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THE EFFECTS OF THE CHENEY SEWAGE EFFLUENT ON THE WATER QUALITY OF THE RECEIVING STREAM

A Research Report

Presented to

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Master of Science

in

Biology

By

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INTRODUCTION

Stabilization ponds or lagoons are some of the most commonly employed secondary waste treatment systems. In 1968, stabilization ponds constituted 34.7 percent of the 9,951 secondary treatment systems operating in the United States (Brown and Caldwell, 1973). Communities with populations of 10,000 or less are commonly served by lagoons.

The city of Cheney, Washington (Spokane, Co.), population 6,998, has an aerobic lagoon system for sewage treatment consisting of four cells and two chlorine contact basins. The sewage effluent from the chlorine contact basins flows into Minnie Creek which parallels the SP&S railroad tracks. The city of Cheney monitors the water quality parameters required by the DOE according to 1972 water quality standards for waste effluents and is presently conducting additional tests for total nitrogen, ammonia nitrogen, phosphorus, conductivity, and fecal coliform bacteria. However, what effects the sewage effluent has on the water quality of the receiving streams has not been determined.

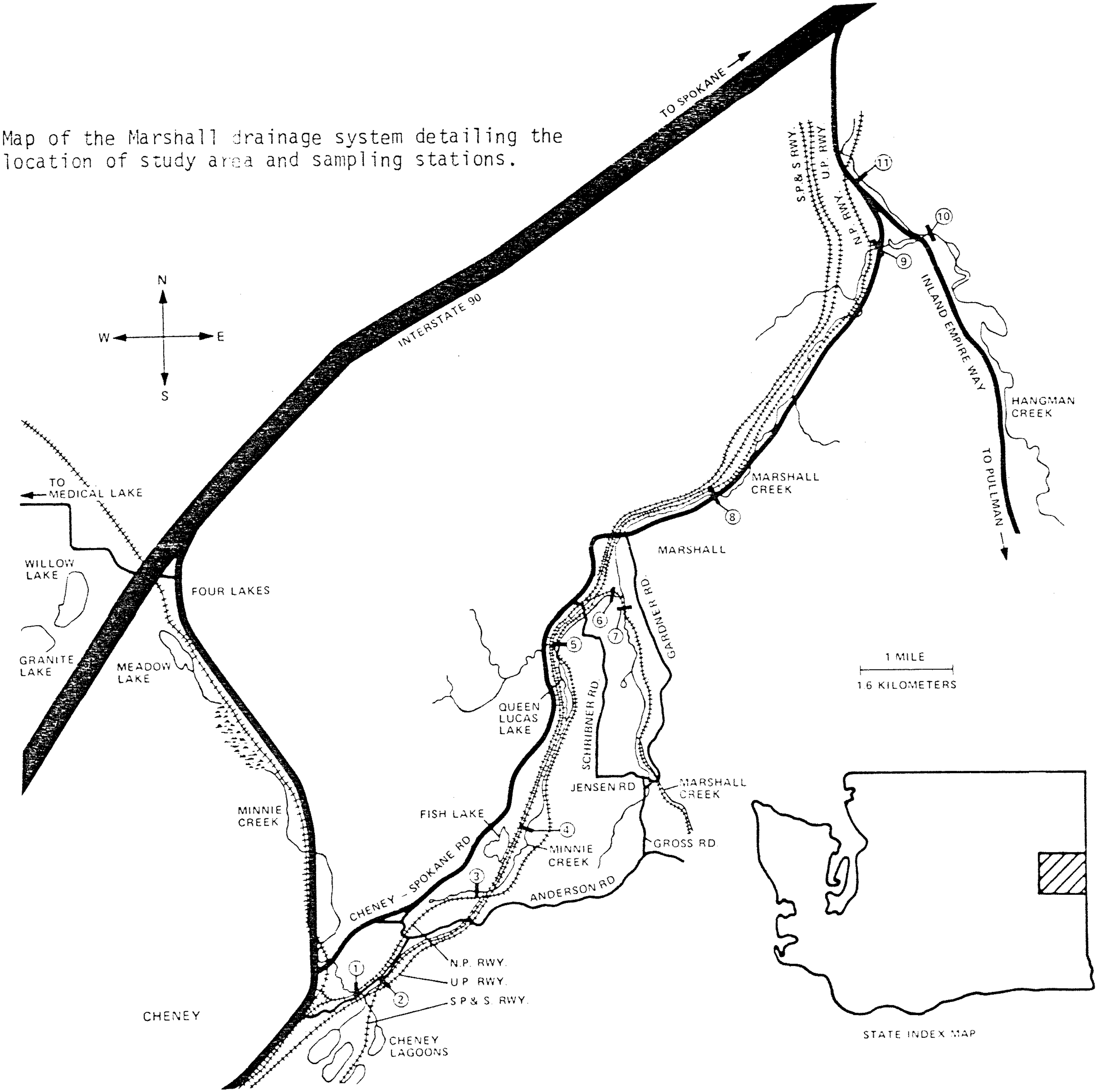
The purpose of this study was to determine the effects of the Cheney sewage effluent on the water quality of Minnie Creek, Marshall Creek, and Hangman Creek. Chemical and physical measurements were made on samples from selected sites over a seven month period from October 1974 to April 1975, encompassing low and high flow periods.

DESCRIPTION OF STUDY AREA

Minnie Creek converges with the Cheney sewage effluent just outside the city limits and flows along the SP&S railroad tracks into Queen Lucas Lake (Fig. 1). During the high flow period (March through April 1975) Queen Lucas Lake overflowed into Marshall Creek, 1.6 km above the town of Marshall, Washington (Spokane, Co.). Approximately 8.8 km downstream, Marshall Creek empties into an oxbow lake and into Hangman Creek. During the low flow period (October 1974 through February 1975) the headwaters of Minnie Creek were dry and the flow in Minnie Creek was due to the sewage effluent and a small spring. Throughout the low flow period the only discharge into Hangman Creek was from Marshall Creek.

Eleven sampling stations were established for this study. Station 1 was located on Minnie Creek just above its convergence with the Cheney sewage effluent. Station 2 was established on Minnie Creek 0.6 km below the confluence with the sewage effluent at the wooden bridge adjacent to Anderson Road. Station 3 was at a small spring, called Big Springs, 0.3 km above its confluence with Minnie Creek. Station 4 was located on Minnie Creek 3.8 km downstream from station 2, behind D.J.'s Tavern at Fish Lake across the N.P. tracks. Station 5 was established on a runoff ditch above its confluence with Queen Lucas Lake. Station 6 was situated on Minnie Creek, 4.8 km from station 4 and 0.4 km above its confluence with Marshall Creek. Station 7 was located on Marshall Creek as it passes under the N.P. tracks, 1.2 km before entering the town of Marshall and 0.4 km above its confluence with Minnie Creek. Station 8 was established on Marshall Creek as it crosses the Cheney-Spokane Road, 2.8 km downstream from station 7. Station 9 was situated on Marshall Creek, 5.6 km below station 8 just before flowing under the Cheney-Spokane Road into an oxbow lake. Station 10 was established on Hangman Creek, approximately 0.8 km above its confluence with Marshall Creek. Station 11 was located on Hangman Creek, 0.8 km below its confluence with Marshall Creek.

