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ALASKA DEPARTMENT OF FISH AND GAME
SUSITNA HYDRO AQUATIC STUDIES

REPORT NO. 3 PART II, Chapter 8

AQUATIC HABITAT AND INSTREAM FLOW INVESTIGATIONS (MAY-OCTOBER 1983)

ALASKA DEPARTMENT OF FISH AND GAME
SUSITNA HYDRO AQUATIC STUDIES REPORT SERIES

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AQUATIC HABITAT AND INSTREAM FLOW INVESTIGATIONS (MAY-OCTOBER 1983)

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EVALUATIONS OF SALMON-SPAWNING HABITAT IN SELECTED TRIBUTARY-MOUTH HABITATS OF THE MIDDLE SUSITNA RIVER

1984 Report No. 3, Chapter 8

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ABSTRACT

Salmon spawning in tributary mouth habitat locations was evaluated. Lane Creek and Fourth of July Creek tributary mouth areas were selected as study areas for this investigation due to their historical importance as chum salmon spawning areas. During the 1983 field season, chum salmon were observed spawning in the clearwater plume of the Fourth of July Creek. However, salmon were not observed spawning at the Lane Creek mouth area.

Location and area of the available and useable salmon spawning area at each study site was determined. Available habitat size was positively correlated to changes in mainstem discharge at both mouth areas, while useable salmon spawning areas increased only at the Fourth of July Creek mouth area with increasing mainstem discharge. Useable salmon spawning area within the Lane Creek mouth decreased as mainstem discharge increased. This difference is probably related to the different type of confluence area of each site. Lane Creek flows directly into the mainstem while Fourth of July Creek empties into a side channel.

Spawning activity was not observed beyond the clearwater plume at the Fourth of July mouth area. High mainstem tributaries prevented spawning observations beyond the plume. Spawning may have taken place beyond the plume. Because of this uncertainty, the importance of the clearwater plume in determining the usable salmon spawning area and criteria at tributary mouth habitats is unknown.

GLOSSARY

Available Habitat - the wetted portion of the study area.

Clearwater Plume - the extension of the clearwater of a tributary into the turbid mainstem at and below the confluence of the two. Due to the different densities of the mainstem and tributary waters, these two water bodies do not readily mix, causing a clearly defined clearwater extension of the tributary along the river bank at and below the actual confluence. Size of the plume is a function of tributary flow and mainstem discharge.

Digitizing - a graphics analysis procedure used to determine surface area.

Discharge - Water volume passing a fixed point per unit time. Specifically refers to mainstem habitat.

Flow - Water volume passing a fixed point per unit time. Refers to slough, side channel, and tributary habitats.

IFG-2 model - a water surface profile computer program, based on hydraulic theory and formulae, which provides detailed descriptions of the depth and velocity distributions at each cross section of a study site. Requires one set of field data to operate.

GLOSSARY (continued)

IFG-4 model - a water surface profile computer program similar to the IFG-2 model, but is more strongly based on field observations and empiricism. Requires two, preferably three sets of field data to operate.

Isopleth - a line which connects points on a map that have equal values with regard to certain variables (depth, velocity, elevation, etc).

Project Datum - true elevation.

Usable Habitat - that portion of available habitat which provides the hydraulic and substrate conditions deemed necessary to support successful salmon spawning.

Utilization Data - hydraulic and physical data collected at active salmon redds. This includes: water depths; mean column water velocity, substrate size, and surface and intragravel water temperatures.

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1.0 INTRODUCTION

This chapter presents an evaluation of tributary mouth spawning. This study was conducted at Fourth of July and Lane Creeks (Figure 8-1) to: establish baseline physical data at selected tributary mouth areas which would be helpful in ascertaining direct impacts of the proposed Susitna Hydroelectric Project; and, develop specific salmon habitat requirement criteria for tributary mouth spawners.

Specific objectives of the tributary mouth habitat investigations were to:

1. locate and quantify the wetted surface area (available habitat) within the tributary mouth habitat study areas for selected mainstem discharges;

2. monitor and record the hydraulic and other physical conditions which appear to be influencing the selection of spawning sites (redds) by chum salmon within the tributary mouth habitat areas; and

3. locate and quantify that portion of the wetted surface area (available habitat) which represents potential chum salmon spawning habitat (usable habitat) within the tributary mouth habitat study area for selected mainstem discharges.

For the purpose of this investigation, the tributary mouth habitat extends from the uppermost point in the tributary influenced by mainstem

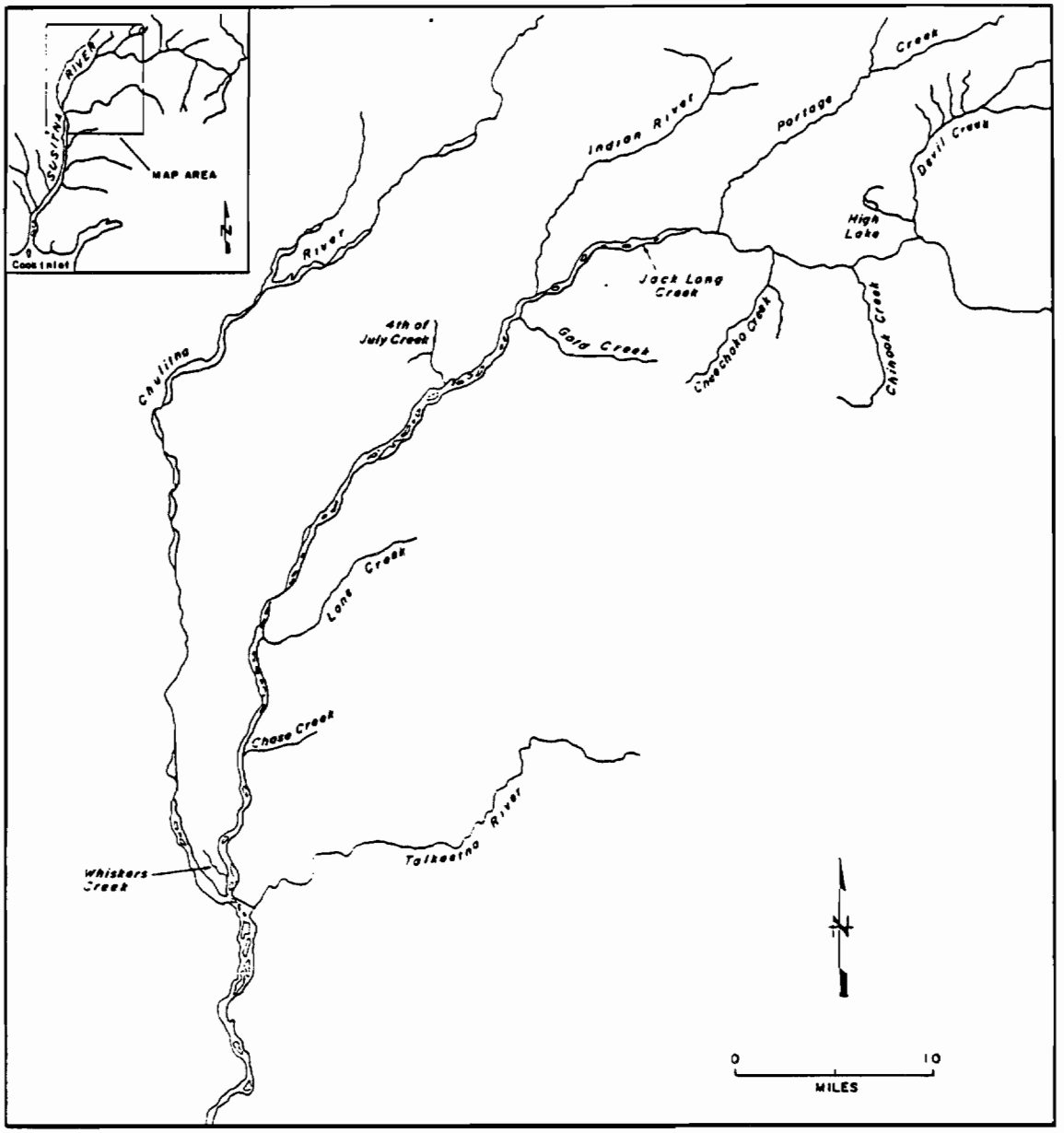


Figure 8-1 Lane Creek and Fourth of July Creek location map.

Susitna River effects, to the downstream extent of the tributary plume which extends into the mainstem Susitna River. Every combination of Susitna River discharge and tributary flow affects the boundary where the free-flowing tributary habitat ends and the tributary mouth habitat area begins. Designation of this boundary line is important for delineating and differentiating between habitat utilization data for salmon which spawn in the tributary habitat versus salmon which spawn in the tributary mouth habitat.

In general, tributary mouth areas of the Talkeetna to Devil Canyon reach of the Susitna River provide spawning habitat for pink and chum salmon. These tributary-mouth areas have also been found to provide rearing habitat for various resident fish species (Schmidt et. al. 1984). In spite of the importance of these tributary mouth habitats, analysis of these areas is lacking because of limited resources and a higher priority placed on other habitat types. Also, because of sampling problems associated with the dynamics of these habitats, very little descriptive work has been done on these areas.

Evaluations of salmon spawning habitat in side slough and side channel habitats are presented in Chapter 7. The purpose of the slough and side channel investigations has been to predict the availability of spawning habitat in slough and side channel habitats as a function of flow. These studies have relied on the use of computer simulation through mathematical models to achieve their purpose.

The hydraulic models used in those studies cannot be adapted to tributary mouth habitat because the variable flow conditions present

within tributary mouth habitat violate the steady flow assumption, which is a basic premise of the models. Existing mathematical models are incapable of simulating the hydraulic interactions of tributary/mainstem confluence areas. This tributary mouth habitat investigation was therefore designed to describe, evaluate, and quantify the presence of physical conditions as a function of combined mainstem discharges and tributary flows which were observed. The results of this investigation cannot be used as a predictive tool. Instead, they describe the baseline physical conditions present within these selected areas for the observed sampled combinations of mainstem discharges and tributary flows.

The various sections of the tributary mouth habitat evaluation investigation are divided into three subsections based on available habitat (wetted surface area), useable salmon spawning habitat, and salmon spawning utilization habitat. The next section summarizes the methods used for this investigation.

2.0 METHODS

2.1 Site Selection

Tributary mouth habitat investigations were conducted at Lane (RM 113.6) and Fourth of July Creeks (RM 131.1). These locations were selected based on their historical importance as salmon spawning areas.

The tributary mouth study area boundaries (upstream and downstream) were initially established to include the area at and below the actual tributary/mainstem confluence (Figures 8-2 and 8-3). After consultation with a hydraulic engineer, the mainstem portion of the study area was expanded to better describe the overall hydraulics within the original study area. This included adding two transects in the mainstem above the confluence at both study areas and adding a downstream transect at the Lane Creek study area (Figure 8-1).

Transects were established to represent reaches having similar hydraulic and related characteristics. Transects located within the mainstem and tributary portions of the study areas were perpendicular to the discharge or flow, respectively.

The additional transects at both sites were added after the first sampling period had been completed at the Lane and Fourth of July Creeks study areas. Discharges were 23,000 cfs and 24,000 cfs, respectively. Comparisons between the data derived from the graphical analyses of the overall study areas collected during the first sampling period

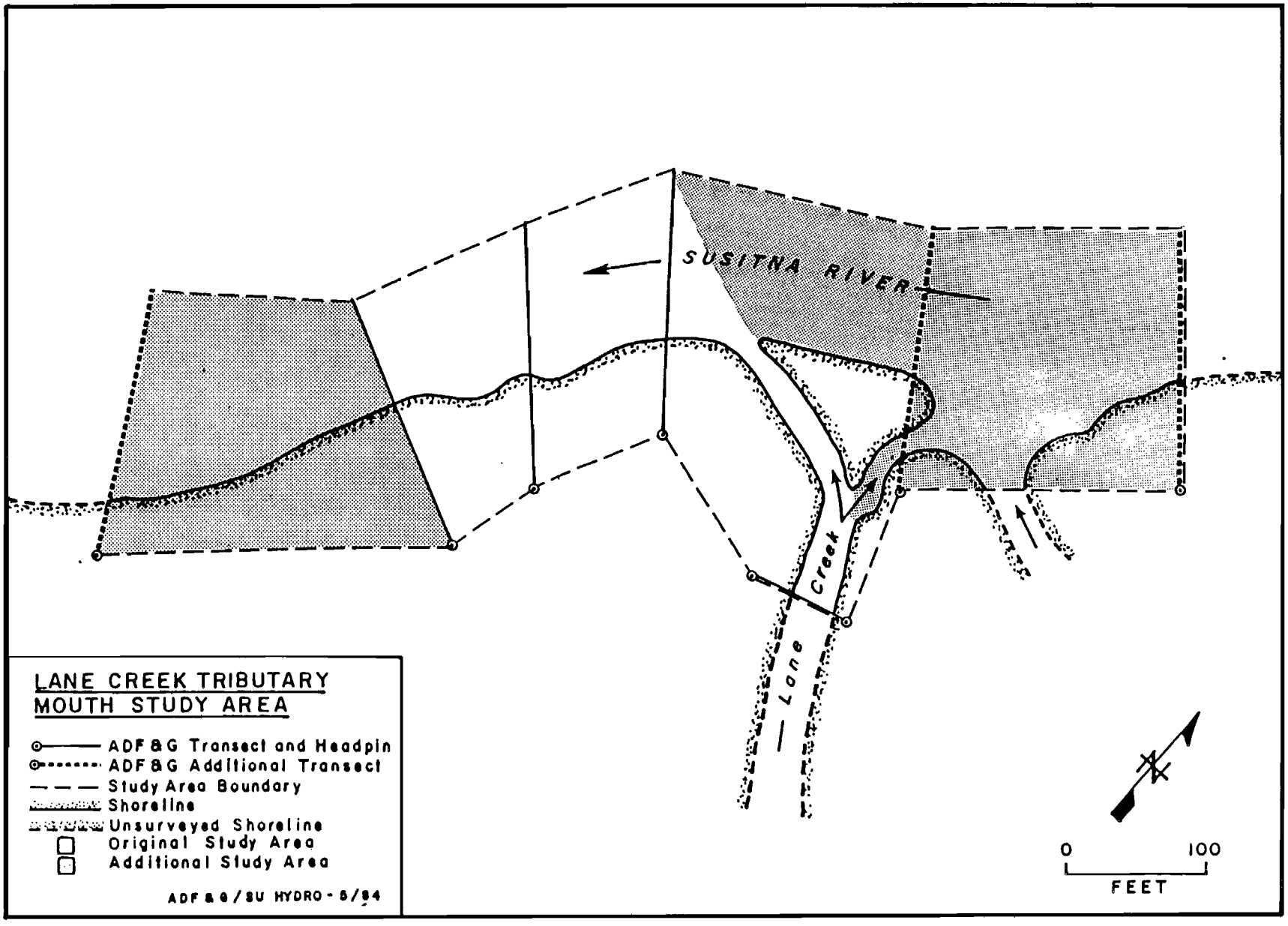


Figure 8-2 Lane Creek study area boundaries.

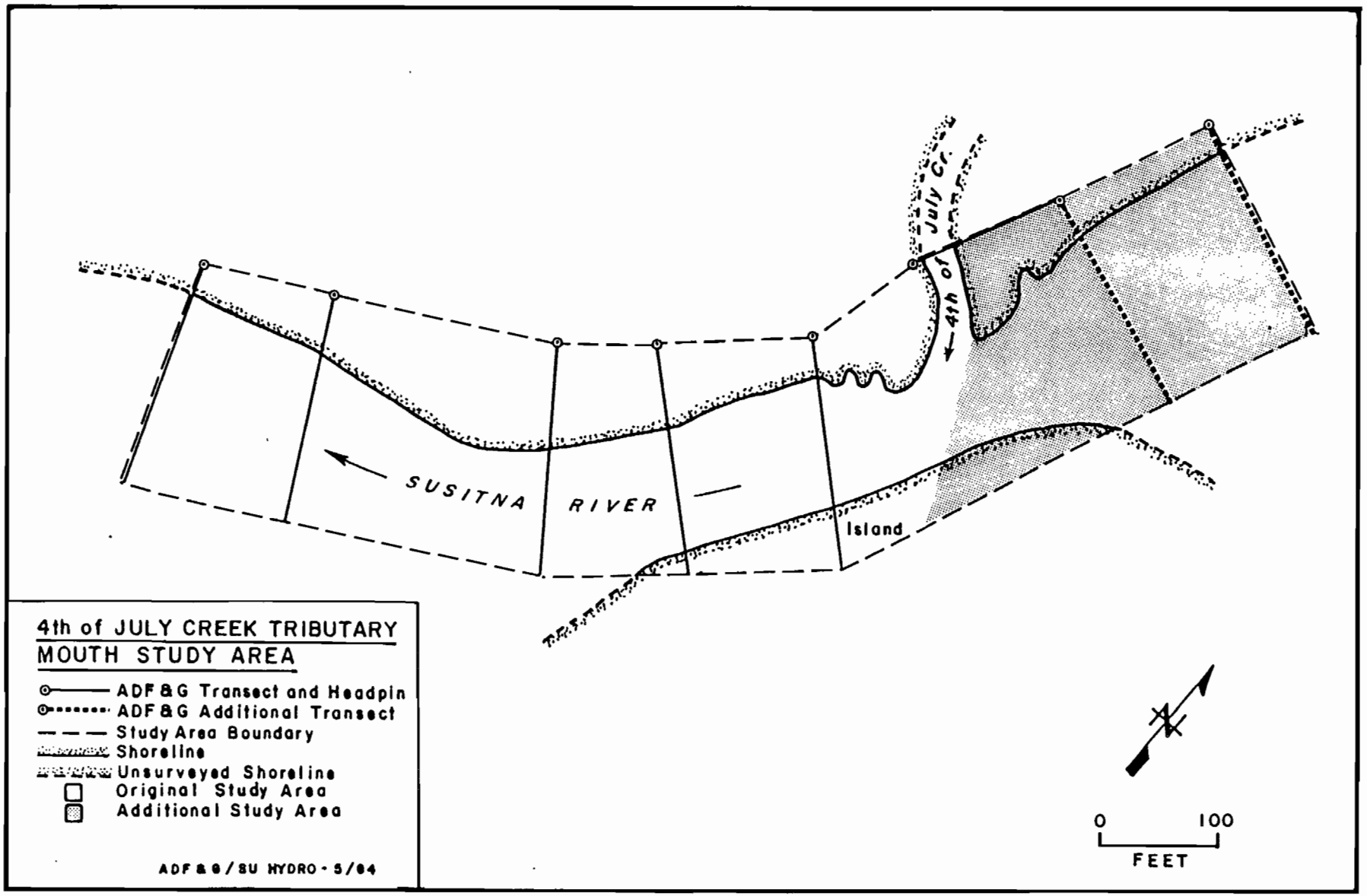


Figure 8-3 Fourth of July Creek study area boundaries.

should not be compared with the habitat analyses of data collected at other mainstem discharge levels for these sites. Comparisons of habitat evaluation maps, however, are valid for the area between boundaries of the originally sampled transects for all mainstem discharges sampled.

The clearwater tributary mouth plume, within the mainstem, for both study areas was within the confines of the original study area boundaries for both creeks during the first sampling period at the 23,000 cfs and 24,000 cfs discharge levels. The clearwater plume was not, however, contained within the original or expanded boundaries of the Fourth of July and Lane Creeks study areas at mainstem sampling discharge levels of 16,000, 12,000 and 8,000 cfs. The boundaries of the tributary mouth study areas did contain the major portion of these two tributary mouth habitat areas at all of the mainstem discharge levels sampled. Although spawning activity was observed beyond the boundary of the Fourth of July Creek tributary mouth study area, this activity was minimal and therefore, not considered as important as the spawning activity within the study area.

In summary, both study areas were considered representative of the entire tributary/mainstem confluence area. The exclusion of habitats beyond the established study areas was not considered to be an obstacle to the attainment of the study objectives. Limited manpower and time were also factors governing the scope of this study. It was therefore decided that the second set of established study area boundaries should remain fixed and not be changed to accommodate the increases in plume length experienced at the lower dishcarges.

Chum salmon was selected as the target species for this investigation because it is the dominant salmon species using the tributary mouth habitat area for spawning (ADF&G observations).

