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Governor

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DEPARTMENT OF ECOLOGY
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MEMORANDUM

December 12, 1983

To: John Bernhardt

JaD BMC

From: Tim Determan and Barbara Carey

Subject: Progress Report No. 4; Burley Lagoon and Minter Bay Survey

This is the fourth interim report on the Burley Lagoon/Minter Bay bacteriological survey.

Ambient Monitoring

Burley Lagoon and Minter Bay and their respective watersheds are classified as AA (extraordinary) waters under the Washington State Water Quality Standards. Fecal coliform criteria are summarized below:

Freshwaters

Part 1. Fecal coliform organisms shall not exceed a geometric mean value of 50 organisms/100 mL;

Part 2. Not more than 10 percent of samples shall exceed 100 organisms/100 mL.

Marine Waters

Part 1. Fecal coliform organisms shall not exceed a geometric mean value of 14 organisms/100 mL;

Part 2. Not more than 10 percent of samples shall exceed 43 organisms/100 mL.

In addition to water quality criteria, DSHS and FDA policy states that shellfish exceeding 230 FC organisms per 100 gr of tissue are not deemed to be marketable.

Figure 1 shows the locations of routine ambient stations. Results of fecal coliform samples are shown in Tables 1, 2, and 3. Each table indicates whether water quality violations have occurred for each station. The shellfish results are shown in the same format.

A previous report (Determan and Bernhardt, 1983) showed degradation of water quality in streams and estuaries during the summer months (Tables 1 and 2). These degradations did not result in excessively high FC densities in shellfish.

The most recent data (Table 3) suggest a slight improvement at several stream stations. Average FC values decreased at all Burley Creek, Purdy Creek, and Bear Creek stations in Burley watershed. In Minter watershed streams, the same pattern occurred. However, this general improvement was not enough to prevent them from violating the standards. Among upstream stations, only UN 2.0 continued to violate water quality standards. The baseline stream draining into Purdy Creek (V 0.0) also improved. The mouths of several tributary streams (M 0.0, H 0.1) showed no violations this time, while others (BU 0.6, BU 0.3, P 0.1) continued their summertime violation pattern. The lower end of Minter Creek above the confluence with Huge Creek (M 1.3) also continued to violate the standards.

Overall improvement also occurred in fecal coliform levels in both estuaries since August 8. In Burley Lagoon (BES), the average FC value decreased to just above the standard. The highest single value occurred on September 19 which coincided with violation-level FC densities in the oyster sample. Fecal coliform levels in Minter Bay continue to be high, although there was improvement during October. Correlation between high FC values in water and oyster tissue is not strong. Prior to August 22, high water values did not produce violations of the oyster marketability standard. Since that time, tissue samples have shown violations on three occasions when FC densities in water were somewhat lower than might be expected. This may be due to interaction between the onset of autumn rainfall resulting in short-term, heavy runoff and elevated oyster filtration rates due to seasonally high water temperatures. A more detailed examination of this interaction will be included in the final study report.

The importance of individual sources within the watershed to water quality in the estuary may be related to several interacting factors. The survivability of fecal coliforms that enter streams may change due to environmental factors such as light, temperature, salinity, etc. If the time of travel is sufficiently long, the fecal coliforms may die before they enter the estuary. Thus, the importance of a source on estuarine water quality is lessened by increased distance from the estuary. There are also seasonal aspects. Sources that may not be important during low-flow periods, when time of travel is greatest, may be more important during high-flow (minimum time of travel) periods. Thus, knowledge of fecal coliform mortality rates and stream time of travel may be used to gauge the importance of sources within the watershed.

Table 1. Summary of Burley and Minter watersheds fecal coliform sampling data during the period prior to May 31.

	Sampling Results									Geometric Mean	Percent Exceeding Maximum Limit	Violation Summary		
	January		February		March	April		May				Water		Shellfish
Sampling Location	10-11	17-18	7-8	21-22	21-22	4-5	18-20	2-3	31-6/1			Part 1	Part 2	
BURLEY WATERSHED														
Burley Creek														
Headwaters (BU 5.2)	--	--	--	21	1	7	2	12	5	5	0	No	No	--
Lower Creek (BU 0.6)	--	--	--	/379/	17	46	/58/	85	/258/	68	20	Yes	Yes	--
Near Mouth (BU 0.3)	36	--	/89/	/184/	25	/202/	/69/	/71/	/208/	76	29	Yes	Yes	--
Unnamed Trib. (X 0.2)	--	--	--	<1	<1	1	<1	2	10	1	0	No	No	--
Purdy Creek														
Headwaters (P 3.6)	--	--	--	4	2	1	<1	2	7	2	0	No	No	--
Near Mouth (P 0.1)	122	14	5	/255/	6	46	9	/95/	/102/	29	25	No	Yes	--
Unnamed Trib. (V 0.0)	--	--	--	3	1	9	<1	2	38	2	0	No	No	--
Bear Creek														
Headwaters (BR 1.8)	--	--	--	3	1	4	49	17	/2800/	6	0	No	No	--
Near Mouth (BR 0.0)	--	/53/	--	/58/	40	/76/	7	22	/152/	34	0	No	No	--
Marine Waters														
Mid-lagoon (BES)	10*	3*	/14*/	5*	3	<1	6	5	/43/	3	0	No	No	--
Lagoon Outlet (BEX)	5*	4*	6*	<1*	4	6	/20/	7	/16/	8	0	No	No	--
Oyster Tissue	--	230	130	50	70	50	11	130	140	69	0	--	--	No
MINTER WATERSHED														
Minter Creek														
Headwaters (M 4.4)	46	5	3	34	/71/	4	1	2	13	8	0	No	No	--
Lower Creek (M 1.3)	/88/	21	15	41	/54/	12	23	32	/344/	29	0	No	No	--
Near Mouth (M 0.0)	48	42	12	24	24	15	12	28	/75/	23	0	No	No	--
Huge Creek														
Headwaters (H 3.1)	11	2	1	4	1	<1	<1	<1	/630/	2	0	No	No	--
Near Mouth (H 0.1)	14	25	9	16	24	15	7	21	/145/	15	0	No	No	--
Unnamed Creek														
Headwaters (UN 2.0)	/114/	16	2	29	2	4	51	35	/138/	14	13	No	Yes	--
Near Mouth (UN 0.0)	/78/	15	5	7	3	/64/	/63/	22	/67/	18	0	No	No	--
Marine Waters														
Mid-bay (MES)	/63*/	10*	5*	9*	/62/	12	/17/	/71/	/218/	20	38	Yes	Yes	--
Bay Outlet (MEX)	/75*/	3*	3*	/17*/	/43/	13	2	10	--	20	38	Yes	Yes	--
Oyster Tissue	/1300/	230	20	15	130	80	11	5	110	52	0	--	--	No

NOTES:

1. Membrane filter (MF) analyses were performed on river samples. Starred (*) marine samples were done with MF; other marine samples by most-probable-number (MPN) method.
2. Single values exceeding Part I water quality standards are boxed (/__/).

* = Marine sample analysis performed with membrane filter method.

Table 2. Summary of Burley and Minter watersheds fecal coliform sampling data from June 1 through August 8.

