SOUTH CAROLINA WATER RESOURCES COMMISSION

Report No. 10

A Tracer Study of the Flushing Time of the Sampit River Estuary, Georgetown, South Carolina

By

F. A. Johnson

Prepared by
U. S. Geological Survey, Water Resources Division
in cooperation with
South Carolina Water Resources Commission
Columbia, South Carolina
1978

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ABSTRACT

Rhodamine WT dye was injected into lower and upper areas of Sampit River at Georgetown, S.C. in April 1977 to determine flushing time of the river during a period of moderately dry weather. In the lower section, dye had flushed from the river or was undectable after 35 days, although approximately 90 percent was undetectable after 2 weeks. In the upper section, dye did not flush out but decreased greatly in concentration due to dispersion and dye losses. Results of an accompanying laboratory examination could not account totally for the natural dye losses which occurred in Sampit River.

INTRODUCTION

Purpose and Scope of the Investigation

If the quality of a river environment is to be maintained (or perhaps improved) waste discharges must be released into the stream at a rate which will not allow a waste build-up to exceed certain specified limits. Wastewater may be discharged into a stream at an optimum rate only when the volume of streamflow and the flushing time of that stream is known.

It is important for the industrial and shipping interests now located along the lower part of Sampit River to gain knowledge of the flushing time for the purpose of managing stream quality. Other industries, now proposed for location in the upper Sampit River also may utilize data on the flushing time.

This report summarizes results of a limited study of flushing time of Sampit River estuary during April and May 1977. The available funds for this project restricted the study to one critical period -- a time of low overland runoff when the flushing time would be expected to be greater than normal.

Acknowledgements

The South Carolina Water Resources Commission aided significantly in the study by providing personnel, technical aid and other supporting services. Especially helpful were: Frank Nelson, Assistant Executive Director; Ed Duncan, Environmental Biologist; and Joe Dennis, Graphic Supervisor. Appreciation is extended to Mr. Gene Miller, owner of the Gulf Marina, Georgetown, S.C. for kind permission to use one of the piers as a base for dye-decay experiments during the study.

Cooperation

The investigation was part of a cooperative program between the U.S. Geological Survey and the South Carolina Water Resources Commission, Mr. Clair P. Guess, Jr., Executive Director.

DESCRIPTION OF THE STUDY AREA

Location

The Sampit River (Fig.1) drains approximately 100 mi^2 of the Coastal Plain in the vicinity of Georgetown, South Carolina. A number of tributaries feed into the river but drainage is poor and water movement is sluggish. The river empties into Winyah Bay at Georgetown. The main stem of the river is bordered both by well-wooded banks and marshland. The highland beyond the marshland is fairly well wooded. The woodland protects the river, except in lower reaches, from wind effects and encourages the use of small boats by many sportsmen. The lower part of the river is bordered by International Paper Co., South Carolina State Ports Authority docks, and the city of Georgetown waterfront. The waterfront along the loop of the original Sampit River channel includes a public recreation area, both public and private marinas and Georgetown Steel Corporation.

Channel Geometry

Channel depths at low tide range from about 25 to 35 feet in the lower 3 miles of the river, decreasing to 10 feet at mile 10 and 5 feet at mile 11. Channel widths decrease from 1500 feet at mile 0 to 500 feet at mile 6 and to 50 feet at mile 11.5. Thus, it is quite evident that there is considerably more channel volume per unit length in lower reaches of the Sampit River than in upper reaches.

Tidal Conditions

Tides at the mouth of Sampit River have a range of about 3 feet during neap tides and about 4 feet during spring tides. Mean range is slightly less than 3 1/2 feet. Tidal range at mile 11 averages about 2 feet. Above mile 11 tidal effect decreases rapidly due to the increase in elevation and slope of the streambed. A rapid decrease in tidal action is also noticeable in tributaries which join the main stem at locations farther downstream. Tidal occurrences at the mouth of Sampit River are predicted in standard tide tables of the National Ocean Survey.

SALINITY CONDITIONS

The U.S. Naval Oceanographic Office defines salinity as "a measure of the quanitity of dissolved salts in sea water. It is formally defined as the total amount of dissolved solids in sea water in parts per thousand by weight when all the carbonate has been converted to oxide, the bromide and iodide to chloride, and all organic matter is completely oxidized. These qualifications result from the chemical difficulty in drying the salts in seawater. In practice, salinity is not determined directly but is computed from chlorinity, electrical conductivity (specific conductance measured in micromhos per centimeter at 25°Celsius) refractive index, or some other property whose relationship to salinity is well established". In this report, specific conductance is used an as indicator of salinity.

Specific Conductance of the Sampit River

Specific conductance at high tide in the Sampit River in mid-April indicated the lower two miles of the river to be stratified but changed upstream to well-mixed by mile 6. The specific conductance at mile 1 ranged from 7500 micromhos near the bottom to 920 micromhos near the surface. At mile 3 the range was from 1340 micromhos near the bottom to 1150 near the surface. The range at mile 6 was 320 micromhos near the bottom to 295 near the top. This changed very little to mile 11.5 where the bottom and surface specific conductance were 240 and 230 micromhos respectively.

During the first few days of the study, bottom and surface specific conductance was 200 micromhos or less for areas above mile 4. These early indications of low conductivity were the result of rainfall in the study area prior to the beginning of the investigation.

Freshwater Inflow

Freshwater inflow to the Sampit River by overland runoff is known to be very low during seasonal periods of sparse rainfall; although, no precise figures have been determined. About 10 percent of the time, freshwater enters the system from the river mouth during rising tides. This occurs when freshwater flow from the Peedee River into the northern end of Winyah Bay is sufficient to push saltwater below the mouth of the Sampit River.

THE DYE STUDY

Dye Injection and Sampling

Rhodamine WT dye in 20 percent solution was slug-injected into the Sampit River at 2 sites to simulate accidental spills of a solute. Tracing the dye over a time period is the method use. About 125 pounds of dye solution was slug-injected midstream at mile 2.9 (at the mouth of Whites Creek), during the afternoon low slack tide of April 5, 1977 (Fig.2). Following the injection, grab samples were obtained at high and low slack tides by boat at the points along the main stem and tributaries shown in Fig.2. Other points on tributaries were sampled from bridge crossings. Because of field time limitations of the study, when it appeared that another injection at an upper site would not greatly overlap the earlier one, about 125 pounds of dye solution was dumped in midstream at mile 10.3 (at the mouth of Spring Gully Creek) at high slack tide on the afternoon of April 8. Prior to dye injection, raw water samples were collected for background fluorescence analyses.

Sample Analyses

Samples were analysed for fluorescence in a Turner 111[1/], filter-type fluorometer; principles and techniques of its use are described by Wilson (1968). Calibration of the fluorometer and subsequent periodic calibration checks were made using distilled water with a sample of the same batch of dye used in the injection as described by F.A. Kilpatrick (written commun., 1969). Although dye decay was determined (and discussed later in this report) it is not reflected in figures 3-24 which show dye concentrations at high and low slack tides along the main stem. However, most solutes that would be accidentally spilled, likely would decay more rapidly than the tracer used in this test (Kilpatrict and Cummings, 1972).

1/ The use of a brand name in this report is for identification purposes only and does not imply endorsement by the U.S.Geological Survey.

ANALYSIS OF DYE STUDY

Tidal Excursion

Examination of figures 3-24 show that highest concentrations of dye produced by the first injection were found generally between miles 6 and 7 at high tide and between miles 2 and 3 at low tide. Highest concentrations of dye resulting from the second injection were found generally between miles 10 and 11 at high tides and between miles 9 and 10 at low tides. This indicates that the tidal excursion in the lower Sampit River is about 4 miles and diminishes to about 1 mile in the upper areas. The considerably higher dye concentration in the upper areas resulted from smaller channel volumes.

Higher dye concentrations were usually found in the Sampit River during low tides (figures 14-24). This occurred because the water with higher concentrations moved into small runnels and marshes on rising tides while the remainder in the main channel was diluted by incoming tidal flows. On falling tides, water with the more diluted concentrations in the main channel moved downstream while that with higher concentrations from the marshes returned to the main channel.

Flushing of Lower Sampit River

The injection at mile 2.9 exhibited some flushing into Winyah Bay at low tides. With the incoming tides, remaining concentrations were diminished and tidal turbulence accelerated dispersion. Only a trace of dye showed up along the Georgetown waterfront. Tributary streams at high tides showed about the same dye concentrations as equivalent mile points on the main stem Sampit River. Exceptions were those peripheral sites, noted in figure 2, which were beyond the limit of dye penetration. Time necessary for the dye injected into the lower Sampit River to diminish beyond normal detectability was about 35 days, although probably no more than 10 percent was detectable in that area after about 2 weeks. It should be noted that this flushing time was for moderately dry conditions; greater freshwater runoff would cause faster flushing.

Flushing of Upper Sampit River

Flushing of the upper Sampit River did not occur, at least during the period between injection on April 8 and May 10. The dye diminished by slow dispersion through tidal action, and its gradual movement in the downstream direction took about 1 week to become very pronounced. It is possible that small increments of dye may have eventually reached Winyah Bay on the low tides.

EXAMINATION OF DYE LOSSES

Data shown in figures 7-13 and 17-24 indicate large dye losses occurred within Sampit River. For example, dye is substantially less in evidence in figure 24 than it is in figure 17. The reasons for dye losses are complex and can be attributed in large measure to decay and to a physical affinity for organic matter in the water. A definitive study of dye losses under natural conditions is unknown to the author. Smart and Laidlow (1977) published a discussion of decay losses, including analyses for many types of tracer dyes. However, the study was made only under laboratory conditions. Yotsukura and Kilpatrick (1973) published a paper which suggests that a mass-balance dye study under natural conditions would best define total dye losses; yet, this has never been done. Subsequently Yotsukura and Kilpatrick (personal commun., 1977) have suggested that this method would be adaptable to other similar situations. The upper areas of Sampit River presented a near "text book" situation for just such a mass-balance study. However, because of limitations in available funds, only a laboratory approach to determining dye losses was made.

Laboratory Analyses of Dye Losses

It was reasoned after discussion with Dr. Sam Boyd of the DuPont Corp. (manufacturers of rhodamine WT dye) that the major losses to be encountered would be from photodecay. Accordingly, dye standards were made from a supply of both raw Sampit River water (240 micromhos conductivity) and distilled water and put into bottles which were subjected to varying amounts of daylight. One set of both water types of dye standards was exposed to that daylight in a motel room having a plate-glass window. A second set was immersed in the Sampit River at a point 1 ft below low tide to simulate dye under natural conditions. It was recognized that the natural dispersion and the resulting dilution of an element of dye solution would not be perfectly duplicated by such a test.

Each container of an immersed Sampit standard had 10 percent of its soution withdrawn periodically for analysis and the same amount of uncontaminated Sampit River water replaced from the original supply. This was done to simulate, in part, the dilution of undyed water from Winyah Bay. The mathematical results of the dye-concentration analyses of immersed Sampit standards were increased to account for withdrawals from the original volume of dye.

Figure 25 shows the results of the photodecay analyses. The smallest decay rate was found in the dye sample subjected to daylight in the room. Here the distilled-water standards and the Sampit Water samples (after negating background readings) yielded the same decay results.

A greater decay rate was shown by the submerged distilled standards --probably because the submerged standards received more actual light than those exposed in the room. Temperature was not of significance because all samples were analysed at the same temperature and there was not enough difference in the ambient temperatures at the two locations to cause a difference in the chemistry of the dye standards.

The greatest decay was shown by the submerged Sampit water standards. This may be attributed to the addition of raw water which caused a corresponding increase in dissolved oxygen (a factor of considerable importance in the decay of organic solutes, although Smart and Laidlaw (1977) experimented with the bubbling of free oxygen through WT dye solution with negligible results. However, no early decay rate persisted for very long in any of the standards regardless of whether they were submerged or not.

It should be noted from figure 25 that the decay rate had decreased considerably within 14 days. This is shown more clearly in table 1 which lists decay rates between 5-day increments. The implication of the analyses is that the dye has only a limited amount of either photodecay or decay from dissolved ocygen or other causes. However, figures 3-24 indicate that the rhodamine WT injected into the Sampit River continued to exhibit losses (for whatever cause) at a greater rate than that shown in the laboratory "bottle" type experiment. It has been suggested by Kilpatrick (personal communication, 1977) that such tests do not wholly simulate actual conditions because a continuous supply of fresh oxygen, sediment, etc. is not available as is the case with naturally occurring dispersion and dilution in an extuary or river.

The laboratory study of standards subjected to differing light conditions tgether with the study of the flushing time of the Sampit River point out the need for further investigations of dye losses under natural conditions. Dye loss percentages derived under laboratory conditions should, therefore, be used with reservation when applied to studies made under natural conditions. No attempt has been made in this report to apply laboratory factors to the Sampit River study because of uncertainties in the relationship.

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Kilpatrick, F.A. and Cummings, T. Ray, 1972, Tracer simulation study of potential solute movement in Port Royal Sound, South Carolina: U.S. Geol. Survey Water-Supply Paper 1586-J, 27 p., 18 figs., 1 table

____________1972, A tracer simulation study of potential solute movement in Port Royal Sound, Port Royal Sound Environmental Study: South Carolina Water Resources Comm., p.47-72

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U.S. Naval Oceanographic Office, 1966, Glossary of oceanographic terms: U.S. Naval Oceanographic Office Spec. Pub. 35, 204 p.

Wilson, J.F., Jr., 1968, Fluorometric procedures for dye tracing: U.S. Geol. Survey Techniques of Water-Resources Inv., book 3, chap. A12, 31 p.

Yotsukura, N., and Kilpatrick, F.A., 1973, Tracer simulation of soluble waste concentration: Am. Soc. Civil Engineers Proc., Jour. Environmental Eng. Div., v. 99, no. EE4, paper 9947, p. 499-515.

Table 1. Decay rates of dye standards, in percent, from exposure to light.

