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Assessment of Stormflow and Water Quality from Undisturbed and Site Prepared Forest Land in East Texas, Interim Report

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ASSESSMENT OF STORMFLOW AND WATER QUALITY FROM UNDISTURBED AND SITE PREPARED FOREST LAND IN EAST TEXAS

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ABSTRACT

In 1979, 9 small watersheds were instrumented in East Texas to determine the effect of intensive forest management practices on water quantity and quality. Three replications of three treatments were used: 1) clearcutting - followed by shearing and windrowing, 2) clearcutting - followed by roller chopping, and 3) undisturbed control. Following treatment, during the first eight months of 1981, stormflow volumes increased with the intensity of the site disturbance. Sites sheared and windrowed produced the greatest amount of stormflow (3.06 inches), followed by roller chopping (1.65 inches), and the undisturbed watershed (0.30 inches). Precipitation during this period was 33.3 inches. The shearing site preparation treatment exposed 57% of the surface soil as compared to 16 percent for the chopped watersheds. Sediment losses were significantly ($P \leq .05$) higher on the sheared watersheds (2203.2 lb/acre) than the chopped (12.0 lb/acre) or undisturbed watersheds (5.0 lb/acre). Nitrate export was 0.218, 0.074 and 0.003 lb/acre for the sheared, chopped and undisturbed watersheds, respectively. Total nitrogen losses were nearly 20 times greater on the sheared (1.91 lb/acre) than on the undisturbed (0.102 lb/acre) watersheds and 3 times greater than the chopped (0.676 lb/acre) watersheds. Total phosphorus loss during 1981 was only 0.18 lb/acre from the sheared watersheds, but was significantly ($P \leq .05$) higher than the chopped and undisturbed treatments. Potassium, magnesium and sodium export, following treatment, was highest on the sheared watersheds; however, calcium export was greater from the chopped watersheds.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ASSESSMENT OF STORMFLOW AND WATER QUALITY FROM UNDISTURBED AND SITE PREPARED FOREST LAND IN EAST TEXAS

INTRODUCTION

This study is spurred by the concern over the potential decline in forest productivity and the possible environmental effects of sediment and nutrient losses resulting from harvesting and site preparation activities. This project examines the influence of intensive forestry practices on water quality and yield, soil, and vegetation parameters. The Federal Water Pollution Control Act Amendments of 1972 (PL 92-500) make nonpoint pollution from forest practices increasingly more important, however, the effect of these practices on water quality in East Texas is not known.

This study is part of a regional program, with similar investigations being conducted in Arkansas. The regional collection of data is essential for characterizing the effects of forestry practices on water quality over a broad physiographic range. Extrapolation of water quality data between sites may not be feasible due to the variability in soil-physiographic-geologic conditions within the regions. However, an accurate accumulation of comparable information can be effectively generated for developing and evaluating sound predictive techniques with regional applications. Such predictive models will aid land managers in selecting practices that are environmentally sound as well as productive.

The treatments to be evaluated are the two most widely used methods of site preparing harvested forests in East Texas: 1) shearing and windrowing and 2) roller chopping. Nine six and one-half acre watersheds are being used to compare differences between site preparation treatments. Six of these experimental watersheds were harvested during the summer of 1980. Three of these six were then sheared with a V-blade, windrowed and the windrows burned. The remaining three harvested watersheds were roller chopped and then broadcast burned. Site preparation treatments were applied during November of 1980. All treatments were applied using the best state-of-the-art techniques. Three watersheds were left undisturbed as controls.

This report attempts to familiarize the reader with the forest practices currently being used in East Texas, and the accompanying water quality problems. Results of the first twenty months of pre- and post-treatment soil, vegetation, precipitation, water yield, and water quality data are included.

STATE-OF-THE-ART HARVESTING AND SITE PREPARATION PRACTICES IN EAST TEXAS

The majority of forest land in East Texas is managed primarily for pine sawtimber and/or pulpwood. Clearcutting and planting is the predominant regeneration system. Approximately 353,000 acres of trees are harvested in East Texas each year (Blackburn et al., 1978) (Table 1). Of these acres, 192,768 are clearcut, 127,413 are selectively harvested and 32,919 are harvested by the seed tree and shelterwood system. Harvesting activities are carried out through most of the year, with about 66 percent occurring between March and August.

Of the forest land receiving a final harvest cut each year, about 142,820 acres receive some form of site preparation prior to reestablishment of a new forest (Blackburn et al., 1978) (Table 2). Mechanical means alone, or in combination with prescribed burning are the most frequently used methods.

The following site preparation activities are employed on East Texas managed forest lands: 1) shearing, 2) windrowing, 3) roller chopping, 4) disking, 5) bedding, 6) burning windrows, 7) broadcast burning, and

Table 1. Estimated acreage of sawtimber and pulpwood sized material annually receiving a final harvest cut on forest land in East Texas by regeneration system (Blackburn et al., 1978).

Regeneration System	Sawtimber	Pulpwood	Total	Percentage of Total
Clearcut	134,054	58,714	192,768	55%
Selection*	74,941	52,872	127,413	36
Seed Tree	14,410	3,293	17,703	5
Shelterwood	12,090	3,126	15,216	4
Total	235,495	118,005	353,500	

*The figure reported for the selection regeneration system largely reflects intermediate harvest cuttings.

Table 2. Estimated acres of East Texas forest land receiving a site preparation treatment annually (Blackburn et al., 1978).

Site Preparation Technique	Forestland
Mechanical	100,428
Prescribed Burning	33,163
Herbicide	9,229
Total	142,820*

*Actual area treated is less due to overlapping activities.

8) herbicide treatment. These activities may be employed singly or in various combinations. Shearing and windrowing are the most commonly used site preparation techniques. Roller chopping ranks second in usage among mechanical means. The windrows are usually burned following shearing and windrowing and the roller chopped areas are normally broadcast burned after completion of chopping. Bedding and disking are only used on the poorly drained soils of southeast Texas. Herbicide spraying or injection is usually used in combination with one of the mechanical site preparation methods.

LITERATURE REVIEW

Water Yield

Water yield from undisturbed forests is regulated by the vegetation, soils, topography, and climate. Precipitation in the form of rain is the most common input for the humid region of the southeastern United States. Of the precipitation falling on a mature forested watershed, from 10 to 30 percent is intercepted by the forest canopy and lost as evaporation (Rogerson 1967). In most cases, the rain reaching the forest floor filters through the litter covered surface and infiltrates into the soil. Under certain circumstances of prolonged rainfall, where the soil becomes saturated, the infiltration rate is reduced and overland flow may occur. Pierce (1967) found evidence of overland flow occurring over accumulated leaf debris and laterally at the interface of humus and/or litter layers and the mineral surface. Nonetheless, contribution to streamflow is primarily the result of subsurface flow (Hursh 1944; Whipkey 1967). Hewlett and Nutter (1970) explain streamflow as resulting from the expanding source area of subsurface flow near the stream channel. Evidence has also been presented to show the contribution of subsurface flow from upper slopes to the stream channel (Beasley 1976).

Forest management activities will significantly influence the timing and quantity of water yield. It has been well documented that harvesting the forest vegetation will increase streamflow (Douglass and Swank 1972; Hornbeck 1975; and Hewlett 1979). When the vegetative cover is removed, evapotranspiration is reduced and soil moisture is increased (Troendle 1970). The result is an increase in the water available for streamflow. The intensive forest practices of harvesting, site preparation, and machine planting may also disturb the forest floor enough to cause overland flow.

The impact of overland flow on the storm hydrograph will be a rapid response time, an increased volume of runoff, and a higher peak discharge rate. Ursic (1979) found storm peak flows from small catchments, a sensitive index to changes in the components of storm flow and sediment production due to forestry activities. However, significant increases in peak flow are usually limited to a few large events. Although these events may produce a large percentage of the annual water and sediment yield, they do not persist with forest regeneration.

Water yield increases following clearcutting, is the rule rather than the exception. On the Fernow Experimental Forest in West Virginia, Reinhart (1962) found that stream discharge was increased in proportion to the amount of timber cut or killed. In this study, the annual discharge increased up to 5 area-inches the first year following clearcutting. Another study (Aubertin and Patric 1974) on the Fernow Experimental Forest found that clearcutting increased streamflow 8 area-inches during the first year following cutting. Rapid revegetation reduced the increase in streamflow to 2.5 area-inches by the second year.

Clearcutting followed by roller chopping, in the Georgia Piedmont, resulted in a first year water yield increase of 10 area-inches (Hewlett 1979). This represented an increase of 27 percent above pretreatment stormflow. The cumulative effects of forest operations more than doubled small stormflows and peaks, but were proportionally less influential in large flood producing flows. Beasley (1979) studied the effect of three different site preparation treatments on stormflow in northern Mississippi. The first year following chopping, shearing and windrowing, bedding, and no treatment, stormflows were 20, 18, 20, and 3 area-inches, respectively. Stormflow as a percentage of rainfall decreased the second year following treatment.

The initial increase in water yield and peak flow following forest disturbance, appears to be short-lived for most of the eastern and southern United States. The rapid revegetation in these areas, quickly stabilizes the site and increases evapotranspiration. Douglass and Swank (1972) conclude that water yield increases decline rapidly with regeneration of the forest and seldom persits beyond the fifth year.

Water Quality

Sediment

Sediment is often regarded as the primary pollutant from silvicultural activities. Generally, three types of erosion on forested watersheds are recognized: 1) surface erosion - the detachment and removal of individual soil particles or small aggregates from the land surface. It results in sheet erosion, rills and gullies, and is caused by the action of raindrops, then film flow, or concentrated surface runoff; 2) channel cutting - the detachment and moving of material from a stream channel, and; 3) mass movement - such as landslides and slumps, which are an important form of erosion in mountainous regions; but are not considered a significant source of erosion in East Texas.

The process of erosion involves three phase: 1) detachment, 2) transport, and 3) deposition. Factors affecting the erosion process include: soil characteristics - texture, mineralogy, aggregate stability, organic matter, percolation, infiltration rates; topography, rainfall; and most importantly, vegetative and litter cover. Erosion does not necessarily mean sedimentattion, as sediment may be deposited in places other than a stream (Satterlund 1972).

Erosion from the undisturbed forest is seldom a water quality problem. The mature forest intercepts rainfall either in the canopy or at the litter layer of the forest floor and prevents the destructive effects of rainfall impact. Rainfall then infiltrates into the soil and travels to the stream channel via subsurface flow. High infiltration rates for the undisturbed forest, prevent surface runoff in most circumstances, and hence, surface erosion is rare. This leaves channel cutting as the primary source of erosion from undisturbed forests.

The natural rate of sedimentation from undisturbed forests, varies with location, geology, vegetation, watershed size, and season. Inference from studies in the southeast demonstrate that the natural erosion rate is very low from forested lands. A review of the literature (Yoho 1980) on sediment production from undisturbed forests in the South, revealed a range of sediment yields from trace levels to .32 tons/acre/year.

Ursic (1977) has suggested 60 mg/l (13.5 lb/acre-inch of stormflow) as the average annual sediment concentration in stormflows from small, undisturbed southern pine catchments. However, concentrations for individual events, due to natural variation, may be higher by a factor of ten or more. Periodic flushing of sediments collected in the stream channel result in these occasionally higher values.

A study in northern Mississippi of five undisturbed forested watersheds, yielded sediment concentrations of 54, 47, 269, 143, and 120 mg/l for the year (Duffy et al. 1978). This is an indication of the variability that often occurs even between similar watersheds. After reviewing erosion from eastern forests, Patric (1976) concluded that erosion from undisturbed, as well as carefully managed forest land, is from .05 to .10 tons/acre/year.

Logging and site preparation increase the potential for sediment production by disturbing the soil and the protective forest floor. Compaction and destruction of surface soil structure and macropore space cause an increase in surface runoff, thus increasing the sediment production potential

(Dixon 1975; Lull 1959; Moehring and Rawls 1970). Disturbing the protective vegetation and litter, bares the soil to raindrop impact, which breaks soil aggregates into smaller particles. These smaller particles are more easily detached and may leave the site in runoff water and/or clog larger soil pores. Thus, infiltration is reduced and the possibility of surface runoff is increased (Edwards and Larson 1964). Removal of vegetation and litter also reduce resistance to overland flow and increase velocity, which in turn increases the carrying power of runoff (Douglass 1975).

Ursic (1974) has stated that intensive site preparation of hilly areas in the South, presents the most serious erosion problem. Shearing and windrowing is generally recognized as causing more site disturbance than roller chopping. Shearing and windrowing increase susceptibility to erosion by removing the protective surface cover and exposing the mineral soil. The shearing process tends to scalp the soil and then raking often carries this surface soil into the windrow. This results in a relocation of the nutrient rich surface horizon and a loss of available nutrients to a portion of the watershed. Soil-site equations indicate a reduction in site index and productivity as a result of such top soil loss (Switzer et al. 1978). Also, increased compaction caused by heavy shear-and-pile tractors reduce infiltration and thereby, increase surface runoff potential (McClurkin and Moehring 1978).

Roller chopping causes less disturbance and exposure of mineral soil and leaves more debris on the surface than shearing and windrowing. The blade of the roller chopper has a tillage effect which usually improves aeration, detention storage and soil density. Organic matter is incorporated into the soil and the slits left by the chopping blade help to reduce surface flow and minimize sediment movement. Maximum benefit is derived when the blade runs parallel to contour lines so that water collection in the blade slits will not start rill or gully erosion (Switzer et al. 1978).

Beasley (1979) studied the impact of three intensive site preparation treatments on four small (1.7-2.5 acre) watersheds in northern Mississippi. These watersheds have slopes ranging from 30 to 50 percent and prior to logging were occupied by a mixture of shortleaf pine and hardwoods. The treatments studied were: 1) roller chopping and burning; 2) shearing, windrowing into the stream channel, and burning; 3) bedding on the contour, following shearing, windrowing into the stream channel, and burning; and 4) control, with no logging, site preparation, or other disturbance. After site preparation, the treated sites were fertilized, sown with subterranean clover, and planted with loblolly pine seedlings.

Exposed mineral soil following site preparation was 69%, 53%, and 37% for the bedded, sheared and windrowed, and chopped watersheds, respectively. The first year following treatment, stormflow was similar for the three treated watersheds (17.8 to 20 area-inches) (Table 3). In the second year, the chopped watershed had the highest stormflow (13.6 area-inches) and the bedded watershed the lowest treatment stormflow (9.3 area-inches).

Discharge-weighted sediment yields for the first year, were similar among all four watersheds (.24 to .32 tons/acre-inch of stormflow). Channel scouring attributable to the increased stormflow produced by vegetation removal, was a significant course of sediment. A single storm accounted for 90% of the annual sediment loss from the control watershed. By April of the second year, soil was exposed on only 1, 4, and 6 percent of the chopped, sheared, and bedded sites and sediment losses dropped accordingly. Second year sediment losses ranged from .05 tons/acre-inch of stormflow on the control watershed to .26 tons/acre-inch of stormflow on the bedded treatment. The relatively high sediment yield on the bedded watershed was due to the formation of a gully above the flume site.

Table 3. Stormflow and sediment yields following site preparation in northern Mississippi (Beasley 1979).

Treatment	Storm Flow (area-inches)	Sediment Yield (tons/acre)	Discharge Weighted Sediment Yield (tons/acre-inches of stormflow)
	First Year		
Control	1.1	0.28	0.24
Chop and Burn	20.0	5.59	0.28
Shear, Windrow and Burn	17.8	5.71	0.32
Shear, Windrow, Burn and Bed	20.0	6.36	0.32
	Second Year		
Control	1.1	0.05	0.05
Chop and Burn	13.6	1.03	0.08
Shear, Windrow and Burn	11.0	0.99	0.09
Shear, Windrow, Burn and Bed	9.3	2.47	0.26

Douglass and Goodwin (1980) evaluated intensive site preparation practices, using four replications of three treatments: 1) shearing; 2) shearing and disking, and; 3) shearing, disking, fertilizing, and grass seeding, in the North Carolina Piedmont. All treatments except the control were windrowed, burned, and planted with loblolly pine seedlings. One year after treatment, the shearing and shearing and disking treatment produced the largest sediment yield (.32 and .29 tons/acre-inch of stormflow, respectively) (Table 4). The higher value for the shearing treatment reflects the result of windrowing in the channels on two of the sheared watersheds. The sheared, disked, fertilized, and seeded treatment reduced sediment by one-third (0.09 tons/acre-inch of stormflow) but produced five times more sediment than the control (0.02 tons/acre-inch of stormflow).

Table 4. First year sediment yields following site preparation in the North Carolina Piedmont (Douglass and Goodwin 1980).

Treatment	Sediment Yield (tons/acre)	Discharge Weighted Sediment Yield (tons/acre-inch of stormflow)
Control	0.04	0.02
Shear, Windrow and Burn	2.24	0.32
Shear, Windrow, Burn and Disk	1.06	0.29
Shear, Windrow, Burn, Disk, Fertilize and Seed	0.26	0.09

A paired watershed experiment in the Piedmont forest of Georgia, has shown relatively low levels of sediment loss following clearcutting and double roller chopping (Hewlett 1979). Harvesting increased sediment production by 16 lb/acre-inch of stormflow over the control watershed; whereas, roller chopping increased sediment production by 94 lb/acre-inch of stormflow. Modeling for the thirty year cutting cycle, predicted the average annual sediment delivery to the channel under silvicultural practices, to be 157 lb/acre/year. This included the normal (geologic erosion) export rate of 82 lb/acre/year, but did not include sediment produced from road and channel damage (725 lb/acre/year). Ninety percent of all mass export from the basin during the thirty year rotation was attributed to roads and channel damage.

Nutrients

Undisturbed forested watersheds are a primary source of high quality water (Satterlund 1972). Mineral and organic nutrients enter the forest soil from rock and mineral decomposition, atmospheric input, and biological sources. Nutrient cycling within the forest is a continuous process of nutrient uptake from the soil by vegetation-temporary storage-decomposition and nutrient release. Loss of nutrients from the forest ecosystem results from erosion, leaching, and volatilization. The amount of nutrients leaving a watershed fluctuates constantly in response to natural stress; but is subject to additional losses resulting from timber harvesting and residue removal or treatment (Moore and Norris 1974).

The quantity of nutrients lost following harvesting and site preparation is a function of soils, geomorphology, vegetation, and climate characteristics, as well as the degree of disturbance. The removal of trees will trigger a number of significant reactions directly affecting the soil solution and rates of leaching. For example: 1) the forest will no longer be actively removing ions from the soil solution; 2) there will be an increase in soil surface temperature and moisture content, which influences the processes of decomposition, mineralization, and carbon dioxide production, and; 3) there will be a greater quantity of water passing through the soil because of decreased evapotranspiration and interception (Cole et al. 1975). If the increased amount of water available does not infiltrate the soil, then surface runoff and erosion are likely to occur. This runoff water may deliver an increased quantity of soluble nutrients to the stream along with any sediment associated nutrients. Recovery depends on revegetation, which reestablishes nutrient and soil water uptake and protection against surface runoff and erosion.

Schreiber et al. (1976) conducted a study to determine dissolved nutrient losses from forested watersheds in northern Mississippi. A replication of five watersheds (3.7 to 6.9 acres) were used on land previously eroded by agriculture and now stabilized with 32-year-old loblolly and slash pine. Nutrient concentrations in runoff exceeded rainfall concentrations for all nutrients except NO_3N (Table 5). However, a look at the annual import and export (lb/acre) of nutrients, shows a net gain for all nutrients except Mg. Generally, nutrient concentrations were not significantly correlated with storm runoff volumes, but nutrient losses were.

Table 5. The average dissolved nutrient concentrations for rainfall and runoff from five undisturbed watersheds in northern Mississippi for 1973 (Schreiber et al 1976).

	Rainfall (74.44 inches)		Runoff (15.26 inches)	
Nutrient	mg/l	lb/acre	mg/l	lb/acre
NO_3H	0.170	2.78	0.08	0.28
NH_4N	0.300	5.10	0.84	2.98
PO_4P	0.004	0.06	0.01	0.04
Ca	0.410	6.92	1.62	5.57
Mg	0.160	2.72	0.80	2.74
K	0.260	4.47	0.86	2.97

In a companion study (Duffy et al. 1978) on the same watersheds, the following year (1973), aqueous and sediment-phase phosphorus yields were analyzed. The mean concentration of total P for the year was 0.027 mg/l; of this, .006 mg/l were organic-P, .012 mg/l hydrolyzable-P, and .009 mg/l ortho-P. Sediment P concentrations varied significantly between the five watersheds. Sediment total P concentrations ranged from 192 to 779 μg/g for inorganic-P and 82 to 318 μg/g for organic-P. These levels were 2 to 8.9 times as high as found in the watershed soils. This was attributed to the selective erosion of fine sediments and/or deposition of coarse sediments in transport. For the year, 70 percent of the total P transported in stormflow was associated with the sediment. Thus, suggesting significant increases in P yields if forest management activities increase sediment losses.

A paired watershed study in West Virginia (Abertin and Patric 1974) compared the effects of clearcutting with an undisturbed forest. In the first year following the clearcut of the hardwood forest, nutrient losses were higher than on the undisturbed forest (Table 6). The higher loss of NO_3N from the clearcut watershed (2.59 lb/acre) compared to the control (0.53 lb/acre), is probably due to the flushing of nitrates from the soil during dormant season high flows. During the dormant season, decomposition of slash occurs at a greater rate than can be taken up by the existing vegetation. The maximum NO_3N concentration reached on the clearcut watershed was 1.32 mg/l, during a 2.5 inch rainfall event. Total P loss increased from .13 to .28 lb/acre following cutting. The authors concluded that both nitrogen and phosphorus concentrations increased irregularly and temporarily after clearcutting and that nutrient outflow decreased as vegetative regrowth occurred.

Table 6. First year nutrient losses from a clearcut and undisturbed forest in West Virginia (lb/acre) (Aubertin and Patric 1974).

Treatment	NO_3N	NH_4N	Total P	Ca	Mg	K
Clearcut	2.59	1.34	0.28	5.48	3.00	4.44
Undisturbed	0.53	0.75	0.03	3.90	2.17	2.79

Changes in nutrient concentrations following clearcutting and roller chopping in the Georgia Piedmont were studied by Hewlett (1979). Analysis of stormflow shows NO_3N levels increased only slightly following harvesting (.06 to .08 mg/l) and roller chopping (.12 to .14 mg/l) (Table 7). Total phosphorus did not show an increase until after site preparation. Values for K, Ca, and Mg were all higher following roller chopping.

Weekly samples of base flow from the control watershed had higher concentrations of NO_3N, total P, K, CA, and Mg than on the site prepared treatment. This was apparently due to natural variation between the watersheds. Total N averaged 3.0 mg/l on both watersheds and showed no difference after treatment, by season or between base flow and stormflow. Comparison of the nutrient losses in base flow during calibration and after roller chopping, showed only minimal differences.

Following planting, all elements except phosphorus, were similar to pretreatment levels, despite continued increases in water yield. Apparently, regrowing vegetation was effective in tieing up mobile ions.

Table 7. Mean concentration (mg/l) of stormflow waters following harvesting and roller chopping in Georgia (Hewlett 1979).

Treatment	NO_3N	Total P	K	Ca	Mg
Harvest					
Control	.06	.30	1.00	2.68	1.71
Treated	.08	.79	0.94	3.50	1.44
Roller Chopped					
Control	.12	.93	1.62	6.58	2.41
Treated	.14	.69	2.06	12.07	5.92

STUDY SITE

Before the actual selection process of the nine proposed watersheds began, certain criteria were established (Beasley et al. 1978) for the optimum requirements for each study site: 1) it is critical that each of the watersheds be located on soils with similar characteristics and ideally, all of the same soil series; 2) each of the proposed sites should have similar geomorphology, with slopes ranging from 8 to 20 percent. Slopes on the upper end of forestry conditions in Texas were chosen so that near maximum results could be monitored; 3) the size of each watershed should range from 5 to 10 acres. A size of greater than 5 acres is needed to allow normal harvesting and site preparation activities. Ten acres was set as a maximum size so that stream flow would not exceed the capacity of

3-foot H-flumes to be used in measuring water flow; 4) each site should be as near undisturbed as possible to permit preharvest monitoring of conditions. It is important that results are not biased by any previous, poorly conducted harvesting activities; 5) vegetation of the nine sites should be of similar composition, as this will affect both pre- and post-treatment results; 6) it is also necessary that the sites be located as near one another as possible. This reduces instrumentation, such as rain gaging equipment, and increases the likelihood that each drainage would be affected by the same storm event; 7) ease of access to each of the flume locations is also important, both for flume construction and servicing the watersheds. No attempt was made to lcoate the study sites with similar aspects, due to the difficulty of locating nine, otherwise suitable watersheds all oriented in the same direction. This is not expected to significantly influence the results of the study.

The area selected is located approximately 10 miles west of Alto (Figure 1). The nine watersheds are part of an 8,000-acre tract of Temple-Eastex land just east of the Neches River in southern Cherokee County. The nine ephemeral watersheds range in size from 6.37 to 6.78 acres and average 6.58 acres (Table 8, Appendix C).

Table 8. Acreage for each watershed.

Watershed Number	Acres
1	6.46
2	6.37
3	6.52
4	6.58
5	6.70
6	6.58
7	6.78
8	6.46
9	6.76
Mean	6.58

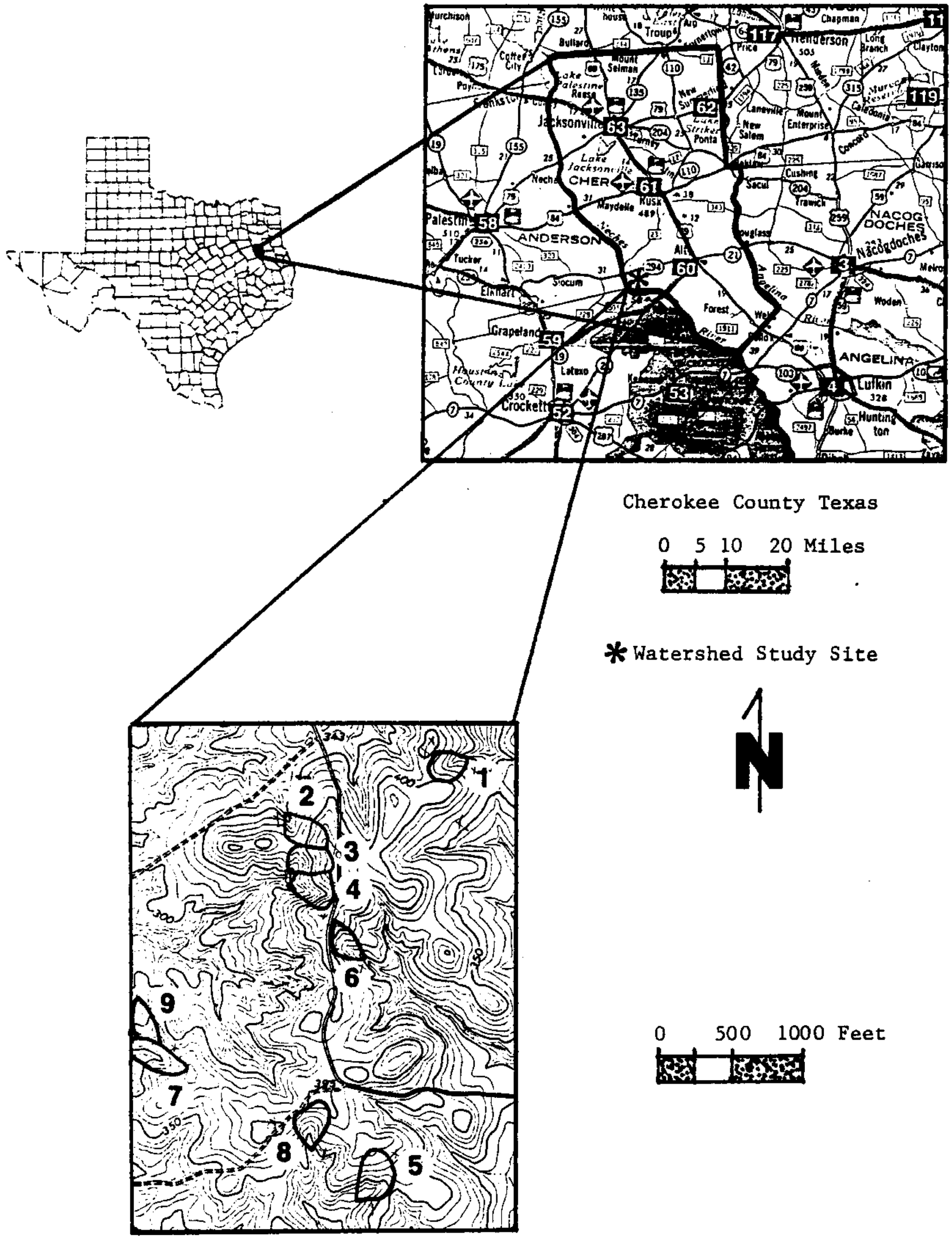


Figure 1. Study site location.

The area is characterized by rolling topography intersected with numerous drainages. Slopes range from 4% on the hilltops to as much as 25% for short distances on some of the side slopes near the stream channel. Vegetation is predominately the shortleaf pine-hardwood type (SAF forest cover type #80). The area has been managed under a selective cutting system with the last harvest occurring in 1972 for watersheds 1 and 6, and in 1971 for the others.

An attempt was made when selecting the watersheds to locate each on the same soil series. However, the extreme variability of soils in East Texas, particularly in the marine deposited upland areas, has made that requirement difficult to achieve. Seven different soil series are found among the nine watersheds (Table 9).

Table 9. Percent of watershed area by soil series.

Watershed Number	Briley	Cuthbert	Darco	Kirvin	Lilbert	Rentzel	Tenaha
1	-	41.5	0.9	8.2	36.5	1.9	10.8
2	-	77.1	-	13.3	-	1.3	-
3	5.7	47.4	-	2.6	14.4	0.5	29.4
4	-	74.6	-	5.2	2.0	0.9	17.2
5	-	63.9	-	11.7	12.7	2.8	8.7
6	-	88.7	-	4.0	4.6	0.7	1.9
7	-	47.6	-	17.9	30.4	3.7	0.4
8	-	65.7	-	6.5	18.9	3.2	5.5
9	-	73.9	-	5.5	1.5	0.6	18.5
Avg.	0.7	68.8	.11	8.9	10.1	1.8	9.7

The Cuthbert series is predominant and covers approximately 70% of the nine watersheds. This series is described as a fine sandy loam to 10 inches; overlaying a red clay B horizon to 40 inches. The C horizon is composed of stratified red sandstone and grey shale to 55 inches. These soils are well drained and are located on sloping to steep sides, with slopes usually greater than 8%.

The competing series to Cuthbert is the Kirvin series. Whereas, the solum thickness for Cuthbert ranges from 20 to 40 inches thick, the Kirvin series ranges from 40 to 60 inches and occurs on ridges with slopes of less than 8%.

Soils of the Lilbert series, are deep loamy fine sands with a yellowish sandy clay loam B horizon from 28 to 80 inches. It is located on ridge tops with slopes from 2 to 6%.

Similar to the Lilbert series, is the Briley series. It is also a loamy fine sand, but the sandy clay loam B horizon is located at 23 inches and is reddish in color. This series occurs on convex ridges with 2 to 5% slope.

The Tenaha series is one of the competing series to Lilbert and Briley. It is a deep loamy fine sand with the A horizon up to 40 inches thick. The B horizon is a reddish sandy clay loam overlaying a soft red sandstone. This series is located on the more steeply (3-15%) side slopes.

The Rentzel series is a deep loamy fine sand to 33 inches; overlaying a mottled brown and grey sandy clay loam B horizon to 80 inches. This soil is located along drainage ways, parallel to stream channels. The Darco series is a very deep loamy fine sand with an A horizon up to 52 inches thick. The B horizon is a yellowish-red sandy clay loam to 80 inches. This series is found along the ridge tops.

In summary, the Cuthbert and Kirvin series are similar in development, both having a shallow sandy loam surface horizon and a clayey B horizon. Kirvin dominates the upper slopes and Cuthbert the side slopes. The Lilbert, Briley and Darco series occur on the ridges, while Tenaha is found on the side slopes. All four of these series are deep loamy fine sands, with the clayey B horizon found much deeper than in Cuthbert and Kirvin. The loamy fine sand Rentzel series occurs along the stream channel.

All of these soil types are extensive throughout Texas and much of the Southern Coastal Plain. For this reason, results should have wide applicability for much of the forested areas of Texas and the South. A complete description of the soils is found in the Soil Survey prepared by the Soil Conservation Service (1980).

EXPERIMENTAL DESIGN

A replicated watershed approach, in randomized blocks, is being used to measure the effects of silvicultural practices on the quantity and quality of receiving waters. Three replications of three treatments (including the control) are used. Blocking of the watersheds into groups of three was based on several factors. Geomorphological considerations, such as shape, slope, and stream density were compared for similarities. Soil characteristics also played an important role in determining which watersheds to block.

Several formulas are available (Chow 1964) for numerical comparison of geomorphological characteristics (Table 10). Drainage density is used to measure the amount of stream channels per unit area. The larger the drainage density, the closer the stream channel spacing will be and possibly the greater susceptibility to erosion. The circularity ratio is a measure of shape, which expresses the departure from circularity of a watershed; a ratio of 1 indicates a circular basin. Long, narrow watersheds have high sediment yield, but low runoff; whereas, circular watersheds have high runoff and low sediment yield. Stream slope measures the amount of fall in elevation in relation to the length of the stream channel. The relief ratio is a measure of the overall steepness of a drainage basin and is an indicator of the intensity of erosion processes operating on the slopes of the basin.

Variation among these geomorphic measures proved to be relatively small. However, an attempt was made to group the watersheds according to similar traits.

Table 10. Geomorphic variables considered in blocking the experimental watersheds (Chow 1964).

Watershed Number	Drainage Density (Dd)[1]	Circularity Ratio (Rc)[2]	Stream Slope (Ss)[3]	Relief Ratio (Rr)[4]
1	8.35	0.89	783	0.110
2	8.56	0.74	1126	0.174
3	15.77	0.85	1185	0.131
4	11.14	0.82	846	0.134
5	10.41	0.81	894	0.123
6	9.49	0.78	841	0.103
7	10.55	0.72	582	0.077
8	11.54	0.88	945	0.108
9	10.31	0.88	725	0.126
Mean ($\overline{X}$)	10.68	0.818	880.78	0.121
Std. dev. (S)	2.19	0.063	188.04	0.0266

[1]Drainage density, (Dd) = L/A

[2]Circularity ratio, (Rc) = $\dfrac{A}{\left(\dfrac{P}{2\sqrt{\pi}}\right)^2}$

[3]Stream slope, (Ss) = R/SL

[4]Relief ratio, (Rr) = R/SL^1

L = length of all storm segments (mi)
A = area of watershed $(mi)^2$
P = perimeter of watershed (mi)
SL = stream length, main channel (mi)
SL^1 = straight line, main channel stream length, mouth to divide (ft)
R = total fall (ft)

Soil factors were also considered in the blocking process. Although Cuthbert was the dominant series among all watersheds, sites with similar soil types were grouped together. Soil factors received weighted consideration over geomorphic factors when watershed blocking was determined. Although the nine watersheds are quite similar to one another, blocking should allow more comparable responses.

Random selection was used to determine watershed treatment for each block (Table 11). Prior to treatment, storm events were monitored on the nine watersheds for six months. This was to assess both the natural variability in water yield and water quality among the watersheds, and to collect pre-treatment information on the undisturbed forest.

Table 11. Watershed treatment and blocks.

Treatment	Block 1	Block 2	Block 3
Control	4	8	6
Shear/windrow	3	1	2
Chop	7	5	9

TREATMENTS

Harvest

Clearcut harvesting of the six watersheds to be treated, began in June 1980. All merchantable pine sawlogs and pulpwood were removed in tree lengths. Normal hand felling techniques were used. Where possible, trees were felled parallel to the skidding direction, with log butts toward the landing. Care was taken not to fell trees into or across stream channels. All trees were limbed in place before skidding.

Skidding was performed by a single rubber-tired skidder. Skid trails were located along contours, where possible, to minimize steep gradients and to keep soil displacement to a minimum. The watershed's drainage characteristics allowed each side of the main stream channel to be logged separately, so that the skidder would not have to cross the stream channel.

Trees were skidded to landings located outside the watershed boundary. The influence of a landing on such a small watershed would mask results obtained from harvesting and site preparation activities. Logs were then loaded on a truck and removed. No logging haul roads were located within the watershed boundary.

A buffer strip of undisturbed vegetation was left along all major stream channels, with only merchantable pines removed from these areas. Hardwood trees, shrubs, and herbaceous vegetation within this zone, were left to protect the integrity of the stream channel. All heavy equipment was kept out of the buffer strip. The width of the buffer strip varied from 20 to 60 feet, depending on slope and channel size.

Merchantable trees unsuitable for tree length removal (generally low grade hardwoods and small pines) were removed by several pulpwood trucks. All six watersheds received essentially the same treatment during harvesting, which was completed in October 1980.

Site Preparation

Variation in treatment began with site preparation, in November 1980. Three of the designated watersheds were treated by shearing all remaining vegetation with a D-8 dozer equipped with a V-blade. Slash and debris were then raked into windrows with D-6 and D-8 dozers using a brush rake. Windrows were located along the contours to help bar excessive erosion along the slopes. Windrows were later burned in January 1981. The remaining three treatment watersheds were roller chopped following clearcutting, with a D-8 dozer pulling a single drum chopper. A broadcast burn was used to reduce slash in February 1981. All sites were handplanted in February 1981 with 1-0 improved loblolly pine seedlings.

MEASUREMENT AND ANALYSIS

The following measurements are made on each watershed:

Water

Precipitation

Precipitation amounts are measured in Forest Service type raingages located in a network on each site to provide a minimum of two gages for every watershed. Timing and intensity is obtained from two recording raingages (Belfort weighing bucket type).

Water Yield

Timing, rates, and volumes of runoff are measured with 3-foot H-flumes equipped with FW-1 type water level recorders. Approach sections to the flume are 12-feet long. Output will include runoff volumes in cubic feet and area inches, flow duration, peak discharges, and timing of flow.

Water Sample and Bedload Collection

Suspended sediment and water quality samples are collected at each flume with a Coshocton wheel sampler coupled to a splitter. The wheel samplers are set below the lips of the flumes so as to just miss the small prolonged flows that often occur on small watersheds during the wet season or after large storms. Such flows are usually low in sediment; their inclusion would only dilute the sample and bias the results. Low flows are manually sampled periodically and their sediment and nutrient concentrations measured to see if results are biased by disregarding low flows. Water collected by the wheel sampler (about 0.5% of total flow) is further divided by 10 as it flows through the splitter constructed from 4-inch PVC water pipe. The sample is collected in a chemically inert container. Volume of sampled water is measured and collected for laboratory analysis the day following the runoff event.

Single stage non-proportional samplers are installed in the side walls of the flumes (at 6, 12, 18, and 24 inches) to provide data on stage-concentration relationships for sediment and nutrients. The devices, which sample the rising limb, will also serve as insurance against malfunctions in the wheel samplers and splitters.

Watersheds 2, 6, and 9 are equipped with Isco water pump samplers. Water samples are automatically collected at a predetermined time sequence by a floating intake nozzle in the approach section of the flume. This provides data on sediment and nutrient concentrations at discrete time intervals throughout the storm hydrograph.

Bedload is collected in a 32" x 68" x 9" concrete drop box located at the front of the approach section to the flume. The volume of bedload deposited is determined after each storm and subsamples are collected for analysis.

Sediment

Suspended sediment is determined by vacuum filtering a liter sample through 0.45 micron Millipore filters, then oven drying and weighing. Sediment is expressed in terms of parts per million (ppm).

Bedload samples are dried and weighed to determine the bedload loss. Analysis is also made to determine the aggregate stability, texture, and nutrient content.

Turbidity

Turbidity of each sample is measured with a Hach Model No. 2424 Nephelometer. Turbidity measurements are important because many state water quality standards applicable to non-point source pollution are specified in terms of turbidity. Although efforts to correlate turbidity with sediment concentrations have generally been unsuccessful, an attempt will be made to develop local relationships between the two parameters.

Water Chemistry

Water samples are analyzed for organic nitrogen, ammonia, nitrite and nitrate nitrogen; ortho, poly, and total phosphate; potassium, calcium, magnesium, conductivity and pH. Nitrogen and phosphorus concentrations are analyzed with Instrument Laboratory's 457 Auto-absorption spectrophotometer. Conductivity and pH are determined in the field with Hach portable meters.

Vegetation and Surface Condition

The following methodologies are used to sample vegetation and surface cover.

Overstory and Intermediate Vegetation

A minimum 10 percent inventory was made of the dominant and codominant trees and woody stems greater than 1 inch dbh by using one-tenth acre circular plots. Data recorded includes dbh, height, and species. Volume and stand density is computed from the data.

Understory

Permanent milacre plots have been established to measure pretreatment understory vegetation and to evaluate the development of woody plants after treatment. Species and heights of the dominant understory plants are measured. Total area of sample plots is approximately one percent of the watershed area.

Ground Surface Condition

Surface cover or condition is measured by point sampling at 20 cm intervals on 20 meter transects. Sampling intensities are adjusted to provide standard errors of no more than ± 20 percent for the major cover criteria. The surface condition is sampled for vegetation, litter, slash, rock, and mineral soil. The presence of erosion is recorded as sheet, rill or deposition. This survey is made prior to treatment, after site preparation and planting, and then each fall thereafter.

Litter

Litter weight and depth are determined from samples collected in .25 square meter plots located a pre-determined distance from the permanent milacre plots. Sampling intensity is such as to provide for a precision of ± 10 percent of litter dry weight.

Soil Properties

Soil Bulk Density, Texture, Moisture, and Organic Matter

Bulk density determinations of the 0 to 3 inch depth zone using a core sampler were made at approximately 20 locations in each watershed prior to treatment. Sampling of each watershed is repeated in the spring (the season when soil moisture conditions are conducive to sampling) of each year, beginning the spring after logging and site preparation. The samples are taken to the lab and oven-dried at 220°F for dry weight determinations. An additional sample from the 0 to 3 inch depth is collected for texture analysis by the hydrometer method and organic matter determination by the Walkley Black (1934) method.

Soil moisture in the primary rooting zone is an important factor for many streamflow models. Bi-monthly measurements are made on each of the watersheds by the use of a neutron soil probe. Six to eight neutron probe access tubes are located on each watershed, with soil moisture readings taken at 6, 16, 28, 39, and 51 inches.

RESULTS AND DISCUSSION

Watershed Condition

Pretreatment - 1980

An inventory of the vegetation prior to treatment was conducted in June 1980, according to the procedures outlined in the section on Measurement and Analysis. Pine volumes on the nine watersheds ranged from 2,061 to 4,573 bd. ft./acre for sawlogs and from 17 to 43 cords/acre for pulpwood (Table 12). Hardwood sawlogs and pulpwood were relatively sparse and volumes averaged only 300 bd. ft./acre and 14 cords/acre on the watersheds. The number of stems in the 1"-5" dbh category, were uniform among the watersheds and averaged 289 stems/acre.

Woody stems less than one inch in diameter are listed in Table 13. Pine numbers varied from 1,410 stems/acre on watershed 3 to 20,440 stems/acre on watershed 5. There was no appreciable difference in the number of hardwoods, shrubs or vines among the watersheds.

Litter, humus, and slash covered an average of 94.5% of the nine watersheds (Table 14). Average vegetative cover of the watershed surface was 1.6%. Thus, 96.1% of the watershed's surface were covered with a protective layer of vegetation or litter.

Mineral soil was exposed on 3.3% of the watersheds. Rill and sheet erosion were evident on only .21% of the mineral soil, hence, the remaining mineral soil was in a stable condition.

Herbaceous biomass was very low on all watersheds because of the dense canopy cover (Table 15). Above ground plant production ranged from 2.4 lb/acre on watershed 7 to 39.6 lb/acre on watershed 5. Litter accumulation on the watersheds averaged 2273.7 lb/acre with an average depth of 1.7 inches.

Table 12. Tree volumes and stems/acre, June 1980.

Watershed No.	Pine		Hardwood		Stems (dbh 1"-5")/Acre					
	Sawlogs bd.ft./acre	Pulpwood cords/acre	Sawlogs bd.ft./acre	Pulpwood cords/acre	Pine	Oaks	Hickory	Sweetgum	Others	Total
1	4,494	23	341	13	122	121	24	54	58	330
2	4,573	43	107	7	76	123	17	68	49	333
3	4,092	28	232	13	70	165	34	35	45	349
4	2,789	26	80	16	36	119	37	14	16	222
5	2,673	19	137	12	29	51	21	25	24	100
6	2,061	17	596	19	94	84	23	59	57	317
7	4,386	41	789	17	91	177	10	29	57	364
8	3,373	37	-0-	7	79	141	26	31	21	298
9	4,208	40	421	19	89	88	25	35	52	289
Average	3,628	30	300	14	76	119	24	39	42	289

Table 13. Pre-treatment understory vegetation (stems <1" dbh/acre), June 1980.

	Watershed No. 1	2	3	4	5	6	7	8	9	Avg.
Pine										
Loblolly & Shortleaf	8,260	4,110	1,410	2,960	20,440	1,460	7,180	7,980	9,480	7,031
Hardwoods										
Oak	4,470	3,870	2,910	5,700	3,240	2,830	2,790	4,820	2,390	3,172
Elm	1,200	360	130	130	710	1,250	60	80	430	483
Dogwood	1,040	90	680	1,110	170	710	1,060	640	1,140	738
Sweetgum	260	730	780	1,770	1,460	1,480	1,590	1,320	630	1,113
Other	2,490	1,400	1,850	2,050	1,590	1,520	2,740	1,900	1,430	1,886
TOTAL	9,460	6,450	6,350	10,760	7,170	7,790	8,240	8,760	6,020	7,392
Shrubs										
American Beautyberry	1,230	2,980	1,740	1,520	1,980	1,310	2,040	1,500	700	1,667
Blackberry	1,720	2,250	2,310	3,000	1,070	3,040	790	1,820	1,380	1,931
South Waxmyrtle	300	160	2,240	2,050	620	420	2,130	1,540	860	1,147
Other	1,860	480	700	440	1,160	850	470	220	1,160	816
TOTAL	5,110	5,870	6,990	7,010	4,830	5,620	5,430	5,080	4,100	5,561
Vines										
Virginia Creeper	3,320	1,200	4,040	2,680	2,140	1,300	4,530	1,760	2,300	2,586
Greenbriar	3,140	2,850	1,350	1,610	2,540	3,420	2,660	4,040	1,340	2,550
Poison Ivy	1,420	2,980	1,220	1,380	2,860	440	1,530	8,440	2,110	2,487
Other	3,680	5,600	1,220	3,710	3,730	1,850	2,340	1,600	2,070	2,867
TOTAL	11,560	12,630	7,830	9,380	11,270	7,010	11,060	15,840	7,820	10,490

Table 14. Pre-treatment ground surface condition (percent), June 1980.

	Watershed No.									
	1	2	3	4	5	6	7	8	9	Avg.
Surface Condition										
Litter or Humus	88.6	89.5	88.9	89.8	83.6	91.7	90.2	87.8	86.4	88.5
Slash	6.7	4.3	6.3	5.6	5.8	3.3	6.8	7.2	8.4	6.0
Rock	0.4	-0-	0.1	-0-	3.1	0.1	0.3	0.3	0.4	0.5
Mineral Soil	2.9	3.9	3.4	2.6	5.8	3.4	1.5	3.7	2.3	3.3
Erosion										
Rill	--	1.3	0.1	0.1	--	--	--	--	--	0.2
Sheet	--	--	--	--	0.5	--	--	--	--	0.01
Deposition	--	--	--	--	--	--	--	--	--	--
Tree	0.5	0.4	0.5	0.8	0.5	0.3	0.4	0.4	0.8	0.5
Shrub	0.1	0.5	0.1	0.3	0.1	0.2	0.2	0.2	0.4	0.2
Grass	0.7	0.8	0.7	0.7	1.1	0.8	0.3	0.3	1.0	0.7
Forb	-0-	0.4	-0-	0.2	-0-	0.2	-0-	0.1	0.2	0.1
Moss	0.1	0.2	-0-	-0-	-0-	0.1	0.3	-0-	0.1	0.1

Table 15. Pre-treatment herbaceous biomass and litter accumulation (lb/acre), June 1980.

	Watershed No.									
	1	2	3	4	5	6	7	8	9	Avg.
Grass	17.5	9.6	11.7	25.0	30.4	10.4	2.4	24.4	5.7	15.2
Grasslike	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	0.9
Forb	3.0	3.1	0.4	4.9	9.2	2.0	0.0	1.5	1.2	2.8
Litter	2270.4	2264.9	2675.6	2039.7	1549.8	1621.9	3475.5	2412.0	2153.7	2273.7
Litter depth (in)	1.2	2.0	1.6	1.6	1.6	1.6	2.0	2.0	2.0	1.7

Soil samples were collected from each of the watersheds at the same time as the vegetation inventory. Results of the textural analysis support the soil series classification made by the USDA Soil Conservation Service (1980). The Cuthbert and Kirvin series both have sandy loam surface horizons and the Lilbert, Tenaha, and Rentzel series have loamy sand surface horizons (Table 16). No samples were collected from the Briley and Darco series because of the small area involved. Organic matter in the surface horizon ranged from 3 to 4.5%. Bulk density at a 0-3 in depth, averaged 1.10 g/cc for all soil series.

Table 16. Pre-treatment soil analysis, June 1980.

Soil Series	Texture Sand %	 Silt %	 Clay %	Class	Organic Matter %	Bulk Density gm/cc
Cuthbert	72	19	9	Sandy loam	3.9	1.09
Kirvin	72	18	10	Sandy loam	3.9	1.10
Lilbert	77	17	6	Loamy sand	3.3	1.10
Tenaha	81	12	7	Loamy sand	3.3	1.10
Rentzel	78	14	8	Loamy sand	3.8	1.10

Post-treatment

Immediately following harvesting and site preparation, Crawley (1982) made an in-depth study of site disturbance. He found clearcutting left 35% of the watersheds undisturbed, 17% in primary skid trails, and 24% in secondary skid trails, with 23% covered in slash. Mineral soil was exposed on 34% of the primary skid trails on on 5% of the secondary skid trails. Bulk density was significantly different between primary trails (1.16 g/cc), secondary trails (1.06 g/cc), and the undisturbed forest (.99 g/cc).

During June 1981, the vegetation survey was repeated on the treated watersheds, using the same plots and transect lines. Understory vegetation was reduced on all watersheds from the proceeding year. The chopped watersheds contained a larger number of pine, hardwood, and vine stems per acre than the sheared watersheds (Table 17). Pine densities on chopped watersheds were 25% higher and hardwoods 65% higher than the sheared watersheds. The average number of shrub stems on the sheared watersheds (4,908/acre) were slightly higher than on the chopped watersheds (4,440/acre).

The ground surface condition following site preparation was significantly different between the two treatments. Slash and litter cover averaged 34% on the sheared watersheds and 79% on the chopped watersheds (Table 18). Mineral soil exposure was 3.5 times greater on the sheared watersheds (57% on the sheared and 16% on the chopped). Evidence of active erosion was found on 83% of the exposed mineral soil and 47% of the entire watershed on the sheared watersheds. In comparison, 35% of the exposed mineral soil on the chopped watersheds showed evidence of erosion and only 5.6% of the total area was in some stage of erosion. Vegetative cover averaged about 4% of the surface area on both of the treatments. The bulk density of the sheared watersheds (1.11 g/cc) were significantly higher than the roller chopped (.95 g/cc), and the undisturbed forest (.92 g/cc).

Above ground herbaceous production for the treated watersheds did not differ substantially. Grass production on both treatments averaged about 42 lb/acre (Table 19). The largest difference was in forb production; the sheared watersheds produced an average of 65.5 lb/acre and the chopped watersheds 41.8 lb/acre. Litter accumulation was 4 times greater on the chopped watersheds (841.5 lb/acre) than on the sheared watersheds (213.0 lb/acre).

Table 17. Post-treatment understory vegetation (stems <1" dbh/acre), June 1981.