2.2 Available Habitat

Available habitat was defined as the wetted surface area within the study area boundaries at each combination of mainstem discharge and tributary flow sampled. In order to determine the amount, location, and type of available habitat present within the study area for each discharge/flow combination sampled, the wetted surface area of hydraulic and substrate conditions evaluated were delineated on maps.

Base maps were developed from survey data which included transects. Surveys were referenced to project datum. Streambed elevations along established transects were obtained during low Susitna River discharge conditions (8,000 cfs). One foot contours were added to the maps as determined from survey data.

The clearwater plume of the tributary was defined for each sampled Susitna River discharge by measuring the distance from the headpin of each established transect to the water's edge and then to the interface of the clear and turbid waters. The downstream extent of the clearwater plume within the study area was also noted. Study area transects, shoreline and clearwater plumes were defined on study area base maps at each combination of mainstem discharge and tributary flow measured.

Hydraulic data (water depths and mean column velocities) were collected along transects when Susitna River discharges at Gold Creek (USGS gaging station 15292000) were in the ranges of 8,000, 12,000, 16,000, and 20,000 cfs by wading or from a boat when depths and/or velocities

dictated. These data were plotted along study area transects on respective parameter specific maps. Water velocity and depth isopleths (increments of 1.0 ft/sec and 1.0 ft, respectively) were drawn between identical readings on study transects on each parameter specific map. If the actual isoplethic value was not observed, the value was interpolated. A sample isoplethic map is presented in Figure 8-4. Quantification of areas characterized by an incremental velocity or depth was achieved by determining the water surface area associated with each specific increment by digitizing.

Large substrate size and relatively high water velocities precluded the visual detection of upwelling groundwater below the water surface at both study areas at all sampled mainstem discharges and tributary flows. However, a limited number of temperature differences between surface and intragravel waters observed at active chum redds indicate possible groundwaters venting within the Fourth of July Creek tributary mouth study area. Because of the limited amount and tentative nature of these data, possible upwelling areas are only depicted on the spawning area map (Figure 8-27).

Substrate composition was determined along transects by visual observation during the low, clear, autumnal flows of the Susitna River (18,000 cfs). Turbidity levels associated with higher open water mainstem discharges prohibited evaluation earlier in the season. Substrate composition was assumed to be static throughout the sampling period. Accordingly, one substrate composition map delineating substrate data observed along study area transects was constructed for each study area.

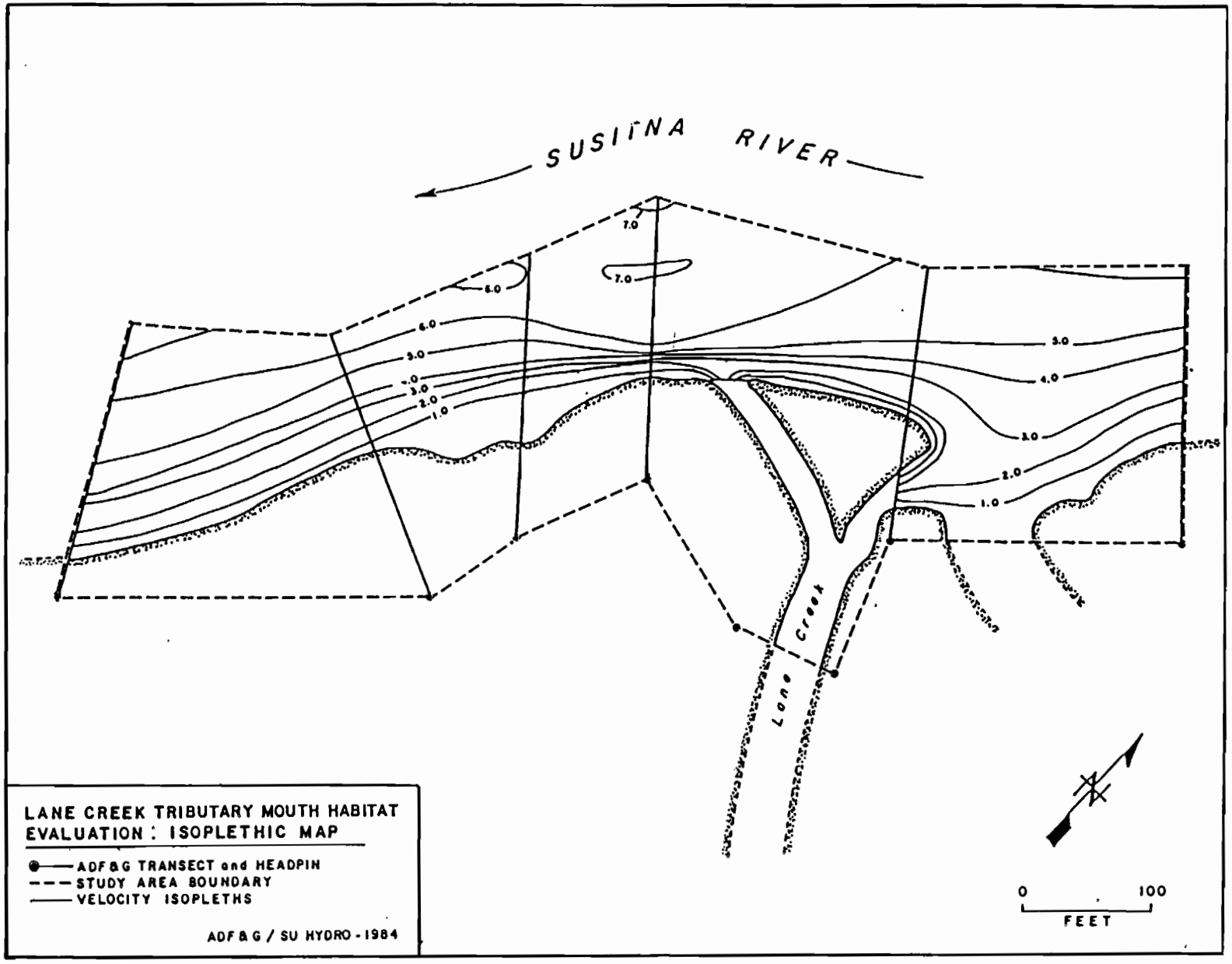


Figure 8-4 Sample isoplethic map.

2.3 Usable Salmon Spawning Habitat

Usable salmon spawning habitat was defined as the portion of available habitat area where an acceptable range of water velocities, depths, and substrate conditions all existed for supporting spawning by chum salmon. Earlier investigations have not focused on chum salmon spawning requirements at tributary mouth habitat areas. Therefore, overall ranges of water velocities, water depths, and substrate spawning conditions for chum salmon were derived from literature, the study presented in Chapter 7, and data collected as part of this study. Hale (1981), in his review of several authors' work, summarized values of specific variables observed at chum spawning sites. That and the utilization data collected by the ADF&G at chum salmon redds in sloughs and side channels during 1982 (ADF&G 1983) and 1983 (Chapter 7) and chum salmon habitat utilization data from this study were also incorporated into the analysis. The resulting ranges of hydraulically related habitat parameters considered to be acceptable for chum salmon spawning in tributary mouths for this study were determined to be:

Parameter	Range
Water velocity	0.0 - 4.5 feet/sec.
Water depth	0.2 - 4.0 feet
Substrate	Small gravel - boulders

Usable habitat areas were determined by first outlining on each parameter-specific map the areas where the observed values were within the acceptable range. The three maps (water velocity, water depth, and substrate composition) constructed for a particular combination of mainstem discharge and tributary flow were than overlaid. The resulting surface area where the observed values of all three variables were within acceptable ranges was defined as usable chum salmon spawning habitat. These areas were quantified by digitizing and the location within each study area was delineated on a final habitat map for each mainstem/tributary discharge.

The range of usable hydraulically related habitat requirements for spawning by chum salmon in tributary mouth habitat is broad. It is derived from the best information known to be available. Subsequent chum salmon spawning investigations at tributary mouth habitats should be considered in order to refine this range of habitat usability characteristics and/or stratify the overall usable habitat into graded or other similar categories (e.g. optimal, preferred, and marginal).

2.4 Utilized Habitat

Utilized habitat is defined as that portion of usable habitat actually used for spawning by chum salmon. Utilization data were gathered according to methods outlined in Chapter 7 when spawning salmon were present and within the tributary mouth study area.

Chum salmon spawning habitat utilization data were collected only within the clearwater plume of the study area. It could not be determined if salmon were actually spawning beyond the plume because the turbid water of the mainstem prevented visual observations. Utilization data collected within the tributary clearwater plume were used in defining usable habitat and are presented in the Results Section of this chapter. The relative importance of the clearwater plume in defining usable chum salmon spawning habitat is unknown.

Preference curves could not be developed since the available habitat within the tributary clearwater plume was not determined during the collection of the utilization data because of resource limitations. That is, available habitat collected at the sampled combinations of mainstem discharge and tributary flows differed from these flows which existed when utilization data was collected.

3.0 RESULTS

General summaries of the habitat analyses for the tributary mouth studies conducted at Lane Creek and Fourth of July Creek are presented in Tables 1 and 2, Figure 8-5, Tables 3 and 4, and Figure 8-6, respectively. Comparisons of data analyses presented for mainstem discharges of 23,000 and 24,000 and other sampled discharges should not be attempted due to unavailable transect data when these discharges were observed. Results from these abbreviated sampled areas are, therefore, presented in tables and figures but are not discussed in the text. Morphometric and substrate maps of the Lane and Fourth of July Creek tributary mouth study area are presented in Figures 8-7 and 8-8, 8-9 and 8-10, respectively.

Available Habitat

Water surface area of available habitat (wetted surface area) at both tributary mouth study areas was positively correlated to the mainstem discharge at Gold Creek (Figures 8-11 and 8-12). There were no correlations between associated water surface area of available habitat with tributary flow (Figures 8-13 and 8-14).

Fluctuations in percent available habitat were much more dramatic at the Fourth of July tributary mouth study area than the Lane Creek study area. Available habitat at the Lane Creek tributary mouth study area ranged from a low of 60% of the study area at a mainstem discharge of

Table 8-1. Lane Creek tributary mouth study area habitat analysis, 1983.

	Discharge (cfs)		Surface Area (ft^2)					
Date	Susitna River	Lane Creek	Sampled Area	Available Habitat	Useable Habitat	Clearwater Plume	Useable Habitat of Clearwater Plume	Total Unacceptable Habitat
831007	9,240	39	160,500	96,500	79,100	25,400	22,450	17,380
830912	11,600	21	160,500	101,600	45,900	13,100	12,600	55,700
830908	13,700	28	160,500	107,000	35,900	13,000	11,300	71,140
830625	23,000	20	41,200[a]	35,200	9,850	0[b]	0[b]	25,350

[a] Sample area reduced because of unavailable transect data.

[b] Clearwater plume surface area occurs outside of sampled area. Total surface area of clearwater plume is 850 square feet. Usable habitat area of clearwater plume outside of sample area is 840 square feet.

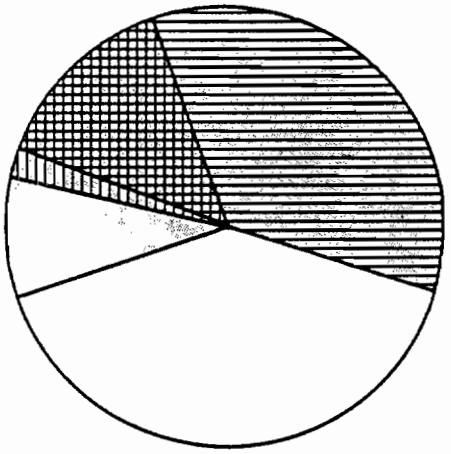
Table 8-2. Analysis of the total unacceptable available habitat in the Lane Creek mouth study area.

Date	Total Unacceptable Habitat	Unacceptable Habitat [surface area (ft^2)]			
		Depth	Velocity	Substrate	Combination [description]
831007	17,380	1,800 (+)[c] 2,410 (-)[d]	9,790	3,400	100 [depth (-) and velocity]
830912	55,700	47,110 (+) 1,970 (-)	41,150	3,550	38,000 [depth (+) and velocity] 80 [depth (-) and velocity]
830908	71,140	60,970 (+) 1,970 (-)	58,835	3,770	54,280 [depth (+) and velocity] 80 [depth (+) and velocity] 50 [depth (+) and substrate]
830625	25,350[e]	21,210 (+) 570 (-)	20,590	3,820	250 [depth (-) and substrate] 20,590 [depth (+) and velocity]

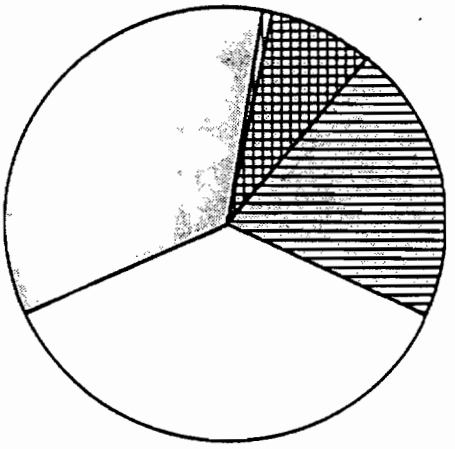
[c] (+) indicates habitat unacceptable due to deep water depths (4.0 ft.)

[d] (-) indicates habitat unacceptable due to shallow water depths (0.2 ft.)

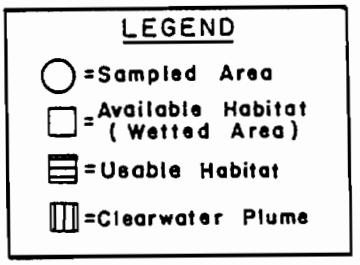
[e] sampled area reduced because of unavailable transect data

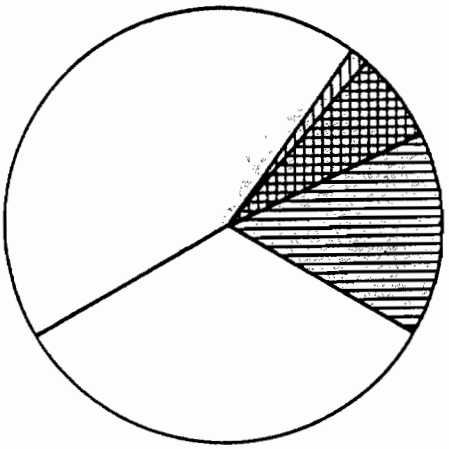


Susitna River Q = 9,240 cfs
Tributary Q = 39 cfs
October 7, 1983



Susitna River Q = 11,600 cfs
Tributary Q = 21 cfs
September 12, 1983





Susitna River Q = 13,700 cfs
Tributary Q = 28 cfs
September, 8, 1983

Susitna River Q = 23,000 cfs
Tributary Q = 20 cfs
June 25, 1983

Figure 8-5 Proportioned area pie charts of the sampled area, clearwater plume, and available and usable salmon spawning habitats of the Lane Creek tributary mouth study area (RM 113.6) at the four sampled mainstem discharges (USGS gaging station, 15292000), 1983. (Note: sampled area at the sampled mainstem discharge of 23,000 cfs was reduced by 74% because of unavailable transect data).

Table 8-3. Fourth of July Creek tributary mouth habitat analysis, 1983.

Date	Discharge (cfs)		Surface Area (ft)					
	Susitna River	Fourth Of July Creek	Sampled Area	Available Habitat	Useable Habitat	Clearwater Plume	Useable Habitat of Clearwater Plume	Total Unacceptable Habitat
831008	8,040	55	199,600	80,700	66,700	45,500	37,800	14,030
830912	11,600	33	199,600	119,100	106,100	46,200	40,800	13,000
830907	14,800	63	199,600	131,400	120,600	42,800	40,000	10,800
830624	24,000	11	143,900[a]	117,200	105,000	3,100[b]	2,600[b]	12,200

[a] Sampled area reduced because of unavailable transect data.

[b] Clearwater plume and substrate area is not affected by sampled area reduction.

Table 8-4. Analysis of the total unacceptable available habitat in the Fourth of July Creek tributary mouth study area.

Date	Unacceptable Habitat [surface area (ft^2)]				
	Total Unacceptable Habitat	Depth (+ or -)	Velocity (+)	Substrate	Combination [description]
830810	14,030	8,070 (-)[c]	0	6,180	220 [depth (-) or substrate]
831209	13,000	5,960 (-)	0	7,080	0
830709	10,800	3,720 (-)	0	7,080	0
832406	12,200[d]	4,570 (-)	6,160	1,500	0

[c] (-) indicates habitat unacceptable due to shallow water depth (0.2 ft.)

[d] sampled area reduced because of unavailable transect data

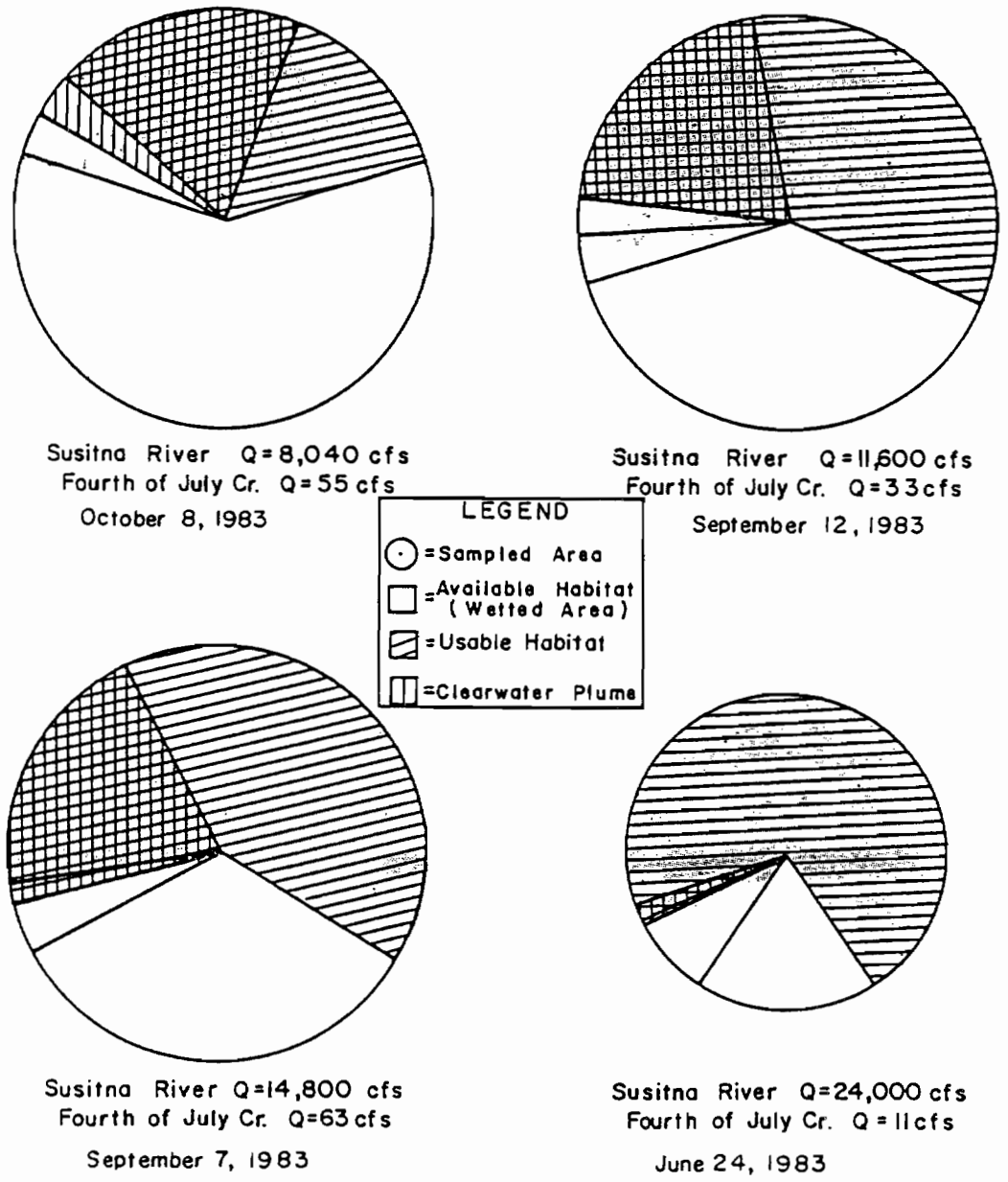


Figure 8-6 Proportioned area pie charts of the sampled area, clearwater plume, and available and usable salmon spawning habitats of the Fourth of July tributary mouth study area (RM 131.2) at the four sampled mainstem discharges (USGS gaging station, 15292000), 1983. (Note: sampled area at the sampled mainstem discharge of 24,000 cfs was reduced by 28% because of unavailable transect data)..