Day	Sampit water and distilled water not submerged			Distilled water submerged			Sampit water submerged		
	Concentration, in percent of day 0	Daily decay rate from day 0	Decay rate from previous 5-day period	Concentration, in percent of day 0	Daily decay rate from day 0	Decay rate from previous 5-day period	Concentration, in percent of day 0	Daily decay rate from day 0	Daily rate from previous 5-day period
0	100	---	---	100	---	---	100	---	---
5	88.7	2.4	2.4	86.6	2.9	2.9	67.1	8.3	8.3
10	82.6	1.9	1.4	79.5	2.3	1.7	57.7	5.7	3.1
15	79.7	1.5	.7	75.5	1.9	1.0	54.9	4.1	1.0
20	78.1	1.2	.4	72.8	1.6	.7	53.8	3.1	.4
25	77.0	1.1	.3	71.2	1.4	.4	53.2	2.6	.2
30	76.4	.9	.2	70.1	1.2	.3	52.9	2.1	.1
35	76.0	.8	.1	69.4	1.0	.2	52.8	1.8	.0+
40	75.6	.7	.1	68.7	.9	.2	52.7	1.6	.0+

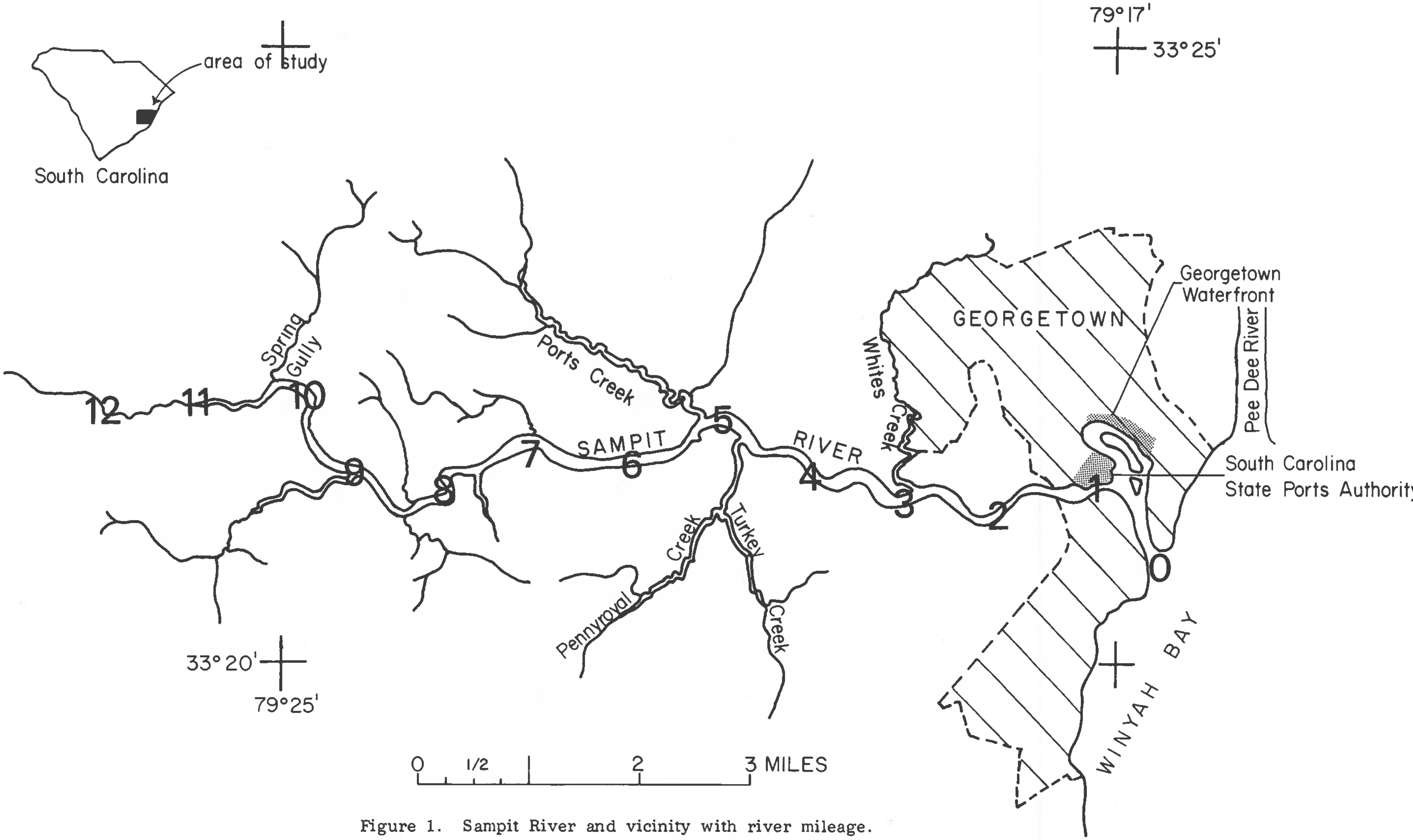

Figure 1. Sampit River and vicinity with river mileage.

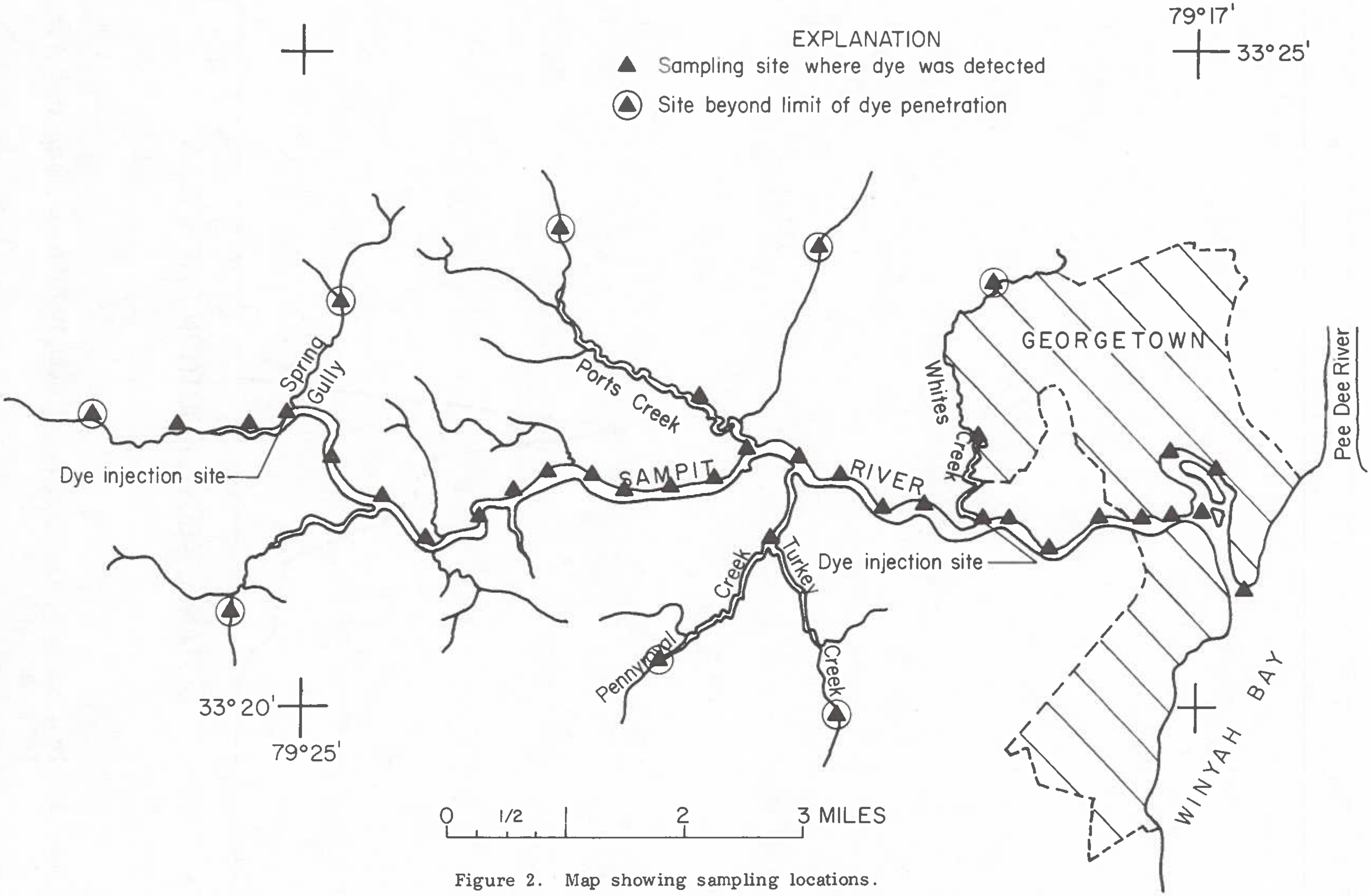

Figure 2. Map showing sampling locations.

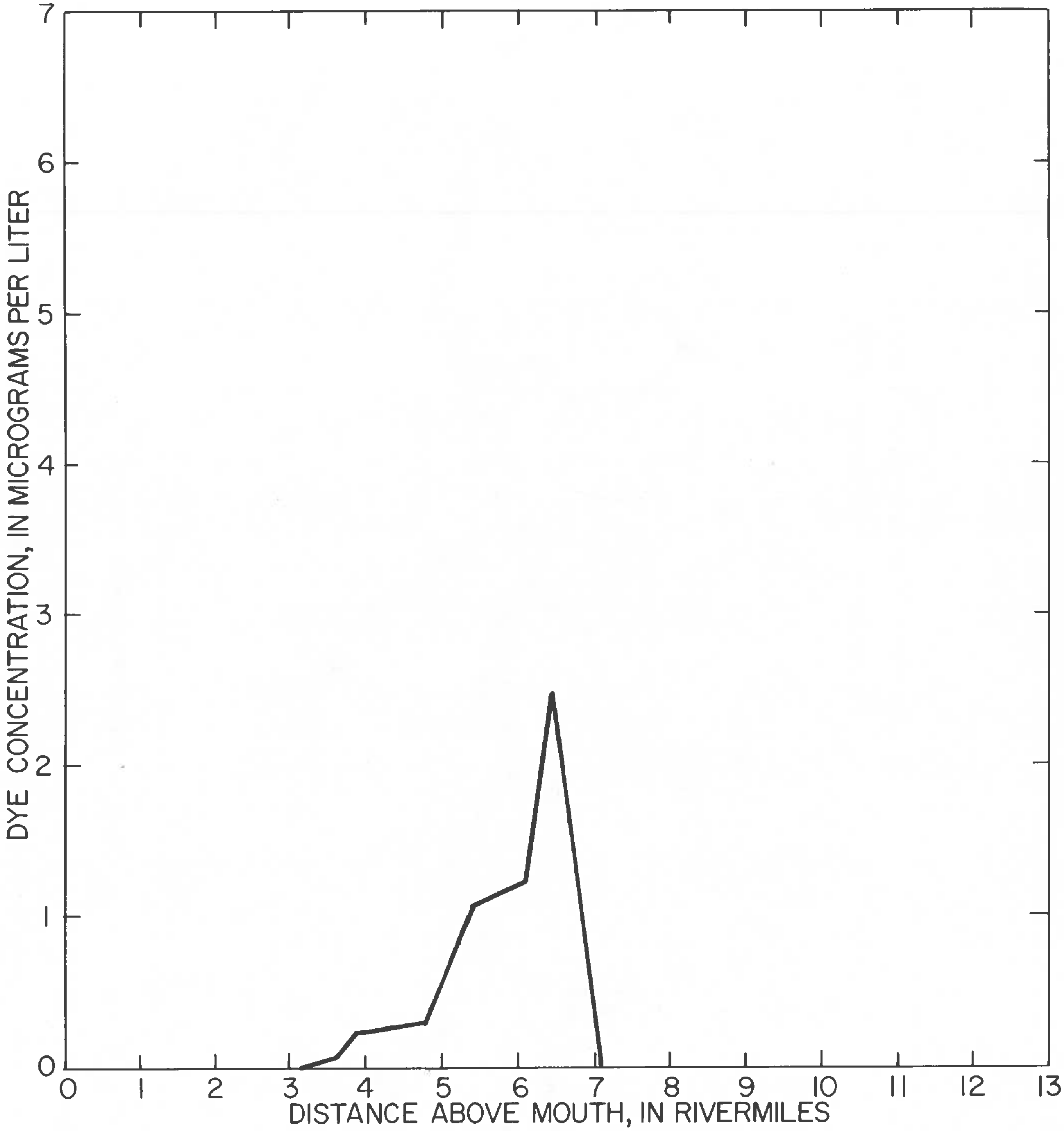

Figure 3. Dye concentration profile of Sampit River at high tide April 5, 1977, at 2300 hours.