	Shear and Windrow				Roller Chop			
	Watershed No.							
	1	2	3	Avg.	5	7	9	Avg.
Pine								
Loblolly & Shortleaf	444	654	500	533	685	813	500	666
Hardwoods								
Oak	1,460	981	1,922	1,454	1,981	1,781	904	1,555
Elm	333	115	-0-	149	55	47	135	79
Dogwood	508	288	229	342	815	563	538	639
Sweetgum	32	-0-	167	66	296	203	269	256
Hickory	143	192	83	139	296	109	38	148
Other	2,270	1,788	1,542	1,867	1,944	7,922	1,981	3,949
TOTAL	4,746	3,364	3,945	4,017	5,387	10,625	3,865	6,626
Shrubs								
American Beautyberry	2,508	3,250	1,521	2,426	2,759	3,140	1,500	2,466
Blackberry	1,413	1,711	2,021	1,715	333	1,234	1,654	1,074
South Waxmyrtle	32	-0-	1,208	413	19	1,266	404	563
Other	603	250	208	354	667	172	173	337
TOTAL	4,556	5,211	4,958	4,908	3,778	5,812	3,731	4,440
Vines								
Virginia Creeper	95	634	1,729	819	1,055	1,797	1,673	1,508
Greenbriar	1,270	846	333	816	1,963	1,313	1,019	1,432
Poison Ivy	32	731	250	338	926	547	654	709
Other	1,317	865	708	963	1,222	1,906	1,712	1,613
TOTAL	2,714	3,076	3,020	2,936	5,166	5,563	5,058	5,262

Table 18. Post-treatment ground surface condition (percent), June 1981.

	Shear and Windrow				Roller Chop			
	Watershed No.							
	1	2	3	Avg.	5	7	9	Avg.
Surface Condition								
Litter or Humus	21.3	26.4	29.3	25.7	60.4	56.4	53.7	56.8
Slash	6.3	7.5	9.3	8.7	15.5	21.1	30.8	22.5
Rock	0.5	1.7	0.7	2.0	5.9	1.1	0.0	2.3
Mineral Soil	65.3	59.7	48.5	56.8	15.2	17.3	14.5	15.7
Erosion								
Rill	0.0	1.0	1.5	0.8	0.0	0.1	0.1	0.07
Sheet	15.1	25.8	19.6	20.2	2.4	0.9	0.8	1.4
Deposition	26.5	23.3	29.2	26.3	5.7	4.3	2.4	4.1
Tree	0.1	0.0	0.0	0.03	0.1	0.3	0.2	0.2
Shrub	0.1	0.2	0.1	0.1	0.1	0.2	0.1	0.1
Grass	2.9	1.7	1.5	2.0	1.2	2.1	3.0	2.1
Grasslike	0.9	0.1	0.5	0.5	0.1	0.3	0.4	0.3
Forb	1.7	1.3	2.2	1.7	1.1	0.8	2.4	1.4
Moss	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.03

Table 19. Post-treatment herbaceous biomass and litter accumulation (lb/acre), June 1981.

	Shear and Windrow				Roller Chop			
	Watershed No.							
	1	2	3	Avg.	5	7	9	Avg.
Grass	44.1	33.6	50.2	42.4	45.3	39.0	40.1	41.5
Grasslike	2.2	10.1	8.4	6.9	1.2	3.7	11.8	5.6
Forb	75.7	72.4	48.3	65.5	61.4	27.9	36.1	41.8
Litter	167.0	46.7	425.3	213.0	1004.3	704.8	815.5	841.5

Precipitation and Runoff

Precipitation during the pretreatment year (1980) was 31.15 inches, which is about 14 inches below normal (Table 20). Two-thirds of the precipitation fell between January and May. Precipitation for the first 8 months of 1981 (33.29 inches) was greater than the 1980 total. An exceptionally wet May and June account for almost half of the 1981 precipitation.

Runoff from these small watersheds is dependent on several factors: 1) rainfall amount - obviously, the input of water is important to the volume of runoff; however, the amount of rainfall necessary to initiate runoff varies with; 2) rainfall intensity - storms of high intensity, especially falling on saturated and/or disturbed soils will show an increase in runoff; 3) antecedent moisture - the time since the last rain and the soil moisture level will significantly influence runoff; and 4) watershed condition - the size, shape, slope, vegetation, ground cover, and soil type all modify the amount of runoff. As treatments were applied, changes in the vegetation, ground cover, and soil structure were reflected in the quantity and quality of runoff water.

Table 20. Precipitation record (inches), from January 1980 to August 1981.*

1980					1981			
Date		Rainfall	Total	Normal	Date		Rainfall	Total
January	3	.02			January	6	.79	
	10	.03				8	.29	
	16	.61				19–20	1.31	
	20	1.03				31	.36	2.75
	21	1.93						
	28–30	.56	4.18	3.54				
February	3	.06			February	2–4	.83	
	5	.05				9–10	1.50	
	8	1.52				21	.60	
	9	.56				28	.92	3.97
	29	.60	2.79	3.36				
March	15–17	.69			March	3	1.99	
	19–20	.40				7	.42	
	23	.21				13	.24	
	25	.09				29	1.02	3.67
	27	1.20						
	29	.02	2.61	3.26				
April	11	.82			April	4	.22	
	13	1.87				14	.07	
	25	1.14	3.83	4.70		23	1.28	1.57
May	1	.04			May	3	.35	
	2	.23				4	.73	
	3	.03				9	2.94	
	9	.17				13	.23	
	12	1.23				15	1.06	
	13	1.15				24	1.02	
	14	.48				26	.05	
	15	3.20				30	2.17	8.55
	16	.08						
	19	.39	7.00	4.42				
June	20	.64	.64		June	2	.80	
						3	1.10	
						4–5	2.03	
						10	.53	
						11	.28	
						12	1.19	
						14	.02	
						15	.02	
						16	.44	
						23	.83	
				3.41		25	.07	7.31
July	21	.82			July	2	.24	
	27–28	.71	1.53			5	1.18	
						7	1.82	
						8	.41	
						11	.22	
				2.67		26	.62	4.49
August	15	.11			August	16	.05	
	27	.06				18	.05	
	29	.12	.29			27	.30	
				2.55		30–31	.58	.98
September	6	.46						
	8	.15						
	18	.93						
	25	.23						
	28	.10						
	29	.50	2.37	3.76				
October	17	.20						
	18	.13						
	27–28	.78	1.11	2.88				
November	16	2.69						
	23	.68						
	25	.72	4.09	3.53				
December	7	.10						
	8	.61	.71	3.95				
TOTAL			31.15	42.03	TOTAL (Jan.Aug.)			33.29

*Rainfall amounts are reported as an average from all watersheds.

Pretreatment - 1980

During the pretreatment year (1980), there were nine storms of sufficient size to produce measurable runoff (Table 21). All runoff events occurred between January and May (Fig. 2) and only the January 21, Februry 9, and May 15 storms generated runoff from all nine watersheds. Base flow was absent, except for one or two days, following a major storm. Total runoff for the year ranged from .84 inches on WS 3 to 2.32 inches on WS 9 and averaged 1.44 inches for all nine watersheds. Runoff as a percent of precipitation, averaged 8% for the nine watersheds. A single storm on May 15 produced 72% of the total runoff for the year. A maximum peak discharge rate of 13.7 cfs was reached on WS 9 during the May 15 storm. The next highest disharge rate was .48 cfs on the same watershed during the January 21 storm.

Hydrographs for the major runoff events are found in Appendix B. These events are reported by blocks for each storm. The x-axis on the graph is time in hours. The left, y-axis, is the rate of runoff in inches per hour and the right y-axis is precipitation intensity in inches per hour. When comparing runoff events, note that the scales for the y-axis vary with each storm.

On January 20, 1980 a 1.3 inch rainfall event produced the first measurable stormflow (Table 21). Only WS 2 responded to this storm, with a stormflow of .015 inches. Not until the next day, was there a sufficient amount of rainfall to produce runoff from all watersheds. Rainfall on January 21 totaled 1.93 inches, with a maximum intensity of .46 inches per hour (Appendix B). Because of the previous days rain, soil antecedent moisture was high. Runoff began about five hours after the rain started for blocks 1 and 3 and about eight hours after for block 2.

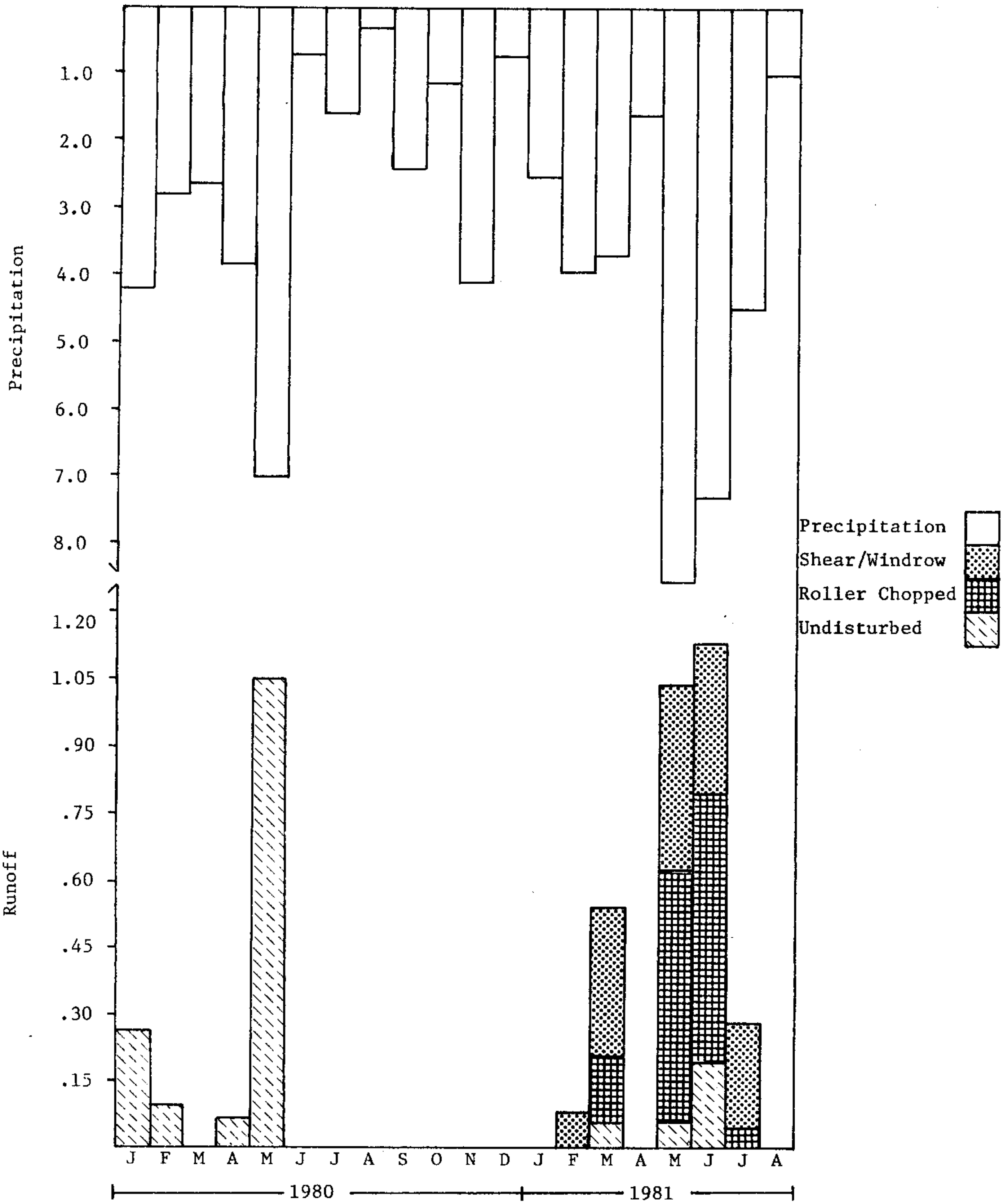
Runoff from the January 21 storm averaged .17, .13, and .46 inches for blocks 1, 2, and 3, respectively. This general pattern of response, by the three blocks, was followed for the remaining 1980 storms. Block 3 watersheds

Table 21. Precipitation, runoff, and peak discharge by watershed, for storms producing runoff prior to treatment, 1980.

Storm Date	Watershed No.	Precipitation	Runoff	Runoff as a Percentage of Precipitation*	Peak Rate of Discharge
		area inches		%	cfs
1/20/80	2	1.13	0.015	1	0.01
1/21/80	1	1.79	0.121	7	0.17
	2	1.81	0.429	24	0.44
	3	1.85	0.115	6	0.12
	4	1.91	0.128	7	0.15
	5	2.03	0.175	9	0.16
	6	1.97	0.408	21	0.46
	7	1.99	0.252	13	0.22
	8	2.00	0.089	4	0.15
	9	1.95	0.554	28	0.48
2/8/80	1	1.56	0.025	2	0.08
	2	1.51	0.081	1	0.15
	3	1.54	0.021	1	0.03
	4	1.55	0.017	1	0.03
	5	1.51	0.004	<1	0.02
	6	1.54	0.091	6	0.16
	7	1.51	0.044	3	0.06
	9	1.48	0.105	7	0.16
2/9/80	1	.58	0.026	-	0.07
	2	.56	0.088	-	0.17
	3	.57	0.021	-	0.03
	4	.57	0.017	-	0.03
	5	.56	0.031	-	0.05
	6	.57	0.084	-	0.17
	7	.56	0.048	-	0.07
	8	.54	0.006	-	0.02
	9	.55	0.113	-	0.18
3/27/80	2	1.21	0.005	<1	0.01
	6	1.20	0.004	<1	0.01
	9	1.20	0.004	<1	0.01
4/13/80	1	1.79	0.030	2	0.06
	2	1.90	0.157	8	0.31
	3	1.88	0.025	1	0.03
	4	1.88	0.021	1	0.05
	6	1.86	0.091	5	0.17
	7	1.89	0.055	3	0.08
	9	1.86	0.096	5	0.15
5/13/80	2	1.31	0.043	3	0.21
	3	1.26	0.005	<1	0.02
	4	1.21	0.001	<1	0.01
	6	1.09	0.006	<1	0.02
	9	1.27	0.013	1	0.06
5/14/80	2	.46	0.012	-	0.03
	3	.45	0.001	-	0.01
	6	.48	0.002	-	0.01
	7	.47	0.001	-	0.01
	9	.47	0.005	-	0.01
5/15/80	1	3.01	0.751	25	7.06
	2	3.08	1.235	40	8.98
	3	3.03	0.654	22	5.76
	4	3.10	0.792	26	6.11
	5	3.45	1.192	35	6.87
	6	3.23	1.341	42	11.20
	7	3.15	0.953	30	10.05
	8	3.42	0.913	27	8.98
	9	3.18	1.433	45	13.70
1980	1		0.953	6	1.84
	2		2.050	9	1.65
	3		0.842	5	1.19
	4		0.976	6	1.27
	5		1.402	7	2.35
	6		2.027	12	2.00
	7		1.353	8	2.60
	8		1.008	5	4.57
	9		2.323	14	2.43
Average			1.437	8	2.21

*Calculated for storms with greater than one inch of precipitation.

Figure 2. Precipitation and runoff (inches) for 1980-81, by treatment.



usually have the fastest response time and the greatest volume of runoff, with blocks 1 and 2 following, respectively. Watersheds 5 and 8 in block 2 are usually the least response to precipitation input, especially when soil moisture is low. The reason for this is uncertain, however, several factors could contribute to this delayed response and relatively low volume of runoff. Both watersheds contain about 25 percent sandy soils, which tend to retard runoff. The geology of the particular watersheds may also influence response by routing subsurface water flow to deeper drainage or allowing substantial detention storage of soil water. In the case of WS 5, there is a large percentage of stones in the surface horizon, which generally provide macropores for rapid infiltration of rainfall. However, soil storage is reduced in volume and with high soil antecedent moisture, the likelihood of runoff is increased. This is evident from the storm on May 15, in which WS 5 reported a volume of runoff similar to the watersheds in the more responsive block 3.

As mentioned earlier, the nine watersheds are divided into blocks of three, according to similarities. Analysis of the hydrographs (Appendix B) support this classification, as responses and volumes are very similar within each block.

On February 8, a 1.52 inch rainfall event generated stormflow from all watersheds except WS 8. Volume of runoff was low from all drainages with the lowest (WS 5) producing only .004 inches and the highest (WS 9) .105 inches of stormflow. Again, block 3 showed the greatest response to precipitation. The next day, February 9, a .56 inch rain generated runoff from all watersheds. This storm, although appreciably less in total rainfall, had higher intensities than the February 8 storm (Appendix B). This plus the high antecedent moisture and did not generate stormflow from block 1 and 2 watersheds.

On April 13, an intermittent storm with a maximum intensity of 2 inches per hour, produced runoff from all watersheds except 5 and 8 (Table 21). Maximum stormflow for the 1.87 inch rainfall event was from WS 2.

A series of storms beginning on May 12 produced several runoff events. A 1.23 inch rainfall event on May 12 failed to generate stormflow from any watershed, however, a May 13 storm of 1.15 inches generated stormflow from watersheds 2, 3, 4, 6 and 9. The volume of runoff from this storm was less than .014 inches. A third storm occurred the following day, May 14, although precipitation was only .48 inches, it produced a measurable volume of runoff from watersheds 2, 3, 6, 7 and 9.

On May 15, after three consecutive days of rain (2.86 inches total), a 3.20 inch rainfall event occurred. Soil antecedent moisture was high and a large volume of stormflow was recorded on all watersheds. Runoff volumes ranged respectively from .65 inches to 1.43 inches for watersheds 3 and 9 (Table 21). Runoff as a percent of precipitation was 22 and 45 percent for the same two watersheds. Maximum rainfall intensity for the storm was 2.10 inches per hour. Note on the hydrograph (Appendix B) that the runoff scale for this storm is 25 times greater and the precipitation scale is 50 times greater than for the next largest runoff event on January 21, 1980.

The combination of a high intensity and relatively large rainfall event on an already saturated soil, produced the large runoff volumes and sharp peak discharge rates. Evidence of overland flow was observed during this storm and is supported by the rapid response and the volume of discharge shown on the hydrograph.

Posttreatment - 1981

During the first eight months following treatment (January-August, 1981), 44 storms produced 23 runoff events. Runoff was generated from all watersheds during 5 events and was exclusive on the sheared and windrowed watersheds for

13 of the events. All runoff occurred between February and July, with the greatest stormflow during May and June (Fig. 2). Sheared and windrowed watersheds produced the largest volume of runoff (3.06 inches) for the 8-month period, followed by the roller chopped (1.65 inches) and then the undisturbed control (.30 inches) watersheds (Table 22). Runoff volumes for the year were significantly different between all three treatments ($P<.05$). Runoff as a percent of precipitation averaged respectively, 14, 7 and 2 percent for the sheared and windrowed, chopped, and undisturbed watersheds. A maximum peak discharge rate of 6.96 cfs was reached on the sheared WS 2, during the March 3 runoff event. This is 50% lower than the maximum peak rate reached during the May 15, 1980 storm prior to treatment. Precipitation and runoff for the year, by watershed and storm, is summarized in Table 22, with the accompanying hydrographs found in Appendix B.

The winter and early spring of 1981 was unusually dry. During January, 2.75 inches of rain fell with no runoff occurring. Rainfall for February was 3.97 inches which produced only minor amounts of runoff from the sheared watersheds and from one of the control watersheds.

On March 1, a 0.92 inch rainfall event produced from the sheared watersheds, 0.015 inches of runoff. Two days later on March 3, a 1.99 inch rainfall generated runoff from all 9 watersheds. Runoff from the sheared watersheds averaged 0.51 inches, as compared to 0.21 inches from the chopped, and 0.05 inches from the control watersheds. This storm also produced the highest rate of discharge (6.96 cfs on WS 2) for the year. Two small runoff events were recorded on the sheared watersheds on March 7 and 29.

April, which is normally the wettest month of the year, had a total rainfall of only 1.57 inches. Only a trace amount of runoff was recorded on WS 3 (sheared), following a 1.28 inch rainfall event.

Table 22. Precipitation, runoff and peak discharge by watershed, for storms producing runoff after treatment, 1981.

Storm Date	Watershed No.	Precipitation	Runoff	Runoff as a Percentage of Precipitation*	Peak Rate of Discharge
		area inches		%	cfs
2/5/81	3	.83	0.016	-	0.04
2/10/81	1	1.46	0.027	2	0.03
	2	1.43	0.132	9	0.72
	3	1.49	0.035	2	0.16
	6	1.58	0.003	< 1	0.01
3/1/81	1	1.00	0.006	-	0.09
	2	.92	0.028	-	0.17
	3	.95	0.011	-	0.06
3/3/81	1	1.99	0.364	18	3.53
	2	2.05	0.754	37	6.96
	3	2.02	0.406	20	3.94
	4	2.02	0.021	1	0.08
	5	1.93	0.152	8	0.22
	6	2.00	0.137	7	0.57
	7	1.97	0.166	8	0.75
	8	1.96	0.005	< 1	0.23
	9	1.98	0.301	15	1.56
3/7/81	2	.42	0.002	-	0.02
	3	.42	0.004	-	0.01
3/29/81	1	1.00	0.006	< 1	0.21
	2	1.05	0.019	2	0.23
	3	1.04	0.020	2	0.33
4/23/81	3	1.28	0.002	< 1	0.01
5/4/81	1	.63	0.001	-	0.03
	2	.65	0.001	-	0.02
	3	.64	0.006	-	0.11
	9	.84	0.001	-	0.01
5/9/81	1	2.84	0.338	12	2.20
	2	2.78	0.692	25	4.23
	3	2.81	0.445	16	2.97
	4	2.89	0.005	< 1	0.03
	5	3.03	0.165	5	0.57
	6	2.98	0.051	2	0.30
	7	2.95	0.051	9	1.48
	8	3.05	0.003	< 1	0.02
	9	2.96	0.656	22	2.91
5/16/81	1	1.07	0.055	5	0.75
	2	1.06	0.086	8	1.56
	3	1.04	0.094	9	1.52
	4	1.05	0.001	< 1	0.01
	5	1.06	0.002	< 1	0.02
	7	1.05	0.002	< 1	0.01
	9	1.04	0.050	5	0.15
5/24/81	1	1.06	0.003	-	0.11
	2	.94	0.008	-	0.12
	3	.95	0.012	-	0.17
5/30/81	1	1.94	0.411	21	5.67
	2	2.07	0.540	26	6.11
	3	2.05	0.437	22	5.67
	4	2.07	0.010	< 1	0.09
	5	2.28	0.069	3	0.22
	6	2.23	0.093	4	0.72
	7	2.28	0.201	9	1.96
	8	2.24	0.005	< 1	0.03
	9	2.28	0.458	20	4.23
6/2/81	1	.80	0.005	-	0.17
	2	.78	0.003	-	0.09
	3	.80	0.008	-	0.07
6/3/81	1	1.12	0.152	14	0.48
	2	1.10	0.306	28	0.75
	3	1.11	0.166	15	0.62
	4	1.12	0.015	1	0.03
	5	1.08	0.057	5	0.08
	6	1.13	0.047	4	0.11
	7	1.08	0.116	11	0.21
	8	1.10	0.001	< 1	0.01
	9	1.09	0.269	25	0.44

Table 22. (continued).

Storm Date	Watershed	Precipitation (area inches)	Runoff (area inches)	Runoff as a Percentage of Precipitation* (%)	Peak Rate of Discharge (cfs)
6/4/81	1	2.21	0.701	32	3.53
	2	2.08	0.935	45	5.16
	3	2.05	0.556	27	4.45
	4	2.03	0.122	6	0.15
	5	1.98	0.375	19	0.48
	6	2.05	0.315	15	0.89
	7	1.96	0.474	24	1.15
	8	1.96	0.051	3	0.09
	9	1.95	0.753	39	1.56
6/10/81	2	.46	0.006	–	0.17
	3	.47	0.019	–	0.62
6/11/81	2	.30	0.001	–	0.01
	3	.30	0.001	–	0.01
6/12/81	1	1.18	0.117	10	1.36
	2	1.16	0.197	17	2.51
	3	1.16	0.141	12	2.68
	4	1.12	0.005	< 1	0.01
	5	1.24	0.033	3	0.08
	6	1.09	0.013	1	0.04
	7	1.25	0.093	7	0.21
	9	1.24	0.207	17	0.48
6/16/81	1	.42	0.002	–	0.08
	2	.48	0.004	–	0.11
	3	.49	0.008	–	0.23
6/23/81	1	.83	0.012	–	0.44
	2	.81	0.021	–	0.40
	3	.78	0.022	–	0.57
7/5/81	2	1.26	0.002	< 1	0.08
	3	1.25	0.006	< 1	0.13
7/7/81	1	1.86	0.168	9	2.46
	2	1.79	0.284	16	3.27
	3	1.81	0.202	11	2.79
	4	1.81	0.003	< 1	0.03
	6	1.84	0.007	< 1	0.05
	7	1.81	0.013	1	0.05
	9	1.80	0.072	4	0.40
7/8/81	1	.44	0.016	–	0.78
	2	.57	0.091	–	2.25
	3	.56	0.073	–	2.35
1981	1		2.384	11	1.37
	2		4.112	19	1.66
	3		2.690	12	1.28
	4		0.182	1	0.05
	5		0.853	3	0.24
	6		0.666	4	0.34
	7		1.332	6	0.73
	8		0.065	< 1	0.08
	9		2.767	13	1.30
Average by Treatment					
Undisturbed (4,6,8)			0.304	2	0.16
Shear/Windrow (1,2,3)			3.062	14	1.44
Roller chop (5,7,9)			1.650	7	0.76

During May, over 8.5 inches of rainfall resulted in 5 runoff events. Beginning on May 4, 0.73 inches of rain generated less than .01 inches of stormflow from watersheds 1, 2, 3, and 9. On May 9, several scattered storms with intensities of up to 3 inches per hour, produced runoff from all 9 watersheds. The amount of runoff ranged from .003 inches on WS 8 (control) to .692 inches on WS 2 (sheared). On May 16, runoff from a 1.06 inch rain, produced runoff of less than 0.10 inches from all watersheds except 6 and 8 (controls), which had no runoff. A similar storm on May 24 caused runoff from only the sheared watersheds. A large 2.14 inch rain on May 30, generated runoff from all watersheds. Runoff averaged 0.46 inches for the sheared watersheds, 0.24 inches for the chopped, and 0.04 inches for the undisturbed control watersheds. As a percent of precipitation, runoff was respectively, 23, 11, and 2 percent for the sheared, chopped, and undisturbed watersheds.

An unusually wet June, 7.31 inches of precipitation on soils with high antecedent soil moisture, resulted in 8 separate runoff events. Rainfall on June 2 (0.80 inches), produced less than 0.10 inches of stormflow from the more responsive sheared watersheds. However, on June 3, runoff ranged from 0.001 inches on WS 8 (control), to 0.31 inches on WS 2 (sheared), following a 1.10 inch rain. The following day, June 4, 2.03 inches of rain fell on the already saturated soils. A maximum rainfall intensity of 3.3 inches per hour was reached during one 10 minute period. This storm produced the largest volume of runoff and the highest runoff as a percentage of rainfall for the year. Watershed 2 (sheared) recorded the highest volume of runoff (0.94 inches) and peak discharge rate (5.16 cfs). Average runoff by treatment was: 1) sheared (0.73 inches), 2) chopped (0.54 inches), and 3) undisturbed (0.16 inches). The volume of runoff was significantly different (P .05) between treatments for this storm. Two small storms occurred on June 10 and 11 and produced runoff from WS 2 and 3 (sheared). On June 12, 1.19 inches of rain generated runoff from all watersheds except WS 8 (control). Volumes ranged from 0.20 inches on WS 2 (sheared) to 0.01 inches on WS 6 (control). On June 16 and 23, measurable runoff was recorded for the sheared watersheds following two small storms.

During July, three storms produced runoff. The first storm on July 5, generated only trace amounts of runoff from WS 2 and 3 (sheared), following a 1.25 inch rain. However, on July 7, a 1.82 inch rainfall event generated stormflow from all watersheds except WS 8 (control) and WS 5 (chopped). Runoff value from the sheared, chopped, and undisturbed watersheds averaged 0.22, 0.04, and 0.005 inches. The last runoff event during this eight month period occurred on July 8. An average runoff volume of 0.06 inches was recorded on the sheared watersheds, following a 0.52 inch rainfall event.

Water Quality

Sediment

During 1980 five runoff events were of sufficient size to initiate water sampling equipment on some or all of the undisturbed watersheds. Discharge weighted suspended sediment concentrations for the 1980 pretreatment period averaged 213 ppm (Table 23). The mean total sediment loss for the year was 183 lb/acre; this includes 79.4 lb/acre of suspended sediment and 103.6 lb/acre of bedload deposition. Bedload deposits occurred only during the May 15 runoff event. The May 15 storm accounted for 97% of the total sediment export for the year. Exclusion of this storm results in a discharge weighted sediment concentration of 50 ppm and a total sediment loss of 6.0 lb/acre for the year. Sediment concentrations ranged from 12 ppm on WS 8 and 9 during the January 21 storm, to 1309 ppm on WS 2 during the May 15 storm. Sediment

Table 23. Sediment loss and stormflow from undisturbed watersheds - 1980.

Storm Date	Watershed	Runoff (inches)	Suspended ppm	Sediment lb/acre	Bedload (lb/acre)	Total Sediment lb/acre
January 21	1	.121	24	0.7	0	0.7
	2	.429	48	4.8	0	4.8
	3	.115	80	2.2	0	2.2
	4	.128	60	1.8	0	1.8
	5	.175	60	2.4	0	2.4
	6	.408	48	4.5	0	4.5
	7	.252	36	2.1	0	2.1
	8	.089	12	0.2	0	0.2
	9	.554	12	1.5	0	1.5
February 8-9	2	.169	76	2.9	0	2.9
	6	.175	44	1.7	0	1.7
	9	.218	20	1.0	0	1.0
March 27	9	.004	17	0.02	0	0.02
April 13	1	.030	56	0.4	0	0.4
	2	.157	141	5.0	0	5.0
	6	.091	79	1.6	0	1.6
	9	.096	31	0.7	0	0.7
May 15	1	.751	174	29.5	124.6	154.1
	2	1.235	1309	365.5	93.8	459.3
	3	0.654	169	25.0	254.5	279.5
	4	0.792	435	78.0	116.4	194.4
	5	1.192	34	9.2	37.7	46.9
	6	1.341	199	60.4	165.9	226.3
	7	0.953	108	23.3	32.1	55.4
	8	0.913	108	22.2	37.9	60.1
	9	1.433	144	46.8	69.5	116.3
Mean discharge weighted sediment concentration - 1980[1/]			213			
Mean total sediment loss - 1980				79.4	103.6	183.0

[1/] Mean concentration is weighted by stormflow.

Table 24. Mean sediment losses and stormflow following treatment - 1981.

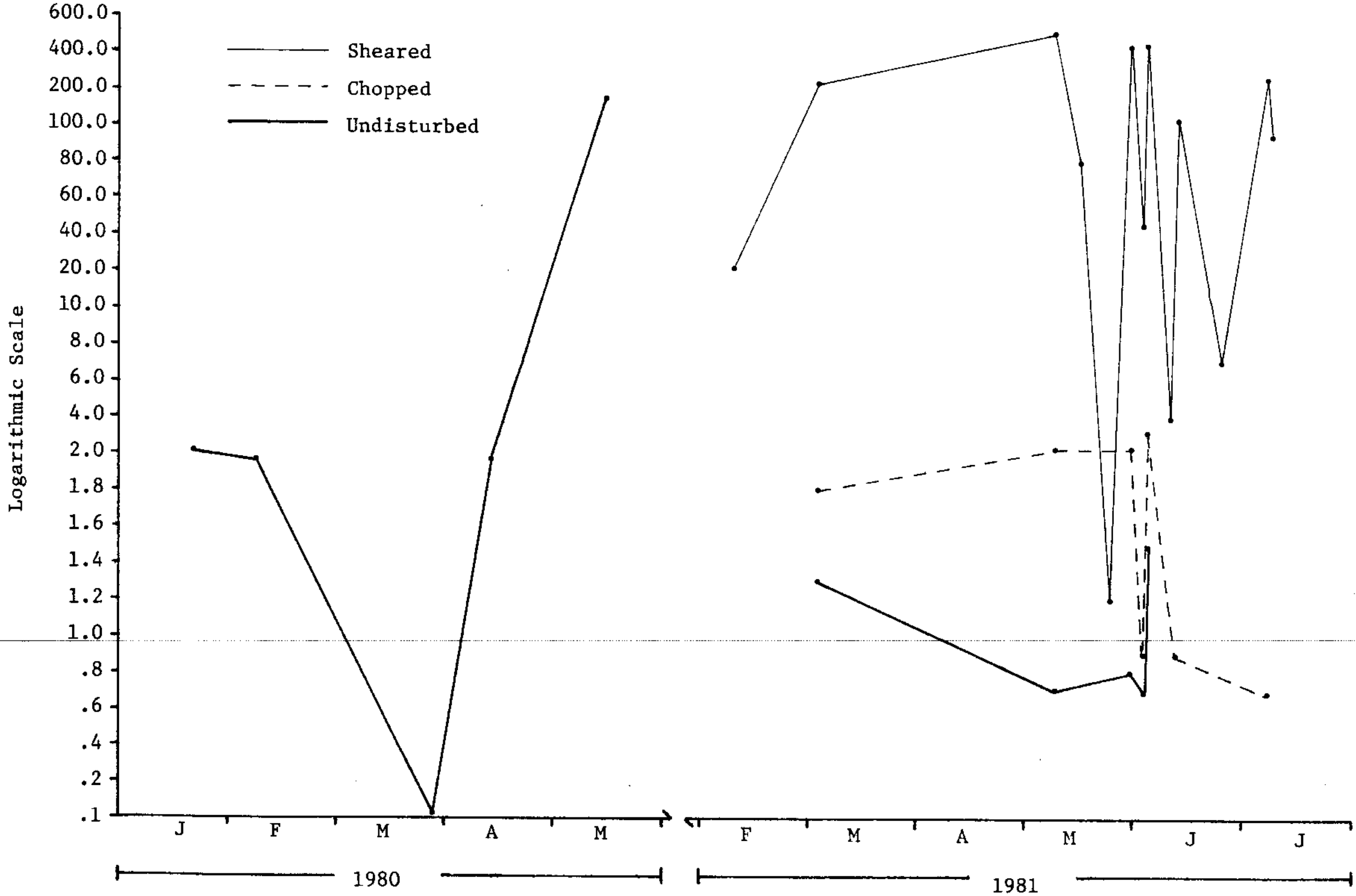
Storm Date	Treatment	Runoff (inches)	Suspended Sediment ppm	Suspended Sediment lb/acre)	Bedload (lb/acre)	Total Sediment lb/acre
February 10	Shear (2) [1/]	.084	2231	21.5	--	21.5
March 3	Shear (3)	.508	1518 a[2/]	137.4 a	83	220.4 a
	Chop (3)	.206	38 a	1.8 a	--	1.8 b
	Control (1)	.137	42 a	1.3 a	--	1.3 b
May 9	Shear (3)	.492	888 a	310.7 a	198	508.7 a
	Chop (3)	.291	39 b	2.3 a	--	2.3 b
	Control (1)	.051	57 a,b	0.7 a	--	0.7 b
May 16	Shear (3)	.078	1711	30.7	49	79.7
May 24	Shear (1)	.008	673	1.2	--	1.2
May 30	Shear (3)	.463	1680 a	186.1 a	251	437.1 a
	Chop (3)	.243	43 b	2.3 a	--	2.3 b
	Control (1)	.093	40 b	0.8 a	--	0.8 b
June 3	Shear (3)	.208	656 a	29.1 a	16	45.1 a
	Chop (3)	.147	26 b	0.9 b	--	0.9 b
	Control (1)	.047	64 b	0.7 b	--	0.7 b
June 4	Shear (3)	.731	1157 a	188.5 a	210	398.5 a
	Chop (3)	.534	25 b	3.1 b	--	3.1 b
	Conrol (3)	.163	46 b	1.5 b	--	1.5 b
June 10	Shear (2)	.013	425	1.0	3	4.0
June 12	Shear (3)	.152	1022	31.7	87	118.7
	Chop (3)	.111	28	0.9	--	0.9
June 23	Shear (2)	.022	624	3.0	4	7.0
July 7	Shear (3)	.218	1468	70.2	196	266.2
	Chop (1)	.072	42	0.7	--	0.7
July 8	Shear (2)	.082	1533	28.1	67	95.1
Discharge weighted sediment concentration - 1981[3/]	Shear		1280 a			
	Chop		31 b			
	Control		47 b			
Total sediment - 1981	Shear			1039.2 a	1164	2203.2 a
	Chop			12.0 b	0	12.0 b
	Control			5.0 b	0	5.0 b

[1/] The number of samples in each mean.

[2/] Means for each storm and within a variable followed by the same letter are not significantly different ($P \leq .05$) according to Duncan's multiple range test.

[3/] Mean concentration is weighted by stormflow.

Figure 3. Total sediment export (lb/acre) during 1980-1981 from the sheared, chopped, and undisturbed watersheds.



losses resulted primarily from channel scouring, although overland flow was evident following the May 15 runoff event.

Sediment samples following treatment were collected from 13 storm events during the first 8 months of 1981. Sediment losses were recorded from February to July, with 75% of the loss occurring during May and June. During this period, sediment losses for the sheared, chopped, and undisturbed watersheds were 2203.2, 12.0, and 5.0 lb/acre, respectively. Discharge weighted sediment concentrations were 1280, 31, and 47 ppm (Table 24). Bedload deposition occurred only on the sheared watersheds and totaled 1164 lb/acre for the year. Thus, over 50% of the sediment export from the sheared watersheds was attributed to bedload. Suspended sediment concentration and total sediment export was significantly ($P \leq .05$) higher on the sheared watersheds. Whereas, the chopped and undisturbed watersheds were not significantly different.

Five storms during 1981 produced runoff from all three of the treatments. These five storms account for 73, 87, and 100 percent of the first year sediment loss from the sheared, chopped, and undisturbed watersheds, respectively. It was only during the June 4 runoff event that water samples were collected from all three of the control watersheds. On the remaining four runoff events, WS 6 was the only undisturbed watershed to reach sampling stage. Total sediment export for the treated and untreated watersheds during 1980 and 1981 is shown in Figure 3.

On March 3, a 1.99 inch rainfall generated a runoff event with a mean sediment concentration of 1518, 38, and 42 ppm from the sheared, chopped, and undisturbed watersheds. Suspended sediment concentration and loss were not significantly ($P \leq .05$) different between treatments for this storm, because of the large variation within treatment samples. Inclusion of the bedload loss (82 lb/acre) from the sheared watersheds makes the total sediment export (220.4 lb/acre) significantly higher than the chopped (1.8 lb/acre) and undisturbed (1.3 lb/acre) watersheds.

The second major runoff event occurred two months later on May 9. Runoff volumes from this storm were respectively, .49, .29, and .05 inches, for the sheared, chopped, and undisturbed watersheds. The corresponding suspended sediment concentrations and total losses were, respectively, 888 (508.7), 30 (2.3), and 57 ppm (0.7 lb/acre). Total sediment exports were significantly ($P \leq .05$) higher on the sheared watersheds, and no significant differences were found between the chopped and the undisturbed watersheds. This relationship continued for the remaining storm events, with total sediment export significantly higher on the sheared watersheds.

On May 30, a 2.14 inch rainfall event, generated stormflow from all of the sheared and chopped watersheds and from one of the undisturbed controls. Stormflow sediment concentration from the sheared watersheds (1680 ppm) was 40 times greater than the chopped (43 ppm) and undisturbed (40 ppm) watersheds. Total sediment export was 437.1, 2.3, and 0.8 lb/acre for the sheared, chopped, and undisturbed watersheds.

Because of the increase in soil antecedent moisture, a small storm (1.10 inches) on June 3 produced runoff from seven of the watersheds. Runoff volumes were smaller during this event; hence, sediment loss was smaller. Sediment concentrations were, respectively, 656, 26, and 64 ppm for the sheared, chopped, and undisturbed watersheds. The undisturbed watersheds generally had a higher suspended sediment concentration than the chopped watersheds because of the concentration effect with a lower volume of runoff. Total sediment loss, however, was consistently higher on the chopped watersheds.

On the following day, June 4, a 2.01 inch rainfall generated the largest volume of runoff for the year. The sheared watersheds averaged .73 inches of runoff with a suspended sediment loss of 188.5 lb/acre and a bedload deposit of 210 lb/acre. The chopped watersheds averaged .53 inches of runoff with a suspended sediment loss of 3.1 lb/acre. All three of the undisturbed controls responded with a mean runoff of .16 inches and a suspended sediment loss of 1.5 lb/acre.

In summary, shearing and windrowing results in significantly larger first year losses of sediment. The primary reason for the higher values on sheared as compared to chopped watersheds, is the amount of surface cover and the disruption of the soil surface. The sheared watersheds following site preparation had 57 percent of the surface soil exposed as compared to 16 percent for the chopped watersheds. The bare soil offered no resistance to raindrop impact and overland flow. Thus, sheet and rill erosion resulted, with larger volumes of runoff carrying higher concentrations of sediment.

The chopped watersheds were covered with a layer of slash and organic matter which impeded overland flow and allowed time for infiltration and detention storage. As a result sediment concentrations from the chopped watersheds were not significantly ($P \leq .05$) different from the undisturbed watersheds. The source of the sediment from the chopped areas was mostly from channel scouring. The greater volume of runoff on the chopped watersheds accounts for the higher sediment loss than from the undisturbed watersheds. Although both the sheared and the chopped watersheds have shown excellent revegetation responses, it may be several years before the sheared watersheds have established a litter layer sufficient enough to reduce overland flow and lower sediment concentrations to pretreatment levels.

Nutrients

Nitrogen and Phosphorus

Water samples were analyzed for the different forms of nitrogen and phorphorus from all 1980 and 1981 runoff events. Samples were analyzed both filtered and unfiltered to determine the best analytical procedure and to distinguish between aqueous and sediment related nutrients. Because of the difficulty in extracting a homogeneous aliquot from each sample, concentrations will not balance for the different nutrient forms. For this reason, along with analytical errors, filtered samples often tested higher in concentration than unfiltered samples. A summary of nutrient concentrations and production is found in Tables 25 to 32.

Water samples were tested for five different forms of nitrogen-nitrite, nitrate, ammonia, organic, and total nitrogen. Nitrite levels were very low from all watersheds both before and after site preparation. The maximum value recorded during the 1980 pretreatment period was 10 ppb on WS 9 during the April 13 runoff event (Table 25). Following treatment a maximum value of 20 ppb was found on the sheared watersheds during the July 7 storm (Table 29). Minimum values of less than the 5 ppb detection limit were common from all watersheds. Annual export of unfiltered nitrite for 1980 was .0015 lb/acre (Table 26). The total nitrite losses for the eight month period in 1981 were .0054, .0022, and .0006 lb/acre from the sheared, chopped, and undisturbed watersheds, respectively (Table 30). Although their nitrite losses were very low, they were significantly ($P \leq .05$) different between all three treatments.

Nitrate concentrations were somewhat higher than nitrite levels, but still very low. During 1980 unfiltered nitrate concentrations reached a maximum of 57 ppb on WS 3 during the May 15 runoff event (Table 25). Nitrates were not associated with the sediments and hence, filtered and unfiltered samples showed little variation. Total nitrate (unfiltered) loss for 1980 was .01 lb/acre from the undisturbed watersheds (Table 26). Nitrate concentrations for 1981 showed significant ($P \leq .05$) differences between sheared and chopped watersheds for the May 9, June 3, 4 and 12 runoff events. Chopped and undisturbed watersheds were only significantly different on the May 9 storm. Total nitrate (unfiltered) export for 1981 was .2180, .0738, and .0029 lb/acre for the sheared, chopped, and undisturbed watersheds (Table 30 and Figure 4). The sheared watersheds had significantly ($P \leq .05$) higher nitrate exports than the chopped and undisturbed watersheds.

The concentration of ammonia in the stormflow also showed minor variation between filtered and unfiltered samples. Unfiltered ammonia samples for 1980 had a discharge weighted sediment concentration of 141 ppb and a total export of .0705 lb/acre (Tables 25 and 26). Ammonia concentrations following treatment ranged from less than 24 ppb for the March 1 storm to 425 ppb for the May 24 runoff event on the sheared watersheds (Table 29). Discharge weighted sediment concentrations were 175, 100, and 86 ppb for the sheared, chopped, and undisturbed watersheds. Unfiltered ammonia production for 1981 was significantly ($P \leq .05$) higher on the sheared watersheds (.1017 lb/acre) than on the chopped (.0372 lb/acre) or the undisturbed (.0065 lb/acre) watersheds (Table 30 and Figure 4).

Organic nitrogen (unfiltered) concentrations during 1980 ranged from 46 ppb on WS 2 for the April 13 storm to 1206 ppb on WS 6 during the February 8-9 runoff event (Table 25). Total organic nitrogen (unfiltered) lost in stormflow for 1980 was .2646 lb/acre (Table 26). The May 15 storm was the major contributor to total export. A comparison of filtered and unfiltered organic nitrogen concentrations following site preparation shows the unfiltered organics to be 4 times greater on the sheared watersheds and 2 times greater on the chopped watersheds than the control watersheds (Table 29). The reason for this is the high concentration of suspended organic sediments found on the more disturbed watersheds. The greatest export of nitrogen regardless of treatment was from losses in organic nitrogen. For the first 8 months of 1981 the sheared, chopped, and undisturbed watersheds lost 1.61, .38, and .09 lb/acre of organic nitrogen, respectively (Table 30). The chopped and undisturbed watersheds were significantly ($P \leq .05$) lower than the sheared watershed.

Total nitrogen is a summation of ammonia and organic nitrogen and in this case is almost entirely derived from organic nitrogen. For the 1980 pretreatment period, discharge weighted total nitrogen (unfiltered) was 891 ppb, with a total export of .304 lb/acre (Tables 25 and 26). Total nitrogen (unfiltered) discharge weighted concentrations for 1981 were respectively, 2789, 1665, and 920 ppb for the sheared, chopped and undisturbed watersheds (Table 29). Concentrations from the undisturbed watersheds are essentially the same for both years. Total nitrogen (unfiltered) export for 1981 is 19 times higher on the sheared (1.91 lb/acre) than on the undisturbed (.102 lb/acre) watersheds and 3 times higher than the chopped (.676 lb/acre) watersheds (Table 30 and Figure 5).

Water samples were analyzed for ortho, poly, organic, and total phosphorus. On all watersheds and treatments every form of phosphorus appears to be associated with the sediment, as filtered samples showed largely undetectable levels of phosphorus. All the phosphate concentrations were very low from all watersheds both before and after treatment. The 1980 discharge weighted concentration for ortho was less than the detection limit of 10 ppb for both filtered and unfiltered samples (Table 27). Following treatment unfiltered discharge weighted concentrations were 44, 21, and 13 ppb for the sheared, chopped, and undisturbed watersheds (Table 31). Total ortho phosphorus export ranged from .0296 lb/acre on the sheared watersheds to .0013 lb/acre on the undisturbed controls (Table 32). Annual ortho losses are very low, as the ortho form of phosphorus is apparently not available for transport in solution.

Poly-phosphate (unfiltered) showed slightly higher concentrations than ortho for all treatments. Discharge weighted concentrations in 1980 were less than 10 ppb filtered and 44 ppb unfiltered (Table 27). Total poly loss for 1980 was .011 lb/acre (Table 28). Following site preparation discharge weighted poly (filtered) concentrations were less than 10 ppb for all treatments.

Unfiltered samples had discharge weighted concentrations of 186, 26, and 40 ppb for the sheared, chopped, and undisturbed watersheds (Table 31). Total exported poly phosphates from the sheared watersheds were significantly ($P \leq .05$) higher than the chopped or undisturbed watersheds.

Organic phosphorus concentrations in 1980 ranged from 20 ppb on WS 1 during the April 13 runoff event to 75 ppb on WS 4 during the May 15 event (Table 27). Annual export of organic phosphorus for the undisturbed watersheds was .0104 lb/acre (Table 28). The treated watersheds in 1981 had discharge weighted concentrations of 107, 15, and 10 ppb, for the sheared, chopped, and undisturbed watersheds (Table 31). Organic export was greatest for the sheared watersheds (.0609 lb/acre) followed by the chopped (.0035 lb/acre) and undisturbed (.002 lb/acre) watersheds (Table 32).

Total phosphorus loss is the summation of ortho, poly, and organic phosphorus. Discharge weighted concentration (unfiltered) for the undisturbed watersheds in 1980 was 72 ppb (Table 27). This is approximately double the undisturbed concentration (31 ppb) in 1981, but still very low. Annual export from the undisturbed watersheds in 1980 was .0257 lb/acre (Table 28). Discharge weighted concentrations for the sheared watersheds were 36 ppb (filtered) and 310 ppb (unfiltered) for 1981. This is an indication of the large percentage of phosphorus associated with the sediment. Total phosphorus export during 1981 was significantly ($P \leq .05$) higher from the sheared watersheds (.1758 lb/acre) than from the chopped (0.109 lb/acre) or undisturbed (.0014 lb/acre) watershed (Table 32 and Figure 5).

In summary, nitrogen concentrations and losses were increased following treatment. Nitrite losses were very low from all watersheds both before and after treatment; however, significant ($P \leq .05$) differences were found between all three treatments. Nitrate and ammonia concentrations, as well as total exports, were highest on the sheared watersheds, followed by the chopped and

Table 25. Nitrogen concentrations (ppb) by storm from undisturbed watersheds - 1980.

Storm Date	Watershed	Nitrite		Nitrate		Ammonia		Organic		Total	
		filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered
January 21	1	--[1]	--	31	--	146	78	493	776	639	854
	2	--	--	24	24	213	213	722	964	935	1177
	3	--	--	25	--	132	85	534	816	666	901
	4	--	--	37	--	65	132	332	130	397	262
	5	--	--	24	--	194	176	1985	389	2179	565
	6	--	--	25	--	146	206	726	291	872	497
	7	--	--	20	--	132	274	682	264	814	538
	8	--	--	<10	--	206	166	507	776	713	942
	9	--	--	<10	--	220	206	910	803	1130	1009
February 8-9	2	--	--	20	--	179	146	442	798	621	944
	6	--	--	83	--	213	980	1014	1206	1227	2186
	9	--	--	44	--	220	819	590	883	810	1702
March 27	9	8	9	0	7	77	668	652	169	729	836
April 13	1	8	9	34	37	104	473	591	73	695	547
	2	7	9	5	<5	82	741	872	46	954	787
	6	8	9	8	5	110	524	775	143	885	667
	9	8	10	10	10	81	407	612	618	692	1025
May 15	1	6	7	<5	<5	66	436	913	203	979	639
	2	<5	7	11	36	36	26	394	550	429	576
	3	<5	9	25	57	102	103	683	1188	785	1291
	4	<5	5	14	36	61	61	439	1201	500	1282
	5	<5	<5	<5	49	49	39	297	489	346	528
	6	<5	5	61	51	49	50	680	1174	729	1224
	7	<5	5	9	39	69	78	531	801	600	878
	8	<5	5	26	46	37	34	734	941	771	974
	9	<5	5	23	49	26	21	901	699	926	720
Mean discharge weighted concentrations - 1980[3]		<5	<5	22	44	142	141	658	749	739	891

[1] No sample.

[2] Mean concentration is weighted by stormflow.

Table 26. Nitrogen loss (lb/acre) by storm from undisturbed watersheds - 1980.