Figure 1. Map of the Marshall drainage system detailing the location of study area and sampling stations.



MATERIALS AND METHODS

Samples were collected monthly between 0800 hours and 1400 hours and stored in clean one liter polyethylene bottles. Chemical determinations were completed within 48 hours of collection.

Hydrogen ion concentrations were measured with an Electro-Chem Fet pH Meter (Model 430, 1036). Conductivity @25 C was determined with a Lab-Line Lectro mho-Meter accompanied with a Lab-Line Instruments 1 cm dipping cell. Temperature measurements were made *in situ* with a standard centigrade thermometer. Dissolved oxygen samples were fixed in the field and titrated in the laboratory utilizing the Pomeroy and Kirshman modification of the Winkler Method.

Magnesium, calcium, sodium, potassium, bicarbonate, sulfate, chloride, nitrite nitrogen, nitrate nitrogen, ammonia nitrogen, orthophosphate, silica, and turbidity determinations were made as described by the American Public Health Association (1971). The colorimetric equipment used in the various analyses was either a Bausch and Lomb "Spectronic 20" or a Klett-Summerson colorimeter. Total and fecal coliform bacteria were determined with Millipore® Coli-Count samplers, incubated for 18-24 hours at 37 C and 44.5 C, respectively. Colonies of blue-green color were counted.

Student "t" test was used to compare chemical and physical data during the low flow period and differences are expressed as significant ($P>0.05$) or not significant ($P<0.05$). Statistical analysis for the high flow period was not possible due to insufficient data.

RESULTS

Minnie, Marshall, and Hangman Creeks are primarily magnesium bicarbonate waters.

During the low flow period all flow at station 2 issued directly from the effluent of cell 2. Nutrient levels of ammonia nitrogen and orthophosphate at station 2 were 53 and 16 times greater, respectively, than at station 3 (Figs. 2 and 3).

Overall comparison of chemical concentrations between stations 2 and 4 showed dilution of the sewage effluent by Big Springs, except in nitrate nitrogen and dissolved oxygen (Figs. 2 and 5). Nitrate nitrogen concentrations were slightly higher at station 4 because of greater concentrations at station 3. Big Springs flows through pasture land and the oxidation of ammonia in dung and urine may account for these higher nitrate nitrogen levels. Dissolved oxygen was also higher at station 4 due to the nature of the reach. At this point the stream was shallow and overgrown with vegetation and photosynthetic activity along with physical diffusion of oxygen may have accounted for the increase.

Big Springs contributed approximately one-half of the flow to Minnie Creek during the low flow period. Significant decreases in conductivity, bicarbonate, and chloride, and a significant increase in dissolved oxygen were observed between stations 2 and 4. Although total and fecal coliforms were not significantly different, counts were approximately 10 times higher at station 2 (sewage effluent).

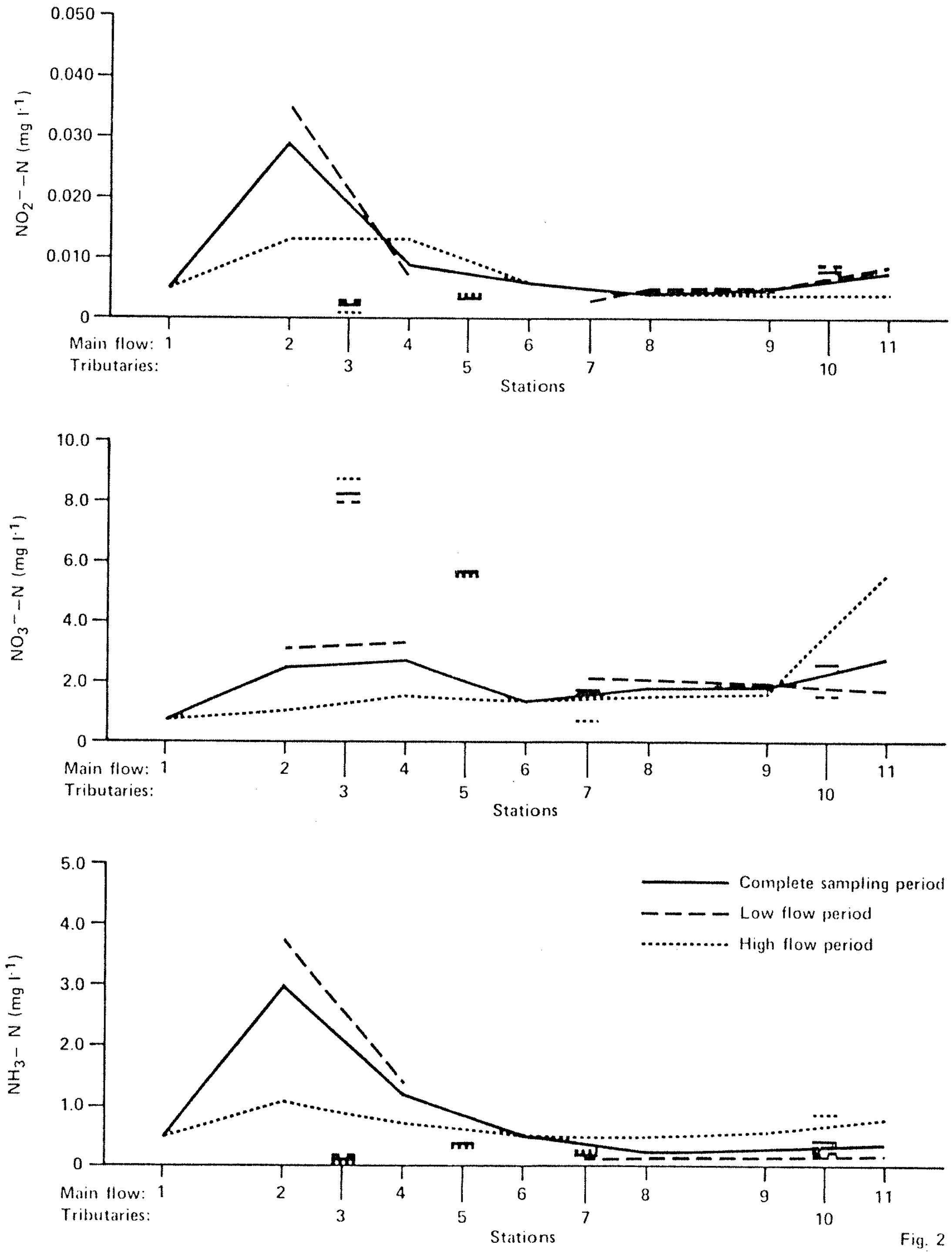


Fig. 2

Figure 2. Average concentration of the inorganic nitrogen fractions for all stations during low flow, high flow, and complete sampling periods.

