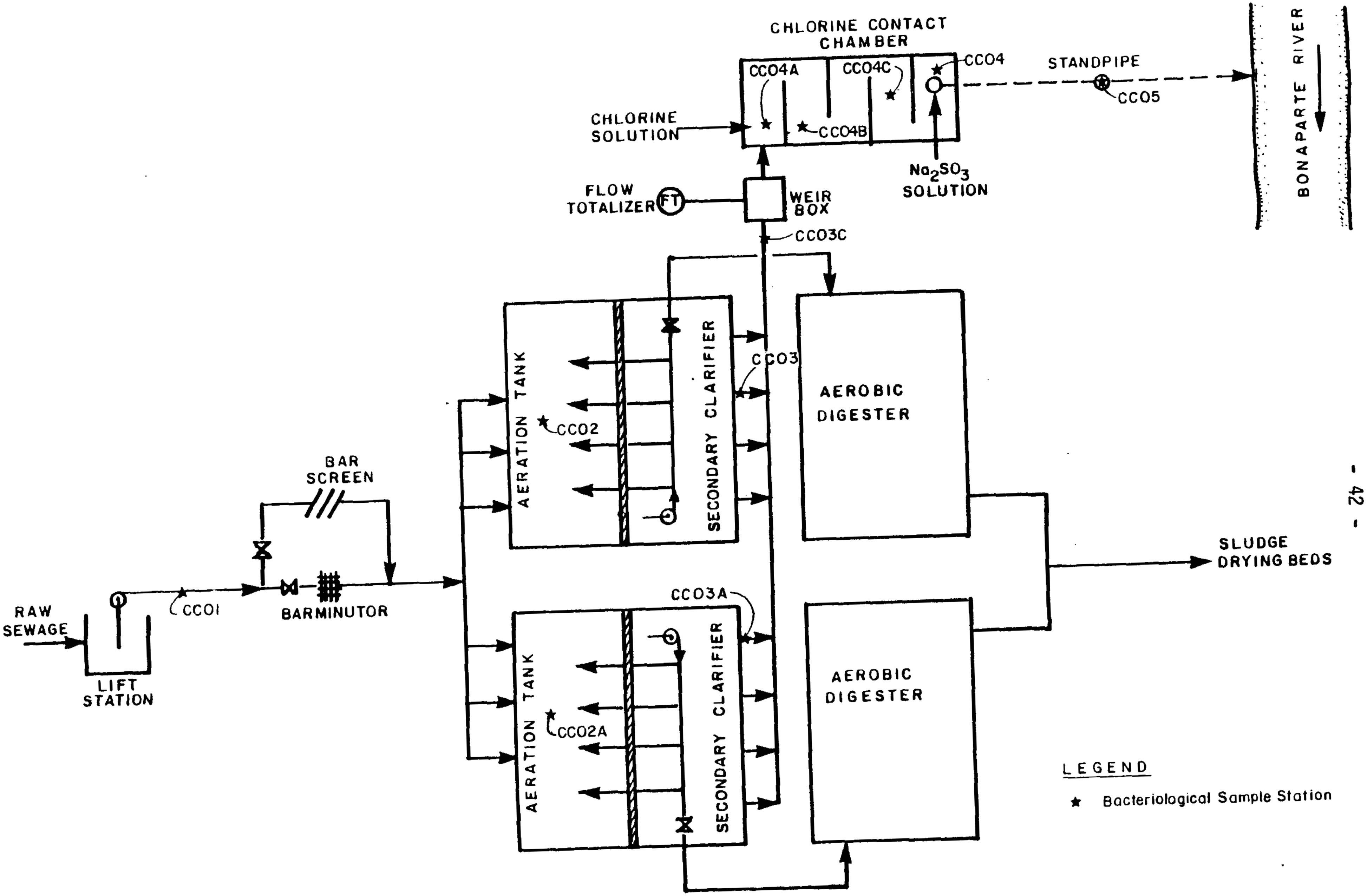

FIGURE 7a BACTERIOLOGICAL SAMPLE STATIONS

TABLE 4a. DAILY BACTERIOLOGICAL RESULTS

			PARAMETER			
STATION	DATE	TIME	TOTAL COLIFORMS (Count/100 mL)	FECAL COLIFORMS (Count/100 mL)	FECAL STREPTOCOCCI (Count/100 mL)	STANDARD PLATE COUNT 48h @35°C (Count/mL)
CC01	7/11/81	0800	--	1.1×10^7	5.0×10^6	4.4×10^6
		1100	--	5.5×10^6	2.8×10^6	7.1×10^6
	8/11/81	0800	--	--	--	2.6×10^6
		1100	--	--	--	5.6×10^6
	9/11/81	0800	--	1.0×10^6	8.0×10^5	1.9×10^6
		1100	--	1.6×10^6	6.0×10^5	2.9×10^6
		1300	3.8×10^6	6.1×10^6	1.7×10^6	4.0×10^6
CC02	7/11/81	0800	--	5.8×10^5	7.3×10^6	--
		1100	--	9.2×10^5	--	--
	8/11/81	0800	--	--	--	1.3×10^6
	9/11/81	0800	--	3.2×10^5	1.9×10^6	--
		1100	--	4.0×10^5	1.9×10^6	--
		1300	--	3.2×10^5	5.4×10^6	--
	10/11/81	0800	--	1.9×10^5	6.1×10^5	--
		1100	--	2.8×10^5	1.8×10^6	--
		1300	--	5.7×10^5	2.1×10^6	--
CC02A	7/11/81	0800	--	3.9×10^5	3.5×10^6	--
		1100	--	4.9×10^5	2.8×10^6	--
	8/11/81	0800	--	--	--	1.2×10^5
	9/11/81	0800	--	3.1×10^5	3.4×10^6	--
		1100	--	2.6×10^5	1.7×10^6	--
		1300	--	1.8×10^5	3.5×10^6	--
	10/11/81	0800	--	3.9×10^5	2.5×10^6	--
		1100	--	3.6×10^5	1.6×10^6	--
		1300	--	3.7×10^5	2.0×10^6	--

Continued...

TABLE 4a. DAILY BACTERIOLOGICAL RESULTS
(Continued)

			PARAMETER			
STATION	DATE	TIME	TOTAL COLIFORMS (Count/100 mL)	FECAL COLIFORMS (Count/100 mL)	FECAL STREPTOCOCCI (Count/100 mL)	STANDARD PLATE COUNT 48h @35°C (Count/mL)