Storm Date	Watershed	Nitrites		Nitrates		Ammonia		Organic		Total	
		filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered
January 21	1	-- 1/	--	.0008	--	.0040	.0021	.0135	.0212	.0175	.0234
	2	--	--	.0023	--	.0207	.0207	.0700	.0935	.0907	.1142
	3	--	--	.0007	--	.0034	.0022	.0139	.0212	.0173	.0234
	4	--	--	.0011	--	.0019	.0038	.0096	.0038	.0115	.0076
	5	--	--	.0009	--	.0077	.0070	.0786	.0154	.0862	.0223
	6	--	--	.0023	--	.0135	.0190	.0670	.0268	.0805	.0459
	7	--	--	.0011	--	.0075	.0156	.0389	.0150	.0464	.0307
	8	--	--	.0002	--	.0042	.0033	.0102	.0156	.0143	.0190
	9	--	--	.0013	--	.0776	.0258	.1140	.1006	.1416	.1264
February 8-9	2	--	--	.0008	--	.0068	.0056	.0169	.0305	.0237	.0361
	6	--	--	.0033	--	.0084	.0388	.0401	.0477	.0486	.0865
	9	--	--	.0022	--	.0108	.0404	.0291	.0435	.0399	.0839
March 27	9	*	*	*	*	.0001	.0008	.0007	.0002	.0008	.0009
April 1	1	*	.0001	.0002	.0002	.0007	.0032	.0040	.0005	.0047	.0037
	2	.0002	.0003	.0002	.0002	.0029	.0263	.0310	.0016	.0339	.0279
	6	.0002	.0002	.0002	.0001	.0023	.0108	.0159	.0029	.0182	.0137
	9	.0002	.0002	.0002	.0002	.0018	.0088	.0133	.0134	.0150	.0222
May 15	1	.0010	.0012	.0008	.0008	.0112	.0740	.1550	.0345	.1663	.1085
	2	.0014	.0020	.0031	.0101	.0101	.0073	.1100	.1536	.1198	.1609
	3	.0007	.0013	.0037	.0084	.0151	.0152	.1010	.1757	.1161	.1909
	4	.0009	.0009	.0025	.0064	.0109	.0109	.0786	.2151	.0895	.2296
	5	.0013	.0013	.0013	.0132	.0132	.0105	.0801	.1318	.0933	.1423
	6	.0015	.0015	.0185	.0155	.0149	.0152	.2062	.3560	.2211	.3712
	7	.0011	.0011	.0019	.0084	.0149	.0168	.1144	.1726	.1293	.1892
	8	.0010	.0010	.0054	.0095	.0076	.0070	.1515	.1943	.1592	.2011
	9	.0016	.0016	.0075	.0159	.0084	.0068	.2920	.2265	.3001	.2333
Mean total nitrogen loss - 1980		.0014	.0015	.0064	.0100	.0325	.0705	.2348	.2646	.2673	.3041

*Less than .0001

1/ No sample.

Table 27. Phosphorus concentrations (ppb) by storm from undisturbed watersheds - 1980.

Storm Date	Watershed	Ortho		Poly		Organic		Total	
		filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered
January 21	1	<10	--[1]	--	--			<20	50
	2	<10	--	--	--	--	--	<20	50
	3	<10	--	--	--	--	--	<20	50
	4	<10	--	--	--	--	--	<20	50
	5	<10	--	--	--	--	--	<20	50
	6	<10	--	--	--	--	--	<20	50
	7	<10	--	--	--	--	--	<20	50
	8	<10	--	--	--	--	--	<20	40
	9	<10	--	--	--	--	--	<20	40
February 8-9	2	<10	17					<20	47
	6	<10	<10					<20	33
	9	<10	<10					<20	31
March 27	9	<10	<10	<10	13	34	43	40	57
April 13	1	<10	<10	<10	20	<10	20	<20	40
	2	<10	<10	<10	35	<10	32	<20	67
	6	<10	<10	<10	28	<10	35	<20	53
	9	<10	<10	<10	20	12	26	<20	47
May 15	1	<10	<10	<10	51	<10	52	<20	103
	2	14	<10	<10	30	<10	27	<20	57
	3	<10	<10	<10	42	<10	30	<20	73
	4	<10	<10	<10	84	<10	75	<20	159
	5	<10	<10	<10	36	<10	21	<20	57
	6	<10	<10	<10	57	<10	59	<20	116
	7	<10	<10	<10	39	<10	34	<20	73
	8	<10	<10	<10	37	<10	38	<20	75
	9	<10	<10	<10	39	<10	45	<20	84
Mean discharge weighted concentrations - 1980[2]		<10	<10	<10	44	<10	41	<20	72

[1] No sample.

[2] Mean concentration is weighted by stormflow.

Table 28. Phosphorus loss (lb/acre) by storm from undisturbed watersheds - 1980.

Storm Date	Watershed	Ortho		Poly		Organic		Total	
		filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered
January 21	1	.0003	--[1/]	--	--	--	--	.0005	.0014
	2	.0010	--	--	--	--	--	.0019	.0049
	3	.0003	--	--	--	--	--	.0005	.0013
	4	.0003	--	--	--	--	--	.0006	.0014
	5	.0004	--	--	--	--	--	.0008	.0020
	6	.0009	--	--	--	--	--	.0018	.0046
	7	.0006	--	--	--	--	--	.0011	.0028
	8	.0002	--	--	--	--	--	.0004	.0008
	9	.0013	--	--	--	--	--	.0025	.0050
February 8-9	2	.0004	.0006	--	--	--	--	.0008	.0018
	6	.0004	.0004	--	--	--	--	.0008	.0013
	9	.0005	.0005	--	--	--	--	.0010	.0015
March 27	9	*	*	*	*	*	*	*	*
April 13	1	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0003
	2	.0004	.0004	.0004	.0012	.0004	.0011	.0007	.0024
	6	.0002	.0002	.0002	.0006	.0002	.0007	.0004	.0011
	9	.0002	.0002	.0002	.0004	.0003	.0006	.0004	.0010
May 15	1	.0017	.0017	.0017	.0087	.0017	.0088	.0034	.0175
	2	.0034	.0028	.0028	.0084	.0028	.0075	.0056	.0159
	3	.0015	.0015	.0606	.0062	.0015	.0044	.0030	.0108
	4	.0018	.0018	.0018	.0150	.0018	.0134	.1136	.0285
	5	.0027	.0027	.0027	.0097	.0027	.0057	.0054	.0154
	6	.0030	.0030	.0030	.0173	.0030	.0179	.0061	.0352
	7	.0022	.0022	.0022	.0084	.0022	.0073	.0043	.0157
	8	.0021	.0021	.0021	.0076	.0021	.0078	.0041	.0155
	9	.0032	.0032	.0032	.0126	.0032	.0146	.0065	.0272
Mean total phosphorus loss - 1980		.0037	.0030	.0091	.0110	.0025	.0104	.0071	.0257

*Less than .0001.

[1/] No sample.

Table 29. Mean nitrogen concentrations (ppb) by storm and treatment - 1981.

	Treatment	Nitrite		Nitrate		Ammonia		Organic		Total	
		filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered
February 10	Shear (2)[1/]	<5	<5	133	139	163	125	790	1629	902	1754
March 1	Shear (1)	<5	<5	23	179	<24	<24	655	1249	671	1263
March 3	Shear (3)	--[3/]	13 a [2/]	--	189 a	--	--	--	--	830 a	2011 a
	Chop (3)	--	9 a	--	177 a	--	--	--	--	480 a	894 a
	Control (1)	--	<5 a	--	57 a	--	--	--	--	499 a	800 a
March 29	Shear (2)	<5	<5	357	606	218	172	748	1848	966	2019
May 9	Shear (3)	<5 a	<5 a	904 a	911 a	235 a	215 a	779 a	4250 a	1014 a	4465 a
	Chop (3)	<5 a	<5 a	558 b	601 b	188 a	190 a	856 a	4908 a	1043 a	5098 a
	Control (1)	<5 a	<5 a	<5 c	<5 c	138 a	99 a	1004 a	1103 a	1143 a	1202 a
May 16	Shear (3)	<5	12	430	439	255	248	515	4802	770	5050
May 24	Shear (2)	<5	<5	555	581	386	425	1170	7222	1556	7646
May 30	Shear (3)	8 a	7 a	272 a	191 a	122 a	326 a	425 a	4887 a	547 a	5213 a
	Chop (3)	6 a	6 a	182 a	188 a	171 a	101 a	895 a	1212 a	1066 a	1313 a
	Control (1)	<5 a	<5 a	39 a	41 a	138 a	98 a	645 a	862 a	783 a	960 a
June 3	Shear (3)	9 a	14 a	367 a	381 a	84 a	63 a	1220 a	1806 a	1304 a	1870 a
	Chop (3)	<5 b	6 b	28 b	33 b	71 a	46 a	1975 a	1480 a	2046 a	1526 a
	Control (1)	<5 b	7 ab	<5 b	<5 b	77 a	152 a	1615 a	1388 a	1682 a	1440 a
June 4	Shear (3)	6 a	8 a	160 a	166 a	163 a	108 a	492 a	744 a	655 a	852 a
	Chop (3)	<5 a	<5 b	19 b	23 b	58 a	70 a	649 a	824 a	707 a	893 a
	Control (3)	<5 a	<5 b	7 b	7 b	172 a	85 a	441 a	673 a	613 a	759 a
June 10	Shear (2)	<8	8	307	319	29	330	778	2791	805	3121
June 12	Shear (3)	6 a	7 a	101 a	105 a	98 a	149 a	628 a	558 a	726 a	706 a
	Chop (3)	6 a	6 a	<5 b	<5 b	64 a	112 a	707 a	594 a	770 a	706 a
June 23	Shear (2)	9	14	425	433	89	181	651	2579	739	2760
July 7	Shear (3)	<5 a	20 a	96 a	92 a	88 a	128 a	697 a	3031 a	778 a	3159 a
	Chop (1)	<5 a	<5 a	<5 b	<5 a	48 a	42 a	534 a	945 a	582 a	987 a
July 8	Shear (2)	<5	10	185	189	56	92	501	2790	557	2881
Discharge weighted[4/] concentrations - 1981											
	Shear	6	8	342	311	151	175	637	2695	793	2789
	Chop	<5	<5	159	171	106	100	860	1798	915	1665
	Control	<5	<5	15	27	146	86	732	880	771	920

[1/] The number of samples in each mean.

[2/] Means for each storm and within a variable followed by the same letter are not significantly different ($P \leq .05$) according to Duncan's multiple range test.

[3/] No sample.

[4/] Mean concentration is weighted by stormflow.

Table 30. Mean nitrogen loss (lb/acre) by storm and treatment - 1981.

Storm Date	Treatment	Nitrite		Nitrate		Ammonia		Organic		Total	
		filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered
February 10	Shear (2)[1/]	* [2/]	*	.0026	.0027	.0029	.0027	.0148	.0304	.0173	.0331
March 1	Shear (1)	*	*	.0001	.0011	.0001	.0001	.0041	.0079	.0042	.0080
March 3	Shear (3)	--	.0014 a[3/]	--	.0203 a	--	--	--	--	.0914 a	.2011 a
	Chop (3)	--	.0005 b	--	.0077b	--	--	--	--	.0223 b	.0436 b
	Control (1)	--	.0002 b	--	.0018 b	--	--	--	--	.0155 b	.0248 b
March 29	Shear (2)	*	*	.0015	.0027	.0010	.0007	.0033	.0081	.0043	.0088
May 9	Shear (3)	.0004 a	.0005 a	.0985 a	.0995 a	.0271 a	.0230 a	.0826 a	.4886 a	.1097 a	.5117 a
	Chop (3)	.0003 ab	.0003 ab	.0456 b	.0520 ab	.0174 ab	.0163 ab	.0722 a	.3340 a	.0896 ab	.3503 a
	Control (1)	* b	* a	* b	* b	.0016 b	.0011 b	.0116 b	.0127 a	.0132 b	.0139 a
May 16	Shear (3)	*	.0002	.0078	.0080	.0043	.0044	.0098	.0849	.0141	.0893
May 24	Shear (2)	*	*	.0012	.0013	.0010	.0011	.0028	.0185	.0038	.0195
May 30	Shear (3)	.0009 a	.0006 a	.0291 a	.0189 a	.0133 a	.0348 a	.0444 a	.5411 a	.0577 a	.5759 a
	Chop (3)	.0004 ab	.0004 a	.0099 ab	.0106 ab	.0110 a	.0059 b	.0562 a	.0890 ab	.0673 a	.0748 ab
	Control (1)	.0001 b	.0001 a	.0008 b	.0009 a	.0029 a	.0021 b	.0136 a	.0181 b	.0165 a	.0202 b
June 3	Shear (3)	.0004 a	.0006 a	.0182 a	.0189 a	.0040 a	.0029 a	.0533 a	.0745 a	.0573 a	.0775 a
	Chop (3)	.0002 ab	.0002 b	.0010 b	.0011 b	.0024 ab	.0014 ab	.0735 a	.0568 a	.0759 a	.0581 a
	Control (1)	* b	.0001 b	* b	* b	.0008 b	.0005 b	.0172 a	.0148 a	.0179 a	.0153 a
June 4	Shear (3)	.0009 a	.0013 a	.0285 a	.0296 a	.0288 a	.0178 a	.0828 a	.1243 a	.1116 a	.1421 a
	Chop (3)	.0006 ab	.0006 b	.0018 b	.0023 b	.0064 b	.0094 ab	.0844 a	.1036 ab	.0908 a	.1129 ab
	Control (3)	.0002 b	.0002 b	.0002 b	.0002 b	.0057 b	.0028 b	.0187 a	.0250 b	.0244 a	.0278 b
June 10	Shear (2)	*	*	.0008	.0008	.0001	.0001	.0020	.0095	.0200	.0100
June 12	Shear (3)	.0002 a	.0002 a	.0037 a	.0039 a	.0035 a	.0054 a	.0216 a	.0192 a	.0251 a	.0246 a
	Chop (3)	.0002 a	.0002 a	.0001 a	.0001 a	.0015 a	.0036 a	.0199 a	.0166 a	.0215 a	.0202 a
June 23	Shear (2)	*	*	.0021	.0021	.0004	.0009	.0032	.0124	.0036	.0133
July 7	Shear (3)	.0002 a	.0009 a	.0048 a	.0047 a	.0041 a	.0062 a	.0302 a	.1370 a	.0343 a	.1432 a
	Chop (1)	* a	* a	* a	* a	.0008 a	.0006 a	.0087 a	.0154 a	.0095 a	.0161 a
July	Shear (2)	*	.0002	.0035	.0035	.0010	.0016	.0092	.0512	.0101	.0529
Total nitrogen loss (Jan.-Aug. 1981)											
	Shear	.0030 a	.0054 a	.2024 a	.2180 a	.0916 a	.1017 a	.3641 a	1.6076 a	.5645 a	1.9110 a
	Chop	.0017 ab	.0022 b	.0584 b	.0738 b	.0395 ab	.0372 b	.3149 a	.6154 b	.3779 a,b	.6760 a,b
	Control	.003 b	.006 c	.0010 b	.0029 b	.0110 b	.0065 b	.0611 a	.0106 b	.0875 b	.1020 b

1/ The number of samples in each mean.

2/ Less than .0001.

3/ Means for each storm and within variable followed by the same letter are not signficantly different (P≤.05) according to Duncan's multiple range test.

Table 31. Mean phosphorus concentrations (ppb) by storm and treatment - 1981.

Storm Date	Treatment	Ortho filtered	Ortho unfiltered	Poly filtered	Poly unfiltered	Organic filtered	Organic unfiltered	Total filtered	Total unfiltered
February 10	Shear (2)[1]	49	78	64	61	8	98	117	231
March 1	Shear (1)	53	69	<10	92	48	80	109	241
March 3	Shear (3)	107 a[2]	104 a	--[3]	--	--	--	--	--
	Chop (3)	85 a	89 a	--	--	--	--	--	--
	Control (1)	22 a	29 a	--	--	--	--	--	--
March 29	Shear (2)	89	117	11	68	95	<10	139	29
May 9	Shear (3)	29 a	53 a	<10	45 a	25 a	79 a	69 a	203 a
	Chop (3)	24 a	28 a	<10	15 a	16 a	28 a	45 a	70 a
	Control (1)	<5 a	11 a	--	11 a	--	--	37 a	--
May 16	Shear (3)	12	47 a	10	329 a	--	257 a	20 a	633 a
	Chop (1)	--	<5 b	--	20 a	<10	14 b	<20 a	38 b
May 24	Shear (2)	88	98	160	747	<10	152	572	995
May 30	Shear (3)	8 a	35 a	<10 a	209 a	<10 a	129 a	<20 a	372 a
	Chop (3)	10 a	13 a	<10 a	41 a	28 a	<10 a	44 a	48 a
	Control (1)	<5 a	<5 a	<10 a	63 a	<10 a	<10 a	<20 a	53 a
June 3	Shear (3)	<5 a	<5 a	<10 a	109 a	<10 a	90 a	<20 a	204 a
	Chop (3)	<5 a	<5 a	<10 a	27 b	<10 a	<10 b	<20 a	35 b
	Control (1)	<5 a	<5 a	55 b	30 ab	<10 a	<10 b	<20 a	26 b
June 4	Shear (3)	<5 a	22 a	<10 a	311 a	<10 a	54 a	<20 a	322 a
	Chop (3)	<5 a	6 b	<10 a	26 b	<10 a	<10 a	<20 b	<20 b
	Control (3)	<5 a	6 b	<10 a	44 b	<10 a	<10 a	<20 b	<20 b
June 10	Shear (2)	6	20	11	144	<10	16	<20	170
June 12	Shear (3)	14 a	10 a	<10 a	163 a	16 a	163 a	31 a	336 a
	Chop (3)	<5 a	<5 a	<10 a	27 b	<10 a	10 b	<20 a	38 b
June 23	Shear (2)	<5 a	24	<10	149	<10	55	<20	227
July 7	Shear (3)	<5 a	28 a	<10 a	132 a	<10 a	212 a	<20 a	370 a
	Chop (1)	<5 a	<5 a	<10 a	<10 a	<10 a	29 a	<20 a	41 b
July 8	Shear (2)	<5	27	<10	151	<10	193	<20	370
Discharge weighted concentrations - 1981[4]									
	Shear	29	44	<10	186	14	107	36	310
	Chop	19	21	<10	26	<10	15	<20	39
	Control	10	13	<10	40	<10	<10	<20	31

[1] The number of samples in each mean.

[2] Means for each storm and within a variable followed by the same letter are not significantly different ($P \leq .05$) according to Duncan's multiple range test.

[3] No sample.

[4] Mean calculation is weighted by stormflow.

Table 32. Mean phosphorus loss (lb/acre) by storm and treatment - 1981.

Storm Date	Treatment	Ortho		Poly		Organic		Total	
		filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered
February 10	Shear (2)[1/]	,0014	.0017	.0011	.0010	.0001	.0019	.0024	.0045
March 1	Shear (1)	.0003	.0004	*	.0001	.0003	.0005	.0007	.0015
March 3	Shear (3)	.0114 a[2/]	.0110 a	--[3/]	--	--	--	--	--
	Chop (3)	.0047 b	.0048 b	--	--	--	--	--	--
	Control (1)	.0007 b	.0009 b	--	--	--	--	--	--
March 29	Shear (2)	.0004	.0005	*	.0003	.0004	*	.0006	.0001
May 9	Shear (3)	.0028 a	.0052 a	.0001 a	.0041 a	.0015 a	.0045 a	.0048 a	.0115 a
	Chop (3)	.0025 a	.0028 ab	.0004 a	.0013 ab	.0015 a	.0024 a	.0045 a	.0065 a
	Control (1)	* a	.0001 b	* a	.0001 b	* a	* a	.0004 a	* a
May 16	Shear (3)	.0002	.0008	.0002	.0058	--	.0046	.0004	.0112
May 24	Shear (2)	.0002	.0002	.0004	.0020	*	.0003	.0012	.0026
May 30	Shear (3)	.0008 a	.0038 a	.0001 a	.0239 a	.0008 a	.0142 a	.0017 a	.0419 a
	Chop (3)	.0006 ab	.0009 ab	.0005 a	.0016 a	.0021 a	.0002 b	.0032 a	.0016 a
	Control (1)	.0001 b	.0001 b	* a	.0013 a	* a	* b	.0001 a	.0011 a
June 3	Shear (3)	.0002 a	.0002 a	.0002 a	.0046 a	.0003 a	.0045 a	.0007 a	.0092 a
	Chop (3)	.0001 ab	.0001 ab	.0004 a	.0009 b	* b	.0002 b	.0005 ab	.0011 b
	Control (1)	* b	* b	.0006 a	.0003 b	* b	* b	.0001 b	.0003 b
June 4	Shear (3)	.0009 a	.0034 a	.0003 a	.0527 a	.0011 a	.0096 a	.0022 a	.0556 a
	Chop (3)	.0005 ab	.0007 b	.0004 a	.0036 b	* b	* a	.0004 b	* b
	Control (3)	* b	.0002 b	* a	.0012 b	* b	.0002 a	* b	* b
June 10	Shear (2)	*	*	*	.0004	*	.0001	*	.0005
June 12	Shear (3)	.0005 a	.0004 a	.0001 a	.0053 a	.0006 a	.0052 a	.0012 a	.109 a
	Chop (3)	.0001 a	* a	.0001 a	.0007 b	.0002 a	.0002 b	.0004 a	.0010 b
June 23	Shear (2)	*	.0001	*	.0007	*	.0003	.0001	.0011
July 7	Shear (3)	.0002 a	.0014 a	.0001 a	.0054 a	.0003 a	.0117 a	.0005 a	.0184 a
July 8	Chop (1)	* a	* a	* a	.0001 a	.0001 a	.0005 a	.0002 a	.0007 a
	Shear (2)	.0001	.0005	.0001	.0029	*	.0035	.0002	.0068
Total phosphorus loss (Jan.-Aug. 1981)									
	Shear	.0194 a	.0296 a	.0027 a	.1092 a	.0054 a	.0609 a	.0167 a	.1758 a
	Chop	.0085 ab	.0093 b	.0018 a	.0082 b	.0039 a	.0035 b	.0092 ab	.0109 b
	Control	.0008 b	.0013 b	.0006 a	.0029 b	* a	.0002 b	.0006 b	.0014 b

*Less than .0001.

1/The number of samples in each mean.

2/Means for each storm and within a variable followed by the same letter are not significantly different ($P \leq .05$) according to Duncan's multiple range test.

3/No sample.

Figure 4. Nitrate and ammonia export (lb/acre) during 1980-1981 from the sheared, chopped and undisturbed watersheds.

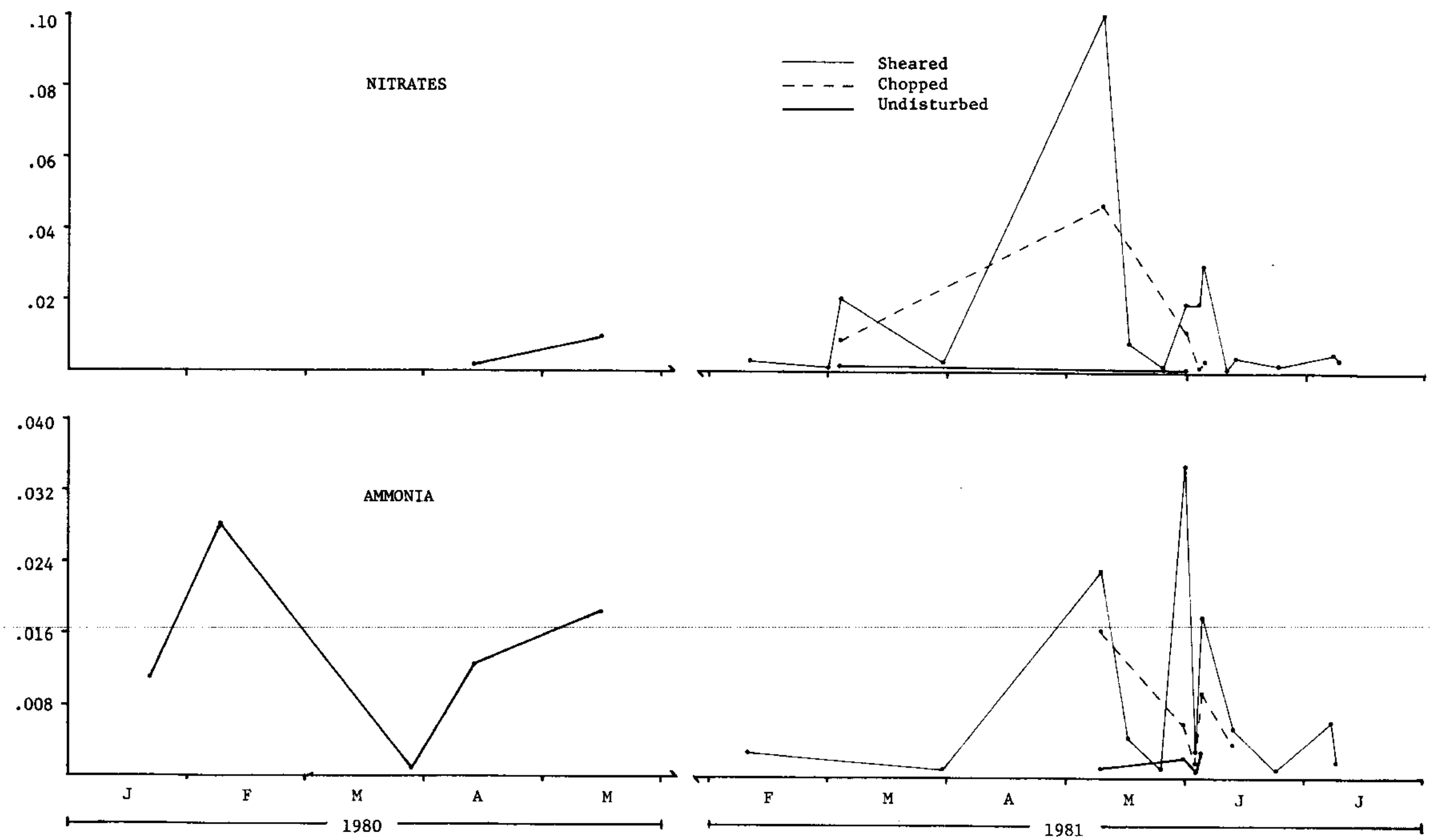
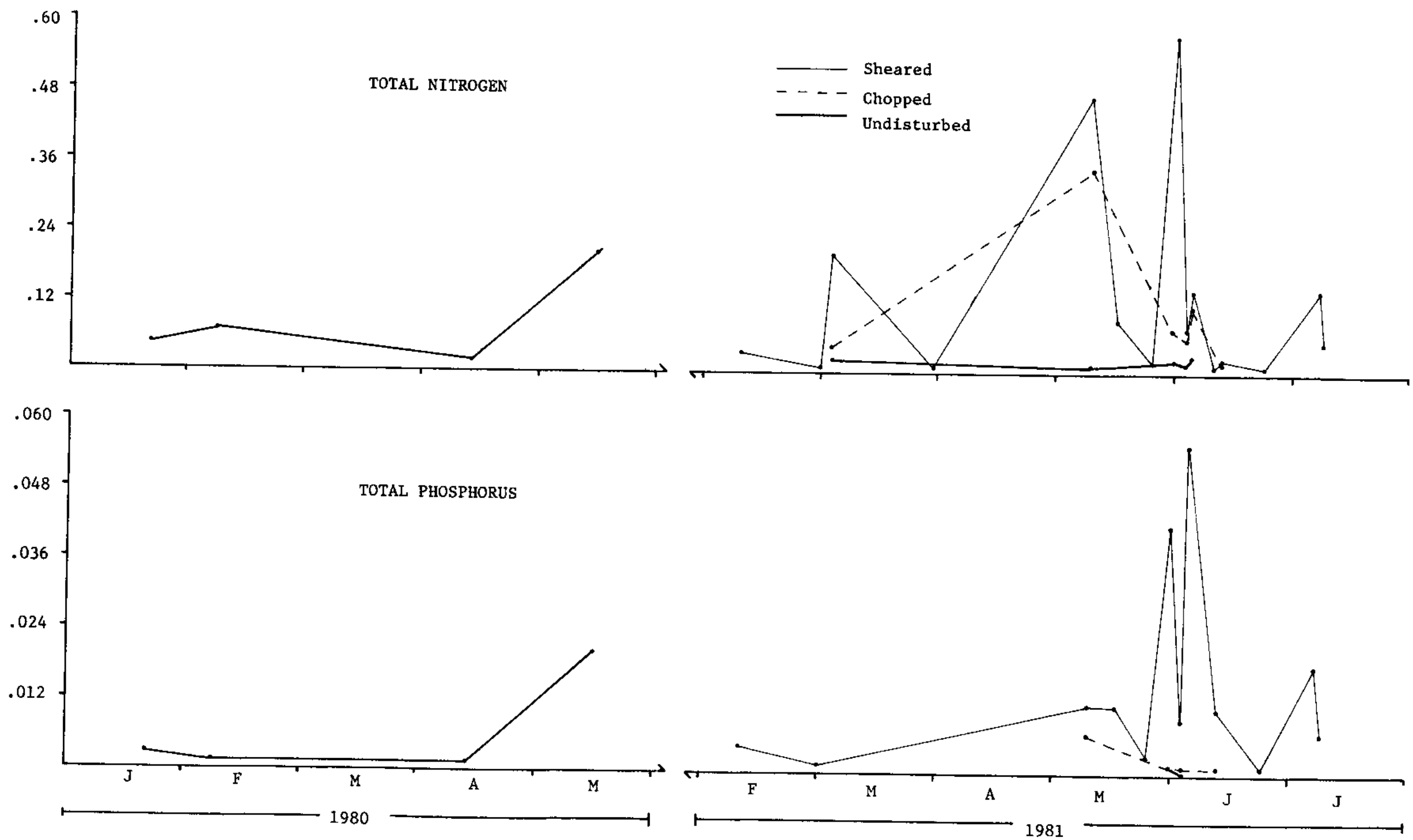


Figure 5. Total nitrogen and phosphorus export (lb/acre) during 1980-1981 from the sheared, chopped and undisturbed watersheds.



undisturbed watersheds. Organic nitrogen concentrations, which were related to suspended sediment levels, were the greatest source of nitrogen loss. The sheared treatments recorded organic nitrogen losses significantly ($P \leq 0.5$) higher than the chopped and undisturbed treatments. Total nitrogen export for 1981 was less than 2.0 lb/acre on the sheared watersheds. Although this is low, it is still nearly 20 times higher than the undisturbed watersheds and 3 times higher than the chopped watersheds.

Phosphorus concentrations and losses also increased following treatment. All forms of phosphorus were associated with the sediment; hence, the sheared watersheds having the highest suspended sediment levels also had the highest concentrations of phosphorus. Ortho and poly phosphate export was very low from all treatments. The large volume of runoff from the sheared watersheds resulted in significantly ($P \leq 0.5$) greater losses of ortho and poly phosphates than the chopped and undisturbed watersheds. Poly phosphates contributed the greatest amount to total phosphorus loss from all treatments. Organic phosphorus export was also low, with the largest loss from the sheared watersheds, followed by the chopped and undisturbed watersheds. Total phosphorus loss during 1981 was only .18 lb/acre on the sheared treatments, but was significantly ($P \leq .05$) higher than the chopped and undisturbed treatments.

Potassium, Calcium, Magnesium and Sodium

Stormflow water samples during 1980 and 1981 were analyzed for four elements: potassium, calcium, magnesium and sodium. Potassium (K) concentrations during 1980 ranged from 0.2 ppm on WS 6 during the January 21 storm event to 3.0 ppm for WS 3 during the same event (Table 33). Total K export during 1980 was 0.662 lb/acre (Table 34). Potassium concentrations and export increased following treatment. During 1981 discharge weighted K concentrations were 4.6, 5.6 and 2.4 ppm for the sheared, chopped and undisturbed watersheds, respectively (Table 35). Significant ($P \leq .05$) differences in concentrations between treatments were found only on the June 3 runoff event. During this event K concentrations were significantly higher on the sheared watersheds than on the chopped or undisturbed watersheds. Total K export was significantly ($P \leq .05$) higher on the sheared watersheds (3.92 lb/acre) than the undisturbed (0.26 lb/acre); however, the chopped watersheds (2.21 lb/acre) were not significantly different than either the sheared or the undisturbed watersheds (Table 36). Potassium losses for all treatments were higher than calcium, magnesium and sodium losses.

The discharge weighted calcium (Ca) concentration during 1980 was 2.2 ppm (Table 33). Following treatment the chopped watersheds had the highest discharge weighted Ca concentrations (30 ppm) followed by the undisturbed (1.6 ppm) and the sheared (0.8 ppm) watersheds (Table 35). The total export of Ca for the pretreatment year was 0.82 lb/acre (Table 34). This is higher than the 0.64 lb/acre loss recorded on the sheared watersheds during 1981. The chopped watersheds had the highest Ca export with 1.06 lb/acre, which was significantly ($P \leq .05$) greater than the controls (0.17 lb/acre), but not different from the sheared watersheds (Table 36).

Magnesium (Mg) concentrations and losses were the lowest of the elements analyzed prior to treatment. During this period discharge weighted concentrations averaged 0.8 ppm for all watersheds (Table 33). Magnesium export during the pretreatment year was 0.3 lb/acre (Table 34). Posttreatment discharge weighted Mg concentrations increased to 1.5 ppm for the sheared and chopped watersheds and 1.3 ppm on the undisturbed watersheds (Table 35). Significant ($P \leq .05$) differences in Mg export was found only between the sheared and undisturbed watersheds (Table 36). Total Mg loss for 1981 was 1.29, 0.63 and 0.14 lb/acre for the sheared, chopped and undisturbed watersheds, respectively.

Table 33. Potassium, calcium, magnesium and sodium concentrations (ppm) by storm from undisturbed watersheds - 1980.

Storm Date	Watershed	Potassium	Calcium	Magnesium	Sodium
January 21	1	1.6	3.0	1.0	--[1]
	2	2.2	4.0	1.3	--
	3	3.0	5.0	1.3	--
	4	2.8	4.0	1.4	--
	5	0.5	3.0	0.8	--
	6	0.2	1.3	0.4	--
	7	2.6	4.0	1.5	--
	8	2.4	3.0	1.1	--
	9	2.8	5.0	1.7	
February 8-9	2	0.4	3.3	0.8	--
	6	0.5	1.8	0.5	--
	9	1.6	4.0	1.6	--
April 13	1	1.0	3.0	0.9	1.1
	2	2.0	2.9	0.9	1.9
	6	1.6	2.1	1.0	1.9
	9	1.3	1.3	0.6	--
May 15	1	0.4	2.3	0.4	0.9
	2	0.4	1.6	0.9	2.0
	3	7.6	2.3	0.6	--
	4	2.2	2.1	0.7	1.1
	5	2.3	1.9	0.8	1.4
	6	1.0	0.6	0.5	0.3
	7	2.2	2.1	0.9	1.1
	8	2.3	2.3	0.8	1.1
	9	2.4	2.1	0.8	1.5
Discharge weighted concentrations - 1980[2]		2.0	2.2	0.8	1.2

[1] No sample.

[2] Mean concentration is weighted by stormflow.

Table 34. Potassium, calcium, magnesium and sodium loss (lb/acre) from undisturbed watersheds - 1980.

Storm Date	Watershed	Potassium	Calcium	Magnesium	Sodium
January 21	1	.044	.082	.027	--[1/]
	2	.213	.388	.126	--
	3	.078	.130	.034	--
	4	.081	.116	.041	--
	5	.021	.119	.032	--
	6	.018	.115	.032	--
	7	.148	.228	.085	--
	8	.048	.060	.022	--
	9	.351	.627	.213	--
February 8-9	2	.015	.124	.031	--
	6	.018	.069	.020	--
	9	.079	.197	.079	--
April 13	1	.007	.020	.006	.007
	2	.071	.104	.032	.034
	6	.032	.043	.020	.040
	9	.029	.029	.012	--
May 15	1	.071	.387	.068	.156
	2	.123	.458	.263	.556
	3	.118	.346	.093	--
	4	.385	.381	.129	.204
	5	.617	.509	.213	.375
	6	.288	.173	.139	.082
	7	.463	.459	.190	.233
	8	.477	.473	.169	.223
	9	.768	.671	.250	.493
Mean total loss - 1980		.66	.82	.30	.32

[1/] No sample.

Table 35. Mean potassium, calcium, magnesium, and sodium concentrations (ppm) by storm and treatment - 1981.

Storm Date	Treatment	Potassium	Calcium	Magnesium	Sodium
February 10	Shear (2)[1/]	6.8	0.9	2.5	5.1
March 3	Shear (3)	6.0 a[2/]	1.5 a	1.6 a	2.5 a
	Chop (3)	6.8 a	4.4 a	1.1 a	2.1 a
	Control (1)	2.2 a	1.4 a	1.0 a	2.1 a
May 9	Shear (3)	6.7 a	0.8 a	2.5 a	1.3 a
	Chop (3)	7.1 a	4.1 a	2.0 a	2.4 a
	Control (1)	1.6 a	1.5 a	1.5 a	1.4 a
May 16	Shear (3)	5.0 a	0.3 a	1.8 a	1.1 a
	Chop (1)	5.0 a	2.1 a	2.4 a	3.1 b
May 24	Shear (2)	6.4	1.0	2.8	2.3
May 30	Shear (3)	5.4 a	0.9 a	2.3 a	2.9 a
	Chop (3)	3.6 a	2.2 b	1.4 b	0.9 a
	Control (1)	1.8 a	1.4 ab	1.4 b	1.0 a
June 3	Shear (3)	7.8 a	1.3 a	2.4 a	2.0 a
	Chop (3)	3.7 b	1.8 a	1.5 b	1.8 a
	Control (1)	1.7 b	1.3 a	1.5 b	1.5 a
June 4	Shear (3)	5.1 a	0.8 a	1.5 a	0.8 a
	Chop (3)	6.3 a	2.9 a	1.5 a	2.1 a
	Control (3)	3.3 a	2.1 a	1.3 a	1.6 a
June 10	Shear (2)	6.4	0.9	1.5	2.7
June 12	Shear (3)	6.1 a	0.6 a	1.4 a	0.9 a
	Chop (3)	4.8 a	2.1 b	1.5 a	1.8 a
June 23	Shear (2)	4.9	0.5	1.6	3.2
July 7	Shear (3)	3.5 a	0.8 a	1.1 a	0.9 a
	Chop (1)	2.8 a	1.7 b	1.0 a	1.6 b
July 8	Shear (2)	4.0	0.8	1.4	3.0
Discharge weighted [3/] concentrations - 1981	Shear	4.6	0.8	1.5	1.4
	Chop	5.6	3.0	1.5	1.9
	Control	2.4	1.6	1.3	1.6

[1/] The number of samples in each mean.

[2/] Means for each storm and within a variable followed by the same letter are not significantly different ($P \leq .05$) according to Duncan's multiple range test.

[3/] Mean concentration is weighted by stormflow.

Table 36. Mean potassium, calcium, magnesium and sodium loss (lb/acre) by storm and treatment - 1981.

Storm Date	Treatment	Potassium	Calcium	Magnesium	Sodium
February 10	Shear (2)[1/]	.128	.017	.048	.085
March 3	Shear (3)	.684 a[1/]	.172 a	.175 a	.244 a
	Chop (3)	.314 a	.205 a	.053 b	.099 a
	Control (1)	.068 a	.044 a	.030 b	.065 a
May 9	Shear (3)	.741 a	.086 a	.284 a	.142 a
	Chop (3)	.540 a	.255 a	.186 a	.138 a
	Control (1)	.018 a	.017 a	.018 a	.016 a
May 16	Shear (3)	.090 a	.006 a	.034 a	.020 a
	Chop (1)	.056 a	.023 a	.027 a	.035 a
May 24	Shear (2)	.015	.002	.007	.005
May 30	Shear (3)	.576 a	.091 a	.241 a	.316 a
	Chop (3)	.246 a	.123 a	.076 b	.063 a
	Control (1)	.039 a	.030 a	.030 b	.021 a
June 3	Shear (3)	.357 a	.062 a	.107 a	.094 a
	Chop (3)	.137 a	.063 a	.051 a	.066 a
	Control (1)	.018 a	.013 a	.016 a	.016 a
June 4	Shear (3)	.828 a	.123 a	.257 a	.155 a
	Chop (3)	.736 a	.314 b	.177 ab	.228 a
	Control (3)	.121 b	.067 a	.050 b	.042 a
June 10	Shear (2)	.018	.002	.004	.006
June 12	Shear (3)	.212	.021	.047	.030
	Chop (3)	.138	.052	.039	.042
June 23	Shear (2)	.024	.002	.008	.016
July 7	Shear (3)	.173 a	.037 a	.052 a	.042 a
	Chop (1)	.046 a	.028 a	.016 a	.025 a
July 8	Shear (2)	.073	.014	.025	.051
Total loss (Jan.-Aug. 1981)	Shear	3.92 a	0.64 ab	1.29 a	1.21 a
	Chop	2.21 ab	1.06 a	0.63 ab	0.70 ab
	Control	0.26 b	0.17 b	0.14 b	0.16 b

1/The number of samples in each mean.

2/Means for each storm and within a variable followed by the same letter are not significantly different ($P \leq .05$) according to Duncan's multiple range test.

Discharge weighted sodium (Na) concentrations for the 2 storms analyzed in 1980 was 1.2 ppm (Table 33). Following treatment discharge weighted concentrations were ranked: chopped (1.9 ppm), control (1.6 ppm) and sheared (1.4 ppm) (Table 35). Sodium concentrations showed no significant ($P \leq .05$) differences between treatments except on the May 16 and July 7 runoff event, where chopped watersheds were significantly higher than sheared watersheds. Total Na export for the undisturbed watersheds was 0.32 lb/acre during 1980 and 0.16 lb/acre during 1981 (Tables 34 and 36). Sodium export on the treated watersheds were 1.21 lb/acre on sheared and 0.70 lb/acre on the chopped.

Although element concentrations were greatest on the chopped watersheds, the higher volume of runoff on sheared watersheds produced higher export for all elements except Ca. Apparently the lower concentration of elements on the sheared watersheds results from dilution.

pH, Specific Conductivity, and Turbidity

During 1980 and 1981, pH, specific conductivity, and turbidity were determined for the majority of stormflow samples. A pH of 5.4 during the May 15, 1980 storm event was the only pH sample taken in 1980 (Table 37). Specific conductivity averaged 25.5 µmhos/cm for the two storms sampled in 1980. Turbidity during the pretreatment year ranged from 36 NTU on the April 13 storm event to 66 NTU during the large runoff event on May 15.

Following site preparation, pH values had little variation between treatments. Sheared watersheds averaged 6.3, chopped 6.4 and undisturbed watersheds 6.1 pH (Table 38). Mean specific conductivity ranged from 5 µmhos/cm on the chopped watersheds during the March 3 runoff event to 75 µmhos/cm on the sheared watersheds following the February 10 storm. The chopped watersheds for 1981 had the highest mean conductivity for the year with 40 µmhos/cm, followed by the sheared (39 µmhos/cm) and undisturbed watersheds (29 µmhos/cm). A mean turbidity of 165 NTU was measured on the sheared watersheds during the 1981 stormflows. Chopped and undisturbed watersheds had much lower means of 18 NTU and 36 NTU, respectively.

Table 37. Mean pH, specific conductivity, and turbidity prior to treatment - 1980.

Storm Date	pH	Specific Conductivity µmhos/cm	Turbidity NTU
January 22 (9)[1/]	--[2/]	27	--
February 8-9 (9)	--	24	--
April 13 (9)	--	--	36
May 15 (9)	5.4	--	66

[1/] The number of samples in each mean.
[2/] No sample.

Table 38. Mean pH, specific conductivity, and turbidity following treatment - 1981.

Storm Date	Treatment	pH	Specific Conductivity µmhos/cm	Turbidity NTU
February 10	Shear (2)[1/]	6.8	75	233
March 3	Shear (3)	5.4	11	213
	Chop (3)	5.2	5	33
	Control (1)	4.9	9	36
May 9	Shear (3)	6.7	49	186
	Chop (3)	7.3	53	21
	Control (1)	6.7	34	62
May 16	Shear (3)	5.8	30	220
	Chop (1)	6.6	56	14
May 24	Shear (2)	--[2/]	--	84
May 30	Shear (3)	6.6	43	130
	Chop (3)	6.0	36	17
	Control (1)	5.7	30	27
June 3	Shear (3)	6.4	46	130
	Chop (3)	6.5	40	10
	Control (1)	6.9	35	35
June 4	Shear (3)	6.1	33	150
	Chop (3)	6.4	43	12
	Control (3)	6.3	35	22
June 10	Shear (10)	6.9	52	143
June 12	Shear (3)	6.0	41	178
	Chop (3)	6.5	45	15
June 23	Shear (2)	6.4	37	170
July 7	Shear (3)	5.9	25	140
	Chop (1)	6.7	40	19
July 8	Shear (2)	6.1	28	175
Mean - 1981	Shear	6.3	39	165
	Chop	6.4	40	18
	Control	6.1	29	36

[1/] The number of samples in each mean.

[2/] No sample.