Sampling Location	Sampling Results June 12-13	June 27	July 11	July 25	August 8	Geometric Mean	Percent Exceeding Maximum Limits	Violation Summary Water Part 1	Water Part 2	Shellfish
BURLEY WATERSHED										
Burley Creek										
Headwaters (BU 5.2)	18	10	18	/1284/	36	30	17	No	Yes	--
Lower Creek (BU 0.6)	/143/	/61/	/154/	/2179/	/163/	223	83	Yes	Yes	--
Near Mouth (BU 0.3)	/210/	50	/130/	/<400/	/178/	165	83	Yes	Yes	--
Unnamed Trib. (X 0.2)	5	1	3	29	5	5	0	No	No	--
Purdy Creek										
Headwaters (P 3.6)	3	5	8	/250/	16	10	17	No	Yes	--
Near Mouth (P 0.1)	/134/	/238/	/701/	/3250/	/186/	334	100	Yes	Yes	--
Unnamed Trib. (V 0.0)	/56/	3	6	/170/	17	22	17	No	Yes	--
Bear Creek										
Headwaters (BR 1.8)	/160/	/205/	/64/	/5250/	/68/	409	67	Yes	Yes	--
Near Mouth (BR 0.0)	/550/	/67/	/118/	/702/	/194/	212	83	Yes	Yes	--
Marine Waters										
Mid-lagoon (BES)	/27/	8	/27/	/31*/	/26/	24	0	Yes	No	--
Lagoon Outlet (BEX)	2	<2	5	2*	<2	4	0	No	No	--
Oyster Tissue	20	90	80	230	80	85	0	--	--	No
MINTER WATERSHED										
Minter Creek										
Headwaters (M 4.4)	34	7	6	/74/	21	17	0	No	No	--
Lower Creek (M 1.3)	/309/	/54/	/56/	/810/	/96/	178	50	Yes	Yes	--
Near Mouth (M 0.0)	/114/	/64/	41	/323/	/54/	85	33	Yes	Yes	--
Huge Creek										
Headwaters (H 3.1)	/105/	8	32	/1849/	15	89	50	Yes	Yes	--
Near Mouth (H 0.1)	/70/	/125/	/59/	/278/	45	99	50	Yes	Yes	--
Unnamed Creek										
Headwaters (UN 2.0)	/59/	/370/	/95/	/134/	/79/	120	50	Yes	Yes	--
Near Mouth (UN 0.0)	/69/	46	/355/	/173/	/76/	100	33	Yes	Yes	--
Marine Waters										
Mid-bay (MES)	/51/	/32/	/101/	/42*/	--	77	60	Yes	Yes	--
Bay Outlet (MEX)	2	/40/	2	1*	<2	4	0	No	No	--
Oyster Tissue	50	20	130	20	230	63	0	--	--	No

NOTES:

1. Membrane filter (MF) analyses were performed on river samples. Starred (*) marine samples were done with MF: other marine samples by most-probable-number (MPN) method.
2. Single values exceeding Part I water quality standards are boxed (/‾‾/).

8 = Marine sample analysis performed with membrane filter method.

Table 3. Summary of Burley and Minter watersheds fecal coliform sampling data from August 22 through October 31.

	Sampling Results								Violation Summary		
	August	September		October				Percent Exceeding	Water		Shellfish
Sampling Location	22	6	19	3	17	31	Geometric Mean	Maximum Limits	Part 1	Part 2	
BURLEY WATERSHED											
Burley Creek											
Headwaters (BU 5.2)	24	20	17	14	7	23	16	0	No	No	--
Lower Creek (BU 0.6)	/59/	/58/	/125/	43	/383/	/176/	104	50	Yes	Yes	--
Near Mouth (BU 0.3)	47	/51/	/169/	36	/94/	/267/	85	33	Yes	Yes	--
Unnamed Trib. (X 0.2)	3	3	2	2	1	1	2	0	No	No	--
Purdy Creek											
Headwaters (P 3.6)	28	28	12	4	4	1	7	0	No	No	--
Near Mouth (P 0.1)	/519/	/265/	/205/	/288/	/860/	36	251	83	Yes	Yes	--
Unnamed Trib. (V 0.0)	5	10	3	2	3	1	3	0	No	No	--
Bear Creek											
Headwaters (BR 1.8)		/55/	/82/	6	7	/88/	28	0	No	No	--
Near Mouth (BR 0.0)	13	44	/455/	7	46	/619/	38	20	No	Yes	--
Marine Waters											
Mid-lagoon (BES)	4	/15/	/59/	14	2	5	17	17	No	Yes	--
Lagoon Outlet (BEX)	<2	<2	<2	3	2	8	3	0	No	No	--
Oyster Tissue	20	130	/440/	70	230	230	127	17	--	--	Yes
MINTER WATERSHED											
Minter Creek											
Headwaters (M 4.4)	23	19	36	2	2	10	9	0	No	No	--
Lower Creek (M 1.3)	/1350/	/72/	/157/	/94/	/130/	40	140	50	Yes	Yes	--
Near Mouth (M 0.0)	/52/	46	/68/	13	40	/52/	40	0	No	No	--
Huge Creek											
Headwaters (H 3.1)	3	14	3	1	5	2	3	0	No	No	--
Near Mouth (H 0.1)	/59/	30	21	7	27	21	23	0	No	No	--
Unnamed Creek											
Headwaters (UN 2.0)	/86/	/120/	/140/	/359/	/1149/	/82/	191	67	Yes	Yes	--
Near Mouth (UN 0.0)	/290/	/57/	/59/	14	29	30	48	17	No	Yes	--
Marine Waters											
Mid-bay (MES)	/94/	/62/	/130/	9	/33/	/20/	41	50	No	Yes	--
Bay Outlet (MEX)	<2	3	<2	<2	4	11	2	0	No	No	--
Oyster Tissue	35	/2400/	/790/	230	/330/	230	324	60	--	--	Yes

NOTES:

1. Membrane filter (MF) analyses were performed on river samples; marine samples by most-probable-number (MPN) method.
2. Single values exceeding Part I water quality standards are boxed (/ /).

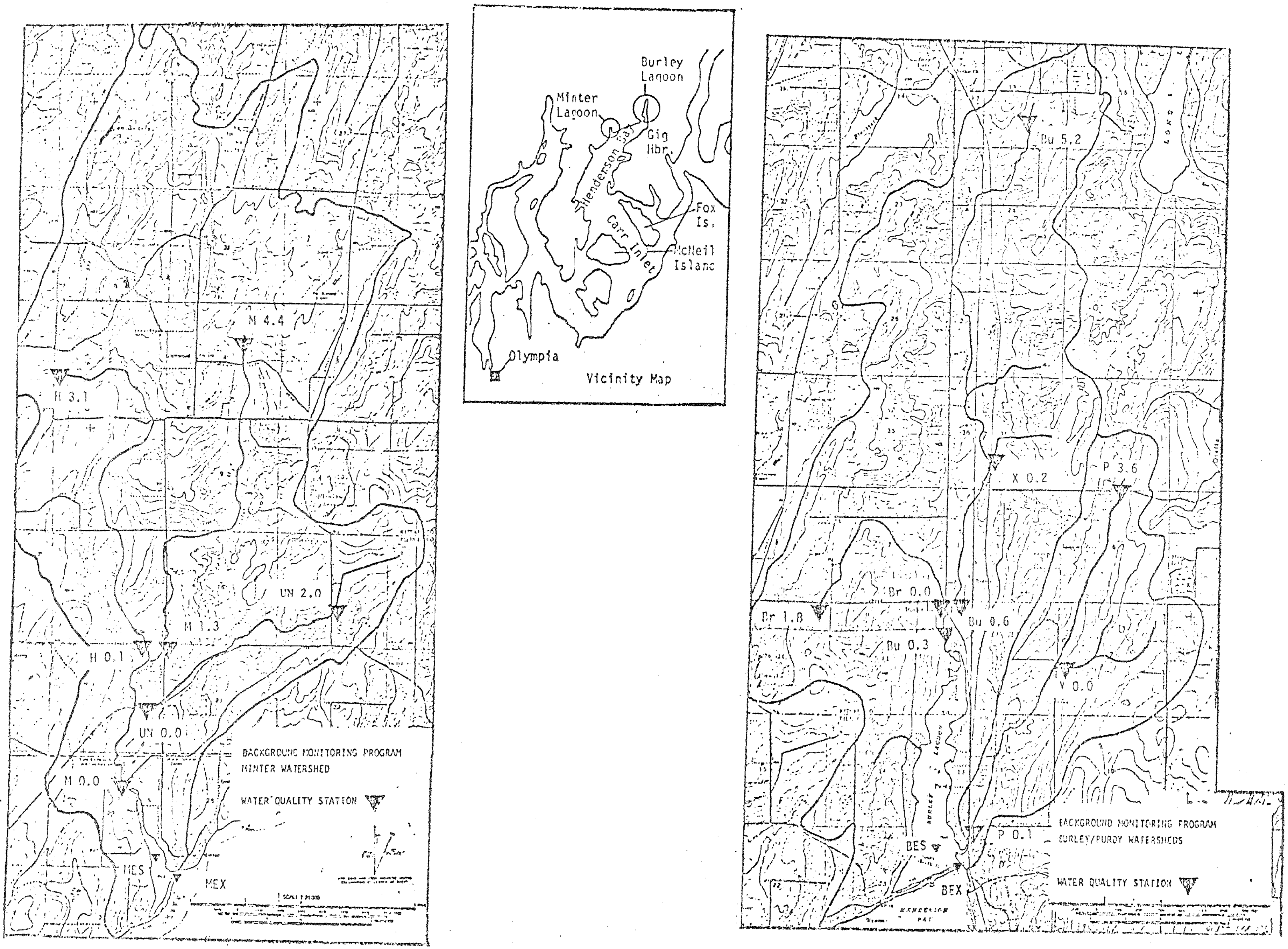

Figure 1. Minter and Burley watershed and estuaries showing locations of routine background sampling stations.

