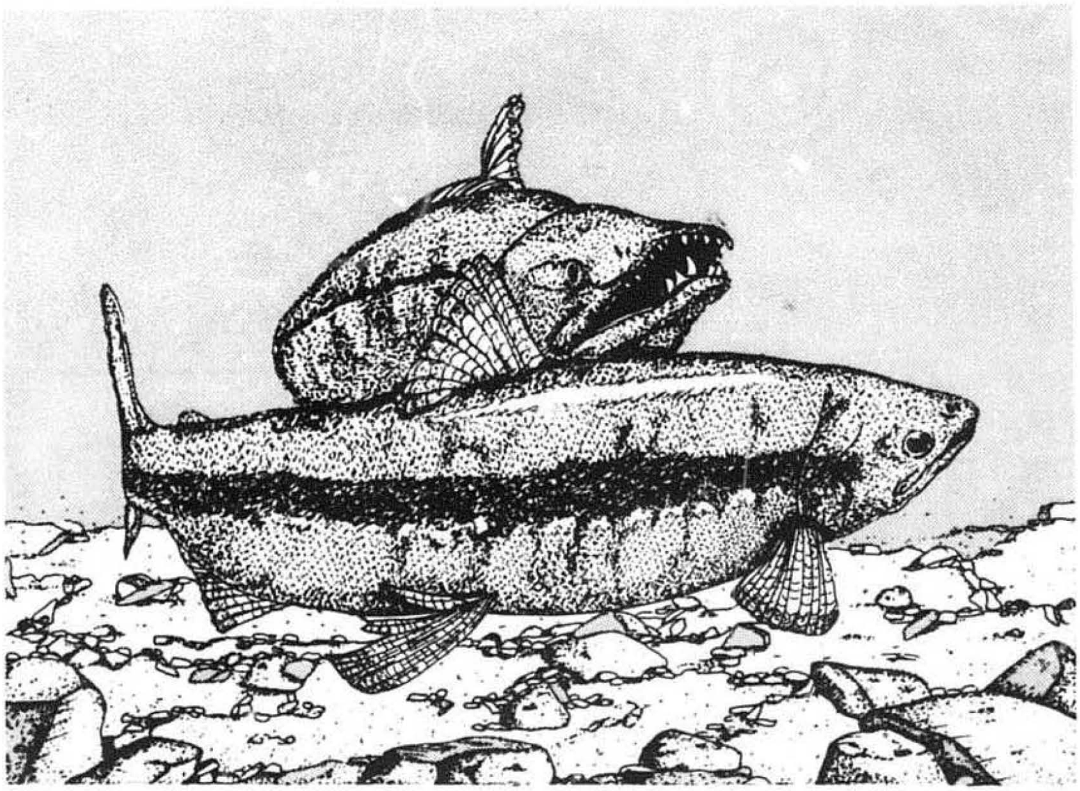
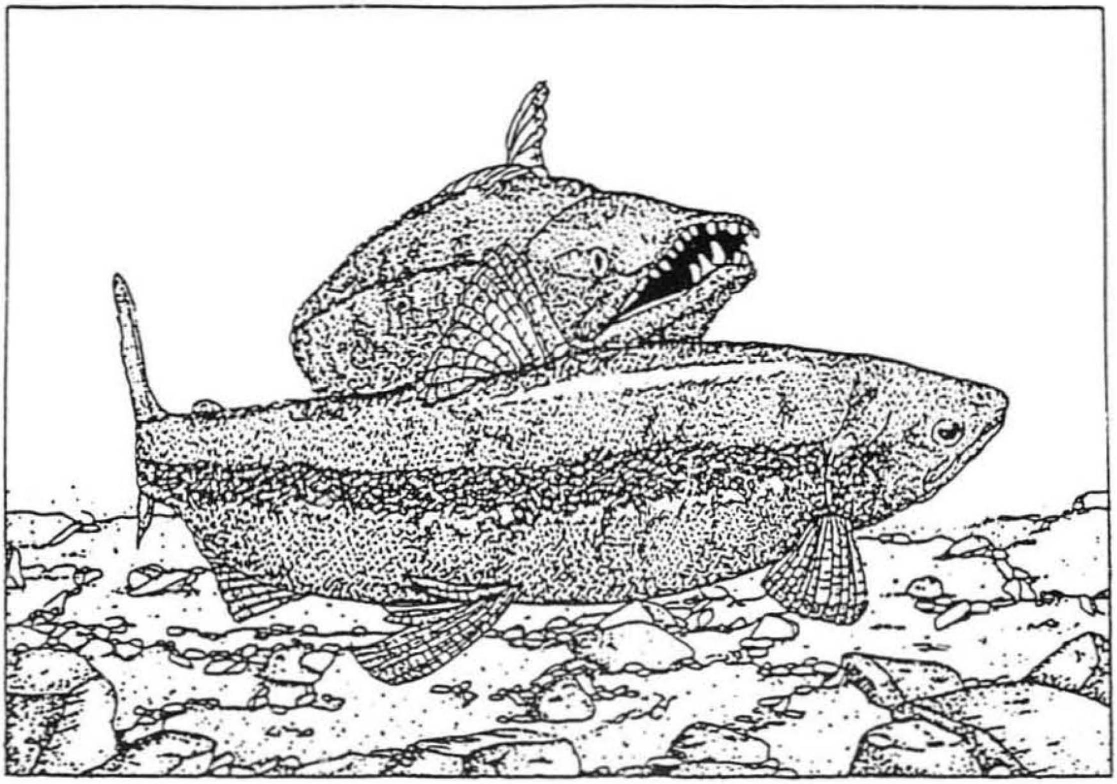


SUSITNA HYDRO AQUATIC STUDIES
PHASE II REPORT

Synopsis of the 1982
Aquatic Studies and Analysis of
Fish and Habitat Relationships

ALASKA
DEPARTMENT OF FISH AND GAME



SUSITNA HYDRO AQUATIC STUDIES
PHASE II REPORT

Synopsis of the 1982 Aquatic Studies and Analysis of Fish and Habitat Relationships

— APPENDICES —

by

ALASKA DEPARTMENT OF FISH AND GAME
Susitna Hydro Aquatic Studies
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1983

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APPENDIX A

Analysis of the Species Selectivity of Fishwheels for the Capture of Adult Salmon in the Susitna River.

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INTRODUCTION

In Alaska, fishwheels have been utilized for commercial and subsistence fishing since before the turn of the century. They are used primarily in glacial, turbid rivers such as the Yukon, Kuskokwim, Copper and Susitna rivers. In the early 1950's fisheries scientists began using fishwheels to monitor salmon escapement timing, abundance and to obtain salmon age, length, weight and sex composition samples. Fishwheels are still used for these purposes today.

One of the early recognized limitations of fishwheels in fisheries management and research programs was species selectivity. Meehan (1961) reported that chinook and coho salmon in the Taku River were least susceptible to recapture by fishwheel while pink salmon were more susceptible to recapture. He also noted fishwheel selectivity within a species; the smaller "jack" chinook salmon were more readily captured than the larger, older chinook salmon. He felt that fishwheel selectivity was manageable when the data were used as a relative index of the escapement and not as a definitive measure of the escapement.

It is the purpose of this report to address the question of whether fishwheels used in the Susitna River are in fact species selective and if so, to what extent.

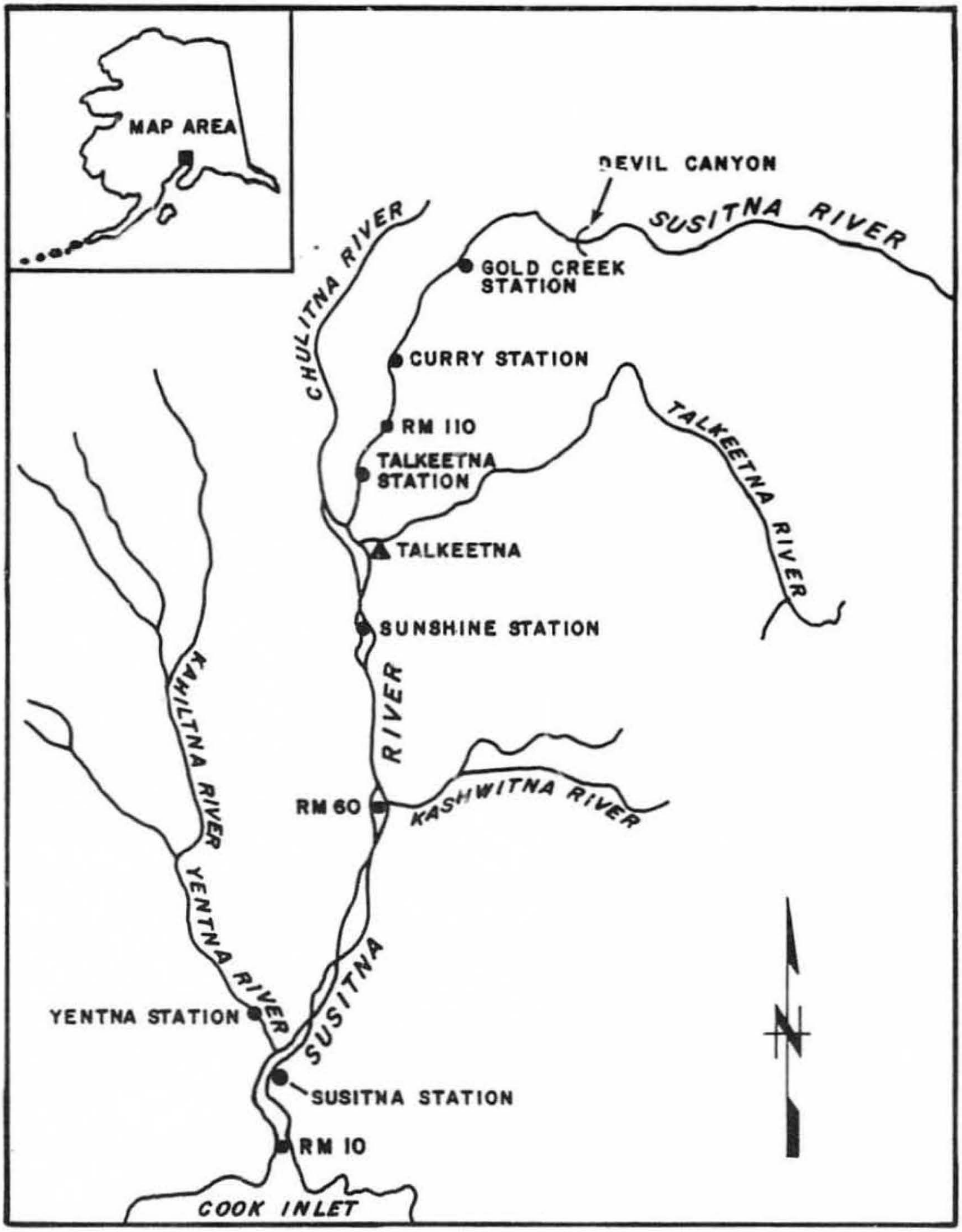
The Alaska Department of Fish and Game (ADF&G) Su Hydro, Adult Anadromous staff deployed fishwheels for tag/ recapture programs at several locations on the Susitna River mainstem including Sunshine, Talkeetna and Curry stations. Side scan sonar units were operated at Susitna, Yentna, Sunshine and Talkeetna stations with species apportionment of sonar counts provided by fishwheel catch data (Appendix Figure A-1). The equipment located at Susitna Station was managed by ADF&G, Commercial Fisheries Division, Soldotna.

METHODS

Tagging Process

Fishwheels, designed and built by ADF&G/Su Hydro, Adult Anadromous staff, were used to intercept salmon for tag application at Sunshine, Talkeetna and Curry stations in 1981 and 1982. Four fishwheels were located at Sunshine and Talkeetna stations and two at Curry Station. Fishwheel site locations and specifications may be obtained by consulting the Phase I, ADF&G/Su Hydro, Adult Anadromous Report (ADF&G 1981).

Rotating baskets of the fishwheels trapped adult salmon and exited them via a padded chute into a water filled live box. Individual captures were then dipnetted from the live box and placed on a padded platform. The fish were next tagged with a floy FT-4 spaghetti tag or a Petersen disc secured beneath the dorsal fin and released. Both tag types were color coded to identify capture station. Total time of the tagging process, from dipnetting to release, was 10 to 15 seconds.



Appendix Figure A-1. Susitna River basin map showing field stations and major tributaries.

Tag Recovery

Marked salmon were recovered during surveys of salmon spawning streams and sloughs above the tagging sites. Streams and sloughs were surveyed repetitively throughout the season at seven to ten day intervals. Surveyors recorded the number of tagged live salmon by tag type, color and species and the number of live untagged salmon by species. Results of the repetitive surveys were summed and provided the total number of salmon observed that had tags (r) and the total number of salmon examined for tags (c), by species and station. Only those surveys with good to excellent visibility conditions were used in computing the seasonal r/c proportions.

Tag Loss

The percent tag loss was used to adjust the number of tags recovered (r) for each species tagged at stations with reported tag loss. The adjustment was made as follows with the results presented in Appendix Table A-1:

$$r_{adjusted} = (1 + \text{percent tag loss}) \times r_{observed}$$

Data Analysis

Determination and quantification of fishwheel selectivity required two procedures. The first procedure statistically addresses the question of fishwheel selectivity and the second procedure is used to quantify fishwheel selectivity.

Appendix Table A-1 Percent tag loss based on surveys conducted between Talkeetna Station and Devil Canyon in 1981 and 1982

Tag Type	Tagging Station	Year	No. tagged fish examined	No. shed tags	Percent tag loss
FT-4/Spaghetti	Talkeetna	1981	397	27	7.5
FT-4/Spaghetti	Talkeetna	1982	386	26	6.3
Petersen disc	Curry	1982	325	3	0.9

Step 1: Determination of fishwheel selectivity

If fishwheels were non-species selective in capture it would follow that the number of salmon caught and tagged would be proportionally the same for each species. This can be tested by using the tag recovery data accumulated from surveys of streams and sloughs. Again, if fishwheels were non-species selective in capture the number of tagged salmon observed during tag recovery surveys should be proportionally the same for each species. A chi-square test of association was used to test the null hypothesis that the proportion of tagged salmon of each species observed during the tag recovery surveys was equal or:

$$H_o: \; r_1/c_1 = r_2/c_2 = \ldots r_i/c_i$$

where: r_i = total number of tagged adult salmon observed during tag recovery surveys for the i^{th} species

c_i = total number of the i^{th} species of adult salmon examined for tags during tag recovery surveys

This test incorporated the following assumptions:

1) Fishwheels were not selective for stocks within a species. Chinook salmon less than 351 millimeters in fork length were not tagged and therefore not considered in the analysis.

2) Tagged salmon mixed randomly with untagged salmon and exhibited essentially no behavioral differences.

3) Reported tag loss, by station and tag type, occurred at the same rate for all species.

4) Tagged and untagged salmon had no differential mortality.

5) Fishwheel efficiency and operation remained constant throughout the season.

Determination of fishwheel selectivity proceeded as follows:

1) The expected frequency of r for each species was calculated by:

$$r_i \text{ expected} = \frac{\sum r_i}{\sum c_i} \times c_i$$

It should be noted that r_i expected values are weighted by sample size.

2) A chi-square contingency table was calculated in the following form (Summer et al. 1981):

	Species 1	Species 2	Species 3	Species 4
r	cell X^2	cell X^2	cell X^2	cell X^2
r-c	cell X^2	cell X^2	cell X^2	cell X^2

The individual cell chi-square values are summed and with the appropriate degrees of freedom compared to a tabled value to determine if observed values differed significantly from expected values.

Step 2: Quantification of fishwheel selectivity

The second procedure was to quantify species selectivity if present. To accomplish this an expected value for r (E_r) not weighted by sample size was derived for each species. This expected value is not the same and should not be confused with the expected values used for the chi-square contingency table. These E_r values were determined by using the arithmetic mean of the observed r_i/c_i proportions (both r_i and c_i continue to be the observed number of tagged salmon (r_i) and the number of salmon observed (c_i) for the i^{th} species during tag recovery surveys) for all species at each station and multiplying this value by the total number of each species (c_i) examined for marks during tag recovery surveys. The resultant expected value for r (E_r) and the observed value for r (O_r) for each species were expressed as the ratio $O_r:E_r$. Setting E_r equal to one to define a base for comparison O_r then becomes a function of fishwheel selectivity herein referred to as the coefficient of selectivity (CS). CS values less than one indicate fewer tagged salmon of that species were observed during surveys than expected and conversely CS values greater than one indicate more tagged salmon of that species were observed during surveys than expected.

The percent deviation between observed r values (O_r) and expected r values (E_r) were determined for each species at each station. These values were derived by subtracting O_r from E_r and expressing this value as a percent of E_r. Observed r values that were greater than expected r values resulted in a negative percent deviation (-) and observed r values less than expected r values resulted in positive percent deviations (+). Percent deviations, regardless of sign, were divided into three categories:

1) $<$ 15% low deviation from expected value

2) 15% to 30% moderate deviation from expected value

3) $>$ 30% high deviation from expected value

RESULTS

Fishwheel Selectivity

All survey results and fishwheel catch data were provided in previous reports (ADF&G 1981; ADF&G 1983).

The null hypothesis, that proportion of tagged salmon of each species observed during tag recovery surveys was equal, was tested for salmon tagged at Talkeetna and Curry stations in 1981 and 1982. Salmon tagged at Sunshine Station were not included in the test as fishwheels there did not operate continuously and therefore had a disproportionate amount of capture effort expended for each species.

Results of the chi-square test indicated a highly significant ($1-P<.001$) difference between observed and expected values of r for sockeye, pink, chum and coho salmon tagged at Talkeetna and Curry stations in 1981 (Appendix Table A-2). Similarly, the results of the chi-square test for data collected in 1982 also indicated a highly significant ($1-P<.001$) difference between observed and expected values of r for chinook, sockeye, pink, chum and coho tagged at Talkeetna Station and chinook, sockeye, chum and coho salmon tagged at Curry Station (Appendix Table A-3). Fifty percent of the pink salmon captured at Curry Station in 1982 were tagged and subsequently they were not included in the analysis. Based on the chi-square test results, fishwheels operated at Talkeetna and Curry stations in 1981 and 1982 were species selective in capturing adult salmon.

Appendix Table A-2 Chi-square test results of observed versus expected number of tag recoveries during stream and slough surveys for salmon tagged at Talkeetna and Curry stations in 1981.

TALKEETNA STATION

Species	c[1/]	Observed[2/] r	Expected r	Cell X^2[3/]	Significance[4/] DF=3
Sockeye	4,167	286	296	.37	N.S.
Pink	724	82	51	11.36	**
Chum	5,944	346	423	16.98	***
Coho	852	117	61	27.21	***
Total	11,687	831	831	91.39[5/]	***

CURRY STATION

Species	c	Observed r	Expected r	Cell X^2	Significance DF=3
Sockeye	3,040	403	324	15.55	***
Pink	69	12	7	1.80	N.S.
Chum	4,033	345	430	20.76	***
Coho	105	12	11	.05	N.S.
Total	7,247	772	772	43.67	***

1/ c = Total number of fish examined for marks during stream and slough surveys

2/ r = Total number of tags (adjusted) recovered during stream and slough surveys

3/ X^2 = Chi-square

4/ Significance denotes 1-P values represented at: *< 0.05, **< 0.01, ***< .001, N.S. ≥ 0.05.

5/ Total cell X^2 includes all cells of chi-square table (that is including the X^2 associated with observed and expected c-r cells).

Appendix Table A-3 Chi-square test results of observed versus expected number of tag recoveries during stream and slough surveys for salmon tagged at Talkeetna and Curry stations in 1982.

TALKEETNA STATION

Species	c[1]	Observed[2/] r	Expected r	Cell X^2 [3/]	Significance[4/] DF=4
Chinook	1,436	88	183	49.52	***
Sockeye	2,128	287	272	.88	N.S.
Pink	13,936	2,597	1,779	376.61	***
Chum	9,588	503	1,223	424.42	***
Coho	1,065	118	136	2.36	N.S.
Total	28,153	3,593	3,593	978.70[5/]	***

CURRY STATION

Species	c	Observed r	Expected r	Cell X^2	Significance DF=3
Chinook	642	35	35	.00	N.S.
Sockeye	1,970	171	108	36.67	***
Chum	7,802	361	428	10.46	*
Coho	398	26	22	.80	N.S.
Total	10,812	593	593	50.72	***

1/ c = Total number of fish examined for marks during stream and slough surveys

2/ r = Total number of tags (adjusted) recovered during stream and slough surveys

3/ X^2 = Chi-square

4/ Significance denotes 1-P values represented as: * < 0.005, ** < 0.01, *** < 0.001, N.S. ≥ 0.05.

5/ Total cell X^2 includes all cells of chi-square table (that is including the X^2 associated with observed and expected c-r cells).

Quantification of Fishwheel Selectivity

The unweighted mean value of the r/c proportions and subsequently derived expected r values provided a quantitive method to assess the species selectivity of fishwheels located at Talkeetna and Curry stations. The deviation of the observed number of tag recoveries from stream and slough surveys and the calculated expected number of tag recoveries, provided the assumptions previously described are true, reflects the selectivity or non-selectivity of fishwheel captures for each species. Results for each species are summarized below:

Chinook salmon

Chinook salmon were tagged at Talkeetna and Curry stations in 1982 only. Chinook salmon less than 351 mm were not tagged. The coefficients of selectivity were 0.56 at Talkeetna Station and 0.61 at Curry Station. The percent deviation between the number of tag recoveries observed and the number expected was high, +44.0 percent at Talkeetna Station and +34.0 percent at Curry Station (Appendix Table A-4).

Sockeye salmon

Between year comparisons for sockeye, pink, chum and coho percent deviations and coefficients of selectivity required an analysis without chinook salmon, which were tagged in 1982 only. The results are provided in Appendix Table A-5 and A-6. Fishwheels were not selective toward

Appendix Table A-4 Coefficient of selectivity and percent deviation for chinook, sockeye, pink, chum and coho salmon tagged at Talkeetna and Curry stations in 1982.

TALKEETNA STATION

Species	Observed[1/] Values c	Observed Values r	Observed Values r/c	Expected[2/] Values r/c	Expected Values r	Coefficient of Selectivity	Percent Deviation
Chinook	1,436	88	.06	.11	157	.56	+44.0
Sockeye	2,126	284	.13	.11	233	1.22	-21.9
Pink	13,936	2,596	.19	.11	1,473	1.76	-76.2
Chum	9,588	502	.05	.11	1,054	.48	+47.6
Coho	1,065	117	.11	.11	117	1.0	0.0

CURRY STATION

Species	Observed Values c	Observed Values r	Observed Values r/c	Expected Values r/c	Expected Values r	Coefficient of Selectivity	Percent Deviation
Chinook	642	35	.06	.09	57	.66	+34.0
Sockeye	1970	171	.09	.09	177	1.05	- 4.9
Pink	4,470	726	.16	.09	371	1.96	-95.7
Chum	7,802	359	.05	.09	647	.55	+44.5
Coho	398	26	.07	.09	33	.79	+21.2

1/ c = total number of fish examined for marks during stream and slough surveys
r = total number of tags (adjusted) recovered during stream and slough surveys

2/ Expected values calculated by multiplying the non-weighted arithmetic mean of the observed r_i/c_i ratio for all species by the individual species observed c_i value.

Appendix Table A-5 Coefficient of selectivity and percent deviation for sockeye, pink, chum and coho salmon tagged at Talkeetna Station in 1981 and 1982.

1981

Species	Observed Values[1/] c	Observed Values[1/] r	r/c	Expected Values[2/] r/c	Expected Values[2/] r	Coefficient of Selectivity	Percent Deviation
Sockeye	4,167	299	.07	.10	416	.72	+28.1
Pink	724	86	.12	.10	72	1.19	-19.4
Chum	5,944	357	.06	.10	594	.60	+39.9
Coho	852	125	.15	.10	85	1.47	-47.1

1982

Species	Observed Values c	Observed Values r	r/c	Expected Values r/c	Expected Values r	Coefficient of Selectivity	Percent Deviation
Sockeye	2,126	284	.13	.12	257	1.11	-10.5
Pink	13,936	2,596	.19	.12	1,686	1.54	-54.0
Chum	9,588	502	.05	.12	1,160	.43	+56.7
Coho	1,065	117	.11	.12	128	.91	+8.6

1/ c = total number of fish examined for marks during stream and slough surveys
r = total number of tags (adjusted) recovered during stream and slough surveys

2/ Expected values calculated by multiplying the non-weighted arithmetic mean of the observed r_i/c_i ratio for all species by the individual species observed c_i value.

Appendix Table A-6 Coefficient of selectivity and percent deviation for sockeye, pink, chum and coho salmon tagged at Curry Station in 1981 and 1982.

1981

Species	Observed Values[1/] c	Observed Values[1/] r	r/c	Expected Values[2/] r/c	Expected Values[2/] r	Coefficient of Selectivity	Percent Deviation
Sockeye	3,040	386	.13	.13	380	1.02	- 1.6
Pink	69	12	.17	.13	8	1.50	-50.0
Chum	4,033	333	.08	.13	504	.66	+33.9
Coho	105	12	.11	.13	13	.92	+ 7.7

1982

Species	Observed Values c	Observed Values r	r/c	Expected Values r/c	Expected Values r	Coefficient of Selectivity	Percent Deviation
Sockeye	1,970	172	.09	.09	177	.97	+ 2.8
Pink	4,470	732	.16	.09	402	1.82	-82.1
Chum	7,802	362	.04	.09	702	.52	+48.4
Coho	398	26	.07	.09	35	.74	+27.7

1/ c = total number of fish examined for marks during stream and slough surveys
r = total number of tags (adjusted) recovered during stream and slough surveys

2/ Expected values calculated by multiplying the non-weighted arithmetic mean of the observed r_i/c_i ratio for all species by the individual species observed c_i value.

sockeye salmon in 1982 at either Talkeetna or Curry stations. The coefficients of selectivity in 1981 were 0.72 and 1.02 at Talkeetna and Curry stations and 1.11 and 0.97 in 1982. The percent deviation between observed and expected tag recoveries was -10.5 percent at Talkeetna Station and +2.8 percent at Curry Station, both low values. In 1981 sockeye salmon were caught at less than the expected rate (moderate percent deviation of +28.1 percent) at Talkeetna Station while fishwheels at Curry Station did not appear to be selective in capture (low percent deviation of -1.6 percent) (Appendix Table A-5 and A-6).

Pink salmon

Pink salmon tended to have consistently higher observed r values than expected. The coefficients of selectivity in 1981 were 1.19 and 1.50 at Talkeetna and Curry stations, respectively (Appendix Table A-5 and A-6). The CS values increased in 1982, the dominant pink salmon year in a two year cycle, to 1.54 and 1.82 at Talkeetna and Curry stations. In 1982, due to the large number of pink salmon in the Susitna River drainage and manpower constraints 50 percent of the pink salmon intercepted at Curry Station were tagged and in deriving the E_r values all tag recoveries were increased by a factor of two.

The percent deviation in 1981 was -19.4 and -50.0 percents at Talkeetna and Curry stations and increased to -54.0 and -82.1 percents in 1982 (Appendix Table A-5 and A-6). Pink salmon were captured by fishwheels at a rate that exceeded expectations regardless of the location.

Chum salmon

The number of chum salmon tag recoveries were lower than expected for fish tagged at Talkeetna and Curry stations in both 1981 and 1982. In 1981 the coefficients of selectivity were 0.60 and 0.66 at Talkeetna and Curry stations, respectively. In 1982 the coefficients of selectivity were lower, 0.43 and 0.52 in the above station order. The percent deviation remained high, greater than +30 percent at both Talkeetna and Curry stations in 1981 and 1982 (Appendix Table A-5 and A-6).

Coho salmon

Coho salmon tag recoveries and expected tag recoveries varied considerably between years and between sites. The coefficients of selectivity were 1.47 and 0.92 at Talkeetna and Curry stations in 1981 and 0.91 and 0.74 in 1982. In 1981 the percent deviation at Talkeetna and Curry stations were -47.1 and +7.7 percents, respectively. In 1982 for the same stations the percent deviations were +8.6 and +27.7 percents (Appendix Table A-5 and A-6).

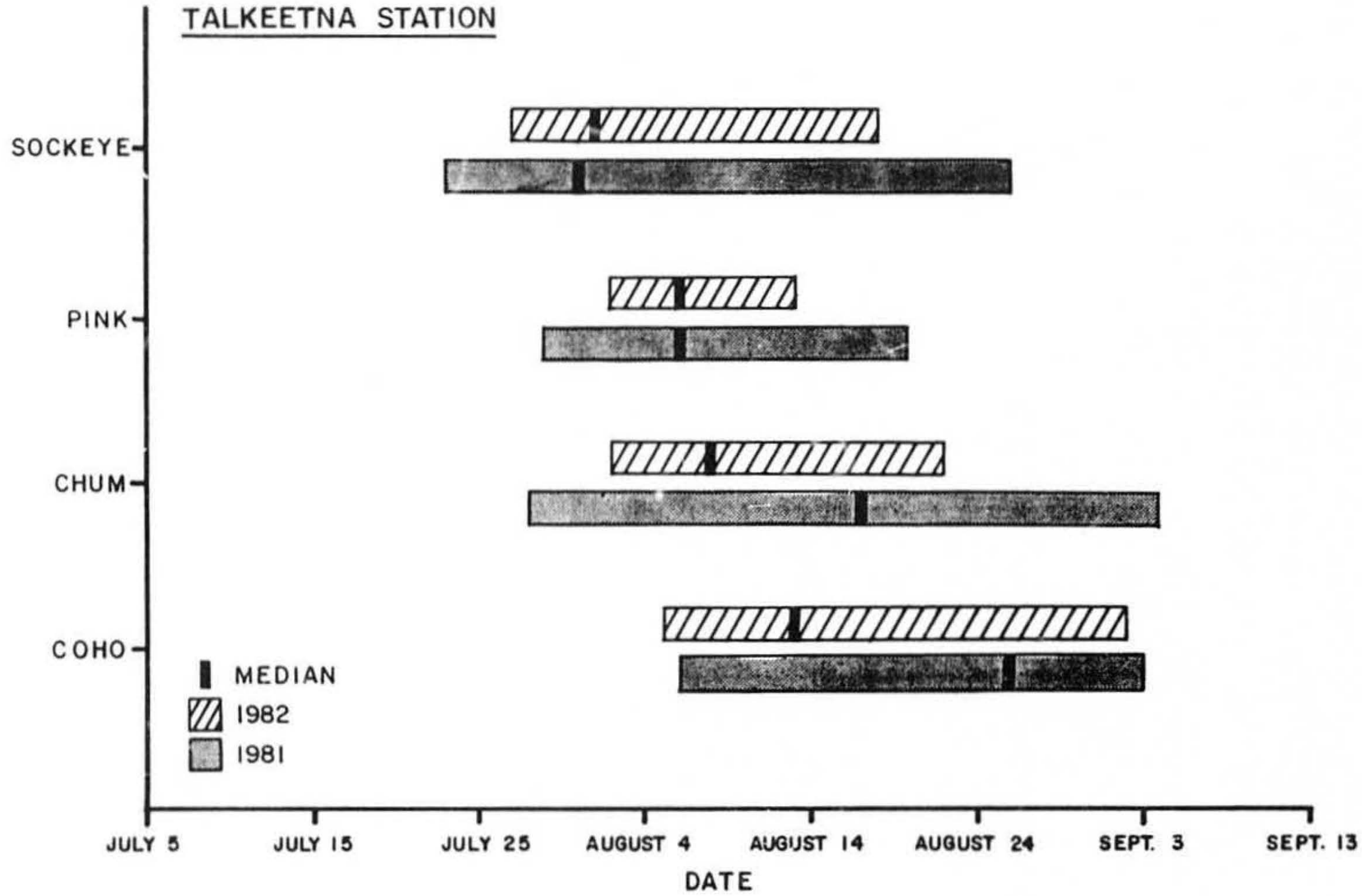
DISCUSSION

It has been determined that fishwheels are species selective at two sites on the Susitna River. Selectivity can be a function of many parameters such as fishwheel site, channel configuration, water velocity, fish size and behavioral traits. These parameters have been considered intuitively by fisheries biologists but were difficult to quantify. The large number of fish tagged and the extensive random surveys pursuant to goals of this project provided a means for quantifying fishwheel selectivity. For reasons yet to be defined chinook and chum salmon are under-caught by fishwheels at Talkeetna and Curry stations while pink salmon are over-caught. Sockeye and coho salmon were caught at rates that deviated from expected catch rates but were not consistently under- or over- caught by fishwheels at Talkeetna and Curry stations.

Having established fishwheel selectivity, it becomes apparent that using fishwheels to apportion sonar counts in the Susitna River would bias the counts based on the selectivity of the fishwheels at that site. This bias can change constantly, from no bias (one species present) to bias which severely impacts daily sonar estimates of the number of each species present (when two or more species temporally overlap). This is graphically portrayed in Appendix Figure A-2 where as many as four species overlapped in migrational timing in 1981 and 1982 at Talkeetna Station.

It may be possible, in the future, to formulate reasonable escapement estimates based on fishwheel catch statistics. Analysis indicates that fishwheels intercept a near constant proportion of the escapement (Talkeetna and Curry stations). Based on r/c proportions, fishwheel catches between years usually vary 5 percent or less for an individual species.

Additional data would be required to assess the feasibility of using fishwheel catch data as a method of determining escapement size.



Appendix Figure A-2. Migrational timing of sockeye, pink, chum and coho salmon at Talkeetna station in 1981 and 1982.

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APPENDIX B

Timing and Passage of Adult Salmon in the Mainstem Susitna River and Access into Selected Sloughs Upstream of the Chulitna River Confluence

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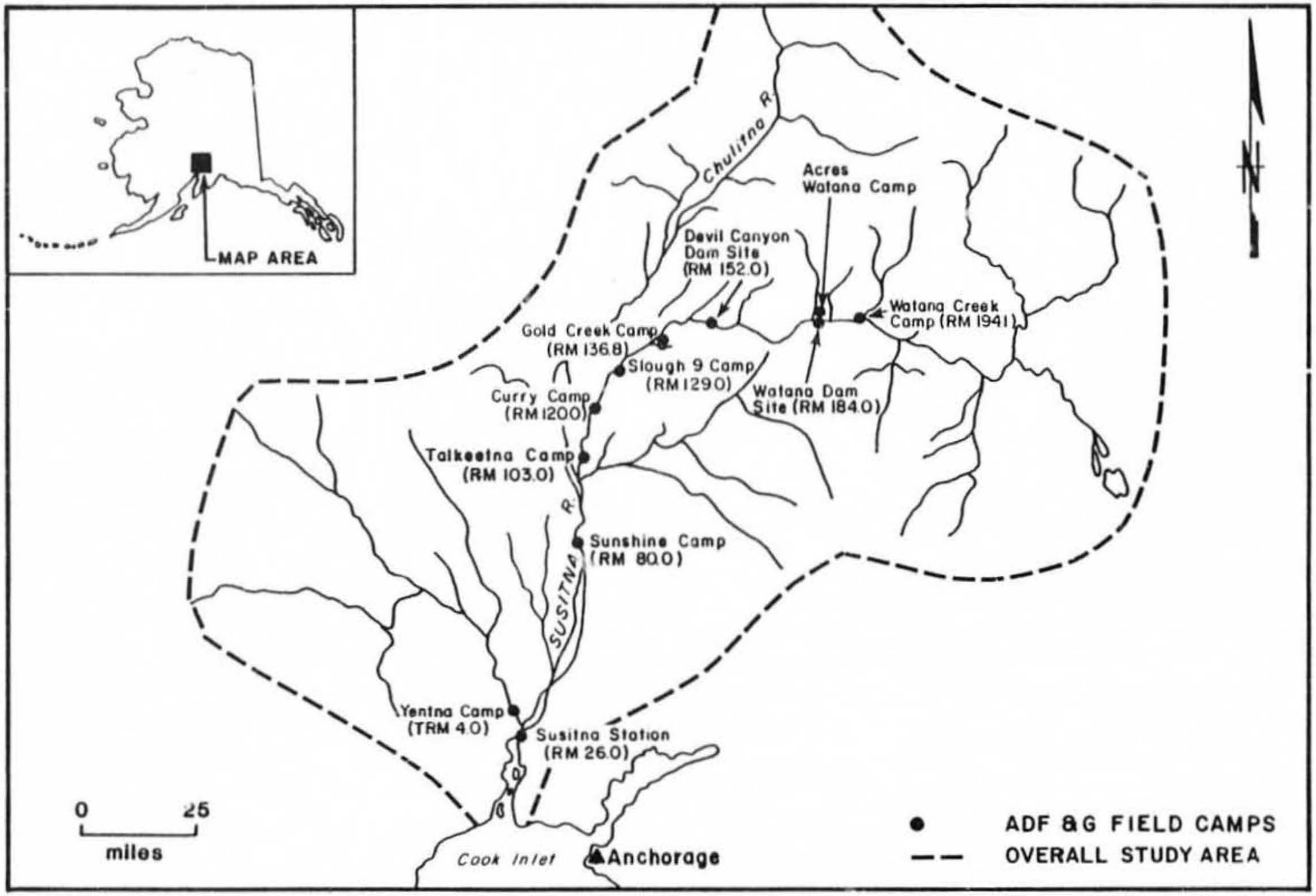
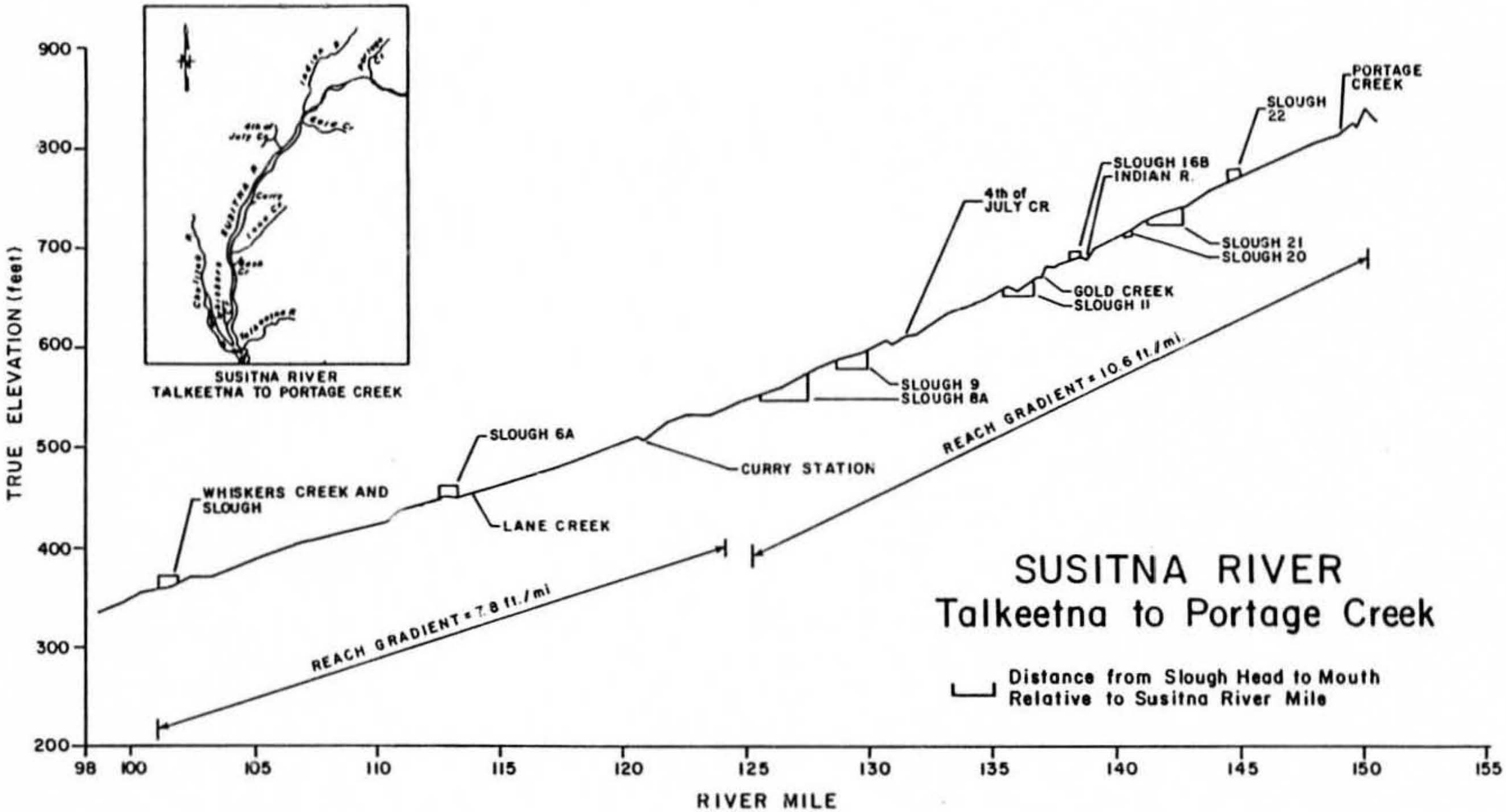
INTRODUCTION

This appendix is an assessment of the timing of upstream migration patterns of adult Pacific salmon (*Oncorhynchus* spp.) in the Susitna River (Appendix Figure B-1), and an analysis of access conditions for adult salmon passage into the mouths of nine selected sloughs (Appendix Figure B-2) located in the reach between Talkeetna (RM 103.0) and Devil Canyon (RM 157.0, Appendix Table B-1). The slough access portion of this appendix is an expansion of an earlier analysis (Trihey 1982) of Slough 9 data collected by the Alaska Department of Fish and Game (ADF&G). Adult salmon access conditions into the mouths of selected tributaries in the Talkeetna to Devil Canyon reach have been evaluated in a separate report by Trihey (1983). Qualitative analyses of general spawning habitat conditions for salmon in 14 sloughs and relative usage within 34 sloughs (including the 9 sloughs evaluated for fish access conditions in this appendix) and 22 tributaries are presented in Appendix C. A quantitative analysis of the influence of slough flows on the availabiltity of selected spawning habitat criteria within three of the sloughs evaluated in Appendices B and C is reported in Appendix D.

Five species of Pacific salmon (chinook, *O. tshwayscha*; coho, *O. kisutch*; sockeye, *O. nerka*; chum, *O. keta*; and pink, *O. gorbuscha*) use various habitats within the Cook Inlet (RM 0) to Devil Canyon (RM 157) reach of the Susitna River (ADF&G 1983b: Volume 4). Hydraulic barriers within Devil Canyon prevent access of salmon to habitats above RM 156.8 (ADF&G 1983b: Volumes 2, 4). Use of each habitat type varies for species and life phases. Appendix Table B-2 lists the habitats which



Appendix Figure B-1. Overall study area of the Susitna Hydroelectric Feasibility Study Program, Susitna River, Alaska.



Appendix Figure B-2. Slough locations and gradient of the Susitna River from Talkeetna (RM 99.6) to Portage Creek (RM 148.8).

Appendix Table B-1 Summary index (by river mile) for locations referred to in this appendix.

River Location	River Mile
Susitna Station	26.0
Sunshine Station	80.0
Whiskers Creek Slough	101.2
Talkeetna Station	103.0
Slough 6A	112.3
Lane Creek Slough	113.6
Curry Station	120.0
Slough 8A	125.3
Slough 9	129.2
Slough 11	135.3
Gold Creek Station	136.8
Slough 16B	138.0
Slough 19	139.7
Slough 20	140.1
Slough 21	142.0
Slough 22	144.3
Devil Canyon	157.0

Appendix Table B-2 Known distribution of salmon species by life phase and habitat type in the Susitna River Basin.

SALMON SPECIES & LIFE PHASE	HABITAT TYPES UTILIZED ON MODERATE BASIS					
	TRIBUTARY	TRIBUTARY MOUTH	UPLAND SLOUGH	SIDE SLOUGH	SIDE CHANNEL	MAINSTEM
Chinook						
Adult Passage	X	X			X	X
Spawning	X	X				
Incubation	X	X				
Rearing	X	X	X	X	X	X
Coho						
Adult Passage	X	X			X	X
Spawning	X	X				
Incubation	X	X				
Rearing	X	X	X	X	X	X
Chum						
Adult Passage	X	X		X	X	X
Spawning	X	X		X	X	X
Incubation	X	X	X	X	X	X
Rearing	X	X	X	X	X	X
Sockeye						
Adult Passage				X	X	X
Spawning				X		
Incubation				X		
Rearing			X	X		
Pink						
Adult Passage	X	X			X	X
Spawning	X	X				
Incubation	X	X				
Rearing						

are utilized on a moderate basis by each life phase of salmon in the Susitna River. The most intensively used spawning areas within the Talkeetna to Devil Canyon reach are located in tributaries and sloughs. Tributaries are used most heavily for spawning by chinook, coho, chum and pink salmon, whereas sloughs are used primarily by chum, pink, and sockeye salmon. Mainstem and side channel habitats are used to a limited extent by chum salmon.

The proposed Susitna hydroelectric project would alter the existing streamflow, sediment and thermal characteristics of the Susitna River. Streamflows would be reduced during the summer and increased during the winter (Acres 1982). Suspended sediment, turbidity, and water temperatures are expected to follow similar patterns. Unregulated preproject flows of the Susitna River at Gold Creek commonly range between 20,000 and 30,000 cfs in June, July, and August (Scully et al. 1978) during the adult salmon migrations. Average monthly postproject streamflows at Gold Creek would range between 7,000 and 11,000 cfs during June, July, and early August, with a proposed controlled flow of no less than 12,000 cfs from mid-August to mid-September (Acres 1982).

At the projected postproject flows of the mainstem Susitna River, sloughs are hydraulically similar to small stream systems and convey clear water originating from small tributaries and/or upwelling groundwater (ADF&G 1981b, 1982, 1983b: Volume 4). At intermediate and higher flows, the stage of the mainstem Susitna River forms a hydraulic plug at the downstream end (mouth) of the slough and creates a backwater zone. Water depth and the surface area of these slough backwater zones varies with mainstem discharge. Depth and surface area responses of these backwater areas to various mainstem discharges appears to influence the immigration of adult salmon from the mainstem river into the sloughs.

Importance of Timing

The tendency of adult salmon to return to their natal stream to spawn is well established (Hasler 1966, 1978; Tesch 1980, Groot 1982, Brannon 1982). The timing of the life phases of salmon have evolved in such a way that their life functions are timed to correspond with the seasonal changes of the natural environment which will ensure their continued existence. Maturing salmon undergo physiological changes which trigger their upstream migration from saltwater to freshwater spawning grounds. Brannon (1982), Hasler (1978) and Johnson (1982) suggest that migrating salmon cue on flow, temperature and odor to locate their natal stream for spawning. If unfavorable discharges, water temperatures, turbidity levels or water quality delay or prevent arrival at natal spawning grounds, it may reduce the likelihood that spawning will be successfully completed (Reiser and Bjornn 1979).

Importance of Access

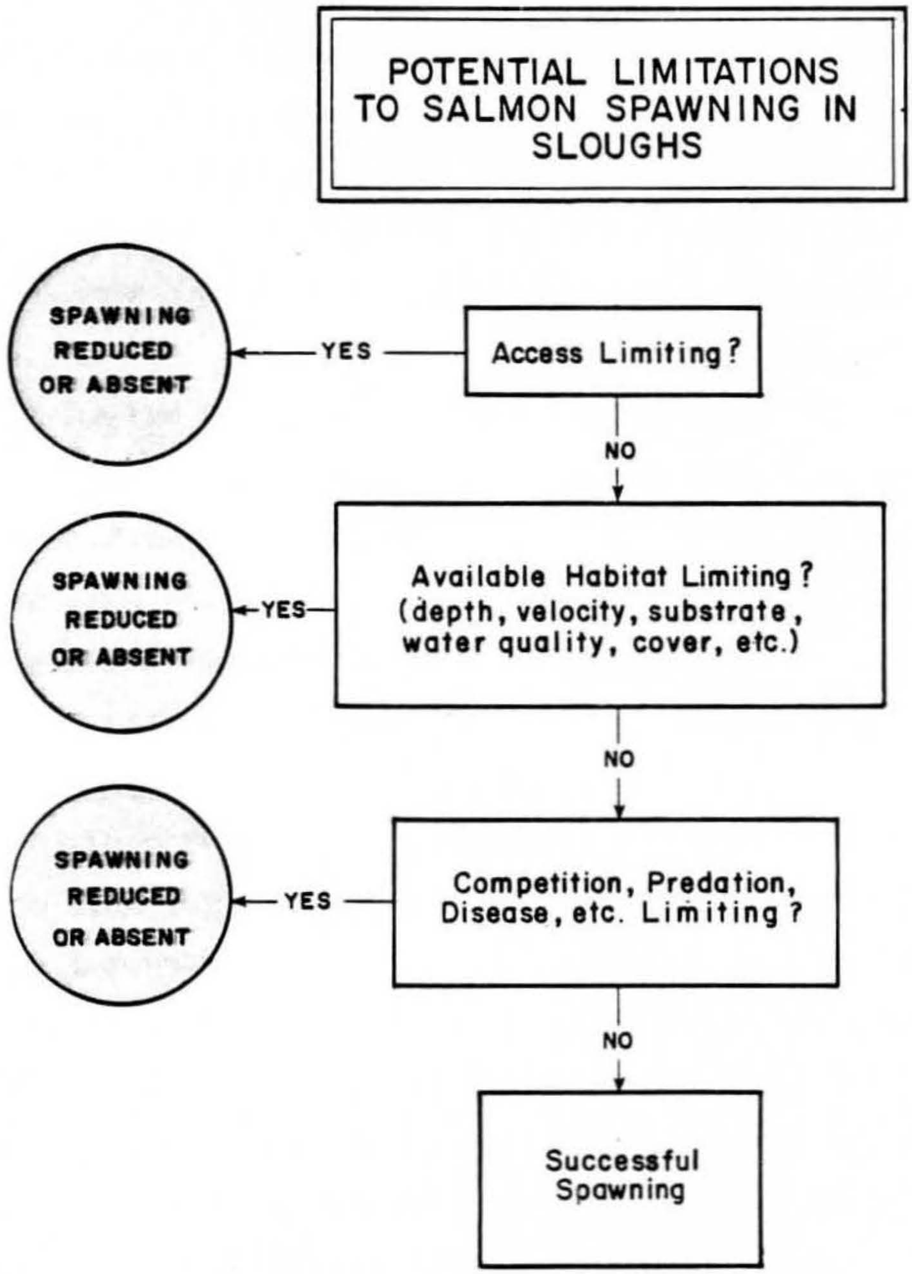
Positive rheotactic migration of salmon from the Susitna River into natal tributary and slough spawning areas is dependent upon adequate water velocities and depths which will allow passage. When access is denied into a spawning area, all habitat above the impass is unavailable for use by adult salmon (Appendix Figure B-3).

Field observations of entrance conditions at several sloughs in the Talkeetna to Devil Canyon reach (ADF&G 1983b: Volume 4) indicate that it is unlikely that velocity barriers will exist at these locations under the proposed post project flow regime discussed above. Thus, the ease with which adult salmon can enter sloughs from the mainstem Susitna River under post project conditions would primarily be a function of depth.

METHODS

Timing of Upstream Migration

To evaluate whether timing of upstream migration of adult salmon is affected by mainstem discharge and/or surface water temperature, numbers of salmon captured in fishwheels were plotted against Susitna River discharge data and surface water temperatures. Adult salmon were counted daily at fishwheels located at four mainstem sites on the Susitna River: Susitna Station (RM 26), Sunshine Station (RM 80), Talkeetna Station (RM 103) and Curry Station (RM 120). Specific methods and data are presented in ADF&G (1983b: Volume 2). Discharge data (USGS 1982) for the fishwheels at Susitna Station were recorded at Susitna Station (#15294350), RM 25.7; for the Sunshine Station fishwheels at Sunshine (#15292780), RM 83.9; and for the Talkeetna and Curry Station fishwheels at Gold Creek (#15292000), RM 136.7.



Appendix Figure B-3. Factors potentially limiting salmon spawning in sloughs.

Daily surface water temperatures were recorded by Ryan thermographs at four locations near the fishwheels. Thermograph recorders were located in the Susitna River above the confluence of the Yentna River (RM 29.5), at the Parks Highway Bridge (RM 83.9) and at Talkeetna (RM 103) and Curry Stations (RM 120). Specific methods and data are presented in ADF&G (1983b: Volume 4).

Timing of Movement into Sloughs and Tributaries

Fish survey data from 1981 (ADF&G 1981a) and 1982 (ADF&G 1983b: Volume 2) were compared with discharge data from the Gold Creek gaging station for the respective years (USGS 1981, 1982) to evaluate timing and discharge relationships. In 1981 and 1982, ADF&G observers surveyed sloughs and tributaries approximately once each week counting live, dead and total numbers of salmon from mid-July through September. In 1982, an additional survey was conducted in late October. In sloughs, numbers of the adults of each species were censused at each visit; whereas in tributaries, numbers of each species were counted only in a portion (index area) of each tributary. In 1981, foot surveys to count chum, sockeye, pink and coho salmon began in late July and ended in early October. Surveys for chinook salmon were performed by helicopter, fixed-wing aircraft, and in one instance, by foot. In 1982, surveys for all species were performed on foot and/or helicopter, and began in mid July and ended in late October. A detailed discussion of methods is included in ADF&G (1981a, 1983b: Volume 2).

Slough Access Conditions

Two analytical methods were used to evaluate slough access conditions for adult chum salmon. These methods are adaptations of procedures summarized by Stalnaker and Arnette (1976), Thompson (1972, 1983), and Bovee (1982). The first method, the most data intensive of the two, was applied to sloughs 8A, 9, 11, and 21. The second method was applied to Whiskers Creek Slough and sloughs 6A, 16A, 20, and 22. Selection of the method was dependent upon the amount and type of information available.

Chum salmon were selected for this study because they are the most abundant of the adult salmon species to utilize slough habitat. They also appear to have the most restrictive of passage requirements of adult salmon (Scott and Crossman 1973).

Method one

Access conditions into sloughs 8A, 9, 11 and 21 for adult chum salmon were evaluated by 1) determining water depths and longitudinal distance in passage reaches* at the mouths of each slough at various mainstem flows of the Susitna River and 2) comparing the length and depths of these passage reaches to fish spawning criteria. Water depths and lengths of reaches within sloughs were determined by surveying streambed

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* Reaches within the slough mouth which the salmon pass through to access spawning habitat within the slough.

profiles (thalwegs*). The water surface elevations (WSEL) at staff gages were recorded at the same time. Fish criteria for passage were developed from a combination of visual observations and physical measurements.

Thalwegs

Thalwegs were surveyed along the entire length of the four study sloughs during low water conditions in October 1982. Thalweg data were collected using a surveying level, standard surveying rod, and rod level employing standard surveying techniques of differential leveling (Trihey and Wegner 1981). At the beginning of each survey, a temporary bench mark (TBM) was established that was later surveyed to a known elevation. Two steps were followed when surveying the thalweg in a slough. First, points of significant change of the slough bed elevation along a longitudinal gradient were determined by visual assessment (i.e., tops and bottoms of riffles, bottoms of pools, etc.). Upon completion of the initial step, an observer stood at the point of longitudinal gradient change and visually evaluated a perpendicular crossection passing through the point and selected the location where the water was deepest. Longitudinal distances between the location of greatest water depth in each crossection were measured (to the nearest foot) by using a surveying tape or by recording the stadia rod values observed with a level and computing distances. When survey data (i.e., crossections at

* The line following the deepest part or middle of the bed or channel of a river or stream (Arnette 1975).

study sites, staff gage sites or the mouth or head of a slough) were available from previous work in a slough and met the requirements for developing a thalweg profile, they were used in conjunction with or in lieu of additional thalweg survey work.

Staff gages

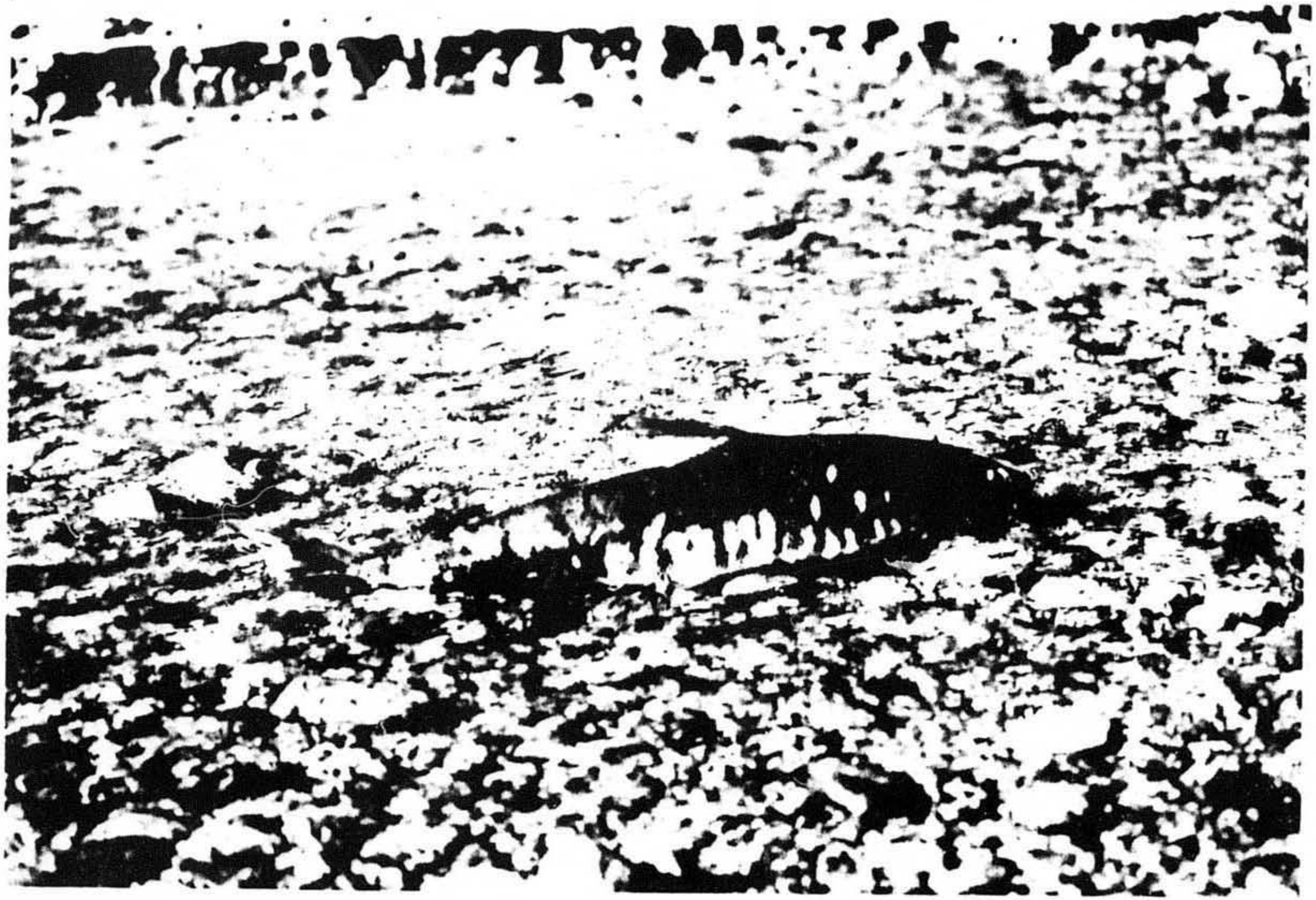
Sites for staff gage installations at the mouths of sloughs were selected in order to evaluate the influence of mainstem discharge on water depth in fish passage reaches within the slough mouth. An assumed elevation, which was referenced to a temporary bench mark (TBM), was determined for each staff gage using basic survey techniques of differential leveling (Bovee and Milhous 1978, Trihey and Wegner 1981, ADF&G 1983a). All TBM's were surveyed to a known elevation (project datum) so that resultant stage readings could be converted to true WSEL. Water surface elevations in Slough 8A were determined from stage readings obtained at R&M staff gage #125.2W1 at the mouth of the slough. Stage data in Slough 9 were obtained at staff gages (#1292W1A and #129.2W1B) located 500 ft downstream of the slough mouth. In Slough 11, two gages were used. One gage was installed at the mouth (gage #135.3W1) and one in the side channel approximately 250 ft downstream from the mouth (gage #135.3M4A). In Slough 21, three gages were used: one at the mouth (gage #142.0W5), one approximately 500 ft upstream from the mouth (gage #142.0S7) and one approximately 500 ft downstream from the mouth (gage #142.0S6).

When possible, stage data were collected over a range of high, medium and low discharges. The data were then were converted to WSEL and plotted against corresponding average daily mainstem discharges at the USGS Gold Creek gaging station. A linear fit was constructed by interconnecting the data points. These graphs also provide the basis for interpolating WSEL data for unobserved mainstem flows.

Fish passage reaches with shallow water depths were identified by plotting the WSEL at the slough mouth at various mainstem discharges on the same graph as the streambed profile. Each passage reach was then evaluated at various mainstem discharges on the basis of depth of water and length of the passage reach (see Fish passage criteria below) to determine critical mainstem discharges required for passage of fish.

Fish passage criteria

Fish passage criteria were developed to define threshold conditions for water depths which would prevent or allow access of adult chum salmon into the mouths of sloughs from the mainstem Susitna River. They were not designed to evaluate interim passage conditions within these two extremes. Criteria for access into sloughs by adult chum salmon are based upon a combination of visual observations (Vining et al. 1982, Vining 1982, Trihey 1982) of chum salmon passage from the mainstem Susitna into the mouths of sloughs and a series of point water depth measurements in the proximity of adult chum salmon attempting to ascend a 250 ft riffle in Slough 9 on August 24, 1982 (Appendix Plate B-1). The point specific depth measurements were collected throughout a fish



Appendix Plate B-1. Chum salmon stranded in riffle (approximate water depth = 0.2 ft) near mouth of Slough 9 on August 24, 1982. Slough discharge was approximately 3 cfs.

passage riffle area in the mouth of Slough 9. Fish stranding was observed to occur in water depths averaging 0.3 ft or less. Although the distance ascended varied among individual fish, the average maximum distance that fish ascended within a riffle before becoming stranded was estimated to be 100 ft. Reaches having water depths greater than 0.3 ft (regardless of their length) were not considered to be impassable for adult chum salmon. Therefore, if the water depth in a slough reach was equal to or less than 0.3 ft for a distance equal to or exceeding 100 ft, it was considered to be impassible for adult chum salmon and designated as being an "acute" condition. Reaches having water depths greater than 0.3 ft were designated as "unrestricted" fish passage conditions. Data to quantify interim degrees of passage conditions were not evaluated.

Method two

To expand the fish access evaluation analysis to sloughs other than those, surveyed for streambed profiles, adult salmon access conditions into Whiskers Creek Slough and sloughs 6A, 16B, 20 and 22 were estimated by 1) determining average water depths in the mouth of the slough at various mainstem flows of the Susitna River; and 2) comparing the depths to fish passage criterion.

Stage

Data from cross sections, staff gages, and rating curves for slough stage/ mainstem discharges (ADF&G 1983b: Appendix 4-A) were combined with professional judgement (based on field observations) to estimate an average minimum water depth for the mouth of each slough. Specific methods for collecting the staff gage and cross section data are presented in ADF&G (1983b: Volume 4). Staff gage and cross sectional data were collected from the following locations: Whiskers Creek - gage site 101.2W1; Slough 6A - 112.3W1; Slough 16B - gage site 138.0W1 and an additional cross section at RM 137.8; Slough 20 - gage site 140.1W4; and Slough 22 - gage site 144.3W3.

The mainstem flow at Gold Creek at which the cross section at the mouth of the slough would be dewatered was determined from a comparison between the cross sectional profile at the slough mouth and the WSEL versus mainstem flow relationship. Values were then adjusted by field personnel to reflect what they considered representative of the fish passage reach of slough at the mouth. This adjustment was necessary because: 1) cross sections did not necessarily represent the most critical access conditions in the slough because they were established during periods of high flow; and 2) thalweg data were unavailable to determine specific lengths of reaches in which passage problems would be encountered.

Fish passage criterion

A minimum water depth of 0.5 ft was defined as the threshold condition which would prevent or allow access of adult chum salmon into the mouths of sloughs from the mainstem Susitna River. This criterion was not designed for evaluating interim passage conditions within these two extremes.

The passage criteria in Method One could not be utilized because lengths of specific passage reaches could not be defined. Therefore a more conservative value of 0.5 ft was selected as the limiting variable for passage by combining the fish passage criteria in Method One with those of Thompson (1972, 1983) and professional judgement.

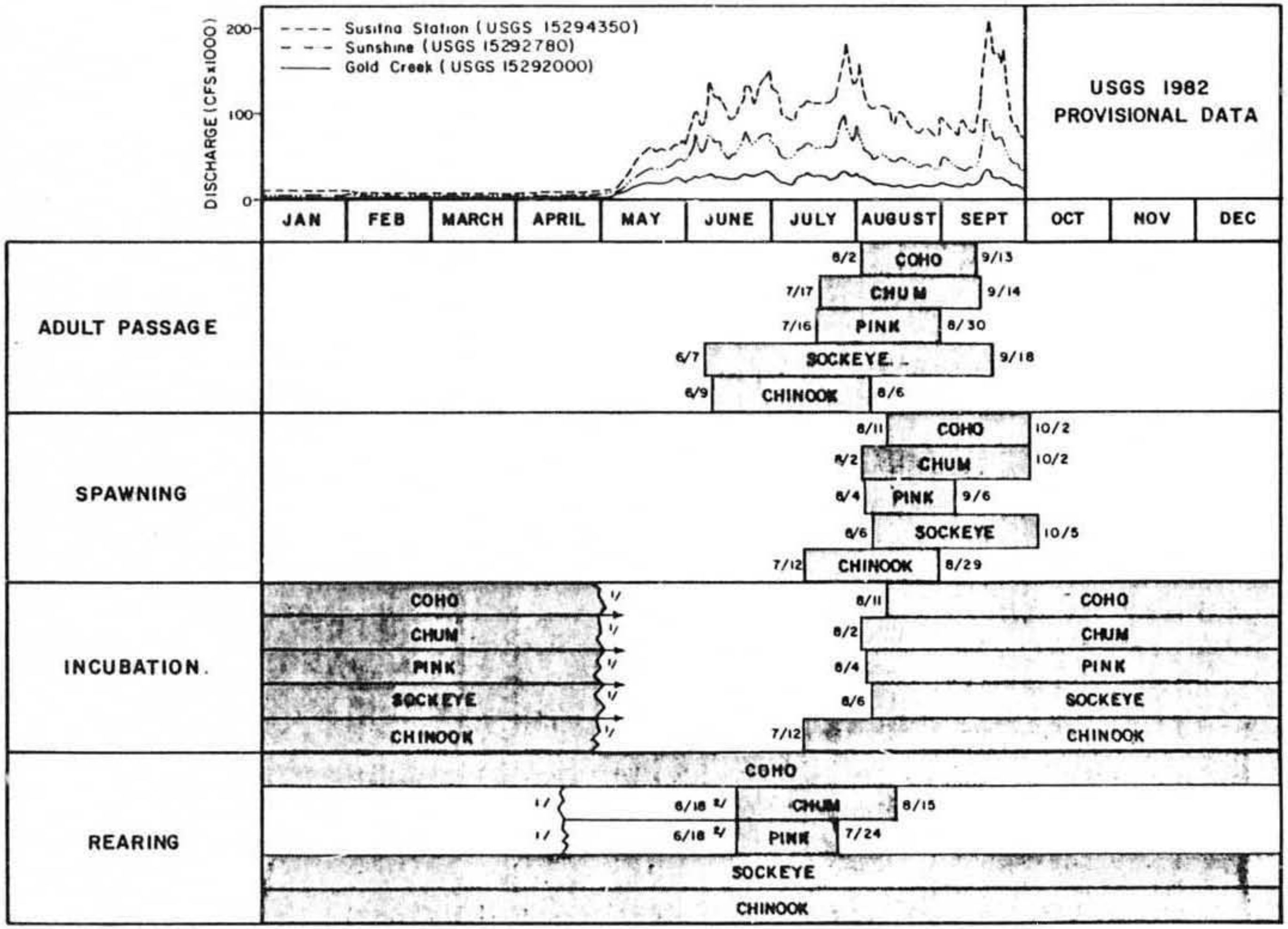
Thus, for this second approach to passage analysis, mainstem flows resulting in an average minimum water depth less than 0.5 ft at the slough mouth were considered acute and those providing depths of 0.5 ft or greater were considered unrestricted.

RESULTS

Timing of Upstream Migration

Although the migration periods of several species of salmon overlapped, median points for each species were generally distinct (Appendix Figure B-4 and 5). Following an early run of sockeye salmon, chinook salmon were the first species of salmon to immigrate into the Susitna system in significant numbers. The median for numbers of chinook salmon were followed by the medians for numbers of sockeye, pink, chum and coho salmon, respectively.

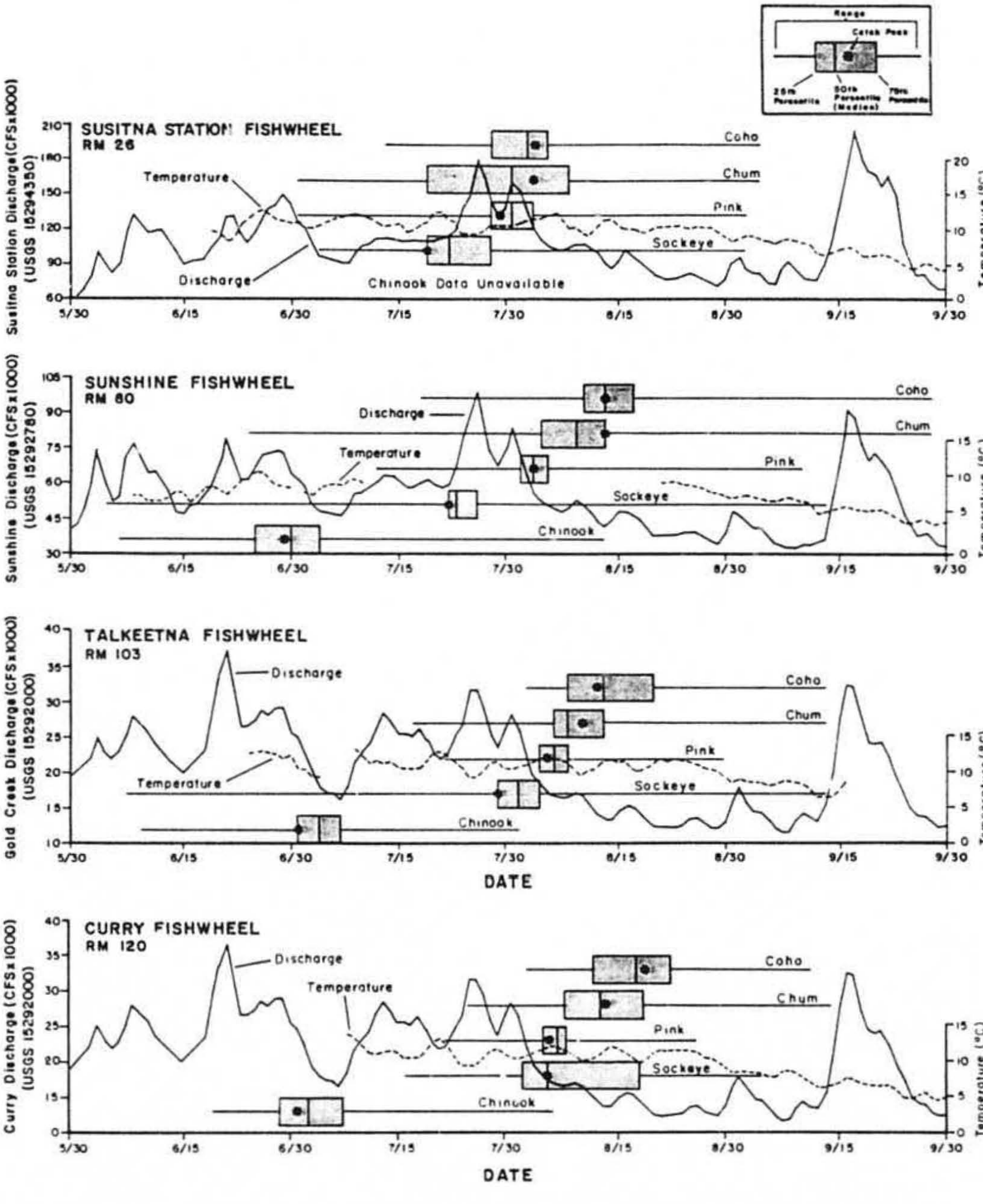
Because there appears to be an inverse relationship between discharge and temperature (Appendix Figure B-5) it is not possible to distinguish their separate effects on upstream movements of salmon. Both of these variables undoubtedly affect a host of other physical and chemical



1/ EMERGENCE DATA NOT AVAILABLE AT TIME OF PREPARATION

2/ DATA FROM SMOLT TRAP, INSTALLED 6/18/82

Appendix Figure B-4. Timing of salmon migration, spawning, incubation and rearing in the Susitna River system above Talkeetna, and Susitna River discharge at Gold Creek RM 136.6, #15292000 (USGS 1982).



Appendix Figure B-5. Comparison of salmon fishwheel catches (ADF&G 1983b: Volume 2) to discharge (USGS 1982) and temperature (ADF&G 1983b: Volume 4) at Susitna, Sunshine, Talkeetna and Curry Stations, Susitna River, Alaska, 1982.

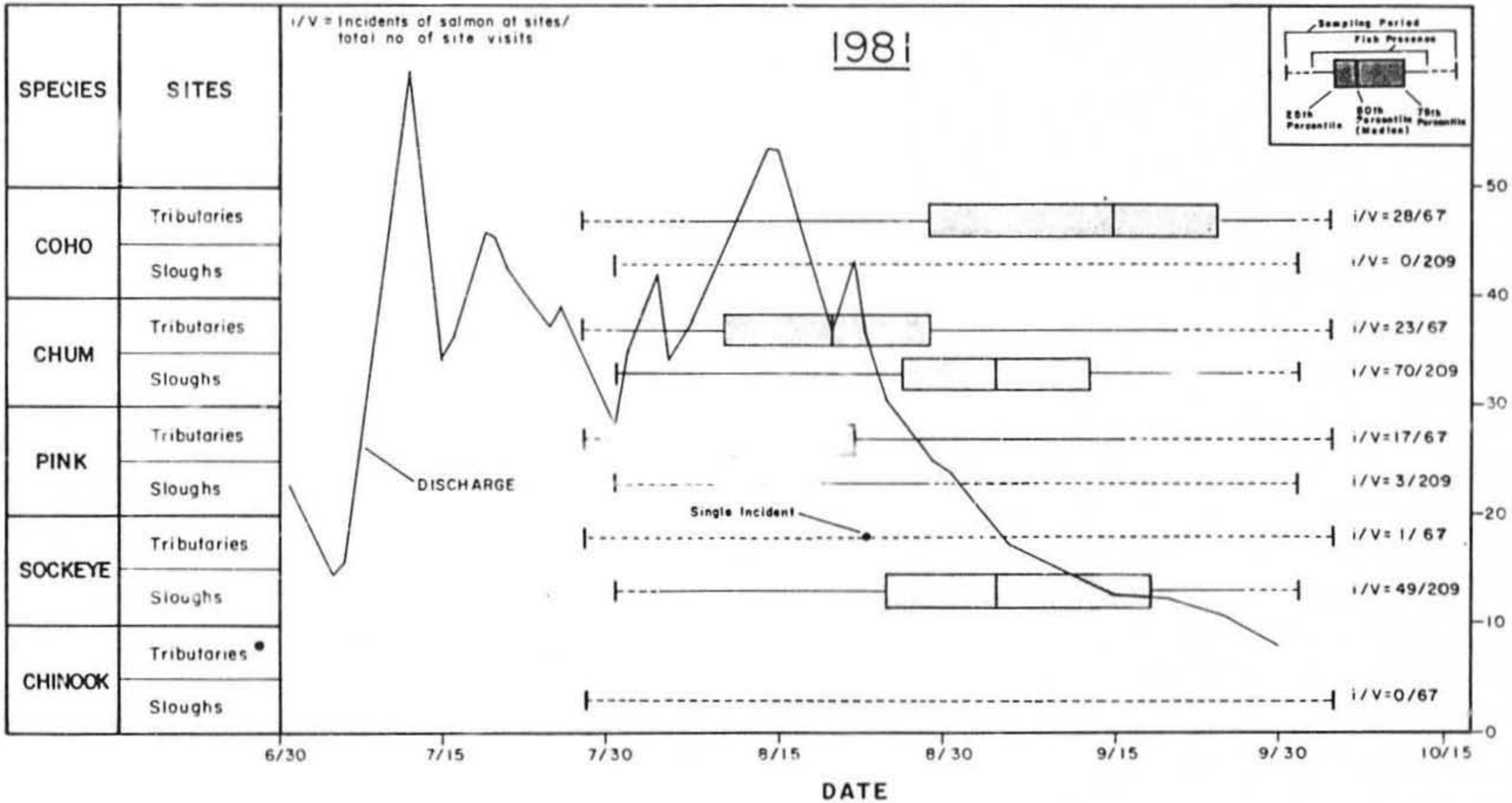
variables, many of which may be affecting salmon migration. In spite of these interpretative limitations it is important to establish the range of conditions encountered by adult salmon during migration. In 1982, salmon migrated up the Susitna River when surface water temperatures ranged between 7 and 12°C and when discharges ranged from 12,000 to greater than 50,000 cfs (at Gold Creek). Peak upstream movement for each species seemed to occur when discharge was stable or decreasing and when temperatures were stable or increasing (Appendix Figure B-5).

Timing of Movement into Sloughs and Tributaries

The order in which salmon species migrated up the mainstem Susitna River in 1981 and 1982 (chinook, sockeye, pink, chum, and coho salmon, respectively) differed from the order (Appendix Figures B-6 and B-7) in which they entered sloughs and/or tributaries (chinook, pink, chum, sockeye and coho salmon, respectively). The difference occurred in the relative timing of sockeye movements and is probably not of significance in terms of differences in access to spawning habitat.

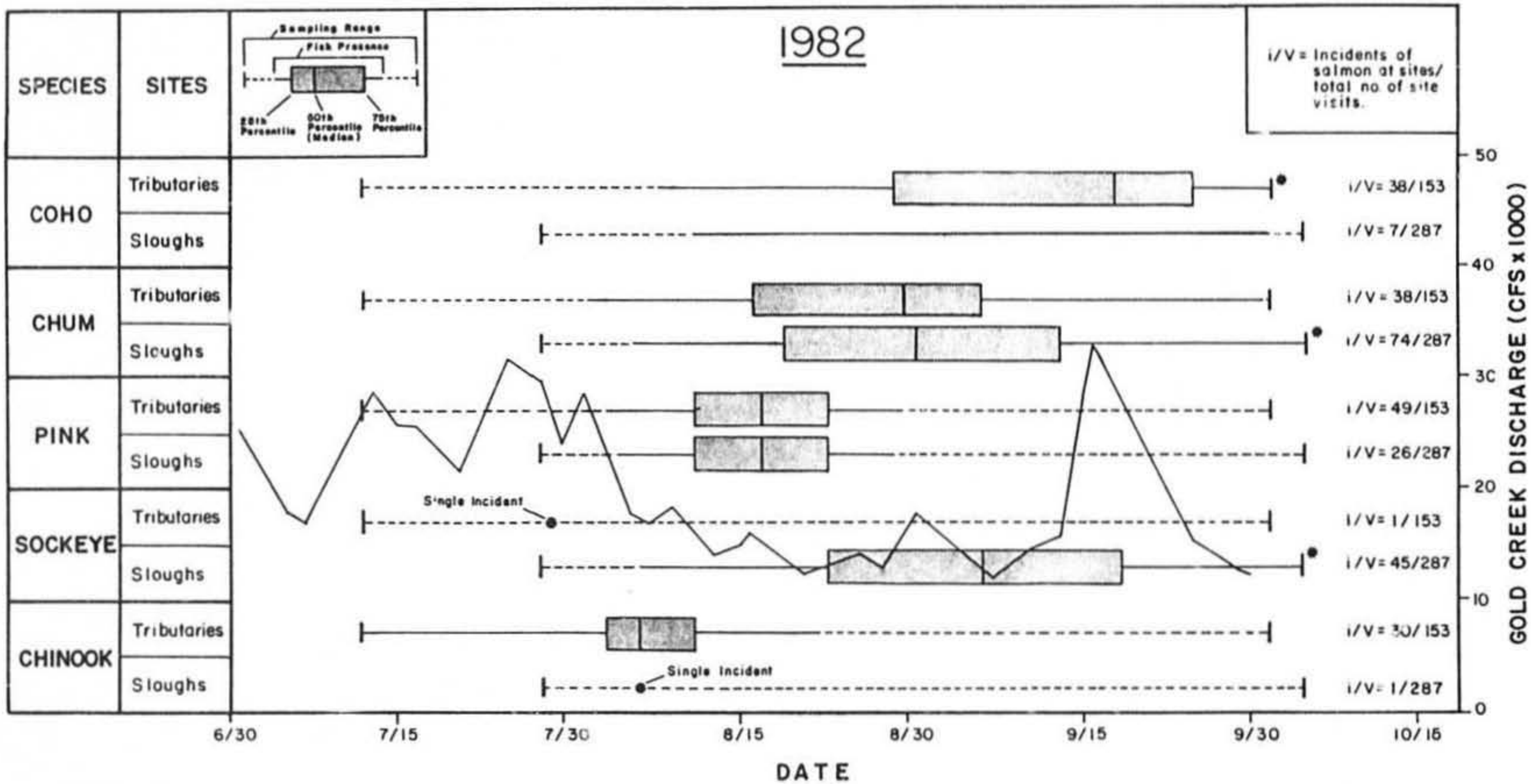
The median dates of arrival for a species in sloughs and tributaries were similar in 1981 and 1982 (Appendix Figures B-6 and B-7). The largest difference for any species in median arrival time between the two years was less than 10 days. This difference is relatively small in light of the large differences in mainstem discharges between years.

Timing for median numbers of each fish species passing Talkeetna fishwheels and the timing when median numbers of each species were



•Tributaries were sampled for chinook salmon using a different method; therefore, data are not included.

Appendix Figure B-6. Comparison of periodicity of live salmon (ADF&G 1981) in tributaries (RM 101.0 - 113.6) and sloughs (RM 99.6 - 145.5) with discharge (USGS 1981) at Gold Creek (USGS #15292000), Susitna River, Alaska.



* Sloughs and tributaries were visited one additional time on October 25 ; no live salmon found.

