

TECHNICAL REPORT

**Water Quality Study Along the Lake Huron Shoreline
Between Canatara Beach and Brights Grove**

By:

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INTRODUCTION

A water quality study was undertaken during the summer of 1990 in the nearshore area along the Lake Huron shoreline between Canatara Beach and Brights Grove (Figure 1). The purpose of the study was to determine possible sources of bacterial contamination which were responsible for numerous beach closures in 1989. This study was undertaken at the request of the Abatement Section, Sarnia District office, who have received queries from the Lambton County Health Unit, Municipal Officials and the local media as to the sources of the bacterial contamination.

The study was designed to investigate potential sources such as municipal storm drains, septic tank systems (direct/indirect discharges), the seasonal lagoon discharge from Brights Grove and agricultural runoff inputs.

Sampling locations were established at various access points along the 14 kilometres of shoreline between Canatara Beach and Brights Grove (Figure 2). Two surface water tributaries flow into Lake Huron within this reach; Pulse Creek and Perch Creek. Perch Creek receives the seasonal discharge from the Brights Grove lagoons.

The entire area is used for water use activities including swimming, boating and wind surfing. Two main beaches are the Canatara and the Brights Grove beaches. Owing to restricted access along this reach, smaller public beach areas exist at public access points such as at the ends of major roads (Murphy, Modeland, etc.).

METHODS

Water samples were collected from each of the sampling locations shown on Figure 2. Samples were collected just below the surface in approximately one metre (depth) of water.



Figure 1: Location map indicating the study area.

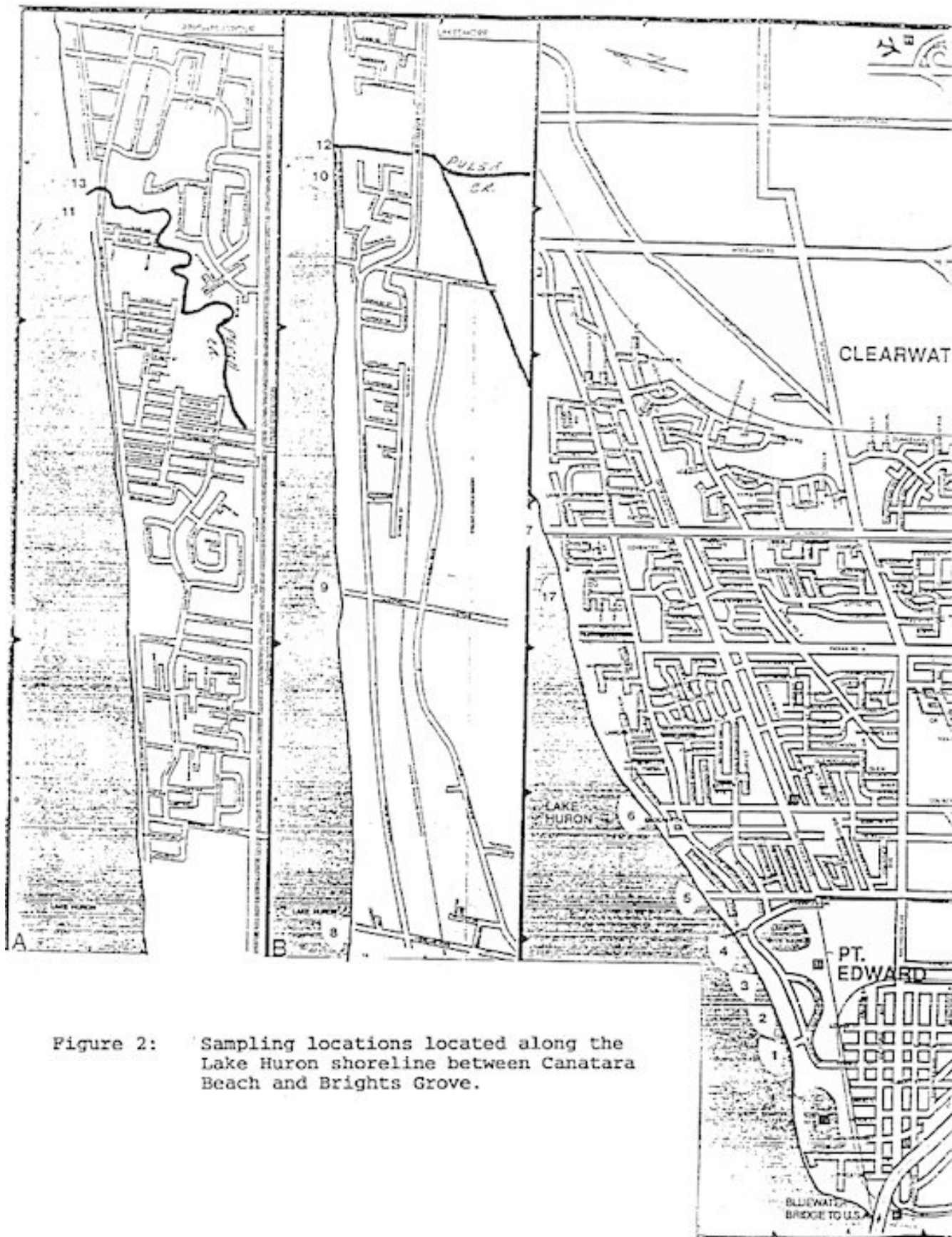


Figure 2: Sampling locations located along the Lake Huron shoreline between Canatara Beach and Brights Grove.

Additional water samples were collected from any storm drains known to be within the study area.

Water samples were submitted to our London laboratory for chemical and bacterial analyses. Chemical analyses included biochemical oxygen demand (BOD), suspended solids, free ammonia, total Kjeldahl, nitrate, nitrite, total phosphorus, soluble phosphorus, pH and conductivity. Bacterial analyses included total coliforms, fecal coliforms, fecal streptococci, *Pseudomonas aeruginosa* and *Escherichia coli* (*E. coli*).

Sediment samples were collected from each of the sampling locations (Figure 2). Samples were collected at a depth of approximately one metre. These samples were submitted to our London laboratory for bacterial analyses which included fecal coliforms, fecal streptococci, *E. coli* and *P. aeruginosa*.

Both sediment and water isolates of *Pseudomonas aeruginosa* were serotyped and pyocin typed in an attempt to trace certain isolates from one station to another. This approach was used for source identification.

In addition, water temperature readings were recorded every time a water sample was collected. Field notes were also kept on weather conditions prior to and on the day of sampling.

Routine water sampling was also carried out by the Lambton County Health Unit during the summer months (June, July and August). The Health Unit sampled the two main beaches within the study area; Canatara Beach and the beach at Brights Grove. Their sampling was done weekly and consisted of five sites at the Canatara Beach and five sites at Brights Grove. Samples were analyzed for fecal coliforms only. If the geometric mean value for the five samples exceeded 100 per 100 ml, a second round of samples were collected immediately. If the geometric mean value for the second round of samples still exceeded 100 per 100 ml then the beach was posted.

