RURAL BEACHES STRATEGY PROGRAM

AUSABLE BAYFIELD CONSERVATION AUTHORITY

Target Sub-basin Study Report

Study Period: April 1, 1988 to April 30, 1989

Prepared by:

Doug Hocking - Rural Beaches Program Supervisor

and Donna Dean - Water Quality Technician

April 1989

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF MAPS

LIST OF ILLUSTRATIONS

ACKNOWLEDGEMENTS

The authors would like to thank Garry Palmateer, Edna Janzen, Jennifer Doyle, Maureen Walsh and Dawn McLean of the microbiology department and the staff of the chemistry department at the Ministry of the Environment - Southwestern Region for their expertise and dedication. We would also like to thank Tom Prout and Alec Scott of the A.B.C.A. for their valuable comments and suggestions throughout the study. Thanks also goes to the Provincial Steering Committee and the local Steering Committee for their continued support. We also thank the Ontario Ministry of the Environment for their financial support for what we feel is a valuable program. Thanks also goes to the A.B.C.A. secretarial staff for their assistance during the compilation of this report.

SUMMARY

Monitoring of the Desjardine Drain's water and sediments for bacterial and chemical contaminants continued for the 1988 - 1989 fiscal year. Minor remedial work performed in 1988, involved repairs to a septic system and a barn bank which had been installed by the beaches program in 1988 and 1987 respectively. Water quality continues to follow seasonal trends and appears to be improving. While there were significant improvements in water quality in the summer of 1987 compared to summer 1986, little change was noted between the spring of 1987 and spring of 1988. E. coli concentrations continued to decrease at the downstream sampling station in 1988, possibly due to continued septic system repair. Further statistical analysis is required. There were no beach closures at Grand Bend due to bacterial contamination during the 1988 swimming season.

Special research conducted in cooperation with the Ministry of the Environment -Southwestern Region continues including tracer experiments to determine the downstream movement of bacteria and the impact of sunlight on bacterial survival as well as pyocin work to pinpoint specific sources of bacteria.

RECOMMENDATIONS

The following recommendations are made following two years of remedial action and three years of water quality analysis on the Target Sub-basin.

1. CONTINUATION OF STREAM WATER QUALITY MONITORING AND STATISTICAL ANALYSIS

It is important to continue to monitor the water quality of the Desjardine Drain to prove without doubt that the remedial construction had a positive impact on the bacterial and chemical water quality of the Desjardine Drain. Data collected to date indicates that this is true, however the effect of natural fluctuations should be examined further through analysis of covariance.

Limited precipitation in the spring and summer of 1988 significantly reduced the data base compared to the summer of 1987 and 1988. In addition, there is possibly a source of septic contamination above the upstream reference sample station in the Target Sub-basin. As a result the statistical analysis has been limited. Additional statistical analysis will be required to utilize Control Sub-basin data.

2. CONTINUATION OF COOPERATIVE RESEARCH

The cooperative research conducted in conjunction with the M.O.E.-S.W.R. has proven to be very valuable in the A.B.C.A. C.U.R B. modelling exercise and is potentially widespread in its applications. It is therefore important to carry on with the tracer experiments, and pyocin and serologic typing to further understand transportation of and identification of sources of bacteria within the Target Sub-basin.

3. INCREASED COOPERATION WITH THE MINISTRY OF HEALTH

The Huron County and Sarnia-Lambton Health Units take the water samples at the swimming areas along the Lake Huron shoreline to determine when to close the beaches due to bacterial contamination. Cooperation between the M.O.E., Conservation Authorities and

Health Units in the interpretation of and exchange of water quality data of the beaches on Lake Huron is essential to future water quality studies.

4. REVIEW TARGET FARM OPERATIONS AND OTHER FARMS IN THE DESJARDINE DRAIN

It is recommended that changes in farming practices that have occurred in the past three years in the Desjardine Drain watershed be documented. One new swine farming operation has begun and others may have changed practices. It is essential to have this information when interpreting recent water quality data.

5. SEPTIC SYSTEM SURVEY

Septic systems have been identified as the single greatest source of fecal contamination in the A.B.C.A. watersheds by the Clean Up Rural Beaches (C.U.R.B.) predictor model (Hocking and Dean 1989). A 60 percent rate of failure of septic systems in the Desjardine Drain (Hocking 1988) suggests that a detailed survey of the septic systems in the A.B.C.A. watershed should be conducted. The septic systems on the Lake Huron shoreline are of particular interest because they have the greatest potential to pollute due to the short travel time to the Lake Huron beaches.

Legislation with respect to septic system installation and maintenance is included in Part 7 of the Environmental Protection Act (E.P.A.). Regulatory staff of both the Health Units and the Ontario Ministry of the Environment have the power to prosecute. In the lakeshore area of the A.B.C.A., the Huron County Health Unit has jurisdiction over Huron County covering the area between Grand Bend and the northern boundary of the A.B.C.A. watershed and the Ministry of the Environment in Sarnia has jurisdiction over Lambton County covering the area between Grand Bend and the southern boundary of the watershed (Blackie 1989, personal communication).

Septic systems which were repaired in the course of the study should be tested for their continuing efficiency in removing pollutants. Also, any suspected new sources of septic contamination should be investigated and documented, particularly those along the Lake

Huron shoreline. Conservation Authority staff should carry out the investigation and report violations to the appropriate regulatory agency.

6. INFORMATION EXTENSION

A Water Quality Information Day should be held in 1990. The Water Quality Information Day held in February of this year in conjunction with the St. Clair Region Conservation Authority was a success. This kind of information exchange should continue since it is an excellent way to inform the public of our water quality concerns and of the work being conducted by the conservation authorities.

It is also recommended that one of the target farms be included in the A.B.C.A. watershed tours. In addition, separate tours should be arranged for farmers, professional agricultural workers and any other interested people.

In addition, a brochure outlining best management practices for livestock operations and septic systems as well as an overview of the findings of the Target Sub-basin Study should be sent to each household in the watershed.

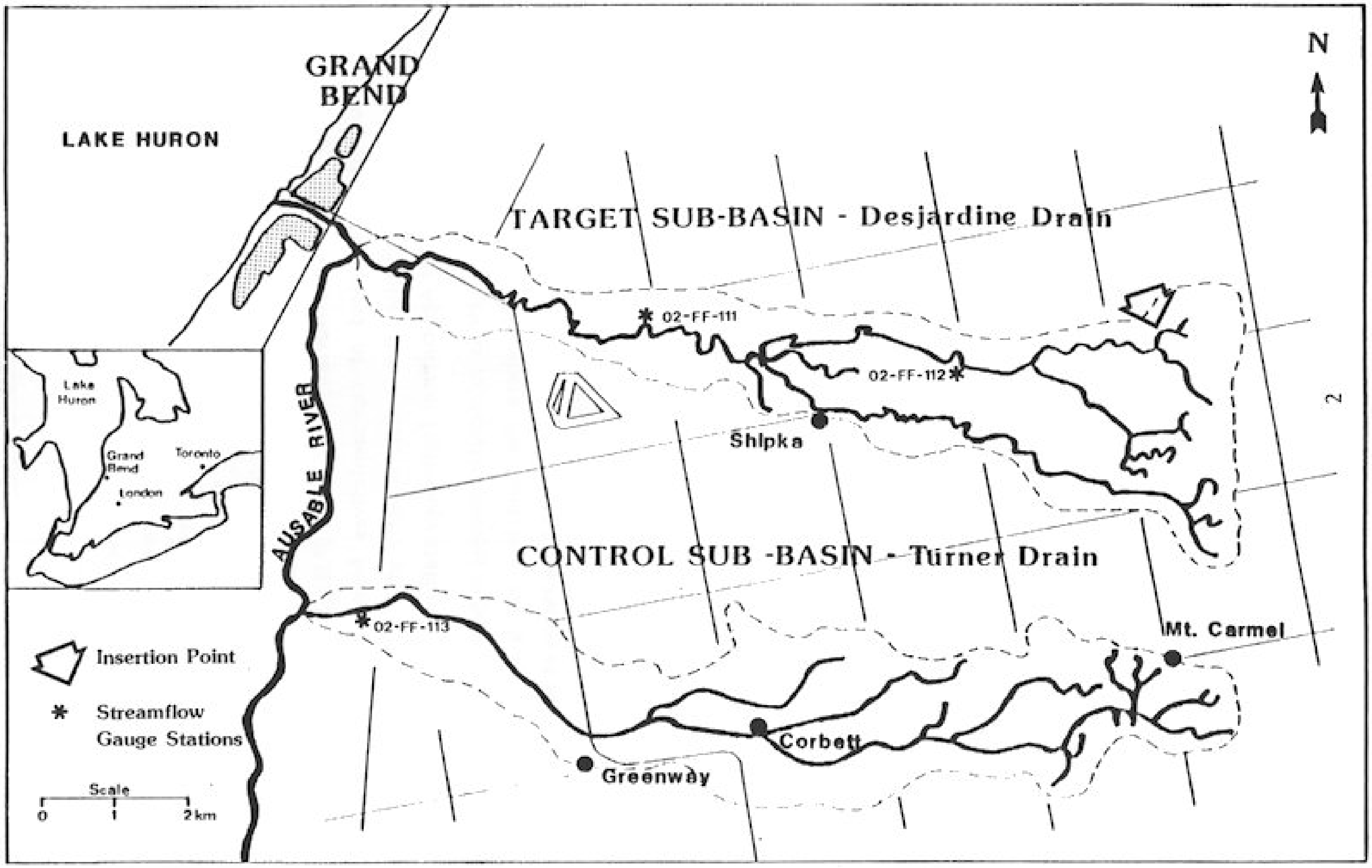
1.0 INTRODUCTION

This is the third annual report of the Ausable Bayfield Conservation Authority's Target Sub-basin Study (T.S.S.), summarizing the period from April I, 1988 to March 31, 1989. This study is a component of the Provincial Rural Beaches Strategy Program which is funded and administered by the Ontario Ministry of the Environment (M.O.E.). The Rural Beaches program was brought into existence as a result of beach closures across Ontario. Direction is provided by the Provincial Rural Beaches Environmental Management Strategy Planning and Advisory Committee (P.R.U.B.E.M.S.P.A.C.) and a local steering committee comprised of representatives from the Ministry of the Environment - South Western Region, the Ontario Ministry of Agriculture and Food in Clinton and a Centralia College of Agricultural Technology staff member.

The goal of the A.B.C.A. study is to monitor changes in bacterial and chemical contaminants in the Desjardine Drain where the main land use is agriculture. The Desjardine Drain flows into Parkhill Creek and hence into Lake Huron at the resort town of Grand Bend. Map 1 shows the location of the Target Sub-basin and the Control Sub-basin. Remedial construction of faulty domestic septic systems and improper manure storages and encouragement of best manure management practices has been conducted in the headwaters of the Desjardine Drain on demonstration livestock operations. The remedial activities are intended to reduce bacteria contamination in rural watercourses which can impact Lake Huron beaches.

The Sarnia-Lambton Health Unit takes weekly water samples at the beach in Grand Bend. Five samples are taken and the geometric mean is calculated. During the 1988 swimming season the Ontario M.O.E. guideline of 100 fecal coliform per 100 ml (Ontario M.O.E., 1984, p.43) was exceeded on four occasions, however officials at the Health Unit did not feel those counts exceeded the limits sufficiently to warrant a beach closure (Wardell, 1989, personal communication). The results of the weekly samples taken at Grand Bend and Port Franks by the Sarnia-Lambton Health Unit are in Appendix I.

The two preceding Target Sub-basin Study reports, September 1987 and October 1988, described the routine sampling, special research and remedial construction from June 1986 to March, 1988. This report will focus on the special research and minor remedial construction conducted between April 1, 1988 and March 31, 1989, in addition to regular



Map 1: Location of the Target and Control Sub-basins

water column and sediment analysis done during this time period. For comparative purposes the sampling data has been presented over the three year time span of the study. From April 1988 to March 1989 five biological tracer experiments were conducted. Collection of animal feces (both wild and domestic) for pyocin and serological typing in the laboratory at the Ministry of the Environment, Southwestern Region was also done. In addition, two die-off studies were conducted during the summer of 1988 to determine the effects of sunlight on die-off rates of water column bacteria in the Desjardine Drain.

A consultant was engaged to perform additional statistical analysis on accumulated data. This report, in its entirety, forms Appendix II.

In addition to the research described above a submission of the Clean Up Rural Beaches (C.U.R.B.) plan has been made. The C.U.R.B. plan is based on a series of algorithms designed to predict the magnitude of bacteria and phosphorous that will reach swimming areas from various agricultural sources, sewage treatment plants, industry and domestic septic systems for the entire A.B.C.A. watershed. Recommendations of the C.U.R.B. Plan outline strategies to reduce bacterial contamination of Lake Huron beaches and A.B.C.A.'s watercourses. The Target Sub-basin Study provided detailed information regarding:

1. domestic septic system failure rates (60%)
2. average number of rural residents per dwelling (3.5)
3. typical manure stack size (average of pre and post remedial construction, 173 m^2
4. typical intensive feedlot/pasture size (0.0345 ha, including related livestock buildings)
5. stream-borne bacteria travel time to Lake Huron (approximately 1 day, average of spring tracer studies)
6. typical volume of milkhouse waste per dairy cow per day (14.2 litres)
7. pollutant concentrations in septic-contaminated tiles (1×10^6 fecal coliform/100 ml, 30.8 mg P/liter) and feedlot runoff (5×10^4 fecal coliform/100 ml)
8. comparative costs for comprehensive remedial work ($72,000 to $26,000, averaging $46,600 per farm)

It has been presented as a separate report.

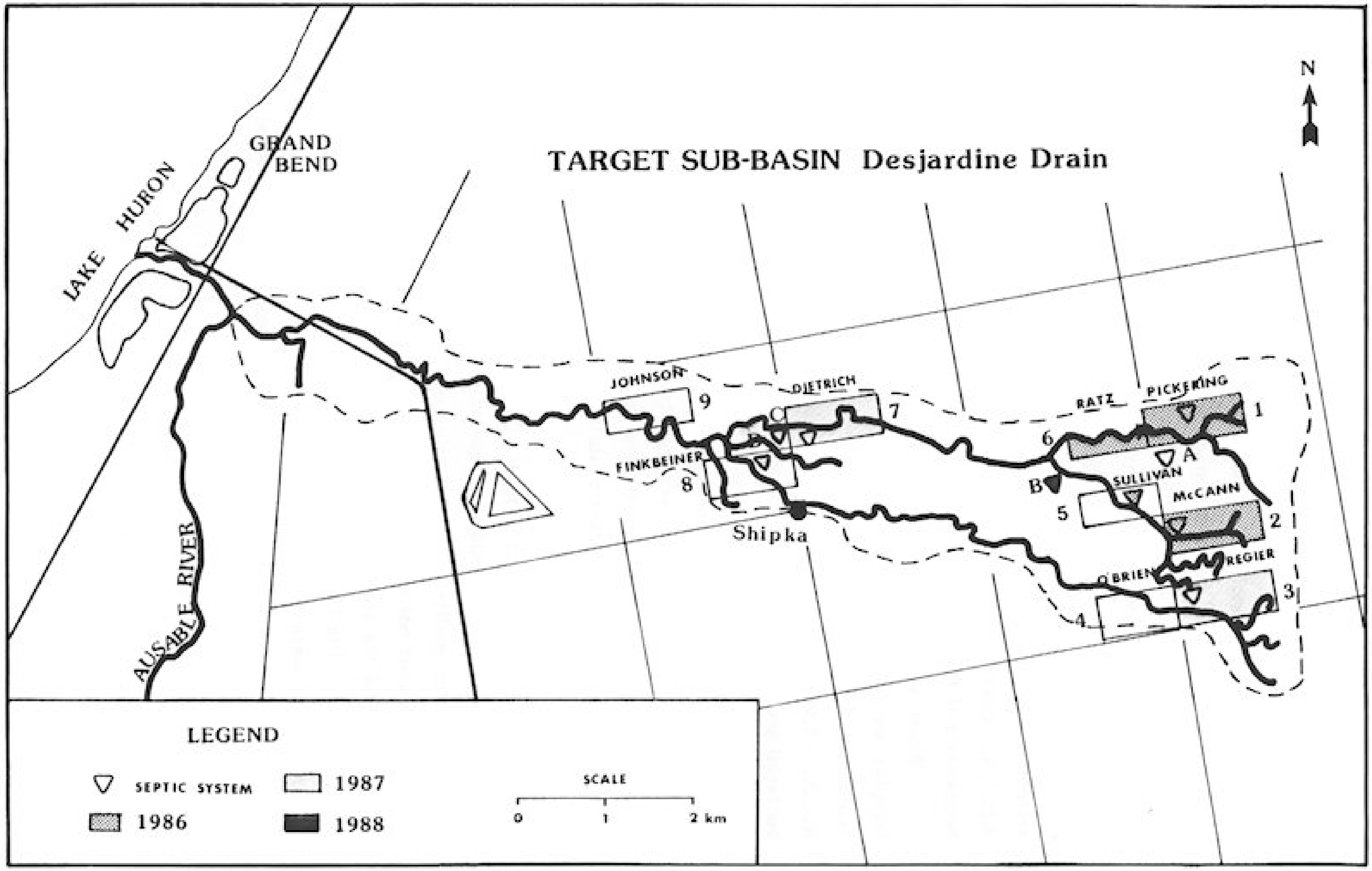
2.0 REMEDIAL CONSTRUCTION

Locations of properties where remedial construction took place are indicated on Map 2.

