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AT
PEORIA, ILLINOIS

SWS Contract Report 412

AN ASSESSMENT OF INDIAN CREEK BOTTOM SEDIMENTS IN THE VICINITY OF COMBINED SEWER OVERFLOW 25 IN AURORA, ILLINOIS

by Thomas A. Butts

Prepared for the Aurora Sanitary District
in cooperation with Walter E. Deuchler Associates,
Aurora, Illinois

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INTRODUCTION

Indian Creek, a tributary to the Fox River, is a small creek running through residential, industrial, and commercial areas of Aurora, Illinois. The Indian Creek interceptor sewer, a segment of the Aurora Sanitary District's combined sewer system, runs parallel to the creek. During wet weather, the hydraulic capacity of the interceptor is exceeded, and excessive flow is discharged to Indian Creek at a point approximately 5600 feet above the confluence of the creek with the Fox River. The overflow has been designated combined sewer overflow (CSO) 25, and its location is shown on figure 1. The 7-day, 10-year low flow is zero at all locations along the creek (Singh and Stall, 1973).

The Aurora Sanitary District needs information to assess the long-term or chronic effects the CSO has on benthic sediment and benthos conditions downstream of the CSO. This study provided the minimum amount of information needed to make this assessment to satisfy the requirements of the CSO Rules and Regulations set forth in Section 306.361(b) of Subtitle C of Chapter 1 of the Illinois Pollution Control Board's (IPCB) Rules and Regulations (Illinois Pollution Control Board, 1986).

Study Plan

Sediment and benthos (bottom macroinvertebrate) conditions were evaluated at four locations in the creek in August 1986. Sampling stations were located approximately 150 feet above the outfall, at the immediate outfall point, 250 feet below the outfall, and at a point approximately 2640 feet downstream of the outfall (figure 1). These four points appeared to be adequate for assessing the effects of combined sewage overflow on Indian Creek bottom sediments. A photograph of overflow 25 is shown as figure 2, and a photographic view of the creek in the vicinity of the overflow is shown as figure 3.

On-site sediment oxygen demand (SOD) determinations were made by using the methods and procedures developed and employed by the Illinois State Water Survey (Butts, 1974; Butts and Evans, 1977; Butts and Evans, 1978; Butts et at., 1982; Butts, 1986). Direct measurements of total and carbonaceous SOD were made, and from these results, the nitrogenous fraction was ascertained.

Three benthic biological (benthos) samples were taken at each station with a Petite Ponar sediment dredge. The samples were sieved and the residue was preserved for laboratory use for enumerating and identifying the benthos.

Benthic sediment samples were collected with the Petite Ponar dredge. The samples were characterized and described in the field as to their general makeup. A portion of the top 1 to 2 inches of each dredge sample was retained and returned to the laboratory to determine the consistency of the sediment (percent moisture content) and the organic content (percent volatile solids).

Plankton (algae) samples were collected and preserved. The algae were enumerated and identified in the laboratory. Black-bottle incubations of ambient water samples were carried out in the field commensurate with measuring the SODs so that dissolved BOD and suspended algae respiration could be isolated from respiration due strictly to bottom sediments and periphyton.

Acknowledgements

This study was sponsored and funded by a grant from the Aurora Sanitary District. Thanks are extended to Ajit Singh Bhamrah of Walter E. Deuchler Associates who provided guidance during the study. The work was performed under the general supervision of the Chief of the Illinois State Water Survey, Richard Semonin. Peter Berg assisted in the field work. Jud Williams picked the benthos, and Tom Hill identified and enumerated the organisms. The illustrations were prepared by Jud Williams; Linda Johnson prepared the original manuscript; and Gail Taylor edited the report.

SAMPLING EQUIPMENT AND PROCEDURES

Sediment oxygen demand can be defined broadly as the usage of dissolved oxygen in the overlying water by benthic organisms. In some instances, it can include or result from inorganic chemical oxidation reactions. However, under aerobic conditions it is principally the result of the biochemical oxygen demands of micro- and macroorganisms. The major microdemand is due to bacteria; however, diatoms, protozoa, and aquatic fungi respiration can be significant at times. Macrodemand is caused by aufwuch communities (surface-Iiving organisms) and burrowing fauna. Worms, insect larvae and nymphs, leaches, and mussels are the principal burrowing types. Periphyton, or organisms which are attached to underwater substrates, represent an important source of SOD in some streams, in some deep areas of some clear lakes, and in the littoral zones of most lakes.

Sampling Equipment

The SOD measurement equipment and procedures used for this study are adaptations and modifications of those originally developed by the Water Quality Section of the State Water Survey for determining the influence of sediments on the dissolved oxygen balance along the upper reaches of the Illinois Waterway (Butts, 1974). Bowman and Delfino (1978) have compiled an excellent review of the state of the art of measuring SOD in the laboratory and in the field. These authors place SOD methodologies into five classes. One is designated as the batch system, and it is the basis around which State Water Survey equipment and operating procedures have been designed.

The so-called batch system, as employed by the Water Survey, entails the use of a chamber respirometer equipped with a means of internally circulating water. Its operation consists essentially of containing a known volume of water over a given bottom area using either a bell, box, or pyramidal-domed chamber, and measuring the DO drop with a galvanic cell oxygen probe implanted internally. For this study, a small box-type sampler, which had produced excellent results for numerous shallow streams and lakes within Illinois, was used. The detailed design of the sampler is given by Butts and Evans (1978).

The sampler is 12 inches long, 7 inches wide, and 7 inches deep to the top of the seating flange. It is fabricated of 3/16-inch steel plate welded all around. The seating flanges are 3/16-inch steel plate extending 1-1/2 inches from the outside faces of the box sides; a 2-inch seating depth is provided. Removable water-proofed plywood extension flanges can be bolted to the steel flanges when needed.

This sampler was designed to accommodate three methods of internal water circulation or movement: two different pumping systems and an electrical stirring mechanism. The pumping can be accomplished by using either a submersible or nonsubmersible pump. For this study, the stirring system was used. The stirring mechanism is attached to a large split collar that has been adapted to fit YSI 5795A and YSI 5695 submersible stirrers. The DO-temperature probe is housed within the stirrer. The stirrers operate on size D flashlight batteries. A YSI Model 58 DO-temperature meter fitted with a YSI 5695A stirrer was used, and the results were manually recorded for each incremental time lapse.

Benthos and sediment samples were collected with a 6-inch-square Petite Ponar dredge, a hand-held clam-shell type dredge suitable for small-stream biological and sediment work. Benthos samples were washed through a Wildco Model 190-E20 plastic bucket equipped with a No. 30 sieve to retain all macroinvertebrates.

Sampling Procedures

Runs were initiated by calibrating the DO probe according to the standard wet-chemistry Winkler method (American Public Health Association et al., 1985). Two DO bottles were then filled with creek water and incubated in the creek under dark conditions for the duration of a run to check for algal respiration. The calibrated probe was fitted into the SOD chamber, and the unit was sealed in the sediment up to the side flanges. At all four locations, the stream bottoms were rocky and hard; consequently, the plywood extension flanges were used, and the seal was secured by sandbagging on and around these flanges (figure 4).

