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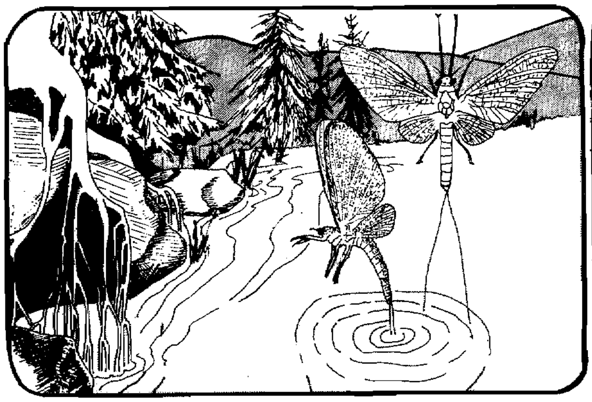

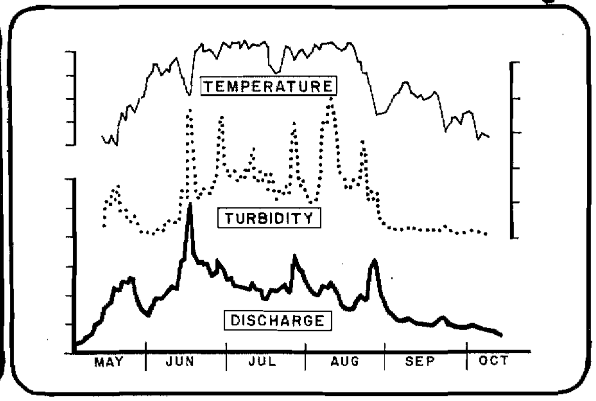

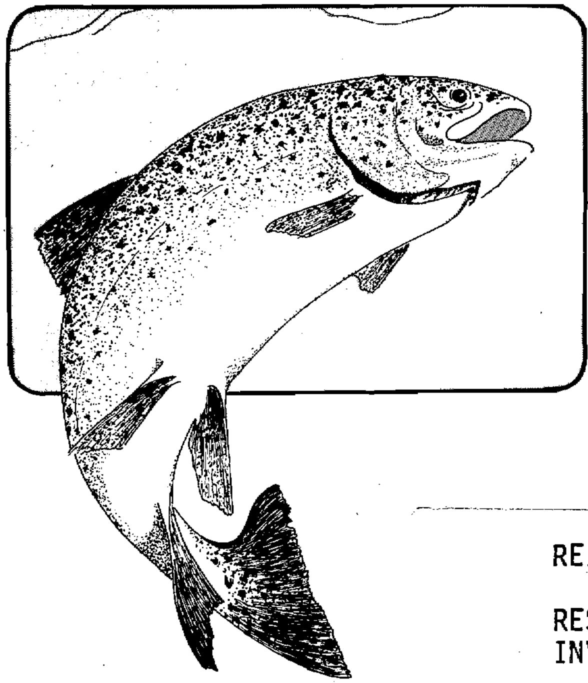

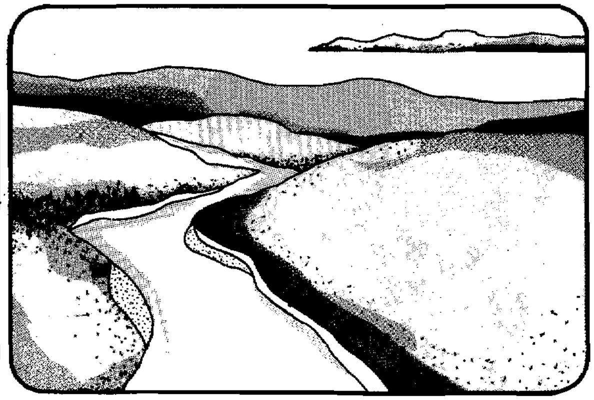

REPORT NO. 7

RESIDENT AND JUVENILE ANADROMOUS FISH INVESTIGATIONS (MAY - OCTOBER 1984)

PARTS 1 AND 2

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

ALASKA DEPARTMENT OF FISH AND GAME

SUSITNA RIVER AQUATIC STUDIES PROGRAM

REPORT NO. 7

RESIDENT AND JUVENILE ANADROMOUS FISH INVESTIGATIONS (MAY - OCTOBER 1984)

PARTS 1 AND 2

Editors: Dana C. Schmidt, Stephen S. Hale, and Drew L. Crawford

Prepared for: Alaska Power Authority
334 W. Fifth Avenue, Second Floor
Anchorage, Alaska 99501

July 1985

PREFACE

This report is one of a series of reports prepared for the Alaska Power Authority (APA) by the Alaska Department of Fish and Game (ADF&G) to provide information to be used in evaluating the feasibility of the proposed Susitna Hydroelectric Project. The ADF&G Susitna River Aquatic Studies Program was initiated in November 1980.

The report covers studies conducted from May through October 1984 of juvenile salmon and resident fish species of the Susitna River. In addition, some information is included on overwintering of resident fish radio-tagged in 1983. The majority of the effort during the 1984 open-water season was on the lower river (from the mouth to the Chulitna River confluence). No studies were conducted this year in the area above Devil Canyon. This volume consists of three parts.

Part 1 (RSA Tasks 16A and 16B) covers the migration and growth of juvenile salmon. Coded wire tagging of chum and sockeye fry in the middle river (Chulitna River confluence to Devil Canyon) and collecting of all species of outmigrating fry at Talkeetna Station were similar to 1983 studies. In addition, a mark-and-recapture cold branding study was conducted in tributaries, sloughs, and side channels of the middle river to obtain estimates of chinook and coho juvenile salmon population size and residence time in these rearing areas. Also, outmigrant traps were operated near the mouth of the river at Flathorn Station (River Mile 22.4) to obtain a timing index of outmigration from the lower river. A statistical time series analysis of 1983 and 1984 discharge, turbidity, and juvenile salmon outmigration data from the middle river is included as an appendix.

Studies of the distribution and relative abundance of juvenile salmon and modelling of rearing habitat in the lower river are discussed in Part 2 (RSA Tasks 14 and 36). These studies were similar to those conducted in the middle river in 1983. Habitat suitability criteria developed for the middle river were used for the lower river unless evidence of different conditions in the lower river necessitated modifications. Results from habitat modelling at 14 RJHAB model sites and 6 IFIM model sites are presented. The RJHAB and IFIM models were compared by using both at two sites. IFIM model calibration is contained in Appendix D.

Part 3 (RSA Task 14) presents the results of resident fish studies in both the middle and lower river. Monitoring of fish movement through use of radio tags was continued. Index sites in the middle river were sampled as part of the long term monitoring effort. Population estimates for rainbow trout, Arctic grayling, round whitefish, and longnose suckers in the middle river were made from multiple year mark-recapture data.

Questions concerning this report should be directed to:

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TITLES IN THIS SERIES

Report Number	Title	Publication Date
1	Adult Anadromous Fish Investigations: May - October 1983	April 1984
2	Resident and Juvenile Anadromous Fish Investigations: May - October 1983	July 1984
3	Aquatic Habitat and Instream Flow Investigations: May - October 1983	September 1984
4	Access and Transmission Corridor Aquatic Investigations: May - October 1983	September 1984
5	Winter Aquatic Investigations: September 1983 to May 1984	March 1985
6	Adult Anadromous Fish Investigations: May - October 1984	June 1985
7	Resident and Juvenile Anadromous Fish Investigations: May - October 1984	July 1985
8	Availability of Invertebrate Food Sources for Rearing Juvenile Chinook Salmon in Turbid Susitna River Habitats	1985
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CONTENTS OF REPORT NO. 7

PART 1

The Migration and Growth of Juvenile Salmon in the Susitna River

THE MIGRATION AND GROWTH OF JUVENILE SALMON IN THE SUSITNA RIVER

Report No. 7, Part 1

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ABSTRACT

Studies of salmon spawning, embryo incubation, and juvenile rearing are all critical in understanding the current life history and habitat dynamics of salmon in the Susitna River. However, the final measure of the value of a reach of river to the freshwater life stages of salmon is the number and condition of the fry which outmigrate from the reach to the ocean. Baseline data on salmon outmigration have been collected at Talkeetna Station (river mile 103.0) for the past three years. The data from 1982 and 1983 have shown that a substantial number of chinook, coho, and sockeye fry outmigrate from the middle river during their first summer. Because the majority of returning adults have spent at least one winter rearing in freshwater, an important question was whether these age 0+ fish overwintered in the lower river or had a low survival rate. To help answer this question, outmigrant traps were also operated near the mouth of the Susitna River (RM 22.4) during 1984. Mark and recapture studies gave population estimates for chum and sockeye fry (marked by coded wire tags) in the Susitna River above Talkeetna Station (middle river) and for chinook fry (marked by cold branding) in Indian River and other rearing sites. The cold branding study also monitored outmigration timing from Indian River and obtained estimates of juvenile chinook residence time in mainstem rearing areas. The Talkeetna River and Deshka River were intermittently sampled to help explain the mainstem outmigrant trap data. A portion of the age 0+ chinook fry apparently outmigrate from the middle river upon reaching a critical size but a large number remain to overwinter and then outmigrate during their second summer. Coho fry outmigrate at a wider range of lengths than chinook fry so the cumulative biomass of coho fry lags behind the cumulative numbers of individuals by one or two weeks. Age 0+ chinook and coho fry grow about 30 mm in length during the

open-water season. Juvenile sockeye salmon appear to seek out lake-like rearing areas at a size of about 50 mm. The limited amount of this habitat type in the middle river is the major influence on their redistribution to the lower river. The estimated 1984 middle river population size was about 300,000 for age 0+ sockeye and 2,040,000 for chum fry. Chum fry rearing in the middle river was demonstrated by their growth and by analysis of stomach contents.

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1.0 INTRODUCTION

Studies of the migration and growth of juvenile salmon in the mainstem Susitna River are a part of the ongoing investigations being conducted by the Resident and Juvenile Anadromous Fish Project (RJ) of the Susitna River Aquatic Studies Program. The scope of these studies has been to describe the periods of freshwater residence, growth, and timing of outmigration for juvenile salmon in the Susitna River and to provide population estimates for the reach of river between the Chulitna River confluence and Devil Canyon. This report presents the results of juvenile salmon outmigration studies conducted on the Susitna River between Cook Inlet and Devil Canyon during the 1984 open-water season. Five Pacific salmon species are addressed in this report: chinook (Oncorhynchus tshawytscha), coho (O. kisutch), sockeye (O. nerka), chum (O. keta), and pink (O. gorbuscha).

Investigations of the distribution, abundance, and migration of juvenile salmon during 1982 and 1983 were focused primarily on the Susitna River reach above the Chulitna River confluence (ADF&G 1983a; Schmidt et al. 1984). These studies included the operation of stationary outmigrant traps at Talkeetna Station, river mile (RM) 103.0, during 1982 and 1983 and a mark-recapture program for post-emergent chum and sockeye salmon fry using half-length coded wire tags in 1983 (Roth et al. 1984). These techniques have provided valuable information on the success of previous spawning runs, the effect of discharge on redistribution of young-of-the-year salmon juveniles, and the population size and egg-to-outmigrant fry survival rates for chum and sockeye salmon fry.

During the 1984 open-water season, additional tasks were added to further describe juvenile salmon growth, migration timing, and response to changing habitat conditions. The study area was expanded to include the entire river between Cook Inlet and Devil Canyon. New tasks begun in 1984 were the addition of stationary and mobile outmigrant traps at Flathorn Station (RM 22.4), intermittent trapping of migrating chinook salmon juveniles in the Deshka and Talkeetna rivers, and mark-recapture by cold branding of juvenile chinook and coho salmon in the Curry Station to Devil Canyon reach.

Investigations of the migration and growth of juvenile salmon in the Susitna River above the Chulitna River confluence during 1982 and 1983 indicated extensive migration of pre-smolt juveniles of all species to areas below this reach. This migration of pre-smolt chinook salmon was also observed in the Deshka River in 1980 (Delaney et al. 1981). If this movement is common in the major tributaries entering the Susitna River, extensive rearing and growth of juvenile salmon, particularly chinook, may occur in habitats associated with the mainstem river. Small habitat changes in the reach of river below Talkeetna could impact large numbers of rearing salmon.

The combined studies of juvenile salmon growth and migration conducted during the 1984 open-water season were developed to provide data to meet the following objectives:

- Estimate the timing, relative abundance, and size of outmigrating juvenile salmon in the Susitna River above the Chulitna River confluence.

- Estimate the population size of outmigrating chum and sockeye salmon fry and egg-to-outmigrant fry survival in this reach of river.

- Estimate the timing and size of outmigrating chum salmon from the Talkeetna River.

- Estimate the timing and rate of movement of juvenile chinook and coho salmon out of Indian River and their residence time at selected macrohabitats associated with the mainstem Susitna River.

- Estimate the timing and rate of outmigration of chinook salmon juveniles from the Deshka River into the mainstem Susitna.

- Estimate the timing and rate of outmigration of juvenile salmon from the Susitna River into Cook Inlet.

- Estimate the rate of growth of juvenile chum and chinook salmon from the time they enter the lower river (below the Chulitna River confluence) until they enter the marine environment.

- Estimate the relationship of mainstem Susitna discharge and other environmental variables to juvenile salmon outmigration.

Sampling of chum salmon fry in the Talkeetna River was hindered by equipment failure; insufficient data were collected for this species, although some growth and relative abundance data for chinook salmon were collected.

Although initially designed as a survey of Portage Creek using a stationary outmigrant trap, the cold branding study was relocated to Indian River with minnow traps serving as the primary collection technique. The design of the original collection equipment did not lend itself well to the continually fluctuating hydraulic conditions present at Portage Creek. The low numbers of juvenile salmon observed in Portage Creek after June 15, combined with the comparative logistical inaccessibility of this stream, made Indian River a better choice.

The data presented in this report provide information that can be used to determine the size of the present fishery resource, potential changes caused by the proposed hydroelectric development, and mitigation requirements necessary to compensate for any reductions of the juvenile salmon populations in the Susitna River.

2.0 METHODS

2.1 Study Locations

Studies on the migration and growth of juvenile salmon in the mainstem Susitna River were conducted at survey sites from Flathorn Station (RM 22.4) upstream to Slough 22 (RM 144.3) during the 1984 open-water season (Fig. 1).

2.1.1 Flathorn Station

A stationary outmigrant trap was operated on the west bank of the Susitna River at Flathorn Station (RM 22.4) and a mobile outmigrant trap was used to sample a total of ten points along transects spanning three channels of the mainstem river at this station (Fig. 2). Five sampling points were located in the west channel (RM 22.8), one in the middle channel (RM 22.8), and four in the east channel (RM 23.9). A bottom profile of the Susitna River at these sampling points is provided in Fig. 3.

2.1.2 Deshka River

An outmigrant fyke net weir was operated in the Deshka River (RM 40.6) between tributary river mile (TRM) 2.5 and TRM 5.0 to estimate the timing and rate of outmigration for juvenile chinook salmon (Fig. 4).

2.1.3 Talkeetna River

A beach seine sampling site for outmigrants was located in the north channel of the Talkeetna River (RM 97.5) approximately one mile upstream from the river's mouth (Fig. 5).

2.1.4 Talkeetna Station

Two stationary outmigrant traps were deployed on the mainstem Susitna River above the Chulitna River confluence at Talkeetna Station (RM 103.0) at the same locations used in 1983. One trap was set off the east bank (Trap 1) and the other off the west bank (Trap 2) of the river (Fig. 5).

2.1.5 Coded wire tagging

Coded wire tagging sites were selected from those locations above the Chulitna River confluence where high density spawning by adults was recorded (Barrett et al. 1984), and from surveys of the availability of sufficient numbers of post-emergent chum and sockeye salmon fry for collection and tagging (Fig. 5). Specific coded wire tagging sites (Fig. 6) were:

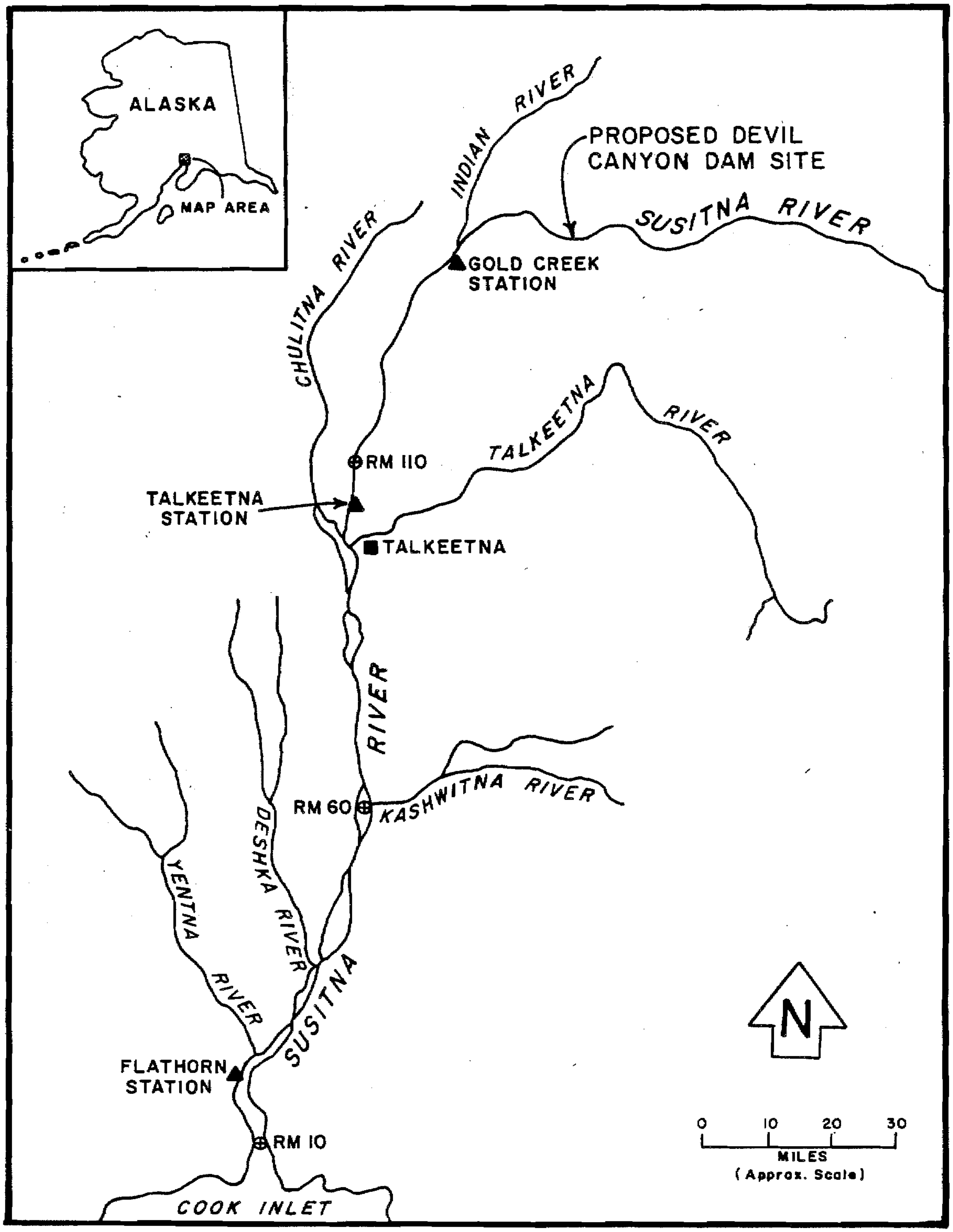


Figure 1. Map of juvenile salmon outmigration study field stations in the Susitna River basin, 1984.

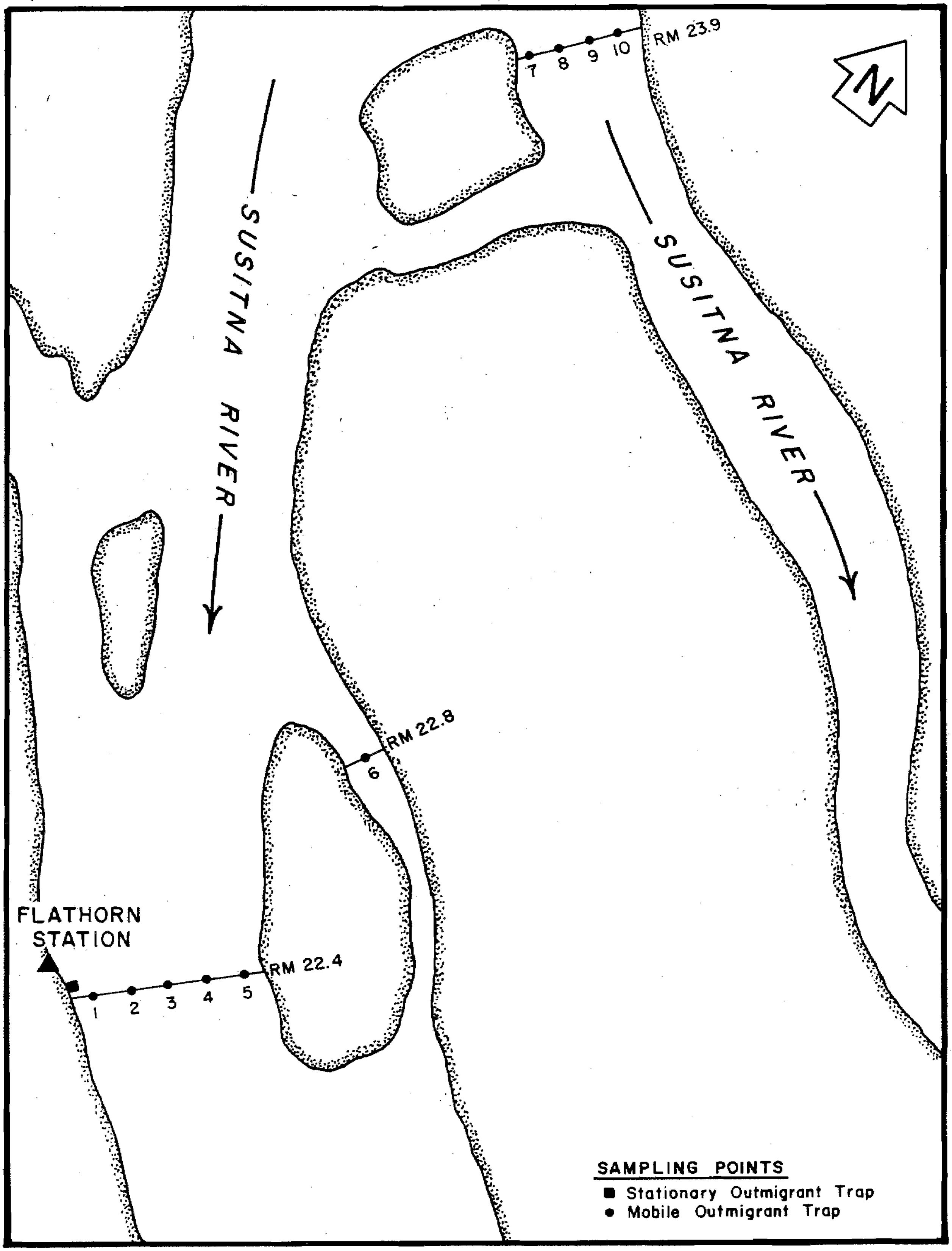


Figure 2. Map of the stationary outmigrant trap and the mobile outmigrant trap sampling points on the Susitna River at Flathorn Station, 1984.

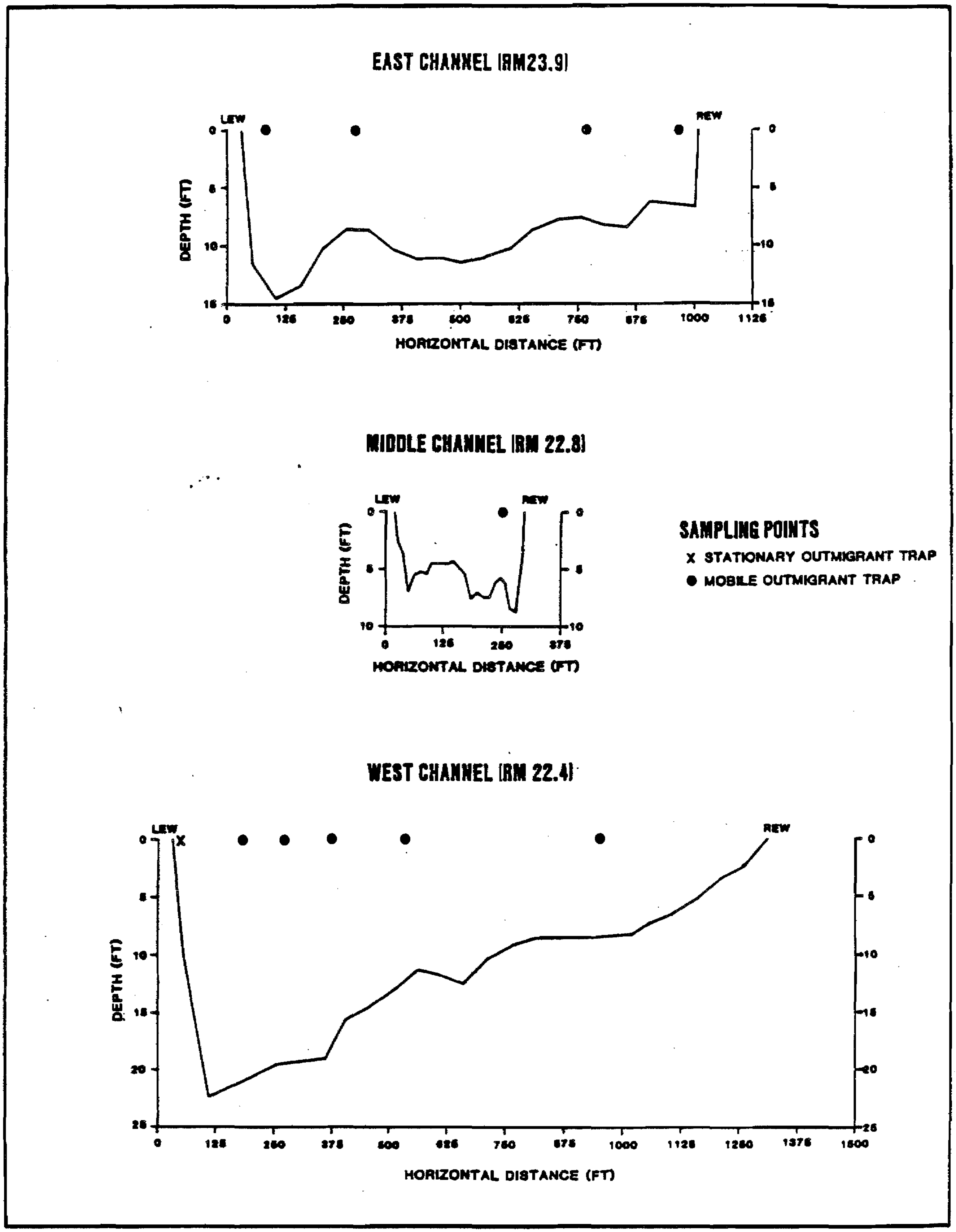


Figure 3. Bottom profile of the Susitna River at the stationary and mobile outmigrant trap sampling points at Flathorn Station. Measured on August 23, 1984 at a mainstem discharge of 114,000 cfs at the USGS gaging station at Susitna Station.

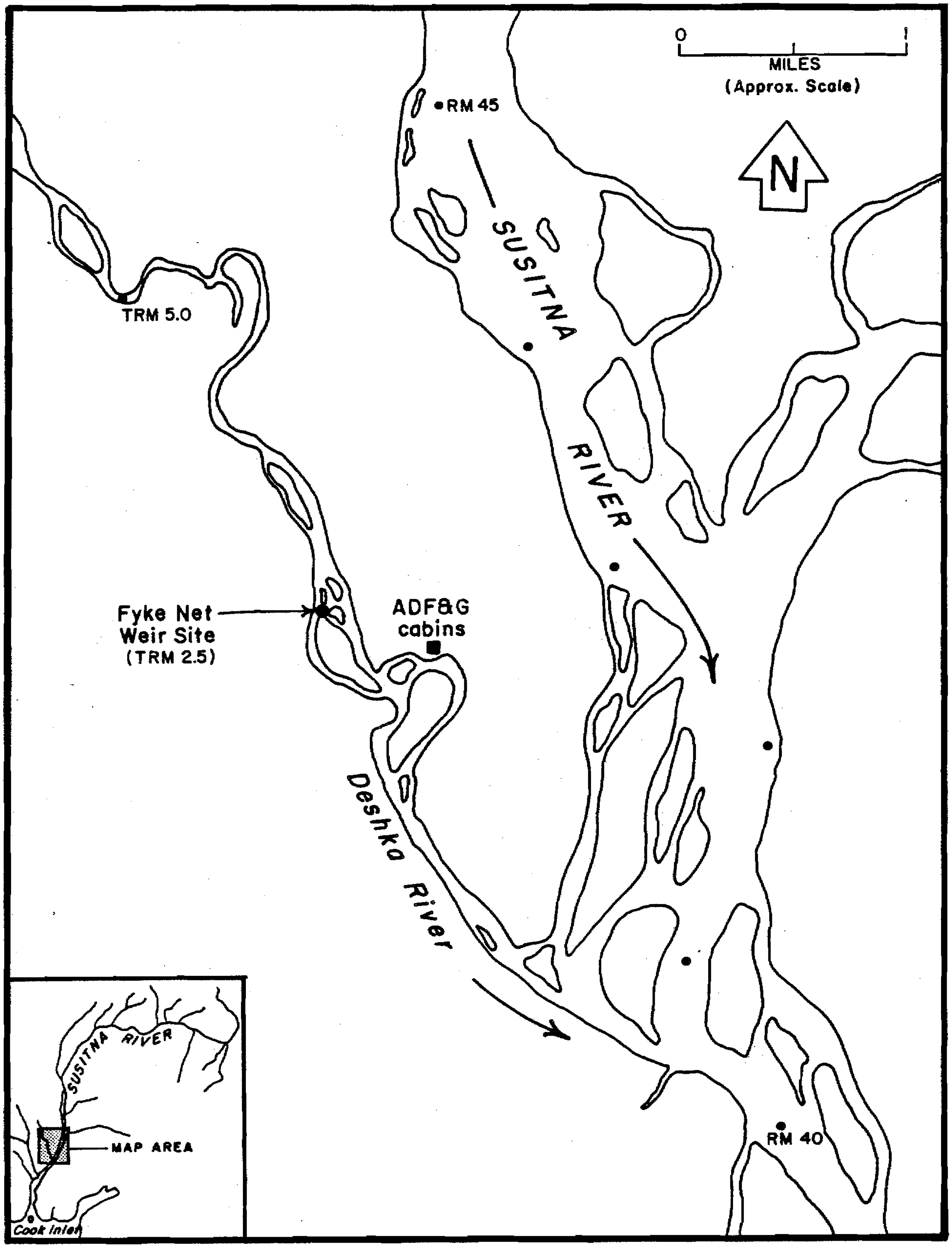


Figure 4. Map showing the location of the fyke net weir on the Deshka River, 1984.

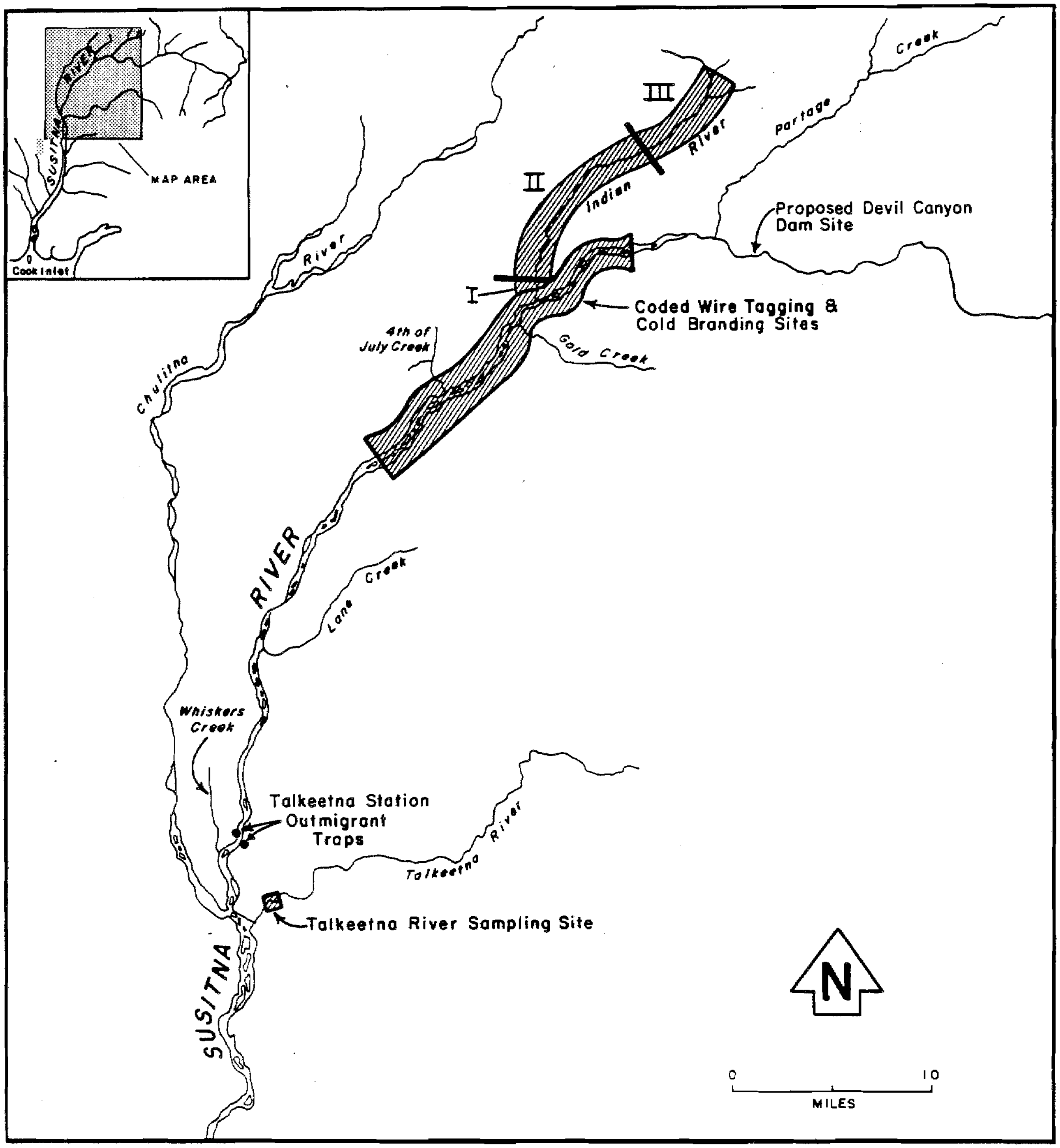


Figure 5. Map showing the reach where juvenile salmon mark-recapture sites are located (RM 122.2 to 144.8 and Indian River) and the locations of the Talkeetna stationary outmigrant traps (RM 103.0), and the Talkeetna River sampling site (TRM 1.0), 1984.

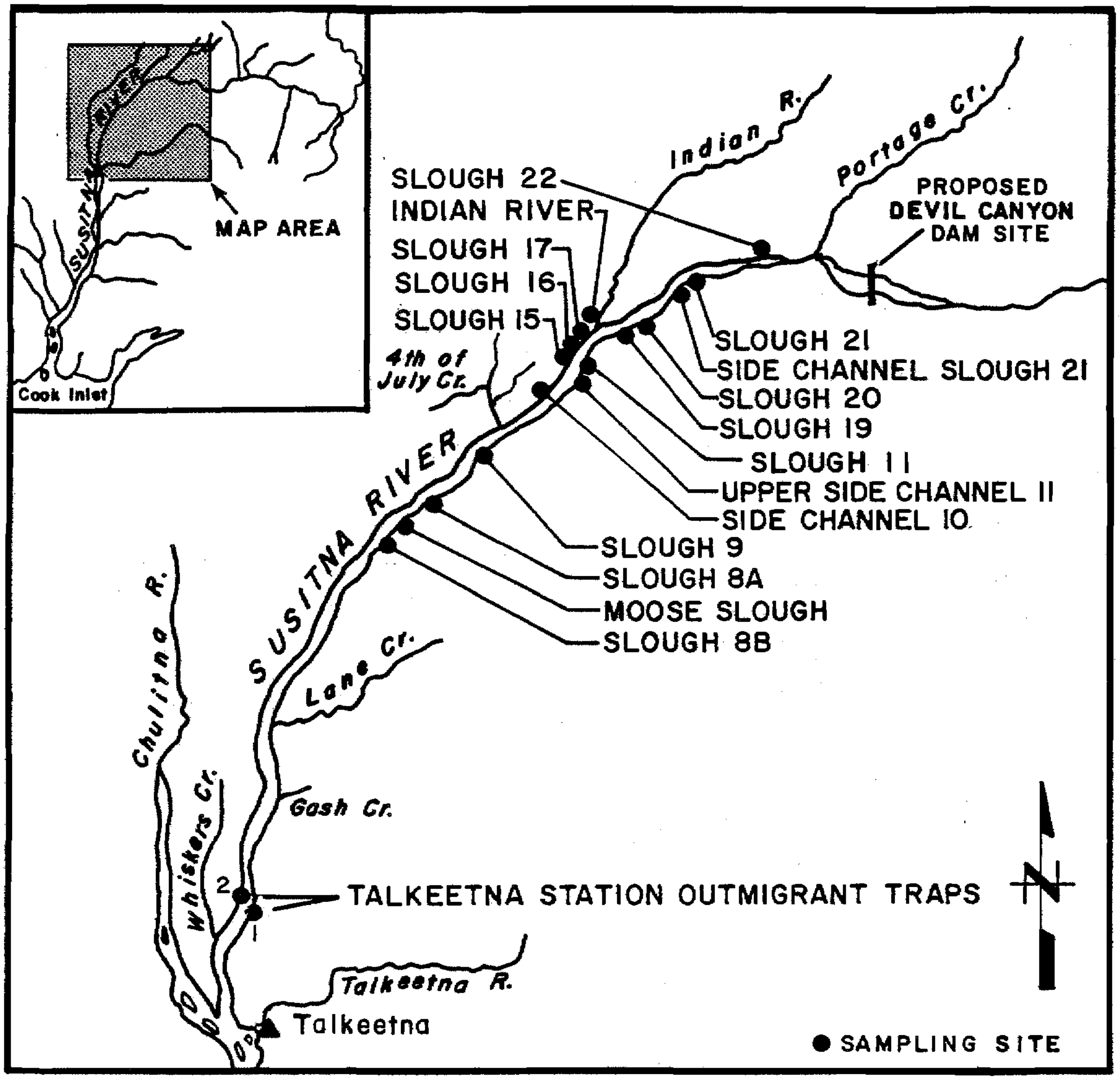


Figure 6. Map of coded wire tagging and cold branding sites in the middle reach of the Susitna River, 1984.

CODED WIRE TAGGING SITES	RIVER MILE
Slough 8B	122.4
Slough 8A	125.3
Slough 9	129.2
Slough 11	135.3
Slough 15	137.3
Indian River	138.6
Slough 20	140.1
Slough 21	142.0
Slough 22	144.3

2.1.6 Cold branding

A cold brand mark-recapture study was conducted at the mouth and at numerous side channels and side sloughs of Indian River (RM 138.6) which were found to contain large concentrations of juvenile chinook and coho salmon. Indian River was divided into three sections for this study. Section I included the mouth upstream to TRM 0.5, Section II was the portion of Indian River from TRM 0.5 to 7.5 and Section III was from TRM 7.5 upstream to TRM 12.3 (Fig. 5).

Cold branding was also used to estimate the populations and study the movements of juvenile salmon at the following study sites (Fig. 6):

COLD BRANDING SITES	RIVER MILE
Moose Slough	123.2
Side Channel 10	133.8
Lower Side Channel 11A	135.9
Slough 16	137.7
Slough 17	138.9
Slough 19	139.7
Slough 20	140.1
Side Channel 21	141.1
Slough 22	144.3

2.2 Field Data Collection and Recording

2.2.1 Flathorn Station outmigrant traps

The stationary outmigrant trap on the west bank of the Susitna River at Flathorn Station (RM 22.4) was operated from May 20 through October 1, 1984. A description of this outmigrant trap is provided in ADF&G (1985). The trap was checked at least twice each day to remove the captured fish and to clean the trap.

The mobile outmigrant trap at Flathorn Station was operated for 43 days during the period July 12 through September 13, 1984. A description of the trap and its operation is presented in ADF&G (1985). The trap was fished for 20-minute periods at ten different transect points during a fishing day.

Habitat and biological data recorded for each check of the stationary outmigrant trap included fishing effort (hours), trap depth (feet), distance from shore (feet), and catch by species and age class. Mainstem stage was recorded once each day. The first 25 fish of each species and age class collected daily were measured for total length (tip of snout to tip of tail) in millimeters (mm).

Biological and habitat data for the stationary trap were entered directly into an Epson HX-20 microcomputer in the field. Operational procedures for the microcomputer and the associated data form program are presented in ADF&G (1985). Computer entries were made for each trap check throughout the field season. Printouts and cassettes were periodically transferred to Data Processing to be entered into a mainframe computer for later data retrieval and analysis.

Transect number, fishing effort, total water column depth, set velocity, and drift velocity (if the trap was not held stationary during the set) were recorded for each individual transect point at which the mobile outmigrant trap was fished. Total catch by species and age class was also recorded, and total length measurements were taken for all captured fish. Data were recorded on a field data form for later analysis.

2.2.2 Deshka River outmigrant weir

A weir was established on the Deshka River (RM 40.6) using a fyke net (3/16 inch square mesh) to block a portion of the river. The fyke net is described in ADF&G (1985). The weir was operated at varying tributary miles (TRM 2.0 - 5.0) periodically from May 10 through June 22. The weir was moved to TRM 2.5 on July 11 and was fished periodically through September 18. Minnow traps were fished intermittently from late June through mid October to supplement the weir data.

Fishing effort and total catch by species and age class were recorded for the outmigrant weir and the minnow traps. A sample of each species and age class captured were measured for total length and scale samples were collected for age determination.

2.2.3 Talkeetna River beach seining

Beach seining (1/8 inch square mesh) was conducted one to two times each week from June 5 through September 15. Sampling was conducted to obtain a sufficient sample for comparative length and outmigration timing data. An attempt was made to use a Fyke net weir in late May and June. This did not work, so we changed to a beach seine.

Total catch by species and age class was recorded. All captured fish were measured for total length and released.

2.2.4 Talkeetna Station outmigrant traps

Two inclined plane outmigrant traps were operated continuously in the mainstem Susitna River at Talkeetna Station (RM 103.0) from May 14 through October 6, 1984 using the methods outlined by Roth et al. (1984).

Measurements of the following habitat parameters were recorded daily at the outmigrant traps: air and surface water temperature (°C), turbidity (NTU), water velocity (ft/sec), and mainstem stage data. The equipment and methods used to collect the habitat data are given in ADF&G (1985).

Trap fishing depths and distances from shore were adjusted to maximize catches while maintaining trap efficiency. All juvenile fish captured were anesthetized using MS-222 (Tricaine methanesulfonate). Field specimens were identified using the guidelines set forth by McConnell and Snyder (1972), Trautman (1973), and Morrow (1980). Juvenile chinook and coho salmon collected at the traps were checked for a cold brand mark and all recovered marks were recorded. Chum and sockeye salmon juveniles with a clipped adipose fin were passed through a detector to verify the presence of a coded wire tag. All coded wire tagged fish recovered at the traps were preserved and tags were later removed and decoded using a reading jig and a binocular microscope. All other fish recovered at the traps were held until anesthetic recovery was complete and then released downstream of the traps.

Scales were collected from a sub-sample of fish captured for comparison to length frequency data for final age class determination. Biological and habitat data were entered directly into an Epson HX-20 microcomputer.

Length and weight relationship data were also collected from samples of juvenile chinook, coho, and sockeye salmon collected in the outmigrant traps at Talkeetna Station. Total length was recorded to the nearest millimeter and live weights were determined to the nearest 0.1 gram.

2.2.5 Coded wire tagging

The coded wire tagging was conducted at Slough 11 (RM 135.3) from May 16 through June 20, 1984. The fish were transported from the collection areas to Slough 11 in an aerated tub, tagged, held for at least 24 hours, and then returned to the collection areas. The fish were also held overnight at the collection areas prior to release.

Beach seines were used to weir off the downstream end of the collection area and were checked at least once each day to collect fish and remove debris. Beach seining and dip netting supplemented the weir catches at sites where weiring alone did not provide enough fish for the tagging operation.

The coded wire tagging equipment and implantation procedures are similar to those outlined by Roth et al. (1984) using the guidelines provided by Koerner (1977) and Moberly et al. (1977). One-half length binary coded wire tags measuring 0.02 inches (0.533 mm) in length and 0.01 inches (0.254 mm) in diameter were used in the study. Separate head molds were required for each species and length class of fish. Fifty fish of each group were measured to determine mean length and the proper head molds for the tagging procedure. The adipose fin was clipped from each fish prior to tagging to provide a visual indicator of the presence of a coded wire tag. At the end of each tagging day, a subsample of 100 tagged fish were anesthetized and passed through the quality control device to determine the tag retention rate. Mortalities were recorded the following day and again just prior to release. A single tag code was used for each species tagged and for each collection site. Six distinct tag codes were used for juvenile sockeye salmon and fourteen distinct tag codes were used for juvenile chum salmon.

Coded wire tagging data recorded at each site included date tagged, tag code, species, number of fish tagged, percent tag retention, mortality, and date and time of release. Total numbers of fish tagged by species, collection site, and release date as well as final tag retention and mortality were tabulated for each tag code.

2.2.6 Cold branding

Mark-recapture studies of chinook and coho salmon populations were conducted from July through mid October. Cold branding was used as a marking technique because it is less expensive than coded wire tagging. Cold branding was not used on chum and sockeye because it has not been proven effective on these fish at the post-emergent stage. Sites in Indian River were sampled twice a month and fish were captured, branded, and released continually throughout the field season. Sampling in the sloughs and side channels of the Susitna River was conducted for five consecutive days and captured fish were either branded and released the same day or held until the end of the five day period before release.

Minnow traps, beach seines, and dip nets were used to capture fish which were then transported from the areas of collection to the Gold Creek field camp for cold brand marking. Cold branded fish from all sites except Indian River were held for 24 hours to determine marking mortality before being released at the area of collection. Fish collected in Indian River were marked, held for 24 hours, and then released at a side slough at TRM 7.2.

The brands consisted of single brass letters or symbols measuring approximately three millimeters in height which were soldered onto threaded brass caps. Liquid nitrogen was used as the cooling agent and branding procedures were similar to those outlined by Raleigh et al. (1973). The cold branding equipment is described in ADF&G (1985).

Juvenile chinook and coho salmon were marked with a distinctive brand to signify the collection site and date of their capture. Fish were marked on one side of the body at one of three target branding areas (Fig. 7), and a branding time of two seconds was used.

Date, collection site, gear type, fishing effort, species, number of fish captured, and brand symbol were recorded for each site. The number of recaptures by species and the symbols for previously marked fish were also recorded. Total length was measured for 50 fish of each species during each sampling trip.

2.3 Data Analysis

2.3.1 Juvenile salmon catch per unit effort

The catch per unit effort (CPUE) data collected for juvenile salmon at the stationary outmigrant traps are presented as the average catch per hour for each calendar day of sampling effort. The catch was expanded to 24-hour intervals by dividing the number of hours fished on a given day into 24 and then multiplying this ratio by the catch for each species and age class.

The catch rates plotted for each species and age class of juvenile salmon collected at the stationary traps were smoothed using the von Hann linear filter (Dixon et al. 1981). The equation is:

$$Z_{(t)} = \tfrac{1}{4}Y_{(t-1)} + \tfrac{1}{2}Y_{(t)} + \tfrac{1}{4}Y_{(t+1)}$$

where: $Z_{(t)}$ = smoothed catch per hour for day (t) and

$Y_{(t)}$ = observed catch per hour for day (t)

This is similar to a three day moving average except that the current day is weighted twice as heavily as the preceding and subsequent days.

The cumulative catch totals were adjusted for days not fished by tabulating the mean of the total catches recorded for the three days preceding and the three days following an unsampled day.

Length frequency distribution and scale analysis data were used to determine the age class composition of chinook, coho, and sockeye salmon juveniles.

A regression was done on the natural logarithm of weight versus the natural logarithm of length for chinook, coho, and sockeye salmon. The regression equations were used to provide estimates of the total biomass passing the Talkeetna and Flathorn station outmigrant traps by sampling period through the season.

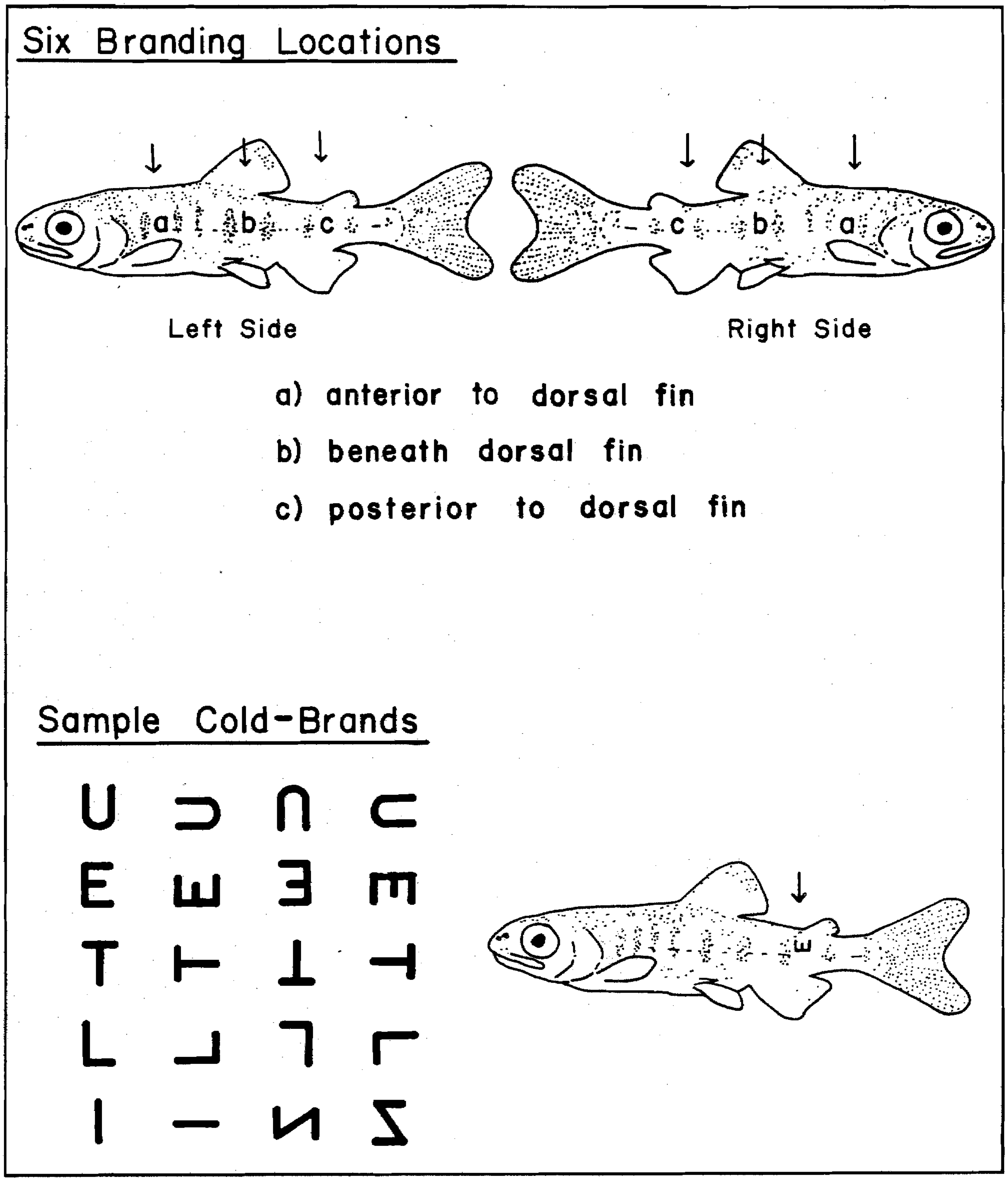


Figure 7. Branding locations and sample brands used for cold branding chinook and coho salmon juveniles, 1984.

2.3.2 Population and survival estimates

Potential egg deposition for chum and sockeye salmon was calculated by multiplying the average fecundity for each species by the estimated number of female spawners that passed Curry Station in 1983 (Barrett et al. 1984). The chum, sockeye, and chinook salmon adult population estimates were reduced by 40%, 39%, and 7% respectively, to account for milling fish which eventually spawned below the Chulitna River confluence (Barrett 1984; Barrett et al. 1984). The following formula was used to determine egg deposition:

$$\text{Total potential egg deposition} = (E) \times (1-M) \times (P) \times (F)$$

where:

E = Adult population estimate at Curry Station
M = Proportion milling
P = Proportion females
F = Average fecundity

Population estimates for chum and sockeye outmigrants were calculated by the Schaefer (1951) method (Appendix B). Estimates of survival for both species were determined by dividing the population estimates by the calculated potential egg deposition for each species. Only valid tagged fish were used in the calculations. The total number of valid tagged fish was determined by subtracting the mortalities for each day of tagging from the total number of fish tagged and then multiplying this by the tag retention rate. Total tag recoveries at the Talkeetna Station outmigrant traps include only those fish with a coded wire tag. Fish having a clipped adipose fin but no tag were not considered in the population estimates.

Population estimates for chinook salmon were calculated from the data collected during the cold branding study by using the Petersen, Schaefer, or Jolly-Seber methods (Ricker 1975). The Schaefer and Jolly-Seber methods were used at sites where conditions allowed five consecutive days of sampling. The Peterson method was used when there was one marking period and one recapture period. Confidence limits for the Jolly-Seber estimate of population size were developed using the method of Manly (1984). The Jolly-Seber model was run on a commercial spreadsheet program for microcomputers. The potential egg deposition for chinook salmon in Indian River was determined using the technique listed above except that the estimate was reduced to represent the percentage of chinook (determined from peak spawning counts) which spawned in Indian River. Fecundities used were those measured by Healy and Heard (1984) for Kenai River chinook salmon.

2.3.3 Time series analysis

The 1983 and 1984 discharge, turbidity, and age 0+ chinook and sockeye salmon outmigration time series are analyzed in Appendix C.

3.0 RESULTS

The results of the juvenile salmon outmigration studies are presented by species. The catch per unit effort (CPUE) data are presented as a percentage of the highest CPUE (after smoothing) recorded at the stationary traps during 1984. The cumulative catch data are presented as a percentage of the total adjusted cumulative catch after application of the smoothing functions. Juvenile salmon length data collected at Flathorn Station are from both the stationary and mobile traps and the length information presented for Talkeetna Station is from both stationary traps located at this site.

3.1 Chinook Salmon

3.1.1 Catch per unit effort

3.1.1.1 Age 0+

Chinook salmon fry collected incidentally during the coded wire tagging study in May and June were observed to be most abundant at Slough 22 and Indian River.

The cold branding study captured 26,823 chinook salmon fry in Indian River from July 1 through October 15. Fifty-eight percent of this catch was recorded near the mouth of the river (section I), 30% in the lower portion (section II) and 12% in the upper portion (section III). Beach seining of sections II and III during July captured 3,280 chinook salmon fry; 66% in section III and 34% in section II. Minnow trapping begun in Indian River in late July collected a total of 23,543 chinook fry during 947 minnow trap days (defined as one trap day for each overnight minnow trap set) for a season average of 24.9 fish per trap day.

Catch rates in Indian River (Fig. 8) were generally highest in section II except during late August when high and turbid water conditions reduced trapping effectiveness. The CPUE for chinook fry in Indian River for all sections combined was highest during late July (average of 36 fish per trap day) and steadily declined through the season to a low of 15 fish per trap day in early October.

A total of 11,875 chinook salmon fry were captured in sloughs and side channels in the middle reach of the Susitna River during the cold branding study from July 1 through October 15. Sloughs accounted for 84% of the catch while the remaining 16% were collected in side channels. Beach seining during July and August collected 39% of the total catch at these sites while minnow trapping begun in early September captured 61% of the chinook fry.

The 7,291 chinook salmon fry captured by minnow trapping at slough and side channel sites in the middle river were collected during 378 minnow trap days for an average of 19 fish per trap day. Mean CPUE by study site ranged from a high of 48 fish per trap day at Slough 22 during early October to a low of 3 fish per trap day at Side Channel 21 in late September.

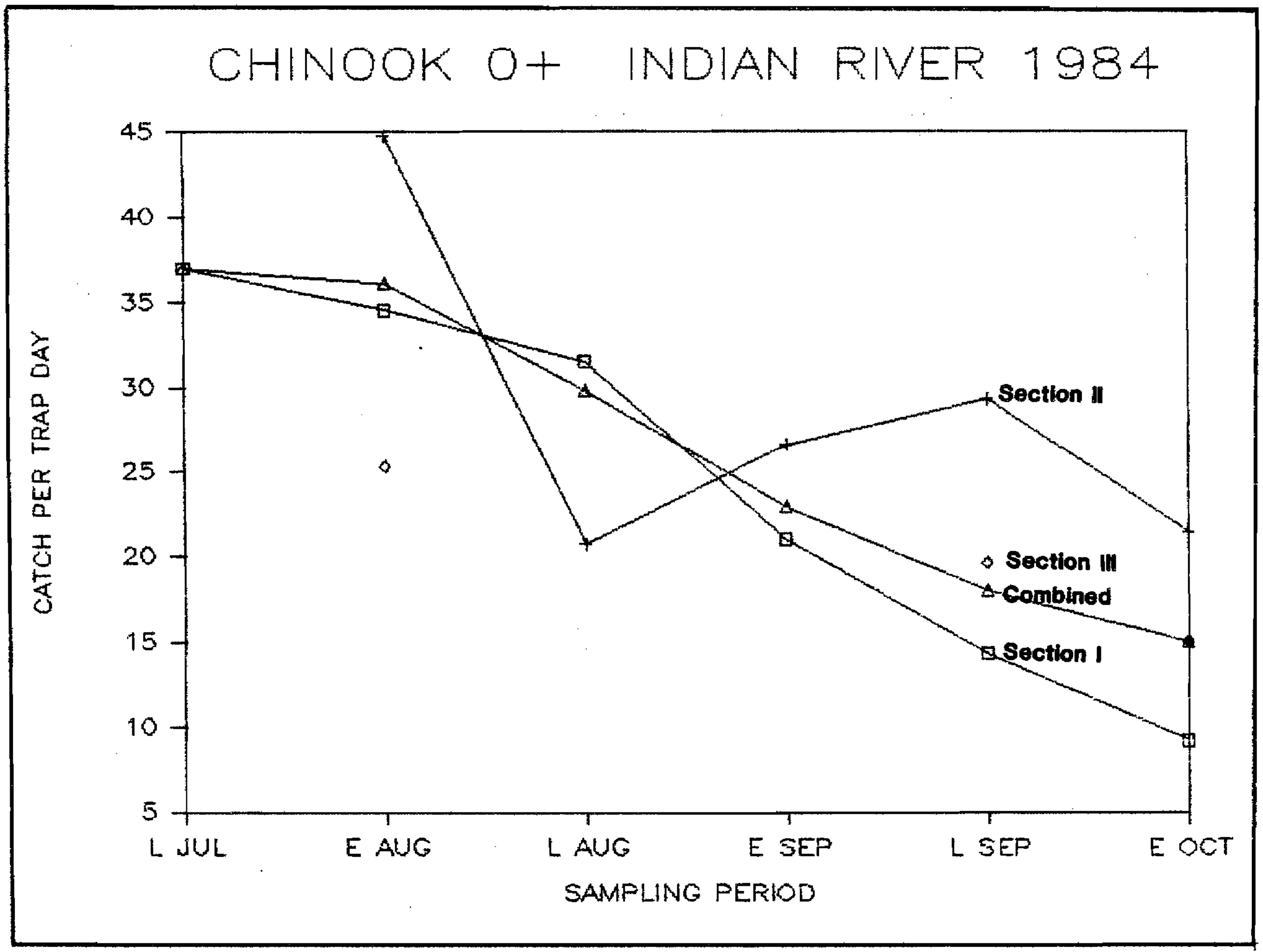


Figure 8. Chinook salmon (age 0+) average catch per minnow trap by sampling period and survey section in Indian River, 1984.

A total of 14,110 chinook salmon fry were collected at the Talkeetna Station outmigrant traps. Peak catches were recorded from late June through early August and the highest catch rate of 17.3 chinook fry per hour was recorded on July 26 (Fig. 9). Fifty percent of the catch was recorded by July 20. Catches decreased after early August and the last capture of chinook fry at this site was recorded on September 29.

A total of 2,118 chinook salmon fry were captured in the stationary outmigrant trap at Flathorn Station. Catch rates were greatest between late June and late August (Fig. 10). The chinook fry catch rate at this site peaked at 7.8 fish per hour on July 23, 50% of the captures were recorded by July 13, and the last capture was recorded on September 30.

The highest catch rate of the Flathorn Station mobile trap was 16.2 fish per hour, recorded on July 23 (Fig. 11). Of the 189 chinook fry collected in the mobile trap during 1984, 60% were captured at bank transect sampling points and the remaining captures occurred at center channel sampling sites (Fig. 12).

The Deshka River weir captured 1,808 chinook salmon during 1984 (Appendix Table A-1). Eighty-eight percent of the captures were recorded during July and the peak catch rate of 21.2 fish per hour was recorded on July 25. Minnow trap catches at this site were highest during late June at 8.7 fish per trap (Appendix Table A-2).

A total of 1,356 chinook salmon fry were collected in the lower reach of the Susitna River by the Juvenile Aquatic Habitat Studies (JAHS) surveys from June through early October (see Part 2 of this report). Catch rates for all sites combined peaked in August and then decreased through early October (Fig. 13).

3.1.1.2 Age 1+

Age 1+ chinook salmon were captured incidentally during the coded wire tagging study in May and June and were most abundant at Indian River and Slough 11. No age 1+ chinook were captured during the cold branding study begun in July, as most of these fish had outmigrated by that time.

Peak catch rates of the 1,321 age 1+ chinook captured at the Talkeetna Station outmigrant traps were recorded during the deployment of the traps in mid May and again in mid and late June (Fig. 14). Fifty percent of the season catches occurred by June 23. The highest catch rate for this age class was 3.6 fish per hour recorded on May 15 and the last age 1+ chinook was captured in the traps on August 7.

Catch rates for the 346 age 1+ chinook salmon captured at Flathorn Station were highest during early June (Fig. 15). The highest CPUE of 6.4 fish per hour was recorded on June 14 (50% of the season total by this date) and the last age 1+ chinook was collected at this site on August 23.

Nine age 1+ chinook salmon were collected in the Deshka River during weir and minnow trap sampling, with the last capture recorded on October 10.

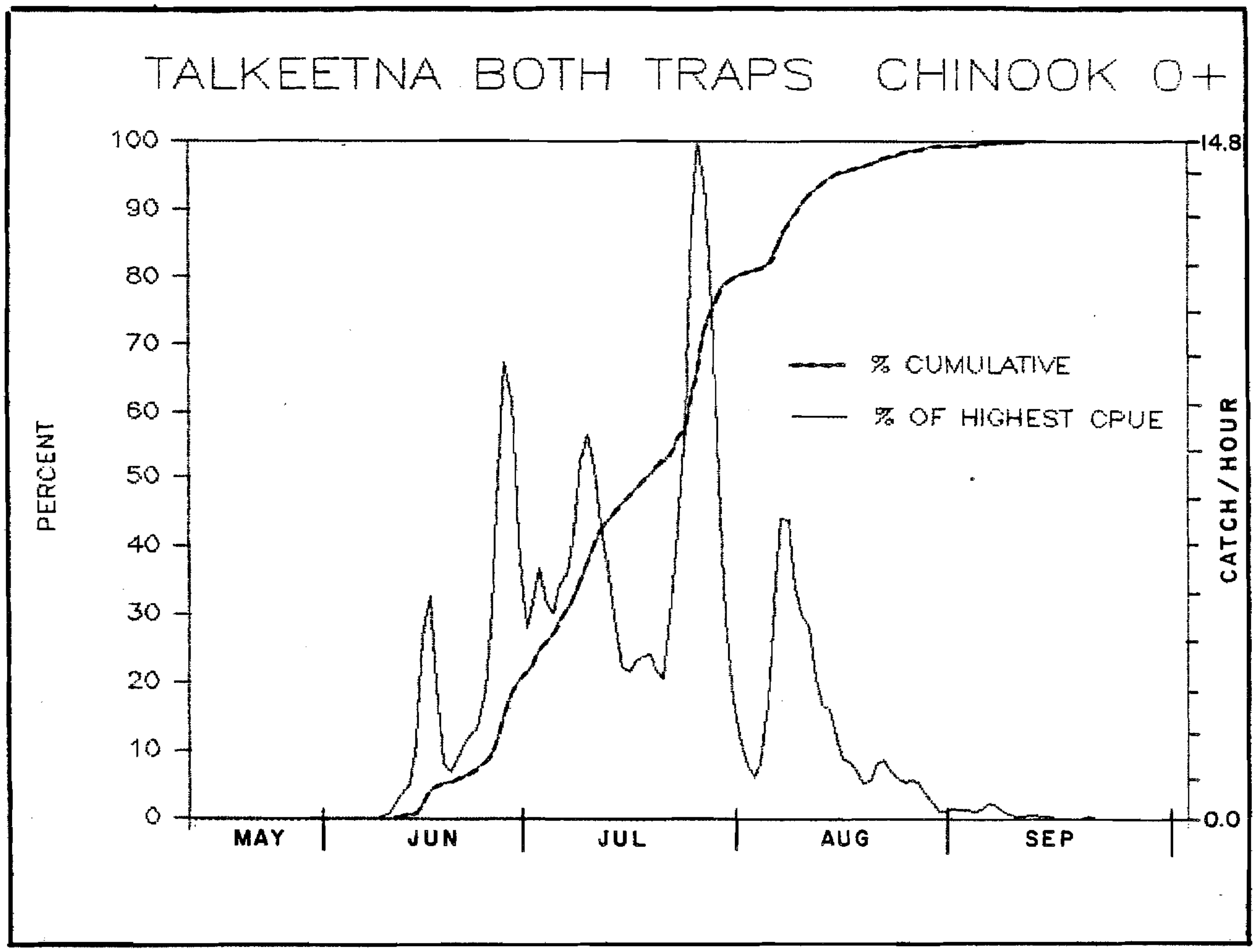


Figure 9. Chinook salmon (age 0+) smoothed daily catch per unit effort and adjusted cumulative catch recorded at the Talkeetna stationary outmigrant traps, May 14 through October 6, 1984.

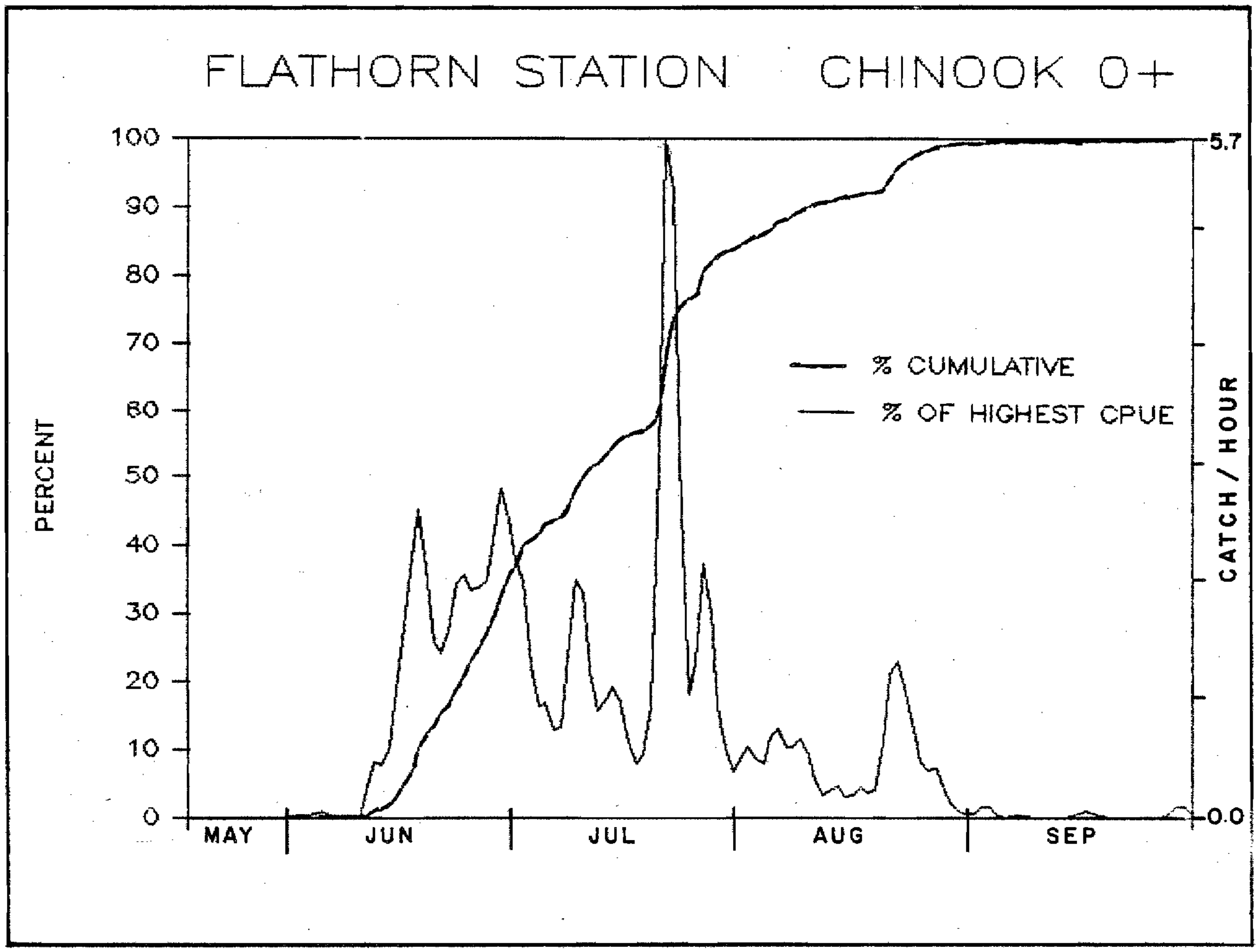


Figure 10. Chinook salmon (age 0+) smoothed daily catch per unit effort and adjusted cumulative catch recorded at the Flathorn stationary outmigrant trap, May 20 through October 1, 1984.

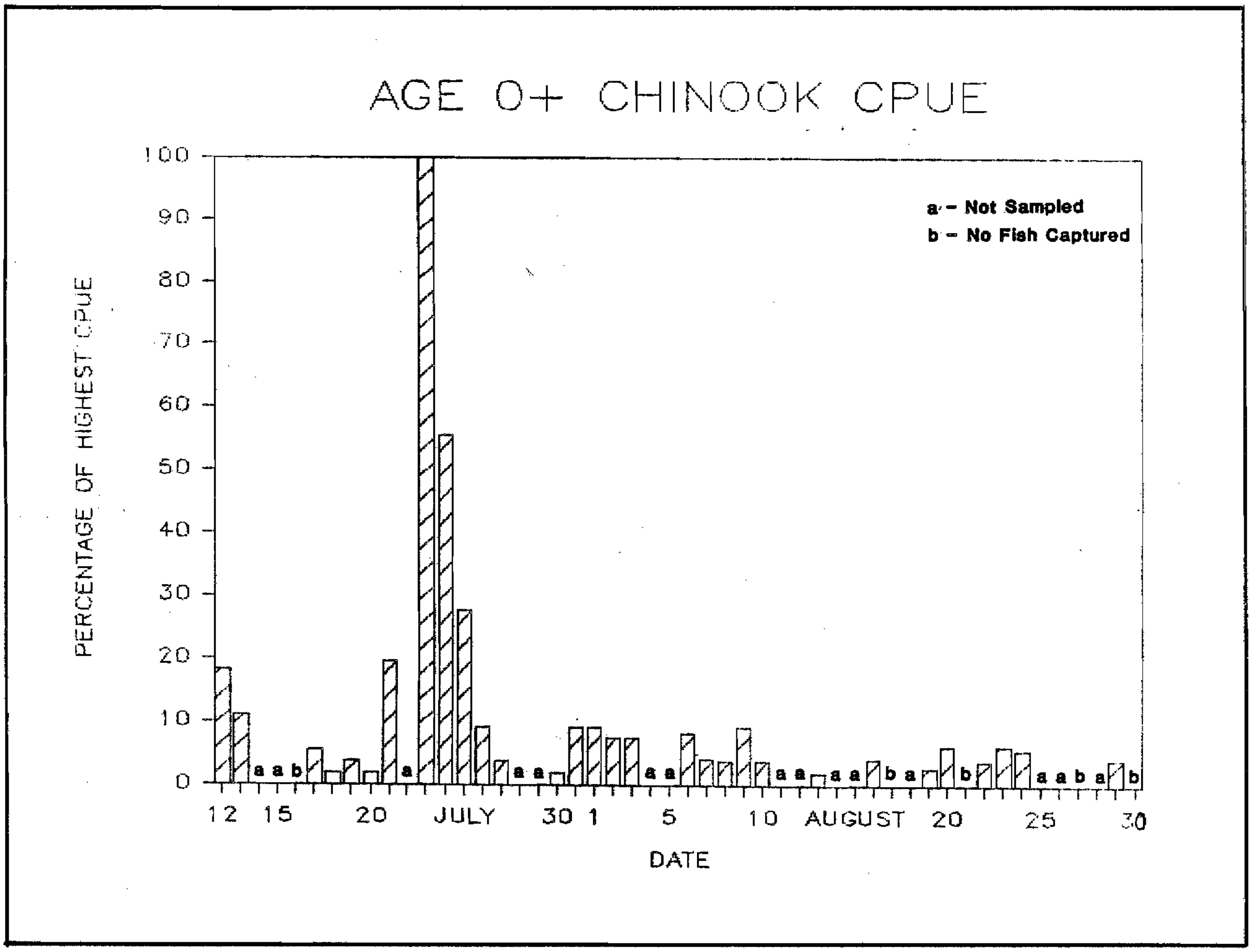


Figure 11. Chinook salmon (age 0+) daily catch per unit effort recorded at the Flathorn mobile outmigrant trap, July 12 through August 30, 1984.

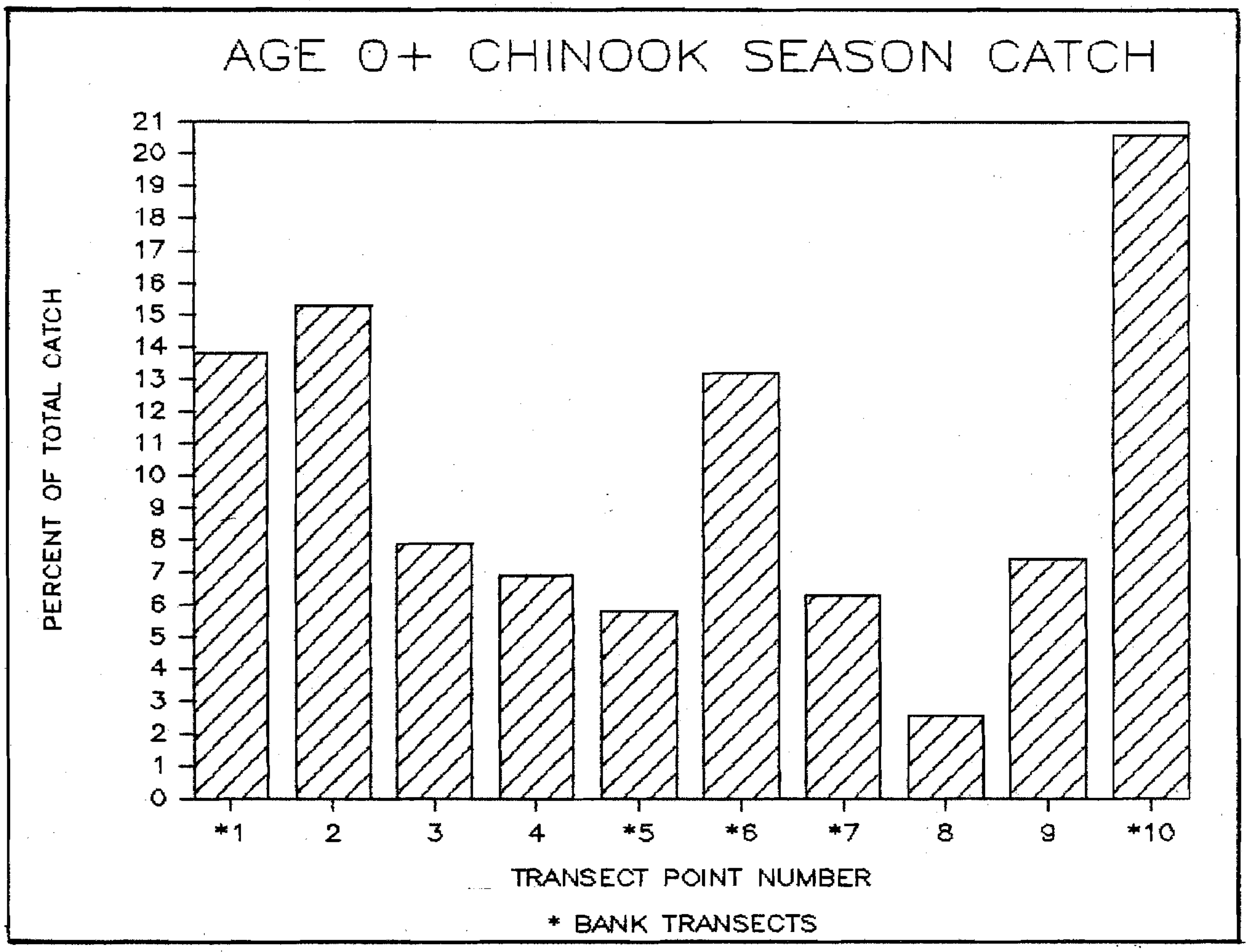


Figure 12. Chinook salmon (age 0+) percent of total catch by sampling point recorded at the Flathorn mobile outmigrant trap, 1984.

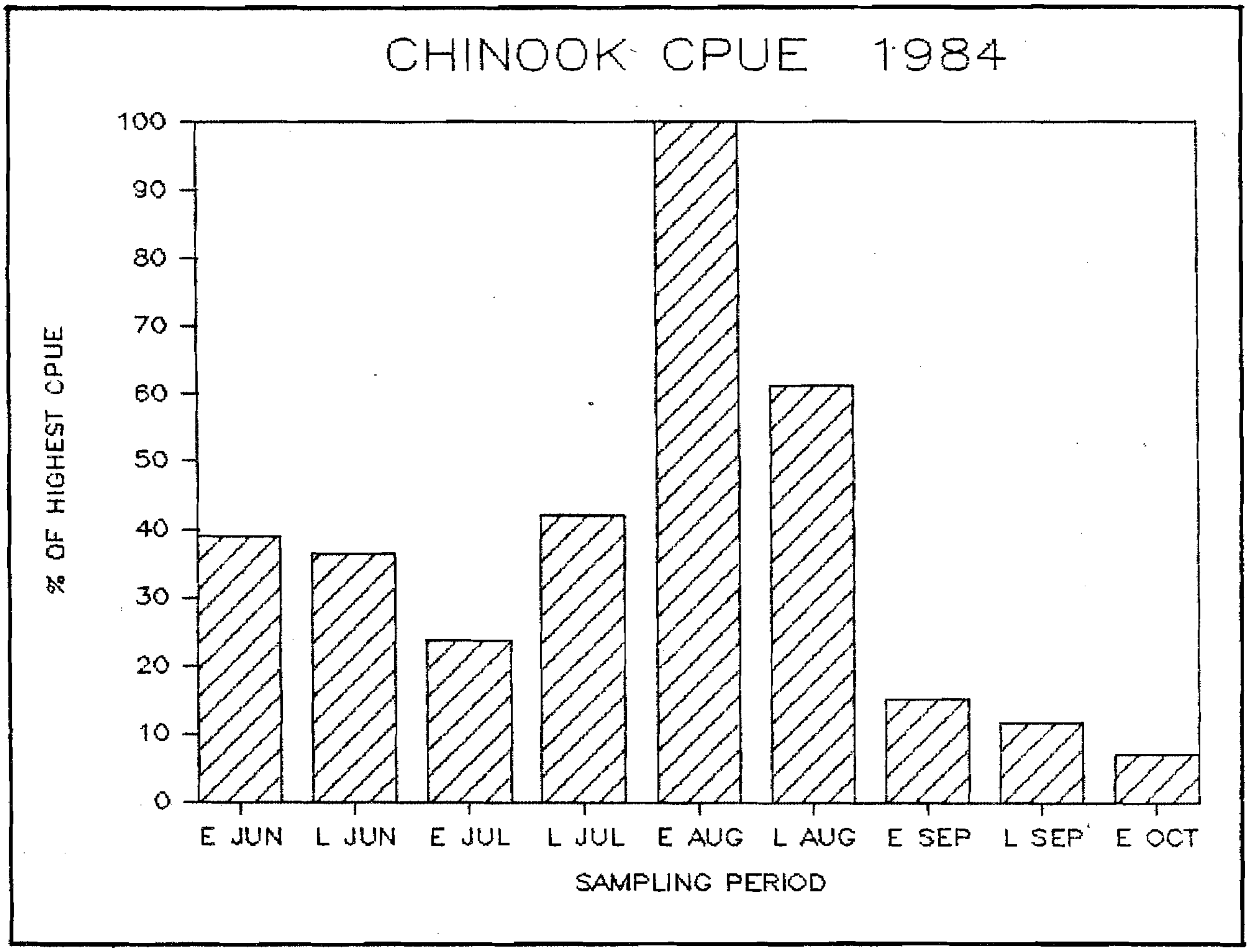


Figure 13. Chinook salmon (age 0+) catch per unit effort by sampling period recorded at JAHS sites in the lower reach of the Susitna River, 1984.