RESULTS

Field data pertaining to water temperatures and the weather conditions are summarized in Appendix A.

Bacterial results for the water samples are summarized in Table 1. A total of nine sampling runs were carried out between March 28 and August 28, 1990. The first two sampling runs were carried out prior to the discharge of the Brights Grove lagoons which discharged to Perch Creek between April 9 and 13, 1990. The Brights Grove lagoons consist of a three cell facultative lagoon system with a capacity of 2,020 cubic metres per day.

Each cell is approximately 6 hectares in size with a depth of 1.5 metres. The lagoons discharge twice a year (Spring and Fall).

From a bacterial standpoint, water is considered to be impaired (swimming and bathing use) when the total coliform geometric mean density for a series of water samples exceeds 1000 per 100 ml. A potential health hazard exists if the fecal coliform geometric mean density for a series of water samples exceeds 100 per 100 ml or when pathogenic organisms such as *Pseudomonas aeruginosa* can be frequently isolated.

The results specifically pertaining to Canatara Beach (stations 1 to 4) did not reveal any elevated counts of coliform bacteria during the months of March through to July. The two sampling runs carried out in August did however reveal slightly elevated counts of fecal coliforms, ranging as high as 288 per 100 ml. The presence of *Pseudomonas aeruginosa* was documented on two occasions; at two locations on July 23, 1990, at one location on August 28, 1990.

Results for stations 5 through 9, representing the area from Christina Street to Blackwell Street, were generally acceptable with the exception of the August 28, 1990 sample results. Fecal coliform levels on that day exceeded 100 per 100 ml at all sites except at Baxter Beach (Station 6). This sampling followed a rainfall event the previous

TABLE 1: Canatara Beach Study 1990 - Water Bacteria Data**STATION: 1****DESCRIPTION: CANATARA BEACH, WEST**

DATE	Total Coliforms	Fecal Coliforms	Fecal Strep.	Pseudo. Aer.	E. Coli
03/28/90	L10	L4	L4	L4	L4
04/09/90	L4	L4	L4	L4	L4
04/23/90	4.0	L4	8.0	L4	L4
05/14/90	24.0	L4	8.0	L4	L4
06/18/90	32.0	L4	4.0	L4	L4
07/16/90	16.0	4.0	L4	L4	L4
07/23/90	A50	16.0	28.0	32.0	16.0
08/14/90	C136	120.0	60.0	L4	96.0
08/28/90	140.0	220.0	112.0	8.0	164.0

STATION: 2**DESCRIPTION: CANATARA BEACH, MIDWEST**

DATE	Total Coliforms	Fecal Coliforms	Fecal Strep.	Pseudo. Aer.	E. Coli
03/28/90	L10	L10	L10	L4	L10
04/09/90	L4	L4	L4	L4	L4
04/23/90	8.0	L4	8.0	L4	L4
05/14/90	12.0	L4	L4	L4	L4
06/18/90	16.0	L4	4.0	L4	L4
07/16/90	12.0	4.0	44.0	L4	L4
07/23/90	100.0	20.0	104.0	L4	4.0
08/14/90	C172	124.0	28.0	L4	124.0
08/28/90	C340	288.0	196.0	L4	288.0

STATION: 3**DESCRIPTION: CANATARA BEACH, MIDEAST**

DATE	Total Coliforms	Fecal Coliforms	Fecal Strep.	Pseudo. Aer.	E. Coli
03/28/90	L10	L10	L10	L4	L10
04/09/90	L4	L4	L4	L4	L4
04/23/90	L4	L4	12.0	L4	L4
05/14/90	12.0	L4	4.0	L4	L4
06/18/90	L4	L4	L4	L4	L4
07/16/90	8.0	8.0	4.0	L4	8.0
07/23/90	A30	28.0	24.0	L4	20.0
08/14/90	C128	120.0	88.0	L4	84.0
08/28/90	C150	196.0	156.0	L4	68.0

STATION: 4**DESCRIPTION: CANATARA BEACH, EAST**

DATE	Total Coliforms	Fecal Coliforms	Fecal Strep.	Pseudo. Aer.	E. coli
03/28/90	L10	L10	L10	L4	L10
04/09/90	L4	L4	4.0	L4	L4
04/23/90	8.0	L4	16.0	L4	L4
05/14/90	12.0	L4	L4	L4	L4
06/18/90	4.0	8.0	4.0	L4	L4
07/16/90	16.0	8.0	8.0	L4	4.0
07/23/90	A60	28.0	44.0	20.0	20.0
08/14/90	C104	56.0	68.0	L4	56.0
08/28/90	C250	188.0	108.0	L4	136.0

STATION: 5**DESCRIPTION: CHRISTINA STREET**

DATE	Total Coliforms	Fecal Coliforms	Fecal Strep.	Pseudo. Aer.	E. coli
03/28/90	L10	L10	L10	L4	L10
04/09/90	L4	L4	L4	L4	L4
04/23/90	L4	L4	28.0	L4	L4
05/14/90	12.0	4.0	8.0	L4	L4
06/18/90	C308	88.0	96.0	L4	88.0
07/16/90	L10	4.0	8.0	L4	L4
07/23/90	A50	16.0	20.0	L4	16.0
08/14/90	C100	48.0	44.0	L4	48.0
08/28/90	C120	244.0	92.0	4.0	88.0

STATION: 6**DESCRIPTION: BAXTER BEACH**

DATE	Total Coliforms	Fecal Coliforms	Fecal Strep.	Pseudo. Aer.	E. coli
03/28/90	L10	L10	L10	L4	L10
04/09/90	L4	L4	L4	L4	L4
04/23/90	L4	L4	4.0	L4	L4
05/14/90	12.0	L4	L4	L4	L4
06/18/90	C24	20.0	28.0	L4	20.0
07/16/90	L4	L4	L4	L4	L4
07/23/90	A60	28.0	44.0	L4	16.0
08/14/90	C92	64.0	60.0	L4	64.0
08/28/90	C90	92.0	120.0	4.0	72.0

STATION: 7
DESCRIPTION: MURPHY ROAD

DATE	Total Coliforms	Fecal Coliforms	Fecal Strep.	Pseudo. Aer.	E. coli
03/28/90	L10	L10	L10	L4	L10
04/09/90	L4	L4	8.0	L4	L4
04/23/90	12.0	L4	8.0	L4	L4
05/14/90	20.0	L4	4.0	L4	L4
06/18/90	A600	132.0	136.0	L4	96.0
07/16/90	L10	L4	L4	L4	L4
07/23/90	A50	12.0	8.0	L4	12.0
08/14/90	C88	44.0	28.0	L4	32.0
08/28/90	C130	116.0	172.0	L4	56.0

