INTERNATIONAL JOINT COMMISSION

MENOMONEE RIVER
PILOT WATERSHED STUDY

SEMI-ANNUAL REPORT

COOPERATING AGENCIES

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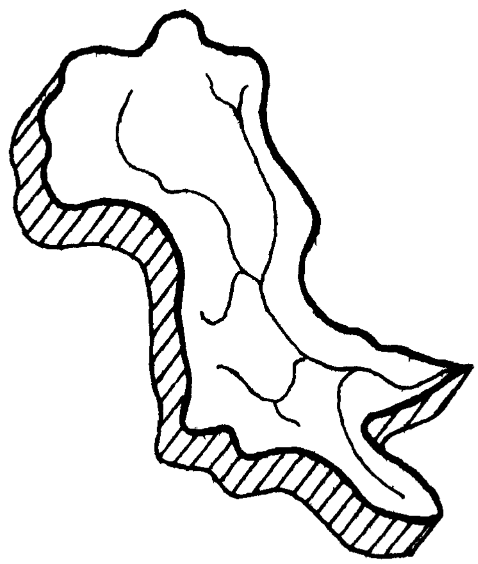

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SUMMARY - SEMIANNUAL REPORT

Introduction

The International Joint Commission, through the Great Lakes Water Quality Board, established the International Reference Group on Great Lakes Pollution from Land Use Activities (PLUARG) to study and report the effects of land use on water quality and recommend remedial measures. The "Task C" assignment requires the detailed investigation of six major watersheds in Canada and the United States, which are representative of the full range of urban and rural land use found in the Great Lakes basin. The objectives of the Menomonee River Pilot Watershed Study are to investigate the extent of pollutant contribution from urban and urbanizing land use activities and to extrapolate these results to the entire Great Lakes basin. The report will review the progress towards achieving the objectives of the study since the April 1976 Semiannual Report.

Progress

The two principal approaches used to investigate the extent of pollutant contribution to surface or ground waters from different land use activities in the Menomonee River watershed were observing the levels of pollutant loading in surface water runoff, ground water and the atmosphere (the geohydrochemical cycle) and providing an inventory of land use activities. The quality of surface water runoff was investigated by the River Monitoring Activities (Appendix A) and the Specific Land Use Studies (Appendix B).

The river monitoring activities have generated pollutant loading values for multiple use land areas and relatively homogeneous land use areas. Runoff water was sampled during events 18 times between April 24 and October 26, 1976 at various automatic monitoring stations on the Menomonee River and its principal tributaries. Water quality samples were collected routinely at the same stations under baseflow conditions. Water loading during events was approximately 40 percent of the total water load in 1975 at most stations. If the 70th Street station (413005) is assumed to represent the integrated loading from the entire watershed that could potentially reach Lake Michigan, then the event loadings of suspended solids during the March 4, May 5, and May 15 events were about 4,000,000, 60,000 and 20,000 kg, respectively. The total loading (event and baseflow) of suspended solids that could reach Lake Michigan for a 7-month period in 1975 was about 12,000,000 kg and about 50 percent of that occurred in March 1975. The total and event suspended solids loading data demonstrated a trend toward higher suspended loadings for areas which had larger percentages of residential land use. Loading values for all events are being calculated and a method for estimating missing data is being evaluated. Completion of this task will allow observation of long-term trends in pollutant loadings from different land use areas. The results will be compared to the relationships observed at the specific land use study sites.

The specific land use studies complement the pollutant loading data from the river stations by following the extent of pollutant loading from principal homogeneous land use activities in the watershed. The concentration of pollutants during runoff events at the specific land use study sites is also being used to calibrate the overland flow model, "LANDRUN." The construction of nine sampling sites has been completed, and monitoring of runoff events at most sites began in May 1976. The data have been summarized from four events at the Brookfield Shopping Center sampling site. Usually, the initial flush (beginning of event to peak flow) carried most of the dissolved constituents. Concentrations of most metals increased with increasing discharge. The high level of lead observed in each event was equivalent to the lead in about 400 gallons of gasoline. In addition to the specific land use studies, investigations of the dynamic relationship between metals and suspended solids during sediment transport are being conducted.

The biological program (Appendix D) was implemented to provide information elucidating the relationship between pollution loadings from various land use areas and the stream macroinvertebrate communities present in the river. The data from the biological samplings indicated that the effects of nonpoint urban and urbanizing land use activities were being masked by pollution from such point sources as sewage treatment plants and creosol waste. Future biological samplings will be conducted on tributaries to the river where the biological communities are less affected by point source pollution.

Ground water (Appendix C) was investigated along with surface runoff as an additional transport mechanism for pollutants. The ground water study is used to assess: 1. the degree to which chemical contaminants are discharged to the river from ground waters and 2. the possibility that surface contaminants are moving to ground water by infiltration through the stream bed. Thirty-eight observation wells have been drilled at 14 sites in the watershed. The observation wells were surveyed in August and groundwater levels were measured. Generally, the August data indicated that conductivity and pH were highest in the deeper portions of the aquifer, lower in the shallower wells and lowest in the river. A river sediment survey showed that much of the Menomonee River below the confluence with the Little Menomonee River flows on bedrock while the remainder of the river system largely flows over organic silty muck underlain by gray clay.

The atmosphere is a potentially important transport pathway for pollutants in the overall geohydrochemical cycle. The atmospheric study (Appendix E) is being used to establish the deposition and release of several major and trace substances in the Menomonee River watershed. Since April 1976, the emphasis has been on wet deposition sampling. Installation of four modified Wong rain samplers has been completed. Although no conclusions can be obtained from the limited amount of rainwater collected, a preliminary estimate was made of the atmospheric contributions of magnesium and calcium to the entire watershed. The loading for magnesium and calcium for a 2-week period was calculated to be 760 kg and 3,900 kg, respectively. The constant flow controllers from the Hi-volume air samplers are presently being calibrated and installed in the watershed. Filters for collection of PCBs are also being tested for use in the air samplers.

In order to relate the pollutant levels observed in the surface runoff, ground water and atmosphere to land use activities in the watershed, the Land Data Management System (Land DMS) was devised to summarize the land data for the watershed. The Land DMS (Appendix H) is a digital computer-based system designed to store, retrieve, analyze and display land data for the watershed. The Land DMS will also provide input data to the overland flow-water quality model, "LANDRUN." Ten data types have been coded for the entire watershed, and the coding of three data types is in progress.

Since April 1976, the coding of 1970 land use data has been completed and the coding of 1975 land use data has been initiated.

A remote sensing program (Appendix F) is developing a technique for generating land cover maps. The technique involves converting aerial imagery into digital representations which can be interpreted by a computer. Land cover maps and data summaries of the watershed will be prepared using the automatic data processing procedures. The technique is being tested for three small subwatersheds within the Menomonee River watershed.

The results of investigating the extent of pollution from different land use activities in the Menomonee River watershed will be used in the extrapolation effort. The extrapolation process involves rating the urban and urbanizing land uses for loading of various parameters and estimating the total pollutant loading for other major urban areas in the Great Lakes basin. The first step in the extrapolation process will be determining which parameters from the Menomonee River watershed reach critical levels of loading to Lake Michigan. The twelve areas tributary to the twelve river monitoring stations will then be ranked as to their importance as sources of the critical parameters. Since the twelve tributary areas consist of varying percentages of different land use activities, relating the pollutant loading to a single land use activity could require a more detailed analysis. Thus, an analysis of variance will be used to correlate the loading of the various parameters with single land use activities. Information from the specific study sites and the model "LANDRUN" will also assist in identifying critical land use activities. The number of parameters needed to identify critical areas of pollution might be reduced by using a cross-tabulation analysis to determine the degree of correlation between various parameters.

A tabulated ranking of the critical land use activities for the Menomonee River watershed will assist other urban areas in prioritizing their remedial efforts, but will not permit the calculation of total pollutant loadings from an urban watershed. Estimates of loading from an entire urban watershed would be based on a regression equation using available watershed characteristic information. The final number produced will be an estimate of total loading of various parameters from all the major urban areas in the Great Lakes basin. All the above statistical modeling will be verified by using two other models that are being developed to assist in the interpretation of the observed pollutant loading data from the Menomonee River watershed. One model is the more sophisticated model called "LANDRUN," and the other one involves simple empirical modeling of runoff quality from small watersheds.

The "LANDRUN" model (Appendix G) represents a dynamic hydrological transport model which transforms precipitation into quantity and quality of surface runoff, interflow, and groundwater aquifer recharge. A major portion of the activities related to the development and initial calibration of the model has been concluded. The model has been shown to be capable of reproducing field data for medium and large storms with acceptable accuracy. The model is capable of modeling many environmental processes, including pollutant transformation and transport through the soil column and over the soil surface. The model will assist in the indentification of critical source areas of pollution and will predict the effects on pollutant loading of changing land use in the Menomonee River watershed. The model is also being evaluated as a means of filling in gaps in the loading data. The "LANDRUN" model and the development of a simple empirical model could provide insight into several of the phenomena responsible for the differences in water quality between different land uses in the Menomonee River watershed.

The objective of the Empirical Modeling of Runoff Quality from Small Watersheds Study (Appendix G) is the development of a simple model for runoff quality which uses a series of empirical curves to arrive at the end product of mass loading hydrographs for various dissolved solids from small watersheds. Mean concentration values of materials in runoff were shown to have a definite relationship to land use, runoff quantity and types of storms. During the development and testing of relative concentration curves it was found that certain related dissolved solids show virtually identical relative concentration distribution for a given watershed. It may be possible to use relative concentration curves as a means of predicting mean concentration and flow values for estimating loading curves. The empirical modeling technique has been developed using data from a watershed outside the Menomonee River watershed and currently is being evaluated using Menomonee River data to develop the curves.

In summary, the Menomonee River Pilot Watershed Studies investigating the impact of urban and urbanizing land use on water quality are proceeding on schedule. Much of the activity conducted since the last Semiannual Report (April 1976) has been related to preliminary evaluation of the monitoring data. This report illustrates several of the techniques which can be used for this data evaluation. Specific progress since April 1976 includes: 1) continued monitoring of runoff water quality and calculation of pollutant loadings for the river monitoring and specific land use sites, 2) drilling and surveying of ground water observation wells for the ground water study, 3) measurement of rainfall water quality at several sites in the watershed for the atmospheric study, 4) continued coding of land types into the Land Data Management System, and 5) continued development of land cover maps using remote sensing.

A simple statistical modeling technique has been selected as the means for extrapolating to other urban watersheds. The development of the land use-water quality model "LANDRUN" and a simple empirical water quality modeling technique continued as methods to assist in the interpretation of pollutant loading data in the Menomonee River watershed and the verification of the statistical extrapolation model. This extrapolation technique will identify critical land use areas and will identify minimal data needs from other urban watersheds in the Great Lakes basin. Following the identification of these data needs, several urban watersheds will be selected--as needed data is obtained--and an attempt made to extrapolate Menomonee River watershed findings to broader-based urban settings in the Great Lakes basin. This activity will be conducted in cooperation with the basinwide extrapolation activities of PLUARG and will include an estimate of the level and type of remedial programs which will be needed.

APPENDIX A

RIVER MONITORING ACTIVITIES

Introduction

The objective of the river monitoring program is to determine levels and quantities of the important water quality parameters in the Menomonee River and its principal tributaries. Parameters of concern are the core list established by the Task C Technical Committee of PLUARG. The river monitoring activities provide information about the hydrology, hydraulics, and water quality of the watershed. The monitoring data are interpreted and assessed by observation of trends of pollutant yields from various land use areas in the watershed, development of land runoff-stream water quality relationships, and the application of a land use-water quality model, namely, "LANDRUN."

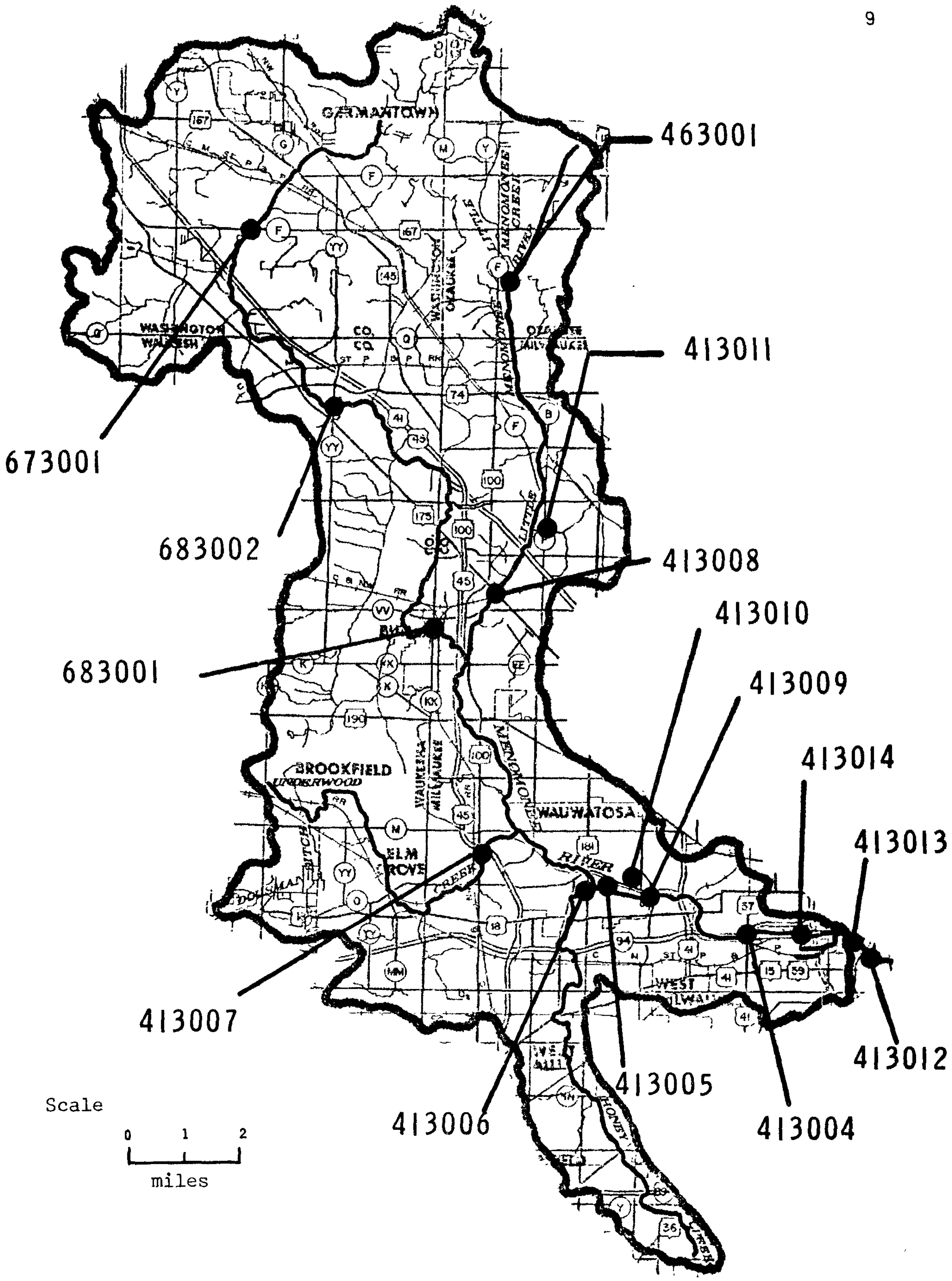
Progress

Field Activities

The field activities include baseflow surveys and runoff event sampling. Baseflow survey samples are collected biweekly from twelve automated river stations and two grab sampling sites (Appendix A Fig. 1). The river baseflow surveys were conducted on April 6, May 11, May 26, June 8, June 23, July 7, July 21, August 4, August 19 and September 16, 1976. Quality control samples were collected by hand at one of the automated river stations during each river baseflow survey. Baseflow samples also were collected biweekly from three grab sites, namely, stations 413014, 413013, and 413012, at three depths in the estuary area on April 14, April 28, May 12, May 26, June 9, June 24, July 14, August 3, September 2, and September 23, 1976. Parameters for the baseflow surveys are Group A of the core list, dissolved oxygen (DO), conductivity, pH and temperature.

Continuous *in situ* monitoring of temperature, conductivity, pH and DO was undertaken at the same five automated river stations (673001, 683001, 413005, 413004, 413008). However, some interruption of the monitoring occurred during periods of equipment repair.

Water quality was surveyed at the three waste water treatment plants in the watershed. Composite 24 hr samples were obtained from the Germantown



Appendix A Fig. 1. Location of monitoring stations.

plant on July 13 and from the two Menomonee Falls plants on September 1 and 2. Microbiological and nutrient analyses were performed, and in addition the Germantown samples were analyzed for toxic metals.

A macrobenthic survey was completed on samples collected between mid-April and September, 1976 at five stations (413005, 683001, 413008, 673001, and 683002).

On April 23, 1976 river bottom sediments were collected near ten of the river stations (413004, 673001, 463001, 413011, 413008, 683001, 413062, 413007, 413006, 413005) for total P, organic N, metals and particle size distribution.

On a continuous basis, flow at eleven automated river stations was monitored by the United States Geological Survey (USGS). Rainfall data were collected at eight sites (673001, 683002, 683001, 463001, 413011, 413007, 413005, and at Greenfield High School in Greenfield). The USGS continued to monitor suspended sediment concentrations at the twelve automated river stations. Samples for particle size analyses were collected at all river stations for runoff events on April 24, July 14, July 30, October 4 and September 19, 1976. Runoff event samples were collected for 18 events at the eight stations designated for event sampling and analyzed for parameters in Group A of the core list. The samples also were analyzed for metals on April 24 and June 14, 1976, and for microbiological and organic components on July 28, 1976 (Appendix A Table 1).

Due either to equipment failure or to insufficient flow, samples were not collected at all the designated event stations during some events. Clogging of intake pipes continues to be a major cause of automated sampler failure. Expansion of the event sampling to include all twelve automated river stations will be undertaken for the duration of the study. Different techniques were investigated for estimating missing event water quality data and identifying areas of critical pollutant loading.

Water Quality Data

The objectives of PLUARG require that runoff event data from the Menomonee River watershed be summarized to demonstrate the extent and relative importance of pollutant loadings from land uses. Summarization of the Menomonee River monitoring data has included calculations of 1) parameter loadings for runoff events and 2) seasonal water loadings for

Appendix A Table 1. Dates, stations and parameters for runoff events between April 24 and October 26, 1976

Date 1976	Parameters* measured for following stations								
	683001	463001	413011	413007	413006	413005	413010	413009	413004
4-24	EF	N,M	N,M	N,M	N,M	N,M	N,M	DS	DS
5-5	N	N	N	EF	EF	N	EF	DS	DS
5-15	DS	N	N	DS	N	N	N	DS	DS
5-28	N	IF	EF	DS	N	N	EF	DS	DS
6-14	N,M	N,M	EF	EF	N,M	EF	N,M	DS	DS
6-18	IF	IF	N	DS	EF	N	N	DS	DS
7-28	N	N,B,O	N	DS	N	N,B,O	N	DS	DS
7-30	N	N	EF	DS	EF	N	EF	DS	DS
8-5 (AM)	IF	IF	N	DS	N	N	IF	DS	DS
8-5 (PM)	IF	IF	EF	DS	N	N	IF	DS	DS
8-25	IF	IF	N	DS	N	EF	EF	N	DS
8-28	N	IF	N	DS	N	N	N	N	DS
9-1	IF	IF	N	DS	N	EF	N	N	DS
9-9	DS	DS	DS	DS	DS	N	N	DS	N
9-19	N	IF	N	DS	N	EF	N	EF	DS
10-5	DS	N	N	DS	EF	N	N	EF	DS
10-24	IF	IF	N	EF	N	N	IF	EF	DS
10-26	IF	IF	EF	EF	N	N	IF	EF	DS

*The letters N (nutrients), M (metals), B (bacteriological), O (organics) represent parameters from Group A, Group C (inorganic), Group B and Group C (organic) respectively of the PLUARG core list. Insufficient flow during an event is represented by IF, equipment failure by EF, and station not sampled during the event by DS.

1975. The loadings values for the individual events have been normalized by land area, rainfall quantity, rainfall intensity, and water loading to allow comparisons of the relative significance of contributions from different land uses.

Runoff events on March 5, May 5 and May 15, 1976 were chosen to determine the loadings of various parameters during these events. The loadings were calculated using a program that integrated by parts across the hydrograph after multiplying the concentration values by corresponding flow values. For those parts of the hydrograph where the concentration values were unavailable, concentration values were determined by linear interpolation between two known concentration values. The loading values have not been adjusted for baseflow contribution because of uncertainty in choosing values. The loading values (kg) were determined for total solids, suspended solids, total phosphorus (P), dissolved reactive P (DRP) and (NO_3 + NO_2)-N and water (m^3/sec) (Appendix A Table 2).

If the loading value for the 70th Street station (413005) represents the cumulative loading from all upstream stations, the values probably represent a large portion of the loading from the entire watershed. The land area represented by the area above 70th Street is 91 percent of the entire watershed. The 70th Street values were considerably larger than the contribution from the individual upstream stations. The portion of the 70th Street loading attributable to areas tributary to a single station (i.e., having no station upstream, namely, Donges Bay Road, Schoonmaker, Noyes and Honey Creeks) was 13 percent or less for all parameters for each of the three events (Appendix A Table 3).

For the above-mentioned areas, the largest contributor to total solids, total P and DRP found at the 70th Street station was Donges Bay Road station (463001) for the March 4 and May 5 events; Donges Bay Road was the largest contributor to (NO_3 + NO_2)-N for all three events. The suspended solids loading at Noyes Creek (413011) was higher than at Donges Bay Road on May 5 and lower on March 4. Loading values of dissolved species at the 124th Street station (683001) were approximately 50 percent of those at 70th Street on May 5, 1976. The particulate loadings at 124th Street were a smaller portion of the 70th Street particulate loading (10 to 30 percent). Loading values were low for all parameters at Schoonmaker Creek (413010).

Appendix A Table 2. Runoff event loadings and rainfall intensity at monitoring stations

Sampling date 1976	Station	Average rainfall intensity cm/hr	Loadings for following parameters					Water
			Total solids kg x 10^3	Susp. solids kg x 10^3	Total P kg	Diss. react. P kg	(NO_3+NO_2)-N kg	Cubic meters x 10^3
March 4	Donges Bay Rd.	0.35	443	125	336	124	4,493	915
	Schoonmaker Cr.	0.40	13	4	10	2	33	32
	Noyes Cr.	0.41	296	79	82	19	461	423
	70th St.*	0.40	12,822	4,300	6,835	2,240	34,040	22,080
May 5	Donges Bay Rd.	0.37	63	7	18	4	282	99
	Noyes Cr.	0.36	24	14	15	1	16	36
	70th St.*	1.09	1,817	568	1,168	296	2,352	2,967
	124th St.*	0.45	586	59	286	148	1,207	1,006
May 15	Donges Bay Rd.	0.17	64	4	9	3	260	108
	Schoonmaker Cr.	0.21	2	1	3	0.6	7	7
	70th St.*	0.21	1,724	272	919	313	2,975	2,998
	Honey Cr.	0.13	63	21	43	7	169	178

*Loadings not adjusted for loading from upstream stations.

Appendix A Table 3. Runoff event loadings at river monitoring stations as a percentage of runoff event loadings at the 70th Street station*

Sampling date 1976	Station	Percentages for following parameters					
		Total solids	Susp. solids	Total P	Diss. react. P	(NO_3+NO_2)-N	Water
March 4	Donges Bay Rd.	3	3	5	6	13	4
	Schoonmaker Cr.	<1	<1	<1	<1	<1	<1
	Noyes Cr.	2	2	1	1	1	2
May 5	Donges Bay Rd.	3	1	2	1	12	3
	Noyes Cr.	1	2	1	<1	1	1
	124th St.**	32	10	24	50	51	34
May 15	Donges Bay Rd.	4	1	1	1	9	4
	Schoonmaker Cr.	<1	<1	<1	<1	<1	<1
	Honey Cr.	4	8	5	2	6	6

*Loadings from all watershed areas above 70th Street were included in the 70th loading values.
**Loading not adjusted for loading from upstream stations.

Pollutant loadings approximately parallel flow at each station relative to the values determined at 70th Street. For the events evaluated, although Donges Bay Road (463001) and Honey Creek (413006) contributed the largest relative loadings, the significance of the findings from these stations relative to the entire watershed cannot be fully assessed until the contributions from all stations have been calculated. Furthermore, the total loading values do not allow direct comparison between stations because differences in land area between the stations are not accounted for.

The relative pollutant loadings from Noyes and Schoonmaker Creeks increased for some parameters when the loadings were expressed in terms of loading per unit area (Appendix A Table 4). The total solids and suspended solids loadings were greater at Noyes Creek than at Donges Bay Road for March 4 and May 5. The total solids value was highest for Donges Bay Road on May 15, while the suspended solids value was highest at Honey Creek. The total P and DRP loadings at Noyes Creek were either greater or about the same as the values for Donges Bay Road on March 4 and May 5. Schoonmaker Creek had total P and DRP loading values similar to that at Honey Creek on May 15, which were higher than the loading values for Donges Bay Road. Donges Bay Road still had the highest $(NO_3 + NO_2)$-N loading value for all three events. Water yield was highest for the Noyes Creek area on March 4 and May 5 and highest at Honey Creek on May 15. Since the loading trends observed were for areas tributary to a single station, the loading values were related to land use activities. However, the trends are only tentative because the data represent only three events, and each land use area except the Donges Bay Road area was sampled only in one or two runoff events. The 1970 land use information provided by the Southeast Wisconsin Regional Planning Commission for each area tributary to the automated river stations was used to make some initial observations (Appendix A Table 5).

The $(NO_3 + NO_2)$-N loading was more critical from the agricultural land use area of Donges Bay Road (463001) compared to the area containing a higher percentage of residential land use. The suspended solids loading was greater for the medium density residential areas of Noyes and Honey Creeks (413011 and 413006) than at the primarily agricultural land use area of Donges Bay Road. A consistent trend relating land use to total P and DRP loading was not observed. The above relationships were based on

Appendix A Table 4. Runoff event loadings per unit area for areas tributary to monitoring stations

Sampling date 1976	Station	Sta. basin area, hectare	Loading yields in kg/hectare for following parameters					Water yield cubic meters/ hectare
			Total solids	Susp. solids	Total P	Diss. react. P	(NO_3+NO_2)-N	
March 4	Donges Bay Rd.	2,145	210	60	0.16	0.06	2.1	430
	Schoonmaker Cr.	183	70	20	0.05	0.01	0.2	170
	Noyes Cr.	553	540	140	0.15	0.03	0.8	760
	70th St.*	32,219	400	130	0.21	0.07	1.1	690
May 5	Donges Bay Rd.	2,145	30	3	0.01	0.002	0.1	46
	Noyes Cr.	553	43	30	0.03	0.002	0.03	65
	124th St.*	15,500	40	4	0.02	0.01	0.1	60
	70th St.*	32,219	60	20	0.04	0.01	0.1	90
May 15	Donges Bay Rd.	2,145	30	2	0.004	0.001	0.1	50
	Schoonmaker Cr.	183	11	5	0.02	0.003	0.04	38
	Honey Cr.	2,783	23	7	0.02	0.002	0.06	64
	70th St.*	32,219	53	8	0.03	0.01	0.1	93

*Loadings not adjusted for loadings from upstream stations.

Appendix A Table 5. Land use for 1970 by monitoring stations in the Menomonee River watershed

Station	General comments	Area tributary to station, hectare	Percentage of land use for following categories*				
			Institution and government	Croplands, pasture and unused	Woodlands and recreation	Right-of-way	Residential
673001		4775	1	72	10	3	4
463001		2145	1	74	8	3	8
413008		2465	1	57	11	5	16
683002		4026	1	55	7	6	17
683001		6660	1	47	4	8	26
413011	Developing medium density residential	553	4	19	9	11	37
413005	Established residential and mixed use	3839	10	8	12	14	34
413007	Low density residential	4973	5	17	11	12	42
413006	Medium density residential and mixed use	2783	6	8	8	17	51
413010	Established medium density residential	183	3		1	21	69

*All land use categories are not included and the percentages are approximate.

normalizing loading values for land areas and do not reflect differences in rainfall, rainfall intensity and the amount of water discharged from each land area during the events. Therefore, the loading values were also normalized by the following combinations of water and land area data: 1) area and rainfall depth; 2) area, rainfall depth and rainfall intensity; and 3) event water loading (mean concentration).

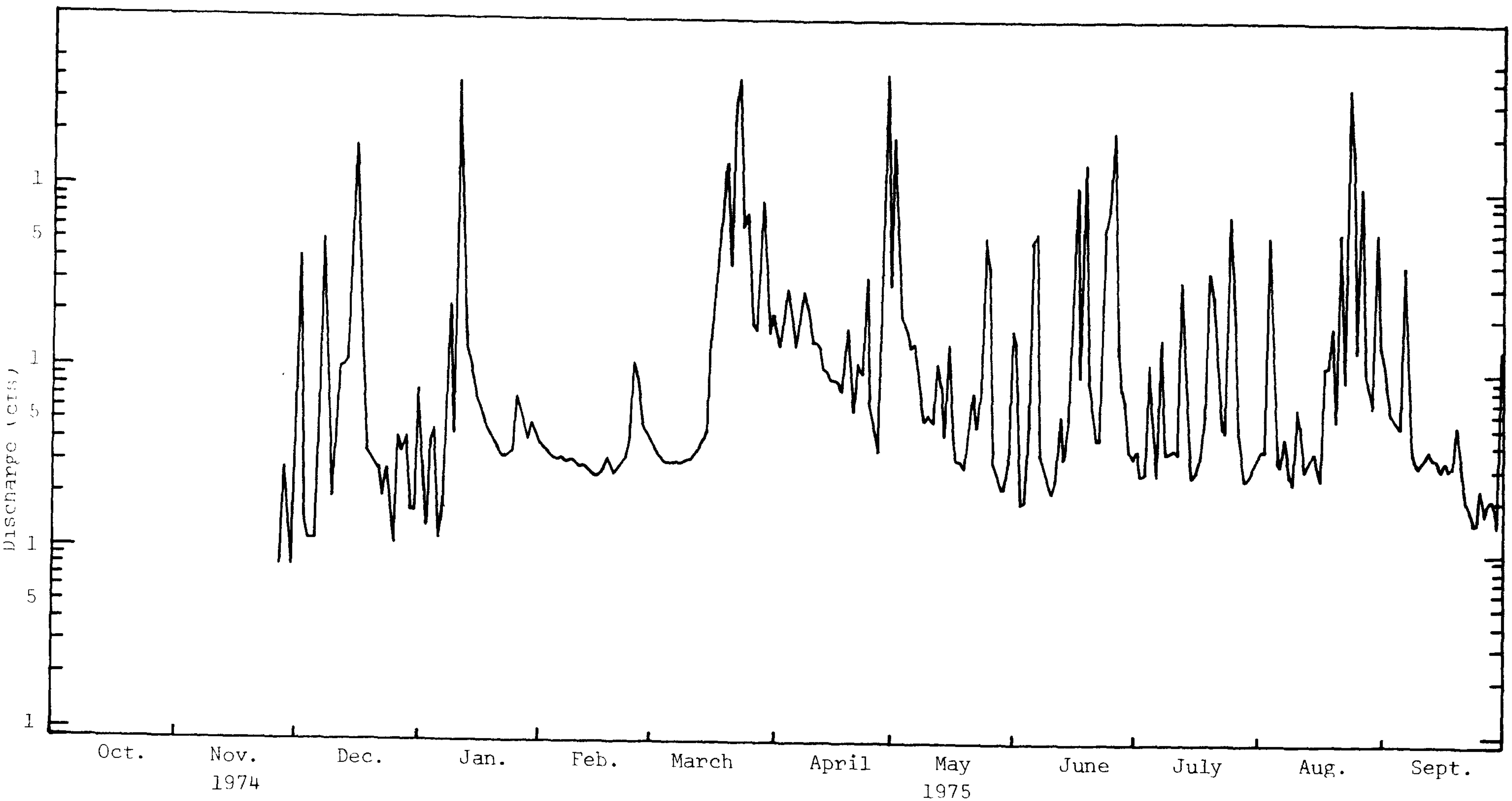
The relative magnitude of pollutant loading assigned to a particular land area varied for some parameters with each method of normalizing the loading data. Further evaluation of the methods of normalizing loading data is necessary before the method most correlated with land use activities is determined. The correlation of land use activities to ways of normalizing with rainfall data will be evaluated using analysis of variance. Because of the need to express the loading data in a form compatable with other data for the Great Lakes basin, the data will always be expressed in kilograms per hectare per season. The above loading trends normalized for land area for the three events should only be considered as preliminary observations, since the trends were determined from isolated events and not from summaries of long-term data divided into seasons. Before seasonal loadings can be presented, many more events must be summarized, and the trends observed must be given statistical significance. The data from other events are being analyzed presently and will contribute to an understanding of the pollutant contribution from different land uses.

The determination of seasonal loading values depends upon estimating loading values for events that were not sampled. Multiplying a seasonal mean concentration value by the water loading for an unsampled event is one method under consideration. The other method would involve developing a rating curve which relates flow values to concentration values. Although seasonal pollutant loadings are not presented, some preliminary indication of monthly and seasonal loading trends was possible after summarizing daily suspended sediment loadings determined by the USGS for 1975. Event and daily mean discharge values also were summarized on a monthly and seasonal basis for 1975. Due to the methods used to summarize the data, the accepted criteria for defining the beginning and end of a season were not used. The beginning and end of the spring season will be based in the future on the general rise and decline of discharge values, and the end of the summer and fall season will be based on a change in general climatic conditions which will probably be close to the solar season dates of September 21 and December 21 respectively.

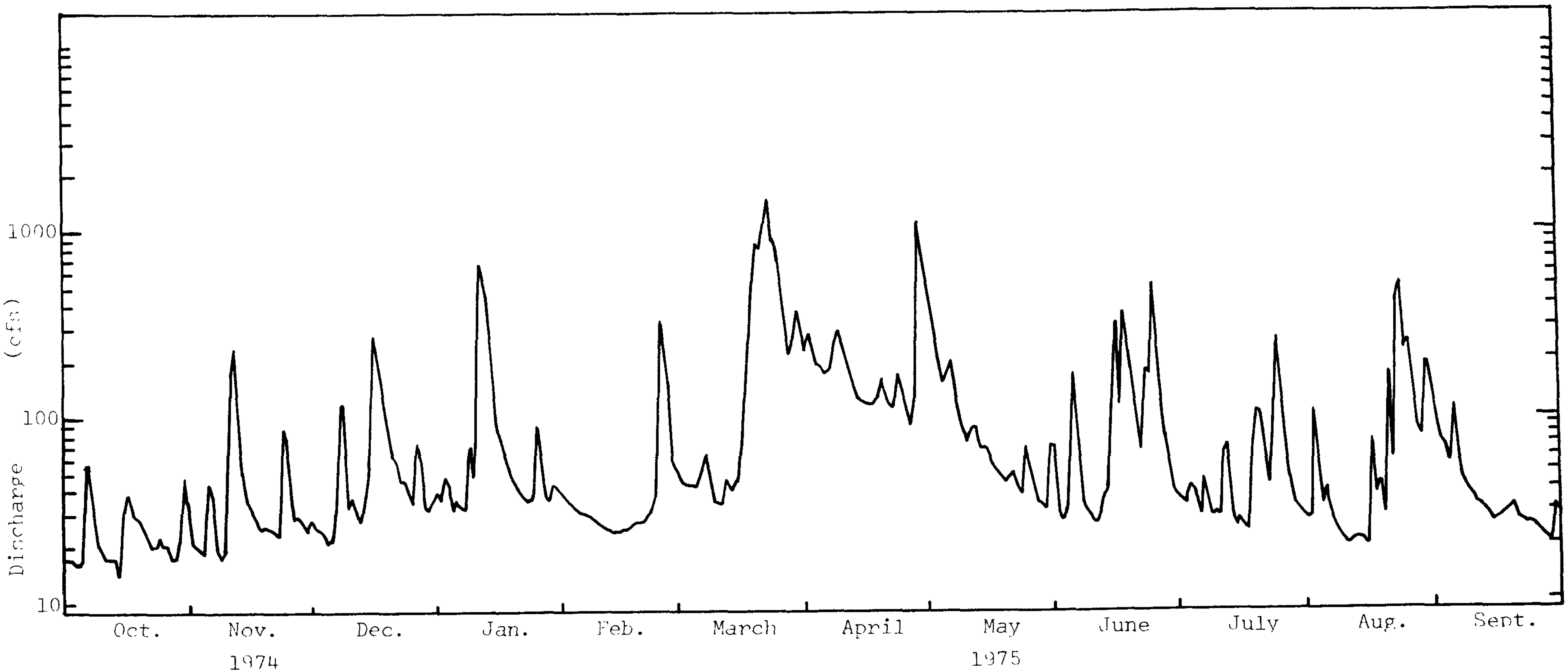
Approximately 40 runoff events were observed on the hydrograph based on mean daily discharge for Noyes Creek and 70th Street stations for the 1974 to 1975 water year (Appendix A Fig. 2 and 3). The number of events for the other stations was probably in the same range. In order to summarize all the event water loadings by month, a computer program was written to separate all the discharge values by event from the baseflow value at each station. The program indicated the start of an event if either of the following conditions was met: 1) if the flow was 1.5 times the average baseflow the computer backed up to the point where flow was 1.25 times the average baseflow and indicated this point as the start of an event, or 2) if the slope of the flow curve changed by a factor of 2.5 over a period of 1.5 hr the computer indicates the start of an event. Each of the following conditions had to be met to indicate the end of an event: 1) if the flow value reached a value which was the difference between the maximum flow value and average baseflow value times 0.2 plus the average baseflow value, and 2) the flow value had to reach 1.33 times the average baseflow value. The average baseflow value was continually updated.

The above algorithm was applied to the discharge data between January and September 1975 and generated runoff event water loadings in cubic meters (Appendix A Table 6). The event loadings were adjusted for baseflow loading during the event. Since some of the monthly loadings were zero or negative in value, the monthly event loadings for some of the stations were probably not accurate. The trend in the data indicated the algorithm was extending the event time past the appropriate end point and allowed some of the events to last longer than a month. The extended event times were especially apparent during the spring runoff and for stations in the upper part of the watershed with longer response times for flow.

Although the water loading values totaled over the 9 months were probably higher than they should be, the values were used for some tentative observations of water loading trends between the stations. Assuming the unadjusted water loading values at 70th Street (413005) represented the



Appendix A Fig. 2. Mean daily discharges for 1974-75 water year at Noyes Creek.



Appendix A Fig. 3. Mean daily discharges for 1974-75 water year at 70th Street.

Appendix A Table 6. Runoff event water loadings adjusted for baseflow loadings for January through September, 1975

Station	Event water loadings* in cubic meters x 10^6 for following months									Total water loading m^3 x 10^6	% of total 70th St. loading	Cubic meter per hectare per month
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.			
673001	0.45	0.00	0.00	0.02	0.41	0.02	0.09	0.00	0.14	1.13	4	25
683002	0.02	0.01	0.00	0.00	5.12	0.29	0.53	0.02	0.92	6.9	24	190
683001	1.56	0.20	0.00	0.00	1.77	0.69	0.53	0.03	1.54	6.4	22	107
463001	0.08	0.02	0.00	0.00	0.20	0.02	0.05	0.00	0.08	0.45	2	23
413011	0.08	0.01	0.01	0.01	0.12	0.12	0.15	0.14	0.00	0.64	2	129
413008	0.72	0.00	0.02	0.20	0.7	0.42	0.00	0.00	0.64	2.7	9	122
413007	0.53	0.00	0.29	0.13	1.0	0.72	0.12	0.49	0.03	3.3	12	74
413006	0.28	0.02	0.28	0.06	0.80	0.41	0.09	0.40	0.04	2.38	8	95
413005	1.53	1.46	**	1.32	**	2.11	0.05	**	1.93	8.4	29	243
413010	0.00	0.00	0.02	0.01	0.02	0.05	0.00	0.01	0.00	0.11	0	67
413005***	5.25	1.7	0.14	1.71	7.15	4.8	1.7	0.9	5.33	28.68		100

* Water loading values adjusted for water loadings from upstream stations.
** Adjustment for water loading from upstream stations resulted in negative values.
***Values not adjusted for water loadings from upstream stations.

total water loading value for the watershed, then the water loading from areas tributary to each station were calculated as a percentage of the unadjusted 70th Street value. The percentages of water loading were not clearly related to land use (Appendix A Table 5), although the relative magnitude of water contribution from various areas in the watershed was observed. The area tributary to 70th Street with 34 percent residential land use had the highest percentage of the water loading, while stations 673001, 463001 and 413011, with 4, 8 and 37 percent residential land use area respectively, had the lowest water loading. The percentage values could not be used to compare the contribution from various land use activities since the differences in land areas were not compensated for. No clear trends existed in the water loading values expressed as cubic meters per hectare per month except for the two stations identified as 463001 and 673001, the farthest up-river stations, which are sampling runoff from predominantly crop land and pasture and had the lowest water loading values. Again, station 413005 had the highest loading value.

More identifiable trends in the event water loading data might have been apparent if the data could have been expressed in terms of seasonal loadings and if the water loading was normalized for the amount of rainfall in each tributary area. Also, the water loading values might only relate to land cover (e.g., percent of impervious area) instead of land use. Future analyses of water loading trends will include comparing the values to land cover estimates for each area tributary to a station. A different algorithm is presently being developed to determine a more reasonable end-point for the events. The event water loadings will then be expressed as seasonal loadings, and any relationships between event water loadings and event water quality loadings will be evaluated.

However, trends in seasonal water loading were observed for this program report by summarizing the monthly total water loadings (event loadings plus baseflows) based on mean daily discharges for 9 months in 1975. Since the total of the monthly water loadings, based on daily mean flows for January through September 1975, included baseflow loadings, the values were significantly higher than the total event water loadings (Appendix A Table 7). If the unadjusted 70th Street water loading values were considered to represent the combined loading from most of the watershed,

Appendix A Table 7. Total water loading* for January through September 1975 based on daily mean flow

Station	Total water loading in cubic meter x 10^6	Percent of total 70th St. water loading	Cubic meters per hectare per month	Event loading as percent of total loading
673001	11.1	13	260	10
683002	9.8	12	270	70
683001	16.6	20	280	39
463001	4.1	5	210	11
413011	1.4	2	280	46
413008	7.9	9	360	34
413007	11.2	13	250	29
413006	5.8	7	230	41
413005	17.1	20	490	49
413010	0.2	0	120	55
413005**	85		290	34

* Water loading values adjusted for water loading from upstream stations.
**Values not adjusted for water loading from upstream stations.

the event water loadings for the 9 months were approximately 34 percent of the total water loadings in the same period. The values for event loadings as a percentage of total loadings ranged from 10 percent for the two uppermost stations in the watershed, 463001 and 673001, to 70 percent for station 683002. For most of the other stations the percentages of event loadings were near 40 percent. The distribution of the values for the total loading at each station as a percentage of the unadjusted 70th Street loadings was very similar to the distribution for the event water loadings except for the two uppermost Menomonee River stations, 673001 and 683002; the percentage value at station 673001 increased significantly. This increase might be the result of relatively high baseflow loadings contributed by recreational ponds near the station. The percentage at station 683002 dropped by 50 percent.

A large overestimate in the event loadings might account for these differences in percentages. The area tributary to stations 683001 and 413005 had the largest percentages of the unadjusted 70th Street loading, while the areas tributary to stations 413010 and 413011 contributed the smallest percentages of the 70th Street loading. Again, as with the event loading percentages, a well-defined relationship between total loading percentages and land use activities (Appendix A Table 5) was not observed, and part of the difficulty in observing a trend was probably due to differences in land area sizes. The similarity in percentage distributions between event and total water loadings indicated that the event loading estimates might be reasonable.

The total water loadings expressed in terms of cubic meters per hectare per month were surprisingly similar among the stations except for relatively high values at stations 413008 (a crop and pasture land area) and 413005 (an established residential and mixed use area) and the low value for the established medium density residential area tributary to station 413010. The baseflow water loading might have been sufficient at each station to normalize the effect of the runoff events.

The loading percentages and loadings in terms of cubic meters per hectare per month were also evaluated by seasons. The percentage of the unadjusted 70th Street loading that occurred at each station decreased slightly for most stations from winter to spring and then decreased by a large amount between spring and summer (Appendix A Table 8). The percentages were not highest for the spring season because the spring season for 1975 began before March 15 and was not included in the April through June values. The seasons were not determined by water flow but by the more traditional method of using the solar seasons. The different tributary areas contributed similar percentages of the water loadings for each 3-month period. The trends between seasonal total water loadings expressed as cubic meters per hectare per month were the same as observed for the loadings expressed as percentages of unadjusted 70th Street loadings. The loading values were similar for most of the stations for any of the 3-month periods except for higher values at stations 413008 and 413005 and lower values at station 413010.

All the observed trends in the total water loadings did not indicate the water quality contributed from each area tributary to a station. The only long-term data available for this purpose was the suspended sediment data collected by the USGS. The suspended sediment loadings between March and September 1975 were determined by summarizing data expressed as kilograms per day and included runoff events and baseflow loadings (Appendix A Table 9). The total unadjusted 70th Street loading value of about 12,000,000 kg of suspended sediment during the 7-month period represents the approximate amount of suspended sediment that reached the Menomonee River estuary in that time period. How much of the suspended sediment reached the boundary water of the lake was unknown. Adjusting loading values at 70th Street for loading values from the upstream stations resulted in some negative values, indicating that some deposition of the suspended sediment occurred during 5 of the 7 months evaluated. The suspended sediment loadings or percentages of the unadjusted 70th Street loadings were highest at stations 413008, 683001 and 413005, and lowest at stations 673001, 463001 and 413011.

Although the percentage values indicated the relative contributions of the various areas to the total suspended solids loading for the Menomonee River watershed, the values were not normalized for land area and therefore were difficult to relate to the different land use activities. The loading values expressed as kilograms per hectare per month were highest for the land use activities tributary to station 413008 and lowest for the land

Appendix A Table 8. Total seasonal water loading* in 1975 based on daily mean flows

Station	Total seasonal water loading as percent of 9-month total			Total seasonal water loading in cubic meters/hectare/month		
	Jan.-Mar.	April-June	July-Sept.	Jan.-Mar.	April-June	July-Aug.
673001	47	38	15	360	290	120
683002	43	36	21	350	290	170
683001	37	43	20	310	360	170
463001	53	37	10	340	230	60
413011	36	36	28	300	300	240
413008	47	37	16	500	390	180
413007	46	38	16	350	280	120
413006	41	38	21	290	260	140
413005	45	40	15	660	600	230
413010	30	55	15	110	200	50
413005**	44	39	17	380	340	150

* Water loading values adjusted for water loading from upstream stations.
**Values not adjusted for water loading from upstream stations.

Appendix A Table 9. Suspended solids loading* for March through September 1975 at the river monitoring stations

Station	Susp. solids loading, kg x 10^3, for following months							Total for 7 months kg x 10^3	Total as % of unadjusted 70th St.	Kilograms/ hectare/ month
	Mar.	April	May	June	July	Aug.	Sept.			
673001	113	98	34	43	36	56	26	405	3	12
683002	431	131	20	125	298	116	**	1,113	9	39
683001	215	455	23	455	326	657	79	2,210	19	47
463001	281	63	4	25	34	24	3	434	4	29
413011	36	34	15	68	10	38	1	202	2	52
413008	429	278	73	765	159	618	22	2,344	20	136
413007	764	440	73	249	48	77	8	1,659	14	48
413006	297	417	74	274	43	177	7	1,290	11	66
413005	3,339	**	**	108	**	**	**	2,089	18	79
413005***	5,905	1,009	291	2,112	605	1,734	89	11,746		52

* Loading values adjusted for loadings from upstream stations.
** Adjustment for upstream station loading resulted in negative value.
***Loading values not adjusted for loading from upstream stations.

use area represented by station 673001. A general trend in suspended solids loading was the increase in loading with increase in percentage of residential and commercial land use (Appendix A Table 5). This agrees with the higher suspended solids loading observed at station 413011 when compared to station 463001 during the March 4 and May 5, 1976 runoff events, and station 413006 demonstrating a higher loading than station 463001 on May 15, 1976 (Appendix A Table 4). The exception to this trend was the land use activities represented by stations 413008 and 673001. The lower-than-expected value at station 673001 might be the result of settling in a pond above the station.

The seasonal loading values indicated the spring season usually had higher suspended sediment loading than summer (Appendix A Table 10). Since spring began in early March in 1975, the March loading values should be combined with the April, May and June loading values. The seasonal suspended solids loadings expressed as kilograms per hectare indicated higher loadings for spring than for summer. The loadings expressed as kilograms per hectare were highest for station 413008 and lowest for station 673001 for the spring and summer.

Appendix A Table 10. Seasonal suspended solids loading* for March through September 1975 at river monitoring stations

Station	Susp. solids loading, kg x 10^3, for following seasons			Susp. solids loading in kg/hectare for following seasons		
	March**	April-June	July-Sept.	March**	April-June	July-Sept.
673001	113	174	119	23	36	25
683002	431	278	403	107	69	100
683001	215	932	1,065	32	140	160
463001	281	92	61	131	43	28
413011	36	117	49	65	212	89
413008	429	1,116	800	174	450	325
413007	764	762	133	154	153	27
413006	297	765	228	107	270	82
413005	3,339	***	***	870	***	***
413005+	5,905	3,412	2,429	183	105	75

* Values adjusted for loading from upstream stations.
** Data only available for March.
***Adjustment for loadings from upstream stations resulted in negative value.
\+ Values not adjusted for loadings from upstream stations.

APPENDIX B

SPECIFIC LAND USE STUDIES

Introduction

The heterogeneity of land use in the Menomonee River watershed precludes the use of most of the river and tributary sampling stations as specific land use study sites. Additional monitoring stations have been built at the outlets of homogeneous and/or predominate land use areas in the watershed to define more precisely the quantity and quality of stormwater from these areas. These study sites are representative of the major land uses in the watershed, and data gathered at the stations will complement data from the major river and tributary monitoring stations. Data from the specific land use stations will be used to calibrate an overland flow model.

Study Sites

Construction of the sampling stations continued through the summer months and is now complete at the sites listed in Appendix B Table 1. It should be noted that the last three stations are major river stations and water quality data from these is discussed in Appendix A. All residential, transportation and service sites have been completed and additional stations will be built this fall at a recreational area, landfill sites, light industrial site and an upland area.

Sampling this past field season commenced in May and was limited due to drought conditions in the watershed. Rainfall levels for the months June through September averaged 34% below normal levels, while May and October were slightly above normal. At study sites with a high percentage of previous surfaces this has resulted in reduced flows or no flow at all. At station 683090, for example, no stormwater discharge has occurred during the sampling period. Appendix B Table 1 gives a listing of the number of events sampled during the period January to October, 1976. It should be noted, that some of the low sampling numbers are due to equipment failure.