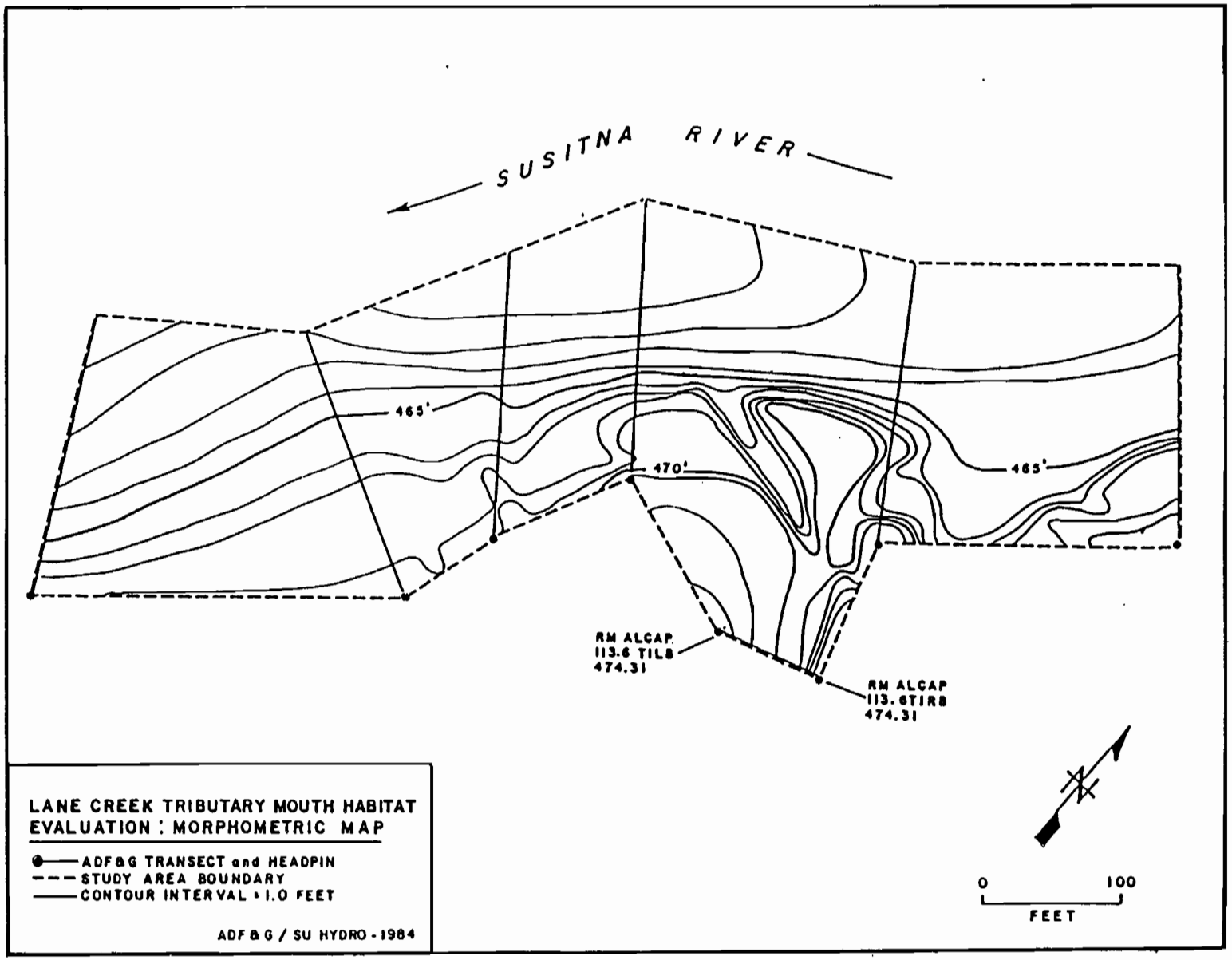


Figure 8-7 Morphometric map contour map of the Lane Creek tributary mouth study area (RM 113.6), 1983.

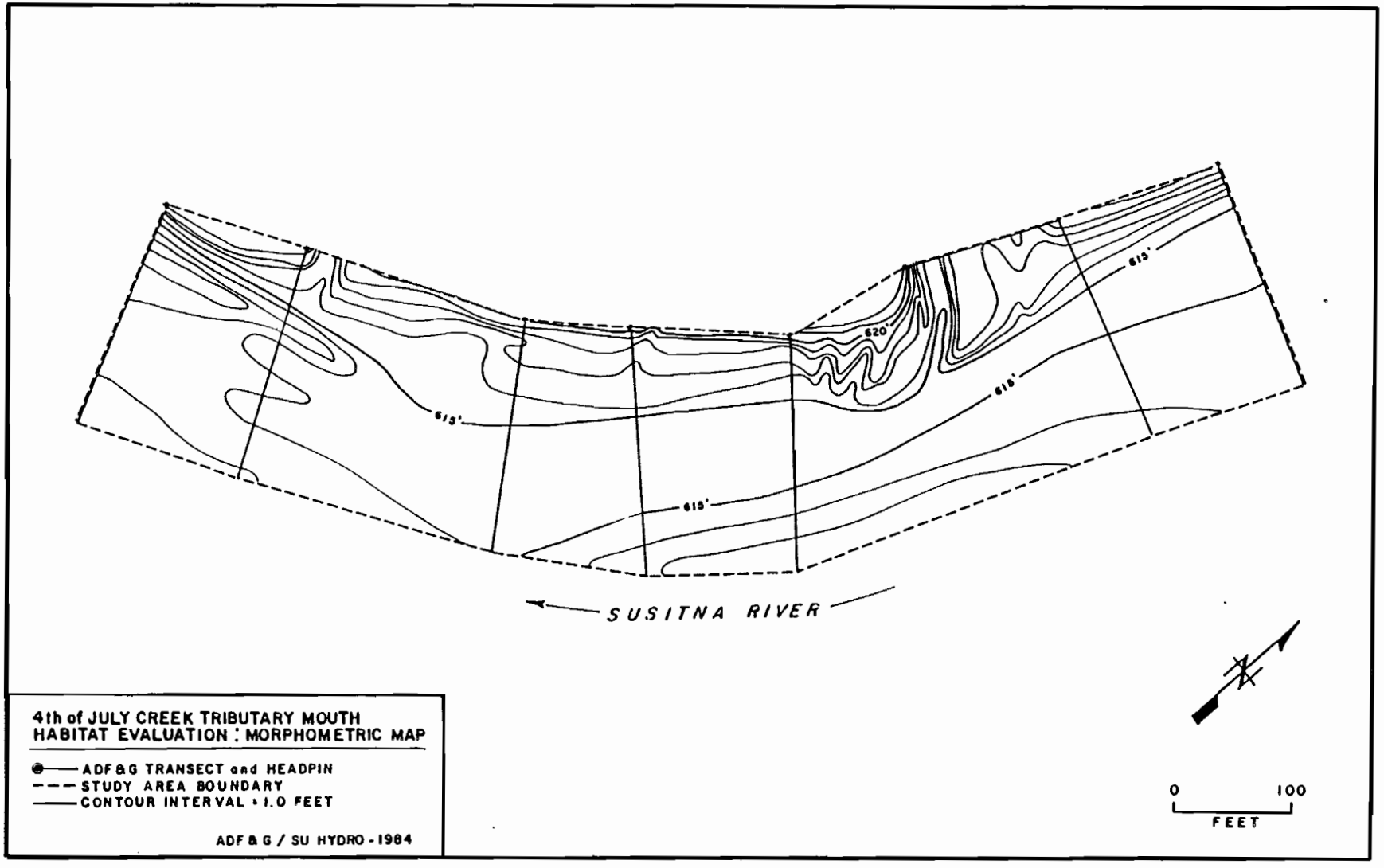


Figure 8-8 Morphometric map of the Fourth of July Creek tributary mouth study area (RM 131.2), 1983.

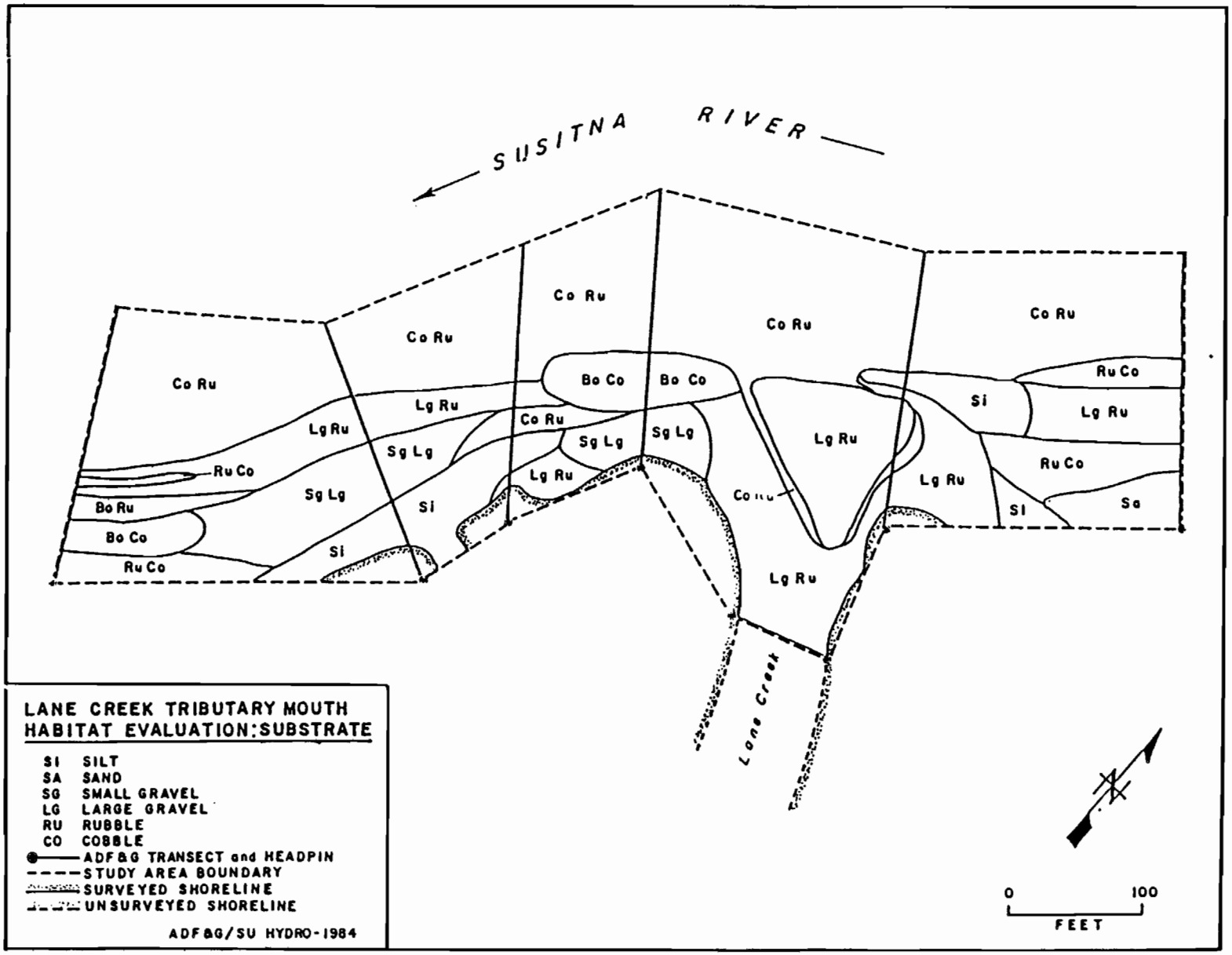


Figure 8-9 Substrate map of the Lane Creek tributary mouth study area (RM 113.6), 1983.

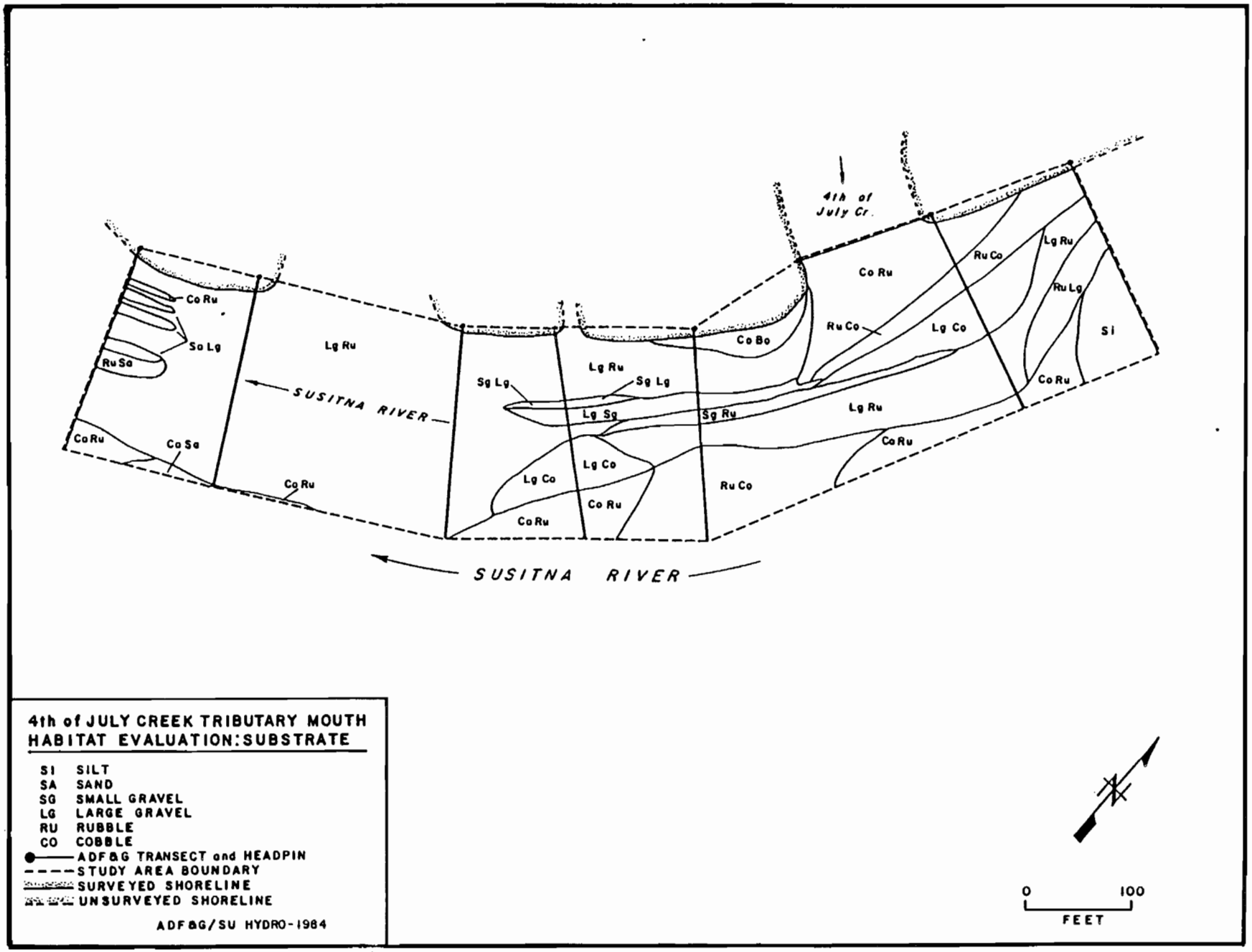


Figure 8-10 Substrate map of the Fourth of July tributary mouth study area (RM 131.2), 1983.

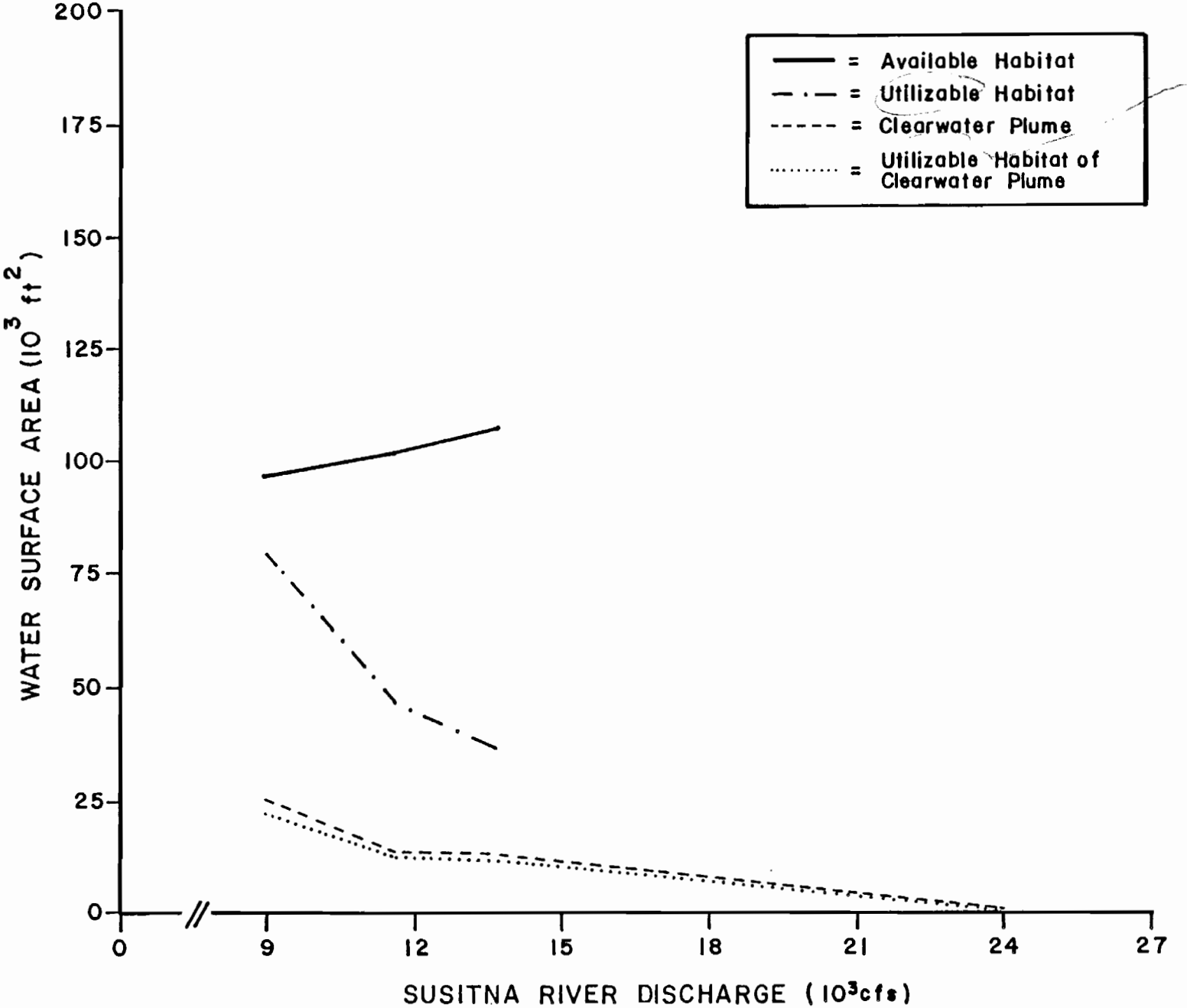


Figure 8-11 Habitat and clearwater plume area (expressed as surface water area) at the Lane Creek tributary mouth study area (RM 113.6) versus Susitna River discharge (USGS gaging station, 15292000), 1983.

(Note: total available and usable salmon spawning habitat area data were unavailable at the sampled 23,000 cfs mainstem discharge).