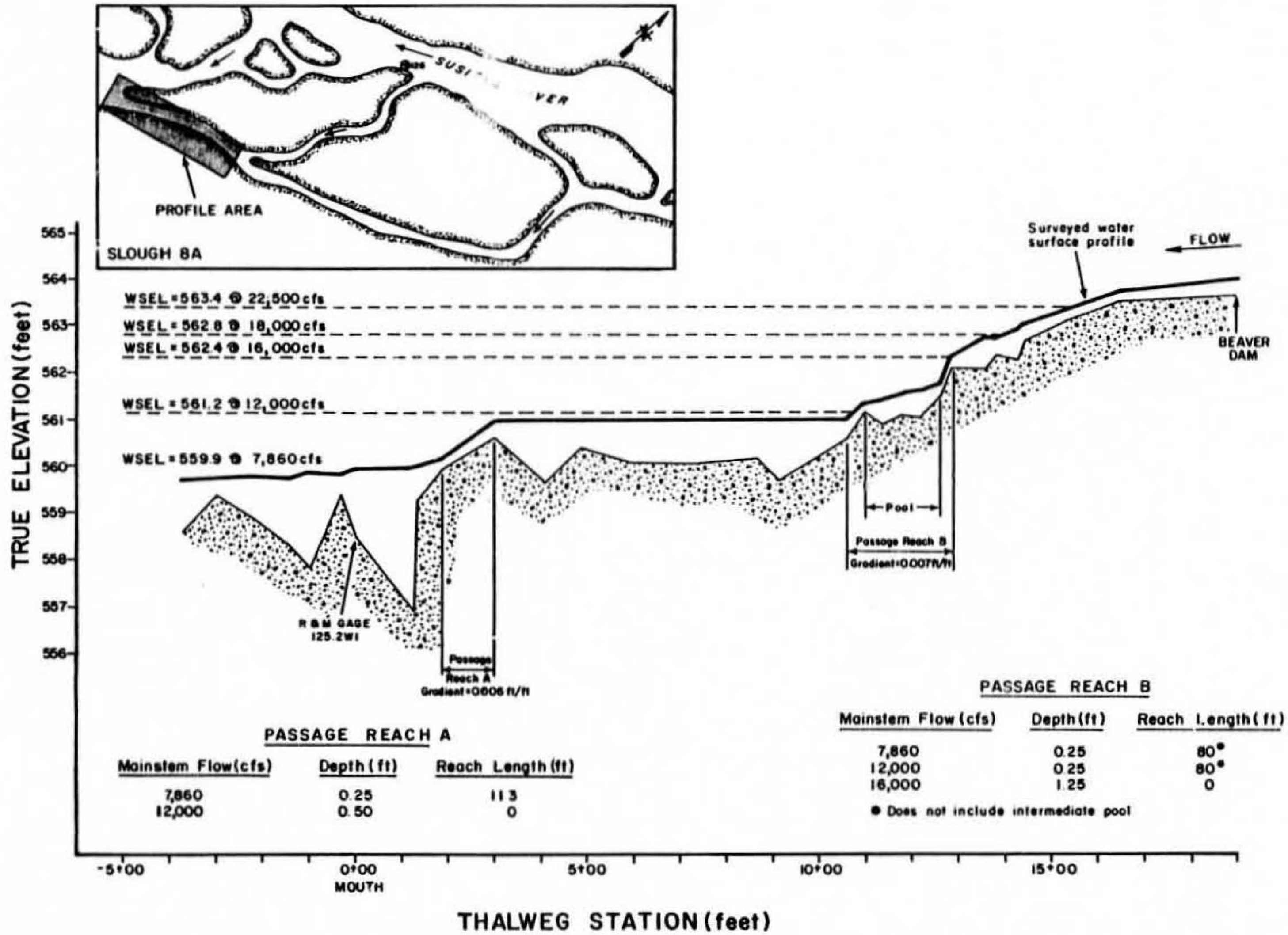
Appendix Figure B-7. Comparison of periodicity of live salmon (ADF&G 1983b: Volume 2) in tributaries (RM 101.4 - 161.0) and sloughs (RM 99.6 - 144.3) with discharge (USGS 1982) at Gold Creek (USGS #15292000), Susitna River, Alaska.

observed in sloughs and/or tributaries differed between species. In 1982, median numbers of pink salmon were observed in sloughs and tributaries (Appendix Figure B-7) less than 10 days after they were observed at Talkeetna fishwheels (Appendix Figure B-5). The time difference was approximately two weeks for chum salmon and a month or more for chinook, sockeye and coho salmon. Reasons for these differences may be related to variations in lengths of time that each species mill before entering spawning areas.

Slough Access Conditions

Slough 8A

Access conditions for adult chum salmon into the lower reach of Slough 8A are illustrated for five mainstem discharges ranging from 7,860 to 22,500 cfs (Appendix Figure B-8). At a mainstem discharge at, or below 7,860 cfs, there are two restrictive passage reaches (A and B). Passage Reaches A and B are located approximately 200 ft and 1,100 ft above the slough mouth, respectively. At 12,000 cfs Passage Reach A has a depth of approximately 0.5 ft and would not restrict fish passage. However, Passage Reach B remains a barrier to fish passage until mainstem flows equal or exceed 12,500 cfs. At 12,000 cfs, passage reach B has a depth of 0.25 ft for a distance of approximately 80 feet. Note that the reach length reported for Passage Reach B does not include the intermediate pool between the upper and lower ends of this reach. At a mainstem discharge of 16,000 cfs or greater neither passage reach is restrictive.



Appendix Figure B-8. Thalweg profile and water surface elevations in the lower reach of Slough 8A at various mainstem discharges of the Susitna River at Gold Creek. Passage reaches are those segments of the channel where water depth may restrict access of adult salmon into the slough.

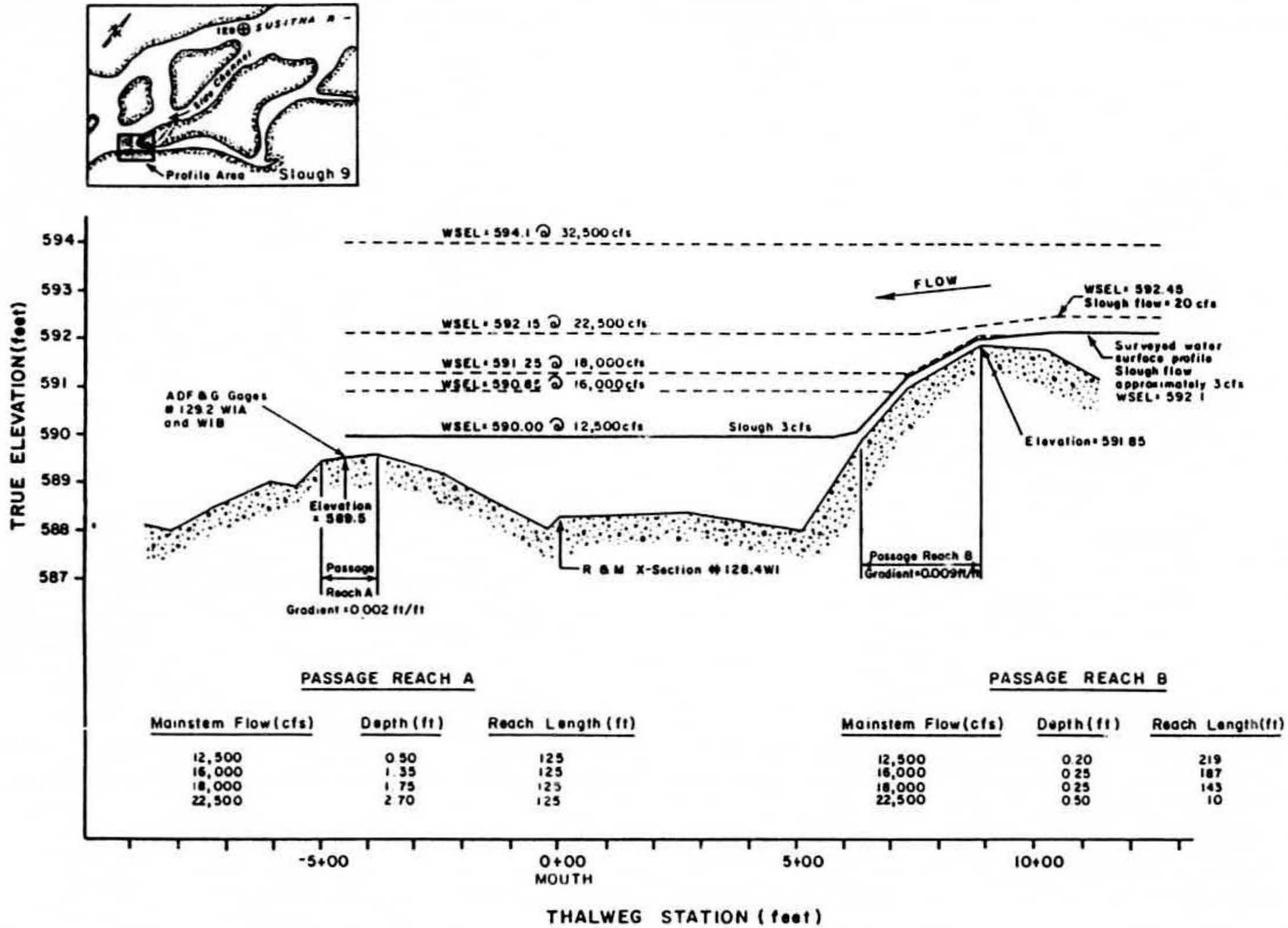
Slough 9

Access conditions for adult chum salmon in the lower reach of Slough 9 are illustrated for five mainstem discharges ranging from 12,500 to 32,500 cfs (Appendix Figure B-9). Two reaches (A and B) were identified as potentially restricting fish passage. Observations at Passage Reach A, located approximately 500 ft below the slough mouth, indicate that water depths are maintained at 0.3 feet or greater by base slough flow (Appendix Figure B-10) and/or mainstem flows. This reach is therefore not expected to be restrictive to fish passage for mainstem flows equal to or exceeding 12,500 cfs.

Passage Reach B is located approximately 700 ft above the slough mouth and unlike Passage Reach A, poses different degrees of access difficulties under varying mainstem discharges. At 18,000 cfs, the average depth is 0.25 ft and the reach extends for a distance of 143 ft. As mainstem discharges increase, the length of the reach changes markedly. At 22,500 cfs, the average depth is 0.5 ft and the length of reach at this depth is only 10 ft. Thus, at mainstem discharges at approximately 20,000 cfs or above, acute passage restrictions are not expected for either reach.

Slough 11

Access conditions for adult chum salmon in the lower reach of Slough 11 are illustrated for four mainstem discharges ranging from 6,660 to 24,000 cfs (Appendix Figure B-11). A single reach, located approxi-



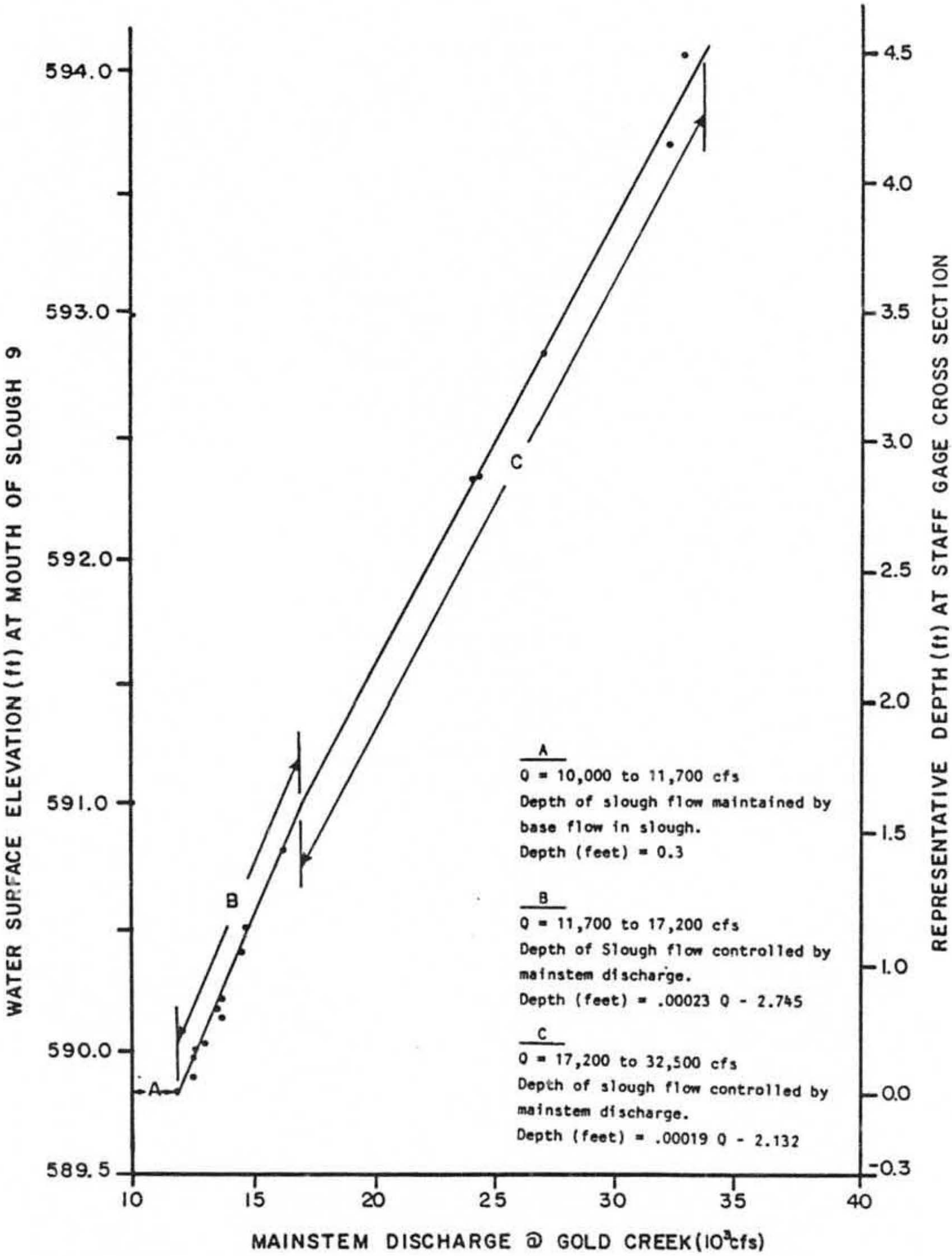
PASSAGE REACH A

Mainstem Flow (cfs)	Depth (ft)	Reach Length (ft)
12,500	0.50	125
16,000	1.35	125
18,000	1.75	125
22,500	2.70	125

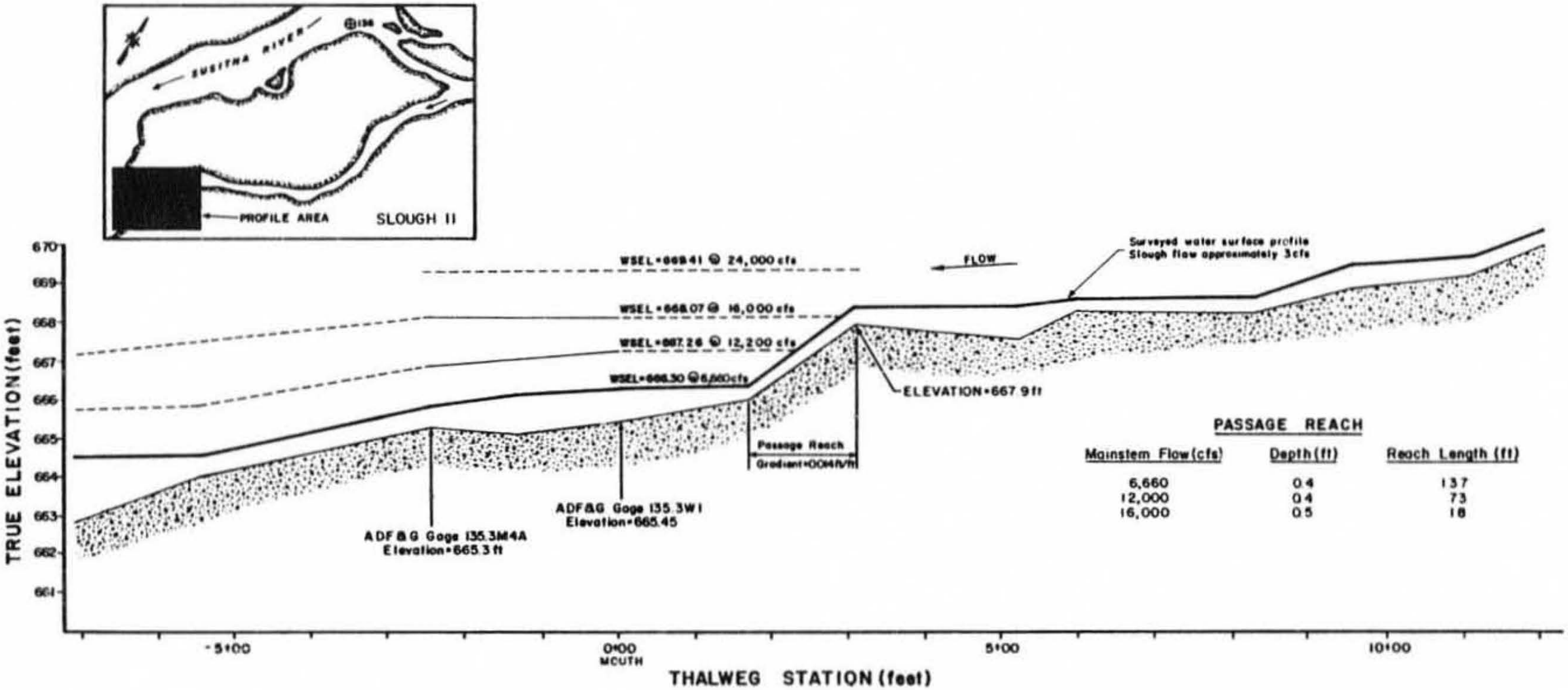
PASSAGE REACH B

Mainstem Flow (cfs)	Depth (ft)	Reach Length (ft)
12,500	0.20	219
16,000	0.25	187
18,000	0.25	143
22,500	0.50	10

Appendix Figure B-9. Thalweg profile and water surface elevations in the lower reach of Slough 9 at various mainstem discharges of the Susitna River at Gold Creek. Passage reaches are those segments of the channel where water depth may restrict access of adult salmon into the slough.



Appendix Figure B-10. Water surface elevation and depths at gage site number 129.2 W1A in Slough 9 versus mainstem discharge (USGS 1982) at Gold Creek (Gage # 15292000).



Appendix Figure B-11. Thalweg profile and water surface elevations in the lower reach of Slough 11 at various mainstem discharges of the Susitna River at Gold Creek. Passage reaches are those segments of the channel where water depths may restrict access of adult salmon into the slough.

mately 200 ft above the slough mouth, was identified as potentially restrictive to fish passage. However at a mainstem discharge of 6,660 cfs the minimum depth for this passage reach is 0.4 ft for 137 feet. This is not considered to be acutely restrictive to passage of adult chum salmon. However, because the depth is only slightly greater than the minimal criteria and the length of reach is 137 ft, access is expected to be partially restricted at these conditions.

Slough 21*

Access conditions for adult chum salmon in the lower reach of Slough 21 are illustrated for three mainstem discharges ranging from 16,000 to 32,000 cfs (Appendix Figure B-12). A single restrictive passage reach was identified approximately 600 ft above the mouth of the slough. This reach remains a problem at a mainstem discharge of 22,500 cfs due to its shallow depth. At 23,000 cfs however, the head of the slough is breached, resulting in sufficient water depth to support passage.*

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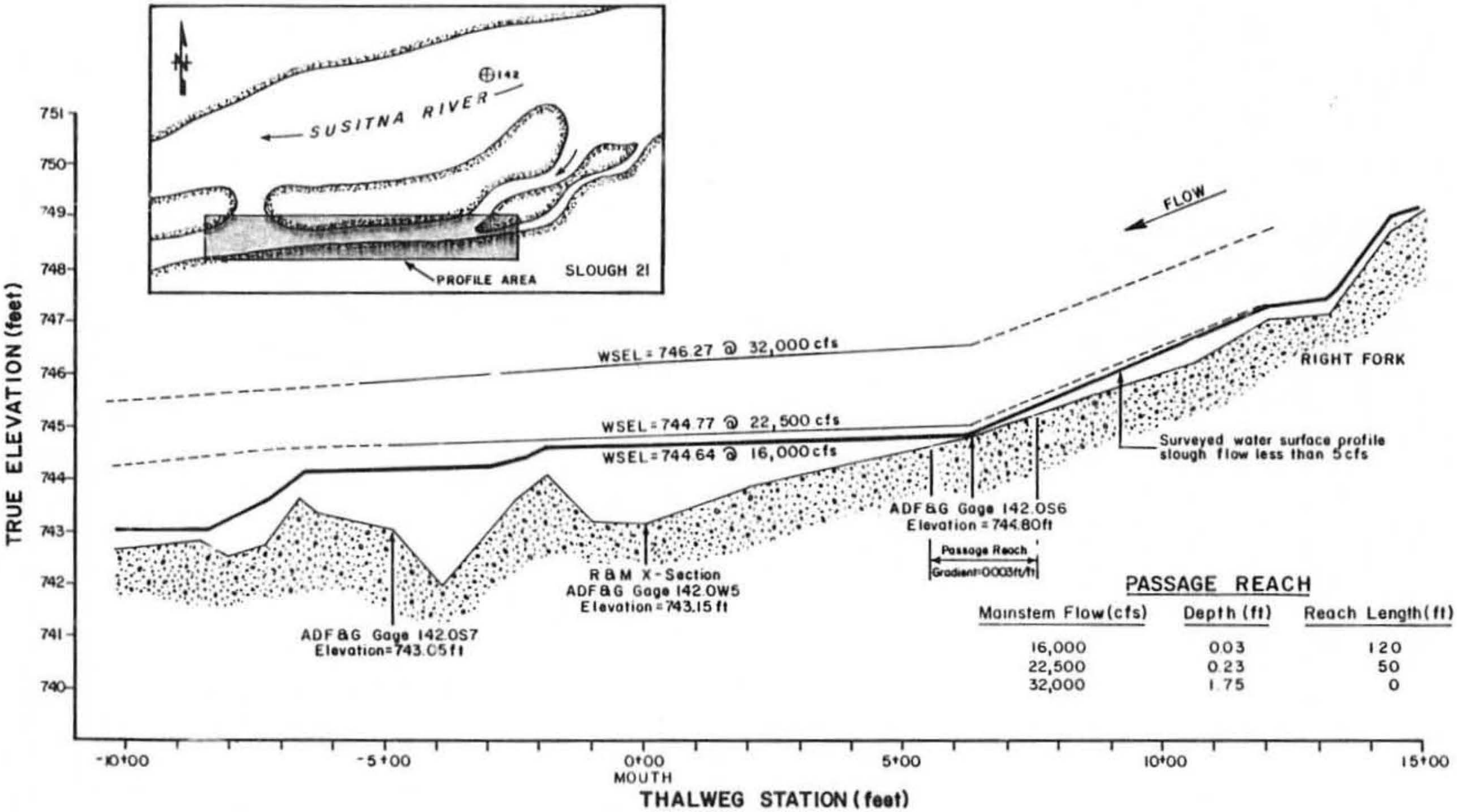
* In this report, Slough 21 has been defined to include the slough, as described in the Aquatic Habitat and Instream Flow Phase I Final Draft (ADF&G 1981b), and the extended access channel oriented parallel to the mainstem Susitna River (see ADF&G 1983b: Volume 4: Figure 4I-3-14). Fish data reported in all years for Slough 21 includes all visible portions in the Slough 21 complex.



PASSAGE REACH

Mainstem Flow (cfs)	Depth (ft)	Reach Length (ft)
16,000	0.03	120
22,500	0.23	50
32,000	1.75	0

Appendix Figure B-12. Thalweg profile and water surface elevations in the lower reach of Slough 21 at various mainstem discharges of the Susitna River at Gold Creek. Passage reaches are those segments of the channel where water depth may restrict access of adult salmon into the slough.

Other sloughs

The effects of mainstem discharge on access of adult chum salmon into the five sloughs evaluated by the second method are summarized in Appendix Table B-3. The most significant finding of this assessment is the general trend toward lower mainstem flow requirements for access by salmon into sloughs in a downstream direction from Devil Canyon toward Talkeetna.

DISCUSSION

General

Passage of adult salmon into the Susitna River and its sloughs can be partitioned into three phases, each defined by specific hydraulic conditions. In the first phase, adult salmon return to the Susitna River where passage conditions are mediated by the hydraulic conditions present in the mainstem river. In their second migrational phase, salmon enter a hydraulic zone within the mouths of sloughs and mill before entering the slough. This zone is influenced by both slough and mainstem conditions. In the third phase of their migration, fish ascend above the influence of the mainstem river water into upper slough reaches where hydraulic conditions are primarily a function of slough base flow and channel morphology.

In this Appendix we have primarily focused on the second phase of the upstream migration of chum salmon in the Susitna River. The first phase

Appendix Table B-3. Comparison of fish access conditions in 1982, in the lower reaches of selected sloughs at various mainstem Susitna discharges (USGS 1982) at Gold Creek (Gage #15292000).

		Access[a]	
	River Mile	Acute	Unrestricted
Whiskers Creek Slough	101.2	8,000 cfs	10,000 cfs
6A	112.3	--	8,000 cfs
16B	138.0	18,000 cfs	26,400 cfs
20	140.1	20,000 cfs	21,500 cfs
22	144.3	20,000 cfs	22,500 cfs

[a]Estimated from cross sections, staff gage readings rating curves and field observations.

-- Data unavailable.

of migration in the mainstem river has been limited to consideration of timing of upstream movements of fish relative to mainstem discharge and temperature. Consideration of a third phase of the salmon migration, has been limited to a comparison between distributions of spawning salmon within sloughs in 1981 and 1982 and a comparison of fish distribution within sloughs prior to and following a high water event in which the heads of the sloughs were breached.

Timing

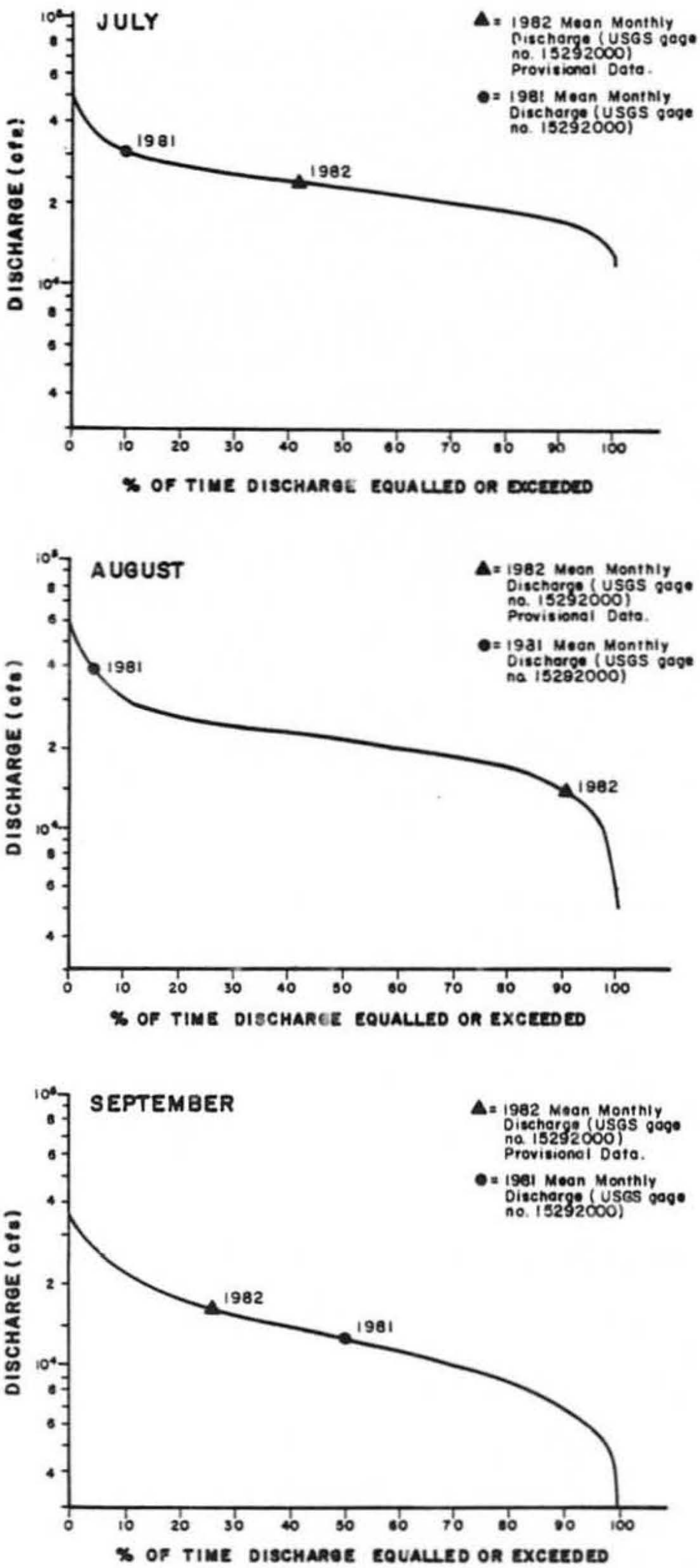
The timing of peak movements of salmon generally corresponded with stable or declining mainstem discharges and stable or increasing water temperatures. However, because there appears to be an inverse relationship between water temperature and discharge level in the mainstem Susitna River it is not possible to determine their individual effects on fish migration.

During upstream migration of salmon in 1982, temperatures ranged from 7 to 12°C in the Susitna River. These values are in the lower range of temperatures reported by Bell (1973) for species in other areas of North America: fall chinook salmon (10.6 - 19.4°C), chum salmon (8.3 - 15.6°C), coho salmon (7.2 - 15.6°C), pink salmon (7.2 - 15.6°C) and sockeye salmon (7.2 - 15.6°C). However, it should be noted that abrupt changes from the normal temperature pattern could alter the timing of migration and adversely affect survival (Reiser and Bjornn 1979).

Compared to a 30 year average, mainstem discharge levels (at Gold Creek) for 1982 were relatively low and levels in 1981 were relatively high (Appendix Figure B-13). This basic difference was particularly large during August when chum salmon were entering sloughs to spawn. However, despite this dramatic difference in mainstem water levels, the time when individual salmon species entered sloughs (and tributaries) were remarkably similar between years (Appendix Figures B-6 and B-7). This suggests that factors other than mainstem Susitna River discharge level regulates timing of arrival of fish to slough habitats.

Slough Access Conditions

Two methods were applied for analyzing slough access conditions. Both provided the means to define mainstem flows of the Susitna River for acute or unrestricted passage of adult chum salmon into sloughs with the existing data base and analytical resources. These methods were based on adaptations of previous studies summarized by Stalnaker and Arnette (1976), Thompson (1972, 1983) and Bovee (1982). It is important to recognize that our techniques were specifically designed to provide a data base for analyzing the impacts of this proposed project for the particular species, life phase and habitat targeted. Use of the other methods referenced without these adaptations were not considered relevant to this study at this time. Other variables which can influence passage, such as temperature (Brannon 1982), should also be considered.



Appendix Figure B-13. Flow duration curves for the Susitna River at Gold Creek for July, August and September. Curves based upon mean daily flows for water years 1950-1981 (adapted from Acres American Inc. 1982).

Slough 8A

Passage problems are not anticipated for returning adult salmon in Slough 8A when mainstem discharge at Gold Creek equal or exceed 12,500 cfs. When mainstem flows are less than 12,500 cfs (Appendix Figure B-8) access by adult salmon into Slough 8A probably depends upon levels of base slough flow.

Appendix Table B-4 is a summary of available data for Slough 8A showing discharges into the slough relative to those in the mainstem. Based upon the range of base slough discharges (2.76 to 22.28 cfs) in Slough 8A, it appears that local precipitation events can influence slough flow. However, the extent of influence precipitation conditions have on access conditions in the mouth of this slough is unknown at the present time.

Appendix Table B-4. Range of base flow measurements obtained in Slough 8A during unbreached conditions in 1981 and 1982 (ADF&G 1981b, 1983b: Volume 4) compared to mainstem discharge at Gold Creek (USGS 1981, 1982) at Gold Creek (gage #15292000).

Date	Slough 8A Discharge (cfs)	Mainstem Discharge (cfs) Gold Creek
810930	2.76	N/A
820907*	6.21	11,700
820822*	3.84	13,600
810625	6.36	17,100
820919*	22.28	24,100

* 1982 slough discharges are averages of several transect measurements.

Slough 9

Upstream passage into Slough 9 by adult salmon does not appear to be acute when mainstem flows are 20,000 cfs or higher. Upstream access becomes increasingly more difficult for salmon as mainstem discharges increase and become acute at mainstem streamflows of 18,000 cfs and less. Because this slough has two small tributaries that influence the base slough flow, local rainfall would substantially effect access conditions. If base slough discharges were elevated to 10 to 15 cfs it is likely that passage restrictions would be minimal for fish under these conditions.

Slough 11

When mainstem flows are 6,700 cfs or greater, adequate depths for passage exist throughout the lower reach of Slough 11. In part this is attributable to the confinement of slough flow in this lower reach to a very narrow channel. Thus, the naturally occurring flow from Slough 11 appears adequate to provide for fish passage provided the existing channel morphology of the slough is maintained.

Slough 21

Fish passage into Slough 21 is acute until mainstem flows exceed 22,500 cfs and breach the upstream end of the slough. This breaching flow has been defined at 23,000 cfs (ADF&G 1983b: Volume 4).

Other sloughs

Of the five other sloughs evaluated, Slough 22 required the highest flows for unrestricted passage (22,500 cfs) and Slough 6A the lowest (8,440 cfs).

Combined sloughs

In general, chum salmon are the predominant species to utilize sloughs for spawning. Chum salmon were observed in 17 of 34 sloughs surveyed in 1982 (ADF&G 1983b: Volume 2), with sloughs 8A, 9, 11 and 21 containing over 80 percent of the total slough index counts.

A summary of access conditions for all study sloughs are listed in Appendix Table B-5. These data suggest that there is a general trend toward lower mainstem flow requirements for access by salmon into sloughs in a downstream direction from Devil Canyon toward Talkeetna. With the exception of Slough 9, it appears that access problems do not exist downstream of RM 140 (Slough 20) for mainstem flows of 20,000 cfs whereas, access conditions upstream of RM 140 are acute at this flow (sloughs 20, 21, and 22). Also included in Appendix Table B-5 is a ranking of the relative abundance of adult salmon in the nine sloughs evaluated. These data are derived from Appendix C of this report and indicate that sloughs 8A, 9, 11 and 21 have the highest abundance of chum salmon and Slough 11 the highest abundance of pink and sockeye salmon of the nine sloughs evaluated.

Appendix Table B-5. Comparison of fish access conditions in the lower reaches of selected sloughs at various mainstem Susitna River discharges (USGS 1982) at Gold Creek (Gage #15292000). Relative abundance of salmon by location is provided for comparison.

Sloughs	River Mile	Access		Relative Abundance of Salmon in 1982[c]		
		Acute	Unrestricted	Sockeye	Pink	Chum
Whiskers Creek Slough[b]	101.2	8,000 cfs	10,000 cfs	0	L	0
6A[b]	112.3	--	8,000 cfs	0	L	L
8A[a]	125.3	7,860 cfs	12,500 cfs	M	L	H
9[a]	129.2	18,000 cfs	20,000 cfs	L	L	H
11[a]	135.3	--	6,700 cfs	H	H	H
16B[b]	138.0	18,000 cfs	26,400 cfs	0	0	0
20[b]	140.1	20,000 cfs	21,500 cfs	0	M	L
21[a]	142.0	20,000 cfs	23,000 cfs	M	M	H
22[b]	144.3	20,000 cfs	22,500 cfs	0	0	0

[a] Determined from surveyed thalwegs cross sections and staff gage readings, and field observations.

[b] Estimated from cross sections, staff gage readings, rating curve, and field observations.

[c] Relative abundance in slough (from Appendix C)
- (H) High 100
- (M) Medium 50-100
- (L) Low 50
- (0) None observed.

-- Data unavailable.

Additional evidence for access problems

In contrast to the similarity between years in the arrival time of salmon in to sloughs and tributaries (Appendix Figures B-6 and B-7), four types of evidence suggest that passage problems for salmon existed in 1982 (low water year). These are:

1) hydraulic evidence presented in the body of this report for entrance conditions of selected sloughs suggests that entrance conditions were partially restrictive for adult chum salmon in some sloughs during 1982 (previously discussed);

2) chum salmon were present in more sloughs in 1982 (high water year) than in 1982 (low water year);

3) in 1982, the uppermost limit of occurrence of spawning chum salmon was significantly extended after a high water event (September 15, 1982) in the mainstem Susitna River caused water to breach the heads of several sloughs. The difference in distribution was most dramatic in sloughs 9 and 21; and

4) escapement estimates (ADF&G 1983b: Volume 2) for chum salmon at Talkeetna Station were higher in 1982 (low water year) than in 1981 (high water year), although the actual numbers of chum salmon observed in sloughs were similar in both years.

Although these problems may have existed for other species using sloughs for spawning, only chum salmon are considered in the following discussion.

Chum salmon spawned in Lane Creek Slough and sloughs 19 and 22 during 1981 but were absent from these sloughs during 1982. In contrast, index counts in tributaries were much higher in 1982. Although reasons for this apparent discrepancy are as yet undetermined, it is possible that it is related to differences in the relative effect of mainstem discharge on entrance conditions of sloughs verses tributaries. A complete analysis on access into tributaries has not been conducted; however the analysis of access into two primary tributaries (Indian River and Portage Creek) of the Susitna River suggests that access has not been a problem in past years and is not expected to be a problem even under operational discharges (Trihey 1983a) as outlined in Chapter 2 of the draft <u>Exhibit E</u> of the <u>FERC License Application</u> (Acres American Incorporated 1982).

In addition to the major differences between occurrence of chum salmon in sloughs in 1981 verses 1982, evidence from differences in distributions of spawning chum salmon before and after the high water event in mid-September, 1982 suggests that fish were denied access into upper slough reaches (particularly in sloughs 9 and 21).

Observed distributions of spawning chum salmon before and after the heads of sloughs 9 and 21 were breached in September 1982 indicate that access was restricted prior to this event (see discharge level on

September 15 in Appendix Figure B-7). Significant numbers of chum salmon spawned in the uppermost reaches of sloughs 9 and 21 in 1981; however, in 1982, prior to September 15, fish were concentrated in the lower half of Slough 9 and in the mouth region in Slough 21 until a breaching event occurred which allowed fish to access spawning areas in upper Slough 9 near the confluence of Slough 9B, as well as in the upper reaches of Slough 21. These observations indicate that the distribution of spawning fish within sloughs 9 and 21 were restricted because of low water conditions.

Escapement estimates for chum salmon at Talkeetna Station were 2.4 times higher in 1982 (low water year) than in 1981 (high water year). Yet, the actual number of chum salmon observed in sloughs (slough index counts) were similar in both years (ADF&G 1981a, 1983b: Volume 2). If one assumes that decreased index counts in sloughs reflects a loss of spawning habitat for chum salmon, a simple method for evaluating the extent of habitat loss can be performed by comparing actual verses expected escapement index counts for both years. "Expected" is defined as the ratio of the Talkeetna station 1982 escapement estimate for chum salmon to the 1981 escapement estimate (2.4), multiplied by the 1981 slough index counts. This provides an expected 1982 total escapement count for the sloughs of 6,200 chum salmon as compared to an actual count of 2,250. This actual count is only 36 percent of the expected number of fish, which could be interpreted as the result of a 64 percent reduction in accessibility of usable spawning habitat under the 1982 flow conditions.

There are factors other than access problems which could account for lower than expected numbers of returning chum salmon into sloughs. These are:

1) the 1982 escapement may have been a high year and the expected number may have not been able to use the available habitat, regardless of flow conditions. The actual numbers counted may have reflected a saturation of available slough habitat so the remainder of the escapement required use of the tributary or mainstem habitats; or

2) the differential between the escapement counts of 1981 and 1982 may have been caused by exceptional survival in the clear water tributaries and not related to slough conditions at all. As we have no data for the respective brood years, this possibility will have to remain untested.

Regardless of the limitations of the above analysis, the numbers of salmon observed spawning in the sloughs versus the escapement, the distribution of fish within the sloughs, and their response to the short term changes in discharge (fish remaining in the sloughs during the September high water period were able to move further upstream), provide evidence that some habitat was lost in 1982 and that flows in 1982 had an adverse effect on the access of adult chum salmon into sloughs.

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APPENDIX C

Qualitative Analysis of Salmon Spawning Habitat in Sloughs Located Within the Talkeetna to Devil Canyon Reach of the Susitna River.

APPENDIX C

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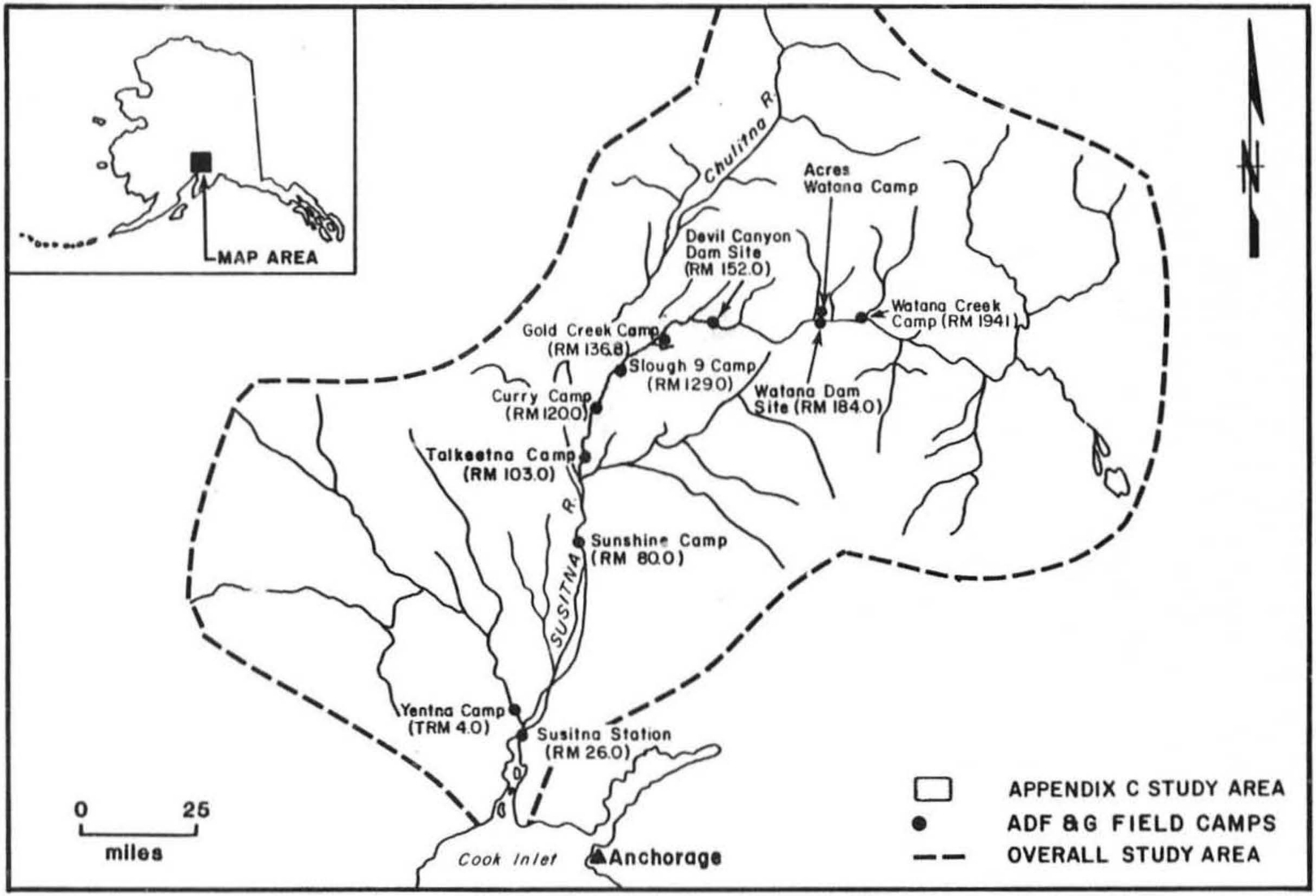
INTRODUCTION

This appendix addresses adult salmon (Oncorhynchus sp.) distribution and spawning habitat utilization. It represents an intermediate step in a narrowing focus of investigation. Appendix B analyzes the migration of adult chinook salmon, O. tschawytscha; coho salmon, O. kisutch; sockeye salmon, O. nerka; chum salmon, O. keta; and pink salmon, O. gorbuscha up the Susitna River and access conditions in the mouths of nine selected sloughs between Talkeetna and Devil Canyon. This appendix describes the distribution and abundance of adult salmon in 34 sloughs and 20 tributaries located in the Talkeetna to Devil Canyon reach of the Susitna River (Appendix Figure C-1). In addition, general habitat characteristics (substrate composition, upwelling ground water, and ice-free areas) at 13 of these sloughs were also evaluated and compared with the salmon distribution of adult salmon in these sloughs. A fourteenth slough (not included in the distribution and abundance analysis) was also included in the general habitat surveys. Appendix D compares available and utilized ranges of three hydraulic habitat variables (water depth and velocity, and substrate composition). These variables are analyzed in detail for spawning chum salmon suitability in three sloughs.

Each species of fish has adapted to a particular range of habitat conditions (Gorman and Karr 1978). In this way, a species lessens competition for a scarce resource (e.g., food or spawning habitat) by selecting a specific range of acceptable conditions. Spawning habitat for salmon is a limited resource in the Talkeetna to Devil Canyon reach



Appendix Figure C-1. Appendix C study area within the overall study area of the Susitna Hydroelectric Feasibility Study Program, Susitna River, Alaska, 1982.

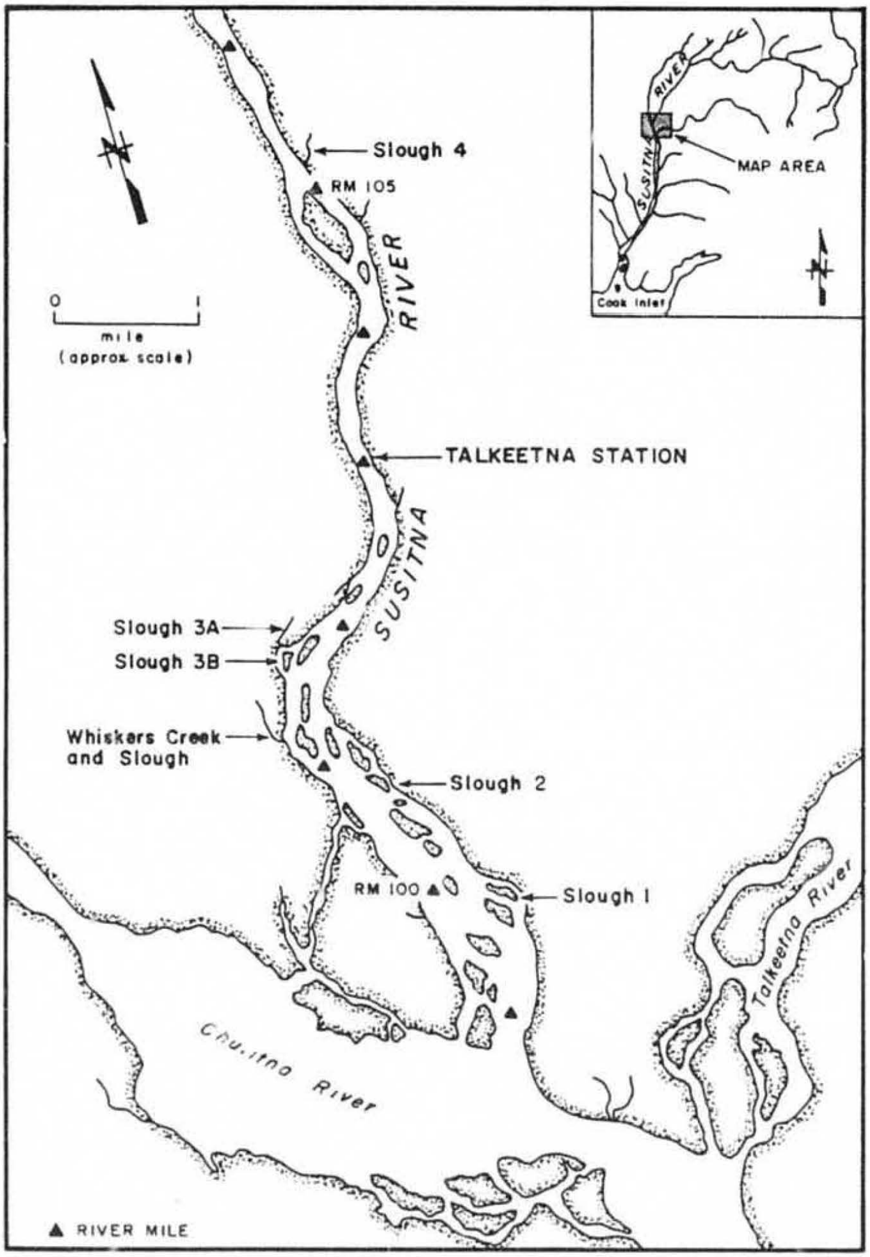
of the Susitna River. Few salmon, primarily chum salmon, spawn in the mainstem river or side channels. Tributaries provide the primary spawning habitat for chinook and coho salmon, whereas sloughs and tributaries provide the principal spawning habitat for chum, pink, and sockeye salmon.

Adult salmon usually return to their natal waters to spawn (Hasler 1966). Access into these spawning areas is the first critical obstacle to overcome and access into Susitna River sloughs depends on mainstem discharge (Appendix B). One of the major effects of the proposed hydroelectric project would be a change in flow regime. The slough habitats would be affected by these changes to a much greater extent than the tributaries.

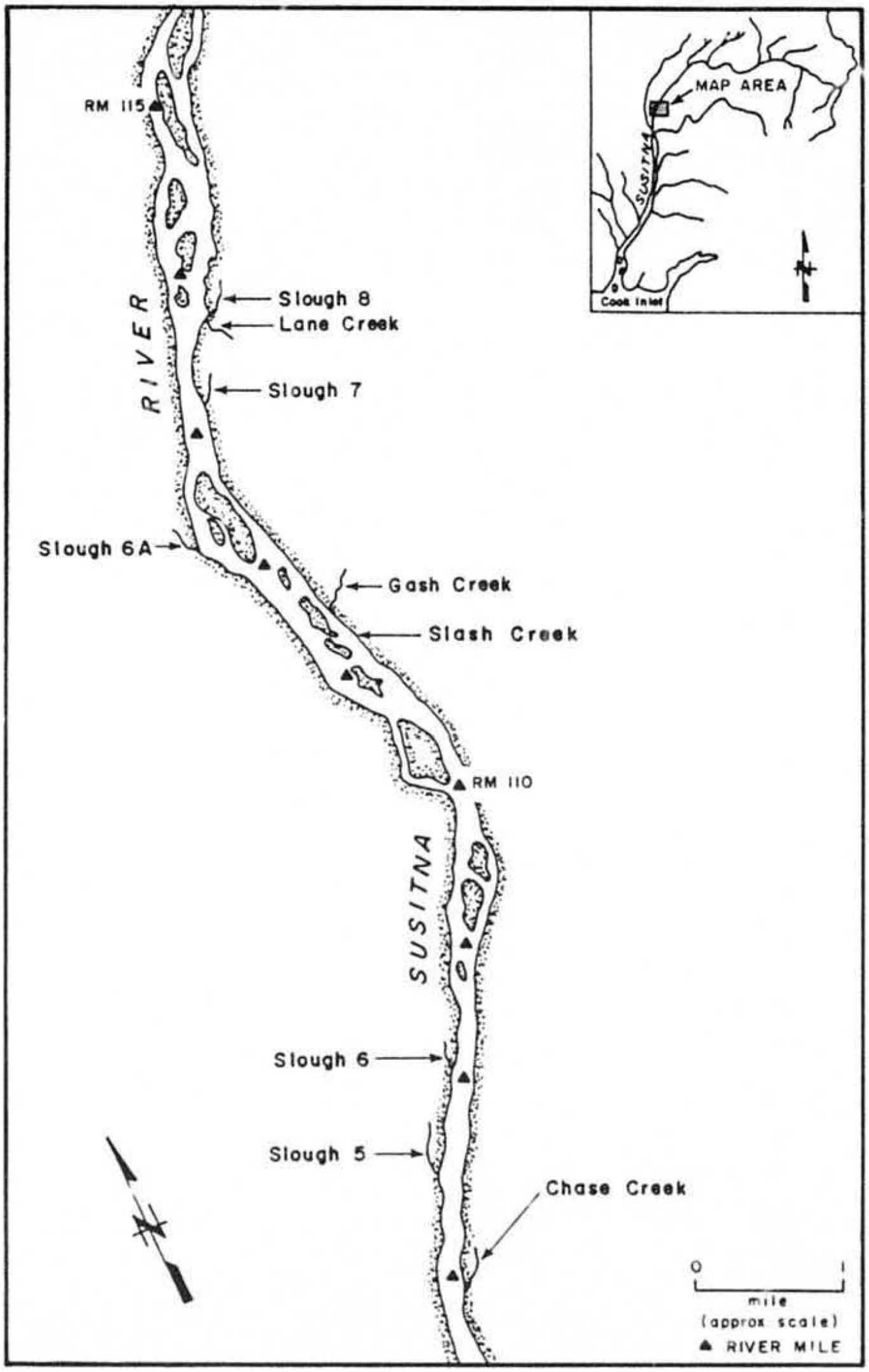
METHODS

Salmon Distribution and Abundance

Distribution and abundance of adult salmon in 34 principal sloughs and 20 tributaries of the Susitna River between the Chulitna River and upper Devil Canyon (Appendix Figures C-1 and C-2) were determined in 1981 and/or 1982. Survey methods and data are presented in the ADF&G Basic Data Reports (ADF&G 1981a, 1983b: Volume 2). Procedures are described in the 1981 and 1982 Procedures Manuals (ADF&G 1981b, 1983a). To complete this evaluation, peak numbers of live salmon in a slough were tabulated under the assumption that they indicate the relative importance of a slough for spawning salmon.



Appendix Figure C-2. Location of sloughs and tributaries of the Susitna River between the Chulitna River (RM 99) and upper Devil Canyon (RM 162).



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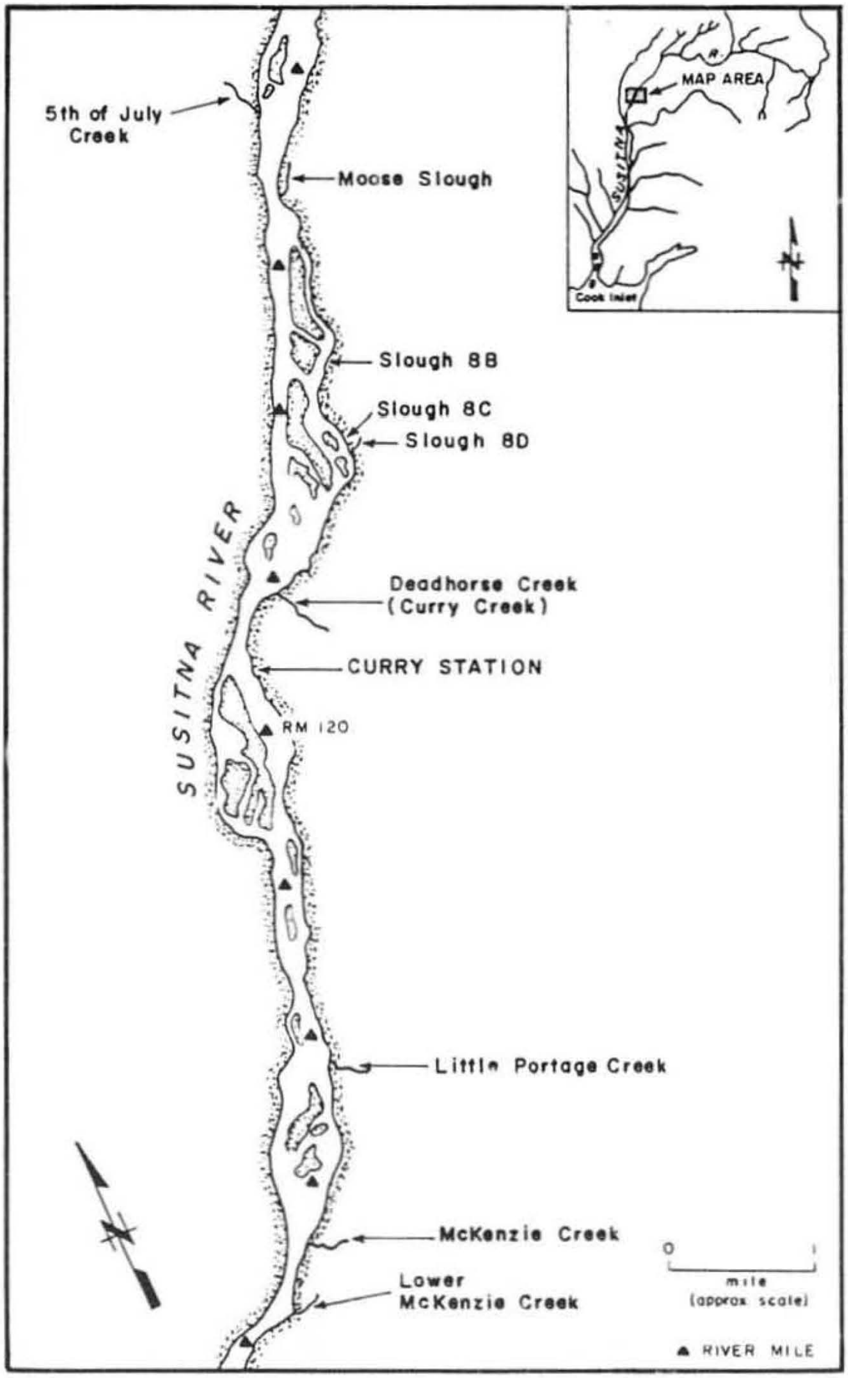

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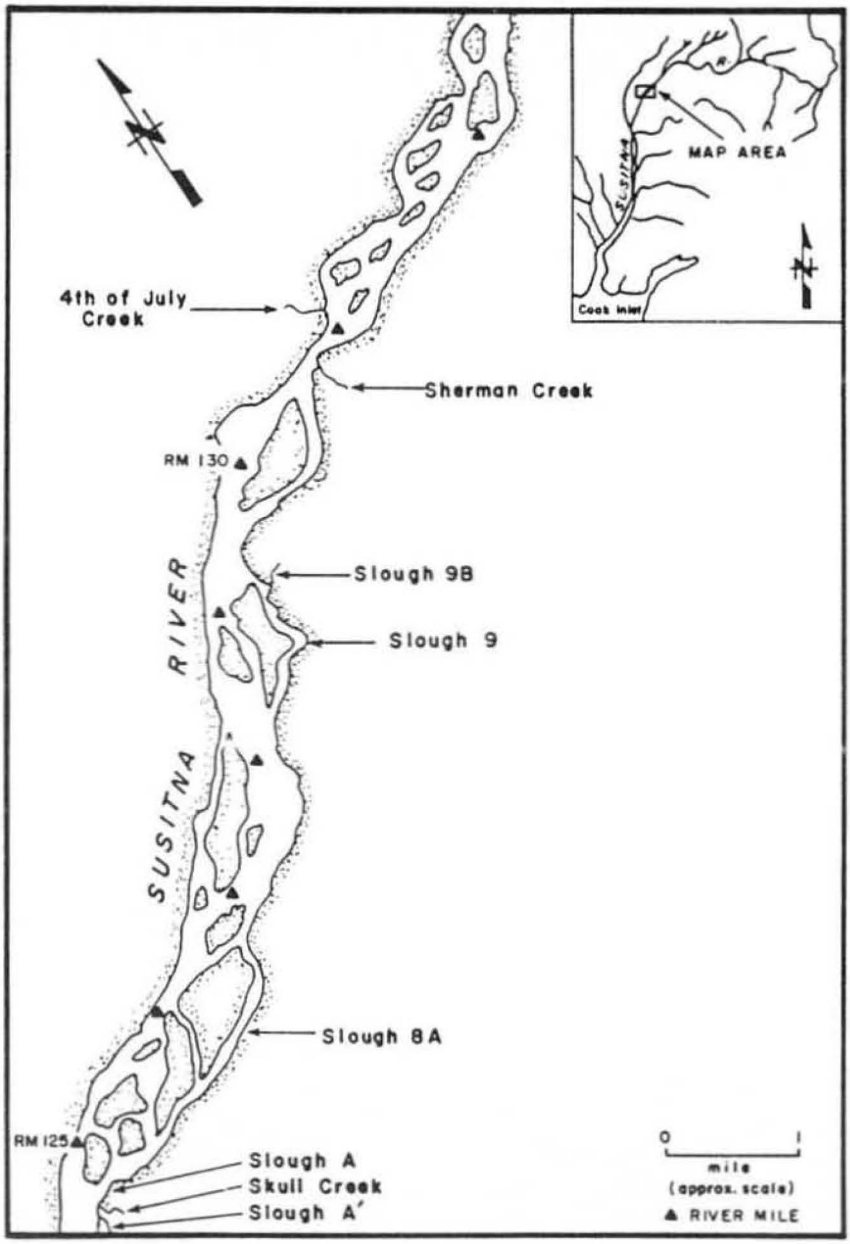

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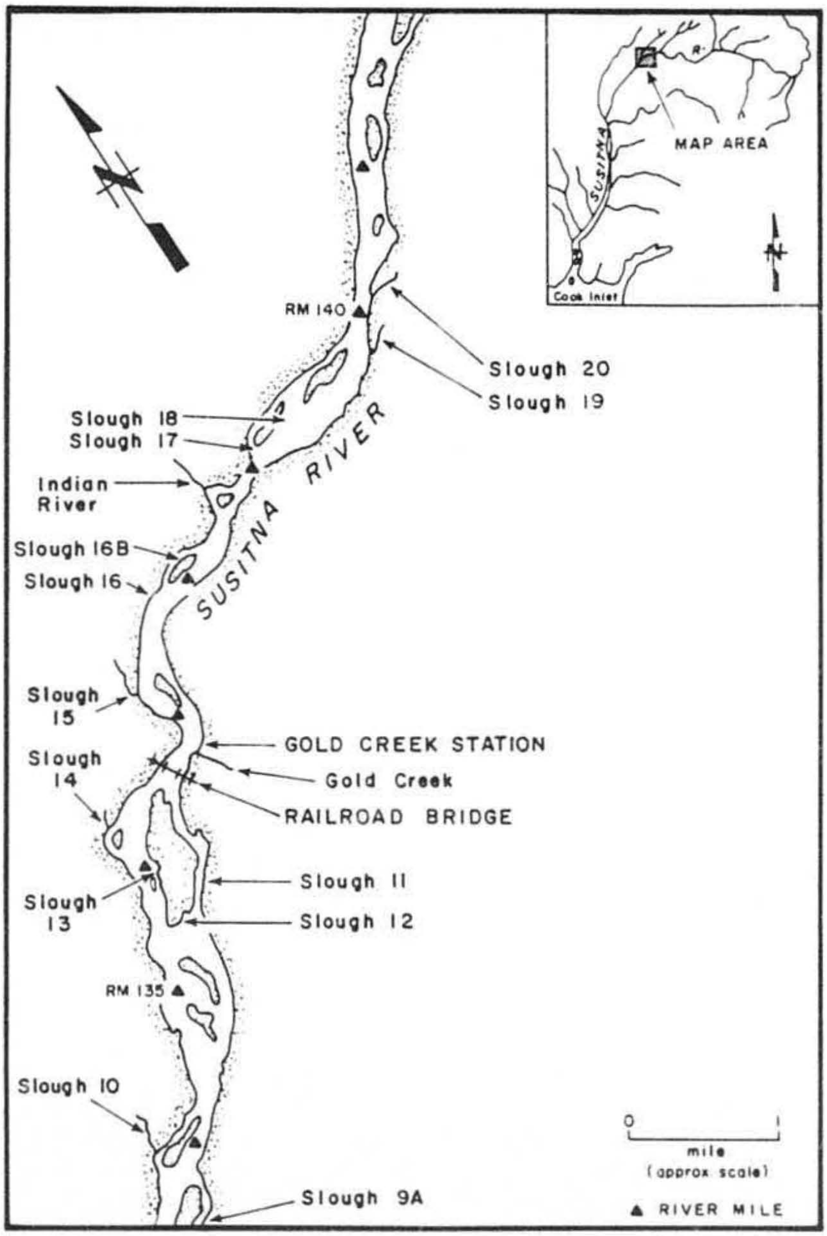

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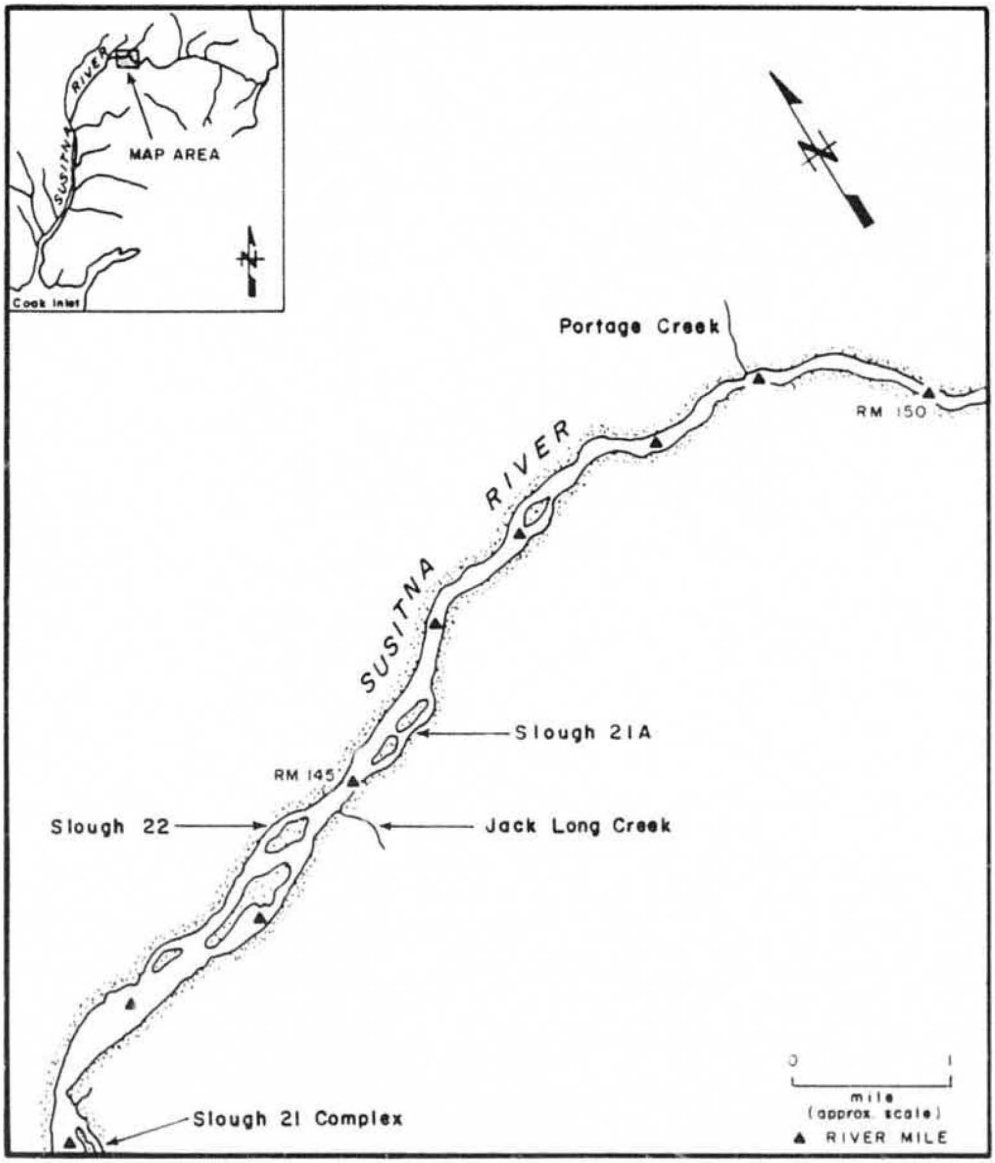

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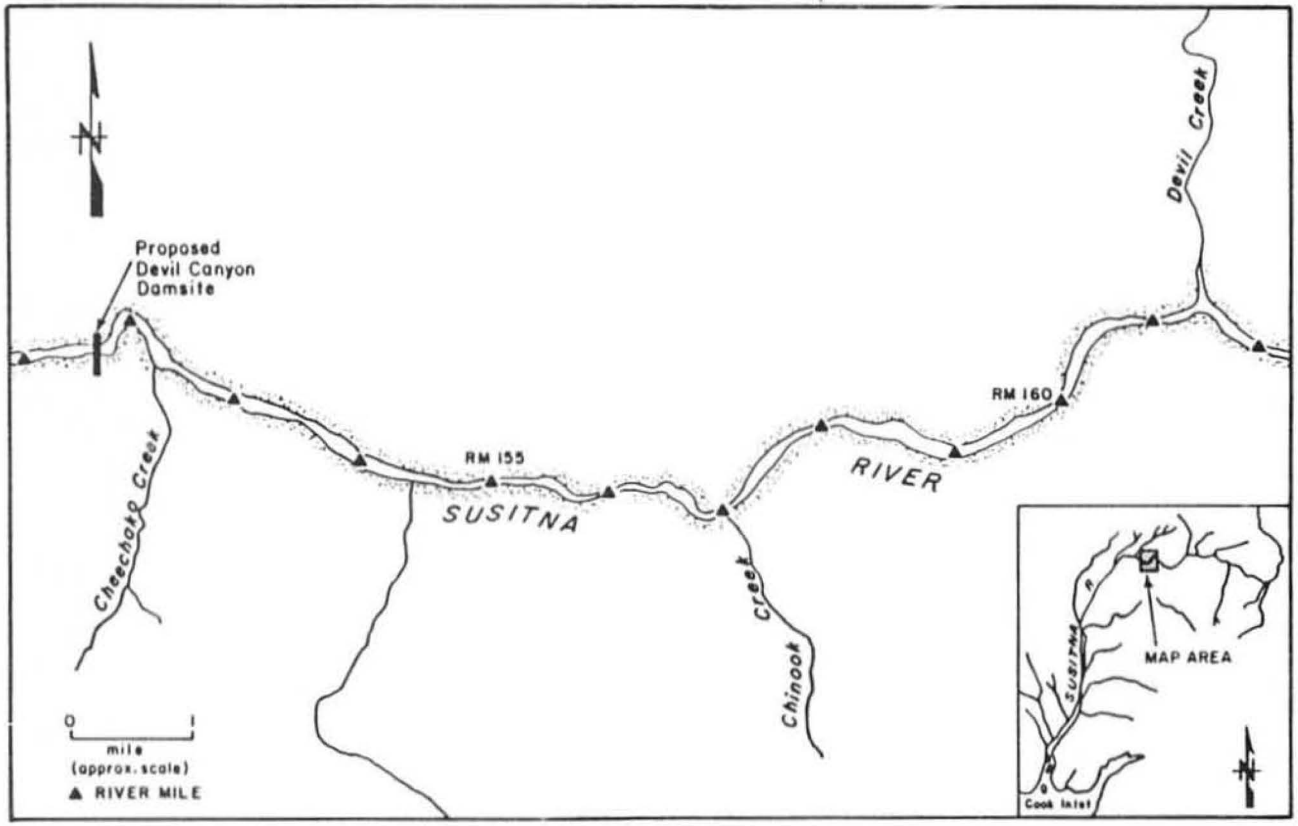

Appendix Figure C-2. (Continued).

Slough Habitat Characteristics

Habitat characteristics of 13 of these sloughs were evaluated during the open-water and ice-covered seasons. Whiskers Creek Slough, Slough 6A, Lane Creek Slough (Slough 8), and sloughs 8A, 9, 9B, 9A, 10, 11, 16B, 19, 20, 21* and 22** were sampled to represent a cross section of slough habitat in this reach of river. During the open-water season upwelling ground water, substrate composition, and salmon spawning activity were evaluated.

Upwelling was detected by observing the movement of small streambed particles as the ground water exited the substrate. Upwelling areas were easily visible in silt and sand substrates but were difficult to detect visually when larger streambed particle sizes predominated. Thus, the presence and extent of upwelling was difficult to quantify accurately in gravel, rubble or cobble substrates.

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* In this report the Slough 21 Complex has been defined to include the slough, as described in ADF&G (1981c, 1982, 1983b: Volume 4), and the adjoining access channel which parallels the mainstem Susitna River (Appendix Figure C-11). Surveys of spawning salmon included the entire Slough 21 Complex.

** Slough 22 was only surveyed for spawning fish on an infrequent basis.

Substrate categories were classified by visual observation. The area of various substrate sizes was indicated on field maps. Substrates were classified by one or a combination of two of the following codes, with the first of the two codes being the most predominant (i.e. 70% rubble - 30% cobble = RUCO).

Classification	Code	Size*
Silt	SI	--
Sand	SA	--
Gravel	GR	¼ - 3
Rubble	RU	3 - 5
Cobble	CO	5 - 10
Boulder	BO	>10

Salmon spawning locations within the sloughs were recorded by the stream survey crew during the distribution and abundance survey of the thirty four sloughs. Spawning locations at Slough 22 were recorded on an infrequent basis as part of other study program elements.

Open-water season observations were recorded and mapped on bluelines of aerial photographs** (scale 1"=50') during foot surveys in the sloughs. During the ice-covered months, the same sloughs were surveyed for open leads in the ice cover. Open leads were suspected indicators of upwelling ground water or other warm water sources. Helicopter observations of open leads were mapped on the same series of bluelines as the open-water season data from an altitude of 600 feet above the sloughs

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* Particle size range in inches.

** The aerial imagery was obtained on May 31, 1983, when the mainstem flow was 20,000 cfs at Gold Creek.

during two flights (November 18, 1982, and February 23, 1983). From the air it was difficult to determine differences between open leads and areas covered with clear ice unless a recent snow or wind left a layer of snow on the ice.

To complete the habitat evaluation, the relative density of open water season upwelling/seepage areas in sloughs was rated subjectively* on a scale of 0 to 3. A slough with no observed upwelling/seepage was assigned a rank of 0. A slough where upwelling/seepage was infrequently observed was assigned a rank of 1. A slough with a few localized areas of strong upwelling/seepage or numerous areas of weak upwelling/seepage was assigned a rank of 2. A slough with numerous areas of strong upwelling/seepage was assigned a rank of 3.

Surface areas of substrate types and open leads were computed indirectly from the scaled blueline maps using a digitizer. These areas were expressed as a proportion of total water surface area in the slough.

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* It is important to stress that this rating is based on visual detection of upwelling sources. Limitations such as substrate particle size may have biased some of these ratings. Additionally this method does not evaluate other important ground water sources which contribute to slough flow but are not readily detected by visual observation.

Spawning Distribution and Slough Habitat Analysis

The habitat and spawning distribution information for the 14 sloughs was tabulated and combined to permit a qualitative analysis of spawning habitat characteristics in sloughs.

RESULTS

Salmon Distribution and Abundance

The distribution and abundance of adult salmon differed between each slough and tributary location. Distribution and abundance also varied between years (1981 and 1982) at each location. Chinook salmon spawned exclusively in tributaries; whereas, sockeye salmon spawned predominantly in sloughs (Appendix Tables C-1 to C-4). Chum, pink and coho salmon spawned in both tributary and slough habitats.

Abundance of live salmon in tributaries is not comparable to abundance in the sloughs because entire tributaries were not surveyed. Relatively few sloughs contained large numbers of spawning salmon (Appendix Table C-5). Only sloughs 8A, 9, 9A, 11, 15 and 21 contained more than 100 salmon of a given species (ADF&G 1983b: Volume 2).

Spawning Distribution and Slough Habitat Characteristics

Maps of sampling sites, substrate types, upwelling ground water and open leads in ice cover for 14 sloughs are included in the ADF&G Basic Data

Appendix Table C-1 Number of observations of salmon in Susitna River sloughs in the Talkeetna to Devil Canyon reach during 1981 (adapted from ADF&G 1981a).

Slough	River Mile	Total # of visits	Number of visits live salmon were observed in sloughs					Sampling Period
			Chinook[a]	Sockeye	Pink	Chum	Coho	
1	99.6	6	-	0	0	1	0	8/21 - 10/2
2	100.2	7	-	0	0	3	0	8/2 - 10/2
3B	101.4	8	-	2	0	0	0	8/5 - 10/2
3A	101.9	8	-	4	1	0	0	8/4 - 10/2
4	105.2	8	-	0	0	0	0	8/4 - 10/2
5	107.2	5	-	0	0	0	0	8/7 - 9/22
6	108.2	5	-	0	0	0	0	8/2 - 9/22
6A	112.3	4	-	2	0	3	0	8/19 - 9/22
7	113.2	3	-	0	0	0	0	8/7 - 8/29
8	113.7	7	-	0	1	3	0	8/7 - 9/28
8D	121.8	4	-	0	0	0	0	8/1 - 8/27
8C	121.9	4	-	0	0	0	0	8/1 - 8/27
8B	122.2	4	-	0	0	1	0	8/1 - 8/27
Moose	123.5	5	-	0	0	5	0	8/27 - 9/27
A'	124.6	4	-	0	0	4	0	8/27 - 9/21
A	124.7	7	-	0	1	4	0	8/7 - 9/24
8A	125.1	7	-	4	0	4	0	8/7 - 9/27
9	128.3	8	-	3	0	4	0	8/7 - 9/27
9B	129.2	7	-	7	0	6	0	8/11 - 9/27
9A	133.3	8	-	3	0	5	0	7/31 - 9/27
10	133.8	5	-	0	0	0	0	7/31 - 9/20
11	135.3	10	-	8	0	7	0	7/31 - 9/26
12	135.4	7	-	8	0	0	0	7/31 - 9/26
13	135.7	8	-	0	0	2	0	7/31 - 9/26
14	135.9	7	-	0	0	0	0	7/31 - 9/26
15	137.2	7	-	0	0	1	0	7/31 - 9/19
16B	137.3	7	-	0	0	0	0	8/6 - 9/26
17	138.9	8	-	4	0	7	0	8/6 - 9/26
18	139.1	5	-	0	0	0	0	8/6 - 9/3
19	139.7	8	-	6	0	1	0	8/6 - 9/26
20	140.0	7	-	1	0	2	0	8/6 - 9/19
21	141.1	8	-	5	0	4	0	8/6 - 9/26
21A	144.3	3	-	0	0	3	0	8/26 - 9/11
TOTAL		209		49	3	70	0	

[a] Not included in the same survey - data not comparable.

Appendix Table C-2 Number of observations of salmon in Susitna River sloughs in the Talkeetna to Devil Canyon reach during 1982 (adapted from ADF&G 1983b: Volume 2).

Slough	River Mile	Total # of visits	Number of visits live salmon were observed in sloughs					Sampling Period
			Chinook	Sockeye	Pink	Chum	Coho	
1	99.6	6	0	0	0	0	0	8/8 - 9/29
2	100.2	6	0	0	0	0	0	8/8 - 9/29
3B	101.4	7	0	0	0	0	0	8/8 - 9/29
3A	101.9	6	0	0	0	0	0	8/8 - 9/21
4	105.2	7	0	0	0	0	0	8/13 - 9/29
5	107.2	7	0	0	0	1	0	8/7 - 9/21
6	108.2	6	0	0	0	0	0	8/13 - 9/21
6A	112.3	9	0	0	1	2	2	8/7 - 9/27
7	113.2	8	0	0	0	0	0	8/8 - 9/27
8	113.7	10	0	0	0	0	0	7/28 - 9/21
8D	121.8	8	0	0	0	1	0	8/6 - 9/25
8C	121.9	7	0	2	0	3	0	8/6 - 9/25
8B	122.2	10	0	4	0	6	0	8/6 - 9/25
Moose	123.5	8	1[a]	2	2	7	0	8/6 - 9/25
A'	124.6	9	0	0	0	0	0	7/29 - 9/19
A	124.7	9	0	0	0	0	0	7/29 - 9/19
8A	125.1	10	0	9	3	10	3	8/6 - 10/2
B	126.3	9	0	4	2	6	0	8/12 - 10/2
9	128.3	8	0	4	3	6	0	8/6 - 9/25
9B	129.2	3	0	1	0	1	0	8/6 - 9/25
9A	133.3	11	0	1	0	3	0	8/6 - 10/1
10	133.8	9	0	0	0	2	0	8/6 - 9/25
11	135.3	12	0	11	4	10	0	8/2 - 10/5
12	135.4	10	0	0	0	0	0	8/2 - 9/25
13	135.7	10	0	0	0	0	0	8/6 - 9/25
14	135.9	10	0	0	0	0	0	8/6 - 9/25
15	137.2	9	0	0	3	1	2	8/4 - 9/25
16B	137.3	9	0	0	0	0	0	8/4 - 9/25
17	138.9	10	0	0	0	3	0	8/4 - 9/30
18	139.1	10	0	0	0	0	0	8/4 - 9/30
19	139.7	10	0	0	1	0	0	8/4 - 9/30
20	140.0	10	0	0	4	4	0	8/4 - 9/30
21	141.1	10	0	7	3	8	0	8/4 - 9/30
21A	144.3	4	0	0	0	0	0	8/4 - 9/23
TOTAL		287	1	45	26	74	7	

[a]Single chinook salmon observed milling in slough.

Appendix Table C-3 Number of observations of salmon in Susitna River tributaries in the Talkeetna to Devil Canyon reach during 1981 (adapted from ADF&G 1981a).

Tributary	River Mile	Total # of visits	Number of visits live salmon were observed in tributaries: Chinook[a]	Sockeye	Pink	Chum	Coho	Sampling Period
Whiskers Creek	101.4	8	-	0	0	0	7	8/5 - 10/2
Chase Creek	106.9	9	-	0	2	1	7	8/4 - 10/2
Gash Creek	111.6	2	-	0	0	0	2	9/23 - 9/28
Lane Creek	113.6	7	-	0	3	6	2	8/19 - 9/28
Lower McKenzie Creek	116.2	6	-	1	0	2	4	8/23 - 9/28
McKenzie Creek	116.7	2	-	0	0	0	0	8/11 - 8/23
Deadhorse	120.9	2	-	0	0	0	0	8/11 - 9/25
5th of July	123.7	1	-	0	1	0	0	8/11
Skull Creek	124.7	3	-	0	2	1	0	8/20 - 9/19
Sherman Creek	130.8	6	-	0	3	4	0	7/31 - 9/25
4th of July Creek	131.0	6	-	0	4	4	2	7/31 - 9/25
Gold Creek	136.7	1	-	0	0	0	0	8/25
Indian River	138.6	8	-	0	1	5	3	8/6 - 9/26
Jack Long Creek	144.5	3	-	0	1	0	0	8/21 - 9/24
Portage Creek	148.9	3	-	0	0	0	1	8/21 - 9/24
TOTAL		67	-	1	17	23	28	

[a] Not included in same survey - data not comparable.

Appendix Table C-4 Number of observations of salmon in Susitna River tributaries in the Talkeetna to Devil Canyon reach during 1982 (adapted from ADF&G 1983b: Volume 2).

Tributary	River Mile	Total # of visits	Number of visits live salmon were observed in tributaries					Sampling Period
			Chinook	Sockeye	Pink	Chum	Coho	
Whiskers Creek	101.4	6	0	0	4	0	5	8/8 - 9/24
Chase Creek	106.9	8	1	0	4	0	3	8/8 - 9/27
Slash Creek	111.2	1	0	0	0	0	1	9/21
Gash Creek	111.6	7	0	0	0	0	3	8/7 - 10/2
Lane Creek	113.6	11	4	0	5	8	4	7/12 - 9/21
Lower Mckenzie Creek	116.2	10	0	0	2	0	4	8/7 - 10/2
Mckenzie Cr	116.7	10	0	0	1	0	0	8/7 - 10/2
Little Portage Cr	117.7	10	0	0	4	3	3	8/7 - 10/2
5th of July Creek	123.7	8	1	0	4	1	0	8/6 - 9/20
Skull Creek	124.7	8	0	0	3	1	0	8/6 - 9/19
Sherman Cr	130.8	8	1	0	3	0	0	8/6 - 10/1
4th of July Creek	131.0	11	3	0	4	9	3	8/28 - 10/1
Gold Creek	136.7	5	1	0	2	0	1	8/3 - 8/30
Indian River	138.6	13	6	0	6	9	7	7/21 - 9/30
Jack Long Creek	144.5	9	2	0	3	1	1	8/4 - 9/30
Portage Cr	148.9	12	4	1	4	6	3	7/21 - 9/30
Cheechako Creek	152.5	8	4	0	0	0	0	8/5 - 9/24
Chinook Cr	156.8	4	3	0	0	0	0	8/6 - 8/22
Devil Cr	161.4	4	0	0	0	0	0	8/6 - 8/22
TOTAL		153	30	1	49	38	38	

Appendix Table C-5 Abundance of adult salmon in Susitna River sloughs during peak observations in 1982. Relative abundance: High (H) 100, Medium (M) 50-100, Low (L) 50, None observed (-).