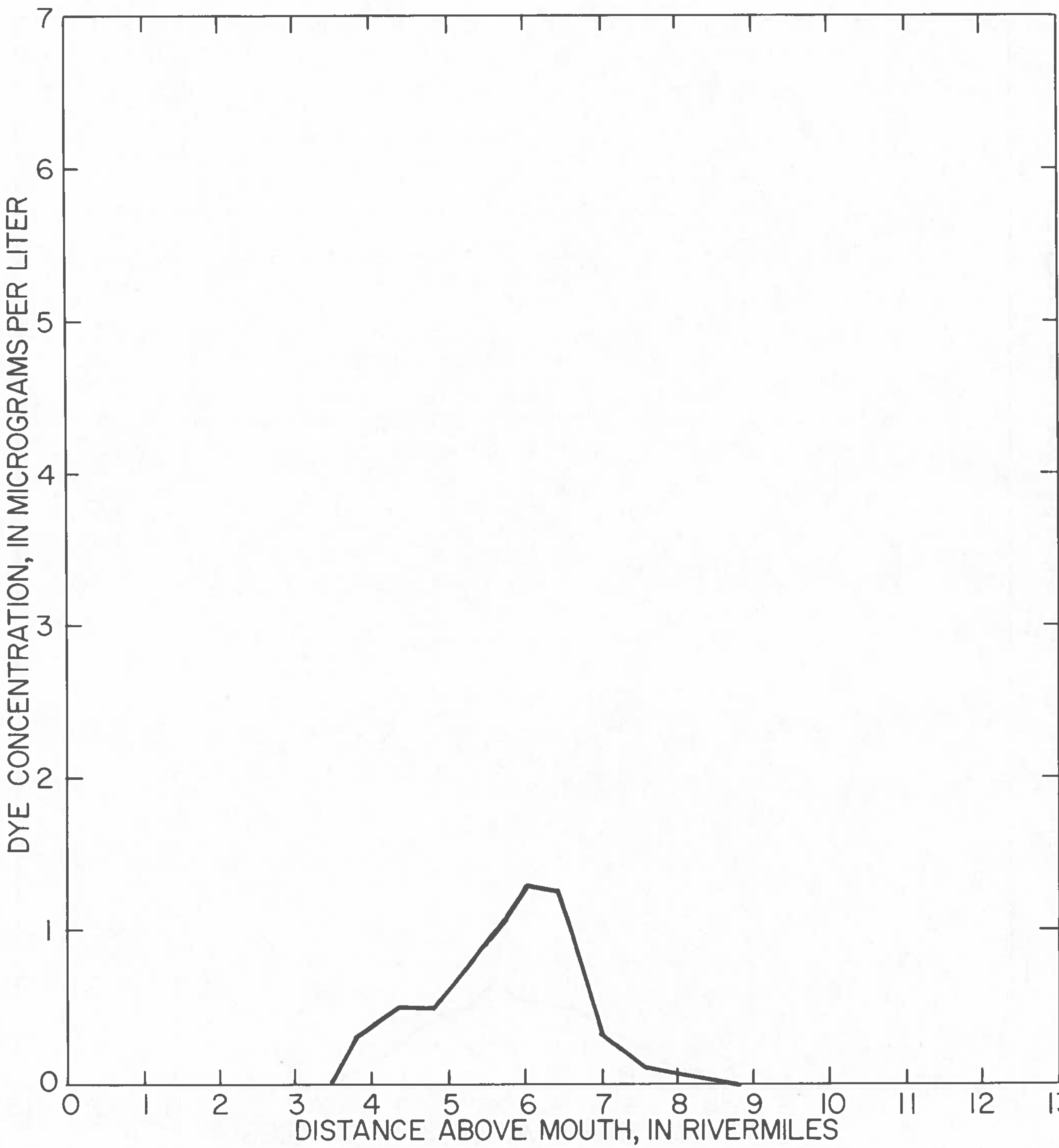

Figure 4. Dye concentration profile of Sampit River at high tide April 6, 1977, at 1130 hours.

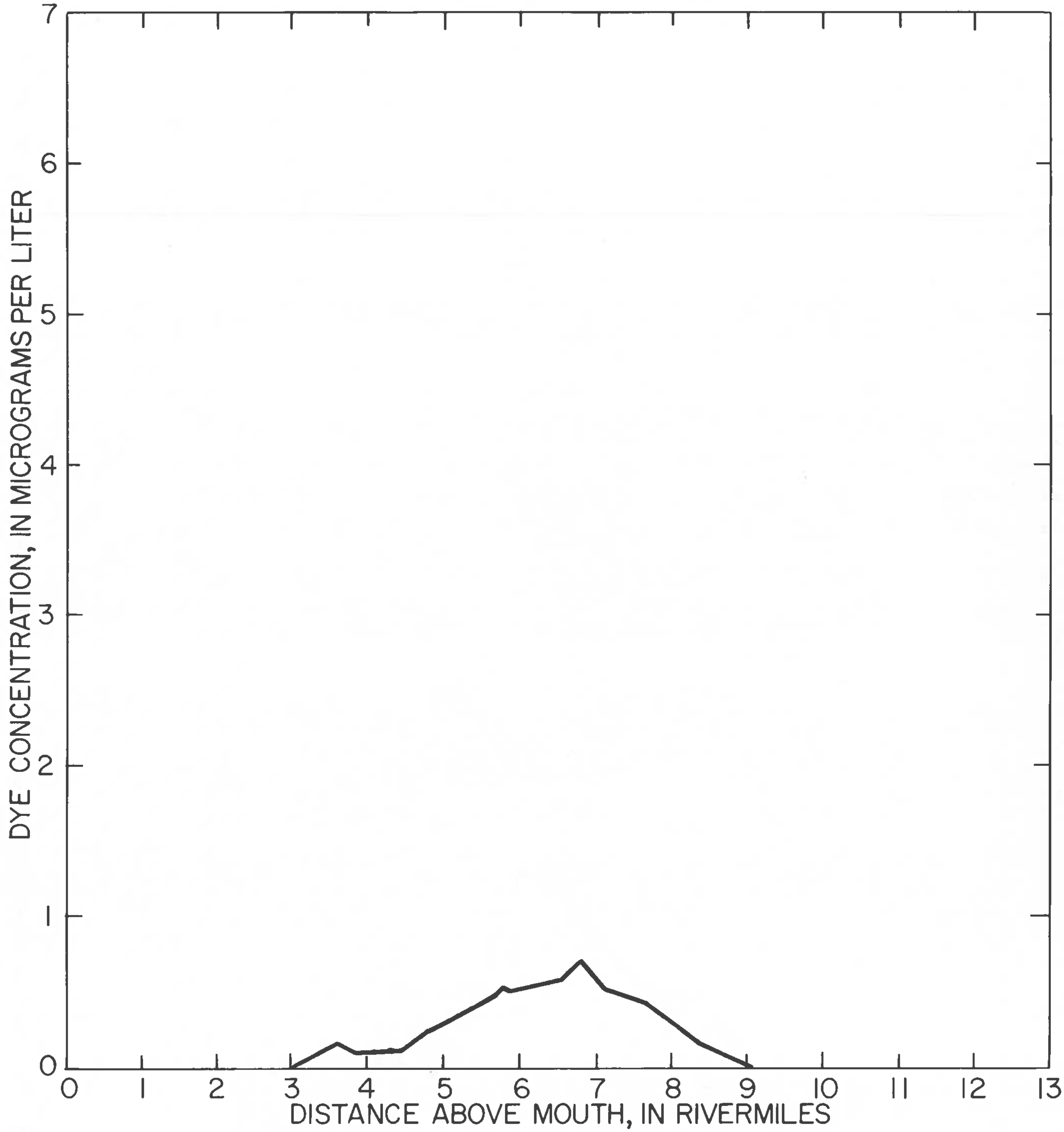

Figure 5. Dye concentration profile of Sampit River at high tide April 7, 1977, at 1300 hours.

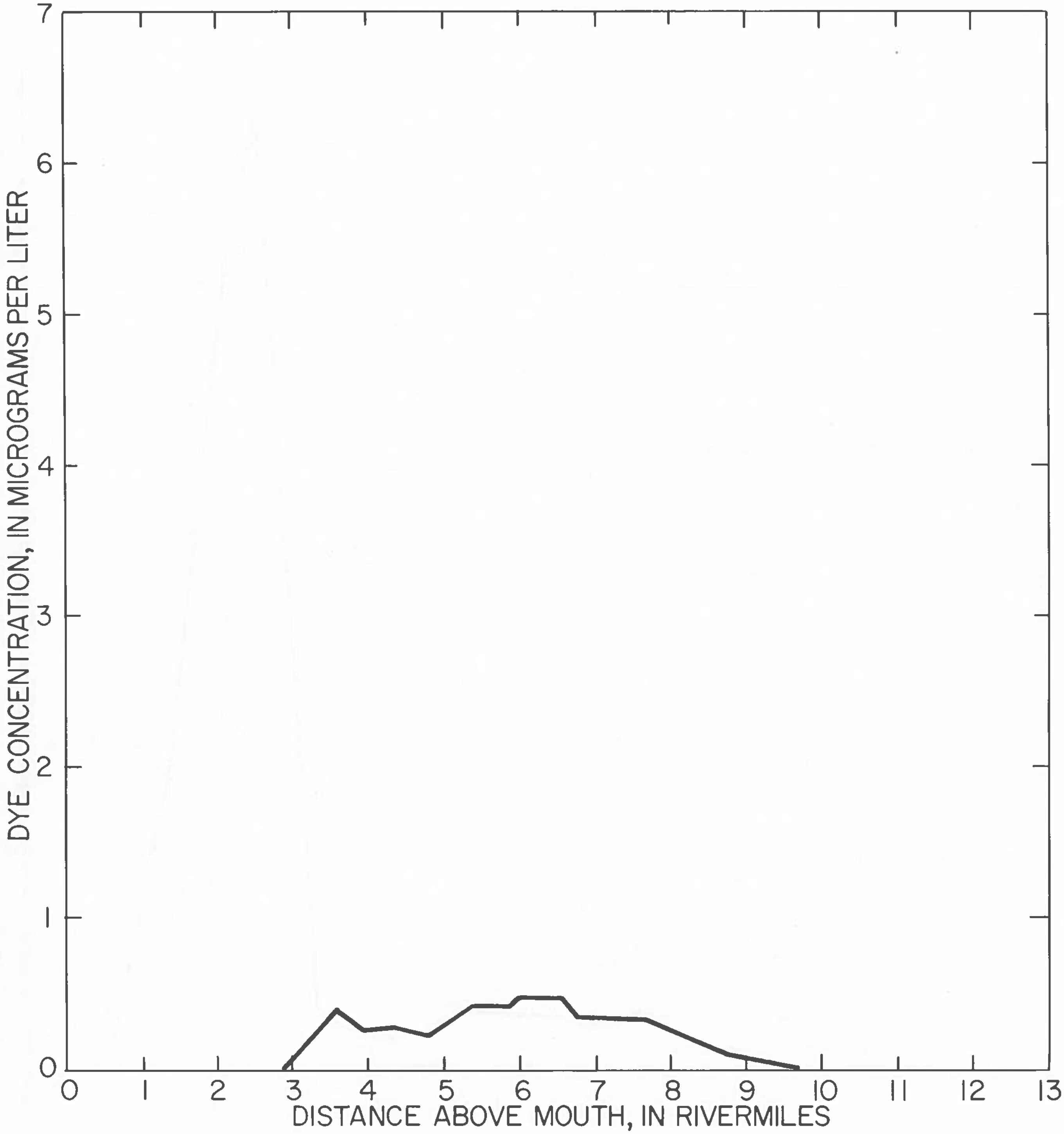

Figure 6. Dye concentration profile of Sampit River at high tide April 8, 1977, at 1330 hours.

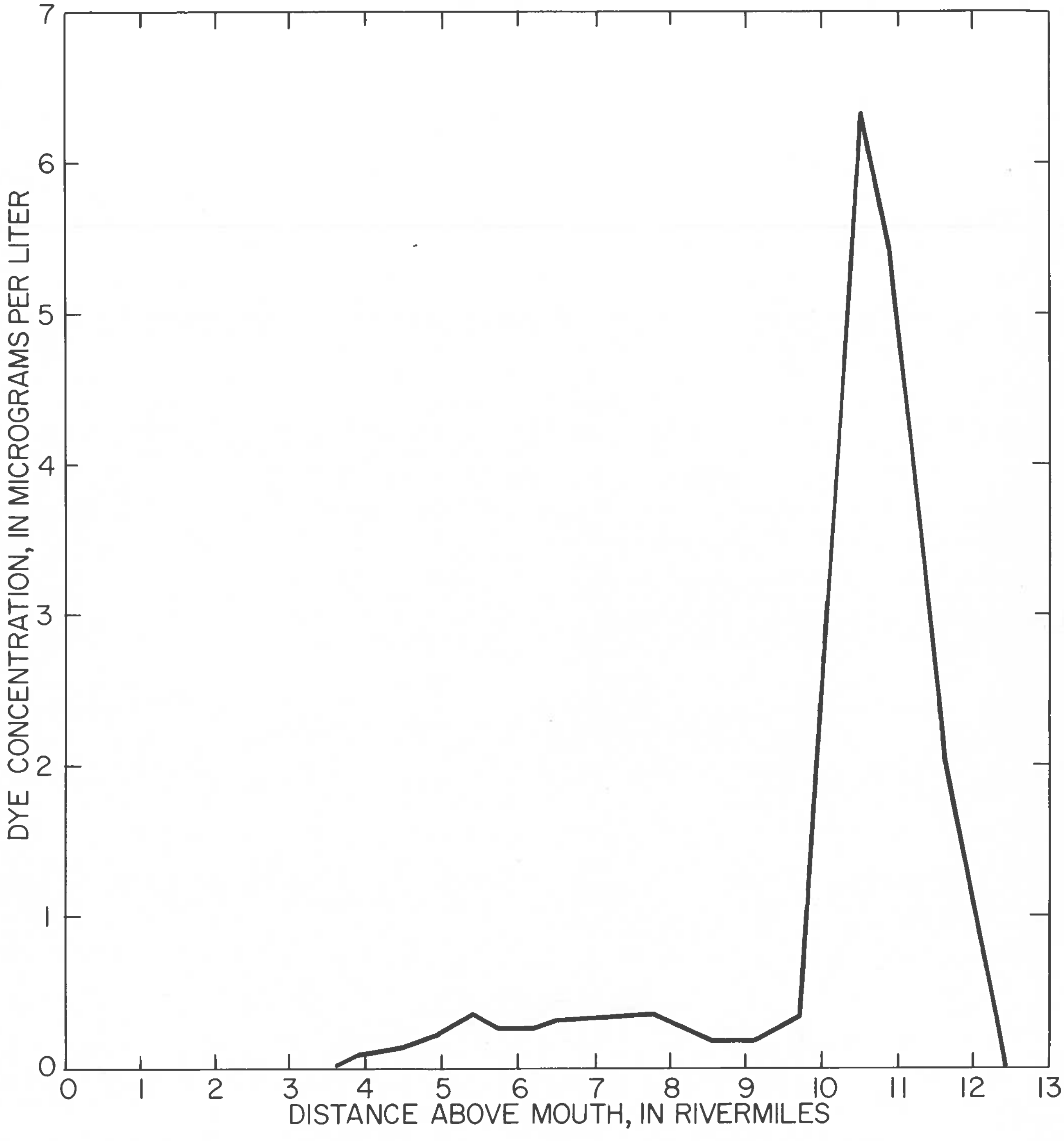

Figure 7. Dye concentration profile of Sampit River at high tide April 9, 1977, at 1430 hours.

