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Canada - Ontario Agreement on Great Lakes Water Quality

Ontario    Ministry of the Environment

# Brucewood Urban Test Catchment

## Research Report No. 100

Research Program for the Abatement of Municipal Pollution
nder Provisions of the Canada-Ontario Agreement
on Great Lakes Water Quality

# CANADA-ONTARIO AGREEMENT

## RESEARCH REPORT

These RESEARCH REPORTS describe the results of investigations funded under the Research Program for the Abatement of Municipal Pollution within the provisions of the Canada-Ontario Agreement on Great Lakes Water Quality. They provide a central source of information on the studies being carried out in this program through in-house projects by both Environment Canada and the Ontario Ministry of Environment, and contracts with municipalities, research institutions and industrial organizations.

The Scientific Liaison Officer for this project was Mr. J. Marsalek, Environment Canada.

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Pollution Control Branch
135 St. Clair Avenue West
Toronto, Ontario M4V 1P5

# BRUCEWOOD URBAN TEST CATCHMENT

by

James F. MacLaren Limited
Environmental Consultants

RESEARCH PROGRAM FOR THE ABATEMENT
OF MUNICIPAL POLLUTION WITHIN THE
PROVISIONS OF THE CANADA-ONTARIO
AGREEMENT ON GREAT LAKES WATER QUALITY

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# ABSTRACT

The purpose of this study was to examine a typical modern subdivision and evaluate the feasibility of using a computer model to predict the quantity and quality of storm water runoff from the subdivision due to rain storms and melting snow.

The Brucewood subdivision in North York, Toronto was selected as a typical modern subdivision. It is a 48-acre development consisting of single-family and semi-detached residences built in the later 1960's.

During the period February 15, 1974 to December 31, 1975 the quantity and quality of storm water flows were monitored, and other field data (e.g., rainfall, temperature, street cleaning frequency, etc.) were gathered. The collected data were used to develop and verify the U.S. Environmental Protection Agency's Storm Water Management Model (SWMM).

Several events were simulated using the model (SWMM). Quantity simulations compared reasonably well with recorded flows in general and with medium and higher intensity rainfalls in particular. Quality simulations were not as accurate as flow simulations. This was attributed to the more complex phenomena involved in quality simulation. In general, the simulated pollutant concentrations were of the same order of magnitude as those recorded.

# RÉSUMÉ

Cette étude a pour but d'évaluer, à partir de l'examen des conditions dans une subdivision moderne typique, la possibilité d'utiliser un modèle informatisé pour prédire la quantité et la qualité des eaux de pluies qui s'y écoulent, à l'occasion d'averses et à la fonte des neiges.

Brucewood, à North York (Toronto), a été choisie comme subdivision moderne typique. Il s'agit d'un quartier de 48 acres composé de résidences individuelles et jumelées bâties à la fin des années 60.

Du 15 février 1974 au 31 décembre 1975, on a contrôlé la quantité et la qualité des eaux de pluie au sol et on a recueilli d'autres données (précipitations, température, arrosage des rues, etc.). Les renseignements obtenus ont servi à étoffer et à vérifier le Modèle de gestion des eaux pluviales (Storm Water Management Model) de l'Agence américaine de protection de l'environnement.

Plusieurs facteurs ont été simulés au moyen de ce modèle. En général, le résultat des simulations quantitatives correspondait assez bien aux quantités enregistrées, surtout en ce qui concerne les pluies d'intensité moyenne ou supérieure. Les simulations qualitatives étaient, cependant, moins précises en raison de la plus grande complexité des phénomènes intervenant sur le plan de la qualité. Par ailleurs, les concentrations simulées de polluants étaient, en général, du même ordre que celles observées.

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# 1 INTRODUCTION

## 1.1 Purpose of the Study

J.F. MacLaren Limited was commissioned by Environment Canada (Canada Centre for Inland Waters, Burlington) under the Canada-Ontario Agreement on Great Lakes Water Quality to collect data from a typical modern subdivision and evaluate the feasibility of using a computer model to predict the quantity and quality of storm water runoff from the subdivision due to rain storms and snowmelts.

This report collects the more important data, conclusions and recommendations which were originally presented in three separate reports prepared during the course of the project. The methodology, types of data, and data summaries are discussed in this report for each phase of the study. Detailed plots and tabulations of the results are not included, but may be obtained from the contract liaison officer or from the contractor.*

## 1.2 Scientific Liaison During the Study

The contract liaison officer for the project was Mr. J. Marsalek of the Hydraulic Research Division, Canada Centre of Inland Waters (CCIW), Burlington, Ontario. Samples collected during the course of the study were analysed at the laboratories of the Ontario Ministry of the Environment under the direction of Mr. J. Hipfner. A number of bacteriological samples were also analysed at CCIW under the supervision of Dr. B. Dutka.

## 1.3 Scope of Work

The terms of reference for this study under the provisions of the Canada/U.S., Canada-Ontario Agreement on Great Lakes Water Quality were as follows:

1) To collect precipitation, runoff, snowmelt and other field data suitable for the testing and verification of the U.S. Environmental Protection Agency Storm Water Management Model (SWMM) on the Brucewood subdivision study area.

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* J. Marsalek, Hydraulic Research Division, National Water Research Institute, P.O. Box 5050, Burlington, Ontario, L7R 4A6; or J.F. MacLaren Ltd., 435 McNicoll Avenue, Willowdale, Ontario.

2) To present this information in a format compatible with the requirements of the SWMM and to provide other related information.

3) To simulate selected runoff events using the SWMM and compare the results of the simulation with the results of observations made on the study area.

4) To report the findings of the study.

### 1.4 The Study Area

The consultant selected the Brucewood subdivision in North York, Toronto, as an area representative of a typical modern subdivision. It is a 48.23-acre development located in the northeast corner of the Borough of North York, approximately 15 miles north of the centre of the metropolitan area.

The development consists of 169 single-family and 43 semi-detached residences built in the later 1960's. The roof leaders of the homes are connected to separate storm sewers which in turn are connected to the main trunk (39" diameter) of the storm sewer system which discharges into the East Don River. The drainage boundary of the study area is well defined by the East Don River Valley on the north, west and south, and by the CNR tracks on the east. Surface slopes are moderate, being in the order of 3%. A topographic map showing the sewer system and drainage subcatchment boundaries is presented in Figure 1; a general view of the site is shown in Figure 2. Detailed information for each subcatchment area within the study area is summarized in Table 1.

### 1.5 Study Program

Monitoring during the study period (February 15, 1974 to December 31, 1975) was divided into three phases:

Phase I : February 15, 1974 to December 31, 1974.
Phase II : January 1, 1975 to May 15, 1975.
Phase III: July 2, 1975 to December 31, 1975.

The results of monitoring were published in interim reports at the end of each phase. The final interim report, dealing with Phase III, also included an evaluation of the SWMM.

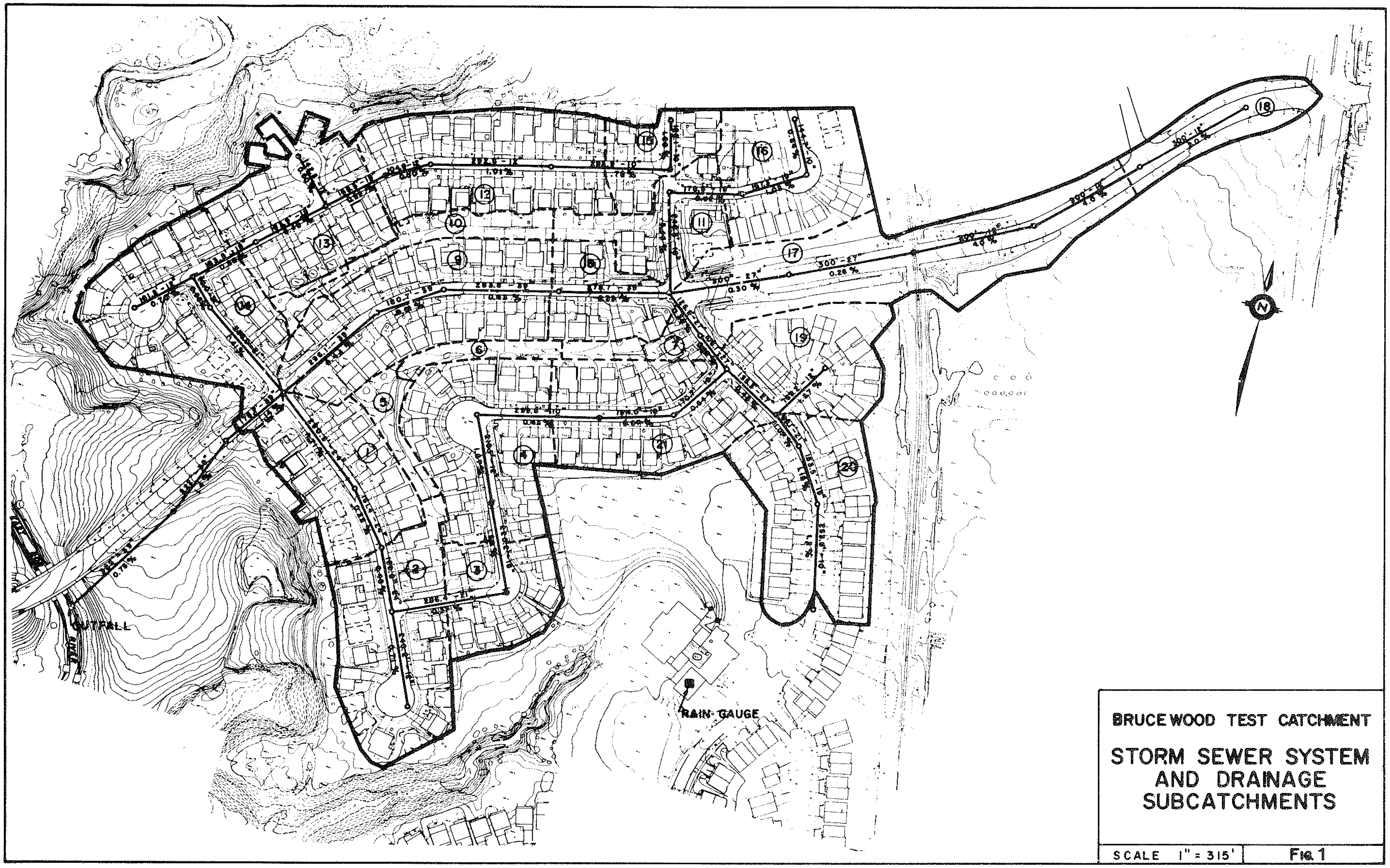
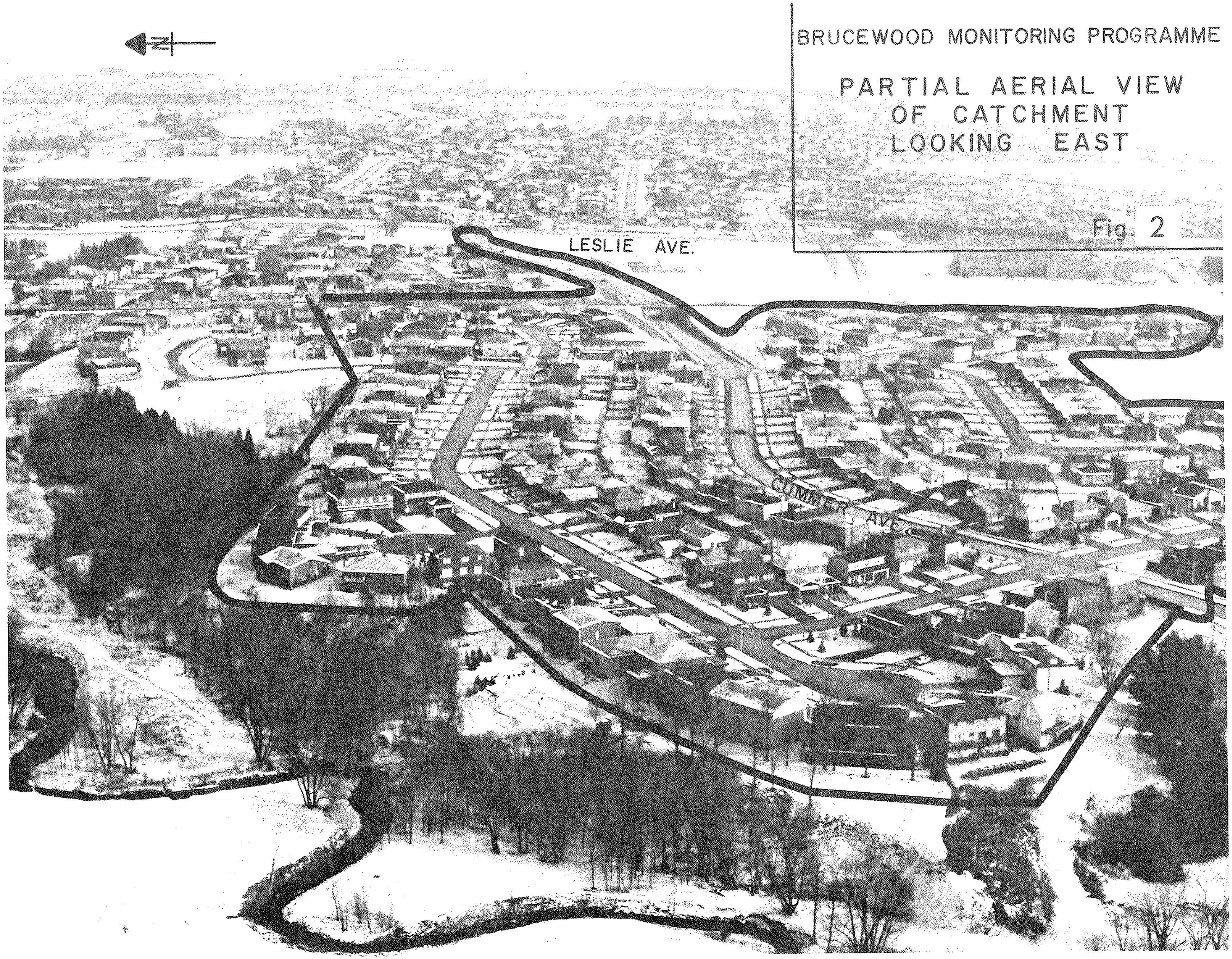


FIGURE 1. STORM SEWER SYSTEM AND DRAINAGE SUBCATCHMENTS



BRUCEWOOD MONITORING PROGRAMME

PARTIAL AERIAL VIEW
OF CATCHMENT
LOOKING EAST

Fig. 2

TABLE 1. BRUCEWOOD WATERSHED SUBCATCHMENT DATA

| Number | Area (Acres) | Imperviousness % | Ground Slope % |
|---|---|---|---|
| 1 | 2.22 | 64 | 2.8 |
| 2 | 3.32 | 53 | 1.9 |
| 3 | 1.58 | 58 | 1.8 |
| 4 | 3.06 | 61 | 2.3 |
| 5 | 0.56 | 0 | 4.1 |
| 6 | 0.58 | 0 | 2.0 |
| 7 | 0.50 | 0 | 2.3 |
| 8 | 1.47 | 56 | 2.3 |
| 9 | 3.83 | 58 | 2.4 |
| 10 | 0.87 | 0 | 2.9 |
| 11 | 1.57 | 27 | 4.1 |
| 12 | 2.80 | 74 | 3.0 |
| 13 | 2.77 | 59 | 3.8 |
| 14 | 3.52 | 71 | 4.2 |
| 15 | 1.08 | 67 | 2.4 |
| 16 | 2.55 | 50 | 2.3 |
| 17 | 4.38 | 27 | 23.8 |
| 18 | 1.19 | 40 | 20.0 |
| 19 | 3.68 | 27 | 2.6 |
| 20 | 3.10 | 52 | 4.4 |
| 21 | 3.60 | 40 | 4.7 |
|  | 48.23 | 48.3 |  |

## 2 EXPERIMENTAL DETAILS

### 2.1 Instrumentation and Monitoring

The data were collected at two locations (shown in Figure 1) in the study area: at the sewer outfall and at Pineway Public School. The sewer outfall was fitted with instrumentation to measure storm water flow and to take water samples. Details of this monitoring station are shown in Figures 3 and 4. A recording rainfall gauge, located on the roof of the school, was used to monitor precipitation. Output from the measurement instruments was transmitted, using leased telephone lines, to the offices of J.F. MacLaren and recorded. Because of various equipment malfunctions program monitoring was inoperative during the following periods:

July 3, 1974 to October 23, 1974,
February 25, 1975 to March 11, 1975,
March 24, 1975 to March 31, 1975.