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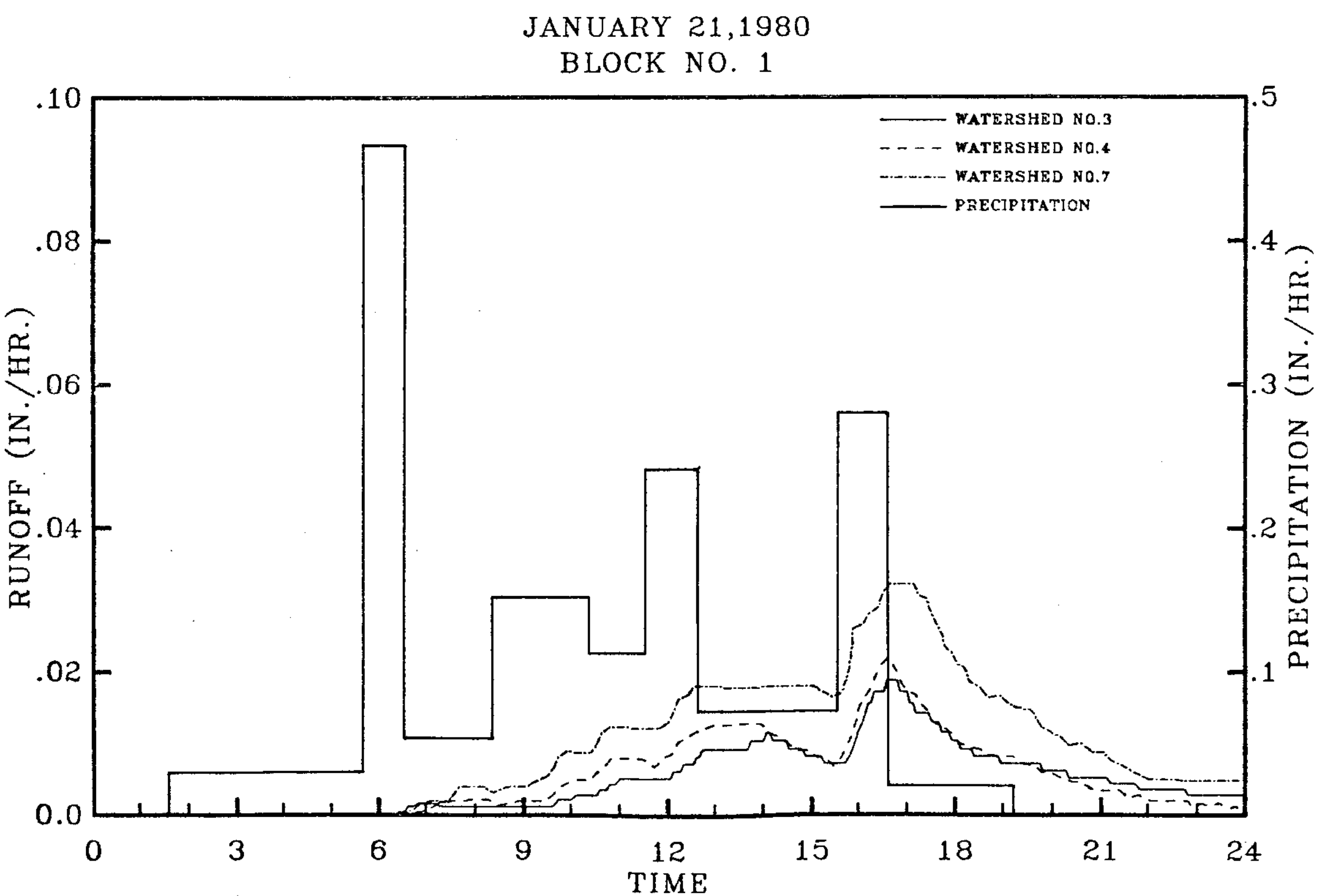
APPENDIX A

Table of Scientific Names

Common Names	Scientific Names
Trees	
Pine	
Loblolly Pine	_Pinus taeda_
Shortleaf Pine	_Pinus echinata_
Oak	
Southern Red Oak	_Quercus falcata_
Blackjack Oak	_Quercus marlandica_
Post Oak	_Quercus stellata_
White Oak	_Quercus alba_
Water Oak	_Quercus nigra_
Hickory	
Mockernut Hickory	_Carya tomentosa_
Elm	
Winged Elm	_Ulmus alata_
Slippery Elm	_Ulmus rubra_
Sweetgum	_Liquidambar styraciflua_
Dogwood	_Cornus florida_
Shrubs and Vines	
American Beautyberry	_Calicarpa americana_
Blackberry	_Rubus_ spp.
Southern Waxmyrtle	_Myrica cerifera_
Virginia Creeper	_Parthenocissus quinquefolia_
Greenbriar	_Smilax_ spp.
Poison Ivy	_Toxicodendron radicans_

APPENDIX B

Storm Hydrographs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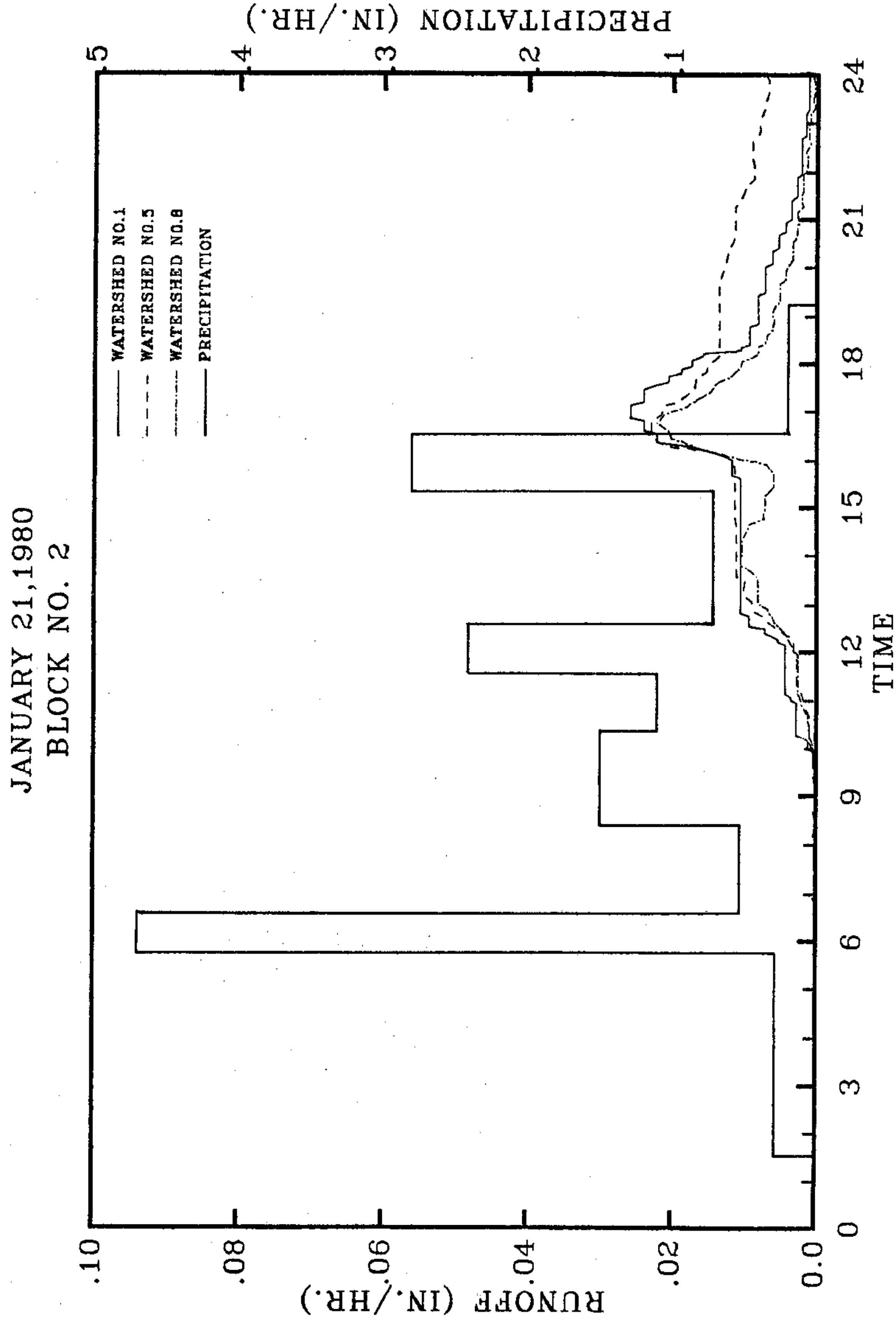
TIME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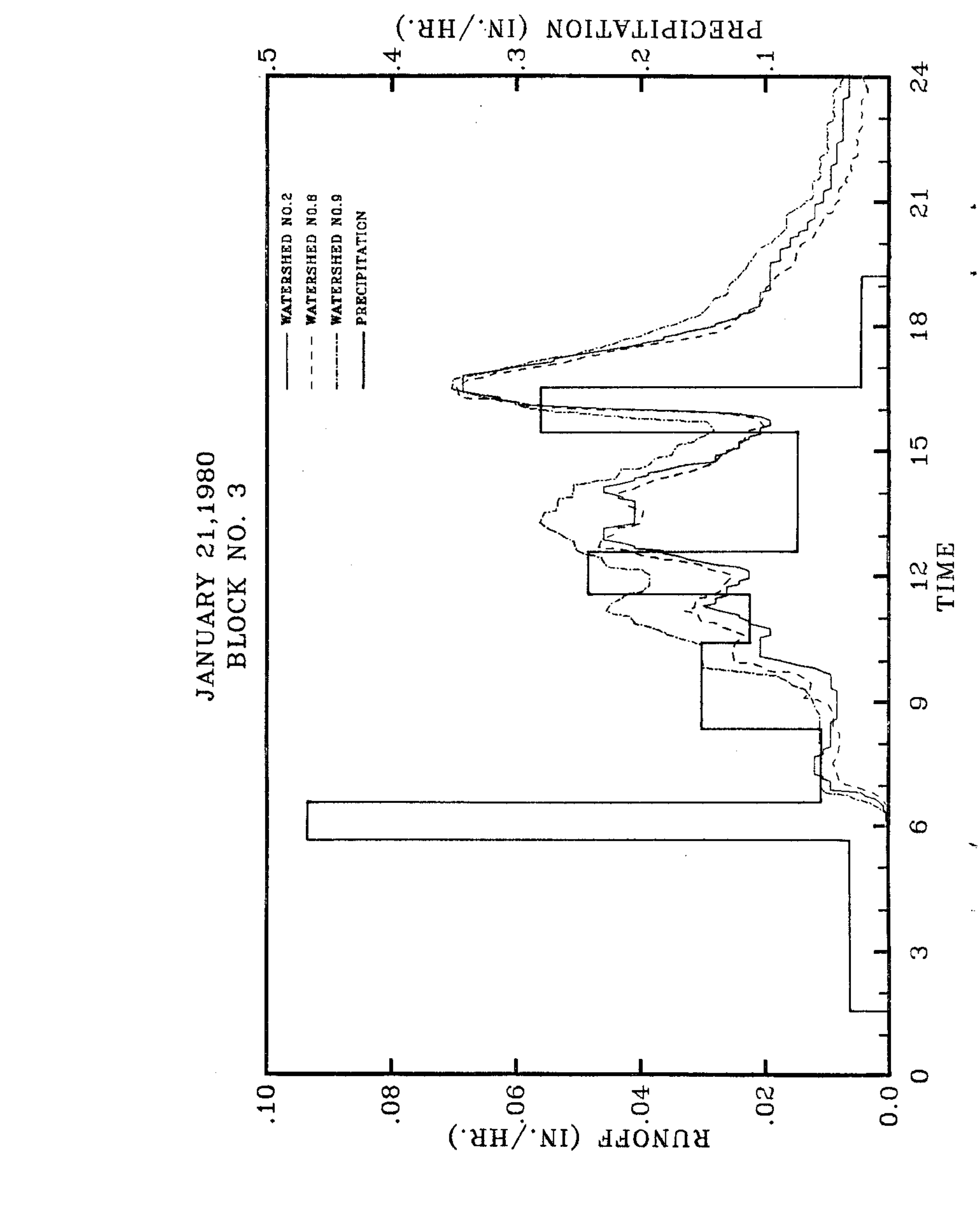

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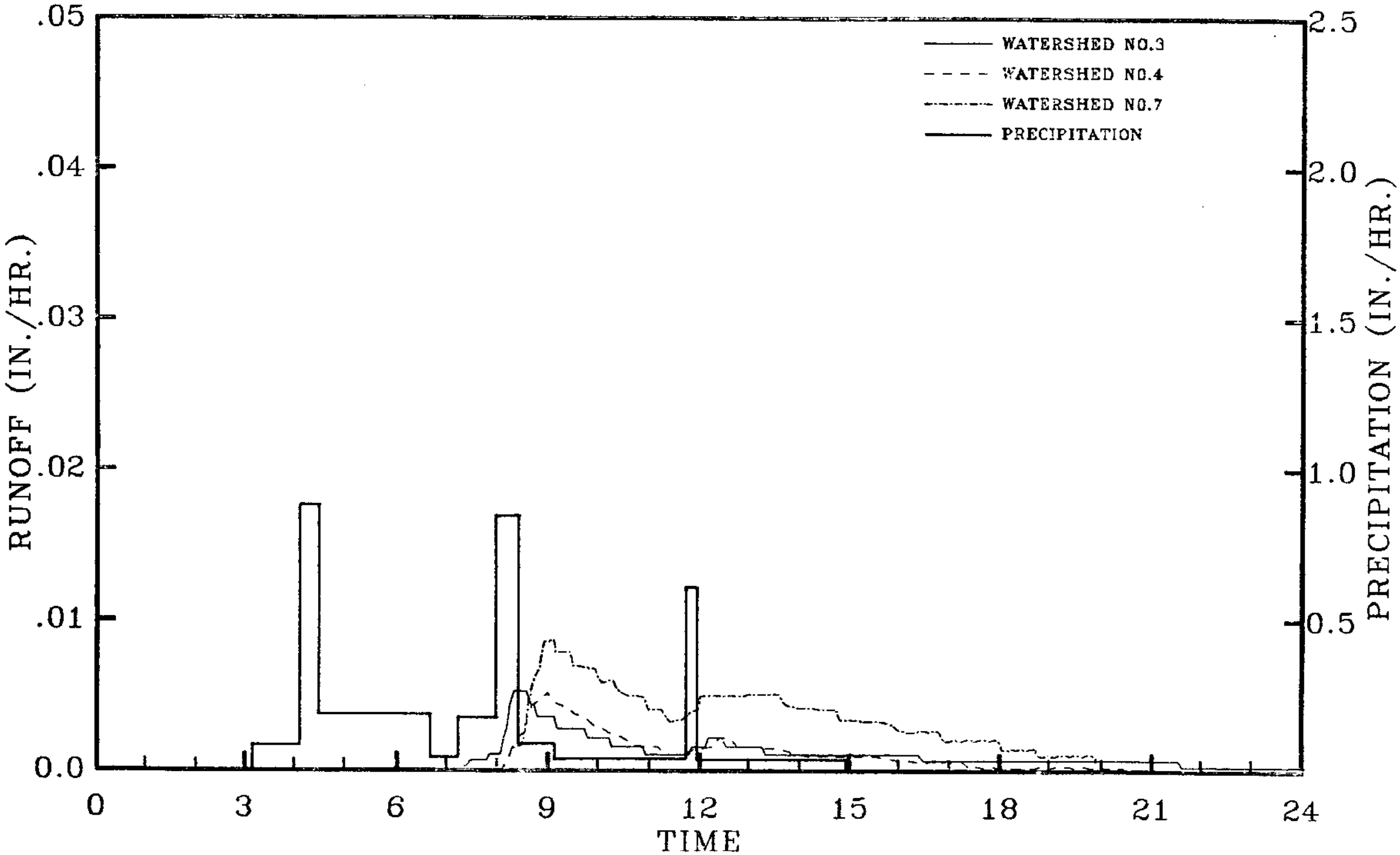

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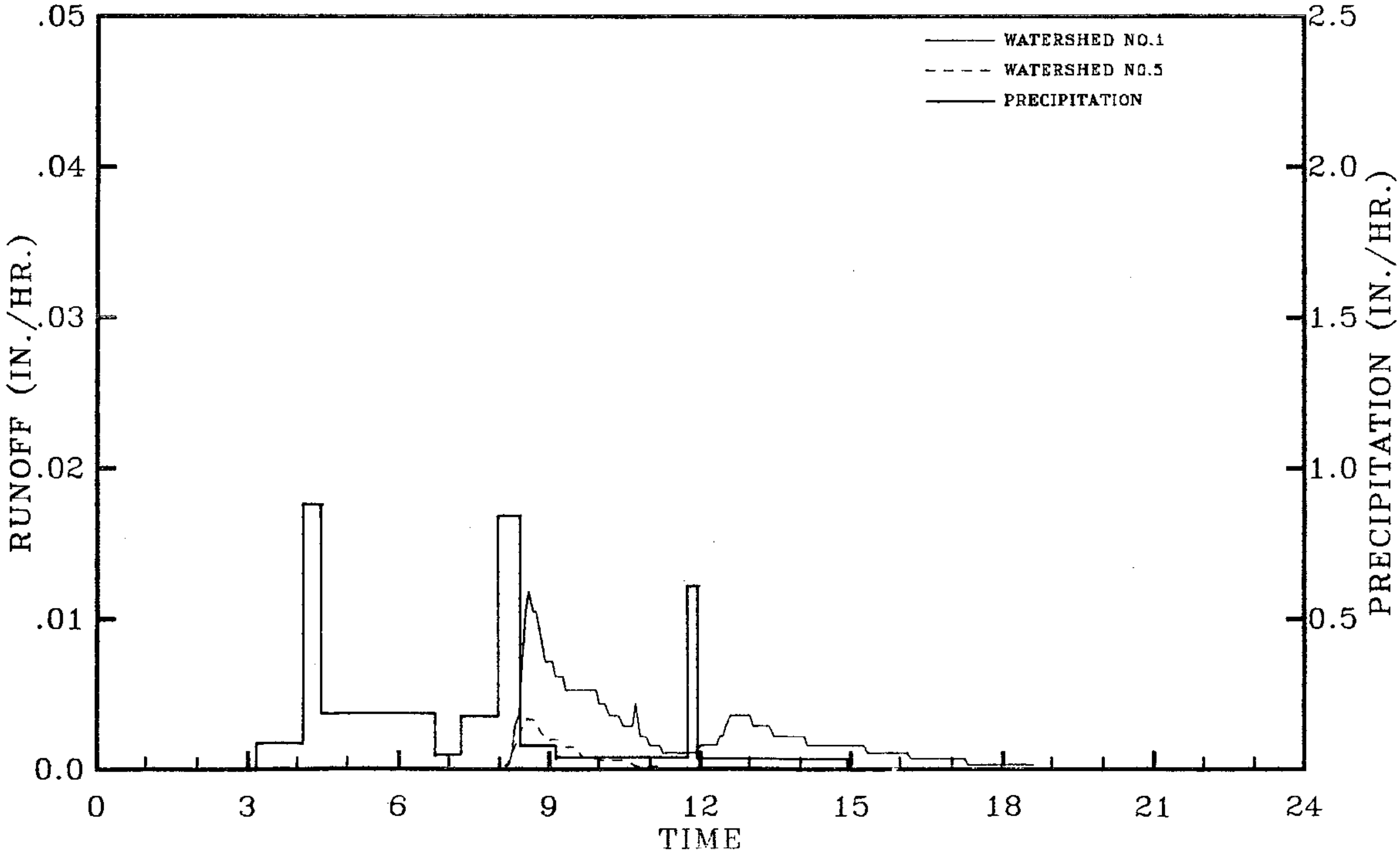

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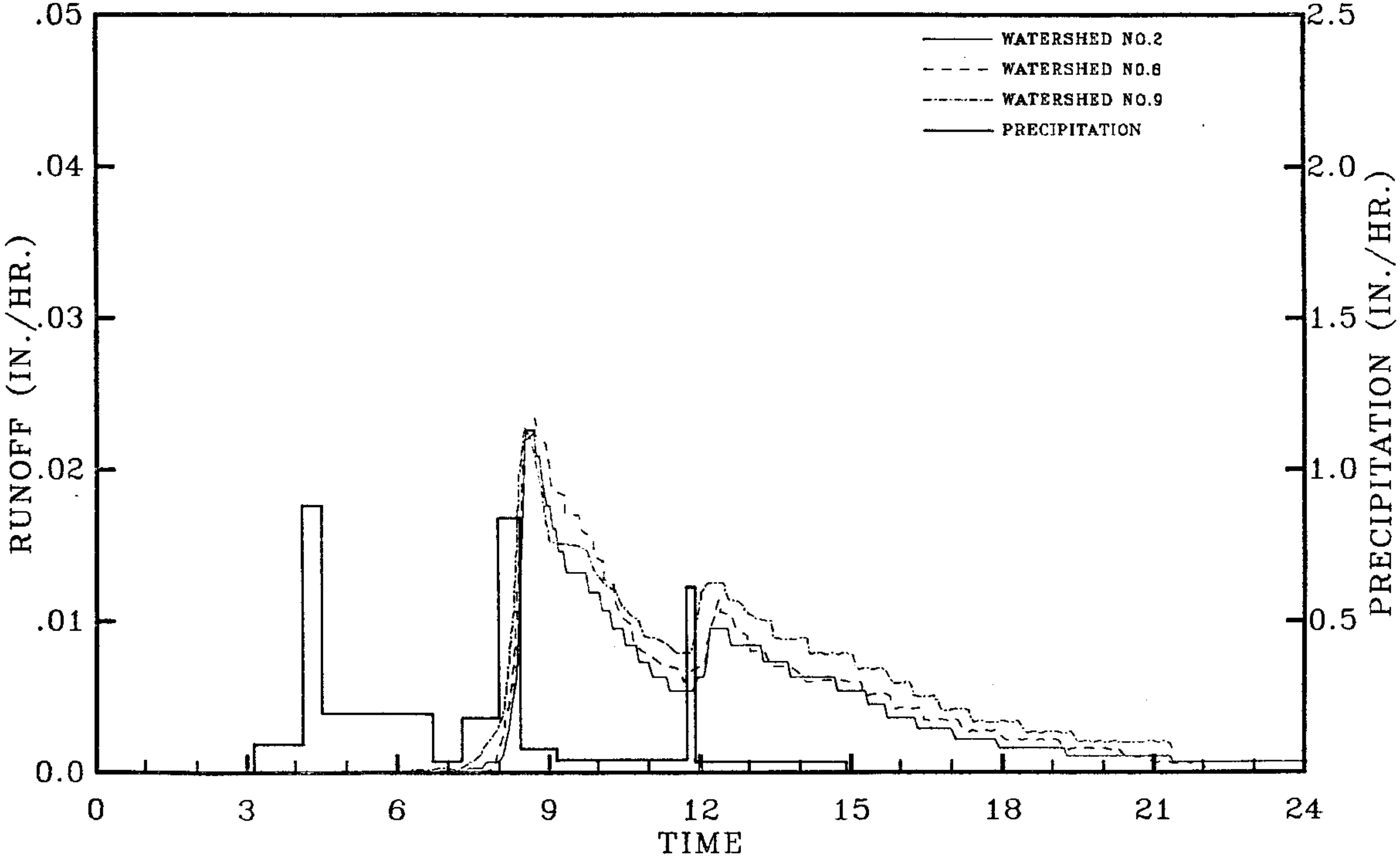

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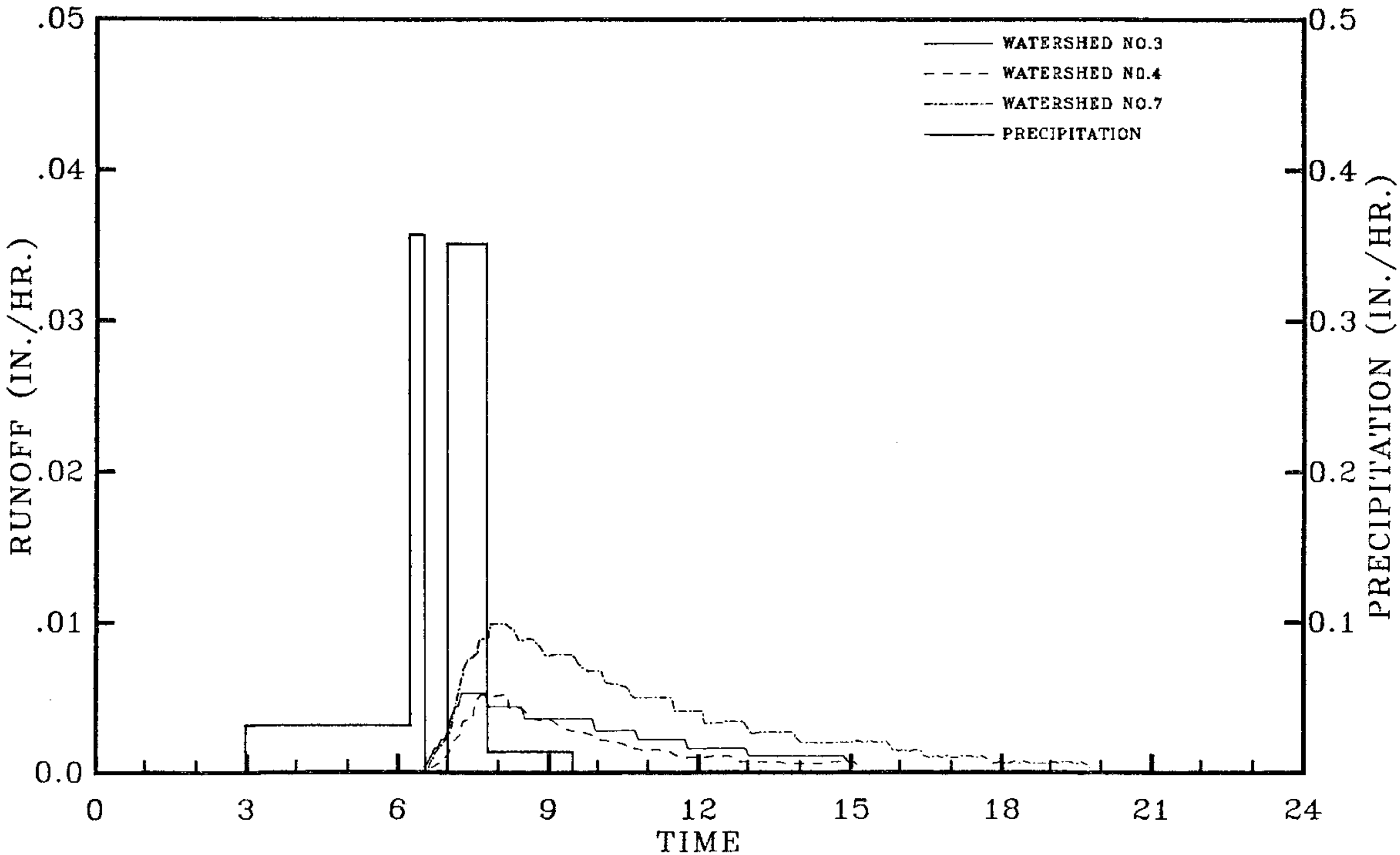

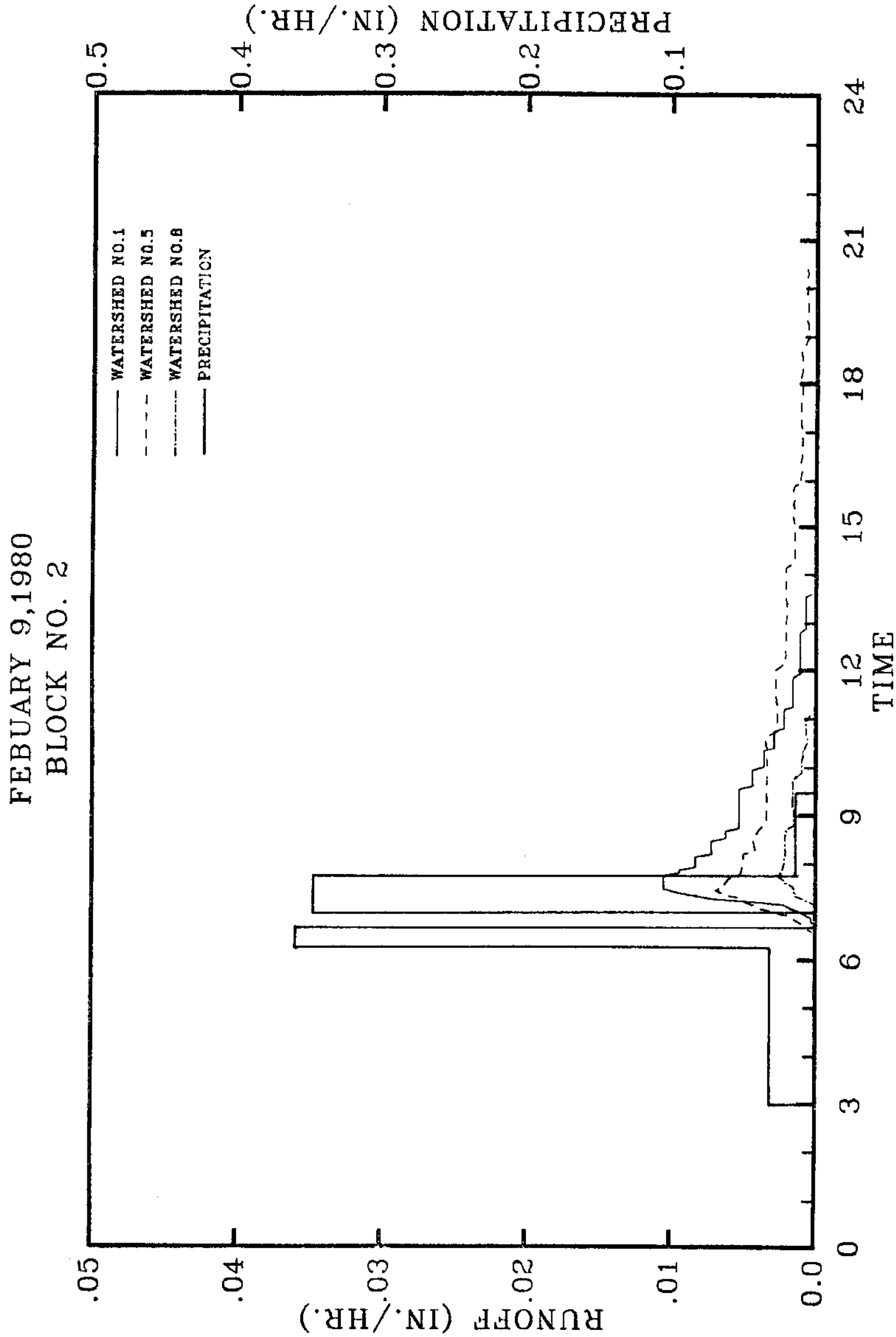
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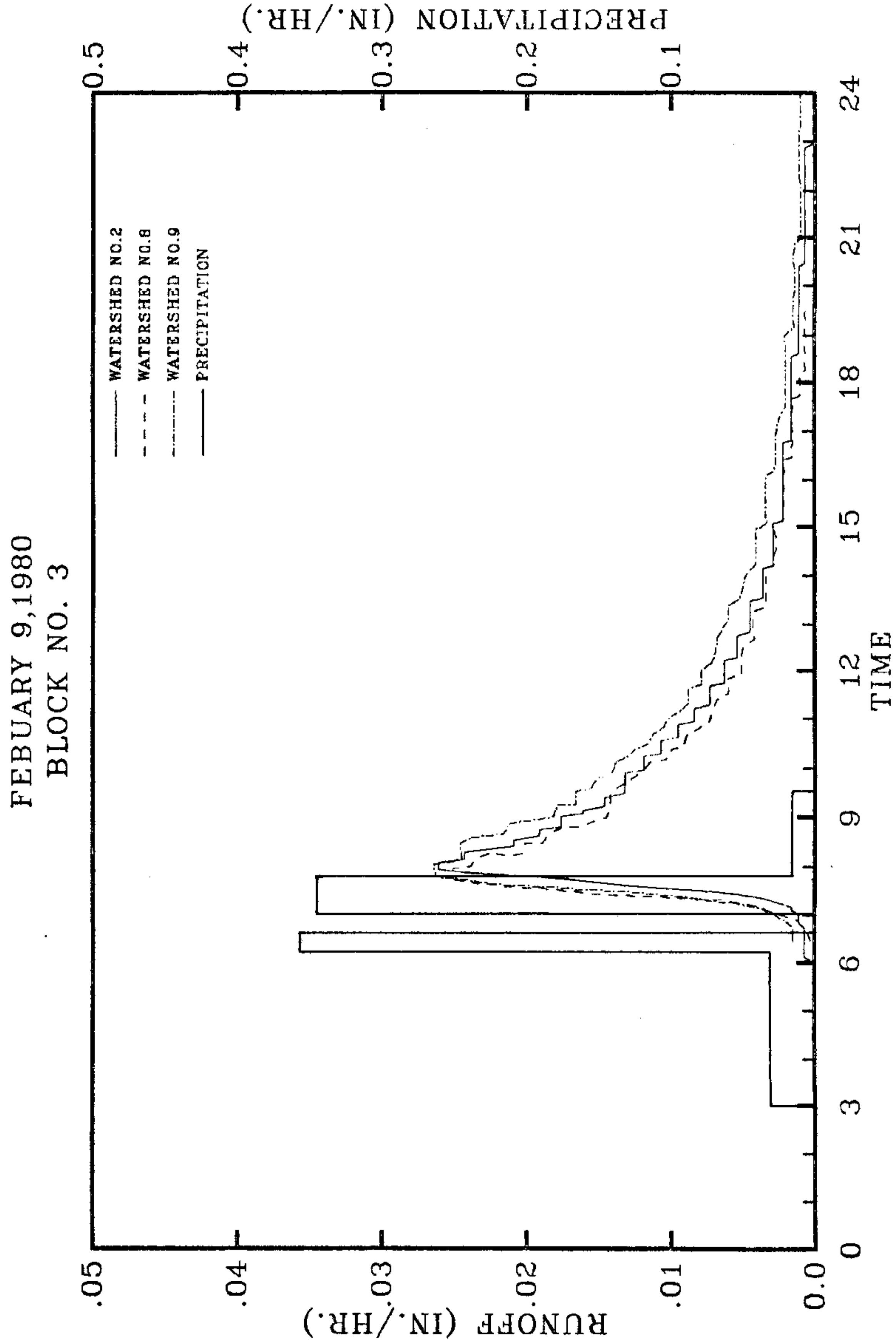
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TIME

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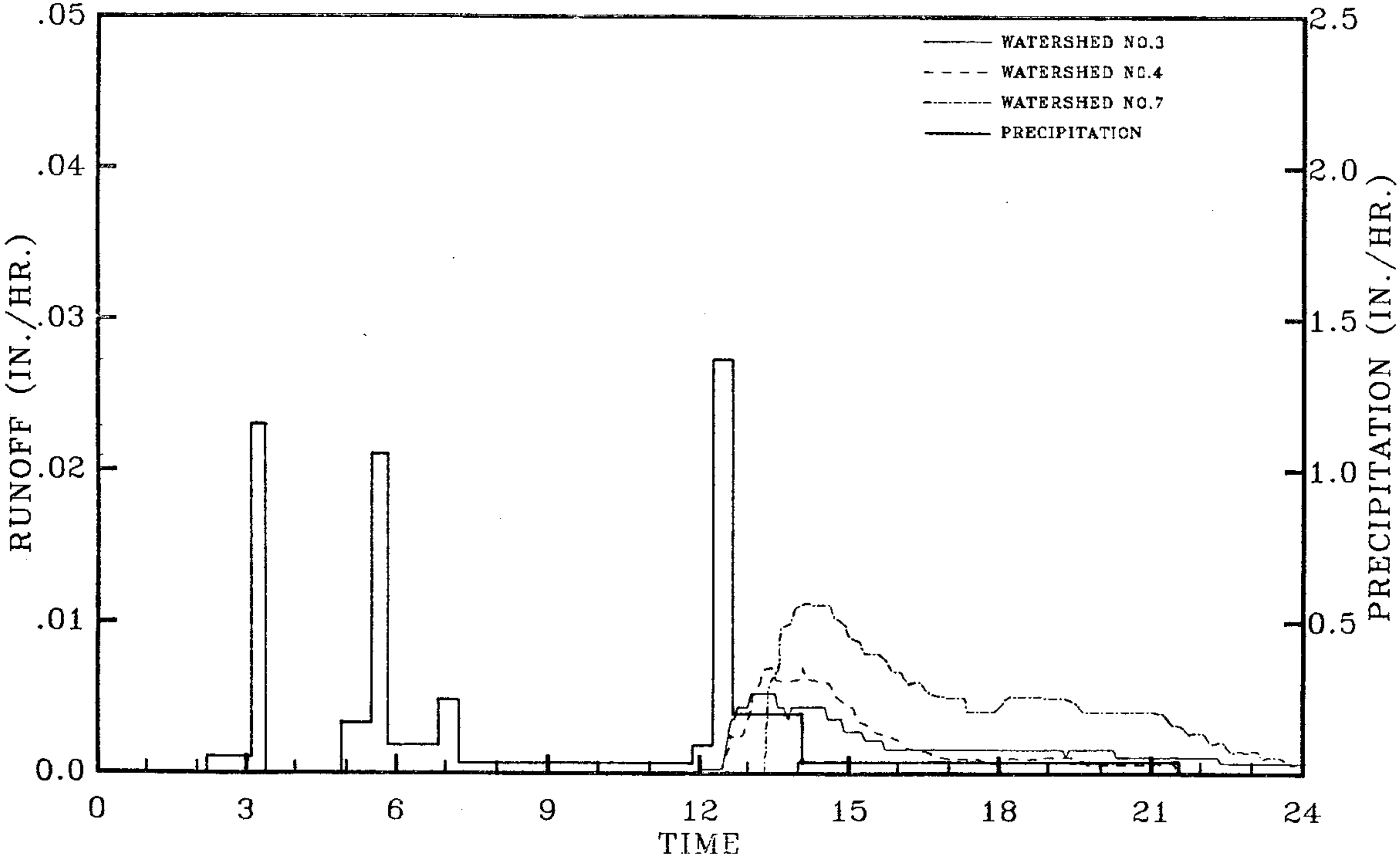

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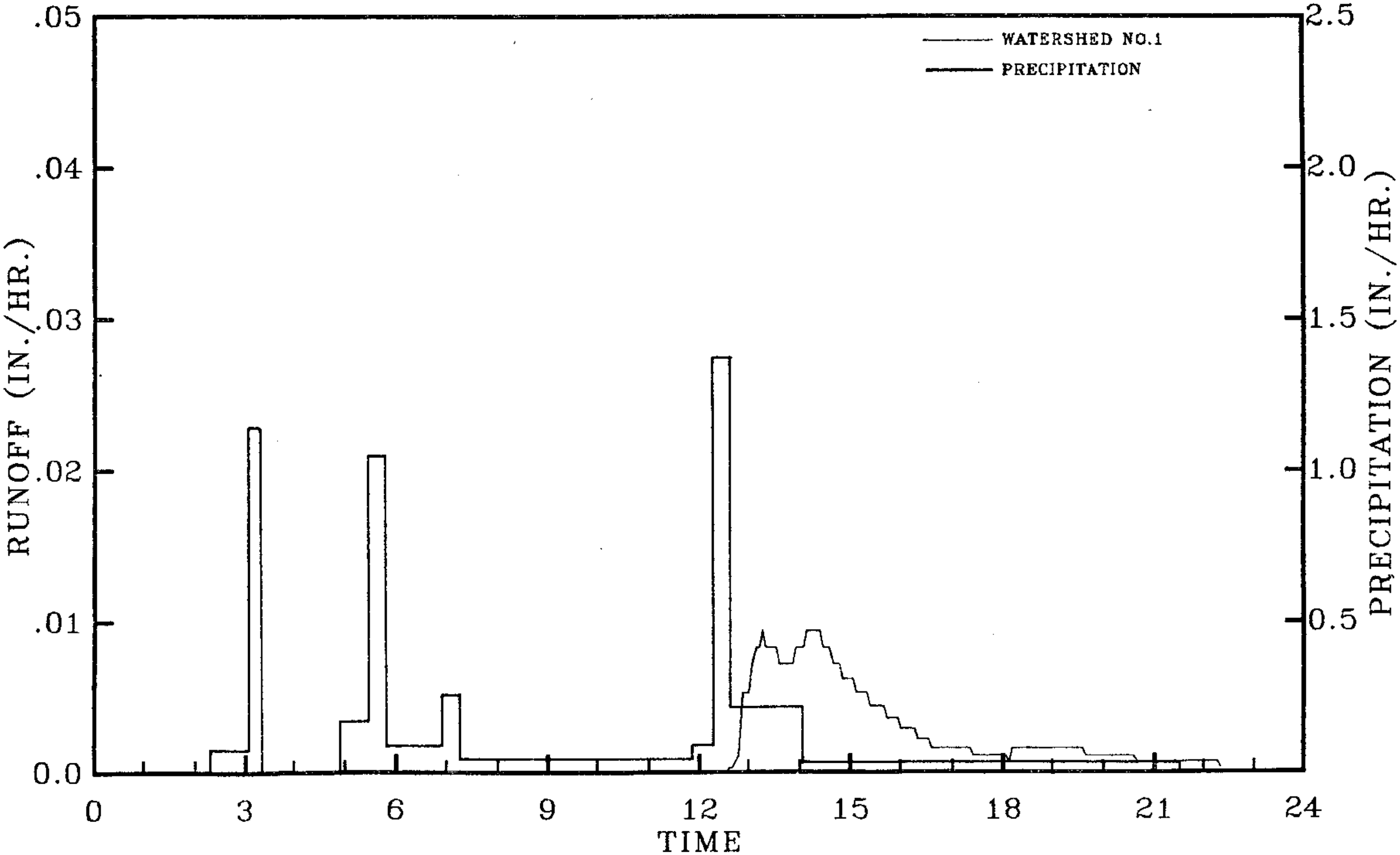

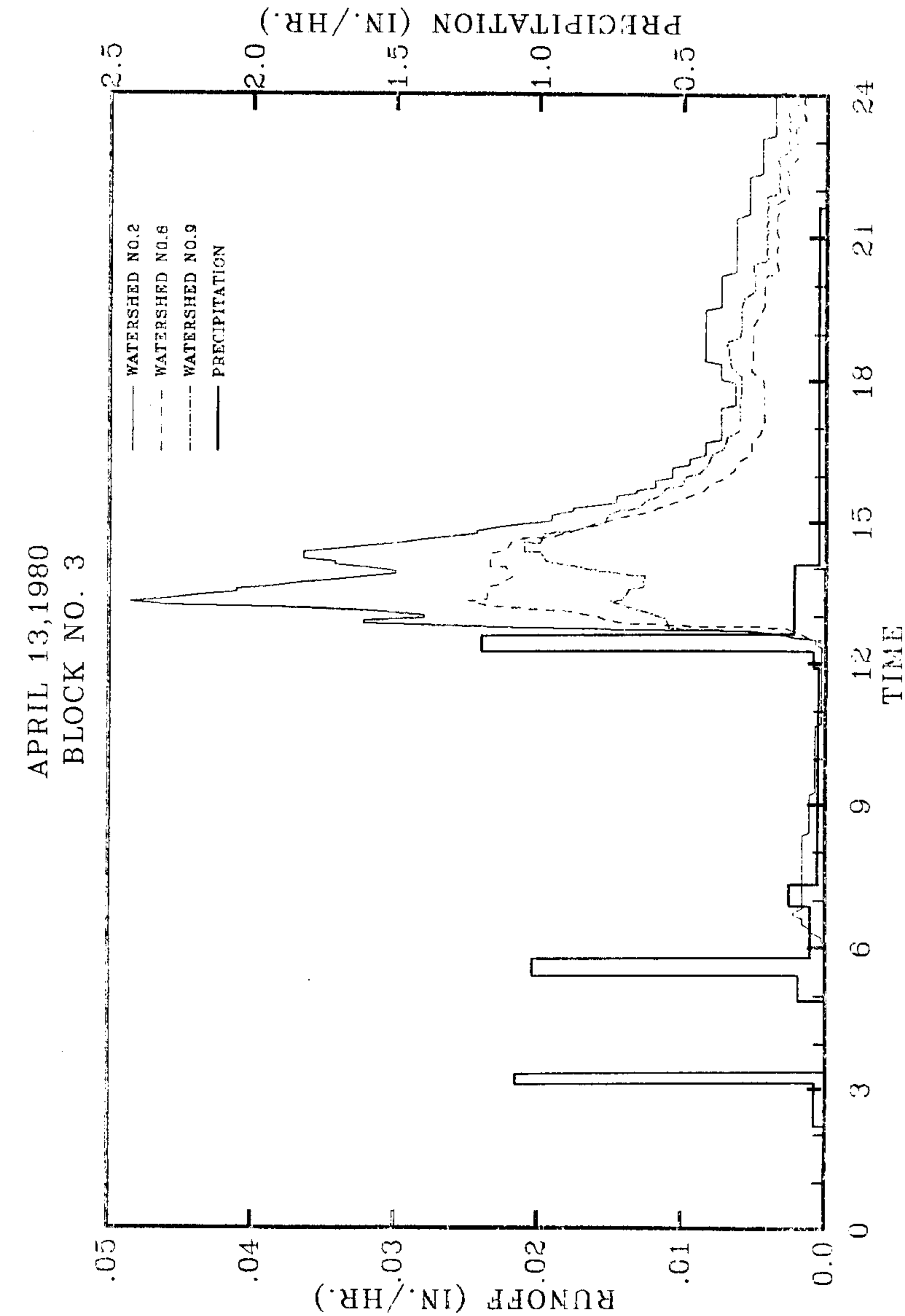
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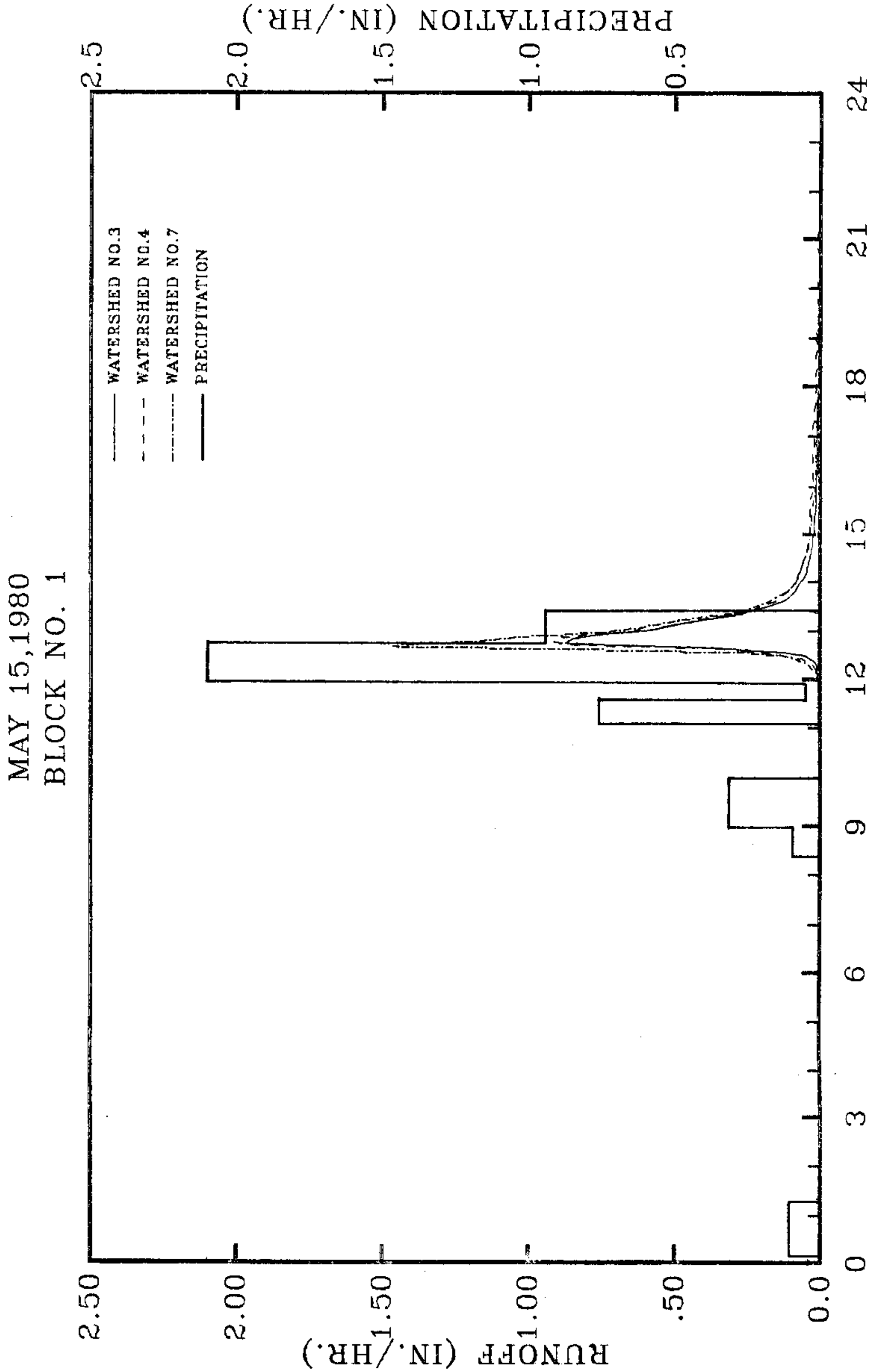
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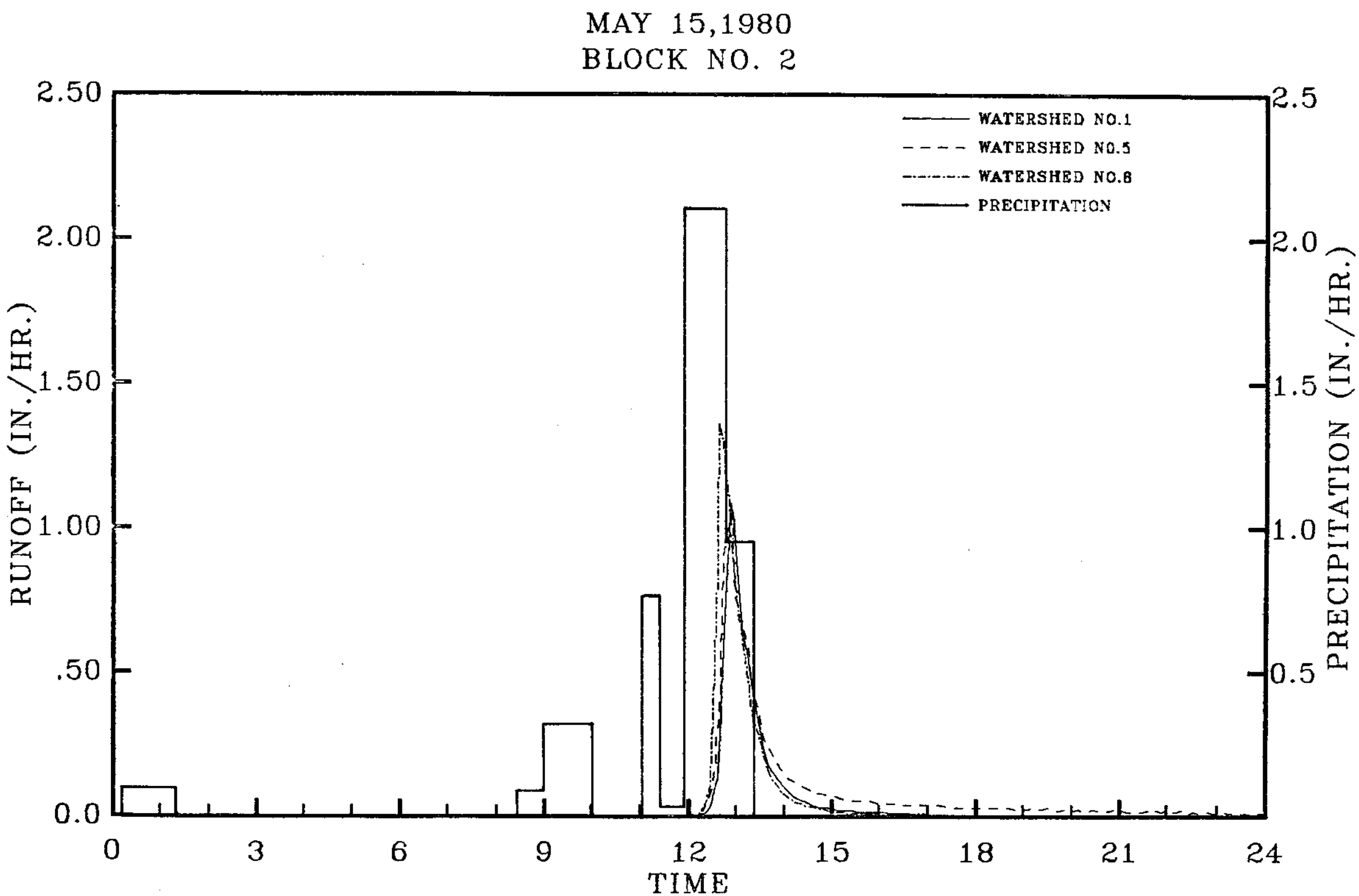
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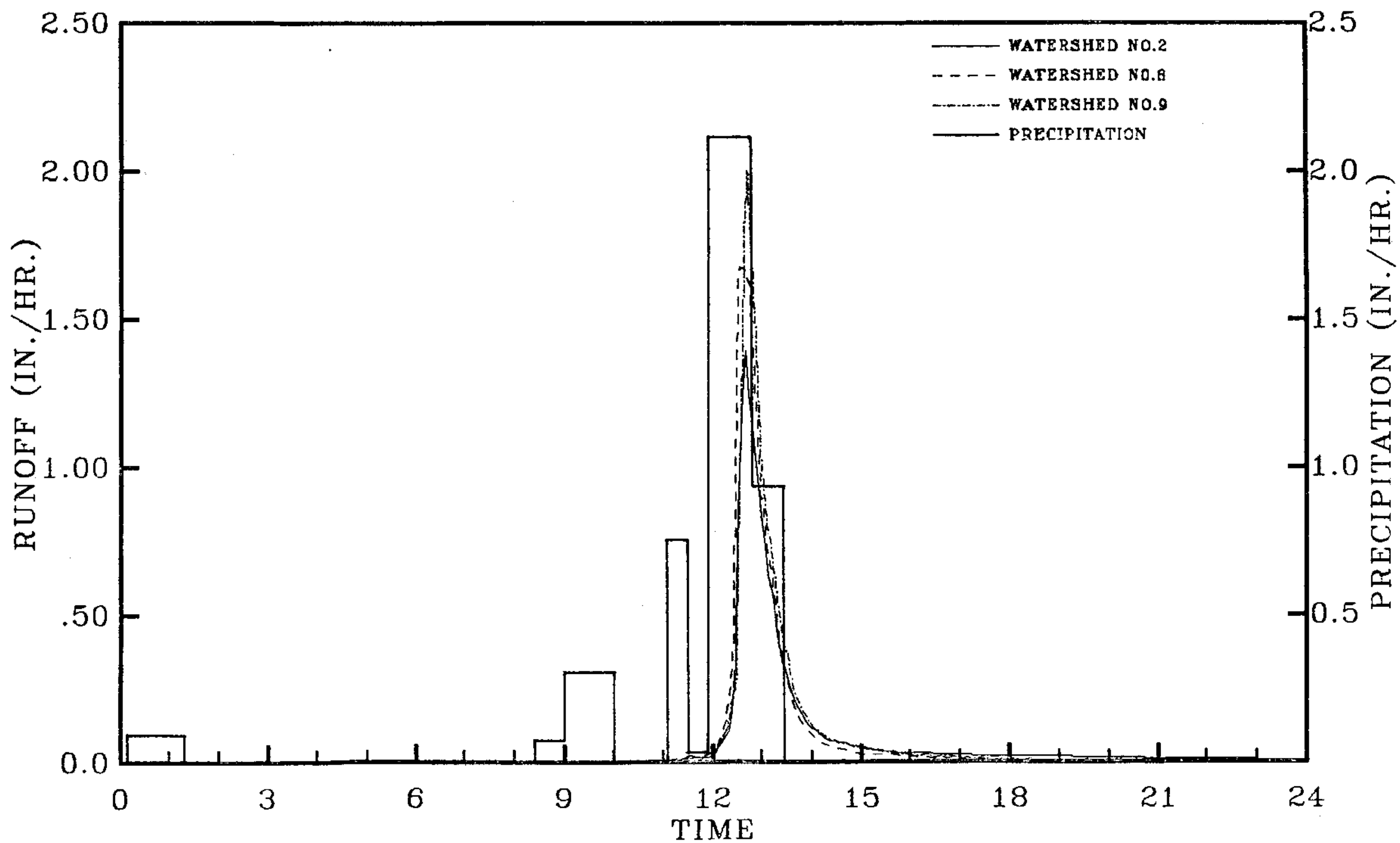

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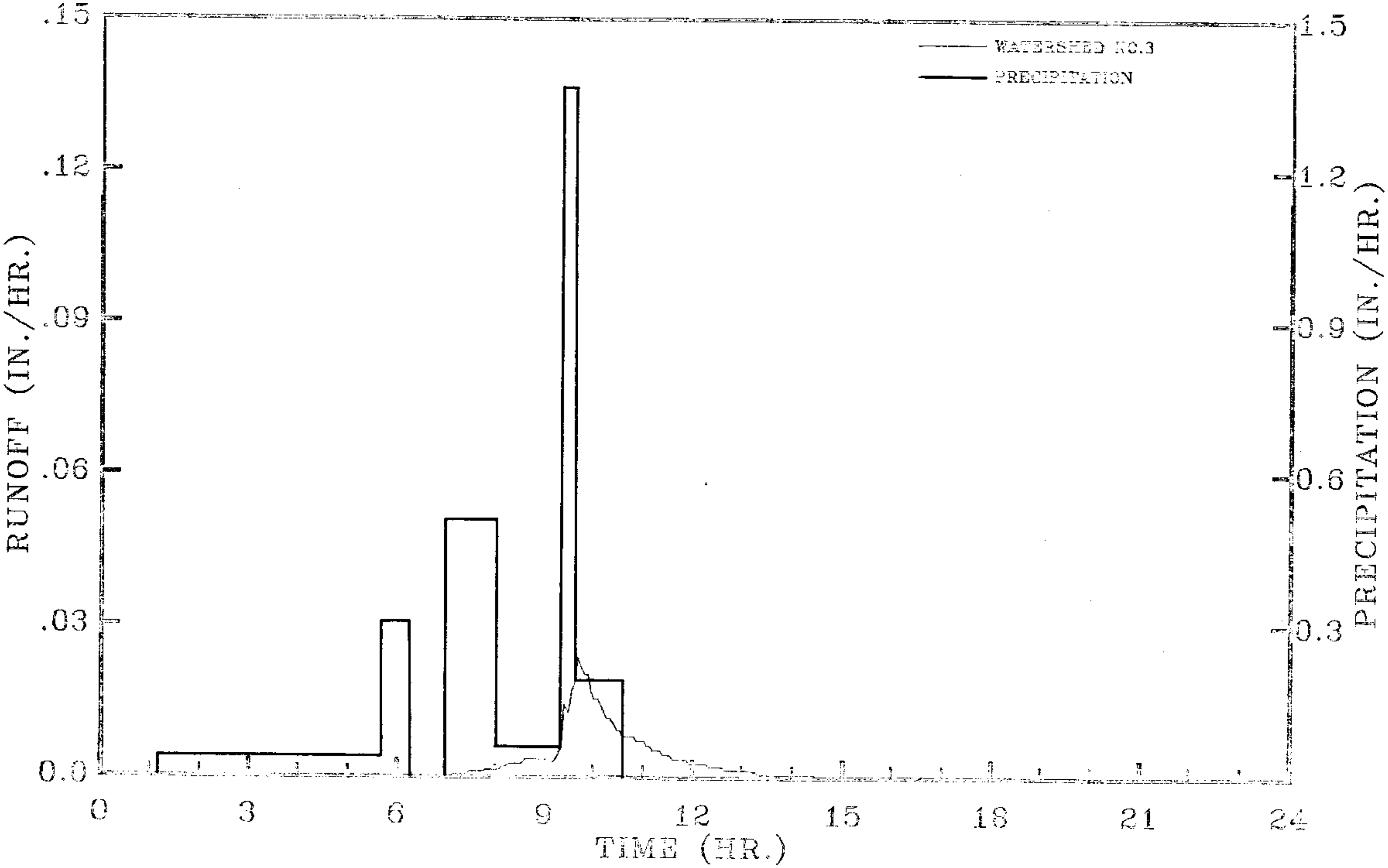

