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PACIFIC GAS AND ELECTRIC COMPANY
DEPARTMENT OF ENGINEERING RESEARCH

STREAMFLOW STUDY
DE SABLA-CENTERVILLE PROJECT, FERC 803

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INTRODUCTION

The DeSabla-Centerville Project is located in the northeastern corner of Butte County, California, with a portion of the project area within the Lassen National Forest. The downstream project facilities lie approximately 15 miles east of Chico, California (Figure 1).

The project is supplied by two separate drainages, the West Branch Feather River and Butte Creek. The West Branch Feather River drainage above the Hendricks Diversion Dam contains approximately 45 square miles. This section ranges in elevation from 5497 feet at stream mile 42 (Round Valley Reservoir) to 3100 feet at stream mile 29 (Hendricks Diversion Dam) (Figure 2). The Butte Creek drainage above the Butte Creek Diversion Dam contains approximately 60 square miles. Additionally, there is approximately 10-15 square miles of drainage between Butte Creek Diversion Dam and Centerville Diversion Dam. This section of stream ranges in elevation from approximately 2300 feet at stream mile 67.5 (Butte Creek Diversion Dam) to 1000 feet at stream mile 58 (Centerville Diversion Dam). The elevation declines to 750 feet at stream mile 51.7 (Centerville Powerhouse) (Figure 3).

Streamflow studies to evaluate the relationships between different flows and various parameters of fish habitat were conducted below Butte Creek and Centerville Diversion Dams in August 1974 and were conducted below the Hendricks Diversion Dam in August 1975.

Description of the West Branch Feather River (WBFR) Below Hendricks Diversion Dam

The WBFR below the Hendricks Diversion Dam is characterized by a

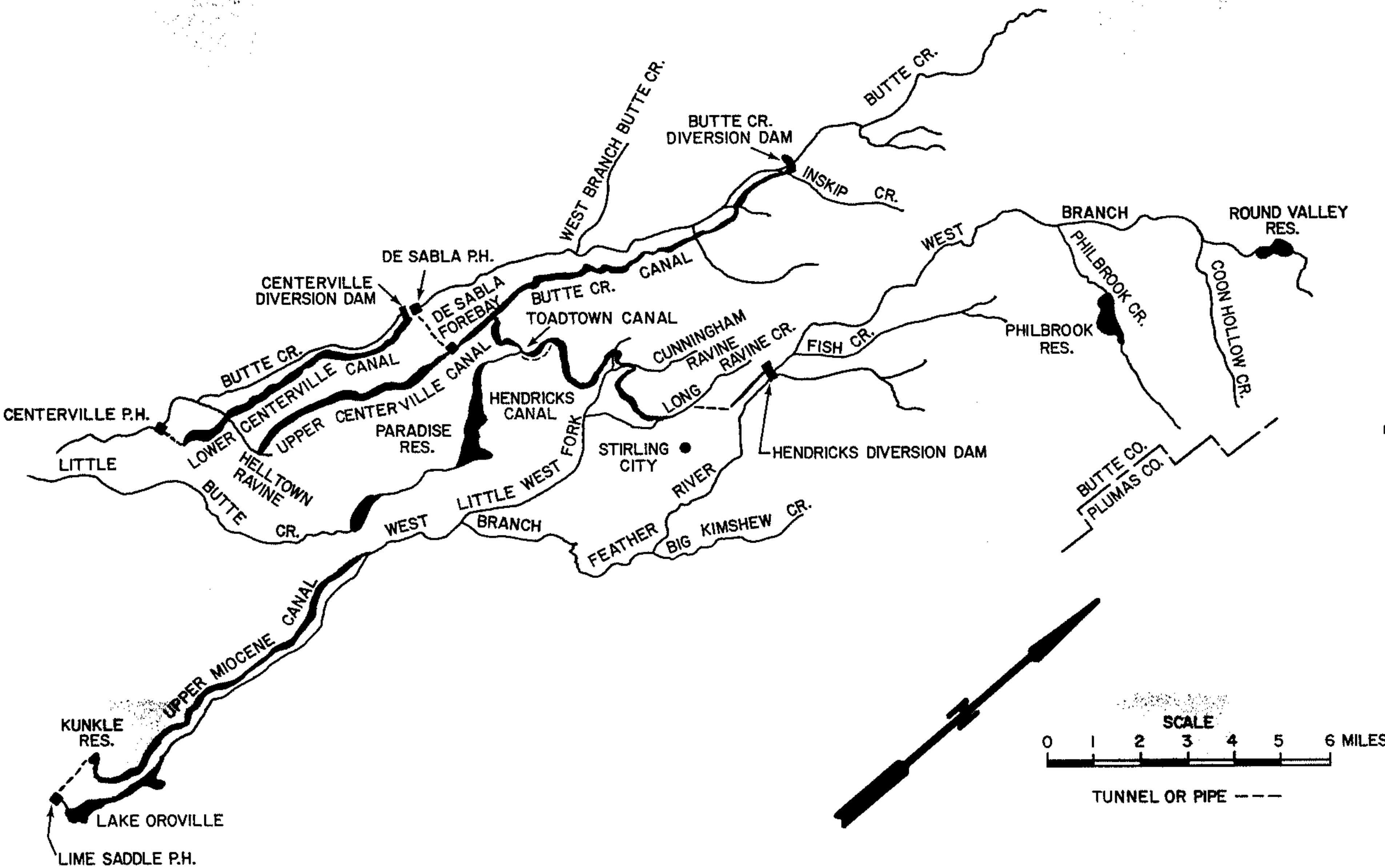

Figure 1. Location map showing the DeSabla-Centerville Project facilities relative to the Feather River and Butte Creek drainages

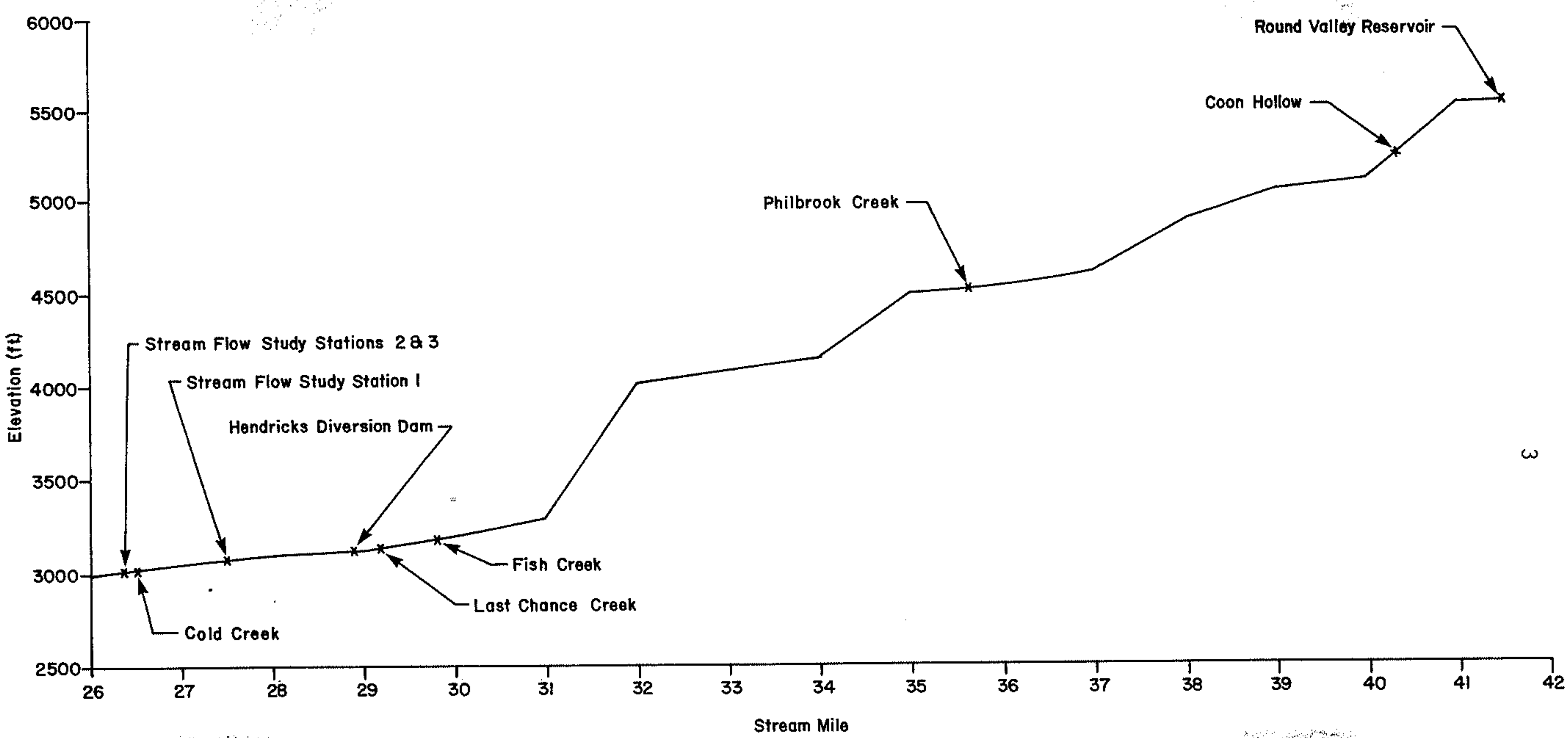

Figure 2. Stream mile profile of the West Branch Feather River showing location of streamflow study stations and project facilities

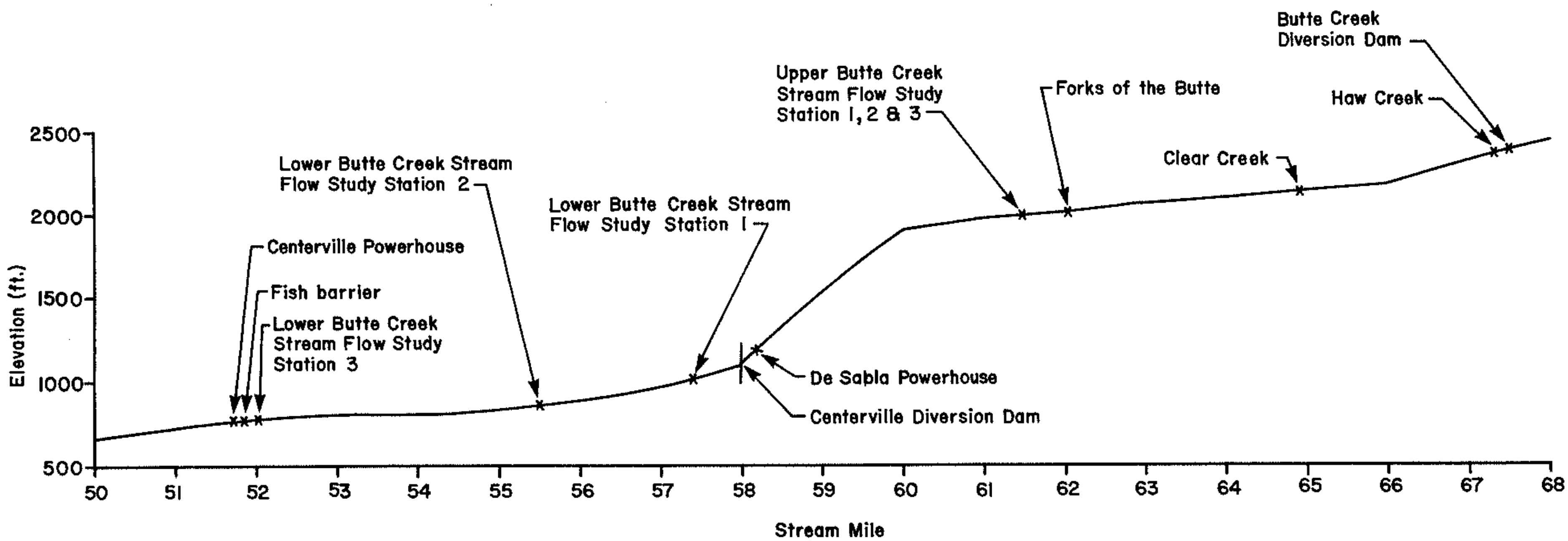

Figure 3. Stream mile profile of Butte Creek showing locations of streamflow study stations and project facilities

good pool to riffle relationship representing good trout habitat. Two major tributaries, Big Kimshew Creek and Cold Creek, feed the stream. Fish habitat is reduced in this section during late summer and during summers of dry years as a result of reduced flows. Presently, a leakage flow of 1-3 cfs enters the stream channel from Hendricks Diversion Dam. Downstream of the dam this flow is augmented by natural accretion into the stream channel. Table 1 lists the mean monthly flows above and below the dam. Water quality is excellent above and below the dam.

Rainbow and brown trout are the only fish species present. Downstream dams preclude any anadromous fish migrations up the West Branch Feather River.

Description of Butte Creek Below Butte Creek Diversion Dam

Butte Creek below Butte Creek Diversion Dam downstream to the Centerville Diversion Dam (9.5 miles) (Figures 1 and 3) is characterized by low summer streamflows due to low natural flows and mean monthly water diversions ranging from 55.5 to 88.2 cfs into the Butte Creek Canal at Butte Creek Diversion Dam (Table 2). When the flow is adequate, this stream section provides excellent trout habitat with good riffle and pool areas. Only one major stream, West Branch of Butte Creek, provides significant water input and additional trout habitat to Butte Creek in this section. The other tributaries are very small and the majority are diverted into the Butte Creek Canal system. Fishing is fair to poor in this section. Because of the low water flows during the summer and fall

Table 1. Mean monthly streamflows (cfs) in West Branch Feather River below Hendricks Diversion Dam and percentages of available streamflow diverted.*

	Available Streamflow (Derived)	Hendricks Dam Spill	Canal Flow	Percent Diverted at Hendricks Dam
January	297.2	191.2	106.0	35.7
February	268.6	148.7	119.9	44.6
March	328.1	206.1	122.0	37.2
April	328.1	205.1	123.0	37.5
May	332.3	203.5	128.8	38.8
June	204.8	93.6	111.2	54.3
July	71.6	5.15	66.5	92.9
August	41.8	0**	41.8	100.0
September	38.1	0**	38.1	100.0
October	43.7	6.5	37.2	85.1
November	134.5	91.1	43.4	32.3
December	146.9	133.8	13.1	8.9

*Derived from ten years (water years) of PGandE data (1965-1967; 1968-1974) for water gage BW-7 (Hendricks Diversion Dam spill) and total available flows above the Hendricks Diversion Dam.

**Indicates no spillage over dam but nevertheless represents 1-3 cfs leakage through the dam.

Table 2. Mean monthly streamflows (cfs) in Butte Creek below Butte Creek Diversion Dam and percentages of available runoff diverted.*

	Available Streamflow (Derived)	Butte Creek Dam Spill	Canal Flow	Percent Diverted at Butte Creek Dam
January	315.2	250.1	65.1	20.7
February	215.9	157.0	58.9	27.3
March	258.9	185.8	73.1	28.2
April	266.0	193.2	72.8	27.4
May	250.8	167.8	83.0	33.0
June	160.3	72.1	88.2	55.0
July	100.8	16.2	84.6	83.9
August	77.6	0.1	77.5	99.9
September	70.5	1.0	69.5	98.6
October	68.3	12.8	55.5	81.3
November	149.0	83.1	65.9	44.2
December	154.1	105.2	48.9	31.7

*Derived from ten years (water years) of PGandE data (1965-1974) for water gauge BW-13 (Butte Creek Diversion Dam spill) and total natural flows above the Butte Creek Diversion Dam.

months of drought years and the fall months of normal years, the creek cannot be considered to provide stable trout habitat. Between stream miles 58.5 and 60 exist natural fish barriers consisting of large boulders, high waterfalls, and debris. These barriers do not allow upstream passage of trout or anadromous fish species. It is estimated that flows upwards of 150 to 200 cfs could allow fish to negotiate some of the existing barriers, and other barriers would still be impassable.

Description of Butte Creek Below Centerville Diversion Dam

Butte Creek below Centerville Diversion Dam downstream to the Centerville Powerhouse (6.3 miles) (Figures 1 and 2) is characterized by low summer streamflows due to low natural flows and mean monthly water diversions ranging from 100 to 152 cfs into the Lower Centerville Canal at the Centerville Diversion Dam (Table 3). The estimated natural unimpaired flow that would be available on Butte Creek below the Centerville Diversion Dam is also listed in Table 3. This stream section consists of three different physical habitat types:

1. The first (approximately) five miles of stream below the Centerville Diversion Dam are characterized by large boulders (5 to 20 feet in diameter), deep pools, and steep rocky canyon walls. Fishing is poor and fishing access is difficult. During the summer months, spring-run king salmon are usually present in the deeper pools.
2. The next (approximately) two miles downstream consists of good trout habitat, having smaller boulders, more gravel, and, when adequate

Table 3. Mean monthly estimated natural unimpaired streamflows, available flows below Centerville Diversion Dam, Centerville Dam Spill, Centerville canal flow, and percentages of available flows diverted.[1]

	Estimated[2] Natural Unimpaired Streamflow (Derived)	Available[3] Flow During Hydroelectric Operations (Derived)	Centerville Dam Spill	Center-ville Canal Flow	Percent of Available Flow Diverted
January	389	473	350	123	26
February	315	409	274	135	33
March	374	481	352	129	27
April	357	466	328	138	30
May	325	431	279	152	35
June	200	291	139	152	52
July	92	166	29	137	83
August	74	137	6	131	96
September	62	121	21	100	83
October	81	125	12	113	90
November	225	277	159	118	43
December	181	252	137	115	46

1. Derived from 12 years (water years) of PGandE data (1966-1977) for water gauges BW-19 (Centerville Diversion Dam Spill), BW-20 (Lower Centerville Canal flow) and BW-12 (Toadtown Canal-West Branch Feather River water). All flows are measured in cfs.

2. Estimated natural unimpaired streamflows were derived by subtracting each monthly average input from PGandE water gauge BW-12 from the total monthly averages of PGandE water gauges BW-19 and BW-20.

3. The available flow during hydroelectric operation is derived by adding the totalled monthly averages of PGadE water gauges BW-19 and BW-20.

flows are available, a good pool to riffle relationship. Canyon walls are steep, but streamside vegetation is abundant. Nongame fish populations are high and trout populations are low. Angler access to this section is difficult.

3. In the last (approximately) three miles, the stream is wider and shallower, and is characterized by slower currents. Streamside vegetation is heavy, and at low summer flows, blue-green algae blooms are present, and fishing is poor. There are no major tributaries entering this stream section. Fish populations consist of numerous nongame species, trout, some steelhead, and spring-run king salmon. An additional feature of this section is a wooden, removable fish barrier that is located about 100 feet above the Centerville Powerhouse. It was designed to prevent the upstream migration of spring-run king salmon into Butte Creek below the Centerville Diversion Dam because of the low flows that exist in this section during the summer months.

METHODS

Prior to conducting streamflow evaluations, specific release flows below the three PGandE diversion dams were discussed and agreed upon by conservation agency and PGandE biologists. The release flows listed in Table 4 were adopted and carried out in the streamflow studies. A PGandE hydrographer measured and verified the flow releases during each flow measurement day. Specific flows were released at the diversion dam starting at 1700 hours preceding each day that instream flow measurements were taken. Streamflow study locations on the WBFR below Hendricks Diversion Dam, Butte Creek below Butte Creek Diversion Dam, and Butte Creek below Centerville Diversion Dam are depicted in Figures 2 and 3 and Table 5.

For each streamflow release (4, 8, 16, and 32 (31 WBFR) cfs), relative units of resting microhabitat, food producing habitat, and spawning habitat were calculated using the methodology described by Waters (1976) (see Appendix A).

The percentage increase in each fish habitat parameter above that level existing at the normal 0 cfs release was calculated for different flow releases (0, 4, 8, 12, 16, 24, 32 (31 WBFR), and 50 cfs). For those flow values not actually evaluated during the streamflow study (0, 12, 24, and 50), mean relative units of each fish parameter were calculated through linear regression methods. Based on the results of the streamflow studies and for purposes of these calculations, it was assumed that a linear relationship existed for streamflow versus units of trout habitat parameters below 4 cfs and between 8-16 cfs, 16-32 cfs, and above 32 cfs.

RESULTS

Results of Streamflow Studies

Plots of the quantitative results of the streamflow studies are presented in Appendix B. Mean relative units (MRU) of resting microhabitat, food producing habitat and spawning habitat for trout are graphically depicted for each station. Means of all stations are also graphically shown for each trout habitat parameter.

Table 4. Study release flows for streamflow evaluations below Hendricks, Butte Creek, and Centerville Diversion Dams.

Date	Time Release Started	Release Flow (cfs)
Hendricks Diversion Dam		
8/25/75	1700	31
8/26/75	1700	16
8/27/75	1700	8
8/28/75	1700	4
Butte Creek Diversion Dam		
8/25/74	1700	32
8/26/74	1700	16
8/27/74	1700	8
8/28/74	1700	4
Centerville Diversion Dam		
8/18/74	1700	32
8/19/74	1700	16
8/20/74	1700	8
8/21/74	1700	4

Table 5. Station locations, number of transects, and average stream widths for the streamflow study conducted below Hendricks, Butte Creek, and Centerville Diversion Dams.

Station	No. of Transects	Average Stream Width (ft.)	Location
Below Hendricks Diversion Dam			
1	5	32	Stream Mile 27.5; about 1800 yards below Hendricks Diversion Dam
2	3	88	Stream Mile 26.4; about 100 feet downstream of the Cold Creek junction
3	5	50	Stream Mile 26.2; about 400 feet downstream of the Cold Creek junction
Below Butte Creek Diversion Dam			
1	4	46	Stream Mile 61.5; about 100 yards above Ponderosa Road Bridge
2	4	31	Stream Mile 61.4; about 100 feet below Ponderosa Road Bridge
3	3	65	Stream Mile 61.3; about 300 feet below Ponderosa Road Bridge
Below Centerville Diversion Dam			
1	6	35	Stream Mile 57.4
2	6	41	Stream Mile 55.5
3	6	52	Stream Mile 52

Since each streamflow study was independent of the other streamflow studies and designed to represent a defined stream section, it was decided to discuss the relationships between trout habitat parameters and flow releases in each study in terms of MRU instead of optimum quality ft^2 (or m^2) of the habitat parameter (Waters 1976, see Appendix A).

Even though results of all habitat parameters are reported, some are more important limiting factors in a particular stream than others and should be weighed more heavily when evaluating the data for an appropriate streamflow release.

Evaluation of the Effects of Different Streamflow Releases on Resting Micorhabitat, Food Producing Habitat, and Spawning Habitat Below Hendricks Diversion Dam

The limiting trout habitat parameters on the West Branch Feather River in order of importance are resting microhabitat and food producing habitat. Both parameters were found to increase with increasing flow releases, up to the highest flow tested (31 cfs) (Table 6) (see Appendix B). The data show that the higher flows will support larger trout populations in this stream section.

Uncontrolled leakage at the diversion dam and natural accretion from springs and tributaries in this stream section provide an adequate flow to maintain the existing trout populations during the critical summer months. Streamflow records (Table 1) show adequate streamflow during the spring and fall months in this stream section for rainbow and brown trout

Table 6. Percentage increase in mean relative units (MRU) of resting microhabitat, food producing habitat, and spawning habitat above those existing at 0 cfs release, calculated for actual streamflow releases (4, 8, 16, 31 cfs) and hypothetical streamflow releases (0, 12, 24, 50 cfs) below Hendricks Diversion Dam, West Branch Feather River.

Release Flow	Mean Relative Units	Increase in Units Above that Level Existing at 0 cfs	Percentage Increase
Resting Microhabitat			
0	0.172	-	-
4	0.225	0.053	31
8	0.278	0.106	62
12	0.319	0.147	85
16	0.360	0.188	109
24	0.366	0.194	113
31	0.371	0.199	116
50	0.385	0.213	124
Food Producing Habitat			
0	0.026	-	-
4	0.033	0.007	27
8	0.040	0.014	54
12	0.049	0.023	88
16	0.058	0.032	123
24	0.064	0.038	146
31	0.070	0.044	169
50	0.085	0.059	227
Spawning Habitat			
0	0.014	-	-
4	0.056	0.042	300
8	0.098	0.084	600
12	0.129	0.155	821
16	0.160	0.146	1043
24	0.195	0.181	1293
31	0.225	0.211	1507
50	0.307	0.293	2093

reproduction, respectively. Thus, spawning habitat is not a limiting factor for rainbow or brown trout in the West Branch Feather River below Hendricks Diversion Dam due. Therefore, it is suggested that streamflow recommendations for this stream section be evaluated against the resting microhabitat and food producing habitat data.

Evaluation of the Effects of Different Streamflow Releases on Resting Microhabitat, Food Producing Habitat, and Spawning Habitat Below Butte Creek Diversion Dam

All trout habitat parameters reported are considered limiting factors to trout production in the stream section below Butte Creek Diversion Dam, but food producing and spawning habitat are the two that can be most affected by a change in release flows (see Appendix B). Even though the mean monthly streamflow data (Table 3) show spillage over the diversion dam (Table 3) during the critical rainbow and brown trout spawning and incubation periods, spawning habitat is considered stressed because of high silt loading that occurs during the year and the minimal number of tributaries entering this section of Butte Creek.

Resting microhabitat was greatest at the 16 cfs release flow, but only 15 percent over that existing at 0 cfs release flow (Table 7 and Appendix B). Spawning habitat and food producing habitat increased dramatically with increased flows.

Table 7. Percentage increase in mean relative units (MRU) of resting microhabitat, food producing habitat, and spawning habitat above those existing at 0 cfs release, calculated for actual streamflow releases (4, 8, 16, and 32 cfs) and hypothetical streamflow releases (0, 12, 24, and 50 cfs) below Butte Creek Diversion Dam, Butte Creek.

Release Flow	Mean Relative Units	Increase in Units Above That Level Existing at 0 cfs	Percentage Increase
Resting Microhabitat			
0	0.295	-	-
4	0.310	0.015	5
8	0.325	0.030	10
12	0.333	0.038	13
16	0.340	0.045	15
24	0.328	0.033	11
32	0.315	0.020	7
50	0.287	0.008	-3
Food Producing Habitat			
0	0.043	-	-
4	0.053	0.010	23
8	0.063	0.020	47
12	0.076	0.033	77
16	0.088	0.045	105
24	0.113	0.070	163
32	0.138	0.095	221
50	0.194	0.151	351
Spawning Habitat			
0	0.019	-	-
4	0.030	0.011	58
8	0.041	0.022	116
12	0.079	0.060	316
16	0.116	0.097	510
24	0.186	0.167	879
32	0.255	0.237	1247
50	0.411	0.392	2063

It is suggested that all trout habitat parameters be considered, particularly food producing and spawning habitat, when evaluating these data for appropriate release flow recommendations.

Evaluation of the Effects of Different Streamflow Releases on Resting Microhabitat, Food Producing Habitat, and Spawning Habitat Below Centerville Diversion Dam

Resting microhabitat and food producing habitat are considered the two major limiting factors to trout production in the stream section below Centerville Diversion Dam. Similar seasonal flow conditions exist at the Centerville Diversion Dam as at the Hendricks and Butte Creek Diversion Dams, that is, adequate water supply is available during the critical spawning periods for rainbow and brown trout. Resting microhabitat increased to its maximum value at the 16 cfs flow release, 28 percent over that existing at 0 cfs release (Table 8). Very little resting microhabitat is gained at higher flows in what is considered an important limiting trout habitat parameter. Food producing habitat both decreased and increased between the different release flows investigated in this study. A limited gain with increasing flows was evident for spawning habitat. At the highest release flow, 32 cfs, a 17 percent increase in habitat over that existing at 0 cfs release occurred.

It is suggested that resting microhabitat and food producing habitat be considered when evaluating these data for appropriate flow release recommendations.

Table 8. Percentage increase in mean relative units (MRU) of resting microhabitat, food producing habitat, and spawning habitat above those existing at 0 cfs release, calculated for actual streamflow releases (4, 8, 16, and 32 cfs) and hypothetical streamflow releases (0, 12, 24, and 50 cfs) below Centerville Diversion Dam, Butte Creek.