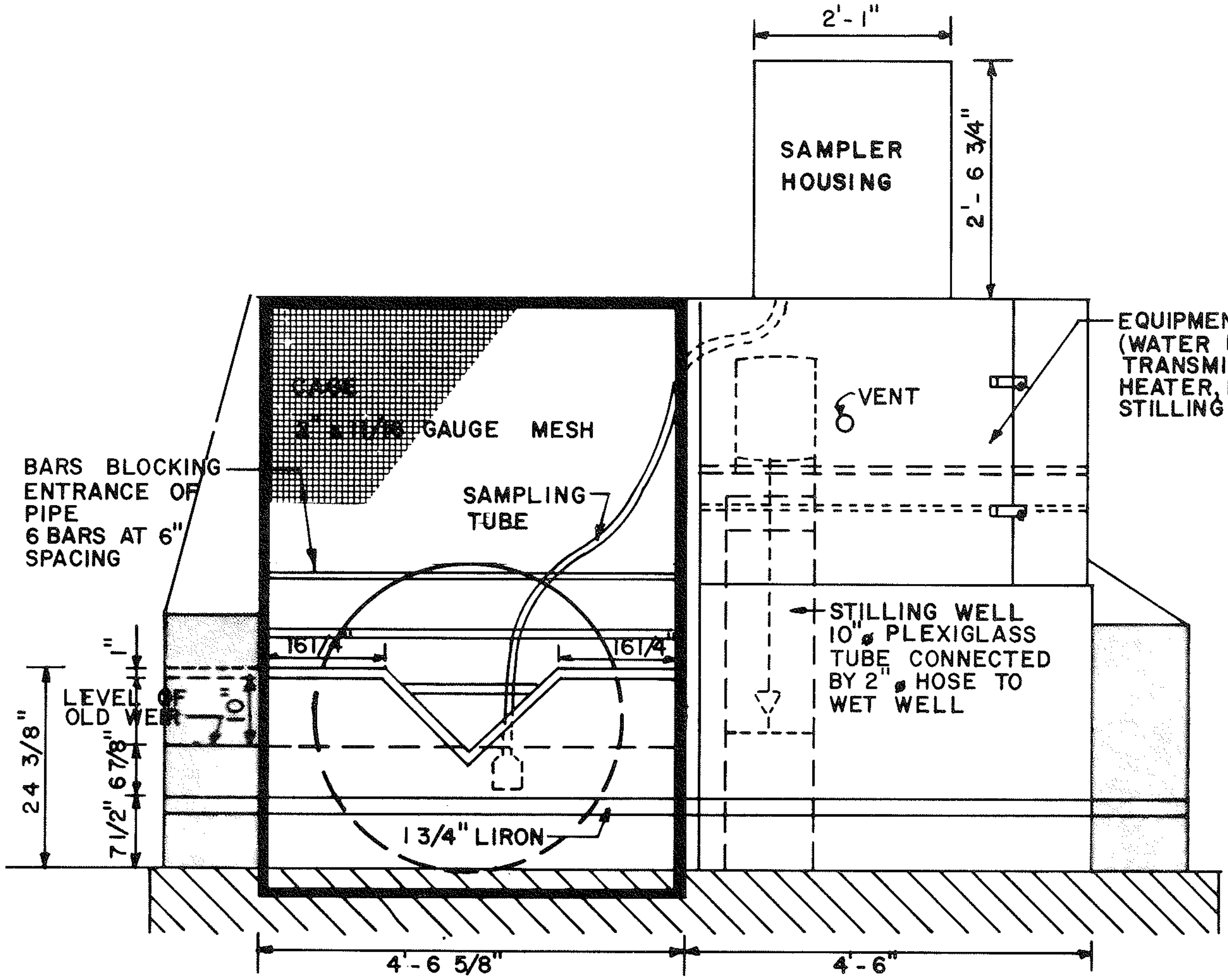
#### 2.1.1 Precipitation measurement

An Atmospheric Environment Service (AES) of Environment Canada tipping bucket rain gauge was used to measure precipitation. It was located on the roof of Pineway Public School, approximately ¼ mile from the centre of the catchment. The gauge measured each 0.01" of rainfall and transmitted a signal each time the bucket tipped. The first impulse from the gauge initiated both rainfall and water level recorders, which were set to run for two hours after the last impulse was received from the rain gauge. Rainfall was recorded on a Rustrack Event Recorder 292-4. It had a chart speed of six inches per hour, enabling a chart resolution of one minute.

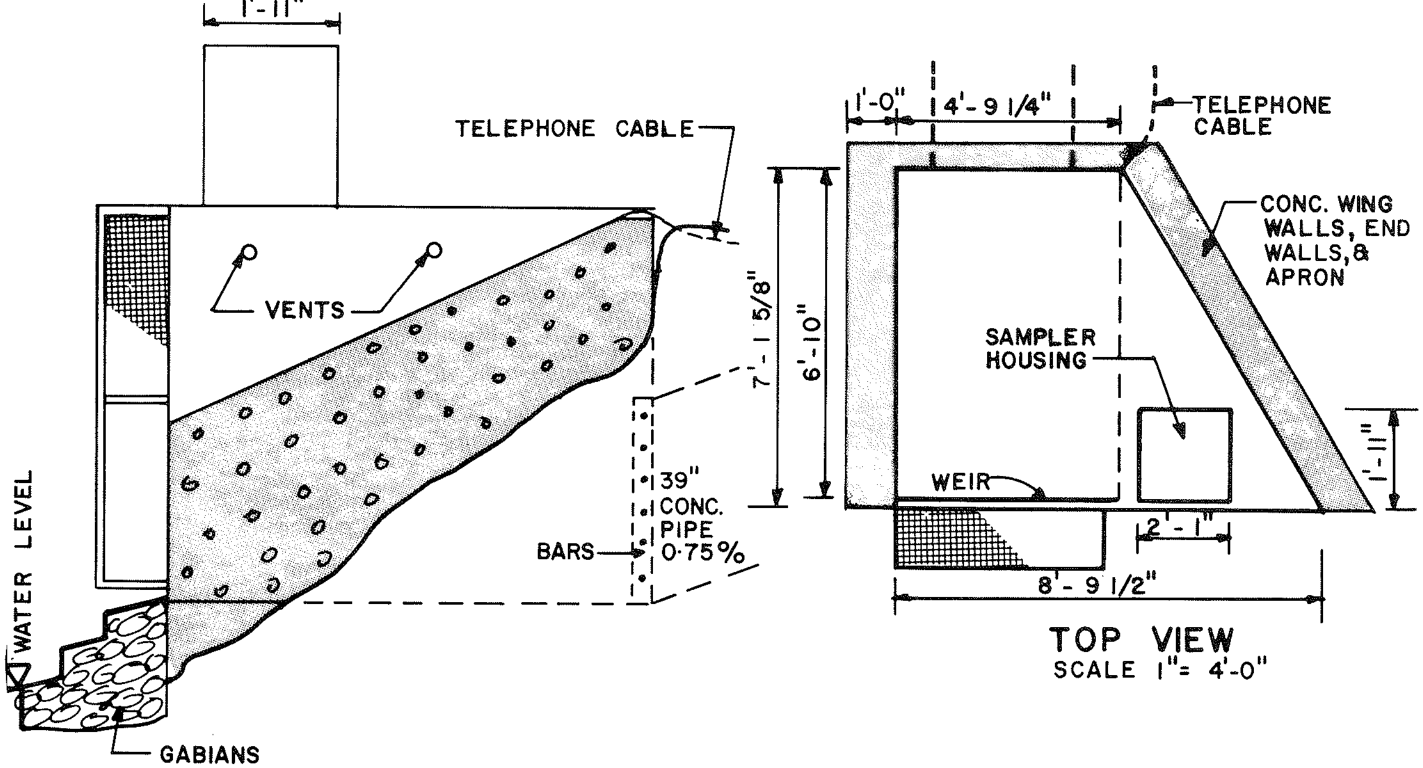
The rain gauge transmitter proved to be very reliable. Accidental disconnection of the transmission line to the recorder was the only problem encountered.

#### 2.1.2 Flow measurements

Storm water flow was calculated from measurement of the head-of-water generated over a weir located across the outfall to the sewer system. The water level was measured in a stilling well, a 10" diameter plexiglass tube connected to the wet-well (situated just upstream of the weir) with a two-inch hose (see Figure 3), using a Manning "Dipper" Transmitter (T1120-02-F-07).



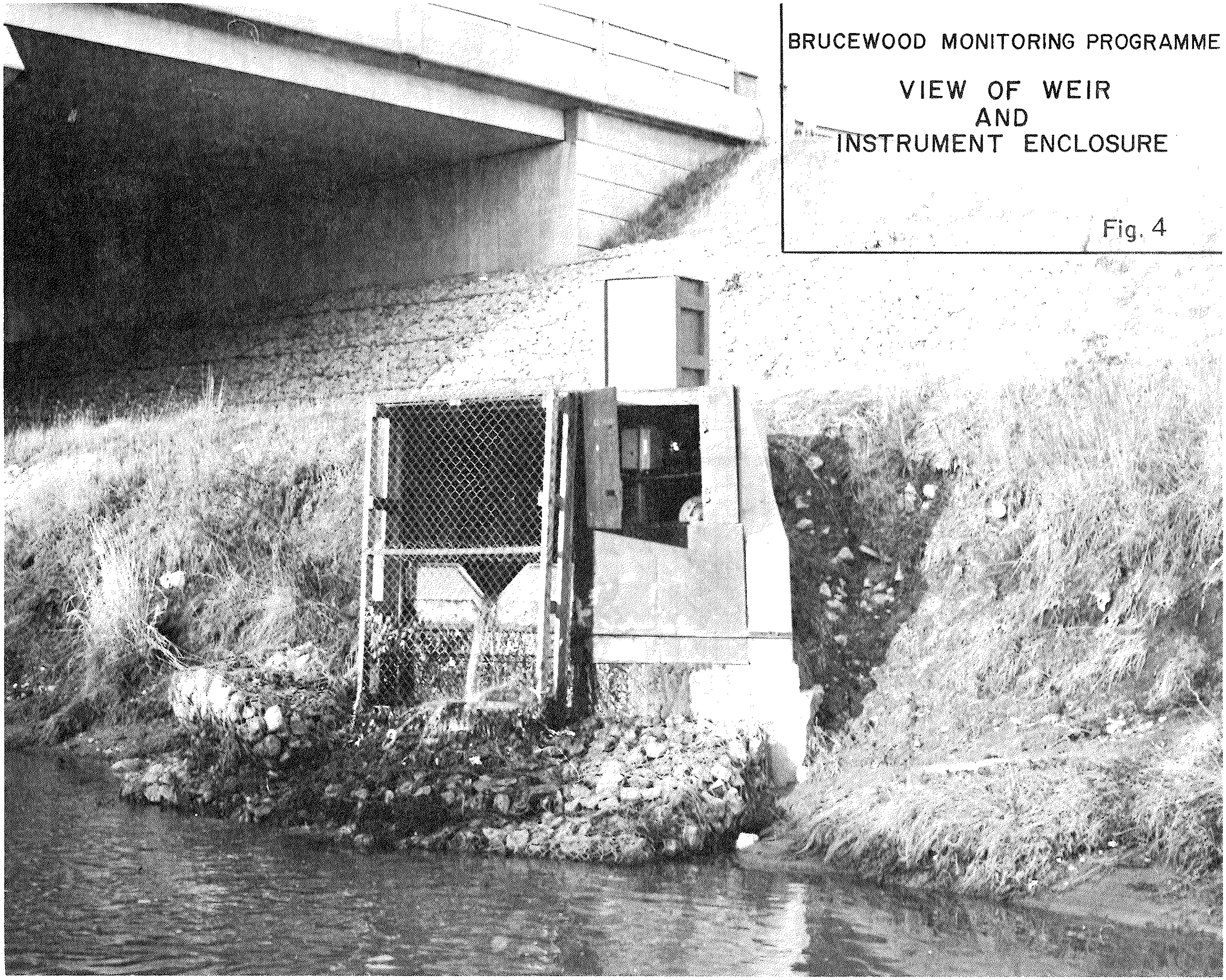
FRONT VIEW
SCALE 1"=2'-0"



SIDE VIEW
SCALE 1"=3'-0"

TOP VIEW
SCALE 1"= 4'-0"

FIGURE 3. DETAILS OF WEIR AND OUTFALL ENCLOSURE



BRUCEWOOD MONITORING PROGRAMME

VIEW OF WEIR
AND
INSTRUMENT ENCLOSURE

Fig. 4

Two weir configurations were used in this study; a horizontal sharp-crested weir for those months when reasonably high flows could be expected, and a compound V-notch sharp-crested type for winter operation when lower flow rates, and hence a greater sensitivity requirement, were anticipated for snowmelt runoff events. The flow over the horizontal weir was related to the measured water level by calibration of the weir at the CCIW laboratory; calibration curves obtained are shown in Figure 5. The V-notch weir, which was installed on October 16, 1974 for the 1974-75 winter, was not experimentally calibrated. With this type of weir the head-of-water can be related accurately to water flow by calculation based upon the dimensions of the weir. The theoretical calibration curve used is shown in Figure 6.

The output from the "Dipper" transmitter was recorded on a BlF 233-01 chart recorder which was started, by the impulse from the rain gauge, simultaneously with the rainfall recorder. A chart speed of six inches per hour was used, which facilitated synchronization with the rainfall measurements.

The "Dipper" transmitter also proved to be operationally reliable. However, it was discovered that the initial calibration between the transmitter and the recorder had been improperly carried out by the instrument's supplier. It required repairs over the winter of 1974-75 and, because of delays in the return of the instrument from the dealer in the spring, a mechanical OTT water level recorder was used in conjunction with a standard AES rainfall recorder for the period between May 1 and May 28, 1974. Both these instruments used spring-driven daily charts which allowed a minimum resolution of only five minutes.

Problems also occurred with the telephone line; on one occasion it was accidentally disconnected by the telephone company, and on another occasion it was found to be broken at the monitoring site.

### 2.1.3 Water quality samples

Water samples were taken from an intake located in the wet-well behind the weir (see Figure 3). It was intended that they would be obtained by a Sirco Sampler (MKS V11) located at the sewer outfall and actuated automatically by the Dipper transmitter when the water level rose

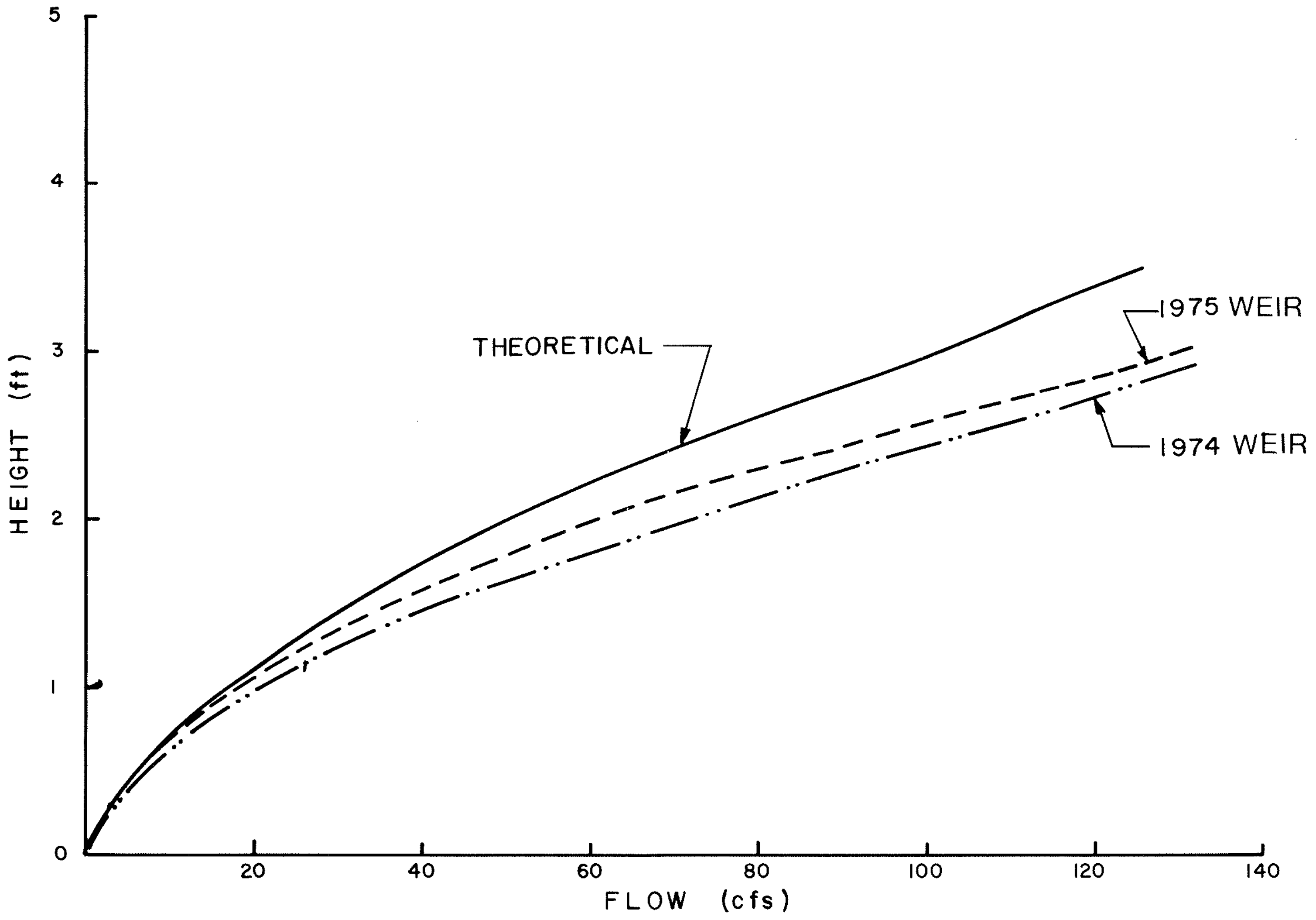


FIGURE 5. RATING CURVES FOR HORIZONTAL WEIRS

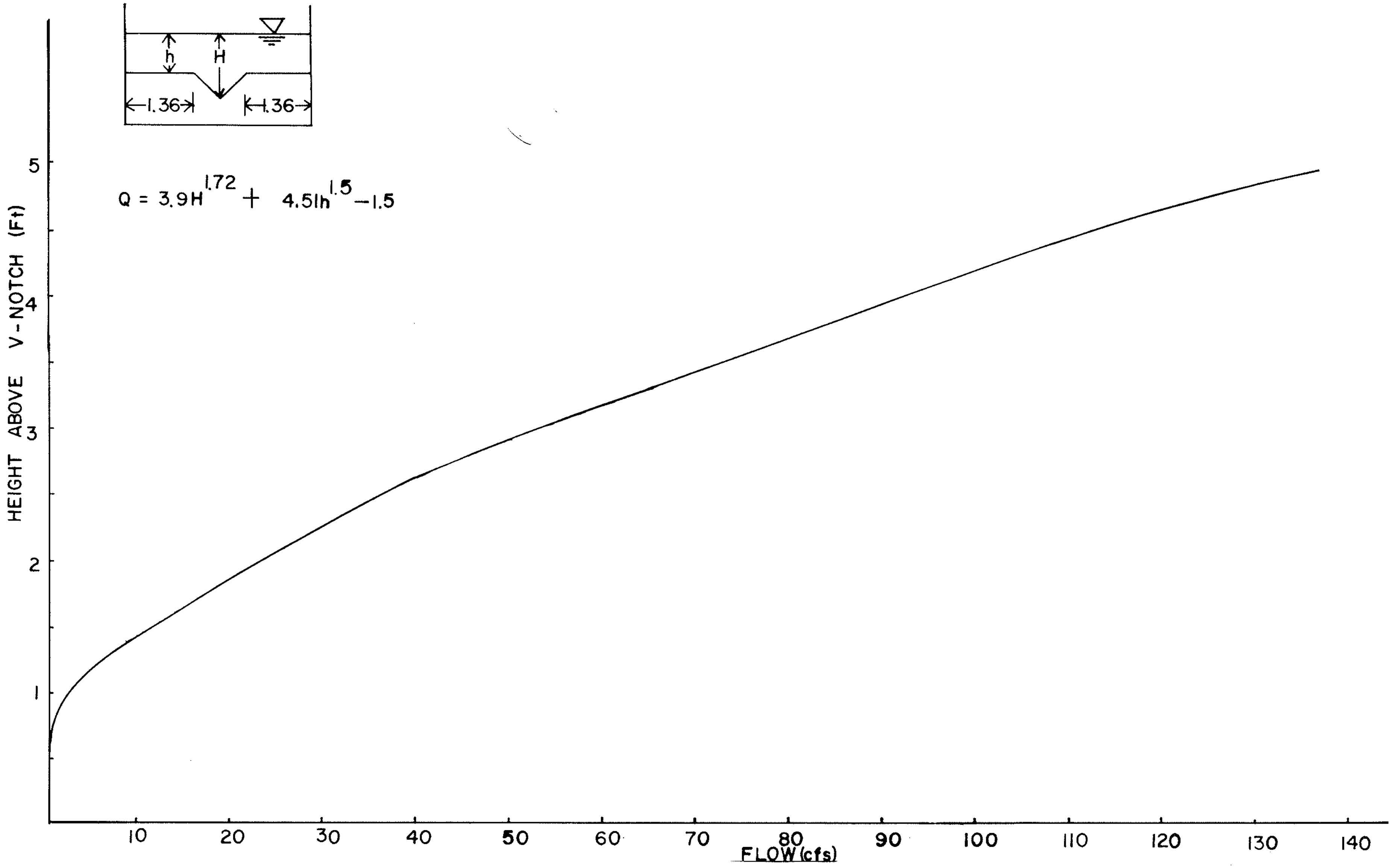


FIGURE 6. RATING CURVE FOR COMPOUND WEIR INSTALLED ON OCTOBER 16, 1974

above a predetermined level. The Sirco Sampler collects up to 24 discrete 500-ml samples at fixed time intervals which can be varied from a few minutes to several hours. However, during the periods preceding December 10, 1974, the sampler was inoperative, and samples were taken manually at the sewer outfall. The sampling interval during this period was generally five minutes or some multiple thereof. The necessity for hand-sampling also resulted in missing all or part of some storm events.