Dissolved oxygen and temperature readings were taken at 5-minute intervals. The runs were terminated when the demand curve appeared to stabilize linearly. If the curve leveled off abruptly, this signalled a leak and the chamber was pulled up and reset in another nearby area.

Two types of SODs were ascertained during a given run: the total sediment oxygen demand and the total demand minus that caused by nitrification. The total SOD minus that caused by nitrification was isolated from the total SOD by adding a nitrifying inhibitor to the chamber after a total (uninhibited) run was completed. This inhibitor, 2-chloro-6-(trichloromethyl)pyridine, is the same chemical, N-serve, that is used by farmers to stabilize fall applications of anhydrous ammonia. Nitrification is the process by which specialized bacteria, thriving in the water or in bottom sediments, oxidize dissolved ammonia (NH_3) in water or benthic (bottom) sediments.

Approximately 1.6 grams of inhibitor was added to the chamber. This was done by delivering 32 Hach dispenser cap injections into the chamber; this dispenser is designed to inoculate a standard BOD bottle with 0.05 grams of inhibitor, and the volume of the SOD sampler is equivalent to about 32 BOD bottles. After an inhibited run was completed, the inside of the chamber was thoroughly scrubbed with acid-detergent washing solution to remove all traces of the inhibitor to eliminate the possibility of any residual effects during the next uninhibited run.

Three Ponar dredge samples were collected, and from these, 65 to 75 grams of sediment were retained for laboratory analyses for water content and volatile solids. The remainder was sieved, and the sieved residue was preserved with alcohol in plastic bottles for the determination of bottom dwelling macroinvertebrate populations (benthos). Physical descriptions of both unsieved and sieved sediments were recorded. Approximately 400 ml of water was collected and preserved with formalin for use in algal identification and enumeration in the laboratory.

DATA REDUCTION AND ANALYSES

Curves showing DO used versus time were drawn and used to a great extent in analyzing and interpreting the SOD data. Interpretation of these types of curves can at times be subjective. However, knowledge of the chemical, physical, and biological conditions existing during the sampling period can greatly aid in interpreting causes and effects.

The SOD rates as taken from the curves are in units of milligrams per liter per minute (mg/l/min) of dissolved oxygen usage and must be converted into grams per square meter per day (g/m /day) for practical applications. The general conversion formula is:

$$SOD = (1440\ SV)/10^3 A \qquad (1)$$

where

SOD = sediment oxygen demand, g/m^2 /day
S = slope of stabilized portion of the curve, mg/I/min
V = volume of sampler, liters.
A = bottom area of sampler, m^2

The specific formula for the box sampler and the stirrer combination when seated up to the flanges in sediment is:

$$SOD = 205.5\ S \qquad (2)$$

Generally, equation 2 is applied to the portion of a curve which is linear or which approaches linearity. Many curves, especially those generated for polluted sediments, evolve into a straight line after the effects of initial bottom disturbances have subsided. Often this evolution is clear and distinct, but at other times it is not. Defining SOD curve forms or trends can be a valuable aid in data interpretation.

The in situ SOD measurements taken at ambient water temperatures were corrected to 20 C and 25 C for comparative purposes by the equation:

$$SOD_T = SOD_{20}(1.047^{T-20}) \qquad (3)$$

where

SOD_T = SOD rate at any temperature, T°C
SOD_{20} = SOD rate at 20°C

This equation is a form of the Arrhenius model widely used in water quality studies involving the stabilization of carbonaceous materials in aqueous environments (Butts et al., 1973).

RESULTS AND DISCUSSION

Sampling was completed at station 1 during the afternoon of August 18, at station 2 during the morning of August 19, at station 3 during the afternoon of August 19, and at station 4 during the morning of August 20. Although the study was limited in scope, the results appear to be interesting and informative.

During the period when the field measurements and samples were taken, Indian Creek flow was very low. The stream consisted of well-defined riffles and shallow pools. The SOD measurements and benthos samples were taken in shallow pools about 14 inches deep at stations 1, 3, and 4. At station 2, a hole, about 6 feet deep, has been eroded around the outfall. The station 2 measurements and samples were taken in about 3 feet of water on the downstream edge of this pool. Photographs of the station 1, 2, 3, and 4 locations are shown as figures 4, 5, 6, and 7, respectively. The stream is shrouded in a canopy of trees and bushes (figure 3) to a point about 500 feet below the High Street overpass. The water was crystal clear when undisturbed. However, in the area of station 3, walking in the stream caused the water to become gray-black and septic looking because of churned-up sediments.

Results

The data on accumulated DO used in terms of mg/l versus elapsed time in minutes, as derived from field notes, are presented in Appendix A. Plots representing these data in the form of SOD curves are presented as figures 8 through 11. Specific SOD rates, derived by using equation 2 in conjunction with the information contained in Appendix A and the SOD curves, are presented in Appendix B. The incremental differences represent various slope differences exhibited by the curves over the duration of each run with appropriate corrections made for algal respiration. The underlined values in Appendix B represent the stabilized linear portions of the curves which appeared to provide the best estimate of the rates at given locations. The overall results are summarized in table 1. The nitrogenous rate, as presented in table. 1, equals the total rate minus the inhibited rate.

The supplemental physical and biological data and information collected in conjunction with each SOD run are summarized in table 2. Detailed benthic macroinvertebrate and algae data are contained in Appendices C and D, respectively. The term benthos in table 2 refers to benthic or bottom-dwelling macroinvertebrate organisms. The percent solids parameter serves as a general indicator of consistency (i.e., the degree of liquidity of the sediments), while the percent volatile solids (V.S.) or loss-on-ignition parameter serves as a general indicator of organic content. The DO values represent values obtained at the beginning of an SOD run.

Discussion

The sediment classifications listed in table 1 are those presented by Butts and Evans (19783) (table 3). They are appropriate for use only when sediments contain low macroinvertebrate numbers or when large numbers of pollution-tolerant organisms exist in the absence of diversity. Very high SODs can exist in sediments which are highly populated with organisms intolerant to organic, oxygen-consuming wastes.

Butts et al. (1982) found that Mississippi River muds containing over 48,000 organisms per square meter of intolerant macroinvertebrates produced an SOD rate of 5.47 g/m^2/day. In this case, classification according to table 3 is not appropriate, although this value is much higher than any of the four rates measured in Indian Creek. What differentiates the Indian Creek rates from the Mississippi River value is the fact that the macroorganisms in Indian Creek are relatively low in numbers, and the organisms that are present are mostly moderately pollution-tolerant midge-fly larvae and highly pollution-tolerant sludge worms (Appendix C).

The pollution tolerance values for individual organisms and the biotic index values presented in Appendix C were derived from information contained in the IEPA's Field Methods Manual - Biological Monitoring (1980). The biotic index is merely the weighted average (based on numbers) of individual organism tolerance values. The tolerance values range from 0 for highly intolerant organisms to 11 for highly tolerant ones. Pollution tolerance in this case refers to tolerance to organic, oxygen-consuming wastes.