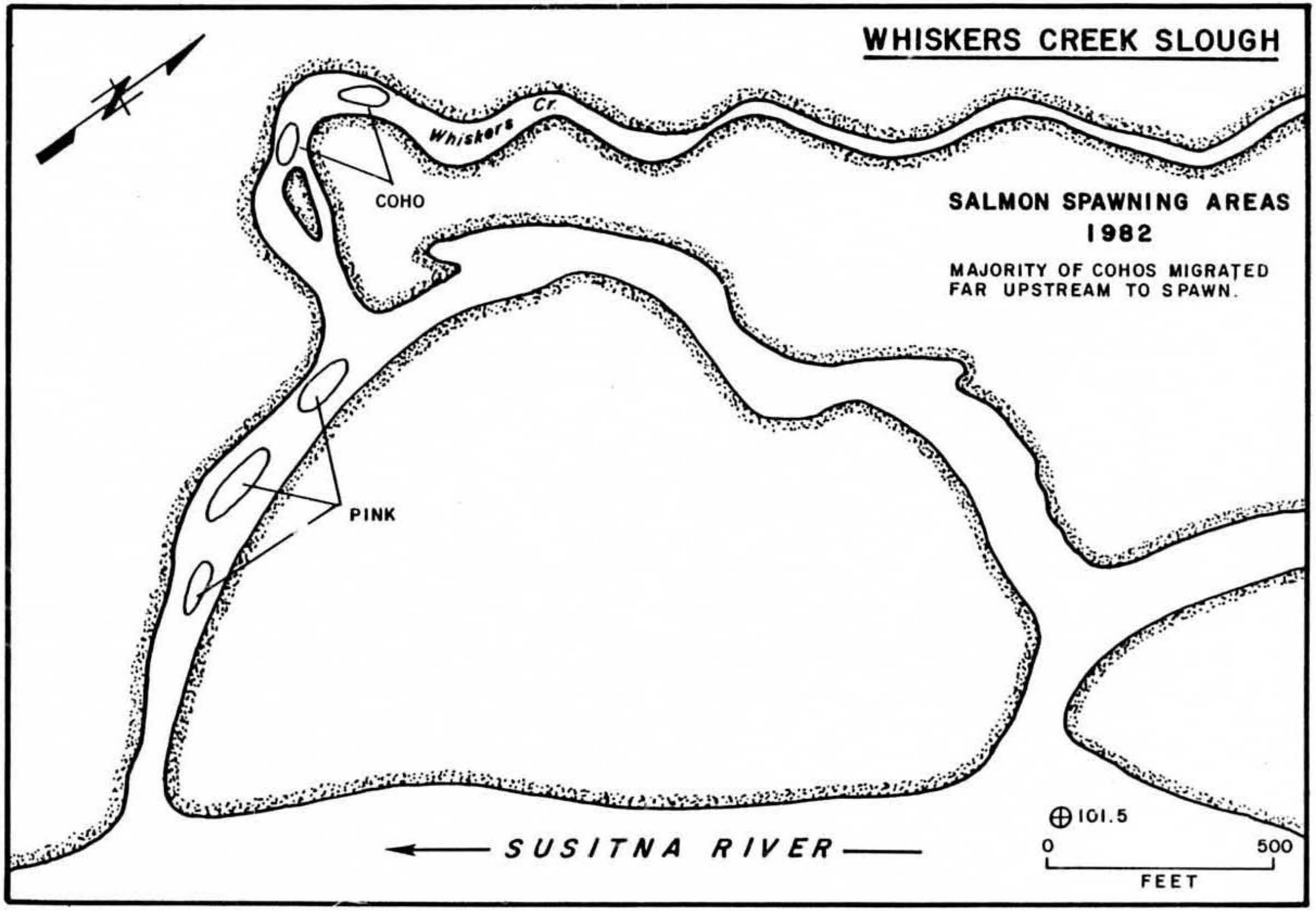
Slough	River Mile	Chinook	Sockeye	Pink	Chum	Coho
1-4	99.6-105.2	-	-	-	-	-
5	107.2	-	-	-	L	-
6	108.2	-	-	-	-	-
6A	112.3	-	-	L	L	L
7	113.2	-	-	-	-	-
8	113.7	-	-	-	-	-
8D	121.8	-	-	-	L	-
8C	121.9	-	L	-	L	-
8B	122.2	-	L	-	M	-
Moose	123.5	L[a]	L	L	L	-
A'	124.6	-	-	-	-	-
A	124.7	-	-	-	-	-
8A	125.1	-	M	L	H	L
B	126.3	-	L	L	L	-
9	128.3	-	L	L	H	-
9B	129.2	-	L	-	L	-
9A	133.3	-	L	-	H	-
10	133.8	-	-	-	L	-
11	135.3	-	H	H	H	-
12	135.4	-	-	-	-	-
13	135.7	-	-	-	-	-
14	135.9	-	-	-	-	-
15	137.2	-	-	H	L	L
16B	137.3	-	-	-	-	-
17	138.9	-	-	-	L	-
18	139.1	-	-	-	-	-
19	139.7	-	-	L	-	-
20	140.0	-	-	M	L	-
21	141.1	-	L	M	H	-
21A	144.3	-	-	-	-	-

[a]Single chinook salmon observed milling in slough.

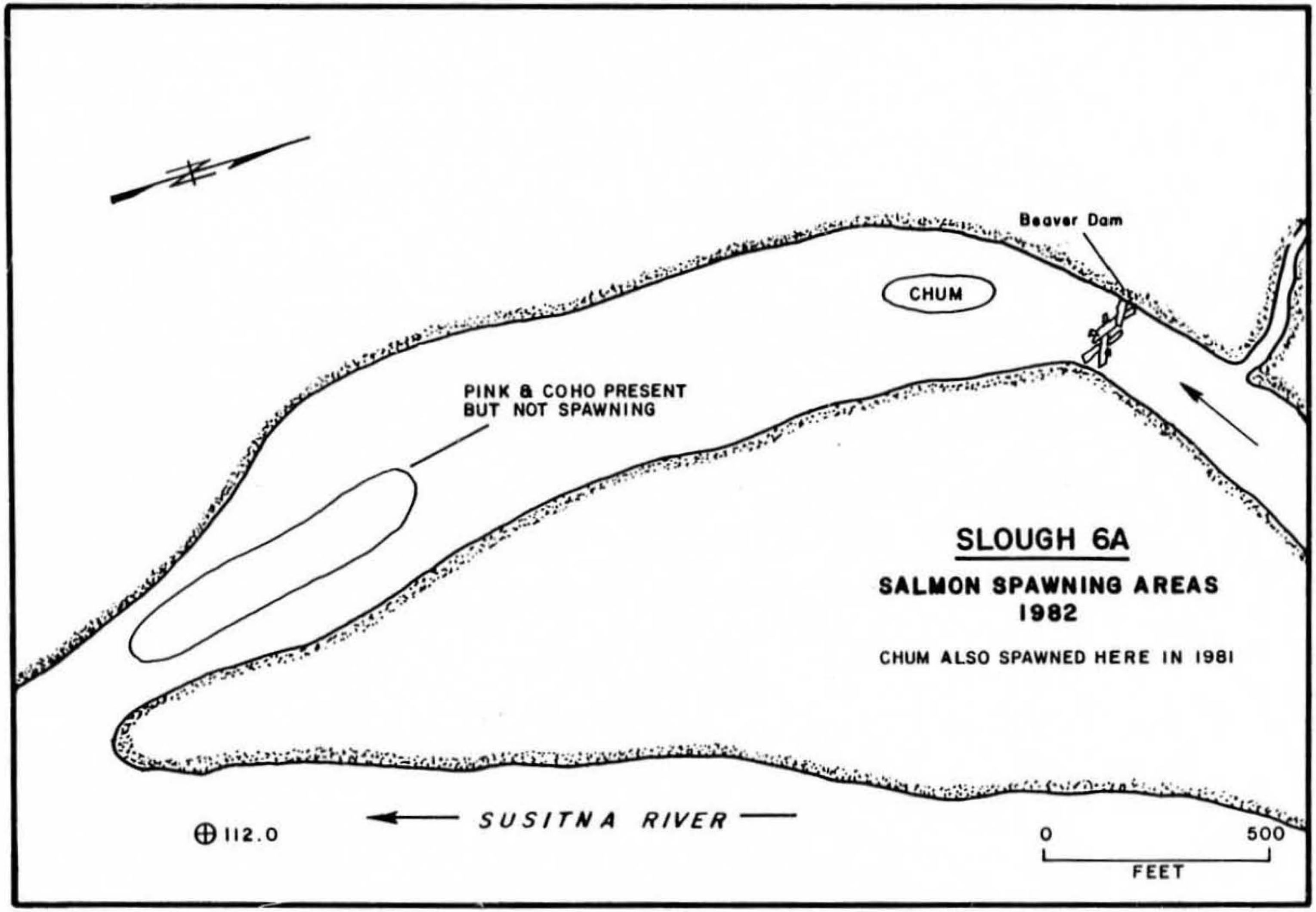
Report (ADF&G 1983b: Appendix Figures 4-F-15 to 4-F-69). Salmon spawning areas were observed in 10 of these sloughs during 1982 (Appendix Figures C-3 to C-11). In addition, locations of redds (ADF&G 1983b: Appendix 4-F) were mapped in more intensively studied sloughs (8A, 9, 11 and 21). A list of the maps produced and their locations is summarized in Appendix Table C-6. Information from all of these maps has been synthesized in Appendix Table C-7 and is discussed below.

Due to our dependence on visual observations to detect areas of upwelling, and our inability to observe upwelling if silts and sand substrates were absent, the relationship between open leads and areas of upwelling ground water was not always established. Field observations in which this relationship could be detected appeared to indicate that open leads occur immediately downstream from the point of upwelling. This trend was noted at Lane Creek Slough and sloughs 9, 9A, 11, 21 and 22. Other sloughs had many open leads yet little or no observed upwelling. In most of these instances, open leads were probably due to the presence of a nearby tributary or source of flowing water which was not observed. This occurred at Whiskers Creek Slough and sloughs 6A, 10 and 20. Slough 19 had a concentrated upwelling area yet very few open leads, none in the vicinity of the upwelling. Open leads were present in Slough 16B yet no upwelling was observed (perhaps because upwelling was so difficult to observe in rubble-cobble substrate).

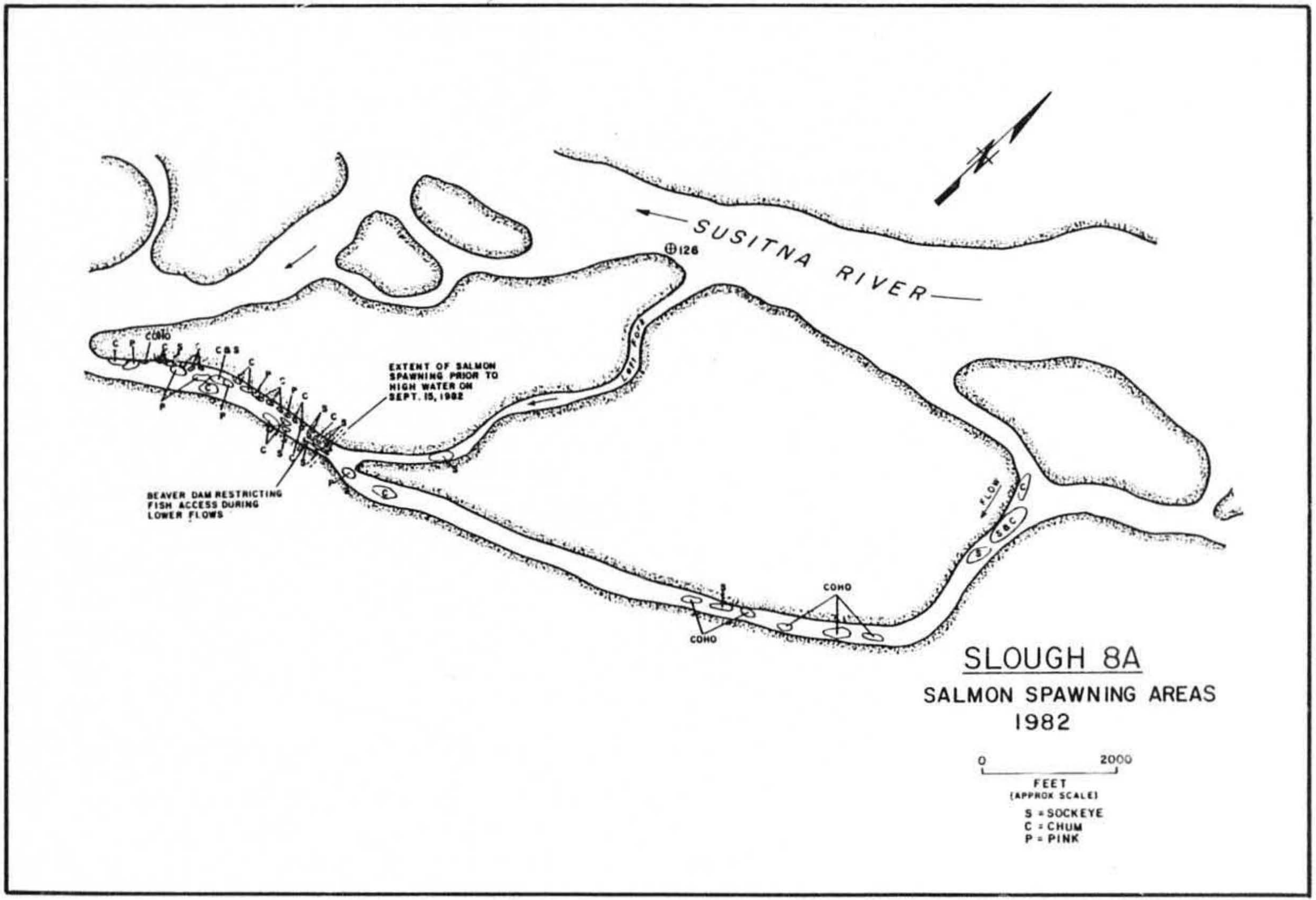
Substrate in sloughs varied from silt to cobble and boulders. The majority of salmon spawning in the sloughs were observed utilizing a



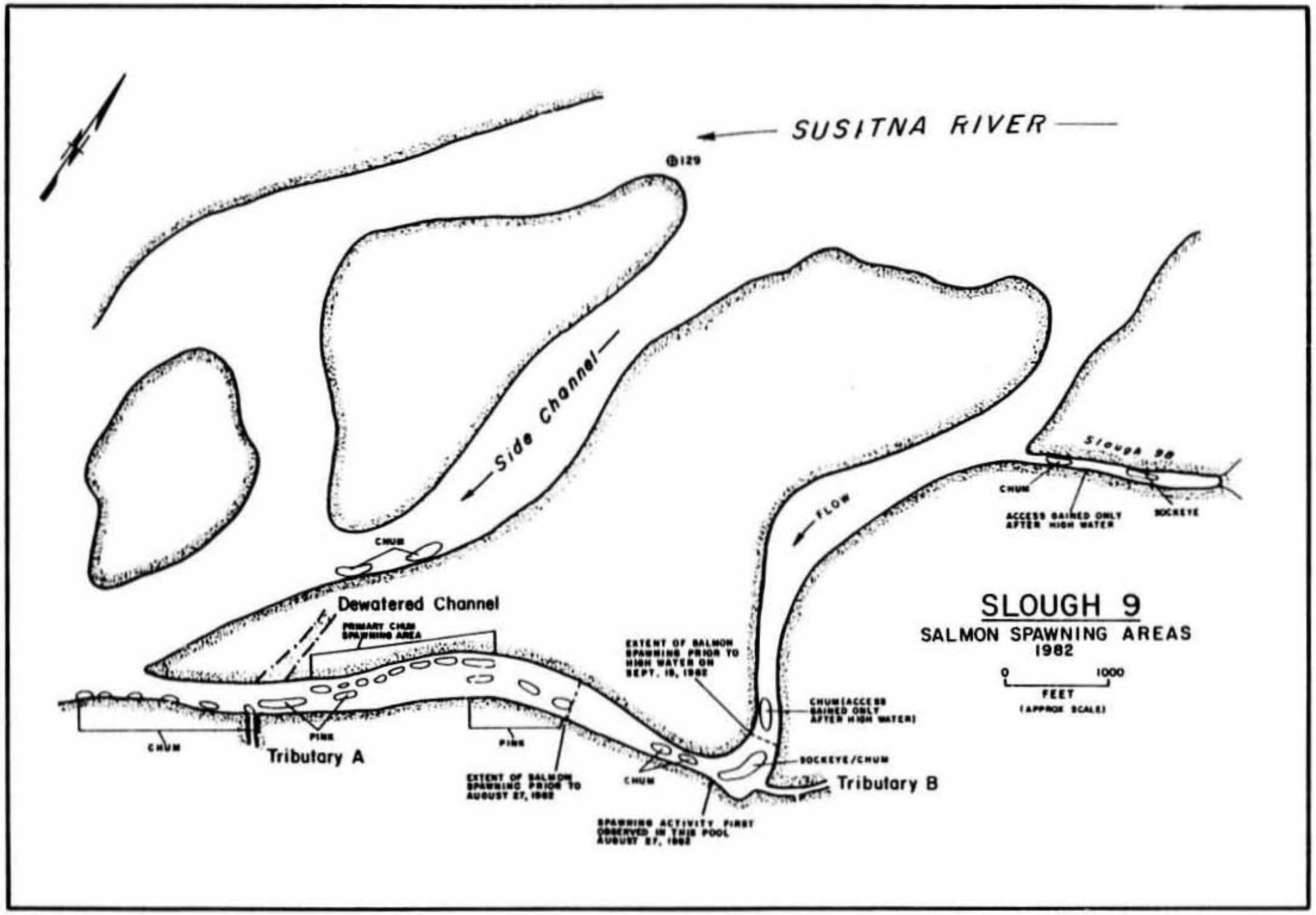
Appendix Figure C-3. Salmon spawning areas in Whiskers Creek Slough.



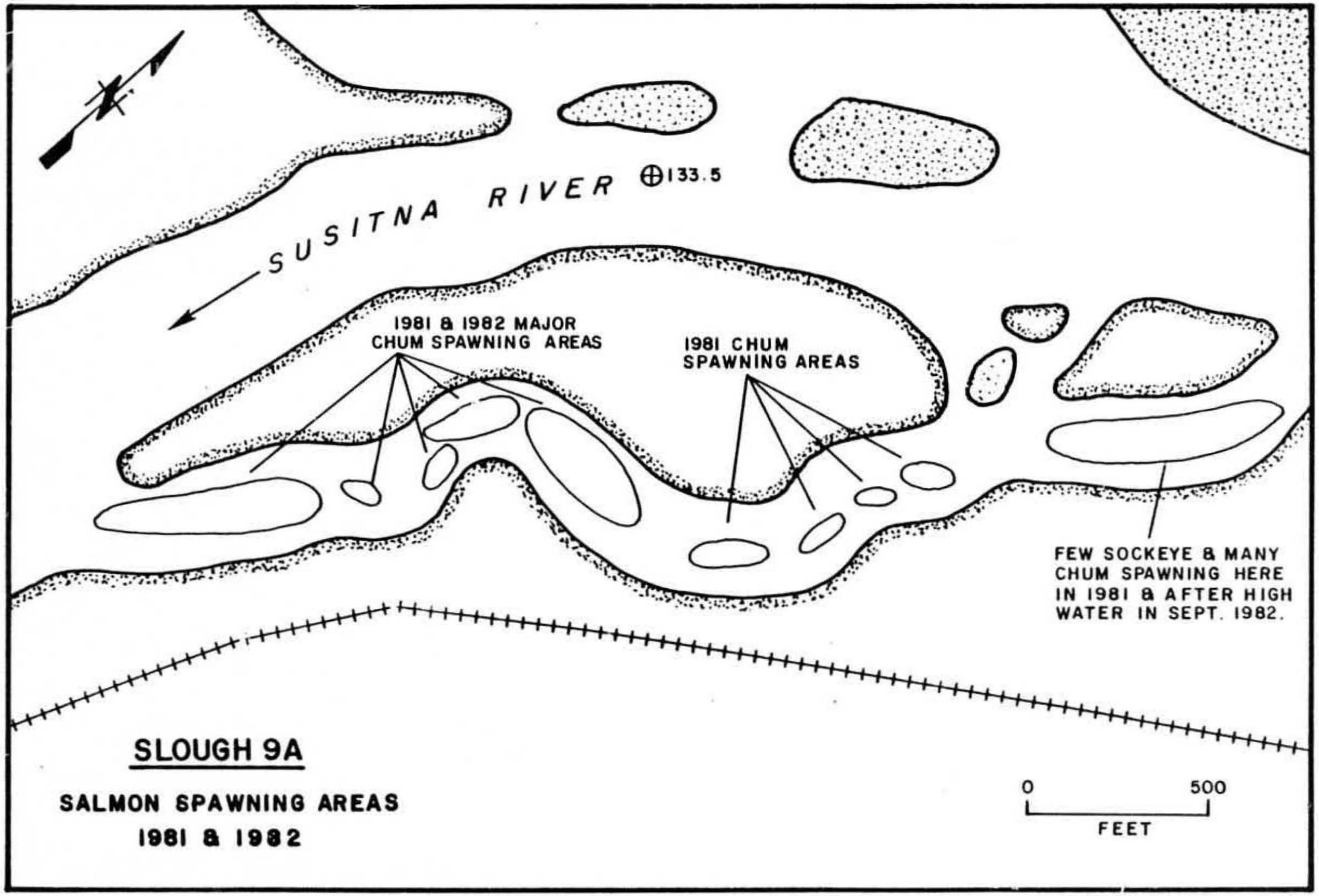
Appendix Figure C-4. Salmon spawning areas in Slough 6A.



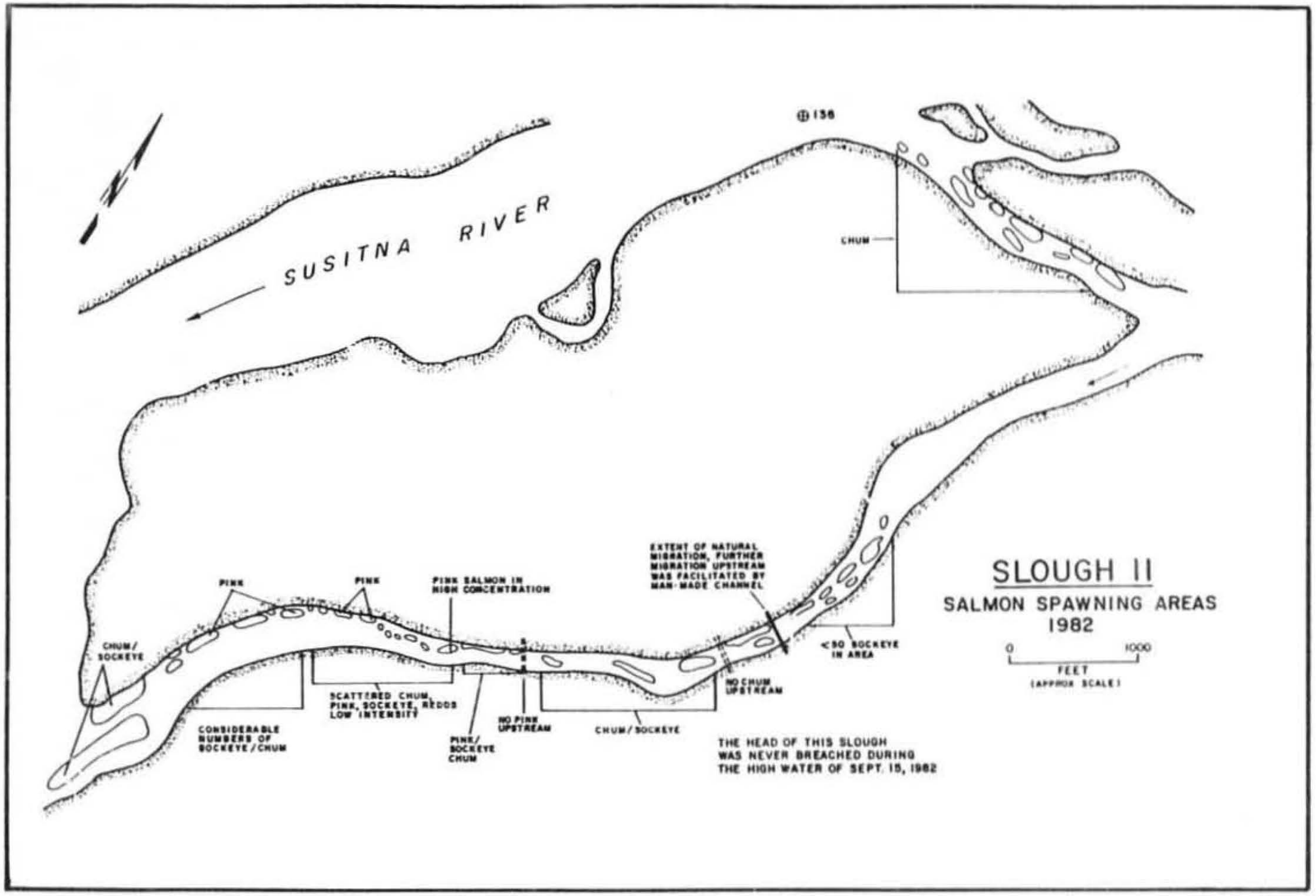
Appendix Figure C-5. Salmon spawning areas in Slough 8A.



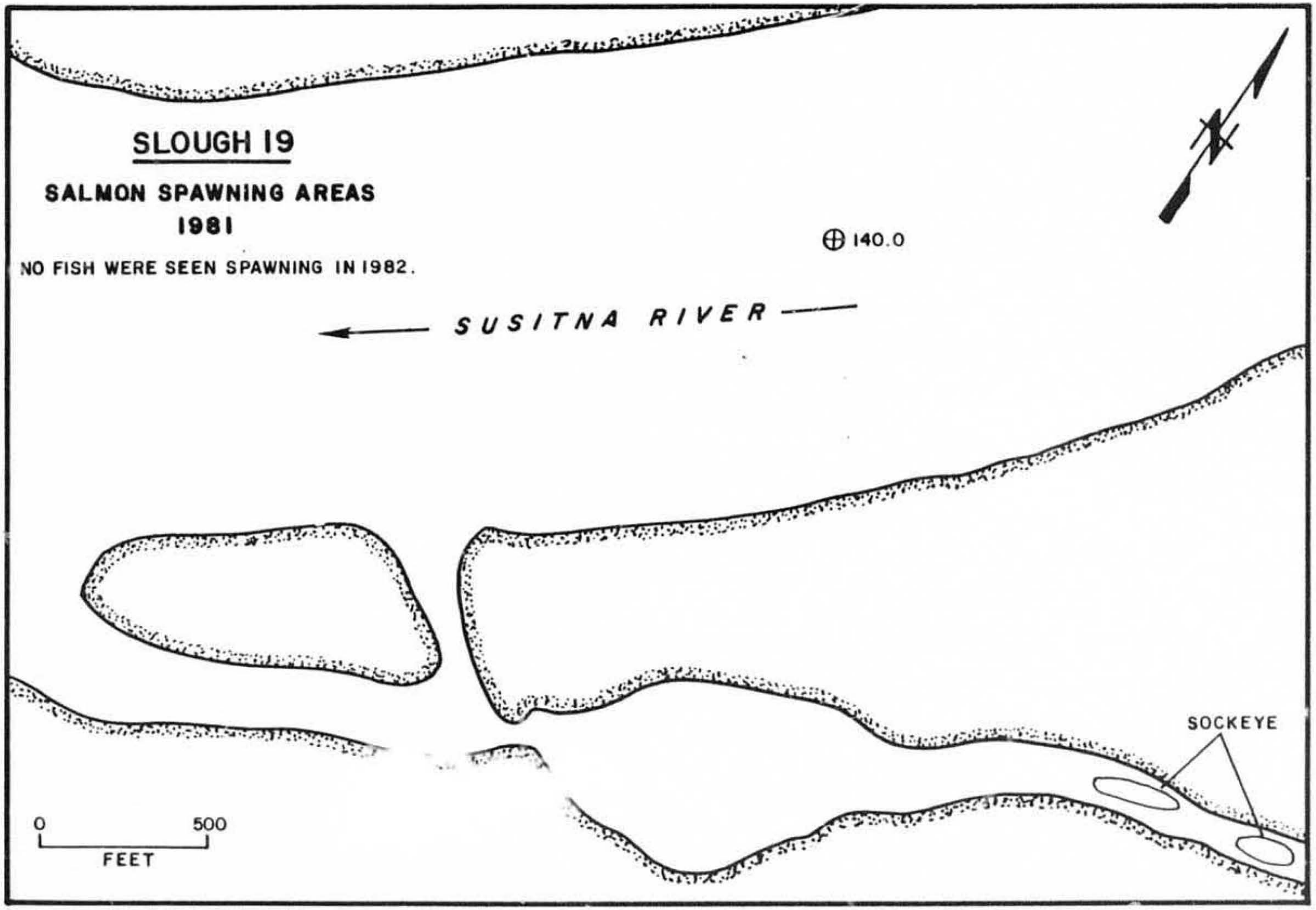
Appendix Figure C-6. Salmon spawning areas in sloughs 9 and 9B.



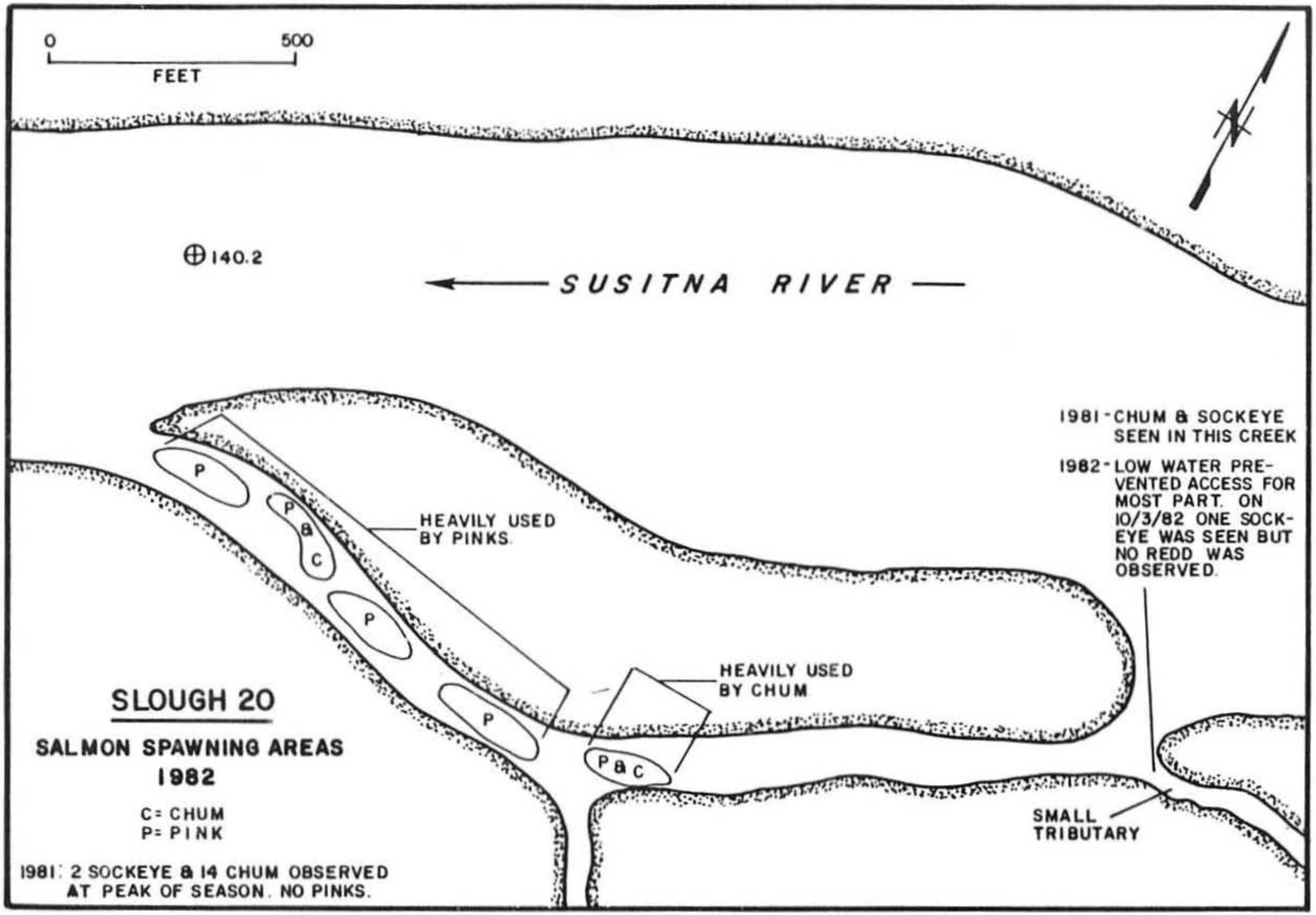
Appendix Figure C-7. Salmon spawning areas in Slough 9A.



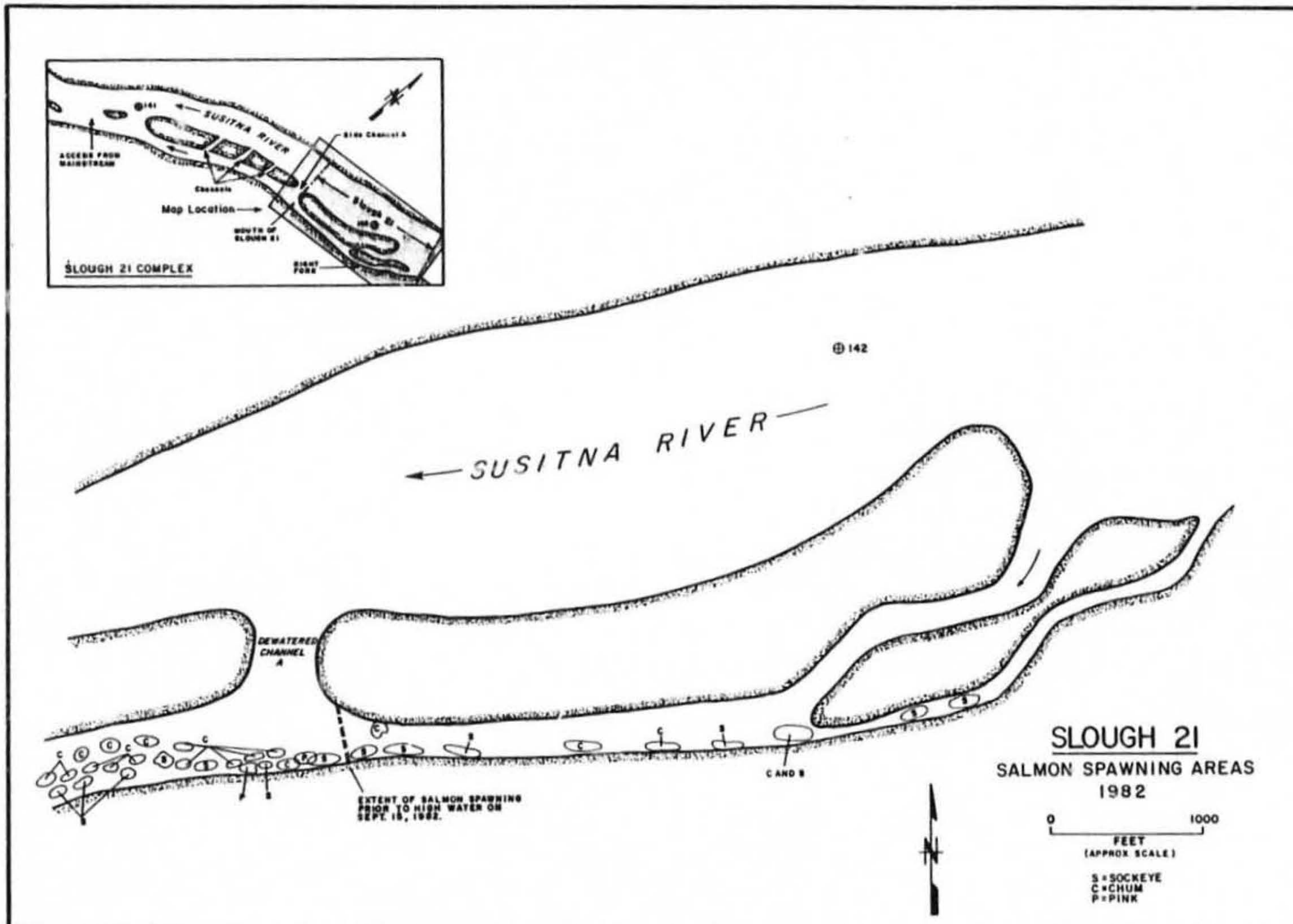
Appendix Figure C-8. Salmon spawning areas in Slough 11.



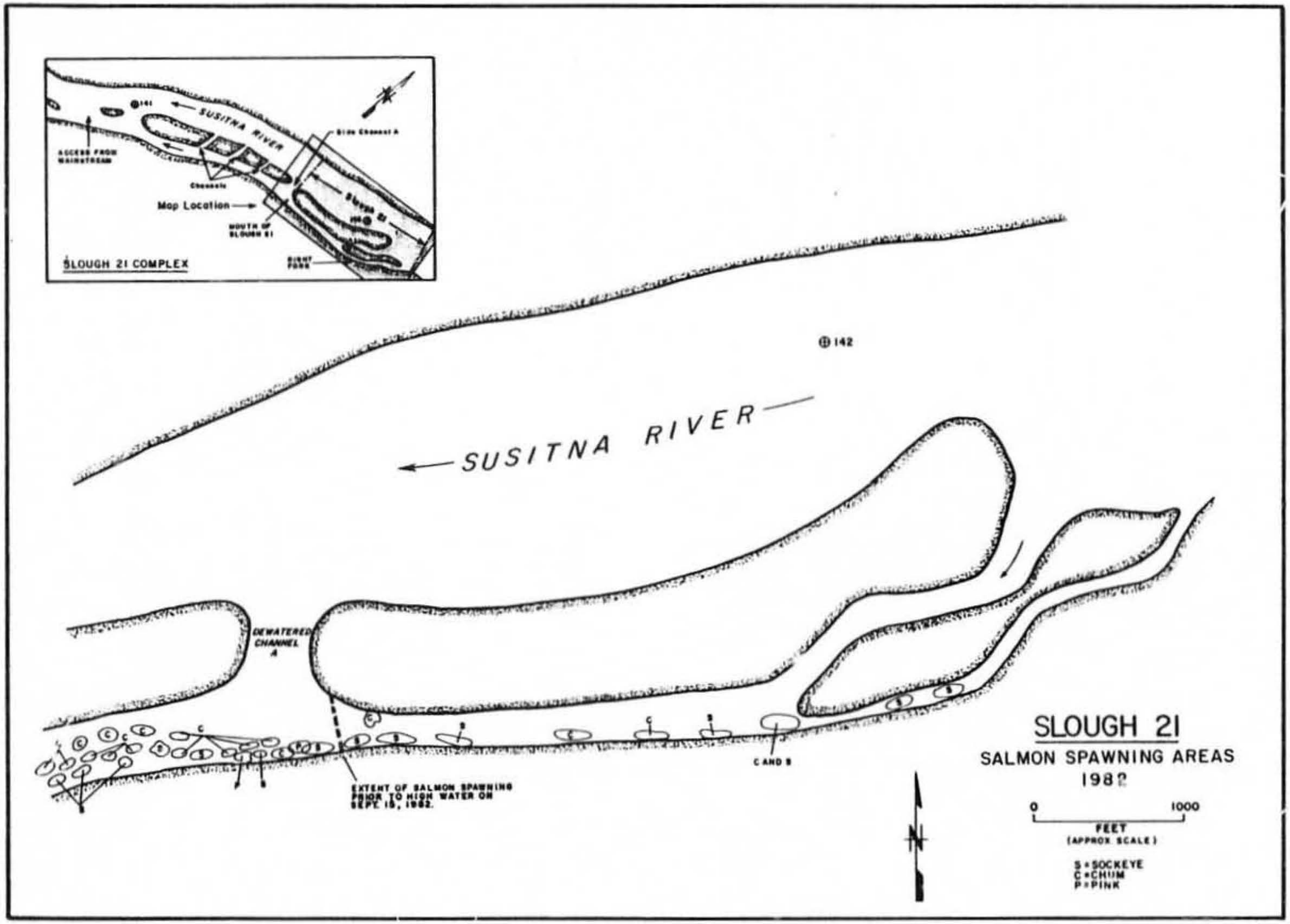
Appendix Figure C-9. Salmon spawning areas in Slough 19.



Appendix Figure C-10. Salmon spawning areas in Slough 20.



Appendix Figure C-11. Salmon spawning areas in Slough 21.



Appendix Figure C-11. Salmon spawning areas in Slough 21.

Appendix Table C-6 Summary of available maps of sampling sites, substrate types, ground water upwelling, open leads in ice cover and salmon spawning areas in 14 sloughs of the Susitna River, 1982.

Sloughs	Sampling Site[a]	Substrate[a]	Upwelling[a]	Ice Free Lead[a]	Spawning Area[a]
Whiskers Creek	X	X	0	X	X
Lane Creek	X	X	X	X	--
6A	X	X	0	X	X
8A	X	X	X	X	X
9, 9B	X	X	X	X	X
9A	X	X	X	X	X
10	X	X	0	X	0
11	X	X	X	X	X
16B	X	X	0	X	0
19	X	X	X	X	X
20	X	X	0	X	X
21	X	X	X	X	X
22	X	X	X	X	0

[a]ADF&G 1983b: Appendix Figures 4-F-15 to 4-F-69.

[b] X = Locations shown on map.
0 = No map, none observed.
-- = Salmon observed spawning but locations not mapped.

Appendix Table C-7 Summary of ground water upwelling, substrate composition and distribution of spawning salmon among some Susitna River sloughs, 1982.

Slough	Open leads in ice-cover (% total slough area)	Upwelling/ seepage[a]	Substrate Type[b]	Substrate Area(%)	Spawning[c] 1981	Spawning[c] 1982
Whiskers Creek Slough	52	1	GRRUCO SISA	98 2		P
Slough 6A	33	0	SICO SI	4 96	C,S	C,P, Coho
Lane Creek Slough	59	2	CORU SISA	44 56	C,P	
Slough 8A	10	3	GRRUCO SISA	91 9	C,S, Coho	C,P,S Coho
Slough 9	24	2	GRRUCO SISA	40 60	C,S	C,P,S
Slough 9B	8	2	CORU SISA	1 99	C,S	C,S
Slough 9A	52	2	RUCO SISA	95 5	C,S	C,S
Slough 10	19	2	RUCO SISA	58 42		C
Slough 11	48	3	GRRUCO GRSI	60 40	C,S	C,P,S
Slough 16B	8	0	GRRUCO SA	96 4		
Slough 19	11	2	RUCO SI	45 55	C,S	P
Slough 20	6	1	GRRUCO SI	67 33	C,S	C,P
Slough 21	70	3	RUCO SISA	64 36	C,S	C,P,S
Slough 22	15	2	RUCO SI	65 35	C	

[a] Upwelling/seepage observation rating scale (rating may be biased by limitation of visual observation method).

0 - none observed
1 - infrequently observed
2 - several localized areas of strong upwelling/seepage or numerous areas of weak upwelling/seepage
3 - numerous areas of strong upwelling/seepage

[b] SI - silt, SA - sand, GR - gravel, RU - rubble, CO - cobble, BO - boulder

[c] C - chum salmon, S - sockeye salmon, P - pink salmon, Coho - coho salmon

combination of gravel, rubble and/or cobble. In most sloughs the substrate was overlain with a thin layer of silt that could easily be fanned away by spawning fish. However, very few fish were observed spawning in areas where the overlying silt or sand deposits were more than 4-6 inches deep.

Access into sloughs can be a limiting factor regardless of the presence of upwelling ground water or good spawning substrate. Access difficulties may have prevented chum salmon spawning in Lane Creek Slough and sloughs 19 and 22 in 1982 (Appendix B).

DISCUSSION

Chum Salmon

Most chum salmon spawning appeared to occur in or near areas where upwelling ground water could be observed. Other investigators have also associated chum salmon spawning habitat with upwelling ground water (Kogl 1965, Francisco 1977, Wilson et al. 1981). In 1982, the sloughs with the most chum salmon (Appendix Table C-5) were observed to have intermediate or abundant levels of upwelling (Appendix Table C-7). The other salmon species were not abundant in these sloughs, except in Slough 11. In 1981, Lane Creek Slough (Slough 8) also had an intermediate level of upwelling and spawning chum salmon were abundant. Substrate composition differed among these sloughs, ranging from a high proportion of gravel, rubble and cobble, to a high proportion of sand and silt. Some sloughs with substantial upwelling ground water, such as

Lane Creek Slough and Slough 19 did not attract spawning chum salmon during 1982, perhaps due to limited access.

Because of its apparant importance to chum salmon spawning, it is recommended that specific studies to identify mainstem/slough ground water relationships be initiated and that existing studies be continued to further evaluate the relationship between this variable and spawning.

Pink Salmon

Pink salmon apparently select tributary-like areas for spawning within the sloughs. In sloughs 8A, 9, 11, 20 and 21 they were found spawning in shallow riffle zones containing gravel-rubble-cobble substrate. Because pink salmon return to spawn after two years in the ocean, interchange between alternate years is rare and one population is generally larger than the other. In the Susitna River basin the even years have the most abundant runs of pink salmon and this increase is evident in Appendix Table C-7.

Sockeye Salmon

Sockeye salmon apparently select the slower, deeper pools with a rubble-cobble substrate such as those in sloughs 8A, 9 (near the 90° bend), 11, 19 (1981 only) and 21.

Coho Salmon

Coho salmon are not nearly as abundant in the sloughs as chum, pink and sockeye salmon. Coho salmon seem to prefer to spawn in the tributaries but were observed in Whiskers Creek Slough in 1981 and observed spawning in the upper reaches of Slough 8A during both 1981 and 1982. Coho salmon were not observed in upper Slough 8A until after the water level rose in mid September 1982. However, coho salmon also arrived in Slough 8A in mid September 1981. Water levels were high throughout the summer of 1981 and turbid water may have obscured the arrival of the earliest coho salmon.

Chinook Salmon

Chinook salmon were observed to spawn exclusively in tributaries.

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APPENDIX D

Models of Hydraulic Conditions and Chum Salmon Spawning Habitat in Selected Susitna River Sloughs.

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INTRODUCTION

This appendix presents three models: 1) a model of available hydraulic conditions in sloughs as determined by slough discharge; 2) a model of chum salmon selection of redd sites in sloughs as determined by slough hydraulic conditions; and 3) a model of the wetted surface area of available hydraulic habitat categories in sloughs versus their suitability* for spawning by chum salmon at different slough flows. It represents the final step in a narrowing focus of investigation. Appendix B analyzes adult salmon migration up the Susitna River and access conditions into the mouths of nine selected sloughs between Talkeetna and Devil Canyon. Appendix C describes the distribution and abundance of adult salmon in 34 sloughs and 20 tributaries in the Talkeetna to Devil Canyon reach of the Susitna River. In Appendix C spawning areas in sloughs are also compared with substrate composition and areas of upwelling ground water.

Spawning is a critical period in the life cycle of any fish, particularly salmon. In the Susitna River basin, salmon often spawn in sloughs. Reduction in Susitna River discharges that occur as a result of filling and operation of the proposed hydroelectric facility is expected to affect hydraulic conditions in sloughs. Chum salmon were the most abundant salmon spawning in sloughs in 1981 and 1982. Consequently their spawning requirements were selected for this initial phase of analysis.

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* Habitat suitability is the relationship between fish habitat preference and habitat availability (Baldridge and Amos 1983).

In the first model, two hydraulic variables, water depth and velocity, were analyzed in four sloughs over a wide range of predicted slough discharges. The second model is a frequency distribution of chum salmon redds among available water depths, velocities and substrate types in three sloughs at low slough flows (4-8 cfs). The quantity and quality of chum salmon spawning habitat in sloughs is dependent upon environmental factors, some of which are flow dependent. Significant differences in the hydraulic variables of water depth and velocity, substrate composition and upwelling ground water* are expected to affect habitat suitability for spawning salmon in sloughs. The third model, a habitat suitability model developed for three sloughs, combined available water depths, velocities and substrate types at a predicted slough flow of 5 cfs with the frequency distributions of chum salmon redds.

METHODS

Hydraulic Model

Hydraulic data were collected and analyzed to predict the hydraulic conditions that would be available in a slough for a range of slough

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* Substrate composition was assumed to remain static for the range of predicted slough flows. Upwelling ground water is not evaluated in this appendix because of an inability to accurately identify point-specific sources in gravel, rubble, cobble, or boulder substrates. These variables are addressed qualitatively in Appendix C and a quantitative evaluation is planned in future studies.

flows. Supplemental information which supports this analysis is tabulated and summarized in the Basic Data Report (ADF&G 1983: Volume 4) as follows: location maps of sloughs, study reaches and transects (Appendix 4-F), survey data for each cross section (Appendix 4-E), cross sectional profiles of each transect (Appendix 4-A) and thalweg profiles (Volume 4).

Site selection and data collection

Five sloughs (8A, 9, 21, Rabideux and Chum Channel) were initially selected for a model of hydraulic and habitat conditions in sloughs of the Susitna River (RM 76.0 to 141.0). These sloughs were selected because they included a wide variety of slough characteristics and were assumed to represent hydraulic conditions present in most Susitna River sloughs (ADF&G 1981a, 1982, 1983: Volume 4). Rabideux Slough was not modeled because at high mainstem stages the right bank was overtopped by the mainstem and at low mainstem stages water ceased flowing through the slough.

Each slough study area consisted of a representative reach with transects. Study reach and transect locations were selected based on criteria described in Bovee and Milhous (1978) and Trihey and Wegner (1981) and represented proportions of each lotic habitat type present within a slough. They were also selected to encompass areas known to support chum salmon spawning during 1981. A study team consisting of a fishery biologist and a hydraulic engineer familiar with the U.S. Fish and Wildlife Service Instream Flow Group (IFG) methodology (Bovee 1982) directed the site selection, transect location, data reduction, and hydraulic model calibration.

Representative reaches included a minimum of 10 percent of the total length of the slough (ADF&G 1983: Volume 4). The length of wetted surface area in each slough decreased as the upper portion of the slough became dewatered (ADF&G 1983: Volume 4). Thus, the relative proportion of each representative reach to total slough length increased in sloughs 8A, 9 and 21 during periods of low flow when chum salmon were observed spawning (August - September).

Selecting a representative reach in each slough presented a problem generally limited to the mainstem confluence area. A backwater zone extended up into the sloughs from the confluence of the slough mouth with the mainstem river.* The size of the backwater zone varied with mainstem discharge. A discussion of the influence of mainstem flows on backwater zones in sloughs is included in several ADF&G reports (ADF&G 1981a, 1982, 1983: Appendix 4-F). Accordingly, the representative reach for each slough was located in a portion of the sloughs which would be upstream of the backwater zone for all mainstem flow conditions less than those required to breach the head of the slough.

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* The hydraulic model used for this study cannot be applied to lentic conditions.

Techniques for collecting hydraulic data at points (verticals) along transects are described by Trihey and Wegner (1981) and Bovee and Milhous (1978).

Data analysis

The hydraulic conditions in the sloughs were simulated using the IFG-4 computer program (Milhous et al. 1981). The program was designed for use by resource specialists to model hydraulic conditions for a wide range of discharges.

Field data were reduced and coded according to the procedures described by Trihey (1980). Procedures for entering the data into the IFG-4 computer program and for model calibration are described in Milhous et al. (1981).

The IFG-4 hydraulic model, is intended for use where hydraulic variables are assumed to be one of the major determinants affecting fish distribution and abundance. It is based on the assumption of steady flow conditions within a rigid channel. Observed shifts in slough bottom profiles across transects in study sloughs varied at the most 0.1 - 0.2 ft between discharges. These variations were probably attributable to acceptable errors in measurement. In these cases the different values were averaged. Also, discharge can increase or decrease during measurement of a series of transects within a study area. Transect discharges measured during and immediately following the highest measured flow event at Slough 9 were averaged for use in the computer simulation.

Observed water depths, velocities, water surface elevations and slough flows were used to calibrate the hydraulic models. Calibrating the IFG-4 model, as described by Milhous et al. (1981), involved slight adjustments to observed depths, velocities and water surface elevations within the range of accuracy of the field measurements (0.1 ft in depth, 0.1 ft/sec in velocity, or 0.01 ft in water surface elevation). Predicted depth and velocity values were compared with actual field measurements at known flows. Computer generated roughness coefficients ("Manning's n" values) were adjusted when necessary to better approximate observed velocities. Values for roughness coefficients were assigned within an acceptable range of potential values (Trihey 1980). Observed water surface elevations and discharges were compared with predicted water surface elevations and discharges. To determine whether the calibration process was completed, the velocity adjustment factors (VAF) were evaluated. The VAF is the ratio between the calibration and predicted discharge which is used to calculate predicted point velocities and is rated as either good, fair, marginal, poor, or very poor. A VAF for a calibrated model which is between 0.9 and 1.1 is considered good. A VAF less than 0.70 or greater than 1.30 is considered very poor.

After it is calibrated, the IFG-4 program can predict hydraulic conditions for individual slough cells* at any discharge within the calibration range. Depending on how accurately the model fits observed values, hydraulic conditins can only be modeled for given flows which range from 40 percent of the lowest measured flow to 250 percent of the highest measured flow (Bovee and Milhous 1978).

Direct comparison of observed hydraulic conditions in the four study sloughs is not feasible because the specific flow values and the range of flows measured at each slough varied. Thus, four predicted slough discharges (5, 50, 150, and 300 cfs) were chosen to standardize hydraulic conditions so that comparisons between the sloughs could be made. Sloughs 9 and 21 were evaluated for all four flow ranges; Chum Channel for three of the flows (5, 50, and 150 cfs); and Slough 8A for two of the flows (5 and 50 cfs). The lowest predicted discharge for the four sloughs, 5 cfs, was selected because low flow discharges ranging between 4 and 8 cfs were measured at sloughs 8A, 9, and 21 during the period of salmon spawning. A low intermediate flow for the four sloughs, 50 cfs, was selected because it was the maximum predictable flow within the calibration range of the model for Slough 8A. A high intermediate flow of 150 cfs was selected for sloughs 9, 21, and Chum Channel because it was a high predictable flow for Chum Channel. The high flow for sloughs 9 and 21, 300 cfs, was selected because the highest predictable flow for Slough 21 was in this range.

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* A slough cell encompasses the surface area surrounding each vertical between adjacent verticals and transects which is assumed to have the same habitat characteristics as the vertical at the center of the cell.

Spawning Habitat Model

The spawning habitat model presents the relationships of chum salmon selection of redd sites in sloughs to slough hydraulic conditions. Water depth, velocity and substrate composition are considered important physical variables which determine acceptable spawning habitat for Pacific salmon (Reiser and Bjornn 1979). Significant amounts of variation in spawning location can be explained by distributions in water depths, velocity and substrate (Gorman and Karr 1978). Evaluation of these characteristics to develop a slough spawning habitat model were initiated in 1982.

Site selection and data collection

Five sloughs (8A, 9, 21, Rabideux and Chum Channel) were initially selected for a study to model salmon spawning habitat. These sloughs were selected because of their relative importance to the fishery, based on observed numbers of spawning salmon in previous years (ADF&G 1981a, b, 1982, 1983: Volume 4).

Low flows in the Susitna River during 1982 apparently prevented access of adult salmon to some 1981 spawning areas (Appendix B); thus, anticipated salmon redds were not observed in Chum Channel or Rabideux Slough in 1982. Consequently, these two sloughs were deleted from the spawning habitat model study.

Slough spawning habitat study areas encompassed the entire slough (with the exception of the backwater zone). Water depth, velocity and substrate composition were examined at all active salmon spawning redds in the sloughs between August 25 and September 6, 1982. Specific techniques for locating spawning salmon and sampling redd sites are described in other publications (ADF&G 1981b, c, 1983: Volume 4; Estes et al. 1981; Wilson et al. 1981). Spawning salmon were observed directly from the slough banks. During observations the sloughs were clear, shallow, and slow-moving. Therefore, salmon were easily seen and identified.

Sufficient numbers of chum, pink, and sockeye salmon redds must be sampled to determine a multivariant suitability function based on probability (see suitability model section below); Bovee and Cochnauer (1977) recommend a minimum of 200. Although observations of redds for the three species were insufficient to meet this criterion, chum salmon were the most abundant salmon observed spawning in the sloughs (37 redds measured in Slough 8A, 48 in Slough 9, and 33 in Slough 21). Consequently, their spawning requirements were selected for detailed analysis.

Data analysis

Frequency distributions of water depths, velocities and substrate composition at chum salmon redds, measured at slough flows of 4-8 cfs, were plotted. To reduce variability of the continuous variables (depth and velocity) associated with small sample sizes of redds, adjacent values were grouped (Bovee and Cochnauer 1977). A difference of $\pm$ 0.1

ft or ft/sec was considered to be within the range of potential field measurement error. Therefore, 0.2 ft was chosen as the depth increment and 0.2 ft/sec was chosen as the velocity increment. The same increments were used for water surface area of available depths and velocities so that frequency distributions of depth and velocity at redds would be comparable. A previous habitat suitability study in Alaska used depth increments of 0.3 and 0.4 ft and velocity increments of 0.5 ft/sec (Wilson et al. 1981, Baldrige and Amos 1983).

Suitability Model

In order to determine whether a particular type of habitat is important for a particular fish species/life stage (e.g., spawning chum salmon), the utilized habitat must be compared to the total amount and types of available habitat.

Habitat suitability is defined by the percent occurrence of a fish observed within increments of an environmental variable weighted against the corresponding percent occurrence of available area within increments of the same variable (Baldrige and Amos 1983). The IFG provides a computer program, the Physical Habitat Simulation System (PHABSIM), which merges the IFG-4 model with habitat preferences of fish (Milhous et al. 1981).

There are four methods which quantify the combined habitat preference of a fish species/life stage for water depth, velocity and substrate composition. These techniques are: multivariate suitability functions, preference curves, binary criteria, and multivariate functions in association with preference curves. Each technique has certain strengths, weaknesses and limiting assumptions (Bovee 1982).

Our intention to use a multivariate suitability function was precluded. A multivariate suitability function cannot be derived without sufficient data and it is difficult, if not impossible, to supplement the function with professional judgment (Bovee 1982). Insufficient redds were available for measurement during 1982 to determine the probability of finding a certain combination of environmental conditions given the presence of a fish (Bovee and Cochnauer 1977, Voos 1981).

The preference curve method (Bovee and Cochnauer 1977, Baldrige and Amos 1983) was a possibility but preference curves are environmentally dependent (Bovee 1982). That is, individual stocks of a species/life stage have adapted to the environmental conditions of the stream system they are found in. Habitat criteria for a species that are collected in one system should not be applied to another unless their applicability to one another is validated (Estes et al. 1981, Wilson et al. 1981, Bovee 1982). Thus, it cannot be assumed that preferences of salmon in Susitna River sloughs are similar to those in other watersheds. Differences in preference curves from other watersheds may represent real differences in microhabitat preference, availability, or sampling bias. Given that equivalent sampling procedures were used, another bias that must be considered is one that would be present if the range of available habitat values is less than the range that would otherwise be utilized by the fish species/life stage.

The binary criteria method was too simplistic. Dealing only with presence or absence of a fish in a habitat, it makes no distinction between varying degrees of habitat suitability. However, analysis of criteria has an advantage over the use of statistical functions which describe species behavior. That is, criteria need no statistical justification and do not "require more than professional judgment as to sufficiency of conditions" (Bovee 1982).

Our analysis borrowed concepts from both the binary criteria and preference curve methods. The compromise was to increase the number of categories of fish preference. Rather than considering simple presence or absence, predictions of habitat availability were used to categorize habitat as optimal, preferred, utilized, or unacceptable. These hierarchical categories are based on an ordinal scale of measurement (i.e., no value is placed on the interval between each category). In contrast, preference curves, used to determine weighted usable areas, are necessarily based on the ratio scale of measurement, where values between 0 (unacceptable habitat) and 1 (optimal habitat) are specified by a probability-of-use curve (Bovee 1982).

Because a distinction was made between those conditions that were optimal, preferred or utilized, our method approximates the utility of a weighted usable area analysis without the use of probability functions, which require a minimum sample size. Because the preference criteria were determined from field observations, rather than hypothesized or adapted from a literature review of chum salmon spawning in other streams, they are relevant to conditions observed in Susitna River sloughs during 1982.

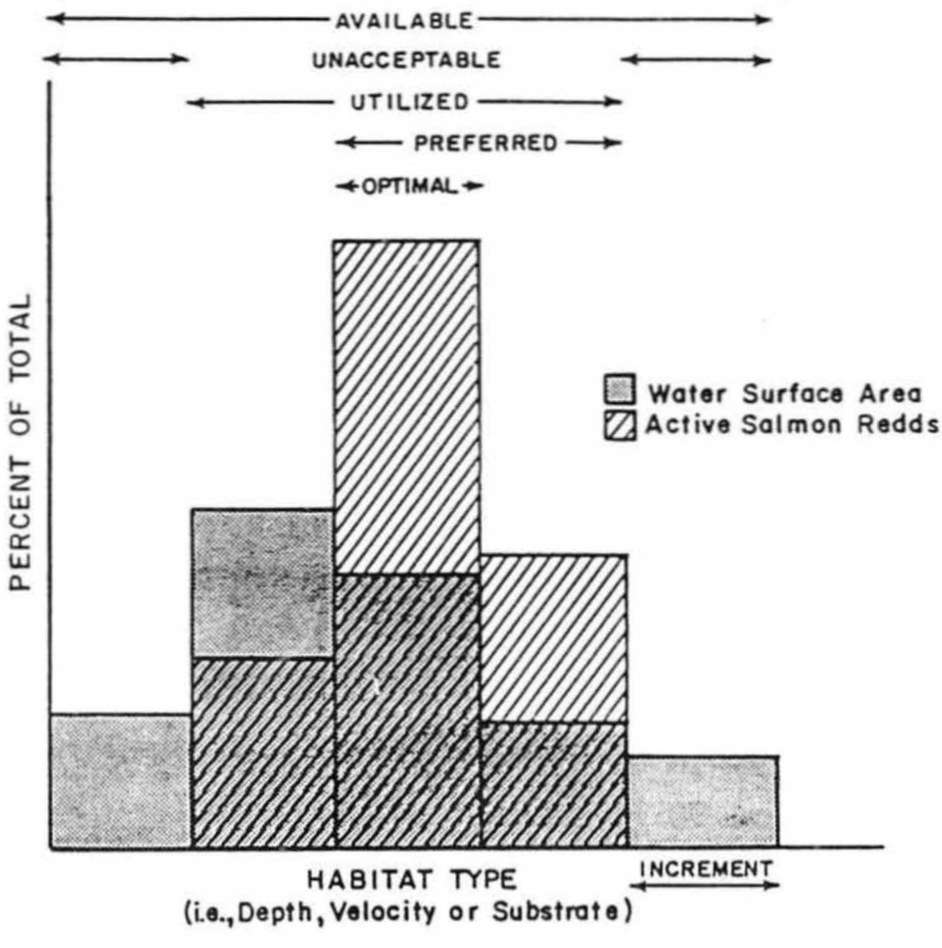
In developing a suitability model for the evaluation of fish habitats, the following assumptions (Baldridge and Amos 1983) adapted from Bovee and Cochnauer (1977) were applied:

1) individual fish tend to select the most favorable habitat from within the total range of available habitat. They use less favorable habitat with lesser frequency and eventually leave the area, if possible, before microhabitat conditions become lethal;

2) individual fish are most frequently observed in their most preferred habitat conditions; therefore, frequency of observation can be accepted as an indication of habitat utilization and frequency of observation weighted by habitat availability can be accepted as an indication of suitability; and

3) individual fish select values of one habitat variable independently of the other habitat variables as long as all these other variables are within the tolerable range of the species/life stage.

Habitat suitability was determined in six steps. First, the frequency distribution of active redds and corresponding frequency distributions of available habitat variables predicted by the hydraulic model were superimposed. Second, spawning habitat was categorized (unacceptable, utilized, preferred, or optimal) based upon a combination of the percent



Appendix Figure D-1. Illustration of habitat categories based on fish preference.

occurrences of redds and each available habitat variable (Appendix Figure D-1). Criteria for each habitat preference category were:

- o Unacceptable spawning habitat in a slough included those available increments of a particular habitat variable (i.e., water depth, velocity or substrate composition) where active redds were not observed.

- o Utilized spawning habitat in a slough included those available increments of a particular habitat variable where active redds were observed. Utilized spawning habitats included those that were also preferred and optimal.

- o Preferred spawning habitat in a slough included those available increments of a particular habitat variable where the proportion of active redds exceeded the proportion of water surface area. Preferred spawning habitats included optimal habitat.

- o Optimal spawning habitat in a slough included those available increments of a particular habitat variable in which the largest proportion (mode) of redds occurred.

Third, the cumulative frequencies of utilized water depths, velocities and substrate types were compared with those that were available and tested for significant differences in distribution with a Kolmogorov-Smirnov two-sample test (Conover 1971). This test allows for comparisons between two distributions and can distinguish differences associated with both central tendency (e.g., median) and variability (e.g., variance). If there is no statistically significant difference between what was available and what the fish selected, then no preference could be inferred with the existing data base.* Fourth, the habitat preference categories of each significant habitat variable representing a slough cell were compared. If all habitat variables within a cell were in the same category, the surface area of that cell was assigned to that category. If different categories were assigned to the habitat variables within a cell, the least selective category was assigned to the surface area of the cell (e.g. if depth were classified as optimal and substrate classified as utilized in a cell, that cell would be classified as utilized). Fifth, the surface area of all cells were summed to determine the water surface area of the study reach.* Sixth, the surface area of each habitat preference category was divided by the total water surface area of the study reach to determine the percentage of total water surface area for each category within the study reach.

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* Regardless of the outcome of the statistical test, available and utilized data will continue to be collected for all three habitat variables because of the low sample sizes used in this test and the biological significance of these variables. Another Kolmogorov-Smirnov two-sample or similar test will be performed after the 1983 field season, when sample size and observed range of available depths, velocities or substrate types are considered to be sufficient.

Appendix Table D-1. Calibration of water surface elevations and discharges at two flows (6.7 and 90 cfs) for transects in Chum Channel: 1982.

Transect	Water Surface Elevation (ft)		Discharge (cfs)			Velocity Adjustment Factor
	Observed	Predicted	$\bar{X}$ Observed	Predicted	% Diff	
1	172.10	172.10	6.7	6.5	-3	1.0000
2	172.28	172.28	6.7	6.8	+1	1.0000
3	172.32	172.32	6.7	6.8	+1	.9995
4	172.32	172.32	6.7	6.7	0	.9862
5	172.35	172.35	6.7	7.1	+6	.9746
6	172.35	172.35	6.7	6.5	+3	.9977
7	172.50	172.50	6.7	6.8	+1	1.0000
8	172.66	172.66	6.7	6.5	-3	.9484
1	172.45	172.45	90.0	88.3	-2	.9879
2	172.72	172.72	90.0	90.8	+1	.9968
3	172.79	172.79	90.0	90.9	+1	.9960
4	172.81	172.81	90.0	89.0	-1	.9873
5	172.93	172.93	90.0	93.9	+4	1.0035
6	173.02	173.02	90.0	91.4	+2	.9992
7	173.10	173.10	90.0	92.1	+2	.9658
8	173.13	173.13	90.0	89.6	-1	.9971

Appendix Table D-2. Calibration of water surface elevations and discharges at three flows (4, 7 and 20 cfs) for transects in Slough 8A: 1982.

Transect	Water Surface Elevation (ft)		Discharge (cfs)			Velocity Adjustment Factor
	Observed	Predicted	$\overline{X}$ Observed	Predicted	% Diff	
1	565.47	565.50	4.0	4.1	+3	.9539
2	565.48	565.51	4.0	4.0	0	.9288
3	565.52	565.55	4.0	4.0	0	.9344
4	565.84	565.87	4.0	4.0	0	1.0043
5	566.01	566.02	4.0	4.0	0	.9124
6	566.05	566.06	4.0	4.1	+3	1.0036
7	566.31	566.32	4.0	4.0	0	1.0108
8	566.62	566.63	4.0	4.0	0	1.0060
9	567.20	567.21	4.0	4.0	0	.9866
10	567.20	567.21	4.0	4.0	0	.9851
11	567.20	567.21	4.0	4.0	0	.9884
1	565.65	565.60	7.0	7.1	+1	.9895
2	565.66	565.61	7.0	7.1	+1	.9746
3	565.69	565.64	7.0	7.1	+1	.9617
4	566.05	566.03	7.0	7.0	0	1.0076
5	566.13	566.13	7.0	7.0	0	.9740
6	566.15	566.15	7.0	7.1	+1	1.0146
7	566.37	566.37	7.0	7.0	0	.9833
8	566.68	566.68	7.0	7.0	0	1.0350
9	567.28	567.28	7.0	7.0	0	.9991
10	567.29	567.29	7.0	7.0	0	.9955
11	567.29	567.29	7.0	7.0	0	1.0107
1	565.76	565.80	20.05	20.1	+1	1.0206
2	565.77	565.81	20.05	20.1	+1	1.0082
3	565.80	565.84	20.05	20.1	+1	1.0086
4	566.37	566.38	20.05	20.2	+1	.9898
5	566.36	566.36	20.05	19.9	-1	1.0198
6	566.37	566.37	20.05	20.1	+1	.9367
7	566.48	566.48	20.05	20.0	0	1.0103
8	566.79	566.79	20.05	19.9	-1	1.0009
9	567.44	567.44	20.05	20.0	0	1.0048
10	567.46	567.46	20.05	20.0	0	1.0052
11	567.45	567.45	20.05	20.1	+1	.9920

Appendix Table D-3. Calibration of water surface elevations and discharges at three flows (8, 145 and 232 cfs) for transects in Slough 9: 1982.

Transect	Water Surface Elevation (ft)		Discharge (cfs)			Velocity Adjustment Factor
	Observed	Predicted	$\bar{X}$ Observed	Predicted	% Diff	
1	592.40	592.40	8.0	8.0	0	.9908
2	592.60	592.60	8.0	8.1	+1	1.0026
4	592.75	592.75	8.0	8.0	0	.9961
6	593.40	593.36	8.0	8.1	+1	1.0212
7	593.45	593.44	8.0	8.0	0	1.0117
8	593.40	593.39	8.0	7.9	-1	1.0054
9	593.50	593.50	8.0	8.2	+3	.9930
10	593.60	593.59	8.0	8.0	0	.9945
1	593.43	593.42	145.0	146.4	+1	1.0073
2	593.60	593.57	145.0	144.7	0	1.0148
4	593.60	593.65	145.0	145.3	0	1.0450
6	594.00	594.18	145.0	144.9	0	.9973
7	594.20	594.25	145.0	147.0	+1	1.0028
8	594.20	594.29	145.0	143.3	-1	1.0182
9	594.30	594.35	145.0	145.4	0	1.0221
10	594.30	594.37	145.0	144.7	0	1.0118
1	593.70	593.71	232.0	234.6	+1	.9903
2	593.80	593.83	232.0	231.0	0	.9987
4	594.00	593.94	232.0	232.6	0	.9848
6	594.50	594.36	232.0	231.4	0	.9621
7	594.50	594.45	323.0	235.9	+2	.9814
8	594.20	594.52	232.0	229.5	-1	.9798
9	594.60	594.56	232.0	231.8	0	.9920
10	594.60	594.54	232.0	231.4	0	.9893

Appendix Table D-4. Calibration of water surface elevations and discharges at three flows (5, 10 and 157 cfs) for transects in Slough 21: 1982.

Transect	Water Surface Elevation (ft)		Discharge (cfs)			Velocity Adjustment Factor
	Observed	Predicted	$\bar{X}$ Observed	Predicted	% Diff	
3	744.23	744.28	5.0	5.0	0	1.0067
4	744.25	744.29	5.0	5.0	0	.9726
5	744.27	744.31	5.0	4.8	-4	1.0295
6	744.55	744.57	5.0	4.8	-4	.9952
7	744.74	744.77	5.0	5.0	0	.9655
3	744.60	744.50	10.0	10.0	0	.9951
4	744.59	744.51	10.0	10.0	0	.9990
5	744.61	744.51	10.0	9.7	-3	.9968
6	744.78	744.72	10.0	9.8	+2	1.1046
7	744.99	744.93	10.0	10.0	0	1.0641
3	745.84	745.90	157.0	156.8	0	.9906
4	745.85	745.90	157.0	156.2	-1	.9882
5	745.87	745.96	157.0	158.3	+1	.9562
6	745.89	745.94	157.0	157.8	+1	.9970
7	745.98	746.02	157.0	157.7	0	.9558

RESULTS

Hydraulic Model

Accuracy and precision

The IFG-4 model must be calibrated to meet required standards of precision (Milhous et al. 1981). The IFG-4 models for hydraulic simulation in sloughs 8A, 9, 21, and Chum Channel predicted the water surface elevation and discharge at each transect. Seventy-three percent of the predicted water surface elevations were within 0.05 foot of observed water surface elevations (Appendix Tables D-1 to D-4). Overall, predicted water surface elevations were highly correlated with observed values (r = 0.999). Eighty-two percent of the predicted discharges at each transect differed from mean observed discharges for each slough by no more than 1 percent. Only one predicted transect discharge deviated by more than 5 percent from its observed mean discharge (Chum Channel Transect 5). Overall, predicted discharges at each

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* If a backwater zone within a slough were to exist for any of the predicted discharge values, that area would have been subtracted from the total surface area of the slough before the model was applied. Backwater areas within sloughs are also used by spawning salmon. Therefore, plans for the 1983 field season include sampling these areas and, if possible, developing a suitability model.

Appendix Table D-5. Comparison of observed and predicted water depths and velocities along Slough 8A Transect 1 in 1982 at two slough flows: 4 and 20 cfs.

	4 cfs				20 cfs			
	Depth (ft)		Velocity (ft/sec)		Depth (ft)		Velocity (ft/sec)	
Segment[a]	obs.	pred.	obs.	pred.	obs.	pred.	obs.	pred.
LWE 12	.40	.60	.00	.00	.70	.90	.05	.05
14	.80	.85	.00	.00	1.05	1.15	.05	.05
16	.90	.90	.10	.00	1.20	1.20	.10	.05
18	1.00	.95	.00	.00	1.20	1.25	.10	.05
20	1.00	1.00	.00	.00	1.30	1.30	.10	.05
22	1.00	1.00	.00	.02	1.30	1.30	.10	.11
24	1.05	1.10	.05	.02	1.40	1.40	.10	.11
26	1.20	1.25	.05	.04	1.40	1.55	.10	.12
28	1.30	1.35	.05	.04	1.50	1.65	.10	.12
30	1.45	1.40	.03	.04	1.70	1.70	.10	.12
32	1.40	1.40	.10	.03	1.70	1.70	.10	.11
34	1.50	1.45	.10	.04	1.65	1.75	.10	.13
36	1.60	1.50	.05	.04	1.80	1.80	.10	.12
38	1.55	1.55	.05	.04	1.80	1.85	.10	.12
40	1.60	1.60	.00	.06	1.90	1.90	.20	.18
42	1.65	1.60	.05	.06	1.80	1.90	.20	.18
44	1.60	1.60	.05	.06	1.85	1.90	.30	.30
46	1.60	1.60	.05	.06	1.90	1.90	.20	.25
48	1.60	1.55	.10	.08	1.90	1.85	.35	.32
50	1.55	1.50	.05	.07	1.80	1.80	.30	.32
52	1.50	1.50	.05	.10	1.80	1.80	.40	.32
54	1.50	1.50	.05	.10	1.70	1.80	.45	.37
56	1.50	1.45	.05	.07	1.75	1.75	.30	.32
58	1.40	1.35	.05	.06	1.65	1.65	.30	.30
60	1.25	1.20	.05	.06	1.50	1.50	.35	.35
62	1.10	1.05	.00	.06	1.35	1.35	.30	.30
64	1.00	.95	.00	.06	1.30	1.25	.25	.26
66	.95	.90	.05	.06	1.30	1.20	.20	.20
68	.95	.90	.00	.06	1.30	1.20	.20	.20
70	.95	.85	.00	.09	1.30	1.15	.20	.20
72	.85	.80	.00	.07	1.10	1.10	.20	.13
74	.90	.80	.00	.03	1.10	1.10	.20	.12
76	.80	.80	.00	.03	1.10	1.10	.15	.12
78	.85	.75	.00	.01	1.00	1.05	.15	.07
80	.80	.65	.00	.01	1.00	.95	.10	.07
82	.60	.60	.00	.01	.90	.90	.10	.07
84	.65	.55	.00	.01	1.00	.85	.10	.07
86	.50	.45	.00	.01	.80	.75	.10	.07
88	.45	.35	.00	.00	.65	.65	.05	.05
90	.30	.20	.00	.00	.60	.50	.00	.05
RWE 92	.10	.05	.00	.00	.40	.30	.00	.05
94					.20	.15	.00	.11
RWE 96					.00	.05	.00	.00
	r = .99		r = .44[b]		r = .99		r = .93[b]	

[a] Distance (ft) along transect from left bank head pin. LWE and RWE are left and right water's edge at the two discharges.

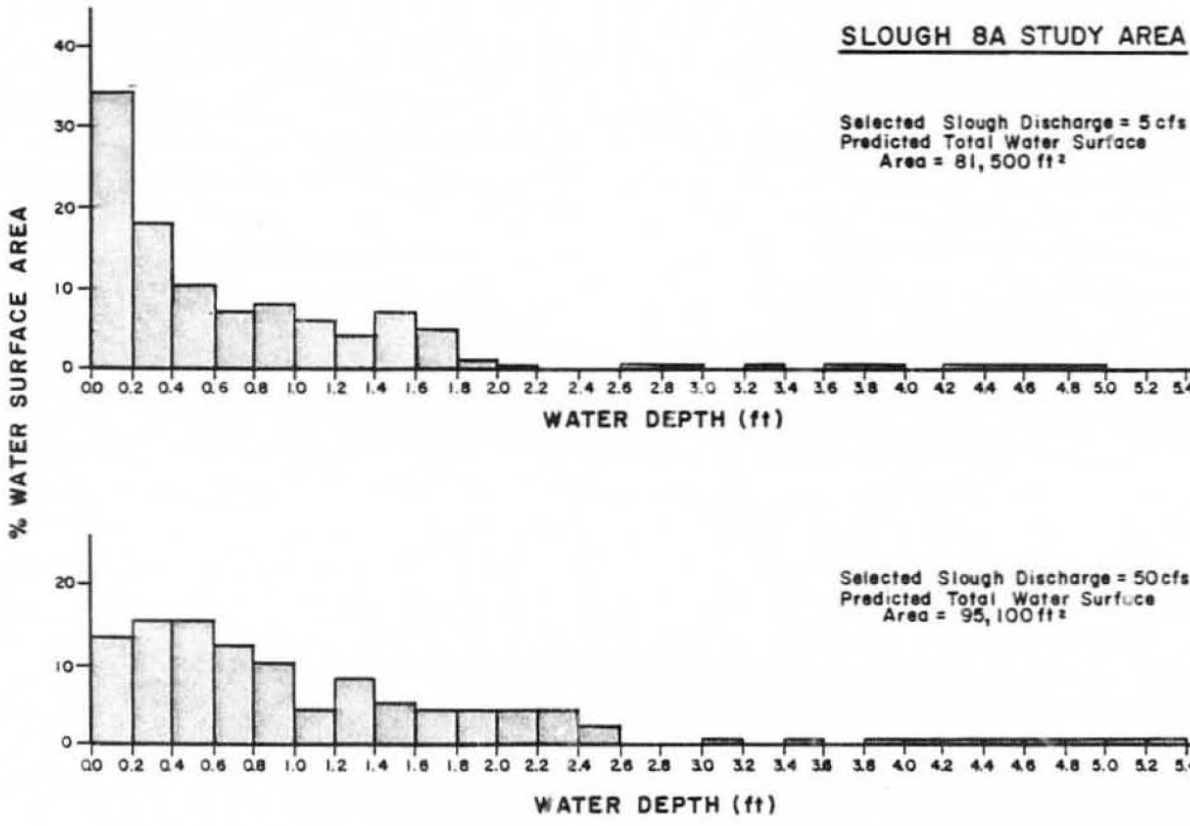
[b] Predicted velocities in each segment rounded to nearest 0.05 ft/sec before determining correlation coefficient to compensate for rounding of observed velocity measurements in the field.

Appendix Table D-6. Comparison of observed and predicted water depths and velocities along Chum Channel Transect 5 in 1982 at two slough flows: 6.7 and 90 cfs.

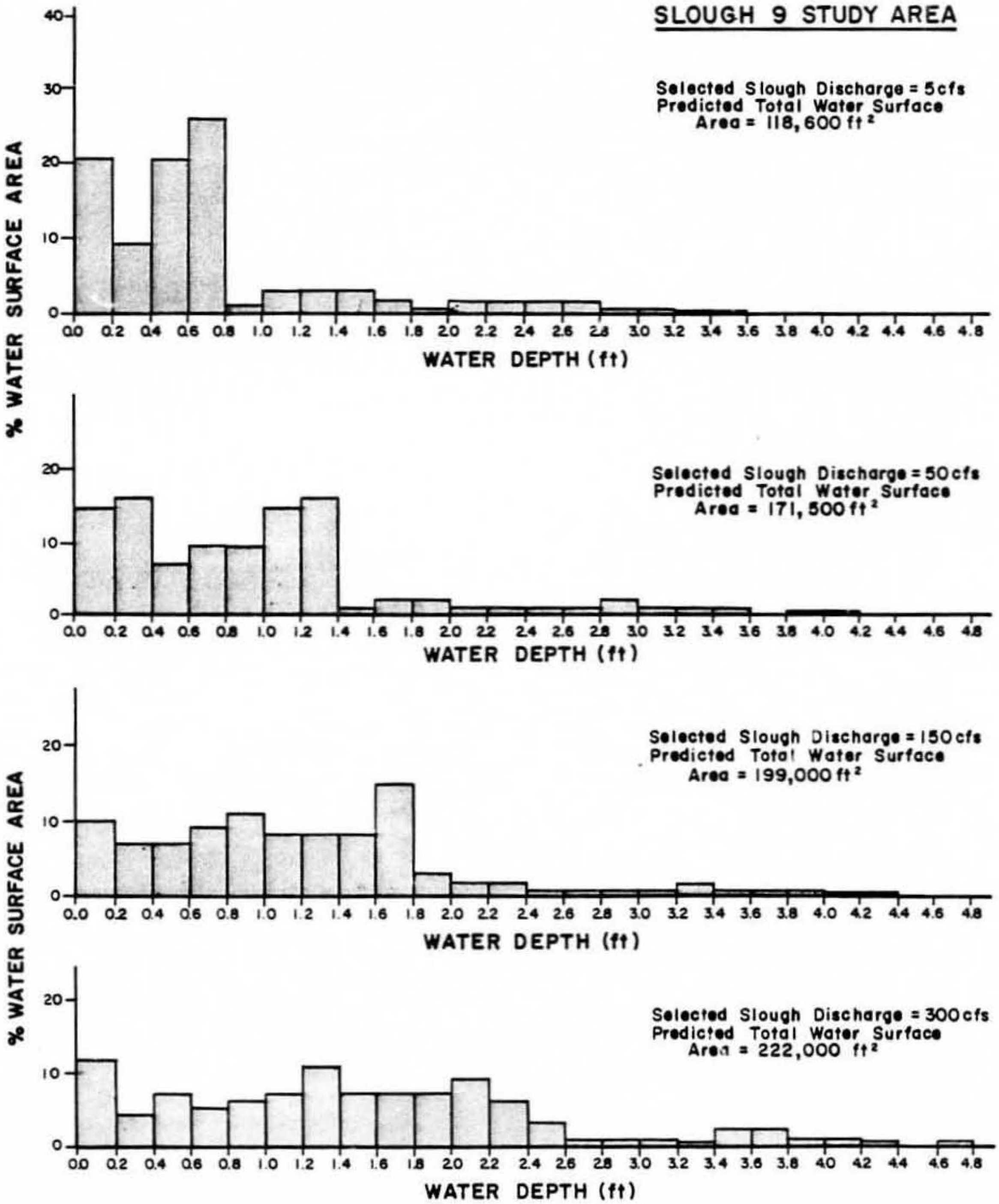
	6.7 cfs				90 cfs			
	Depth (ft)		Velocity (ft/sec)		Depth (ft)		Velocity (ft/sec)	
Segment[a]	obs.	pred.	obs.	pred.	obs.	pred.	obs.	pred.
LWE 24					.00	.08	.00	.04
26					.10	.18	.10	.10
28					.20	.28	.60	.61
30					.30	.38	.80	.81
32					.40	.48	1.30	1.29
34					.50	.53	1.30	1.32
LWE 35.2	.00		.00					
36		.08		.00	.60	.63	1.90	1.40
37	.10		.00					
38		.15		.58	.60	.73	1.90	1.73
39	.20		.20					
40		.25		.24	.80	.83	1.80	1.81
41	.30		.30					
42		.45		.29	1.00	1.03	2.10	2.11
43	.50		.30					
44		.60		.29	1.20	1.18	2.20	2.21
45	.50		.30					
46		.65		.39	1.30	1.23	2.20	2.21
47	.70		.50					
48		.75		.49	1.30	1.33	2.40	2.41
49	.70		.50					
50		.85		.44	1.40	1.43	2.50	2.51
51	.70		.40					
52		.85		.39	1.50	1.43	2.30	2.31
53	.70		.40					
54		.85		.39	1.50	1.43	2.30	2.31
55	.70		.40					
56		.80		.44	1.50	1.38	2.20	2.21
57	.70		.50					
58		.75		.44	1.40	1.33	2.20	2.21
59	.60		.40					
60		.70		.39	1.40	1.28	2.10	2.11
61	.50		.40					
62		.60		.34	1.20	1.18	2.20	2.21
63	.50		.30					
64		.50		.39	1.20	1.18	2.00	2.01
65	.40		.30					
66		.40		.24	1.10	.98	2.00	2.01
67	.30		.20					
68		.20		.24	1.00	.78	1.80	1.81
69	.10		.00					
70		.03		.28	.70	.58	1.30	1.57
RWE 71	.00		.00					
72		.00		.00	.50	.53	1.30	1.40
74					.50	.48	1.30	1.32
76					.40	.48	1.10	1.12
78					.50	.48	.90	.90
80					.40	.38	.70	.71
82					.30	.28	.50	.50
84					.20	.23	.40	.39
86					.20	.23	.50	.50
88					.20	.18	.40	.40
90					.10	.13	.20	.20
92					.10	.08	.20	.20
RWE 94					.00	.02	.00	.08
	r = .98		r = .56[b]		r = .99[b]		r = .99[b]	

[a]Distance (ft) along transect from left bank head pin. LWE and RWE are left and right water's edge at the two discharges.