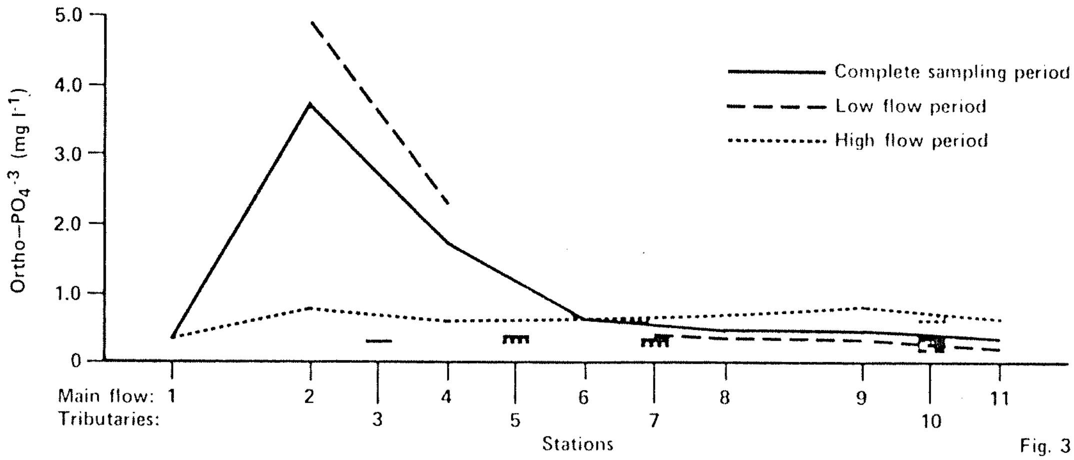


Figure 3. Average concentration of orthophosphate for all stations during low flow, high flow, and complete sampling periods.

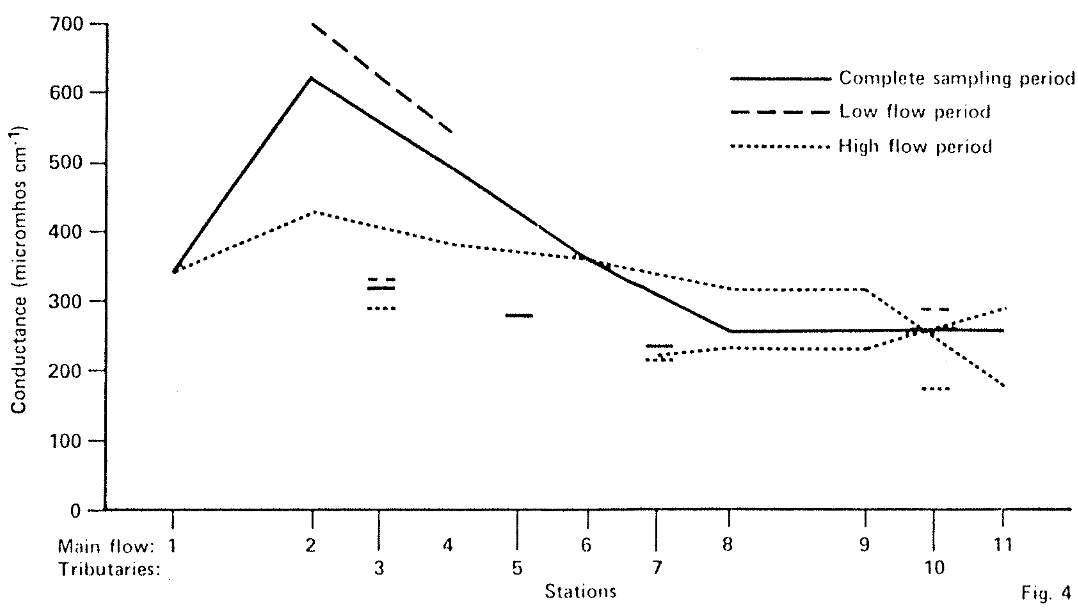


Figure 4. Average conductance @25 C for all stations during the low flow, high flow, and complete sampling periods.