STATION: 8
DESCRIPTION: END OF MODELAND

DATE	Total Coliforms	Fecal Coliforms	Fecal Strep.	Pseudo. Aer.	E. coli
03/28/90	L10	L10	L10	L4	L10
04/09/90	L4	L4	L4	L4	L4
04/23/90	36.0	L4	L4	L4	L4
05/14/90	L4	L4	L4	L4	L4
06/18/90	36.0	8.0	20.0	L4	4.0
07/16/90	L4	8.0	L4	L4	L4
07/23/90	L10	L4	L4	L4	L4
08/14/90	C60	12.0	12.0	L4	12.0
08/28/90	C150	124.0	220.0	8.0	56.0

STATION: 9
DESCRIPTION: BLACKWELL STREET

DATE	Total Coliforms	Fecal Coliforms	Fecal Strep.	Pseudo. Aer.	E. coli
03/28/90	A30	L10	L10	L4	L10
04/09/90	L4	L4	L4	L4	L4
04/23/90	140.0	4.0	4.0	L4	L4
05/14/90	4.0	L4	L4	L4	L4
06/18/90	A60	24.0	24.0	L4	16.0
07/16/90	4.0	4.0	4.0	L4	4.0
07/23/90	110.0	40.0	24.0	4.0	8.0
08/14/90	C110	48.0	28.0	L4	44.0
08/28/90	C280	224.0	190.0	L4	108.0

STATION: 10**DESCRIPTION: PULSE CREEK, WEST**

DATE	Total Coliforms	Fecal Coliforms	Fecal Strep.	Pseudo. Aer.	E. coli
03/28/90	1000.0	A20	L10	L4	A20
04/09/90	184.0	L4	L4	L4	L4
04/23/90	1800.0	4.0	L4	L4	L4
05/14/90	2100.0	12.0	12.0	4.0	4.0
06/18/90	A60	52.0	52.0	L4	52.0
07/16/90	C 44	4.0	4.0	L4	L4
07/23/90	1800.0	180.0	260.0	L4	100.0
08/14/90	5300.0	280.0	130.0	L4	220.0
08/28/90	C540	420.0	500.0	24.0	220.0

STATION: 11**DESCRIPTION: PERCH CREEK, WEST**

DATE	Total Coliforms	Fecal Coliforms	Fecal Strep.	Pseudo. Aer.	E. coli
03/28/90	10.0	L10	L10	L4	L10
04/09/90	16.0	L4	L4	L4	L4
04/23/90	216.0	4.0	L4	L4	L4
05/14/90	A600	12.0	8.0	L4	4.0
06/18/90	A50	L4	4.0	L4	L4
07/16/90	L4	L4	24.0	L4	L4
07/23/90	150.0	24.0	20.0	L4	16.0
08/14/90	C80	32.0	12.0	L4	24.0
08/28/90	C600	400.0	650.0	100.0	330.0

STATION: 12**DESCRIPTION: PULSE CREEK MOUTH**

DATE	Total Coliforms	Fecal Coliforms	Fecal Strep.	Pseudo. Aer.	E. coli
03/28/90	--	--	--	--	--
04/09/90	4700.0	130.0	A70	L4	A60
04/23/90	A6000	210.0	110.0	L4	A80
05/14/90	10000.0	280.0	340.0	112.0	250.0
06/18/90	A300	A70	120.0	L4	L10
07/16/90	C2800	430.0	1200.0	C60	310.0
07/23/90	4000.0	310.0	300.0	L4	270.0
08/14/90	14000.0	1200.0	110.0	20.0	A100
08/28/90	C2200	670.0	76.0	L4	670.0

STATION: 13**DESCRIPTION: PERCH CREEK, MOUTH**

DATE	Total Coliforms	Fecal Coliforms	Fecal Strep.	Pseudo. Aer.	E. coli
03/28/90	--	--	--	--	--
04/09/90	18000.0	A60	A30	L4	A60
04/23/90	A8000	68.0	52.0	L4	48.0
05/14/90	1000.0	540.0	430.0	12.0	540.0
06/18/90	2100.0	660.0	130.0	12.0	560.0
07/16/90	2200.0	2200.0	1200.0	L4	1100.0
07/23/90	4900.0	1200.0	GI500	8.0	1200.0
08/14/90	1200.0	A800	1000.0	L4	A800
08/28/90	C4200	2100.0	L10	16.0	2100.0

STATION: 17**DESCRIPTION: MILLS STREET STORM SEWER**

DATE	Total Coliforms	Fecal Coliforms	Fecal Strep.	Pseudo. Aer.	E. coli
03/28/90	--	--	--	--	--
04/09/90	100.0	L4	L4	L4	L4
04/23/90	--	--	--	--	--
05/14/90	1600.0	110.0	92.0	4.0	110.0
06/18/90	C59000	8700.0	G240000	C132	7700.0
07/16/90	C 132	48.0	140.0	L4	48.0
07/23/90	A40	L10	A30	L4	L10
08/14/90	C100	A70	52.0	L4	A30
08/28/90	C140	72.0	132.0	L4	52.0

C = Approx. Count Obtained From An Analysis With Total Count

G = Actual Count Is Greater Than Reported

A = Approximate Count, Too Few Colonies

L = Less Than

Fecal Strep. - Fecal Streptococci

Pseudo. Aer. - Pseudomonas Aeruginosa

E. Coli - Escherichia Coli

EXTRA STATIONS

STATION: 14

DESCRIPTION: 8" PIPE OF CORRUGATED, PERFORATED STEEL

DATE	Total Coliforms	Fecal Coliforms	Fecal Strep.	Pseudo. Aer.	E. coli
04/09/90	L4	L4	L4	L4	L4

STATION: 16

DESCRIPTION: MURPHY DRAIN PIPE, 16"

DATE	Total Coliforms	Fecal Coliforms	Fecal Strep.	Pseudo. Aer.	E. coli
04/09/90	L4	L4	L4	L4	L4

STATION: 18

DESCRIPTION: 18" STORM DRAIN AT BREAKWALL

DATE	Total Coliforms	Fecal Coliforms	Fecal Strep.	Pseudo. Aer.	E. coli
04/09/90	16.0	4.0	L4	L4	60.0

L = LESS THAN

Fecal Strep. - Fecal Streptococci
Pseudo. Aer. - Pseudomonas Aeruginosa
E. Coli - Escherichia Coli

evening and there were strong winds and waves during the sampling.

Stations 10 through 13 represent the Pulse Creek and Perch Creek discharge areas. Bacterial results were generally poorer at the creek mouths and consequently the adjacent Lake Huron beach areas. Total coliforms were elevated above 1000 per 100 ml on several occasions more often at the creek mouths. The same scenario existed for counts of fecal coliforms. *Pseudomonas aeruginosa* was documented on several occasions.