Standard methods were used in the analysis of storm runoff samples. Bacteriological samples were collected manually in sterilized containers and stored in ice for delivery to the CCIW laboratory in Burlington for analysis.

Numerous problems with the sampler were encountered; its operation was erratic and it was necessary to bring it in from the field for testing on several occasions. Eventually, the unit was returned to the factory for replacement of the timing mechanism.

### 2.1.4 Monitoring in winter

To maintain the rain gauge in an ice-free condition, a 40-watt light bulb was installed inside the gauge. However, this instrument could not be used to collect direct snowfall measurements. When a significant snowfall occurred during or before an anticipated snowmelt event, depth and density measurements of the accumulated snow were taken at the locations shown in Figure 7. A propane heater was also installed in the instrument enclosure at the outfall, along with a maximum-minimum thermometer to monitor its operation, to prevent the possibility of instrument freeze-up.

## 2.2 Data Collected

### 2.2.1 Runoff events

A total of 76 events were monitored during the study period. Thirty-six of these were not considered further due to incomplete data or very small runoff rates. Data from these deleted events may be obtained from CCIW. A record of all events monitored appears in Table 2, and Tables 3, 4 and 5 summarize the results of the laboratory analysis of the samples collected. Detailed data for each event may be obtained, as mentioned earlier, if requested.

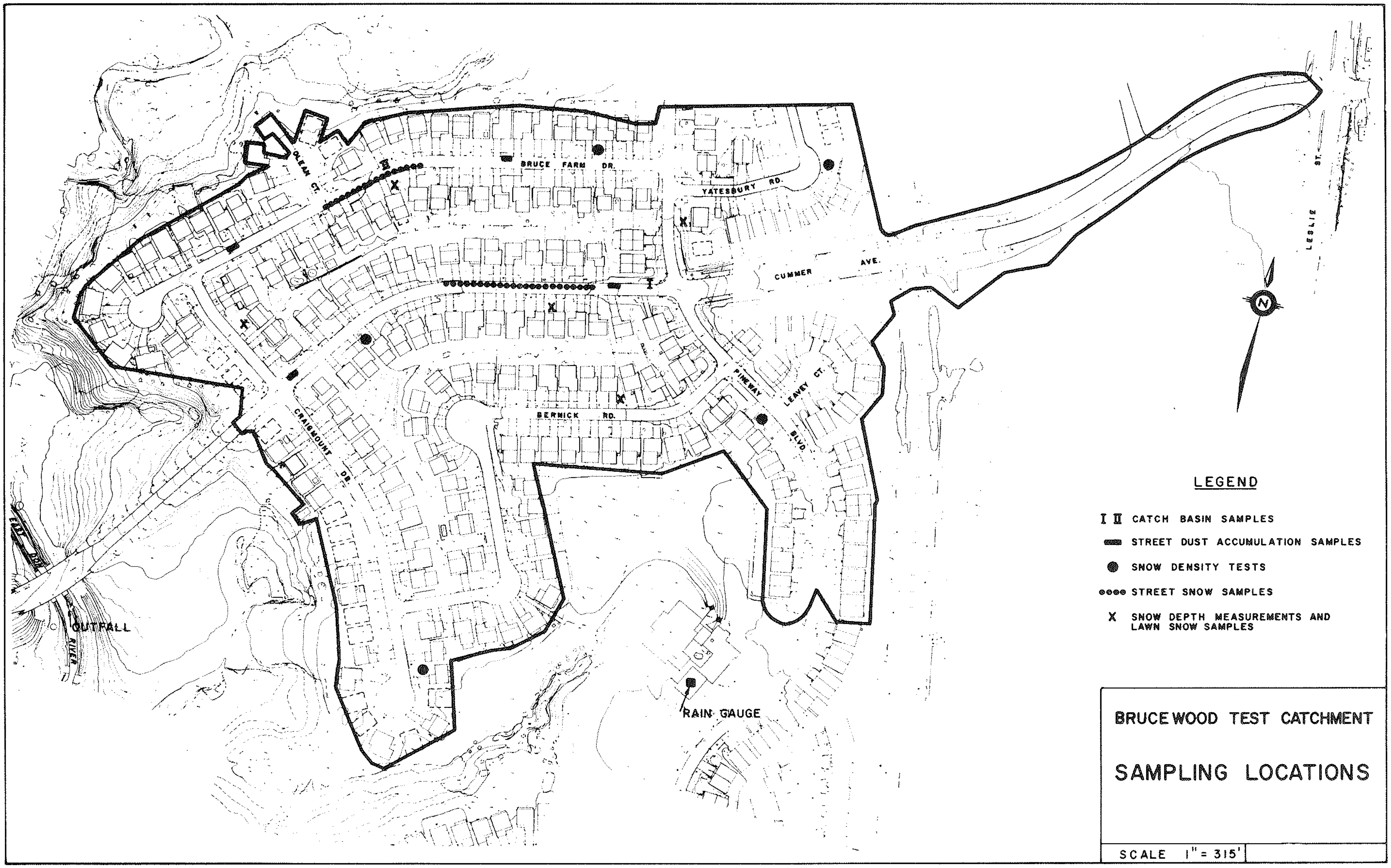


FIGURE 7. SAMPLING LOCATIONS

TABLE 2. LIST OF MONITORED EVENTS

a) Phase I, February 15 to December 31, 1975

| Event Number | Date | Precip. (inches) | Runoff Measurements<br>Quantity & Quality | <br>Only Quantity | <br>Only Quality | Comments |
|---|---|---|---|---|---|---|
| 1 | May 3 | 0.30 | X | | | Deleted |
| 2 | 5 | 0.34 | | X | | |
| 3 | 9 | 0.41 | | X | | |
| 4 | 11 | 1.37 | | X | | |
| 5 | 12 | 0.04 | | X | | Deleted |
| 6 | 14 | 0.28 | X | | | Limited quality data-missing initial runoff |
| 7 | 16-1 | 0.16 | X | | | |
| 8 | 16-2 | 0.76 | | X | | |
| 9 | 17 | 0.23 | | X | | Deleted |
| 10 | 27 | 0.03 | | | | No runoff data-deleted |
| 11 | June 13 | 0.11 | X | | | Missing initial runoff |
| 12 | 17-1 | 0.02 | | X | | Deleted |
| 13 | 17-2 | 0.16 | | X | | Deleted |
| 14 | 17-3 | 0.15 | | X | | |
| 15 | 19-1 | 0.52 | | X | | |
| 16 | 19-2 | 0.14 | | X | | Deleted |
| 17 | 25 | 0.49 | | X | | |
| 18 | 26 | 0.09 | | X | | Deleted |
| 19 | 27 | 0.09 | | X | | |
| 20 | July 2 | 0.25 | | X | | Deleted |
| 21 | 3 | 0.14 | | X | | Deleted |
| 22 | Oct. 23 | 0.10 | | X | | Deleted |
| 23 | Nov. 3 | - | | | X | Rainfall/runoff data-deleted |
| 24 | 5 | - | | | X | Rainfall/runoff data missing-deleted |
| 25 | 12 | 0.13 | X | | | Runoff plus snowmelt |
| 26 | 20 | 0.31 | X | | | Initial quality data missing |
| 27 | 24 | 0.15 | | | X | Rainfall/runoff data missing-deleted |
| 28 | Dec. 2 | 0.36 | X | | | Runoff plus snowmelt |
| 29 | 5 | 0.20 | | X | | Very limited data deleted |
| 30 | 8 | 0.19 | X | | | |
| 31 | 15 | - | | | X | Very limited data |
| 32 | 25 | - | | | X | deleted |

TABLE 2. (CONT'D)

b) Phase II, January 1 to May 15, 1975:

| Event Number | Date | Precip. (inches) | Runoff Measurements Quantity & Quality | Only Quantity | Only Quality | Comments*** |
|---|---|---|---|---|---|---|
| 1 | Jan. 3 | Wet snow | | | X | Deleted |
| 2 | Jan. 8 | Snowmelt | | | X | Deleted |
| 3 | Jan. 9 | 0.25" rain* | X | | | |
| 4 | Jan. 25 | Freezing rain and wet snow | | X | | Deleted |
| 5 | Jan. 29 | 0.17" rain | | | X | Deleted |
| 6 | Feb. 17-18 | 17-0.30" rain<br>18-0.22" rain + $1\frac{1}{2}$" snow | X | | | |
| 7 | Feb. 22 | Snowmelt | | | X | Deleted |
| 8 | Feb. 24 | ** | | X | X | Deleted |
| 9 | Mar. 6 | 1-$1\frac{1}{2}$" wet snow | X | | | |
| 10 | Mar. 12 | Trace rain + snowmelt | X | | | |
| 11 | Mar. 19 | 0.44" rain from 7:30 a.m. | X | | | |
| 12 | May 4 | ** | | X | X | Deleted |

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* Total precipitation for weekend.

** Equipment malfunction, no rainfall recorded

***Events marked 'Deleted' are not included in the report due to limited or incomplete data. Data for these events can be obtained from CCIW.

TABLE 2. (CONT'D)

c) Phase III, August 2 to December 31, 1975

| Event Number | Date | Precip. inches | Runoff Measurements Quantity & Quality | Runoff Measurements Only Quantity | Comments |
|---|---|---|---|---|---|
| 1 | Aug. 2(i) | 0.60 | | X | Weekend total precipitation |
| 2 | (ii) | 0.40 | | X | |
| 3 | Aug. 11 | 0.10 | X | | |
| 4 | Aug. 13 | 0.09 | X | | |
| 5 | Aug. 26 | 0.02 | X | | Rain gauge malfunction/deleted |
| 6 | Aug. 29 | 0.43 | X | | |
| 7 | Aug. 31 | 0.07 | X | | Weekend total precip./deleted |
| 8 | Sept.11 | 0.90 | X | | |
| 9 | Sept.20(i) | 0.12 | | X | |
| 10 | (ii) | 0.17 | | X | |
| 11 | Oct. 1 | 0.16 | XB | | |
| 12 | Oct. 11(i) | 0.04 | | X | Deleted |
| 13 | (ii) | 0.04 | | X | Deleted |
| 14 | Oct. 13 | 0.03 | X | | Weekend total precipitation |
| 15 | Oct. 20 | 0.03 | XB | | Deleted |
| 16 | Nov. 1 | 0.29 | | | |
| 17 | Nov. 2 | 0.08 | | X | Deleted |
| 18 | Nov. 3(i) | 0.04 | | X | Deleted |
| 19 | (ii) | 0.04 | X | X | Deleted |
| 20 | (iii) | 0.05 | | X | Deleted |
| 21 | Nov. 7 | 0.19 | | X | |
| 22 | Nov. 10 | 0.79 | B | X | |
| 23 | Nov. 20 (i) | 0.07 | X | | Deleted |
| 24 | (ii) | 0.09 | | X | |
| 25 | Nov. 27 | 0.61 | XB | | |
| 26 | Nov. 29(i) | 0.03 | X | | Deleted |
| 27 | (ii) | 0.05 | | X | Deleted |
| 28 | Nov. 30 | 0.17 | | X | |
| 29 | Dec. 2 | 0.09 | X | | Rain on snow |
| 30 | Dec. 6 | 0.31 | X | | |
| 31 | Dec. 9 | 0.82+S | X | | S = 3½" wet snow |
| 32 | Dec. 14 | 0.31 | X | | |

B = manual sampling for bacteriological analysis

TABLE 3. AVERAGE STORM WATER POLLUTANT CONCENTRATIONS IN EVENTS MONITORED (Phase I)

| DATE | AVERAGE FLOW RATE (cfs) | $BOD_5$ mg/L | COD mg/L | SOLIDS mg/L | | P mg/L | | Cl mg/L | Pb mg/L | TKN mg/L | $NO_3^-$ mg/L | $NH_4^+$ mg/L | PHENOLS ppb | COLIFORM (MPN/100 mL) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | TOTAL | SUSP. | TOTAL | SOL. | | | | | | | TOTAL | FECAL |
| 4-29-74 | - | - | 105.7 | - | - | 0.61 | 0.08 | 87.3 | 0.49 | 4.00 | 2.9 | 0.88 | - | - | - |
| 5-3-74 | 0.16 | 3.1 | 27.5 | 1023 | 30 | 0.05 | 0.03 | 283.5 | 0.04 | 0.62 | 2.25 | 0.2 | - | - | - |
| 5-14-74 | 3.5 | 7.8 | 25 | - | 118 | 0.43 | 0.06 | 61.0 | - | 11.5 | 0.83 | 0.13 | - | - | - |
| 5-16-74 | 1.26 | 4.8 | 30 | 809 | 71 | 0.02 | <0.02 | 151 | 0.13 | 1.22 | 1.9 | 0.26 | - | 2100 | 225 |
| 5-18-74 | - | 3.0 | <20 | - | 15 | 0.15 | 0.03 | 248 | 0.06 | 0.75 | 2.00 | 0.2 | - | - | - |
| 5-27-74 | - | 8.0 | - | - | 66 | 0.18 | 0.02 | 202 | 0.11 | 1.83 | 3.36 | 0.04 | - | 27600 | 2400 |
| 6-13-74 | - | 53.0 | 367.5 | - | 263 | 0.65 | 0.02 | 132.5 | 1.06 | 4.9 | 2.42 | 1.58 | - | - | - |
| 11-3-74 | - | 11.7 | 52 | - | 18 | 0.1 | <0.02 | 53 | 0.06 | 1.5 | 1.7 | 0.8 | 4 | - | - |
| 11-5-74 | - | 5.9 | 33 | - | 50 | 0.19 | <0.02 | 55 | 0.13 | 0.54 | <0.2 | 0.2 | <1 | 2680 | 1070 |
| 11-12-74 | 0.15 | 2.2 | <20 | - | <15 | 0.05 | <0.02 | 7 | 0.08 | 0.5 | <0.2 | 0.1 | 4 | 2220 | 520 |
| 11-20-74 | 3.9 | 12.9 | 52 | - | 281 | 0.38 | 0.02 | 5 | 1.11 | 1.4 | 0.4 | <0.1 | 7 | 6940 | 1500 |
| 11-24-74 | - | 4.7 | 36 | - | 30 | 0.12 | 0.02 | 65 | 0.22 | 2.0 | 0.8 | 0.2 | 1 | 4948 | 1525 |
| 12-2-74 | 0.39 | 6.6 | 70 | - | 132 | 0.19 | 0.02 | 681 | 0.76 | 1.2 | <0.2 | <0.1 | 9 | 4619 | 1700 |
| 12-15-74 | - | 4.2 | - | 49 | - | 0.09 | <0.02 | 2050 | <0.05 | 0.93 | 0.8 | 0.38 | 5.7 | - | - |
| 12-25-74 | - | 2.3 | - | - | 46 | 0.15 | 0.04 | 1225 | 0.18 | 1.00 | 0.9 | <0.1 | 2.4 | - | - |