Release Flow	Mean Relative Units	Increase in Units Above That Level Existing at 0 cfs	Percentage Increase
Resting Microhabitat			
0	0.276	-	-
4	0.273	-0.003	1
8	0.270	-0.006	2
12	0.312	0.036	13
16	0.353	0.077	28
24	0.303	0.027	10
32	0.253	-0.023	-8
50	0.141	-0.135	-49
Food Producing Habitat			
0	0.119	-	-
4	0.112	-0.007	-6
8	0.105	-0.014	-12
12	0.087	-0.032	-27
16	0.069	-0.050	-42
24	0.091	-0.028	-24
32	0.113	-0.006	-95
50	0.163	0.044	37
Spawning Habitat			
0	0.070	-	-
4	0.068	-0.002	-3
8	0.066	-0.004	-6
12	0.071	0.001	1
16	0.075	0.005	7
24	0.079	0.009	13
32	0.082	0.012	17
50	0.090	0.020	29

DISCUSSION

Interpretation of Results[1]

"The plotted results (Appendix B) should not in themselves be construed as making recommendations for a streamflow release regime. Rather, they represent relationships that have been determined in as quantitative and least subjective manner as possible. They also depict relationships which all interested parties can agree to as representing the best judgement of professional fisheries biologists, prior to interdisplinary evaluation of their application to the final resolution of the release flow regime under consideration. This leaves flexibility for interpretation and consideration of management alternatives based on all relevant factors, including fisheries management needs, comparisons with natural unimpaired flows, water rights, economics, conflicting recreational uses, safety, esthetics, and other interdisciplinary interests.

From the fisheries management standpoint, the limiting factor concept should be utilized in using the plotted results in a recommendation/ decision making process. For example, the importance of the relationship shown in a spawning curve is primarily during the spawning and egg and larval rearing season. Attention should be given to this relationship if spawning success is likely to be a limiting factor to fish production in the stream.

Another example would be if a stream receives heavy use and is managed on a put-and-take basis, the curves for resting microhabitat and food producing may be given greater consideration than the curve for

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1/This section is an excerpt of the discussion section in Waters (1976) (Appendix A).

spawning, whereas the reverse may be true in a stream managed as a wild trout fishery or one managed for the preservation of a unique or endangered species.

In some cases, some of the plotted curves should not be considered in evaluating flow needs at all. An example of this would be on a stream with much slow and deep water, in which resting microhabitat and possibly subjective cover could be dismissed as not being possible limiting factors, and attention would be given only to the other habitat parameters.

The relative importance of the limiting factors that can be controlled by flow releases is also affected by other fisheries management considerations such as real and potential fisherman use in the stream section, fishability by fishermen at different flows (including access and safety), and the relationship between streamflow and water temperature regimes. It is also possible that other fisheries management programs, such as the eradication of predator or competitor species, stream channel alterations, management of overhead cover, or planting fish where it is not possible or practical to get enough natural production, may be more cost effective and productive to the fishery than relying only on changes that are possible with changes in flows."

APPENDIX A

A METHODOLOGY FOR EVALUATING THE EFFECTS OF DIFFERENT STREAMFLOWS ON SALMONID HABITAT

A METHODOLOGY FOR EVALUATING THE EFFECTS OF DIFFERENT STREAMFLOWS ON SALMONID HABITAT*

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ABSTRACT

Stream resource managers need to be able to determine the relationships between flows and various fish habitat parameters in order to evaluate the effects of a present or proposed project which can alter flow regimes. A technique was developed which uses field measurements and a digital computer to quantitatively express the relationships between streamflow and available food producing, spawning, resting microhabitat, and cover areas for trout. Changing a few weighting factors can adapt the program to various species of salmonids. An example of a plot of study results utilizing this methodology is presented. A discussion of the benefits from application of the methodology to release flow evaluations is given.

INTRODUCTION

Increasing storage and diversion of water over the last half century has resulted in altered flow regimes in many rivers and streams. In order to best evaluate the effects of a present or proposed project which can alter flow regimes, stream resource managers need to be able to determine the relationships between flows and various fish habitat parameters. In order to accommodate this need, a methodology has been developed and used in the analysis of a number of trout streams in northern and central California. The purpose of this paper is to describe that methodology.

In 1960, the California Department of Fish and Game proposed a method for investigating the flow required by trout below dams[1]. This method considered that the basic requirements of trout included food, spawning area, and shelter. Binary depth, velocity, and bottom substrate criteria for each of these requirements were established in order that the changes in each could be quantified with direct observation and measurement of a stream section at different flows. Steps toward the adoption of this approach, which has served as a basis for the methodology described herein, were initiated

[1] Kelley, D. W., A. J. Cordone, and G. Delisle. 1960. A Method to Determine the Volume of Flow Required by Trout Below Dams: A Proposal for Investigation. California Department of Fish and Game.

*From Proc. Instream Flow Needs Symp. and Specialty Conf., West. Div. Am. Fish Soc. and Power Div. Am. Soc. Civil Engr., Boise, Idaho, May 3-6, 1976. Vol. 2, pp. 254-266.

at a California Department of Fish and Game training session at Taylor Creek in 1960.

By the mid-1960's there was still little standardization of methodology for recommending appropriate streamflows below impoundments. Those of us working on the subject recognized that professional stream resource biologists and managers should place the emphasis of their flow analysis work on determining the quantitative relationships between streamflows and various habitat parameters, over a range of flows for which there are reasonable management alternatives. When all parties concerned agree on the objective relationships, organization recommendations based on the relationships and other relevant factors can then be made.

A change in flow results in a change in the physical characteristics of all microhabitats of all fish species present, their predators, their competitors, and the food organisms down through the food chain upon which they depend. For each organism category, at different life history stages, there are microhabitat requirements for upstream and downstream passage, reproduction, egg and larvae rearing, resting, feeding, and cover, including escape cover. Each microhabitat requirement can be defined by water depth, water velocity, and bottom substrate. Hence we have the basis for a model.

METHODOLOGY

Described below are the steps, materials, techniques and analytical methods followed in a typical streamflow study using our methodology.

Preliminary Planning and Field Work Preparation

Representatives of all organizations cooperating in the study meet to agree on which section(s) of stream will be studied, which release flows will be studied, how release flows will be verified, when the study will occur, the number and locations of stations and transects, the spacing of measuring points along each transect, the identity of individual field workers, the location of photographic stations, and other related matters. It is agreed that each cooperating organization will receive a copy of all original field data sheets with which to do anything it wishes, independently of an agreement to share results of the analysis resulting from the computer program described later in this paper.

On some streams a preliminary field review is undertaken to observe typical sections under several flows. These observations, possibly documented by photography, may then be used as a basis for selecting study stations and release flows.

If more than one crew of workers will be involved in data collection, an attempt is made during the planning phase to balance the capabilities of each crew after considering such factors as employer organization, experience on studies of this type, logistic support (if it covers a large geographic area), and which days people are available. For continuity, it is desirable to have the same personnel available for all days of the study. In particular, if cover is included as a study parameter it is imperative that the same worker does the subjective evaluation each day

The number of stations per stream section, the number of transects per station, and the distance between measuring points along each transect will depend on the variability in stream types (cascades, runs, riffles, pools) and mean stream width. Based on past experience with stream habitat variability and practical logistics problems, around 600 measuring points per stream section are generally selected. A three-person crew with one meter should be able to collect at least 300 point measurements per day, and a five or six-person crew with two meters should be able to collect at least 600 point measurements per day. These work budget figures include consideration of average travel time, normal accessibility, and a normal workday. Table 1 gives guidance as to the number of measuring points which various combinations of stream width, measurement interval along transects, and total number of transects would indicate.

Table 1. Number of measuring points resulting from various combinations of stream width, measurement interval along transects, and total number of transects. Transects are divided evenly between stations, usually two or three stations.

If mean stream width at highest test flow is (ft):	And measurements are taken at intervals of (ft):	At a total number of transects of:	The number of measuring points will be:
0- 15	0.5	18	0-540
16- 20	0.5	12	380-480
21- 30	1.0	18	380-540
31- 40	1.0	12	360-480
41- 50	2.0	18	370-450
51- 75	2.0	15	380-560
76-100	4.0	18	340-450
101-150	5.0	15	300-450
151-200	5.0	12	360-480
201-300	10.0	15	300-450

Station locations are selected to be representative of the stream section in question. Major pool areas are avoided because they are not habitats where significant ecological changes occur with changes in flow. However, if resting habitat is likely to be a limiting factor, slow water areas may be given special consideration. Ease of access is a consideration in station location selection only when the representativeness of the final locations selected is assured. If uncontrolled accretion is significant in a stream section, stations should be spaced to include the range of accretion flow conditions that exist.

After station locations and the number of transects per station have been determined, the ends of transects are identified with stakes firmly installed above the water line of the highest flow studied. The distance between transects (commonly 20 to 50 feet) depends mostly on the length of stream available at the station. Stakes are located on one side of the stream by measuring the fixed pre-determined interval along the streambank. Stake locations for the ends of the transects on the opposite streambank are selected by eye such that the transect is perpendicular to the flow at that point in the stream, even if this results in adjacent transects not being parallel.

Field Data Collection

Prior to the initiation of field measurements, all participants should meet to review individual responsibilities, resolve any questions, stress the importance of a standard systematic approach to all aspects of the field study, and inventory equipment and review its use.

A typical equipment list, which would be duplicated with multiple crews, includes: backpack; Gurley Pygmy flow meter(s) with spare parts; measuring tapes (non-stretchable); stop watches; extra transect stakes; data recording forms; clipboard(s); pencils; tape clamps and/or pullers; chalk board; chalk; thermometer; plastic flagging tape; maps; camera and color film; first aid kit; snake bite kit; rope; suntan lotion; and felt soled shoes. Flow meters should be calibrated before and after the study to assure that the calibration did not change.

An example of the field data recording form is given in Table 2, and the general instructions for using it are given in Table 3.

Upon arriving at a transect, crew members stretch the tape tightly between the two stakes. At this point, it is especially important to have the zero end of the tape <u>exactly</u> over the base of the stake. The zero has to

Table 2. Example of streamflow evaluation field data recording form.

PLEASE PRINT CLEARLY

Page____ of____

Stream	Sta No	Tr. No	Depth of Meas.	Date Mo	Date Day	Date Yr	Time
1 2 3 4 5 6 7 8 9 10 11 12	13 14	15 16	17 18 . 19	20 21	22 23	24 25	26 27 28 29

Notes:

Water Temp. °F	Test Flow	Meter No.	Measured by	Recorded by
30 31 . 32	33 34 35 36 . 37 38	39 40 41 42 43 44 45	46 47 48 49 50 51 52	53 54 55 56 57 58 59

Distance on Transect	Btm Code	Cvr. Code	Depth in feet	Revolutions	Time in Seconds
60 61 62 63 . 64	65 66	67 68	69 70 . 71 72	73 74 75	76 77 78 79 . 80

Distance on Transect	Btm Code	Cvr. Code	Depth in feet	Revolutions	Time in Seconds
60 61 62 63 . 64	65 66	67 68	69 70 . 71 72	73 74 75	76 77 78 79 . 80

Bottom Type Code:

1 Plant Detritis
2 Clay
3 Silt
4 Sand
5 Gravel (1/8"-3")
6 Rubble (3"-12")
7 Boulder (>12")
8 Bedrock
9 Other

Subjective Cover Code:

1 No Cover
2 Fair Cover
3 Good Cover

PLEASE PRINT CLEARLY

be at the same place for each study flow. The zero end of the tape is always on the study access side of the stream.

The highest flow to be studied is released first, immediately confirming that transect stakes have been placed appropriately in relation to water elevation. Study participants are then able to fill in columns 60-64 of the field data recording forms (distance on transect) in advance for all subsequent (lower) flows to assure that all required depth, velocity, and substrate data are collected. Actual release flows are verified, as well as the actual flows existing at the stations (release plus accretion). Flows are allowed to stabilize before any measurements are made. Usually this is done by having only one study flow per day, with releases set late in the afternoon of the previous day. On uncontrolled streams, study participants must attempt to obtain differing flows as they occur naturally, even if this requires long time periods between field study days.

Velocity measurements for our salmonid stream studies are taken at 0.2 feet above the substrate. The data analysis takes this into account to the extent possible. Substrate type (bottom code) is recorded as that which best typifies the substrate at the given point along the transect and is recorded

Table 3. Instructions for filling out streamflow evaluation data recording form.

Note: Always print clearly with medium soft pencil (No. 2 or 2-1/2)

Columns	Recorded Information
1-12	Name of stream. Be as specific as possible as to location. Use AB=Above, BL=Below. Use abbreviations when necessary (e.g., NFKINGSABWIS = North Fork Kings River above Wishon).
13-14	Station number in the section of stream being tested, 1-99.
15-16	Transect number at the station, 1-99.
17-19	Depth of measurement. Usually held constant at 0.2 feet.
20-25	Date. Use normal sequence of month, day, year.
26-29	Time. Military time approximately half way through transect.
30-33	Water temperature in °F to nearest 0.1° if taken.
34-38	Test flow in cfs to nearest 0.1 cfs. This is the release flow that exists at the time of the study. Do not record intended test flow. Record only after actual release flow is verified.
39-45	Meter No. (right adjusted). If more than seven alpha-numeric characters long, use last seven.
46-52	Measured By (left adjusted). Name of person who does all or majority of metering. Use sequence of first initial, second initial, last name. If more than five letters in last name, record only the first five.
53-59	Recorded By (left adjusted). Same instructions as Measured By.
60-64	Distance on Transect. The point along the tape in feet where the measurement is taken. Skip all dry areas that occur at the first (highest) flow.
65-66	Bottom code (right adjusted) using the key at the bottom of the recording form. This only has to be recorded once, and is done at the lowest test flow for convenience in evaluating substrate type. It has to be recorded for all points at which any measurements are taken on any day of the study, even if that point is dry on the day it is recorded.
67-68	Subjective cover code (right adjusted) using the key at the bottom of the recording form. Recorded only if this option is to be included in the study.
69-72	Total water depth to nearest 0.1 feet at point of measurement. If substrate is dry at the point on that day, record as 0.
73-75	The number of complete revolutions counted after the revolution noted when the stopwatch is started. Flow meter is set at depth indicated in Columns 17-19. Epic counter may be used.
76-80	Elapsed time to the nearest 0.1 second (minimum of 30 seconds) from when stopwatch started until it is stopped at a completed revolution of the flow meter. Record as 30 seconds if no depth or too shallow to get a velocity (revolutions) reading. Epic counter may be used.

at the lowest flow.

Each day of the study, photographs are taken in a standardized fashion at each station. The photographs are scheduled to be taken as close to mid-day as possible, allowing for travel time between stations, and at as close to the same time of the day at each of the stations each day so that lighting and shade conditions are comparable. Usually three photographs are taken at each station each day: one directed upstream; one directed across the stream; and one directed downstream. The station number, date, and intended release flow are recorded on a slate placed within view of each photograph for ease of identification. The photographs are later presented so that all photographs taken looking in a particular direction at a given station may be viewed at the same time (e.g., on facing pages) for ease of comparison. Accompanying each photograph is a label which lists the station number, actual release flow, the flow being viewed at the station (release plus accretion), the direction of the view, and the date.

Data Processing

Field data are keypunched and verified prior to analysis by computer. A computer program has been developed which calculates the velocity at each measuring point for each study flow, and stores bottom substrate and depth data. As described below, it then calculates a relative value between zero and one for each measuring point along each transect at each station for each study flow and habitat parameter. The habitat parameters are resting microhabitat, food production, spawning, and subjective cover. Subjective cover is optional, and may not be included if the researchers want to look only at the other three quantitatively determined habitat parameters.

The relative values for each measuring point for each parameter at each flow are determined by assigning weighting factors (coefficients in the model) to the individual water velocity, bottom substrate, and depth values, and then multiplying them together to get a single composite relative value. Weighting factors can be varied as a function of the species of fish of concern in the stream, its life history stage, and those of its principal food organisms. The distribution of weighting factors for a typical analysis of the three quantitative habitat parameters in a California trout stream are shown in Figure 1. Weighting factors for subjective cover (not shown in Figure 1) are 0.0 for no cover, 0.5 for fair cover, and 1.0 for good cover.

The original determination of weighting factors to be used in our

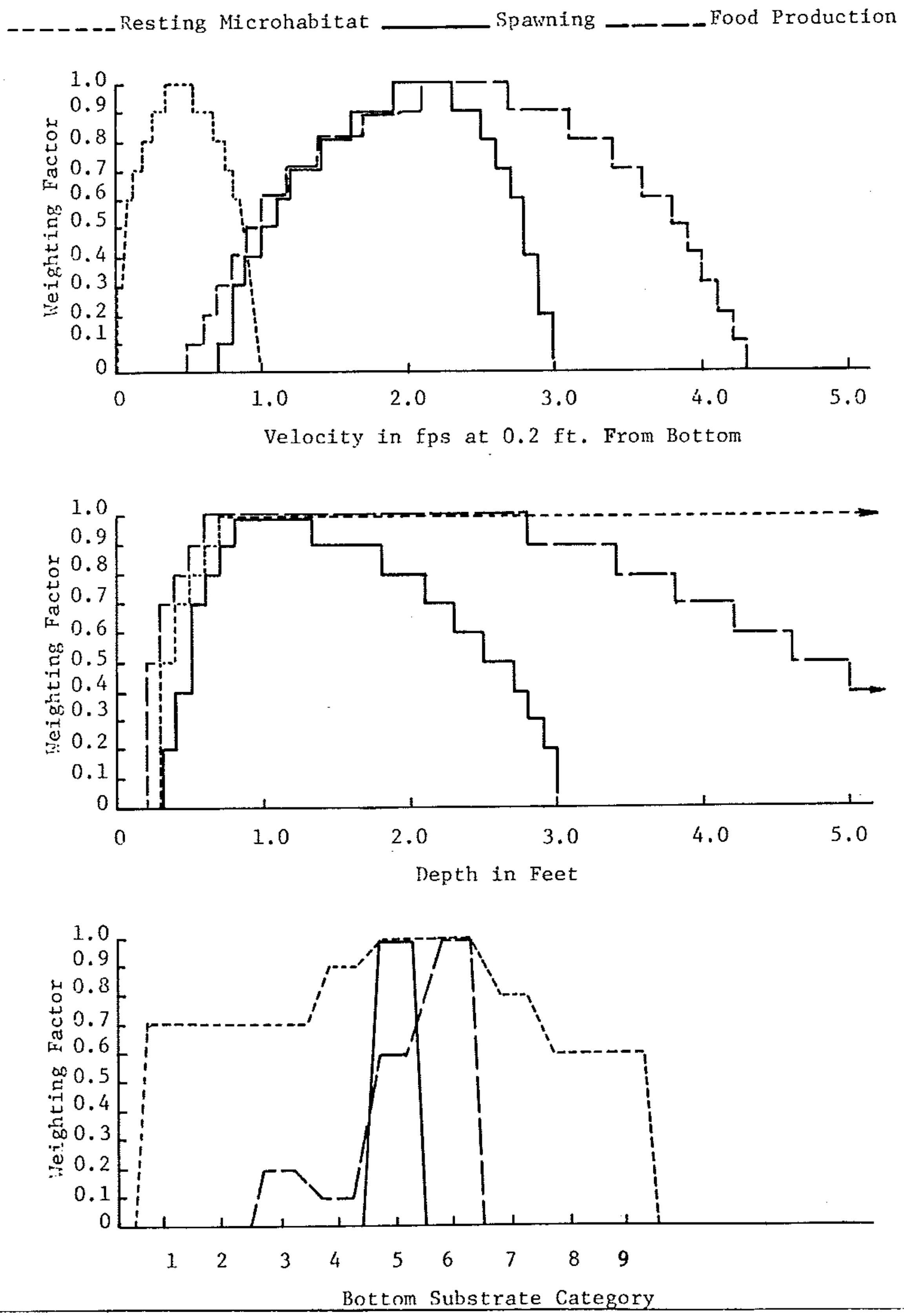

Figure 1. Weighting factors for habitat parameters in a typical trout stream flow analysis.

analyses was based on a review[2] of all available sources of information which related physical characteristics (substrate, velocity, and depth) of trout habitat to habitat parameters (resting, food production, and spawning). Steps to determine weighting factors for a particular stream and its biota (some of which may require new research) are given in the discussion.

The computer program, which is written in PL/I and used on an IBM 370 Model 168 with Calcomp plotter support, provides the following data in tabulated form for each habitat parameter for each stream studied:

1. Total relative units for each series of transects within each station, including a station total.
2. Total relative units for each series of stations within the stream section under study, including a stream section total.
3. Tables from 1 and 2 in mean relative units.
4. Standard deviation of values in tables from 3.
5. 90 percent confidence limits of values in tables from 3.
6. Relative distribution of different categories of bottom substrate.

The program can also provide results in plot form, an example of which is given in Figure 2. This can be provided for each habitat parameter by station, and for all stations combined in the stream section under study. These plotted results are the most usable product of the program, in that they show the relationship between the magnitude of the habitat parameter of interest (as a dependent variable) and release flow (as the independent variable). The plots provide a tool that biologists and others can use when evaluating the potential effects of different release flows below impoundments, recognizing the constraints mentioned in the discussion.

Plotting results with only relative units on the vertical scale should suffice if there is only one section of one stream involved in an evaluation, since knowledge of relative changes is all that is probably desired. In order to compare values from one stream to another, or from two or more sections of the same stream, the mean relative units can be multiplied in the program by actual streambed area included in the study to get the equivalent number of optimum quality ft^2 (or m^2) of the habitat parameter for each, as shown on the area unit scales.

The program utilizes control cards to enable the user to specify the fol-

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[2]Hooper, Douglas R. 1973. Evaluation of the Effects of Flows on Trout Stream Ecology. Dept. of Engineering Research, Pacific Gas and Electric Co., Emeryville, CA. 97 pp.

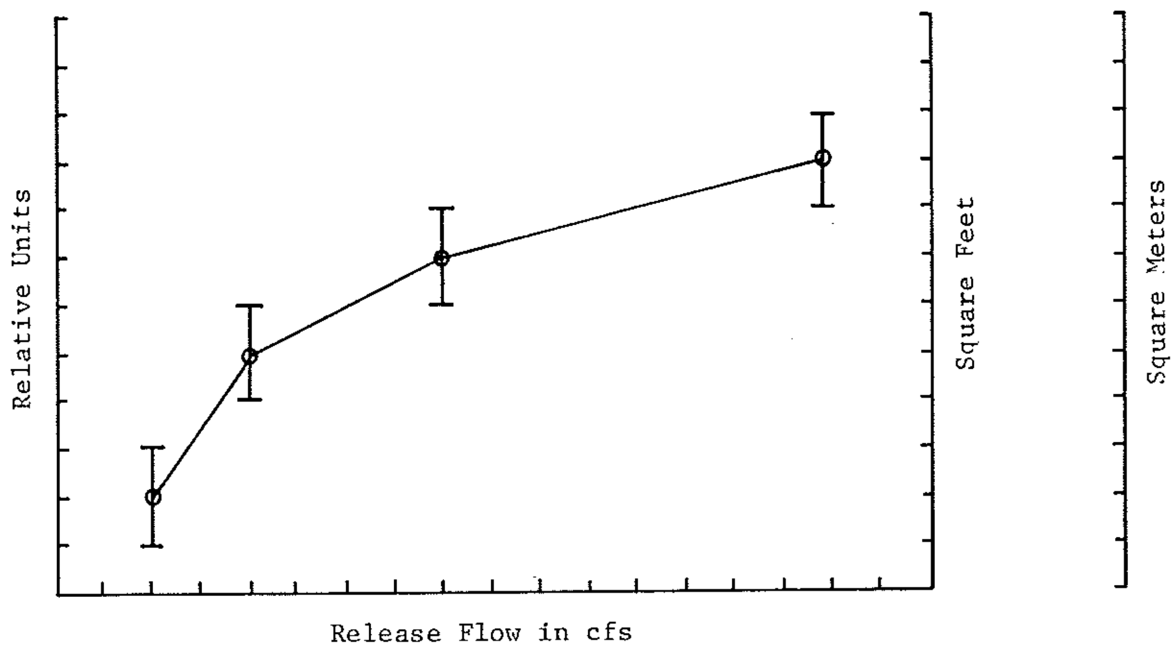


Figure 2. Representative example of plot showing relationship between relative units of habitat parameter and release flow. Ninety percent confidence intervals are shown.

lowing (Existing limits are shown in parentheses):

1. Name of stream section under study.
2. Number of stations (3 per stream section).
3. Number of transects per station (9).
4. Measurement interval along transects (100 measurements per transect).
5. Length in feet of stream section under study.
6. Percentage of stream length under study that is represented by the study (from aerial photographs or field reconnaissance if area unit scales are desired on the plots).
7. Number of study flows (5).
8. Whether or not subjective cover is included in the study.
9. Whether or not relative unit plots are desired.
10. Whether or not area unit plots are desired.

The weighting factors are accessed from a file at the time of program and data submittal to the computer.

DISCUSSION

Interpretation of Results

The plotted results (Figure 2) should not in themselves be construed as making recommendations for a streamflow release regime. Rather, they represent relationships that have been determined in as quantitative and least subjective manner as possible. They also depict relationships which all interested parties can agree to as representing the best judgement of professional fisheries biologists, prior to any interdisplinary evaluation of their application to the final resolution of the release flow regime under consideration. This leaves flexibility for interpretation and consideration of management alternatives based on all relevant factors, including fisheries management needs, comparisons with natural unimpaired flows, water rights, economics, conflicting recreational uses, safety, esthetics, and other interdisciplinary interests.

From the fisheries management standpoint, the limiting factor concept should be utilized in using the plotted results in a recommendation/decision making process. For example, the importance of the relationship shown in a spawning curve is primarily during the spawning and egg and larval rearing season. Attention should be given to this relationship if spawning success is likely to be a limiting factor to fish production in the stream. Curves can be determined for different species of fish in the same stream, and be applied to flow recommendations during different seasons. An example of this would be different spawning curves based on slightly different weighting factors for rainbow and brown trout, which would be applicable in the spring and fall, respectively. Another example would be if a stream receives heavy use and is managed on a put-and-take basis, the curves for resting microhabitat and food production may be given greater consideration than the curve for spawning, whereas the reverse may be true in a stream managed as a wild trout fishery or one managed for the preservation of a unique or endangered species.

In some cases, some of the plotted curves should not be considered in evaluating flow needs at all. An example of this would be on a stream with much slow and deep water, in which resting microhabitat and possibly subjective cover could be dismissed as not being possible limiting factors, and attention would be given only to the other habitat parameters.

The relative importance of the limiting factors that can be controlled by flow releases is also affected by other fisheries management considerations such as real and potential fisherman use in the stream section, fishability by fishermen at different flows (including access and safety), and the relationship between streamflow and water temperature regimes. It is also possible that other fisheries management programs, such as the eradication of predator or competitor species, stream channel alterations, management of overhead cover, or planting fish where it is not possible or practical to get enough natural production, may be more cost effective and productive to the fishery than relying only on changes that are possible with changes in flows.

An ideal trout stream might have the following percentages of its wetted area available for providing the following habitat parameters:

Cover (shelter)	10 Percent
Resting Microhabitat	15 Percent
Spawning Area	60 Percent
Food Production	80 Percent

There is considerable overlapping of bottom area for these habitat parameters in the same area of a stream. Comparing this to what is available or even possible in a study stream by looking at the relative distribution of bottom substrate materials and other study results, fisheries managers and others might conclude that it is desirable to consider other management alternatives, such as those listed above, in addition to or in conjunction with a controlled flow program.

Improvements in Using this Methodology

In addition to the previously described advantages of utilizing this methodology which are primarily based on not having to rely on subjective evaluations of the relationships between streamflows and fish habitat, another advantage is that users can alter and improve the weighting factors as the results of new applicable research become available, without having to do additional field work. The field measurements will always represent the stream, barring any major morphological and/or hydraulic changes. Field measurement efficiency can, however, be improved with the use of a direct readout current meter.

A primary research need to enhance the value of this methodology for application to a specific stream situation is investigation to establish the most appropriate weighting factors for the depth, velocity and substrate values that best describe spawning, resting microhabitat, and food production in the specific stream.

To carry out this research, the following steps should be followed:

1. Identify the specific stream section in question.
2. Identify the species of fish and important fish food organisms that can be most significantly affected by changes in flows.
3. Identify those habitat parameters (e.g., spawning, resting microhabitat, food production) of importance to the fish species that can be most significantly affected by changes in flows.
4. Identify those physical characteristics of the habitat [substrate, velocity (at what point in water column?), depth] that define the habitat parameters.
5. Develop weighting factors for ranges of the physical characteristics relative to each habitat parameter.
6. Fill in voids on weighting factors, and use in the model.

A second research need to improve on this methodology is to conduct long term (≥3 years) evaluations of the responses in streams where controlled flow regimes have been changed in order to compare results to those predicted so that the predictive model can be modified if necessary.