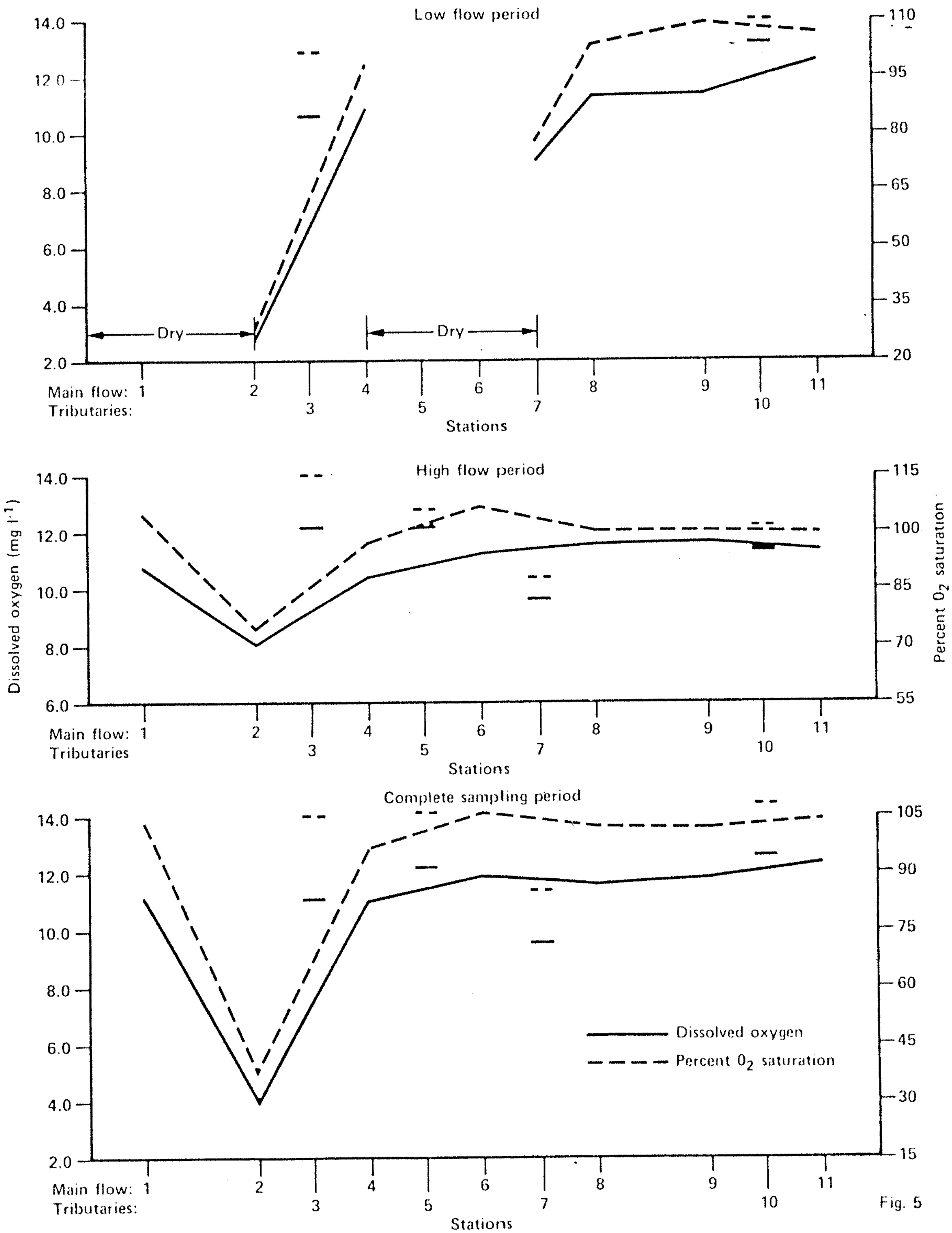


Figure 5. Average percent O_2 saturation and dissolved oxygen concentrations for all stations during the low flow, high flow, and complete sampling periods.

No significant differences were found for the other chemical parameters.

Chemical analyses of Marshall Creek at stations 7, 8, and 9, showed little change and no significant differences. Marshall Creek during the low flow period was not influenced by any outside sources.

Analysis of Hangman Creek before and after its confluence with Marshall Creek showed no significant differences in the concentrations of the chemical determined parameters. Therefore, during the low flow period Marshall Creek had no significant effect on Hangman Creek for those parameters determined.

During the high flow period the effects of the Cheney sewage effluent on Minnie Creek were markedly reduced due to the dilution volume contributed by Minnie Creek. Comparison of Minnie Creek water quality before and after its confluence with the sewage effluent (stations 1 and 2) showed moderate concentration decreases in dissolved oxygen (Fig. 5), total coliforms (Fig. 7), sulfate, turbidity, pH, and temperature. Moderate increases were found in the other parameters (Figs. 2, 3, 4, and 6).

Water quality of flow leaving Queen Lucas Lake (station 6) was similar to the water quality of Minnie Creek, except in silica, nitrate nitrogen, and orthophosphate concentrations. Higher silica concentrations at stations 3 were responsible for the greater concentrations found at station 6. Nutrient levels were low at both

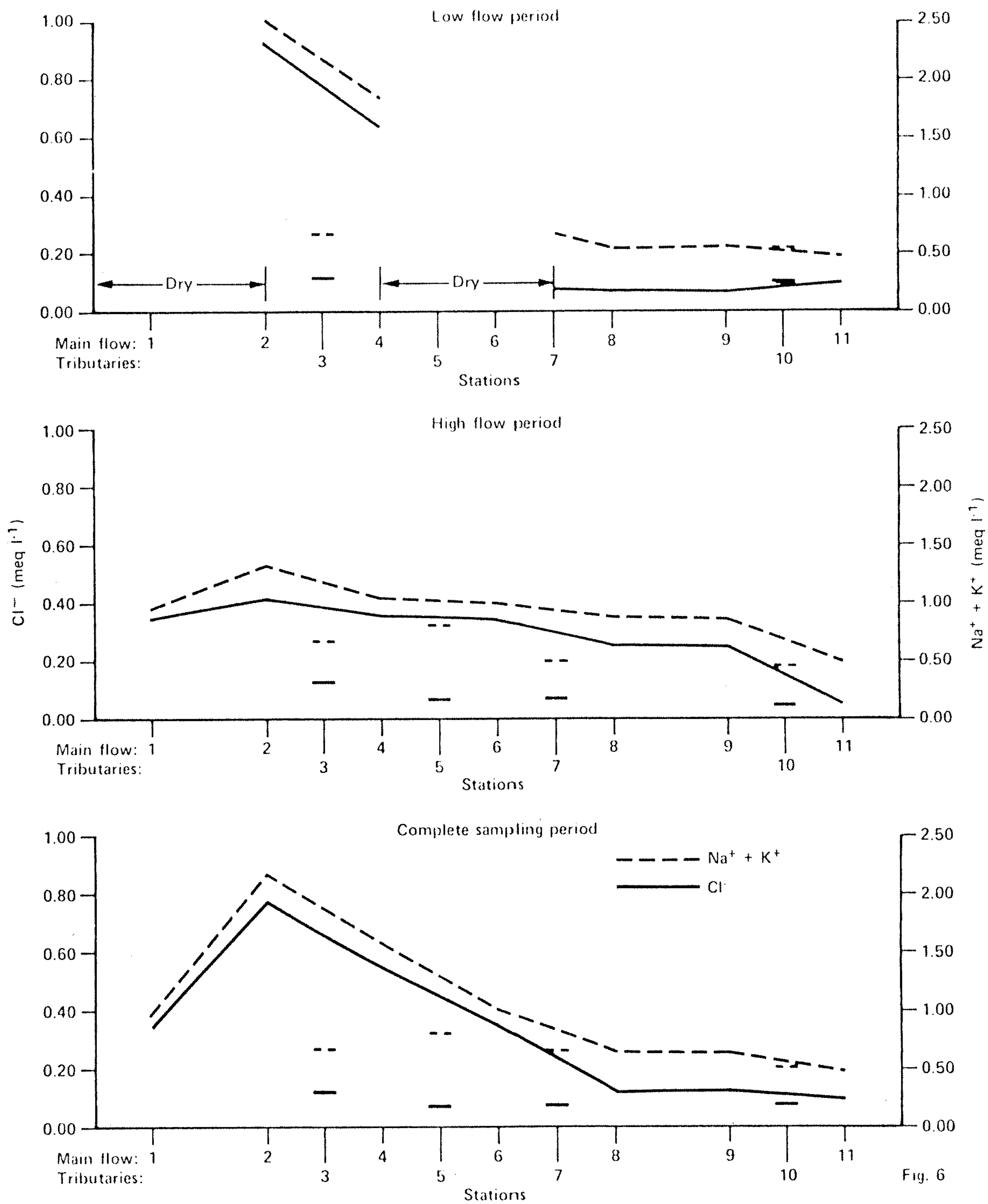


Figure 6. Average concentration of sodium plus potassium and chloride ions for all stations during the low flow, high flow, and complete sampling periods.