TABLE 4. AVERAGE STORM WATER POLLUTANT CONCENTRATIONS IN EVENTS MONITORED (Phase II)

| DATE | AVERAGE FLOW RATE (cfs) | $BOD_5$ mg/L | COD mg/L | SOLIDS mg/L | | P mg/L | | Cl mg/L | Pb mg/L | TKN mg/L | $NO_3^-$ mg/L | $NH_4^+$ mg/L | PHENOLS ppb | COLIFORM (MPN/100 mL) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | TOTAL | SUSP. | TOTAL | SOL. | | | | | | | TOTAL | FECAL |
| SNOWMELT ONLY | | | | | | | | | | | | | | | |
| Jan. 8/75 | - | 41 | - | - | 502 | .95 | .07 | 509 | 1.46 | 3.8 | 1.6 | .30 | 7 | - | - |
| Feb. 17 | .23 | 10 | - | - | 88 | .80 | .34 | 350 | .43 | 4.6 | 1.4 | 1.30 | 20 | - | - |
| Feb. 22 | - | 6 | 66 | - | 107 | .48 | .23 | 163 | .23 | 3.5 | 1.2 | .68 | 15 | - | - |
| Mar. 6 | .01 | 9 | - | - | 90 | .14 | .03 | - | .30 | 1.4 | 2.8 | .25 | 15 | 4457 | 10 |
| Mar. 12 | .31 | 8 | 61 | - | 82 | .31 | .09 | 801 | .34 | 8.4 | 1.6 | .52 | 16 | - | - |
| SNOWMELT AND RAINFALL | | | | | | | | | | | | | | | |
| Jan. 3 | - | 12 | - | - | 232 | .20 | .02 | 5390 | .57 | 2.3 | 1.1 | .17 | 11 | - | - |
| STORM RUNOFF ONLY | | | | | | | | | | | | | | | |
| Jan. 9 | .33 | 2 | - | - | 38 | .12 | .02 | 252 | - | .9 | 1.9 | .1 | 1 | - | - |
| Jan. 29 | - | 13 | - | - | 105 | .34 | .12 | 224 | .28 | .29 | .2 | .2 | 12 | - | - |
| Feb. 24 | 5.50 | 3 | 49 | - | 337 | .77 | .23 | 55 | .32 | 2.3 | .22 | .21 | 1 | - | - |
| Mar. 19 | .27 | 7 | 79 | - | 60 | .39 | .10 | 373 | - | 1.44 | 1.6 | .17 | 9 | - | - |
| May 4 | .19 | 2.1 | 22 | - | 45 | .11 | .02 | 19 | .14 | .72 | .4 | .32 | 1.6 | 499 | 306 |

TABLE 5. PEAK STORM WATER POLLUTANT CONCENTRATIONS IN EVENTS MONITORED (Phase III)

| DATE | PEAK FLOW RATE (cfs) | $BOD_5$ mg/L | COD mg/L | SUSP. SOLIDS mg/L | P mg/L |  | Cl mg/L | Pb mg/L | TKN mg/L | $NO_3^-$ mg/L | $NH_4^+$ mg/L | PHENOLS ppb | COLIFORM (MPN/100 mL) |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  | TOTAL | SOL. |  |  |  |  |  |  | TOTAL | FECAL |
| Aug. 11 | 2.88 | 22.0 | 170 | 90 | .55 | .02 | 33 | .25 | 4.0 | 2.5 | .6 | 5 |  |  |
| Aug. 13 | 1.55 | 14.0 | 53 | 30 | .20 | .02 | 30 | .13 | 1.7 | 1.1 | 1.1 | 4 |  |  |
| Aug. 26 | 0.11 | 7.0 | 72 | 40 | .36 | .06 | 194 | .20 | 1.8 | 2.8 | .4 | 1 |  |  |
| Aug. 29 | 4.85 | 8.0 | 100 | 140 | .24 | .06 | 201 | .26 | 1.8 | 3.7 | .3 | 6 |  |  |
| Aug. 31 | 1.00 | 4.0 | 28 | 30 | .20 | .06 | 193 | .10 | 1.2 | 2.4 | .2 | 4 |  |  |
| Sept.11 | 28.5 | 12.0 | - | 45 | .28 | .10 | 145 | - | 2.2 | 2.7 | .6 | - | 110000 | 18000 |
| Oct. 1 | 2.77 | 13.0 | 115 | 255 | .60 | .02 | 28 | .28 | 2.8 | 2.9 | 1.8 | 4 | 35000 | 19000 |
| Oct. 13 | 10.12 | 25.0 | 130 | 160 | .36 | .02 | 113 | .45 | 3.0 | 2.9 | .7 | 6 |  |  |
| Oct. 20 | 0.29 | 3.0 | 38 | 15 | .12 | .08 | 31 | .05 | 1.0 | 1.6 | .2 | 6 | 66767 | 7500 |
| Nov. 1 | 3.58 | 16.0 | 135 | 145 | .50 | .02 | 169 |  | 5.7 | 2.6 | .4 | 4 |  |  |
| 3(ii) | 1.00 | 8.0 | 61 | 45 | .24 | .30 | 118 | .16 | 1.3 | 1.2 | .2 | 3 |  |  |
| 20(i) | 0.49 | 90.0 | 170 | 50 | .56 | .06 | 182 | .10 | 3.6 | 4.7 | 1.4 | 16 |  |  |
| Nov. 27 | 3.25 | 6.5 | - | 60 | .24 | .01 | 69 | - | 1.4 | 1.2 | .5 | 3 | 9900 | 4100 |
| Nov. 29 | 0.23 | 33.0 | 89 | 30 | .08 | .02 | 199 | - | 1.6 | 1.8 | .2 | 15 |  |  |
| Dec. 2 | 0.10 | 3.0 | 47 | 25 | .12 | .02 | 149 | - | .8 | 1.4 | .2 | 22 |  |  |
| Dec. 6 | 3.18 | 34.0 | 225 | 405 | .60 | .12 | 932 | 1.60 | 2.4 | 1.6 | .5 | 4 |  |  |
| Dec. 9 | 0.91 | 6.0 | 315 | 185 | .28 | .01 | 2631 | 0.73 | 1.6 | 1.0 | .3 | 3 |  |  |
| Dec. 14 | 1.92 | 20.0 | 260 | 410 | .60 | .10 | 1247 | 1.60 | 2.7 | 2.7 | .4 | 9 |  |  |

### 2.2.2 Dust and dirt samples

Samples of street dust were taken during 1974 and 1975 at the four locations shown on Figure 7. These samples were taken over an area extending 2 ft out from the curb and running for a length of 10 ft. Curb gutters were swept on the same days the catch basin samples were taken when road conditions permitted. Average values of accumulation rates and constituent concentrations for 1974 samples are given in Table 6.

### 2.2.3 Storm water analyses under dry weather flow conditions

In order to simulate water quality during a storm event the SWMM requires adjustments to take into account the contribution of pollutants from the dry weather (or background) flow. Accordingly samples of the base sewer-flow were taken at the outfall monitoring station during Phases I and II. Water quality analyses of these samples are presented in Table 7.

### 2.2.4 Catch basin samples

Catch basin samples were taken twice weekly at two locations, one on Cummer Avenue at Pineway and the other on Bruce Farm Drive over the period from October 15, to November 5, 1974. After this date, samples were taken less frequently mainly to check if conditions changed over more prolonged periods. In order to standardize the procedures for sampling catch basin residues, the contents of the catch basins were agitated vigorously for one minute before a sample was taken. A summary of the analytical results is presented in Table 8.

### 2.2.5 Precipitation samples

Precipitation samples were collected in enamelled trays on the roof of James F. MacLaren Limited, about three miles to the east of the study area. Samples for 15 events were collected from February to December, 1975. For samples obtained after November 2, care was taken to ensure the collecting trays were clean and rinsed with distilled water before the sampling began. The average constituent concentrations found in these samples are given in Tables 9 and 10.

### 2.2.6 Snowmelt runoff events

A number of snowmelt runoff events were monitored in Phases I and II. Due to light snowfalls and generally warm weather during Phase I snowmelt runoff data were only nominal and are given in Table 11. Snowmelt runoff data collected in Phase II are summarized in Table 4.

TABLE 6. AVERAGE VALUES FOR ACCUMULATION RATES AND COMPOSITION OF DUST AND DIRT

| Date | Dust and Dirt Accumulation lb/day/100 ft curb | mg Pollutant per g of Dust and Dirt | | | | |
|---|---|---|---|---|---|---|
| | | N | P | COD | LOI | Pb |
| October 15, 1974 | 2.13 | 0.7 | 0.48 | 33.5 | 3.06 | 4.5 |
| October 22, 1974 | 1.37 | 0.35 | 0.50 | 26.8 | 2.80 | - |
| October 25, 1974 | 1.19 | 1.09 | 0.58 | 63.2 | 7.80 | - |
| October 29, 1974 | 1.08 | 0.68 | 0.48 | 59.0 | 4.70 | - |
| November 15, 1974 | 1.95 | 0.60 | 0.45 | 39.0 | 3.40 | - |
| November 19, 1974 | 0.09 | 0.65 | 0.37 | 42.5 | 2.70 | - |
| November 22, 1974 | 1.80 | 0.47 | 0.46 | 36.0 | 2.80 | - |
| November 26, 1974* | - | 0.51 | 0.12 | 50.0 | 2.80 | - |
| December 6, 1974* | 0.08 | 0.52 | 0.55 | 30.0 | 3.50 | 9.20 |
| December 23, 1974* | 0.25 | 0.54 | 0.30 | 32.5 | 3.50 | 4.20 |
| January 20, 1975* | 0.17 | 0.50 | 0.34 | 35.0 | 3.80 | 8.40 |

* Possible influence of snowmelt runoff.

TABLE 7. POLLUTANT LEVELS IN STORM WATER UNDER DRY WEATHER FLOW CONDITIONS

| DATE | $BOD_5$ mg/L | COD mg/L | SS mg/L | P mg/L TOTAL | P mg/L SOL. | Cl mg/L | Pb mg/L | TKN mg/L | $NO_3^-$ mg/L | $NH_4^+$ mg/L | PHENOLS ppb | COLIFORM (MPN/100 mL) TOTAL | COLIFORM (MPN/100 mL) FECAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Feb. 4/74 | 3.0 | <200 | | <.1 | <.1 | 351 | | .46 | 3.9 | .2 | | | |
| Oct. 22/74 | 2.0 | < 20 | <15 | .08 | .04 | 125 | | .6 | .8 | .2 | .03 | 163 | 17 |
| March 6/75 | 1.0 | 50 | <15 | .02 | <.02 | 669 | .05 | .4 | <.2 | <.1 | <1 | | |
| March 12/75 | 1.6 | 20 | 20 | .02 | <.02 | 464 | .04 | .7 | 1.6 | .2 | 1 | | |
| April 8/75 | 3.0 | 70 | 70 | .20 | <.02 | 662 | .22 | .6 | <.2 | <.1 | <1 | | |

TABLE 8. SUMMARY OF WATER QUALITY ANALYSES OF CATCH BASIN SAMPLES

a) Bruce Farm Dr.

| Analysis | Range mg/L | Average Values mg/L May - Oct. | Nov. - Jan. |
|---|---|---|---|
| BOD | 30-190 | 57 | 127 |
| COD | 190-2100 | 717 | 1130 |
| SS | 1300-15 970 | 3680 | 9610 |
| Total P | 2-17 | 8.5 | 6.6 |
| Cl | 18-3150 | 35 | 66 |
| Pb | 2.5-10 | 4.1 | 7.7 |
| TKN | 15-70 | 25 | 52 |
| Phenols (ppb) | 2-110 | 33 | 46 |
| Total Coliform (MPN/100 mL) | | | 79 333* |
| Fecal Coliform (MPN/100 mL) | | | 4566* |

b) Cummer Av.

| Analysis | Range mg/L | Average Values mg/L May - Oct. | Nov. - Jan. |
|---|---|---|---|
| BOD | 20-260 | 94 | 70 |
| COD | 250-4100 | 594 | 1640 |
| SS | 1000-37 605 | 2150 | 16 600 |
| Total P | 1.6-12 | 4.5 | 8.6 |
| Cl | 31-47 700 | 414 | 16 600 |
| Pb | 9-120 | 26 | 57 |
| TKN | 8-80 | 26 | 48 |
| Phenols (ppb) | 8-170 | 32 | 72 |
| Total Coliform (MPN/100 mL) | | | 2000* |
| Fecal Coliform (MPN/100 mL) | | | 113* |

*Only one bacteriological sample taken.

TABLE 9. ANALYSES OF PRECIPITATION SAMPLES, PHASE II

| DATE | TOTAL RAIN-FALL (inches) | $BOD_5$ mg/L | COD mg/L | SS mg/L | P mg/L TOTAL | P mg/L SOL. | Cl mg/L | Pb mg/L | TKN mg/L | $NO_3^-$ mg/L | $NH_4^+$ mg/L | PHENOLS ppb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Feb. 18/75 | 0.22 | 55 | * | 60 | 0.90 | 0.08 | * | * | * | 2 | 0.1 | 20 |
| Feb. 22/75 | 0.09 | 12 | * | 35 | 0.84 | 0.70 | * | 0.05 | 3.0 | 3.4 | 1.4 | 30 |
| Feb. 23/75 | 0.20 | 4.0 | * | 30 | 0.28 | 0.20 | * | 0.03 | 1.6 | 1.2 | 0.6 | 7 |
| Feb. 24/75 | 0.20 | 3.0 | 20 | <15 | 0.10 | 0.02 | * | * | 1.0 | 0.4 | 0.3 | 21 |
| Mar. 24/75 | - | 3.0 | 20 | 20 | 0.12 | <0.02 | 5 | 0.14 | 0.8 | 0.4 | 0.6 | 2 |
| May 4/75 |  | 5.0 | 20 | 10 | 0.10 | 0.02 | 9 | - | 1.0 | 0.2 | 0.3 | 8 |

* Sample exhausted.

TABLE 10. AVERAGE RAIN WATER POLLUTANT CONCENTRATIONS, PHASE III

| Date Sample Collected 1975 | SS mg/L | COD mg/L | TKN mg/L | Phenols ppb | Total Rainfall (inches) | Antecedent Dry Period (hr) | Remarks |
|---|---|---|---|---|---|---|---|
| August 11 | 25.0 | 68.0 | 3.20 | 4 | 0.12 | 106 | These samples collected before controlled conditions set up |
| November 2 | 14.0 | - | 1.00 | 10 | 0.44 | 96 | |
| November 7 | 2.0 | 39.0 | 1.10 | 11 | 0.19 | 88 | |
| November 10 | 2.0 | 35.0 | 0.36 | 4 | 0.79 | - | Two sample bottles filled and analysed -weekend total |
| November 10 | 1.0 | 33.0 | 0.34 | 5 | | - | |
| November 20 | >15.0 | 60.0 | 1.40 | 15 | 0.17 | 152 | |
| November 27 | - | >20.0 | 1.40 | - | 0.64 | 86 | Rain and snow |
| December 2 | >15.0 | 20.0 | 1.20 | 1 | 0.09 | 42 | Snow |
| December 8 | >15.0 | 34.0 | 1.00 | 21 | - | 16 | Snow |

TABLE 11. SPRING SNOWMELT RUNOFF SAMPLES 1974

| | March 19 | March 21 | March 25 |
|---|---|---|---|
| Approximate depth of snow | 2.6" | 1" | 1" |
| $NH_4^+$ (mg/L) | 0.04 | 0.06 | 0.08 |
| TKN (mg/L) | <1 | <1 | <1 |
| $NO_2^-$ (mg/L) | 0.4 | 0.16 | 0.08 |
| $No_3^-$ (mg/L) | 1.4 | 1.2 | 1.1 |
| Total P (mg/L) | <0.1 | <0.1 | <0.01 |
| Soluble P (mg/L) | 0.098 | 0.022 | 0.006 |
| Cl (mg/L) | 668 | 1020 | 2090 |
| Pb (mg/L) | 0.05 | 0.13 | 0.11 |
| BOD (mg/L) | 8.0 | 6.0 | 5.5 |
| COD (mg/L) | | | |
| Total Solids (mg/L) | 1600 | 2100 | 3800 |
| Suspended Solids (mg/L) | 50 | 120 | 50 |
| Dissolved Solids (mg/L) | 1550 | 1980 | 3750 |
| Phenols (ppb) | N/D | N/D | N/D |

N/D = non detectable

### 2.2.7 Snowfall accumulation samples

Snow samples were taken for laboratory analysis from the front lawn and curb locations shown in Figure 7 during the winter of 1974-1975. Only snowfalls in excess of two inches were monitored. The results of the sample analyses are given in Tables 12 and 13.

## 2.3 Municipal Maintenance Practices

### 2.3.1 Summer street maintenance - sweeping and flushing

Street sweeping is conducted by the Borough of North York on a regular basis during the period between the spring cleanup in April-May and the cessation of operations for the winter season in October. Cummer Avenue and Pineway Boulevard are swept weekly and all the other streets, once every two weeks. However, wet weather often interferes with this routine, so a street will not always be swept on a particular day of the week. The days on which particular streets were swept are available on request. Street flushing is also carried out in the study area. Cummer Avenue was flushed in 1975 approximately on a weekly basis in May and June and about every other week thereafter, until mid-October. Pineway Boulevard and Bruce Farm Drive were flushed somewhat less frequently and the remaining roadways were not flushed at all. The dates when street flushing was carried out in 1975 are available if requested.

### 2.3.2 Winter street maintenance - deicing procedures

Salt and sand are used on roads for deicing purposes. Salt is applied to Cummer Avenue and Pineway Boulevard, while salt and sand mix (20 parts sand to 1 part salt) is used sporadically on the back streets. The policy of the North York Public Works Department is to salt streets such that all residences are within two blocks of a salted route. The salt application rate is approximately 1/2 to 3/4 tons/mile, although the actual distribution of the salt is left to the discretion of the driver. Bus routes, hills, and bridges with a tendency to ice up usually receive the largest applications of salt. Deicing compounds other than salt and sand are not employed. Details of salting and sanding operations may be had on request.

TABLE 12. POLLUTANTS IN SNOW SAMPLES, PHASE I

| DATE & LOCATION | $BOD_5$ mg/L | COD mg/L | Solids mg/L | P mg/L TOTAL | SOL. | Cl mg/L | Pb mg/L | TKN mg/L | $NO_3^-$ mg/L | $NH_4^+$ mg/L | PHENOLS ppb |
|---|---|---|---|---|---|---|---|---|---|---|---|
| December 2, 1974 | | | | | | | | | | | |
| CUMMER<br>(Curb) | 1.2 | 200 | 1620* | .36 | <.02 | 178 | 2.7 | 1.4 | <.4 | <.1 | 15 |
| December 6, 1974 | | | | | | | | | | | |
| BRUCE FARM<br>(Curb)<br>3:40 p.m. | | | 1100* | | | 17 | 1.9 | | | | 3 |
| CUMMER<br>(Curb)<br>3:55 p.m. | | | 5975* | | | 420 | 9.8 | | | | 5 |
| PINEWAY #137<br>(Lawn)<br>4:00 p.m. | | | 4410* | | | 153 | 11.0 | | | | 3 |

* Dirt particles present in snow sample.