CC03	7/11/81	0800	--	2.1×10^4	3.2×10^4	--
		1100	--	6.5×10^4	1.5×10^5	--
	8/11/81	0800	--	3.2×10^4	3.7×10^4	1.1×10^5
		1100	--	1.3×10^5	1.3×10^5	--
	9/11/81	0800	--	4.0×10^4	8.0×10^4	--
CC03A	7/11/81	0800	--	3.3×10^4	8.0×10^4	--
		1100	--	7.0×10^4	5.0×10^4	--
	8/11/81	0800	--	1.6×10^4	1.1×10^4	1.5×10^5
		1100	--	6.2×10^4	2.2×10^4	--
	9/11/81	0800	--	9.0×10^3	8.0×10^3	--
CC03C	9/11/81	1100	--	4.3×10^4	2.6×10^4	--
		1300	--	5.3×10^4	3.5×10^4	--
	10/11/81	0800	--	2.2×10^4	3.2×10^4	--
		1100	--	6.0×10^4	2.7×10^4	--
		1300	--	6.3×10^4	1.5×10^4	--
CC04	7/11/81	0800	--	< 10	320	--
		1100	--	90	460	--
	8/11/81	0800	--	10	10	--
		1100	--	40	50	--

Continued...

TABLE 4a. DAILY BACTERIOLOGICAL RESULTS
(Continued)

			PARAMETER			
STATION	DATE	TIME	TOTAL COLIFORMS (Count/100 mL)	FECAL COLIFORMS (Count/100 mL)	FECAL STREPTOCOCCI (Count/100 mL)	STANDARD PLATE COUNT 48h @35°C (Count/mL)
CC04	9/11/81	0800	--	< 10	40	--
		1100	--	20	20	--
		1300	--	< 10	50	--
	10/11/81	0800	--	90	320	--
		1100	--	790	120	--
		1300	--	500	1.6×10^3	--
CC04A	8/11/81		--	> 800	2.8×10^3	--
	9/11/81		--	6900	6400	--
	10/11/81		--	1.5×10^4	--	--
CC04B	8/11/81		--	1.9×10^3	1.2×10^3	--
	9/11/81		--	1400	1900	--
	10/11/81		--	5.9×10^3	--	--
CC04C	8/11/81		--	440	600	--
	9/11/81		--	10	290	--
	10/11/81		--	2.9×10^3	--	--
CC05	7/11/81	0800	800	< 10	450	1.4×10^4
		1100	500	< 10	710	2.6×10^4
		1300	1.7×10^4	160	1200	4.7×10^4

Continued...