A third research need could be to establish a coding system of stream types in order to eventually utilize results from studies in some streams to other streams of similar characteristics. This is a longer term research priority which would only follow much experience and verification of the physical and biological characteristics used as a basis for such a coding.

ACKNOWLEDGEMENTS

I would like to acknowledge the cooperation of biologists employed by the Pacific Gas and Electric Company, the California Department of Fish and Game, the U.S. Forest Service, and the U.S. Fish and Wildlife Service in the development of this methodology. Appreciation is also extended to Barry L. Landsman who handled the computer programming which allowed biological thoughts to be quantitatively expressed and displayed.

APPENDIX

(Supplemental Tables and Figures Not Included in *Proceedings*)

Table A-1. Example of tabulated computer output.

PIT RIVER

RELATIVE UNITS OF FOOD PRODUCING HABITAT

STATION	TRANSECT	84.0 CFS	128.0 CFS	191.0 CFS	234.0 CFS
4	1	0.0998	0.5899	0.2896	0.1398
	2	2.7691	1.4487	2.6893	4.6488
	3	1.1998	1.1998	1.4487	1.5991
	4	0.4499	0.1999	0.9347	1.3498
	5	0.4498	1.8734	1.1997	3.1495
	6	6.9589	9.2087	11.5382	11.5483
	TOTAL	11.9273	14.5204	18.1002	22.4353

Table A-2. Example of tabulated computer output.

90 % CONFIDENCE LIMITS OF MEAN
RELATIVE UNITS OF RESTING MICROHABITAT

1	0.3247	0.3133	0.3272	0.2688
	0.4473	0.4443	0.4604	0.4227
2	0.1900	0.2427	0.2302	0.1831
	0.3033	0.3730	0.3602	0.3042
3	0.1501	0.1272	0.1424	0.1466
	0.2597	0.2393	0.2604	0.2620
4	0.0988	0.1460	0.0832	0.0920
	0.1856	0.2533	0.1784	0.1824
5	0.1372	0.1445	0.1255	0.1083
	0.2420	0.2717	0.2365	0.2154
6	0.1864	0.1954	0.1683	0.2187
	0.3246	0.3297	0.2960	0.3574
MEAN	0.2125	0.2301	0.2127	0.2047
	0.2585	0.2869	0.2614	0.2528
MEAN ALL STN.	0.2327	0.2506	0.2555	0.2559
	0.2680	0.2877	0.2930	0.2933

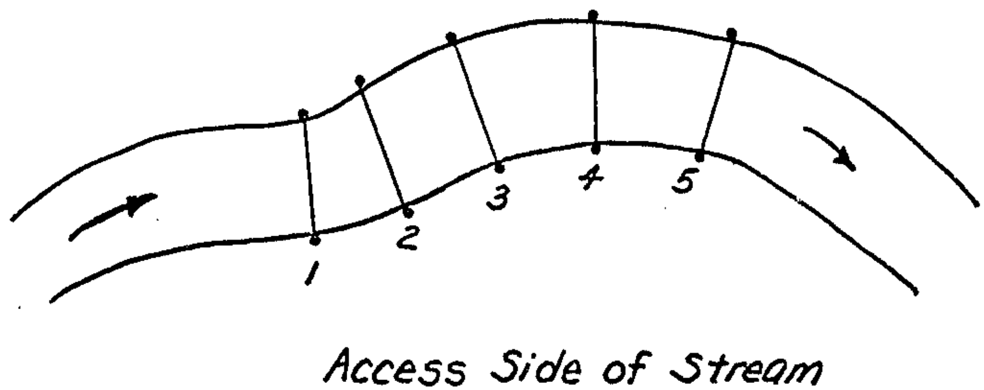


Figure A-1. Example of layout of transects at a single station. Ends of transects are evenly spaced on access side of stream. Transects are perpendicular to the flow of the stream.

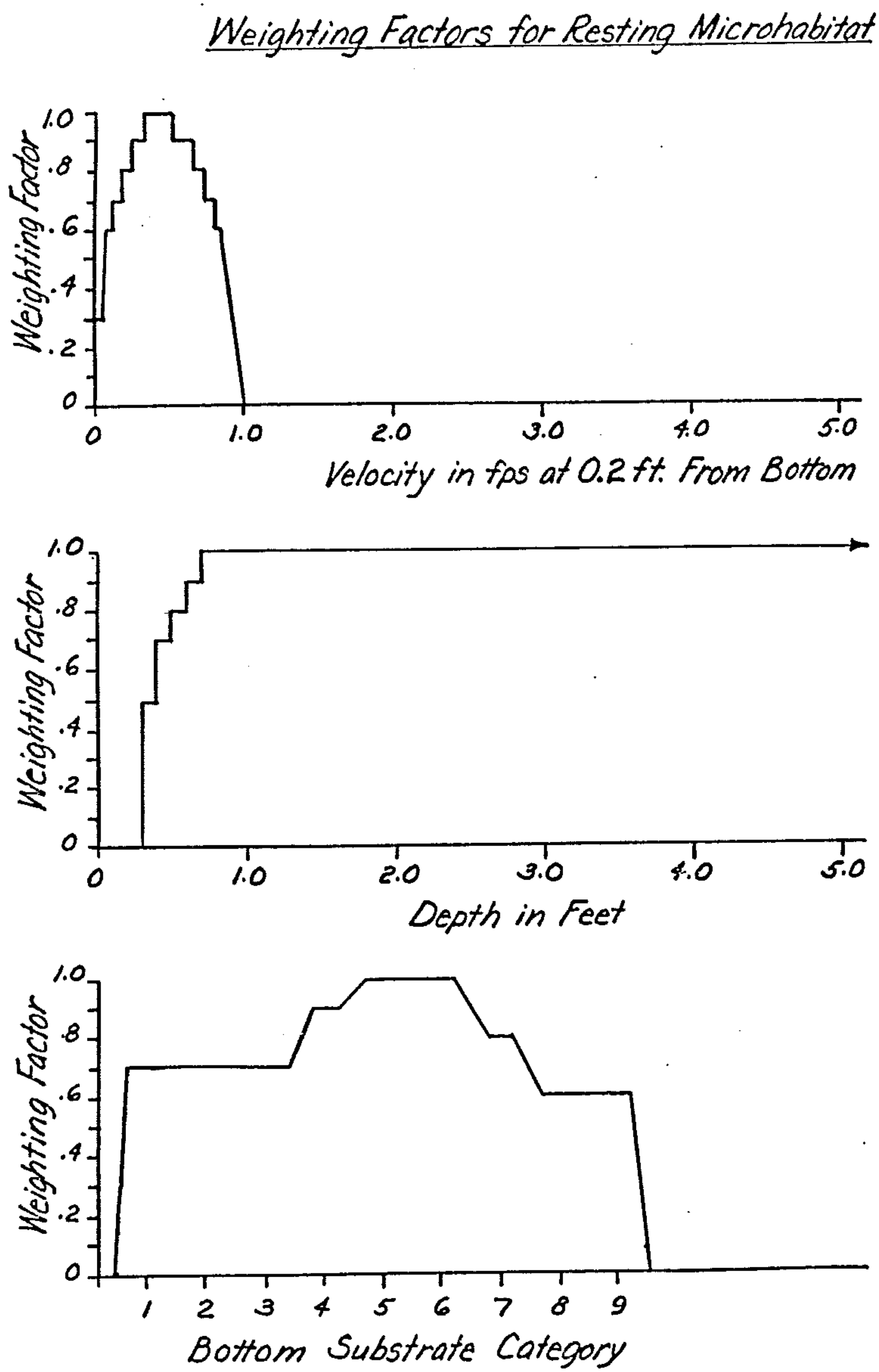


Figure A-2. Weighting factors for resting microhabitat in a typical trout stream flow analysis.

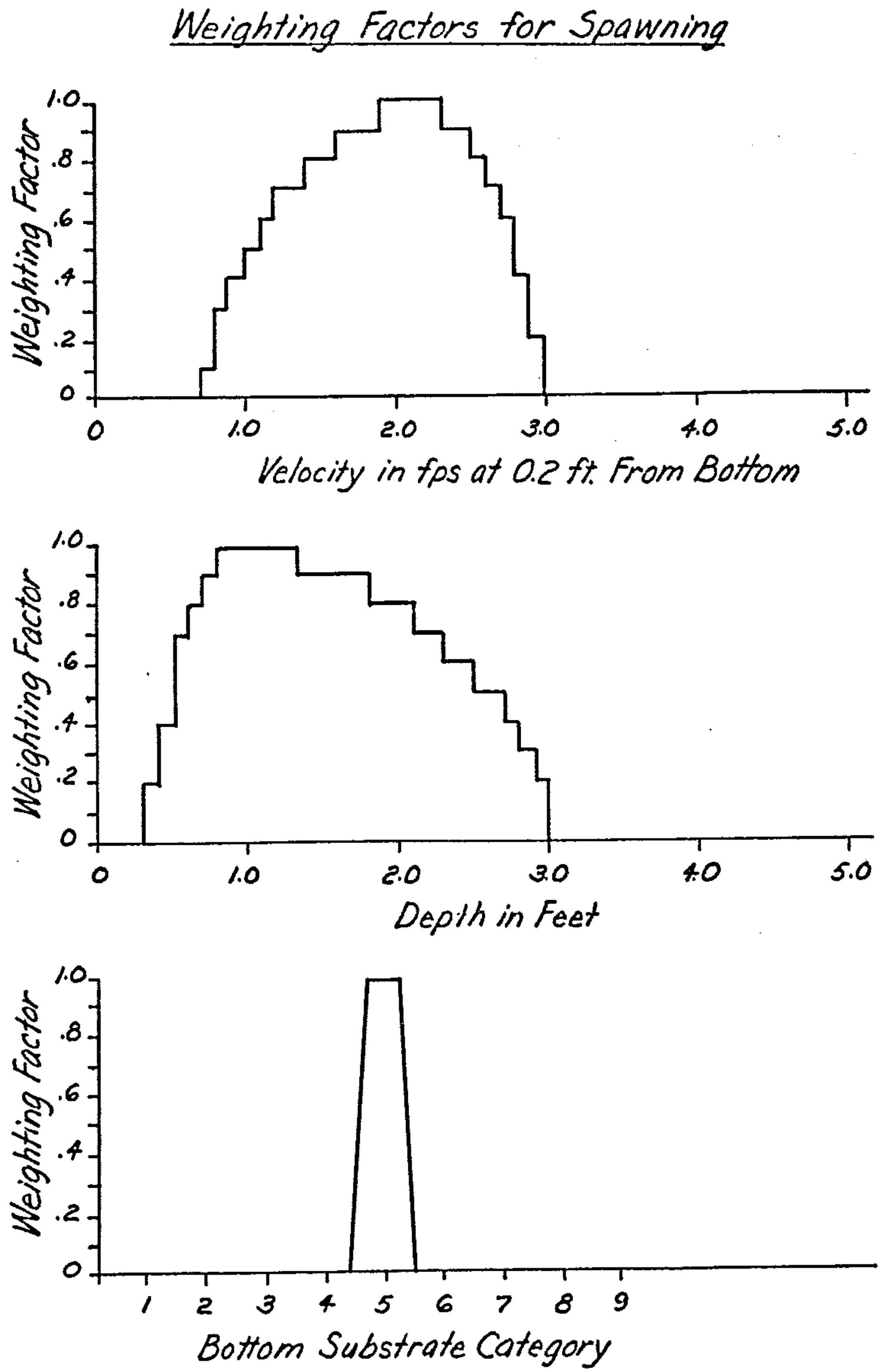


Figure A-3. Weighting factors for spawning habitat in a typical trout stream flow analysis.

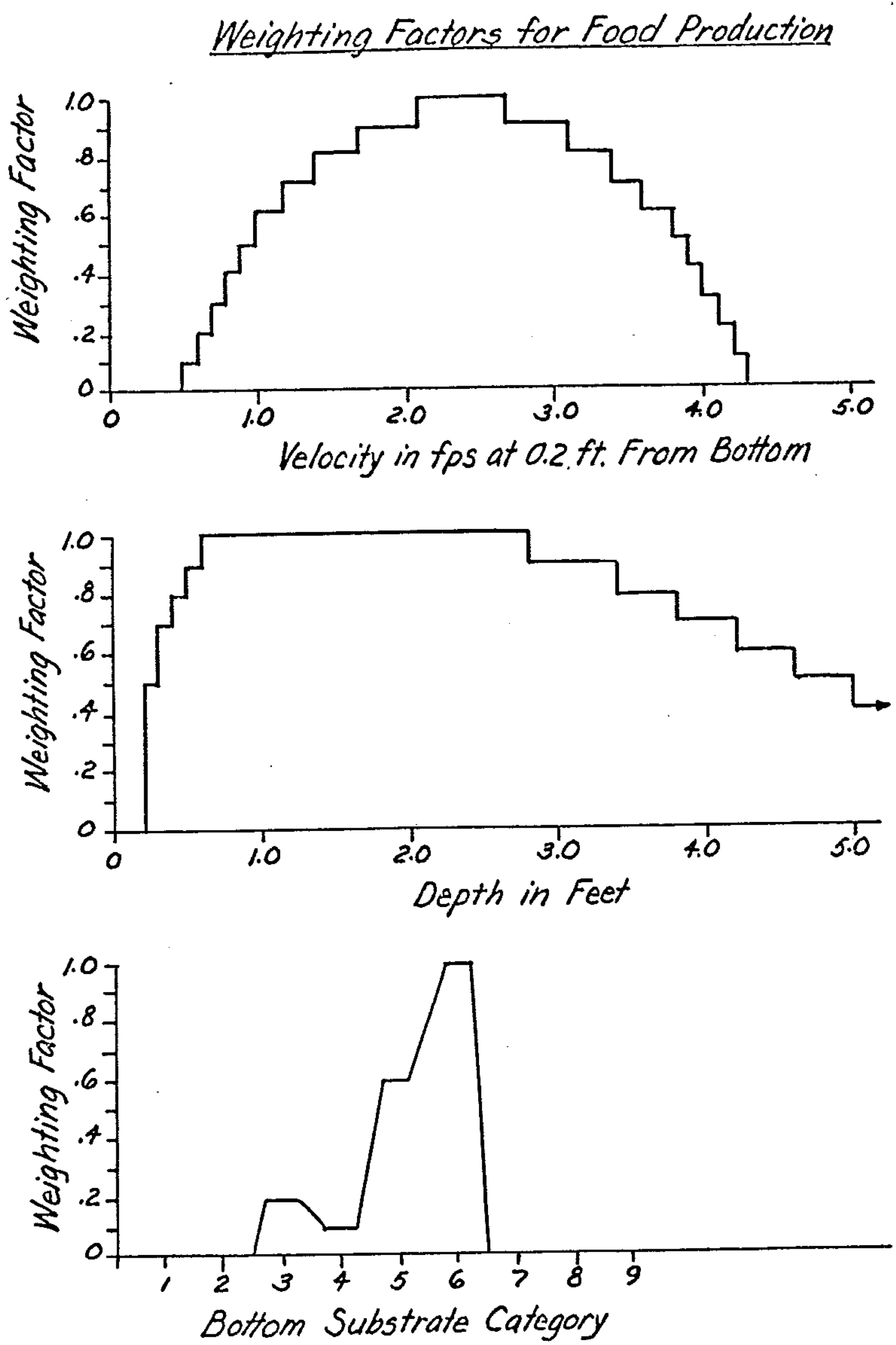


Figure A-4. Weighting factors for food producing area in a typical trout stream flow analysis.

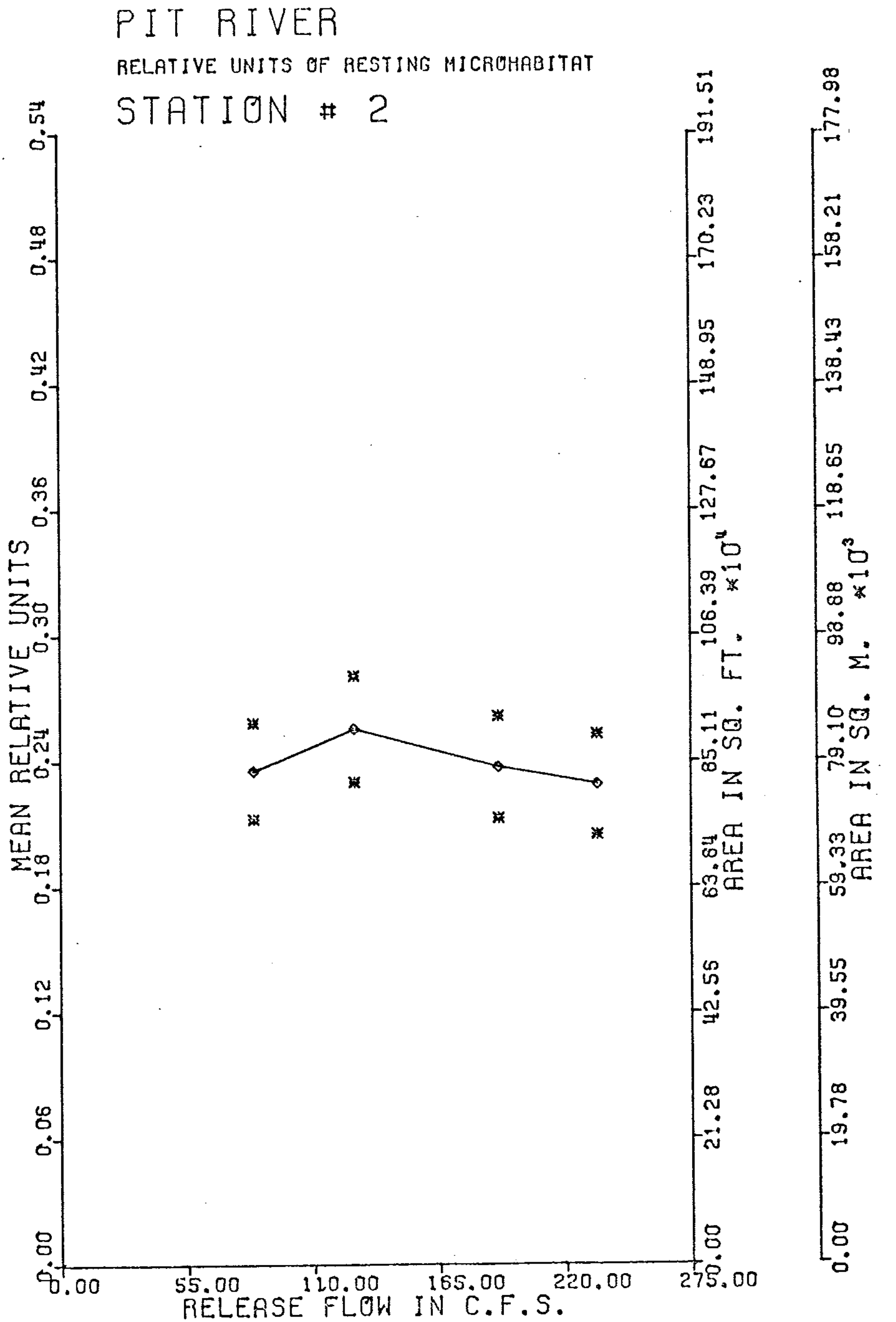


Figure A-5. Example of computer generated plot.

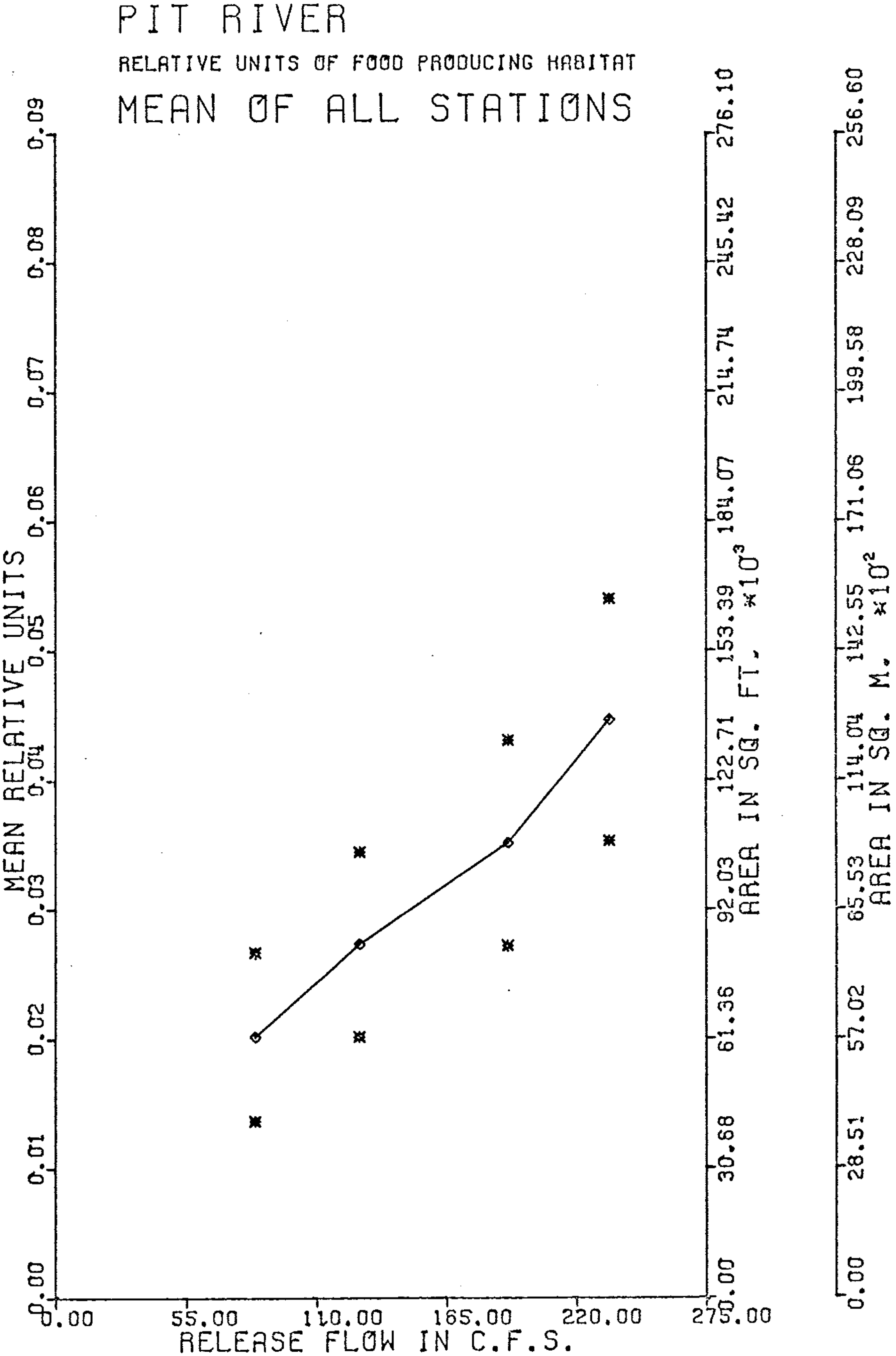
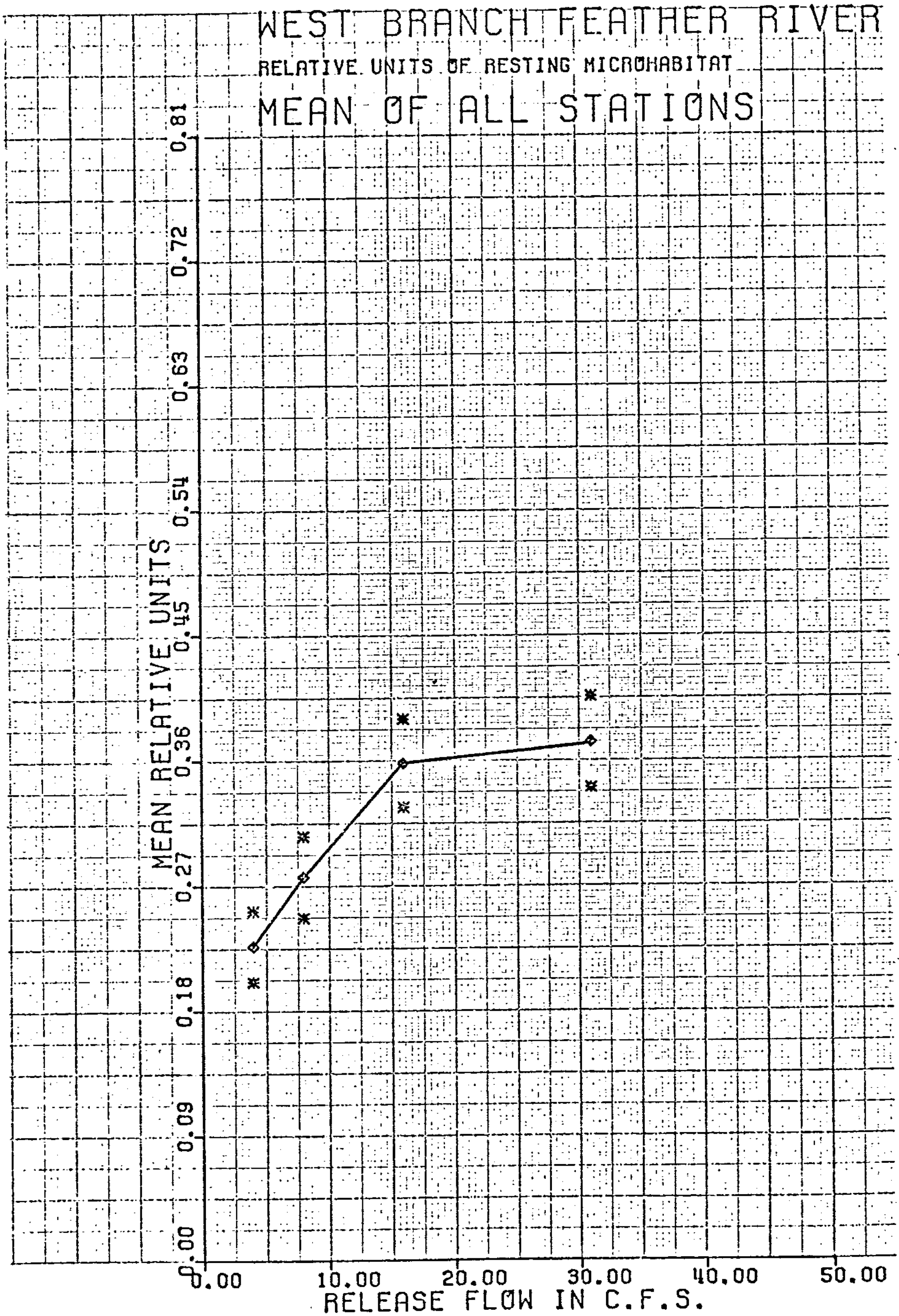


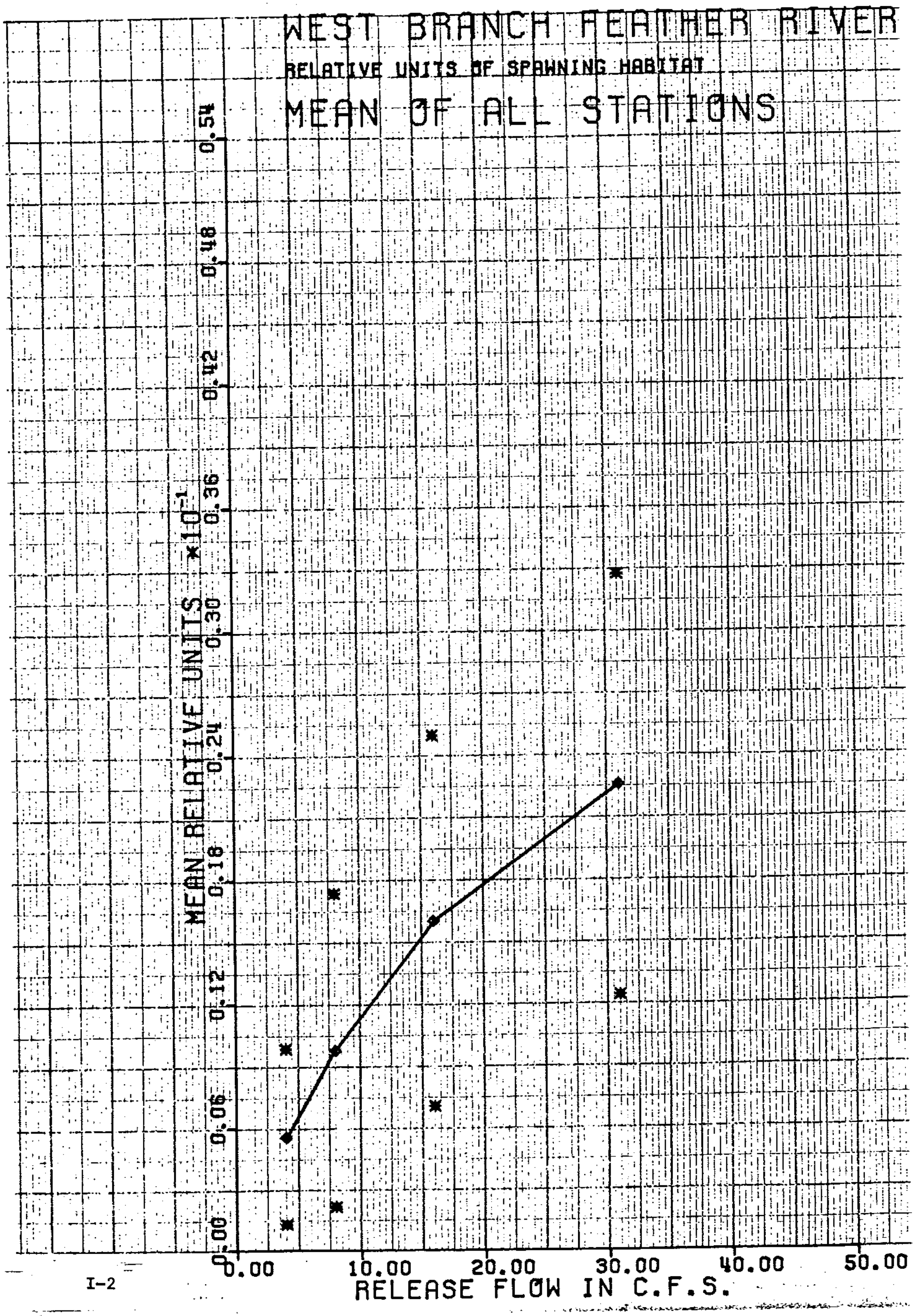
Figure A-6. Example of computer generated plot.