TABLE 13. POLLUTANTS IN SNOW SAMPLES, PHASE II

| DATE AND LOCATION | BOD$_5$ mg/L | COD mg/L | SOLIDS SOLIDS mg/L | P mg/L | | Cl mg/L | Pb mg/L | TKN mg/L | NO$_3^-$ mg/L | NH$_4^+$ mg/L | PHENOLS ppb |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | TOTAL | SOL. | | | | | | |
| Jan. 20/75 | | | | | | | | | | | |
| CUMMER # 785 (Lawn) | 3.0 | | 145 | <0.02 | - | | | 3.5 | | 2 | 10 |
| BRUCEFARM (Curb) | 18 | | 1755 | 1.0 | <0.02 | 846 | | 3.5 | | <0.1 | 10 |
| Feb. 17/75 | | | | | | | | | | | |
| CUMMER #785 (Lawn) | 5.0 | | 70 | 0.12 | <0.02 | 98 | 0.07 | 1.1 | 1.4 | 0.2 | 3 |
| BERNICK #54 (Lawn) | 6.5 | | 45 | 0.50 | 0.02 | 16 | 0.25 | * | 1.0 | 0.8 | 4 |
| PINEWAY #209 (Lawn) | 6.0 | | 50 | 0.50 | 0.02 | * | * | 1.5 | 0.8 | 0.2 | 1 |
| CRAIGMOUNT #49 (Lawn) | 3.0 | | 50 | 0.20 | 0.02 | 100 | * | 1.4 | 1.0 | 0.2 | 3 |
| April 6/75 | | | | | | | | | | | |
| BRUCEFARM (Curb) | 18 | 90 | 130 | 0.30 | 0.24 | 82 | 0.20 | 1.0 | 2.0 | 0.1 | <1 |
| CUMMER #785 (North Curb) | 3.5 | 2300 | 2800 | 4.4 | <0.02 | 162 | 0.33 | 8.0 | <0.2 | <0.1 | <1 |
| CUMMER #785 (Lawn) | 3.0 | 40 | 55 | 0.20 | 0.04 | 6 | 0.07 | 1.2 | 1.2 | 0.3 | <1 |
| April 8/75 | | | | | | | | | | | |
| BRUCEFARM #25-27 (Curb) | 13 | 140 | 975 | 0.70 | 0.50 | 104 | 1.5 | 5.0 | <0.2 | 2.8 | 3 |

### 2.3.3 Catch basin maintenance

Catch basins are pumped out once a year in North York. According to the Borough, catch basins in the Brucewood area were pumped early in June 1974 and at a similar time in 1975, although the exact dates were not available.

### 2.3.4 Use of pesticides and herbicides

Pesticides and herbicides are used only occasionally by the Parks Department, and never for weed control on sidewalks and curbs. Since there is no parkland within the drainage boundaries, there is no contribution of pesticides and herbicides to the runoff from municipal activities.

## 2.4 Supplementary Meteorologic Data

### 2.4.1 Air temperature and daily precipitation

The nearest AES facility is the Downsview 'A' station, about 14 miles from the Brucewood catchment. The air temperatures recorded by Downsview were considered applicable to the study area. As a check, the maximum and minimum temperatures recorded at Downsview were compared to those at Castlemere, only four miles from the site. It was generally found that the temperatures at the two locations agreed to within a few degrees on most days during this period, although the variation in November 1974 was sometimes greater. Records were kept of the daily total precipitation at the Brucewood site and these together with the pertinent temperature data may be obtained on request.

### 2.4.2 Snow cover and density

The snow depth and densities were measured at the locations indicated in Figure 7. The major snow coverages were assessed from aerial photographs while the remainder were investigated from the ground. Aerial inspections were carried out on December 23, 1974, and January 20, March 11, March 13 and April 10, 1975. The contract liaison officer and the contractor have records of the snow depth and densities, the distribution of snow cover, and field observations pertaining to these aspects. Prints of the aerial photographs and plans indicating their locations can be obtained from CCIW.

# 3 DISCUSSION OF RESULTS OF MONITORING PROGRAM

## 3.1 Phase I: February 15, 1974 - December 31, 1974

### 3.1.1 Storm runoff samples

Table 3 shows the average concentration of runoff constituents for storms monitored during April through December, 1974. In determining these averages, weighting corrections (to make allowance for the elapsed time between samples and for the corresponding runoff volume) were not applied to individual sample values. The decision not to apply weighting corrections was made because most of the data do not relate to periods of peak runoff, but were the result of relatively low flow rates of approximately constant magnitude. The range of concentrations found for various constituents are of the same order as those reported from other watersheds with similar land use [1].

The recorded runoff rates during most of the storms were very low, and this resulted in low surface washoff rates for pollutants; small flow rates cause less scouring in the sewer pipes and result in a reduced capacity for the transport of the heavier particulate matter. No general relationship between BOD and COD appeared to exist; neverthless, a relationship between the time of year and the concentration of some pollutants is apparent. Data from storms occurring between April and June, 1974 indicate that those occurring in spring and early summer carried increased concentrations of nitrate nitrogen and orthophosphate. This increase may be explained by the use of lawn fertilizers during this period. However, fertilizer use was not investigated in the study.

Chloride levels were considerably higher in December than in other months. These high levels can be attributed to the use of deicing salts during the winter season. Concentrations of lead ranging from 0.04 mg/L to 1.11 mg/L were also found in most runoff events. Significant bacteriological concentrations in the storm runoff were also apparent, with coliform counts of several thousand/100 mL being common.

### 3.1.2 Catch basin samples

There are 75 catch basins in the study area. Samples for analysis were taken from two of them, located on Cummer Avenue and Bruce Farm Crescent (see Figure 8), and very high concentrations of most

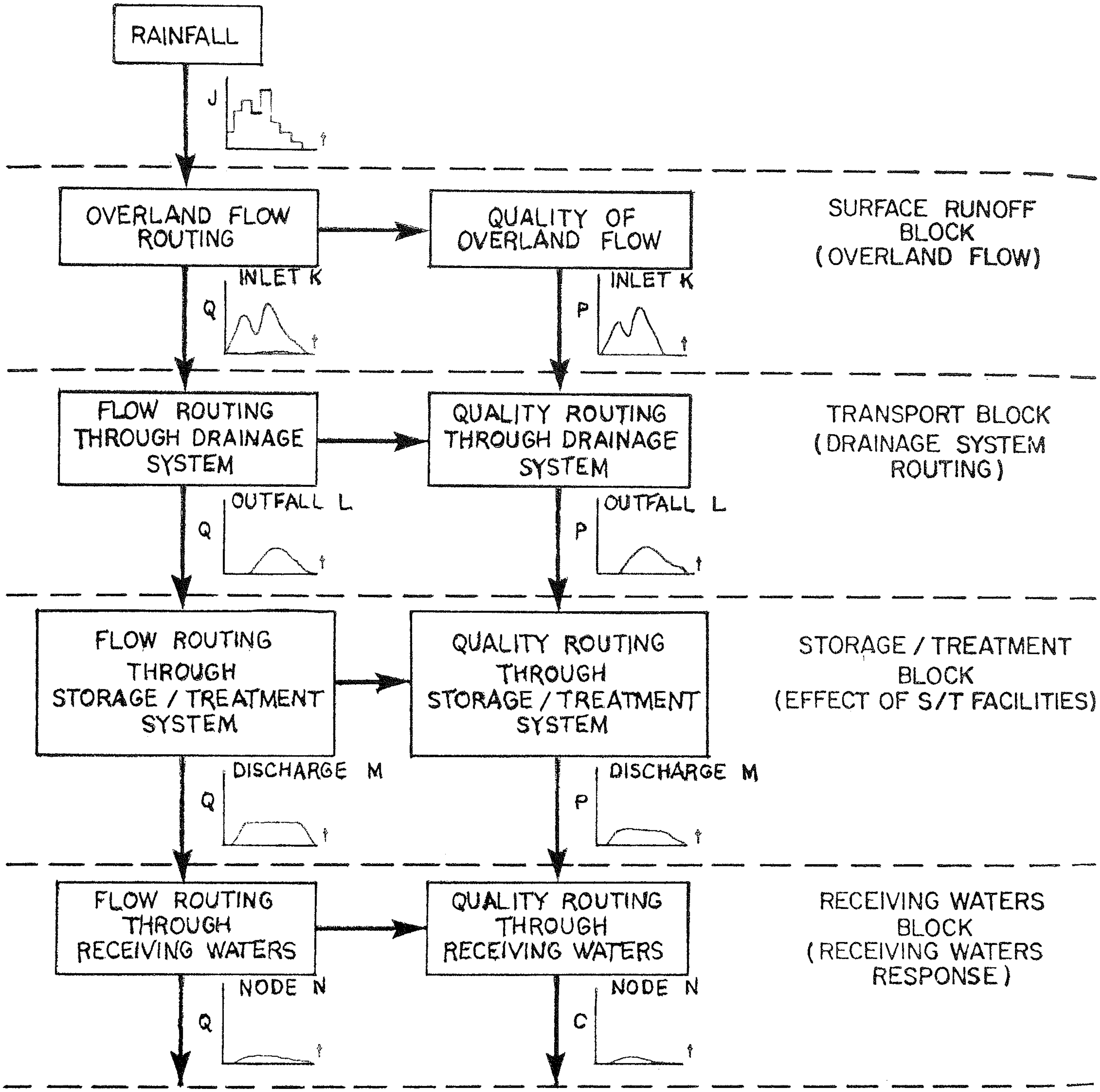

FIGURE 8. OVERVIEW OF THE STORM WATER MANAGEMENT MODEL

pollutants were found (Table 8). This can be partly attributed to the fact that in the Borough of North York, catch basins are generally cleaned only once a year. Thus, during the storm events, these basins become a significant source of first-flush or shock pollution, even though their volume is small in comparison to storm flow quantities. The residue in a catch basin tends to become septic between runoff events, and the solids trapped in the basin take on the general characteristics of anaerobic sludge. It is apparent, therefore, that catch basins may contribute significant amounts of pollution during the early stages of runoff events or in events of low rainfall intensity.

Considerably higher concentrations of chlorides and suspended solids were found for samples taken on November 12, November 26, and December 20, 1974, than those obtained earlier in the year. These high concentrations probably result from the use of sand and salt for deicing purposes. High lead concentrations in the latter part of the year probably indicated an accumulation of lead from automobile exhaust.

### 3.1.3 Snow samples

Snow samples were collected from streets and lawns during December and analysed for pollutants (Table 12). Very high concentrations of lead and solids were found in almost all the samples collected. Chloride levels were also high for the Cummer Avenue sample taken on December 6, 1974. The high levels of chlorides and solids probably resulted from the practice of using salt and sand for deicing purposes. However, automobile emission is the likely source of lead, particularly since most of the samples were taken from snow accumulated at the roadside. The high lead concentrations found in catch basin samples, mentioned in the previous section, may be a reflection of the high lead content of the snow. The lead particles trapped in the snow may be more susceptible to washoff during periods of snowmelt than those particles which lie directly on soil or in surface depressions of street pavements.

### 3.1.4 Snowmelt runoff

No significant snowfalls occurred in the Brucewood area during this phase of the study. Of the snowfalls recorded, none were greater than three inches and most were of the order of one to two inches. Accumulated snow generally melted completely at a slow rate between snowfalls, except in isolated locations where it was piled up at the side of a road or driveway. Because of this, periods of snowmelt runoff were few and runoff rates small.

As expected, chloride levels were very high after salt applications began in late November with concentrations reaching as high as 3200 mg/L on December 15, 1974. High concentrations of lead, up to 0.87 mg/L on December 2, 1974, were also found. BOD levels were generally low (less than 10 mg/L) but coliform counts and phenol levels were both comparable to those found earlier in the year from rain storm runoff.

These data may be compared with results of the snowmelt sampling carried out in the spring of the same year (Table 11).

### 3.1.5 Dry weather flow

Dry weather flow samples were taken on February 4 and October 27, 1974 and the results are shown in Table 7. The samples had relatively high chloride levels, while BOD concentrations were the same order of magnitude as those found in the storm runoff samples. Coliform counts and lead levels in the October sample were relatively low in comparison with those obtained later in the year from snowmelt.

### 3.1.6 Street dust and dirt samples

Street dust and dirt samples were collected from four different locations, two on Bruce Farm Road and the other two on Cummer Avenue (see Figure 7), during the period from October 1974 to January 1975. Sieve analysis generally showed that more than 50 percent of the dust and dirt fraction was finer than 30 mesh. This tends to confirm the results of a similar study conducted in Chicago by the APWA [2].

In Table 6, the average values of accumulation rates and the composition of dust and dirt for each of the sampling events are given. The daily dust and dirt rates found in this study appear to be somewhat higher than those reported in the APWA study, which are also used in the SWMM [3] for single-family residential areas. However, values for nitrogen and COD were found to be of the same order of magnitude.

Accumulation rates were estimated on the basis that dust and dirt were only removed due to municipal street cleaning and to washoff from accumulated rainfall of more than 0.5" (in both cases 100% efficiency was assumed). Samples taken after November, 1974 showed a noticeable reduction in accumulation rates. This may have resulted from influence of snowmelt runoff occurrences which were not considered in the accumulation rates.

Pollutant composition of the dust and dirt generally appeared consistent with results reported in the APWA study. The high lead content of the samples collected during December and January probably resulted from trapping of lead particles in the accumulated snow along the curb.

It is evident from the above results that the data collected in this phase of the study alone are insufficient to make final conclusions regarding these accumulation rates and composition of dust and dirt in the Brucewood area.

## 3.2 Phase II: January 1, 1975 - May 15, 1975

### 3.2.1 Snowmelt runoff events

The flow rates from the snowmelt runoff events during this period were low (uniformly less than 1 cfs) and relatively constant. Consequently, average constituent concentrations for each event (Table 4) were calculated assuming each sample to have equal weight.

It may be seen from an inspection of Tables 3, 4 and 5 that the observed concentrations for suspended solids and phenols are somewhat higher in winter runoff events than those recorded at other seasons. For example, the maximum average concentration of suspended solids for events recorded between January 1, and May 15, 1975 was 502 mg/L while the maximum for events prior to this date was 281 mg/L. The higher concentration may have resulted from the application of sand to the streets for deicing.

Average phenol concentrations for events in Phase II reached 20 ppb, compared to a maximum average 9 ppb recorded in the 1974 program and values generally ranging from 3-6 ppb in Phase III. Since the precipitation samples suggest that a major source of phenols in surface runoff is the rainfall itself (see Sections 3.2.2 and 3.3.2), higher phenol concentrations in the winter months may result from the increased combustion of fuel oils for domestic heating. As expected, chloride levels were much higher during the winter months, reaching a peak of 10 300 mg/L on January 3 when a moderate rain fell on accumulated snow. Because chlorides originate primarily from deicing salt the recorded chloride concentrations showed a strong seasonal tendency.

Concentrations of other parameters such as BOD, phosphorous, ammonia and nitrates, lead and total Kjeldahl nitrogen were generally comparable in both the snowmelt and storm runoff events.

### 3.2.2 Precipitation samples

It is evident from the results of sample analysis (Table 9) that the measured concentrations of most constituents were of the same order and magnitude as those observed in storm runoff (Table 4). This was unexpected since, although runoff would likely be contaminated by the same atmospheric pollutants as rain, the levels should be higher. Rain would be expected to wash off several days accumulated atmospheric fallout as well as pollutants from other sources. The reason may lie in the fact that few high-intensity rainfall runoff events were monitored, which resulted, consequently, in low washoff rates and thus lower concentrations.

Chloride, COD and suspended solids concentrations were lower in rainfall than in runoff (expected as these pollutants generally stem from municipal activities). Phenol levels were, on the other hand, much higher.

### 3.2.3 Residual snow samples

The results of the analysis of samples taken from the residual snow on the ground are presented in Table 13. The concentrations were found to be similar to those in the rainfall samples, except when the sample was taken at the curb where high solids and chloride concentrations were evident.

### 3.2.4 Catch basin samples

The effect of street salting and sanding was again evident in the high concentrations of suspended solids and chlorides found in the Cummer Avenue location (37 065 mg/L and 47 700 mg/L, respectively) on January 20, 1975).

### 3.2.5 Storm sewer base flow samples

The results of the analysis of the base flow samples are shown in Table 7. The levels of all constituents measured were comparable to those of base flow samples collected in 1974. Concentrations of most parameters were low with the exception of chlorides, which were somewhat higher than those recorded in October 1974 (averaging 608 mg/L for the three winter samples compared to 125 mg/L for the October sample).

## 3.3 Phase III: July 2, 1975 - December 31, 1975

### 3.3.1 Runoff quantity

Peak recorded flows ranged from 0.1 cfs on December 2, 1975 to 29 cfs on September 11, 1975 (Table 5). The average five-minutes-rainfall intensity exceeded one inch per hour in only two of the storms monitored (August 2 and September 11, 1975).

### 3.3.2 Runoff quality

Unlike the tendencies observed during Phase II, pollutant concentrations in runoff samples were consistently higher than those observed in rainwater (Tables 5 and 10). Only phenol and TKN levels were comparable in the two water samples. This suggests that the principal sources of these pollutants may be airborne, possibly from automobile exhaust gases and heavy industrial plant emissions. In future studies, it would be important to monitor rainfall quality as well as runoff quality in order to quantify airborne pollutant contributions to urban runoff [4].

Peak BOD concentrations were frequently higher than those in typical secondary municipal effluents, although suspended solids concentrations were of a similar order of magnitude to those found in untreated sanitary sewage. Total and fecal coliform counts consistently exceeded normal primary contact standards. Measured COD concentrations were generally an order of magnitude higher than BOD concentrations, which suggests that much of the pollution of urban runoff was non-organic in origin.

Chloride concentrations appeared reasonably constant until December, when salting operations were started. Lead levels were occasionally very high (over 1.5 mg/L). The primary source of lead was probably automobile exhausts; it has been reported that lead particles can represent about 0.75% of airborne suspended particulate matter in suburban locations [5].

The average daily dust and dirt accumulation rate during August was about 0.69 lb/100 ft of gutter. This value was based on all the daily loads measured in all the areas and did not reflect losses due to sweeping or washoff. It compares with the value determined in the APWA study for a single-family residential area in Chicago of 0.7 lb/day/100 ft of gutter [2]. The accumulation rate for the main road in the Brucewood area (Cummer Avenue) was measured at 0.96, while for the back streets the average daily rate was 0.43 lb/100 ft.