Fecal Coliform Die-off

Fecal coliform mortality experiments were conducted in August. 10 mL of primary STP effluent was diluted in 15 L of water in three pairs of aquaria. One pair of aquaria contained saltwater obtained from mid-Henderson Bay due east of Minter Bay. Another pair contained freshwater from Minter Creek adjacent to the Minter Creek Salmon Hatchery. The third pair contained a mixture of both types of water. Thus, FC mortality could be evaluated for three salinity regimes. The six aquaria were placed in flowing raceways at the Minter Creek Hatchery and were fully exposed to environmental conditions.

Fecal coliform populations dropped very rapidly in each of the experimental tanks under cloudless skies in all three salinity regimes: saltwater, half saltwater, and freshwater (Figures 2 and 3). Densities of fecal coliforms were below 10 percent of the beginning estimates after only five hours. Fijioka *et al.* (1981) obtained similar results during field tests and observed that the lethal effects of visible light penetrated clear saltwater to at least 3.3 m. These authors and others (Chojnowski *et al.*, 1979; Hendricks and Morrison, 1967) found that the destructive effect of sunlight on fecal coliform bacteria is less rapid in freshwater. Daytime summer die-off was so rapid in our uncovered experimental tanks that it was not possible to distinguish the effect of varying salinity.

Damage to fecal coliform cells due to sunlight, if not lethal, facilitates predation by protozoans and naturally occurring bacteria (McCambridge and McMeekin, 1981). The degree of harm caused by solar radiation varies among the difference species of fecal coliform. *E. coli* is more sensitive to radiation than *Salmonella typhimurium*, *S. faecium*, *Enterobacter aerogenes*, or *Erwinia herbicola* (McCambridge and McMeekin, 1981). *Klebsiella pneumoniae* was less sensitive than *E. coli* in the above study.

A second study was conducted to test the effects of light intensity on FC mortality. Fifteen liters of water was placed in two pairs of aquaria. Each aquaria was seeded with 10 mL of primary effluent from the LOTT Wastewater Treatment Plant in Olympia. One pair was exposed to direct sunlight; the other pair was shaded with cloth to produce light levels similar to shading by a forest canopy. An additional pair of tanks was each filled with 15 liters of water from upper Bear Creek. This sample was not seeded because the water was obtained from a site known to be contaminated. These Bear Creek tanks were also shaded with cloth (Figure 4).

In the aquaria filled with water from upper Bear Creek, fecal coliform populations survived and increased to nearly three times the initial density in three days. The population dropped off markedly later due to predation, starvation, or both.

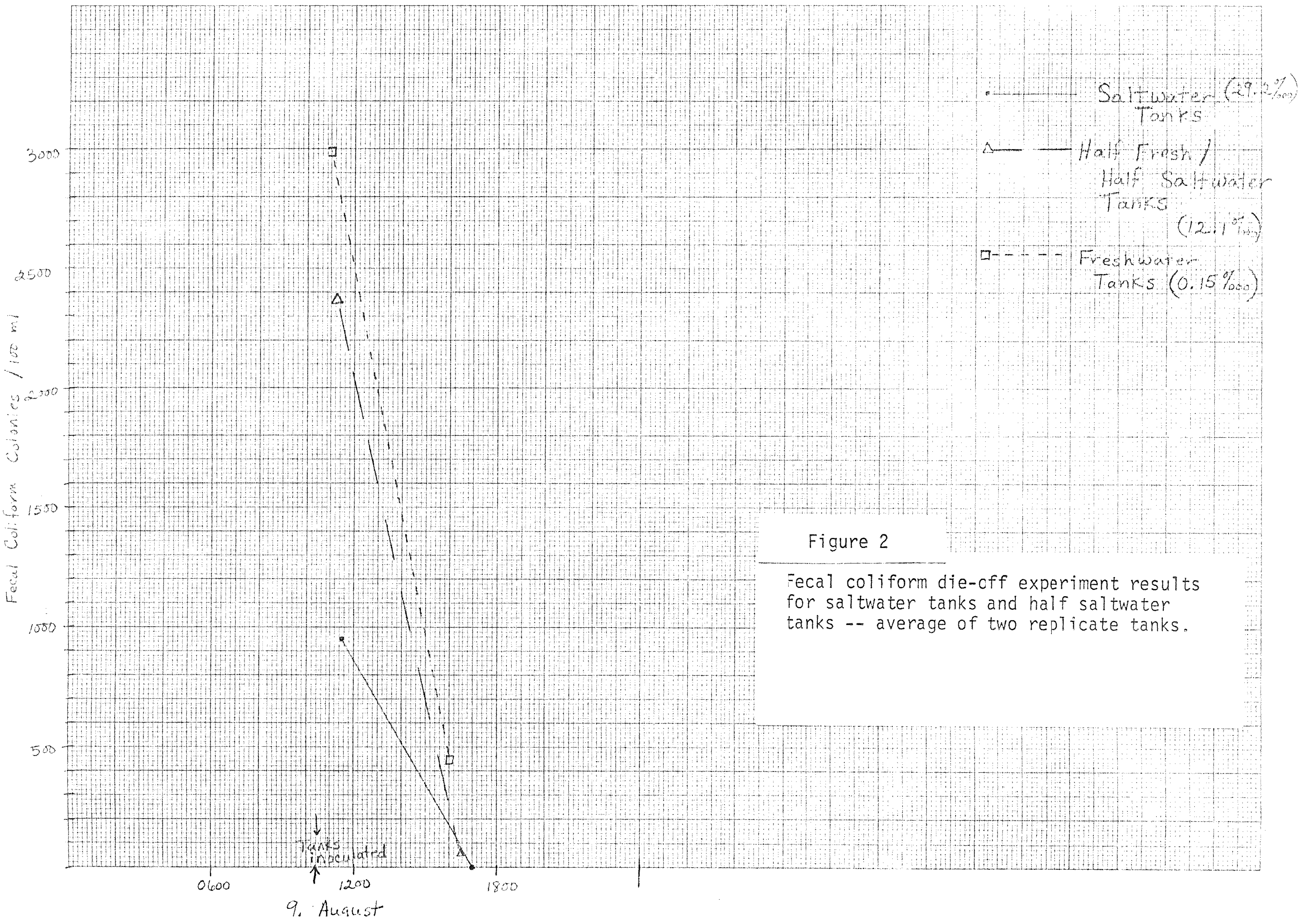

Figure 2

Fecal coliform die-off experiment results for saltwater tanks and half saltwater tanks -- average of two replicate tanks.