APPENDIX B

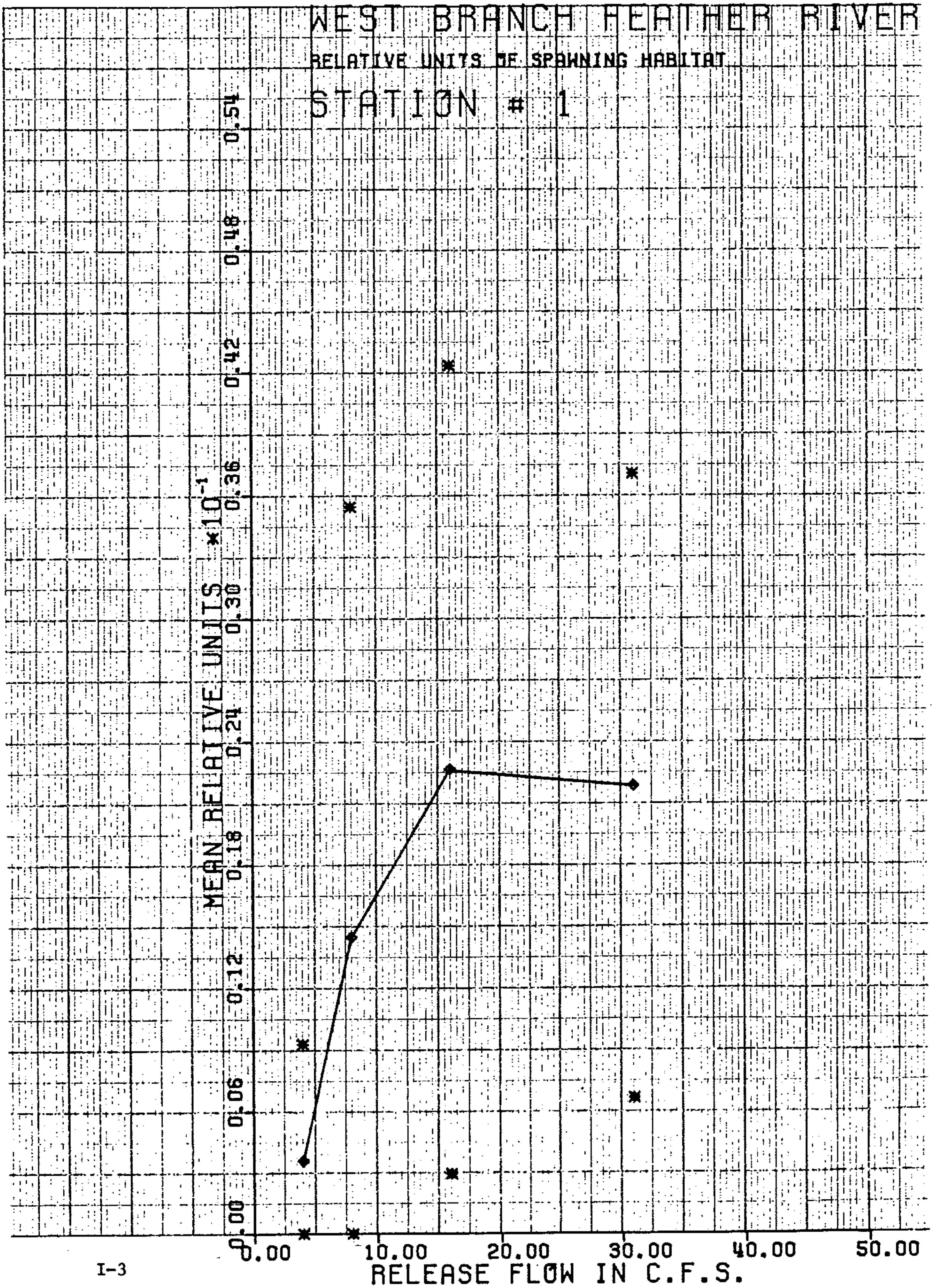
PLOTTED STREAMFLOW STUDY RESULTS[1]

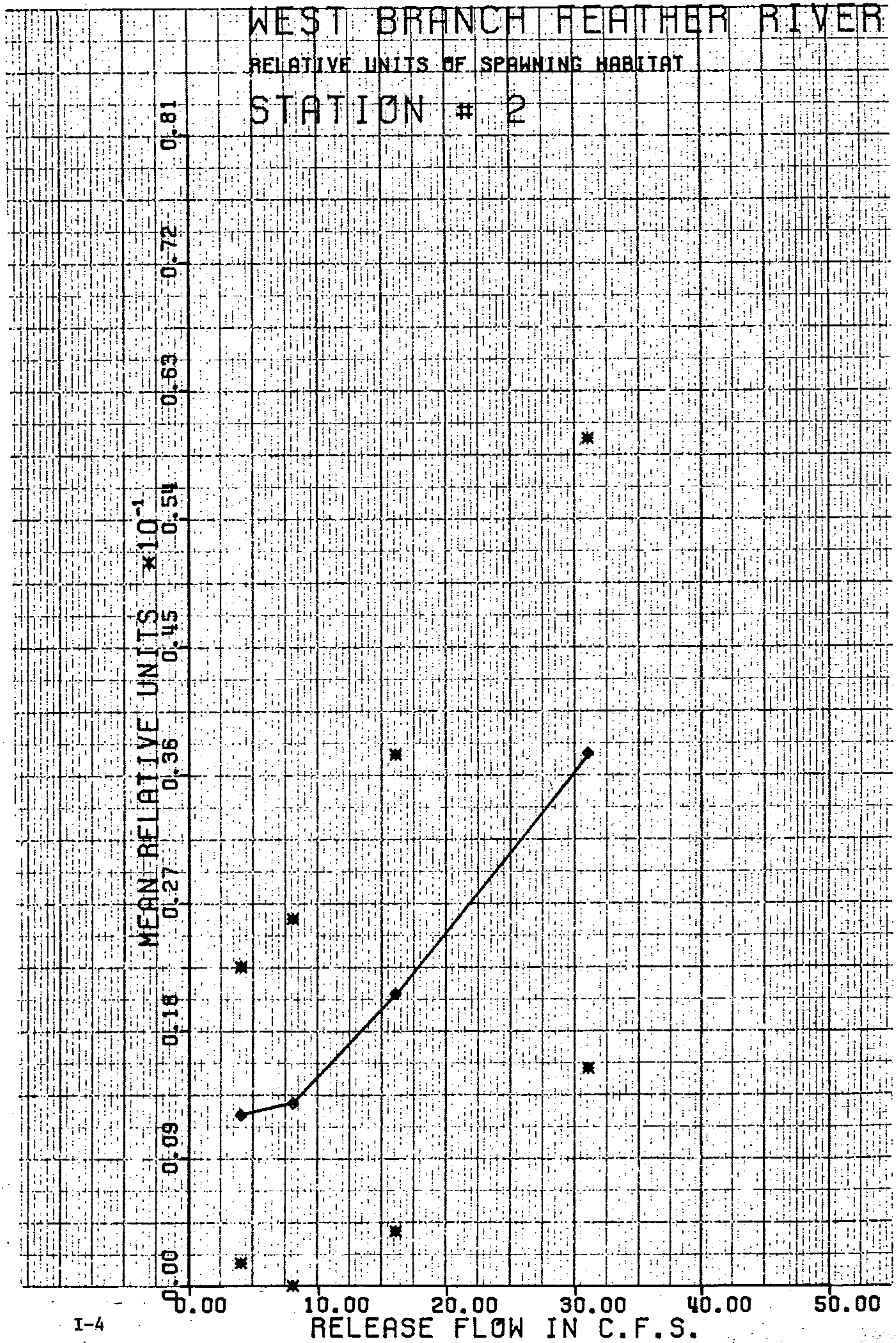
1. The asterisks indicated on both sides of each mean (MRU/cfs) in the enclosed figures represent 90 percent confidence limits.

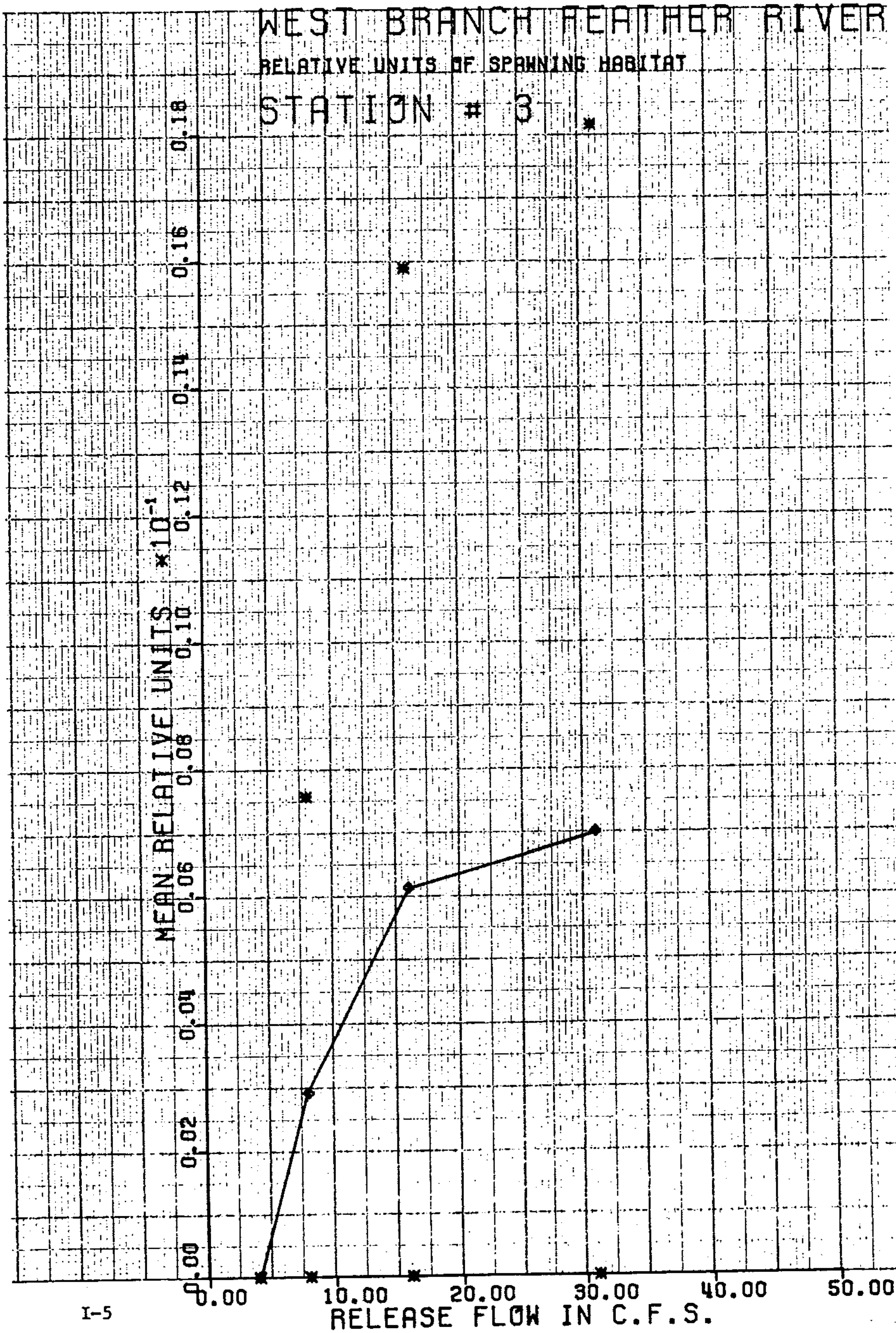

WEST BRANCH FEATHER RIVER
RELATIVE UNITS OF RESTING MICROHABITAT
MEAN OF ALL STATIONS
MEAN RELATIVE UNITS
0.00
0.09
0.18
0.27
0.36
0.45
0.54
0.63
0.72
0.81
0.00
10.00
20.00
30.00
40.00
50.00
RELEASE FLOW IN C.F.S.

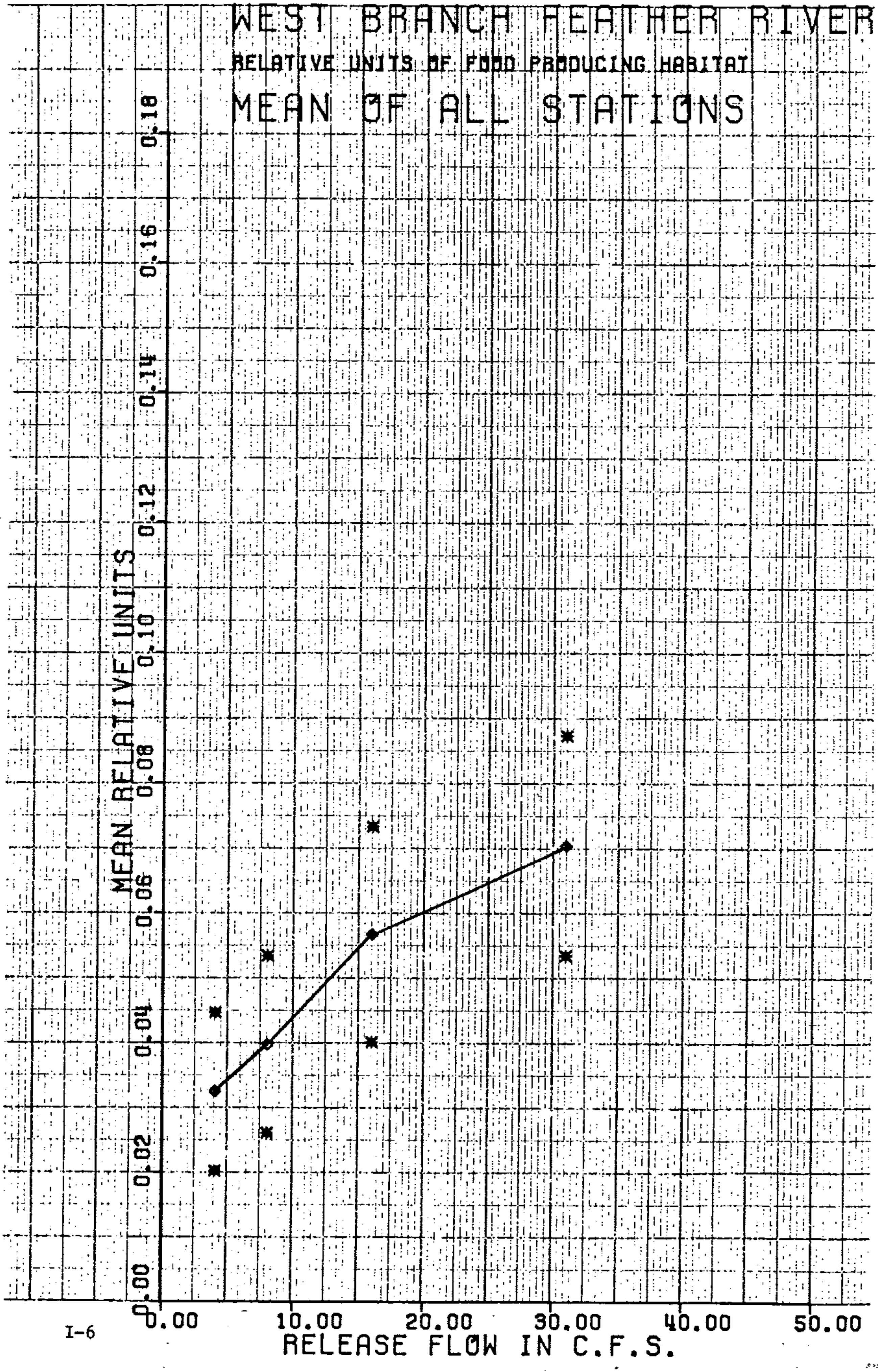


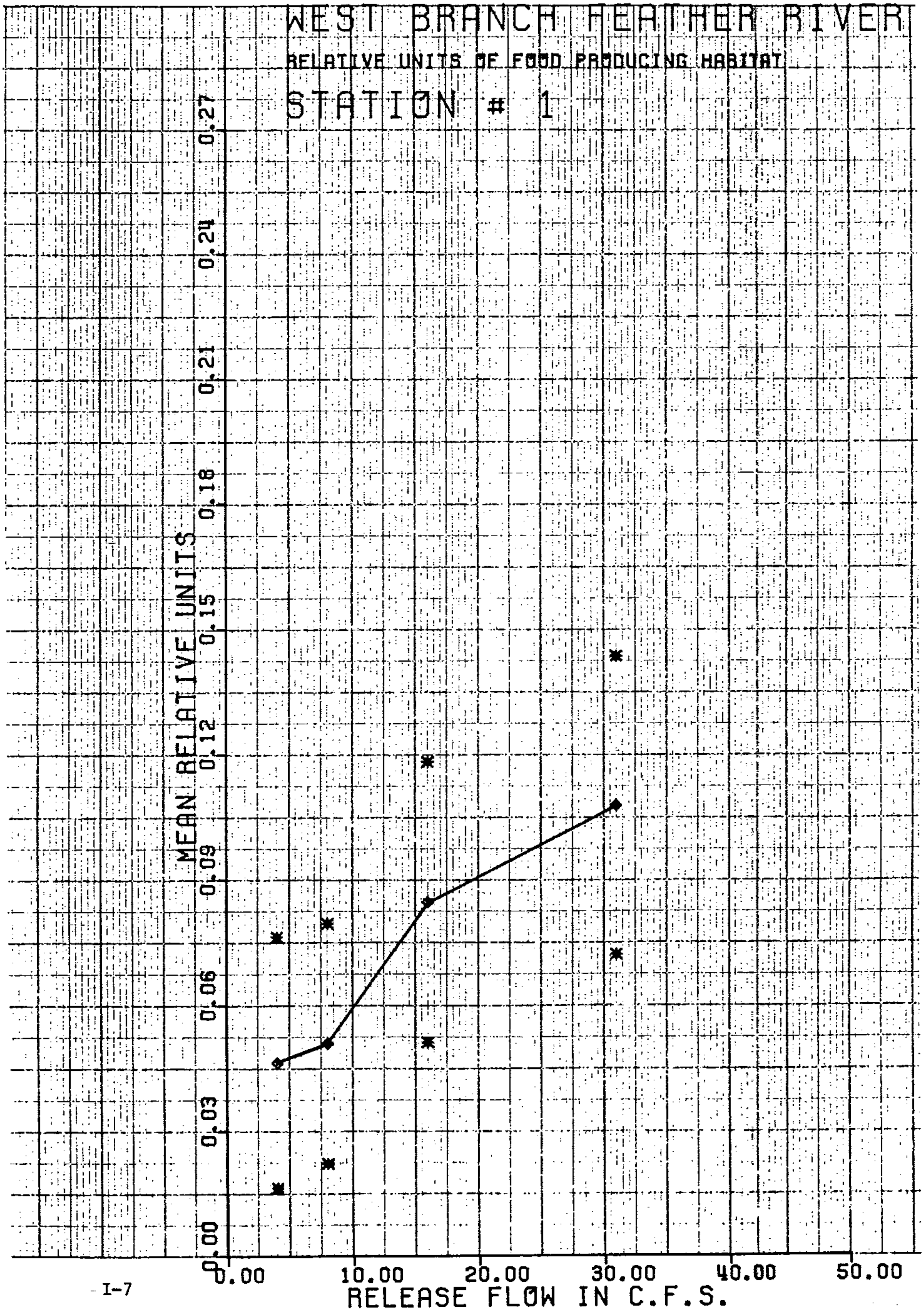
WEST BRANCH FEATHER RIVER
RELATIVE UNITS OF SPAWNING HABITAT
MEAN OF ALL STATIONS
MEAN RELATIVE UNITS *10⁻¹
0.00
0.06
0.12
0.18
0.24
0.30
0.36
0.42
0.48
0.54
0.00
10.00
20.00
30.00
40.00
50.00
RELEASE FLOW IN C.F.S.

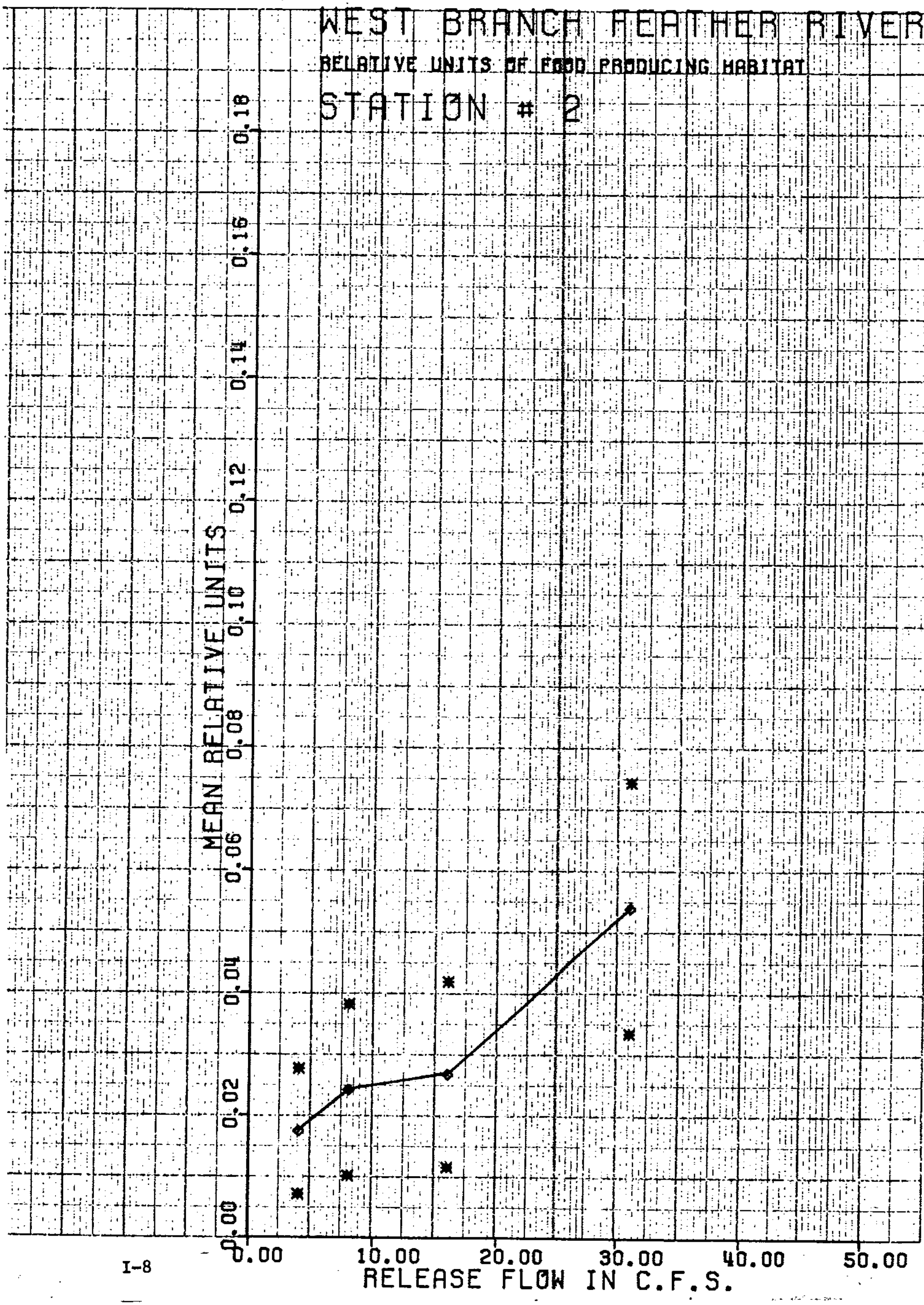

WEST BRANCH FEATHER RIVER
RELATIVE UNITS OF SPAWNING HABITAT
STATION # 1
MEAN RELATIVE UNITS *10⁻¹
0.00
0.06
0.12
0.18
0.24
0.30
0.36
0.42
0.48
0.54
0.00
10.00
20.00
30.00
40.00
50.00
RELEASE FLOW IN C.F.S.

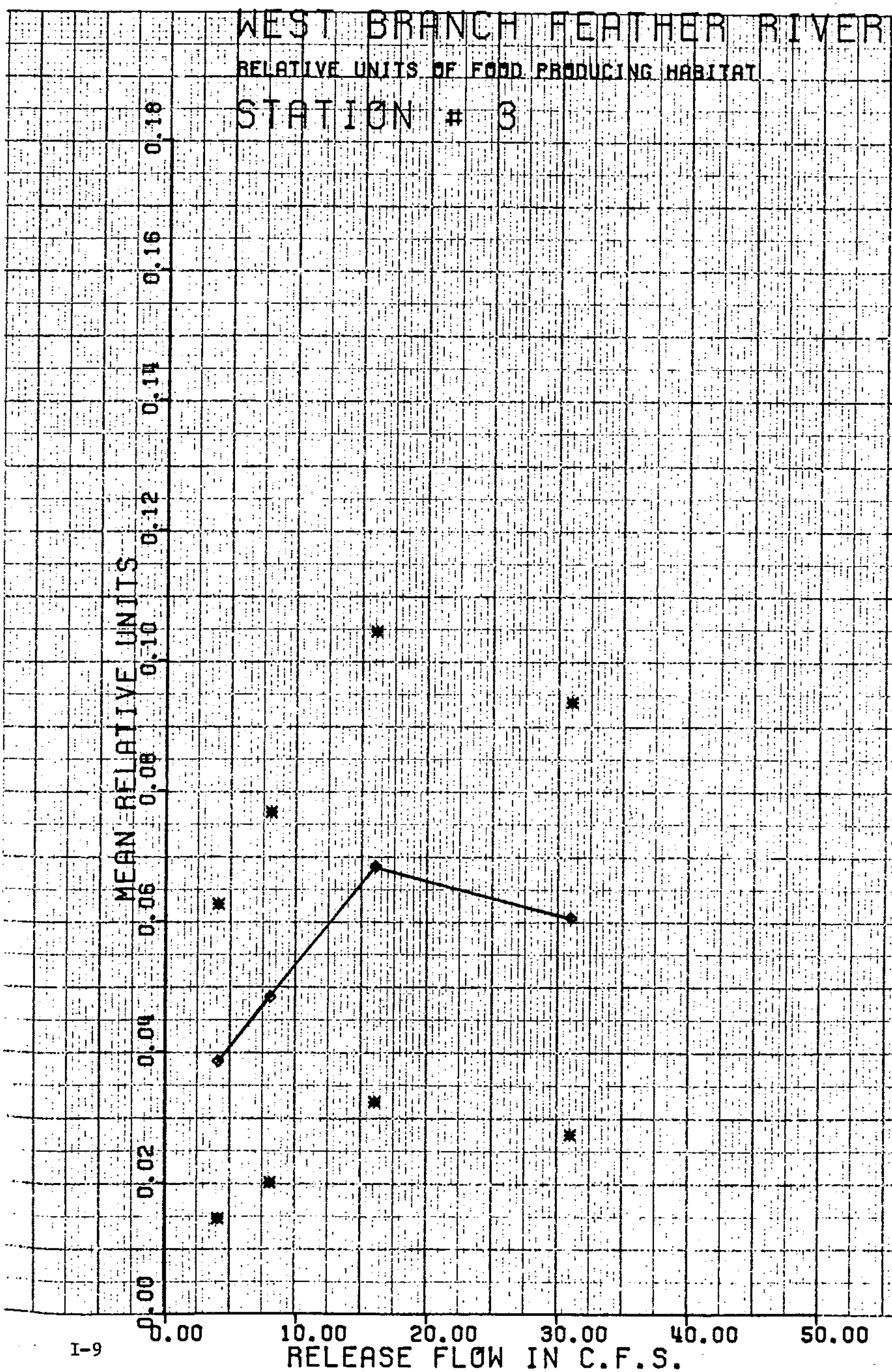

WEST BRANCH FEATHER RIVER
RELATIVE UNITS OF SPAWNING HABITAT
STATION # 2
MEAN RELATIVE UNITS *10^-1
0.00
0.09
0.18
0.27
0.36
0.45
0.54
0.63
0.72
0.81
0.00
10.00
20.00
30.00
40.00
50.00
RELEASE FLOW IN C.F.S.