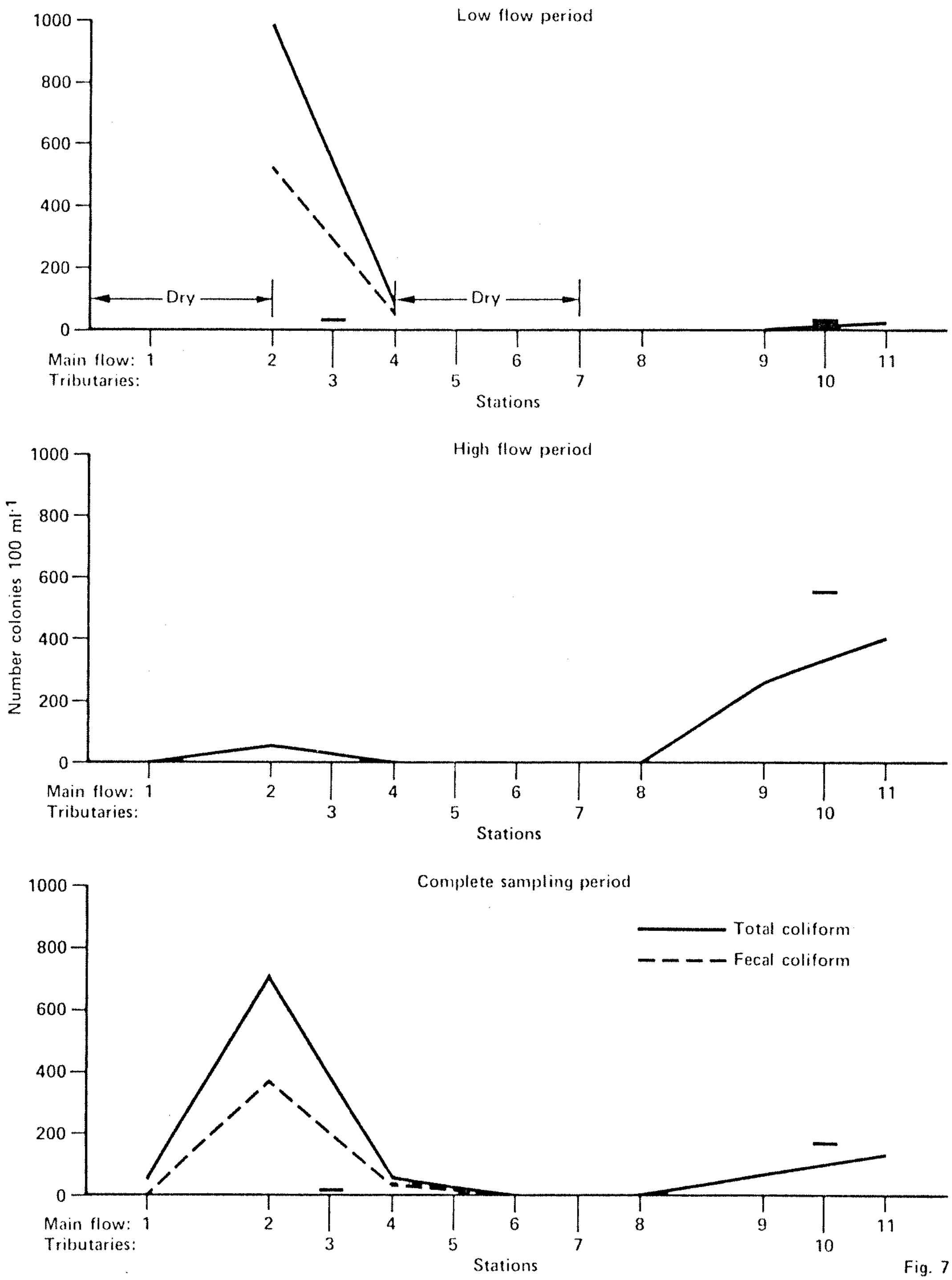


Figure 7. Average total and fecal coliform colonies per 100 ml for all stations during the low flow, high flow, and complete sampling periods.

stations 1 and 6, but nitrate nitrogen and orthophosphate concentrations at station 6 were 60 percent greater due to the relatively high nutrient input from sewage effluent (Figs. 2 and 3). Minnie Creek had nearly recovered from the effects of the sewage effluent approximately 8.6 km downstream from station 2.

Minnie Creek, however, altered the water quality of Marshall Creek. Comparison of water quality data between stations 7 and 8 showed larger concentration increases for most parameters, but decreases for silica and temperature. Station 7 (Marshall Creek headwaters) was high in silica and was diluted by station 6 (Minnie Creek). Total and fecal coliform counts were zero at both stations. Comparison between stations 1 and 8 shows that the water quality of Marshall Creek at this point was similar to the water quality of Minnie Creek headwaters.

Marshall Creek had no detectable effect on Hangman Creek. Comparison between stations 10 and 11 shows little change in all parameters (Figs. 2 through 7).

The complete sampling period included all data for each station during the seven month study. The initial effect of the sewage effluent on Minnie Creek was an alteration in all determined chemical and physical parameters. Chemically, Minnie Creek recovered from the discharge of the sewage effluent by the time flow reached station 6. There were few detectable changes in the water quality of Hangman Creek before and after its confluence with Marshall Creek (Figs. 2 through 7).

DISCUSSION

During the low flow period (October 1974 to February 1975) the tributary waters of Big Springs were significantly altered by the Cheney sewage effluent, particularly levels of conductivity, bicarbonate, chloride, and dissolved oxygen.

During the high flow period (March 1975 to April 1975) the Cheney sewage effluent was diluted to such an extent that its influence was minimal by the time flow reached station 4 (Minnie Creek). Changes in Marshall Creek water quality was due to the influence of Minnie Creek water quality. Marshall Creek had no effect on Hangman Creek water quality. The sewage effluent had no effect on Hangman Creek because its upstream tributaries added sufficient volume to the drainage system to dilute any changes created by the sewage effluent.

The presence of coliforms at staion 2 indicated inadequate chlorination. In February, the sewage effluent had total and fecal coliforms counts of 4300 and 1900/100 ml, respectively. These high counts were the result of mechanical failure in the chlorination process (personnal communication, Fred Steiner*). The following

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month after repairs were completed, coliforms were absent at station 2. The reduction in coliforms however, may have also been a result of sewage effluent dilution by spring runoff. Fecal coliforms were not found beyond station 4, but total coliforms were found above and below the sewage effluent (stations 1, 3, 9, 10, and 11). These counts were from other probable sources (Kabler and Clark, 1960; Geldreich, 1966; and California Water Quality Control Board, 1963).

Queen Lucas Lake may inadvertantly function as a final stabilization lagoon for the Cheney sewage effluent. At present, little is known of the lake's physical and chemical conditions other than the existence of a high retention time which results in extensive evaporation during low flow. From October 1974 to February 1975, flow at station 4 entered Queen Lucas Lake where it remained until the onset of the high flow period in March 1975. During high flow, the chemical composition of the water leaving Queen Lucas Lake was similar to Minnie Creek headwaters. Dissolved oxygen levels in Queen Lucas discharge were high. However, the opposite would be expected if the lake was functioning as an additional lagoon receiving large quantities of organic wastes.