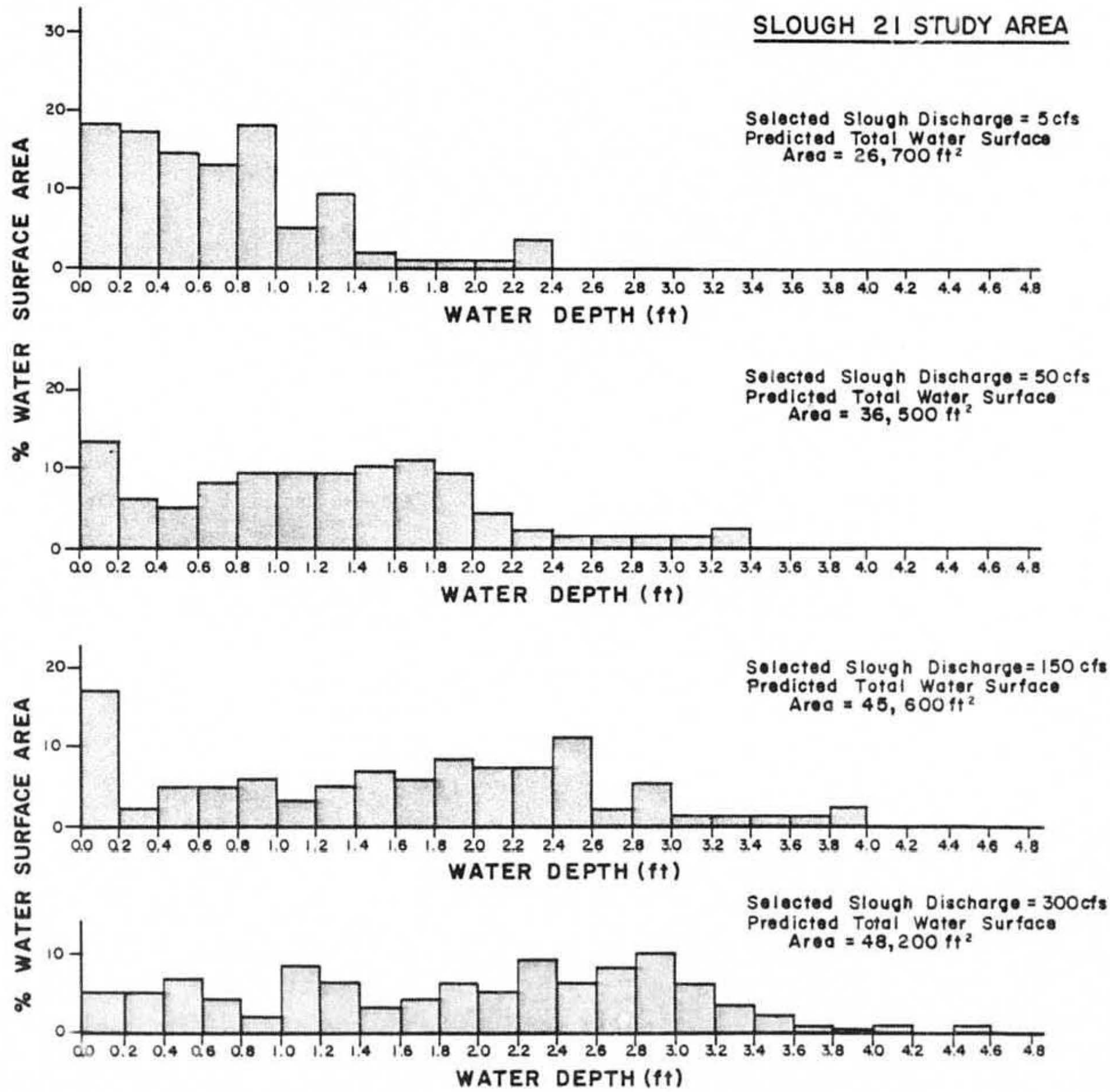
[b]Predicted water depths and velocities in each segment rounded to nearest 0.05 ft and 0.05 ft/sec, respectively, before determining correlation coefficent to compensate for rounding of observed velocity.



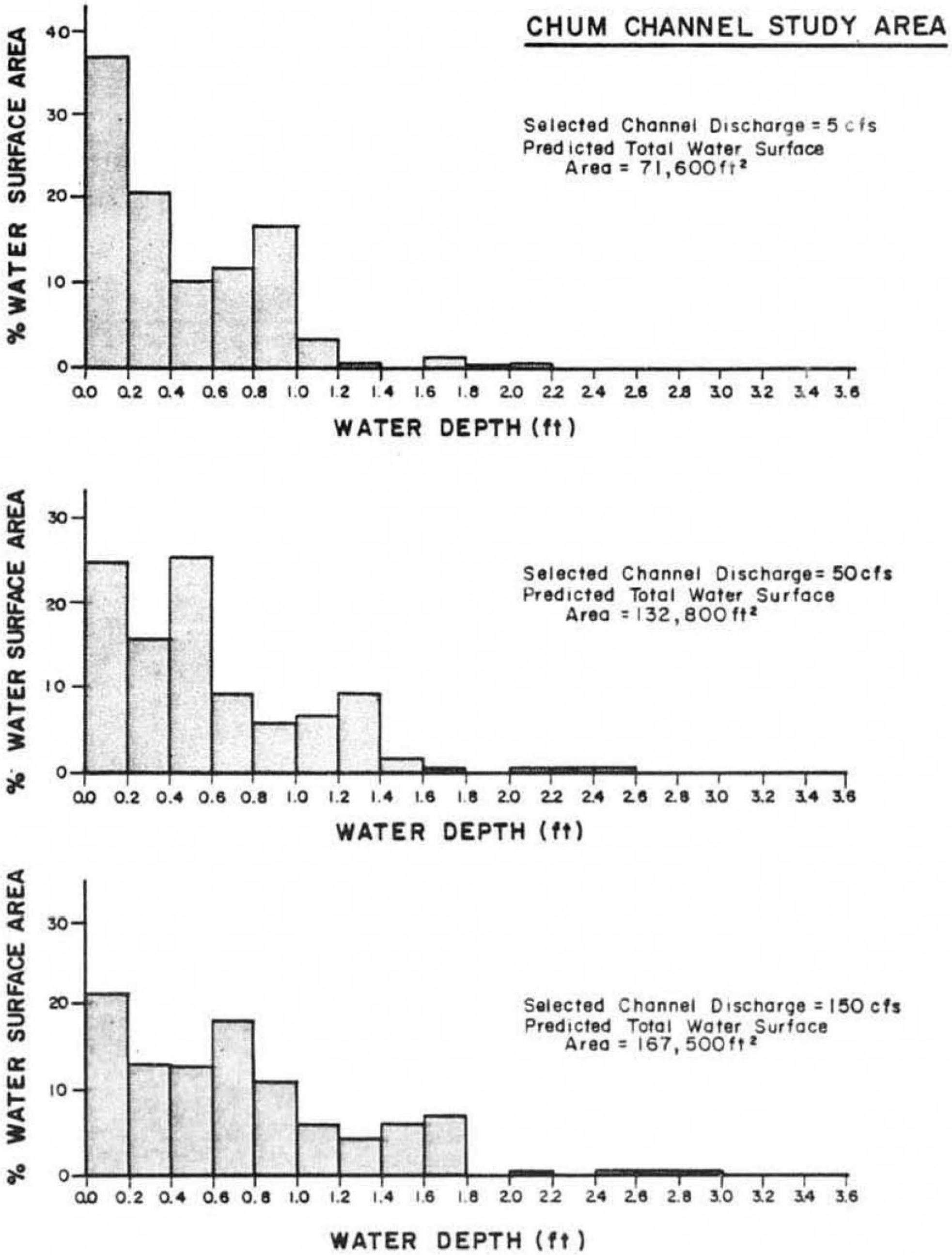
Appendix Figure D-2. Frequency distribution of the predicted water depths available for two selected discharges (5 and 50 cfs) in the Slough 8A study area.



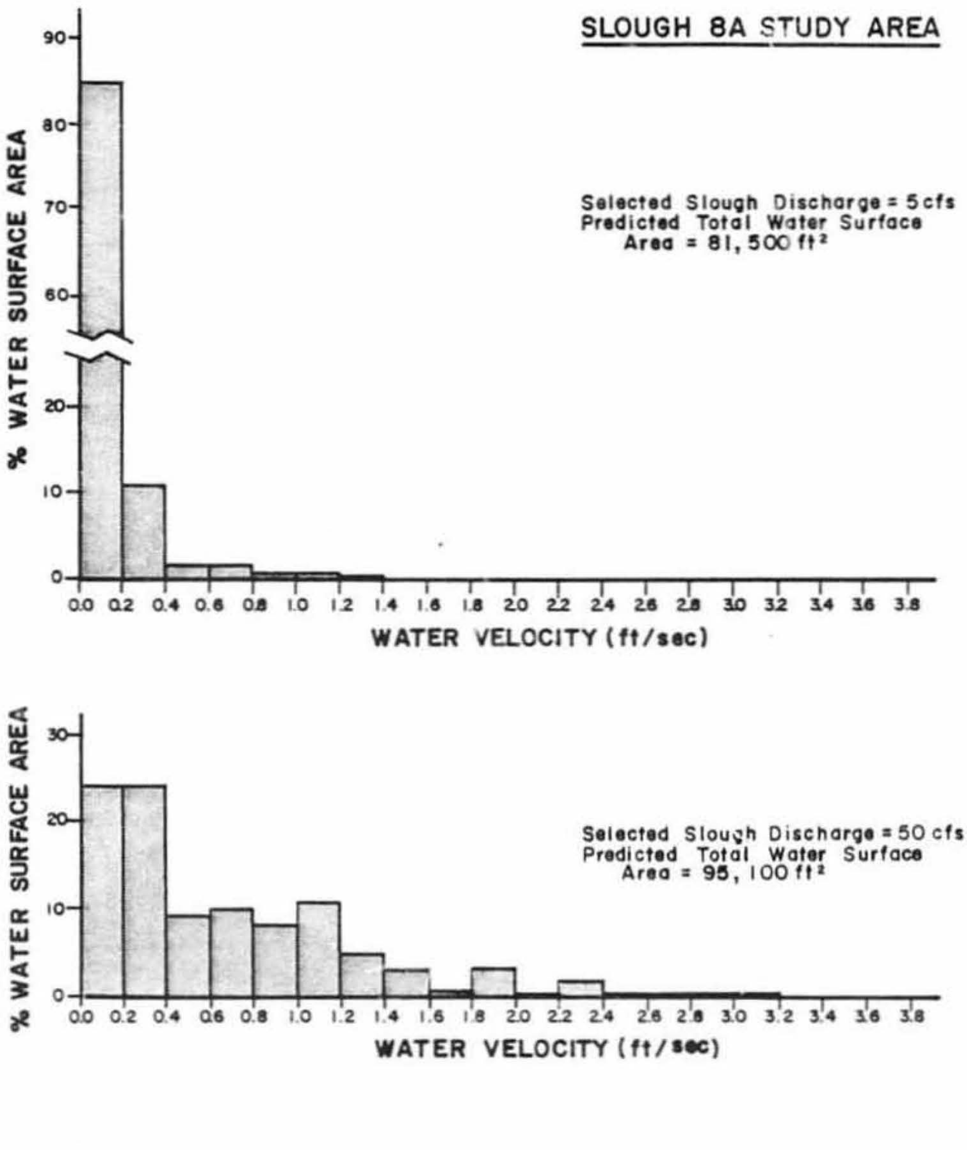
Appendix Figure D-3. Frequency distribution of the predicted water depths available for four selected discharges (5, 50, 150 and 300 cfs) in the Slough 9 study area.



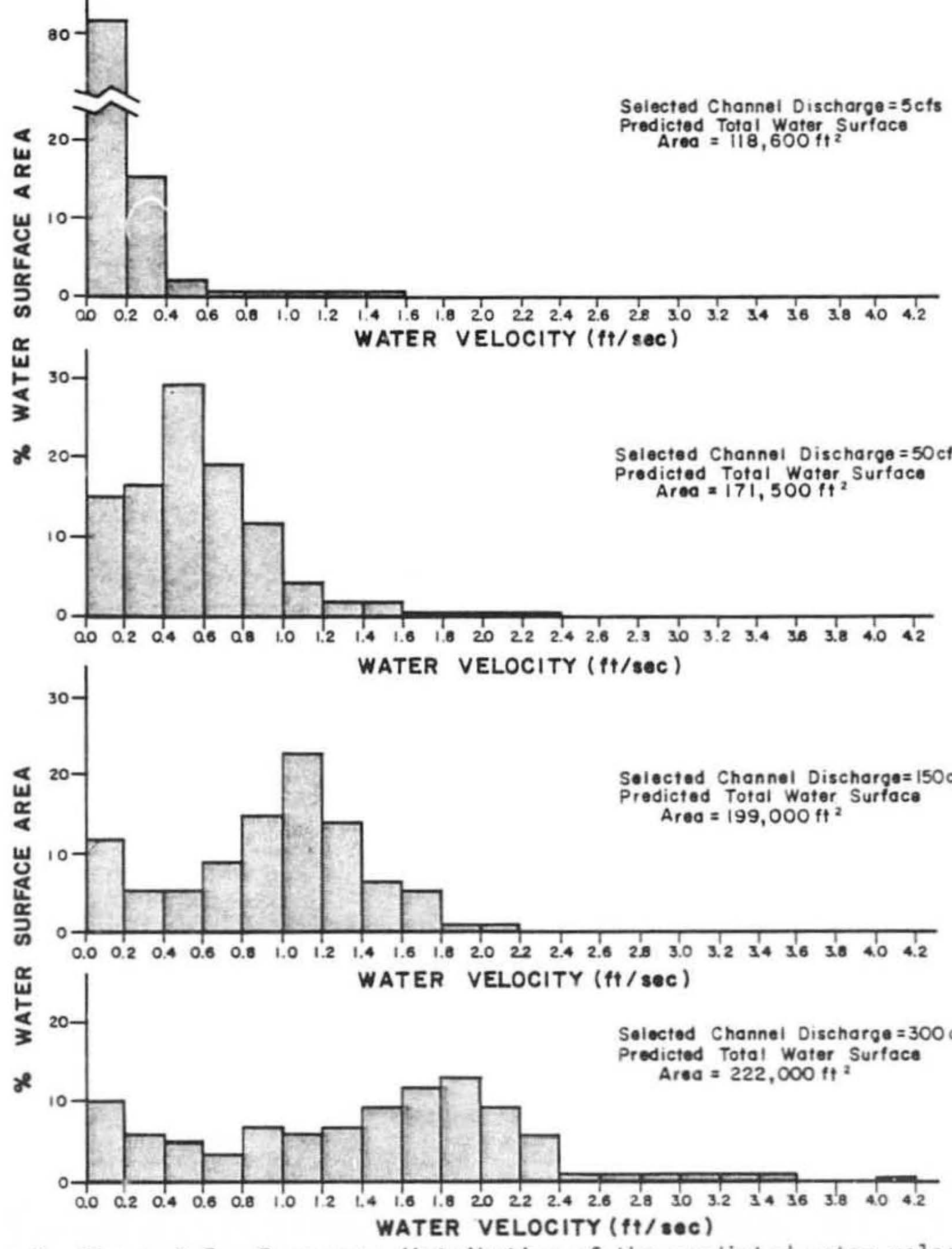
Appendix Figure D-4. Frequency distribution of the predicted water depths available for four selected discharges (5, 50, 150 and 300 cfs) in the Slough 21 study area.



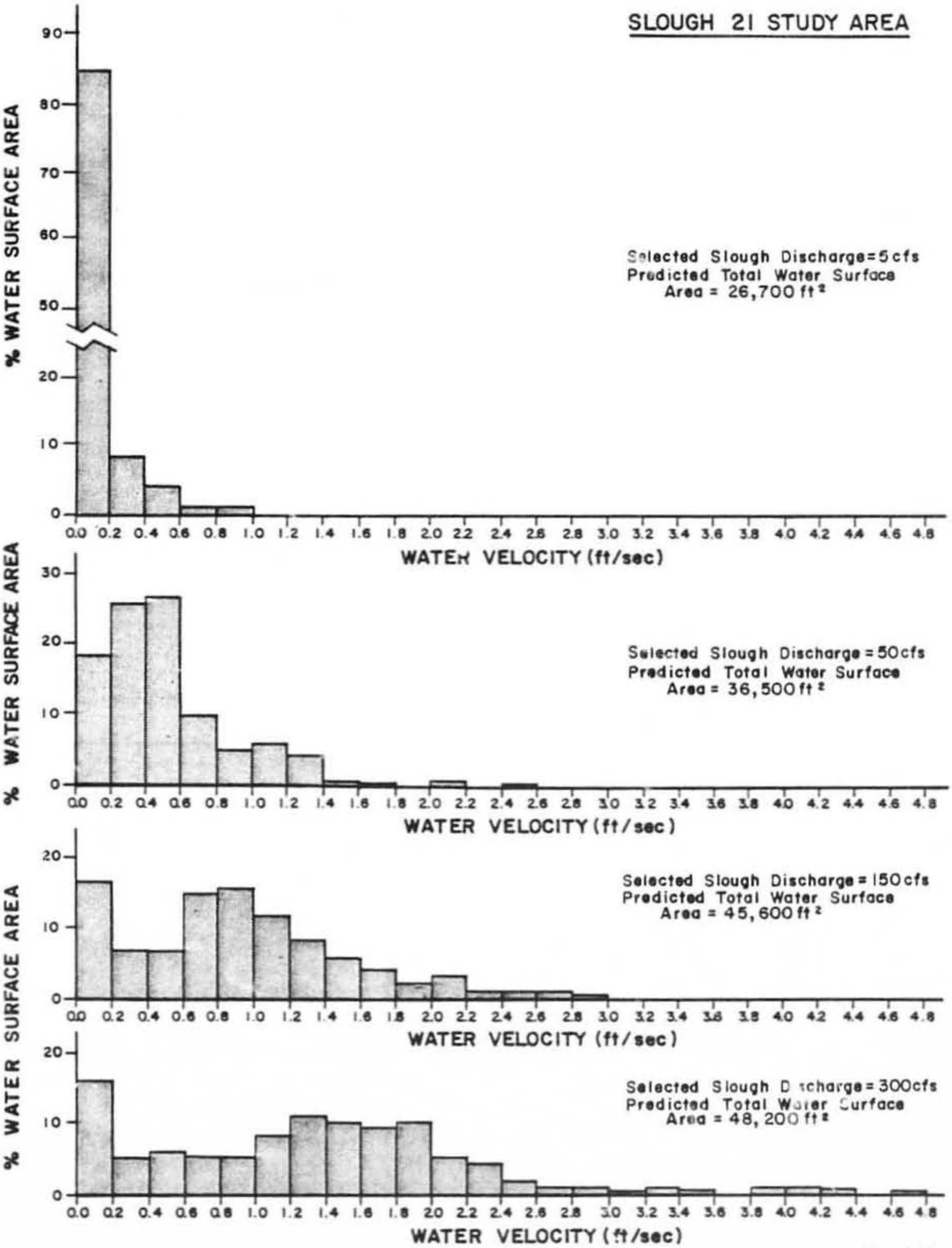
Appendix Figure D-5. Frequency distribution of the predicted water depths available for three selected discharges (5, 50 and 150 cfs) in the Chum Channel study area.



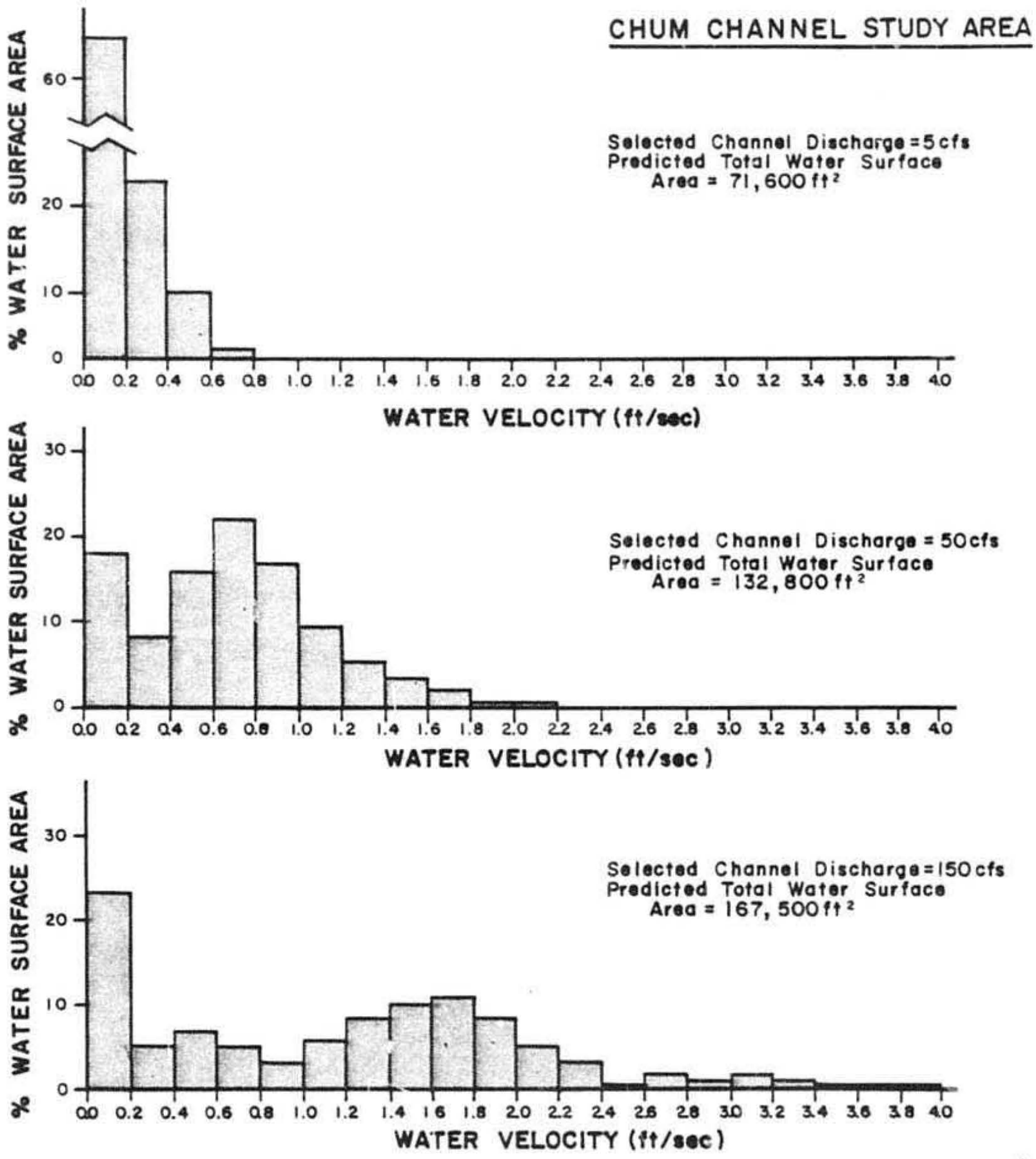
Appendix Figure D-6. Frequency distribution of the predicted water velocities available for two selected discharges (5 and 50 cfs) in the Slough 8A study area.



Appendix Figure D-7. Frequency distribution of the predicted water velocities available for four selected discharges (5, 50, 150 and 300 cfs) in the Slough 9 study area.



Appendix Figure D-8. Frequency distribution of the predicted water velocities available for four selected discharges (5, 50, 150 and 300 cfs) in the Slough 21 study area.



Appendix Figure D-9. Frequency distribution of the predicted water velocities available for three selected discharges (5, 50 and 150 cfs) in the Chum Channel study area.

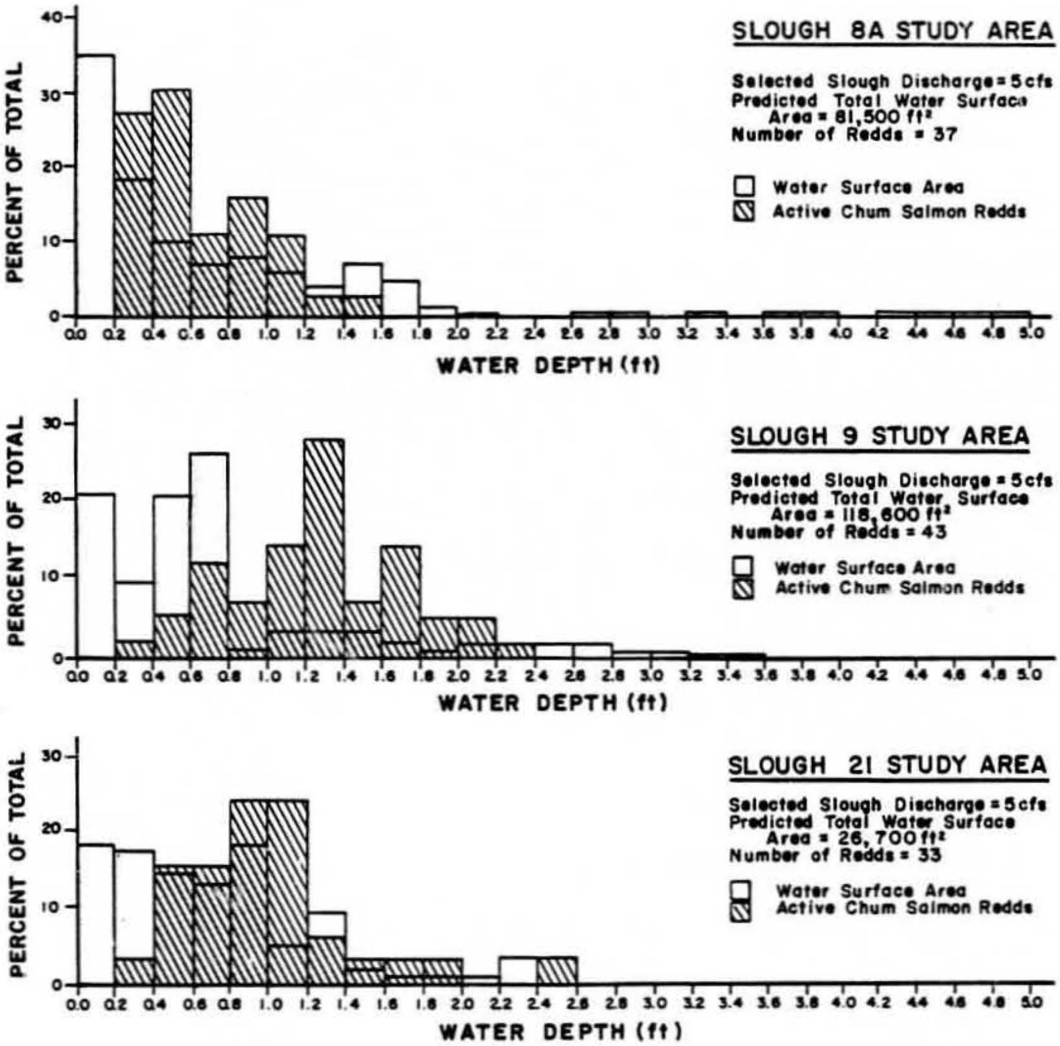
transect were highly correlated with mean slough discharges (r = 0.999). All but one vaf were considered good (0.9 < VAF < 1.1). Forty-seven percent of the VAF values were 1.00 ± 0.01. The single exception was the velocity adjustment factor for Slough 21 Transect 6 (at 10 cfs) which was considered fair (VAF is 0.85-0.9 or 1.1-1.15).

Precision standards also recommend keeping predicted water depths and velocities in each cell within 0.1 ft and 0.2 ft/sec of the observed depths and velocities (Milhous et al. 1981). A comparison of observed and predicted depths and velocities along two transects at two discharges with some of the lowest correlation coefficients (Appendix Tables D-5 and D-6) are provided. Correlation coefficients may be somewhat misleading at the discharge level at which the models were calibrated. At shallow depths and low velocities, differences of 0.1 ft or ft/sec can appear disproportionally large.

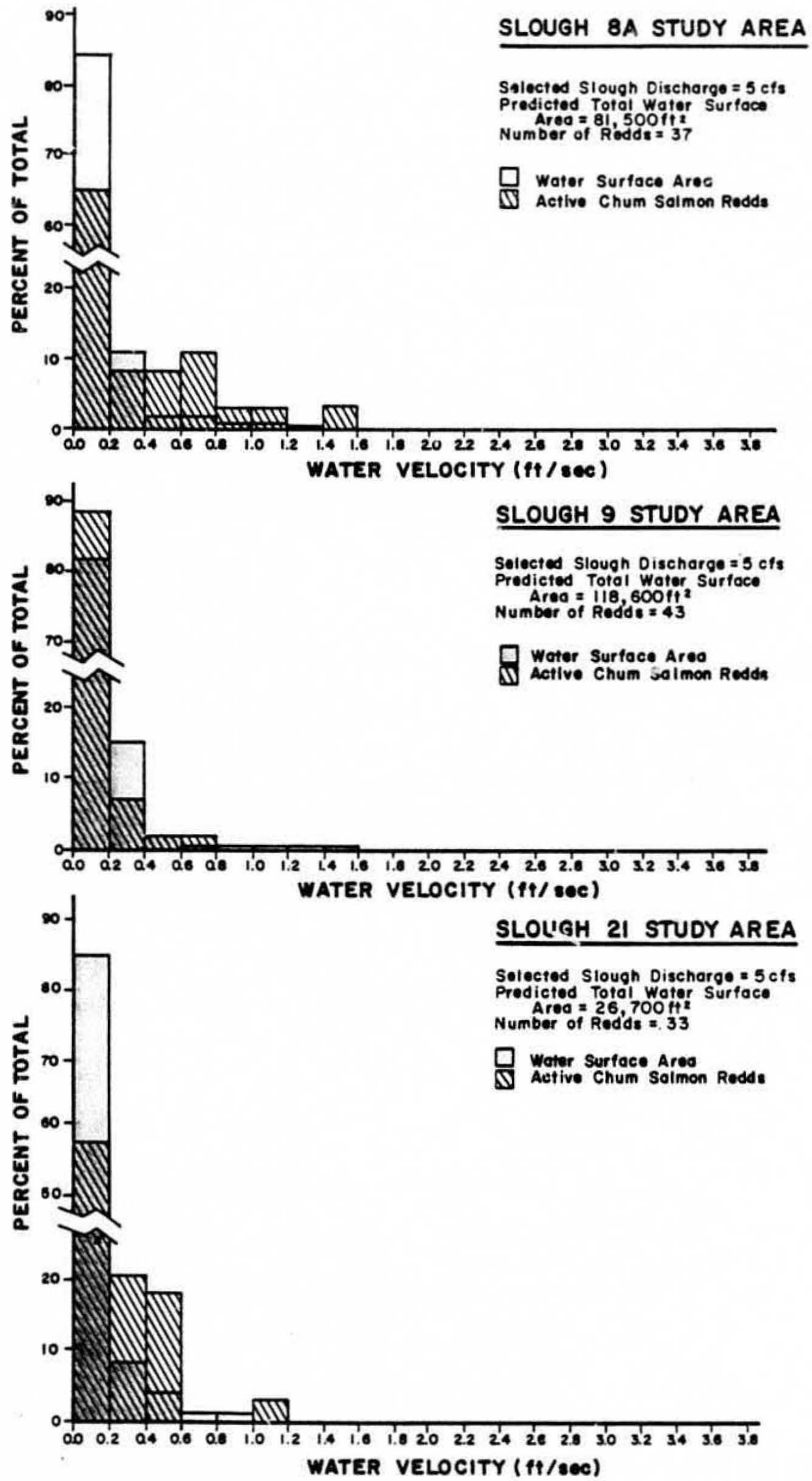
Predicted hydraulic conditions

The predicted proportions of available depths and velocities are presented for slough flows of 5 and 50 cfs for all four sloughs; 150 cfs for sloughs 9, 21, and Chum Channel; and 300 cfs for sloughs 9 and 21 (Appendix Figures D-2 to D-9) for comparative purposes.

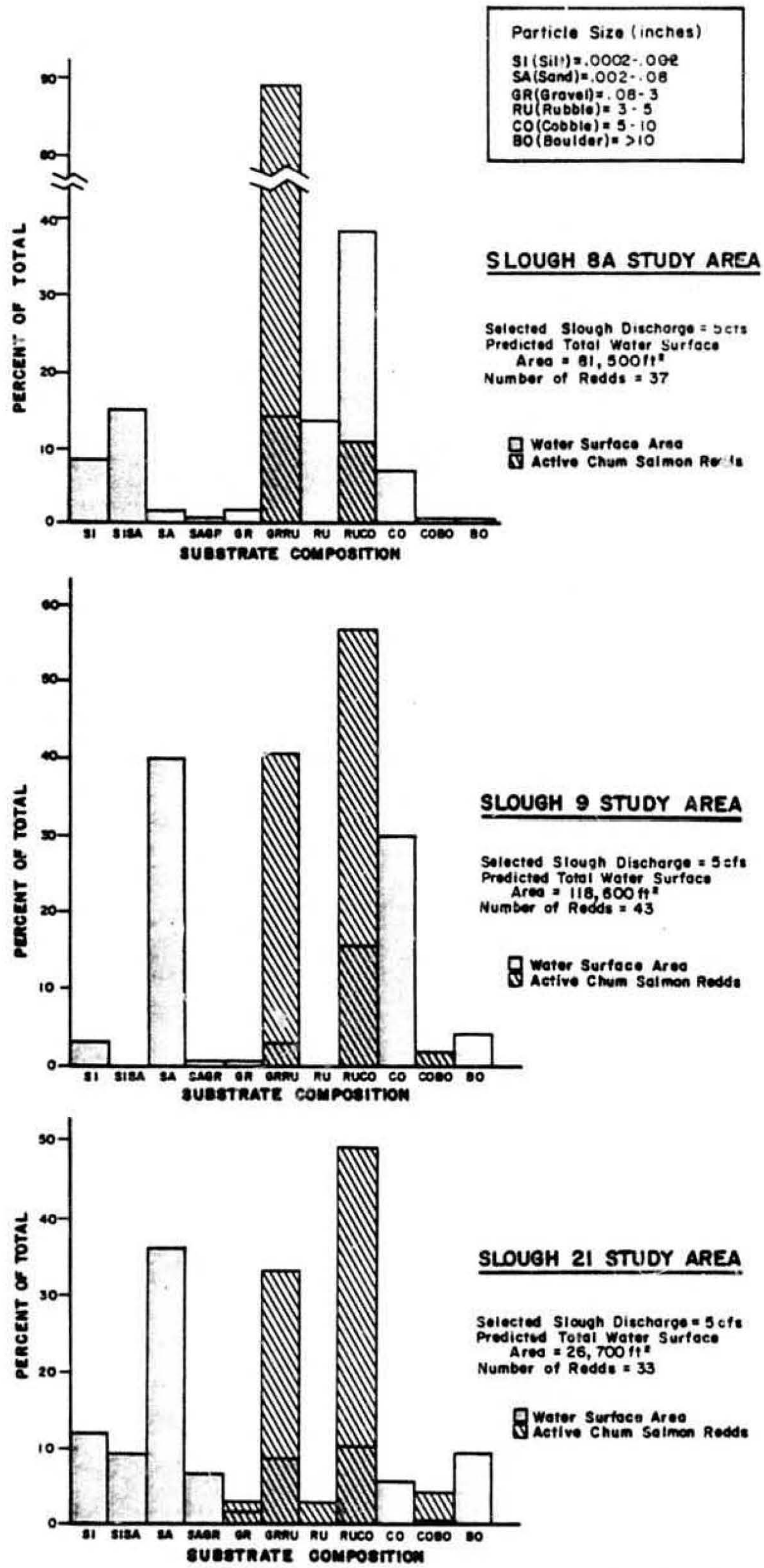
Water depths, velocities and discharge in a slough increase substantially when the slough head is breached by water from the mainstem. Sloughs 8A, 9, 21 and Chum Channel were breached at mainstem flows of 33,000 cfs, 19,500 cfs, 25,000 cfs and 53,000 cfs, respectively. When sloughs



Appendix Figure D-10. Comparisons of the frequency distributions of observed water depths at chum salmon redds (August-September 1982) with predicted water depths available in sloughs 8A, 9 and 21 for slough flows of 5 cfs.



Appendix Figure D-11. Comparisons of the frequency distributions of observed water velocities at chum salmon redds (August-September 1982) with predicted water velocities available in sloughs 8A, 9 and 21 for slough flows of 5 cfs.



Appendix Figure D-12. Comparisons of the frequency distributions of observed substrate composition at chum salmon redds (August-September 1982) with predicted substrate composition available in sloughs 8A, 9 and 21 for slough flows of 5 cfs.

8A, 9 and 21 were not breached, their discharges were generally less than 30 cfs (ADF&G 1983: Volume 4).

As breaching occurred, slough flows increased rapidly. On July 21, 1981, the discharge in Slough 8A was 551 cfs at a mainstem flow of 40,000 cfs at Gold Creek (ADF&G 1981b). Conversely, slough flows decreased rapidly when mainstem stage fell below breaching stage. Therefore, in these three sloughs, discharges greater than 30 cfs were of short duration in late summer and winter months, as recorded during the past two years.

Suitability of Available Habitat for Chum Salmon Spawning

Data from the hydraulic and spawning habitat models were combined in the suitability model (Appendix Figures D-10 to D-12). Available water depths, velocities and substrate types were compared with those found at chum salmon redds. Distributions of each hydraulic variable differed significantly ($p < 0.05$) between sloughs 8A, 9 and 21 at 5 cfs. Depths and substrate types at chum salmon redds in all three sloughs (4-8 cfs) differed significantly ($p < 0.05$) from those available (5 cfs). The importance of velocity at low slough flows was difficult to determine. Velocities measured at active redds (Appendix Figure D-11) did not differ significantly ($p > 0.05$) from available velocities in sloughs 8A and 9 at predicted slough flows of 5 cfs. However, available and utilized velocities were significantly different in Slough 21 at 5 cfs. Therefore, at slough flows of 5 cfs, water depth and substrate composition were considered the most important of these habitat variables evaluated for determining salmon habitat preference.

Preferences of spawning chum salmon for specific ranges of water depth and substrate composition in sloughs 8A, 9 and 21 are summarized in the following paragraphs. Gaps in the ranges of utilized water depths and substrate types can probably be attributed to the low sample size of redds rather than actual avoidance of those depths and substrate types by the spawning salmon. In addition, the proportion of total water surface area that was utilized, preferred and optimal for spawning is estimated.

In Slough 8A, at 5 cfs, the water depths used by spawning chum salmon were 0.2-1.6 and 1.8-2.0 ft. Gravel-rubble and rubble-cobble substrates were used. Preferred water depths were 0.2-1.2 ft and the preferred substrate was gravel-rubble. Optimal water depths were 0.4-0.6 ft and the optimal substrate was gravel-rubble. The Slough 8A study area was comprised of 30.5 percent usable spawning area. Only 6.0 percent of the total water surface area was preferred and 1.0 percent was optimal for spawning.

In Slough 9, at 5 cfs, the water depths used by spawning chum salmon were 0.2-2.4 ft. Gravel-rubble, rubble-cobble and cobble-boulder substrates were used. Preferred water depths were 0.8-2.2 ft and the preferred substrates were gravel-rubble and rubble-cobble. Optimal water depths were 1.2-1.4 ft and optimal substrates were gravel-rubble and rubble-cobble. The Slough 9 study area was comprised of 24.4 percent usable spawning area. Only 0.8 percent of the total water surface area was preferred and 0.3 percent was optimal for spawning.

In Slough 21, at 5 cfs, the water depths used by spawning chum salmon were 0.2-2.0 and 2.4-2.6 ft. Substrate types used for spawning ranged from gravel to cobble-boulder. Preferred water depths were 0.4-1.2 and 1.4-2.0 ft. The preferred substrates ranged from gravel to rubble-cobble and cobble-boulder. Optimal water depths were 1.0-1.2 ft and optimal substrates were gravel-rubble and rubble-cobble. The Slough 21 study area was comprised of 21.4 percent usable spawning area. Only 8.2 percent of the total water surface area was preferred and 1.5 percent was optimal for spawning.

DISCUSSION

Chum salmon did not spawn in sloughs at water depths less than 0.2 ft. The upper limit of depths used for spawning was probably not reached because of low flows in August and September 1982. Water depths used for spawning in all three sloughs were within the range of depths (0.16-3.9 ft) reported for chum salmon redds in the Chena River (Kogl 1965). Similarly, water depths in the sloughs were within the range of depths (0.25-3.5 ft) reported for chum salmon redds in the Terror and Kizhuyak Rivers on Kodiak Island (Wilson et al. 1981).

The frequency distributions of water velocities at redds in the three sloughs were not significantly different ($p > 0.05$) at a predicted flow of 5 cfs. As with depths, the upper limit of velocities used for spawning was probably not observed because of low flows in August and September 1982. Water velocities used for spawning in all three sloughs were within the range of velocities (0.0-2.0 ft/sec) reported at chum salmon redds in the Chena River (Kogl 1965). Velocities reported at chum salmon redds in the Terror and Kizhuyak rivers (0.0-3.9 ft/sec) were even higher (Wilson et al. 1981).

Adequate aeration of chum salmon eggs, like those of other salmonids, requires moving water (Wesche and Rechard 1980, Hale 1981). When redds were located in velocities of 0.0-0.2 ft/sec, upwelling ground water was frequently observed. Chum salmon were found to prefer areas of upwelling ground water in the Alaskan interior (Kogl 1965, Francisco 1977) and on Kodiak Island (Wilson et al. 1981). Upwelling ground water, which is warmer in winter than surface water, also prevents substrate freezing in shallow water and in slow currents (Levanidov 1954, Kogl 1965, Sano 1966, Francisco 1977). Upwelling ground water may be the principal variable influencing the suitability of habitat for spawning by chum salmon, and water depth, velocity and substrate composition the secondary factors, within the limits of tolerance.

The specific relationships between base slough flows and Susitna River mainstem discharges, when mainstem flows are lower than breaching stage, is presently unknown. Intuitively, it would seem that increases in local surface runoff or ground water seepage (due to rainfall or accelerated snow melt, for example) would increase base slough flows. However, rainfall or accelerated snow melt events that are likely to cause increases in local runoff would also likely be coincident with increases in basin runoff that would stimulate an increase in mainstem discharge and overtop the sloughs. Thus, it is difficult to identify the specific relationship between local runoff and slough flow under natural flow conditions.

An increase in slough flow may not result in a proportional increase in spawning habitat or production. That is, not all added water surface area may be of sufficient depth, have suitable substrate composition or upwelling conditions. Under these circumstances, a reduction in the proportion of habitat acceptable for spawning could result. Secondly, salmon eggs and alevin remain in the gravel of redds for months and require a long term supply of water. Peaks in the Susitna River flow that are large enough to breach sloughs are generally short term. Spawning in this ephemeral habitat would result in unsuccessful incubation if it became dewatered and ground water were absent.

Although incubation and rearing can be successful during low water conditions, this in no way reduces the necessity for seasonally timed high discharges in the mainstem. Medium to high mainstem water levels are important to slough access and subsequent movement into upper reaches of the slough (where upwelling ground water may then be sufficient to prevent complete dewatering at low flows) often depends on breaching at the slough heads (Appendices B and C). High flows also flush accumulations of silt and sand from spawning substrate.

Substrate composition at redds in these three Susitna River sloughs differed from that found in other Alaskan chum salmon spawning areas. Redds in the three sloughs were not observed in substrate smaller than gravel, including the combination of sand-gravel. Rubble mixed with either gravel or cobble was the optimal spawning substrate. Most other studies found gravel (0.08-3 inches) substrate to be most commonly used (Francisco 1976, Morrow 1980, Wilson et al. 1981). Rubble substrates, with particles as large as 5 inches, were utilized on the Delta River (Francisco 1976).

Water depths, velocities and substrate types at chum salmon redds in sloughs are comparable with spawning sites in the Susitna River, where a much wider range of environmental conditions prevail. Chum salmon spawn infrequently in side channels of the Susitna River. However, at 15 mainstem chum salmon redds observed between September 4-14, 1982, water depths ranged from 0.5-2.5 ft (ADF&G 1983: Volume 4). Water velocities measured at the same 15 redds ranged from 0-0.2 ft/sec. These water depths and velocities were within the ranges measured at chum salmon redds in sloughs and more closely resembled side channel habitat conditions than those of the mainstem. Substrate composition at 13 of the 15 redds was 60-90 percent gravel, rubble and/or cobble.

No attempt was made to calculate utilized proportions of water surface area at predicted flows other than 5 cfs (i.e., 50, 150, or 300 cfs). Therefore, at present, the proportion of water surface area used by spawning chum salmon can only be predicted at this slough flow. Because breaching events are of short duration in late summer and water conditions were unusually low during the spawning period in 1982, we were unable to establish an upper limit of water depth and velocity tolerated by spawning chum salmon in the Susitna River sloughs. It would be misleading to try to predict salmon habitat preferences at slough discharges where water depths and velocities exceeded those available at measured low flows of 4-8 cfs. However, as discussed previously, this does not seriously hamper our analysis because base slough flows during the spawning season generally are low.

The analysis of water depth and substrate composition with our spawning habitat suitability model, should not be the sole decision-making factor for evaluating salmon spawning habitat conditions in sloughs. Ground water upwelling and seepage, water velocity, water quality, intragravel and surface water temperatures, backwater zones, and access into sloughs must also be considered. A better understanding of the relationships of mainstem flows to slough flows and the relative contributions of various water sources (e.g., ground water upwelling and seepage, and surface waters) to slough flows is also required in order to link the suitability model to changes in mainstem flow.

Plans for data collection during the 1983 field season are based on the observations in this and other ADF&G reports. Additional data from chum salmon redds in sloughs are required if we are to develop multivariate suitability curves for a habitat model. It may be possible to combine samples collected within study areas during different years if they are not found to be significantly different. Additional hydraulic data must also be collected at intermediate and high flows in order to calibrate the hydraulic models over a wider range of discharges. Other plans for 1983 include collecting hydraulic and habitat data from transects and redds in slough backwater zones, side channels, and tributaries of the Susitna River between Talkeetna and Devil Canyon. An attempt will also be made to collect data from pink, sockeye, coho, and chinook salmon redds to include these species in the spawning habitat model. Intragravel and surface water temperatures are planned for collection at transects while the salmon are spawning to compare available temperatures with those observed at redds. Methods for accurately detecting presence of upwelling ground water, in an early stage of development, will be used to quantify upwelling conditions in sloughs if proven feasible.

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APPENDIX E

Effects of Mainstem Susitna Discharge on Total Wetted and Backwater Surface Areas at Selected Study Sites

APPENDIX E

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INTRODUCTION

Backwater areas are zones of low velocity water which result from hydraulic barriers created by mainstem stage effects. The relationship between backwater surface areas and incremental changes in mainstem Susitna River discharge has been addressed in Volume 4, Part 1 of the Basic Data Report (ADF&G 1983). This appendix provides additional information concerning the response of these backwater surface areas to changes in mainstem discharge and provides information on wetted surface areas. The relationship between the backwater and wetted surface areas, and data on the abundance of pools formed by berms in free flowing stream areas at these study sites is also discussed.

METHODS

Fourteen slough and tributary mouths, between Susitna River miles 73.1 and 142.0, were visited once every two weeks from the beginning of June to the end of September during 1982. Maps of the wetted surfaces present at each site were drawn for each sampling. The total wetted and backwater surface areas represented on the maps were planimetered after ensuring that the study boundaries were identical from trip to trip.

Details of the methodology are described in the Basic Data Report, Volume 4, Part I ADF&G, 1983. A detailed narrative describing each study site is available in Appendix F, Volume 4 of the Basic Data Report.

Aerial photographs of each of the study sites are presented as Appendix Plates E-1 to E-14. The sampling boundaries illustrated in these photographs bracket those reaches of each site where the surface area measurements were taken. The entire wetted surface found within this area during each sampling is termed the "total" wetted surface area although it is a partial total for the slough or tributary as a whole. Inspection of the photographs will show the reader the extent to which the total wetted surface areas reported actually represent the larger physical or hydraulic features of these habitat areas.

Some changes have been made in the definition of "study" boundaries at the Sunshine Creek, Slough 9, Lane and Goose Creek sites from those shown previously in the Basic Data Report. At the Lane and Goose Creek sites, the creek portion of the sites have been omitted because mapping of these areas was not always complete. At the Slough 9 location, maps of the upper half of the study area were not made during low water samplings. Thus, the upper half of the area was not included in the study boundary.

At the Sunshine site, a section of the previously defined study area was also deleted due to inconsistent mapping of the uppermost reaches of the creek. As a result, 15,000 ft^2 at 60,100 cfs and 24,000 ft^2 at 82,400 cfs (of the true total) backwater area present during the July samplings was omitted in this study in order to obtain comparable total and backwater area measurements.

In general, the sampling boundaries at each site were chosen to encompass the backwater areas present over the range of flows sampled, and as much additional free flowing slough or tributary water as was necessary for the fish collection aspect of the study.

RESULTS

Appendix Table E-1 displays by two weeks intervals between June and September, 1982, the backwater and total wetted surface areas mapped within the boundaries at Designated Fish Habitat locations. Surface areas are tabulated with the corresponding mean daily discharge reported for the Gold Creek or Sunshine gaging station. Plots of the total wetted surface areas versus mainstem discharge are found as Appendix Figures E-1 to E-14. At most sites, the relationship between total wetted surface area and discharge was plotted by fitting least squares linear regressions to the data. For Whitefish Slough and Slough 21, a hand drawn curve was best fitted to the data. The relationship between backwater surface area and discharge is replotted in the manner developed previously (Volume 4, Part I, Basic Data Report, ADF&G 1982) on a site by site basis.

DISCUSSION

Even though sampling was centered around slough and tributary reaches where mainstem backwater zones were a dominant feature, a very diverse set of hydraulic and physical habitats were sampled. The total wetted surface areas measured decreased with decreasing mainstem discharges.

Appendix Table E-1. Total wetted and aggregate type II (backwater) surface areas of selected regions of Designated Fish Habitat (DFH) sites, and mainstem Susitna River discharges[a], June through September, 1982.

DFH Site	Discharge cfs[a]	Date	Total Wetted Surface Area (Ft²)	Surface Area Type II (Ft²)
Slough 21[b]	31,900	7/25	316,000	72,800
	28,500[c]	6/19	203,000	16,300
	24,000	7/11	166,000	0
	17,000	8/09	160,000	73,600
	13,800	9/27	89,000	48,200
	12,500	8/20	96,000	47,300
	12,200	9/06	99,000	61,200
Slough 20	33,250[c]	6/20	139,000	20,600
	26,800	7/24	137,000	0
	23,000	6/04	115,000	0
	16,500	8/07	68,900	0
	14,400	9/04	68,900	500
	14,000	9/26	69,700	---[e]
	12,500	8/20	55,700	1,800
Slough 19	24,900	7/23	46,000	26,000
	22,000	6/17	30,000	10,000
	22,000	6/05	39,000	16,500
	16,800	8/06	29,000	12,300
	16,600	7/07	25,000	4,800
	15,000	9/25	20,000	0
	14,400	9/04	17,000	0
	13,300	8/19	15,000	4,200
Slough 11	33,250[c]	6/20	153,000	128,000
	27,300	7/14	135,000	92,800
	23,600	7/29	155,000	124,000
	23,000	6/04	132,000	95,000
	14,400	8/12	69,000	25,600
	12,400	9/29	50,000	19,300
	12,200	9/06	68,000	25,300
	12,200	8/22	53,000	23,700

[a] USGS provisional data at Gold Creek, 1982, 15292000.

[b] June 10, 1982, data for Slough 21 incomplete.

[c] Amended mainstem discharge at Gold Creek as determined from ADFG stage discharge curve.

[e] No backwater area mapped. A very small area probably existed.

Appendix Table E-1 (Continued).

DFH Site	Discharge cfs[a]	Date	Total Wetted Surface Area (Ft²)	Surface Area Type II (Ft²)
Slough 9	31,500	6/22	269,000	---[b]
	29,100	7/27	321,000	0
	28,400	7/13	305,000	0
	26,000	6/10	298,000	---[b]
	19,400	9/23	168,000	118,000
	16,700	8/10	185,000	133,000
	12,200	8/21	134,000	0
	11,700	9/07	172,000	0
Slough 8A	28,000	6/08	223,000	210,000
	26,500	7/12	218,000	202,000
	26,500[c]	6/23	223,000	210,000
	25,600	7/28	257,000	205,000
	17,100	9/24	169,000	143,000
	15,400	8/11	220,000	193,000
	12,200	8/21	185,000	158,000
	11,700	9/07	182,000	155,000
Lane Creek	28,500[c]	6/19	57,000	48,200
	25,000	6/07	61,000	45,000
	22,400	7/22	45,000	14,400
	18,100	7/08	54,000	14,700
	16,600	8/08	37,000	12,700
	15,000	9/25	32,000	8,000
	14,400	9/10	38,000	9,400
	12,500	8/20	36,000	6,100
Slough 6A	33,250[c]	6/20	138,000	138,000
	24,900	7/23	135,000	135,000
	23,000	6/06	131,000	131,000
	21,500	7/09	134,000	134,000
	16,600	8/08	131,000	131,000
	14,400	9/10	129,000	129,000
	14,000	9/26	131,000	131,000
	12,200	8/21	127,000	127,000

[a]USGS provisional data at Gold Creek, 1982, 15292000.

[b]June 10 and June 22 data for Slough 9 incomplete.

[c]Amended mainstem discharge at Gold Creek as determined from ADFG stage discharge curve.

Appendix Table E-1 (Continued).

DFH Site	Discharge cfs[a]	Date	Total Wetted Surface Area (Ft²)	Surface Area Type II (Ft²)
Whisker Creek and Slough	37,000[g]	6/21	217,000	76,000[b]
	31,900	7/25	236,000	56,000[b]
	25,000	6/03	217,000	160,000[c]
	23,000	7/10	213,000	83,900
	16,600	8/08	163,000	46,600
	13,800	5/27	190,000	---[d]
	13,400	9/09	195,000	29,200
	12,200	8/22	150,000	28,500
Birch Creek and Slough	99,300	7/26	458,000	424,000
	61,600	6/23	388,000	354,000
	59,700	6/04	394,000	359,000
	58,400	7/11	422,000	398,000
	52,500	8/09	370,000	157,000
	38,000	8/23	362,000	147,000
	35,900	9/28	376,000	59,500
	33,800	9/11	363,000	81,900
Sunshine Creek and Sidechannel	82,400[e]	7/27	332,000	218,000[f]
	70,200	6/09	277,000	121,000
	62,700	6/24	275,000	134,000
	60,100	7/12	259,000	163,000[f]
	51,600	8/10	214,000	128,000
	38,700	8/24	180,000	46,300
	35,000	3/12	179,000	12,200
	33,400	9/30	154,000	25,300

[a] USGS provisional data at Gold Creek 15292000 (with Whisker Creek data).

[b] Surface area measurements for June 21 and July 25, 1982, are lower limits.

[c] Surface area measurement for June 3, 1982 is an upper limit.

[d] High tributary discharge this date eliminated zone 2 (see ADFG Basic Data Report, 1982).

[e] USGS provisional data at Sunshine 15292780.

[f] Differs from value in ADFG Basic Data Report, 1982 (see text).

[g] Amended mainstem discharge at Gold Creek as determined from ADFG stage discharge curve.

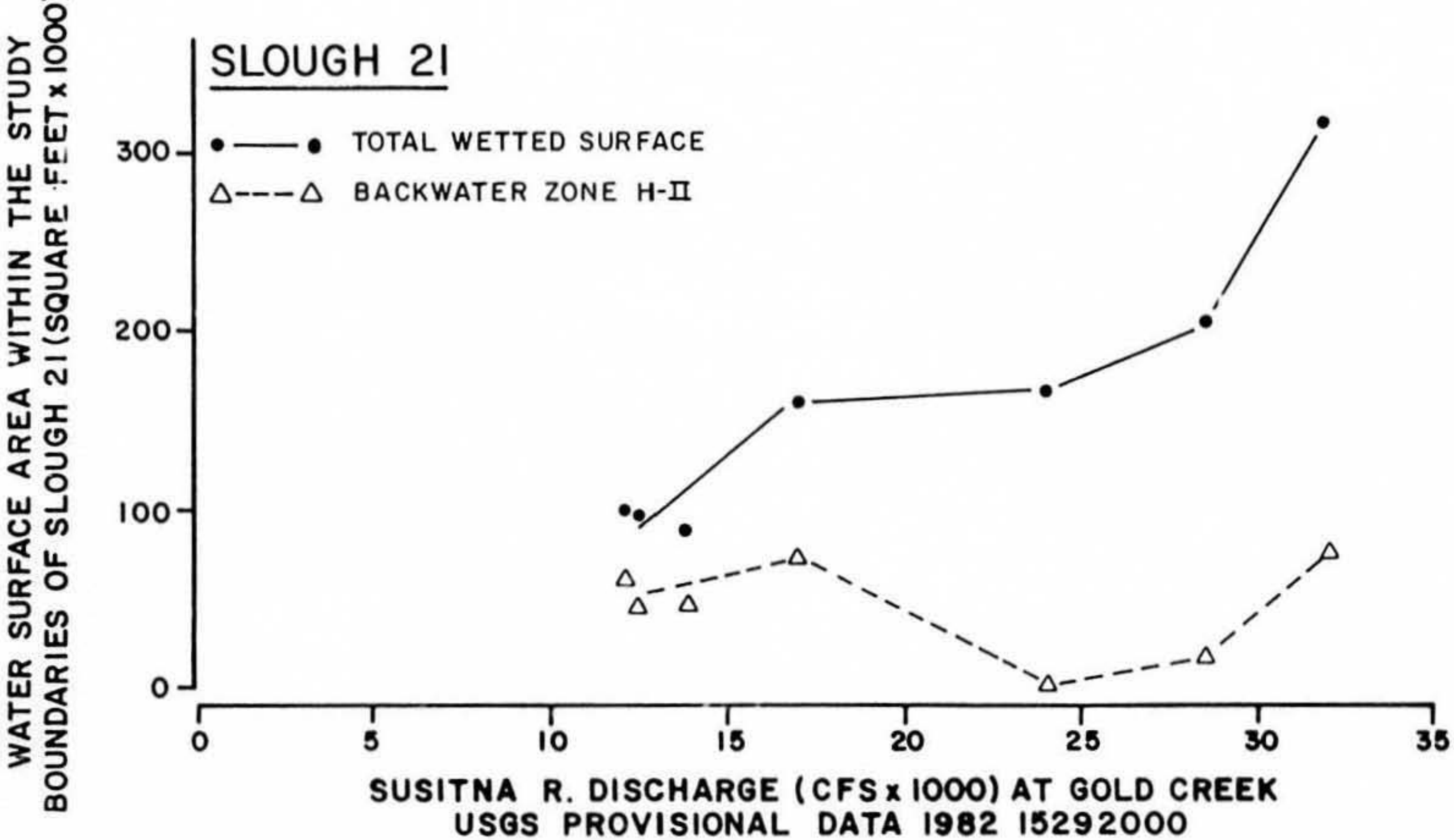
Appendix Table E-1 (Continued).

DFH Site	Discharge cfs[a]	Date	Total Wetted Surface Area (Ft²)	Surface Area Type II (Ft²)
Rabideux Creek and Slough[b]	71,700	6/26	1,170,000	1,160,000
	67,900	7/29	1,120,000	1,180,000
	53,000	9/14	1,220,000	965,000
	44,000	8/12	1,070,000	876,000
	38,700	8/25	1,080,000	836,000
	33,400	9/30	968,000	344,000
Whitefish Slough[c]	72,000	7/28	85,800	85,800
	66,700	6/25	75,000	75,000
	60,100	7/12	65,800	65,800
	53,000	9/14	71,000	71,000
	47,900	8/11	56,200	56,200
	38,700	8/25	32,200	32,200
	33,900	9/29	14,200	14,200
Goose Creek and Sidechannel	72,000	7/28	166,000	75,000
	66,700	6/25	170,000	83,000
	64,200	6/10	176,000	87,000
	63,000	7/13	158,000	74,400
	47,900	8/11	154,000	113,000
	38,700	8/25	148,000	122,000
	36,400	9/13	137,000	0
	33,900	9/29	134,000	0

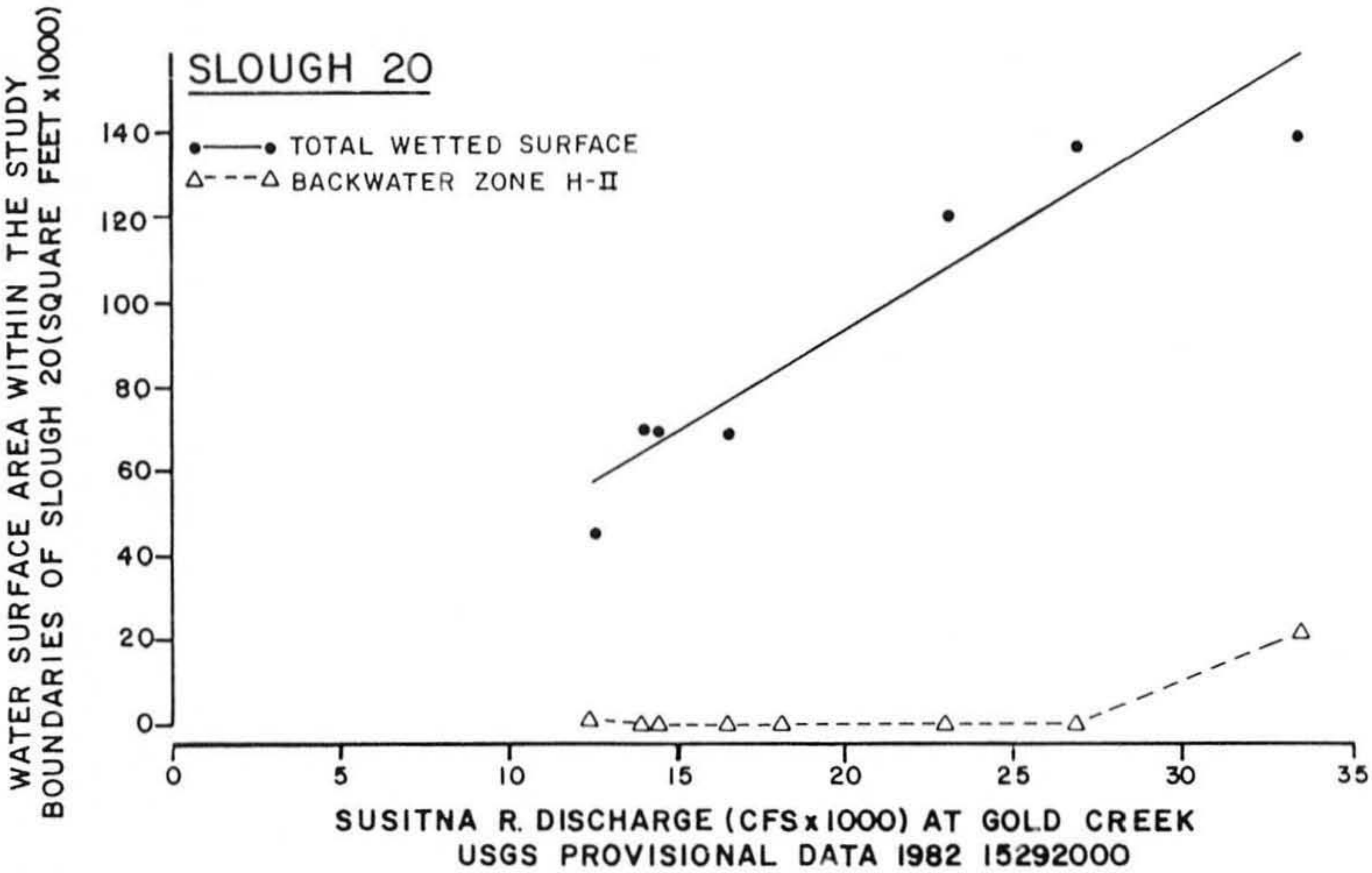
[a]USGS provisional data at Sunshine, 1982, 15292780.

[b]Not sampled in early June or in early July.

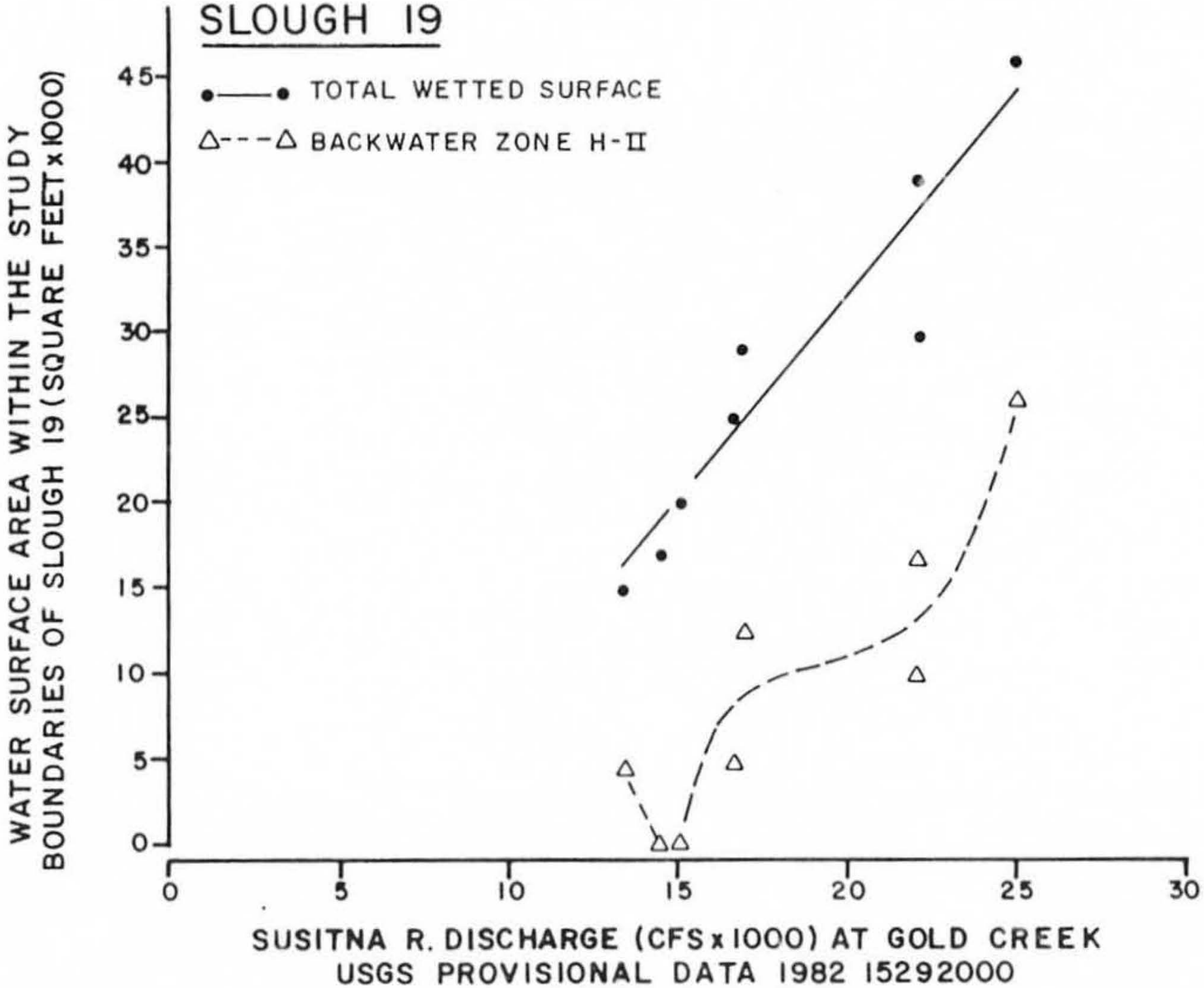
[c]Not sampled in early July.



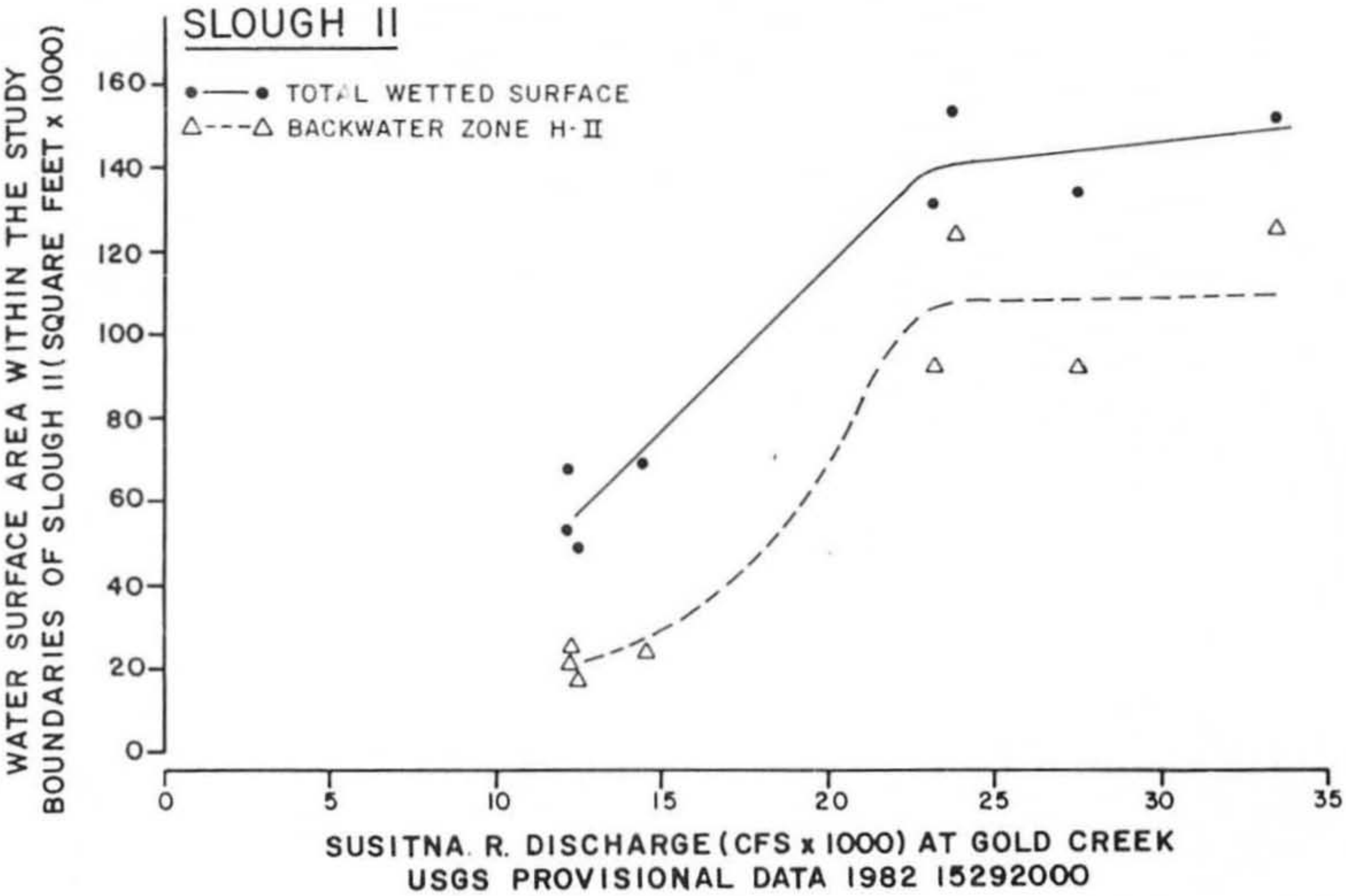
Appendix Figure E-1. Wetted surface area at Slough 21 versus mainstem discharge at Gold Creek. The measurements represent the areas within the study boundaries illustrated in Appendix Plate E-1.



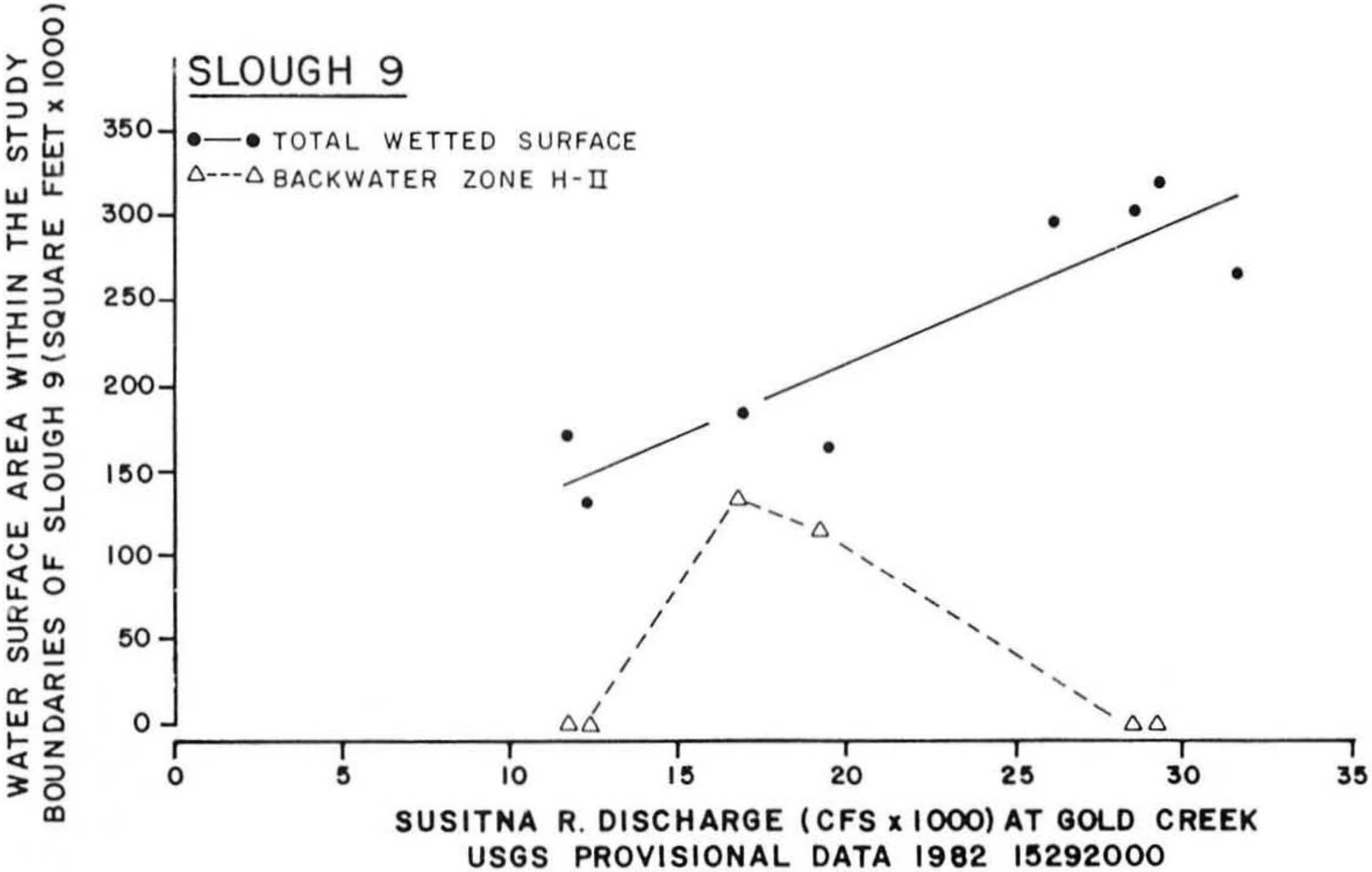
Appendix Figure E-2. Wetted surface area at Slough 20 versus mainstem discharge at Gold Creek. The measurements represent the areas within the study boundaries illustrated in Appendix Plate E-2.



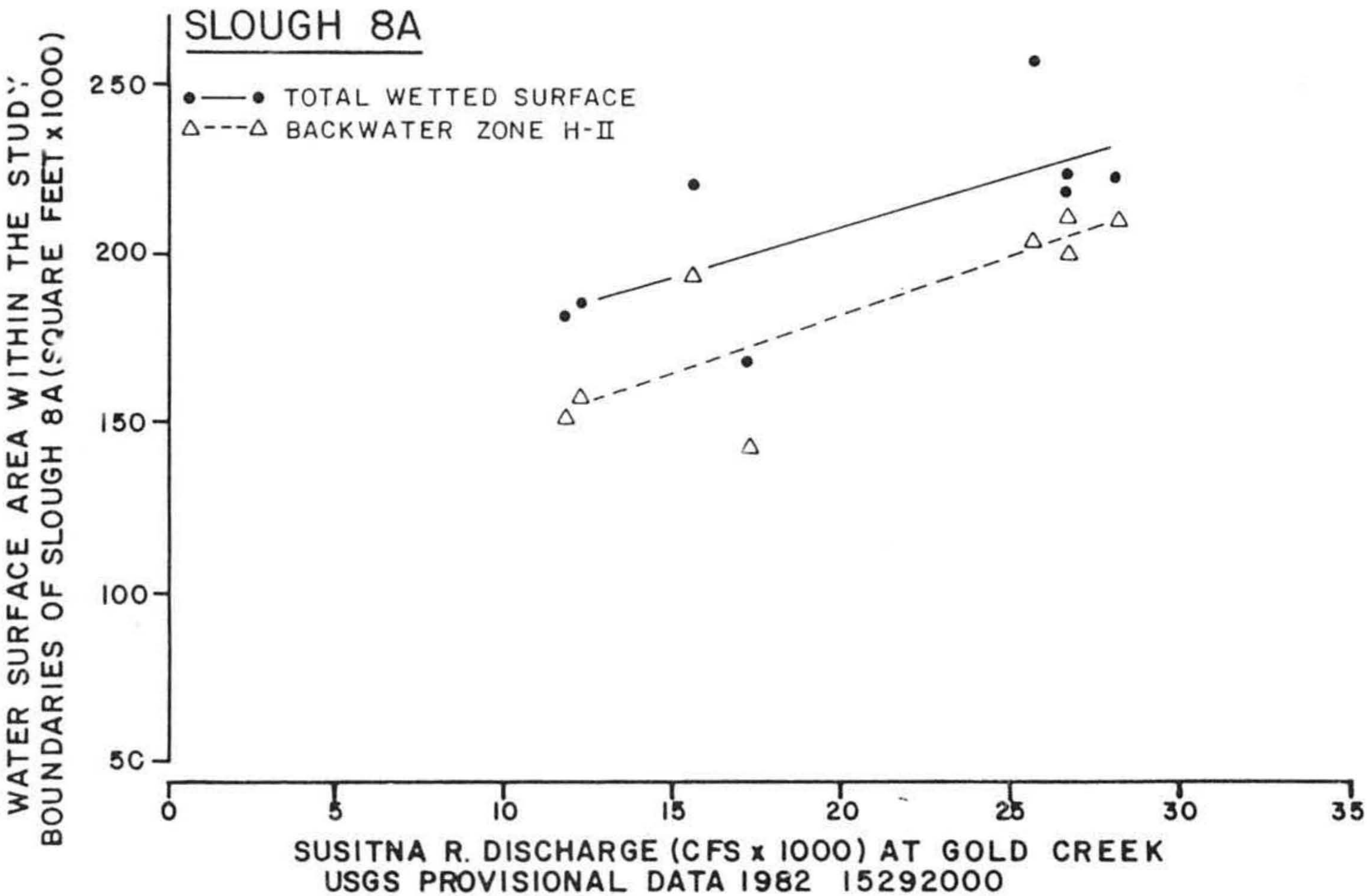
Appendix Figure E-3. Wetted surface area at Slough 19 versus mainstem discharge at Gold Creek. The measurements represent the areas within the study boundaries illustrated in Appendix Plate E-3.