Equipment

Sampling stormwater in urban areas poses a problem in that the high

Appendix B Table 1. Completed specific land-use study sites

STORET station no.	Location	Type*	Monitoring Activity	Events sampled May to Oct. 1976
413625	City of West Allis at 124th St. and Greenfield Ave. Drainage from New Berlin	1	Medium-density residential. Stormsewer tributary to south branch Underwood Creek	1
683090	Village of Elm Grove, ditch at Underwood Parkway	1	Low-density residential. Open stormsewer tributary to Underwood Creek	0
683089	City of Brookfield, the Brookfield Square shopping center	1	Retail and service area. Stormsewer and drainage ditch tributary to Underwood Creek	6
413616	Allis-Chalmers Corp., West Allis	1	Heavy industry. Stormsewer tributary to Menomonee River	5
413614	Timmerman Airport, manhole #6, Milwaukee	1	Airport runways and facilities. Stormsewer and drainage ditch tributary to Little Menomonee River	7
413615	Stadium Interchange, I-94. Manhole #120 off S. 44th Street	1	Highway pavement and grass areas. Stormsewer tributary to Menomonee River	1
463001	Donges Bay Road, City of Mequon	1	Mostly rural, some urban development. Little Menomonee River	6
413011	Noyes Creek at 91st St., Milwaukee	1	Medium-density residential development. Stormsewers tributary to Noyes Creek.	10
413010	Schoonmaker Creek at Vliet St., Milwaukee	1	High-density residential. Stormsewers tributary to Schoonmaker Creek	9

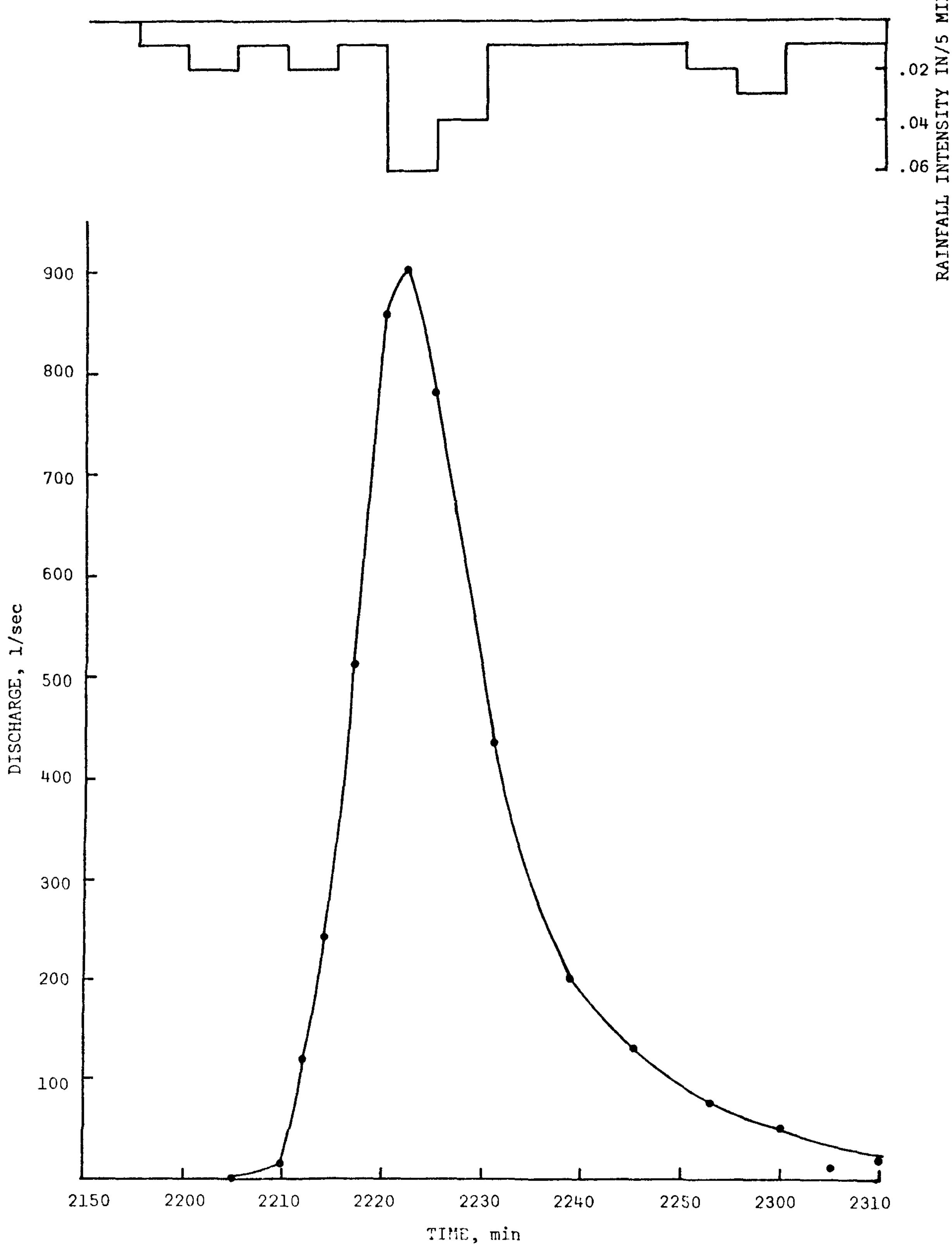
*Station type is 1 -- automatic sampling and continuous flow percentage of impervious surfaces results in a rapid increase and decrease in discharge and stage. In addition, the shape of the hydrograph is quite variable being dependent on rainfall intensity. It is not uncommon for peak discharge to be reached in thirty minutes or less (Appendix B Fig. 1).

Generally, sampling proportional to flow is unsatisfactory since a fixed water load must be used to actuate the sampler. To partially eliminate this problem at the specific land use study sites, activation of the Instrument Specialties Company (ISCO) 1680 sampler and event marker of the Leupold and Steven, Inc. type A model 71 stage recorder strip chart, is accomplished using an electromechanical system (Appendix B Fig. 2). Mounted on the 750 mm circumference float pulley of the stage recorder are fifteen magnets spaced 5 cm apart. As the float pulley rotates, with changing stage, the magnets come to near contact with a magnetic reed switch. The closure of this switch, induced by the magnetic field, activates the ISCO sampler. The system is set up such that at the initial change in stage the ISCO will sample. After this sequence, the sampler operates after a set number of pulse counts (magnetic reed switch closures) determined from field observations and the hydraulic characteristics of the drainage system.

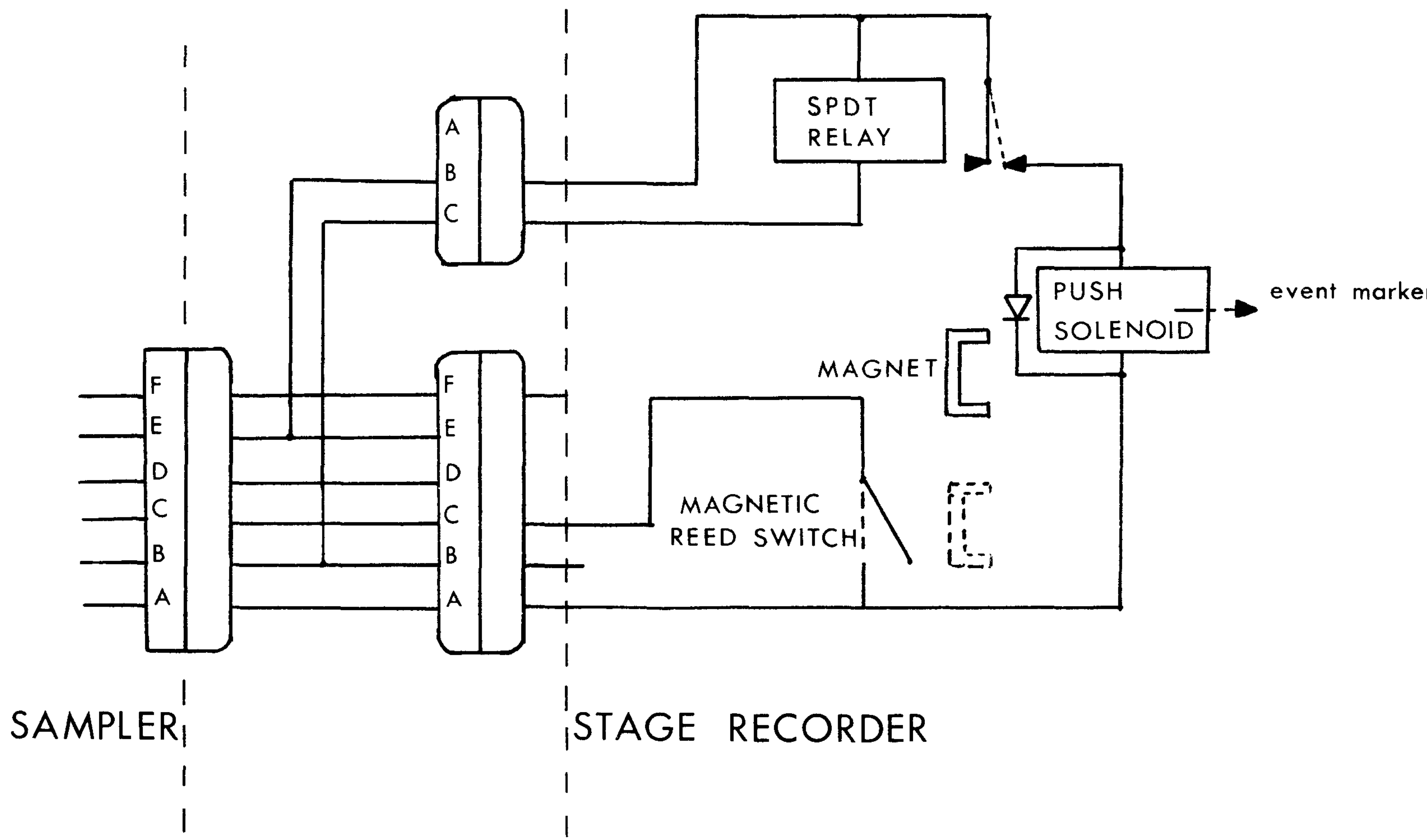
During the interval of sampling the ISCO sampler's event signal is used to activate a single pole double throw (SPDT) relay (Appendix B Fig. 2). This SPDT relay controls the event marker push solenoid to which a pen is mounted. For the duration of sampling, an event mark is written on the strip chart. After the sampling is completed the SPDT relay, push solenoid and pen return to a relaxed position.

Water Quality Data

Twenty-nine storm events occurred in the watershed from May 1, 1976 to November 1, 1976 with only 19 events of sufficient rainfall to produce runoff for sampling. The number of events sampled during the period from six specific site stations is as follows: Brookfield Shopping Center - 5; Timmerman Airport - 6; Allis Chalmers - 5; Stadium Interchange - 1; New Berlin - 1 and Elm Grove - 0. Runoff samples were analyzed for Group A parameters and metals. Although a majority of the



Appendix B Fig. 1. Relationship between discharge and rainfall at Brookfield Shopping Center station (683089) during June 13, 1976, runoff event.



Appendix B Fig. 2. Schematic of electromechanical system for sampler actuation and event marker.

samples has already been analyzed, only the data on four storm events at the Brookfield Shopping Center station (683089) are presented in this report. At some stations samplings over the major discharge portions of the runoff hydrographs at the other stations were incomplete. Due to this problem, the ISCO automatic samplers were readjusted to give a better distribution of samples over the major discharge portion of the hydrograph.

Runoff samples from four storm events at the Brookfield Shopping Center were collected on May 28, June 13 and 18, and July 28. Runoff duration lasted for about 20 hr on May 28, 8 hr on June 13, 6 hr on June 18, and 8 hr on July 28. Although the runoff durations were relatively long, time and occurrence of major discharges varied among the events. The runoff hydrograph of the May 28 storm event displayed no distinct major discharge. On the June 13 and 18 storm events, major discharges occurred early in the storms and lasted for about 30 and 60 min, respectively. In contrast, the storm event on July 28 showed a broad peak with the major discharge lasting for almost 4 hr.

Appendix B Fig. 1 shows the relationship between rainfall and runoff on June 13. The rainfall data was obtained from a rain gauge at station 683001 in Butler about 6 miles northeast of the station. The lack of correlation between rainfall and runoff indicates that the rainfall in Butler is not representative of that around the area of the Brookfield station. Variations in rainfall occurrence might have been due to isolated thunderstorms during the summer months.

Group A Parameters

The concentrations of Group A parameters are presented in Appendix B Table 2. In general, solids, phosphorus, nitrogen, organic carbon, chlorides, alkalinity, and hardness tended to have the highest concentrations during the rising stage of the runoff hydrograph particularly in events where the increase of discharge was rapid. Concentrations of dissolved solids (total solids minus suspended solids), chlorides, alkalinity, and hardness were highest during the initial discharge which indicates that the initial flush carries most of the dissolved constituents.

Appendix B Table 2. Concentrations of Group A parameters in runoff samples from four events at Brookfield Shopping Center station (683089)

Storm date	Time of sampling, min**	pH	Total solids	Suspended solids	Vol. susp. solids	Total P	Diss. react.P	Total org. N	NH_3-N	(NO_3+NO_2)-N	Total alka. as $CaCO_3$	Hardness as $CaCO_3$	Chlorides	Total org.C
		Parameters*												
5-28-76	1118	8.3	1,700	71	7	0.19	0.063	0.37	0.07	0.81	275	+	440	5.5
	1408	8.0	1,580	44	8	0.23	0.068	0.59	0.15	1.01	280		400	11.0
	1828	6.9	235	67	28	0.25	0.026	1.40	0.16	1.92	38		24	16.5
	1832	7.0	190	51	26	0.17	0.018	0.95	0.15	2.30	36		18	13.0
	1837	7.0	195	43	18	0.18	0.013	0.86	0.18	2.20	36		20	14.0
	1842	7.2	178	35	16	0.13	0.018	0.98	0.12	2.10	34		16	17.5
	1938	6.8	172	44	18	0.14	0.012	0.85	0.25	2.10	28		16	12.0
	2117	6.9	138	87	26	0.18	0.008	0.91	0.13	1.02	23		6	9.5
	2223	7.2	124	20	8	0.077	0.008	0.64	0.10	1.26	34		16	8.0
6-13-76	2212	7.9	1,210	33	13	0.30	0.068	0.97	0.07	1.13	274	+	280	17.0
	2214	6.9	990	716	116	0.65	0.006	3.80	0.07	1.29	57		50	62.5
	2217	6.9	850	678	108	0.51	0.110	3.50	0.24	1.00	38		22	58.0
	2220	6.8	756	628	90	0.47	0.005	2.30	0.25	0.80	28		16	43.0
	2225	6.8	438	402	56	0.30	0.004	2.20	0.18	0.65	21		2	21.0
	2231	7.0	310	266	44	0.25	0.004	1.70	0.20	0.70	20		3	17.0
	2239	6.9	186	107	23	0.20	0.004	1.20	0.19	1.04	20		2	12.5
	2253	7.1	192	91	20	0.17	0.032	1.00	0.38	1.41	28		2	15.0
6-18-76	1310	7.7	1,250	194	28	0.38	0.055	1.10	0.38	1.29	196	+	260	26.5
	1312	6.5	490	293	46	0.37	0.058	1.90	0.74	1.72	24		13	44.5
	1322	6.4	305	211	28	0.21	0.048	1.20	0.52	0.91	15		<1	24.5
	1324	6.4	275	197	27	0.19	0.039	1.50	0.47	0.78	14		2	24.5
	1331	6.5	230	182	18	0.15	0.032	0.72	0.42	0.60	12		<1	14.5
	1335	6.4	230	175	17	0.15	0.029	0.70	0.38	0.52	12		<1	10.5
	1339	6.5	185	135	14	0.13	0.026	1.00	0.33	0.49	12		<1	13.0
7-28-76	0304	8.1	1,025	11	5	0.51	0.26	0.92	0.99	0.53	278	605	125	7.5
	0316	6.6	595	260	64	0.79	0.061	3.75	0.50	2.70	60	133	28	53.5
	0354	6.5	165	121	34	0.26	0.003	1.06	0.04	0.79	26	34	4	13.5
	0511	6.4	85	64	17	0.12	<0.003	0.57	0.02	0.56	22	24	<1	6.0
	0624	6.4	50	19	10	0.08	0.005	0.64	0.04	0.61	20	32	1	5.5
	0848	7.4	140	6	6	0.08	0.014	0.72	0.03	1.05	42	81	9	6.5

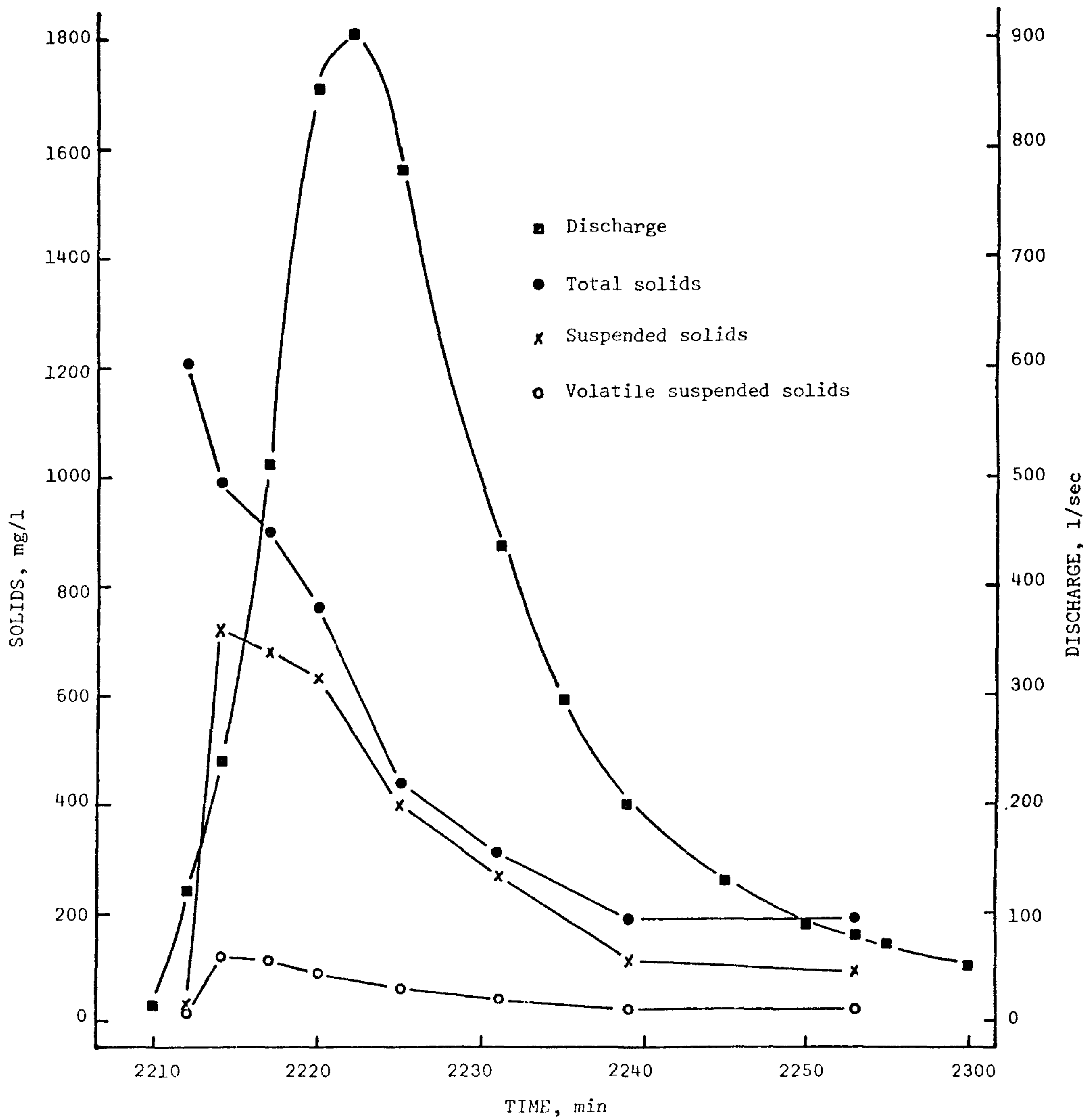
*Expressed in mg/l except pH
**Peak discharges occurred at: 1930 on May 28, 2222 on June 13, 1335 on June 18 and 0455 on July 28.
+Not determined

The concentration of $(NO_3 + NO_2)$-N was consistently higher in all events than the concentration of NH_3-N. It seems that this inorganic N species predominates in runoff waters.

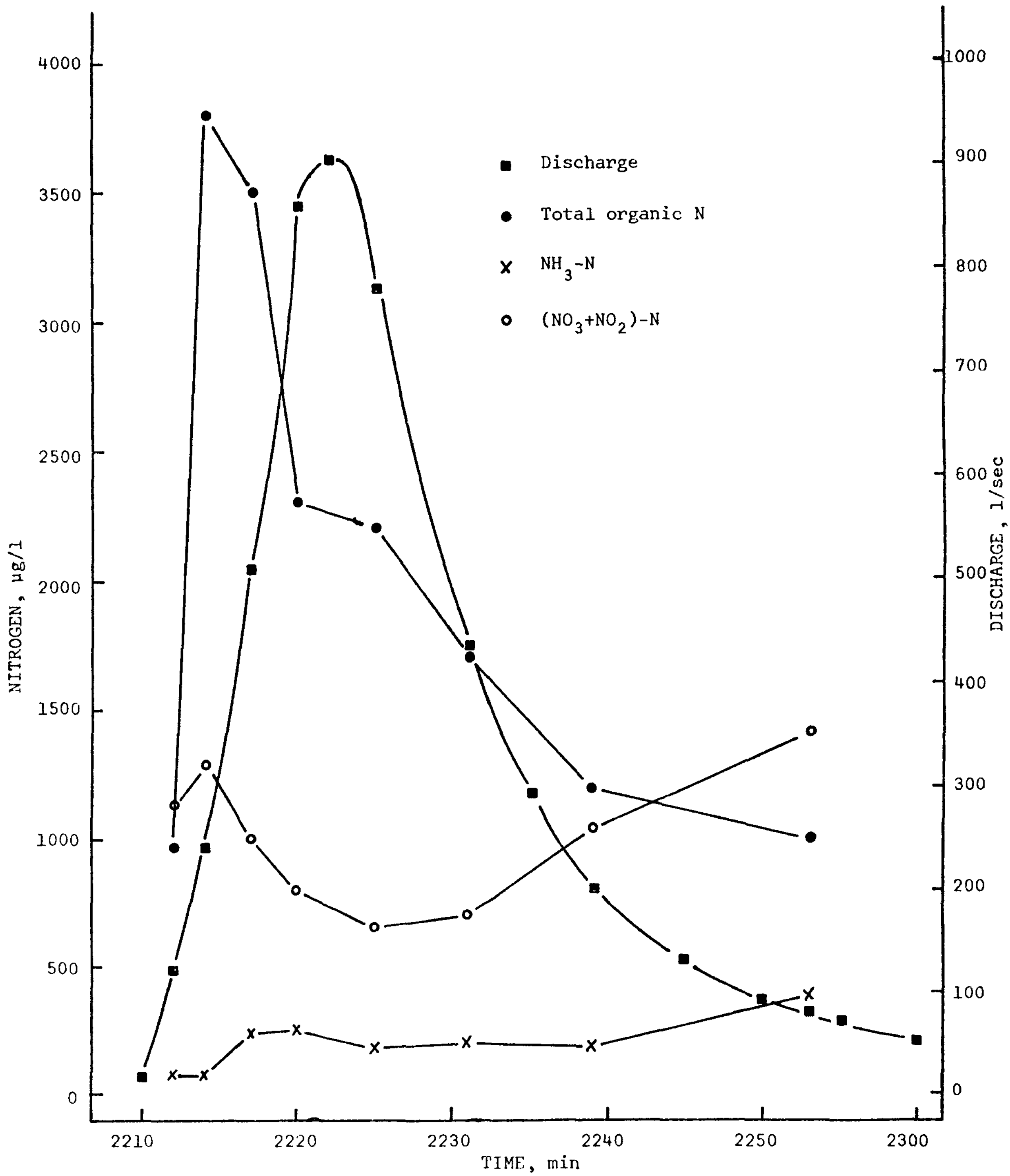
General comparisons of concentrations between events show the following: (a) chlorides were highest during the May 28 event possibly due to the washing off of residual salts on the parking lot and surrounding areas applied the previous winter; (b) suspended solids, volatile suspended solids, total P, total organic N, and total organic C were significantly higher in the June 13 event than in the May 28 event which might be due to the accumulation of dust and dirt on the impervious drainage areas of the station during the 2-week dry period; (c) the observation in (b) was not apparent in the June 18 and July 28 events despite the prolonged dry spell indicating that some form of dust and dirt removal was done during the 6-week dry spell; and (d) runoff samples in an event (June 18) occurring close to another one (June 13) contained appreciably less total solids, suspended solids, volatile suspended sediment, total P, total organic N, and total organic C.

Data of the June 13th event are used to illustrate the relationship of concentrations and loading rate and time of runoff. Appendix B Fig. 3 shows that total solids concentration was highest (1,210 mg/l) during the initial discharge and decreased gradually stabilizing after about 30 minutes of runoff. Suspended solids and volatile suspended solids increased with the rise of discharge but the highest concentrations of 716 and 116 mg/l, respectively, were observed 8 minutes before the peak flow; thereafter decreased gradually and stabilized at the same time the total solids did. The high initial concentration of suspended sediment is an indication that most of the soluble materials are transported by the first flush of runoff. This is further confirmed by the high initial concentrations of chlorides (280 mg/l) and total alkalinity (274 mg/l) (Appendix B Table 2), the latter being represented mostly by soluble carbonates and bicarbonates.

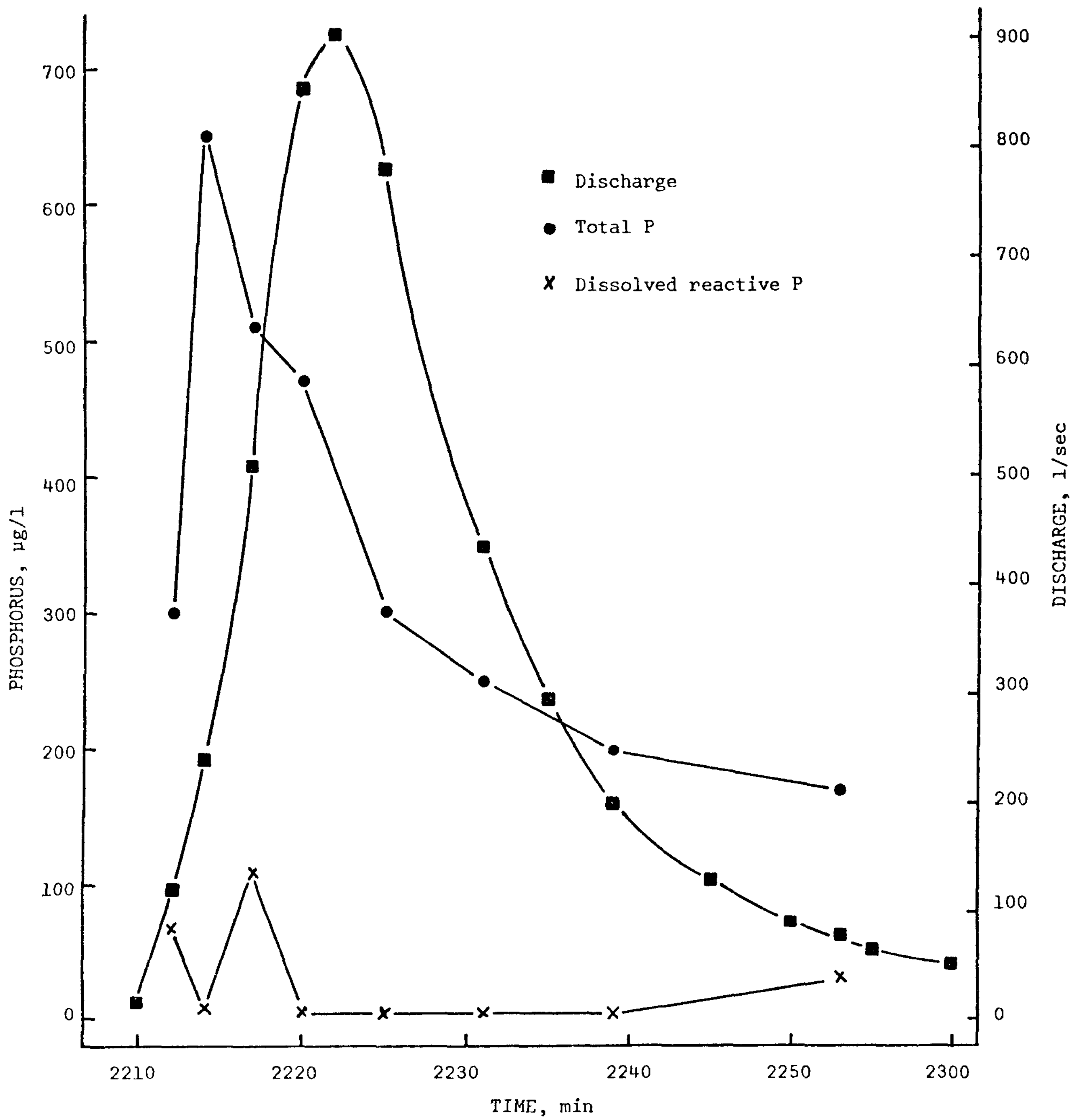
The concentration curves of total organic N (Appendix B Fig. 4) and total P (Appendix B Fig. 5) followed the behavior of the discharge curve except that the peak concentrations of these components -- 3.80 and 0.65



Appendix B Fig. 3. Concentrations of solids at Brookfield station (683089) during June 13, 1976, runoff event.



Appendix B Fig. 4. Concentrations of various N forms at Brookfield station (683089) during June 13, 1976, runoff event.



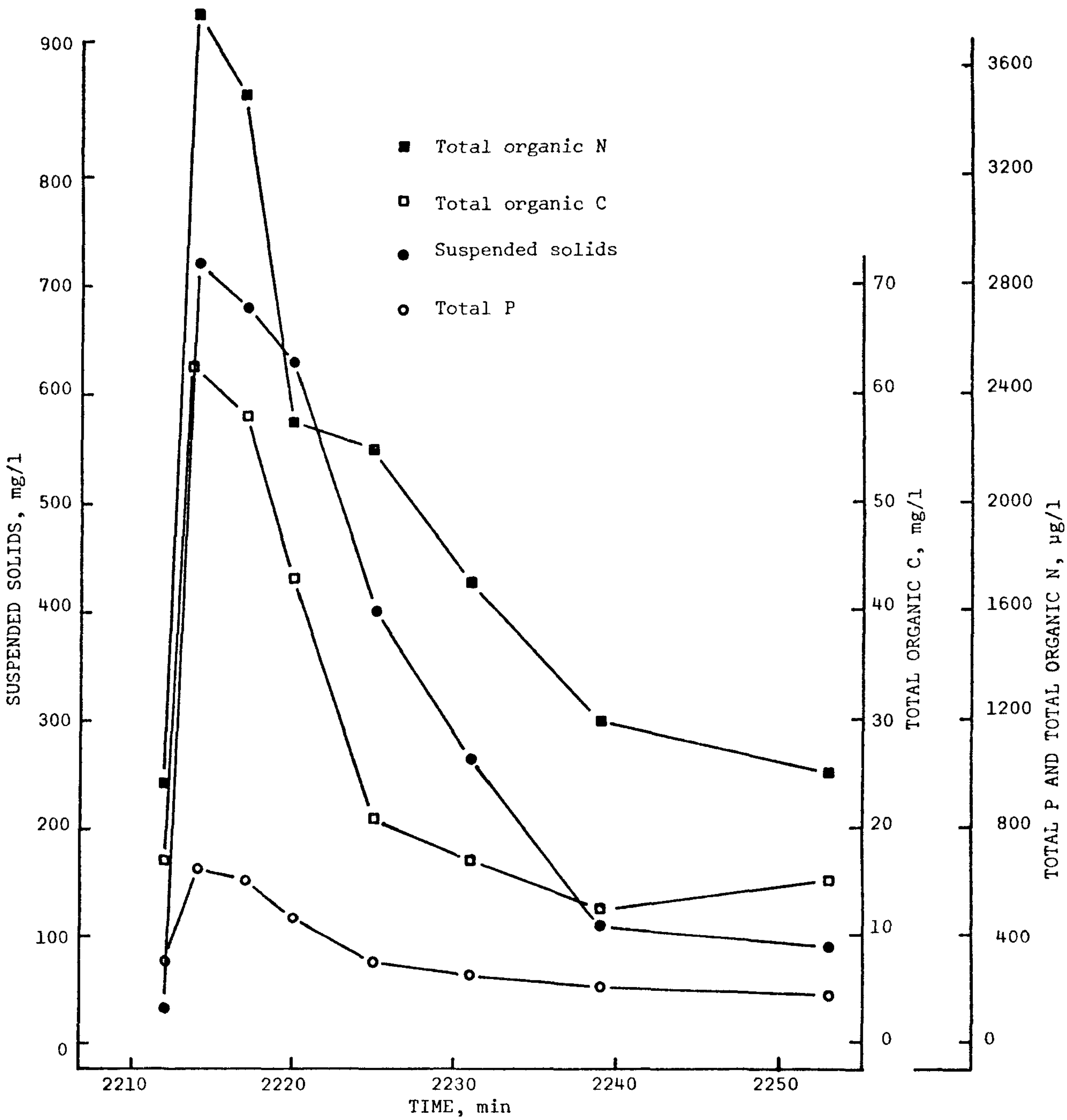
Appendix B Fig. 5. Concentrations of phosphorus at Brookfield station (683089) during June 13, 1976, runoff event.

mg/l, respectively -- occurred 8 minutes before the peak discharge. No definite trend was observed on the concentrations of NH_3-N and (NO_3 + NO_2)-N with discharge (Appendix B Fig. 4). Dissolved reactive P (DRP) concentration was highest (0.110 mg/l) 5 min before peak flow but decreased rapidly and stabilized even before the maximum flow was over (Appendix B Fig. 5). Concentrations of the inorganic N and DRP increased towards the end of the major discharge. These anomalous increases might be due to the delayed transport of these constituents from less impervious sections (residential and drive-in theater areas) of the drainage area west of the shopping center. Drainage waters from the small residential area have to pass through a marsh before reaching the stormwater sewer line.

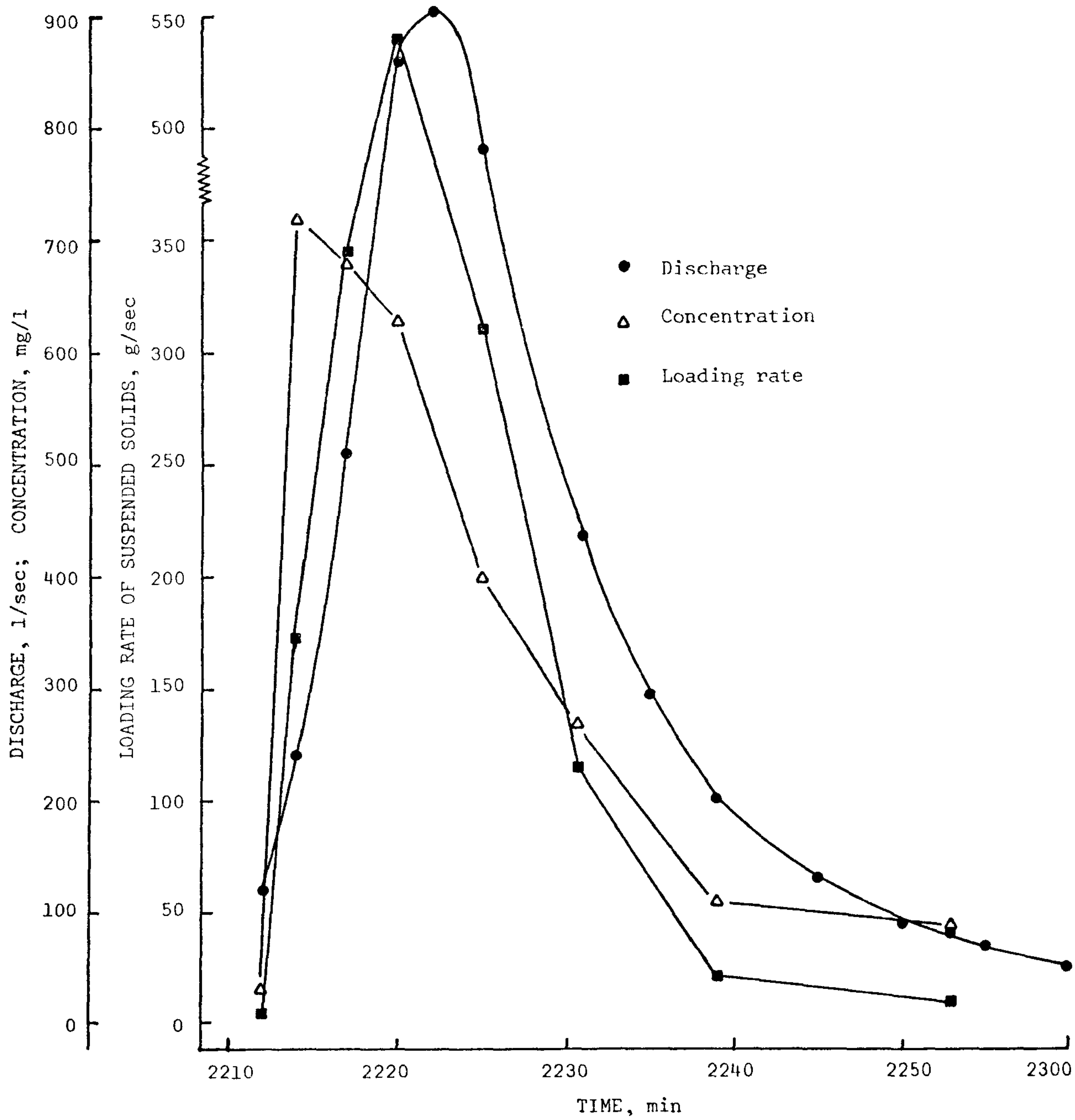
The concentrations of total organic N, total P, total organic C were closely related with the concentration of suspended solids (Appendix B Fig. 6). It appears that major fractions of these components are associated with the suspended particulate load.

Relationships of discharge and loading rates of suspended solids, DRP, NH_3-N, and (NO_3 + NO_2)-N are presented in Appendix B Figs. 7 and 8. The loading rate was calculated by multiplying the concentration of the particular constituent by the discharge at the time a sample was collected. Peak loadings of suspended solids (538 g/sec), NH_3-N (214 mg/sec), and (NO_3 + NO_2)-N (685 mg/sec) almost coincided with the peak flow, i.e., just 2 minutes before maximum discharge. Highest loading of DRP (56 mg/sec) was reached earlier (5 minutes before peak flow).

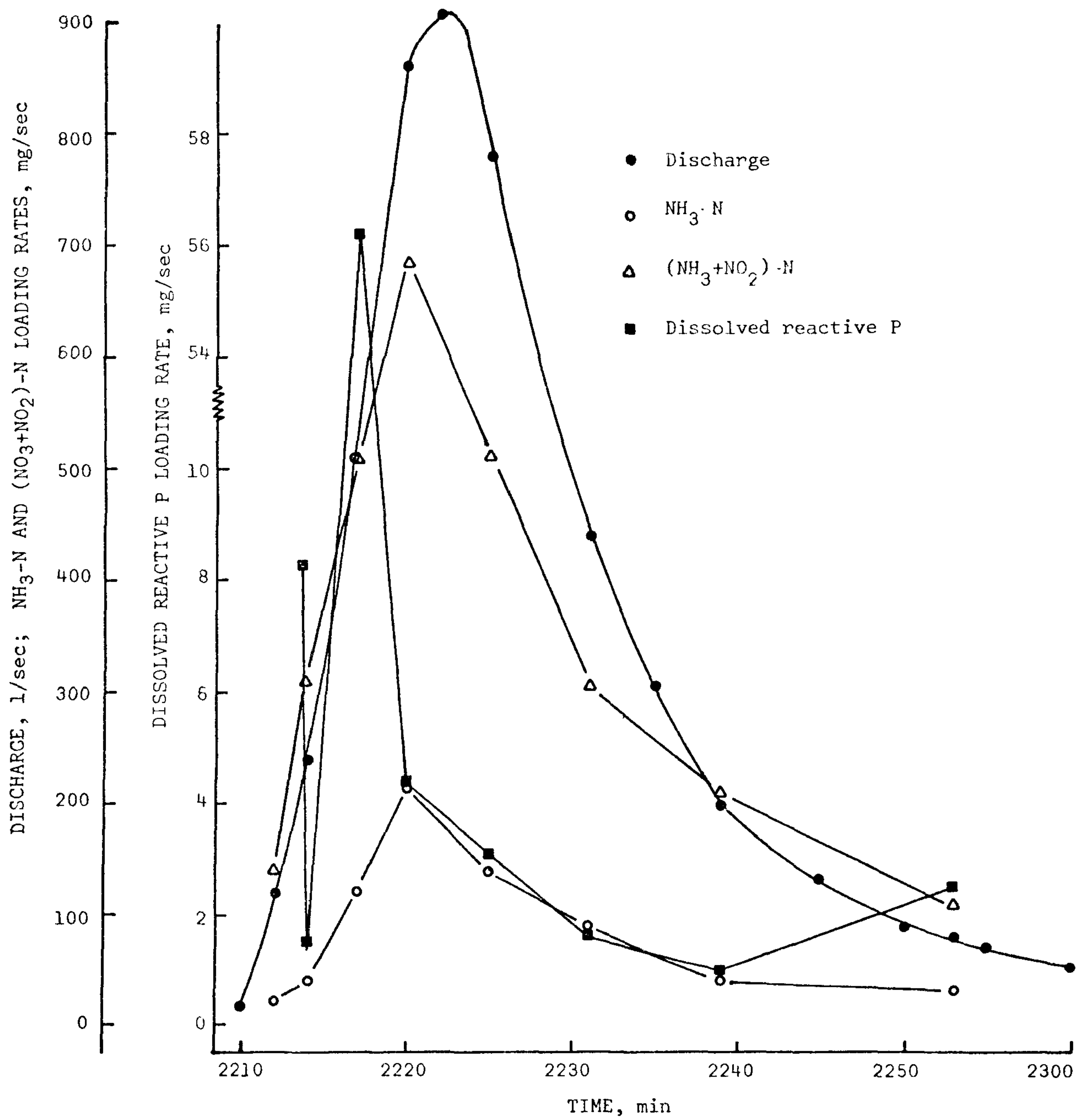
Total loadings of suspended solids and nutrients for three storm events are given in Appendix B Table 3. These loadings represent major discharges either partially or wholly during runoff periods. Substantial amounts of suspended solids was transported from the drainage area of the station ranging from 237 to 388 kg. Based on the 23.5 ha drainage area, the suspended solids load was 10 to 16.5 kg/ha. The high suspended solids load of the runoff water could have originated mainly from dust and dirt accumulated on impervious surfaces particularly on the parking lot of the shopping center. Ranges of nutrient loads were: 15 to 62 g for DRP, 197 to 749 g for NH_3-N, and 792 to 2371 g for (NO_3 + NO_2)-N.



Appendix B Fig. 6. Relationship of the concentrations of suspended solids, total P, total organic N, and total organic C at Brookfield station (683089) during June 13, 1976, runoff event.



Appendix B Fig. 7. Concentration and loading rate of suspended solids and discharge at Brookfield Shopping Center station (683089) during June 13, 1976, runoff event.



Appendix B Fig. 8. Loading rates of dissolved reactive P, NH_3-N and (NO_3+NO_2)-N and discharge at Brookfield Shopping Center station (683089) during June 13, 1976, runoff event.

Appendix B Table 3. Water, suspended solids, and nutrient loadings for three storm events at Brookfield Shopping Center station (683089)

Storm date	Sampling duration, hr	Loading					
		Water, m^3		Suspended solids, kg	DRP, g	NH_3-N, g	(NO_3+NO_2)-N, g
		Major discharge	Sampled discharge				
6-13-76	0.68	975	948 (97)*	388	15	197	792
6-18-76	0.48	3161	1757 (56)	320	62	749	1233
7-28-76	6.32	2707	2707 (100)	237	33	237	2371

*( ) per cent of the major discharge that was sampled.

Higher nutrient values were observed in storm events with greater discharges which indicate that soluble nutrient load of runoff is dependent primarily on the volume of water transported.

Group C and D Parameters

Runoff samples from four events at the Brookfield Shopping Center were analyzed for twelve metals and dissolved reactive silica (Appendix B Table 4). Metals were determined by atomic absorption method after digestion of the unfiltered sample by nitric acid or hydrochloric acid for 20 min. Since the samples were digested only partially the values obtained were less than total.

Appendix B Table 4 shows that the concentration of dissolved reactive silica was high in all events particularly during the first flush. Likewise, concentrations of Fe and Al were high and tended to increase as the flow increased. Arsenic and Se were undetected consistently in all events. Nickel was only detected in samples collected during the storm event on July 28. It was possible that atmospheric deposition of Ni occurred during the 6-week dry period after the June 18th storm event. Mercury was only analyzed in the May 28th samples and results showed that the levels of this element was either at detection limit or below it.

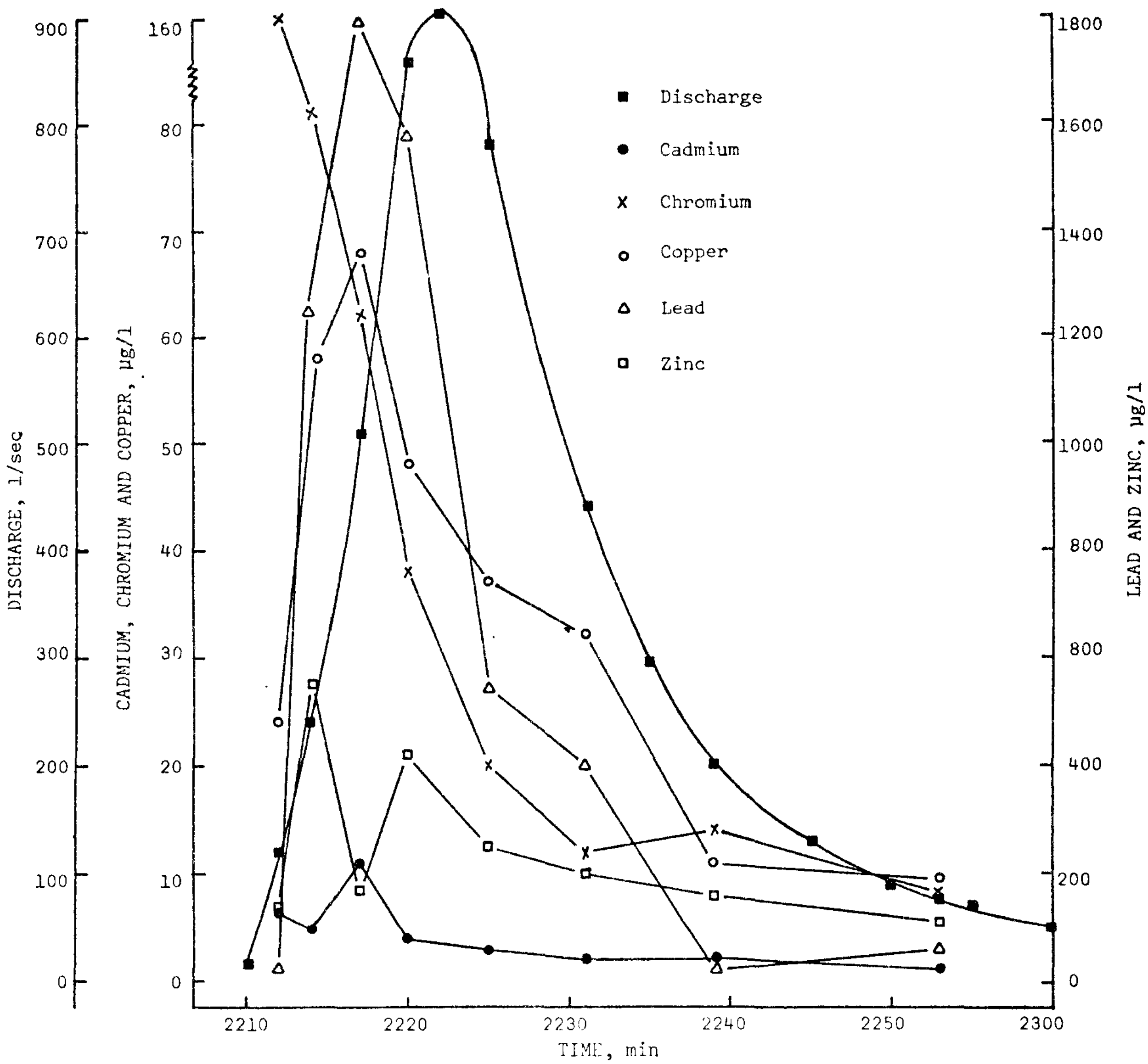
Concentrations of Cd, Cr, Cu, Pb, and Zn were generally higher during the rising stage of the runoff hydrograph and tended to taper off as the flow progressed (Appendix B Table 4). Runoff after long dry spells (June 13 and July 28 storm events) contained, in general, higher levels of Cd, Cu, Pb, and Zn than in runoff of storm events immediately preceding the dry period (May 28 and June 18). Concentrations of Cd, Cr, Cu, Pb, and Zn in runoff samples of the June 18th storm event were significantly lower than those of the June 13th storm event. Since the interval between storm events was only five days, it was possible that less materials were available for wash off from the impervious drainage areas of the site.