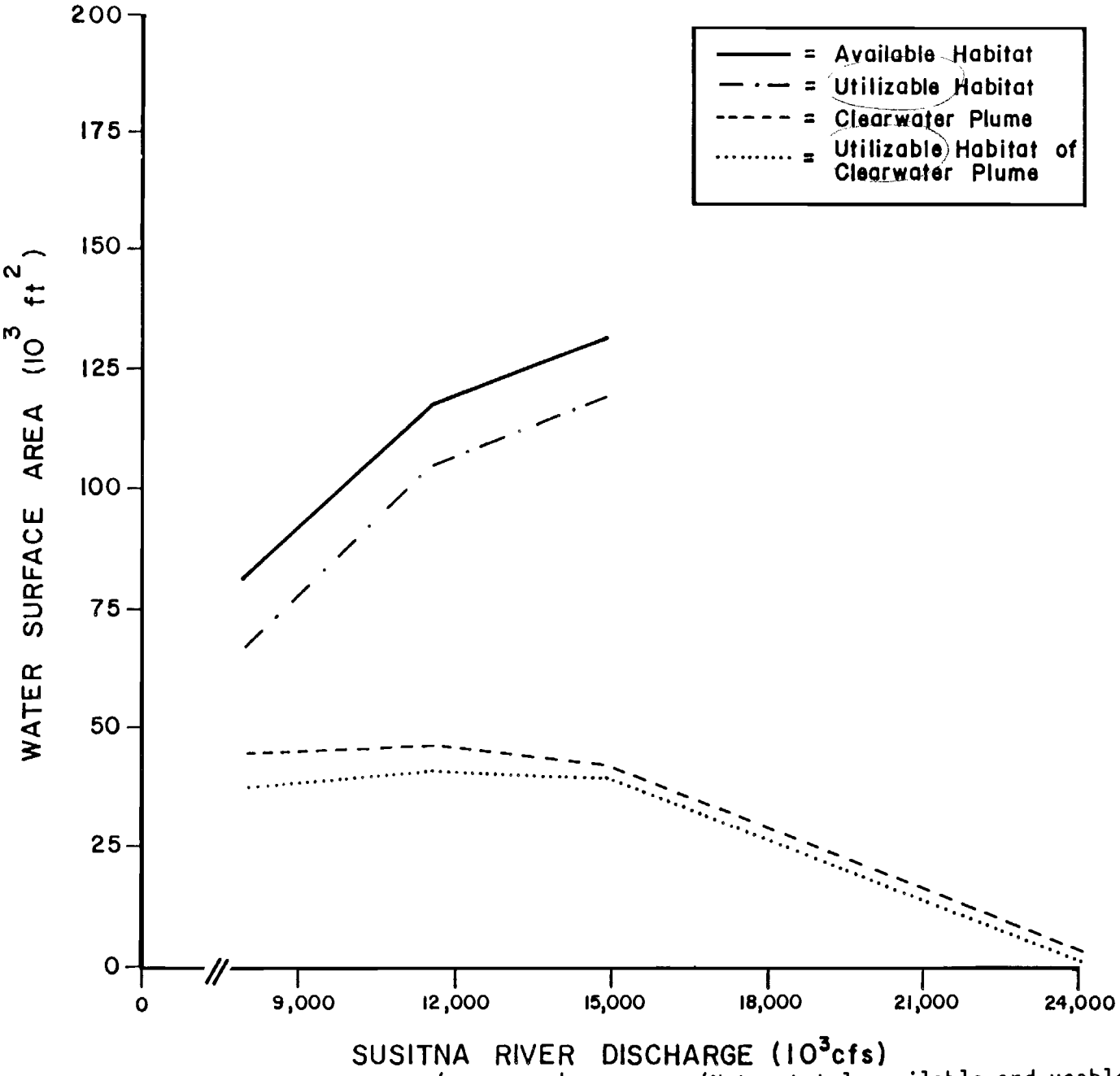


Figure 8-12 Habitat and clearwater plume areas (expressed as surface water area) at the Fourth of July tributary mouth study are (RM 131.2) versus Susitna River discharge (USGS gaging station, 15292000), 1983. (Note: total available and usable salmon spawning habitat area data were unavailable at the sampled 24,000 cfs mainstem discharge).

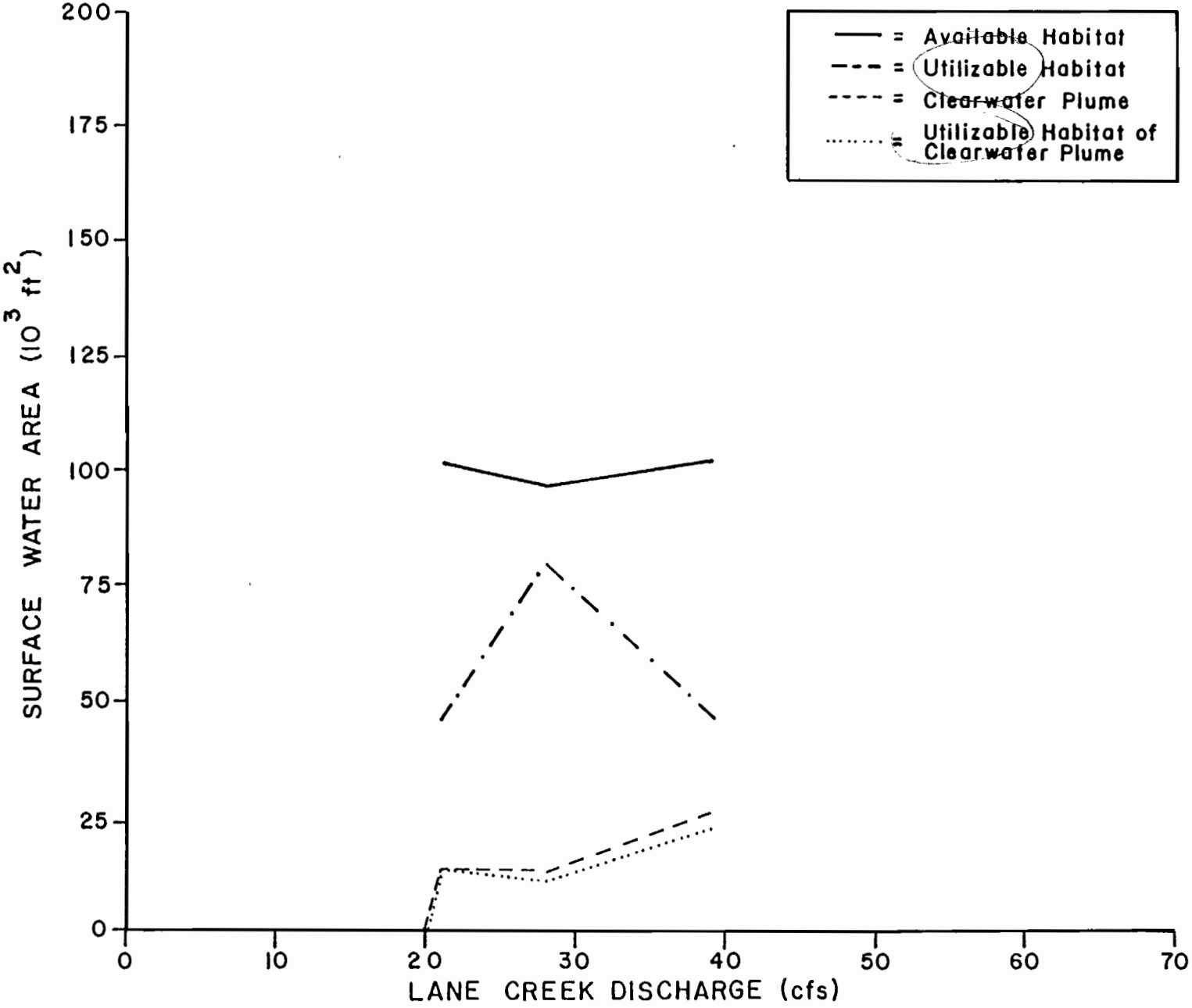


Figure 8-13 Habitat and clearwater plume areas (expressed as surface water area) at the Lane Creek tributary mouth study area (RM 113.6) versus Lane Creek flow, 1983 (Note: total available and usable salmon spawning habitat area data were unavailable at the 20 cfs tributary flow).

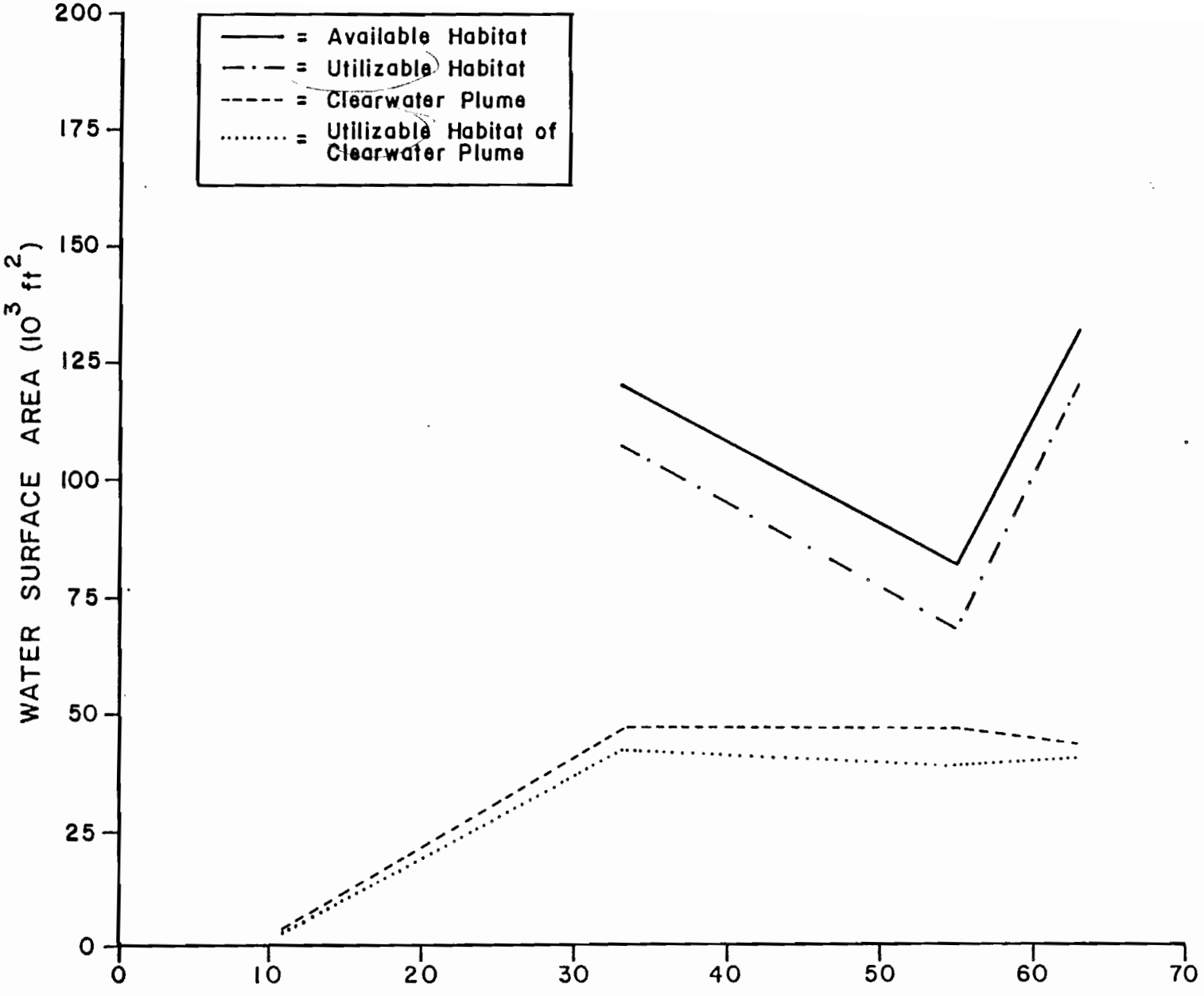


Figure 8-14 Habitat and clearwater plume areas (expressed as surface water area) at the Fourth of July tributary mouth study area (RM 131.2) versus Fouth of July Creek flow, 1983 (Note: total available and [illegible] habitat area data were unavailable at the 11 cfs tributary flow).

9,240 cfs to 67% at 13,700 cfs. The available habitat within the Fourth of July Creek tributary mouth study area, however, ranged from 40% to 66% of the study area over a similar mainstem discharge and time period (Figure 8-15).

Frequency distributions of the water surface areas associated with the incremental velocities and depths of the Lane Creek tributary mouth study area were generally skewed toward the deeper and faster waters (Tables 5 and 6; Figure 8-16). Fourth of July tributary mouth velocities and depths were skewed toward the shallower and slower waters (Tables 7 and 8, Figure 8-17).

Due to the time consuming method of digitizing each surface area between isopleths, it was deemed impractical to determine water surface area for all combinations of depth, velocity and substrate for each study area at each combination of mainstem discharge and tributary flow sampled. However, this time constraint could have been overcome if a computer linked digitizer had been available.

Usable Habitat

Water surface area of usable salmon spawning habitat at the Fourth of July tributary mouth study area (Figure 8-12), was positively correlated to the Susitna River discharge (at Gold Creek), but negatively correlated at the Lane Creek tributary mouth study area (Figure 8-11).

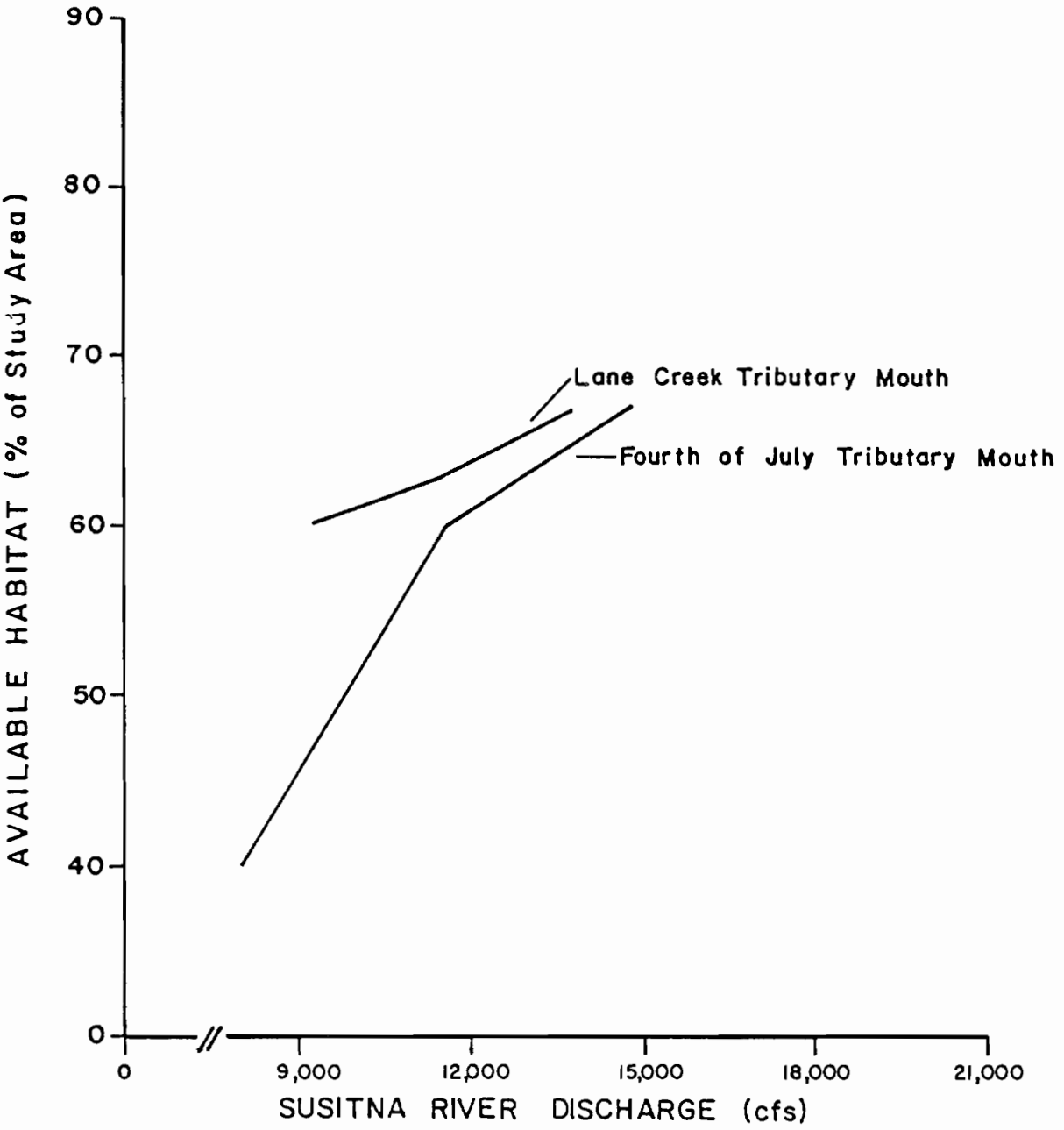


Figure 8-15 Available habitat versus Susitna River discharge (USGS gaging station, 15252000) for the Lane Creek and Fourth of July Creek tributary mouth study areas, 1983. (Note: data unavailable for the 23,000 and 24,000 cfs sampled Susitna River discharge, respectively).

Table 8-5. Lane Creek tributary mouth water surface area associated with increments of observed velocities at four Susitna River discharges (USGS gaging station 15292000), 1983.

Discharge (cfs)			Water Velocity Area (ft^2/(%))											
	Susitna	Lane	Water Surface Increments (ft/sec)											
Date	River	Creek	0.0-1.0	1.1-2.0	2.1-3.0	3.1-4.0	4.1-5.0	5.1-6.0	6.1-7.0	7.1-8.0	8.1-9.0	9.1-10.0	(10.0)	Total
831007	9240	39	17100	16200	14990	7060	37880	3250						96500
			(18)	(17)	(16)	(7)	(39)	(3)						(100)
830912	11600	21	10950	15490	16720	8330	26760	23340						101600
			(11)	(15)	(16)	(8)	(26)	(23)						(100)
830908	13700	28	11180	9720	12520	9310	11950	26580	25300	470				107000
			(10)	(9)	(12)	(9)	(11)	(25)	(24)	(1)				(100)
830625	23000	20	10840	2060	300	290	300	290	2280	2100	2260	1400	13110	35200[1]
			(31)	(6)	(1)	(1)	(1)	(1)	(6)	(6)	(6)	(4)	(37)	(100)

1 - Total water surface area sampled reduced due to unavailable (see text for explanation.

Table 8-6. Lane Creek tributary mouth water surface area associated with increments of observed water depths at four Susitna River discharges (USGS Gold Creek gaging station), 1983.

Date	Discharge (cfs)		Water Surface Area (ft^2(%))							
			Water Depth Increments (ft)							
	Susitna River	Lane Creek	0.0-1.0	1.1-2.0	2.1-3.0	3.1-4.0	4.1-5.0	5.1-6.0	6.1-7.0	Total
831007	9240	39	14050 (15)	19100 (20)	23650 (25)	38440 (40)	1250 (1)			96500 (100)
830912	11600	21	10940 (11)	20290 (20)	11550 (11)	11850 (12)	29650 (29)	17300 (17)		101600 (100)
830908	13700	28	11420 (11)	16200 (15)	9580 (9)	9360 (9)	23470 (22)	31820 (30)	5180 (5)	107000 (100)
830625	23000	20	3790 (11)	6340 (18)	2190 (6)	2140 (6)	2808 (8)	5232 (15)	12733 (36)	35200[1] (100)

1 - Total water surface area sampled reduced due to unavailable (see text for explanation).