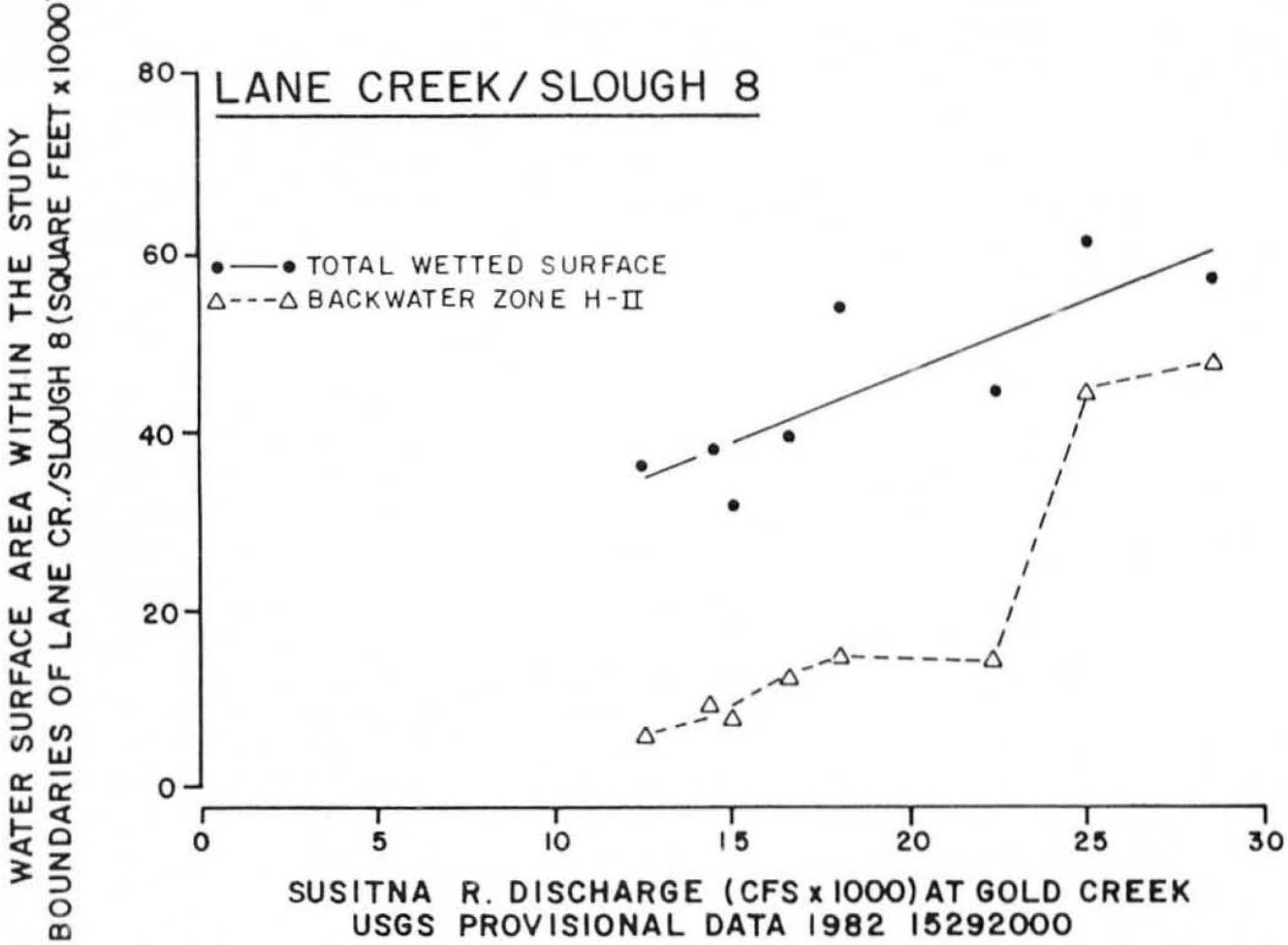
Appendix Figure E-4. Wetted surface area at Slough 11 versus mainstem discharge at Gold Creek. The measurements represent the areas within the study boundaries illustrated in Appendix Plate E-4.



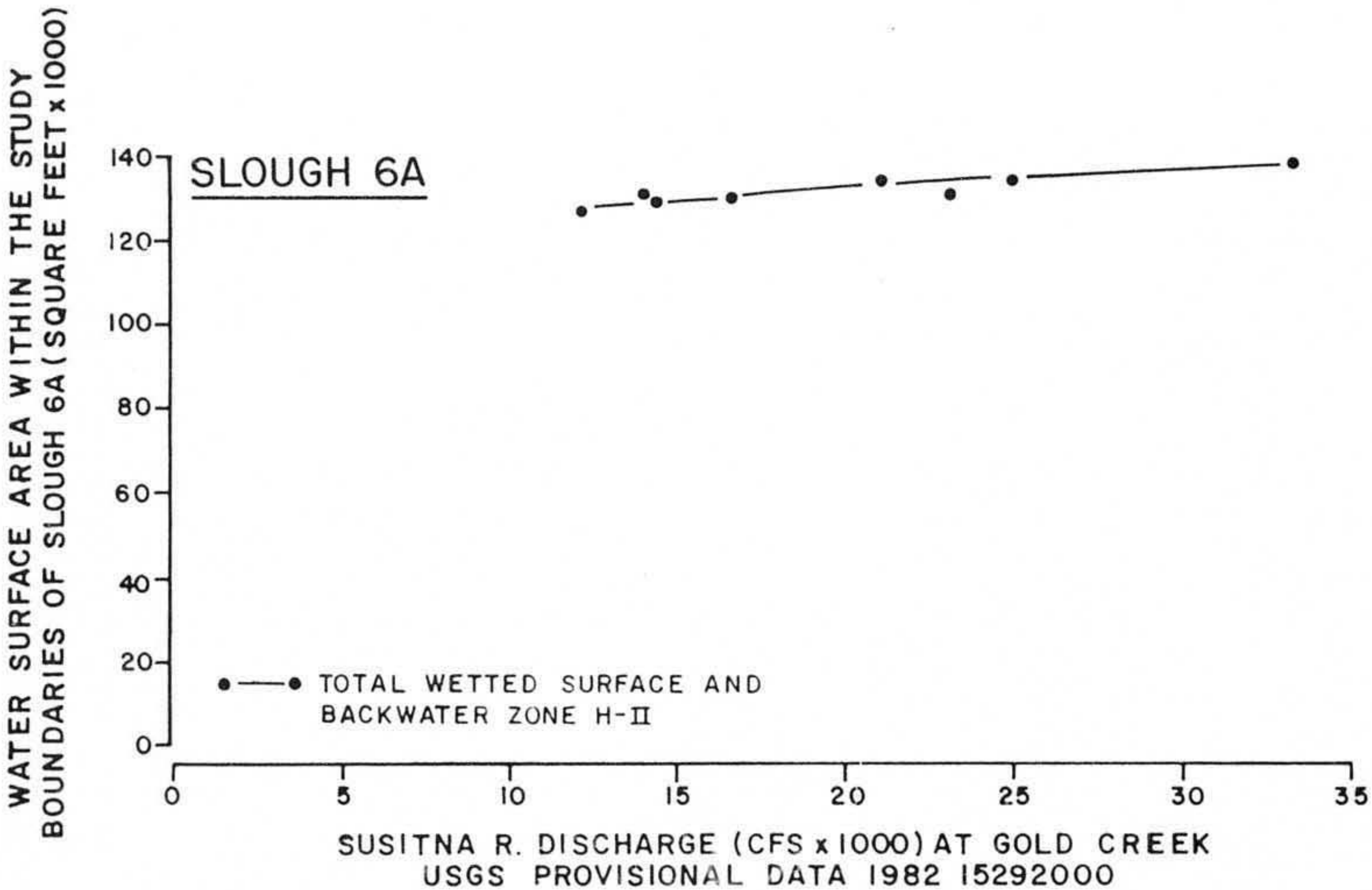
Appendix Figure E-5. Wetted surface area at Slough 9 versus mainstem discharge at Gold Creek. The measurements represent the areas within the study boundaries illustrated in Appendix Plate E-5.



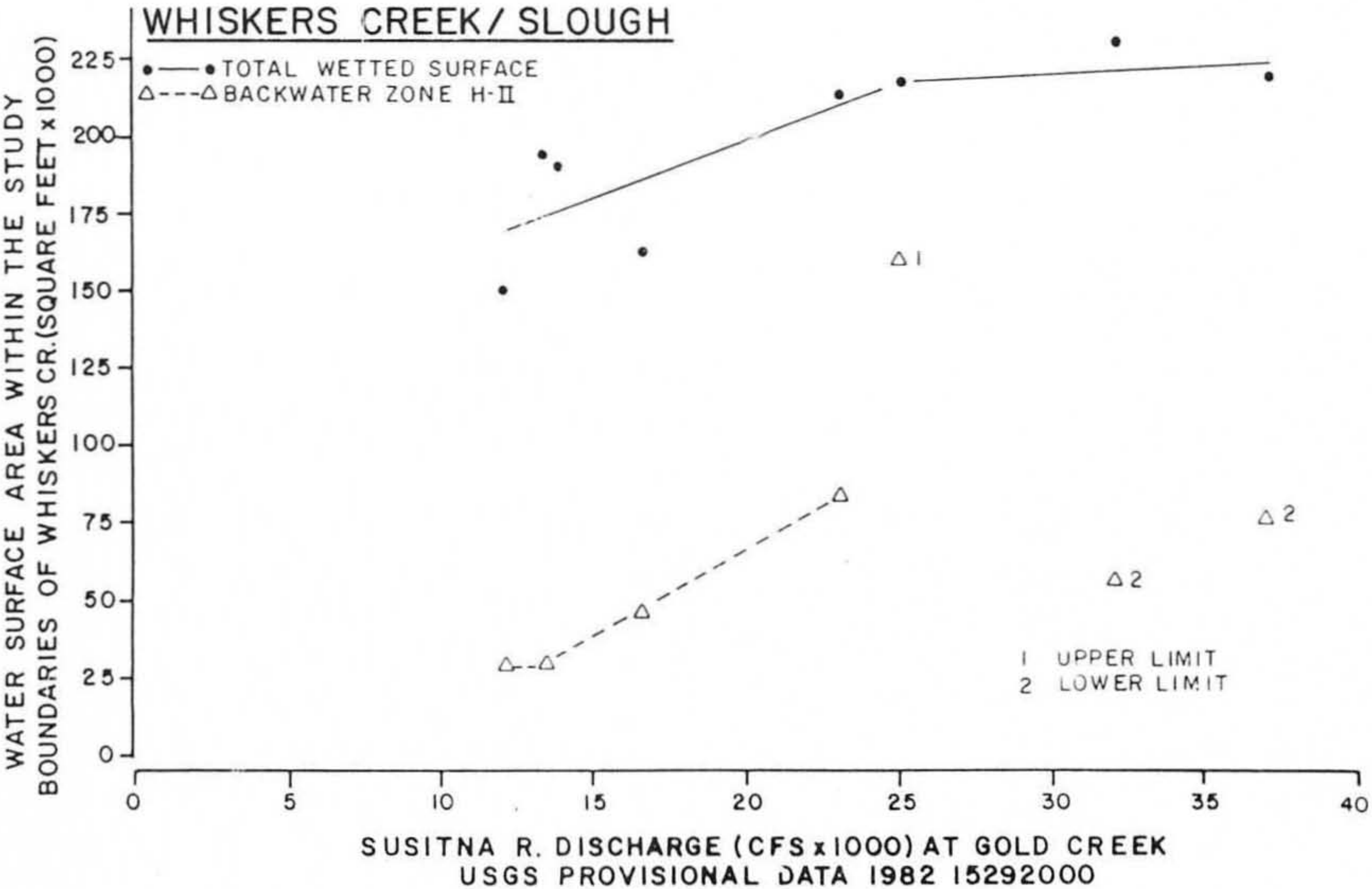
Appendix Figure E-6. Wetted surface area at Slough 8A versus mainstem discharge at Gold Creek. The measurements represent the areas within the study boundaries illustrated in Appendix Plate E-6.



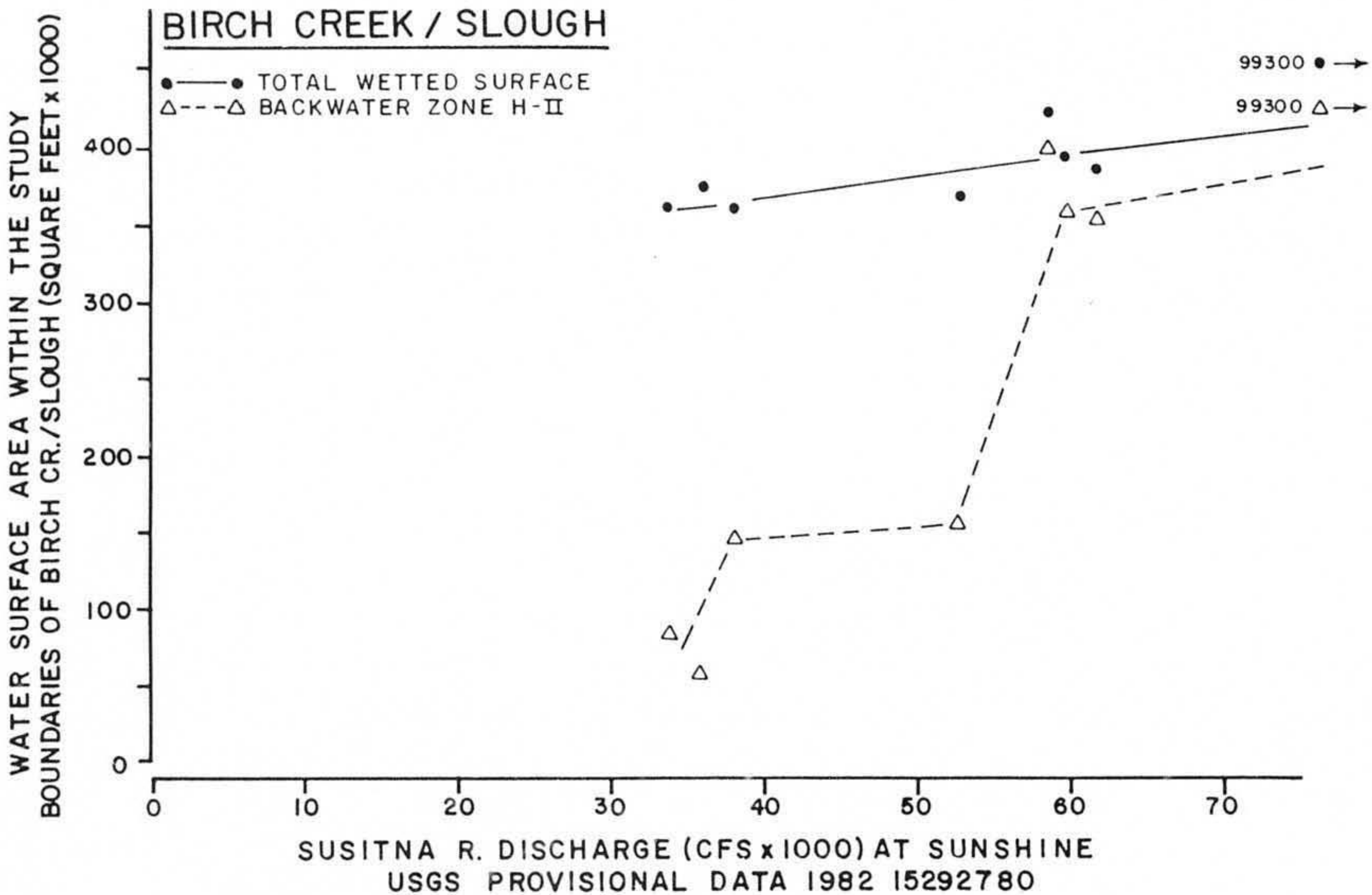
Appendix Figure E-7. Wetted surface area at Slough 8 / Lane Creek versus mainstem discharge at Gold Creek. The measurements represent the areas within the study boundaries illustrated in Appendix Plate E-7.



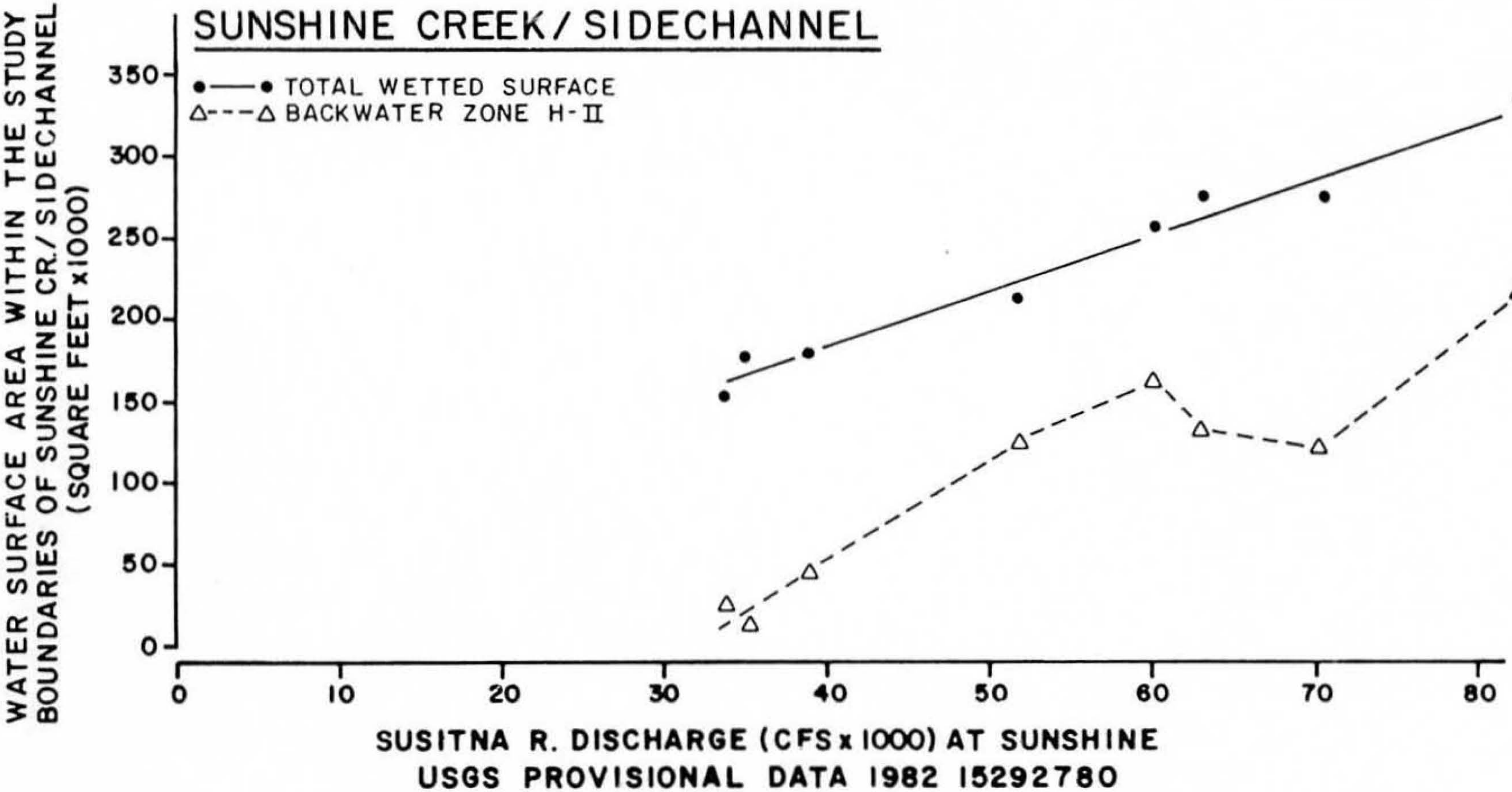
Appendix Figure E-8. Wetted surface area at Slough 6A versus mainstem discharge at Gold Creek. The measurements represent the areas within the study boundaries illustrated in Appendix Plate E-8.



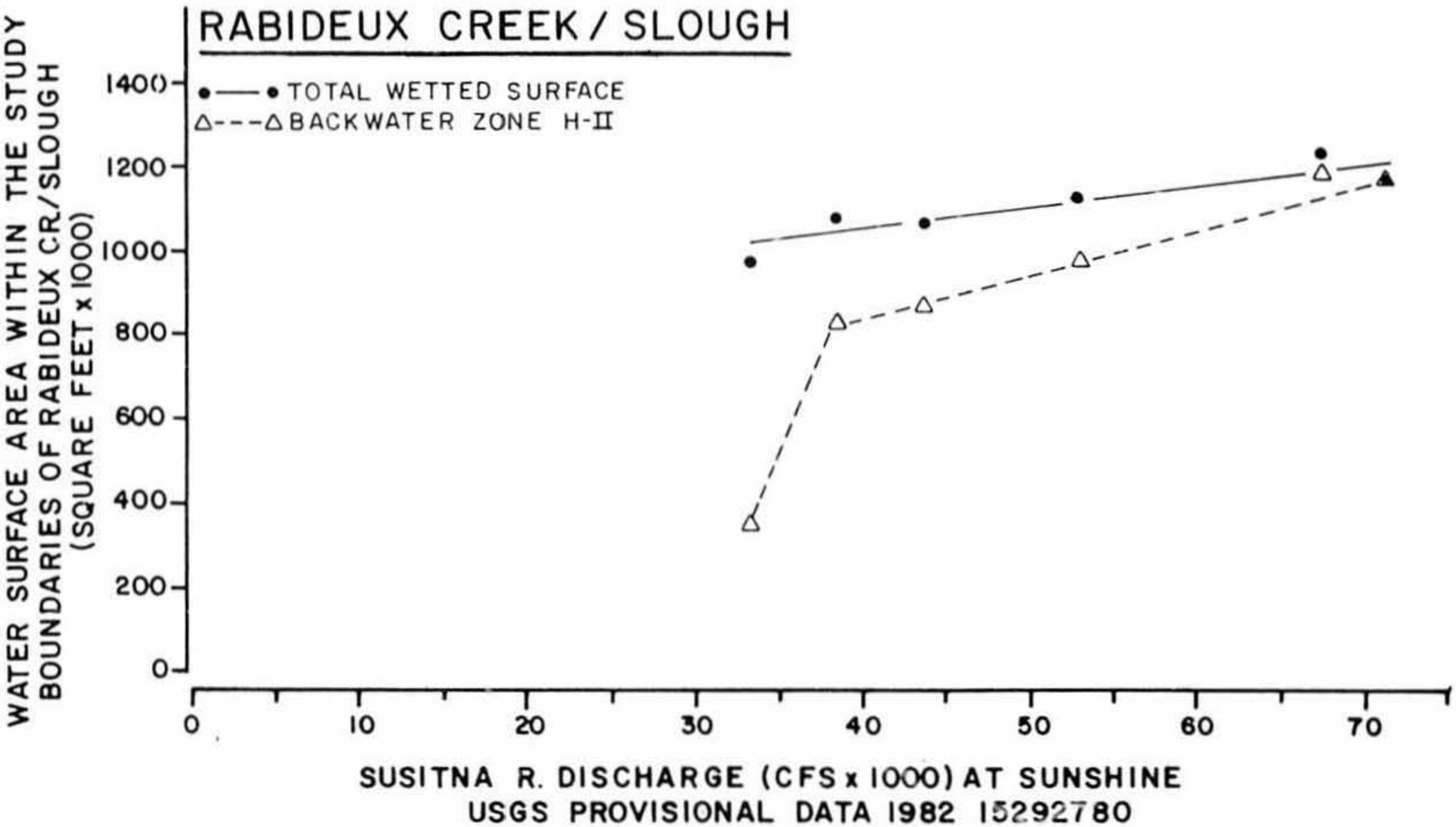
Appendix Figure E-9. Wetted surface area at Whiskers Creek / Slough versus mainstem discharge at Gold Creek. The measurements represent the areas within the study boundaries illustrated in Appendix Plate E-9.



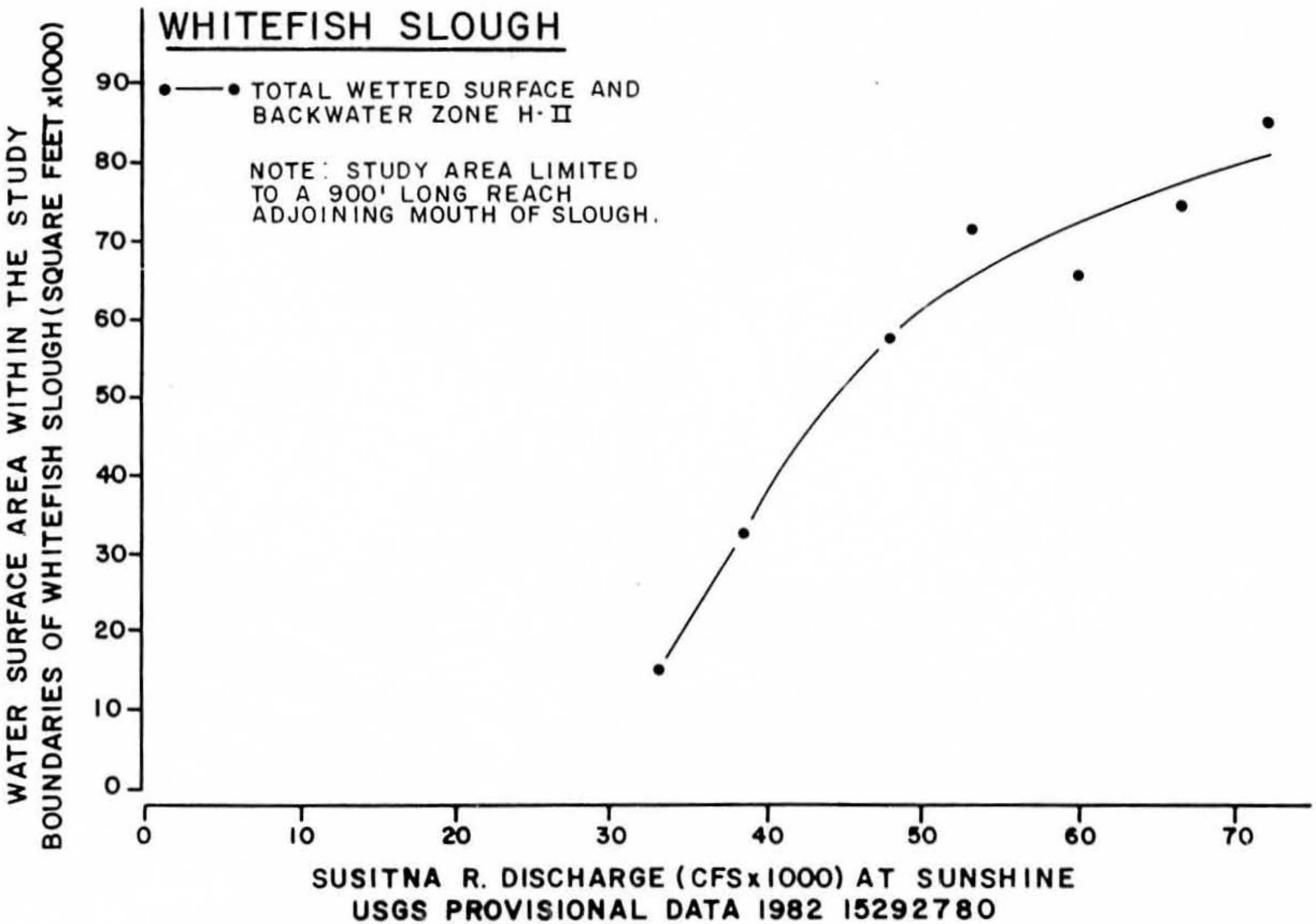
Appendix Figure E-10. Wetted surface area at Birch Creek / Slough versus mainstem discharge at Sunshine. The measurements represent the areas within the study boundaries illustrated in Appendix Plate E-10.



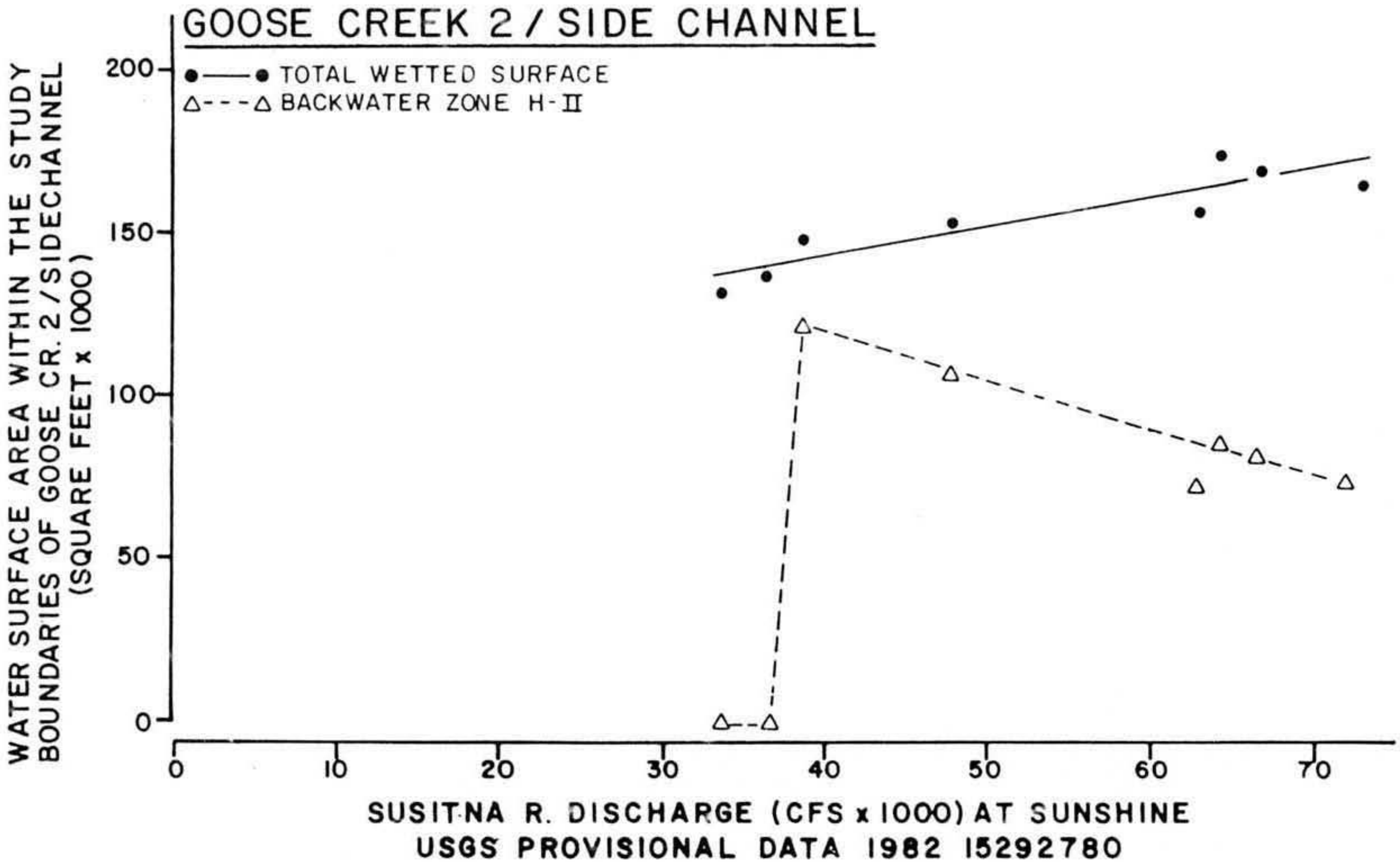
Appendix Figure E-11. Wetted surface area at Sunshine Creek/Side Channel versus mainstem discharge at Sunshine. The measurements represent the areas within the study boundaries illustrated in appendix Plate E-11.



Appendix Figure E-12. Wetted surface area at Rabideux Creek/Slough versus mainstem discharge at Sunshine. The measurements represent the areas within the study boundaries illustrated in Appendix Plate E-12.



Appendix Figure E-13. Wetted surface area at Whitefish Slough versus mainstem discharge at Sunshine. The measurements represent the areas within the study boundaries illustrated in Appendix Plate E-13.



Appendix Figure E-14. Wetted surface area at Goose Creek 2/ Side Channel versus mainstem discharge at Sunshine. The measurements represent the areas within the study boundaries illustrated in Appendix Plate E-14.

The wetted surface areas of the upper portions of several sites were greatly reduced as flows declined, and the habitat (types) present in many of these areas changed considerably over the range of mainstem discharges observed. Total wetted surface area plots are typically represented by simple linear regressions. In contrast, backwater area plots are more complex. In part, this complexity is attributed to these areas receding and reforming downstream as flow decreased (see Volume 4 for more discussion of this topic).

At Slough 6A and at Whitefish Slough, the total wetted and backwater surface areas are identical within the range of discharges observed.

The reaches of Sloughs 8A and 11 which were mapped consisted predominantly of backwater areas. At these and other habitat locations, except when zone 9 (calm water) pools were present (Appendix Table E-2), the difference between the total wetted and backwater surface areas reported equals the surface area of water present in the study area which had appreciable velocity. Appreciable velocity was generally defined as a velocity of 0.5 ft/sec or greater (Volume 4, Part II). Conversely, the sum of the pool plus backwater surface area equals the low velocity (0.0 to 0.5 ft/sec) surface areas present within the boundaries mapped at a habitat site. Additional discussion relating surface areas to habitat is found in Appendix F of this report.

A summation of the total wetted surface areas, within the boundaries of all upper and lower Susitna River study sites sampled, is shown in Appendix Tables E-3 and E-4, and in Appendix Figures E-15 and E-16.

Appendix Table E-2. Surface areas of morphological pools[a] not regulated by mainstem Susitna River discharge at Designated Fish Habitat (DFH) sites, and mainstem Susitna River discharges, June through September, 1982.

DFH Site	Discharge cfs	Date	Zone 9 Surface Area
Goose Creek and Sidechannel	36,400	9/13	64,200
	33,900	9/29	77,400
Lane Creek/Slough 8	22,400	7/22	22,200
	18,100	7/08	23,100
	16,600	8/08	19,500
	15,000	9/25	18,800
	14,400	9/10	18,900
	12,500	8/20	18,700
Rabideux Creek and Slough	33,400	9/30	308,000
Slough 20	33,250	6/20	40,500
	26,800	7/24	54,800
	23,000	6/04	36,300
	18,100	7/08	11,500
	16,500	8/07	20,300
	14,400	9/04	18,100
	14,000	9/26	18,100
	12,500	8/20	15,900
Whisker Creek and Slough	37,000	6/21	41,400
	31,900	7/25	8,400
	25,000	6/03	none
	23,000	7/10	55,200
	16,600	8/08	25,100
	13,800	9/27	23,500
	13,400	9/09	23,500
	12,200	8/22	19,500

[a] These areas were identified as zone 9 and occurred (as calm water morphologic pools) in free flowing tributary or ground water areas.

Appendix Table E-2. (Continued).

DFH Site	Discharge cfs	Date	Zone 9 Surface Area
Sunshine Creek and Sidechannel	35,000	9/12	8,400
	33,400	9/30	7,700
Birch Creek and Slough	38,000	8/23	33,900
	35,900	9/28	37,400
	33,800	9/11	37,400
Slough 19	15,500	9/25	5,500
	14,400	9/04	5,100
	13,300	8/19	4,600
Slough 8A			Approx 8,000[a]

[a]A small pool was located below the first beaver dam throughout most of the sampling year. This pool was not mapped as such but was the site of systematic fish captures.

Appendix Table E-3. Total wetted surface areas measured within the boundaries of nine study areas on the upper Susitna River, versus Gold Creek discharge[a], June through September, 1982.

	Surface Areas[b] (Square Feet x 1000) at Habitat Location, by Discharge						
Habitat Location	12,500	15,000	17,500	20,000	22,500	25,000	27,500
Slough 21	88.	129.	160.	161.	163.	173.	194.
Slough 20	57.	69.	82.	94.	106.	118.	130.
Slough 19	16.[c]	20.	26.	32.	38.	44.[d]	44.[d]
Slough 11	58.	77.	97.	116.	136.	143.	145.
Slough 9	150.	171.	193.	215.	237.	259.	280.
Slough 8A	186.	194.	201.	208.	215.	223.	230.
Lane Creek/Slough 8	35.	39.	43.	47.	51.	55.	59.
Slough 6A	128.	129.	131.	132.	134.	135.	137.
Whiskers Creek/Sidechannel	170.	179.	189.	198.	208.	217.	218.
Total by Discharge	888.	1007.	1122.	1203.	1288.	1367.	1437.

[a]USGS Provisional data at Gold Creek, 1982, 15292000.

[b]Data compiled from Appendix Figures E-1 through E-9.

[c]Area measured at 13,300 cfs.

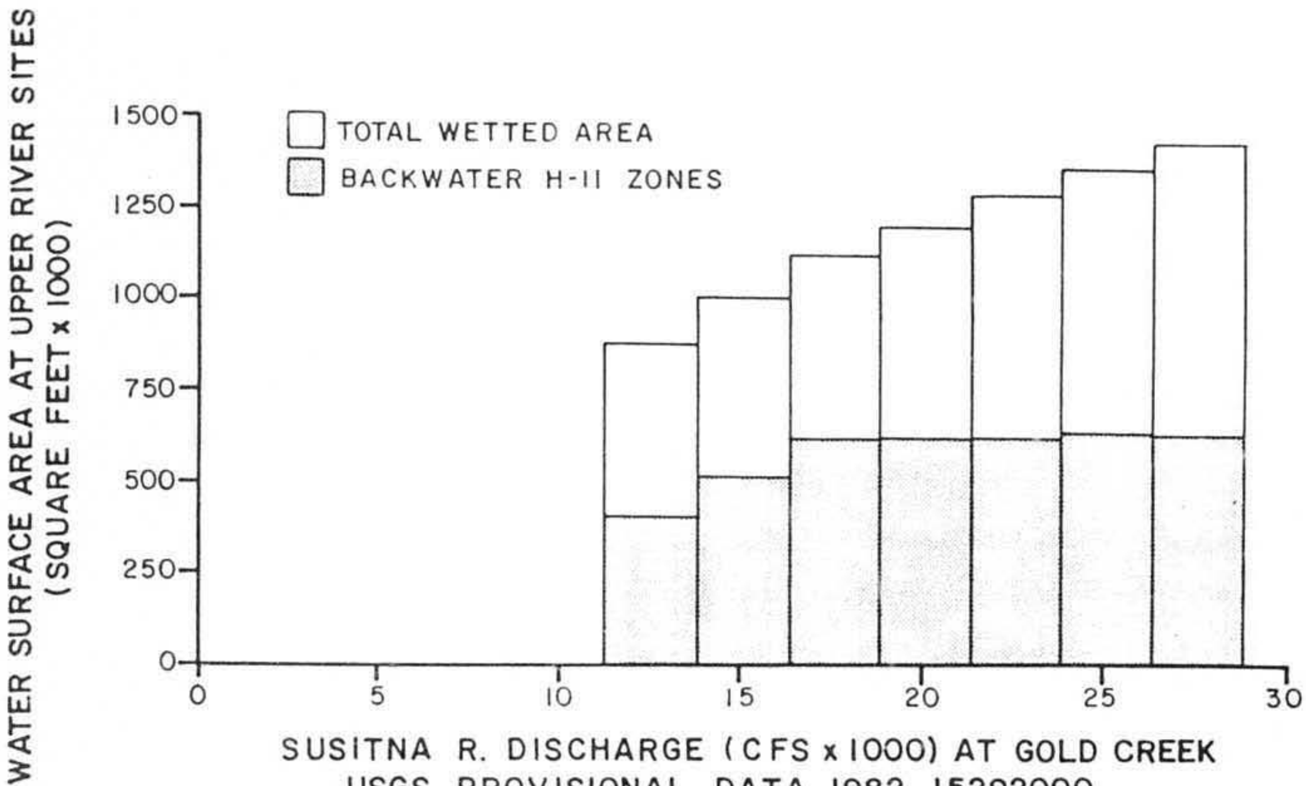
[d]Area measured at 24,900 cfs.

Appendix Table E-4. Total wetted surface areas measured within the boundaries of five study areas on the Lower Susitna River, versus Sunshine discharge[a], June through September, 1982.

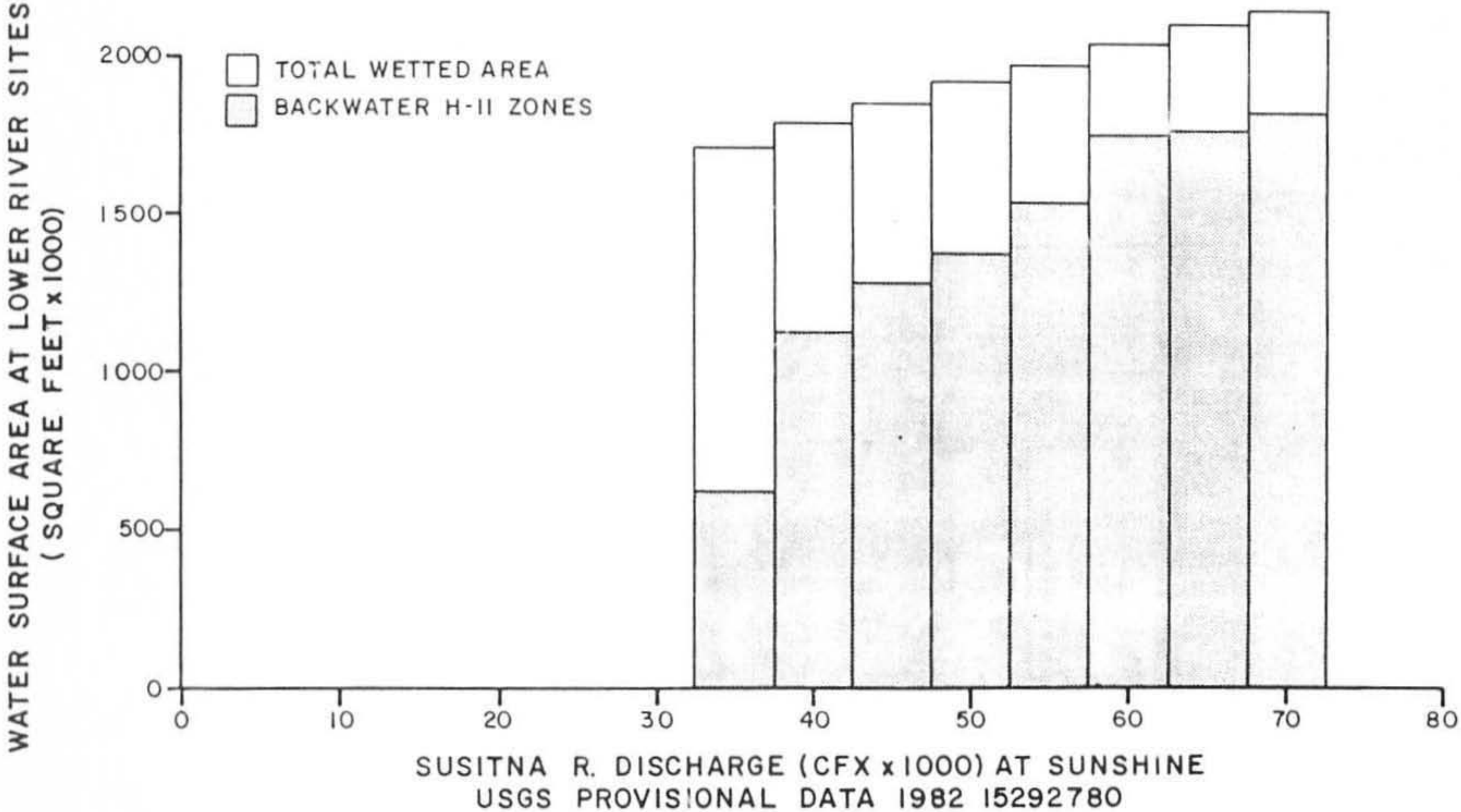
	Surface Areas[b] (Square Feet x 1000) at Habitat Location, by Discharge							
Habitat Location	35,000	40,000	45,000	50,000	55,000	60,000	65,000	70,000
Birch Creek	362.	368.	374.	380.	386.	394.	400.	406.
Sunshine Creek/Sidechannel	168.	185.	202.	219.	236.	253.	270.	287.
Rabideux Creek/Slough	1020.	1050.	1070.	1110.	1120.	1150.	1180.	1200.
Whitefish Slough	21.	37.	51.	61.	67.	72.	77.	80.
Goose Creek/Sidechannel	139.	143.	148.	152.	157.	161.	166.	170.
Total by Discharge	1710.	1783.	1845.	1922.	1966.	2030.	2093.	2143.

[a]USGS Provisional data at Sunshine, 1982, 15292780.

[b]Data compiled from Appendix Figures E-10 through E-14.



Appendix Figure E-15. Wetted surface area summations for the nine upper Susitna sites versus mainstem discharge at Gold Creek. The measurements represent the areas within the study boundaries illustrated in Appendix Plates E-1 through E-9.



Appendix Figure E-16. Wetted surface area summations for the five lower Susitna sites versus mainstem discharge at Sunshine. The measurements represent the areas within the study boundaries illustrated in Appendix Plates E-10 through E-14.

These values were obtained by determining the areas indicated at 2500 and 5000 cfs discharge intervals from Appendix Figures E-1 to E-14. The lower river plot indicates that a linear relationship between total wetted surface areas and mainstem discharge exists within the range of discharges observed. The upper river total wetted area versus Susitna River discharge data is best described by two straight lines. Below 17,500 cfs a given change in mainstem flows results in greater changes in total wetted surface areas than does a given change in flow above 17,500 cfs.

Appendix Figures E-15 and E-16 also display the corresponding backwater surface data as adapted from Tables 4I-4-1 and 4I-4-2 of the Basic Data Report. A comparison of the total wetted and backwater surface area plots requires careful interpretation. As noted above, the backwater areas occurring at each site were normally mapped in their entirety. The "total" wetted surfaces mapped were, however, selectively limited in area by study design and sampling logistics. Within the lower river slough and tributary areas sampled, the backwater surface areas decrease faster at mainstem discharges below approximately 60,000 cfs, than do total wetted areas. At mainstem discharges above 60,000 cfs, the total wetted areas increase faster than the backwater areas and the highest proportion of backwater area occurs at about 60,000 cfs. At upper river sites, the inflection point (in the backwater plot) near 17,500 cfs appears to be similar to the 60,000 cfs point in the lower river plot because above 17,500 cfs the total wetted area increases faster than backwater area. Below 17,500 cfs (in the upper river plot), it is not clear that backwater surface areas decrease faster than do total wetted surfaces as is apparent in the lower river areas. However, data at discharges of 10,000 cfs and below may show that this is the case in the upper river as well.

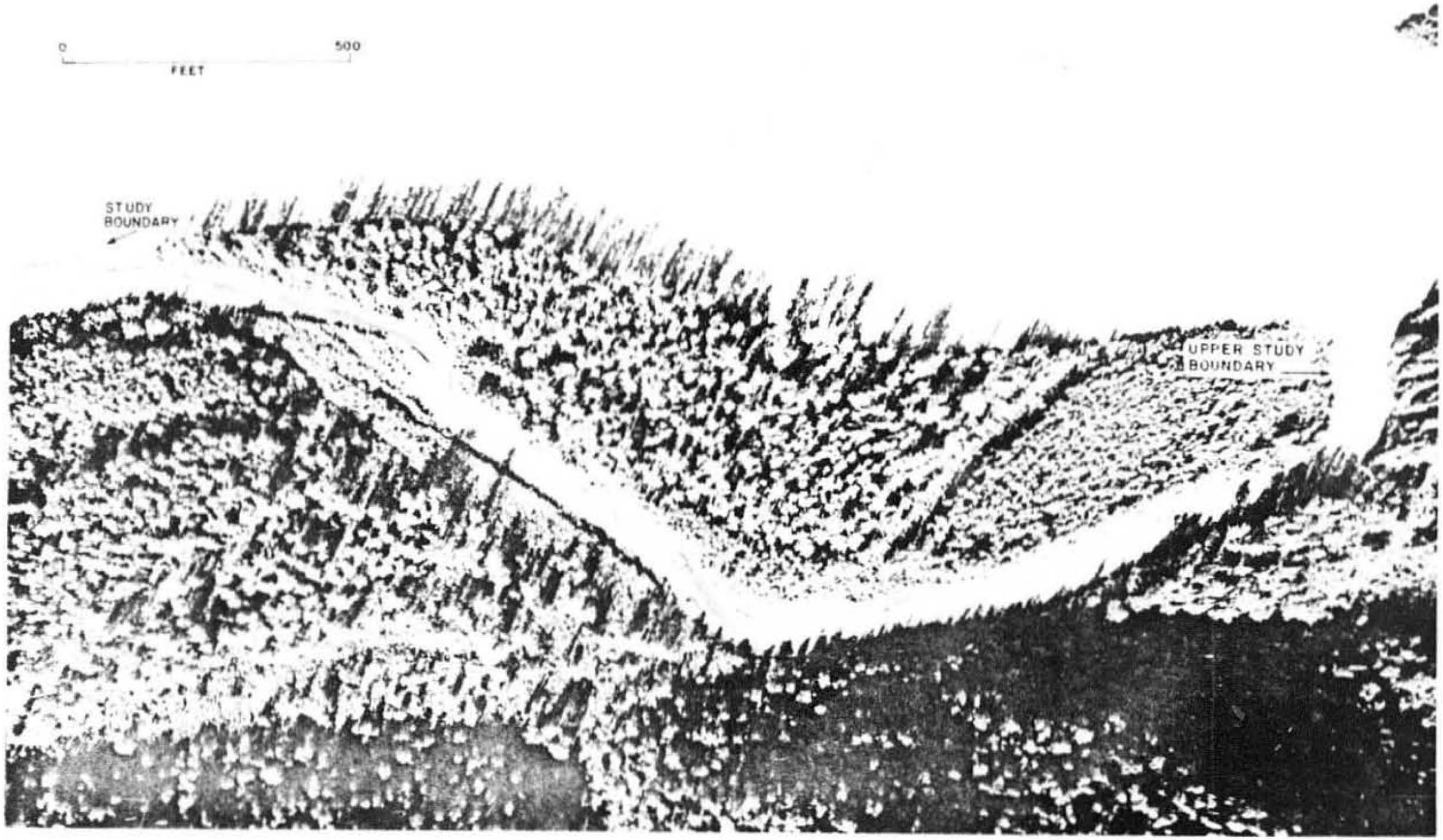
Use of the slough and tributary mouth wetted surface area data to model the total wetted surfaces of the Susitna River with decreasing flows should not be attempted. These data were not obtained from areas representative of the average mainstem environment, as the proportion of free flowing mainstem surfaces included represent a small and insignificant proportion of the Susitna River's total free flowing mainstem surfaces. There is, however, confidence for using the backwater data to represent the true backwater surface area versus discharge relationship for larger reaches of the Susitna (as was done) as a significant percentage of the backwater surfaces were actually measured. At low mainstem discharges such as are present during early spring and late fall, reductions in surface area were observed at several sloughs suggesting that the total wetted and backwater surface area relationships presented should not be used to infer surface areas at mainstem discharges beyond those observed.

This information illustrates that many difficulties might be involved in attempting discharge related assessments of available juvenile fish (slough and tributary) habitat based on overly simplified parameters, such as total wetted surface areas. Total backwater area relationships, which appear to be more complex, may be better indicators for selected species and life history stages. In addition, separating those backwater areas that re-form downstream (in mainstem type environments during low mainstem flows) from the slough and tributary backwater habitats present at higher flows, are also necessary for a habitat analysis.

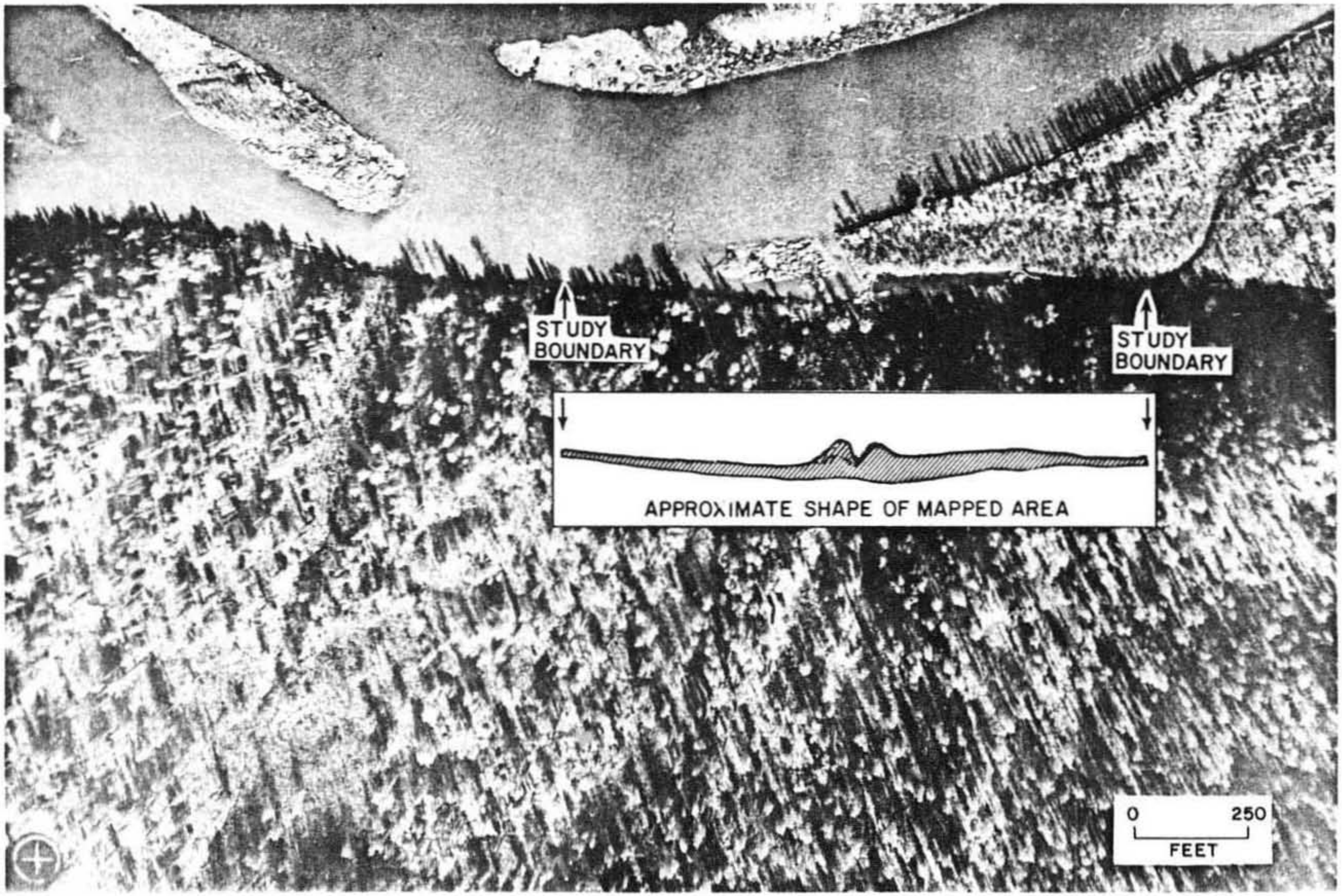
LITERATURE CITED

Alaska Department of Fish and Game. 1983. Aquatic Habitat and instream flow studies. Volume 4 of ADF&G Susitna Hydro Aquatic Studies Program, Phase II, Basic Data Report. Anchorage, Alaska.

Appendix Plate E-1. August 1980 photograph of Slough 21 (RM 142.0). The surface area measurements reported are for the slough between the study boundaries shown.



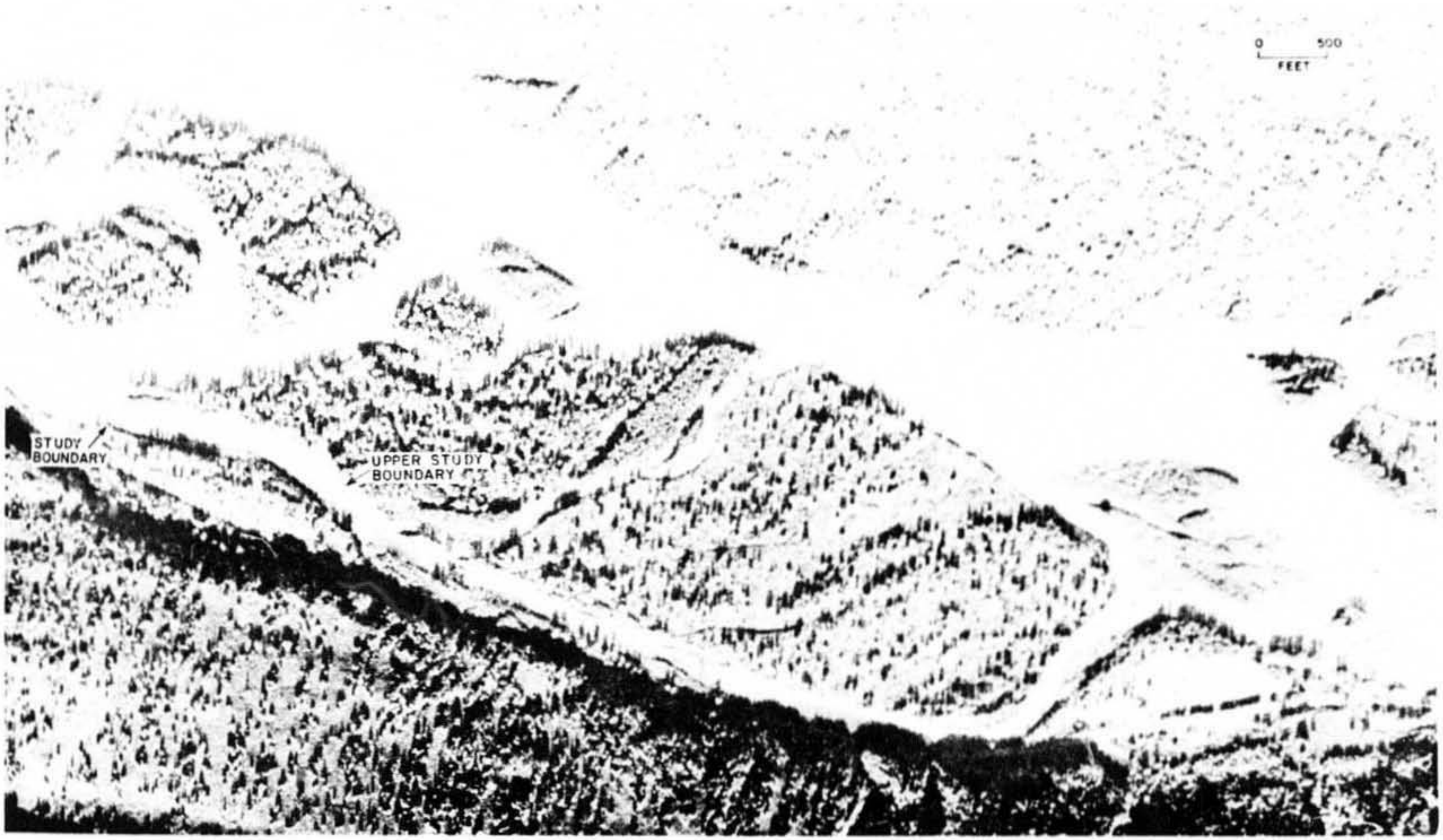
Appendix Plate E-2. August 1982 photograph of Slough 20 (RM 140.1). The surface area measurements reported are for the slough between the study boundaries shown.



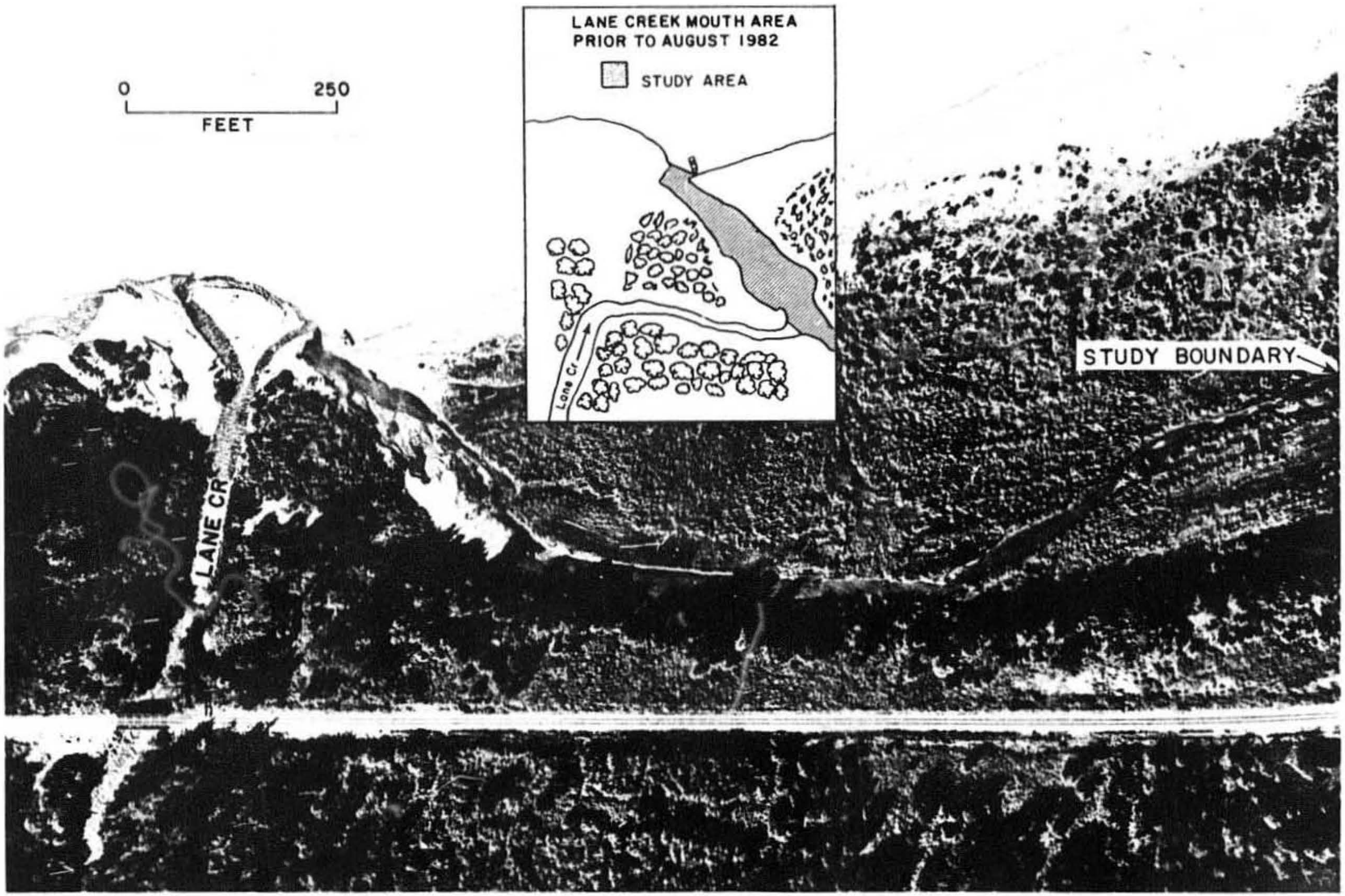
Appendix Plate E-3. May 1982 photograph of Slough 19 (RM 140.0). The surface area measurements reported are for the slough and its immediately downstream reach between the study boundaries shown.

Appendix Plate E-4. August 1980 photograph of Slough 11 (RM 135.3). The surface area measurements reported are for the slough between the study boundaries shown.

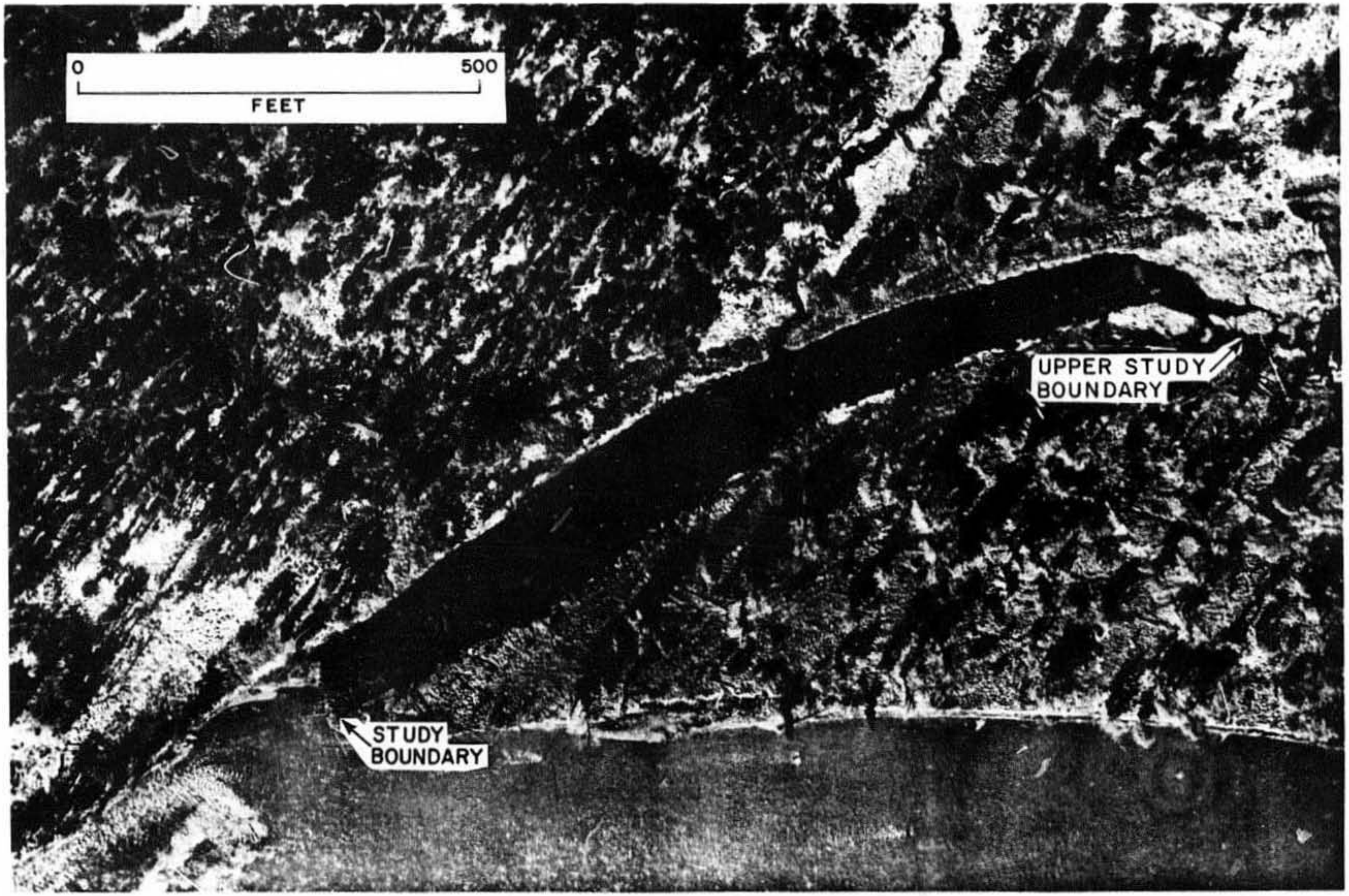
Appendix Plate E-5. August 1980 photograph of Slough 9 (RM 129.2). The surface area measurements reported are for the slough between the study boundaries shown.



Appendix Plate E-6. August 1980 photograph of Slough 8A (RM 125.3). The surface area measurements reported are for the slough between the study boundaries shown.

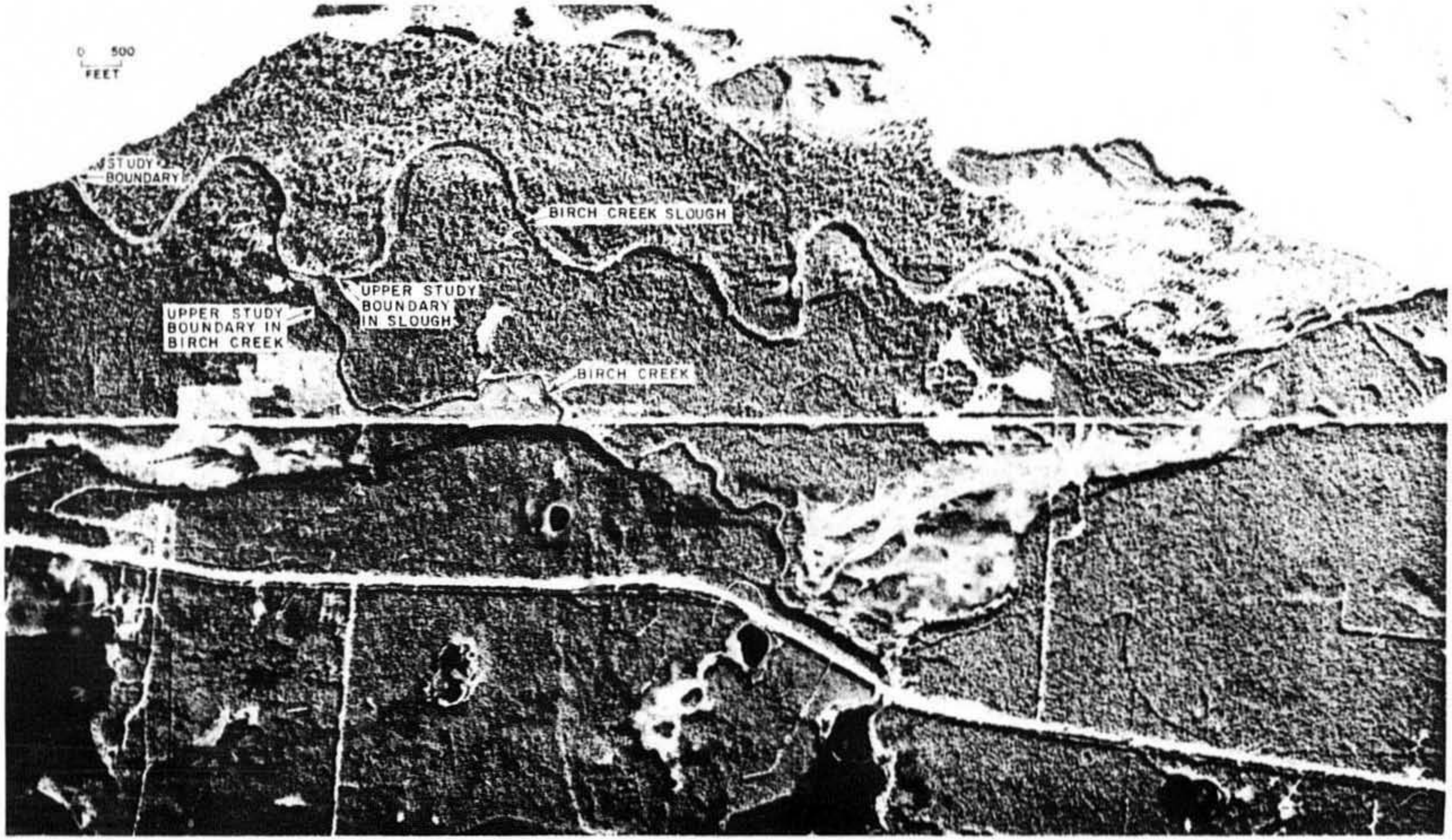


Appendix Plate E-7. August 1982 photograph of Lane Creek mouth and Slough 8 (RM 113.6). The surface area measurements reported are for the slough between its mouth (see inset) and the upper boundary shown.

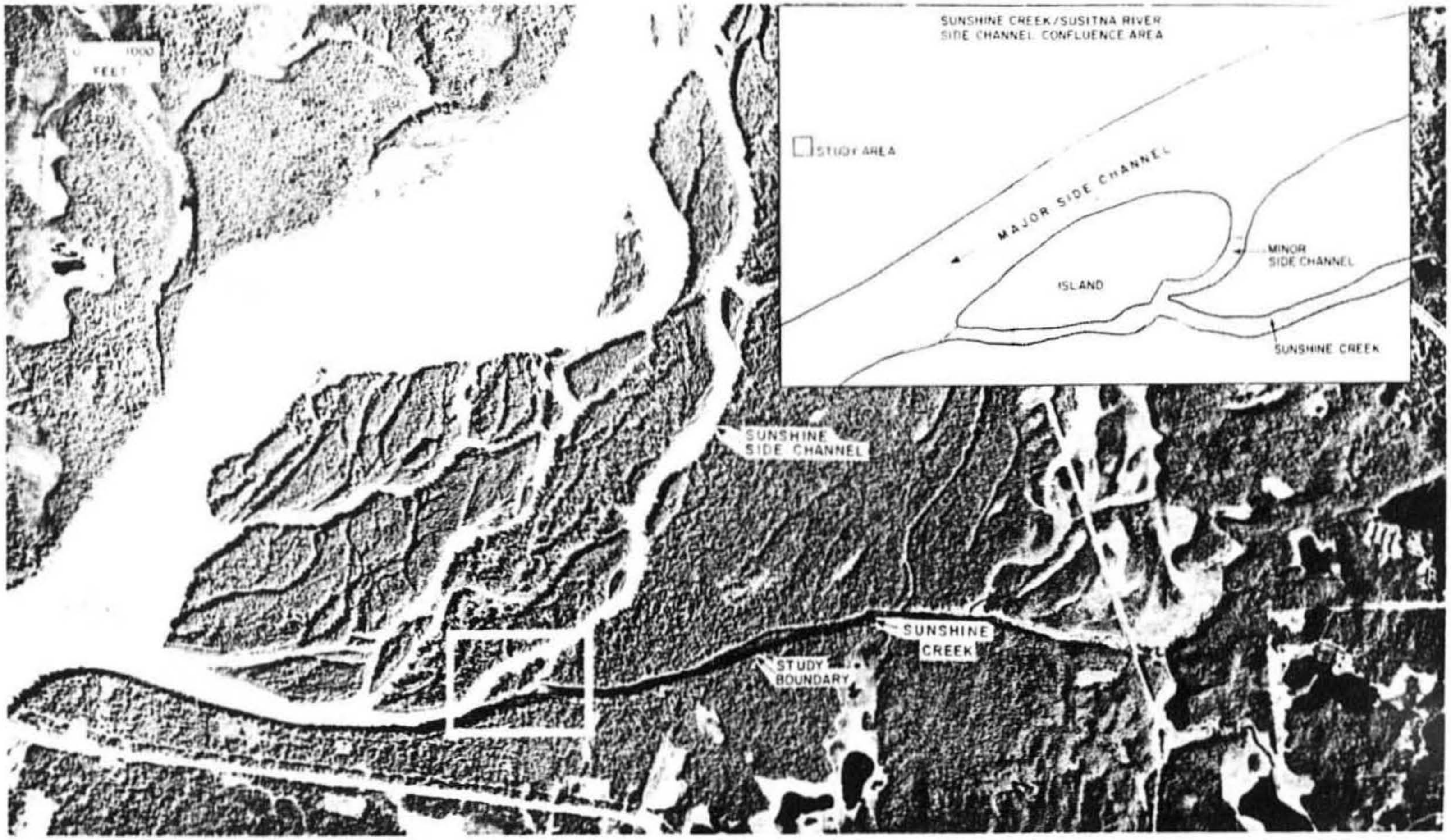


Appendix Plate E-8. May 1982 photograph of Slough 6A (RM 112.3). The surface area measurements reported are for the slough between the study boundaries shown.

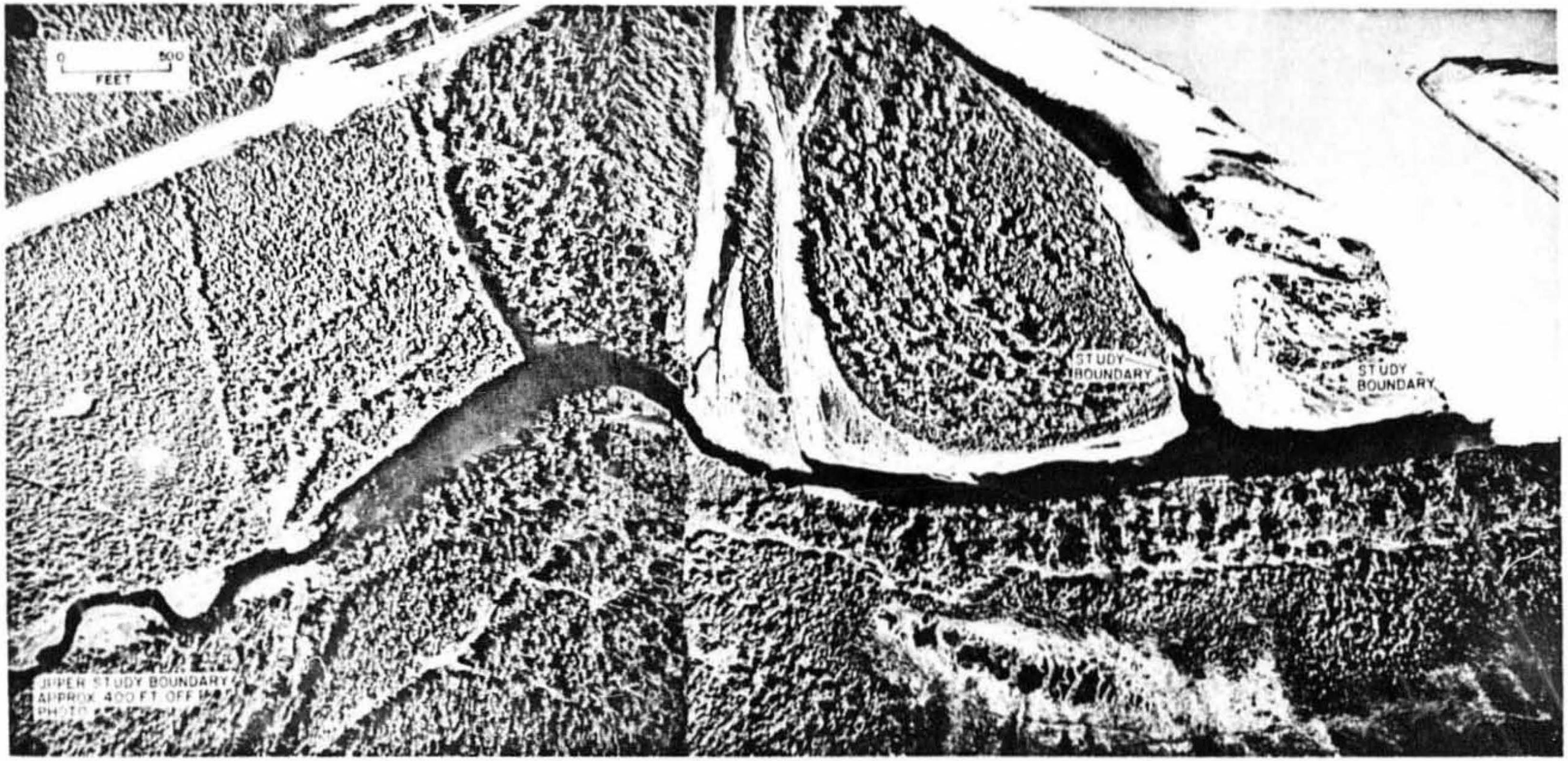
Appendix Plate E-9. May 1982 photograph of Whiskers Creek and Slough (RM 101.2). The surface area measurements reported are for the creek and slough between the study boundaries shown.



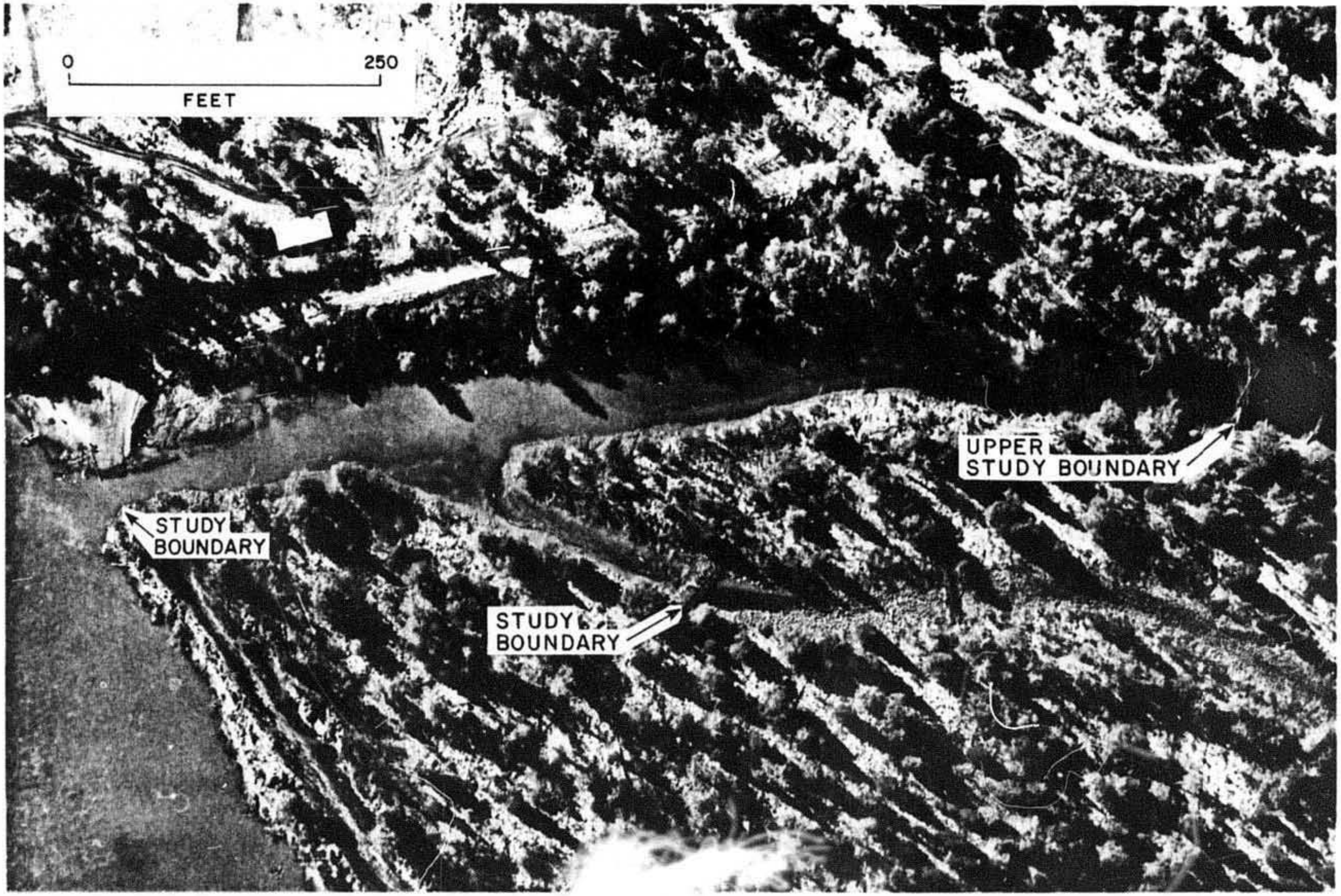
Appendix Plate E-10. August 1980 photograph of Birch Creek and Slough (RM 88.4). The surface area measurements reported are for the creek and slough between the study boundaries shown.