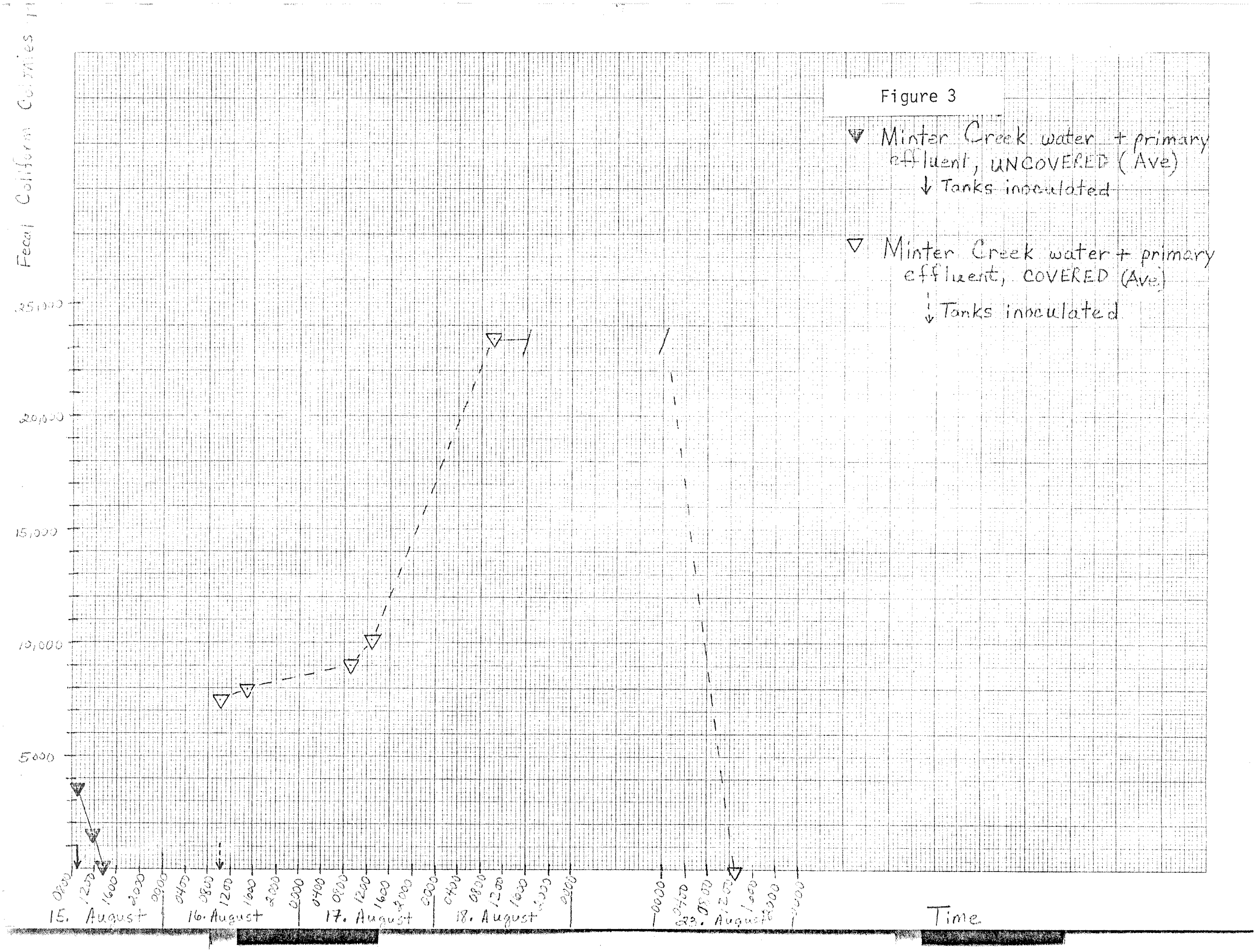

Figure 3

Fecal Coliform Colonies
25,000
20,000
15,000
10,000
5000
Minter Creek water + primary effluent, UNCOVERED (Ave)
↓ Tanks inoculated
Minter Creek water + primary effluent, COVERED (Ave)
↓ Tanks inoculated
0800
1200
1600
2000
0000
0400
0800
1200
1600
2000
0000
0400
0800
1200
1600
2000
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0400
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Time

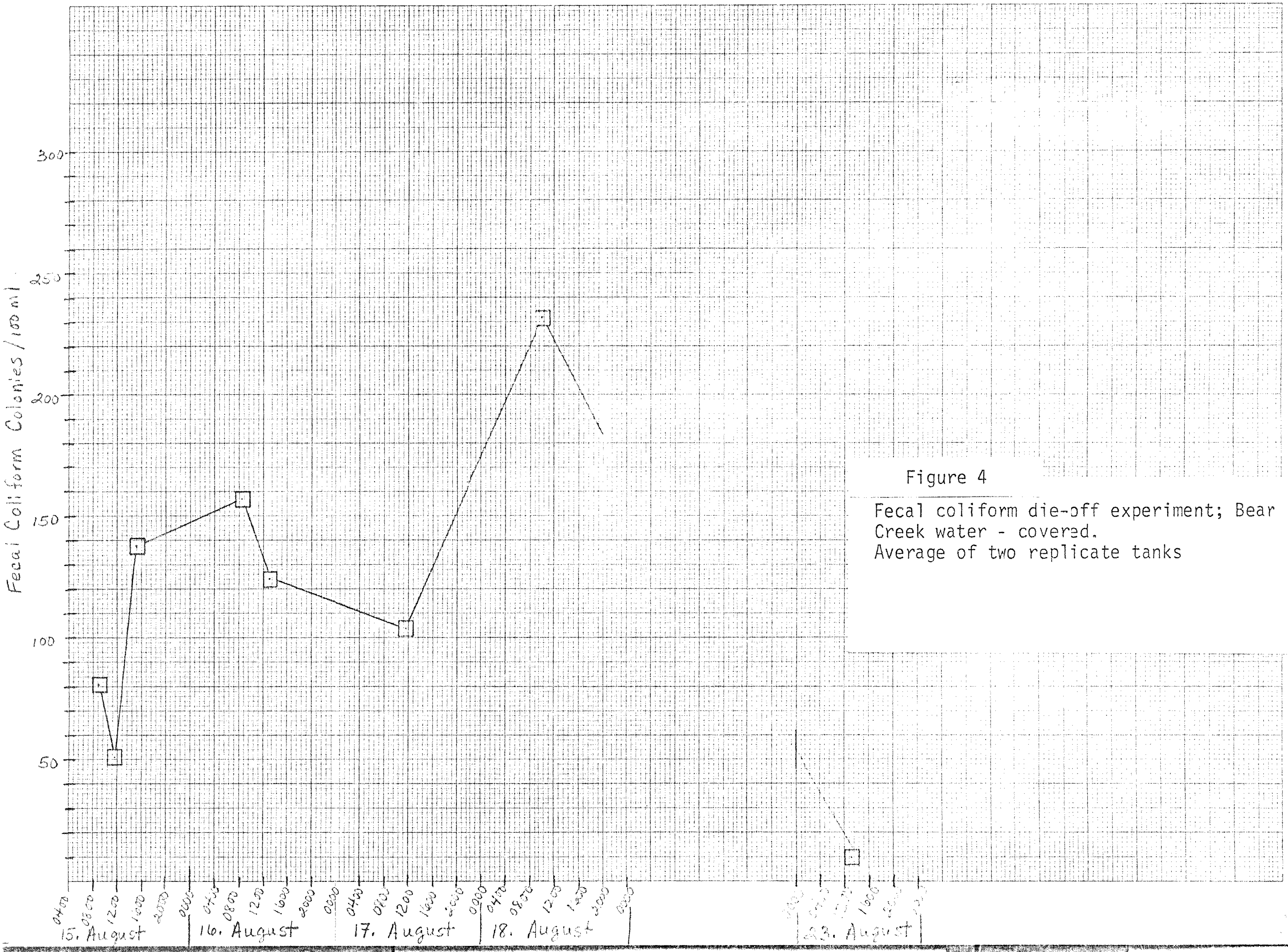


Figure 4

Fecal coliform die-off experiment; Bear Creek water - covered.
Average of two replicate tanks

FCs in the shaded tank seeded with LOTT effluent increased even more dramatically over two days to four times the original density (Figure 3). The FCs in the exposed tank with sewage effluent displayed very rapid die-off, with more than 98 percent inactive after 3-1/2 hours.

Portions of the Minter and Burley watersheds are also densely forested and fecal bacteria may survive there longer than previously thought. Sediment may also protect fecal coliforms from light.

Time of Travel Studies

Travel times for Burley and Minter creeks were estimated by following a slug dose of fluorescent dye from the upstream reach to the mouth of each creek. These creeks were selected because they were the main creeks in their respective watersheds. The variety of flow regimes required that the creeks be divided into stretches and the time of travel for each stretch added to give a total time of travel.

During the autumn low-flow period, it took an average of 18 to 20 hours for dye to travel the 4.6 miles of Burley Creek (from Bu 5.2 to Bu 0.6). Time of travel in the upper 1.5 miles of the creek was much longer than in the lower 3.1 miles. It took most of the dye about 11 hours to flow through the upper one-third of the creek, and between 7 and 8 hours to pass through the lower two-thirds.

The average total travel time for the main 4.1-mile stretch of Minter Creek was 37 hours. The range of time-of-travel estimates for the dye cloud was 22 to 60 hours. Minter Creek was divided into three sections and the travel time measured for each: the free-flowing, uppermost 0.7 mile; the next 1.4 miles of bog; and the lower 2 miles of free-flowing water. The bog zone was much slower than the rest of the creek with an average travel time of 28 hours.

Neither Huge nor Unnamed creeks in the Minter watershed contain any sizeable bog areas. Both tributaries are shorter than Minter Creek and enter the mainstem below the large bog. Therefore, the travel time for these creeks is probably less than that for Minter Creek.

