each pair of data indicates no discernable difference due to the effect of temperature. This is corroborated further by plots of turbidity versus time for the two temperatures, shown in Figures G-7 to G-10, Appendix G. Figure G-8 and G-9 show no differences in the plots of effluent turbidity versus time at 5°C and 18°C. The two plots are different in Figure G-10, where polymer was added to the first rapid mix basin and alum was added to the second, for each of the two tests at 5°C and 18°C. This result is not consistent with the others (where alum was added first); an explanation is not offered. All tests were done at coagulant dosage which gave minimum effluent turbidities.

Those same plots, e.g. Figures G-7 to G-10, show an appreciable difference in the headloss versus time curves between 5°C and 18°C. The initial headloss at time zero for the 18°C water temperature was nominally 7 cm of Hg, and about 9.5 cm Hg for the 5°C tests for each of the four pairs of headloss versus time curves. Further, the rate of headloss increase was the same for both temperatures for three of the four pairs. The difference is due to the effect of temperature on dynamic viscosity of water. This can be seen by examining the ratio of initial headlosses for 5°C and 18°C, respectively, in Figure G-8, e.g. 10.2 cm Hg/7.0 cm Hg (which equals 1.45), and comparing with the ratio of dynamic viscosities of water at the two temperatures, which is 1.46 (using Darcy's law as the basis). This close comparison establishes that the headloss difference was due to the effect of temperature of the viscosity of water.

The effect of temperature on removals cannot be discerned from these few tests. But if a temperature effect does exist these data indicate that it may not be strong within the range 5°C to 18°C.

<u>Run Time</u>

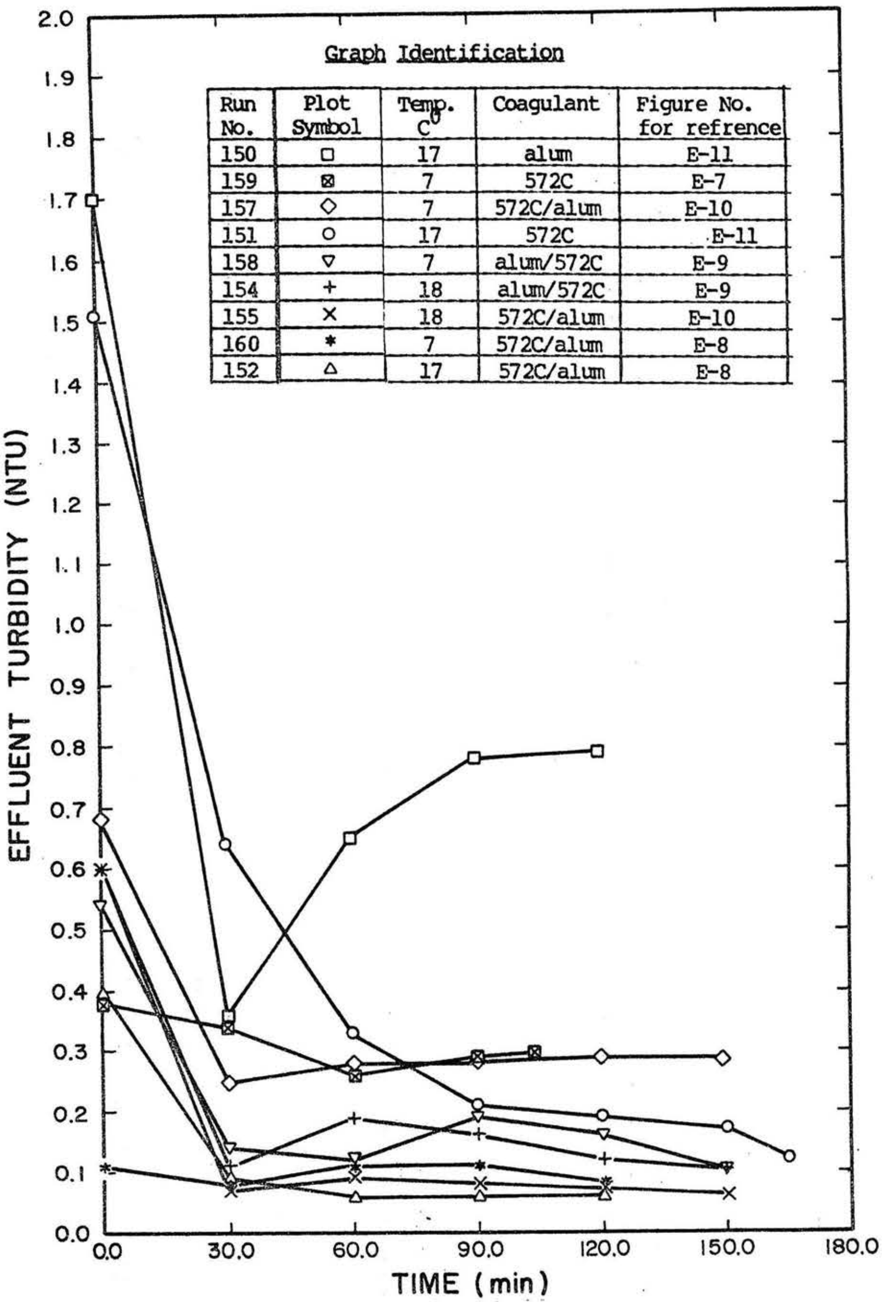
Of widespread interest is the effectiveness of rapid rate filtration with respect to elapsed time after backwash, called "run time" here. This question was of interest with respect to removals of turbidity and other parameters measured, including <u>Giardia</u> cysts. It was of interest also with respect to sampling protocol, since it was desired to obtain samples after the run had "stabilized."

Figure 36 and 37 show the effect of run time on effluent turbidity, and headloss, respectively using water having turbidity less than 1 NTU. Figure 36 shows that effluent turbidity was about constant after 30 minutes of run time. The rapid decline between 0-30 minutes was due to the fact that the detention time in the tubes, pipes, and filter was nominally about 30 minutes (it was 30 minutes from the coagulant box to the filter effluent for a flow fo 450 mL/min to a 5 cm filter). This means that the system is essentially "steady state" after 30 minutes and that representative sampling can be done after this time. Complete conditions associated with the test runs in Figure 36 are described in Figures G-7 to G-11.

Test Conditions

Run number(s) : 150-152, 154-160
Raw water turbidity : 0.45 NTU
Temperature : 18C
Primary coagulant : 0-9 mg/L alum

Secondary coagulant : 0.42-1.8 mg/L 572C



Run No.	Plot Symbol	Temp. C°	Coagulant	Figure No. for refrence
150	□	17	alum	E-11
159	⊠	7	572C	E-7
157	◇	7	572C/alum	E-10
151	○	17	572C	E-11
158	▽	7	alum/572C	E-9
154	+	18	alum/572C	E-9
155	×	18	572C/alum	E-10
160	*	7	572C/alum	E-8
152	△	17	572C/alum	E-8

Figure 36. Effect of run time on turbidity reduction for different temperatures and coagulants. Figures H-7 to H-11, Appendix H describe complete conditions.

Test Conditions

Run number(s)	:	150-152, 154-160
Raw water turbidity	:	0.45 NTU
Temperature	:	18C
Primary coagulant	:	0-9 mg/L alum
Secondary coagulant	:	0.42-1.8 mg/L 572C

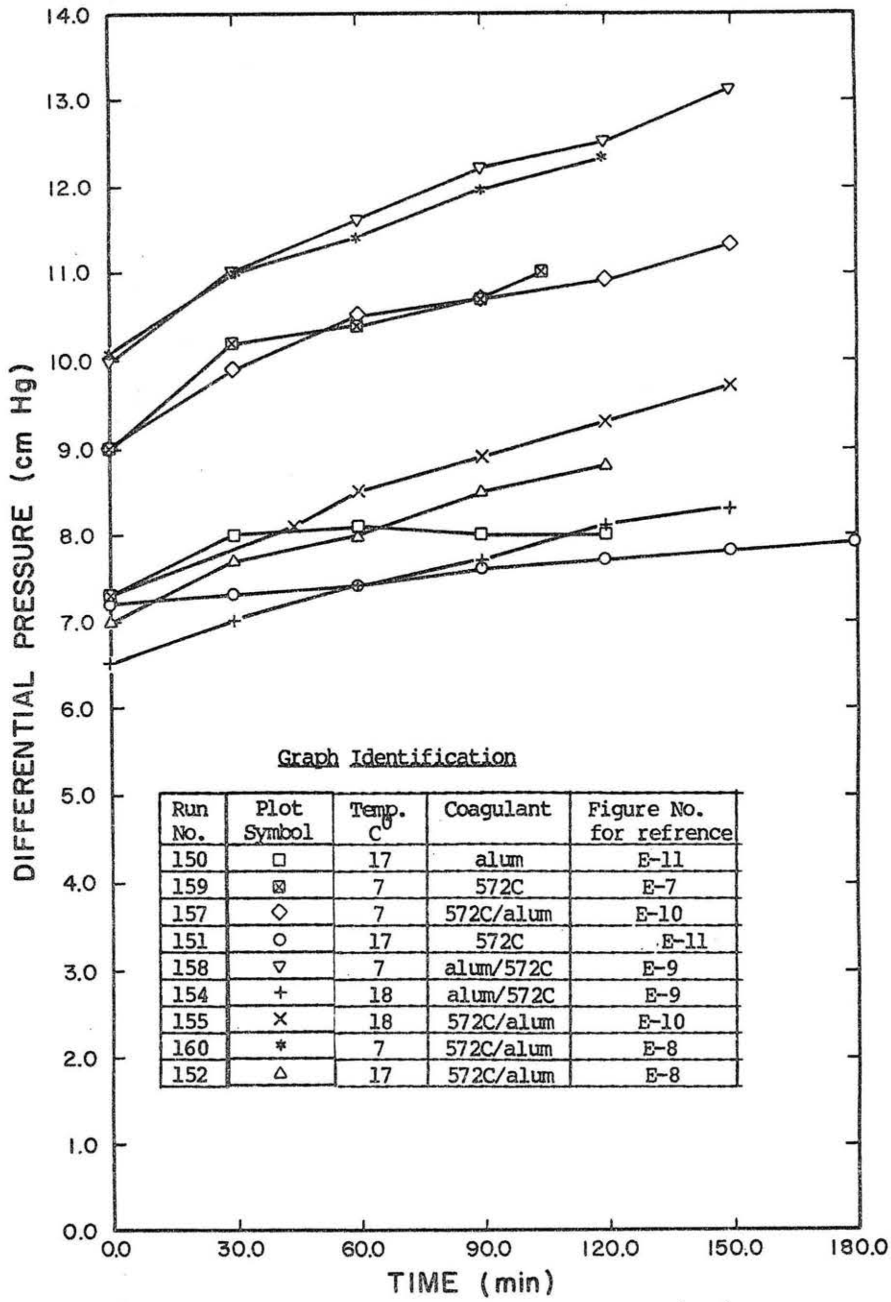


Figure 37. Effect of run time on headless for different temperatures and coagulants. Figures H-7 to H-11, Appendix H, describe complete conditions.

Figure 37 shows headloss increase with time for the same test runs used to plot Figure 36. As explained in the section on temperature effects the differences between the initial headloss values is due to temperature differences. The rate of headloss increase is due to the differences in coagulants, or coagulation conditions. For alum/572C the rate of headloss increase was about 0.5 cm Hg/hr. For 24 hour run this would be 12 cm Hg, which is 1.6 meters of water. If the allowable headloss is 3 meters, the run time could be about 45 hours, assuming turbidity breakthrough does not occur first and assuming the headloss increase is linear, and not exponential. The longest run time in these experiments was about 6 hours, during which turbidity was stable.

Table 17 shows removals of five parameters, turbidity, particles, total plate count bacteria, total coliform bacteria, and Giardia cysts, for sampling at 30 minutes run time and at 90 minutes. The table shows two categories of coagulant dosages, "optimum" and "nonoptimum." Removals are uniformly high for all parameters at optimum chemical dosages. But in relation to the question at hand, there is essentially no difference in percent removals at these two times. In practical terms it means there is little need to run filter to waste after the coagulants have become effective in interacting with the filter media. These conclusions do not mean that filter to waste is not advisable. After backwash the incoming coagulant water will mix with the backwash water and there could be a reduction in filter effectiveness during this period.

RELATIONSHIPS BETWEEN DEPENDENT VARIABLES

The most common indicator of water treatment effectiveness is finished water turbidity. It is common practice to use finished water turbidity as an operating parameter when raw water turbidity exceeds 1 NTU. For low turbidity waters, however, this parameter is monitored, but it is not used to control operation; the turbidity standard of 1 NTU is simply not exceeded. But since turbidity is easy to measure and to measure accurately, its use as an operating parameter for low turbidity water was examined. At the same time, other parameters were examined, such as particles, standard plate count bacteria, and total coliform bacteria. Of casual interest was to ascertain whether percent turbidity removal could be an effective surrogate measure for percent removals of any of the foregoing parameters. But the main quest was to determine whether percent removal of turbidity, or any of the other parameters, mentioned above could serve as an index of percent removal of Giardia cysts. It should be noted also that when using low turbidity mountain waters that levels of total coliform bacteria in mountain streams are very low, e.g. less than 100 per 100 mL (Psaris and Hendricks, 1982). This means that coliform bacteria may not be an effective indicator of percent removal of any parameter if ambient concentrations of coliforms are used. Despite this possible practical limitation it was examined experimentally. Its use as an indicator of filtration would be nullified also if prechlorination is practiced.

Therefore, the test data obtained in this work, and reported in the foregoing sections, were plotted in terms of one parameter versus another,

Table 17. Effect of elapsed time after backwash on removal of Giardia cysts, particles, standard plate count bacteria, total coliform bacteria, for low turbidity, low temperature water at "optimum" and "non-optimum" coagulant dosages.1/

Run No.	Water Source	Influent 2/ Turbidity (NTU)	Coagulant 3/ Dosages	Percent Removal: 30 Minutes Run Time 4/					Percent Removal: 90 Minutes Run Time 4/				
				Turbidity	Particle Count	Standard Plate	Total Coliform	Giardia Cysts 5/	Turbidity	Partical Count	Standard Plate	Total Coliform	Giardia cysts 5/
85	HDE	2.2	Optimum	95.9	99.3	96.9	>99.9	>99.9	94.6	75.9	95.0	98.6	99.8
86	HDE	2.2	Optimum	95.2	99.5	99.0	99.8	99.9	97.6	99.8	99.0	96.7	>99.9
87	HDE	2.2	Optimum	96.0	91.4	99.4	99.5	>99.9	97.2	>99.9	99.7	99.7	>99.9
88	HDE	2.2	Optimum	94.2	99.7	95.9	99.9	99.9	76.8	56.7	92.6	99.9	99.8
89	HDE	2.2	Optimum	96.8	>99.9	94.1	98.8	>99.9	97.1	92.7	98.9	97.8	99.9
90	HDE	2.2	Optimum	95.5	99.9	- 6/	>99.9	>99.9	96.4	99.9	- 6/	>99.9	>99.9
91	HDE	2.2	Optimum	95.0	99.9	72.4	99.9	>99.9	96.7	99.9	86.4	94.8	99.9
101	CLP	4.8	Optimum	87.5	99.7	97.9	99.9	99.4	68.9	99.8	>99.9	99.9	99.7
102	CLP	6.2	Nonoptimum	76.5	27.1	00.0	00.0	98.6	41.9	34.7	00.0	00.0	95.4
104	CLP	1.1	Nonoptimum	16.7	98.8	50.4	-24.4	97.4	82.4	98.6	99.5	79.8	98.7
107	CLP	0.7	Nonoptimum	60.3	95.4	96.7	90.0	99.7	92.7	95.4	96.7	90.0	99.9

1/ Abstracted from Table A-1 and Table A-2, Appendix A.
2/ Turbidity level after contaminate of raw sewage and dog feces were added to milk cooler, turbidity level prior to these additons ranged from .45 to.70 NTU.
3/ Coagulants used for test runs 85,86,87 were alum and 572C. For other test run the coagulants used were alum and 572C. The term "optimum" coagulant dosage means any dosage resulting lowest effluent turbidity levels.
4/ Time elapsed after back wash when sampling was initiated. Sampling duration was about 30 minutes for Giardia cysts, and only long enough to fill the sample bottle for grab sample.
5/ Percent recovery is reported as detection limites where zero cysts were recovered, and are indicated by the "greater than" symbol. The calculation of detection limit is showen in Appendix G.
6/ No sample taken.

e.g. percent removals of turbidity versus Giardia cysts, total coliform bacteria versus Giardia cysts, turbidity versus total coliform bacteria, and turbidity versus standard plate count bacteria. These relationships were plotted by histograms and then were examined further by means of statistical tests. All relationships discussed in this section have used data obtained from operation of the laboratory-scale pilot plant.

Surrogate Indicators for Giardia Cyst Removal

Detection and measurement of Giardia cysts requires the services of a skilled parasitologist, knowledgeable of techniques for concentration, and having continuing practice in identification of the organism. Thus it is desirable that a surrogate be found to substitute for routine measurement of Giardia cysts which can be incorporated into water treatment practice. Therefore, a surrogate for percent removal of Giardia cysts, is another quest of this research. Several were investigated, including turbidity, particles, standard plate count bacteria, and total coliform bacteria. Histogram plots were developed for two of these possible surrogates, turbidity and total coliform bacteria, using data from Table A-1 and Table A-2. These were selected for examination because both are easy to measure and could be used in evaluation of performance of the filtration process.

Turbidity--

Figure 38 is a histogram showing percent removal of Giardia cysts and corresponding values of percent removal of turbidity. Figure G-12 is a plot of observations, used partially to construct Figure 38, but with all data shown. Figure 38 shows that if turbidity removal is high, then removal of Giardia cysts will be high also. To be more specific, the plot shows 44 observations when turbidity removal is greater than 70 percent. Of these, 37 have removals of Giardia cysts of 99 percent or more. In other words, if turbidity removal exceeds 70 percent the probability is 0.85 (e.g. 37/44) that removal of Giardia cysts will be equal to or exceed 99 percent.

Figure 39 is a "probability of occurrence" plot, explained in Appendix F. It was obtained by ordering the data shown in Figure G-12 for statistical analysis, as explained in Appendix F. This plot shows that if percent removal of turbidity is at a given level, say 70 percent, then there is an 0.85 probability that removal of Giardia cysts will exceed 95 percent. This is a result only slightly different than obtained using the histogram, Figure 38. The histogram is a visual intuitive representation of the same information. Figure 38 is more quantitative.

While Figure 39 is useful in understanding the relationships shown (e.g. percent turbidity removal and probability of having a certain percent removal of Giardia cysts) it probably is not accurate for the lower percent removals of turbidity. This is due to the fact that data were not abundant in this range. In other words, while the plot generated represents the "sample," it may not necessarily represent accurately the "population," at least not in the lower ranges of percent removal of turbidity.

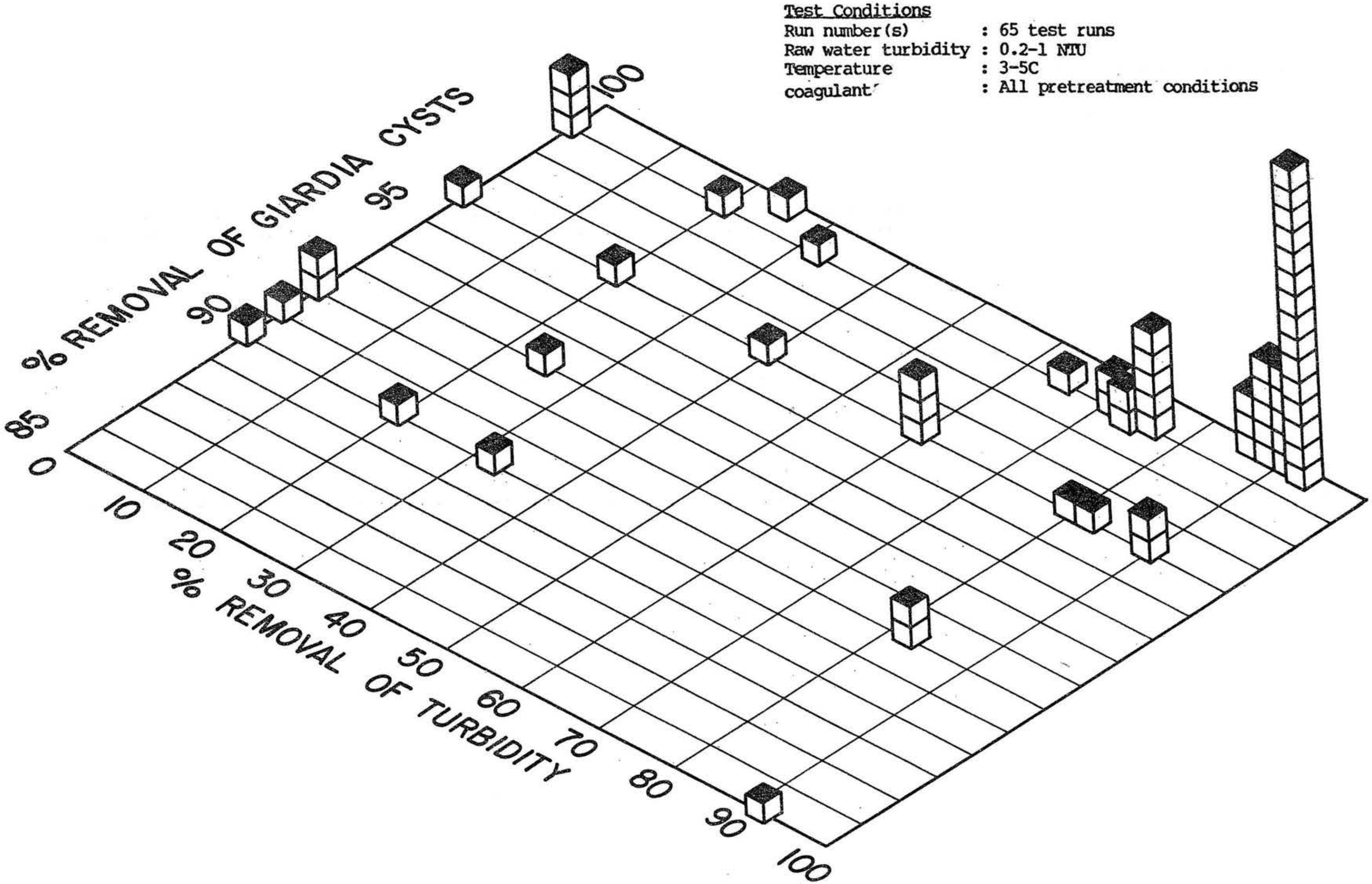


Figure 38. Histogram showing percent removal of Giardia cysts with corresponding percent removal of turbidity. Each block represents one measurement set. Data points are for water having turbidity of less than 1 NTU, and temperature 3-5°C.

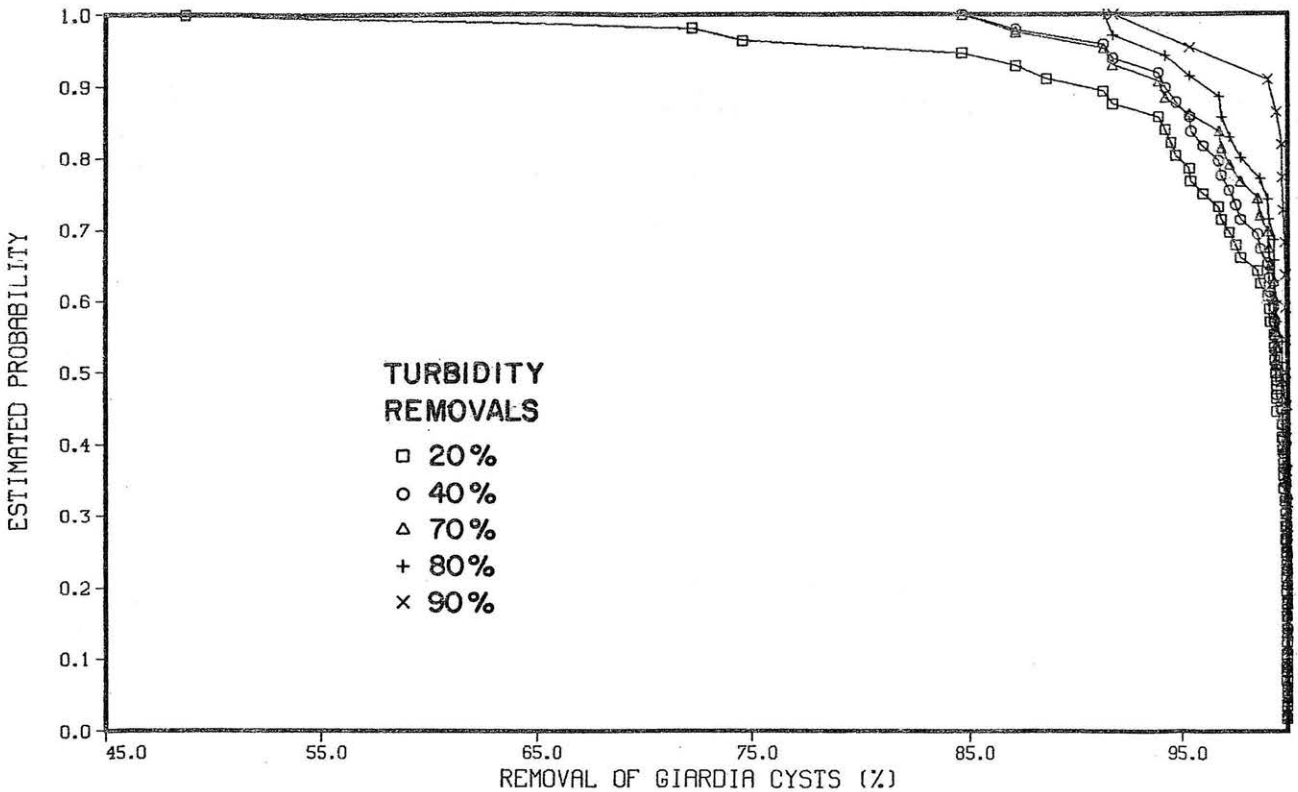


Figure 39. Probability of a given percent removal of <u>Giardia</u> cysts for specified percent removals of turbidity. Data obtained from Table A-1 and Table A-2 plotted in Figure H-12.

A statistical test between the two variables (percent removal of *Giardia* cysts and percent removal of turbidity) showed that a positive association exists, with 99.5 percent confidence level, as tested by the student t-distribution. In other words, it is virtually certain that a functional relationship exists betweeen the two variables.

Total Coliform Bacteria--

Figure 40 is another histogram showing percent removal of *Giardia* cysts and corresponding values of percent removal of total coliform bacteria showing all observations available. Figure 40 shows that if percent removal of total coliform bacteria is high, then high percent removals of *Giardia* cysts can be expected. Counting the observations in the range of 90 to 100 percent removal of total coliform bacteria, there is 0.70 probability that removal of *Giardia* cysts will be 99 percent or greater, and 0.85 probability that *Giardia* removal will exceed 96 percent. Figure 41 is another probability of occurrence plot for the sample of data shown in Figure G-13. By comparison, it shows that if percent removal of total coliform bacteria is 98 percent, then there is 0.82 probability that percent removal of *Giardia* cysts is 96 percent or greater, which compares closely with the same calculation using the histogram data.

A statistical test between the two variables (percent removal of *Giardia* cysts and percent removal of total coliform bacteria) shows that a positive association exists, with 99.5 percent confidence level, as tested by the student t-distribution. Again, this says that it is virtually certain that a functional relationship exists between the two variables.

Standard Plate Count Bacteria--

Grab samples obtained for bacteria sampling were analyzed for standard plate count bacteria as well as total coliform bacteria. Relationhips obtained between percent removals of standard plate count bacteria and percent removals of *Giardia* cysts were virtually the same as obtained using percent removal of total coliform bacteria. Figure G-14 shows percent removals of *Giardia* cysts plotted against percent removals of standard plate count bacteria. Both the plot and the student t-distribution statistics are essentially the same as obtained for total coliform bacteria vs *Giardia* cyst plots in the preceding paragraphs. Figure G-15 is a probability of occurrence plot for the data shown in Figure G-14. This plot is similar to Figure 41 where total coliform bacteria is used as indicator.

Particles--

Particle counting of grab samples of raw water and finished water was done for 12 test runs out of a total of 178. Percent removals of particles were not plotted against percent removals of *Giardia* cysts. But inspection of Table A-1 and Table A-2 shows that the correlation is not high when compared with the other surrogates.

Turbidity Removal As A Surrogate

As noted previously, turbidity is easy to measure and it can be accurate as well. It is also used routinely in water treatment practice. The

Test Conditions
Run number(s) : 51 test runs
turbidity : 0.2-3 NTU
re : 3-5C
: All pretreatment conditions

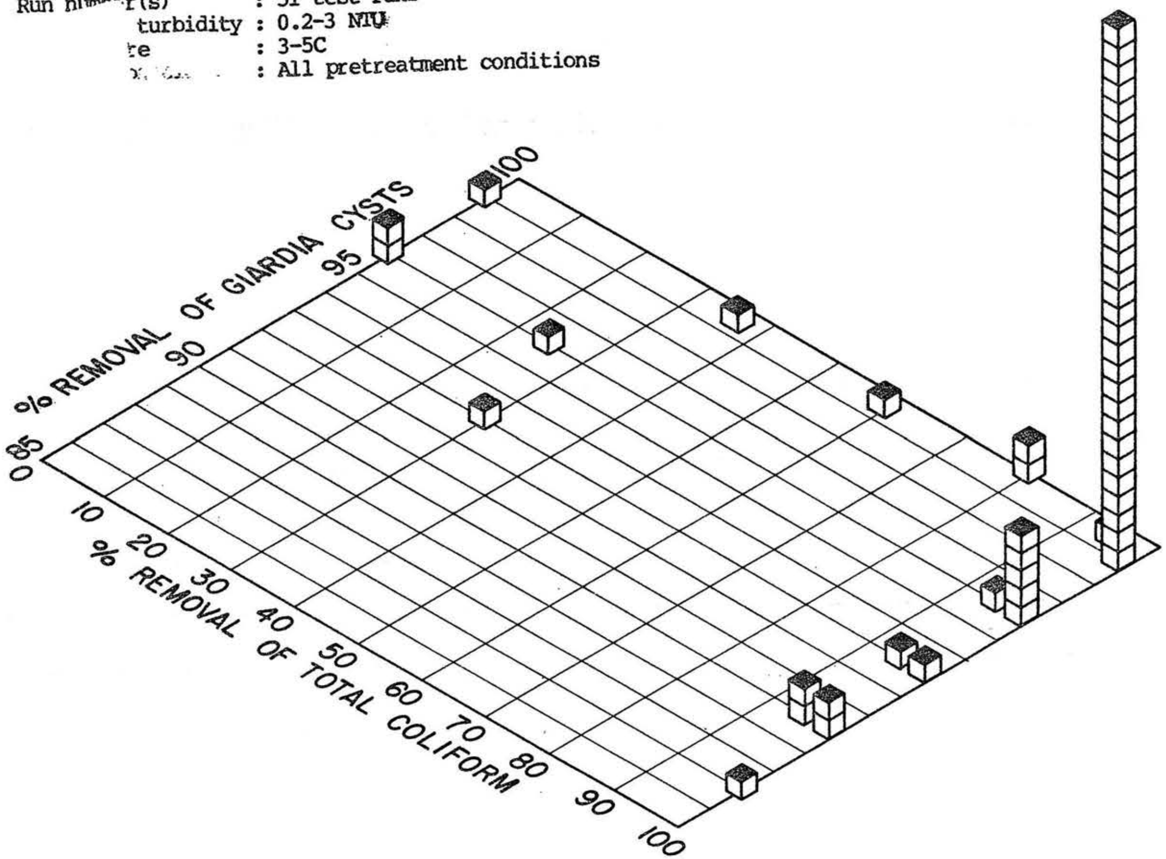


Figure 40. Histogram showing percent removal of Giardia cysts with corresponding percent removal of total coliform bacteria. Each block represents one measurement set.