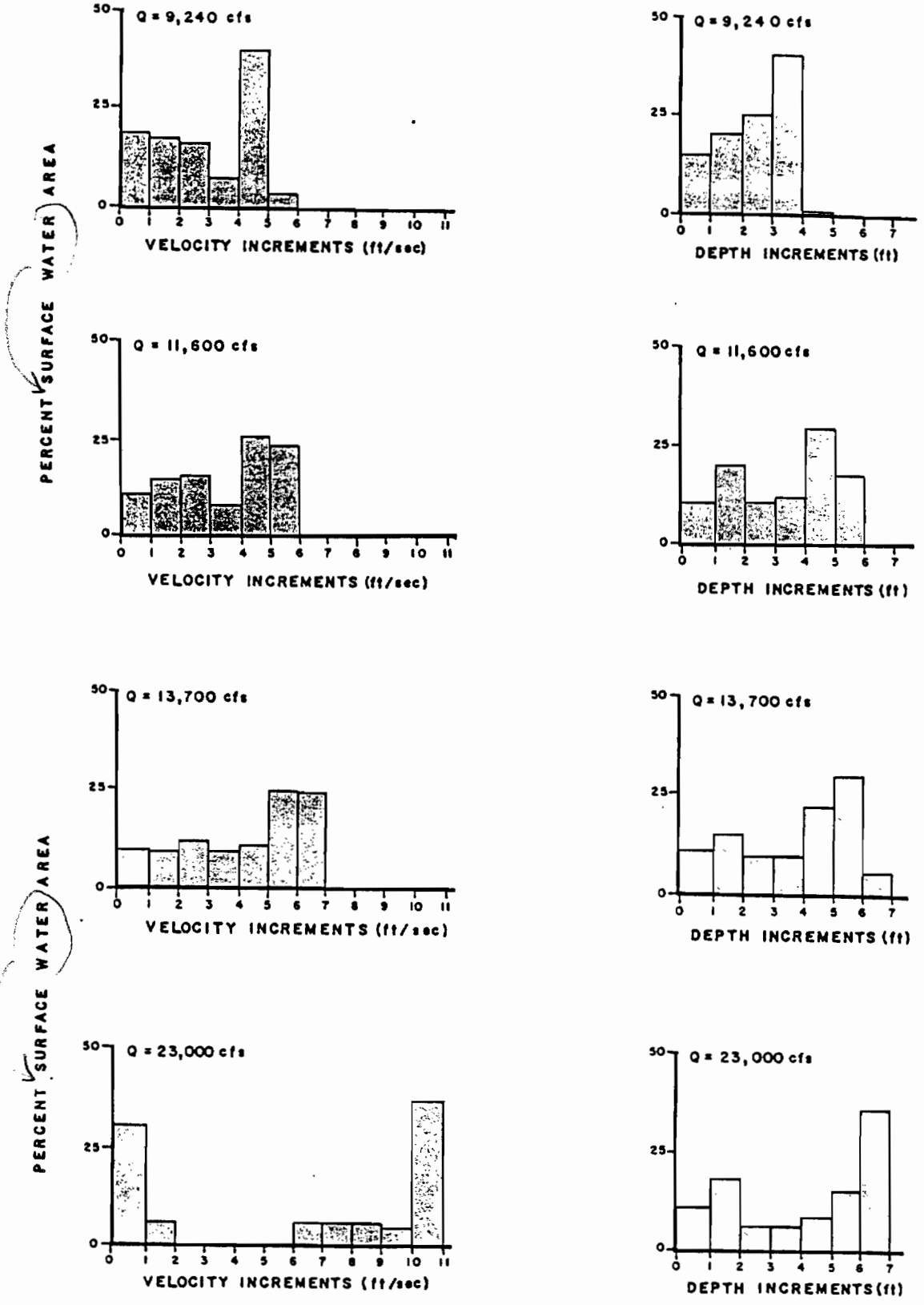


Figure 8-16 Frequency distributions of observed water velocities and depths at the Lane Creek tributary mouth study area (RM 113.6) at the four Susitna River discharges sampled, 1983.

DRAFT May 5, 1984

Table 8-7. Fourth of July tributary mouth water surface area associated with increments of observed water velocities at four Susitna River discharges (Gold Creek USGS gaging station), 1983.

Date	Discharge (cfs)		Water Surface Area (ft^2(%))						
			Water Velocity Increments (ft/sec)						
	Susitna River	Fourth of July Creek	0.0-1.0	1.1-2.0	2.1-3.0	3.1-4.0	4.1-5.0	5.1-6.0	Total
830810	8040	55	61080 (76)	16510 (20)	2820 (3)	280 (1)	20 (1)		80700 (100)
830912	11600	33	61600 (52)	35580 (30)	21910 (18)				119100 (100)
830907	14800	63	58230 (43)	41820 (32)	26560 (20)	3760 (3)	1030 (1)		131400 (100)
830624	24000	11	39220 (33)	32120 (27)	22340 (19)	16250 (14)	5020 (4)	2250 (2)	17200 (100)

DRAFT May 5, 1984

Table 8-8. Fourth of July tributary mouth water surface area associated with increments of observed water depths at four Susitna River discharges (Gold Creek USGS gaging station), 1983.

	Discharge (cfs)		Water Surface Area (ft^2(%))					
			Water Surface Increments					
Date	Susitna River	Fourth of July Creek	0.0-1.0	1.1-2.0	2.1-3.0	3.1-4.0	4.1-5.0	Total
830810	8040	55	49780 (62)	30496 (38)	440 (1)			80700 (100)
830912	11600	33	55540 (47)	51570 (43)	12000 (10)			119100 (100)
830907	14800	63	38790 (30)	68490 (52)	23950 (18)	160 (1)		131400 (100)
830624	24000	11	30050 (26)	20950 (18)	34990 (30)	30640 (26)	520 (1)	17200 (100)

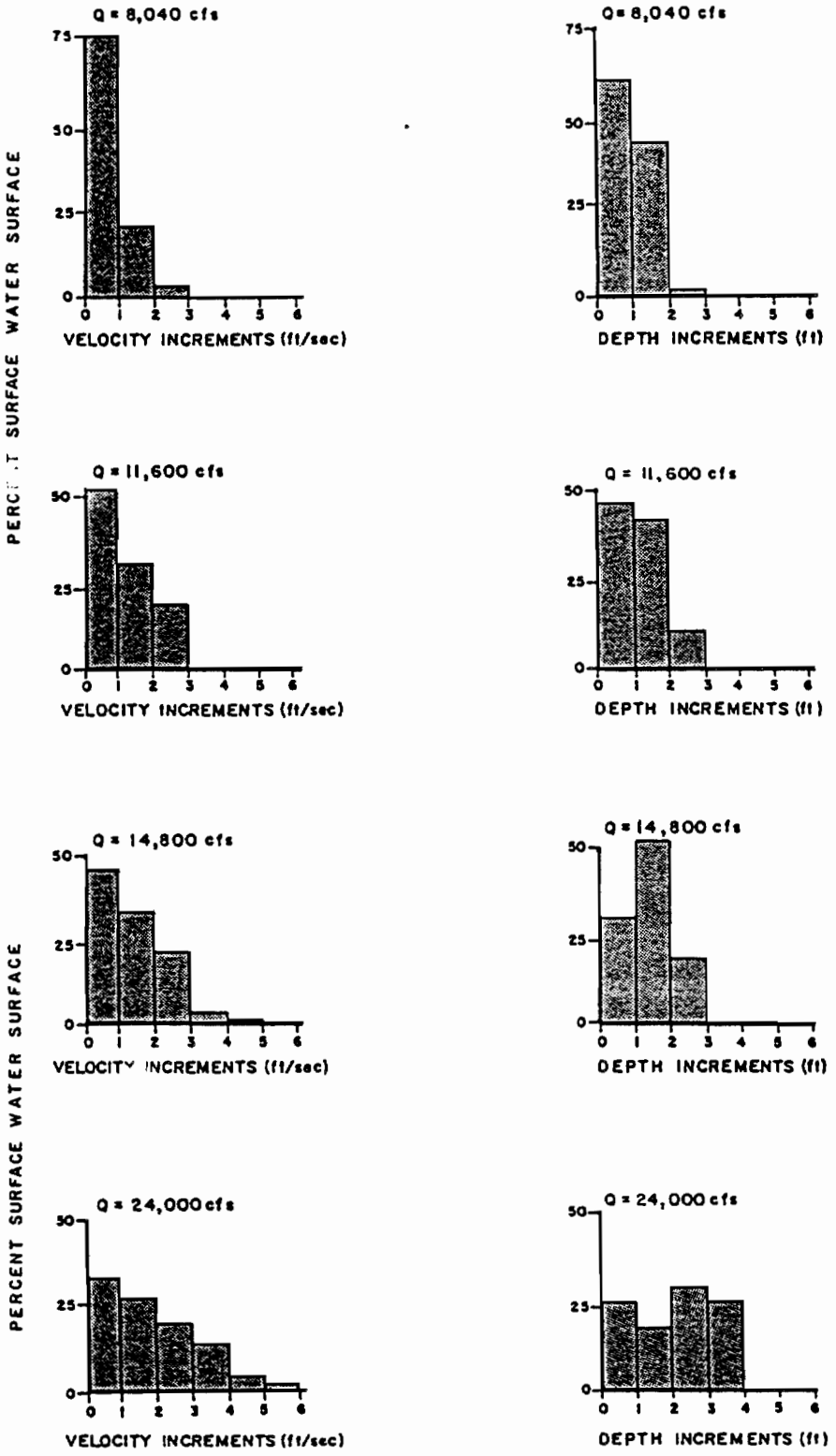


Figure 8-17 Frequency distribution of observed water velocities and depths of the Fourth of July tributary mouth study area (RM 132.0) at the four Susitna River discharges sampled, 1983.

There were no correlations between water surface area of usable habitat and respective tributary discharge (Figures 8-13 and 8-14). Locations of surface areas associated with the usable habitat at the Lane Creek and Fourth of July tributary mouth study areas at each combination of mainstem discharge and tributary flow sampled are delineated in Figures 8-18 through 8-25.

Usable salmon spawning habitat was restricted and confined at the Lane Creek tributary mouth study area mainly by unacceptably high water velocities and deep water depths. As Susitna River discharge increased, the surface area of usable habitat within the study area decreased (Table 1 and 2, Figure 8-26). Usable habitat area at the Fourth of July mouth study area was limited by high water velocities (but not by deep water depths) only at the 24,000 cfs. mainstem streamflow. Shallow water near shore was the main restriction on this habitat. Since the upper limit of acceptable ranges of water velocities and water depths was not a major restricting force at the Fourth of July tributary mouth study area, usable habitat increased as available habitat increased. (Table 3 and 4, Figure 26).

Overall, substrate composition had minimal influence on the usability of the available habitat by spawning chum salmon at both study sites because substrate composition was generally within the acceptable range.

Water surface of the tributary clearwater plume is obviously dependent upon tributary discharge but is also affected by Susitna River discharge. Increasing Susitna River discharge had a dampening effect on the surface area of the tributary clearwater plume at the Lane Creek tributary mouth study area (Figure 8-5). As Lane Creek discharge

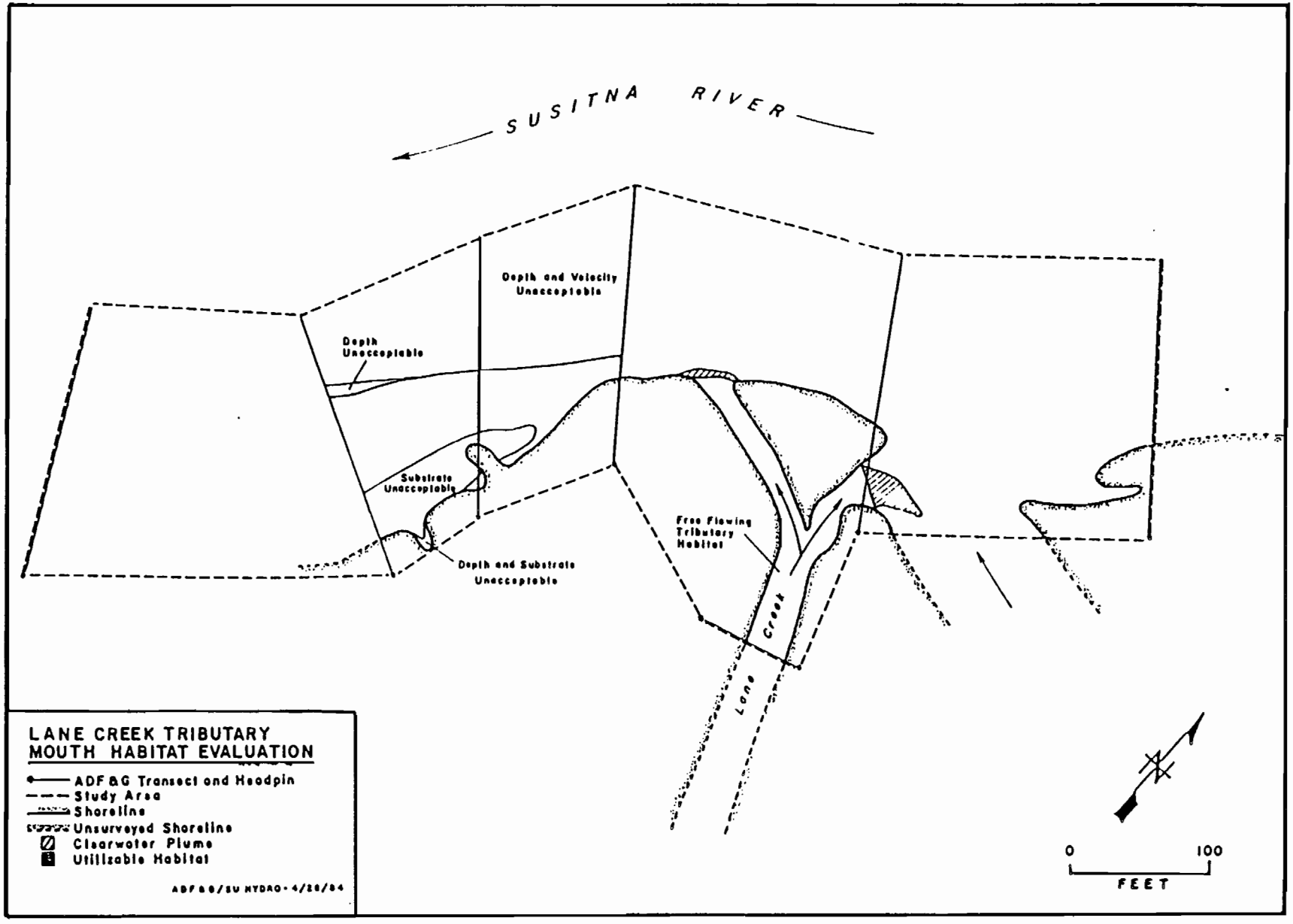


Figure 8-18 Habitat evaluation of the Lane Creek tributary mouth study area (RM 113.6) at a combination of a Susitna River discharge of 23,000 cfs. (USGS gaging station 15292000) and a Lane Creek flow of 20 cfs, 1983. (Note: sample area reduced due to tail [illegible] t[illegible]ect [illegible]a).

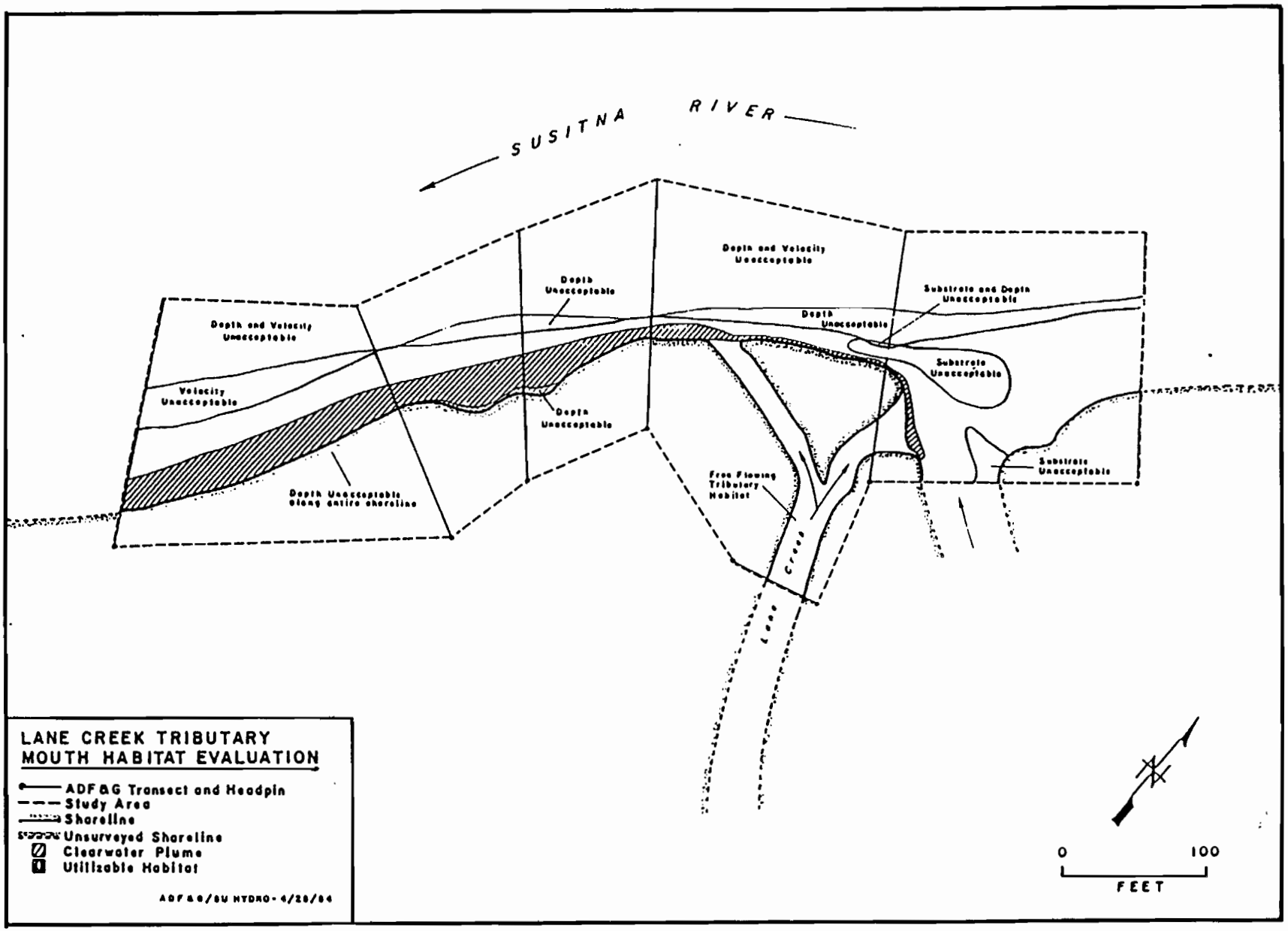


Figure 8-19 Habitat evaluation of the Lane Creek tributary mouth study area (RM 113.6) at a combination of a Susitna River discharge of 16,000 cfs (USGS gaging station 15292000) and a Lane Creek flow of 21 cfs, 1983.