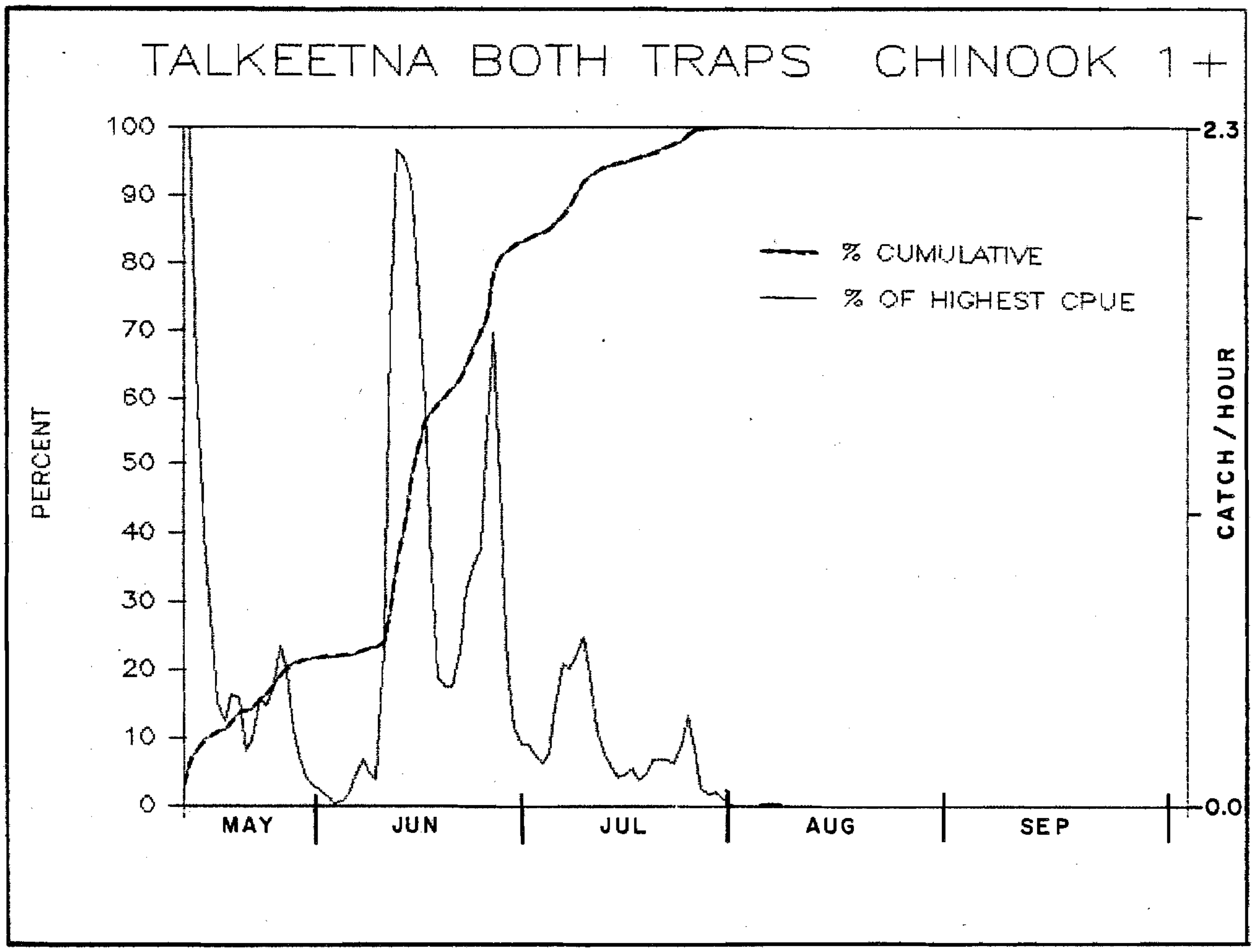


Figure 14. Chinook salmon (age 1+) smoothed daily catch per unit effort and adjusted cumulative catch recorded at the Talkeetna stationary outmigrant traps, May 14 through October 6, 1984.

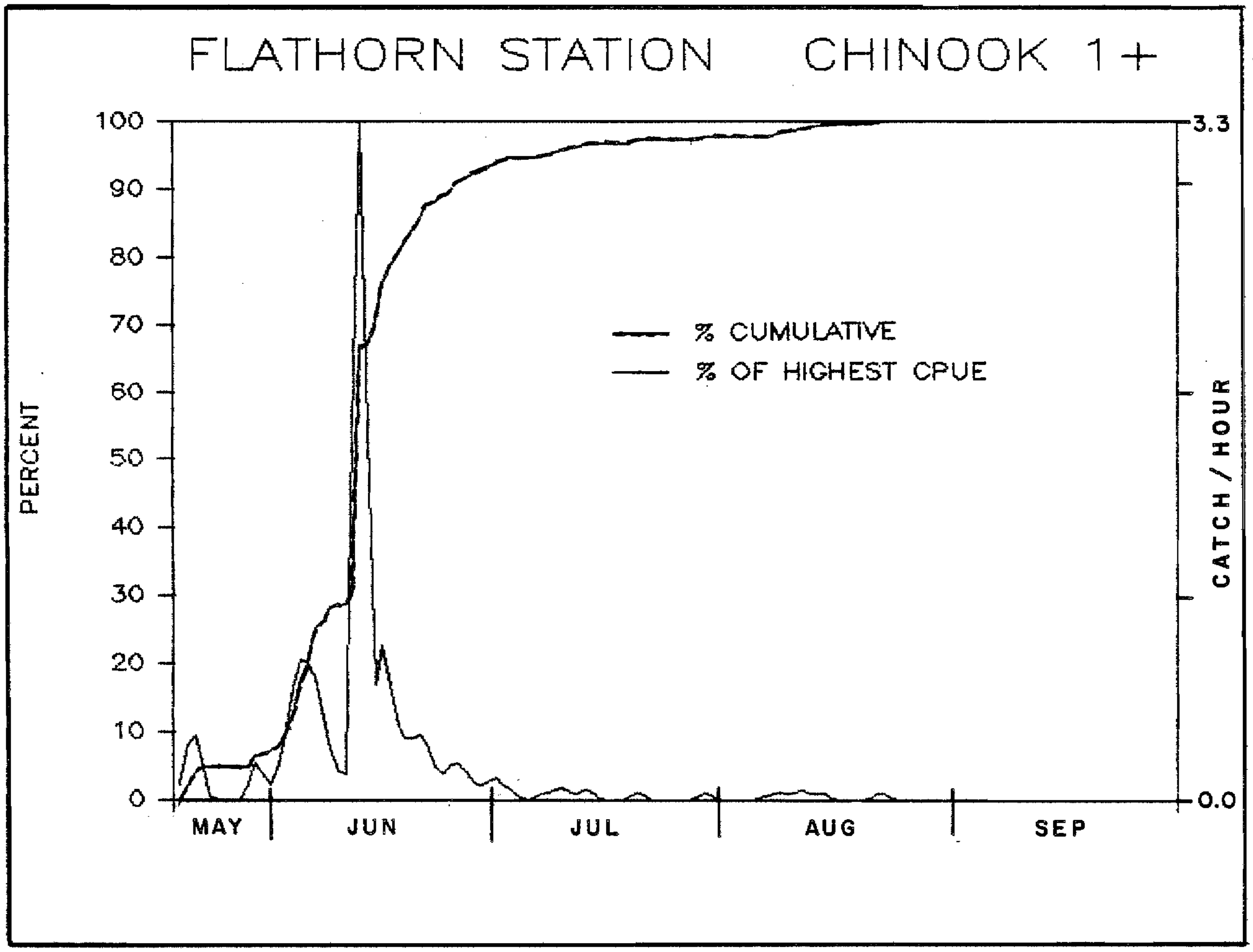


Figure 15. Chinook salmon (age 1+) smoothed daily catch per unit effort and adjusted cumulative catch recorded at the Flathorn stationary outmigrant trap, May 20 through October 1, 1984.

3.1.2 Growth

3.1.2.1 Age 0+

Chinook fry collected between the Chulitna River confluence and Devil Canyon (middle river) averaged 43 mm during late May and showed a steady growth through the season to a mean length of 64 mm by early October (Fig. 16). Age 0+ chinook collected between Cook Inlet and The Chulitna River confluence (lower river) during the same period averaged consistently larger than fry collected in the middle river. Chinook fry in the lower river increased from a mean length of 41 mm in late May to 75 mm in early October. The number of fish measured, mean length, and range of lengths by sampling period for chinook salmon fry are presented for each data collection area in Appendix Table A-3 and A-4.

3.1.2.2 Age 1+

Age 1+ chinook salmon for all sites sampled averaged 78 mm during May and the mean length increased to 90 mm during early June (Appendix Table A-5). Average lengths for this age class stayed the same through late July by which time most of the age 1+ chinook had migrated out of the Susitna River.

The length/weight relationship of juvenile chinook (both age classes) at Talkeetna Station is shown in Fig. 17.

3.1.3 Cold branding

A total of 23,406 chinook salmon fry were cold branded in Indian River between July 1 and October 15, 1984 (Table 1). One hundred forty-seven of these marked fish were later recaptured in Indian River, five were captured in the Talkeetna Station outmigrant traps, and five were captured below Indian River in side channels and sloughs associated with the mainstem Susitna River. The time between release of marked chinook fry in Indian River at TRM 7.2 and their subsequent recapture at the mouth of this tributary ranged from nine to 70 days with a mean of 30 days. The five chinook fry branded in Indian River which were collected in the outmigrant traps at Talkeetna Station averaged 17 days between release and recapture with a range from 8 to 26 days.

A total of 9,802 chinook salmon fry were cold branded in sloughs and side channels in the middle river between July 1 and October 15. Of these fish, 643 (6.6%) were later recaptured; 637 in the same slough where they were originally marked and released, seven fish in sloughs and side channels downstream from their release sites, four fish in the Talkeetna Station traps and two fish at sites upstream from their points of release. Of the 637 fry recaptured in the same slough where they were marked, 136 were caught 5 to 30 days later, and 113 were caught 30-60 days later. The branded chinook fry collected in the Talkeetna outmigrant traps averaged 12 days between release and recapture with a range from 8 to 17 days.

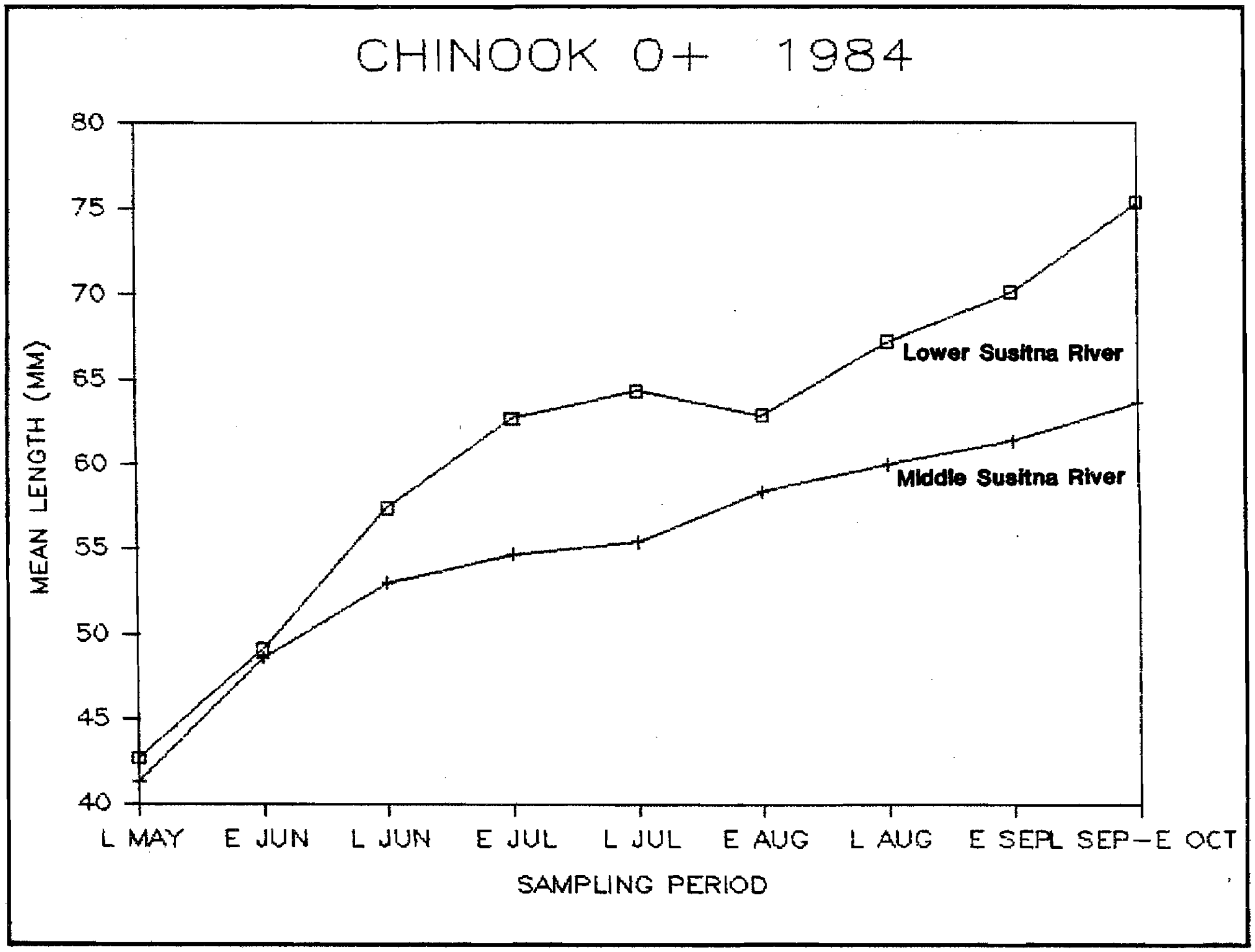


Figure 16. Chinook salmon (age 0+) mean length and range of lengths by sampling period for fish collected in the lower and middle reach of the Susitna River, 1984.

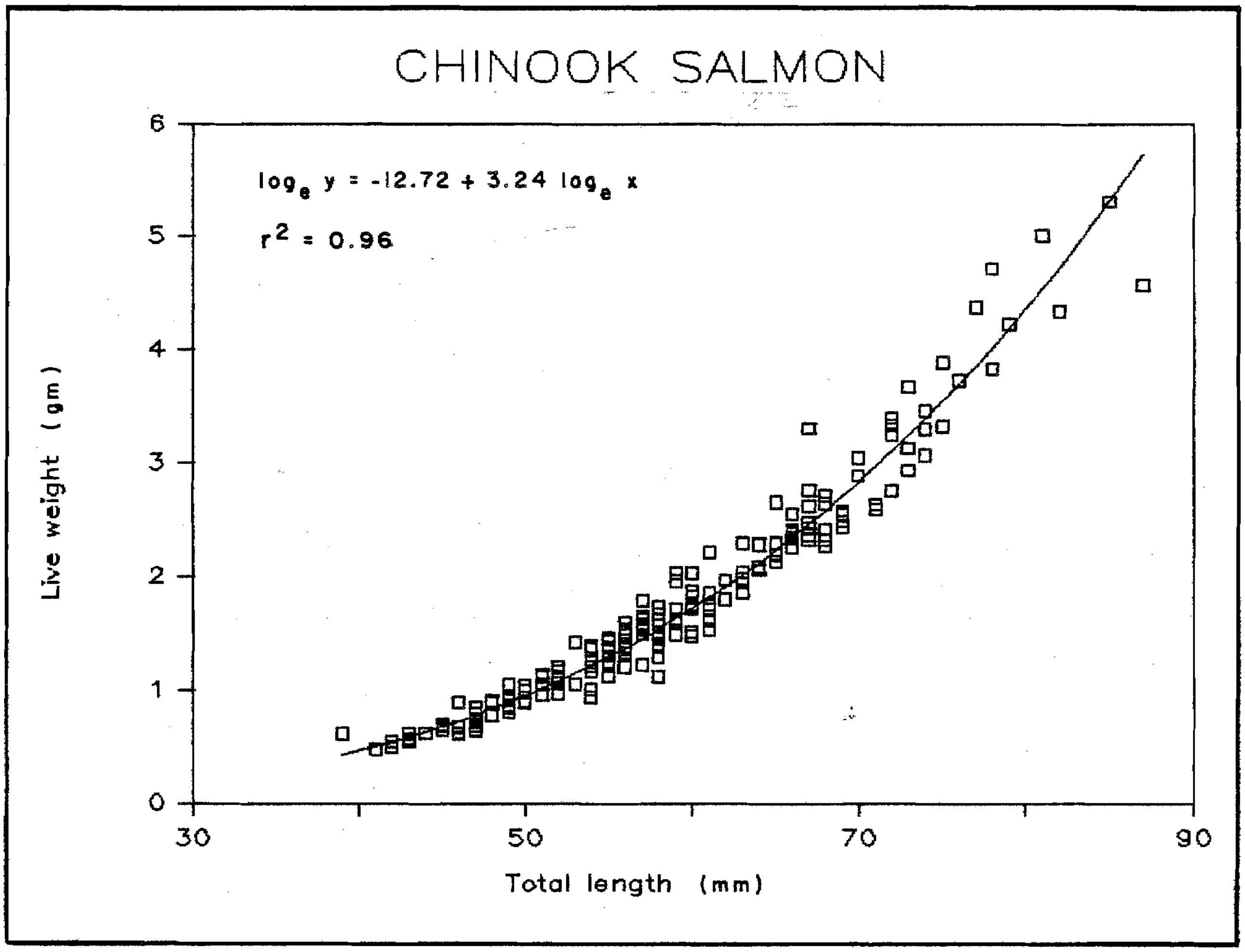


Figure 17. Weight/length relationship for juvenile chinook salmon collected at the Talkeetna stationary outmigrant traps, 1984.

Table 1. The number of chinook salmon fry marked and recovered in Indian River by sampling period, 1984.

Marking Period	Number of Fish Marked	Recapture Period: July 16-31	August 1-15	August 16-31	Sept. 1-15	Sept. 16-30	Oct 1-15	Total
July 1-15	2,093	26	10	5	2	3	3	49
July 16-31	1,924	-	5	4	5	5	2	21
August 1-15	6,735	-	-	8	17	8	8	41
August 16-31	3,806	-	-	-	4	5	2	11
September 1-15	5,492	-	-	-	-	17	7	24
September 16-30	3,356	-	-	-	-	-	1	1
TOTALS	23,406	26	15	17	28	38	23	147

3.1.4 Population estimates

Using the mark-recapture data of Table 1 with the Schaefer method (Appendix B), there were an estimated 3,211,000 age 0+ chinook fry in Indian River after mid July. Females comprised 41.7% of the estimated population of 8,482 (9120-7% milling) adult chinook salmon (greater than 350 mm) which passed Curry Station in 1983 [95% confidence interval (C.I.) on estimate of 9120 of 6,148 to 14,212 fish; Barrett et al. 1984]. Indian River chinook comprised 27% of the peak spawning survey counts (Barrett et al. 1984). Using a fecundity estimate of 10,622 eggs per female (Healy and Heard 1984), an estimated 10,143,000 eggs were deposited in Indian River during 1983. It is not possible to calculate the egg to outmigrant survival rate because of unknowns in both the adult and the fry population estimates.

Population estimates were made at three sloughs and two side channels in the middle river during the cold branding study (Table 2). Populations were estimated at a high of 47,000 chinook fry in Slough 22 to a low of 3,400 in Lower Side Channel 11A. No Jolly-Seber estimate of population size was made for August 11 at Moose Slough because the head of site closed the night of August 11 and almost all of the fish left. Only one chinook fry was captured on August 12; there were no recaptures.

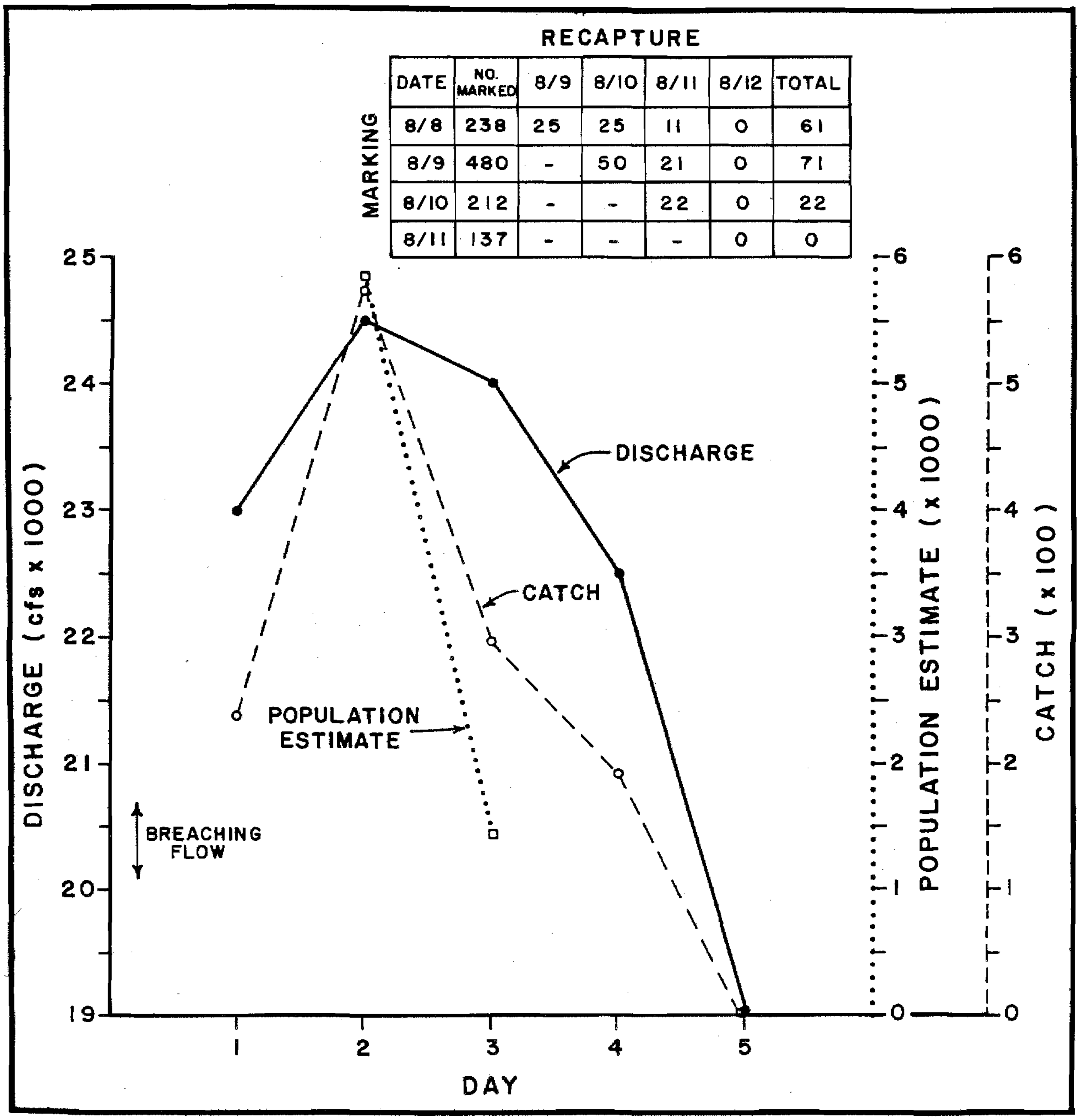
The effect of fluctuating discharge levels on the density (beach seine catch with constant effort) and total number (population estimate) of chinook fry in sloughs and side channels can be seen in Figs. 18 and 19. Estimates of population size were made using the Jolly-Seber method which allows for inmigration, recruitment, outmigration, and mortality. Recruitment does not occur, so all gains to the population were a result of migration into the site. Similarly, assuming that mortality during a five day period is negligible, all losses to the population were a result of migration from the site.

The total number of fry in Moose Slough during these five days paralleled the density of fry and the discharge level (Fig. 18). This pattern suggests that habitat quality was best at the highest observed flow and declined with a drop in discharge level. As the surface area of the site and the habitat quality decreased, so did the total number of fish at the site. Evidently, the site is of little rearing value to chinook salmon when the head of the site is not breached. A partial explanation is that the water clears when the head is closed; there is little cover other than turbid water at this site. The marked/unmarked ratio for each day was diluted by the entry of new fish into the site through the slough head, until the head closed. By that time, most of fish that had been at the site the previous four days had left. Residence time in this slough was low. This site probably acts mainly as an outmigration corridor and temporary rearing area.

At Lower Side Channel 11A, the density of fry stayed relatively constant over the five days even though the discharge level steadily decreased (Fig. 19). Meanwhile, the total number of fry at the site declined with the lowering in discharge level. The table of recaptures (Fig. 19) indicates a longer residence time than at Moose Slough. This fact, and the fairly constant density, suggests that the habitat quality at this

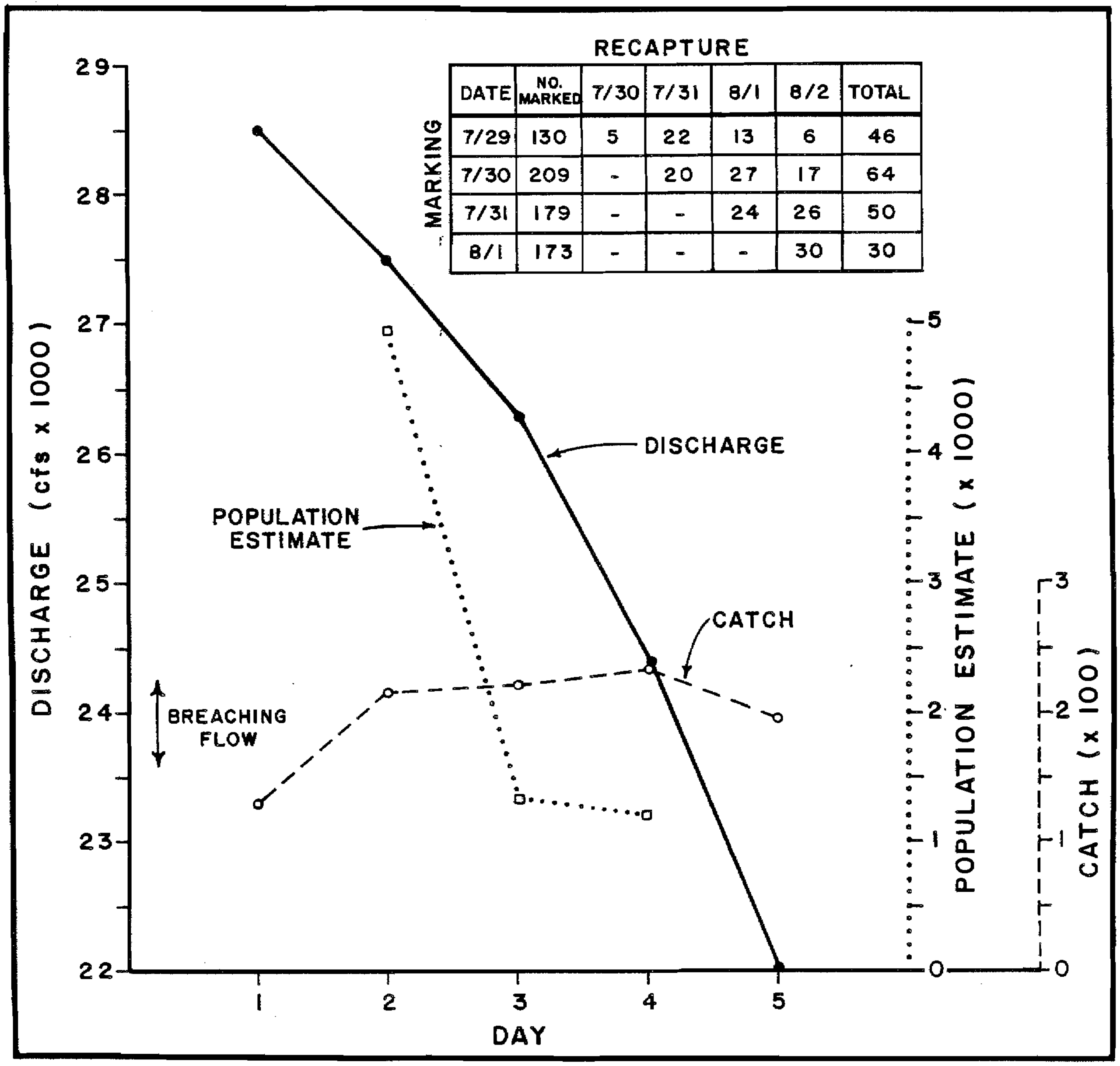
Table 2. Chinook salmon fry population estimates by site for middle Susitna River sloughs and side channels and for Indian River, 1984.

Sampling Site	Branding Dates	Recapture Dates	Estimate Method	Population Estimate	95% Confidence Interval
Lower Side Channel 11A	7/29 - 8/1	7/30 - 8/2	Schaefer	3,420	-
		7/30	Jolly-Seber	4,962	2,466 - 14,441
		7/31	Jolly-Seber	1,370	1,038 - 2,106
		8/1	Jolly-Seber	1,245	958 - 1,874
Side Channel 10	7/16 - 7/19	7/17 - 7/20	Schaefer	7,630	-
Moose Slough	8/8 - 8/11	8/9 - 8/12	Schaefer	4,990	-
		8/9	Jolly-Seber	5,884	3,888 - 11,141
		8/10	Jolly-Seber	1,455	1,159 - 2,071
Slough 22	9/8 - 9/13	10/8	Petersen	47,050	39,000 - 56,750
			Schaefer	43,761	-
Slough 19	8/29	9/26	Petersen	4,550	3,200 - 6,700
Indian River	7/1 - 9/30	7/15 - 10/15	Schaefer	3,211,000	-



DATE	NO. MARKED	8/9	8/10	8/11	8/12	TOTAL
8/8	238	25	25	11	0	61
8/9	480	-	50	21	0	71
8/10	212	-	-	22	0	22
8/11	137	-	-	-	0	0

Figure 18. Catch, estimated population size, and mainstem discharge level at Moose Slough, August 8 - August 12, 1984.



DATE	NO. MARKED	7/30	7/31	8/1	8/2	TOTAL
7/29	130	5	22	13	6	46
7/30	209	-	20	27	17	64
7/31	179	-	-	24	26	50
8/1	173	-	-	-	30	30

Figure 19. Catch, estimated population size, and mainstem discharge level at Lower Side Channel 11A, July 29 - August 2, 1984.

site is relatively unaffected by changes in level of discharge. However, the total number of fry at the site necessarily declines with a lowering discharge level because the amount of habitat (surface area) available decreases. The constant density of fry even after the head of the site closed is perhaps attributable to a greater amount of object cover at this site than at Moose Slough.

3.2 Coho Salmon

3.2.1 Catch per unit effort

3.2.1.1 Age 0+

Juvenile coho salmon were observed during the coded wire tagging study to be most abundant at Indian River. Catch rates were not recorded. The cold branding study collected 1,548 coho salmon fry in Indian River from July 1 through October 15. Of this catch, 31% of the coho were captured in Section I, 44% in section II and 26% in section III. Beach seining of sections II and III during July captured 444 juvenile coho salmon; 76% in section II and 24% in section III. Minnow trapping begun in late July captured 1,129 juvenile coho salmon during 947 minnow trap days for a season average of 1.2 coho per trap day. Of these catches, 43% were recorded in the lower section, 31% in the middle section, and 26% in the upper section.

The catch per unit effort for all Indian River sections combined was steady through the season ranging from 1.1 to 1.5 fish per trap day (Fig. 20). Coho fry catches were highest in section III with an average of 5.0 coho per trap day over the season. Season average CPUE in section II was 1.4 coho per trap day and Section I averaged 0.8 coho per trap day.

A total of 90 coho salmon fry were captured during the cold branding study in sloughs and side channels in the middle Susitna River. Ninety-five percent of the coho catch was recorded in slough habitats in this reach. Beach seining during July and August captured 40% of the season's total catch while minnow trapping during September and early October collected the remaining 60% (average of 0.2 coho per trap day). Daily minnow trap CPUE ranged from a low of 0.01 at Slough 22 and Side Channel 21 in September to a high of 7.6 coho per trap day at Slough 14 on September 10.

Peak catches for the 1,830 age 0+ coho salmon collected at the Talkeetna Station outmigrant traps were recorded during late July and August, and the highest catch rate of 2.9 coho fry per hour was recorded on July 30, by which time 50% of the season total had been recorded (Fig. 21). The last coho fry was captured in the traps on October 4.

A total of 441 age 0+ coho salmon were captured at the Flathorn stationary outmigrant trap during 1984. Catch rates were highest during late August and late September and the peak catch rate of 1.5 fish per hour was recorded in the trap on September 30 (Fig. 22). Fifty percent of the catch at this site occurred by August 26. Only 16 age 0+ coho were captured in the mobile trap at Flathorn Station.

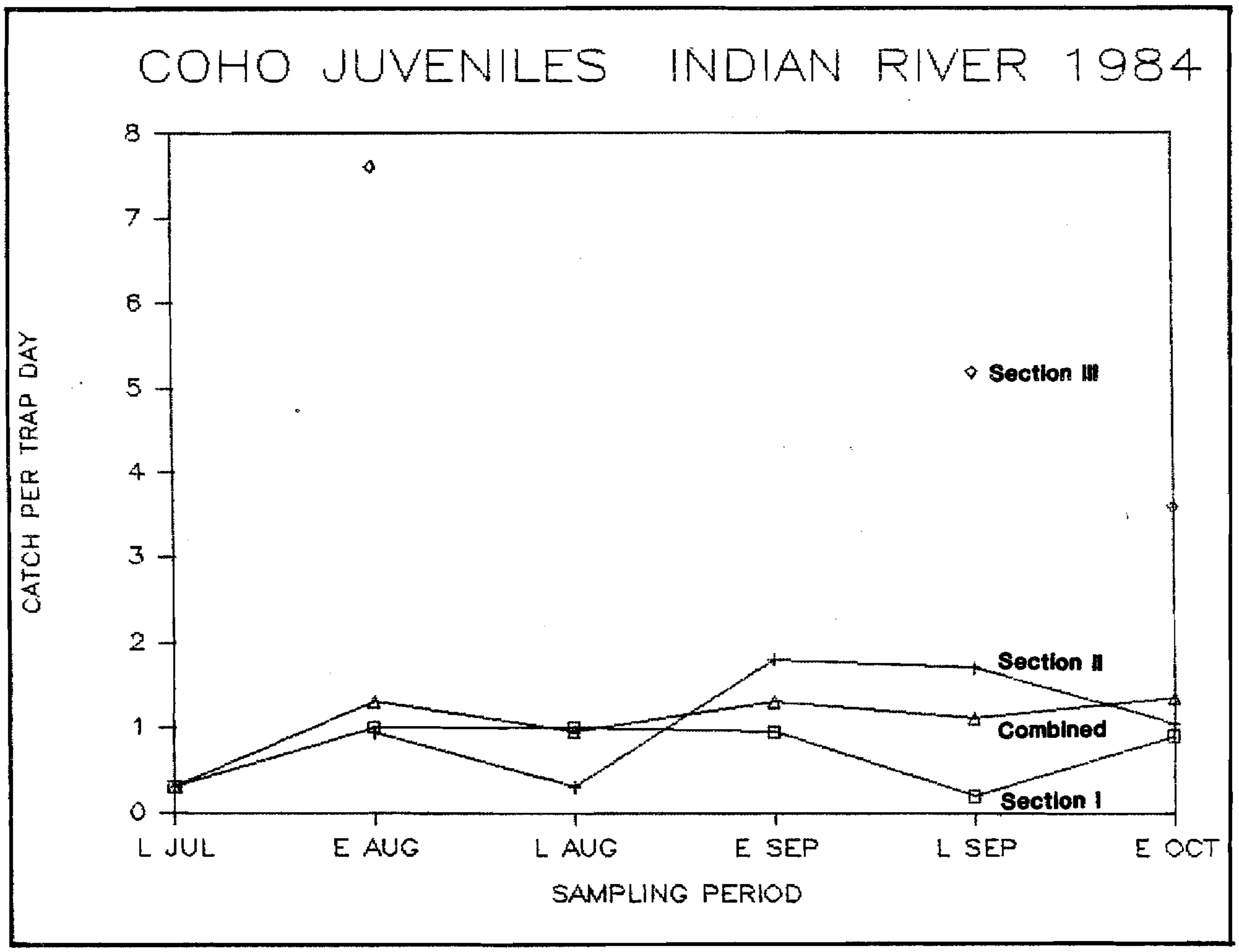


Figure 20. Coho salmon (age 0+) average catch per minnow trap by sampling period and survey section in Indian River, 1984.

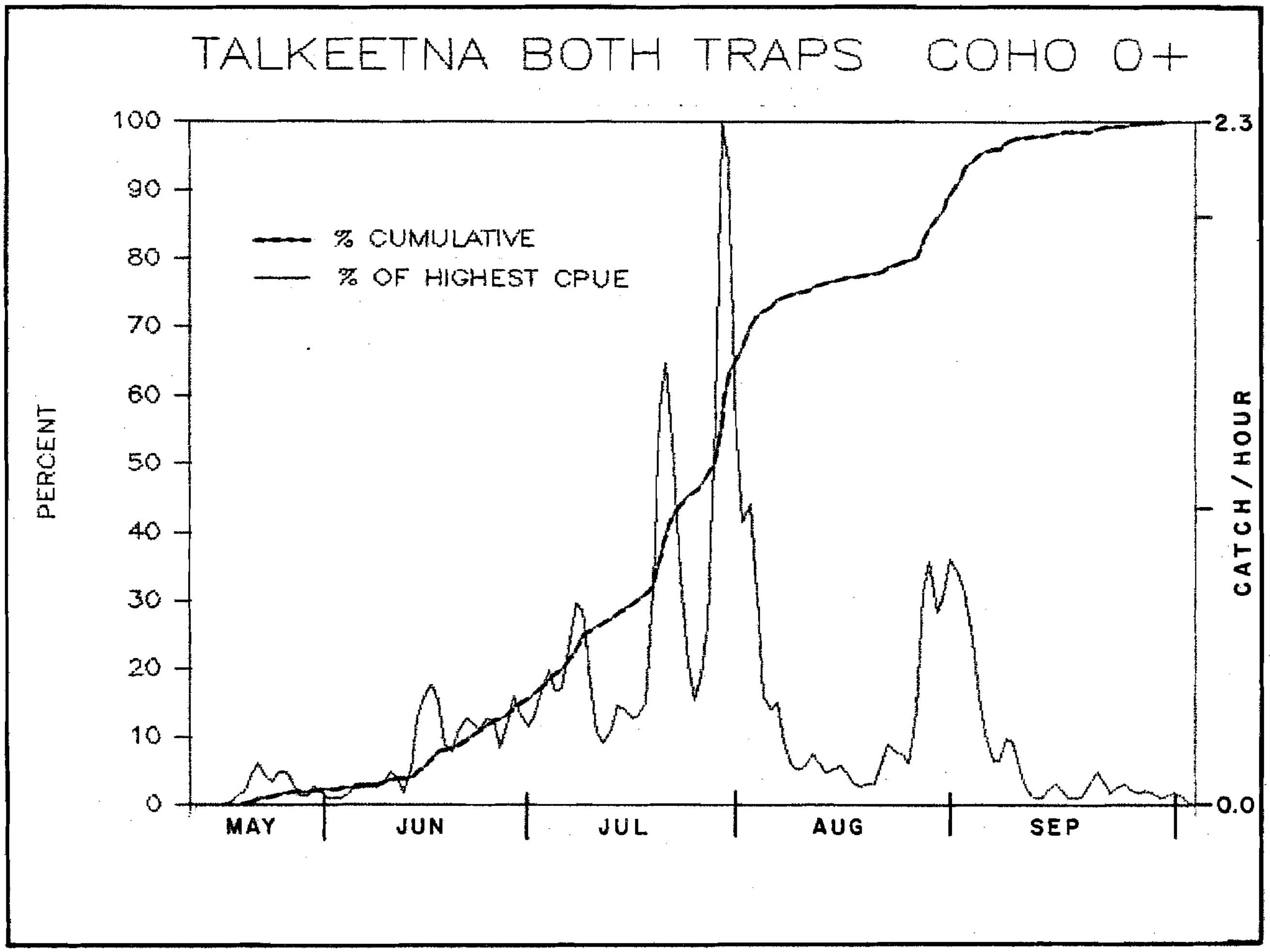


Figure 21. Coho salmon (age 0+) smoothed daily catch per unit effort and adjusted cumulative catch recorded at the Talkeetna stationary outmigrant traps, May 14 through October 6, 1984.

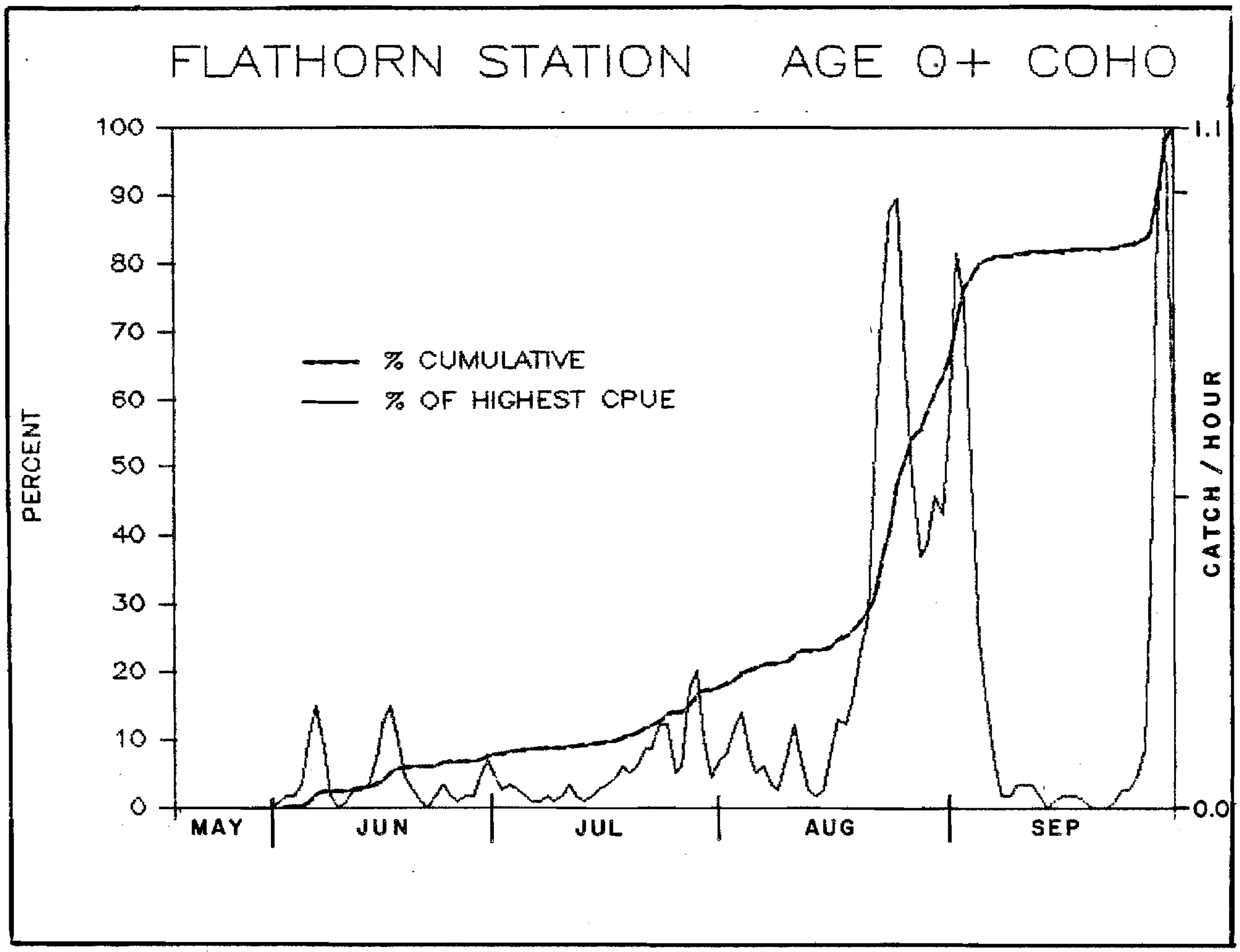


Figure 22. Coho salmon (age 0+) smoothed daily catch per unit effort and adjusted cumulative catch recorded at the Flathorn stationary outmigrant trap, May 20 through October 1, 1984.

A total of 380 age 0+ coho salmon were captured in the lower Susitna River during the JAHS study (see Part 2 of this report). Catch rates were highest during the late summer sampling and the peak catch rates were recorded in early October (Fig. 23).

The Deshka River weir captured 95 coho salmon fry during 1984; the peak catch rate of 1.3 fish per hour was recorded on July 25 (Appendix Table A-1). Minnow trap catches at this site were highest during late August at 2.6 coho per trap (Appendix Table A-2).

3.2.1.2 Age 1+ and older

Age 1+ coho salmon were collected sporadically during the coded wire tagging study in May and June with the highest concentrations observed in Slough 11 and Indian River. The cold branding study from July through early October captured 25 age 1+ coho at Indian River and 18 at middle river slough and side channel sites during the season.

Peak catches for the 1,425 age 1+ coho salmon juveniles captured at the Talkeetna Station outmigrant traps were observed in mid June and were again high in late July and late August (Fig. 24). Fifty percent of the catch was recorded by June 25. The highest catch rate for these age classes was 1.6 fish per hour recorded on June 18 and the last capture was on October 2.

Catch rates for the 291 age 1+ coho salmon juveniles captured at the Flathorn stationary outmigrant trap were highest during late August and September (Fig. 25) and the highest CPUE of 0.8 coho per hour was recorded on September 3. Fifty percent of the total catch was recorded by August 30 and the last capture of these age classes was October 1. The mobile outmigrant trap captured 10 age 1+ coho salmon during the season.

The JAHS study in the lower river collected 62 age 1+ coho salmon juveniles with most of the captures being recorded at tributary sites in this reach.

The Deshka River weir collected 26 age 1+ coho while minnow trapping at this site captured 119 fish. Catches were observed throughout the season with a peak rate of 6.2 coho per trap recorded in late August.

A total of 44 age 2+ coho salmon juveniles were collected during the 1984 studies. Talkeetna Station, Flathorn Station, and the Deshka River accounted for 95% of the captures of this age class.

3.2.2 Growth

3.2.2.1 Age 0+

Coho fry collected in the lower river were consistently larger than the fry collected in the middle river throughout the season (Fig. 26). Coho fry collected in the middle river averaged 40 mm total length during late May and showed a steady growth to a mean of 58 mm by late August. Coho fry in the lower river averaged 42 mm in early June and had grown

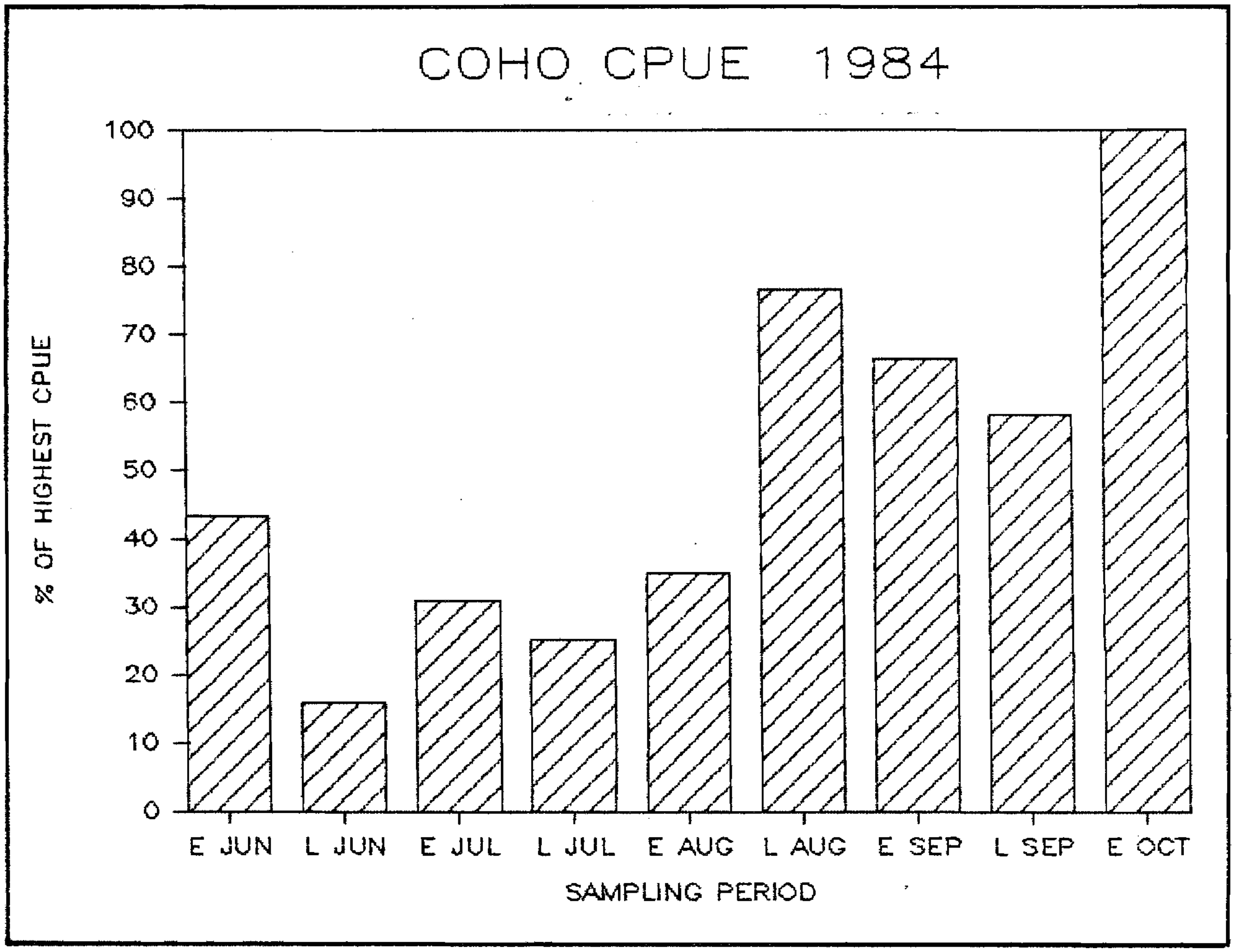


Figure 23. Coho salmon juvenile catch per unit effort by sampling period recorded at JAHS sites in the lower reach of the Susitna River, 1984.

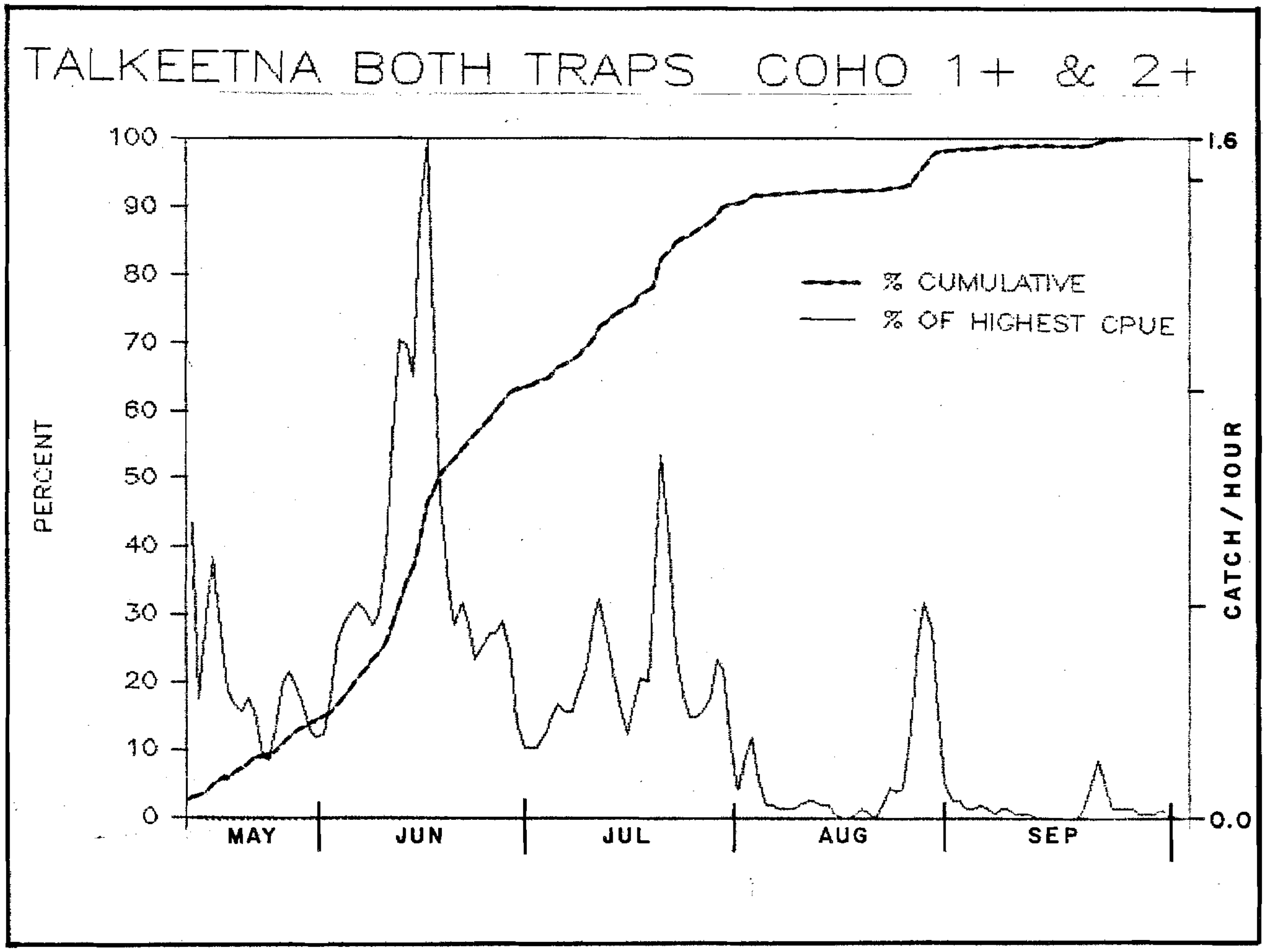


Figure 24. Coho salmon (age 1+ and older) smoothed daily catch per unit effort and adjusted cumulative catch recorded at the Talkeetna stationary outmigrant traps, May 14 through October 6, 1984.

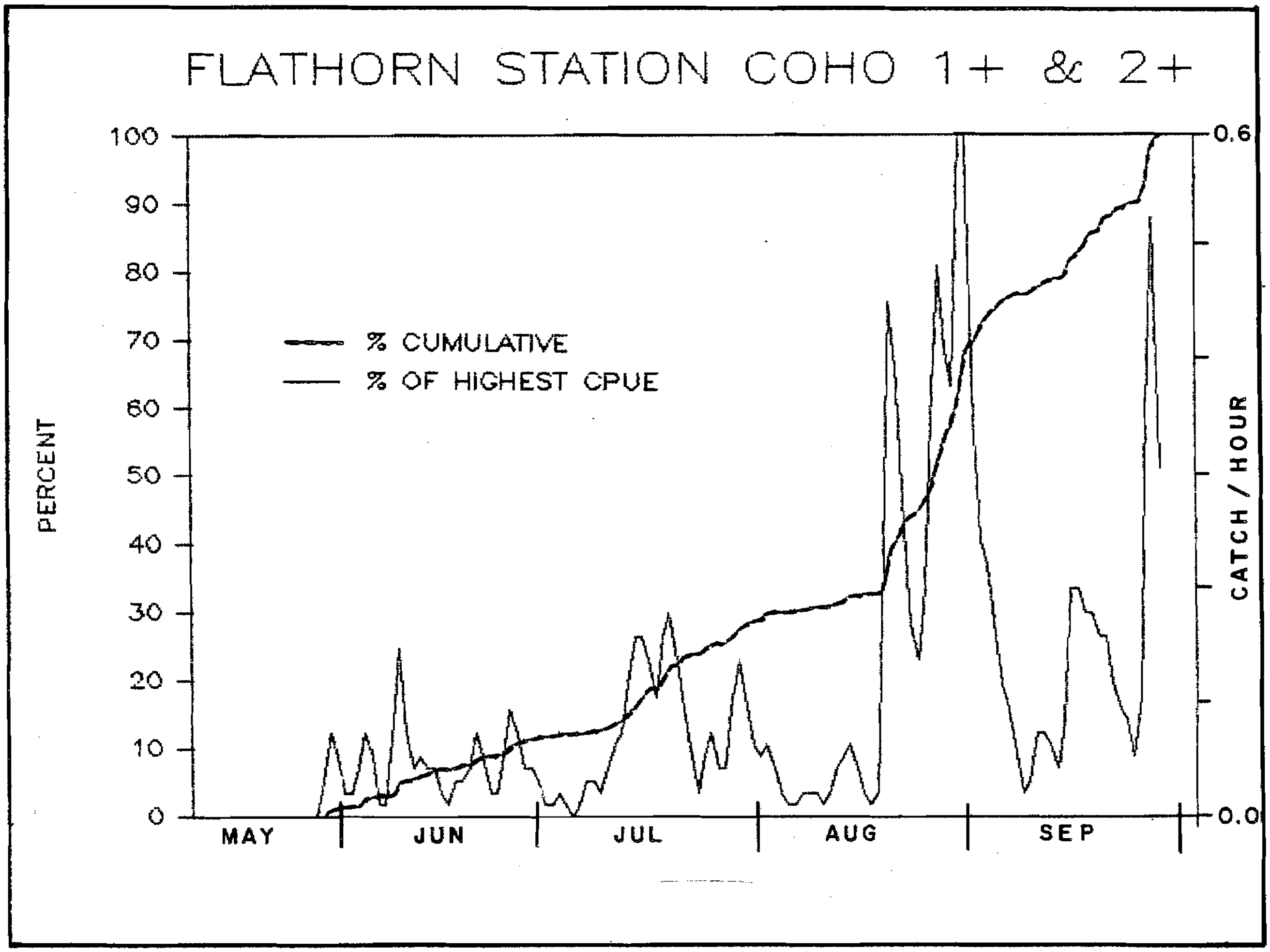


Figure 25. Coho salmon (age 1+ and older) smoothed daily catch per unit effort and adjusted cumulative catch recorded at the Flathorn stationary outmigrant trap, May 20 through October 1, 1984.

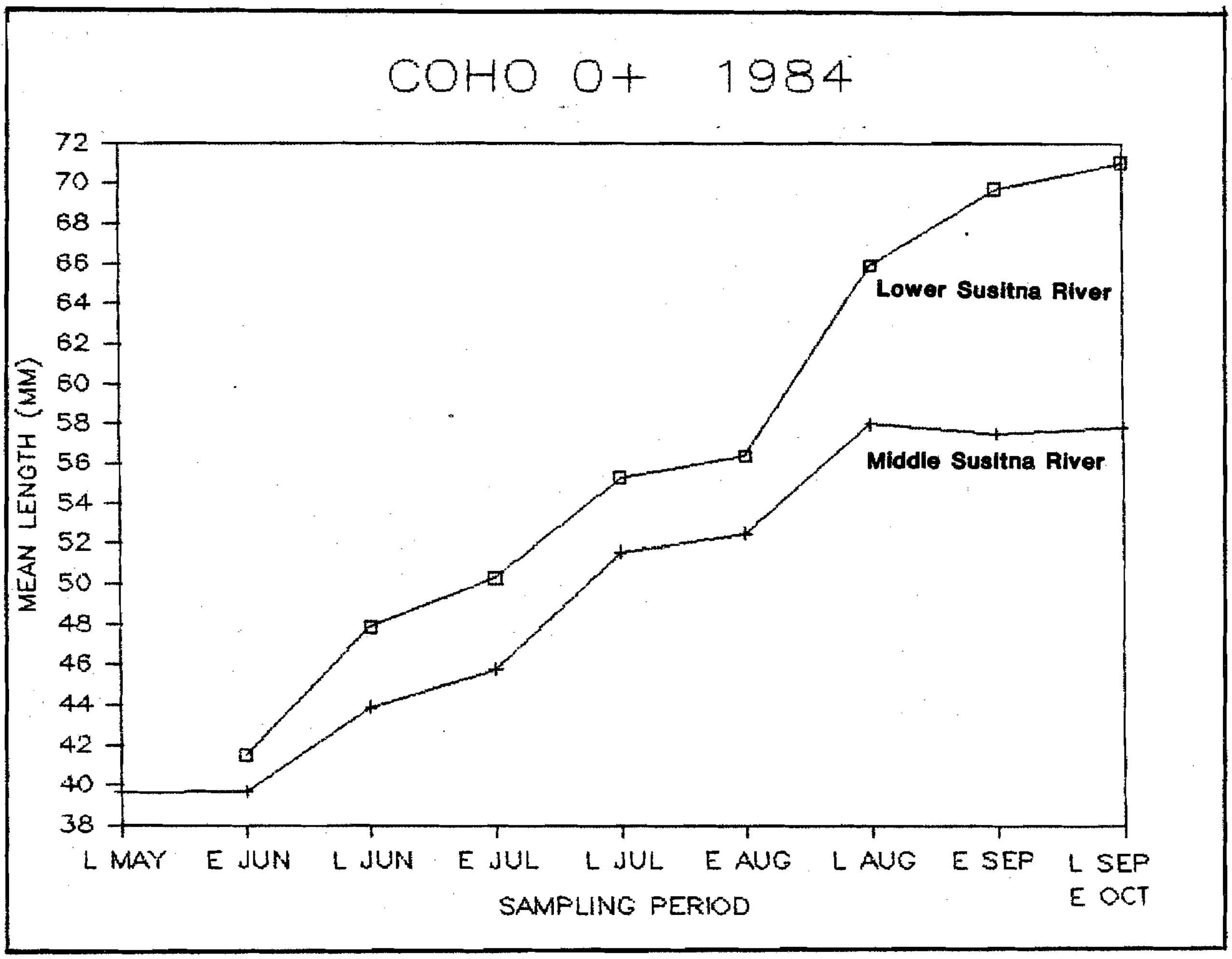


Figure 26. Coho salmon (age 0+) mean length and range of lengths by sampling period for fish collected in the lower and middle reach of the Susitna River, 1984.

to a mean length of 71 mm by late September. The number of fish measured, mean length, and range of lengths by sampling period for coho fry are presented for each data collection area in Appendix Table A-6 and A-7.

3.2.2.2 Age 1+ and older

The average length of age 1+ coho salmon juveniles collected in the lower river during the open water season was greater than that of fish of the same age class collected in the middle river (Fig. 27). Age 1+ coho averaged 70 mm total length in both reaches during May and increased to 104 mm in the middle river and 111 mm in the lower river by early October. Length data by collection area and sampling period are provided in Appendix Table A-8 and A-9.

Age 2+ coho salmon juveniles collected during the 1984 studies averaged 137.1 mm and ranged from 114 to 176 mm (Appendix Table A-10).

A sample of juvenile coho salmon were measured at Talkeetna Station to provide a relationship between length and weight for fish passing this site (Fig. 28).

3.2.3 Cold branding

A total of 1,480 juvenile coho salmon were cold branded in Indian River from July 1 through October 15. Of these fish, five were recaptured in Indian River and two were recovered at the Talkeetna Station outmigrant traps. The marked coho recaptured in Indian River were branded and released at TRM 11.5 on July 17 and recaptured at TRM 2.2 between September 9 and 11, for an average of 55 days between release and recovery. The two branded coho recovered at Talkeetna Station were released in Indian River on August 12 and were recovered in the outmigrant traps on August 31 and September 22; 19 days and 41 days, respectively, between release and recovery.

A total of 106 juvenile coho salmon were cold branded at slough and side channel sites, and the only recapture was recorded at Talkeetna Station. The recaptured fish was marked and released at Slough 14 on September 10 and was recovered in the traps on September 16.

3.2.4 Population estimates

Since only 100 to 200 of the estimated 750 adult coho passing Curry Station in 1983 entered Indian River, and since juvenile coho of the same brood year outmigrate as age 0+, 1+, and 2+ fish, few juvenile coho salmon were captured for marking during the 1984 cold branding studies. Too few branded coho salmon were recaptured to provide population estimates for any of the sites surveyed.

3.3 Sockeye Salmon

3.3.1 Catch per unit effort

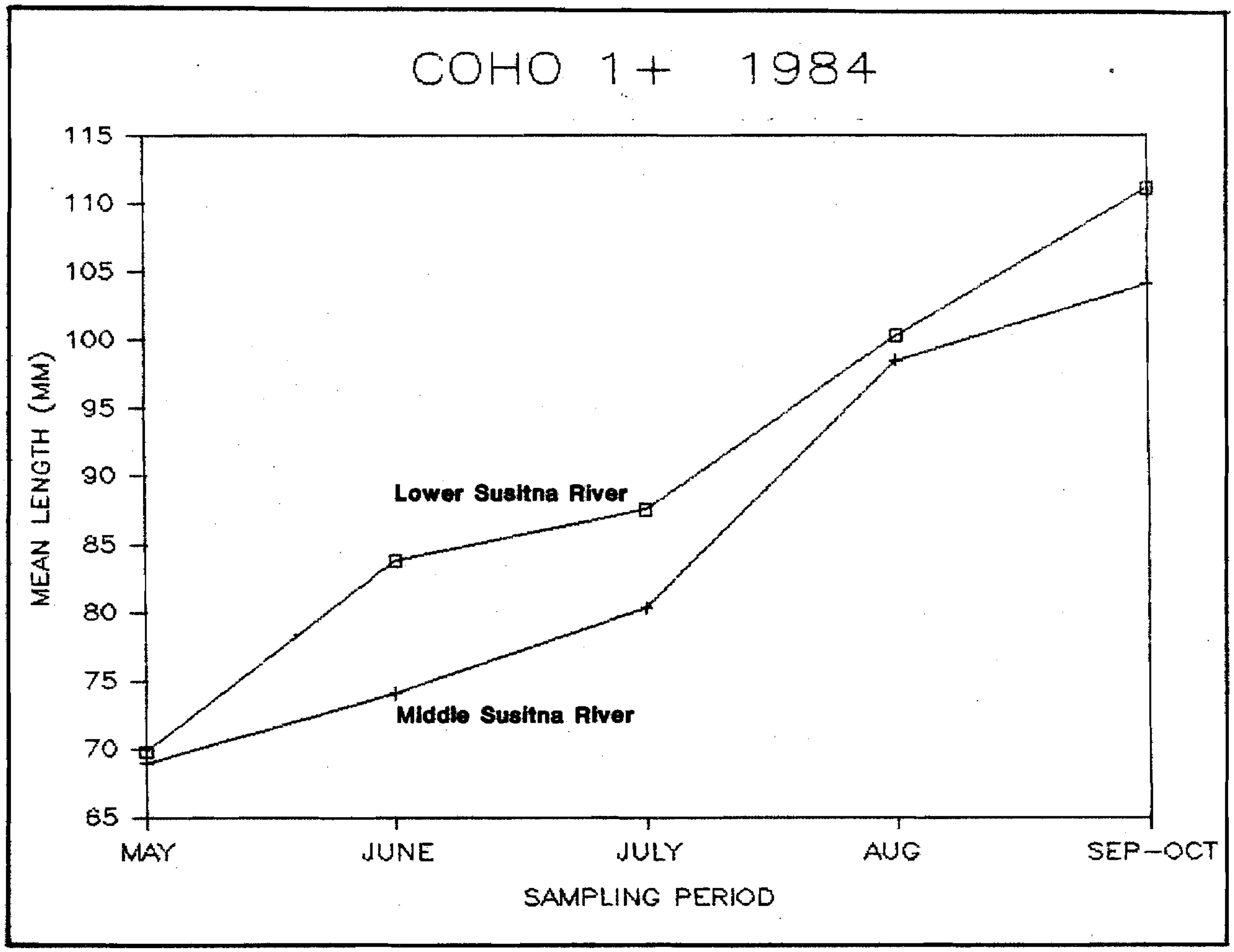


Figure 27. Coho salmon (age 1+) mean length by month for fish collected in the lower and middle reach of the Susitna River, 1984.

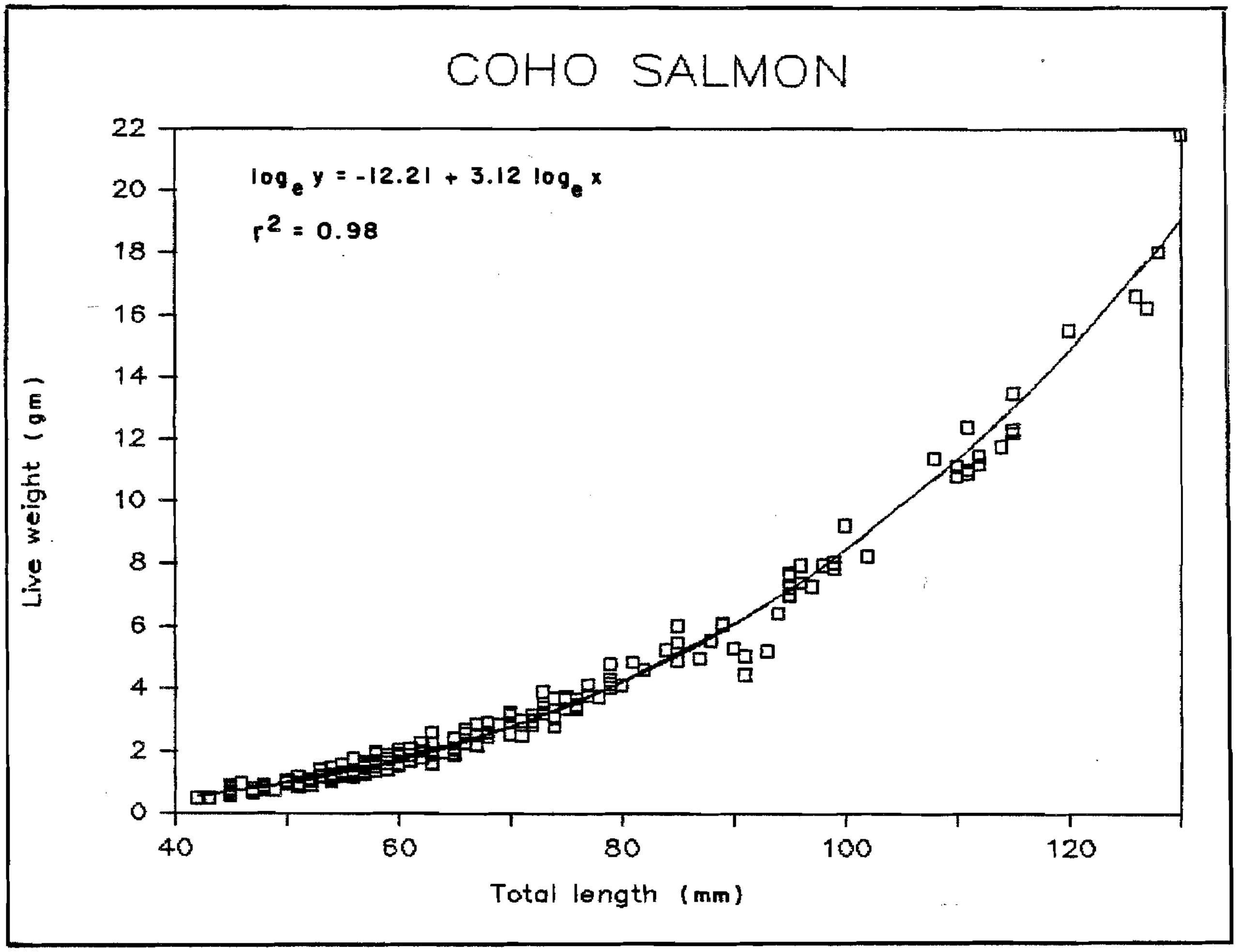


Figure 28. Weight/length relationship for juvenile coho salmon collected at the Talkeetna stationary outmigrant traps, 1984.

3.3.1.1 Age 0+

Sockeye salmon fry were collected during the coded wire tagging study in May and June at sloughs 8A, 9, 11, and 21 but catch rates were recorded only for Slough 21. These data were determined from 24 hour fyke net catches and are presented in Appendix Table A-11.

A total of 248 sockeye salmon fry were captured at slough and side channel sites in the middle river and in Indian River during beach seine sampling conducted in July and August. Of these fish, 94% were collected in sloughs and the remaining 6% were collected in Indian River and at mainstem side channels.

Peak catch rates for the 7,484 age 0+ sockeye salmon fry collected at the Talkeetna Station outmigrant traps were recorded in mid June and early July with the highest daily catch rate of 13.0 sockeye fry per hour occurring on June 18 (Fig. 29). The major downstream redistribution of sockeye fry in this reach had occurred by mid July (50% by July 4). The last sockeye fry at Talkeetna Station was observed on October 4.

Juvenile sockeye catches at the Flathorn stationary outmigrant trap were greatest during May and June but the downstream movement of sockeye fry continued through the open water season (Fig. 30). A total of 2,315 sockeye fry were collected in the trap during 1984, and the peak catch rate of 4.6 fish per hour was recorded on June 8. Fifty percent of the catches had occurred by June 29 and the last capture was October 1.

Mobile trap catches of sockeye fry at Flathorn Station were highest during June and the peak catch rate of 5.4 fish per hour was recorded on July 12 (Fig. 31). Of the 114 sockeye collected in the mobile trap during 1984, 59% were captured at bank transect points (Fig. 32).

A total of 412 sockeye salmon fry were collected in the lower river during JAHS surveys from June through October (see Part 2 of this report). Catch rates at JAHS sites peaked in late June and then were low throughout the remainder of the season (Fig. 33). An increase in catch rates was recorded at some sites including Rolly Creek (RM 39.0) and Beaver Dam Slough (RM 86.3) in late August and September, indicating the movement of sockeye into these sites during late summer.

3.3.1.2 Age 1+

A total of 90 age 1+ sockeye salmon juveniles were collected. Nineteen were captured at Talkeetna Station and 63 were collected at Flathorn Station.

Ninety-six percent of the catch for age 1+ sockeye collected at the outmigrant traps (Talkeetna and Flathorn combined) was recorded during May and June (Fig. 34). The last age 1+ sockeye was captured at Talkeetna Station on July 29.

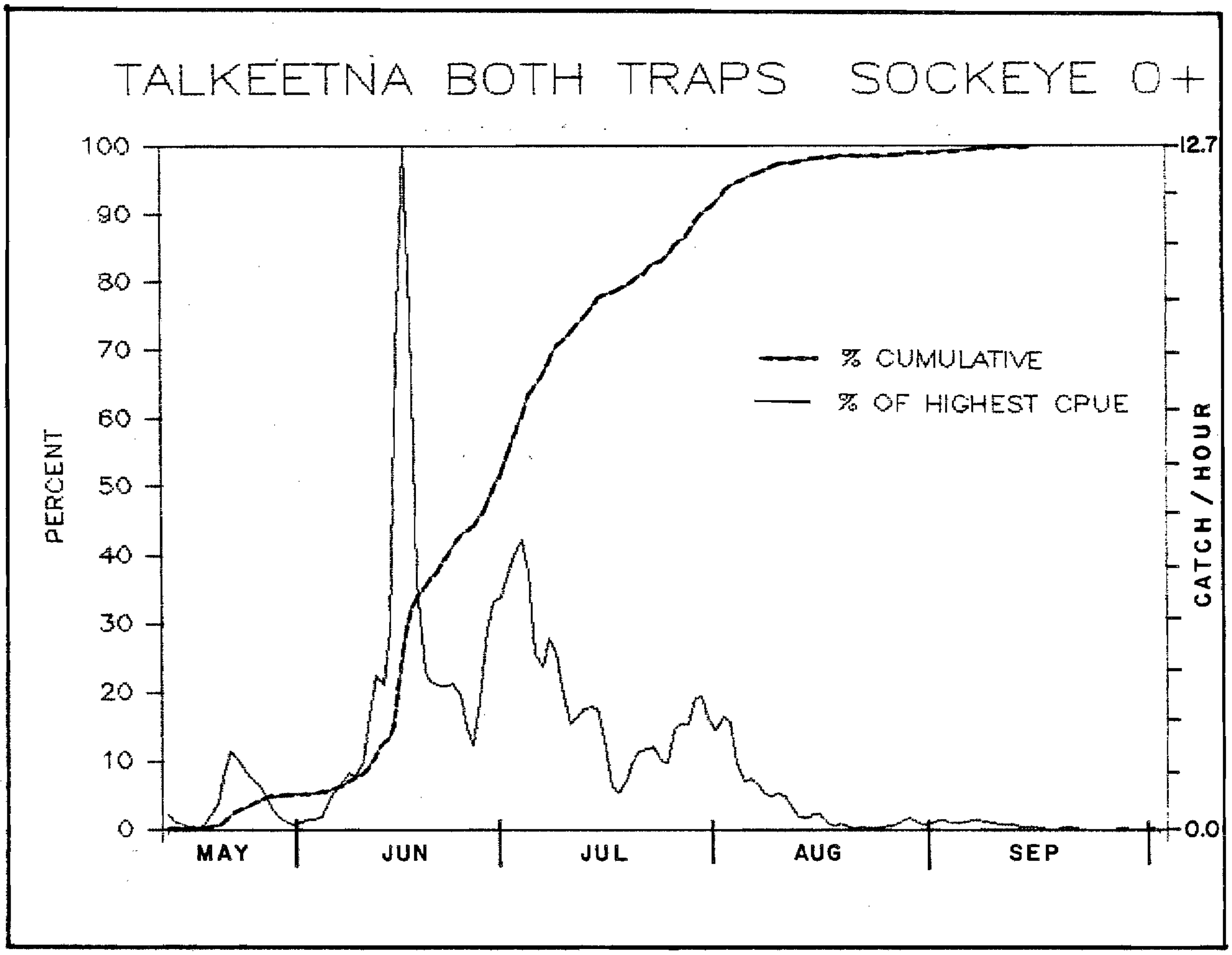


Figure 29. Sockeye salmon (age 0+) smoothed daily catch per unit effort and adjusted cumulative catch recorded at the Talkeetna stationary outmigrant traps, May 14 through October 6, 1984.

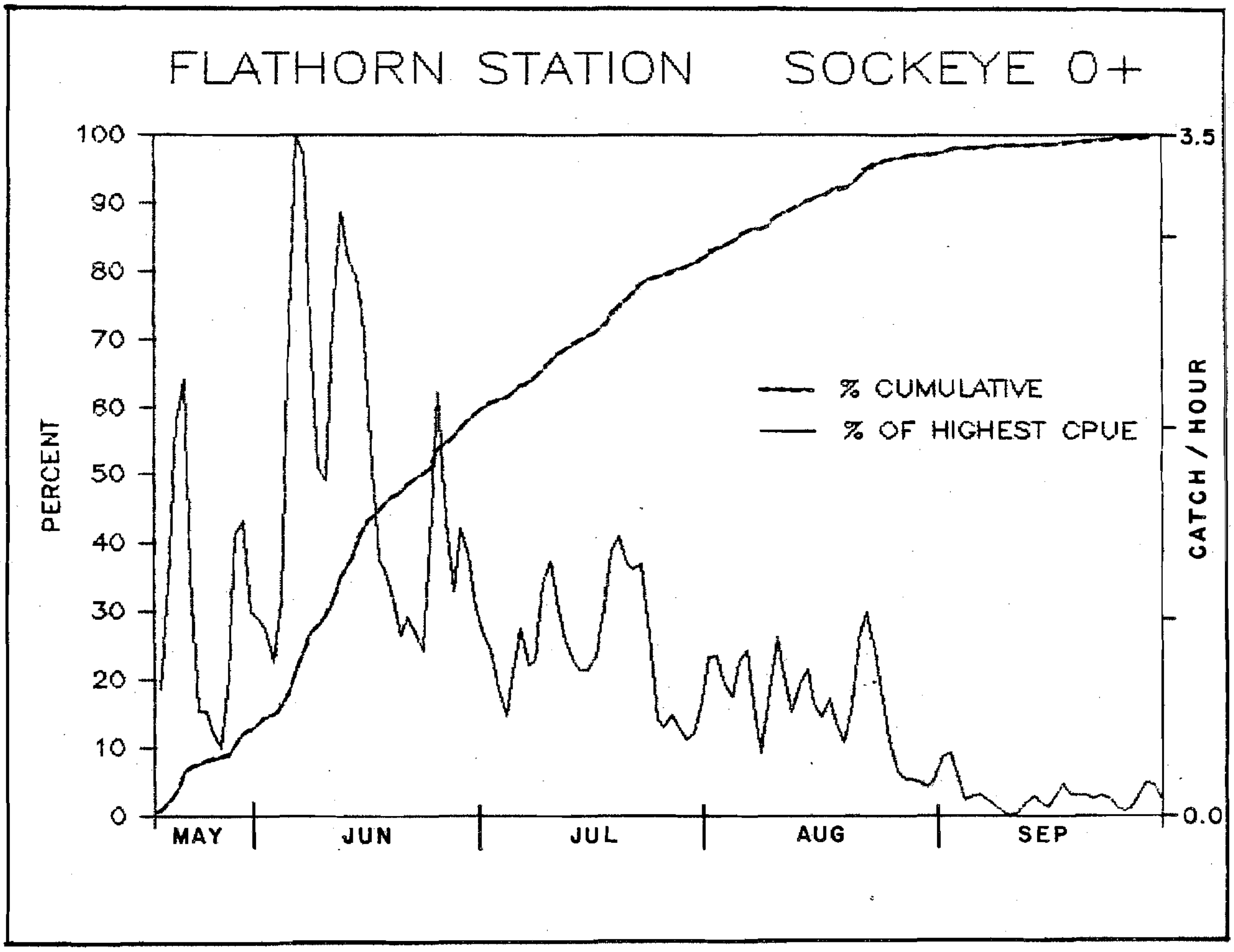


Figure 30. Sockeye salmon (age 0+) smoothed daily catch per unit effort and adjusted cumulative catch recorded at the Flathorn stationary outmigrant trap, May 20 through October 1, 1984.