Time of travel decreases during winter high-flow conditions. Discharge and time of travel are usually inversely related (Singleton and Joy, 1982). A slight increase in discharge will greatly reduce travel times. If a straight logarithmic relationship between discharge and time of travel exists, then the travel times for both Burley and Minter creeks would have been about 6 to 7 hours during the mid-November high-flow period. The effects of shorter travel time and decreased solar radiation during the winter should decrease fecal coliform die-off and allow more loading to the estuaries. On the other hand, reduced salinities and temperatures along with increased turbidity during the rainy season cause less than ideal feeding conditions for oysters. This may explain the low oyster tissue coliform levels of last winter.

Fecal Coliforms in Sediments

Sediment release studies were performed to assess the possible contribution of sediment bacterial populations to the overlying water during disturbance by high stream flows. Study sites were chosen based on past data and land-use issues (Figure 5). On September 20, 1983, a set of FC water samples was taken. Suspended solids were assumed to be the same as on the previous day when ambient samples were collected. Sediments were then systematically raked and a second set of FC and suspended solids samples collected 7 meters downstream. The results were "normalized" by dividing fecal coliform density by suspended solids concentration (B. Yake, WDOE, personal communication). The ratio of normalized fecal coliform density after disturbance to that before disturbance is referred to as sediment fecal coliform release capacity (Table 4).

Samples of the top 1-2 cm of sediment were collected at the same sites six days later and analyzed for FC (Table 4).

The degree of FC contribution from the sediments appeared to be related to certain sediment characteristics such as particle size and adsorptive properties. In places where sediment concentrations were low, FC release capacity was highest, except at Station M 0.3. Likewise, sediment content was high where release capacity was low. The data may be suggesting that a negative correlation exists between FC densities in sediment and the capacity to release them upon disturbance. However, the data set is too small to test this hypothesis.

Several factors influence the accumulation or concentration of fecal coliforms in sediments, including water velocity, sediment type, and loading from surrounding land. Both extremes of creek discharge rate (highest and lowest) were measured at the three sites with the maximum sediment fecal coliform release capacity (Table 4). Intermediate flows were associated with lower release capacity and higher sediment fecal coliform concentration.

Visual observations indicated that the areas with high sediment fecal coliform release capacity contained more fine sediment than those with low capacity. This may indicate a greater affinity of fecal coliforms for fine materials or increased survival when associated with that substrate.

Content of organic matter as well as particle size composition and water velocity influence sediment fecal coliform adsorption and entrainment. Nutrient availability and predation which were not addressed here also influence fecal coliform survival.

The highest sediment fecal coliform levels seemed to be in areas of combination small farm/residential land use. The sediment fecal coliform content was quite low at the E. Horizon Lane station which is in a low-density residential area with no farm animals.

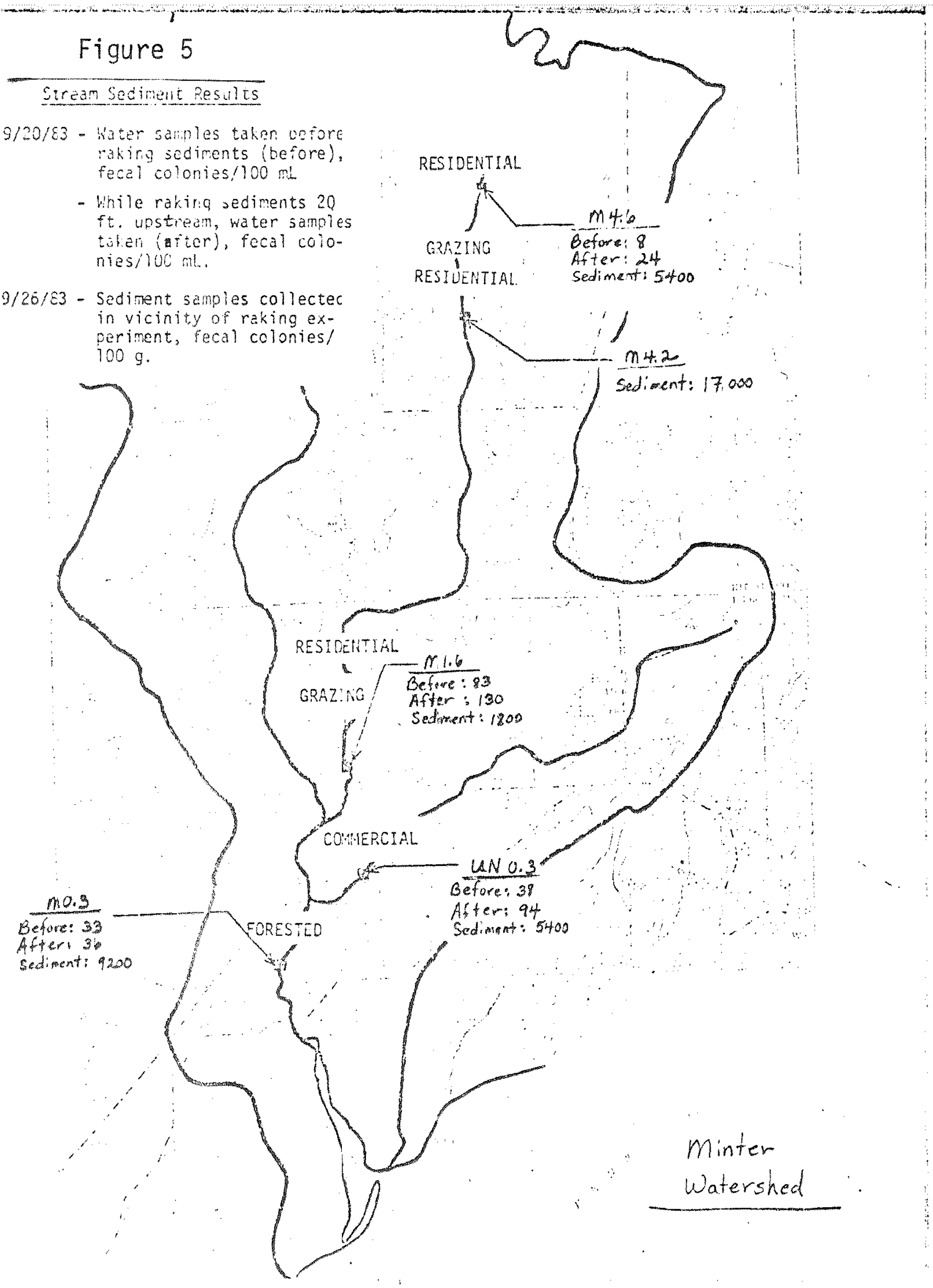
Figure 5

Stream Sediment Results

9/20/83 - Water samples taken before raking sediments (before), fecal colonies/100 mL

- While raking sediments 20 ft. upstream, water samples taken (after), fecal colonies/100 mL.

9/26/83 - Sediment samples collected in vicinity of raking experiment, fecal colonies/100 g.