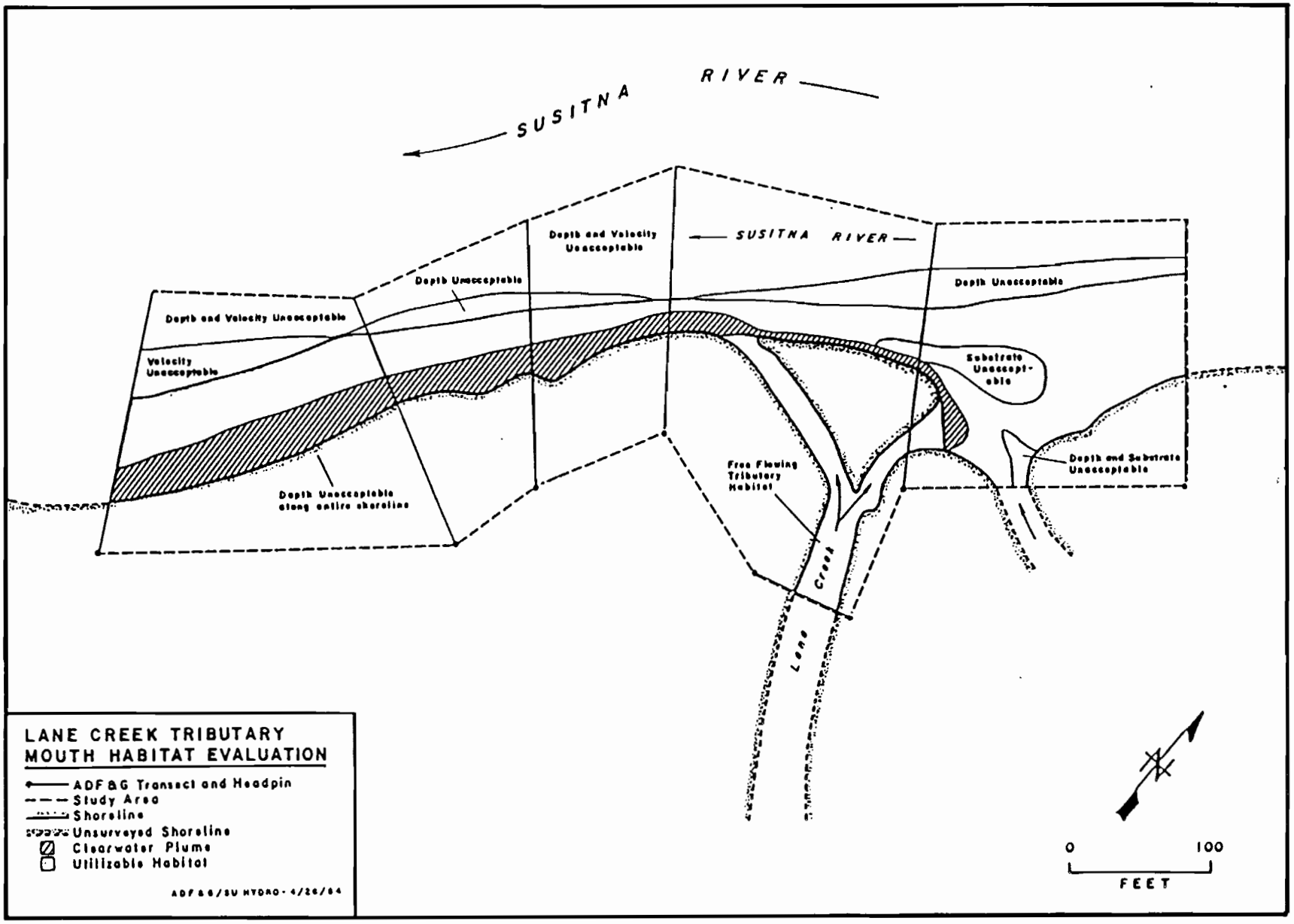


Figure 8-20 Habitat evaluation of the Lane Creek tributary mouth study area (RM 113.6) at a combination of a Susitna River discharge of 13,700 cfs (USGS gaging station 15292000) and a Lane Creek flow of 28 cfs., 1983

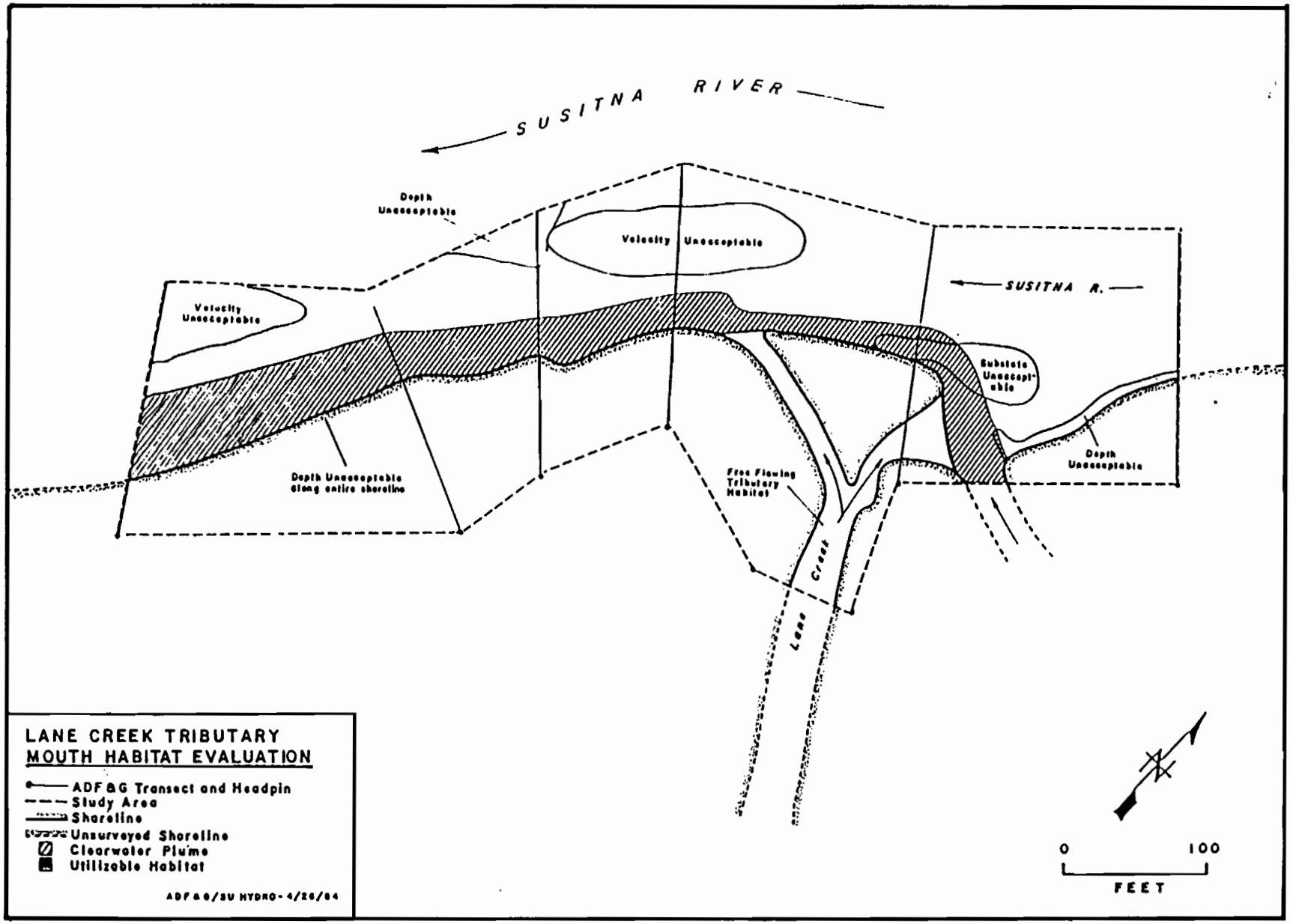


Figure 8-21 Habitat evaluation of the Lane Creek tributary mouth study area (RM 113.6) at a combination of a Susitna River discharge of 9,240 cfs (USGS gaging station 15292000) and a Lane Creek flow of 39 cfs, 1983.

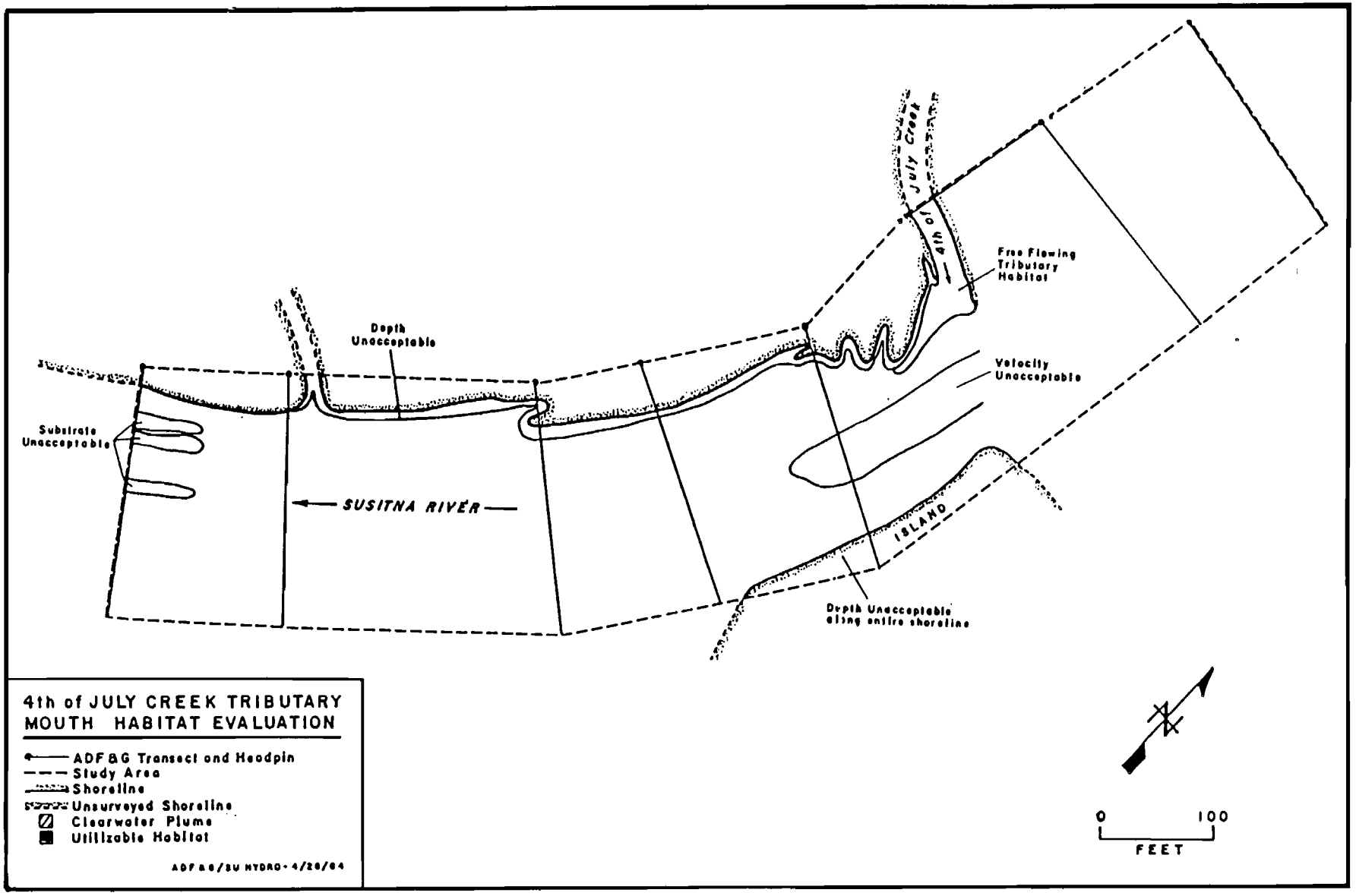


Figure 8-22 Habitat evaluation of the Fourth of July Creek tributary mouth study area (RM 131.2) at a combination of a Susitna River discharge of 24,000 cfs (USGS gaging station 15292000) and a Fourth of July Cr fl f 1 s, B.

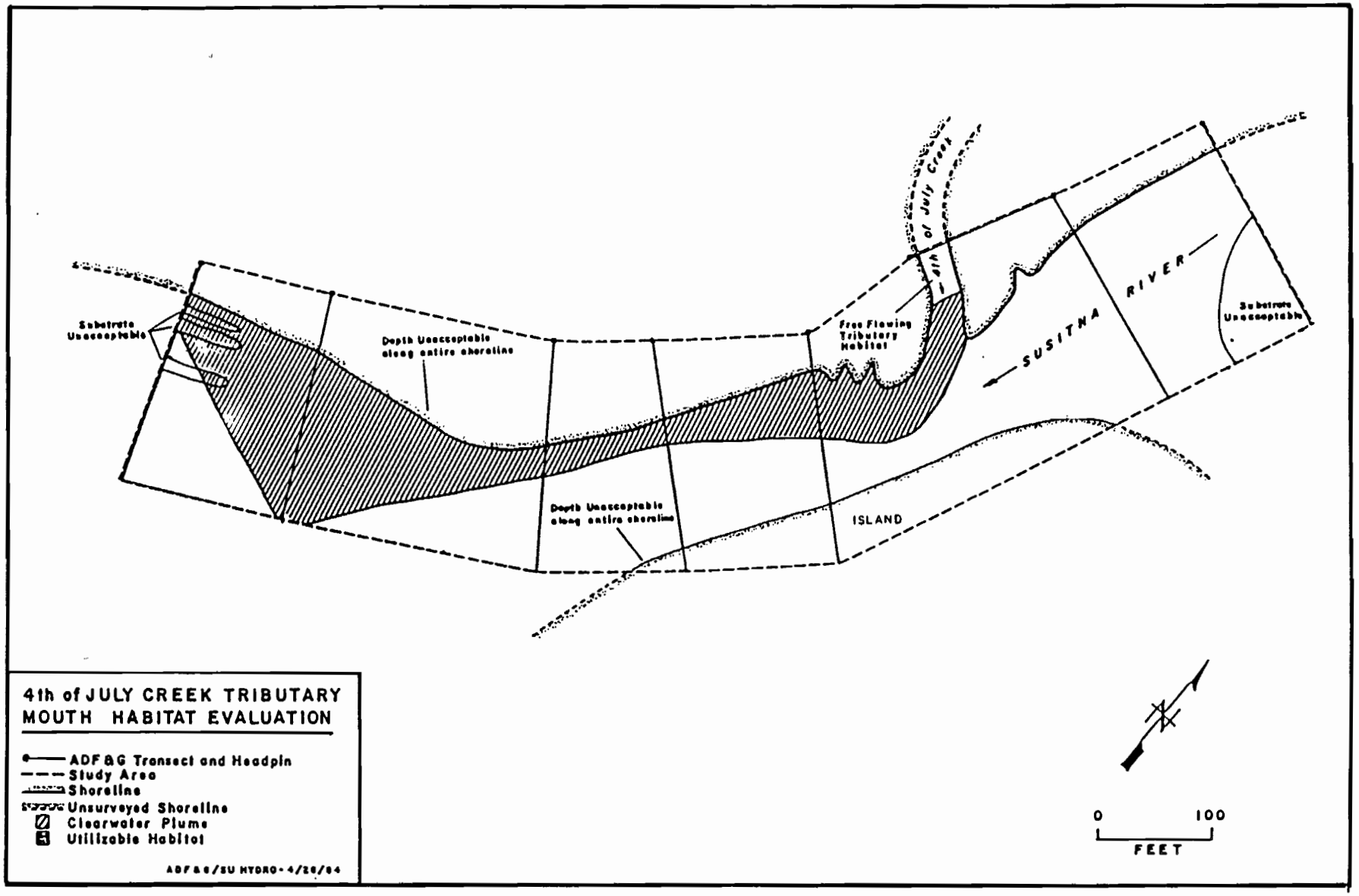


Figure 8-23 Habitat evaluation of the Fourth of July Creek tributary mouth study area (RM 131.2) at a combination of a Susitna River discharge of 14,800 cfs (USGS gaging station 15292000) and a Fourth of July Creek discharge of 63 cfs, 1983.

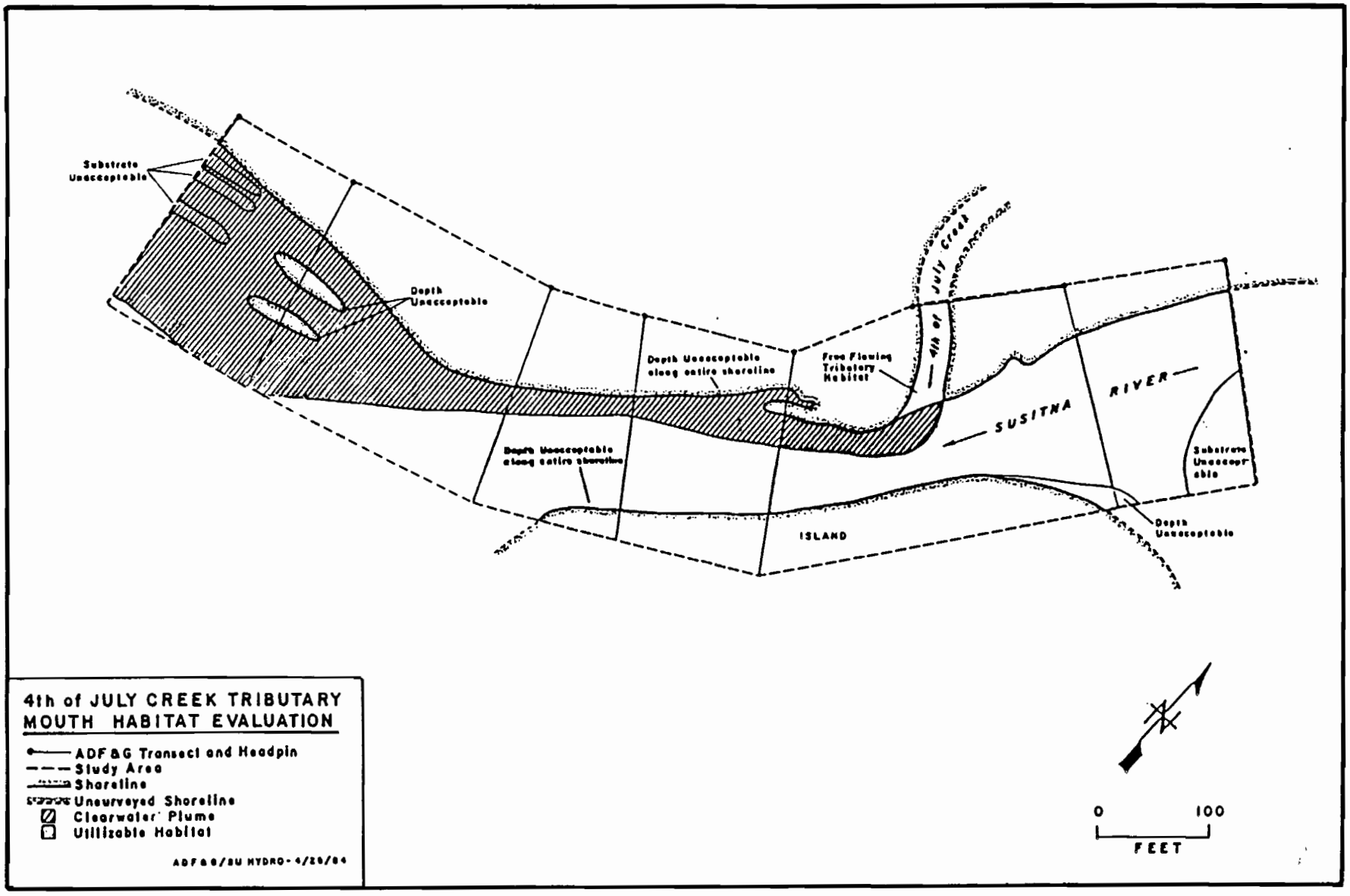


Figure 8-24 Habitat evaluation of the Fourth of July Creek tributary mouth study area (RM 131.2) at a combination of a Susitna River discharge of 11,600 cfs (USGS gaging station 15292000) and a Fourth of July Creek discharge of 33 cfs, 1983.

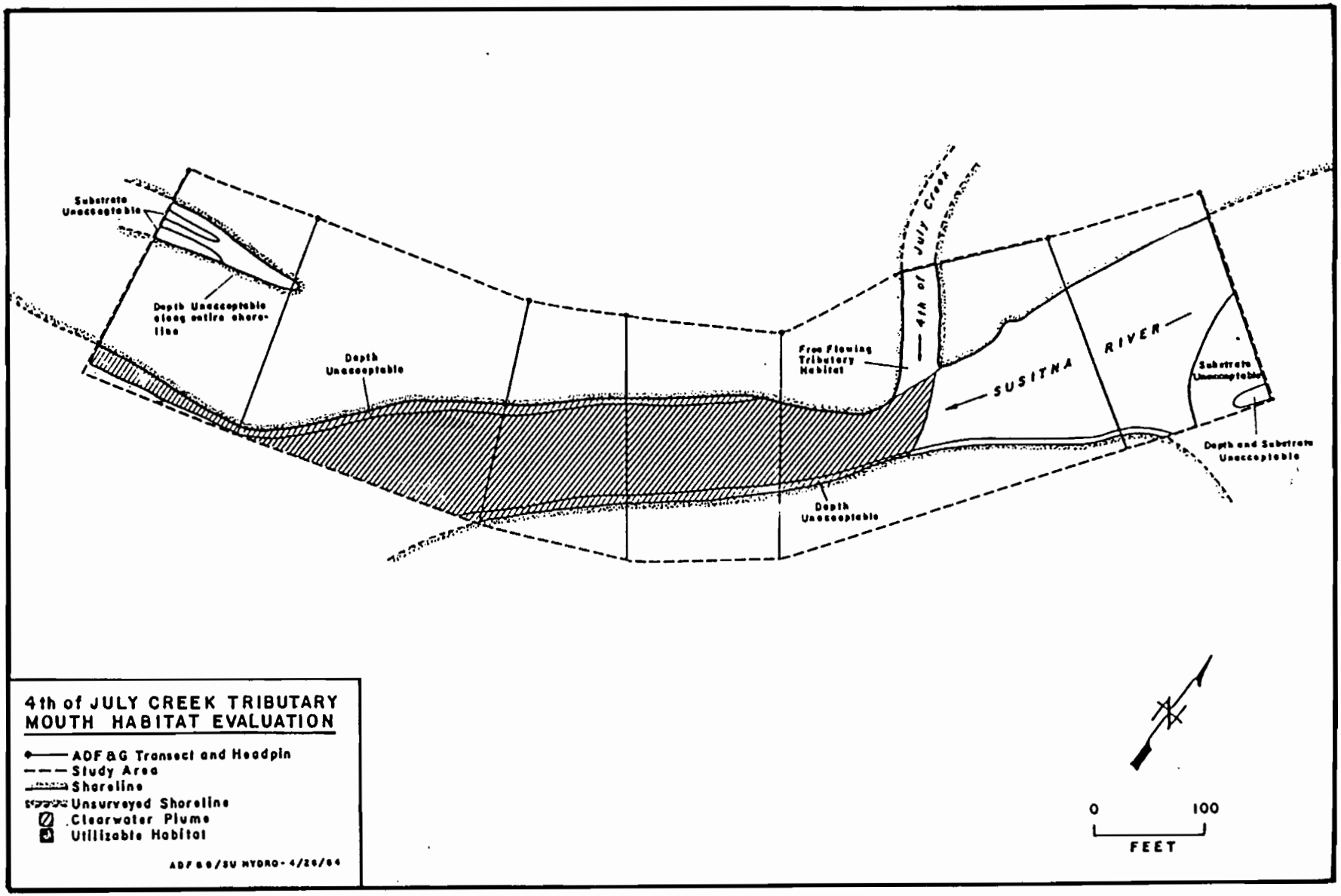


Figure 8-25 Habitat evaluation of the Fourth of July Creek tributary mouth study area (RM 131.2) at a combination of a Susitna River discharge of 8,040 cfs (USGS gaging station 15292000) and a Fourth of July Creek discharge of 55 cfs, 1983.