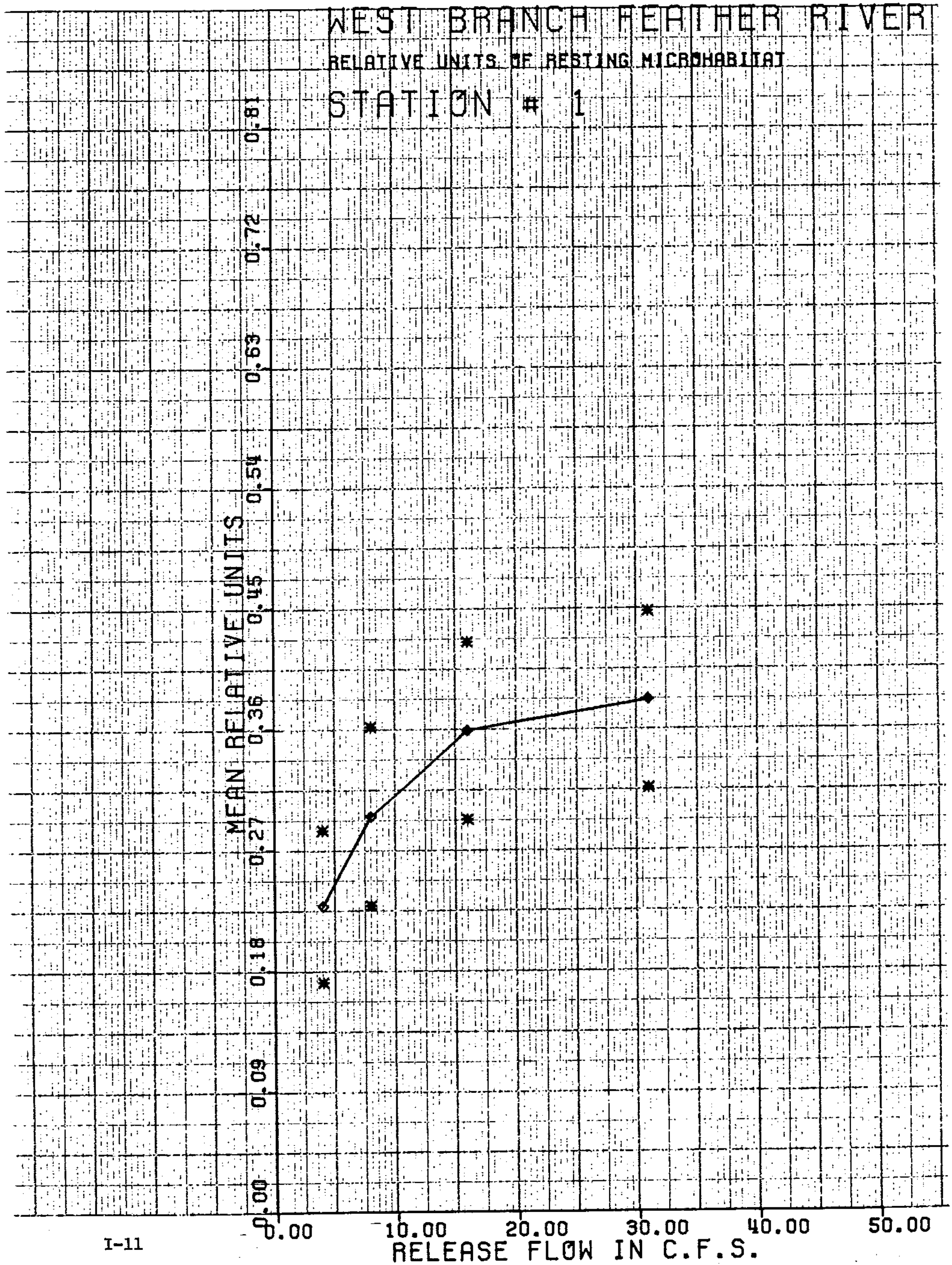

WEST BRANCH FEATHER RIVER
RELATIVE UNITS OF SPAWNING HABITAT
STATION # 3
MEAN RELATIVE UNITS *10^-1
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.00
10.00
20.00
30.00
40.00
50.00
RELEASE FLOW IN C.F.S.

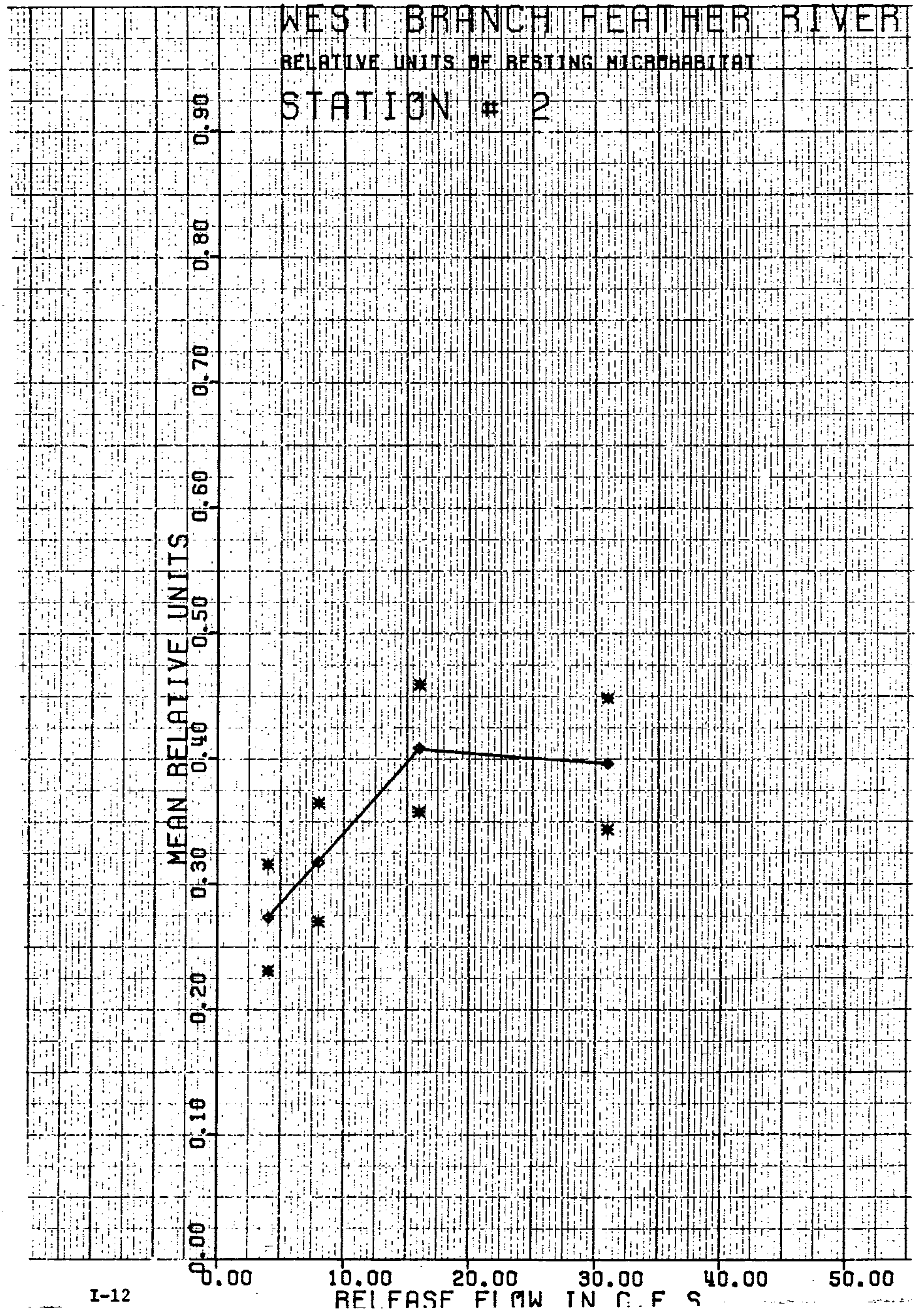

WEST BRANCH FEATHER RIVER
RELATIVE UNITS OF FOOD PRODUCING HABITAT
MEAN OF ALL STATIONS
MEAN RELATIVE UNITS
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.00
10.00
20.00
30.00
40.00
50.00
RELEASE FLOW IN C.F.S.

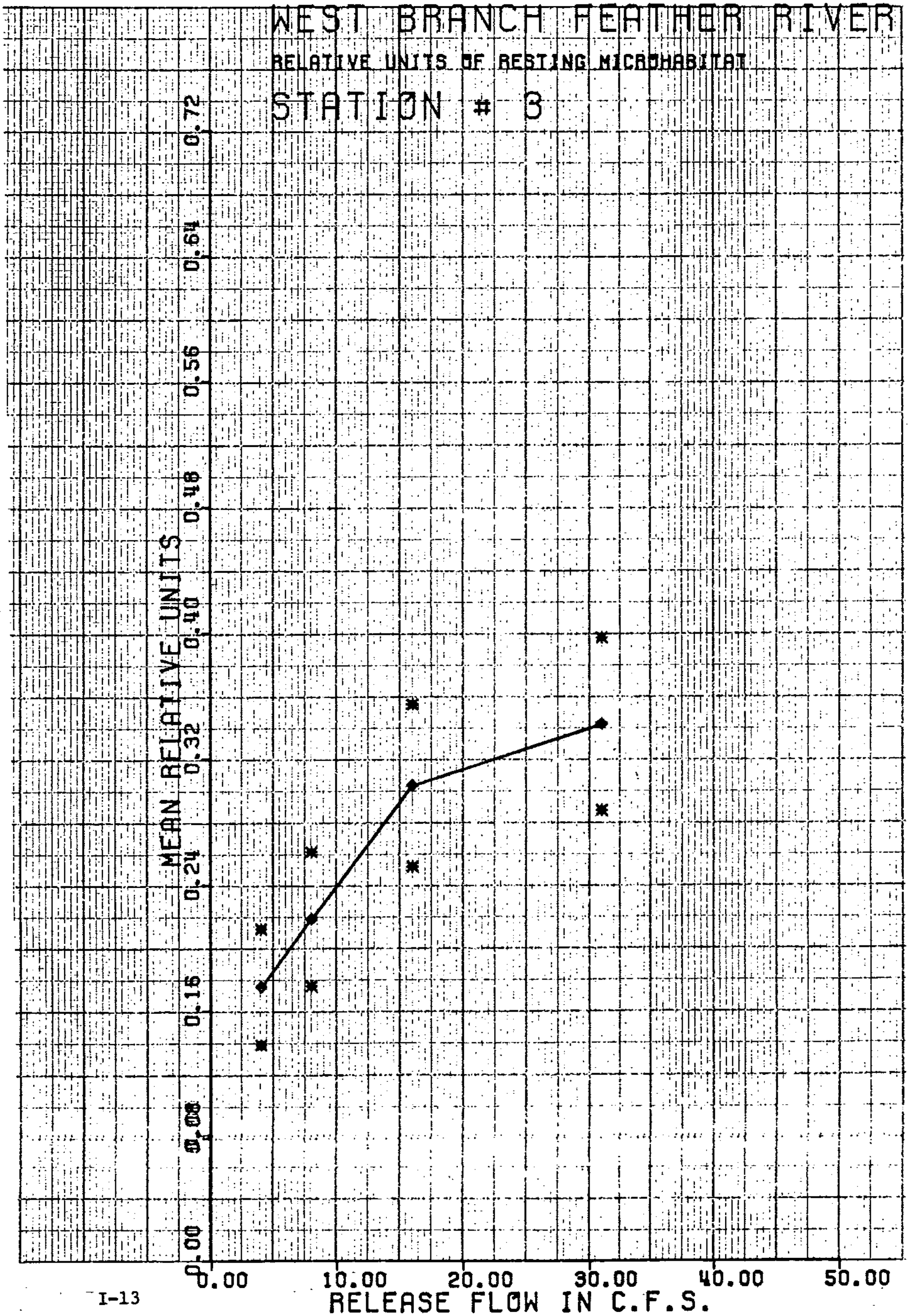

WEST BRANCH FEATHER RIVER
RELATIVE UNITS OF FOOD PRODUCING HABITAT
STATION # 1
MEAN RELATIVE UNITS
0.00
0.03
0.06
0.09
0.12
0.15
0.18
0.21
0.24
0.27
0.00
10.00
20.00
30.00
40.00
50.00
RELEASE FLOW IN C.F.S.


WEST BRANCH FEATHER RIVER
RELATIVE UNITS OF FOOD PRODUCING HABITAT
STATION # 2
MEAN RELATIVE UNITS
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.00
10.00
20.00
30.00
40.00
50.00
RELEASE FLOW IN C.F.S.

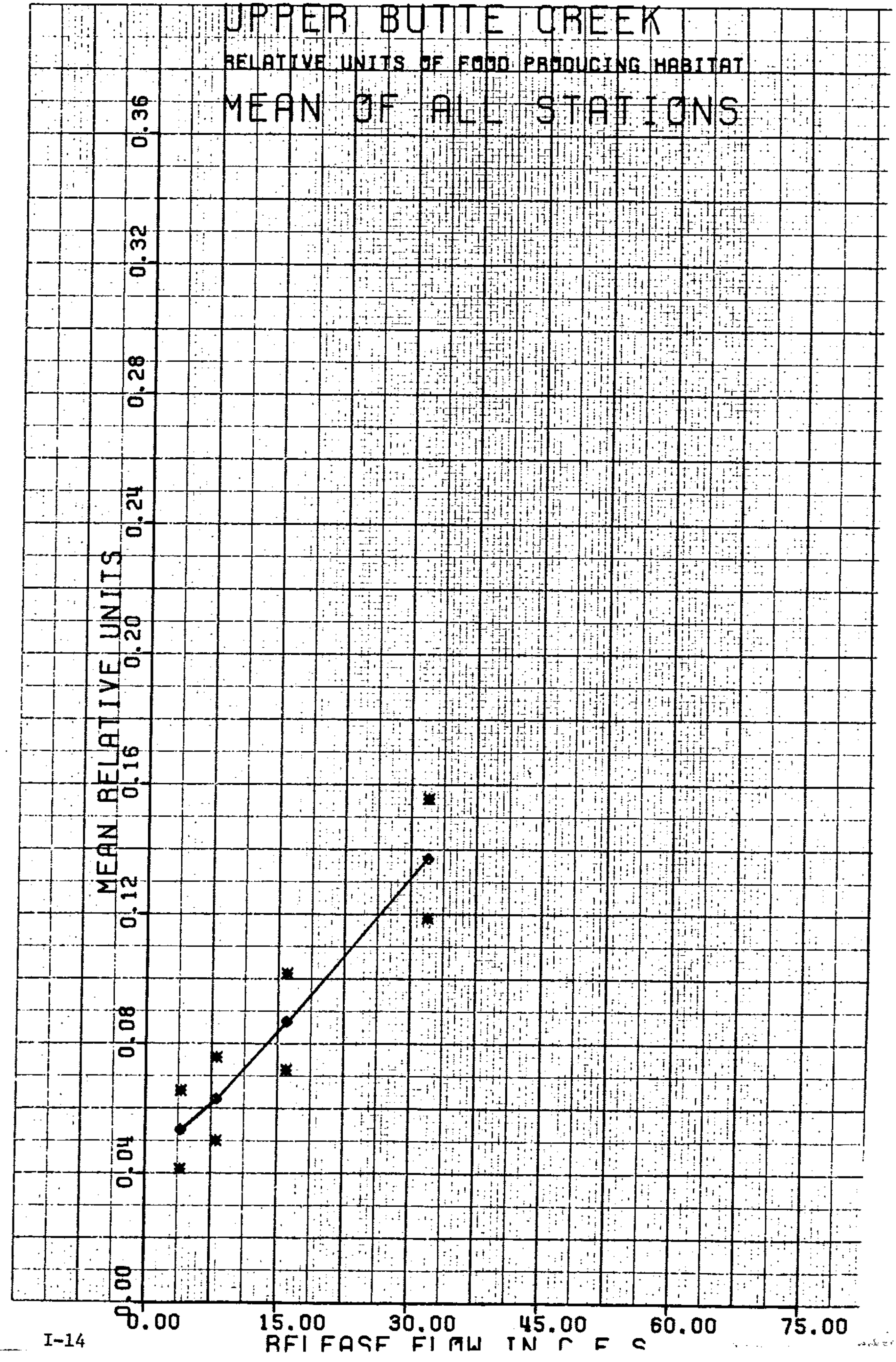

WEST BRANCH FEATHER RIVER
RELATIVE UNITS OF FOOD PRODUCING HABITAT
STATION # 3
MEAN RELATIVE UNITS
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.00
10.00
20.00
30.00
40.00
50.00
RELEASE FLOW IN C.F.S.


WEST BRANCH FEATHER RIVER
RELATIVE UNITS OF RESTING MICROHABITAT
STATION # 1
MEAN RELATIVE UNITS
0.00
0.09
0.18
0.27
0.36
0.45
0.54
0.63
0.72
0.81
0.00
10.00
20.00
30.00
40.00
50.00
RELEASE FLOW IN C.F.S.

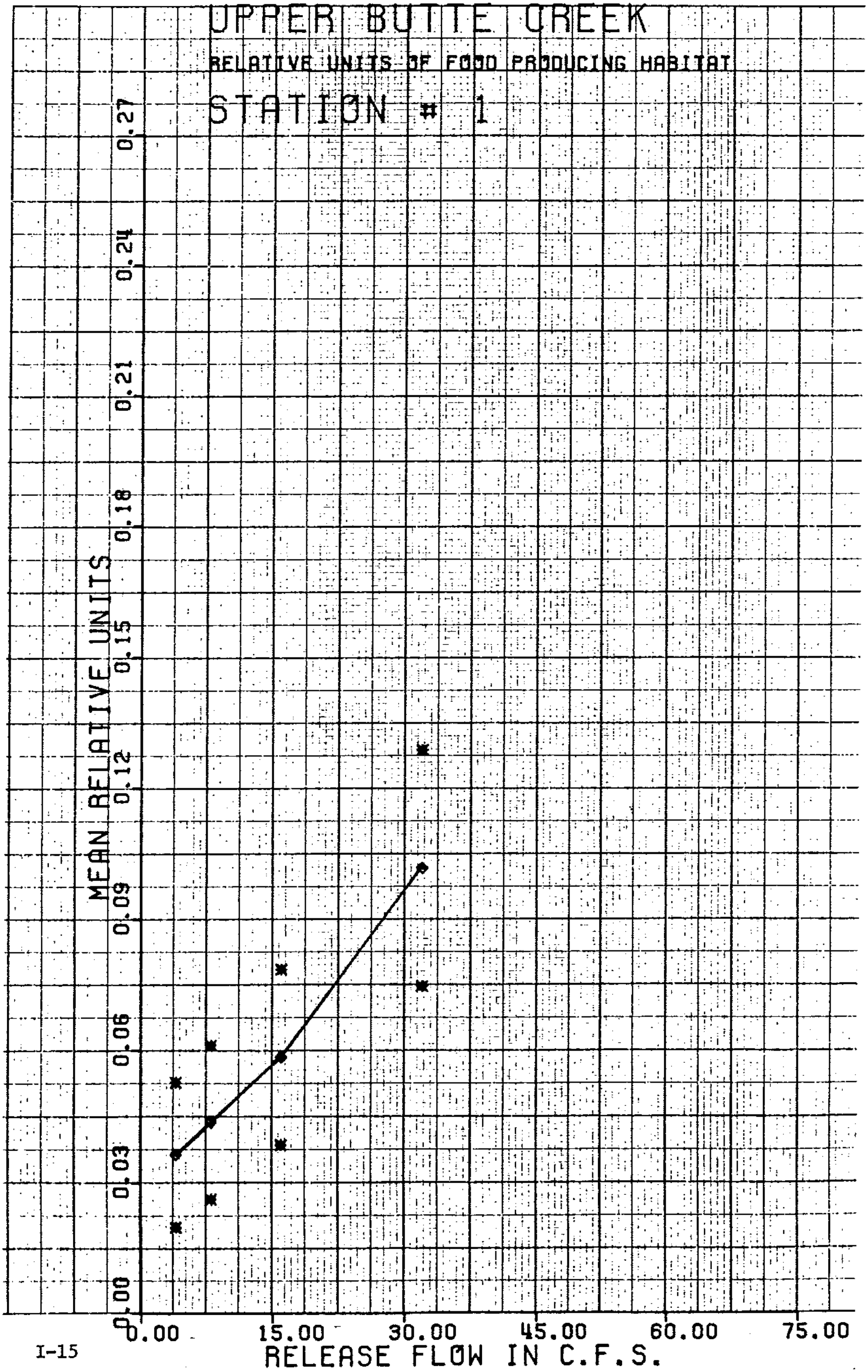

WEST BRANCH FEATHER RIVER
RELATIVE UNITS OF RESTING MICROHABITAT
STATION # 2
MEAN RELATIVE UNITS
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
0.00
10.00
20.00
30.00
40.00
50.00
RELEASE FLOW IN C.F.S

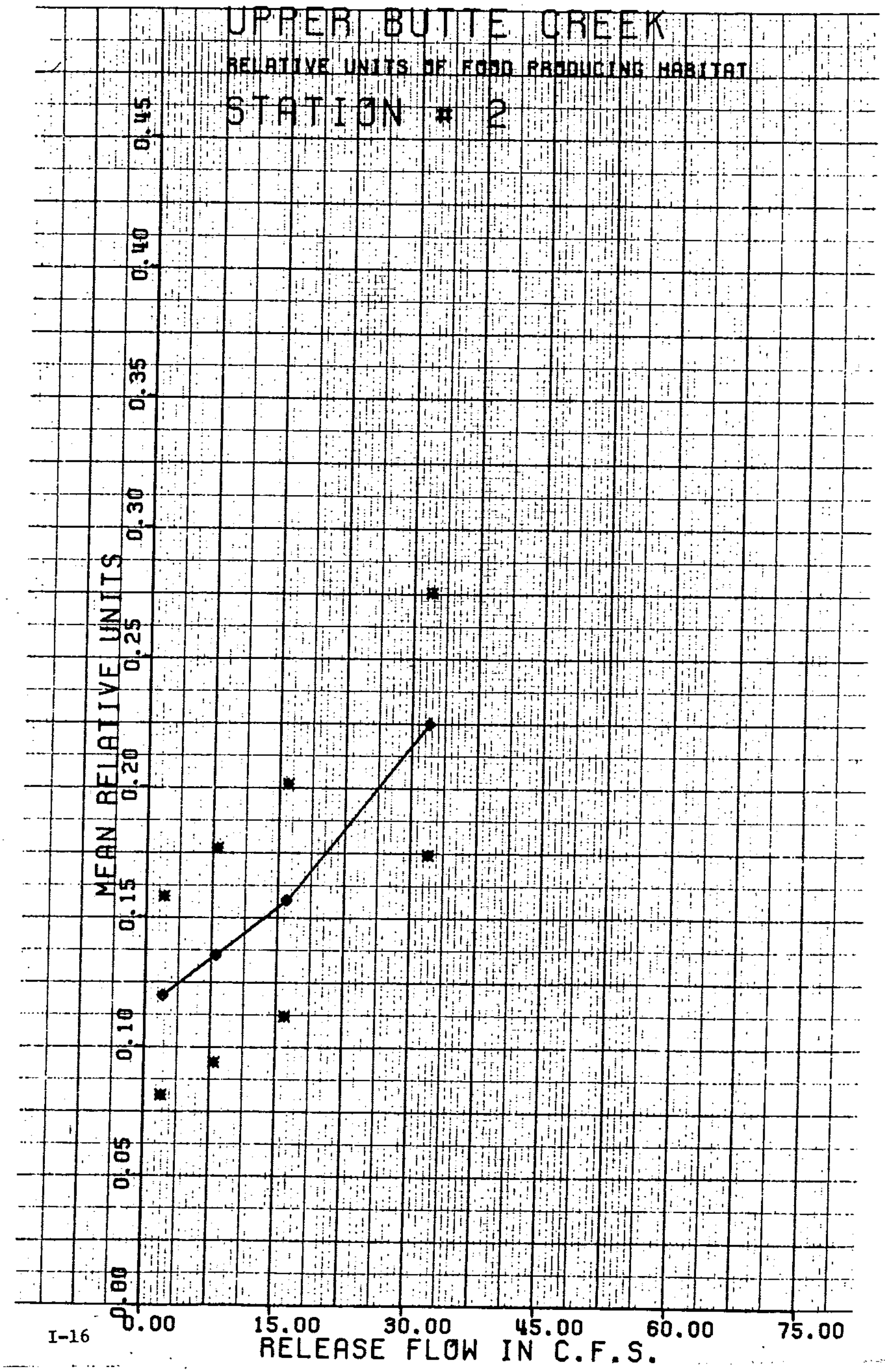


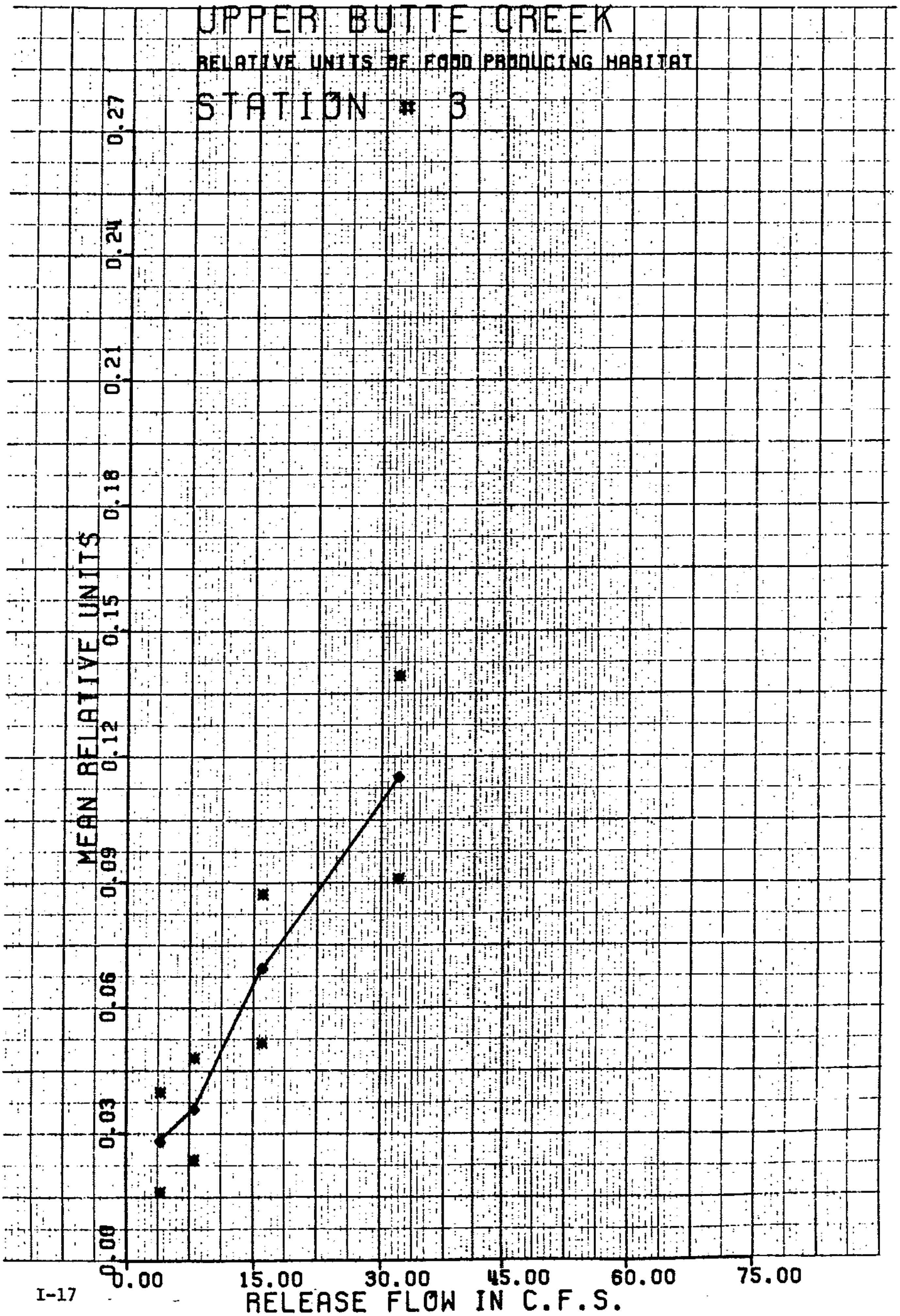
WEST BRANCH FEATHER RIVER
RELATIVE UNITS OF RESTING MICROHABITAT
STATION # 3
MEAN RELATIVE UNITS
0.00
0.08
0.16
0.24
0.32
0.40
0.48
0.56
0.64
0.72
0.00
10.00
20.00
30.00
40.00
50.00
RELEASE FLOW IN C.F.S.