Data of the June 13th storm event are utilized to illustrate the relationship between concentrations of Cd, Cr, Cu, Pb, and Zn and time of runoff (Appendix B Fig. 9). Maximum level of Cr (162 μg/l) was observed during the initial discharge then decreased rapidly and stabilized 26 min

Appendix B Table 4. Metals and silica concentrations in runoff samples from four events at Brookfield Shopping Center station (683089)

Storm date	Time of sampling, min*	Element, µg/l												
		Al	As	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Si**	Zn
5-28-76	1118	<50	<10	0.3	930	12	440	6	130	0.20	<20	<5	15,900	160
	1408	<50	<10	0.2	810	25	480	12	140	<0.2	<20	<5	14,700	180
	1828	200	<10	0.5	44	25	2,400	304	<40	0.33	<20	<5	1,700	140
	1832	256	<10	0.5	30	16	1,400	272	50	0.35	<20	<5	2,100	140
	1837	256	<10	0.5	23	16	1,600	320	50	0.23	<20	<5	2,000	140
	1842	256	<10	0.7	12	18	1,400	280	50	0.23	<20	<5	2,400	200
	1938	228	<10	0.4	11	16	1,600	280	50	<0.20	<20	<5	2,100	230
	2117	256	<10	0.4	10	22	1,800	376	40	<0.20	<20	<5	1,400	120
	2223	152	<10	0.2	4	8	800	118	<40	<0.2	<20	<5	1,600	100
6-13-76	2212	120	<10	6.5	162	24	1,000	24	130	+	<20	14	13,700	130
	2214	1,100	<10	5.0	81	58	16,000	1,250	280		<20	6	2,300	550
	2217	1,400	<10	11.0	62	68	13,600	1,800	50		<20	<5	1,000	120
	2220	1,200	<10	4.0	38	48	11,800	1,580	220		<20	<5	1,000	430
	2225	688	<10	2.8	20	37	8,600	540	140		<20	<5	400	250
	2231	648	<10	2.0	12	32	6,400	400	100		<20	<5	500	200
	2239	100	<10	2.3	14	11	3,600	25	70		<20	<5	1,000	160
	2253	184	<10	1.3	8	12	2,900	58	80		<20	<5	800	110
6-18-76	1310	1,320	<10	3.4	104	26	3,800	276	190	+	<20	<5	9,800	180
	1312	1,160	<10	3.2	19	35	6,400	710	120		<20	<5	1,300	300
	1322	800	<10	2.6	11	40	4,000	500	80		<20	<5	600	190
	1324	728	<10	1.7	9	36	3,400	388	60		<20	<5	600	160
	1331	600	<10	1.4	6	19	2,900	324	60		<20	<5	600	100
	1335	504	<10	3.8	6	21	3,100	236	60		<20	<5	600	110
	1339	384	<10	3.1	5	21	2,600	216	50		<20	<5	600	100
7-28-76	0304	236	<10	9.8	78	20	500	22	60	+	70	<5	11,800	110
	0316	2,500	<10	5.3	300	143	6,800	1,000	220		138	<5	1,700	610
	0354	1,500	<10	4.3	58	55	2,600	460	70		48	<5	380	220
	0511	590	<10	4.5	31	39	1,200	180	40		290	<5	280	170
	0624	53	<10	7.2	10	35	500	72	<40		78	<5	440	120
	0848	196	<10	2.8	10	20	700	25	<40		74	<5	1,540	120

*Peak discharge occurred at: 1930 on May 28, 2222 on June 13, 1335 on June 18 and 0455 on July 28.
**Dissolved reactive silica
+Not determined



Appendix B Fig. 9. Concentrations of cadmium, chromium, copper, lead, and zinc at Brookfield Shopping Center station (683089) during June 13, 1976, runoff event.

after the initiation of runoff. Concentrations of the other elements increased with rising discharge although peak levels were attained before the maximum discharge. Maximum concentrations of Cd (11.0 μg/l), Cu (68 μg/l), and Pb (1800 μg/l) were attained 5 minutes before the peak discharge while highest level of Zn (550 μg/l) occurred 3 min earlier.

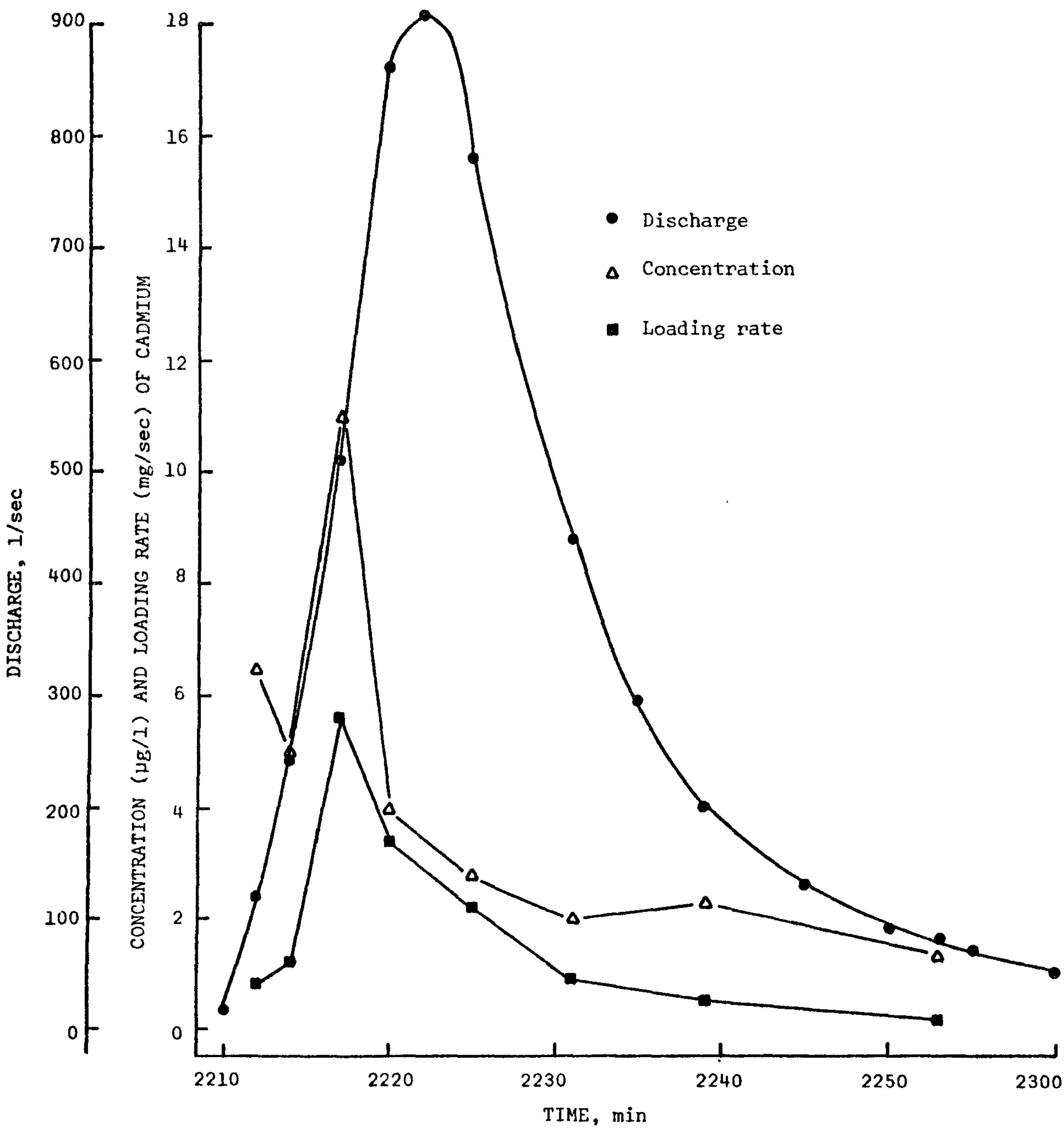
Loading rates of Cd and Pb during the June 13th event are presented in Appendix B Figs. 10 and 11. The maximum loading rate of Cd (5.6 mg/sec) coincided with its highest level, i.e., 5 min before peak flow (Appendix B Fig. 9). The loading rate of Pb followed closely the discharge curve with the peak (1352 mg/sec) occurring just 2 minutes before maximum flow.

Appendix B Table 5 shows total loadings of Cd, Cr, and Pb for three storm events at Brookfield Shopping Center station. Considerable amount of Pb was carried by the runoff water in all events. The range was from 580 to 845 g. These loads are equivalent to the Pb content of about 335 to 490 gallons of leaded gasoline (average Pb concentration is 1.72 g/gal). It appears that high levels of Pb are deposited on the parking lot of the shopping center mainly from car exhausts and drippings and some from atmospheric fallout. Cadmium and Cr loadings were 3.5 to 13.5 and 19 to 164 g, respectively. The main source of Cd and Cr is probably atmospheric deposition.

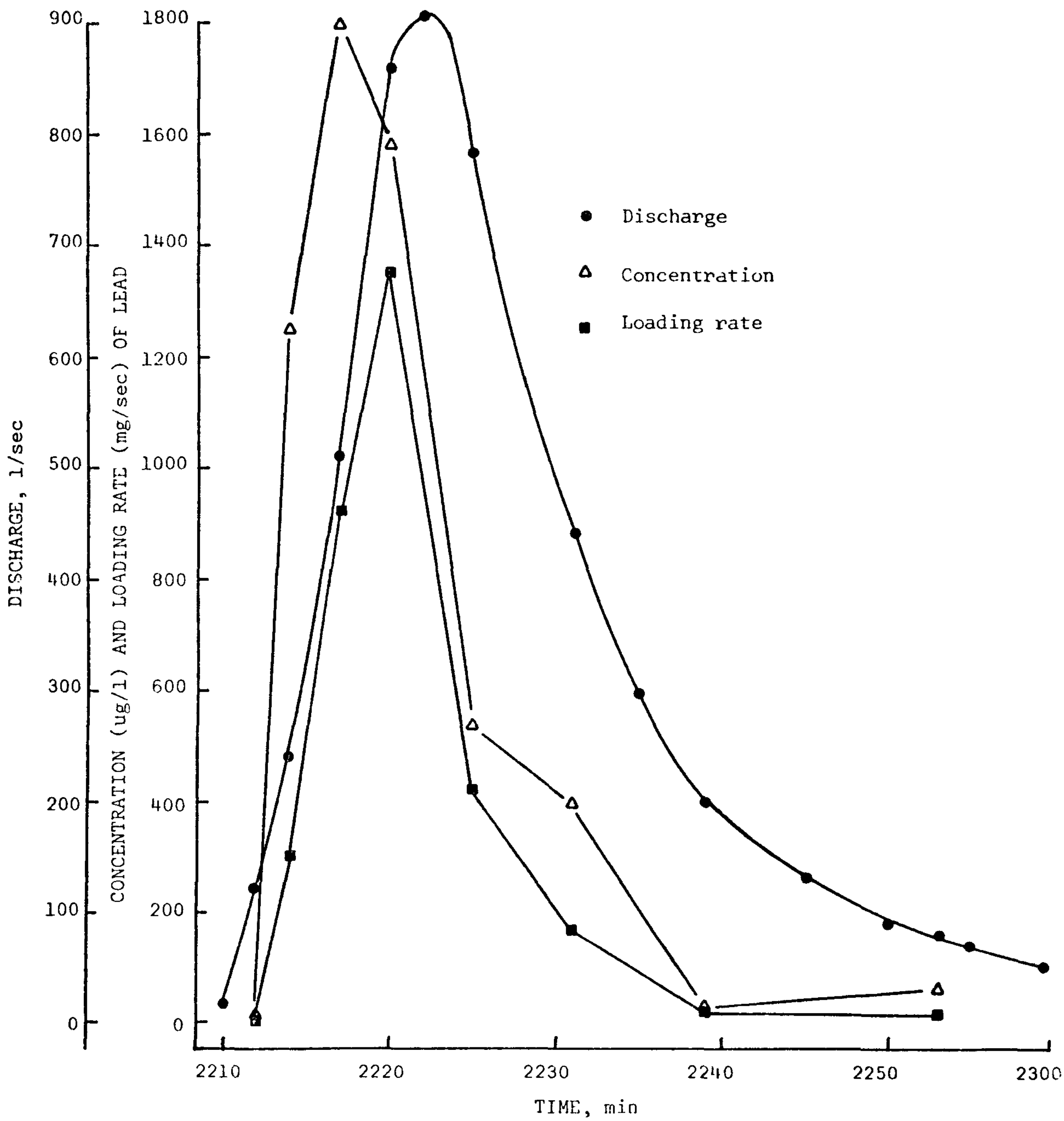
Future Studies

Metal Concentration in Particle Size Fractions of River Sediments and Suspended Sediments During Transport

Grab samples of bottom sediments from the river, estuary and 10 miles beyond the breakwater were found to contain a lower percentage of clay as compared to the dominant soils of the watershed. In addition, suspended sediments in the river water during storm events were found to have high clay content. This is probably the result of washing the surface soil into the river and subsequent settling of the coarse textured material along the river bed and estuary, while the clay is transported to the lake. The estuary may serve as a trap for the coarser sediments but not necessarily a trap for clayey materials. Since metals tend to sorb on to the surfaces of the suspended sediments, especially



Appendix B Fig. 10. Concentration and loading rate of cadmium and discharge at Brookfield Shopping Center station (683089) during June 13, 1976, runoff event.



Appendix B Fig. 11. Concentration and loading rate of lead and discharge at Brookfield Shopping Center station (683089) during June 13, 1976, runoff event.

Appendix B Table 5. Water and metal loadings for three storm events at Brookfield Shopping Center station (683089)

Storm date	Sampling duration, hr	Loading				
		Water, m^3		Cd, g	Cr, g	Pb, g
		Major discharge	Sampled discharge			
6-13-76	0.68	975	948 (97)*	3.5	27	754
6-18-76	0 48	3161	1757 (56)	4.6	19	580
7-28-76	6.32	2707	2707 (100)	13.5	164	845

*( ) per cent of major discharge.

finer particles, they may also be transported to the lake. The movement of metals particularly lead, zinc, cadmium, and chromium to the estuary is indicated by their higher concentration in the estuary than in the river bottom sediments.

The following experiments are proposed to investigate the dynamic relationship between metals and suspended solids during sediment transport from the watershed to the lake.

Experiment 1

Determination of the particle size distribution of suspended sediments and the metal concentration in each particle size in the base flow and storm event water and in the bottom sediments along the river and estuary. The primary focus will be on the suspended sediments during an event and sampling will be undertaken several times during the year. If most of the metal pollutants are associated with either the dissolved fraction or the clay size fraction then this would indicate that most of the metal pollutants will reach the lake even though the estuary can trap the coarser particles.

The Brookfield Square Shopping Center specific study site is of particular interest because of the substantial distance which the runoff water travels between the sewer outfall and Underwood Creek. Although high metal concentrations are being discharged from the storm sewer, these levels may be altered before entering Underwood Creek which is a main tributary of Menomonee River. The water course flows through a natural drainage ditch (Dousman Ditch) that contains soil with high organic matter which could possibly remove some of the metal pollutants before entering into the creek.

Method

Sediment samples from 13 stations in the watershed and approximately 21 sites in the estuary and beyond the mouth of the river will be collected. The collection will be made with a Ponard sampler and acrylic tube sampler and stored in 1 liter glass and plastic bottles. Sediments in glass bottles will be analyzed for organics while the samples in the plastic bottle will be used for metal analyses.

Sediments with intact organic matter will be dispersed with an ultrasonic probe. The probe being made from approximately 100% titanium is not considered to be a source of metal contamination. The separation of sand from silt and clay will be done by gravity settling. Separation of silt from clay will be done by centrifugation at 750 rpm for 2.9 min in an International centrifuge #2. The centrifuged silt is then resuspended and filtered through a preweighed 2.0 μ nucleopore filter. The supernate from centrifugation and resuspension of silt is filtered through a 0.4 μ nucleopore filter paper. The sediment separates will be dried at 110° C and weighed. After weighing, the solids and the filter paper will be wet-ashed in a teflon bomb to determine the total concentration of metals in each separate. A test will also be done to determine the dissolved metal concentration in the river water before and after ultrasonic treatment of the sediment to determine whether ultrasonic dispersion increases or decreases the dissolved metal concentration. Event samples from selected stations (river and specific land use sites) will be collected by automatic samplers. This means sacrificing one set of the normal storm event data for each set of analyses. Grab samples of base flow water will be used without any sacrifice of data. The particle size distribution of the suspended solids will be determined by the method used for bottom sediments.

The possible alteration of metal concentrations in the Brookfield Shopping Center runoff will be evaluated as follows. Several sites along Dousman Ditch will be selected for determination of the metal concentrations in the suspended sediments and in water during an event using a tracer dye. Bottom sediments at these sites will also be analyzed for metal concentrations and particle size distribution.

Experiment 2

A determination of dissolved metal concentration in the river water samples (base flow and storm event) will be made before and after mixing the river water with lake and estuary water. This would indicate whether the metal pollutants are being desorbed or adsorbed after mixing the water with lake or estuary water. If the metals in the suspended solids are desorbed after mixing river water with lake or estuary water, then the efficiency of the estuary as a pollutant trap is even less than expected. On the other hand if the dissolved metals are adsorbed on to the suspended solids then a longer residence time in the estuary will facilitate the trapping of sediments and the associated metals.

Method

Unfiltered estuary and lake water collected for part 1 under methodology of the experiment will be added at 1:1, 2:1, 5:1, and 10:1 ratios with unfiltered river water and agitated for approximately 6 hr before filtering. The dissolved metal will be determined. Metal concentrations in the filtered estuary and lake water will also be determined.

Experiment 3

A comparison of dissolved metal concentration in river and estuary water will be made before and after the addition and resuspension of river and estuary sediments. This will evaluate the "scavenging" effect of the sediment during storm events on the dissolved metal concentration in the water.

Method

The resuspension experiment will use unfiltered base flow and storm event water. Water (200 ml) and various amounts of bottom sediments (10 to 100 mg, which approximates the range of suspended sediment concentration during an event) will be added to a polypropylene centrifuge tube (250 ml). The suspension will be shaken at two different frequencies (60 and 120 cycles/min) for 24, 48 and 72 hours to determine whether equilibrium is attained. After centrifugation, the supernate will be collected and analyzed for metal concentration. Control (no sediment and/or no shaking) will be carried out during the experiment.

APPENDIX C

GROUNDWATER STUDY

Introduction

The groundwater study got underway in June, 1976. The objectives of the groundwater study are: 1) to define the flow system in the immediate vicinity of the Menomonee River system; 2) to analyze groundwater for a number of chemical and physical parameters and note changes in water chemistry in different parts of the watershed; 3) to assess the degree to which chemical contaminants are being discharged from groundwater into the river; 4) to investigate the possibility that surface contaminants are moving into groundwater via infiltration through the streambed; and 5) to assist in the modeling effort by developing a groundwater model to be used as a component in the watershed model.

Existing Data

Several maps developed by the U.S. Geological Survey (U.S.G.S.) for a groundwater study done in cooperation with Southeastern Wisconsin Regional Planning Commission (SEWRPC) have been copied from those on file at SEWRPC. U.S.G.S. well schedules, Wisconsin State Geological Survey well logs and Department of Transportation bridge boring logs have been compiled. High capacity wells within the watershed have been located and historical records of water-level fluctuations in selected U.S.G.S. wells in the basin as well as U.S.G.S. groundwater quality records have been obtained. This information will be useful in defining the groundwater flow system and in interpreting anomalies produced by human activities.

Operating landfill sites as well as a number of old landfill sites have been mapped. The Wisconsin Department of Natural Resources (WDNR) files on operating landfills are being examined and relevant data will be extracted.

Field Work

Emplacement of Observation Wells

In July, permission was obtained to install observation wells at 16 sites in the watershed. In August, 38 observation wells were drilled at 14 sites. Two of the proposed sites were abandoned because of shallow bedrock.

The wells are 1-1/4 inches (3.18 cm) in diameter and are screened with one foot (30 cm) plastic well points. Approximately one-half of the wells are constructed of PVC pipe and the rest are constructed of galvanized pipe. Five of the wells are located in recharge (upland) areas; the rest are located adjacent to the river system. Appendix C Fig. 1 shows the well locations and the number of wells at each location. Most of the well sites are in the vicinity of previously established surface water monitoring stations. This was done in order that groundwater data could be correlated with surface water data. Appendix C Table 1 gives the street locations of the well sites.

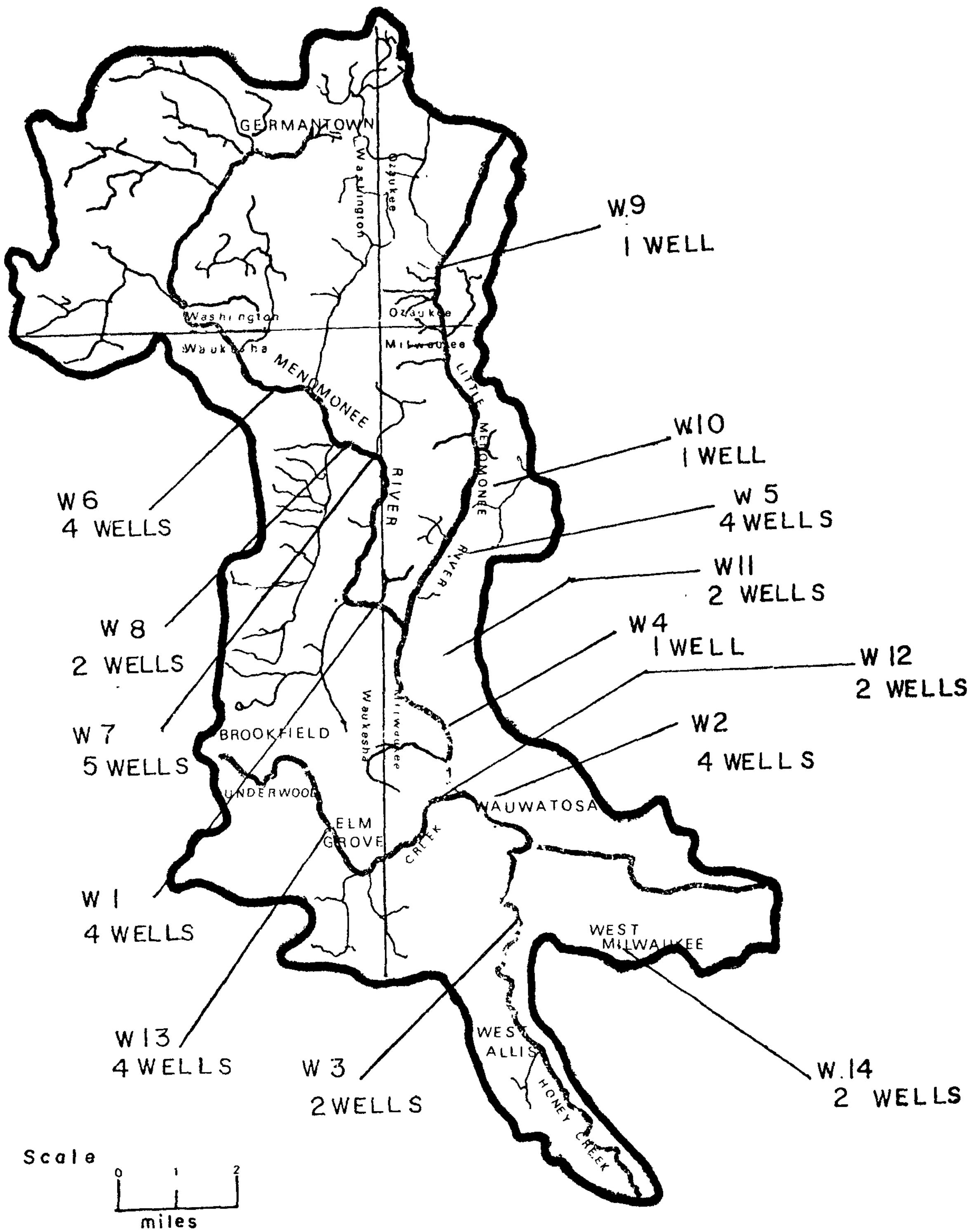
Where possible, wells were located on both sides of the river and piezometer nests were installed. The shallow wells are 12 to 23 feet (3.7 to 7.0 m) in depth and the deeper wells are up to 53 feet (16 m) in depth. These wells will be used to monitor groundwater quality and water levels. Variations in groundwater on opposite sides of the stream, in different depths of the aquifer and in recharge and discharge areas will be noted.

Surficial Geology

During installation of the observation wells, augered sediment samples were obtained. Appendix C Fig. 2 shows diagrams for two of the drilling sites. The most prevalent material is a gravelly clay till. This till is often overlain by compacted gray clay. Extensive sand and gravel lenses were found only at Elm Grove (W13) and Menomonee Falls (W6). The general nature of the material throughout most of the area investigated is that of highly variable glacial material of low permeability and poor sorting.

Streambed Sediment Samples

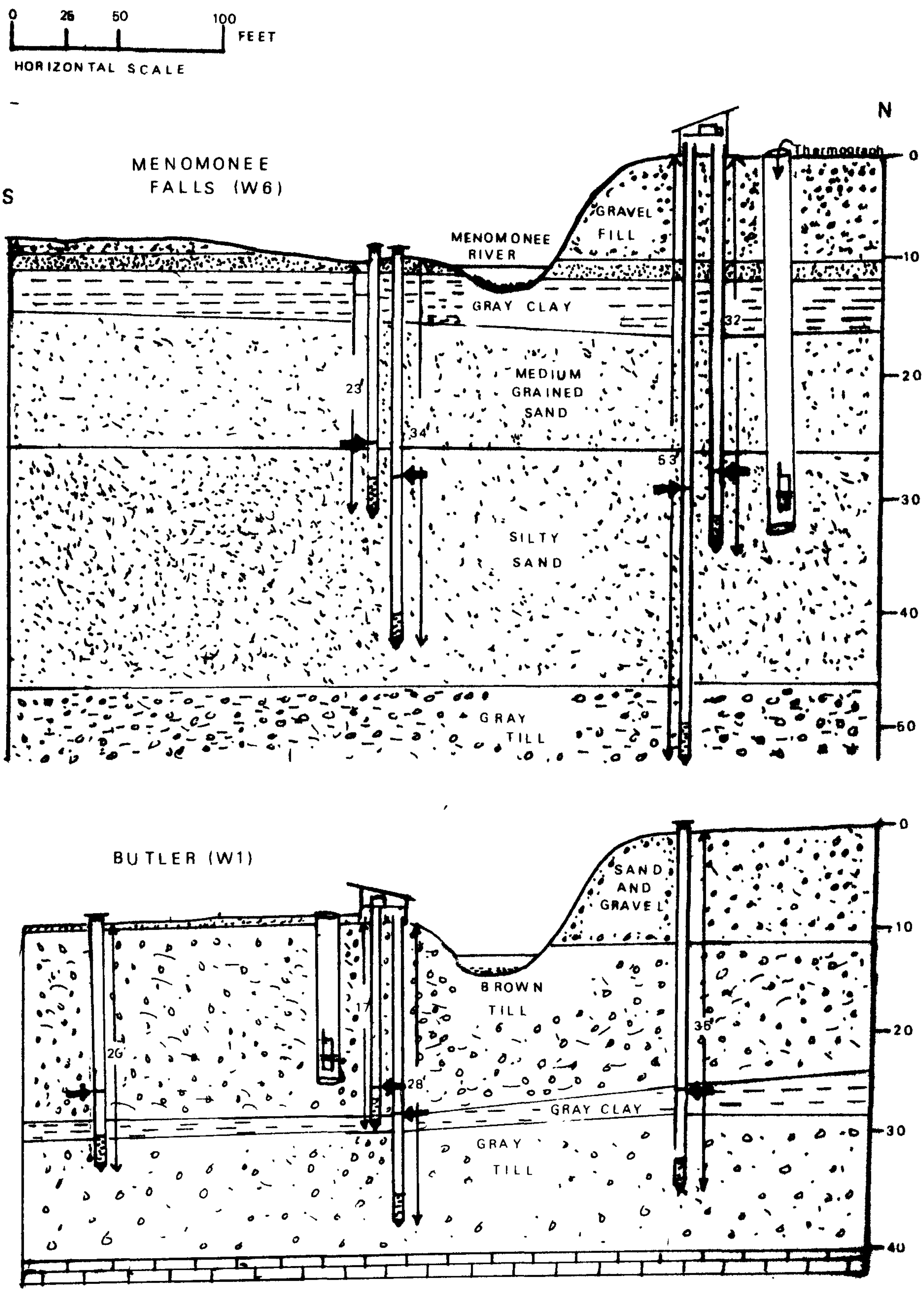
Sediment samples were taken at eleven sites in the Menomonee River, four sites in the Little Menomonee, and two in Underwood Creek. Samples were obtained with a hand auger and were retrieved from up to



Appendix C Fig. 1. Locations of well sites and number of wells at each site.

Appendix C Table 1. Street locations of well sites

Site Number	Location
W1	Menomonee River at 124th St., Butler
W2	Menomonee River at 70th St., Wauwatosa
W3	Honey Creek, west of West Honey Creek Pkwy., Milwaukee
W4	Menomonee R. in Currie Park, Milwaukee
W5	Little Menomonee R. at Appleton Ave., Milwaukee
W6	Menomonee R. at Pilgrim Rd., Menomonee Falls
W7	Menomonee R. near Fondulac Ave. at Milwaukee-Waukesha County line
W8	Menomonee R. at Lilly Rd., Menomonee Falls
W9	Little Menomonee R. at Donges Bay Rd., Mequon
W10	South of Good Hope Rd. in Noyes Park, Milwaukee
W11	South of Concordia Pkwy. in Concordia Park, Milwaukee
W12	Underwood Creek above Hwy 45 off of North Ave., Milwaukee
W13	Underwood Creek at Municipal Grounds, Elm Grove
W14	West Milwaukee Park, West Milwaukee



Appendix C Fig. 2. Cross-sections of well sites at Menomonee Falls and Butler. Water levels indicated by arrows.

four-foot (1.2 m) depths. It is probable that these samples are fairly representative of the medium that groundwater would move through in discharging to the river except for those areas where the river flows directly on bedrock.

Much of the Menomonee River System is underlain by compacted gray clay. A black organic silty muck which at times reaches depths of two to three feet often overlies the clay. Extensive sand and gravel deposits were found along much of the streambed near Menomonee Falls and in Underwood Creek in Elm Grove. The bottom sediment of the Little Menomonee River contains high amounts of organic silt. Creosote occurs in a layer up to 6 in (15 cm) thick near Bradley Road and is still evident in the sediment as far downstream as Appleton Avenue. Much of the Menomonee River past the confluence with the Little Menomonee flows directly on bedrock. No augering was done downstream of the 70th street bridge.

Stream Gaging

During July discharges on two reaches of the Menomonee River and one reach along Underwood Creek were gaged. Base flow was measured in an attempt to investigate the magnitude of surface water infiltration. That surface water is entering the groundwater aquifer is suggested by a groundwater map produced by the U.S.G.S. in cooperation with SEWRPC.

Gaging was completed twice for a 2.6 mile reach of the Menomonee River in Menomonee Falls and a 2 mile reach of the Menomonee River in the Currie Park area of Milwaukee. Similar results were recorded for both gaging periods. The stream gaging results are inconclusive with respect to the magnitude of surface water infiltration.

Discharge along the Menomonee Falls reach increased downstream 72% and 83% during the two gaging periods. On later investigation it was discovered that the increase was probably due to discharges from two Menomonee Falls sewage treatment plants. The discharge through the reach in the Currie Park area was essentially constant for four gaging points. Stream gaging was also attempted for a 1.5 mile length of Underwood Creek in the Village of Elm Grove. Flow was too low to be gaged. Two-thirds of a mile of the stream was dry. Flow was again noted just before the stream crossed under 124th Street.

Initial Groundwater Data

The observation wells have been surveyed and August groundwater levels have been measured. Initial data show that the groundwater level is lower than the surface water level by more than 20 ft (6 m) in Menomonee Falls (W6) and by approximately 10 ft (3 m) in Butler (W1). Groundwater gradients as measured in piezometer nests show a downward gradient at not only the two sites mentioned above but also at W3, W7 and W12. The water levels at W1 and W6 probably indicate that groundwater is not discharging to surface water. Piezometers should be placed in the streambed to help clarify the ground/surface water relationship.

Conductivity, pH and temperature were recorded at well sites and at corresponding reaches of the stream. The general trend exhibited by the August data shows that conductivities and pH are highest in the deeper portions of the aquifer, lower in shallow wells and lowest in the stream. Temperature shows the opposite trend.

Work in Progress

Field Work

Two Leupold-Stevens water-level recorders have recently been installed at W6 in Menomonee Falls and W1 in Butler. It is expected that water levels at these sites will be monitored continuously for several months in order that seasonal changes in water levels and gradients can be measured. The water-level recorders are housed in locked metal shelters about 3 ft (1 m) high and recorders are securely bolted to the shelter. On September 11, it was discovered that the Menomonee Falls station had been vandalized and the strip chart removed. The equipment was not damaged.

Within the next few weeks two Peabody Ryan thermographs will be put into operation. These temperature monitoring devices will be used in conjunction with the water-level recorders to assess changes in groundwater storage caused by streambank storage and groundwater recharge.

Work plans for water quality analyses are being finalized. It is expected that water sampling will begin at the end of September.

Groundwater Model

Several groundwater flow models are being tested. It is anticipated that a two-dimensional groundwater flow model of several representative cross-sections will be used to simulate groundwater flow in the vicinity of the river. Either this model or a one-dimensional flow model of the upper aquifer will be coupled with a one-dimensional contaminant transport model. Because restrictions on the size of time and space increments are necessary to maintain computational stability and result in increased computer time, it is likely that coupled one-dimensional models will prove to be most expedient. It is expected that calibration runs will be made after several months of field data have been collected and analyzed.

APPENDIX D

BIOLOGICAL STUDIES

Introduction

The biological study was implemented to provide information elucidating the relationship between pollution loadings from the various land use areas in the Menomonee River watershed, an urbanizing area, and the stream macroinvertebrate communities present in the river. A Hester-Dendy artificial substrate sampler was used to collect quantitative data allowing precise inter- and intrasite comparisons of the stream community at different sites overtime (for a sampler description see Menomonee River Semi-Annual Report for April, 1976). To circumvent the problem of vandalism, Surber samples were later added.

Study Sites

Five sites equipped with artificial substrates were studied from mid-April to September, 1976. Four of these sites were chosen because they coincide with continuous stations (413005, 683001, 413008, 673001) and one is an additional upstream station (683002) (Appendix D Table 1).

Field Procedures

Artificial substrate

Dendy samplers were placed on the float two at a time at two week intervals with six weeks allowed for colonization (Appendix D Table 2). They were disassembled in the field and all plates plus conservation webbing were placed in a plastic container containing 70% ethanol plus glycerine.

Surber sampler

Two appropriate sections within the riffle area were chosen at random except at site 3 which has no appropriate riffle area. The Surber sampler (Wards, Rochester, N.Y.) was set in place and the substrate within brushed with a toothbrush to a depth of 10 cm. The sample was preserved in 70% ethanol plus glycerine.

Appendix D Table 1. Site descriptions

Biological station	STORET #	Location	Area (sq. m.)*	Dominant land use	Modifications	Substrate	Min.† discharge (cfs)	Max. discharge (cfs)	Ft. width†	Min.† depth	Max. depth
1	413005	70th St. Bridge	123.0	urban development, light industry express-way development	one bank walled	large rubble					
2	683001	124 St. (Butler)	60.64	above sewage treatment plant, industrial	storm drain out-let between Dendy and Surber sites	Dendy: clay & silt Surber: large rubble	7.2	1160	33	10.84	15.5
3	413008	Little Menomonee @ Appleton Ave., Hwy. 175	19.64	rural to urban transition, creosote plant	channel section straightened	Dendy: clay and silt Surber: fine gravel & sand	1.8	313	18.5	4.9	9.15
4	683002	Pilgrim Rd., Hwy YY	34.54	rural to urban land use, suburban area		Dendy: med-large rubble Suber: large rubble	3.3	527	28	2.48	5.59
5	673001	Riverland Rd. Hwy. F	18.77	rural (agricultural), golf course, housing construction		Dendy: med-large rubble Surber: large rubble & silt	2.8	325	17	1.33	5.88

*SEWRPC 1976

†1974-75 data collected by USGS. Courtesy of Roger MacFarlane, USGS, Waukesha.

Appendix D Table 2. Implementation of field procedure

Field date	In	Out	
April 19	AA*		
April 23	BB		No sampler at 1
May 7	CC		No sampler at 2 or 4
May 21	A'A'	AA	Installed sampler at 1 and 4
June 4	B'B'	BB	
June 18	C'C'	CC	
July 2	AA	A'A'	Installed sampler at 2, site 4, vandalized, all Dendys lost
July 16	BB	B'B'	
July 30	CC	C'C'	
August 13	A'A'	AA	
August 27	B'B'	BB	
September 10	C'C'	CC	

*Artificial substrate numbering system.

Laboratory Procedures

Dendy and Surber samples

Dendy field samplers were rinsed and scrapped into a pan. This wash water was concentrated with a 1.25 mm net until as many organisms as possible were removed. The conservation webbing was then picked with a forceps and the organisms added to the concentrate. Dendy and Surber samples were then preserved in 70% ethanol plus glycerine and identified. When the sample count exceeded 100, the sample was subsampled at 100 organisms.

Discussion

Dendy artificial substrate sampler

This method of sampling allows uniformity between sites as well as providing a suitable method for deep water sites, however, its greatest merit comes in its use for quantitative work (Appendix D Table 3).

As presently designed, this method proves to be size selective for *Chironomidae* which are time consuming to identify to species or even genera. However, Mason (1975) has developed a system applicable to water quality assessment based on the identification of *Chironomidae* which may be used for these samples.

With a slight modification in sampler design where washers or masonite spacers (Hester and Dendy, 1962) are used in place of the conservation webbing, the size selectivity of this sampler would be reduced and the in-lab sample preparation time shortened.

While the procedure of removing the organisms from the sampler is time consuming, these standarized procedures do allow reasonable accuracy in total organism counts (total counts) per sampler.

The present design for this sampling method which includes both cement weight anchors and riverbed stakes, seems to be weather proof and fairly vandalism resistant. A full day's field work is required every two weeks for sample collection and installation. Laboratory time is then needed for sample preparation and organism identification and counting.

Appendix D Table 3. Total average organism counts projected from Dendy samples

Date	Site 1	Site 2	Site 3	Site 4	Site 5
5/21/76			28		73
6/4/76			42		392
6/18/76			112		1,000
7/2/76	250		121		700
7/16/76	142		66		500
7/30/76	87		7		1,990
8/13/76	102	102	12	151	10,000

Surber sampler

This sampling method provides a view of the natural faunal community present in the stream bed and is standarized from site to site by sampling only in riffle areas to a defined depth and width. All surfaces within the selected area are brushed free of organisms. While this method is somewhat quantitative in that it samples a uniform area at each site, the substrates at each site may differ. By sampling the riffle areas one is biasing samples toward obtaining the maximum variety of clean water organisms present since these sites will have the maximum D.O. for that particular point in the river.

Composite samples or duplicate samples at each site would provide qualitative as well as quazi-quantitative data through identification and counts of the organisms present.

While this method is somewhat time consuming in the fieldwork, the laboratory time is minimized by the elimination of sampler cleaning. Time spent in organism identification and counting exceeds that spent on Dendy samples because of the greater variety of organisms retrived by this method.

The Hilsenhoff Biotic Index (1976) is directly applicable to this data and provides a qualitative assessment of each site without having to compare organisms found at one site to those found at another very different site.

Surber sampling is restricted to waters of one foot or less in depth and is therefore restricted to the shallower riffle areas in the watershed.

Analysis Procedure

Diversity Index vs. Biotic Index

Probably the most widely employed biological method presently used in stream pollution analysis is the Diversity Index calculated for the stream benthic community. The two basic assumptions of analysis by Diversity Index are:

A. Natural, clean-water streams are inhabitated by benthic communities with maximum diversity.

B. Pollution of the stream results in increased stress upon the organisms thereby causing a formerly balanced aquatic community to be replaced by an unbalanced community dominated by a small number of species.

The validity of these assumptions, however, must be questioned for several reasons. Firstly, the composition of aquatic communities is influenced by more than just the quality of the water. Physical and chemical stream and watershed parameters as well as competition, chance and history all influence the biotic community structure at a particular site. Because of the fallacy in this first assumption, a pristine, first-order stream could be ranked as polluted by the Diversity Index system because of the stream's low faunal diversity. Secondly, while it is recognized that changes occur in benthic communities in response to pollution, the community responses are not always unidirectional as implied by Wihlm and Dorris (1968). For example, should organic wastes be introduced into a stream section which has low natural inputs of potential food, the diversity of the benthic community may actually increase, thus presenting a distorted image of stream condition when analyzed with the Diversity Index (Hocutt, 1975).

To avoid these problems of interpreting stream community diversity, some biologists (Chutters, 1972; Hilsenhoff, 1976) have utilized existing information of pollution tolerance levels of organisms for the assignment of organism quality values. These assigned values constitute a subjective assessment of the organism's ability to withstand an inhospitable aquatic environment. Organisms found only in clean water receive low values while organisms found in very polluted waters receive high values. By multiplying the number of organisms of specie "a" times its quality value and continuing for all species in the sample, an average quality value or Biotic Index (BI) can be calculated for the sampled site. Therefore, if careful attention has been given to the assignment of specie quality values, the Biotic Index will not be greatly affected by sample size or exact location within the riffle area, whereas the Diversity Index value might greatly be affected. A comparison of Biotic Index values and Diversity Index values calculated for the five biological stations sampled in this study show that the Biotic Index is a much more sensitive and descriptive index for use in assessing water quality biologically (Appendix D Fig. 1). A low Biotic Index indicates high water quality.

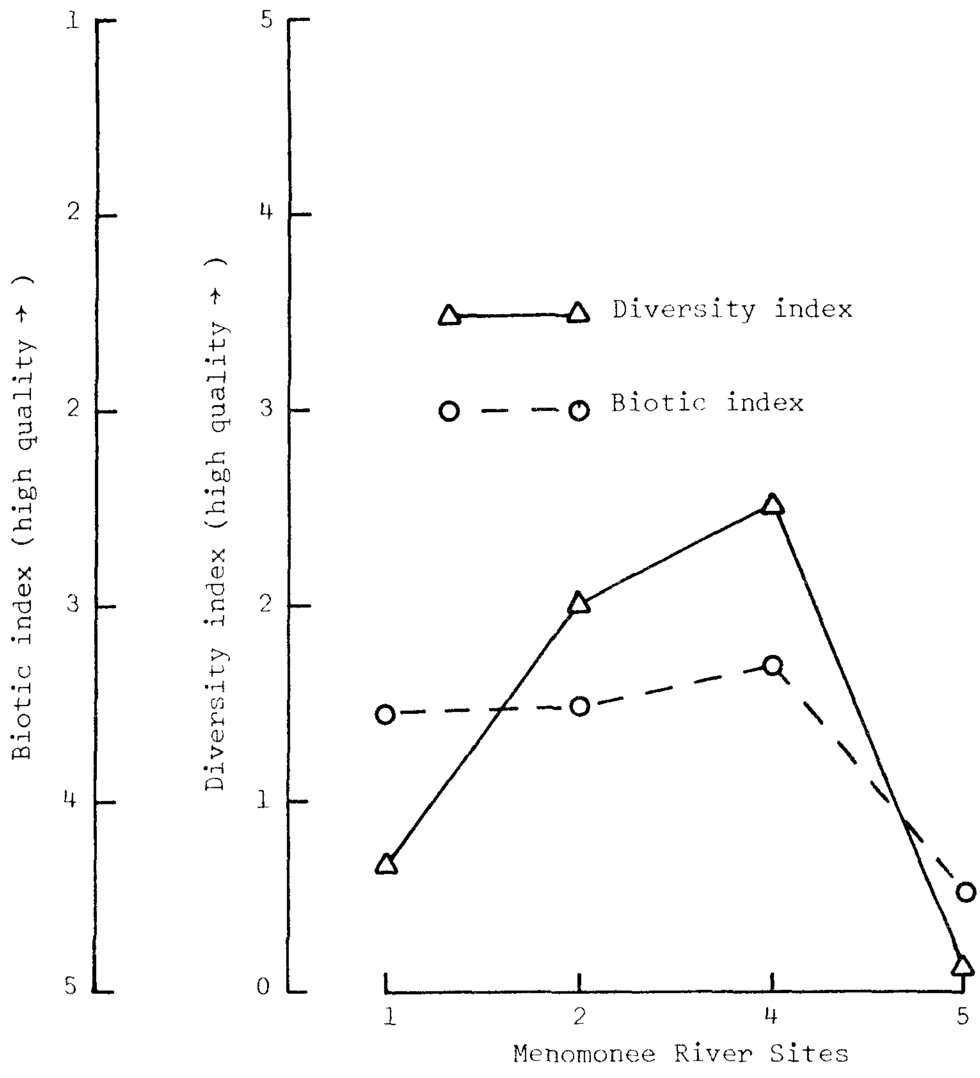
Therefore, the Biotic Index method of data analysis was chosen as the analytic tool to be used on this biological data. In addition, this method of analysis is applicable to the Stream Classification Index (Eilers and Wolfe, 1976) which links water quality to local physiographic factors.

Explanation of Biotic Index calculations on Spring 1976 biological data

All aquatic organisms belonging to the class *Insecta* and orders *Isoposa* and *Amphipoda* were identified to genera with the exception of most of the *Chironomidae*. Due to the tremendous amount of time required to identify all *Chironomidae* to generic level, only random individuals were selected at each site for further study. For sites 1 through 4 most of the *Chironomidae* consisted of genera with quality values between 3 and 4 (i.e. *Chypptochironomus*, *Cricotopus*). Therefore, at sites 1 through 4, the *Chironomidae* are considered as a single taxon with the quality value of 3.5. At site 5, however, the vast majority of the *Chironomidae* were "blood-worms" which possess hemoglobin, an adaptation for surviving very low oxygen concentrations (i.e. *Chironomus*, *Glyptotendipes*). The values for these *Chironomidae* were averaged to give a quality value of 4.5 for these organisms at site 5. All other organisms, with the exception of *Berosus*, were given quality values assigned by Hilsenhoff (1976) (Appendix D Table 4).

Results

The analysis of Surber sample BI values (Appendix D Table 5) demonstrates the degree of pollution present in the Menomonee River (Appendix D Fig. 2), however, it does not identify the exact cause and effects relationships of different urban land use pollution loadings on the stream biota. The BI vs. SCI (Stream Classification Index)



Appendix D Fig. 1. Diversity Index vs. Biotic Index (mean values)

Appendix D Table 4. Quality values of organisms found in the Menomonee River

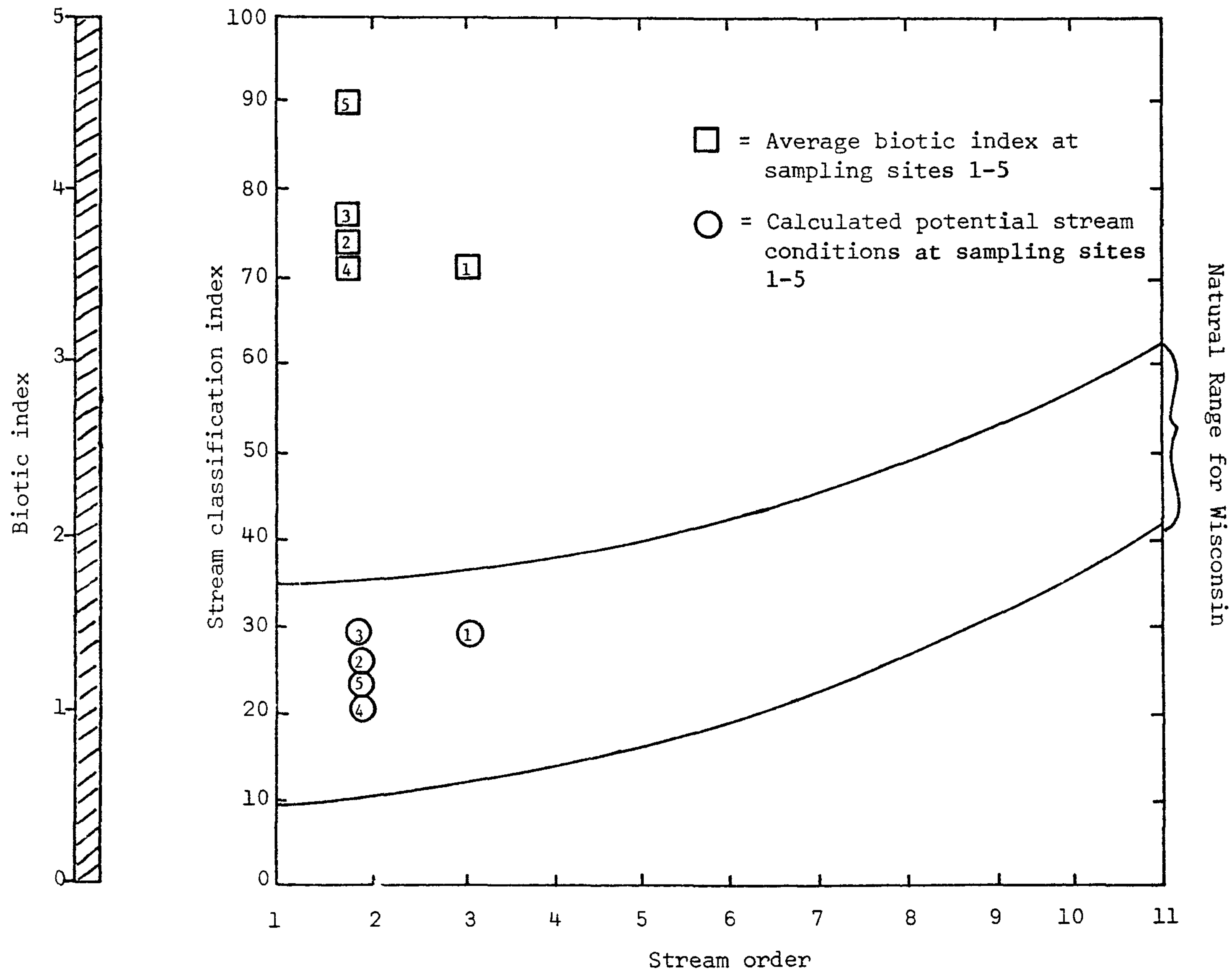
Organism	Value*
Antocha	2
Asellus intermedius	5
Baetis	3
*Berosus***	4
Bezzia - Palpomyia	3
Canenis	4
Cheumatopsyche	4
Chironomidae	3 to 5
Empididae	4
Ephemerella	1
Gammarus	2
Hyalella azteca	4
Hydropsyche	3
Hydroptilidae (Ochrotrichia)	3
Optioservus	3
Simulium	4
Stenacron	3
Stenelmis	3
Stenonema	3

*From Hilsenhoff (1976)
**Estimated from EPA macroinvertebrate tolerance classifications

Appendix D Table 5. Average Biotic Index value

Dendy samples					
Sites	1	2	3	4	5
Biotic Index	3.50	3.50	3.86	3.60	4.48
Standard deviation	0.01	0.01	0.37	0.11	0.13
Number of samples based on	10	4	16	5	18

Surber samples					
Biotic Index	3.46	3.48	No appropriate riffle area	3.38	4.50
Standard deviation	0.15	0.23		0.19	0.02
Number of samples based on	7	6		7	4



Appendix D Fig. 2. Stream Order vs Stream Classification Index and Biotic Index on Menomonee River watershed survey sites comparison (Appendix D Fig. 2) provides a relative qualitative assessment of stream pollution for each site in relation to each other as well as in relation to each site's potential water quality status (SCI). The Stream Classification Index was developed for the purpose of defining the predicted quality of the stream if the watershed was uninhabited by man. Since the standard deviation in BI values calculated over the entire sampling period (Appendix D Table 5) are relatively small, it may be concluded that an average BI or a BI obtained from any one particular spot-sample from a site is adequate for stream pollution analysis at this level.

The positions of the biotic quality of the sites as presented in Appendix D Fig. 2 indicate that the present condition of the river (BI values) is considerably degraded from the potential water quality (SCI) at all sites sampled. The severity of the pollution in the Menomonee River is demonstrated by the location of the number in the upper portion of the figure representing the Average Biotic Index at the sampling site.

The analysis of data obtained from Dendy samples provides a quantitative assessment of degradation at each site. The very high number of organisms occurring at site 5 is probably attributable to nutrient loadings from the fertilized cropland, golf course, and the Germantown sewage treatment plant immediately above this location. The very low organism counts at site 3 are most likely the result of toxic effects from the creosote present at this site. Investigations of the stream above this site revealed significant amounts of creosote in and on the channel substrate.