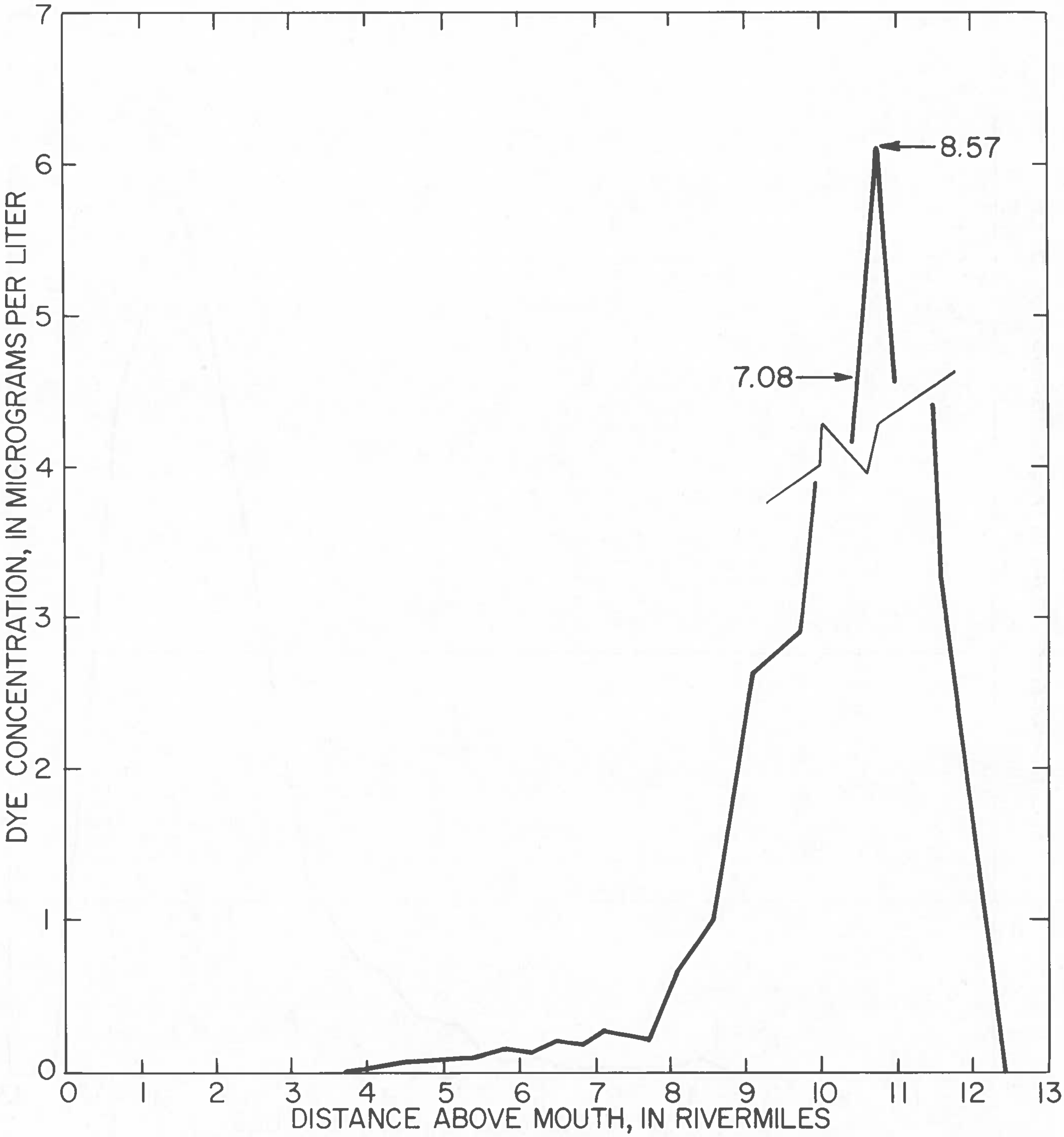

Figure 8. Dye concentration profile of Sampit River at high tide April 11, 1977, at 1615 hours.

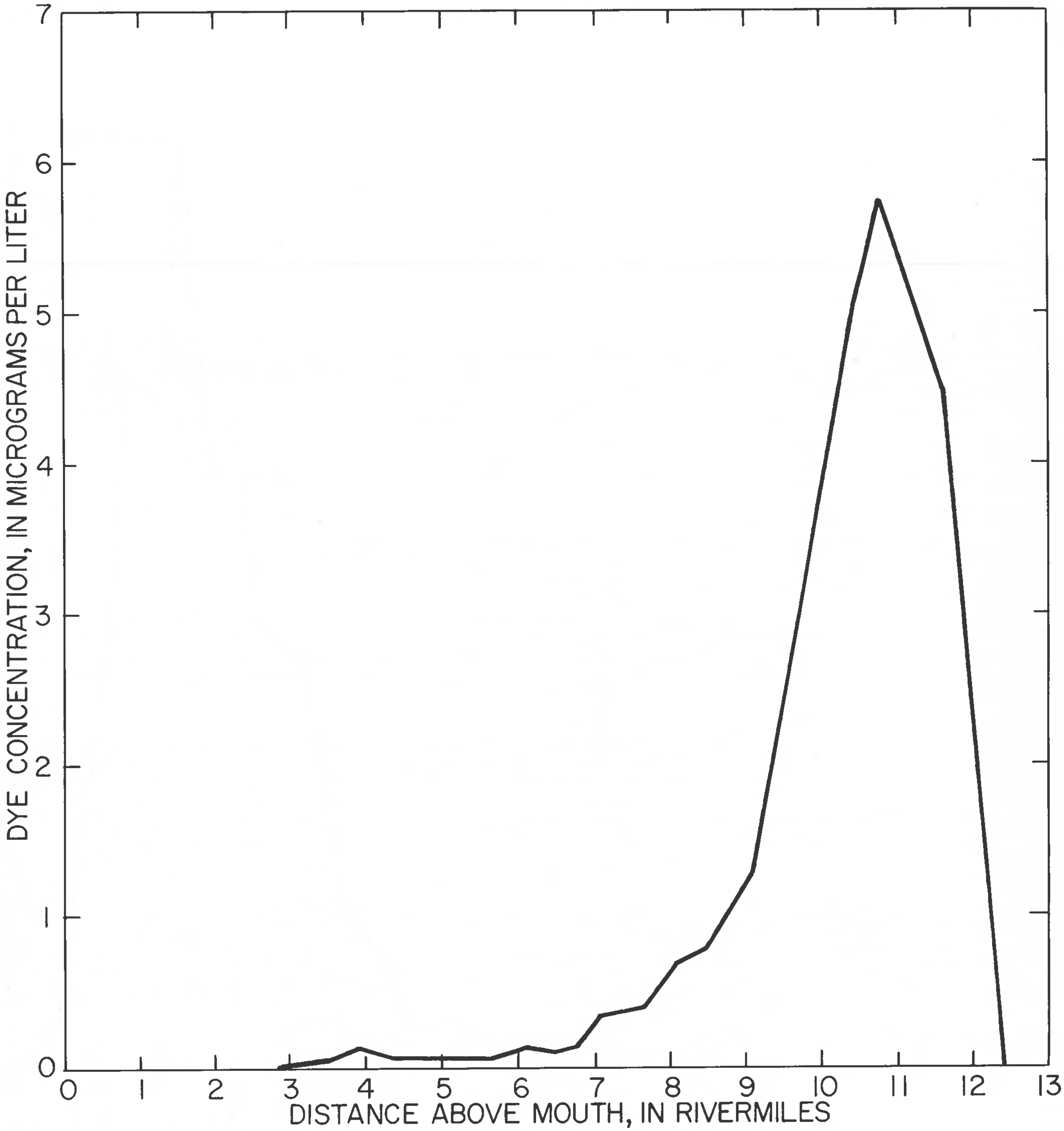

Figure 9. Dye concentration profile of Sampit River at high tide April 14, 1977, at 1630 hours.

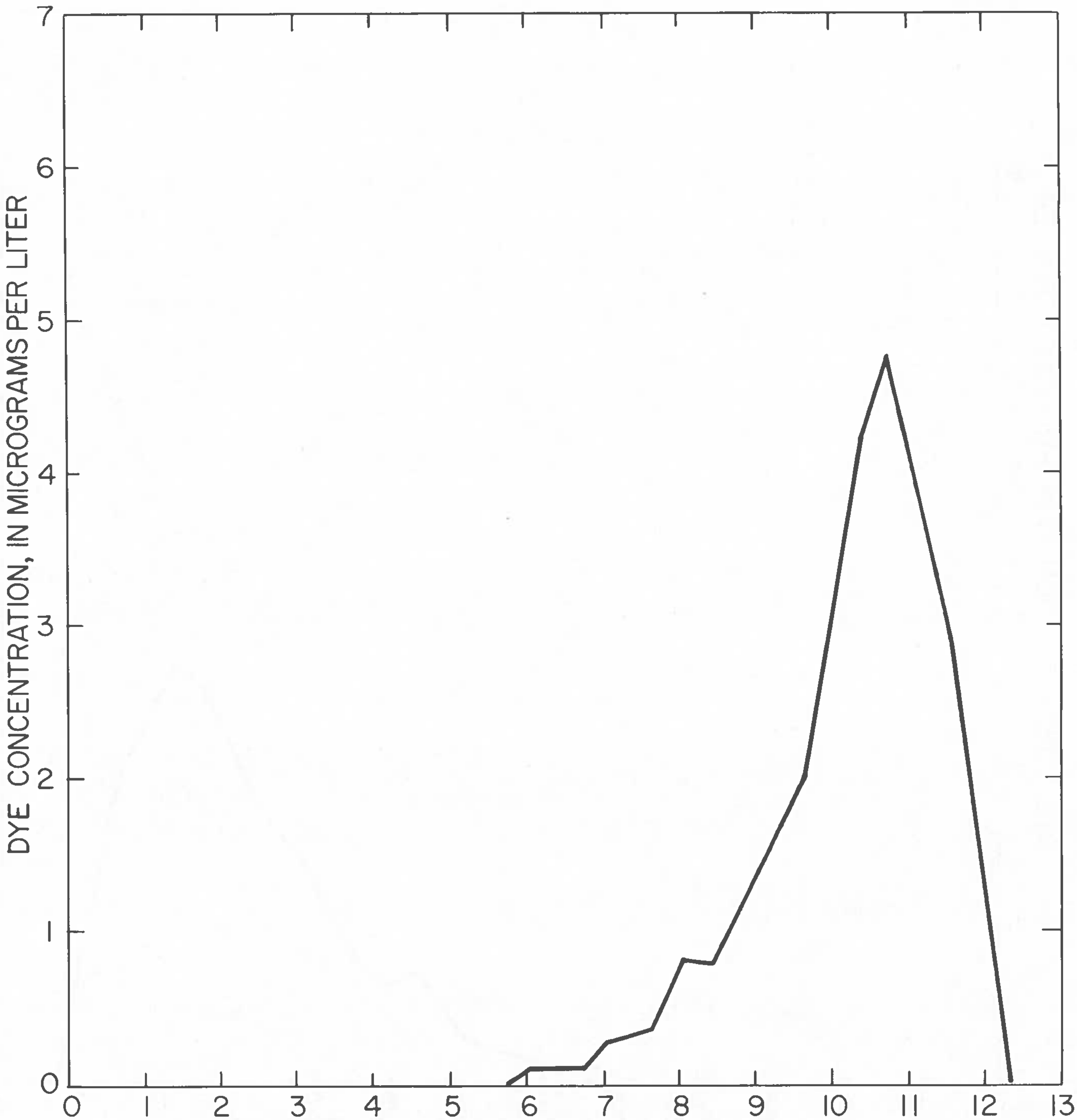

Figure 10. Dye concentration profile of Sampit River at high tide April 15, 1977, at 0800 hours.

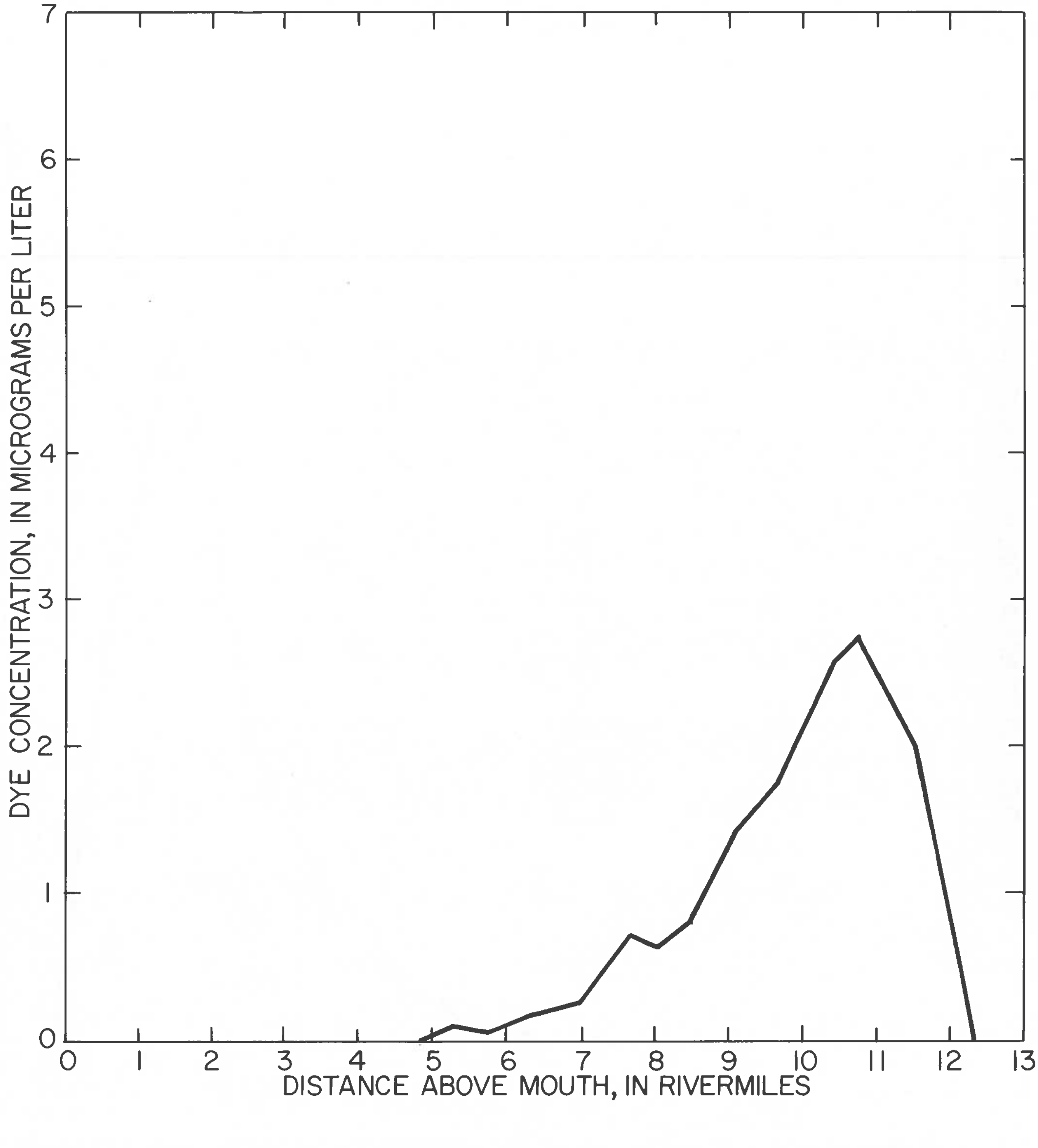

Figure 11. Dye concentration profile of Sampit River at high tide April 9, 1977, at 1000 hours.