Although the sewage effluent seemed to have little effect on the entire drainage system, its effect on a particular reach through increased Biochemical Oxygen Demand (BOD) and productivity may be significant. Lagoon effleunts release large amounts of algal cells (suspended solids) into the receiving streams. Subsequent decomposition of these cells pollutes the stream by increasing the BOD

(Bain *et al.*, 1970). Middleton and Bunch (1970) state that 1 mg/l of dead algae is equivalent to about 1.5 mg/l of five-day BOD. Lagoons effluents having 50 to 125 mg/l algal fresh weight would exert a BOD load in the range of 75 to 150 mg/l or higher. Recent laboratory records show that Cheney's final effluent normally contains from 30 to 50 mg/l of BOD in the summer months and 60 to 80 mg/l during the winter months (Gray and Osborne, 1975).

The important nutrients that the Cheney sewage effluent contributes to the receiving streams are nitrogen and phosphorus. High nitrate nitrogen and orthophosphate concentrations in water has been shown to stimulate the growth of algae and aquatic plants (Mackenthun, 1965; Edmondson, 1970; Brylinsky and Mann, 1973; and Soltero, Gasperino, and Graham, 1974). A possible benefit of increased algal growth and thus other fish food organisms is an increased fisheries (Hynes, 1969).

The Federal Water Pollution Control Act Amendments of 1972 regulates pollutant discharge through the issuance of waste discharge permits under the National Pollutant Discharge Elimination System (NPDES). According to the provisions of the February 18, 1975 waste discharge permit (WA - 002084 -2), the city of Cheney must upgrade its waste treatment facilities to secondary treatment standards. The State of Washington Department of Ecology has established effluent limitations for BOD, suspended solids, fecal coliform bacteria, and pH. Failure to meet these requirements will result in the revision of the discharge permit.

Gray and Osborne Consulting Engineers are presently evaluating the performance of Cheney's wastewater lagoons to determine the most effective method of operation. Under the operation and maintenance improvement program, sewage flows will be routed through the lagoon cells in several operational modes; initial, series, parallel, and series-parallel. The effects of each flow pattern will be carefully monitored to evaluate the performance of a particular flow pattern. The resulting base line information will help the operator to maximize waste treatment and effluent quality. The results of the study will also determine if the existing system will meet secondary treatment standards.

Barsom (1973) lists 18 recommendations for improving lagoon performance. The first and most logical approach to improve lagoon performance is to increase retention time. This can be accomplished through intrapond and interpond recirculation (Brown and Caldwell, ibid). Intrapond recirculation involves the cyclic return of one cell's effluent. Interpond recirculation is the passing of an effluent from one cell into another; the resulting flow patterns are commonly referred to as series, parallel, and series-parallel operational modes. Thus, the city of Cheney is presently conducting interpond recirculation as a means of improving lagoon performance.

In meeting the requirements of secondary treatment, supplemental areation of the initial lagoons may be necessary during certain times of the year. In the winter months ice formation decreases the availability of light for photosynthesis, thereby decreasing oxygen production. Anaerobic conditions may result and a lower quality effleunt enters the receiving waters. Aeration increases dissolved oxygen levels and at the same time prevents surface freezing. Marais (1970) and Haynes (1975) have shown that aeration tends to promote algal growth and reoxygenation. They found that the turbulence created by aeration prevented the nonmotile algae (Chlorella) from falling below the photic zone and dying. By increasing algal concentrations they raised the organic loading capacity of the lagoons. Surface agitation also disrupts developing scum layers which, if left untreated, decrease the photosynthetic rate and oxygen diffusion from the atmosphere.

Selective effluent drawoffs can also improve effluent quality. King, Tolmseff, and Atherson (1970) demonstrated that diurnal vertical migration of algae could substantially alter the amount of organic matter discharged from a lagoon. Selective drawoffs at specific times and depths may insure an effluent lower in algal cells. Selective effluent drawoff for algal reduction in the effluent is simple, effective in BOD reduction, and requires no elaborate mechanical machinery. However, rapid sand filtration with the backwash returned to the initial cell may be more effective in algal reduction.

Application of one or several of these principles to Cheney's existing treatment facility may effectively improve lagoon performance and effluent quality.

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Appendix 1. Range and mean water quality parameters during the low flow period from October 1974 to February 1975.

	1	2	3	4	5	6	7	8	9	10	11
pH Range		7.0-7.2	7.4-7.4	7.5-8.0			7.1-7.4	7.6-7.7	7.7-7.8	7.4-8.4	7.4-8.4
Conductance (micromhos/cm)		589-820 698	318-358 332	532-562 544			227-294 244	219-246 231	219-243 231	181-337 286	181-331 286
Ca^{++}(meq/1)		0.84-1.64 1.18	0.72-0.76 0.74	0.92-1.00 0.97			0.44-0.54 0.50	0.44-0.58 0.52	0.46-0.60 0.53	0.38-0.80 0.67	0.36-0.82 0.67
Mg^{++}(meq/1)		2.36-4.60 3.31	1.74-2.20 1.91	2.58-2.64 2.62			1.22-1.34 1.26	1.14-1.30 1.24	1.10-1.30 1.22	0.86-2.04 1.65	0.88-2.16 1.71
Na^{+} + K^{+}(meq/1)		1.96-2.83 2.50	0.26-0.90 0.67	1.68-1.98 1.84			0.50-1.14 0.68	0.47-0.66 0.55	0.49-0.63 0.56	0.50-0.58 0.54	0.25-0.57 0.48
HCO_3^-(meq/1)		4.03-4.75 4.53	2.07-2.18 2.11	3.36-3.62 3.54			1.75-1.85 1.80	1.70-1.88 1.78	1.70-1.88 1.78	0.82-3.11 2.35	0.80-2.90 2.28
Cl^-(meq/1)		0.87-0.99 0.92	0.11-0.13 0.12	0.58-0.74 0.64			0.07-0.08 0.08	0.06-0.09 0.07	0.06-0.09 0.07	0.05-0.12 0.10	0.05-0.12 0.10
$SO_4^{=}$(meq/1)		0.48-2.67 1.29	0.27-0.38 0.31	0.82-1.07 0.91			0.23-0.35 0.29	0.23-0.35 0.29	0.23-0.36 0.30	0.33-0.51 0.37	0.32-0.51 0.37
NO_2^- -N(mg/1)		0.009-0.100 0.035	0.001-0.006 0.003	0.004-0.012 0.007			0.001-0.004 0.003	0.003-0.006 0.005	0.004-0.006 0.005	0.001-0.025 0.009	0.003-0.025 0.009
NO_3^- -N(mg/1)		0.21-7.90 3.14	4.29-12.30 7.98	1.72-5.20 3.33			0.96-2.50 2.06	0.91-2.40 1.96	0.95-2.48 1.94	0.33-3.56 1.57	0.61-2.99 1.69
NH_3 -N(mg/1)		1.22-7.80 3.73	0.04-0.13 0.07	0.15-2.90 1.39			0.03-0.22 0.12	0.05-0.21 0.12	0.05-0.24 0.15	0.08-0.41 0.18	0.04-0.43 0.17