No major remedial construction projects were undertaken in the report period. Generally there were no major complaints offered by operators with respect to the operation of the new septic and manure storage systems installed in the earlier years of the study.

There was one minor repair to Target Farm 3's barn bank that had been altered to accommodate the square run-off tank. Spring rain water weakened and washed out the rear bank corner. Total repair costs were $594.30 of which the farmer paid 10 per cent. Bank repair was completed in May 1988.

The domestic septic system at (A) continued to be troublesome after excessive slope in weeping bed tiles were corrected in March 1988 (Map 2). It was discovered that the repaired weeping bed tiles were contaminating the cellar drain. Throughout the spring and summer of 1988, septic odours emanated from this drain, especially after household laundry was completed. The basement tile was connected to a field tile which discharged to the Desjardine drain 3 meters upstream of the headwater reference station. An August sample of this field tile effluent indicated septic contamination in the opinion of M.O.E. staff. In addition, the contaminated tile may have been transporting contaminants discharged by the new septic weeping bed tiles to the Target Sub-basin drain since March 31, 1988. This has had severe ramifications in terms of data analysis for the study because the contamination problem is occurring upstream of the control sample site. The basement drain was re-routed from the weeping bed in mid November 1988, and the original connections were severed. The total cost was $422.73 of which the farmer's share was 10 percent.



Map 2: Remedial Construction Sites in the Desjardine Drain .

3.0 WATER QUALITY ANALYSIS

Water column analysis has been continuing from June 1986 to present, monitoring the effects of remedial construction and better management practices on the Desjardine Drain. Water samples are also taken on the Turner Drain, the Control Sub-basin to the south of the Desjardine Drain for future comparative data analysis (Map 1). Remedial work on Farms 1, 2, and 6, was completed in October 1986. In October of 1987 remedial work was completed on Farms 3 and 7. Location and time of repair of domestic septic systems and Target Farms are indicated on Map 2. Remedial construction is detailed in A.B.C.A. reports (Hocking 1987; Hocking 1988). There is no water quality data for the headwaters of the Desjardine Drain prior to June 1986 for comparative trend analysis.

Water sampling continued once weekly from April 1, 1988 to March 31, 1989. Samples were analyzed for both bacterial and chemical parameters. From June to September, 1988 bacterial samples were taken twice weekly. All analysis was done by M.O.E. - S.W.R. staff in London with the exception of the summer months when the bacterial analysis was done at the M.O.E. mobile laboratory in Grand Bend. From April to December 1988 the total number of sample sites was thirty with the exception of the late summer when water was present at only twenty sample sites. As of January 1, 1989 the number of sample sites was reduced to seventeen due to limited laboratory capacity. Sample sites remaining were those directly associated with the Target Farms in the Desjardine Drain, the control stations in the Turner Drain, and two sample sites on the Ausable River.

From June 7, 1988 to October 10, 1988 surface flow in the Desjardine Drain was intermittent. Field tile drains ran periodically. This affects the interpretation of the data since water quality will be the result of local influence only. Downstream transport of pollutants could not occur. Since reliable water quality data was not available for the summer of 1988 the statistical analysis attempted to compare the spring of 1987 to the spring of 1988. The 1987-1988 report used the summer months for statistical analysis. Fewer samples were taken during the spring of 1988 than in the summers of previous years. For 1989, sampling frequency during the spring was increased in anticipation of intermittent surface flow in the summer.

3.1 Water Column Bacteria

The concentrations of fecal coliform bacteria at Target Farms 1, 2, 6, 7, and 9 are shown in Figures 1, 2, 3, 4, and 5, respectively. The concentrations of fecal coliform at the upstream reference site (dashed lines) are used for comparison on each figure. The guideline bacteria concentration for water used for recreational purposes is labelled "M.O.E.". "A potential health hazard exists if the fecal coliform geometric mean density for a series of water samples exceeds 100/100 mL" (M.O.E. 1984, p. 43). Time periods prior to remedial work and following remedial work undertaken by this study are labelled "Preconstruction" and "Post Construction" respectively. The "Dry" label indicates ponded conditions (no inlet and/or outlet) or dry stream bed conditions at the Target Farm illustrated. Gaps in concentration data indicate uncollected samples (due to unaccessible sites or stream frozen to bed) or laboratory incidents such as sample expiry or accidents.

These figures indicate seasonal trends in the concentration of fecal coliform bacteria over the three year period of the study. At each of the Target Farms the bacterial counts tend to be lower in the winter months, approaching the M.O.E. guideline for fecal coliform, and higher in the summer months, more often exceeding the guideline.

Target Farm 2, a beef operation, underwent remedial construction to increase manure storage and provide runoff control structures in 1986. This is an independent headwater site. This farm exhibited the best bacterial water quality following remedial construction, meeting the M.O.E. guideline 50 percent of the time. The best water quality was exhibited during the winter months for 1987, 1988 and 1989.

On three occasions after remedial work was completed this site exhibited concentrations three orders of magnitude higher than the M.O.E. guideline for fecal coliform. These peaks occurred in late summer and likely resulted from intensive rainfall causing overland flow and flushing of the tile drains. On September 17, 1987 greater than 330,000 fecal coliform per 100 mL was found in the tile and 32 mm of rain fell that day. On September 30, 1987 1.3 million fecal coliform per 100 mL was found in the tile and a total of 9 mm of rain fell that day and the previous day. On October 3, 1988, 110,000 fecal coliform per 100 mL was found in the drain and a total of 26.1 mm of rain fell that day and the previous day.

The remaining farms rarely met the M.O.E. guideline for recreational swimming during the summer months. Of the three winter periods examined, the winter of 1989 appears to exhibit the most improved water quality. Over the long term it appears that bacterial concentrations are decreasing, however this requires statistical verification.