A total of four storm water discharges were located and sampled on April 9, 1990. Results were all extremely low therefore no further sampling was carried out with the exception of the Mills Street storm sewer (Station 17). Further sampling at this location revealed periodically elevated levels of both total and fecal coliforms. *Pseudomonas aeruginosa* was also documented on two occasions.

Fecal coliform results for Canatara Beach and the Brights Grove Beach, which were reported by the Lambton Health Unit, are summarized in Table 2. Neither beach was posted during the summer of 1990. Canatara Beach was re-sampled on two occasions due to a high fecal coliform counts while the Brights Grove Beach was re-sampled on four occasions.

The sediment bacterial data are summarized in Table 3. Analyzing sediments for bacteria is a relatively new technique and is carried out in order to determine if bacteria are being resuspended and contributing to elevated water counts. There are no guidelines or objectives which pertain to sediment data.

A total of four sediment sampling runs were carried out between March 28 and July 23, 1990. The first run (March 28, 1990) was completed prior to the discharge of the Brights Grove lagoons in order to determine if the eventual discharge was impacting on the Lake Huron beaches.

TABLE 2: Fecal Coliform Counts For Canatara Beach And Brights Grove As Reported By The Lambton Health Unit- 1990.

A) CANATARA BEACH

DATE/90	STN.1	STN.2	STN.3	STN.4	STN.5	G.M.
06/05	10.0	10.0	10.0	10.0	10.0	10.0
06/11	20.0	30.0	20.0	20.0	20.0	21.7
06/18	20.0	50.0	10.0	10.0	20.0	18.2
06/25	70.0	80.0	70.0	60.0	150.0	81.2
07/03	10.0	30.0	50.0	10.0	10.0	17.2
07/09	70.0	40.0	90.0	60.0	80.0	65.5
07/16	10.0	10.0	30.0	20.0	80.0	21.7
07/23	90.0	50.0	80.0	180.0	60.0	82.8
07/30	10.0	60.0	20.0	10.0	150.0	28.3
08/07	260.0	600.0	90.0	390.0	320.0	281.0
08/09*	130.0	100.0	90.0	10.0	30.0	51.2
08/13	40.0	170.0	100.0	90.0	100.0	90.6
08/20	380.0	380.0	480.0	440.0	500.0	433.2
08/22*	180.0	200.0	100.0	70.0	200.0	138.2
08/27	20.0	50.0	20.0	10.0	20.0	20.9

B) BRIGHTS GROVE

DATE/90	STN.1	STN.2	STN.3	STN.4	STN.5	G.M.
06/05	140.0	40.0	10.0	10.0	10.0	22.4
06/11	250.0	220.0	180.0	280.0	110.0	198.1
06/13*	10.0	10.0	10.0	10.0	10.0	10.0
06/18	20.0	30.0	60.0	20.0	40.0	31.0
06/25	370.0	520.0	560.0	470.0	410.0	460.7
06/28*	70.0	120.0	10.0	40.0	50.0	44.2
07/03	20.0	10.0	10.0	20.0	10.0	13.2
07/09	390.0	480.0	200.0	150.0	120.0	232.1
07/11*	10.0	10.0	50.0	20.0	20.0	18.2
07/16	30.0	10.0	10.0	10.0	10.0	12.5
07/23	60.0	20.0	30.0	10.0	20.0	23.5
07/30	100.0	40.0	130.0	600.0	600.0	179.7
08/01*	100.0	90.0	70.0	80.0	30.0	68.5
08/07	30.0	30.0	60.0	70.0	40.0	43.2
08/13	600.0	200.0	180.0	150.0	220.0	234.7
08/20	50.0	140.0	60.0	140.0	110.0	91.7
08/27	60.0	10.0	10.0	60.0	30.0	25.5

G.M. - GEOMETRIC MEAN

* - RESAMPLE

TABLE 3: Canatara Beach Study 1990 - Sediment Bacteria.

STATION: 1

LOCATION: CANATARA BEACH, WEST

DATE	Fecal Coliforms	Fecal Strep.	E. Coli	Pseudo. Aer.
03/28/90	40	L 40	40	--
04/23/90	L 40	L 40	L 40	N.D.
06/18/90	--	--	--	N.D.
07/23/90	L 40	--	L 40	L 40

STATION: 2

LOCATION: CANATARA BEACH, MIDWEST

DATE	Fecal Coliforms	Fecal Strep.	E. Coli	Pseudo. Aer.
03/28/90	L 40	L 40	L 40	--
04/23/90	L 40	L 40	L 40	N.D.
06/18/90	40	40	40	N.D.
07/23/90	L 40	--	L 40	L 40

STATION: 3

LOCATION: CANATARA BEACH, MIDEAST

DATE	Fecal Coliforms	Fecal Strep.	E. Coli	Pseudo. Aer.
03/28/90	L 40	L 40	L 40	--
04/23/90	L 40	L 40	L 40	N.D.
06/18/90	40	340	40	N.D.
07/23/90	260	--	260	L 40

STATION: 4

LOCATION: CANATARA BEACH, EAST

DATE	Fecal Coliforms	Fecal Strep.	E. Coli	Pseudo. Aer.
03/28/90	--	--	--	--
04/23/90	L 40	L 40	L 40	N.D.
06/18/90	--	--	--	N.D.
07/23/90	1000	--	1000	L 40

STATION: 5

LOCATION: CHRISTINA STREET

DATE	Fecal Coliforms	Fecal Strep.	E. Coli	Pseudo. Aer.
03/28/90	L 40	L 40	L 40	--
04/23/90	L 40	L 40	L 40	N.D.
06/18/90	260	L 40	160	N.D.
07/23/90	80	--	80	40

STATION: 6

LOCATION: BAXTER BEACH

DATE	Fecal Coliforms	Fecal Strep.	E. Coli	Pseudo. Aer.
03/28/90	L 40	L 40	L 40	--
04/23/90	L 40	L 40	L 40	N.D.
06/18/90	L 40	40	L 40	N.D.
07/23/90	600	--	600	L 40

STATION: 7

LOCATION: MURPHY ROAD

DATE	Fecal Coliforms	Fecal Strep.	E. Coli	Pseudo. Aer.
03/28/90	L 40	L 40	L 40	--
04/23/90	220	L 40	220	N.D.
06/18/90	180	40	180	N.D.
07/23/90	160	--	160	140

STATION: 8

LOCATION: MODELAND ROAD

DATE	Fecal Coliforms	Fecal Strep.	E. Coli	Pseudo. Aer.
03/28/90	L 40	L 40	L 40	--
04/23/90	L 40	L 40	40	N.D.
06/18/90	L 40	40	L 40	N.D.
07/23/90	80	--	80	40

STATION: 9

LOCATION: END OF BLACKWELL ROAD

DATE	Fecal Coliforms	Fecal Strep.	E. Coli	Pseudo. Aer.
03/28/90	L 40	L 40	L 40	--
04/23/90	L 40	L 40	L 40	N.D.
06/18/90	40	L 40	40	N.D.
07/23/90	80	--	40	40