The ambient SOD rates are relatively low at all four stations; however, a significant difference does occur between the upper three stations and station 4 when the measured rates are corrected to common temperatures of 20 C and 25 C. The higher rate at station 4 can probably be attributed to a great extent to the luxuriant periphytonic growth of diatoms and iron bacteria prominent in this stretch of the creek. Although station 1 was above the CSO, it exhibited a higher SOD rate than station 2 at the outfall and station 3 located 250 feet below it. This can be explained by the fact that the stream area above the outfall was covered with periphytic algae, whereas the areas around stations 2 and 3 were essentially devoid of periphytonic growths. The SOD rates at stations 2 and 3 probably represent true <u>sediment</u> oxygen demand rates and are probably good indicators of the chronic or lasting effects overflows from CSO 25 have on the stream bottom.

Table 4 lists some SOD rates measured in comparable-sized streams in northern Illinois. Blackberry Creek, tributary to the Fox River, is a semi-rural stream located in the Aurora area; Flint Creek is a semi-rural stream tributary to the Fox River and receives some treated sewage from the Barrington area; Woods Creek is tributary to the Kiswaukee River and receives treated sewage from Crystal Lake; and Cedar Creek is a rural stream eventually tributary to the Mississippi River -- its headwaters receive CSO and treated sewage from Galesburg. Note that the Indian Creek total SODs are comparable to those measured at the Blackberry Creek, Flint Creek (Station 2), and Woods Creek stations. However, the Indian Creek values are much lower than those measured below Galesburg on Cedar Creek. This creek periodically receives combined sewer overflow from the relatively large community of Galesburg, and it continually receives treated effluent from the Galesburg Sanitary District's sewage treatment plant.

This is the second in situ SOD study conducted by the Water Quality Section of the State Water Survey in which an attempt was made to isolate the nitrogenous SOD from the gross or total rate. This attempt appears to have been fairly successful as evidenced by the results in table 1. The Cedar Creek study (Butts, 1986) was the first attempt made at isolating the nitrogenous SOD fraction.

Note in table 4 that approximately 91 percent of the SOD was nitrogenous in Cedar Creek at station 2 located about 300 feet downstream of the Galesburg sewage treatment plant outfall. Similarly, as shown in table 1, the highest nitrogenous percentage in Indian Creek occurred in the immediate area of the discharge point of overflow 25. About two-thirds of the SOD at station 2 on Indian Creek was due to ammonia oxidation. At the other two downstream stations, the nitrogenous percentage compositions were significantly less. The upstream control station 1 exhibited no nitrogenous demand. In fact, the SOD rate increased after the inhibitor was added (see Appendix B).

The creek bed was walked between the outfall and Highway 25. No extensive sludge deposits were found, but some small localized depositions were observed. For about 600 feet below the outfall, walking in the stream disturbed bottom sediments which caused the clear stream water to turn gray-black. Farther downstream, the bottom rocks and other substrates were covered with thick, slippery mats of diatom and iron bacterial growths. The relatively low DO of 4.4 mg/l observed at station 4 (table 2) during the morning of August 20, 1986 can probably be attributed to nocturnal respiration of this periphytonic growth. Extensive areas of the bottom appear rust-colored. About 200 feet below station 4, a small patch of septic sludge was observed along the water edge. The creek did not appear to contain a significant accumulation of rags and other types of debris normally associated with chronic, large combined sewer overflows. However, the creek was littered with the hardware type of trash often seen in urban streams.

CONCLUSIONS

1. Indian Creek below overflow 25 exhibits some benthic sediment degradation. This degradation is relatively minor and is in line with that of other streams receiving intermittent combined sewage overflows or a steady flow of well-treated sewage. The sediment oxygen demand rates fall into the slightly degraded to moderately polluted categories.

2. Benthos and phytoplankton productivity is low both upstream and downstream of the outfall. Benthos numbers and diversity are small. Suspended algae production is very low throughout the reach studied. The IEPA Macroinvertebrate Biota Index indicates a slight degradation in streambed biology in the downstream direction. Station 3, which had loose septic sediments, had a relatively high density of pollution-tolerant Oligochaeta (sludge worms) and moderately pollution-tolerant Chironomidae (midge fly larvae).

3. The stream supports lush and extensive periphyton growth. Most of the measured SOD at station 1 above the outfall is probably due to the respiration of

bottom dwelling diatoms, while much of that at station 4 is probably due to a combination of diatom and iron bacteria respiration. The SOD rates at stations 2 and 3 are relatively free of the influence of periphytic respiration.

4. Nitrogenous sediment oxygen demand is significant in the immediate area of the outfall. Almost two-thirds of the SOD in the outfall area was attributable to ammonia oxidation, whereas none was attributable to it above the outfall and 20 percent or less was attributable to it at the other two stations below the outfall.

5. Gross visual and aesthetic pollution due to discharges from overflow 25 was not evident. The stream channel did not contain rags, paper, and other types of debris which often become residual after recent combined sewer overflows. The deep hole eroded at the outfall contained some hardware trash of overland origin, but otherwise it was clean and contained small bluegills and large schools of minnows.

6. A reduction in the frequency and quantity of the overflow probably would enhance downstream conditions to some degree. Retainment of most of the settleable solids would probably completely eliminate the small patches of sludge observed. Overall enhancement probably could be achieved by eliminating 50 to 60 percent of the liquid flow. Attendant upon this would be the need to strain out all floating debris since the presently high overflow rates appear to prevent rags and paper from accumulating in the immediate area of the outfall.