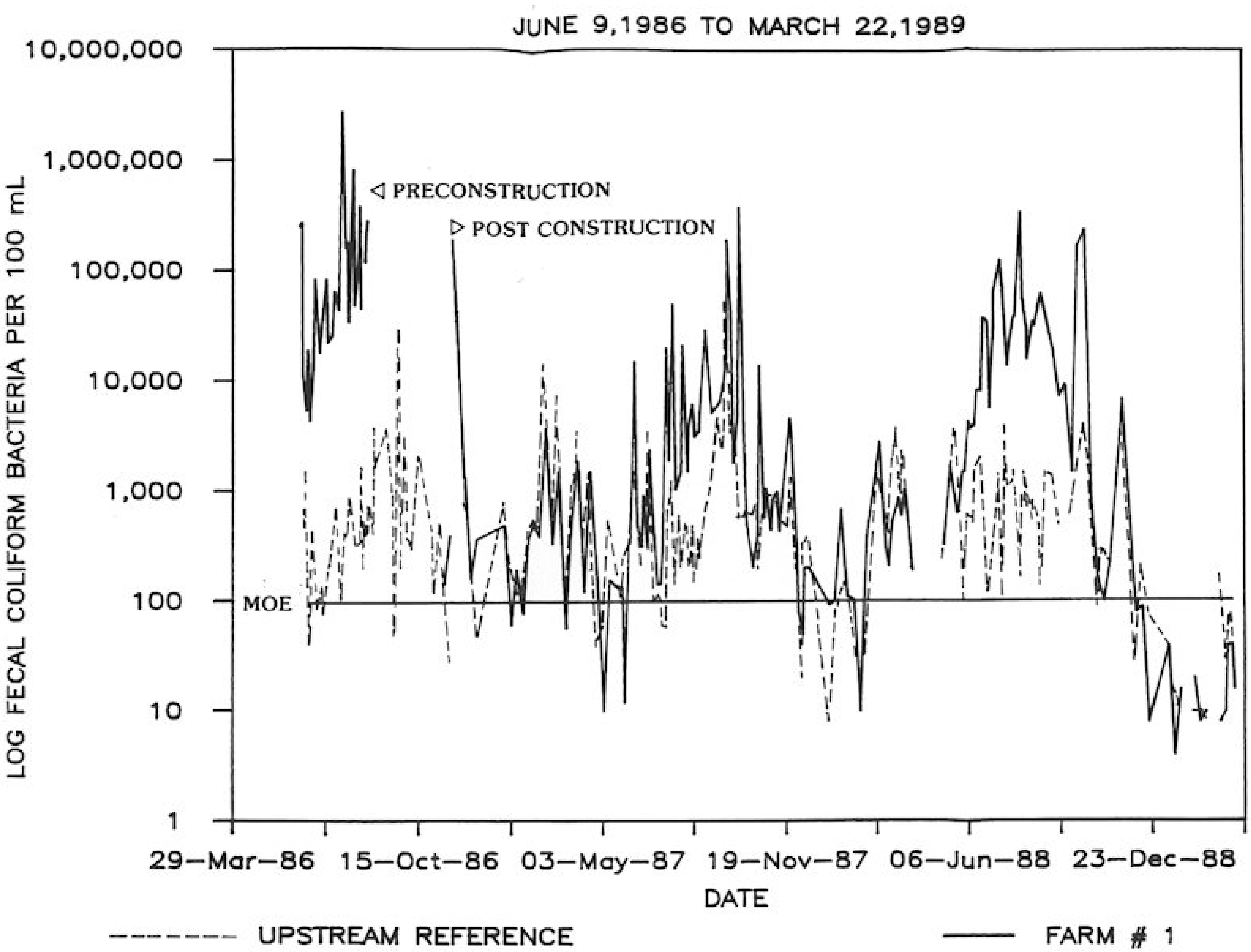


FIGURE 1: TARGET FARM # 1

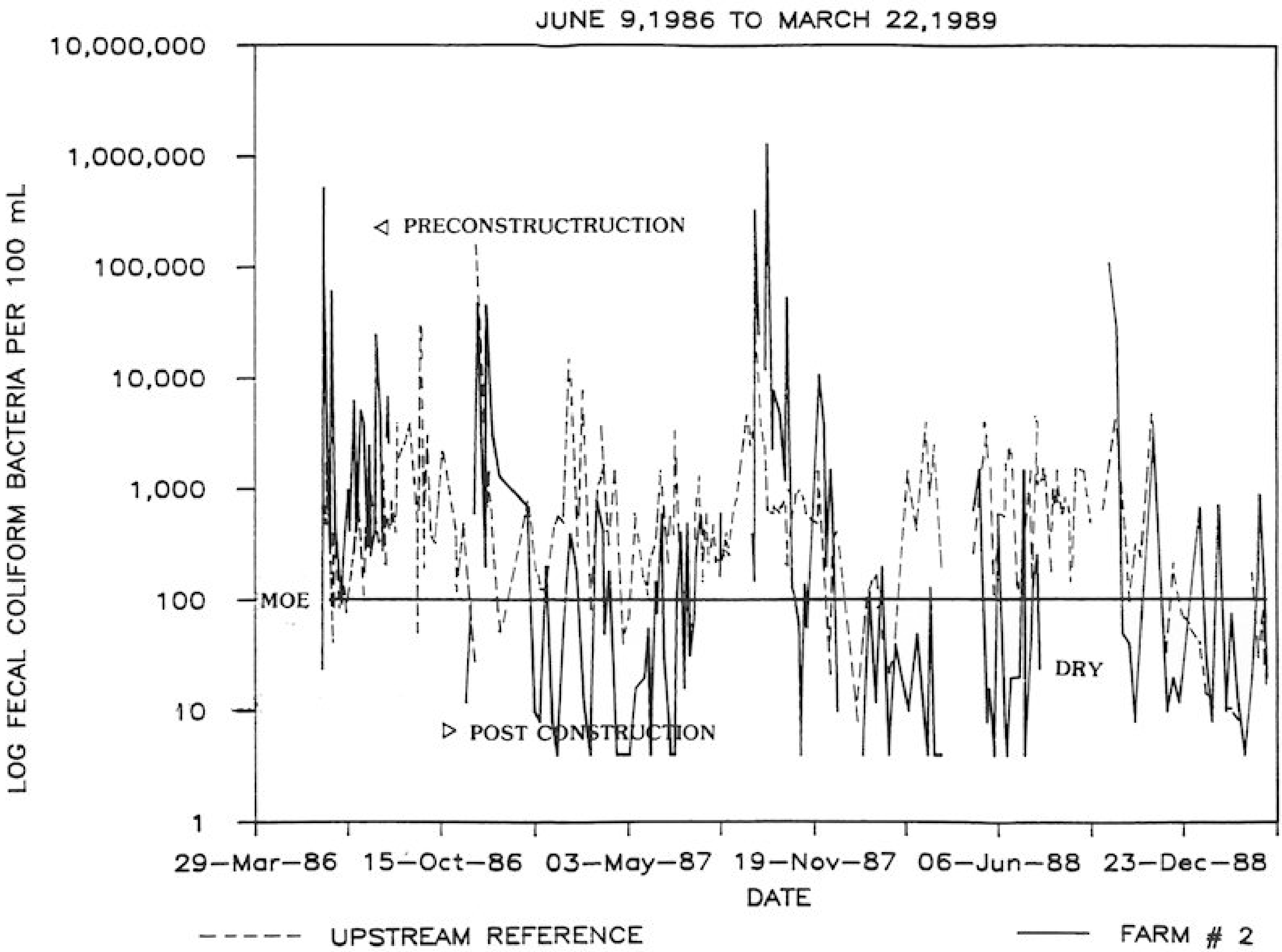


FIGURE 2: TARGET FARM # 2

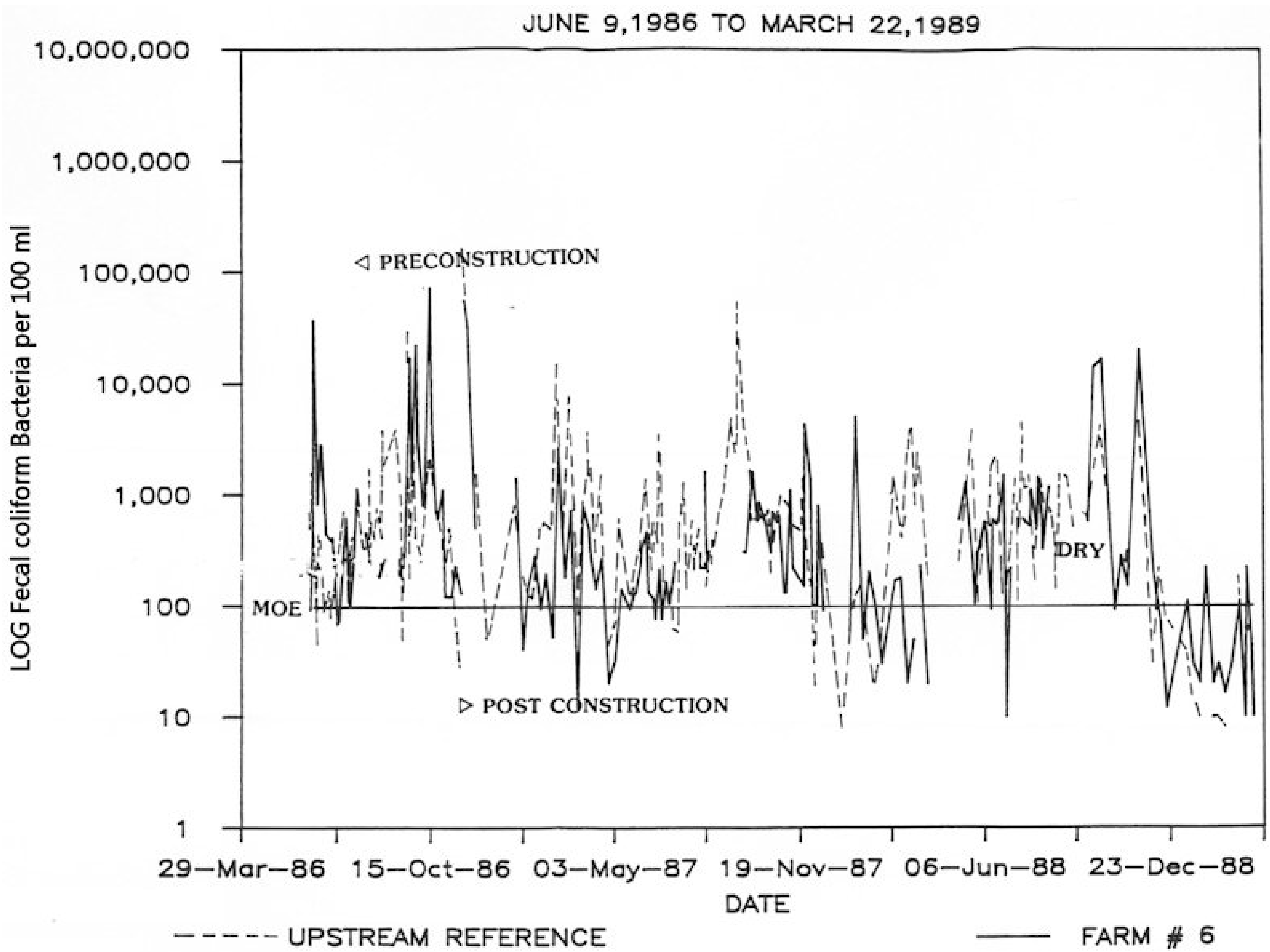


FIGURE 3: TARGET FARM # 6

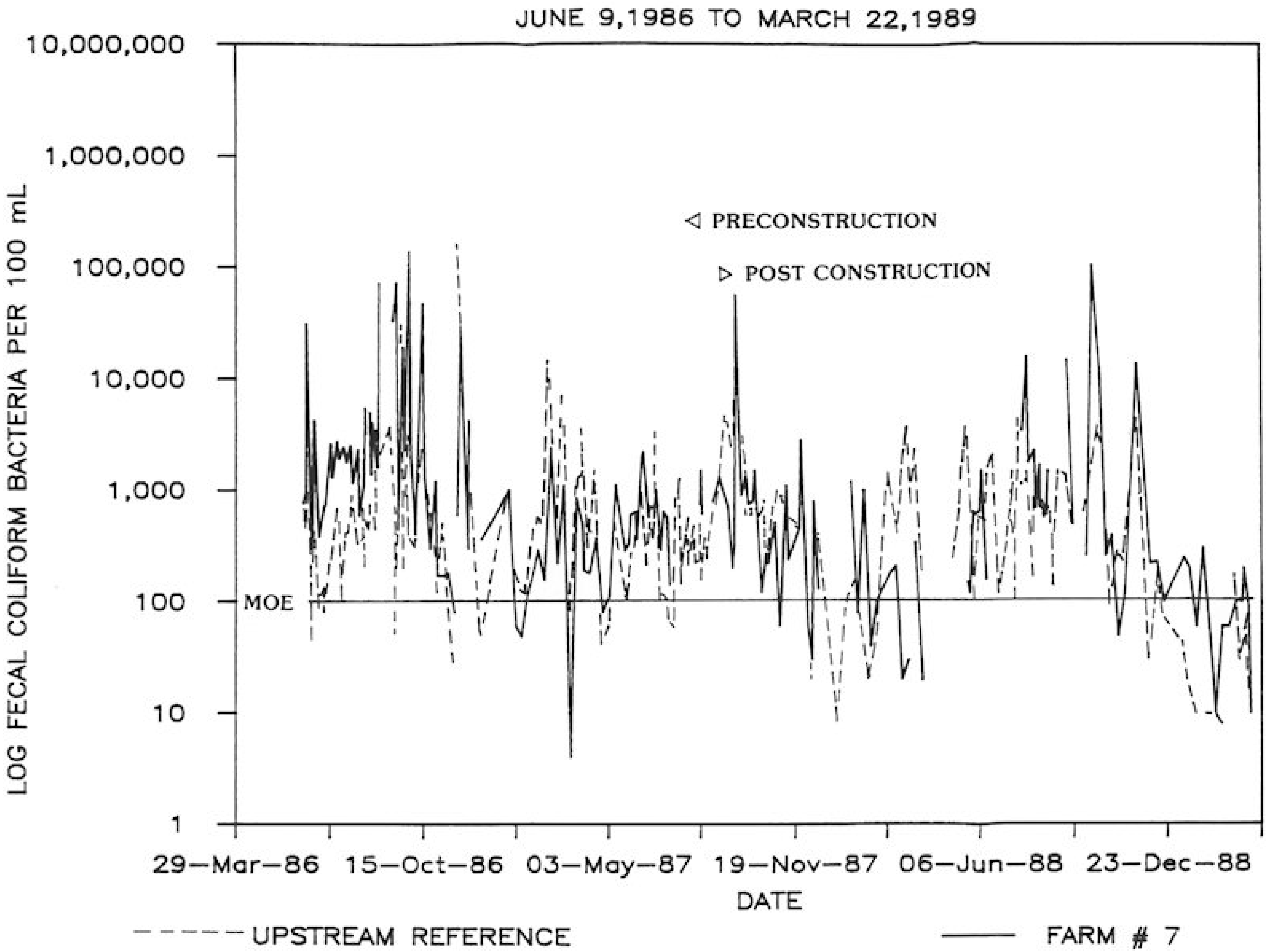


FIGURE 4: TARGET FARM # 7

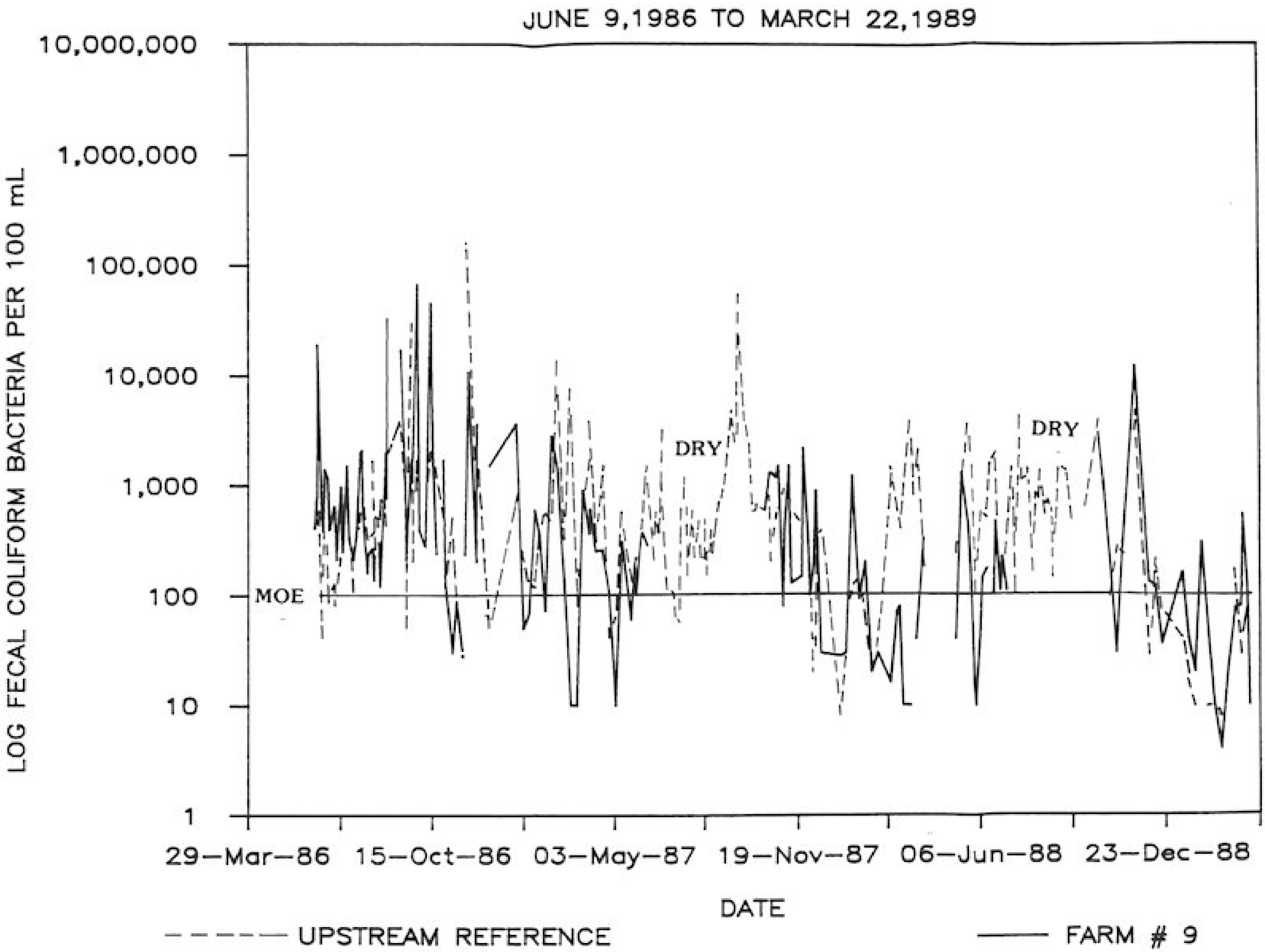


FIGURE 5: TARGET FARM # 9

3.2 Water Column Total Phosphorus

The concentration of total phosphorus at Target Farms 1, 2, 6, 7, and 9 with respect to the concentration at the upstream reference site are shown in Figures 6, 7, 8, 9, and 10 respectively. The same labelling scheme (described in 3.1) has been used in this section. The M.O.E. total phosphorus guideline to eliminate excessive plant growth in rivers and streams is 0.03 mg/L (M.O.E., 1984, p.34). This guideline is rarely met at any Target Farm.

Prior to remedial construction on Farms 1 and 2, phosphorus concentrations were up to one order of magnitude greater than the concentrations at the upstream reference site (Figures 6 and 7). Following the remedial construction, concentrations of phosphorus are similar to those at the upstream reference station.

Target Farms 6 and 7 generally exhibit lowest phosphorus concentrations during the spring of each year (Figures 8 and 9). One would expect increased phosphorus uptake during the spring due to aquatic plant growth.

The upstream reference site exhibited the highest phosphorus concentration of any sample site in June of 1988. This is possibly due to contamination resulting from continuing efforts to repair the septic weeping tiles at A (Map 2). This contamination entered the Desjardine Drain by way of a cellar drain discharging weeping tile leachate to field tiles above the upstream reference station.

A phosphorus concentration of 11.2 mg/L was found at Target Farm 7 on August 4, 1987 (See "septic", Figure 9). Phosphorus concentrations in a field tile discharging septic wastes (black water) 10 meters upstream of the sample site for Target Farm 7 were 10.5 mg/L on this date. The septic system has since been repaired as reported in the 1988 Target Sub-basin Study Report.