The non-point source pollution from the agricultural areas in the headwaters of the Menomonee River and the point source pollution from the industrial and commercial areas of the watershed are so large that they mask any effects of the loadings received from additional non-point urban sources. The physical effect of high currents on the benthic organisms is an additional variable which cannot be separated from the pollution load. The anticipated decline in water quality from the urban non-point source pollution is apparently too short-lived in a small river system to cause much damage to an already severely polluted river. On the contrary, the storm events may be beneficial to the aquatic community by flushing accumulated anaerobic and toxic deposits from the river bed. By observing the positions of the Biotic Index at each site on the Stream Classification diagram (Appendix D Fig. 2) it is evident that there is little room left for responses to additional sources of pollution.

Proposed Plans

The conclusions drawn from the Spring 1976 data will be studied further due to the problems listed below in the sampling and data analysis procedures.

1. Physical-chemical data from the in situ monitors were not yet available for comparison with the biological data.

2. Surber and Dendy samples had not been routinely taken to genus level for the Chironomids, therefore, calculated BI's suffer a loss in accuracy.

3. The decision to use Surber samples as the main collection method was not made until July 1976.

4. None of the sites selected were representative of a predominately agricultural area.

To assess the biological effects of non-point pollution from land use areas draining into the river, a less complicated drainage system such as a tributary will be examined. By studying these smaller more homogeneous areas, the complex interactions between land use and water become more approachable.

Study sites were chosen from those areas with monitoring stations, natural substate bottoms and flowing water throughout the year.

Noyes Creek represents a system influenced predominately by residential, transportation and open land use. The macroinvertebrate populations will be compared from multiple Surber samples taken in riffle areas on Noyes Creek, where it enters the Little Menomonee River and at similar sites above and below the confluence. These samples will be examined in relation to the physical-chemical data received from the monitoring station (413011) on Noyes Creek. The lower watershed, affected by commercial and industrial inputs, will be sampled at riffle sites on the Menomonee River immediately above the Honey Creek mergence, below the 70th Street station

(413005) and directly on Honey Creek. The Little Menomonee River will be studied at the Donges Bay Road station (463001), a predominantly agricultural area which is free from point sources of pollution.

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APPENDIX E

ATMOSPHERIC MONITORING PROGRAM

Introduction

The objective of the atmospheric studies is to quantify the deposition and release of several major and trace substances in the Menomonee River watershed in order to assess the relative importance of atmospheric transport pathways in the overall geochemical cycle.

Since April, 1976, the emphasis has been on wet deposition sampling. Installation of modified Wong rain samplers began in July, 1976. Presently four of these samplers are in operation at stations: (1) 413004 (Falk), (2) 413005 (70th Street), (3) 413008 (Appleton Avenue), and (4) 673001 (Lannon Road).

A small scale effort has also been initiated to measure polychlorinated biphenyls (PCBs) in air at selected locations within the watershed. Since June, 1976, several solid absorbers have been evaluated for use in the sampling of PCBs from air.

Equipment Modifications

Wong rain samplers will open automatically during a precipitation event and close during dry weather conditions. A moisture sensing head triggers a motor to open the lid and a heating unit causes residual moisture to evaporate from the head to insure rapid closure when rain ceases. However, the factory-shipped equipment had several major drawbacks that warranted modifications. Of primary concern was accidental sampling of fugitive dust during dry periods when the lid on the sampler was in the closed position. This results because all samplers have a gap between the lid and the container when closed. To avoid dust collection during dry periods the gap was sealed with a foam cushion covered with plastic. Secondly, the factory-shipped rain collector contains a flat-bottomed, large, cylindrical container. This configuration causes a severe evaporation problem. To avoid this water loss, 1/8-inch I.D. Tygon tubing was attached to a small glass funnel imbedded in the neck of a large linear polyethylene funnel. The large funnel provides a wide collection area while the tubing effectively reduces the surface area exposed to evaporation by a factor of over 7000. A 2-liter linear polyethylene screw-top bottle serves as the collection vessel. In addition, a brake made of plastic-covered urethane foam was also placed on the collection equipment to insure a smooth operation of the lid.

Sampling and Preparation

Unless a rain event doesn't occur the sample bottles are changed each week. The volume of the sample is estimated in the field and concentrated nitric acid is added to achieve a pH of approximately one. After transportation to the laboratory the rain sample is then stored at 4^{o} C until analysis begins. Sample volume is calculated by weight by comparison to a known volume of pH 1 tap water. Original volume of the rain is determined by subtracting the weight of the added acid.

Analysis Procedures

Flame atomic absorption was used to analyze for calcium and magnesium. Elements Al, Si, and PO_4 will interfere in the concentration determinations by this method. The practice of adding lanthanum to the sampling has been suggested by several investigators to preclude these interferences. This, however, will add another step to handling and the potential for contamination is also increased. Other matrix problems may necessitate use of the standard addition method in favor of a standard curve. These potential problems were further investigated.

A rain sample from the Appleton Avenue site was selected to compare the Mg analysis with and without the addition of La, and to assess the accuracy of the standard calibration curve. The results indicated that the addition of La to the water sample had a negligible effect on the Mg determination ($[Mg] \sim \mu g/\ell$).

The standard addition method was employed on the sample five successive times. In addition, the sample was analyzed five times using standard curves. The results indicate that the average value determined by the standard curve fell within the 95% confidence limit of the value determined by the standard addition method. It was concluded that analysis by standard curve was accurate for this particular matrix. It should be mentioned, however, that La is added to the standards, as this does seem to make the difference.

For all the data collected thus far, rain samples were analyzed directly for Ca and Mg after acidification to pH 1. The diluent used for standards is sub-boiling point quartz distilled water made from primary distilled water. Presently, a third glass distillation step is being inserted prior to sub-boiling point distillation for maximum decontamination in our subsequent trace metal studies.

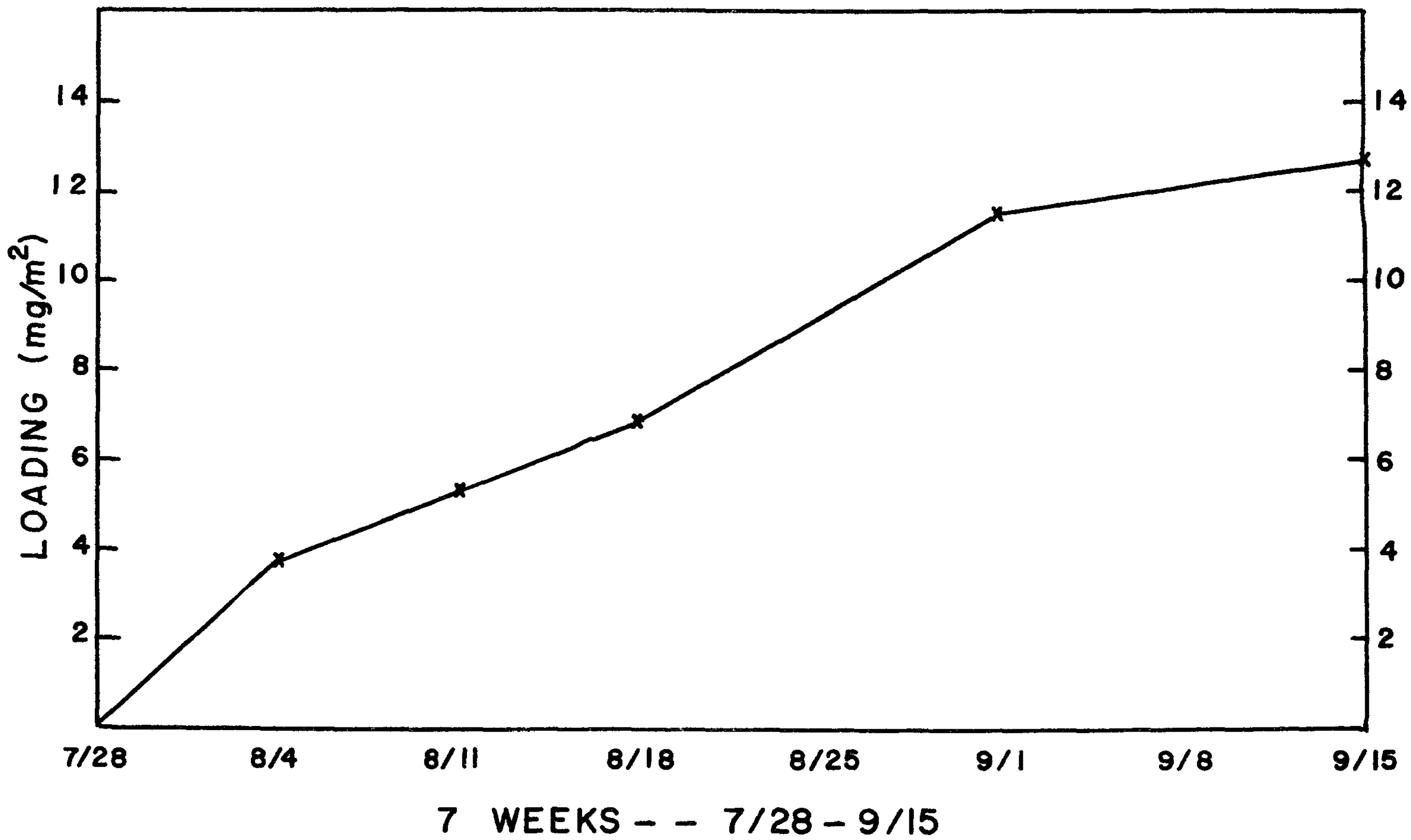
Preliminary Wet Deposition Data

Beginning July 22, 1976, at least two rain samplers have been operational. Shut downs have occurred because of vandalism at one site and equipment failure at another. Because of a dry summer, rain events have not occurred at each site in each weekly interval. Complete data does exist for the 70th Street station beginning July 28 (Appendix E Figs. 1 and 2).

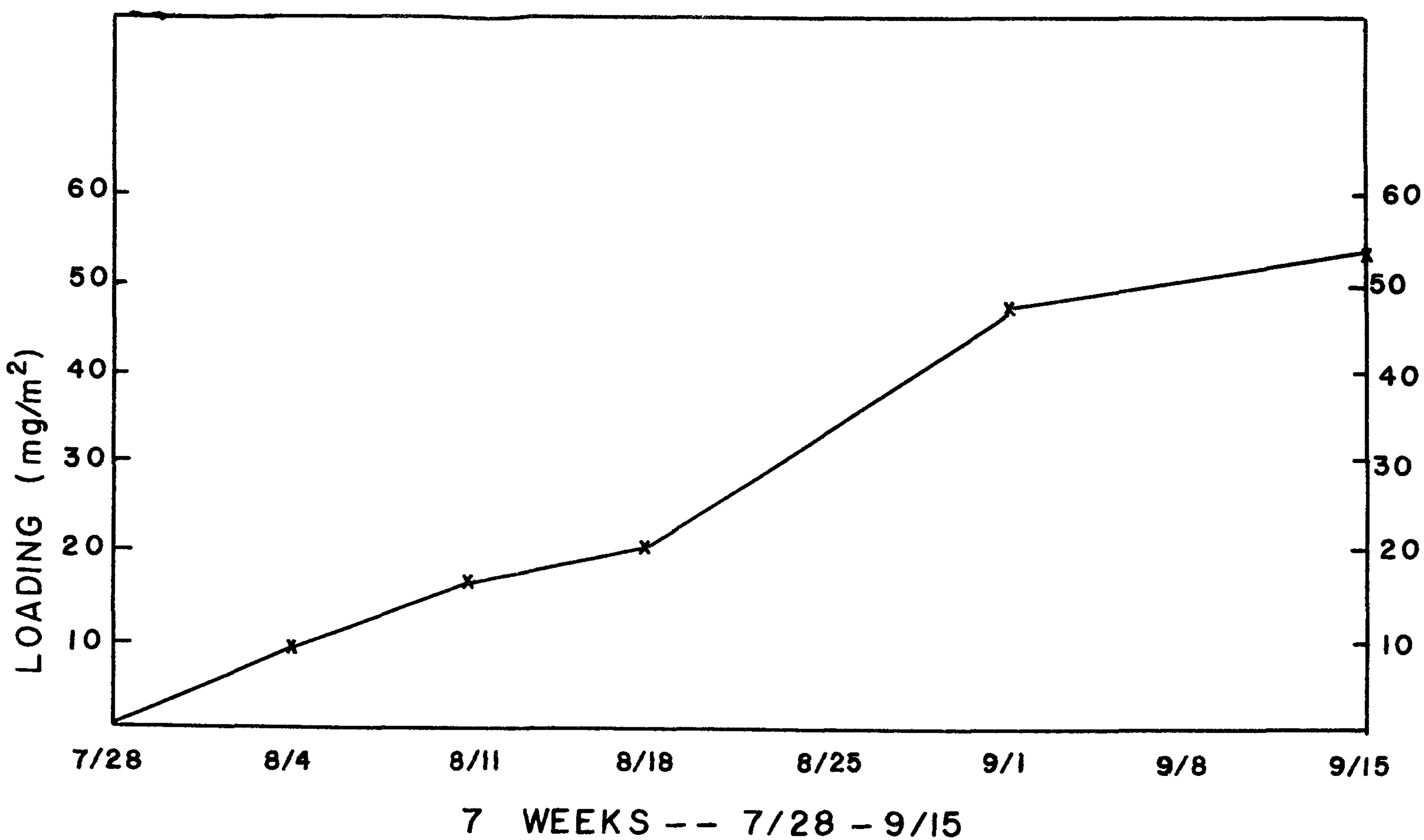
No significant rain event took place in the week of 9/1 -9/8. The collection flasks were left on for the following week and a complete set of data was obtained for the four operational samplers (Appendix E Figs. 3 and 4). Since this data represents limited temporal measurements, and thus can only be considered preliminary, very few conclusions should be drawn, especially with reference to any trends. Based on this data then, the distribution should not be considered typical nor, for that matter, atypical.

However, as a preliminary exercise, and as an insight into how this and subsequent data will be utilized, it might be constructive to calculate the total deposition over the watershed by rain of each element based on the average loading. For Mg, the figure is 760 kg and for Ca 3900 kg. This is thus based on a depositional period of two weeks.

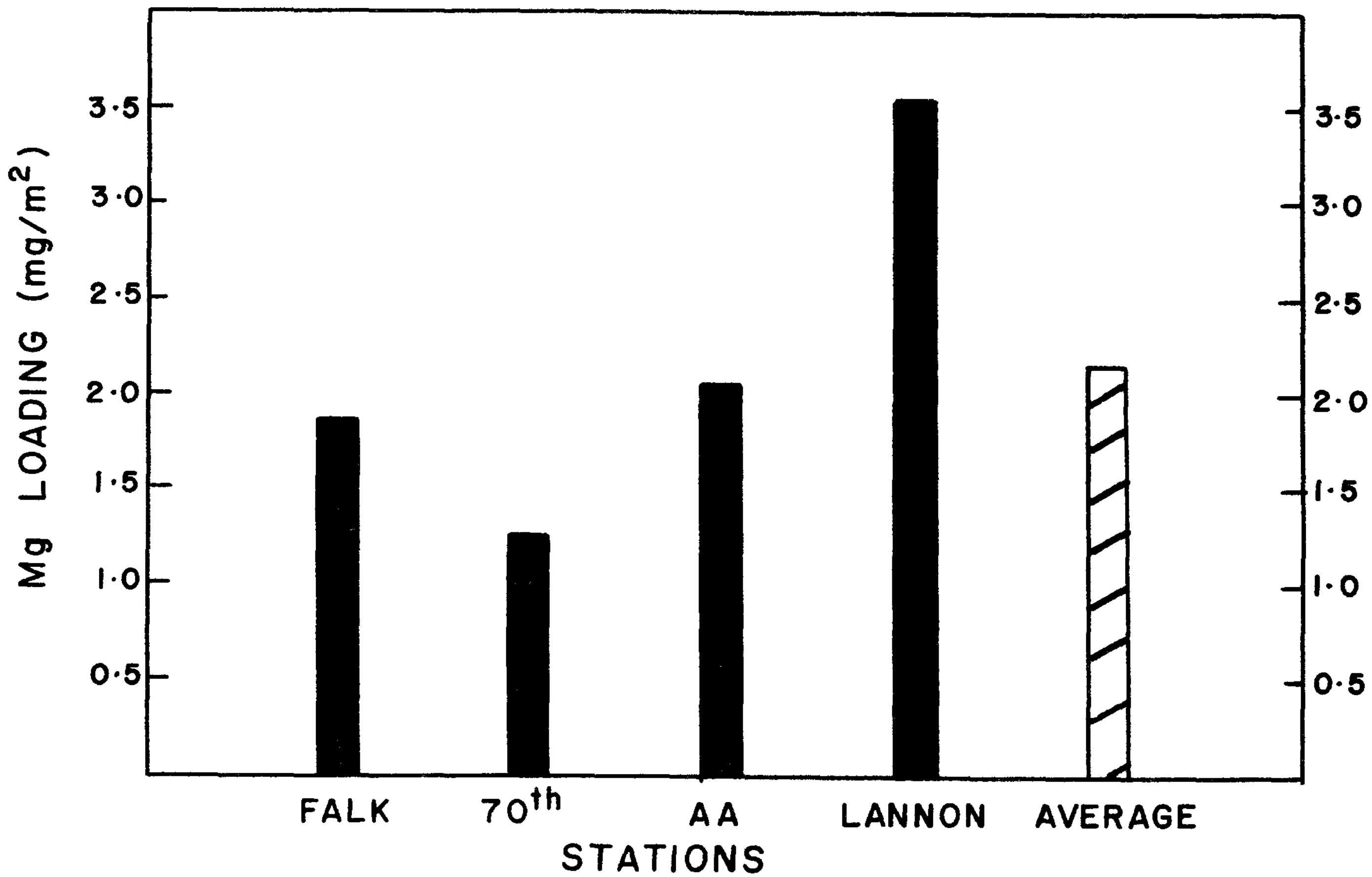
It is expected that the concentration of an element in rain depends upon several factors, i.e.: (1) volume of rain, (2) local sources, (3) time since last precipitation event, (4) time of day, and (5) season. With collection of more data and with a few more sites, it should become easier to detect the correlations between each factor and the elemental



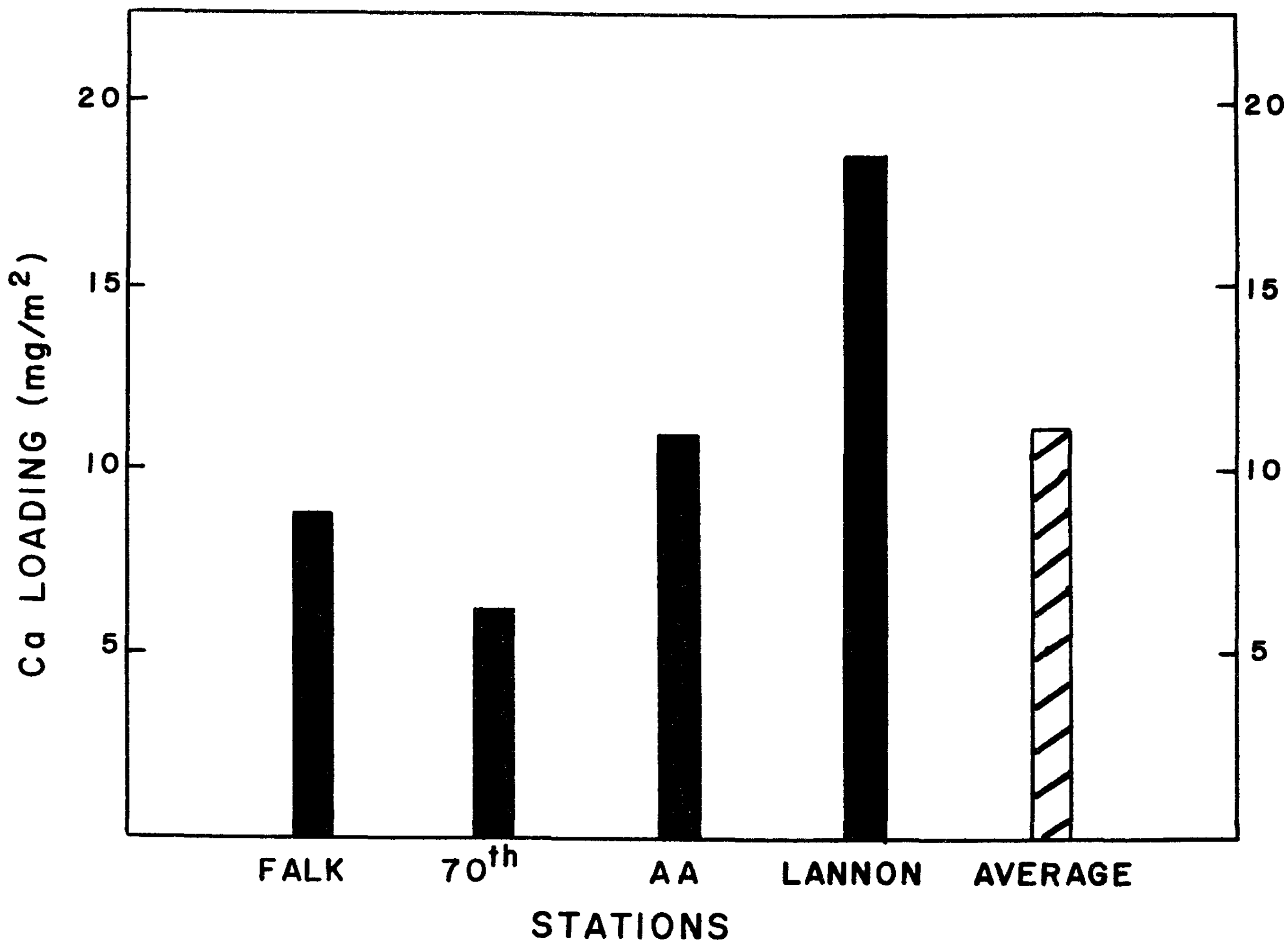
Appendix E Fig. 1. Cumulative magnesium loadings by wet deposition at 70th Street (12.7 mg/m^2 in 7 weeks.



Appendix E Fig. 2. Cumulative calcium loading by wet deposition at 70th Street (53.2 mg/m^2 in 7 weeks).



Appendix E Fig. 3. Magnesium loading by wet deposition, 9/1 - 9/15.



Appendix E Fig. 4. Calcium loading by wet deposition, 9/1 - 9/15.

concentrations in rain. A weak correlation between volume and concentration is already evident.

The data are still subject to modification once figures for the exact amount of precipitation are obtained. The U.S. Geological Survey maintains rain gauges at the 70th Street and Lannon Road sites. Once these data are obtained further comparisons of the different areas will provide more information.

Hi-Volume Sampling Program

An alternate humidity equilibration and weighing system had to be constructed when it became evident that the original equipment needed months of overhauling. The new system is now operational.

Mass flow controllers have now been obtained for each air sampler. From the previous progress report it is recalled that the flow rate of the air sampler can vary considerably over time due primarily to clogging, but also due to humidity, barometric pressure, temperature, and line voltage changes. The error in a calculated concentration of air from an estimated flow proved to be significant, especially over an extended sampling period. The new equipment meets specifications set forth in the Federal Register and satisfies U.S. Environmental Protection Agency conditions.

Each constant flow controller must be calibrated. This is being done at the present time, and the first Hi-volume air sampler has been installed at the watershed. Sampling times extending from 24 hr to weekly intervals will be taken depending upon the information that is required. Weekly intervals will yield composite samples representing several meteorological conditions while shorter times (24-48 hr) yield more information about local sources and atmospheric loadings which can be related to one or two meterological conditions.

PCBs in Air

Previous studies have shown that PCBs in air most likely exist in the vapor phase. Less than 10% of total PCDs in air have been found in the particulate phase in samples taken over the Atlantic Ocean. These results, however, are inconclusive due to the fact that the sampling devices that were used by these researchers may have vaporized some of the PCBs off the particulate matter.

Because no uniformly accepted method presently exists for collecting PCBs in air, our present work has dealt with the evaluation of collection media. Since PCBs may exist partially in the vapor phase, a filter cannot be used by itself, but must be used in conjunction with a PCB adsorbent material. Several materials have been tried in our laboratory--florisil, magnesium-silica gel catalyst, polyurethane foam, XAD-2 resin, and polyurethane foam coated with silicone oil. To determine their respective retention characteristics fro PCBs, each material was spiked with ^{14}C-labeled 2,5,2',5'-tetrachlorobiphenyl. Volumes of air ranging from 10 to 20 m^3 of air were drawn through each respective column material. In each case two successive columns were used and the flow rate ranged from 3 to 9 ℓ/min. The results indicate that XAD-2 resins are the most efficient in retaining the PCB during the above conditions.

As a second aspect of this study PCB retention capacity of the XAD-2 resin has been investigated. The tetrachlorobiphenyl was vaporized in the injection port of a gas chromatograph and then pulled through a series of two columns. Virtually all of the PCB was recovered from the first column.

In the future, samplers which contain both filters for filtering particulate matter and adsorbent material for PCB collections will be tested on the Menomonee River watershed.

APPENDIX F

REMOTE SENSING PROGRAM

The objectives of this portion of the project are to develop remote sensing techniques that will provide information in a compatible form, computer or otherwise, to the modeling and any other interested group. These techniques involve the digital analysis of aerial photographic imagery. The two groups that are presently working on these techniques are based at The Pennsylvania State University and the University of Wisconsin-Madison.

Over the past year a number of new developments have changed our approach to fulfilling the objectives. We have traded in the old scanning microdensitometer system, the Optronics P-1000, which was used to convert the photographic image to a digital image for a new system that is more versatile and compatible with our analysis techniques. This new system, the Optronics P-1700, also gives us the additional capability to not only convert a photographic image to a digital image but to reverse the process and take a digital image and make a photographic image of it. This allows us, for example, to do a land cover classification from a photographic image that has been converted to its digital form and then create a photographic image for the land cover classification. At this time, however, we are in a transition stage between the two scanner systems. The expected operational date for the new Optronics P-1700 system is February 1, 1977.

We are still obtaining high altitude aerial photographic imagery of 80% of the watershed, but have also started to acquire low altitude imagery of the four test subwatershed: Donges Bay Road, Noyes, Schoonmaker, and Honey Creek. Both Kodak color and color infrared imagery is being obtained in a 70mm format. This imagery will be scanned by the Optronics P-1700 system when it becomes operational.

The Pennsylvania State University and the University of Wisconsin personnel are also working on interpretation of color infrared imagery taken on July 24, 1976 and on a ERTS scene of the watershed from the fall of 1975.

In the upcoming year we propose to incorporate the Optronics P-1700 system with its new features into our analysis techniques and provide estimates of land cover and impervious surface in the four subwatersheds. We also hope to continue the photographic flights over the watershed.

APPENDIX G

LAND USE-WATER QUALITY MODELING

I. Development and Calibration of the Land Use - Water Quality Model

The major part of activities related to the development and programming of the model has been concluded. The present version of the LANDRUN model is capable of modeling the following processes:

1. Snowpack - snowmelt by the degree-day method.
2. Infiltration by the Holtan or Philip model.
3. Excess rain from precipitation, minus evaporation, infiltration, and depression and interception storage.
4. Routing of the excess rain by an Instantaneous Unit Hydrograph (IUH) method based on a kinematic wave formula or the empirical IUH formula of Sarma, Delleun and Rao. The routing is performed separately for pervious and impervious areas.
5. Dust and dirt cumulation in urban areas and washout.
6. Surface erosion by a modified quasi-dynamic Universal Soil Loss Equation which includes effects of both rainfall energy and sheet runoff.
7. Routing of the sediment.
8. Routing of volatile suspended solids and soil adsorbed pollutants as fractions of the suspended solids load.
9. Pollutants transport through a soil column which includes convection, adsorption, decay, volatilization and uptake. The dissolved and adsorbed upper layer pollutant is then routed with surface runoff and sediment. This dynamic model is applicable to phosphorus, organic chemicals and heavy metals. A more detailed description of this segment of the model is discussed in a subsequent section of the report.

A soil nitrogen segment has been developed and will be incorporated into the LANDRUN in the near future.

A schematic block diagram of the above models was presented in the April 1976 Semi-Annual Report.

Soil Adsorption Model[1]

Soil Adsorption Process

The process of fixation of pollutants by soil and dust particles can be accomplished either by precipitation or adsorption. Precipitation refers to a process in which pollutants precipitate (e.g. phosphates at higher pH, heavy metals) as compounds with low solubility. Adsorption is a chemical or physical process by which the pollutant molecules or ions are immobilized and adsorbed on the surface of soil particles. In the case of precipitation, the amount of pollutants in the particulate fraction is governed by the solubility of the compound in the soil environment. If adsorption is the prevailing process for removal of pollutants from the soil-water solution, the concentration of the pollutant in the solution is in a dynamic equilibrium with that adsorbed on the soil particle surfaces. The preferred form for describing this distribution is to express the quantity S as a function of C at fixed temperature, the quantity S(μg/g) being the amount of the pollutant adsorbed per unit weight of soil, and C (mg/l) being the concentration of the pollutant remaining in solution in equilibrium. Several mathematical descriptions for describing the adsorption equilibria (isotherms) have evolved in the literature, the Langmuir and Freundlich being the most common and most used. The Langmuir adsorption model is valid for a single layer adsorption and has been reported as

$$S = \frac{Q^o bC}{1+bC} \qquad (1)$$

Where Q^o is the mass of the pollutant adsorbed per unit weight of soil (μg/g) during the maximum saturation of the adsorbent, and b is a constant related to the energy of net enthalpy of adsorption (ml/μg).

The Freundlich isotherm is useful if the energy term, b, in the

---

[1]Excerpt from a paper by Novotny, Tran, Simsiman, and Chesters, "Mathematical Modeling of Runoff Contamination by Phosphorus", presented at the WPCF annual convention, Minneapolis, Oct. 5, 1976.

Langmuir isotherm varies as a function of the surface coverage, S. The Freundlich equation has the general form:

$$S = KC^{1/n} \tag{2}$$

where K and n are constants.

The process of adsorption is best known for phosphorus, but similar models can be applied to other pollutants. The soil sorptivity for phosphorus is related to several parameters. Aluminum and iron oxides and hydroxides are believed to be mainly responsible for phosphate retention in acid soils. In calcerous soils, phosphate is retained by the phosphate reaction with calcium ions of the soil. Sayers et al (1971) pointed out that organic matter as well as iron, aluminum, calcium, or other ions can retain and adsorb phosphate.

Several authors attempted to correlate phosphate sorptivity to various parameters. Representative data for 102 soils gathered from the literature (Vijayachandran and Harter, 1975; Gunary, 1970; Syers et al, 1973; Ballaux, 1975) were selected for the statistical multi-regression analysis. In summarizing the literature findings, it was found that the following parameters may be related to soil adsorption:

Aluminum content	(total, oxalate, exchangeable)
Iron content	(same as Al)
Clay content	
Organic content,	
pH	

Exchangeable Al can be closely correlated to pH of soil (Coleman, Weed, and McCracken, 1959; Franklin and Reisenauer, 1960). The effect of iron oxides and hydroxides is much less than that of aluminum (Franklin and Reisenauer, 1960), and there may be correlation between the iron components and clay content, pH, aluminum and possibly organic content. The best correlation was obtained with the following combination of variables:

CLAYC = clay content as a %; ORGC = organic carbon content as a %; and pH

and yielded the following equations:

For pH $\leq$ 7.0

$$Q^{o} = -3.47 + 11.60 \times 10^{-pH} + 10.66 \times CLAYC + 49.52 \times ORGC \qquad (3)$$

(Multiple correl. coeff. r = 0.80)

for pH > 7.0

$$Q^{o} = 207.09 - 73{,}327 \times 10^{-pH} + 2.81 \times CLAYC + 78.25 \times ORGC \qquad (4)$$

(Multiple correl. coeff. r = 0.63)

and

$$b = 0.061 = 0.027 \times CLAYC + 0.76 \times ORGC + 169{,}832 \times 10^{-pH} \qquad (5)$$

(Multiple correl. coeff. r = 0.54)

Soil adsorption characteristics for most of the common organic chemicals have been extensively reported in a publication edited by Goring and Hamaker (1972). As indicated by the authors, adsorption is almost linearly proportional to the organic carbon content. The soil adsorption characteristics for agricultural organic chemicals range from very low for dicamba to a high adsorption for DDT. It has been found that most of the organic chemicals adsorption follows the Freundlich adsorption isotherm better than the Langmuir isotherm. For computational reasons, the Langmuir isotherm is preferred in a model (Freundlich model is highly non-linear, requiring trial-and-error solution of mass balance equations, while the Langmuir isotherm will yield a quadratic model which can be directly solved). A simple transformation from Freundlich to Langmuir model may be possible assuming $bQ^{o} \rightarrow k$ and $(C^{1-1/m} - 1) \rightarrow bC$.

pH effect on adsorption of organic chemicals depends on their characteristics. Six different categories of chemicals can be distinguished in respect to pH effect: strong acids, weak acids, strong bases, weak bases, polar materials and neutral materials. Again the reader is referred to the publication by Goring and Hamaker (1972). The authors also discuss the effect of clay minerals and hydrated metal oxides present in soils which in addition to organic matter and pH may affect the soil adsorption for organic chemicals.

Adsorption of heavy metals (and other pollutants) by clay and clayey soils was studied by Sanks, LaPlante and Gloyna (1975). The authors studied adsorption of zinc, cadmium, lead and mercury by several Texas clays. The highest percentage of sorption from solution was observed for lead solution equilibrium concentrations never exceeded 0.03 mm/l. They concluded that within their experimental ranges almost all of the lead would be adsorbed. The amount adsorbed ranged from 0.3 mm/kg of clay to 90 mm/kg of clay while that for cadmium varied between 25 to 30 mm/kg of clay. The authors also report the isotherm characteristics.

Kinetics of Adsorption

The kinetics of the soil adsorption process can be expressed as:

$$P\ (s) \underset{K_{-1}}{\overset{K_1}{\rightleftarrows}} P\ (a)$$

where P (s) and P (a) are, respectively, pollutant in solution and in adsorbed form, and K_1 and K_{-1} are respective adsorption rates. Very few data were found which would enable quantification of the adsorption kinetics rates. Most of the information found in the literature relates to phosphorus. From the limited amount of data, (Coleman, Thorup and Jackson, 1960; Rennie and McKercher, 1959; Ryden, Syers and Harris, 1972) it is evident that phosphate sorption is not an instantaneous process. Adsorption studies over several days reveal that there is an initial stage lasting minutes or hours with a relatively fast adsorption rate followed by a slow adsorption process lasting days. For heavy metals and some pesticides, the data indicate that the process seems to be mostly completed within several hours. A first order adsorption model was accepted as a fair representation of the process, i.e.,

$$\frac{dS}{dt} = K\ (S_e - S) \qquad (6)$$

where K is the adsorption kinetic coefficient and S and S_e are, respectively, amount of pollutant adsorbed and adsorption equilibrium. From data by Ryder, Syers and Harris (1972), the adsorption kinetics coefficient for phosphorus was estimated to be about 0.12 $hour^{-1}$. Enfield (1974) discussed two simplified kinetic models. The first equation was a first order model of the type:

$$\frac{dS}{dt} = \alpha\ (KC - S) \tag{7}$$

the second equation was reported in the form:

$$\frac{dS}{dt} = aC^{b}S^{c} \tag{8}$$

In the above equations, α, K, a, b and c are statistical constants. Note that Eq. 7 is almost identical with Eq. 6 assuming that the adsorption equilibrium is linearly proportional to the pollutant concentration in the soil water solution. The experimental data by Enfield confirms the approximate magnitude of the adsorption coefficient as mentioned previously.

Decay, Sublimation and Transformation

Although not important for phosphorus and heavy metals, decay, sublimation or transformation processes must be included if the model is to describe behavior of such pollutants, as e.g. ammonia, pesticides, and herbicides. These processes are usually described by a first order reaction:

$$\frac{dC}{dt} = -K_{d}C - \frac{K_{s}}{Dx}C \tag{9}$$

where K_d is the decay (transformation rate), K_s is sublimation (stripping) rate and Dx is depth of the upper soil zone.

The system involves transport of three materials: water, sediment and pollutants. Although most of the discussion in this section was devoted to soil adsorption processes, it must be remembered that soil adsorption can be treated independently from other processes only in some oversimplified hydrologically steady-state case. In a real situation the model has to be linked to other components of the system.

Soil Adsorption Model

A block diagram of processes involved in the soil-water pollutant interaction is shown on Appendix G Fig. 1. To develop a model based on the diagram, one must perform a mass balance within the soil column system which -- among others -- would involve the following processes:

a) Adsorption and desorption of pollutants in the soil water and soil.

b) Convection of the pollutants by soil-water movement.

c) Dispersion of the pollutants due to a concentration gradient.

d) Pollutant uptake by plants in the root zone.

e) Pollutant uptake by soil microorganisms.

The above processes represent the components of the system. The inputs to the system are the pollutant contribution from rainfall, dust and dirt fallout, fertilizers and other agricultural chemicals. Most of the inputs are related to the land use. The output from the model is the pollutant distribution between the soil-water solution and the soil particles (adsorbed phase). The pollutant adsorbed on the soil particles in the upper soil layer may be lost by erosion processes and the dissolved pollutant at the lower boundary of the system will be transported to the groundwater system. The lower boundary of the soil adsorption system may be related to the depth of the root zone or the tillage depth of the crop land. In many cases, as it has been done in the proposed model, the soil zone depth coincides with the depth of the A-soil horizon.

The model consists of two components:

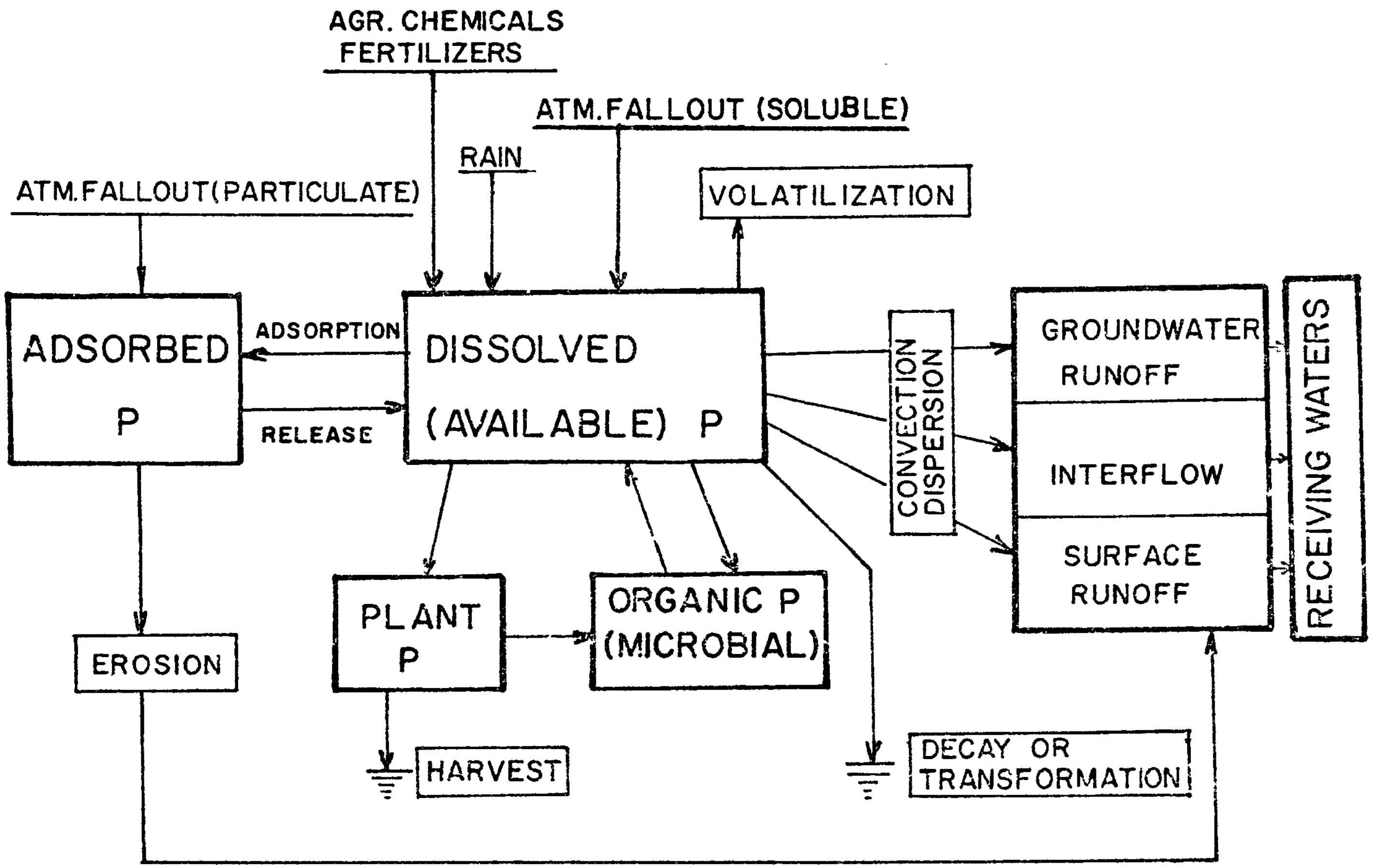
I. Free Phase Model (dissolved pollutant)

II. Sorbed Phase Model

The governing mathematical equations are:

<u>Free Phase</u>

$$\Theta \frac{\partial C}{\partial t} = D_L \frac{\partial^2 C}{\partial x^2} - V \frac{\partial C}{\partial x} - \frac{\partial S}{\partial t} \pm \Sigma N \qquad (10)$$



Appendix G Fig. 1. Block diagram of the soil-water-pollutant interaction.

Sorbed Phase

$$\frac{\partial S}{\partial t} = K\,(S_e - S) \quad \text{where} \quad S_e = \frac{Q^o bc}{1+bc} \tag{11}$$

The above model is a general kinetic model of chemical movement with sorption described by the Langmuir isotherm. In the model:

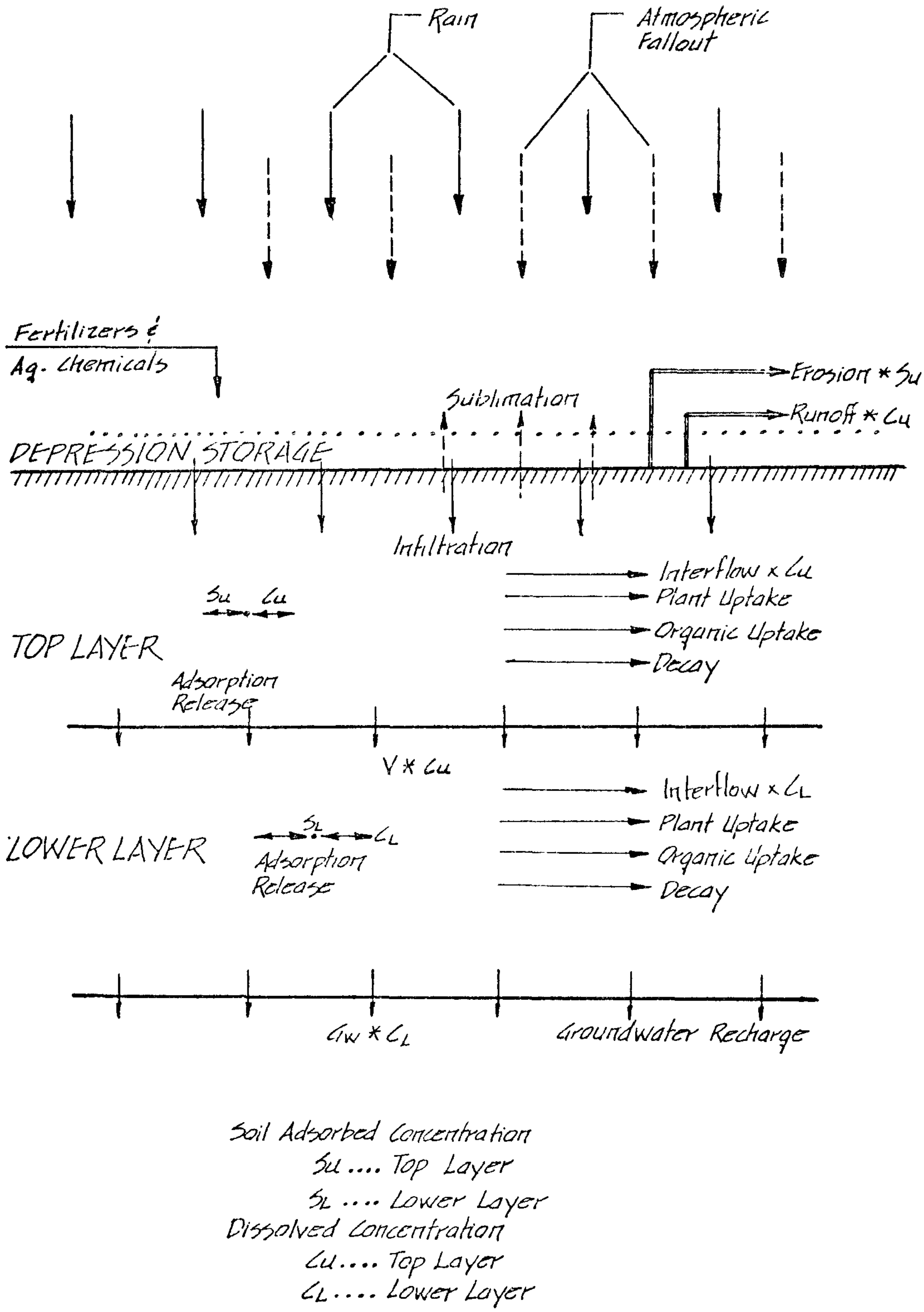
- C is the concentration of dissolved pollutant ($\mu g/cm^3$)
- S is the amount of pollutant sorbed on soil particles ($\mu g/g$)
- ρ is the spec. density of soil (g/cm^3)
- D_L is the apparent dispersion coefficient (cm^2/hr)
- V is the apparent soil water flow velocity (cm/hr)
- ΣN is the sum of sinks and sources of the pollutant within the soil volume ($\mu g/cm^3$ x hour)
- b is the partition coefficient ($cm^3/\mu g$)
- Q^o is the maximal sorptivity of the soil for the pollutant ($\mu g/g$)
- K is the adsorption or release rate coefficient for packed bed sorption (hr^{-1})
- S_e is the equilibrium of the sorbed phase with the free phase ($\mu g/g$)
- t is the time (hr)
- x is the depth (cm)
- Θ is the soil moisture (cm^3/cm^3)

The above model is non-linear and can be solved only numerically.

The schematic representation of the model solution is shown on Appendix G Fig. 2. To simplify the solution, the soil zone is divided into an upper layer exposed to the atmosphere and rest of the soil zone. For the numerical solution, the following relationships replaced the analytical form of Eqs. 10 and 11.

For the free phase of the upper layer model

$$\begin{aligned}\Theta \frac{C_u^{j+1} - C_u^j}{DT} \times VOL_U &= (RAIN \times CR \times A) + (ATMFL_S + FERTIL/DT)A \\ &+ (ORGREL - PLANTU)(VOL_U) - \frac{\partial S_u}{\partial t}\,(VOL_U) \\ &- \frac{C_u^{j+1} + C_u^j}{2}\,(V \times A + K_d \times Vol_u \times \Theta + K_{SUB} \times A \\ &+ ANRAIN \times A)\end{aligned} \tag{12}$$



Appendix G Fig. 2. Pollutant transport and transformation processes in soil columns.

For the sorbed phase of the upper layer model

$$\rho \frac{S_w^{j+1}-S_U^j}{DT} \; VOL_U = K_{SW} \; VOL_U \; S_e - \frac{S_u^{j+1}+S_u^j}{2} - SOILLS \times \frac{S_u^{j+1}+S_u^j}{2} + ATMFL_P \qquad (13)$$

For the free phase of the lower zone model

$$\Theta \frac{C_L^{j+1} - C_L^j}{2DT} VOL_L = V\frac{C_u^{j+1} + C_u^j}{2} - GINFIL \frac{C_L^{j+1} + C_L^j}{2} A \qquad (14)$$

$$+ (ORGREL - PLANTU)(VOL_L) - \rho \frac{\partial S_L}{\partial t} (VOL_L)$$

For the sorbed phase of the lower zone model

$$\frac{\partial S_u}{\partial t} \; VOL_L = K_{SW} \; S_e - \frac{S_L^{j+1} + S_L^j}{2} \; VOL_L \qquad (15)$$

where in addition to the variables described previously:

VOL is the volume of the soil layer (= A x DX)

A is the surface area

RAIN is the rain intensity

CR is the concentration of the pollutants in the rain

FERTIL is the pollutant contribution from fertilizers

ATMFL is the atmospheric fallout

ORGREL is the release of pollutant from the soil organic matter

PLANTU is the uptake of the pollutant into crops tissue

j is the time subscript

DT is the time step

Dx is the depth of soil layer

Using the Langmuir isotherm the adsorbed equilibrium concentration becomes:

$$S_e = \frac{bQ^o \; (C^j + C^{j+1})}{2+b \; (C^j + C^{j+1})}$$

Calibration of the LANDRUN Model

Three subwatersheds have been selected for calibration of the model. The selection was based on the availability of field data and on the character of the land use pattern within the subwatersheds (Appendix G Fig. 3).

Donges Bay Road station (463001) collects water quantity and quality data of the Little Menomonee River. The watershed is mostly rural, slowly urbanizing. The drainage area is 21.4 km^2.

Noyes Creek station (413011) is located on a small (5.4 km^2) tributary of the Little Menomonee River. The prevailing land use in the watershed is residential lower density.

Schoonmaker Creek station (413010) is located in a small high-density residential subwatershed. Drainage area is 2.0 km^2.

From the available field data, three storms provided adequate calibration data:

April 24, 1976 Storm

This is a medium intensity, long duration storm preceded by six wet days. The amount of rain varied between the stations. All three stations measured flow, but only Donges Bay Road measured quality.