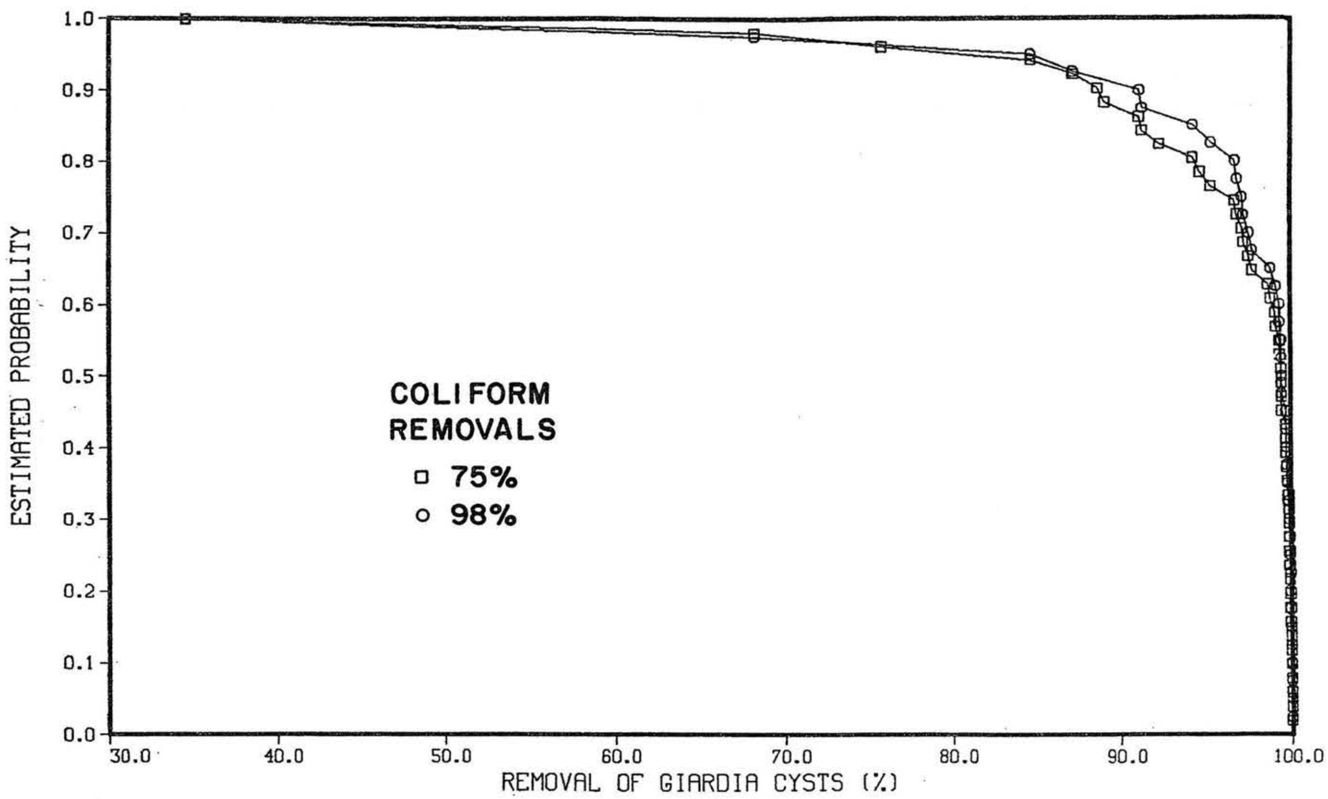


Figure 41. Probability of a given percent removal of _Giardia_ cysts for specific percent removal of total coliform bacteria. Data from Table A-1 and Table A-2 plotted in Figure H-13.

previous section, in Figure 38 and 39, and the associated statistical analysis, showed that it could be used as a surrogate for Giardia cyst removal.

Figure 42 is a histogram showing percent removal of total coliform bacteria and corresponding values of percent removal of turbidity. The historgram shows a strong association between the two variables. When percent removals of turbidity exceed 80 then percent removals of total coliform bacteria exceed 80 also. Figure G-16 shows all data plotted, along with the results of the student t-distribution. The analysis shows that a positive association exists, with 99.5 percent confidence level. Figure G-17 shows that "probability of occurrence" plot corresponding to the data shown in Figure G-16. It shows for example that if percent removal of turbidity exceeds 80, then there is 0.95 probability that percent removal of total coliform will exceed 80.

Figures G-18 and G-19 in Appendix G show similar data and results between percent removal of turbidity and percent removal of standard plate count bacteria. The student t-distribution test of data in Figure G-16 shows again the 99.5 percent confidence that a positive functional relationship exists. Figure G-19, for the probability of occurrence plot of data in Figure G-18, shows a generally lower family of curves than seen for total coliform bacteria.

Figure G-20 and G-21 in Appendix G show similar data and results between percent removal of turbidity and percent removal of particles. The student t-distribution test of data in Figure G-20 shows again the 99.5 percent confidence that a positive functional relationship exists. But examination of the family of curves in Figure G-21 for the probability of occurrence plot shows that the curves are still lower than seen for the standard plate count. For example, if turbidity removal is 80 percent the probability that particle removal is 80 percent is 0.86, whereas the probability was 0.95 for the turbidity-coliform data.

FIELD-SCALE PILOT PLANT TESTING

The objective of the field-scale testing was to confirm findings from the laboratory-scale experiments concerning the role of chemicals and the dosages of chemicals in determining removal efficiencies of Giardia cysts, turbidity, and total coliform bacteria, with particular reference to low turbidity waters. To conduct this testing the pilot plant was set up to obtain water from the Cache La Poudre in its mountain canyon, at the site of Fort Collins Water Treatment Plant No. 1. The work was conducted during the period October 1983 to January 1984, when raw water turbidities are usually less than 1 NTU. The results are reported in this section. It should be noted that testing using the field-scale pilot plant was more limited than when using the laboratory-scale pilot plant. This was due first to the logistic problems of conducting field-scale testing. But also to conduct tests using low turbidity water, it was necessary to find "windows of opportunity", with respect to weather, and sometimes other factors.

<u>Test Conditions</u>
Run number(s) : 135 test run
Raw water turbidity : 0.2-1.4 NTU
Temperature : 2-18C
Coagulant : All pretreatment condition

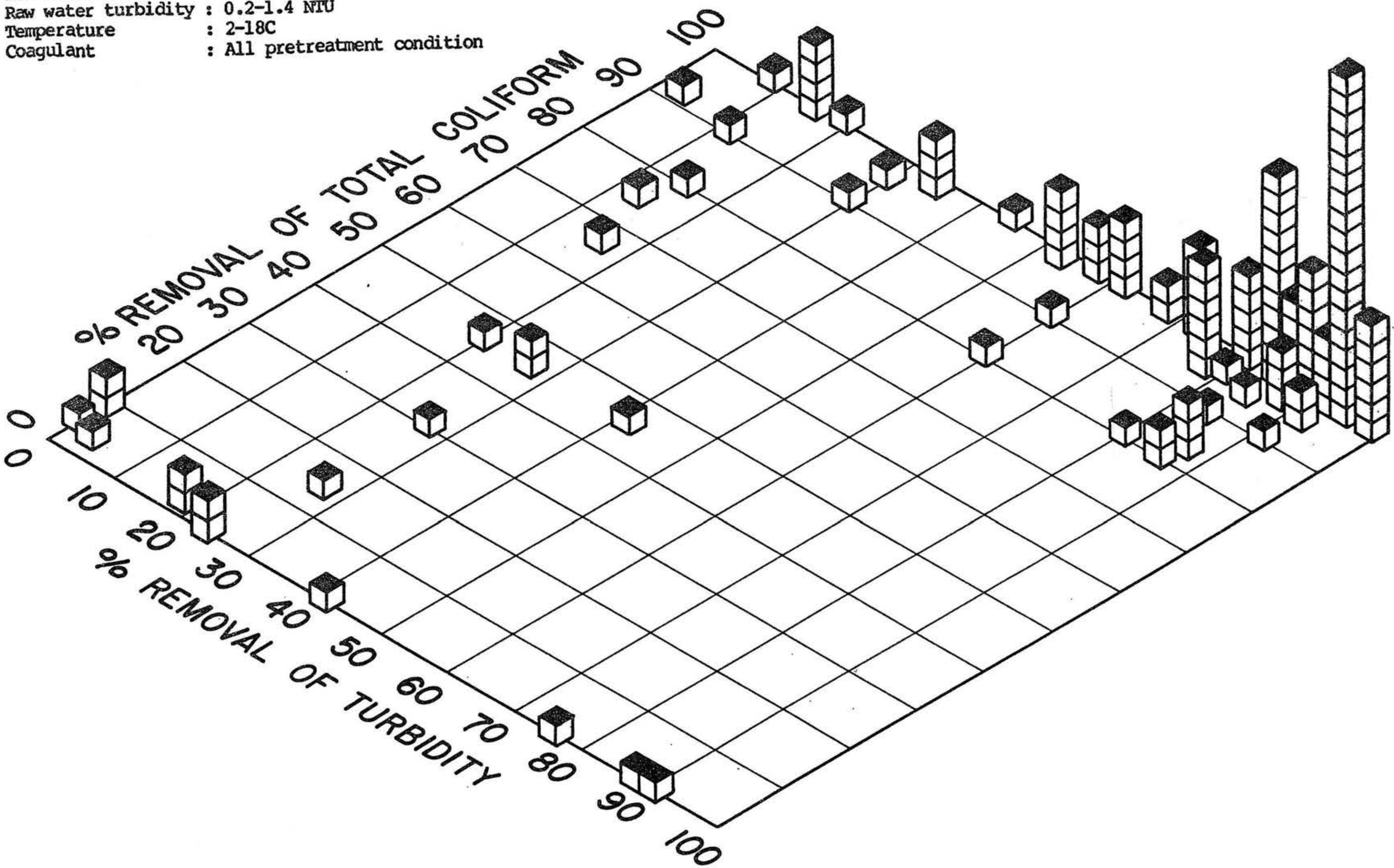


Figure 42. Histogram showing percent removal of total coliform removal with corresponding percent removal of turbidity. Each block represents one measurement set. Data points are for all water tested.

Testing was done also using other waters when low turbidity Cache La Poudre River was was not available and included water from the Cache La Poudre River during spring runoff and water from Horsetooth Reservoir. These results are given in Appendix H.

The low-turbidity testing phase using raw water from the Cache La Poudre River was comprised of 32 test runs. Effluent turbidity vs coagulant dose curves were generated for five combinations of coagulant chemicals, with selction based on results obtained from the laboratory-scale pilot plant work. From these curves, "optimum" and "nonoptimum" coagulant dosages were defined as the dosage range causing minimum effluent turbidities with respect to the turbidity-dose curve, and dosages which given significantly higher effluent turbidities. Evaluations of Giardia cyst and coliform bacteria removals were done in nine tests for coagulant dosages of "none", "optimum", and "nonoptimum". The "none" test category means that coagulant chemicals were not used.

Coagulant Dosage Determination - Field Scale Pilot Plant

Table 18 shows the results of the 23 effluent turbidity vs coagulant dose tests which used low-turbidity water from the Cache La Poudre River. Five coagulants and coagulant combinations were used in this testing, with selection based upon the lab-scale experiments. From the data in Table 18 effluent turbidity vs coagulant dose plots were generated, shown as Figures 43 through Figure 47, for Nalco 8102, Nalco 8102 and alum, alum, Magnifloc 572-C, and Magnifloc 572-C and alum, respectively.

Of these five figures, Figures 43, 46, and 47 are typical U-shaped curves; Figures 44 and 45 are not. The finished water turbidities in Figures 3-10 to 3-13 show only 0 to 25 percent reductions compared to raw water turbidities which ranged from 0.45 to 0.8 NTU. Determination of "optimum" dosages are not well defined for these curves, except in Figures 46 and 47. Figure 47 shows the typical U-shaped curve, using alum at different dosages and a fixed dosage of 2.0 mg/L of Magnifloc 572-C, where an "optimum" dosage is well defined. The finished water turbidity was reduced to 0.35 NTU compared to 0.7 NTU for the raw water. Later, in Run 138, during a Giardia test run at "optimum" dosage of alum and Magnifloc 572-C, the turbidity was reduced to 0.20 NTU after two-hours of operation. For the similar water and using the same coagulants, the turbidity was reduced to 0.05 to 0.10 NTU for the lab-scale work.

Effect of Coagulant Dose on Filtration - Field Scale Pilot Plant

Evaluations of removals of Giardia cysts, coliform bacteria, and turbidity were performed using coagulant dosages categorized as "none", "optimum", and "nonoptimum". Nine such evaluations were performed, and are described in Table 19, for low-turbidity water.

Table 19. Results of twenty three effluent turbidity vs chemical dose tests using low-turbidity raw water and field-scale rapid rate filtration pilot plant.[1/][2/] Data points for chemical dose and corresponding effluent turbidity were used to construct Figures 43 through 47.

Run #	Chemical Species[3/]	Coagulants: Chemical Dose[4/] mg/L	Coagulants: Water Temperature (°)	Turbidity (NTU): Influent	Turbidity (NTU): Effluent[5/]
107	None	0	7	0.55	0.45
108	8102	0.2	7	0.55	0.40
109	8102	0.5	7	0.45	0.50
110	8102	1.0	7	0.50	0.45
111	8102	2.0	7	0.45	0.65
112	8102	0.2	7	0.45	0.35
113	Alum/8102	3.0/0.6	7	0.60	0.75
114	Alum/8102	3.0/0.6	7	0.60	0.75
115	Alum/8102	3.0/0.6	7	0.70	0.70
116	Alum/8102	3.0/0.7	7	0.60	0.60
118	Alum	3.0	2	0.65	0.60
119	Alum	0.5	2	0.65	0.55
120	Alum	1.5	2	0.65	0.55
121	Alum	5.5	2	0.65	0.69
122	Alum	1.0	3	0.65	0.60
130	572-C	0.4	1	0.80	0.65
131	572-C	0.8	1	0.80	0.60
132	572-C	2.0	1	0.80	1.60
133	Alum/572-C	1.5/0.7	1	0.80	0.50
134	Alum/572-C	15/2.0/1/0.70/1.00			
135	Alum/572-C	4.5/2.0	1	0.70	0.35
136:Alum/572-C	9/2.0	1	0.70	0.35	
137	Alum/572-C	30/2.0	1	0.70	3.00

1/ Abstracted from Table B-1.

2/ Cache La Poudre River water with less than 1 NTU.

3/ Nalco 8102, Magnifloc 572-C.

4/ Alum doses are mg/L as $Al_2(SO_4)_3 \ 14 \ H_2O$.

5/ Effluent turbidity after one hour of operation.

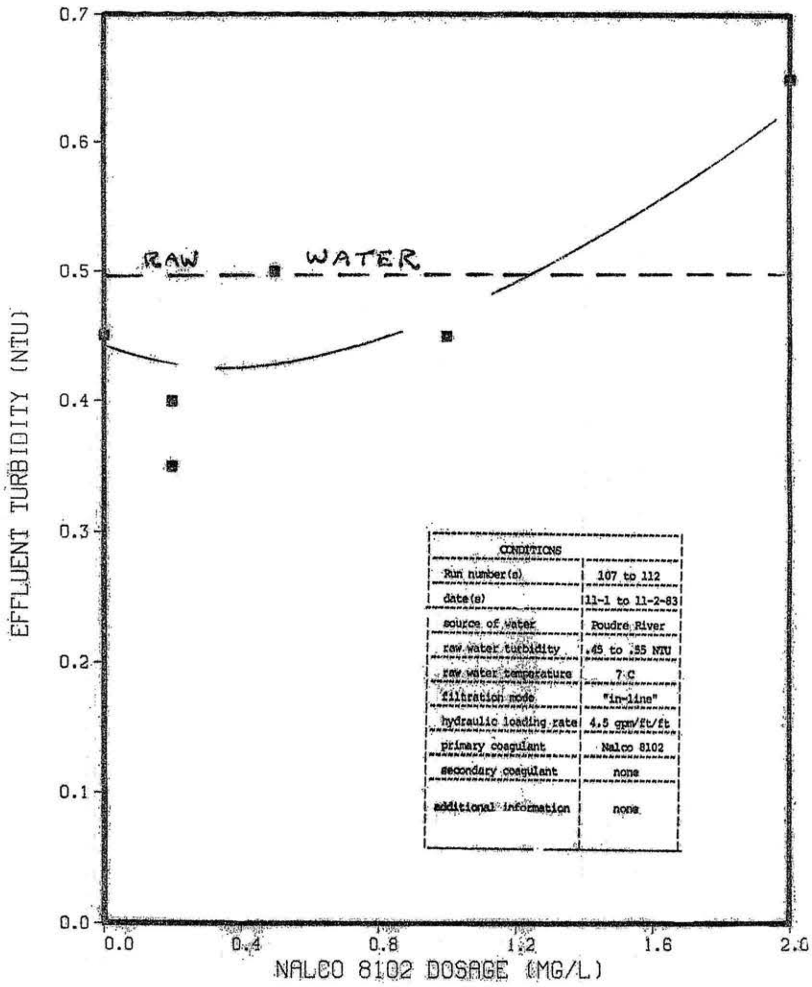


Figure 43. Effluent turbidity vs Nalco 8102 dose using low-turbidity water, and field-scale rapid rate filtration pilot plant.

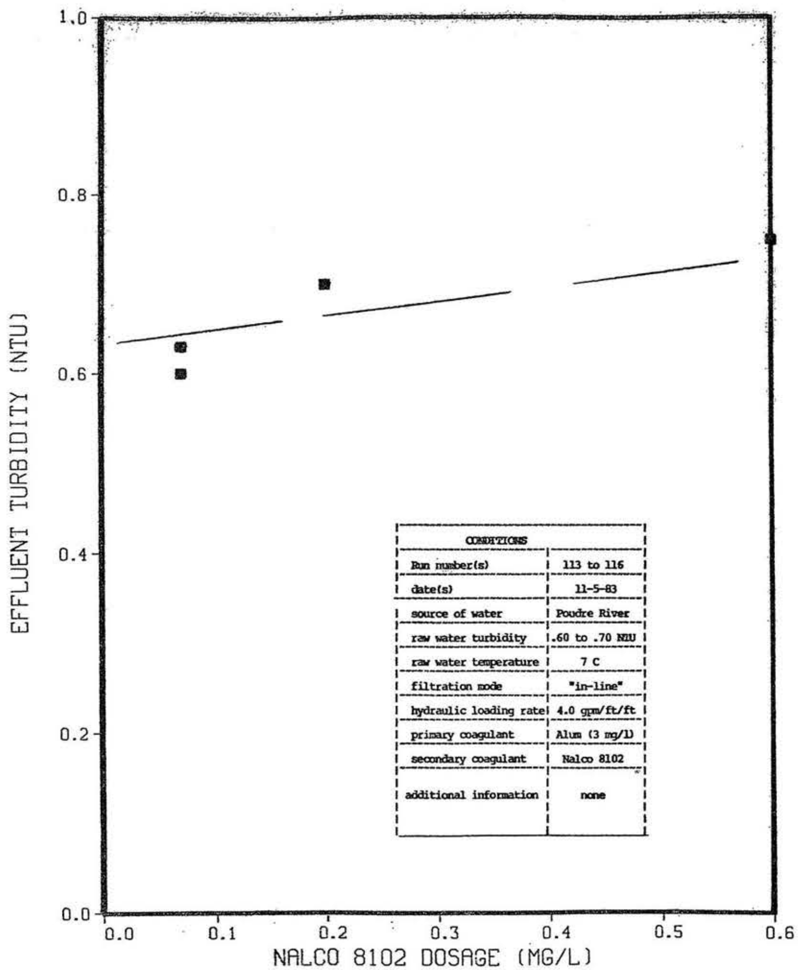


Figure 44. Effluent turbidity vs Nalco 8102 dose using 3 mg/l of alum, $Al_2(SO_4)_3\ 14\ H_2O$, for low-turbidity water and field scale plant.

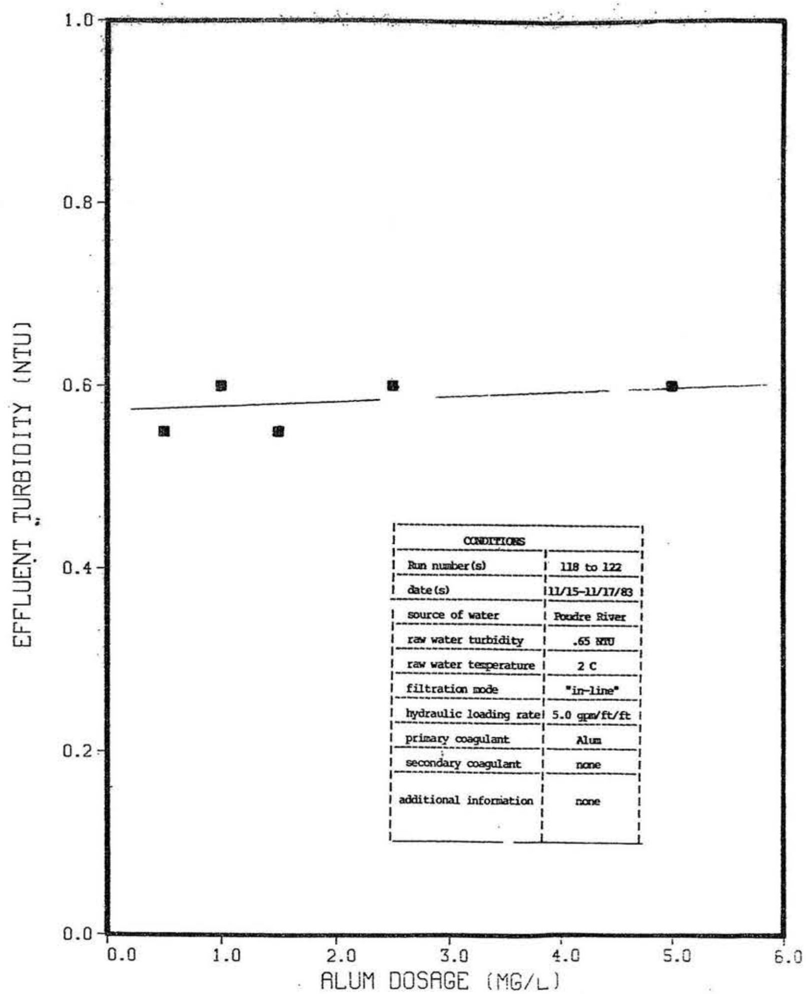


Figure 45. Effluent turbidity vs alum dose, $Al_2(SO_4)_3\ 14H_2O$, for low-turbidity water with field scale pilot plant.

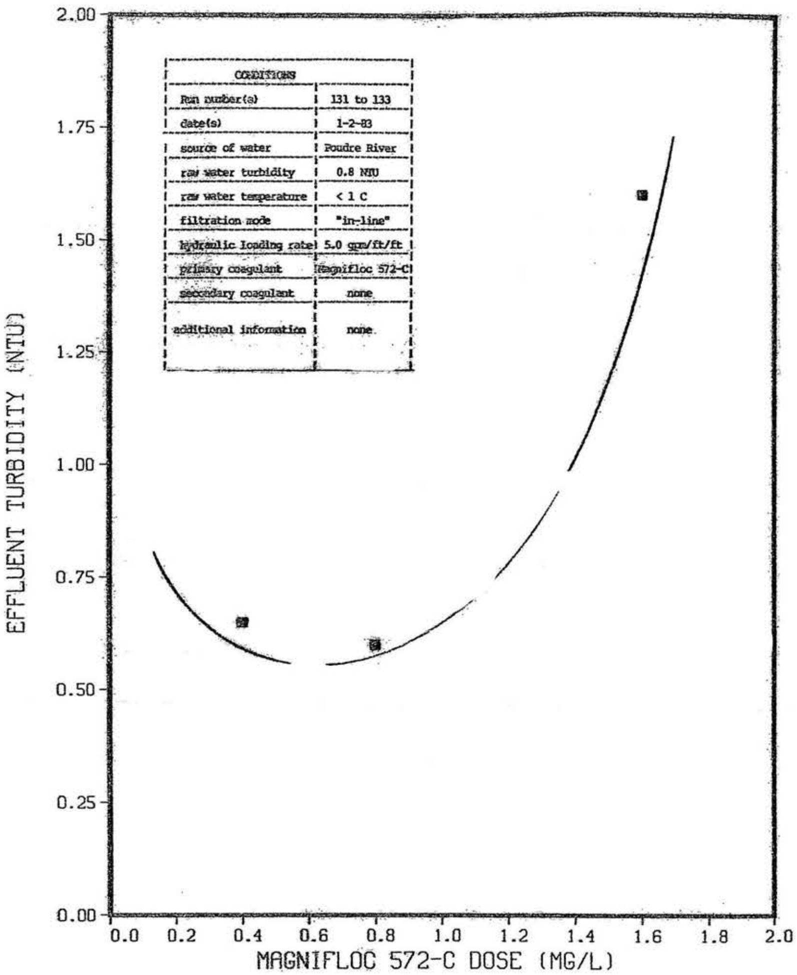


Figure 46. Effluent turbidity vs dose of Magnifloc 572-C. Low-turbidity water. Field scale pilot plant.

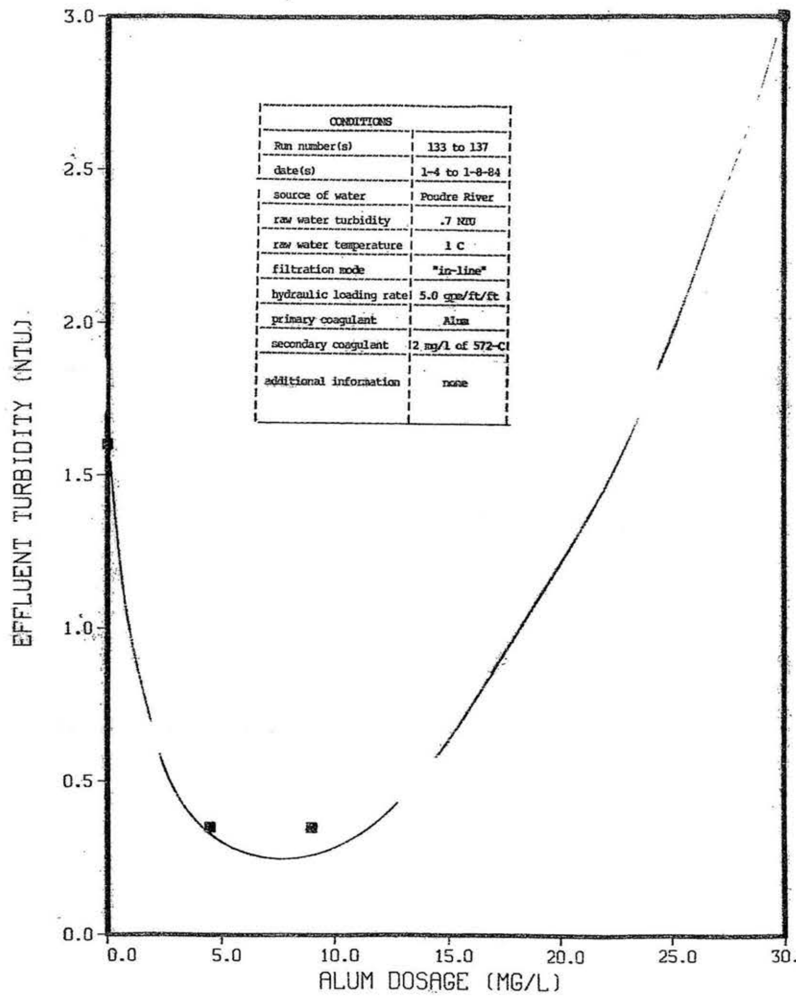


Figure 47. Effluent turbidity vs alum dose, $Al_2(SO_4)_3 \cdot 14H_2O$, using 2 mg/l of Magnifloc 572-C for low-turbidity water. Field scale.

Table 19. Giardia and coliform results from testing using low-turbidity raw water.[1/,2/] Field scale rapid rate filtration pilot plant.

Run No.	Coagulant Dosage Category11/	Coagulants Used		Water Temperature (NTU)	Turbidity			Giardia Cyst 5/7/			Coliforms8/		
		Chemical3/ (mg/L)	Chemical Dose4/ (°C)		Influent10/ (NTU)	Effluent9/ Removal	Percent cysts/liter	Influent5/ cysts/liter	Effluent6/ Removal	Percent No./100 mL	Influent5/ No./100 mL	Effluent6/	Percent Removal
117	None	None	0	2	0.4	0.6	<1	260	180	30	15000	12000	20
129	None	None	0	1	0.6	0.7	<1	**	**	**	3500	3000	15
123	Optimum	8102	0.1	1	0.6	1.1	<1	325	180	45	6900	5700	20
124	Optimum	8102	0.4	1	0.6	0.85	<1	325	100	40	6900	3500	50
138	Optimum	Alum/572-C	7.0/2.0	<1	0.7	0.4	42	1300	70	95	10000	150	>98
125	Nonoptimum	Alum	0.4	1	0.55	1.0	<1	1300	850	35	9000	8500	10
126	Nonoptimum	Alum	5.0	1	0.55	1.0	<1	1300	950	30	9000	6500	30
127	Nonoptimum	Alum/8102	3.0/0.2	1	0.9	1.1	<1	175	100	45	*	*	*
128	Nonoptimum	Alum/8102	3.0/0.4	1	0.9	0.9	<1	175	125	30	*	*	*

1/ Abstracted from Table B-1
2/ Cache La Poudre River water having raw water turbidities less than 1 NTU
3/ Nalco 8102, Magnifloc 572-C
4/ Alum doses are mg/L as $Al_2(SO_4)_3\ 14H_2O$
5/ Detected cyst concentrations, sampling influent stream after mixing by four elbows and before injection of coagulants. Membrane filters used were Nucleopore polycarbonate 5 micrometer pore size, 293 mm diameter. Samples were analyzed by micropipette technique.
6/ Procedures were the same as used for influent sampling and analysis.
7/ Double asterisk indicates cysts were of questionable viability
8/ Single asterisk indicates no data; missed dilution range
9/ Effluent turbidity after one hour of filtration
10/ Influent turbidity prior to contaminant injection
11/ Reference should be made to Figures 3-10 to 3-14 to judge coagulant dosage with respect to turbidity reductions.

Tests With No Coagulation

Runs 117 and 129, in Table 19 show results obtained for coagulant dosage tests in which Giardia cysts and coliform bacteria were injected into low-turbidity, low-temperature raw waters which were filtered without chemical pretreatment. For the "none" coagulant condition, coliform bacteria removals were 20 and 15 percent, respectively. The Giardia cyst removal of Run 117 was only 30 percent. No Giardia removal data is reported for Run 129 because the cysts were questionable with respect to maintaining identity for analysis. The effluent turbidity was greater than the influent turbidity for each of these "no chemical" runs.

Optimum Coagulant Dose Tests--

Chemical dosages for Runs 123, 124 and 138 were classified as "optimum". For Runs 123 and 124 removals of Giardia cysts were 45 and 40 percent, respectively, coliform removals were 20 and 50 percent, while turbidity removal were less than one percent. The chemicals used in these runs were found to be not effective in the laboratory-scale work and so the field-scale testing corroborates this.

For Run 138, however, removals in all three categories were high, i.e 95 percent for Giardia cysts, 98 percent for coliform bacteria, and 42 percent for turbidity. Coagulant chemicals used for Run 138 were 7.0 mg/L of alum, as $Al_2(SO_4)_3 \cdot 14 H_2O$, and 2 mg/L of Magnifloc 572-C. These coagulant dosages were found to be effective in previous bench scale and lab-scale testing. For this test the raw water turbidity was 0.7 NTU, and the effluent turbidity was 0.4 NTU, while the water temperature was $<1^{\circ}C$. Higher percent removals of turbidity, e.g. 70 to 80 percent, were found in the laboratory-scale pilot plant results. It should be noted, however, that the water temperature was less than $1^{\circ}C$ (the thermometer measured $0^{\circ}C$), during Run 138 and so while temperature did not seem to influence filtration down to $3^{\circ}C$ during laboratory-scale work, the $0^{\circ}C$ condition could have an effect.

Nonoptimum Coagulant Dose Tests--

Runs 125 to 128 were classified as "nonoptimum", even though some of the turbidity-dose curves did not show well defined U-shapes. Results for removals of turbidity, coliform bacteria, and Giardia cysts were not significantly different than for the "zero" coagulant dosage tests. It should be noted that chemicals used were those found to be not effective during laboratory-scale pilot plant work.

Associations Between Dependent Variables

Figure 48 is a plot of data taken from Table 19 showing percent removal of Giardia cysts plotted against percent removal of coliform bacteria. Figure 48 indicates that high removals of Giardia cysts can be expected when high removals of coliform bacteria occur. Again, this is consistent with findings in lab-scale experiments with low-turbidity water. It is consistent also with results for Horsetooth water. Other associations were not made because of limited data for the low-turbidity testing phase.

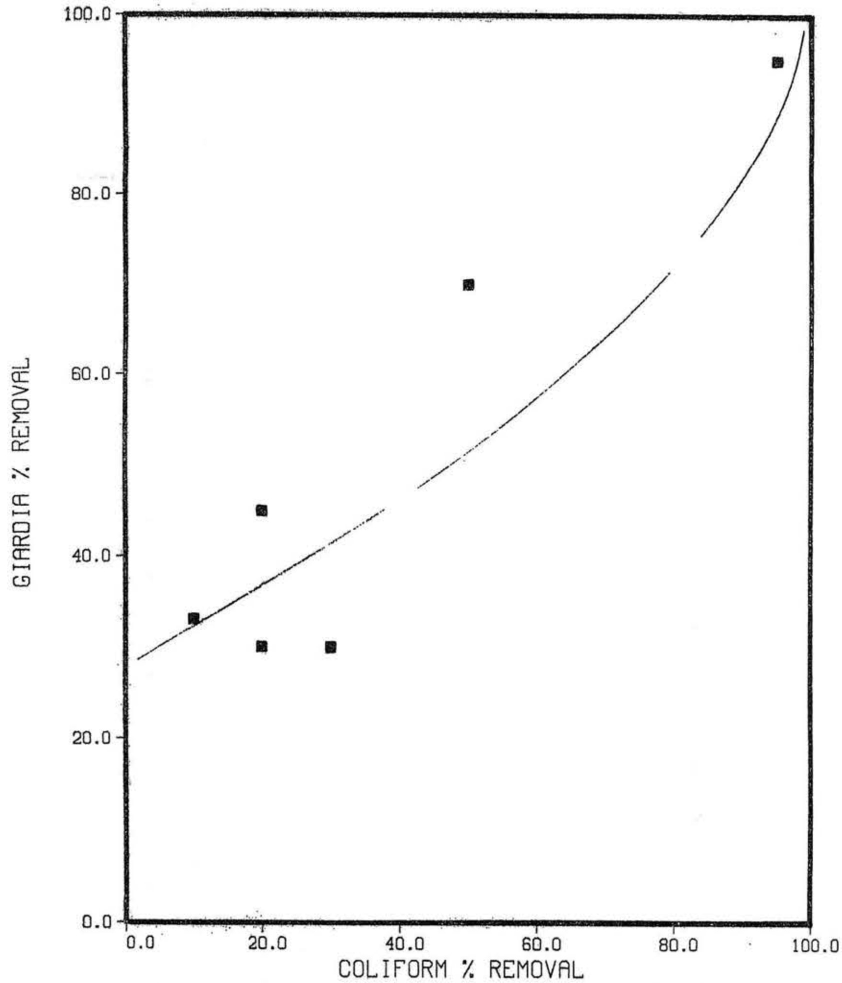


Figure 48. Percent removal of Giardia cysts vs percent removal of coliform bacteria for low-turbidity water. Raw water characteristics were: <1°C and <1 NTU. Field scale pilot plant was used.