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FIGURES AND TABLES

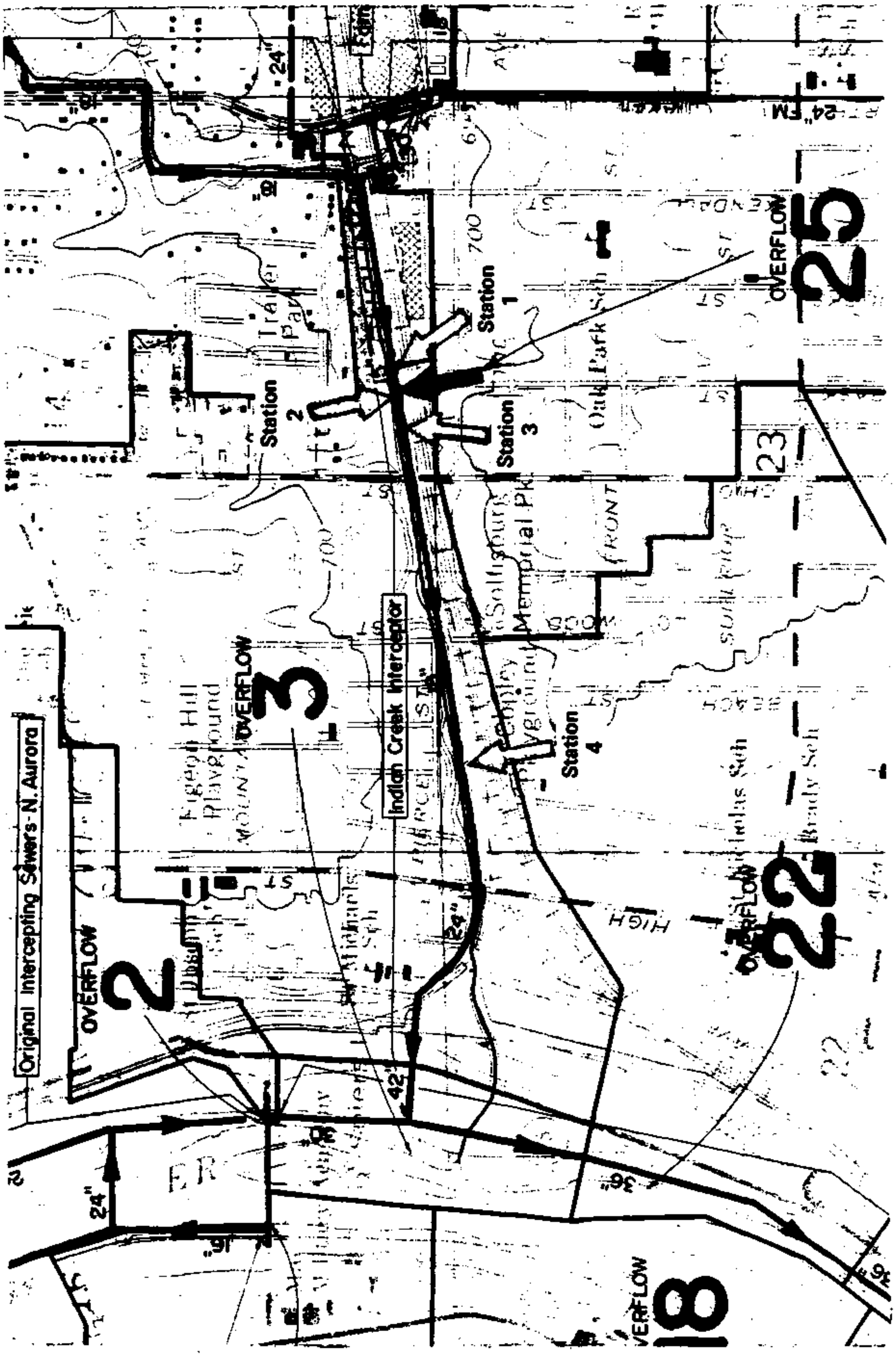

Figure 1. Indian Creek study area and sampling stations

Figure 2. Overflow 25

Figure 3. Indian Creek looking upstream from below overflow 25

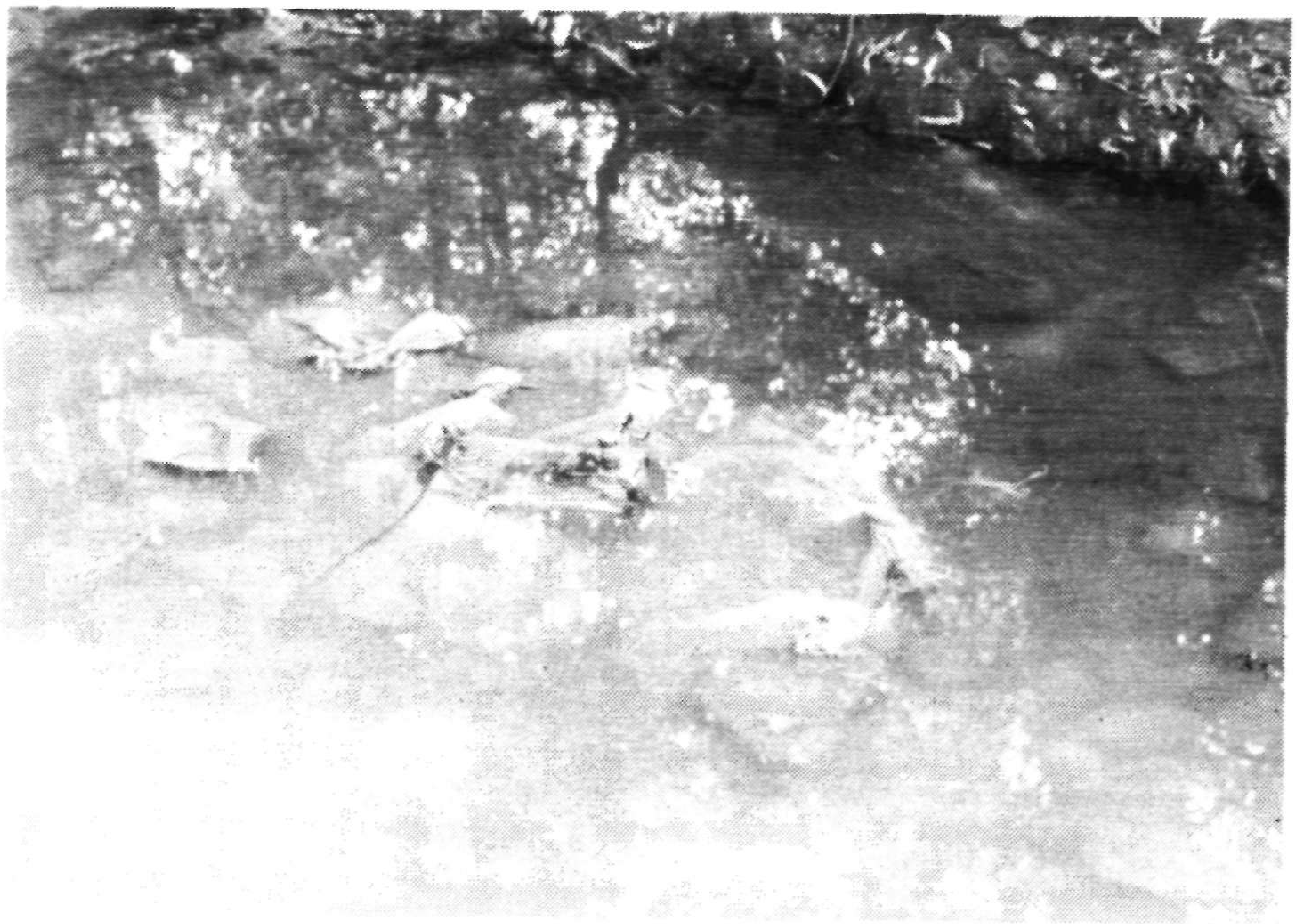

Figure 4. Sampling station 1 showing SOD sampler and sandbag seals

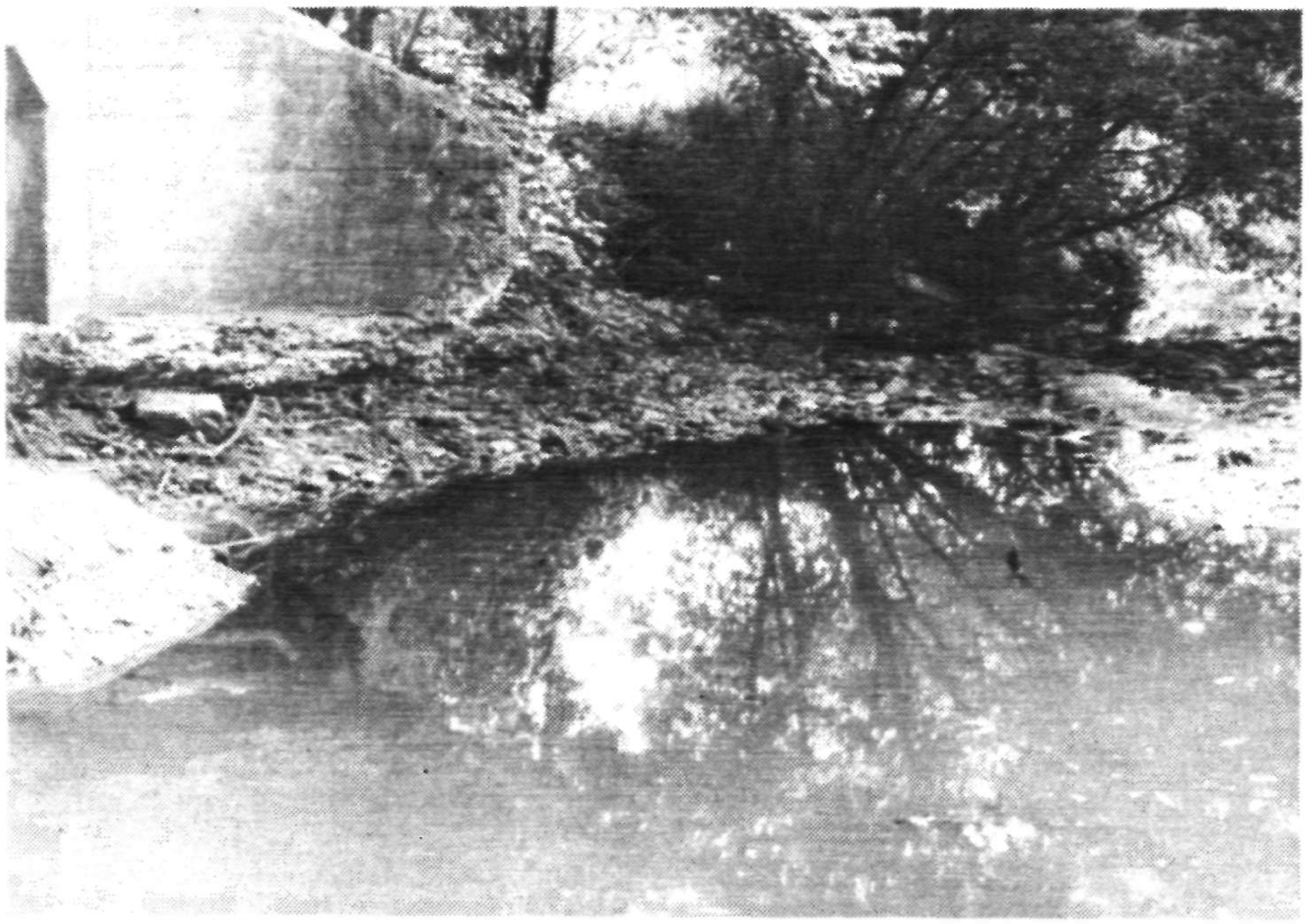

Figure 5. Sampling station 2 looking downstream of overflow 25

Figure 6. Sampling station 3 looking downstream

Figure 7. Sampling station 4 looking upstream