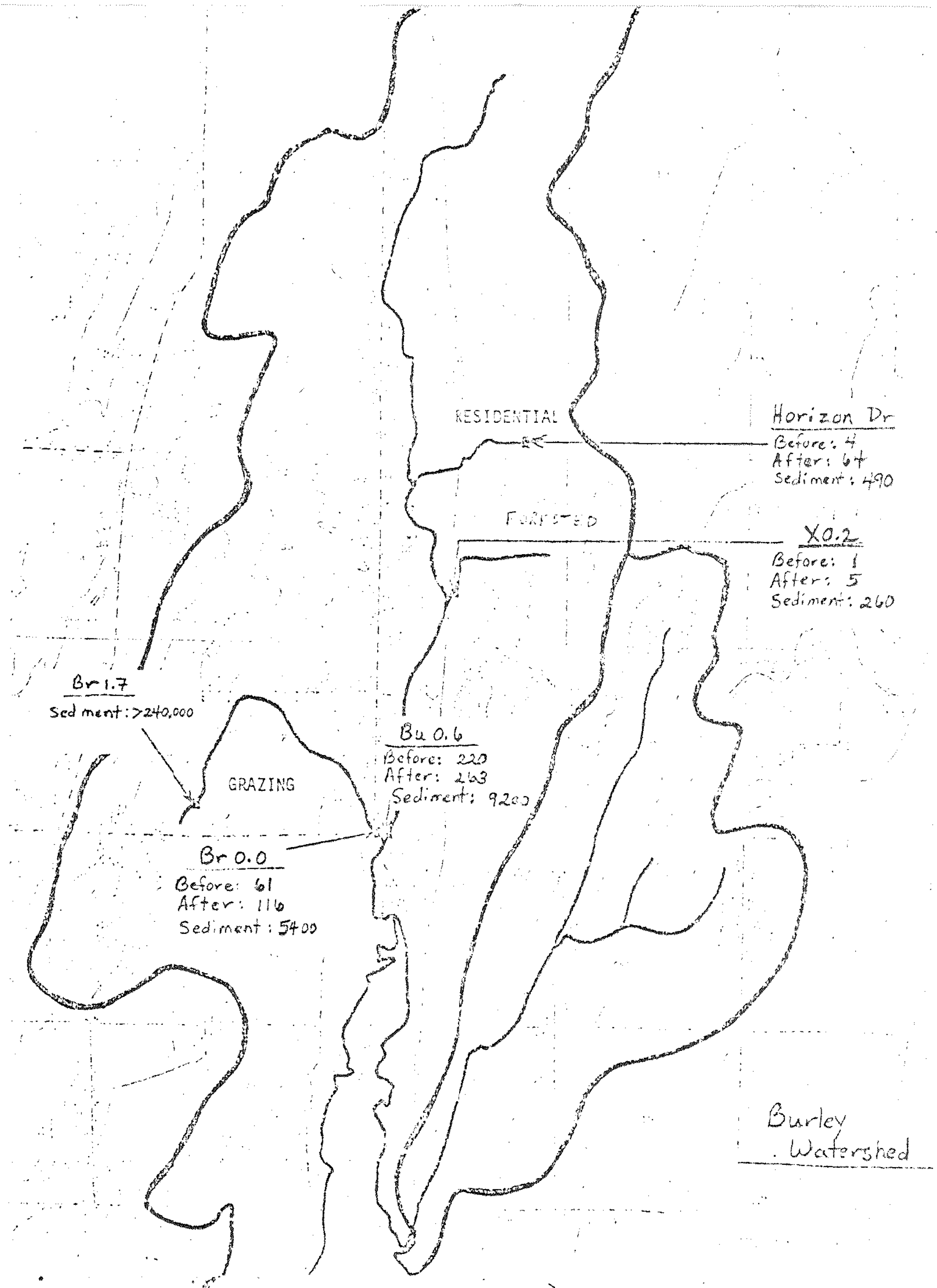


Figure 5.

Table 4. Ranking of stations for sediment fecal coliform release characteristics.

Station	Release Capacity	Sediment Concentration (fc/100 g)	Soil Type (Sediment)	Q (cfs)	Land Use
Horizon Dr.	1.46	460	Clay	≈0.3	Low-density residential
M 0.3	0.54	9,200	Sand	26.0	Undeveloped forest
X 0.2	0.15	260	Silt	0.3	Undeveloped forest
M 1.6	0.08	1,800	Sand, silt	11.3	Residential; grazing
Br 0.0	0.04	5,400	Sand	4.0	Residential; limited agriculture
Bu 0.6	0.03	9,200	Sand	19.5	Residential; limited agriculture
UN 0.3	0.03	5,400	Sand, silt	0.5	Commercial
M 4.6	0.02	5,400	Silt	2.4	Recently developed residential
M 4.2	0.01	17,000	Sand, silt	2.4	Residential; limited agriculture
Br 1.6[1]	--	>240,000	Clay		Agricultural; cattle grazing

[1] BR 1.6 not ranked due to lack of data.

Memo to John Bernhardt
Progress Report No. 4; Burley Lagoon and Minter Bay Survey

A sediment sample taken in upper Bear Creek had the highest fecal coliform density observed, >240,000. This stretch of the creek passes through a heavily grazed cow pasture. The Soil Conservation Service is currently working with the land owner to improve animal-keeping practices.

Water quality standards apply to fecal coliform densities in the water. However, when stream flow suddenly increases, sediment particles can become suspended and fecal coliforms transported to the overlying water independent of external sources (McDonald and Jenkins, 1982).

A similar sediment study was carried out in Minter Estuary. Two points approximately 10 m apart were established near station MES. The sites were aligned parallel to the outgoing tidal flow. The water depth during the study ranged from 36 cm at the beginning to 20 cm at the end. Water movement was measured using Rhodamine WT dye. The velocity of the receding tide ranged from 0.33 m/sec initially to 0.25 m/sec at the end. The shallow depth allowed sampling without the use of subsurface samplers. Samples were taken approximately 10 cm above the bottom. Three sets of eight samples each were taken. One set was taken at the upstream point. Another set was taken at the downstream site. Both sets were taken in the same way, although downstream sampling was started later in order to allow for movement of the water mass. A third set of samples was taken at the downstream site while sediments at the upstream site were mechanically disturbed. Samples were analyzed in the laboratory using the membrane filter technique. The fecal coliform results in the "disturbed" samples were not greatly affected by suspended material. This may be because most of the sediments tended to settle out before the water mass carrying them reached the downstream sampling point.

The variances of the data in the sets of samples were tested for homogeneity in order to assure that the data were normally distributed. They were then analyzed by single-classification analysis of variance (Sokal and Rohlf, 1969). The data and the statistical analysis are summarized in Table 5. There proved to be no difference between average FC levels at the upcurrent and downcurrent undisturbed points. This means that upstream sampling alone produced no significant effect downstream. In addition, although disturbance of the sediments at the upstream site produced a higher calculated average downstream, this did not prove to be significant given the variation in the data.

Fecal coliforms do not seem to travel far when marine sediment substrates are disturbed by current scouring or other means. Instead, effects to water quality and risk to shellfish by this process may be strictly localized within centimeters of the point of entrainment. This may be true in shallow, small inlets with relatively low levels of bacteria in the sediments and small-scale disturbance phenomena. In large estuaries with massive sources of coliforms and high-magnitude disturbance forces (dredging, filling, storms, etc.), this may not be the case. There may be a relationship between the levels of FC and the amount of sediment in the water column.

Autumn Storm Event - Minter Watershed

Bacteriological samples were collected during the fall dry period at 27 locations in the Minter watershed. These samples showed several stream sections with elevated FC levels. Concentrations of fecal coliforms in Minter Creek between M 0.7 and M 1.7 were about 50 col/100 mL (see Table 6). Densities were much lower above and below this stretch. Small farms with horse pastures occupy most of the land along the one-mile stretch.

The highest fecal count found during the dry-period survey was at M 4.2 on Minter Creek (110 FC/100 mL). This area is currently under investigation. The two sampling sites downstream of M 4.2 had relatively high counts: 46 FC/100 mL at M 3.7 and 31 FC/100 mL at M 2.8. Long-term loading upstream may have transported fecal coliform bacteria populations down to the latter stretch. Residential and hobby farm operations occur from M 4.2 to about M 3.6. There is a sand and gravel business at M 3.6 and an extensive bog from here to M 2.8.

There were somewhat increased FC counts in October at the upper end of Unnamed Creek at UN 1.8 and UN 2.0 (see Table 6). A dairy operation lies just above the residential area there.

Huge Creek had relatively high FC concentrations at H 2.5 (Table 6). Most of the land upstream is undeveloped forest with some clearing for future residential development, some non-grazed pasture, and flatland bogs.