The pollutant accumulation on a watershed, and subsequent washoff during storms generally occurs over the whole area. While the maximum accumulation may occur in the curbside region, pollutants also build-up over the rest of the area. Important sources can be:

- atmospheric fallout,
- lawn and garden fertilization,
- concentrated areas of human activity (schools, plazas, institutions, etc.).

These are not directly related to street length (gutter length - an input parameter in the SWMM used in the calculation of pollutant build-up and runoff). Consequently, accumulation might be better expressed on an areal (i.e., lb/acre/day) rather than a linear basis for different land uses.

# 4. COMPUTER SIMULATION OF STORM EVENTS

## 4.1 Description of Storm Water Management Model

The U.S. EPA Storm Water Management Model (SWMM) [3] is a comprehensive mathematical model which requires a high speed digital computer for the simulation of storm events. The inputs to the model include the temporal distribution of rainfall intensity (hyetograph) and data describing the idealized catchment, transport and receiving water systems. The principal object of the model is to completely characterize the temporal and spatial effects of a storm. To achieve this, the flow and associated pollutional aspects are represented as continuous curves referred to as hydrographs and pollutographs, respectively.

The model contains four main submodels or blocks, each representing one part of the urban system (Figure 8). For the purposes of simulating runoff quantity and quality in Brucewood, only the RUNOFF and TRANSPORT blocks were required.

### 4.1.1 Runoff block

This is used to handle events that occur prior to storm water entering the sewer system. The computation treats a storm event as a summation of discrete and equal time intervals (typically five minutes). The rainfall hyetograph, corresponding to the particular time interval, is applied to each subcatchment area. The drainage characteristics of a subcatchment are a function of its size, degree of imperviousness, slope and several factors describing the accumulation of pollutants. Before runoff is considered to have occurred, the depression storage and infiltration potential have first to be satisfied. The overland flow is then considered using a kinematic wave formula based on Manning's equation and continuity at each time interval. The flow may be routed through small pipes and gutters in its travel to the inlet manhole. It is the rate of flow which determines the amount of available surface pollutants incorporated in storm water. Thus, the RUNOFF block provides a temporal description of the flow and the pollutant mass washoff that enter the sewers. These hydrographs and pollutographs form the input to the TRANSPORT block.

### 4.1.2 Transport block

This is used to represent the physical processes that convey surface runoff hydrographs and pollutographs from the contributing subcatchments to the point of discharge. The inlet flows are modified to take into account any dry weather flow in the system. The flows and pollutant discharge rates are attenuated during their passage through the pipe network to an extent which depends on the capacity of the system and on the in-system storage characteristics.

The solution procedure follows a modified kinematic wave approach in which disturbances are allowed to propagate only in the downstream direction. The resultant flow velocity in each element controls the deposition or scour of solids.

Flows may be diverted at various points in the system, either to overflow locations or to treatment. The effect of different storage and treatment facilities can be modelled in the STORAGE/TREATMENT block, and the effects of direct or indirect discharge to the receiving water may be evaluated using the RECEIVING WATER block. However, neither of these operations is pertinent to the Brucewood catchment.

### 4.1.3 Input parameters

A review of the theory upon which the RUNOFF block is based indicated that the following parameters directly affect the surface runoff from a given area [6]:

a) infiltration,
b) retention depth,
c) ground slope,
d) Manning's 'n',
e) imperviousness,
f) width of overland flow.

In the simulations carried out in the present study, default values (supplied by the model in the absence of input data) were used for a), b) and d). Ground slope was obtained from topographic maps, and imperviousness was estimated from aerial photographs. The overland flow width was calculated using standard procedures [7].

The sizes and slopes of the storm sewer pipes, required as input for the TRANSPORT block, were obtained from sewer maps. The default values for Manning's 'n' for pipes, provided by the model, were used.

## 4.2 Simulation of Runoff Quantity

### 4.2.1 Storm of May 14, 1974

This storm produced one of the highest peak flows recorded in the study. The results of the simulation for this event are shown in Figure 9. The computed peak flow was some 18% lower than that recorded, and a general lag of 5-10 minutes was observed between the measured and computed hydrographs. The shape of the computed hydrographs agreed well with those observed, including a slow initial build-up and the presence of an initial peak before the major flow event. The volume of runoff computed was approximately 16% less than that recorded.

### 4.2.2 Storm of August 11, 1975

Figure 10 shows the results of simulation for this small rainfall event. The computed and measured peak flows agreed to within 8% of one another, as did the runoff volumes. The shape of the computed hydrograph was similar to that recorded; however, the SWMM computed a slower drop in flow rate following the peak flow than was actually observed, resulting in a broader hydrograph.

### 4.2.3 Storm of August 29, 1975

Computer simulation resulted in very close agreement between measured and computed peak flows (Figure 11). The initial peaks of this event were also well represented by the SWMM, although a more rapid decrease in rate following peak flows was actually observed. The total computed volume was approximately 10% greater than that recorded.

### 4.2.4 Storm of November 20, 1974

In the simulation (Figure 12), the computed peak flow was 33% less than the recorded value. The first peak recorded was larger and better defined than the computed peak. The computed flow volume was some 25% greater than that recorded.

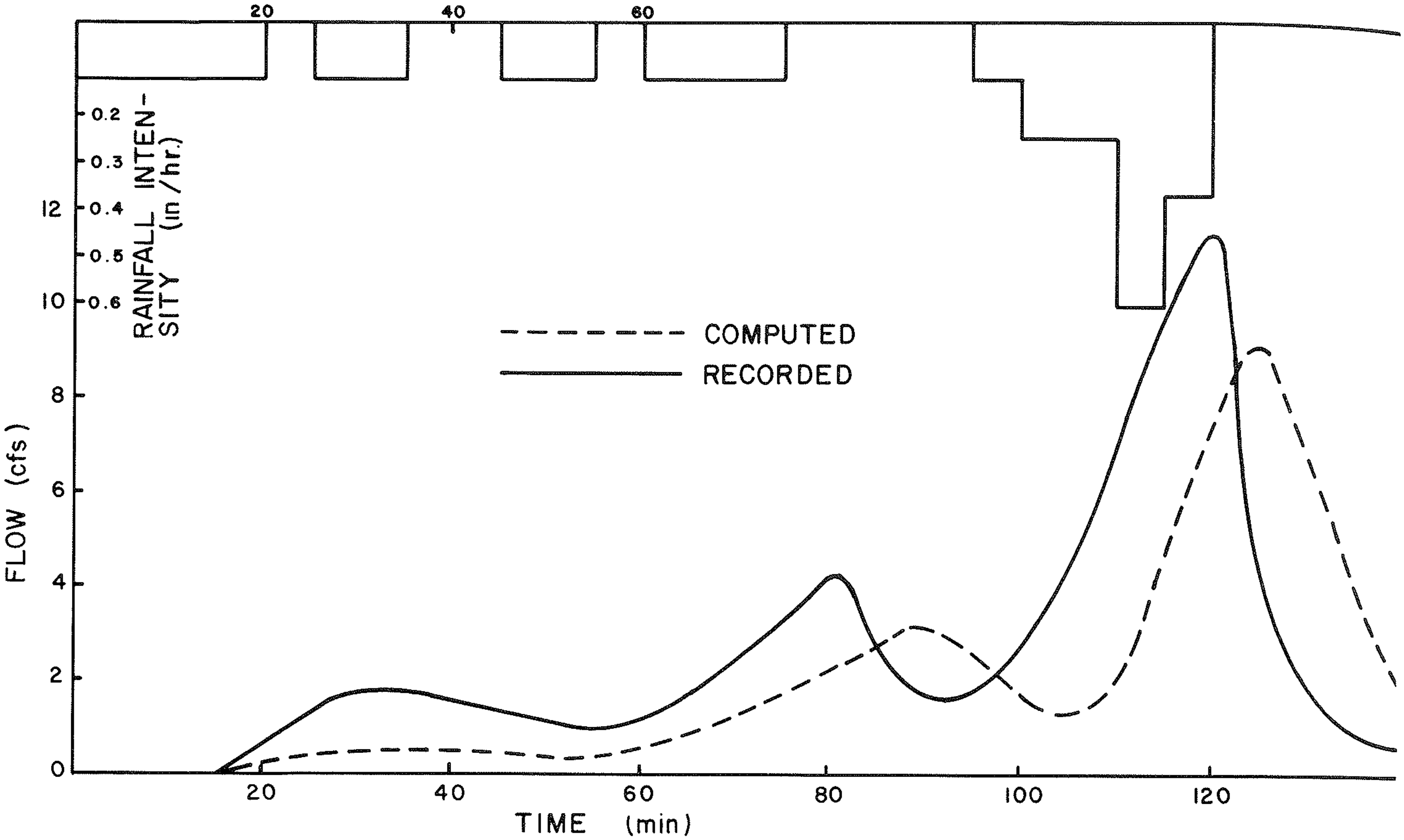

FIGURE 9. STORM OF MAY 14, 1974

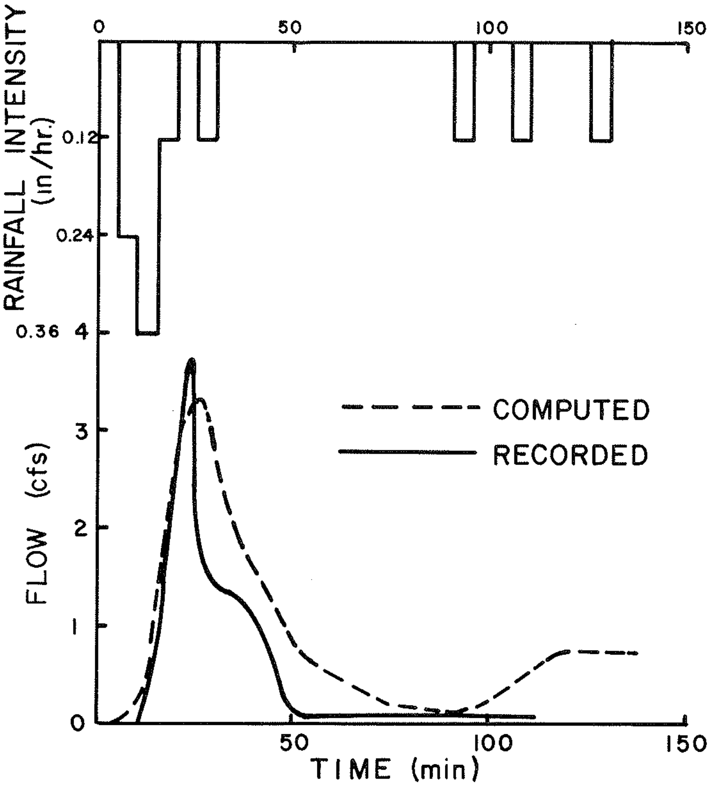

FIGURE 10. STORM OF AUGUST 11, 1975

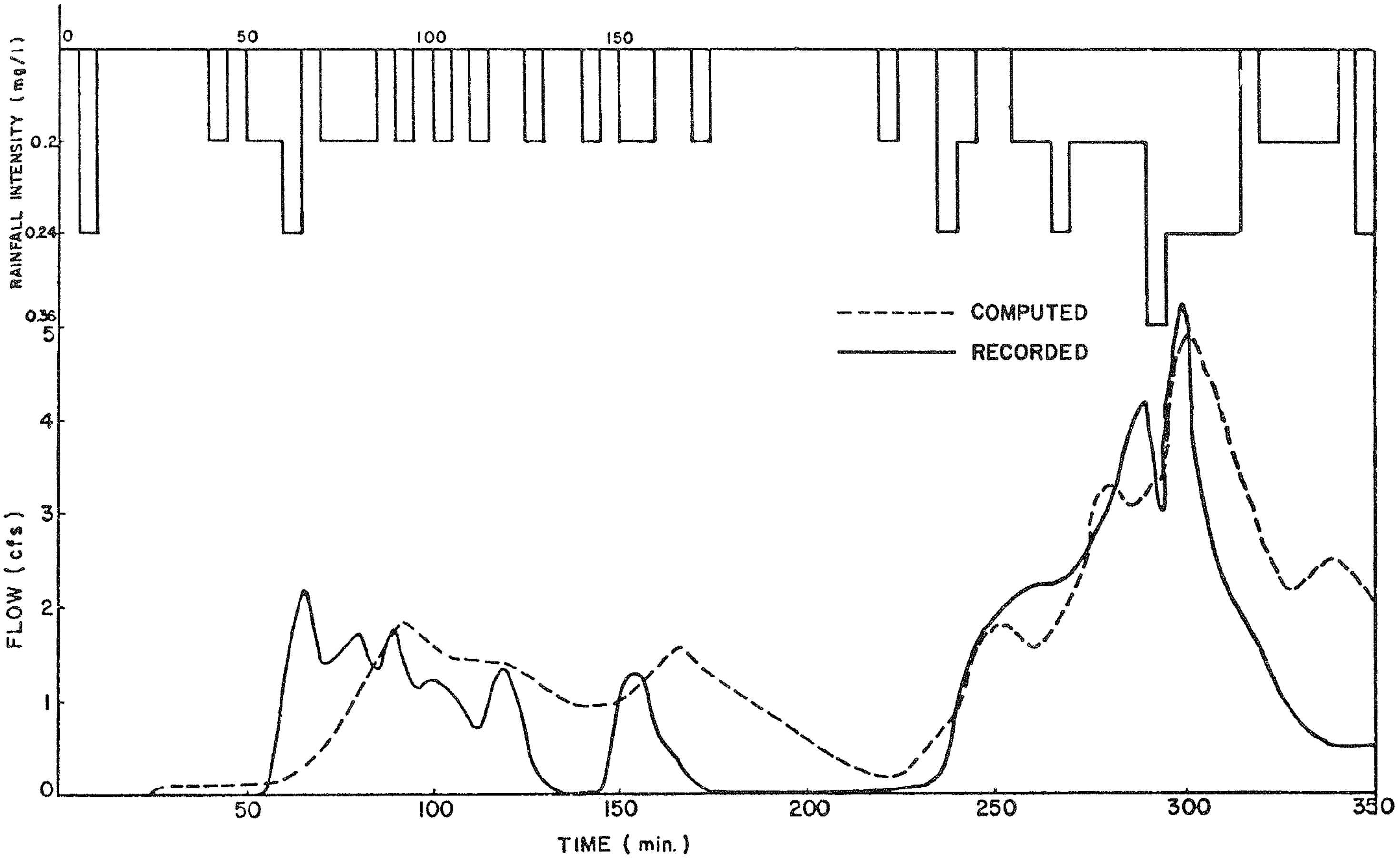

FIGURE 11. STORM OF AUGUST 29, 1975

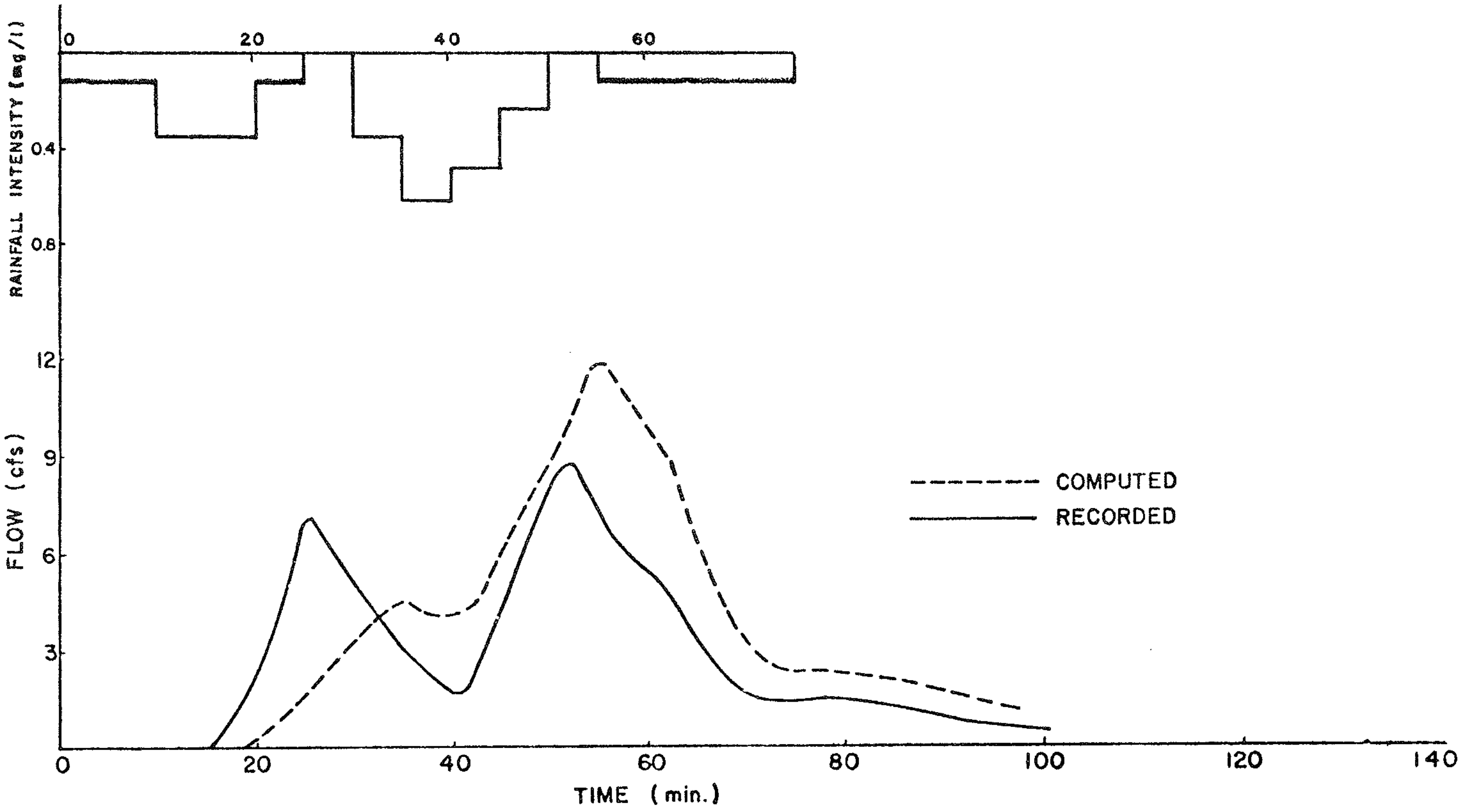

FIGURE 12. STORM OF NOVEMBER 20, 1974

### 4.2.5 Storm of September 11, 1975

This storm was the severest recorded in the 1975 monitoring program. The peak five-minutes-average rainfall intensity was 1.08 in/hr and the total rainfall volume was 0.9 in. The measured peak flow rate was about 20% higher than the computed value. The total measured and simulated runoff volumes were within 10% (Figure 13).