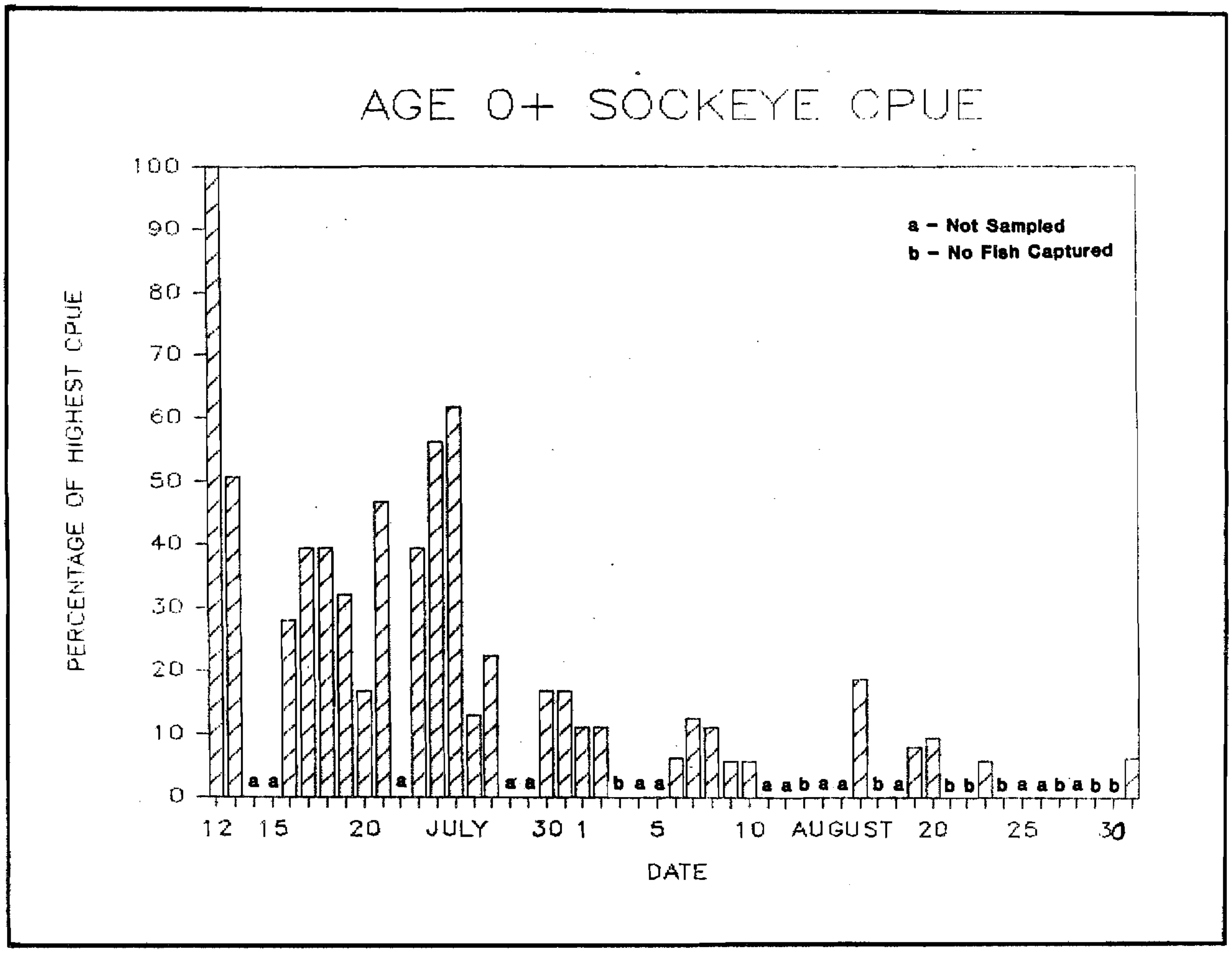


Figure 31. Sockeye salmon (age 0+) daily catch per unit effort recorded at the Flathorn mobile outmigrant trap, July 12 through August 31, 1984.

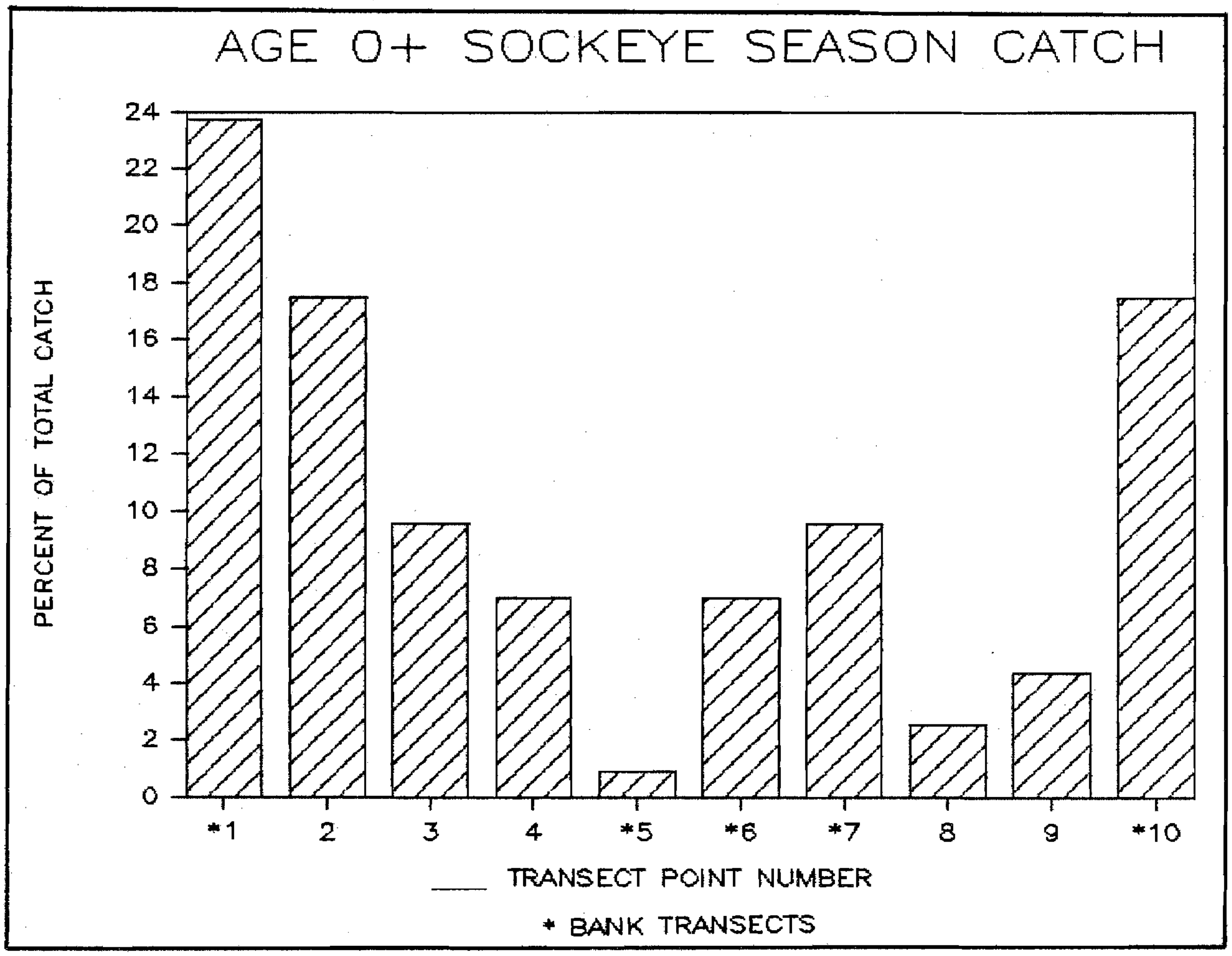


Figure 32. Sockeye salmon (age 0+) percent of the total catch by sampling point recorded at the Flathorn mobile outmigrant trap, 1984.

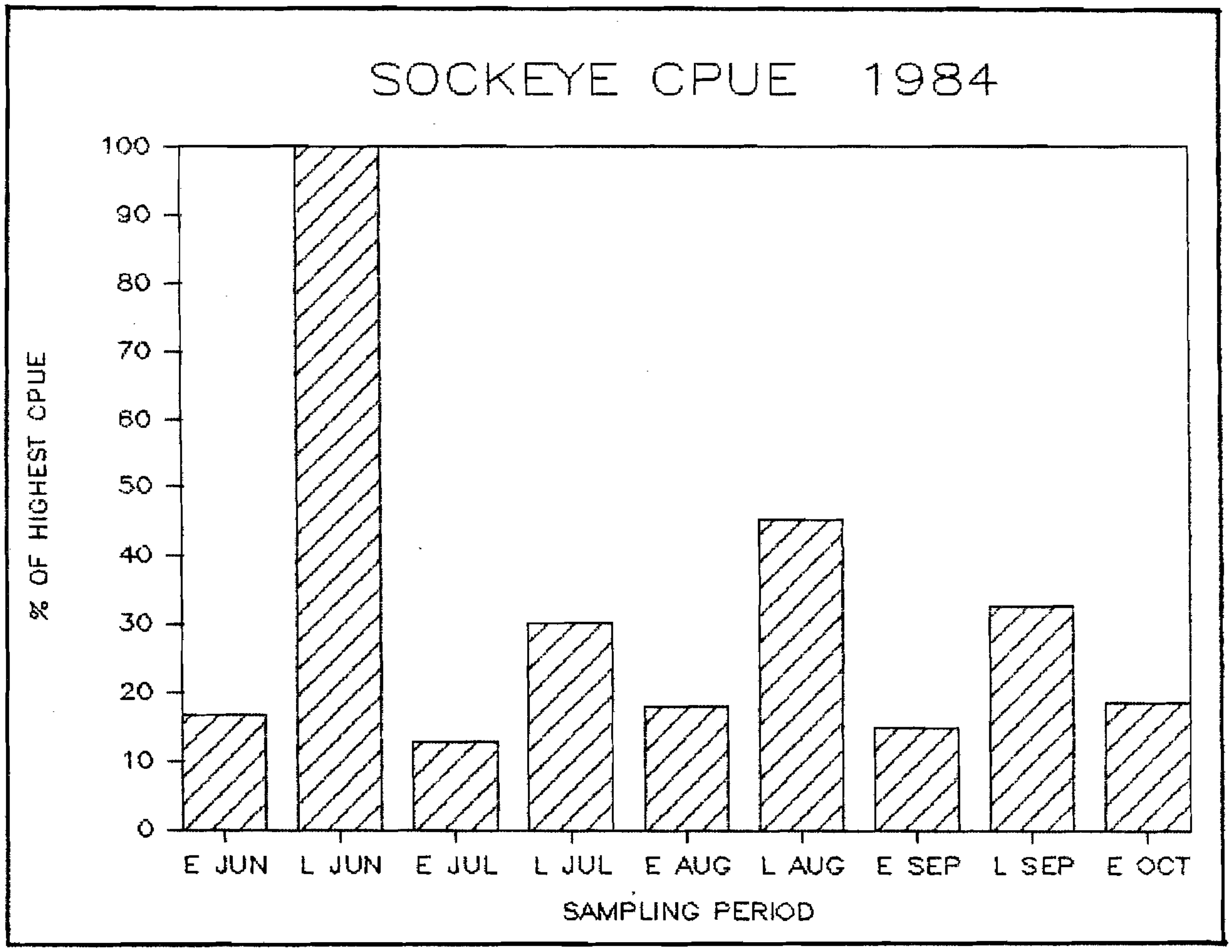


Figure 33. Sockeye salmon juveniles catch per unit effort by sampling period recorded at JAHS sites in the lower reach of the Susitna River, 1984.

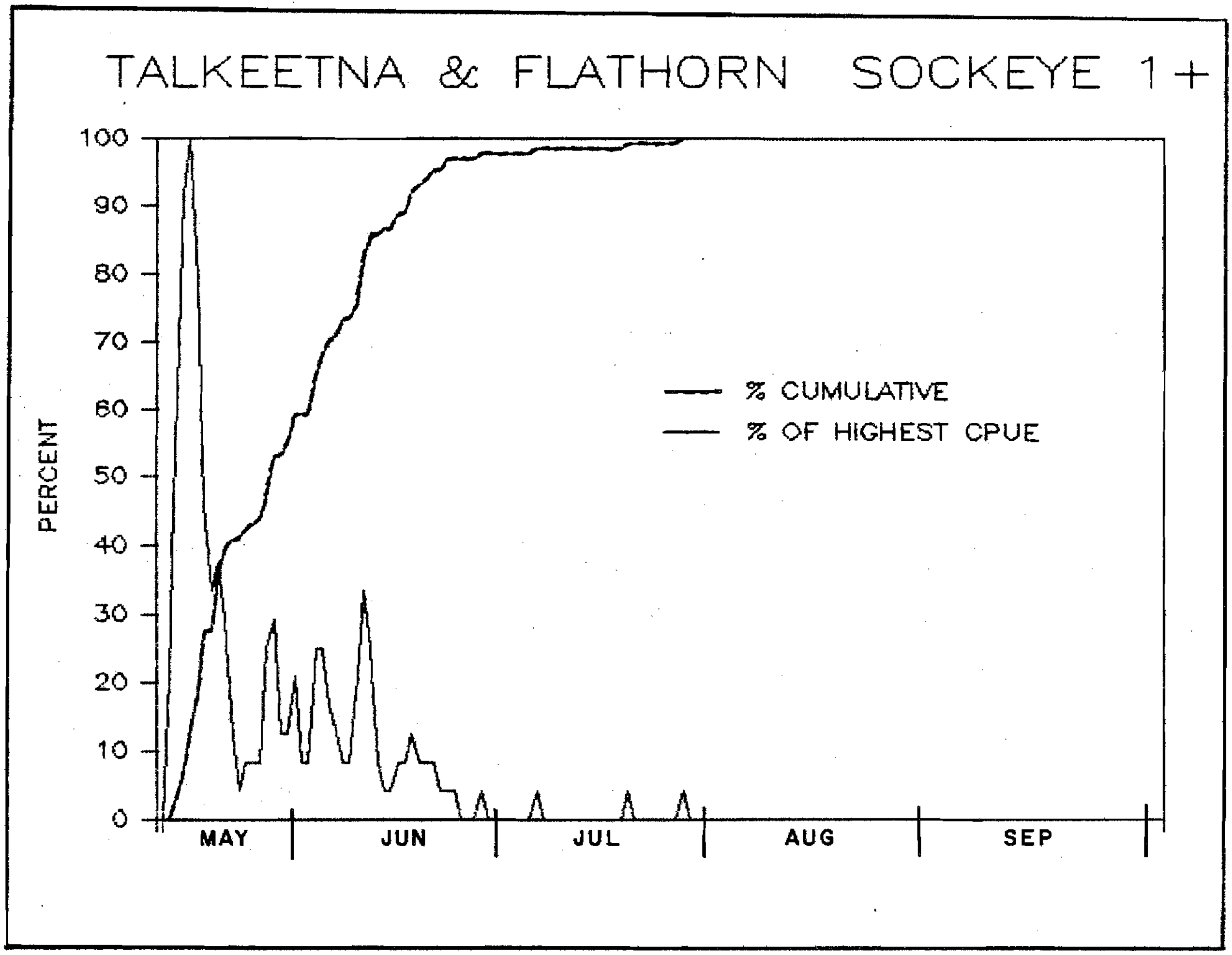


Figure 34. Sockeye salmon (age 1+) smoothed daily catch per unit effort and adjusted cumulative catch recorded at the Flathorn and Talkeetna stationary outmigrant traps, May 14 through October 6, 1984.

3.3.2 Growth

The mean length and range of lengths for age 0+ sockeye salmon by reach of river and sampling period is presented in Fig. 35. During May and June, sockeye fry collected in the middle river reach had a smaller mean length than the same age class sockeye collected in the lower river. By early July, sockeye fry averaged the same length (49 mm) in both reaches, and by late August, middle river sockeye fry were averaging larger than fish collected in the lower river. This trend continued through the remainder of the season. The number of fish measured, the mean length and range of lengths by sampling period for sockeye salmon fry are presented for each of the data collection areas in Appendix Table A-12.

The 90 age 1+ sockeye salmon collected during 1984 ranged from 56 to 102 mm total length (Appendix Table A-13). A coded wire tagged sockeye fry released in 1983 and recaptured in 1984 had increased from 32 mm to 81 mm.

A sample of juvenile sockeye were measured at Talkeetna Station to provide a relationship between length and weight for fish passing this site (Fig. 36).

3.3.3 Coded wire tagging and recovery

A total of 14,532 tagged sockeye salmon fry averaging 33 mm total length were released between May 22 and June 22, 1984 (Table 3). Tag retention rates for sockeye fry averaged 97.1% and ranged from 92.3 to 99.0%. Tagging mortality ranged from 0.6 to 2.6% and averaged 1.3%.

A total of 366 tagged sockeye salmon fry (2.5% of the total tagged sockeye released) were recovered from the 7,484 age 0+ sockeye captured and examined for tags at the Talkeetna Station outmigrant traps during 1984. In addition, 15 sockeye fry with clipped adipose fins but no coded wire tags were recovered in the traps. When compared to the total tagged sockeye salmon fry recovered, this provides a tag retention rate at the traps of 96.1%.

Trap recoveries of coded wire tagged sockeye fry were made from 0 to 109 days (mean = 35 days) following their release at the tagging sites (Fig. 37). In addition, one tagged sockeye fry which was released from Slough 21 on May 28 was recaptured at Flathorn Station on July 7. Seven coded wire tagged sockeye fry were recovered during the cold branding study in early August (Table 4). Six of these fish were recovered at Moose Slough (RM 123.2) and one tagged sockeye fry was recovered at a side channel below Slough 11 (RM 135.2).

A single coded wire tagged sockeye salmon marked and released during 1983 was recovered during the 1984 sampling season. This fish was released June 8, 1983 at Slough 11 and was recovered at Talkeetna Station on July 21, 1984.

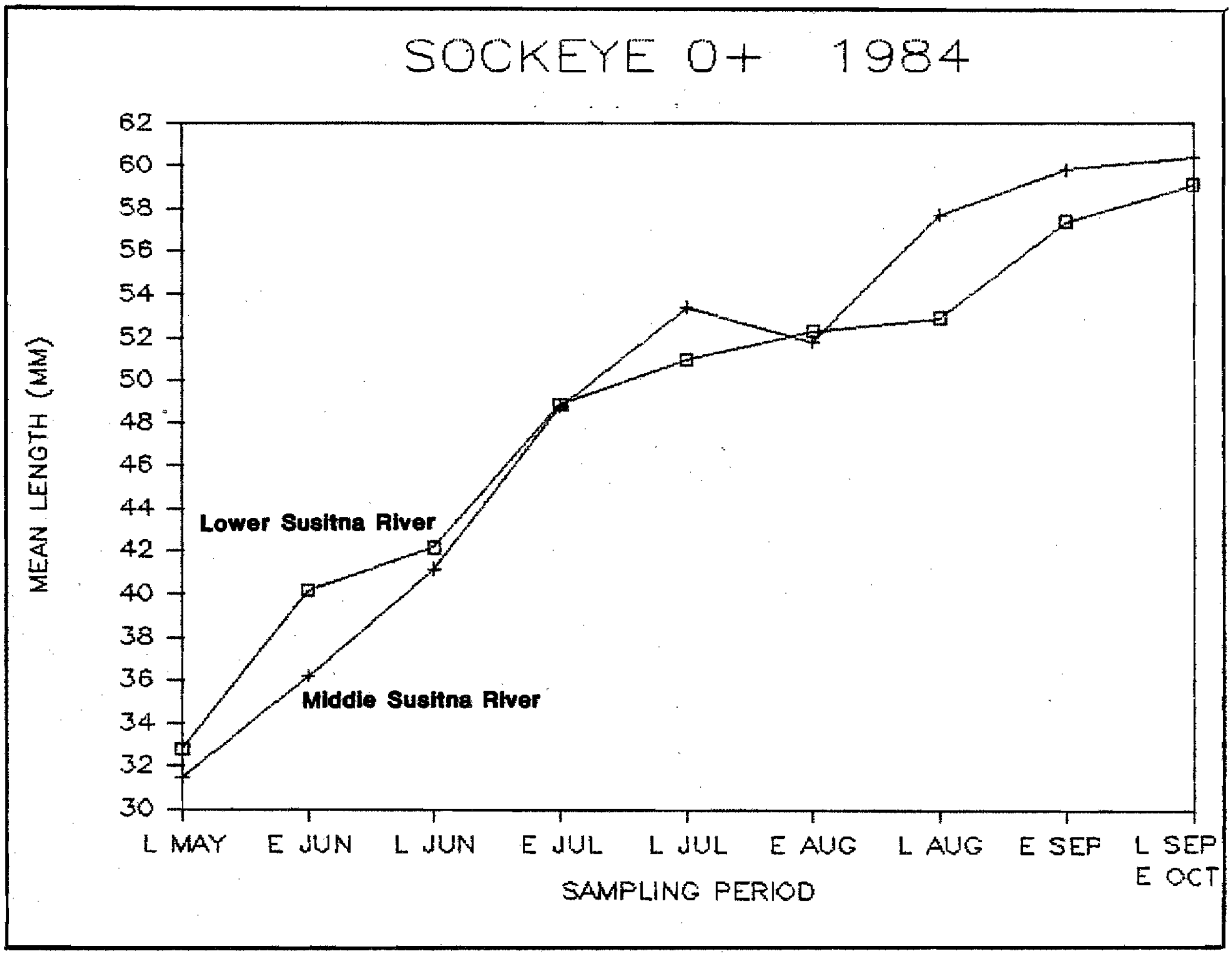


Figure 35. Sockeye salmon (age 0+) mean length and range of lengths by sampling period for fish collected in the lower and middle reach of the Susitna River, 1984.

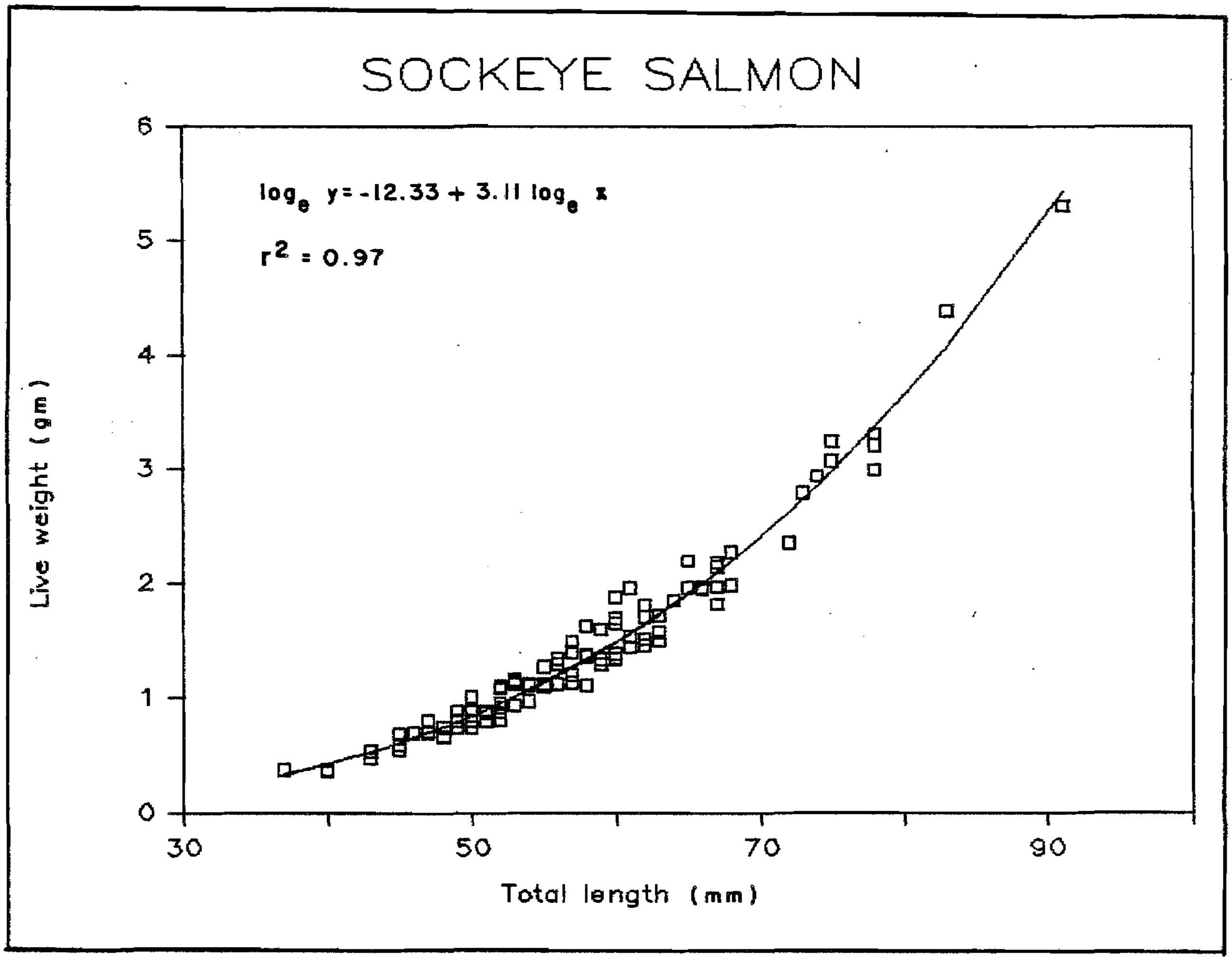


Figure 36. Weight/length relationship for juvenile sockeye salmon collected at the Talkeetna stationary outmigrant traps, 1984.

Table 3. Coded wire tag release data for sockeye salmon fry on the Susitna River by tagging site and release date, 1984.

Tagging Site (River Mile)	Number of Fish Tagged	Date of Release	Percent Tag Retention	Percent Mortality
Slough 21 (RM 142.0)	3,736	5/28	97.9	2.6[a]
Slough 11 (RM 135.3)	2,327	5/22	92.3	1.1
	2,732	5/24	97.7	0.7
	1,537	6/22	96.6	1.1
Slough 9 (RM 128.3)	2,052	6/9	99.0	1.0
Slough 8A (RM 125.3)	2,148	6/19	99.0	0.6
TOTAL - ALL SITES	14,532	5/22-6/22	97.1	1.3

[a] Mortality due to handling, thermal, and anesthetic stresses.

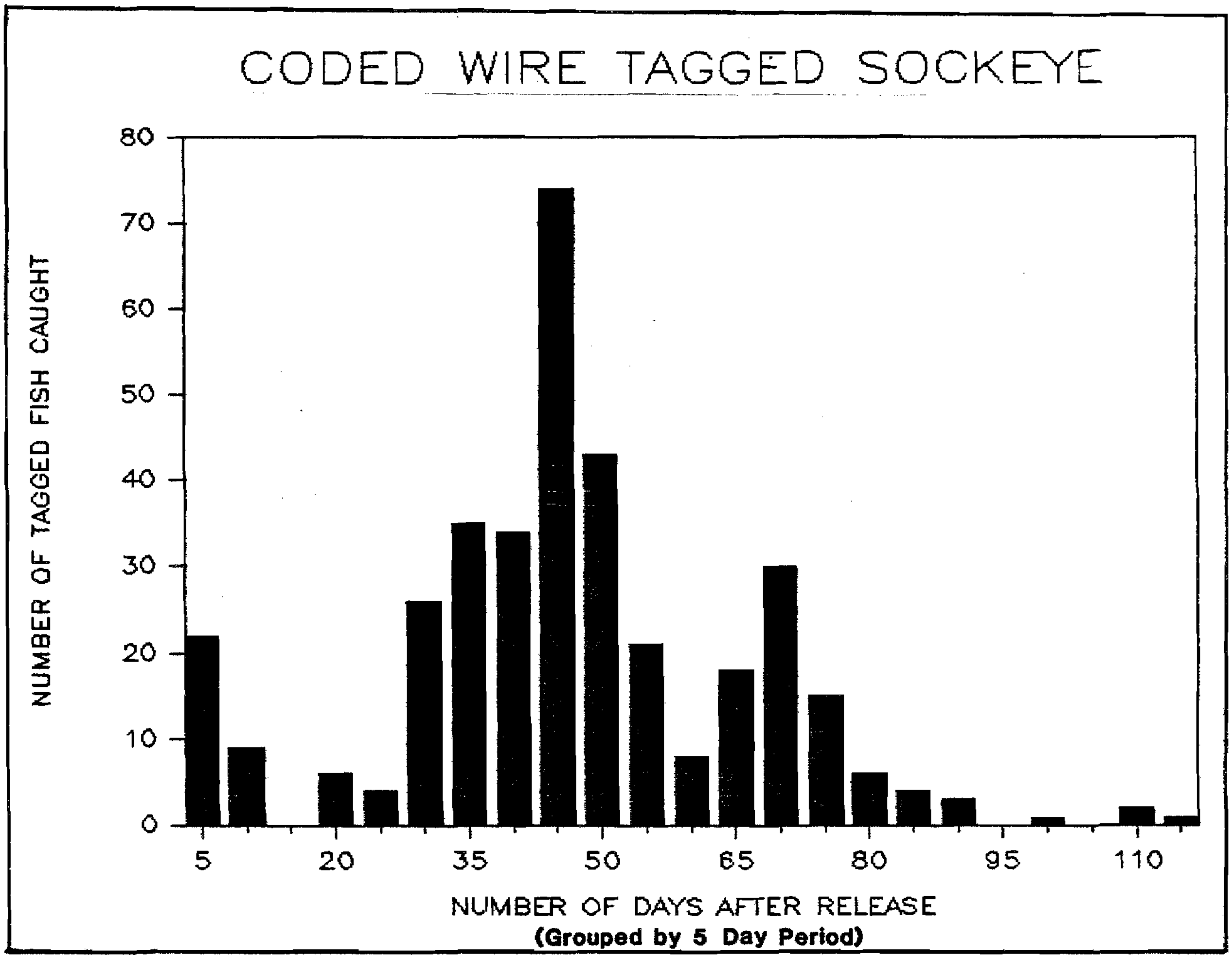


Figure 37. Length of time between the mark and recapture of coded wire tagged sockeye salmon juveniles in the middle reach of the Susitna River, 1984.

Table 4. Recoveries of coded wire tagged sockeye salmon fry at mainstem river sites between Talkeetna and Devil Canyon, 1984.

Collection Site	Collection Date	Release Site	Release Date
Moose Slough[1]	8/8	Slough 21	5/28
Moose Slough	8/8	Slough 21	5/28
Moose Slough	8/8	Slough 11	6/22
Moose Slough	8/8	Slough 9	6/9
Moose Slough	8/8	Slough 8A	6/19
Moose Slough	8/8	Slough 8A	6/19
Slough 11 Side Channel[2]	8/3	Slough 21	5/28

[1] River Mile 123.2

[2] River Mile 134.9

The ratio of coded wire tagged sockeye fry to total sockeye fry was the same (0.05:1.00) in both traps at Talkeetna Station. This indicates that the coded wire tagged fish were uniformly mixed in the total population by the time they migrated past the traps.

3.3.4 Population estimates and survival rates of outmigrants

Females comprised 38.5% of the population of 1,900 adult sockeye salmon estimated past Curry Station in 1983 (95% C.I. - 1,600 to 2,300 adults) and the fecundity of Susitna River sockeye averaged 3,350 eggs per female, with a 95% C.I. of 3131 to 3569 (Barrett et al. 1984). Milling activity was estimated at 30% (Barrett 1984). These data provided a calculation of total potential egg deposition for sockeye salmon of 1,715,000 eggs during 1983.

Using the method outlined by Schaefer (1951), the number of age 0+ sockeye salmon fry above Talkeetna Station during 1984 was estimated to be 299,000 (Appendix Table B-1 and B-2). A comparison of this estimate to the calculated potential egg deposition (dividing the estimated number of fry by the number of eggs) gave an egg-to-outmigrant fry survival rate of 17%. The reliability of this estimate is not currently known because there is no way to estimate the variance of the adult milling estimate and because we do not currently have a method of estimating the variance on the Schaefer estimate of the fry population size.

3.4 Chum Salmon

3.4.1 Catch per unit effort

Chum salmon were collected during the coded wire tagging study in May and June and during beach seine sampling of Indian River in July. Catch rates were not generally recorded during these studies except for 24 hour fyke net sets at Slough 21 (Appendix Table A-10).

Peak catches of chum fry collected at the Talkeetna Station outmigrant traps were recorded during late May and mid June, with the highest daily catch rate of 8.0 fish per hour occurring on June 14 (Fig. 38). Ninety-five percent of the 3,590 chum fry captured at Talkeetna Station were recorded by July 15. The major outmigration had occurred by the end of June (50% by June 13), although the migration continued until September 11.

Chum salmon fry catches at Flathorn Station were greatest during June with a peak catch rate of 10.9 fish per hour recorded on June 14 by which time 50% of the season catch had occurred (Fig. 39). By July 1, 97% of the chum fry collected at this site had been captured; the last chum fry was captured on July 22.

Beach seining and electrofishing at side channel, slough, and tributary sites in the lower river reach collected chum salmon fry during June and July (see Part 2 of this report). Chum fry were abundant in this reach during early June but catches steadily decreased through July (Fig. 40).

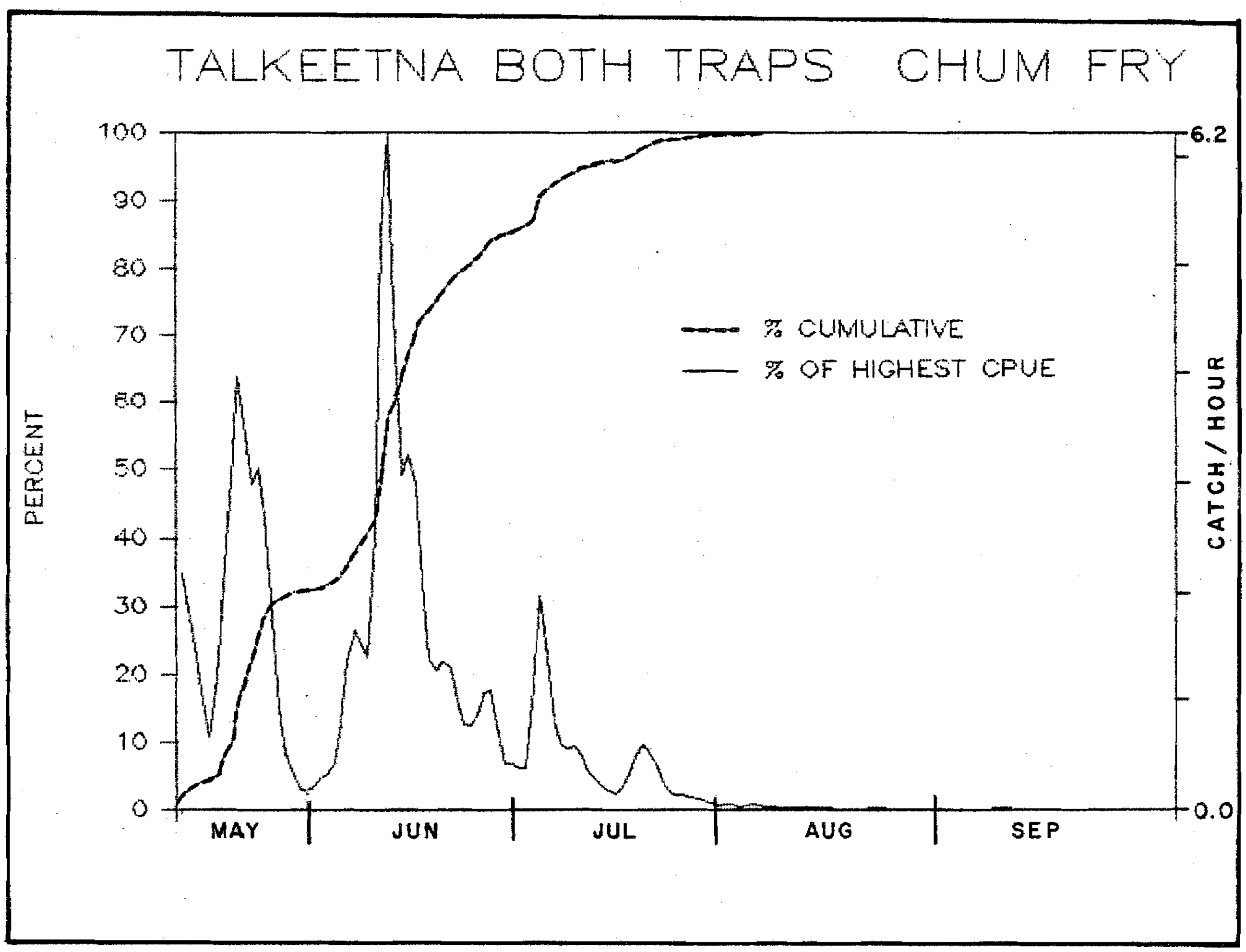


Figure 38. Chum salmon fry smoothed daily catch per unit effort and adjusted cumulative catch recorded at the Talkeetna stationary outmigrant traps, May 14 through October 6, 1984.

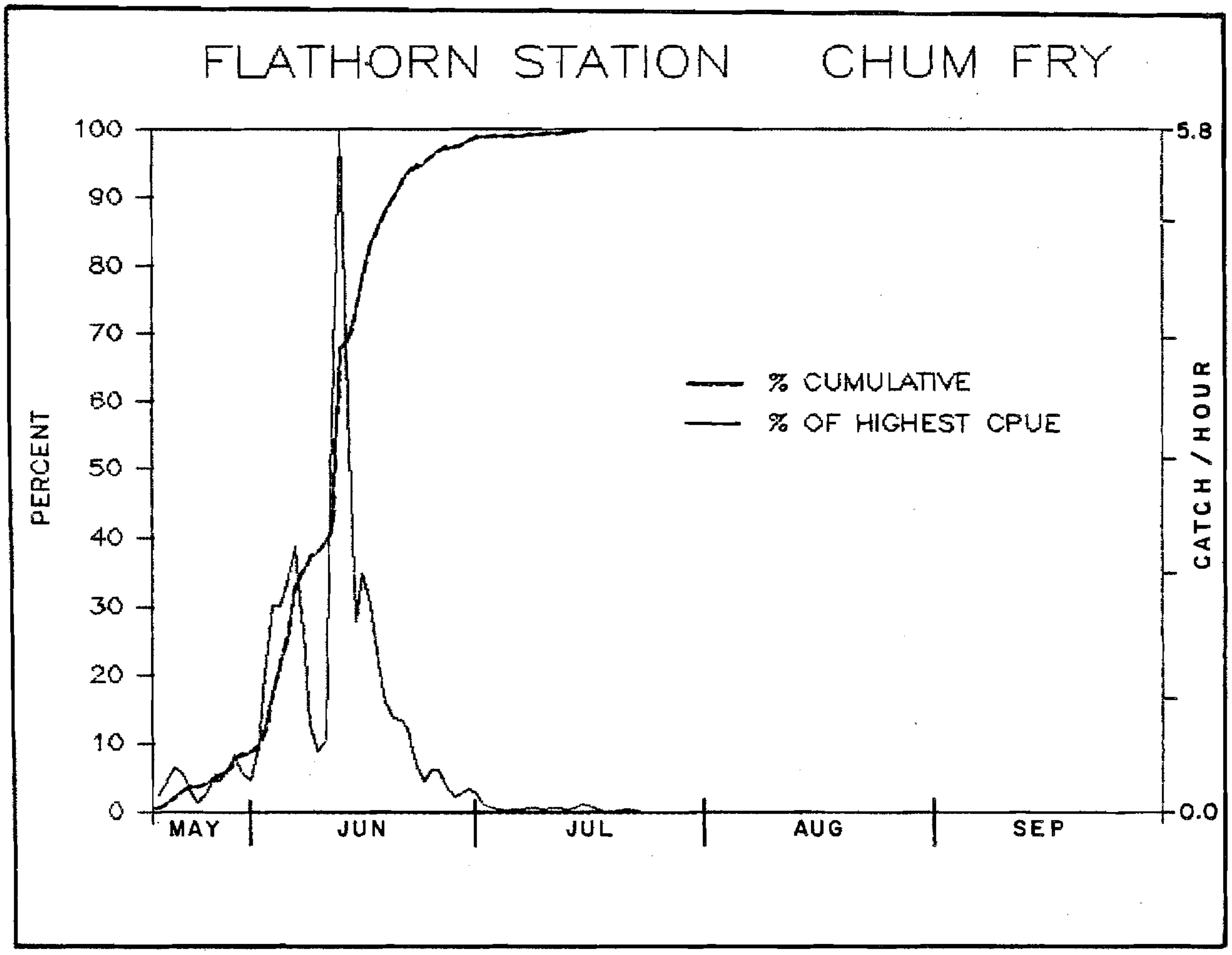


Figure 39. Chum salmon fry smoothed daily catch per unit effort and adjusted cumulative catch recorded at the Flathorn stationary outmigrant trap, May 20 through October 1, 1984.

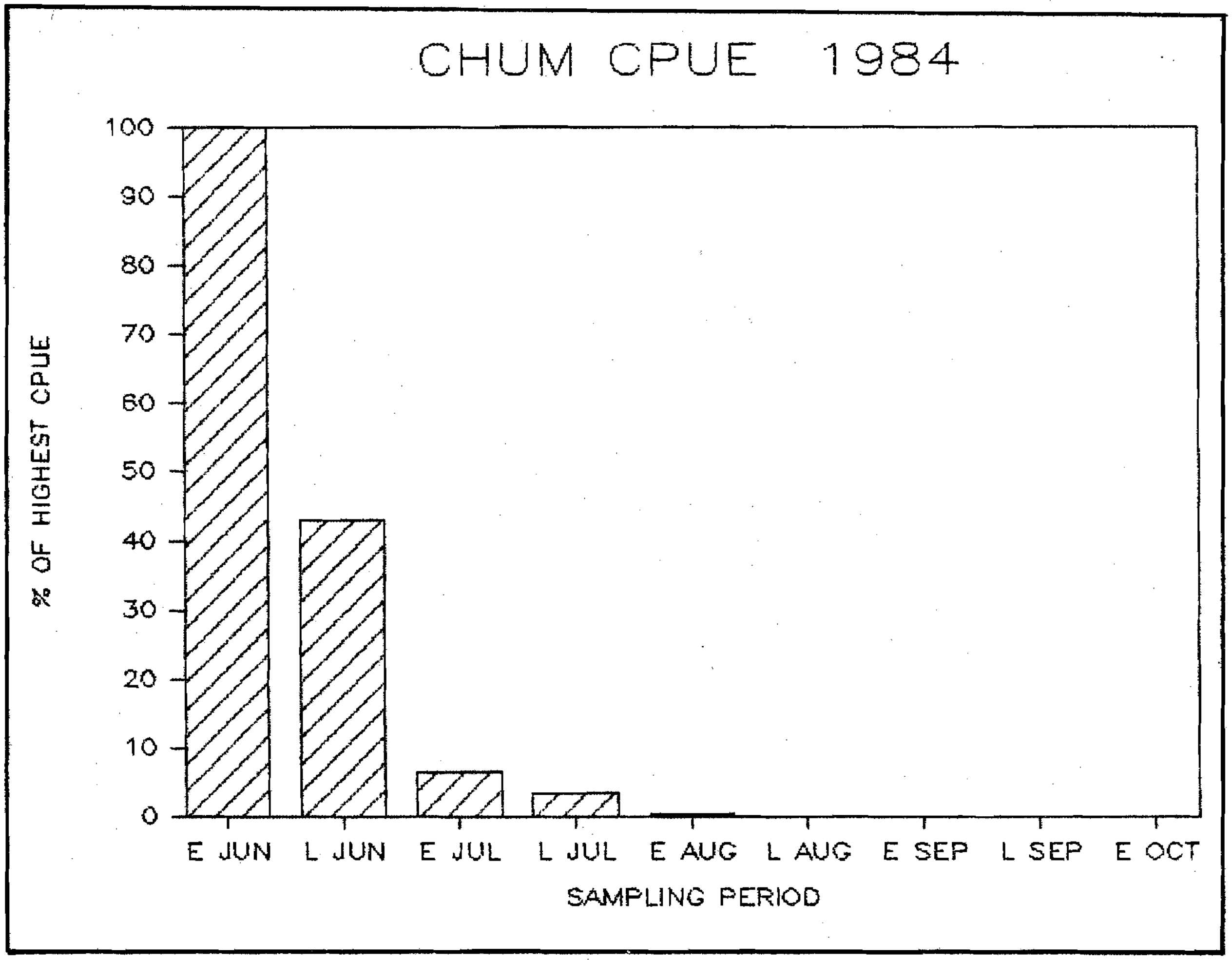


Figure 40. Chum salmon fry catch per unit effort by sampling period recorded at JAHS sites in the lower reach of the Susitna River, 1984.

3.4.2 Growth

At both Talkeetna and Flathorn Stations, chum length ranged from emergent lengths (less than 35 mm) to lengths greater than 60 mm for May, June, and July (Appendix Table A-14). Chum salmon spawn in both tributaries and sloughs and there is a wide range in emergence timing. The fish caught at 30-40 mm are probably recent emergents. The 50-60+ mm fish have gained over 20 mm in length.

During June, Indian River chum fry averaged 40 mm and had increased to a mean length of 48 mm by early July. Limited sampling of the Talkeetna River during June and July indicated a mean length of 43 mm for chum fry outmigrating from this tributary.

3.4.3 Coded wire tagging and recovery

A total of 31,396 tagged chum fry averaging 43 mm total length were released between May 22 and June 22, 1984 (Table 5). Tag retention rates ranged from 93.0 to 100% and averaged 96.4%. Mortality rates between tagging and release averaged 0.9% and ranged from 0.0 to 2.7%.

Fifty-one tagged chum salmon fry (0.2% of the total tagged chum released) were recovered from the 3,590 chum salmon fry captured and examined for tags at the Talkeetna Station outmigrant traps during 1984. In addition, two chum fry with clipped adipose fins but no coded wire tags were recovered in the traps. When compared to the total tagged chum salmon fry recovered, this provides a tag retention rate at the traps of 96.2%.

Trap recoveries of tagged chum fry were made from 0 to 29 days (mean = 8 days) following their release at the tagging sites (Fig. 41).

The ratio of coded wire tagged chum fry to the total number of fish caught at each trap at Talkeetna Station was 0.016:1 at Trap 1 and 0.013:1 at Trap 2, indicating that the tagged chum fry were randomly distributed with the untagged population by the time they migrated past the traps.

3.4.4 Population estimates and survival rates of outmigrants

Adult population estimates at Curry Station during 1983 were 21,100 chum salmon with 95% confidence limits of 19,200 to 23,500 adults. Females comprised 34.5% of these fish and chum salmon milling was estimated at 40% (Barrett et al. 1984). Fecundity of Susitna River chum salmon was determined during 1983 to be 2,850 eggs per female (95% confidence limits of 2,666 to 3,034). These data provided an estimated total potential egg deposition of 12,448,000 eggs.

The population estimated using the Schaefer (1951) method was 2,039,000 chum salmon fry outmigrating past Talkeetna Station during 1984 (Appendix Table B-3 and B-4). Using the above data, an egg-to-outmigrant fry survival rate of 16% was calculated for chum salmon. As with sockeye salmon, there is no way of knowing the reliability of the estimate

Table 5. Coded wire tag release data for chum salmon fry on the Susitna River by tagging site and release date, 1984.

Tagging Site (River Mile)	Number of Fish Tagged	Date of Release	Percent Tag Retention	Percent Mortality
Slough 22 (RM 144.3)	2,383	6/7	98.0	0.5
Slough 21 (RM 142.0)	2,201	6/3	96.6	1.4
Slough 20 (RM 140.1)	1,255	6/11	96.9	0.6
Slough 15 (RM 137.3)	351	6/14	100.0	0.0
Indian River (RM 138.6)	4,612	6/1	94.5	0.7
	341	6/1	93.0	0.0
	4,592	6/21	93.8	2.7[a]
	2,511	6/22	95.0	0.4
Slough 11 (RM 135.3)	2,031	5/22	97.7	0.1
	2,203	5/24	93.9	0.3
	572	5/24	99.0	0.2
	1,916	6/16	98.0	0.4
Slough 9 (RM 128.3)	5,122	6/6	99.4	0.7
Slough 8B (RM 122.4)	1,306	6/13	98.0	0.8
TOTAL - ALL SITES	31,396	5/22-6/22	96.4	0.9

[a] High mortality due to injury from improper headmold.

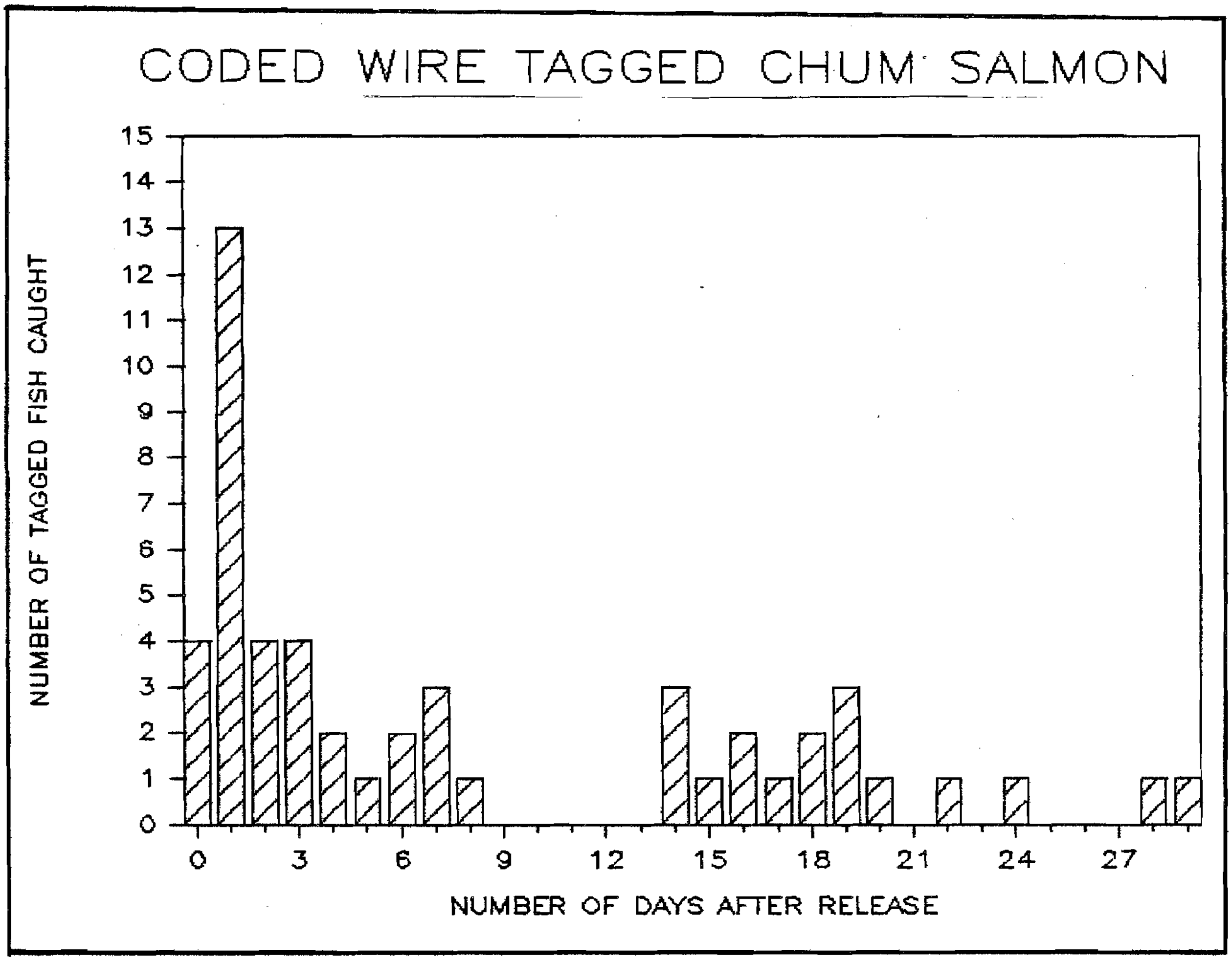


Figure 41. Length of time between the mark and recapture of coded wire tagged chum salmon juveniles in the middle reach of the Susitna River, 1984.

because the variance of the adult milling estimate and the variance of the fry population estimate are not known.

3.5 Pink Salmon

Sixty-eight pink salmon fry were captured between May 15 and July 18 at the Talkeetna Station outmigrant traps during 1984, with the peak catch rate of 0.8 fish per hour being recorded on June 18 (Fig. 42). Pink fry migrating past Talkeetna Station averaged 36 mm total length with a range from 29 to 53 mm.

A total of 405 pink salmon fry were collected in the stationary outmigrant trap at Flathorn Station. Catches occurred from May 21 through July 6 and the peak catch rate of 4.0 fish per hour was recorded on June 5 (Fig. 43). Fifty percent of the catches at this site were recorded by June 11. Pink fry collected at Flathorn Station averaged 34 mm and ranged in length from 25 to 46 mm.

No pink salmon fry were collected during the cold branding studies in the middle river, during sampling of the Deshka River, or at JAHS sites in the lower river during 1984.

3.6 Descriptive Statistics for Catch and Environmental Variables

Summary statistics for Talkeetna Station catch are given in Table 6 and for environmental variables in Table 7. Flathorn data are summarized in Table 8. The influence of discharge peaks on the level of outmigration can be seen by comparing the seasonal discharge level (Fig. 44; Fig. 45) with the outmigration plots presented earlier. Results of a statistical time series analysis of 1983 and 1984 discharge, turbidity, and age 0+ chinook and sockeye salmon outmigration are presented in Appendix C.

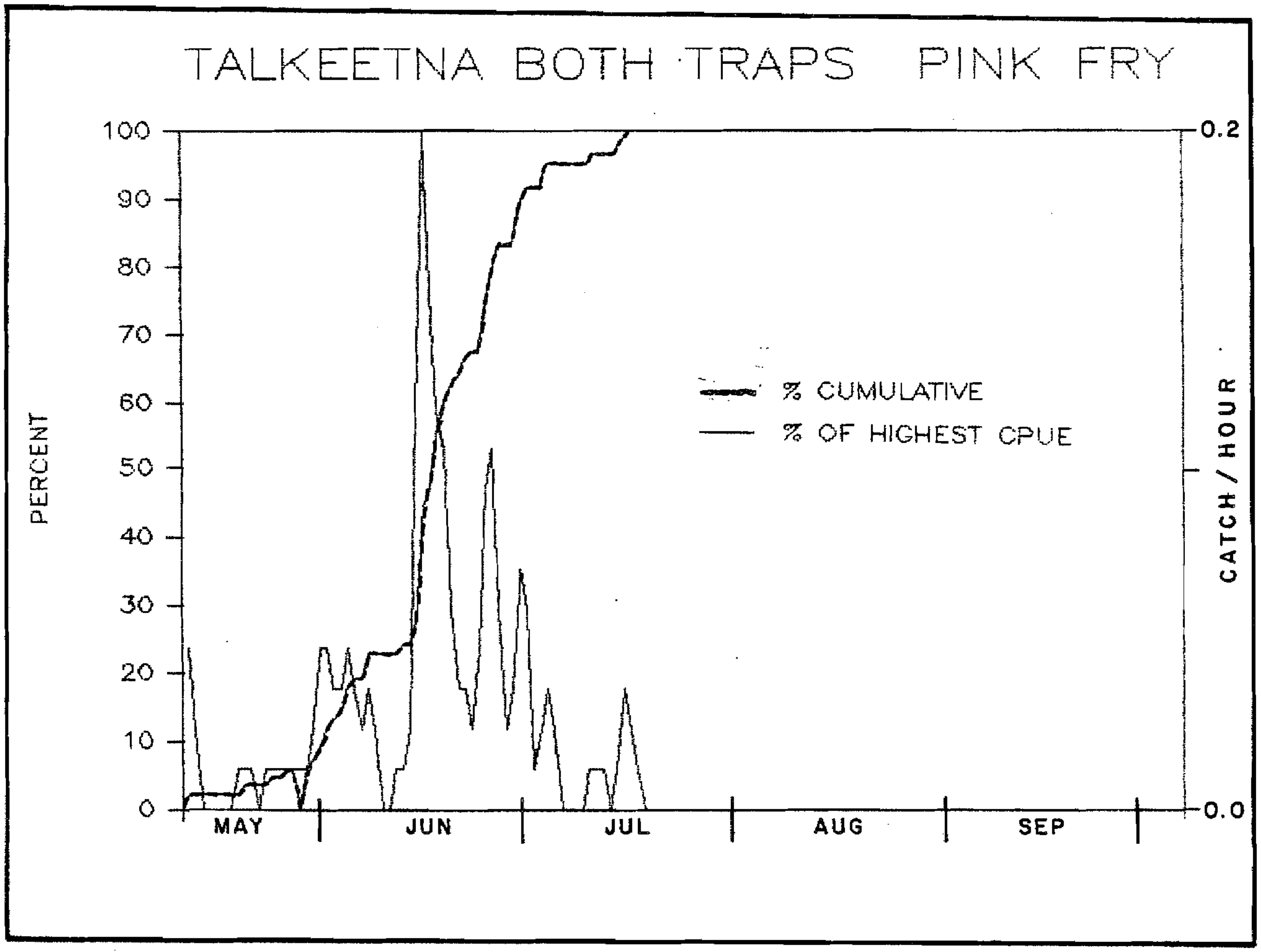


Figure 42. Pink salmon fry smoothed daily catch per unit effort and adjusted cumulative catch recorded at the Talkeetna stationary outmigrant traps, May 14 through October 6, 1984.

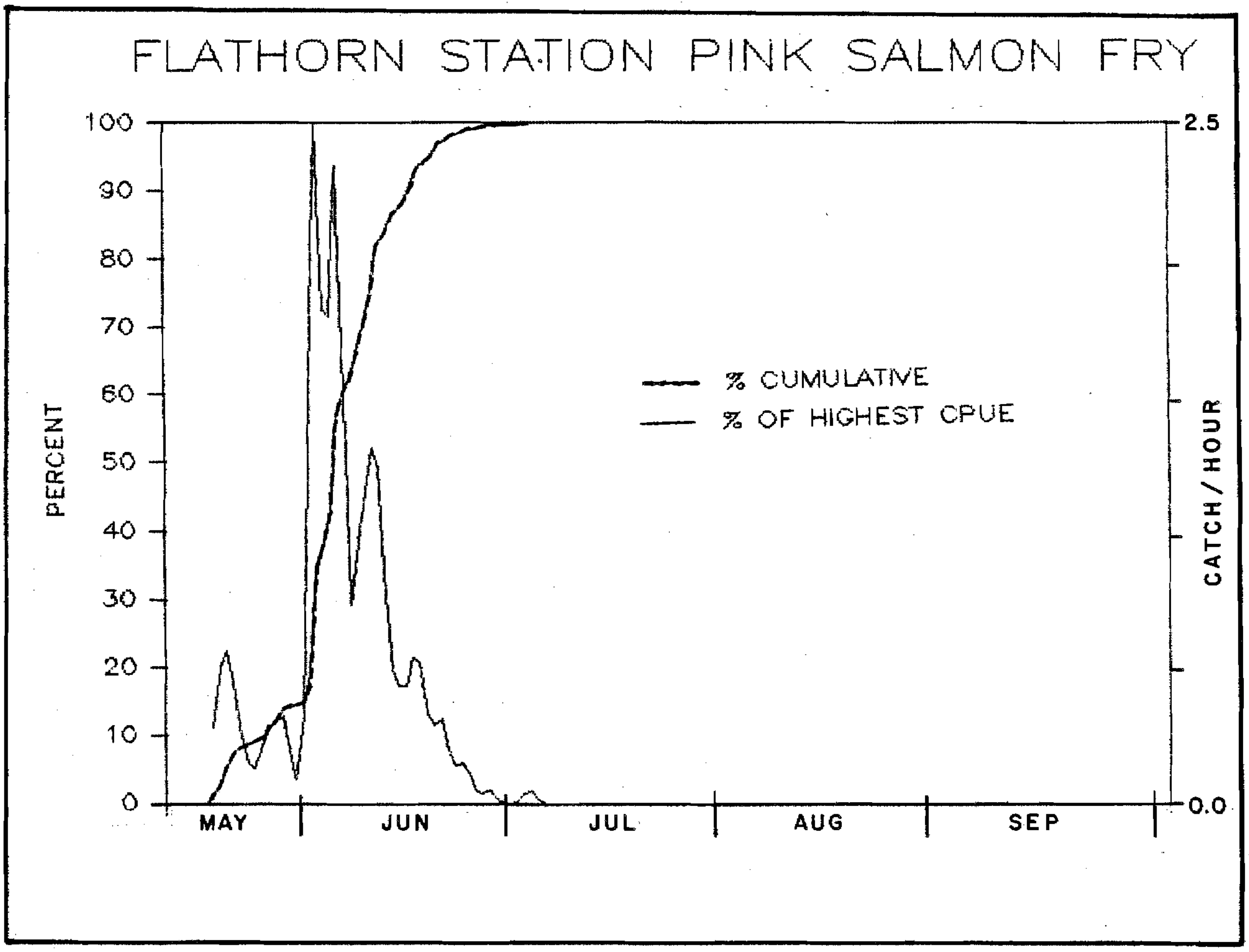


Figure 43. Pink salmon fry smoothed daily catch per unit effort and adjusted cumulative catch recorded at the Flathorn stationary outmigrant traps, May 20 through October 1, 1984.

Table 6. Summary statistics for juvenile salmon catch per hour by species and age class recorded at the Talkeetna Station outmigrant traps, May 14 through October 6, 1984.

	Catch Per Hour, Both Traps[a]			
	Min	Max	Mean	Std. Dev.
Chinook 0+	0.0	17.2	2.2	3.2
Chinook 1+	0.0	3.5	0.3	0.6
Coho 0+	0.0	2.9	0.3	0.4
Coho 1+[b]	0.0	1.7	0.3	0.3
Sockeye 0+	0.0	13.0	1.2	1.8
Sockeye 1+	0.0	0.3	0.0	0.0
Chum	0.0	8.0	0.7	1.2

[a] n = 146

[b] includes all juvenile coho age 1+ or older.

Table 7. Summary statistics for habitat variables recorded on the Susitna River between the Chulitna River confluence and Devil Canyon, May 14 through October 6, 1984.

	Min	Max	Mean	Std. Dev.	n
Discharge (ft^3/sec)[a]	6,780	52,000	19,405	8160.0	146
Water Temperature (°C)[b]	2.0	13.5	8.8	3.0	145
Turbidity (NTU)[b]	13	400	115	92.0	145

[a] USGS provisional data at Gold Creek, 1984.

[b] ADF&G data at Talkeetna Station outmigrant traps, 1984.

Table 8. Summary statistics for juvenile salmon catch per hour by species and age class recorded at the Flathorn Station outmigrant traps, May 20 through October 1, 1984.

Catch Per Hour[a]	Min	Max	Mean	Std. Dev.
Chinook 0+	0.0	7.8	0.7	1.1
Chinook 1+	0.0	6.5	0.1	0.6
Coho 0+	0.0	1.5	0.1	0.3
Coho 1+[b]	0.0	0.8	0.1	0.1
Sockeye 0+	0.0	4.6	0.8	0.8
Sockeye 1+	0.0	0.4	0.0	0.1
Chum	0.0	10.9	0.3	1.1
Pink	0.0	4.0	0.2	0.5
Discharge (ft^3/sec)[c]	40,800	166,000	93,122	28,887.5

[a] n = 134.

[b] Includes all juvenile coho age 1+ or older.

[c] USGS provisional data at Susitna Station, 1984.

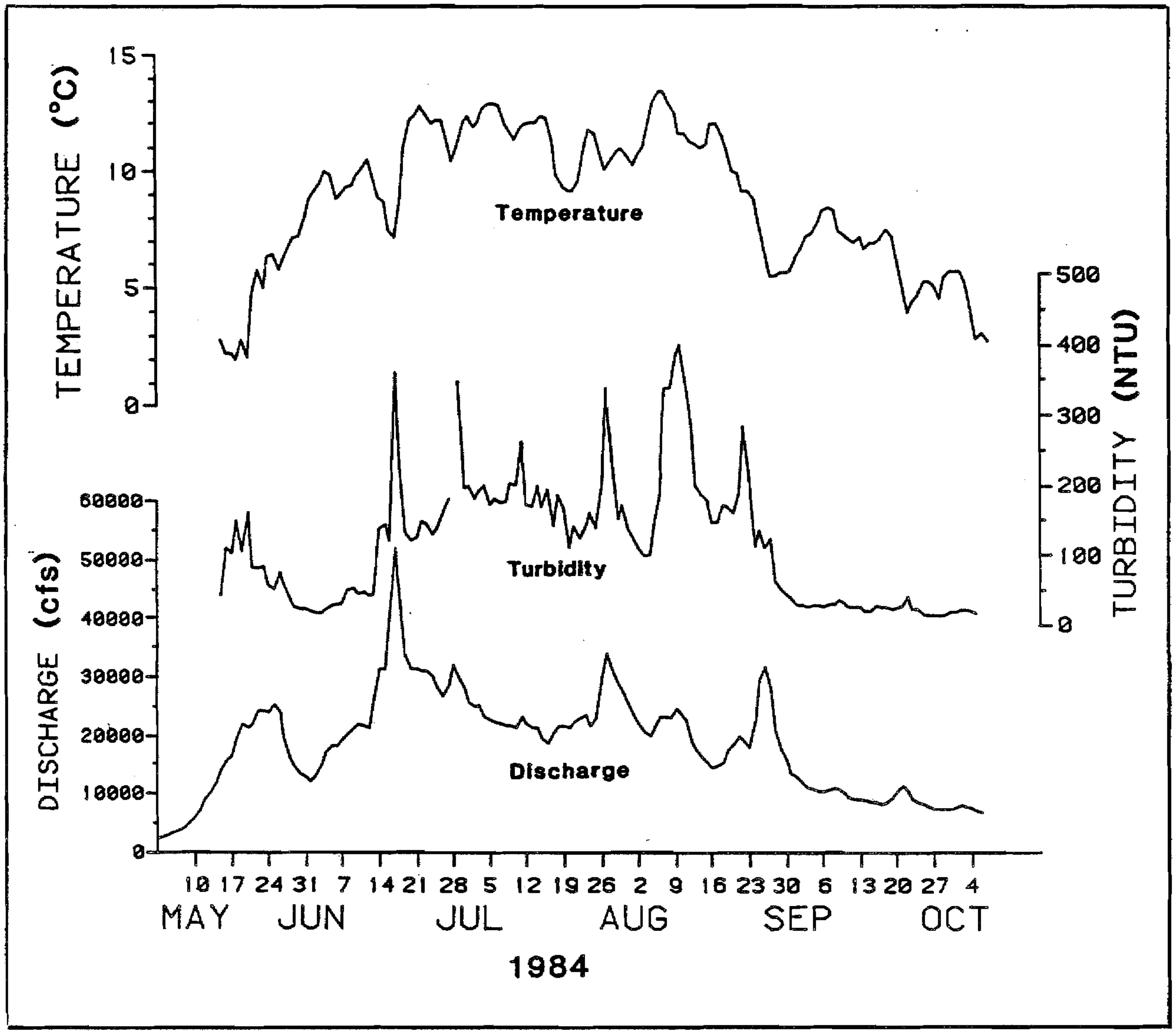


Figure 44. Mainstem discharge, water temperature, and turbidity in the middle reach of the Susitna River, 1984. Discharge was measured at the USGS gaging station at Gold Creek. Water temperature and turbidity were measured at Talkeetna Station.

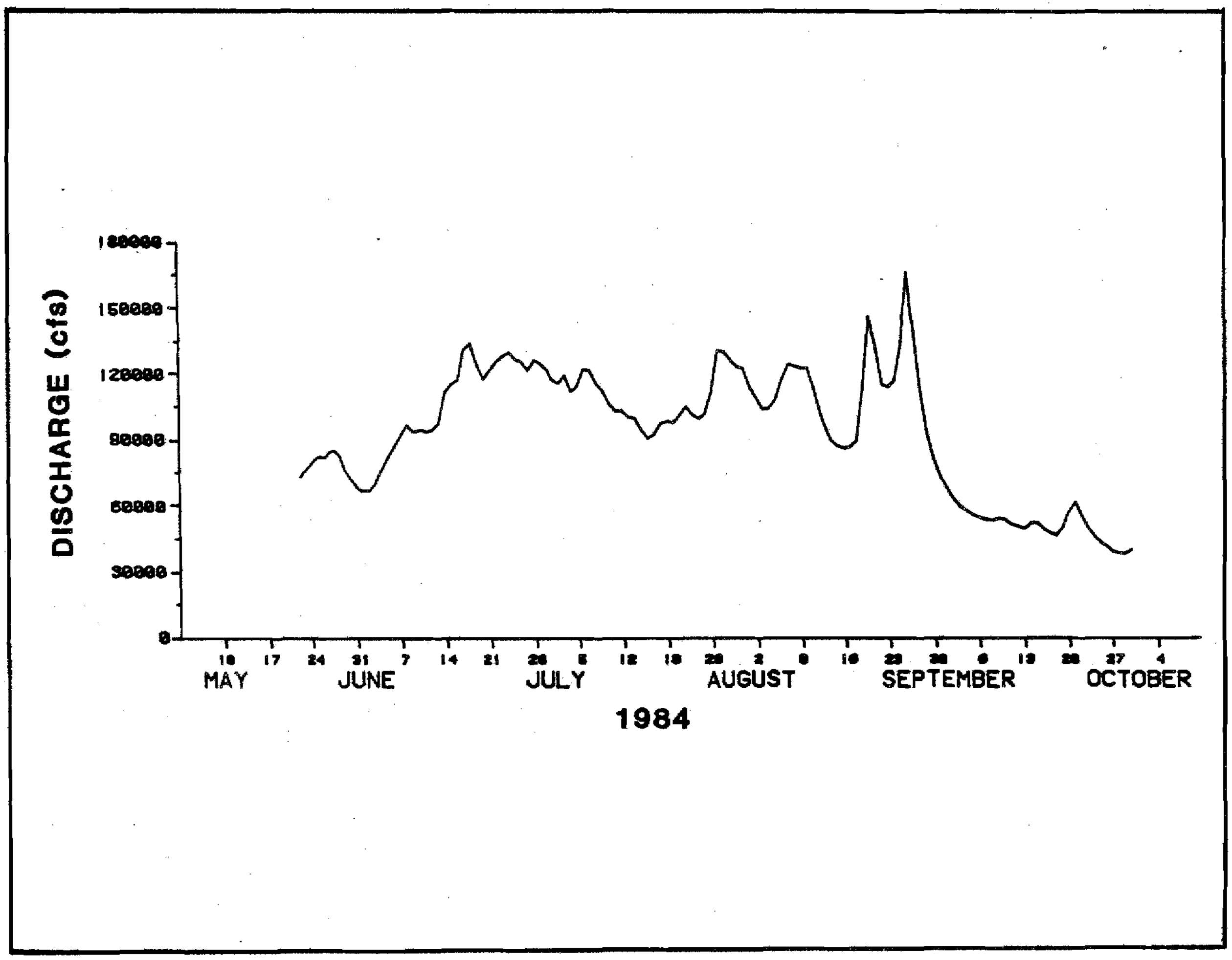


Figure 45. Mainstem discharge in the lower reach of the Susitna River measured at the USGS gaging station at Susitna Station, 1984.

4.0 DISCUSSION

4.1 Chinook Salmon

4.1.1 Outmigration

Fifty percent of the outmigration of age 0+ chinook salmon past Talkeetna Station during both 1983 and 1984 had occurred by mid July, but the rates and timing were different between the two years (Fig. 46). During 1983, two pulses of chinook fry movement were recorded, one in late June and the second in mid August. Conversely, the 1984 outmigration did not start until mid June and was then relatively steady through late August.

Low tributary flows during July of 1983 trapped chinook fry in pools and side channels in Indian River until high tributary flows from heavy rainfall in mid August allowed access or flushed fry to the Susitna River (Roth et al. 1984). In 1984, minnow trap catches of marked and unmarked chinook in Indian River during the cold branding study showed the movement of chinook fry out of this tributary continued from July through early October.

In 1984, age 0+ chinook salmon in the middle river that had outmigrated from the tributaries were found predominately in shallow, turbid, rocky bottom areas in breached sloughs and side channels during July and August. Not until mid August, when mainstem flows had decreased and many of these sloughs and side channels were no longer breached, did catches of juvenile chinook increase at clear water sloughs and side channels. In early September, juvenile chinook were concentrated at the mouths of clearwater sloughs and side channels, but as water temperatures and stage continued dropping through September and early October, these fish slowly dispersed within these sites with the major concentrations being found in areas with non-imbedded substrate and a groundwater source.

The rates of outmigration of age 1+ chinook salmon past Talkeetna Station were similar in 1983 and 1984 (Fig. 47), but the date by which half of the total seasonal outmigration occurred was ten days earlier in 1983 than in 1984, primarily because of the late start of outmigration in 1984.

The chinook fry appear to associate with the banks of the river during their downstream movement. Although juvenile chinook were captured across the entire river at Flathorn Station, 60% of the total mobile trap captures were recorded at bank transect sites.

4.1.2 Freshwater life history

Chinook salmon juveniles in the middle river appear to group into three separate categories. The first group are those juveniles which rear and overwinter in their natal tributaries and outmigrate to the ocean as age 1+ fish during the spring of their second year. The second group of chinook juveniles spend a portion of their first summer in their natal tributaries and then, probably because of density dependent interaction,

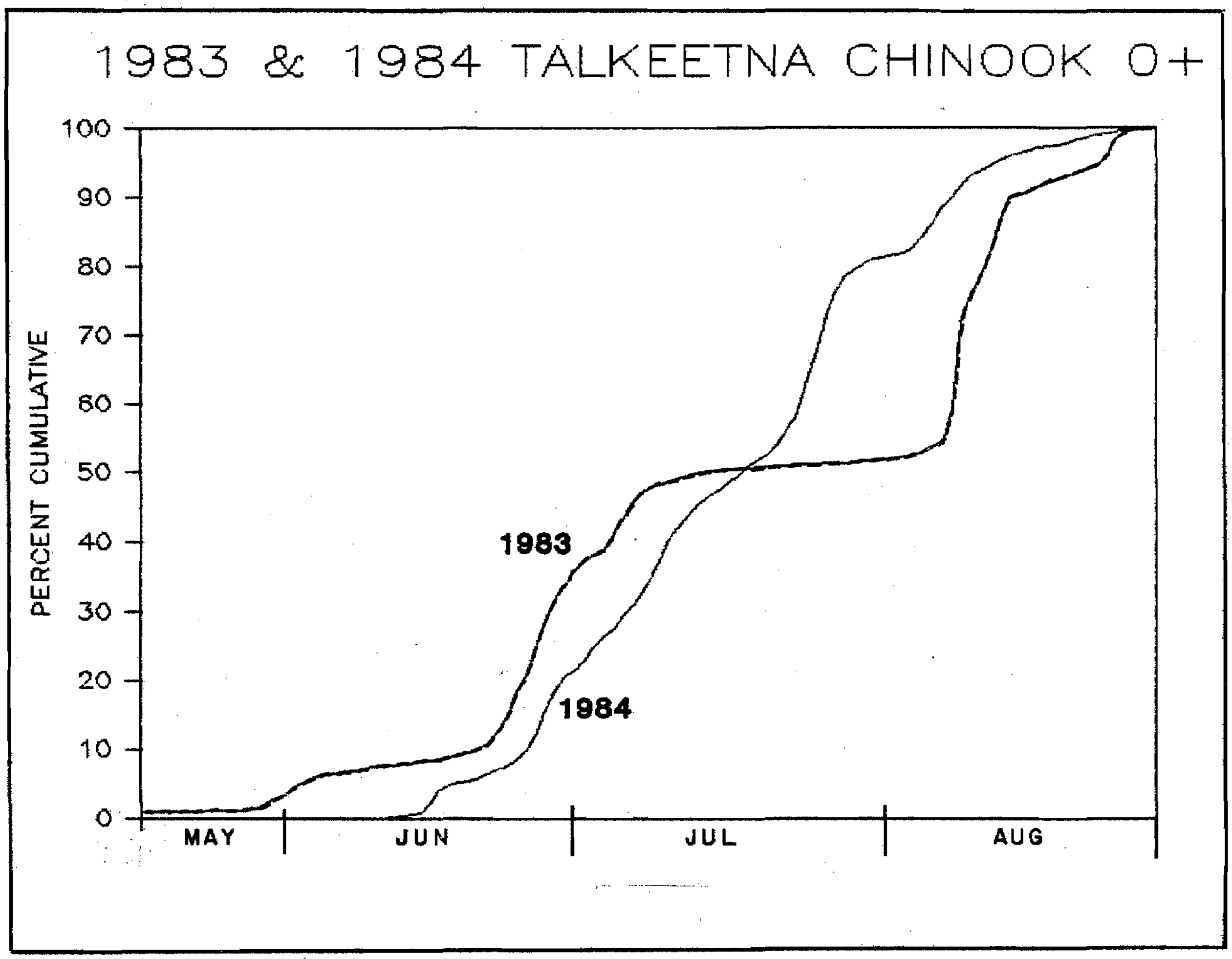


Figure 46. Chinook salmon (age 0+) adjusted cumulative catch recorded at the Talkeetna stationary outmigrant traps, 1983 and 1984.

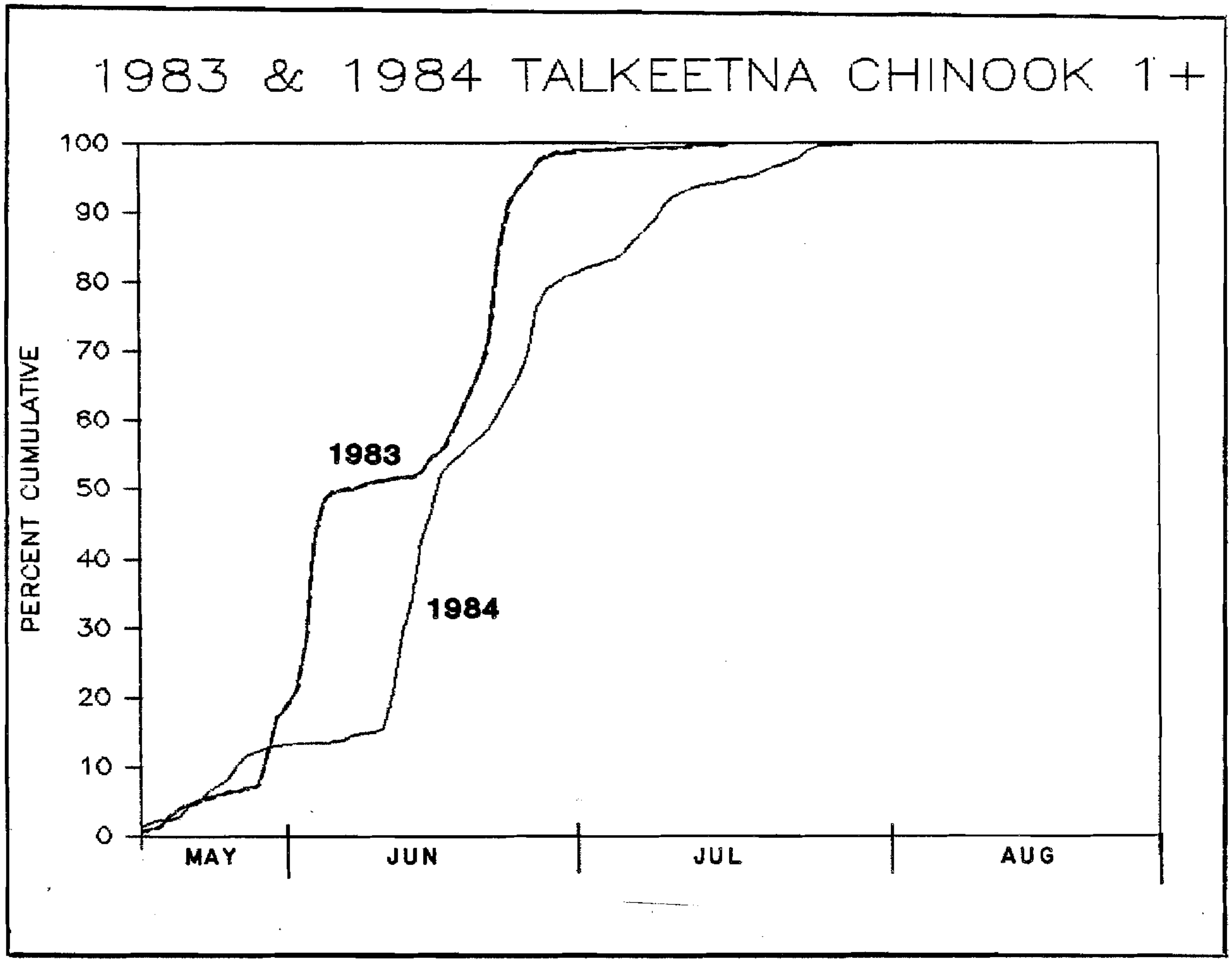


Figure 47. Chinook salmon (age 1+) adjusted cumulative catch recorded at the Talkeetna stationary outmigrant traps, 1983 and 1984.

behavioral changes related to downstream re-distribution, or flushing by high flows, enter the mainstem river. These fish actively search out suitable habitats as they move downstream. Many of the fish enter sloughs and side channels in the middle river to overwinter while others continue downstream to the lower river. Since 80% of the Talkeetna Station trap catch had occurred by August 1, and high catches were still being recorded at Indian River and selected sloughs above Talkeetna Station in August, September, and October, it appeared that a significant percentage of 1983 brood year chinook salmon belonged to one of these two groups. We do not know what this percentage was.

A third group of chinook salmon juveniles may be present in the Susitna River. Data collected at the Flathorn Station outmigrant trap showed that a portion of the age 0+ chinook were moving downstream past this site. Many of these were probably fry from the Deshka River. Although it is possible that these fish overwintered in freshwater habitats below Flathorn Station, it appeared that many of these fish entered the ocean as age 0+ fish because few rearing chinook fry were found at sites below the Deshka River during 1984 (see Part 2 of this report).

Intermittent operation of an outmigrant weir on the Deshka River during 1984 showed that a large number of age 0+ chinook fry were outmigrating from this tributary during July and August. Similar data were collected in 1980 by Delaney et al. (1981), who postulated that the observed outmigration was a size related response as the fish reached approximately 80 mm. It is not known whether these fish remain in habitats associated with the mainstem river or if they continue to the ocean as age 0+ fish.