STATION: 10

LOCATION: PULSE CREEK, WEST

DATE	Fecal Coliforms	Fecal Strep.	E. Coli	Pseudo. Aer.
03/28/90	L 40	L 40	L 40	--
04/23/90	L 40	40	L 40	N.D.
06/18/90	220	80	220	N.D.
07/23/90	220	--	140	40

STATION: 11

LOCATION: PERCH CREEK, WEST

DATE	Fecal Coliforms	Fecal Strep.	E. Coli	Pseudo. Aer.
03/28/90	L 40	L 40	L 40	--
04/23/90	L 40	40	L 40	N.D.
06/18/90	L 40	L 40	L 40	N.D.
07/23/90	40	--	L 40	40

STATION: 12

LOCATION: PULSE CREEK MOUTH

DATE	Fecal Coliforms	Fecal Strep.	E. Coli	Pseudo. Aer.
03/28/90	--	--	--	---
04/23/90	6000	1624	6000	--
06/18/90	1800	4800	1800	PRESENT
07/23/90	6000	--	3400	440

STATION: 13

LOCATION: PERCH CREEK MOUTH

DATE	Fecal Coliforms	Fecal Strep.	E. Coli	Pseudo. Aer.
03/28/90	--	--	--	--
04/23/90	4800	1000	4800	--
06/18/90	32000	32000	32000	PRESENT
07/23/90	7000	--	7000	280

STATION: 17

LOCATION: MILLS STREET STORM SEWER

DATE	Fecal Coliforms	Fecal Strep.	E. Coli	Pseudo. Aer.
03/28/90	--	--	--	--
04/23/90	--	--	--	--
06/18/90	220	140	220	N.D.
07/23/90	80	--	80	40

LEGEND

- - No Sample
- Fecal Strep. - Fecal Streptococci
- E. Coli - Escherichia Coli
- Pseudo. Aer. - Pseudomonas Aeruginosa
- N.D. - Not Detected
- L - Less Than

The results generated from the first three sampling runs were generally low at all stations except for the Perch and Pulse Creek mouths. The last sampling run (July 23, 1990) revealed higher counts at most stations.

Table 4 summarizes the additional bacteriological work carried out on isolates of *Pseudomonas aeruginosa* for both water and sediments. Each isolate of *Pseudomonas aeruginosa*, identified as such, was serotyped in order that isolates from specific locations could be identified and possibly traced. Due to the frequency of serotype 6 occurring, pyocin typing was also carried out. This procedure simply further subdivides the serotypes.

The data revealed firstly that there were only a few occurrences of *Pseudomonas aeruginosa* at Canatara Beach during the entire study, which automatically limits this approach of source identification. The variety of serotypes and pyocin types identified indicate a mixture of both human and animal contributions. Secondly, migration of fecal wastes from the sources (i.e. Brights Grove lagoons or creek mouths) does not appear to be occurring because the serotypes and pyocin types show up as unique (to that site). For example, a serotype or pyocin type identified at one site might have migrated with the lake currents, that is along the shoreline, however this does not appear to be occurring as there are no types being found which are common to other sites.

Water chemistry results are summarized in Table 5. A total of nine sampling runs were completed. Water quality at stations 1 - 4 (Canatara Beach) was generally very good. Concentrations of suspended solids increased on several occasions in response to wind and rain conditions. Concentrations of total phosphorus slightly exceeded our Ministry's guideline of 0.02 mg/L on a few sampling occasions.

Water chemistry results for stations 5 through 9 also revealed good water quality. Once again, periodic increases in the concentrations of suspended solids and total phosphorus were documented.

Table 4. Canatara Beach Study 1990 - Serotype and Pyocin Type Results.

Water Column Samples				Sediment Samples			
Site Location	Isolate Number	Serotype Number	Pyocin Number	Site Location	Isolate Number	Serotype Number	Pyocin Number
Pulse Cr. Mouth	6987-1	6	36753	Christina St.	7598-5	11	77573
	6987-2	9	72461	Murphy Road	7600-1	6	16773
	6987-3	2,11	76773		7600-2	6	16773
	6987-4	6	56773		7600-3	6	17773
	6987-5	6	65373	End of Modeland	7601-1	11	77773
	6987-6	6	56373	Blackwell St	7602-4	13,14	76763
Cana. Beach West	7608-1	6	20431	Pulse Cr West	7603-2	4	77773
	7608-2	6	56353	Perch Cr West	7604-3	6	76773
	7608-3	6	56353	Pulse Cr Mouth	7605-1	5	75773
	7608-4	6	56353		7605-2	5	74773
	7608-5	6	56353		7605-3	6	56373
Cana. Beach East	7611-1	13,14	77373	7605-4	6	56773	
	7611-2	13,14	77373	7605-5	5	75773	
	7611-3	13	77373	7605-6	2	75763	
	7611-4	13	77373	Pulse Cr Mouth	7606-1	6	56733
	7611-5	13,14	77363		7606-2	6	56763
Blackwell St	7616-1	4	77763	7606-3	1	10431	
Perch Cr. Mouth	7620-1	NA	74761	7606-4	6	20432	
	7620-2	2,11	77773	7606-5	2,3	50443	
				Mills St Storm	7607-1	2,3,10	77773

TABLE 5: Canatara Beach Study 1990 Water Chemistry Data

STATION: 1

LOCATION: CANATARA BEACH, WEST

Date	BOD	Susp. Solids	Free NH ₃	TKN	Nitrite	Nitrate	Total P	React. P	pH	Cond.
03/28/90	1.00	22.3	0.013	0.23	0.01	0.7	0.019	0.012	7.92	266
04/09/90	0.74	+	0.005	0.20	0.02	0.4	0.007	0.004	8.02	237
04/23/90	+	7.2	0.012	0.20	0.01	0.4	0.008	0.003	8.07	234
05/14/90	0.65	13.6	0.005	0.21	0.02	0.4	0.012	0.001	8.00	243
06/18/90	1.00	4.8	0.013	0.24	0.01	0.4	0.017	0.001	8.23	223
07/16/90	0.89	5.9	0.037	0.30	0.01	0.3	0.021	0.001	8.29	225
07/23/90	0.94	33.1	0.011	0.41	0.02	0.5	0.030	0.005	8.30	231
08/14/90	I.F.	26.2	0.01	0.47	0.01	0.2	0.042	0.001	8.26	233
08/28/90	0.30	3.9	0.015	0.21	0.01	0.2	0.008	0.008	8.23	221