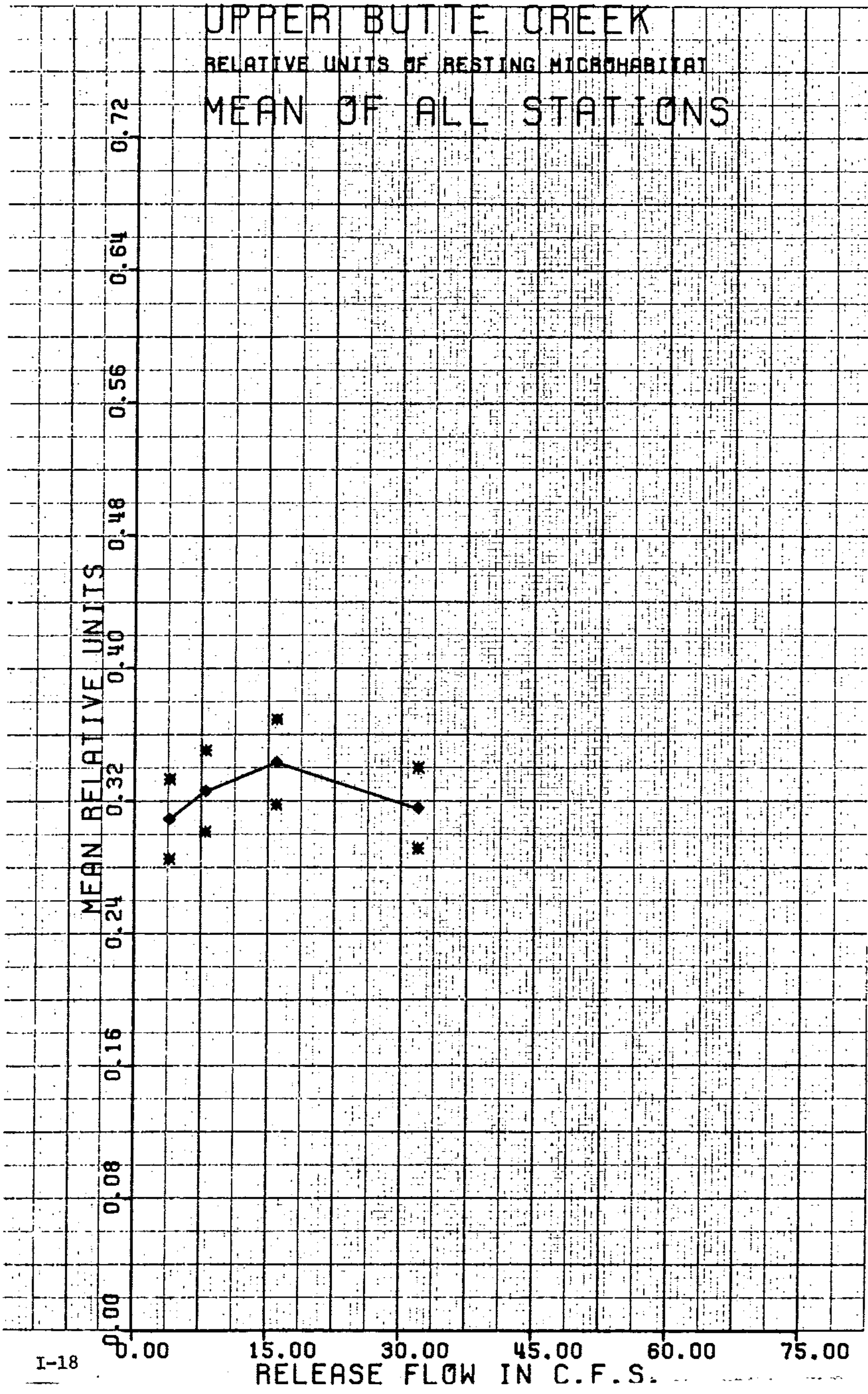
UPPER BUTTE CREEK
RELATIVE UNITS OF FOOD PRODUCING HABITAT
MEAN OF ALL STATIONS
MEAN RELATIVE UNITS
0.00
0.04
0.08
0.12
0.16
0.20
0.24
0.28
0.32
0.36
0.00
15.00
30.00
45.00
60.00
75.00
RELEASE FLOW IN C.F.S.

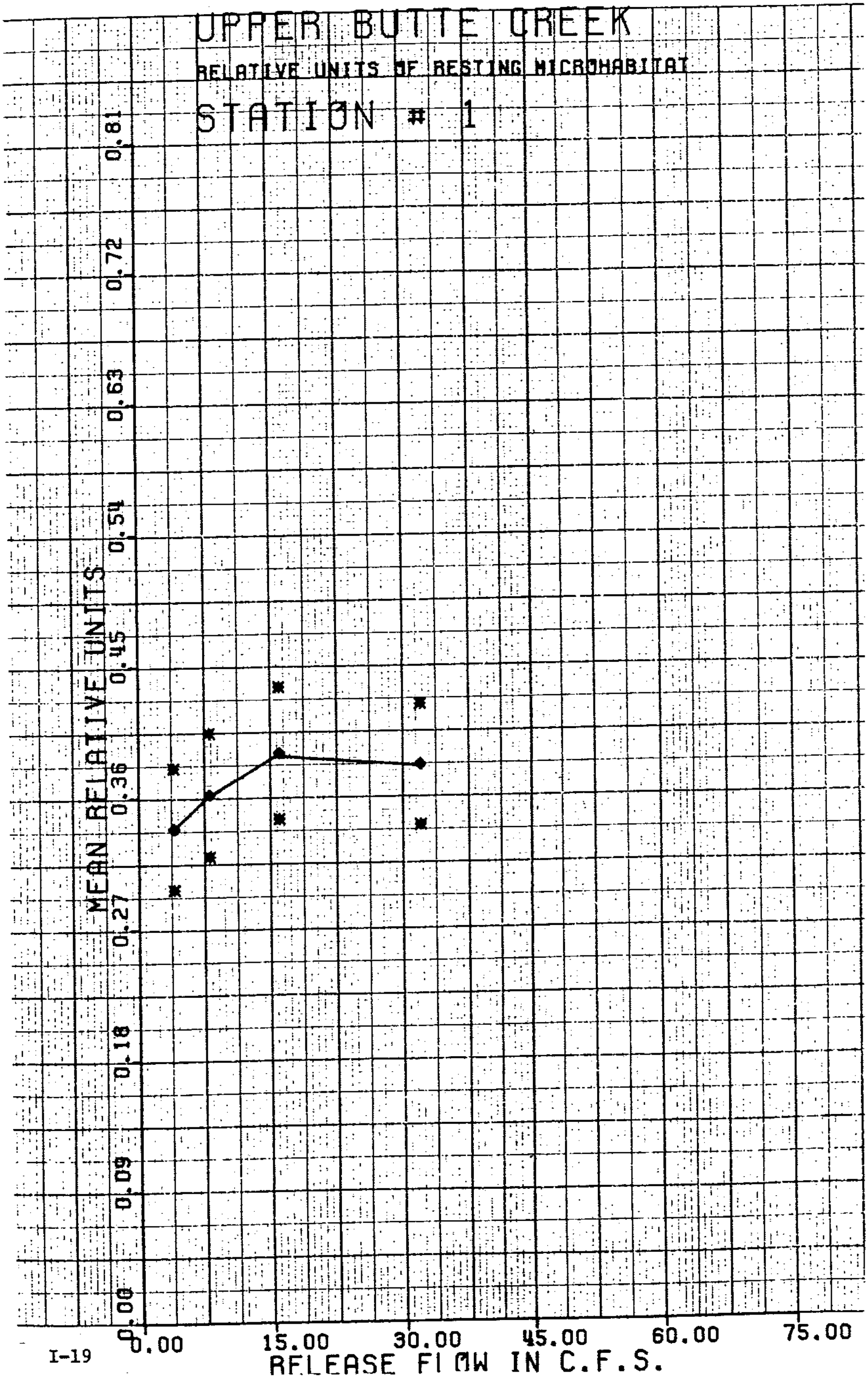

UPPER BUTTE CREEK
RELATIVE UNITS OF FOOD PRODUCING HABITAT
STATIØN # 1
MEAN RELATIVE UNITS
0.27
0.24
0.21
0.18
0.15
0.12
0.09
0.06
0.03
0.00
0.00
15.00
30.00
45.00
60.00
75.00
RELEASE FLØW IN C.F.S.


UPPER BUTTE CREEK
RELATIVE UNITS OF FOOD PRODUCING HABITAT
STATION # 2
MEAN RELATIVE UNITS
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.00
15.00
30.00
45.00
60.00
75.00
RELEASE FLOW IN C.F.S.

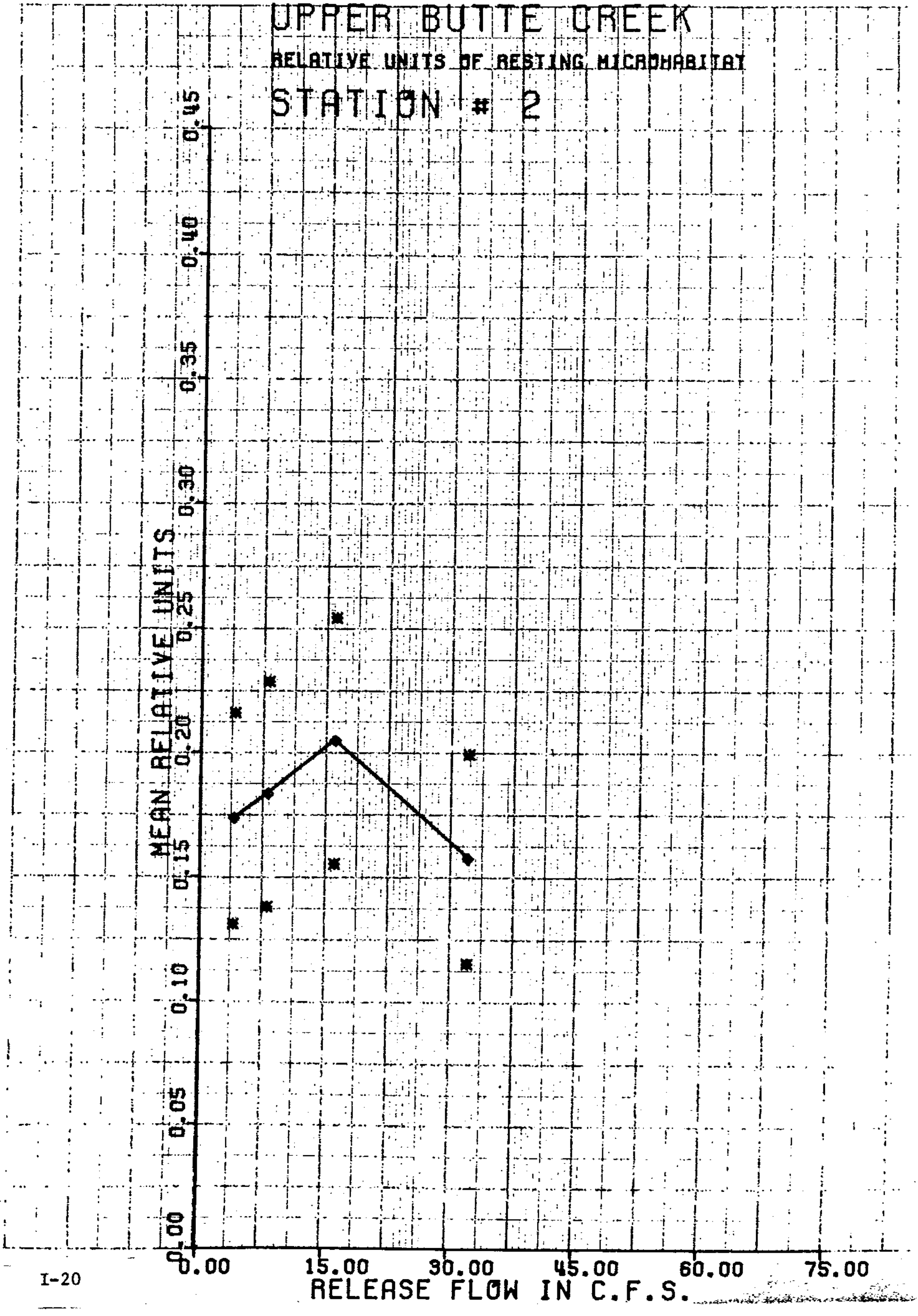


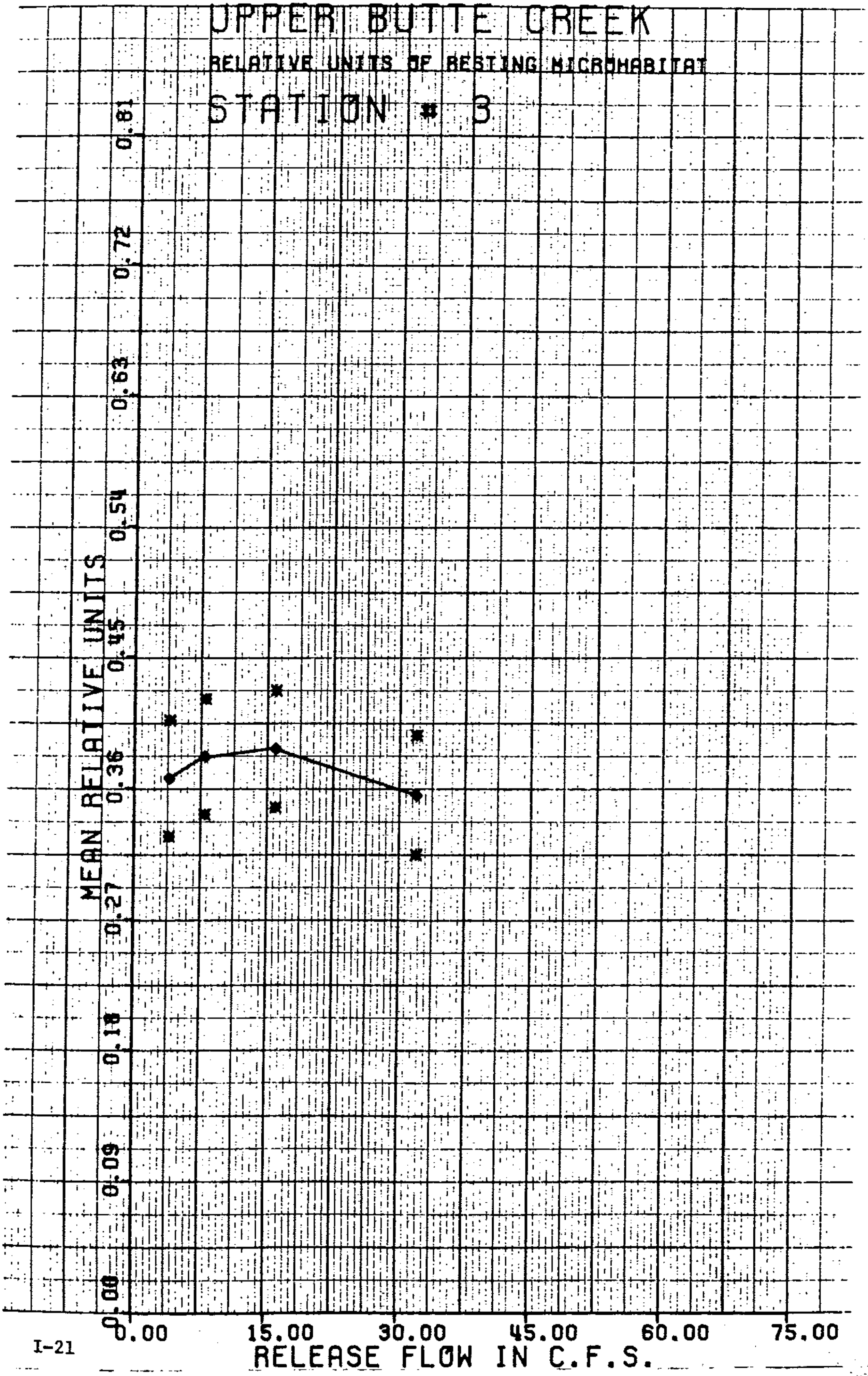
UPPER BUTTE CREEK
RELATIVE UNITS OF FOOD PRODUCING HABITAT
STATION # 3
MEAN RELATIVE UNITS
0.00
0.03
0.06
0.09
0.12
0.15
0.18
0.21
0.24
0.27
0.00
15.00
30.00
45.00
60.00
75.00
RELEASE FLOW IN C.F.S.

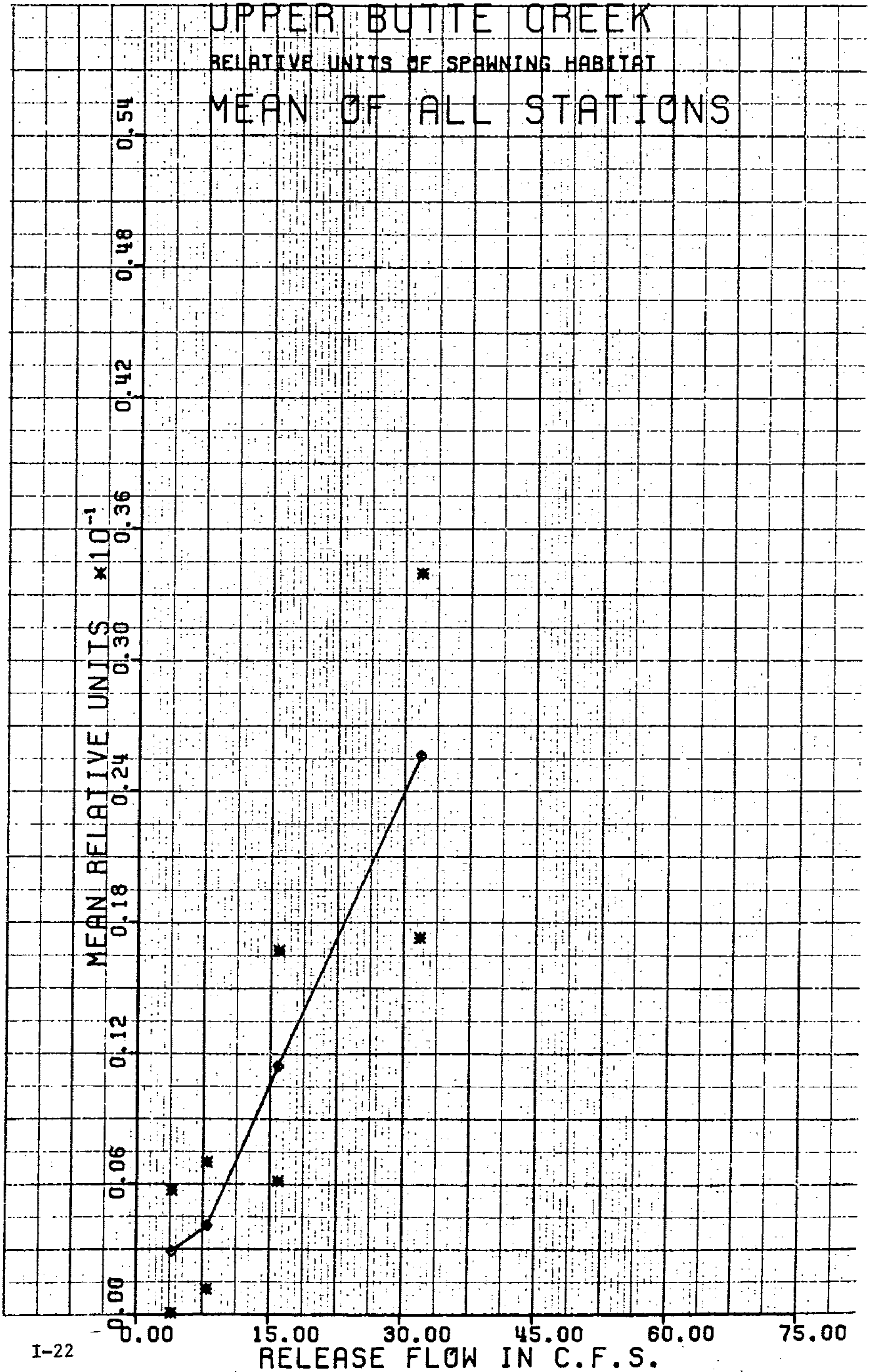

UPPER BUTTE CREEK
RELATIVE UNITS OF RESTING MICROHABITAT
MEAN OF ALL STATIONS
MEAN RELATIVE UNITS
0.72
0.64
0.56
0.48
0.40
0.32
0.24
0.16
0.08
0.00
0.00
15.00
30.00
45.00
60.00
75.00
RELEASE FLOW IN C.F.S.

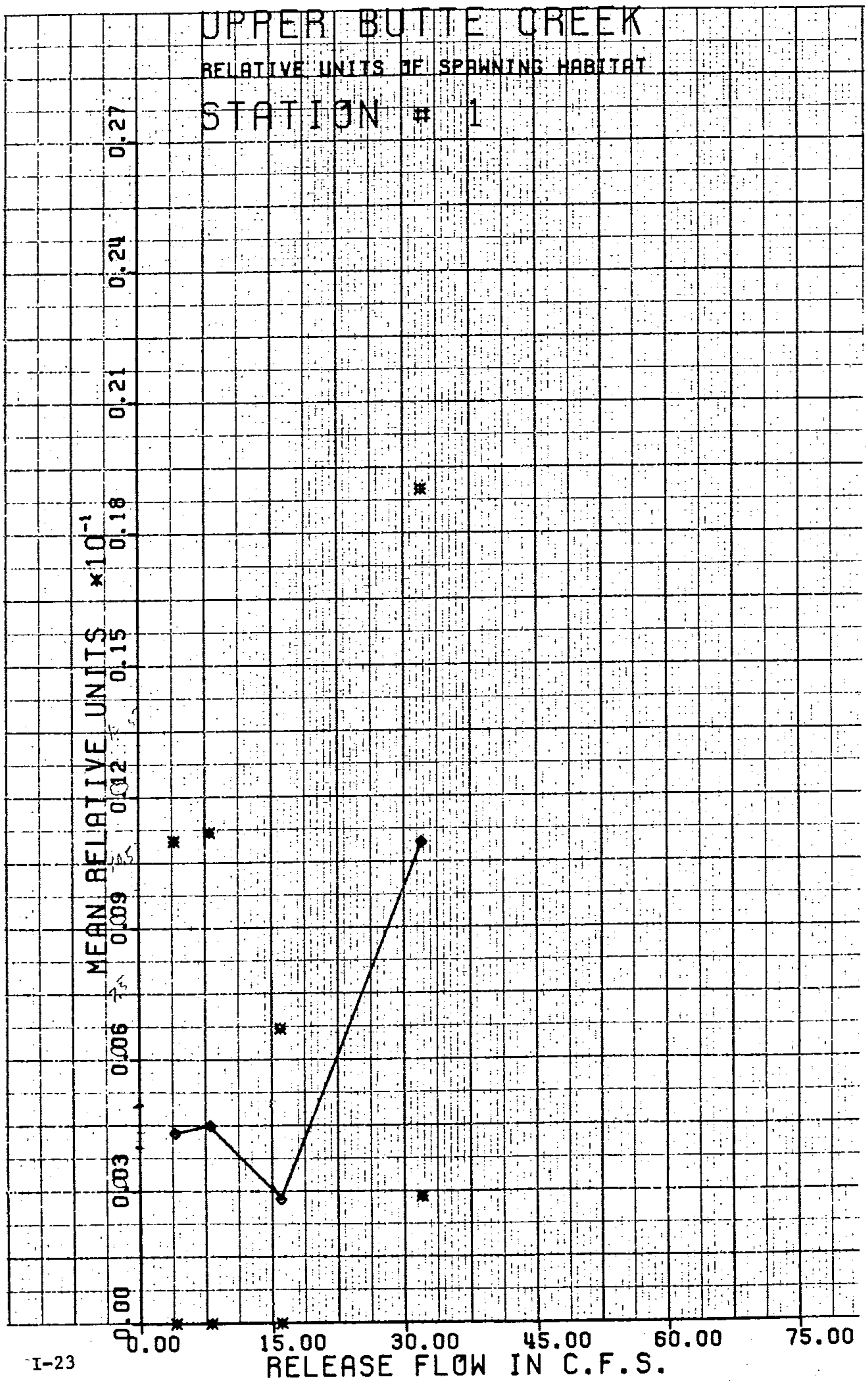


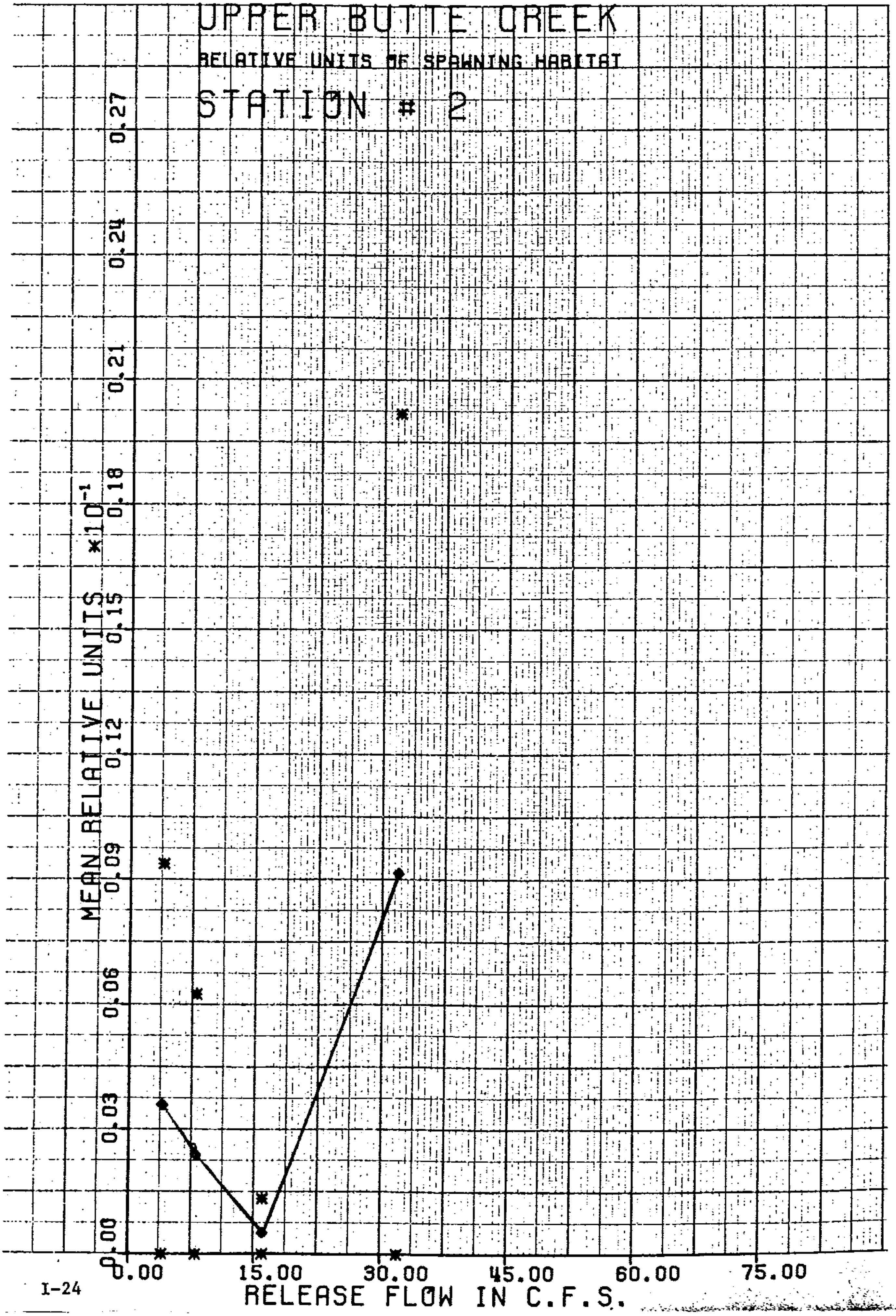
UPPER BUTTE CREEK
RELATIVE UNITS OF RESTING MICROHABITAT
STATION # 1
MEAN RELATIVE UNITS
0.00
0.09
0.18
0.27
0.36
0.45
0.54
0.63
0.72
0.81
0.00
15.00
30.00
45.00
60.00
75.00
RELEASE FLOW IN C.F.S.