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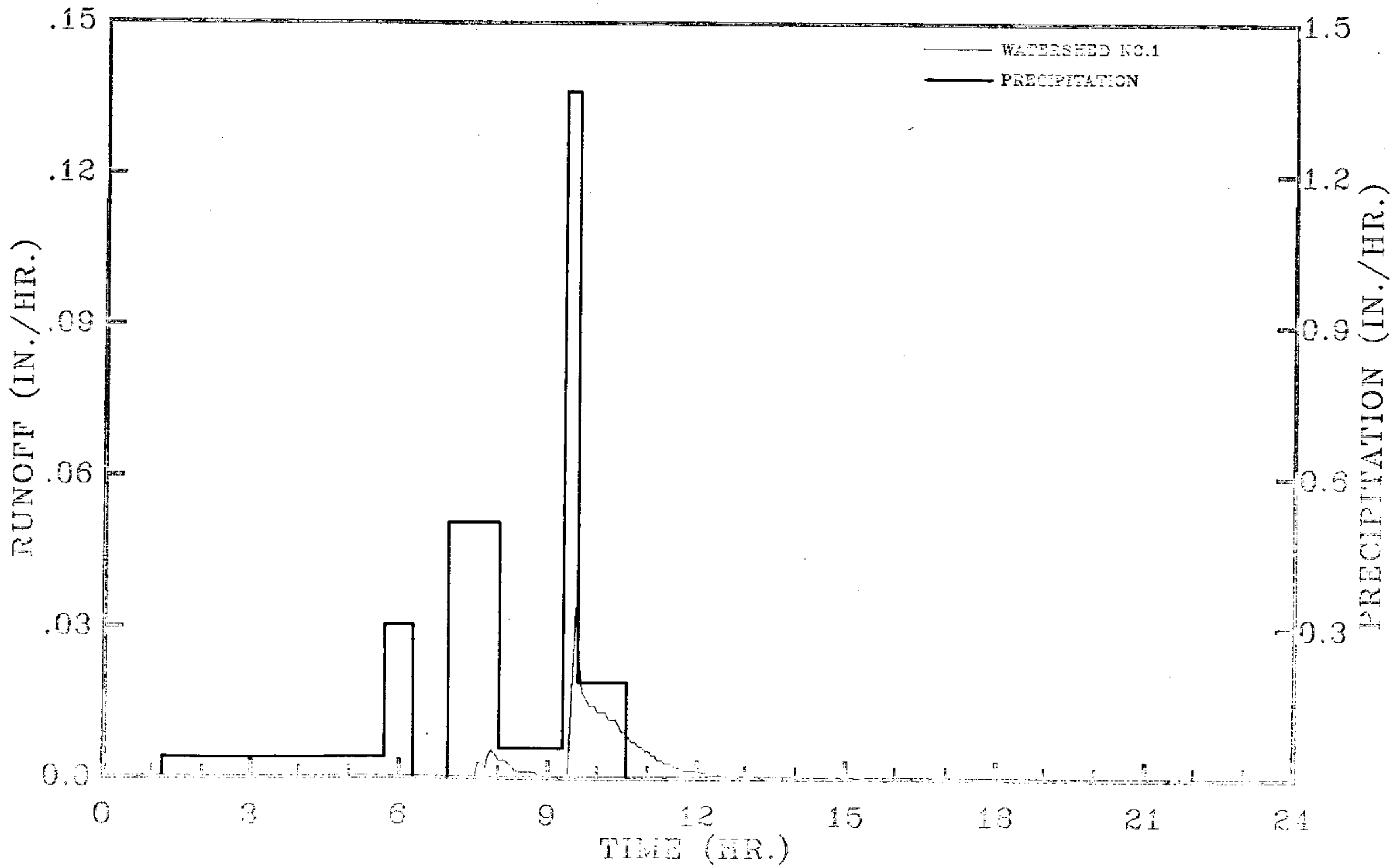

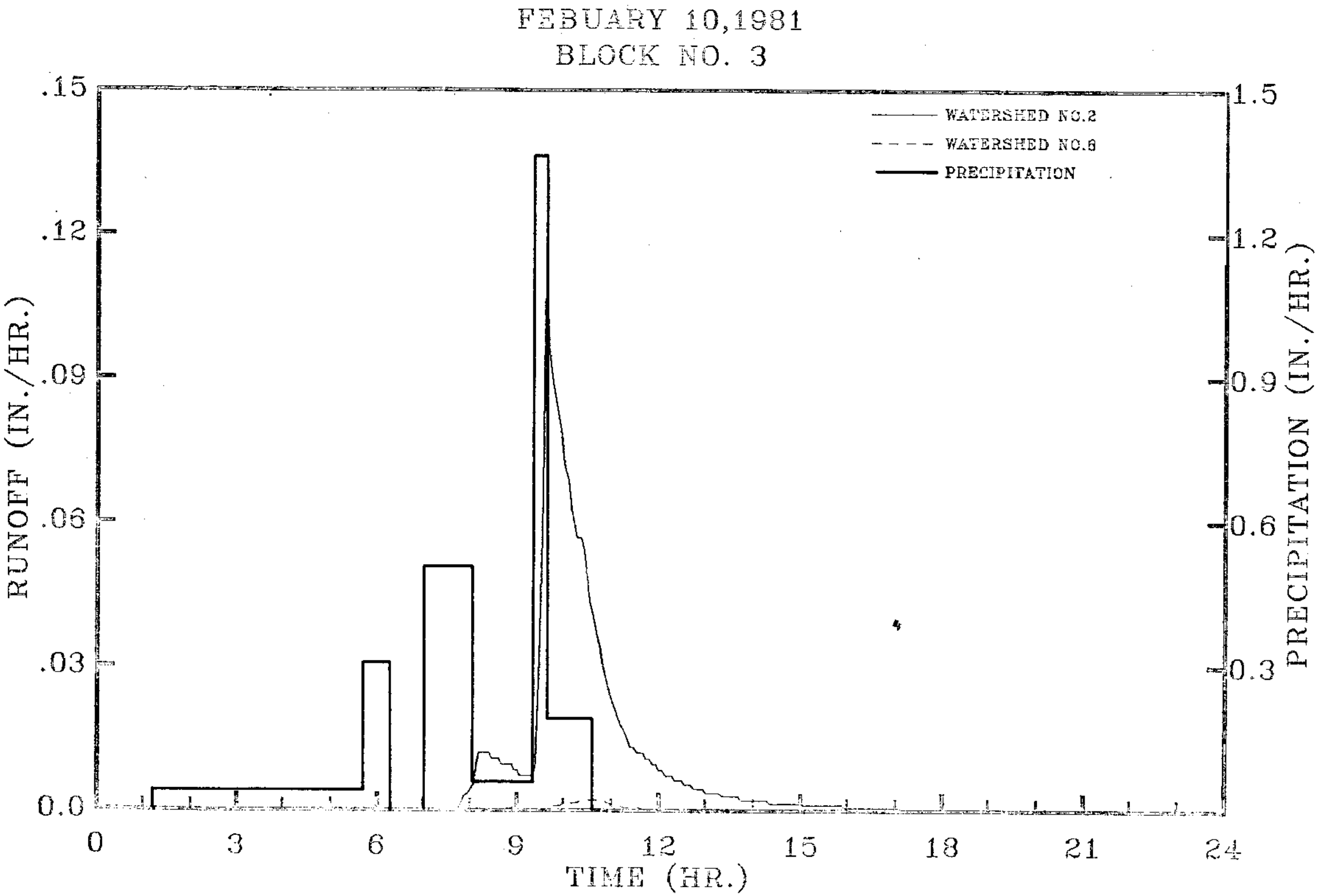
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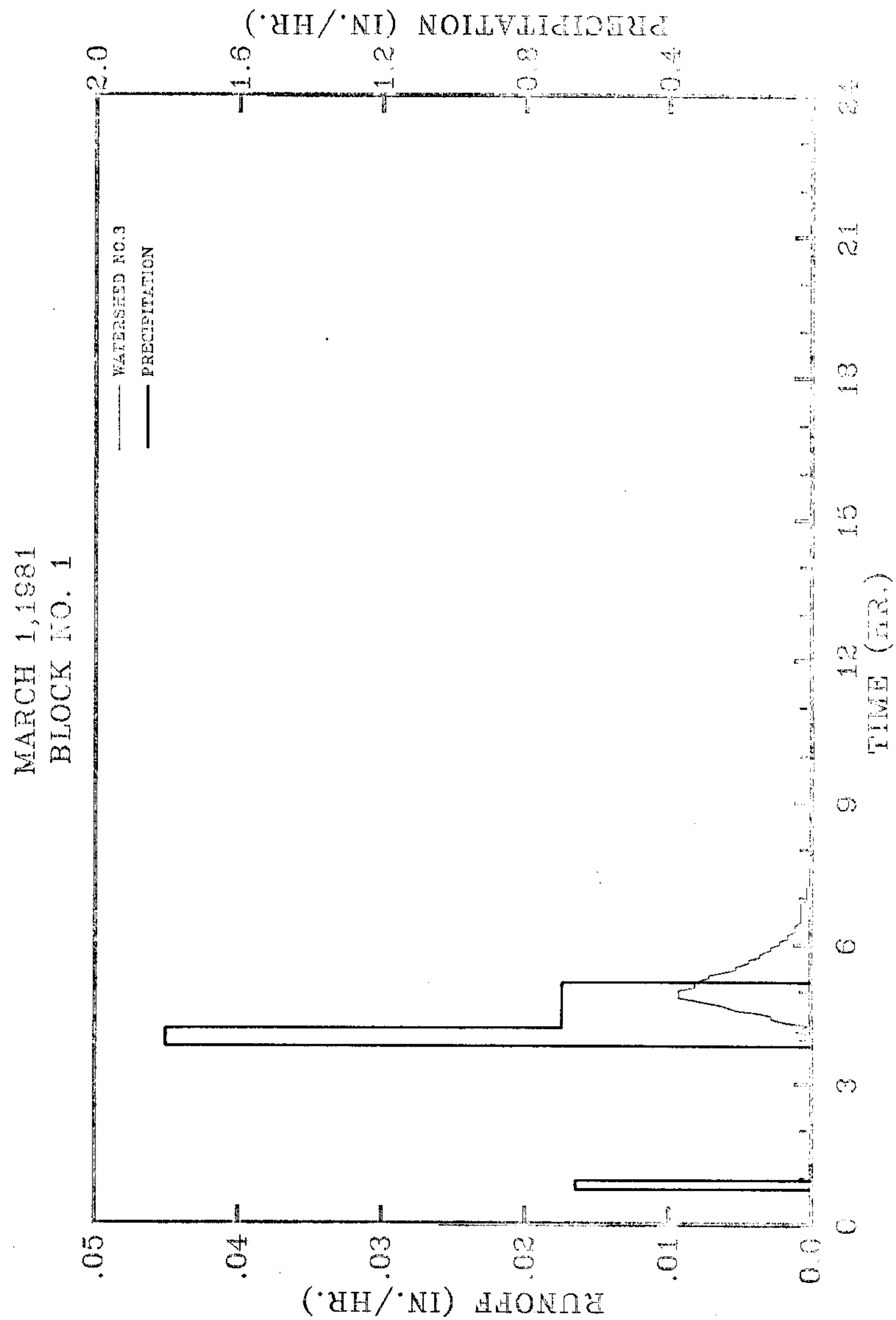
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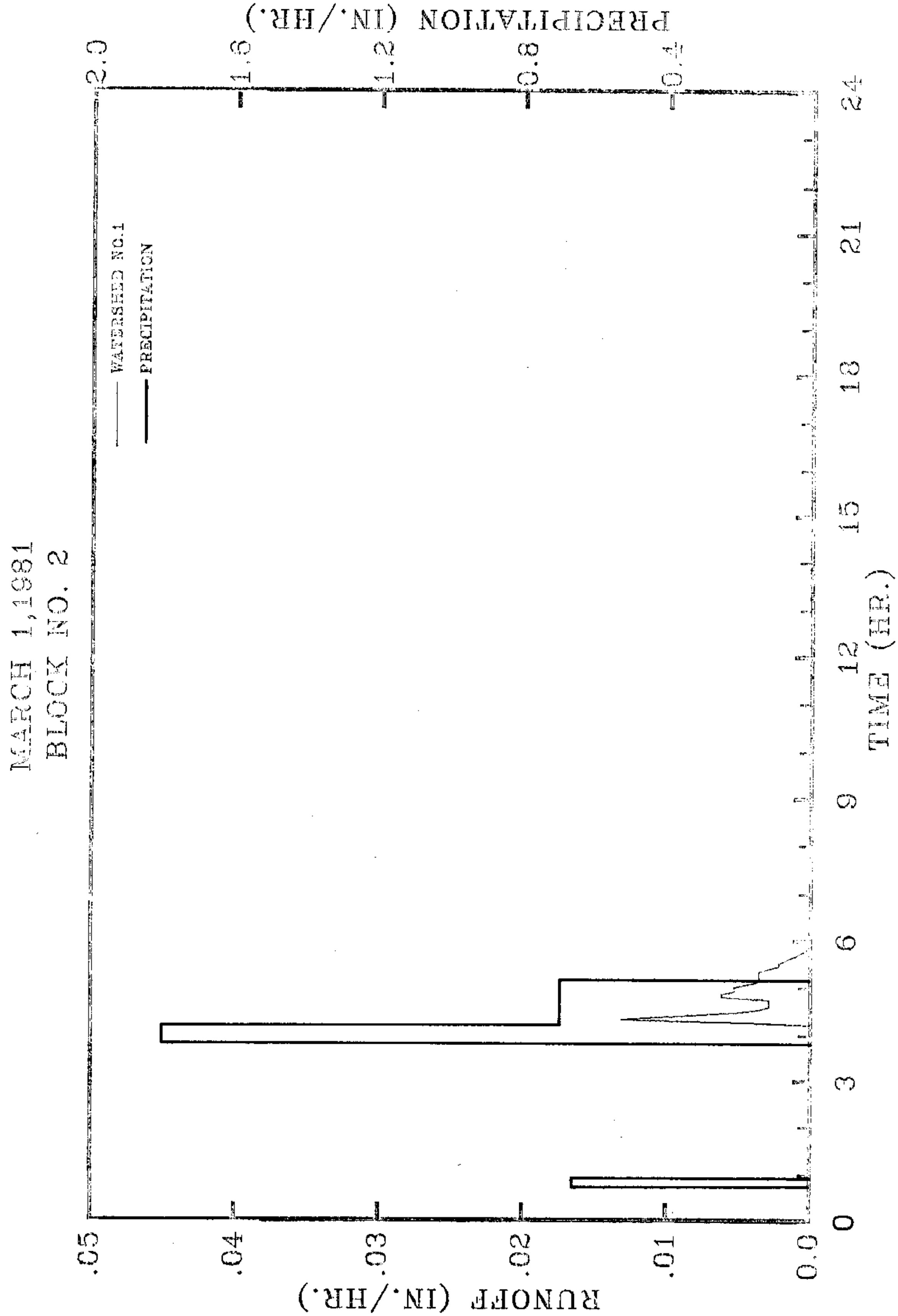
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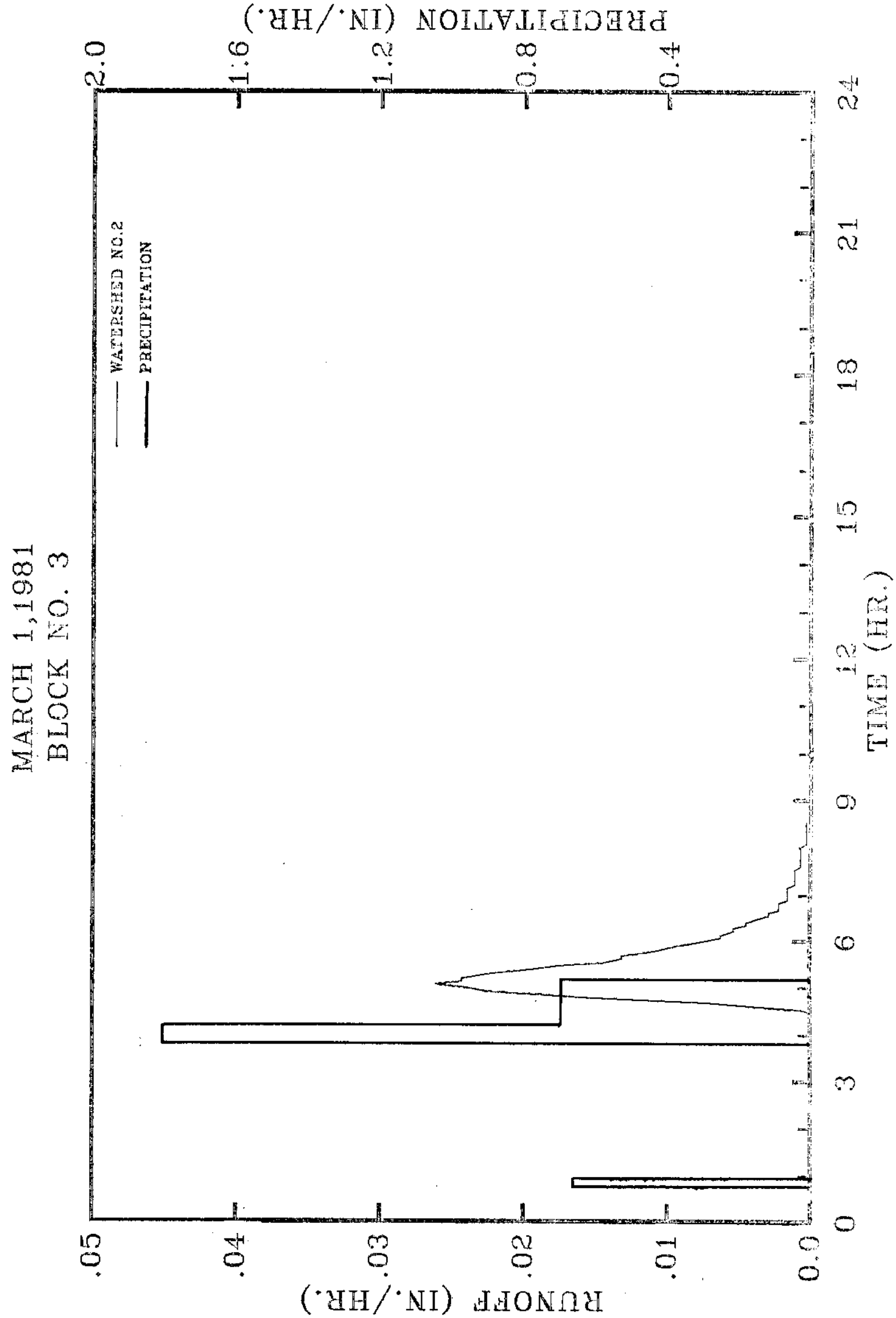
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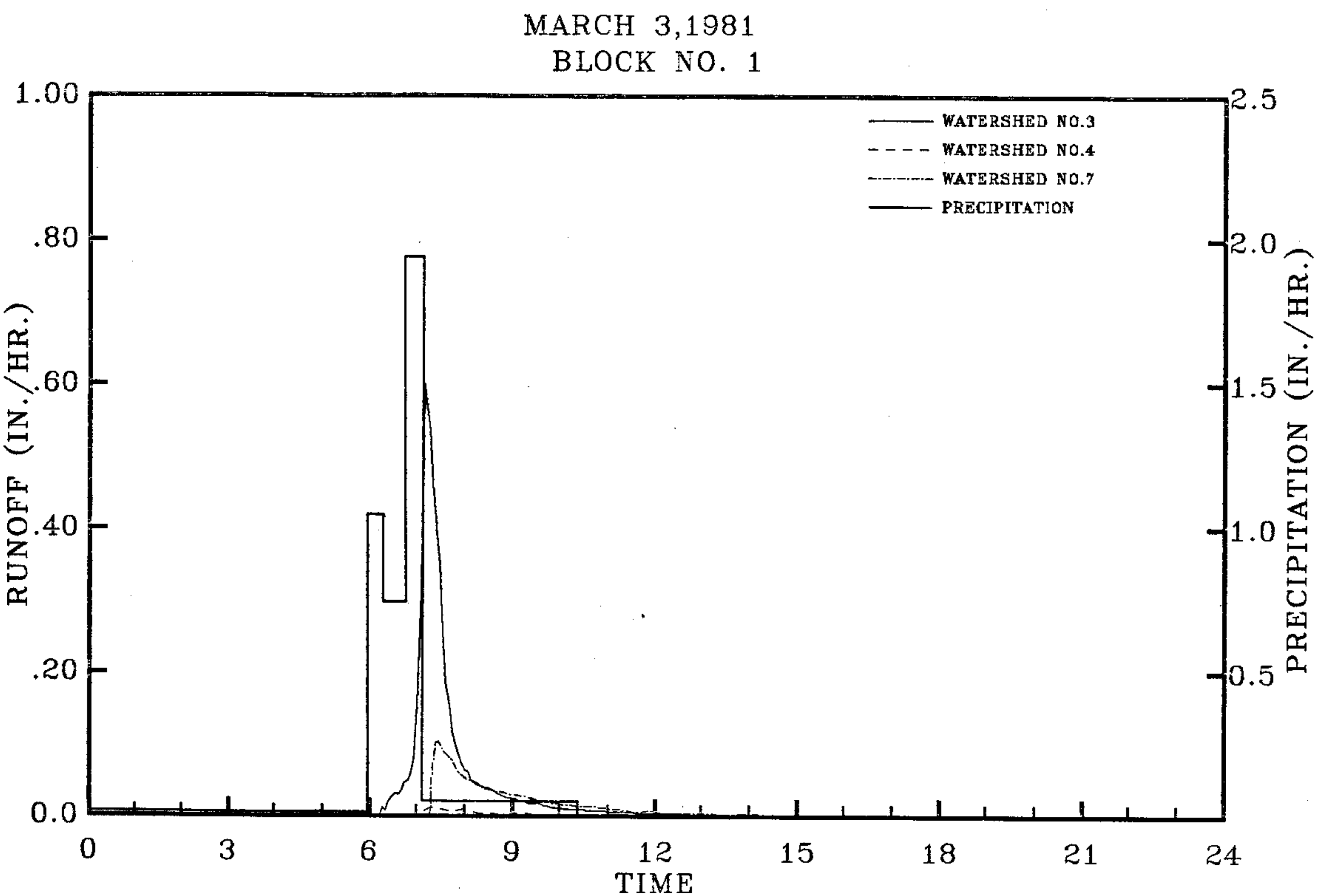
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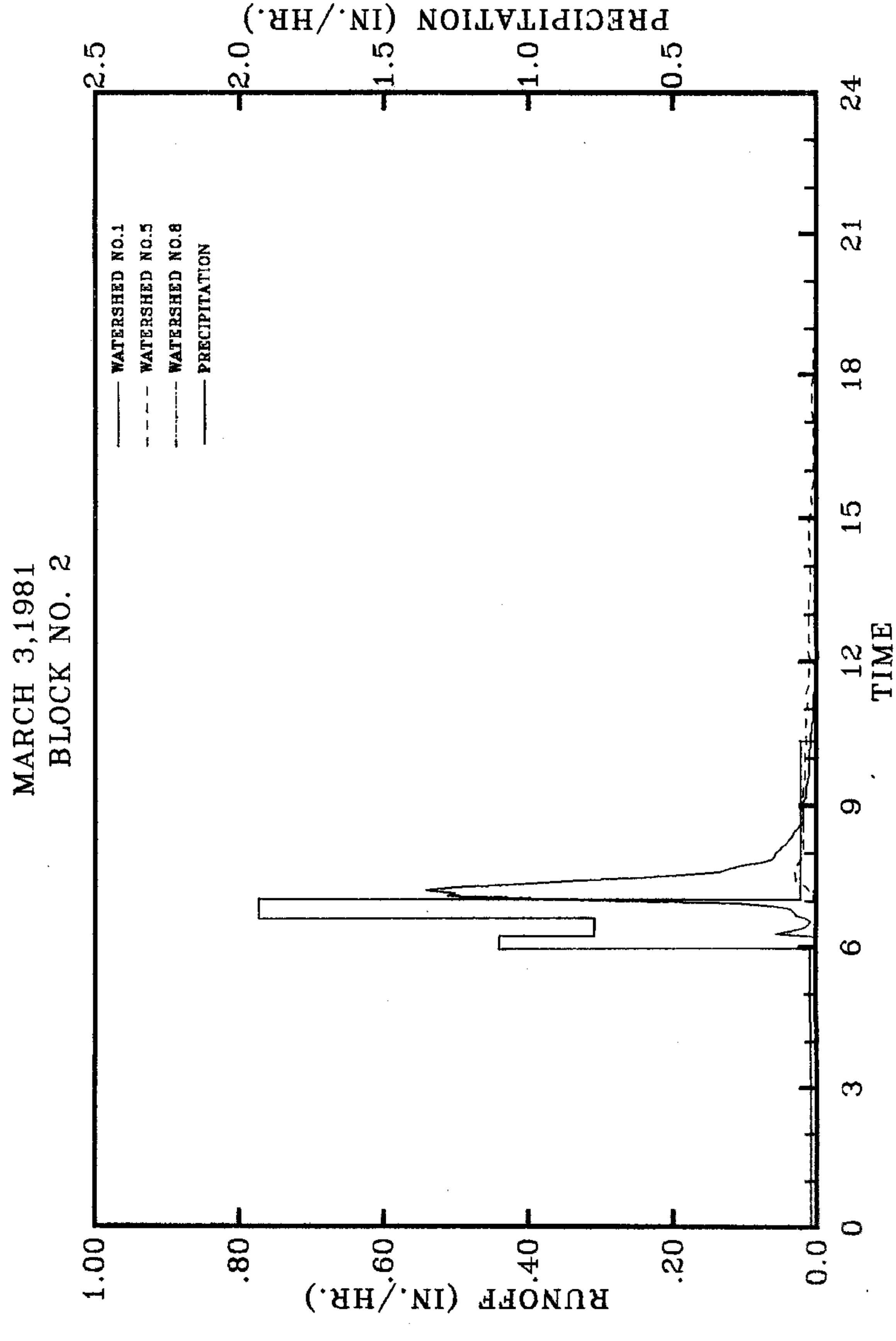
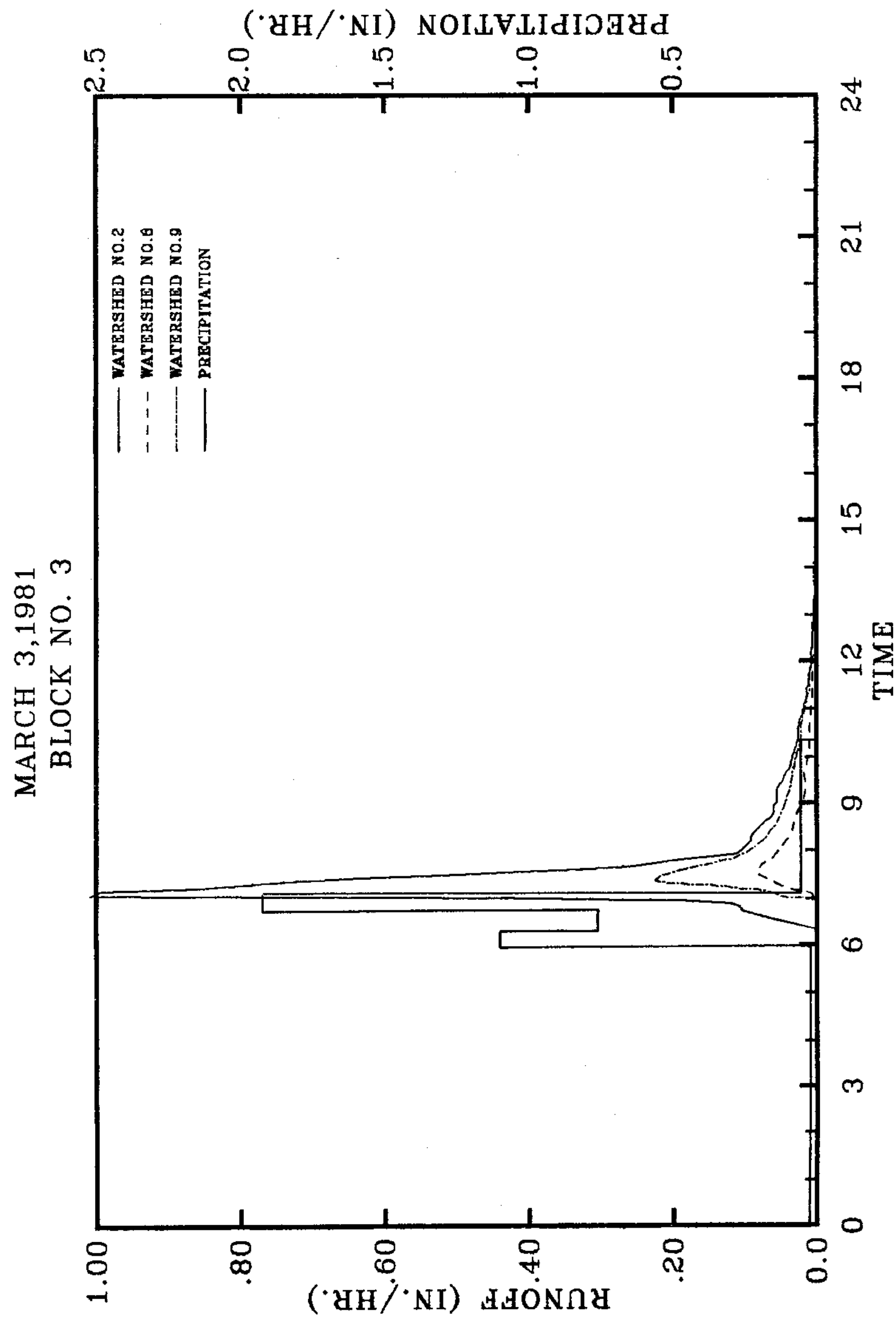
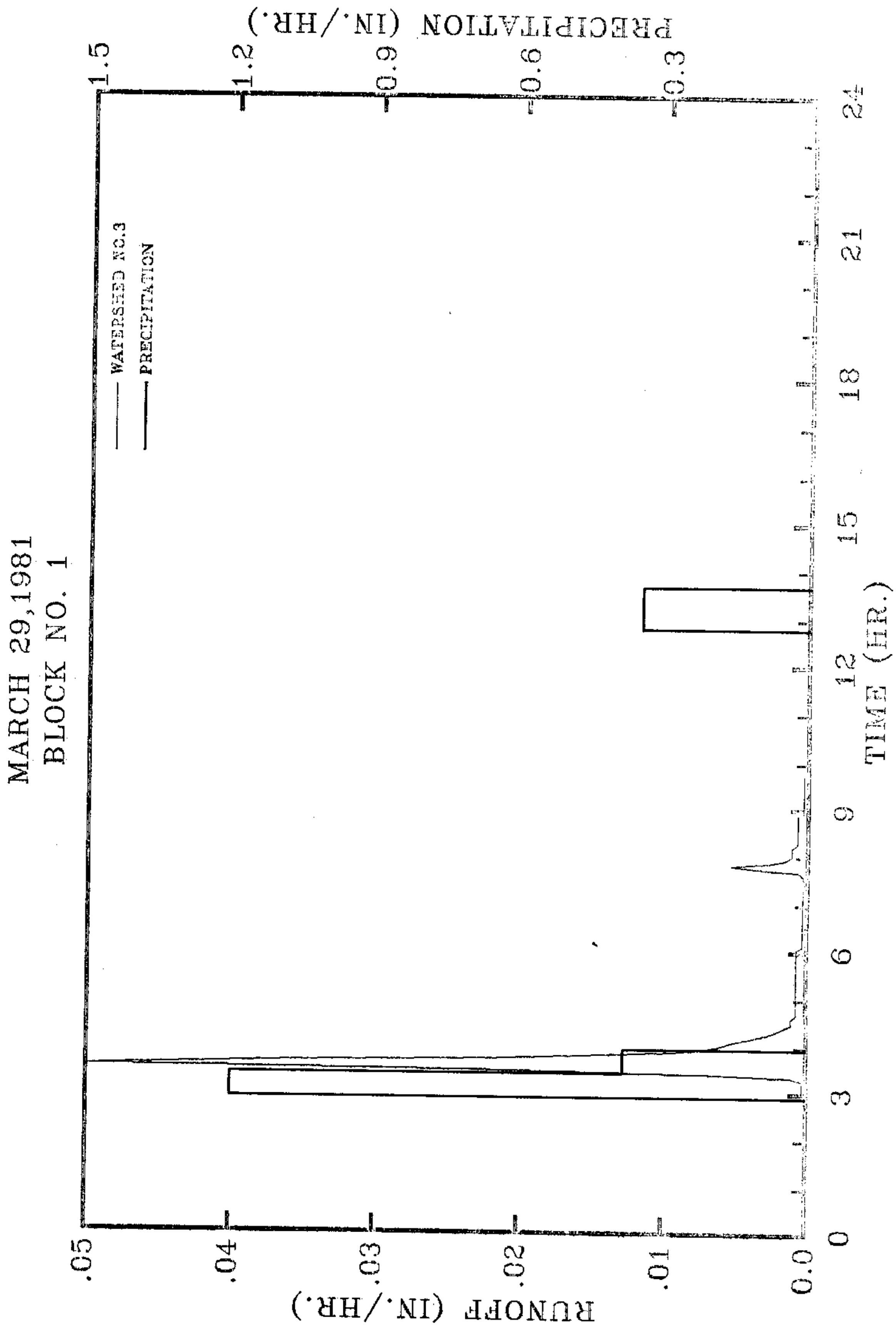
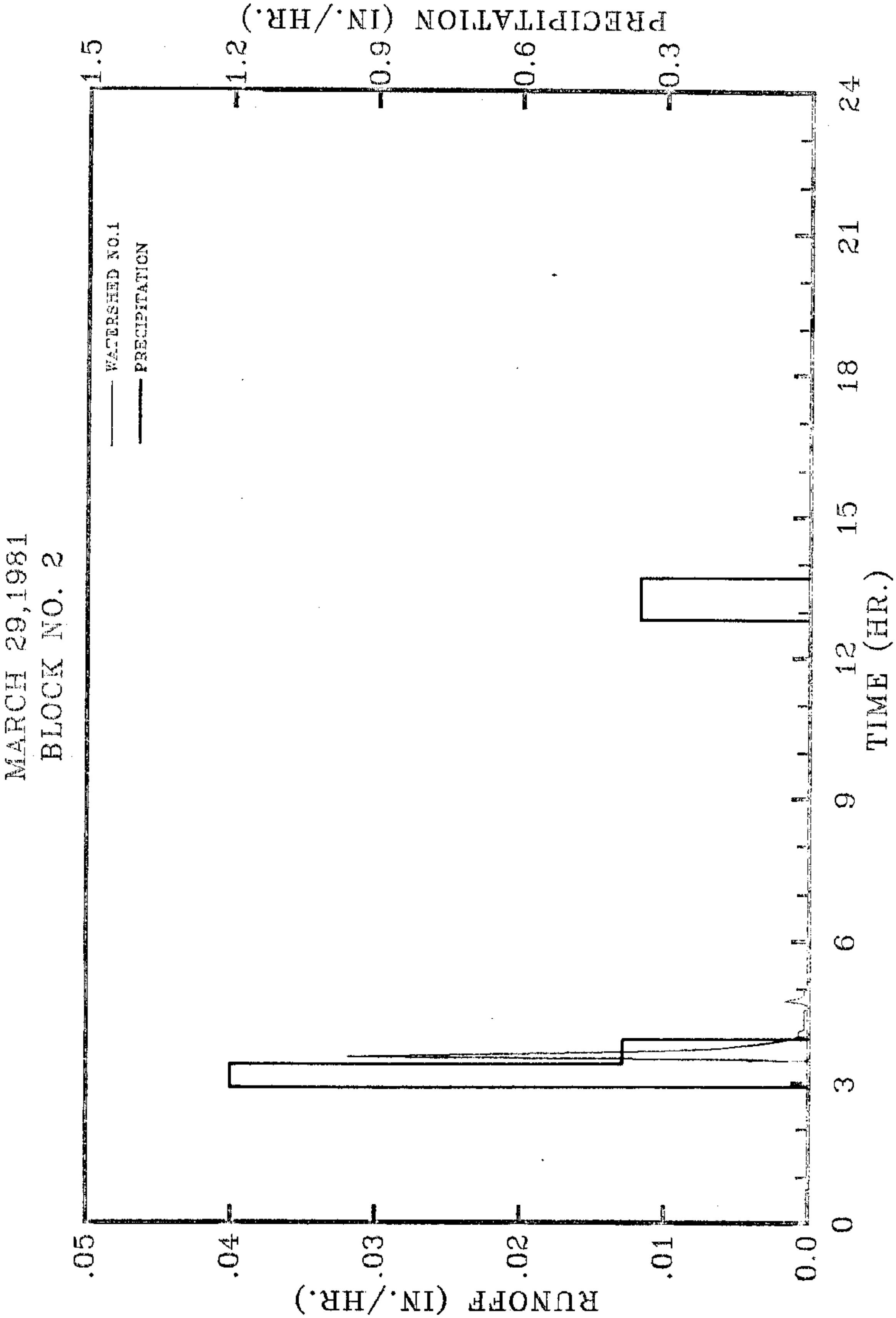
.40
.20
0.0
2.5
2.0
1.5
1.0
0.5
0
3
6
9
12
15
18
21
24

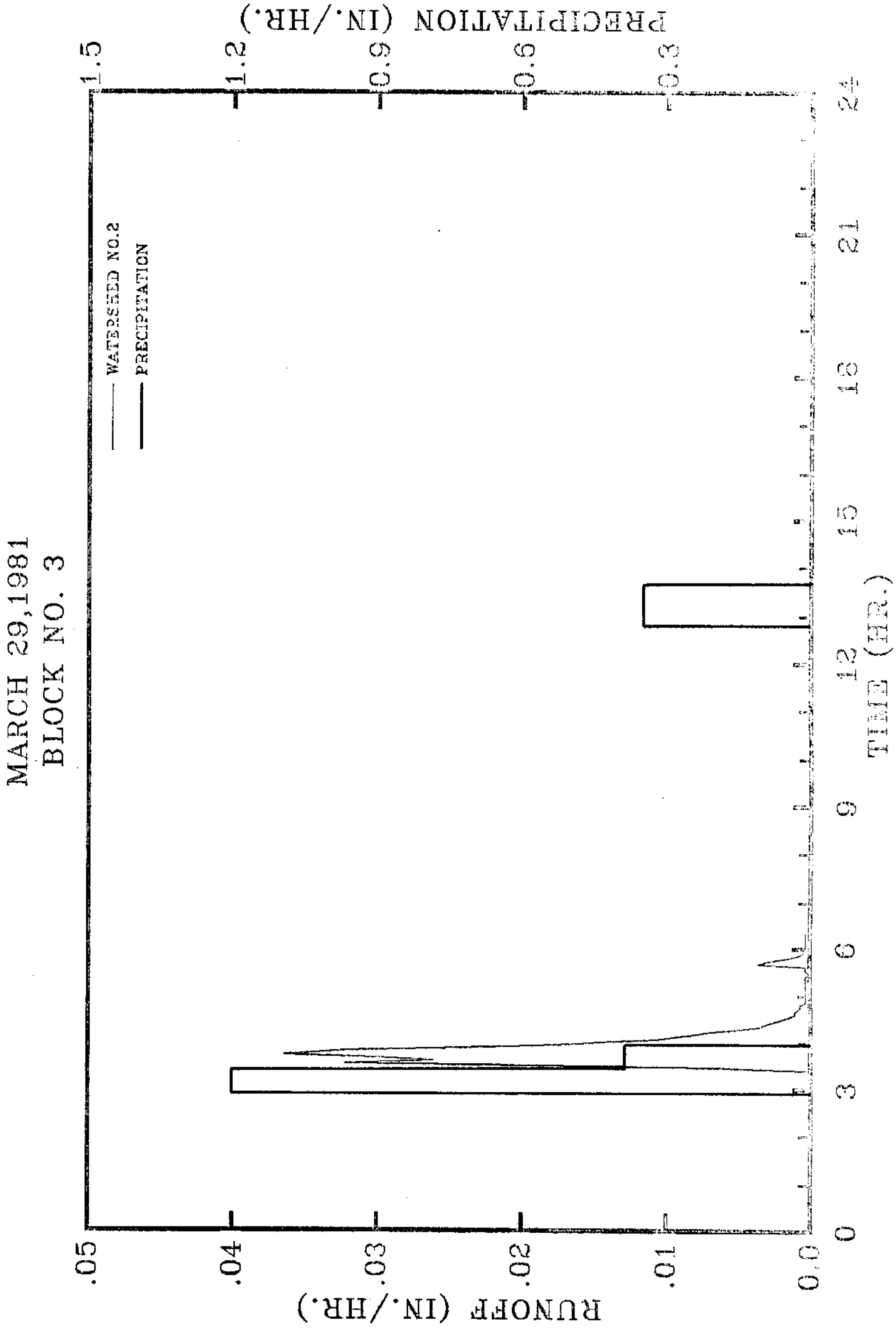

MARCH 3,1981
BLOCK NO. 2
WATERSHED NO.1
WATERSHED NO.5
WATERSHED NO.8
PRECIPITATION
RUNOFF (IN./HR.)
1.00
.80
.60
.40
.20
0.0
PRECIPITATION (IN./HR.)
2.5
2.0
1.5
1.0
0.5
TIME
0
3
6
9
12
15
18
21
24



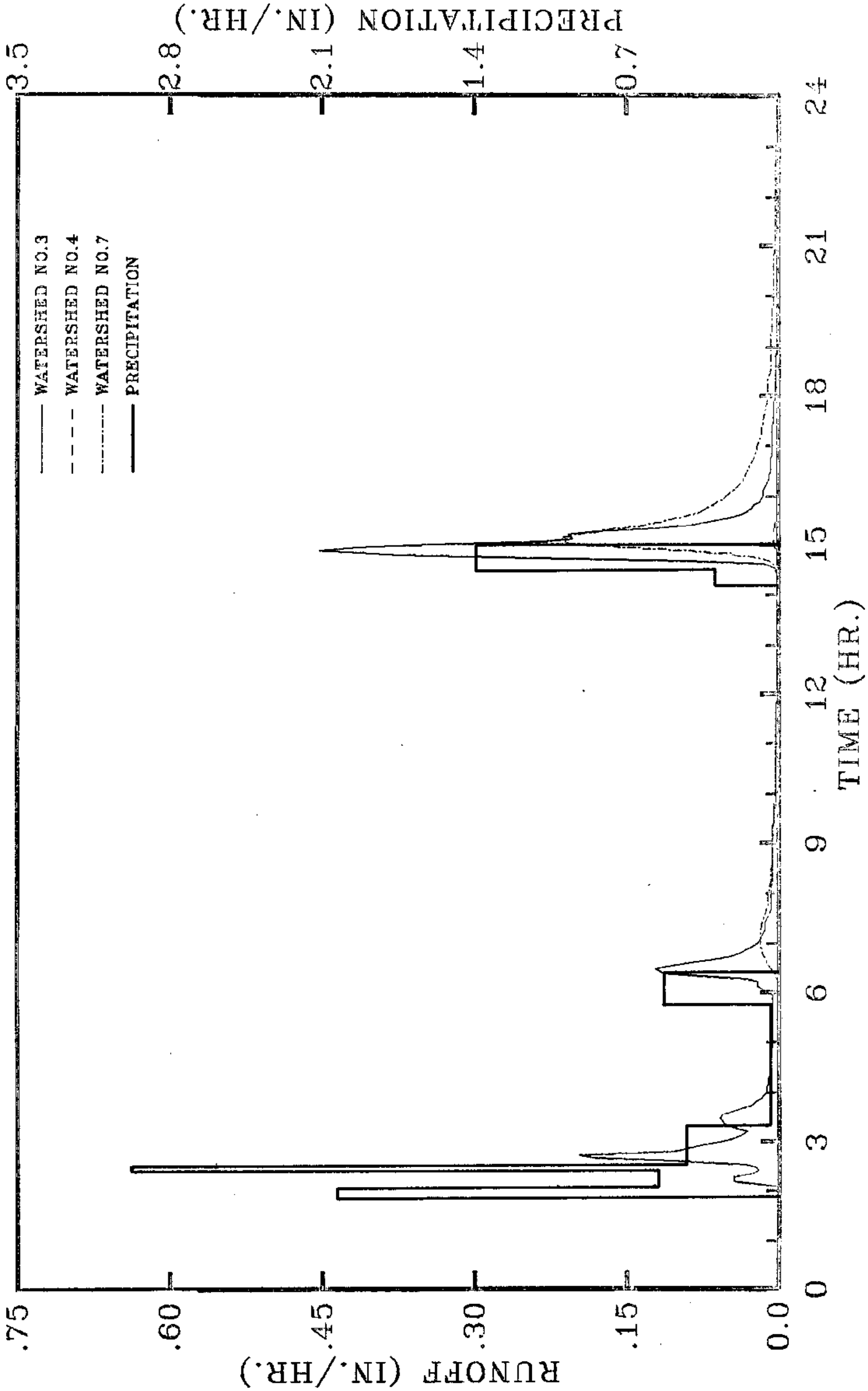
MARCH 3,1981
BLOCK NO. 3
PRECIPITATION (IN./HR.)
2.5
2.0
1.5
1.0
0.5
WATERSHED NO.2
WATERSHED NO.8
WATERSHED NO.9
PRECIPITATION
RUNOFF (IN./HR.)
1.00
.80
.60
.40
.20
0.0
0
3
6
9
12
15
18
21
24
TIME

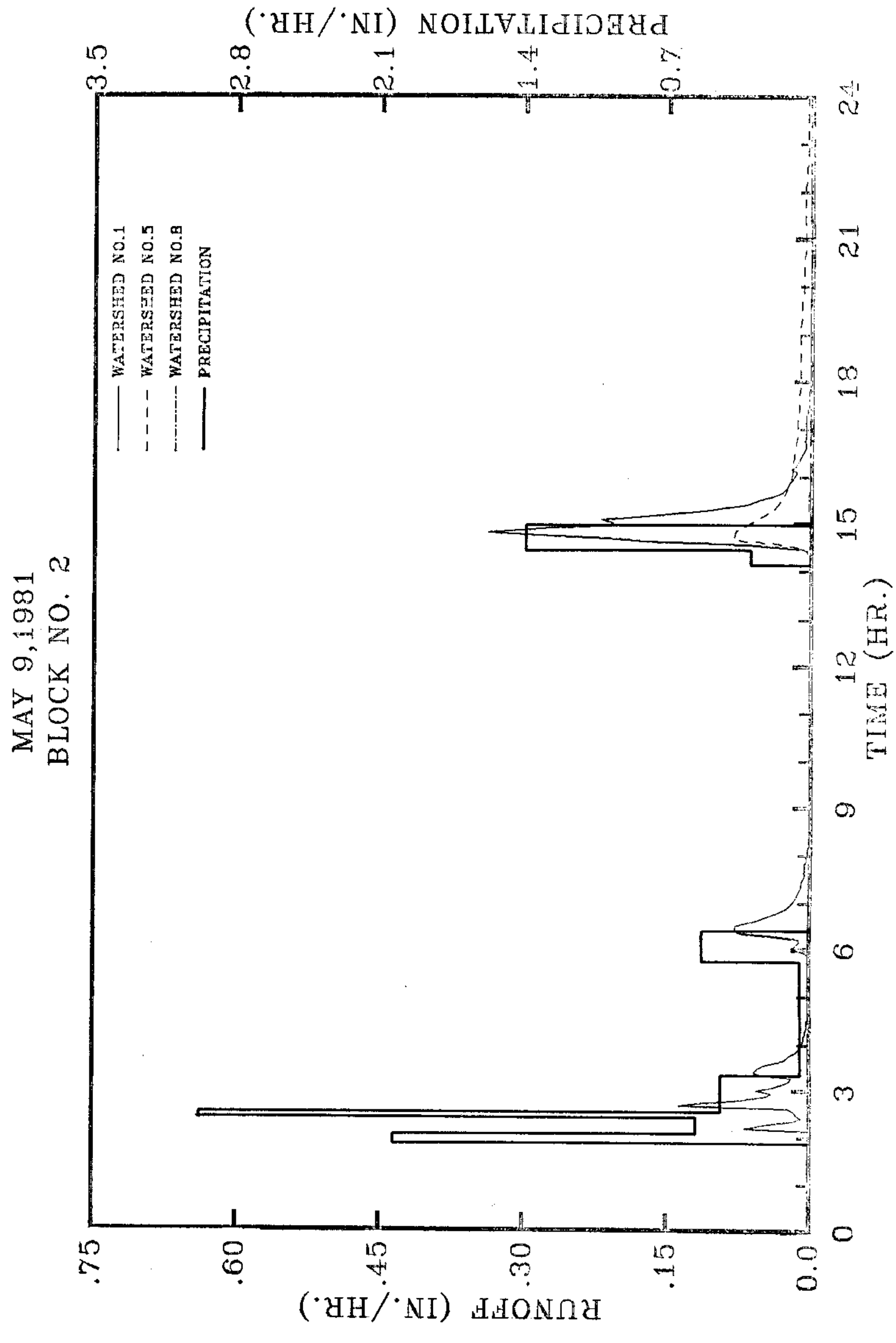

MARCH 29,1981
BLOCK NO. 1
WATERSHED NO.3
PRECIPITATION
PRECIPITATION (IN./HR.)
1.5
1.2
0.9
0.6
0.3
RUNOFF (IN./HR.)
.05
.04
.03
.02
.01
0.0
TIME (HR.)
0
3
6
9
12
15
18
21
24