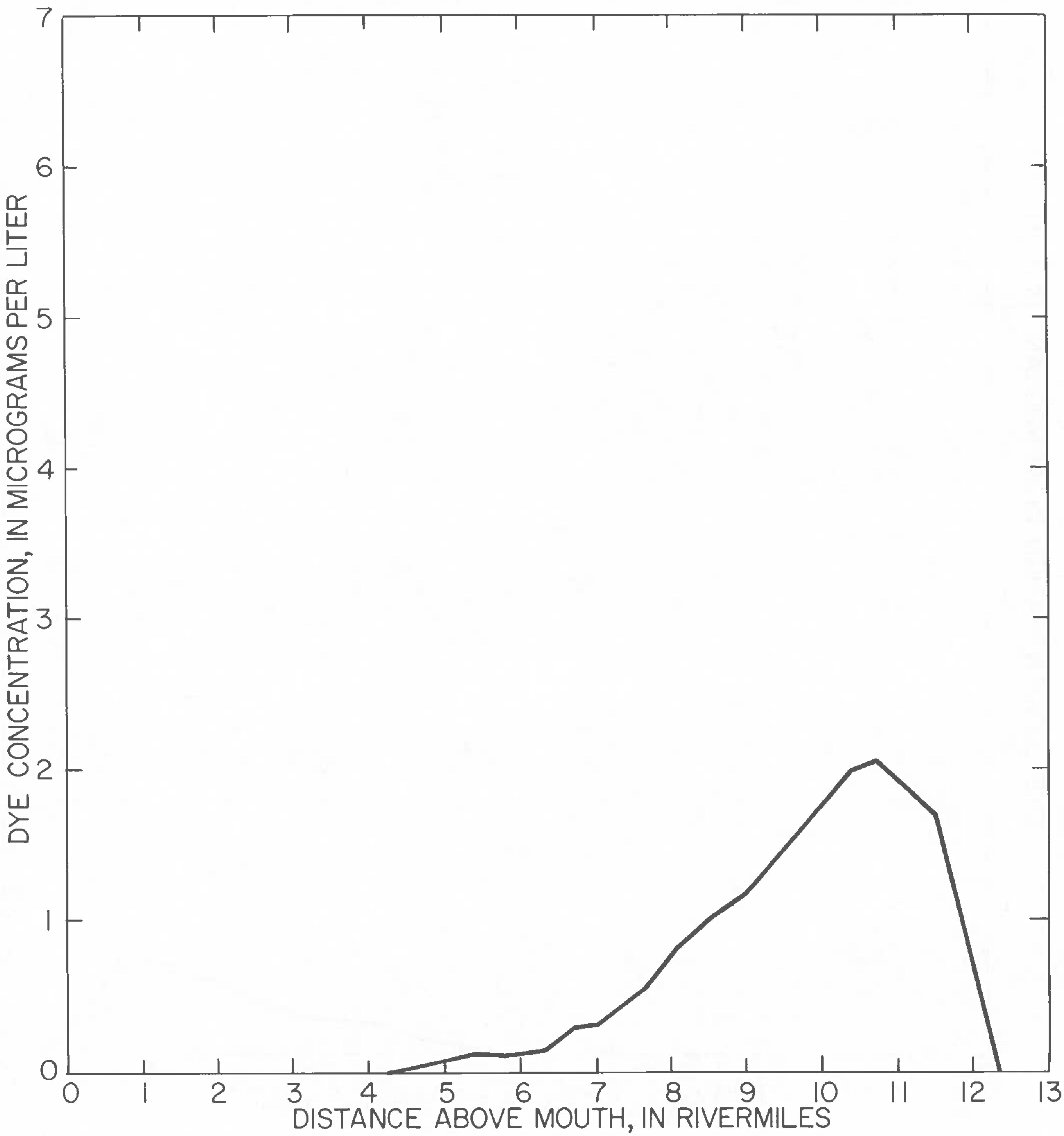

Figure 12. Dye concentration profile of Sampit River at high tide April 26, 1977, at 1630 hours.

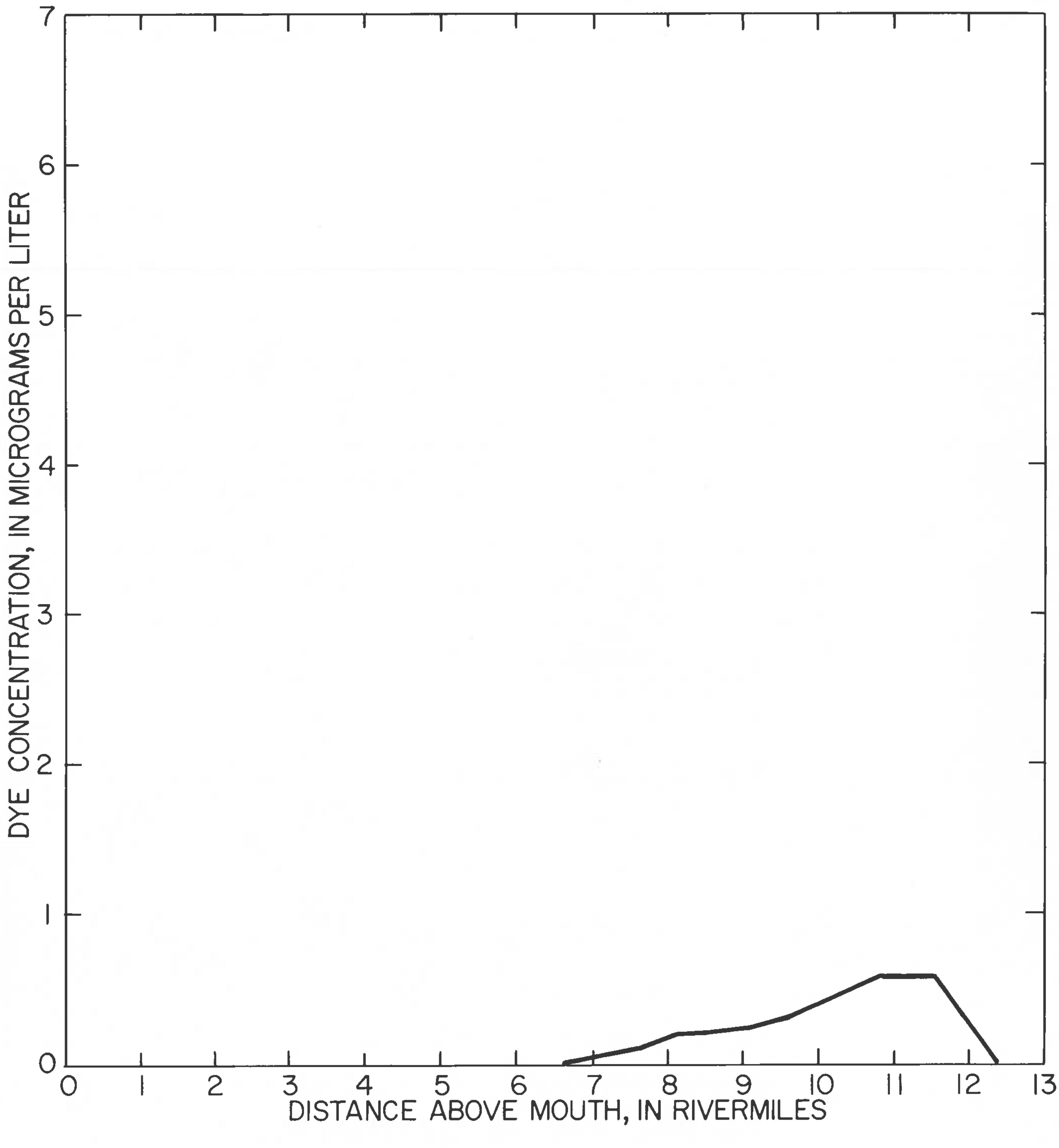

Figure 13. Dye concentration profile of Sampit River at high tide May 10, 1977, at 1650 hours.

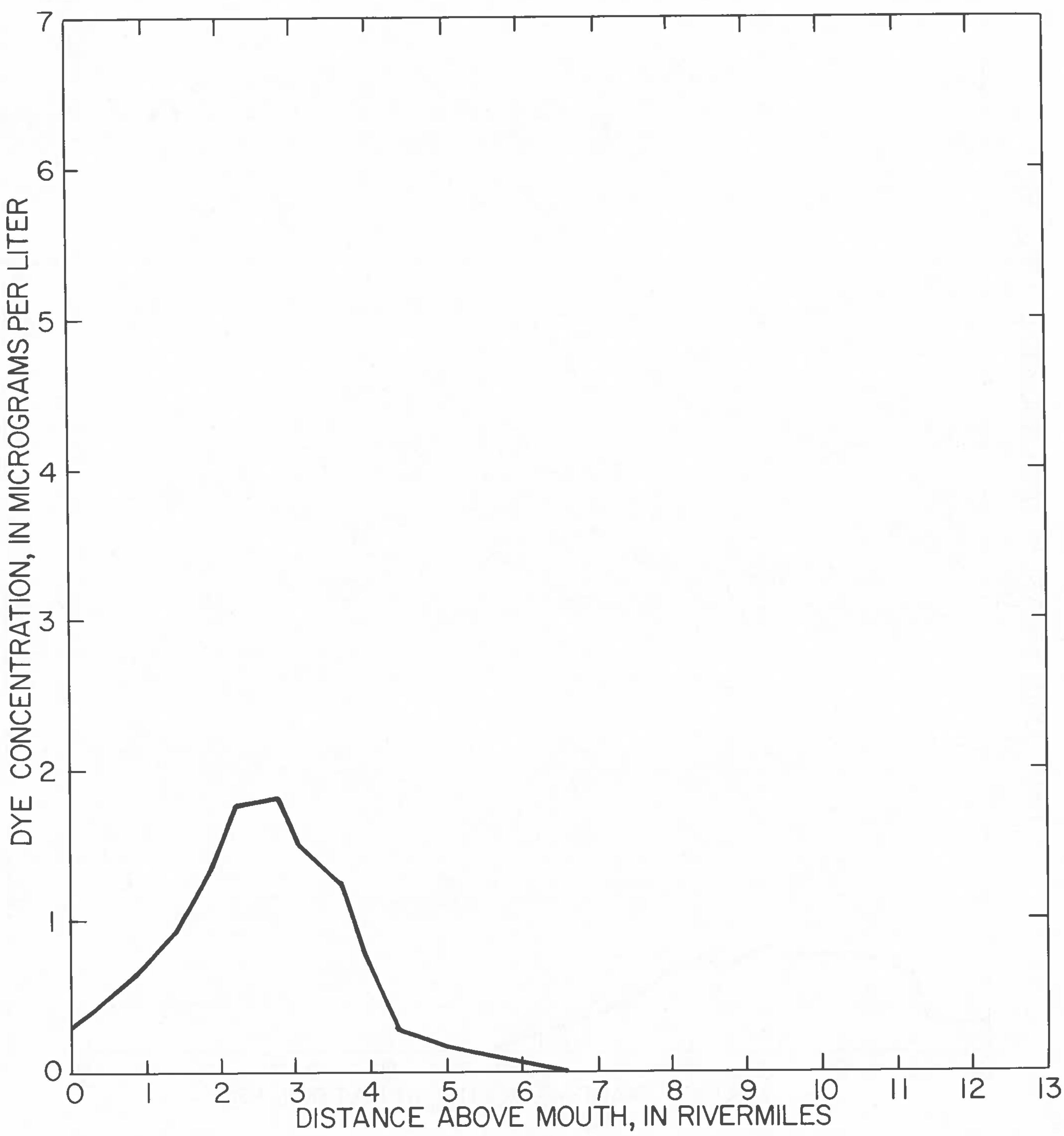

Figure 14. Dye concentration profile of Sampit River at low tide April 6, 1977, at 0530 hours.