May 5, 1976 Storm

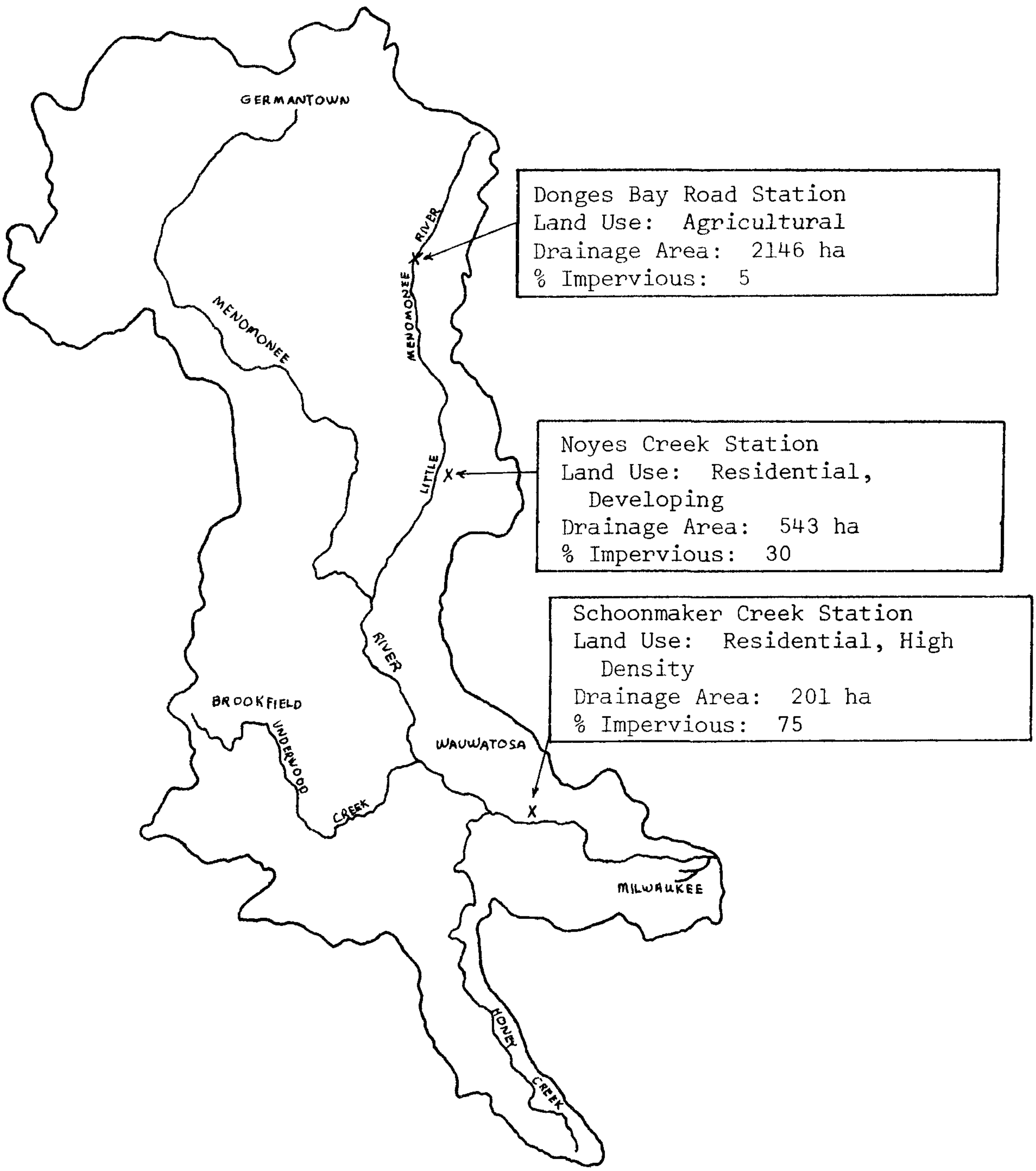
This is a high intensity, short duration (flushing) storm which followed nine days of dry weather. All three stations measured both flow and quality.

May 15, 1976 Storm

This is a long duration, low intensity storm.

Calibration Input Data

The model requires dividing the watershed into uniform areas based on the land use and soil characteristics. A land use with two different soil types must be computed as two sub-areas. For each sub-area the following input parameters must be furnished:



Appendix G Fig. 3. Menomonee River watershed showing locations of model calibration stations.

<u>Area Description</u>

Area as percent of the total area

Percent imperviousness

Slope

Manning roughness coefficient

for pervious areas (default 0.25)

for impervious areas (default 0.012)

Depression and interception storage

for pervious areas (default 0.65 cm)

for impervious areas (default 0.16 cm)

Portion of impervious areas directly connected to the channel

<u>Soil Data</u>

Saturation permeability of A-horizon

Saturation permeability of B-horizon (default = A horizon)

Porosity

0.3 bar moisture

15 bar moisture

Coefficient for Holtan infiltration equation (if selected)

Depth of A-horizon

<u>Erosion Data</u>

Soil erodibility coefficient

Erosion control practice coefficient

Conservation practice coefficient

<u>Soil Adsorption</u>

Clay content

Organic content

pH

Decay and volatilization coefficients

Adsorption isotherm characteristics

Adsorption kinetic coefficient

Dust and Dirt Accumulation Data for Urban Areas

Dust and dirt fallout

Washout coefficient

Sweeping efficiency

Dust and dirt composition

Salting

Percent of impervious areas affected by saltings

Amount of salt applied during a snow storm

Salt composition

Fertilizer Use

Amount of fertilizer applied

Composition

Meteorological Data

Temperature

Evaporation

Rain Data

Rain Contamination

The above is a complete list of variables necessary to successfully run the model. Many variables have default values, i.e. a value will be substituted by the model if the information is not furnished. The default values are based on the literature or on experience with other models.

Data Sources

The land use data along with surface characteristics were obtained from the Southeastern Wisconsin Regional Planning Commission (SEWRPC). Most of the information on soil charactersitics was taken from U.S. Department of Agriculture (U.S.D.A.) soil maps. Additional information was obtained from the University of Wisconsin sources. Appendix G Table 1 shows the soil characteristics of major soils in the Little Menomonee River Basin.

Dust and dirt data were initially obtained from the Chicago study on

Appendix G Table 1. Ten major soil types surrounding the Donges Bay station (463001), Menomonee River watershed

Soil Type	Area (Acre)	% Total	Depth of A-horizon inch	Hydrologic Soil Group	pH	Clay %	Org. C* %	1/3 Bar Moisture %	15 Bar Moisture %	Avail.** h_2O in/in	Ext. Fe %	B.D.[+] g/cc	Permea-bility in/hr	Porosity %	CEC[++] ml/100 g
Ozaukee sil	2,514.4	[illegible]7.5	0-7	C	6.6-7.2	20.3-20.8	1.52-1.70		7.8-8.1	0.20	1.2-1.3	1.44-1.55	[illegible]	[illegible]	[illegible]
Mequon sil	449.7	8.5	0-11	C	7.4-7.8					0.20			0.63-2.0		
Ogden muck	400.0	7.6	0.36	D	6.6-7.8					70.20			0.63-2.0		
Pella sil	250.2	4.7		D											
Theresa sil	179.7	3.4	0-12	B	6.6-7.8	11.7-13.1	3.89-4.30	34.6	10.5	0.20		1.20-1.31	0.63-2.0		21.1-[illegible]
Sebewa sil	117.0	2.2	0.16	D	7.4-7.8					0.20			0.63-2.0		
Colwood sil	[illegible]	2.0	0-9	D	7.4-7.9					0.20			0.63-2.		
Ashkum sil	124.3	[illegible]	0-10	D	7.4-7.8	39.7-39.7	3.60-5.68		16.2-19.2	0.20	[illegible]-1.2	1.50-1.56	0.63-2.0		[illegible]-21.2
Fox	97.0	1.8	[illegible]-9	B	6.1-7.[illegible]					0.16					
Kibbie sil	75.4	1.4	0-7	B	7.4-7.3					0.16			0.63-2.0		
Total	5,297.7														

*Organic carbon. to convert organic carbon to organic matter divide Org. C by 0.60

**Available water

+Bulk density

++Cation exchange capacity

pollution from urban areas. These data did not reflect accurately the pollution loads in the upper part of the watershed and had to be assigned according to the real field data.

Meteorological data for each storm were based on the information from the U.S. Weather Bureau at Mitchell Field, with the exception of rain data which was furnished by the U.S. Geological Survey (U.S.G.S.) rain gauges located near or at the water quantity and quality monitoring stations.

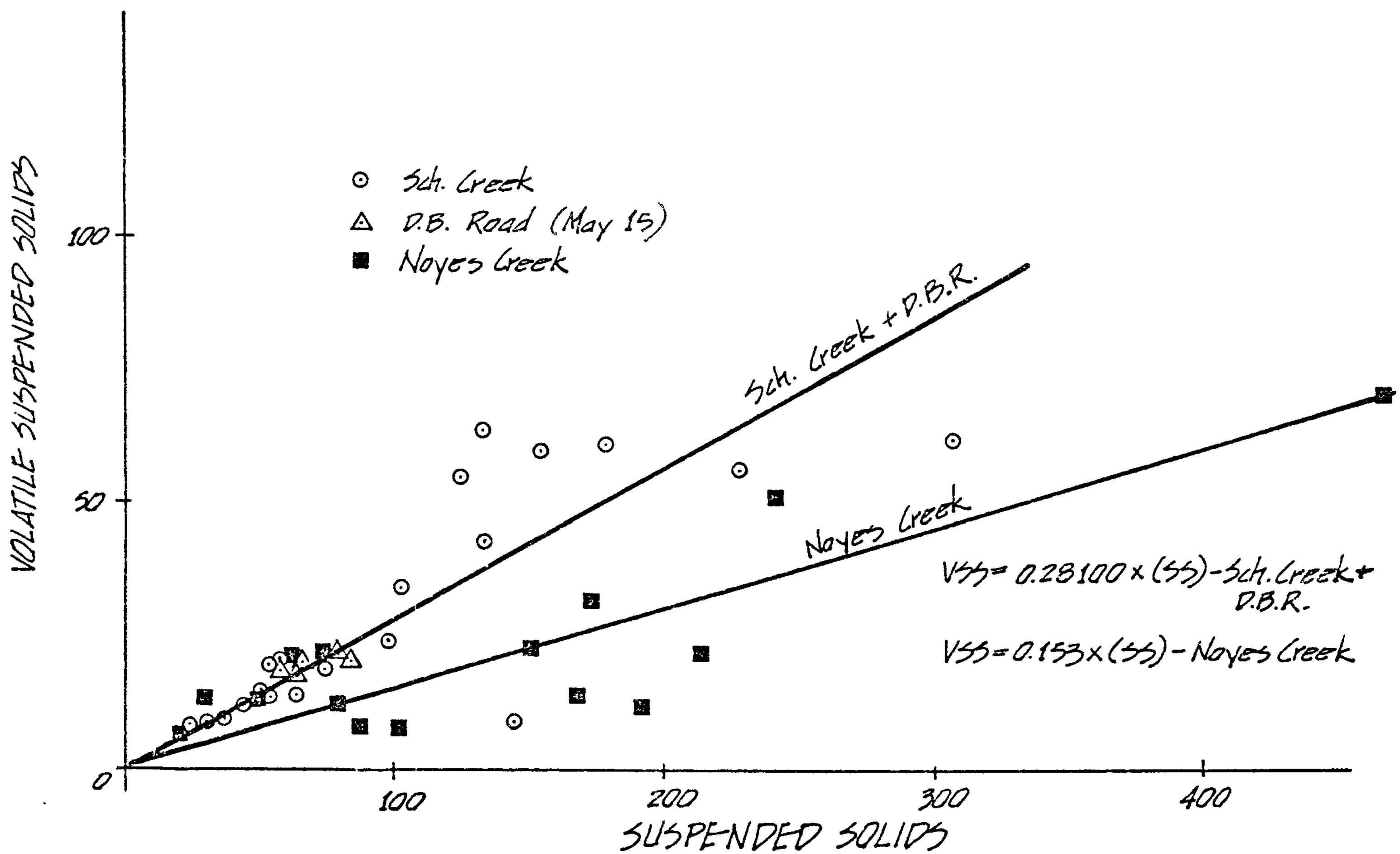
Discussion of Results

As it can be seen from Appendix G Table 1, the input variables are not fixed values, but rather statistical quantities with certain ranges of occurrence. Thus, the true values of the inputs are never known and can be only roughly estimated. The calibration, which is in a sense a trial-and-error process requiring some experience, proceeds in two steps. The coefficients are estimated by comparing output for one storm with measured data; secondly, the coefficients are verified if the input for another storm reflects the measured data. The calibration must be firstly accomplished for the hydrology, i.e. rainfall-runoff relationship, then for sediments and lastly, for pollutants.

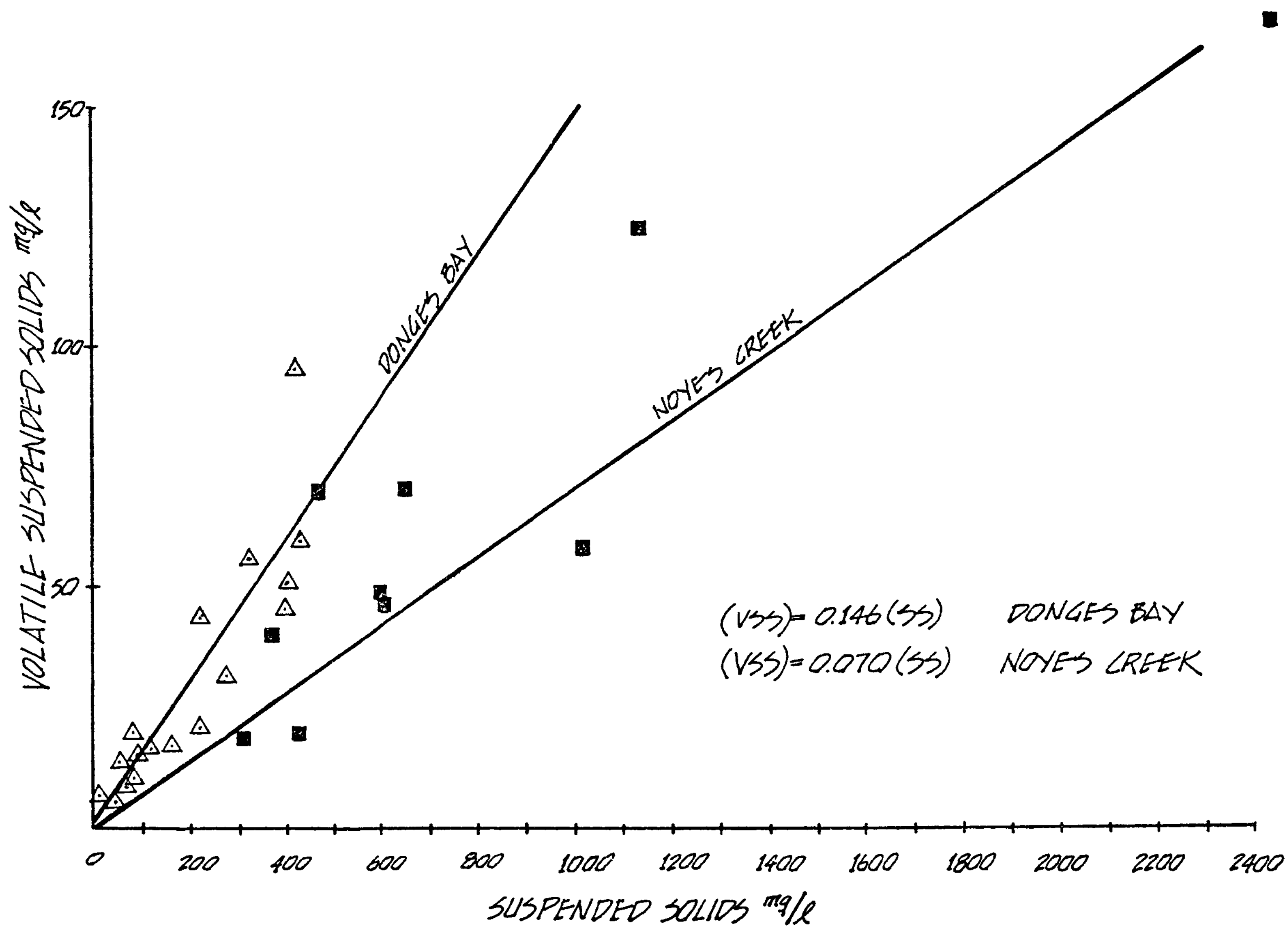
The results of the calibration rains are shown on Appendix G Figs. 4 through 30. At this step of the research the LANDRUN model was calibrated and practically debugged for runoff (hydrology), sediment transport, dust and dirt, volatile suspended solids, and the soil adsorbed pollutant, phosphorous.

The outputs for the April 24 and May 5 storms adequately follow the measured data for all three stations. The May 5 storm was the main calibration storm. Difficulties were encountered with the May 15 storm at Noyes Creek station where the hydrograph seems to be shifted by two hours. This time error seems to be unlikely for such a relatively small watershed.

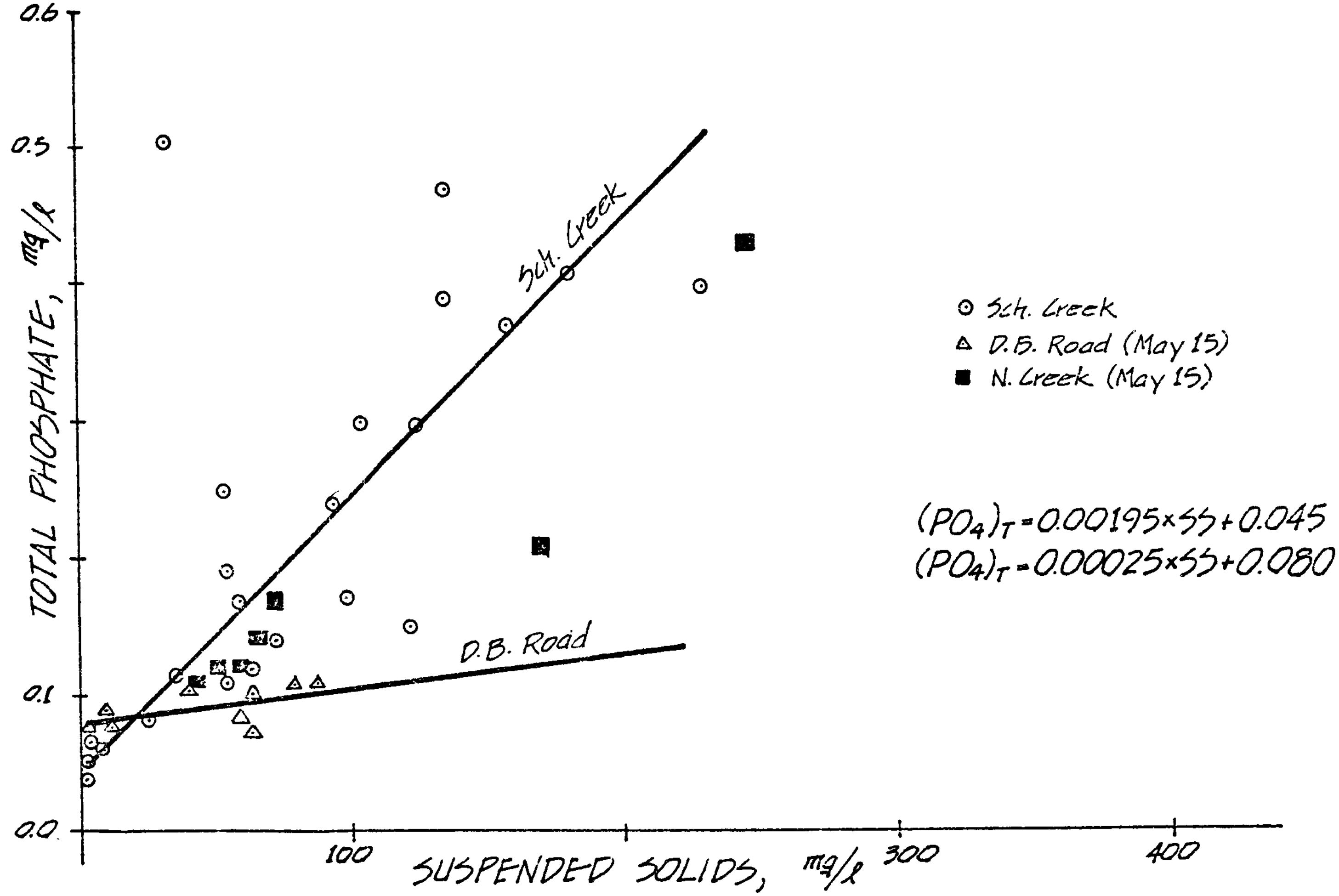
The output in urban areas is most sensitive to the assigned variable which characterizes the portion of impervious areas not directly connected with the channel. This fraction of impervious areas includes rooftops



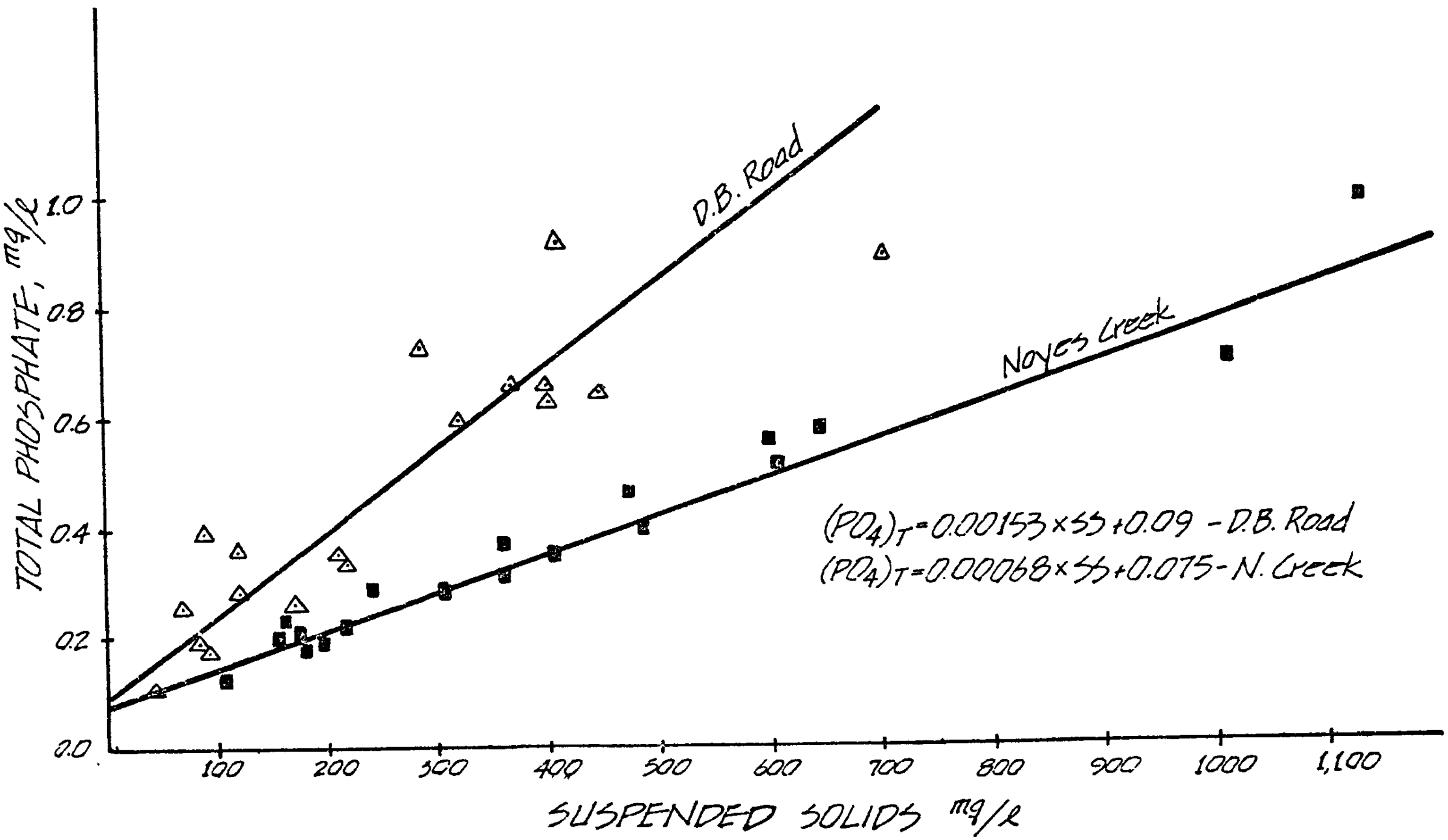
Appendix G Fig. 4. Organic content of dust and dirt at Schoonmaker Creek, Donges Bay Road and Noyes Creek.



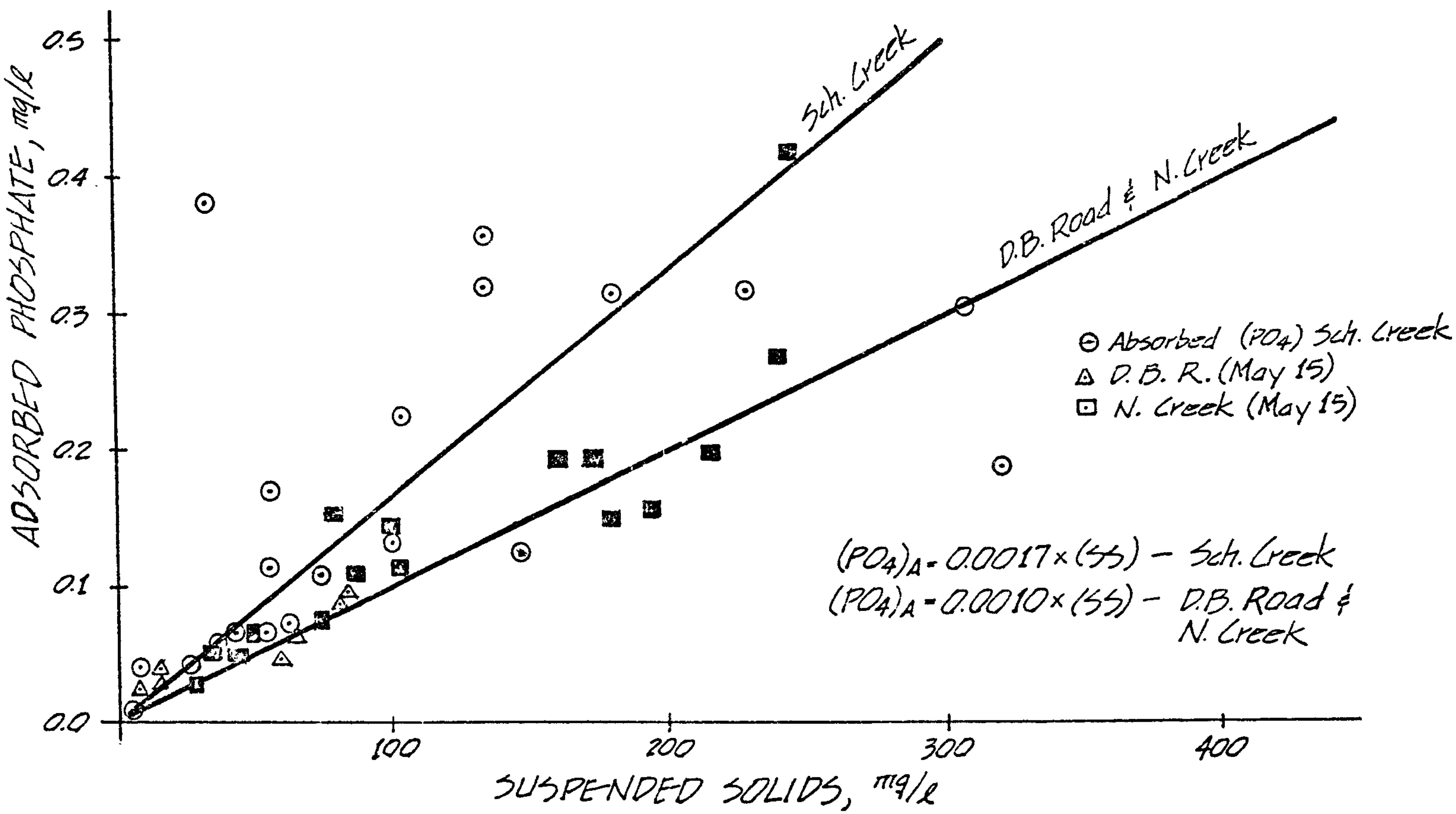
Appendix G Fig. 5. Organic content of soil sediment at Donges Bay Road and Noyes Creek.



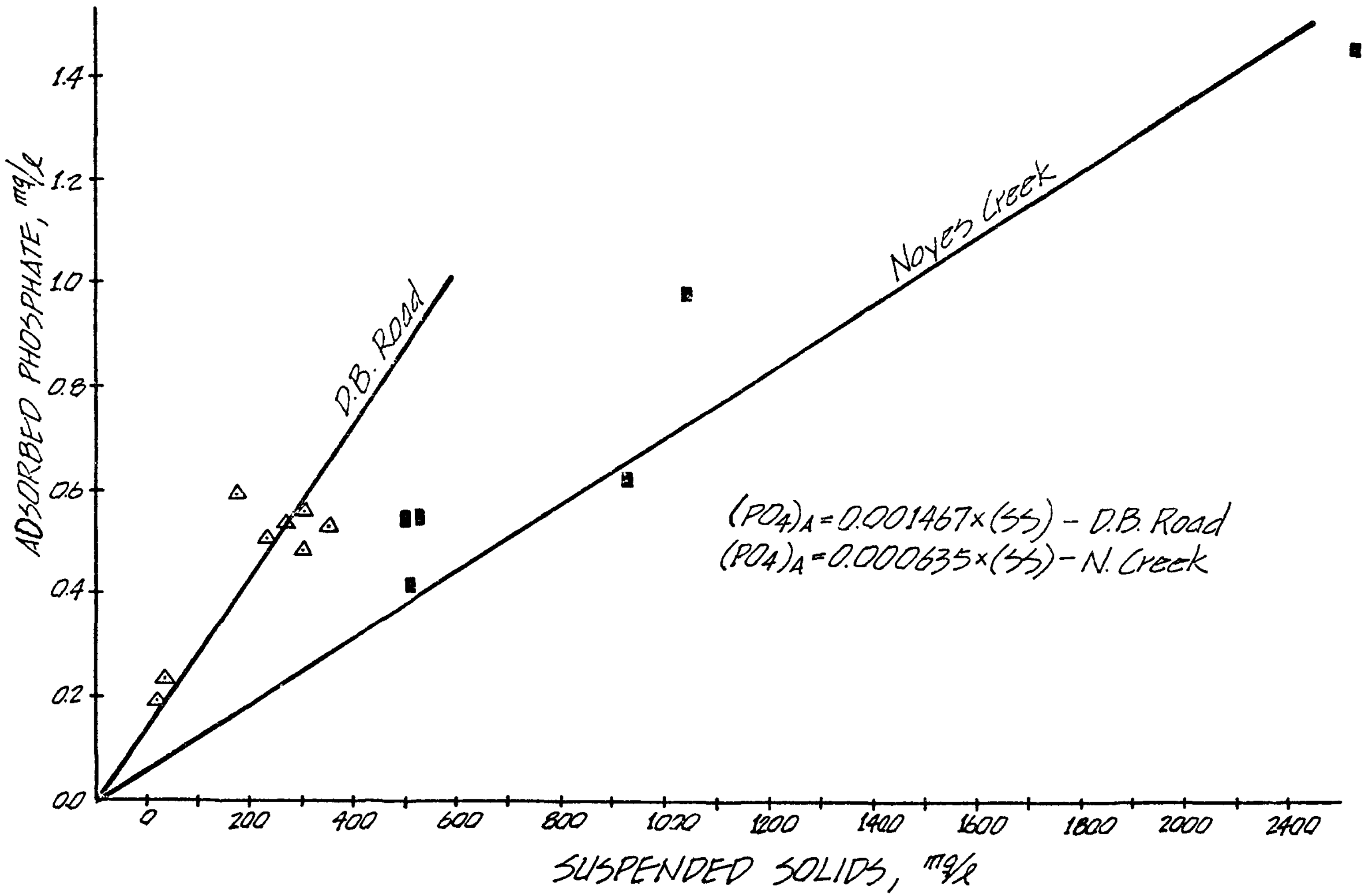
Appendix G Fig. 6. Total phosphate vs. suspended solids (dust and dirt) at Schoonmaker Creek, Donges Bay Road and Noyes Creek.



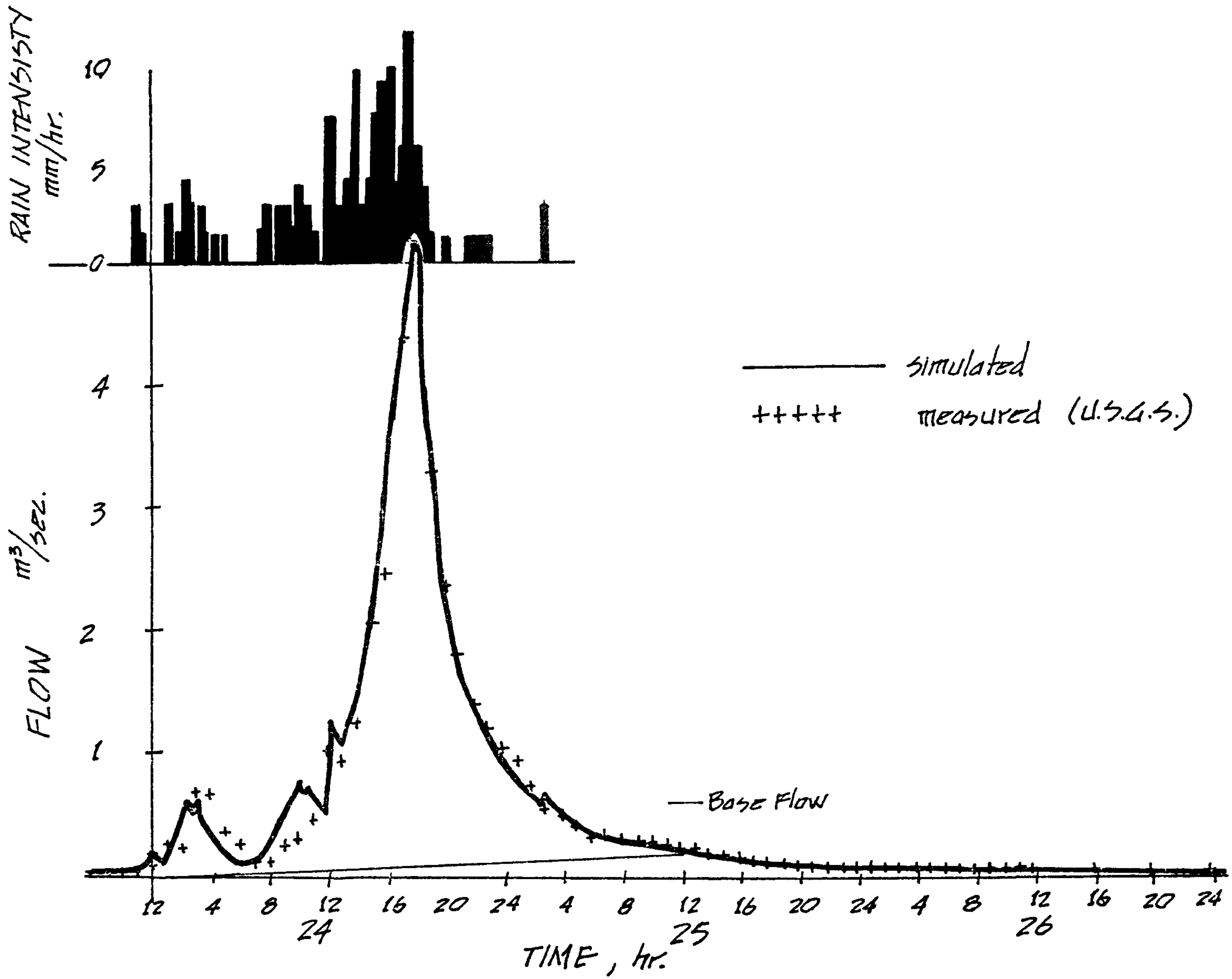
Appendix G Fig. 7. Total phosphate vs. suspended sediment (soil) at Donges Bay Road and Noyes Creek.



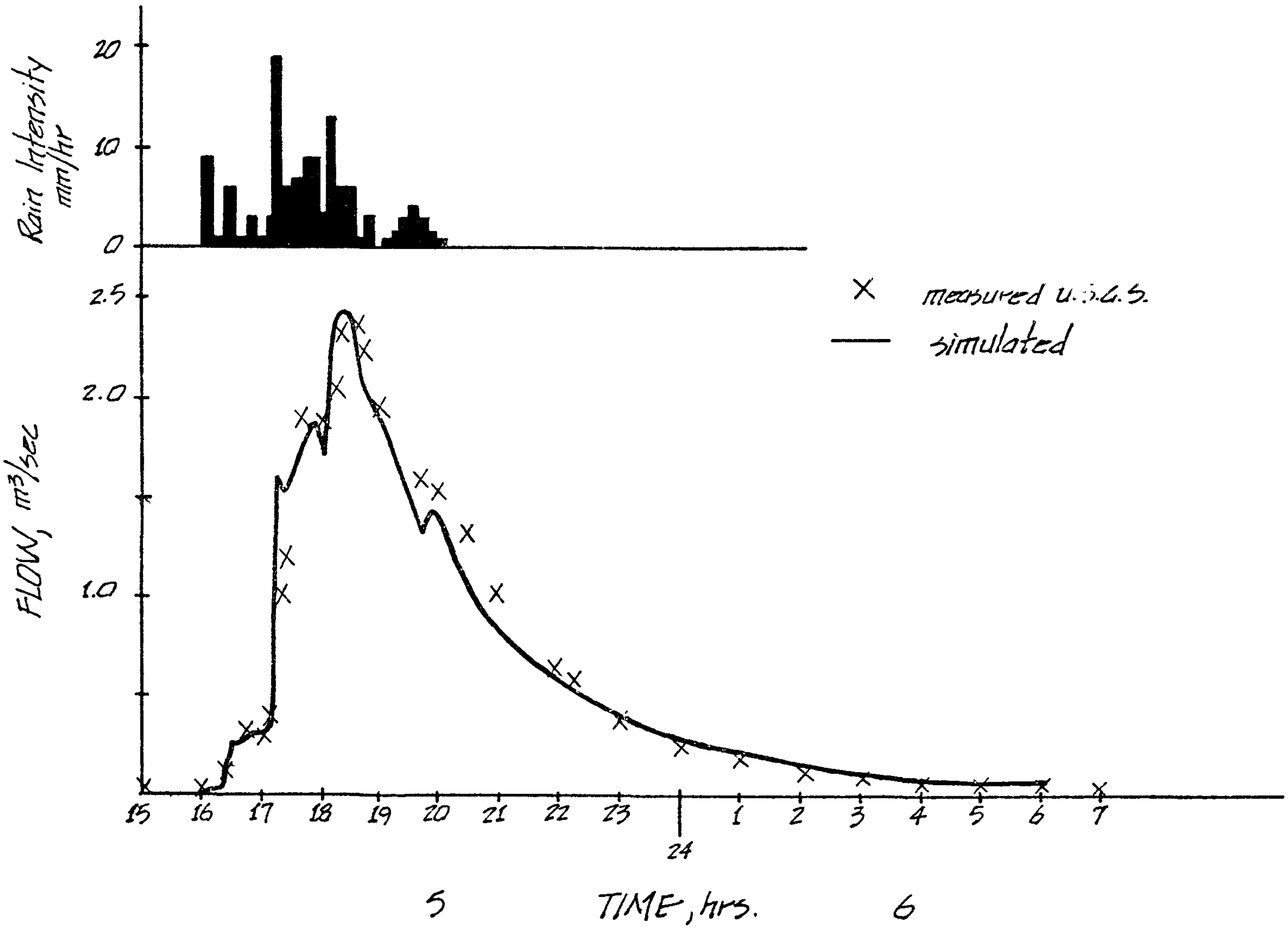
Appendix G Fig. 8. Adsorbed phosphate vs. suspended solids (dust and dirt) at Donges Bay Road, Noyes and Schoonmaker Creeks.



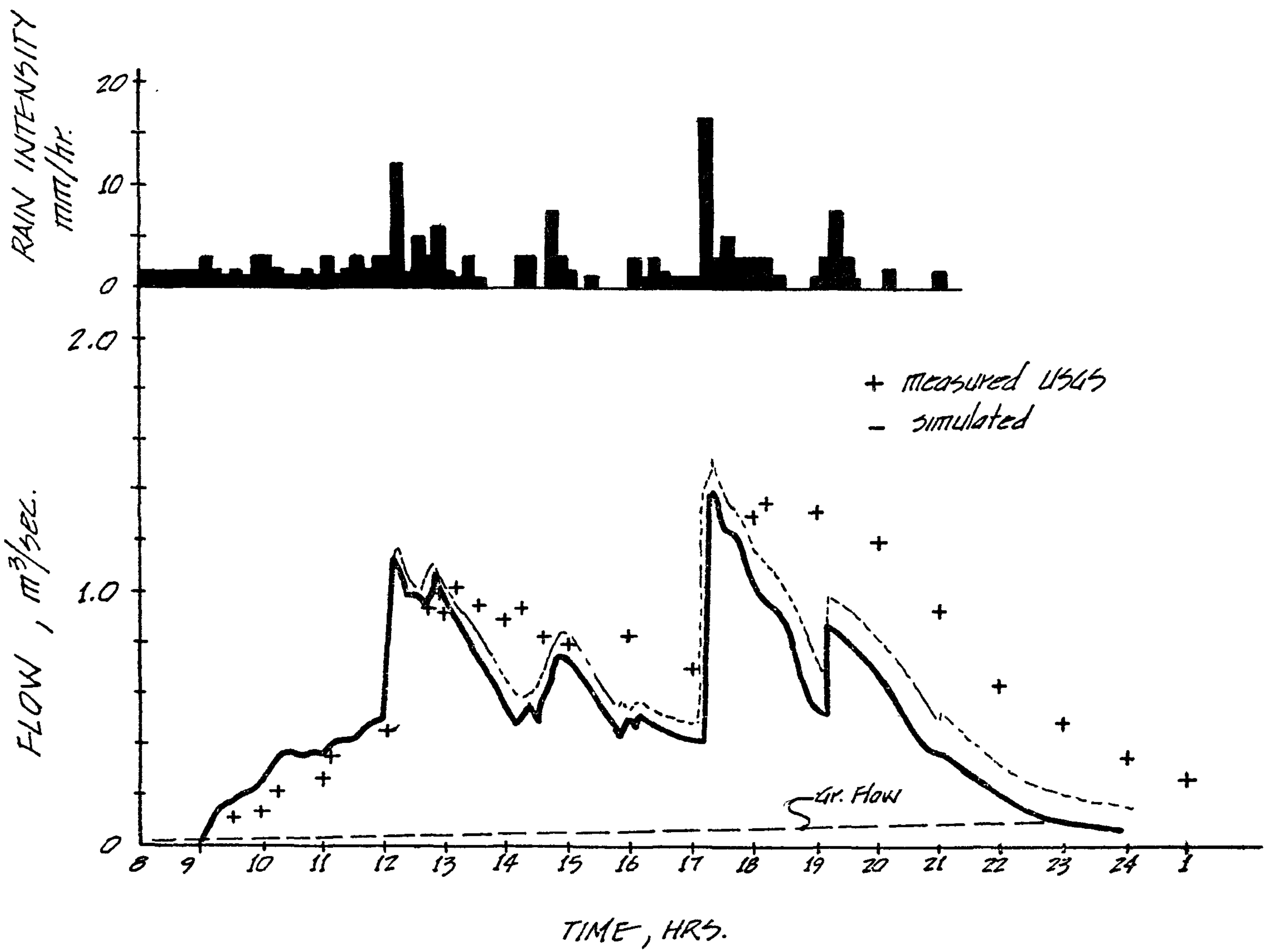
Appendix G Fig. 9. Adsorbed phosphate vs. suspended solids at Donges Bay Road and Noyes Creek.



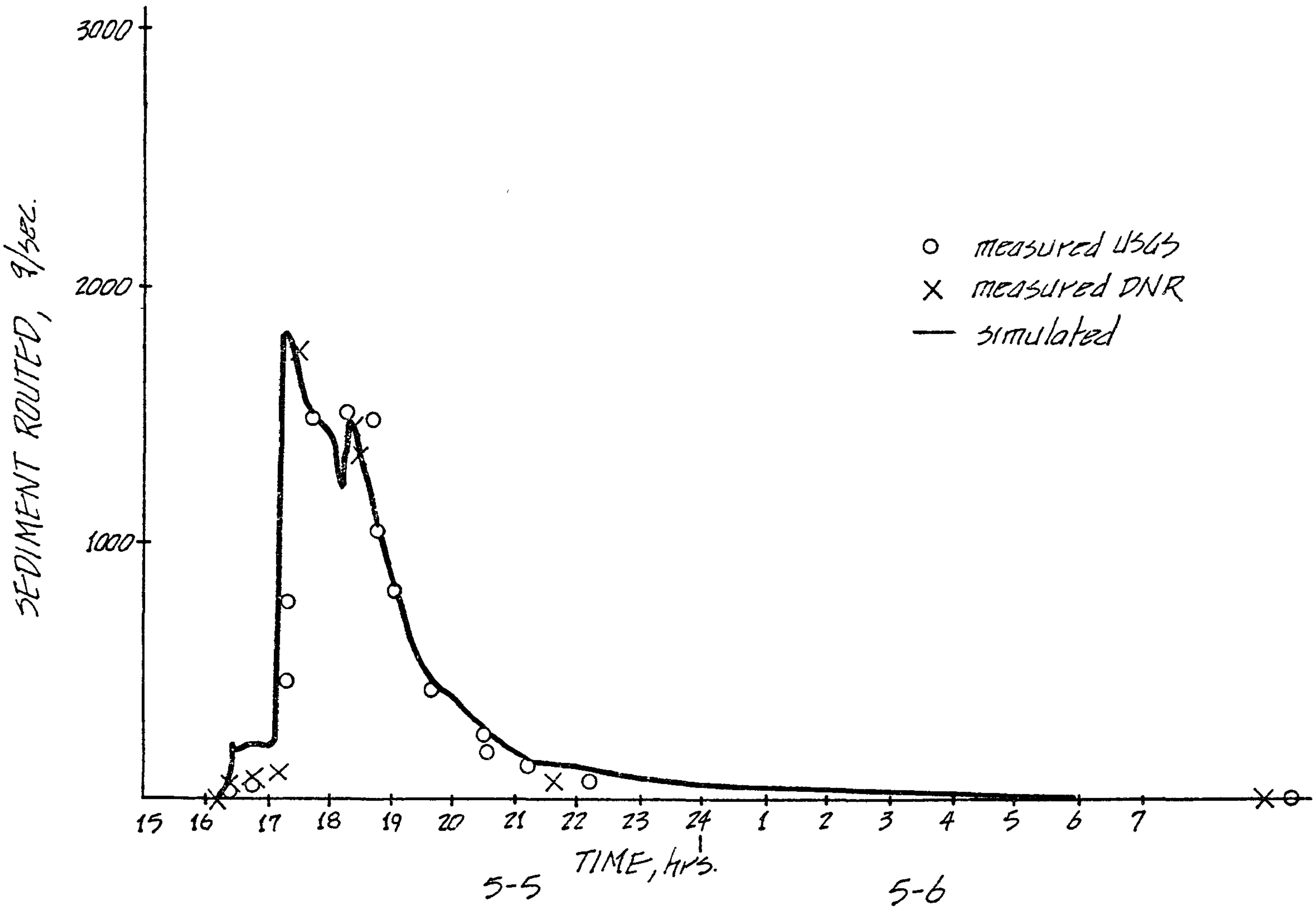
Appendix G Fig. 10. Noyes Creek hydrograph, April 24, 1976 storm.



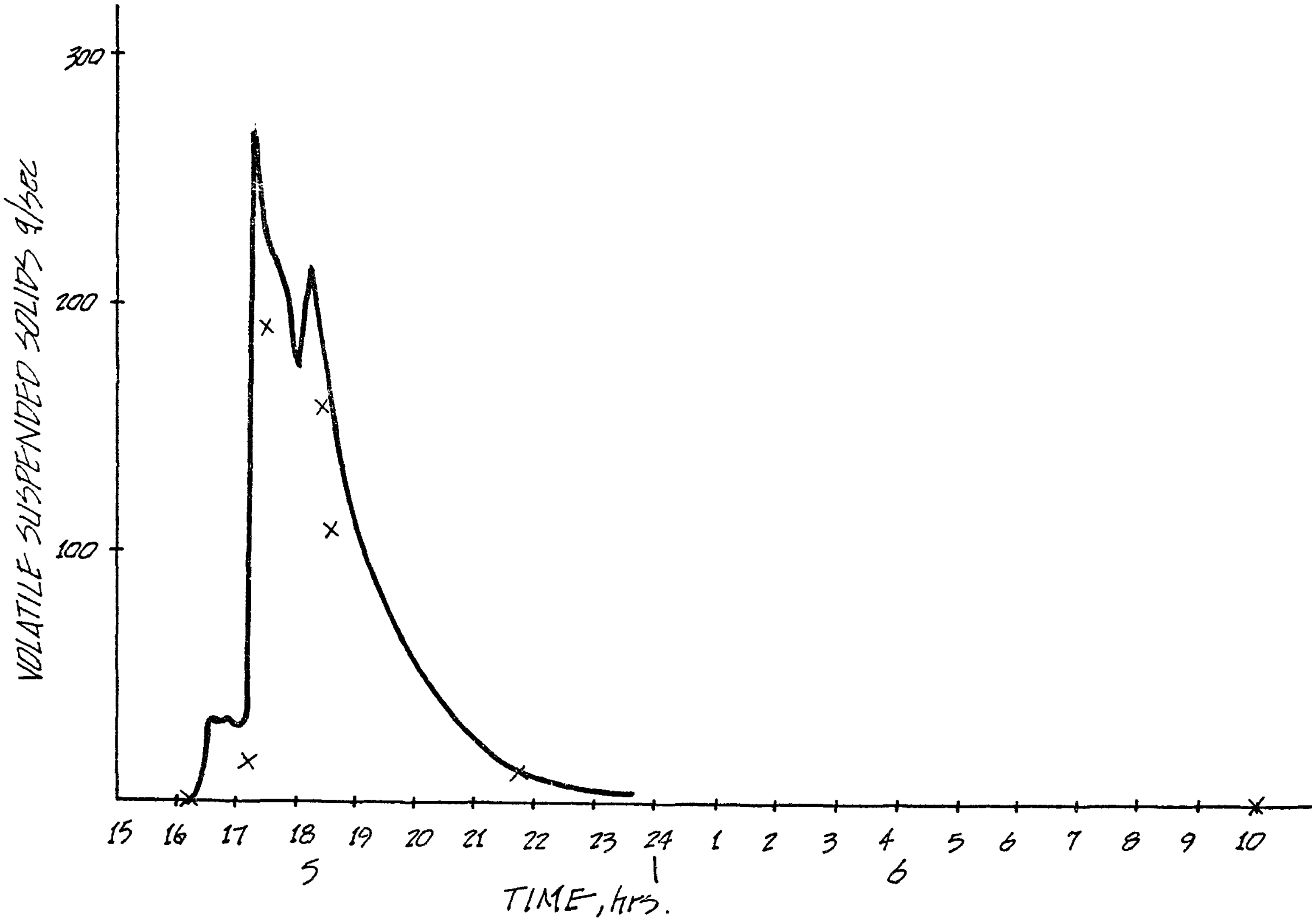
Appendix G Fig. 11. Noyes Creek hydrograph, May 5, 1976 storm.