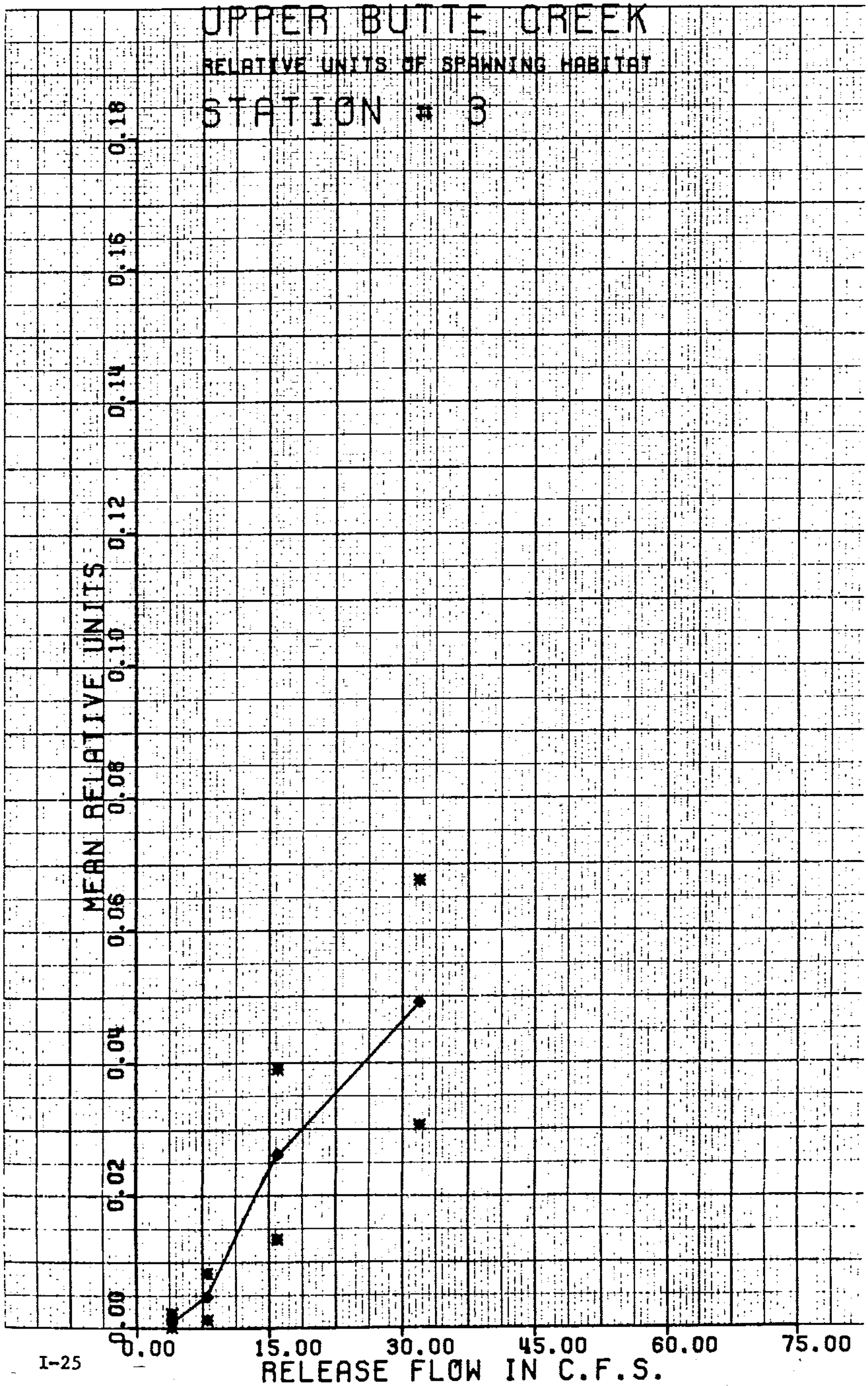

UPPER BUTTE CREEK
RELATIVE UNITS OF RESTING MICROHABITAT
STATION # 2
MEAN RELATIVE UNITS
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.00
15.00
30.00
45.00
60.00
75.00
RELEASE FLOW IN C.F.S.

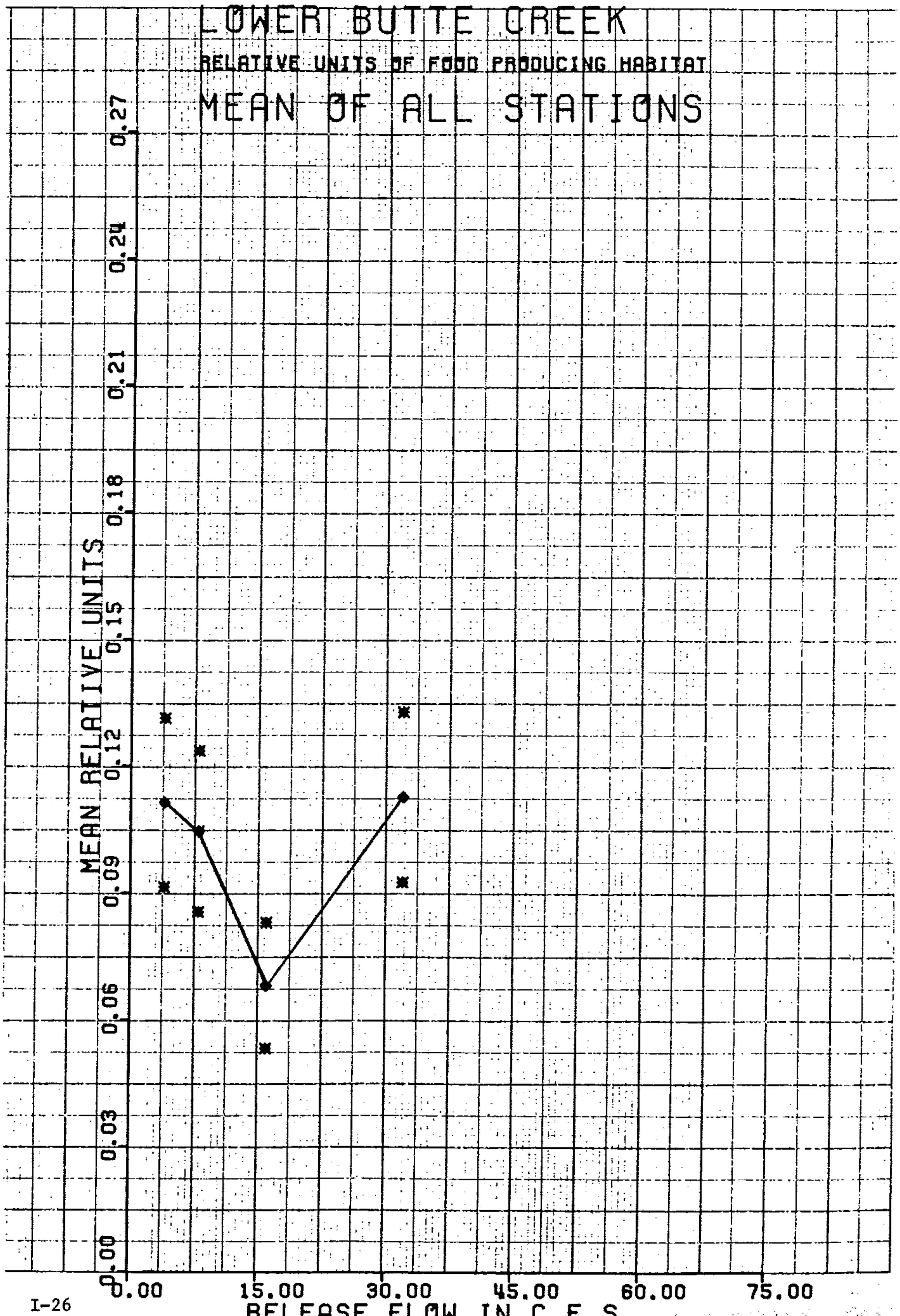

UPPER BUTTE CREEK
RELATIVE UNITS OF RESTING MICROHABITAT
STATION # 3
MEAN RELATIVE UNITS
0.00
0.09
0.18
0.27
0.36
0.45
0.54
0.63
0.72
0.81
0.00
15.00
30.00
45.00
60.00
75.00
RELEASE FLOW IN C.F.S.

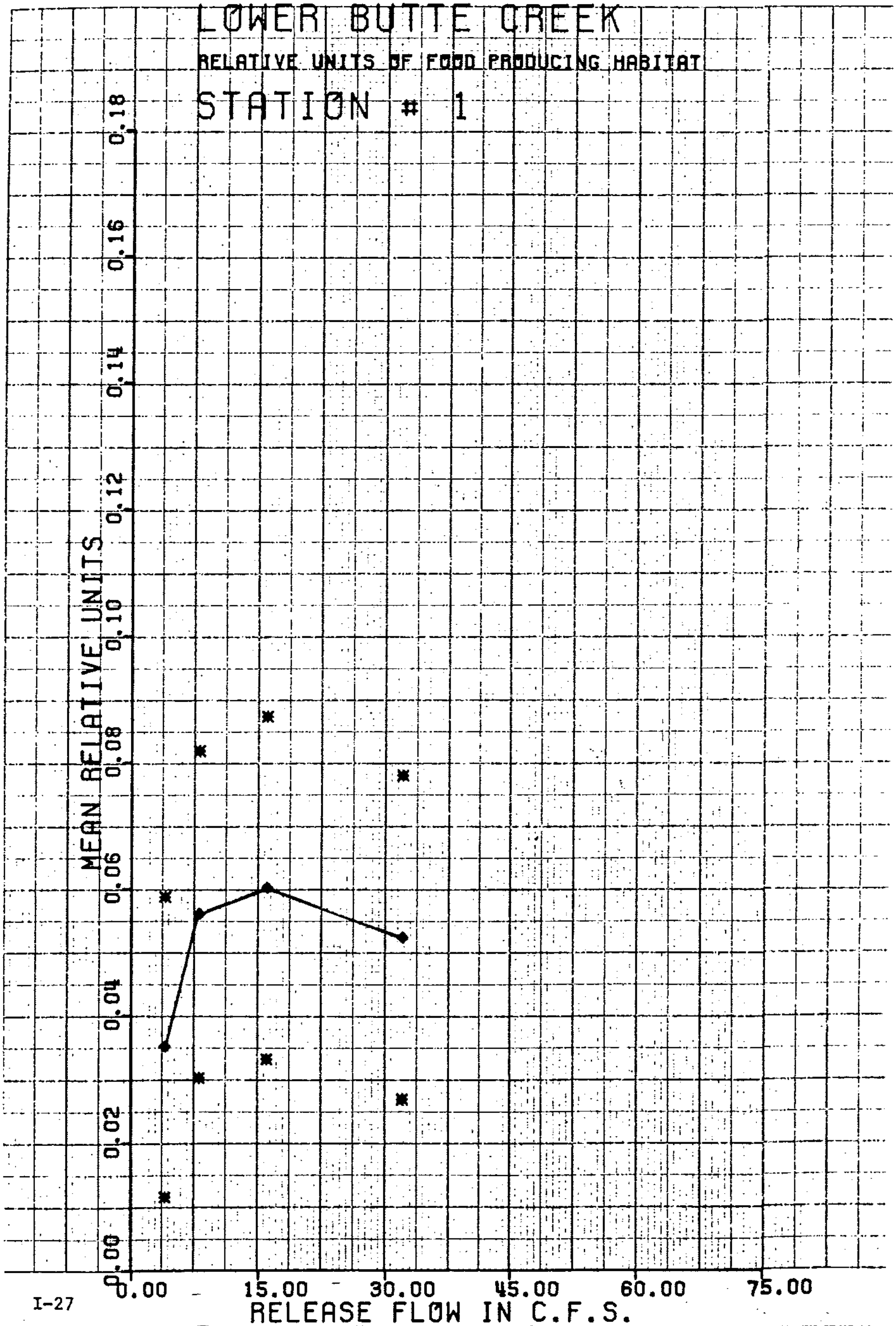

UPPER BUTTE CREEK
RELATIVE UNITS OF SPAWNING HABITAT
MEAN OF ALL STATIONS
MEAN RELATIVE UNITS *10^{-1}
0.00
0.06
0.12
0.18
0.24
0.30
0.36
0.42
0.48
0.54
0.00
15.00
30.00
45.00
60.00
75.00
RELEASE FLOW IN C.F.S.

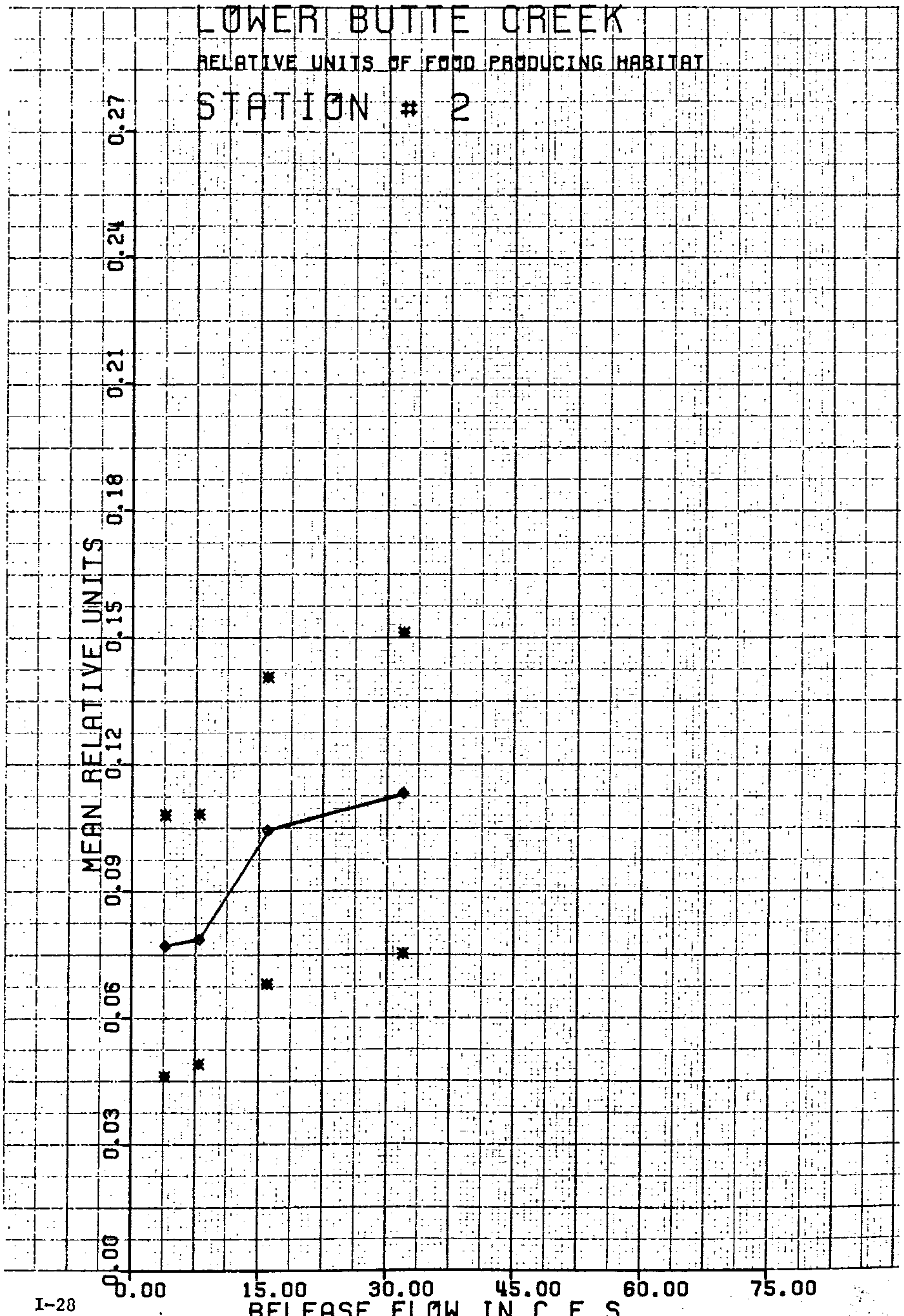

UPPER BUTTE CREEK
RELATIVE UNITS OF SPAWNING HABITAT
STATION # 1
MEAN RELATIVE UNITS ×10⁻¹
0.00
0.03
0.06
0.09
0.12
0.15
0.18
0.21
0.24
0.27
0.00
15.00
30.00
45.00
60.00
75.00
RELEASE FLOW IN C.F.S.

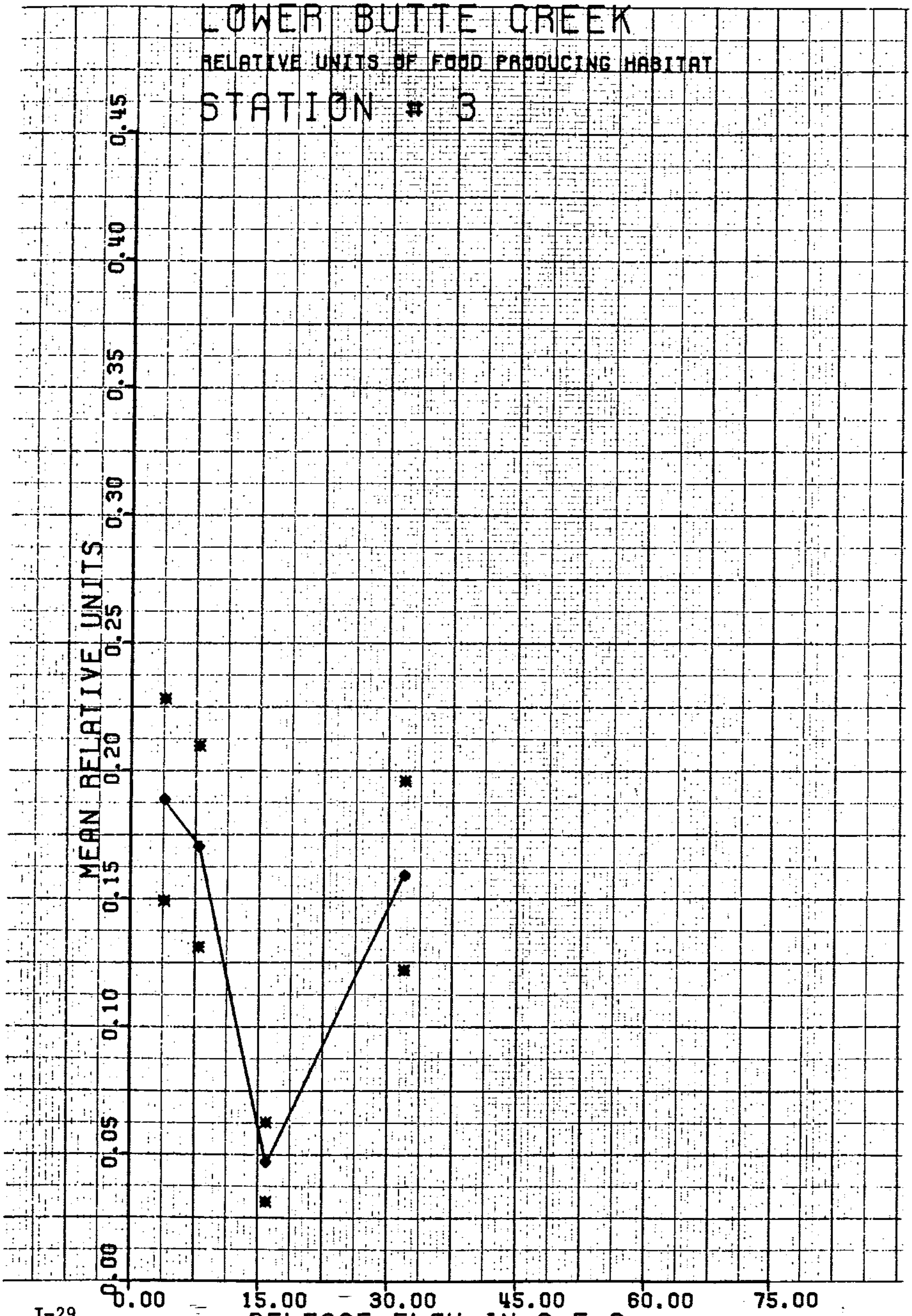

UPPER BUTTE CREEK
RELATIVE UNITS OF SPAWNING HABITAT
STATION # 2
MEAN RELATIVE UNITS *10^-1
0.00
0.03
0.06
0.09
0.12
0.15
0.18
0.21
0.24
0.27
0.00
15.00
30.00
45.00
60.00
75.00
RELEASE FLOW IN C.F.S.


UPPER BUTTE CREEK
RELATIVE UNITS OF SPAWNING HABITAT
STATION # 3
MEAN RELATIVE UNITS
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.00
15.00
30.00
45.00
60.00
75.00
RELEASE FLOW IN C.F.S.

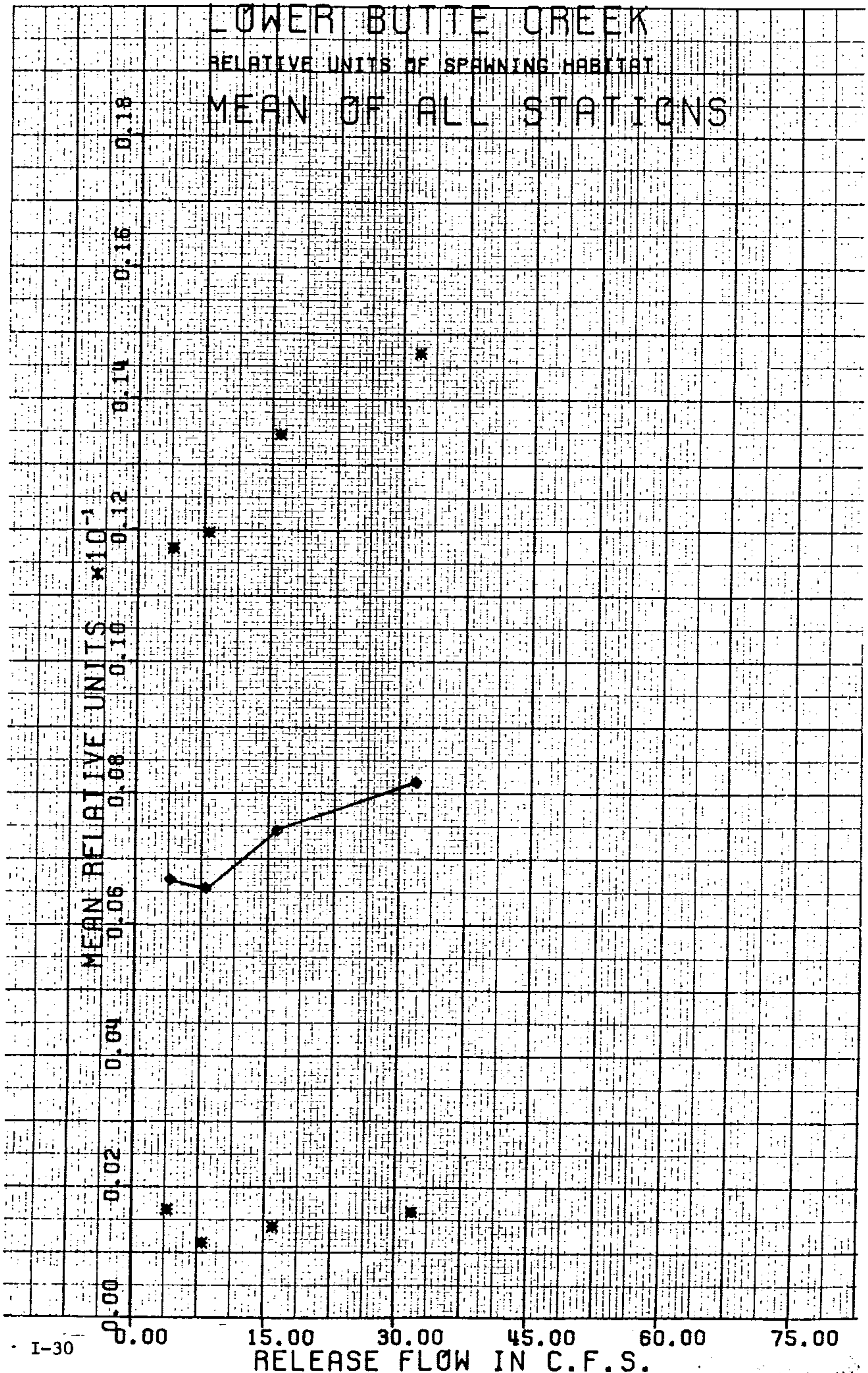

LOWER BUTTE CREEK
RELATIVE UNITS OF FOOD PRODUCING HABITAT
MEAN OF ALL STATIONS
MEAN RELATIVE UNITS
0.00
0.03
0.06
0.09
0.12
0.15
0.18
0.21
0.24
0.27
0.00
15.00
30.00
45.00
60.00
75.00
RELEASE FLOW IN C.F.S.


LOWER BUTTE CREEK
RELATIVE UNITS OF FOOD PRODUCING HABITAT
STATION # 1
MEAN RELATIVE UNITS
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.00
15.00
30.00
45.00
60.00
75.00
RELEASE FLOW IN C.F.S.