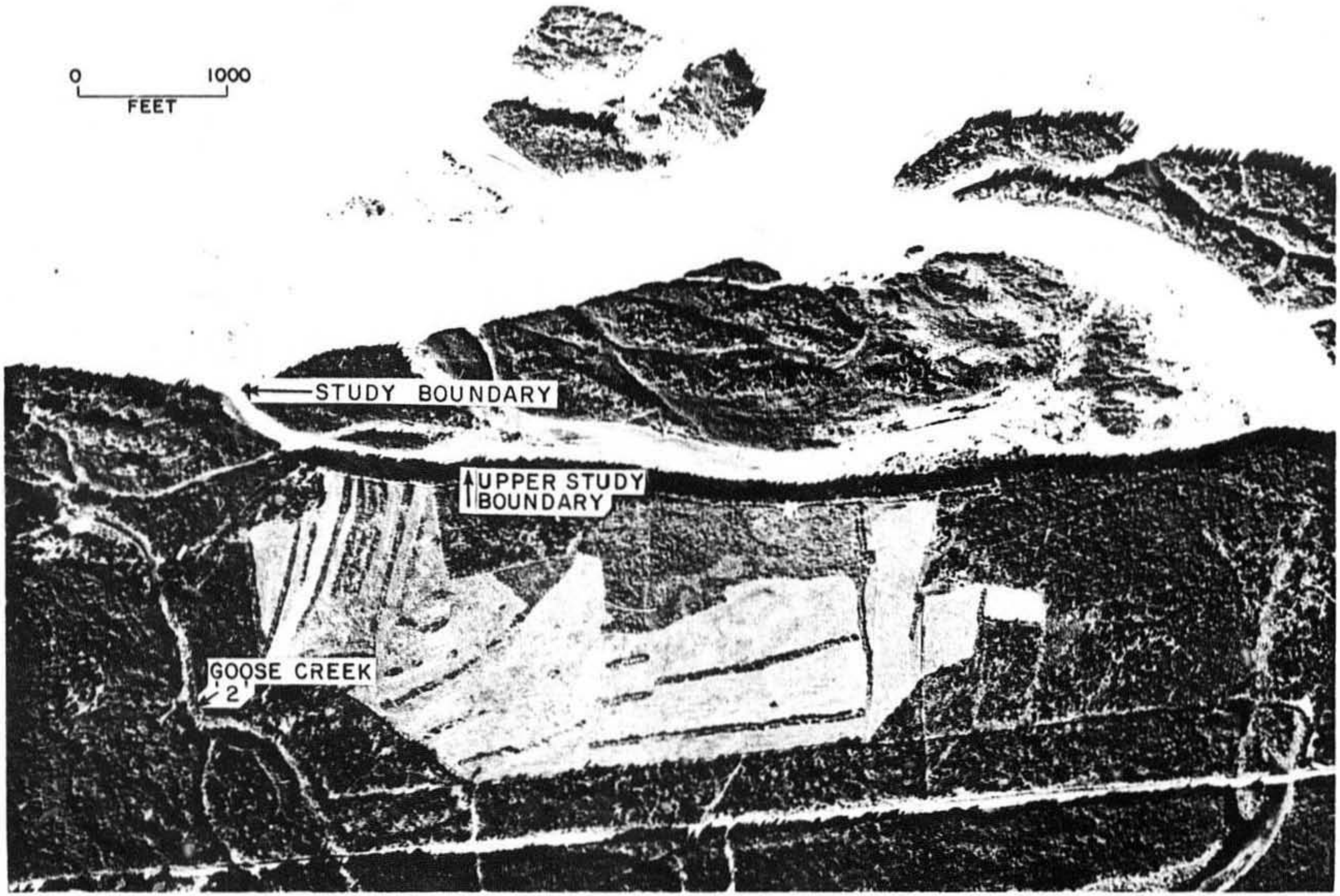
Appendix Plate E-11. August 1980 photograph of Sunshine Creek and Side Channel (RM 85.7). The surface area measurements reported are for the creek and slough areas shown in the inset and the creek above to the study boundary shown.



Appendix Plate E-12. August 1982 photograph of Rabideux Creek and Slough (RM 83.1). The surface area measurements reported are for the site between the study boundaries shown and a point on the creek about 400 ft. off the photograph.



Appendix Plate E-13. May 1982 photograph of Whitefish Slough (RM 78.7). The surface area measurements reported are for the slough between the study boundaries shown.



Appendix Plate E-14. August 1980 photograph of Goose Creek 2 and Side Channel (RM 73.1). The surface area measurements reported are for the slough between the study boundaries shown.

APPENDIX F

Influence of Habitat Parameters on Distribution and Relative Abundance of Juvenile Salmon and Resident Species.

APPENDIX F

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INTRODUCTION

The physical and chemical parameters of the Susitna River such as discharge, surface area, water velocity and depth, temperature, and water quality have wide ranging spatial and temporal variations. Spatial variations range from micro-habitat (on the order of a few feet), to macro-habitat (such as tributary mouths or sloughs), to entire river segments. Temporal variations occur on a scale ranging from daily, to annual, to multi-year cycles. Fish and other organisms respond to these spatial and temporal variations and this response is reflected in the distribution and relative abundance of each species. The proposed hydroelectric project could create physical-chemical conditions which are outside the limits of natural variation with regard to timing, magnitude, or both. This appendix presents an analysis of the cause-effect relationships observed between natural variations in physical and chemical conditions and the distribution and abundance of fish during the 1982 open water season. An understanding of these relationships will be useful in predicting the effect of the proposed project on fish populations.

The emphasis of this appendix is on the relationship between mainstem discharge and juvenile salmon distribution and abundance, although other species and variables are also discussed. Measuring the changes in available juvenile salmon habitat in response to changing Susitna River discharge presents substantial difficulties. Although much research has been conducted elsewhere using hydraulic models to predict the availability of habitats over incrementally varying discharges

(Bovee 1982), these studies have not been directed towards large and diverse glacial systems such as the Susitna River.

Observations made during the 1981 studies indicated the problems associated with evaluating juvenile salmon habitat of the Susitna River on a detailed basis and led to a hypothesis regarding the factors affecting juvenile salmon distribution and abundance at an intermediate level of resolution. The hypothesis is that juvenile salmon distribution and abundance at the important summer rearing areas (sloughs and tributary mouths) are controlled by the hydraulic conditions at these areas which are in turn controlled by variations in mainstem discharge. The 1982 field study plan focused on those factors which were obviously influenced by mainstem discharge.

Central to this approach was the thesis that several sites would have to be examined to adequately address the natural variability among habitat types used by the majority of each species. This decision prevented the quantification of micro-habitat conditions within each of the study sites. To monitor the changes in physical habitat with changing mainstem discharge without an intensive data collection effort, we developed a system to classify the habitat conditions present at a study site into nine possible habitat zones. The surface areas of the zones were measured under the variable flow conditions of the mainstem Susitna during the open water season. Physical and chemical habitat variables of each zone and the distribution and relative abundance of fish among the zones were also measured. Changes in micro-habitat within the zones as a function of discharge were not evaluated during the 1982 study.

An estimate of how juvenile salmon habitat changes with variations in mainstem discharge was developed by combining the catch variations between zones with the changes in the surface area of the zones. The resulting habitat index is plotted as a function of discharge. This work provides a logical step in the quantitative analysis of the available habitats over an incremental range of mainstem Susitna River discharges.

METHODS

Data for this appendix were drawn from the 1982 open-water studies at the 17 Designated Fish Habitat (DFH) sites described in Volume 3 (Section 2.1.3) and Volume 4 (Section 2.1.3.1 of Part I and Section 2.2 and 2.3.2 of Part II) of the Basic Data Report (ADF&G 1983a, ADF&G 1983b). The sites included several different major habitat types located from Goose Creek (RM 73.1) to Portage Creek (RM 148.8). Two reaches were defined - the upper reach included twelve sites above the Chulitna River confluence (RM 98.5) and the lower reach included five sites below this point. These 17 sites were sampled once every two weeks during June, July, August, and September. Each recognizable habitat type at a site was categorized as one of nine possible habitat zones. These habitat zones are defined in Volume 4, Part II, Section 2.2 of ADF&G (1983b) - a summary table is included at the end of this appendix. Criteria used in delineating habitat zones included water source, water velocity, and mainstem backwater influence. Sampling at each site was standardized by zone as much as possible to minimize sampling biases.

Three steps are followed in this appendix. First, the effect of sampling site, sampling period, and habitat zone within a site on the catch per unit effort of each species of fish and on each habitat variable is examined. Inherent in this step are tests to determine if any differences among sites, periods, or zones are statistically significant. Next, the relationships between catch per unit effort for a particular species and the habitat variables are examined. Finally, the effects of variations in mainstem discharge on habitat are investigated. This is done by deriving a quality index for each habitat zone and then multiplying the quality index by the surface area of that zone which was present at a particular level of discharge to obtain a habitat index. Mainstem discharge is treated in this separate analysis because of the likelihood that it is and would be the dominating environmental factor in controlling other habitat variables and fish distribution and abundance in both natural and post-project conditions.

Assumptions

A word model of the factors affecting juvenile salmon catch within a zone can be constructed as follows:

Catch = f (abundance, sampling effort, gear efficiency, and fish catchability) where:

Abundance = f (local habitat suitability, time of season, success of previous fall's spawning, percent incubation survival, proximity to spawning grounds)

where:

Local habitat suitability = f (temperature, water chemistry, water velocity, depth, substrate, turbidity, cover, food)

Some of these parameters can be quantitatively evaluated, while others can only be subjectively evaluated. For others, we have no data.

During data collection and subsequent analysis, we have attempted to eliminate the variables sampling effort, gear efficiency, and fish catchability so that catch reflects abundance. The location of the site integrates such factors as proximity to spawning grounds, success of previous fall spawning, and incubation survival. Local habitat suitability is integrated by hydraulic zone. Therefore, we can simplify the model to:

Catch = f (abundance) = f (time of season, site, and habitat zone within sampling site).

Each species of fish, at each site during any particular sampling period, was assumed to have a choice of habitat types available at a site and presumably would be found in greatest abundance in that habitat type which was most suitable to them.

Spatial and Temporal Variation in Habitat Variables and in Relative Abundance of Fish.

The three variables that cause variation in catch data are sampling site, habitat zone within sampling site, and sampling period. Analysis by sampling site and habitat zone address spatial variation, and sampling period addresses seasonal variation (during the open water season). Sampling site takes into account macro-habitat variations including differences between reaches and differences between major habitat types such as tributary mouths versus upland sloughs. Habitat zone addresses a more narrowly defined habitat and considers the effect of habitat variables such as water temperature and velocity within a site. The resolution of habitat zone falls somewhere in between macro-habitat and micro-habitat (such as would be obtained by point-specific measurements). The emphasis of this report is on differences of habitat variables and fish abundance among zones within a site. Seasonal variation is examined briefly. Differences among sites are analyzed in Appendix G of this report.

The catch and habitat data were sorted and pooled in various ways (as outlined in the results section). One way in which the habitat zones were pooled was by aggregate zone types. Three different criteria were used to aggregate habitat zones - (1) by the presence or absence of a mainstem backwater zone, (2) by water source, and (3) by water velocity. Details describing these aggregate zones were presented in Section 2.2, Part II, Volume 4 of the Basic Data Report (ADF&G 1983b). A summary follows:

	Criterion	Aggregate Zone	Description
1.	presence of mainstem backwater area	H-I	tributary or slough above mainstem backwater area
		H-II	mainstem backwater area
		H-III	mixing zone below mainstem backwater area
2.	water source	W-I	tributary water
		W-II	mainstem water
		W-III	mixed water
3.	water velocity	V-I	fast water
		V-II	slack water

The assumption with each of the categories is that, if the aggregating criterion is important, the habitat quality of all the individual habitat zones in each aggregate zone (e.g., H-I zone) is equal or, stated in another way, differences in habitat quality within an aggregate zone are insignificant when compared with differences among aggregate zones.

The effect of zone on variations in habitat variables and in catch data was examined by t tests and by chi-square tests (Snedecor and Cochran, 1967). The t test was used to compare the pooled means (all sites, all sampling periods) of selected habitat variables by aggregate hydraulic zone.

The t test was also used to test for significant differences between aggregate hydraulic zones for catch/effort data for juvenile chinook salmon, juvenile coho salmon, rainbow trout, and burbot. Catch/minnow trap data were used for chinook and coho and catch/trotline data were used for rainbow and burbot because these sampling techniques were effective for these species and because we were able to consistently use minnow traps and trotlines in the different zones sampled. The minnow trap data have the further advantage of five to ten replicates per zone.

It was not possible to consistently use sampling techniques such as beach seining and backpack electrofishing, which were effective at capturing other species, in all of the zones sampled. Therefore, a chi-square test was used to determine if there were associations of juvenile chum salmon, juvenile sockeye salmon, round whitefish, Arctic grayling, longnose sucker, and slimy sculpin with the three different aggregate zones. Presence/absence data were compiled only from beach seining or backpack electrofishing effort. Only those zones which had such effort were included in the analysis. Sampling effort over the entire open water season was pooled to increase sample size.

Correlation of Fish Abundance and Habitat Variables

Methods for examining the relationship of fish abundance with habitat zone were presented in the previous section. In this section, methods used to examine relationships between fish abundance and individual habitat variables, such as water temperature, are given. Caution should be used in interpreting such an analysis because there are several habitat variables that have an interactive effect on fish. For example, a low level of dissolved oxygen can be more detrimental at a high temperature than at a low temperature. The objective of this section was to detect any single variables that might have a strong effect on the distribution and abundance of a particular species.

A correlation matrix was calculated for four species of fish (juvenile chinook salmon, juvenile coho salmon, rainbow trout, and burbot) and three habitat variables. The habitat variables water temperature, turbidity, and velocity were chosen because they are among the most important of those variables measured in affecting fish distribution.

The matrix was compiled for these seven variables by individual habitat zone. Two zones (zones 5 and 8) were deleted from the analysis because of low sample size. All sites and all sampling periods were pooled for each zone prior to calculating the correlations.

Relationship of a Habitat Index and Mainstem Discharge

The value of a habitat type to a population of fish is a function both of the quality of the habitat and the amount available. In this section, we derive a quality index for each habitat zone and multiply the index by the surface area of that habitat zone available within the study boundaries at incremental levels of mainstem discharge.

The raw catch data from the 17 fish habitat sites used to determine quality indices are contained in Appendices G and H of Volume 4 of the

Basic Data Report (ADF&G 1983b). The surface area data for the sites are for the study boundaries as defined in Appendix E of the present report.

First, the nine separate habitat zones were aggregated into the three types of hydraulic zones. The H-I aggregate hydraulic zone consisted of all habitat zones which occurred above the influence of mainstem backwater areas. The H-II aggregate hydraulic zone included all habitat zones which were backed up by a hydraulic barrier created by mainstem stage at the mouth of tributaries, sloughs, or side channels. The H-III aggregate hydraulic zone was the mainstem mixing area, just below the H-II zone. The hydraulic zone category, rather than the water source or water velocity categories, was used to aggregate the individual habitat zones because of its utility in relating habitat change to mainstem discharge.

A catch ratio (CR) was calculated for each hydraulic zone at each site during each sampling period. This was done for each species. The ratio took the form:

$$CR_i = \frac{(CPUE)_i}{\sum_{\substack{j \geq 1 \\ j \neq i}}^{n} (CPUE)_j \;/n-1}$$

where:

CPUE = catch per unit effort
n = total number of zones sampled
i = zone number of the zone in question
j = zone numbers of all other zones

This is simply the ratio of the CPUE of the zone in question to the mean of the CPUEs of all other zones. The ratio was calculated in this manner in accordance with the original assumption - each species will concentrate in the zone that has the most desirable conditions. This ratio was used because it is independent of the absolute numbers of fish at the site; if a particular zone is preferred, it could have the same ratio whether there were 50 fish or 500 fish present at a site. A further advantage of the ratio is that it is independent of the number of zones sampled, which ranged from two to four. All cases where less than ten fish of any one species were captured at a site during a particular sampling period were dropped from the data set because of the small sample size. This was done to eliminate those instances where a few fish might chance to be in an uncommon zone.

The zone in question was compared to the mean of all other zones rather than to the mean of all zones at the site for two reasons. First, with this method, the possible values of CR will range from zero to infinity. Had the mean of all zones at the site been used as the denominator, then CR would range from zero to some unknown and non-constant number, thus complicating further mathematical manipulation. Secondly, had the site mean been used, CR would be affected by the number of zones sampled for those cases where all the fish at a site were caught in one zone, a situation which was not uncommon. It was desirable to keep CR independent of the number of zones sampled.

Only minnow trap data were used to compile the CPUE for juvenile chinook and coho salmon. The CPUE was defined as catch/trap in a three hour set. Minnow traps were most effective in collecting these two species and were the most reproducible unit of gear between zones. The CPUE for juvenile sockeye and chum salmon were compiled from beach seining and backpack electrofishing data, which were the two methods most effective in capturing these species. Because of the difficulty in replicating effort among zones with these types of gear, a code was established using catch data:

Number Captured	Code
0	0
1-10	1
11-25	2
more than 25	3

The catch ratio (CR) for sockeye and chum salmon was calculated based on these codes. To be included in the analysis, at least two zones at any one site and sampling period had to have been sampled by the gear previously mentioned.

The catch ratio can vary from zero, if no fish were captured in the zone in question, to infinity, if all the fish at the site were captured in this zone. In order to transform this range into the range zero to one, which was desirable from the perspective of a habitat quality index, we derived the following equation:

$$ZQI_i = 1 - \frac{1}{CR_i + 1} = \frac{CR_i}{CR_i + 1}$$

where: ZQI_i = zone quality index for zone i

CR_i = catch ratio for zone i

This asymptotic equation transforms catch ratios to a value ranging from zero to one. The ZQI approaches zero for small values of CR and one for large values of CR. A value of zero means that none of the fish captured at the site were caught in the zone in question and a value of one means that all the fish were caught in this zone. A value of 0.5 means that the catch rate in this zone was equal to the average catch rate of all other zones. Further, if the catch/trap in zone X is twice as great as the catch/trap in zone Y, then the ZQI for zone X is twice as high as that for zone Y. This zone quality index is considered to be independent of mainstem discharge and sampling site surface area.

This zone quality index is unlike the quality index commonly used in habitat suitability index (HSI) models in that it is a relative measure only - one zone relative to other zones. For example, if no fish of a certain species were captured at a site, an HSI of zero would be indicated; in this case, a ZQI would not be calculated because there is no sample to compare one zone against another. The only way to obtain a ZQI of zero are the cases where the species was captured at the site, but none were captured in the zone in question. The zone quality index, like the habitat suitability index, is compiled from catch data rather than from habitat data. However, the ZQI is based on relative abundance of fish among zones, while the HSI is based on frequency distribution of fish compiled from data collected at the micro-habitat level.

ZQI's were calculated for each species, each site, each aggregate hydraulic zone, and each period which met the criteria listed previously. For the present analysis, seasonal ZQI's for each zone at each site were calculated by taking the mean of all sampling periods for that zone at that site. This was performed after examination of the ratios among periods showed that there were no obvious trends over the course of the season. The exception is chum salmon, which were more prevalent in tributaries early in the season than they were later on. The assumption is that the value for a species of each of the zones relative to the other zones was approximately constant over the period June through September. These calculations were done for each species for each of the three aggregate hydraulic zones.

Having obtained a zone quality index (the mean ZQI of all sampling periods) for each zone for each species, the next procedure was to multiply these ZQI's by the total surface area of that zone which was present at a particular level of mainstem discharge. The surface area data used were those which were calculated for discharge increments of 2,500 cfs (upper reach) and 5,000 cfs (lower reach). The surface area values for the aggregate zone H-II were presented in Sections 3.1.3.1 and 4.1.3.1 of Volume 4, Part I, of the Basic Data Report (ADF&G 1983b). Values for the total wetted surface area are included in Appendix E of the present report. Values for the surface area of zone H-I was similarly obtained from the digitized maps. The tributary sites (Portage Creek, Indian River,and Fourth of July Creek) were excluded from the analysis at this point because none of them had a mainstem backwater (aggregate zone H-II) area.

The product of zone quality index times surface area provides a habitat index (HI) for that zone. A site habitat index was calculated according to the following equation:

$$HI = \sum_{i=1}^{n} (ZQI_i \times SA_i)$$

where:

ZQI_i = zone quality index for zone i

SA_i = surface area of zone i

n = number of zones

For the present analysis, this equation took the form:

$$HI = (ZQI_{H-I} \times SA_{H-I}) + (ZQI_{H-II} \times SA_{H-II})$$

where:

H-I = aggregate hydraulic zone H-I

H-II = aggregate hydraulic zone H-II

The site habitat index here is the sum of the zone H-I habitat index and the zone H-II habitat index. The surface area of the aggregate H-III zone was not included because it is assumed to be a constant - this type of habitat was always available to fish, regardless of the level of mainstem discharge observed during 1982, and was therefore not a factor. Zone and site habitat indices are a product of habitat quality and habitat quantity and can be plotted as a function of mainstem discharge.

RESULTS AND DISCUSSION

Spatial and Temporal Variation in Habitat Variables and in Relative Abundance of Fish

Habitat variables

Appendix Table F-1 shows the mean values for the habitat variables that were measured in each of the nine habitat zones. The mainstem backwater zones (zones 2, 6, 7, and 8) were generally warmer than the other zones. There did not appear to be any differences in dissolved oxygen levels among zones that would matter to fish except that the level in zone 9 (morphological pools) was somewhat low. The median pH of tributary water (zones 1 and 2) was lower than that of all other zones, except zone 9. As expected for this time of the year, the turbidity of tributary zones was relatively low compared to the slough and mainstem zones. Zone 9 had a low turbidity because this zone generally occurred within tributaries.

Data from these individual habitat zones were pooled into the aggregate zones (Appendix Table F-2). Slack water areas (zones H-II and V-II) were warmer than areas having a faster water velocity. This is illustrated for aggregate hydraulic zones by sampling period in Appendix Figure F-1. Temperature differences were greater during the first part of the season than they were after cooling began in early September. Slack water zones also had a lower mean dissolved oxygen level than

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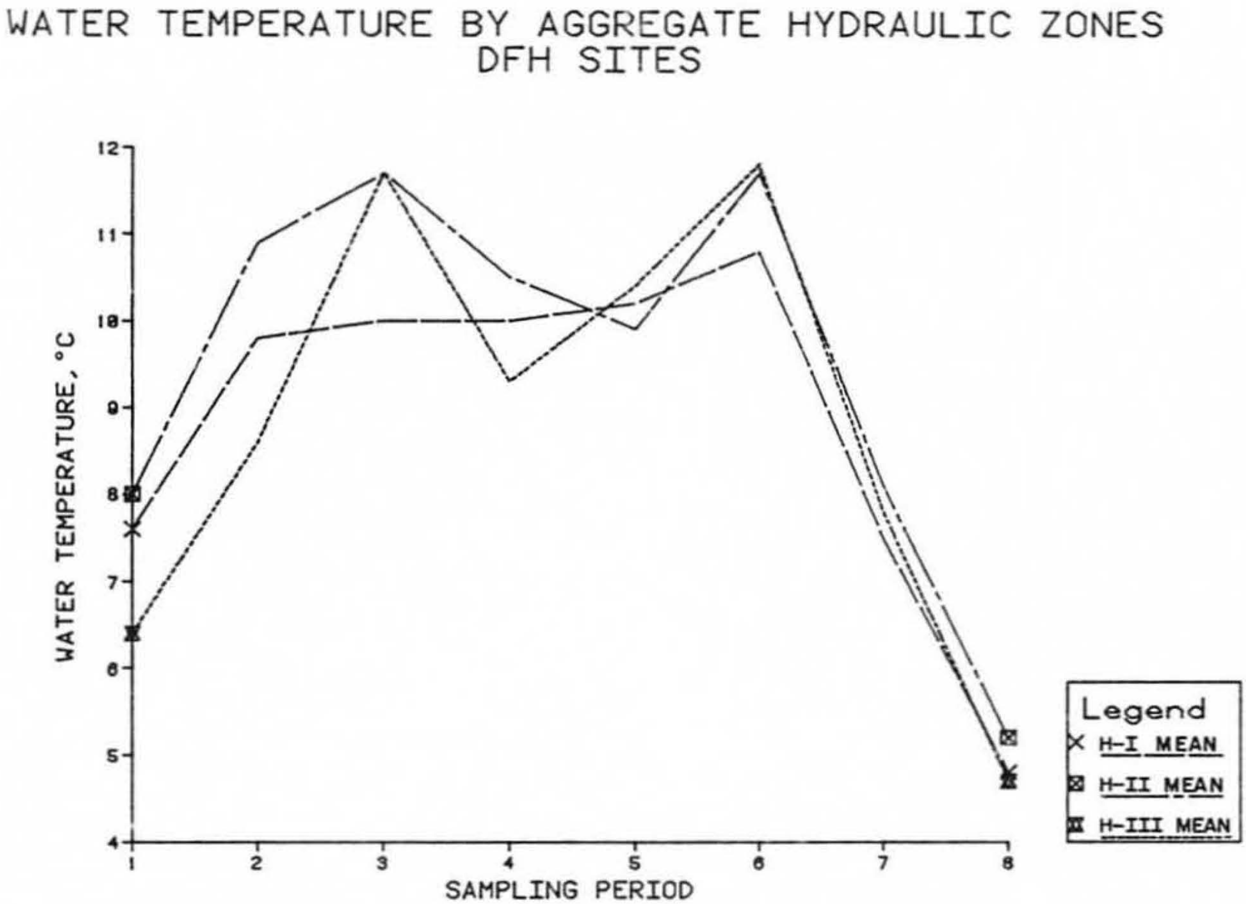
Appendix Table F-1 Matrix table of mean habitat conditions by zone. All sites, all periods, June through September, 1982. Standard error in parentheses.

Zone	Mean Water Temp(°C)	Mean DO (mg/l)	Median pH	Mean Conductivity (umhos/cm)	Mean Turbidity (NTU)	Mean Water Velocity (ft/sec)
1	8.8(0.3)	10.9(0.2)	6.9	81(7)	5(1)	1.4(0.1)
2	9.5(0.4)	10.3(0.2)	6.8	105(8)	6(1)	0.1(0.0)
3	8.7(0.3)	11.0(0.2)	7.1	98(4)	45(4)	1.2(0.1)
4	9.0(0.4)	11.2(0.4)	7.3	101(6)	36(8)	1.1(0.2)
5	6.6*	12.3*	7.0*	75*	17*	1.4*
6	9.2(0.5)	10.7(0.3)	7.0	114(8)	52(12)	0.3(0.1)
7	10.5(0.6)	10.9(0.4)	7.0	62(7)	36(9)	0.5(0.1)
8	15.5*	9.1*	7.4*	82*	85*	--*
9	8.7(0.6)	8.9(0.5)	6.6	78(9)	12(4)	0.1(0.1)

* = sample size ≤ 3

Appendix Table F-2 Matrix table of mean habitat conditions by aggregate zone. All sites, all periods, June through September, 1982. Standard error in parentheses.

Aggregate Zone	Mean Water Temp(°C)	Mean DO (mg/l)	Median pH	Mean Conductivity (umhos/cm)	Mean Turbidity (NTU)	Mean Water Velocity (ft/sec)
H-I	8.8(0.3)	10.7(0.1)	6.8	83(5)	10(2)	1.2(0.1)
H-II	9.7(0.3)	10.4(0.2)	6.8	98(6)	18(3)	0.2(0.0)
H-III	8.7(0.3)	11.0(0.2)	7.1	98(4)	45(4)	1.2(0.1)
W-I	9.1(0.3)	10.7(0.1)	6.9	91(5)	5(1)	0.9(0.1)
W-II	9.3(0.3)	10.9(0.2)	7.2	106(5)	44(7)	0.7(0.1)
W-III	9.0(0.3)	11.0(0.2)	7.0	92(4)	43(4)	1.1(0.1)
V-I	8.8(0.2)	11.0(0.1)	7.0	90(4)	26(3)	1.3(0.1)
V-II	9.5(0.3)	10.2(0.2)	6.8	95(5)	17(3)	0.2(0.0)



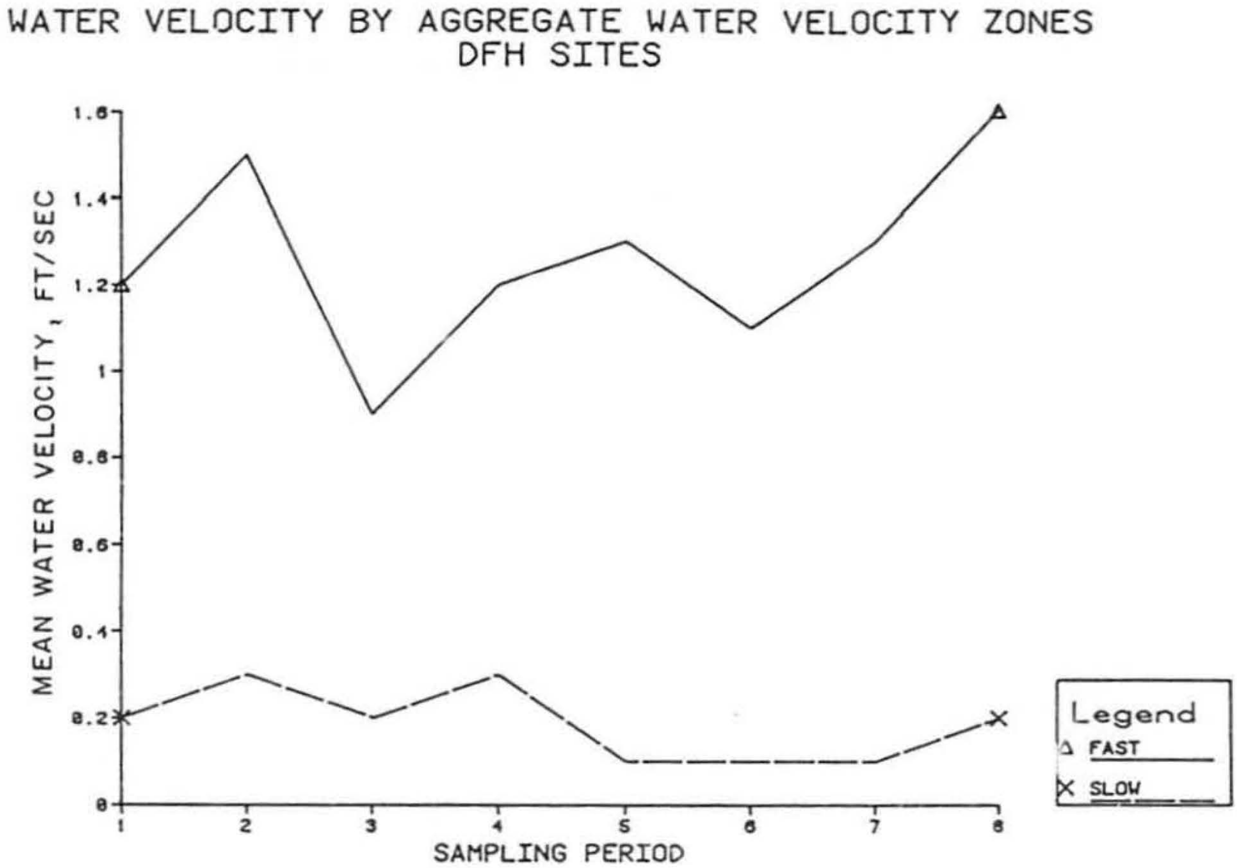
Appendix Figure F-1. Mean water temperature of aggregate hydraulic zones by sampling period, June through September, 1982.

other zones. Mainstem water (zone W-II) had a higher mean conductivity, mean turbidity, and median pH than tributary water (zone W-I). The mainstem backwater zone (H-II) and the low velocity zone (V-II), as would be expected by definition, had lower mean water velocities than the other zones (Appendix Figure F-2).

Data from all 17 sites and all 8 sampling periods for each of the three aggregate hydraulic zone types were pooled and the three variables water temperature, water velocity, and turbidity were tested for statistical differences using a t test. These three variables were chosen because they are the most important of the measured variables in influencing fish distribution. All differences between mean values, with one exception, were statistically significant as shown in the following table:

Pair	Water Temperature	Water Velocity	Turbidity
H-I/H-II	$p < 0.05$	$p < 0.01$	$p < 0.05$
H-I/H-III	NS	no difference	$p < 0.01$
H-II/H-III	$p < 0.05$	$p < 0.01$	$p < 0.01$

Mean water temperatures of the H-I zone and the H-III zone were quite close; mean water velocities of these two zones were equal. Statistically significant differences among the nine individual habitat zones could exist while differences among aggregate zones may not be statistically significant. This can occur because habitat zones which were hydraulically similar, but perhaps different in other habitat variables, were grouped to obtain aggregate hydraulic zones. This indicates whether the aggregating criterion is important.



Appendix Figure F-2. Mean water velocity of aggregate velocity zones by sampling period, June through September, 1982.

The above analysis establishes the uniqueness of the hydraulic zones with regard to a composite of these three habitat variables. Therefore, it is valid to test variations in catch against habitat variations among these zones. Because the aggregate hydraulic zone category can be used to illustrate the effects of changing mainstem flows, further analysis of habitat availability uses this category rather than the aggregate water source or water velocity categories.

Relative abundance of fish

Relative abundance, expressed as the mean of catch per unit effort data for four species of fish for all sites and sampling periods pooled is presented by habitat zone in Appendix Tables F-3 to F-6.

The highest catch rates for chinook salmon juveniles occurred in habitat zones 1 and 2 (tributary) and 7 (mainstem backwater zone below tributary mouth). Juvenile coho salmon catch rates were highest in the tributary habitat zones.

Rainbow trout were more broadly distributed among the habitat zones than the other species analyzed, but showed a preference for clear water tributary zones (zones 1 and 2) over turbid slough or mainstem zones. Burbot were captured most frequently in the turbid mainstem mixing zone (zone 3), followed by turbid slough zones.

These same data were grouped by aggregate zone, using the three separate criteria - hydraulic condition, water source, water velocity. Using a

Appendix Table F-3. Range and mean of chinook salmon juvenile CPUE (catch per minnow trap) by zone at DFH sites on the Susitna River below Devil Canyon, all periods, June through September, 1982.

Zone	Min CPUE	Max CPUE	Mean CPUE	No. of sites
1	0.0	6.9	0.4	15
2	0.0	5.8	0.2	13
3	0.0	1.0	0.1	17
4	0.0	0.2	0.0	7
5	0.0	0.0	0.0	2
6	0.0	0.7	0.1	5
7	0.0	13.0	0.9	6
8	0.0	0.0	0.0	1
9	0.0	0.4	0.0	5

Aggregate Zone	Mean CPUE	No. of Sites
Hydraulic		
H-I	0.3	15
H-II	0.4	14
H-III	0.1	17
Water Source		
W-I	0.3	17
W-II	0.1	8
W-III	0.2	17
Water Velocity		
V-I	0.2	17
V-II	0.3	15

Appendix Table F-4. Range and mean of coho salmon juvenile CPUE (catch per minnow trap) by zone at DFH sites on the Susitna River below Devil Canyon, all periods, June through September, 1982.

Zone	Min CPUE	Max CPUE	Mean CPUE	No. of Sites
1	0.0	25.6	1.2	15
2	0.0	18.1	0.9	13
3	0.0	1.4	0.0	17
4	0.0	0.3	0.0	7
5	0.0	1.8	0.9	2
6	0.0	0.7	0.1	5
7	0.0	1.7	0.3	6
8	0.0	0.0	0.0	1
9	0.0	1.9	0.1	5

Aggregate Zone	Mean CPUE	No. of Sites
Hydraulic		
H-I	1.2	15
H-II	0.8	14
H-III	0.0	17
Water Source		
W-I	1.0	17
W-II	0.0	8
W-III	0.1	17
Water Velocity		
V-I	0.6	17
V-II	0.8	15

Appendix Table F-5. Range and mean of rainbow trout CPUE (catch per trotline) by zone at DFH sites on the Susitna River below Devil Canyon, all periods, June through September, 1982.

Zone	Min CPUE	Max CPUE	Mean CPUE	No. of Sites
1	0.0	2.0	0.2	15
2	0.0	4.0	0.3	13
3	0.0	5.0	0.2	17
4	0.0	1.0	0.1	7
5	0.0	0.0	0.0	2
6	0.0	0.0	0.0	5
7	0.0	2.0	0.2	5
8	0.0	0.0	0.0	1
9	0.0	1.0	0.1	4

Aggregate Zone	Mean CPUE	No. of Sites
Hydraulic		
H-I	0.2	15
H-II	0.3	14
H-III	0.2	17
Water Source		
W-I	0.3	17
W-II	0.1	8
W-III	0.2	17
Water Velocity		
V-I	0.2	17
V-II	0.3	14

Appendix Table F-6. Range and mean of burbot CPUE (catch per trotline) by zone at DFH sites on the Susitna River below Devil Canyon, all periods, June through September, 1982.

Zone	Min CPUE	Max CPUE	Mean CPUE	No. of Sites
1	0.0	2.0	0.0	15
2	0.0	5.0	0.3	13
3	0.0	4.0	0.7	17
4	0.0	2.0	0.6	7
5	0.0	0.0	0.0	2
6	0.0	2.0	0.6	5
7	0.0	2.0	0.5	5
8	0.0	0.0	0.0	1
9	0.0	2.0	0.3	4

Aggregate Zone	Mean CPUE	No. of Sites
Hydraulic		
H-I	0.1	15
H-II	0.2	14
H-III	0.7	17
Water Source		
W-I	0.1	17
W-II	0.6	8
W-III	0.6	17
Water Velocity		
V-I	0.5	17
V-II	0.2	14

t test, the mean catch rate of all sites for each pair of aggregate hydraulic zones was tested for significant differences for each of the four species.

The mean catch rate for juvenile chinook salmon was approximately equally balanced between zone H-I and zone H-II; the mean rate for zone H-III was significantly ($p < 0.05$) lower than zone H-II (Appendix Table F-3). Chinook juveniles showed a slight preference for tributary water (W-I) over slough or mainstem water. There was not as strong a preference demonstrated for water velocity aggregates (V-I versus V-II).

Juvenile coho salmon preferred the area above the mainstem backwater zone over the backwater zone itself (Appendix Table F-4). The mean catch rate in the mainstem mixing zone (H-III) was significantly ($p < 0.05$) lower than zone H-I. Coho juveniles strongly preferred tributary water (W-I) over slough or mainstem water (W-II or W-III).

Rainbow trout did not show any strong separation by the aggregate zone categories, but they appeared to least prefer mainstem water (zone W-II) (Appendix Table F-5). Burbot clearly demonstrated a preference for the mainstem mixing zone (H-III), mainstem water (W-II), and higher velocity water (V-I) (Appendix Table F-6). The mean catch rate in zone H-III was significantly ($p < 0.01$) higher than that of zones H-I or H-II.

Results of the chi-square tests performed with the other species are shown in Appendix Tables F-7 to F-10. The distribution of juvenile

Appendix Table F-7. Chi-square tests of association between juvenile salmon presence/absence and aggregate zones at DFH sites, all periods, June through September, 1982.

Aggregate Zone Category	Juvenile Sockeye Salmon Chi-square	Juvenile Sockeye Salmon Probability	Juvenile Chum Salmon Chi-square	Juvenile Chum Salmon Probability
Hydraulic zone df=2	18.9	$p < 0.01$	6.3	$p < 0.05$
Water source df=2	9.4	$p < 0.01$	4.5	NS
Velocity df=1	16.3	$p < 0.01$	3.5	NS

Appendix Table F-8. Ratios of observed to expected presence of juvenile sockeye and chum salmon in aggregate zones with significant differences in use.

Aggregate Zone Category	Juvenile Sockeye Salmon	Juvenile Chum Salmon
Hydraulic Zone		
I - Not Mainstem Backwater	0.80	0.96
II - Mainstem Backwater	1.58	1.34
III - Mainstem Mixing Zone	0.52	0.35
Water Source		
I - Tributary	1.11	--
II - Mainstem	1.66	--
III - Mixing	0.65	--
Velocity		
I - Fast	0.65	--
II - Slack	1.51	--

Appendix Table F-9. Chi-square tests of association between resident fish presence/absence and aggregate zones at DFH sites, all periods, June to September, 1982.

Aggregate Zone Category	Round Whitefish		Arctic Grayling		Longnose Sucker		Slimy Sculpin	
	χ^2	Prob.	χ^2	Prob.	χ^2	Prob.	χ^2	Prob.
Hydraulic	22.4	$p < 0.01$	25.2	$p < 0.01$	3.8	NS	0.7	NS
Water Source	25.5	$p < 0.01$	19.8	$p < 0.01$	14.6	$p < 0.01$	0.0	NS
Velocity	1.3	NS	11.6	$p < 0.01$	2.9	NS	0.6	NS

Appendix Table F-10. Ratios of observed to expected presence of resident fish by species in aggregate zones. Only those ratios from significant chi-square tests are presented.

Aggregate Zone Category	Round Whitefish	Arctic Grayling	Longnose Sucker
Hydraulic			
I - Not Mainstem Backwater	0.46	0.68	--
II - Mainstem Backwater	0.82	0.19	--
III - Mainstem Mixing Zone	1.74	2.24	--
Water Source			
I - Tributary	0.43	0.29	0.70
II - Mainstem	1.48	0.89	2.86
III - Mixing	1.58	1.95	0.80
Velocity			
I - Fast	--	1.51	--
II - Slack	--	0.25	--

sockeye salmon was significantly associated with aggregate zone type for all three zone groupings (Appendix Table F-7). Juvenile chum salmon showed a significant association with the aggregate hydraulic (H) zones, but no association with aggregate water source (W) zones or aggregate velocity (V) zones. Ratios of observed to expected presence for those associations that were found to be significant (Appendix Table F-8) indicate that both species preferred the mainstem backwater zone (zone H-II) over adjacent zones. Sockeye salmon juveniles showed a preference for slow water, originating from the mainstem.

The preference shown by juvenile sockeye salmon for the mainstem backwater zone, rather than the higher velocity areas above and below this zone, is probably related to the common use of lakes for rearing by this species. Chum salmon juveniles, which also were more likely to occur in the mainstem backwater zone than in other zones, did not show as strong an association as did sockeye. The tendency of sockeye salmon juveniles to be present in mainstem rather than tributary water was not always shared by chum salmon juveniles which were also captured in tributaries as they outmigrated from tributary spawning grounds.

Slimy sculpin showed no significant associations with any of the aggregate zones (Appendix Table F-9). In other words, the likelihood of capture for this species was equal in all of the zones. The distribution of Arctic grayling was significantly associated with particular zones within all three of the zone groupings. Water source was of importance to round whitefish and longnose sucker; hydraulic zone mattered to round whitefish. Ratios of observed to expected presence

(Appendix F-10) shows a preference of round whitefish and Arctic grayling at these sites for mixing water, rather than for pure tributary or mainstem water. Longnose sucker clearly preferred mainstem water. Arctic grayling also showed a preference for fast water over slack water.

Round whitefish and Arctic grayling were frequently captured in the mainstem just below the confluence of tributary mouths and were less commonly captured in sloughs or in tributaries just above the mouth. This distributional pattern is reflected in the observed association with a mixed water source with a relatively high velocity.

Correlation of Fish Abundance and Habitat Variables

Juvenile chinook salmon abundance showed a good correlation with water temperature, but not with turbidity or water velocity (Appendix Table F-11). The abundance of juvenile coho salmon did not show any relationship with temperature but was negatively related to turbidity. The capture rate for burbot was strongly correlated with turbidity. Rainbow trout capture rates did not exhibit significant correlations with any of the three habitat variables.

Turbidity was a strong factor influencing fish distributions in this study. Rearing coho salmon apparently avoided turbid water while burbot were captured almost exclusively in turbid areas. These preferences were probably related to differences in feeding behavior of the two species. Juvenile chinook salmon apparently were attracted to warm

Appendix Table F-11. Correlation matrix for four species of fish and three habitat variables by individual habitat zone (7 cases for each variable).

		TMP	TRB	VEL	CHN	COH	RBT	BRB
Temperature	(TMP)	1.00						
Turbidity	(TRB)	0.15	1.00					
Velocity	(VEL)	-0.35	0.11	1.00				
Juvenile Chinook	(CHN)	0.82*	-0.04	0.04	1.00			
Juvenile Coho	(COH)	0.07	-0.76*	0.14	0.33	1.00		
Rainbow Trout	(RBT)	0.27	-0.56	0.10	0.39	0.61	1.00	
Burbot	(BRB)	0.13	0.90*	-0.03	-0.19	-0.86*	-0.36	1.00

* = correlation significant at 95% level

water areas; none of the other three species showed such a tendency, although the sign was positive for all four species. Zone water velocity was not a factor for any of these species.

Relationship of a Habitat Index and Mainstem Discharge

Zone quality indices

Zone quality indices (ZQI) calculated for the aggregate hydraulic zones for four species of juvenile salmon for each of the two reaches are given in Appendix Table F-12. The value shown is the mean of the seasonal ZQI's of all the sampling sites in the reach where the data from at least one sampling period met the criteria explained in the methods section.

Chinook salmon apparently do not have strong preferences between the backwater areas (zone H-II) and the free-flowing areas above the backwater zone (zone H-I), as the mean ZQI's are fairly evenly balanced. There is a slight preference shown for zone H-I. Chinook also show more association with the mixing zone (zone H-III) below the backwater area than other juvenile salmon species. These results suggest that chinook juveniles are associated with broader ranges of habitat parameters than the other species. Similar results were obtained when examining chinook distribution among the major habitat types (tributary mouths, upland sloughs, and so on) in Appendix G.

Appendix Table F-12. Range and mean zone quality indices (ZQI) for aggregate hydraulic zones by reach by species, June through September, 1982. The means are the mean of the seasonal ZQI's for all the sites in the reach. The sample size (n) equals the number of sites included in calculating the mean.

	Zone H-I				Zone H-II				Zone H-III			
Species	Min	Max	Mean	n	Min	Max	Mean	n	Min	Max	Mean	n
ZQI-Lower reach												
Chinook	0.49	0.71	0.59	4	0.46	0.66	0.53	4	0.32	0.32	0.32	1
Coho	0.71	0.88	0.82	3	0.18	0.45	0.32	3	0.00	0.05	0.02	3
Sockeye	0.00	0.00	0.00	1	1.00	1.00	1.00	1	-	-	-	-
Chum	0.28	0.67	0.54	3	0.33	0.72	0.57	3	0.00	0.00	0.00	1
ZQI-Upper reach												
Chinook	0.52	0.52	0.52	1	0.48	0.48	0.48	1	0.00	0.00	0.00	1
Coho	0.94	1.00	0.97	3	0.04	1.00	0.40	3	0.00	0.03	0.01	4
Sockeye	0.00	1.00	0.59	6	0.33	1.00	0.70	5	0.00	0.50	0.20	6
Chum	0.00	0.33	0.29	4	0.67	1.00	0.88	5	0.00	0.00	0.00	3

Coho salmon showed the strongest association of all the species for the area above the backwater zone (zone H-I). If the nine separate habitat zones had been aggregated using water source as a criterion rather than mainstem backup, a strong preference by coho for tributary water would have been evident. This kind of aggregation would separate the turbid H-I area of sloughs with a mainstem water source (zone 4) from the clear water H-I area of tributaries (zone 1). Very few juvenile coho salmon were caught in zone H-III. There was one site in the upper reach (Slough 6A) which never had a zone H-I present during the samplings. All the coho salmon caught at the site were in zone H-II; none were caught in zone H-III. This is the reason for the maximum ZQI of 1.00 in zone H-II for coho in the upper reach.

All of the sockeye salmon present at the one site in the lower reach which met the previously defined criteria were caught in zone H-II. In the upper reach, a preference for zone H-II is apparent. However, there was at least one site where all the sockeye present were in zone H-I, leading to the maximum value of 1.00 for that zone. Field observations indicated that the sockeye present in zone H-I were often associated with the small calm water morphological pools present in these areas. This was the case in sites such as Slough 8A and Slough 19. If point-specific data were available for sockeye juveniles, they would probably show a very strong preference by sockeyes for low-velocity water.

Chum salmon in the lower reach were approximately equally divided between zone H-I and zone H-II, with a slight preference shown for the latter. A strong preference for zone H-II was shown in the upper reach. Chum salmon were rarely caught in zone H-III. Although chum salmon juveniles showed a preference for the mainstem backwater zone (zone H-II), there were several cases where they were present in zone H-I. Juvenile chum salmon were captured in tributaries (zone I) during outmigration from tributary spawning grounds (as at Goose Creek). Also, they were frequently present in sloughs above the backwater zones (zone 4), having emerged from nearby redds (Slough 11) or having entered the slough head during outmigration.

Zone and site habitat indices

We have included in this report plots of the zone and site habitat indices as a function of mainstem discharge at three or four sites for each of the four salmon species. The sites selected in each case were among the top four or five in total catch for the season for the species and had zone quality indices which were typical for that species among the several sites in the reach. Together, the graphs include all the major habitat types, represent both reaches, and illustrate all the main points which result from this kind of analysis.

The shape of the zone habitat index curves for the mainstem backwater zone (zone H-II) resembles the shape of the mainstem backwater surface area curves (see Appendix E of this report) because the zone habitat index is a multiple of surface area. There are slight differences because the surface area curves (Appendix E) were plotted from the raw data, while the zone habitat indices used surface area values extracted from these curves at evenly spaced increments of mainstem discharge. The shape of the site habitat index curves do not usually resemble the shape of the total wetted surface area curves (shown in Appendix E) because zones H-I and H-II are given different weighting factors (the ZQI) and because there are small differences resulting from interpolation of the raw surface area versus discharge curves at incremental discharge levels.

Many of the zone habitat index curves have a steeper slope at lower discharges than at higher discharges. This results from the greater effect of a given change in discharge on zone surface area at lower discharges than at higher discharges.

Juvenile chinook salmon

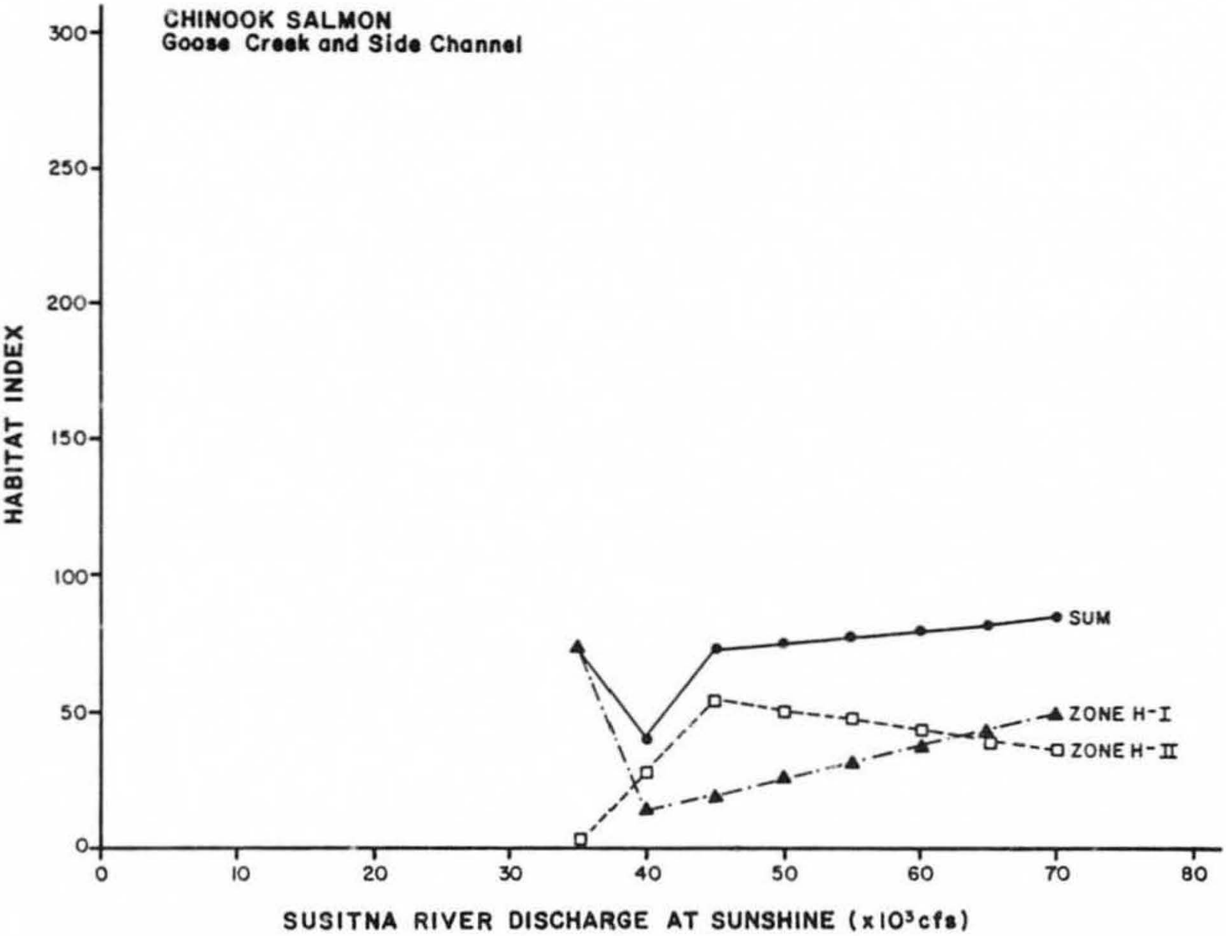
Zone and site habitat indices for juvenile chinook salmon were calculated for three sites in the lower reach and one site in the upper reach (Appendix Table F-13). The zone quality index for juvenile chinook salmon at three of the four sites selected was close to 0.5 for both zones. Rabideux Creek and Slough had a higher ZQI in the H-I area.

The site habitat index at the Goose Creek and Side Channel site (Appendix Figure F-3) shows a steady decrease with a decrease in discharge until discharge drops to about 40,000 - 45,000 cfs. At this point, the head of the slough closed, the H-II area began to decrease, and the tributary section of the H-I area moved out into the slough channel. For a more detailed explanation of the hydraulics of these

Appendix Table F-13. Habitat indices for juvenile chinook salmon for aggregate hydraulic zones at four sites, June through September, 1982.

Susitna Discharge at Sunshine (cfs)	Goose Creek and Side Channel: Zone H-I (ZQI=0.54)	Zone H-II (ZQI=0.46)	Site Habitat Index (ΣHI)	Rabideux Creek and Slough: Zone H-I (ZQI=0.71)	Zone H-II (ZQI=0.48)	Site Habitat Index (ΣHI)	Birch Creek and Slough: Zone H-I (ZQI=0.49)	Zone H-II (ZQI=0.51)	Site Habitat Index (ΣHI)
35,000	73	0	73	355	238	593	144	43	187
40,000	13	27	40	142	396	538	105	75	180
45,000	19	54	73	121	422	543	104	77	181
50,000	25	50	75	99	448	547	103	78	181
55,000	31	47	79	78	474	552	74	115	189
60,000	37	43	80	57	499	556	15	186	201
65,000	43	39	82	36	523	559	15	193	208
70,000	49	36	85	14	552	566	15	196	211

Susitna Discharge at Gold Creek (cfs)	Whiskers Creek and Slough: Zone H-I (ZQI=0.52)	Zone H-II (ZQI=0.48)	Site Habitat Index (ΣHI)
12,500	73	14	87
15,000	74	18	92
17,500	71	25	96
20,000	69	32	101
22,500	66	39	105
25,000	69	40	109
27,500	70	40	110

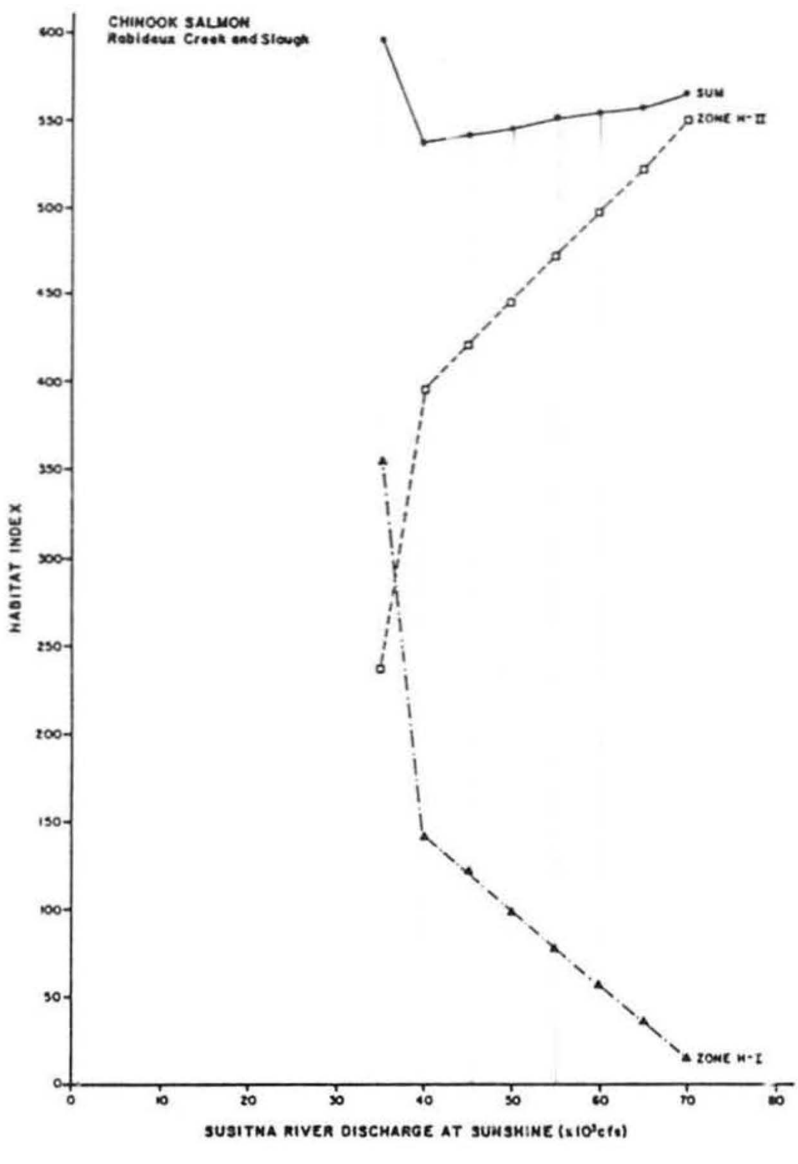


Appendix Figure F-3. Zone and site habitat indices for juvenile chinook salmon at Goose Creek and Side Channel study site as a function of mainstem discharge, June through September, 1982.

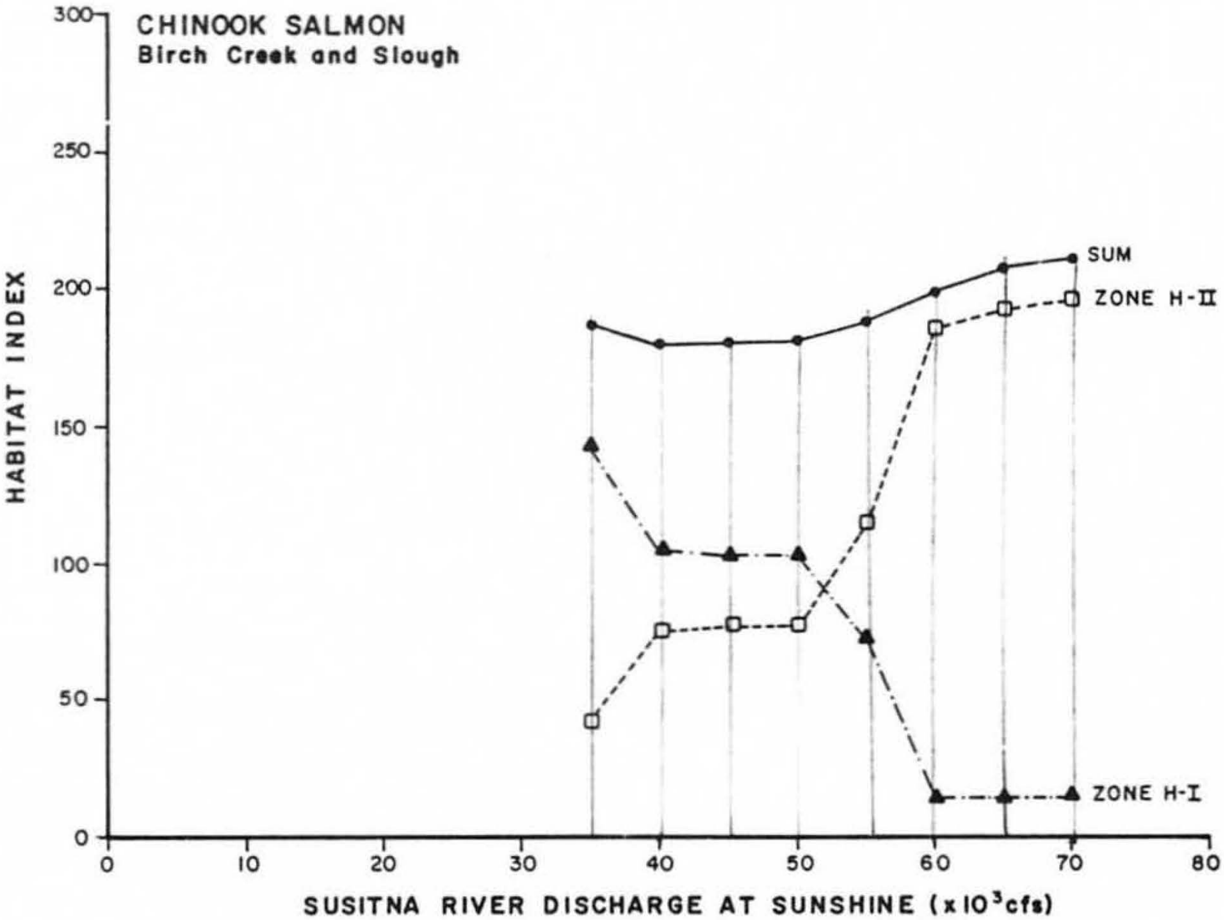
sites, refer to Appendix E of this report and Volume 4, Part I, Section 3.1.3.1 of the Basic Data Report (ADF&G 1983b).

Large changes in surface area occurred in both zones at the Rabideux Creek and Slough site with changes in mainstem discharge, but the site habitat index remained relatively constant (Appendix Figure F-4). As mainstem discharge decreased from the maximum observed, the mainstem backwater zone (H-II) receded and was replaced by the tributary (H-I) zone. Because the tributary area was better habitat than the backwater area for rearing chinooks, the site habitat index is highest at the lowest discharge observed. At about 40,000 cfs, a large pond-like pool (included in zone H-II) which had been backed up by mainstem stage at greater flows was no longer affected by mainstem stage and became zone H-I. However, the pond-like area remained (although at a lower level) as a zone 9 (morphological pool) within the aggregate zone H-I and probably did not undergo a great deal of change with regard to the quality of habitat.

The pattern shown at the Birch Creek and Slough site (Appendix Figure F-5) was typical for juvenile chinook salmon at several of the sampling sites. With an increase in mainstem discharge, the habitat index for zone H-I decreases, and then levels off; the habitat index for zone H-II does exactly the opposite. The site habitat index (sum of the habitat index for the two zones) gradually increases with an increase in mainstem discharge because of increasing total wetted surface area. Because the seasonal zone quality indices for the two zones at Birch Creek and Slough for chinook salmon were fairly similar (Appendix Table



Appendix Figure F-4. Zone and site habitat indices for juvenile chinook salmon at the Rabideux Creek and Slough study site as a function of mainstem discharge, June through September, 1982.



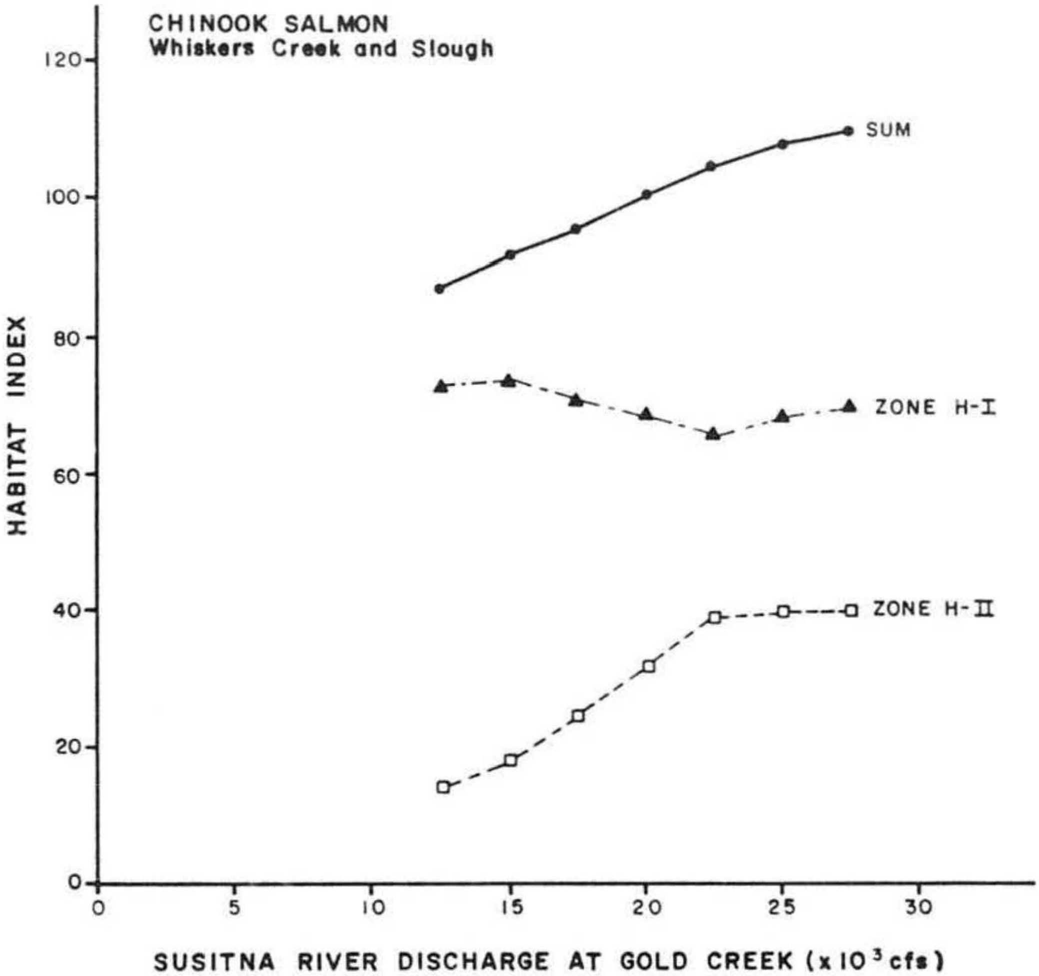
Appendix Figure F-5. Zone and site habitat indices for juvenile chinook salmon at the Birch Creek and Slough study site as a function of mainstem discharge, June through September, 1982.

F-13), both zones had nearly equal weight in compiling the site habitat index. If the ZQI for each zone had been equal to 0.5, which means that chinook salmon showed no preference for either zone over the other, then the shape of the site habitat index curve would be similar to the shape of the total wetted surface area. In this case, if one zone decreased in areal extent, the fish would simply move to the other zone. In fact, the fish might remain where they were, but the zone designation (and habitat characteristics) at that location would change. The site habitat index would decrease as the total wetted surface area decreased.

The site habitat index for chinook salmon at the Whiskers Creek and slough site shows a steady increase with increasing discharge (Appendix Figure F-6). The shape of the zone H-II curve is typical for sites in the reach in that it steadily increases with an increase in mainstem discharge and then levels off. The zone H-I surface area curve is relatively flat. At the lower discharge levels, the length of zone H-I increased (downstream) as the backwater zone (zone H-II) receded. At the same time, however, the width of zone H-I was decreasing. The net result of the two was a slight increase in zone H-I surface area as discharge decreased below about 22,000 cfs.

Juvenile Coho Salmon

Juvenile coho salmon showed a strong preference for zone H-I at all of the sites (Appendix Table F-14). This preference was least apparent at the Sunshine Creek and Side Channel site, where the zone H-II area was not greatly different from the zone H-I area in physical and habitat



Appendix Figure F-6. Zone and site habitat indices for juvenile chinook salmon at the Whiskers Creek and Slough study site as a function of mainstem discharge, June through September, 1982.

Appendix Table F-14. Habitat indices for juvenile coho salmon for aggregate hydraulic zones at three sites, June through September, 1982.

	Sunshine Creek and Slough			Birch Creek and Slough		
Susitna Discharge at Sunshine (cfs)	Zone H-I (ZQI=0.71)	Zone H-II (ZQI=0.45)	Site Habitat Index (ΣHI)	Zone H-I (ZQI=0.88)	Zone H-II (ZQI=0.18)	Site Habitat Index (ΣHI)
35,000	99	11	110	245	15	260
40,000	87	25	112	194	26	220
45,000	74	39	113	197	27	224
50,000	62	53	115	200	28	228
55,000	59	67	126	142	40	182
60,000	60	80	140	26	66	92
65,000	98	58	156	19	68	87
70,000	106	54	160	18	69	87

	Lane Creek and Slough 8		
Susitna Discharge at Gold Creek (cfs)	Zone H-I (ZQI=0.94)	Zone H-II (ZQI=0.17)	Site Habitat Index (ΣHI)
12,500	18	1	19
15,000	19	2	21
17,500	20	2	22
20,000	21	2	23
22,500	21	3	24
25,000	7	8	15
27,500	2	8	10

Appendix Table F-14. Habitat indices for juvenile coho salmon for aggregate hydraulic zones at three sites, June through September, 1982.

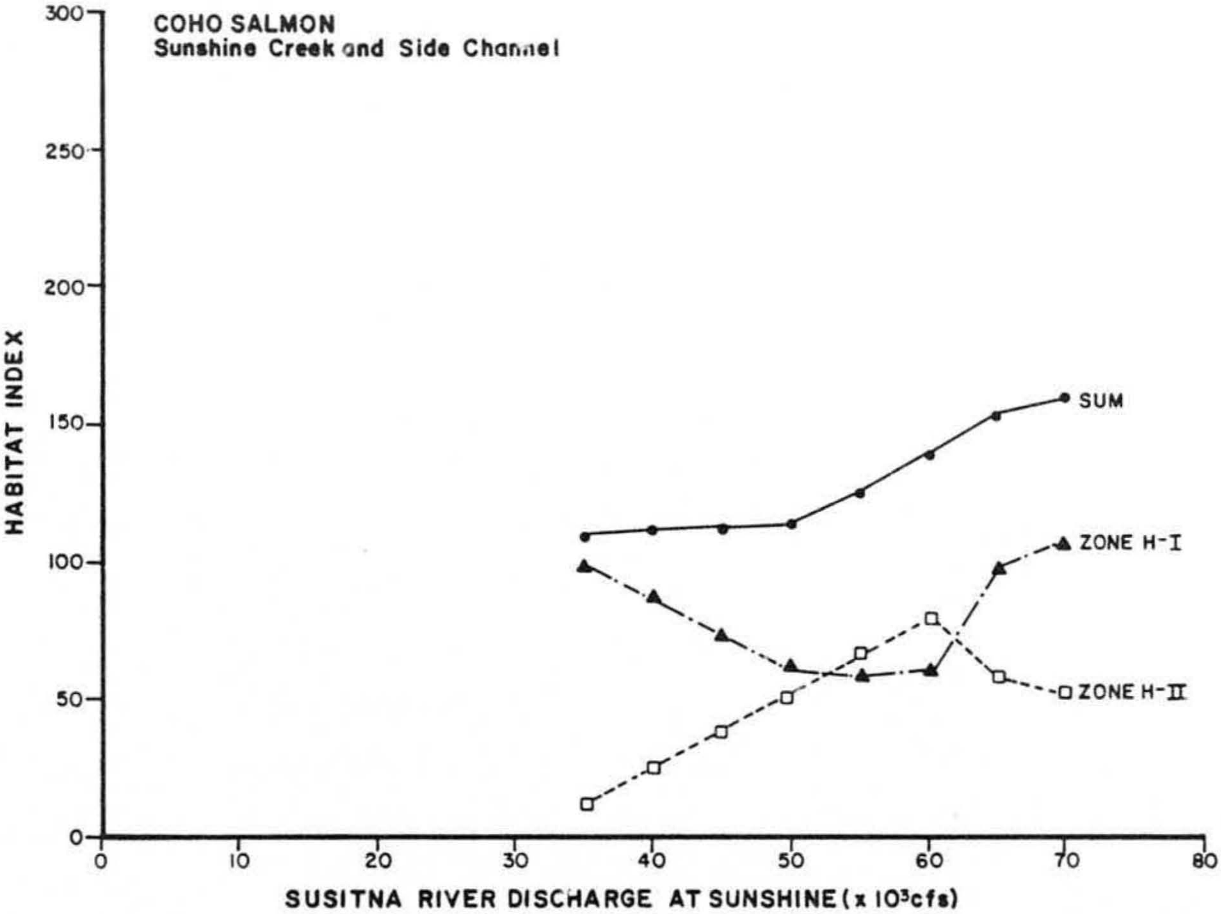
Susitna Discharge at Sunshine (cfs)	Sunshine Creek and Slough: Zone H-I (ZQI=0.71)	Sunshine Creek and Slough: Zone H-II (ZQI=0.45)	Sunshine Creek and Slough: Site Habitat Index (ΣHI)	Birch Creek and Slough: Zone H-I (ZQI=0.88)	Birch Creek and Slough: Zone H-II (ZQI=0.18)	Birch Creek and Slough: Site Habitat Index (ΣHI)
35,000	99	11	110	245	15	260
40,000	87	25	112	194	26	220
45,000	74	39	113	197	27	224
50,000	62	53	115	200	28	228
55,000	59	67	126	142	40	182
60,000	60	80	140	26	66	92
65,000	98	58	156	19	68	87
70,000	106	54	160	18	69	87

Susitna Discharge at Gold Creek (cfs)	Lane Creek and Slough 8: Zone H-I (ZQI=0.94)	Lane Creek and Slough 8: Zone H-II (ZQI=0.17)	Lane Creek and Slough 8: Site Habitat Index (ΣHI)
12,500	18	1	19
15,000	19	2	21
17,500	20	2	22
20,000	21	2	23
22,500	21	3	24
25,000	7	8	15
27,500	2	8	10

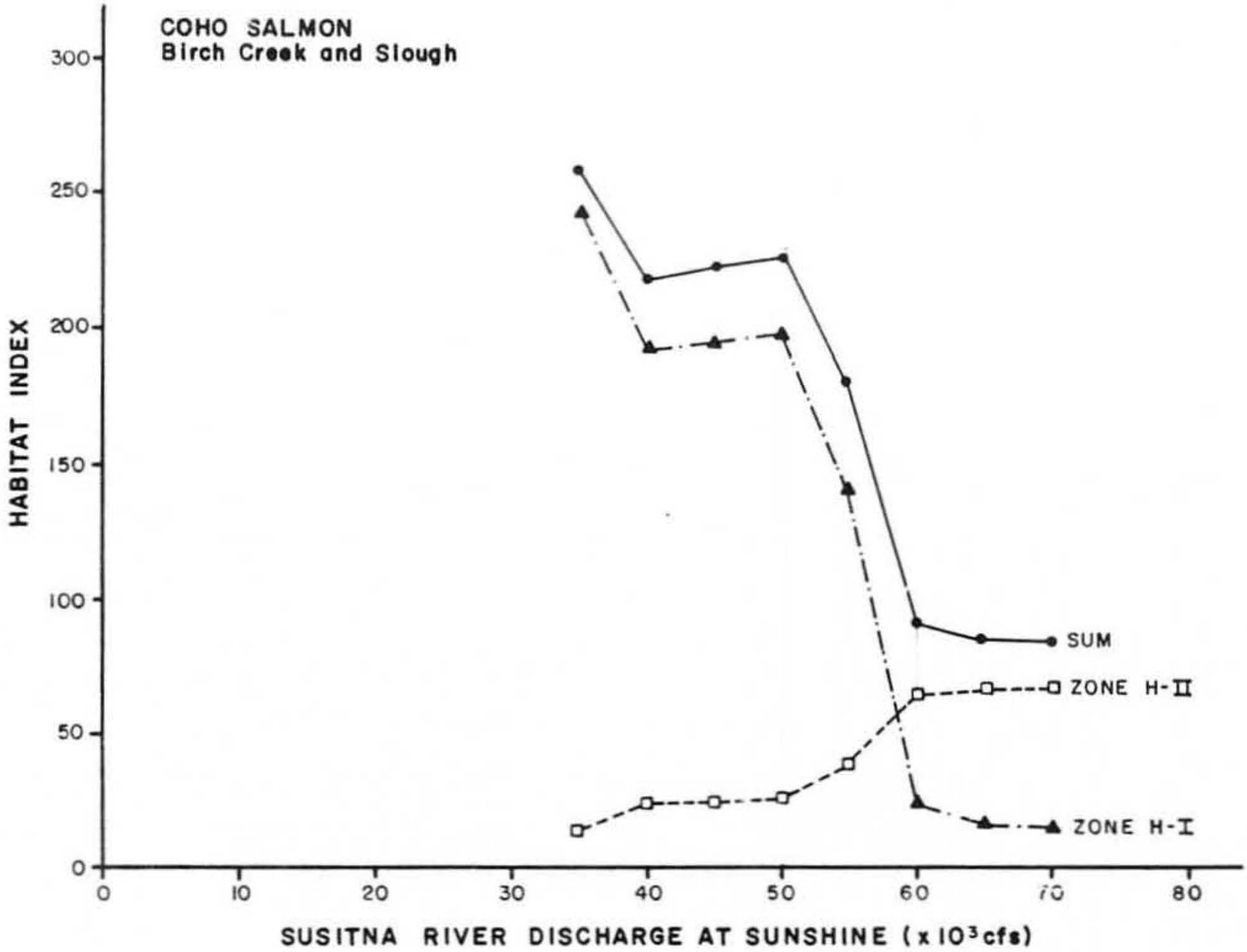
characteristics. Both areas had a low gradient, abundant aquatic vegetation for cover, and provided excellent habitat for rearing coho salmon. As a result, the habitat index for zone H-II has a greater weight than at other sites and the site habitat index shows a steady increase with increasing mainstem discharge (Appendix Figure F-7). This situation was not typical for coho at most other sites.

The shape of the coho salmon habitat index curves for zones H-I and H-II at the Birch Creek and Slough site reflect a pattern which was more common for the study sites (Appendix Figure F-8). With increasing mainstem discharge, the zone H-I habitat index decreases and then levels off while the zone H-II habitat index increases and then also levels off. The zone H-I surface area decreases because the zone H-II (backwater area) encroaches upon it as mainstem discharge level increases. Because zone H-I was strongly preferred by coho salmon (Appendix Table F-14), the site habitat index curve is heavily weighted by the zone H-I habitat index and the two curves have a similar shape (Appendix Figure F-8). Basically, this means that a loss of zone H-I reflects an important loss of habitat for coho salmon at this site, because they apparently do not have the capability of compensating for a decrease in zone H-I surface area by moving into zone H-II.

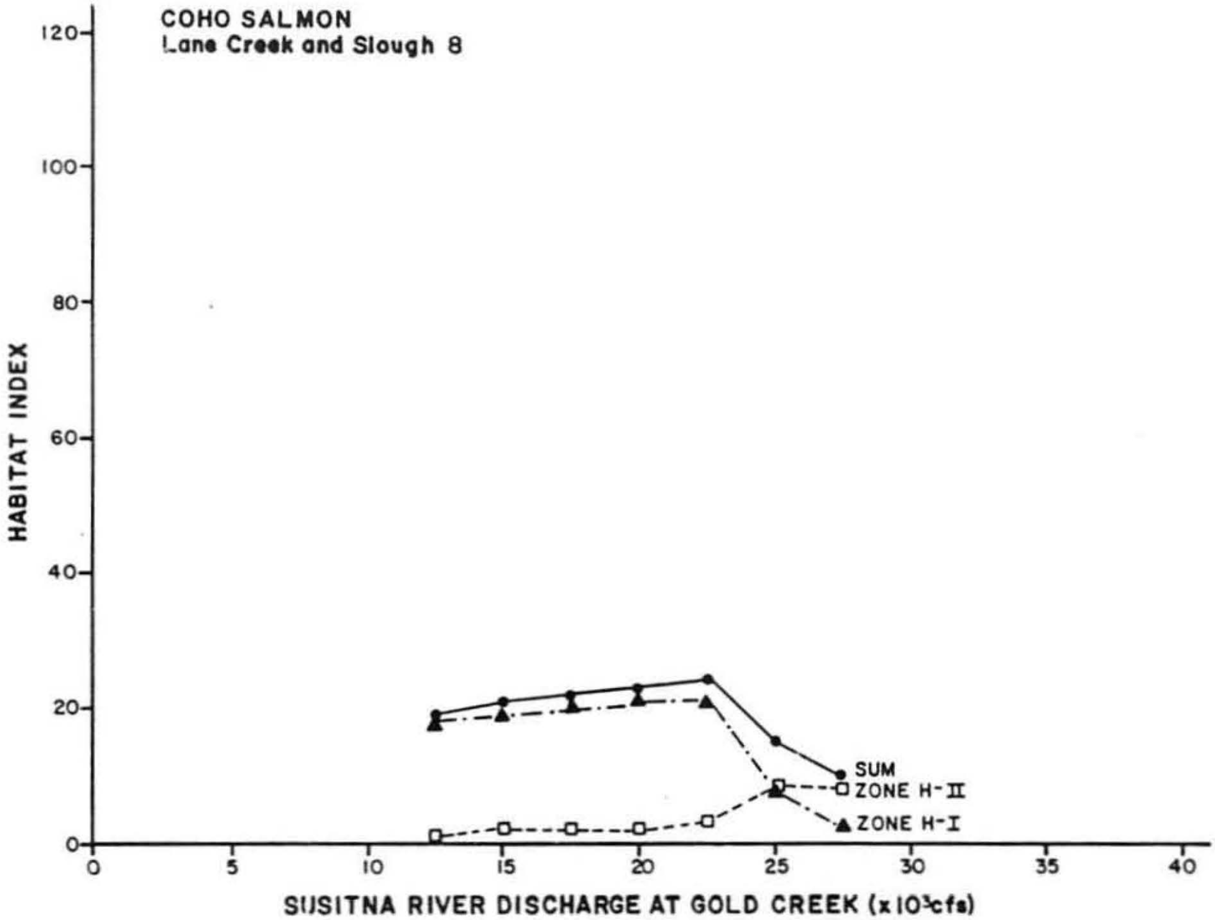
The site habitat index at the Lane Creek and Slough 8 site closely parallels the habitat index for zone H-I because of the strong weighting given zone H-I by the ZQI (Appendix Figure F-9). The changes at about 25,000 cfs were related to the breaching of the slough head at this discharge level.



Appendix Figure F-7. Zone and site habitat indices for juvenile coho salmon at the Sunshine Creek and Side Channel study site as a function of discharge, June through September, 1982.



Appendix Figure F-8. Zone and site habitat indices for juvenile coho salmon at the Birch Creek and Slough study site as a function of discharge, June through September, 1982.



Appendix Figure F-9. Zone and site habitat indices for juvenile coho salmon at the Lane Creek and Slough 8 study site as a function of mainstem discharge, June through September, 1982.

Juvenile sockeye salmon

Juvenile sockeye salmon at most of the sites showed a strong preference for zone H-II, a preference opposite that of rearing coho salmon. However, as mentioned previously, there were several sites where sockeye juveniles also occurred in small low velocity pools within zone H-I. At Slough 19, this occurred often enough so that the ZQI for zone H-I was greater than that of zone H-II (Appendix Table F-15). The sockeye ZQI at the Birch Creek and Slough site and the Slough 8A site were more typical.

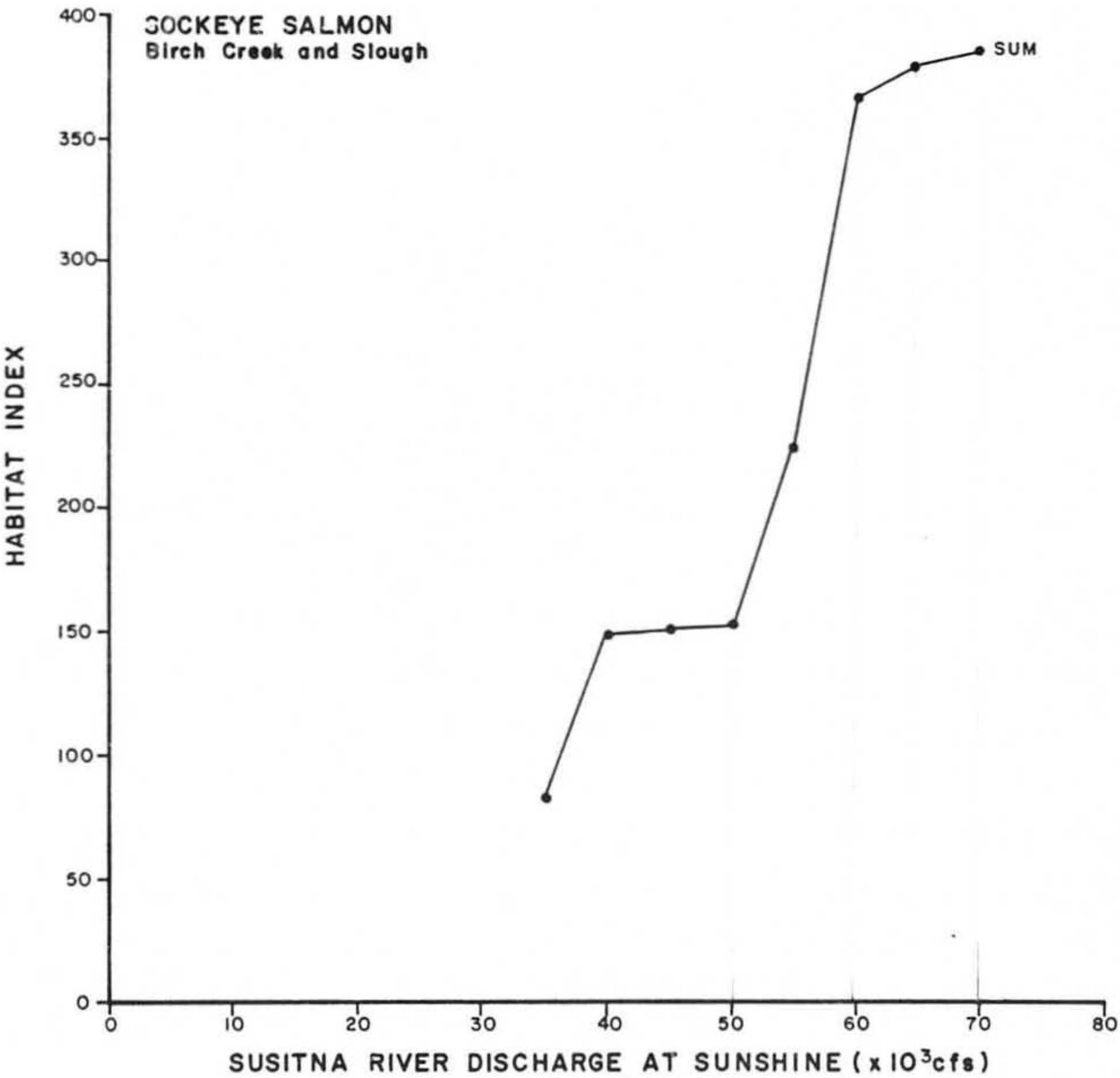
Because the ZQI for zone H-I at Birch Creek and Slough was equal to zero, the site habitat index was equal to the habitat index for zone H-II (Appendix Figure F-10). As the mainstem backwater area increased with an increase in mainstem discharge, the value of the site increased for rearing sockeye salmon.