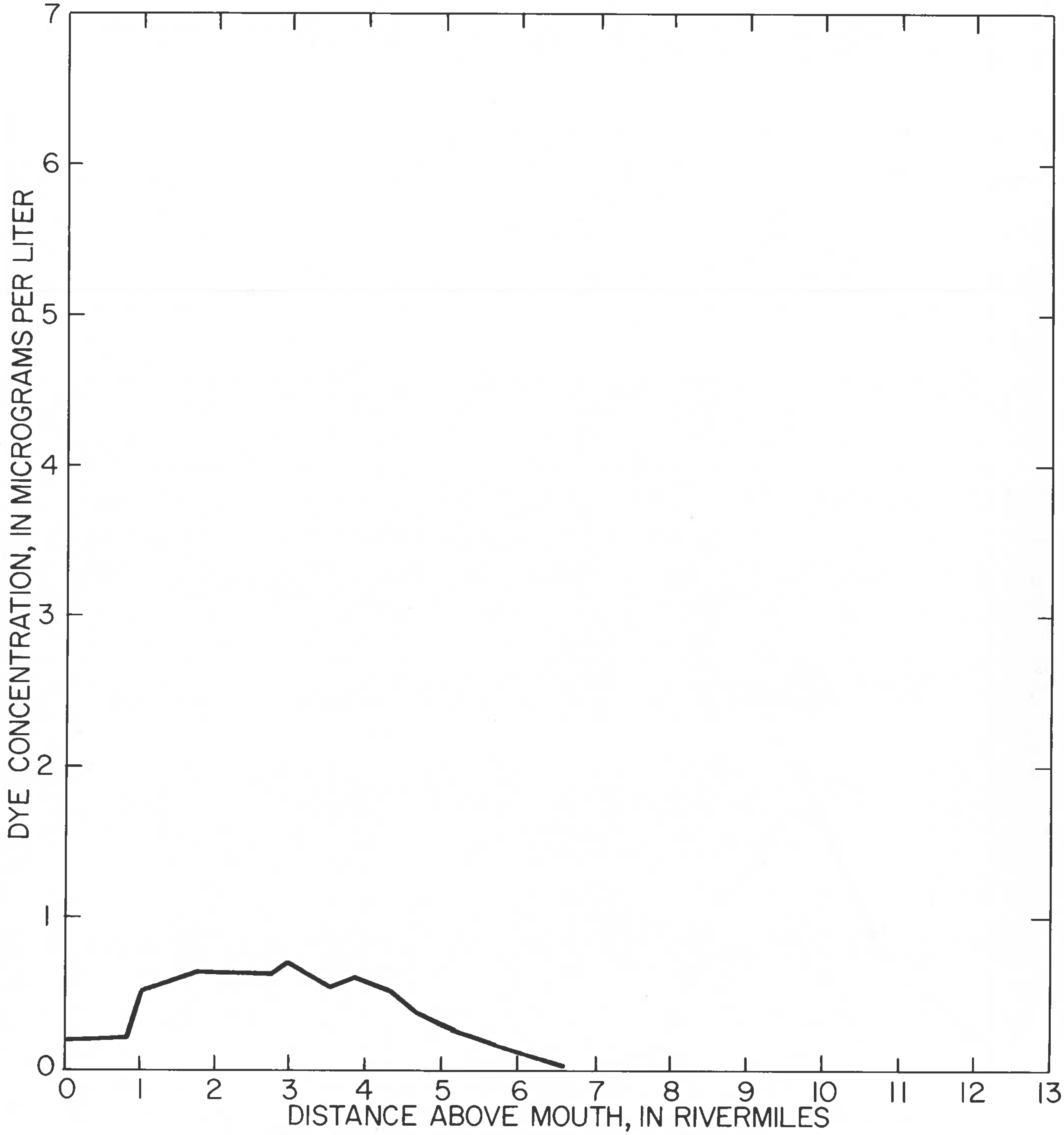

Figure 15. Dye concentration profile of Sampit River at low tide April 7, 1977, at 0700 hours.

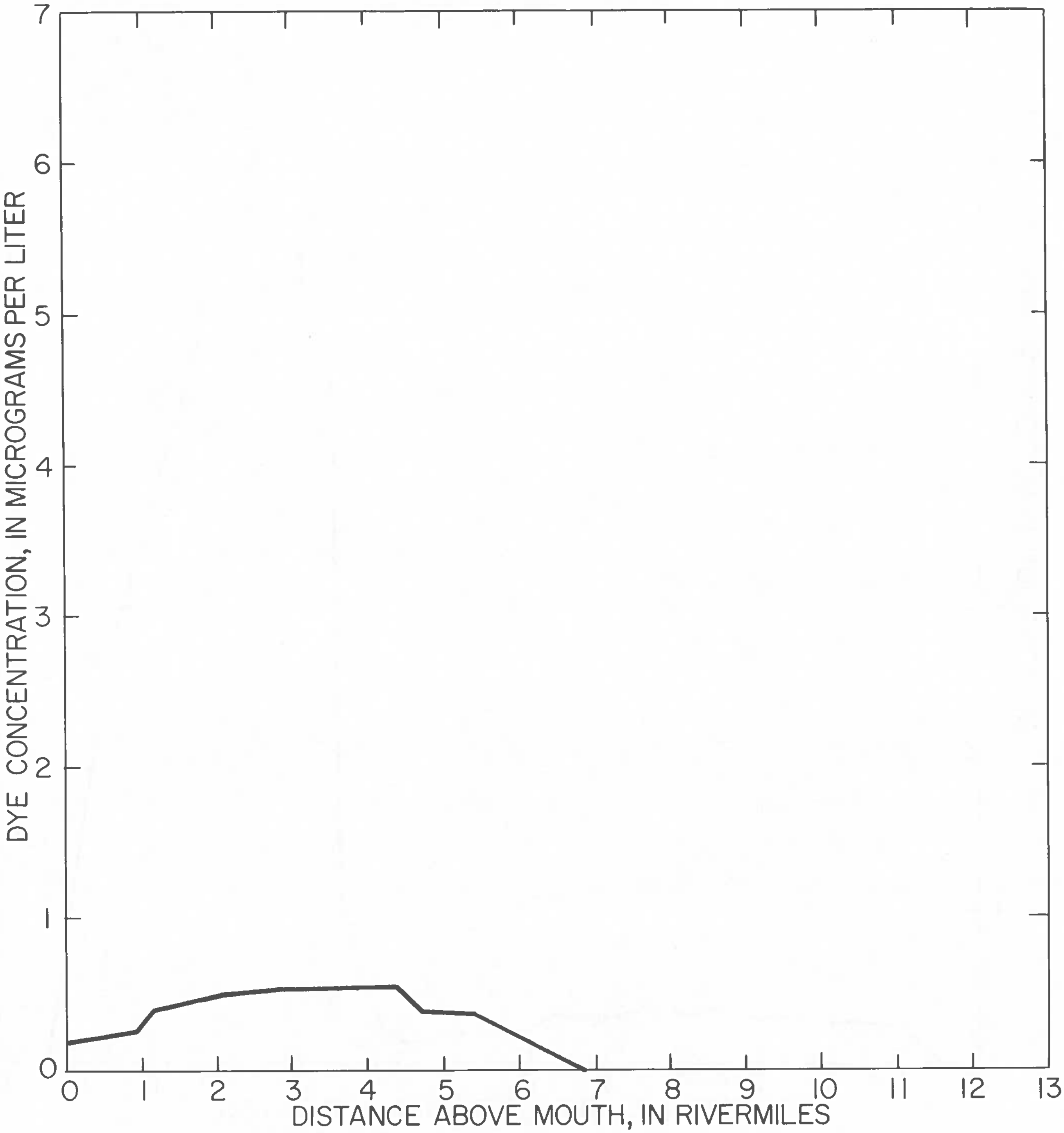

Figure 16. Dye concentration profile of Sampit River at low tide April 8, 1977, at 0730 hours.

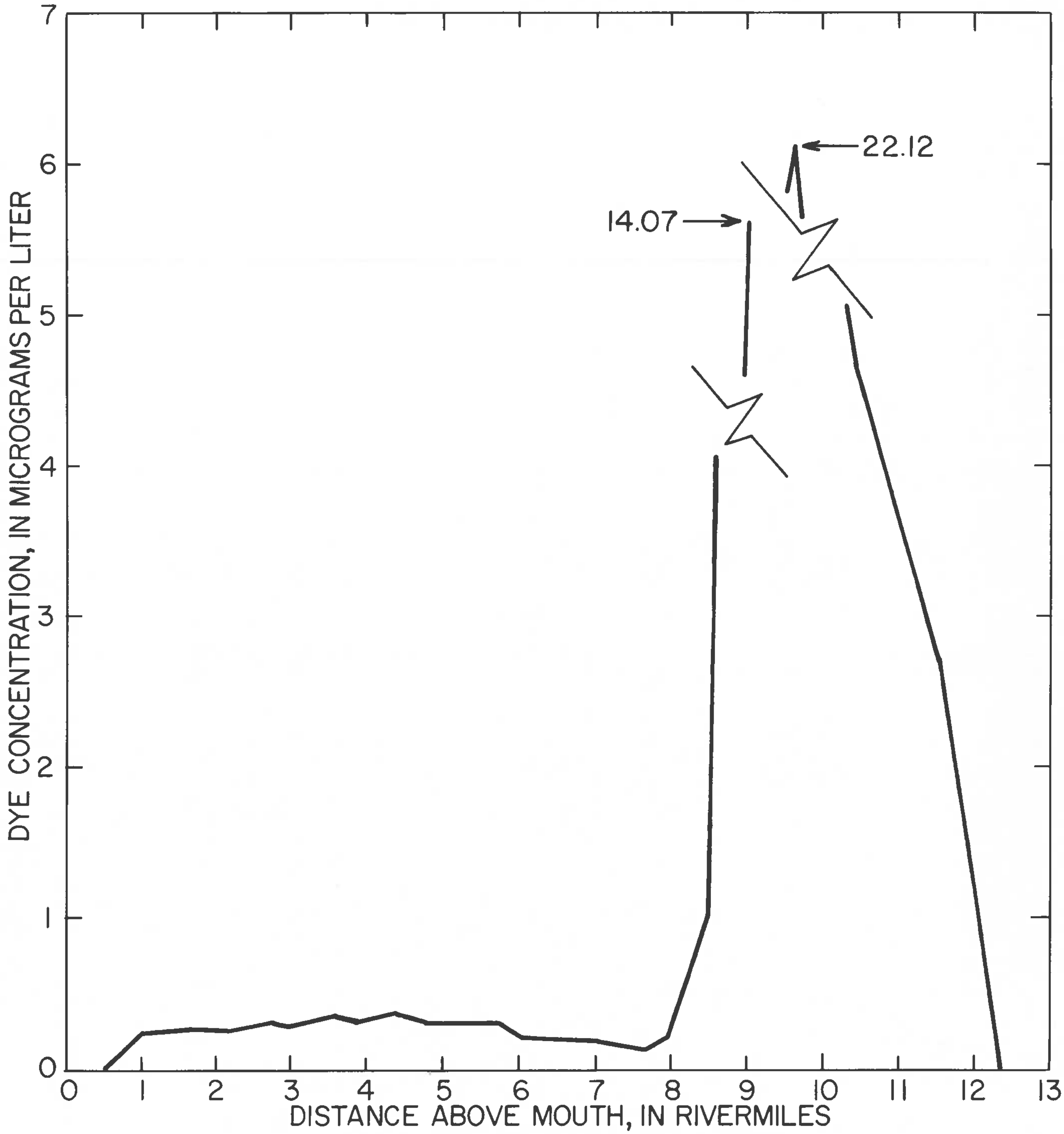

Figure 17. Dye concentration profile of Sampit River at low tide April 9, 1977, at 0830 hours.

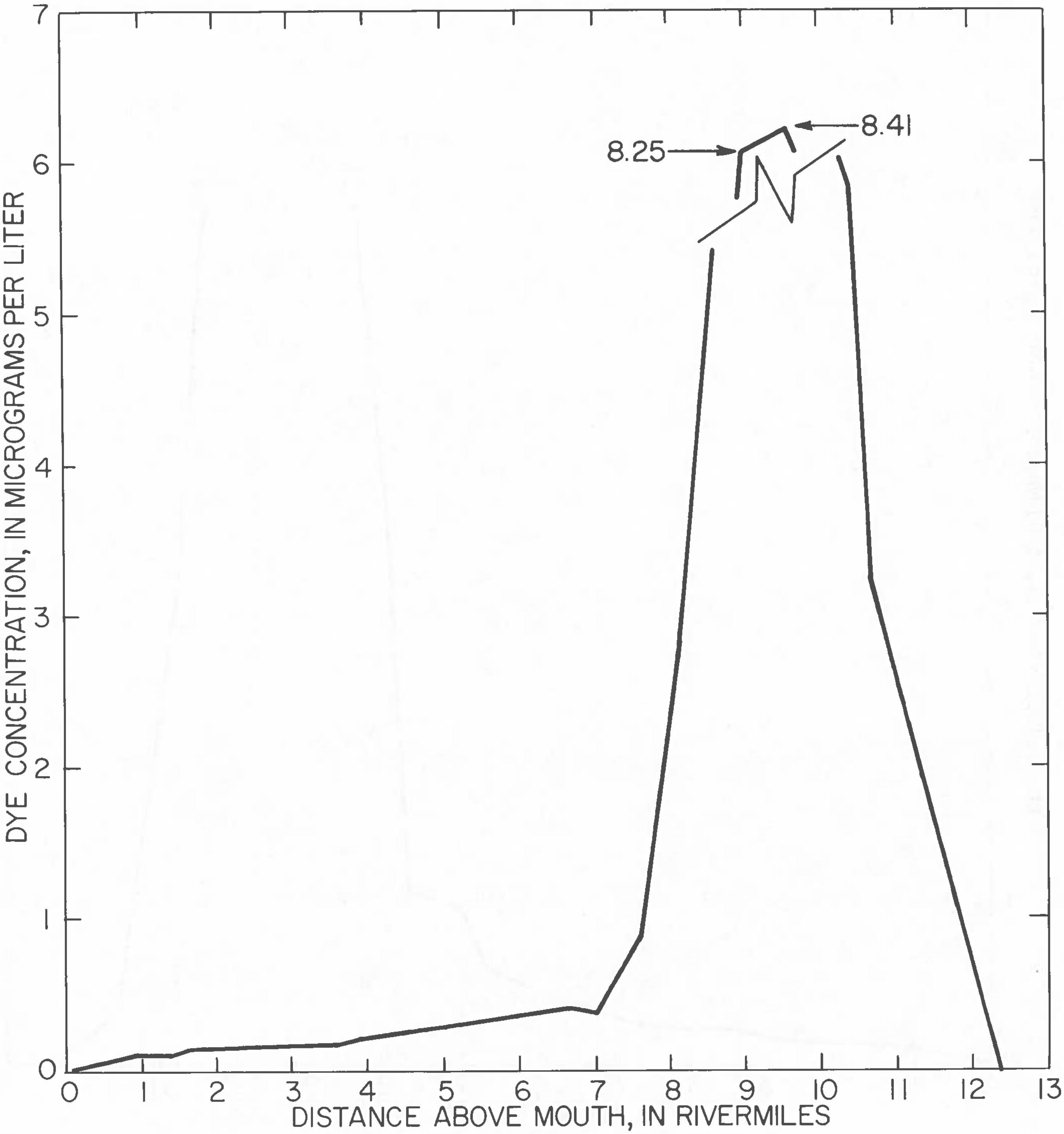

Figure 18. Dye concentration profile of Sampit River at low tide April 11, 1977, at 1030 hours.