STATION: 2

LOCATION: CANATARA BEACH, MIDWEST

DATE	BOD	Susp. Solids	Free NH ₃	TKN	Nitrite	Nitrate	Total P	React. P	pH	Cond.
03/28/90	0.60	15.9	0.014	0.23	0.01	0.7	0.017	0.014	7.92	269
04/09/90	0.64	+	0.003	0.19	0.01	0.4	0.007	0.004	7.98	240
04/23/90	+	7.1	0.011	0.19	0.01	0.4	0.006	0.004	8.02	239
05/14/90	1.48	16.0	0.005	0.22	0.02	0.4	0.013	0.001	7.99	246
06/18/90	0.64	4.5	0.008	0.23	0.01	0.4	0.010	0.001	8.23	223
07/16/90	0.64	7.4	0.037	0.29	0.01	0.3	0.013	0.001	8.29	226
07/23/90	1.18	41.6	0.011	0.42	0.02	0.4	0.041	0.003	8.30	231
08/14/90	I.F.	22.2	0.008	0.28	0.01	0.2	0.020	0.001	8.26	236
08/28/90	0.05	3.4	0.014	0.26	0.02	0.3	0.008	0.006	8.20	227

STATION: 3

LOCATION: CANATARA BEACH, MIDEAST

DATE	BOD	Susp. Solids	Free NH ₃	TKN	Nitrite	Nitrate	Total P	React. P	pH	Cond.
03/28/90	0.30	16.3	0.014	0.23	0.01	0.8	0.016	0.012	7.90	273
04/09/90	0.78	+	0.007	0.20	0.02	0.3	0.008	0.004	7.98	243
04/23/90	+	7.3	0.014	0.20	0.01	0.4	0.008	0.002	8.02	239
05/14/90	1.08	17.9	0.008	0.21	0.02	0.4	0.014	0.001	8.00	249
06/18/90	0.45	8.0	0.006	0.23	0.01	0.4	0.017	0.001	8.23	223
07/16/90	0.99	8.5	0.04	0.27	0.01	0.3	0.020	0.001	8.27	227
07/23/90	1.14	41.3	0.009	0.46	0.01	0.4	0.032	0.002	8.30	232
08/14/90	I.F.	31.0	0.01	0.35	0.01	0.2	0.025	0.001	8.24	238
08/28/90	0.20	3.8	0.017	0.23	0.01	0.2	0.009	0.005	8.19	226

STATION: 4

LOCATION: CANATARA BEACH, EAST

DATE	BOD	Susp. Solids	Free NH ₃	TKN	Nitrite	Nitrate	Total P	React. P	pH	Cond.
03/28/90	0.02	19.4	0.02	0.21	0.01	0.7	0.017	0.012	7.90	278
04/09/90	0.99	+	0.011	0.22	0.02	0.3	0.011	0.004	7.95	248
04/23/90	+	11.4	0.02	0.23	0.01	0.4	0.014	0.002	7.97	247
05/14/90	0.90	18.8	0.015	0.28	0.02	0.4	0.015	0.001	7.96	256
06/18/90	0.15	5.0	0.007	0.22	0.01	0.4	0.008	0.001	8.25	221
07/16/90	0.74	7.5	0.04	0.29	0.01	0.3	0.016	0.001	8.25	230
07/23/90	0.84	28.7	0.014	0.39	0.01	0.3	0.026	0.002	8.32	233
08/14/90	I.F.	29.1	0.014	0.29	0.01	0.2	0.021	0.001	8.25	237
08/28/90	0.15	3.6	0.017	0.22	0.01	0.2	0.007	0.001	8.20	227

STATION: 5

LOCATION: CHRISTINA STREET

DATE	BOD	Susp. Solids	Free NH ₃	TKN	Nitrite	Nitrate	Total P	React. P	pH	Cond.
03/28/90	0.50	15.8	0.007	0.23	0.01	0.8	0.016	0.012	7.93	261
04/09/90	1.08	15.8	0.014	0.20	0.02	0.4	0.006	0.004	7.95	266
04/23/90	1.58	6.5	0.012	0.19	0.01	0.4	0.009	0.003	8.03	240
05/14/90	1.58	15.0	0.003	0.21	0.02	0.4	0.012	0.001	8.02	244
06/18/90	0.55	13.5	0.009	0.30	0.01	0.4	0.013	0.001	8.22	224
07/16/90	0.64	5.9	0.034	0.24	0.01	0.3	0.012	0.001	8.29	228
07/23/90	1.28	42.0	0.01	0.38	0.01	0.3	0.028	0.001	8.29	232
08/14/90	I.F.	28.2	0.006	0.40	0.01	0.2	0.025	0.001	8.29	236
08/28/90	0.05	3.3	0.014	0.21	0.02	0.2	0.008	0.001	8.24	231

STATION: 6

LOCATION: BAXTER BEACH

DATE	BOD	Susp. Solids	Free NH ₃	TKN	Nitrite	Nitrate	Total P	React. P	pH	Cond.
03/28/90	0.70	12.6	0.007	0.22	0.01	0.8	0.015	0.013	7.93	263
04/09/90	0.84	12.6	0.005	0.20	0.02	0.4	0.010	0.004	7.97	247
04/23/90	1.54	7.5	0.009	0.19	0.01	0.4	0.008	0.002	8.03	233
05/14/90	3.16	12.7	0.007	0.22	0.02	0.3	0.012	0.001	8.01	238
06/18/90	1.13	55.7	0.013	0.42	0.01	0.5	0.024	0.001	8.21	230
07/16/90	0.59	5.4	0.038	0.28	0.01	0.3	0.022	0.001	8.32	225
07/23/90	1.76	76.0	0.030	0.63	0.01	0.4	0.050	0.003	8.26	230
08/14/90	I.F.	32.4	0.006	0.27	0.01	0.2	0.023	0.001	8.30	235
08/28/90	0.10	4.0	0.014	0.20	0.02	0.2	0.006	0.001	8.27	223

STATION: 7

LOCATION: MURPHY ROAD

DATE	BOD	Susp. Solids	Free NH ₃	TKN	Nitrite	Nitrate	Total P	React. P	pH	Cond.
03/28/90	0.40	12.7	0.009	0.24	0.01	0.8	0.015	0.011	7.95	266
04/09/90	1.03	+	0.001	0.20	0.01	0.4	0.006	0.004	7.96	246
04/23/90	+	6.3	0.008	0.19	0.01	0.5	0.008	0.003	7.96	247
05/14/90	0.83	9.7	0.004	0.21	0.01	0.3	0.010	0.001	7.98	227
06/18/90	0.69	46.8	0.001	0.42	0.01	0.5	0.022	0.001	8.20	224
07/16/90	0.69	6.3	0.036	0.26	0.01	0.3	0.012	0.001	8.28	225
07/23/90	0.90	29.1	0.013	0.35	0.01	0.4	0.026	0.001	8.25	229
08/14/90	I.F.	32.5	0.008	0.30	0.01	0.1	0.026	0.001	8.27	232
08/28/90	0.10	3.5	0.013	0.23	0.02	0.3	0.008	0.001	8.22	234