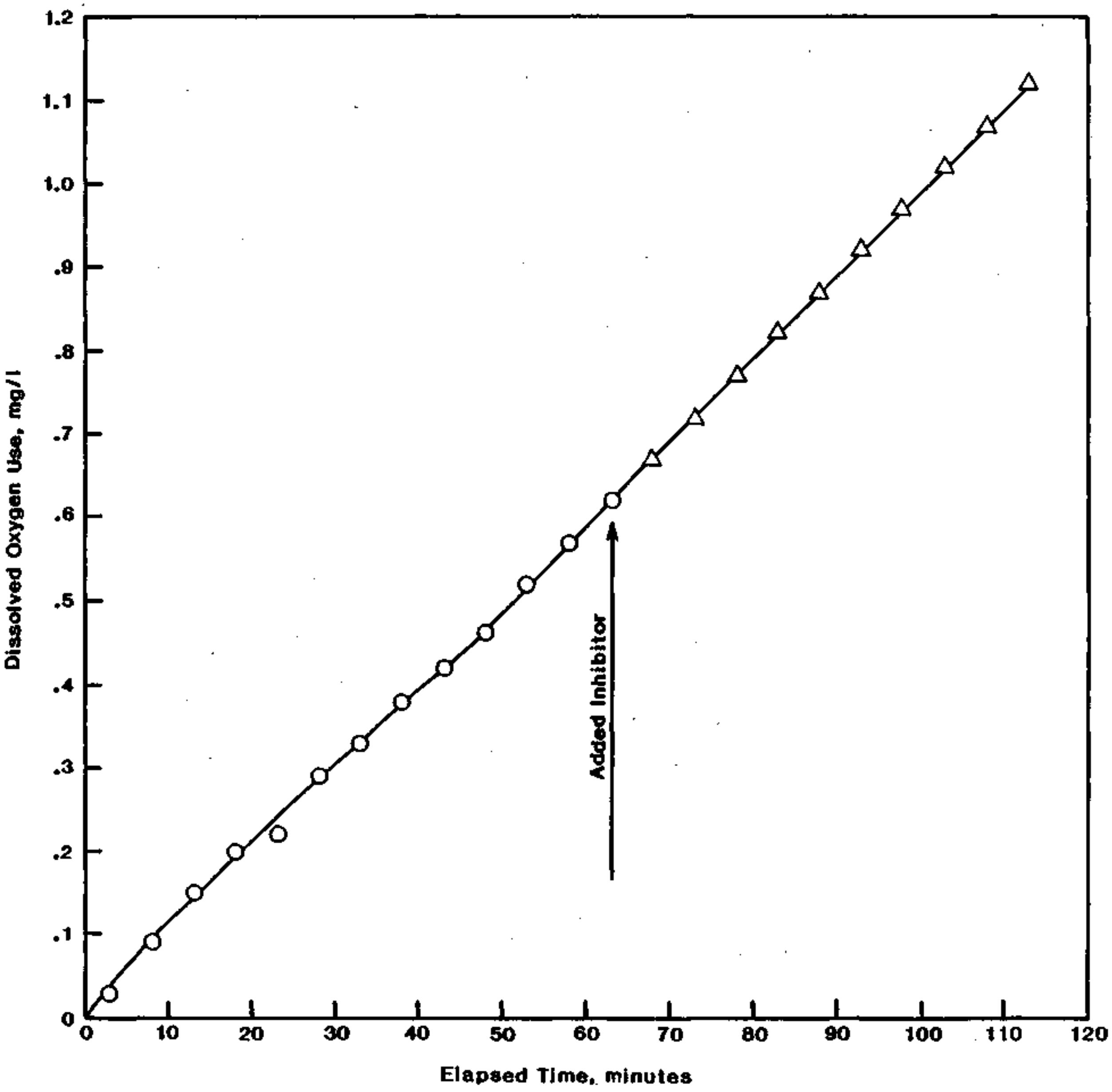

Figure 8. Sediment oxygen demand curve at station 1

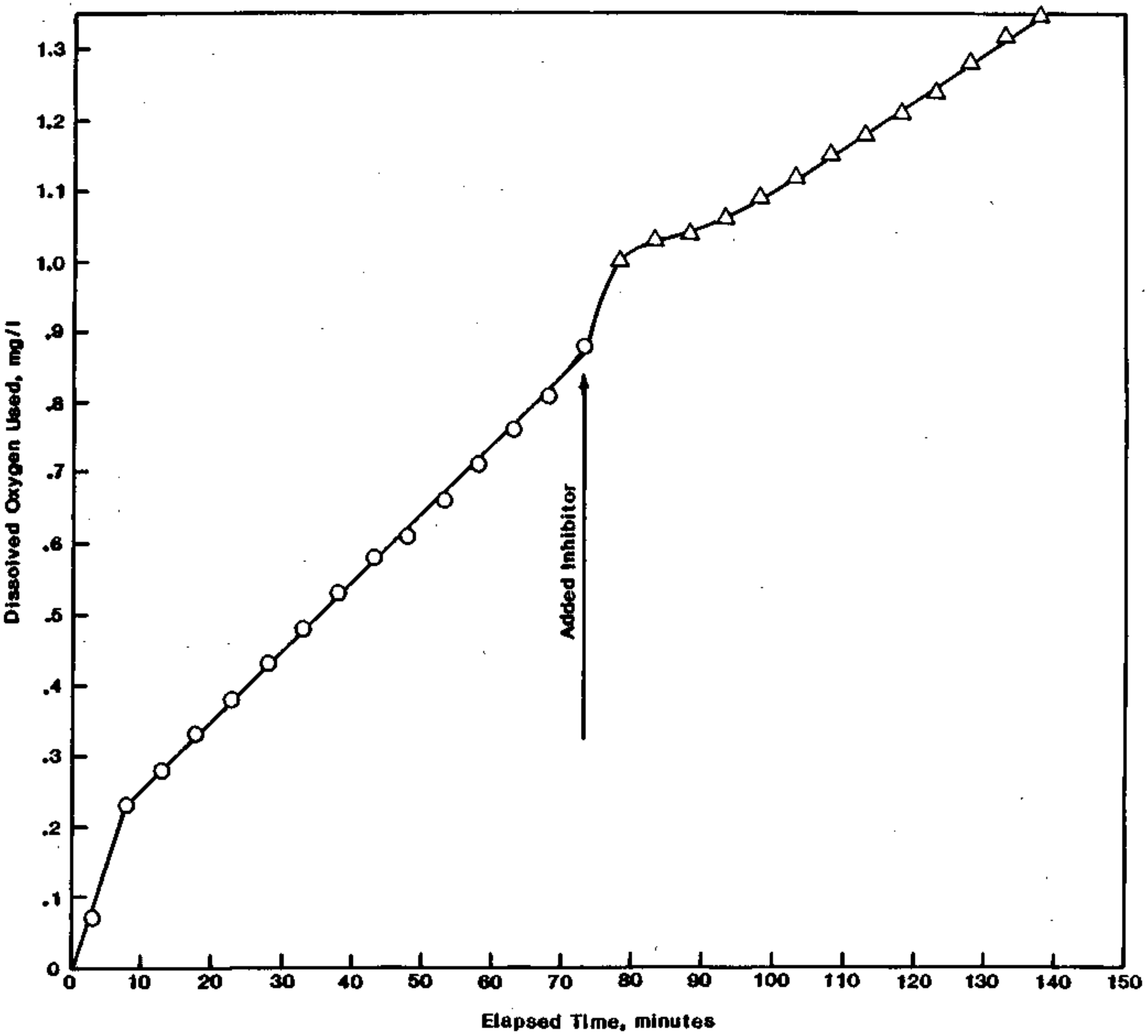

Figure 9. Sediment oxygen demand curve at station 2

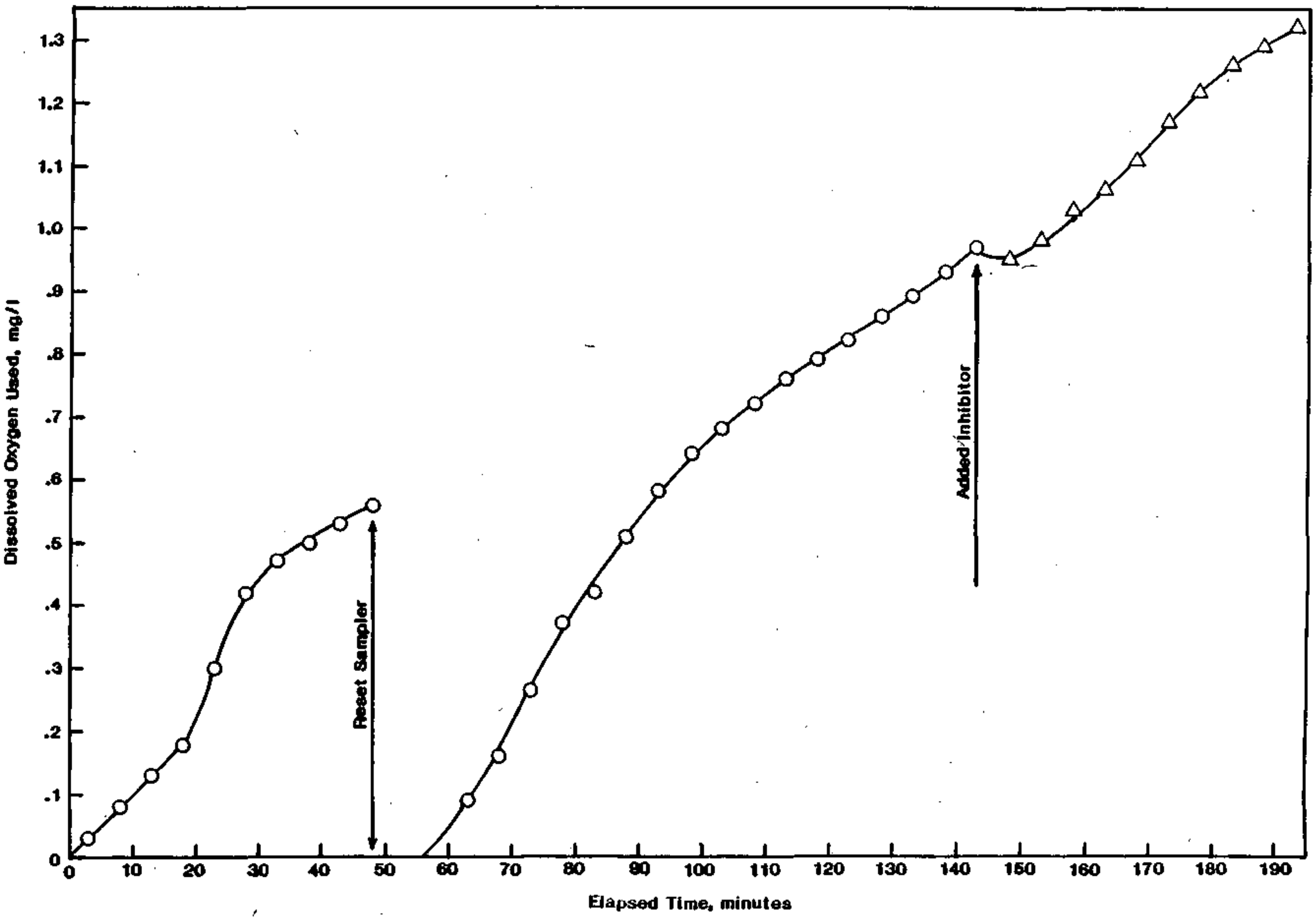

Figure 10. Sediment oxygen demand curve at station 3

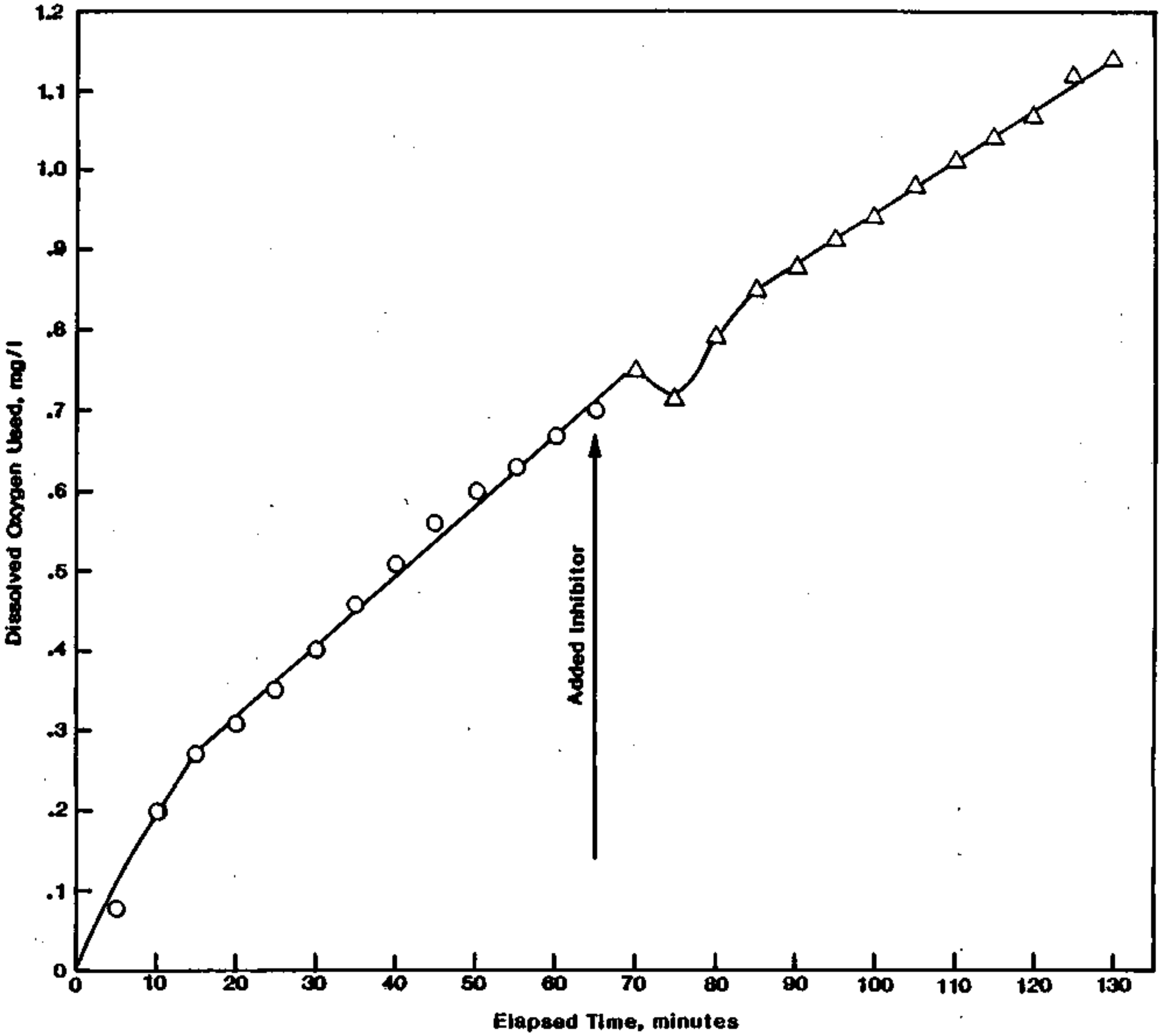

Figure 11. Sediment oxygen demand curve at station 4

Table 1. Best Estimate SOD Rates, Percentage Nitrogenous Composition, and Sediment Classification

	Temperature T (°C)		SOD Rates (g/m²/day)						%	
			Total at			Nitrogenous at				