Appendix 1. (continued)

	1	2	3	4	5	6	7	8	9	10	11
Ortho $-PO_4^{=}$ (mg/l)		0.91-9.60 4.87	0.27-0.36 0.31	0.79-4.00 2.29			0.28-0.43 0.37	0.27-0.44 0.36	0.21-0.44 0.35	0.06-0.46 0.20	0.10-0.30 0.20
Silica (mg/l)		42.5-86.0 55.5	38.0-63.5 47.2	40.0-62.0 45.8			40.0-50.0 43.3	40.0-62.0 46.5	34.0-62.0 46.2	18.0-36.4 26.8	22.2-33.3 26.0
Dissolved Oxygen (mg/l)		1.00-2.78 2.30	9.23-12.00 10.71	11.02-11.92 11.25			8.38-11.26 9.61	10.94-12.18 11.74	10.91-12.80 11.96	12.52-14.06 13.23	12.13-13.46 12.75
Total Coliform		0-4300 980	0-100 25	0-300 75			0-0 0	0-0 0	0-0 0	0-100 20	0-100 20
Fecal Coliform		0-1900 520	0-0 0	0-200 50			0-0 0	0-0 0	0-0 0	0-0 0	0-0 0
Turbidity (N.T.U.)		2-13 7	0-1 1	1-3 2			1-4 2	2-3 2	3-5 4	2-34 11	2-35 11
Temperature (C)		3.2-10.0 5.9	6.3-9.6 7.8	1.7-6.3 4.3			6.4-10.1 7.9	3.3-10.0 6.1	2.0-7.1 4.6	0.0-9.1 3.1	0.0-9.8 3.6

Appendix 2. Range and mean water quality parameters during the high flow period from March 1975 to April 1975.

	1	2	3	4	5	6	7	8	9	10	11
pH Range	7.6-8.3	7.2-7.4	7.6-7.7	7.4-7.6	7.6-8.0	7.6-8.2	7.0-7.2	7.7-7.8	7.8-7.8	7.6-7.6	7.2-7.5
Conductance (micromhos/cm)	339-341 340	400-455 427	289-296 292	365-396 380	271-289 280	356-364 360	217-224 220	295-333 314	296-335 315	171-182 176	174-185 179
Ca^{++}(meq/l)	0.72-0.78 0.75	0.90-0.98 0.94	0.70-0.72 0.71	0.66-0.84 0.75	0.64-0.64 0.64	0.82-0.88 0.85	0.52-0.60 0.56	0.72-0.84 0.78	0.76-0.86 0.81	0.46-0.50 0.48	0.42-0.54 0.48
Mg^{++}(meq/l)	1.68-1.72 1.70	1.84-2.20 2.02	1.52-1.58 1.55	1.78-2.26 2.02	1.28-1.44 1.36	1.74-1.76 1.75	1.12-1.14 1.13	1.38-1.60 1.49	1.46-1.52 1.49	0.76-0.90 0.83	0.76-0.88 0.82
$Na^{+} + K^{+}$(meq/l)	0.91-0.99 0.95	1.26-1.37 1.31	0.66-0.67 0.66	1.03-1.04 1.03	0.79-0.81 0.80	1.00-1.00 1.00	0.51-0.52 0.51	0.73-1.01 0.87	0.74-0.97 0.85	0.45-0.46 0.45	0.44-0.55 0.49
HCO_3^-(meq/l)	2.70-2.75 2.73	2.85-3.29 3.07	1.67-1.80 1.74	2.62-2.93 2.78	1.88-1.92 1.90	2.49-2.74 2.61	1.64-1.85 1.75	2.26-2.31 2.29	2.23-2.31 2.27	0.98-0.98 0.98	0.92-1.02 0.97
Cl^-(meq/l)	0.29-0.40 0.34	0.36-0.46 0.41	0.12-0.13 0.13	0.31-0.39 0.35	0.07-0.08 0.07	0.29-0.38 0.34	0.06-0.08 0.07	0.20-0.30 0.25	0.20-0.30 0.25	0.04-0.05 0.05	0.05-0.05 0.05
$SO_4^=$(meq/l)	0.45-0.57 0.51	0.35-0.57 0.46	0.30-0.32 0.31	0.37-0.55 0.46	0.32-0.35 0.33	0.37-0.52 0.44	0.25-0.25 0.25	0.40-0.52 0.46	0.42-0.57 0.50	0.45-0.64 0.55	0.45-0.54 0.50
NO_2^- -N(mg/l)	0.004-0.006 0.005	0.009-0.018 0.013	0.001-0.001 0.001	0.010-0.016 0.013	0.003-0.005 0.004	0.005-0.007 0.006	0.001-0.001 0.001	0.004-0.004 0.004	0.004-0.005 0.004	0.001-0.008 0.004	0.001-0.008 0.004
NO_3^- -N(mg/l)	0.61-0.90 0.75	0.70-1.32 1.01	7.68-9.80 8.74	1.11-1.82 1.46	4.72-6.47 5.60	0.99-1.56 1.27	0.28-1.12 0.70	0.84-2.28 1.56	0.92-2.28 1.60	3.12-6.96 5.04	2.68-8.32 5.50
NH_3 -N(mg/l)	0.34-0.59 0.46	0.70-1.40 1.05	0.01-0.09 0.05	0.59-0.80 0.69	0.18-0.60 0.39	0.52-0.55 0.53	0.14-0.35 0.24	0.35-0.61 0.48	0.41-0.72 0.56	0.55-1.15 0.85	0.40-1.13 0.76

Appendix 2. (continued)

	1	2	3	4	5	6	7	8	9	10	11
Ortho -$PO_4^{=}$(mg/l)	0.23-0.52 0.37	0.67-0.90 0.78	0.29-0.33 0.31	0.31-0.85 0.58	0.28-0.43 0.35	0.60-0.62 0.61	0.27-0.32 0.29	0.47-0.91 0.69	0.50-1.11 0.80	0.42-0.84 0.63	0.45-0.77 0.61
Silica (mg/l)	12.6-27.4 20.0	22.7-25.2 23.9	47.0-50.0 48.5	31.0-38.0 34.5	26.0-45.0 35.5	27.0-38.0 32.5	43.0-45.0 44.0	32.0-38.0 35.0	32.0-43.0 37.5	31.6-38.0 34.8	32.6-38.0 35.3
Dissolved Oxygen (mg/l)	11.08-11.20 11.14	7.22-8.94 8.08	11.86-12.22 12.14	10.40-10.88 10.64	11.92-12.46 12.19	10.98-12.72 11.85	8.56-10.14 9.35	11.04-11.16 11.10	11.28-11.62 11.45	10.52-11.62 11.07	10.40-11.66 11.03
Total Coliform	0-100 50	0-0 0	0-0 0	0-0 0	0-0 0	0-0 0	0-0 0	0-0 0	200-300 250	100-1000 550	0-800 400
Fecal Coliform	0-0 0	0-0 0	0-0 0	0-0 0	0-0 0	0-0 0	0-0 0	0-0 0	0-0 0	0-0 0	0-0 0
Turbidity (N.T.U.)	4-4 4	2-4 3	1-1 1	3-6 4	5-26 15	3-7 5	2-3 2	4-8 6	7-15 11	28-52 40	28-58 43
Temperature (C)	4.0-10.3 7.1	4.5-8.5 6.5	7.5-8.9 8.6	4.2-8.0 6.1	3.9-5.8 4.8	3.6-8.6 6.1	7.0-7.6 7.3	4.5-6.5 5.5	4.5-6.2 5.3	4.0-8.9 6.4	3.9-8.4 6.1

Appendix 3. Range and mean water quality parameters during the complete sampling period from October 1974 to April 1975.