TABLE 4a. DAILY BACTERIOLOGICAL RESULTS
(Continued)

			PARAMETER			
STATION	DATE	TIME	TOTAL COLIFORMS (Count/100 mL)	FECAL COLIFORMS (Count/100 mL)	FECAL STREPTOCOCCI (Count/100 mL)	STANDARD PLATE COUNT 48h @35°C (Count/mL)
CC05	8/11/81	0800	--	390	< 10	5.0×10^3
		1100	> 800	1400	70	8.6×10^3
		1300	> 800	230	210	3.2×10^4
	9/11/81	0800	< 10	10	10	1.0×10^3
		1100	2700	20	40	6.2×10^3
		1300	--	190	90	1.6×10^4
	10/11/81	0800	< 10	60	490	--
		1100	--	510	2.4×10^3	--
		1300	< 10	1.3×10^3	4.3×10^3	--
BR01A	7/11/81		62	24	130	164
	8/11/81		20	14	< 160	487
	9/11/81		66	50	28	146
	10/11/81		6	12	34	--
BR01B	7/11/81		8	22	150	196
	8/11/81		14	16	38	354
	9/11/81		52	30	32	161
	10/11/81		18	4	50	--
BR02A	7/11/81		36	32	64	341
	8/11/81		10	36	30	259
	9/11/81		78	82	24	231
	10/11/81		158	12	58	--

Continued...

TABLE 4a. DAILY BACTERIOLOGICAL RESULTS
(Continued)

STATION	DATE	TIME	PARAMETER TOTAL COLIFORMS (Count/100 mL)	FECAL COLIFORMS (Count/100 mL)	FECAL STREPTOCOCCI (Count/100 mL)	STANDARD PLATE COUNT 48h @35°C (Count/mL)
BR02B	7/11/81		70	14	66	220
	8/11/81		10	28	24	301
	9/11/81		34	42	40	155
	10/11/81		148	8	64	--

APPENDIX 2

BIOASSAY RESULTS

by
D. Moul

Objectives

- to determine the acute lethal toxicity of the Cache Creek Sewage Treatment Plant's final effluent
- to field test the Aquatic Toxicity Laboratory's Continuous Flow Diluter

Terminology

An aquatic bioassay is any test in which aquatic organisms are used to detect or measure the presence or effect of one or more substances, wastes, or environmental factors, alone or in combination, on aquatic organisms (Standard Methods, 1973).

Acute - involving a stimulus, severe enough to bring about a response speedily, usually within 96 hours for fish.

Lethal - causing death, or sufficient to cause it, by direct action.

A continuous flow or flow through fish bioassay is one in which measured quantities of dilution water and toxicant solution are mixed and delivered to test vessels containing fish to give a continuous flow-through of the test toxicant. [Flow-through tests are desirable for wastes that are suspected of having a high bio-chemical oxygen demand.]

96 hour LC_{50} - this term refers to median lethal concentration or that level of a measurable lethal agent required to kill the 50th percentile in a group of test organisms, over the time period of 96 hours. The 50th percentile is meant to represent the average organism.

LT_{50} - this term refers to median lethal time or the time to death of the 50th percentile organism in a specified concentration or level of measurable lethal agent. The maximum exposure time may be specified.

Materials and Methods

The Aquatic Toxicity Laboratory's Mobile Laboratory containing a continuous flow-through diluter was used for the survey.

[The diluter permits the replication of 5 effluent concentrations and of a fresh water control. It is constructed so that the sample and the dilution water are withdrawn from header tanks and are combined in mixing chambers to obtain specified concentrations (dilutions). These concentrations are then split (to create replicates) and are delivered at a fixed flow rate to twelve 30 liter test vessels into which 10 fish are added. The fish mortalities in each vessel are monitored over 96 hours and the results are plotted on semi-log paper to establish LT and LC_{50} values.]