Scale samples collected from returning adults at Sunshine Station and above indicated that the age 0+ class of outmigrants represented less than 3% of the middle river returning chinook during 1983 (Barrett et al. 1984) and less than 1% in 1984 (Barrett et al. 1985). However, no adult chinook scale samples were taken in 1984 at Flathorn Station, which did not begin operation until early July. It may be that a significant proportion of the adults bound for lower river tributaries such as the Deshka did outmigrate during their first summer.

Otherwise, if it is assumed that a significant percentage of Susitna River chinook salmon migrate to the ocean as age 0+ fish, then either the marine survival of this age class is very low or the freshwater life histories on adult scales were not interpreted correctly. Richards (1979) reported that a major portion (72%) of the adult scales analyzed from the Deshka River during 1978 indicated that the fish had migrated to the ocean during their first summer as age 0+ fish. Scale analysis from creel census samples collected in the Deshka River have classed these fish as predominantly age 1+ outmigrants (Kubik 1967; Kubik and Wadman 1978; Kubik and Delaney 1980).

There are many unanswered questions about chinook fry life history in the Susitna River. Aging of adult chinook at Flathorn Station during 1985 will help answer the question of whether there is a significant proportion of returning adults which outmigrated during their first summer. However, we still do not know the proportion of returning adults which, as fry, followed one or the other of the three life history strategies discussed above. The answer to this question is of major importance in assessing dam-related effects on the population.

4.1.3 Estimates of population size and residence time

The Schaefer population estimate of 3.2 million chinook salmon juveniles in Indian River in 1984 must be qualified. A successful method of sampling large numbers of juvenile chinook and a location containing large numbers were not found until mid July, at which time over 50% of the Talkeetna Station trap catch of age 0+ chinook fry had occurred. Therefore, this estimate is only for those fish in Indian River for the period July 15 to Oct. 15.

The efficiency of minnow traps decreases when flows are high. Because the marked fish were not randomly re-introduced into the system, we have to assume that the recapture was random. However, there is some reason to believe that the unmarked fish were more likely to redistribute downstream during high flows than were the marked fish, which were re-introduced into side sloughs.

Having two separate groups of juvenile chinook within Indian River, those fish which overwinter in Indian river and the middle Susitna River and those fish which migrate out of this reach, further complicates the population estimate. Most marked fish were marked near the mouth of Indian; it is likely that fish captured near the mouth were going to migrate out of Indian River during the first summer. Also, it has to be assumed that these fish, when transported back upriver, randomly mixed with the other fry. The estimate of 3.2 million fry for Indian River should be used as a rough approximation, obtained by an experimental project. Information gathered during the 1984 season will enable a more refined estimate for the 1985 season.

The chinook fry population estimates made for sloughs and side channels give a general idea of how many fry these sites can support. The day-to-day variation in total number of fish at these sites, which results from variation in discharge level, is striking. Another important result of this study is the residence time of rearing chinook fry at these sites because of the implications this has on the results of the IFIM and RJHAB models of rearing habitat (presented in Part 2 of this report). Habitat value from the models is measured by weighted usable area (WUA), which depends only on water depth, water velocity, cover, and substrate. The model will predict discharge levels at which habitat value of a site is high. However, there may not be many fish at a site, even when WUA is high, because of previous flushing of the site by a high discharge or because of a seasonal effect in level of outmigration. More importantly, if the fish are using a site only as an outmigration corridor, as appeared to be the case at Moose Slough in mid August, then it really doesn't matter if the WUA is high or low, because WUA measures only rearing habitat quality. On the other hand, if the fish have a longer residence time at a site, such as at Lower Side Channel 11A in late July, then the amount of WUA is important.

Of the 643 chinook fry which were captured in a slough or side channel, cold-branded, and later recaptured at the same site, 113 were still present 30-60 days later. This indicates that a substantial amount of chinook fry rearing occurs at these sites.

4.1.4 Growth

The increase in mean length of age 0+ chinook by sampling period for the combined data collected at the Talkeetna Station outmigrant traps during 1982, 1983 and 1984 is presented in Fig. 48. Chinook fry, which emerge from the gravel at an average length of approximately 37 mm, had increased to an average of 44 mm by early June. By the end of the open-water season, their mean length was 63 mm. Chinook fry collected in the lower river in 1984 averaged from two to ten mm larger than their counterparts in the middle river through the season (Fig. 16).

Chinook fry which overwinter in Indian River show little growth between late October (when they are a little less than 70 mm long) and late March (ADF&G, unpublished data). Outmigrating age 1+ fish at Talkeetna station averaged 90 mm during the peak of outmigration, so they had grown about 20 mm during April, May, and June.

Examination of the downstream redistribution of juvenile chinook salmon in the Susitna River by age class during 1984 shows that chinook fry in the middle river averaged approximately the same length (50 to 55 mm) throughout the period of peak outmigration (late June through early August). This results in very little separation between cumulative movements recorded for catch and biomass at Talkeetna Station (Fig. 49). The outmigration of chinook fry in the middle river appears to be triggered, in part, by the fish reaching a critical size. As they reach this critical size (estimated at 55 mm), chinook fry redistribute downstream to other rearing areas.

In the lower river, total biomass movements were delayed in comparison to the total number of chinook fry moving past Flathorn Station (Fig. 49). This was due to the growth occurring in the lower river and because of the mixed stocks present in this reach.

4.2 Coho Salmon

4.2.1 Outmigration

The downstream movement of coho salmon fry past Talkeetna Station is compared for 1983 and 1984 in Fig. 50. Although the outmigration from May through early July was slower during 1984, 50% of the total season outmigration was recorded ten days earlier in 1984 than in 1983. The delay in downstream movement observed during July of 1983 was due in part to low tributary water levels during this period, and the high rates of downstream movement recorded in mid August corresponded to a period of heavy rainfall and high tributary discharges.

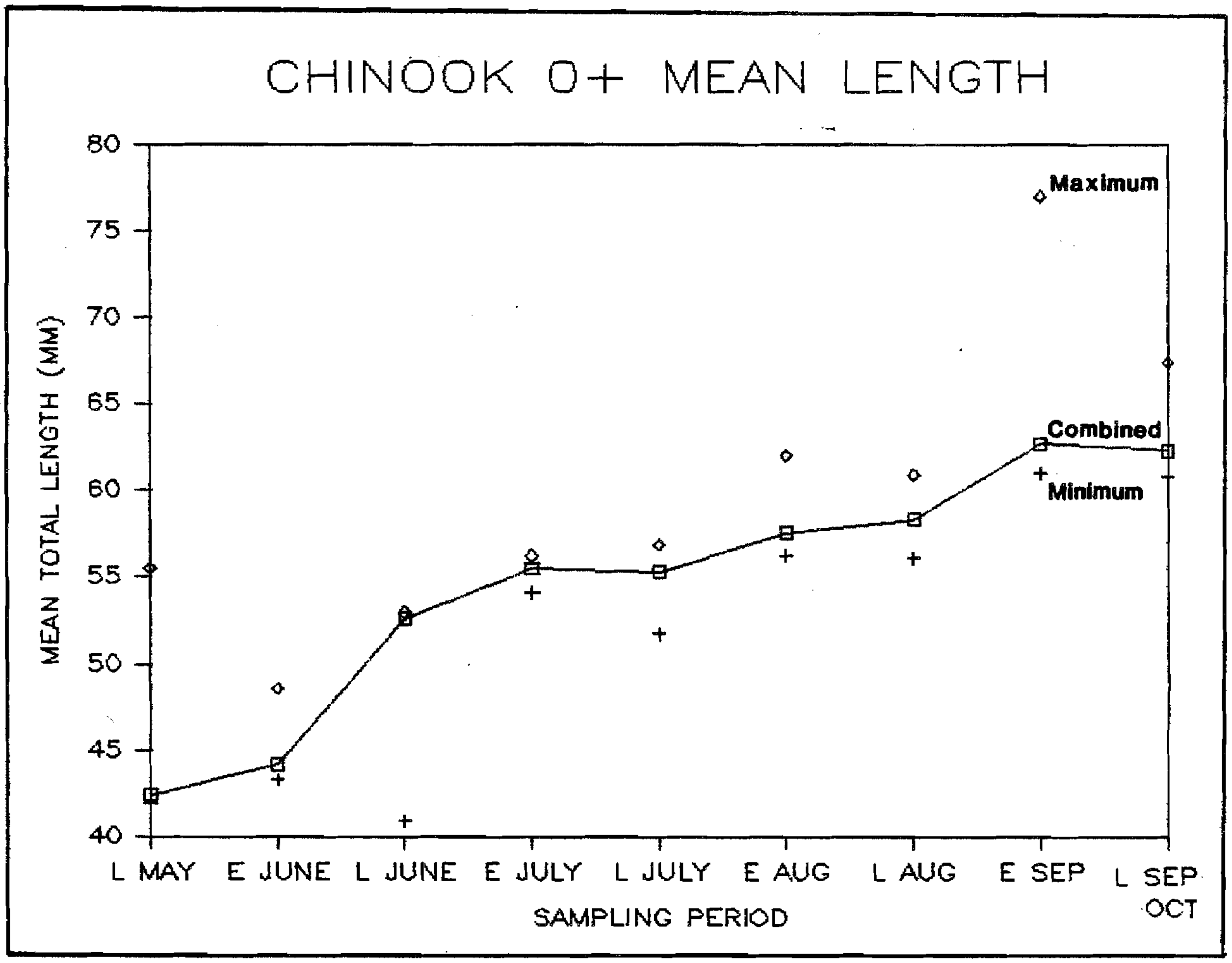


Figure 48. Chinook salmon (age 0+) mean length and range of mean lengths by sampling period recorded at the Talkeetna stationary outmigrant traps during 1982, 1983, and 1984.

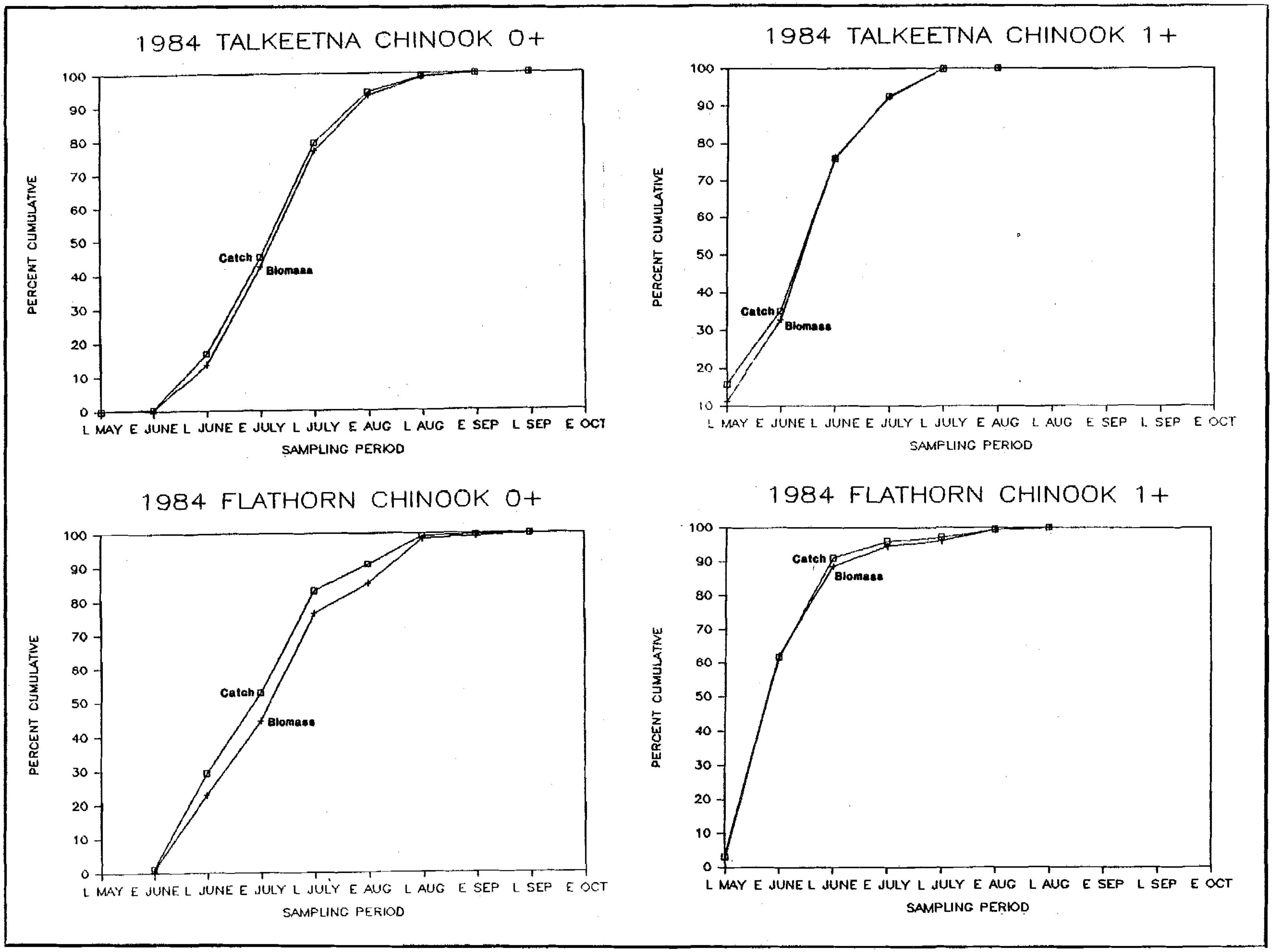


Figure 49. Chinook salmon adjusted cumulative catch and biomass by age class recorded at Talkeetna and Flathorn stations, 1984.

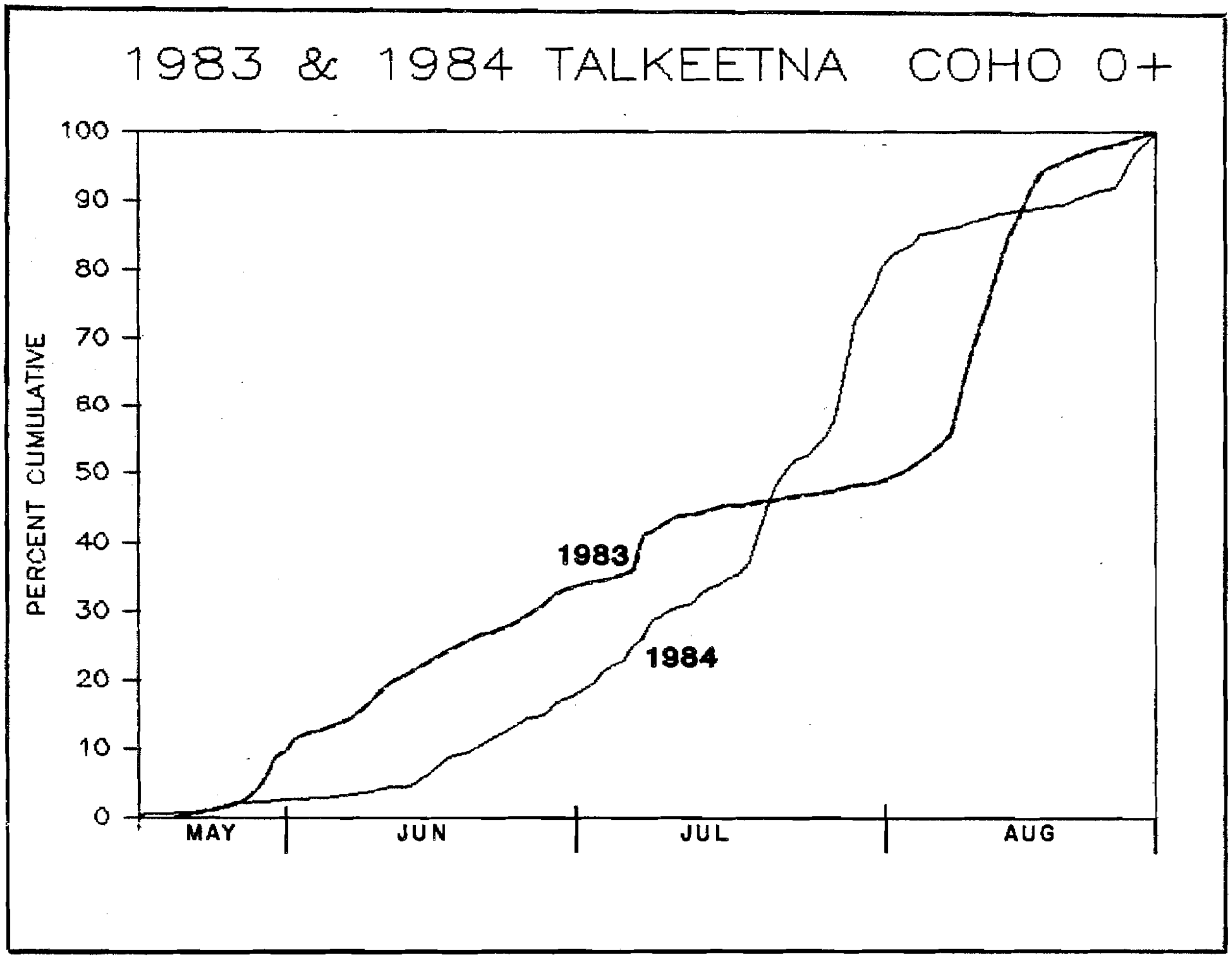


Figure 50. Coho salmon (age 0+) adjusted cumulative catch recorded at the Talkeetna stationary outmigrant traps, 1983 and 1984.

The downstream movement of age 1+ coho salmon past Talkeetna Station was approximately two weeks later in 1984 than in 1983 while the rates of movement were fairly stable throughout both seasons (Fig. 51).

4.2.2 Freshwater life history

Most coho salmon juveniles spend one or more years in the Susitna River before migrating to the ocean. Analysis of scales from returning adults indicate that most juvenile coho outmigrate as either age 1+ or age 2+ but the proportion of each age class has varied between years (ADF&G 1982; ADF&G 1983; Barrett et al. 1984; Barrett et al. 1985).

Coho salmon in the middle Susitna River spawn almost exclusively in the tributaries. The fry, after emergence, rear in their natal tributaries or enter the mainstem river in search of suitable habitats. Outmigrant trap data collected at Talkeetna Station have shown a downstream redistribution of juvenile coho occurring throughout the open-water season. During the fall, coho fry move into tributaries, sloughs, beaver ponds, or other habitats to overwinter. Similar redistributions of juvenile coho were observed by Delaney and Wadman (1979) and by Tschaplinski and Hartman (1983).

Trap catches recorded at Talkeetna Station during 1982 and 1984 showed that high catches of age 0+ and 1+ juvenile coho occurred during September or early October. It was presumed that these fish were redistributing to habitats in the lower river to overwinter, but the data collected at Flathorn Station in 1984 indicate that a portion of these fish may migrate to the ocean during the fall (Fig. 22).

4.2.3 Growth

The change in mean length for age 0+ coho by sampling period for the combined data collected at the Talkeetna Station outmigrant traps during 1982, 1983, and 1984 is presented in Fig. 52. Coho salmon in the middle river emerge from the gravel at approximately 35 mm and grow to 45 mm by early July. By the end of the open-water season, coho fry have obtained a mean length of approximately 68 mm. Throughout the season, age 0+ coho in the lower river averaged at least five millimeters larger than fish collected in the middle river (Fig. 26).

Age 1+ coho salmon in the middle river also showed a steady growth through the season (Fig. 53) increasing approximately 45 mm between late May and early October. Similar to age 0+ coho, age 1+ coho collected in the lower river averaged larger than fish captured in the middle river reach (Fig. 27).

The downstream redistribution (as shown by the cumulative biomass) of juvenile coho salmon in the Susitna River by age class during 1984 averaged one to two weeks later than the redistribution of the total number of individuals recorded at both the Talkeetna and Flathorn stations outmigrant traps (Fig. 54). The difference between the cumulative biomass movement and the movement of total numbers of fish results from the growth of juvenile coho occurring during the open-water

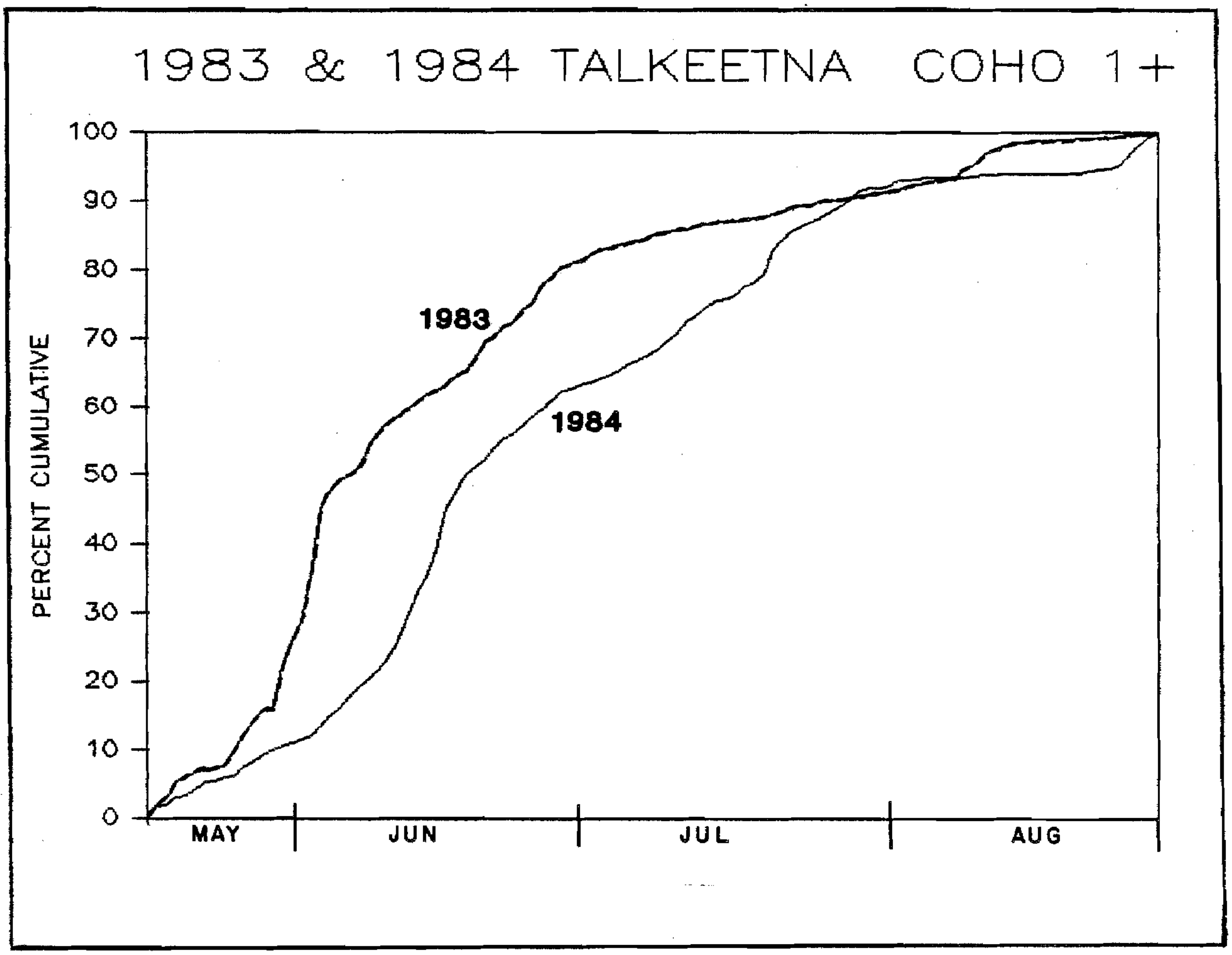


Figure 51. Coho salmon (age 1+) adjusted cumulative catch recorded at the Talkeetna stationary outmigrant traps, 1983 and 1984.

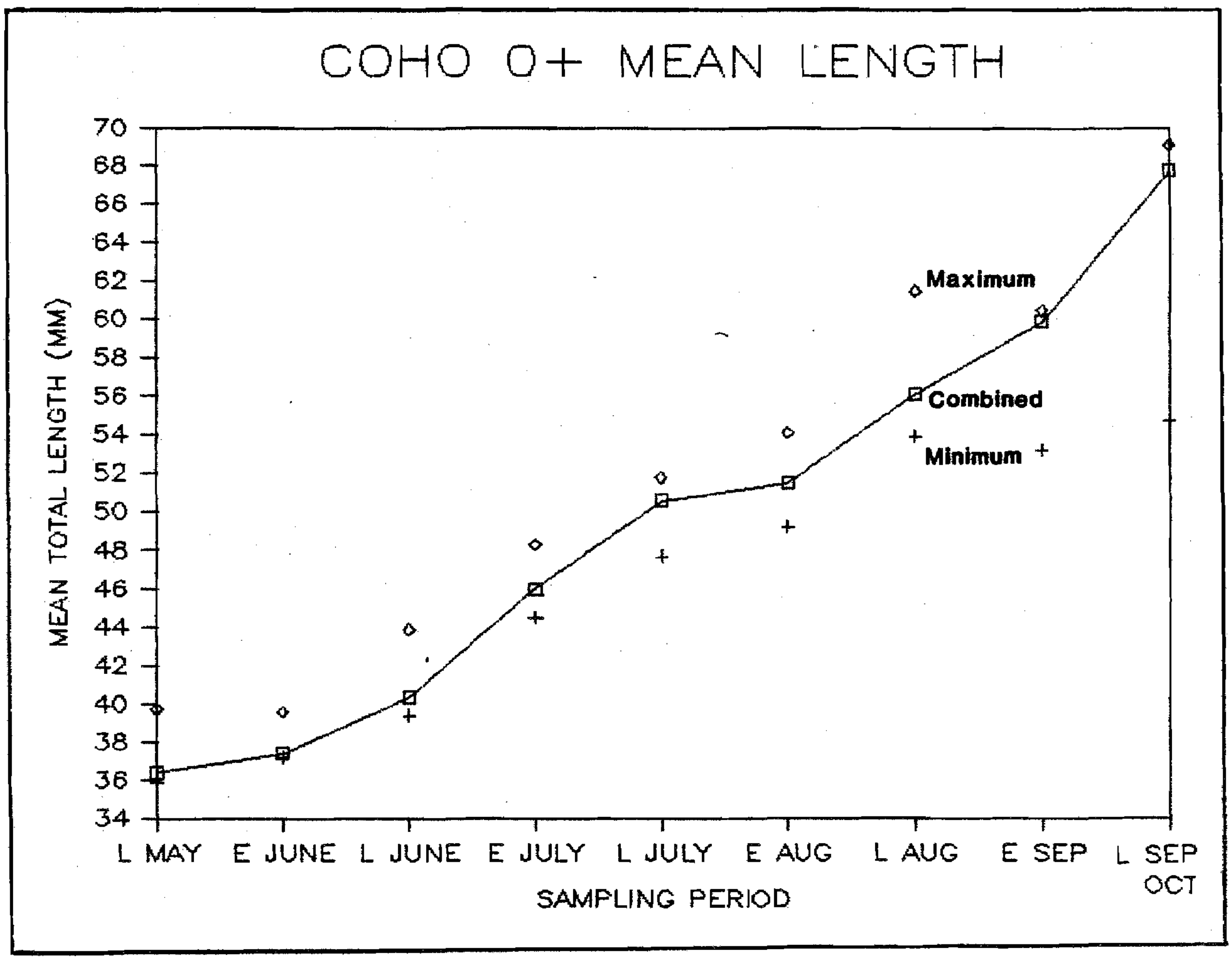


Figure 52. Coho salmon (age 0+) mean length and range of mean lengths by sampling period recorded at the Talkeetna stationary outmigrant traps during 1982, 1983, and 1984.

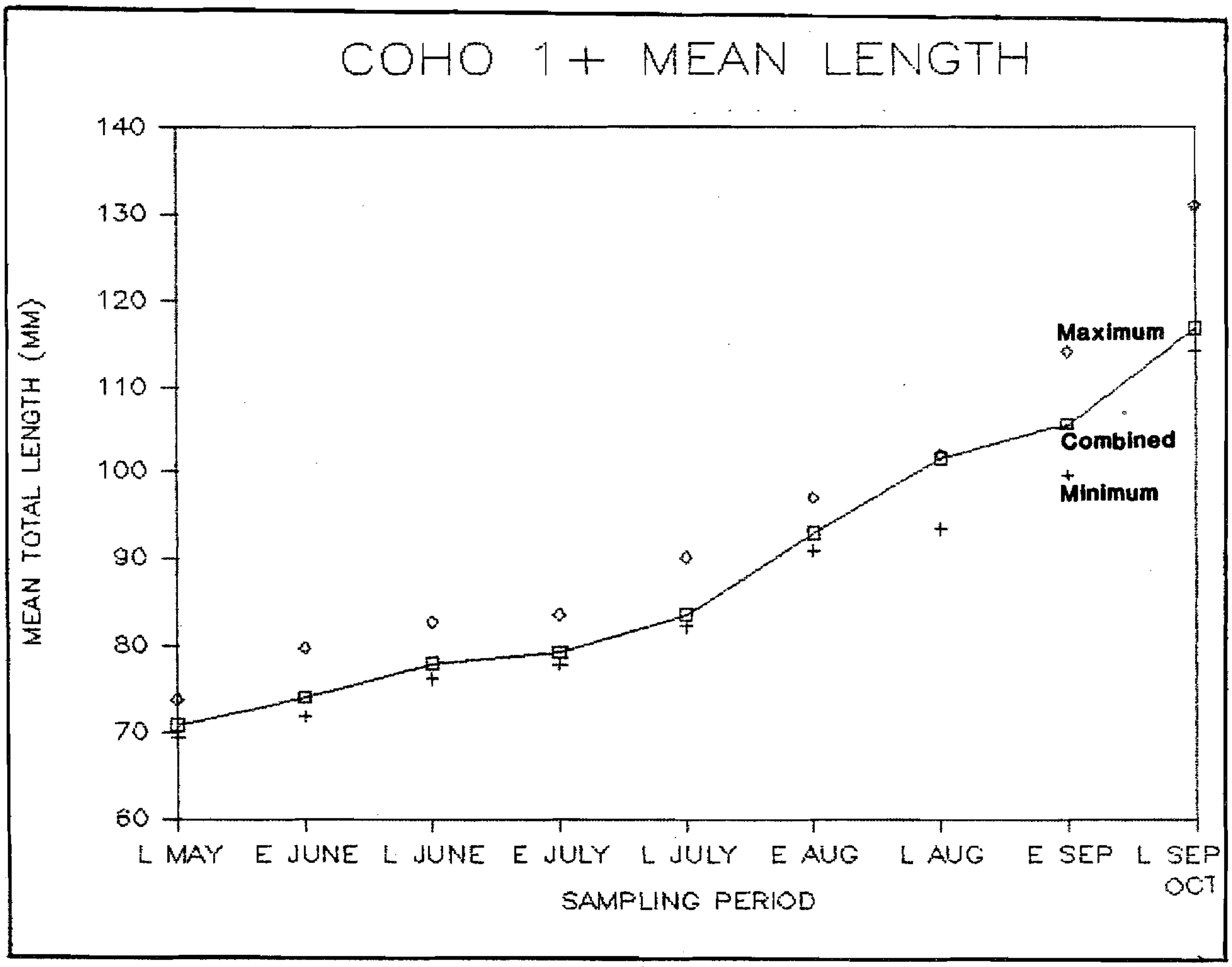


Figure 53. Coho salmon (age 1+) mean length and range of mean lengths by sampling period recorded at the Talkeetna stationary outmigrant traps during 1982, 1983, and 1984.

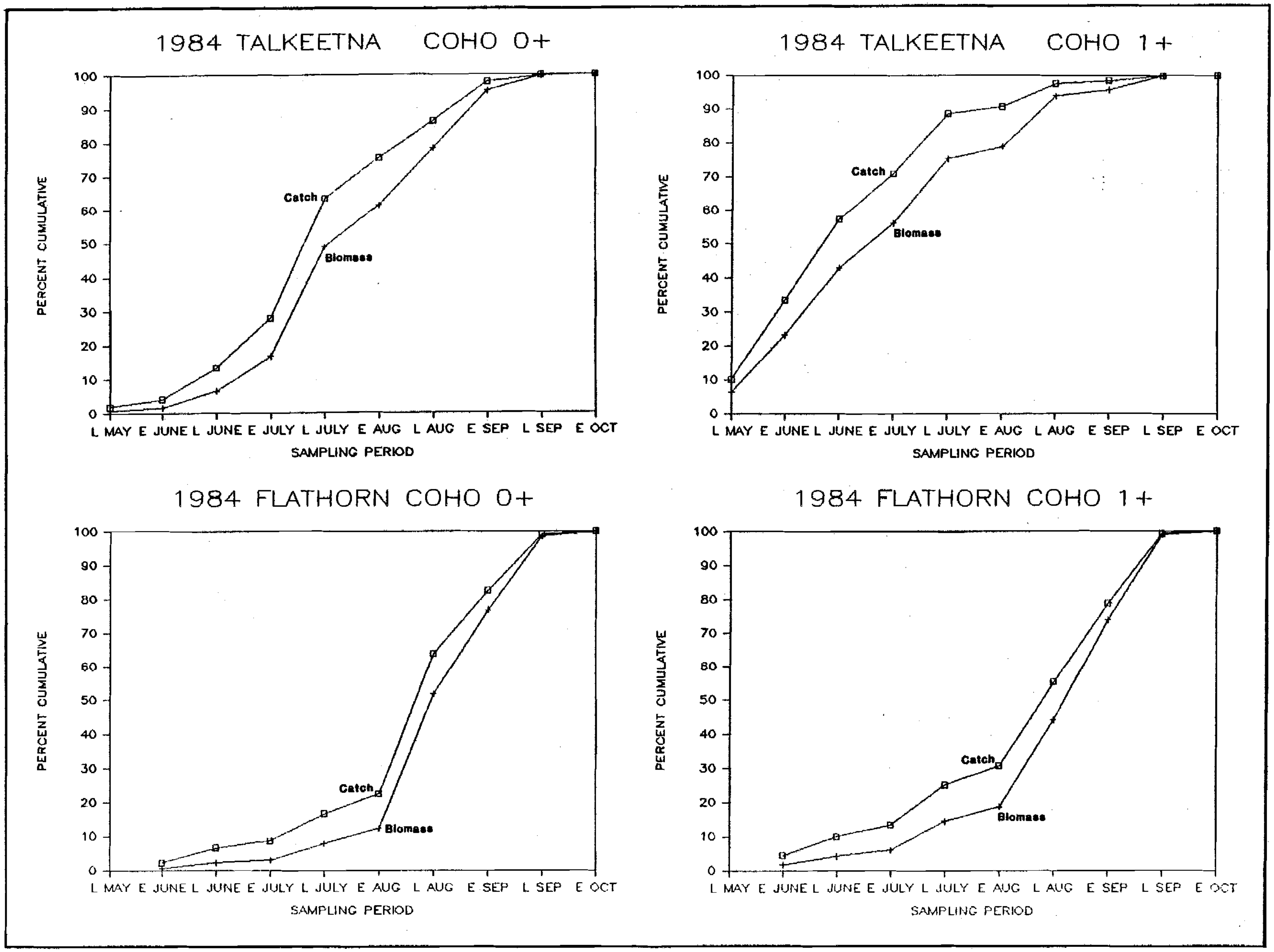


Figure 54. Coho salmon adjusted cumulative catch and biomass by age class recorded at Talkeetna and Flathorn stations, 1984.

season. The cumulative biomass curve is probably a better indicator of the value of coho rearing habitat in the reach than is the cumulative numbers curve. That is, the greater the amount of time the fry spend rearing in a particular reach of river, the greater the benefit they have gained from that particular reach. Not only are they larger, having consumed more food in this reach, they also have a higher probability of survival than smaller fry and therefore are of more value. Any management determination for these fish should consider the timing of movement of total biomass in the river rather than formulating actions only from the catch data.

4.3 Sockeye Salmon

4.3.1 Outmigration

The migration of sockeye salmon fry past Talkeetna Station during 1984 was similar to the timing recorded during 1983 (Fig. 55). Fifty percent of the total outmigration was recorded by the end of June during both seasons. Sockeye fry were steadily redistributing to areas below the sampling site from break-up through late August. Sampling of sloughs and side channels in the middle river during the cold branding study showed that sockeye fry were not actively outmigrating but were entering habitats along the margins of the river as they moved downstream. The fry probably remain at these sites until (1) they are displaced by flows or density interactions, (2) adequate food supplies are no longer available, (3) the habitats become otherwise unsuitable, or (4) the critical size is reached.

The tendency of sockeye fry to orient along the banks of the river during their downstream migration was observed at Flathorn Station where 59% of the total sockeye fry collected in the mobile trap were captured at bank transect points.

The rates of downstream movement for coded wire tagged sockeye fry during 1984 showed that fry in the middle river, after tagging, spent an average of 35 days (range from 0 to 109 days) in the middle river before migrating past Talkeetna Station.

4.3.2 Freshwater life history

Outmigrant trap data collected at Talkeetna Station during the past three seasons (1982-1984) show that a large number of sockeye fry migrate out of this reach as age 0+ fish, but scale analysis of adult sockeye collected at Curry Station showed that this age class represented only 6.4% of the returning adults during 1984 (Barrett et al. 1985). The largest percentage of returning adults were comprised of fish which had spent one winter in freshwater before going to the ocean. There fore, the majority of age 0+ fry from the middle river either rear in the lower river or have a low survival rate.

Bernard et al. (1983) analyzed scale patterns from samples of adult sockeye salmon collected from four different sites in the Susitna River watershed in an attempt to delineate the differences in scale patterns

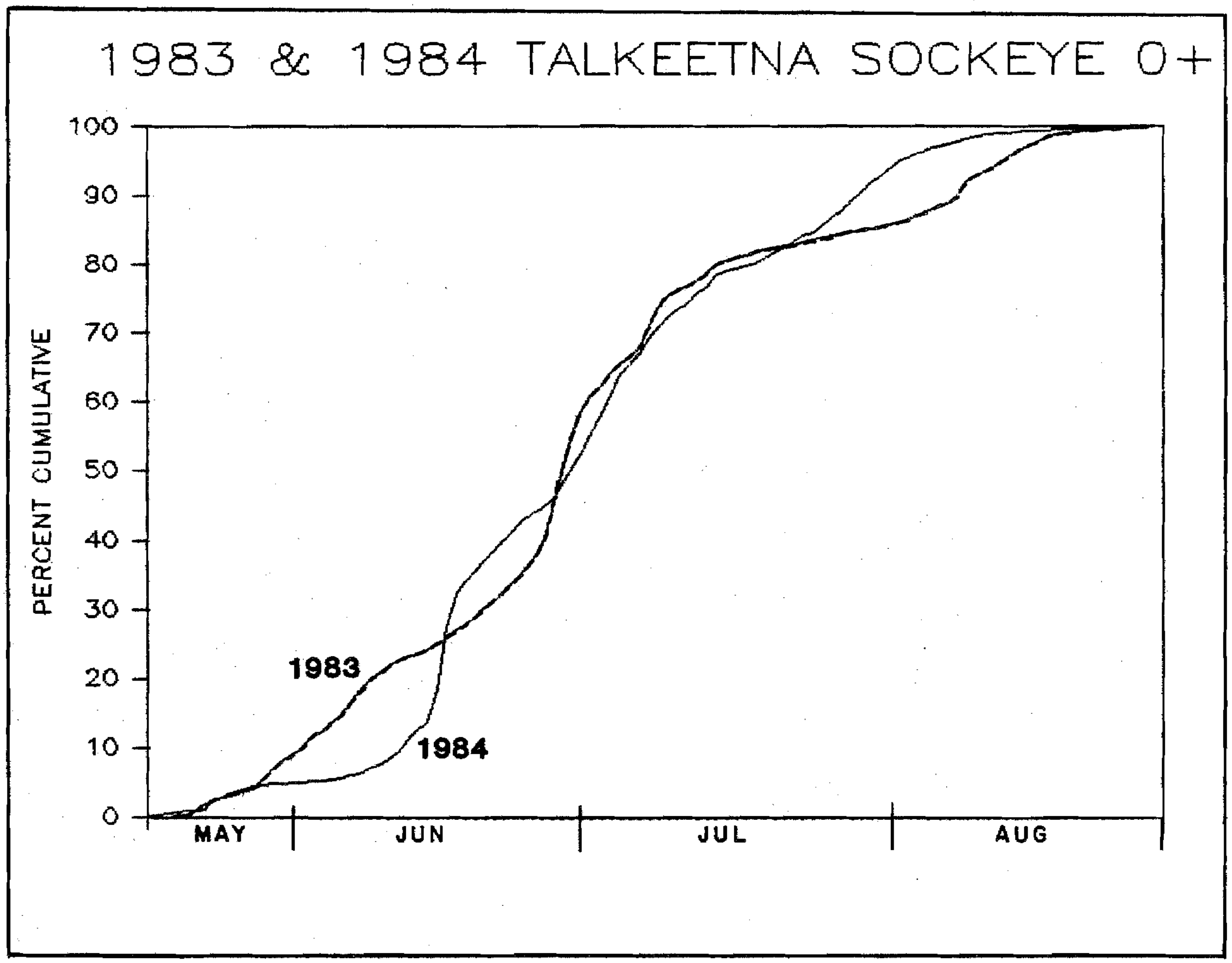


Figure 55. Sockeye salmon (age 0+) adjusted cumulative catch recorded at the Talkeetna stationary outmigrant traps, 1983 and 1984.

for the period of freshwater growth for each of the sites. Samples were collected from escapements of sockeye salmon at Curry and Talkeetna stations on the Susitna River, from the outlet of Larson Lake on the Talkeetna River, and from the Tokositna River which is a tributary to the Chulitna River. One of the results of this study was that sockeye salmon scale samples collected from the Susitna River sites could not be distinguished from those of Tokositna or Larson Lake fish.

Six hypotheses were suggested by Bernard et al. (1983) for the lack of unique differences in the scale patterns between Susitna River fish and those collected from the other sites. In general, these hypotheses can be placed into two groups: 1) The Susitna River fish are a unique stock but the fry rear in environments similar to those found in Larson Lake or the Tokositna River, or 2) the sockeye salmon spawning in the Susitna River are strays from either the Talkeetna or Chulitna watersheds and their fry move into these watersheds to rear or are displaced downstream and enter the ocean as age 0+ fish. If these fish enter the ocean as age 0+ fish, scale analysis of returning adults indicates that survival of these fish is very low.

However, the study conducted by Bernard et al. was based on the assumption that sockeye fry did not rear in the middle Susitna River. Data collected at the Talkeetna Station outmigrant traps during the past three years have shown that a significant amount of sockeye rearing occurs in this reach. The Susitna River samples collected by Bernard et al. were taken at the fishwheel sites rather than at the spawning grounds. Barrett (1984) has pointed out that a high percentage of these fish (30% estimated in 1983) are milling fish which eventually spawned in areas other than the middle Susitna River. Comparisons of the scales of fish collected at the spawning grounds in these rivers may provide more accurate differentiation of Susitna River fish from those observed in the Talkeetna and Chulitna rivers. Also, Bernard et al. analyzed scales from only 1.3 age fish (European formula); Barrett et al. (1984) have shown that multiple age classes are present in the middle Susitna River escapements. Juvenile sockeye salmon outmigrating from Larson Lake predominantly spend two winters in freshwater before outmigrating from the lake as smolts (Marcuson 1985).

Although it is possible that sockeye salmon which spawn in the middle reach of the Susitna River are strays from the stocks originating from the Talkeetna and Chulitna rivers, it is more likely that the Susitna sockeye are a separate and viable stock. However, the amount of rearing habitat in this reach is limited. The age 0+ fish which outmigrate from the middle reach of the Susitna probably imprint to their natal areas in the early stages after hatching and then later distribute to suitable habitats throughout the expanse of the lower river to overwinter. These fish then enter the ocean during their second year of life and finally return to their natal areas as adults to spawn. Also, a limited amount of overwintering by sockeye fry in the middle reach does occur, as shown by the capture of age 1+ fry at Talkeetna Station.

More definitive information on the viability of middle Susitna River sockeye may be obtained through the continued monitoring of returning adults at the fishwheel sites and during spawning ground surveys to collect returning fish which were marked with coded wire tags as fry.

Juvenile sockeye salmon life histories in the middle Susitna River can be grouped into three categories. The first group includes those fish which spend their entire freshwater period rearing in the middle river, overwintering in this reach and then migrating to the ocean during the spring of their second year (age 1+). The second group includes those fish which rear for a portion (one to four months) of their first summer in the middle river and then migrate to areas below the Chulitna River confluence to overwinter and then enter the ocean during the spring of their second year. The third group of juvenile sockeye spend a portion of their first summer rearing in the middle river and then begin a downstream migration, eventually entering the marine environment during their first summer or fall as age 0+ fish.

Currently, it is not known what contribution each group provides to the total outmigration of juvenile sockeye from the middle Susitna River. Outmigrant trap data collected at Flathorn Station during 1984 collected a large number of age 0+ sockeye; most of these fish were probably destined for the ocean as 0+ fish.

Although trap catches of age 1+ sockeye at Talkeetna Station have been low (only 19 fish during 1984), it is possible that this age class (group 1) migrates out of the middle river prior to the initiation of spring sampling or that they differ from their age 0+ counterparts in that they migrate further from shore and are not intercepted by the bank traps in proportion to their relative abundance. Also, the bank traps are less effective at capturing these larger fish (Roth et al. 1984).

4.3.3 Estimate of population and survival

The estimated 1983-1984 egg-to-emergent fry survival rate of 17%, based on an estimated 299,000 sockeye fry produced during 1984 from the approximately 1,900 adults which migrated past Curry Station in 1983, was lower than the 1982-1983 estimate of 42%, based on the 1,300 adult sockeye past Curry Station during 1983 which produced an estimated 575,000 fry. The substantial differences between the estimates of survival in 1983 and 1984 are due in part to the data used in the calculations. During both years, survival rates were calculated by dividing the number of fry produced by the estimated number of eggs carried by adults past Curry Station during the previous season. Barrett et al. (1984) pointed out that the estimates provided at Curry Station represent only the fish which passed this site but do not necessarily reflect the number of fish which actually spawned in the middle river reach. As sockeye salmon in this reach are almost strictly slough spawners, more reasonable estimates were calculated by Barrett et al. (1984) by comparing slough escapement counts to observation life data to estimate the total slough escapement in the middle river. During 1983, this comparison provided an estimate that 1,060 adult sockeye had spawned in sloughs in the middle river. The stream life data were then used to provide comparable estimates for 1982 showing approximately 1,500 sockeye had spawned in the sloughs that year. These data were then used to recalculate the sockeye egg-to-outmigrant survival rates. A survival rate of 22% was estimated for 1983-1984 and a rate of 35% was calculated for 1982-1983.

4.3.4 Growth

The weekly growth rate for sockeye fry which were coded wire tagged in 1983 and 1984 (Fig. 56) most accurately represent the growth rates for sockeye salmon fry in the middle river because the dates of release and recovery and the mean lengths for each period were known.

These fry grew approximately three millimeters each week until they reached a critical size and then the growth rates slowed (Fig. 56). Schmidt (1984) postulated that the cessation of sockeye growth after reaching a certain size was associated with evolved behavioral patterns and morphological changes. Schmidt suggested that the sockeye fry were able to rear in the middle river habitats for part of the summer but began a downstream migration in search of plankton rich environments after reaching a critical size. The small number of habitats which provide this type of environment in areas associated with the Susitna River is a major factor in controlling the production of sockeye in the middle river.

A comparison of the length data collected at Talkeetna Station during 1982, 1983, and 1984 and during the previous winter studies above Talkeetna in 1981 and 1982 show that Susitna River sockeye average approximately 32 mm total length at emergence, 35 mm by early June, and have increased to approximately 50 mm by late July (Fig. 57). From late July through August, no significant growth was observed for sockeye fry collected at Talkeetna Station, indicating that the critical size postulated by Schmidt (1984) may be 50 to 55 mm in the middle river. The apparent growth of sockeye fry after late August (Fig. 57) is attributed to the collection of fish which had continued rearing in the small number of sites in the middle river which provide the necessary food and habitat requirements. These fish were probably forced to migrate out of these areas as water levels and available habitat decreased. The number of sockeye collected after late August represent less than 2% of the total outmigration of age 0+ fish from this reach.

A comparison of the downstream redistribution of sockeye salmon in the Susitna River by age class during 1984 as the percent cumulative of the total catches recorded at Talkeetna and Flathorn stations compared to the calculated percent cumulative biomass moving past these sites, indicated that the redistribution by weight of sockeye in the Susitna River was up to two weeks later than the redistribution observed when comparing only total numbers of fish (Fig. 58).

Age 1+ sockeye salmon collected during 1984 averaged approximately 75 mm. This is approximately 10 mm longer than the average length of sockeye fry collected at the end of the open-water season indicating that the fry are growing through the winter and early spring prior to outmigrating as smolts. The average length of age 1+ sockeye migrating out of the Susitna River was approximately 10 mm smaller than the same

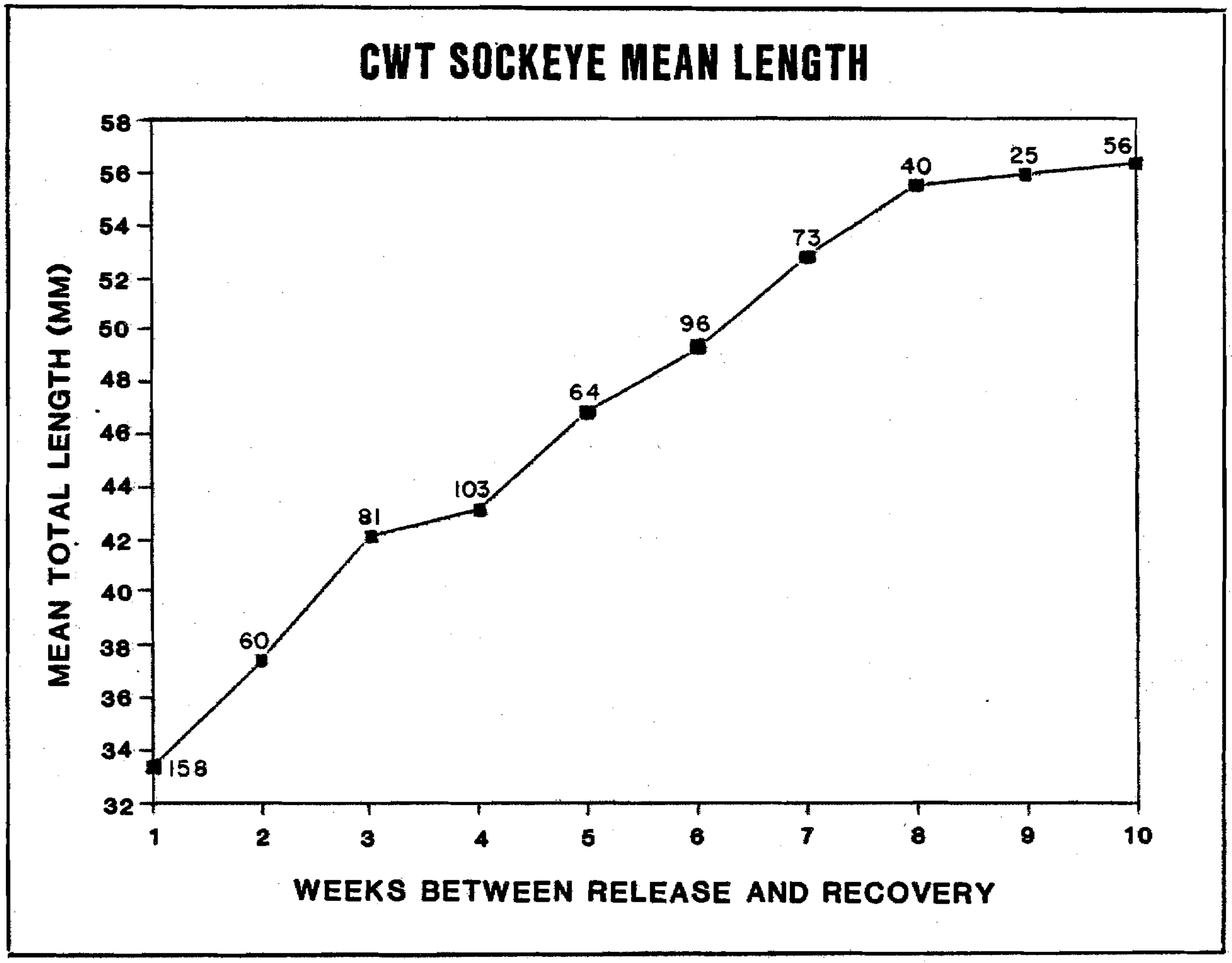


Figure 56. Mean length of coded wire tagged sockeye salmon fry at recovery sites in the middle reach of the Susitna River by week, 1984. Number of fish shown by data points.

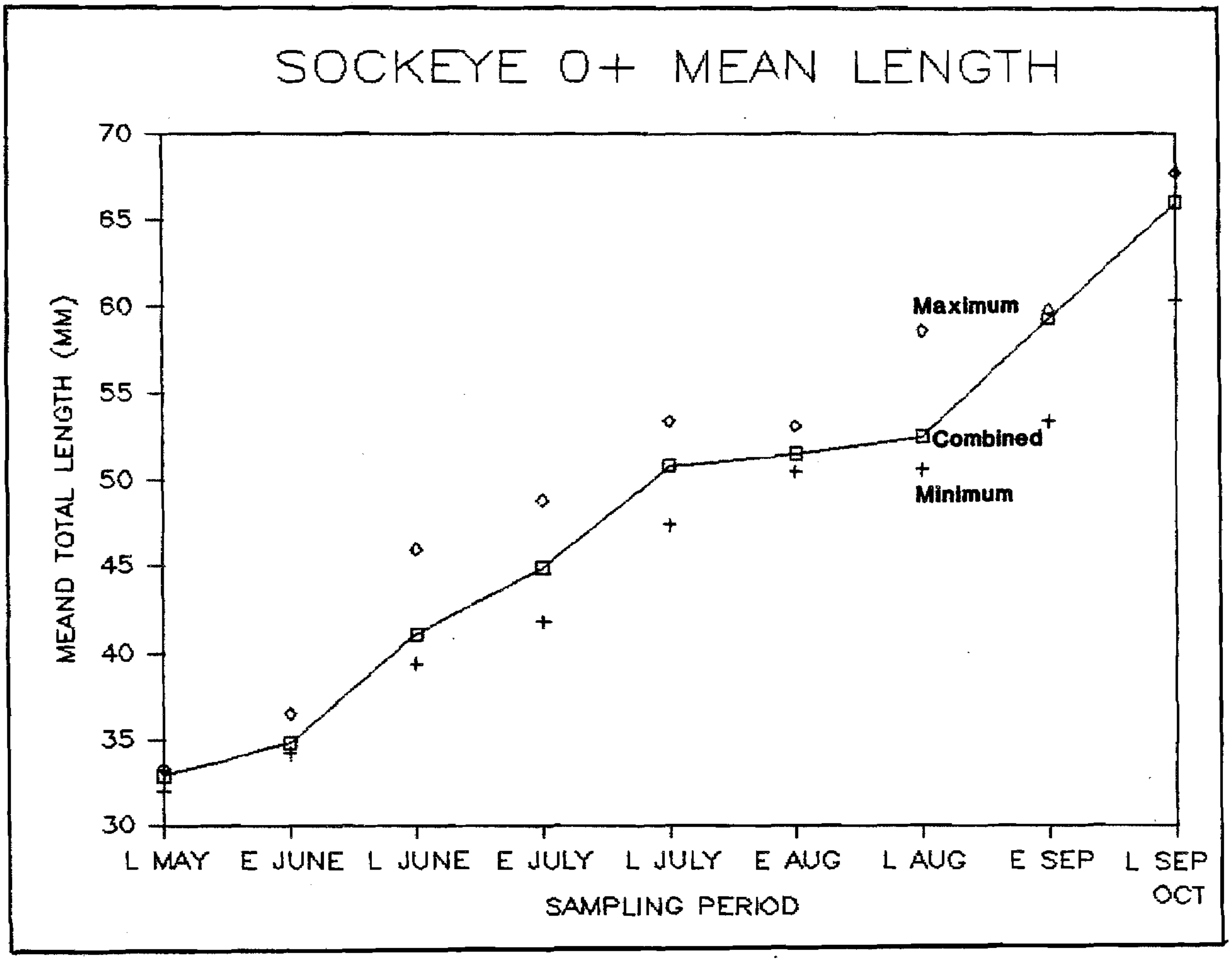


Figure 57. Sockeye salmon (age 0+) mean length and range of mean lengths by sampling period recorded at the Talkeetna stationary outmigrant traps during 1982, 1983, and 1984.

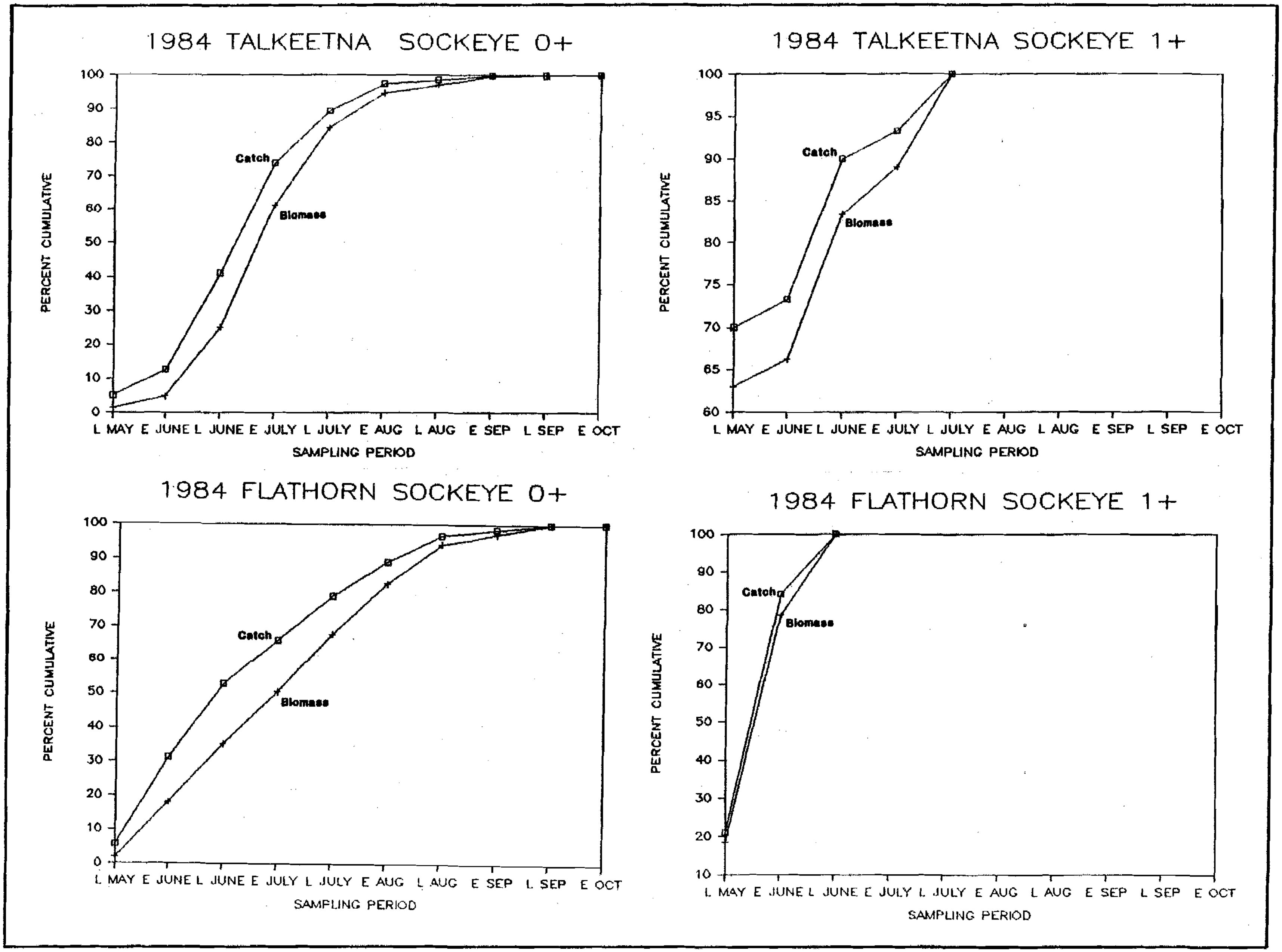


Figure 58. Sockeye salmon adjusted cumulative catch and biomass by age class recorded at Talkeetna and Flathorn stations, 1984.

age fish outmigrating during 1984 from Larson Lake, a major spawning site in the Talkeetna River (Marcuson 1985).

4.4 Chum Salmon

4.4.1 Outmigration

The migration of chum salmon fry past Talkeetna Station during 1984 was similar to the timing recorded during 1983 (Fig. 59). Fifty percent of the total outmigration past this site had occurred by mid June and over 95% of the chum fry had migrated out of the middle river by mid July. At Flathorn Station, the peak chum fry outmigration also occurred in mid June during 1984.

4.4.2 Freshwater life history

Chum salmon fry spend from one to eight weeks in the middle Susitna River before outmigrating from the reach. A portion of the population of chum fry probably begins outmigration shortly after emergence whereas other fry stay in the river to rear for a few weeks before outmigrating. It is not possible to determine the percentage which each group provides because of the difficulty in sampling outmigrant fishes prior to and during breakup, a time when many newly emerged chum fry may outmigrate.

4.4.3 Estimates of population and survival

The estimated 1982-1984 egg-to-outmigrant fry survival rate of 16%, based on an estimated 2,039,000 chum salmon fry produced during 1984 from the approximately 21,100 adults past Curry Station in 1983, was similar to the estimated 1982-1983 rate of 14%, based on the 17,600 adult chum which passed Curry Station during 1982 which produced an estimated 3,322,000 fry.

The calculation of survival rates is based upon the estimated number of parent spawners which is difficult to obtain because of the extent of tributary spawning by chum salmon. Also a substantial percentage of chum salmon passing Curry Station are milling fish which eventually spawn below this site, and although estimates have been provided for 1982 and 1983 (Barrett 1984), these percentages are, at best, only indicators of the amount of chum salmon milling occurring. As these estimates have a large influence on the calculated rates of survival, the rates presented for 1983 and 1984 should be used to compare differences between years rather than absolute values of middle river chum salmon survival.

4.4.4 Growth

Many chum fry from the middle reach move downstream at lengths not much longer than their emergence length (less than 35 mm), but there are also many that spend several weeks in freshwater and attain lengths of over 60 mm, an increase of more than 20 mm. The mean length by one-week periods of recovery after release for coded wire tagged chum fry which were tagged and recaptured during 1983 and 1984 (Fig. 60) most

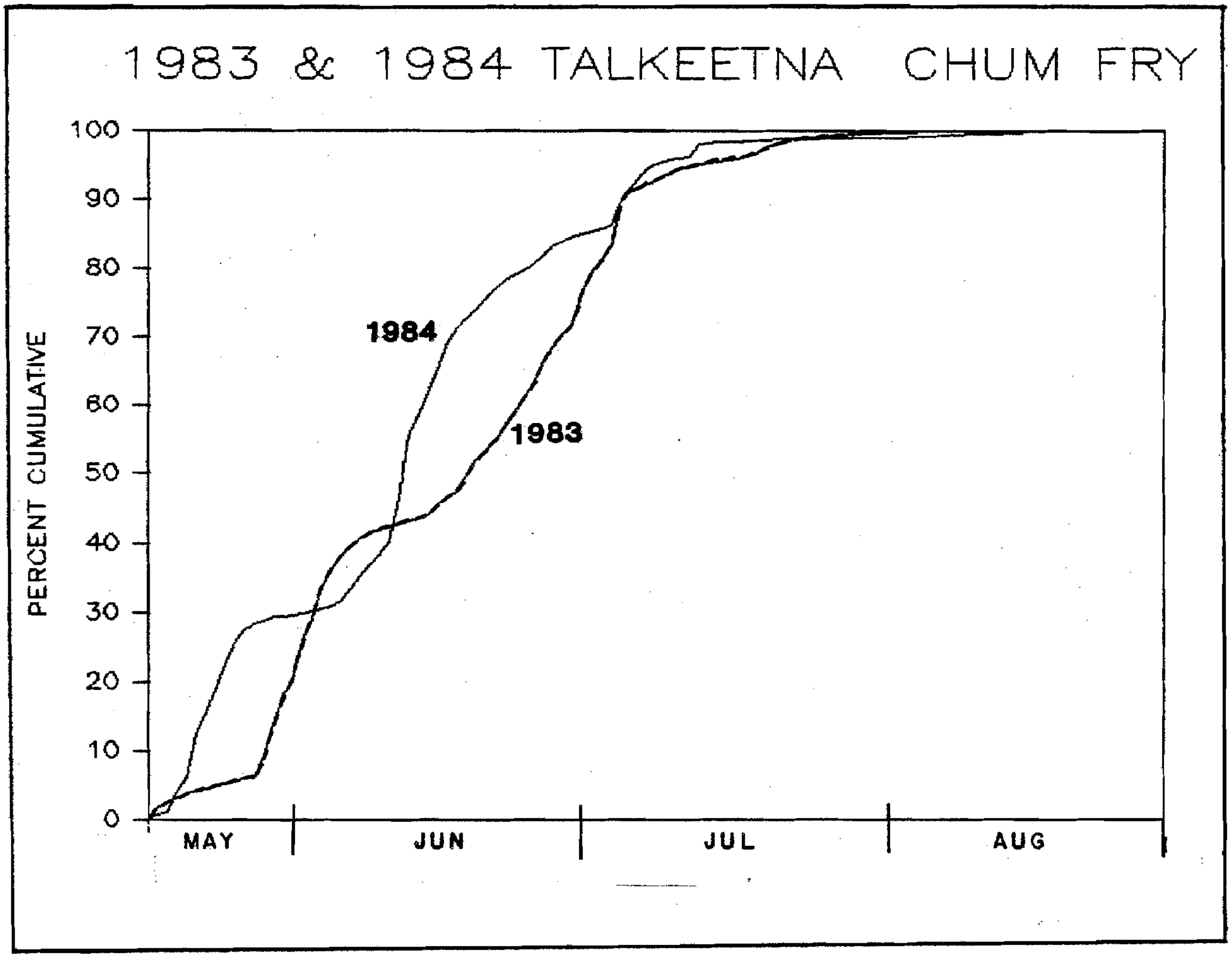


Figure 59. Chum salmon fry adjusted cumulative catch recorded at the Talkeetna stationary outmigrant traps, 1983 and 1984.

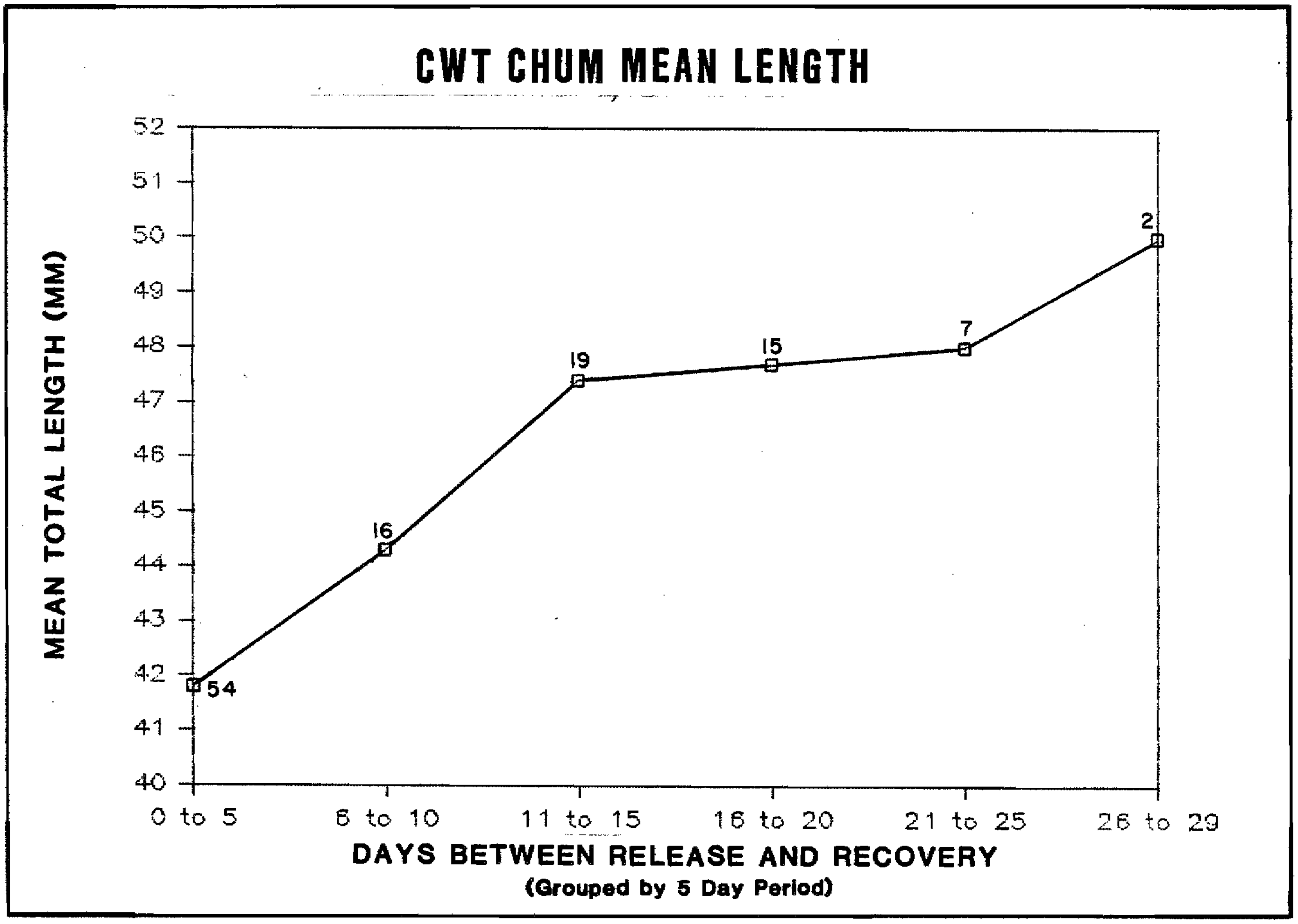


Figure 60. Mean length of coded wire tagged chum salmon fry at recovery sites in the middle reach of the Susitna River by 5 day period, 1984. Number of fish shown by data points.

accurately represent the growth rates of chum fry in the middle river because the dates of release and recovery and the lengths for the fish for each period were known. The 15% increase in length by fish captured more than 20 days after release (mean length significantly different from release length at 95% confidence level) would correspond to an even larger percentage increase in weight. The chum fry greater than 50 mm in length collected during the three years of this program had a noticeably greater girth than shorter fry. Similarly, chum fry in the Tokachi River of Japan grew 1.0 to 1.3 times in length and 1.0 to 3.1 times in weight during April and May (Kaeriyama et al. 1978).

These data indicate that the chum fry in the middle river are actively rearing after emergence. Chum fry rearing was also shown from the analysis of stomach samples from tagged fish recovered at Talkeetna Station during 1983. These fish had been eating various life stages of mayflies, stoneflies, blackflies, midges, and other dipterans.

4.5 Pink Salmon

4.5.1 Outmigration

The rates of downstream migration of pink salmon fry past Talkeetna Station for 1983 and 1984 were very similar between the two years but the timing was approximately two weeks later in 1984 than in 1983 (Fig. 61). Differences in spawning times, winter temperatures, and spring breakup account for the differences in timing between the two years.

The low catches of juvenile pink salmon recorded at Talkeetna Station during the past three seasons is due to the pattern and timing of outmigration. Pink salmon fry outmigrate shortly after emergence and most of the fry probably have migrated past the traps prior to the initiation of sampling. Those fish which are still in the middle river after breakup appear to outmigrate in association with center channels and high velocities.

4.5.2 Freshwater life history

Pink salmon fry in the Susitna River outmigrate to the ocean shortly after emergence during a relatively short (in comparison to the other species) timing window whose boundaries are determined by the timing of spawning the previous season, incubation temperature, and the level of discharge. The pink fry collected during 1984 averaged approximately 35 mm which is similar to their mean length at emergence. A few pink fry which ranged in length from 40 to 50 mm were collected, indicating that a small percentage of fry may be feeding for a short period of time in freshwater before outmigrating to the ocean.

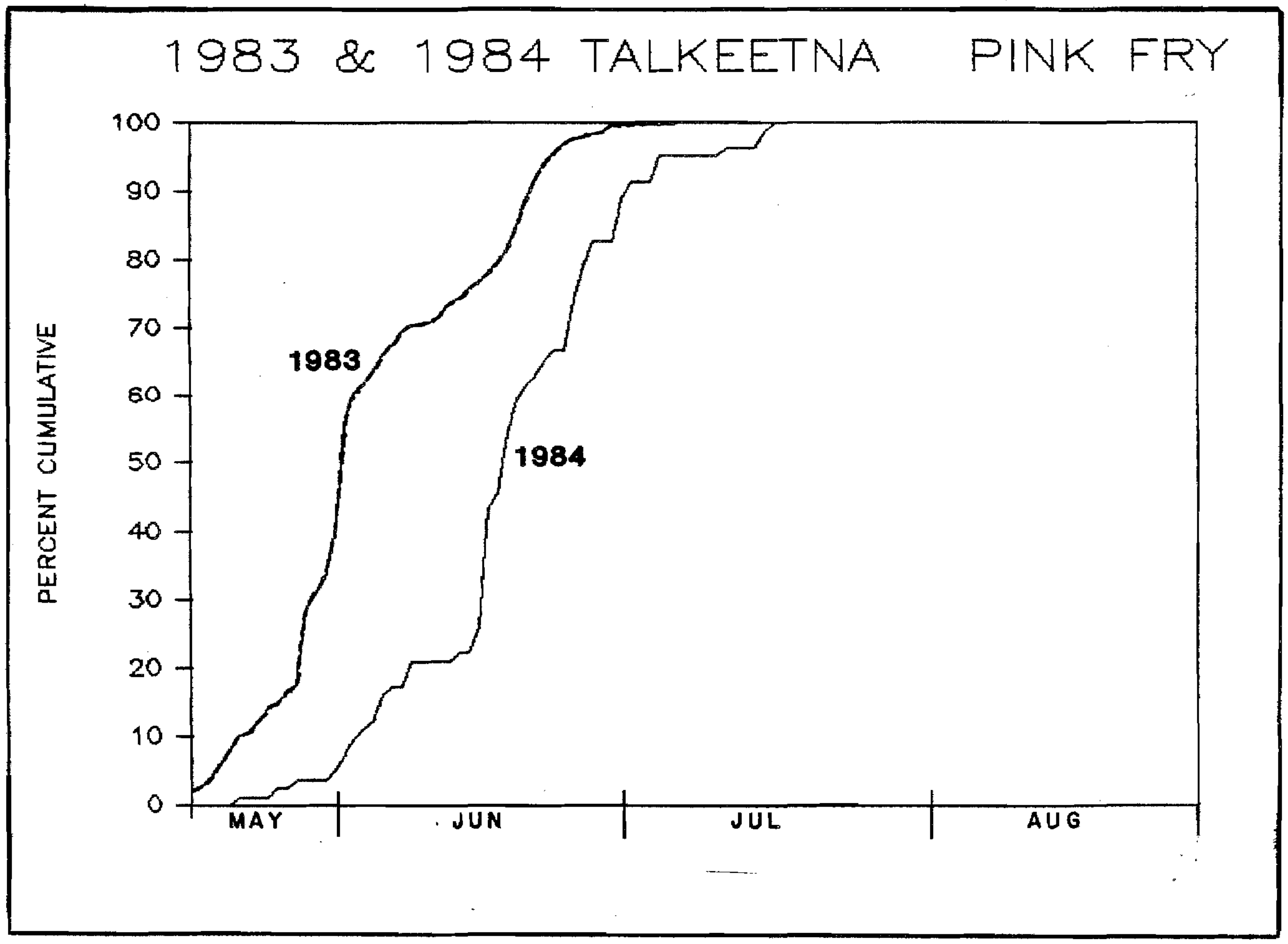


Figure 61. Pink salmon fry adjusted cumulative catch recorded at the Talkeetna stationary outmigrant traps, 1983 and 1984.

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APPENDIX A

JUVENILE SALMON CATCH AND LENGTH DATA, 1984

Appendix Table A-1. Weir catches of juvenile chinook and coho salmon on the Deshka River, May 10 through September 19, 1984.

Date	Tributary River Mile	Hours Fished	Chinook Daily Catch	Chinook Catch Per Hour	Coho Daily Catch	Coho Catch Per Hour
May 10	2.0	21.5	2	0.1	0	0.0
12	2.0	15.0	9	0.6	1	0.1
13	2.0	21.0	3	0.1	0	0.0
27	5.0	12.0	50	4.2	1	0.1
28	5.0	12.5	7	0.6	0	0.0
29	4.5	12.5	3	0.2	0	0.0
31	5.0	12.0	4	0.3	0	0.0
June 1	5.0	12.5	21	1.7	0	0.0
21	5.0	11.5	1	0.1	0	0.0
22	5.0	21.5	3	0.1	0	0.0
July 11	2.5	14.5	209	14.4	5	0.3
12	2.5	24.0	144	6.0	2	0.1
13	2.5	24.0	268	11.2	3	0.1
14	2.5	23.5	186	7.9	4	0.2
15	2.5	24.0	27	1.1	0	0.0
16	2.5	24.0	130	5.4	1	0.0
25	2.5	15.0	318	21.2	21	1.4
26	2.5	24.0	149	6.2	8	0.3
31	2.5	20.0	168	8.4	4	0.2
August 13	2.5	14.0	45	3.2	15	1.1
14	2.5	23.0	4	0.2	2	0.1
15	2.5	23.0	5	0.2	5	0.2
16	2.5	23.0	27	1.2	12	0.5
31	2.0	21.5	5	0.2	22	1.0
September 11	1.5	13.5	1	0.1	0	0.0
12	1.5	23.0	6	0.3	0	0.0
13	1.5	23.0	8	0.3	1	0.0
14	1.5	23.0	2	0.1	0	0.0
15	2.5	18.0	1	0.1	2	0.1
16	2.5	24.0	0	0.0	6	0.3
17	2.5	24.0	1	0.0	0	0.0
18	2.5	23.0	1	0.0	2	0.1
Season Totals		621.0	1,808	2.9	117	0.2

Appendix Table A-2. Results of incidental minnow trapping in the Deshka River, 1984.

Date	Tributary River Mile	Hours Fished	Number of Traps	Chinook Daily Catch	Chinook Catch Per Trap	Coho Daily Catch	Coho Catch Per Trap
June 21	5.5	16	6	56	9.3	14	2.3
August 28	2.5	9	6	15	2.5	48	8.0
29	2.7	7	7	23	3.3	50	7.1
September 17	5.5	24	4	20	5.0	4	1.0
October 10	2.2	24	2	1	0.5	2	1.0
10	6.0	24	4	30	7.5	4	1.0
11	5.0	27	7	23	3.3	21	3.0
13	2.0 to 6.0	54	5	2	0.4	10	2.0
14	2.0 to 6.0	28	5	1	0.2	4	0.8
15	4.0	24	5	41	8.2	9	1.8
Season Totals			51	212	4.2	166	3.3

Appendix Table A-3. Mean length and range of lengths for age 0+ chinook salmon by sampling period in the lower reach of the Susitna River, 1984.

Sampling Period	Flathorn Station			Deshka River			Lower Susitna JAHS Sites[a]		
	n	Mean Length	Range of Lengths	n	Mean Length	Range of Lengths	n	Mean Length	Range of Lengths
May	0	-	-	77	42.7	36-49	b	-	-
June 1-15	24	56.6	40-67	21	42.4	40-46	74	48.5	34-63
June 16-30	374	58.5	39-74	56	55.7	46-69	63	52.0	36-70
July 1-15	357	62.0	40-84	236	66.8	52-83	84	54.5	39-74
July 16-31	436	64.3	43-88	201	69.7	52-93	171	58.1	39-80
August 1-15	189	66.6	47-89	53	74.4	60-91	330	58.9	40-82
August 16-31	193	72.7	46-94	65	71.7	55-89	238	61.5	42-94
September 1-15	8	77.3	68-84	15	77.9	69-88	52	66.8	52-95
September 16 - October 15	10	78.7	68-95	102	76.0	68-85	53	73.2	51-92

[a] Includes all mainstem, slough and side channel sites sampled during the JAHS study in the Susitna River between Cook Inlet and the Chulitna River confluence.

[b] Not sampled.

Appendix Table A-4. Mean length and range of lengths for age 0+ chinook salmon by sampling period in the Talkeetna River and the middle reach of the Susitna River, 1984.

Sampling Period	Talkeetna River			Talkeetna Station			Middle Susitna Marking Sites[a]			Indian River		
	n	Mean Length	Range of Lengths	n	Mean Length	Range of Lenghts	n	Mean Length	Range of Lengths	n	Mean Length	Range of Lengths
May	b	-	-	2	55.5	53-58	60	40.8	35-45	b	-	-
June 1-15	0	-	-	54	48.6	36-66	b	-	-	b	-	-
June 16-30	26	52.2	43-64	475	53.0	37-70	b	-	-	b	-	-
July 1-15	159	56.0	44-70	538	56.2	38-75	100	47.8	38-67	50	48.9	42-64
July 16-31	155	56.1	40-74	1131	55.5	37-80	50	52.2	42-69	50	54.9	47-67
August 1-15	257	60.7	44-84	748	57.9	40-90	50	52.4	40-77	100	58.8	47-90
August 16-31	114	65.2	51-84	612	59.5	39-95	100	56.1	43-72	100	61.1	49-80
September 1-15	0	-	-	119	62.7	45-91	100	57.6	47-88	100	63.8	47-90
September 16 - October 15	b	-	-	13	60.8	51-90	200	61.0	45-90	300	65.5	50-89

[a] Includes all mainstem, slough, and side channel sites sampled during the coded wire tagging and cold branding studies in the Susitna River between the Chulitna River confluence and Devil Canyon.

[b] Not sampled.

Appendix Table A-5. Mean length and range of lengths for age 1+ chinook salmon by sampling period in the Susitna River, 1984.