Juvenile sockeye salmon at Slough 8A preferred the zone H-II area (ZQI = 0.66) over the zone H-I area (ZQI = 0.55) (Appendix Table F-15). This, along with the fact that the surface area of the zone H-I area changed very little with variation in discharge, gave a site habitat index for Slough 8A for sockeye salmon which closely resembled the shape of the zone H-II habitat index (Appendix Figure F-11). The flatness of the zone H-I curve at Slough 8A is in part due to the gradually sloping banks of the H-II zone at Slough 8A. The increasing backwater area

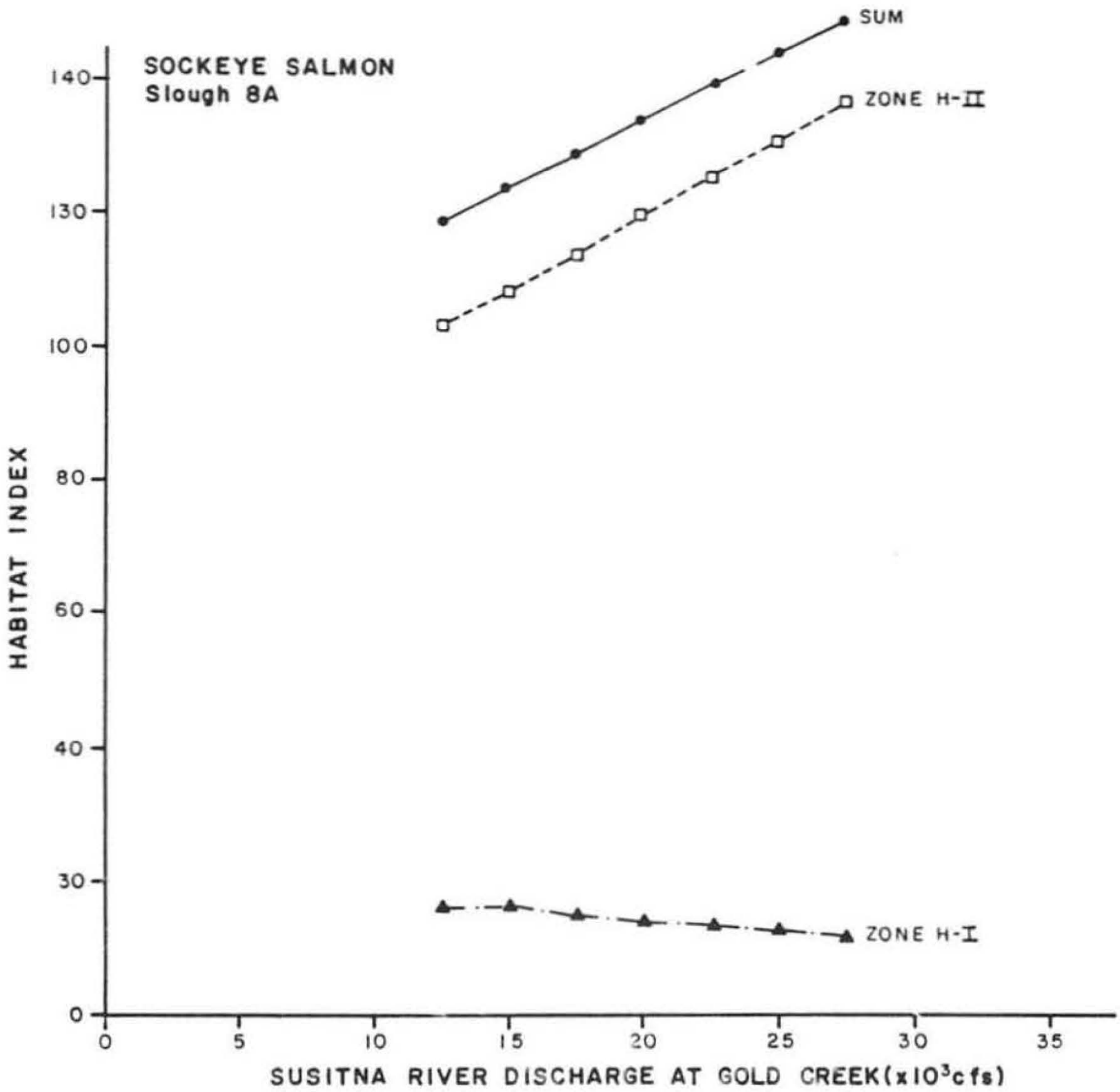
Appendix Table F-15. Habitat indices for juvenile sockeye salmon for aggregate hydraulic zones at three sites, June through September, 1982.

	Birch Creek and Slough		
Susitna Discharge at Sunshine (cfs)	Zone H-I (ZQI=0.0)	Zone H-II (ZQI=1.00)	Site Habitat Index (ΣHI)
35,000	0	84	84
40,000	0	147	147
45,000	0	150	150
50,000	0	153	153
55,000	0	225	225
60,000	0	365	365
65,000	0	378	378
70,000	0	385	385

	Slough 8A			Slough 19		
Susitna Discharge at Gold Creek (cfs)	Zone H-I (ZQI=0.55)	Zone H-II (ZQI=0.66)	Site Habitat Index (ΣHI)	Zone H-I (ZQI=1.00)	Zone H-II (ZQI=0.33)	Site Habitat Index (ΣHI)
12,500	16	103	119	11	1	12
15,000	16	108	124	14	0	14
17,500	15	114	129	3	3	6
20,000	14	120	134	3	4	7
22,500	14	125	139	3	4	7
25,000	13	131	144	0	9	9
27,500	12	137	149	0	9	9



Appendix Figure F-10. Zone and site habitat indices for juvenile sockeye salmon at the Birch Creek and Slough study site as a function of mainstem discharge, June through September, 1982.



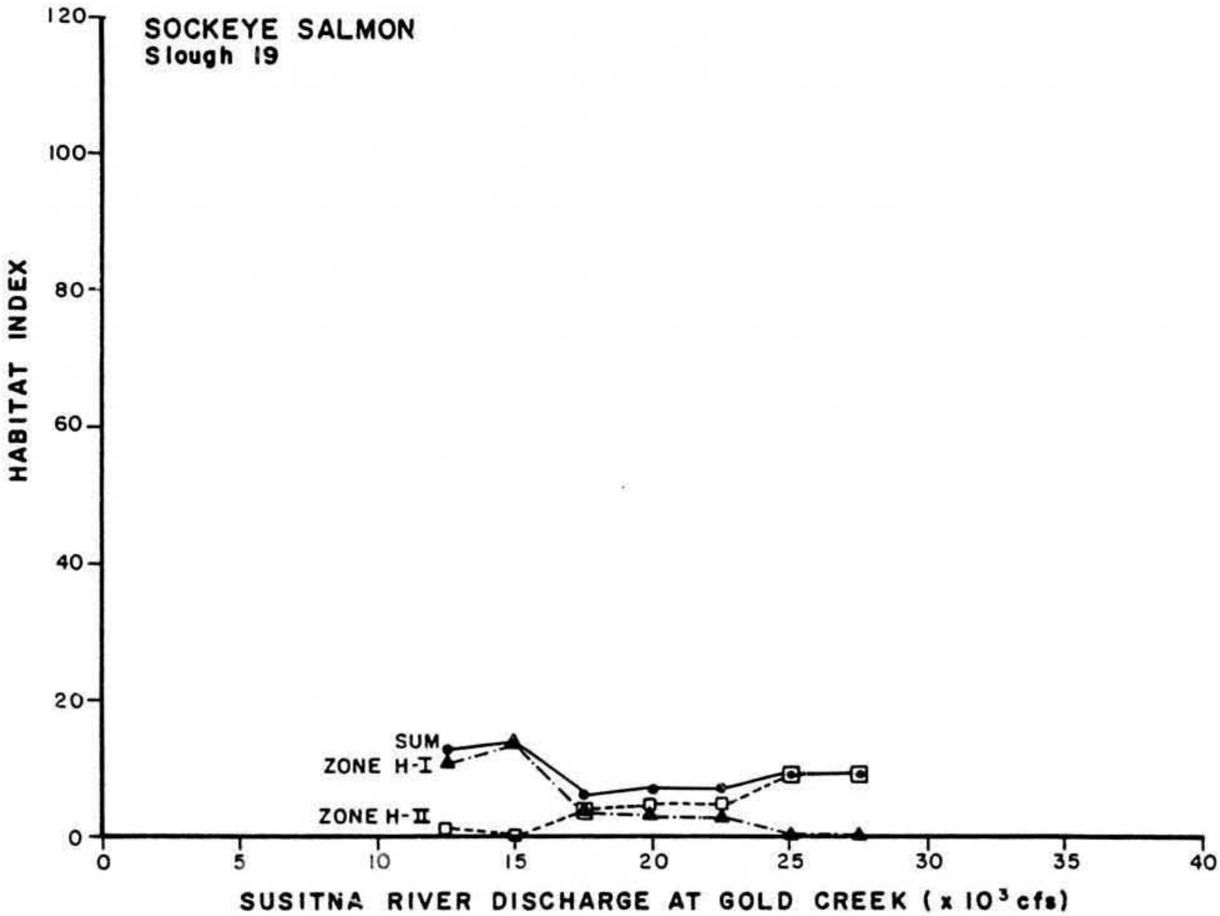
Appendix Figure F-11. Zone and site habitat indices for juvenile sockeye salmon at the Slough 8A study site as a function of mainstem discharge, June through September, 1982.

caused by an increasing mainstem discharge was absorbed by these low gradient banks and the H-I area was not greatly encroached upon.

The site habitat index at Slough 19 is atypical of the sites in that rearing sockeye salmon at this site were frequently captured in zone H-I in greater numbers than in zone H-II and the resulting site habitat index does not resemble the shape of the H-II habitat index (Appendix Figure F-12). A hydraulic situation occurred at Slough 19 which was similar to what occurred at Rabideux Creek and Slough (as discussed for juvenile coho salmon). Early in the season, juvenile sockeye were present in an area of the slough which was backed up by the mainstem (hence, this was zone H-II). As the flow decreased, the slack water area no longer resulted from mainstem stage, yet it continued to exist in the same area because of a morphological control at the mouth of the slough. The rearing sockeye also remained in this area, now designated zone H-I. These events are reflected in Appendix Figure F-12. Aggregating the individual habitat zones using water velocity as a criterion, rather than the presence of a mainstem backwater zone, would group both slack water areas, regardless of the causative factor.

Juvenile chum salmon

Juvenile chum salmon always preferred the zone H-II area at the selected sites (Appendix Table F-16); this was typical of most of the fourteen sites sampled. As a result, the site habitat indices closely resemble the shape of the habitat indices for zone H-II (Appendix Figures F-13 to F-15). The results at Birch Creek and Slough in the lower reach

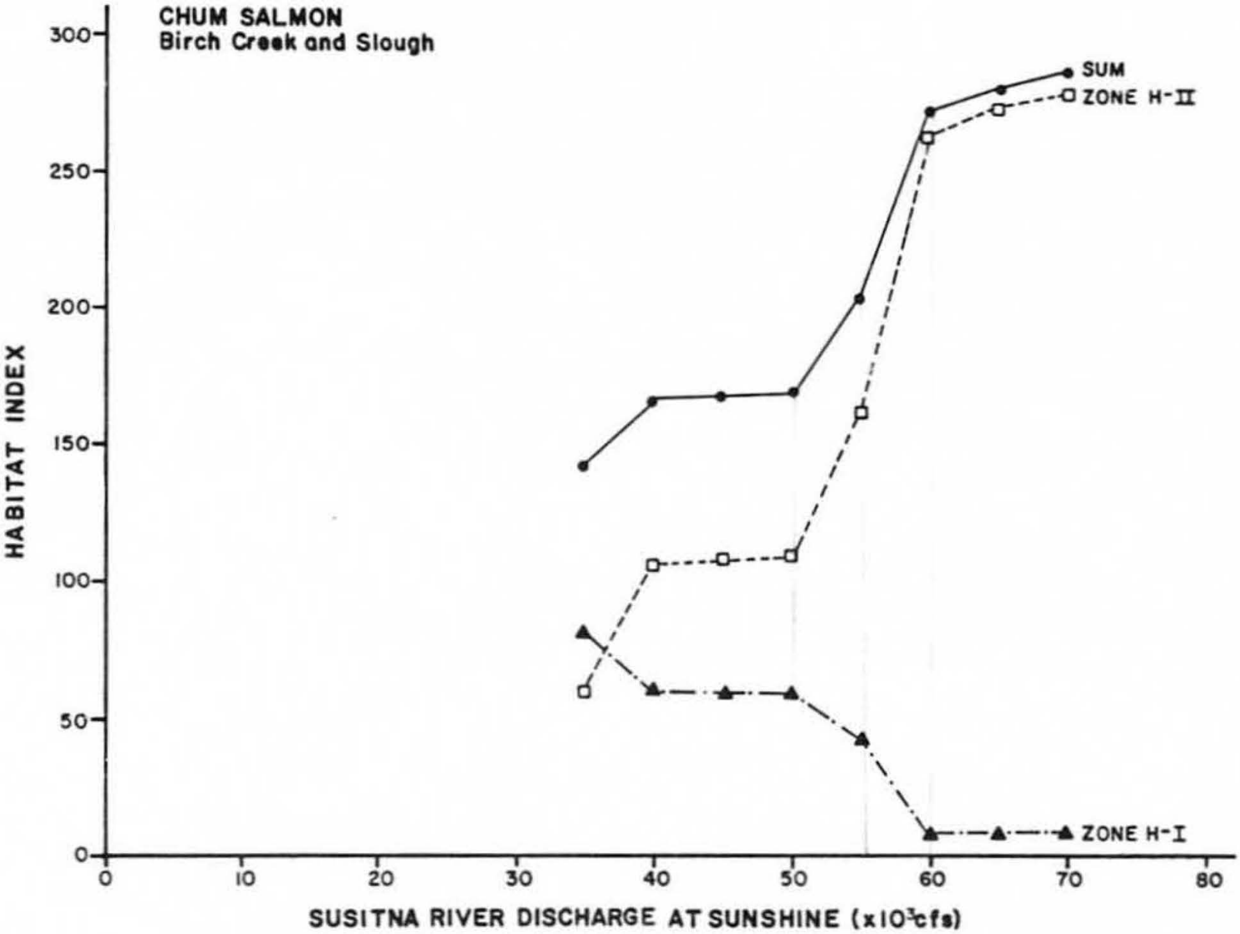


Appendix Figure F-12. Zone and site habitat indices for juvenile sockeye salmon at the Slough 19 study site as a function of mainstem discharge, June through September, 1982.

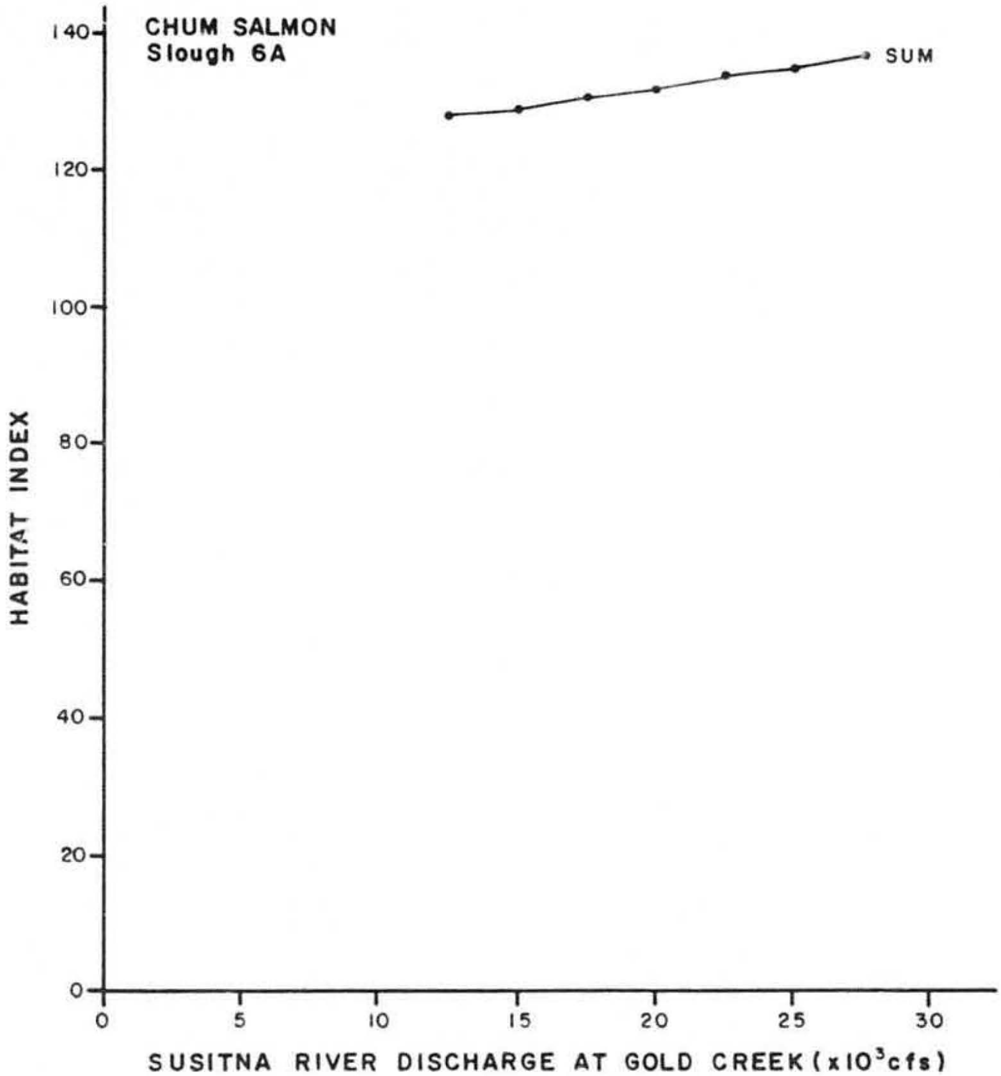
Appendix Table F-16. Habitat indices for juvenile chum salmon for aggregate hydraulic zones at three sites, June through September, 1982.

	Birch Creek and Slough		
Susitna Discharge at Sunshine (cfs)	Zone H-I (ZQI=0.28)	Zone H-II (ZQI=0.72)	Site Habitat Index (ΣHI)
35,000	82	60	142
40,000	60	106	166
45,000	59	108	167
50,000	59	110	169
55,000	42	162	204
60,000	8	263	271
65,000	8	272	280
70,000	8	277	286

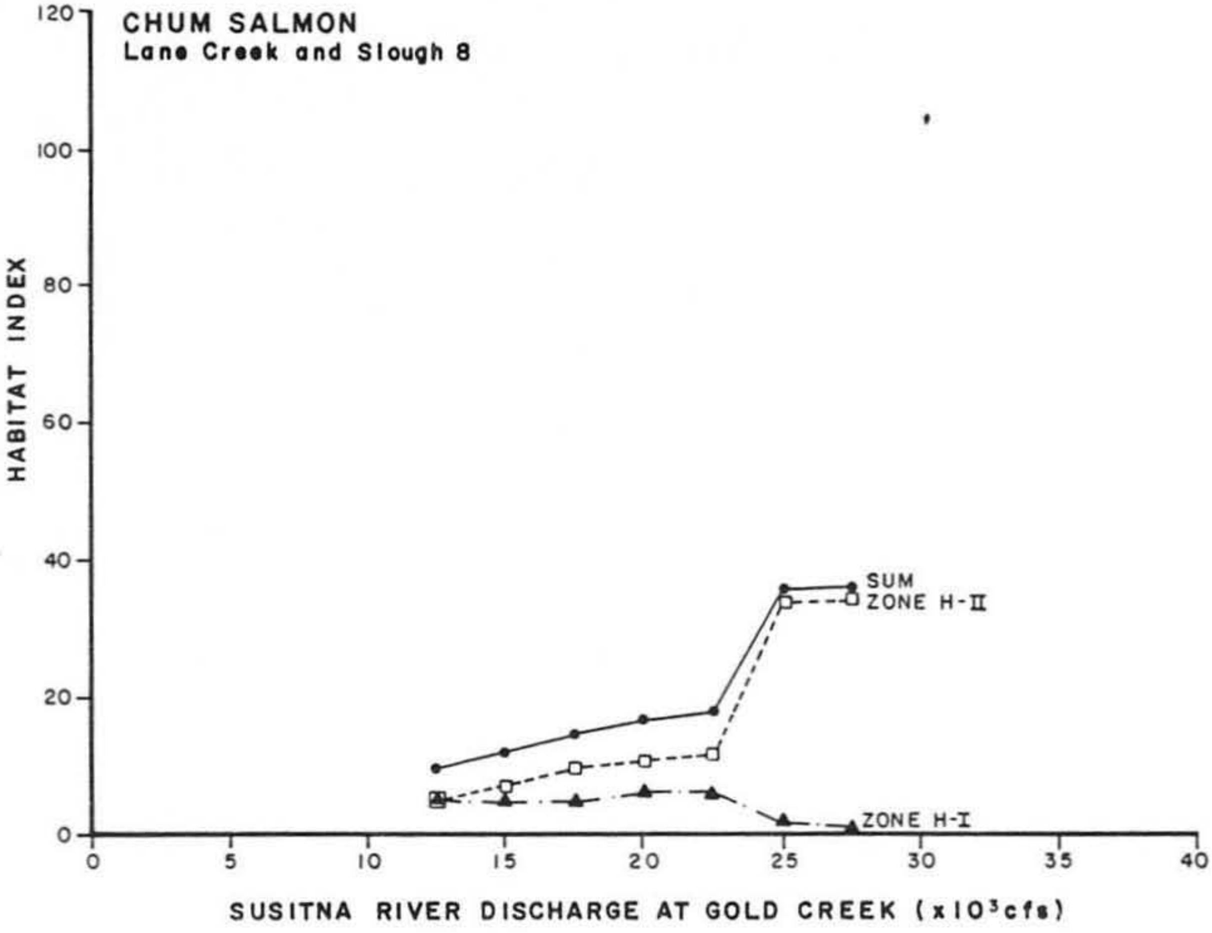
	Slough 6A			Lane Creek and Slough 8		
Susitna Discharge at Gold Creek (cfs)	Zone H-I (ZQI=N/A)	Zone H-II (ZQI=1.00)	Site Habitat Index (ΣHI)	Zone H-I (ZQI=0.25)	Zone H-II (ZQI=0.75)	Site Habitat Index (ΣHI)
12,500	--	128	128	5	5	10
15,000	--	129	129	5	7	12
17,500	--	131	131	5	10	15
20,000	--	132	132	6	11	17
22,500	--	134	134	6	12	18
25,000	--	135	135	2	34	36
27,500	--	137	137	1	35	36



Appendix Figure F-13. Zone and site habitat indices for juvenile chum salmon at the Birch Creek and Slough study site as a function of mainstem discharge, June through September, 1982.



Appendix Figure F-14. Zone and site habitat indices for juvenile chum salmon at the Slough 6A study site as a function of mainstem discharge, June through September, 1982.



Appendix Figure F-15. Zone and site habitat indices for juvenile chum salmon at the Lane Creek and Slough 8 study site as a function of mainstem discharge, June through September, 1982.

(Appendix Figure F-13) and at Lane Creek and Slough 8 in the upper reach (Appendix Figure F-15) are very similar in form.

The study boundary for Slough 6A, an upland slough, did not include an H-I zone. This slough has steep banks and a deep entrance channel, so the surface area of the slough showed only a small response to variations in mainstem discharge. All of the juvenile chum salmon captured at this site were in the H-II zone, which gives that zone a seasonal ZQI of 1.00 and zone H-III a ZQI of 0.00. The net result of the above is that the site habitat index is exactly the same as the zone H-II habitat index and that this index did not vary much with variations in discharge (Appendix Figure F-14). The flatness of the site habitat index curve is not typical of the sites. This situation occurs only at steep banked upland sloughs which are completely backed up by the mainstem.

CONCLUSIONS

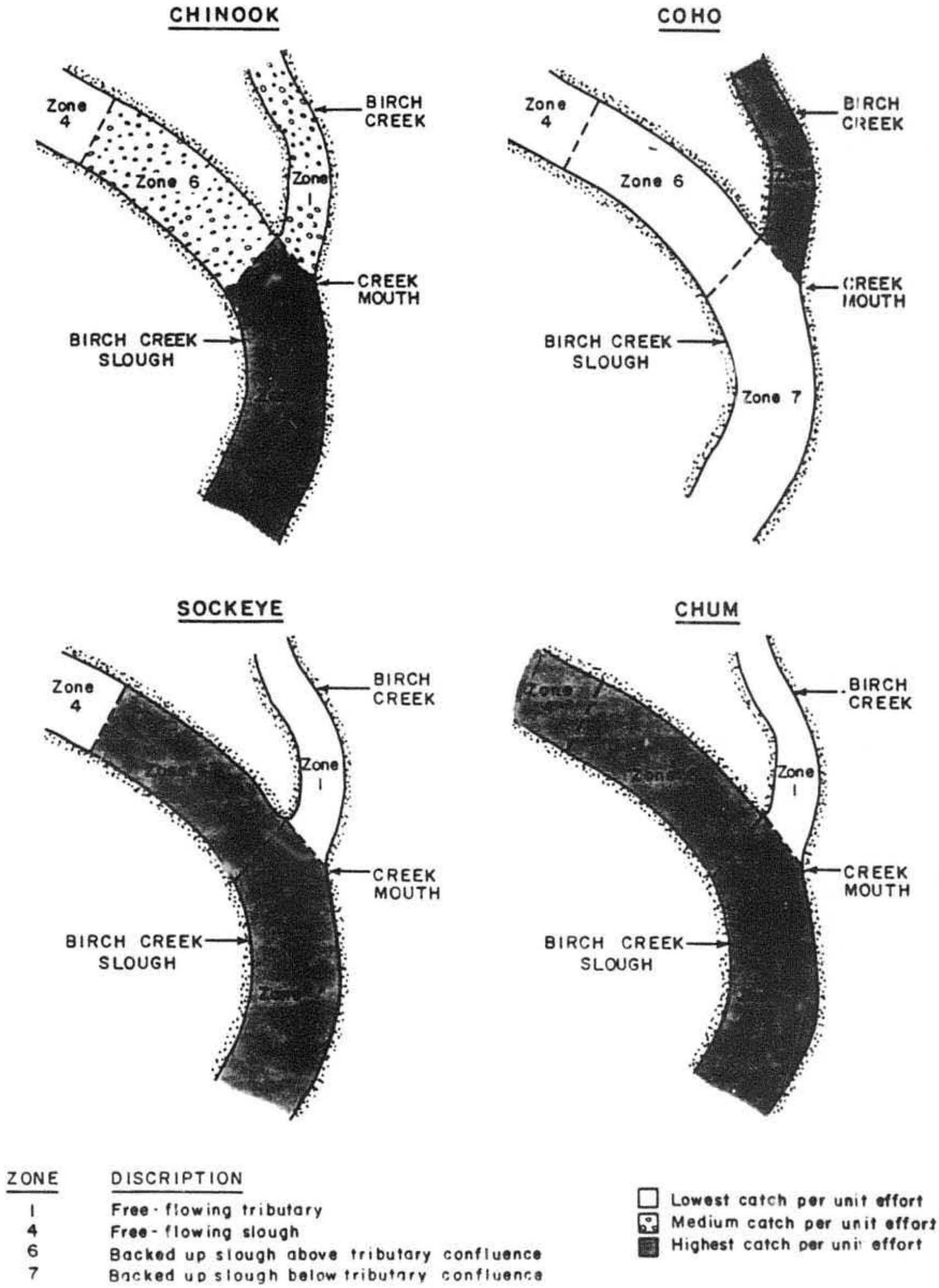
The results have established that the sampling zones were distinctly different habitats. These differences were maintained over the course of the season and over variations in mainstem discharge. Significant differences in distribution of fish among these zones demonstrated that the fish respond to the variability of the habitat components. Some possible causes for fish preference for one zone instead of another were explored by examining the relationship of fish abundance with key habitat variables. The validity of calculating zone quality indices from the catch data was established by demonstrating the above statistical differences.

The measure of habitat quality which was derived for this study, the zone quality index (ZQI), provides logical results which reflect actual juvenile salmon habitat preferences as established by statistical analysis of the catch data. Again, this index is not an index of absolute abundance nor does it consider the differences in quality among the sites; it only considers differences in quality among the zones.

The zone and site habitat indices which were presented in this report represent only one of the several possible approaches using this kind of analysis. The nine individual habitat zones could be treated separately or they could be aggregated using criteria other than the influence of the mainstem backwater. These other approaches could provide further insight into the factors controlling fish distribution and abundance. The approach used in this appendix (aggregate hydraulic zones) was chosen for its relative strength in relating habitat to mainstem discharge.

In interpreting the zone and site habitat index curves, one should be careful about extending the curves beyond the range of mainstem discharge which was observed, because the trends may not hold outside that range and large errors could result. Also, it is important to keep in mind that these curves reflect the situation only within the study boundaries. These boundaries usually included a tributary or slough mouth, some of the area above, and a small area of the mainstem mixing zone below. A decrease in surface area of a preferred habitat within the study boundary does not mean that the habitat was completely lost. For example, the coho salmon present in zone H-I at Birch Creek and Slough may be able to move further up the creek as a rising mainstem discharge causes the backwater zone to advance on zone H-I. However, there may not be replacement habitat available for decreasing areas of backwater zones, such as are used by sockeye and chum salmon. Since the study sites were chosen in part because of their importance to the fish populations, the loss of surface area within a study boundary can correctly be interpreted as a habitat loss which will influence the populations.

Analysis of the conditions at the Birch Creek and Slough study site provides a good summary of the conclusions that have resulted from the site habitat index method. Juveniles of the four salmon species showed a good segregation by habitat zone at this site (Appendix Figure F-16). Most of chinook juveniles were captured in the slough below the tributary mouth (zone 7), the rest were evenly distributed between the tributary (zone 1) and the backed-up slough above the tributary confluence (zone 6). Almost all of the rearing coho were captured in the tributary (zone 1). Most of the sockeyes were captured in the mainstem backwater zone above (zone 6), and below (zone 7), the tributary confluence; a few were captured in the slough above the mainstem backwater area (zone 4). Juvenile chum salmon were captured in the slough above the mainstem backwater zone (zone 4) and in the mainstem backwater area (zones 6 and 7). A summary of the zone quality indices for juveniles of each species at this site is as follows



Appendix Figure F-16. Generalized distribution of juveniles of four species of salmon at the Birch Creek and Slough study site, open water season, 1982.

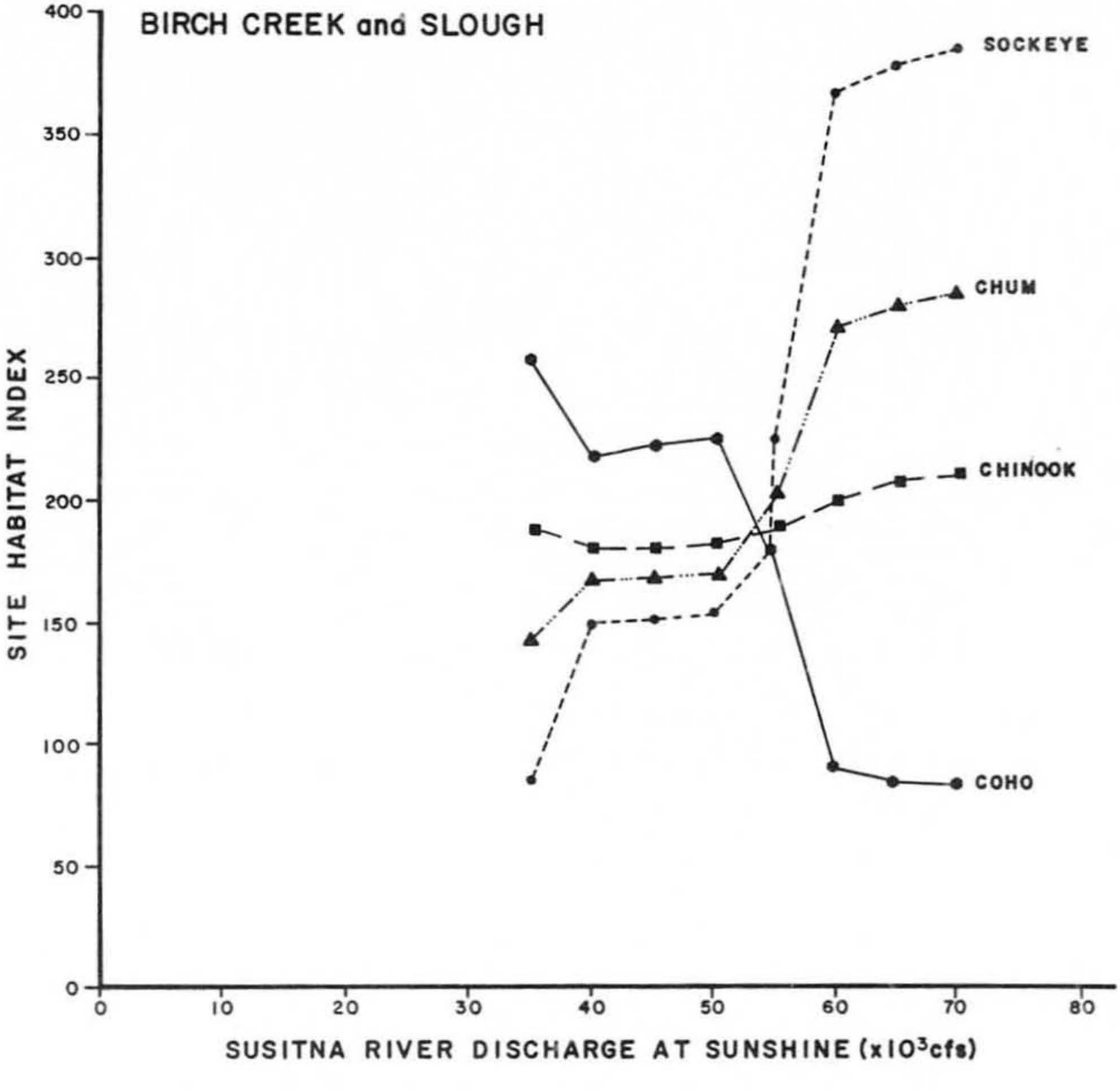
(aggregate hydraulic Zone H-I includes habitat zones 1 and 4 and aggregate hydraulic zone H-II includes habitat zones 6 and 7):

Species	Zone H-I	Zone H-II
Chinook	0.49	0.51
Coho	0.88	0.18
Sockeye	0.00	1.00
Chum	0.28	0.72

The zone quality indices (ZQI) for each species are typical of those shown by the species at the fourteen different sites.

The site habitat indices for juveniles of each of the four salmon species at the Birch Creek and Slough site are shown together in Appendix Figure F-17. The relative values between species have no meaning; only the shape of the curves is comparable from one species to another. All four of the species show an inflection at a discharge of around 53,000 cfs. This is the discharge at which the head of the slough is breached.

The shape of each site habitat index curve in Appendix Figure F-17 is representative of the majority of the fourteen sites. The ZQI for chinook salmon juveniles is approximately 0.5 for each zone, so the site habitat index curve for chinook is a function of total wetted surface area. The site habitat index curve for coho salmon, which are strongly associated with zone H-I, declines with an increase in discharge because the mainstem backwater zone (H-II) encroaches upon zone H-I. Chum salmon, which tend to occur in zone H-II, have a site habitat index which increases with increasing discharge. The site habitat index curve



Appendix Figure F-17. Site habitat indices for juveniles of four species of salmon at the Birch Creek and Slough study site as a function of mainstem discharge, June through September, 1982.

for sockeye salmon, which are even more strongly associated with zone H-II, shows a sharper increase. Variations in mainstem discharge affect habita+ of different species in different ways, both in direction and in magnitude.

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______. Bovee, K.D. 1982. A guide to habitat analysis using the instream flow incremental methodology. Instream Flow Information Paper. No. 12. FWS/035-82/26.

Snedecor, G.W., and W.G. Cochran. 1967. Statistical methods. The Iowa State University Press, Ames. 593 pp.

Summary table of habitat zones sampled at Designated Fish Habitat sites, June through September, 1982.

Zone Code	Description
1	Areas with a tributary or ground water source which are not influenced by mainstem stage and which usually have an appreciable[a] surface water velocity.
2	Backwater areas resulting from a hydraulic barrier created at the mouth of a tributary or slough by mainstem stage, which have a tributary or ground water source.
3	Areas of appreciable water surface velocities, primarily influenced by the mainstem, where tributary or slough water mixes with the mainstem water.
4	Areas of appreciable surface water velocities which are located in a slough or side channel above a tributary confluence (or in a slough where no tributary is present) when the slough head is open.
5	Areas of appreciable surface water velocities which are located in a slough or side channel below a tributary confluence, when the slough head is open.
6	Backwater areas resulting from a hydraulic barrier created by mainstem stage which occur in a slough or side channel above a tributary confluence (or in a slough or side channel where no tributary is present), when the head of the slough is open.
7	Backwater areas resulting from a hydraulic barrier created by mainstem stage which occur in a slough or side channel below a tributary confluence, when the head of the slough is open.
8	Backwater areas consisting of mainstem eddies.
9	A pool with no appreciable surface water surface velocities which is created by a geomorphological feature of a free-flowing zone or from a hydraulic barrier created by a tributary; not created as a result of mainstem stage.

[a]"Appreciable" surface water velocity means a velocity of at least 0.5 ft/sec. However, there are site-specific exceptions to this, based on local morphology.

APPENDIX G

Use of Major Habitat Types by Juvenile Salmon and Resident Species

APPENDIX G

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INTRODUCTION

The preference of fish for a certain kind of habitat varies with species, life history stage, time of year, and other factors. This appendix presents an analysis of preferences of resident fish and juvenile salmon during the open water season for six major habitat types occurring on the Susitna River between Cook Inlet and Devil Canyon. The six major habitat types were defined as tributary mouths, side channels with large tributary mouth, side sloughs with large tributary mouth, side sloughs with small tributary mouth or groundwater input, upland sloughs, and mainstem channels or side channels.

METHODS

Two types of proportions were analyzed using chi-square analysis (Snedecor and Cochran 1974; Summers et al. 1981). The first type was the distribution of a group of species among several different habitat types. The second was similar except that the distribution of a single species among these habitat types was tested. These tests were performed for both juvenile salmon (pink salmon not included because of low numbers captured) and resident species. A third type of comparison which was conducted graphically but not with chi-square analysis was the proportion of the four juvenile salmon species at one particular habitat type.

Statistical significance for all the chi square tests was set at the 95% confidence level. Continuity correction factors were calculated for all 2 X 2 contingency tables. Species, dates, or sites were pooled where necessary to keep the expected values greater than five.

Presence/absence data were extracted from Volume 3 of the Basic Data Report (ADF&G 1983) and were collected by a number of gear types and methods (Appendix Table G-1). Appendix Table G-2 shows how the 17 Designated Fish Habitat (DFH) sites were grouped into five major habitat types along with sampling effort at each type.

RESULTS

Juvenile Salmon

The presence/absence of the four species of juvenile salmon at the five major habitat types at DFH sites is shown in Appendix Table G-2. A 4 x 5 chi-square test of the presence/absence of four species of juvenile salmon versus five major habitat types (Appendix Table G-3) indicated that juvenile salmon did exhibit habitat preferences. A closer examination conducted by individual species revealed that coho and sockeye salmon exhibited a significant preference for certain habitat types but no such preference by chinook and chums was demonstrated (Appendix Table G-3).

Appendix Table G-1. Summary of chi square analyses performed on 1982 presence/absence or species proportion data.

Method and Type of Data	Where Collected	Species	Chi-Square Comparisons
All gear types[a] except boat electrofishing, presence/absence by species	17 DFH sites[b]	All juvenile salmon species	Among habitat types by all species
		Chinook salmon Coho salmon	Among habitat types by species
Beach seine or backpack electrofishing[c], presence/absence by species	17 DFH sites	Chum salmon Sockeye salmon Round whitefish Arctic grayling Longnose sucker Slimy sculpin	Among habitat types by species
Boat electrofishing, catch numbers	Cook Inlet to Devil Canyon	All resident species	Comparison of species proportions between habitat types and by season within mainstem and tributary types
Boat electrofishing, presence/absence by species	Above Chulitna River confluence (RM 98.5)	Round whitefish Arctic grayling Longnose sucker Burbot Humpback whitefish Rainbow trout Dolly varden	1) Among habitat type or pooled habitat type by species 2) Within habitat types by season by species

[a] Gear types include minnow traps, beach seines, and backpack electrofishing units.

[b] The 17 DFH (Designated Fish Habitat) sites ranged from Goose Creek (RM 73.1) to Portage Creek (RM 148.8).

[c] These methods were the only effective techniques for capturing these species at these sites.

Appendix Table G-2. Effort (number of sampling trips) and presence (number of trips that each species was present) of juvenile salmon at DFH sites. Compiled from catch by all gear types, June through September, 1982.

		Presence				Sub-
	Effort	Chinook	Coho	Chum	Sockeye	Total
Tributary mouths						
Fourth of July Creek	8	5	2	1	1	
Indian River	8	6	1	1	2	
Portage Creek	7	0	0	0	0	
sub-total	23	11	3	2	3	19
Upland sloughs						
Whitefish Slough	7	3	4	0	3	
Slough 6A	8	7	7	2	8	
Slough 19	8	3	0	1	6	
sub-total	23	13	11	3	17	44
Side sloughs w/large tribs						
Rabideux Creek	6	5	6	0	1	
Birch Creek	8	6	8	5	4	
Whiskers Creek	8	8	7	2	2	
Lane Creek	8	6	4	1	4	
Slough 20	8	5	1	1	3	
sub-total	38	30	26	9	14	79
Side sloughs w/small trib or groundwater						
Slough 8A	8	5	1	1	7	
Slough 9	8	7	1	3	4	
Slough 11	8	3	2	1	3	
Slough 21	8	5	1	2	4	
sub-total	32	20	5	7	18	50
Side channels w/trib						
Goose Creek	8	6	6	2	5	
Sunshine Creek	8	6	8	1	1	
sub-total	16	12	14	3	6	35
TOTAL	132	86	59	24	58	227

Appendix Table G-3. Summary of results of chi-square tests of association between juvenile salmon presence/absence and habitat type at DFH sites. Habitat types were tributary mouths, upland sloughs, side sloughs with large tributaries, side sloughs without large tributaries and side channels with large tributaries, June through September, 1982.

Species	Chi-square	df	Significance Level
All four species of juvenile salmon[a]	22.8	12	$p < .05$
Chinook[a]	7.8	4	NS[c]
Coho[a]	40.9	4	$p < .01$
Chum[b]	0.0	1[d]	NS
Sockeye[b]	11.1	4	$p < .01$

[a] All gear types

[b] Beach seining and electrofishing only

[c] NS = Not significant

[d] Habitat types were pooled into tributary sites and sloughs with no large tributaries.

Ratios of observed presence to expected presence show an association of coho salmon juveniles with upland sloughs, side sloughs with large tributary mouths, and side channels with large tributary mouths (Appendix Table G-4). Sockeye salmon juveniles were associated with upland sloughs and side sloughs without large tributary mouths. The distribution of each species among the major habitat types is illustrated in Appendix Figure G-1.

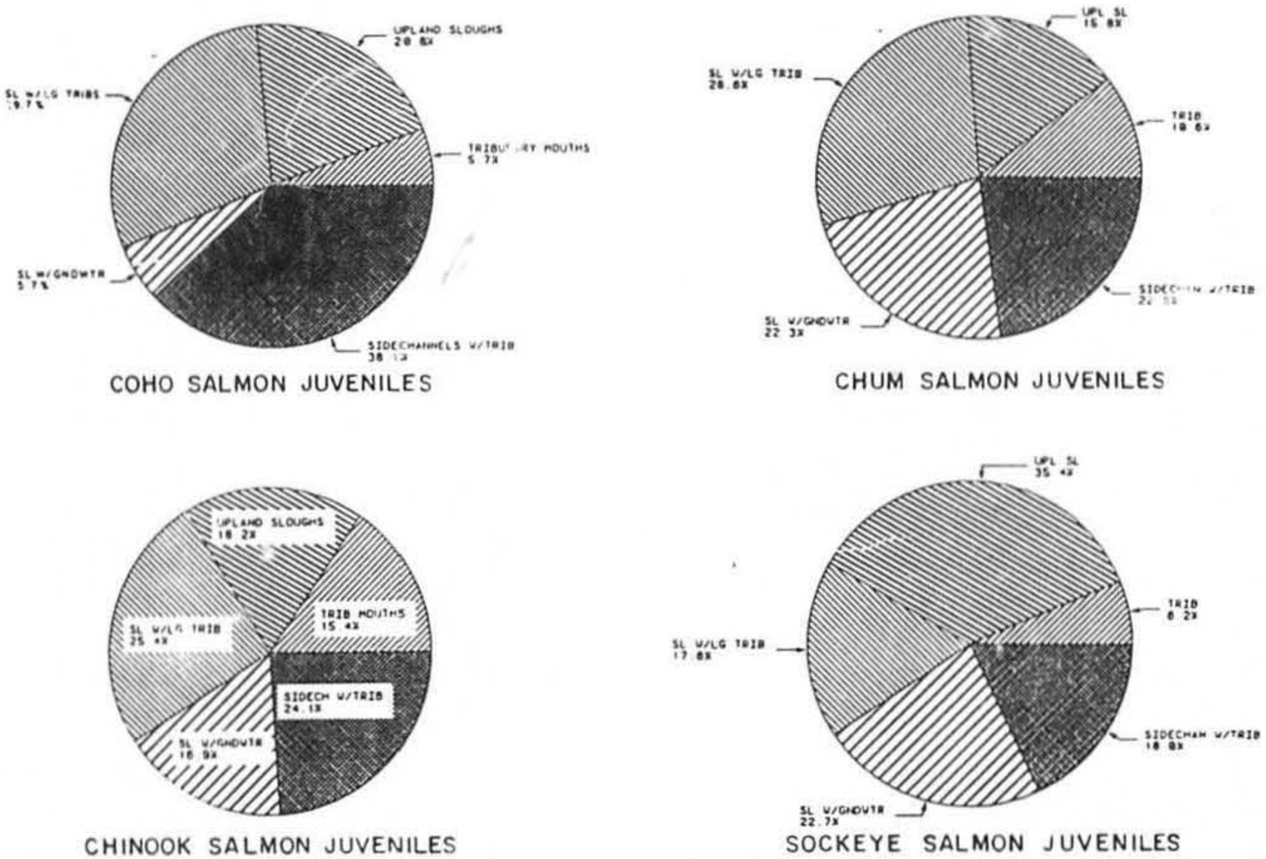
An examination of juvenile salmon species proportions at each of the five major habitat types (Appendix Figure G-2) shows that each habitat type had a rather distinctive community of juvenile salmon. Chi-square tests were not performed on these proportions.

Resident Species

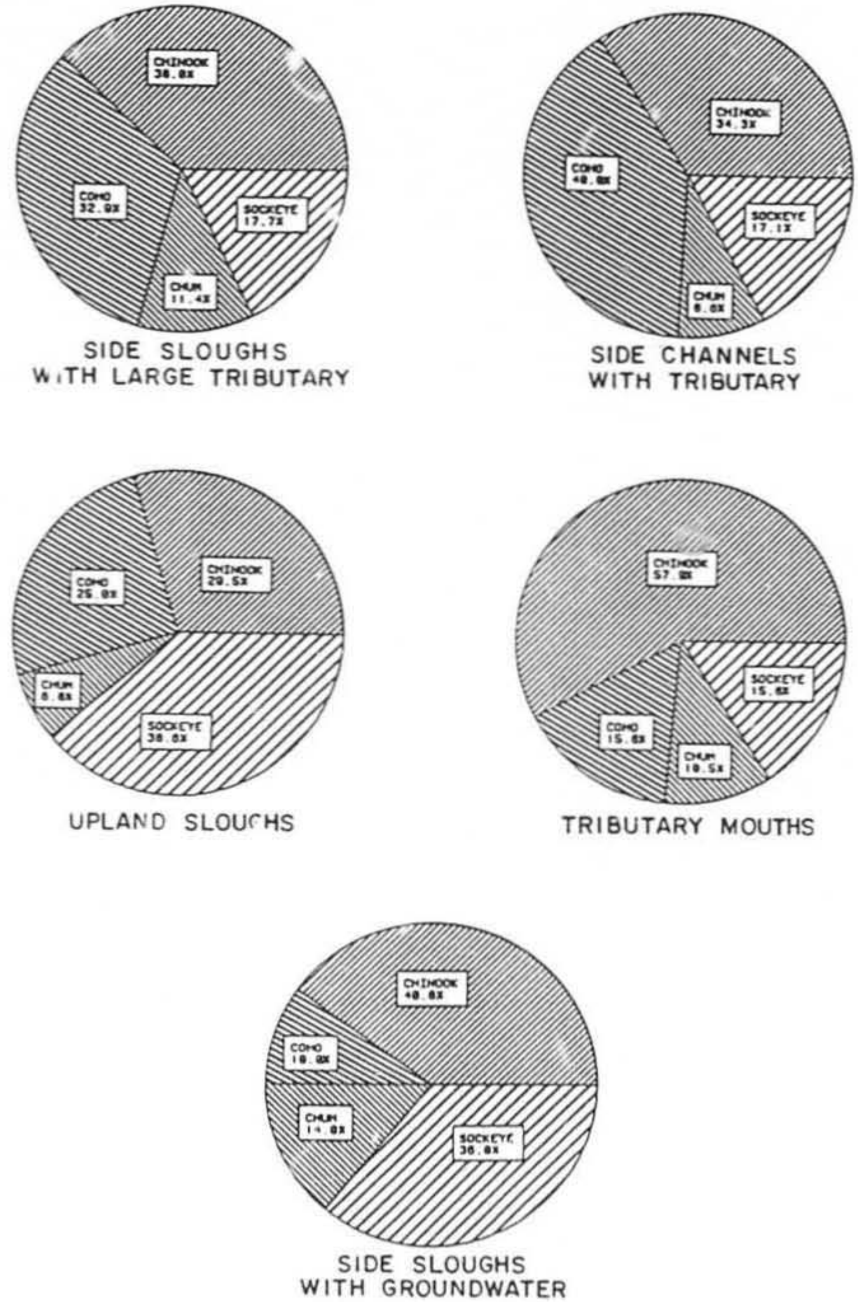
Boat electrofishing catch data were used to characterize species proportions of the resident fish community at five different habitat types of the Susitna River at sites both above and below the Chulitna River confluence (Appendix Table G-5). After less abundant species were pooled to increase sample sizes, species proportions between habitat types were tested, using actual numbers from catch data, with chi-square analysis and found to be significantly different (Appendix Table G-6). The seasonal differences in species proportions at mainstem and tributary sites were also significantly different (Appendix Table G-6).

Appendix Table G-4. Ratios of observed to expected presence of coho and sockeye salmon juveniles at five different habitat types at DFH sites, June through September, 1982. Based on results presented in Appendix Table G-3.

Habitat type	Coho	Sockeye
Tributary	0.29	0.36
Upland Slough	1.07	1.46
Side Slough with large tributary	1.53	0.78
Side Slough w/o large tributary	0.35	1.25
Side channel with tributary	1.96	0.92



Appendix Figure G-1. Distribution of juvenile salmon by species among the major habitat types at DFH sites, June through September, 1982. Based on the number of times the species was present as a percentage of the total number of times the sites were sampled. Effort by all gear types included. Percentages corrected for unequal sampling effort at the different habitat types.



Appendix Figure G-2. Proportions of juveniles of four species of salmon at each of five major habitat types located on the Susitna River, June through September, 1982. Based on the number of times the species was present as a percentage of the total number of times the sites were fished. Effort by all gear types included. Percentages corrected for unequal sampling effort at the different habitat types. Chum percentages are low because chums were not present in the Susitna system for the entire sampling season.

Appendix Table G-5. Resident species percentages by habitat type and by season within two habitat types at sites boat-electrofished between Cook Inlet and Devil Canyon, May through September 1982.

	No. of Resident Fish Captured	Percentage by Species						
		Rainbow	Arctic Grayling	Burbot	Round Whitefish	Humpback Whitefish	Longnose Sucker	Other
Habitat Type								
Mainstem	1057	2.4	20.2	7.2	30.9	3.3	30.7	5.2
Tributary mouths	1494	5.0	28.6	2.1	38.5	2.9	18.5	4.4
Upland sloughs	263	3.8	12.9	2.7	30.0	12.5	33.8	4.2
Side sloughs without trib	119	5.9	18.5	1.7	47.1	5.0	16.8	5.0
Side sloughs w/large tribs	377	5.6	19.4	2.1	19.4	2.4	47.5	3.7
Mainstem								
Month								
May-June	347	2.9	30.8	2.9	38.9	1.2	14.1	9.2
July-August	356	0.8	8.7	14.3	23.0	5.6	43.0	4.5
September	354	3.4	21.5	4.5	31.1	3.1	34.5	2.0
Tributary								
Month								
May-June	599	4.3	29.4	1.3	42.2	3.0	15.2	4.5
July-August	509	1.0	30.1	4.1	34.4	3.5	20.0	6.9
September	386	11.1	25.4	0.8	38.1	2.1	21.8	0.8

Appendix Table G-6. Comparison of species proportions of resident fish (rainbow trout, round whitefish, Arctic grayling, longnose sucker, and other) between habitat types and by season within each habitat type, May through September, 1982.

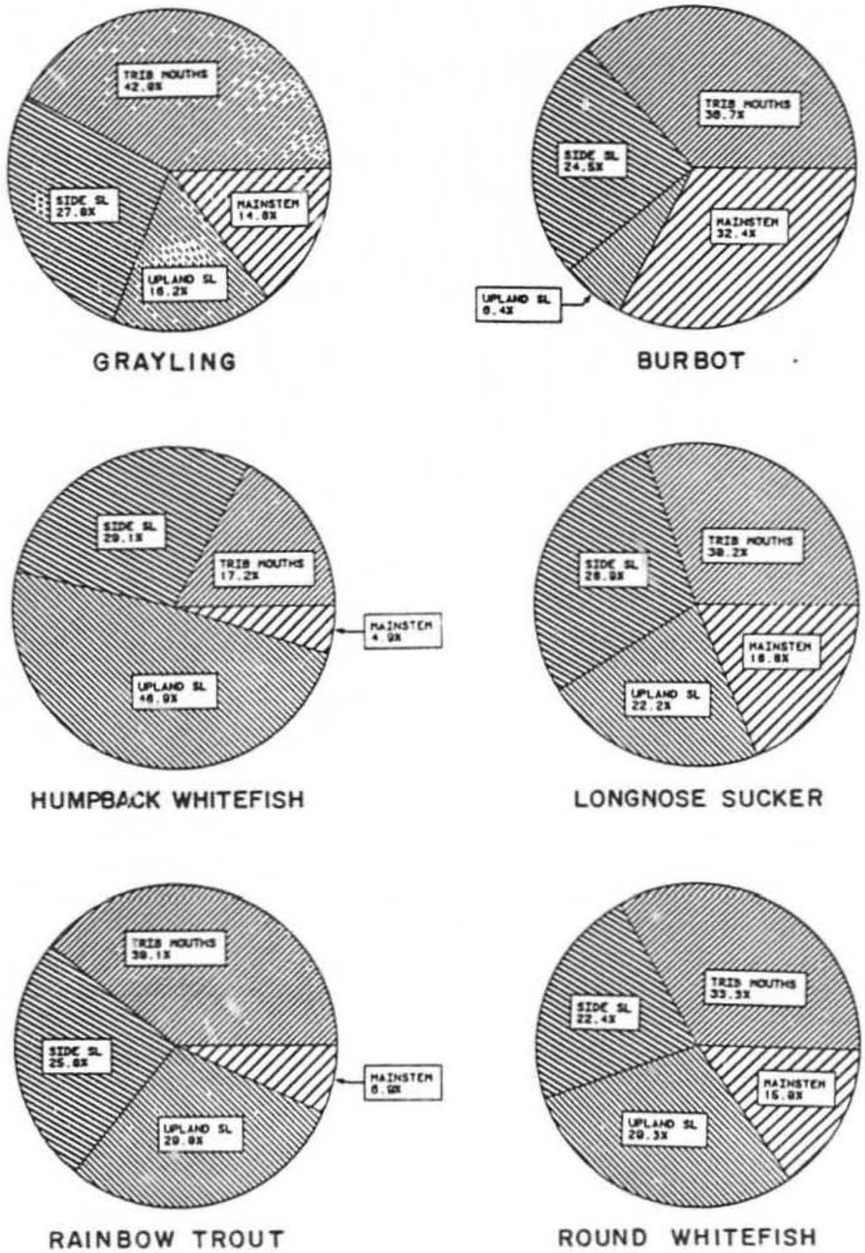
1 - Upland Sloughs
2 - Side Sloughs
3 - Mainstem
4 - Trib
5 - Slough w/tributary

Comparison	Chi-square	df	Significance level
1 vs 2 vs 3 vs 4 vs 5	244.0	16	$p < .01$
1 vs 2	20.4	4	$p < .01$
4 vs 5	145.5	4	$p < .01$
By season for mainstem sites:			
May-Jun vs Jul-Aug vs Sept	139.7	8	$p < .01$
By season for Trib sites:			
May-Jun vs Jul-Aug vs Sept	87.3	8	$p < .01$

Resident species proportions at tributary, side slough, upland slough, and mainstem sites above the Chulitna River confluence were further examined with presence/absence data collected with boat electrofishing gear for six species of resident fish. The relative distribution of each species among the four major habitat types is illustrated in Appendix Figure G-3.

Differences in species presence/absence at the four different habitat types above the confluence were tested for seven species of resident fish. If necessary, habitat types were pooled to increase sample sizes. Significant differences in habitat use were found for all except burbot (Appendix Table G-7). Ratios of observed to expected use of the various habitat types by species (only for those that were significantly different) are presented in Appendix Table G-8. A few seasonal differences in species use of a given habitat type were also significant (Appendix Table G-9). In July and August, use of a given habitat type was often lower than in May, June and September (Appendix Table G-10).

In another series of tests, resident fish distribution among five different habitat types at the 17 DFH sites were examined using catch data collected with beach seines and backpack electrofishing gear (Appendix Table G-11). Of the four species of resident fish examined, only Arctic grayling showed significant differences in their use of different habitat types. Arctic grayling were present at tributary sites relatively more than they were present at sloughs.



Appendix Figure G-3. Relative distribution of six resident species among four major habitat types located above the Chulitna River confluence and sampled by boat electrofishing, May through September, 1982. Based on presence/absence data which were corrected for unequal effort at the different habitat types.

Appendix Table G-7. Chi-square tests of resident fish presence/absence associations among four major habitat types at sites above the Chulitna River confluence sampled by boat electrofishing. The four habitat types were tributaries, upland sloughs, side sloughs with no large tributaries, and mainstem sites, May through September, 1982.

Species	Chi-square	df	Significance level
Round whitefish	38.5	3	$p < .01$
Arctic grayling	46.0	3	$p < .01$
Longnose sucker	9.5	3	$p < .05$
Burbot	4.7	3	NS
Humpback whitefish	32.3	3	$p < .01$
Rainbow trout[a]	31.5	2	$p < .01$
Dolly varden[b]	7.5	1	$p < .01$

[a] Upland and side sloughs were pooled due to small sample size

[b] Tributaries and mainstem only. No Dolly Varden were captured in upland or side sloughs.

Appendix Table G-8. Ratios of observed to expected presence of resident fish by species at four different habitat types on the Susitna River between the Chulitna River and Devil Canyon, May through September, 1982. Only for those chi-square tests which were statistically significant.

	Round Whitefish	Arctic Grayling	Longnose Sucker	Humpback Whitefish
Tributaries	1.62	1.94	1.36	1.22
Side sloughs	1.08	1.25	1.30	2.04
Upland sloughs	1.42	0.75	1.00	3.45
Mainstem	0.73	0.69	0.85	0.50

	Dolly Varden
Tributaries	2.42
Mainstem	0.52

(No Dolly Varden were captured in upland or side sloughs)

	Rainbow
Tributaries	2.31
Upland & Side Sloughs (pooled)	1.61
Mainstem	0.41

Appendix Table G-9. Chi-square tests of seasonal associations of resident fish presence within a major habitat type at sites above the Chulitna River confluence which were boat electrofished, May through September, 1982.

Species	Chi-square	df	Significance Level
Rainbow			
within tributaries: Spring (May, Jun) & Fall (Sep) vs Summer (Jul, Aug)	7.4	1	$p < .01$
Grayling			
within tributaries: Spring & Fall vs Summer	0.5	1	NS
within side sloughs & upland sloughs: Spring & Fall vs Summer	3.3	1	NS
within mainstem sites: Spring & Fall vs Summer	14.5	1	$p < .01$
Round Whitefish			
within tributaries: Spring & Fall vs Summer	0.1	1	NS
within side sloughs & upland sloughs: Spring & Fall vs Summer	0.7	1	NS
within mainstem sites: Spring vs Summer vs Fall	36.6	2	$p < .01$
Longnose Sucker			
within tributaries: Spring & Fall vs Summer	1.2	1	NS
within side sloughs & upland sloughs: Spring & Fall vs Summer	0.1	1	NS
within mainstem sites: Spring vs Summer vs Fall	15.5	2	$p < .01$
Burbot			
within tributaries: Spring & Summer vs Fall	0.0	1	NS
within mainstem sites: Spring & Summer vs Fall	0.0	1	NS

Appendix Table G-10. Ratios of observed to expected presence of resident fish by season at sites above the Chulitna River confluence which were boat-electrofished, May through September, 1982. Only those ratios from significant chi-square tests are presented.

Species	Season	Obs/Exp
Rainbow Tributaries	Spring & Fall	1.5
	Summer	0.5
Grayling Mainstem	Spring & Fall	1.6
	Summer	0.6
Round Whitefish Mainstem	Spring	2.7
	Summer	0.6
	Fall	1.2
Longnose Sucker Mainstem	Spring	2.1
	Summer	0.7
	Fall	1.1

Appendix Table G-11. Chi-square tests of resident fish presence/absence associations among five major habitat types (the same as those used in Appendix Table G-3) at DFH sites, May through September, 1982. Only catch data from beach seining or backpack electrofishing were used.

Species	Chi-square	df	Significance Level
Round whitefish	8.6	4	NS
Arctic grayling[a]	6.9	1	$p < .01$
Longnose sucker[a]	0.4	1	NS
Slimy Sculpin	6.9	4	NS

[a] Sites were pooled into tributary mouths versus sloughs because of small sample size.

DISCUSSION

Juvenile Salmon

Chinook salmon juveniles apparently show less preference for particular major habitat types than the other species and are more broadly distributed.

No significant association of juvenile chum salmon with any of the five major habitat types was demonstrated; this was probably a result of the relatively short time chum juveniles are present in the Susitna system. Because most chums have outmigrated by the end of July, there were only four or five possible sampling periods that they could have been present, as opposed to eight periods for the other species.

Coho salmon juveniles showed a definite preference for side sloughs with large tributary mouths and side channels with large tributary mouths. This results from their preference for tributary water as demonstrated in Appendix F of this report. Sockeye salmon juveniles exhibited a strong preference for upland sloughs and side sloughs not associated with tributary mouths. Possibly many did not move from their natal areas (sloughs) to other habitat types.

The attractiveness of different major habitat types for juvenile salmon can be seen from examining Appendix Figure G-2. Sites that include large tributary mouths (both sloughs and side channels) attract chinook and coho salmon. Side sloughs without large tributary mouths attract chinook and sockeye.

Resident Species

Definite major habitat type preferences were demonstrated for all species except burbot. Burbot have a strong preference for turbid water (see Appendix F), but this was not established with the present analysis probably because all of the sampling sites included areas of turbid water.

Of the six species examined, longnose suckers showed the least preference for certain habitat types (the chi-square test for longnose sucker was significant at the 95% level, but not at the 99% level). Arctic grayling preferred tributary mouths and side sloughs over upland sloughs and the mainstem. Rainbow trout and Dolly Varden mainly used tributary mouths. Round whitefish were most likely to be found in tributary mouths and upland sloughs and humpback whitefish preferred sloughs.

Additionally, seasonal differences in habitat use were demonstrated for rainbow trout, Arctic grayling, round whitefish, and longnose suckers. Rainbow trout were more likely to be found at tributary mouths in the spring and fall than in the summer. This probably results from migration patterns into and out of tributaries.

Arctic grayling, round whitefish, and longnose suckers were all more likely to be found in the mainstem in the spring and fall than in the summer. These species apparently use tributaries and sloughs in the summer, the mainstem in the spring and fall during migrations, and the mainstem in the winter as over-wintering habitat.

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APPENDIX H

Habitat Relationships of Juvenile Salmon Outmigration

APPENDIX H

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INTRODUCTION

This appendix presents an analysis of the relationships between the outmigration timing of juvenile salmon and environmental variables for the Susitna River between the Chulitna River confluence and Devil Canyon. The purpose is to evaluate how environmental factors influence the outmigration of juvenile salmon. The proposed hydroelectric project will change the timing and magnitude of several environmental parameters. If the effect of these changes on the outmigration of juvenile salmon can be predicted, subsequent effects on the production of juvenile salmon by this reach of river can be better analyzed.

METHODS

Parameters examined included mainstem discharge, water temperature, turbidity and photoperiod. Time of season, which integrates and sums other parameters such as photoperiod, water temperature and fish size, was also examined. The variation in size (mean length) of the juvenile salmon species was also examined as a factor influencing outmigration. The catch data for this appendix came from an outmigrant trap located at Susitna river mile 103.0, 4.5 miles above the Chulitna River confluence. The trap was operated from June 18 to October 12, 1982. Details of the methods used to operate the trap and the results are outlined in the Basic Data Report (ADF&G 1983a). Capture rates of juveniles of four species of salmon (chinook, coho, sockeye, and chum) were analyzed.

Juvenile pink salmon were not captured in large enough numbers to draw any conclusions about this species.

Discharge levels are the provisional data taken by the U.S. Geological Survey at the Gold Creek station. To obtain water temperatures representative of the area from which the juvenile salmon were migrating, most of the mainstem water temperature data were obtained from a continuous temperature recorder located at Curry (river mile 120.7), 17.7 miles above the outmigrant trap location (ADF&G 1983b). Since this recorder was not operated for the entire season, data were taken from recorders located at river miles 130.0 and 113.0 for the periods from June 24 to July 6 and from October 1 to 12, respectively. Data for June 18 to 24 were extracted from temperatures recorded by fish distribution crews at sites upstream of the trap. Turbidity readings were taken at the trap location (ADF&G, 1983a) only from August 14 to the end of the season. Day length information was obtained from the National Weather Service. Time of season was computed as the number of days from the first day (June 18) the outmigrant trap began fishing.

Mean length for each species (age 0+ only) was calculated by summing the daily catches of fish until a sample size of at least 25 fish was obtained, and then taking the mean length of these fish. In some cases, it took only one day to get a sample size of at least 25, and in other cases, it took several days. The number of fish caught in this period was divided by the number of hours that the trap was fished to obtain an overall catch/hour. The median date during the period was used as the time marker.

Outmigration timing was examined using catch/hour data taken on a daily basis for each of the four species of juvenile salmon. Age classes were not separated. The relationship of these data to the habitat variables was examined through the use of linear regression using one or multiple independent (habitat) variables and correlation analysis (Snedecor and Cochran 1967). Because the catch/hour data were quite variable from day to day, various data manipulations, including moving averages, exponential smoothing, time lags, and logarithmic transformations, were performed. We also used first-difference regressions, in which change (on a daily basis in our case) in a dependent variable is regressed against the daily change in an independent variable (Summers et al. 1981). This has the advantage that any existing cause/effect relationships can be detected without problems caused by differences in relative magnitude.

RESULTS

Habitat Variables

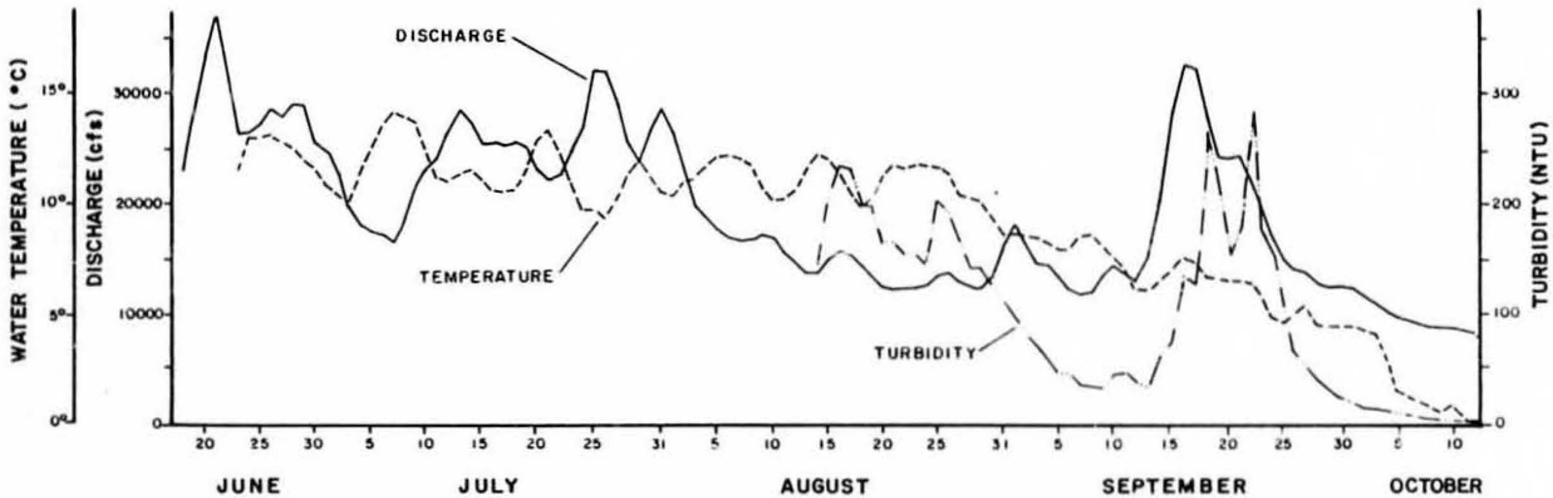
The mean and range for the physicochemical variables are summarized in Appendix Table H-1. The pattern of water temperature was exactly opposite that of the discharge pattern during the middle part of the season, but during the early and late part of the season, water temperature more closely paralleled discharge (Appendix Figure H-1). Turbidity fluctuations lagged discharge by two or three days. Day length (Appendix Table H-2) remained at 24 hours/day from the beginning of the

Appendix Table H-1. Range and mean for habitat variables and juvenile salmon catch/hour, outmigrant trap, June 18 - October 12, 1982.

	min	max	mean	n
Discharge (ft^3/sec)	7,950	37,000	19,225	104
Water temperature (°C)	0.5	14.1	9.2	104
Turbidity (NTU)[a]	8	284	103	51
Daylength (hrs)	11.8	24.0	18.4	104
Catch/hour				
chinook	0.0	1.2	0.2	104
coho	0.0	19.5	0.7	104
sockeye	0.0	16.2	1.2	104
chum[b]	0.0	10.0	0.6	55

[a] Aug 14 - Oct 12 only

[b] Jun 18 - Aug 15 only



Appendix Figure H-1. Variation of Susitna River mainstem environmental variables above the Chulitna River confluence from June 18 to October 12, 1982. See text for exact source of data.

Appendix Table H-2. Civil twilight at Talkeetna, Alaska
(Source: National Weather Service)

Date	Daylength (hours)	Date	Daylength (hours)	Date	Daylength (hours)
June 18	24.0	August 01	19.8	September 14	14.6
June 19	24.0	August 02	19.7	September 15	14.5
June 20	24.0	August 03	19.5	September 16	14.4
June 21	24.0	August 04	19.4	September 17	14.3
June 22	24.0	August 05	19.3	September 18	14.2
June 23	24.0	August 06	19.1	September 19	14.1
June 24	24.0	August 07	19.0	September 20	14.0
June 25	24.0	August 08	18.9	September 21	13.9
June 26	24.0	August 09	18.7	September 22	13.8
June 27	24.0	August 10	18.6	September 23	13.7
June 28	24.0	August 11	18.5	September 24	13.6
June 29	24.0	August 12	18.4	September 25	13.5
June 30	24.0	August 13	18.2	September 26	13.4
July 01	24.0	August 14	18.1	September 27	13.3
July 02	24.0	August 15	18.0	September 28	13.2
July 03	24.0	August 16	17.9	September 29	13.1
July 04	24.0	August 17	17.7	September 30	13.0
July 05	24.0	August 18	17.6	October 01	12.9
July 06	24.0	August 19	17.5	October 02	12.8
July 07	24.0	August 20	17.4	October 03	12.7
July 08	24.0	August 21	17.3	October 04	12.6
July 09	24.0	August 22	17.2	October 05	12.5
July 10	24.0	August 23	17.0	October 06	12.4
July 11	24.0	August 24	16.9	October 07	12.3
July 12	24.0	August 25	16.8	October 08	12.2
July 13	24.0	August 26	16.7	October 09	12.1
July 14	23.7	August 27	16.6	October 10	12.0
July 15	23.0	August 28	16.5	October 11	11.9
July 16	22.7	August 29	16.3	October 12	11.8
July 17	22.4	August 30	16.2		
July 18	22.2	August 31	16.1		
July 19	22.0	September 01	16.0		
July 20	21.8	September 02	15.9		
July 21	21.6	September 03	15.8		
July 22	21.4	September 04	15.7		
July 23	21.2	September 05	15.6		
July 24	21.0	September 06	15.5		
July 25	20.9	September 07	15.4		
July 26	20.7	September 08	15.3		
July 27	20.6	September 09	15.2		
July 28	20.4	September 10	15.0		
July 29	20.3	September 11	14.9		
July 30	20.1	September 12	14.8		
July 31	20.0	September 13	14.7		

sampling season until mid-July, after which it steadily declined, usually by no more than 0.2 hours/day, to 11.8 hours/day on October 12.

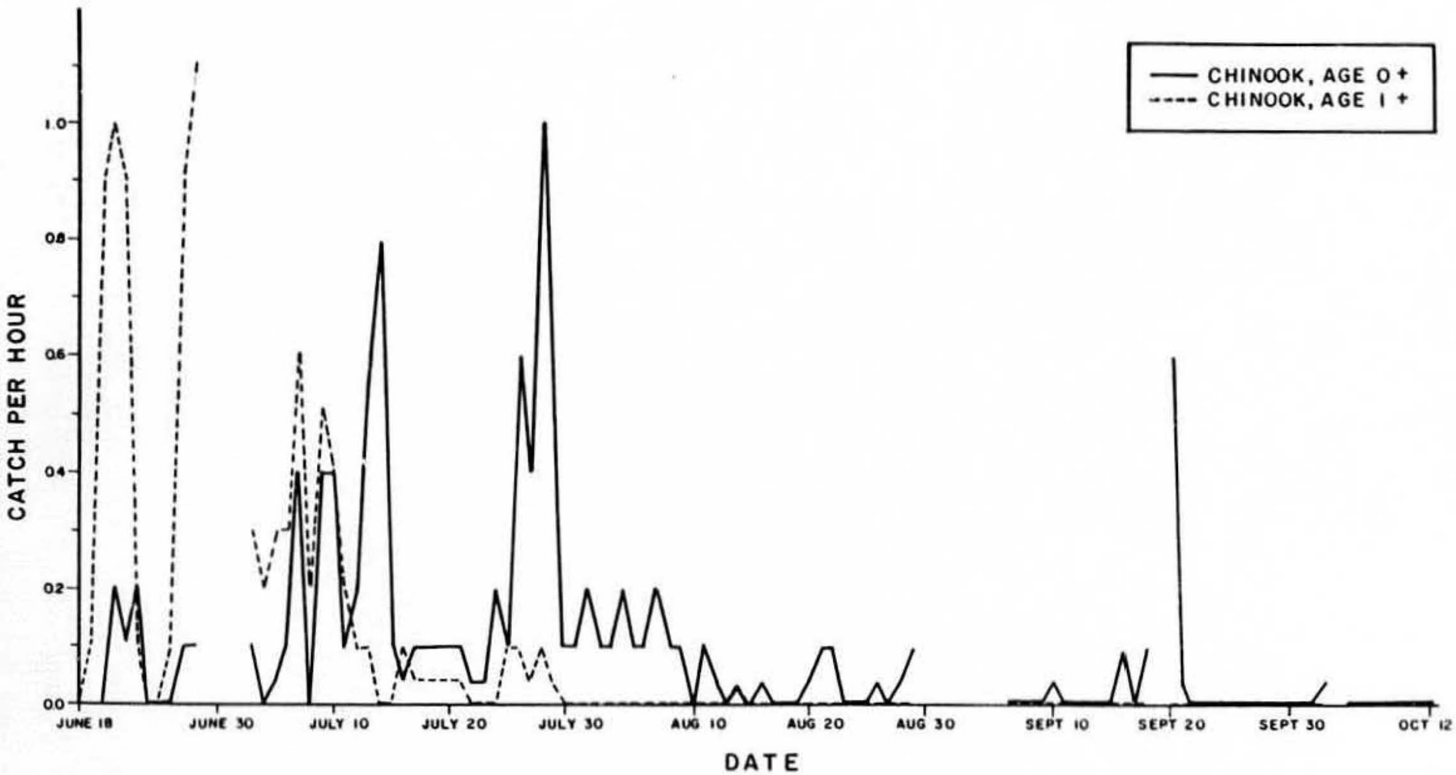
Except for a peak in mid-September, discharge generally declined over the course of the season. The correlation coefficient (r) between discharge and time of season was -0.65, $p < 0.01$. Temperature also generally decreased with time of season ($r = -0.83$, $p < 0.01$). The correlation between discharge and water temperature was highly significant ($p < 0.01$) but relatively low ($r = 0.42$). This correlation was not improved by lagging water temperature one day behind discharge.

Juvenile Salmon Catch - All Species

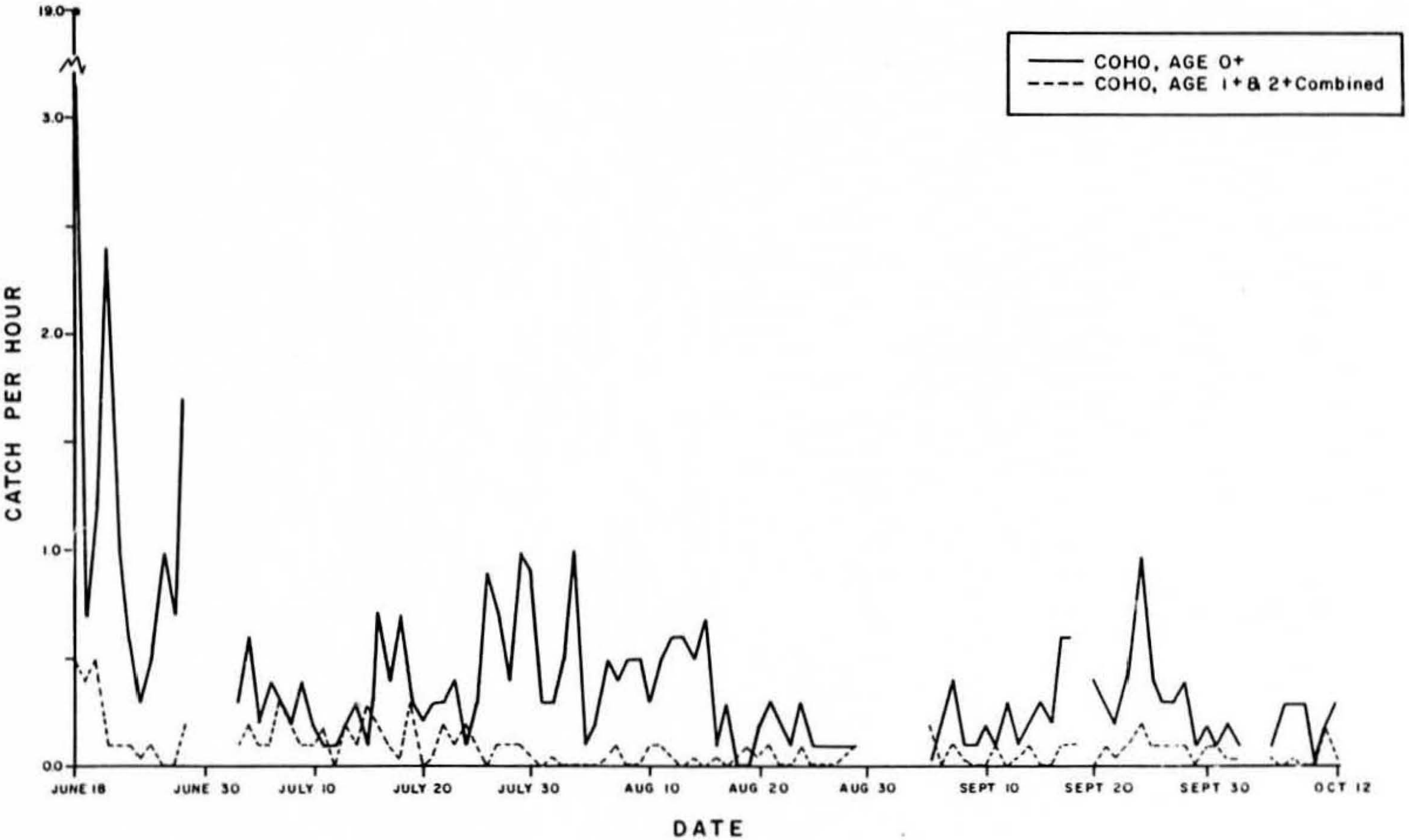
The catch/hour for the four species of juvenile salmon was initially relatively high and then declined over the course of the season (Appendix Figures H-2, H-3, and H-4). Appendix Table H-1 gives the range and mean catch/hour observed for each species.

Generally, a highly significant ($p < 0.01$) relationship was found between catch/hour for each individual species and the physical variables, but correlation coefficients were usually not very high.