Horsetooth Water

Results of field-scale pilot plant testing using raw water from Horsetooth water are given in Appendix H. The turbidity of Horsetooth Reservoir water is about 4 to 10 NTU, and it is more easily treatable by a wider range of chemical coagulants. Some polymers not effective for the low turbidity waters were effective when using Horsetooth water. Percent removals of turbidity, Giardia cysts, and total coliform bacteria were generally 90-97, 95-99, and 97-99, respectively when chemical pretreatment was used. When no chemical pretreatment was used, percent removals were generally 3-14, 27-33, and 0-41, respectively for the turbidity, cysts, and bacteria.

Summary of Results for Field-Scale Pilot Plant Testing

The field-scale pilot plant testing underlines the importance of using chemical coagulants in the rapid rate filtration process. Further, not all coagulants are effective, and so selection of coagulant chemicals is important. Chemicals can be selected and dosages can be determined by generating the classical turbidity-dose curves using a pilot plant. If percent removal of turbidity is high, the percent removal of *Giardia* cysts and total coliform bacteria should be high also.

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APPENDIX A

All reduced data and results from the laboratory-scale testing are included in Tables A-1 and A-2. Table A-1 summarizes all test conditions and results, categorized by test identification, influent water characteristics, chemical basin conditions, filter conditions, and filter effluent data. It contains all data obtained during test runs of the laboratory scale rapid rate filtration pilot plant. Each row in the table constitutes the data obtained during a given test run. The table can be read by each page using Run No. and Col. No. to coordinate between pages. Alternatively a large table can be constructed from the pages of Table A-1 by cutting along the match marks indicated on each sheet and using the Run No. and Col. No. as guides to place the sheets.

Table A-2 contains effluent results of _Giardia_ cyst testing corrected for sampling efficiency data and detection limits. The basic data were obtained from Table A-1. It should be noted that _Giardia_ cysts were not used in Runs 1-41. The use of cysts to spike the influent water in the milk cooler was deferred until this time in order to become familiar with operation of the pilot plant and to do preliminary testing.

Table A-1. Master data table for laboratory-scale rapid-rate filtration pilot plant (page 1 of 12).

Test IDENTIFICATION		INFLUENT		WATER		CHARACTERISTIC		
Date	Run No.	Temperature (°C)	Turbidity (NTU)	Particle Count (No./10 ml) 2.52 - 0.8 µm	Standard Plate Count (No./ml)	Total Coliform (No./100 ml)	Giardia Cyst Designed (cysts/l)	Giardia Cyst Detected (cyst/l)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
5-13-82	1	6.5	6.00H	-	-	-	0.00	0.000
5-13-82	1	6.5	6.00H	-	-	-	0.00	0.000
5-31-82	2	7.0	3.60H	74,265	59,000	10,500	0.00	0.000
5-31-82	2	7.0	3.60H	74,265	59,000	10,500	0.00	0.000
6- 2-82	3	11.0	3.00H	18,892	7,000	230	0.00	0.000
6- 2-82	3	11.0	3.00H	18,892	7,000	230	0.00	0.000
6- 4-82	4	16.0	3.80H	35,380	97,000	10,000	0.00	0.000
6- 4-82	4	16.0	3.80H	35,380	97,000	10,000	0.00	0.000
6- 8-82	5	11.0	3.70H	36,181	36,000	9,000	0.00	0.000
6- 8-82	5	11.0	3.70H	36,181	36,000	9,000	0.00	0.000
6-10-82	6	13.0	3.50H	38,266	-	-	0.00	0.000
6-10-82	6	13.0	3.50H	38,266	-	-	0.00	0.000
6-14-82	7	14.0	3.20H	45,241	25,300	350,000	0.00	0.000
6-14-82	7	14.0	3.20H	45,241	25,300	350,000	0.00	0.000
6-16-82	8	14.0	3.30H	41,904	27,000	180,000	0.00	0.000
6-16-82	8	14.0	3.30H	41,404	27,000	180,000	0.00	0.000
6-17-82	9	14.0	3.30H	53,498	387,000	54,000	0.00	0.000
6-18-82	10	14.5	3.30H	-	161,300	6,100	0.00	0.000
6-23-82	11	14.5	3.50H	-	127,000	6,400	0.00	0.000
6-23-82	11	14.5	3.30H	-	127,000	6,400	0.00	0.000
6-25-82	12	16.0	3.30H	7032	28,000	1,250	0.00	0.000
6-25-82	12	16.0	3.30H	7032	28,000	1,250	0.00	0.000
7- 6-82	13	16.0	4.20H	228,036	15,000	1,595	0.00	0.000
7- 7-82	14	14.5	4.50H	123,593	11,300	2,000	0.00	0.000
7-13-82	15	13.5	3.40H	73,540	13,600	800	0.00	0.000
7-14-82	16	14.5	3.70H	71,485	20,000	805	0.00	0.000
7-19-82	17	13.0	3.70H	-	-	-	0.00	0.000
7-21-82	18	13.0	0.60H	7860	5,700	4	0.00	0.000
7-22-82	19	20.0	0.58H	-	-	-	0.00	0.000
7-26-82	20	20.5	0.41H	32,048	464,000	50	0.00	0.000
7-27-82	21	21.0	0.42H	58,247	399,000	70	0.00	0.000
7-28-82	22	21.0	0.42H	58,247	399,000	70	0.00	0.000
7-29-82	23	16.0	0.91H	26,856	-	220	0.00	0.000
7-30-82	24	18.5	0.91H	26,856	286,500	110	0.00	0.000
8- 2-82	25	20.0	0.91H	26,856	286,500	110	0.00	0.000
8- 4-82	26	21.0	0.13H	-	-	-	0.00	0.000
8- 6-82	27	20.0	0.22H	-	286,500	110	0.00	0.000
8- 9-82	28	20.0	0.16H	-	4,150	50	0.00	0.000
8-10-82	29	20.0	0.16H	-	4,150	50	0.00	0.000
8-12-82	30	13.5	0.17H	-	210	180	0.00	0.000
8-18-82	31	16.0	0.22H	3840	24,500	95	0.00	0.000
8-19-82	32	18.0	0.22H	5599	32,500	650	0.00	0.000
8-20-82	33	18.5	0.22H	5599	32,500	650	0.00	0.000
8-20-82	34	18.5	0.22H	5599	32,500	650	0.00	0.000
8-25-82	35	18.5	0.31H	14,923	-	-	0.00	0.000
8-30-82	36	2.0	0.27H.DE	8,210	21,400	-	-	-
8-31-82	37	2.0	0.19H.DE	-	-	-	-	-
9- 1-82	38	2.0	0.19H.DE	12,616	19,250	210.0	-	-
9- 2-82	39	2.0	0.19H.DE	12,616	14,300	160.0	-	-
9- 3-82	40	2.0	0.19H.DE	12,616	2,750	65.0	-	-
9- 9-82	41	2.0	0.25H.DE	-	-	-	-	-
9-13-82	42	2.0	0.64H.DE	-	-	-	500.8	76.628
9-13-82	43	2.0	0.64H.DE	-	-	-	50.0	81.632
9-15-82	44	2.0	0.76H.DE	-	-	-	500.0	57.866
9-15-82	45	2.0	0.76H.DE	-	-	-	500.0	23.255
9-29-82	46	3.0	0.22H.DE	5,001	1,950	4,000.0	480.6	260.000
9-29-82	47	3.0	0.22H.DE	5,001	1,950	4,000.0	480.6	260.000
9-30-82	48	3.0	0.22H.DE	5,001	1,825	1,300.0	480.6	458.300
10- 4-82	49	2.0	0.29H.DE	5,001	3,650	1,300.0	480.0	458.330
10- 4-82	50	4.0	0.36H.DE	27,613	12,700	45.0	480.6	112.500
10- 5-82	51	3.0	0.36H.DE	34,216	7,125	70.0	480.6	383.330
10- 6-82	52	4.0	0.36H.DE	30,419	16,750	14.0	480.6	522.220
10- 7-82	53	4.0	0.46H.DE	37,380	-	12.5	480.6	372.400
10-12-82	54	4.0	0.35H.DE	-	18,875	1475.0	500.0	340.000

Table A-1. Master data table for laboratory-scale rapid rate filtration pilot plant (page 2 of 12).

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
10-13-82	55	4.0	0.40H.DE	45,121	29,900	315.0	500.0	404.540
10-14-82	56	4.0	0.47H.DE	63,388	114,500	195.0	500.0	170.000
10-15-82	57	4.0	0.47H.DE	63,388	29,790	96.0	500.0	170.000
10-19-82	58	4.0	0.50H.DE	102,705	84,250	10.0	500.0	225.000
11-23-82	59							
11-23-82	60	3.0	0.34H.DE	-	-	-	-	-
12- 1-82	61	15.0	4.20H.DE	1,248,438	39,000	330.0	461.5	-
12- 2-82	62	4.0	4.20H.DE	675,325	161,000	38.0	461.5	0.000
12- 3-82	63	4.0	4.20H.DE	-	-	-	461.5	0.000
12- 3-82	64	4.0	4.20H.DE	961,881	196,000	6.0	461.5	0.000
12- 7-82	65	4.0	4.30H.DE	961,881	11,350	-	461.5	0.000
12- 4-82	66	3.0	0.45H.DE	39,649	4,625	3500	500	368.750
12-15-82	67	4.0	0.51H.DE	39,629	1,370	10	500	333.330
12-16-82	68	4.0	0.53H.DE	45,606	1,330	42	500	435.480
12-17-82	69	4.0	0.53H.DE	45,606	6,050	100	500	519.230
12-17-82	70	4.0	0.53H.DE	45,606	6,050	100	500	519.230
1- 6-83	71	3.0	0.96H.DE	150,011	175,500	625	1000	628.200
1- 7-83	72	3.0	0.99H.DE	110,814	151,000	50	1000	700.000
1-11-83	73	3.0	1.10H.DE	-	36,750	-	1000	-
1-12-83	74	3.0	1.33H.DE	142,932	35,800	160	1000	416.000
1-14-83	75	3.0	1.33H.DE	144,924	-	-	1000	324.440
1-27-83	76	3.0	0.47H.DE	10,837	-	-	1000	200.000
1-27-83	77	3.0	0.47H.DE	10,837	-	-	1000	200.000
1-27-83	78	3.0	0.47H.DE	10,837	-	-	1000	200.000
1-27-83	79	3.0	0.47H.DE	10,837	-	-	1000	200.000
1-28-88	80	4.0	0.47H.DE	4,377	12,500	22	1000	-
1-31-83	81	3.0	0.48H.DE	14,864	7,100	9	1000	-
2- 1-83	82	3.0	0.59H.DE	,927	30,000	9	1000	-
2- 2-83	83	3.0	0.59H.DE	25,961	-	-	1000	-
2- 8-83	84	3.0	2.2H.DE	-	-	-	5000	2789.470
2- 9-83	85A	3.0	2.2H.DE	115,643	17,500	200,000	5000	3000.000
2- 9-83	85B	3.0	2.2H.DE	115,643	17,500	200,000	5000	3000.000
2-10-83	86A	3.0	2.5H.DE	211,356	30,000	10,000	5000	843.750
2-10-83	86B	3.0	2.5H.DE	211,356	30,000	10,000	5000	843.730
2-11-83	87A	3.0	2.5H.DE	394,600	192,500	100,000	5000	1783.780
2-11-83	87B	3.0	2.5H.DE	394,600	192,500	100,000	5000	1783.780
2-15-83	88A	3.0	3.8H.DE	482,002	300,000	16,400,000	5000	2368.411
2-15-83	88B	3.0	3.8H.DE	482,002	300,000	16,400,000	5000	2368.411
2-16-83	89A	3.0	3.8H.DE	785,263	665,000	12,600,000	5000	2650.000
2-16-83	89B	3.0	3.8H.DE	785,263	665,000	12,600,000	5000	2650.000
2-17-83	90A	3.0	2.2H.DE	21,570	-	46,000	5000	4040.4001
2-17-83	90B	3.0	2.2H.DE	21,570	-	46,000	5000	4040.4001
2-18-83	91A	3.0	2.4H.DE	90,836	277,500	28,000	5000	3181.8181
2-18-83	91B	3.0	2.4H.DE	90,836	277,500	28,000	5000	3181.8181
2-22-83	92A	3.0	9.6CLP	-	-	-	10,000	-
2-22-83	92B	3.0	9.6CLP	-	-	-	10,000	-
2-23-83	93A	3.0	9.6CLP	-	-	-	10,000	-
2-23-83	93B	3.0	9.6CLP	-	-	-	10,000	-
2-28-83	94	3.0	1.7CLP	75,465	101,500	20,000	787	753.850
2-28-83	95	3.0	1.7CLP	75,465	101,500	20,000	787	753.850
2-28-83	96	3.0	1.7CLP	75,465	101,500	20,000	787	753.850
2-28-83	97	3.0	1.7CLP	75,465	101,500	20,000	787	753.850
3- 2-83	98	3.0	2.4CLP	83,427	175,000	-	500	1025.640
3- 3-83	99	3.0	3.2CLP	49,666		59,000	1500	1012.130
3- 8-83	100	4.0	3.2CLP	61,053	-	-	6000	975.600
3-14-83	101A	4.0	4.8CLP	494,482	277,000	83,000	700	159.760
3-14-83	101B	4.0	4.8CLP	494,482	277,000	83,000	700	159.760
3-15-83	102A	3.0	6.2CLP	63,696	30,000	14,000	700	422.080
3-15-83	102B	3.0	6.2CLP	63,696	30,000	14,000	700	422.080
3-23-83	103	3.5	1.08CLP	-	105,000	5000	602	408.160
3-24-83	104A	3.5	1.08CLP	80,805	60,500	450	602	56.690
3-24-83	104B	3.5	1.08CLP	80,805	60,500	450	602	56.690
3-25-83	105	14.0	1.08CLP	80,759	9,300	1010	602	-
3-28-83	106	3.5	0.51CLP	82,013	15,000	45	440	183.10
3-31-83	107A	3.0	0.68CLP	59,007	30,500	10	594	298.270
3-31-83	107B	3.0	0.68CLP	59,007	30,500	10	594	298.270
4- 1-83	108	7.0	0.60CLP	43,554	21,000	-	0	0.000
4- 7-83	109	9.0	1.04CLP	97,820	16,000	4500	0	0.000
4- 8-83	110	2.0	1.14CLP	80,074	160	150	0	0.000
4-14-83	111	3.5	1.13CLP	71,716	30,000	1500	240	233.160
4-14-83	112	3.5	1.13CLP	71,716	30,000	1500	240	233.160
4-15-83	113	3.5	1.13CLP	60,330	27,500	695	240	115.380

Table A-1. Master data table for laboratory-scale rapid rate filtration pilot plant (page 3 of 12).

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
4-15-83	114	3.5	1.13CLP	60,330	27,500	695	240	115.380
4-20-83	115	3.0	1.28CLP	45,533	12,500	1400	200	238.940
4-20-83	116	3.0	1.28CLP	45,533	12,500	1400	200	238.940
4-21-83	117	3.0	1.24CLP	34,962	9,000	790		858.180
4-21-83	118	3.0	1.24CLP	34,962	9,000	790		858.180
4-24-83	119	3.0	1.60CLP	72,520	15,500	4650	300	269.000
4-24-83	120	3.0	1.60CLP	72,520	15,500	4650	300	269.000
4-24-83	121	3.0	1.60CLP	72,520	15,500	4650	300	269.000
4-24-83	122	3.0	1.60CLP	72,520	15,500	4650	300	269.000
4-25-83	123	3.0	1.60CLP	72,520	13,000	200	300	245.450
4-25-83	124	3.0	1.60CLP	72,520	13,000	200	300	245.450
5- 3-83	125	3.0	33.00CLP	-	12,500	1900	0	
5- 5-83	126A	3.0	33.00CLP	-	-	35	0	
5- 5-83	126B	3.0	33.00CLP	-	-	35	0	
5-10-83	127A	16.5	14.20CLP	-	5,000	2600	0	-
5-10-83	127B	16.5	14.20CLP	-	5,000	2600	0	-
5-11-83	128A	4.0	14.20CLP	-	12,500	1350	0	-
5-11-83	128B	4.0	14.20CLP	-	12,500	1350	0	-
5-12-83	129	4.0	14.20CLP	-	-	1010	0	-
5-12-83	130	10.0	14.20CLP	-		27	0	
5-16-83	131A	16.0	14.20CLP	-		10	0	-
5-16-83	131B	16.0	14.20CLP	-		10	0	-
5-17-83	132	4.0	14.20CLP	-	36,000	<10	0	-
5-30-83	133	5.0	18CLP	-	18,600	1285	400	450.000
6- 6-83	134	3.0	1.19CDE	-	15,500	12,850	660.7	745.257
6- 6-83	135	3.0	1.19CDE	-	15,500	12,850	660.7	745.257
6- 7-83	136	4.0	1.19CDE	-	15,500	5850	0.0	-
6- 7-83	137	4.0	1.19CDE	-	15,500	5850	0.0	-
6- 8-83	138	3.0	1.19CDE	-	9,450	2350	0.0	-
6- 8-83	139	4.0	1.19CDE	-	9,450	2350	0.0	-
6-13-83	140	12.0	1.19CDE	-	23,700	40	0.0	-
6-13-83	141	13.0	1.19CDE	-	23,700	-	0.0	-
6-14-83	142	14.0	1.19CDE	-	24,800	<1	0.0	-
6-14-83	143	14.0	1.19CDE	-	24,800	<1	0.0	-
6-15-83	144	14.0	1.19CDE	-	900	<1	0.0	-
6-15-83	145	14.0	1.19CDE	-	900	<1	0.0	-
7-19-83	146	3.5	0.89HDE	-	9,420	24,500	605.8	385.700
7-20-83	147	3.5	0.89HDE	-	4,050	7,500	605.8	51.540
7-26-83	148	3.0	1.06HDE	-	51,500	12,500	605.8	75.000
7-27-83	149	3.0	1.06HDE	-	38,000	37,000	-	-
8- 2-83	150	18.0	0.45HDE	-	16,950	7,500	0.0	-
8- 2-83	151	18.0	0.45HDE	-	16,950	7,500	0.0	-
8- 3-83	152	17.0	0.45HDE	-	17,000	1,000	0.0	-
8- 3-83	153	17.0	0.45HDE	-	17,000	1,000	0.0	-
8- 5-83	154	18.0	0.45HDE	-	38,500	3,650	0.0	-
8- 5-83	155	18.0	0.45HDE	-	38,500	3,650	0.0	-
8- 8-83	156	4.0	0.45HDE	-	53,500	5,700	0.0	-
8- 9-83	157	4.0	0.45HDE	-	56,500	21,500	0.0	-
8- 9-83	158	4.0	0.45HDE	-	56,500	21,500	0.0	-
8-10-83	159	4.0	0.45HDE	-	56,500	40,000	0.0	-
8-10-83	160	4.0	0.45HDE	-	56,000	4,000	0.0	-
8-28-83	161	20.0	0.85HDE	-	9,150	350	0.0	-
9- 5-83	162	3.0	0.85HDE	-	12,800	20,000	0.0	-
11- 7-83	163	15.0	0.85HDE	-	8,233	4300	0.00	0.000
11- 8-83	164	16.0	0.85HDE	-	36,700	1150	0.00	0.000
11- 9-83	165	17.0	0.85HDE	-	56,300	1100	0.00	0.000
11-10-83	166	18.0	0.85HDE	-	51,000	1000	0.00	0.000
11-11-83	167	18.0	0.85HDE	-	-	-	0.00	0.000
11-14-83	168	18.0	0.85HDE	-	79,800	-	0.00	0.000
11-15-83	169	19.0	0.85HDE	-	23,400	-	0.00	0.000
11-16-83	170	20.0	0.85HDE	-	-	-	0.00	0.000
11-17-83	171	20.0	0.85HDE	-	10,500	600	0.00	0.000
11-18-83	172	20.0	0.85HDE	-	38,800	150	0.00	0.000
11-21-83	173	20.0	2.30HDE	-	18,200	1850	0.00	0.000
12-12-83	174	2.0	0.60CLP	-	14,700	1000	0.00	0.000
12-14-83	175	3.5	0.65CLP	-	5,500	3470	0.00	0.000
12-15-83	176	3.5	0.69CLP	-	3,300	300	0.00	0.000
12-16-83	177	4.0	0.77CLP	-	6,000	6550	0.00	0.000
12-19-83	178	4.0	0.78CLP	-	4,100	6850	0.00	0.000

Table A-1. Master data table for laboratory-scale rapid rate filtration pilot plant (page 4 of 12).

CHEMICAL BASIN CONDITIONS

+	Alum (mg/l) as $Al_2(SO_4)_3 \cdot 14H_2O$ (10)	Velocity Gradient G (sec^{-1}) for Alum Basin (11)	Detention Time T (sec) Alum Basin (12)	GT for Alum Basin (13)	Polymer (mg/l) (14)	Brand of Polymer (15)	Velocity Gradient G (sec^{-1}) for Polymer Basin (16)	Detention Time T (sec) for Polymer Basin (17)	GT for Polymer Basin (18)
1	0.00	40.9	186.0	7607	0.00	-	57.2	186.0	10,639
1	0.00	40.9	186.0	7607	0.00	-	57.2	186.0	10,639
2	0.00	40.9	186.0	7607	0.00	-	57.2	186.0	10,639
2	0.00	40.9	186.0	7607	0.00	-	57.2	186.0	10,639
3	0.00	40.9	186.0	7607	4.60	8100N	57.2	186.0	10,639
3	0.00	40.9	186.0	7607	4.60	8100N	57.2	186.0	10,639
4	0.00	40.9	186.0	7607	0.31	8102N	57.2	186.0	10,639
4	0.00	40.9	186.0	7607	0.31	8102N	57.2	186.0	10,639
5	0.00	40.9	186.0	7607	1.77	8170N	57.2	186.0	10,639
5	0.00	40.9	186.0	7607	1.76	8170N	57.2	186.0	10,639
6	0.00	40.9	186.0	7607	2.02	8181N	57.2	186.0	10,639
6	0.00	40.9	186.0	7607	2.02	8181N	57.2	186.0	10,639
7	0.00	40.9	186.0	7607	2.46	8102N	57.2	186.0	10,639
7	0.00	40.9	186.0	7607	2.46	8102N	57.2	186.0	10,639
8	0.00	40.9	186.0	7607	1.10	8102N	57.2	186.0	10,639
8	0.00	40.9	186.0	7607	1.10	8102N	57.2	186.0	10,639
9	0.00	40.9	186.0	7607	1.93	8102N	57.2	186.0	10,639
10	0.00	40.9	186.0	7607	28.00	650N	57.2	186.0	10,639
11	23.38	40.9	186.0	7607	0.05	8181N	57.2	186.0	10,639
11	23.28	40.9	186.0	7607	0.05	8181N	57.2	186.0	10,639
12	16.90	40.9	186.0	7607	0.09	8181N	57.2	186.0	10,639
12	16.90	40.9	186.0	7607	0.09	8181N	57.2	186.0	10,639
13	14.05	40.9	186.0	7607	0.02	8181N	57.2	186.0	10,639
14	32.69	40.9	208.3	8519	-	-	57.2	208.3	11,914
15	12.96	40.9	95.3	3897	0.02	8102N	57.2	95.3	5,451
16	13.40	40.9	186.3	7607	0.05	8102N	57.2	186.0	10,639
17	19.37	40.9	186.3	7607	1.40	8102N	57.2	186.0	10,639
18	0.00	40.9	186.3	7607	21.55	572C	57.2	186.0	10,639
19	0.00	40.9	186.3	7607	16.00	572C	57.2	186.0	10,639
20	0.00	40.9	186.3	7607	0.80	572C	57.2	186.0	10,639
21	0.00	40.9	186.3	7607	16.30	752C	57.2	186.0	10,639
22	5.12	40.9	186.3	7607	6.40	572C	57.2	186.0	10,639
23	5.46	40.9	186.3	7607	0.62	572C	57.2	186.0	10,639
24	0.83	40.9	186.3	7607	0.32	572C	57.2	186.0	10,639
25	6.33	40.9	186.3	7607	0.77	572C	57.2	186.0	10,639
26	1.17	40.9	186.3	7607	0.30	572C	57.2	186.0	10,639
27	2.92	40.9	186.3	7607	0.27	573C	57.2	186.0	10,639
28	4.45	40.9	186.3	7607	0.17	573C	57.2	186.0	10,639
29	4.85	40.9	186.3	7607	0.25	573C	57.2	186.0	10,639
30	21.82	40.9	186.3	7607	0.79	573C	57.2	186.0	10,639
31	5.85	40.9	186.3	7607	0.45	572C	57.2	186.0	10,639
32	4.68	40.9	186.3	7607	1.70	572C	57.2	186.0	10,639
33	4.19	40.9	186.3	7607	1.59	572C	57.2	186.0	10,639
34	3.16	40.9	186.3	7607	1.38	572C	57.2	186.0	10,639
35	3.34	40.9	186.3	7607	2.10	572C	57.2	186.0	10,639
36	8.57	46.0	186.0	8566	4.09	572C	46.0	186.0	8,566
37	15.33	46.0	186.0	8566	8.33	572C	46.0	186.0	8,566
38	1.47	46.0	186.0	8566	1.97	572C	46.0	186.0	8,566
39	3.02	46.0	287.0	213,209	1.40	572C	46.0	278.0	13,209
40	5.57	32.9	278.0	9165	2.59	572C	46.0	278.0	12,790
41	15.07	33.4	282.5	9454	0.03	NP10	46.7	282.5	13,213
42	8.47	32.0	178.6	5716	1.45	572C	45.0	178.6	8,037
43	5.48	33.4	266.0	8901	2.81	572C	46.7	266.0	12,439
44	3.55	32.9	182.0	6001	3.85	572C	46.0	182.0	8,376
45	3.13	32.9	270.0	8903	1.47	572C	46.0	270.0	12,425
46	0.00	-	-	-	0.00	-	-	-	-
47	0.00	-	-	-	0.00	-	-	-	-
48	0.00	-	-	-	0.00	-	-	-	-
49	0.00	-	-	-	0.00	-	-	-	-
50	2.14	33.4	184.8	6184	0.90	572C	48.2	184.8	8,917
51	4.08	33.4	258.2	8639	1.68	572C	46.7	258.2	12,075
52	2.07	33.4	179.4	6003	1.17	572C	46.7	179.4	8,391
53	3.44	33.9	261.5	8880	2.13	572C	47.5	261.5	12,421
54	2.11	33.4	184.8	6184	$4.2x10^{-3}$	8102N	-	-	-

Table A-1. Master data table for laboratory-scale rapid rate filtration pilot plant (page 5 of 12).

	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
55	3.16	34.9	273.1	9556	17.00	8102N	-	-	-
56	5.30	33.4	186.2	6231	0.30	8102N	-	-	-
57	5.07	33.4	267.1	8940	2.17	8102N	-	-	-
58	2.47	33.2	180.7	6001	1.47	572C	46.3	180.7	8,383
59									
60	13.7	34.4	256.2	8826	0.50	572C	48.2	256.0	12,354
61	15.97	38.6	180.2	6963	0.73	573C	54.0	180.2	9,737
62	16.63	33.4	180.2	6029	0.90	573C	46.7	180.2	8,428
63	18.52	32.9	198.2	6534	0.50	573C	46.0	198.2	9,119
64	28.02	32.9	187.6	6185	1.00	573C	46.0	187.6	8,631
65	18.52	33.2	180.7	6002	0.44	573C	46.3	180.7	8,383
66	17.17	160.0	184.0	29,440	0.52	573C	160.0	184.0	29,440
67	17.12	160.0	184.0	29,440	0.26	573C	160.0	184.0	29,440
68	12.07	160.0	184.8	29,570	1.61	573C	160.0	184.8	29,570
69	14.96	160.0	267.1	42,749	1.08	573C	160.0	267.2	42,749
70	7.64	160.0	273.1	43,696	1.33	573C	160.0	273.1	43,696
71	15.00	617.0	178.6	110,196	1.31	573C	617.0	178.6	110,196
72	16.62	446.0	178.1	79,432	1.30	573C	446.0	178.6	79,432
73	24.60	300.0	285.8	85,740	1.22	573C	300.0	285.8	85,740
74	13.15	300.0	281.8	84,566	1.37	573C	300.0	281.8	84,566
75	12.70	300.0	273.1	81,935	2.00	573C	300.0	273.1	81,935
76	0.00	- .0	-	-	-	-	-	-	-
77	0.00	- .0	-	-	-	-	-	-	-
78	0.00	- .0	-	-	-	-	-	-	-
79	0.00	- .0	-	-	-	-	-	-	-
80	5.56	300.0	183.4	55,031	0.74	572C	300.0	183.4	55,031
81	6.77	300.0	181.5	54,462	0.80	572C	300.0	181.5	54,462
82	8.82	300.0	270.1	81,035	0.55	572C	300.0	270.1	81,035
83	75.63	300.0	270.1	81,035	11.00	572C	300.0	270.1	81,035
84	12.60	300.0	270.1	81,035	1.97	572C	300.0	270.1	81,035
85A	13.03	300.0	279.1	83,797	1.31	572C	300.0	279.1	83,797
85B	13.00	300.0	279.1	83,797	1.31	572C	300.0	279.1	83,797
86A	15.64	300.0	186.2	55,865	1.28	572C	300.0	186.2	55,865
86B	15.64	300.0	186.2	55,865	1.28	572C	300.0	186.2	55,865
87A	14.77	300.0	186.2	55,865	2.19	572C	300.0	186.2	55,865
87B	14.77	300.0	186.2	53,865	2.19	572C	300.0	186.2	55,865
88A	17.55	300.0	258.7	77,623	4.42	573C	300.0	258.7	77,623
88B	24.14	300.0	258.7	77,623	4.42	573C	300.0	258.7	77,623
89A	16.57	300.0	273.1	81,935	2.0	573C	300.0	273.1	81,935
89B	16.57	300.0	273.1	81,935	2.0	573C	300.0	273.1	81,935
90A	22.69	300.0	180.7	54,222	1.76	573C	300.0	180.7	54,222
90B	22.69	300.0	180.7	54,222	1.76	573C	300.0	180.7	54,222
91A	15.10	300.0	180.7	54,222	3.2	573C	300.0	180.7	54,222
91B	15.10	300.0	180.7	54,222	3.2	573C	300.0	180.7	54,222
92A	2.85	300.0	273.1	81,935	3.36	573C	300.0	273.1	81,935
92B	2.85	300.0	273.1	81,935	3.56	573C	300.0	273.1	81,935
93A	5.30	300.0	256.0	76,814	3.33	573C	300.0	256.0	76,814
93B	5.30	300.0	256.0	76,814	2.66	573C	300.0	256.0	76,814
94	0.00	-	-	-	-	-	-	-	-
95	0.00	-	-	-	-	-	-	-	-
96	0.00	-	-	-	-	-	-	-	-
97	0.00	-	-	-	-	-	-	-	-
98	0.00	-	-	-	8.79	573C	237.1	186.2	44,159
99	0.00	-	-	-	7.46	573C	237.1	183.4	43,493
100	0.00	-	-	-	7.51	572C	237.1	184.5	43,754
101A	9.70	237.1	186.2	44,159	0.00	-	-	-	-
101B	9.70	237.1	186.2	44,159	0.00	-	-	-	-
102A	7.70	237.1	183.4	43,493	0.00	-	-	-	-
102B	7.70	237.1	183.4	43,493	0.00	-	-	-	-
103	17.20	237.1	183.4	43,494	1.34	573C	237.1	183.4	43,494
104A	9.60	237.1	183.4	43,494	1.5	573C	237.1	183.4	43,494
104B	13.40	237.1	183.4	43,494	0.6	573C	237.1	183.4	43,494
105	11.50	237.1	183.4	43,494	0.82	573C	237.1	183.4	43,494
106	0.00	-	-	-	0.49	8102N	-	-	-
107A	11.34	237.1	180.7	42,853	0.47	572C	237.1	180.7	42,853
107B	11.34	237.1	180.7	42,857	0.47	572C	237.1	180.7	42,853
108	12.30	237.1	180.7	42,837	0.49	572C	237.1	180.7	42,853
109	17.70	237.1	178.1	42,232	0.87	572C	237.1	178.1	42,232
110	18.64	237.1	178.1	42,232	0.8	572C	237.1	178.1	42,232
111	18.59	298.1	148.1	44,152	0.96	572C	298.1	148.1	44,152
112	18.50	237.1	186.2	44,152	0.95	572C	237.1	186.2	44,152
113	18.50	150.1	294.0	44,152	0.98	572C	150.1	294.0	44,152

Table A-1. Master data table for laboratory-scale rapid rate filtration pilot plant (page 6 of 12).