Sampling Period	Flathorn Station			Talkeetna Stations			Flathorn & Talkeetna Stations Combined		
	n	Mean Length	Range of Lengths	n	Mean Length	Range of Lengths	n	Mean Length	Range of Lengths
May	11	79.7	67-105	209	77.9	61-101	220	78.0	61-105
Early June	104	89.1	70-122	126	89.6	71-112	230	89.7	70-122
Late June	101	85.2	75-122	335	88.4	71-107	436	87.7	71-122
Early July	17	94.1	86-113	218	85.7	76-117	235	86.3	76-117
Late July	4	97.5	95-102	96	87.7	81-115	100	88.1	81-115
Early August	8	98.6	90-113	1	91.0	91	9	97.8	90-113
Late August	2	96.0	95-97	0	-	-	2	96.0	95-97

Appendix Table A-6. Mean length and range of lengths for age 0+ coho salmon by sampling period in the lower reach of the Susitna River, 1984.

Sampling Period	Flathorn Station			Deshka River			Lower Susitna JAHS Sites[a]		
	n	Mean Length	Range of Lengths	n	Mean Length	Range of Lengths	n	Mean Length	Range of Lengths
May	0	-	-	0	-	-	b	-	-
June 1-15	10	42.7	32-60	0	-	-	18	40.9	33-50
June 16-30	19	48.7	32-64	0	-	-	9	46.2	34-61
July 1-15	11	49.3	36-65	0	-	-	26	50.7	35-65
July 16-31	38	58.6	44-73	21	57.3	47-65	33	50.2	37-65
August 1-15	30	62.1	49-79	19	63.6	53-72	45	49.6	41-68
August 16-31	181	66.8	40-89	59	71.2	51-89	71	59.1	40-85
September 1-15	84	75.0	55-94	2	68.0	67-69	59	62.2	49-86
September 16 - October 15	67	75.1	57-94	29	77.0	60-95	105	66.7	49-95

[a] Includes all mainstem, slough and side channel sites sampled during the JAHS study in the Susitna River between Cook Inlet and the Chulitna River confluence.

[b] Not sampled.

Appendix Table A-7. Mean lengths, and range of lengths for age 0+ coho salmon by sampling period in the middle reach of the Susitna River, 1984.

Sampling Period	Talkeetna Station			Middle Susitna Marking Sites[a]			Indian River		
	n	Mean Length	Range of Lengths	n	Mean Length	Range of Lengths	n	Mean Length	Range of Lengths
May	35	39.7	35-46	b	-	-	b	-	-
June 1-15	40	39.6	30-51	b	-	-	b	-	-
June 16-30	156	43.9	31-58	b	-	-	b	-	-
July 1-15	242	47.8	32-63	0	-	-	62	38.0	34-51
July 16-31	439	51.8	33-69	0	-	-	10	44.1	42-49
August 1-15	221	54.1	41-74	0	-	-	80	48.0	39-58
August 16-31	198	61.5	42-80	38	50.8	39-62	46	49.0	42-61
September 1-15	212	60.5	42-85	41	56.8	40-70	90	50.9	44-64
September 16 - October 15	39	69.1	51-90	5	59.4	48-76	166	55.1	44-73

[a] Includes all mainstem, slough, and side channel sites sampled during the coded wire tagging and cold branding studies in the Susitna River between the Chulitna River confluence and Devil Canyon.

[b] Not sampled.

Appendix Table A-8. Mean length and range of lengths for age 1+ coho salmon by sampling period in the lower reach of the Susitna River, 1984.

Sampling Period	Flathorn Station			Deshka River			Lower Susitna JAHS Sites[a]		
	n	Mean Length	Range of Lengths	n	Mean Length	Range of Lengths	n	Mean Length	Range of Lengths
May	0	-	-	5	69.8	58-89	b	-	-
June 1-15	7	87.4	62-110	0	-	-	1	70	70
June 16-30	15	78.1	65-96	14	78.6	58-108	11	97.4	62-111
July 1-15	12	84.9	70-111	13	79.0	62-95	6	81.3	72-101
July 16-31	39	89.8	75-120	6	101.7	65-118	4	85.3	73-92
August 1-15	16	92.8	80-112	2	97.5	83-112	4	102.0	98-109
August 16-31	68	103.4	91-122	68	98.2	90-123	11	105.2	90-123
September 1-15	68	109.4	95-129	1	118.0	118	3	105.3	104-108
September 16 - October 15	53	112.9	95-133	31	111.8	92-134	4	112.0	99-110

[a] Includes all mainstem, slough and side channel sites sampled during the JAHS study in the Susitna River between Cook Inlet and the Chulitna River confluence.

[b] Not sampled.

Appendix Table A-9. Mean lengths, and range of lengths for age 1+ coho salmon by sampling period in the middle reach of the Susitna River, 1984.

Sampling Period	Talkeetna Station			Middle Susitna Marking Sites[a]			Indian River		
	n	Mean Length	Range of Lengths	n	Mean Length	Range of Lengths	n	Mean Length	Range of Lengths
May	139	69.4	51-105	18	63.0	52-85	b	-	-
June 1-15	332	71.8	52-102	b	-	-	b	-	-
June 16-30	340	76.1	59-115	b	-	-	b	-	-
July 1-15	192	77.8	64-118	0	-	-	2	67.0	64-70
July 16-31	252	82.2	70-125	0	-	-	7	85.7	79-90
August 1-15	28	93.5	79-120	0	-	-	17	86.1	74-99
August 16-31	96	101.9	81-131	2	103.5	102-105	0	-	-
September 1-15	14	99.6	86-127	10	93.2	83-101	0	-	-
September 16 - October 15	21	114.4	93-135	4	93.5	90-99	0	-	-

[a] Includes all mainstem, slough, and side channel sites sampled during the coded wire tagging and cold branding studies in the Susitna River between the Chulitna River confluence and Devil Canyon.

[b] Not sampled.

Appendix Table A-10. Mean length and range of lengths for age 2+ coho salmon by sampling period on the Susitna River between Cook Inlet and Devil Canyon, 1984.

Sampling Period	n	Mean Length	Range of Lengths
May	5	133.2	120 - 160
E. June	7	135.6	114 - 157
L. June	1	136.0	136
E. July	2	130.0	130
L. July	0	-	-
E. August	1	126.0	126
L. August	13	138.0	125 - 176
E. September	2	134.0	134
L. September - E. October	13	141.0	135 - 150
All Season	44	137.1	114 - 176

Appendix Table A-11. Daily catches of outmigrant chum and sockeye salmon fry in a fyke net located at the mouth of Slough 21, May 23 to June 12, 1984.

Check Date	Sockeye	Chum	Check Date	Sockeye	Chum
May 23	1,005	74	June 3	155	8
24	694	83	4	140	8
25	810	60	5	164	10
26	2,150	355	6	419	12
27	1,479	399	7	1,024	82
28	400	83	8	570	85
29	1,777	198	9	761	59
30	253	89	10	31	34
June 1	156	44	11	23	8
2	344	33	12	29	8
			13[a]	2	1

[a] Slough breached allowing fish passage around net. Net pulled.

Appendix Table A-12. Mean length and range of lengths for age 0+ sockeye salmon by sampling period on the Susitna River between Cook Inlet and Devil Canyon, 1984.

Sampling Period	Flathorn Station			Lower Susitna[a] JAHS Sites			Talkeetna Station			Middle Susitna[b] Marking Sites		
	n	Mean Length	Range of Lengths	n	Mean Length	Range of Lengths	n	Mean Length	Range of Lengths	n	Mean Length	Range of Lengths
May	134	32.8	27-45	c	-	-	213	32.0	26-41	100	30.5	25-37
June 1-15	284	40.4	29-60	15	36.0	26-52	305	36.5	28-60	100	35.2	29-49
June 16-30	343	42.7	25-70	80	40.1	26-66	509	41.9	25-71	50	34.2	28-44
July 1-15	313	49.2	25-80	20	43.6	30-65	570	48.8	30-75	0	-	-
July 16-31	337	52.2	30-85	54	43.5	28-76	748	53.4	35-87	8	53.1	47-68
August 1-15	239	53.0	29-85	38	47.9	30-76	547	51.8	33-88	49	51.4	43-62
August 16-31	185	52.8	30-93	106	53.0	28-86	90	58.6	42-79	50	56.2	36-69
September 1-15	41	55.6	42-75	20	61.2	45-71	95	59.8	40-91	0	-	-
September 16 - October 15	37	57.2	38-81	62	60.3	35-79	15	60.4	48-90	0	-	-

[a] Includes all mainstem, slough, and side channel sites sampled during the JAHS study in the Susitna River between Cook Inlet and the Chulitna River confluence.

[b] Includes all mainstem, slough, and side channel sites sampled during the coded wire tagging and cold branding studies in the Susitna River between the Chulitna River confluence and Devil Canyon.

c Not sampled.

Appendix Table A-13. Mean length and range of lengths for age 1+ sockeye salmon by sampling period on the Susitna River between Cook Inlet and Devil Canyon, 1984.

Sampling Period	n	Mean Length	Range of Lengths
May	32	71.3	56 - 99
June 1-15	40	71.3	61 - 100
June 16-30	15	77.8	71 - 91
July	3	91.7	81 - 102
Season	90	73.1	56 - 102

Appendix Table A-14. Mean length and range of lengths for chum salmon fry by sampling period on the Susitna River between Cook Inlet and Devil Canyon, 1984.

Sampling Period	Flathorn Station			Lower Susitna[a] JAHS Sites			Talkeetna Station			Middle Susitna[b] Marking Sites		
	n	Mean Length	Range of Lengths	n	Mean Length	Range of Lengths	n	Mean Length	Range of Lengths	n	Mean Length	Range of Lengths
May	35	42.7	36-62	c	-	-	367	40.1	32-52	150	39.9	33-47
June 1-15	198	41.9	30-55	298	43.2	31-58	357	45.6	35-68	300	44.5	36-60
June 16-30	209	42.7	32-63	109	39.4	31-50	427	42.9	36-62	50	40.2	36-48
July 1-15	17	42.5	30-59	37	42.3	33-57	337	44.0	35-65	50	48.2	39-54
July 16-31	3	43.3	31-52	21	40.4	36-47	172	44.6	36-59	10	46.5	40-51

a Includes all mainstem, slough, and side channel sites sampled during the JAHS studies in the Susitna River between Cook Inlet and the Chulitna River confluence.

b Includes all mainstem, slough, and side channel sites sampled during the coded wire tagging and cold branding studies in the Susitna River between the Chulitna River confluence and Devil Canyon.

c Not sampled.

APPENDIX B

THE SCHAEFER ESTIMATE OF POPULATION SIZE

The Schaefer method of estimating population size is useful with migrating fish which can be sampled and marked at one point and recovered later at a different point on the migratory route (Ricker 1975). The Schaefer estimate of population size (N) is given by Ricker as:

$$N = \sum N_{ij} = \sum \left(R_{ij} \cdot \frac{M_i}{R_i} \cdot \frac{C_j}{R_j} \right)$$

where: R_{ij} = number of fish which were marked during a tagging period (i) and subsequently recaptured during a recovery period (j).

M_i = number of fish marked during a single tagging period.

R_i = total recaptures of fish tagged in the ith period

C_j = number of fish captured and examined for marks during a recovery period.

R_j = number of marked fish which were recaptured during a recovery period.

N_{ij} = estimate of the number of fish available for marking during a period (i) and the number available for recovery in a period (j).

Tagging and recovery periods for the Susitna River study were grouped by eight-day intervals. The data collected for the estimate of the population of sockeye salmon outmigrants are tabulated by the Schaefer method in Appendix Table B-1. The computation of the population estimate is presented in Appendix Table B-2.

Because only age 0+ sockeye fry were tagged and because some of these remained in the middle river to overwinter (therefore, there was no chance of recapturing them as age 0+ fry at Talkeetna Station), we had to assume that the marked/unmarked ratio was the same for the fry that outmigrated as it was for the fry that remained to overwinter. The purpose of sampling at Talkeetna Station was to estimate this ratio. Data collected so far indicate that the number of overwintering sockeye fry in this reach is low in comparison to the number that outmigrate, so the consequences of violating this assumption are not severe.

The mark-recovery data for chum salmon are presented in Appendix Table B-3, and the computations and final population estimate are provided in Appendix Table B-4.

Appendix Table B-1. Data collected on the coded wire tag, mark-recapture experiment for sockeye salmon fry to provide a Schaefer population estimate. Tagging and recovery periods are by eight day intervals, May 22 through September 18, 1984.

Period of Recovery (j)	Period of Tagging (i)				Tagged Fish Recovered (Rj)	Total Fish Recovered (Cj)	Cj/Rj
	1	2	3	4			
1	27	-	-	-	27	339	12.6
2	4	-	-	-	4	71	17.8
3	7	-	-	-	7	414	59.1
4	26	-	6	5	37	1,293	34.9
5	21	-	5	24	50	931	18.6
6	70	-	16	15	101	1,627	16.1
7	32	-	9	7	48	976	20.3
8	16	-	1	3	20	428	21.4
9	29	-	5	10	44	693	15.8
10	6	-	2	4	12	360	30.0
11	6	-	-	-	7	173	24.7
12	-	-	1	-	1	20	20.0
13	1	-	-	-	1	46	46.0
14	2	-	-	-	2	60	30.0
15	1	-	-	-	1	31	31.0
Total Tagged Fish Recovered (Ri)	248	0	45	69	362	7,462	
Total Fish Tagged (Mi)	8,795	0	2,052	3,685	14,532		
Mi/Ri	35.5	-	45.6	53.4			

Appendix Table B-2. Computation of the sockeye salmon for outmigrant population from the data presented in Appendix Table B-1.

Period of Recovery (j)	Period of Tagging (i)				
	1	2	3	4	Total
1	12,077	-	-	-	12,077
2	2,528	-	-	-	2,528
3	14,686	-	-	-	14,686
4	32,213	-	9,549	9,318	51,080
5	13,866	-	4,241	23,838	41,945
6	40,009	-	11,747	12,896	64,652
7	23,061	-	8,331	7,588	38,980
8	12,155	-	976	3,428	16,559
9	16,266	-	3,602	8,437	28,305
10	6,390	-	2,736	6,408	15,534
11	5,261	-	-	1,319	6,580
12	-	-	912	-	912
13	1,633	-	-	-	1,633
14	2,130	-	-	-	2,130
15	1,101	-	-	-	1,101
TOTAL	183,376	-	42,094	73,232	298,702

Appendix Table B-3. Data collected on the coded wire tag, mark-recapture experiment for chum salmon fry to provide a Schaefer population estimate. Tagging and recovery periods are by eight day intervals, May 22 through July 24, 1984.

Period of Recovery (j)	Period of Tagging (i)				Tagged Fish Recovered (Rj)	Total Fish Recovered (Cj)	Cj/Rj
	1	2	3	4			
1	11	-	-	-	11	932	84.7
2	-	1	-	-	1	104	104.0
3	3	4	2	-	9	860	95.6
4	-	3	3	6	12	526	43.8
5	1	3	-	8	12	361	30.1
6	-	-	-	1	1	334	334.9
7	-	-	-	4	4	154	38.5
8	-	-	-	1	1	132	132.0
Total Tagged Fish Recovered (Ri)	15	11	5	20	51		
Total Fish Tagged (Mi)	4,806	12,276	5,295	9,019	31,396		
Mi/Ri	320.4	1,116.0	1,059.0	451.0			

Appendix Table B-4. Computation of the chum salmon for outmigrant population from the data presented in Appendix Table B-3.

Period of Recovery (j)	Period of Tagging (i) 1	2	3	4	Total
1	298,517	-	-	-	298,517
2	-	116,064	-	-	116,064
3	91,891	426,758	202,481	-	721,130
4	-	146,642	139,153	118,523	404,318
5	9,644	100,775	-	108,601	219,020
6	-	-	-	150,634	150,634
7	-	-	-	69,454	69,454
8	-	-	-	59,532	59,532
TOTAL	400,052	790,239	341,634	506,744	2,038,669

APPENDIX C

Time Series Analysis of Discharge,
Turbidity, and Juvenile Salmon Outmigration
in the Susitna River, Alaska

TIME SERIES ANALYSIS OF DISCHARGE, TURBIDITY, AND JUVENILE SALMON OUTMIGRATION IN THE SUSITNA RIVER, ALASKA

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ABSTRACT

During the three years of study of juvenile salmon outmigration from the middle reach of the Susitna River, a correspondence has been noted between the peaks of river discharge and the peaks of outmigration. Further investigation of the relationship of outmigration to discharge was required because two large hydroelectric dams have been proposed for a region above the salmon rearing areas. These dams will markedly change the downstream discharge and turbidity regimes, factors which influence not only salmon outmigration, but almost all fish species and life stages including juvenile salmon rearing. Box-Jenkins models were developed for the 1983 and 1984 time series of river discharge, turbidity, and chinook and sockeye salmon fry outmigration rates in order to better understand the forces that shape the series and to statistically describe the natural conditions as a baseline against which future changes can be measured. The time series examined were described by relatively simple models, using mostly first-order autoregressive terms. About 85% of the variance in turbidity for one day was explained by the value for turbidity of the previous day. This figure was 44% for chinook salmon outmigration and 43% for sockeye salmon outmigration, the lower numbers indicating the effect of behavioral decisions on biological time series. Although the form of the time series plots of discharge and chinook salmon outmigration was different between the two years, the underlying stochastic processes which generated these series were the same. Bivariate transfer function models were constructed for turbidity and salmon outmigration rates which explain present values of these variables in terms of their own past values as well as past values of discharge.

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1.0 INTRODUCTION

While examining the plots of daily catch rate of outmigrating juvenile salmon at the Talkeetna Station outmigrant traps, an apparent correspondence was noted between the peaks of the time series of mean daily discharge and the time series of salmon outmigration (Hale 1983; Roth et al. 1984). Correlation analysis showed that there was a relatively strong relationship between discharge and the outmigration rates of various species/age classes of salmon during certain periods of time. The term outmigration rate is used here to mean the number of outmigrating fry captured at the traps per hour, not the distance travelled per hour. This relationship is not simply a matter of a greater volume of water being fished at higher discharges. The correlations of catch rate of age 0+ salmon with water velocity at the mouths of the traps were not significantly different from zero (Roth et al. 1984, Appendix A). There was in fact a greater number of fry per unit volume of water at high levels of discharge than at low levels.

A correspondence between discharge rate and salmonid outmigration has also been reported by other investigators (Cederholm and Scarlett 1982 - coho salmon; Congleton et al. 1982 - chum and chinook salmon; Godin 1982; Grau 1982; Solomon 1982b). The selective advantages of this behavior, according to Solomon (1982b), include easier passage over long distances or shallow areas and protection from predators provided by increased turbidity and by the large numbers resulting from a coordinated mass migration in response to an environmental cue.

There are probably two mechanisms which account for this relationship in the Susitna River. One is that the fish, which have gradually become physiologically ready for outmigration by growth and in response to photoperiod and temperature, are stimulated by a rise in mainstem discharge to begin that outmigration (Grau 1982). The second mechanism is that high flows physically displace the fish downstream. This latter mechanism may frequently occur for fry rearing in side sloughs, particularly for chum salmon (*Oncorhynchus keta*) and sockeye salmon (*O. nerka*). The natal sloughs for many chum and sockeye salmon have berms at the heads which prevent water from the mainstem from entering the site at low levels of discharge. When high flows occur, the slough heads are overtopped and the fry which had been rearing in low velocity water are subjected to a strong current.

Because two large hydroelectric dams have been proposed for the Susitna River in an area upstream of the rearing areas of the juvenile salmon (Fig. 1), and because these dams would markedly alter the natural discharge and turbidity regimes, it is necessary to quantify the relationship between the discharge and turbidity regimes and the outmigration patterns of the juvenile salmon. After the dams begin operation, the annual patterns of river discharge and turbidity level would be smoothed - both would be lower than normal in the summer and higher than normal in the winter. Also, the high frequency (daily) oscillations of these two time series would be dampened; there would be less day to day variation.

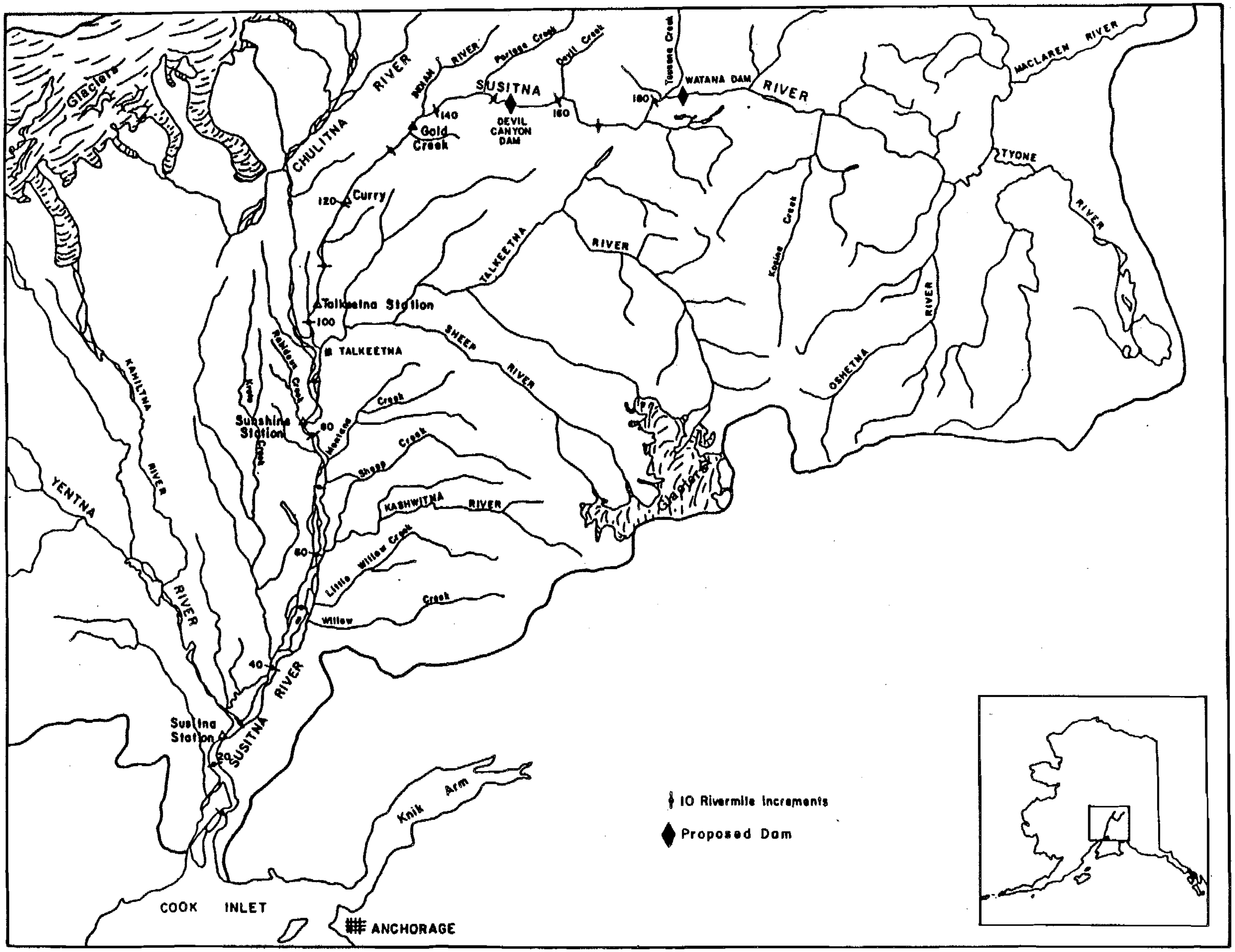


Figure 1. Map of the Susitna basin study region. (Source: Arctic Environmental Information Data Center).

There are many factors other than discharge and turbidity which affect the outmigration timing of juvenile salmon including time of year, size of fish, photoperiod, light intensity, and temperature (Brannon and Salo 1982); however, discharge and turbidity bear further investigation because of the changes in these two variables which would be caused by the proposed dams. Changes in river flow can affect the survival rate of young salmon (Stevens and Miller 1983). Potential negative effects of an altered flow regime include accelerated or delayed timing of outmigrations. Changes in outmigration timing may place the fish in their rearing areas at an unfavorable time from the standpoint of food supply, which could cause reduced survival (Hartman et al. 1967). Lower discharge levels can result in a shorter distance covered per day (Raymond 1968). Decreasing mainstem flows can lead to stranding of fish in pools which have been isolated from the mainstem (Solomon 1982a). Lower flows and clearer water than normal may also result in increased predation (Stevens and Miller 1983).

Turbidity level in the Susitna River probably does not have much direct effect on the daily number of fry which outmigrate or on the initiation of outmigration. In clear water streams, however, an increase in turbidity level can directly increase the number of outmigrating salmon by providing cover from predators (Solomon 1982b). Turbidity level in the Susitna River does change outmigration timing because fry in turbid water outmigrate during the day as well as during the night (Godin 1982; Roth et al. 1984). Clearing of the water could force the fry to shift to a nocturnal outmigration to avoid predators. However, this would be of marginal benefit for fry during the continuous daylight in June and July at 63° N latitude.

To avoid or alleviate the above problems, it is necessary to understand the mechanisms producing the present discharge, turbidity, and outmigration regimes. Knowledge of the discharge-outmigration relationships will be useful in trying to establish a post-project flow regime which will not interfere with the natural outmigration timing.

Also, because discharge and turbidity level are important variables affecting salmon life stages other than the outmigration phase as well as other species, it is necessary to statistically describe the natural discharge and turbidity regimes as a baseline against which future changes in these variables can be measured. Turbidity provides cover for salmon fry (Suchanek et al. 1984; Part 2 of this report) but also decreases primary production and affects the feeding, movement, and distribution of many of the fish species present in the river. Turbidity level after the dams begin operation will not only be influenced by a changed discharge regime, but will also be directly changed by the dams because settling of suspended sediment in the reservoir will create a turbidity regime substantially different from the present regime. Turbidity was included as a variable of interest in this paper more because of its effect on other life stages and species than because of its effect on salmon outmigration.

Further, discharge is the major variable in the extensive instream flow habitat modeling effort which has been conducted in the Susitna River; turbidity is also an important factor (Hale et al. 1984; Suchanek et al.

1984; Part 2 of this report). The current discharge and turbidity regimes that are driving these habitat models must be accurately described so that the models can be put into a proper perspective.

1.1 Time Series Analysis

The statistical methods collectively known as time series analysis are a logical choice for analyzing the natural discharge, turbidity, and outmigration regimes. A time series is a collection of observations ordered in time such as daily water temperature measurements. Time series analysis includes frequency domain (spectral analysis) and time domain problems. Spectral analysis is concerned with transforming a time series with a Fourier transform to a sum of sines and cosines (see Priestley 1981) and is appropriate with periodic series such as the classical example of the Canada lynx/snowshoe hare ten year cycle (Bulmer 1978). Methods for time domain problems (or Box-Jenkins models) are referred to as ARIMA (autoregressive, integrated, moving average) models (Box and Jenkins 1976). ARIMA models have been used extensively in economic forecasting (Nelson 1973; Granger and Newbold 1977).

Time series are shaped by both deterministic and stochastic (random) events. The series has a "memory" of the random events (or "shocks") operating on the series, that is, the effect of these disturbances may be apparent for several time units after the event occurred. One aspect of time series analysis consists of removing deterministic trends from a time series so that the values fluctuate around a mean level. A transformation may be necessary to ensure a constant variance. The random processes that generated the observed series can then be mathematically defined. The residuals left over after this model is fitted should be "white noise" (completely random) if the model is adequate.

Time series can be passed through a mathematical filter which changes the form of the input series. A "low pass filter" dampens high frequency perturbations and allows low frequency perturbations to pass unchanged. This is useful in smoothing noisy time series so that the basic pattern may be more readily observed. High pass filters are used when it is desirable to remove obvious (low frequency) trends in order to focus on the high frequency events.

Box-Jenkins models can be constructed using only the information contained in the time series itself. For example, although the discharge time series results from several independent variables including rainfall, air temperature, and solar insolation on the glaciers, it is not necessary to quantify these inputs in order to model the output (discharge). Information on the effects of all the inputs is already contained in the past history of the discharge record. However, information on the input series can be used in a transfer function model to obtain an equation with more predictive power. This is a model where an output series is a function of one or more independent input series as well as its own past history.

An observed series is one realization of all possible time series which could have been generated from a random process. Time series analysis examines the nature of the probablistic process that generated the observed series. The model should have similar properties to the generating mechanisms of the stochastic process (Granger and Newbold 1977). Then, one can form summary statistics about the series and make inferences about the nature of the stochastic process. After a model has been developed, it can be used to test some hypothesis about the generating mechanism of the time series, to forecast future values of the series, or to make decisions on how to control future values of the series (Granger and Newbold 1977).

1.2 Applications of Time Series Analysis

Time series analysis has been extensively used in examining physical data, particularly in oceanography. Salas and Smith (1981) demonstrated that ARIMA models can be used to model the time series of annual flows in streams. Srikanthan et al. (1983) analyzed the time series of annual flows in 156 streams in Australia. Time series models have also been used to examine the effect of the Aswan dam on the discharge of the Nile River and the effect of a hydroelectric dam on the discharge regime of the Saskatchewan River (Hipel et al. 1978).

Time series analysis methods have been also been used in examining time series of abundance and catch in marine fisheries (Van Winkle et al. 1979; Botsford et al. 1982; Peterman and Wong 1984; and Taylor and Prochaska 1984). These methods have been used by Saila et al. 1980, Mendelssohn 1981, Stocker and Hilborn (1981), Kirkley et al. (1982), and Jensen (1985) for forecasting future abundance or catch of marine fish stocks. Mendelssohn (1981) used transfer function models in addition to univariate Box-Jenkins models to forecast fish catch. Botsford et al. (1982) focused on searching for causal mechanisms of observed cycles in salmon fisheries in California rather than on defining models for the fisheries.

Applications to freshwater fish ecology problems are much more limited. Saila et al. (1972) used time series methods to cross correlate upstream migration activity of the alewife to solar radiation and water temperature. O'Heeron and Ellis (1975) considered a time series model for judging the effects of reservoir management on fish. Applications of spectral analysis to ecological problems have been reviewed by Platt and Denman (1975) and time series analysis in ecology was the subject of a symposium proceedings edited by Shugart (1978).

1.3 Objectives

The objective of this paper was to develop mathematical models for the times series of mean daily Susitna River discharge at the Gold Creek gaging station (river mile 136.7), daily turbidity level, and daily outmigration rates of chinook salmon (*Oncorhynchus tshawytscha*) and sockeye salmon (*O. nerka*) at the Talkeetna Station outmigrant traps (river mile 103.0) during the open water seasons of 1983 and 1984. Because time series analysis can provide an efficient summarization of a data set by a few parameters (Hipel et al. 1978), these models will be used to statistically describe the present conditions as a baseline against which future changes can be measured. The discharge and turbidity information will be useful for examining their relationship with salmon fry outmigration as well as with other species and life history stages. In addition, discharge was used as an input in transfer function models of discharge-turbidity, discharge-chinook outmigration and discharge-sockeye outmigration in order to describe the relationship between these variable and to be used as a possible technique to forecast future values or to examine the probable effects of the proposed dams.

Turbidity was chosen as a variable of interest because of its relationship with discharge and because of its importance in determining the distribution of rearing juvenile salmon (Suchanek et al. 1984; Part 2 of this report) and other species. It was selected more for this reason than for its effect on salmon outmigration, so it was not used as an input in a transfer function model with salmon outmigration. Chinook salmon were chosen because this species rears in sloughs and side channels affected by mainstem discharge and because chinook salmon have been selected as the evaluation species of the impact assessment study (EWT&A 1985). The sockeye salmon time series was chosen because mainstem discharge affects sloughs which are both natal and rearing areas for this species. While chinook salmon spawn mainly in tributaries in this system, sockeye salmon spawn mostly in mainstem sloughs.

2.0 METHODS

2.1. The Data

Mean daily discharge values for 1983 and 1984 (Fig. 2, Fig. 3) were obtained from the U.S. Geological Survey gaging station on the Susitna River at Gold Creek, river mile 136.7 (Still et al. 1984; U. S. Geological Survey provisional data, 1984). The time frame examined was May 18 to August 30 (105 observations). Discharge levels begin to decline in September when glacier melting decreases; hence, a longer series would not be stationary. Throughout this paper, the unit for discharge is one thousand cubic feet per second.

Daily water samples for turbidity (Fig. 2, Fig. 3) were taken at the outmigrant trap station and measured with an HF Instruments Model No. DRT-15B field turbidometer (Roth et al. 1984). Units are in nephelometric turbidity units (NTU). Only the 1984 turbidity series was examined.

Outmigration rate (Fig. 2, Fig. 3) was measured by two outmigrant traps, one on each bank, located at river mile 103.0 (Roth et al. 1984). The rate is reported as number of fish per trap hour with catch from the two traps combined. Only age 0+ fry were used in the analysis because the traps were not efficient at capturing age 1+ fry and, consequently, the numbers were low. Further, age 1+ chinook and sockeye salmon have essentially completed their outmigration from this reach of river by the end of July so the time series are shorter.

The chinook salmon time series for 1983 runs from May 18 (shortly after ice-out) to August 30 (when outmigration is winding down), a total of 105 observations. The 1983 sockeye salmon data were not examined. There were six days during the 105 day series when the outmigrant traps were not fished - a one day, a two day, and a three day period. Although values for gaps in time series can be estimated by a spline method, the gaps in the outmigration series are short enough so that a simple interpolation of values is sufficient (Sturges 1983).

In 1984, the traps were continuously operated from May 14 to October 6. However, the series were cut off at the end of August in order to be comparable to 1983 and to achieve a stationary series. About 98% of the cumulative outmigration of age 0+ chinook and sockeye fry in 1984 had occurred by the end of August.

2.2. Identification and Estimation of Time Series Models

Univariate models were developed for the four time series: discharge, turbidity, and chinook and sockeye salmon outmigration. Methods for developing Box-Jenkins ARIMA and transfer function models are described in section 7.0. Basically, there are three steps in developing an ARIMA model: model identification, parameter estimation, and diagnostic checking (Box and Jenkins 1976). The autocorrelation (AC) and partial autocorrelation (PAC) plots for each series were examined to help identify possible autoregressive (AR) and moving average (MA) components. A tentative model was developed and the parameters estimated.

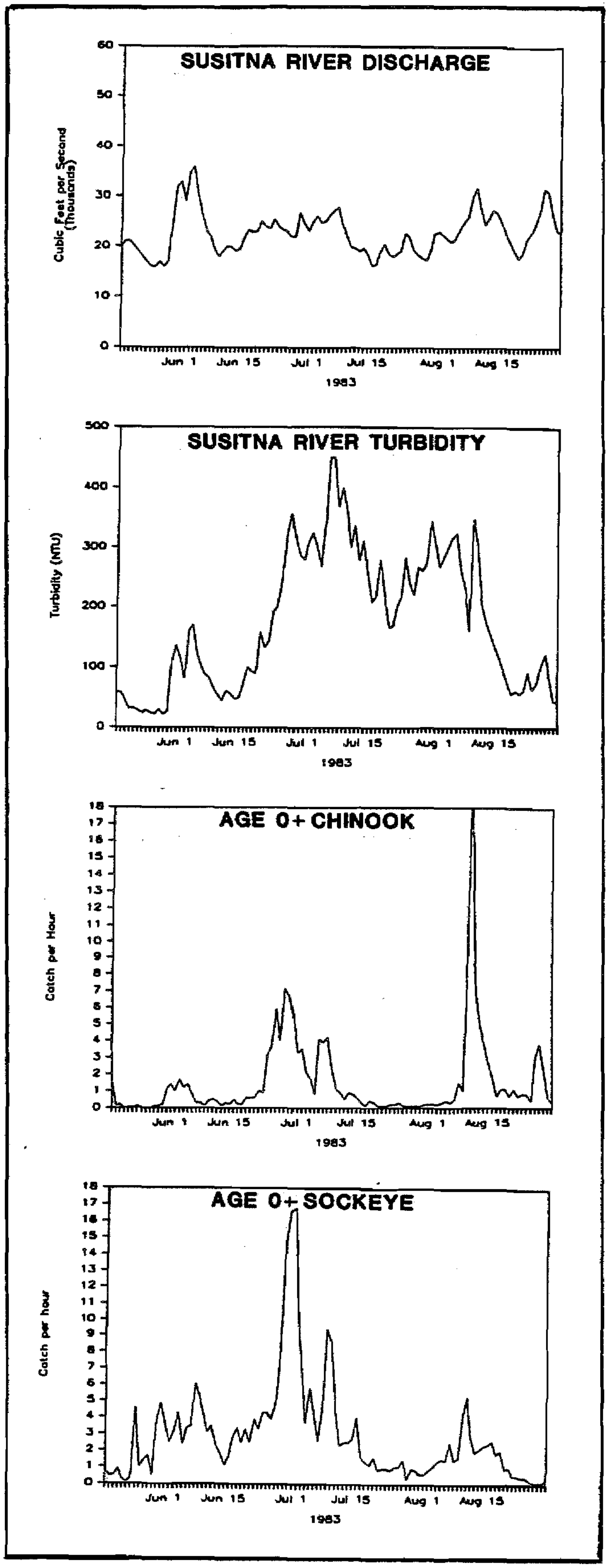


Figure 2. Discharge, turbidity, and chinook and sockeye salmon outmigration rate, 1983.

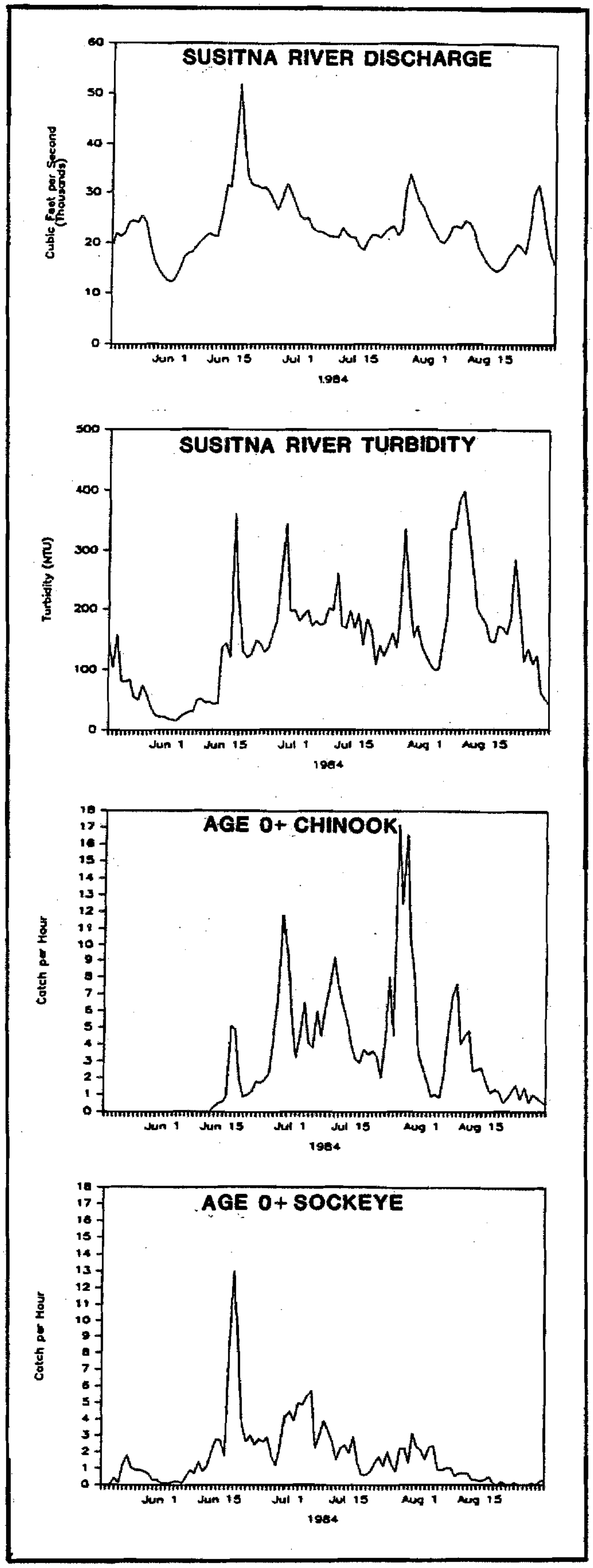


Figure 3. Discharge, turbidity, and chinook and sockeye salmon outmigration rate, 1984.

Insignificant components were removed from the model. The residuals were checked to see if there was significant departure from the assumption that they were white noise. If the residuals were white noise, the model was considered to be adequate. If not, a new model was identified and the process repeated until the residuals were reduced to a white noise process.

All of the time series work was done using the BMDP statistical package (Dixon et al. 1981). The BMDP Box-Jenkins program estimates parameters by both the conditional least squares method and the backcasting method. The estimates chosen for this paper were from whichever method gave the lowest residual mean square.

The time series of mean daily discharge from May 18 to August 30 appeared to be stationary so no differencing was done. A plot of the range of sub-groups of the series against the mean of the sub-groups (as suggested by Hoff (1983) indicated that a logarithmic transformation of the data would be helpful in stabilizing the magnitude of the fluctuations throughout the series; therefore, a model was also developed for the natural log of the raw data. As the turbidity time series was questionably stationary, models were developed for both the original series and for a differenced series.

Models were developed for the chinook and sockeye salmon outmigration rate time series on both the raw data and on data transformed by ln (x + 1). This transformation was used to avoid taking logarithms of zero; there was zero catch on some days.

2.3 Transfer Function Models

Transfer function models (see section 7.0) were developed for discharge/turbidity, discharge/chinook outmigration, and discharge/sockeye outmigration. Only one input (discharge) was used. Multiple input transfer function models (Liu and Hanssens 1980) or multivariate time series models (Mendelssohn 1982) can be developed, but are substantially more complex.

3.0 RESULTS

3.1. Univariate Model for Mean Daily Discharge

The time series of mean daily discharge during the summer of 1983 is shown in Fig. 4; the log-transformed data are in Fig. 6. Autocorrelation function (ACF) and partial autocorrelation function (PACF) plots for the raw data are given in Fig. 5 and for the log- transformed data in Fig. 7. In all the ACF and PACF plots, the "+" symbol on either side of the vertical axis indicates the 95% confidence interval. The first order autoregressive component was strong in both the raw and the transformed series. The ACF and PACF plots for the raw data indicated that a moving average component was required. Models containing various combinations of first and second order AR and MA terms were examined. Of the acceptable models identified, the model with the lowest standard errors on the parameter estimates and the least significant residuals was an ARMA(2,2). However, the ARMA(1,1) was nearly as good as the ARMA (2,2) so, in keeping with Box and Jenkins' (1976) advice that a parsimonious model (i.e., the one with the fewest possible parameters) is desirable, the ARMA(1,1) is considered the "best" model for the non-transformed data. Parameter estimates were:

$$\hat{\phi}_1 = .992 \text{ with std. error of } .0135$$

$$\hat{\theta}_1 = -.580 \text{ with std. error of } .0807$$

The model is:

$$y_t = 22.7 + .99\,(y_{t-1} - 22.7) - .58\,a_{t-1} + a_t$$

where: y_t is the discharge level at time t and

a_t is a white noise process at time t

Neither the mean nor any of the autocorrelations or partial autocorrelations of the residuals was significant; therefore, the model is considered to be adequate. This equation can be interpretted as: The discharge level for any given day is a function of (the mean level, 22.7 cfs, of discharge during the period) plus (most of the previous day's discharge level minus the mean level) minus (about half of the previous day's noise component) plus (the given day's noise component).

The plots of both the ACF and PACF on the residuals from this model showed a slightly significant spike at a lag of 15 or 16 days. This could indicate that the discharge time series has a periodicity of about 15 days, or slightly more than two weeks. This possibility was further examined by spectral analysis. The spectrum of discharge (Fig. 8) did in

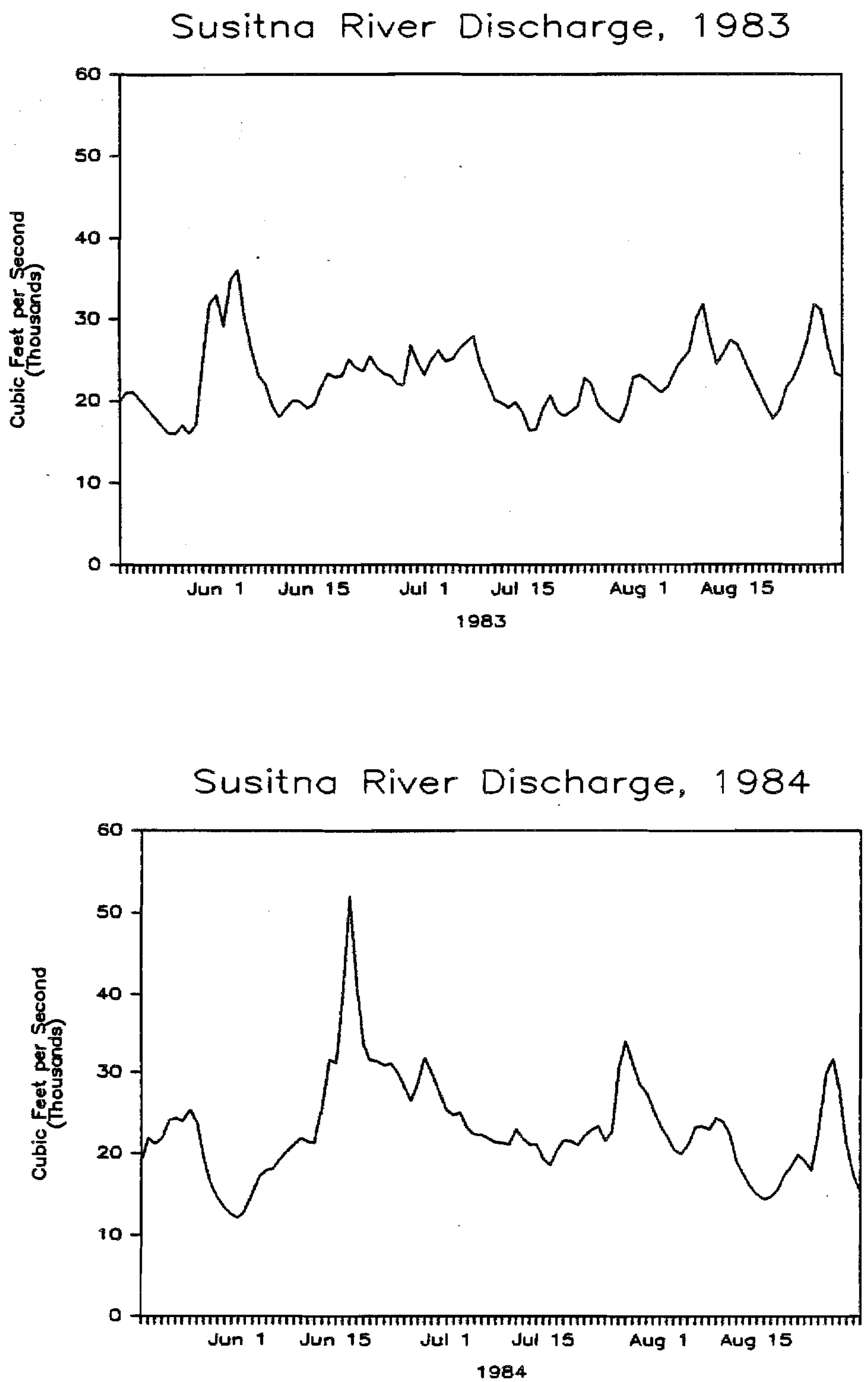


Figure 4. Susitna River discharge time series at the Gold Creek gaging station, 1983 and 1984.

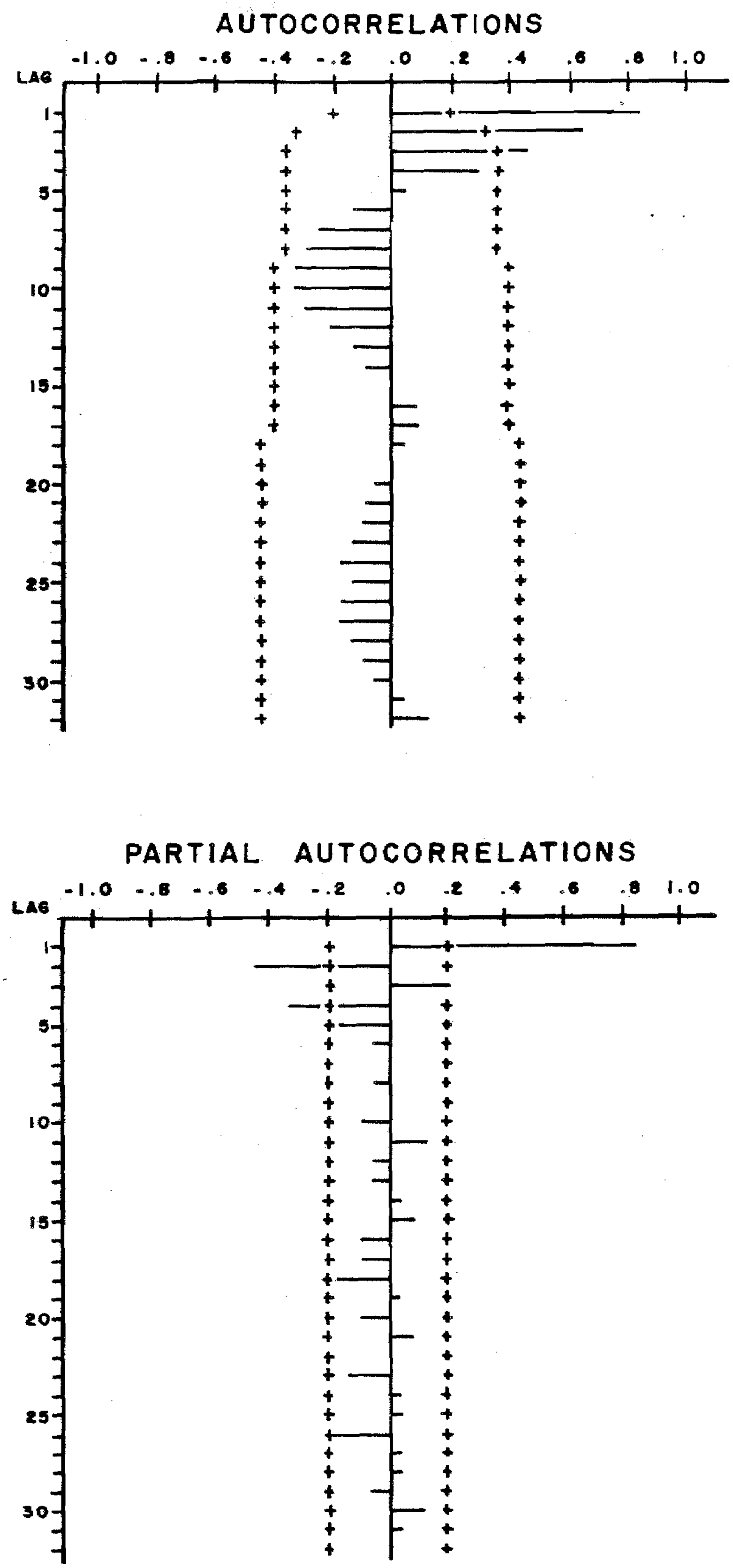


Figure 5. Plots of autocorrelations and partial autocorrelations for 1983 discharge time series.

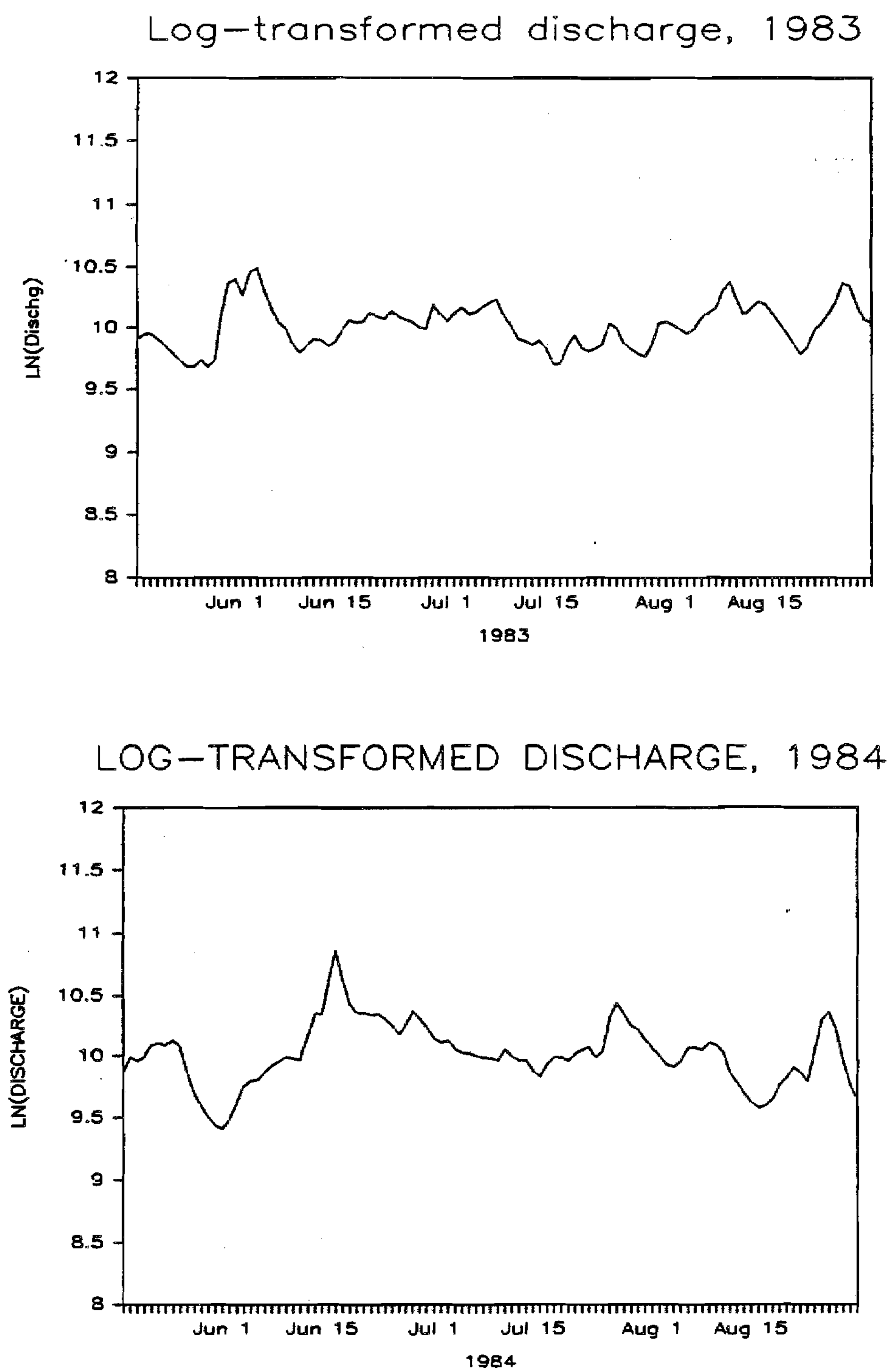
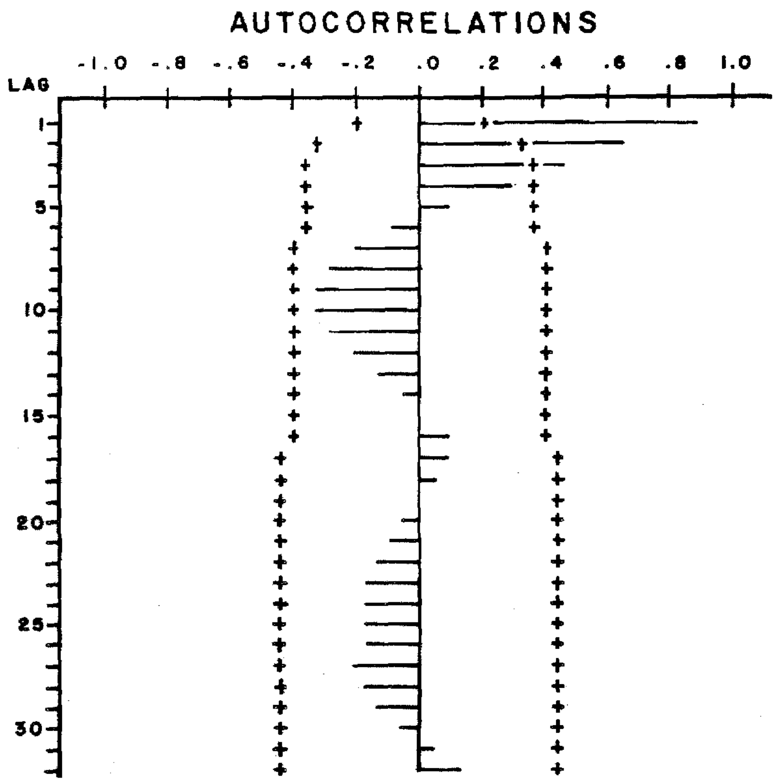


Figure 6. Log-transformed discharge time series, 1983 and 1984.



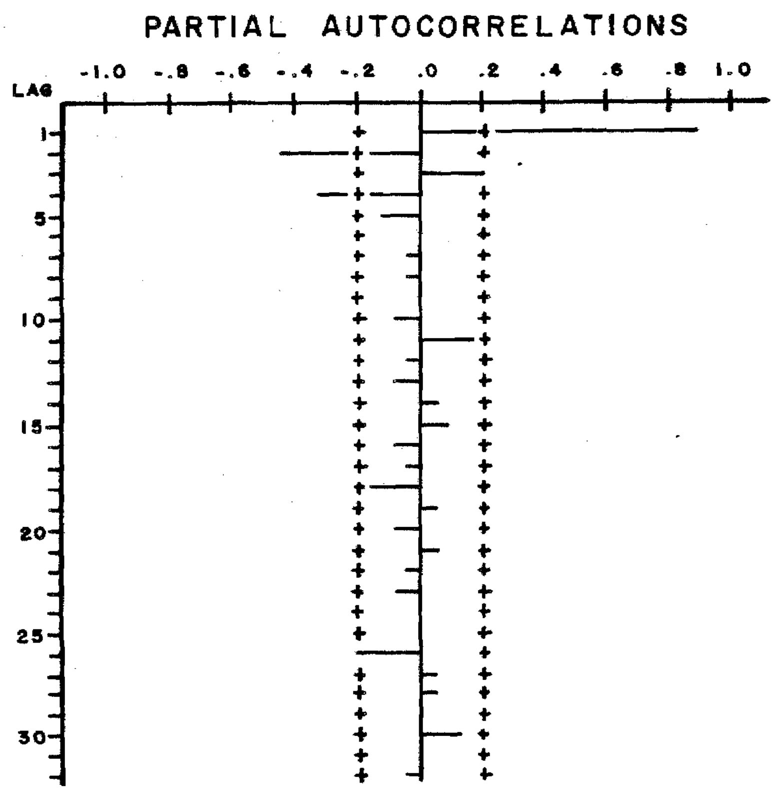


Figure 7. Plots of autocorrelations and partial autocorrelations for 1983 log-transformed discharge time series.

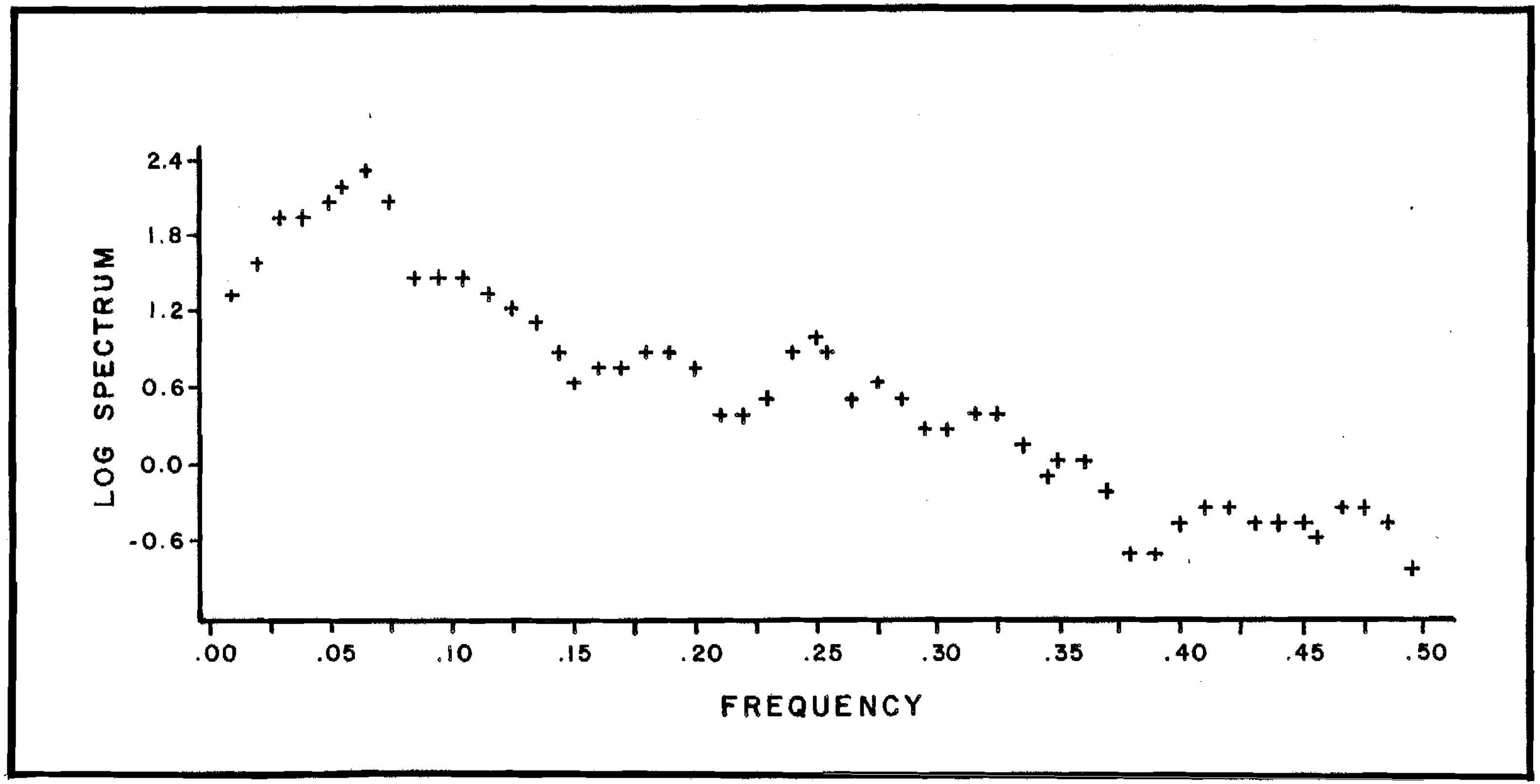


Figure 8. Spectrum of 1983 discharge time series.

fact indicate a peak at a frequency of .065 (a period of 15 days). It is not known at this time if this periodicity is "real". It may be related to weather patterns in the basin which control solar insolation (cloud cover) and rainfall. A much longer time series of discharge would have to be examined to answer this question. A periodic term could be added to the ARMA(1,1) model (Box and Jenkins 1976) but, given the low significance level of the periodicity, it does not seem appropriate at this stage of model development.

Carrying the idea of parsimony a step further, it can be seen that an ARMA(1,0) model using the log-transformed data is adequate and has the lowest number of parameters. The parameter estimates for this model were:

$$\hat{\phi}_1 = .994 \text{ with std. error of } < .00005$$

giving

$$\ln y_t = 10.0 + .99\,(\ln y_{t-1} - 10.0) + a_t$$

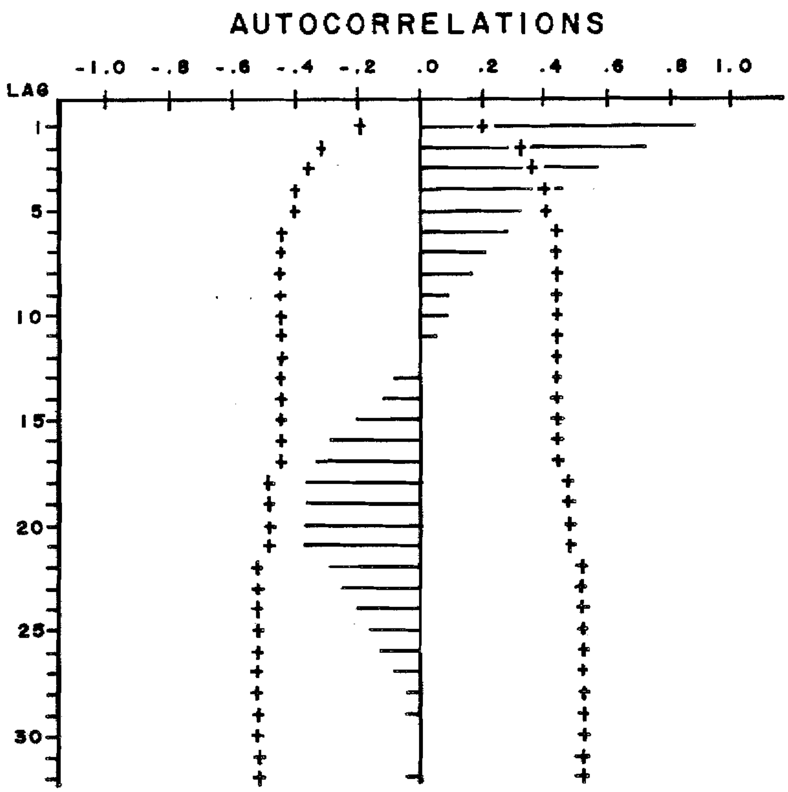
The parameter $\hat{\phi}_1$ was very close to unity. If $\hat{\phi}_1$ were equal to 1.000, the model would be reduced to a random walk model (Chatfield 1984). That is, the log of the discharge for today is the same as the log of the discharge for yesterday plus a random error term. When $\hat{\phi}_1$ approaches 1.000 in a model with only one AR term, the series could be non-stationary (Hoff 1983). To test this, the series was differenced. The residuals from an ARIMA(1,1,0) model showed significant spikes, so the differencing did not help; the ARIMA(1,0,0) model is better.

The AC's on the residuals of the ARMA(1,0) model were a little better than those of the ARMA(1,1) on the non-transformed data. However, the mean of the residuals was slightly significant, so the ARMA(1,1) model on the raw data is probably superior to this one.

The 1984 discharge time series is shown in Fig. 4 and Fig. 6. The ACF and PACF plots (Fig. 9) were similar to those of 1983. An ARMA(1,1) model on the 1984 raw data was adequate, as it was in 1983. Parameter estimates were: $\bar{y}$ = 23.2; $\hat{\phi}_1$ = .808 (std. error = .0638); and $\hat{\theta}_1$ = -.692 (std. error = .0750). An AR(1) model on the log-transformed data was also adequate but, again, had a slightly significant mean residual. The ACF and PACF plots, using log-transformed data (Fig. 10), were similar to those of 1983, but perhaps showed less indication of a moving average process. The estimate for $\hat{\phi}_1$ was .994 (exactly the same as the 1983 data), with a standard error of 0.0001, and the estimate for $\bar{y}$ was 10.0.

3.2. Univariate Model for Turbidity

The time series for turbidity in 1983 (Fig. 11) was more complex than that of discharge. The ACF and PACF plots (Fig. 12) indicated a strong AR(1) component. However, AR(1), AR(2), and ARMA(1,1) models were not adequate to explain the series.



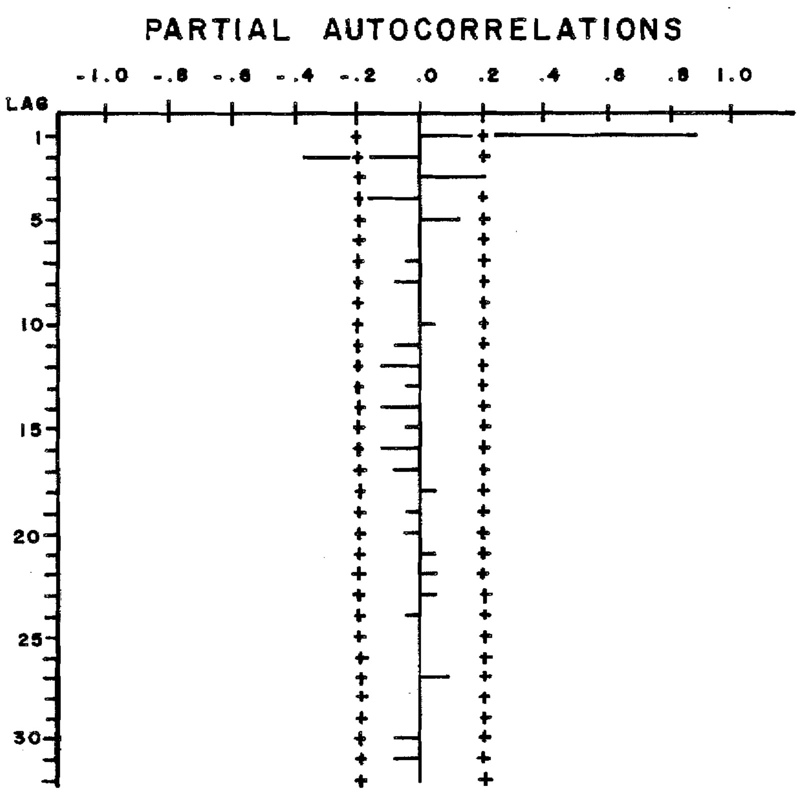
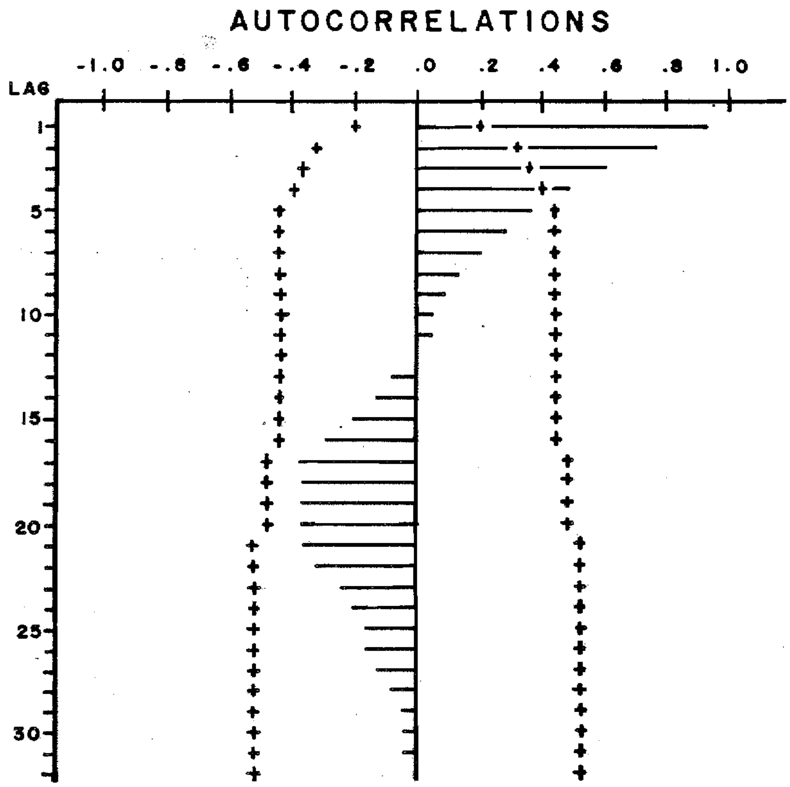


Figure 9. Plots of autocorrelations and partial autocorrelations for 1984 discharge time series.



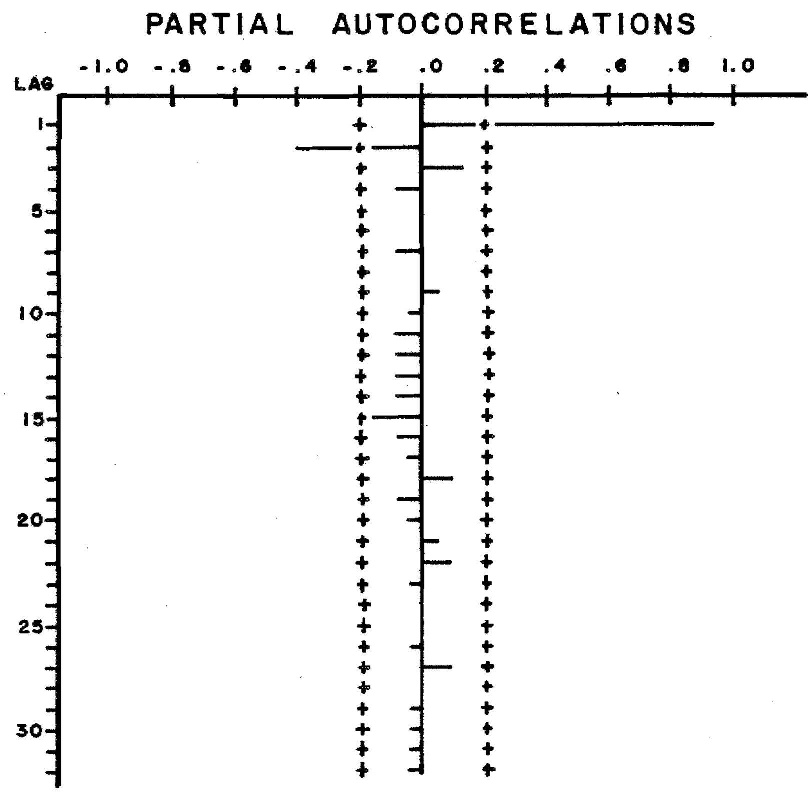


Figure 10. Plots of autocorrelations and partial autocorrelations for 1984 log-transformed discharge time series.

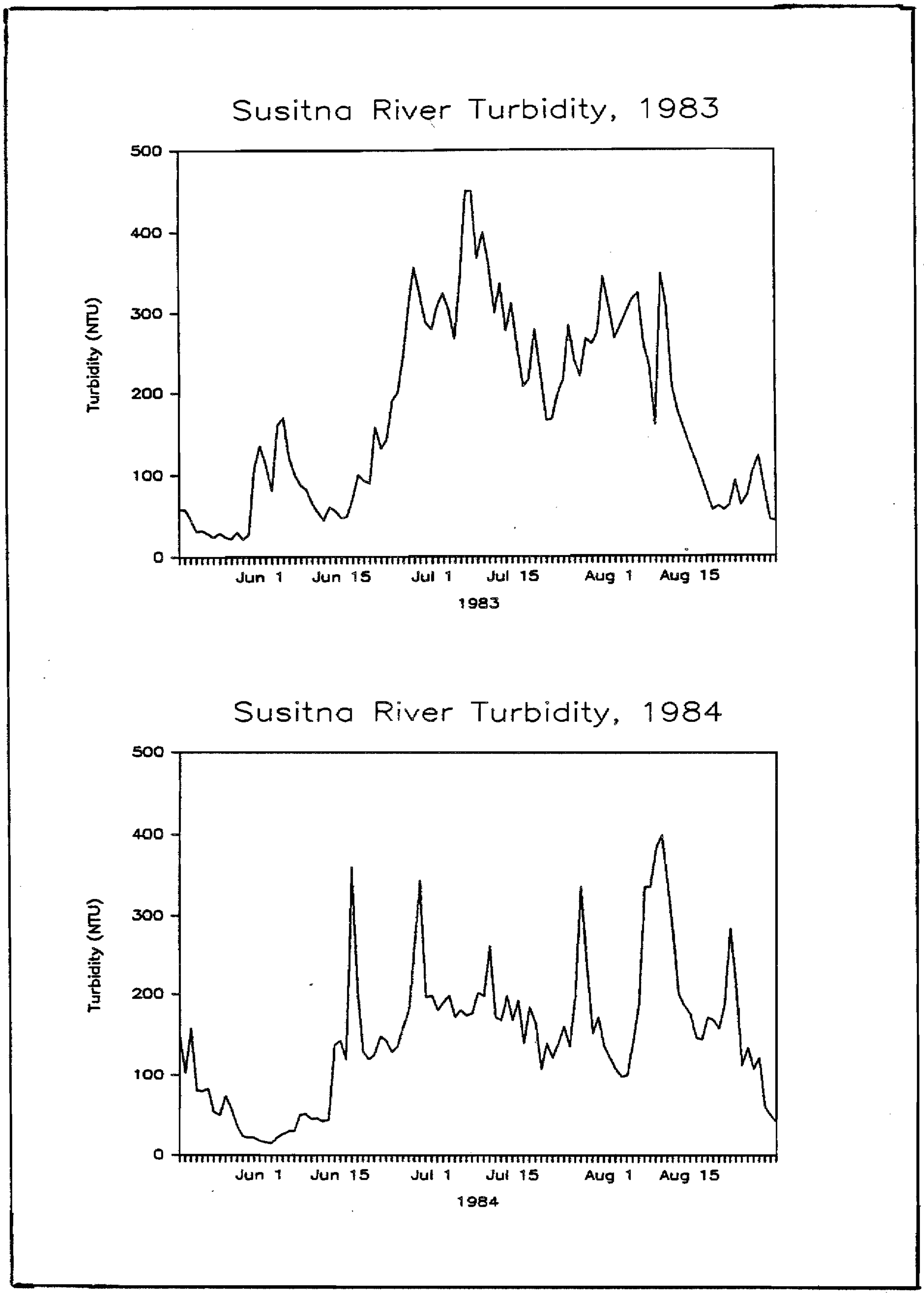
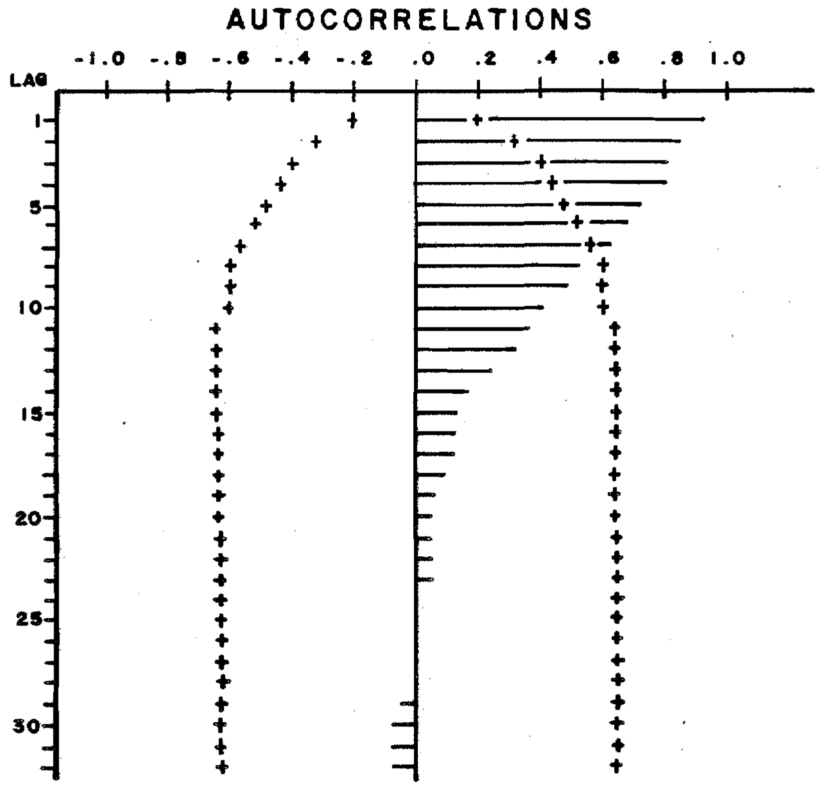


Figure 11. Turbidity time series at Talkeetna Station, 1983 and 1984.



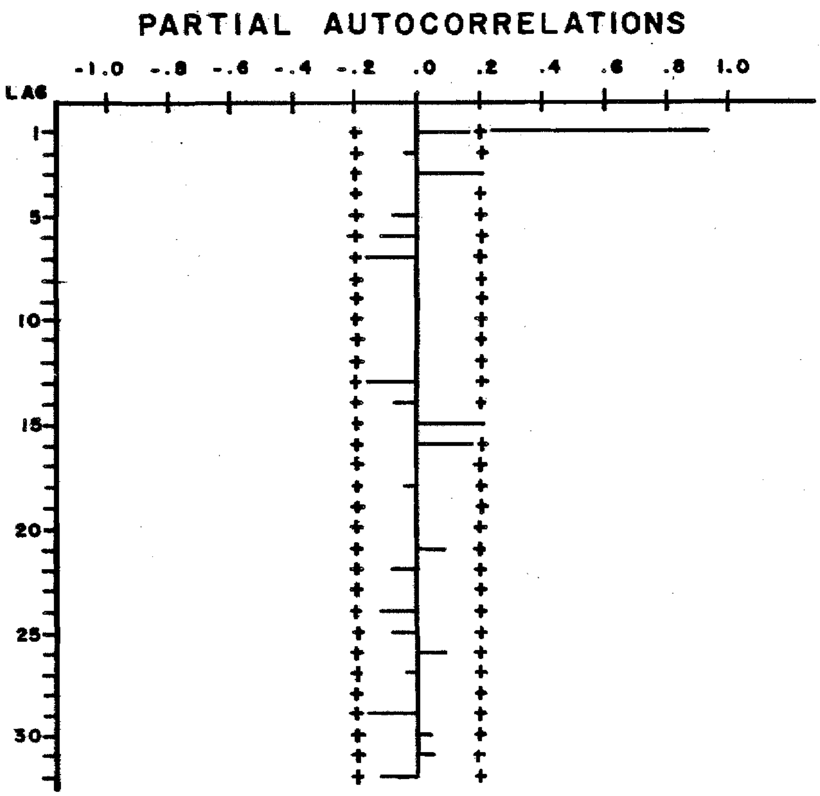


Figure 12. Plots of autocorrelations and partial autocorrelations for 1983 turbidity time series.

The series appears to border on being non-stationary because it increases in the spring as glacier melt increases and then declines in the fall. (This series would certainly be non-stationary over a longer time frame because the turbidity level is very low in the winter). The slow decay of the autocorrelations in the ACF (Fig. 12) also indicated non-stationarity.

Further investigation using the raw data showed that the series had a significant second order MA term, while the first order MA term was not significant. Both first and second order AR terms were significant. This gives the model:

$$y_t = 176.1 + .94(y_{t-1} - 176.1) + .06(y_{t-2} - 176.1)$$
$$+ .23\, a_{t-2} + a_t$$

with std. errors: on $\hat{\phi}_1$ = .0122

on $\hat{\phi}_2$ = .0234

on $\hat{\theta}_2$ = .0988

Note that even though the same notation is used, the white noise process (a_t) here is different from that in section 3.1.