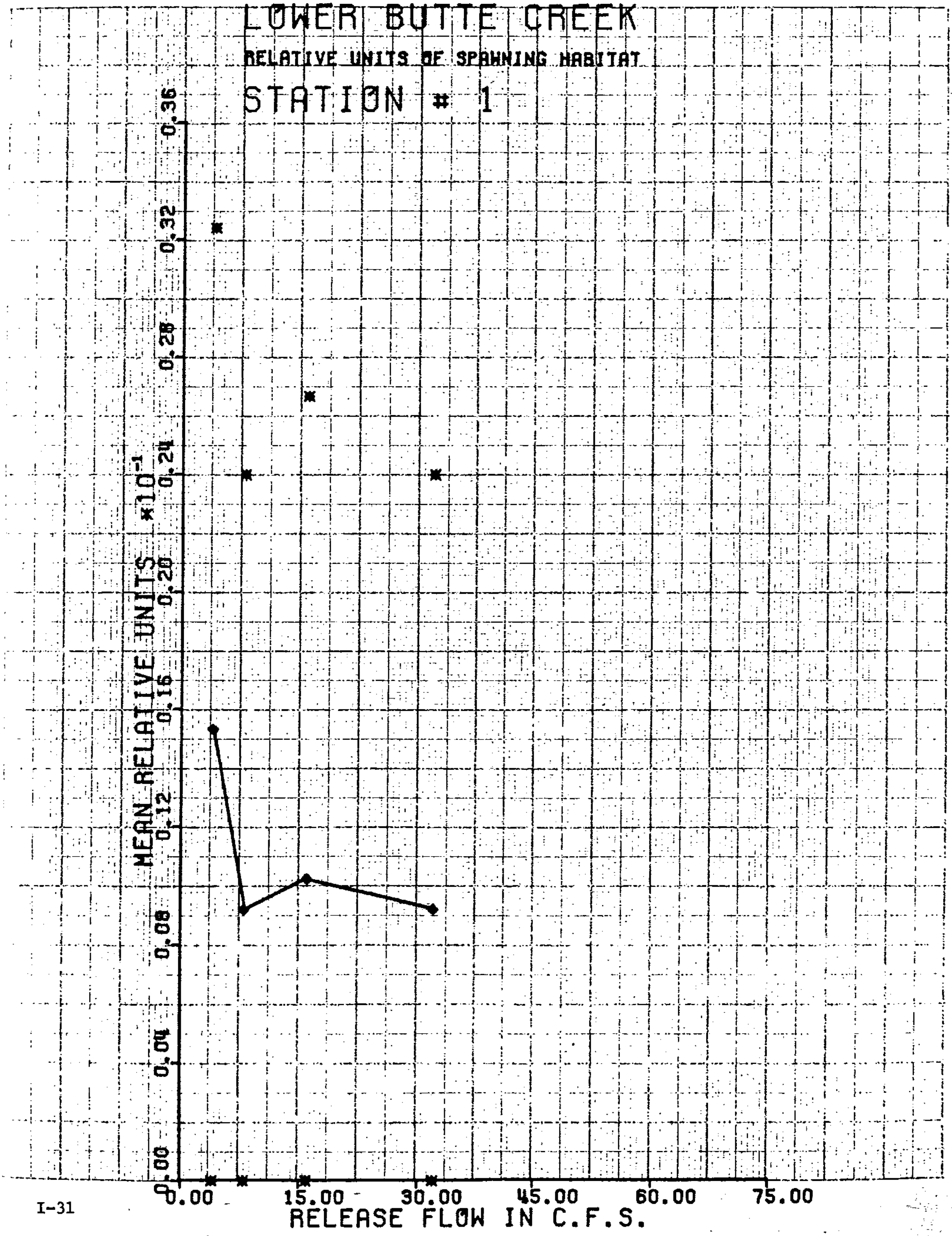

LØWER BUTTE CREEK
RELATIVE UNITS OF FØØD PRØDUCING HABITAT
STATIØN # 2
MEAN RELATIVE UNITS
0.27
0.24
0.21
0.18
0.15
0.12
0.09
0.06
0.03
0.00
0.00
15.00
30.00
45.00
60.00
75.00
RELEASE FLØW IN C.F.S.

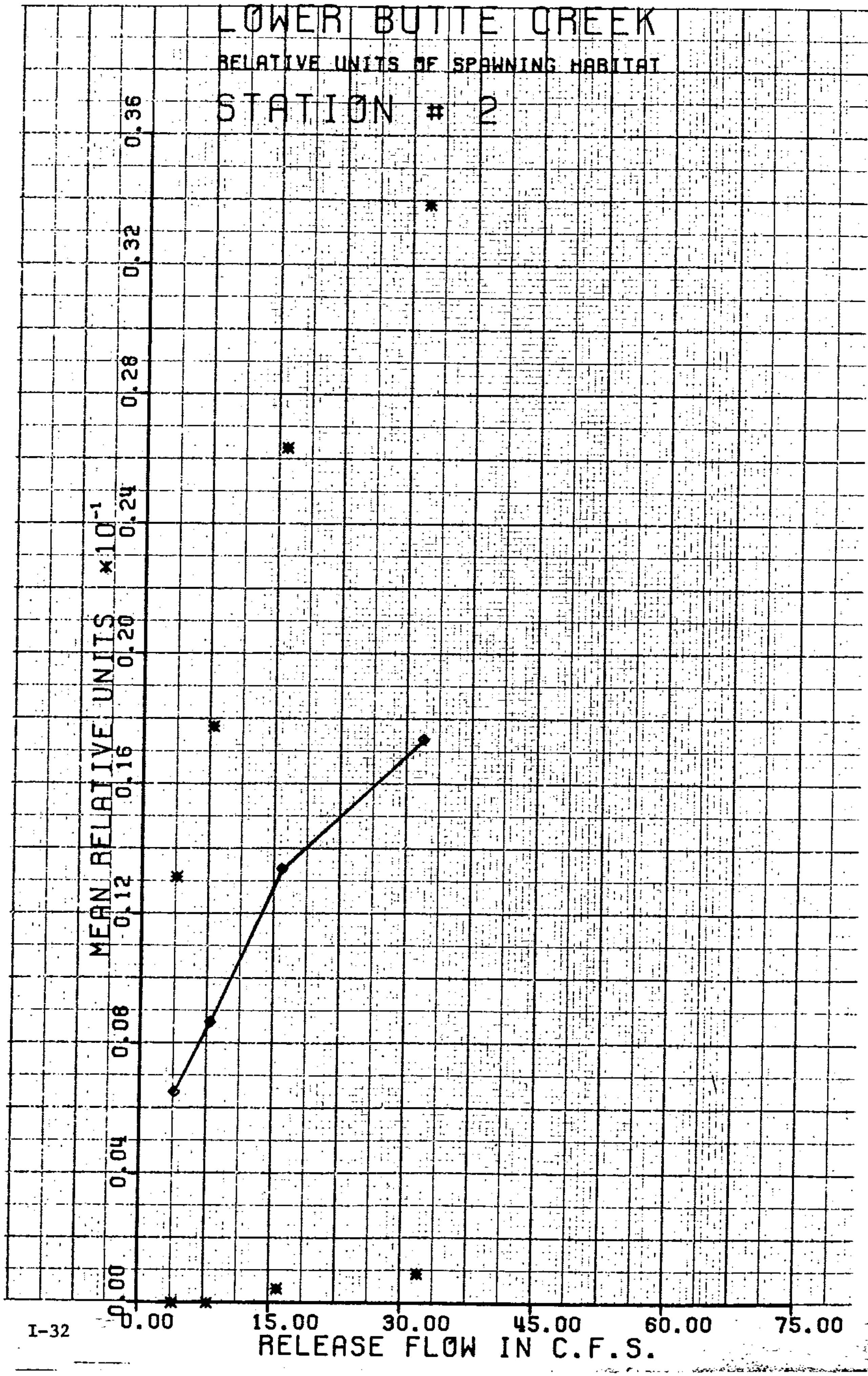


LOWER BUTTE CREEK
RELATIVE UNITS OF FOOD PRODUCING HABITAT
STATION # 3
MEAN RELATIVE UNITS
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.00
15.00
30.00
45.00
60.00
75.00
RELEASE FLOW IN C.F.S.

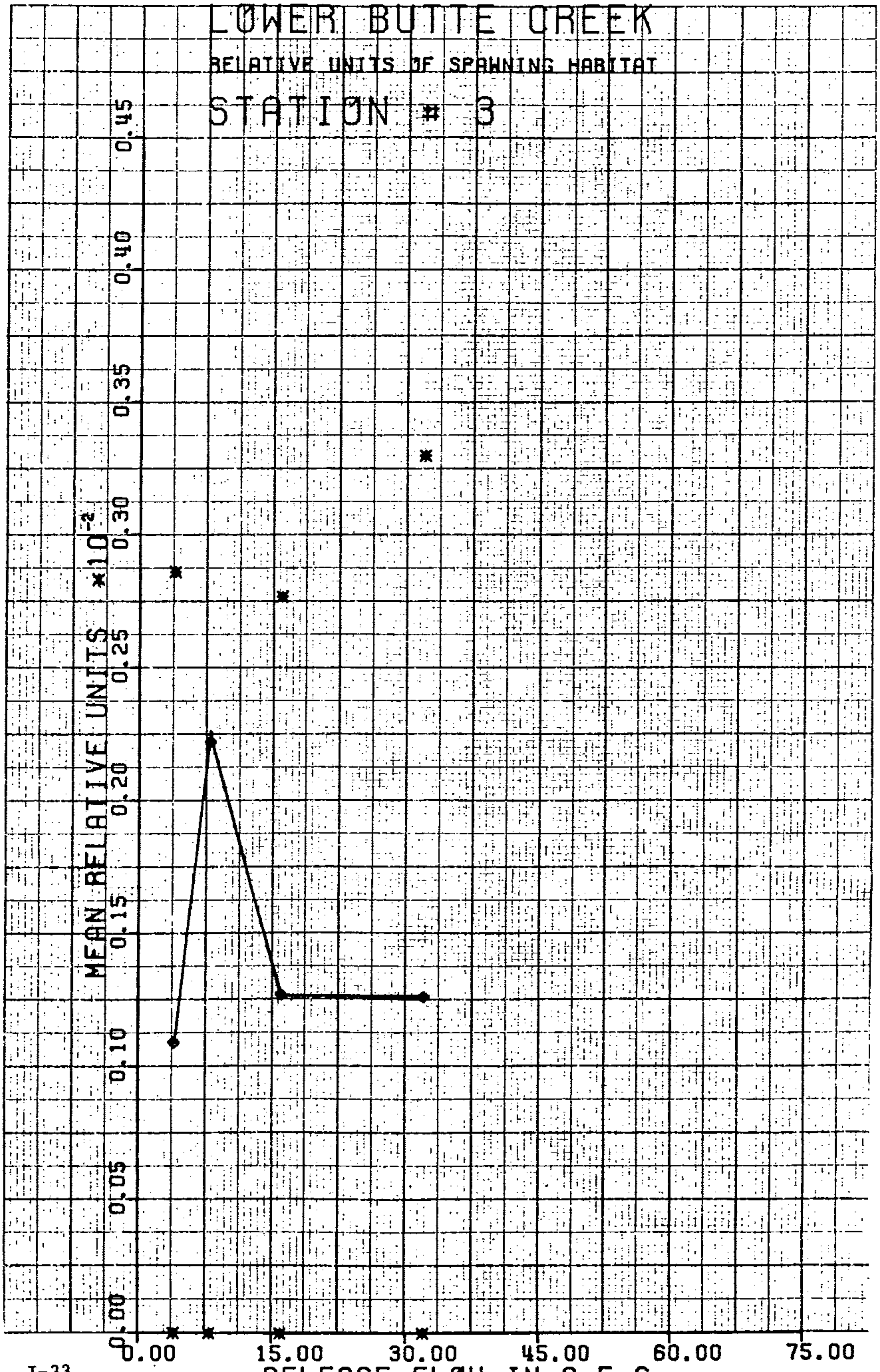


LOWER BUTTE CREEK
RELATIVE UNITS OF SPAWNING HABITAT
MEAN OF ALL STATIONS
MEAN RELATIVE UNITS $\times 10^{-1}$
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.00
15.00
30.00
45.00
60.00
75.00
RELEASE FLOW IN C.F.S.

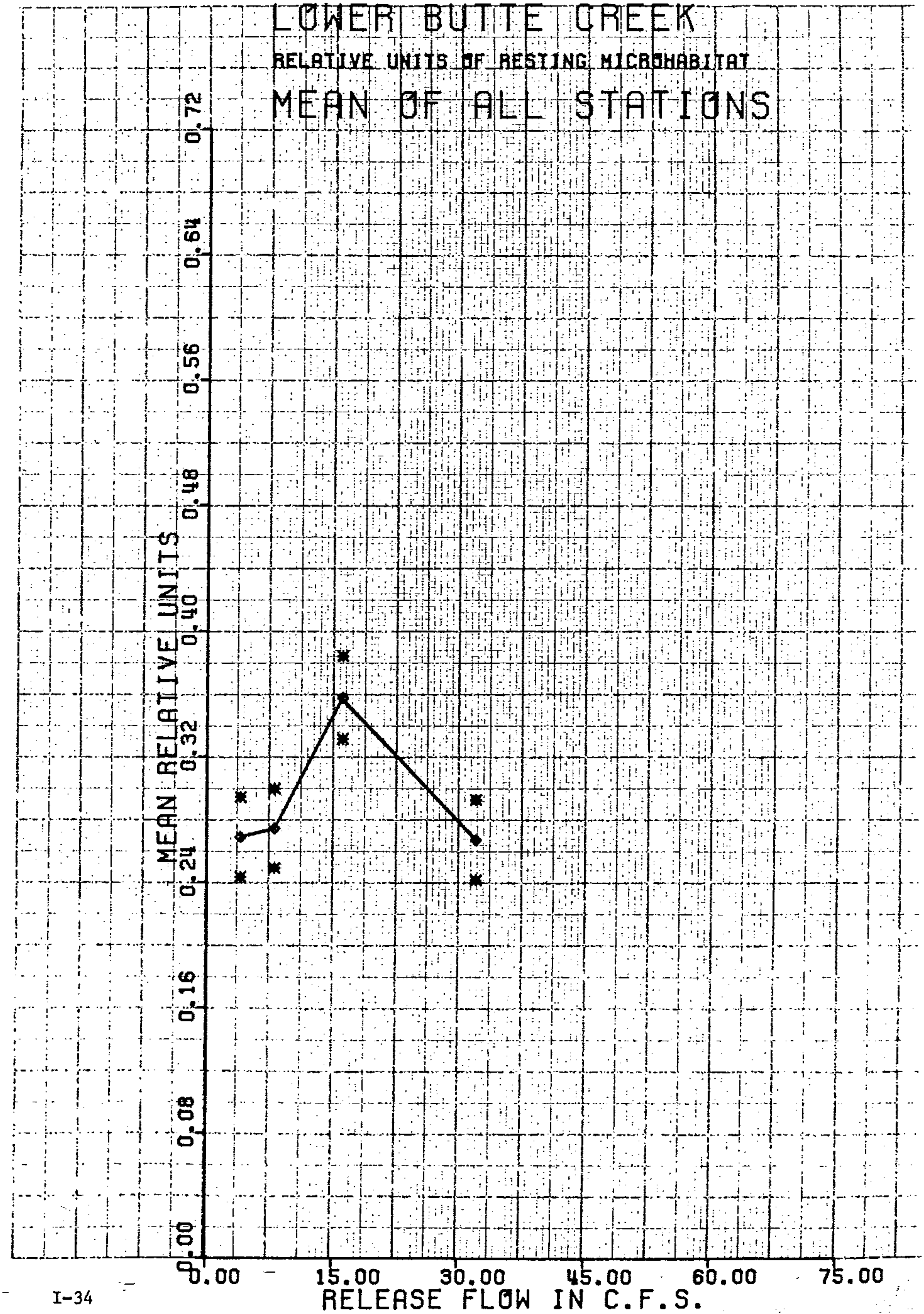

LOWER BUTTE CREEK
RELATIVE UNITS OF SPAWNING HABITAT
STATION # 1
MEAN RELATIVE UNITS *10^-1
0.00
0.04
0.08
0.12
0.16
0.20
0.24
0.28
0.32
0.36
0.00
15.00
30.00
45.00
60.00
75.00
RELEASE FLOW IN C.F.S.



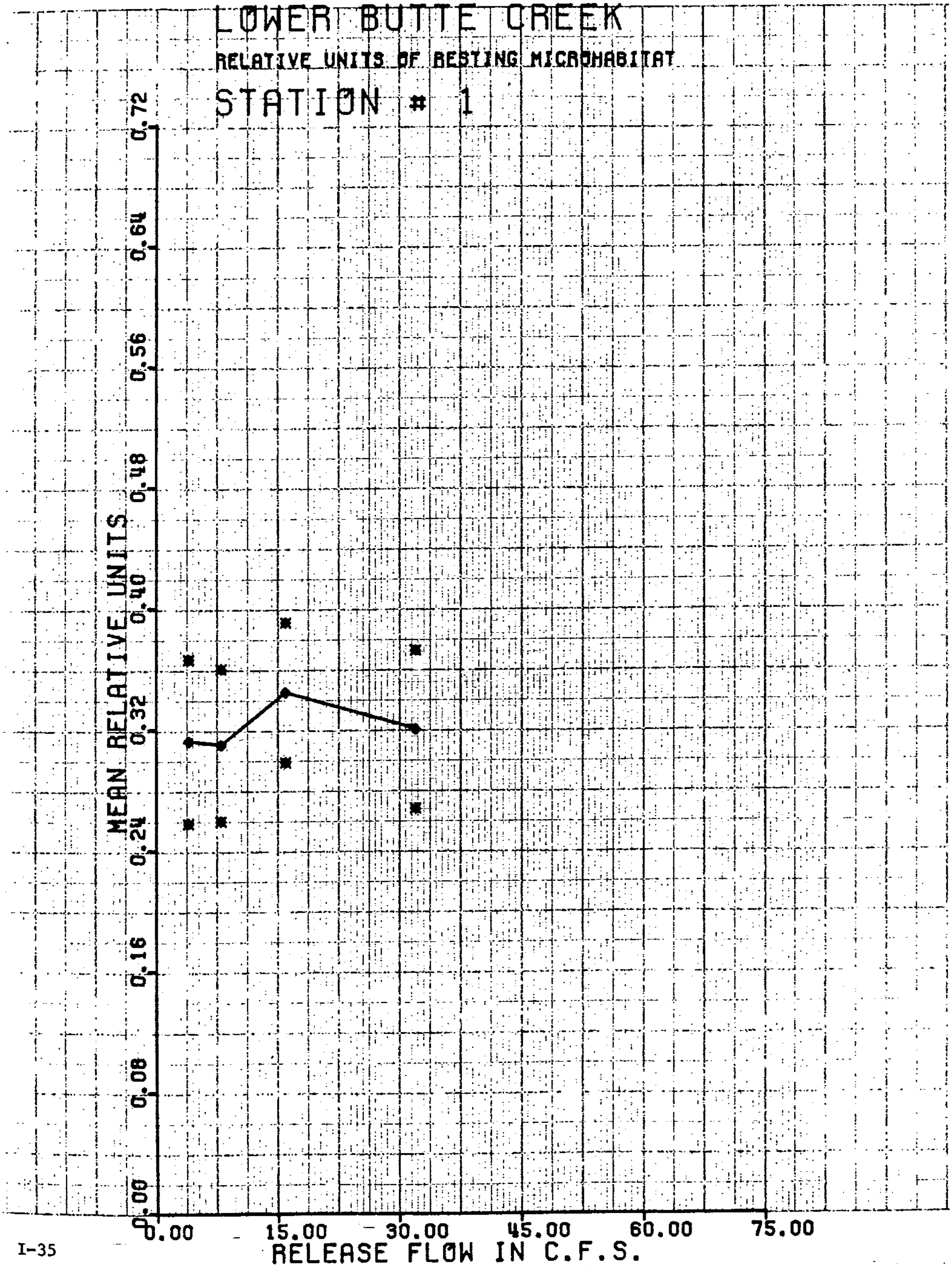
LØWER BUTTE CREEK
RELATIVE UNITS OF SPAWNING HABITAT
STATIØN # 2
MEAN RELATIVE UNITS ×10⁻¹
0.00
0.04
0.08
0.12
0.16
0.20
0.24
0.28
0.32
0.36
0.00
15.00
30.00
45.00
60.00
75.00
RELEASE FLØW IN C.F.S.



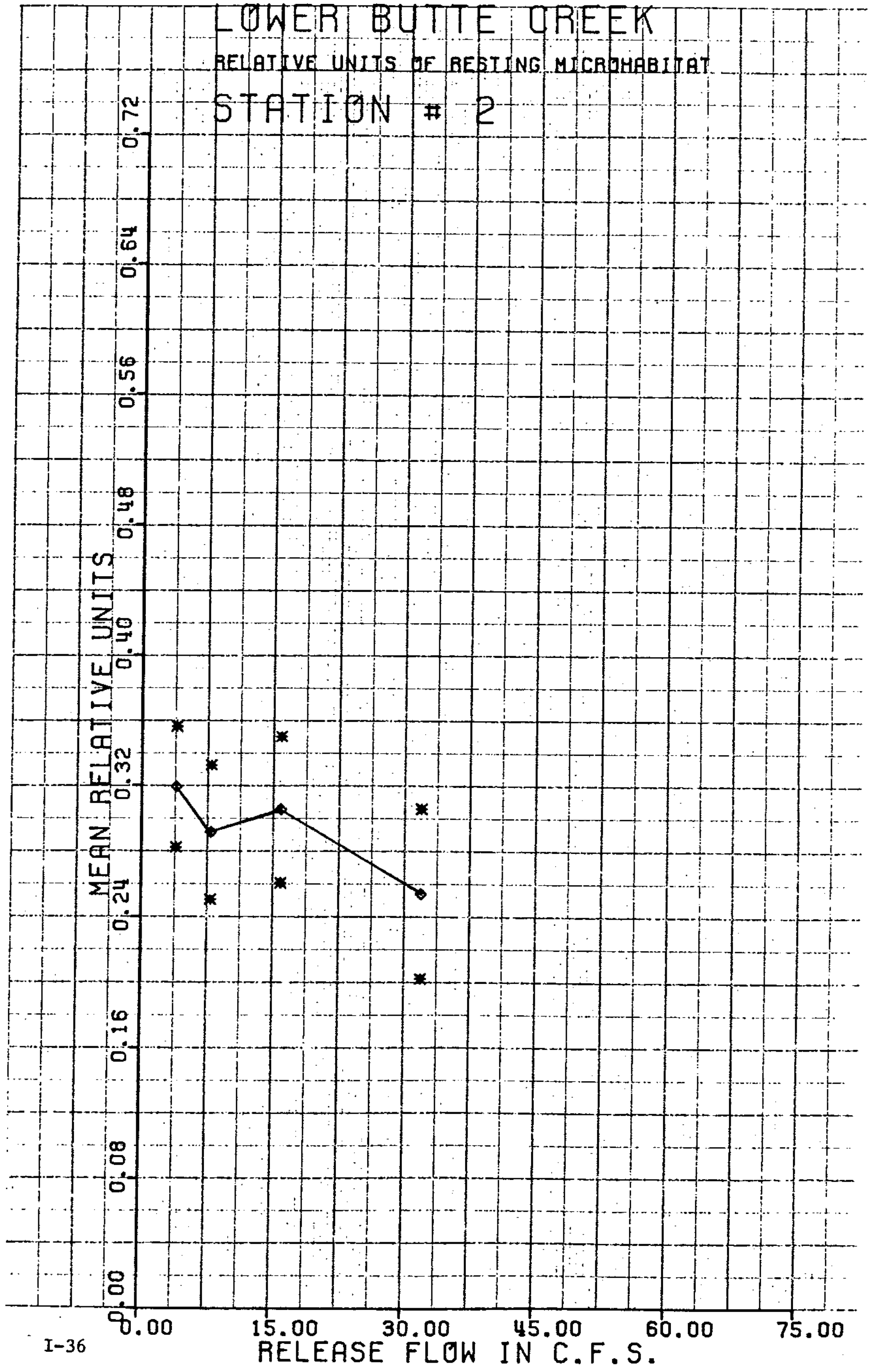
LØWER BUTTE CREEK
RELATIVE UNITS OF SPAWNING HABITAT
STATIØN # 3
MEAN RELATIVE UNITS *10^-2
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.00
15.00
30.00
45.00
60.00
75.00
RELEASE FLØW IN C.F.S.

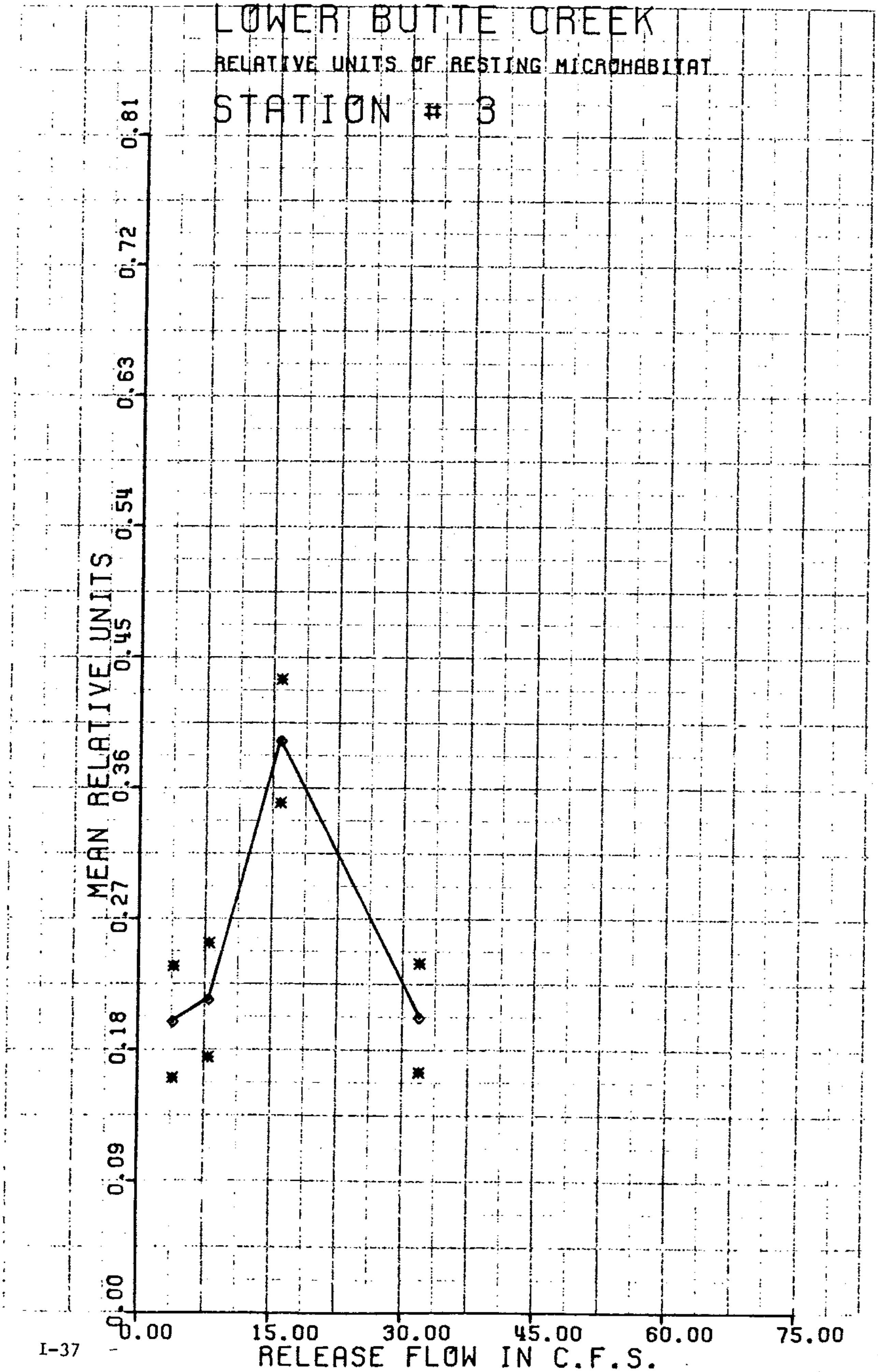


LOWER BUTTE CREEK
RELATIVE UNITS OF RESTING MICROHABITAT
MEAN OF ALL STATIONS
MEAN RELATIVE UNITS
0.00
0.08
0.16
0.24
0.32
0.40
0.48
0.56
0.64
0.72
0.00
15.00
30.00
45.00
60.00
75.00
RELEASE FLOW IN C.F.S.



LOWER BUTTE CREEK
RELATIVE UNITS OF RESTING MICROHABITAT
STATION # 1
MEAN RELATIVE UNITS
0.00
0.08
0.16
0.24
0.32
0.40
0.48
0.56
0.64
0.72
0.00
15.00
30.00
45.00
60.00
75.00
RELEASE FLOW IN C.F.S.


LØWER BUTTE CREEK
RELATIVE UNITS OF RESTING MICROHABITAT
STATION # 2
MEAN RELATIVE UNITS
0.00
0.08
0.16
0.24
0.32
0.40
0.48
0.56
0.64
0.72
0.00
15.00
30.00
45.00
60.00
75.00
RELEASE FLOW IN C.F.S.



LØWER BUTTE CREEK
RELATIVE UNITS OF RESTING MICROHABITAT
STATIØN # 3
MEAN RELATIVE UNITS
0.00
0.09
0.18
0.27
0.36
0.45
0.54
0.63
0.72
0.81
0.00
15.00
30.00
45.00
60.00
75.00
RELEASE FLOW IN C.F.S.

Report Issued: Report 430-78.22

PACIFIC GAS AND ELECTRIC COMPANY
DEPARTMENT OF ENGINEERING RESEARCH

REPORT ROUTING STAMP
1. ~~J. W. Icanberry~~ Writer
2. ~~B. F. Waters~~
3. Typist
4. JRA ... BFW
5. Typist
6. Chk. JK 2/13/79 Initial Date
7. Typist/Distribution Date

JRA and BFW asked me to sign their names off due to the urgency of this document

STREAMFLOW STUDY
DE SABLA-CENTERVILLE PROJECT, FERC 803

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