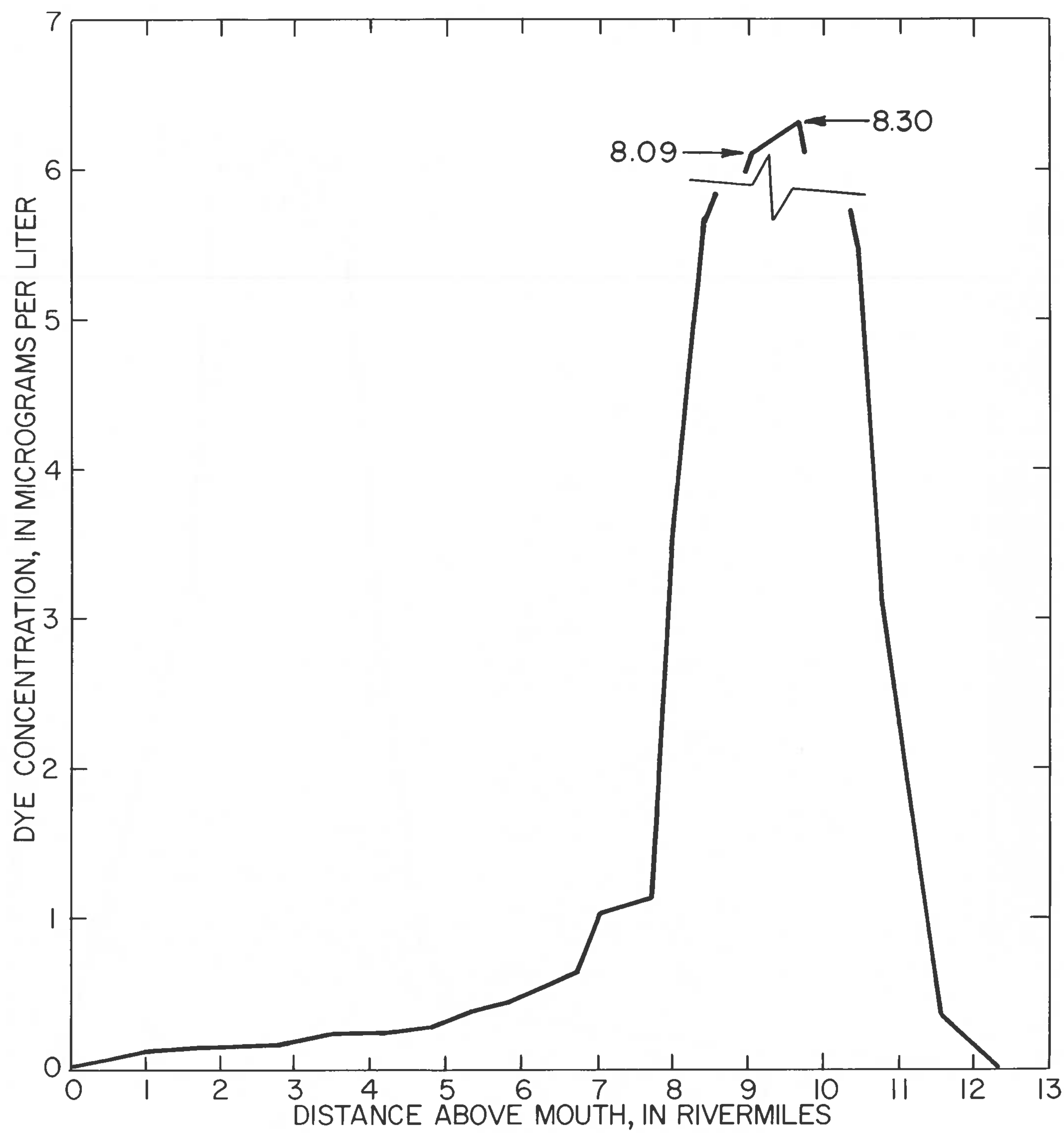

Figure 19. Dye concentration profile of Sampit River at low tide April 12, 1977, at 1100 hours.

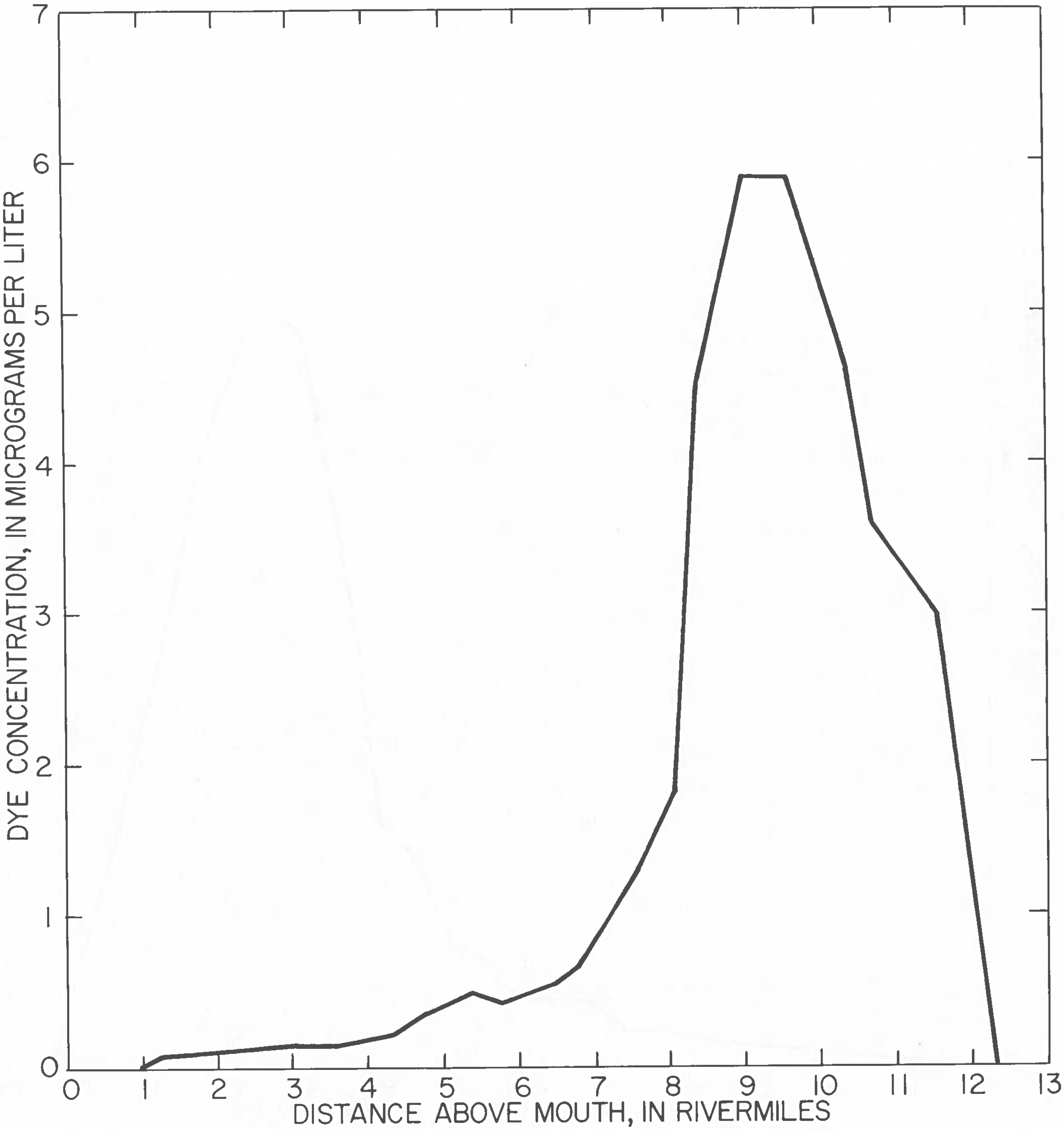

Figure 20. Dye concentration profile of Sampit River at low tide April 14, 1977, at 1330 hours.

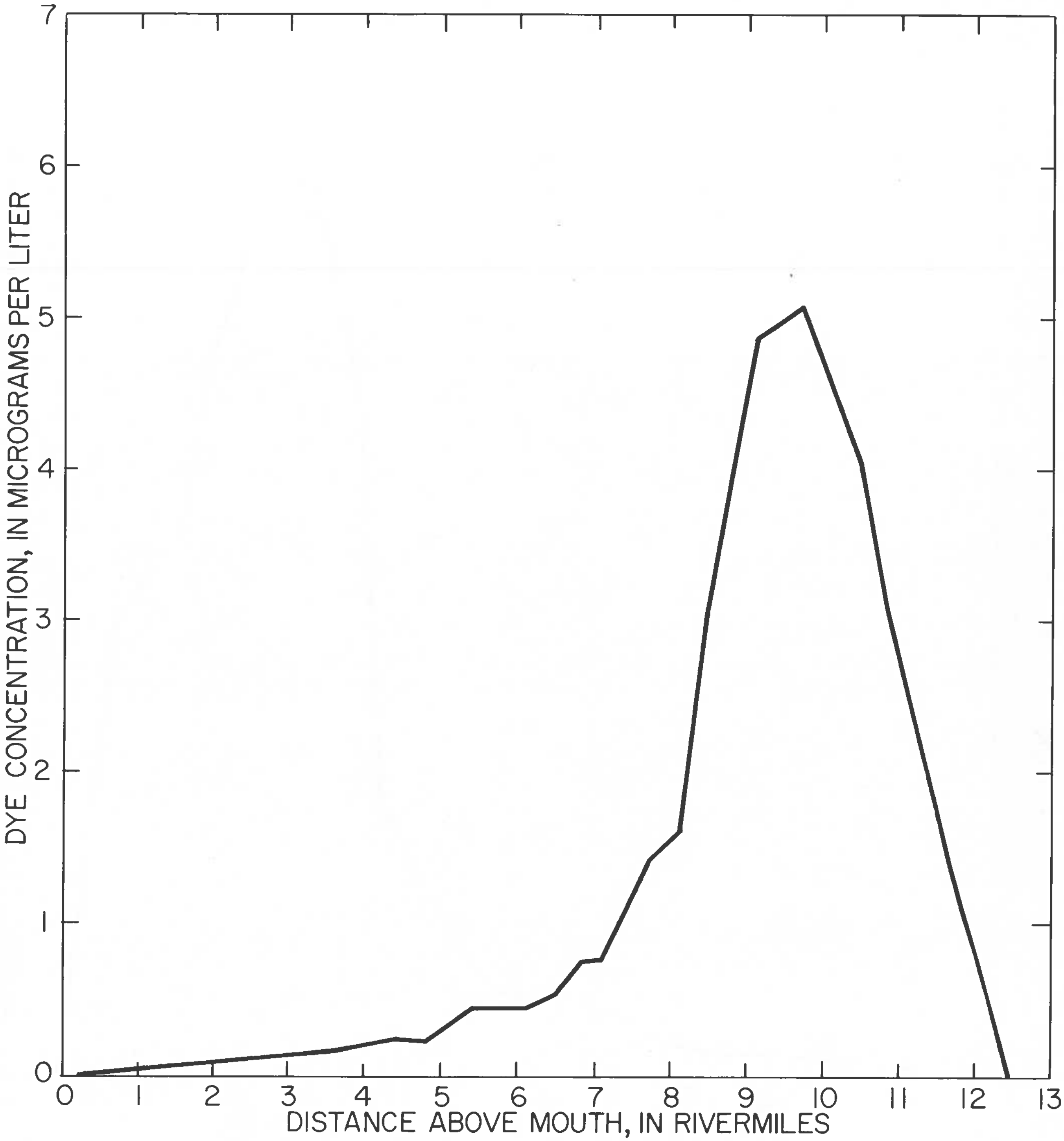

Figure 21. Dye concentration profile of Sampit River at low tide April 15, 1977, at 1415 hours.