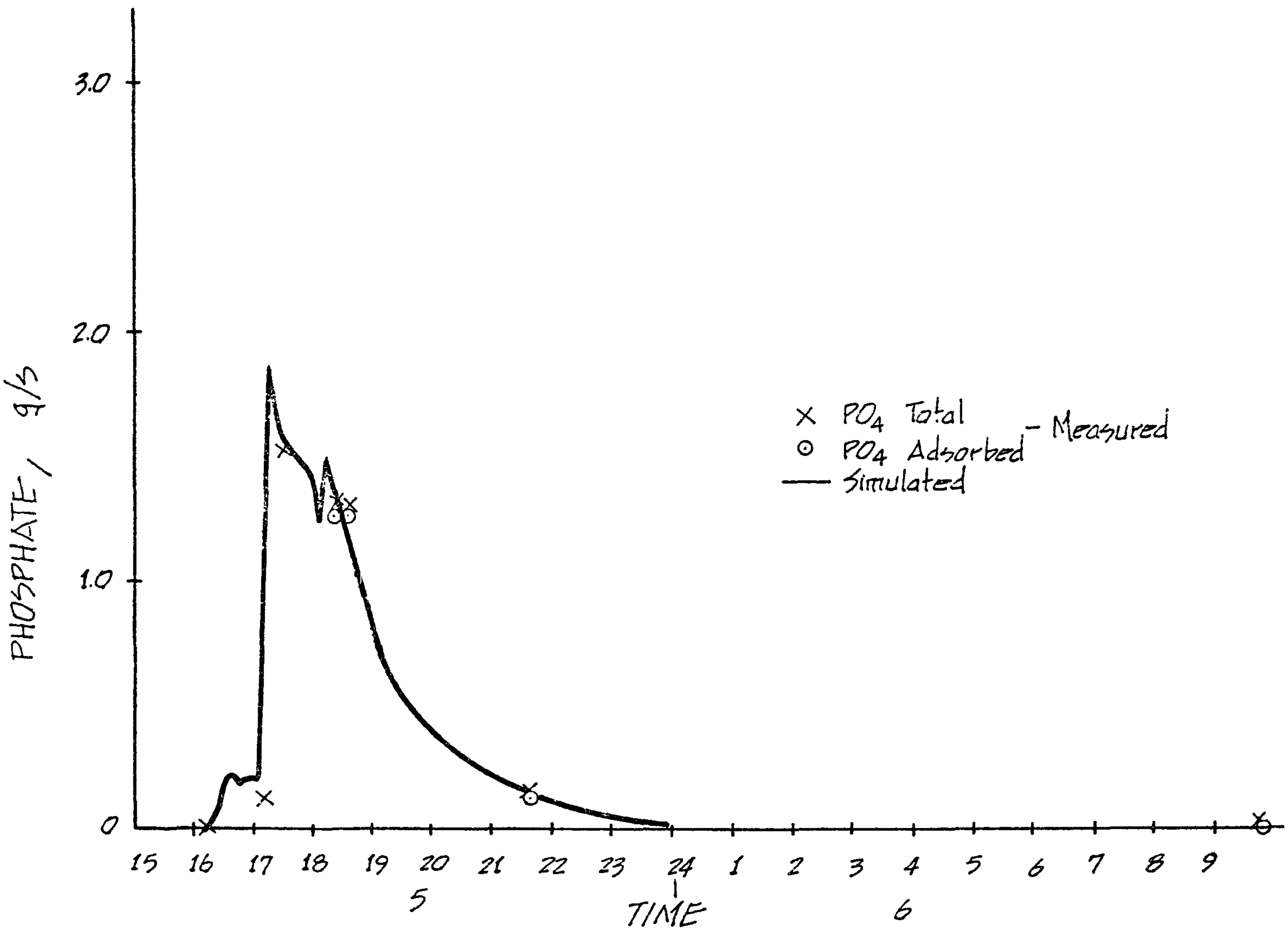
Appendix G Fig. 12. Noyes Creek hydrograph for May 15, 1976 storm.



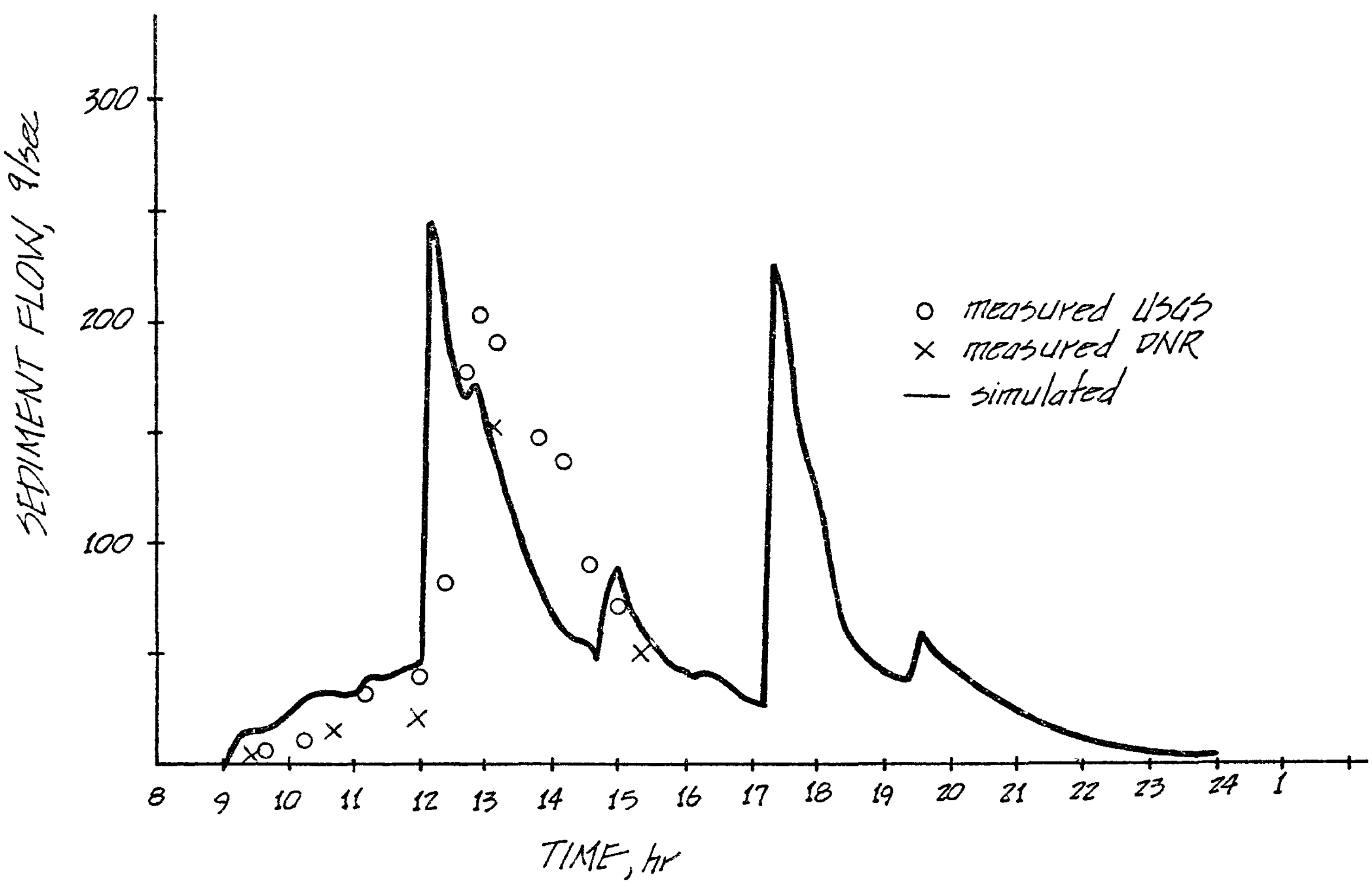
Appendix G Fig. 13. Noyes Creek suspended sediment pollutograph, May 5, 1976 storm (dust and dirt fallout equals 1.25 tons/sq. km./day).



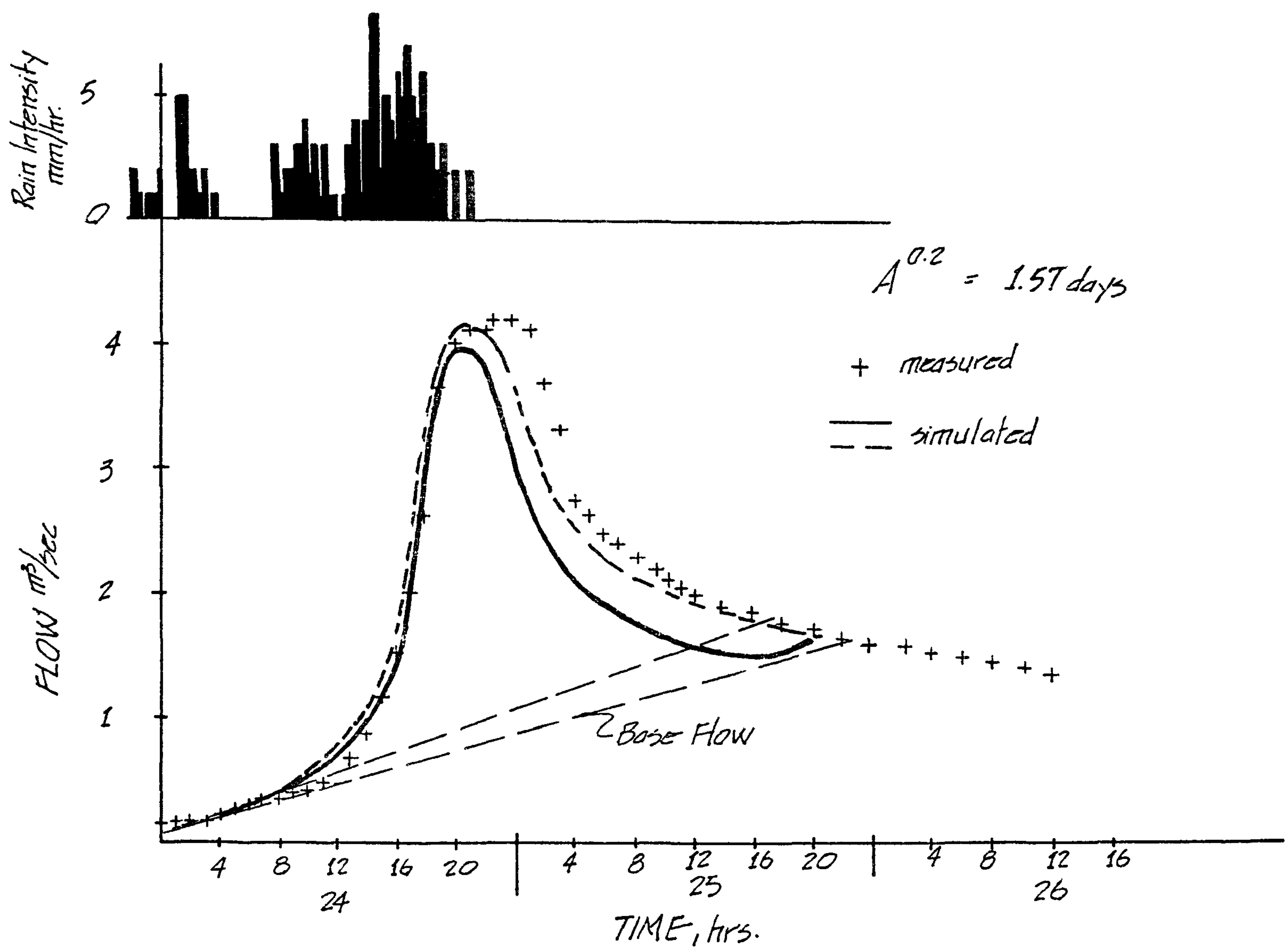
Appendix G Fig. 14. Volatile suspended solids pollutograph for Noyes Creek, May 5, 1976 storm.



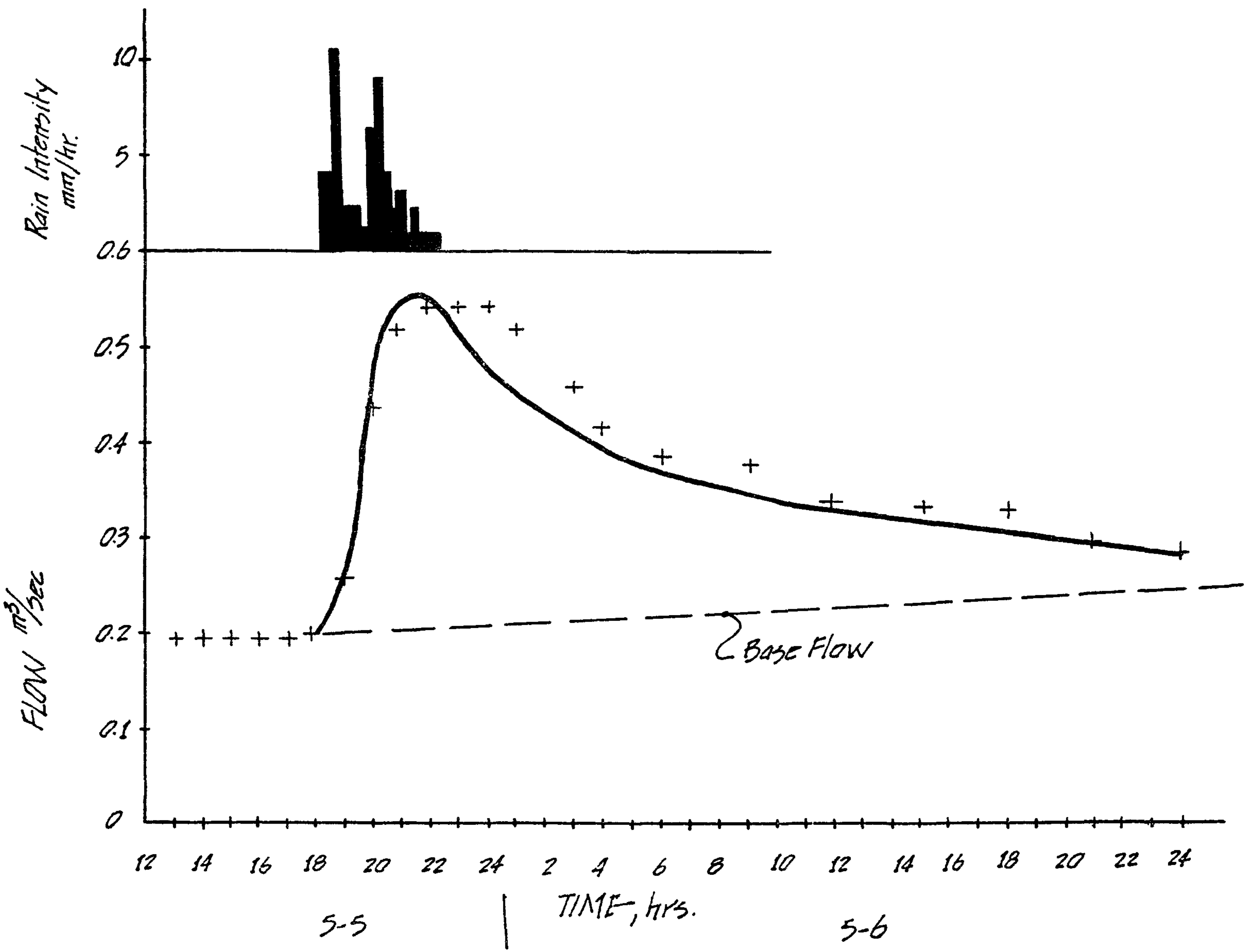
Appendix G Fig. 15. Phosphate pollutograph for Noyes Creek, May 5, 1976 storm.



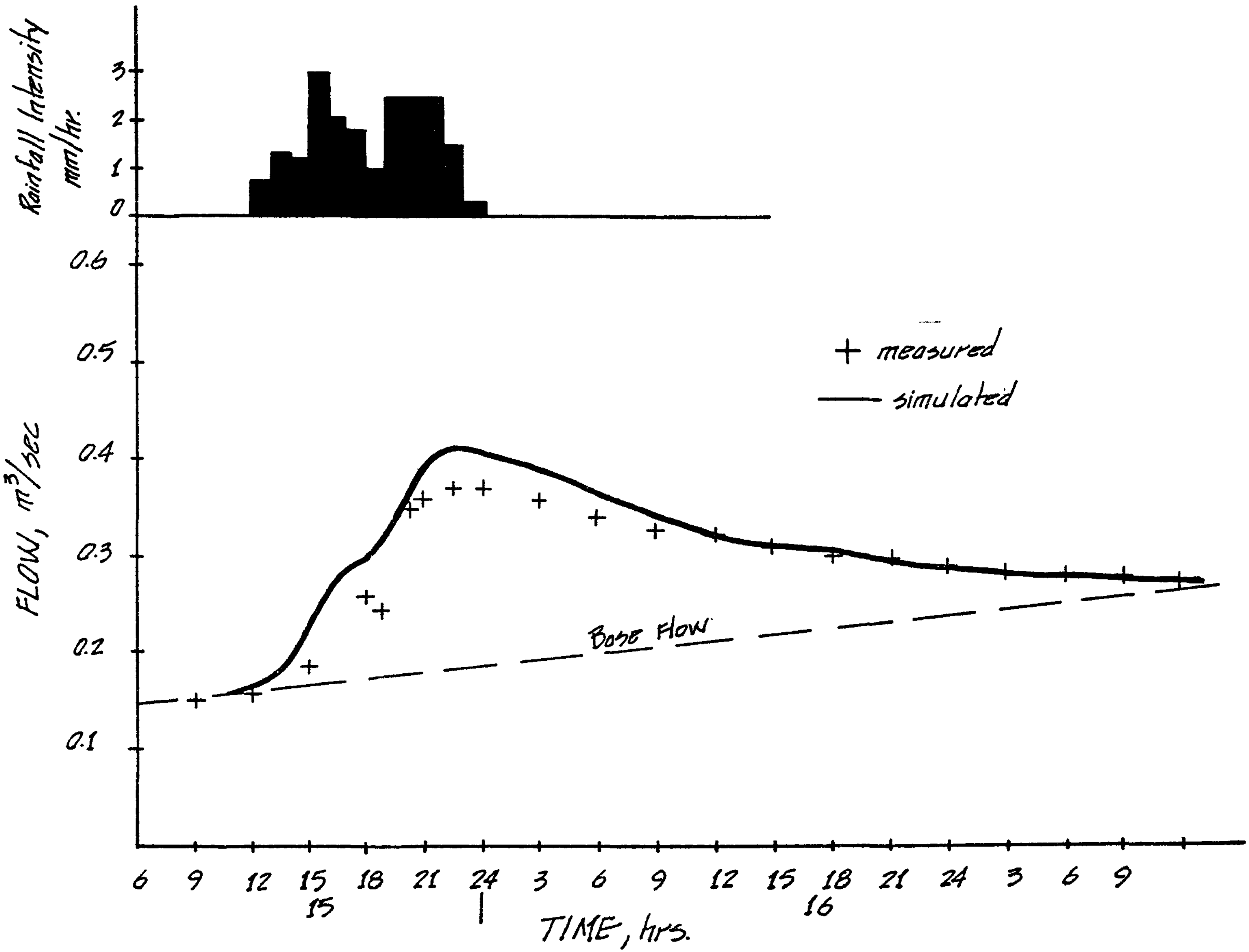
Appendix G Fig. 16. Noyes Creek sediment pollutograph for May 15, 1976 storm.



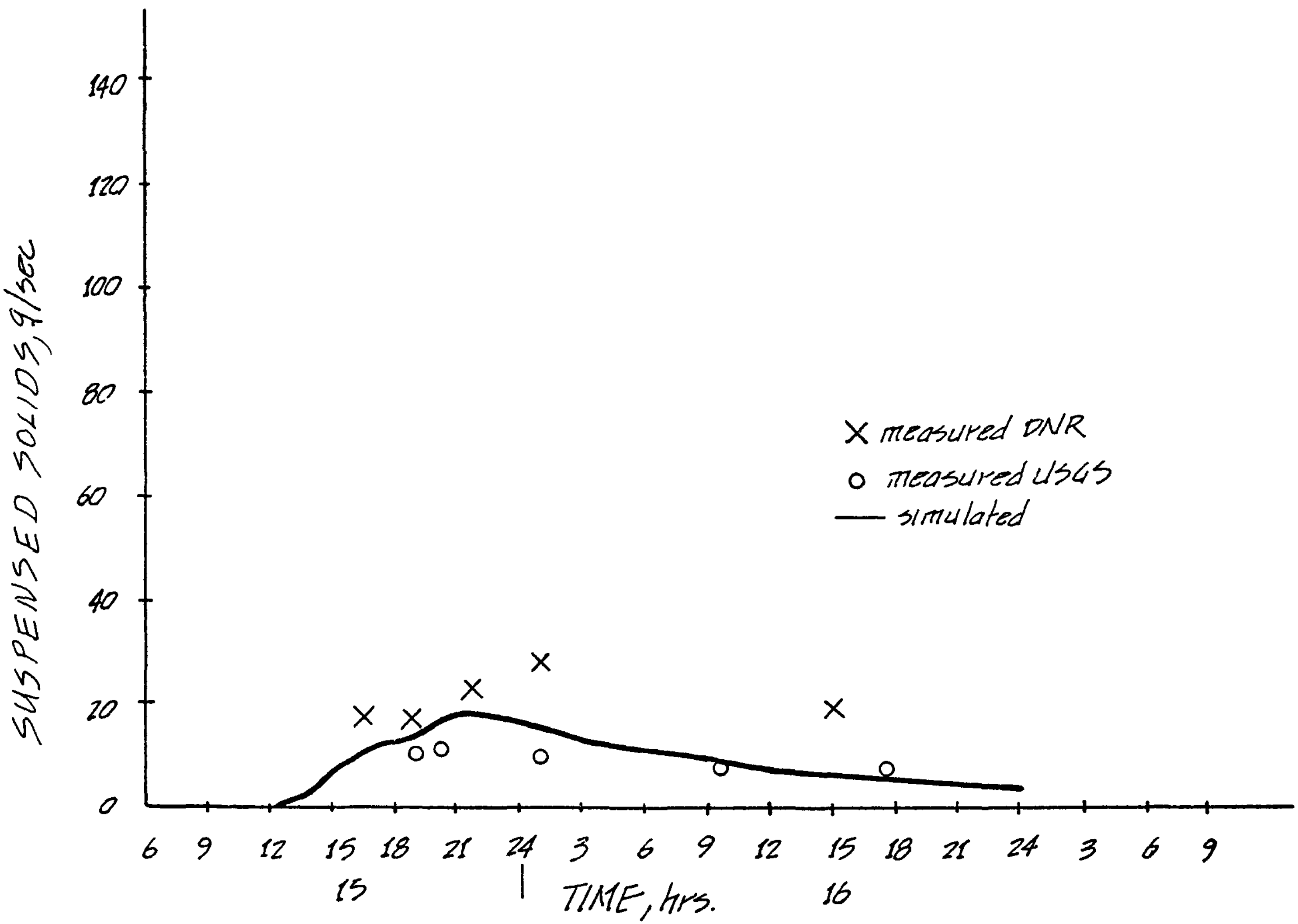
Appendix G Fig. 17. Donges Bay Road hydrograph for April 24, 1976 storm.



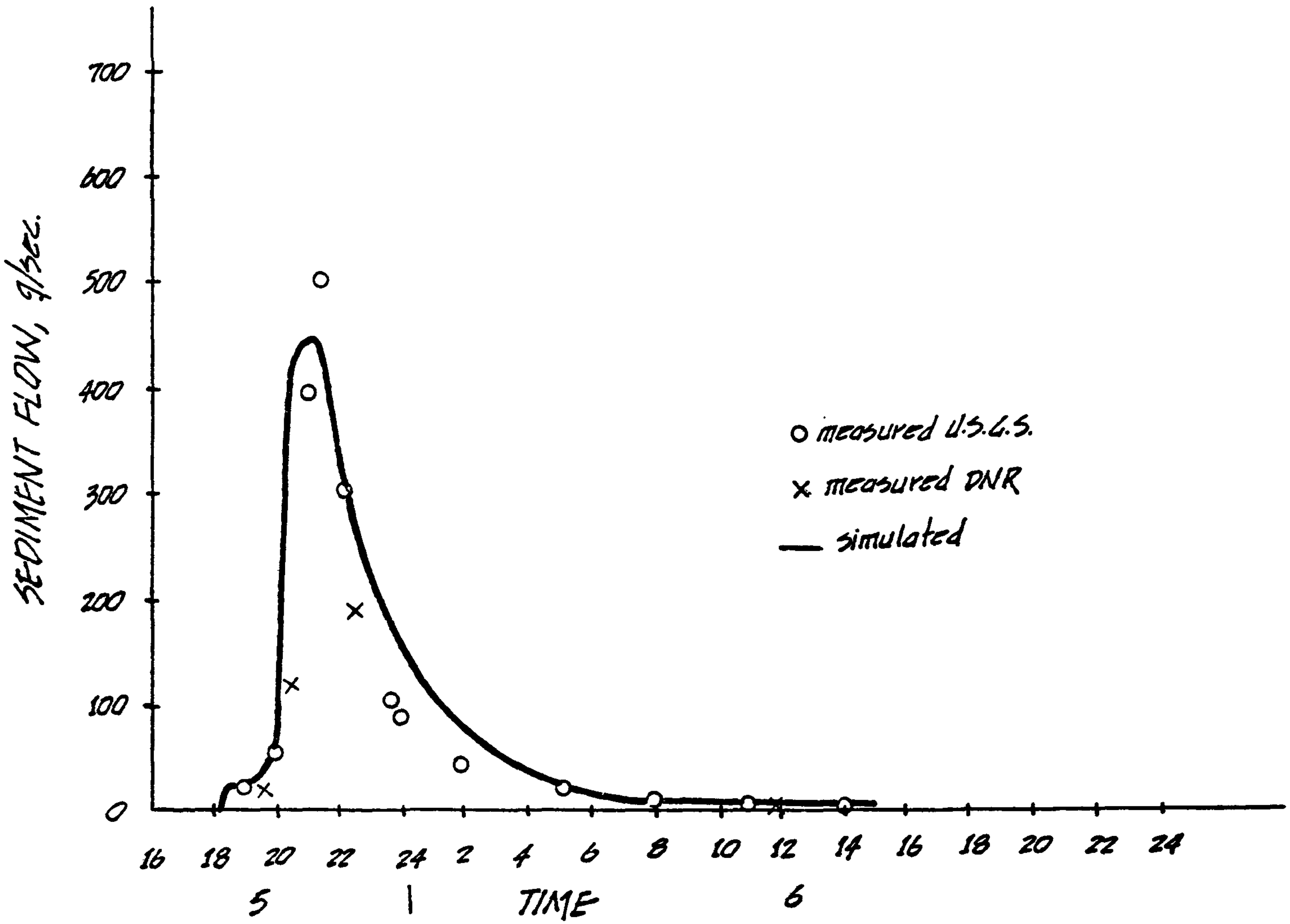
Appendix G Fig. 18. Donges Bay Road hydrograph for the May 5, 1976 storm.



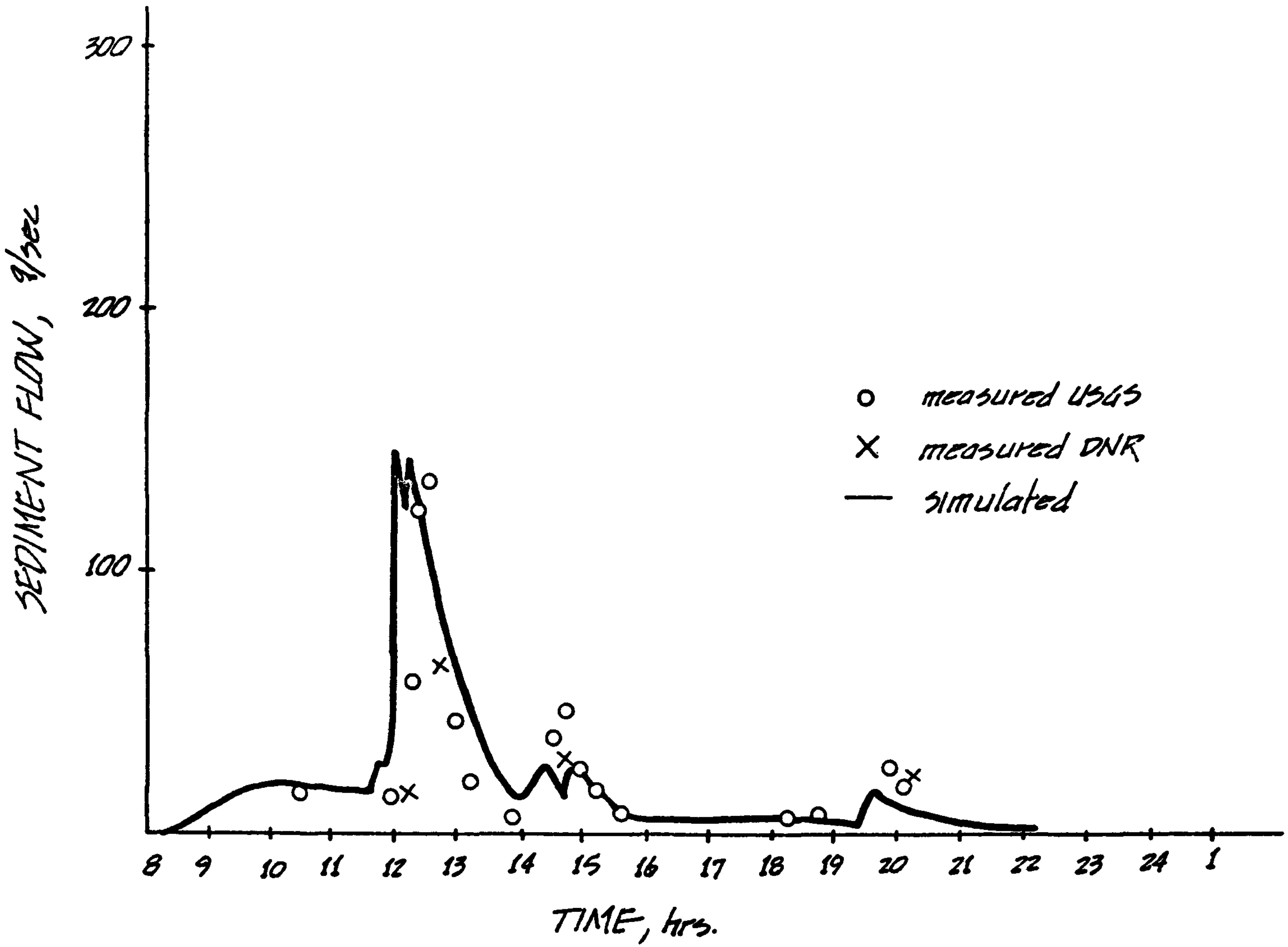
Appendix G Fig. 19. Donges Bay Road hydrograph for the May 15, 1976 storm.



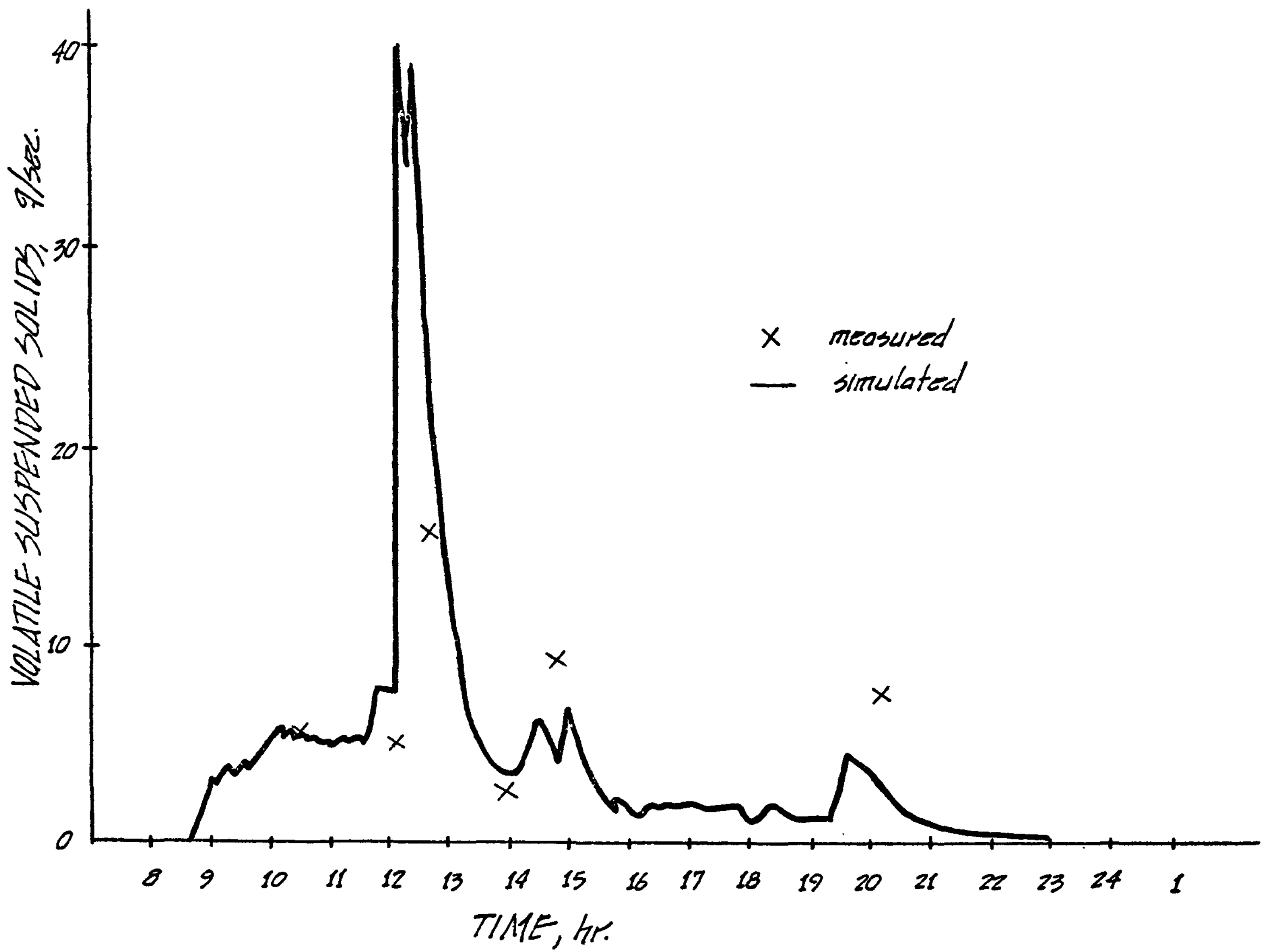
Appendix G Fig. 20. Donges Bay Road pollutograph for May 15, 1976 storm (dust and dirt fallout equals 0.4 ton/sq. km./day, no sediment movement).



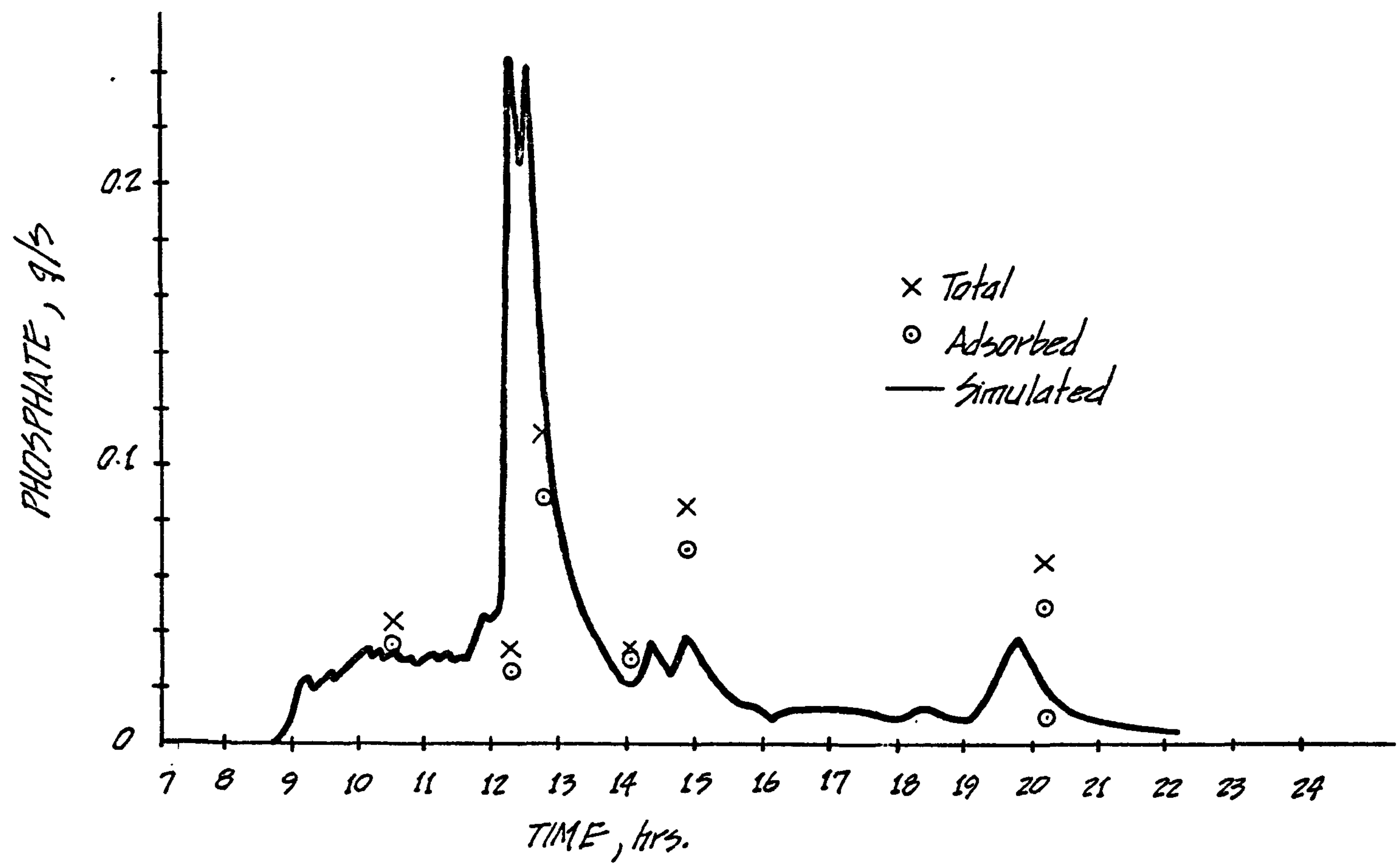
Appendix G Fig. 21. Donges Bay Road sediment pollutograph for May 5, 1976 storm (dust and dirt fallout equals 0.4 tons/sq. km./day).



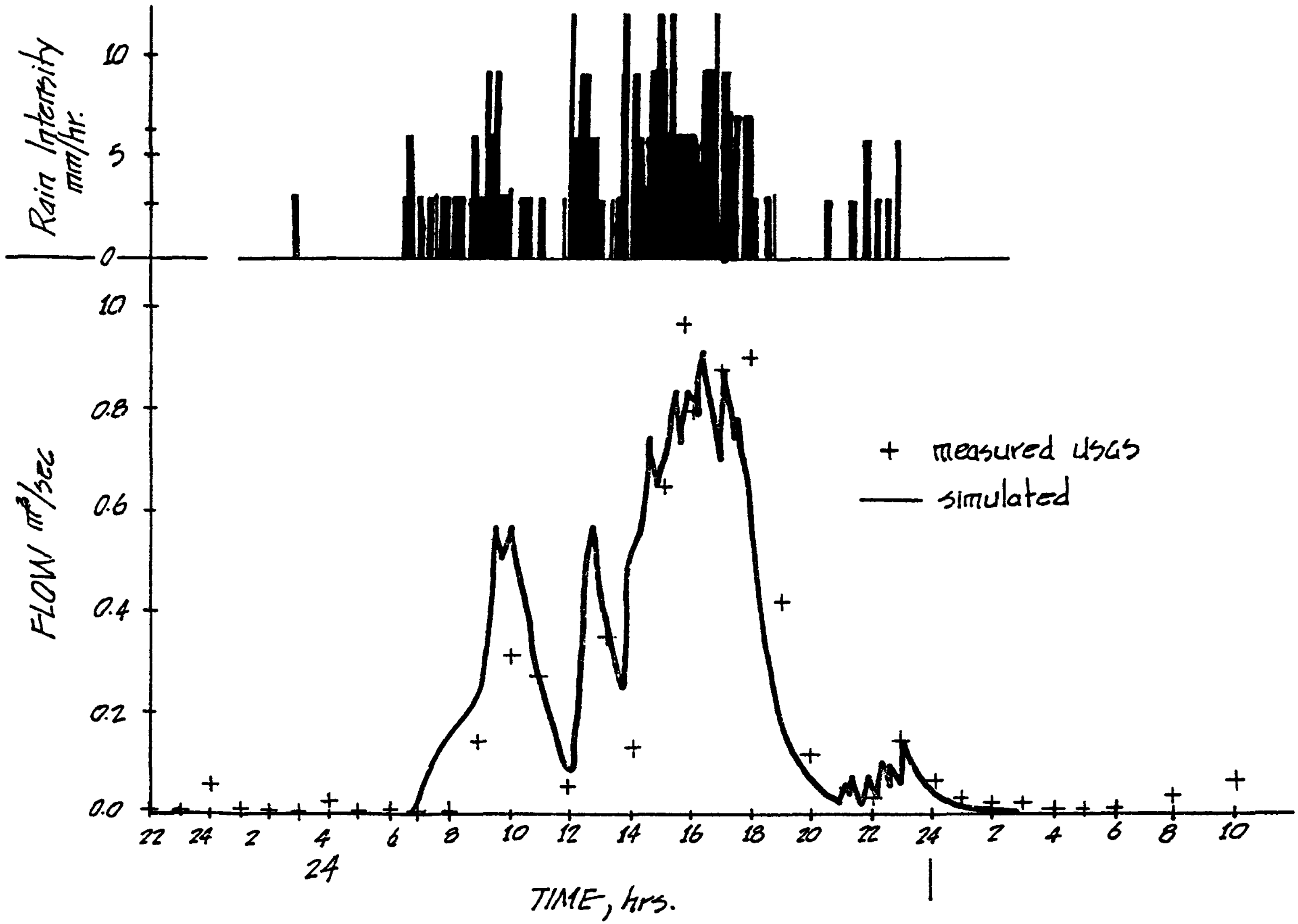
Appendix G Fig. 22. Schoonmaker Creek sediment pollutograph for May 15, 1976 storm (dust and dirt fallout equals 0.9 tons/sq. km./day).



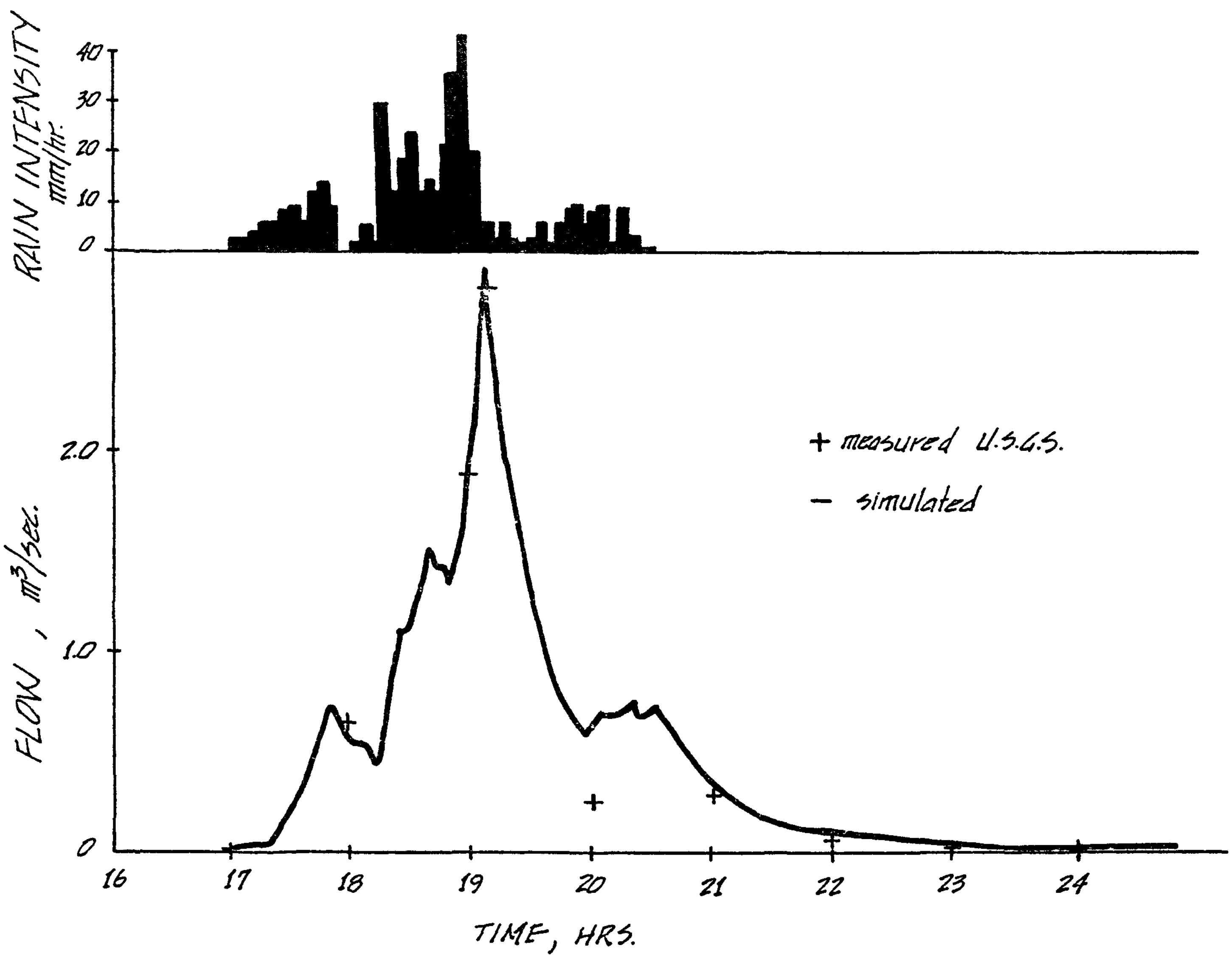
Appendix G Fig. 23. Volatile suspended solids pollutograph for Schoonmaker Creek, May 15, 1976 storm.



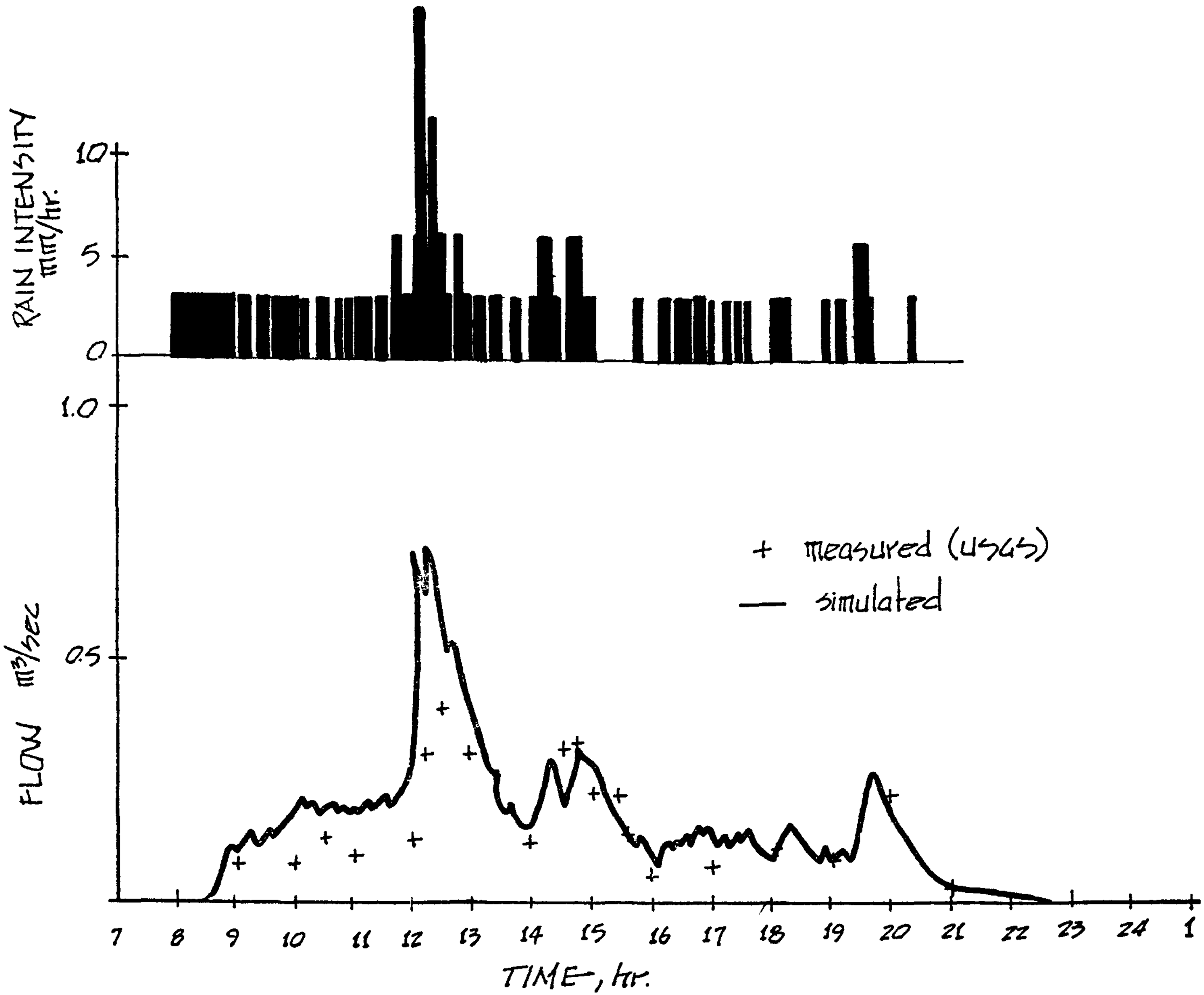
Appendix G Fig. 24. Phosphate pollutograph for Schoonmaker Creek, May 15, 1976 storm.