While this ARMA model is adequate for the time frame examined, in general, an integrated model (i.e., one with a differencing operation) is probably more appropriate because of the suspected non-stationarity of the raw data. The differenced series (Fig. 13), which represents consecutive changes in the original series values, is clearly stationary with a mean close to zero. The ACF and PACF plots for the differenced series (Fig. 14) showed that the differenced series could be adequately modeled with just the second order MA term; the first order autoregression term was not significant in the differenced series. The equation is:

$$Z_t = .23\, a_{t-2} + a_t$$

$$\text{where: } Z_t = y_t - y_{t-1}$$

with std. error on $\hat{\theta}_2$ = .0972 and the mean of the residuals insignificant.

3.3. Univariate Model for Age 0+ Chinook Salmon Outmigration

The time frame chosen for Age 0+ chinook salmon was the same as that of discharge (Fig. 15). The plots of the ACF and the PACF for 1983 (Fig. 16) showed a strong first order autoregresssive component. In fact, an ARMA(1,0) model, abbreviated as AR(1), adequately represents the data. Although the plot of the range of sub-groups against the mean of the

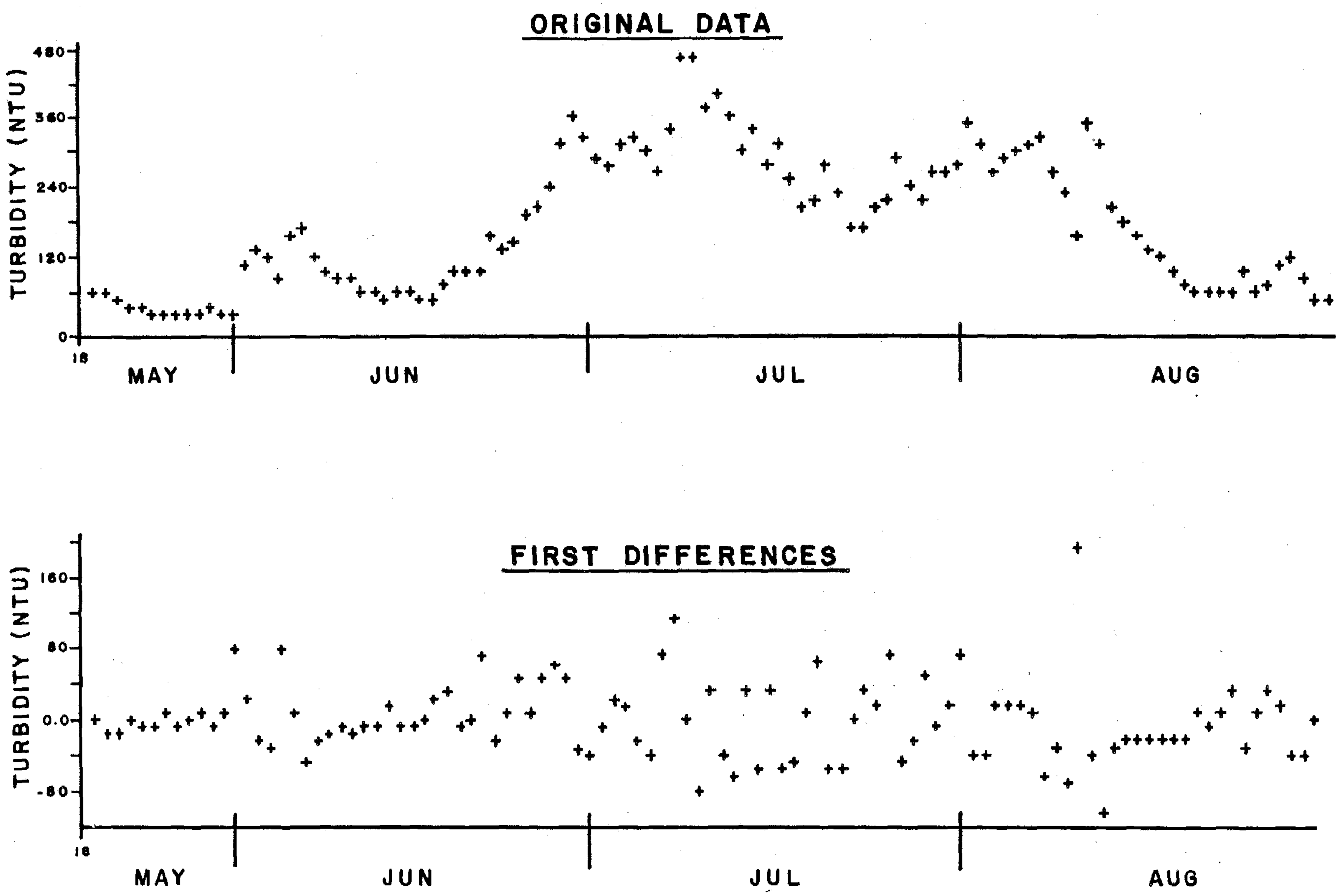
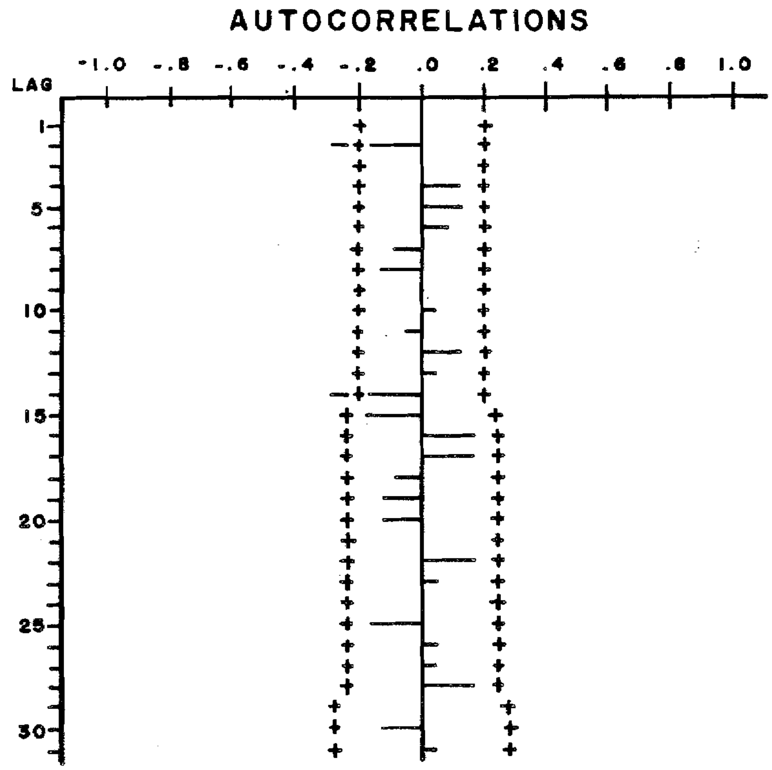


Figure 13. Differenced turbidity time series, 1983.



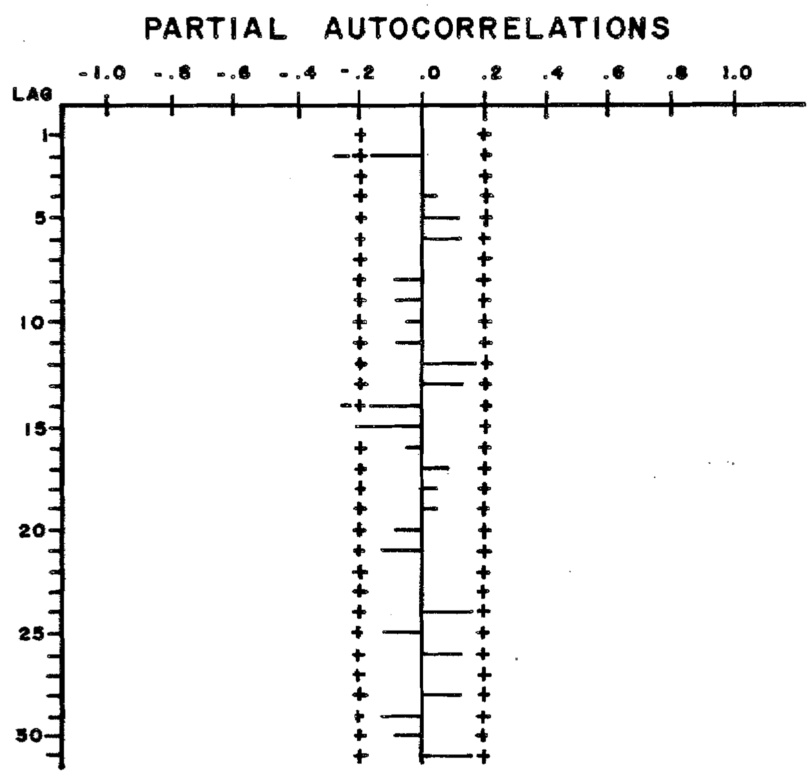


Figure 14. Plots of autocorrelations and partial autocorrelations for differenced 1983 turbidity time series.

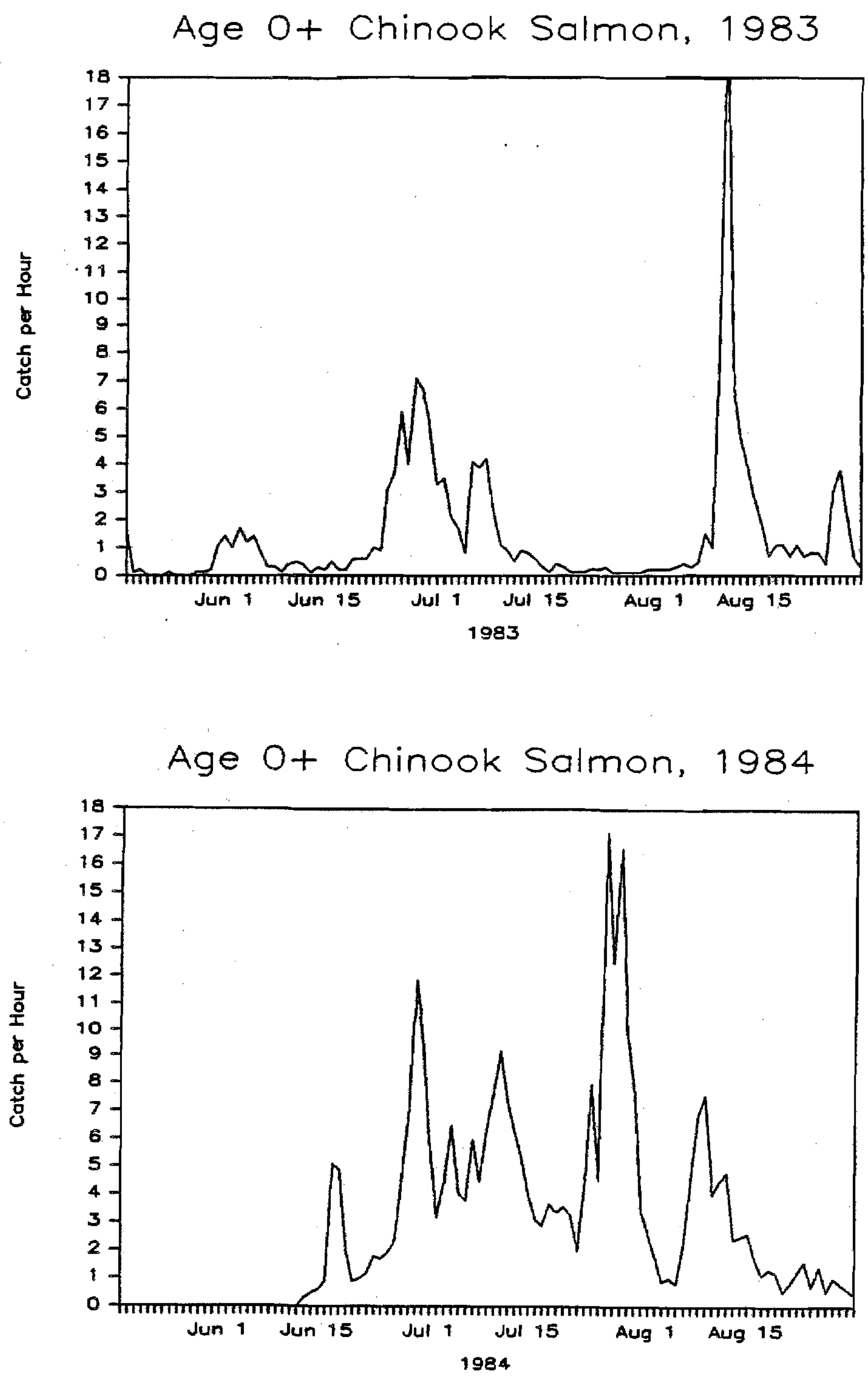


Figure 15. Age 0+ chinook salmon outmigration rate time series, 1983 and 1984.

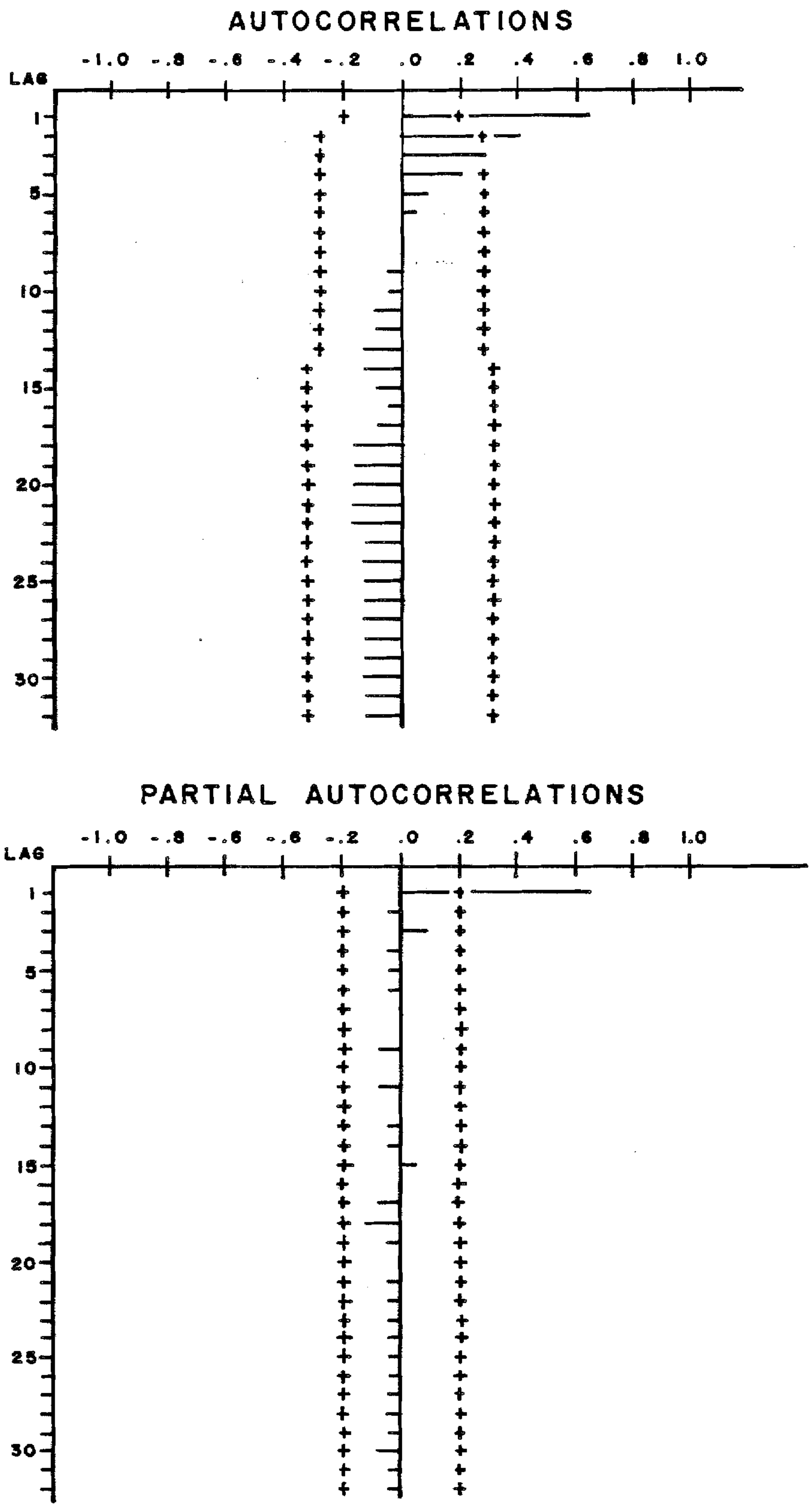


Figure 16. Plots of autocorrelations and partial autocorrelations for 1983 chinook salmon outmigration time series.

sub-groups indicated the need for a logarithmic transformation, the residual AC's of an AR(1) model on the log- transformed data (Fig. 17) were slightly larger (but still insignificant) than those of the AR(1) model on the raw data. The standard error on $\hat{\phi}_1$, however, was lower with the log-transformed data. ACF and PACF plots for the log-transformed data are shown in Fig. 18. The AR(1) model for the raw data is:

$$y_t = 1.52 + .66\,(y_{t-1} - 1.52) + a_t$$

with standard error on $\hat{\phi}_1$ = .0743.

The AR(1) model for the log-transformed data is:

$$\ln(y_t + 1) = .67 + .92\,(\ln(y_{t-1} + 1) - .67) + a_t$$

with standard error on $\hat{\phi}_1$ = .0363.

The mean of the residuals was not significant.

The time series plot for age 0+ chinook salmon outmigration in 1984 (Fig. 15) shows a different pattern from that of 1983. The fry did not begin to migrate in 1984 until about June 12. The low level of out-migration early in the season causes a time series which is non-stationary. To avoid this problem, the time frame selected for 1984 ran from June 12 to August 31 (79 cases). Analysis of this shorter series is not as strong as that of the longer series in 1983 but the series is long enough from a statistical point of view; Hoff (1983) suggests that about 40 or 50 observations is the minimum necessary for attempting an ARIMA model. Although logarithmic transformation did not appear to be strictly necessary for the 1983 data, it was required (to produce an AR(1) model) with the 1984 data, perhaps because of the shorter time series in 1984.

The ACF plot for 1984 on the log-transformed data (Fig. 19) was similar to that of 1983, although it did decay a little more quickly. The 1984 PACF plot (Fig. 19) was very similar to that of 1983 in indicating a strong AR(1) component. The estimated value of ϕ_1 in 1984 was 0.973 (very close to that of 1983), with a standard error of 0.0265. The 1984 model is:

$$\ln(y_t + 1) = 1.39 + .97\,(\ln(y_{t-1} + 1) - 1.39) + a_t$$

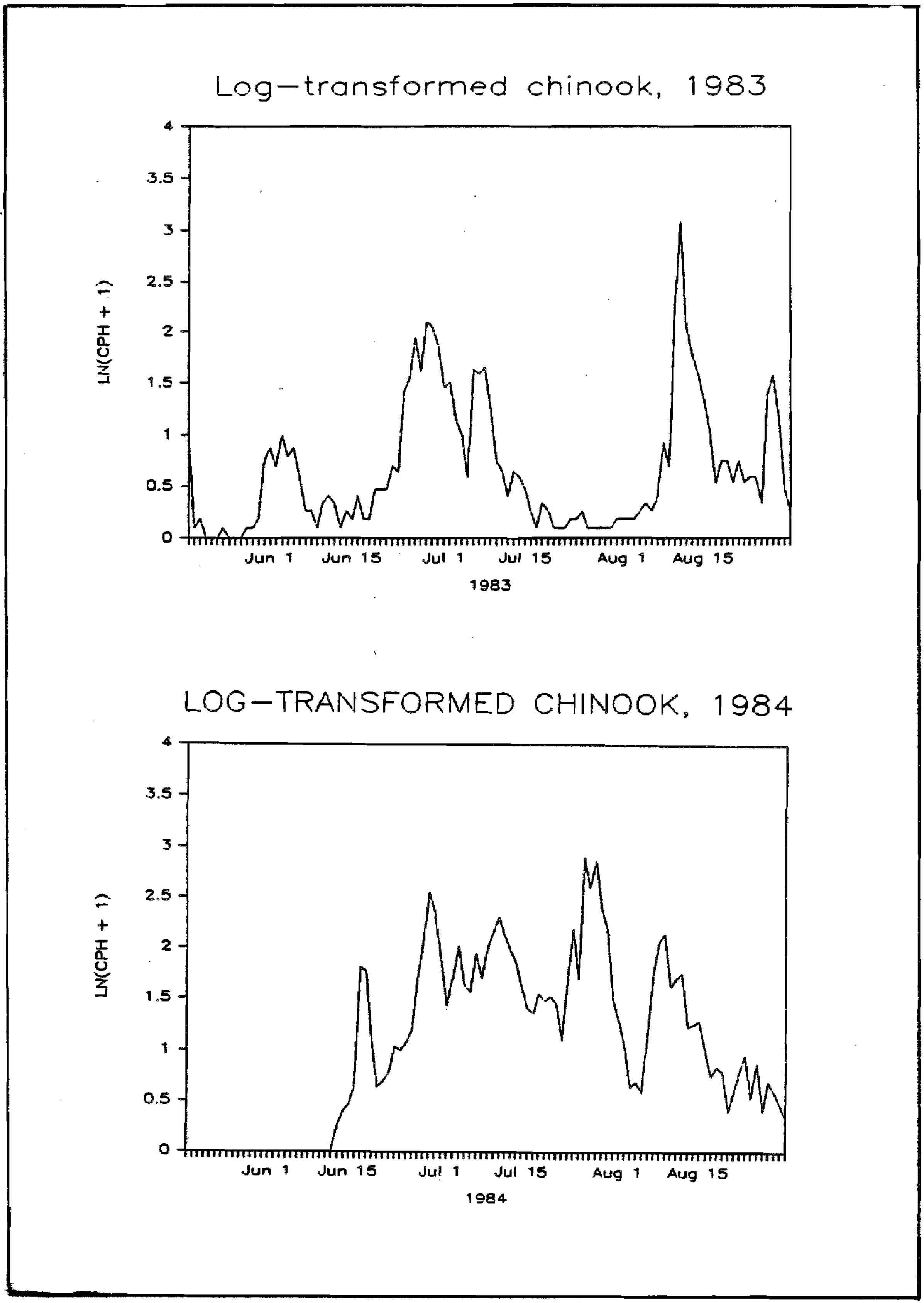
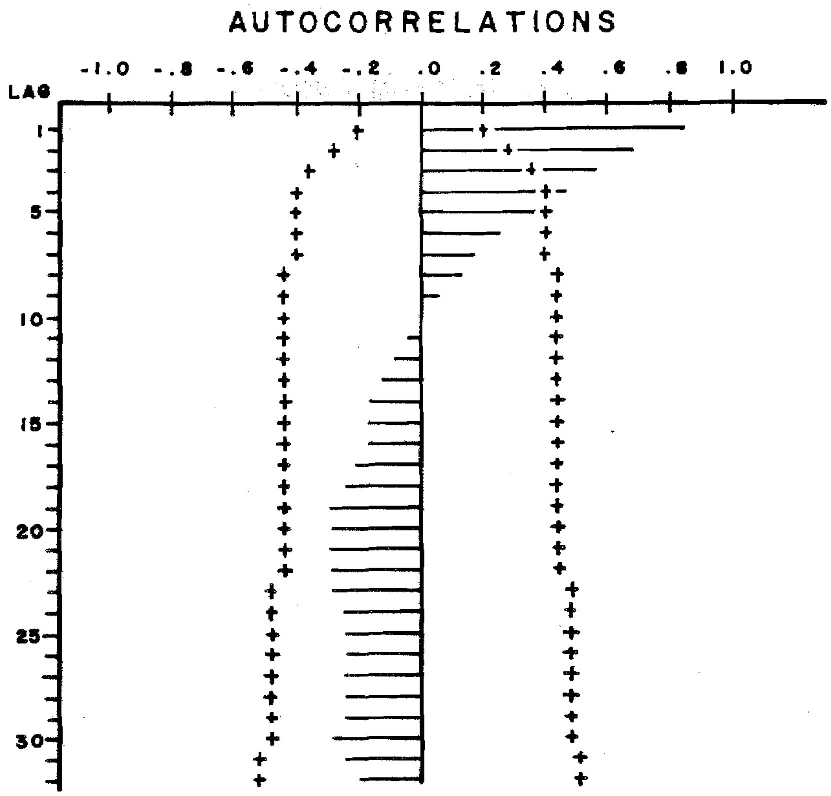


Figure 17. Log-transformed age 0+ chinook salmon outmigration rate, 1983 and 1984.



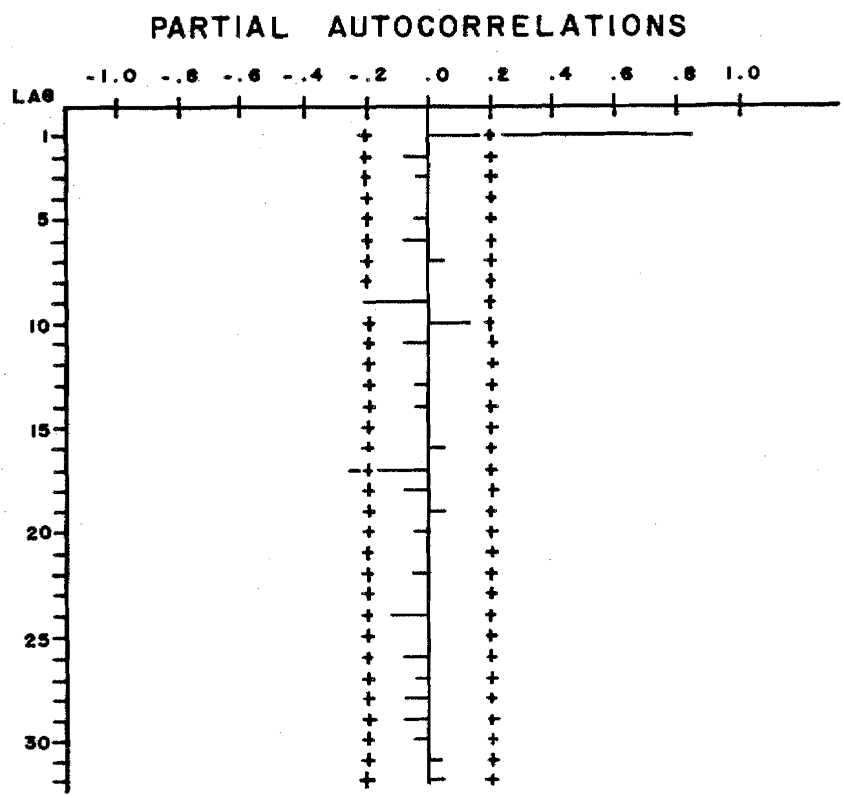
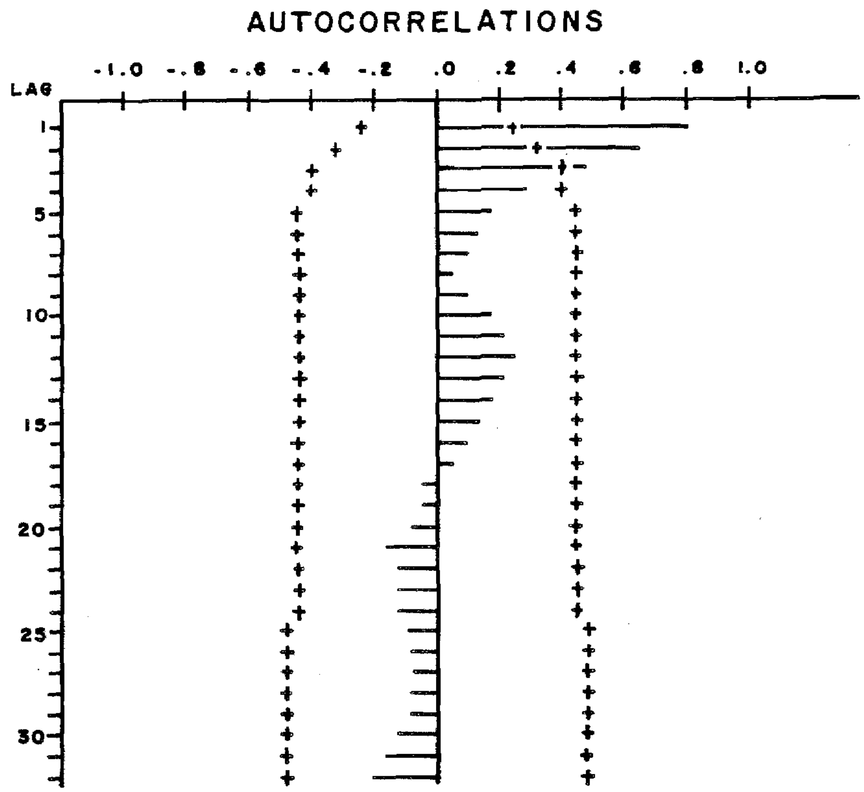


Figure 18. Plots of autocorrelations and partial autocorrelations for log-transformed 1983 chinook salmon outmigration time series.



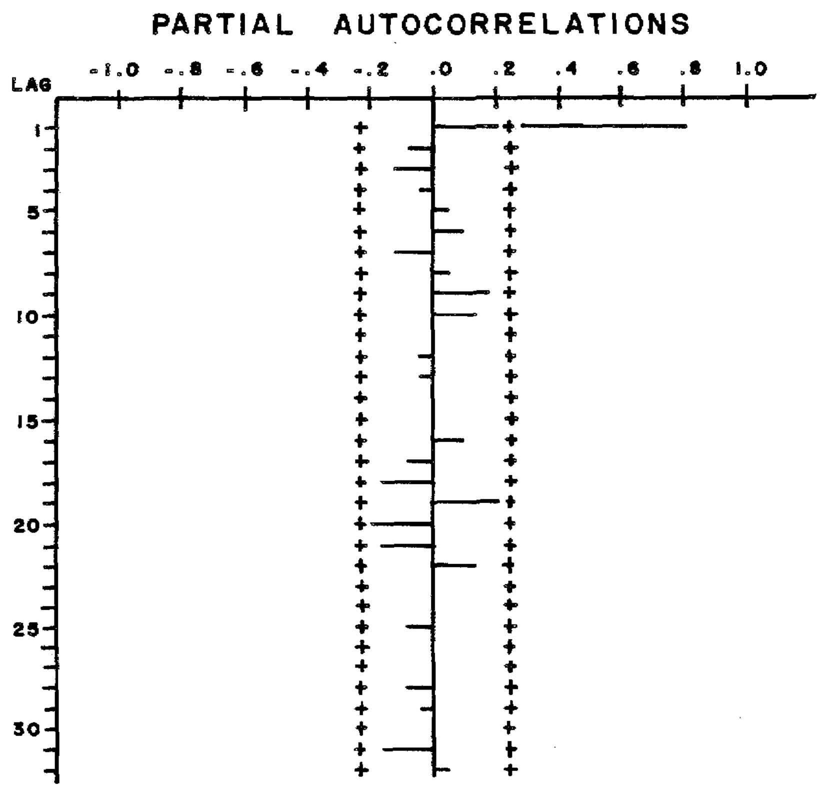


Figure 19. Plots of autocorrelations and partial autocorrelations for log-transformed 1984 chinook salmon outmigration time series.

The mean of the residuals was insignificant. This model does not differ from that of 1983, except that the mean level was higher. This was a result of a higher escapement of adult chinook salmon in 1983 than in 1982.

All three of the ACF plots for chinook fry outmigration (Figs. 16, 18, and 19) had AC's after lag 18 which did not appear to decay further. This may indicate the presence of a weak non-stationary or periodic element which should be explored with subsequent data sets.

3.4. Univariate Model for Age 0+ Sockeye Salmon Outmigration

Age 0+ sockeye salmon outmigration was examined from May 23 through August 31, 1984 (Fig. 20). This time series showed a strong AR(1) component (Fig. 21), similar to that of the chinook salmon time series. However, neither an AR(1) model on the raw data or on the log-transformed data was adequate. A MA(1) component was also significant in the raw data, leading to the model:

$$y_t = 1.76 + .78\,(y_{t-1} - 1.76) - .57\,a_{t-1} + a_t$$

The standard error on $\hat{\phi}_1$ (.775) was .0681 and on $\hat{\theta}_1$ (-.567) was .0883. Although the mean of the residuals was slightly significant, none of the autocorrelations or partial autocorrelations were, so the model is reasonable.

3.5. Discharge-Turbidity Transfer Function Model

The cross correlations for the residuals from the 1983 discharge series and the 1983 turbidity series, both filtered by the ARMA(1,1) model for discharge, had a significant spike at lag = 1 day (Fig. 22). This suggested a candidate model (Box and Jenkins 1976; McCleary and Hay 1980):

$$y_t = \frac{\omega_0 B}{1 - \delta_1 B}\, x_t + N_t$$

where: y_t is the output series (turbidity)

ω_0 and δ_1 are transfer function parameters

B is the backward shift operator

x_t is the input series (discharge)

N_t is the noise component, an ARIMA model

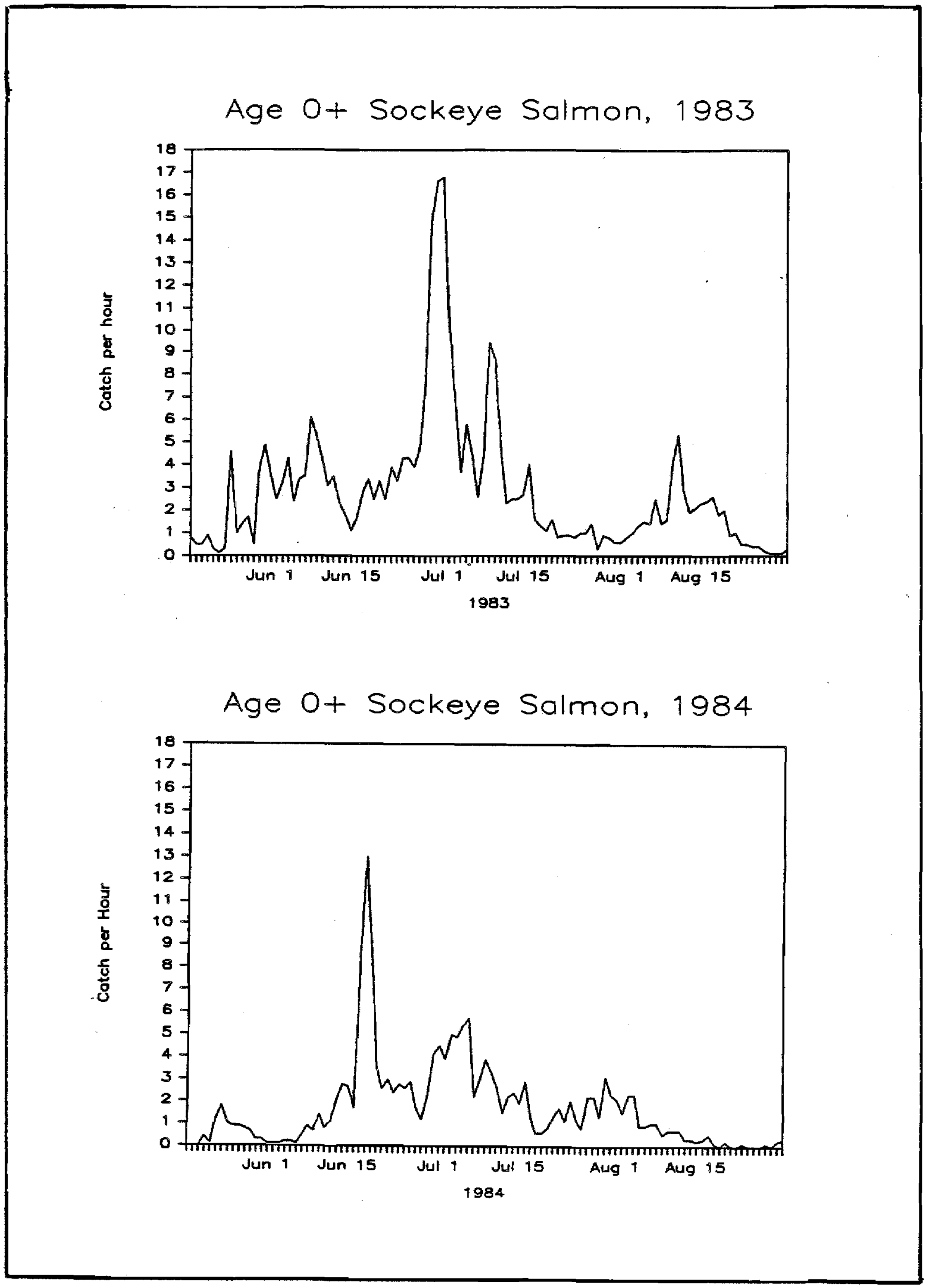


Figure 20. Age 0+ sockeye salmon outmigration rate time series, 1983 and 1984.

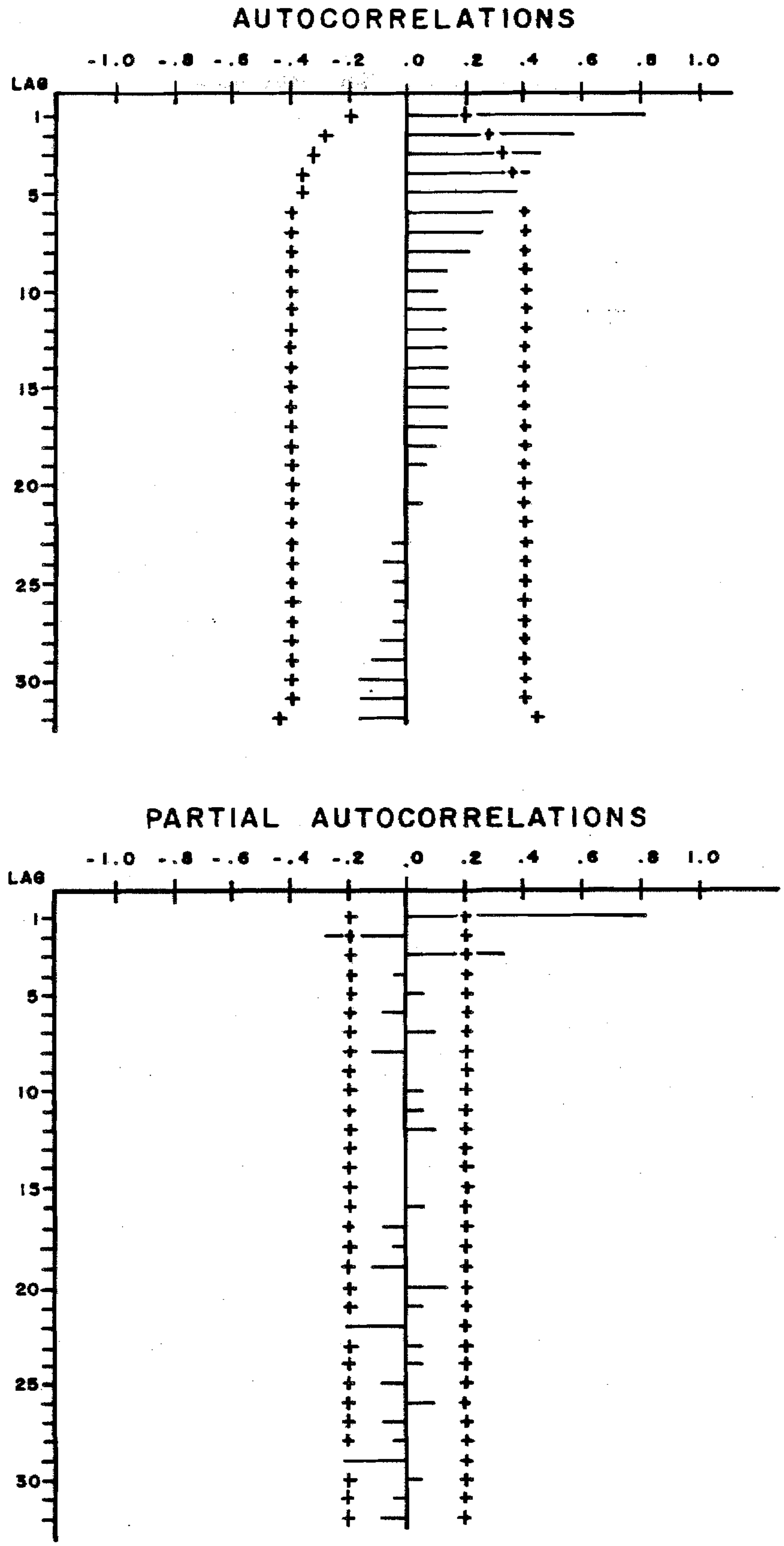


Figure 21. Plots of autocorrelations and partial autocorrelations for 1984 sockeye salmon outmigration time series.

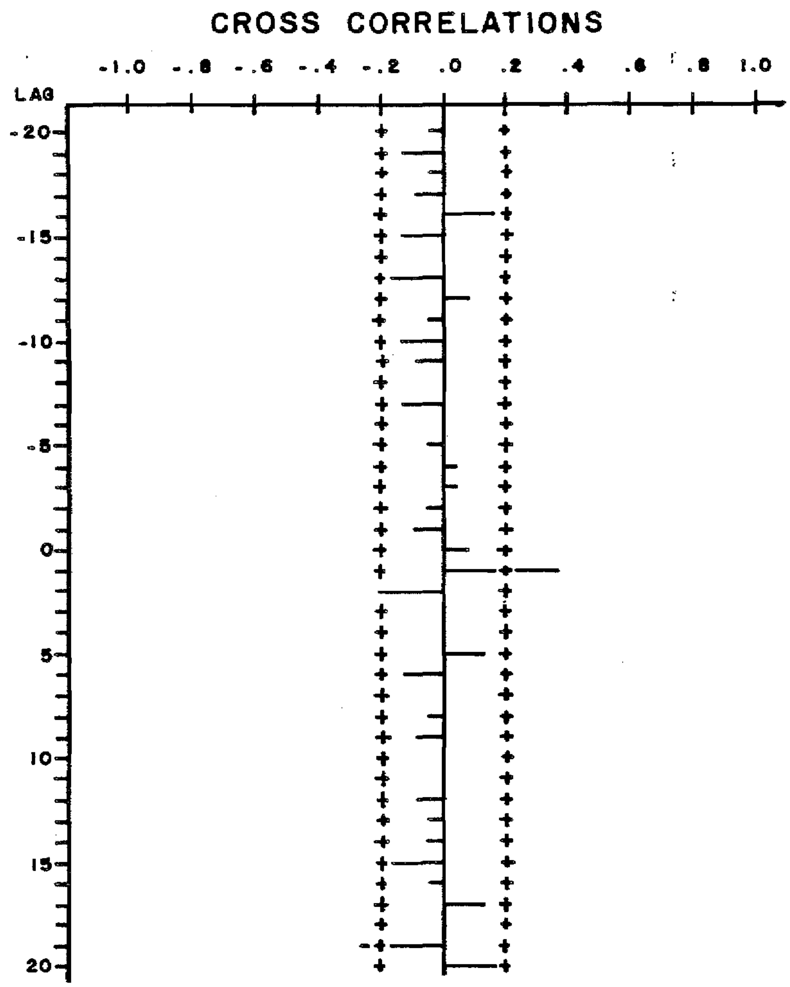


Figure 22. Plot of cross correlations between the residuals of the ARMA (1,1) discharge model and the prewhitened turbidity time series, 1983 data.

The assumption that the ARIMA component of the model was white noise led to significant AC's in the residuals series and was therefore rejected. The ACF and PACF plots on the residuals from this model suggested an AR(1) model for the N_t component, leading to the full model:

$$y_t = \frac{\omega_0 B}{1 - \delta_1 B} x_t + \frac{a_t}{1 - \phi_1 B}$$

Parameter estimates were:

$\hat{\omega}_0$ = 8.349 with std. error of 1.7044

$\hat{\delta}_1$ = -0.559 with std. error of 0.1718

$\hat{\phi}_1$ = 0.993 with std. error of 0.0009

The t statistic for each of these estimates was significant, leading to the conclusion that discharge and turbidity are related by the equation:

$$y_t = \frac{8.35\, B}{1 + .56\, B} x_t + \frac{a_t}{1 - .99\, B}$$

The ACF and PACF plots on the residuals from this model showed no significant spikes; therefore, the model is adequate.

3.6. Discharge-Chinook Transfer Function Model

After both the input series (discharge) and the output series (chinook salmon outmigration rate) from 1983 were filtered by the ARMA(1,1) model for the discharge series and the residuals from both series were cross correlated, there was a significant correlation at lag = 1 day (Fig. 23). This suggested the transfer function model, as given by McCleary and Hay (1980):

$$y_t = \omega_0 x_{t-1} + N_t$$

or, using the backward shift notation of Box and Jenkins (1976):

$$y_t = \omega_0 B x_t + N_t$$

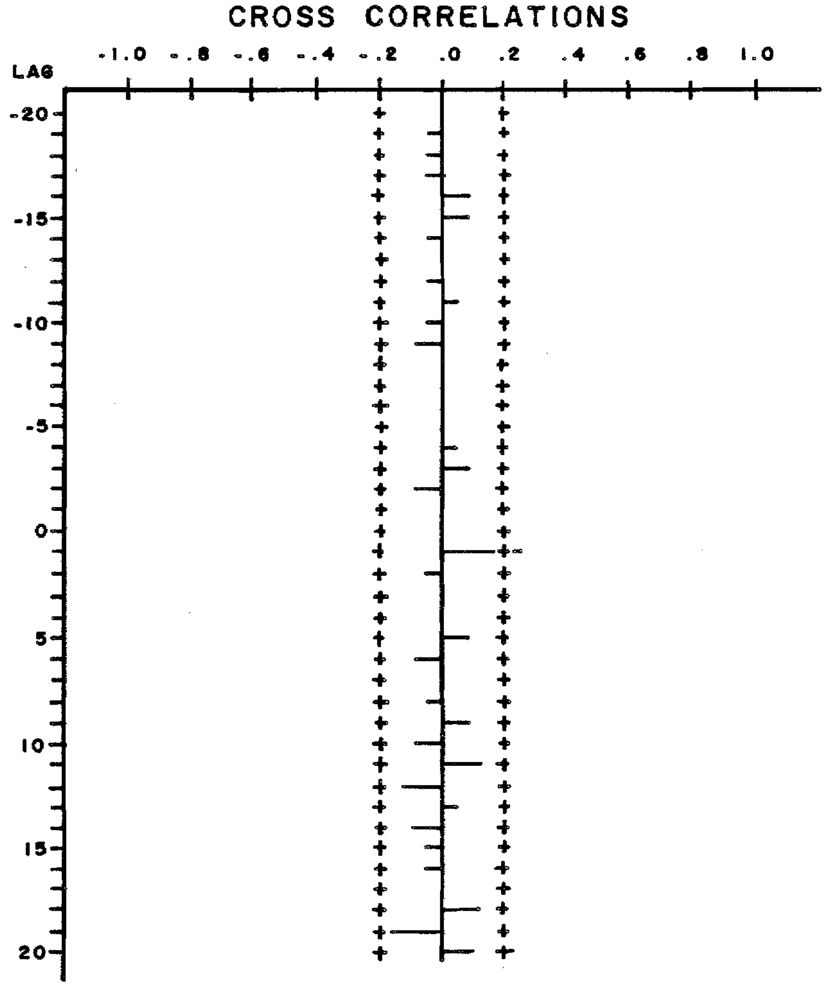


Figure 23. Plot of cross correlations between the residuals of the ARMA (1,1) discharge model and the prewhitened chinook salmon outmigration time series, 1983 data.

This model implies that the current day's discharge rate has an effect on the next day's outmigration rate. The estimate of ω_0 was 0.02. The residual ACF using this model suggested that the assumption of white noise for the N_t component was not valid; it appeared that an ARMA(1,0) model would be appropriate. The full model is:

$$y_t = \omega_0 B x_t + \frac{a_t}{1 - \phi_1 B}$$

The parameters for this model were estimated as:

$\hat{\omega}_0$ = .025 with std. error of .0249

$\hat{\phi}_1$ = .667 with std. error of .0751

The t statistic on the estimate for ω_0 was not significant. However, because the practice of prewhitening the output series with the model for the input series tends to underestimate the significance of the results (Botsford et al. 1982) and because there was a significant cross correlation between discharge and outmigration rate at a lag of one day, it seemed best to leave this term in the model. This would have to be verified with more years of data. The model is:

$$y_t = .025\, B\,(x_t) + \frac{a_t}{1 - .67\, B}$$

The ACF and PACF for the residuals from this model showed no significant spikes so we may conclude that the model is adequate.

This model does not imply that the discharge series is a strong predictor for the outmigration series. But adding discharge does result in an expression which has more predictive value than would be obtained by looking at the outmigration series by itself.

3.7. Discharge-Sockeye Transfer Function Model

As with the discharge-chinook relationship, the cross-correlations of the 1984 discharge and sockeye series, filtered by an ARMA(1,1) model for discharge, showed a significant spike when the sockeye series was lagged one day behind the discharge series (Fig. 24). This spike was stronger for sockeye than it was for chinook. A candidate model (Box and Jenkins 1976; McCleary and Hay 1980) was:

$$y_t = \frac{\omega_0 B}{1 - \delta_1 B} x_t + N_t$$

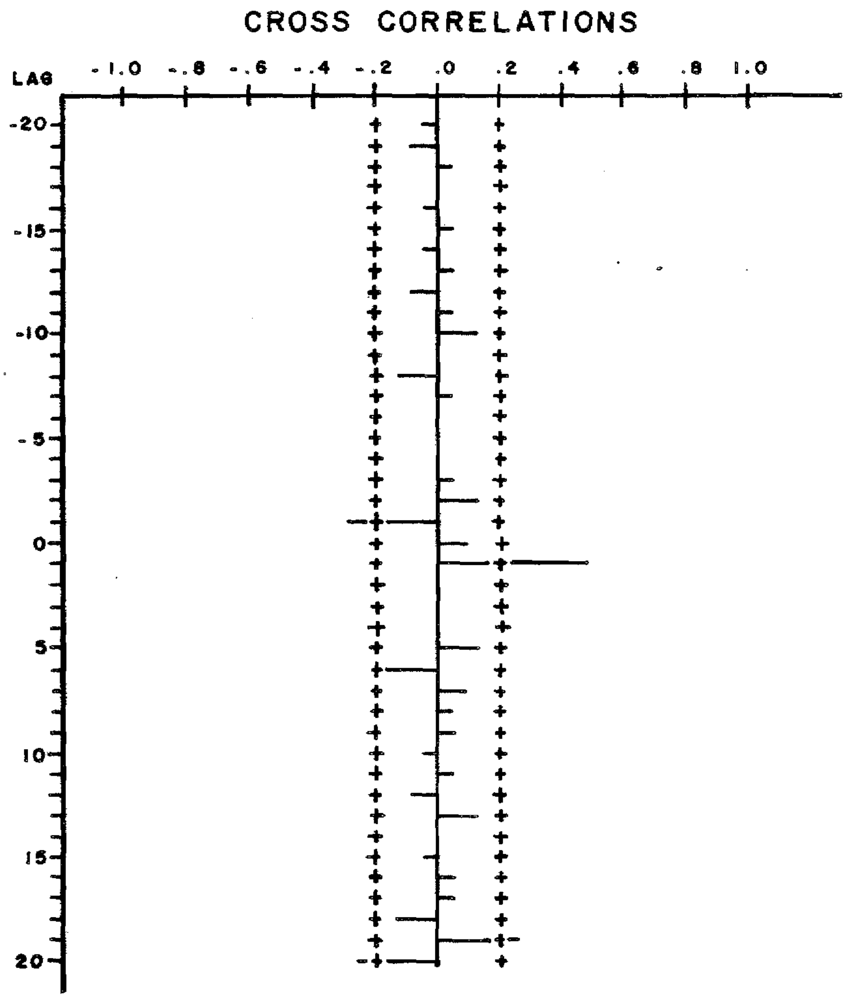


Figure 24. Plot of cross correlations between the residuals of the ARMA (1,1) discharge model and the prewhitened sockeye salmon outmigration time series, 1984 data.

The ACF and PACF plots on the residuals from this model suggested an ARMA(1,1) model for the N_t component, leading to the full model:

$$y_t = \frac{\omega_0 B}{1 - \delta_1 B} x_t + \frac{(1 - \theta_1 B)}{(1 - \phi_1 B)} a_t$$

Parameter estimates were:

$\hat{\omega}_0$ = .206 with std. error < .00005

$\hat{\delta}_1$ = -.190 with std. error .1848

$\hat{\phi}_1$ = .952 with std. error .0483

$\hat{\theta}_1$ = -.318 with std. error .1078

The t statistic for each of these estimates except $\hat{\delta}_1$ was significant, giving:

$$y_t = .21 B (x_t) + \frac{(1 + .32 B)}{(1 - .95 B)} a_t$$

where x_t = discharge X 10^{-3}

The ACF and PACF plots on the residual series from this model showed no significant spikes and the mean of the residuals was barely significant; therefore, the model is deemed adequate.

4.0 DISCUSSION

Time series analysis is a useful method for dealing with time ordered data sets, including ones that do not appear to make much sense at first glance because they are too noisy or because they drift as a result of random events. The modeling effort helps us to understand why the plots look as they do and what factors shape them. It also is useful in trying to understand what effect a change in the controlling factors might produce.

The influence of discharge level on turbidity and chinook and sockeye salmon outmigration is clearly seen upon inspection of Fig. 2 and Fig. 3. Of course, these latter three series are shaped by several factors other than discharge, so the correlation coefficient between them and discharge is not normally expected to be high, unless a relatively short section is examined. For example, the discharge peak in early June of 1983 is reflected in the other three series (Fig. 2). The bimodal discharge peak in August of 1983 is reflected in the turbidity and the chinook outmigration series, but only the first August peak is shown by the sockeye outmigration series. This was because most age 0+ sockeye salmon in the reach above the traps had left by the middle of August. Similarly, the late August discharge spike in 1984 had no effect on the sockeye series (Fig. 3). However, the high discharge peak in mid June of 1984 is strongly reflected in the sockeye series because this was a time when many age 0+ sockeye salmon were present in the reach.

Another example of a change in the relative effect of a discharge spike is shown by the 1984 chinook salmon series. The high discharge peak is mid-June had less effect on chinook outmigration than did the lower discharge peak in late July, a time when more age 0+ chinook fry were ready, because of physiological and behavioral reasons, to outmigrate.

The segments of the time series examined (discharge, turbidity, chinook and sockeye salmon outmigration) were described by relatively simple Box-Jenkins models, using mostly first-order terms. The usefulness of Box-Jenkins models is shown by the relative simplicity of the models developed for the salmon outmigration series; a visual inspection of the plots of the raw data for these series (Figs. 15 and 20) gives the impression of an erratic series of events. None of the series appeared to require differencing (although turbidity was on the borderline) to achieve stationarity nor did they appear to have a periodic component (discharge being a possible exception) which would require seasonal differencing. However, this should be re-examined when subsequent seasons of data are available. All of the series showed a strong first order autoregressive term, indicating that the value for any one day is greatly influenced by the value for the previous day. Similar results for the flow regimes of several streams in Australia was reported by Srikanthan et al. (1983), who found that most of the discharge series which were not white noise had a first order autoregressive term.

Examination of the autocorrelation coefficients of the four time series at lag = 1 day (adjacent values) gives an idea of the smoothness of the time series. Typically, the coefficient for physical/chemical variables is higher than that of biological variables and the time series for discharge (Fig. 4) and turbidity (Fig. 11) are less jagged than those for chinook salmon outmigration rate (Fig. 15) and sockeye salmon outmigration rate (Fig. 20). Saila et al. (1972) reported similar results for the autocorrelations of alewife upstream migration activity in relation to incident solar radiation and water temperature.

The square of the autocorrelation coefficient at lag = 1 gives a measure of the percentage of the variance of the value for today which is explained by what was measured yesterday (Murray and Farber 1982). In 1983, $(.86)^2 = 74\%$ of the variance of discharge for one day was explained by the value for discharge on the previous day. The percentage for turbidity was $(.92)^2 = 85\%$ while, for chinook salmon outmigration rate, it was only $(.66)^2 = 44\%$, and, for sockeye salmon, $(.65)^2 = 42\%$.

So, although fish tend to move in pulses more so than water or suspended sediments, fish outmigration is far from being a random event. That is, when an outmigration pulse occurs, the impetus has affected many fish and the phenomenon extends over a three or four day period. When we look at an outmigration time series, we are seeing the integrated results of several factors operating on sub-groups of the population in different locales. The fry in one slough may have emerged two weeks earlier than those of another slough because of a higher intragravel temperature. Or the head of one slough may have overtopped at a lower discharge level than the head of another slough, thus providing an environmental cue to the two groups at different points in time. But there is also a behavioral effect in that fry are stimulated to migrate when they see other fry migrating. This is particularly true for those species that form schools during outmigration.

The turbidity time series was the only one examined which included a second order term. The second order moving average term is likely related to the random "shock" caused by a rising discharge (which is in turn caused by rainfall) which resuspends sediment. It takes a few days after the rainfall is over for this perturbation in turbidity level to drop to the pre-rainfall level.

The discharge-turbidity transfer function model does not necessarily imply that discharge level is a strong causal factor for turbidity. These two variables are correlated largely because when glacial melting is high, both discharge and turbidity are high. This phenomenon provides the seasonal trend of the two series; the discharge of clear water tributaries such as Portage Creek and Indian River (which increases discharge but not turbidity) is a noise component. However, discharge does in fact have some direct causal effect on turbidity by resuspending sediments and other particles during a rapid rise in discharge level. Certainly turbidity is not a cause of discharge, so it makes sense to take discharge and noise as the input and turbidity as the output of a transfer function model. The value of the model is that it allows levels of turbidity for a few days ahead to be predicted from past values of both turbidity and discharge.

Turbidity level after the dams begin operation will not only be influenced by a changed discharge regime, but will also be directly changed by the dams because of settling of suspended sediments in the reservoir.

By building Box-Jenkins models for these four time series, a better understanding of the processes which control these variables was developed in that the structure of the random processes which generate an observed series has now been specified. Also, we have statistically described the natural time series as a baseline against which future changes can be assessed. This description of the discharge and turbidity regimes is important not only because of their effects on salmon outmigration, but also because of their effects on other life stages and species. It is important to explore the effect on salmon outmigration of a construction project which will change the basic rules, that is, change the underlying physical processes. Whereas the present discharge regime can be described as a mixed first order autoregressive and moving average process, the discharge regime under a post-project scenario could include entirely different terms.

An important point is that the underlying processes (the autoregressive and moving average components) were essentially the same in 1983 and in 1984 even though the actual time series, or "realizations," looked very different between the two years. This was true for both discharge and for chinook salmon outmigration; only a single year of turbidity and sockeye salmon outmigration was examined. Even though the discharge peaks do not match between the two years and the mean levels between years may have been different, the process which generated these peaks in both years was the same and can be described by an ARMA(1,1) model with similar parameter estimates for both years.

In a sense, the proposed dams would operate like a gigantic low pass filter on the discharge regime, dampening out the high frequency perturbations and letting the low frequency (annual cycle) events pass, but at a reduced amplitude. In other words, there are two effects of introducing a reservoir into this system: 1) the day-to-day changes in discharge would be smoothed and 2) the general discharge level would be higher than normal in winter and lower than normal in summer. However, this is an oversimplification because a new element would be present if the dams are built - namely, power demand. Power demand is not in phase with the natural discharge fluctuations, so dam operation to accommodate power demand will change the mechanisms which generate the current discharge regime.

The important question is, how would the salmon outmigration rates be affected if these discharge spikes were not present, as with a dam-regulated discharge regime? Further, what effects would these changes have on the population survival rate? Relatively high levels of discharge, and possibly four or five day peaks, in the late spring and early summer may be necessary to facilitate normal outmigration timing of juvenile salmon. On the other hand, very high discharge levels at this time of year, which occur naturally, may be harmful to juvenile chinook salmon if these floods displace the fry downstream from what would otherwise be their rearing areas.

Time series analysis is a statistical tool which has many potential applications to the Susitna River Aquatic Studies Program. It would be useful to build Box-Jenkins models for the 36 year record of discharge at Gold Creek gaging station. Because this information is continuous, it can be digitized as monthly, weekly, daily, or even hourly means. Turbidity, temperature, and dissolved gas time series could also be modeled in this manner. Developing time series models for the proposed post-project discharge regime to see whether the post-project discharge regime is also an ARMA(1,1) process would be informative in assessing dam-related effects. Intervention analysis, which is an extension of Box-Jenkins models concerned with a natural or human caused change to a system, would be an appropriate method to use (Box and Tiao 1975; Hipel et al. 1978; Thompson et al. 1982). One could determine if the intervention (construction of the dams) would have a significant effect on the time series processes. This method has been used to model the effects of the Aswan dam on the Nile River and of the Gardiner dam on the South Saskatchewan River in Canada (Hipel et al. 1978). Before and after mean levels can not be compared using normal analysis of variance because the observations are serially correlated.

Developing forecast models for the annual return of adult salmon or the annual total number of outmigrants would be an excellent use of time series analysis. The adult salmon return of a particular year is strongly related to the return of the previous year (that is, when catch is high one year, it tends to be high for several years) and there is probably a periodic component based on strong year classes. With such a model, one could predict the size of next year's adult salmon return, a piece of information which would be very useful to both fishery and hydroelectric dam managers. However, the time series of adult salmon return to the Susitna River is not long enough (only seven or eight years of data) to develop Box-Jenkins models. A minimum of about 40 or 50 observations is necessary (McCleary and Hay 1980; Huff 1983), although the method has been applied by Jensen (1985) to fish catch data with as few as 32 observations. The annual abundance of adult chinook and coho salmon in the California marine fishery has been successfully examined with time series analysis by Botsford et al. (1982) and Peterman and Wong (1984) have looked at sockeye salmon cycles in British Columbia and Bristol Bay. For the present, analysis of salmon time series in the Susitna River will have to be restricted to daily rates of a single year.

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7.0 BOX-JENKINS ARIMA AND TRANSFER FUNCTION MODELS

Box-Jenkins models can be summarized as follows (Box and Jenkins 1976; McCleary and Hay 1980; Chatfield 1984). Suppose there is a time series y_t, $t = 1..N$. Then y_t is a moving average process of order q (or an MA(q) process) if

$$y_t = \theta_0 a_t + \theta_1 a_{t-1} + \theta_2 a_{t-2} + \ldots + \theta_q a_{t-q}$$

where θ_i are constants and $\theta_0 = 1$. The term a_t is a white noise process. White noise consists of a series of random shocks, each distributed normally and independently about a zero mean with a constant variance. The series y_t is an autoregressive process of order p (or an AR(p) process) if

$$y_t = \phi_1 y_{t-1} + \phi_2 y_{t-2} + \ldots + \phi_p y_{t-p} + a_t$$

where ϕ_i are constants. This is similar to a multiple regression model except that y_t is regressed not on independent variables but on past values of itself. A first order autoregressive process, AR(1), has the form:

$$y_t = \phi_1 y_{t-1} + a_t$$

Box and Jenkins (1976) define a backward shift operator B as:

$$B^m(Y_t) = Y_{t-m}$$

For m = 1,

$$BY_t = Y_{t-1}$$ or, the previous value.

Using B, the AR(1) equation can be written:

$$y_t = \frac{a_t}{1 - \phi_1 B}$$

Time series resulting from a mixture of AR and MA processes are called ARMA(p,q) models and have the form:

$$y_t = \phi_1 y_{t-1} + \ldots + \phi_p y_{t-p} + a_t + \theta_1 a_{t-1} + \ldots + \theta_q a_{t-q}$$

Using the backward shift operator B, an ARMA (1,1) may be written as:

$$y_t = (1 - \phi_1 B)^{-1} (1 - \theta_1 B) a_t$$

ARMA (p,q) models are appropriate only when the time series is stationary. Stationary in an ARMA model means that there is no systematic change in the mean or the variance over time and that there are no strictly periodic variations (Chatfield 1984); in other words, the mean, variance, and autocovariance are not dependent on time. Time series which are not stationary can sometimes be handled by "differencing" the series. Taking the difference of adjacent values gives a differencing order, d, of one:

$$\nabla^d Y_t = Y_t - Y_{t-d} \quad , \quad d = 1$$

Such models are said to be "integrated" and are denoted by ARIMA(p,d,q) where p is the order of the autoregressive component, d is the order of differencing, and q is the order of the moving average component.

Time series with seasonal variations, such as would occur in a multiple year series of daily water temperature measurements, can be made stationary by seasonal differencing. For example, the value for April 15 of one year is subtracted from the value for April 15 of the following year, and so on for all days of the year.

It has been assumed above that the time series had a mean value of zero. With stationary time series which have a non-zero mean, the mean has to be subtracted from every y_i term. For example, the form of an AR(1) model would be:

$$y_t = \mu + \phi_1 (y_{t-1} - \mu) + a_t$$

The autocorrelation function plays a major role in identifying and building time series models. A regular correlation coefficient measures the correlation between N pairs of observations on two variables. The autocorrelation coefficient is somewhat similar except that it measures the correlation between all observations of the same variable at a given distance apart in time (that is, between Y_t and Y_{t-k} for all values of t, where k = time lag). Also, the covariance is estimated only over N-k pairs of observations (McCleary and Hay 1980). Autocorrelation coefficients at different lags indicate the extent to which one value of the series is related to previous values and can be used to evaluate the duration and the degree of the "memory" of the process. The autocorrelation function (ACF) is the set of autocorrelation (AC) coefficients at different lags associated with a time series; a plot of the ACF is called a correlogram (Chatfield 1984).

The ACF is defined as:

$$ACF_k = \frac{\text{covariance}(Y_t, Y_{t+k})}{\text{Variance}(Y_t)}$$

and is estimated by:

$$ACF_k = \frac{\sum_{t=1}^{N-k} (Y_t - \bar{Y})(Y_{t+k} - \bar{Y})}{\sum_{t=1}^{N} (Y_t - \bar{Y})^2} \cdot \frac{N}{N-k}$$

A partial autocorrelation (PAC) coefficient measures the excess correlation at lag k which is not accounted for by an autoregressive model of order k-1. The set of PAC's at different lags associated with a time series is called the partial autocorrelation function (PACF).

There are three steps in developing an ARIMA model: model identification, parameter estimation, and diagnostic checking (Box and Jenkins 1976). ARIMA model building is an iterative process. The first thing to do is to look at a plot of the time series. Time series that are not stationary must be made so by trend removal which can be accomplished by such methods as differencing the series or by polynomial (or other) regression. Examination of the autocorrelation function (ACF) and the partial autocorrelation function (PACF) of a stationary series helps to identify a possible ARIMA model. The next step is to estimate the parameters of the model and again examine the ACF and PACF plots, this time on the residuals from the model. This process is repeated until the residuals show no significant AC's or PAC's at any lag, which indicates that the residuals consist of only a white noise process.

When there is an independent variable which is also a time series, a transfer function model can be developed. This model consists of the transfer function component from the independent variable as well as the ARIMA component (or noise component) from the dependent variable (McCleary and Hay 1980) and can be represented as:

$$Y_t = f(X_{t-b}) + N_t$$

where: Y_t is the output time series

X_t is the input time series

$f(X_{t-b})$ is the transfer function component

N_t is the noise or ARIMA component

Transfer function models can be bivariate (when there is one independent variable) or multivariate (more than one independent variable).

The steps to take in developing a transfer function model (Box and Jenkins 1976; McCleary and Hay 1980; Dixon et al. 1981) are: (1) develop an ARIMA model for the input series, obtaining the pre-whitened input (residuals), (2) filter the output series by the model for the input series, (3) cross-correlate the residuals from the first two steps, (4) identify the form of the transfer function component from the cross correlation function, (5) assuming the errors are white noise, estimate the values for the parameters, (6) identify an ARIMA model for the residuals, (7) if the ARIMA component is not white noise, combine the ARIMA component with the transfer function component to form a new model, (8) estimate the parameter values, and (9) examine the ACF and PACF plots on the residuals from the new model to see if the model is adequate.

PART 2

The Relative Abundance, Distribution, and Instream Flow Relationships of Juvenile Salmon in the Lower Susitna River.

THE RELATIVE ABUNDANCE, DISTRIBUTION, AND INSTREAM FLOW RELATIONSHIPS OF JUVENILE SALMON IN THE LOWER SUSITNA RIVER

Report No. 7, Part 2

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ABSTRACT

Juvenile salmon abundance and distribution were studied in the lower Susitna River (below the Chulitna River confluence) and juvenile salmon rearing habitat was modelled at 20 sites within the reach. Chinook, chum, and sockeye salmon juveniles made use of side channels; however, high turbidity limited use of side channels located in the Chulitna River plume. Coho salmon juveniles were found primarily in tributary mouths; sockeye, chinook, and chum salmon also were present in these areas. Sloughs, which were limited in occurrence, were not used heavily by any of the salmon species.

Both tributary mouths and side channel/slough sites were modelled using one of two habitat models. At tributary mouths, an increase in weighted usable area with a rise in mainstem discharge resulted from the formation of backwater areas which led to lower velocities and an expansion of the area and amount of cover inundated. At side channels, chinook weighted usable area increased after overtopping due to a gain in cover suitability (turbidity), velocity, and area. The weighted usable area response to a rise in mainstem discharge for sockeye and chum salmon juveniles at side channels was also usually positive. Habitat indices at side channels for chinook, chum, and sockeye juveniles at mainstem discharges and side channel flows above the overtopping discharge declined as velocities became unsuitably high. Weighted usable area for these species did not always decline at high discharges, however, because of the compensating effect of a larger surface area.

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1.0 INTRODUCTION

The Susitna River Aquatic Studies Program juvenile anadromous distribution and abundance studies initiated during 1981 and 1982 outlined the general distribution patterns of juvenile salmon and their habitat utilization within the Susitna River (ADF&G 1981a, 1981b, 1983a, 1983b). The 1982 studies also investigated the response of selected areas to mainstem discharge changes and demonstrated species differences in the use of "hydraulic zones" (ADF&G 1983c). These zones were subsections of slough and tributary mouth areas. Some zones were affected by mainstem backwater, other zones were above the backwater, and other zones included mixing areas of the mainstem with slough or tributary flow. The relative use of the hydraulic zones by each species of juvenile salmon was analyzed to provide an incremental index of habitat availability at each site for each species. This analysis provided evidence that the relative use by juvenile salmon of these sites was affected by changes in mainstem discharge. Also, the distribution of juvenile salmon suggested certain microhabitat factors within the zone such as turbidity and the amount of instream cover responded to discharge changes at a higher rate than did zone surface area.

Studies conducted during the 1983 open-water season concentrated on the instream flow relationships of juvenile salmon in the middle reach of the Susitna River between the Chulitna River confluence and Devil Canyon (Schmidt et al. 1984). Suitability criteria for juvenile salmon were developed and these were used in two types of habitat models to model the site-specific response of juvenile salmon habitat to variations in mainstem discharge. Additional information was gathered on juvenile salmon abundance and distribution in the middle reach.

The 1983 studies suggested that juvenile chinook salmon made heavy use of mainstem side channels and used the turbid water in these areas as cover. Juvenile coho, chum, and sockeye salmon tended to occupy areas that were less influenced by mainstem flow.

In the Susitna River below the Chulitna River confluence (lower river), the braided nature of the river and lower gradient provides large amounts of potential side channel habitat for juvenile salmon. A study plan was formulated, therefore, to examine juvenile salmon distribution and the usability of different morphological components of the lower Susitna River for juvenile salmon during the 1984 open-water season. The results of these studies, which include the responses of rearing juvenile salmon and their habitat within these morphological components to variations in mainstem discharge, are detailed in this paper. These results will be integrated with responses of side channel and slough complex wetted surface areas to variations in mainstem discharge in order to estimate the response of juvenile salmon habitat in the lower river to flow regulation.

Large scale aerial mapping of lower Susitna River side channel and slough complex changes in area with variations in mainstem discharge has been done by Ashton and Klinger-Kingsley (1985). Habitat types identified in the mapping included tributaries, tributary mouths, side sloughs, primary side channels, secondary side channels, clearwater areas, and turbid backwaters. Tributaries, tributary mouths, and side sloughs were defined as in the middle river by Klinger and Trihey (1984). Primary side channels have characteristics similar to the mainstem in the middle river and therefore offer little potential habitat for juvenile salmon and are not discussed in this report. Turbid backwaters are unbreached channels which contain turbid water from being overtopped at higher mainstem discharges and therefore are a transitional habitat type between secondary side channels and side sloughs or clearwater areas. Turbid backwaters are not addressed in this report but their habitat values are probably similar to barely breached side channels. Clearwater areas were also not sampled but are thought to have habitat value similar to that of side sloughs.

The major emphasis of this report is the evaluation of juvenile salmon use of secondary side channels and their related habitat values. Some of the larger secondary side channels are considered primary side channels at higher mainstem discharges. Juvenile salmon use of tributary mouths and side sloughs was also evaluated. The macrohabitat evaluation data presented here will be integrated with the aerial mapping data contained in Ashton and Klinger-Kingsley (1985) in later reports to formulate the reach-wide response of juvenile salmon habitat to discharge variations.

2.0 METHODS

2.1 Field Sampling Design

Three Juvenile Anadromous Habitat Study (JAHS) field crews, composed of two biologists, examined rearing habitats used by juvenile salmon at selected side channels, tributary mouths, sloughs, and mainstem sites of the Susitna River between the Yentna River confluence (RM 28.5) and Chulitna River confluence (RM 98.5). JAHS sampling was conducted from river boats during the open-water season, with helicopter support enlisted as needed. The crews operated out of camps located on the Susitna River at the Deshka River (RM 40.6), Sunshine Station (RM 79.0), and Talkeetna (RM 97.5).

The JAHS field crews sampled three categories of sampling sites. Most of the sampling occurred at Resident Juvenile Habitat (RJHAB) model sites where the response of the site to changes in mainstem discharge was evaluated along with juvenile salmon use of the site. Crews also sampled Instream Flow Incremental Methodology (IFIM) model sites for fish distribution and abundance at which hydraulic habitat models were developed. The third category of sites, at which further data on fish distribution and habitat were gathered, were known as "opportunistic" sites. Further details on specific sampling techniques and methods used in the JAHS studies are given in earlier reports (ADF&G 1984a, 1984b).

2.1.1 Study locations and selection criteria

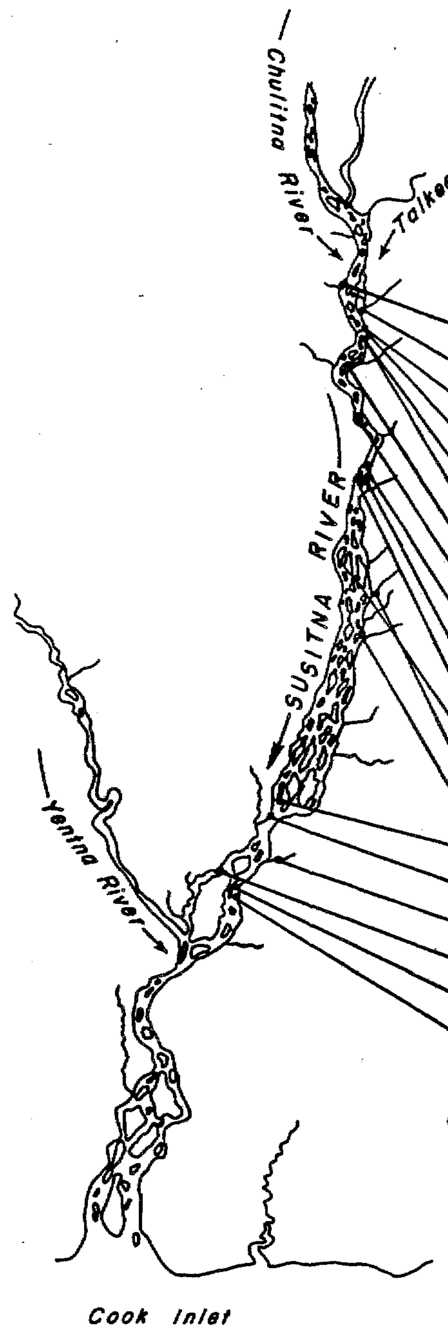
The sampling sites modelled were chosen from side channels, tributary mouths, and side sloughs, which met the following basic criteria:

A. The effects of mainstem discharge (stage and flow) on the sites are measurable.

B. The sites are documented or thought to contain potential habitat for rearing juvenile salmon. Sites with extremely high (>3 feet/sec) velocities were assumed to have little value and were not evaluated.

C. The sites are accessible by boat at normal mainstem discharges during the open-water season.

The 20 sites modelled with RJHAB and IFIM models were distributed between the Yentna River confluence and Talkeetna (Figure 1). Fourteen of the sites were modelled only with the RJHAB model, four with only IFIM models, and two with both RJHAB and IFIM models. Eight of the sites are located within slough or side channel complexes which were picked by R&M Consultants and E.W. Trihey and Associates as representative of lower Susitna River slough or side channel complexes for extrapolation purposes. For purposes of extrapolation, the side channel complex area data need to be integrated with the habitat modelling data by comparing breaching flows and channel size and type between modelled sites and individual channels within the representative complexes.



SITE	RIVER MILE	MODEL RJHAB	MODEL IFIM
Trapper Creek S.C.	91.6	X	X
Birch Slough[a]	88.4	X	
Sunrise S.C.[a]	87.0	X	
Sunset S.C.[a]	86.9		X
Beaver Dam Slough[a]	86.3	X	
Beaver Dam S.C.[a]	86.3	X	
Sucker S.C.[a]	84.5	X	
Sauna S.C.	79.8		X
Circular S.C.	75.3		X
Goose 2 S.C.	74.8	X	
Mainstem West Bank	74.4		X
Island S.C.	63.2	X	X
Caswell Creek Mouth[a]	63.0	X	
Rustic Wilderness S.C.	59.5	X	
Last Chance S.C.	44.4	X	
Bear Bait S.C.	42.9	X	
Rolly Creek Mouth	39.0	X	
Kroto Slough Head	36.3	X	
Eagles Nest S.C.[a]	36.2	X	
Hooligan S.C.[a]	35.2	X	

[a] LOCATED WITHIN REPRESENTATIVE SIDE CHANNEL OR SLOUGH COMPLEXES MAPPED BY ASHTON & KLINGER-KINGSLEY (1985).

Figure 1. Location of study sites on the lower Susitna River at which juvenile salmon habitats were modelled, June through October 1984.

Proportionately more sampling effort was expended within smaller side channels in this study because that is where potential habitat is greatest. Only a portion of the habitat modelling sites were selected to occur within the representative complexes because further data on distribution of juvenile salmon at locations throughout the lower river were desired.

Four of the sites were normally clear-water sloughs or tributary mouths while the other sites were turbid secondary side channels at normal summer flows. Secondary side channels selected for sampling ranged greatly in size, shape, and overtopping discharge. The majority of the habitat model sites selected were secondary side channels because most of the potential habitat for juvenile fish in areas of the lower Susitna River affected by the mainstem is composed of secondary side channels. Primary side channel and mainstem velocities were so high that they were not considered viable habitat.

Opportunistic sampling sites were selected by sampling crews as potential habitat which upon sampling might provide for a better analysis of fish abundance and distribution. Sites sampled were more diverse than the RJHAB and IFIM model sites and included areas within alluvial island complexes.

2.1.2 Field data collection

2.1.2.1 Resident Juvenile Habitat (RJHAB) model sites

Two types of data were collected at RJHAB model sites. Habitat data were collected for the purpose of modelling the response of the site to changes in mainstem discharge. Fish distribution data were collected for use in verifying the habitat model data, documenting abundance and distribution, and modifying suitability criteria, if necessary. A discussion of the techniques used in the collection of habitat modelling data will be followed by a discussion of methodology used in the collection of fish sampling data.

Each of the RJHAB sites was sampled within a grid consisting of a series of transects with associated sampling cells which intersect the channel of the study site at right angles (Figure 2). Grids were located so that water quality within them was uniform and so that they encompassed a variety of habitat types. Survey stakes and orange flagging were used to mark each transect within a grid. Initial measurements within each grid included distances and angles between transect bench marks. Transects were spaced from 50 to 300 feet apart in order to encompass a variety of habitat types within each grid. Aerial photos of all the RJHAB sites showing placement of all transects within each site are presented in Quane et al. (1985).