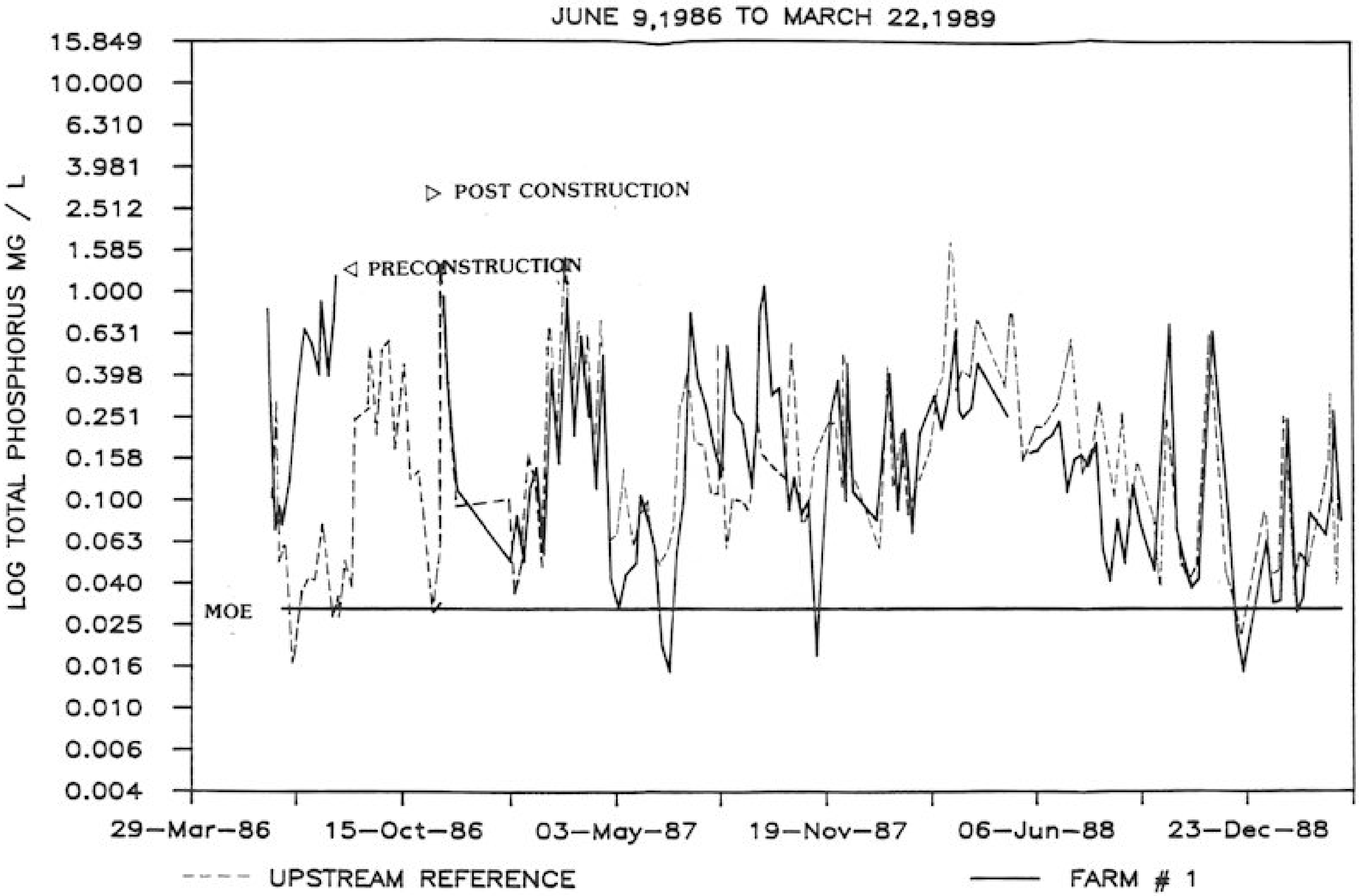


FIGURE 6: TARGET FARM # 1

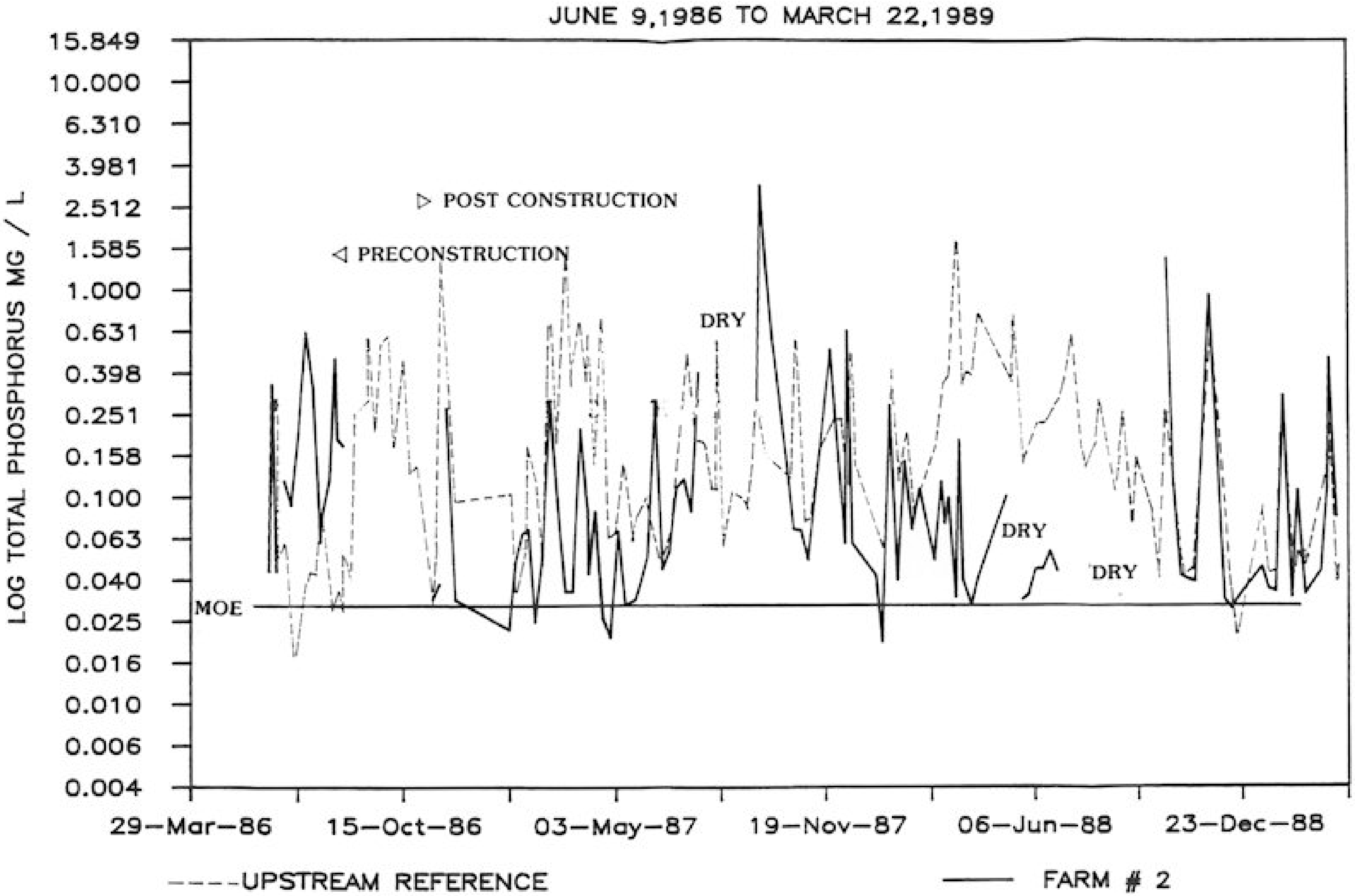


FIGURE 7: TARGET FARM # 2

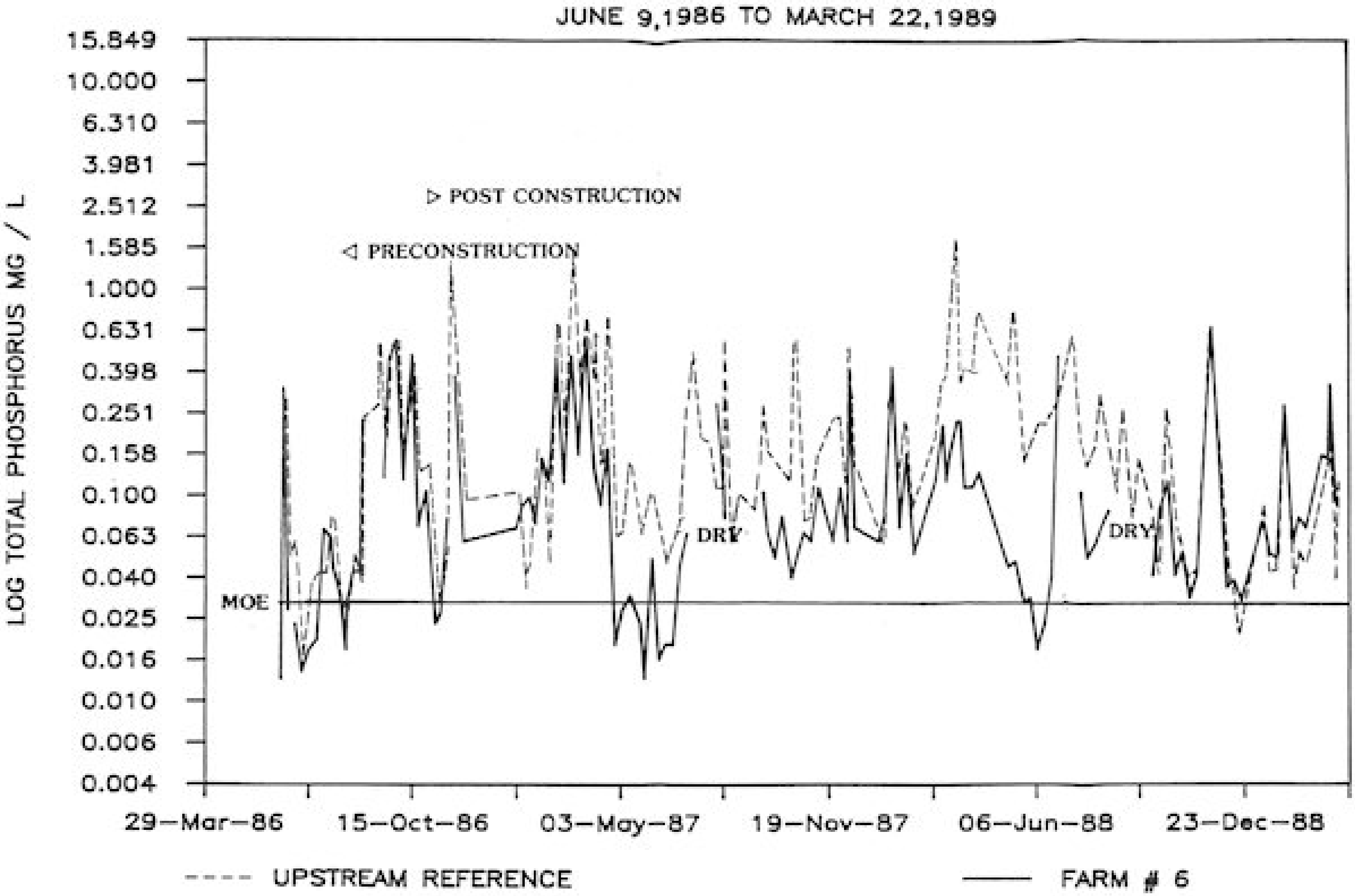


FIGURE 8: TARGET FARM # 6

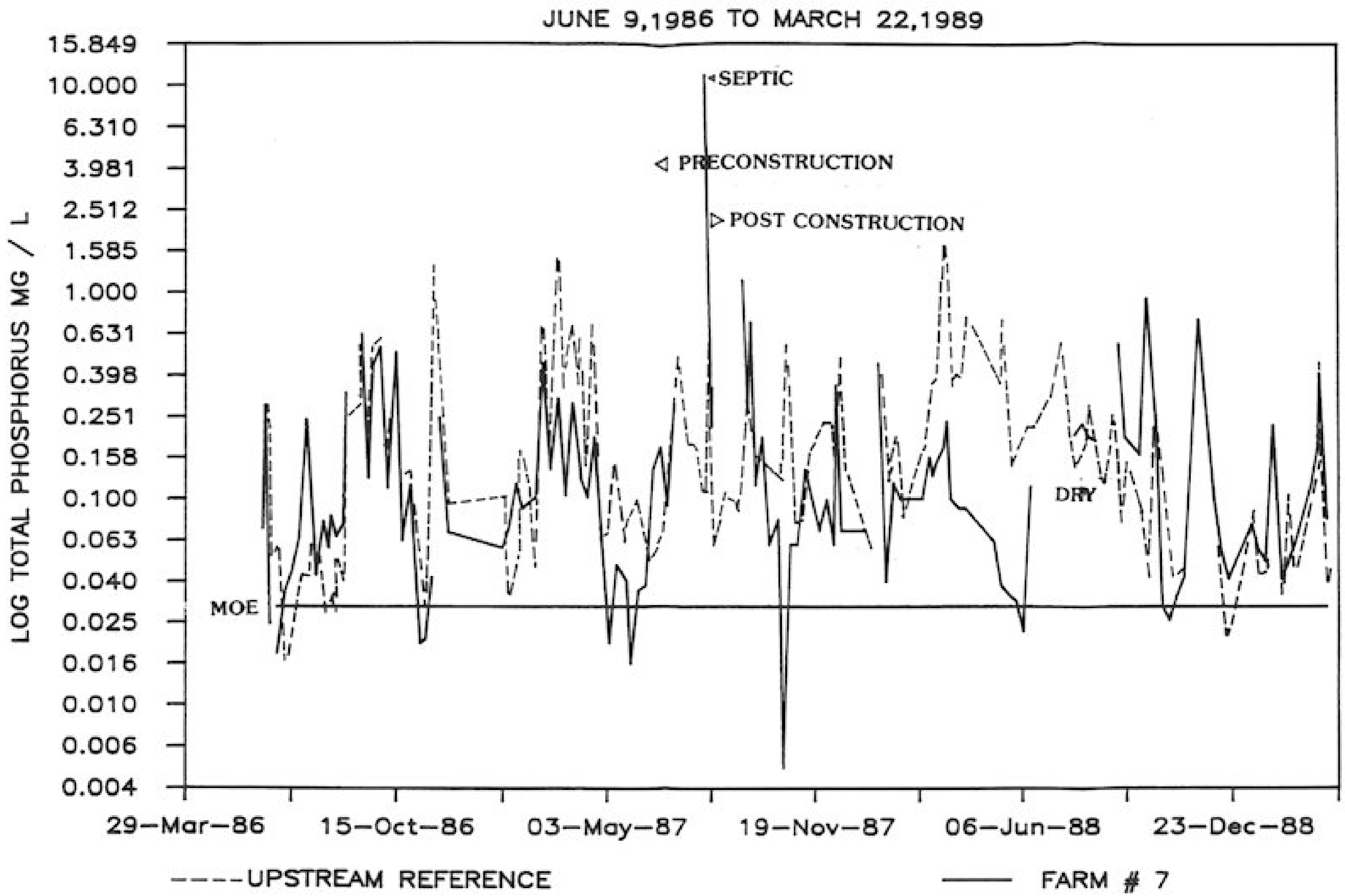


FIGURE 9: TARGET FARM # 7

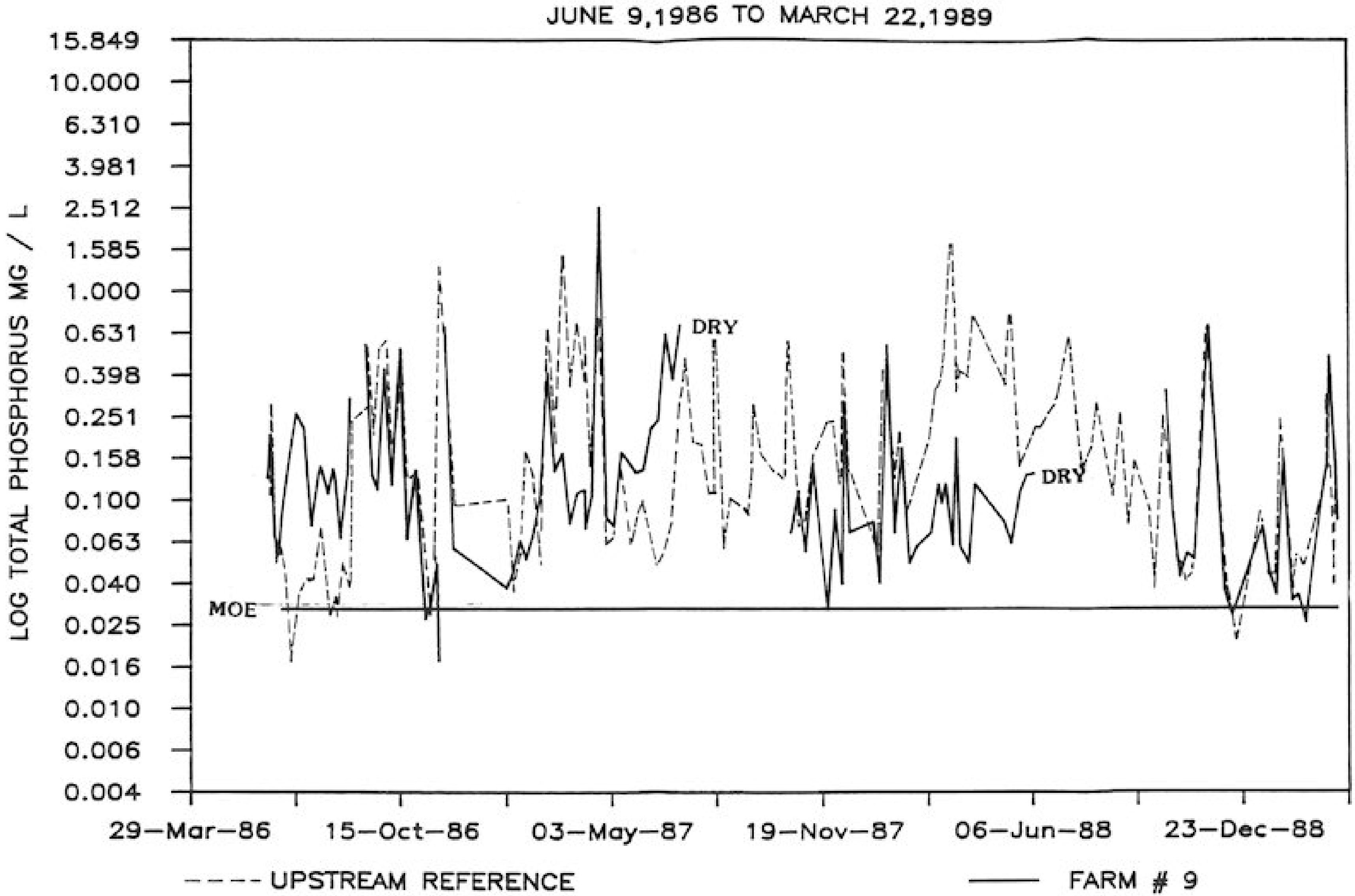


FIGURE 10: TARGET FARM # 9

3.3 Sediment Bacteria

The concentration of fecal coliform bacteria in the sediments on the north branch of the Desjardine Drain at Target Farms 1, 2, and 7 where remedial construction has taken place are shown in Figure 11. The concentration of fecal coliform bacteria in the sediments on the south branch of the Desjardine Drain at Shipka, Target Farm 8 and Target Farm 3, where remedial construction has not taken place are shown in Figure 12. In addition, the concentrations at the upstream control site are shown in each of the figures. Target Farm 3 did receive a concrete solid storage and runoff tank, however it is suspected that leachate from the bunker silo continues to enter a tile draining to the south branch of the Desjardine Drain. Drainage from the repaired part of the farm is to the north away from the regular sampling station.