STATION: 8

LOCATION: END OF MODELAND

DATE	BOD	Susp. Solids	Free NH ₃	TKN	Nitrite	Nitrate	Total P	React. P	pH	Cond.
03/28/90	0.30	15.8	0.210	0.01	0.01	0.8	0.016	0.014	7.97	258
04/09/90	0.79	+	0.004	0.20	0.02	0.4	0.006	0.005	8.00	232
04/23/90	+	5.2	0.010	0.19	0.01	0.6	0.007	0.002	7.98	255
05/14/90	0.88	8.2	0.009	0.26	0.01	0.3	0.013	0.001	8.01	219
06/18/90	1.32	40.4	0.001	0.53	0.01	0.5	0.034	0.001	8.21	228
07/16/90	0.59	6.5	0.043	0.27	0.01	0.3	0.015	0.001	8.31	224
07/23/90	0.90	33.9	0.016	0.42	0.01	0.4	0.028	0.002	8.25	229
08/14/90	I.F.	16.6	0.010	0.54	0.01	0.1	0.021	0.001	8.34	223
08/28/90	0.25	3.4	0.018	0.22	0.01	0.3	0.008	0.001	8.24	228

STATION: 9

LOCATION: BLACKWELL STREET

DATE	BOD	Susp. Solids	Free NH ₃	TKN	Nitrite	Nitrate	Total P	React. P	pH	Cond.
03/28/90	0.20	16.3	0.010	0.29	0.01	1.1	0.017	0.010	7.98	274
04/09/90	0.79	+	0.003	0.20	0.01	0.4	0.007	0.005	8.00	234
04/23/90	+	10.8	0.009	0.28	0.01	1.0	0.015	0.002	8.03	278
05/14/90	1.28	11.4	0.014	0.28	0.02	0.3	0.016	0.001	8.04	218
06/18/90	1.57	70.1	0.001	0.54	0.01	0.5	0.024	0.001	8.18	225
07/16/90	0.88	8.9	0.050	0.34	0.01	0.3	0.023	0.001	8.28	224
07/23/90	0.64	26.8	0.009	0.26	0.01	0.4	0.023	0.001	8.24	232
08/14/90	I.F.	24.5	0.012	0.28	0.01	0.1	0.019	0.001	8.29	232
08/28/90	0.30	5.4	0.022	0.25	0.01	0.2	0.011	0.001	8.21	224

STATION: 10

LOCATION: PULSE CREEK WEST

DATE	BOD	Susp. Solids	Free NH ₃	TKN	Nitrite	Nitrate	Total P	React. P	pH	Cond.
03/28/90	0.02	17.6	0.006	0.48	0.02	3.1	0.026	0.012	8.09	425
04/09/90	1.08	+	0.001	0.21	0.02	1.2	0.009	0.005	8.03	289
04/23/90	+	18.5	0.008	0.48	0.02	3.1	0.025	0.003	8.05	422
05/14/90	0.70	19.3	0.051	0.55	0.04	1.8	0.035	0.001	7.99	356
06/18/90	1.33	40.8	0.001	0.42	0.01	0.4	0.034	0.001	8.23	223
07/16/90	0.74	8.8	0.043	0.30	0.01	0.4	0.016	0.001	8.31	229
07/23/90	1.28	53.7	0.074	0.62	0.04	0.5	0.064	0.003	8.20	333
08/14/90	I.F.	39.7	0.036	0.66	0.02	0.2	0.066	0.002	8.02	422
08/28/90	0.29	21.1	0.019	0.33	0.02	0.2	0.028	0.001	8.20	285

STATION: 11

LOCATION: PERCH CREEK WEST

DATE	BOD	Susp. Solids	Free NH ₃	TKN	Nitrite	Nitrate	Total P	React. P	pH	Cond.
03/28/90	0.60	16.4	0.008	0.24	0.01	0.6	0.017	0.010	8.01	254
04/09/90	1.20	11.6	0.005	0.25	0.01	0.9	0.009	0.005	8.03	268
04/23/90	+	6.8	0.003	0.28	0.01	2.0	0.015	0.002	8.09	319
05/14/90	0.90	6.7	0.008	0.28	0.02	0.7	0.012	0.001	8.06	251
06/18/90	1.23	76.6	0.004	0.50	0.01	0.4	0.040	0.001	8.20	223
07/16/90	0.94	11.9	0.049	0.39	0.01	0.3	0.023	0.001	8.29	224
07/23/90	1.18	54.7	0.009	0.60	0.02	0.4	0.052	0.001	8.25	223
08/14/90	I.F.	11.1	0.01	0.23	0.01	0.1	0.013	0.001	8.34	220
08/28/90	0.29	14.0	0.017	0.27	0.02	0.2	0.020	0.001	8.24	222

STATION: 12

LOCATION: PULSE CREEK MOUTH

GATE	BOD	Susp. Solids	Free NH ₃	TKN	Nitrite	Nitrate	Total P	React. P	pH	Cond.
03/28/90	--	--	--	--	--	--	--	--	--	--
104/09/90	1.96	68.8	0.015	0.92	0.05	11.1	0.084	0.023	8.04	878
104/23/90	+	76.9	0.006	1.01	0.08	9.7	0.083	0.015	7.89	844
05/14/90	5.12	93.3	0.187	1.38	0.11	5.7	0.136	0.001	7.97	808
06/18/90	0.74	12.3	0.002	0.24	0.01	0.5	0.014	0.001	8.25	225
07/16/90	3.94	51.4	0.026	1.10	0.04	1.2	0.128	0.001	8.19	413
07/23/90	2.94	87.8	0.149	0.94	0.05	0.6	0.098	0.005	8.15	434
08/14/90	I.F.	29.0	0.024	0.56	0.01	0.2	0.058	0.001	8.05	385
08/28/90	0.74	53.4	0.018	0.48	0.02	0.2	0.056	0.004	8.08	357

STATION: 13

LOCATION: PERCH CREEK MOUTH

DATE	BOD	Susp. Solids	Free NH ₃	TKN	Nitrite	Nitrate	Total P	React. P	pH	Cond.
03/28/90	--	--	--	--	--	--	--	--	--	--
04/09/90	1.23	+	0.004	0.69	0.03	9.6	0.015	0.017	7.99	796
04/23/90	+	19.6	0.008	0.78	0.06	10.5	0.054	0.024	7.98	774
05/14/90	1.78	23.5	0.041	0.95	0.1	7.2	0.061	0.001	7.97	904
06/18/90	2.01	99.1	0.006	0.84	0.02	0.7	0.096	0.004	8.11	310
07/16/90	2.46	50.6	0.104	1.20	0.02	0.7	0.146	0.001	7.98	401
07/23/90	2.54	77.4	0.093	1.14	0.06	1.8	0.118	0.003	8.10	477
08/14/90	I.F.	31.8	0.187	0.96	0.01	0.1	0.104	0.020	7.87	600
08/28/90	0.54	35.7	0.018	0.45	0.02	0.2	0.048	0.009	8.09	399