Up to four 6-by-50 foot rectangular sampling cells extending upstream from every transect within each grid were characterized by habitat measurements (Figure 2). If the top width of the wetted channel was greater than 42 feet, two of the four cells paralleled both edges of the channel and the third and fourth cells were located parallel to the shoreline cells so as to split the channel into thirds. If the channel

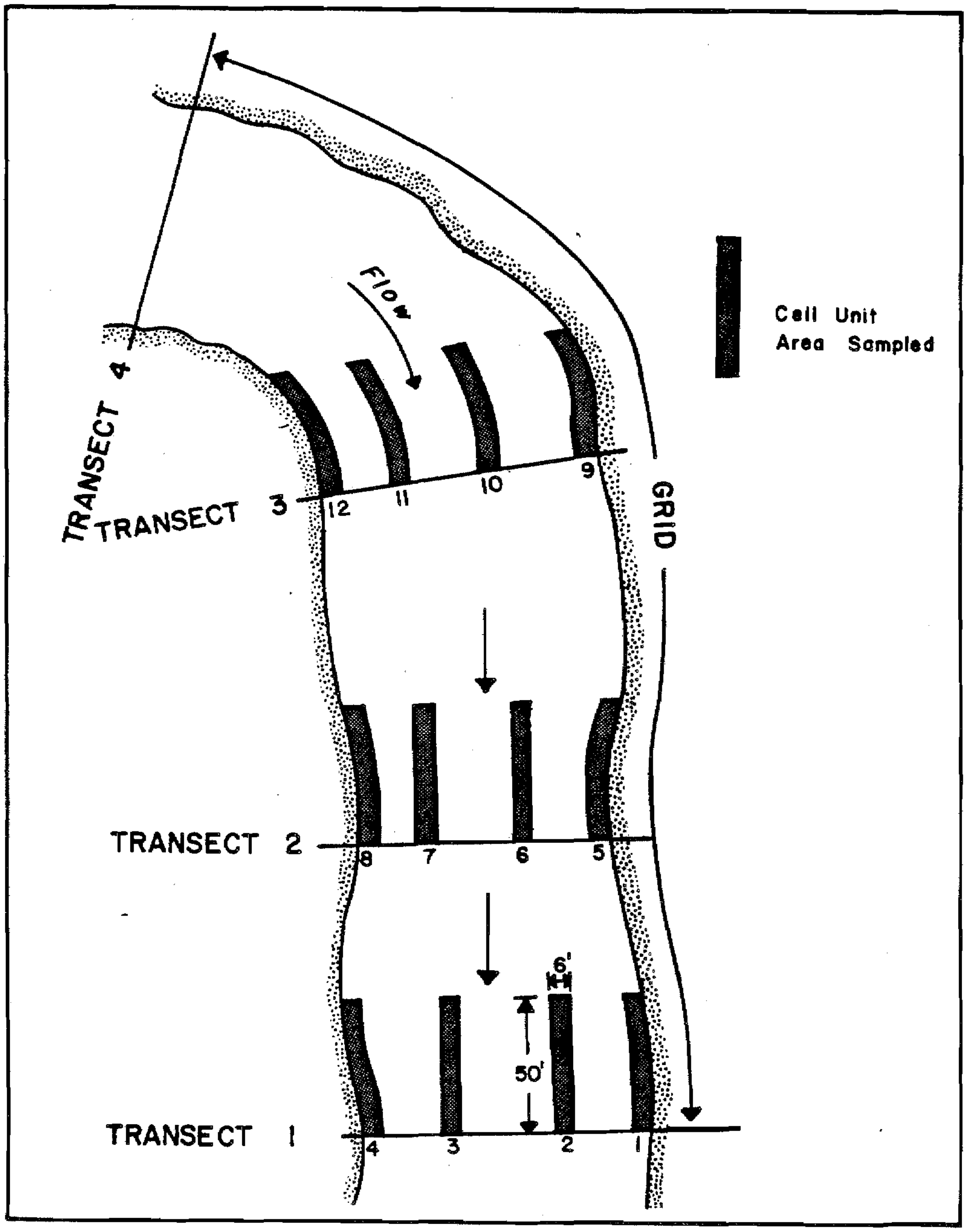


Figure 2. Arrangement of transects and sampling cells within a grid at a hypothetical RJHAB modelling site.

measured 30 to 41 feet in width at the transect, there was a cell on each shoreline of the channel and one cell located approximately mid channel. If the wetted edge was 18 to 29 feet in width, there was one cell on each side of the channel parallel with the bank. If the channel was less than 18 feet in width, there was only one cell.

Transects were numbered consecutively beginning with the transect furthest downstream within the site. Cells were also numbered consecutively from right to left looking upriver. If there were less than four cells within a transect, cells were numbered as if the missing cells were present.

One or more staff gages were installed by Aquatic Habitat and Instream Flow Project (AH) personnel at each site to document changes in the stage at each site with changes in mainstem discharge. These gages provided an index to the changes in habitat and hydraulic conditions at the site between sampling occasions. AH staff also developed mainstem stage and site flow relationships and mapped the thalweg at selected sites.

Habitat modelling data were collected over a broad range of mainstem discharges. Emphasis was placed on data collection at mainstem discharges of 30,000 to 60,000 cfs as measured at the Sunshine USGS gaging station. When staff gage readings and observations indicated that the stage at the site had changed little from a previous sampling occasion, no habitat data were taken.

Habitat data taken at each grid on a modelling occasion included the following. At each transect, the distance between the left and right edge of water and the left bank transect marker was measured. If the water quality within the grid or grids was uniform, one measurement of water pH, temperature, conductivity, and dissolved oxygen was taken. A turbidity sample was collected in a 250 ml plastic bottle and stored in a cool dark location for up to two days prior to analysis. Turbidity was measured in nephelometric turbidity units (NTU) with an HF Instruments Model No. DRT-15B field turbidometer. If the water quality within the grid appeared to vary because of mixed water sources, additional water quality and turbidity measurements were taken as necessary to describe these within grid variations.

In addition to the above measurements, each sampling cell within the grid was characterized by several habitat measurements. A representative depth and velocity were measured by taking one or more point measurements along the midline of each cell. The entire cell was walked so measurements taken were representative. A velocity measurement was taken at 0.6 of the distance from the top of the water column at one representative location for the entire cell.

Additionally, cover type and amount were estimated in each cell and coded into categories (Table 1). Aquatic vegetation was defined as aquatic plants which are normally completely submerged and do not stand upright. Emergent vegetation consisted of plants such as Equisetem sp. which normally are only partially submerged and stand upright. Overhanging riparian vegetation consisted of vegetation whose roots are submerged only at flood stage and which typically grow in moist or dry soil. Initially, the total amount of cover of all types was estimated for the entire cell. Next, the primary and secondary cover type was recorded along with a percentage of the total for each. Cover was defined as hiding or escape locations for fish less than or equal to 100 mm in total length.

Table 1. Percent cover and cover type categories.

Group #	% Cover	Group #	Cover Type
1	0-5%	1	No object cover
2	6-25%	2	Emergent vegetation
3	26-50%	3	Aquatic vegetation
4	51-75%	4	Debris or deadfall
5	76-96%	5	Overhanging riparian vegetation
6	96-100%	6	Undercut banks
		7	Gravel (1"to 3" diameter)
		8	Rubble (3" to 5" diameter)
		9	Cobble (larger than 5" diameter)

In September, when the water levels in the Susitna River were low, the cover on all the transects within each site was systematically recorded. One person did the systematic cover coding for all the sites so that between site observer bias was minimized. The cover was recorded by distance from the left bank transect marker along the transect line.

Fish distribution data were normally collected from a minimum of seven cells within each RJHAB site during each sampling occasion. Cells to be sampled were selected randomly by using a random numbers table (ADF&G 1985). If a cell was missing or could not be sampled due to high velocities or large depths, an additional cell was randomly chosen for sampling. Consequently, the sampling was not totally random. Each cell selected was then sampled for fish with one pass through the entire cell with a backpack electroshocker or beach seine. The gear type used was considered the most efficient for sampling the cell. Typically, beach seines are more efficient in turbid water while electrofishing gear is most efficient in clear water (Dugan et al. 1984). The area of the cell was recorded so that catches in cells with areas different than 300 ft^2 could be adjusted to this standard cell size. Sampling efficiency of electrofishing and beach seining was assumed to be equal.

Additional selected cells were occasionally fished at the site if sampling of the random cells failed to capture many fish because the cells had high water velocities. In this case, the sampling crew fished areas which had more suitable water velocities. Areas fished were not limited to cells on the transects. These data were pooled with the randomly selected cell data for analysis.

After each cell was sampled, juvenile salmon captured were identified to species and then released. The total length of each of the first 50 fish of each species in each size class was measured in millimeters.

If staff gage readings indicated the stage at the site had not changed from a previous sampling period only limited habitat measurements were taken. These included water chemistry data and a turbidity sample. Fish distribution data were taken during each visit to the site, however. Each cell sampled for fish was also characterized by a representative velocity, depth, and estimate of cover type and abundance.

2.1.2.2 Instream Flow Incremental Methodology (IFIM) sites

In addition to the RJHAB model sites, there were also six sites modelled for juvenile fish using the "instream flow incremental methodology" (IFIM) (Bovee 1982). A summary of this methodology and specific data collection and modelling techniques are presented in Appendix D of this report. All habitat data used in the IFIM models were collected and analyzed by Aquatic Habitat (AH) personnel. Two of the IFIM sites were also modelled with RJHAB models using the same transects in order to compare output from the two modelling methods. At these two sites, RJ personnel collected the RJHAB and fish distribution data and AH personnel collected the IFIM data, so the two models were independent.

Fish abundance and distribution data were also collected at the other four IFIM model sites. Sampling effort at these sites was secondary in importance to the sampling of the RJHAB sites. Cells were sampled for fish using the transects placed for the IFIM models. Cells were randomly selected and then sampled with the same procedures used at RJHAB sites. Cell numbering was the same as that used in the RJHAB studies. The distance from the transect end markers to the cell edge was measured, however, so that the location of the cell on the transect was specified. Other data collected at each cell fished included amount and type of cover, water depth, and water velocity. Water chemistry measurements and a turbidity sample were also taken at a selected location within the site.

2.1.2.3 Opportunistic sites

In addition to the RJHAB and IFIM sites, other sites were sampled for fish as time permitted to gather juvenile abundance and distribution information at a wider variety of sites and to obtain further data for juvenile suitability criteria. Selected 6-by-50 foot cells were sampled for juvenile salmon at opportunistic sites but no permanent grids or transects were marked. Water chemistry was measured at mid-site. If time permitted, each cell sampled for fish was characterized to amount and type of cover, water depth, and water velocity as were cells sampled at RJHAB and IFIM sites.

Early in the sampling season, large differences in turbidity were noted between sites located on the east and west banks of the Susitna River mainstem below the Chulitna River confluence. In order to better understand the reason for these differences, turbidities were taken within the Talkeetna and Chulitna rivers just above their respective confluences with the Susitna and also in the middle Susitna River above its confluence with the Chulitna River. The turbidity measurements were then repeated in the lower Susitna River below the Chulitna River on the left (west) bank channel, center channel, and right (east) bank channel at several locations from RM 92.7 downstream to RM 60.6. Blueline maps detailing the precise sampling locations are available at the Susitna Aquatic Studies office. Two sets of measurements were taken, on July 19 and on August 16. The measurements were recorded within a four hour period on each date. Turbidity samples were taken at least 30 feet off shore near the middle of the channel.

2.1.3 Schedule of activities and frequency of sampling

Field sampling trips, lasting approximately 7-10 days, were conducted bimonthly from June through mid-October. Each RJHAB site was sampled for fish on each sampling occasion if fish habitat was present. Habitat data were collected on at least three occasions when staff gage readings or observations suggested a change in the habitat within a site. The collection of habitat data was therefore dependent upon mainstem discharge.

The IFIM sites were sampled at least once a month during the open-water season. Opportunistic sites were sampled as time permitted and some were only sampled once. Opportunistic sites were sampled mainly in September and early October when many of the RJHAB and IFIM sites were dewatered.

2.2 Data Analysis

All field data were recorded on the appropriate data forms and transmitted to the office where the fish distribution data and much of the habitat data were entered into a mainframe computer data base. Data sorts, summary retrievals, and selected computer files were extracted from this data base as needed. Other habitat data were entered directly into basic programs or commercial software on a personal computer.

2.2.1 Physical data

Overtopping flows at the study sites were observed or estimated from staff gage measurements and flow observations. Data were grouped into nine half-month sampling periods from early June (June 1 - June 15) to early October (October 1 - October 15). Due to logistical constraints, the actual sampling periods did not always run from the 1st to the 15th and 16th through the end of the month.

An index to the amount and type of cover within the RJHAB and IFIM model sites was calculated by totalling the linear feet of all the cover types along the transects at a mainstem discharge within the range of 49,000 to 57,000 cfs. In addition, at Rolly Creek mouth, Caswell Creek mouth, and Beaver Dam Slough, the response of physical cover to changes in mainstem discharge was plotted by totalling the cover along the transects at all measured discharges.

The response of RJHAB site wetted areas to mainstem discharge was plotted using a BASIC language geometry program to calculate wetted area at each transect within a site on each modelling occasion. After fitting these points by hand using professional judgement, site areas at 3000 cfs increments were measured on the graphs with a digitizer. The IFG HABTAT program calculated wetted areas at the six IFIM sites as a function of side channel flow, and these were also plotted using a mainstem discharge-side channel flow relationship.

2.2.2 Abundance and distribution

The same classification of macrohabitats was used to examine differences in fish distribution among the sites as that discussed in Dugan et al. (1984). The sites were classified as tributary mouths, side sloughs, and side channels. Tributary mouths are sites which are influenced by tributary flows and backwater effects from the mainstem. Side channels are channels whose upstream berms (heads) are breached by the mainstem while side sloughs are channels whose heads are not breached and whose water sources are upwelling, local runoff, or small tributaries. Side sloughs transform to side channels when their heads are breached by the mainstem. Birch Creek Slough was classified as a tributary mouth in 1984 because road building activities in the upper part of the slough closed the head off from the mainstem. Beaver Dam Slough was also classified as a tributary mouth because it only overtops at discharges greater than 80,000 cfs and normally runs clear. Beaver Dam Slough is much more similar to Rolly Creek mouth than to any of the other side sloughs in the lower reach.

Catches within cells with areas other than the standard 300 ft^2 were adjusted to correspond to this standard cell area. The analysis was then based on the adjusted mean catch per cell.

2.2.3 Habitat modelling of rearing salmon

2.2.3.1 Suitability criteria development

Suitability criteria have been developed to model the response of juvenile salmon habitat to variations in mainstem discharge at sites located in the middle reach of the Susitna River (Suchanek et al. 1984). As habitat data collection techniques used in the lower river in 1984 were similar to those used during 1983, the middle river suitability criteria were compared to the lower river distribution data and modified, if necessary, in Appendix A. The suitability criteria developed in Appendix A are used in all subsequent habitat modelling for the lower river.

2.2.3.2 Instream Flow Incremental Methodology (IFIM) models

The IFIM PHABSIM system of computer programs was developed by the U.S. Fish and Wildlife Service as a means of describing the mosaic of physical features of a stream which includes hydraulic variables such as depth and velocity and other features such as substrate or cover (Bovee 1982). A hydraulic model is first calibrated which describes the response of hydraulic variables such as depth and velocity to stream flow (Milhous et al. 1981). The HABTAT program is then used to incorporate output from the hydraulic model and substrate data with the suitability criteria to produce estimates of the habitat potential (weighted usable area) for a given life stage of a species. Weighted usable area (WUA) is calculated as follows (Bovee 1982):

$$WUA = C_{i,s} \times A_i$$

where: $C_{i,s}$ = the composite weighting factor (sometimes called the joint preference factor) for cover, velocity, and depth of the cell (i) for the species and life stage (s)

A_i = the surface area of the cell

Each cell is a small section of the study channel which is bounded by other cells or the shoreline and extends midway between transects. The WUA for the study site at a given discharge was calculated by totalling all the individual cell WUA's. The composite weighting factor was calculated by multiplying the suitability indices for cover, velocity, and depth of the cell together. WUA's at each study site were calculated at flows which corresponded to 3,000 cfs increments of mainstem discharge as measured at Sunshine gaging station.

Much more detailed descriptions of the IFIM data analysis methods and hydraulic simulation results are presented in Appendix D. Only selected WUA results as a function of mainstem discharge are presented here. All species and site combinations were run and are available on request but space limitations prevent presentation here. Site/species combinations presented were selected on the basis of fish catches at the site.

2.2.3.3 Resident Juvenile Habitat (RJHAB) models

The original RJHAB model was designed to calculate weighted usable areas for the habitat within a site without using hydraulic models (Marshall et al. 1984). The model divided the site into shoreline and mid-channel sections, and calculated weighting factors for cover and velocity for each section which were then multiplied together with area to produce a weighted usable area estimate at each of the discharges measured.

The original RJHAB model was greatly modified for the 1984 analyses. These changes were made so that the RJHAB model calculates weighted usable areas similarly to the HABTAT program described by Milhous et al. (1981) that is used in IFIM analysis. Also the cover coding has been standardized so that observer variations in rating cover at different discharges do not lead to variations in cover estimates unrelated to changes in wetted area.

The current RJHAB model is a spreadsheet developed on commercial software. Though no hydraulic model is developed, the current RJHAB model closely resembles the HABTAT model in its procedures for calculating weighted usable areas within a site. Instead of calculating weighting factors for cover and velocity in shoreline and mid-channel sections on a given sampling occasion as did the original RJHAB model, each site is partitioned into "stream cells" each with a unique area, cover type, cover percentage, velocity, and depth. The site weighted usable area (WUA) is then the sum of the "stream cell" WUA's which are calculated by multiplying the area, cover, velocity, and depth suitabilities together.

The velocity and depth measurements of the 6' x 50' sampling cells are assumed to represent a much larger stream cell. The wetted surface area between transects was partitioned into one to four stream cells dependent upon wetted transect width (Table 2).

Table 2. Partitioning of wetted channel width into stream cells.

Wetted Channel Width	No. of Stream Cells	How Area Partitioned
> 42 ft	4	Cell on each shoreline 6 ft in width, two center cells split the difference.
30-41 ft	3	Cell on each shoreline 6 ft in width, middle cell is the rest.
18-29 ft	2	Each cell with half the width.
< 18 ft	1	Entire width.

Occasionally, islands prevented a simple partitioning of the site but in each case, areas were partitioned so that sampling cells best represented a given stream cell. Once the wetted width of stream cells was partitioned, a computer program written in BASIC was used to calculate the surface area of each stream cell on each sampling occasion. The areas of islands were estimated from width measurements, observations, and sketch maps and then subtracted from the area of each stream cell.

Cover suitabilities for each stream cell were calculated with a BASIC program which integrated the standard cover data taken on each transect with the partitioned wetted width of each stream cell. The cover suitability of each cover type on the stream cell wetted width was averaged with the other cover suitabilities present (proportional to their occurrence) to give an average cover suitability. For example, if the stream cell was 15 feet in width and ten feet of the width was a cover type with a suitability of 0.5 and the other five feet was a cover type with a suitability of 1.0, the average cover suitability for the cell would be : $[(10 \times 0.5)+(5 \times 1.0)]/15 = 0.67$.

The RJHAB spreadsheet then took the stream cell areas and cover suitabilities, and multiplied these with the depth and velocity suitabilities which it assigned to the sampling cell depth and velocity measurements. The products of these calculations (stream cell WUA's) are then totalled to calculate site WUA's for each sampling occasion. Weighted usable areas for chinook salmon in turbid and clear water and chum, coho, and sockeye salmon were all calculated concurrently.

Weighted usable areas were plotted over the range of mainstem discharges sampled. Since initial overtopping flows were estimated for each side channel, WUA response was extrapolated in the range around breaching using this information. Habitat indices were calculated by dividing the WUA of the site at a given discharge by the site area at the same discharge and these were also plotted. Only selected site and species combinations are presented here, all other WUA calculations are available upon request. Individual sampling cell measurements are also available upon request.

In order to compare output from the RJHAB model with that of the IFIM methodology, two sites (Island and Trapper Creek side channels) were modelled with both techniques. Output from both techniques were graphed as a function of mainstem discharge and then correlated with each other at the measured RJHAB discharges.

2.2.3.4 Model verification

Fish abundance data were collected at all of the IFIM and RJHAB sites. High mean catches per cell (CPUE's) should reflect high densities of fish within the site. Since WUA on a per site basis reflects the size of a site, WUA/site is not an index to habitat quality of a site. The habitat index calculated by dividing WUA by site area (at any given discharge), however, does reflect site habitat quality, independently of site area.

Variations in mainstem discharge cause fluctuations in the habitat value of a given site. Fish populations within a site may not respond immediately to such variations in habitat value but should adjust after a period of time. Over a season, average densities of fish (as expressed by CPUE) should be positively correlated to the average seasonal habitat index if there is a relationship between the two. A test of the significance of the correlation between mean seasonal habitat indices and mean catch per cell by species was used to verify the habitat modelling efforts.

Mean seasonal habitat indices for each site were calculated for each species with the following procedure. Mean daily discharges for each day between May 15 and October 15 were rounded to the nearest 3,000 cfs increment in the range from 12,000 to 75,000 cfs. The season for chum salmon ran from May 15 to July 15. If the discharge was greater than 75,000 cfs, the discharge was assumed to be 75,000 cfs because WUA's were calculated only up to 75,000 cfs. Corresponding WUA's and site areas corresponding to these discharges were then totalled to find the total WUA and site area for the season. The mean seasonal habitat index was then calculated by dividing the total WUA by the total site area. For chinook and chum salmon, WUA's were adjusted by a turbidity factor before the habitat index was calculated. The turbidity factor was calculated by fitting a suitability index from 0 to 1.0 on the distribution of mean chum and chinook juvenile salmon catch by 50 NTU turbidity increments. Site mean CPUE's were regressed against site habitat indices at each site.

3.0 RESULTS

3.1 Seasonal, Spatial, and Discharge Related Variations in Habitat

3.1.1 Macrohabitat type classifications of study sites

All the study sites were classified into one of three macrohabitat types: tributary mouths, side channels, or side sloughs. Classification and habitat characteristics of the twenty modelled study sites are given in Table 3. Initial breaching discharges for the side channels ranged from approximately 14,000 to 46,000 cfs with flows controlled by the mainstem at least 50% of the time. Channels with input into the tributary mouth sites were never breached at flows less than 54,100 cfs and site flows were controlled by the mainstem less than 5% of the time. Backwater effects were the only effects attributable to mainstem discharge at the tributary mouths on all sampling occasions except at Beaver Dam Slough where discharges greater than 75,000 cfs caused the head to overtop and flow to increase through the site. Even at discharges greater than 75,000 cfs however, the major effect of mainstem discharge on Beaver Dam Slough was a backwater response.

The side slough macrohabitat type was not represented by any of the sites when mainstem discharges were highest during the period from late June through early August. Side slough habitat increased with decreases in mainstem discharges.

Major object cover differences among the modelling sites were differentiated by macrohabitat type. An index of cover for each site at a discharge of approximately 52,000 cfs (range 45,500 to 58,800 cfs) was calculated for between-site comparisons of cover (Table 4). The percentage of the site with the primary cover type, submerged aquatic vegetation, varied from 8.5% to 68.5% for the tributary mouths, while none of the side channel/sloughs had any submerged aquatic vegetation. Substrate in the form of large gravel (1-3" diameter) and rubble (3-5" diameter) was the primary cover type and averaged 62% of the side channel area while these two cover types only covered an average of 14% of the area of tributary mouth sites. The density of cover at tributary mouths was almost three times that of side channels also. Side sloughs, which by definition are unbreached side channels, typically have less object cover than side channels.

Cover, in the form of turbidity was much more frequent within side channels than at tributary mouths and side sloughs. Turbidities were consistently higher in the side channels than in the tributary mouths during the open-water season (Figure 3). A few turbidities of 100 to 150 NTU were recorded at Rolly Creek mouth and Beaver Dam Slough due to rapid increases in mainstem stage which caused turbid water to intrude into the sites, or in the case of Beaver Dam Slough, by a slight overtopping of the channel head by mainstem water. Turbidities within the side sloughs ranged from 1 to 19 NTU with a mean of 5.2 NTU.

Table 3. Classifications and habitat characteristics of study sites on the lower Susitna River at which juvenile salmon habitat was modelled, June through October 1984.

Site	River Mile	Initial Breaching Discharge (cfs)	Percent of Time Flow Controlled by Mainstem in 1984[1]	Non-mainstem Water Sources
Side Channels (head open)/ Sloughs (head closed)				
Hooligan Side Channel	35.2	23,100	80	Pools only
Eagles Nest Side Channel	36.2	14,000	94	Unknown
Kroto Slough Head	36.3	36,000	62	Minor upwelling
Bear Bait Side Channel	42.9	35,000 (Est.)	64 (Est.)	Pools only
Last Chance Side Channel	44.4	22,700	79	Pools only
Rustic Wilderness Side Channel	59.5	19,000	86	Pools only
Island Side Channel	63.2	34,000	64	Major upwelling
Mainstem West Bank	74.4	19,000	86	Major upwelling
Goose 2 Side Channel	74.8	30,000	68	Minor upwelling
Circular Side Channel	75.3	36,000	64	Major upwelling
Sauna Side Channel	79.8	37,000	62	Minor upwelling
Sucker Side Channel	84.5	27,500	71	Minor upwelling
Beaver Dam Side Channel	86.3	46,000	50	Unnamed tributary
Sunset Side Channel	86.9	31,000	68	Major upwelling
Sunrise Side Channel	87.0	34,300	64	None
Trapper Creek Side Channel	91.6	43,000	57	Cache Creek
Tributary Mouths				
Rolly Creek Mouth	39.0	-	0	Rolly Creek
Caswell Creek Mouth	63.0	-	0	Caswell Creek
Beaver Dam Slough	86.3	75,000+	< 5	Unnamed tributary
Birch Creek Slough[2]	88.4	54,100	< 5	Birch Creek

1 These percentages based on controlling breaching discharges presented in Quane et al. (1985) for the period from May 15 to October 15, 1984.

2 A culvert at the head of this slough is frequently blocked and therefore little mainstem water flows into the slough, even if the slough head is breached. The effect of mainstem discharge on this site is minimal for this reason.

Table 4. Percentages of lower river habitat modelling sites associated with nine cover-type categories. Percentages are based on the width of transect with each cover type. Cover index calculated by dividing total cover by total area of site.

Side Channels/Sloughs	River Mile	Date	Discharge (cfs)	Percentage of Site With Primary Cover Type: No Cover	Emergent Veg.	Aquatic Veg.	Large Gravel	Rubble	Cobble	Debris	Overhang. Riparian Veg.	U.C. Banks	Total	Cover Density[1] (%)
Hooligan Side Channel	35.2	7/14	52400	18.9	0.0	0.0	72.0	0.0	0.0	8.5	0.6	0.0	100.0	13.7
Kroto Slough Head	36.3	7/17	49600	56.4	0.0	0.0	8.6	0.0	0.0	33.5	1.6	0.0	100.1	1.8
Bear Bait Side Channel	42.9	7/13	52400	0.0	0.0	0.0	66.8	0.0	0.0	28.1	3.7	1.4	100.0	11.5
Last Chance Side Channel	44.4	7/12	54100	23.5	0.0	0.0	63.5	0.0	0.0	12.3	0.8	0.0	100.1	5.9
Rustic Wilderness Side Channel	59.5	8/12	52900	0.0	0.0	0.0	60.9	30.0	0.0	7.8	0.8	0.5	100.0	13.7
Island Side Channel	63.2	7/19	51600	13.4	0.0	0.0	62.0	21.6	0.0	0.0	1.4	1.6	100.0	10.5
Mainstem West Bank	74.4	Extrapolated	54100	1.0	0.4	0.0	43.4	49.3	0.0	2.2	3.4	0.4	100.1	22.7
Goose 2 Side Channel	74.8	7/20	52600	2.0	0.9	0.0	24.3	51.8	13.7	3.5	3.5	0.2	99.9	22.5
Circular Side Channel	75.3	7/24	56600	20.4	0.0	0.0	48.4	21.3	0.0	5.3	4.6	0.1	100.1	9.3
Sauna Side Channel	79.8	7/23	56600	93.4	0.0	0.0	0.0	0.0	0.0	4.3	2.4	0.0	100.1	0.5
Sucker Side Channel	84.5	7/09	55400	80.2	8.4	0.0	6.6	0.0	0.0	3.9	1.0	0.0	100.1	1.1
Beaver Dam Side Channel	86.3	7/08	57100	55.9	0.9	0.0	18.6	5.9	0.0	18.6	0.0	0.0	99.9	1.9
Sunset Side Channel	86.9	7/22	57800	15.0	0.0	0.0	66.8	9.7	0.0	7.7	0.5	0.3	100.0	4.8
Sunrise Side Channel	87.0	7/07	58800	4.0	0.0	0.0	51.4	44.6	0.0	0.0	0.0	0.0	100.0	10.0
Trapper Creek Side Channel	91.6	8/19	57200	2.2	0.0	0.0	39.1	58.8	0.0	0.0	0.0	0.0	100.1	12.3
			MEAN	25.8	0.7	0.0	42.2	19.5	0.9	9.0	1.6	0.3	100.0	9.5
<u>Tributary Mouths</u>														
Rolly Creek Mouth	39.0	7/11	55100	6.9	25.2	46.2	0.0	0.0	0.0	21.5	0.1	0.0	99.9	24.2
Caswell Creek Mouth	63.0	8/18	45400	2.9	5.3	48.2	17.6	0.0	0.0	18.4	1.6	6.1	100.1	19.0
Beaver Dam Slough	86.3	7/08	57100	6.8	9.9	68.5	0.0	0.0	0.0	11.1	3.1	0.6	100.0	57.8
Birch Creek Slough	88.4	7/20	52600	36.8	0.5	8.5	29.2	9.0	0.0	13.6	2.2	0.3	100.1	6.3
			MEAN	13.4	10.2	42.9	11.7	2.3	0.0	16.2	1.8	1.8	100.0	26.8

[1] Cover density is the average density of object cover within the site on a percentage basis.

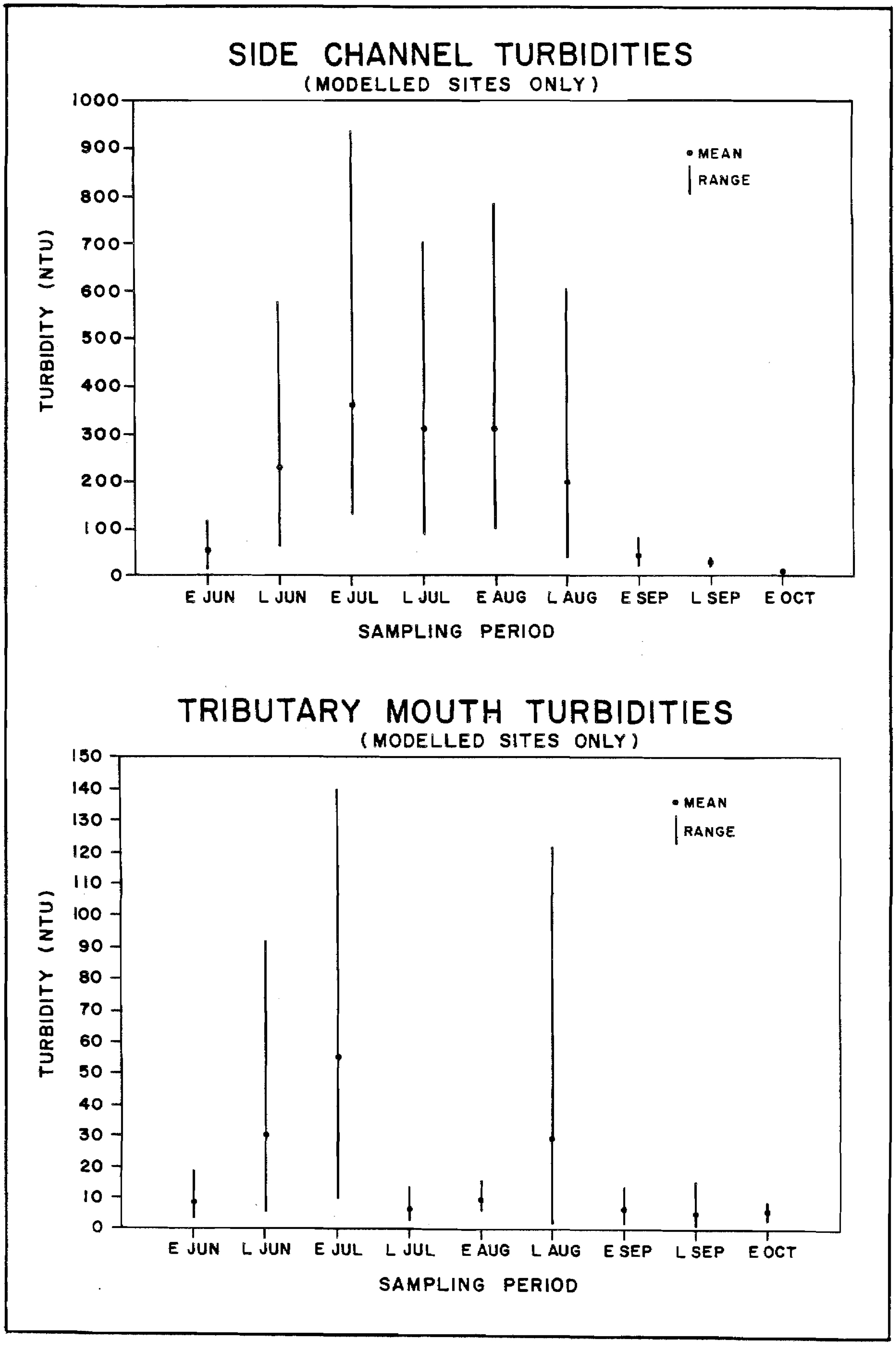


Figure 3. Turbidities of modelled side channels and tributary mouths on the lower Susitna River, June through October 1984.

3.1.2 Chulitna and Talkeetna River plume influences on turbidity of side channels

Turbidity measurements of the lower Susitna River taken in west bank, mid-channel, and east bank portions of the mainstem indicate that plume influences of the Chulitna and Talkeetna Rivers extend at least 20 to 30 miles downriver (Figure 4). On September 2, turbidities at RM 83.8 ranged from 60 NTU on the east bank, to 77 NTU in mid-channel, and 88 NTU on the west bank. West bank turbidities are much higher than on the east bank, because the Chulitna River is three or more times as turbid as the Talkeetna River and middle reach of the Susitna River.

A comparison of turbidities at the modelled side channels located above RM 70 also suggests that the plumes have major effects on turbidities downstream. Mean turbidity at lateral side channels located on the west bank (Mainstem West Bank, Sauna S.C., and Trapper Creek S.C.) during June through late August was 377 NTU. During the same time period, lateral side channels located on the east bank (Goose 2 S.C., Sunset S.C., and Beaver Dam, S.C.) had a much lower mean turbidity of 158 NTU. Mean turbidities for all the side channels modelled with the exception of Eagle's Nest Side Channel have been calculated in Appendix Table B-1.

Many more turbidities would have to be taken to better delineate the Chulitna River and Talkeetna River plumes. The large east bank clear water tributaries such as Montana Creek and Goose Creek make the differences in turbidity between the east and west banks of the lower river even larger, and confound analysis of the extent of plumes from the Chulitna and Talkeetna rivers.

3.1.3 Physical responses of sampling sites to mainstem discharge variations

Variations in mainstem discharge cause the heads of side channels to alternately be overtopped or dewatered, thereby altering macrohabitat classifications due to changes in water quality, flows, wetted areas, and the amount of cover. The relationships between side channel flows and mainstem discharge at the sampling sites are presented in Quane et al. (1985).

Changes in wetted area of sites due to variations in mainstem discharge are important because these changes may directly increase or decrease fish habitat. Areas measured from aerial photos have been compiled for selected side channel and slough complexes by Ashton and Klinger-Kingsley (1985) for a variety of discharges. Mainstem backwater effects at tributary mouths are also important because object cover inundated by backwater is an important component of these sites for juvenile salmon. Discharge related responses of site area for all sites pooled and cover for selected tributary mouths will be presented in the next two sections.

3.1.3.1 Area

The areas of the RJHAB study sites were calculated geometrically at modelled discharges, and then plotted against mainstem discharge by eye. Measurements of area were then read from these graphs in the range

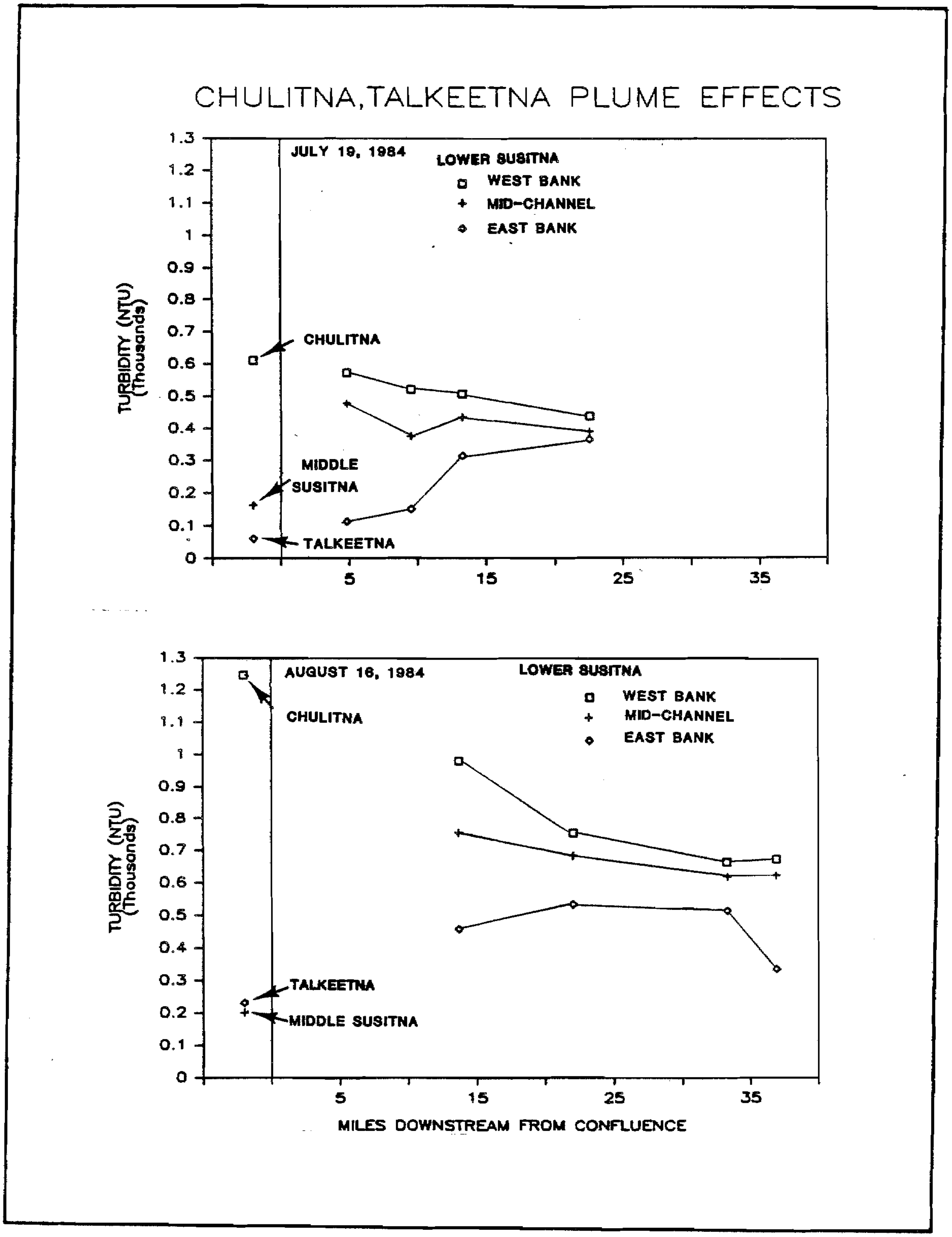


Figure 4. Comparison of turbidities in the lower Susitna River below the Chulitna and Talkeetna River confluences on July 19 and August 16, 1984.

between 12,000 to 75,000 cfs at 3,000 cfs increments. Since Eagles Nest Side Channel was modelled only at discharges less than 20,000 cfs, we did not try to extrapolate values over this range for this site. Similarly, area response at the six IFIM sites were calculated by the IFG program at side channel flows which corresponded to increments of 3000 cfs within the 12,000 to 75,000 cfs mainstem discharge range.

Individual area responses for all the modelling sites have been tabulated in Appendix Table B-4 at 3,000 cfs discharge increments. Also, side channel flows associated with these increments have been tabulated. By summing areas of the sites by macrohabitat type, the response of the pooled sites can be illustrated. The combined area of three tributary mouths increased greatly at discharges greater than 27,000 cfs (Figure 5). Since sloughs transform to side channels at greater discharges, slough habitat decreased with discharge while side channel habitat steadily increased (Figure 6). Slough habitat was broken into two categories: total and accessible. The total category includes ponded water with no access from the mainstem while the accessible sloughs are those with potential access from the mainstem.

3.1.3.2 Cover

Since instream cover is an important component of fish habitat, the response of available cover to mainstem discharge at individual sites is of interest. Increases in instream cover (debris, riparian vegetation) at side channels were often accompanied by large increases in flows and related water column velocities. Therefore, increases in suitable cover at side channels were often offset by increases in velocities which made the site unsuitable. Turbid water in side channels also provides cover for juvenile chinook salmon and therefore, instream object cover may be less necessary for chinook salmon under turbid conditions (Suchanek et al. 1984).

At tributary mouths, on the other hand, tributary flows are independent of mainstem discharge, the water is often clear, and the primary effect of mainstem discharge is the formation of a backwater zone. Increases in mainstem stage typically decrease velocities and inundate cover at tributary mouths.

Cover responses to mainstem discharge at the four tributary mouths varied. At Birch Creek Slough, there were no changes in cover as a result of changes in mainstem stage during 1984 sampling because the sampling site was located high enough (0.7 miles) up the channel that it was not influenced by mainstem stage. At Beaver Dam Slough, increases in total cover caused by rises in mainstem discharge were limited because most of the cover was submerged aquatic vegetation (Figure 7). At Rolly Creek and Caswell Creek mouths, however, the amount of cover increased rapidly at discharges larger than 45,000 cfs. Increases in total cover at Rolly Creek mouth were caused primarily by inundation of emergent vegetation while both emergent vegetation and overhanging riparian vegetation cover became more abundant at Caswell Creek mouth at high mainstem discharges.

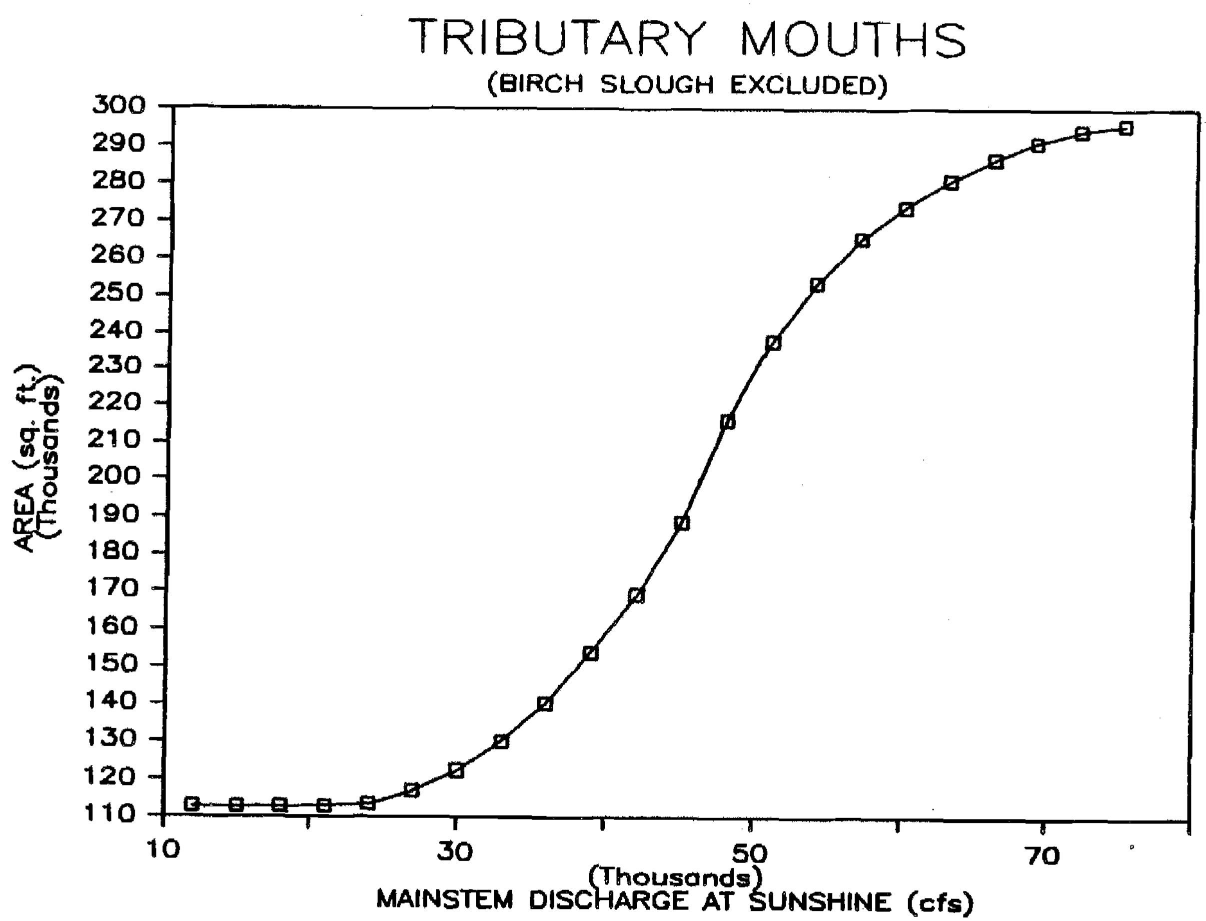


Figure 5. Area within modelled tributary mouths as a function of mainstem discharge at the USGS Sunshine gaging station, 1984. Boundaries of the site were fixed.

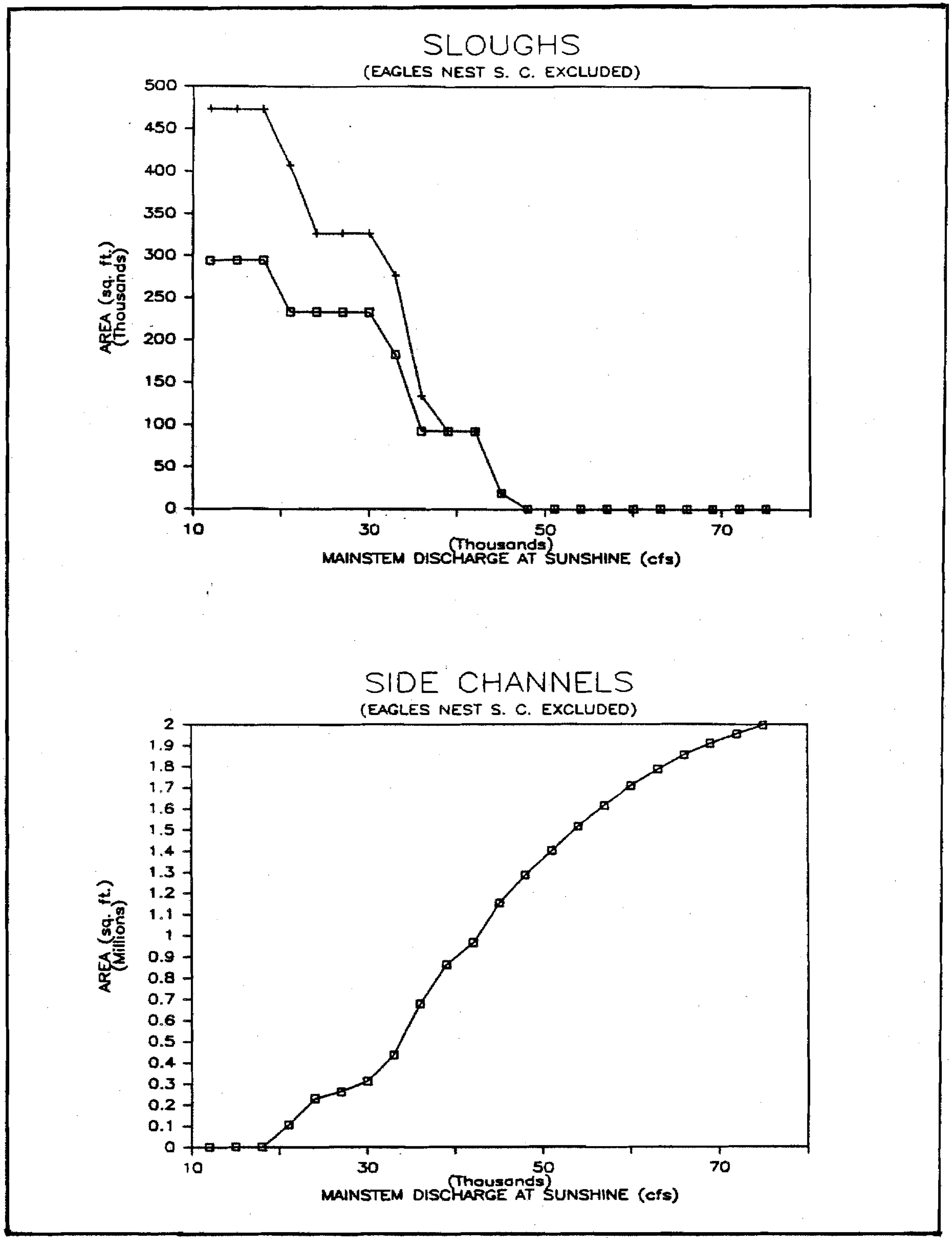


Figure 6. Area within modelled sloughs and side channels as a function of mainstem discharge at the USGS Sunshine gaging station, 1984.

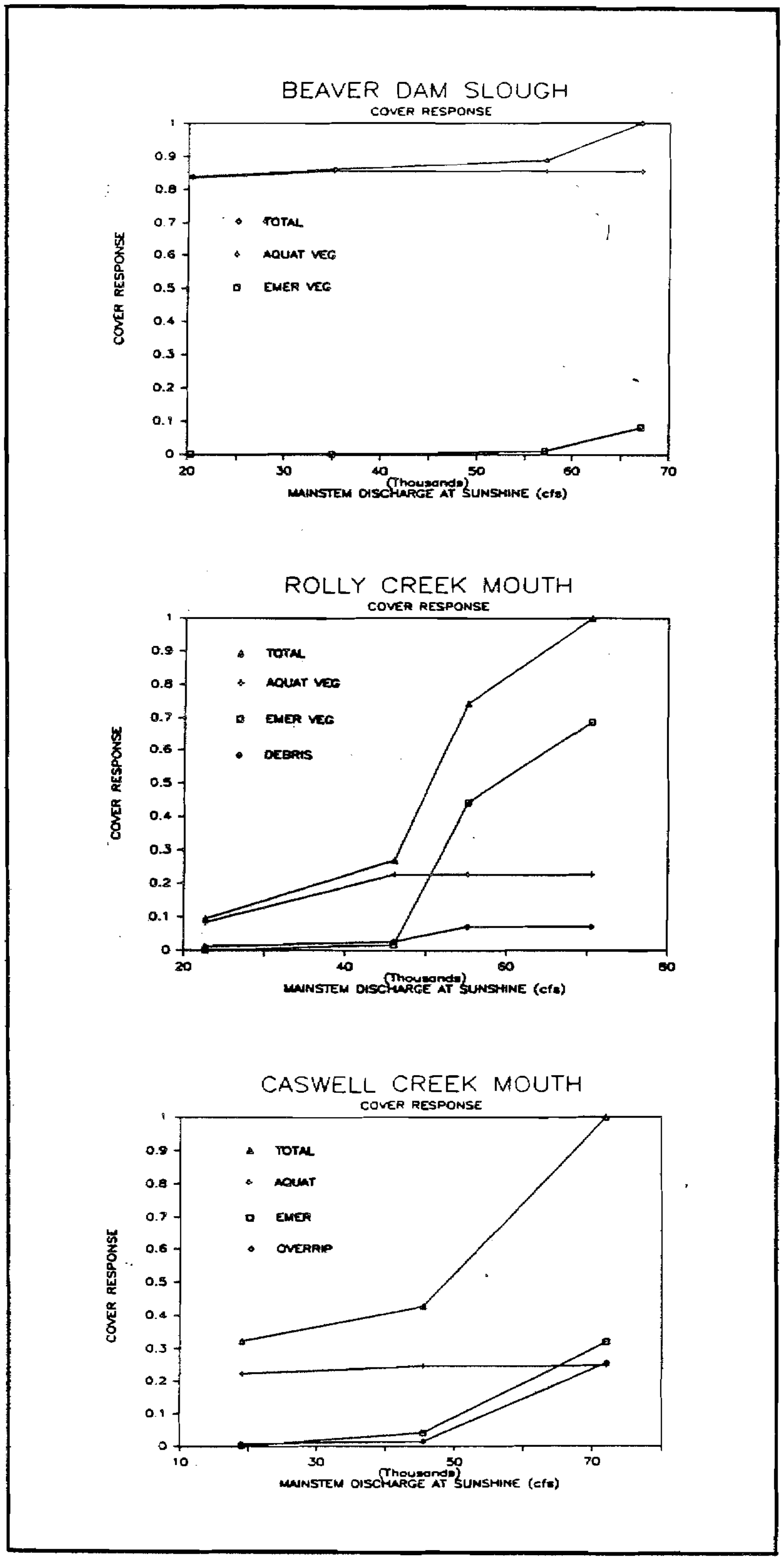


Figure 7. Instream cover response at Beaver Dam Slough, Rolly Creek, and Caswell Creek mouths as a function of mainstem discharge at the USGS Sunshine gaging station, 1984.

3.2 Distribution and Abundance of Juvenile Salmon

Chinook, coho, chum, and sockeye salmon juveniles were captured at the twenty habitat model sites, but only one pink salmon fry was captured. Pink salmon outmigrate early and our methods are not effective at capturing them. A summary of the juvenile chinook, coho, chum, and sockeye salmon catch and catch per cell (CPUE) data by site is given in Appendix Table B-2.

3.2.1 Chinook salmon

Fourteen hundred fifty-eight juvenile chinook salmon were collected in the lower reach of the Susitna River from June through early October. Approximately 83% of these fish were captured at the 20 habitat model sites. Age 0+ fry accounted for 93% of the chinook salmon juveniles captured. The percentage of 0+ fry increased from 66% in late June to 99% in early August. All chinook fry captured after early August were 0+ fish, indicating that 1+ chinooks had outmigrated from the study reach prior to August 15.

Chinook fry were widely distributed at the modelling sites from early June through late August (Figure 8). Last Chance Side Channel was the only site where no chinook juveniles were captured. Chinook juveniles were captured at 80% or more of the sites sampled in early June and late August. In September and early October, the proportion of sites where chinook salmon were captured decreased.

Mean juvenile chinook CPUE was highest at tributary mouths, where 1.5 fish per cell (fpc) were captured. At side channels, the mean CPUE for juvenile chinook was 0.8 fpc. Slough catch rates were consistently low (0.1 fpc). Mean catch rates at side channels were relatively constant throughout the season, while tributary mouth CPUE's peaked in August (Figure 9). The peak CPUE for tributary mouths occurred in late August at Caswell Creek mouth (20.2 fpc). The peak CPUE at a modelled side channel (4.4 fpc) occurred at Sunset Side Channel. CPUE's within the side channels peaked at turbidities of 100 to 150 NTU (Figure 10). The correlation (r) between mean turbidity of the modelled side channels and mean catch per cell of chinook salmon was -0.63 ($p < 0.05$).

Catches at Trapper Creek Side Channel appeared to reflect the effect of turbidity upon chinook fry use. This west bank site, located below the Chulitna River, had a high CPUE in early June (2.7 fpc) when turbidity was low but then no chinook were captured in late June and early July when turbidities were above 550 NTU. Chinook fry catches increased slightly on subsequent trips when turbidities began to decrease.

3.2.2 Coho Salmon

Four hundred forty-two juvenile coho salmon were captured within the lower Susitna River study areas of which only five were not captured within the habitat model sites. Three age classes of juvenile coho salmon were captured. Eighty-six percent of the juvenile coho captures were age 0+ and 14% were age 1+. Only one age 2+ juvenile was captured.

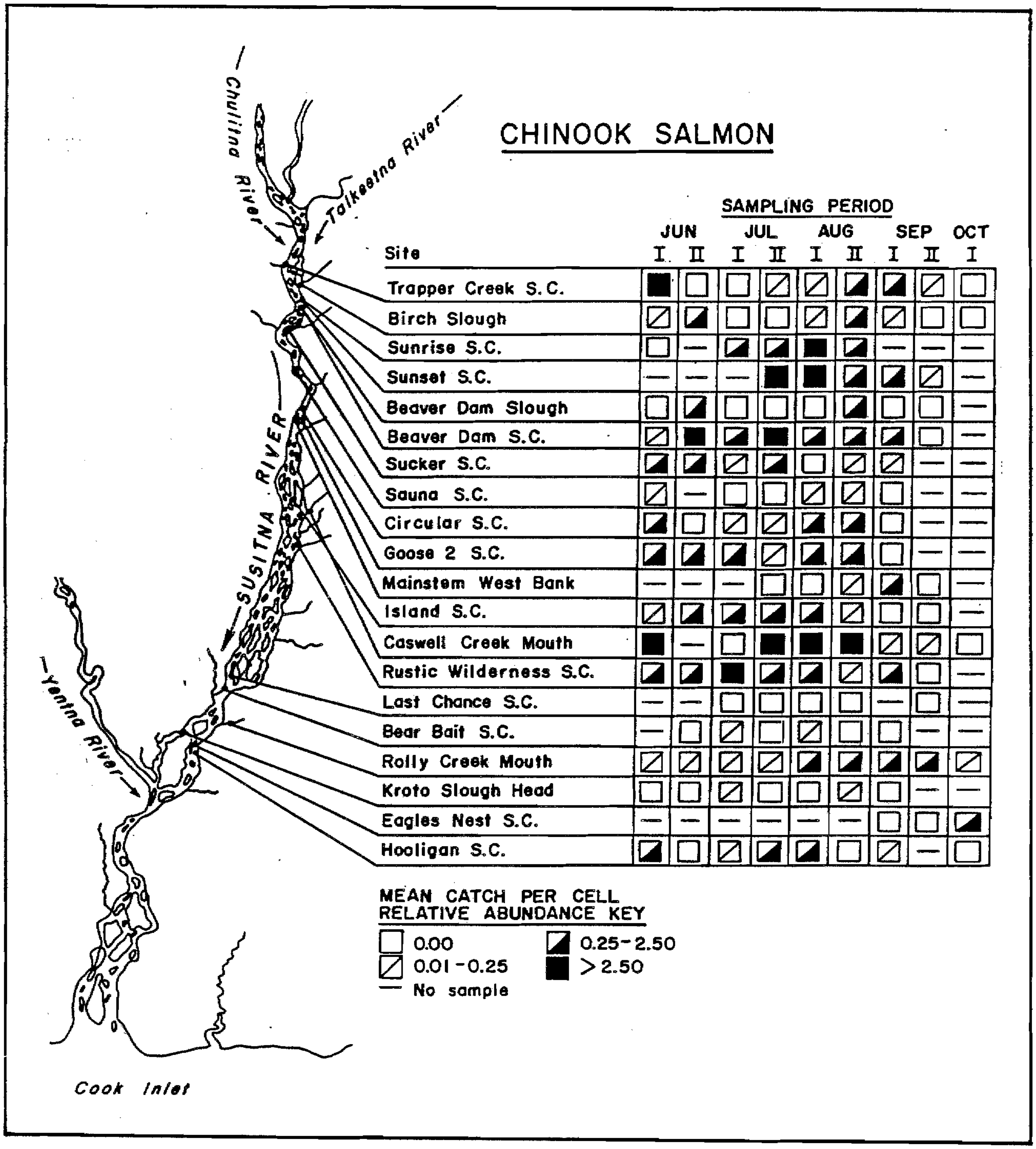


Figure 8. Seasonal distribution and relative abundance of juvenile chinook salmon on the lower Susitna River, June through mid-October 1984.

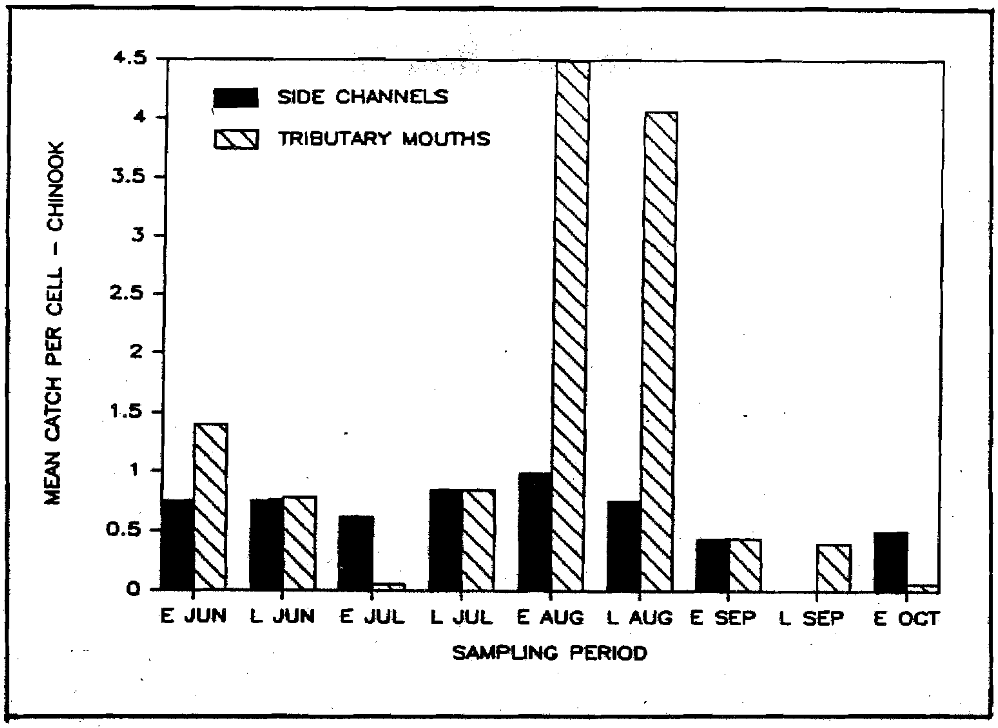


Figure 9. Juvenile chinook salmon mean catch per cell at side channels and tributary mouths on the lower Susitna River by sampling period, June through mid-October 1984.

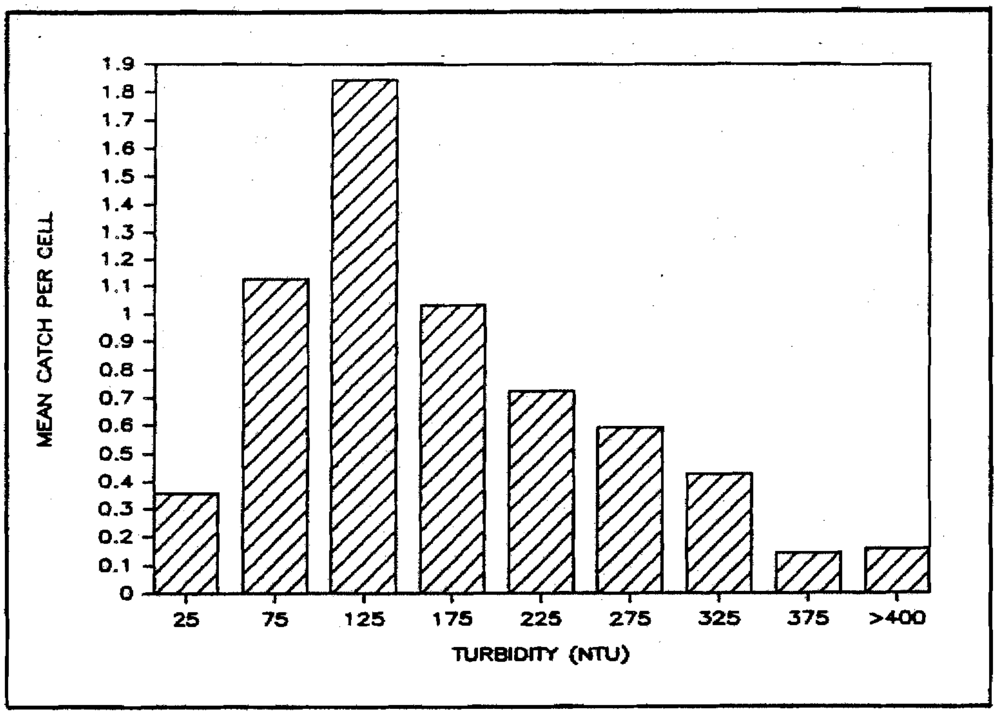


Figure 10. Juvenile chinook salmon mean catch per cell at modelled side channels on the lower Susitna by turbidity increment, June through mid-October 1984.

The percentage of age 1+ fry captured decreased from approximately 50% in early June to 2% in early October.

Juvenile coho salmon were unevenly distributed in the study area, being captured at only 50% of the 20 modelled sites (Figure 11). Only one coho was captured at four of these sites. In most instances, juvenile coho CPUE's tended to be higher in late summer.

Juvenile coho salmon catches varied greatly among the three macrohabitat types. Tributary mouths had a mean juvenile coho CPUE of 1.2 fpc while sloughs and side channels had CPUE's of 0.02 and 0.01 fpc, respectively. Juvenile coho were captured at all four tributary mouths, five of the 16 side channels (31%) and two of the 14 sloughs (14%) sampled. Over half of the juvenile coho were captured at Caswell Creek mouth, with the majority in mid to late August. The juvenile coho catch rate at tributary mouths ranged from near ten juveniles per cell at Caswell Creek in late August to zero fish per cell at several sites during various sampling periods throughout the open-water season (Figure 12). With the exception of Birch Creek Slough, coho CPUE's were higher during late summer and fall than during early summer sampling periods.

3.2.3 Chum salmon

Six hundred eight juvenile chum salmon were collected in the lower Susitna River of which only ten were captured at opportunistic sites. In early June, chum fry were captured at 13 of 15 (87%) modelling sites sampled (Figure 13). By late July, chum were only captured at six of 19 (32%) sites sampled. Over 99% of the total catch was made prior to August and no chum salmon fry were captured after August 15. The majority of sites with high CPUE's were located in the reach from Island Side Channel (RM 63.2) to Sucker Side Channel (RM 84.5).

Chum fry CPUE's declined steadily from early June to mid-August (Figure 14), reflecting outmigration of juvenile chum salmon from the Susitna system. In a pre-study trip in late May, chum fry were collected at a number of lower river sites and appeared widely distributed in the river.

Juvenile chum CPUE's were highest in side channels (0.6 fpc) and tributary mouths (0.1 fpc). Slough CPUE's of juvenile chum were low (0.01 fpc), however, sampling effort at sloughs was limited from early June through early July. Tributary mouth densities were unequally distributed by a single site catch of 39 fry at Birch Creek Slough in late June. Juvenile chum catches at side channels were affected by turbidity. Peak chum catches were made in side channels with a turbidity of less than 50 NTU (Figure 15).

3.2.4 Sockeye salmon

Four hundred twelve juvenile sockeye salmon were captured in the lower Susitna River study reach. Ninety percent (369) of these fish were captured at the habitat modelling sites. Age 0+ sockeye comprised 99% of the catch. Age 1+ sockeye were found in early June at Hooligan Side Channel, a site which produced no further sockeye juveniles all season,

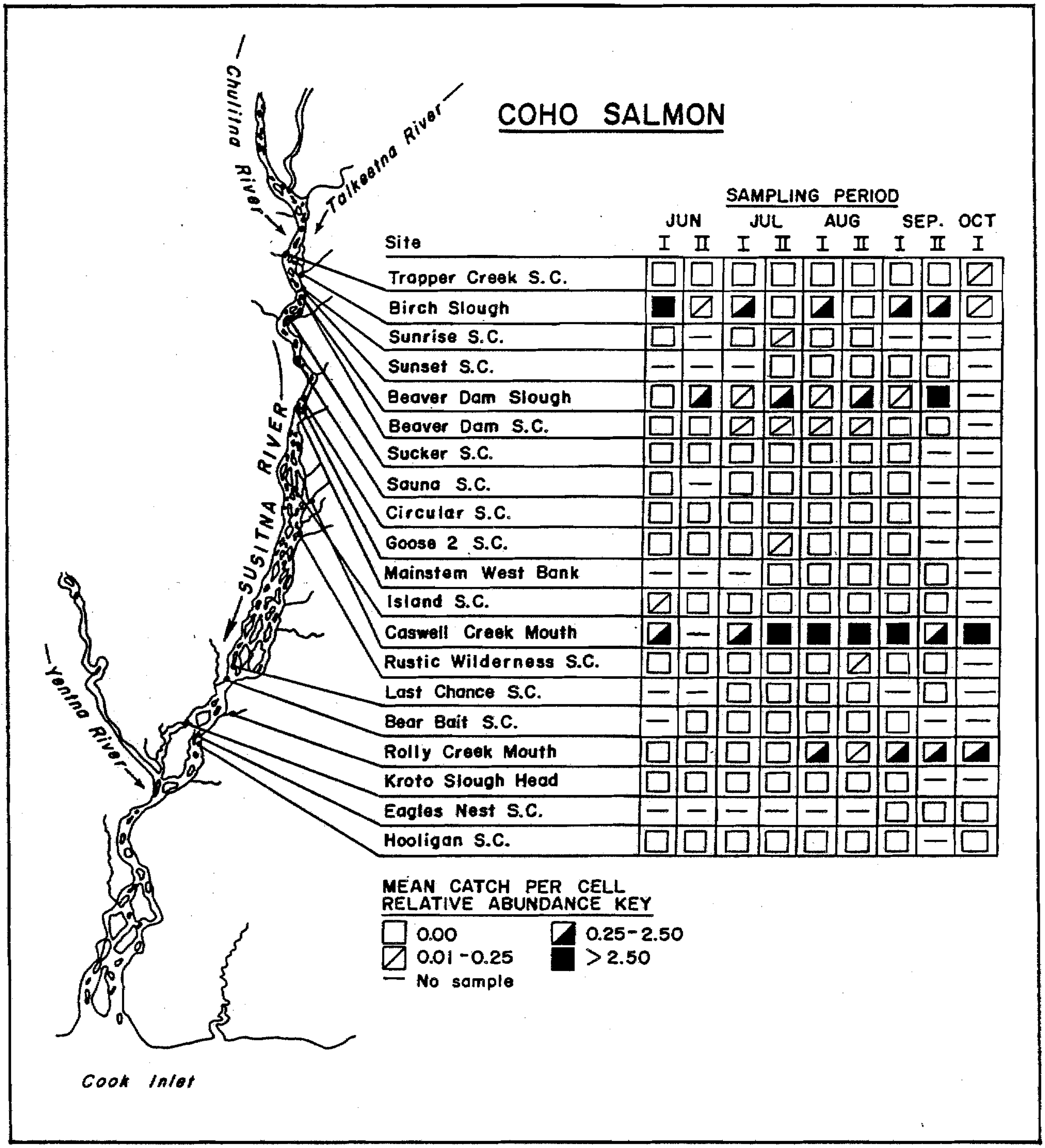


Figure 11. Seasonal distribution and relative abundance of juvenile coho salmon on the lower Susitna River, June through mid-October 1984.

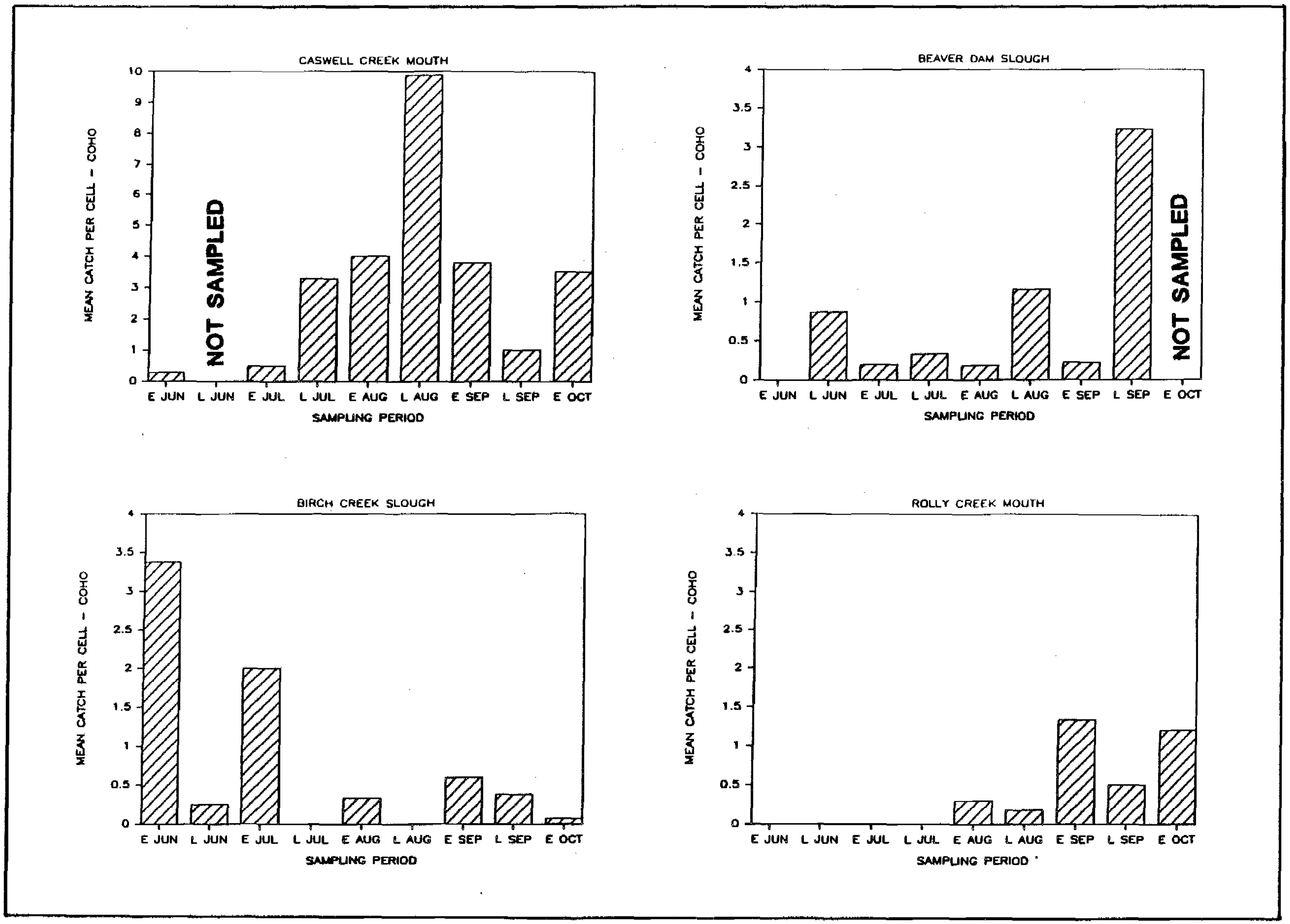


Figure 12. Juvenile coho salmon mean catch per cell at four tributary mouths on the lower Susitna River by sampling period, June through mid-October 1984.

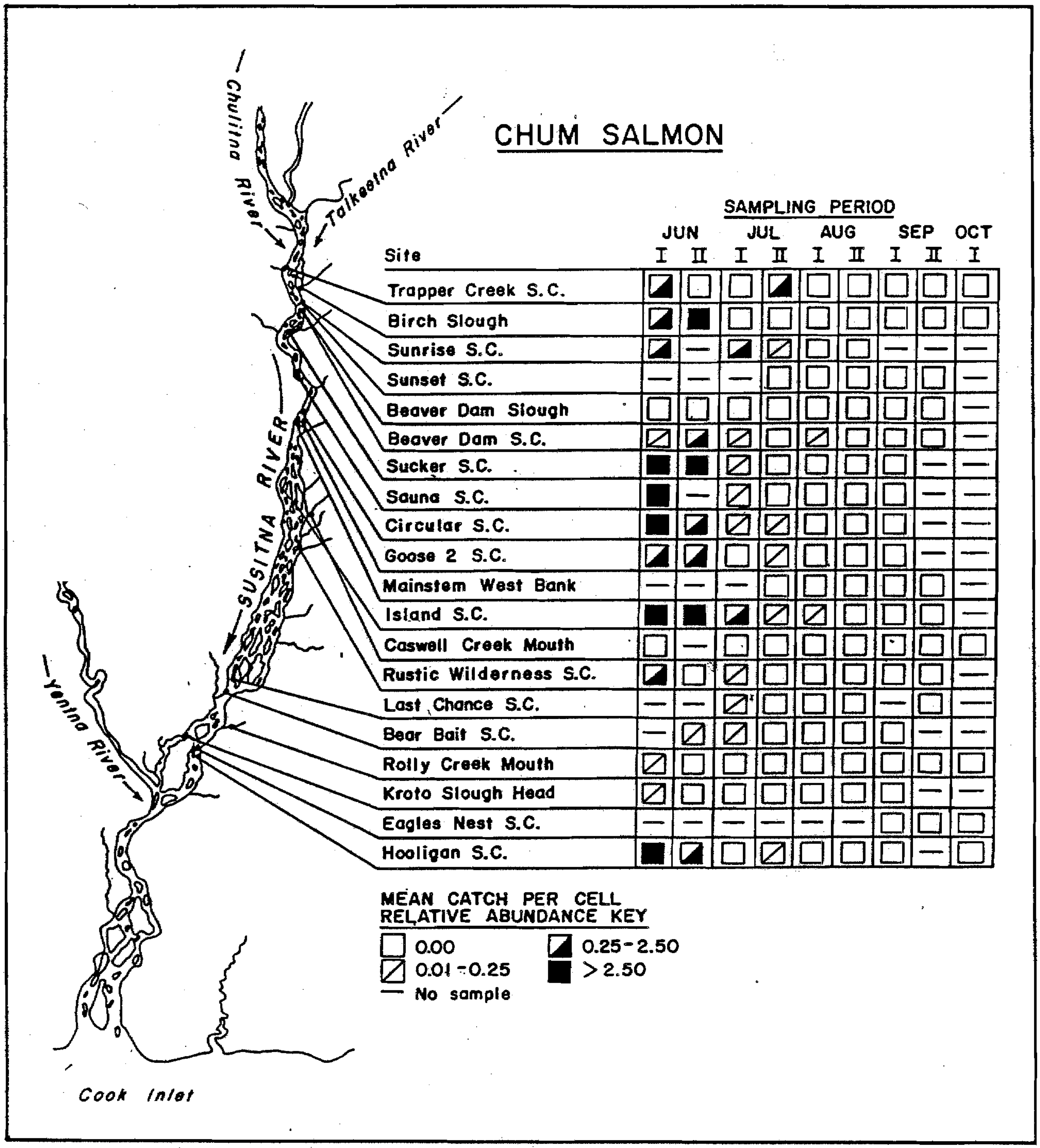


Figure 13. Seasonal distribution and relative abundance of juvenile chum salmon on the lower Susitna River, June through mid-October 1984.

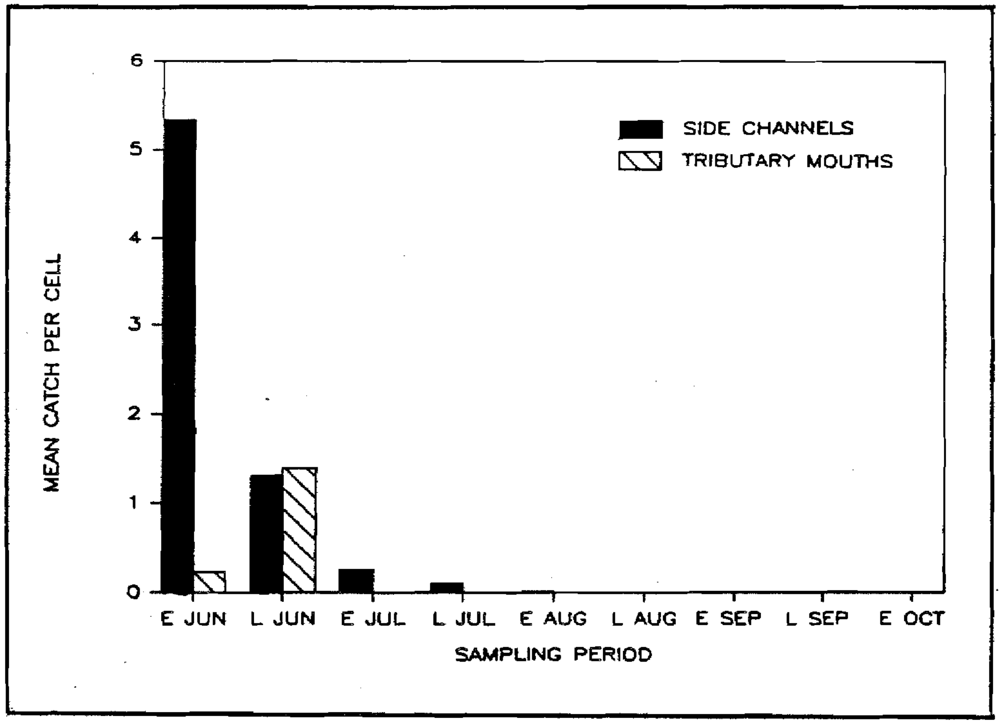


Figure 14. Juvenile chum salmon catch per cell at modelled side channels and tributary mouths on the lower Susitna River by sampling period, June through mid-October, 1984.

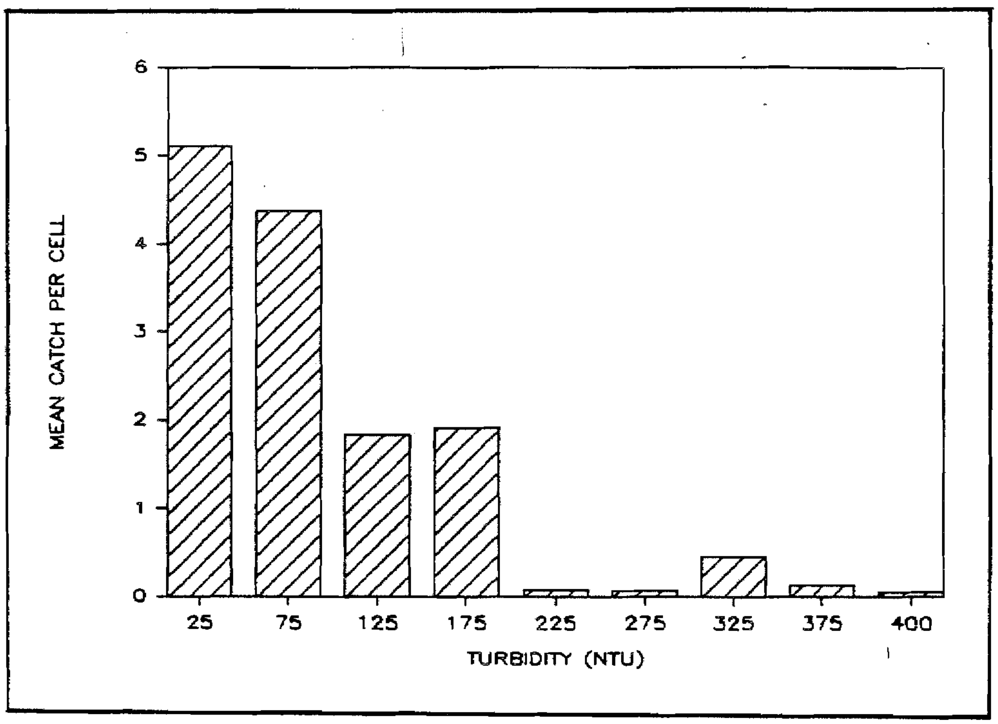


Figure 15. Juvenile chum salmon mean catch per cell at modelled side channels on the lower Susitna River by turbidity increment, June through mid-July 1984.

and in late June at Beaver Dam Slough. Sockeye juveniles were most widely distributed within modelled sites upstream of Goose 2 Side Channel (Figure 16).