As part of the regular maintenance of the stream bed, excavation of accumulated sediment in a portion of the Desjardine Drain between the upstream control site and Farm 6 took place from July 14 to July 20, 1988. This event is indicated on Figures 11 and 12 by the word "cleaned". No sediment sampling took place during that time.

3.4 Discharge and Precipitation

Precipitation during the study period from June 1986 to November 1988 is shown in Figure 13.

Stream gauging continued at the three stream gauges 02-FF-111, 02-FF-112 on the Desjardine Drain and 02-FF-113 on the Turner Drain (Map 1). The stream gauges at each of the stations were left running throughout the winter (1988-1989) due to unusually warm temperatures. Neither the Target nor the Control Sub-basin froze to the bottom although there were times at 02-FF-111 and 02-FF-112 when the water in the well froze resulting in a straight line on the chart; however, the float remained ice free at 02-FF-113 on the Turner Drain. Figure 14 shows the mean daily discharge at 02-FF-111, 02-FF-112 and 02-FF-113.

Stream discharge data has been accumulated in the Desjardine Drain since the fall of 1987. Since only one spring-summer period has been documented at time of this report preparation, there has been no opportunity for statistical analysis parallel to water column analysis recorded in the 1988 T.S.S. report.

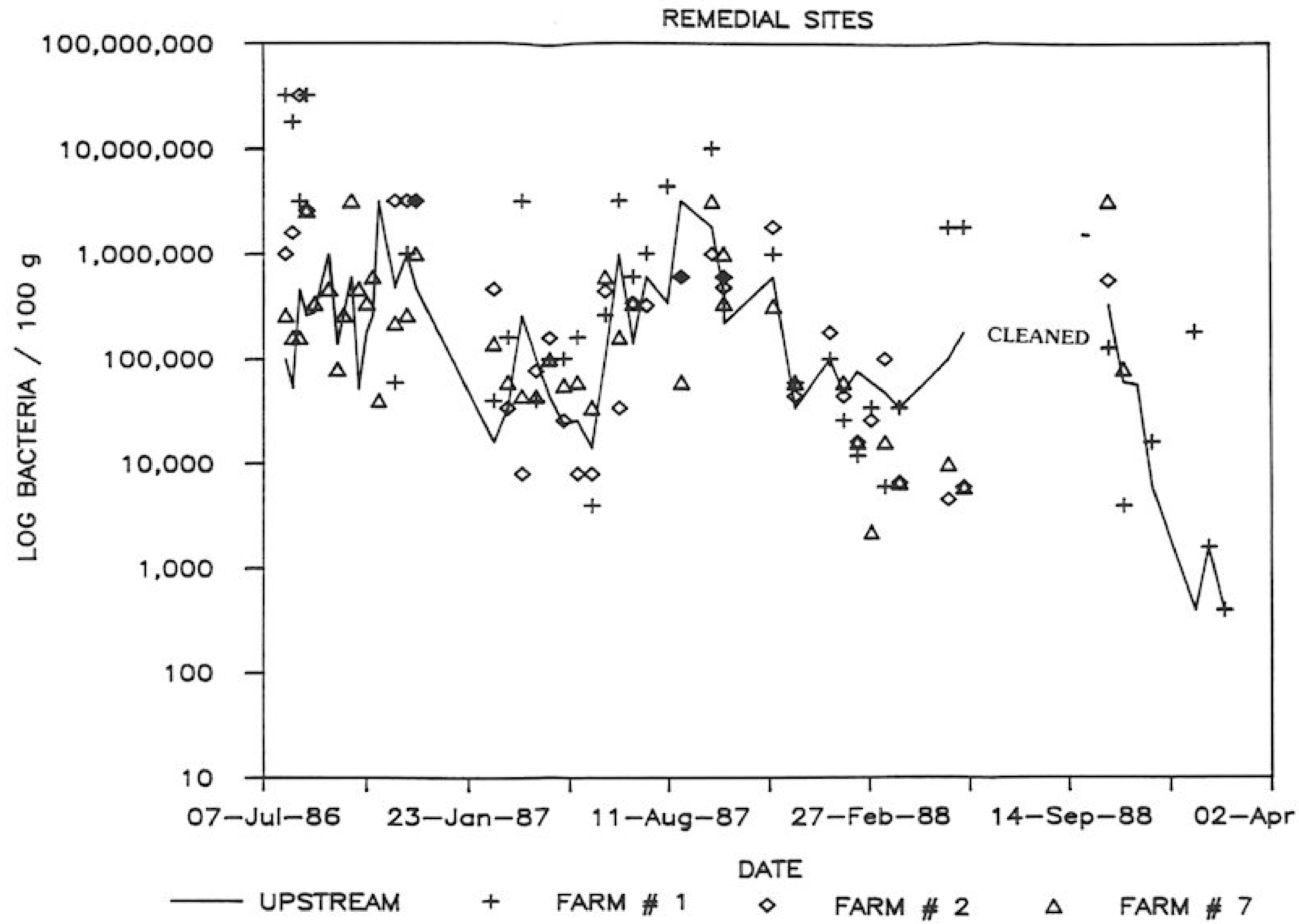


FIGURE 11: SEDIMENT FECAL COLIFORM

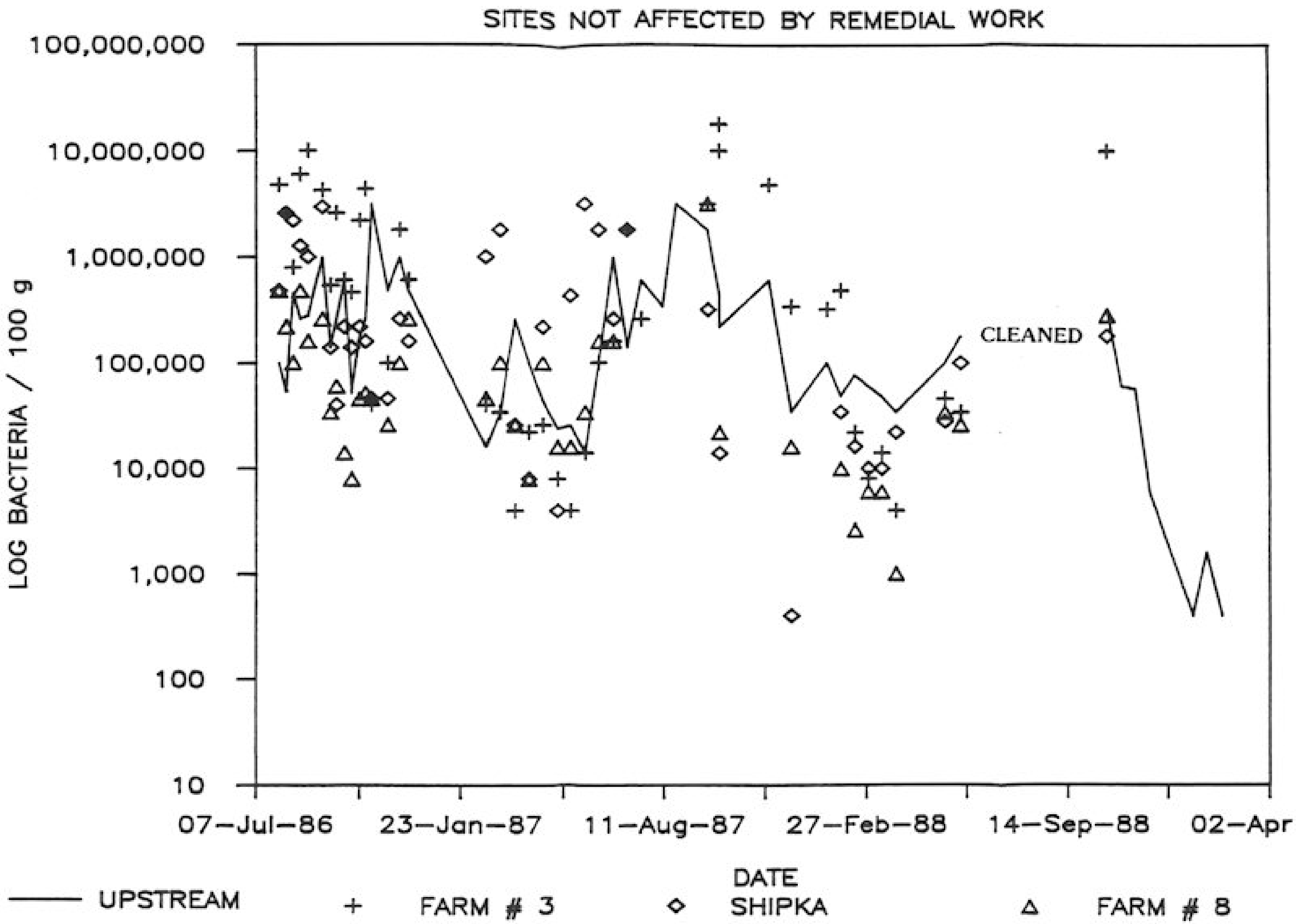


FIGURE 12: SEDIMENT FECAL COL1FORM

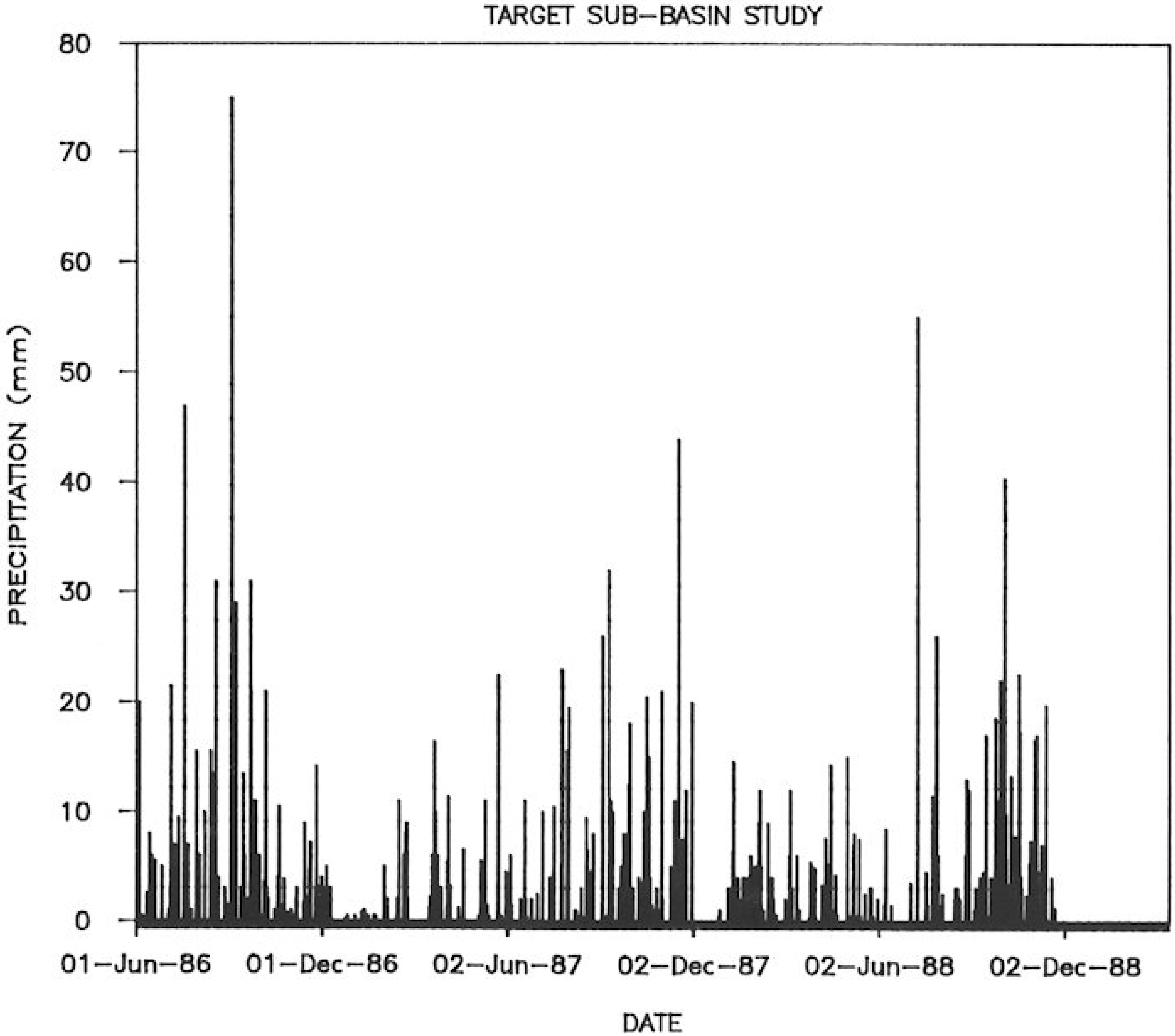


FIGURE 13: PRECIPITATION

3.5 Statistical Analysis

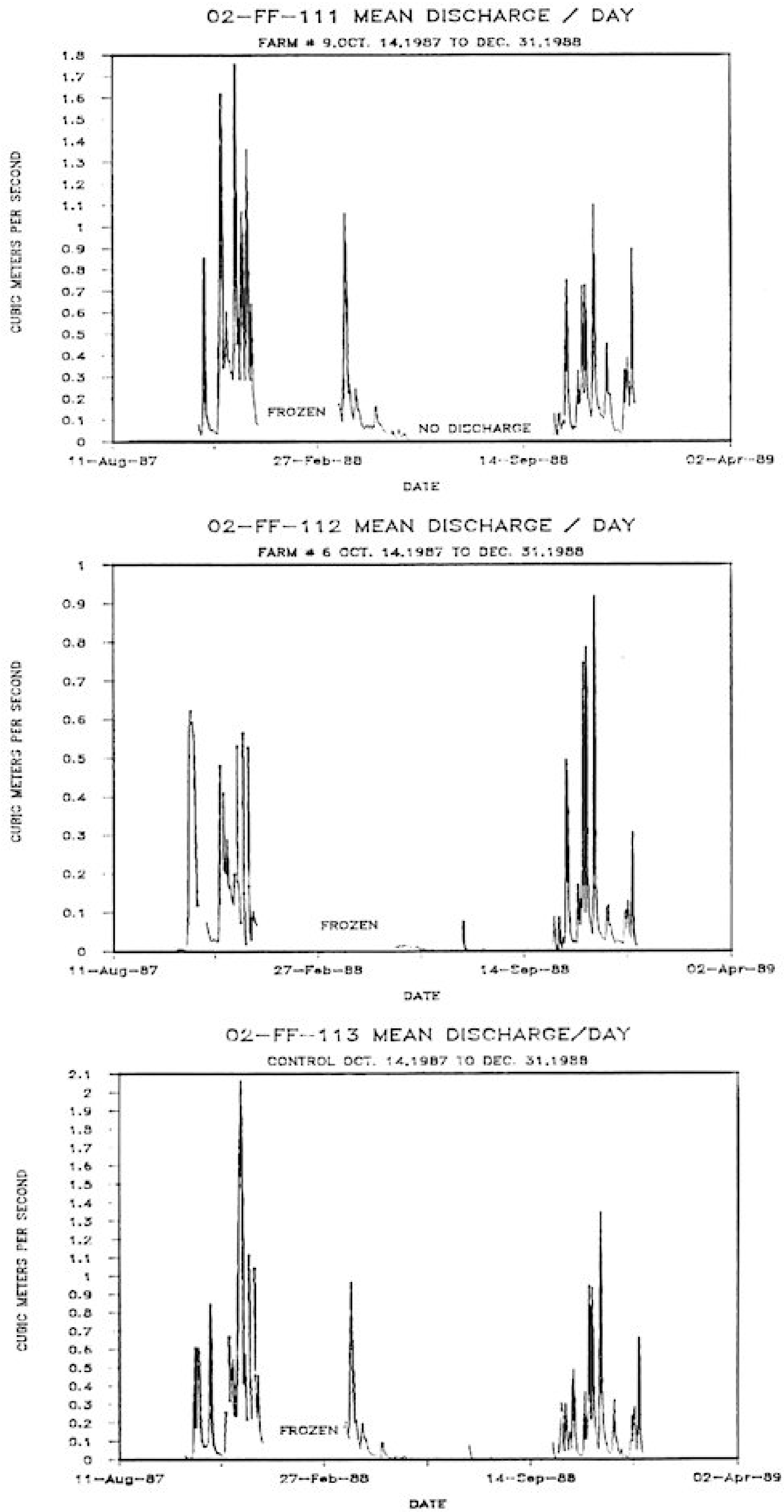
Analysis of 1988-1989 data has been compromised by events described below.