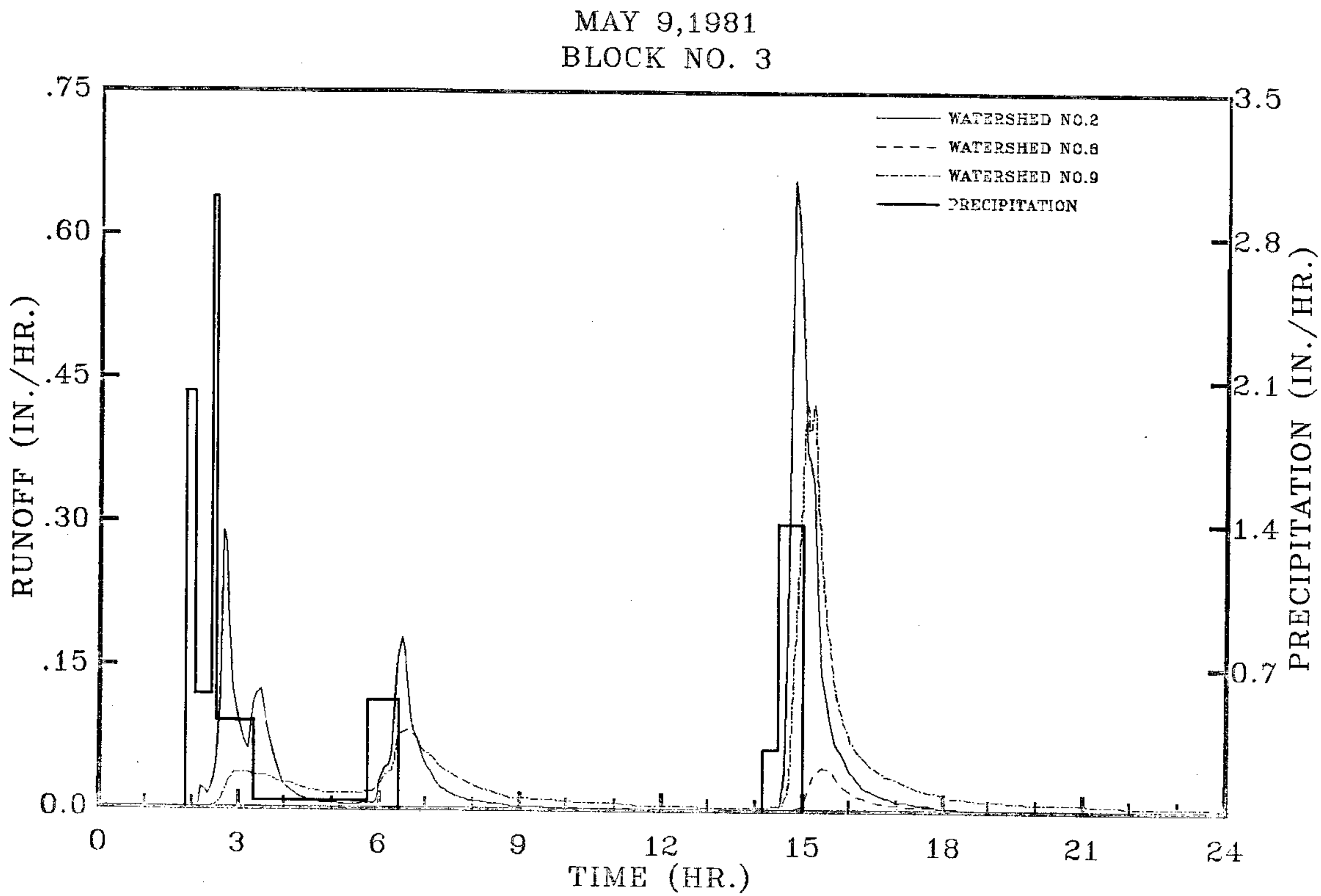

MARCH 29,1981
BLOCK NO. 2
WATERSHED NO.1
PRECIPITATION
PRECIPITATION (IN./HR.)
1.5
1.2
0.9
0.6
0.3
RUNOFF (IN./HR.)
.05
.04
.03
.02
.01
0.0
TIME (HR.)
0
3
6
9
12
15
18
21
24


MARCH 29,1981
BLOCK NO. 3
WATERSHED NO.2
PRECIPITATION
PRECIPITATION (IN./HR.)
1.5
1.2
0.9
0.6
0.3
RUNOFF (IN./HR.)
.05
.04
.03
.02
.01
0.0
TIME (HR.)
0
3
6
9
12
15
18
21
24

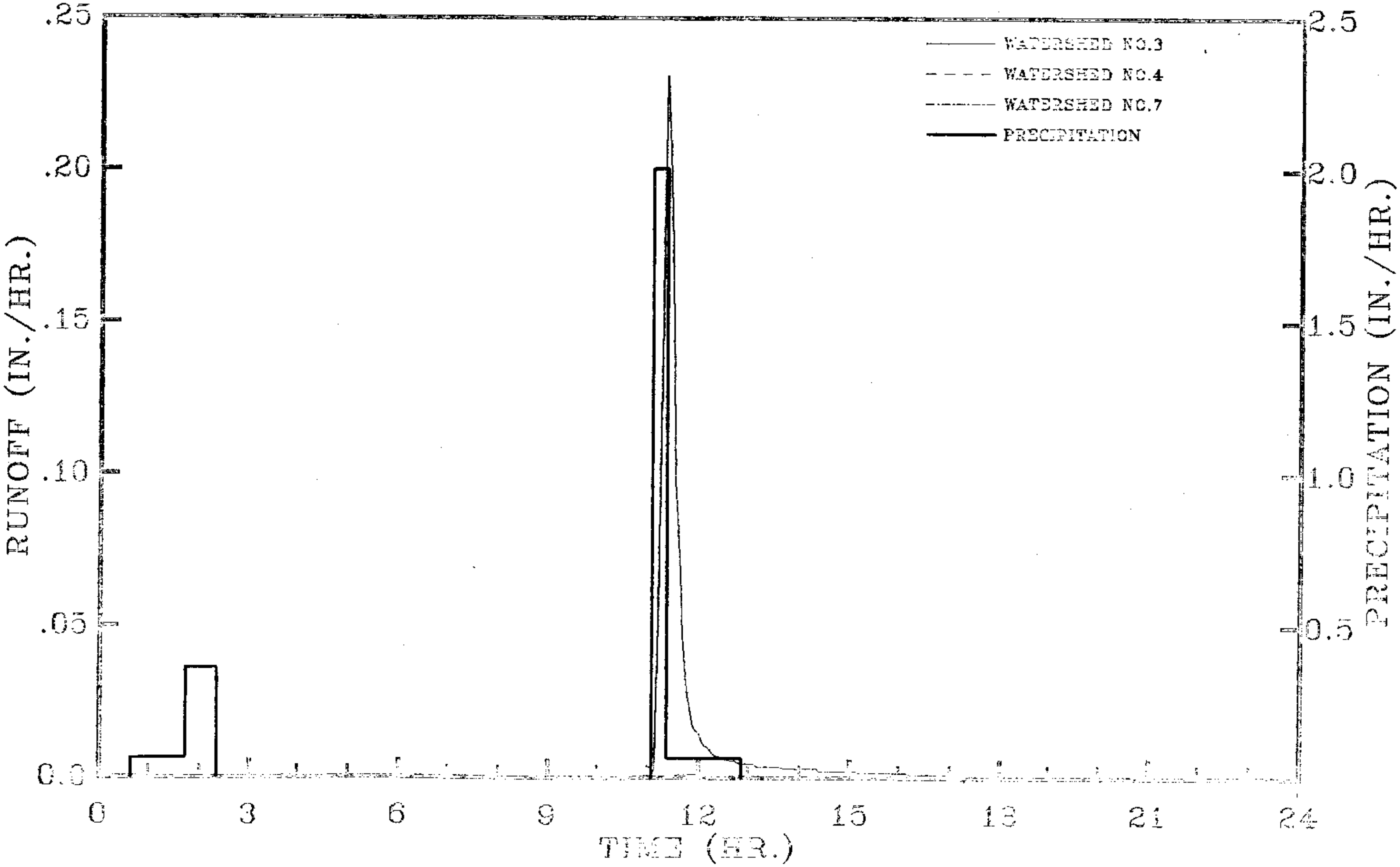
MAY 9,1981
BLOCK NO. 1



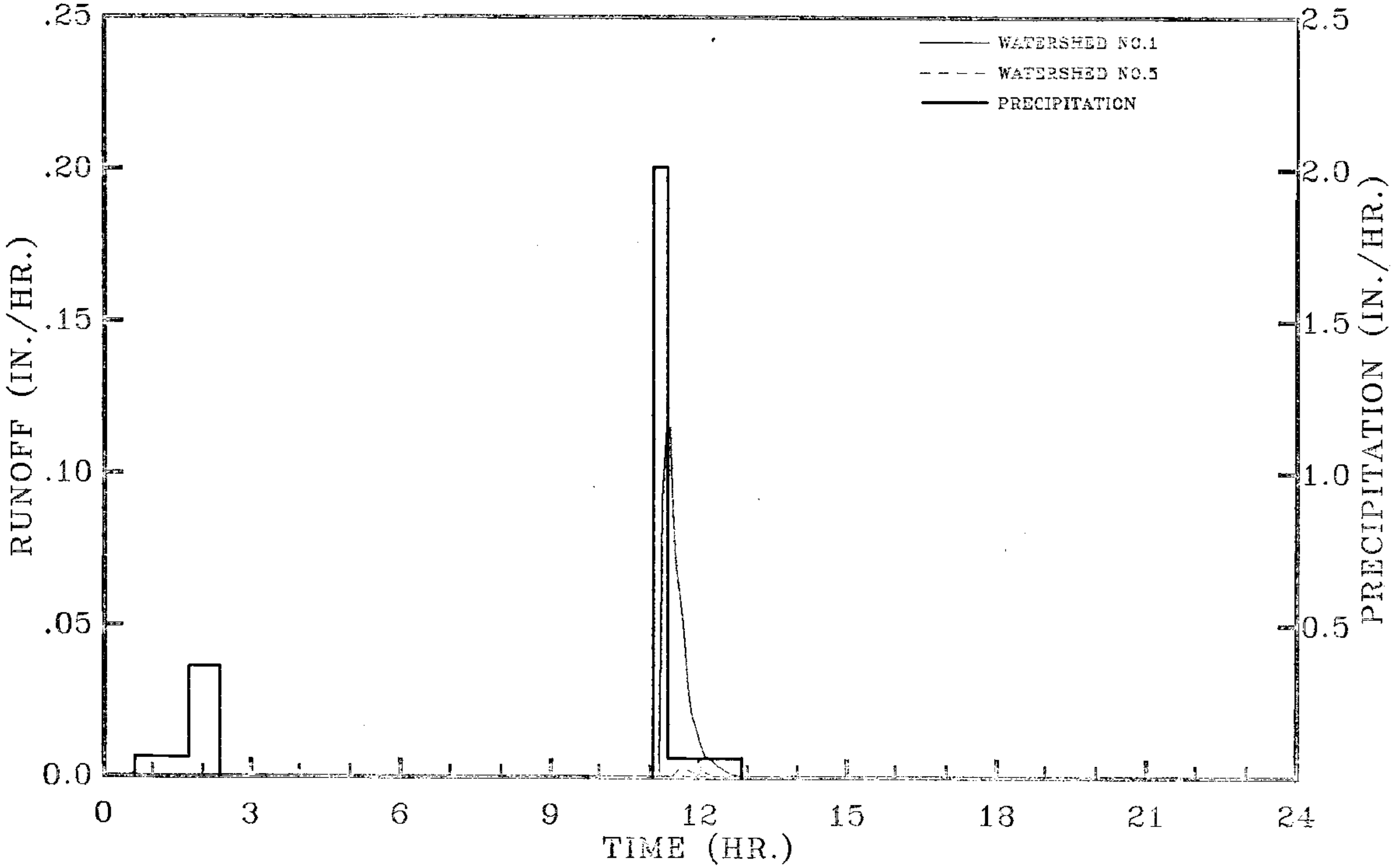

MAY 9,1981
BLOCK NO. 2
WATERSHED NO.1
WATERSHED NO.5
WATERSHED NO.8
PRECIPITATION
RUNOFF (IN./HR.)
.75
.60
.45
.30
.15
0.0
PRECIPITATION (IN./HR.)
3.5
2.8
2.1
1.4
0.7
TIME (HR.)
0
3
6
9
12
15
18
21
24

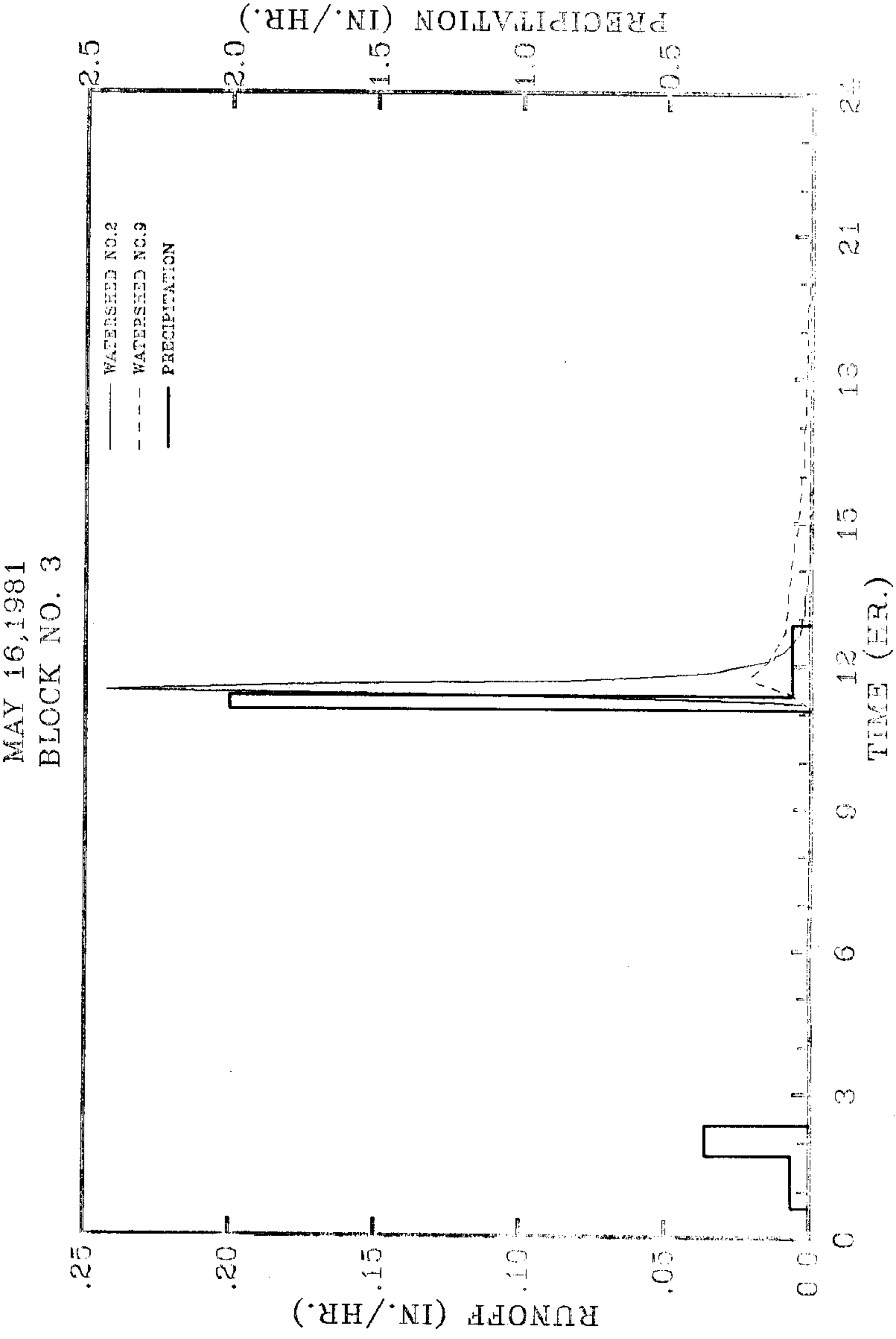

MAY 9,1981
BLOCK NO. 3
RUNOFF (IN./HR.)
.75
.60
.45
.30
.15
0.0
PRECIPITATION (IN./HR.)
3.5
2.8
2.1
1.4
0.7
TIME (HR.)
0
3
6
9
12
15
18
21
24
WATERSHED NO.2
WATERSHED NO.8
WATERSHED NO.9
PRECIPITATION

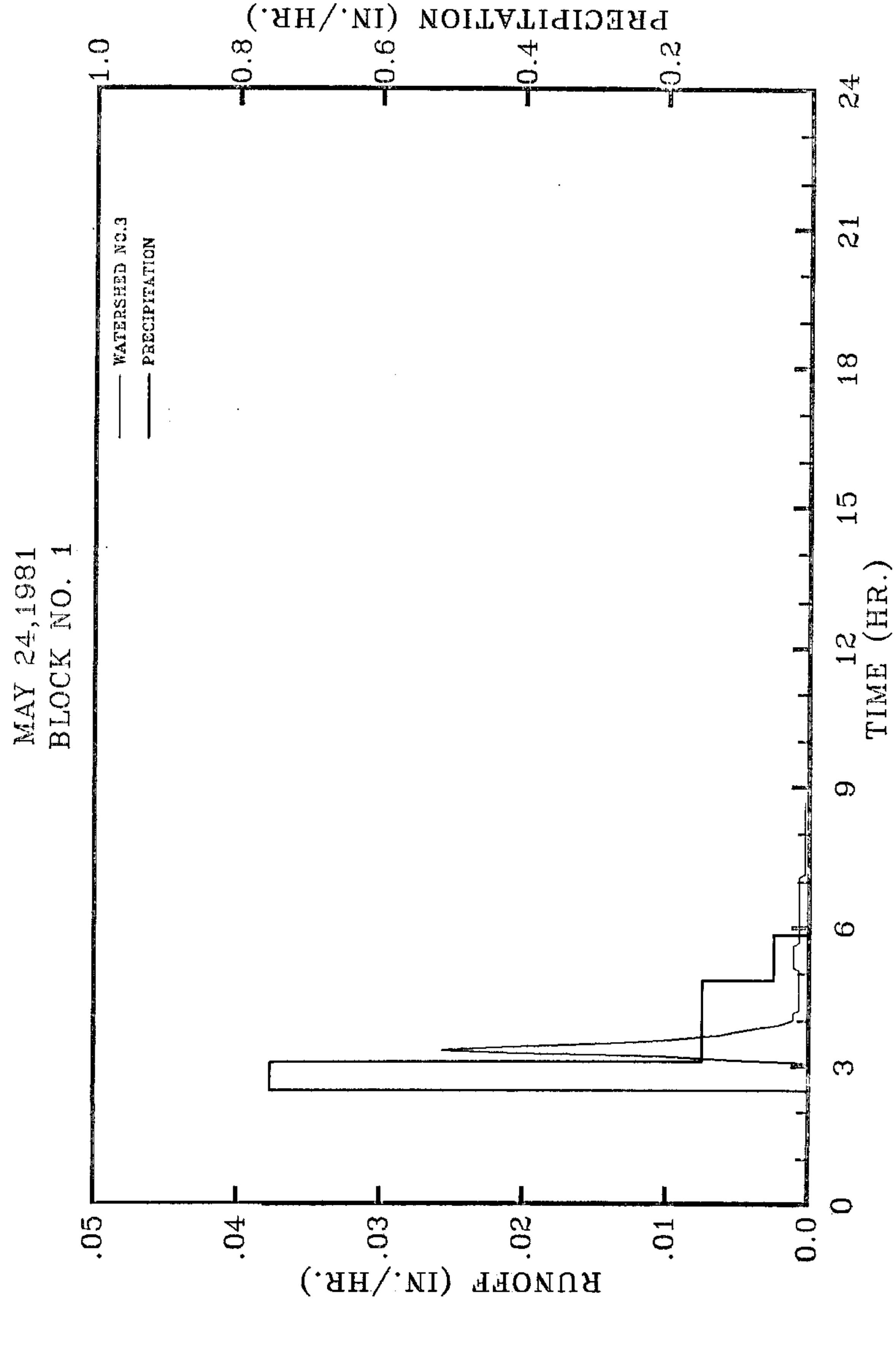
MAY 16,1981
BLOCK NO. 1

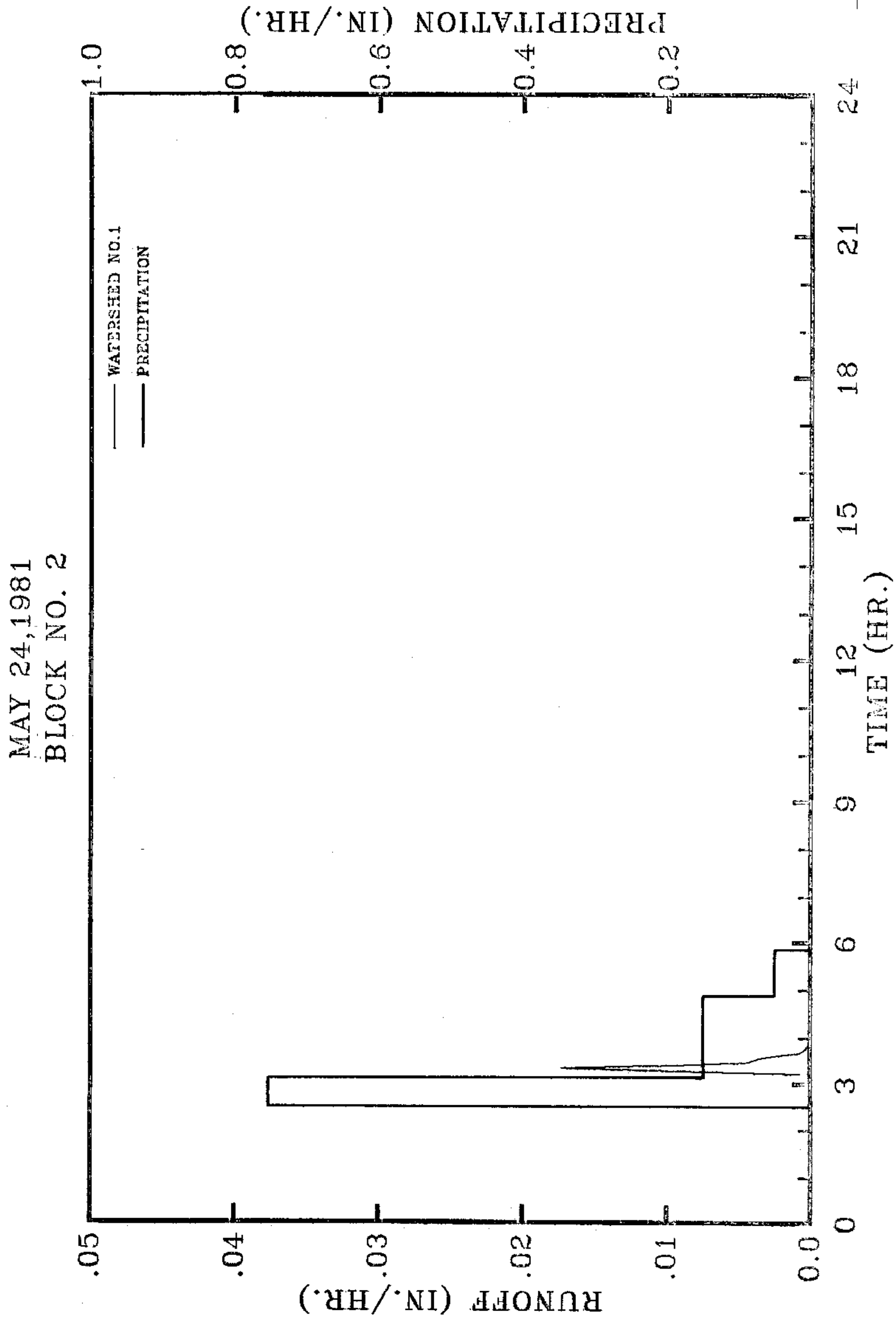


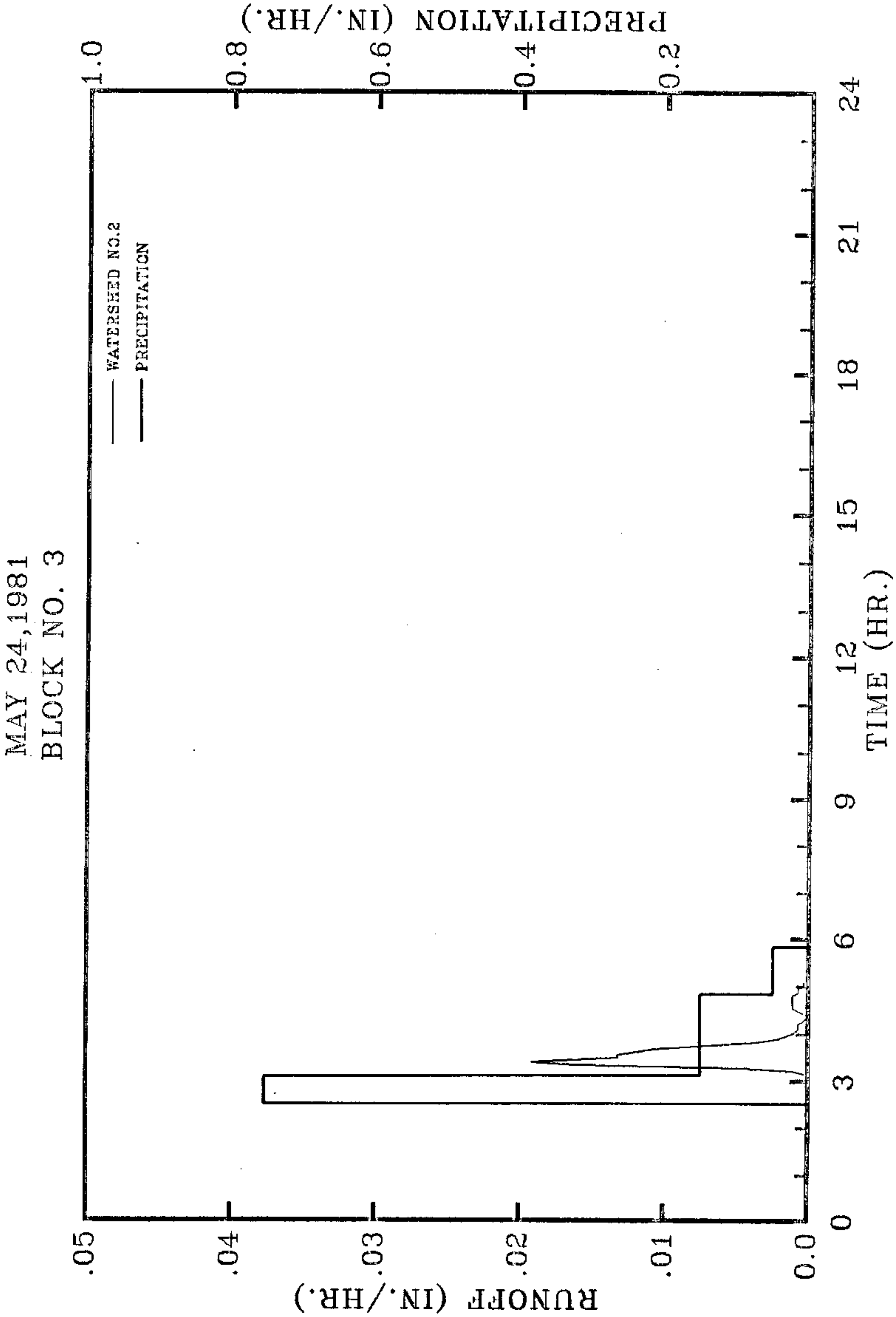
MAY 16,1981
BLOCK NO. 2

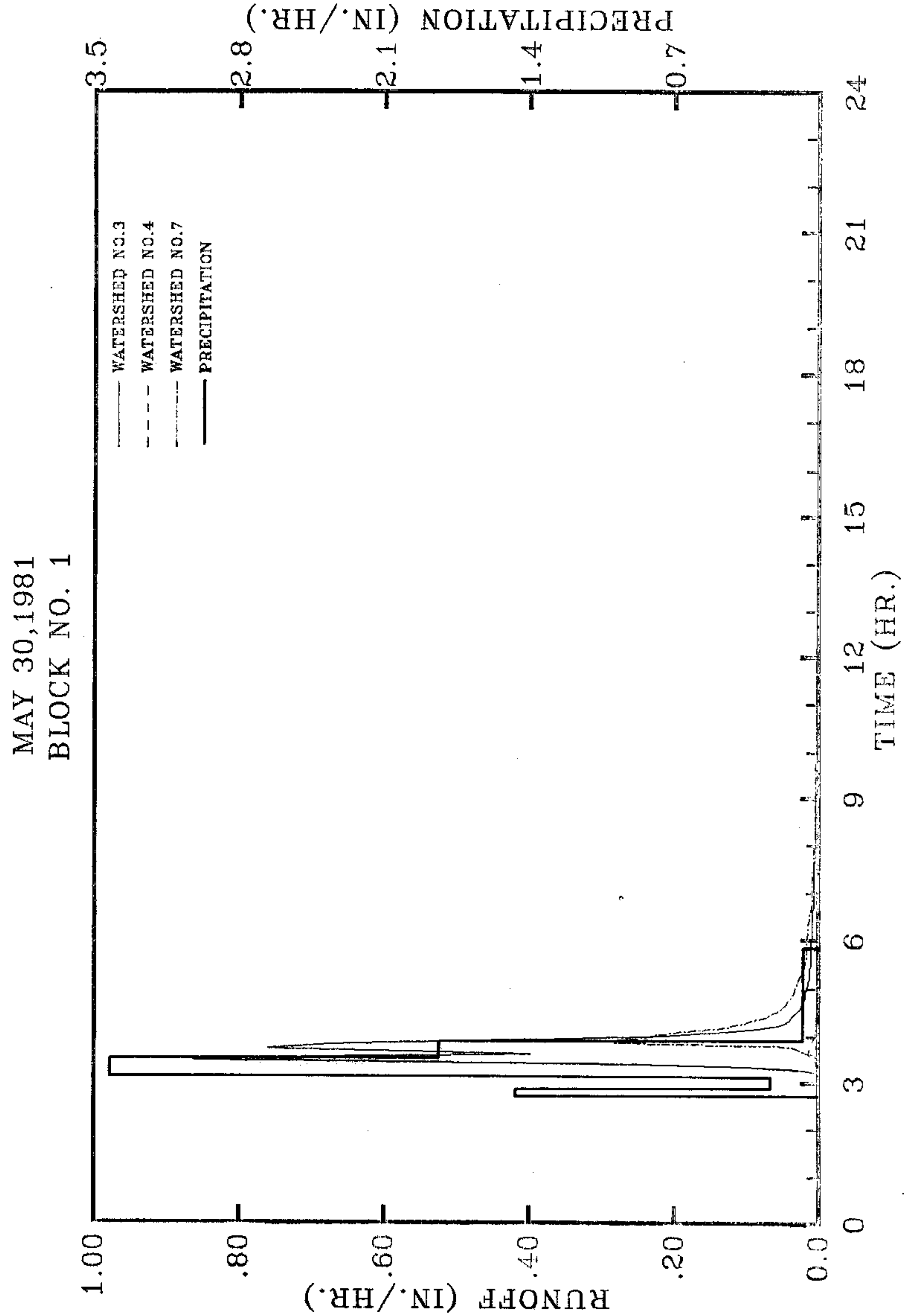


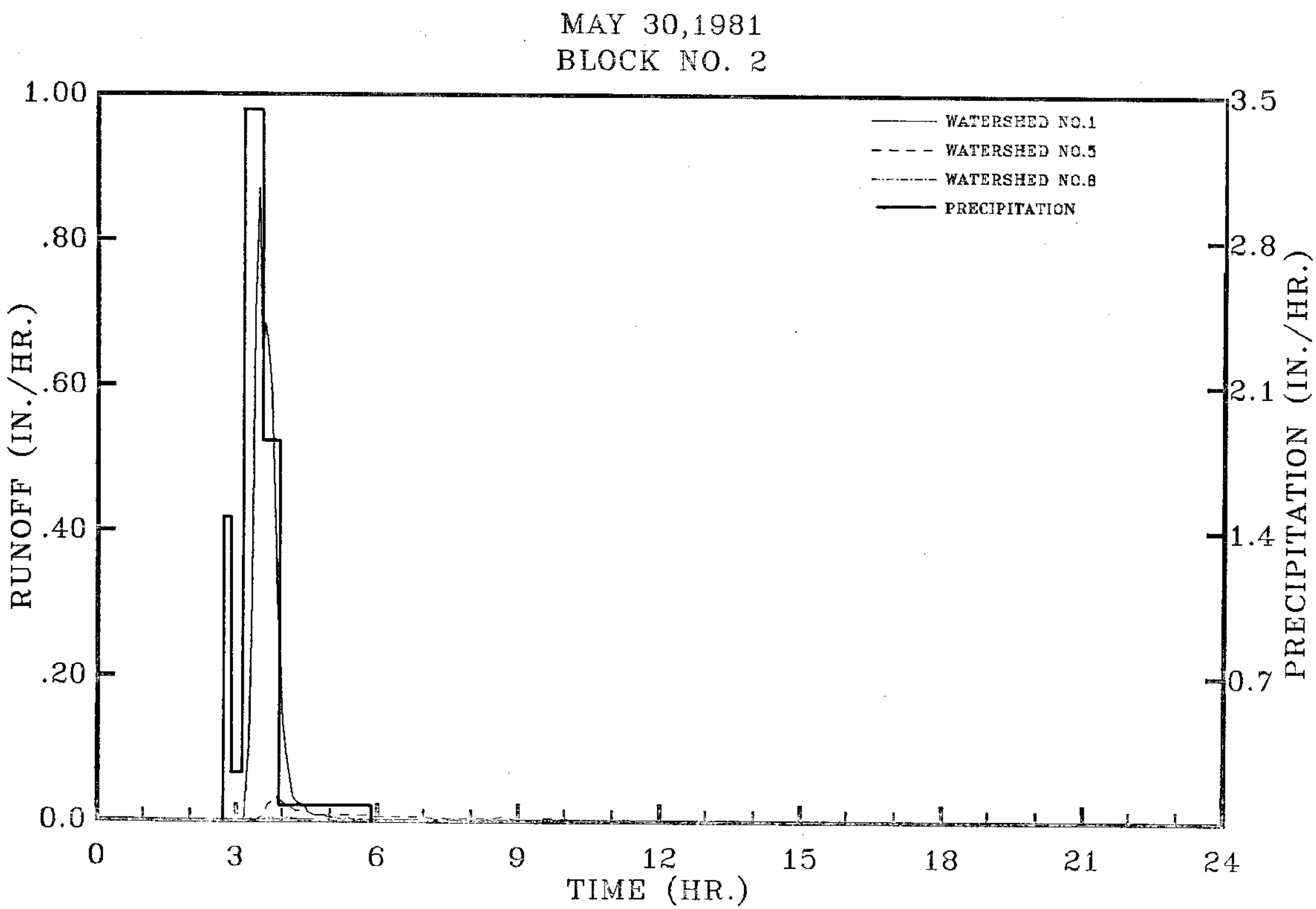

MAY 16,1981
BLOCK NO. 3
WATERSHED NO.2
WATERSHED NO.9
PRECIPITATION
PRECIPITATION (IN./HR.)
2.5
2.0
1.5
1.0
0.5
RUNOFF (IN./HR.)
.25
.20
.15
.10
.05
0.0
TIME (HR.)
0
3
6
9
12
15
18
21
24

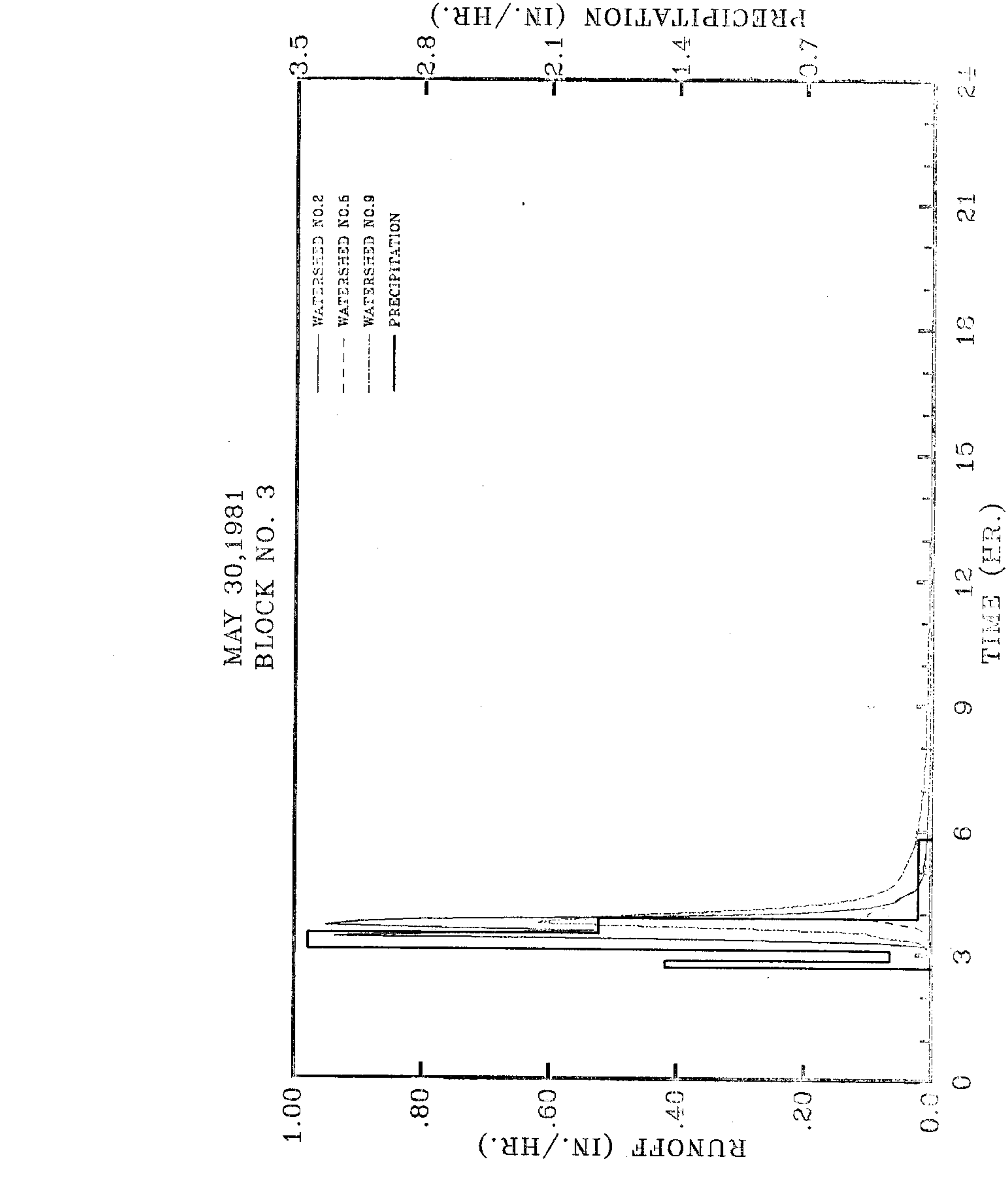

MAY 24,1981
BLOCK NO. 1
WATERSHED NO.3
PRECIPITATION
PRECIPITATION (IN./HR.)
1.0
0.8
0.6
0.4
0.2
RUNOFF (IN./HR.)
.05
.04
.03
.02
.01
0.0
0
3
6
9
12
15
18
21
24
TIME (HR.)

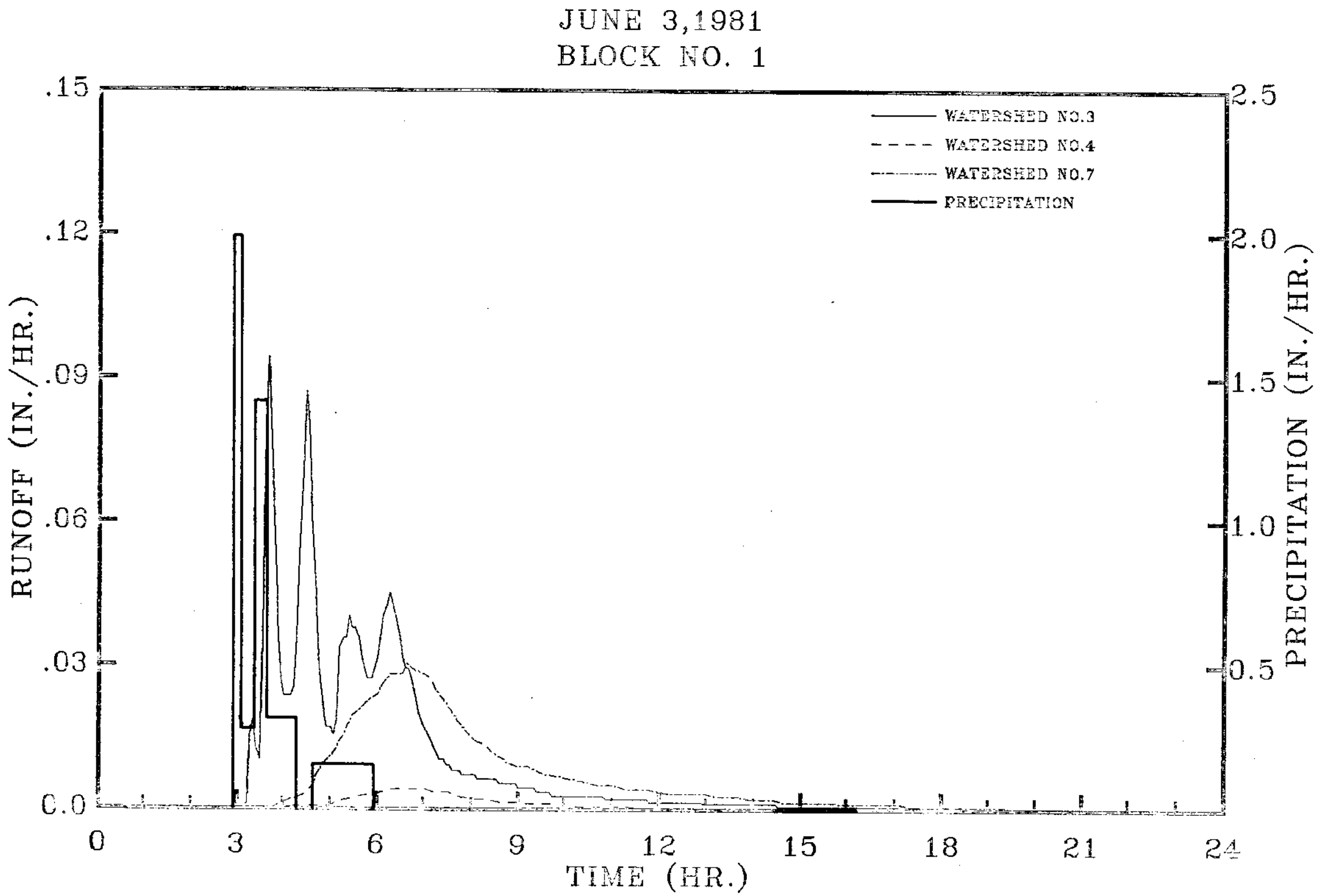

MAY 24,1981
BLOCK NO. 2
WATERSHED NO.1
PRECIPITATION
PRECIPITATION (IN./HR.)
1.0
0.8
0.6
0.4
0.2
RUNOFF (IN./HR.)
.05
.04
.03
.02
.01
0.0
TIME (HR.)
0
3
6
9
12
15
18
21
24

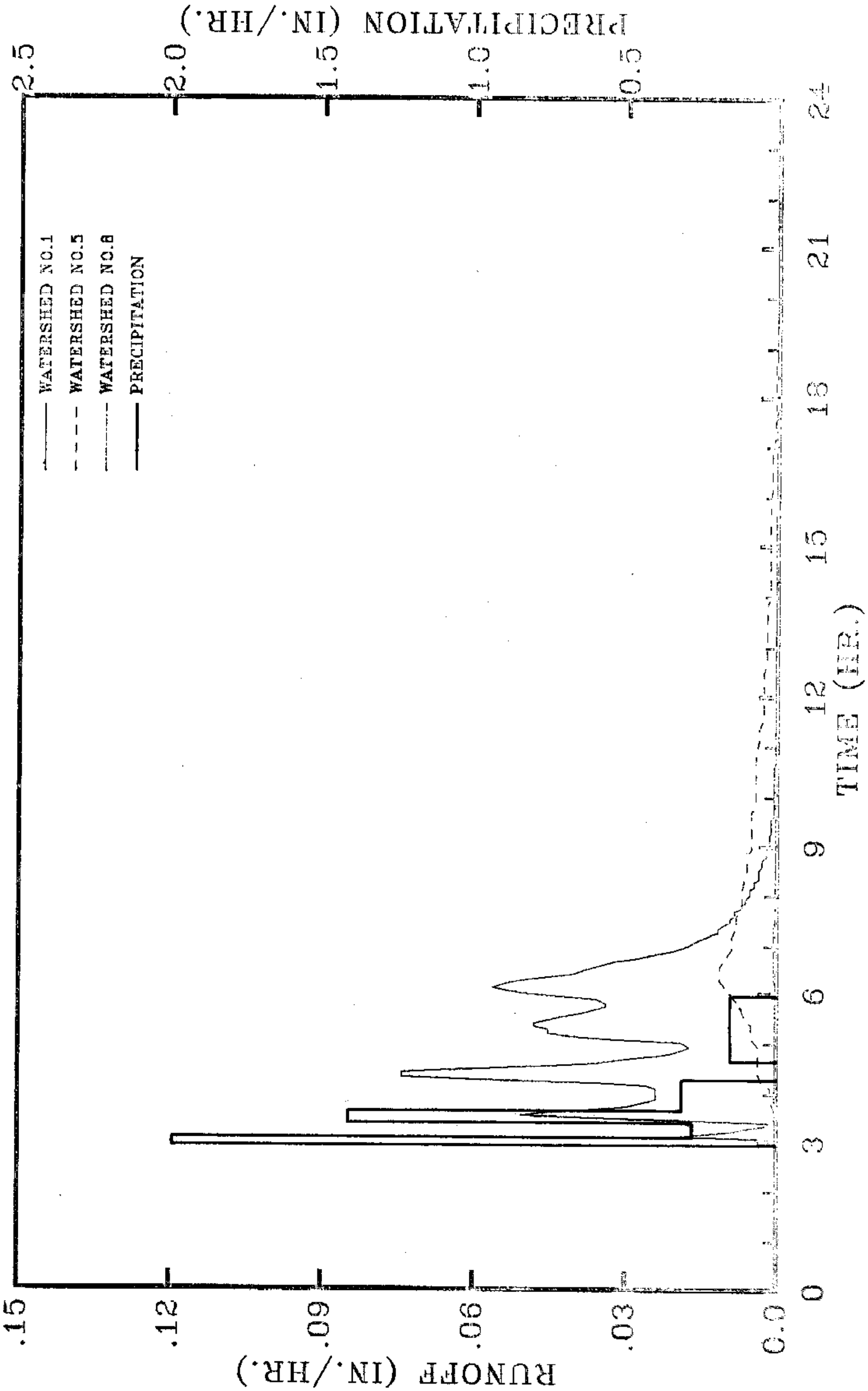

MAY 24,1981
BLOCK NO. 3
WATERSHED NO.2
PRECIPITATION
PRECIPITATION (IN./HR.)
1.0
0.8
0.6
0.4
0.2
RUNOFF (IN./HR.)
.05
.04
.03
.02
.01
0.0
TIME (HR.)
0
3
6
9
12
15
18
21
24


MAY 30,1981
BLOCK NO. 1
WATERSHED NO.3
WATERSHED NO.4
WATERSHED NO.7
PRECIPITATION
RUNOFF (IN./HR.)
1.00
.80
.60
.40
.20
0.0
PRECIPITATION (IN./HR.)
3.5
2.8
2.1
1.4
0.7
TIME (HR.)
0
3
6
9
12
15
18
21
24

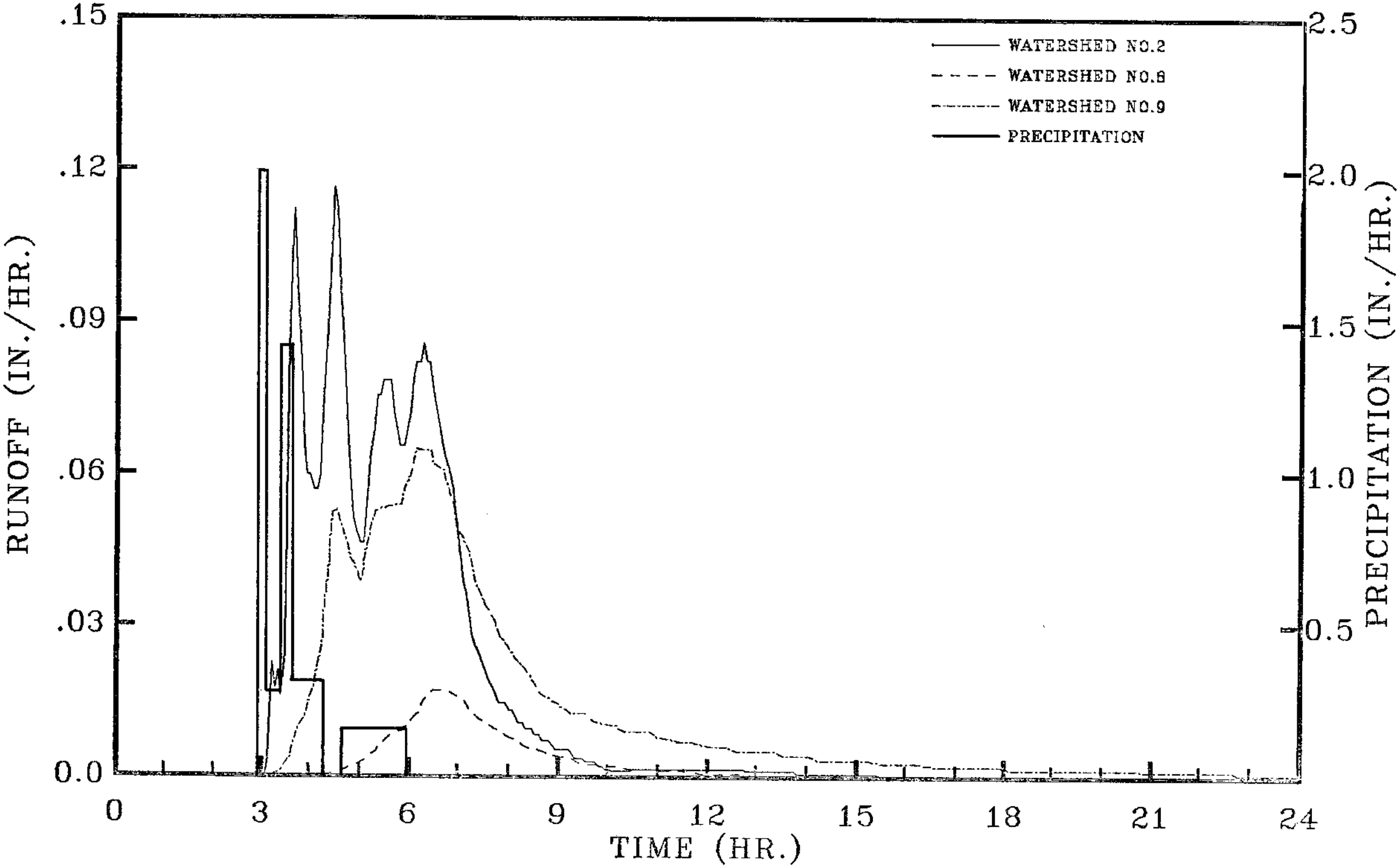

MAY 30,1981
BLOCK NO. 2
WATERSHED NO.1
WATERSHED NO.5
WATERSHED NO.8
PRECIPITATION
RUNOFF (IN./HR.)
1.00
.80
.60
.40
.20
0.0
PRECIPITATION (IN./HR.)
3.5
2.8
2.1
1.4
0.7
TIME (HR.)
0
3
6
9
12
15
18
21
24

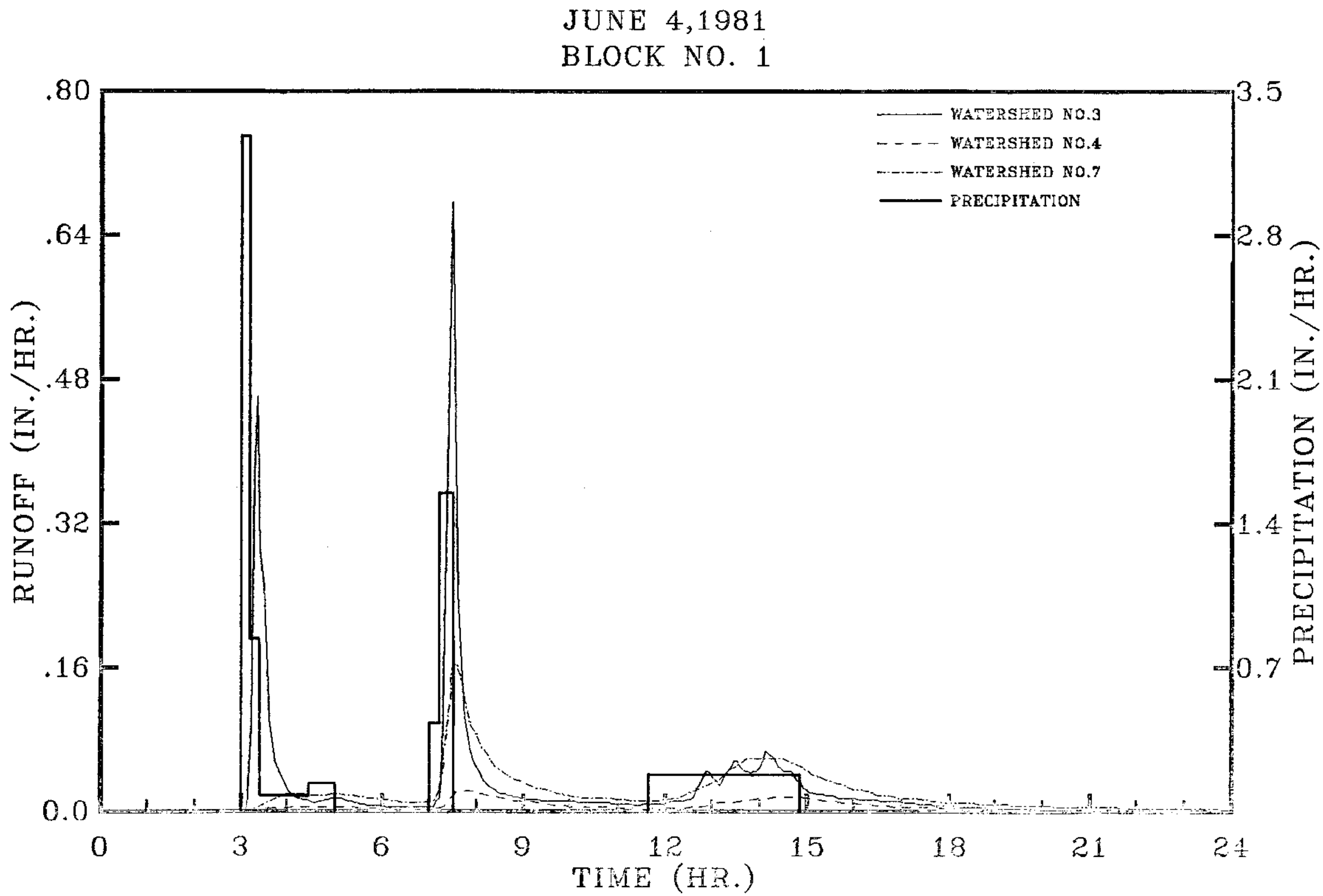

MAY 30,1981
BLOCK NO. 3
WATERSHED NO.2
WATERSHED NO.5
WATERSHED NO.9
PRECIPITATION
PRECIPITATION (IN./HR.)
3.5
2.8
2.1
1.4
0.7
RUNOFF (IN./HR.)
1.00
.80
.60
.40
.20
0.0
TIME (HR.)
0
3
6
9
12
15
18
21
24

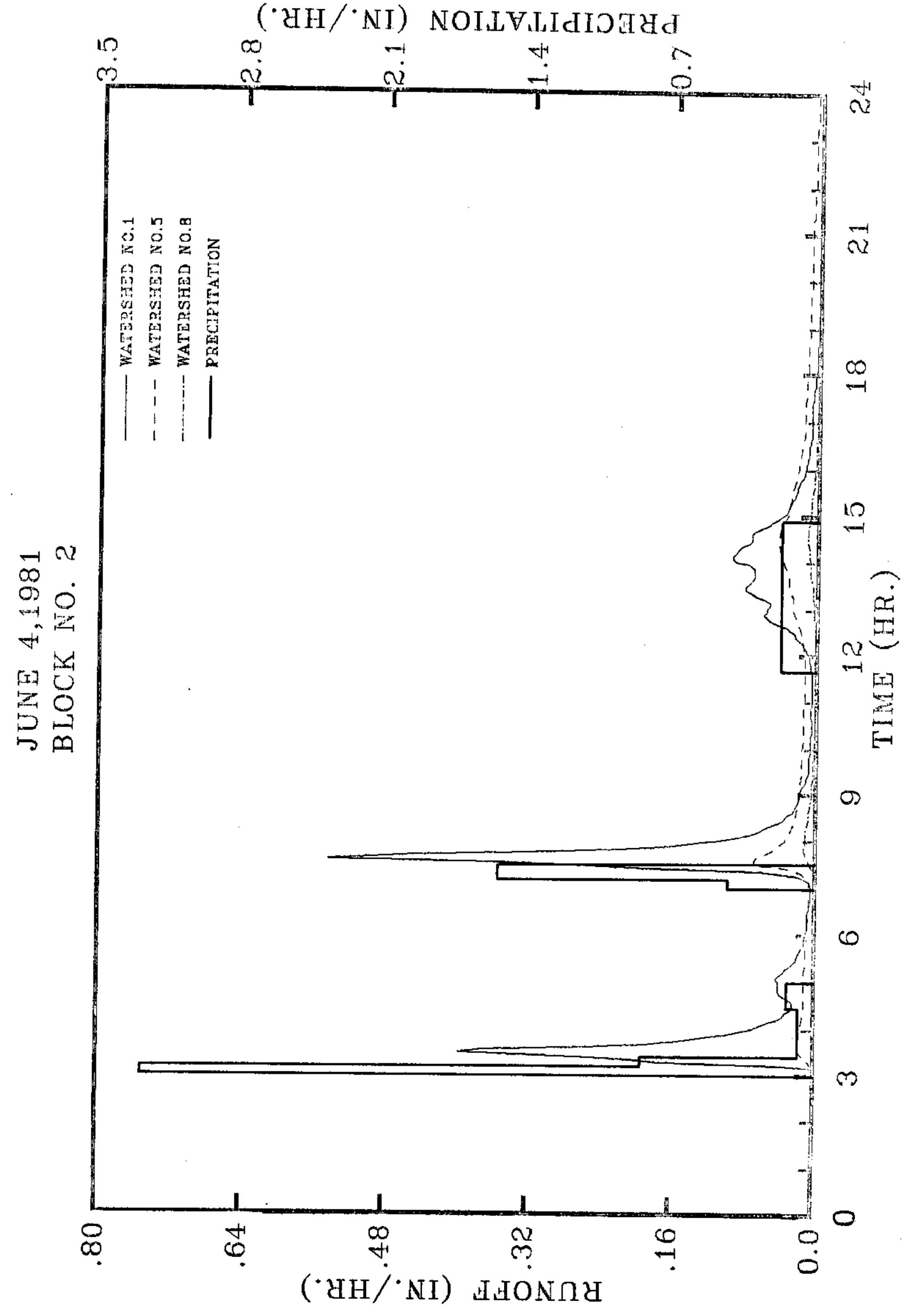

JUNE 3,1981
BLOCK NO. 1
WATERSHED NO.3
WATERSHED NO.4
WATERSHED NO.7
PRECIPITATION
RUNOFF (IN./HR.)
.15
.12
.09
.06
.03
0.0
PRECIPITATION (IN./HR.)
2.5
2.0
1.5
1.0
0.5
0
3
6
9
12
15
18
21
24
TIME (HR.)