### 4.3 Simulation of Runoff Water Quality

Six storms were selected for simulation of water quality parameters using the SWMM. There were generally insufficient water quality data obtained during the other storms for worthwhile comparisons with simulated values to be made. Of the storms selected, three had maximum rainfall intensities less than 0.60 inches per hour and only the storm of September 11, 1975 had a peak rainfall intensity greater than 1.0 inch per hour.

SWMM default values for the dust and dirt loading rates and pollutant composition were used in initial simulations of the chosen storms. The procedure outlined in the User's Manual [7] was followed to determine the antecedent number of dry days; that is, prior days were counted as "dry" if the cumulative sum of the antecedent rainfall was less than one inch.

The general trends observed in these initial runs are summarized below and formed the basis for subsequent model adjustments.

a) For events with a low number of antecedent dry days, suspended solids concentrations were severely underestimated when using the exponential equation (ISS=0). On the other hand, more "reasonable" estimates were obtained for the storms of August 29, 1975 and September 11, 1975, with 10 and 12 antecedent dry days, respectively.

b) BOD concentrations were generally slightly underestimated when the exponential equation was used for suspended solids computations (the model considers 5% of the computed SS to contribute to BOD). However, simulated BOD concentrations were much closer to measured BOD values than were simulated SS to measured values.

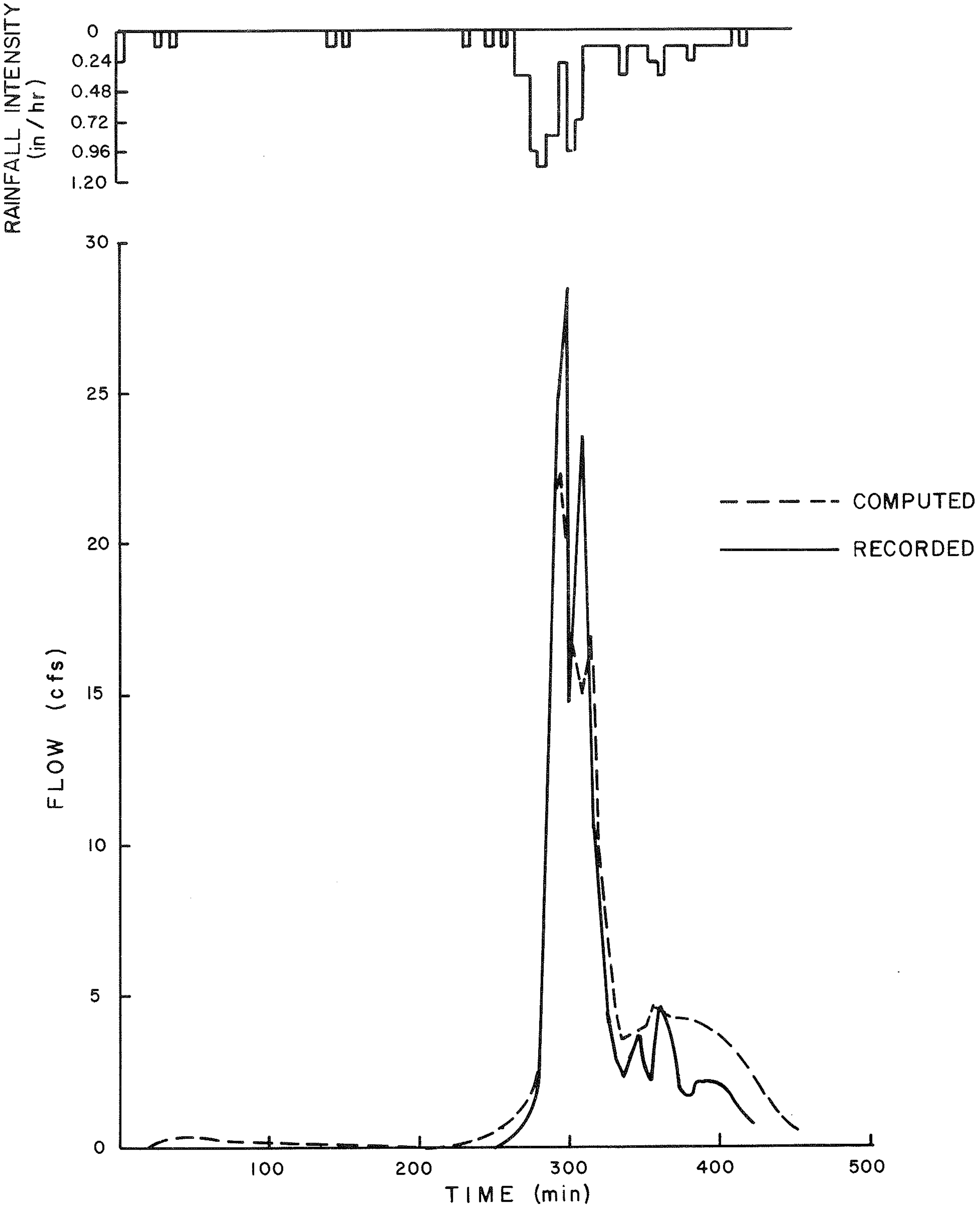

FIGURE 13. STORM OF SEPTEMBER 11, 1975

c) Simulated coliform concentrations were much higher than the measured values.

These observations indicated that improved simulations could be achieved by making the following adjustments:

a) The empirical (ISS=1) option for suspended solids calculations should be used when initial surface pollutant loads are low.

b) Measured composition of pollutants should be supplied wherever possible. This included using the average measured value for catch basin BOD concentration of 60 mg/L compared to the default value of 100 mg/L for all the events, and the dust and dirt accumulation rates measured prior to the events of August 11 and August 29, 1975. For these two events, the measured suspended solids fraction in the dust and dirt was taken as the percentage which was finer than the 30 mesh obtained from sieve analysis of representative samples. The measured values for these storms are indicated on Figures 17 and 18. (The BOD composition measured in the dust and dirt was essentially the same as the default value.)

c) The MPN of coliforms in the dust and dirt should be changed from the default value of $1.3 \times 10^6$ to $0.65 \times 10^6$ MPN per gram. This value was determined by trial and error simulations and used for the three events where coliform measurements were available for comparison.

The six storms were simulated with the input to the model adjusted as outlined, and final results are presented in Figures 14 to 19. (Default values were used unless otherwise noted in Table 14.) For events in which the antecedent number of dry days was fewer than 10, the use of the empirical equation (ISS = 1) resulted in much better simulation of suspended solids concentrations than the exponential equation, although estimated BOD concentrations were, if anything, only marginally improved. For the storms of May 16, 1974, November 20, 1974 and September 11, 1975 (Figures 15, 16, 19), simulated and measured coliform MPN's were the same order of magnitude. This indicates that coliform estimates for separate sewer systems (using the corrected exponential decay equation) can give