Septic contaminants from A (Map 2) periodically discharged to the Desjardine Drain above the upstream reference sample site from March to September 1988. From the fall of 1987 to March 1988 following initial remedial construction these septic contaminants may have been discharging to the Desjardine Drain at or below the Target Farm 1 sample site. This has limited the application of the most recent statistical analysis. 1989-1990 data analysis shall attempt to identify suitable alternative reference sampling stations and continue analysis techniques initiated. Analysis of covariance requires a reference site unaffected by rernedial work performed by the A.B.C.A. or independently by landowners to provide baseline data. Changes in farm management practices (for example reductions in manure application rates) may also render a site unsuitable for reference or control purposes (R. Griffiths, 1989, personal communication). Analysis of covariance requires pairing of reference sample sites with Target Farm sites to detect significant changes in water quality trends resulting from remedial work.

Statistical analysis for 1986-1987 indicating significant water quality improvements at remedial construction sites remains valid as the analyzed period did not extend into the fall of 1987.

Figure 14:

Mean Daily Discharge of Stream Gauges in Target and Control Sub-basins 02-FF-111, 02-FF-112, and 02-FF-113.



4.0 CO-OPERATIVE RESEARCH

4.1 Tracer Experiments

To date seven bacteriological tracer experiments have been performed in the Desjardine Drain. The first one, done in November, 1987 was described in the 1987-1988 Rural Beaches Report. Since then, two experiments were done in April 1988, two in November 1988, one in March of 1989 and one in April 1989.

The purpose of the tracer experiments is to show that bacteria originating in the headwaters of the Desjardine Drain can reach the Lake Huron shoreline at Grand Bend, a distance of approximately 16 km, potentially impairing beach water quality. It was hoped to determine the impact an individual farm could have on the lake in a worst case scenario. Map 1 shows the insertion point of the tracer bacteria in the headwaters of the Desjardine Drain.

Nalidixic acid resistant *E. coli* has been used in each tracer experiment. Starting in the fall of 1988, rifampicin resistant *Fecal Streptococcus* has been used as a tracer bacteria as well. The rifampicin resistant *Fecal Streptococcus* appears to be hardier than the *E. coli* tracer but behaves similarly when released in the drain. These non-virulent organisms are released in the headwaters of the Desjardine Drain at concentrations in the order of millions per 100 ml and their downstream movement has been carefully monitored.

Since the organisms are not visible in the water, fluorescein dye is released simultaneously with the bacteria. The dye is used as a visual indicator of the approximate location of the tracer bacteria.

Water samples are taken at sixteen locations along the drain located approximately 1 km apart. Monitoring of the water column for the tracer bacteria continues until the bacteria have either passed the monitoring points or have dropped below the detection level. Figure 15 shows peak concentrations measured during each of the tracer experiments undertaken in the Desjardine Drain. Tracer bacteria reached the outlet of Parkhill Creek in Grand Bend in the fall of 1987 and 1988 as well as in March of 1989. Tracer bacteria was not detected at the outlet in April 1988 or April 1989. Prior to each experiment the water column and sediments in the drain are tested for the indicator bacteria to ensure there are no residual bacteria.

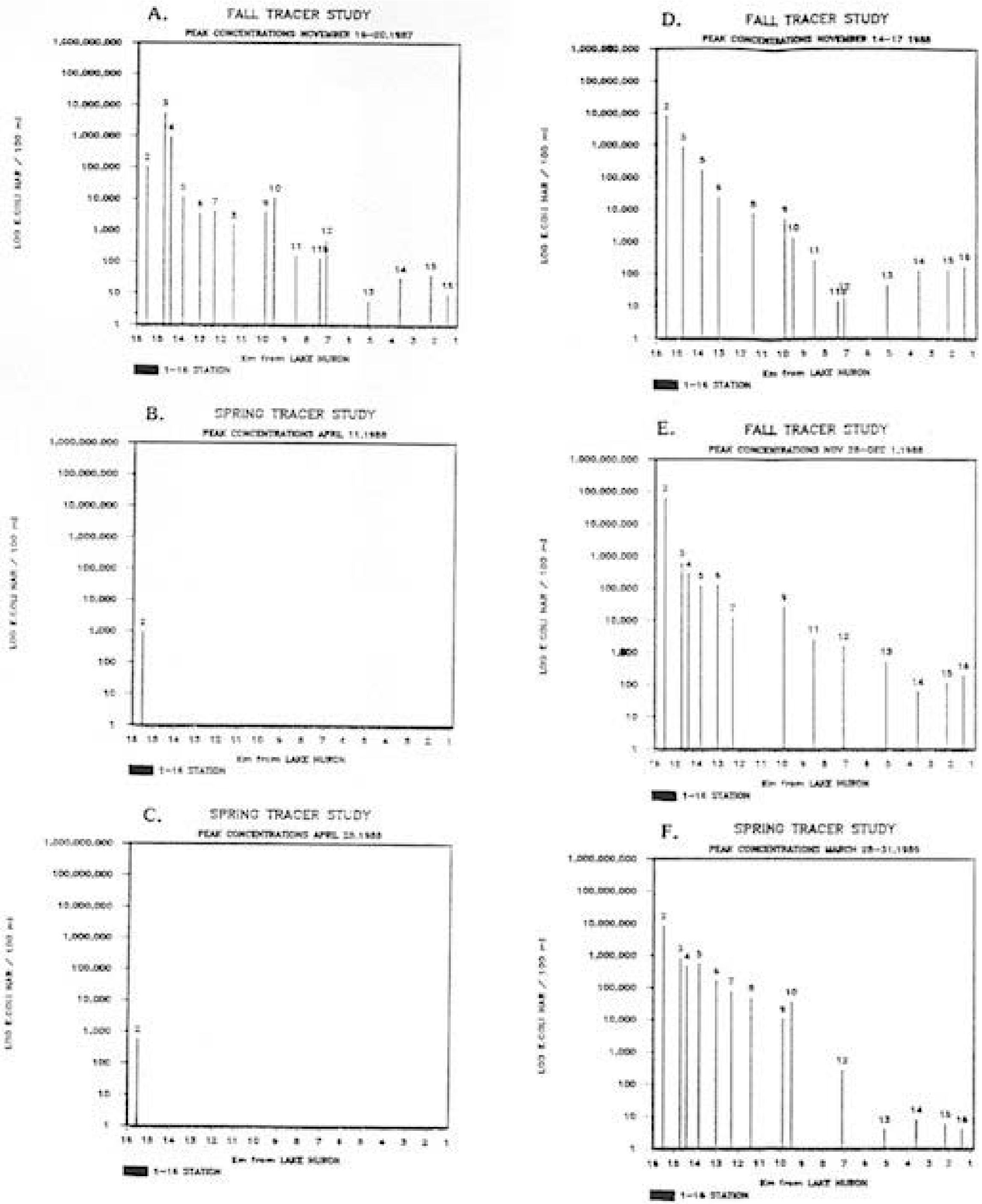
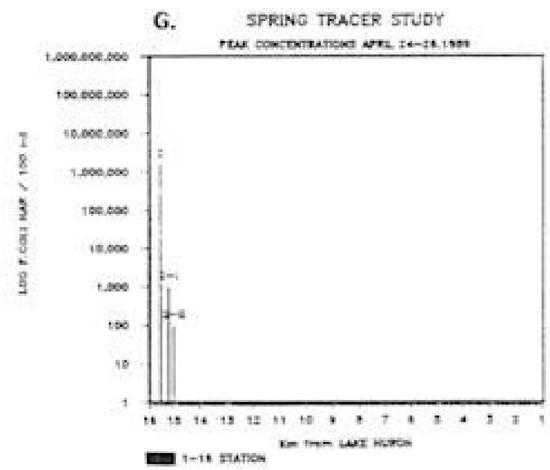


Figure 15:

Peak Tracer Concentrations



Transport of the tracer bacteria is strongly influenced by the discharge rate in the drain at the time of the experiment. Figure 16 shows the influence of discharge rate on the velocity of the tracer bacteria. There appears to be a direct relationship between discharge rate and rate of travel of the bacteria in the drain; the greater the discharge rate in the drain the faster the bacteria move downstream. For example, on March 28, 1989 there was a discharge rate of 0.75 m^3/s and the bacteria were transported at a speed of 1.3 km/hr (0.36 m/s), whereas on November 16, 1987 there was a discharge rate of 0.051 m^3/s and the bacteria were transported at a speed of 0.23 km/hr (0.06 m/s). For the two tracer experiments conducted in April of 1988, the bacteria were undetected further than 2 km from the point of insertion.

The possible effect of sunlight on the decay rate of water column bacteria was evident in April 1988 and April 1989. The tracer bacteria was detected only in very small concentrations near the insertion point. It is believed that the higher dosage of sunlight received in April compared to November tracer experiments caused more rapid die-off of the tracer bacteria in the drain than expected. The stock culture of nalidixic acid resistant *E. coli* bacteria was tested for viability. It was determined that the bacteria culture had retained its resistance and would retain its vitality when released in the environment.

It was suspected that the actual number of bacteria present in the water were not being represented by the conventional standard plate method of counting bacteria. This resulted in the use of an alternative method of counting bacteria by the microbiology staff at M.O.E. in London. It is a direct viable count technique. Nalidixic acid is added to the water sample to stop the division of the cells and they are killed with formaldehyde and stained. The cells are then put on a slide for counting. The stain gives the bacteria a granular centre which is easily seen under a microscope. The counts of bacteria yielded from this method can be much higher than those recovered from the conventional agar plate method (Palmateer 1989, personal communication).

It is suspected that the lower counts found in the standard plate method result from suppressed growth by stressed bacteria in conventional culturing media. If stressed bacteria are still capable of causing infection the standard culture method used to develop health guidelines may underestimate health risks. These results are supported by work being done in Spain by Barcina *et. al.*, 1989, who have found similar results. This could mean that samples collected under sunny conditions and cultured using standard plate culturing techniques could underestimate the health risk. This new technique could have a profound

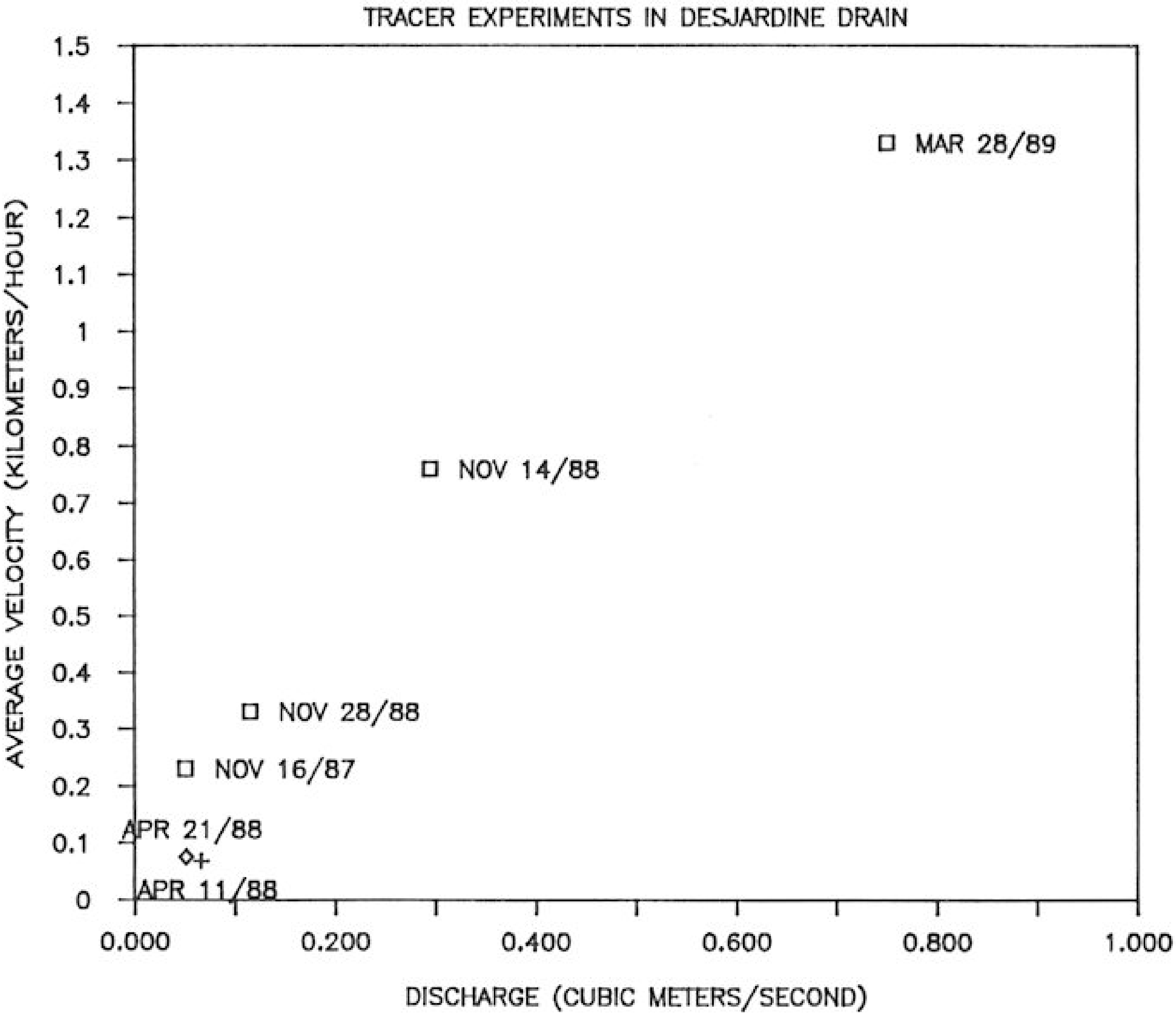


FIGURE 16: DISCHARGE VERSUS VELOCITY

impact on how the M.O.E. sets its swimming limits and other bacterial guidelines. In addition, results from the direct cell count method are available sooner than the results from the conventional methods. The direct cell count method was used in the spring of 1989 tracer experiments. These results are not available at this time.