	1	2	3	4	5	6	7	8	9	10	11
pH Range	7.6-8.3	7.0-7.4	7.4-7.7	7.4-8.0	7.6-8.0	7.6-8.2	7.0-7.4	7.6-7.7	7.7-7.8	7.4-8.4	7.2-8.4
Conductance (micromhos/cm)	339-341 340	400-820 621	289-358 319	365-562 490	271-289 280	356-364 360	217-294 237	219-333 254	219-335 255	171-337 255	174-331 255
Ca^{++}(meq/l)	0.72-0.78 0.75	0.84-1.64 1.11	0.70-0.76 0.73	0.66-1.00 0.90	0.64-0.64 0.64	0.82-0.88 0.85	0.44-0.60 0.52	0.44-0.84 0.59	0.46-0.86 0.61	0.38-0.80 0.62	0.36-0.82 0.62
Mg^{++}(meq/l)	1.68-1.72 1.70	1.84-4.60 2.94	1.52-2.20 1.79	1.78-2.64 2.42	1.28-1.44 1.36	1.74-1.76 1.75	1.12-1.34 1.22	1.14-1.60 1.31	1.10-1.52 1.30	0.76-2.04 1.41	0.76-2.16 1.45
Na^{+} + K^{+}(meq/l)	0.91-0.99 0.95	1.26-2.83 2.16	0.26-0.90 0.67	1.03-1.98 1.57	0.79-0.81 0.80	1.00-1.00 1.00	0.50-1.14 0.65	0.47-1.01 0.64	0.49-0.97 0.64	0.45-0.58 0.52	0.25-0.57 0.48
HCO_3^-(meq/l)	2.70-2.75 2.73	2.85-4.75 4.11	1.67-2.18 1.99	2.62-3.62 3.28	1.88-1.92 1.90	2.49-2.74 2.61	1.64-1.85 1.78	1.70-2.31 1.92	1.70-2.31 1.92	0.82-3.11 1.96	0.80-2.90 1.90
Cl^-(meq/l)	0.29-0.40 0.34	0.36-0.99 0.77	0.11-0.13 0.12	0.31-0.74 0.54	0.07-0.08 0.07	0.29-0.38 0.34	0.06-0.08 0.07	0.06-0.30 0.12	0.06-0.30 0.12	0.04-0.12 0.08	0.05-0.12 0.09
$SO_4^=$(meq/l)	0.45-0.57 0.51	0.35-2.67 1.05	0.27-0.38 0.31	0.37-1.07 0.76	0.32-0.35 0.33	0.37-0.52 0.44	0.23-0.35 0.28	0.23-0.52 0.34	0.23-0.52 0.36	0.33-0.64 0.42	0.32-0.54 0.41
NO_2^- -N(mg/l)	0.004-0.006 0.005	0.009-0.100 0.029	0.001-0.006 0.003	0.004-0.016 0.009	0.003-0.005 0.004	0.005-0.007 0.006	0.001-0.004 0.003	0.003-0.006 0.004	0.004-0.006 0.005	0.001-0.025 0.008	0.001-0.025 0.008
NO_3^- -N(mg/l)	0.61-0.90 0.75	0.21-7.90 2.53	4.29-12.30 8.23	1.11-5.20 2.71	4.72-6.47 5.60	0.99-1.56 1.27	0.28-2.50 1.67	0.84-2.40 1.85	0.92-2.48 1.85	0.33-6.96 2.56	0.61-8.32 2.78
NH_3 -N(mg/l)	0.34-0.59 0.46	0.70-7.80 2.97	0.01-0.13 0.06	0.15-2.90 1.16	0.18-0.60 0.39	0.52-0.55 0.53	0.03-0.35 0.16	0.05-0.61 0.23	0.05-0.72 0.27	0.08-1.15 0.37	0.04-1.13 0.34

Appendix 3. (continued)

	1	2	3	4	5	6	7	8	9	10	11
Ortho -$PO_4^{\equiv}$(mg/l)	0.23-0.52 0.37	0.67-9.60 3.71	0.27-0.36 0.31	0.31-4.00 1.72	0.28-0.43 0.35	0.60-0.62 0.61	0.27-0.43 0.35	0.27-0.91 0.45	0.21-1.11 0.48	0.06-0.84 0.33	0.10-0.77 0.32
Silica (mg/l)	12.6-27.4 20.0	22.7-86.0 46.5	38.0-63.5 47.7	31.0-62.0 42.1	26.0-45.0 35.5	27.0-38.0 32.5	40.0-50.0 43.4	32.0-62.0 43.2	32.0-62.0 43.7	18.0-38.0 29.1	22.2-38.0 28.7
Dissolved Oxygen (mg/l)	11.08-11.20 11.14	1.00-8.94 3.95	9.23-12.22 11.15	10.40-11.92 11.05	11.92-12.46 12.19	10.98-12.72 11.85	8.38-11.26 9.53	10.94-12.18 11.56	10.91-12.80 11.81	10.52-14.06 12.61	10.40-13.40 12.26
Total Coliform	0-100 50	0-4300 700	0-100 17	0-300 50	0-0 0	0-0 0	0-0 0	0-0 0	0-300 71	0-1000 171	0-800 128
Fecal Coliform	0-0 0	0-1900 371	0-0 0	0-200 33	0-0 0	0-0 0	0-0 0	0-0 0	0-0 0	0-0 0	0-0 0
Turbidity (N.T.U.)	4-4 4	2-13 6	0-1 1	1-6 3	5-26 15	3-7 5	1-4 2	2-8 3	3-15 6	2-52 19	2-58 20
Temperature (C)	4.0-10.3 7.1	3.2-10.0 6.1	6.3-9.8 8.1	1.7-8.0 4.9	3.9-5.8 4.8	3.6-8.6 6.1	6.4-10.1 7.7	3.3-10.0 5.9	2.0-7.1 4.8	0.0-9.1 4.1	0.0-9.8 4.3