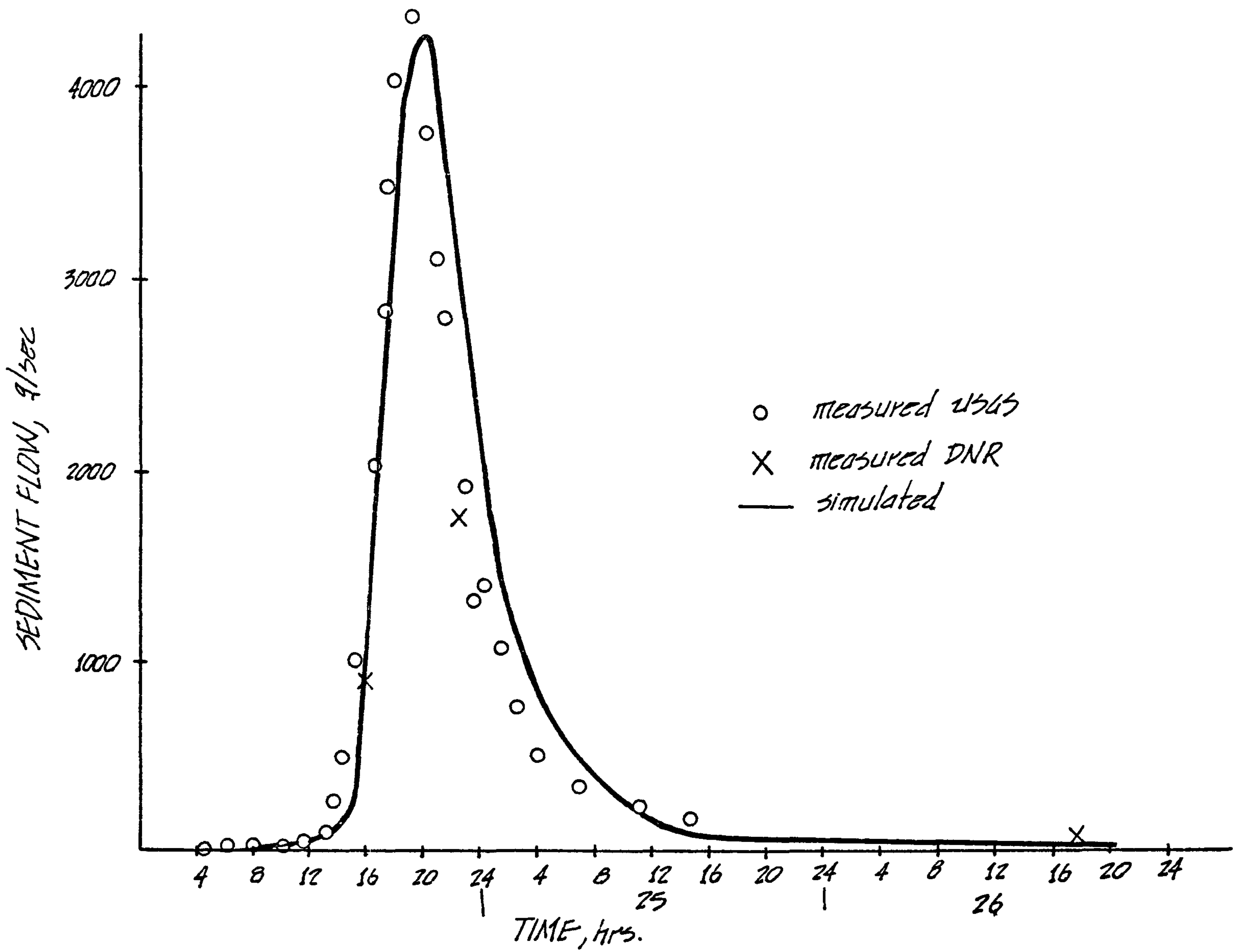
Appendix G Fig. 25. Schoonmaker Creek hydrograph for the April 24, 1976 storm.



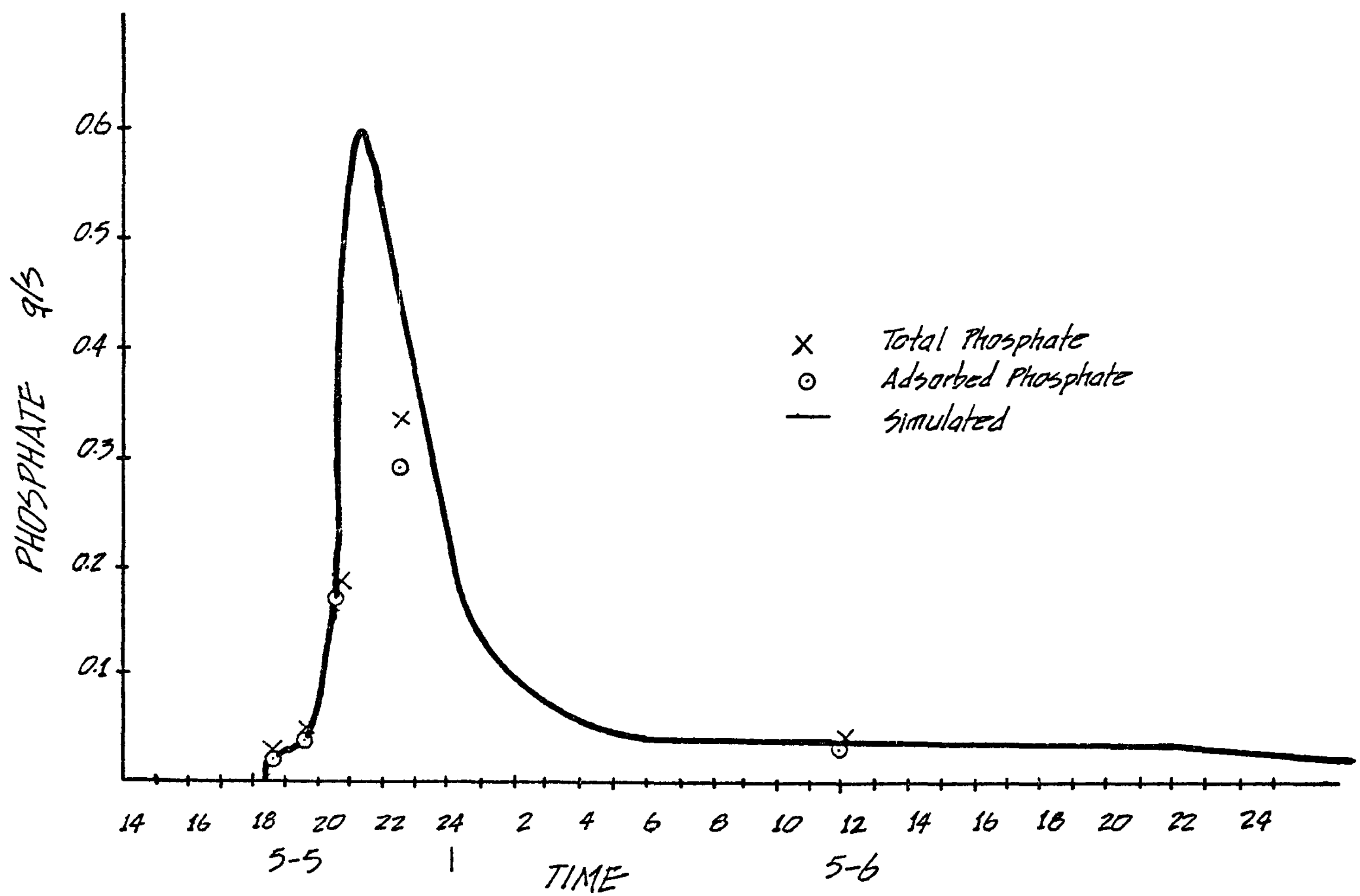
Appendix G Fig. 26. Schoonmaker Creek hydrograph for the May 5, 1976 storm.



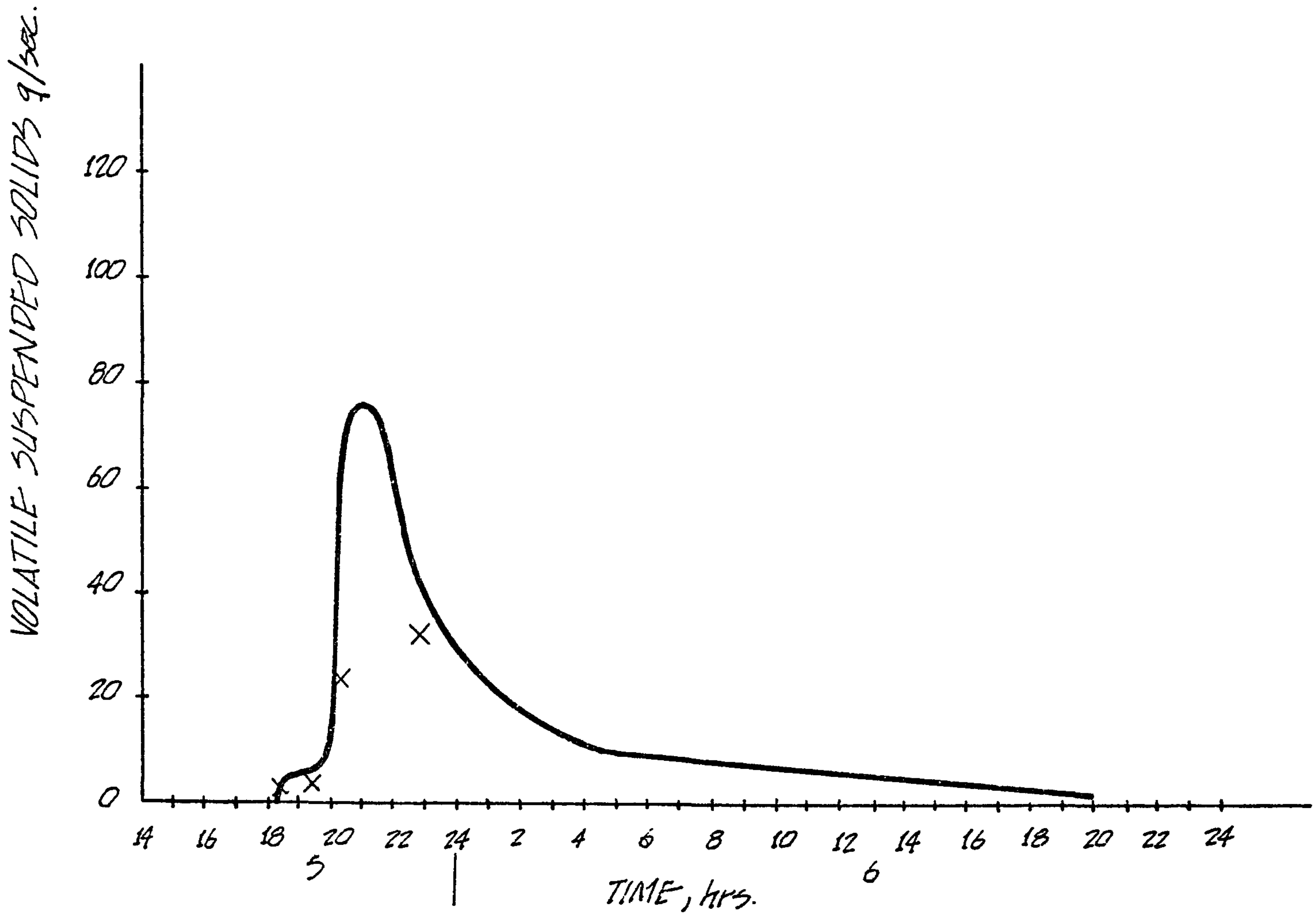
Appendix G Fig. 27. Schoonmaker Creek hydrograph for the May 15, 1976 storm.



Appendix G Fig. 28. Donges Bay Road sediment pollutograph for the April 24, 1976 storm.



Appendix G Fig. 29. Phosphate pollutograph for Donges Bay Road, May 5, 1976 storm.



Appendix G Fig. 30. Volatile suspended solids pollutograph for Donges Bay Road, May 15, 1976 storm.

draining into a subsurface system, flow from impervious areas overflowing onto surrounding pervious areas, etc. From the model outputs, it has been estimated that only about 40% of the impervious areas in the Noyes and Schoonmaker Creek subwatersheds seems to be directly connected to surface runoff. This parameter obviously affects also the amount of pollutants washed off from impervious areas.

In conclusion, it can be stated that the LANDRUN model is capable of reproducing field data for medium and large storms with adequate accuracy. This applies to all parameters modelled so far, i.e. runoff, sediment, volatile suspended solids and adsorbed phosphate.

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II. Empirical Modeling of Runoff Quality from Small Watersheds

In the April, 1976 Semi-Annual Report, work on this portion of the modeling effort was broken into three phases: I. to continue the monitoring of runoff events on three small tributaries to the Milwaukee River adjacent to the Menomonee River watershed, II. to determine the mean concentrations of various materials in runoff from these watersheds plus the small tributaries of the Menomonee River and then evaluate the controlling factors on these concentrations, and III. to develop a set of dimensionless relative concentration curves which show the temporal distribution of instantaneous concentrations about the mean. The objective, again, is the development of a simple, alternative model for runoff quality which uses a series of empirical curves to arrive at the end product of the mass loading hydrographs for various dissolved solids from small watersheds. Larger watersheds may be treated as a series of subwatersheds, and loading hydrographs for the overall watershed developed by routing those from the subwatersheds through it. Work has progressed well on all three phases, as is described below.

As has been the case previously, this work has concentrated on the results from the Milwaukee River tributaries because runoff and quality data are available for a wide variety of events. In addition, data for several events within the Menomonee River watershed have been retrived from storage via teletype and are included below where relevant. These events include July 18, 1975 (Noyes Cr.), August 18, 1975 (Schoonmaker Cr.), and September 5, 1975 (Menomonee R. at 70th St.). The information from the small Menomonee River tributaries (Noyes, Schoonmaker, and others) is especially important in the full development of this model; however, since relatively few events are yet available, most of the emphasis must be placed on the Milwaukee River tributary data. The first three events listed above were also monitored on all Milwaukee River sites, but direct comparisons to the Menomonee River data have not yet been made.

Phase I - Watershed monitoring and initial data analysis

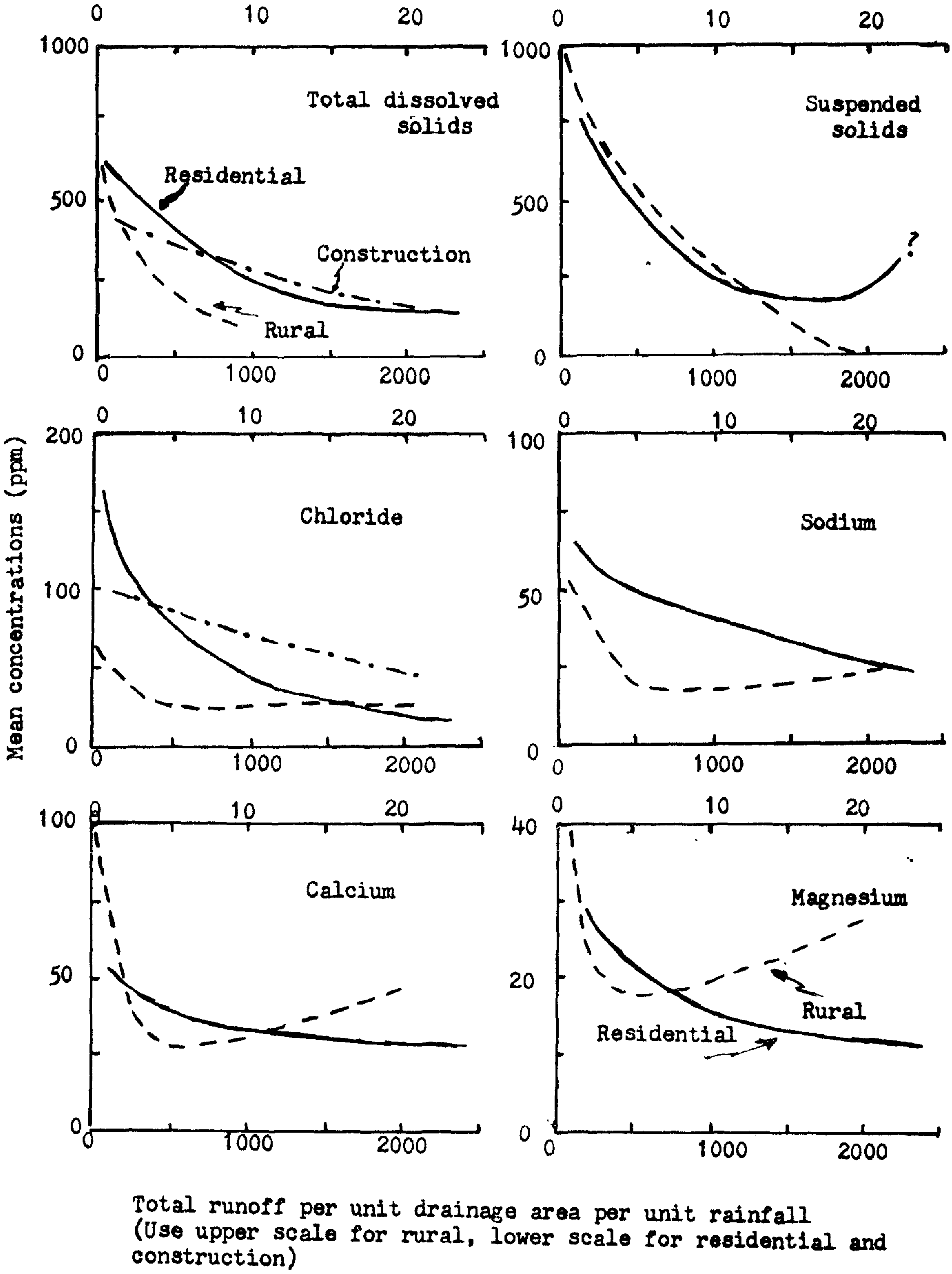
Active monitoring of the Milwaukee River tributary sites continued until June, 1976. Over 20 events have been sampled, so efforts are now geared toward catching a few additional major events with emphasis on nutrient and metal content of the water to tie in with the main objectives of the overall Menomonee River study. An exceptionally dry summer (1976) produced virtually no runoff events in the study area, and none were monitored.

Flow and load hydrographs have been developed, the mean concentrations calculated and relative concentration curves established for each monitored event. The computer software for this work is complete. Statistical work on the data continues and it has recently revealed that, when working with total runoff and mean concentrations of materials within a runoff, it is advantageous to consider thunderstorms and the gentler fall and spring frontal storms separately. For the development of relative concentration curves, however, the storms can still be lumped together.

Phase II - Interpretation of mean chemical concentrations of runoff

This work has continued through the spring and summer of 1976 to the present. The addition of more final results from the Milwaukee River tributaries has shown the mean concentrations of material in runoff have a definite relationship to land use, runoff quantity and type of storm (Appendix G Fig. 31). Only thunderstorm results are shown here because frontal storm curves are somewhat sketchy at this point. It should be emphasized that all curves presented herein are preliminary and subject to modification as additional data become available.

In a medium density residential area (Appendix G Fig. 31), total dissolved solids (TDS) as well as chloride, sodium and calcium all show a definite inverse relationship to runoff quantity for thunderstorms. The magnesium relationship is unclear at this time, while suspended solids (SS) apparently are affected by other controlling factors which need to be distinguished in further work. Results from the watershed under development are only shown for TDS and chloride. The information for the other components is currently being analyzed although preliminary indications are that the construction site



Appendix G Fig. 31. Mean concentrations in runoff as a function of total runoff per unit area per unit rain and land use.

will produce higher concentrations of calcium and magnesium (or hardness in the Menomonee River tributaries) and alkalinity than the residential area because of the increased exposure of carbonate-rich soils.

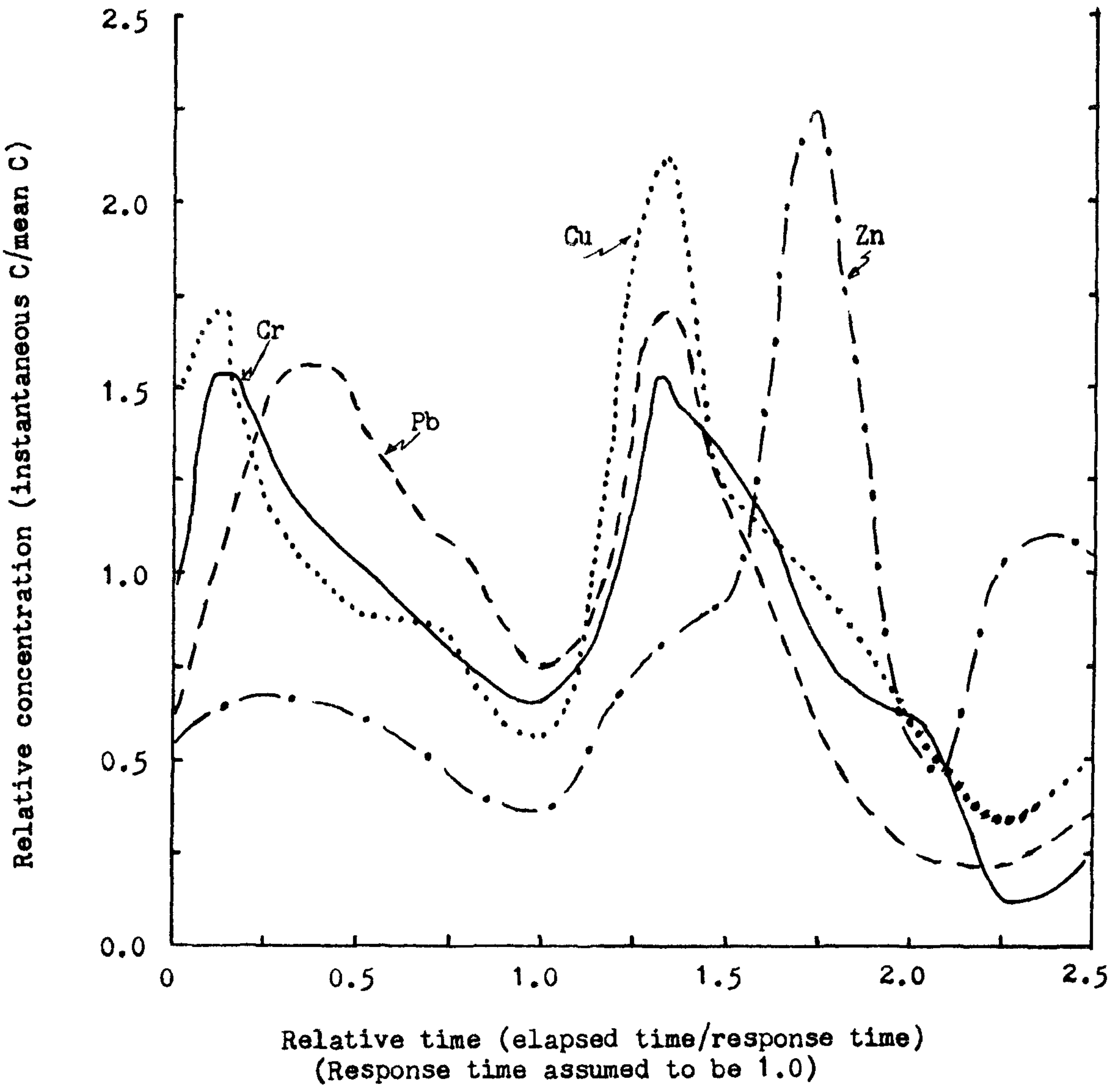
The rural watershed has much lower runoff than the others, so the rural scale has been increased by a factor of 10^2 (Appendix G Fig. 31). This land use produces runoff with lower concentrations of sodium and chloride and higher values of calcium, magnesium and alkalinity than occur for similar runoffs, in the other watersheds. Suspended solids show a strong and surprisingly negative correlation to runoff quantity.

The Menomonee River tributary data are now being worked upon for inclusion. They will provide information on additional land uses as well as on the concentrations of heavy metals and nutrients which have not been monitored in the Milwaukee River tributaries.

Phase III - Development and testing of relative concentration curves

Most of the effort during the summer of 1976 was concentrated here. A number of important conclusions have been made. First, the dimensionless time measure, called relative time (Appendix G Fig. 32), needs redefinition. Originally the ratio of real elapsed time to the length of the storm (both in hours) had been used. However, it has been learned from the Milwaukee River tributaries that the time distribution of the dimensionless relative concentration of water-borne materials in runoff is not a function of storm characteristics. Instead, it is directly related to watershed charactersitics -- a reasonable conclusion. Thus, relative time is now defined as the ratio of real elapsed time during an event to the response time of the watershed being monitored. In the Milwaukee River tributaries, response time is actually the average time-of-travel for runoff within the watershed. The rather nubulous term, response time, has been used at this juncture because it may be somewhat revised as additional data from the Menomonee River tributaries becomes available.

Secondly, it has been found that certain related dissolved solids show virtually identical relative concentration distributions for a given



Appendix G Fig. 32. Relative concentration curves for heavy metals in runoff from Schoonmaker Creek, August 20, 1975.

watershed, allowing use of the same curves for each of them. In the Milwaukee River tributaries, chloride, sodium and total dissolved solids can all be represented by the same relative concentration curve for a given land use. In addition, calcium, magnesium and alkalinity can all be handled by a second curve. Suspended solids, as expected, are unrelated to any of the dissolved solids.

Preliminary evaluation of available data from the Menomonee River tributaries has revealed that both hardness and alkalinity can be covered by a single curve. Since hardness is essentially the sum of calcium and magnesium concentrations this finding corroborates the Milwaukee River tributary data. Furthermore, among the heavy metals in Schoonmaker Creek (Menomonee River watershed) runoff for the August 20, 1975 event, copper, chromium and lead all had very similar relative concentration curves (Appendix G Fig. 32), while zinc appeared unrelated. Thus far all the nutrients appear to be unrelated requiring development of separate curves (Appendix G Fig. 33).

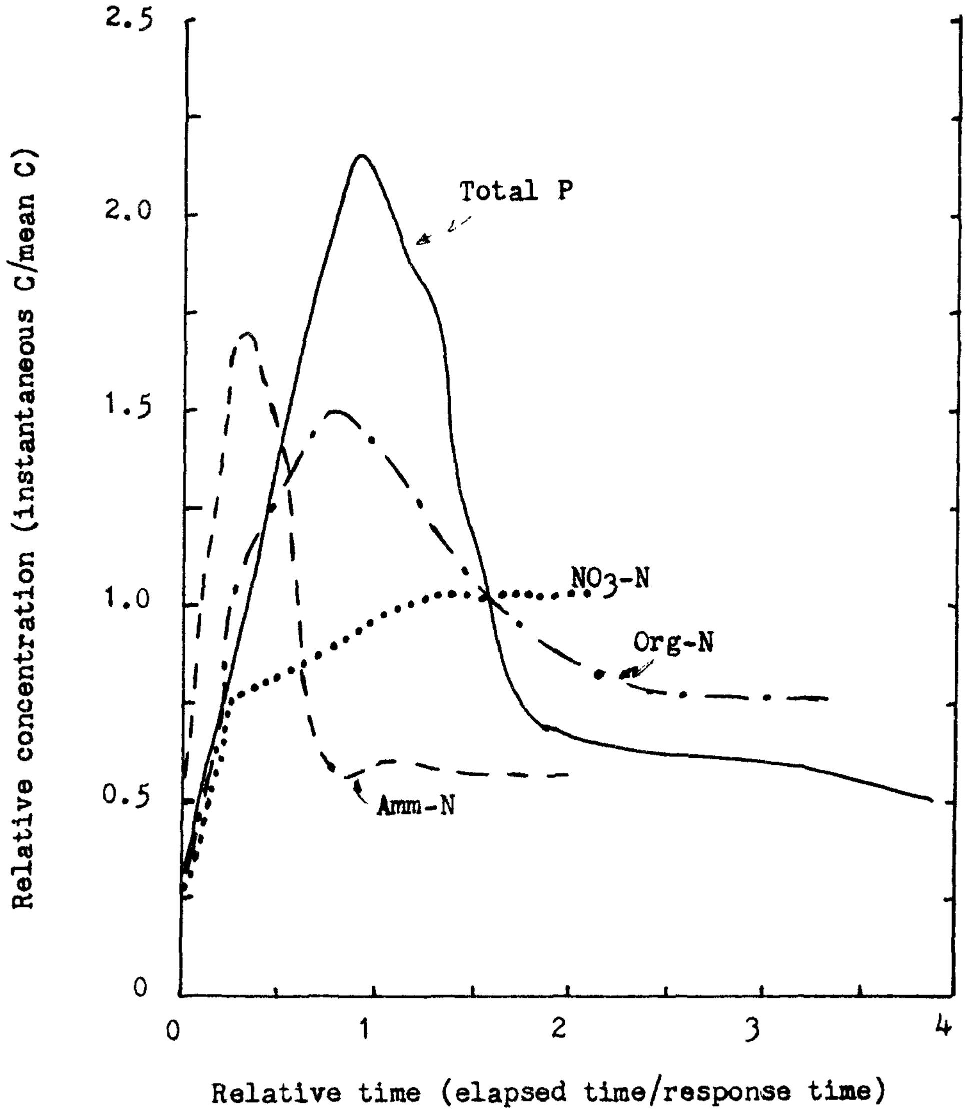
Thirdly, a set of very reliable relative concentration curves has been developed for medium-density residential, active development and rural land uses as represented in the Milwaukee River tributaries (Appendix G Figs. 34, 35 and 36). Inclusion of results from Schoonmaker and Noyes Creeks and other small tributaries as they become available will allow the expansion of these curves to encompass all the land uses under study within the Menomonee River watershed. As has been shown in earlier reports, these curves can then be used with some means of predicting mean concentration (such as Appendix G Fig. 31) and a runoff model to produce very reasonable predicted mass loading hydrographs. The primary future effort of this segment of the study will be to complete the development of these curves and refine the empirical model.

A fourth conclusion has been that preliminary relative concentration curves from Schoonmaker Creek, based on only two events, are totally consistent with the Milwaukee River tributary curves for all mutual chemicals. Thus the Schoonmaker Creek chloride and hardness curves have attributes which one would expect for high-density residential areas. It is anticipated, therefore, that there will be no major problems in combining the Milwaukee and Menomonee River curves.

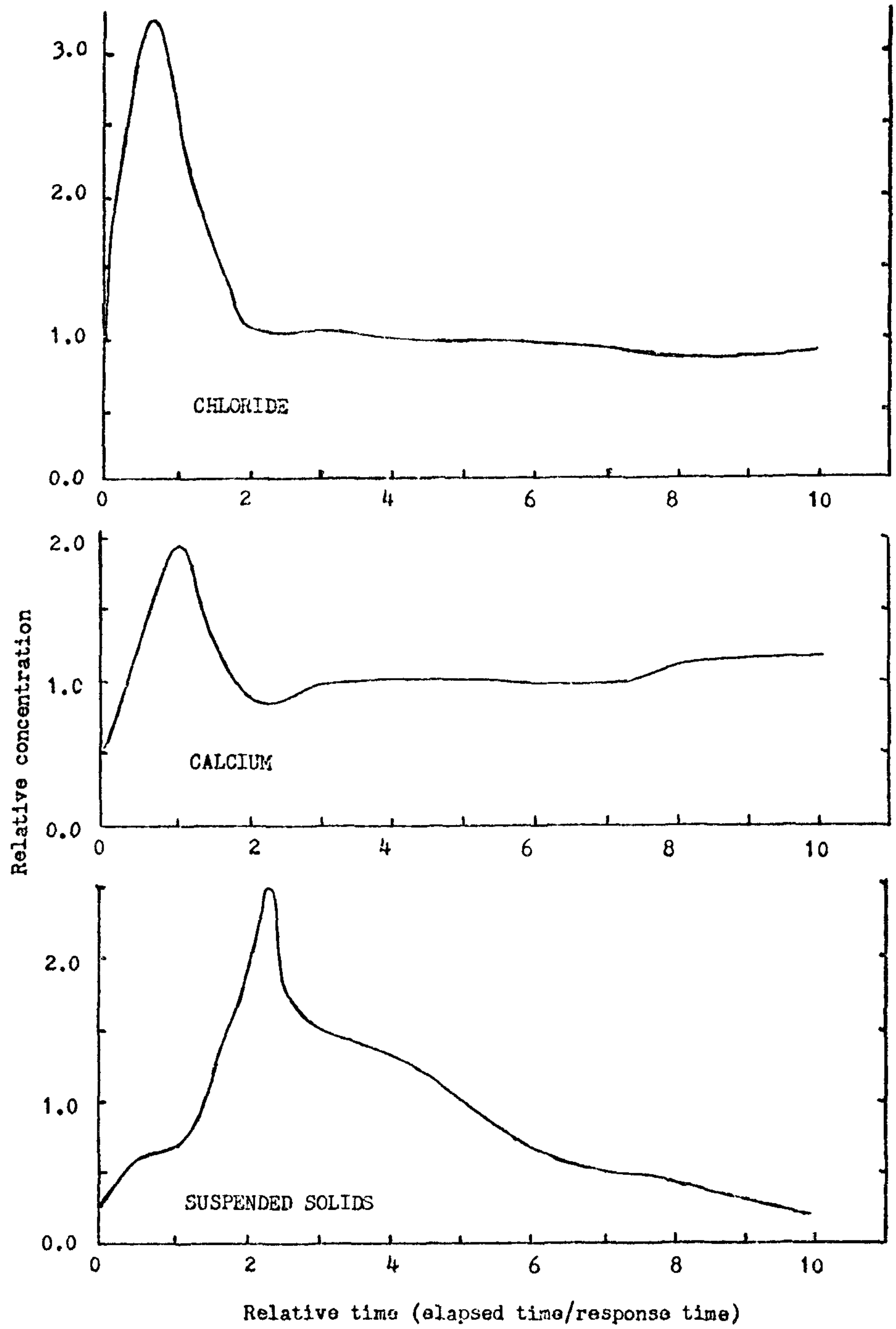
Finally, it is worthwhile to point out that the relative concentration curves also demonstrate the general features of the distribution of water quality during a runoff event from a given land use. They can serve as a ready means to make dimensionless, graphical comparisons of the watershed responses. The curves presented herein (Appendix G Fig. 32, 33, 34, 35 and 36) are a case in point. In medium-density residential areas, each of the dissolved inorganics shows a rapid initial flush of high-concentration followed by a slow recession in concentration (Appendix G Fig. 34). Suspended solids have a similar response, but the flushing peak occurs later.

In comparison (Appendix G Fig. 35), the active development area has a slower flushing effect for all materials. This effect is consistent with the incomplete storm drainage systems and landscaping within the watershed. Overall drainage is less efficient, producing a slower flush. Note also that the chloride peak on this watershed's curve is higher than that for the adjacent medium-density residential watershed. A variety of evidence indicates that the less efficient drainage system is also less efficient in removing the previous winter's road salt. The result is more salt to be flushed off this watershed during the summer and fall storms.

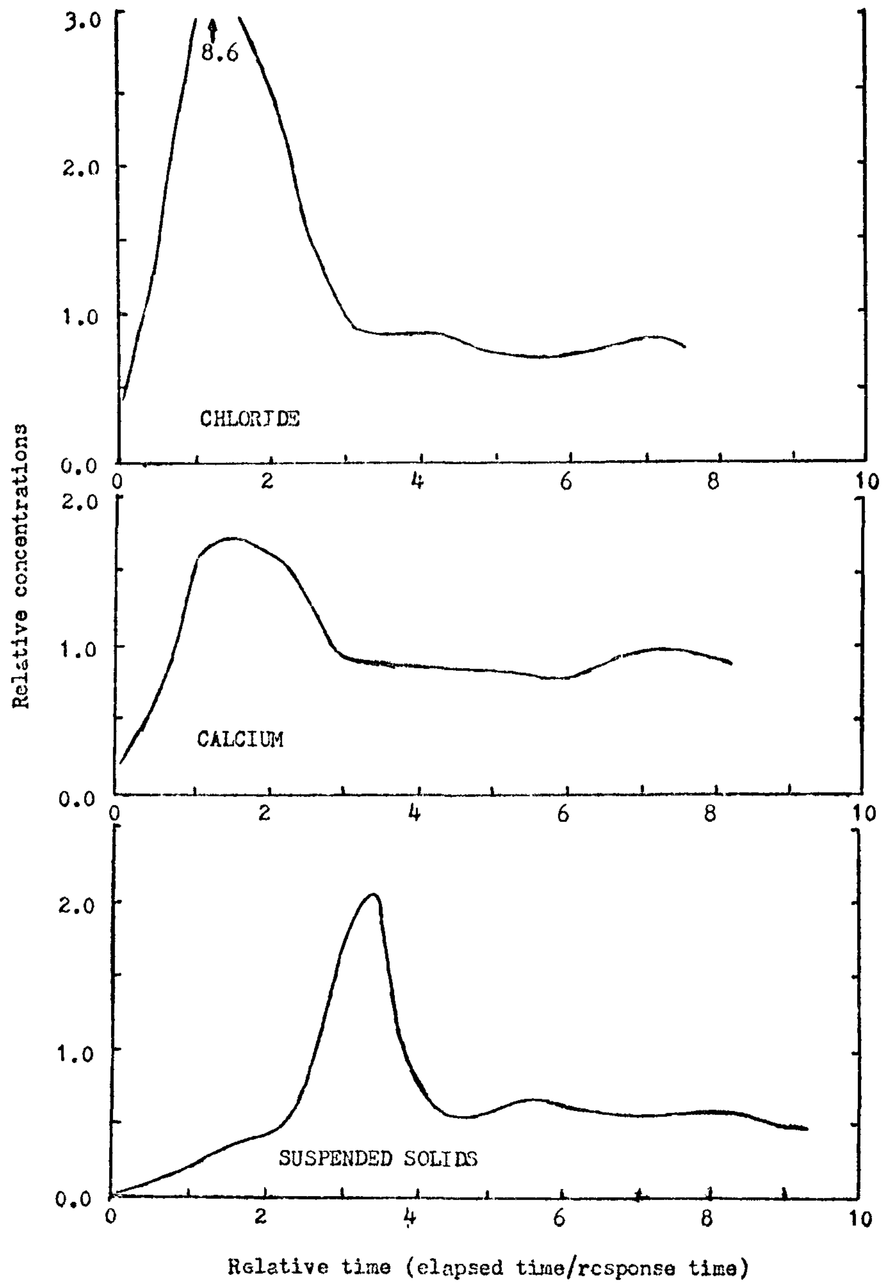
For similar events, the rural watershed has low relative concentration peaks and a very slow response, indicating that little significant flushing of inorganics occurs there (Appendix G Fig. 36). On Noyes Creek (Appendix G Fig. 33), all the nutrients but the nitrite-nitrates have a very rapid flush followed by a recession of concentrations. The nitrites actually increased in concentration during the entire July 18, 1975 event. For the August 20, 1975 event, copper, chromium and lead all showed a double flushing followed by a decline in concentration, while a zinc flush occurred only during the second flush of the other metals (Appendix G Fig. 32).



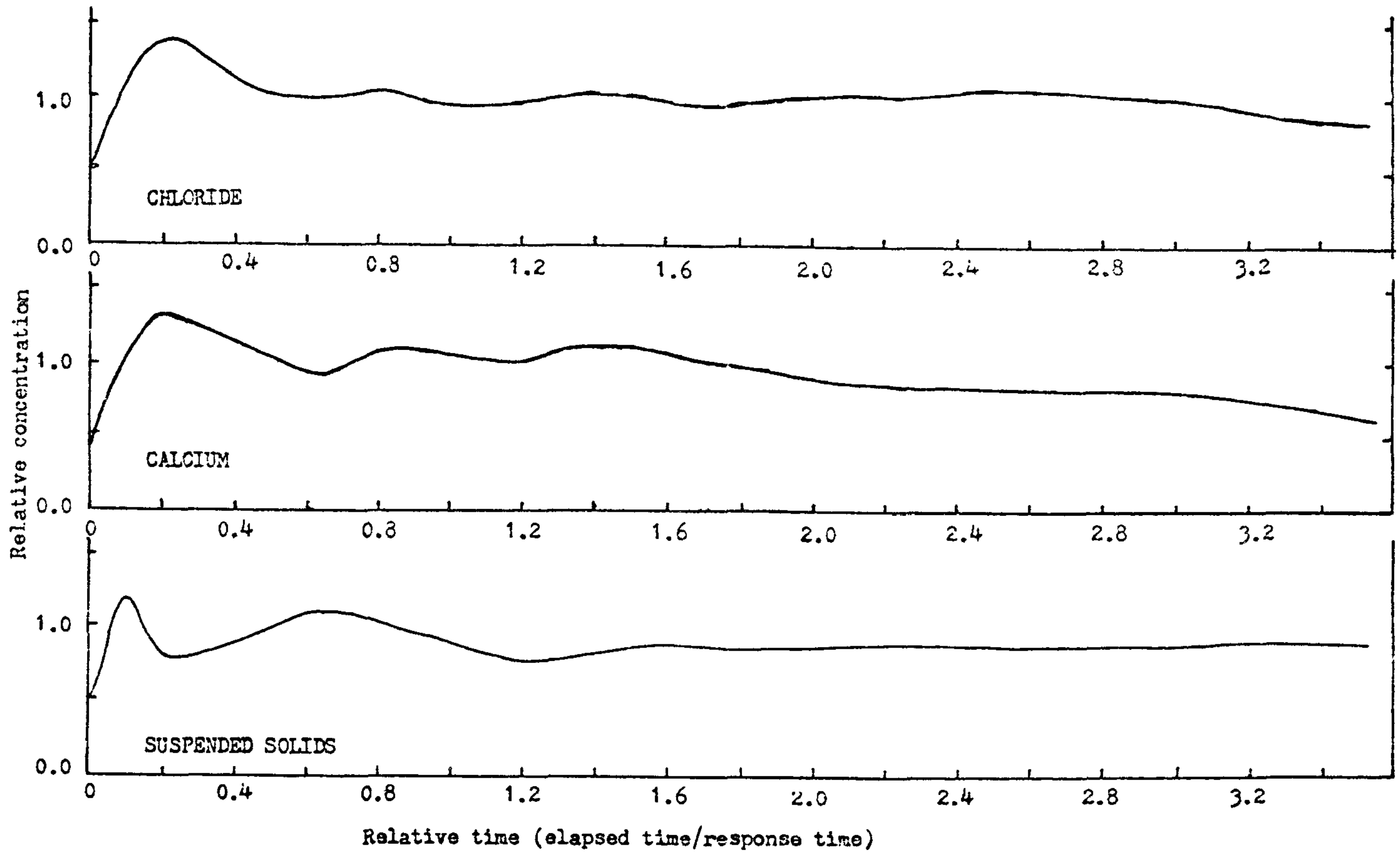
Appendix G Fig. 33. Relative concentration curves for nutrients in runoff from Noyes Creek, July 18, 1975.



Appendix G Fig. 34. Relative concentration curves for indicator materials for runoff from residential land.



Appendix G Fig. 35. Relative concentration curves for indicator materials for runoff from active residential construction area.



Appendix G Fig. 36. Relative concentration curves for runoff from agriculatural land.

III. Channel Transport Modeling

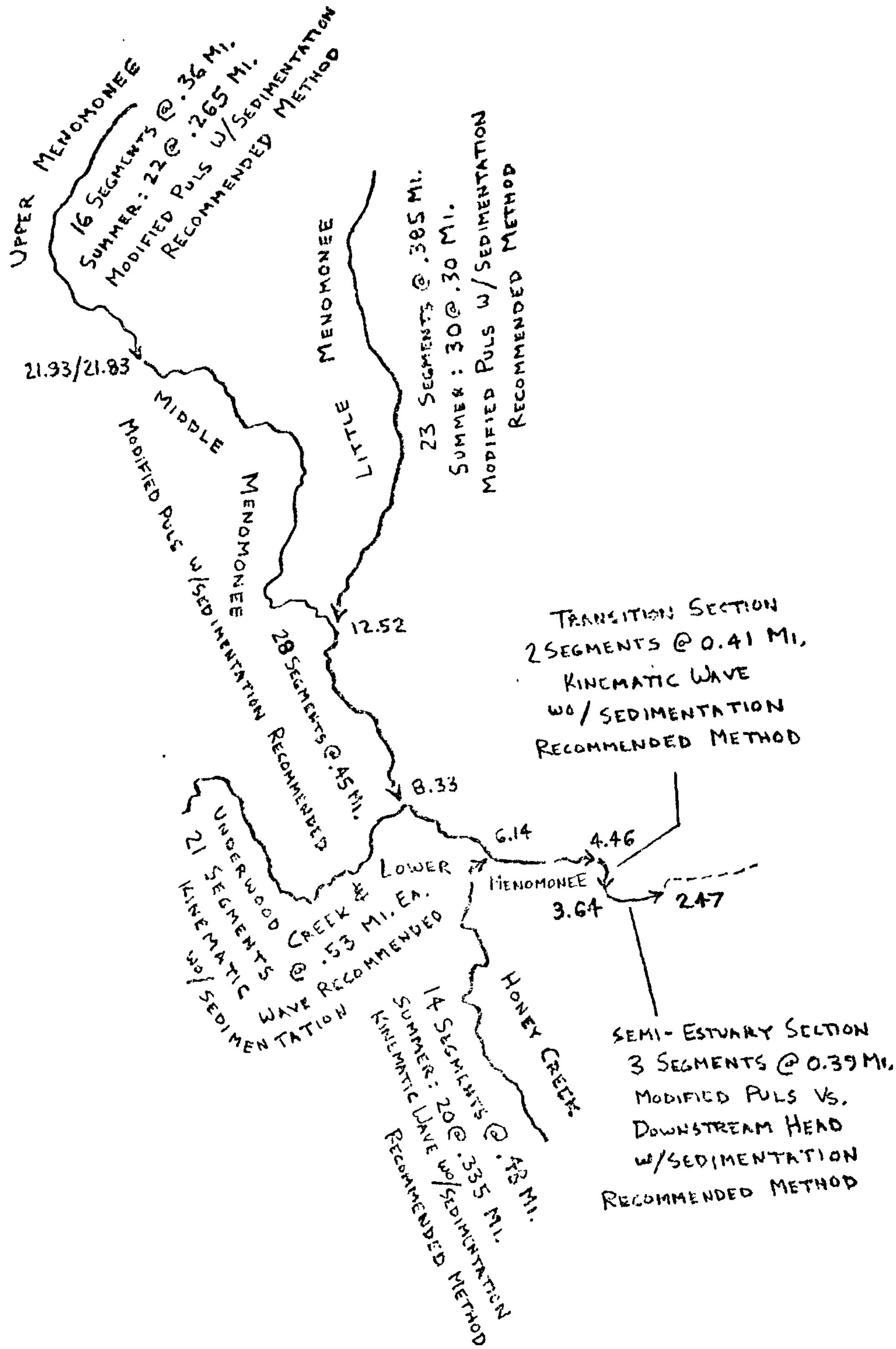
Until now the channel transport model has been viewed as a description of a fast-rushing flume carrying an assortment of materials to which some biological and chemical effects have been overlain, perhaps along the lines of the Streeter-Phelps equation. However, literature review, field investigation and increased attention to U.S. Army Corps of Engineers dredging operations in the estuary/harbor has reinforced the belief that sedimentation (scour and deposition) is the predominant pollutant-transport consideration, if adsorption of pollutants to suspended sediments is strong.

Attempts to describe the sedimentation process by empirical approaches have tended to prove unreliable and ultimately more tedious than a mechanistic approach. The number of controlling factors is large, but furthermore many possibilities exist for each and for interactions between them. For instance, watershed size is critical, insofar as larger watersheds provide more deposition opportunity. Similarly, channel slope and character, bed and bank material type, precipitation amount and distribution, and vegetation/slope/soil character of the surrounding area are all major factors affecting sedimentation processes. Therefore, one should rely on a deterministic (i.e. mechanistic) model, though it might have empirical aspects (such as calibration factors for bank collapse, nutrient uptakes, etc.). Almost certainly, the best approach would be the modification of an existing dynamically routed channel transport model (e.g. U.S. Army Corps of Engineers River-Reservoir Water-Quality Model), drawing on the extensive body of literature which the Civil Engineering profession has developed on sedimentation. Inputs to such a model would, of course, be the hydrologic/pollutant loading outputs of a continous simulation overland runoff and a ground water model (as well as data sharing therewith). This approach would not eliminate the need for model correspondence to observations of watershed sediment loading patterns (these, however, are not yet available for reference in this report). Such observations and sediment size distributions can most easily be explained by the presence of extensive scour.

Above and beyond quantification of scour and deposition on a separable basis, modeling of in-stream processes has other important benefits. These benefits could also be interpreted as critical to the overall project objective of extendibility throughout the Great Lakes Basin. First, calibrations of the overland model would not be distorted. That is to say, that their applicability to small subwatersheds (i.e. up to three square miles) would not be jeopardized in order to account for loadings resultant from an entire 137 square mile watershed. Secondly, better accounting of sediment transport of other pollutants would serve to mechanistically describe the tradeoff of contaminated sediments deposited for the relatively uncontaminated sediments scoured. Lastly, a better recognition of the stochastic character of land use pollutant generation would be effected by the refinement of special studies site derived relationships via a matrix which applies main stem monitoring data. Thus, not only a greater predictative strength results from in-stream modeling incorporation but better land use pollutant generation correlation as well. It is to be remembered that summation of overland effects at subwatersheds should ultimately provide the base upon which statistical methodology would be applied in some future synthesizing extension of Task C results. Therefore, the veracity of results from the present <u>analytic</u> phase should be sufficiently paramount to warrant address of all effects reasoned and observed.

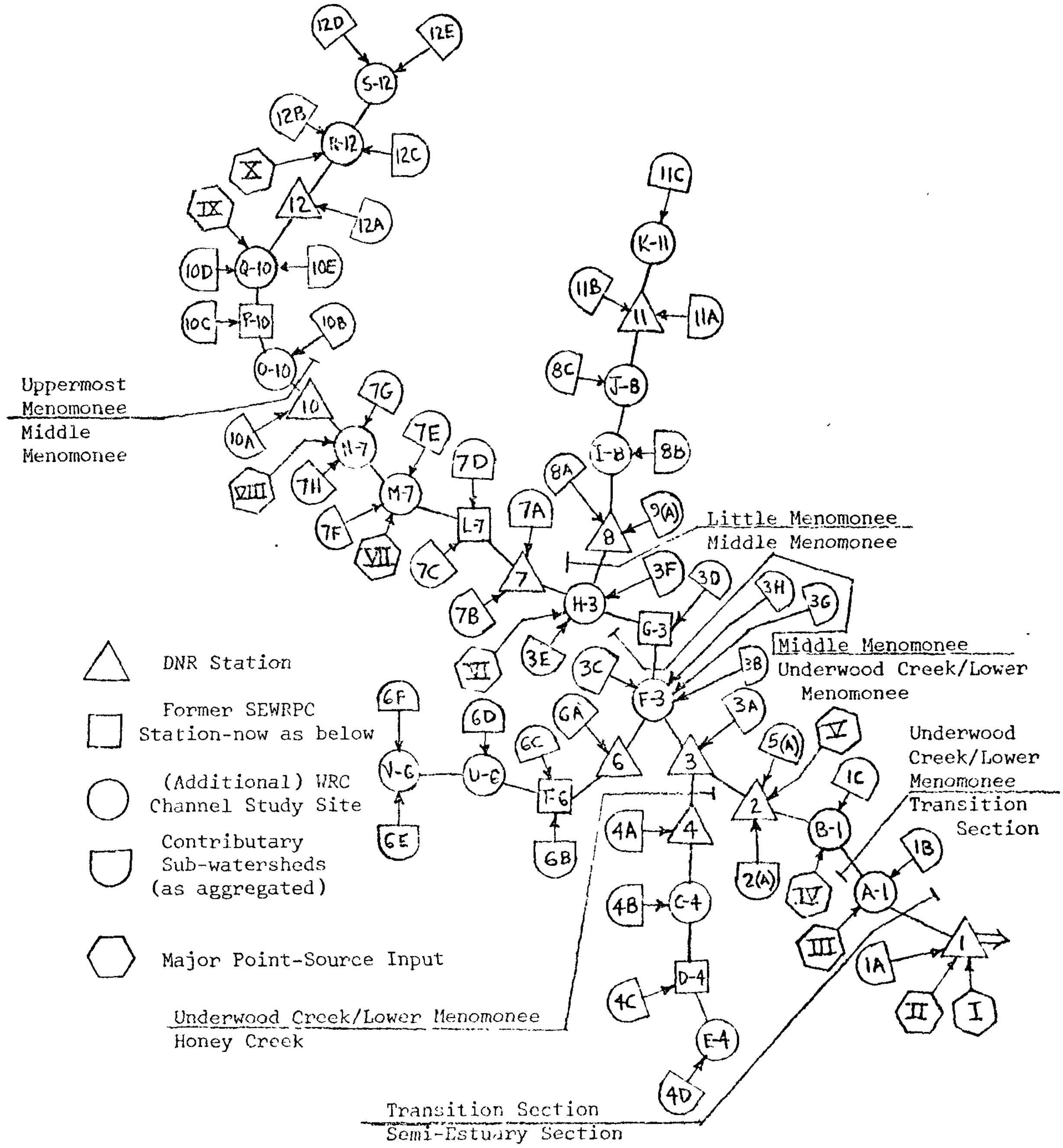
Major modeling consequences can come from increased attention to sedimentation phenomenon, insofar as it is intertied with the hydraulic aspects of the stream flow. While a kinematic-wave approach to the problem of dynamic flow-routing has been available, there does exist a certain recommended prerequisite slope (10 feet drop per mile) throughout the reach of application. Two other methods, Muskingum and Modified Puls are less rigorous in that regard, and the Muskingum method is reportedly more conserving of computer time. However, accessibility to reach storage quantification within the Modified Puls method makes it a better choice for those reaches where sedimentation (i.e. scour and deposition) consideration is adviseable. Thusly, there would be available input information needed to quantify the modification of output water quality resulting from the mixing of sudden turbid input water with that having undergone some clarification during prior retention. In any case, ultimate confirmation of hydraulic calibrations and computations by dye-tracer studies is adviseable in coordination with the modeling framework chosen. It is to be appreciated that these computations apply both to modeling generally and to station sampling equipment settings most specifically.