4.2 Stationary Water Column Die-off Studies

As a result of the rapid rate of decay of tracer bacteria experienced in the April 1983 tracer experiments, it was deemed necessary to examine further the effect of sunlight on bacterial survival in the Desjardine Drain. The nalidixic acid resistant *E. coli* and rifampicin resistant *Fecal Streptococcus* were used in the stationary die-off experiments. The experiments were performed twice, once in June 1988 and once in July 1988.

Bacteria of known concentration were placed in membrane diffusion chambers in the drain and samples were taken daily for approximately two weeks using a sterile syringe. The membrane diffusion chamber has a polycarbonate membrane that allows the passage of water and nutrients but does not allow the passage of bacteria. The water samples were analyzed by the membrane filtration technique for the bacteria mentioned above. A diagram of a membrane diffusion chamber is shown in Illustration 1 below.

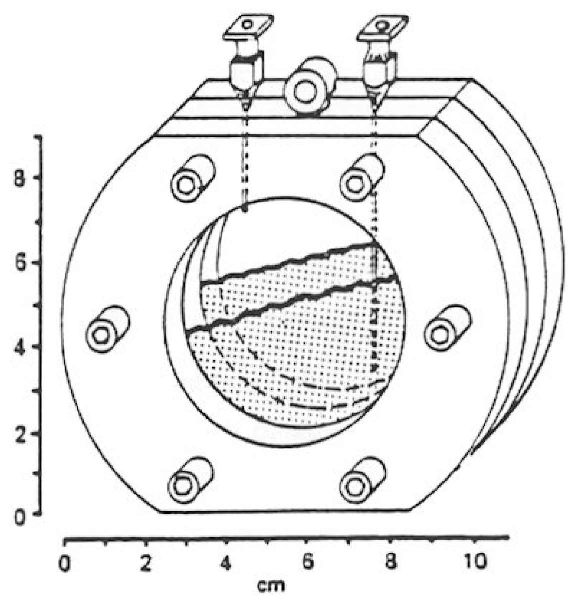


Illustration 1: Schematic Drawing of a Membrane Diffusion Chamber

In the first experiment one chamber was placed in the sunlight and one in the shade under a nearby bridge. All water column factors were constant with the exception of their location with respect to sunlight. The results of this experiment are shown in Figure 17. From the graph it would appear that the E. coli bacteria exposed to sunlight exhibit a greater rate of decline than the bacteria not exposed to light.

Figure 18 illustrates the second die-off experiment which took place in July. The location of the die-off experiments was changed since the water levels at the first location had decreased significantly and it was feared that the chambers might dry out due to receding water levels. This time four chambers were used, two in the sun and two in the shade under a nearby bridge. Problems were experienced as a result of faults with the membranes and or handling of them. Over the course of the experiment some membranes tore and sediments may have plugged the membrane pores. In addition, the bacteria may have adhered to the membrane permanently and possibly used it as a food source (Janzen 1989, personal communication).

It was later discovered that the membrane diffusion chambers did not allow the infiltration of bactericidal ultraviolet wavelengths of sunlight. These experiments were therefore unable to distinguish between shaded versus sunlit conditions.

Due to the above complications with the diffusion membrane, the average decay rate of 0.38 logs per day determined by the die-off experiments are suspect and as a result could compromise bacteria loads predicted by C.U.R.B. algorithms. This may apply to all C.U.R.B. studies using this method to determine the rate of decay of bacteria.

A study of the suitability of a fibrous membrane, which is more resistant to tearing and clogging by suspended sediments is currently being undertaken by M.O.E. - S.W.R. (Janzen 1989, personal communication). If it is more suitable than the carbonate filter, experiments will be carried out using it this summer. The results of the first experiment suggests that exposure to sunlight increases the die-off rate of bacteria and further research is required, however the methodology must be refined first.

Stationary die-off experiments were also performed on the roof top at the M.O.E.-S.W.R. The purpose of these experiments was to determine the effect of sunlight on the decay rate of bacteria. The same nalidixic acid resistant *E. coli* and rifampicin resistant *Fecal Streptococcus* were used in these experiments. Desjardine Drain water was placed in pans approximately 16 inches by 10 inches and 4 inches in depth. One pan was exposed to direct

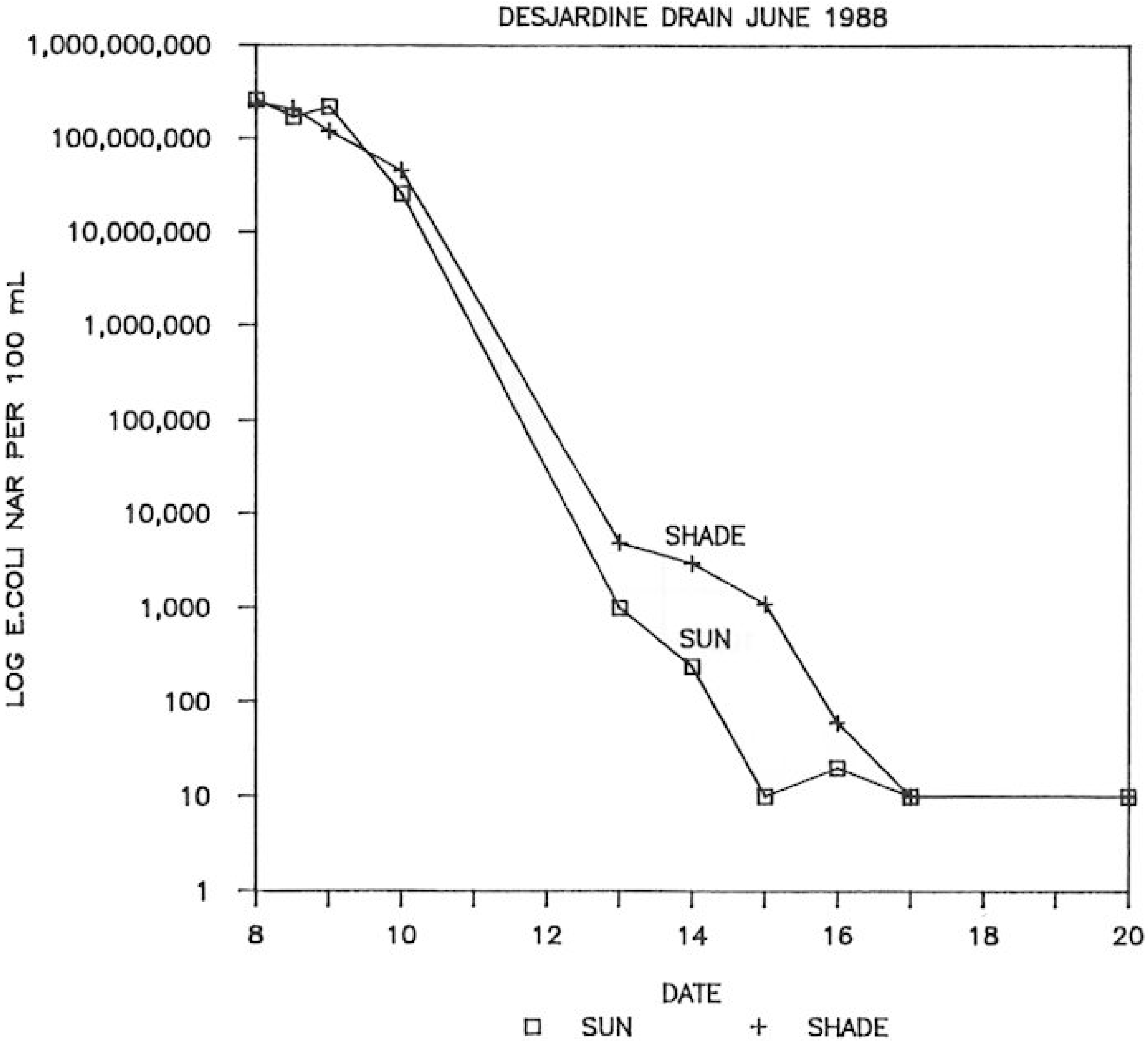


FIGURE 17: BACTERIA DIE-OFF

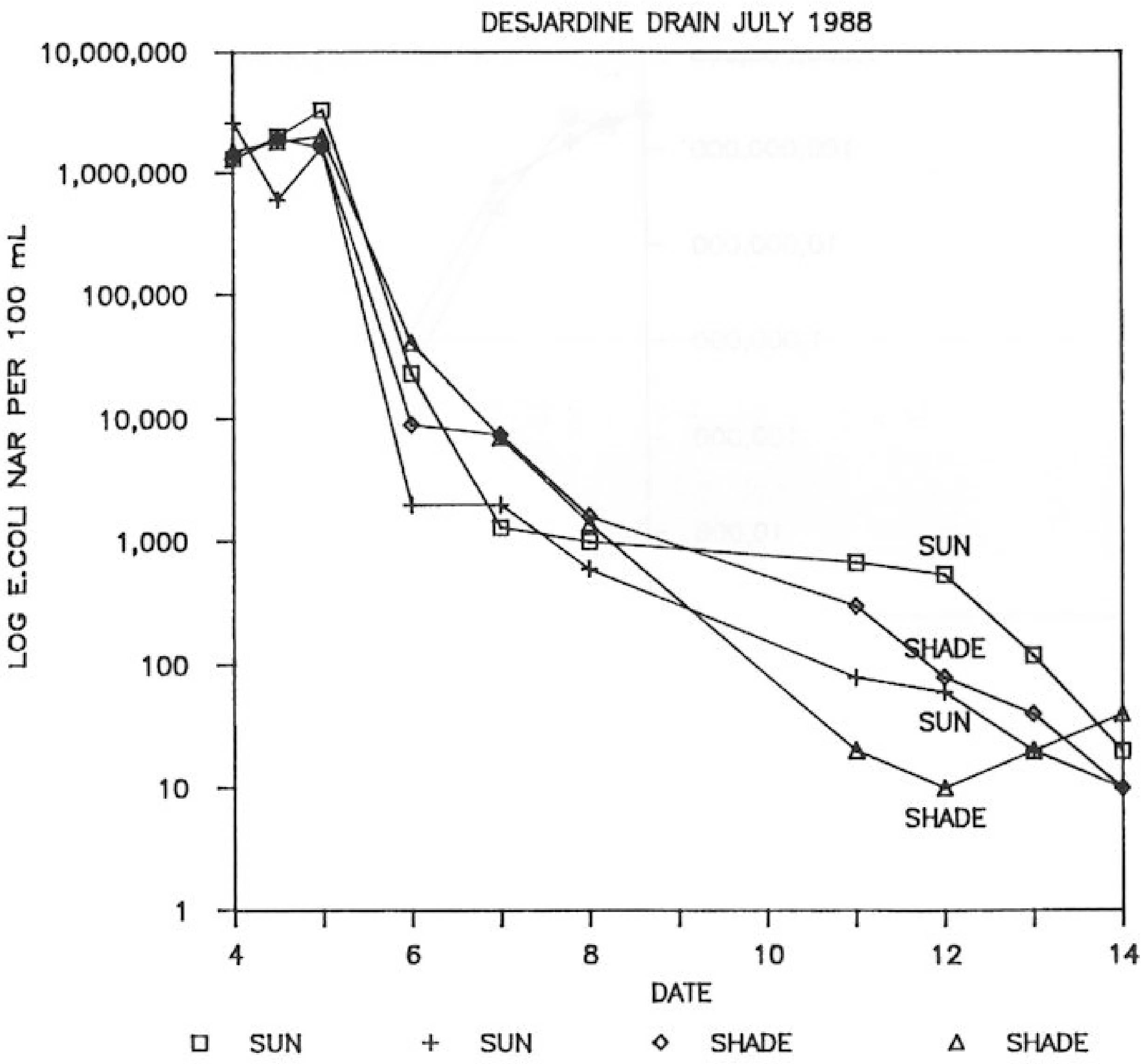


FIGURE 18: BACTERIA DIE-OFF

sunlight while a second pan was blocked from the sunlight. The pans were kept side by side and temperature and volume of water were kept constant. The experiments were one day in length and water samples were taken hourly to determine the bacterial concentrations.

The experiment was performed approximately 15 times with similar results each time. Figure 19 shows the results of one of the roof top sunlight experiments performed on June 23, 1988. The bacteria exposed to sunlight dies off at a higher rate than those in the shade and the *E. coli* experience a higher rate of die-off than the *Fecal Streptococcus*. From the results of the spring tracer experiment described above, these conclusions were expected.

4.3 Pyocin and Serologic Typing

Pyocin and serologic typing were discussed in the 1987 - 1988 A.B.C.A. Beaches report (Hocking 1988, pp. 42 - 43). Pyocin and serologic typing are part of the ongoing research being conducted in co-operation with the Ministry of the Environment - South-Western Region (M.O.E. - S.W.R.). These methods are used to identify and trace sources of *Pseudomonas aeruginosa* in the Desjardine Drain. Pyocin and serological typing have been adopted for environmental studies from clinical work done at the Centre for Disease Control in Atlanta, Georgia. Clinically, pyocin and serologic typing are used to follow the pathway of *P. aeruginosa* for the purpose of explaining outbreaks of *P. aeruginosa* infections and to aid in effective infection control in hospitals.

The result of pyocin typing *P. aeruginosa* bacteria is a five digit number specific for that *P. aeruginosa*. Certain pyocin types or groups of pyocin types may be associated with specific animal species. Serological typing produces a two digit number which is not as specific as the pyocin number however, the serological type is more reproducible in the laboratory than the pyocin type (Schuble, Olson and Smith 1986, p. 1017).

P. aeruginosa does not normally inhabit the intestinal tracts of domestic animals or wildlife. It is more likely to be present in the human intestinal tract and may be transferred to animals, particularly among young calves through handling of feed. Table 1 shows the presence of *P. aeruginosa* in the intestinal tracts of various animals and man from a study done by Hoodley and McCoy (1968).