On site acute lethal continuous flow-through bioassays were performed.

The test species used were underyearling salmo gairdneri (Rainbow trout) that ranged in size from 3.8 cm to 4.7 cm in length and from 0.4 grams to 1.0 grams in weight. The fish were acclimated to the dilution water and to laboratory conditions for one week prior to their use. There were no fish mortalities during this time. Ten fish were used as the test population in each test vessel.

The effluent sample was continually pumped from an inspection vent in the buried discharge pipe leading from the sewage treatment plant to the Bonaparte River. The dilution water was pumped from the Bonaparte River at a point upstream of the sewage treatment plant's outfall pipe.

All test volumes were 30 liters. The test solution flow rate was 150 mL/min which permitted a 90% molecular replacement of test solution over 7.2 hours. The following test dilutions were used; 100%, 87%, 75%, 65%, 56%, and a control.

The effluent sample and diluent water were aerated in the header tanks prior to entering the test vessels. Test vessel dissolved oxygen were measured and recorded periodically throughout the test period.

The pH in one of the 100% concentration test vessels was monitored continously using an Orion pH meter and a Varian Strip Chart recorder.

Results

The diluter did not function properly. A problem involving the vacuum dependent mixing system occurred and continued for the duration of the testing. Proper solution mixing was never attained. Consequently, the delivery rate of solution to the test vessels (which was dependent upon accurate mixing) could not be maintained.

The attempt to determine acute lethality by means of LC_{50} testing was abandoned. Although 90% solution exchange in 7.2 hours was never obtained it was noted that the 100% concentration and fresh water controls (which were not dependent upon mixing) were being replenished - albeit intermittently. Consequently, by using the two 100% concentrations and the two controls, modified LT_{50} tests were performed.

Once an LT_{50} test was completed more fish were introduced, and a new test was begun. As a result, five LT_{50} tests (of various durations) were carried out. The results are presented in Table 5a.

The dilution water temperature in the control tanks ranged from 8.1°C to 10.8°C over the testing period. The effluent temperature in the 100% concentrations ranged from 10.0°C to 14.5°C over the testing period.

The pH of the 100% effluent remained at 7.5 throughout the test period. The pH of the dilution water was 8.4 throughout the test period.

Conclusion

During the first 3 days of the study the sewage treatment plant effluent was toxic to fish, but the toxicity was greatly reduced during the last 2 days.

TABLE 5a. MODIFIED LT_{50} TEST RESULTS

TEST NO.	DATE	TIME	CUMULATIVE MORTALITY 100% EFFLUENT	CUMULATIVE MORTALITY CONTROL	CUMULATIVE TIME (h)	pH EFFLUENT	pH CONTROL	D.O. (mg/L) EFFLUENT	D.O. (mg/L) CONTROL	LT_{50} (h)
1	NOV. 7	2200(start)	-	-	-	7.5	7.5	9.7	12.4	
	NOV. 8	1300	10	0	15	7.5	7.5	9.5	11.3	0 to 15
2	NOV. 7	2200(start)	-	-	-	7.5	7.5	9.1	12.2	
	NOV. 8	1300	6	0	15	-	-	-	-	
	NOV. 8	1630	9	0	18.5	-	-	-	-	
	NOV. 9	2030	10	0	22.5	7.5	7.5	11.3	13.1	0 to 15
3	NOV. 8	1320(start)	-	-	-	7.5	7.5	11.0	12.3	
	NOV. 9	0900	9	0	19.66	-	-	-	-	
	NOV. 9	1400	10	0	24.66	7.5	7.5	9.8	11.4	0 to 15
4	NOV. 9	0950(start)	-	-	-	7.5	7.5	11.4	12.8	
	NOV. 9	1400	0	0	4.3	-	-	-	-	100 % concentration
	NOV.10	0830	0	0	22.66	7.5	7.5	-	-	non-toxic over
	NOV.11	0830	0	0	46.66	7.5	7.5	9.3	11.6	46.66 h
5	NOV. 9	1415(start)	-	-	-	7.5	7.5	9.8	11.2	100% concentration
	NOV.10	0830	0	0	18.25	-	-	-	-	slightly toxic
	NOV.11	0830	1	0	42.25	7.5	7.5	10.2	11.7	over 42.25 h