	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
114	23.24	59.6	740.3	44,152	1.2	572C	59.6	740.3	44,152
115	34.50	294.6	149.9	44,152	1.6	572C	294.6	149.9	44,152
116	33.30	152.7	289.1	44,152	3.0	572C	152.7	289.1	44,152
117	37.30	235.3	187.6	44,152	1.6	572C	235.3	187.6	44,152
118	23.69	68.3	646.8	44,152	1.42	572C	68.3	646.8	44,152
119	0	-	-	-	0.00	-	-	-	-
120	0	-	-	-	0.00	-	-	-	-
121	0	-	-	-	0.00	-	-	-	-
122	0	-	-	-	0.00	-	-	-	-
123	0	-	-	-	0.00	-	-	-	-
124	0	-	-	-	0.00*	-	-	-	-
125	69.00	180	296.0	53,307	14.5	572C	180.0	296.0	53,307
126A	32.53	180	296.0	53,307	12.77	572C	180.0	296.0	53,307
126B	32.50	180	296.0	53,307	12.77	572C	180.0	296.0	53,307
127A	32.50	217	296.0	64,199	5.06	572C	217.0	296.0	64,199
127B	32.50	217	296.0	64,199	5.06	572C	217.0	296.0	64,199
128A	32.50	186	296.0	55,056	5.06	572C	186.0	296.0	55,056
128B	32.50	186	296.0	55,056	5.06	572C	186.0	296.0	55,056
129	32.50	180	296.0	55,307	5.06	572C	180.0	296.0	53,307
130	32.50	197	296.0	58,284	5.06	572C	197.0	296.0	58,284
131A	58.80	217	296.0	64,199	0.00	-	-	-	-
131B	0	-	-	-	19.30	572C	217.0	296.0	64,199
132	0	-	-	-	19.30	572C	186.0	296.0	55,056
133	0.00	-	-	-	8.15	572C	241	267.1	64,371
134	0.00	-	-	-	0.00	-	-	-	-
135	-	237	267.1	63,303	2.48	572C	237	267.1	63,303
136	2.08	241	267.1	64,371	0.00	-	-	-	-
137	3.08	241	267.1	64,371	4.11	572C	241	267.1	64,371
138	3.64	241	267.1	64,371	4.13	572C	241	267.1	64,371
139	3.64	241	267.1	64,371	4.30	572C	241	267.1	64,371
140	0.00	-	-	-	0.00	-	-	-	-
141	3.47	282	267.1	75,322	4.52	572C	282	267.1	75,322
142	3.69	280	267.1	74,788	4.36	572C	280	267.1	74,788
143	4.56	280	267.1	74,788	3.64	572C	280	267.1	74,788
144	0.00	-	-	-	1.97	572C	280	267.1	74,788
145	2.46	280	267.1	74,788	0.00	-	-	-	-
146	1.45	240	270.1	64,824	0.35	572C	240	270.1	64,824
147	1.45	240	270.1	64,824	0.35	572C	240	270.1	64,824
148	0.64	240	279.1	66,984	0.62	572C	240	279.1	66,984
149	0.61	240	285.8	68,592	0.65	572C	240	285.8	68,592
150	0.87	188	248.2	46,661	0.00	-	-	-	-
151	0.00	-	-	-	0.42	572C	188	248.2	46,661
152	0.67	188	248.2	46,661	1.85	572C	188	248.2	46,661
153	0.00	-	-	-	0.00	-	-	-	-
154	0.85	188	248.2	46,661	0.47	572C	188	248.2	46,661
155	1.41	188	248.2	46,661	0.47	572C	188	248.2	46,661
156	1.41	159	248.2	39,464	0.97	572C	159	248.2	39,464
157	1.41	159	248.2	39,464	1.01	572C	159	248.2	39,464
158	0.85	159	248.2	39,464	0.48	572C	159	248.2	39,464
159	0.00	-	-	-	0.40	572C	159	248.2	39,464
160	0.67	159	248.2	39,464	1.82	572C	159	248.2	39,464
161	0.97	188	284.4	53,485	2.31	572C	188	284.4	53,485
162	0.97	159	284.4	45,220	2.31	572C	159	284.2	45,220
163	0.00	-	-	-	0.00	-	-	-	-
164	15.25	217.0	285.8	62,023	0.00	573C	217.0	285.8	62,023
165	0.00	-	-	-	0.48	573C	217.0	285.8	62,023
166	17.04	220.0	285.8	62,881	0.16	573C	220.8	285.8	62,881
167	14.95	220.0	285.8	62,881	2.50	573C	220.0	285.8	62,881
168	7.48	220.0	285.8	62,881	2.02	573C	220.0	285.8	62,881
169	15.55	220.0	285.8	62,881	0.72	573C	220.0	285.8	62,881
170	9.27	180.0	285.8	52,877	0.65	573C	180.0	285.8	52,877
171	22.05	180.0	285.8	52,877	-	573C	180.0	285.8	52,877
172	26.01	180.0	285.8	52,877	0.14	573C	180.0	285.8	52,877
173	0.00	-	-	-	0.00	-	-	-	-
174	0.00	-	-	-	0.00	-	-	-	-
175	0.00	-	-	-	2.6	573C	159.0	280.0	44,615
176	19.18	159.0	280.0	44615	1.57	573C	159.0	280.0	44,615
177	34.05	159.0	280.0	44615	0.46	573C	159.0	280.0	44,615
178	17.61	159.0	280.0	44615	0.57	573C	159.0	280.0	44,615

Table A-1. Master data table for laboratory-scale rapid rate filtration pilot plant (page 7 of 12).

	FILTER CONDITIONS						
	Filtration Rate (cm/min)	Diameter of Filter (cm)	Media	Temperature (°C)	Differential Pressure (cm Hg)	Volume of Filtered Water (liter)	Length of Run (hr)
	(19)	(21)	(21)	(22)	(23)	(24)	(25)
1	32.80	5.08	dual	10.0	10.0	308.0	7.78
1	8.14	10.16	dual	10.0	2.4	308.0	7.78
2	8.22	10.16	single	9.5	5.3	200.0	5.00
2	31.47	5.08	single	8.0	25.0	191.0	5.00
3	30.11	5.08	single	13.0	14.0	92.0	4.00
3	8.10	10.16	dual	14.0	5.0	187.0	4.00
4	8.70	10.16	single	18.0	20.0	116.0	3.50
4	22.80	5.08	dual	17.5	17.0	111.0	4.00
5	43.92	5.08	single	15.5	1.3	80.0	1.50
5	11.80	10.16	dual	15.5	1.3	22.0	1.50
6	9.49	10.16	single	16.5	4.6	105.0	2.50
6	30.30	5.08	dual	15.0	9.1	120.0	2.50
7	7.80	10.16	dual	16.0	2.2	57.0	1.50
7	29.12	5.08	single	16.0	22.5	53.0	1.50
8	9.60	10.16	single	15.5	8.0	140.0	3.00
8	29.90	5.08	single	15.5	15.0	109.0	3.00
9	8.60	10.16	single	14.0	14.0	147.0	3.50
10	34.50	5.08	dual	16.0	9.2	42.0	1.00
11	8.07	10.16	single	19.5	4.7	138.0	3.50
11	24.90	5.08	dual	18.5	9.1	106.0	3.50
12	6.53	10.16	single	18.0	24.0	127.0	4.00
12	30.10	5.08	dual	17.3	17.0	146.0	4.00
13	29.10	5.08	dual	19.0	13.7	- .0	4.75
14	29.10	5.08	dual	17.5	9.1	124.0	3.50
15	15.50	5.28	single	16.5	15.5	271.0	3.50
16	32.91	10.16	dual	17.3	9.2	100.0	2.50
17	9.00	10.16	dual	16.5	3.8	131.0	3.00
18	8.24	10.16	single	20.0	4.4	220.0	5.50
19	32.90	5.08	dual	20.1	8.8	80.0	2.00
20	8.59	10.16	dual	21.0	2.1	188.0	4.50
21	34.40	5.08	single	21.0	17.0	230.0	5.50
22	8.20	10.16	single	21.5	5.1	180.0	4.50
23	32.56	5.08	dual	18.0	12.0	159.0	4.50
24	8.20	10.16	dual	19.0	2.2	120.0	3.00
25	32.56	5.08	single	20.0	20.0	119.0	3.00
26	8.14	10.16	single	20.5	6.4	198.0	5.00
27	32.56	5.08	dual	20.5	10.0	109.0	2.75
28	8.20	10.16	dual	20.5	2.8	160.0	4.00
29	32.07	5.08	single	20.0	22.5	182.0	4.66
30	8.14	10.16	single	13.5	13.0	218.0	5.50
31	8.14	10.16	single	17.5	6.9	132.0	3.33
32	32.56	5.08	dual	18.5	14.0	139.0	3.50
33	8.14	10.16	dual	19.0	3.1	89.0	2.25
34	32.56	5.08	single	19.5	21.0	80.0	2.00
35	8.20	10.16	single	19.0	9.0	106.0	2.67
36	8.14	10.16	single	7.5	9.0	178.2	4.50
37	32.45	5.08	dual	5.2	16.3	598.0	4.00
38	8.14	10.16	dual	7.0	5.1	178.2	4.50
39	21.20	5.08	single	9.5	18.5	90.0	3.50
40	21.80	5.08	dual	8.0	11.7	97.2	3.67
41	5.37	10.16	single	8.0	20.0	143.5	5.50
42	8.48	10.16	single	8.0	9.4	103.2	2.50
43	22.80	5.08	dual	10.0	11.4	27.6	1.00
44	8.32	10.16	dual	7.0	4.2	89.1	2.20
45	22.45	5.08	single	8.5	23.5	56.9	2.08
46	8.47	10.16	single	7.0	6.4	59.8	1.45
47	22.59	5.08	dual	9.0	9.1	27.4	1.00
48	8.26	10.16	dual	7.0	4.2	51.6	1.28
49	22.20	5.08	single	10.0	15.0	40.5	1.50
50	8.20	10.16	single	7.0	9.2	109.7	2.75
51	23.48	5.08	dual	6.0	10.6	115.1	4.00
52	8.45	10.16	dual	7.0	5.0	102.7	2.50
53	23.19	5.08	single	9.5	18.7	65.8	2.33
54	8.20	10.16	single	7.0	6.5	113.0	2.83

Table A-1. Master data table for laboratory-scale rapid rate filtration pilot plant (page 8 of 12).

	(19)	(21)	(21)	(22)	(23)	(24)	(25)
55	22.20	5.08	dual	7.0	10.4	54.0	2.00
56	8.14	10.16	dual	8.0	3.5	103.0	2.60
57	22.69	5.08	single	9.5	16.8	47.0	1.70
58	8.20	10.16	single	7.0	9.0	83.0	2.03
59							
60	23.70	5.08	single	7.0	18.1	108.0	3.00
61	8.41	10.16	dual		15.5	163.0	4.00
62	8.41	10.16	dual	7.0	6.1	193.7	4.73
63	30.60	5.08	single	8.5	37.5	18.6	0.50
64	32.31	5.08	dual	6.5	19.1	59.0	1.50
65	8.39	10.16	single	7.0	39.0	71.4	1.75
66	8.24	10.16	single	6.5	9.4	114.0	2.75
67	8.26	10.16	dual	5.5	5.0	160.8	4.00
68	32.80	5.08	dual	4.5	19.0	80.0	2.00
69	22.69	5.08	dual	4.0	4.1	103.5	3.45
70	22.20	5.08	dual	5.0	25.9	31.5	1.16
71	8.49	10.16	single	5.5	9.8	130.7	2.16
72	8.51	10.16	dual	5.0	5.7	182.8	4.41
73	21.21	5.08	dual	6.0	12.2	103.2	4.00
74	21.50	5.08	single	6.0	22.4	65.2	2.50
75	22.20	5.08	dual	5.0	11.3	117.0	4.33
76	8.14	10.16	single	5.0	6.9	39.6	1.00
77	8.14	10.16	dual	5.0	4.0	33.0	0.83
78	20.72	5.08	single	7.0	15.7	29.4	1.16
79	20.72	5.08	dual	6.5	0.4	25.5	1.00
80	8.26	10.16	single	5.0	8.5	137.3	3.41
81	8.35	10.16	dual	4.0	5.4	206.5	5.08
82	22.45	5.08	dual	4.0	11.6	132.0	4.83
83	22.45	5.08	single	5.0	20.0	27.3	1.00
84	22.45	5.08	dual	7.0	16.1	40.9	1.50
85A	21.70	5.08	single	7.0	20.0	13.2	0.50
85B	21.70	5.08	single	7.0	23.6	26.4	1.00
86A	8.14	10.16	single	5.5	7.0	19.8	0.50
86B	8.14	10.16	single	5.5	11.6	89.1	2.25
87A	8.14	10.16	dual	4.0	4.6	19.8	.50
87B	8.14	10.16	dual	4.0	5.1	77.2	1.95
88A	23.44	5.08	dual	8.0	10.2	14.2	0.50
88B	23.44	5.08	dual	6.0	-	3.8	0.13
89A	22.20	5.08	single	8.0	17.8	6.7	0.25
89B	22.20	5.08	single	8.0	19.9	6.7	0.25
90A	8.38	10.16	single	6.0	7.2	10.2	0.25
90B	8.38	10.16	single	6.0	20.5	68.0	1.66
91A	8.38	10.16	dual	5.5	3.9	10.2	0.20
91B	8.38	10.16	dual	5.5	4.2	20.4	0.50
92A	22.20	5.08	dual	6.0	14.3	31.5	1.16
92B	22.20	5.08	dual	6.0	16.5	40.5	1.50
93A	23.68	5.08	single	12.0	17.9	12.0	0.20
93B	23.68	5.08	single	9.0	27.1	24.0	0.83
94	8.14	10.16	single	7.0	8.0	27.0	0.68
95	8.14	10.16	dual	5.5	3.4	29.7	0.75
96	21.46	5.08	single	6.0	18.0	10.0	0.38
97	21.46	5.08	dual	5.0	9.1	8.7	0.33
98	8.14	10.16	single	6.0	7.9	151.8	3.83
99	8.26	10.16	dual	5.5	3.0	90.5	2.25
100	8.21	10.16	single	6.0	6.5	80.0	2.08
101A	8.14	10.16	single	8.0	6.0	9.2	0.23
101B	8.14	10.16	single	8.0	10.0	63.4	1.6
102A	8.26	10.16	dual	5.0	3.4	2.01	0.05
102B	8.26	10.16	dual	5.0	3.0	20.8	0.52
103	8.26	10.16	dual	5.0	4.4	244.6	6.08
104A	8.26	10.16	dual	5.0	2.6	153.4	3.82
104B	8.26	10.16	dual	5.0	3.0	192.2	4.8
105	8.26	10.16	dual	14.0	2.0	20.1	0.50
106	8.47	10.16	dual	5.0	2.8	199.2	4.83
107A	8.38	10.16	dual	4.0	3.0	10.2	0.25
107B	8.38	10.16	dual	4.0	3.4	87.0	2.13
108	8.38	10.16	dual	7.0	2.7	122.4	3.00
109	8.51	10.16	dual	10.0	2.1	25.5	0.62
110	8.51	10.16	dual	4.0	3.1	20.7	0.50
111	40.95	5.08	dual	5.5	19.2	49.8	1.00
112	32.56	5.08	dual	5.0	15.0	79.2	2.00
113	20.60	5.08	dual	6.0	7.8	37.6	1.50

Table A-1. Master data table for laboratory-scale rapid rate filtration pilot plant (page 9 of 12).

	(19)	(21)	(21)	(22)	(23)	(24)	(25)
114	7.80	5.08	dual	8.0	3.5	10.9	1.10
115	40.40	5.08	dual	6.0	19.0	62.3	1.26
116	20.96	5.08	dual	9.0	9.5	27.6	1.08
117	32.30	5.08	dual	6.0	17.5	61.6	1.56
118	9.37	5.08	dual	11.0	4.0	38.0	3.33
119	41.40	5.08	dual	4.0	17.9	36.1	0.71
120	32.00	5.08	dual	4.0	13.5	26.0	0.66
121	20.70	5.08	dual	4.0	8.8	16.8	0.66
122	9.60	5.08	dual	6.0	4.0	7.8	0.66
123	40.20	5.08	dual	7.0	20.6	33.4	0.68
124	32.56	5.08	dual	6.0	18.5	26.4	0.66
125	20.47	5.08	dual	4.0	13.7	132.3	5.32
126A	20.47	5.08	dual	4.0	9.5	31.1	1.25
126B	20.47	5.08	dual	4.0	9.3	41.5	1.66
127A	20.47	5.08	dual	17.0	6.8	18.7	0.75
127B	20.47	5.08	dual	17.0	7.2	18.7	0.75
128A	20.47	5.08	dual	7.0	10.3	18.7	0.75
128B	20.47	5.08	dual	7.0	9.2	18.7	0.75
129	20.47	5.08	dual	7.0	9.3	18.7	0.75
130	20.47	5.08	dual	12.0	8.0	18.7	0.75
131A	20.47	5.08	dual	16.5	7.0	18.7	0.75
131B	20.47	5.08	dual	15.5	8.1	18.7	0.75
132	20.47	5.08	dual	7.0	9.8	18.7	0.75
133	22.69	5.08	dual	7.5	4.5	17.9	0.65
134	22.69	5.08	dual	7.0	9.0	24.4	0.88
135	22.69	5.08	dual	3.5	10.5	65.3	2.37
136	22.69	5.08	dual	6.0	9.8	20.7	0.75
137	22.69	5.08	dual	4.5	10.7	20.7	0.75
138	22.69	5.08	dual	4.5	10.9	27.6	1.00
139	22.69	5.08	dual	6.0	10.4	20.7	0.75
140	22.69	5.08	dual	14.0	7.1	27.6	1.00
141	22.69	5.08	dual	14.0	8.1	34.5	1.25
142	22.69	5.08	dual	14.5	7.6	20.7	0.75
143	22.69	5.08	dual	14.5	7.8	20.7	0.75
144	22.69	5.08	dual	15.5	7.0	20.7	0.75
145	22.69	5.08	dual	15.5	7.1	20.7	0.75
146	22.45	5.08	dual	7.0	11.1	71.3	2.58
147	22.45	5.08	dual	8.0	11.5	55.2	2.00
148	21.70	5.08	dual	6.0	12.1	132.0	5.00
149	22.22	5.08	dual	7.0	13.2	132.0	5.00
150	22.42	5.08	dual	17.0	8.1	29.7	1.00
151	22.42	5.08	dual	17.0	7.4	29.7	1.00
152	22.42	5.08	dual	17.0	8.0	29.7	1.00
153	22.42	5.08	dual	17.0	7.0	29.7	1.00
154	22.42	5.08	dual	18.0	7.4	29.7	1.00
155	22.42	5.08	dual	18.0	8.5	29.7	1.00
156	22.42	5.08	dual	7.0	10.0	29.7	1.00
157	22.42	5.08	dual	7.0	10.5	29.7	1.00
158	22.42	5.08	dual	7.0	11.6	29.7	1.00
159	22.42	5.08	dual	7.0	10.4	29.7	1.00
160	24.40	5.08	dual	6.5	11.5	29.7	1.00
161	21.30	5.08	dual	19.5	8.2	35.0	1.35
162	21.30	5.08	dual	4.0	10.0	39.0	1.50
163	21.2	5.08	dual	14.5	6.7	25.8	1.00
164	21.2	5.08	dual	16.0	6.6	25.8	1.00
165	21.2	5.08	dual	17.0	6.7	25.8	1.00
166	21.2	5.08	dual	17.5	6.9	51.6	2.00
167	21.2	5.08	dual	19.0	7.5	103.2	4.00
168	21.2	5.08	dual	19.0	8.2	129.0	5.00
169	21.2	5.08	dual	19.0	6.6	25.8	1.00
170	21.2	5.08	dual	2.5	9.0	25.8	1.00
171	21.2	5.08	dual	2.5	10.2	51.6	2.00
172	21.2	5.08	dual	2.5	11.7	103.2	4.00
173	21.2	5.08	dual	3.0	8.0	25.8	1.00
174	21.2	5.08	dual	4.5	9.4	52.0	2.00
175	21.2	5.08	dual	2.0	9.6	52.0	2.00
176	21.2	5.08	dual	3.0	11.0	52.0	2.00
177	21.2	5.08	dual	2.5	11.4	52.0	2.00
178	21.2	5.08	dual	3.0	11.6	59.13	2.25

Table A-1. Master data table for laboratory-scale rapid rate filtration pilot plant (page 10 of 12).

FILTER EFFLUENT DATA

+	Turbidity (NTU) (26)	% Removal of Turbidity (27)	Particle Count (No./10 ml) 2.52 - 50.8 µm (28)	% Removal of Particle Count (29)	Standard Plate Count (No./ml) (30)	% Removal of Standard Plate Count (31)	Total Coliform (No./100 ml) (32)	% Removal of Total Coliform (33)	*Giardia* Cysts (cysts/L) (34)	% Removal of *Giardia* Cysts (35)	Volume Filter for *Giardia* Cyst Sample (36)
1	5.00	16.67	-	-	-	-	-	-	0.000	0.00	0.0
1	4.80	20.00	-	-	-	-	-	-	0.000	0.00	0.0
2	3.60	0.00	22902	69.16	30,250	48.73	9,600	8.57	0.000	0.00	0.0
2	3.60	0.00	19802	73.34	33,000	44.00	10,000	4.76	0.000	0.00	0.0
3	2.50	16.67	6465	65.78	-	-	79	65.65	0.000	0.00	0.0
3	3.80	-26.67	9116	51.70	-	-	81	64.78	0.000	0.00	0.0
4	0.43	88.68	3290	90.70	9,000	90.72	10,000	0.00	0.000	0.00	0.0
4	0.32	91.58	1776	94.98	1,000	98.97	10,000	0.00	0.000	0.00	0.0
5	3.00	18.92	11663	67.76	2,800	92.22	-	-	0.000	0.00	0.0
5	2.10	43.24	11549	68.08	5,800	83.89	-	-	0.000	0.00	0.0
6	1.30	62.86	13860	63.78	-	-	-	-	0.000	0.00	0.0
6	2.30	34.29	10495	72.81	-	-	-	-	0.000	0.00	0.0
7	0.50	84.37	17191	62.00	1,620	93.60	40,000	88.57	0.000	0.00	0.0
7	0.34	89.38	24518	45.81	940	96.28	60,000	82.86	0.000	0.00	0.0
8	0.23	93.03	3155	92.47	1,360	94.96	26,000	85.56	0.000	0.00	0.0
8	0.33	90.00	7221	82.77	880	96.70	25,000	86.11	0.000	0.00	0.0
9	0.22	93.33	5857	89.05	17,600	95.45	5,500	89.81	0.000	0.00	0.0
10	3.20	3.03	-	-	7,250	95.51	5,900	3.28	0.000	0.00	0.0
11	2.80	20.00	-	-	37,667	70.30	3,500	45.31	0.000	0.00	0.0
11	2.40	27.27	-	-	16,350	87.10	4,600	28.13	0.000	0.00	0.0
12	0.44	86.67	783	88.87	3,500	87.50	200	84.00	0.000	0.00	0.0
12	0.24	92.73	652	90.73	3,600	87.10	<1	>99.00	0.000	0.00	0.0
13	0.30	92.86	24518	88.85	9,800	34.62	50	96.87	0.000	0.00	0.0
14	0.08	98.22	12262	90.90	1,050	90.70	<1	>99.95	0.000	0.00	0.0
15	0.08	97.65	15741	78.60	450	96.81	8	99.00	0.000	0.00	0.0
16	0.04	98.92	200	99.70	620	96.90	1	98.80	0.000	0.00	0.0
17	0.70	81.08	-	-	-	-	-	-	0.000	0.00	0.0
18	0.25	58.33	240	96.95	146	97.46	0	100.00	0.000	0.00	0.0
19	0.54	53.45	-	-	-	-	-	-	0.000	0.00	0.0
20	0.54	-31.71	112	99.95	39,300	91.50	<1	>99.00	0.000	0.00	0.0
21	0.44	-4.76	50896	12.60	153,000	61.60	1	98.57	0.000	0.00	0.0
22	0.05	90.48	3760	93.50	5,000	98.70	<1	>98.50	0.000	0.00	0.0
23	0.04	95.60	164	99.40	950	98.30	<1	>99.50	0.000	0.00	0.0
24	0.04	95.60	1090	91.00	1,380	99.50	<1	>99.00	0.000	0.00	0.0
25	0.04	95.60	668	97.50	1,485	99.50	<1	>99.00	0.000	0.00	0.0
26	0.03	76.92	-	-	-	-	-	-	0.000	0.00	0.0
27	0.05	77.27	-	-	295	99.90	<1	>99.09	0.000	0.00	0.0
28	0.03	81.25	-	-	1,040	74.90	<1	>98.00	0.000	0.00	0.0
29	0.06	62.50	-	-	660	84.20	<1	>98.00	0.000	0.00	0.0
30	0.08	52.94	-	-	226	-7.60	<1	>99.00	0.000	0.00	0.0
31	0.09	59.09	694	81.80	9,000	63.27	1	98.95	0.000	0.00	0.0
32	0.03	86.36	41	99.62	2,630	99.90	9	98.60	0.000	0.00	0.0
33	0.04	81.82	4	99.92	2,055	93.70	4	99.38	0.000	0.00	0.0
34	0.05	77.27	3	99.95	4,643	85.71	27	95.80	0.000	0.00	0.0
35	0.04	87.10	494	96.68	-	-	-	-	0.000	0.00	0.0
36	0.05	81.48	160	98.05	910	95.75	-	-	-	-	-
37	0.03	87.21	-	-	-	-	-	-	-	-	-
38	0.03	84.21	10	99.92	1,047	94.56	<0.5	99.90	-	-	-
39	0.03	84.21	423	96.65	8,250	42.23	<1.0	>99.90	-	-	-
40	0.04	78.95	77	99.39	390	85.82	2.5	96.15	-	-	-
41	0.05	80.00	-	-	-	-	-	-	-	-	-
42	0.09	85.94	-	-	-	-	-	-	0.000	100.00	43.3
43	0.06	90.63	-	-	-	-	-	-	0.000	100.00	27.4
44	0.08	89.47	-	-	-	-	-	-	0.000	100.00	18.7
45	0.07	90.79	-	-	-	-	-	-	1.932	91.69	20.7
46	0.16	27.27	711	85.78	4,000	-51.25	3450.0	13.75	66.163	74.55	30.2
47	0.38	-72.73	55	98.90	3,250	-66.67	3000.0	25.00	9.704	96.27	12.3
48	0.26	-18.18	291	94.18	3,800	-108.20	800.0	38.46	0.000	100.00	33.5
49	0.33	-13.79	71	98.58	2,900	20.55	520.0	60.00	0.000	100.00	16.6
50	0.04	88.89	400	98.55	2,250	82.28	<1.0	>99.90	2.506	97.77	39.9
51	0.05	86.11	368	98.92	890	87.51	14.0	80.00	0.000	100.00	6.4
52	0.03	91.67	250	99.18	745	95.55	<1.0	>99.90	0.000	100.00	15.0
53	0.08	82.61	2313	93.82	2,530	-	<1.0	>99.90	0.000	100.0	10.2
54	0.57	-38.60	-	-	1,750	43.05	1040	29.50	16.660	95.10	12.0

Table A-1. Master data table for laboratory-scale rapid rate filtration pilot plant (page 11 of 12).

	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)
55	0.60	33.30	2092	95.36	1,240	95.85	4.5	98.50	0.000	100.00	9.0
56	0.39	17.02	730	98.85	5,800	94.93	2.5	98.70	15.150	91.09	13.2
57	0.12	74.02	809	98.72	6,100	79.52	<1.0	>99.90	0.000	100.00	10.2
58	0.03	94.00	2130	97.93	8,750	89.61	<1.0	>99.90	28.900	87.13	19.0
59											
60	0.07	79.41	-	-	-	-	-	-	-	-	-
61	0.04	99.05	34	>99.90	3,005	92.29	<1.0	>99.90	-	-	143.2
62	0.05	98.81	2394	99.65	2,340	98.55	<1.0	>99.90	0.000	0.00	143.2
63	0.29	93.10	-	-	-	-	-	-	-	-	-
64	0.32	92.38	269415	71.99	3,000	>98.47	<1.0	>99.90	0.000	0.00	3.2
65	0.05	98.84	5132	99.47	1,250	88.99	-	-	0.000	0.00	14.9
66	0.05	88.89	291	99.27	410	91.14	<1	>99.90	<1.000	>99.90	140.2
67	0.05	90.20	88	99.78	173	87.37	<1	>99.90	<1.000	>99.90	120.6
68	0.91	-71.7	182,894	-301.00	1,100	17.29	<1	>99.90	25.060	94.25	17.9
69	0.14	73.58	110,558	-142.42	1,280	78.84	<0.5	>99.90	<1.000	>99.00	4.6
70	0.06	88.68	8237	81.94	97	98.40	<0.5	>99.50	3.220	99.30	34.2
71	0.04	95.83	161	99.89	1,900	98.92	<0.5	>99.90	<1.000	>99.90	61.9
72	0.05	94.95	13	99.99	250	99.83	<1	>99.90	<1.000	>99.90	127.6
73	1.27	-15.45	-	-	30,000	18.00	-	-	-	-	-
74	0.08	93.85	24,232	83.05	595	98.34	<1	>99.99	2.158	99.48	31.8
75	0.52	60.90	-	-	-	-	-	-	13.070	95.97	7.6
76	0.36	23.4	123	98.86	-	-	-	-	11.110	94.44	33.0
77	0.4	14.8	<10	99.92	-	-	-	-	-	-	24.4
78	0.48	-2.1	-	-	-	-	-	-	-	-	25.2
79	0.48	-2.1	496	95.42	-	-	-	-	-	-	22.1
80	0.08	82.9	<10	99.84	710	94.32	<1	>99.90	-		62.3
81	0.07	85.4	240	98.34	161	97.73	<1	>99.90	-	-	90.0
82	0.23	61.0	<10	99.00	127	99.58	<1	>99.90	-	-	20.4
83	0.08	86.4	<10	99.00	-	-	-	-	-	-	30.0
84	1.05	52.2	-	-	-	-	-	-	-	-	-
85A	0.09	95.91	873	99.25	530	96.97	88	99.96	<1.000	>99.90	13.2
85B	0.12	94.55	27,800	75.96	870	95.03	2870	98.57	5.681	>99.81	26.4
86A	0.12	95.20	1117	99.47	300	99.00	20	99.80	<1.000	>99.90	19.8
86B	0.06	97.6	361	99.80	300	99.00	33	96.67	<1.000	>99.90	91.7
87A	0.10	96.00	33,651	91.40	1210	99.37	125	99.48	0.488	99.97	19.8
87B	0.07	97.2	361	99.91	640	99.67	310	99.69	0.336	99.98	106.9
88A	0.22	94.21	1454	99.70	12,200	95.93	1000	99.90	2.185	99.91	14.2
88B	0.88	76.84	20,890	56.66	22,300	92.57	1000	99.90	26.315	98.84	3.8
89A	0.12	96.84	615	99.92	6200	94.07	150,000	98.81	1.481	99.94	13.5
89B	0.11	97.11	57,277	92.71	6700	98.99	276,000	97.81	2.614	99.90	49.9
90A	0.1	95.45	<10	99.90	-	-	13	99.97	<1.000	>99.90	20.4
90B	0.08	96.36	<10	99.90	-	-	33	99.95	<1.000	>99.90	70.0
91A	0.12	95.00	<10	99.90	76,500	72.43	34	99.86	<1.000	>99.90	20.4
91B	0.08	96.67	<10	99.90	37,500	86.44	63	94.78	<1.000	>99.90	68.0
92A	0.47	95.10	-	-	-	-	-	-	-	-	-
92B	0.73	92.40	-	-	-	-	-	-	-	-	-
93A	0.45	95.31	-	-	-	-	-	-	-	-	-
93B	0.51	94.69	-	-	-	-	-	-	-	-	-
94	1.77	-1.12	14,289	81.07	87,000	14.29	2,000	90.00	58.213	92.22	19.8
95	1.50	11.76	18,292	75.76	87,000	14.29	2,000	90.00	184.624	75.51	24.4
96	1.18	30.59	7,481	90.09	79,000	22.17	2,000	90.00	85.823	88.62	17.4
97	1.69	0.59	27,889	63.04	101,000	0.49	2,000	90.00	82.588	89.04	11.7
98	1.59	33.75	4171	95.00	100	99.94	-	-	0.866	99.91	23.1
99	2.40	20.00	15,355	69.08			50	99.92	1.148	99.89	17.4
100	0.73	77.19	1781	97.08	-	-	-	-	0.500	99.95	39.9
101A	0.60	87.50	1494	99.70	85	97.97	100	99.88	1.010	94.37	19.8
101B	1.49	68.96	1034	99.79	65	99.98	125	99.85	0.415	99.74	48.2
102A	1.46	76.45	46,433	27.1	30,000	0.00	>14,000	0.00	5.97	98.59	10.0
102B	3.6	41.94	85,791	34.69	30,000	0.00	>14,000	0.00	19.51	95.38	10.0
103	0.28	74.07	-	-	34	99.97	17	99.66	2.13	99.48	9.4
104A	0.90	16.67	967	98.8	30,000	50.41	560	-24.44	1.492	97.37	20.1
104B	0.19	82.41	1110	98.63	330	99.45	91	79.78	0.740	98.68	20.1
105	0.63	41.67	1821	97.75	190	97.96	555	45.05	-	-	-
106	0.73	-43.10	10,651	87.01	11	99.93	<1	>99.99	110.63	39.58	13.7
107A	0.27	60.29	996	98.31	2,300	92.46	1	90.00	0.980	99.67	20.4
107B	0.05	92.65	2714	95.40	1,000	96.72	1	90.00	0.245	99.92	81.6
108	0.05	91.67	33	99.92	380	98.19	-	-	-	-	-
109	0.16	84.62	<10	>99.00	920	94.25	5	99.8	-	-	-
110	0.06	94.74	121	99.85	1700	-96.25	<1	>99.9	-	-	-
111	0.49	56.61	48,150	32.86	1300	95.67	15	99.0	20.39	91.26	10.8
112	0.30	73.45	44,620	37.78	410	98.63	8	99.47	7.34	96.85	21.8
113	0.12	89.38	134,432	-122.93	30,000	0.00	1	99.86	-	>95.00	6.3

Table A-1. Master data table for laboratory-scale rapid rate filtration pilot plant (page 12 of 12).