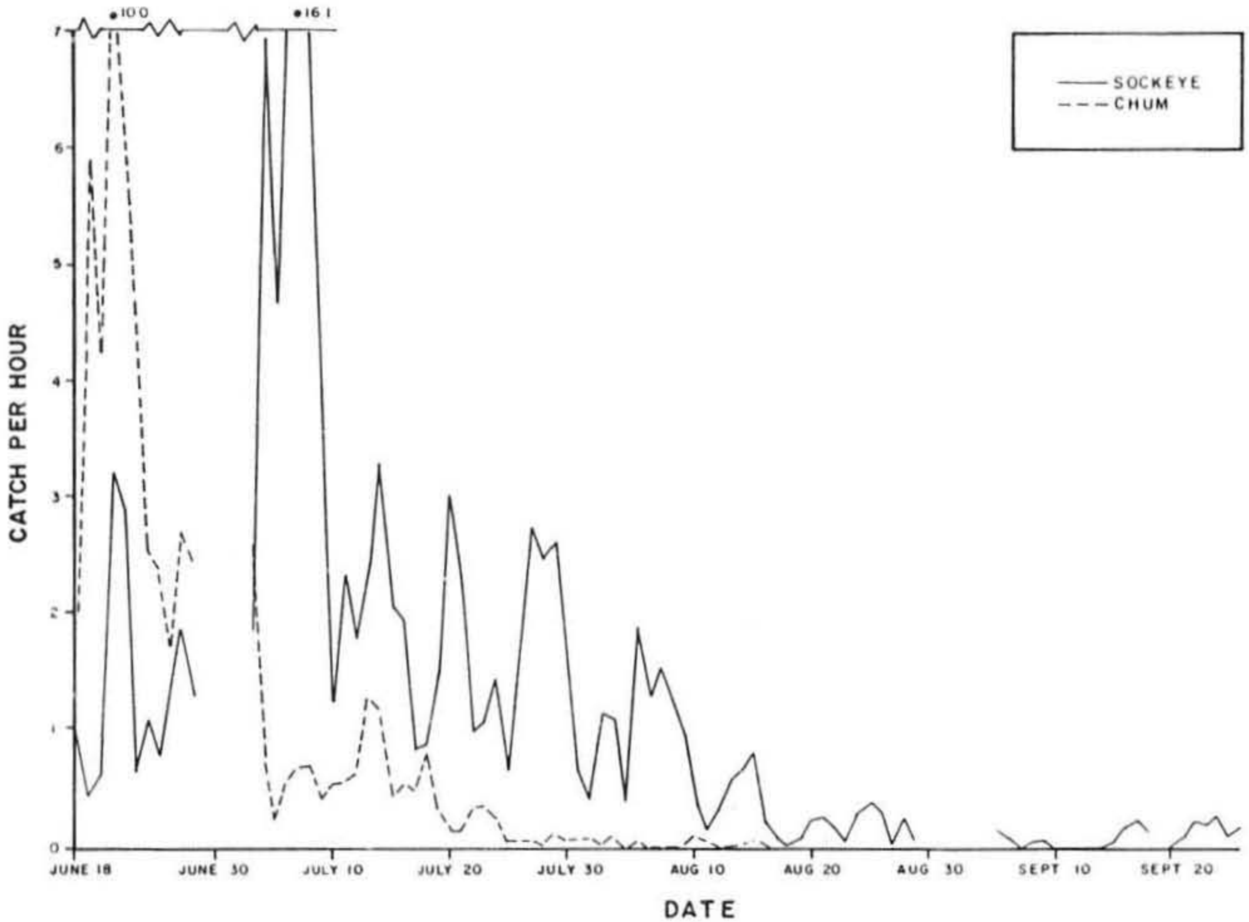
Correlations with turbidity were not calculated because turbidity data were available only after August 14. During this period, turbidity generally appeared to be closely related to discharge, so any correlation that existed between catch/hour and discharge would most likely also exist between catch/hour and turbidity.



Appendix Figure H-2. Catch per hour for Age 0+ and Age 1+ chinook salmon at the outmigrant trap, June 18 to October 12, 1982.



Appendix Figure H-3. Catch per hour for Age 0+ and Age 1+ and 2+ combined coho salmon at the outmigrant trap, June 18 to October 12, 1982.



Appendix Figure H-4. Catch per hour for juvenile sockeye and chum salmon at the outmigrant trap, June 18 to October 12, 1982.

The catch per hour for all species of salmon was summed to determine if there was a dominant factor influencing all species. This total was related to time of season ($r = -.69$, $p < 0.01$) and to daylength ($r = 0.67$, $p < 0.01$), but the correlations of total catch per hour with discharge and water temperature were low.

Juvenile Chinook Salmon

The majority of age 1+ chinook salmon outmigrated in June and early July (Appendix Figure H-2). The peak outmigration for age 0+ chinook occurred in July after the peak for the age 1+ fish.

There was a moderate correlation of juvenile chinook salmon catch/hour with discharge ($r = 0.56$, $p < 0.01$). The correlation was not improved by lagging catch/hour one day behind discharge or using a logarithmic transformation of both variables. A first-difference regression between catch/hour and discharge gave a poor correlation. The correlation of catch/hour with time of season was slightly higher than the one with discharge. The best coefficient of determination ($r^2 = 0.64$, $p < 0.01$) was obtained by regressing the three day moving average of catch/hour versus time of season and temperature. This equation took the form: moving average of catch/hour = 0.93 - 0.01 (time of season) - 0.03 (temperature). Most of the variation in moving average which was accounted for was explained by time of season.

Outmigrating age 0+ chinooks showed two pulses in catch/hour - one at a mean length of 50 mm and one at a mean length of 60 mm (Appendix Figure

H-5). The 60 mm pulse occurred prior to the 50 mm pulse. Relatively large numbers of 50 mm fish outmigrating near the end of July depressed the plot of mean length at that time.

Juvenile Coho Salmon

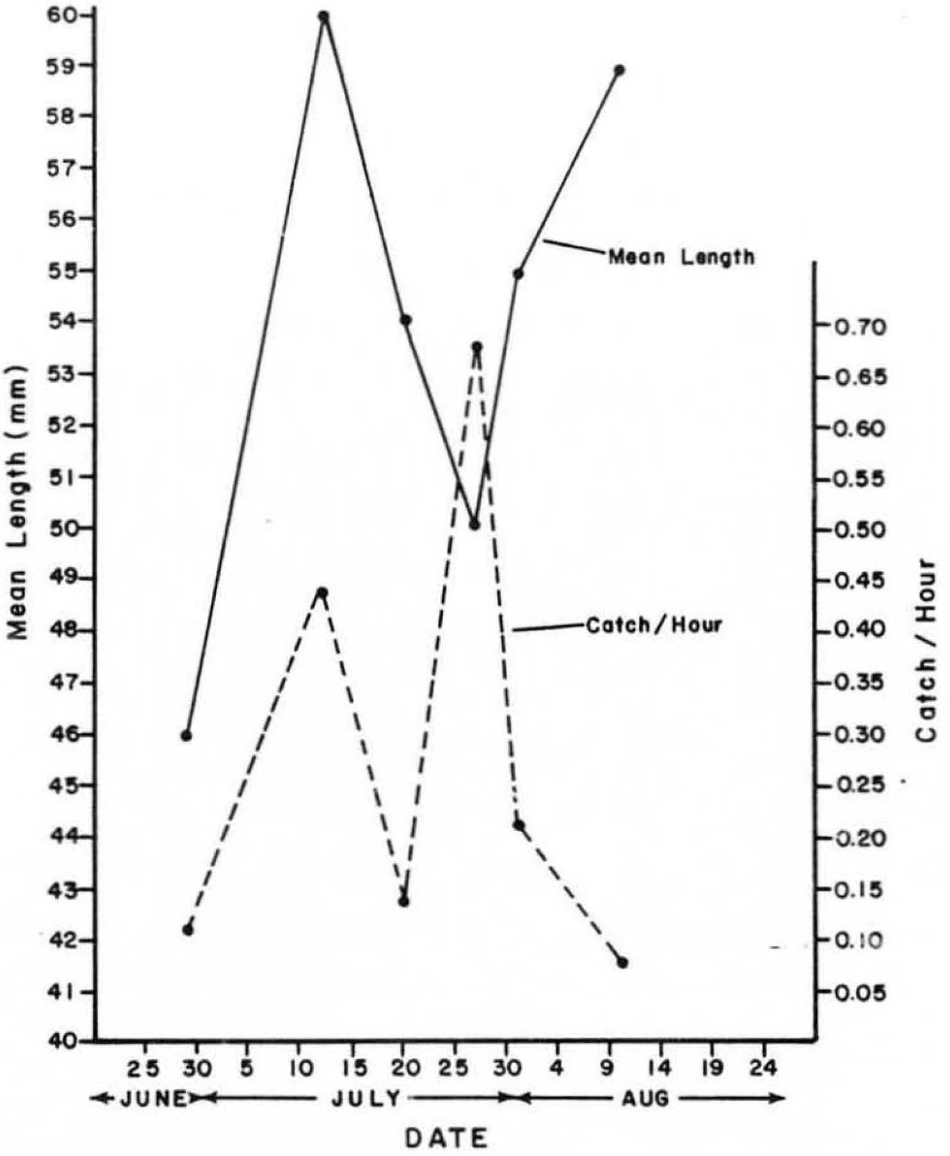
Coho salmon outmigrated in a more consistent manner throughout the season than the other species (Appendix Figure H-3). This was especially true with the age 1+ and age 2+ coho, which showed a marked contrast with the pattern of age 1+ chinook salmon.

The relationships of juvenile coho salmon catch/hour with discharge and time of season were highly significant ($p < 0.01$), but the correlations were modest. These correlations were not much improved by data lags or transformations. The first-difference regression between catch/hour and discharge yielded a poor relationship. The relationship of catch/hour with temperature was not significant.

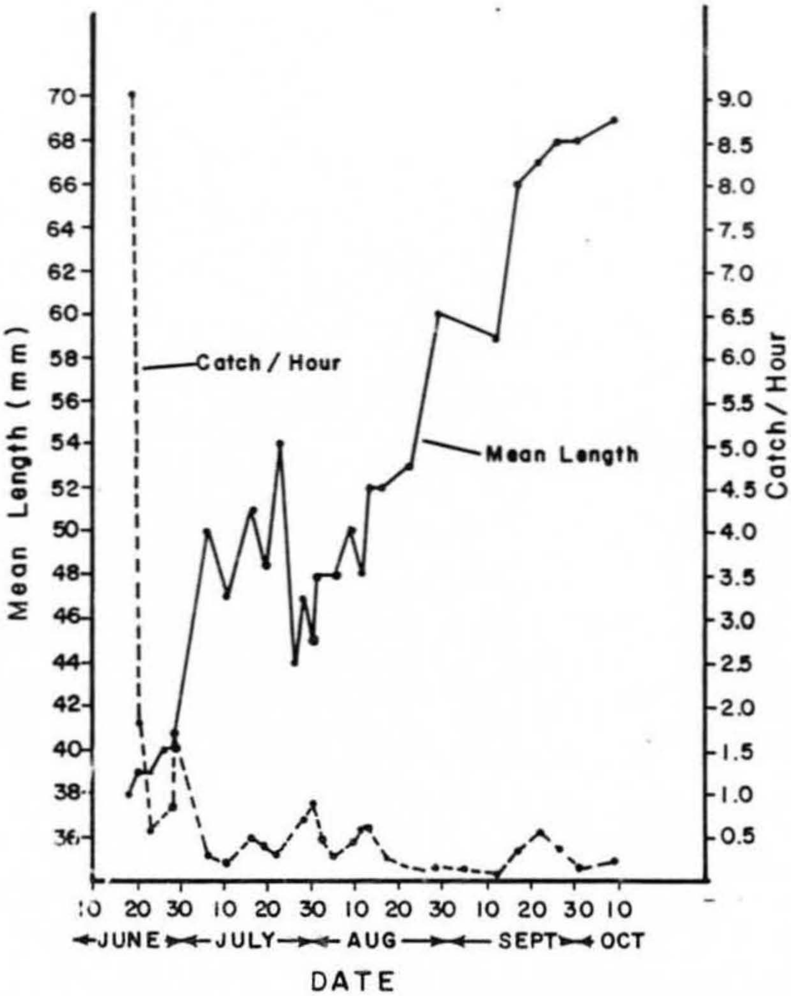
The highest catch/hour for age 0+ coho usually occurred at the smaller size classes (Appendix Figure H-6). Decreases in mean length generally were related to increases in catch/hour.

Juvenile Sockeye Salmon

The correlation of juvenile sockeye salmon catch per hour with discharge was poor and was not improved by time lags, by using a moving average, or by performing a first-difference regression. There was a modest



Appendix Figure H-5. Relationship of mean length and catch per hour for age 0+ chinook salmon captured at the outmigrant trap.



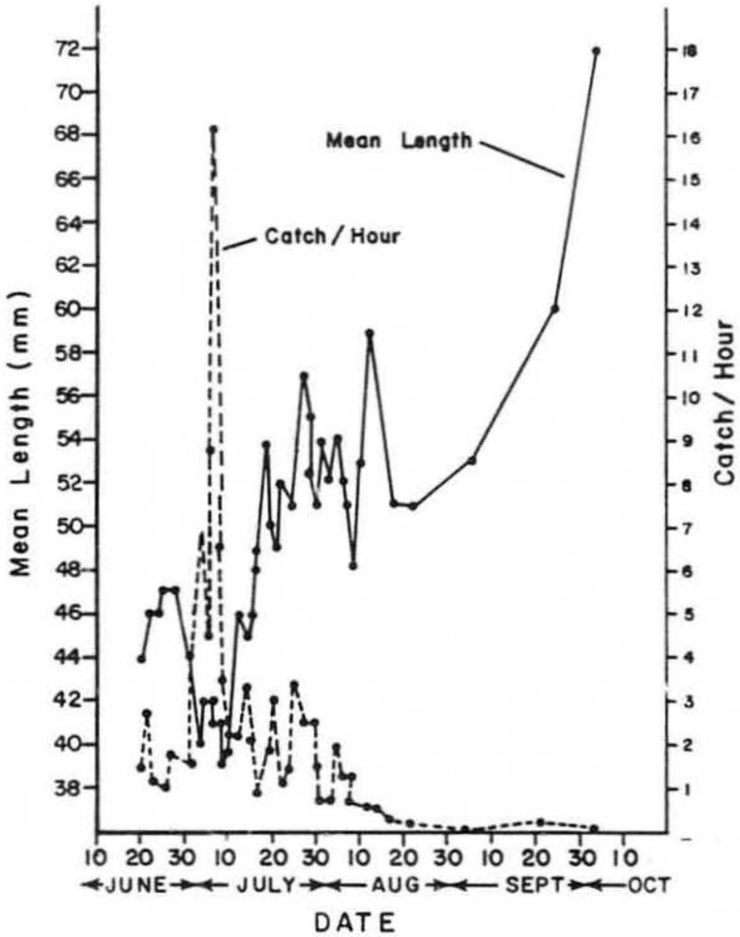
Appendix Figure H-6. Relationship of mean length and catch per hour for age 0+ coho salmon captured at the outmigrant trap.

correlation with time of season. A logarithmic transformation of the catch/hour gave fairly good correlations with time of season ($r = -0.82$, $p < 0.01$) and temperature ($r = 0.71$, $p < 0.01$).

The mean length/catch per hour relationship for age 0+ sockeye salmon was similar to that of age 0+ coho salmon (Appendix Figure H-7) and had a correlation coefficient of $r = -0.53$, $p < 0.01$. The highest catch/hour, occurring in early July, was related to a sharp decrease in the mean length.

Juvenile Chum Salmon

The last juvenile chum salmon was captured on August 15, so only those sampling days from June 18 to August 15 (55 cases) were included in the analysis. The strongest factor relating to catch/hour was time of season ($r = -0.71$, $p < 0.01$). The relationship of catch/hour with discharge was modest and the relationship with temperature was poor. Logarithmic transformation of catch/hour provided no further insight. A first-difference regression of catch/hour with discharge gave inconclusive results. Using the three day moving average of catch/hour in a multiple regression against time of season and daily difference in discharge "explained" the most variation in catch/hour ($r^2 = 0.72$, $p < 0.01$). The equation for this regression is: moving average of chum catch/hour = 3.34 - 0.07 (time of season) + 1.30 (daily change in discharge/10^4). Most of the variation in the moving average was accounted for by time of season.

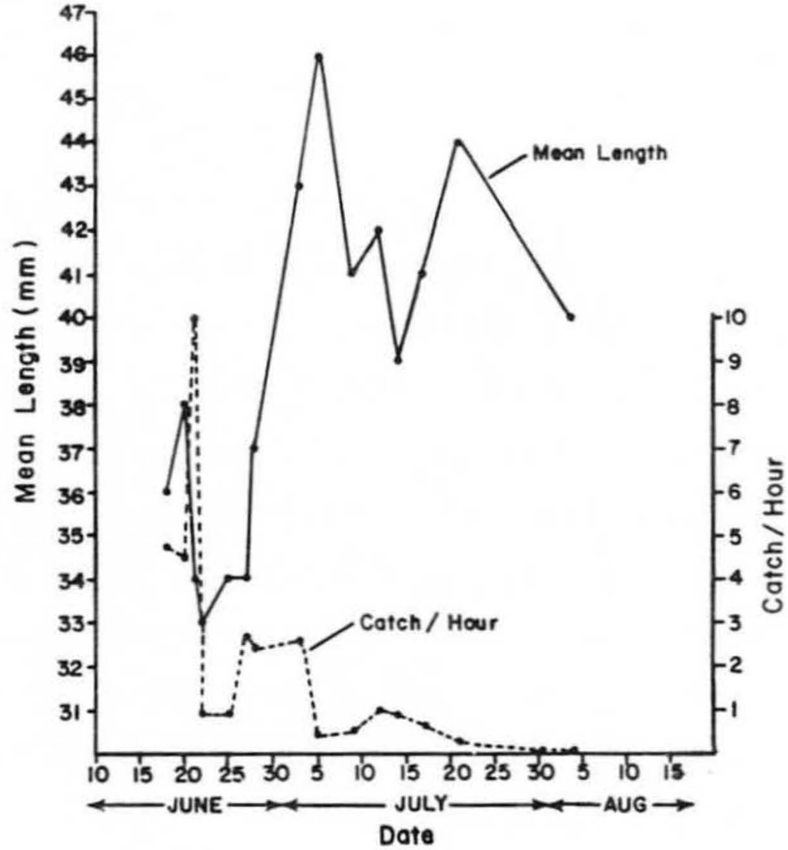


Appendix Figure H-7. Relationship of mean length and catch per hour for age 0+ sockeye salmon captured at the outmigrant trap.

The pattern of catch/hour and mean length was not as clear for chum salmon as it was for the other species (Appendix Figure H-8), but generally, the highest catch/hour occurred early in the season when the mean length was low. When the largest fish were outmigrating, the catch/hour was low.

DISCUSSION

Catch/hour for all species generally declined with time (Appendix Figures H-2, H-3, H-4). Levels of the environmental variables (discharge, water temperature, and daylength) also generally decreased over the course of the season (Appendix Figure H-1, Appendix Table H-2). These two facts alone would probably lead to reasonable correlation coefficients between habitat variables and catch/hour. However, the real question is whether there is a cause-effect relationship between them or whether the correlation is simply coincidental. It may be that the fish are merely outmigrating in response to time of season. Evolution has coded juvenile salmon to outmigrate when conditions (discharge, water temperature, timing of plankton blooms in the estuary, and so on) are most likely to be favorable. Given this, the objective of this study has been to determine if the fish respond to short-term fluctuations (on the order of days) in environmental variables and if changes in those variables, such as might be caused by the proposed hydroelectric project, would affect the timing of outmigration.



Appendix Figure H-8. Relationship of mean length and catch per hour for age 0+ chum salmon captured at the outmigrant trap.

Strength of Correlations

Although the relationships examined were usually highly significant, the correlation coefficients calculated were generally moderate to low. At best, 72 percent of the variation in catch/hour was "explained" by variation in habitat variables. The relationships would probably be much stronger had catch/hour data been available for the entire period of outmigration. Outmigration probably begins some time in late April or early May, so at least one and one-half months of data were not available. By the time the outmigrant trap began operation, the catch/hour for all species was already near the seasonal peak. Good data for outmigration occurring under the ice or during breakup (usually up until mid-May) will probably never be obtained because of sampling problems during that time of year.

Another factor leading to low correlations is that certain variables may have a strong influence on outmigration for a short period of time, but would not show a high correlation when calculated for the entire season. For example, the correlation of catch/hour and discharge was not very high for the whole season, but it can be seen from Appendix Figures H-1, H-2, and H-3 that the mid-September surge in discharge correlated very well with an increase in outmigration of chinook and coho salmon.

Correlations could probably be improved if more habitat data were available. Mainstem water temperatures were used in the calculations; slough and tributary water temperatures might be a better measure of the effect of temperature on outmigration. Also, other factors which may influence outmigration timing, such as rates of egg development, were not measured. Correlations for chinook and coho salmon might be improved by calculating the correlations for separate age classes, rather than for all age classes together.

Importance of the Habitat Variables

Before examining the relative importance of the different habitat variables, one should have a clear understanding of how these parameters interact with juvenile salmon. Discharge is important because an adequate flow is necessary for the fish to outmigrate. Also, an adequate stage of river at the heads and mouths of sloughs and other areas may be necessary for the juveniles to gain access to the mainstem. A faster current probably requires less energy to outmigrate than a slower current. Turbidity is an important factor in providing cover to outmigrating salmon in a large river such as the Susitna. In relatively short non-turbid rivers, juvenile chum salmon outmigrate mainly at night (Neave 1955). In the Susitna area, there is no true darkness during the time most of the juvenile salmon are outmigrating (Appendix Table H-2). Water temperature is a regulator of metabolism; juvenile salmon show a preference for certain ranges (Reiser and Bjornn 1979). Temperature can also serve as an impetus for outmigration (Sano 1966). Day length regulates the biological clocks of juvenile salmon. For example, an increasing day length (photoperiod) affects the pituitary system of juvenile chum salmon, causing an increasing tolerance for salt water (Baggerman 1960; Shelbourn 1966).

The highest correlations were generally obtained between catch/hour and time of season. This was particularly true with chum salmon. As mentioned previously, time of season is an integrator of several variables. The correlation with discharge was modest with all species except sockeye, whose catch/hour was poorly correlated with discharge. The correlation with temperature was never strong for any species, but temperature contributed to explaining catch/hour variation in some of the multiple regressions. Daylength and turbidity correlations were not calculated for each species, but daylength correlated well with the total catch of all salmon species.

Good correlations with some habitat variables were obtained for chum salmon catch/hour, which began high and then declined to zero in mid-August. Coho salmon correlations were the lowest. This species continued to outmigrate the entire time the trap was fishing whereas the others did not outmigrate in large numbers after the end of August.

Comments on Methods

None of the first-difference regressions which were computed gave very good results. There are probably unpredictable time lags of one to three days which occur between the occurrence of an environmental event and the response of catch/hour at the outmigrant trap. If the time lags could be predicted, then a lag could be built into the calculation.

The daily catch/hour for all species is quite variable from day to day (Appendix Figures H-2, H-3 and H-4). The reasons for this variability are not evident at this time. The variability may be a result of juvenile salmon re-distributing themselves throughout the mainstem after migrating out of tributaries and sloughs. Small groups or individuals may hold for various lengths of time in the numerous small eddies, backwaters, and slack-water border areas. On any given day with this scenario, a more or less random number of individuals or groups of individuals migrates past the outmigrant trap. Regardless of the cause, the sharp fluctuations in numbers create problems in data analysis and probably require some sort of smoothing function. Stable results were obtained using a three day moving average. Some preliminary work using exponential smoothing also appeared to be promising. Further investigation with both of these techniques would probably be profitable, as would further calculations using different time lags. Mixed results were obtained using logarithmic transformations of one or two variables in a bivariate analysis.

Future Work

The ultimate goal of this analysis, given the appropriate habitat data, is a prediction of the relative magnitude and timing of juvenile salmon outmigration. This goal was not met during the 1982 studies as the amount and types of data available did not allow for definitive relationships to be developed. In particular, more than one season of data is necessary. For example, a season in which discharge is low early in the season and then increases would be useful in determining whether this kind of discharge regime would override the effect of time of season on outmigration.

This report has provided some insight into the problem of habitat/ outmigration relationships and some direction for future work. During the 1983 studies, two outmigrant traps will be operated, beginning in mid-May. Also, more complete habitat data will be obtained. Furthermore, coded wire tagging, in conjunction with habitat measurements, will be conducted in several sloughs above the outmigrant traps. These studies will contribute a great deal to a more powerful analysis of juvenile salmon outmigration.

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APPENDIX I

A Model of the Effect of Incremental Increases in Sport Fishing on Population Structure of Arctic Grayling above Devil Canyon

APPENDIX I

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INTRODUCTION

The opening of access roads into the proposed impoundment area can be expected to create a substantial Arctic grayling sport fishery in this previously seldom fished drainage. This study was initiated to examine the effects of increased mortality rates (due to fishing pressure) on the age structure and abundance of the Arctic grayling populations in the clear water tributaries studied to date. The results of the analysis can suggest management strategies and should be useful in the impact analysis. The predicted increased access and corresponding fishing pressure can be used with this data set to predict the changes that may be expected in these unexploited populations of grayling.

METHODS

Hook and line sampling methods were used to collect grayling for mark and recapture and age/length data over two open water seasons at eight major clear water tributaries to the Susitna River in the proposed impoundment. Field collection methods and data summaries are presented in ADF&G (1981) and ADF&G (1983) and are not reported here. Because hook and line methods were used to collect the data, the effects of fishing pressure can be projected from these catch records and population estimates.

The theoretical analysis of the data was developed using equations described by Ricker (1975). The equations used show the relationships between mortality, population size and age structure. The Arctic grayling population structure in the proposed impoundment is presently assumed to be unexploited and to have natural mortality rates in a state of equilibrium.

The following equations were used to project population changes:

(1) $N_{t+1} = N_t \times S_{tn}$ where: N_{t+1} = Population number of age class t plus one year.

N_t = Population number of age class t fish

N_t and N_{t+1} are known for each age class and give estimates for S_{tn} for each age class.

S_{tn} = Natural survival rate of age t fish

In an exploited fishery then,

(2) $N_{t+1} = N_t \times S_{tn+F}$ where: S_{tn+F} = Survival rate of age t fish after combined natural and fishing mortalities.

The annual total mortality rate, A, is related to S, as:

(3) $A_{tn+F} = 1 - S_{tn+F}$ and,

(4) $S_{tn+F} = e^{-Z_t}$ and, where: Z_t = Instantaneous rate of total mortalities of age t fish.

(5) $Z_t = F_t + M_t$ and, where: F_t = Instantaneous rate of fishing mortality of age class t fish.

(6) $M_t = -\ln S_{tn}$ where: M_t = Instantaneous rate of natural mortalities of age class t fish.

Since M_t is available from N_t and N_{t+1} data, it is possible to substitute (model) values of F_t for a hypothetical fishery and predict the resulting age structure of the population with time. To do this, the following assumptions are made. (1) The rate of catch for each age class of fish per unit of fishing effort experienced by ADF&G will hold true for the general public. (2) Only grayling of age III and older are subject to increased mortality by (hook and line) fishing. (3) Recruitment of age II class fish is constant.

In an exploited system then, F_t is viewed as:

(7) $F_t = q_t \times f$ where: q_t = catchability of age class t; proportioned fish per unit time fished.

f = fishing effort, (98.25 hrs or 6.05 hrs/mile stream).

and q_t is estimated from:

(8) $q_t = -\ln (1-u_t)$ using,

(9) $u_t = \frac{R_t}{M'_t}$ where: R_t = number of grayling marked in July 1982 that were recaptured in August 1982 by age class t.

M'_t = number of grayling marked in July 1982, by age class t.

The term u_t is called the rate of exploitation and was calculated from the mark-recapture fishing data found in ADF&G (1983).

Calculation of the annual total mortality rate (A_{tn+F}) n equation (3) thus allows calculation of predicted catch at different levels of exploitation.

(10) $A_{tF} = A_{tn+F} - (1-S_{tn})$ where: A_{tF} = annual fishing mortality

$A_{tn} = 1-S_{tn}$ = annual natural mortality

(11) $$C_t = \sum_{t=III}^{t=VIII} A_{tF} \times N_t$$ C_t = total catch

A model of the maximum sustained yield of Arctic grayling at various levels of fishing effort was constructed. The analytical formula and data were manipulated using a microcomputer and a commercial spreadsheet software entitled SuperCalc^R.

Fishing pressure, f, and the exploitation coefficient, $u_{(t)}$, were taken from R/M' values limited to the July and August 1982 samplings. This restriction most closely fulfills the "closed system assumption" (no in- or outmigration) because there is little migration occurring in July and August, thus improving the level of certainty in the model.

Appendix Table I-1 summarizes the July catch and effort. The fishing pressure (f) value, which was varied to calculate C_t in the model, was taken as multiples of the mean effort (mean hours fished per mile = 6.05) reported during this period. An f value of 1.0 was set equal to an effort of 6.05 hours/mile per year.

The effects of exploitation on recruitment was also examined briefly in a separate analysis. This analysis assumed no effect of spawner reduction on recruitment of Age II grayling until the population of spawners is reduced to 10 percent of the unexploited population in year 1982. Two generations after the population of spawners is reduced to this level, the decrease in the Age II population is reduced linearly as a function of the remaining proportion of spawners.

RESULTS

Appendix Table I-2 presents the calculated maximum sustained catches resulting from differing levels of fishing pressure (f). Appendix Figure I-1 graphically illustrates these calculations. The calculated rate of fishing pressure for maximum sustained catch (of all age classes greater than II) is less than 1,000 fish/year.

Appendix Table I-1. Summary of catch and effort made during the July 1982 proposed impoundment grayling tag and recapture sampling program.

Impoundment River Fished	Miles of River Fished	Hours Fished	Catch	CPUE	Hours Fished Per Mile	Fish Per Mile
Oshetna	2.2	21.25	288	13.6	9.66	1103
Goose	1.2	6.75	91	13.5	5.63	791
Jay	3.5	12.00	130	10.8	3.43	455
Kosina	4.5	31.50	491	15.6	7.00	1232
Watana	4.0	18.00	175	9.7	4.50	324
Deadman	0.3	4.50	51	11.3	15.0	1835
Tsusena	0.4	3.00	29	9.7	7.5	
Fog	0.2	1.25	5	4.0	6.25	440
Total	16.3	98.25	1260	--	--	--
Mean	--	--	--	12.8	6.05	665

Appendix Table I-2. Results of age class and total population calculations at variable levels of fishing pressure.

Relative fishing pressure (f) = .00

	Age Class II	Age Class III	Age Class IV	Age Class V	Age Class VI	Age Class VII	Age Class VIII	Total Population Age III and Older Fish	Population of Spawners (Age V & Older)	Spawners as a Percent of Total Population
Natural Instantaneous Mortality (M)		.90	.46	.27	.77	.78	1.06			
Natural Survival (S)		.41	.63	.85	.46	.46	.35			
Fishing Mortality (F)		.00	.00	.00	.00	.00	.00			
Mark/Recapture (R/M') Ratio		.04	.09	.14	.24	.20	.26			
Total Instantaneous Mortality (Z)		.90	.46	.17	.77	.78	1.06			
Total Mortality (A_{n+F})		.59	.37	.15	.54	.54	.65			
Total Survival (S_{n+F})		.41	.63	.85	.46	.46	.35			
Numbers of Fish Year										
1982	11363	4602	2904	2454	1134	521	180	11795	4289	36
1983	11363	4602	2904	2454	1134	521	180	11795	4289	36
1984	11363	4602	2904	2454	1134	521	180	11795	4289	36
1985	11363	4602	2904	2454	1134	521	180	11795	4289	36
1986	11363	4602	2904	2454	1134	521	180	11795	4289	36
1987	11363	4602	2904	2454	1134	521	180	11795	4289	36
1988	11363	4602	2904	2454	1134	521	180	11795	4289	36
1989	11363	4602	2904	2454	1134	521	180	11795	4289	36
1990	11363	4602	2904	2454	1134	521	180	11795	4289	36
1991	11363	4602	2904	2454	1134	521	180	11795	4289	36

Appendix Table I-2 (Continued).

Relative fishing pressure (f) = .50

	Age Class II	III	IV	V	VI	VII	VIII	Total Population Age III and Older Fish	Population of Spawners (Age V & Older)	Spawners as a Percent of Total Population
Natural Instantaneous Mortality (M)		.90	.46	.17	.77	.78	1.06			
Natural Survival (S)		.41	.63	.85	.46	.46	.35			
Fishing Mortality (F)		.02	.05	.07	.13	.11	.15			
Mark/Recapture (R/M') Ratio		.04	.09	.14	.24	.20	.26			
Total Instantaneous Mortality (Z)		.93	.51	.24	.91	.89	1.21			
Total Mortality (A_{n+F})		.60	.40	.21	.60	.59	.70			
Total Survival (S_{n+F})		.40	.60	.79	.40	.41	.30			
Numbers of Fish Year										
1982	11363	4602	2904	2454	1134	521	180	11795	4289	36
1983	11363	4500	2773	2280	992	467	155	11166	3893	35
1984	11363	4500	2712	2177	921	408	139	10857	3646	34
1985	11363	4500	2712	2129	880	379	122	10720	3509	33
1986	11363	4500	2712	2129	860	362	113	10675	3464	32
1987	11363	4500	2712	2129	860	354	108	10662	3451	32
1988	11363	4500	2712	2129	860	354	105	10660	3448	32
1989	11363	4500	2712	2129	860	354	105	10660	3448	32
1990	11363	4500	2712	2129	860	354	105	10660	3448	32
1991	11363	4500	2712	2129	860	354	105	10660	3448	32

Appendix Table I-2 (Continued).

		Relative fishing pressure (f) = 1.0									
		Age Class							Total Population Age III and Older Fish	Population of Spawners (Age V & Older)	Spawners as a Percent of Total Population
		II	III	IV	V	VI	VII	VIII			
Natural Instantaneous Mortality (M)			.90	.46	.17	.77	.78	1.06			
Natural Survival (S)			.41	.63	.85	.46	.46	.35			
Fishing Mortality (F)			.04	.09	.15	.27	.22	.30			
Mark/Recapture (R/M') Ratio			.04	.09	.14	.24	.20	.26			
Total Instantaneous Mortality (Z)			.95	.55	.32	1.04	1.00	1.36			
Total Mortality (A_{n+F})			.61	.42	.27	.65	.63	.74			
Total Survival (S_{n+F})			.39	.58	.73	.35	.37	.26			
Numbers of Fish	Year										
	1982	11363	4602	2904	2454	1134	521	180	11795	4289	36
	1983	11363	4400	2648	2118	868	418	134	10585	3537	33
	1984	11363	4400	2532	1931	749	320	107	10038	3107	31
	1985	11363	4400	2532	1846	683	276	82	9819	2887	29
	1986	11363	4400	2532	1846	653	252	71	9753	2822	29
	1987	11363	4400	2532	1846	653	241	65	9736	2804	29
	1988	11363	4400	2532	1846	653	241	62	9733	2801	29
	1989	11363	4400	2532	1846	653	241	62	9733	2801	29
	1990	11363	4400	2532	1846	653	241	62	9733	2801	29
	1991	11363	4400	2532	1846	653	241	62	9733	2801	29

Appendix Table I-2 (Continued).

Relative fishing pressure (f) = 2.00

		Age Class							Total Population Age III and Older Fish	Population of Spawners (Age V & Older)	Spawners as a Percent of Total Population
		II	III	IV	V	VI	VII	VIII			
Natural Instantaneous Mortality (M)			.90	.46	.17	.77	.78	1.06			
Natural Survival (S)			.41	.63	.85	.46	.46	.35			
Fishing Mortality (F)			.09	.18	.29	.54	.44	.59			
Mark/Recapture (R/M') Ratio			.04	.09	.14	.24	.20	.26			
Total Instantaneous Mortality (Z)			.99	.64	.46	1.31	1.22	1.66			
Total Mortality (A_{n+F})			.63	.48	.37	.73	.70	.81			
Total Survival (S_{n+F})			.37	.52	.63	.27	.30	.19			
Numbers of Fish	Year										
	1982	11363	4602	2904	2454	1134	521	180	11795	4289	36
	1983	11363	4206	2415	1828	664	335	99	9547	2926	31
	1984	11363	4206	2208	1520	494	196	64	8688	2274	26
	1985	11363	4206	2208	1389	411	146	37	8397	1984	24
	1986	11363	4206	2208	1389	376	121	28	8328	1914	23
	1987	11363	4206	2208	1389	376	111	23	8313	1899	23
	1988	11363	4206	2208	1389	376	111	21	8311	1897	23
	1989	11363	4206	2208	1389	376	111	21	8311	1897	23
	1990	11363	4206	2208	1389	376	111	21	8311	1897	23
	1991	11363	4206	2208	1389	376	111	21	8311	1897	23

Appendix Table I-2 (Continued).

Relative fishing pressure (f) = 4.0

	Age Class							Total Population Age III and Older Fish	Population of Spawners (Age V & Older)	Spawners as a Percent of Total Population
	II	III	IV	V	VI	VII	VIII			
Natural Instantaneous Mortality (M)		.90	.46	.17	.77	.78	1.06			
Natural Survival (S)		.41	.63	.85	.46	.46	.35			
Fishing Mortality (F)		.18	.37	.59	1.07	.88	1.19			
Mark/Recapture (R/M') Ratio		.04	.09	.14	.24	.20	.26			
Total Instantaneous Mortality (Z)		1.08	.83	.76	1.84	1.66	2.25			
Total Mortality (A_{n+F})		.66	.56	.53	.84	.81	.89			
Total Survival (S_{n+F})		.34	.44	.47	.16	.19	.11			
Numbers of Fish Year										
1982	11363	4602	2904	2454	1134	521	180	11795	4289	36
1983	11363	3844	2009	1361	388	216	55	7873	2020	26
1984	11363	3844	1678	942	215	74	23	6776	1254	19
1985	11363	3844	1678	787	149	41	8	6506	984	15
1986	11363	3844	1678	787	124	28	4	6466	944	15
1987	11363	3844	1678	787	124	24	3	6460	938	15
1988	11363	3844	1678	787	124	24	2	6459	937	15
1989	11363	3844	1678	787	124	24	2	6459	937	15
1990	11363	3844	1678	787	124	24	2	6459	937	15
1991	11363	3844	1678	787	124	24	2	6459	937	15

Appendix Table I-2 (Continued).

Relative fishing pressure (f) = 6.0

	Age Class II	III	IV	V	VI	VII	VIII	Total Population Age III and Older Fish	Population of Spawners (Age V & Older)	Spawners as a Percent of Total Population
Natural Instantaneous Mortality (M)		.90	.46	.17	.77	.78	1.06			
Natural Survival (S)		.41	.63	.85	.46	.46	.35			
Fishing Mortality (F)		.27	.55	.88	1.61	1.32	1.78			
Mark/Recapture (R/M') Ratio		.04	.09	.14	.24	.20	.26			
Total Instantaneous Mortality (Z)		1.17	1.01	1.05	2.38	2.10	2.85			
Total Mortality (A_{n+F})		.69	.64	.65	.91	.88	.94			
Total Survival (S_{n+F})		.31	.36	.34	.09	.12	.06			
Numbers of Fish Year										
1982	11363	4602	2904	2454	1134	521	180	11795	4298	36
1983	11363	3513	1671	1014	227	139	30	6594	1410	21
1984	11363	3513	1276	583	94	28	8	5502	713	13
1985	11363	3513	1276	445	54	11	2	5301	512	10
1986	11363	3513	1276	445	41	7	1	5283	494	9
1987	11363	3513	1276	445	41	5	0	5281	492	9
1988	11363	3513	1276	445	41	5	0	5281	492	9
1989	11363	3513	1276	445	41	5	0	5281	492	9
1990	11363	3513	1276	445	41	5	0	5281	492	9
1991	11363	3513	1276	445	41	5	0	5281	492	9

Appendix Table I-2 (Continued).

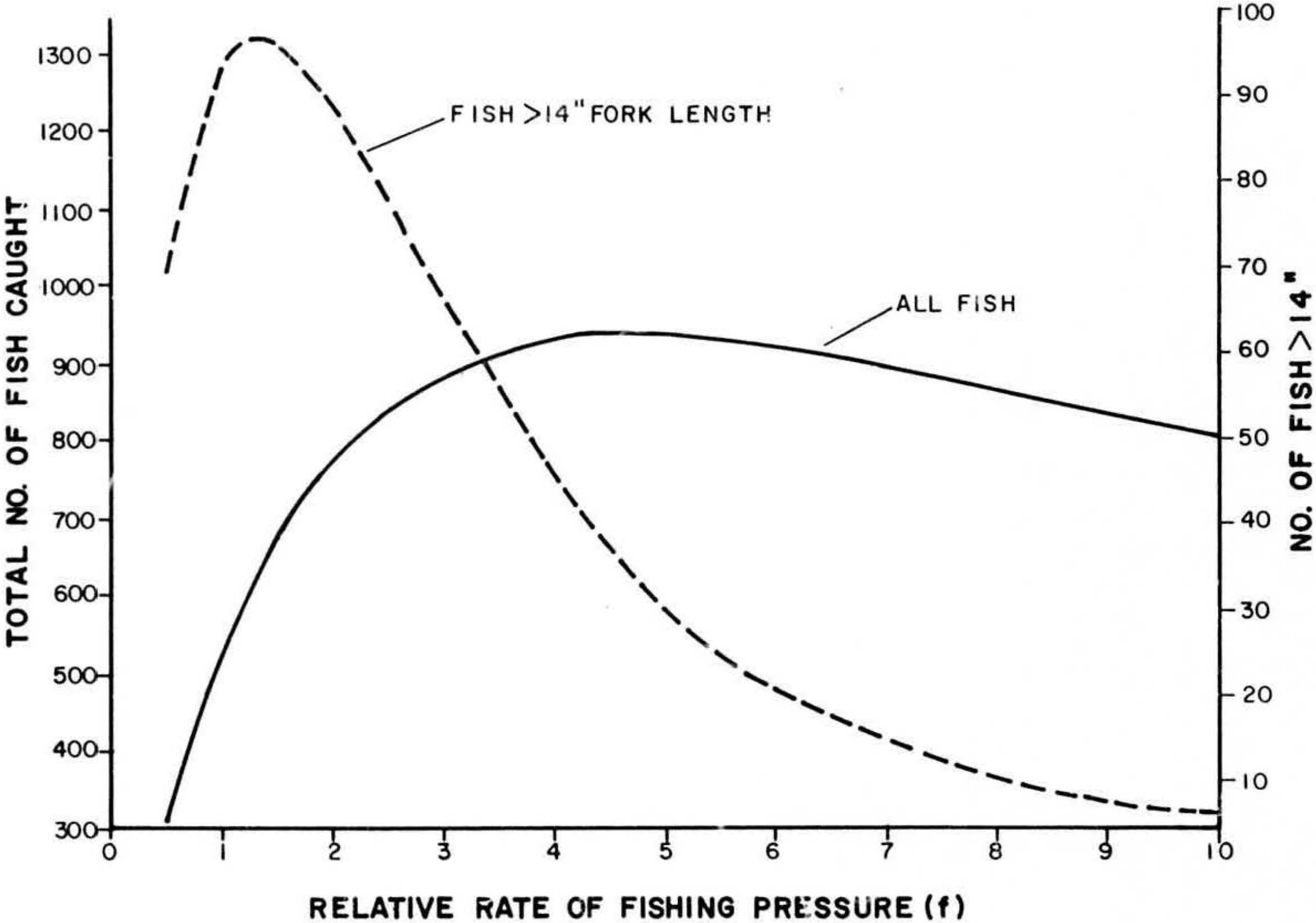
Relative fishing pressure (f) = 8.0

	Age Class II	III	IV	V	VI	VII	VIII	Total Population Age III and Older Fish	Population of Spawners (Age V & Older)	Spawners as a Percent of Total Population
Natural Instantaneous Mortality (M)		.90	.46	.17	.77	.78	1.06			
Natural Survival (S)		.41	.63	.85	.46	.46	.35			
Fishing Mortality (F)		.36	.74	1.18	2.14	1.77	2.38			
Mark/Recapture (R/M') Ratio		.04	.09	.14	.24	.20	.26			
Total Instantaneous Mortality (Z)		1.26	1.20	1.35	2.92	2.54	3.44			
Total Mortality (A_{n+F})		.72	.70	.74	.95	.92	.97			
Total Survival (S_{n+F})		.28	.30	.26	.05	.08	.03			
Numbers of Fish Year										
1982	11363	4602	2904	2454	1134	521	180	11795	4289	36
1983	11353	3211	1390	755	133	89	17	5595	994	1[illegible]
1984	11363	3211	970	361	41	10	3	4596	416	9
1985	11363	3211	970	252	20	3	0	4456	275	6
1986	11363	3211	970	252	14	2	0	4448	267	6
1987	11363	3211	970	252	14	1	0	4447	267	6
1988	11363	3211	970	252	14	1	0	4447	267	6
1989	11363	3211	970	252	14	1	0	4447	267	6
1990	11363	3211	970	252	14	1	0	4447	267	6
1991	11363	3211	970	252	14	1	0	4447	267	6

Appendix Table I-2 (Continued).

Relative fishing pressure (f) = 10.

	Year	Age Class II	III	IV	V	VI	VII	VIII	Total Population Age III and Older Fish	Population of Spawners (Age V & Older)	Spawners as a Percent of Total Population
Natural Instantaneous Mortality (M)			.90	.46	.17	.77	.78	1.06			
Natural Survival (S)			.41	.63	.85	.46	.46	.35			
Fishing Mortality (F)			.45	.92	1.47	2.68	2.21	2.97			
Mark/Recapture (R/M') Ratio			.04	.09	.14	.24	.20	.26			
Total Instantaneous Mortality (Z)			1.35	1.38	1.64	3.45	2.98	4.03			
Total Mortality (A_{n+F})			.74	.75	.81	.97	.95	.98			
Total Survival (S_{n+F})			.26	.25	.19	.03	.05	.02			
Numbers of Fish	Year										
	1982	11363	4602	2904	2454	1134	521	180	11795	4289	36
	1983	11363	2934	1156	562	78	57	9	4797	707	15
	1984	11363	2934	737	224	18	4	1	3918	247	6
	1985	11363	2934	737	143	7	1	0	3822	151	4
	1986	11363	2934	737	143	5	0	0	3819	148	4
	1987	11363	2934	737	143	5	0	0	3819	147	4
	1988	11363	2934	737	143	5	0	0	3819	147	4
	1989	11363	2934	737	143	5	0	0	3819	147	4
	1990	11363	2934	737	143	5	0	0	3819	147	4
	1991	11363	2934	737	143	5	0	0	3819	147	4



Appendix Figure I-1. Sustained yield of Arctic grayling for different levels of fishing pressure. The f value represents multiples of 6.05 hrs per mile of hook and line sport fishing per year.

An additional calculation was made at this point to estimate the maximum sustained yield if catch (mortalities) are limited to individuals VI and older (approximately 350 mm and greater in length). The maximum sustained yield under these conditions occurs at f = 1.5 and is estimated to be less than 100 fish per year. The total harvest of all size classes of fish older than age II is about 650 fish per year at the same level of f. By comparison, the maximum sustained yield is 950 fish per year (which occurs at f = 4.5) when all age classes are harvested.

These values assume equal distribution of effort and success levels similar to those experienced in the field by the ADF&G crews while collecting this data. If access is not limiting, the distribution of fishermen will probably parallel the relative densities of fish.

Possible effects of higher levels of exploitation on recruitment are presented in Appendix Table I-3 and illustrated in Appendix Figure I-2. Under baseline conditions, 36% of the age III and older fish are spawners. At the higher rates of exploitation, this number drops off rather rapidly. Although recruitment is probably in excess of what is required under the current conditions, the projected decrease in the number of the spawners at the high rates of exploitation is probably sufficient to affect recruitment. Using the assumptions of the model and assuming a linear decrease in recruitment following a decrease of spawning aged fish to 10% of the non-exploited population, the number of fish caught annually rapidly decreases when f = 8 (48.8 hrs/mile of river).

Appendix Table I-3. Results of analysis of effects of decreasing spawner populations caused by fishing pressure on twenty year catch rates.

	Numbers of Fish at Relative Fishing Pressure (f) = 6.00			
Year	Total Number of Spawners (Age V & Older)	Total Number of Age VI and Older Fish Caught	Total Catch All Age Classes (Age III & Older)	Spawners as a Percent of Total Population
1982	4289	646	3083	36
1983	1410	139	1427	21
1984	713	46	1014	13
1985	512	24	924	10
1986	494	18	917	9
1987	492	17	916	9
1988	492	17	916	9
1989	492	17	916	9
1990	492	17	916	9
1991	492	17	916	9
1992	492	17	916	9
1993	492	17	916	9
1994	492	17	916	9
1995	492	17	916	9
1996	492	17	916	9
1997	492	17	916	9
1998	492	17	916	9
1999	492	17	916	9
2000	492	17	916	9
2001	492	17	916	9
2002	492	17	916	9

Appendix Table I-3 (Continued).

	Numbers of Fish at Relative Fishing Pressure (f) = 6.50			
Year	Total Number of Spawners (Age V & Older)	Total Number of Age VI and Older Fish Caught	Total Catch All Age Classes (Age III & Older)	Spawners as a Percent of Total Population
1982	4289	668	3244	36
1983	1291	127	1424	20
1984	622	39	999	12
1985	438	19	912	9
1986	423	14	906	8
1987	421	13	906	8
1988	421	13	906	8
1989	421	13	901	8
1990	421	13	894	8
1991	415	13	890	8
1992	414	13	889	8
1993	414	13	889	8
1994	414	13	885	8
1995	414	13	879	8
1996	408	13	875	8
1997	406	13	874	8
1998	406	13	873	8
1999	406	13	869	8
2000	406	13	863	8
2001	401	13	859	8
2002	399	13	858	8

Appendix Table I-3 (Continued).

Year	Total Number of Spawners (Age V & Older)	Total Number of Age VI and Older Fish Caught	Total Catch All Age Classes (Age III & Older)	Spawners as a Percent of Total Population
	Numbers of Fish at Relative Fishing Pressure (f) = 7.00			
1982	4289	686	3395	36
1983	1182	115	1415	19
1984	543	32	983	11
1985	374	15	898	8
1986	362	11	894	7
1987	361	10	893	7
1988	361	10	847	8
1989	361	10	794	9
1990	319	10	760	8
1991	306	9	753	8
1992	304	9	753	7
1993	304	9	716	8
1994	304	9	672	9
1995	271	9	643	8
1996	259	8	635	8
1997	257	7	634	7
1998	256	7	605	8
1999	256	7	569	9
2000	230	7	543	8
2001	219	6	536	8
2002	216	6	534	7

Appendix Table I-3 (Continued).

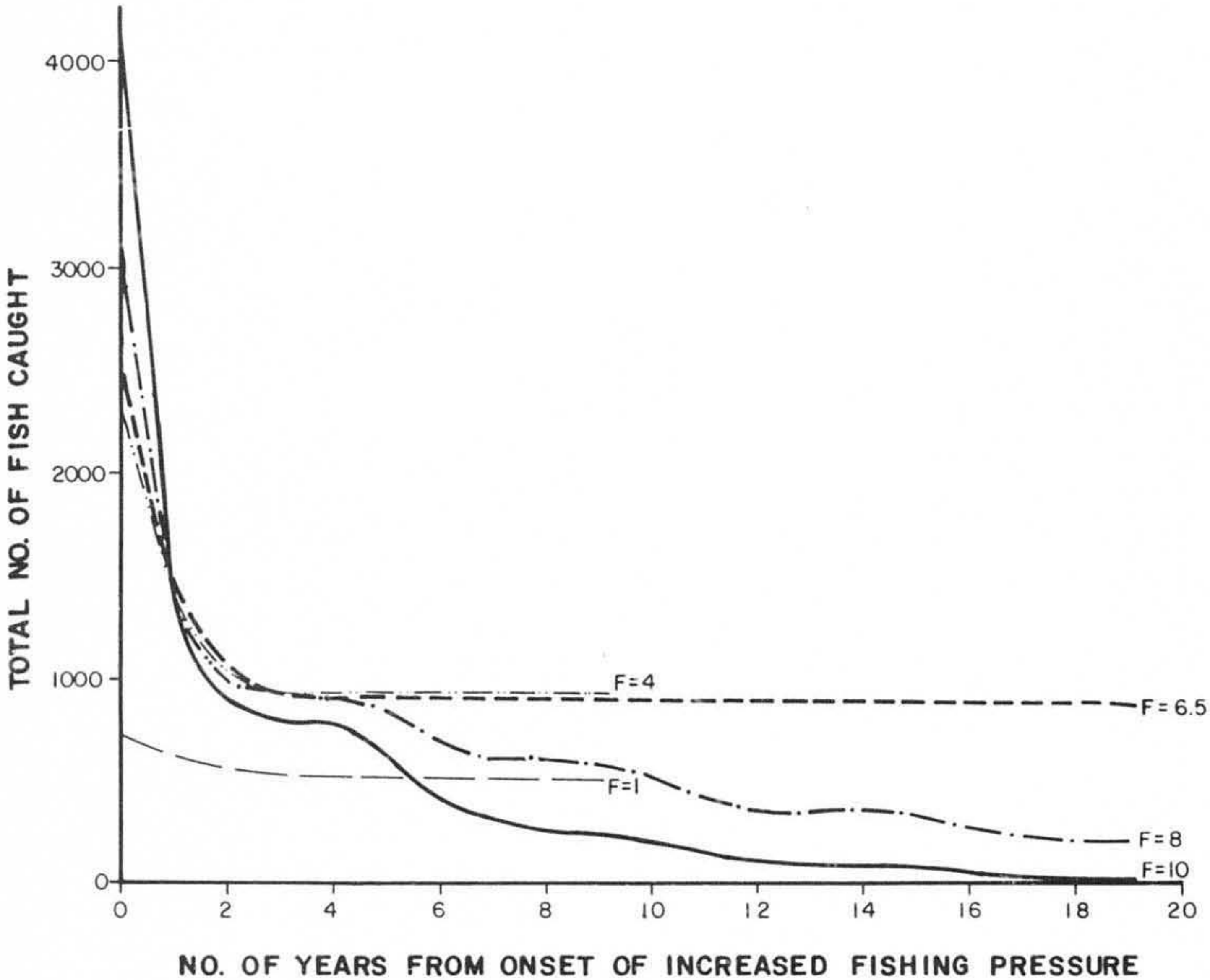
	Numbers of Fish at Relative Fishing Pressure (f) = 8.00			
Year	Total Number of Spawners (Age V & Older)	Total Number of Age VI and Older Fish Caught	Total Catch All Age Classes (Age III & Older)	Spawners as a Percent of Total Population
1982	4289	717	3672	36
1983	994	93	1386	18
1984	416	22	945	9
1985	275	9	869	6
1986	267	6	866	6
1987	267	6	853	6
1988	267	6	715	8
1989	259	6	599	9
1990	176	6	544	6
1991	167	4	539	6
1992	166	4	531	6
1993	166	4	450	8
1994	161	4	377	9
1995	112	4	341	6
1996	104	3	336	6
1997	103	2	331	6
1998	103	2	283	8
1999	101	2	237	9
2000	72	2	213	7
2001	65	2	209	6
2002	64	1	206	6

Appendix Table I-3 (Continued).

Year	Total Number of Spawners (Age V & Older)	Total Number of Age VI and Older Fish Caught	Total Catch All Age Classes (Age III & Older)	Spawners as a Percent of Total Population
	Numbers of Fish at Relative Fishing Pressure (f) = 9.00			
1982	4289	741	3918	36
1983	837	75	1344	16
1984	3[illegible]	14	906	8
1985	203	6	838	5
1986	198	4	836	5
1987	198	4	730	6
1988	198	4	541	9
1989	150	4	425	8
1990	96	3	389	5
1991	92	2	386	5
1992	91	2	339	6
1993	91	2	254	9
1994	70	2	199	8
1995	46	1	180	5
1996	43	1	178	5
1997	42	1	144	7
1998	42	1	98	11
1999	26	1	71	8
2000	16	0	62	5
2001	15	0	61	5
2002	15	0	50	7

Appendix Table I-3 (Continued).

Year	Total Number of Spawners (Age V & Older)	Total Number of Age VI and Older Fish Caught	Total Catch All Age Classes (Age III & Older)	Spawners as a Percent of Total Population
	Numbers of Fish at Relative Fishing Pressure (f) = 10.00			
1982	4289	760	4137	36
1983	707	60	1296	15
1984	247	10	866	6
1985	151	3	807	4
1986	148	2	806	4
1987	147	2	623	6
1988	147	2	407	9
1989	87	2	302	6
1990	53	1	278	4
1991	51	1	277	4
1992	51	1	216	6
1993	51	1	143	9
1994	31	1	105	7
1995	19	0	96	4
1996	18	0	95	4
1997	17	0	75	6
1998	17	0	50	9
1999	11	0	37	7
2000	7	0	33	4
2001	6	0	33	4
2002	6	0	29	5



Appendix Figure I-2. Effort of heavy fishing pressure on Arctic grayling catch rates assuming effort of harvest on recruitment. The f value represents multiples of 6.05 hrs per mile of hook and line sport fishing per year.

CONCLUSION

The model demonstrates that in a closed system fishery, where fisherman access is not limiting, modest levels of fishing pressure can drastically reduce grayling population. In reality, a reduction in the numbers of large fish would probably result in a decrease in fishing pressure before the population would be eliminated. The residual fishery, after such an event, would probably reflect recruitment by immigration of stock from other areas.

Although the data collected pertains to the streams that will be inundated by the impoundment, the similarity in age structure among the streams (ADF&G 1983, Table 5-3-8) suggests that this data base may be applicable to grayling fisheries in other tributaries of the upper Susitna basin. The modeling of the available data results in age/class population structures presently found in exploited grayling systems in other parts of interior Alaska (Armstrong 1982; Grabacki 1981).

The spreadsheet program used in the analysis allows very rapid changes in assumptions and output of usable information with relatively little programming effort. Projections can be made given any reasonable set of assumptions concerning harvest, recruitment, management strategies, and other aspects of the population dynamics of grayling, with minor adjustments to the model presented.

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APPENDIX J

Age-Length Relationships for Arctic Grayling and Rainbow Trout

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INTRODUCTION

Age-length curves and regressions were examined for Arctic grayling to determine if the growth of the population in the proposed impoundment area above Devil Canyon was significantly different from that of the population below Devil Canyon. Preliminary analysis of 1981 data had indicated that such a difference might exist which, if true, would have relevance to proposed mitigation strategies for Arctic grayling in the impoundment area.

Age-length curves for rainbow trout were also analyzed. The Susitna River basin is near the northern limit of the zoogeographical range for rainbow trout and it was hypothesized that growth rates of the Susitna population may be low, compared to that of other populations. If growth rates are low, the Susitna population may be limited in its ability to absorb impacts associated with the proposed hydroelectric project.

METHODS

Scales taken from rainbow trout and Arctic grayling captured and measured during 1981 and 1982 were aged. Logarithmic ($Y = a + b \ln(X)$) and linear ($Y = a + bX$) regressions of age versus length were then calculated for both species. Arctic grayling were divided into three groups by sampling reach: Cook Inlet to Chulitna River confluence, Chulitna River confluence to Devil Canyon, and Devil Canyon to Oshetna River confluence. Since there are no rainbow trout in the impoundment area except for a transplanted population in the High Lakes, rainbow trout were divided into two groups, above and below the Chulitna River confluence. Data from 1981 and 1982 were analyzed. Each year's data was analyzed by reach separately for comparative purposes and as a check on sampling and aging procedures. Selected slopes of different regressions were tested for equality (Dixon and Massey 1969).

Large catches of rainbow trout and Arctic grayling were most often made in May, June, or September and to compare rainbow trout captured in May with other rainbow trout captured in September only by year class would give biased results since most growth occurs during a short period in the summer. Therefore, data were entered by month for each age class of fish. For example, an age 1+ grayling was entered as 1.0 years of age if caught in May and 1.2, 1.4, 1.6, and 1.8 years of age if caught in June, July, August, and September respectively.

RESULTS AND DISCUSSION

Arctic Grayling

Log regressions of Arctic grayling age versus length generally fit the data as well or better than linear regressions (Appendix Table J-1). Although slopes and intercepts varied somewhat by reach and year, all the log regressions are very similar and differences are probably due to chance. Growth rates of Arctic grayling in the impoundment and below the Chulitna River confluence are nearly identical. Comparison of slopes (growth) of the log regressions of Arctic grayling captured in 1982 in the impoundment with those captured between the Chulitna River

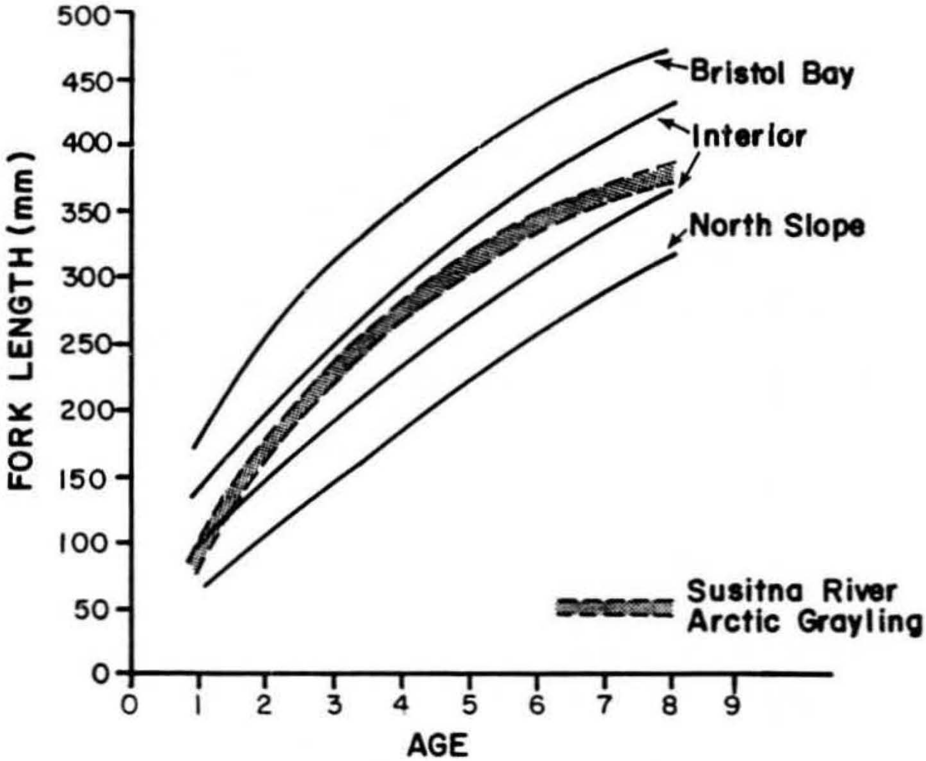
Appendix Table J-1. Results of regression analyses between length and age for Arctic grayling and rainbow trout captured on the Susitna River, 1981 and 1982.

	Area	Slope	Y Intercept	n	r^2	Std Error
Arctic Grayling						
Log	Impoundment, 1982	141.0	84.0	282	.90	14.9
	Above Chulitna, 1982	160.8	23.9	398	.83	27.4
	Below Chulitna, 1982	139.8	74.9	62	.88	24.8
	Impoundment, 1981	155.2	42.6	382	.82	18.4
	Above Chulitna, 1981	117.0	47.6	65	.93	19.0
	Below Chulitna, 1981	152.9	62.6	209	.87	23.5
Linear						
	Impoundment, 1982	29.6	144.5	282	.85	18.3
	Above Chulitna, 1982	45.6	54.6	398	.86	24.8
	Below Chulitna, 1982	47.7	68.3	62	.88	25.2
	Impoundment, 1981	33.2	119.5	382	.81	18.9
	Above Chulitna, 1981	44.8	71.1	65	.91	21.2
	Below Chulitna, 1981	38.2	101.5	209	.87	23.6
Rainbow Trout						
Log	Above Chulitna, 1982	271.3	-104.5	132	.84	34.5
	Below Chulitna, 1982	167.5	50.7	35	.76	--
Linear	Above Chulitna, 1982	57.0	36.4	132	.86	32.2
	Below Chulitna, 1982	42.0	103.0	35	.82	39.8
	Above Chulitna, 1981	50.5	73.6	92	.66	39.4
	Below Chulitna, 1981	62.4	43.5	92	.81	37.6

and Devil Canyon revealed a statistically significant difference ($t=3.71$, $df=676$, $p<.01$), but this difference is probably not biologically important as 1981 data suggest the opposite trend. The growth rates of Arctic grayling in the Susitna River basin are very similar to those of other interior Alaskan populations (Appendix Figure J-1).

Rainbow Trout

Available rainbow trout length-age data from the Susitna River basin fit linear regressions as well or better than log regressions (Appendix Table J-1). Growth rates (slope of age/length regression) of rainbow trout captured above the Chulitna River confluence were not significantly different in 1981 than in 1982 ($t = 1.10$, $df = 220$). These data were pooled and a regression line computed for comparison with other rainbow trout populations (Appendix Figure J-2). The Susitna River rainbow trout were the smallest for any given age class of the populations examined. However, the slope (growth rate) was comparable with the other populations except that of Kootenay Lake.



Appendix Figure J-1. Comparisons of age-length relationship of Arctic grayling in the Susitna River with growth rates of Arctic grayling in other regions of Alaska. Figure is adapted from Armstrong (1982).

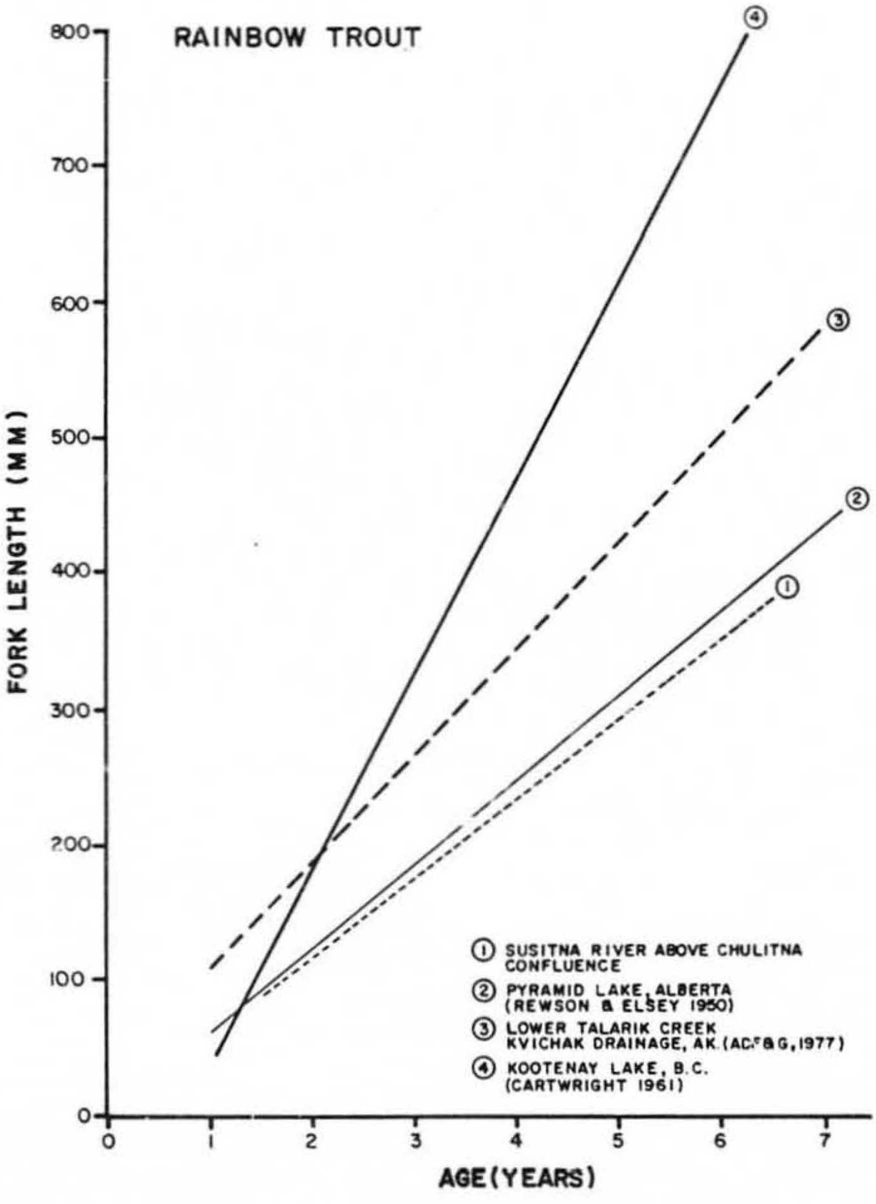


Figure J-2. Comparisons of age-length relationship of rainbow trout in the Susitna River above the Chulitna confluence with other systems. Figure is adapted from TES (1981).

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APPENDIX K

Evaluation of Arctic Grayling Spawning and Rearing Habitat and Notes on Salmon Spawning in the Impoundment Study Area of the Susitna River.

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ARCTIC GRAYLING

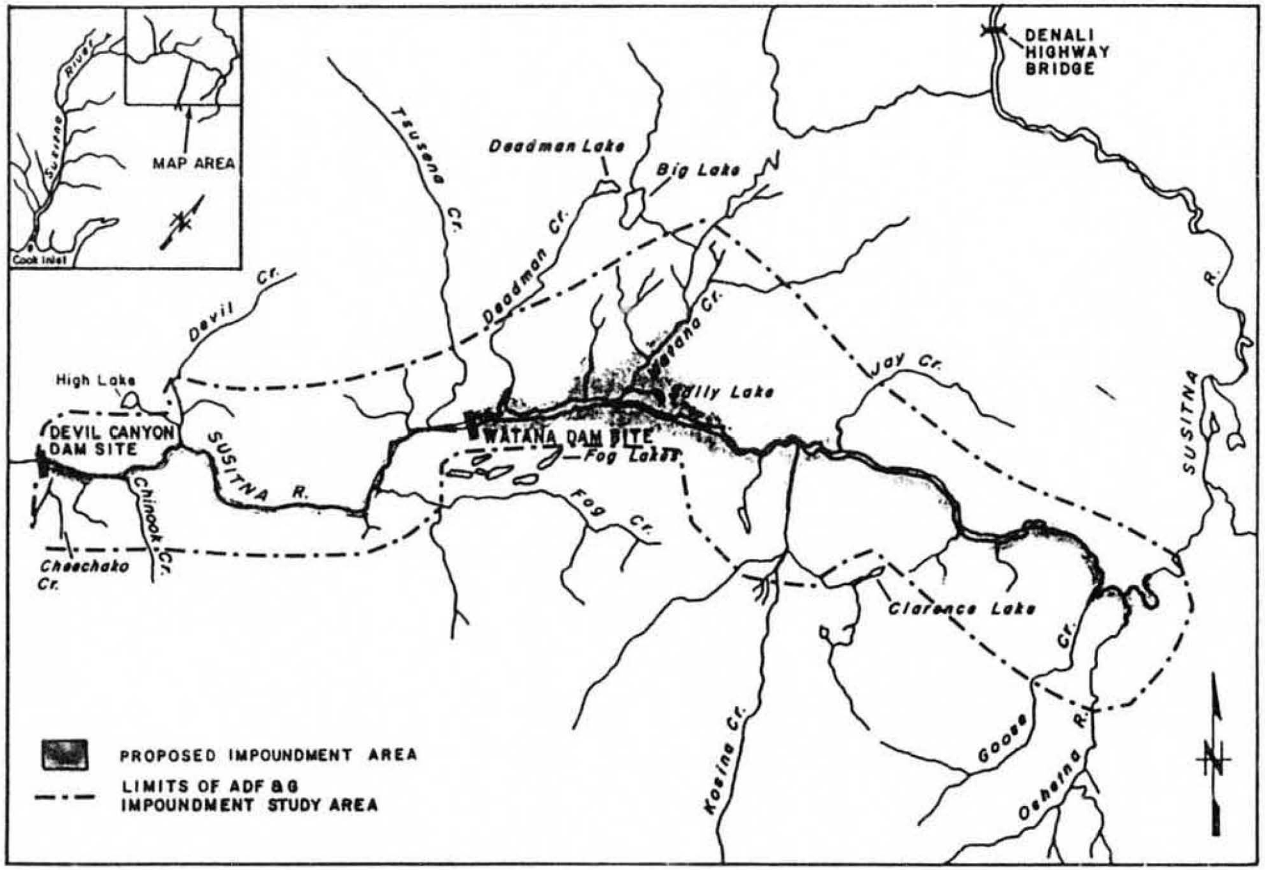
INTRODUCTION

The objective of this study was to document Arctic grayling, *Thymallus arcticus*, spawning and rearing habitats above and below the proposed impoundment elevation (PIE) within the eleven major tributaries of the impoundment study area (Appendix Figure K-1). Inundation of the lower reach of each of these streams below the PIE will result in the loss of existing lotic Arctic grayling spawning and rearing habitats. Therefore, the degree of continued spawning and rearing of Arctic grayling presently occurring in these streams will depend upon the quantity, quality, and availability of habitat above the PIE.

METHODS

Stream surveys were conducted above and below the PIE on eight of the 11 major tributaries within the impoundment study area during 1982. Three small, steep gradient tributaries, Cheechako Creek (RM 152.5), Chinook Creek (RM 156.8), and Devil Creek (RM 161.4) were not adequately surveyed due to time constraints and study priorities during the 1982 field season.* Therefore, these streams have been deleted from further

* A foot survey, conducted at the mouth of Cheechako Creek and along the lower mile of Devil Creek indicated that very few grayling were present in these locations. Habitat was assessed to be poor in the extreme lower reach of Cheechako Creek, while good to excellent habitat was identified in Devil Creek. During aerial surveys above and below the PIE, several fish passage barriers were observed in



Appendix Figure K-1. Proposed Susitna Hydroelectric impoundment study area, 1982.

discussion in this section of Appendix K. Investigations of the eight tributaries studied [Fog (RM 176.7), Tsusena (RM 181.3), Deadman (186.7), Watana (RM 194.1), Kosina (RM 206.8) and Jay (208.5) Creeks and the Oshetna River (RM 233.4)] were limited to the reach between the tributary mouth and a point five miles above the PIE on each stream. Evaluation of spawning and rearing habitats were based on stream gradient, substrate type, stream flow velocities and observations of Arctic grayling in each stream. Specifically, presence of preferred spawning habitat characteristics (gravel substrate and stream velocities ranging from 0.8 to 3.3 ft/sec (Tack 1973)) and/or observed use of habitat for spawning by grayling were the criteria used to identify spawning habitat. Based on previous observations, the presence of slow-flowing and backwater areas and/or observed young-of-the-year grayling (fry) were the criteria used to identify the presence of fry rearing habitat. Presence of juvenile and adult Arctic grayling indicated the presence of adequate rearing habitat for these life stages.

Data collection methods and detailed individual stream descriptions for the tributaries investigated are presented in the Procedures Manual (ADF&G 1982) and the Su Hydro Basic Data Report (ADF&G 1983: Volume 5).

Cheechako and Chinook creeks. One barrier, a large waterfall 0.5 miles above the PIE, was identified in Devil Creek. The inundation of barriers below the PIE on each stream by the proposed Devil Canyon Reservoir will not affect the present inaccessibility to the upper reaches of these streams by Susitna River fish. Spawning and rearing habitats above and below the PIE were not assessed within Cheechako, Chinook, and Devil creeks.

RESULTS

Arctic grayling adults, juveniles, and fry were observed scattered throughout the study reach of all tributaries investigated. Because Arctic grayling fry have been found to spend their first summer near their hatch site (Tack 1980), the observations of fry indicated that spawning had taken place above and below the PIE in all tributaries. Furthermore, all streams contained suitable habitat (gravel substrates and medium to slow stream velocities) assumed necessary for successful spawning throughout their surveyed length. Actual Arctic grayling spawning was not observed because of turbid water conditions during spring.

The observation of fry, juvenile and adult Arctic grayling along with the identification of spawning and rearing habitats within the study reach on each tributary indicated that Arctic grayling of all life stages were supported throughout these reaches.

Large waterfalls located within the study reaches of Deadman and Tsusena Creeks presently prevent fish passage from the Susitna River to the spawning and rearing habitats located in upper reaches of these streams. The waterfall located in Deadman Creek would be inundated by the proposed Watana Reservoir, eliminating this fish passage barrier. However, the proposed Devil Canyon Reservoir will not inundate the waterfall above the PIE on Tsusena Creek but will limit the amount of available habitat below the waterfall. Potential spawning and rearing habitats above this barrier will remain unavailable. Likewise, the proposed inundation of Fog, Watana, and Jay Creeks below possible hydraulic fish passage barriers may also limit the use of available habitat in each stream these barriers. A more complete discussion on fish passage barriers in the study area is presented in the ADF&G Basic Data Report, (ADF&G 1983: Volume 5).

DISCUSSION

All reaches of tributaries studied contained suitable spawning and rearing habitats above and below the PIE. However, the quality, quantity, and accessibility of these habitats varies considerably among and within streams above and below the PIE. Most notable changes within streams above and below the PIE occur on Deadman and Kosina Creeks where an abrupt change in stream gradient and a change in stream gradient pattern, respectively, changes the quality of the available spawning and rearing habitats (ADF&G 1983a). Habitat differences among streams are basically a function of stream gradient, discharge, substrate, and morphology.

Adult Arctic grayling are suspected to spawn* in the same section of river where they were hatched (Tack 1980) and have been shown to return to the same summer feeding station yearly (Schallock and Roguski 1967,

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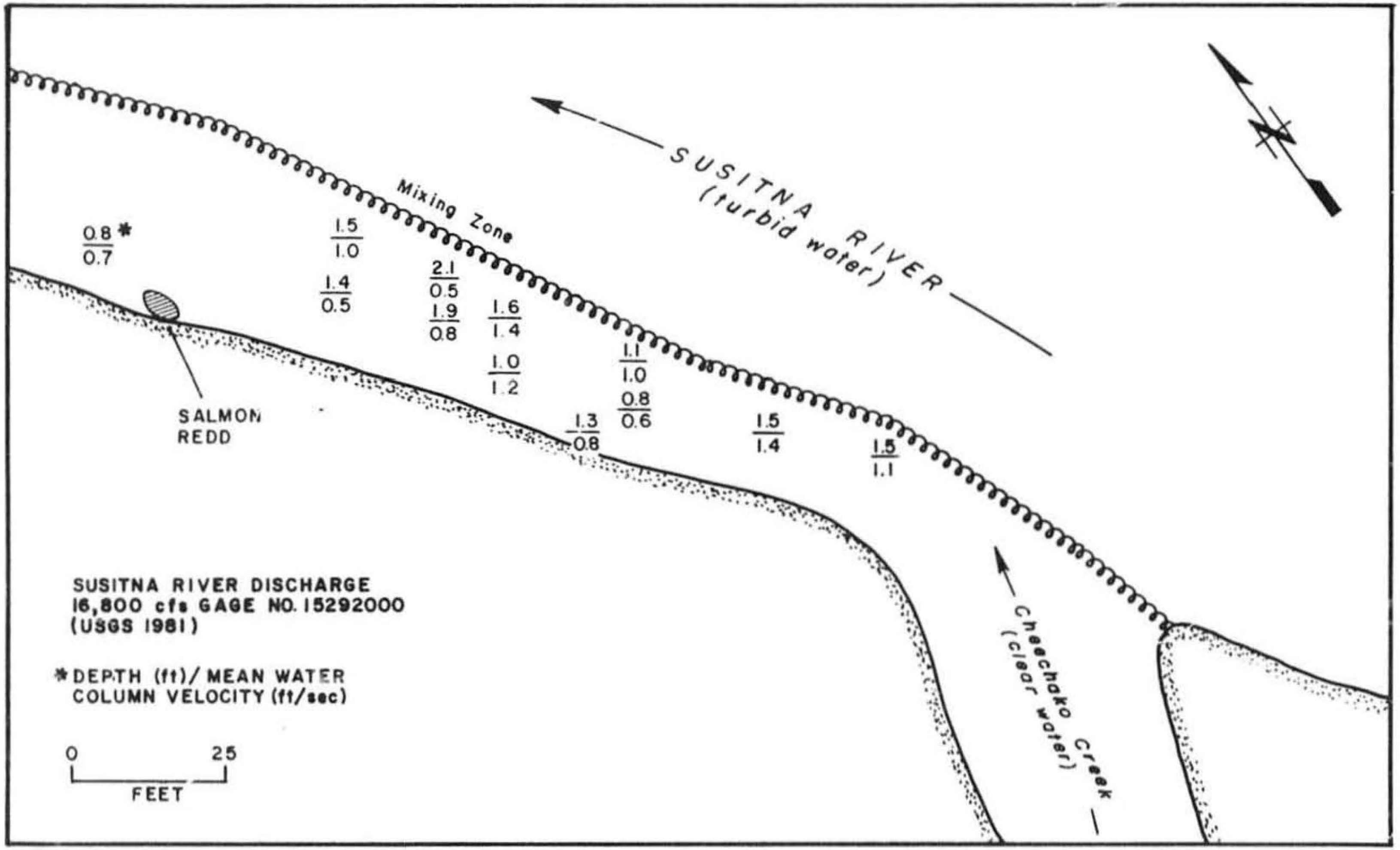
* Spring 1983 field studies located active grayling spawning areas. These data will be reported and compared to the information of this appendix in the FY84 ADF&G report.

ADF&G 1983a). Spawning and rearing habitats above and below the PIE on all tributaries surveyed are seasonally used by Arctic grayling which probably home to these specific areas each spring. However, after reservoir development, Arctic grayling which had homed to the reach of tributary below the PIE will be displaced. The suspected invasion and use of spawning and rearing habitats above the PIE by these displaced grayling will likely affect the grayling population presently homing to habitats above the PIE. Although these effects cannot be predicted at this time, the lotic habitats above the PIE cannot be considered as replacement habitat for habitat lost below the PIE.

SALMON

Cheechako and Chinook Creeks, located within lower Devil Canyon at RM 152.5 and 157.0, respectively, are the only tributaries of the Susitna River within the proposed impoundment areas presently known to be used by salmon for spawning. Although unconfirmed sightings of salmon have been reported near the mouth of Jay Creek, RM 208.5 (USFWS 1959), studies conducted by ADF&G during 1981 and 1982 (ADF&G 1981, 1983: Volume 2) have tentatively placed the upstream limit of the salmon migration in the Susitna River near the mouth of Chinook Creek, RM 157.0. The constricted river channel of Devil Canyon above Chinook Creek creates a fish passage velocity barrier which prohibits further upstream migration of fish.

ADF&G Su Hydro staff initially documented chinook salmon spawning within the Devil Canyon reach of the Susitna River in the glacial/clearwater mixing zones of Cheechako and Chinook Creeks on August 4 and 5, 1982, respectively (ADF&G 1983: Volume 2). On August 6, 1982, ADF&G Su Hydro Aquatic Habitat personnel measured streamflow velocities and depths associated with holding chinook salmon within the clear-water plume and mixing zone of Cheechako Creek (Appendix Figure K-2). Although actual spawning was not observed at this time, a semi-dewatered chinook salmon redd was observed along the water's edge approximately 150 feet downstream from the mouth of Cheechako Creek, indicating that spawning had taken place during a higher discharge period (ADF&G 1983: Volume 2).



Appendix Figure K-2. Chinook salmon holding area near the mouth of Cheechako Creek in the Susitna River at RM 152.4 (GC S32N01E33CCB) August 6, 1982.

Subsequent surveys on Cheechako and Chinook Creeks during August, 1982 indicated that salmon used only a small portion of the habitat above the mouth on each stream. Several fish passage barriers within Cheechako and Chinook Creeks prevented salmon access to the upper reaches of these streams. Most of the lower reach on each stream was characterized by turbulent, high velocity whitewater areas and spawning habitat appeared to be limited.

Additional investigations are planned FY 84 in the Devil Canyon area of the Susitna River to further document the extent of salmon movement above the Devil Canyon dam site, RM 152.0.

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