STATION: 17

LOCATION: MILLS STREET STORM SEWER

DATE	BOD	Susp. Solids	Free NH ₃	TKN	Nitrite	Nitrate	Total P	React. P	pH	Cond.
03/28/90	--	--	--	--	--	--	--	--	--	--
04/09/90	1.08	+	0.001	0.44	0.02	4.4	0.006	0.004	8.03	1850
04/23/90	--	--	--	--	--	--	--	--	--	--
05/14/90	0.35	47.9	0.01	0.51	0.04	4.9	0.044	0.001	8.01	1680
06/18/90	5.59	19.1	0.146	1.12	0.05	3.3	0.144	0.043	8.50	1077
07/16/90	7.01	10.0	0.061	0.60	0.01	0.5	0.033	0.001	8.25	313
07/23/90	0.98	45.7	0.017	0.47	0.02	0.4	0.037	0.001	8.26	230
08/14/90	I.F.	26.7	0.008	0.28	0.01	0.2	0.017	0.001	8.27	252
08/28/90	0.69	9.3	0.02	0.36	0.02	0.4	0.019	0.001	8.06	286

LEGEND

I.F. = INSTRUMENT FAILURE

+

-- NO SAMPLE

BOD - BIOCHEMICAL OXYGEN DEMAND

SUSP. SOLIDS - SUSPENDED SOLIDS

TKN - TOTAL KJELDHAL NITROGEN

TOTAL P - TOTAL PHOSPHORUS

REACT. P - REACTIVE PHOSPHORUS

COND. - CONDUCTIVITY

Results from Pulse and Perch Creek mouths revealed poorer water quality. Elevated concentrations of suspended solids, nitrate and total phosphorus were more frequent at these two sites. As a result, elevated concentrations of these parameters were also documented immediately to the west of the mouth areas in Lake Huron at stations 10 and 11. Water quality in Pulse Creek seemed to be slightly worse than that of Perch Creek.

The discharge from the Mills Street storm drain was sampled on seven occasions. Elevated concentrations of biochemical oxygen demand, suspended solids, nitrates, total phosphorus and conductivity were documented.

CONCLUSIONS

Unlike previous summer months, Canatara Beach and the Brights Grove Beach were not closed due to elevated counts of fecal coliform bacteria during the summer of 1990. This complicated the main goal of this study which was to identify the sources of fecal bacteria which were responsible for beach closures in previous years. Nevertheless, several important points can be concluded from this study.

Firstly, the study showed that the discharge from the Brights Grove lagoons did not impair the bathing use of the near shore water quality of Lake Huron between Brights Grove and Canatara Beach. Both the water sample results and moreso the sediment results support this statement.

Secondly, the study identified three sources of poor water quality; Perch Creek, Pulse Creek and the Mills Street storm drain. Consideration should be given to conducting a thorough water quality study on both Pulse Creek and Perch Creek in order to identify sources of bacterial contamination and sources of nutrients such as nitrogen and phosphorus. Possibly the local Conservation Authority could become involved as the majority of the area consists of agricultural land.

The Mills Street storm drain water quality was shown to be periodically high in bacteria. The City of Sarnia has been advised of elevated bacterial counts previously by both the Lambton County Health Unit (1989 results) and the Ministry of the Environment (1990 results). The outfall from this storm drain discharges onto the beach area where the public could come into contact with it. During the course of this study, staff from the City extended the discharge pipe from the beach area to the water's edge, a few feet into Lake Huron.

This modification to the discharge pipe has alleviated the problem of the public coming into direct contact with the discharge by providing in-pipe mixing with Lake Huron water. The source of the bacteria however has still yet to be determined. The City should be requested to assess this relatively small storm drainage system and determine the possible source(s) of bacteria. Consideration should be given to inspections of septic systems in the area as this area is not serviced by a sanitary sewer system.

Finally, the bacterial component of the study proved that sources of fecal waste can be labelled by a combination of serotyping and pyocin typing of *Pseudomonas aeruginosa* found in the fecal wastes. The study revealed that migration of fecal wastes from the sources does not appear to be occurring based on the isolation of unique serotypes and pyocin types. It would appear from the data that Canatara Beach and the Brights Grove Beach in 1990 were affected only by very localized unidentified pollution sources.

R-SW

Canatara

APPENDIX A

Appendix A

WATER TEMPERATURE DATA (CELSIUS)

CANATARA BEACH STUDY-1990

STATION	DATE/90								
	03/28	04/09	04/23	05/14	06/18	07/16	07/23	08/14	08/28
1	1	4	8	9	15	18	20	20	22
2	1	4	8	9	15	18	20	20	22
3	1	4	8	9	15	18	20	20	22
4	1	4	8	9	15	18	20	20	22
5	1	4	8	9	15	18	20	21	22
6	1	4	8	9	16	18	20	21	22
7	1	4	8	9	16	18	19	22	22
8	1	4	8	9	16	18	19	22	22
9	1	4	8	9	16	19	19	22	22
10	1	4	9	11	17	19	20	23	23
11	1	4	9	10	18	19	20	23	23
12	2	6	13	13	17	22	21	23	23
13	2	6	12	12	17	21	21	23	23
17	--	7	--	11	13	19	19	22	23

LEGEND

- No Data
- 1 Canatara Beach West
- 2 Canatara Beach Midwest
- 3 Canatara Beach Mideast
- 4 Canatara Beach East
- 5 Christina Street
- 6 Baxter Beach
- 7 Murphy Road
- 8 Modeland
- 9 Blackwell Street
- 10 Pulse Creek West
- 11 Perch Creek West
- 12 Pulse Creek Mouth
- 13 Perch Creek Mouth
- 17 Mills Street Storm Drain

Appendix A

WEATHER CONDITIONS PRIOR TO SAMPLING

- 03/28/90 -26th Cold, Very Windy, north Wind
-27th Warmer, Winds Changing From North To Southwest
-28th Warmer, Slight Breeze From The South
- 04/09/90 - No Storms Over The Last 3 Days
- 9th Sunny, No Wind
- Note- Brights Grove Lagoons Start Discharging
- 04/23/90 - 22th Sunny, No Wind
- 23rd Sunny, No Wind
- 05/14/90 - 13th Rained Early Morning
- 14th Warm, Lake Calm, Slight Breeze
- 06/18/90 - 16th & 17th Hot, Sunny, No Wind
- 18th Thunder Storms Early Morning, Southwest Winds
- 07/16/90 - 16th Slight Breeze
- 07/23/90 - 22nd Windy, Wavy, Rain All Day
- 23rd Cloudy, Onshore Wind
- 08/14/90 - 14th Windy, Wavy, Onshore Winds
- 08/28/90 - 27th Strong Evening Rain
- 28th Strong South Winds, Wavy