	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)
114	0.10	91.15	24,797	58.90	880	96.80	<1	>99.99	5.400	95.25	5.5
115	0.27	78.90	28,257	37.94	40	99.68	<1	>99.99	36.585	84.69	4.9
116	0.23	82.03	21,166	53.52	20	99.76	<1	>99.99	7.840	96.72	11.4
117	1.05	15.32	32,907	5.88	2000	77.78	3	99.62	24.427	97.15	9.8
118	0.46	62.90	104,936	-200.14	140	98.44	5	99.37	21.050	97.55	38.0
119	1.3	18.75	7462	89.71	14,000	9.68	4400	5.3	156.540	41.98	16.8
120	1.3	18.75	10,312	85.78	13,000	16.13	5000	-7.53	171.790	36.33	19.5
121	1.31	18.13	12,915	82.19	13,000	16.13	4600	1.08	171.790	36.33	19.5
122	1.35	15.63	13,397	81.15	<1	>99.90	<1	>99.90	85.470	68.32	5.7
123	1.19	25.63	6563	90.95	16,000	-23.08	200	0.00	125.860	48.72	25.2
124	1.23	23.13	7533	89.61	11,000	31.25	200	0.00	68.180	72.22	19.8
125	27.0	9.09	-	-	520	95.84	<1	>99.99	-	-	-
126A	1.20	66.06	-	-	-	-	<1	>99.90	-	-	-
126B	5.30	83.94	-	-	-	-	<1	>99.90	-	-	-
127A	2.00	85.92	-	-	1500	70.00	<1	>94.40	-	-	-
127B	1.38	90.28	-	-	2200	56.00	14	>94.46	-	-	-
128A	8.90	37.32	-	-	9900	20.80	<1	>99.99	-	-	-
128B	9.20	35.21	-	-	1600	87.20	<1	>99.99	-	-	-
129	7.80	45.07	-	-	-	-	<1	>99.90	-	-	-
130	5.60	60.50	-	-			<1	>79.90	-	-	-
131A	2.00	15.49	-	-			<1	>79.90	-	-	
131B	0.23	98.38	-	-	600		<1	>79.90	-	-	
132	0.78	94.51	-	-	510	98.58	<1	>99.90	-	-	-
133	0.32	98.22	-	-	2540	86.54	1	99.99	<20	99.26	6.00
134	1.15	3.36	-	-	17000	-9.68	>1000	<92.22	45.45	93.90	15.20
135	1.86	-56.30	-	-	6800	56.13	>1000	<92.22	>10	>99.90	11.04
136	1.93	-62.18	-	-	8000	48.39	4100	29.91	-	-	-
137	2.20	-84.87	-	-	2600	83.23	10	99.83	-	-	-
138	3.30	- 177.30	-	-	2310	75.56	5	99.79	-	-	-
139	1.76	-47.90	-	-	780	91.75	>1	<99.99	-	-	-
140	1.03	13.45	-	-	18,000	24.05	10	75.00	-	-	-
141	0.26	78.15	-	-	4100	82.70	-	-	-	-	-
142	2.60	- 118.49	-	-	5200	79.03	<1	-	-	-	-
143	1.68	-41.18	-	-	6200	75.00	<1	-	-	-	-
144	1.51	-26.89	-	-	3000	-233.33	<1	-	-	-	-
145	2.90	- 143.70	-	-	6300	-600.00	<1	-	-	-	-
146	0.09	89.89	-	-	3500	62.85	600	97.55	0.602	99.84	33.21
147	0.10	88.76	-	-	26000	-541.98	300	96.00	<8.45	>83.60	5.91
148	0.12	88.68	-	-	1040	97.98	410	96.72	4.55	93.94	5.3
149	0.10	90.57	-	-	900	97.63	19	99.49	-	-	-
150	0.65	-62.50	-	-	17200	-1.47	>1000	<86.67	-	-	-
151	0.33	17.50	-	-	30,000	-76.99	>1000	<86.67	-	-	-
152	0.06	85.00	-	-	3800	77.65	<10	>99.00	-	-	-
153	0.42	-5.00	-	-	30,000	-76.47	1250	-25.00	-	-	-
154	0.19	52.50	-	-	6700	82.60	250	93.15	-	-	-
155	0.09	77.50	-	-	2600	93.25	6	99.84	-	-	-
156	0.52	-30.00	-	-	2500	95.33	113	98.02	-	-	-
157	0.28	30.00	-	-	4800	91.50	80	99.63	-	-	-
158	0.12	70.00	-	-	3800	93.27	60	99.72	-	-	-
159	0.26	35.00	-	-	5600	90.00	>1000	<97.5	-	-	-
160	0.11	75.56	-	-	2300	95.89	200	99.5	-	-	-
161	0.14	83.53	-	-	730	92.02	<1	99.99	-	-	-
162	0.13	84.70	-	-	35	99.73	28	99.86	-	-	-
163	0.62	27.06	-	-	6200	24.69	2233	48.07	0.000	-	-
164	0.13	84.70	-	-	5920	83.87	100	91.30	0.000	-	-
165	0.24	71.76	-	-	730,000	<46.70	10	99.09	0.000	-	-
166	0.06	92.94	-	-	730,000	<41.18	10	99.00	0.000	-	-
167	0.17	80.00	-	-	-	-	-	-	0.000	-	-
168	0.03	96.47	-	-	38000	32.38	-	-	0.000	-	-
169	0.03	96.47	-	-	1290	94.94	-	-	0.000	-	-
170	0.19	85.00	-	-	-	-	-	-	0.000	-	-
171	0.09	89.41	-	-	-	-	0	100.00	0.000	-	-
172	0.39	54.10	-	-	730,000	<22.68	1	99.33	0.000	-	-
173	1.66	27.80	-	-	20900	-14.84	1100	40.54	0.000	-	-
174	0.59	1.00	-	-	12,600	14.29	100	90.00	-	-	-
175	0.30	53.00	-	-	800	85.45	1000	71.18	-	-	-
176	0.24	65.00	-	-	-	-	<1	99.99	-	-	-
177	0.20	74.00	-	-	230	96.17	33	99.50	-	-	-
178	0.16	79.00	-	-	8,120	-98.05	95	98.61	-	-	-

Table A-2. Giardia cyst removal efficiency corrected for detection limits (page 1 of 4).

Run No.	Membrane Filter Sampling Efficiency 1/	Detection Limit 2/	Effluent Giardia Cyst Conc. Corrected for Recovery Efficiency 3/* (cyst/L)	Removal Efficiency 4/
42	15.3	3.039	3.039	99.39
43	16.33	4.469	4.469	99.06
44	11.57	9.244	9.244	94.15
45	4.65	9.5579	41.55	91.69
46	54.1	1.22	122.29	74.55
47	54.1	3.006	17.94	96.27
48	95.37	0.626	0.626	99.87
49	95.37	0.012	0.012	>99.9
50	23.41	2.141	10.700	97.77
51	79.76	4.179	4.179	99.13
52	108.66	1.227	1.227	99.74
53	77.49	2.53	2.53	99.47
54	68.0	2.45	30.85	93.83
55	80.9	2.747	2.74	99.45
56	34.0	4.45	44.56	91.09
57	34.0	5.767	5.767	98.85
58	45.0	2.339	64.22	87.16
59	-	-	-	-
60	-	-	-	-
61	-	-	-	-
62	-	-	-	-
63	-	-	-	-
64	-	-	-	-
65	-	-	-	-
66	73.75	0.1934	0.1934 4	99.96
67	66.67	1.229	1.229	99.75
68	87.0	0.912	28.8	94.24
69	103.85	4.1866	4.186	99.16
70	103.85	0.5631	3.1	99.38
71	62.8	0.514	0.514	99.95
72	70.0	0.2239	0.224	99.97
73	-	-	-	-
74	41.6	1.5116	5.190	99.48
75	32.4	8.122	40.34	95.97
76	20.0	3.03	55.55	94.45
77	20.0	4.098	-	-
78	20.0	3.9683	-	-
79	20.0	4.52	-	-

Table A-2. *Giardia* cyst removal efficiency corrected for detection limits (page 2 of 4).

Run No.	Membrane Filter Sampling Efficiency 1/	Detection Limit 2/	Effluent Giardia Cyst Conc. Corrected for Recovery Efficiency 3/* (cyst/L)	Removal Efficiency 4/
80	-	-	-	-
81	-	-	-	-
82	-	-	-	-
83	-	-	-	-
84	55.79	-	-	-
85A	60.0	2.525	2.525	99.95
85B	60.0	1.2626	9.47	99.81
86A	16.0	6.3131	6.3131	99.87
86B	16.0	1.3631	1.3631	99.97
87A	35.6	2.8374	1.37	99.97
87B	35.6	0.5255	0.52	99.99
88A	47.37	2.9733	4.61	99.91
88B	47.37	11.11	11.11	99.78
89A	53.0	2.7952	2.79	99.94
89B	53.0	0.756	4.93	99.90
90A	80.8	1.2134	1.2134	99.98
90B	80.8	0.3536	0.3536	99.99
91A	63.64	1.5405	1.540	99.97
91B	63.64	0.4622	0.4522	99.9
92A	-	-	-	-
92B	-	-	-	-
93A	-	-	-	-
93B	-	-	-	-
94	95.74	1.05	60.8	92.27
95	95.79	0.8557	192.7	75.71
96	95.79	1.1994	89.9	88.62
97	95.79	1.7845	86.2	89.04
98	68.38	1.266	1.26	99.80
99	67.48	1.703	1.70	99.89
100	13.94	3.59	3.59	99.94
101A	22.82	4.426	4.42	99.37
101B	22.82	1.819	1.82	99.74
102A	60.30	3.3002	9.9	98.59
102B	60.30	3.3002	32.35	95.38
103	66.8	3.192	3.192	99.47
104A	9.42	1.056	15.8	97.37
104B	9.42	1.056	7.85	98.70
105	-	-	-	-

Table A-2. Giardia cyst removal efficiency corrected for detection limits (page 3 of 4).

Run No.	Membrane Filter Sampling Efficiency[1/]	Detection Limit[2/]	Effluent Giardia Cyst Conc. Corrected for Recovery Efficiency[3/]* (cyst/L)	Removal Efficiency[4/]
106	41.61	3.508	265.87	34.57
107A	50.21	1.952	1.952	94.67
107B	50.21	0.488	0.49	99.92
108	-	-	-	-
109	-	-	-	-
110	-	-	-	-
111	97.15	1.906	20.99	91.25
112	97.15	0.945	7.55	96.85
113	48.08	6.63	6.63	97.24
114	48.08	7.59	11.23	95.32
115	119.5	3.416	30.6	84.64
116	119.5	1.459	6.56	96.72
117	85.8	2.3786	28.7	97.15
118	85.8	0.6134	24.50	97.55
119	89.67	1.328	174.57	41.81
120	89.67	1.14	91.5	36.41
121	89.67	1.143	191.26	36.25
122	89.67	3.913	95.3	68.23
123	81.82	0.9767	153.8	48.72
124	81.82	1.2345	83.3	72.22
125	-	-	-	-
126A	-	-	-	-
126B	-	-	-	-
127A	-	-	-	-
127B	-	-	-	-
128A	-	-	-	-
128B	-	-	-	-
129	-	-	-	-
130	-	-	-	-
131A	-	-	-	-
131B	-	-	-	-
132	-	-	-	-

Table A-2. *Giardia* cyst removal efficiency corrected for detection limits (page 4 of 4).

1/ *Giardia* cysts were not used during Runs 1-41.

2/ (Influent No. of cyst detected/No. of cyst added 100 = Membrane filter sampling efficiency recovery.

3/ (20 cysts)/[(Membrane filter sampling efficiency recovery)(Effluent volume sampled)]

4/ (No. of cysts detected effluent)/[(Membrane filter sampling recovery)(Effluent volume sampled)]

5/ 100 {1 - (Effluent cysts concentration corrected for detection limit/Influent cysts concentration added)]

*Detection limit when zero cysts are reported.

Note: Procedures for these calculations are given in Appendix J.

APPENDIX B

MASTER DATA TABLE FOR FIELD-SCALE RAPID RATE FILTRATION PILOT PLANT

Table B-1 contains all experimental data obtained during experiments using the field-scale rapid rate filtration pilot plant, e.g. the Neptune Microfloc Waterboy R. As with Table A-1, each row of the table contains data obtained from a given test run. The table has three parts: i) influent water characteristics, shown in Table B-1(a); ii) chemical basin information, shown in Table B-1(b); and iii) filter conditions and effluent water conditions, shown in Table B-1(c). Table B-1 served as a source from which other tables and graphs were derived related to field-scale testing results. Appendix H and the latter part of Chapter 4 contain these tables and graphs.

Table B-1 is intended to be used either in place, or as a "fold out." The fold out table can be constructed using copies or originals, of Tables B-1(a), B-1(b), and B-1(c), constructed as shown below:

Table B-1(a)	Table B-1(b)	Table B-1(c)
Sheet 1	Sheet 1	Sheet 1
Sheet 2	Sheet 2	Sheet 2
Sheet 3	Sheet 3	Sheet 3

Table B-1(a). Master Data Table (Sheet 1).

Test Identification		Influent Water Characteristics					
Run #	Date	Source of Water	Temp. (°C)	Turbidity (NTU)	Coliforms (#/100ml)	*Giardia* Designed (cyst/liter)	*Giardia* Detected (cyst/liter)
1	11/9/82	HT	10.0	9.0	2/	1/	1/
2	11/14/82	HT	7.5	9.0	2/	1/	1/
3	12/30/82	HT	6.0	9.5	2/	1/	1/
4	12/31/82	HT	6.0	9.5	2/	1/	1/
5	1/2/83	HT	6.0	9.5	2/	1/	1/
5	1/3/83	hT	6.0	9.5	2/	1/	1/
7	1/4/83	HT	6.0	9.6	2/	1/	1/
8	1/5/83	HT	6.0	9.0	2/	1/	1/
9	1/7/83	HT	5.5	9.0	2/	1/	1/
10	1/8/83	HT	5.5	9.0	2/	1/	1/
11	1/8/83	HT	5.5	8.0	2/	1/	1/
12	1/8/83	HT	5.5	8.0	2/	1/	1/
13	1/9/83	HT	5.5	8.5	2/	1/	1/
14	1/9/83	HT	5.5	8.5	2/	1/	1/
15	1/20/83	HT	5.0	9.0	2/	1/	1/
16	1/20/83	HT	5.0	9.0	2/	1/	1/
17	1/2/83	HT	5.0	9.0	2/	1/	1/
18	1/21/83	HT	5.0	9.0	2/	1/	1/
19	1/23/83	HT	5.0	9.5	2/	1/	1/
20	2/2/83	HT	5.0	9.0	2/	1/	1/
21	2/2/83	HT	5.0	9.0	2/	1/	1/
22	2/9/83	HT	5.0	9.0	2/	1/	1/
23	4/23/83	PR	8.0	27.0	2/	1/	1/
24	4/23/83	PR	8.0	27.0	2/	1/	1/
25	4/23/83	PR	8.0	27.0	2/	1/	1/
26	4/23/83	PR	8.0	27.0	2/	1/	1/
27a	4/26/83	PR	9.0	30.0	2/	1/	1/
27b	4/26/83	PR	9.0	30.0	2/	1/	1/
28a	4/26/83	PR	9.0	30.0	2/	1/	1/
28b	4/26/83	PR	9.0	30.0	2/	1/	1/
29	5/25/83	PR	9.0	44.0	2/	1/	1/
30	5/25/83	PR	9.0	44.0	2/	1/	1/
31	5/25/83	PR	9.0	44.0	2/	1/	1/
32	5/25/83	PR	11.0	35.0	2/	1/	1/
33	5/26/83	PR	10.0	32.0	2/	1/	1/
34	5/26/84	PR	10.0	27.0	2/	1/	1/
35	5/29/83	PR	7.5	34.0	2/	1/	1/
36	5/29/83	PR	7.5	35.0	2/	1/	1/
37	5/29/83	PR	7.5	35.0	2/	1/	1/
38	5/31/83	PR	7.0	16.0	2/	1/	1/
39	6/1/83	PR	7.0	17.0	2/	1/	1/
40	6/1/83	PR	8.0	17.0	2/	1/	1/
41	6/1/83	PR	8.0	12.0	2/	1/	1/
42	6/1/83	PR	8.0	12.0	2/	1/	1/
43	7/3/83	HT	10.0	7.0	2/	1/	1/
44	7/3/83	HT	10.0	7.0	2/	1/	1/
45	7/4/83	HT	10.0	7.0	2/	1/	1/
46	7/4/83	HT	10.0	7.0	2/	1/	1/
47	7/4/83	HT	10.0	7.0	2/	1/	1/
48	7/5/83	HT	10.0	7.0	2/	1/	1/
49	7/12/83	HT	10.0	7.0	2/	135	10
50	7/12/83	HT	10.0	7.0	2/	135	130
51	7/13/83	HT	10.0	7.0	300	220	110
52	7/14/83	HT	10.0	7.0	220	220	30

1/ No *Giardia* cysts or coliform bacteria injected
2/ Coliform bacteria were not monitored
3/ Cysts were of questionable viability
4/ No *Giardia* injected, therefore no *Giardia* sampling
5/ No effluent turbidity sample
6/ Alum dosages are in mg/l as $Al_2(SO_4)_3 \cdot 14H_2O$

cut line

Table B-1(a). Master Data Table (Sheet 2).

Test Identification			Influent Water Characteristics				
Run #	Date	Source of Water	Temp. (°C)	Turbidity (NTU)	Coliforms (#/100ml)	*Giardia* Designed (cyst/liter)	*Giardia* Detected (cyst/liter)
53	7/13/83	HT	11.0	7.0	2/	1/	1/
54	7/14/83	HT	10.0	7.0	2/	1/	1/
55	7/14/83	HT	10.0	7.0	2/	1/	1/
56	7/14/83	HT	10.0	7.0	2/	1/	1/
57	7/15/83	HT	10.0	7.0	2/	245	25
58	7/15/83	HT	10.0	7.0	2/	245	45
59	7/18/83	HT	12.0	7.0	1200	210	25
60	7/19/83	HT	12.0	7.0	13,000	150	50
61	7/19/83	HT	12.0	7.0	23,000	150	16
62	7/19/83	HT	12.0	7.0	2/	800	60
63	7/25/83	HT	12.0	7.0	2/	1/	1/
64	7/25/83	HT	12.0	7.0	2/	1/	1/
65	7/25/83	HT	11.0	7.0	2/	1/	1/
66	7/25/83	HT	11.0	7.0	2/	1/	1/
67	8/3/83	HT	12.0	7.0	2/	1/	1/
68	8/3/83	HT	12.0	7.0	2/	1/	1/
69	8/3/83	HT	12.0	7.0	2/	1/	1/
70	8/4/83	HT	12.0	7.0	2/	1/	1/
71	8/11/83	HT	12.0	7.0	2/	1/	1/
72	8/12/83	HT	12.0	7.0	2/	1/	1/
73	8/12/83	HT	11.0	7.0	3600	700	3/
74	8/12/83	HT	11.0	7.0	1500	700	3/
75	8/14/83	HT	13.0	7.0	3600	525	3/
76	8/14/83	HT	13.0	7.0	2700	525	3/
77	8/14/83	HT	13.0	7.0	2/	1/	1/
78	8/15/83	HT	12.0	7.0	2/	1/	1/
79	8/15/83	HT	12.0	7.0	8700	550	35
80	8/16/83	HT	13.0	7.0	2/	1/	1/
81	8/16/83	HT	13.0	7.0	2/	1/	1/
82	8/16/83	HT	13.0	7.0	2/	1/	1/
83	8/16/83	HT	13.0	7.0	2/	1/	1/
84	8/23/83	HT	12.0	7.0	2/	1/	1/
85	8/23/83	HT	12.0	7.0	2/	1/	1/
86	8/23/83	HT	12.0	7.0	2/	1/	1/
87	8/23/83	HT	12.0	7.0	2/	1/	1/
88	8/23/83	HT	12.0	7.0	2/	1/	1/
89	8/23/83	HT	12.0	7.0	2/	1/	1/
90	8/24/83	HT	12.0	7.0	16,000	550	250
91	8/24/83	HT	12.0	7.0	16,000	550	350
92	8/24/83	HT	12.0	7.0	30,000	1000	800
93	8/27/83	HT	12.0	7.0	2/	1/	1/
94	8/28/83	HT	12.0	7.0	2/	1/	1/
95	8/28/83	HT	12.0	7.0	2/	1/	1/
96	8/28/83	HT	12.0	7.0	2/	1/	1/
97	8/28/83	HT	12.0	7.0	2/	1/	1/
98	8/28/83	HT	12.0	7.0	20,000	2400	2000
99	8/28/83	HT	12.0	7.0	15,000	2400	1700
100	8/29/83	HT	12.0	7.0	2/	1/	1/
101	8/30/83	HT	12.0	7.0	2/	1/	1/
102	8/30/83	HT	12.0	7.0	2/	1/	1/
103	8/30/83	HT	12.0	7.0	2/	1/	1/
104	8/31/83	HT	12.0	7.0	2/	1/	1/
105	8/31/83	HT	12.0	7.0	1200	450	200
106	8/31/83	HT	12.0	7.0	2500	1000	75

1/ No *Giardia* cysts or coliform bacteria injected
2/ Coliform bacteria were not monitored
3/ Cysts were of questionable viability
4/ No *Giardia* injected, therefore no *Giardia* sampling
5/ No effluent turbidity sample
6/ Alum dosages are in mg/l as $Al_2(SO_4)_3 \cdot 14H_2O$

Table B-1(a). Master Data Table (Sheet 3).

Test Identification		Influent Water Characteristics					
Run #	Date	Source of Water	Temp. (°C)	Turbidity (NTU)	Coliforms (#/100ml)	*Giardia* Designed (cyst/liter)	*Giardia* Detected (cyst/liter)
107	11/1/83	PR	7.0	.60	2/	1/	1/
108	11/1/83	PR	7.0	.55	2/	1/	1/
109	11/1/83	PR	7.0	.45	2/	1/	1/
110	11/2/83	PR	7.0	.50	2/	1/	1/
111	11/2/83	PR	7.0	.45	2/	1/	1/
112	11/2/83	PR	7.0	.45	2/	1/	1/
113	11/5/83	PR	7.0	.60	2/	1/	1/
114	11/5/83	PR	7.0	.60	2/	1/	1/
115	11/5/83	PR	7.0	.70	2/	1/	1/
116	11/5/83	PR	7.0	.60	2/	1/	1/
117	11/10/83	PR	2.0	.40	15000	1500	260
118	11/15/83	PR	2.0	.65	2/	1/	1/
119	11/15/83	PR	2.0	.65	2/	1/	1/
120	11/15/83	PR	2.0	.65	2/	1/	1/
121	11/15/83	PR	2.0	.65	2/	1/	1/
122	11/17/83	PR	3.0	.65	2/	1/	1/
123	12/3/83	PR	1.0	.60	6900	1400	325
124	12/3/83	PR	1.0	.60	6900	1400	325
125	12/6/83	PR	1.0	.55	9000	1300	1300
126	12/6/83	PR	1.0	.55	9000	1300	1300
127	12/10/83	PR	1.0	.90	2/	400	175
128	12/10/83	PR	1.0	.90	2/	400	175
129	12/15/83	PR	1.0	.60	3500	1/	1/
130	1/4/84	PR	1.0	.80	2/	1/	1/
131	1/4/84	PR	1.0	.80	2/	1/	1/
132	1/4/84	PR	1.0	.80	2/	1/	1/
133	1/4/84	PR	1.0	.80	2/	1/	1/
134	1/6/84	PR	1.0	.70	2/	1/	1/
135	1/6/84	PR	1.0	.70	2/	1/	1/
136	1/6/84	PR	1.0	.70	2/	1/	1/
137	1/8/84	PR	1.0	.70	2/	1/	1/
138	1/8/84	PR	1.0	.70	10000	2600	1300

1/ No *Giardia* cysts or coliform bacteria injected
2/ Coliform bacteria were not monitored
3/ Cysts were of questionable viability
4/ No *Giardia* injected, therefore no *Giardia* sampling
5/ No effluent turbidity sample
6/ Alum dosages are in mg/l as $Al_2(SO_4)_3 \cdot 14H_2O$

Table B-1(b). Master Data Table (Sheet 1).

	Chemical Basin Information					
Run #	Alum Dosage6/ (mg/1)	Polymer Dosage (mg/1)	Type of Polymer	G(sec^{-1})	T(sec)	GT
1	0	1.0	572C	750	202	151,500
2	0	1.0	573C	750	222	166,500
3	0	0.5	573C	714	228	162,700
4	0	0.5	572C	714	212	151,400
5	0	1.5	573C	714	221	157,800
5	0	1.5	572C	714	212	151,400
7	0	4.0	573C	714	204	145,700
8	0	9.0	573C	714	228	163,000
9	0	7.0	8181	702	221	155,100
10	0	4.0	8102	702	217	152,300
11	0	8.0	8102	702	207	145,300
12	0	11.0	8102	702	203	142,500
13	0	1.0	8102	702	205	143,900
14	0	6.5	572C	702	203	142,500
15	0	1.5	572C	691	280	193,500
16	0	4.5	572C	691	256	176,900
17	0	5.5	572C	691	259	178,900
18	0	2.5	572C	691	228	157,500
19	0	2.5	572C	691	242	167,200
20	0	3.0	573C	691	217	150,000
21	0	7.0	573C	691	219	151,300
22	0	2.0	573C	691	223	154,100
23	0	1.5	572C	720	202	145,400
24	0	4.0	572C	720	202	145,400
25	0	8.5	572C	720	202	145,400
26	0	30	572C	720	202	145,400
27a	0	4.0	572C	726	207	150,300
27b	0	9.0	572C	726	207	150,300
28a	0	17.0	572C	726	207	150,300
28b	0	35.0	572C	726	207	150,300
29	0	10.5	572C	726	238	172,800
30	0	8.0	572C	726	238	172,800
31	0	5.0	572C	726	238	172,800
32	0	21.0	572C	767	238	182,500
33	0	6.5	572C	750	217	162,750
34	0	0	none	750	217	162,750
35	0	9.0	572C	774	238	184,200
36	0	0	none	774	240	185,800
37	0	12.5	572C	774	238	184,200
38	0	7.0	572C	782	248	194,000
39	30	0	none	782	269	210,400
40	18	0	none	720	311	223,900
41	12	0	none	720	230	165,600
42	25	0	none	720	238	171,400
43	0	3.0	573C	750	185	137,700
44	0	2.0	573C	750	180	134,700
45	0	1.0	573C	750	175	131,300
46	0	4.5	573C	750	175	131,300
47	0	6.5	573C	750	170	127,500
48	0	2.5	572C	750	180	135,000
49	0	2.5	573C	750	175	131,300
50	0	0	none	750	180	135,000
51	0	8.0	573C	750	180	135,000
52	0	2.5	8102	750	180	135,000

1/ No *Giardia* cysts or coliform bacteria injected
2/ Coliform bacteria were not monitored
3/ Cysts were of questionable viability
4/ No *Giardia* injected, therefore no *Giardia* sampling
5/ No effluent turbidity sample
6/ Alum dosages are in mg/1 as $Al_2(SO_4)_3 \cdot 14H_2O$

cut line

Table B-1(b). Master Data Table (Sheet 2).

	Chemical Basin Information					
Run #	Alum Dose6/ (mg/l)	Polymer Dosage (mg/l)	Type of Polymer	$G(sec^{-1})$	T(sec)	GT
53	0	2.0	8102	755	170	128,400
54	0	0.8	8102	750	180	135,000
55	0	5.0	8102	750	170	127,000
56	0	7.5	8102	750	170	127,000
57	0	0	none	750	180	135,000
58	0	5.5	8102	750	180	135,000
59	0	11.0	8102	760	180	136,800
60	0	0	none	760	180	136,000
61	0	0	none	760	180	136,000
62	0	0	none	760	180	136,000
63	0	1.0	572C	760	180	136,000
64	0	2.5	572C	760	180	136,800
65	0	5.5	572C	755	180	135,900
66	0	11.0	572C	755	180	135,900
67	4	0	none	760	180	136,800
68	12	0	none	760	180	136,800
69	18	0	none	760	180	136,800
70	25	0	none	760	180	136,800
71	0	4.0	572C	760	180	136,800
72	0	2.5	572C	760	180	136,800
73	0	2.5	572C	755	180	135,900
74	0	0	none	755	180	135,900
75	0	1.0	572C	765	180	137,700
76	30	0	none	765	180	137,700
77	30	0	none	765	180	137,700
78	0	3.5	8102	760	180	136,800
79	0	3.5	8102	760	180	136,800
80	0	1.0	8102	765	210	160,700
81	0	4.0	8102	765	210	160,700
82	0	6.0	8102	765	210	160,700
83	0	10.0	8102	765	210	160,700
84	0	3.0	8102	760	210	159,600
85	0	5.0	8102	760	210	159,600
86	0	7.0	8102	760	210	159,600
87	0	15.0	8102	760	210	159,600
88	0	0	8102	760	210	159,600
89	0	4.0	8102	760	180	136,800
90	0	4.0	8102	760	180	136,800
91	0	1.0	8102	760	180	136,800
92	18	0	none	760	180	136,800
93	16	0	none	760	180	136,800
94	20	0	none	760	180	136,800
95	30	0	none	760	180	136,800
96	25	0	none	760	180	136,800
97	10	0	none	760	180	136,800
98	20	0	none	760	180	136,800
99	0	0	none	760	180	136,800
100	0	4.0	8102	760	180	136,800
101	0	4.0	8102	760	180	136,800
102	20	2.0	8102	760	180	136,800
103	20	1.0	8102	760	180	136,800
104	20	4.0	8102	760	180	136,800
105	20	4.0	8102	760	180	136,800
106	20	4.0	8102	760	180	136,800

Cut line

1/ No *Giardia* cysts or coliform bacteria injected
2/ Coliform bacteria were not monitored
3/ Cysts were of questionable viability
4/ No *Giardia* injected, therefore no *Giardia* sampling
5/ No effluent turbidity sample
6/ Alum dosages are in mg/l as $Al_2(SO_4)_3 \cdot 14H_2O$

Table B-1(b). Master Data Table (Sheet 3).

Run #	Chemical Basin Information					
	Alum Dosage6/ (mg/1)	Polymer Dosage (mg/1)	Type of Polymer	G(sec^{-1})	T(sec)	GT
107	0	0	none	782	202	158,000
108	0	0.2	8102	782	235	184,000
109	0	0.5	8102	782	235	184,000
110	0	1.0	8102	782	220	172,000
111	0	2.0	8102	782	220	172,000
112	0	0.2	8102	782	220	172,000
113	3.0	0.6	8102	782	252	197,000
114	3.0	0.6	8102	782	252	197,000
115	3.0	0.2	8102	782	252	197,000
116	3.0	0.07	8102	782	252	197,000
117	0	0	none	645	224	144,000
118	3.0	0	none	645	202	130,000
119	0.5	0	none	645	202	130,000
120	1.5	0	none	645	202	130,000
121	5.5	0	none	645	202	130,000
122	1.0	0	none	661	202	133,000
123	0	0.1	8102	630	224	141,000
124	0	0.4	8102	630	224	141,000
125	0.40	0	none	630	235	148,000
126	5.0	0	none	630	235	148,000
127	3.0	0.2	8102	630	202	127,000
128	3.0	0.4	8102	630	202	127,000
129	0	0	none	630	202	127,000
130	0	0.4	572-C	630	202	127,000
131	0	0.8	572-C	630	202	127,000
132	0	2.0	572-C	630	202	127,000
133	1.5	0.7	572-C	630	202	127,000
134	15	2.0	572-C	630	202	127,000
135	4.5	2.0	572-C	630	202	127,000
136	9.0	2.0	572-C	630	202	127,000
137	30	2.0	572-C	630	202	127,000
138	7.0	2.0	572-C	630	202	127,000

cut line

1/ No *Giardia* cysts or coliform bacteria injected
2/ Coliform bacteria were not monitored
3/ Cysts were of questionable viability
4/ No *Giardia* injected, therefore no *Giardia* sampling
5/ No effluent turbidity sample
6/ Alum dosages are in mg/1 as $Al_2(SO_4)_3 \cdot 14H_2O$

Table B-1(c). Master Data Table (Sheet 1).