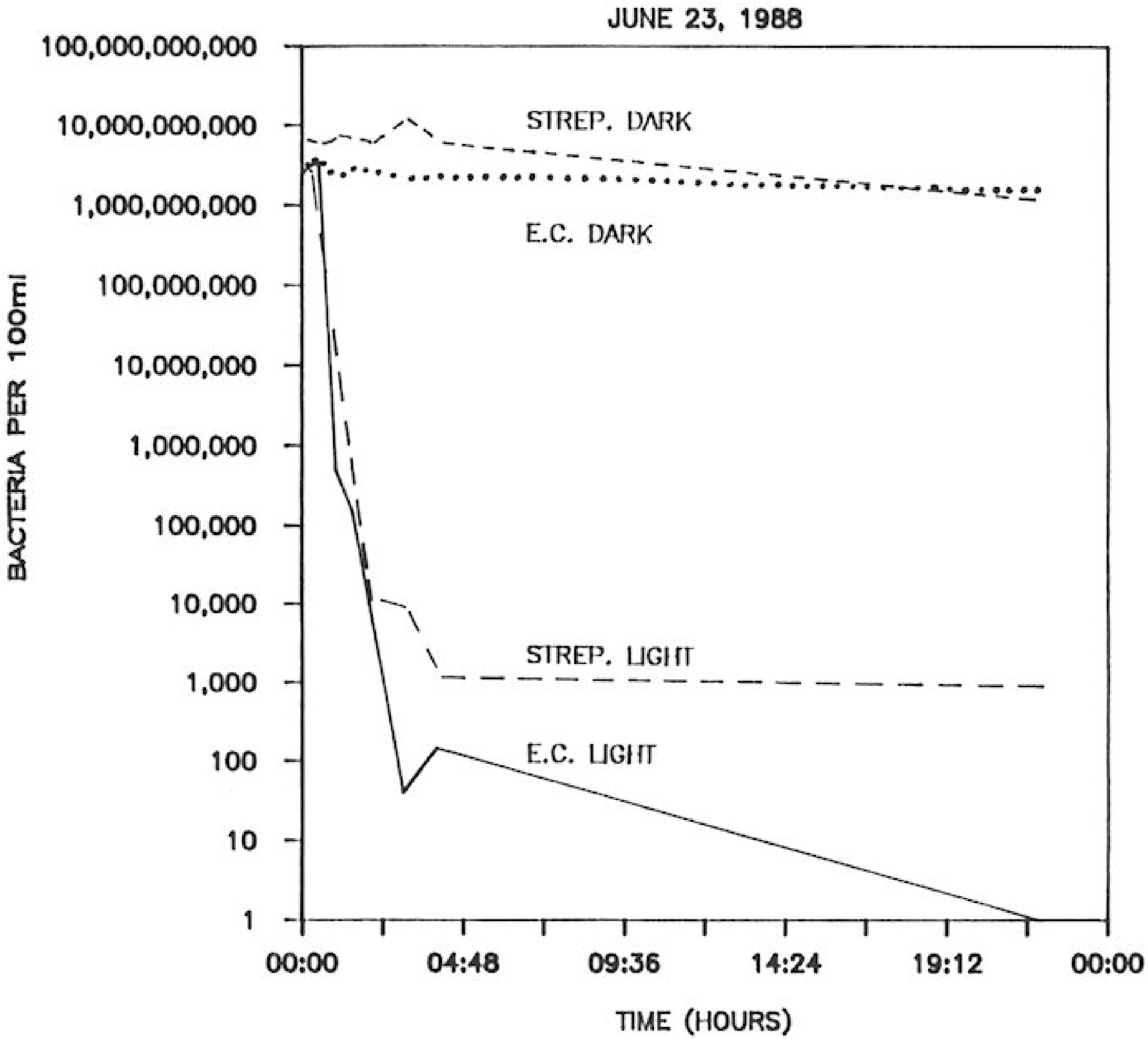


FIGURE 19: ROOF TOP SUNLIGHT EXPERIMENT

TABLE 1: Survey of Human and Animal Carriers of *P. aeruginosa*

Animal	Number of Samples	No. Positive for P. aeruginosa	Percent Positive
Man	52	6	11.5
Beef Cattle	29	0	
Dairy Cows	92	0	
Calves	148	14	9.45
Goats	29	0	
Young Goats	14	1	7.15
Sheep	57	0	
Pigs	18	0	
Young Pigs	27	0	
Dogs	95	26	27.4
Deer (in captivity)	7	0	
Rhesus monkeys	47	3	6.38
Canada Geese (in captivity)	30	2	6.67
Domestic Geese	2	1	50
Canada Geese (wild)	88	0	
Swan (wild)	1	0	
Ducks (domestic)	15	0	

(Hoodley and MacCay 1968, p. 356)

P. aeruginosa has been isolated from both water column and fecal samples from the Desjardine Drain and the banks of the Desjardine Drain respectively. The isolation of *P. Aeruginosa* has occurred over the past three years at farms 1, 2, 6, 7, and 9 at the upstream reference station as well as from a tile drain with a direct septic connection (D), (Map 2). Table 2 shows the resultant pyocin and serologic numbers at the above locations in 1986, 1987 and 1988 as well as the number of occurrences of those types. The majority of the time if a pyocin type is repeatedly present the serologic type will be the same as well. For example at the upstream site in 1986 pyocin type 56373 was present four times and each time serologic type 6 was present.

Serologic types 1 and 6 were predominate in 1986. These serologic types (1 and 6) are likely derived from human sources (G. Palmateer, personal communication, 1989). This would indicate that septic contamination in the Desjardine Drain is ubiquitous and would support the fact that nine of fifteen, or sixty percent, of the septic systems in the Desjardine Drain were faulty in 1986. Since then those nine septic systems have been repaired or replaced. A decline in serological types 1 and 6 should therefore have occurred, however type 1 continues to predominate in 1987 and 1988. It may take a long period of time for the resident flora to be flushed out of the tiles following years of contamination.

At the upstream sample site pyocin type 56373 was predominant and appears to have been eliminated by 1988, however new pyocin types appeared at that time. Often pyocin types are identical with the exception of one digit. In such cases the *P. aeruginosa* may be of the same strain but through a slight variation in the experimental procedures the pyocin number changes.

There appears to be a downstream movement of the various pyocin types from the upstream site to Farm 1. This reach was impacted by dairy cattle access and milkhouse waste discharges combined with direct septic (blackwater) discharges prior to remedial construction in the summer of 1986. Additional solid manure storage and runoff retention facilities were constructed. The number of pyocin types at Farm 1 decreased by almost one half between 1986 and 1987 and increased by three times in 1988. The increase in the number of pyocin types in 1988 may have been caused by septic contamination from an improperly installed septic system upstream of Farm 1 from March 1988 to November 1988.

At Farm 2 the diversity of pyocin types appears to be decreasing although pyocin type 56373 is constantly present. The decrease in the number of pyocin types may be further evidence that the remedial construction at Farm 2 in the summer of 1986 is causing an

TABLE 2: Pyocin Types Found at the Control Site and at the Remedial Farms.

	1986			1987			1988		
	Pyocin Type	Serotype	No. of Occurrences	Pyocin Type	Serotype	No. of Occurrences	Pyocin Type	Serotype	No. of Occurrences
UPSTREAM									
(control site, downstream of a swine lagoon which has septic input)	56373	6	4	56373, 54373	6	1	46773	6	4
	01211	6	1	56373	6	9	46373, 46773	6	1
	no growth		1	36752	6	2	40062, 40022	1	2
							40000	3	1
FARM # 1									
(remedial Farm #1, cattle access, milkhouse waste and runoff controlled late 1986)	77773	6	2	50200		2	77773	11	2
	57773	6	2	50200		1	77773	12	1
	56673	6	2	54373		1	76743	3	1
	56373	6	1	50202		1	76761	5	1
	34723	6	1	40022		2	67773	16	1
	34703,34303	6	1	10022		3	66771	16	1
	14363	6	1				66373	(7, 8)	1
	14323	6	1				66373	(13,14)	1
	01211, 01213	1	1				64373	(13,14)	1
	01211	1	1				46773	6	1
	04233	10	1				46363	13	1
							42122	1	2
							42453	5	1
							40020	1	1
							22651	6	3
							04323	1	1

	1986			1987			1988		
	Pyocin Type	Serotype	No. of Occurrences	Pyocin Type	Serotype	No. of Occurrences	Pyocin Type	Serotype	No. of Occurrences
FARM # 2									
(on a southern branch of the Desjardine)	56373	6	5	56373	6	11	56373	(2, 5)	1
	75763	2	1	74761	5	1	57373, 47373	8	1
	75761	2	2				47673, 57673	11	2
	76373	1	1						
	74373	1	1						
	57373	1	1						
	63272	6	1						
	43252	6	4						
	40261	1	1						
	01211	2	2						
FARM # 6	no growth		1	56373	6	1	77773	11	1
				76373	(7, 8)	2	76773, 66773	(5,16)	1
				52473	9	1			
				50000	3	4			
				14022	0	1			
				01233	6	1			
FARM # 7	no growth		1	77773	4	1	74761	9	2
	56373	6	2	56373, 57373	6	1	47773, 57773	1	1
	57773	0	3				40202	1	1
	77773	4	2						
	23011, 23032	0	1						
	01251	1	1						

	1986			1987			1988		
	Pyocin Type	Serotype	No. of Occurrences	Pyocin Type	Serotype	No. of Occurrences	Pyocin Type	Serotype	No. of Occurrences
DOWNSTREAM									
(downstream of	77373	6	2	77373	8	2	77773	11	2
remedial Farms	77773	4	1	76373	6	1	57773	6	1
#1,2, 3 & 6 cattle	74773	5	2	40623, 40223	5	1			
access)	57773	10	1	40223	3	4			
	23012	6	1	00223	3	1			
SEPTIC CONTAMINATION									
(tile that was being	no data						56773	6	2
contaminated by				56773	10	1	55363, 45363	1	1
septic waste,				65341	1	1	66751	6	1
repaired)				64243	1	1	66751	1	1
				45241	1	3	54341	1	1
				45641	1	5			
				45741	1	1			
				44341	1	1			
				44361	2	1			
				41341	1	3			
				40221	6	1			
				no growth		1			

improvement of the water quality leaving that farm. Remedial construction repaired the faulty septic system as well as providing enlarged solid manure storage and a runoff retention tank.

Pyocin typing was not successful on the *Pseudomonas aeruginosa* isolates collected in 1986. Remedial construction in 1986 did not involve septic repair. A covered solid manure storage was erected to prevent runoff contamination of the covered municipal drain. Analysis in 1988 indicated a decrease in the number of pyocin types detected in 1987, suggesting a reduction in sources of *Pseudomonas aeruginosa*. There was however a decrease in the number of pyocin types present in the 1988 samples.

At Farm 7, pyocin type 56373 is no longer present in 1988 and the diversity of the types appears to be on the decrease overall. Serological type 6 also appears to be on the decrease possibly indicating that the septic problem is under control, however serological type 1 appears twice in 1988. Remedial work on Farm 7 in 1987 included provision of a covered solid swine manure storage as well as terminating blackwater discharges to the Desjardine Drain. The farm has a flock of 500 layer hens whose liquid manure system had, prior to remedial construction, discharged overflows to field tiles contaminated by septic waste. No occurrences have been reported or detected since completion of remedial construction. There is also a small pony, pastured on the slope between the barn and the open drain without access to the drain. No swine have been kept in the barn since the fall of 1988.

The diversity of serological and pyocin types at the downstream sampling site appears to have decreased in 1988. A group of similar pyocin types with four as a first digit was present during 1987 but not in any other year indicating perhaps that a specific animal type was present that year but not in any other.

The tile drain that was contaminated with septic waste had a reduced number of pyocin types from 1987 to 1988. No data is available for that site during 1986. Repair of the septic system occurred in 1987 and may hove resulted in the decreased number of pyocin types present in 1988.

In conclusion, pyocin and serological typing should continue to be performed on a regular basis as this information is potentially very valuable in confirming any estimates of bacteria loads from sources such as faulty septic systems, barnyard runoff, field-spread manure runoff, and livestock access.

5.0 CONCLUSIONS

The A.B.C.A. Target Sub-basin Study has provided much useful information and it has been concluded that research done from April 1988 to March 1989 was successful. Headway was made in data analysis and collection of new information. The mild winter of 1988-89 allowed stream discharge measurements during the winter period for the first time. This will make possible calculation of winter bacteria loadings during 1989.

The dry summer encountered in 1988 caused a reduction in the number of samples taken. The usefulness of the data collected is questionable since there was no continuous flow to allow uniform transport along the drains. In the previous Target Sub-basin reports, statistical analysis was carried out by comparing the summer months from year to year, however the summer of 1988 was so dry that the analysis period had to be shifted to the spring, using a smaller data base. As a result, the 1989 sampling strategy was shifted to one with a greater emphasis on spring sampling.

Some improvements in water quality can be seen although it is difficult to distinguish between the effects of natural fluctuations and effects which may be the result of remedial work. Further statistical analysis will confirm effectiveness of remedial measures by providing comparison to other reference sample sites.

The special research conducted in conjunction with the M.O.E.-S.W.R. may eventually be applied to the Clean Up Rural Beaches (C.U.R.B.) predictor model; in particular the sunlight information. For example the water column decay rate equation modifier for bacteria may be adjusted to reflect the intensity of sunlight and the depth of water.

To date a tremendous amount of data has been collected by this study with considerable opportunity for additional statistical analysis. It is hoped that additional statistical analysis of the data base may provide important information to unknown or uncertain results.

6.0 REFERENCES CITED

Barcina, Isabel *et. al.* 1989. Applied and Environmental Microbiology, American Society for Microbiology, Vol. 55, No. I, pp. 246-251.

Blackie, M., 1989. Agricultural Impact Specialist, M.O.E., London.

Griffiths, R., 1989. Aquatic Ecostudies Limited, Kitchener, Ontario.

Hoadley, A. W. and Elizabeth McCoy, 1968. Some Observations on the Ecology of Pseudomonas aeruginosa, and its Occurrence in the Intestinal Tracts of Animals, Cornell Veterinarian, 58, pp. 354-363.

Hocking, D., October 1988. Rural Beaches Strategy Program - Ausable Bayfield Conservation Authority.

Hocking, D., May 1989. Clean Up Rural Beaches (C.U.R.B.) Model - Ausable Bayfield Conservation Authority.

Janzen, E., February 1989. Microbiology Technician, Ausable Bayfield Conservation Authority.

McFeters, G. A. and D. G. Stuart, 1981. *In Situ* Studies Using Membrane Filter Chambers, Membrane Filtration: Applications, Techniques and Problems, ed. B. J. Dutka, Marcel Dekker Inc., New York.

Ontario Ministry of the Environment, May 1984. Water Management - Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment.

Palmateer, G., 1989. Chief Microbiologist, M.O.E.-S.W.R., London.

Schable, Barbara *et. al.* 1986. Improved, Computer-Generated System for Pyocin Typing of Pseudomonas aeruginosa, American Society for Microbiology, Vol. 24, No. 6, pp. 1017-1022.

Wardell, C. P., April 1989. Director, Public Health Inspection, Sarnia-Lambton Health Unit, personal communication.

APPENDIX I: FECAL COLIFORM COUNTS PER 100mL

BEACH: GRAND BEND

1988	SAMPLE #1	SAMPLE #2	SAMPLE #3	SAMPLE #4	SAMPLE #5	GEOMETRIC MEANS
JUNE 07	120	40	40	50	50	54.5
JUNE 14	10	10	10	10	20	11.5
JUNE 21	10	10	10	10	10	10.0
JUNE 28	170	40	160	40	80	81.0
JULY 05	10	10	10	10	20	11.5
JULY 12	120	190	90	150	60	113.1
JULY 19	60	10	70	50	20	33.5
JULY 25	2600	1500	1100	400	300	875.6
JULY 26	1000	1500	750	520	300	706.1
JULY 27	10	20	240	30	10	27.0
AUG 03	80	20	90	20	20	35.7
AUG 08	30	40	50	30	80	42.8
AUG 15	580	700	680	560	800	658.4
AUG 23	20	10	10	30	30	17.8
AUG 30	10	40	40	10	10	17.4

(Wardell 1989, personal communication)

APPENDIX I: FECAL COLIFORM COUNTS PER 100mL

BEACH: FORT FRANKS

1988	SAMPLE #1	SAMPLE #2	SAMPLE #3	SAMPLE #4	SAMPLE #5	GEOMETRIC MEANS
JUNE 07	80	40	10	10	40	26.4
JUNE 14	10	30	20	10	10	14.3
JUNE 21	40	50	70	60	40	50.7
JUN 28	30	30	50	60	80	46.4
JULY 05	10	10	10	30	40	16.4
JULY 12	90	210	330	60	40	108.4
JULY 18	600	600	600	600	600	600.0
JULY 20	1000	1200	600	300	700	685.3
JULY 21	2500	1400	1100	1500	1600	1,572.3
JULY 25	100	200	500	600	400	299.3
JULY 26	30	160	160	150	80	97.0
JULY 27	140	50	30	130	30	60.6
AUG 03	10	40	10	10	40	17.4
AUG 08	100	130	110	110	110	111.6
AUG 16	700	900	1300	1000	1300	1,080.7
AUG 23	50	20	10	30	50	27.2
AUG 30	20	80	10	10	10	17.4

(Wardell 1989, personal communication)