Sta.	Total	Nit.	T°C	25°C	20°C	T°C	25°C	20°C	Nit.	Sediment Classification
1	24.0	24.0	1.60	1.68	1.33	0	0	0	0	Slightly Degraded
2	20.5	21.0	1.11	1.36	1.08	0.73	0.91	0.72	66	Slightly Degraded
3	23.8	23.9	1.03	1.09	0.87	0.16	0.18	0.14	16	Slightly Degraded
4	16.0	16.1	1.69	2.55	2.03	0.33	0.51	0.41	20	Moderately Polluted

Table 2. Summary of Ambient Physical and Biological Conditions Observed During SOD Runs

	DO	Benthos	Algae	Sediment Characteristics		
Sta.	(mg/l)	(no/m²)	(no/ml)	% Solids	% VS*	Description
1	7.2	344	288	88.8	1.9	Tan-gray coarse sand to large gravel and rocks covered with a profuse layer of diatoms.
2	6.4	588	147	83.0	4.3	Principally brown and gray-black coarse sand with some small to large gravel, little diatom growth on substrate.
3	7.8	3976	158	82.8	2.1	Thin layer of gray-black silt on top of fine to coarse gray sand, pea gravel, medium to large gravel and stones. Overall somewhat septic looking with slight sewage odor. No evidence of benthic diatoms.
4	4.4	373	21	88.0	1.4	Gray-black silt suspended between pea gravel and large gravel and rocks. Very profuse growth of diatoms and what appeared to be iron bacteria.