	Filter Conditions			Effluent Water Conditions			
Run #	Type of Filtration	Length of Run (hr)	Flow Rate (gpm/ft^2)	Turbidity (NTU)	*Giardia* (cyst/liter)	Water Sampled (l)	Coliforms (#/100ml)
1	in-line	9.0	5.0	0.8	1/	4/	2/
2	in-line	8.3	4.6	0.3	1/	4/	2/
3	in-line	6.0	4.4	1.2	1/	4/	2/
4	in-line	5.0	4.8	1.9	1/	4/	2/
5	in-line	4.0	4.6	0.2	1/	4/	2/
5	in-line	4.0	4.8	0.2	1/	4/	2/
7	in-line	5.0	5.0	0.15	1/	4/	2/
8	in-line	2.5	4.4	3.0	1/	4/	2/
9	in-line	2.5	4.6	3.5	1/	4/	2/
10	in-line	3.0	4.7	0.1	1/	4/	2/
11	in-line	4.0	4.9	0.15	1/	4/	2/
12	in-line	3.0	5.0	0.5	1/	4/	2/
13	in-line	3.0	4.9	0.3	1/	4/	2/
14	in-line	3.0	5.0	0.4	1/	4/	2/
15	in-line	1.5	3.6	0.4	1/	4/	2/
16	in-line	1.5	4.0	0.3	1/	4/	2/
17	in-line	1.1	3.9	0.4	1/	4/	2/
18	in-line	2.0	4.4	0.45	1/	4/	2/
19	in-line	2.5	4.2	0.30	1/	4/	2/
20	in-line	1.0	4.7	0.45	1/	4/	2/
21	in-line	0.75	4.6	2.0	1/	4/	2/
22	in-line	5.0	4.1	0.2	1/	4/	2/
23	in-line	0.75	5.0	1.5	1/	4/	2/
24	in-line	0.75	5.0	8.5	1/	4/	2/
25	in-line	0.75	5.0	1.0	1/	4/	2/
26	in-line	0.75	5.0	3.0	1/	4/	2/
27a	in-line	0.80	4.9	3.0	1/	4/	2/
27b	in-line	0.80	4.9	1.5	1/	4/	2/
28a	in-line	0.80	4.9	1.5	1/	4/	2/
28b	in-line	0.80	4.9	6.5	1/	4/	2/
29	in-line	0.80	4.3	2.0	1/	4/	2/
30	in-line	0.80	4.3	1.5	1/	4/	2/
31	in-line	0.80	4.3	2.5	1/	4/	2/
32	in-line	0.80	4.3	3.0	1/	4/	2/
33	in-line	1.0	4.7	1.0	1/	4/	2/
34	in-line	1.0	4.7	10.0	1/	4/	2/
35	in-line	1.0	4.3	1.50	1/	4/	2/
36	in-line	1.0	4.2	1.0	1/	4/	2/
37	in-line	1.2	4.3	1.3	1/	4/	2/
38	in-line	2.8	4.1	1.1	1/	4/	2/
39	in-line	1.0	3.8	4.0	1/	4/	2/
40	in-line	0.8	3.3	12.5	1/	4/	2/
41	in-line	0.7	4.4	10.5	1/	4/	2/
42	in-line	0.5	4.3	10.0	1/	4/	2/
43	in-line	3.0	5.5	0.3	1/	4/	2/
44	in-line	1.0	5.6	0.5	1/	4/	2/
45	in-line	1.0	5.8	1.0	1/	4/	2/
46	in-line	1.0	5.7	0.8	1/	4/	2/
47	in-line	1.0	5.8	2.0	1/	4/	2/
48	in-line	6.0	5.6	0.2	1/	4/	2/
49	in-line	2.0	5.7	0.5	zero	150	2/
50	in-line	1.3	5.6	5/	zero	110	2/
51	in-line	1.3	5.6	5/	zero	110	<1
52	in-line	1.4	5.6	5/	zero	110	10

cut line

1/ No *Giardia* cysts or coliform bacteria injected
2/ Coliform bacteria were not monitored
3/ Cysts were of questionable viability
4/ No *Giardia* injected, therefore no *Giardia* sampling
5/ No effluent turbidity sample
6/ Alum dosages are in mg/l as $Al_2(SO_4)_3 \cdot 14H_2O$

Table B-1(c). Master Data Table (Sheet 2).

Run #	Filter Conditions: Type of Filtration	Length of Run (hr)	Flow Rate (gpm/ft^2)	Effluent Water Conditions: Turbidity (NTU)	*Giardia* (cyst/liter)	Water Sampled (l)	Coliforms (#/100ml)
53	in-line	1.0	5.8	0.6	1/	4/	2/
54	in-line	1.0	5.6	1.5	1/	4/	2/
55	in-line	1.0	5.9	0.45	1/	4/	2/
56	in-line	1.0	6.0	0.55	1/	4/	2/
57	in-line	1.4	5.6	6.0	30	150	2/
58	in-line	1.4	5.6	0.4	zero	190	2/
59	in-line	1.4	5.6	1.0	zero	150	20
60	in-line	1.4	5.6	6.0	8	150	>1000
61	in-line	1.4	5.6	6.2	16	150	>1000
62	in-line	1.4	5.6	6.1	235	150	1/
63	in-line	1.0	5.6	0.7	1/	4/	2/
64	in-line	1.0	5.6	0.55	1/	4/	2/
65	in-line	1.0	5.6	0.6	1/	4/	2/
66	in-line	1.0	5.6	2.3	1/	4/	2/
67	in-line	1.0	5.6	6.3	1/	4/	2/
68	in-line	1.0	5.6	2.3	1/	4/	2/
69	in-line	1.0	5.6	1.3	1/	4/	2/
70	in-line	1.0	5.6	1.6	1/	4/	2/
71	in-line	10.5	5.6	0.5	1/	4/	2/
72	in-line	1.0	5.6	0.6	1/	4/	2/
73	in-line	2.0	5.6	0.5	3/	3/	100
74	in-line	2.0	5.6	6.4	3/	3/	1000
75	in-line	2.0	5.6	1.7	3/	3/	680
76	in-line	4.0	5.6	0.2	3/	3/	100
77	in-line	1.0	5.6	1.8	1/	4/	2/
78	in-line	14.0	5.6	0.15	1/	4/	2/
79	in-line	1.5	5.6	0.15	zero	150	50
80	in-line	1.0	4.8	1.4	1/	4/	2/
81	in-line	1.0	4.8	0.4	1/	4/	2/
82	in-line	1.0	4.8	0.5	1/	4/	2/
83	in-line	1.0	4.8	0.6	1/	4/	2/
84	in-line	1.0	4.8	0.4	1/	4/	2/
85	in-line	1.0	4.8	0.4	-	4/	2/
86	in-line	1.0	4.8	1/	4/	2/	
87	in-line	3.0	4.8	0.8	1/	4/	2/
88	in-line	1.0	4.8	5.8	1/	4/	2/
89	in-line	2.0	5.6	0.3	1/	4/	2/
90	in-line	1.8	5.6	0.4	zero	150	70
91	in-line	1.8	5.6	1.2	zero	150	580
92	in-line	1.8	5.6	1.7	25	150	570
93	in-line	1.0	5.6	1.3	1/	4/	2/
94	in-line	1.0	5.6	1.3	1/	4/	2/
95	in-line	1.0	5.6	2.1	1/	4/	2/
96	in-line	1.0	5.6	1.8	1/	4/	2/
97	in-line	1.0	5.6	8.4	1/	4/	2/
98	in-line	1.8	5.6	1.1	125	150	330
99	in-line	1.8	5.6	6.8	1000	150	11,000
100	in-line	1.0	5.6	0.5	1/	4/	2/
101	in-line	1.0	5.6	0.4	1/	4/	2/
102	in-line	1.0	5.6	0.65	1/	4/	2/
103	in-line	1.0	5.6	1.1	1/	4/	2/
104	in-line	1.0	5.6	0.75	1/	4/	2/
105	in-line	1.8	5.6	0.8	zero	150	30
106	in-line	1.8	5.6	0.7	5	150	100

1/ No *Giardia* cysts or coliform bacteria injected
2/ Coliform bacteria were not monitored
3/ Cysts were of questionable viability
4/ No *Giardia* injected, therefore no *Giardia* sampling
5/ No effluent turbidity sample
6/ Alum dosages are in mg/l as $Al_2(SO_4)_3 \cdot 14H_2O$

cut line

Table B-1(c). Master Data Table (Sheet 3).

Run #	Type of Filtration	Length of Run (hr)	Flow Rate (gpm/ft^2)	Turbidity (NTU)	*Giardia* (cyst/liter)	Water Sampled (l)	Coliforms (#/100ml)
	Filter Conditions				Effluent Water Conditions		
107	in-line	1.0	5.0	0.45	1/	4/	2/
108	in-line	1.0	4.3	0.40	1/	4/	2/
109	in-line	1.0	4.3	0.50	1/	4/	2/
110	in-line	1.0	4.6	0.45	1/	4/	2/
111	in-line	1.2	4.6	0.65	1/	4/	2/
112	in-line	1.0	4.6	0.35	1/	4/	2/
113	in-line	0.7	4.0	0.75	1/	4/	2/
114	in-line	1.0	4.0	0.75	1/	4/	2/
115	in-line	1.0	4.0	0.70	1/	4/	2/
116	in-line	1.0	4.0	0.60	1/	4/	2/
117	in-line	1.0	4.5	0.60	180	22	12000
118	in-line	1.0	5.0	0.60	1/	4/	2/
119	in-line	1.0	5.0	0.55	1/	4/	2/
120	in-line	1.0	5.0	0.55	1/	4/	2/
121	in-line	1.0	5.0	0.60	1/	4/	2/
122	in-line	1.0	5.0	0.60	1/	4/	2/
123	in-line	1.8	4.5	1.1	180	22	5700
124	in-line	1.8	4.5	0.85	100	22	3500
125	in-line	1.8	4.3	1.0	850	22	8500
126	in-line	1.8	4.3	1.0	950	22	6500
127	in-line	1.8	5.0	1.1	100	22	2/
128	in-line	1.8	5.0	0.90	125	22	2/
129	in-line	1.0	5.0	0.70	1/	4/	3000
130	in-line	1.0	5.0	0.65	1/	4/	2/
131	in-line	1.0	5.0	0.60	1/	4/	2/
132	in-line	1.0	5.0	0.80	1/	4/	2/
133	in-line	1.0	5.0	0.50	1/	4/	2/
134	in-line	1.0	5.0	1.0	1/	4/	2/
135	in-line	1.0	5.0	0.35	1/	4/	2/
136	in-line	1.0	5.0	0.35	1/	4/	2/
137	in-line	1.0	5.0	3.0	1/	4/	2/
138	in-line	1.8	5.0	0.40	70	22	150

cut line

1/ No *Giardia* cysts or coliform bacteria injected
2/ Coliform bacteria were not monitored
3/ Cysts were of questionable viability
4/ No *Giardia* injected, therefore no *Giardia* sampling
5/ No effluent turbidity sample
6/ Alum dosages are in mg/l as $Al_2(SO_4)_3 \cdot 14H_2O$

APPENDIX C

DESIGN OF LABORATORY-SCALE RAPID RATE FILTRATION PILOT PLANT

APPENDIX C

DESIGN OF LABORATORY-SCALE RAPID RATE
FILTRATION PILOT PLANT

Figure C-1 is a schematic drawing of the laboratory-scale rapid rate filtration pilot plant showing each of the components comprising it, rapid mix basin, flocculation basin, sedimentation basin and filtration. The design computation for each components are shown in the paragraph following.

1. <u>Rapid Mix Basin Design</u>

A. Design Condition

1. Temperature of water = $4^{o}C$

2. Flow rate = 660 mL/min

B. Criteria

1. Detention time $10 < T < 186$ sec, (Riddick, T. M., 1961)

2. Velocity gradient x time = $3000 < GT < 180{,}000$ (ASCE-AWWA, 1969)

C. Design Procedure

1. Use three basins; first one for lime, second for alum, and third for coagulant aid

2. Detention time 3.1 min = 186 sec

3. Volume of the basin:

$$660 \text{ mL/min} \times 3.1 \text{ min} = 2048.0 \text{ cm}^3$$

$$= 12.7 \text{ cm} \times 12.7 \text{ cm} \times 12.7 \text{ cm}$$

4. Find dimension of tank and impeller, use shape factors

Figure B-2 (Hendricks, 1976) (see Figure C-2)

$\frac{H}{D_t} = 1$ Therefore $H = D_t = 12.7$ cm

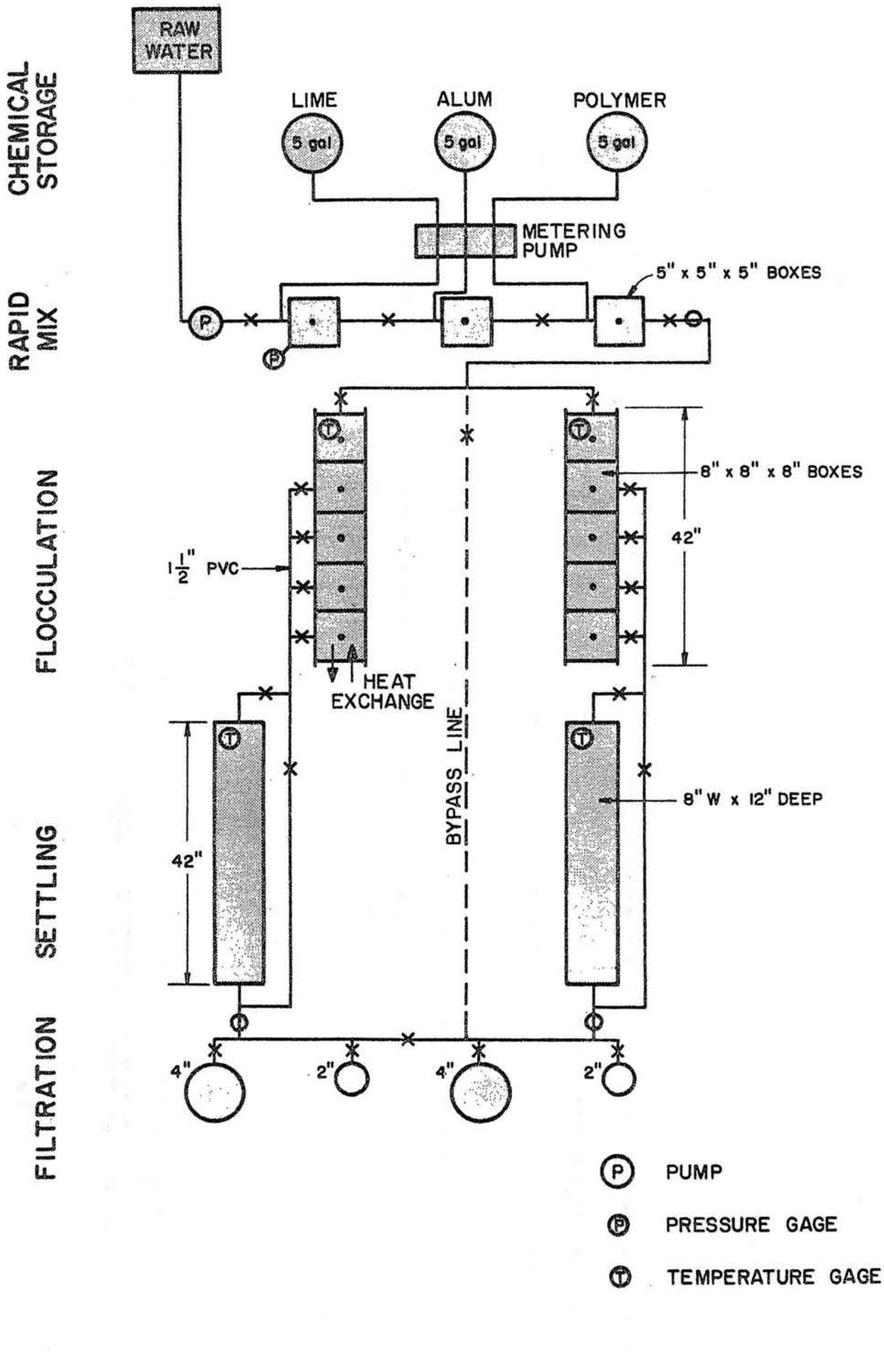

Figure C-1. Schematic drawing of laboratory-scale rapid rate filtration pilot plant.

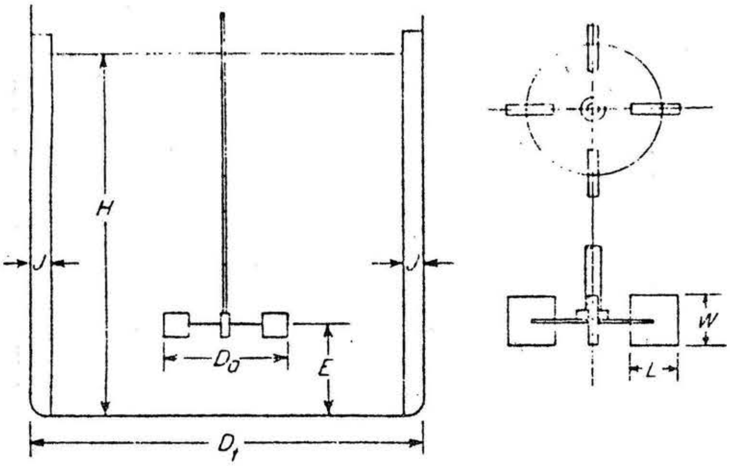

Figure C-2. Measurements of a turbine mixer in a baffle tank (Hendricks, 1976).

$\frac{D_t}{D_a} = 3 \qquad \frac{12.7}{D_a} = 3$ Therefore $D_a = 4.233$ cm

$\frac{E}{D_a} = 1 \qquad \frac{E}{4.233} = 1$ Therefore $E = 4.233$ cm

$\frac{L}{D_a} = 0.25 \qquad \frac{L}{4.233} = 0.25$

$L = 1.0583$ cm

$\frac{W}{D_a} = 0.25 \qquad \frac{W}{4.233} = 0.25 \qquad W = 1.0583$ cm

$\frac{J}{D_t} = 0.1 \qquad \frac{J}{12.7} = 0.1 \qquad J = 1.27$ cm

5. Let speed of shaft = 150 rpm = 2.5 rps

$$W = \frac{239 C_D (1 - k)^3 \, S_s^3}{V} \sum^{n} A_i \cdot r_{bi}^3 \quad \cdots 15.17$$

(Hendricks, 1976)

W = total power dissipated by the volume of basin $lb\text{-}sec^{-1}\text{-}ft^{-2}$

C_D = drag coefficient = 1.16 (H. E. Rouse, page 249)

k = relative speed of water past blade in rps = 0.24

S_s = speed of shaft in rps

V = volume of basin = 0.0723 ft^3

A = projected area of blade = 0.0017 ft^2

r_{bi} = distance to center of blade from shaft = 0.75" = 0.0625 ft

$$W = \frac{239 \times 1.16(1 - 0.24)^3 \ (2.5)^3}{0.0723}$$

$$(0.0017 \times (0.0625)^3 4) = 0.0436 lb - sec^{-1} - ft^2$$

6. $G = \sqrt{\frac{W}{\mu}}$ μ = dynamic viscosity of fluid at 4^oC

$= 3.273 \times 10^{-5}$ lb - sec - ft^{-2}

$$G = \sqrt{\frac{0.0453}{3.275 \times 10^{-5}}} = 37.7028$$

7. Therefore GT = 37.2028 x 3.1 x 60 = 6919.7283 > 3000. See Figure C-3 for design detail.

2. <u>Flocculation Basin Design</u>

A. Design Condition

1. Temperature of water = 4^oC

2. Flow rate = 660 mL/min

B. Criteria (Hendricks, 1976, page 15-36)

1. Detention time D'T = 30 - 60 minutes

2. Number of compartment = 3 - 5

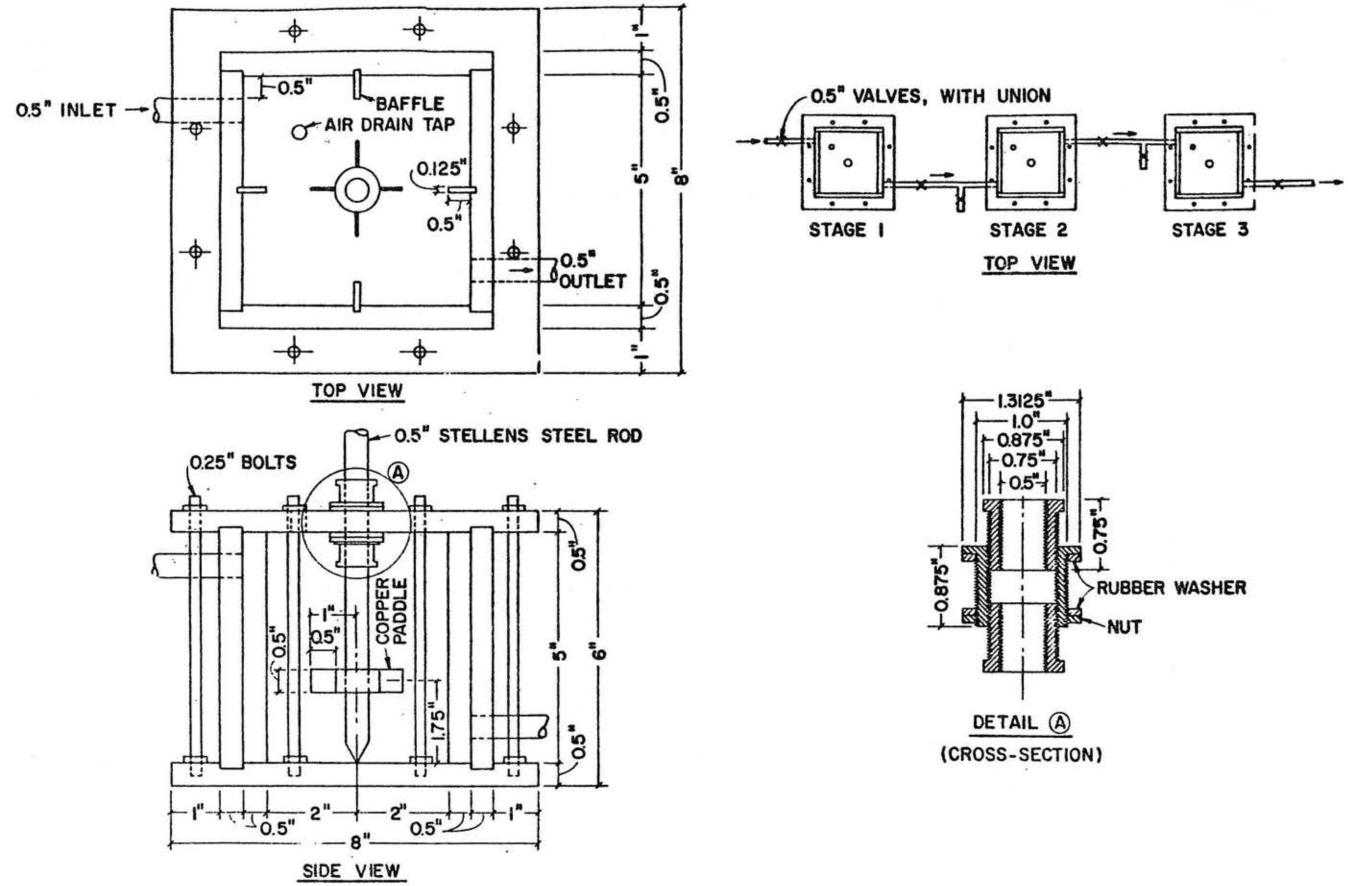

Figure C-3. Detailed design of rapid mix basin.

3. Velocity gradient $G = 20\ sec^{-1} - 74\ sec^{-1}$

4. Velocity gradient x D'T = 23000 - 210,000

5. Area of paddles = (10 - 25)% of the cross-sectional area of basin

6. Speed of paddles = 0.3 - 3.0 ft/sec

C. Design Procedure

1. Let detention time for each compartment = 12.7 min

2. The volume of each compartment = 12.7 min x 660 ml/min

= 8390 cm sup 3

= 20.32 cm x 20.32 cm x 20.32 cm

3. Use five compartment

4. Total detention time = 12.7124 x 5 = 63.5620 min

5. Total volume = 8390.1768 x 5 = 41950.92 cm^3

6. Area of paddle

3/8" x 5 3/4" x 4 = 8.625 $in.^2$ = 55.6451 cm^2

(55.6451/20.32 x 20.32) 100 = 13.48%

7.
$$W = \frac{239 C_D (1 - k)^3 S_s^3}{V} \sum^{n} A_i\ r_{b2}^3 \ldots$$

((15-17) Hendricks, 1978)

W = total power dissipated by the volume of compartment or conduit

$lb - sec^{-1} - ft^{-2}$

C_D = drag coefficient = 1.39 (H. E. Rouse, page 249)

k = relative speed of water past blade in rps = 0.24

S_s = speed of shaft in rps

V = volume of basin = 8" x 8" x 8"/12 x 12 x 12

= 0.2963 ft sup 3

A = projected area of blade =

5 3/4" x 3/8"/12 x 12 = 0.015 ft^2

r_b = distance to center of blade for a shaft

$= \frac{2}{12}$ ft, $\frac{1}{12}$ ft

$$W = \frac{239 \times 1.39(1 - 0.24)^3 \times S_s^3}{0.2936}$$

$$(0.015 \times (\frac{2}{12})^3 \times 2 + 0.015 \times (\frac{1}{12})^3 \times 2)$$

$$W = 0.0768S_s^3$$

8. $G = \sqrt{\frac{W}{\mu}}$

μ = dynamic viscosity of fluid at 4°C

3.273×10^{-5} lb - sec - ft^{-2}

9. $$G = \sqrt{\frac{0.0768(S_s)^3}{3.273 \times 10^{-5}}} = 48.431(S_s)^{3/2}$$

10. Let S_s = 40, 30, 20 rmp or 0.667, 0.5, 0.333 rps

11. $G_1 \cdot T = 26.4 \times 762 = 20116$

$G_2 \cdot T = 17.1 \times 762 = 13030$

$G_3 \cdot T = 9.3 \times 762 = \underline{7,086}$

$\Sigma GT = 40,232$

12. $\Sigma GT = 40,232$

Use three compartment volume of each one is 8390.1768 cm^3 with area of paddle = 8.625 $in.^2$, speed of shaft at 40, 30, and 20 rpm for each one. See Figure C-4, Detail Design of Flocculation Basin.

3. <u>Sedimentation Tank Design</u>

A. Design Condition

1. Temperature of water = 4^oC

2. Flow rate = 1321.358 mL/min = 22.0226 mL/sec

B. Design Criteria

1. Surface flow rate = 20 - 33 m/day

(500 - 800 gpd/ft^2) (E. W. Steel and T. McGhee, page 234)

C. Design Procedure

1. $q = \mu_t \times A$ (Linvil G. Rich, page 87)

q = volumetric rate of clarification cm^3/sec

μ_t = settling velocity cm/sec

A = cross section area of rectangular volume in plan perpendicular to the direction of subsidence cm^2

22.0226 cm^3/sec = 0.023158 cm/sec (20 m/day) x A

A = 950.9730 cm^2

2. Choose 20.32 cm width and 46.8 cm length or 8 inch width and 18.4 inch length

3. Size of particle will settle

$$V = \frac{1}{18}\frac{1}{\mu}(\gamma_{floc} - \gamma_w)\, d^2$$

Stokes law (12-15) (Hendricks, 1976)

V = settling velocity L/T = 0.023158 cm/sec

μ = dynamic viscosity FT/L^2 = 1.567 centpoise at 4^oC

γ_{floc} = specific weight of floc F/L^3 = 1.18 (Table 12-12, Hendricks, 1976)

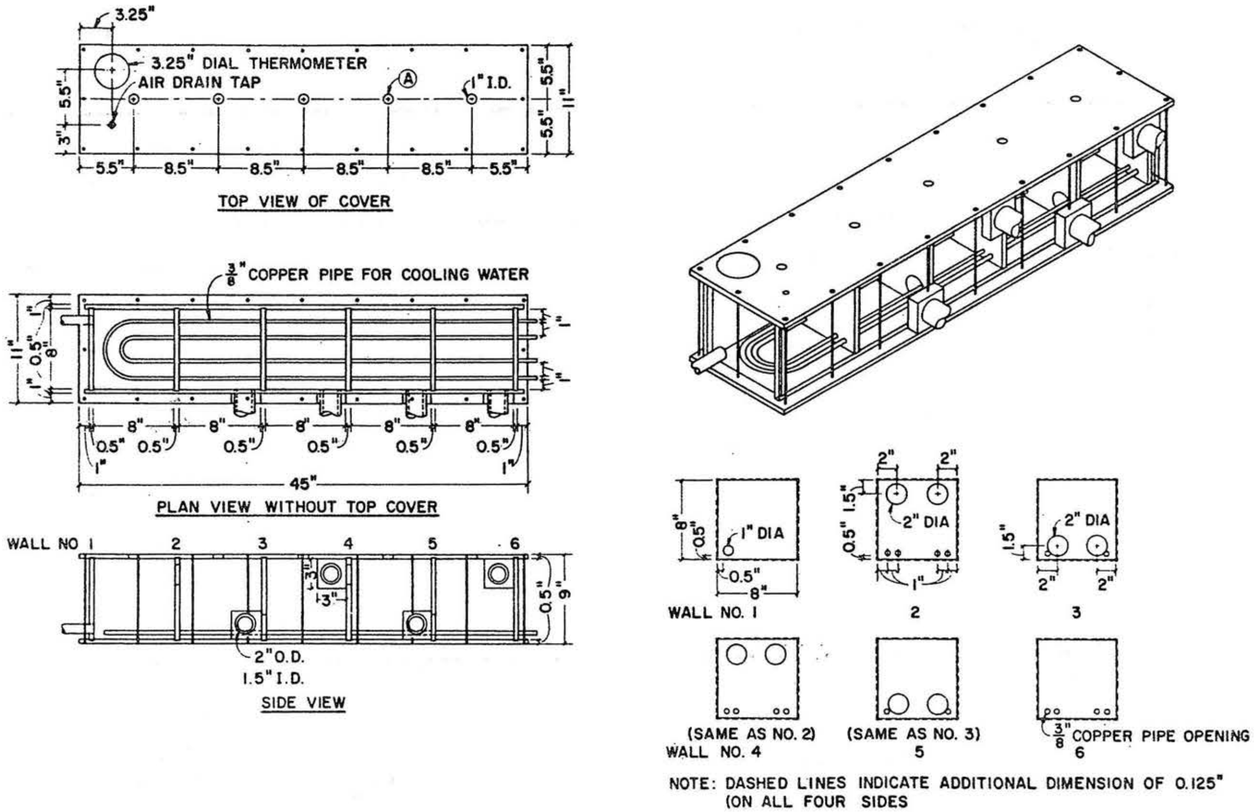

Figure C-4. Detailed design of flocculation basin.

γ_w = specific weight of water $F/L^3 = 1$ at 4^oC

d = diameter of floc L

$$0.023158 = \frac{100 \times 981}{18 \times 1.567} (1.18 - 1) d^2$$

d = 0.0037 cm = 36.99 µm or greater; size of floc will settle

See Figure C-5 for Detail Design of Sedimentation Tanks.

4. Filter Design

A. Design Condition

1. Temperature of water = 4^oC

2. Flow rate = 660 mL/min

B. Design Criteria (Table 16-5, Hendricks, 1976)

1. Filtration rate = single media = 2 - 5 gpm/ft^2

   dual media = 3 - 6 gpm/ft^2

2. Media: singl or dual

3. Depth of media

   Single sand = 24 - 30 "

   Dual sand and anthracite = 12", 18 - 30"

4. Effective size

   Single: Sand = 0.35 - 50 mm

   Dual: Sand = 0.4 - 0.5, anthracite = 0.8 - 1.4

5. Uniformity coefficient

   Single: Sand 1.3 - 1.7

   Dual: Sand 1.3 - 1.7, anthracite = 1.7

6. Under system; porous plates or gravel support-pipe underdrain

7. Backwash rate 10 - 20 gpm/ft^2

8. Backwash period 5 - 10 min

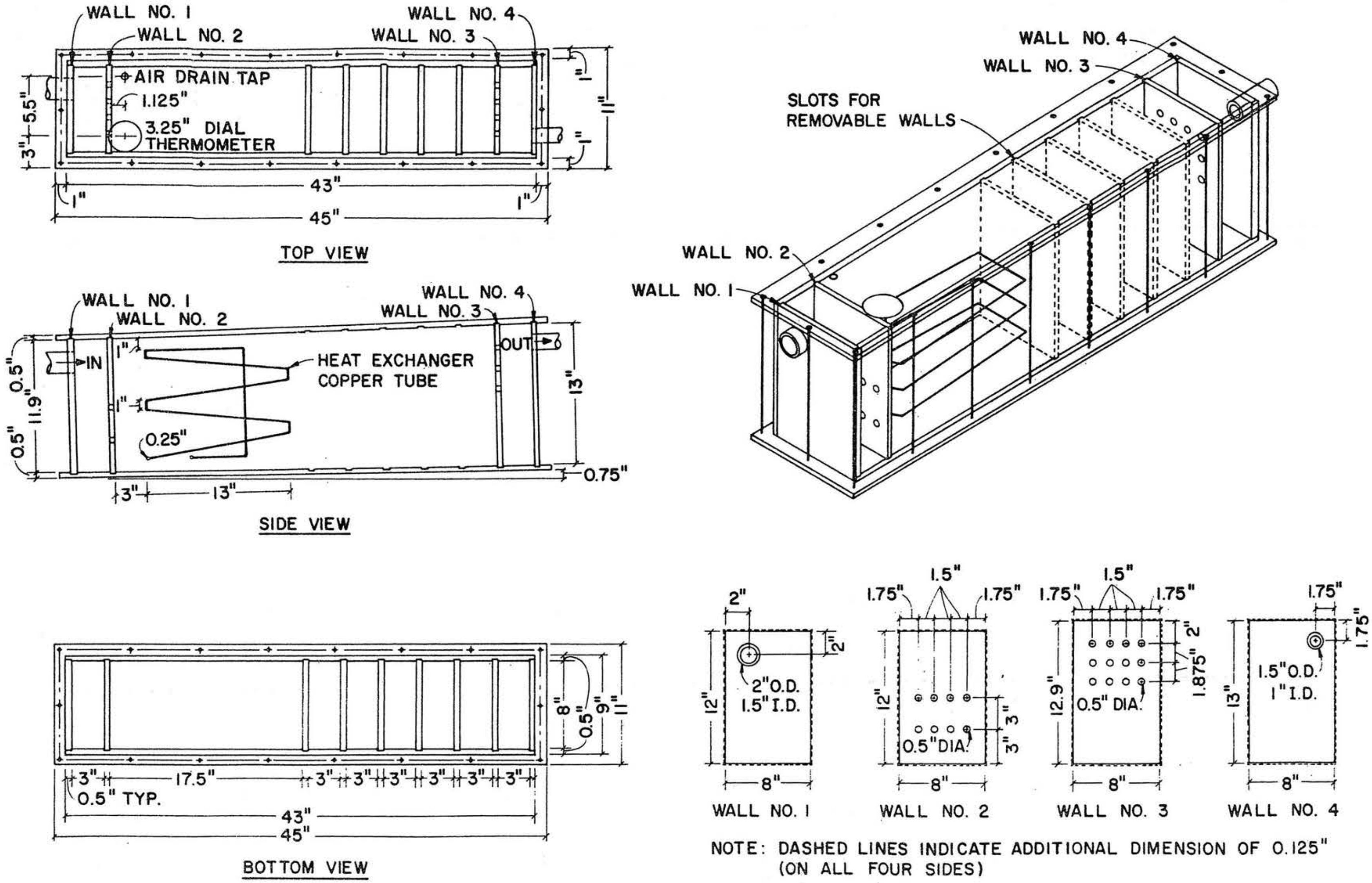

Figure C-5. Detailed design of sedimentation basin.