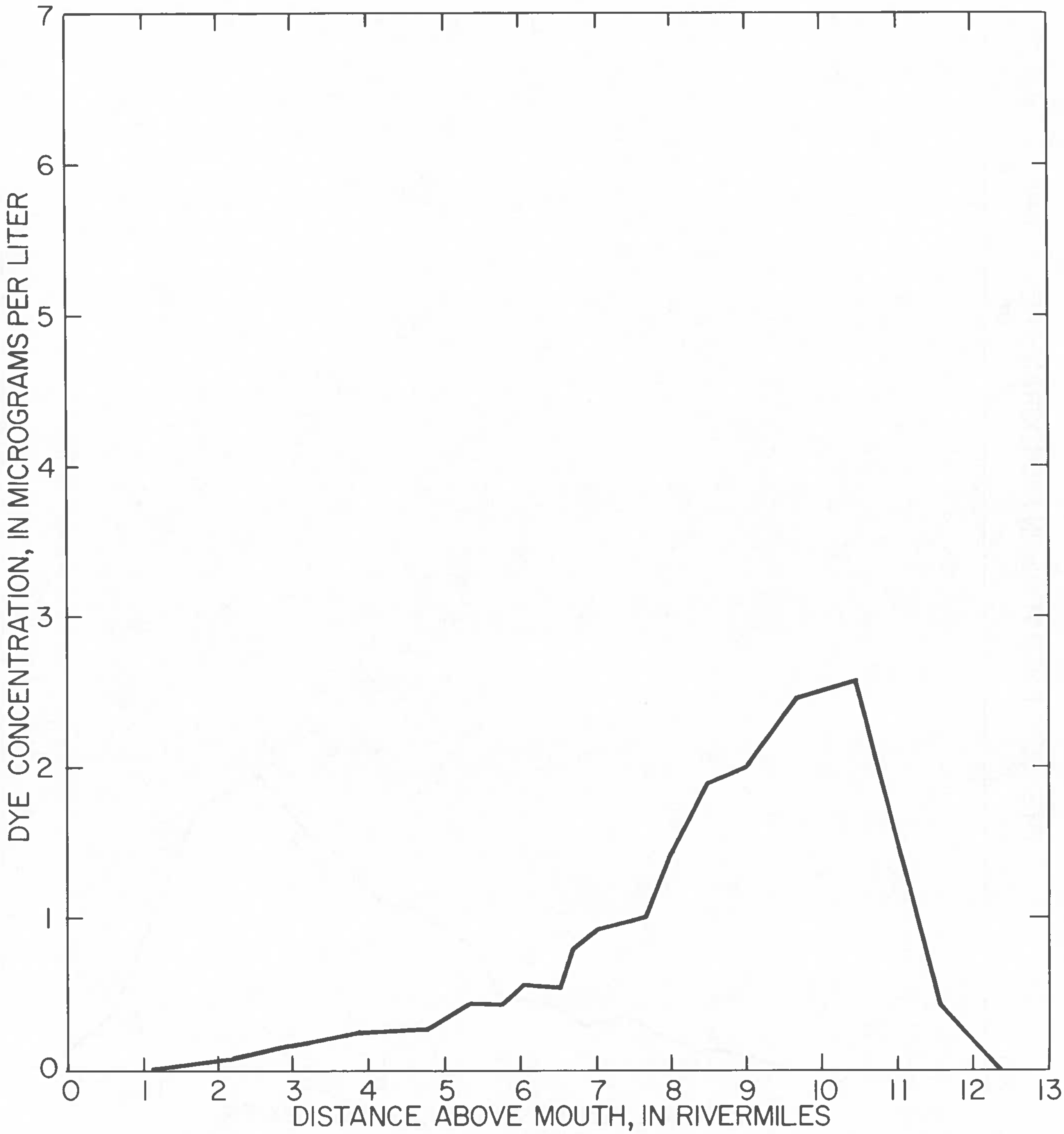

Figure 22. Dye concentration profile of Sampit River at low tide April 19, 1977, at 1630 hours.

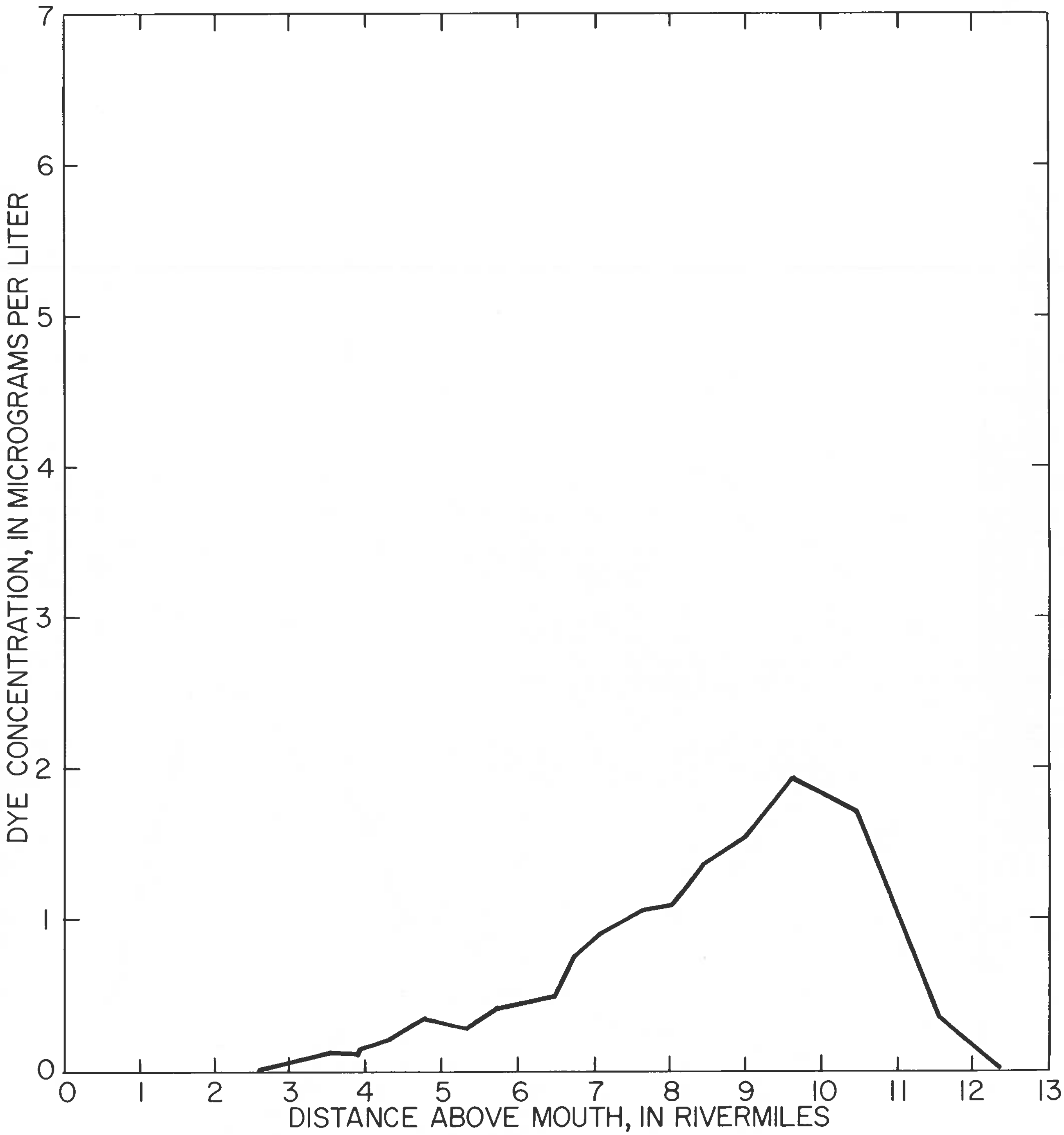

Figure 23. Dye concentration profile of Sampit River at low tide April 26, 1977, at 1000 hours.

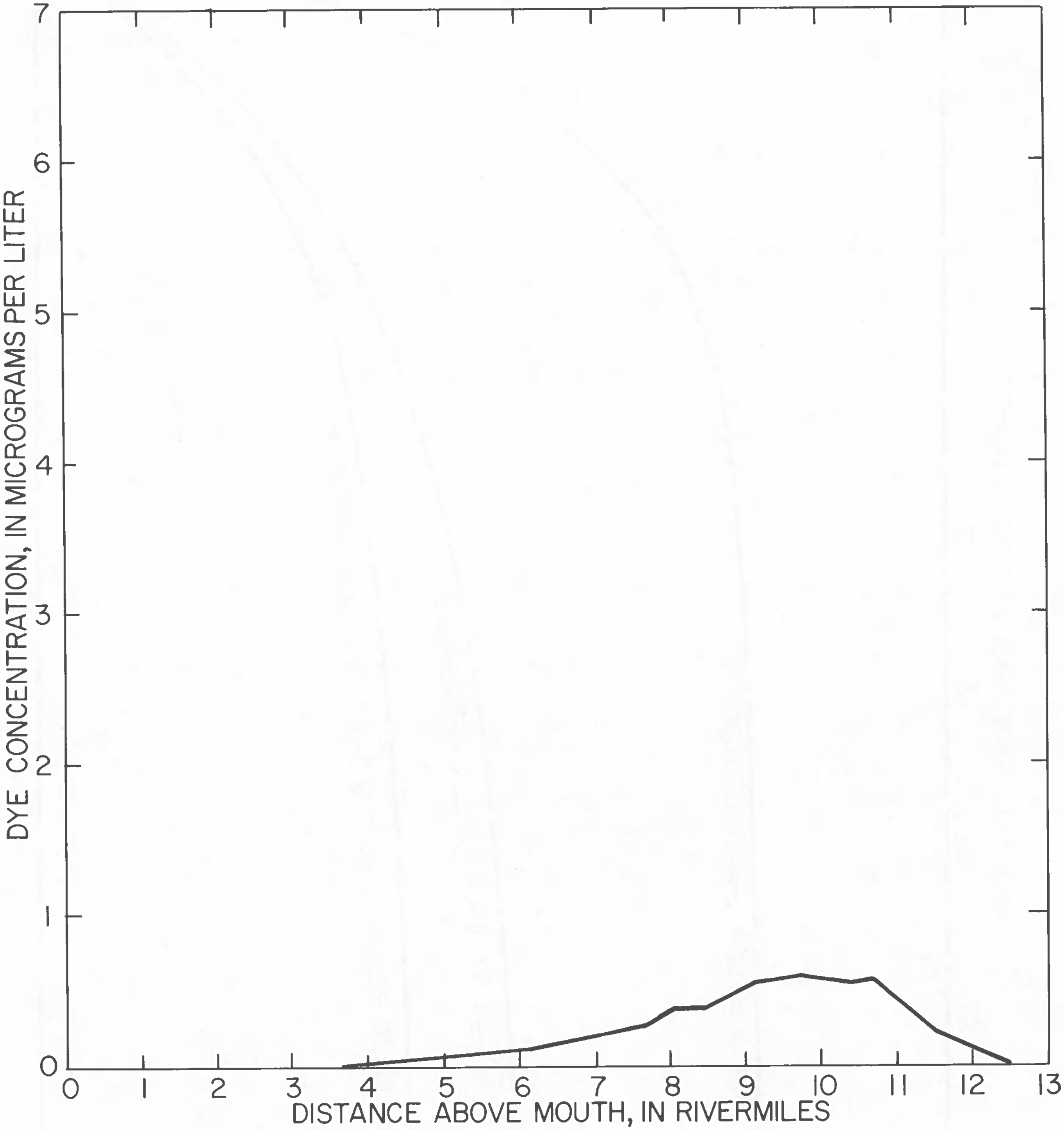

Figure 24. Dye concentration profile of Sampit River at low tide May 10, 1977, at 1100 hours.

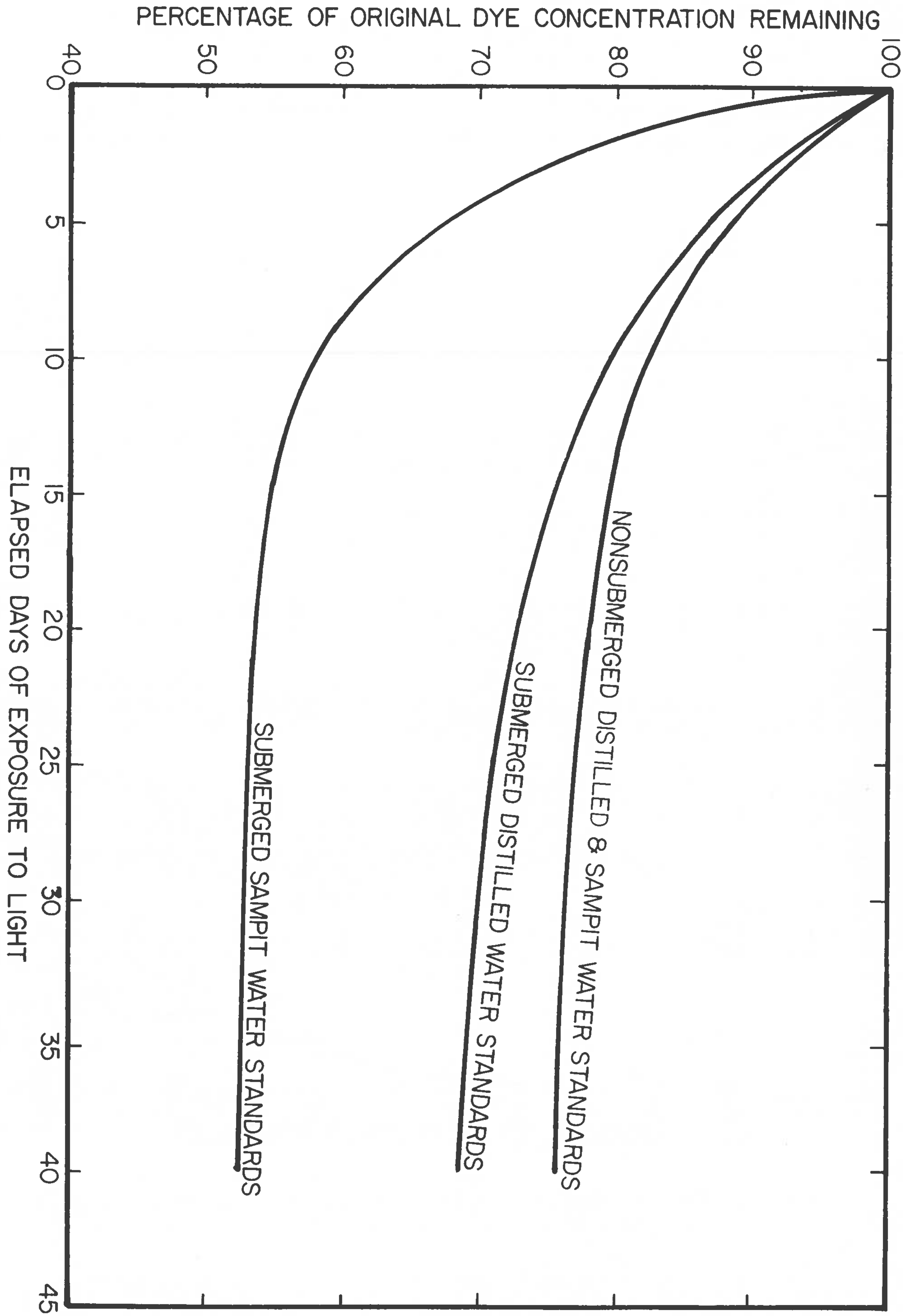

Figure 25. Graphic representation of dye decay from exposure to light.