Sections where attention to deposition is most adviseable are of course those reaches of low slope. The Wisconsin Wurm glaciation (i.e. Green Bay/Lake Michigan interlobe) end moraine/ground moraine topography of the watershed fortuitously places such consideration in the headwater areas, where Modified Puls method is most applicable. Storage in ponds and meandering channel along the uppermost Menomonee River makes that area especially worthy of focus, with regard to deposition and subsequent resuspension during high flows. On the other hand, one cannot assume that scour is necessarily major along the segments of highest slope--again, in our watershed, along the lower reaches. Unlined channel "improvements" along the Little Menomonee River, middle Menomonee River (Menomonee Falls Dam to Underwood Creek confluence), and, to a lesser extent, upper Underwood (and Honey?) Creeks have likely increased the magnitude of scour, while the lined character of channel improvements along the lower Menomonee River and lower Underwood and Honey Creeks have likely reduced it. From the viewpoint of scour then, the Little Menomonee River and middle Menomonee River are especially worthy of focus. The small magnitude of scour-contribution of upper Underwood and Honey Creeks to overall watershed sediment make it adviseable to use kinematic-wave methodology there, and indeed to lump Underwood Creek with the lower Menomonee River from the confluence down to the 45th St. Dam. The result of this approach would be the flow-routing pattern proposed (Appendix G Fig. 37). Not only methodologies are suggested, but computational segment-lengths for use in the U.S. Army Corps of Engineers River-Reservoir model--under consideration for channel transport modeling application--are also recommended, such that GEDA program hydraulically-weighted cross-section summation may be used.



Appendix G Fig. 37. Proposed flow routing.

This outlined plan would be compatible with the framework which has evolved over the past year (Appendix G Fig. 38), utilizing additional channel studies sites (Appendix G Table 2). Spot-checks on water quality at those sites would extend across space the more detailed (in a time-wise sense) monitoring at Wisconsin Department of Natural Resources (DNR) maintained stations, i.e. increase of the "breadth" of sampling throughout the watershed in order to complement the "in-depth" sampling at the WDNR stations. Reference to the end of Appendix G Table 2 will also underscore a problem in modeling (or, for that matter, any other analysis) not previously foreseen, that being the presence of an extensive number of point sources. These will have to be scrutinized and, in many cases, quantified. In any event, the channel studies sites, plus focus on the specifics of the dendritic drainage system, results in the basins for overland-flow/pollutant-loading quantification, as outlined in Appendix G Table 3. It is intended to procure print-out from Southeastern Wisconsin Regional Planning Commission (SEWRPC) of soil-type, slope and, most importantly, land-use information in such format, as soon as 1975 data is read into SEWRPC's computer data-storage system. Preliminary print-out has, however, influenced definition of land use aggregation of SEWRPC classifications, as presented (Appendix G Table 4). It is to be noted that the former Light Industry focus has been dropped (at cost of some management practice decision-making input), in order to increase extendibility to other watersheds. The former Commerical focus has been expanded to Commercial /Rural and Suburban Downtown, as residential categories have been brought into approximate conformity with SEWRPC population densities (in recognition of urban pollutant output-loading sensitivity to imperviousness). While the validity of a [now Extra-] High Density Residential/Urban Downtown Classification remains, the only locales of occurrence are apparently within SEWRPC-labelled subwatersheds LMR-33 and -34, as well as tributary to the Milwaukee River below the North Ave. (vicinity) Dam. Since these are tributary to the estuary section which is evaluated only by grab-sampling, runoff-loading figures might be synthesized from studies in the literature. Previous concern that phthalates be modelled as an



Appendix G Fig. 38. Aggregated subwatersheds pattern for incrementing overland flow and pollutant loadings within a predictative modeling.

Appendix G Table 2. Channel studies sites recommended for definition of time-of-travel and seasonal sampling points

Semi-Estuary Section:
1) DNR Station 413004 (Falk Corp.).

Semi-Estuary Section/Transition Section:
A-1) End of Channelization in vicinity of I-94 undercrossing.

Transition Section/Underwood Creek-Lower Menomonee Reach:
B-1) At base of 45th Street Dam.

2) DNR Station 413009 (Hawley Road).
3) DNR Station 413009 (70th Street).

Honey Creek:
4) DNR Station 413006 (150 yds. above confl. along Honey Cr. Parkway Dr.)
C-4) at R.R. track through State Fair Grounds.
D-4) SEWRPC Sta. TMn-13 site (McCarty Pk.).
E-4) W. Norwich St. extension-crossing (off S. 65th St., adjacent to Armour Pk.).

[Returning to Underwood Creek-Lower Menomonee Reach]
Underwood Creek-Lower Menomonee Reach/Middle Menomonee Reach:
*F-3) Jackson Pk. Blvd. extension-crossing (to tributary side of mid-channel below Underwood Cr.-Menomonee River confluence).

G-3) SEWRPC Sta. Mn-7A site (Currie Park)

Middle Menomonee Reach/Little Menomonee Reach:
*H-3) W. Hampton Ave. crossing (to tributary side of mid-channel below Menomonee-Lower Menomonee Rivers confluence).

8) DNR Station 413008 (Silver Springs Drive).
I-8) at Good Hope Road crossing.
J-8) immediately below Brown Deer Road crossing.
11) DNR Station 463001 (Donges Bay Road).
K-11) at Mequon Road crossing (of Little Menomonee River).

[Returning to Middle Menomonee Reach]:
7) DNR Station 683001 (124th Street).
L-7) SEWRPC Sta. Mn-5 (W. Mill Road).
M-7) Menomonee Falls STP#2 (at mid-channel below STP outfall and Lilly Cr. Confl.)
N-7) [146th St. Extension in subdivision] extension-crossing (to tributary side of mid-channel below Nor-X-Way Channel-Menomonee River Confluence).
10) DNR Station 683002 (Pilgrim Road).

Middle Menomonee Reach/Uppermost Menomonee Reach:
O-10) At base of Menomonee Falls Dam.

P-10) SEWRPC Sta. Mn-3 (County Line Road).
*Q-10) Off Maple Road vicinity Mr. D.I.'s night club, access through field to/S. of Willow Cr, paralleling said creek (to tributary side of mid-channel below Willow Creek-Menomonee River Confluence).
12) DNR Station 673001 (River Lane Road).
R-12) Chicago, Milwaukee and St. Paul R.R. crossing to/S/of Friestadt Road.
S-12) Chicago and Northwestern R.R. crossing to/NE/of Route 145.

*mixing factors may dictate dropping these sites.

Appendix G Table 2 (cont.)

[Returning to Underwood Creek-Lower Menomonee Reach]:

6) DNR Station 413007 (above Highway 45 off North Avenue)
T-6) SEWRPC sta. TMn-12 (S. Underwood Cr. Confluence)
U-6) North Avenue crossing.
V-6) S. Side Brookfield City Park (Franklin Wirth) off North Ave. (to tributary side of mid channel below Dousman Ditch-Underwood Cr. Confluence).

Point Source Inputs to be quantified:

I) Combined Sewer Outfall or Industrial Wastewater Discharge (sources disagree) in vicinity of Falk Corp. (Note 1)
II) Combined Sewer Outfall immediately to south of I-94 crossing.
III) Sum of pair of Combined Sewer Outfalls at Wisconsin Ave. crossing.
IV) Sum of pair of Combined Sewer Outfalls in vicinity of 45th St. Dam. (Note 2)
V) Combined Sewer Outfall at Hawley Road Site. (Note 3)
VI) Butler Bypass Public Sewage Treatment Facility (STP). (Note 4)
VII) Menomonee Falls STP #2 plus Relief Pumping Station. (Note 5)
VIII) Menomonee Falls STP #1.
IX) Sum of three Relief Pumping Stations at site of former Germantown STP #2.
X) Germantown STP #1. (Note 6)

Portable Relief Pumping Stations should be input at nearest more-substantial installation listed above.

Handling of Industrial Waste Discharges requires resolution, probably on a case-by-case basis, to wit:

Note 1-Clarified as two input sites, each combined sewer outfall plus industrial waste discharge.
Note 2-plus one industrial waste discharge.
Note 3-plus two industrial waste discharges.
Note 4-plus five industrial waste discharges.
Note 5-plus one industrial waste discharge.
Note 6-plus one industrial waste discharge.

Additionally: one along Dretzka Park Creek
one along Lilly Creek
four along Little Menomonee River
three along Middle Menomonee River
three along Underwood Creek
five along Honey Creek
one along Lower Menomonee River
eight within the Semi-Estuary Reach area

Appendix G Table 3. Detailed aggregations of subwatersheds

Aggregated Sub-Watershed Identifier	Description or Characteristics	SEWRPC System Sub-Watershed Components
	Basins Contributory to Uppermost Menomonee River	
12E***	Terminates at Proposed Channel Studies Site between UMR-14 and UMR-11 @ NMBR-6 (EAST BRANCH MENOMONEE RIVER BASIN?)	UMR-1,-2,-3,-4,-5,-6,-7,-8, -9,-10 and -11
12D***	NORTH BRANCH MENOMONEE RIVER BASIN	NBMR-1,-2,-3,-4,-5 and -6
12C*****	Terminates at Proposed Channel Studies Site between UMR-14 and UMR-15 (i.e. undifferentiated channel margin)	UMR-12,-13 and -14
12B***	WEST BRANCH MENOMONEE RIVER BASIN	WBMR-1,-2,-3,-4,-5,-6,-7, -8,-9 and -10
12A*****	Terminates at DNR Station 673001 (i.e. #12) (basin is undifferentiated channel margin)	UMR-15 and -16
10E*****	Terminates at Proposed Channel Studies Site between UMR-22 and UMR-23 @ WC-8 (i.e. undifferentiated channel margin)	UMR-17,-18,-19,-20,-21 and -22
10D****	WILLOW CREEK BASIN	WC-1,-2,-3,-4,-5,-6,-7 and -8
10C*****	Terminates at ex-SEWRPC Sta. Mn-3 (i.e. Waukesha-Washington Co. line) (basin is undifferentiated channel margin)	UMR-23 and -24
10B*	Terminates at Menomonee Falls Dam (i.e. undifferentiated channel margin)	UMR-25,-26 and -27
	Basins Contributory to Little Menomonee River	
11C***	Terminates at Proposed Channel Studies Site between LTMR-7 and -8 (PIGEON CREEK BASIN?)	LTMR-1,-2,-3,-4,-5,-6 and -7
11B****	LITTLE MENOMONEE CREEK BASIN	LMC-1,-2,-3,-4,-5,-6 and -7
11A*****	Terminates at DNR Station 463001 (i.e.#11)(basin is undifferentiated channel margin)	LTMR-8,-9,-10 and -11
8C*****	Terminates at Proposed Channel Studies Site between LTMR-17 and -18 (i.e. undifferentiated channel margin)	LTMR-12,-13,-14,-15,-16 and -17
8B*****	Terminates at Proposed Channel Studies Site between LTMR-21 and -22 (i.e. undifferentiated channel margin)	LTMR-18,-19,-20 and -21
9(A)**	Terminates at DNR Station 413001 (i.e.#9)/NOYES CREEK BASIN	LTMR-23,-24,-25 and -26

Appendix G Table 3 (cont.)

Aggregated Sub-Watershed Identifier	Description or Characteristics	SEWRPC System Sub-Watershed Components
	Basins Contributory to Little Menomonee River (cont.)	
8A*****	Terminates at DNR Station 413008 (i.e. #8)(basin is undifferentiated channel margin).	LTMR-22,-27,-28 and -29
	Basins Contributory to Middle Menomonee River	
10A*****	Terminates at DNR Station 683002 (i.e. #10)(basin is undifferentiated channel margin)	UMR-28,-29 and -30B
7H*	Terminates at Proposed Channel Studies Site between UMR-32 and UMR-33 (i.e. NorXway Chnnl. Confl.)(basin is undiff. channel margin)	UMR-30A,-31 and -32
7G***	NOR-X-WAY CHANNEL BASIN	NXWC-1,-2,-3,-4,-5,-6,-7,-8,-9,-10 and -11
7F***	LILLY CREEK BASIN	LC-1,-2,-3,-4,-5,-6,-7,-8,-9,-10 and -11
7E*****	Terminates at Proposed Channel Studies Site between UMR-35 and UMR-41 @ LC-11 (i.e. Lilly Cr. Confl.)(basin is undiff. channel margin)	UMR-33,-34 and -35
7D****	DRETZKA PARK CREEK BASIN	UMR-36,-37,-38,-39 and -40
7C*****	Terminates at ex-SEWRPC Sta. Mn-5 (i.e. W.Mill Rd.)(basin is undifferentiated channel margin)	UMR-41,-42 and -43
7B***	BUTLER DITCH BASIN	BD-1,-2,-3,-4,-5,-6,-7,-8,-9,-10,-11,-12,-13 and -14
7A*****	Terminates at DNR Station 683001 (i.e. #7)(basin is undifferentiated channel margin)	UMR-44,-45 and -47B
3F***** Little Menm. Addition	Terminates at Proposed Channel Studies Site between LTMR-31 and LMR-1 @ UMR-47 (i.e. Little Menomonee Confl.)(basin is undifferentiated channel margin, remainder of Little Menomonee Basin)	LTMR-30 and -31
3E*****	Terminates at Proposed Channel Studies Site between UMR-47 and LMR-1 @ LTMR-31 (i.e. Lower Menomonee Confl.)(basin is undifferentiated channel margin)	UMR-47A and -46
3D*****	Terminates at ex-SEWRPC Sta. Mn-7A (i.e. Curry Park)(basin is undifferentiated channel margin)	LMR-1,-2,-3,-4 and -5

Appendix G Table 3 (cont.)

Aggregated Sub-Watershed Identifier	Description or Characteristics	SEWRPC System Sub-Watershed Components
	Basins Contributory to Honey Creek	
4D****	Terminates at Proposed Channel Studies Site between HC-4 and HC-6 @ HC-5 (i.e. undifferentiated channel margin)	HC-1,-2,-3,-4 and -5
4C*	Terminates at ex-SEWRPC Sta. TMn-13 (i.e. McCarty Park)(basin is undifferentiated channel margin)	HC-6,-7,-8 and -9
4B*	Terminates at Proposed Channel Studies Site between HC-12 and -13 (i.e. undifferentiated channel margin)	HC-10,-11 and -12
4A*	Terminates at DNR Station 413006 (i.e. #4)(basin is undifferentiated channel margin)	HC-13,-14,-15,-16,-17 and -18
	Basins Contributory to Underwood Cr./Lower Menomonee River	
6F***	Terminates at Proposed Channel Studies Site between UC-2 and UC-3 @ DD-9 (i.e. Dousman Ditch Confl.)(UPPERMOST UNDERWOOD CR. BASIN?)	UC-1 and -2
6E***	DOUSMAN DITCH BASIN	DD-1,-2,-3,-4,-5,-6,-7,-8 and -9
6D***	Terminates at Proposed Channel Studies Site between UC-7 and UC-8 (i.e. undifferentiated channel margin)	UC-3,-4,-5,-6 and -7
6C*****	Terminates at ex-SEWRPC Sta. TMn-12 (i.e. South Branch Confluence) (basin is undifferentiated channel margin)	UC-8,-9,-10 and -11
6B**	SOUTH BRANCH UNDERWOOD CREEK BASIN	SBUC-1,-2,-3,-4,-5,-6,-7,-8,-9,-10,-11,-12,-13 and -14
6A*	Terminates at DNR Station 413006 (i.e. #6)(basin is undifferentiated channel margin)	HC-13,-14,-15,-16,-17 and -18
3C* Middle Menm. Addition	Terminates at Proposed Channel Studies Site between UC-19 and LMR-17 @ LMR-16 (i.e. Underwood Cr. Confl.)(basin is undifferentiated channel margin, remainder of Underwood Cr. Basin)	UC-17A,-18 and -19
3B*	Terminates at Proposed Channel Studies Site between LMR-16 and LMR -17 @ UC-19 (i.e. Underwood Cr. Confl.)(basin is undiff.chnnl.margin)	LMR-13,-14,-15 and -16
3H*	Special Studies Basin (Timmerman Field)	LMR-7
3G*	DNR Recommended Sub-Watershed (Special Studies Focus)	LMR-6,-8,-9,-10,-11 and -12

Appendix G Table 3 (cont.)

Aggregated Sub-Watershed Identifier	Description or Characteristics	SEWRPC System Sub-Watershed Components
	Basins Contributory to Underwood Cr./Lower Menomonee River (cont.)	
3A* HoneyCr.Addtn.	Terminates at DNR Sta. 413005 (i.e. #3)(basin is undifferentiated channel margin)	LMR-17,-18,-19 and -20; HC-19
2(A)*	Terminates at DNR Sta. 413009 (i.e. #2)(basin is undifferentiated channel margin)	LMR-21A,-22 and -23
5(A)**	Terminates at DNR Sta. 413010 (i.e. #5)/SCHOONMAKER CR. BASIN	LMR-21B
1C*	Terminates at Proposed Channel Studies Site at 45th St. Dam (i.e. undifferentiated channel margin)	LMR-24
	Basin Contributory to Transition Section	
1B*	Terminates at Proposed Channel Studies Site at End of Channelization (i.e. undifferentiated channel margin)	LMR-25 and -26
	Basin Contributory to Semi-Estuary Section	
1C*	Terminates at DNR Sta. 413004 (i.e. #1)(basin is undifferentiated channel margin)	LMR-27,-28,-29 and -30

* Recommendation is that there be no subchannel or gulley scour/deposit mechanisms.

** Recommendation is to apply a simplified sedimentation subroutine to account for subchannel scour/deposit; however, that there be no gulley erosion/overland deposition mechanism.

*** Recommendation is to apply a simplified sedimentation subroutine to account for subchannel scour/deposit and an empirical extrapolation to extend overland runoff sediment loadings to account for gulley erosion/overland deposition.

**** Recommendation is to apply a simplified sedimentation subroutine to account for subchannel scour/deposit and an empirical extrapolation thereof for extension to account for gulley erosion/overland deposition.

***** Recommendation is that the empirical extrapolations of associated sub-watersheds be applied to account for gulley erosion/overland deposition, corresponding thusly:
for basin 12C, apply the coefficient from basin 12 D;
for basins 12A and 10E, apply the coefficient from basin 12B;
for basin 10C, apply the coefficient from basin 10D;
for basin 11A, apply the coefficient from basin 11B;
for basins 10A, 7C and 7E, apply the coefficient from basin 7F;
for basins 8C, 8B and 8A, apply the coefficient from basin 7D;
for basins 7A, 3F, 3E and 3D, apply the coefficient from basin 7B;
for basin 6C, apply the coefficient from basin 6E.

Appendix G Table 4. Currently-recommended land use aggregations

1) Native-State Wetland; SEWRPC Classes 90+91.
2) Native-State Upland: SEWRPC Classes 49+73+74+94; in rural areas (i.e. more than one * asterick-designated sub-watersheds on Aggregation Table--No. 2) also +92.
3) CROPland: SEWRPC Classes 80+84, as proportioned sub-watershed by sub-watershed; plus weighted proportioning of 54+55+56.
4) Animal Husbandry: SEWRPC Classes 80+84, complementary to proportioning as above; also +83; plus weighted proportioning of 54+55+56.
5) Orchard and Nursery: SEWRPC Class 82; plus weighted proportioning of 54+55+56.
6) Low-Density Residential: SEWRPC Classes 53+93; in rural areas (i.e. as above--for land-use 2) also 00+05+61+71; in urban areas (i.e. one * asterick-designated sub-watersheds on Aggregation Table--No. 2) also 92; plus weighted proportioning of 54+55+56.
7) Medium-Density Residential: SEWRPC Class 01; in rural areas (i.e. as above--for land-use 2) also 03; in urban areas (i.e. as above--for land-use 6) also 00+05+61+71; plus weighted proportioning of 54+55+56.
8) High-Density Residential: SEWRPC Classes 02+04; in urban areas (i.e. as above--for land-use 6) also 03; plus weighted proportioning of 54+55+56.
9) COMMercial/rural and suburban downtown: SEWRPC Classes 10+11+20+21+50+57+58+60+62+63+70+72+75; plus weighted proportioning of 54+55+56.
10) INDustrial: SEWRPC Classes 30+51+52+59; plus weighted proportioning of 54+55+56 [Future attention might be given to Heavy/Light Industry breakdowns in U.S. and Canada; e.g. in Milwaukee area: Heavy Industry seems to be SEWRPC Classes 51+52 and within Class 30, Standard Industrial Classifications (S.I.C.) 29+30+33+35+<u>36</u>+37+39; Light Industry seems to be SEWRPC Classes <u>49</u> (where active) +57+59 and within Class 30, S.I.C. 20+21+<u>22</u>+23 to 27+<u>28</u>+31+<u>32</u>+34+38. Note that characterization of underlined classifications might vary in other locales].
11) [Extra High-Density Residential/Urban Downtown: Only found in estuary-contributory LMR-33 and -34, as well as Milwaukee River margins.]
12) [Extra Low-Density: Not for incorporation within M.P.W.S. project; future visualized class by SEWRPC.]

organic constituent of water quality has become somewhat muted. It has been learned that the more hazardous form is relatively rare in the environment, while the more frequent form seems without biological consequence. Modeling attention (though not all analysis attention) might turn to polychlorinated biphenyls (PCBs), polyaromatic hydrocarbons (PAHs) or some pesticide of high hazard and frequent environmental occurrence. Similarly, toxic metals modeling should preserve the option that cadmium could be incorporated (perhaps substitution--via coefficient changes and input data substitution--for zinc in the visualized triad of lead, copper, and zinc).

Current thinking on the parameters of land use and pollutant focus having been discussed, attention now turns to the channel-transport model's sedimentation subroutine felt to be the key to elucidating their interrelationship.

Modifications to the Einstein Bedload Equation may provide the best quantification of sediment-delivery by watercourses when sand and gravel predominate. However, generally cohesive character of fine-silt and clay conditions tends to lead to the conceptualization that tractive [shearing-] stress and critical tractive stress considerations govern for those circumstances. Certainly each approach has its best conditions of application within a mechanistic sedimentation-effects subroutine, in turn constituting part of a continuous-simulation water-quality modeling on a digital computer. However, insofar as watercourse sediment-delivery is comprised of varying fractions, might the two approaches be linked? Silt, coarse clay, and medium/fine clay fractions (size-convention as per Am. Geophysical Union and U.S. Geological Survey) scour might be determined by tractive-force methodology, deposition of the same by saturated-flow methodology, and scour/deposition of the sand/gravel fraction by Einstein Bedload methodology. It is proposed that initial quantification of scour acting upon the silt/clay matrix would (by correspondence to sediment-size distribution) yield the amount of sand/gravel actually available for scour. Thence Einstein Bedload analysis (applying as D_{65} that of the fraction)--perhaps exploiting the Colby-Hembree modification or revision thereto--would yield either sand/gravel deposition or potential scour. Actual availability as a proportion of the scour potential would similarly reduce available tractive-force upon the silt/clay matrix in an iterative recycle.

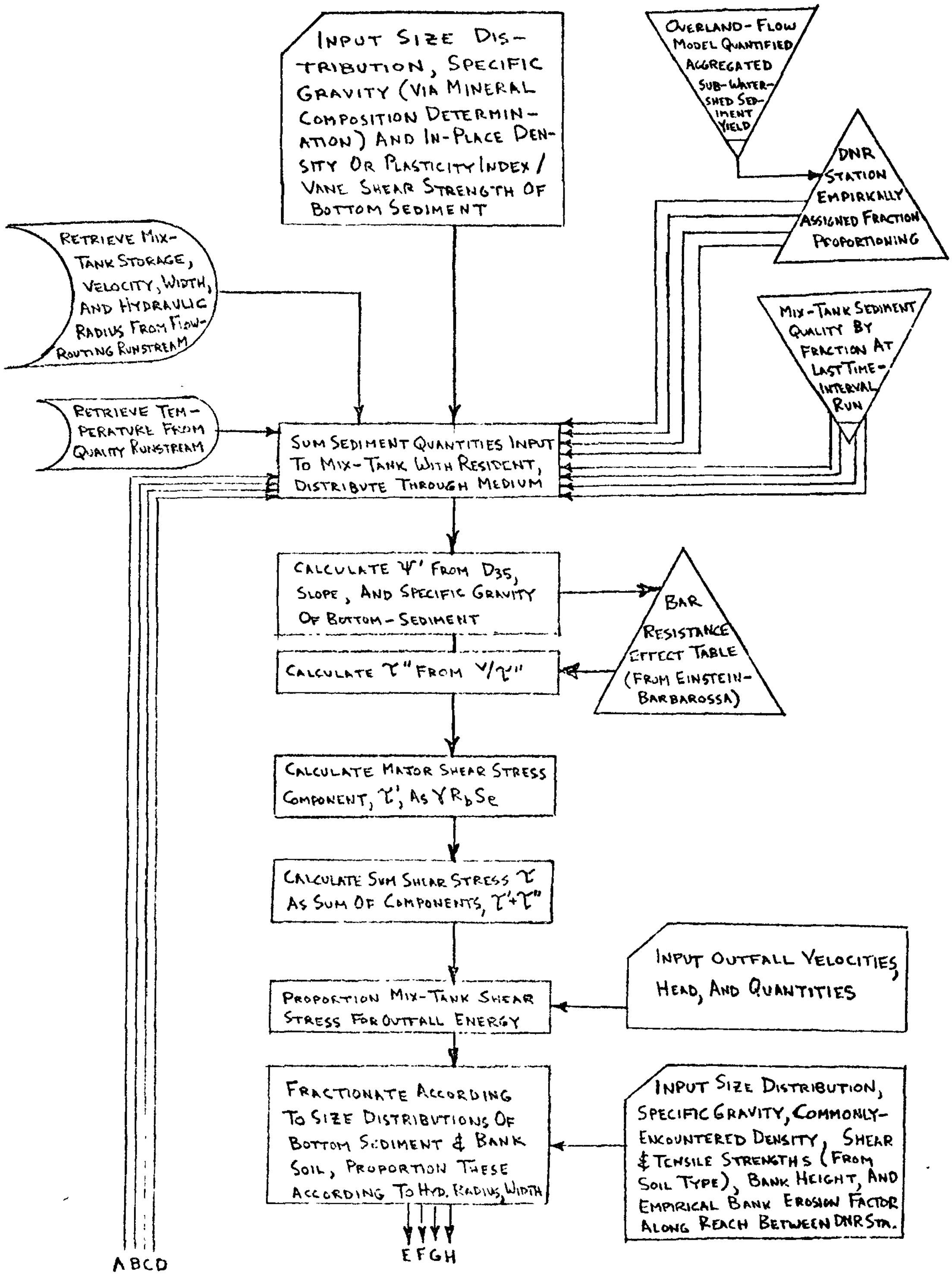
Parallel change in critical tractive-force for the composite aggregation from that of a pure matrix would also require evaluation. Where correspondence to void-ratio (i.e. a measure of consolidation-density) has been felt superior to that of plasticity-index, additional consideration of [vane] shearing-strength probably corrects such deficiency. However, the dearth of information on electrochemical effect is a potential major problem. It is hoped that some inherent dependency between ionic strength and plasticity-index (or, alternatively, to percentage-clay) is at work, thereby allowing some reproducible derivation of equilibrium critical tractive-force from results of in-field [vane] shear-testing (or, alternatively, to void-ratio). Such low-flow testing upon the wetted sediment would probably show development of some manner of smooth "gel" coating, since grooves and ultimately core-like holes seem to develop at higher flows, likely above critical. Similarly, the dictate that salt, detergent, and cement levels be low suggests potential for erosion-controlling management-practices.

Streambank-erosion accompanying streambed-erosion might be stochastically analysed as a contribution linearly-dependent on the soil's tensile (i.e. cohesion-proportionate) strength and composite (i.e. net-interactive) shearing strength. Such gross-simplification is to say that failure might be visualized in bending or, more likely, confined/consolidating shear mode against the unit-weight based mechanics of quantitatively scour-undercut bank ideally-cantilevered. Although actual conditions of fracture in dense silt and dry clay soil would be along an inclined plane approximating the angle of internal friction (generally manifested as a curved surface), assumption of vertical failure would probably be justified as an adequate measure of effective material contribution, more especially given the stochastic character of the analysis and the presence of some delivery-coefficient from field calibration.

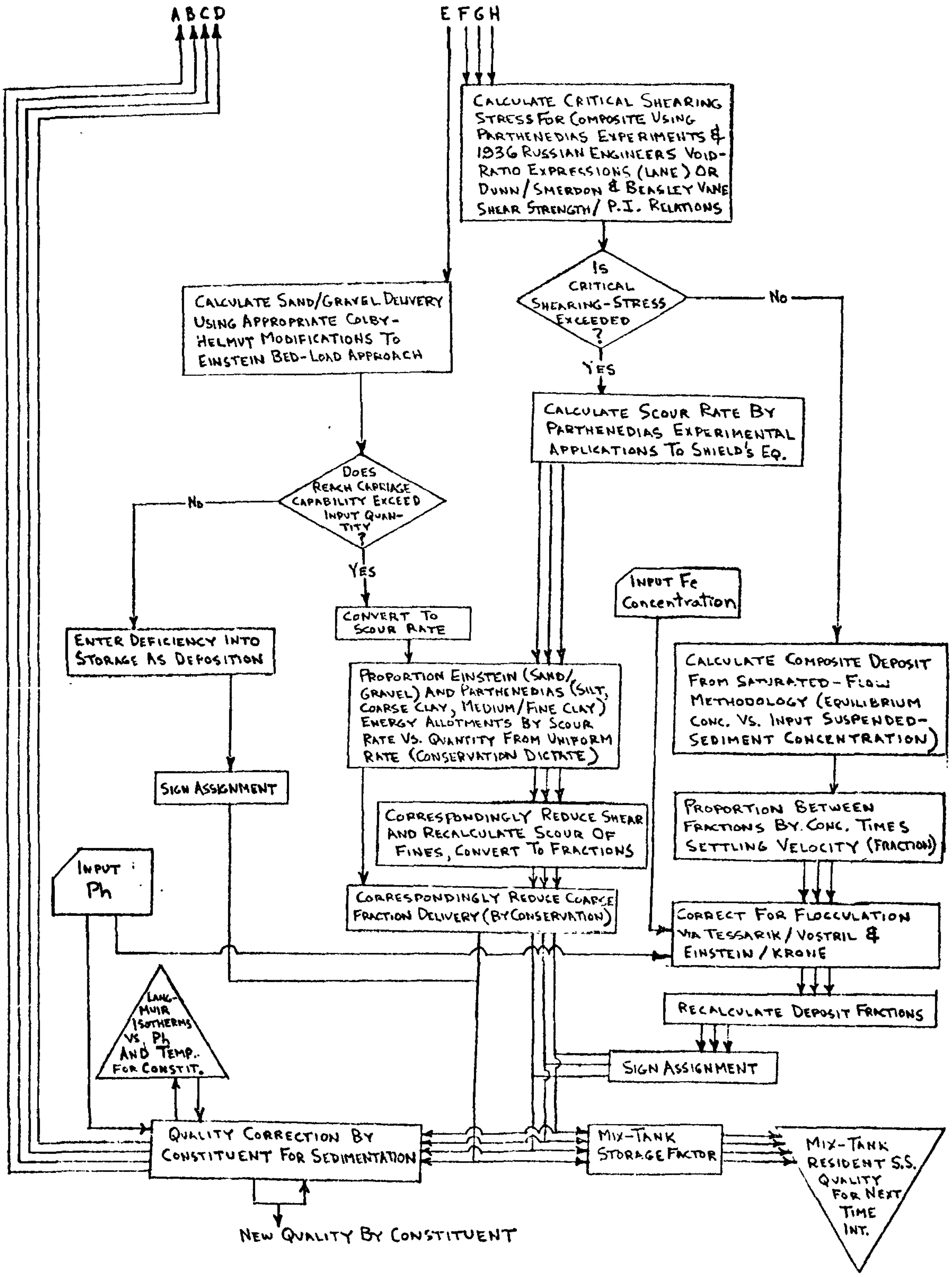
Throughout modeling, sediment input-quantity is available from the main-program's finite-elements, consistent with Modified Puls dynamic flow-routing. Flocculation effect (especially as modified by ferric-ion concentration and pH) must then also be considered (with scour) to assess the complemental saturated-flow derived deposition. Use of Langmuir isotherms, corrected for pH, allows application of the main-program generated temperature to quantify adsorption of other pollutants. Thereby, the sediment-transported portion of the total pollution quantities could be determined for subjection to either deposition-induced reduction (i.e. as a total pollutant load, percentage of total sediment remaining constant) or scoured-material "dilution" (i.e. as a percentage of total sediment, total pollutant load remaining constant). Thus pass to the next "mix-tank" is not only sediment quantity, but some superior estimation of other pollutant quantities as well. An outline of the foregoing sedimentation treatment is presented as a subroutine flow-chart in Appendix G Fig. 39 and represents the design of current program-writing.

It is important to note, that it is a virtual certainty that a sedimentation mechanism applicable to rivers would also be applicable to an estuary, if flows were adequately described. Adequate description of flows require seiche description. Several agencies (Milwaukee Dept. of Bridges and Buildings, Milwaukee Metropolitan Sewage Commission, and the U.S. Great Lakes Survey) have collected water level records, weather inputs from the National Climatic Center are also available, and a graduate student at the University of Wisconsin seeks to construct an analog model describing water levels in Milwaukee Harbor. Secondly, Wisconsin Power Co. power plant withdrawal effects, both flow and thermal stratification, must undergo analysis via processing of available data.

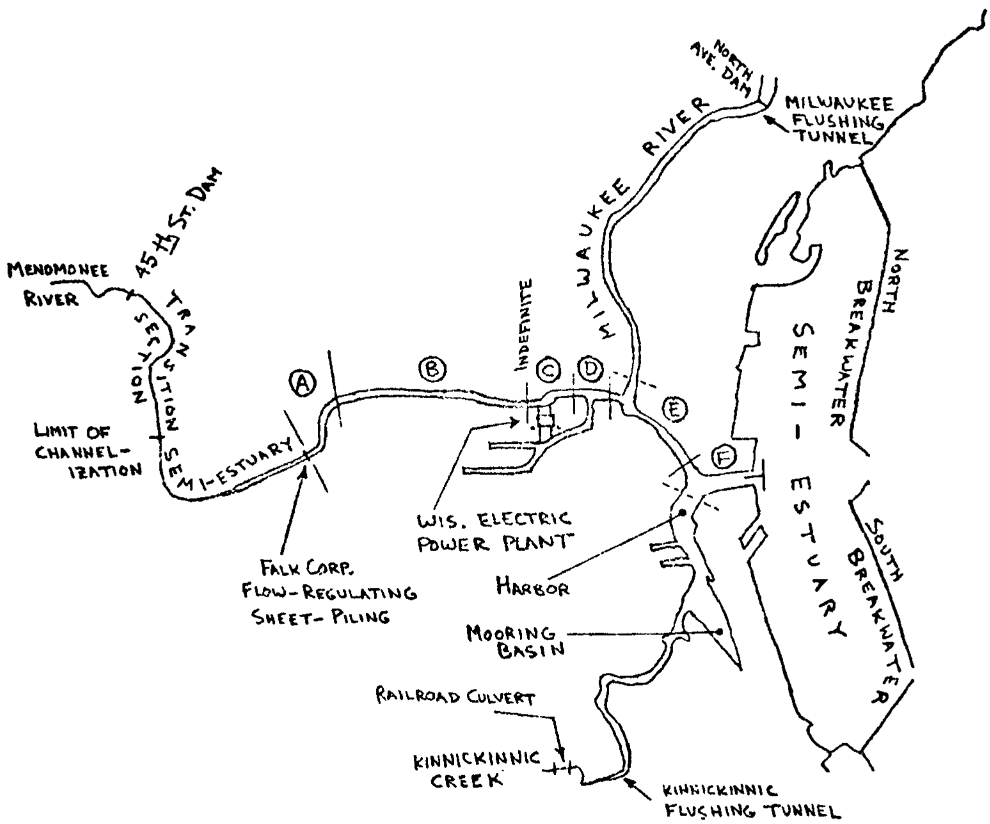
A framework might be the application of several small "reservoir-elements" at critical points, believed made possible by the relatively narrow width and significant [dredged] depth of the focus portion of the estuary. Feeling exists on both sides as to whether this would be a valid approach (Appendix G Fig. 40). Finally, the need exists to apply to the estuary what sedimentation routines have been developed for the river. Though solely-estuary models reportedly exist, they deprive us of the opportunity to assess deposit at the most upstream portion of the



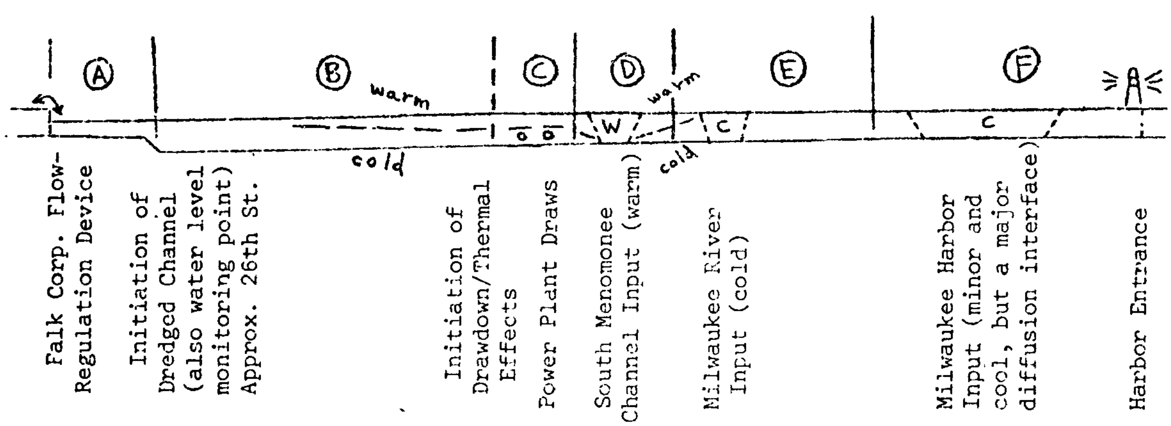
Appendix G Fig. 39. Flow chart of all-purpose sedimentation subroutine.



Appendix G Fig. 39. (cont.).



Section A: Falk Corp. to 26th St.
B: 26th St. to vicinity of Power Plant
C: Power Plant Withdrawal Section
D: So. Menomonee Channel Input Vicinity
E: Milwaukee River Input Vicinity to Harbor Confluence
F: Rivers-to-Harbor Confluence to Harbor Entrance



Appendix G Fig. 40. Plan and profile representation of proposed sectioning of estuary to account Seiche, power plant withdrawal and tributary input effects in applying water quality river-reservoir model.

model. Nonetheless, stripped down to their basic algorithsm, estuary sedimentation mechanisms are seen to be parallel to river sedimentation mechanisms and it seems advisable to have the latter modeling encompass the former, rather than settle for partial effect quantification, possibly of the portion of lesser significance. Interchangeability in application should be a design dictate.

Extensive visits to the watercourse channel system have been undertaken. This field presence not only serves to determine flow-controlling input-constants, but also produces first-hand a familiarity with the river system, e.g. location and character of sediment deposits, indication of problem areas, etc. Similarly, there is implicit suggestion of management-practice alternatives which does not develop in the office or during infrequent field visits, no matter what the technical expertise on hand. It is noteworthy that determination of channel Manning's coefficients in the uppermost Menomonee River has been accomplished. Fortuitously, SEWRPC over-bank coefficients are felt adequate for (MPWS) purposes. Additional channel determinations, in the middle Menomonee River and probably also the Little Menomonee River, are anticipated, but have been delayed pending equipment receipt and the possibility of coordination with bottom-sediment sampling (i.e. size-distribution and in-place densities both). Numerous details continue to require attention. Among these are Hydrologic Season definition. In sum, limited flexibility of flow changes allows for a four season breakdown in accordance with PLUARG's recommendations. It is very important that control establishment via at least one "native-state" wetland and one "native-state" upland site (though it would better to have one of the latter for each of the three hydrologic soil groups present). Continuing problem-locale identification would contribute to scrutiny of, feasibility assessment upon, and development of management-practice alternatives. The data coming in from the field seems to indicate that the modeling should consider the soil character difference in watercourse channels between the western side of the watershed (deep soils, generally silt loam, underlain by clay; possible glacial lake-bed deposits scattered throughout) and the eastern side of the watershed (shallow soils, generally silt loam, underlain by clay). Additionally, coordination with atmospheric fallout input determinations seems to indicate the efficacy of applying an atmospheric diffusion model (Ragland et al., 1975). SEWRPC's urban data-record based modeling could be supplemented by on-going monitoring (with additional wind-velocity recording, however) and use of either ASCE-presented surface-soil wind-erosion equations or Chamberlin's (Vanoni, 1975) deposition work.

Similarly, there remains optimism for successful toxic-metals, CBOD, and strept coliform calibrations (and ultimately perhaps nutrient and organic supplement to Marquette University's more-mechanistic approaches) via shortly-impending "semi-empirical" least squares fit of urban land use generated pollution to a washoff mechanism and rural to a "Wisconsin-form" of the Universal Soil Loss Equation (as derived from the Foster form). Much data input to that process will be extracted from other sections of this report.

References

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APPENDIX H

LAND DATA MANAGEMENT SYSTEM

Introduction

The Land Data Management System (Land DMS) is a digital computer-based system designed to store, retrieve, analyze and display--in tabular or graphic form--land data for the Menomonee River watershed. The term "land data" as used in the context of the Land DMS is a comprehensive concept in that it denotes all those watershed characteristics that have an areal extent. For example, land data encompass land use, soil type and civil division information but do not include water quality or stream flow information.

Uses of the Land DMS

The Land DMS has two principal uses in the Menomonee River Pilot Watershed Study:

1. Interpretation of water quality and quantity data acquired from routine long-term monitoring activities as well as data obtained from short-term specific land use studies.
2. Input to hydrologic-hydraulic-water quality models.

Description of the System

The basic areal unit for storing, retrieving, analyzing and displaying land data is a cell having a nominal area of 1.0 hectare (2.5 acres). The corners of each cell may be referenced to the State Plane Coordinate System, to latitude and longitude, and to the Universal Transverse Mercator System. The digital computer system--hardware and software--needed to support the Land DMS is broken into four phases: the input phase, the data manipulation phase, the data base phase, and the output phase. Under the input phase, data are entered into the Land DMS on either magnetic diskettes or punched cards. The second, or data manipulation, phase is composed of a set of computer programs that perform contingency checks on the incoming data, provide for the maintenance and updating of the data, analyze the data, and prepare it for transfer back to the user. The analysis capability of this phase facilitates--through an "overlay" process--the identification of cells having specified combinations of land data types. The third, or data base, phase of the Land DMS consists of the actual storage of the areal characteristics of each cell in a computer file which is maintained on magnetic tape or on magnetic disc. The fourth or output phase provides transfer of land data from the Land DMS to the user in a variety of media including magnetic tape, punch cards, on-line printer, and plotter.

Work Elements Completed since April 1976

1. Completed coding of 1970 land use and initiated coding of 1975 land use.
2. At the request of study participants, the Land DMS was used to provide various graphic and tabular summaries such as a watershed map showing land use by cell and a tabular summary of land use by sub-basin, sub-watershed, and by total area tributary to each monitoring station.

Land Data Contained in the Land DMS

Appendix H Table 1 summarizes the status of land data within the Land DMS. Ten data types have been coded for the entire watershed, and the coding of three data types is in progress. Other land data types will be added in response to the needs of the Menomonee River Pilot Watershed Study.

Example of Land DMS Output

The simplest use of the Land DMS is to display, in graphic or tabular form, one or more of the land data types contained within the data base for a given geographic area. Typical tabular output is shown in Appendix H Table 2 in the form of quantified land use and soil data for an in-watershed portion of a given U.S. Public Land Survey section. Graphic output from the Land DMS is illustrated in Appendix H Figure 1 in the form of mapped land use data by cell for the same section. Maps can be produced by the system at essentially any scale, and maps, as well as tables, can be constructed in any desired format including the results of "overlaying" specified combinations of land data types. A variety of special graphic displays can be created such as isometric representations of surface topographic features.

Appendix H Table 1. Status of land data in the Land Data Management System

Data type	Status		Type of coding		
	Completed	In progress	Dominant characteristic	Percent of cell	Other
1. Civil division	x		x		
2. Sub-basins and subwatersheds	x		x		
3. Wildlife habitat (with value ratings)	x		x		
4. Woodland-wetlands (with value ratings)	x		x		
5. Park and outdoor recreation sites	x		x		
6. Floodlands	x		x		
7. Perennial streams	x				x
8. Conservancy, floodland and related zoning	x		x		
9. Soils (with degree of erosion and ground slope)	x			x	
10. Ground elevation		x			x
11. Land use-1970	x			x	
12. Land use-1975		x		x	
13. Monitoring stations		x			x

Appendix H Table 2. Example of tabular output from the Land DMS

LAND USE DATA BY LAND USE TYPE

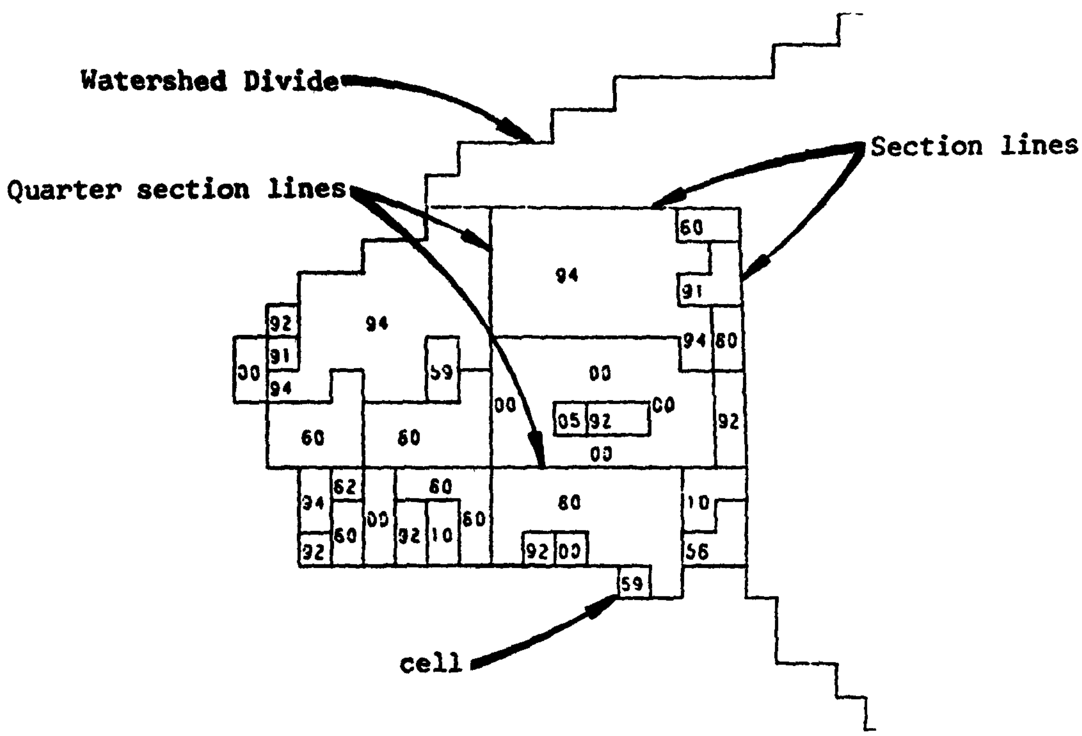
SECTION	LAND USE CODE	AREA IN SECTION (ACRES)	PERCENT OF TOTAL
0720-28	00	65.24	16.46
	05	11.55	2.91
	10	13.02	3.28
	20	.28	.07
	54	10.77	2.72
	55	8.61	2.17
	58	8.24	2.08
	59	15.13	3.82
	60	15.17	3.83
	72	.37	.09
	80	83.82	21.14
	82	1.19	.30
	91	12.17	3.07
	92	22.98	5.80
	94	127.92	32.27
TOTAL		396.44	100.01

SOIL DATA BY CELL

SECTION	CELL NO.	SOIL CODE	ACRES
0720-28-1	01	0073	.73
		0357	1.72
	02	0073	.73
		0076	.99
		0357	.48
		0450	.25
	03	0076	.99
		0450	1.47
	60	0212	.25
		0364	2.27
	61	0299	1.52
		0364	1.01
	62	0299	2.27
		0363	.25
	63	0076	.25
		0363	2.25
	64	0076	.25
		0363	2.25
0720-28-2	01	0450	2.55
	02	0450	2.55
	13	0450	2.55
	14	0450	2.55
	15	0450	2.55
	16	0450	2.55
	17	0450	2.55
	18	0450	2.55
	19	0450	2.55
	20	0450	2.55
	21	0450	2.55

Township 7 North, Range 20 East, Section 28

Land Use Data



Numbers indicate code
of dominant land use.

Scale 1" = 2000'

Appendix H Fig. 1. Example of graphic output from the Land DMS.