C. Design Procedure

1. Area of filter = A

$Q = v \times A$

Q = flow rate = 660 mL/min

v = filtration rate = 2 gpm/ft^2 = 8.2584 cm/min

A = area of filter

660 cm^3/min = 8.2584 cm/min x A

Therefore A = 80.058 cm^2

Therefore Diameter of filter = 5 cm = 2 inches

2. Media: Single: Sand

3. Depth of media = 30" sand

4. Effective size = 0.45 mm

5. Uniformity coefficient = 1-5

6. Constant flow filtration = 660 mL/min

7. Underdrain system = porous plate (see Figure C-6 for detail)

8. Backwash rate = 15 gpm/ft^2 with air

9. Period of backwash = 10 min
See Figure C-6 for filter design detail.

5. <u>Design of Flow Basin</u>

A. Design Condition

1. Temperature of water = 4°C

2. Flow rate = 660 mL/min

B. Design Criteria

1. Convenient velocity of flow carrying flocs without breakup flocs

C. Design Procedure

1. Let the size of pipe = 1 1/2" = 3.81 cm

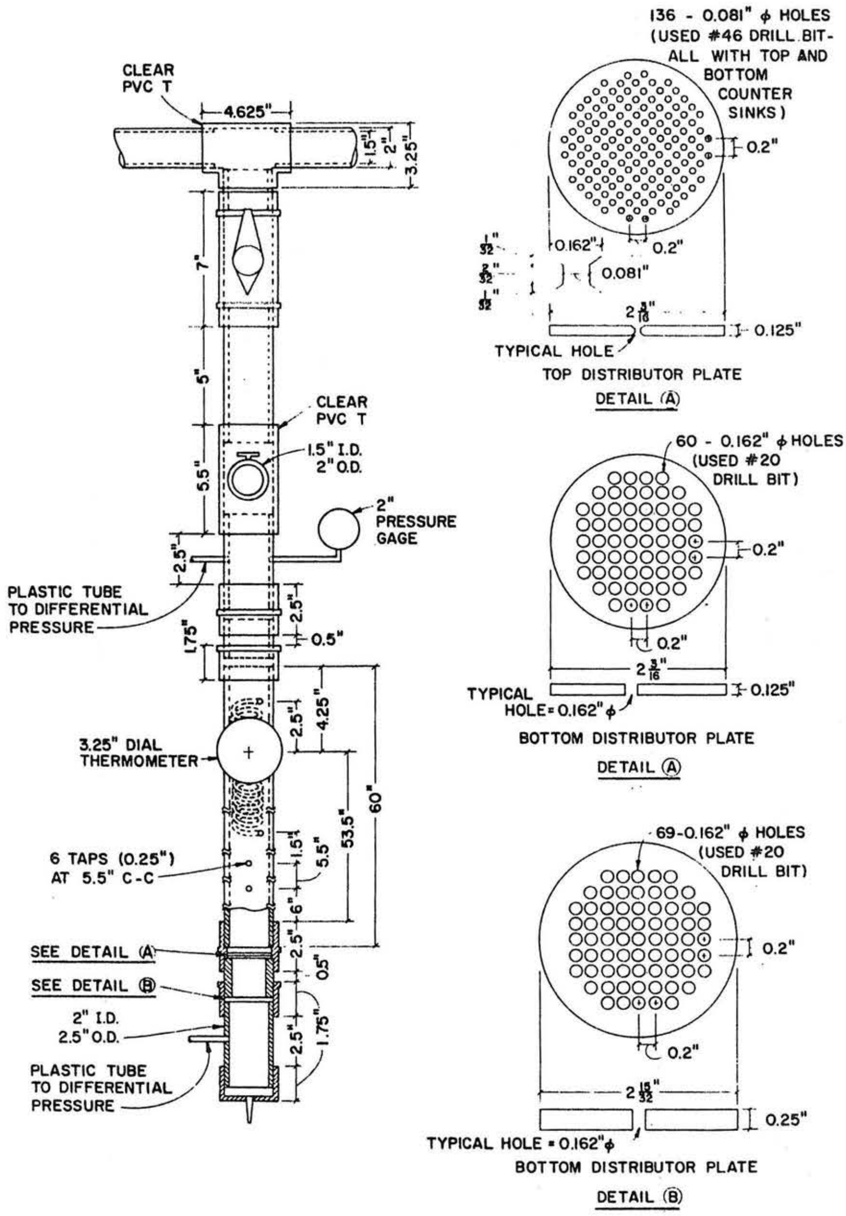

Figure C-6. Filter design detail.

2. Velocity of flow

$Q = A \times v$

Q = flow rate = 660 cm^3/min

A = area of pipe = $(3.81)^2 \times 1/4 \times 3.1416$

= 11.40 cm^2

v = velocity of flow = cm/min

$660 = 11.4 \times v$

Therefore v = 57.8901 cm/min = 0.9648 cm/sec

3. If the maximum size of flocs = 100 µm

$$v = \frac{1}{18\mu} (\gamma_{floc} - \gamma_w)\, d^2$$

Stocks law (12-15) Hendricks

$$= \frac{100 \times 981}{18 \times 1.567} (1.18 - 1)(100 \times 10^{-6} \times 100)^2$$

v = 0.0626 cm/sec = 3.7562 cm/min

Therefore v of flow/v of floc = $\frac{57.8901}{3.7562}$ = 15.41 so the flow will carry the flocs

4. R Reynolds number

$R = \frac{vD}{\nu} < 2{,}000$ (H. Rouse, page 174)

$$\frac{vL\rho}{\mu} = \frac{0.9648 \times 3.81 \times 100}{1.567}$$

= 234.5897 < 2,000

Therefore the flow is stable.

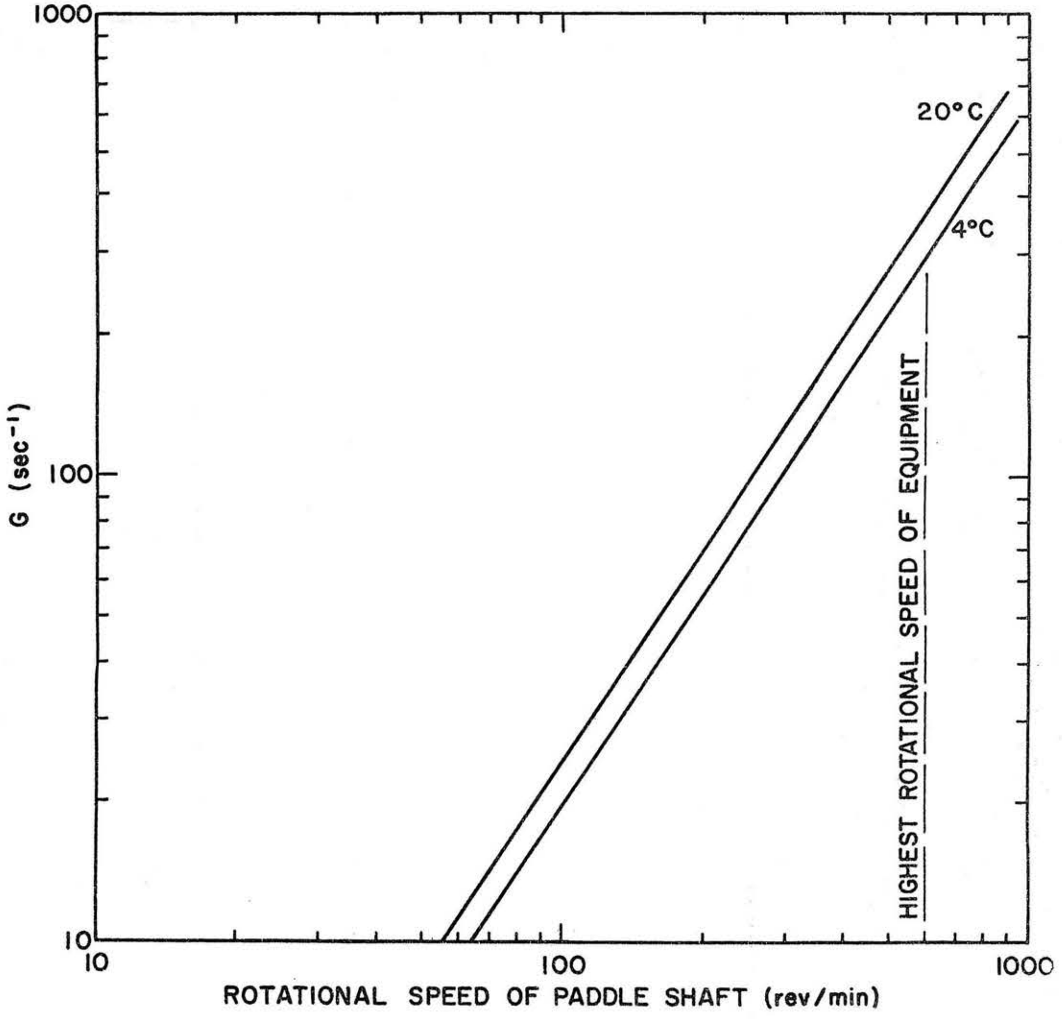

Figure C-7. Velocity gradient (G sec^{-1} versus revolution per minute of paddle shaft for coagulation box. Laboratory scale rapid rate filtration pilot plant. Volume of box is 2048 cm^3. Paddle design shown in Figure C-3.

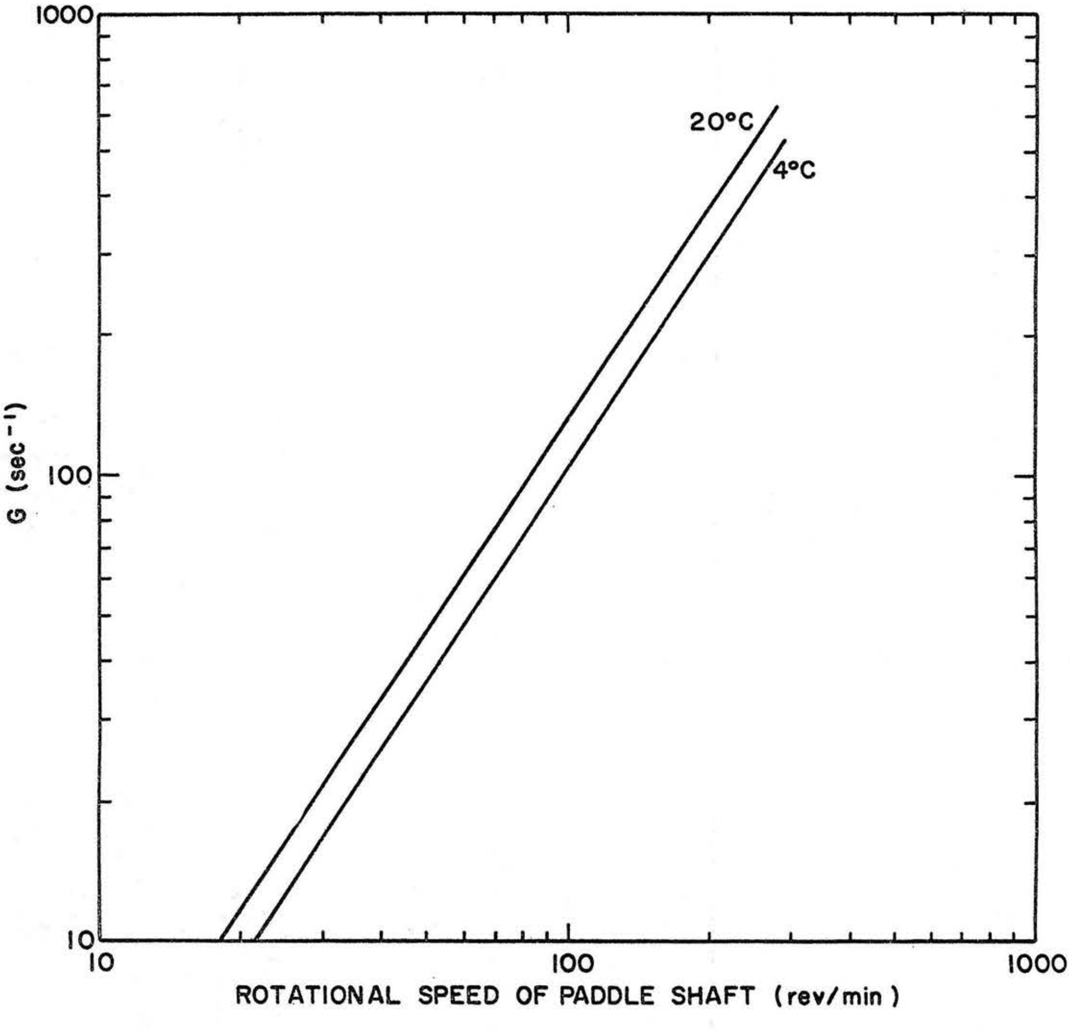

Figure C-8. Velocity gradient (G sec^{-1} versus revolution per minute (rpm) for flocculation compartment. Laboratory-scale rapid rate filtration pilot plant. Volume of compartment is 8390 cm^3.

APPENDIX D

DESCRIPTION OF THE FIELD-SCALE RAPID RATE FILTRATION PILOT PLANT AND ITS OPERATION

APPENDIX D

DESCRIPTION OF THE FIELD-SCALE RAPID RATE FILTRATION PILOT PLANT AND ITS OPERATION

DESCRIPTION

The field-scale rapid rate filtration pilot plant used in this research was a Neptune Microfloc Model WB-27 WATER BOY® package water treatment plant. Its nominal capacity is 76 L/min (20 gpm) and it is capable of satisfying the water needs of a community of 190 people. The plant was purchased by the Drinking Water Research Division of the U.S. Environmental Protection Agency in Cincinnati, who designed a 22 foot trailer to hold the WATER BOY as shown in Figure D-1; thus it became a mobile water treatment plant.

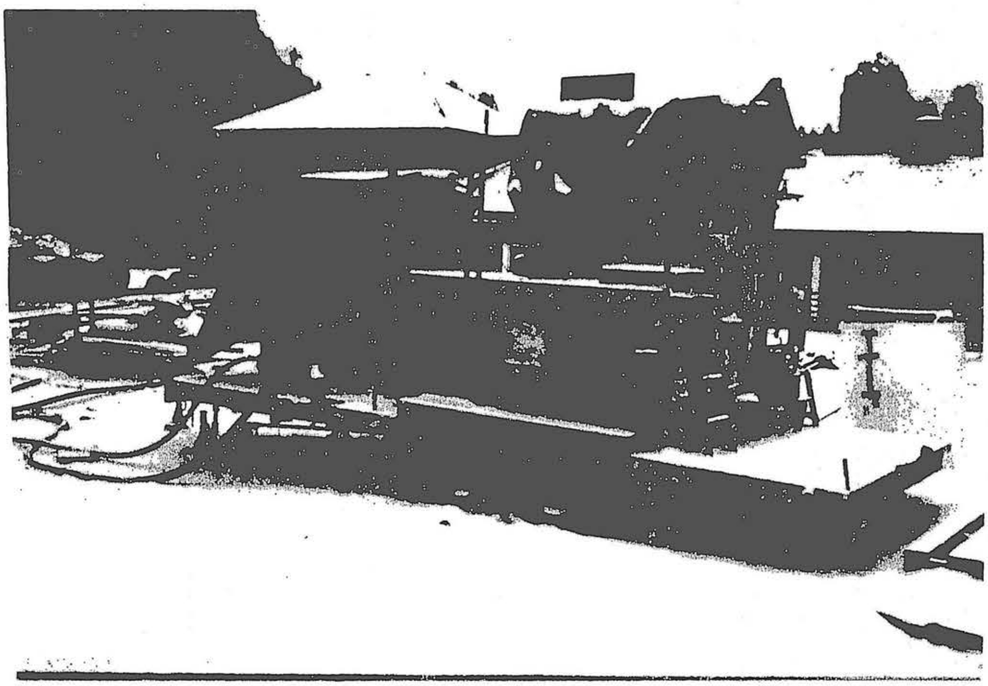

Figure D-1. The Neptune Microfloc WATER BOY® field-scale rapid rate filtration pilot plant as set up at the Fort Collins Water Treatment Plant No. 1 for low-turbidity testing. Water was obtained from the Cache La Poudre River.

Figure D-2 is a drawing of the Neptune Microfloc WATER BOY® showing elevation and plan views. Figure D-3 is a flow diagram for the WATER BOY®,

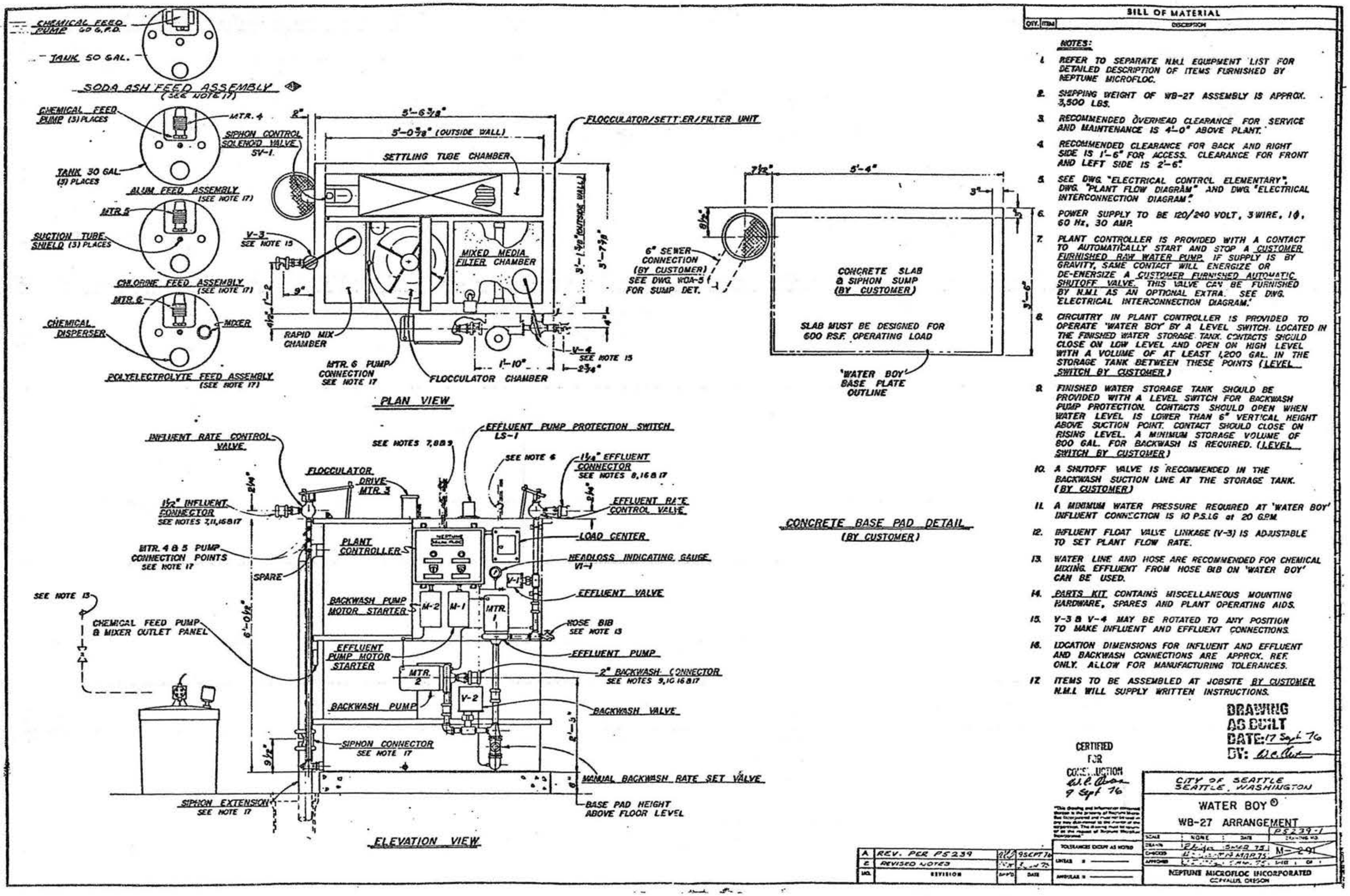

Figure D-2. Neptune Microfloc diagram of the WATER BOY ® showing elevation and plan views.

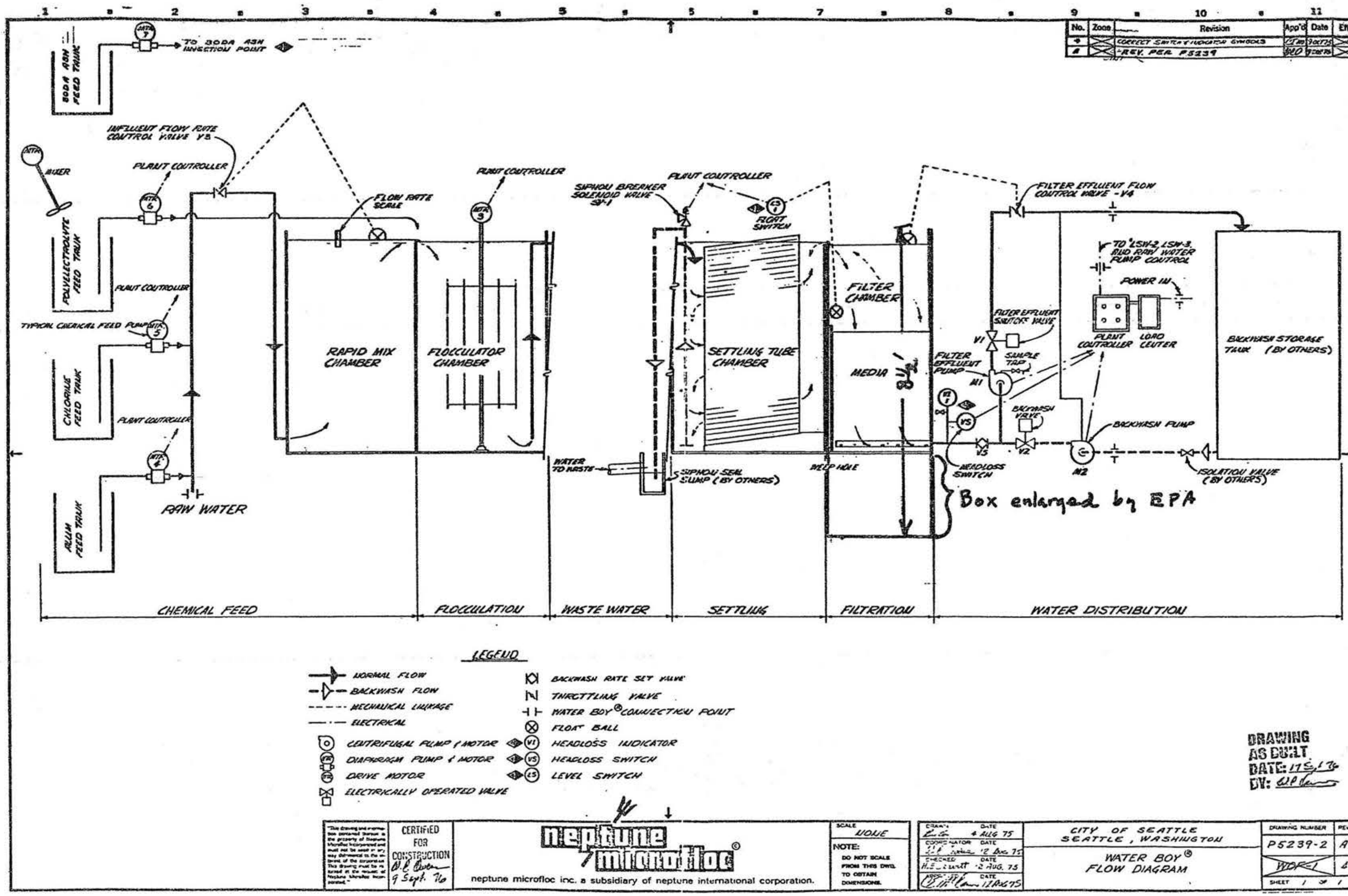

Figure D-3. Neptune Microfloc flow diagram of the WATER BOY ® showing processes and hydraulics.

supplied by Neptune Microfloc Inc., illustrating process hydraulics. As shown in Figures D-2 and D-3, the WATER BOY ® is a complete rapid rate filtration water treatment plant consisting of: rapid mix basin, flocculation basin with variable speed paddle wheel, sedimentation consisting of tube settlers at 7.5 degrees, and filtration box.

When the WATER BOY ® arrived at Colorado State University, in August 1982, after work at Oneida, New York conducted by Clarkson College of Technology, it contained the filtration media shown in Figure D-4. This media was used in experiments here during initial familiarization testing, but was replaced in March 1983 by media obtained locally. Figure D-5 shows the filtration media used after March 1983 and which has remained in the pilot plant filter bed for all subsequent testing.

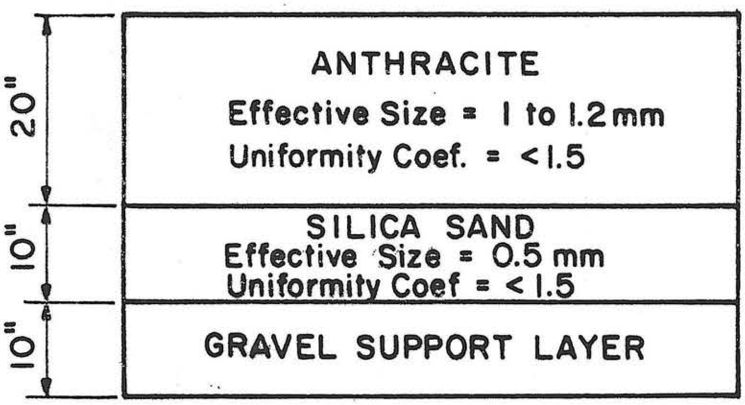

Figure D-4. Filtration media used during familiarization testing. Media used was packed by Clarkson College of Technology, Postdam, New York.

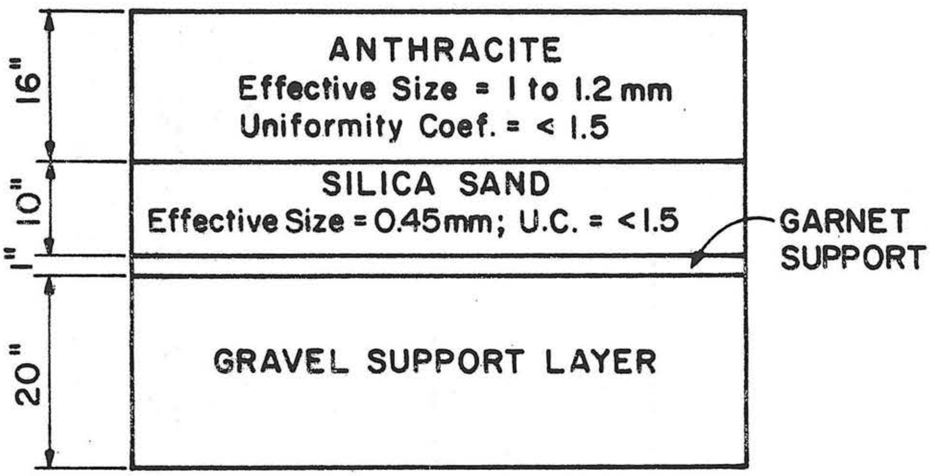

Figure D-5. Filtration media used during Spring Runoff, Horsetooth, and Low-Turbidity testing. Anthracite was obtained from the Fort Collins Water Treatment Plant No. 1, and the sand was obtained from the Fort Collins Treatment Plant No. 2.

Table D-1. Appurtenances for operation of field scale rapid rate filtration pilot plant.

Item	Purpose & Specifications	Manufactor	Model #
Raw Water Pump	Pumps Raw Water into Rapid Mix	Goulds Pumps, Inc.	XSH 15
Contaminant Feed Pump	Meters the contaminant batch into the main flow (0 to 1120 mL/min)	Fluid Metering, Inc	RP-D
Alum Feed Pump	Meters alum solution into main flow (0 to 75 mL/min)	Precision Control	111311-361
Polymer Feed Pump	Meters polymer solution into main flow (0 to 75 mL/min)	Precision Control	111311-361
Sodium Thiosulfate Feed Pump	Feeds $Na_2S_2O_3$ solution into effluent stream for dechlorination (50 to 1000 cc/min)	Cole Parmer	212
Giardia Sampling Pump	Diverts sampling stream from main flow through membrane filter (0 to 8.5 L/min)	Grainger	Rotary Beam Pump 1P771
Giardia Sampling Pump Motor	Drives *Giardia* sampling pump (3/4 hp)	Grainger	27846
Contaminant Batch Mixer	Agitates contaminant batch	Lightnin Mixers	Series 20
Alum Batch Mixer	Mixes alum solution	Wilkens-Anderson Co.	Power Stirrer
Polymer Batch Mixer	Mixes polymer solution	Cole Parmer	4555 H
Rapid Mix Basin Mixer	Disperses chemicals in rapid mix basin (1/4 hp) 1725 rpm	Lightnin Mixers	Mark II
Membrane Filter Holder	Holds 5 μm pore size 293 mm diameter membrane filters made by Nucleopore Corporation	Gelman Sciences	11873
Ratio Turbidimeter	Measures grab samples for turbidity	Hach Chemical Co.	18900-10
Flow-through Turbidimeter	Monitor influent and effluent turbidity	Hach Chemical Co.	1720-A

1/ Neptune Microfloc Model WB-27 WATER BOY ® package water treatment plant, trailer mounted by EPA.

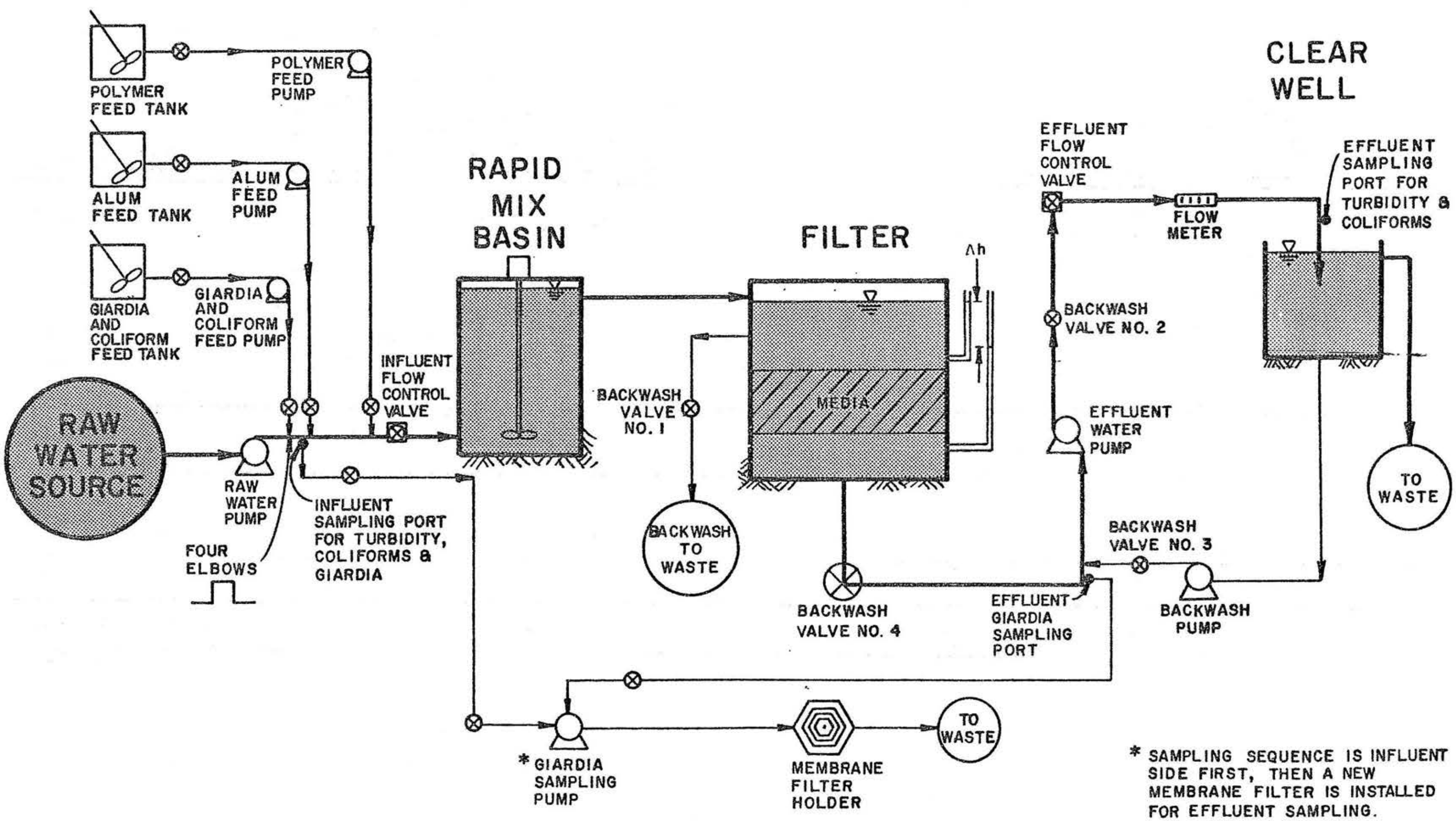

Figure D-6. Schematic diagram of the WATER BOY pilot plant showing chemical feed, contaminant feed, and sampling systems

Table D-1 lists the appurtenances which were used with the WATER BOY® pilot plant. All appurtances except the flow-through turbidimeters were assembled for the purposes of the present research.