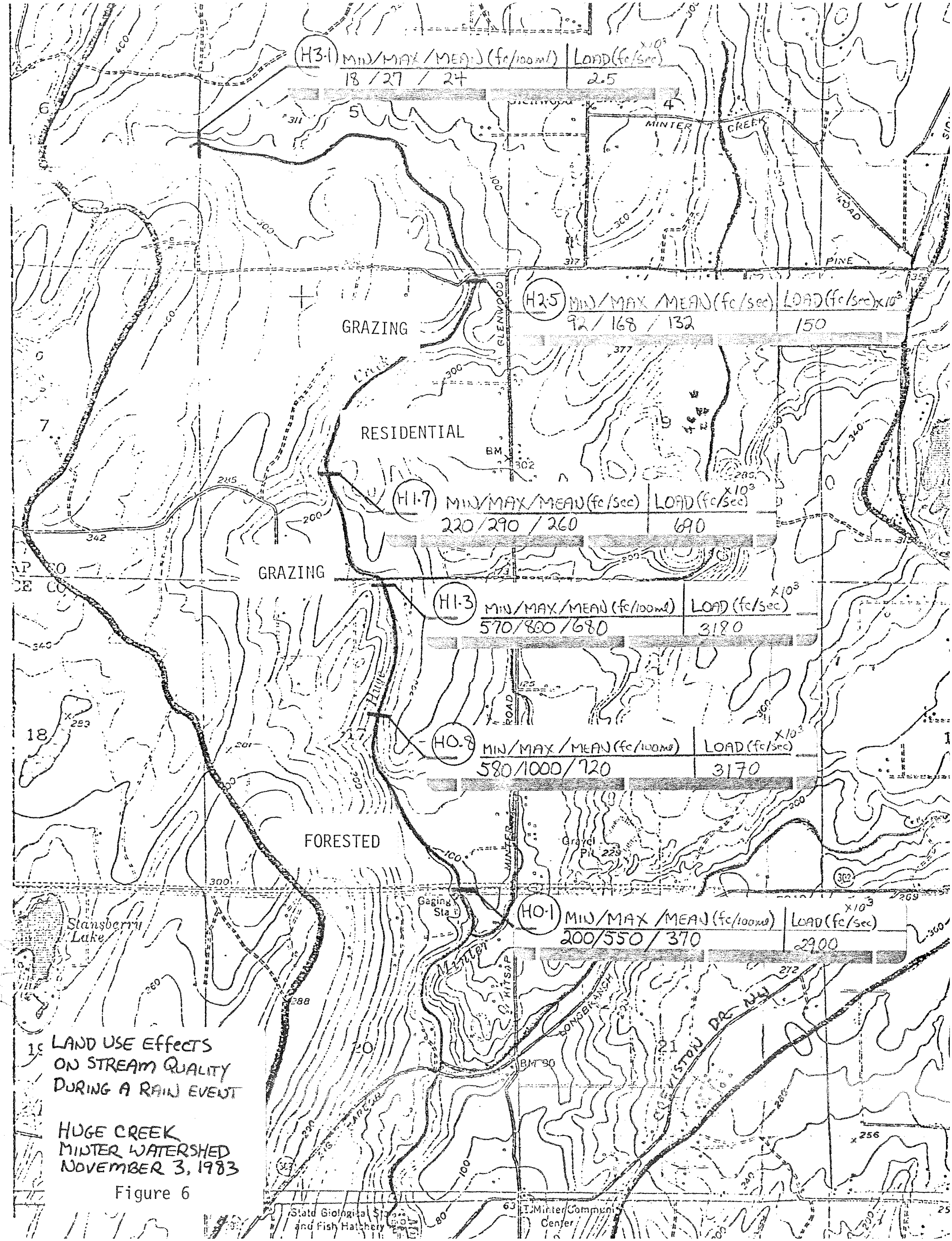
Additional samples were collected on November 3, 1983 during heavy rainfall at 24 of the dry-weather sites (Table 6, Figures 6, 7, and 8). Two new sites were added for a total of 26 stations. Stream flows were determined at most sites to calculate FC loadings. The mean of three samples taken during the day indicated elevated counts at the same places as the dry sampling. Fecal loading calculations also give evidence for storm runoff contamination problems at these sites.

On Huge Creek, an additional area of higher fecal coliform density and loading occurred between H 1.7 and H 1.3. Loading in this 0.4-mile stretch increased 5-1/2 times the immediately upstream value. The surrounding land is used mainly for cattle grazing, small farms, and residential uses.

Soil, waste, and water flow characteristics have major influences on bacterial transport in a rural watershed. Areas where comparatively high FC levels occur under very different environmental and flow conditions would therefore indicate system loading points.

Groundwater Studies

A preliminary study of groundwater discharge and fecal coliform loadings has been carried out in Minter Bay. Stream flow was measured with a



LAND USE Effects ON STREAM QUALITY DURING A RAIN EVENT

HUGE CREEK
MINTER WATERSHED
NOVEMBER 3, 1983

Figure 6

UN3.0	MIN/MAX/MEAN(fc/100ml)	LOAD (fc/sec) x10^3
	3500/6000/4555	N/A

UN2.0	MIN/MAX/MEAN(fc/100ml)	LOAD(fc/sec) x10^3
	1133/2200/1597	3140

UN1.8	MIN/MAX/MEAN(fc/100ml)	LOAD(fc/sec) x10^3
	1433/2300/1788	2090

UN1.0	MIN/MAX/MEAN(fc/100ml)	LOAD (fc/sec) x10^3
	578/1217/899	1690

UN0.4	MIN/MAX/MEAN(fc/100ml)	LOAD(fc/sec) x10^3
	933/1400/1105	3610.

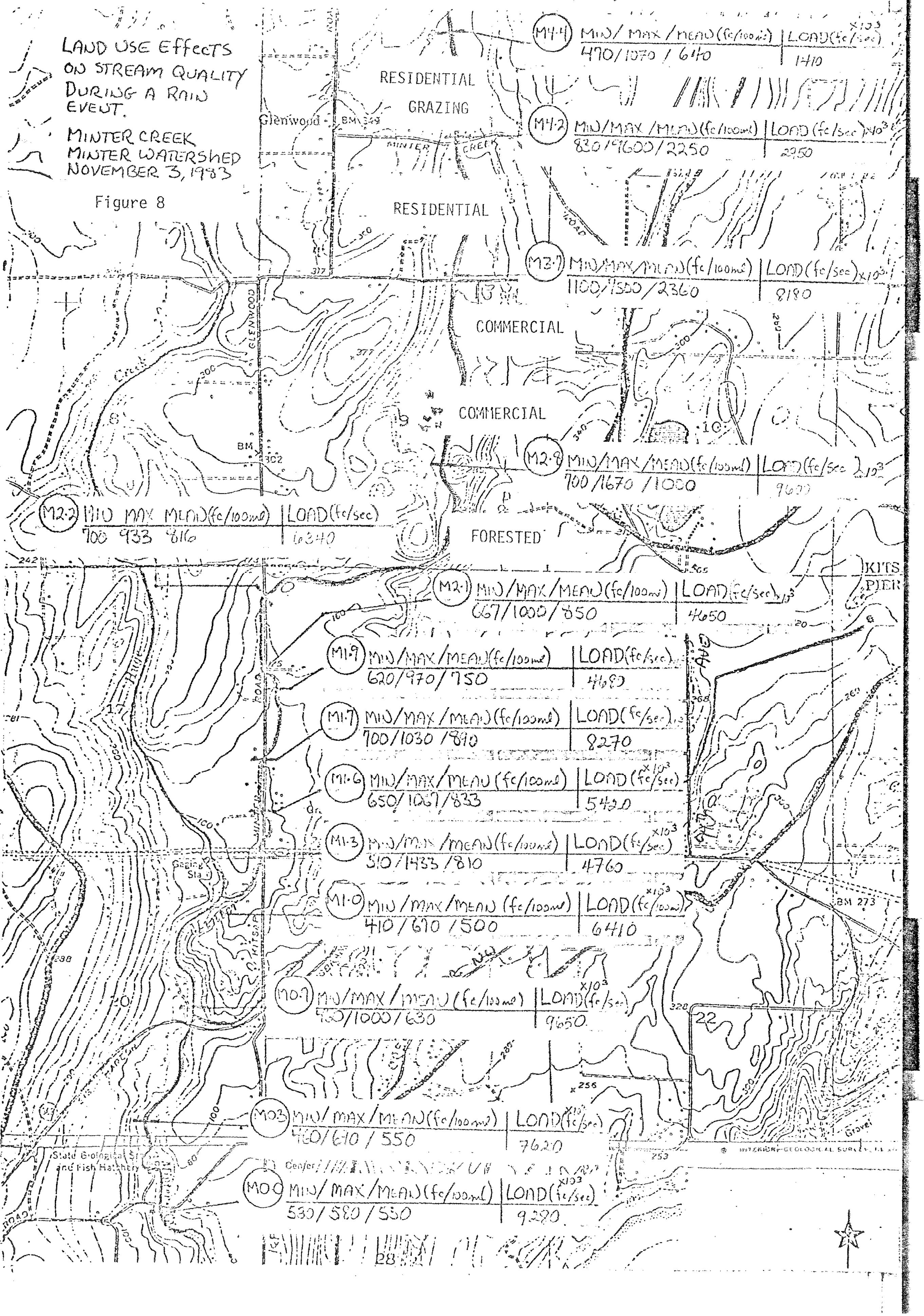
UN0.3	MIN/MAX/MEAN(fc/100ml)	LOAD(fc/sec) x10^3
	867/1800/1185	4130