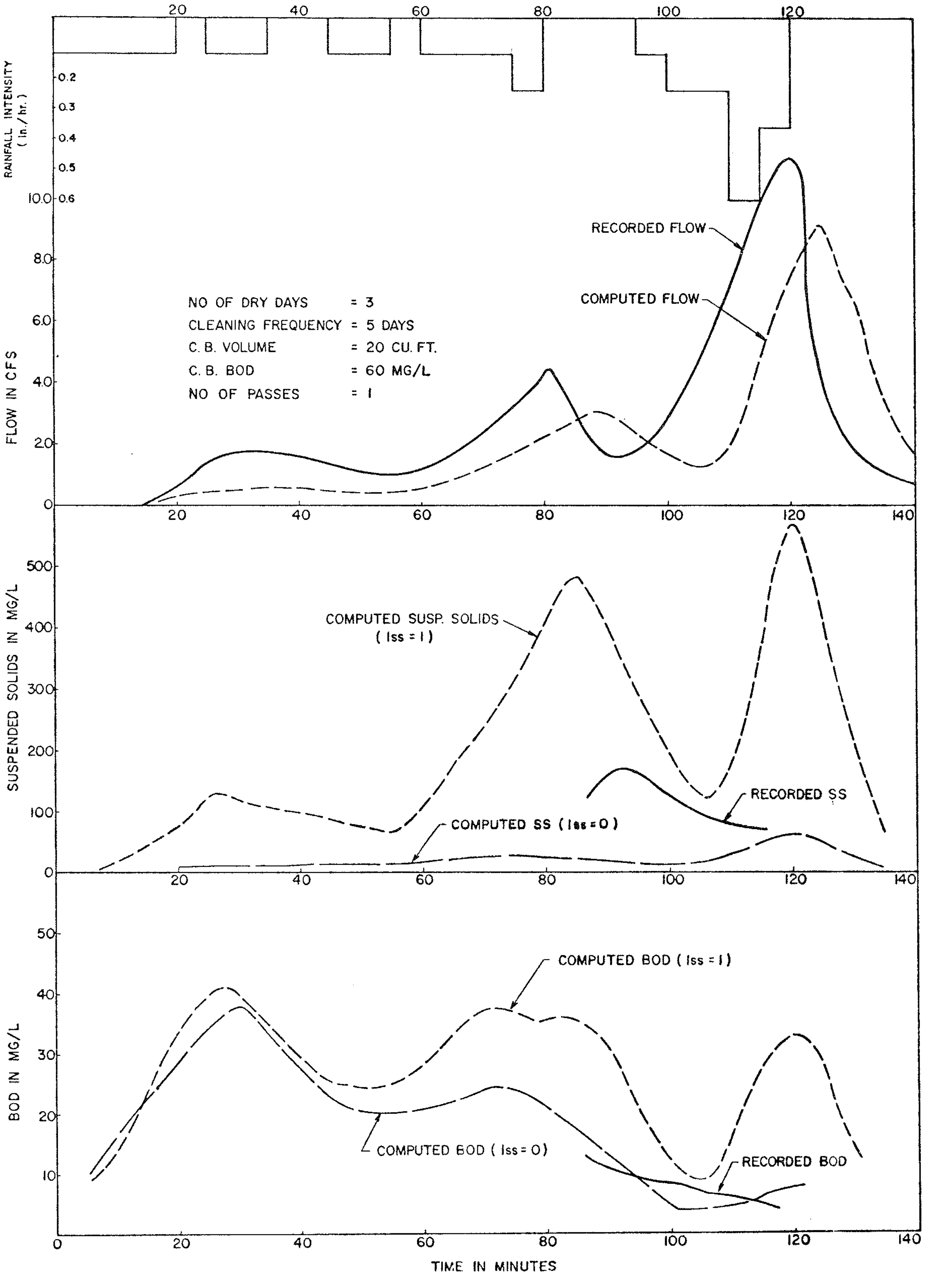

FIGURE 14. FLOW AND POLLUTOGRAPHS FOR STORM OF MAY 14, 1974

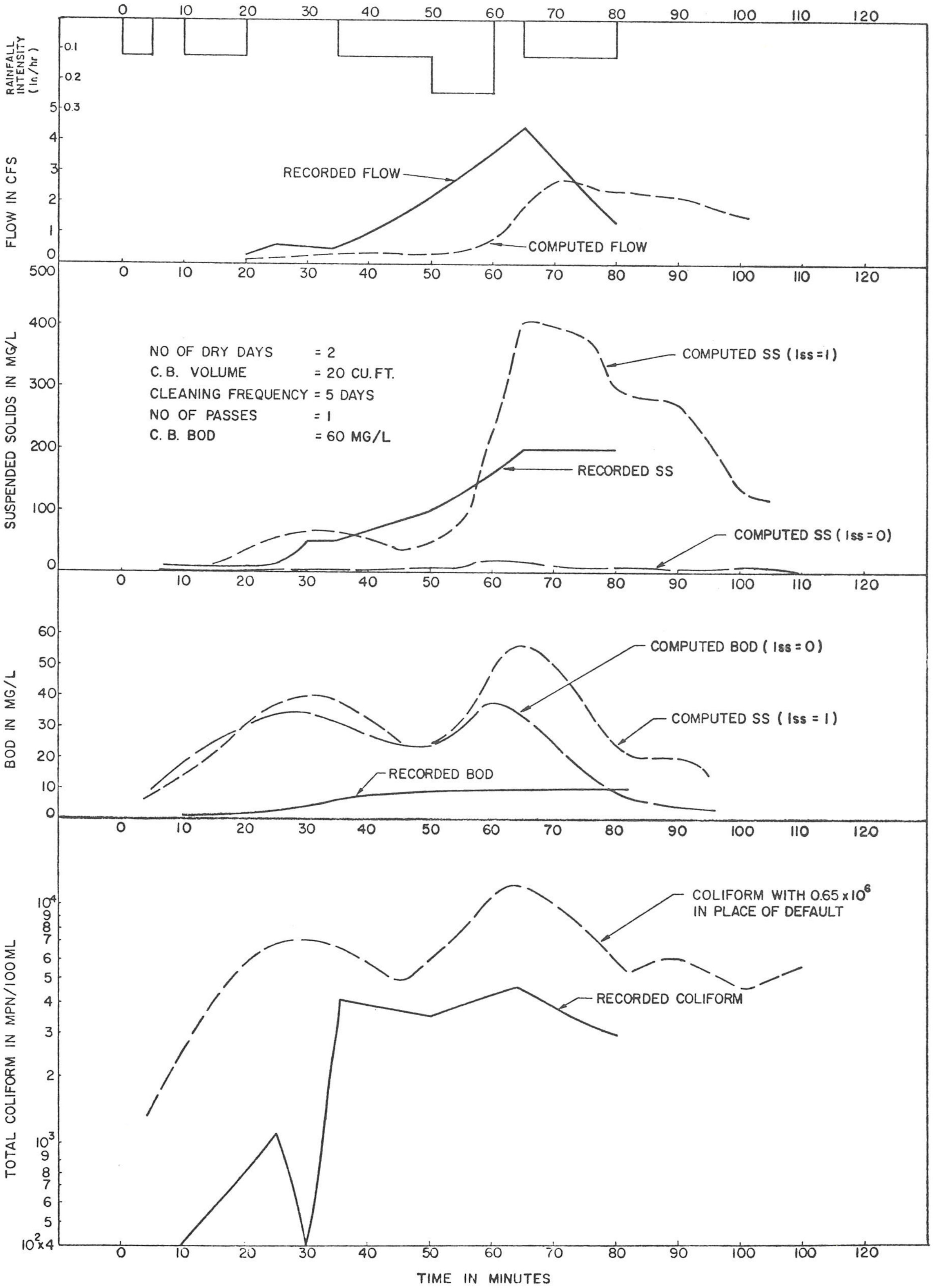

FIGURE 15. FLOW AND POLLUTOGRAPHS FOR STORM OF MAY 16, 1974

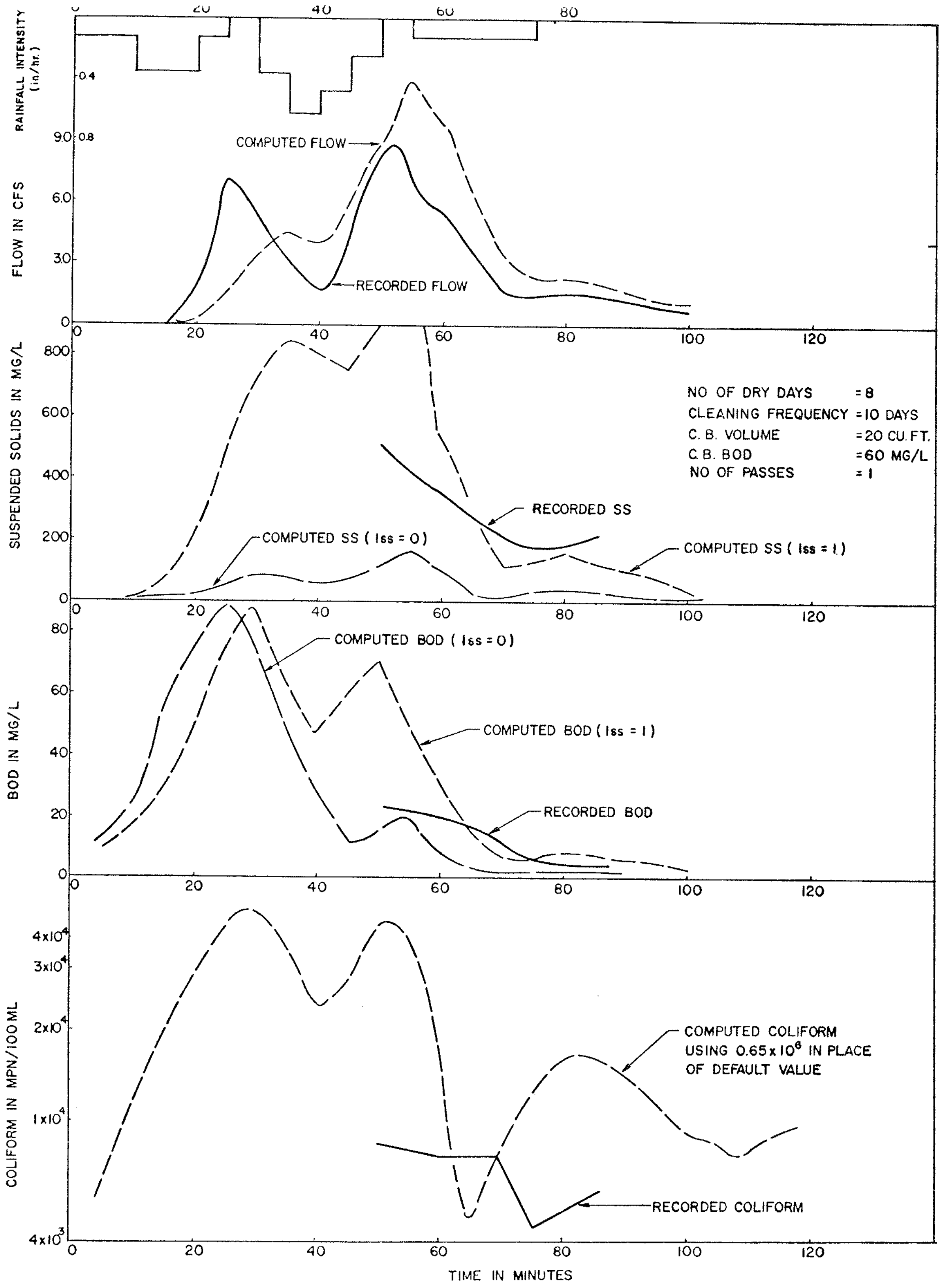

FIGURE 16. FLOW AND POLLUTOGRAPHS FOR STORM OF NOVEMBER 20, 1974

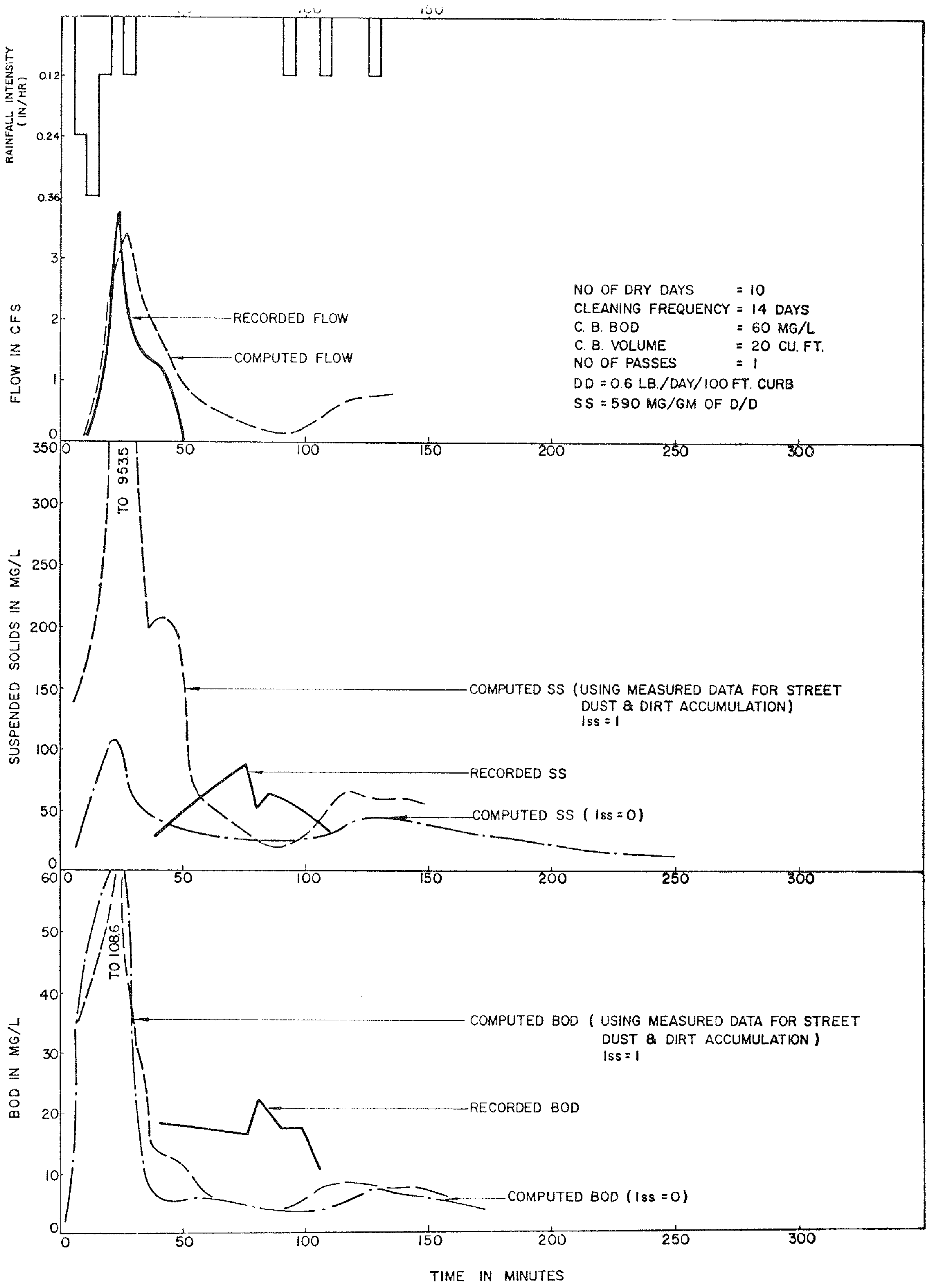

FIGURE 17. FLOW AND POLLUTOGRAPHS FOR STORM OF AUGUST 11, 1975

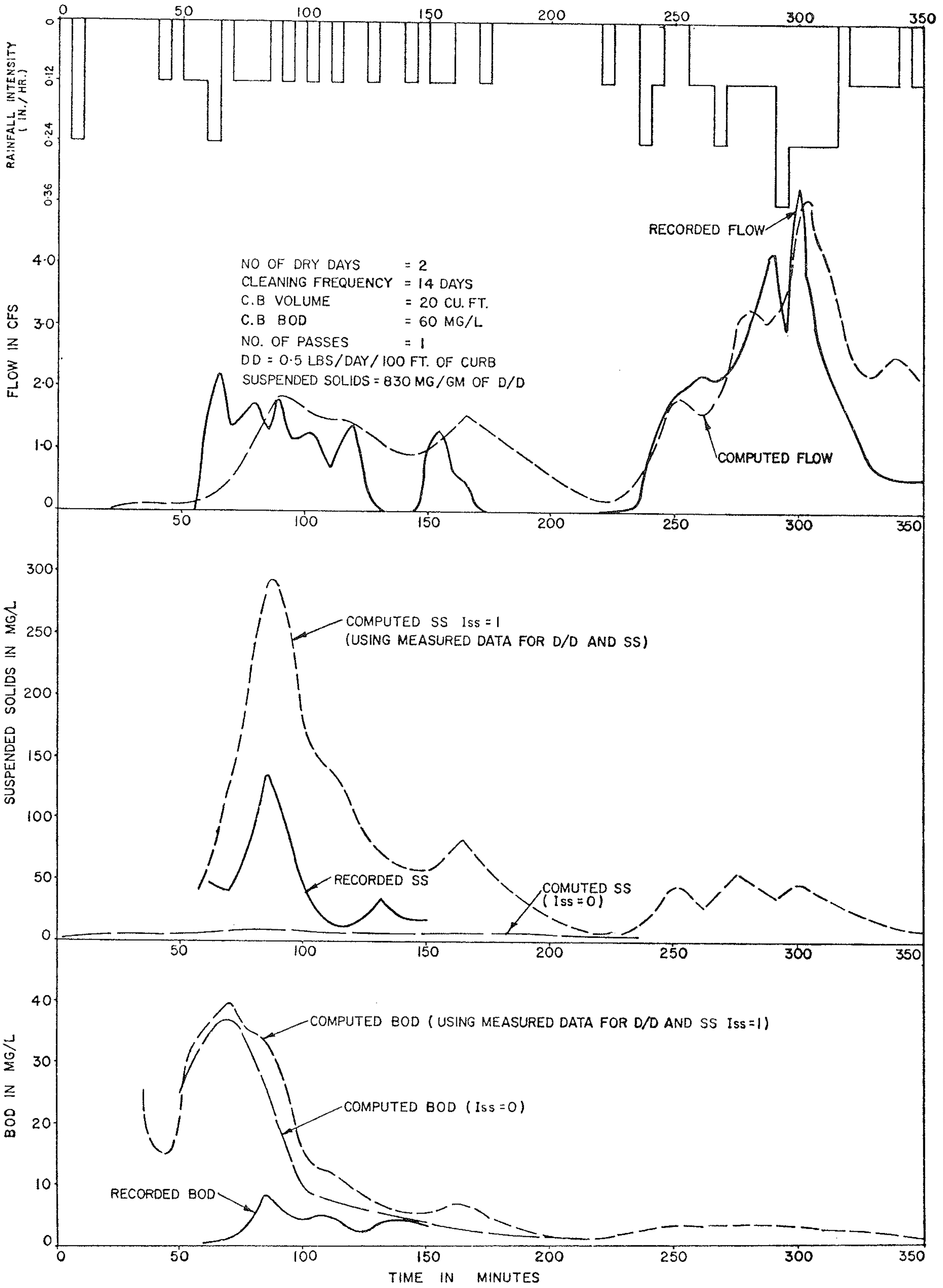

FIGURE 18. FLOW AND POLLUTOGRAPHS FOR STORM OF AUGUST 29, 1975

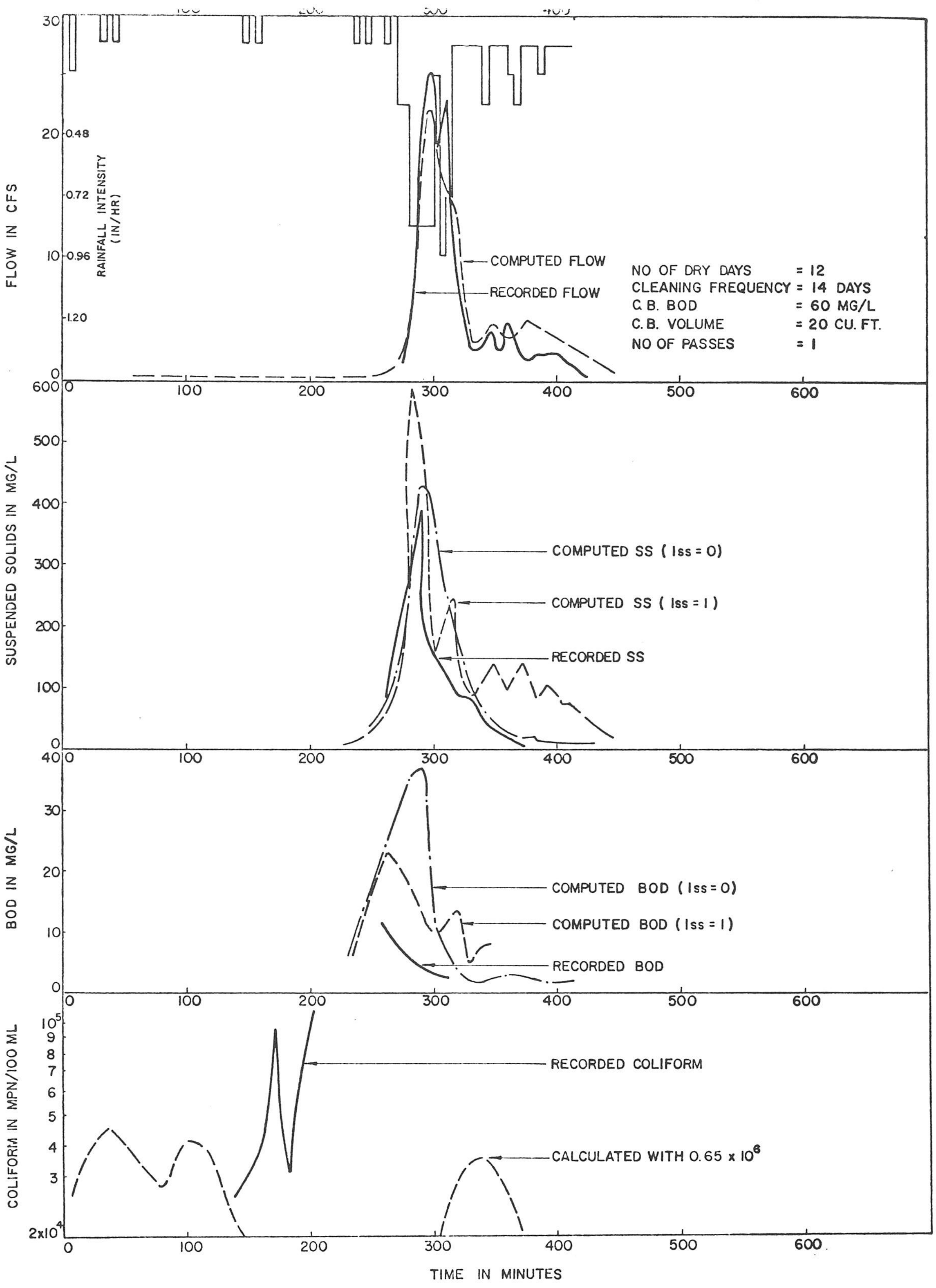

FIGURE 19. FLOW AND POLLUTOGRAPHS FOR STORM OF SEPTEMBER 11, 1975

TABLE 14. COMPARISON OF DEFAULT VALUES WITH ADJUSTED VALUES USED IN SWMM SIMULATIONS

| Parameter (concentrations) | Default Value | May 14 1974 | May 16 1974 | Nov. 20 1974 | Aug. 11 1975 | Aug. 29 1975 | Sept. 11 1975 |
|---|---|---|---|---|---|---|---|
| CB BOD (mg/L) | 100 | 60 | 60 | 60 | 60 | 60 | 60 |
| Coliform (MPN/gram) | $1.3 \times 10^6$ | - | $0.65 \times 10^6$ | $0.65 \times 10^6$ | - | - | $0.65 \times 10^6$ |
| Dust & Dirt Accumlation (lb/day/100 ft of curb) | 0.7 | 0.7 | 0.7 | 0.7 | 0.6 | 0.5 | 0.7 |
| SS Fraction of Dust and Dirt (%) | 100 | 100 | 100 | 100 | 59 | 85 | 100 |

reasonable results in comparison with measured values, provided some calibration is undertaken.

In general, the results of these adjusted simulations indicate that pollutographs computed using the SWMM give values that are of the same order of magnitude as those measured. A fair degree of agreement between the recorded and computed total pollutant loads also appears possible (see Table 15).

## 4.4 Conclusions Related to Modelling

The conclusions reported here are based on the simulations discussed in the preceding sections and on the general findings of the Storm Water Management Model Study [6].

1) A sensitivity analysis of the various parameters and default values confirms that the default values provided by the SWMM are suitable for simulation of storm water hydrographs.
2) For medium and high intensity storms, peak flows are generally simulated by the uncalibrated SWMM to within ± 20 percent of those measured. Further field measurements for calibration of the model solely for flow simulation may, therefore, only be required in special cases.
3) The simulation of the water quality of storm related flows is not as accurate as flow simulation. The simulations of storm water quality conducted for the Brucewood watershed and for other areas, emphasize that calibration is required if an "order of magnitude agreement" is to be achieved.
4) The two optional methods included in the SWMM for suspended solids computations were compared and neither seen to be generally applicable. It is concluded that use of the empirical formulation (ISS = 0) gives superior results to the exponential equation (ISS = 1) when the antecedent dry period is less than 10 days.

TABLE 15. COMPARISON OF POLLUTANT LOADS*

| Storm | Peak Flow (cfs) | | Sampling Period (min) | Flow ($ft^3$) | | BOD (lb) | | SS (lb) | | Total Coliform MPN | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Recorded | Comp'd | | Recor'd | Comp'd | Recor'd | Comp'd | Recor'd | Comp'd | Recorded | Computed |
| May 14/74 | 11.4 | 9.2 | 30 | 8619 | 5068 | 2.63 | 7.89<br>(2.45) | 49.27 | 117.09**<br>(9.55)*** | - | - |
| May 16/74 | 4.5 | 2.7 | 70 | 7401 | 3853 | 4.06 | 9.72<br>(6.83) | 77.66 | 77.47<br>(3.93) | $0.72 \times 10^{10}$ | $0.37 \times 10^{10}$ |
| Nov. 20/74 | 8.7 | 11.9 | 35 | 10362 | 13402 | 12.65 | 33.74<br>(10.85) | 137.18 | 587.38<br>(97.47) | $2.4 \times 10^{10}$ | $4.03 \times 10^{10}$ |
| Aug. 29/75 | 5.3 | 5.1 | 88 | 5653 | 6801 | 1.31 | 9.13<br>(5.4) | 21.7 | 78.19<br>(4.09) | - | - |
| Sept. 11/75 | 25.0 | 22.0 | 80 | 49422 | 53649 | 10.04 | 61.06<br>(45.86) | 345.2 | 875.14<br>(605.8) | - | - |

* All total washoff amounts have been computed for the sampling period only. Flow and pollutant amounts have not been included for the storm of August 11, 1975 since the recorded runoff rate was extremely low during the sampling period.

** ISS = 1

***ISS = 0

# 5 CONCLUSIONS AND RECOMMENDATIONS

## 5.1 General Conclusions

1) The pollutant concentrations measured in the runoff from the Brucewood subdivision were comparable to those typically obtained from secondary effluents of municipal treatment plants. Peak suspended solid concentrations, in particular, were similar to those typically found in untreated domestic sewage.
2) For some pollutants, the ranges of concentrations measured in rainfall samples were of the same order of magnitude as those measured in the surface runoff. It is concluded that in certain meteorological conditions, the washout of pollutants from the atmosphere can be a significant source of pollution.
3) The default values programed in the SWMM are suitable for most runoff quantity simulation purposes when local data are unavailable. Further measurement programs directed solely at the verification of the SWMM quantity routines are not required (with the exception of snowmelt quantity).
4) SWMM flow simulation is noticeably more accurate than SWMM simulation of storm water quality. Even with a calibrated model, measured pollutant concentrations can generally only be reproduced to within an order of magnitude.

## 5.2 Recommendations

1) Additional sampling programs are required in a number of diverse urban and suburban catchments to extend the modelling data base and improve the understanding of the complex inter-relationships governing runoff water quality. Routine sampling of rainfall, for the purpose of analysing for pollutants, should be considered in conjunction with new programs.
2) The units employed in the SWMM for pollutant accumulation rates (i.e., a percentage of the daily accumulation rate of dust and dirt per 100 ft of gutter) are confusing and tend to obscure the fact that pollutants accumulate over an area, not just in a gutter. It is recommended that units be specified, on a per acre basis, as a proportion of the total daily solids accumulations.

# ACKNOWLEDGEMENT

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