Figure D-6 is a flow schematic of the WATER BOY as set up and used in this research. It shows the chemical feed system, contaminant injection system, and contaminant sampling system. Sampling ports for turbidity, coliform bacteria, and Giardia cysts are shown on both the influent side and on the effluent side.

The contaminant injection port is comprised of a 0.64 cm (1/4 inch) diameter tube placed at the center of the 2.54 cm (1 inch) diameter influent pipe. The contaminants were injected at the center of the pipe. Four elbows were added to the piping after the point of contaminant injection to assure mixing prior to sampling of the contaminants on the influent side. The sampling of contaminants on the influent side was almost the same as the injection. The point of withdrawal was located 30 cm (12 inches) downstream from the last of the four elbows. The withdrawal tube was a 0.95 cm (3/8 inch) tube inserted to the center of the pipe. It was cut at 45° with the open side facing the flow. The purpose of this modification was to obtain a representative sample of contaminant concentration as it is fed to chemical pretreatment. This same modification for sampling was fabricated for the effluent side also. The point of effluent sampling was 122 cm (48 inches) downstream from the filter box. The stream sampled was pumped by positive displacement pump through a 293 mm diameter Nucleopore polycarbonate membrane filter, the device used to sample Giardia cysts. Coliform and turbidity samples were obtained from the influent side before connecting the membrane filter. On the effluent side, coliform and turbidity samples were taken from the discharge to the clear well.

OPERATION

The operation of the WATER BOY as it was set up and used at Colorado State University is described in the following sections. Instructions are summarized for the following steps: i) start up, ii) filtration, iii) backwashing, v) backwash flow control, v) filtration flow control, vi) chemical feed, vii) contaminant feed and sampling.

Start Up

i) Turn filter switch (on major control box) and backwash pump switch (minor control box) to off positions. The major and minor control boxes are shown in Figure D-7.

ii) Fill the rapid mix basin by turning on the raw water feed pump. Figure D-8 shows the raw water feed pump. Control raw water flow with the influent-flow-control-valve shown in Figure D-9.

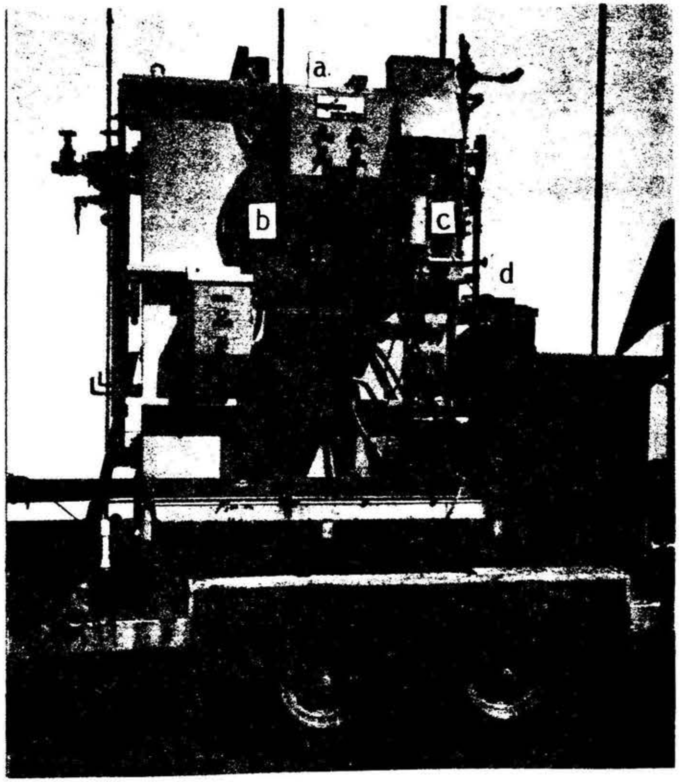

Figure D-7. Side view of WATER BOY: a) major control panel, b) minor control panel, c) effluent-flow pump, d) garden-hose-valve

Figure D-8. Raw water pump (1 1/2 hp)

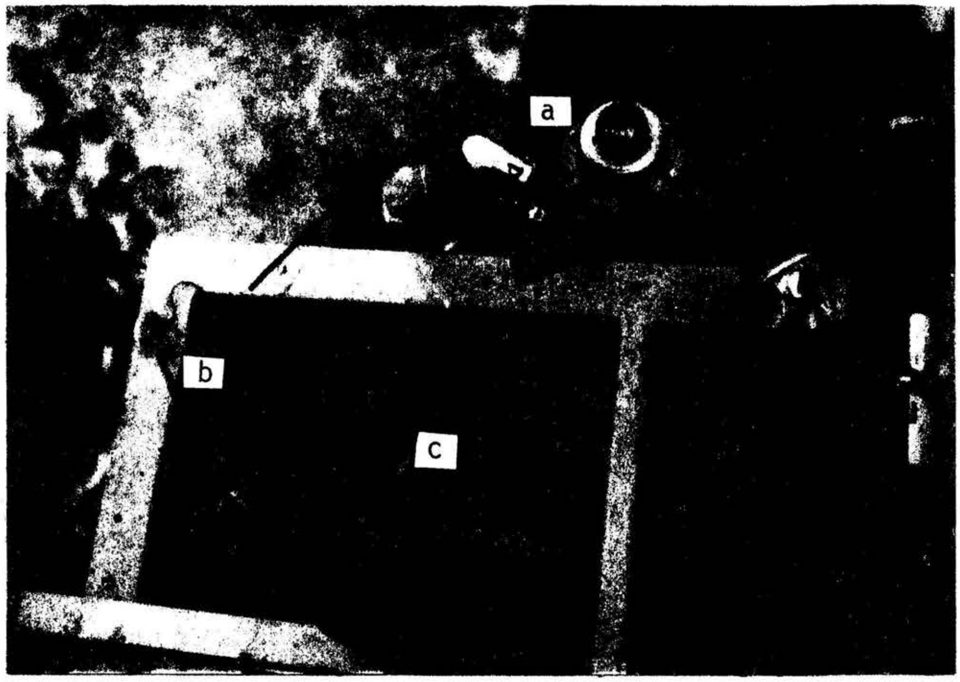

Figure D-9. Top view of rapid mix basin: a) influent-flow-control valve, b) mixer, c) rapid mix basin.

iii) Allow the water to overflow from the rapid mix basin into the filter box until the water level in the filter box is 10-12 cm above the filtration media; then turn off the raw water pump.

iv) Gently stir the filtration media (to a maximum depth of 50 cm) with a broom handle, or similar device, to remove the air bound within the filtration media.

v) After the bound air is removed, fill the filter box, by turning back on the raw water pump, to within 5 to 7 cm of the top, i.e. about 10 to 12 cm above the backwash overflow trough; then turn off raw water pump.

vi) Install the effluent-flow-control-float so the effluent-flow-control valve is about 90 percent open when the filter box is full. Figure D-10 shows the effluent-flow-control valve and the shaft of the float.

vii) Open garden-hose-valve on the effluent-side of the effluent-flow-pump. This primes the effluent-flow-pump, by using the available head within the filter box. Figure D-7 shows the garden-hose-valve, and the effluent-flow-pump.

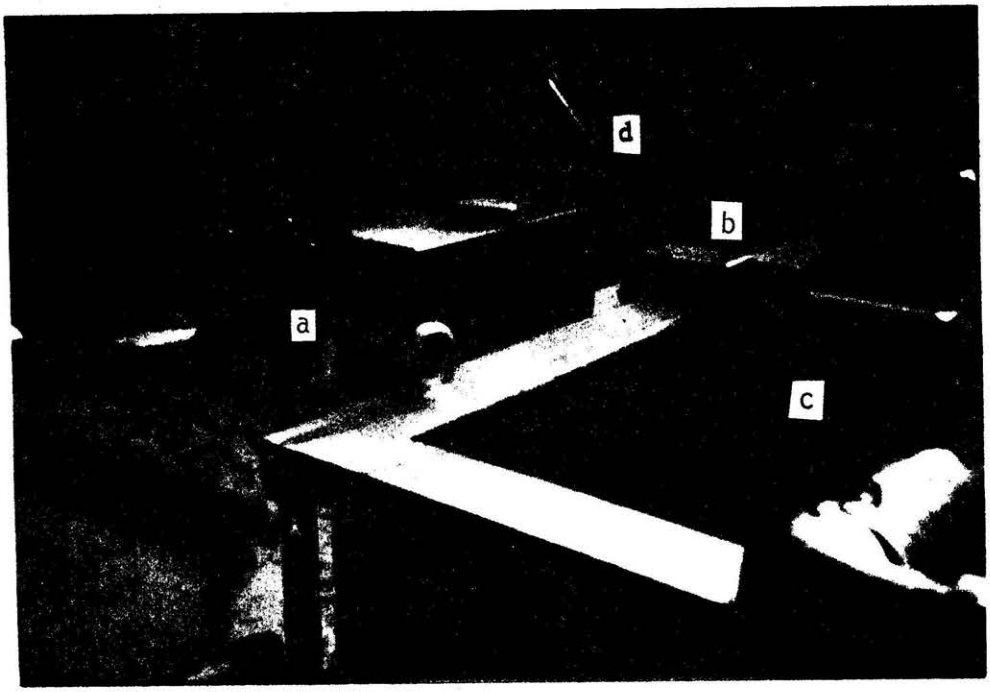

Figure D-10. Effluent flow control: a) effluent-flow-control valve, b) effluent-flow-pump-protector switch, c) shaft connected to effluent-flow-control-float, d) butterfly nut.

viii) Turn filter switch (on main control panel) to manual, green light should turn on. This activates the effluent-flow-pump and opens backwash valve #2.

ix) Turn on raw water pump. The effluent-flow-pump-protector-switch shown in Figure D-10 should be on, i.e. effluent-flow-pump should be on.

x) Adjust influent-flow-control-valve until an equilibrium is estabished within the filter box. Best operation is when the water level is 5 to 8 cm below the top of the filter box. This level can be varied by adjusting the fulcrum length on the effluent-flow-control-float by using the butterfly nut on its shaft. The butterfly nut is shown in Figure D-10.

xi) Once the system is running smoothly, allow it to filter water until the clear well is filled, i.e. about 45 minutes at 76 L/min (20 gpm). below).

xii) Once the clear well is filled, turn-off raw water feed pump and turn-off filter switch on main control panel. The clear well is the large cylindrical tank on the front of the WATER BOY®, and has an effective volume of 4000 liters.

xiii) Backwash the system to prepare the filtration media for a test run, following the backwashing procedures below.

Filtration

i) Prepare chemical feed and contaminant feed systems as described under the appropriate headings below.

ii) Turn-on the raw water pump, then immediately begin step iii) and step iv).

iii) Turn-on rapid mix basin mixer. Figure D-9 shows the 1/4 hp rapid mix basin mixer. This mixer must be plugged into electrical box No. 1 (left hand box as shown in Figure D-11) or an overloading of the circuit breakers will occur.

iv) Turn-on filter switch on main control panel to manual. Once the water level in the filter box raises high enough to activate the effluent-flow-pump-protector-switch, the green light on the main control panel will light indicating that the effluent-flow-pump is on. However, chemical and contaminant feed, and mixing, begin as soon as the filter switch is turned to manual even though the green light has not lit.

v) Adjust flow as described above in step x) of start up.

vi) Stop filtration by turning off raw water pump, filter switch, and rapid mix mixer.

Backwashing

i) Turn-off raw water feed pump, rapid mix mixer, and filter switch. This will automatically close backwash valve No. 2.

ii) Turn on backwash pump using switch on minor control box (directly below major control box). This will automatically open backwash valve No. 1.

iii) Slowly open backwash valve No. 3 (see Figure D-6). This allows the backwash pump to draw water from the clear well and pump it into the bottom of the filter.

iv) Check to insure that the water level in the filter box drops to the top of the overflow weir. If it does not, then either the backwash hose is clogged, possibly with ice, or more head is required between the backwash water discharge, i.e. disposal, point and the top of the overflow weir.

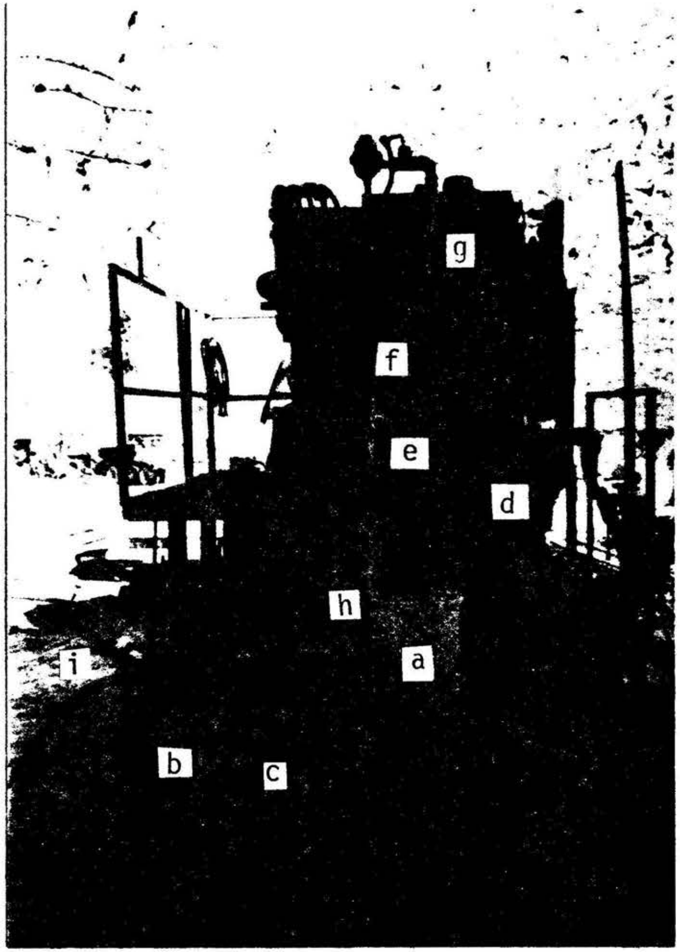

Figure D-11. Chemical feed system: a) polymer tank, b) alum tank, c) alum pump, d) polymer pump, e) electrical boxes, f) speed controller for polymer mixer, g) polymer injection port, h) alum injection port, i) influent raw water

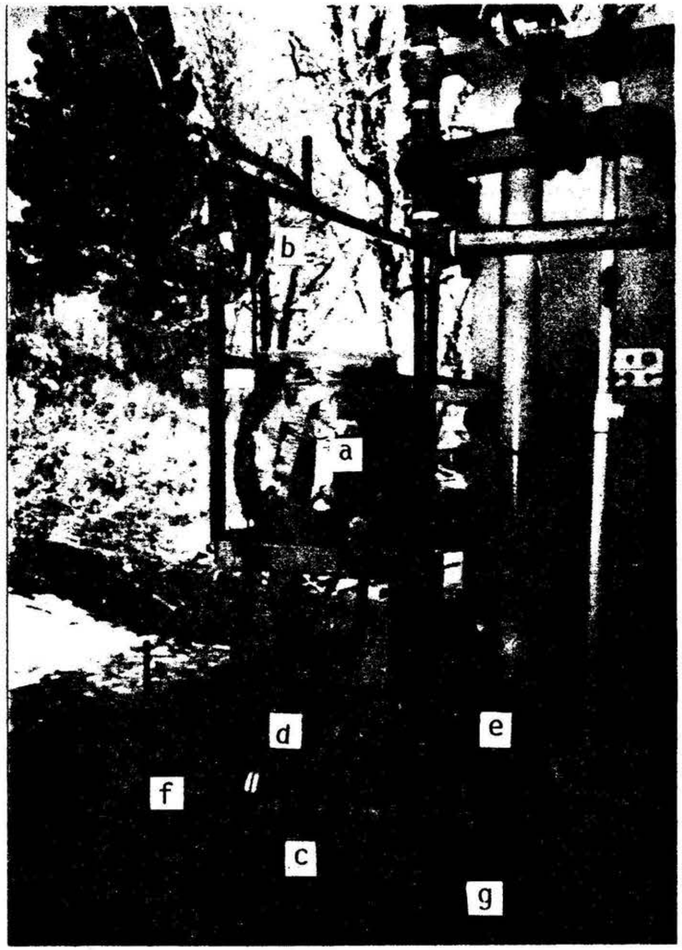

Figure D-12. Contaminant feed system: a) batch tank, b) mixer, c) injection port, d) metering pump, e) four elbows for mixing contminants with raw water, f) raw water influent line, g) influent sampling port for <u>Giardia</u>, coliforms, and turbidity

v) Stop the backwash cycle before the water level in the clear well reaches the pipe used by the backwash pump to draw the water from the clear well. This will prevent the backwash pump from pumping air.

vi) To stop the backwash cycle, turn off the backwash pump, and immediately close backwash valve No. 3. Close this valve <u>fast</u>, so that the filtration media "sets" properly.

vii) Filtration can now be resumed.

<u>Backwash Flow Control</u>

i) The backwash rate should be about 227 L/min (60 gpm), which is 10.2 mm/s (15 gpm/ft^2), which is 61 cm per minute rise within the filter box.

ii) The backwash rate can be adjusted by thottling backwash valve No. 4.

<u>Filtration Flow Control</u>

i) The influent flow is controlled by the influent-flow-control-valve.

ii) The effluent flow is controlled by the effluent-flow-control-float, which is connected to the effluent-flow-control-valve, which the effluent-flow-pump pumps against.

iii) The effluent-flow-pump is protected by the effluent-flow-pump-protector-switch, which is mounted at the top of the filter box and has two small floats attached to it. This protector switch automatically turns off the effluent-flow-pump when the water level in the filter box gets to low.

<u>Chemical Feed</u>

i) The chemical feed system is shown in Figure A-11.

ii) Both alum and polymer injection ports are injection quills which allow injection of the chemicals directly into the center of the flow stream.

iii) The following sample calculations illustrate how alum dosages were determined. Alum is reported as mg/L of $Al_2(SO_4)_3 \cdot 14H_2O$.

<u>Given</u>:
* Raw water flow rate = 75 L/min
* Alum solution feed rate = 15 mL/min
* Alum solution consists of 5 liters of distilled water and 500 mL of commerical grade liquid alum.

* There is 643 milligrams of $Al_2(SO_4)_3\ 14H_2O$ in every milliliter of commerfcal grade liquid alum.

Find: The dosage of alum in mg/L of $Al_2(SO_4)_3\ 14H_2O$ per liter of raw water.

Solution:

$$\frac{643 \text{ mg of } Al_2(SO_4)_3 \cdot 14\ H_2O}{\text{mL of soln}} \times \frac{500 \text{ mL of liquid alum}}{5.5 \text{ L of batch}} \times \frac{0.015 \text{ L of alum soln}}{\text{min}}$$

$$\times \frac{1 \text{ min}}{75 \text{ L raw water}} = \frac{11.5 \text{ mg of } Al_2(SO_4)_3\ 14H_2O}{\text{liter of raw water}}$$

iv) Polymer dosages were calculated as follows:

Given:
* Raw water flow rate = 75 L/min
* Polymer batch feed rate = 70 mL/min
* Polymer batch consists of 20 liters of tap water and 10 mL of polymer
* The specific gravity of the polymer is 1.14

Find: The dosage of polymer is milligrams of polymer per liter of raw water.

Solution:

$$\frac{1,140 \text{ mg of polymer}}{\text{ml of polymer}} \times \frac{10 \text{ mL of polymer}}{20 \text{ L of batch}} \times \frac{0.07 \text{ L of batch}}{1 \text{ min}}$$

$$\times \frac{1 \text{ min}}{75 \text{ l of raw waterL}} = \frac{0.5 \text{ mg of polymer}}{\text{liter of raw water}}$$

Contaminant Feed and Sampling

i) The contaminant feed system is shown in Figure D-12. Notice the four elbows which insure adequate mixing of the contaminants with the raw water prior to influent sampling.

ii) An injection quill, similar to the ones used for chemical feed, was used for injecting the contaminants. The contaminants consisted of raw water, dog feces, and primary effluent from Fort Collins Wastewater Treatment Plant No. 2. These contaminants were mixed in a 50 liter plastic batch tank, shown as a) in Figure D-12. The dog feces served as the Giardia cyst source, and the primary effluent was the coliform bacteria source.

iii) Figure D-6 shows the points in the flow scheme where the influent and effluent were sampled for turbidity, coliform bacteria, and Giardia cysts.

iv) Figure D-13 shows the Giardia sampling pump connected to the effluent Giardia sampling port. A representative effluent sample was obtained by placing the effluent sampling port in a 3.8 cm (1.5

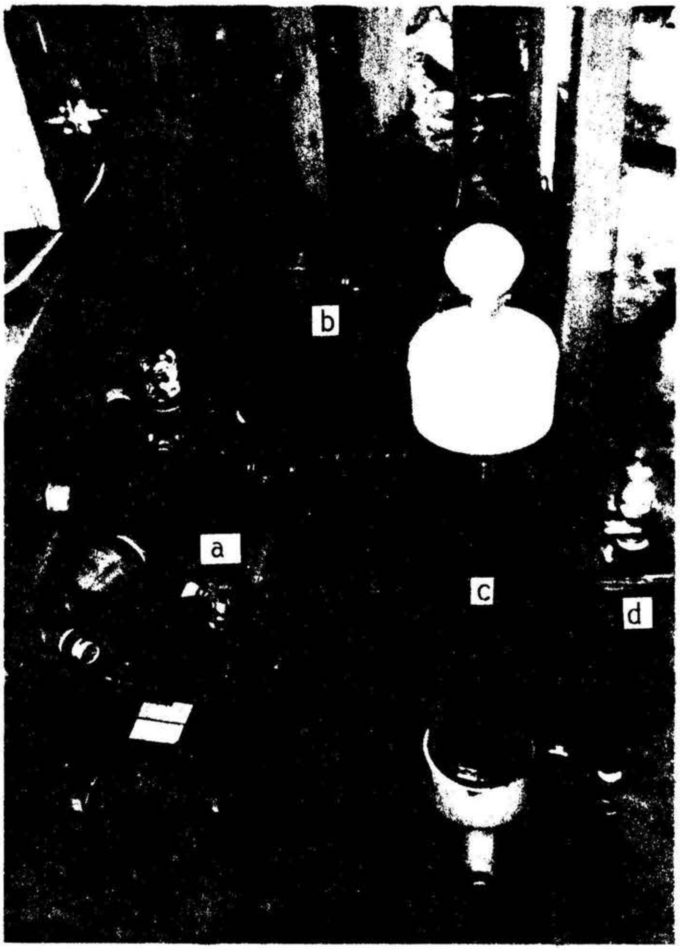

Figure D-13. Portion of apparatus for sampling Giardia cysts in effluent stream: a) Giardia sampling pump, b) effluent sampling port for Giardia, c) dampener to attenuate pressure fluctuations in the sampling stream, d) flow meter used to measure sampling flow rate.

inch) elbow, taking the sampling stream from the center of the pipe, and having the velocity of the sampling stream equal to the velocity of the main flow stream.

v) Representative influent sampling was insured by allowing streamlines direct access to the influent sampling port. This was obtained by having the water velocity in the sampling stream equal to the water velocity in the main flow stream, and by directing the sampling port towards the incoming flow.

APPENDIX E

DATA COLLECTION FORMS

Tables E-1 through E-6 were used during test runs using the laboratory-scale rapid rate filtration pilot plant to collect data for the different measurements and samples. Table E-1 shows an example of data collected from the milk cooler, used as a feed tank. The milk cooler was spiked, depending upon test run, with sewage and *Giardia* cysts, or with pure culture bacteria. Table E-2 is an example of data collected from the rapid mix basin and the filters; it shows also the results of sampling. Tables E-3 through E-6 are data forms used for recording analysis results from samples. Table E-7 illustrates the form used to record data obtained during test runs with the field-scale rapid rate filtration pilot plant.

Table E-1. Example of feed tank data obtained during test run using laboratory-scale rapid rate filtration pilot plant.

DATE 3/31/83 FEED TANK RUN NO. 107

Time	Volume (liters)	Temp (°C)	Turbidity (NTU)	Standard Plate Count (org/ml)	Total Coliform (org/100ml)	*Giardia* Cyst (cyst/l)	Notes
900	370	3	0.57 CLP 0.68				0.57 NTU before Giardia cyst added 0.68 after G. cyst added and 500 ml sewage.
1100	312		0.68				
1145	295	3	0.68	30500	10	2750 cyst / 9.22L	CLP: Cache La Poudre river
1300			0.68				Design G. cyst/L is 44000 cy/L in the tank.
1410	195	3	0.68				

Table E-2. Example of data collection during test run for laboratory-scale rapid rate filtration pilot plant.

DATE 3/31/83 RAPID SAND FILTER RUN NO. 107

TIME	PUMP			FILTER NO. 3 Dual media, Diameter 10 cm F.C. Sand					Alum Conc. 10/990 ml		572C Conc. 1ml/liter		Rapid Mix		Filter Effluent			NOTES
	Flow Rate (ml/min)	Setting	Pressure (psi)	Temp. °C	Pressure (psi)	D-Pressure (Hg/cm)	Flow Rate (ml/min)	Turbidity (NTU)	FLow Rate (ml/min)	Setting	Flow Rate (ml/min)	Setting	RPM	Temp.	Standard Plate (org/ml)	Total Coliform (org/100ml)	Giardia (cysts/l)	
945	680	6	3.7	1	1.5	2.7	680	0.42	0		0		500	1				
1030			3.9	4	1.5	3.5		0.11	1	0.5	0.34	0.1						
1110	680	6	3.9	4	1.6	3.7	680	0.05	1.2	0.5	0.34	0.1		3				
1115	Back wash																	
1130	680	6	3.5	4	1.4	2.8	680	0.99	1.2	0.5	0.34	0.1		4				
1138			4	5	3	3.0		1.22	1.2	0.5	0.34	0.1			2300	1	20 cysts / 20.4 L	start Giardia sample
1210			4	4	1.5	3.0		0.22	1.2	0.5	0.34	0.1						stop A start B
1300			4.2	4	2	3.4	680	0.05	1.3	0.5	0.33	0.1		4	1000	1		
1410	680	6		4	2	3.5	680	0.07	1.3	0.5	0.33	0.1		4			20 cysts / 81.6 L	stop B on the run test

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Table E-3. **Standard plate count bacteria data obtained during analysis of samples taken during operation of laboratory-scale rapid rate filtration pilot plant.**

STANDARD PLATE COUNT BACTERIA
ANALYSIS SHEET
(RAPID RATE FILTRATION)

RUN NUMBER	SAMPLE NUMBER	ANALYSIS START		DILUTION	COUNT (colonies) AT INCUBATION (hr)				RESULTS REPORTED (no./ml)	ANALYSIS BY (initials)	COMMENTS
		TIME	DATE		24	48	72	96			
107	TANK sample A	1400	3/31	0.001		32			35,000	RCW	
				0.001		38					
				0.01		41					
				0.1		139					
107	TANK Sample B.	1400	3/31	0.001		30			26,000	RCW	
				0.001		22					
				0.01		TNC					
				0.01		TNC					
107	Filter 3 sample A	1400	3/31	0.01		23			2,300	RCW	
				0.1		212					
				0.1		725+					
				1		TNC					
107	Filter 3 Sample B	1400	3/31	0.01		17			1,00	RCW	
				0.1		715					
				0.1		91					
				1		TNC					
				1		TNC					

Table E-4. Total coliform bacteria data obtained during analysis of samples taken during operation of laboratory-scale rapid rate filtration pilot plant.

TOTAL COLIFORM BACTERIA
ANALYSIS SHEET
(RAPID RATE FILTRATION)

RUN NUMBER	SAMPLE NUMBER	ANALYSIS START TIME	ANALYSIS START DATE	DILUTION	COUNT (colonies) AT INCUBATION (hr) 24	48	72	96	RESULTS REPORTED (no./100ml)	ANALYSIS BY (initials)	COMMENTS
107	TANK	1400	3/31	0.1	0				10	RCW	
				1	0						
				1	0						
				10	1						
				10	1						
107	TANK Sample B	1400	3/31	0.1	0				10	RCW	
				1	0						
				1	0						
				10	2						
				10	1						
107	Filter 3 Sample A	1400	3/31	10	1				1	RCW	
				10	0						
				100	0						
				100	0						
				100	1						
107	Filter 3 Sample B	1400	3/31	10	0				1	RCW	
				10	0						
				100	1						
				100	1						

Table E-5. Particle count data obtained during analysis of samples taken during operation of laboratory-scale rapid rate filtration pilot plant.

PARTICLE COUNT RESULTS

Date 3/31/83
Sample Rate ______

Run No. 107 — Sample No. TANK; Run No. 107A — Sample No. Filter 3

Ch	Bkgnd. Count	Count	Net Count	Count (No./10ml)	Bkgnd. Count	Count	Net Count	Count (No./10ml)
1	—	—			—	—	—	—
2	—	—			—	—	—	—
3	298	25022	24724	35266	298	651	353	504
4	125	10042	9917	14145	125	287	162	231
5	104	4468	4364	6225	104	150	46	66
6	53	1547	1494	2131	53	85	32	46
7	29	522	493	703	29	37	8	11
8	8	207	199	284	8	17	9	13
9	3	92	89	127	3	16	13	19
10	5	53	48	68	5	4	—	—
11	0	21	21	30	0	9	9	13
12	1	11	10	14	1	3	2	3
13	1	6	5	7	1	3	2	3
14	1	3	2	3	1	10	9	13
15	1	1	0	0	1	12	11	16
16	0	3	3	4	0	43	43	61
Time	100	100						

Run No. 107B — Sample No. Filter 3; Run No. ______ — Sample No. ______

Ch	Bkgnd. Count	Count	Net Count	Count (No./10ml)	Bkgnd. Count	Count	Net Count	Count (No./10ml)
1	—	—	—	—				
2	—	—	—	—				
3	298	1454	1156	1649				
4	125	760	635	906				
5	104	433	329	469				
6	53	242	189	270				
7	29	138	109	155				
8	8	81	73	104				
9	3	33	30	43				
10	5	17	12	17				
11	0	4	4	6				
12	1	2	1	1				
13	1	0	—	—				
14	1	0	—	—				
15	1	0	—	—				
16	0	0	0	0				
Time								

$$\frac{\text{Count}}{10\text{ml}} = \frac{\text{Count} \times 10\text{ml}}{\text{Time} \times \text{Flow}} \times \frac{222\text{ ml}}{207\text{ ml}} = \frac{(X) \times 10}{100 \times 2} \times \frac{222}{207} =$$

26.6

Time in sec., Flow in ml/sec.

WDB 3-82

Table E-6. Giardia cyst data obtained during analysis of samples taken during operation of laboratory-scale rapid rate filtration pilot plant.

GIARDIA QUANTITATION

Filtration System RAPID SAND

Run Information (sample label)	Analysis Date	amt. conc. in sample	Analysis by	Counts of Replicates	Cyst # Reported	Observations and Comments
Run 106 TANK	4-4	—	DGH 1200	1:5 1200 1400	1300	typical tank w/ decreased debris
Run 106 Filter 3	4-4	—	DGH	1:1 1440 1600	1520	algae fairly clean cysts are in good condition.
Run 107 TANK	4-4	—	DGH	1:5 2600 2900	2750	cysts in good condition typical tank w/ increase in amt of small debris
Run 107 A Filter 3	4-4	—	DGH	1:1 0	<20	see below.
Run 107 B Filter 3	4-4	—	DGH	1:1 0	<20	DE diatoms very clean.

Table E-7. Sample data sheet for field-scale pilot plant.

Time	Turbidity (NTU) Inf	Turbidity (NTU) Eff	Diff. Head (ft. of HOH)	Poly tank reading (liters)	Poly feed rate (ml/min)	Alum tank reading (liters)	Alum feed rate (ml/min)	Spike tank reading (liters)	Spike feed rate (ml/min)	Flow meter reading (cu. ft)	Plant flowrate (gpm)	water temperature	COMMENTS
:25				50				40					Start Flow & Feed Pumps
:30			.8							368			WB#2 taken (eff coliform)
0:35	6.5											12°C	WB#3
0:40													WB#4
0:55		1.1											WB#5 & WB#6
1:00			1.2									12°C	Start sampling for inf cysts
1:06													Stop sampling for inf cysts
1:25	6.5	1.0											Start sampling for eff cysts
1:35										559	22		WB#7
1:45			1.3	45.5	65			25	210				Stop sampling for eff cysts

Date: 7/18/83 Run#: 59 Polymer Used: 8102

Polymer Batch Mix: 700 ml / 50 l Alum Batch Mix: ∅

Giardia Batch Mix: (3.6x10⁶ cysts & 3 l of primary eff)/40 l

Type of Filtration: IN-LINE

Type of Water: HT Avg. Plant flow rate (gpm): 22

Purpose of Run: Above opt Giardia removal, & coliform conc vs. time

Avg. poly feed rate (ml/min): 65

Avg. Alum feed rate (ml/min): ∅

Inf Coliform Count (#/100ml): 1200

Eff Coliform Count (#/100ml): @ 1 Hr = 20

Inf Giardia Count (cysts/liter): JMG#13 (12 gal) 25

Eff Giardia Count (cysts/liter): JMG#14 (40 gal) Zero

Calculations:

WB - Coliform samples
JMG - Giardia samples

$$DCC = \text{Designed cyst conc} = \frac{(3.6 \times 10^6)\,.21}{40} \cdot \frac{1}{(22)\,3.785} = \boxed{210 \text{ cyst/liter}}$$

$$\text{Poly Feed} = \frac{(65)\left(\frac{700}{50}\right)}{(22)\,3.785} = 11 \text{ mg/l}$$

COMMENTS: pH of RAW WATER = 6.6
WB#1 is pure primary eff.; WB#6 is inf sample