* Volatile solids

Table 3. Generalized Benthic Sediment Conditions
in Northeastern Illinois Streams
as Characterized by SOD Rates

Generalized Benthic Sediment Condition	SOD Range at 25 C ($g/m^2/day$)
Clean	0-0.5
Moderately Clean	0.5-1.0
Slightly Degraded	1.0-2.0
Moderately Polluted	2.0-3.0
Polluted	3.0-5.0
Grossly Polluted	5.0-10.0
Sewage Sludge-like	>10.0

Table 4. Comparative Stream Results (Butts and Evans, 1978) (Butts, 1986)

				SOD Rates (g/m²/day)							
			Temp	Total at			Nitrogenous at			%	Stream
Creek	City	Sta.	T(°C)	T°C	25°C	20°C	T°C	25°C	20°C	Nit	Classification
Blackberry	Aurora	1	19.0	0.86	1.13	0.90	-	-	-	-	Slightly Degraded
Flint	Barrington	1	12.5	0.27	0.48	0.38	-	-	-	-	Clean
		2	14.7	0.93	1.49	0.93	-	-	-	-	Slightly Degraded
Woods	Crystal Lake	1	29.1	1.94	1.61	1.28	-	-	-	-	Slightly Degraded
Cedar	Galesburg	2	20.7	6.17	7.83	6.22	5.55	7.11	5.64	91	Grossly Polluted
		3	21.1	2.16	2.63	2.09	0.24	0.37	0.29	14	Moderately Polluted
		P	23.6	4.85	5.24	4.17	1.97	2.21	1.76	42	Grossly Polluted
		4	25.7	4.30	4.25	3.38	3.03	3.04	2.42	71	Polluted
		5	24.9	1.51	1.52	1.21	0.97	0.97	0.78	64	Slightly Degraded
		6	25.8	1.04	1.00	0.80	0.07	0.07	0.06	7	Moderately Clean
		8	22.8	2.21	2.45	1.95	0.71	0.85	0.68	35	Moderately Polluted

APPENDICES

Appendix A.

Field-Recorded Total (T) and Inhibited (I) DO Usage in mg/l

Elapsed Time (Min) Sta. 1,2,3	Sta. 1		Sta. 2		Sta. 3		Time Min.	Sta. 4	
	DO Used		DO Used		DO Used			DO Used	
	T	I	T	I	T	I		T	I
0	0		0		0		0	0	
3	0.03		0.07		0.03		5	0.08	
8	0.09		0.23		0.08		10	0.20	
13	0.15		0.28		0.13		15	0.27	
18	0.20		0.33		0.18		20	0.31	
23	0.22		0.38		0.30		25	0.35	
28	0.29		0.43		0.42		30	0.40	
33	0.33		0.48		0.47		35	0.46	
38	0.38		0.53		0.50		40	0.51	
43	0.42		0.58		0.53		45	0.56	
48	0.46		0.61		0.56		50	0.60	
53	0.52		0.66		*		55	0.63	
58	0.57		0.71		*		60	0.67	
63	0.62		0.76		0.09		65	0.70	
68		0.67	0.81		0.16		70		0.75
73		0.72	0.88		0.26		75		0.71
78		0.77		1.00	0.37		80		0.79
83		0.82		1.03	0.42		85		0.85
88		0.87		1.04	0.51		90		0.88
93		0.92		1.06	0.58		95		0.91
98		0.97		1.09	0.64		100		0.94
103		1.02		1.12	0.68		105		0.98
108		1.07		1.15	0.72		110		1.01
113		1.12		1.18	0.76		115		1.04
118				1.21	0.79		120		1.07
123				1.24	0.82		125		1.12
128				1.28	0.86		130		1.14
133				1.32	0.89				
138				1.35	0.93				
143					0.97				
148						0.95			
153						0.98			
158						1.03			
163						1.06			
168						1.11			
173						1.17			
178						1.23			
183						1.26			
188						1.29			
193						1.32			

* Reset (I = 0 at time = 63)

Temperature (°C)									
Begin	24.2	24.0	20.4	20.6	24.0	23.8		15.8	16.0
End	24.0	23.9	20.6	21.2	23.8	23.9		16.0	16.2

Appendix B.

Ambient and Temperature-Corrected Total (t) And Inhibited (i) SOD Rates

Sta.	Date	Temp T (°C)	Time Internal (min)	SOD ($g/m^2/day$) at		
				T°C	25°C	20°C
1t	8/18/86	24.2	0-13	1.91	1.99	1.58
		24.1	13-63	1.48	1.54	1.22
1i		24.0	63-113	1.60	1.68	1.33
2t	8/19/86	20.4	0-8	4.96	6.13	4.87
		20.5	8-113	1.11	1.36	1.08
2i		20.6	113-118	3.98	4.88	3.88
		20.7	118-133	0.00	0.00	0.00
		21.0	133-178	0.38	0.45	0.36
3t	8/19/86	23.7	0-18	1.48	1.58	1.25
		23.7	18-28	4.36	4.63	3.68
		23.7	28-48	0.87	0.92	0.73
3t	reset	23.9	0-33	3.04	3.20	2.54
		23.8	33-83	1.03	1.09	0.87
3i		23.8	0-50	0.87	0.91	0.73
4t	8/20/86	15.9	0-15	3.62	5.51	4.38
		16.0	15-65	1.69	2.55	2.03
4 i		16.0	65-80	1.15	1.74	1.38
		16.1	80-130	1.36	2.04	1.62

Note: The underlined values represent the stabilized linear portions of the curves which appeared to provide the best estimate of the rates at given locations.

Appendix C.

Benthic Macroinvertebrate Numbers and Tolerance Values

Organism	IEPA tolerance value	Station			
		1	2	3	4
Stenonema (may fly)	4		14		
Dubiraphia (riffle beetle)	5		14		
Sphaerium (fingernail clam)	5				29
Caenis (may fly)	6	43	187	43	57
Chironomidae (true midge)	6	115	144	1,206	
Ceratopogonidae (biting midge)	7	14	14		
Stenelmis (riffle beetle)	7	86	43		
Hirudinea (leech)	9			43	29
Oligochaeta (aquatic worm)	10	86	172	2,684	258
Total number of individuals (no/m^2)		344	588	3,976	373
Total number of taxa		5	7	4	4
IEPA Macroinvertebrate Biotic Index		7.3	7.2	8.7	8.9

Appendix D.

Phytoplankton (Suspended Algae) Counts in Terms of Organisms per ml

Organism	Type	Station			
		1	2	3	4
Cymatapleura solea	d	21			
Diatoma vulgare	d		25		
Euglena gracilis	f	23			
Fragilaria intermedia	d		13		
Navicula gastrum	d			78	
Navicula odiosa	d	130			
Navicula radiosa	d			15	21
Navicula sp.	d			17	
Navicula viridula	d		17		
Nitzschia filiformis	d			21	
Pediastrum duplex	g	44	29		
Pediastrum simplex	g	38			
Phacus pleuronectes	f			4	
Rhoicosphenia curvata	d	2	21		
Scenedesmus dimorphus	g	21			
Surirella ovata	d			23	
Surirella striatula	d		42		
Trachelomonas crebea	f	9			
Totals		288	147	158	21

Note:

d = diatom
g = green algae
f = flagellate