JUNE 3,1981
BLOCK NO. 2
WATERSHED NO.1
WATERSHED NO.5
WATERSHED NO.8
PRECIPITATION
RUNOFF (IN./HR.)
PRECIPITATION (IN./HR.)
TIME (HR.)
.15
.12
.09
.06
.03
0.0
2.5
2.0
1.5
1.0
0.5
0
3
6
9
12
15
18
21
24

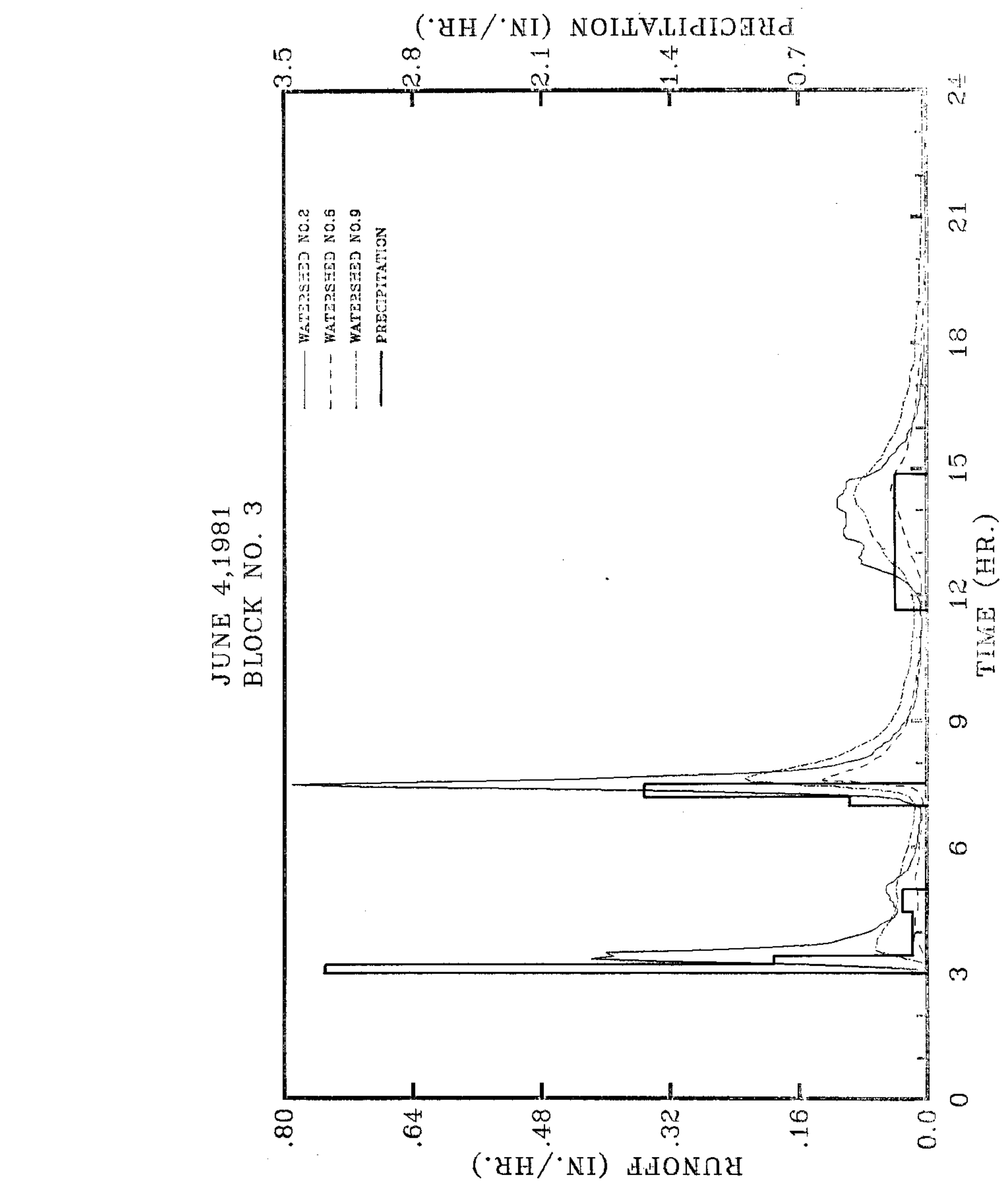
JUNE 3,1981
BLOCK NO. 3

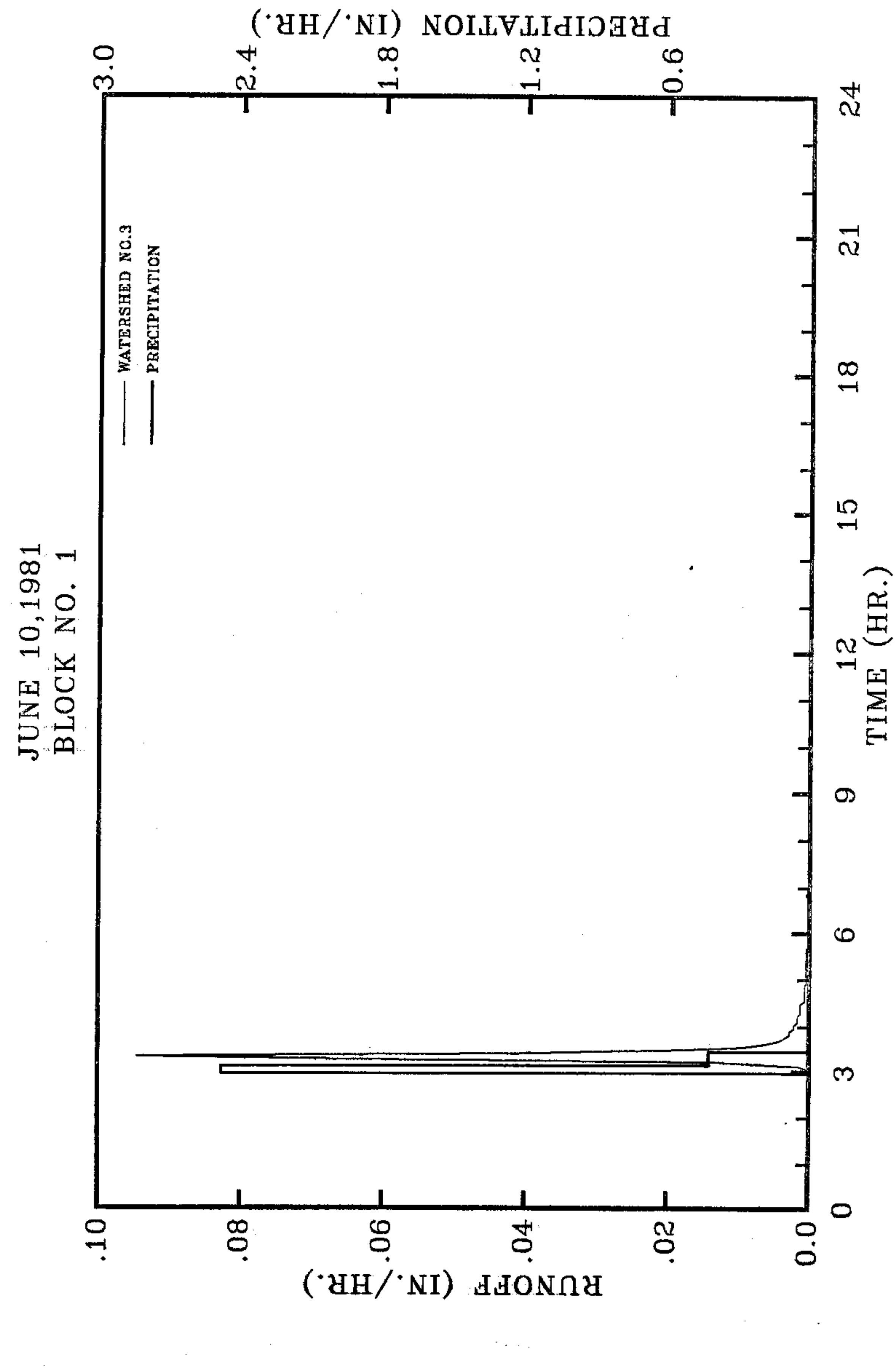


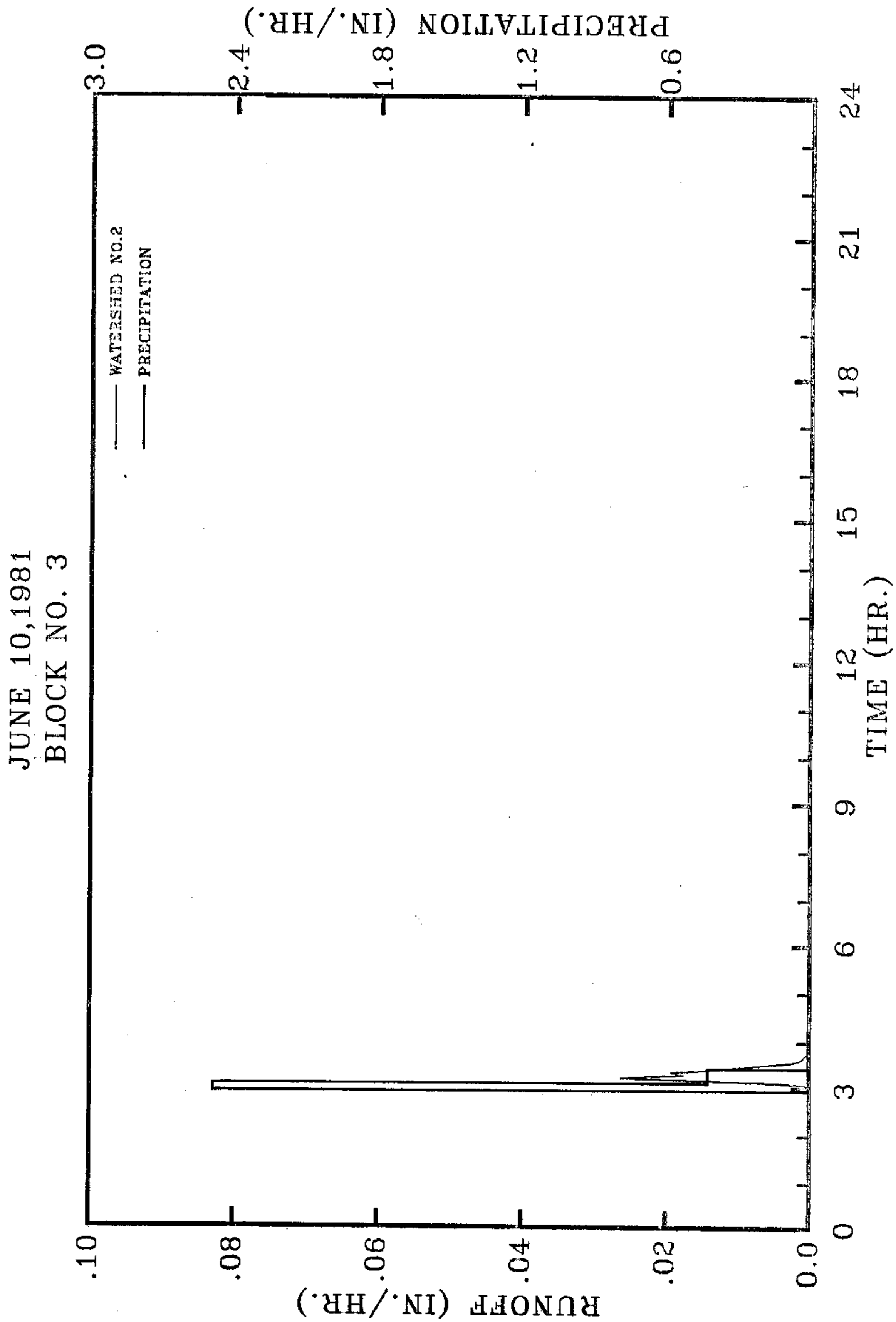

JUNE 4,1981
BLOCK NO. 1
WATERSHED NO.3
WATERSHED NO.4
WATERSHED NO.7
PRECIPITATION
RUNOFF (IN./HR.)
PRECIPITATION (IN./HR.)
TIME (HR.)
.80
.64
.48
.32
.16
0.0
3.5
2.8
2.1
1.4
0.7
0
3
6
9
12
15
18
21
24



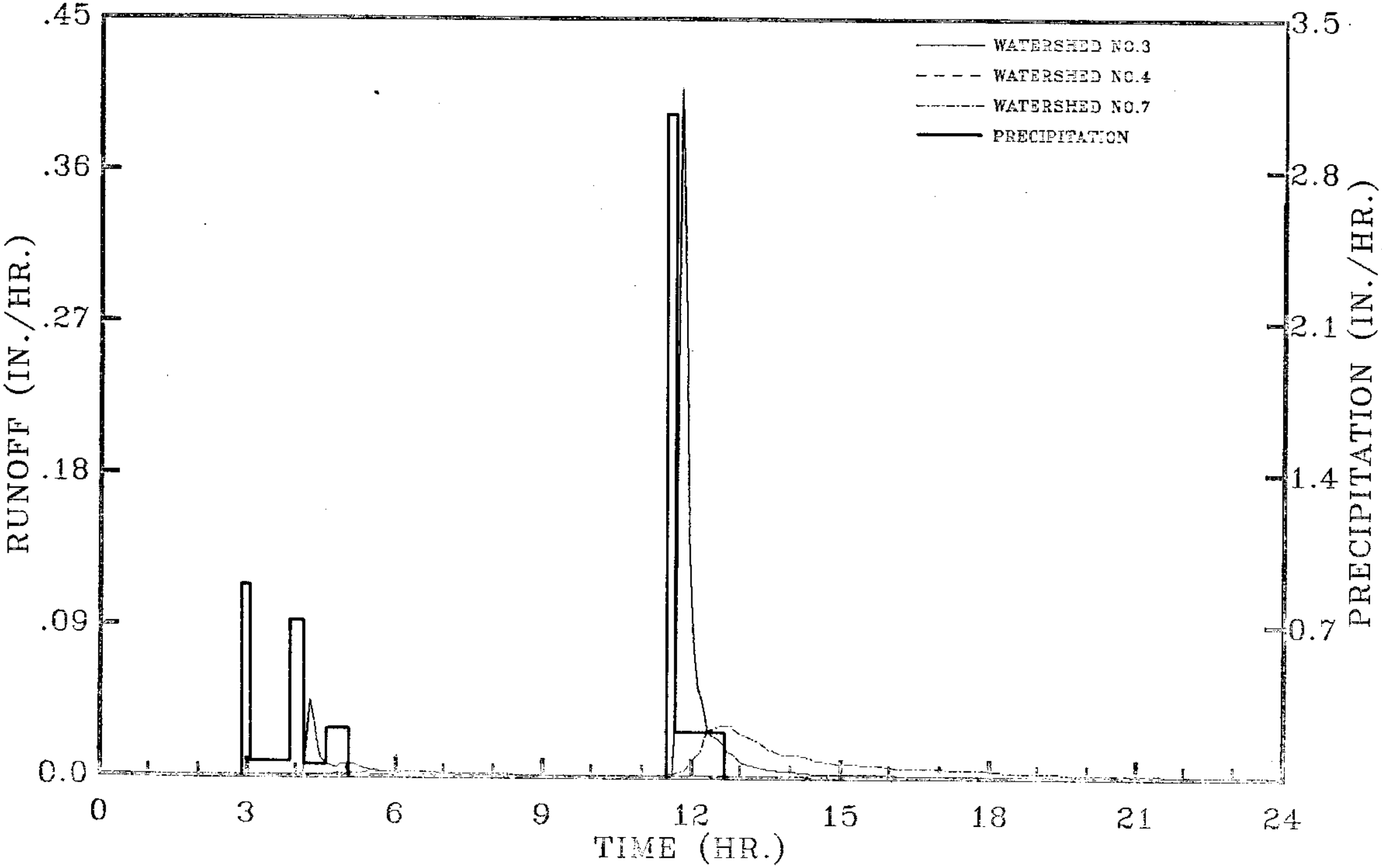
JUNE 4,1981
BLOCK NO. 2
WATERSHED NO.1
WATERSHED NO.5
WATERSHED NO.8
PRECIPITATION
PRECIPITATION (IN./HR.)
3.5
2.8
2.1
1.4
0.7
RUNOFF (IN./HR.)
.80
.64
.48
.32
.16
0.0
TIME (HR.)
0
3
6
9
12
15
18
21
24

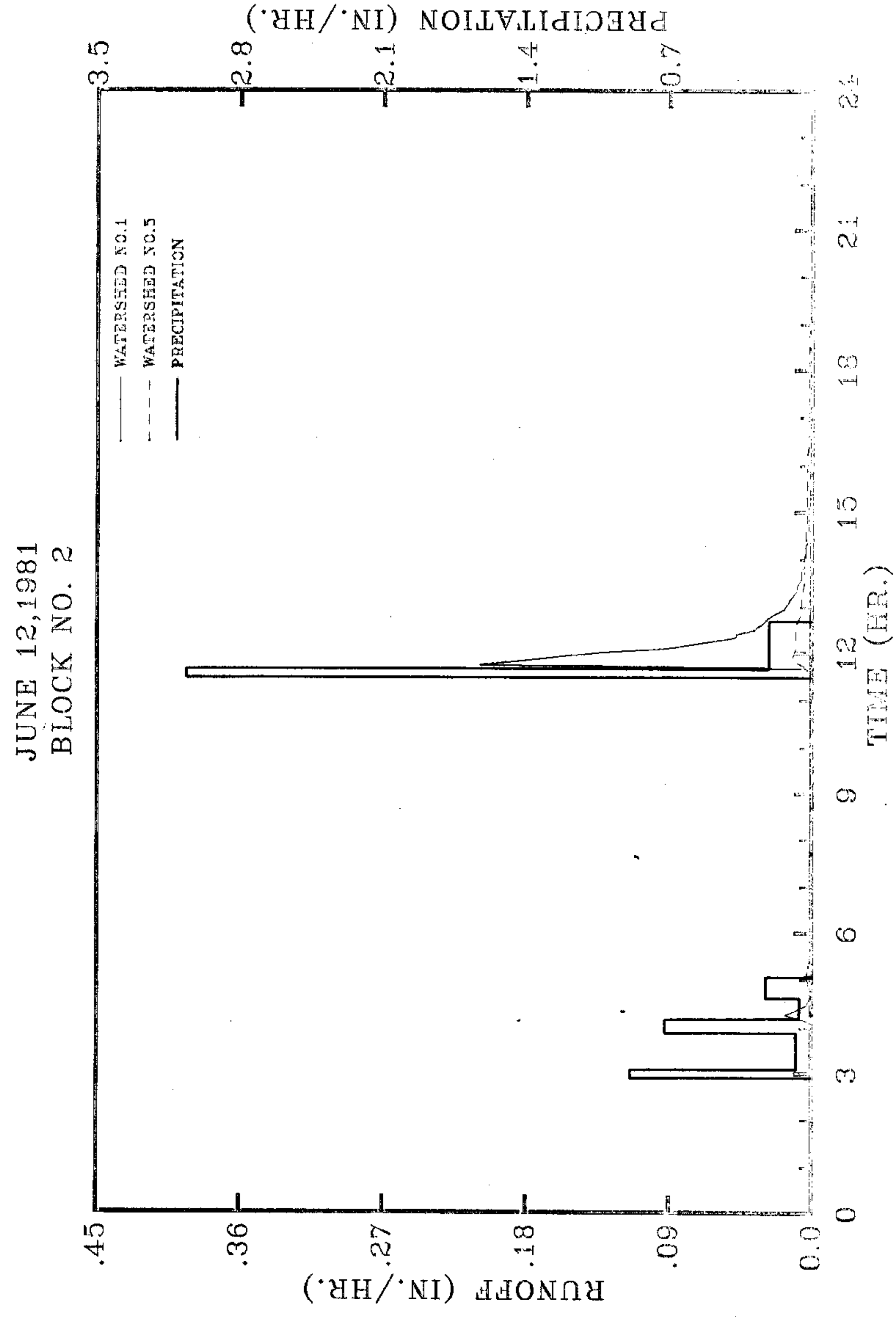

JUNE 4,1981
BLOCK NO. 3
RUNOFF (IN./HR.)
PRECIPITATION (IN./HR.)
TIME (HR.)
WATERSHED NO.2
WATERSHED NO.6
WATERSHED NO.9
PRECIPITATION
.80
.64
.48
.32
.16
0.0
3.5
2.8
2.1
1.4
0.7
0
3
6
9
12
15
18
21
24


JUNE 10,1981
BLOCK NO. 1
WATERSHED NO.3
PRECIPITATION
PRECIPITATION (IN./HR.)
3.0
2.4
1.8
1.2
0.6
RUNOFF (IN./HR.)
.10
.08
.06
.04
.02
0.0
TIME (HR.)
0
3
6
9
12
15
18
21
24


JUNE 10,1981
BLOCK NO. 3
WATERSHED NO.2
PRECIPITATION
RUNOFF (IN./HR.)
.10
.08
.06
.04
.02
0.0
PRECIPITATION (IN./HR.)
3.0
2.4
1.8
1.2
0.6
TIME (HR.)
0
3
6
9
12
15
18
21
24

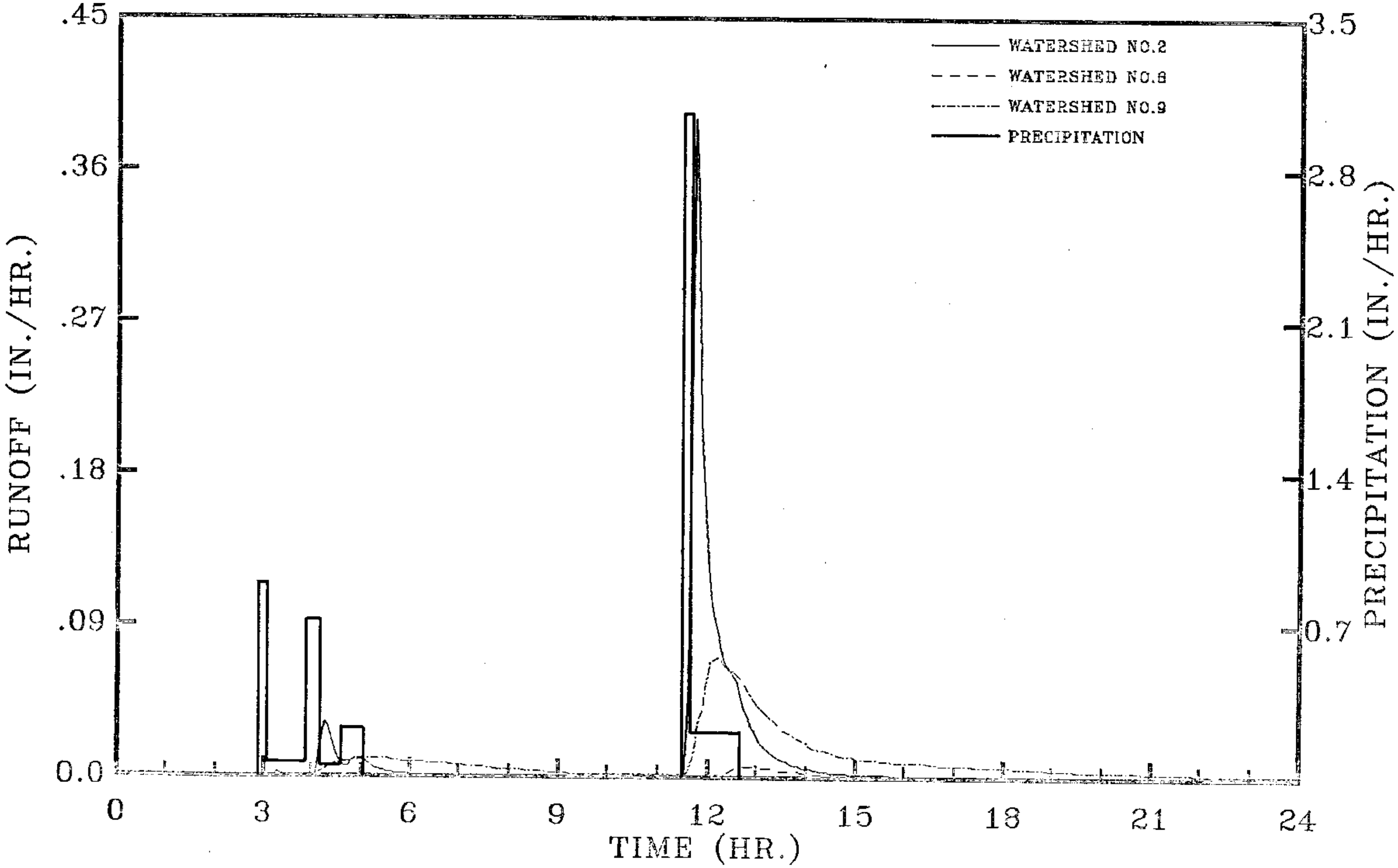
JUNE 12,1981
BLOCK NO. 1

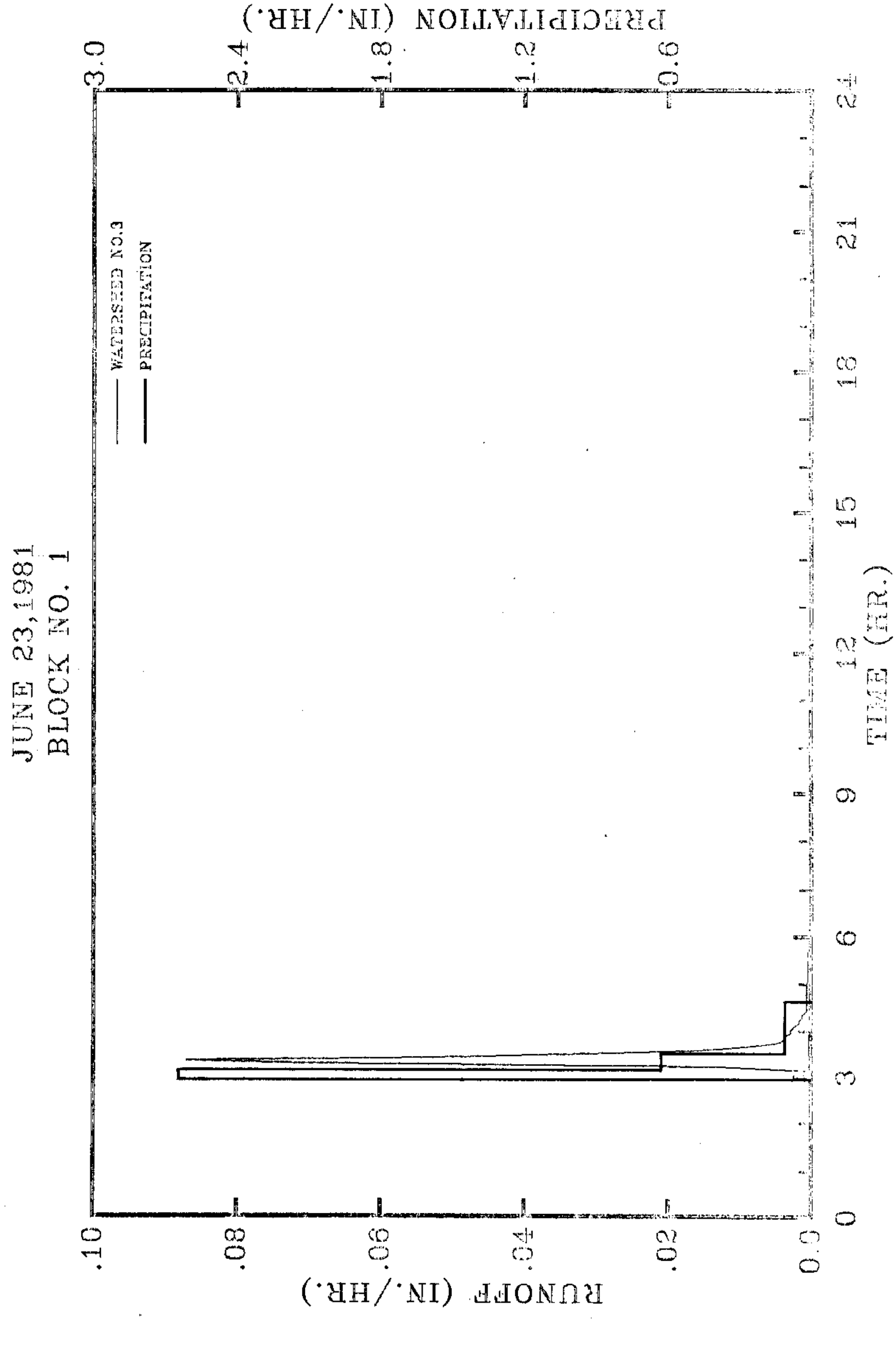


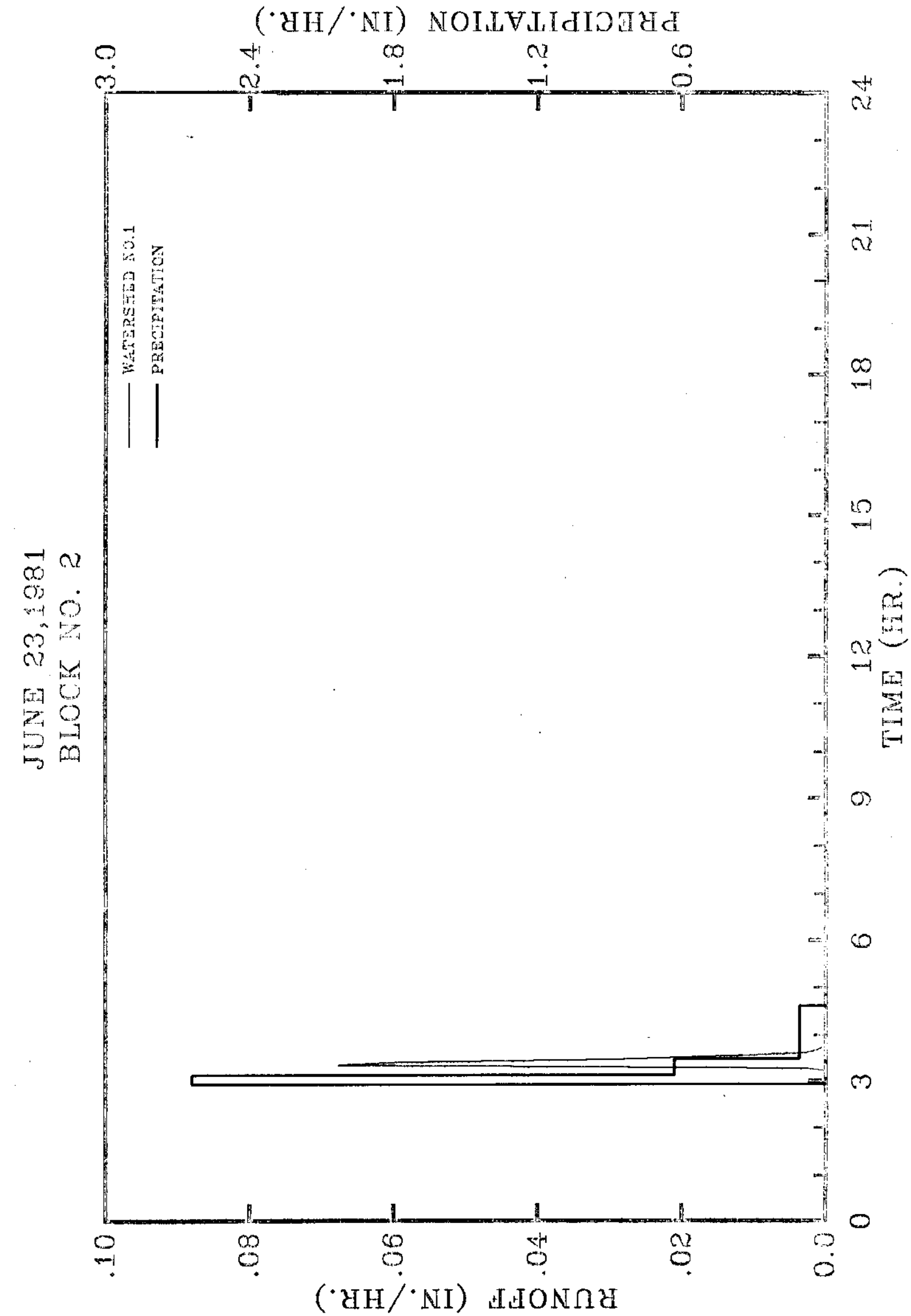


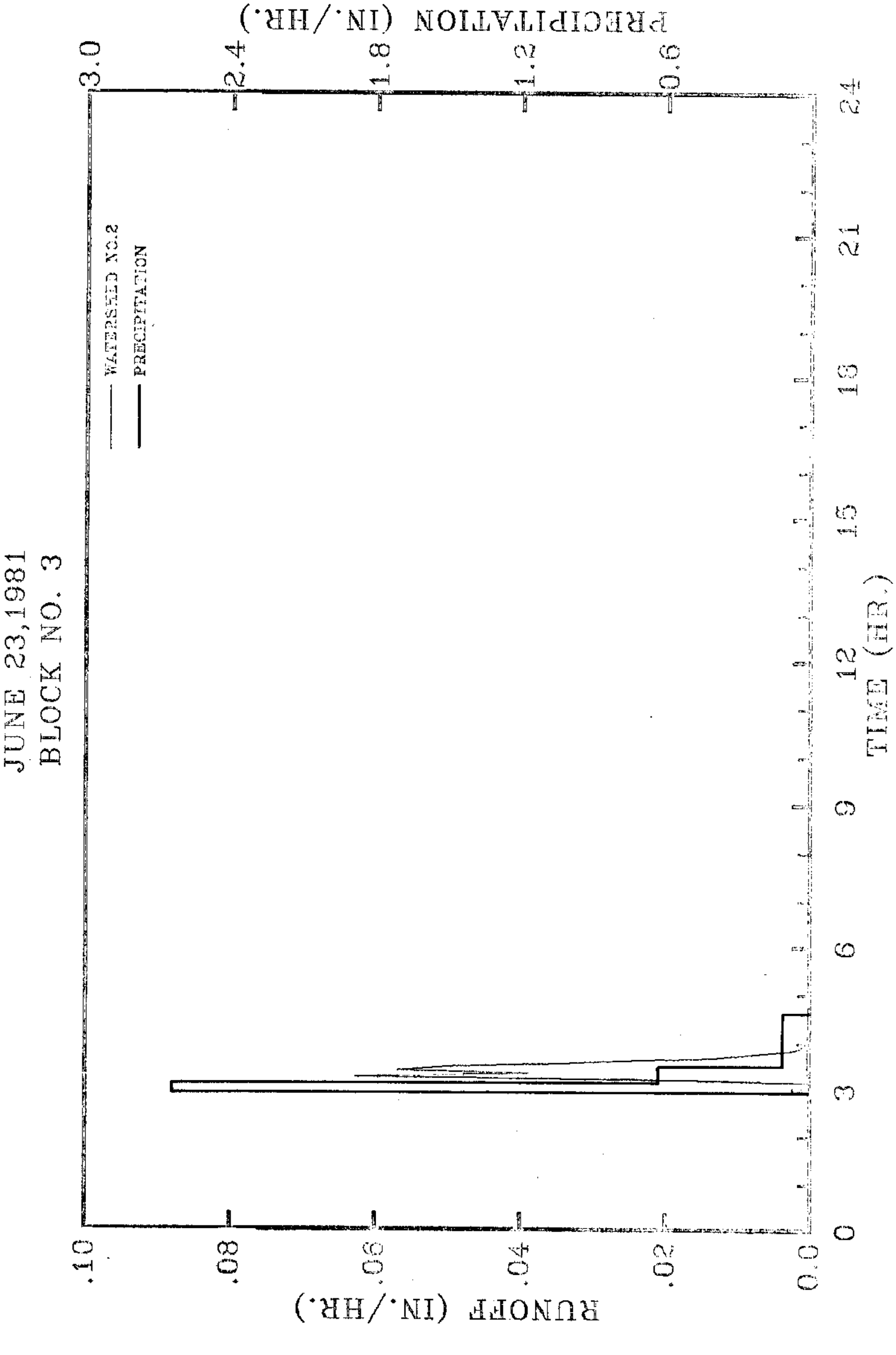
JUNE 12,1981
BLOCK NO. 2
WATERSHED NO.1
WATERSHED NO.5
PRECIPITATION
PRECIPITATION (IN./HR.)
3.5
2.8
2.1
1.4
0.7
RUNOFF (IN./HR.)
.45
.36
.27
.18
.09
0.0
TIME (HR.)
0
3
6
9
12
15
18
21
24

JUNE 12,1981
BLOCK NO. 3

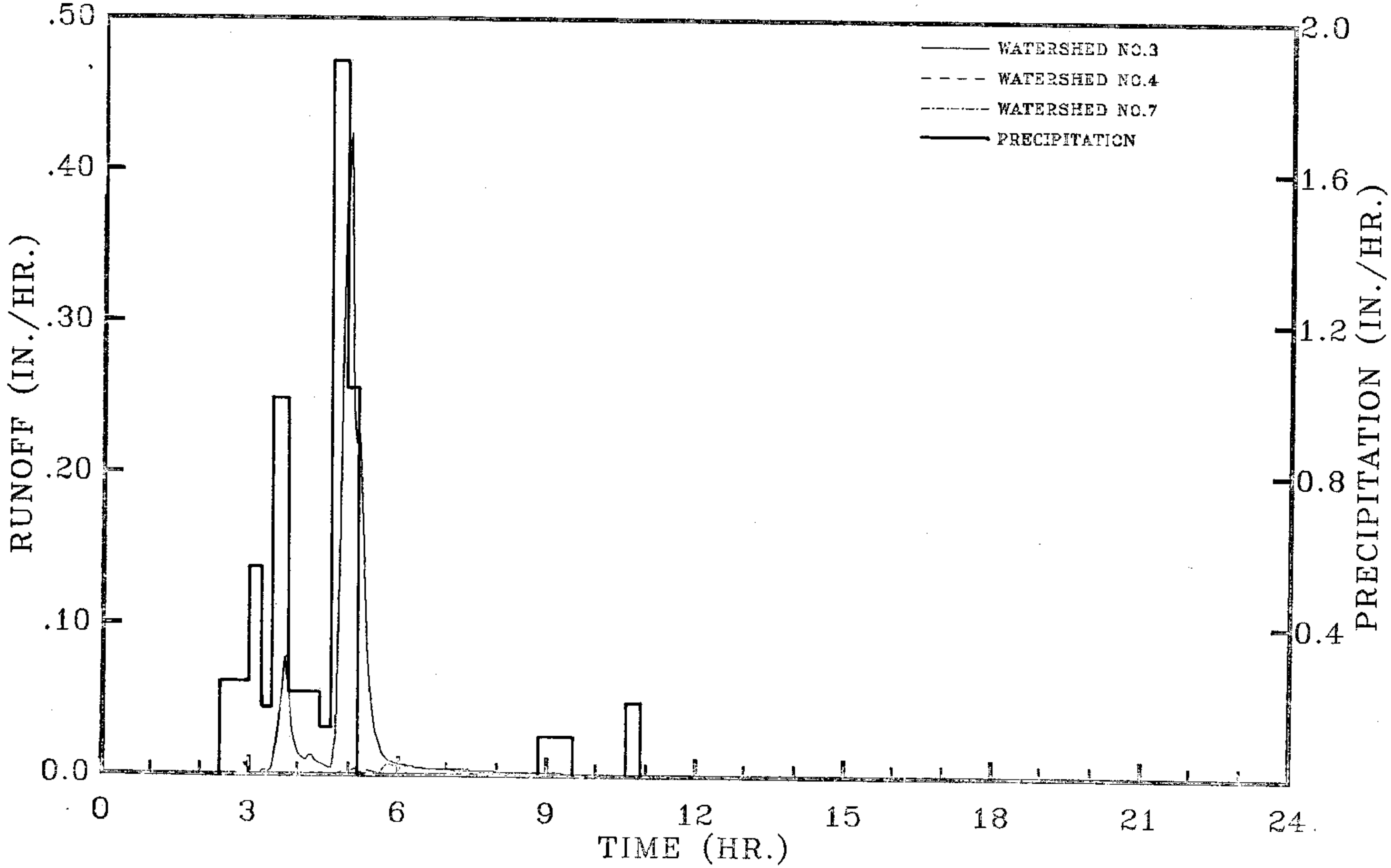


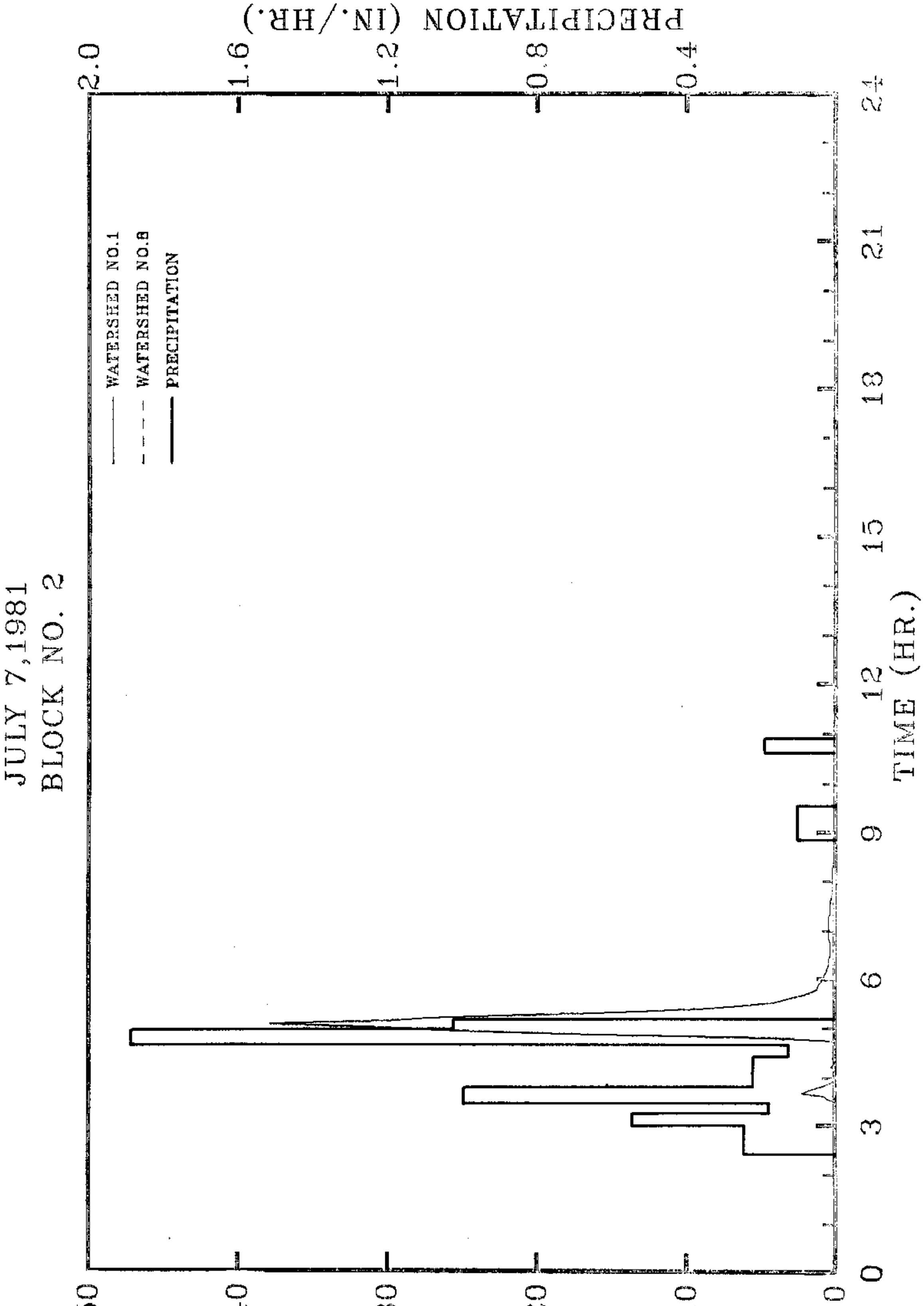

JUNE 23,1981
BLOCK NO. 1
WATERSHED NO.3
PRECIPITATION
PRECIPITATION (IN./HR.)
3.0
2.4
1.8
1.2
0.6
RUNOFF (IN./HR.)
.10
.08
.06
.04
.02
0.0
TIME (HR.)
0
3
6
9
12
15
18
21
24