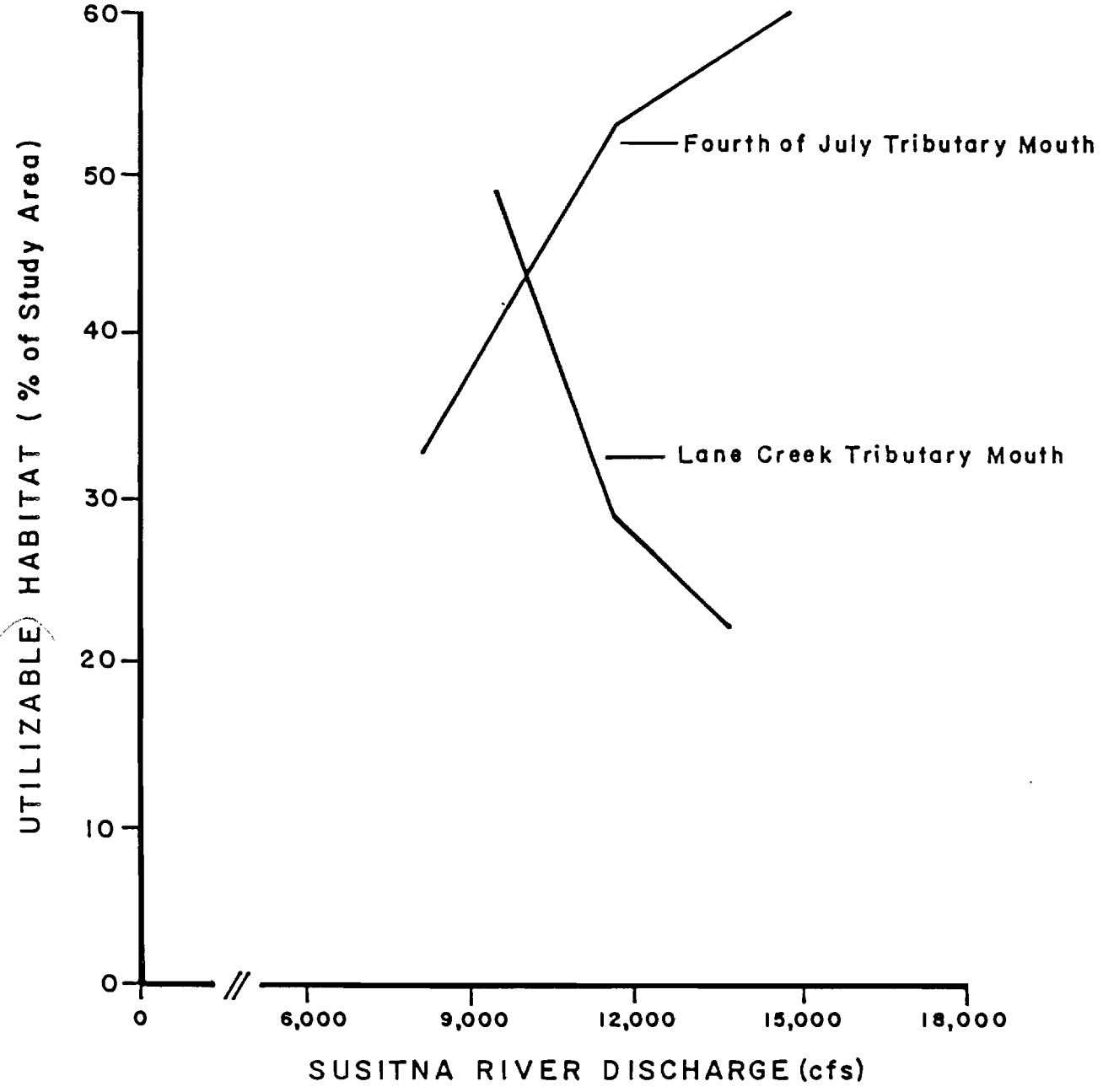


Figure 8-26 Usable habitat at the Lane Creek and Fourth of July Creek study areas versus Susitna River discharge (USGS gaging station 15292000).

increased from 21 to 28 cfs there was a slight decrease in clearwater plume surface area (Figure 8-13). This clearwater plume surface area decrease can be attributed to the dampening effect of a corresponding 2,100 cfs. increase in mainstem discharge. With the exception of the above incident, all other sampled increases in Lane Creek flows were accompanied by a decrease in Susitna River discharge.

In all cases, water surface area of the usable habitat portion of the tributary clearwater plume increased as the size of the plume increased (Figure 8-5, 8-6, 8-11 and 8-12). The area of usable habitat of the clearwater plume reacted to fluctuation in mainstem discharge in the same manner as the tributary clearwater plume did.

Utilized Habitat

Spawning utilization data was collected at 28 active chum salmon redds and 5 active pink salmon* redds within the Fourth of July tributary mouth study area (Table 8-9). Spawning salmon were not observed within the Lane Creek study site. All observations were made when the daily mean Susitna River discharge at Gold Creek was between 21,000 and 26,000 cfs (USGS gaging station 15292000). A map of the study area depicting spawning areas, possible upwelling areas, and shoreline at 24,000 cfs and 8,040 cfs mainstem discharge is presented in Figure 8-27. A large portion of the depicted spawning areas was dewatered before the final transect habitat data was collected on October 8, 1983.

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* These data are incidental and not discussed in this report.

Where are they discussed?

Table 8-9. Salmon spawning habitat utilization data collected at the mouth of Fourth of July Creek August 17-28, 1983.

CHUM SALMON

Date	Mainstem[a] Q (cfs)	Observ. #	Depth (ft)	Velocity (ft/sec)	Water Temp.(C) Substrate[b]	Intra-gravel	Surface
8-17	22,700	01	1.00	0.60	LG/RU	10.6	11.6
		02	1.70	0.75	CO/RU	11.5	11.6
		03	1.60	0.70	LG/RU	11.2	11.6
		04	2.20	0.60	LG/RU	10.2	11.6
		05	2.00	0.60	LG/RU	10.8	11.7
		06	2.30	0.60	LG/RU	10.7	11.6
		07	2.00	0.10	CO/RU	11.0	11.8
		08	1.00	0.25	SG/LG	11.3	11.9
		09	1.00	0.25	RU/LG	11.3	11.9
		10	1.70	0.20	RU/LG	11.2	11.8
8-18	21,000	12	2.10	1.35	RU/CO	11.8	12.2
		13	1.50	0.10	SG/SA	10.4	12.0
		14	1.70	2.10	LG/SG	7.5	12.3
		15	1.90	4.50	RU/CO	8.1	12.3
8-22	21,600	16	2.20	1.30	RU/LG	9.7	11.2
		17	2.00	1.00	RU/LG	11.1	11.3
		18	1.80	1.40	LG/SA	11.0	11.3
		19	2.00	1.80	RU/LG	9.3	11.3
		20	1.30	2.20	RU/LG	9.8	11.2
		21	0.90	2.00	RU/LG	11.4	11.3
		22	1.20	3.10	RU/LG	11.3	11.3
		23	1.70	2.00	RU/CO	11.4	11.3
8-28	26,600	24	0.70	0.40	---	9.5	10.7
		25	1.70	2.50	---	9.4	10.7
		26	0.90	0.80	---	9.0	10.6
		27	0.70	0.75	---	8.7	10.6
		28	0.60	1.20	---	10.1	10.7
		29	1.10	0.10	---	5.7	10.8

[a] Discharge measured at USGS Gold Creek Station.
[b] Substrate Code:

Table 8-9 (continued)

PINK SALMON

Date	Mainstem[a] Q (cfs)	Observ.	Depth #	Velocity (ft)	(ft/sec)	Substrate[b]	Water Temp.(C) Intra-gravel	Surface
8-17	22,700		01	1.80	0.35	LG/RU	11.2	11.9
			02	0.70	0.20	LG/RU	11.1	11.8
8-18	21,000		03	0.50	0.35	SG/LG	12.0	12.3
			04	0.30	0.65	LG/RU	12.4	12.3
			05	0.70	4.30	RU/LG	12.8	12.4

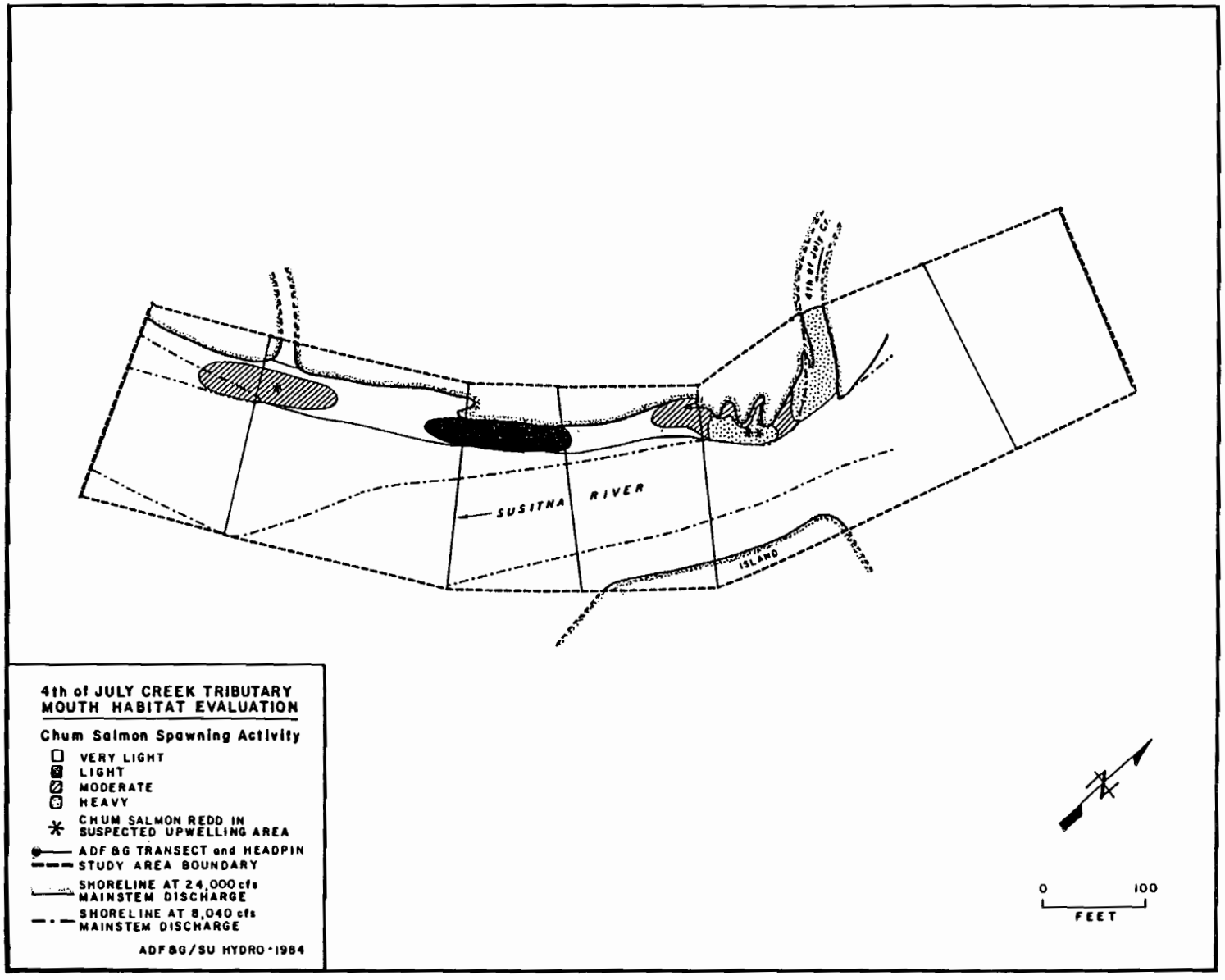

Figure 8-27 Chum salmon spawning areas at the Fourth of July tributary mouth study area (RM 131.2) and shoreline boundaries at the 24,000 and 8,040 cfs Susitna River discharges (USGS gaging station 15292000), 1983.

Water velocities observed at all active chum redds ranged from 0.1 ft sec to 4.5 ft/sec. Water depths ranged from 0.6 ft to 2.3 ft.

The locations of spawning areas of redds measured at Fourth of July tributary mouth are noted on the spawning area map (Figure 8-27). A scatter plot of water depths versus water velocities observed at active chum salmon redds within the Fourth of July tributary mouth study area is presented in Figure 8-28. Water velocity and water depth frequency distributions of active chum redds indicate that spawning salmon most often selected the redd sites in relatively slow (0.1-1.0 ft/sec), shallow (1.1 to 2.0 feet) water (Figure 8-29).

The scatter plot of intragravel versus surface water temperatures (Figure 8-30) can be used as a tool to detect redds located within possible groundwater upwelling areas. The use of this scatter plot to detect redds located in upwelling groundwater area is only effective when discernible temperature differences occur in the two water bodies. At least three chum salmon redds within the Fourth of July tributary mouth study area are probably located in areas influenced by groundwater.

How? Do they differ colder warmer ?

It appears that the physical habitat conditions (water depths, water velocity, and substrate) may be the limiting factors for chum salmon redd site selection at this site. Why?

Isn't there enough data here for habitat preference curves?

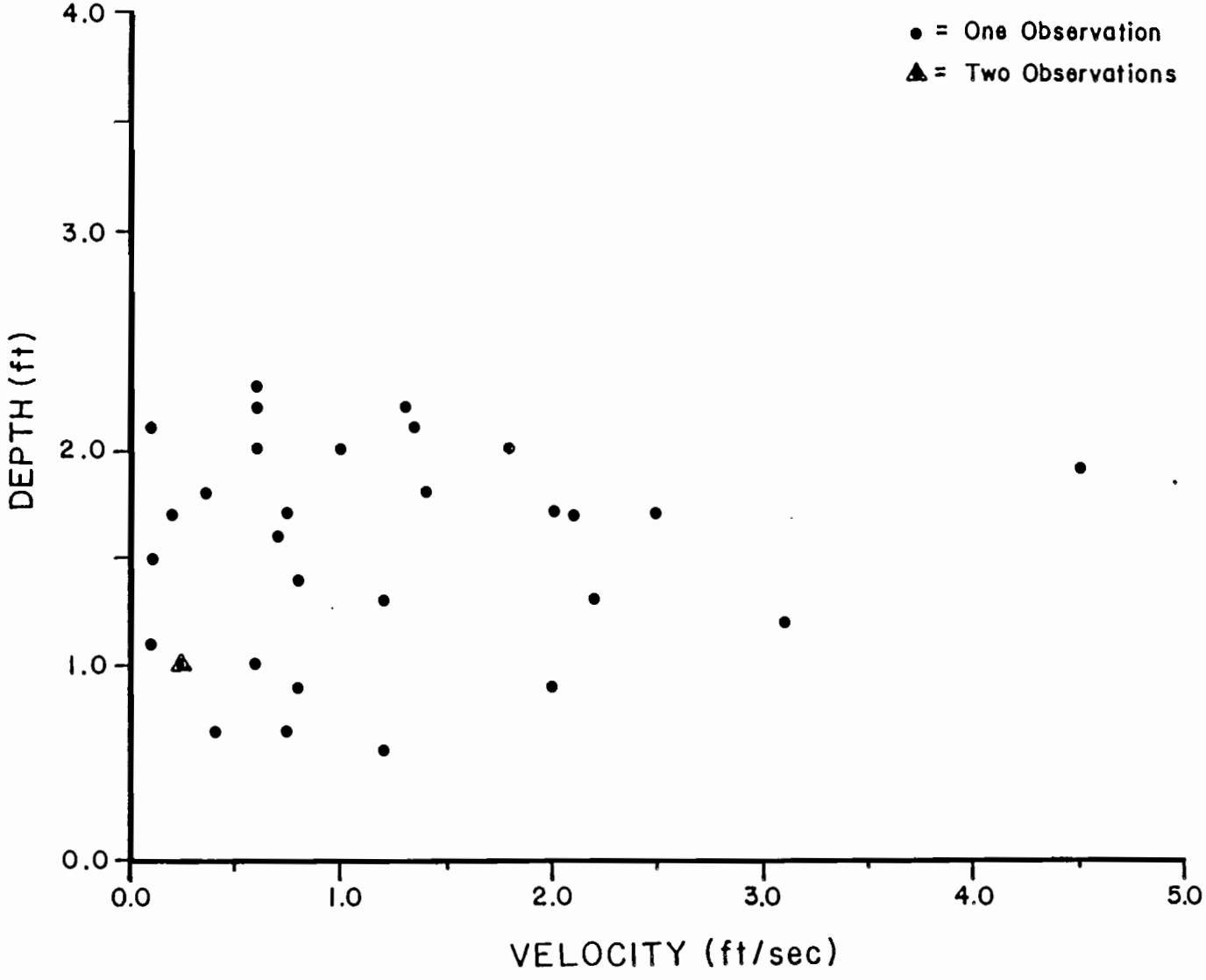

Figure 8-28 Scatter plot of water velocity versus water depths observed at active chum salmon redds at the Fourth of July Creek tributary mouth study area, 1983.