UN0.0	MIN/MAX/MEAN(fc/100ml)	LOAD(fc/sec) x10^3
	500/1567/778	2190

LAND USE EFFECTS ON STREAM QUALITY DURING A RAIN EVENT

UNNAMED CREEK
MINTER WATERSHED
NOVEMBER 3, 1983

Figure 7



LAND USE Effects ON STREAM QUALITY DURING A RAIN EVENT.
MINTER CREEK
MINTER WATERSHED
NOVEMBER 3, 1983

Figure 8

Marsh-McBirney flow meter and samples for FC and salinity were taken for later laboratory analysis. The study was performed during low tide when Minter Bay is typically free of saltwater. During these times, Minter Creek flows through Minter Bay within a well-defined channel. The amount of groundwater contributed within an arbitrarily bounded segment of Minter Bay was estimated by determining the difference in stream flows at the upstream and downstream segment boundaries. The study was conducted during an extended dry period so that contribution from surface sources was minimal or nonexistent. Duplicate fecal coliform samples were taken to calculate loads within each bounded segment. Salinity samples were taken to assure that added stream flow was derived from groundwaters rather than release of saltwater from Minter Bay sediments during the time of exposure. Salinity values ranged from 0.2 parts per thousand (ppt) at transect 1 to 6.5 ppt at transect 5. Results are shown on Table 7. Groundwater flows were very low within Segments A and B and increased greatly downstream. The greatest contribution of fecal coliform loads occurred in Segment C. These loads were diluted by rather high groundwater flows in Segments D and E.

Closing Remarks

A final rain-event sampling is planned in December for the Burley watershed, similar to the previously mentioned scheme carried out at Minter. The last routine monitoring will also take place in December.

The summary report will cover the interim report topics in more detail as well as others which have not yet been addressed in those reports (i.e., role of water chemistry and rainfall in FC dynamics). This report should present more conclusive evidence for the probable causes and remedies for fecal coliform contamination.

TD:BC:cp

Attachments

Table 6. Fecal coliform concentrations (FC/100 mL) during dry period (October 4-5, 1983) and storm event (November 3, 1983). Dry period values are the mean of two samples. Storm event values are the mean of three samples.

Station	Dry Period	Storm Event
M 0.0	8	550
M 0.3	20	550
M 0.7	50	630
M 1.0	--	500
M 1.3	51	810
M 1.6	44	830
M 1.7	51	890
M 1.9	8	750
M 2.1	5	850
M 2.2	9	820
M 2.8	31	1000
M 3.7	46	2360
M 4.2	110	2250
M 4.4	7	640
H 0.1	3	370
H 0.7	9	--
H 0.8	--	720
H 1.3	12	680
H 1.7	3	260
H 2.5	21	130
H 3.1	1	24
UN 0.1	7	780
UN 0.3	13	1190
UN 0.4	6	1100
UN 1.0	18	900
UN 1.8	30	1790
UN 2.0	45	1600

Table 5. Summary of data and ANOVA analysis from a study of fecal coliform entrainment from disturbed sediments in Minter Bay (station MES) on September 9, 1983.

	Experiments		
	Upstream Site; Sediments Undisturbed (FC/100 mL)	Downstream Site; Sediments Undisturbed (FC/100 mL)	Downstream Site; Sediments Undisturbed (FC/100 mL)
Arithmetic average	46.5	49.5	61.6
Mean of logs of data (P)	1.66	1.68	1.79
Standard deviation (S)	.07	.14	.09
Number of samples (n)	8	8	8

ANOVA Table

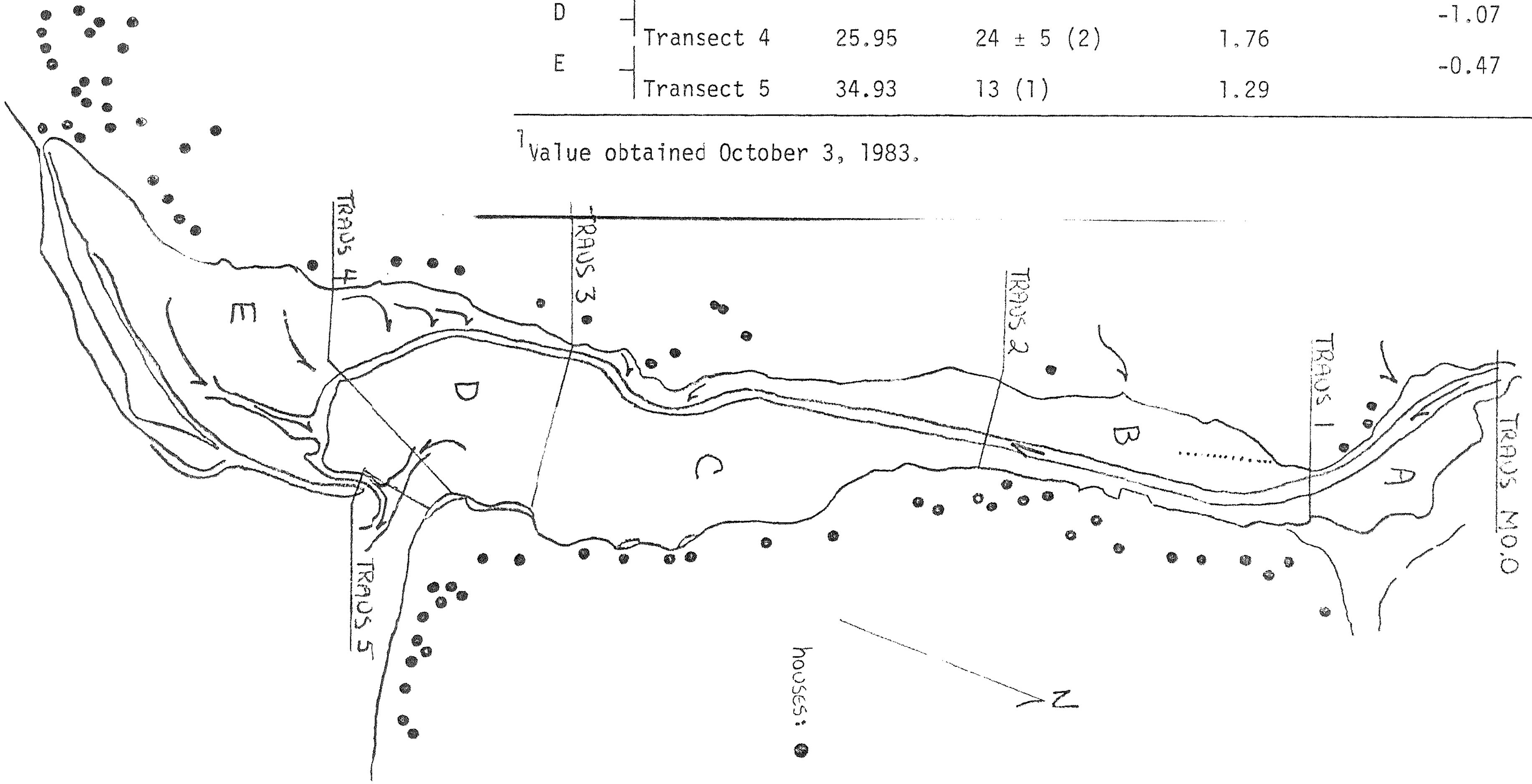
Source of Variation	df	SS	MS	F_s
Between experiments	2	.07	.035	2.92[1]
Within sample set	21	.26	.012	
Total	23	.33		

[1] $F_{.05[2,7]} = 4.74$ (Rohlf and Sokal, 1969); therefore no significant difference among means

Table 7. Groundwater budget and fecal coliform (FC) loadings through several segments of Minter Bay on October 6, 1983.

Segment	Station	Streamflow (ft^3/sec)	Average (FC/100 mL) $\overline{X} \pm S$ (n)	FC Load (FC/sec x 10^5)	Load Share from Each Segment (FC/sec x 10^5)
	M 0.0	21.46	13 ± 4 (2)[1]	0.79	
A					0.67
	Transect 1	21.51	24 ± 1 (2)	1.46	
B					0.49
	Transect 2	21.54	32 ± 5 (2)	1.95	
C					0.88
	Transect 3	23.23	43 ± 20 (2)	2.83	
D					-1.07
	Transect 4	25.95	24 ± 5 (2)	1.76	
E					-0.47
	Transect 5	34.93	13 (1)	1.29	

[1] Value obtained October 3, 1983.



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