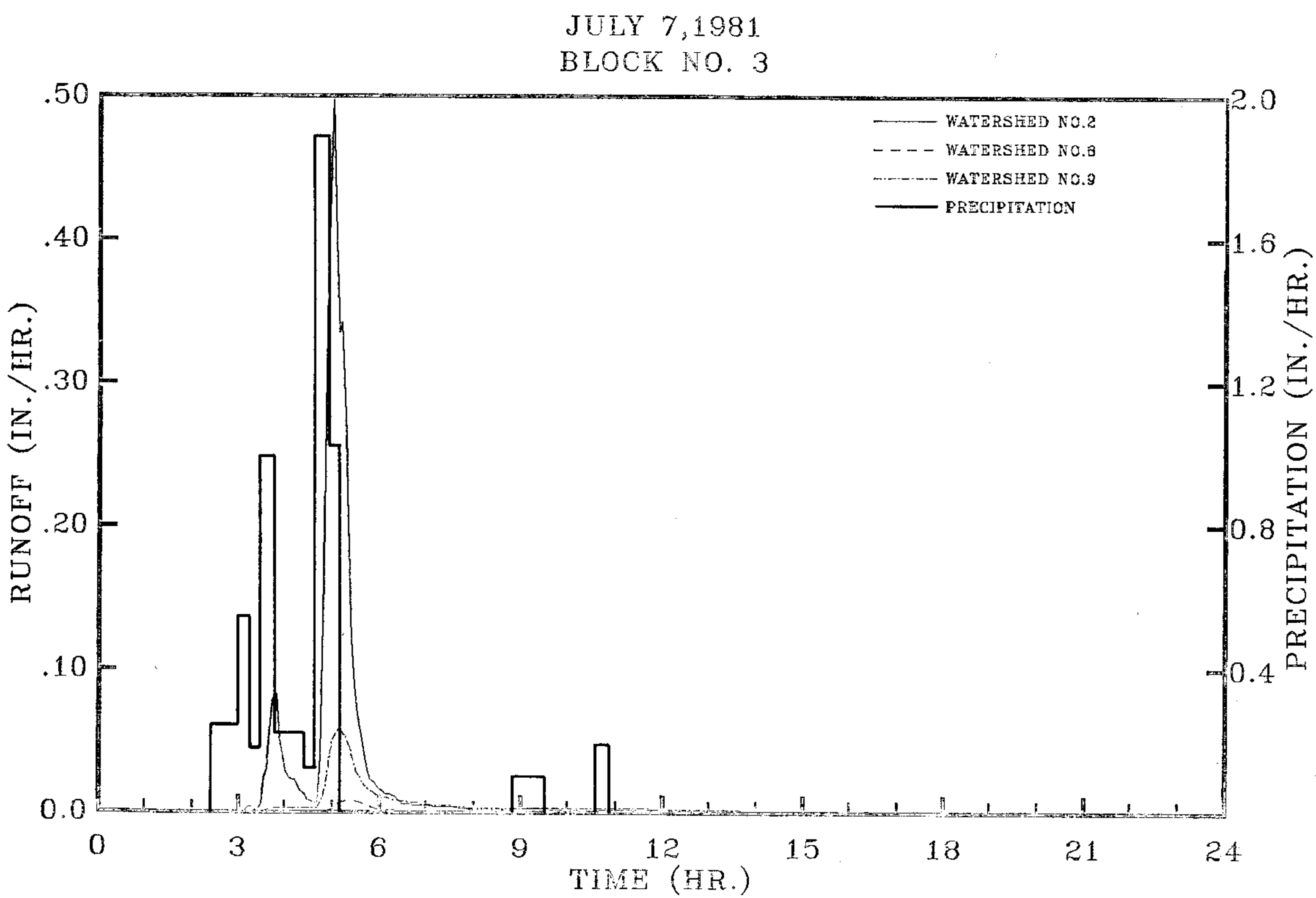

JUNE 23,1981
BLOCK NO. 2
WATERSHED NO.1
PRECIPITATION
PRECIPITATION (IN./HR.)
3.0
2.4
1.8
1.2
0.6
RUNOFF (IN./HR.)
.10
.08
.06
.04
.02
0.0
TIME (HR.)
0
3
6
9
12
15
18
21
24

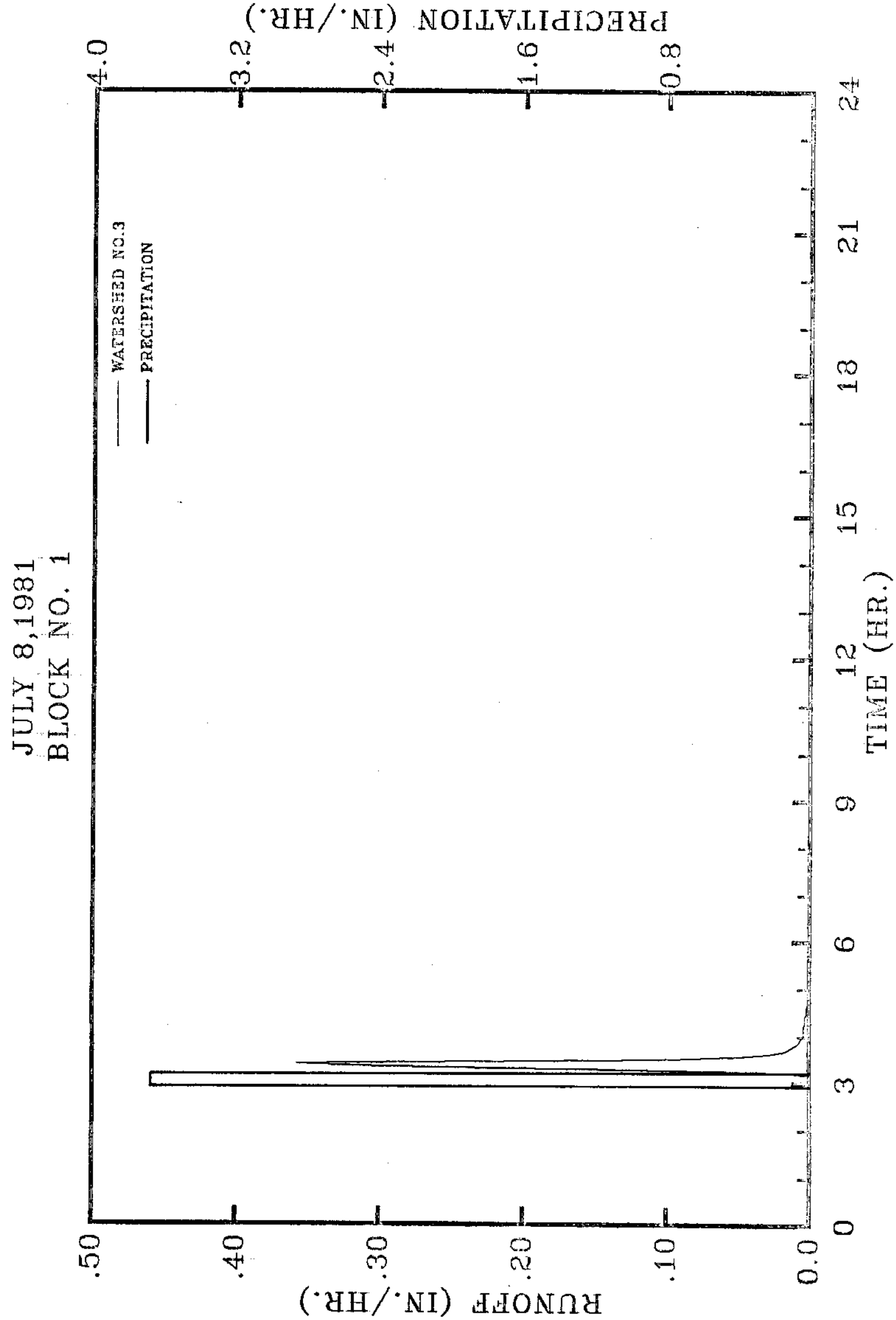

JUNE 23,1981
BLOCK NO. 3
WATERSHED NO.2
PRECIPITATION
PRECIPITATION (IN./HR.)
3.0
2.4
1.8
1.2
0.6
RUNOFF (IN./HR.)
.10
.08
.06
.04
.02
0.0
TIME (HR.)
0
3
6
9
12
15
18
21
24

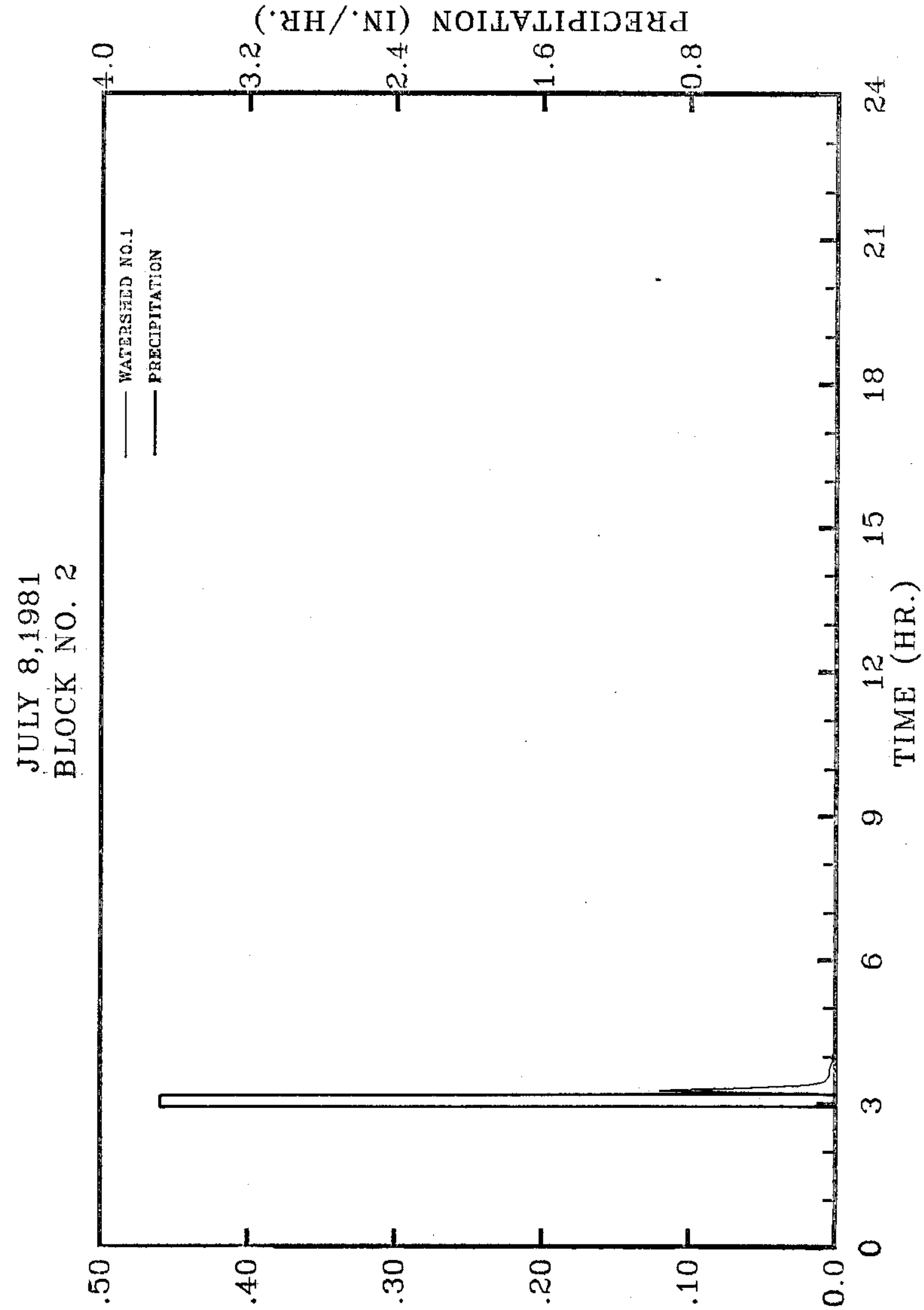
JULY 7,1981
BLOCK NO. 1

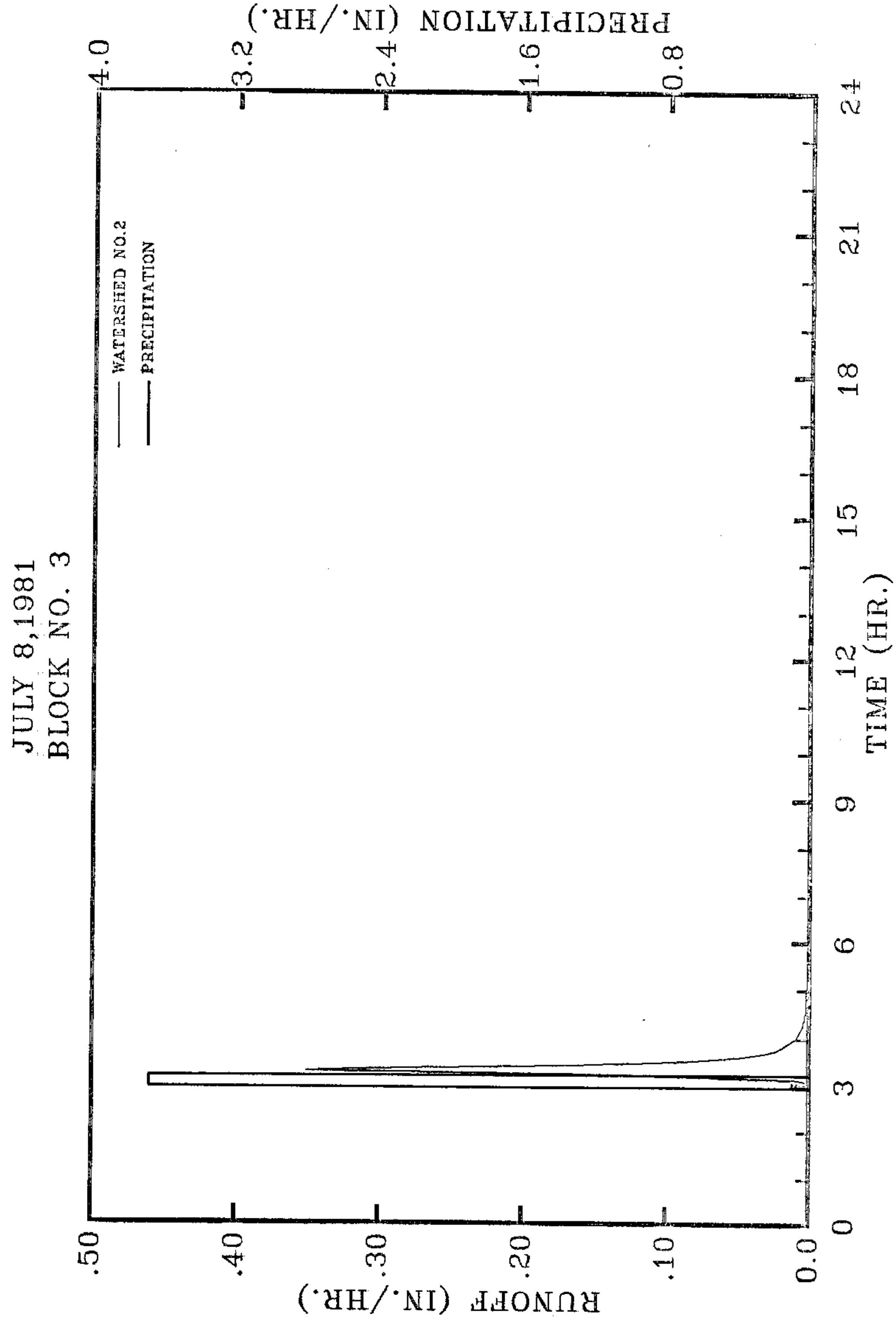



JULY 7,1981
BLOCK NO. 2
WATERSHED NO.1
WATERSHED NO.8
PRECIPITATION
PRECIPITATION (IN./HR.)
2.0
1.6
1.2
0.8
0.4
RUNOFF (IN./HR.)
.50
.40
.30
.20
.10
0.0
TIME (HR.)
0
3
6
9
12
15
18
21
24


JULY 7,1981
BLOCK NO. 3
WATERSHED NO.2
WATERSHED NO.8
WATERSHED NO.9
PRECIPITATION
RUNOFF (IN./HR.)
PRECIPITATION (IN./HR.)
TIME (HR.)
.50
.40
.30
.20
.10
0.0
2.0
1.6
1.2
0.8
0.4
0
3
6
9
12
15
18
21
24


JULY 8,1981
BLOCK NO. 1
WATERSHED NO.3
PRECIPITATION
PRECIPITATION (IN./HR.)
4.0
3.2
2.4
1.6
0.8
RUNOFF (IN./HR.)
.50
.40
.30
.20
.10
0.0
TIME (HR.)
0
3
6
9
12
15
18
21
24


JULY 8,1981
BLOCK NO. 2
PRECIPITATION (IN./HR.)
4.0
3.2
2.4
1.6
0.8
WATERSHED NO.1
PRECIPITATION
RUNOFF (IN./HR.)
.50
.40
.30
.20
.10
0.0
0
3
6
9
12
15
18
21
24
TIME (HR.)

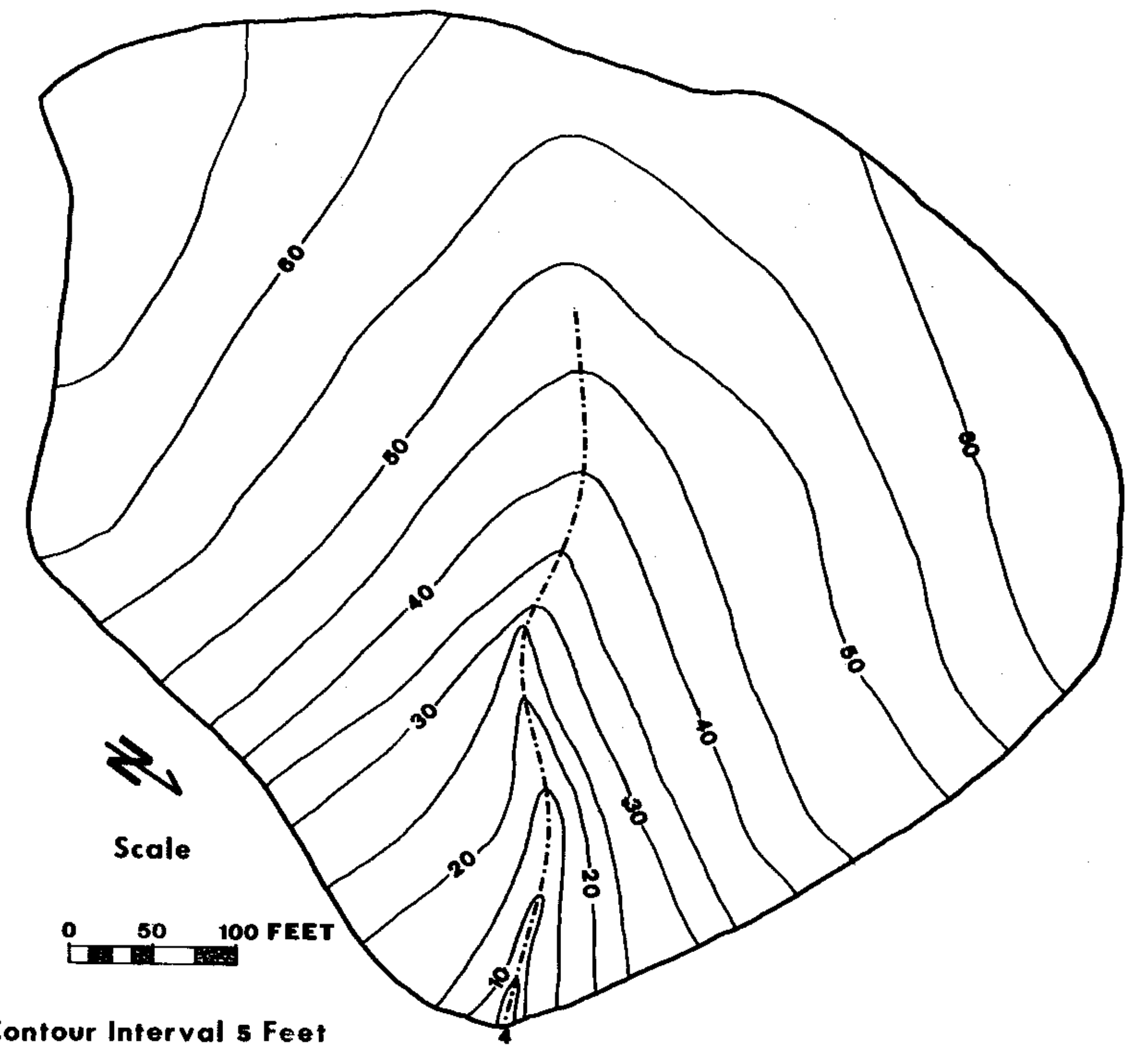

JULY 8,1981
BLOCK NO. 3
WATERSHED NO.2
PRECIPITATION
RUNOFF (IN./HR.)
0.0
.10
.20
.30
.40
.50
PRECIPITATION (IN./HR.)
0.8
1.6
2.4
3.2
4.0
TIME (HR.)
0
3
6
9
12
15
18
21
24

APPENDIX C

Watershed Maps

EXPERIMENTAL WATERSHED

NUMBER 1 6.46 ACRES

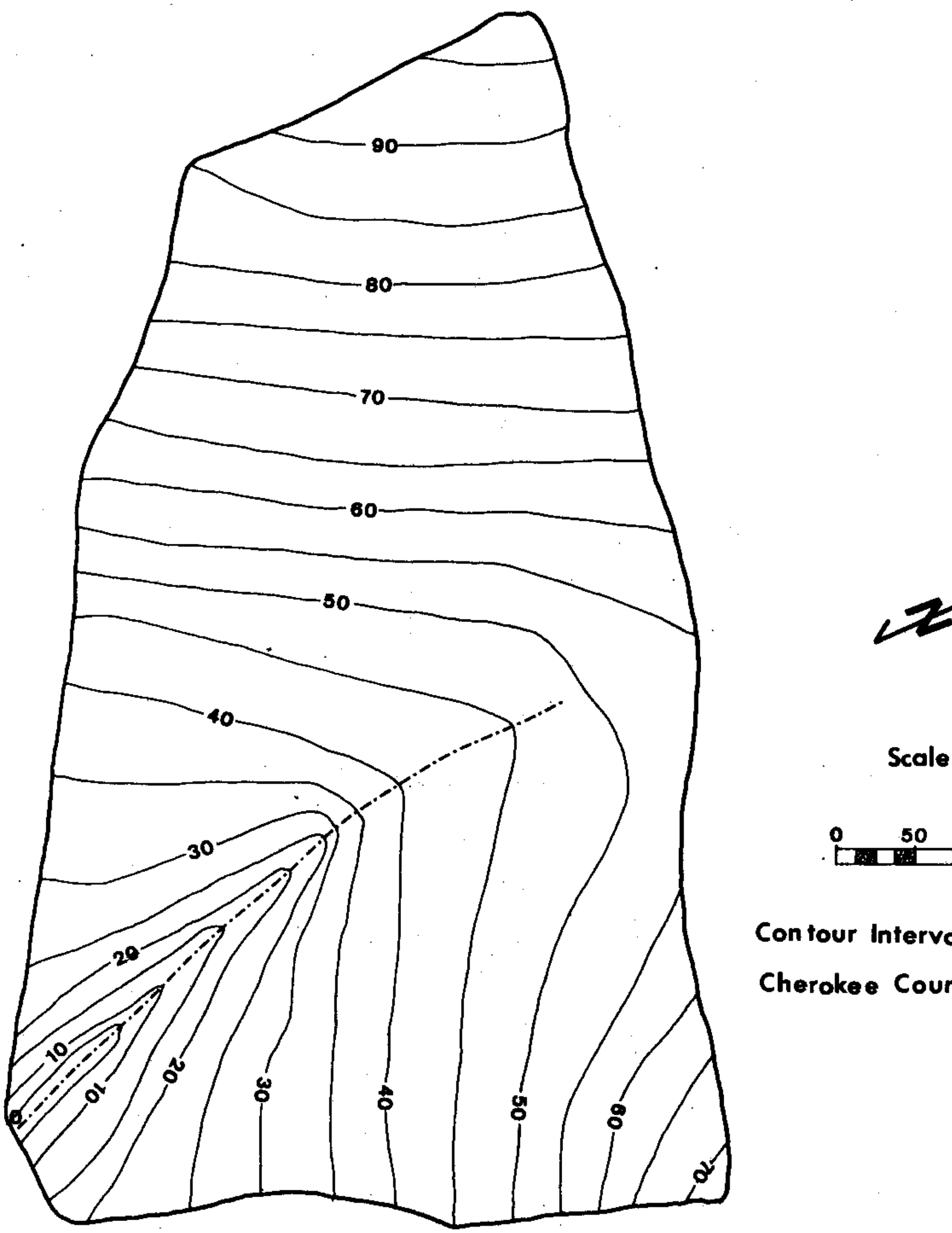


Contour Interval 5 Feet

Cherokee County Texas

EXPERIMENTAL WATERSHED

NUMBER 2 6.37 ACRES



Scale

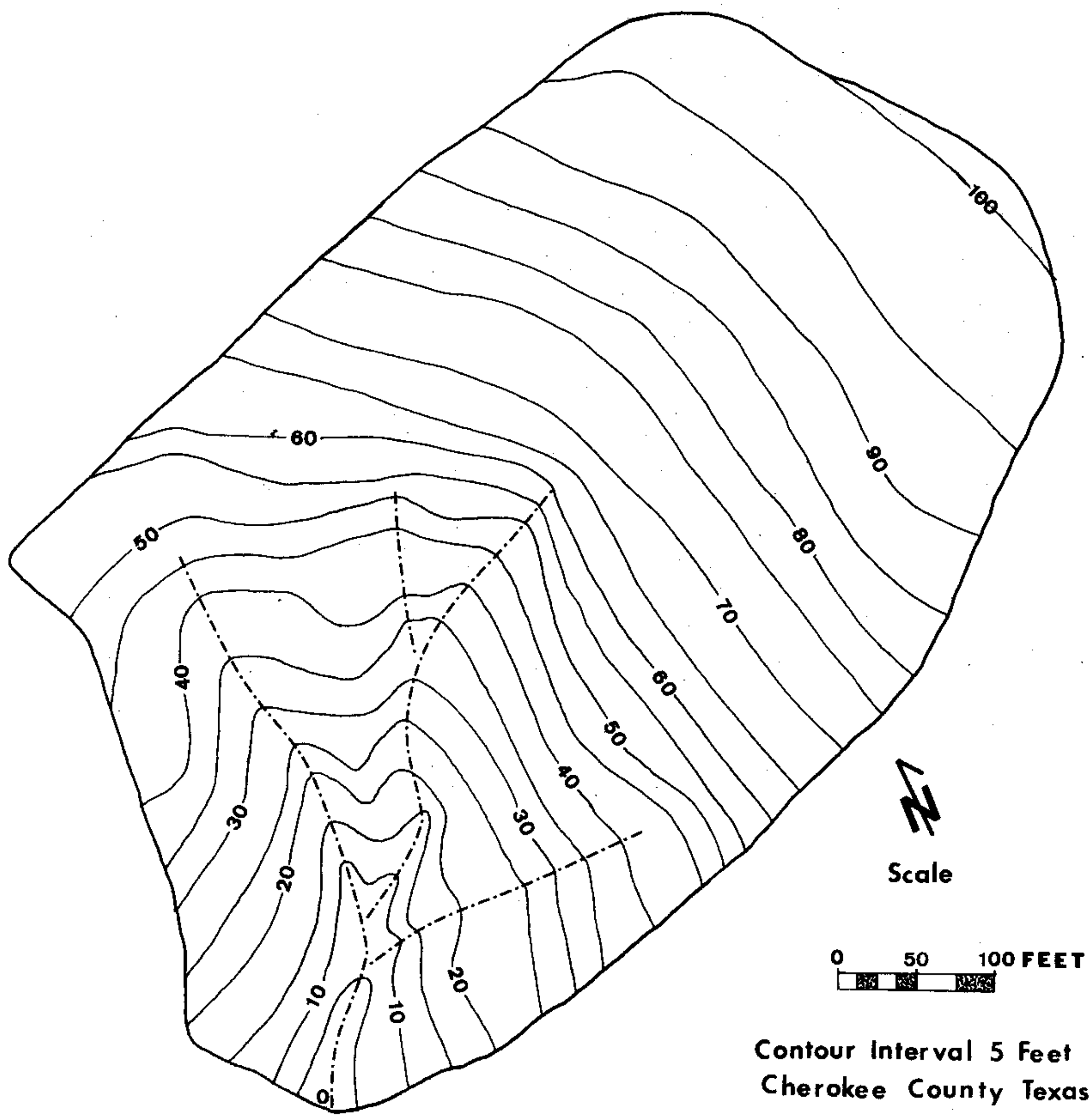
0 50 100 FEET

Contour Interval 5 Feet

Cherokee County Texas

EXPERIMENTAL WATERSHED

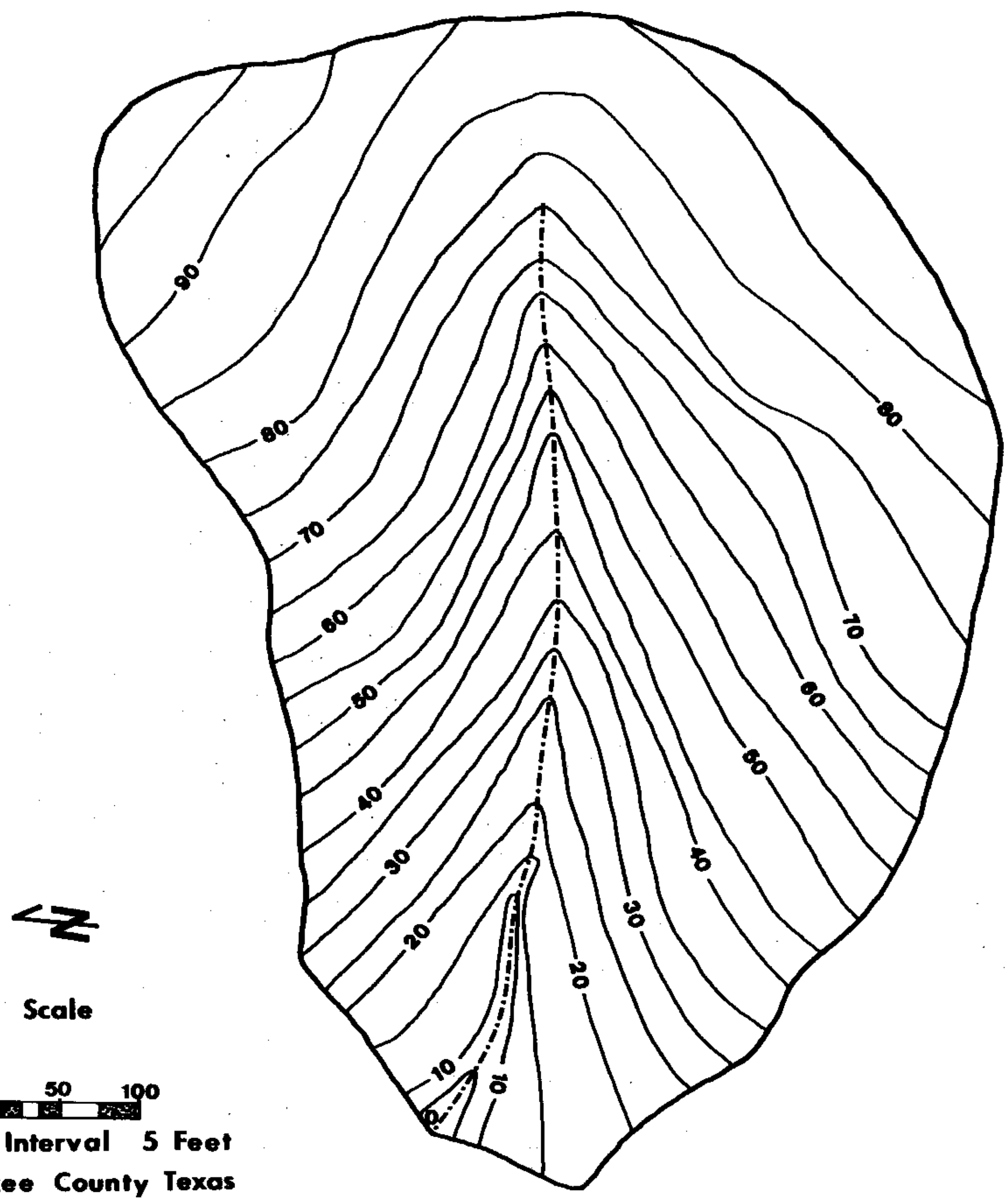
NUMBER 3 6.52 ACRES



Contour Interval 5 Feet
Cherokee County Texas

EXPERIMENTAL WATERSHED

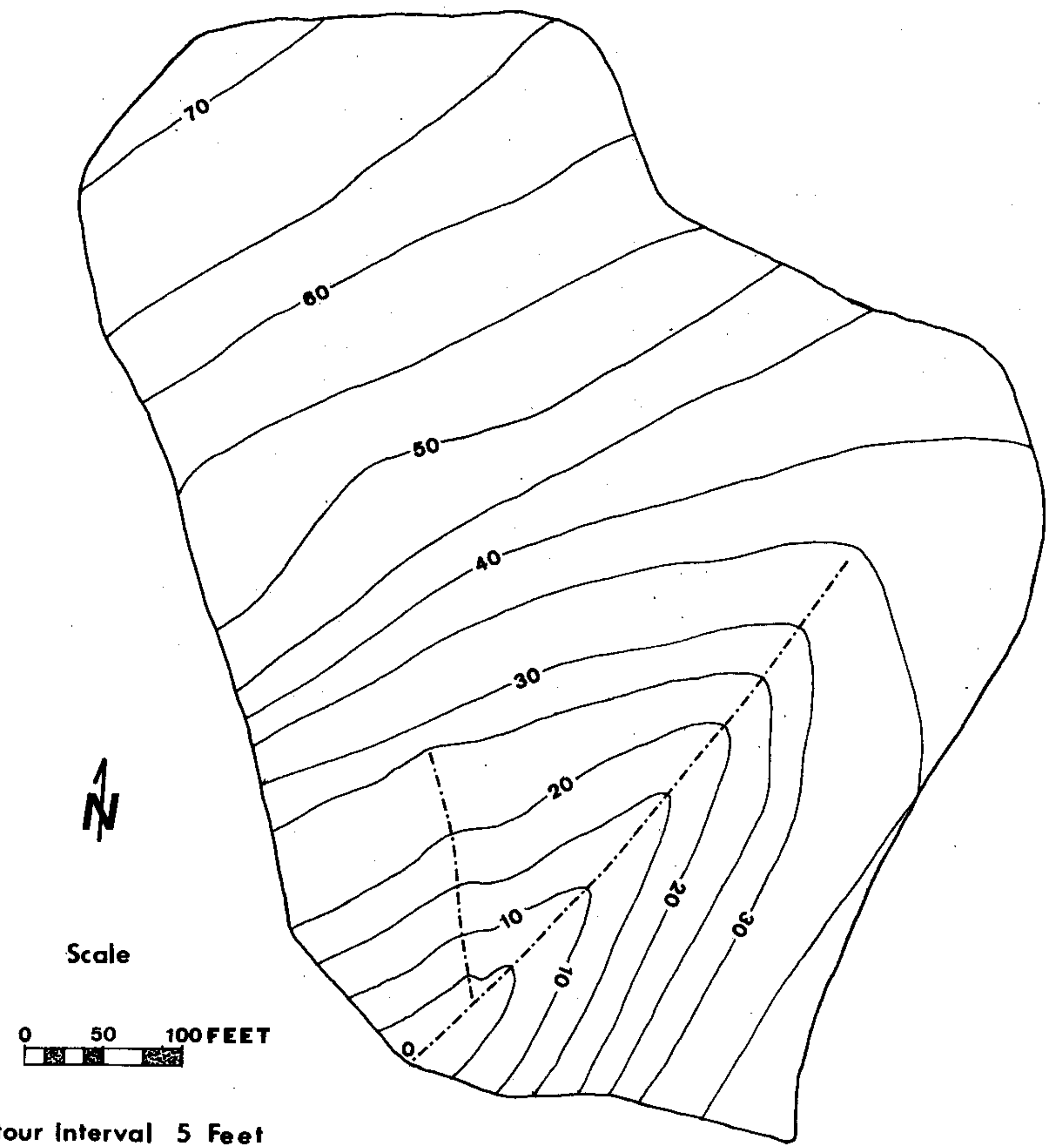
NUMBER 4 6.58 ACRES



Contour Interval 5 Feet
Cherokee County Texas

EXPERIMENTAL WATERSHED

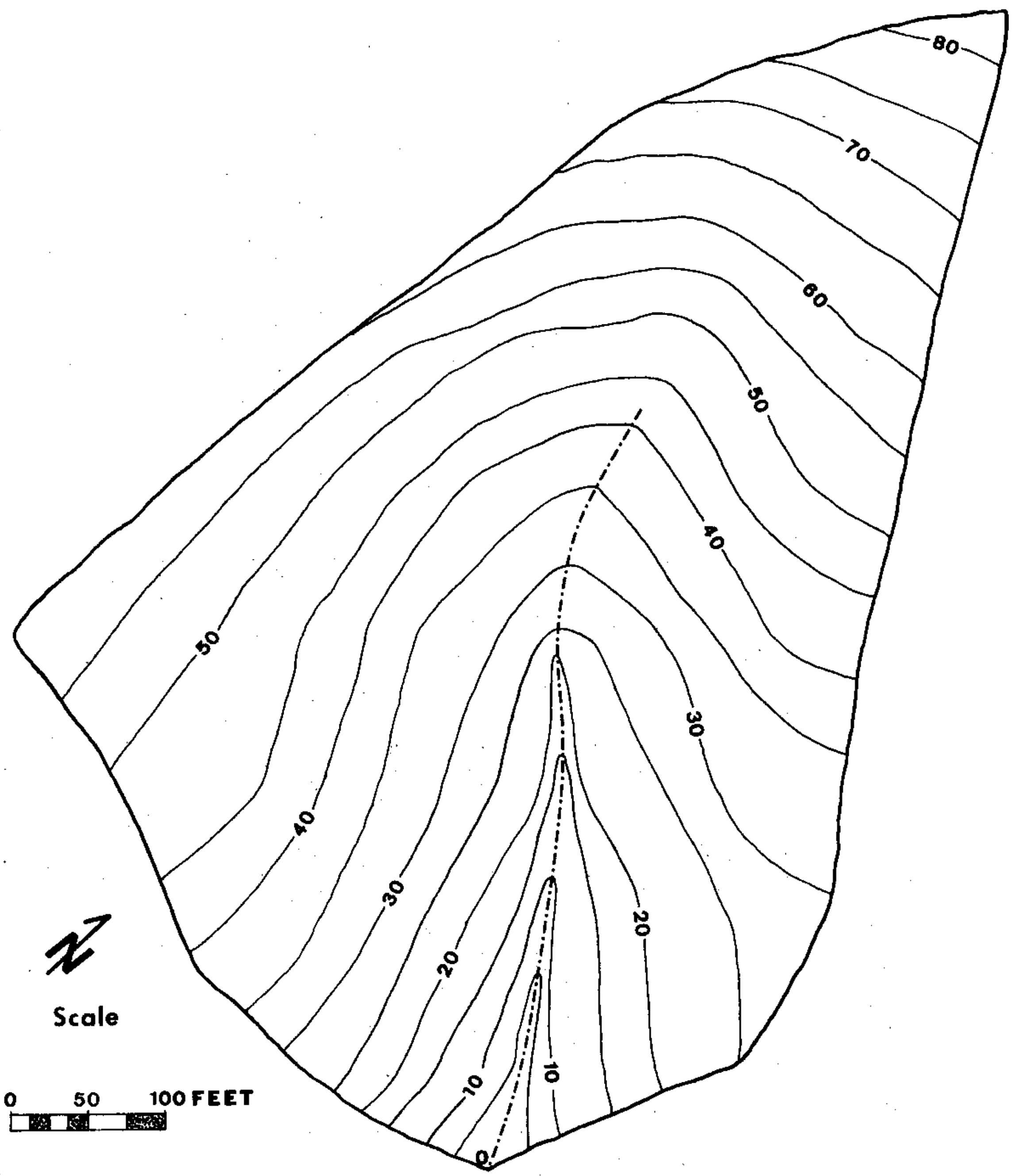
NUMBER 5 6.70 ACRES



Contour Interval 5 Feet
Cherokee County Texas

EXPERIMENTAL WATERSHED

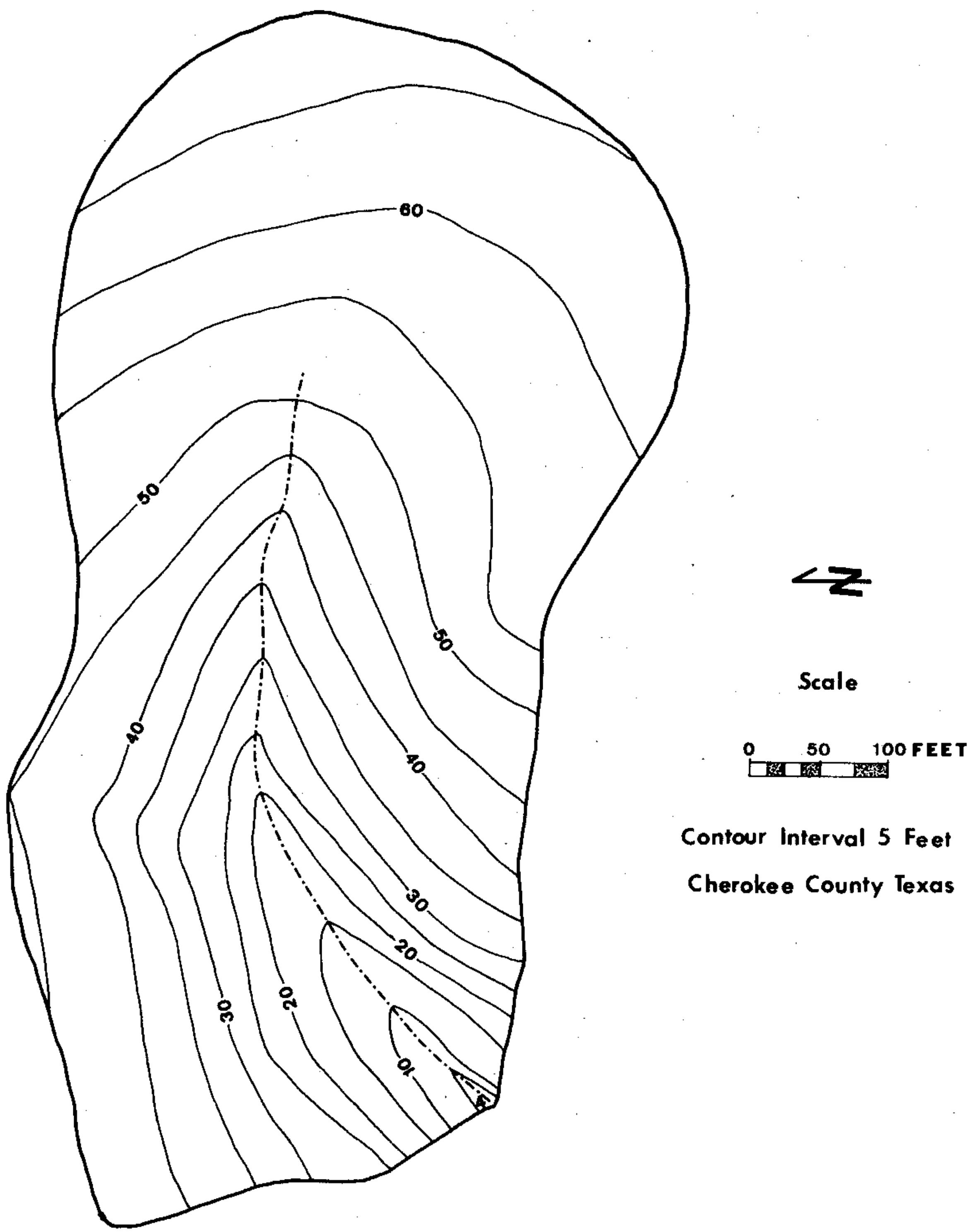
NUMBER 6 6.58 ACRES



Contour Interval 5 Feet
Cherokee County Texas

EXPERIMENTAL WATERSHED

NUMBER 7 6.78 ACRES

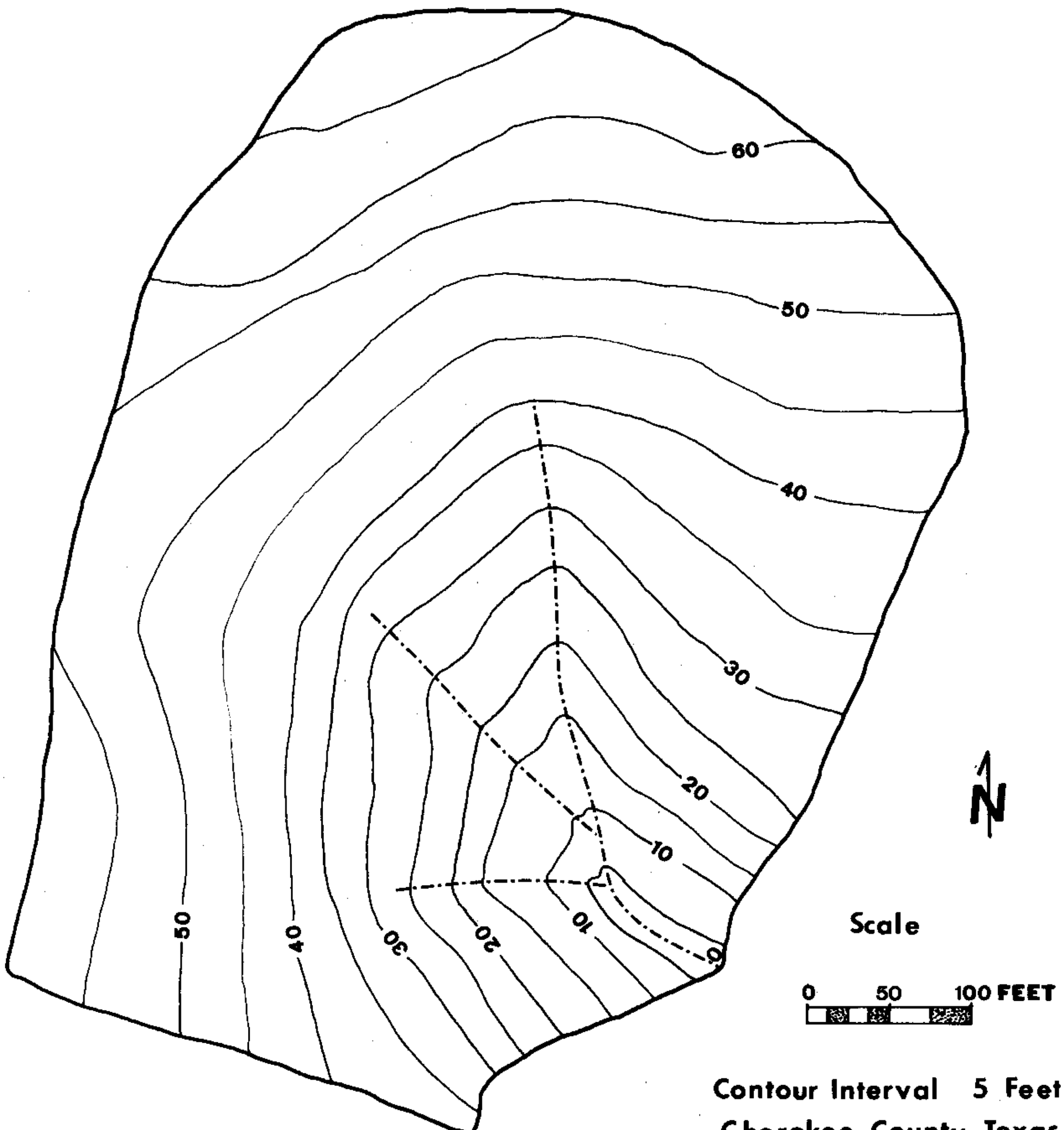


Contour Interval 5 Feet

Cherokee County Texas

EXPERIMENTAL WATERSHED

NUMBER 8 6.46 ACRES

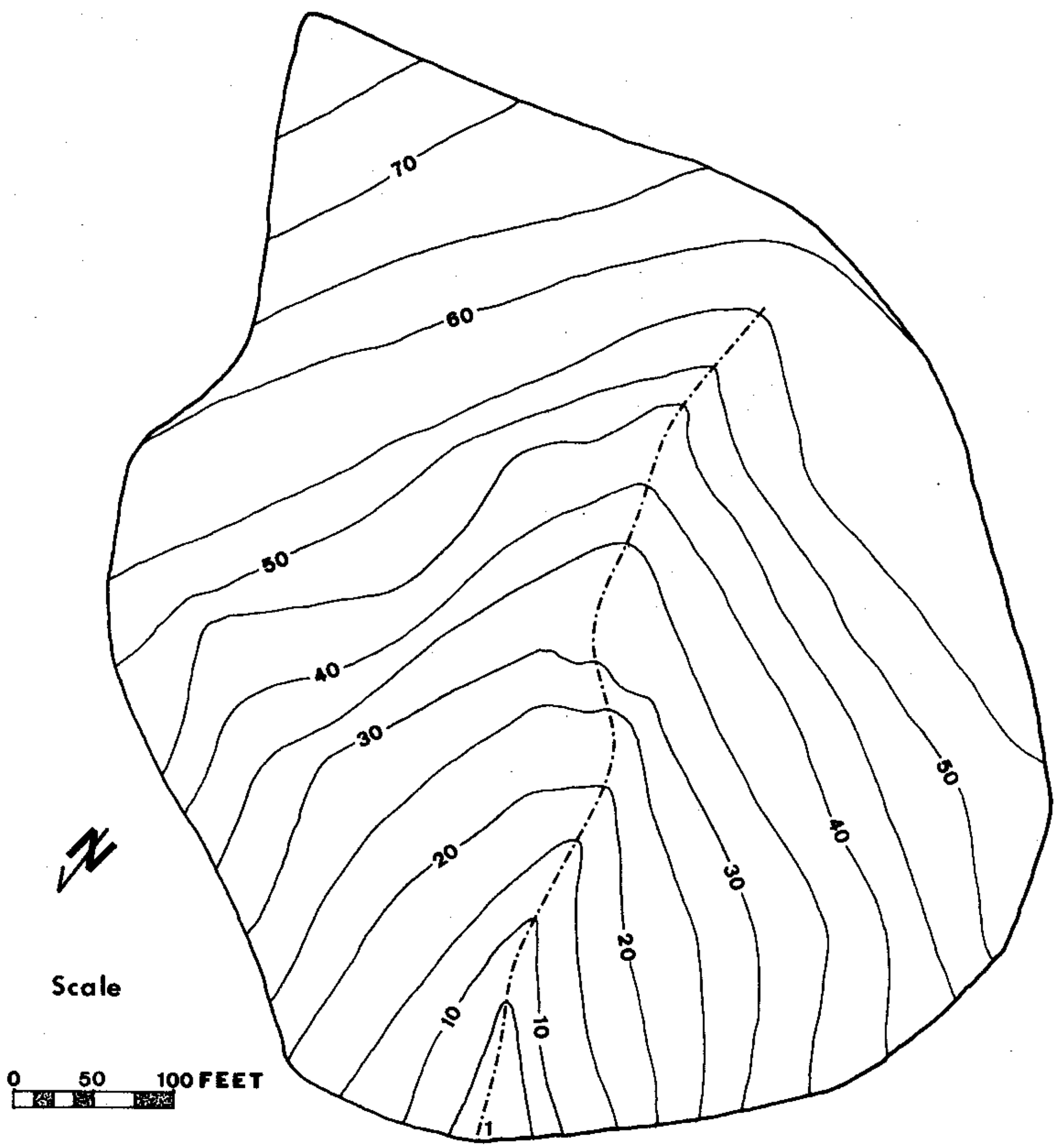


Contour Interval 5 Feet

Cherokee County Texas

EXPERIMENTAL WATERSHED

NUMBER 9 6.76 ACRES



Contour Interval 5 Feet

Cherokee County Texas