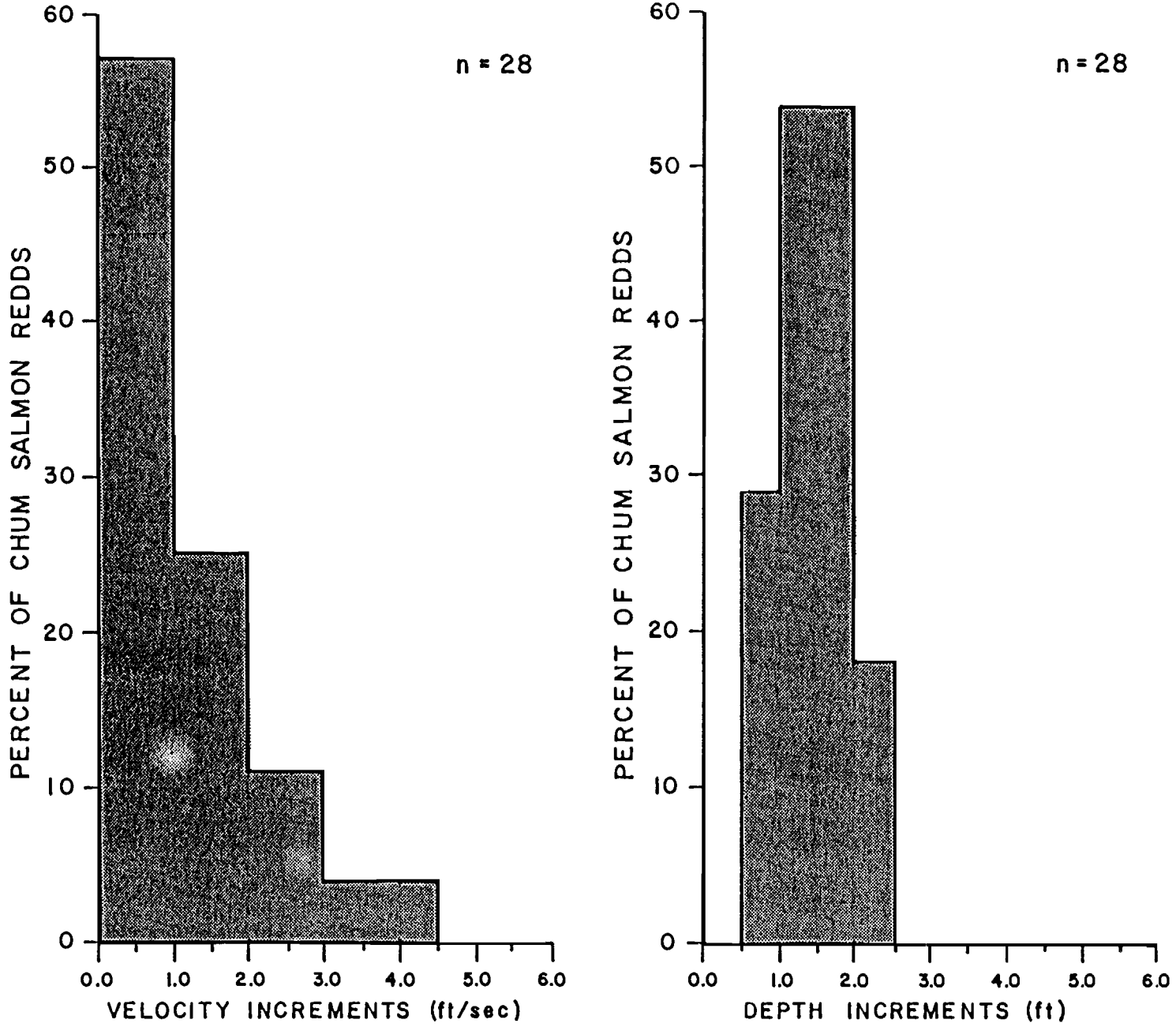

Figure 8-29 Frequency distribution of velocity and depth increments observed at active chum salmon redds at the Fourth of July tributary mouth study area (RM 131.2), 1983.

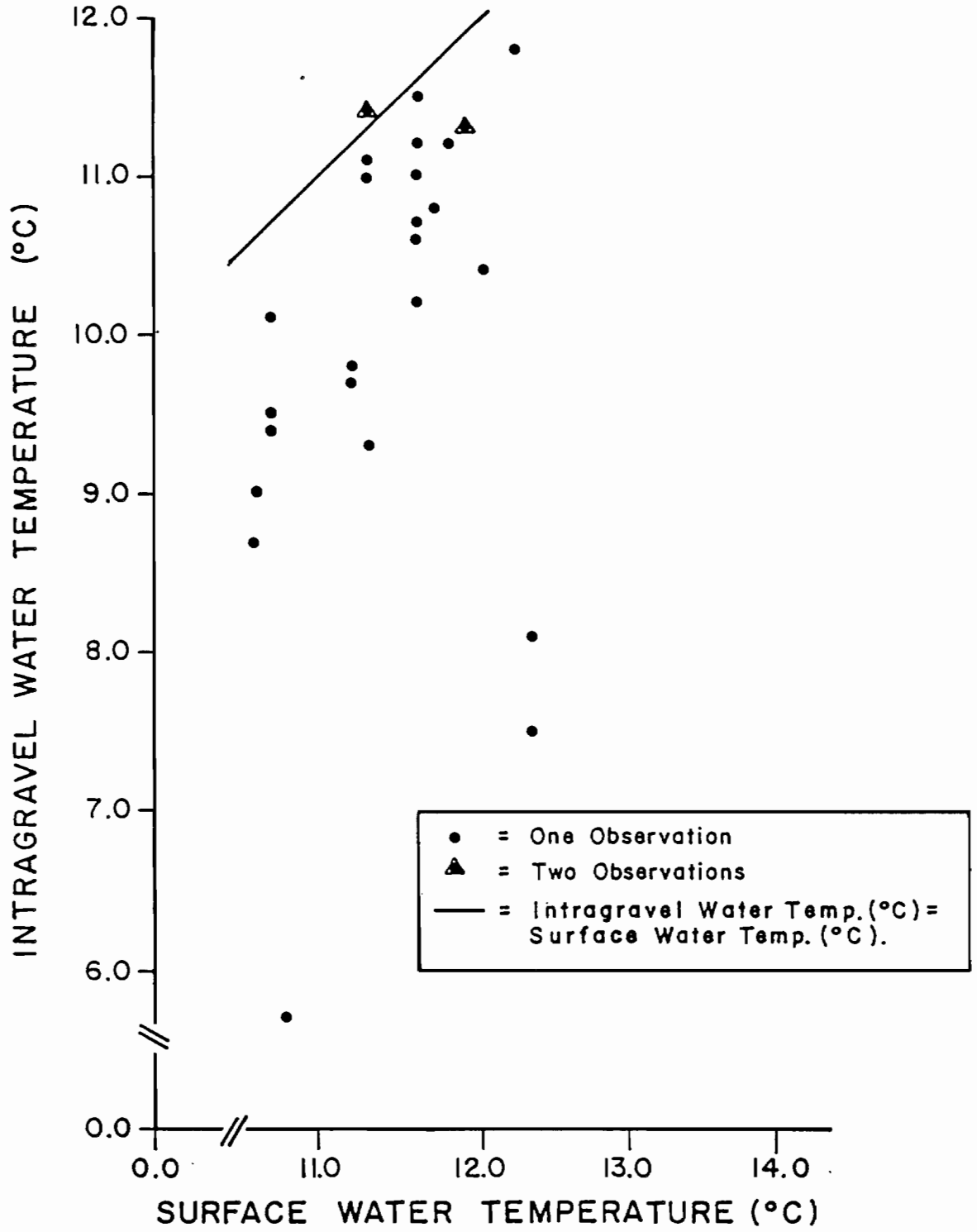

Figure 8-30 Surface water versus intragravel water temperatures observed at active chum salmon redds at the Fourth of July Creek tributary mouth study area, 1983.

4.0 DISCUSSION

Fluctuations in Susitna River discharge affect the Lane Creek tributary mouth area differently than the Fourth of July Creek tributary mouth area. As mainstem discharge increases, the amount of available habitat remains almost constant at the Lane Creek area, while the available habitat within the Fourth of July Creek tributary mouth study area increased dramatically. The large reduction in the usable chum salmon spawning habitat at the Lane Creek tributary mouth study area (from 49 to 22% of the study area) between Susitna River discharges of 9,240 cfs and 13,700 cfs did not occur at the Fourth of July Creek area. In fact, the usable habitat almost doubled (from 33 to 60% of the study area) between similar mainstem discharges. These differences in the available and usable habitats between study areas and the manner in which these habitats react to change in mainstem discharge can be best discussed by first explaining the basic differences in the nature of each tributary/mainstem confluence area.

Lane Creek empties into a main channel of the Susitna River. Mainstem channels are characterized by high water velocities, relatively deep waters depths and wide channels (ADF&G 1983b). These tributary mouth habitats are usually open, that is, the opposite river bank is located far beyond the influence of the tributary on the mainstem. Water velocities and depths increase from shore without reaching a maximum or subsiding within the tributary mouth study area. Populations of water velocity and depths within the study area are skewed toward deeper and faster waters. The generally steeper banks and the openness of the habitat accounts for the small increase in available habitat associated

with increases in mainstem discharge. As water velocities and depths increase, the water surface area corresponding to the resulting unacceptable salmon spawning habitat increases, severely limiting and confining acceptable or usable habitat area.

Alternatively, Fourth of July Creek empties into a side channel of the Susitna River. The tributary mouth habitat associated with the confluence also reflects the characteristics of a side channel habitat. Side channel habitats are characterized by lower velocities, shallower depths and a more constricted channel than the adjacent habitat of the mainstem river (ADF&G 1983b). The tributary mouth habitat area is usually confined, that is, the opposite channel bank is located within or just beyond the 200 foot extension of the study area transects. Study area water velocities and depths increase from shore, reach a maximum, and subside as the transect approaches the opposite bank. Study area water velocity and depth populations are skewed toward shallower, slower waters. The relatively shallow nature of the side channel accounts for the relatively large increases in available and utilizable habitats with corresponding increases in mainstem discharge. In summary, channel morphology dictates the hydraulic conditions present at each tributary mouth area. A list of tributaries to the Susitna River between the Chulitna River and Devil Canyon is presented in Table 8-10.

The small amount of chum salmon utilization data (28 redds) collected at the Fourth of July tributary mouth study area was insufficient to definitely state whether chum salmon which spawn in the tributary mouth area do or do not select different hydraulic conditions than chum salmon which spawn in sloughs and/or side channels. Fish were not observed

Table 8-10. Susitna River tributaries between the Chulitna River (RM 98.3) and Devil Canyon (RM 152.0) and their type of confluence habitat.

Tributary	R.M.	Confluence Habitat
Whiskers Creek	101.4	slough
Chase Creek	106.9	mainstem
Slash Creek	111.2	side channel
Gash Creek	111.6	side channel
Lane Creek	113.6	mainstem
Lower McKenzie Creek	116.2	mainstem
McKenzie Creek	116.7	mainstem
Little Portage Creek	117.7	side channel
Fifth of July	123.7	mainstem
Skull Creek	124.7	side channel
Sherman Creek	130.8	mainstem
Fourth of July Creek	131.0	side channel
Gold Creek	136.7	mainstem
Indian River	138.6	mainstem
Jack Long Creek	144.5	mainstem
Portage Creek	148.9	mainstem

spawning at the Lane Creek site; therefore, utilization data were not collected at that site. At the Fourth of July tributary mouth area chum salmon were observed spawning in water depths which range from 0.6 to 2.3 feet. These depths were within the range of depths (0.16-3.9 ft) reported for chum salmon redds at various locations in a number of reports summarized by Hale (1981) and in the sloughs and side channels of the Susitna River (0.2-2.9 ft) (ADF&G 1983a and Chapter 7).

Chum salmon redd velocities observed at the Fourth of July tributary mouth area ranged from 0.1-4.5 ft/sec. All but one of these 28 velocities (4.5 ft/sec) were within the combined ranges of observed velocities of chum salmon redds reported by Hale (1981) in his literature review. The same outlying velocity was the exception again when tributary mouth area redd velocities were compared with the combined range of slough and side channel chum salmon redd velocities of the Susitna River (ADF&G 1983a and Chapter 7). The combined range of slough redd velocities for 1982 (ADF&G 1983a) and 1983 (Chapter 7) for the Susitna River was 0.0-1.8 ft/sec. A high percentage of velocities observed at chum salmon redds in tributary mouth areas exceeded this range. This may be explained by the unavailability of higher velocities in sloughs.

Predominate substrate types observed at chum salmon redds in the Fourth of July tributary mouth study area ranged from small gravel to cobble. This observed range corresponds well with the range of substrate types reported in the literature (sand to bedrock covered with small boulders) (Hale 1981) and in the sloughs (sand to boulders) and side channels (sand to cobble) of the Susitna River (ADF&G 1983a; Chapter 7) for chum

salmon redds (Note: only 3 of the 305 combined slough and side channel chum salmon redds had sand as the predominate substrate type). Substrate type had little influence in determining the limits of the chum salmon spawning utilizable habitat at the Fourth of July tributary mouth study area.

Although limited, the collection of the utilization data at the Fourth of July tributary mouth area serves as the initiation of an important data base since the tributary mouth area presents a wide range of the parameters deemed important in the selection of redd sites by spawning chum salmon. Based on the limited utilization data collected, it appears that the physical habitat conditions (water depths, water velocity, and substrate) may be the limiting factors for chum salmon redd site selection. Why, aren't they within criteria of other sites? what about upwelling, turbidity, discharge, dewatering as discussed below

Limitations

A limitation of this study is the limited precision of the hydraulic data analysis. Computer simulation of tributary mouth areas was not possible. Therefore, a method of delineating isopleths and digitizing areas between isopleths was devised. This procedure is time consuming and is not as accurate as computer simulation. With isopleth increments of 1.0, it is difficult to accurately estimate the fractional area within an increment which may be necessary to define graded (preferred, optimal) utilizable habitat area. Smaller isopleth increments could be used but determination of surface area between isopleths by digitizing becomes increasingly difficult as increment size decreases.

Another limitation is determining the importance of the tributary clearwater plume in defining utilizable habitat. Visual observations of spawning salmon beyond the clearwater plume is obstructed by the high turbidity associated with mainstem water; delineation of the utilized portion beyond the plume is impossible. If it could be assumed that spawning salmon limit their utilization of the habitat within the plume, utilizable habitat would basically be a function of plume size.

The importance of the clearwater plume may also be complicated by the presence of upwelling waters within the plume area. Since spawning chum salmon have been associated with areas of upwelling ground waters (Kogl 1965, Francisco 1977, Wilson et al. 1981, ADF&G 1983b), it may be possible that tributary waters flowing through the interstitial spaces of the unconsolidated alluvium at the mouth of the Fourth of July Creek are the impetus for chum salmon spawning. Although the seeping water is associated with the tributary, it may be less variable and more specific to the spawners than the plume itself. During times of low tributary discharge and limited clearwater plume surface area, spawning may take place in the turbid water areas downstream of the tributary/mainstem confluence. Although the plume is absent, spawning may be initiated by the detection of the seeping waters from within the gravels by the spawning salmon. Since seepage probably occurs only on the same side of the channel as the tributary, it follows that chum salmon spawning would only occur there. Although not definitive, surface water disturbances caused by spawning salmon were observed in the shallow waters of the clearwater plume but were not noted in the shallow waters near the opposite bank. This may indicate that salmon spawning was restricted to the tributary side of the channel.

A majority of the spawning areas observed at the Fourth of July tributary mouth area at a mainstem discharge of at least 21,000 cfs were dewatered at 8,040 cfs discharge. At winter mainstem discharges which approach 1,100 cfs (USGS 1975), additional spawning areas may also be dewatered. The salmon embryos in these dewatered areas must rely on upwelling or seeping intragravel waters to survive. If the embryos freeze and die in these areas, the observed spawning may be incidental; but, if the embryos are viable, these areas may be extremely important to the Fourth of July Creek stock chum salmon. Reductions in mainstem discharge during the chum salmon spawning period may prevent access by adults to these spawning areas.

Finally, the actual tributary mouth study area boundaries were a limiting factor in describing the habitat conditions within the total tributary mouth area because the study area did not include the total mouth habitat at all sampled tributary/mainstem discharges. However, the tributary mouth study area was considered to be representative of the total mouth habitat. This is especially true at the Lane Creek tributary mouth area since the clearwater plume was contained within the width of the study area at all mainstem/tributary discharges. Physical conditions varied little along the greatest extent of the tributary clearwater plume. At the Fourth of July Creek tributary mouth area, however, conditions changed radically as mainstem discharge decreased. Physical conditions at the tributary mouth area significantly changed at the Fourth of July Creek tributary mouth area. During the final sampling on October 8, 1983, Fourth of July Creek discharge was relatively high (55 cfs) while the side channel, which the tributary flows into, was extremely low (10-70 cfs). The clearwater plume of the

tributary encompassed the entire side channel below the confluence with the tributary to the confluence with the mainstem. Because of the very low stage of the Susitna River during this time, large areas of river bed within the tributary mouth study area were exposed. Total lengths of transects (200 feet) were dewatered. The watered side channel below the tributary confluence migrated beyond the dewatered transects out of the study area. (When the transects were established at a mainstem discharge of 24,000, the exposure of this large portion of riverbed was not anticipated). Upon inspection, the total wetted area of the side channel, including portions within and beyond the study area, appeared to be of usable salmon spawning habitat. If the study area included this portion of the tributary mouth habitat, percent of usable salmon spawning habitat would most likely increase. No appreciable percent increase in usable salmon spawning habitat would occur at the Lane Creek study area if the entire plume area was sampled.

Future investigations should consider the relationship of usable salmon spawning habitat within the tributary mouth habitats at sites where tributaries confluence with side channels and sloughs. Available and usable salmon spawning habitat within tributary mouth areas may be influenced by variations in tributary discharge at lower mainstem discharge (15,000 cfs USGS gaging station 15292000) rather than mainstem Susitna River discharges.

Suggestions to use computer simulation of the Fourth of July Creek tributary mouth area at fixed Susitna River discharges while varying tributary discharge are presently being considered by E.W. Trihey &

Associates and Woodward Clyde. This simulation may provide insight into the available habitat conditions present at the Fourth of July tributary mouth area with the proposed Watana Dam in operation.

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7.0 LITERATURE CITED

ADF&G. 1981. Aquatic habitat and instream flow project. Phase I Final Draft. Subtask 7.10. Prepared for Acres American, Incorporated, by the Alaska Department of Fish and Game/Su Hydro. Anchorage, Alaska.

ADF&G. 1982. Aquatic studies program. Phase II Final Draft. Subtask 7.10. Prepared for Acres American, Incorporated, by the Alaska Department of Fish and Game/Su Hydro. Anchorage, Alaska.

ADF&G. 1983a. Susitna Hydro Aquatic Studies Phase II basic data report. Volume 4. Aquatic habitat and instream flow studies, 1982. Alaska Department of Fish & Game Susitna Hydro Aquatic Studies. Anchorage, Alaska.

_____. 1983b. Susitna Hydro Aquatic Studies Phase II report. Synopses of the 1982 Aquatic Studies and analyses of fish and habitat relationships (2 volumes and appendices). Alaska Department of Fish and Game Susitna Hydro Aquatic Studies. Anchorage, Alaska.

_____. 1984. Susitna Hydro Aquatic Studies, May 1983 - June 1984, Procedures Manual. Alaska Department of Fish and Game Susitna Hydro Aquatic Studies. Anchorage, Alaska.

_____. 1984. Susitna Hydro Aquatic Studies Report Series, Report No. 3. A Aquatic Habitat and Instream Flow investigation, May through October, 1983. (eds. C. Estes and D. Vincent-Lang). (In Press).

LITERATURE CITED (continued)

Francisco, K. 1977. Second interim report of the Commercial Fish-Technical Evaluation Study. Joint State/Federal Fish and Wildlife Advisory Team. Special Report No. 9. Anchorage, Alaska, 46 pp.

Hale, S.S. 1981. Freshwater habitat relationships: chum salmon (Onchorhynchus keta). Alaska Department of Fish and Game, Habitat Division, Resource Assessment Branch. Anchorage, Alaska.

Kogle, D.R. 1973. Evaluation of the effects of flows on trout stream ecology. Dept. Engineering Research, Pacific Gas and Electric Co., Emeryville, California. 97 pp.

Milhous, R.T., D.L. Wegner, and T. Waddle. 1981. User's guide to the physical habitat simulation system. Cooperative Instream Flow Service Group, U.S. Fish and Wildlife Service, Washington DC. Instream Flow Information Paper No. 11. Report FWS/OBS 81/43. 1 Vol.

Schmidt, D.S., S.S. Hale, P. Suchanek and D.L. Crawford, editors. 1984 (in preparation). Resident and juvenile anadromous fish investigations (May-October 1983). Alaska Department of Fish and Game Susitna Hydro Aquatic Studies. Report No. 2. Prepared for Alaska Power Authority. Anchorage, Alaska.

LITERATURE CITED (continued)

U.S. Geological Survey. 1975. Surface water research of Cook Inlet Basin, Alaska through September 1975. U.S. Department of the Interior, Geological Survey 78-498.

U.S. Geological Survey. 1983. Provisional Susitna River discharge data for the 1983 water year ending September 1983.

U.S. Geological Survey. 1984. Provisional Susitna River discharge data for the 1983 water year ending September 1983.

Wilson, W.J., E.W. Trihey, J.E. Baldridge, C.D. Evans, J.G. Thiele and D.E. Trudgen. 1981. An assessment of environmental effects of construction and operation of the proposed Terror Lake hydroelectric facility, Kodiak, Alaska. Instream Flow Studies final report. Arctic Environmental Information and Data Center. Univ. of Alaska. 419 pp.