Tributary mouths had the greatest densities of juvenile sockeye salmon with a mean catch of 0.7 fpc. The highest CPUE for juvenile sockeye at a tributary mouth was 1.2 fpc at Beaver Dam Slough. Side channels had a mean sockeye CPUE of 0.1 fpc. Beaver Dam Side Channel had the highest CPUE for a side channel of 0.7 fpc. Side slough CPUEs of sockeye juveniles were minimal (0.03 fpc). Side channel CPUE's remained at low levels through August in comparison to tributary mouth CPUE's which varied greatly (Figure 17). No sockeye juveniles were captured in side channels after August, however, sampling was limited.

Sockeye fry CPUEs were highest in side channels where turbidities ranged between 100 and 150 NTU (Figure 18). The numbers of sockeye juveniles captured in Beaver Dam Side Channel, immediately below and contiguous with Beaver Dam Slough, may have been enhanced by site to site movement. With Beaver Dam Side Channel captures excluded, the peak CPUE for juvenile sockeye in side channels occurred at turbidities between 50 and 100 NTU.

Catches at Beaver Dam Slough and Beaver Dam Side Channel show the effects of turbidity as cover on the distribution of sockeye juveniles (Figure 19). From late June through August, Beaver Dam Side Channel was breached by the mainstem, the water was turbid, and sockeye CPUE's were high. In early June and September, however, the head of the channel was not breached, the water was clear, and few sockeye juveniles were caught in this environment with little cover. In contrast, Beaver Dam Slough, which had abundant aquatic vegetation cover, had high CPUE's of sockeye juveniles in late August and September. Catches at Rolly Creek also increased in late August and remained fairly high through early October (Figure 19).

3.3 Habitat Modelling of Rearing Juvenile Salmon

The response of juvenile salmon habitat to variations in mainstem discharge was modelled using two techniques: (1) the RJHAB model developed in Marshall et al. (1984) and (2) the IFIM hydraulic models discussed by Bovee (1982). Suitability criteria for important microhabitat variables are necessary as inputs to both models and criteria specific to the lower reach of the Susitna River for juvenile chinook, coho, chum, and sockeye salmon have been developed in Appendix A.

In the following discussion, results are presented by species. Each presentation includes modelling results from selected sites using the RJHAB or IFIM models, pooled results from all the sites modelled, and a test of model verification.

No results from the Birch Creek Slough and Eagles Nest Side Channel modelling sites are presented here. At Birch Creek Slough, there was no measurable effect of mainstem discharge upon the site as mainstem backwater at discharges less than 75,000 cfs did not extend to the site and a blocked culvert at the head of the slough stopped mainstem water

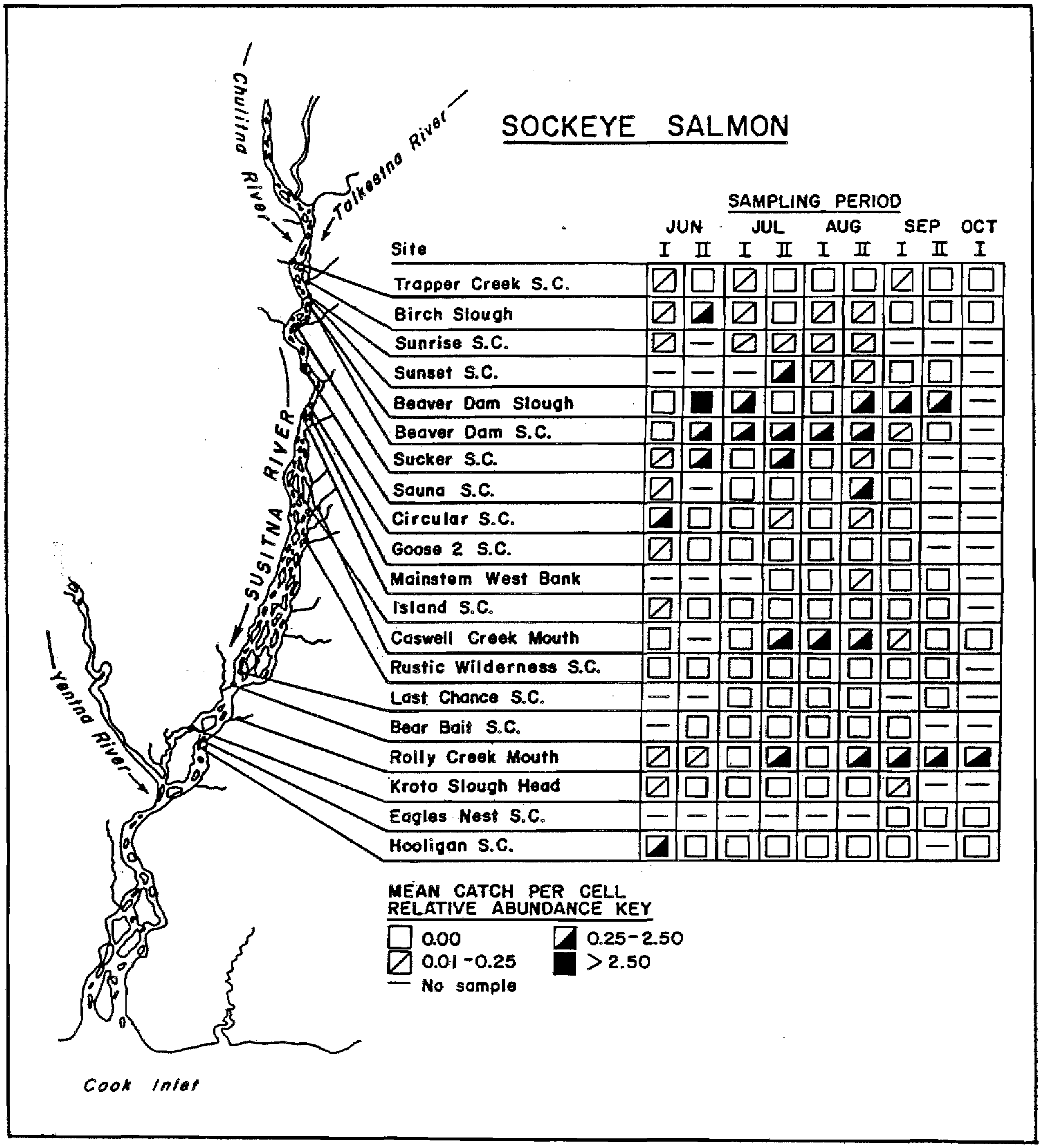


Figure 16. Seasonal distribution and relative abundance of juvenile sockeye salmon on the lower Susitna River, June through mid-October 1984.

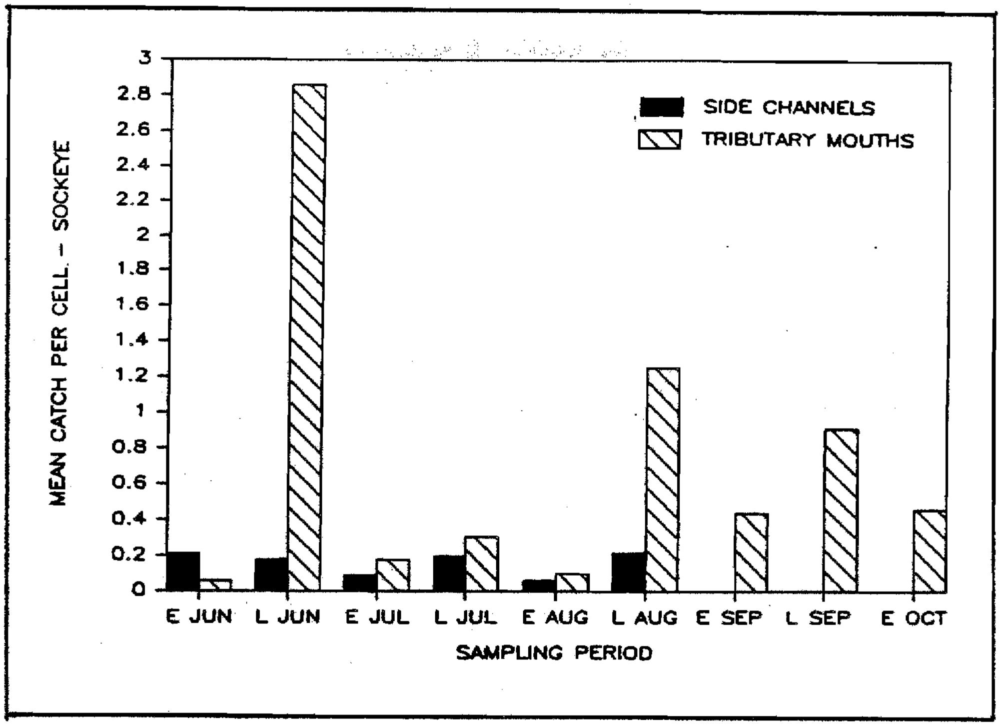


Figure 17. Juvenile sockeye salmon mean catch per cell at side channels and tributary mouths on the lower Susitna River by sampling period, June through mid-October 1984.

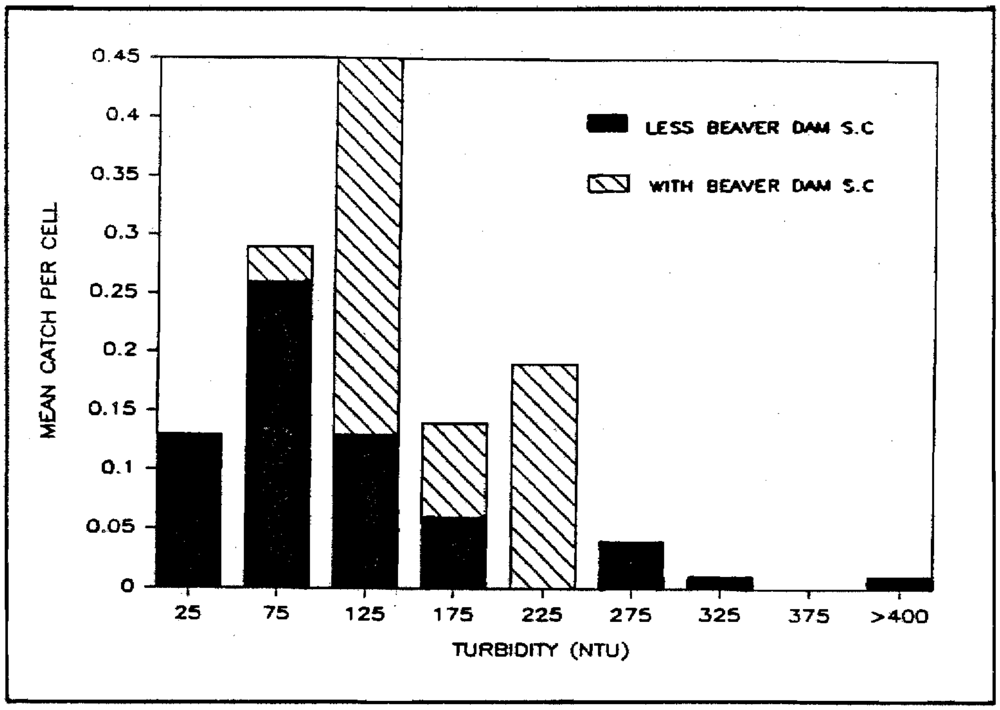


Figure 18. Juvenile sockeye salmon mean catch per cell at modelled side channels on the lower Susitna River by turbidity increment (with and without Beaver Dam Side Channel), June through mid-October 1984.

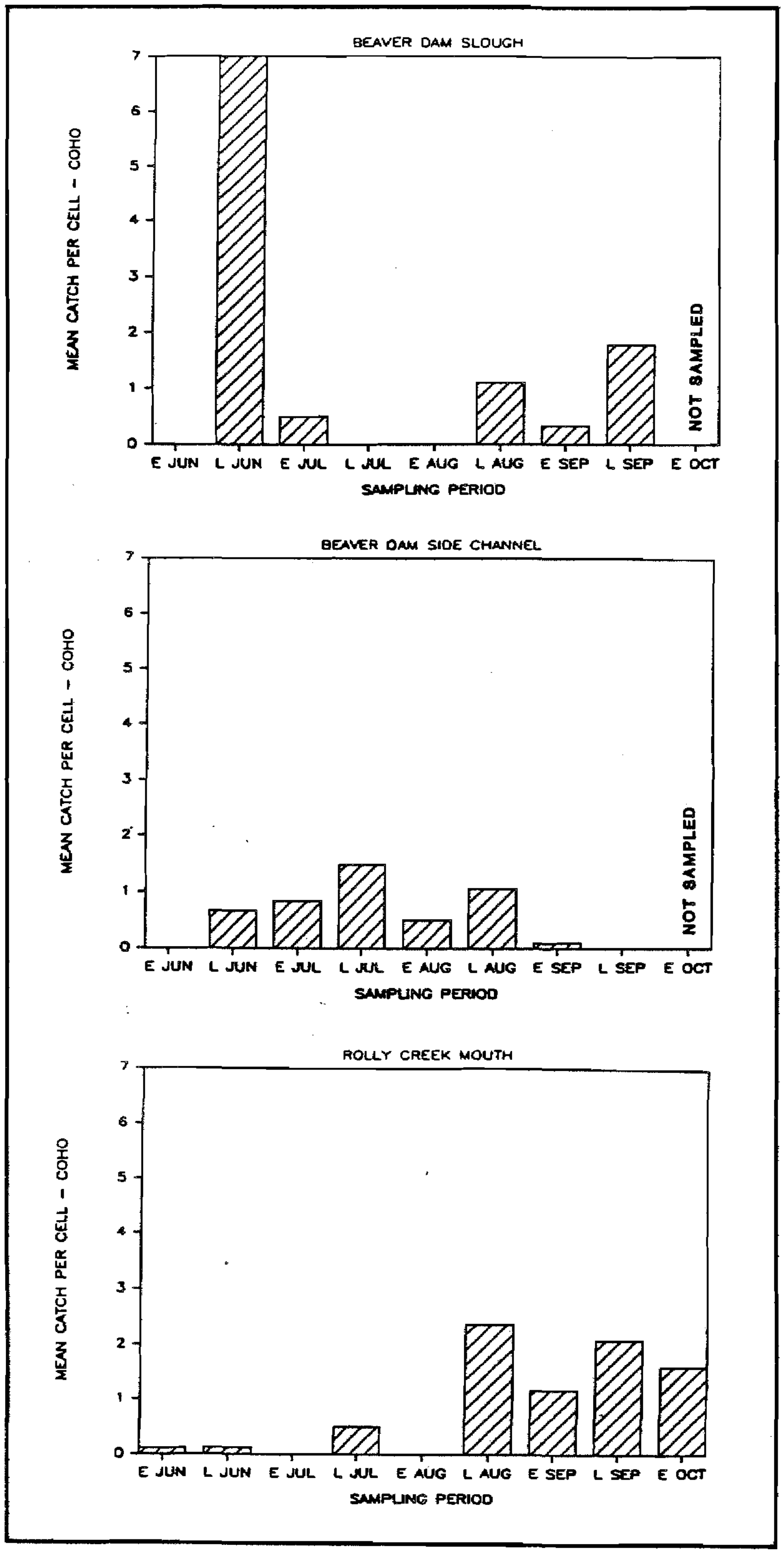


Figure 19. Juvenile sockeye salmon mean catch per cell at Beaver Dam Slough, Beaver Dam Side Channel, and Rolly Creek Mouth by sampling period, June through mid-October 1984.

from flowing through the site. The Eagles Nest Side Channel site was modelled only twice at mainstem flows of 14,900 and 20,400 cfs and therefore could not be readily extrapolated to discharges of 75,000 cfs. All of the other sites were modelled at three or more discharges and results were extrapolated to discharges ranging from 12,000 to 75,000 cfs. The WUAs and site areas at the RJHAB sites were not adjusted to a reach length of 1,000 ft as were the IFIM WUAs. Lengths of all the RJHAB sites are listed in Appendix Table B-3, so that the WUAs could be adjusted if desired.

The instream flow results have been generated only to discharges of 75,000 cfs because it is very difficult to collect data at discharges greater than 75,000 cfs. At 75,000 cfs, most of the side channel sites have very large flows and are poor habitat for juvenile fish. At higher discharges, the entire flood plain becomes full and the flows are barely constrained within the side channels. Refuge for the juvenile fish at these times presumable include large backwater areas and small side channels which are infrequently flooded.

At Island and Trapper Creek side channels, both RJHAB and IFIM models were run on the same transects. Comparative results for these two models are given in Appendix C. The summary figures presented here incorporate data from the RJHAB model at these two side channels.

The ability of the RJHAB models to extrapolate WUA between discharges of 12,000 and 75,000 cfs was rated unacceptable to good (Table 5). Some models were rated fair because there were no habitat measurements taken at discharges just above overtopping of the side channel. Eagle's Nest Side Channel was rated unacceptable because measurements were taken on only two occasions at discharges less than 21,000 cfs.

The IFIM models were evaluated according to hydraulic criteria on the basis of excellent to acceptable (Appendix D). Acceptable ranges of the models usually extend to over 60,000 cfs (Table 6). The models were run and WUAs generated at side channel flows which corresponded to discharges ranging to 75,000 cfs, so reliability at these flows is unknown. At discharges below overtopping, the WUAs of IFIM sites at flows of 5 or 6 cfs were used, except at Trapper Creek Side Channel where a site flow-mainstem discharge rating curve for unbreached conditions developed by Quane et al. (1985) was used to estimate unbreached flows.

Since suitability criteria for chinook salmon juveniles have been developed for both turbid (>30 NTU) and clear (<30 NTU) conditions, several assumptions were made. Tributary mouth sites were assumed to be clear (>30 NTU) at all discharges less than 75,000 cfs. This is not always the case, as occasionally turbid mainstem water may back up into tributary mouths with a rapid increase in mainstem stage. Also spring runoff or large storms may increase turbidities at tributary mouths to over 30 NTU. Available data, however, have indicated turbidities at tributary mouths are normally less than 30 NTU (Figure 3). At side channel/slough sites, turbidities were assumed to be greater than 30 NTU when the site was breached and less than 30 NTU when the site was not breached. In early June, September, and early October, turbidities in side channels were sometimes less than 30 NTU (Figure 3). Many of the

Table 5. Evaluation of RJHAB model quality for extrapolating WUAs over the range of 12,000 to 75,000 cfs as measured at Sunshine gaging station, 1984.

Site	Number of Habitat Measurements	Model Quality[1]
Hooligan Side Channel	5	Good
Eagle's Nest Side Channel	2	Unacceptable
Kroto Slough Head	4	Fair
Rolly Creek Mouth	4	Good
Bear Bait Side Channel	4	Fair
Last Chance Side Channel	5	Fair
Rustic Wilderness Side Channel	5	Good
Caswell Creek Mouth	3	Fair
Island Side Channel	5	Good
Goose 2 Side Channel	4	Fair
Sucker Side Channel	4	Good
Beaver Dam Slough	4	Good
Beaver Dam Side Channel	3	Good
Sunrise Side Channel	4	Fair
Birch Creek Slough	3	Good
Trapper Creek Side Channel	4	Good

[1] Model quality definitions:

1. Good - Side Channels: Measurements spaced so as to cover the range of mainstem discharges above breaching to 75,000 cfs. Models include information about unbreached, barely breached, and a minimum of two other breached flows, one near 75,000 cfs.

   Tributary Mouths: Models include information when no backwater, moderate backwater, and high backwater present.

2. Fair - Side Channels: Model missing information concerning habitat when channel is barely breached, or other flows given above.

   Tributary Mouths: Not enough measurements to accurately describe amount of backwater effect.

3. Unnacceptable - Less than three data points - cannot describe a curve.

Table 6. Discharge ranges of IFIM models at lower Susitna River sites for which hydraulics are rated acceptable, 1984. Data taken from Appendix D.

Site	Acceptable Range
Island Side Channel	35,000 to 70,000 cfs
Mainstem West Bank	18,000 to 48,000 cfs
Circular Side Channel	36,000 to 63,000 cfs
Sauna Side Channel	44,000 to 63,000 cfs
Sunset Side Channel	32,000 to 67,000 cfs
Trapper Creek Side Channel	20,000 to 66,000 cfs

model sites were not breached during these periods of low mainstem discharge. Turbidities in side sloughs were usually less than 10 NTU.

3.3.1 Chinook Salmon

Chinook salmon juveniles were captured at all of the study sites with the exception of Last Chance Side Channel (Figure 8). Since chinook juveniles were widely distributed, results from all sites modelled with RJHAB and IFIM techniques will be presented.

Graphs of the weighted usable area responses to mainstem discharges for all sites not presented here are included in Appendix B. Appendix B also contains the tabulated values of weighted usable areas at 3,000 cfs increments as digitized from these graphs (including site graphs presented here). Also tabulated are habitat indices which were calculated by dividing the weighted usable area at a given discharge by the site area at the same discharge.

At the Rolly Creek, Caswell Creek, and Beaver Dam Slough tributary mouth sites, the responses of weighted usable area to mainstem discharge were very similar. The Rolly Creek mouth weighted usable area response to discharge is presented here as an example (Figure 20). The great increase in weighted usable area with discharge above approximately 45,000 cfs is due to the effect of mainstem backwater causing large increases in area, depth, and amount of cover.

At side channel/slough sites, the responses of weighted usable areas to mainstem discharge was varied. Normally, the weighted usable area increased greatly after overtopping and then decreased with further increases in mainstem discharge as at Kroto Slough Head (Figure 20). The increase in weighted usable area after overtopping is due to increases in area and also increases in cover suitability as turbidity improves cover. As discharge increases with site flow, velocities initially become more suitable, but then as flows continue to rise, velocities become unsuitable and WUA decreases.

At Sucker Side Channel, backwater effects buffer the velocities from becoming too high and so weighted usable area increases after overtopping and then remains nearly the same to a discharge of 45,000 cfs after which it rapidly increases (Figure 20). At approximately 60,000 cfs, WUA's begin to decline at this site, however, as velocities and depths become unsuitable. At other sites, WUA held quite constant after overtopping or slowly increased (see Appendix B).

When WUA's from three tributary mouths are pooled there is no large change in WUA until approximately 45,000 cfs when the WUA increases greatly with discharge (Figure 21). By dividing the WUA at 3,000 cfs increments by pooled area for the three sites and plotting the habitat index, it becomes apparent that the change in WUA is not simply due to increases in site area. Increases in habitat indices are due to increases in the amount of instream cover, more suitable velocities, and deeper water which may also provide cover.

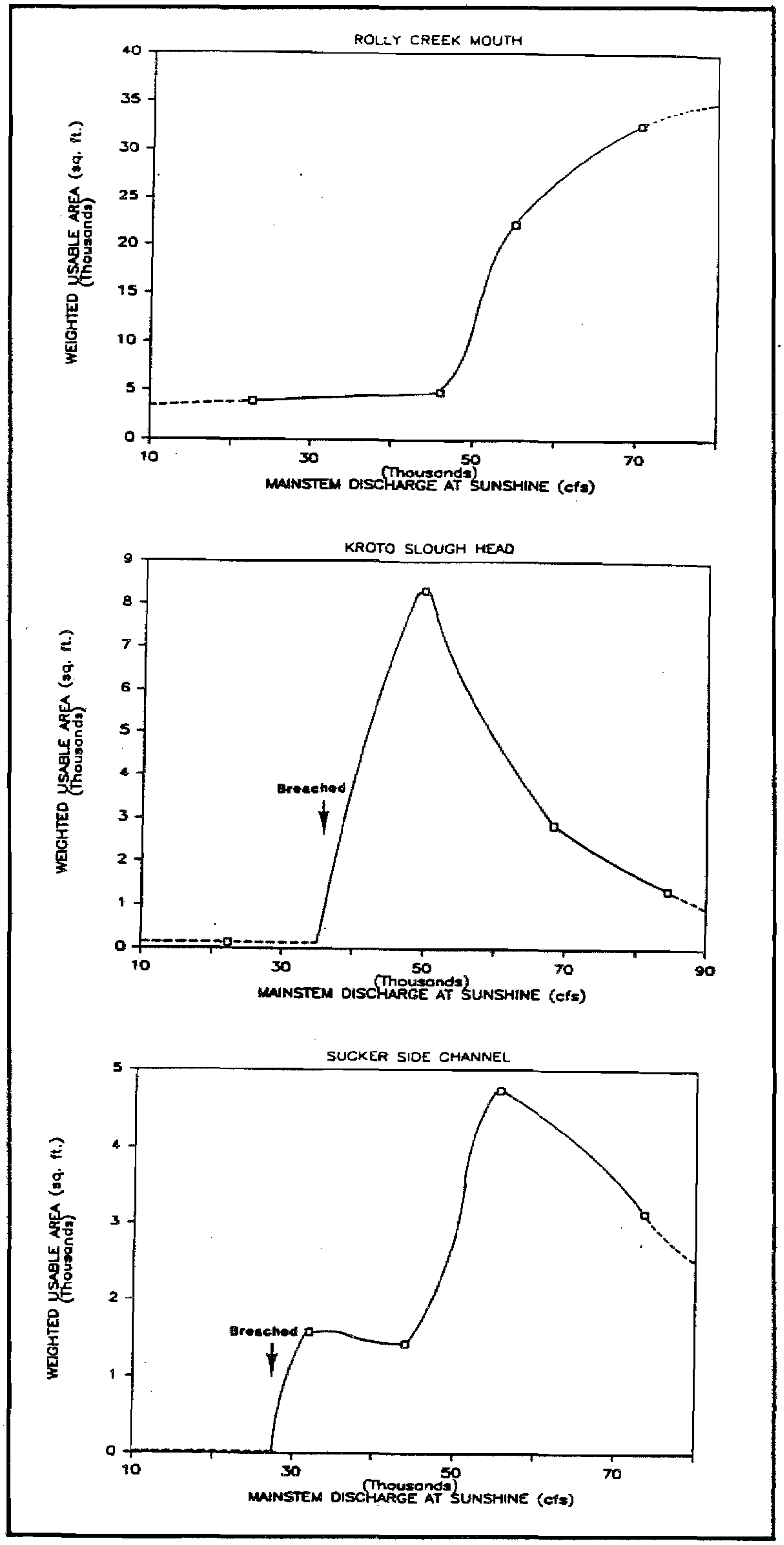


Figure 20. Weighted usable area for juvenile chinook salmon at Rolly Creek Mouth, Kroto Slough Head, and Sucker Side Channel study sites as a function of mainstem discharge, 1984.

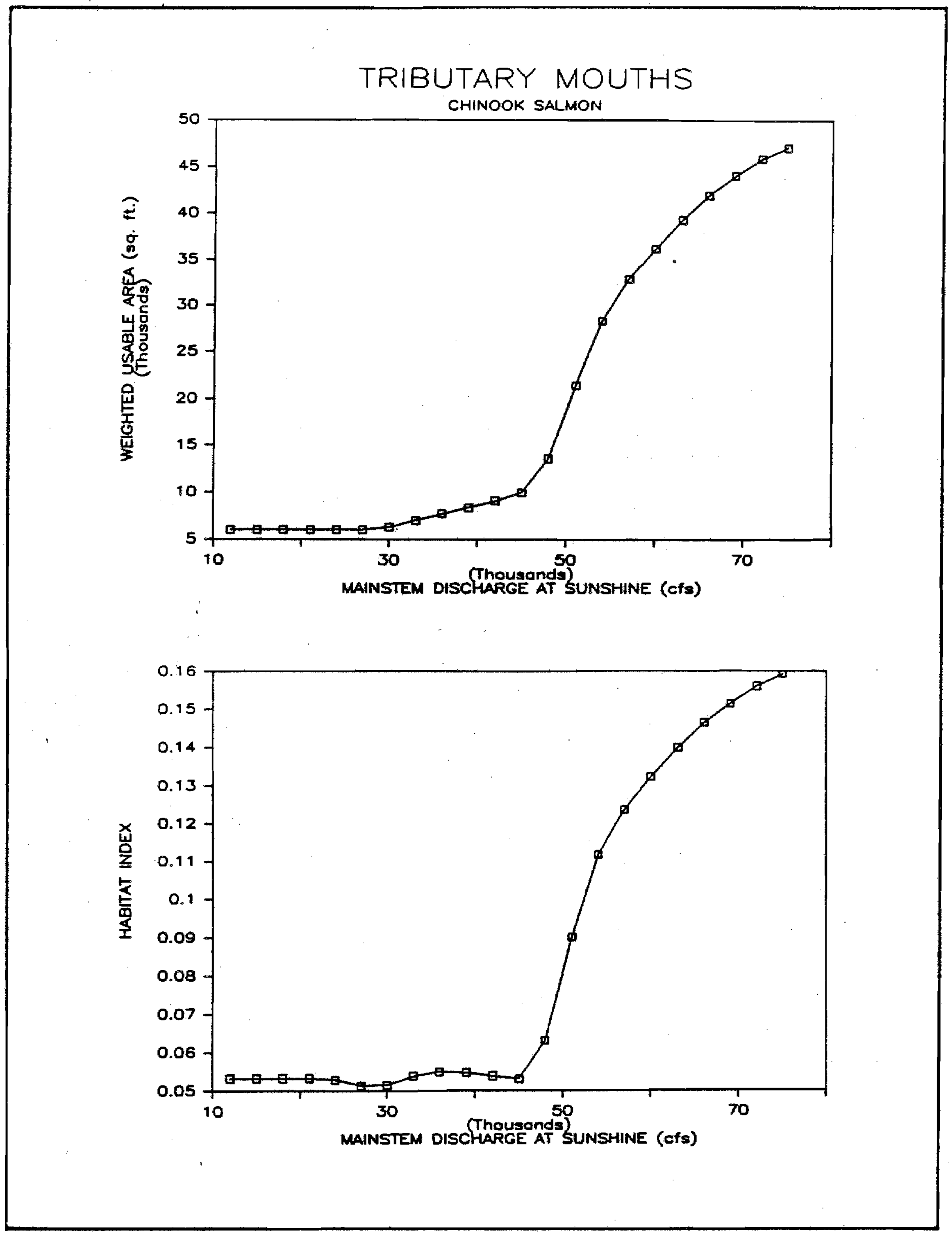


Figure 21. Weighted usable area and habitat indices for juvenile chinook salmon at tributary mouth sites as a function of mainstem discharge, 1984.

When WUA's from the modelled side channels/sloughs are pooled, WUA's increase greatly to approximately 40,000 cfs and then very gradually decline (Figure 22). Habitat indices for the pooled side channels show a similar rise to a peak at 40,000 cfs but then a rapid decrease to approximately 60,000 cfs when the habitat index levels off. The relatively more rapid decrease in the habitat index is due primarily to velocities and depths becoming very unsuitable at the higher discharges.

Turbidity has been shown to be an important determinant of juvenile chinook distribution (Figure 10). Turbidity varies in the Susitna River from the east bank to the west bank downstream from the Chulitna and Talkeetna river confluences (Figure 4). In formulating the pooled side channel/slough response of juvenile salmon habitat, it was desirable to weight turbidity as it varies from site to site.

Although turbidity data for the model sites are limited, an average turbidity for the side channels modelled during the period from June through August was calculated in Appendix Table B-1. A preliminary suitability index for high turbidity was then fit to the data in Figure 10 (Table 7). This index is specific only to the turbidity regimes of lower river side channels and is undefined for application to turbidities of less than approximately 100 NTU. When the turbidity indices and mean turbidities were combined, WUA estimates for the sites were weighted differently (Table 8).

When the WUA estimates for each site are adjusted by these factors and the WUA's are again totalled, the WUA and habitat index response adjusted for turbidity for the side channels combined can again be examined (Figure 23). There is very little change from the previous unadjusted graph in the shape of the WUA response curve, but the magnitude was reduced by almost 40%. Similarly, the shape of the habitat index responses curve has also been changed very little by these adjustments. The lack of change in shape of these curves suggests that the responses of the side channel WUAs and habitat indices are similar for most of the sites.

The mean seasonal chinook salmon habitat index for the 15 side channels and four tributary mouths were calculated and compared with mean chinook catch (Figure 24). The positive relationship was statistically significant ($p \leq 0.001$) but not very strong. Most of the correlation was due to the large catch (5.16 fpc) and habitat index (0.19) at Caswell Creek mouth. Another outlier is Beaver Dam Slough with a habitat index of 0.17 and a mean catch of 0.17 chinook per cell.

3.3.2 Coho Salmon

Since coho salmon were captured in number (more than 20) only at the tributary mouth sites, only results from these sites will be presented here. In Appendix B, values of WUA's and habitat indices at 3,000 cfs increments for these areas are presented.

The response of WUA to mainstem discharge at the three tributary mouths varied (Figure 25). At Caswell Creek mouth, WUA rose with discharge due to increases in area and the amount of preferred cover. At Rolly Creek

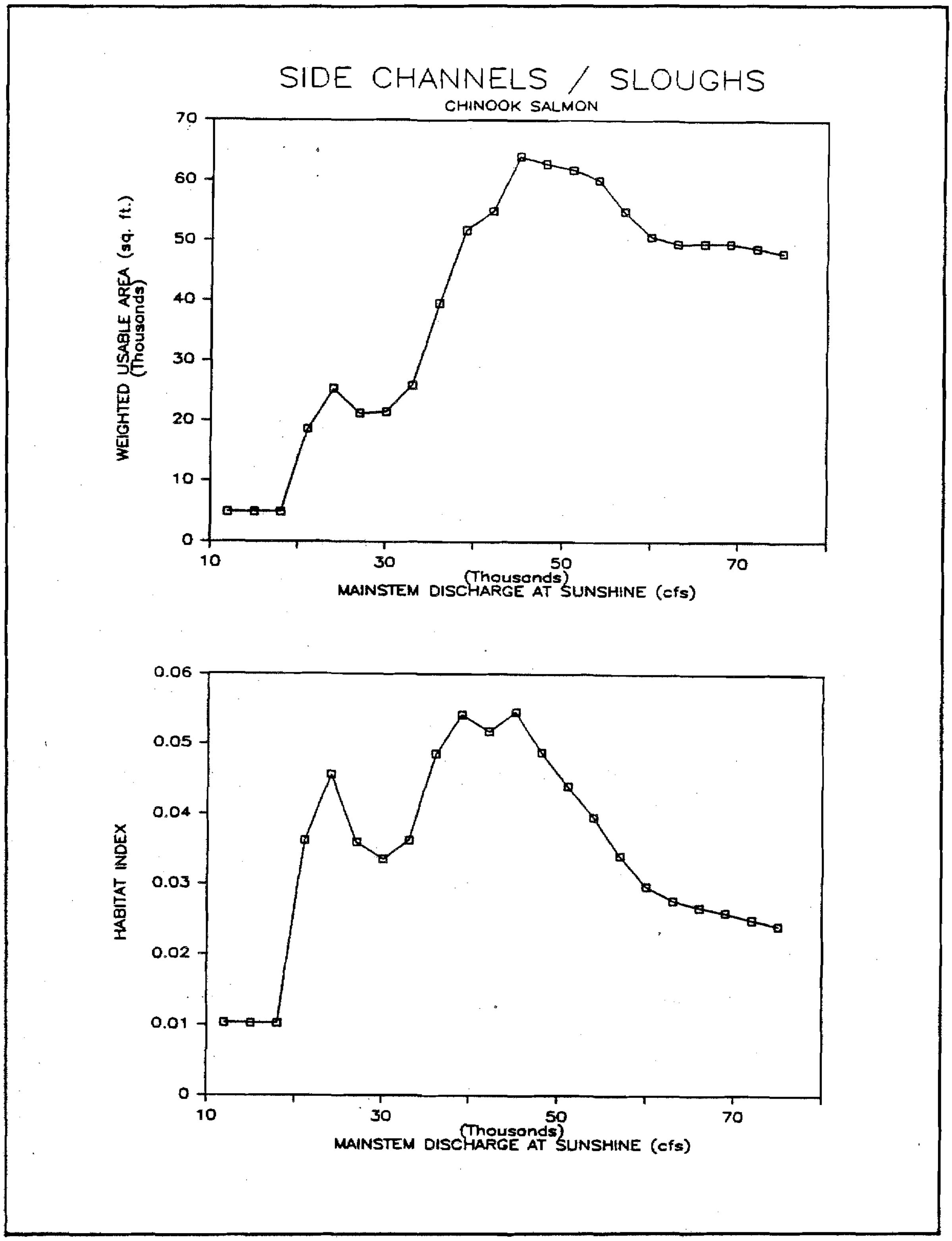


Figure 22. Weighted usable area and habitat indices for juvenile chinook salmon at side channel/slough study sites as a function of mainstem discharge, 1984.

Table 7. Preliminary juvenile chinook salmon turbidity criteria derived from lower Susitna River side channel distribution data for turbidities greater than 100 NTU. These criteria are only applicable to lower Susitna River side channels.

Mean Turbidity (NTU)	Suitability
101 - 200*	1.00
201 - 250	0.65
251 - 300	0.55
301 - 350	0.40
350	0.15

* Suitability index for turbidities of less than 101 NTU is undefined and may be greater than 1.0.

Table 8. Weighting factors for turbidity by side channel site for analysis of juvenile chinook salmon habitat use, 1984.

Site	Mean Turbidity (NTU)	Turbidity Weighting Factor
Hooligan Side Channel	377	0.15
Kroto Slough Head	388	0.15
Bear Bait Side Channel	254	0.55
Last Chance Side Channel	365	0.15
Rustic Wilderness Side Channel	118	1.00
Island Side Channel	215	0.65
Mainstem West Bank	279	0.55
Goose 2 Side Channel	194	1.00
Circular Side Channel	241	0.65
Sauna Side Channel	266	0.55
Sucker Side Channel	140	1.00
Beaver Dam Side Channel	139	1.00
Sunset Side Channel	152	1.00
Sunrise Side Channel	121	1.00
Trapper Creek Side Channel	499	0.15

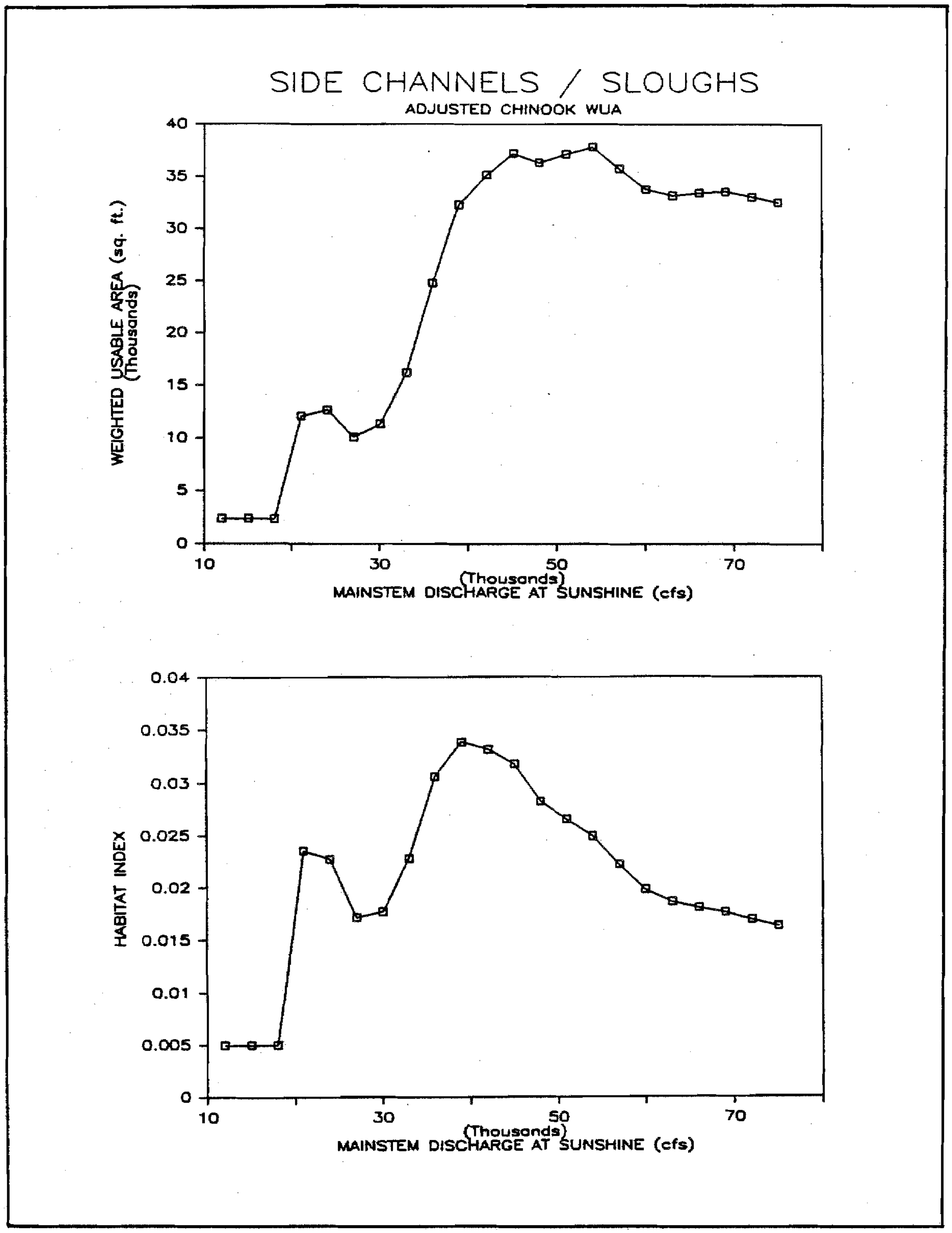


Figure 23. Turbidity adjusted weighted usable area and habitat indices for juvenile chinook salmon at side channel/slough study sites as a function of mainstem discharge, 1984.

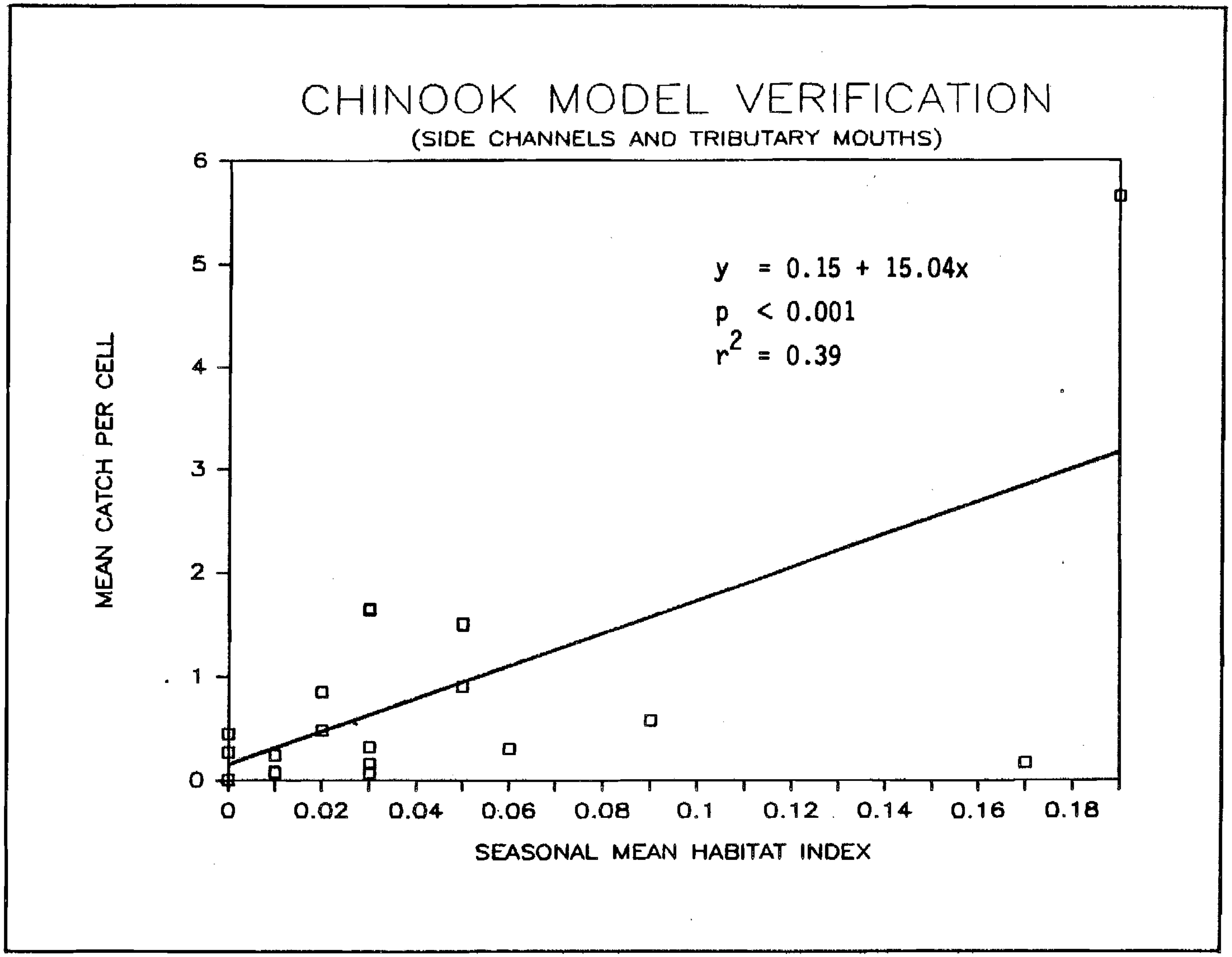


Figure 24. Juvenile chinook salmon mean catch per cell versus seasonal mean habitat indices at side channel and tributary mouth modelling sites on the lower Susitna River, 1984.

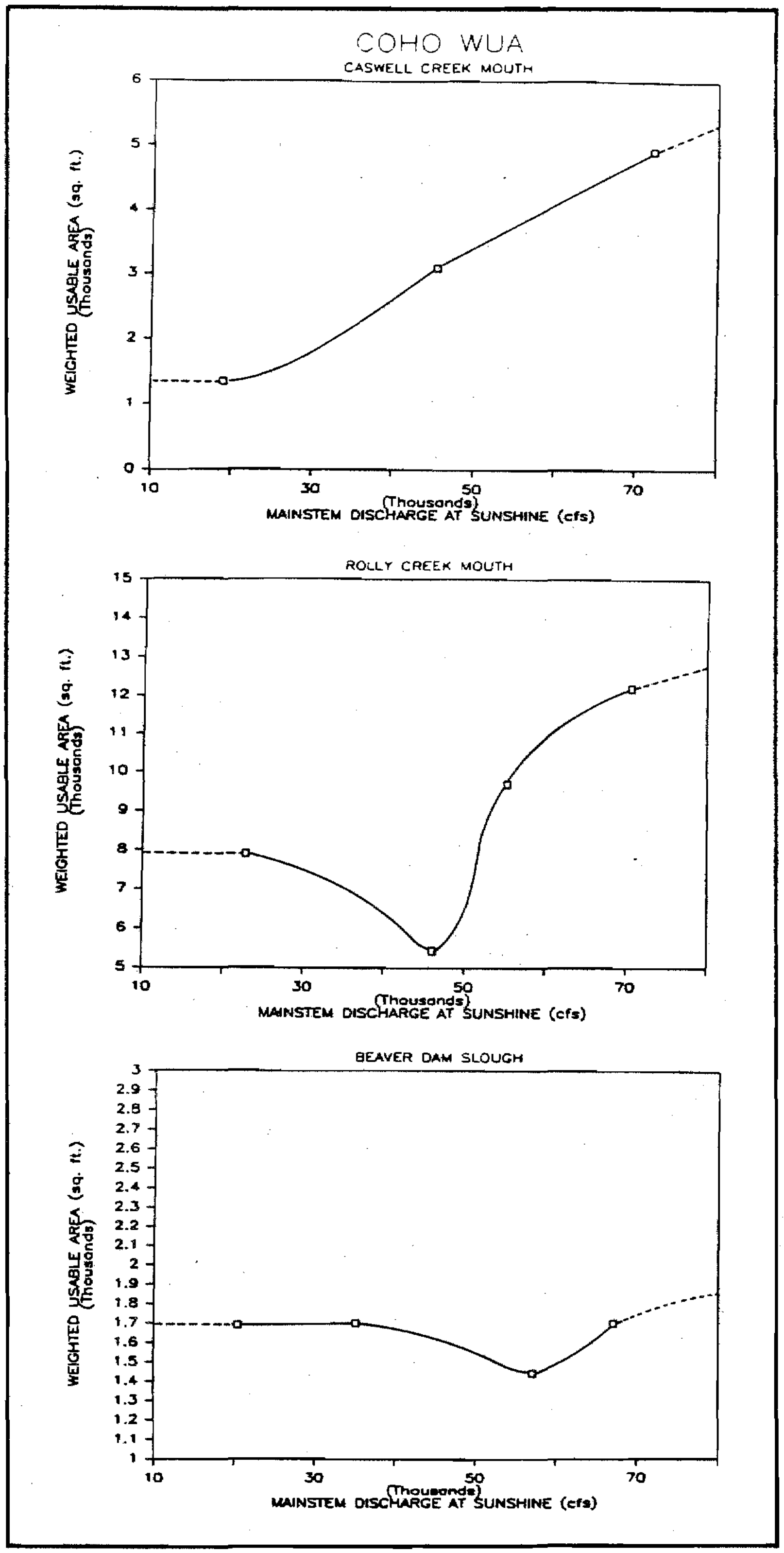


Figure 25. Weighted usable area for juvenile coho salmon at the Caswell Creek, Rolly Creek, and Beaver Dam Slough tributary study sites as a function of mainstem discharge, 1984.

mouth, the WUA first decreased with discharge due to the formation of zero velocity backwater from a free flowing state without major changes in cover or area. At higher discharges, the WUA increases due to a rise in area and usable cover. At Beaver Dam Slough, these effects of backwater formation and increases in cover inundated offset one another so that there was little change in WUA with discharge.

When the WUA's from all three sites are summed (Figure 26), there is little change in WUA until approximately 50,000 cfs when the WUA begins to increase greatly with discharge. When the effect of change in area is taken out by calculating a habitat index, site quality decreases initially as the backwater is formed and then begins to increase as cover is inundated by backwater.

The mean habitat index for the season (May 15 to October 15) was calculated for the four tributary mouths. Since Birch Creek Slough was a natal area, only catches from mid-July through mid-October were used in calculating the mean site catch. The mean catch per cell of coho juveniles increased with the mean habitat index but a linear regression was not statistically significant at the 0.05 level (Figure 27). None of the side channels had mean seasonal habitat indices greater than 0.05 and most were 0.03 or less, primarily due to the lack of suitable cover types.

3.3.3 Chum Salmon

Chum salmon were widely distributed at all of the side channel sites sampled from early June through July 15 (Figure 13). Therefore, graphs of the WUA response as a function of mainstem discharge for all the side channel/slough sites not presented here are included in Appendix B. Also tabulated in Appendix B are values of WUA's and habitat indices at 3,000 cfs increments as digitized from the graphs.

Responses of WUA's at the sites to increases in mainstem discharge were variable. At Rustic Wilderness Side Channel, WUA greatly increased after overtopping and then declined with further increases in discharge as velocities and depths became unsuitable (Figure 28). At other sites, for example Last Chance Side Channel, the increase in WUA after overtopping was considerably less while at Trapper Creek Side Channel (Figure 29), WUA's decreased after overtopping. At Sunset Side Channel, WUA increased after overtopping until about 53,000 cfs when WUA quickly declined. The other sites also showed variations of these response curves (see Appendix B figures).

When WUA's from all modelled side channel/slough sites are pooled, the peak in WUA's for the sites occurs at a discharge of 40,000 to 52,000 cfs (Figure 30). Above this discharge range, WUA's decrease rapidly due to unsuitable velocities and depths. Habitat indices for the same pooled sites are constant through about 24,000 cfs and then decrease steadily.

Chum salmon use of side channels was affected by turbidity (Figure 15), and since turbidity varied from site to site, WUA's for each site were adjusted for turbidity. Since chum salmon outmigration is mostly

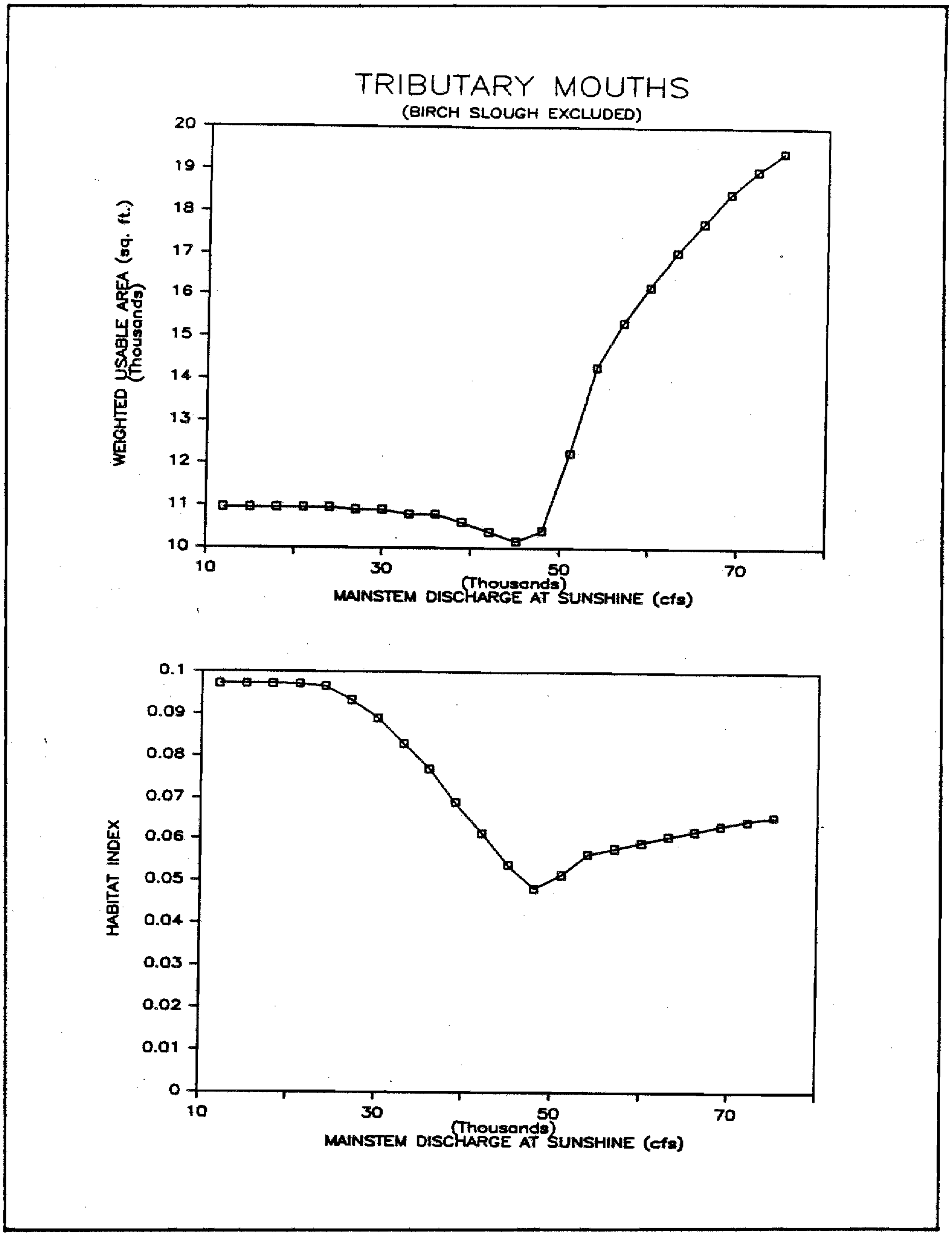


Figure 26. Weighted usable area and habitat indices for juvenile coho salmon at tributary mouth sites (excluding Birch Creek Slough) as a function of mainstem discharge, 1984.

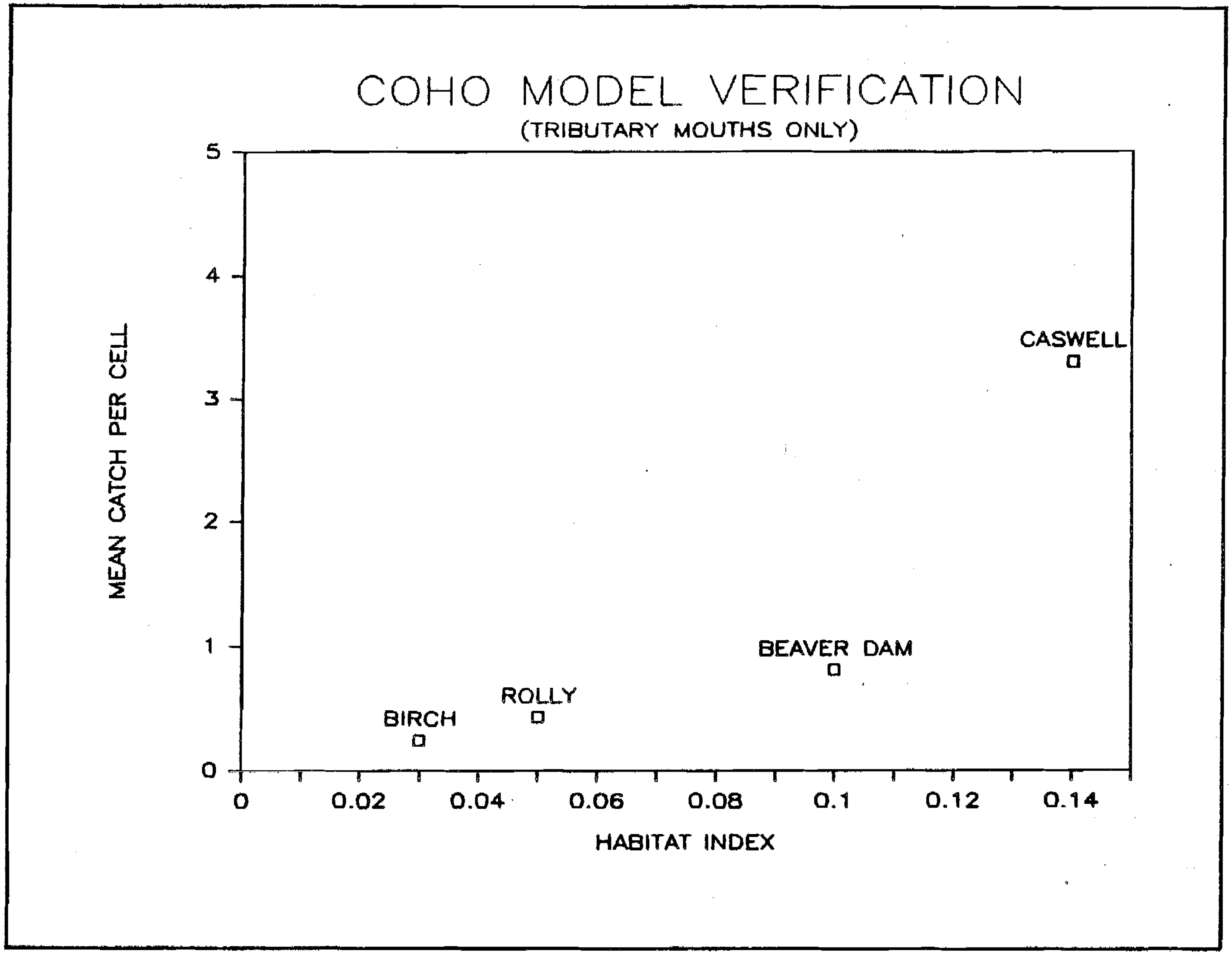


Figure 27. Juvenile coho salmon mean catch per cell versus seasonal mean habitat indices at tributary mouth modelling sites on the lower Susitna River, 1984.

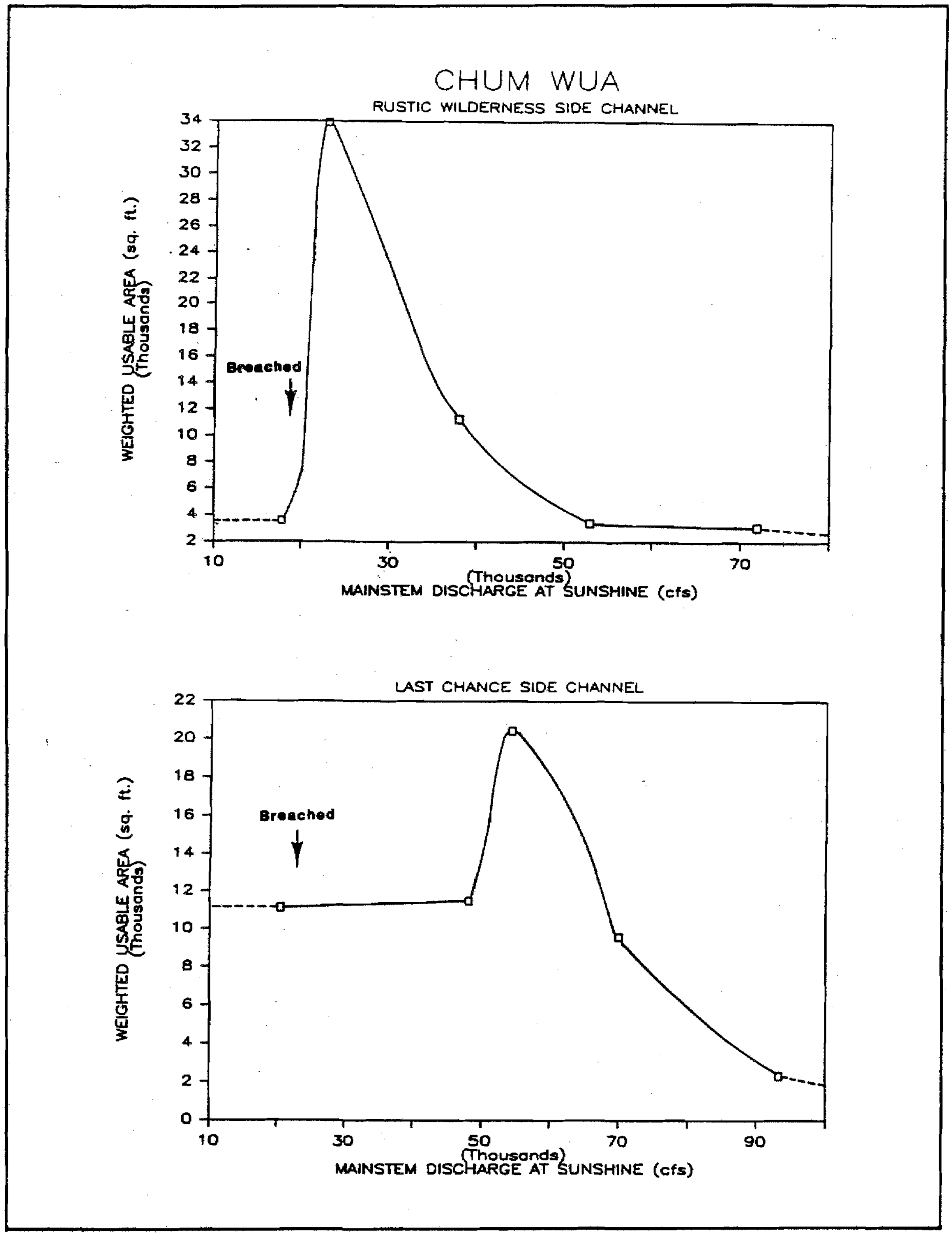


Figure 28. Weighted usable area for juvenile chum salmon at Rustic Wilderness and Last Chance Side Channel study sites as a function of mainstem discharge, 1984.

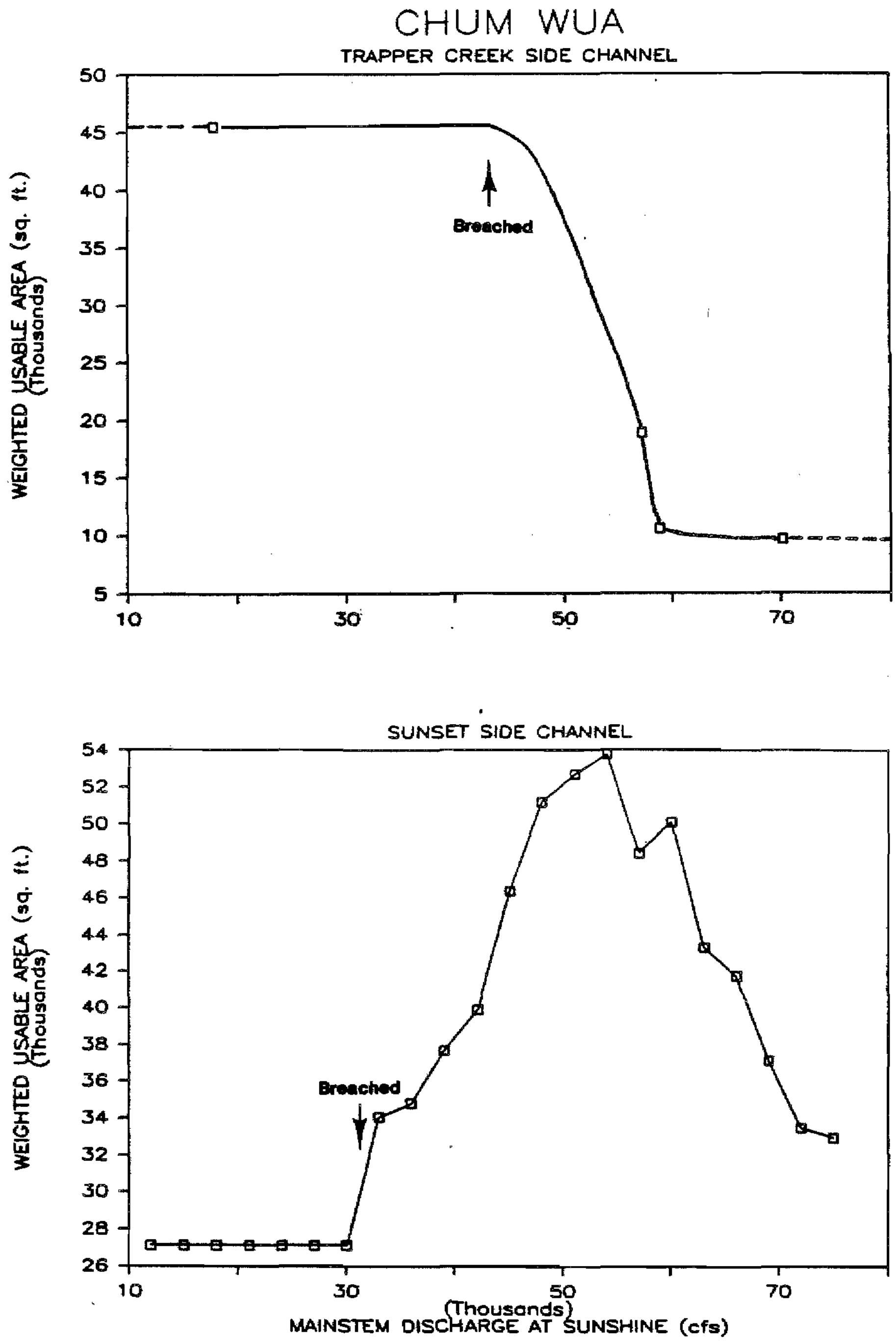


Figure 29. Weighted usable area for juvenile chum salmon at the Trapper Creek and Sunset Side Channel study sites as a function of mainstem discharge, 1984.

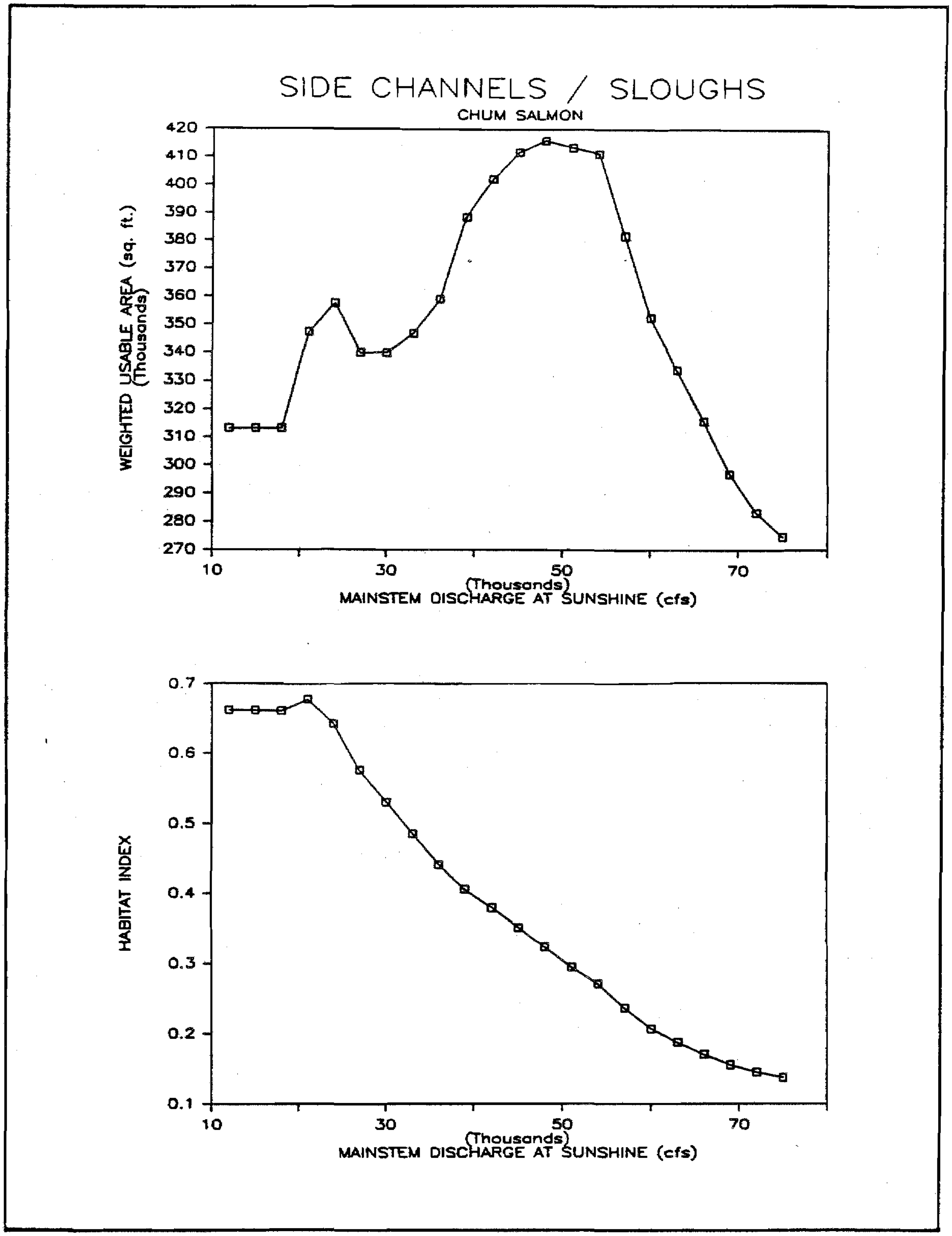


Figure 30. Weighted usable area and habitat indices for juvenile chum salmon at side channel/slough study sites as a function of mainstem discharge, 1984.

completed by July 15, turbidity data contained in Appendix Table B-1 were examined through July 15. Since turbidities greater than 200 NTU appear to affect use greatly (Figure 15), site WUA's were adjusted for periods when the turbidity exceeded 200 NTU. Adjustment factors for the sites ranged from 0.50 to 1.0 (Table 9).

When the chum salmon WUA's were adjusted for turbidity and again totalled, very few changes were noted in the shape of the WUA of habitat index response curves although both WUA's and habitat indices decreased (Figure 31). Since there was little change in these curves, it appears that the shapes of the chum WUA responses at all the side channels are very similar and therefore weighting the sites differently by turbidity only changes the magnitude of the response.

Mean chum salmon adjusted habitat indices were calculated for the period from May 15 through july 15 and compared with mean chum catch during the same time period (Figure 32). There was no sampling effort at two of the side channels, Mainstem West Bank and Sunset Side Channel, during this time so they are not included in this graph. The correlation (0.54) between the seasonal habitat index and chum catch was significant at the 10% probability level but not at the 5% probability level.

3.3.4 Sockeye Salmon

Sockeye salmon were most numerous at the tributary mouth sites with most side channels having some use (Figure 16). Presented here or in Appendix B are graphs of the WUA responses to discharge of the three tributary mouths and the four side channels (Beaver Dam, Sucker, Sunrise and Sunset) which were found to have sockeye salmon present more than half the times sampled.

The typical response of WUA at the tributary mouths to increases in discharge was a steady increase as shown here by the modelling results from Rolly Creek (Figure 33). The WUA increased as the backwater zone increased because sockeye find zero velocity water most suitable and because site area and cover also increased greatly with discharge. The WUA response at Sucker Side Channel was similar to that of the tributary mouths as WUA generally increased with discharge after overtopping. This site is influenced greatly by backwater effects from the side channel at its mouth. At Beaver Dam Side Channel, WUA increased after overtopping and then declined somewhat (Figure 34). At Sunset Side Channel, WUA fluctuated irregularly with discharge as the small amount of usable habitat along the margins of the site moved back and forth with flow changes.

At the combined tributary mouth sites, both WUA and habitat indices increased above discharges of approximately 30,000 cfs (Figure 35). At the pooled side channel/sloughs, on the other hand, WUA's also increased after approximately 30,000 cfs while habitat indices generally declined from the peak at 12,000 to 24,000 cfs (Figure 36). The decrease in the habitat index is due to the steadily increasing velocities in the side channels with increases in flow. No adjustments in turbidity are necessary for the four side channel/slough sites as these have very

Table 9. Weighting factors for turbidity by site for analysis of juvenile chum salmon habitat use, 1984.

Site	Sampling Period When Turbidity Exceeds 200 NTU	Turbidity Weighting Factor
Hooligan Side Channel	June 16-30	0.50
Kroto Slough Head	June 16-30	0.50
Bear Bait Side Channel	June 16-30	0.50
Last Chance Side Channel	June 16-30	0.50
Rustic Wilderness Side Channel	July 16-30	1.00
Island Side Channel	July 1-15	0.75
Mainstem West Bank	June 16-30	0.50
Goose 2 Side Channel	July 1-15	0.75
Circular Side Channel	July 1-15	0.75
Sauna Side Channel	June 16-30	0.50
Sucker Side Channel	July 1-15	0.75
Beaver Dam Side Channel	July 1-15	0.75
Sunset Side Channel	July 1-15	0.75
Sunrise Side Channel	July 1-15	0.75
Trapper Creek Side Channel	June 16-30	0.50

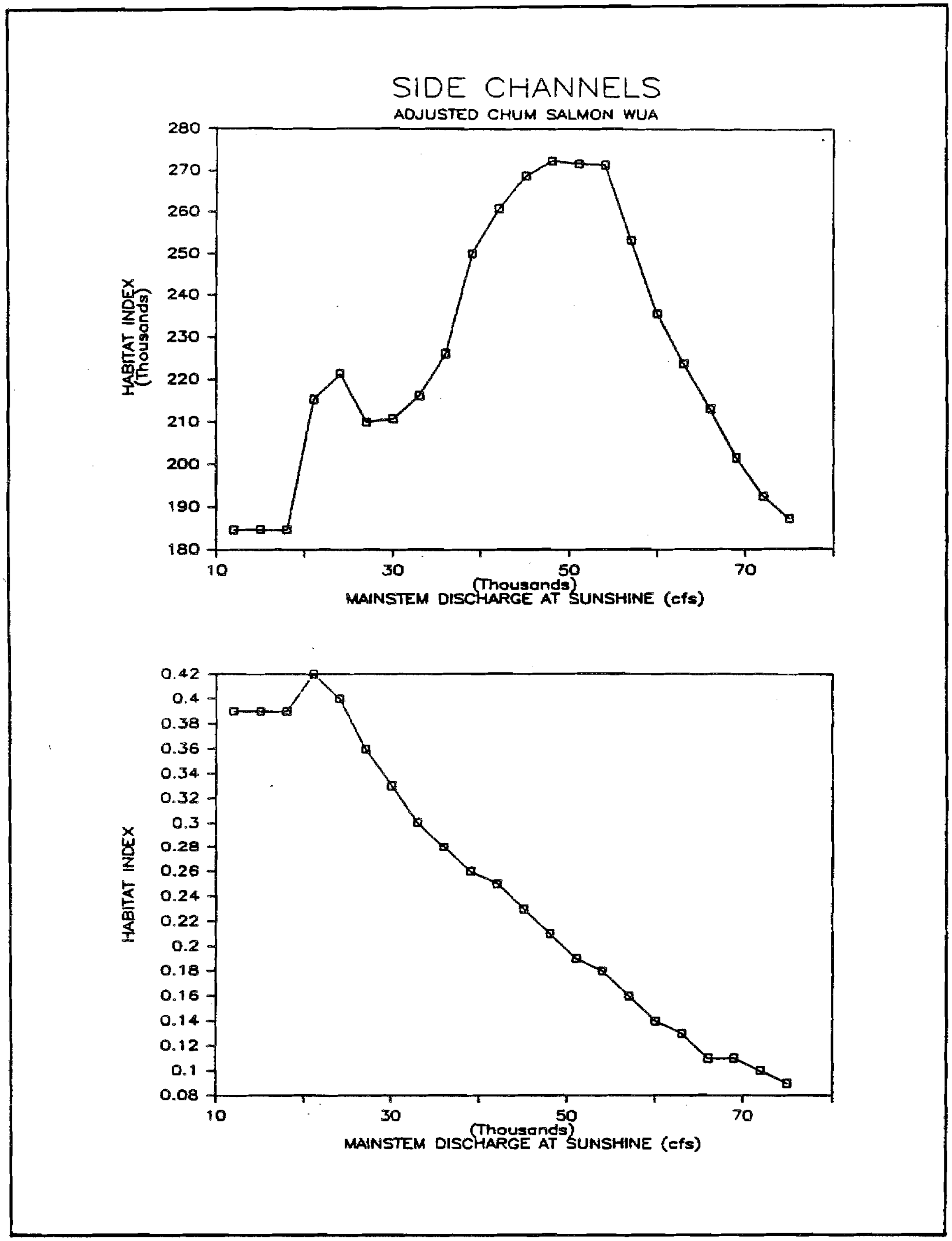


Figure 31. Turbidity adjusted weighted usable area and habitat indices for juvenile chum salmon at side channel/slough study sites as a function of mainstem discharge, 1984.

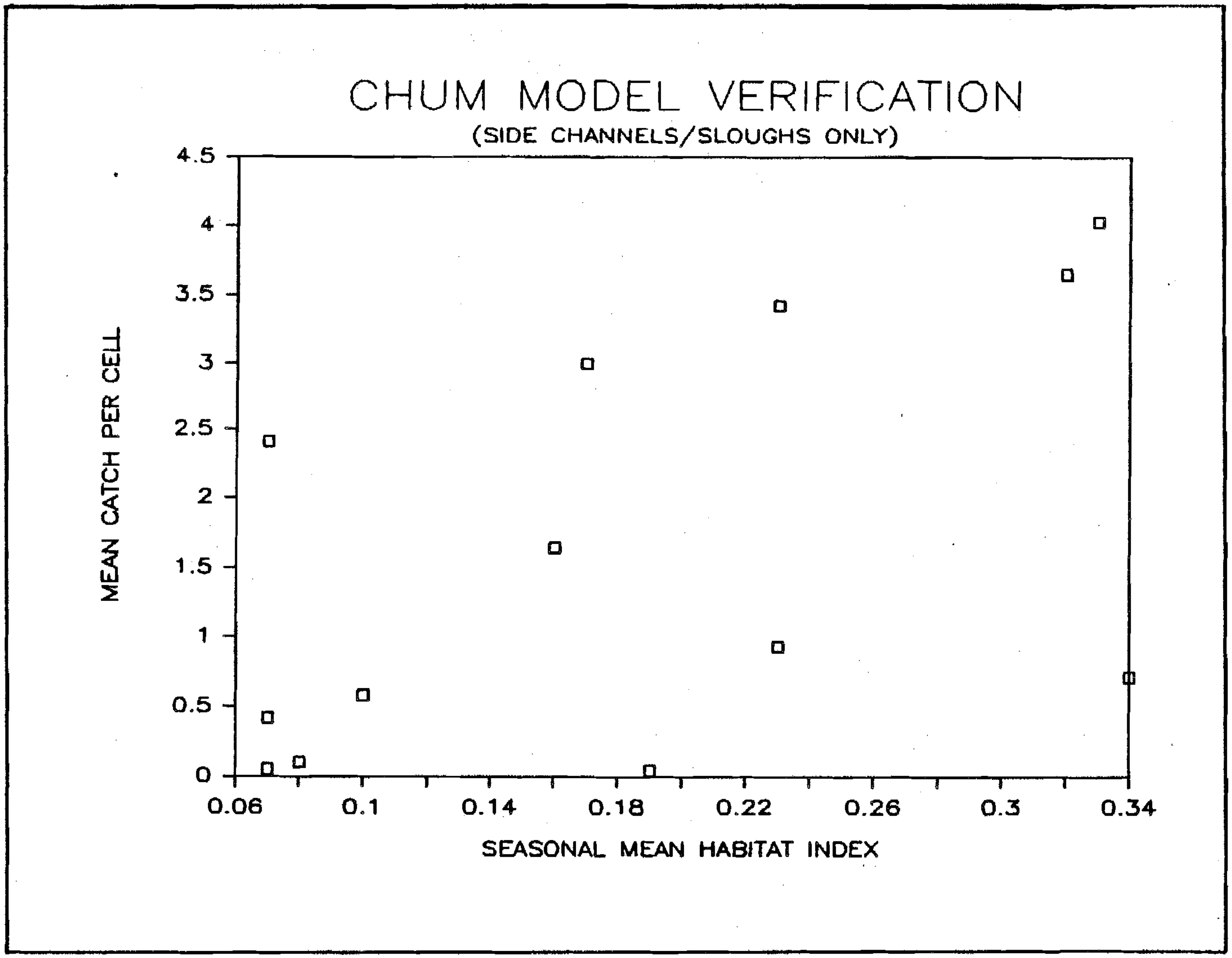


Figure 32. Juvenile chum salmon mean catch per cell versus seasonal mean habitat indices at side channel and slough modelling sites on the lower Susitna River, 1984.

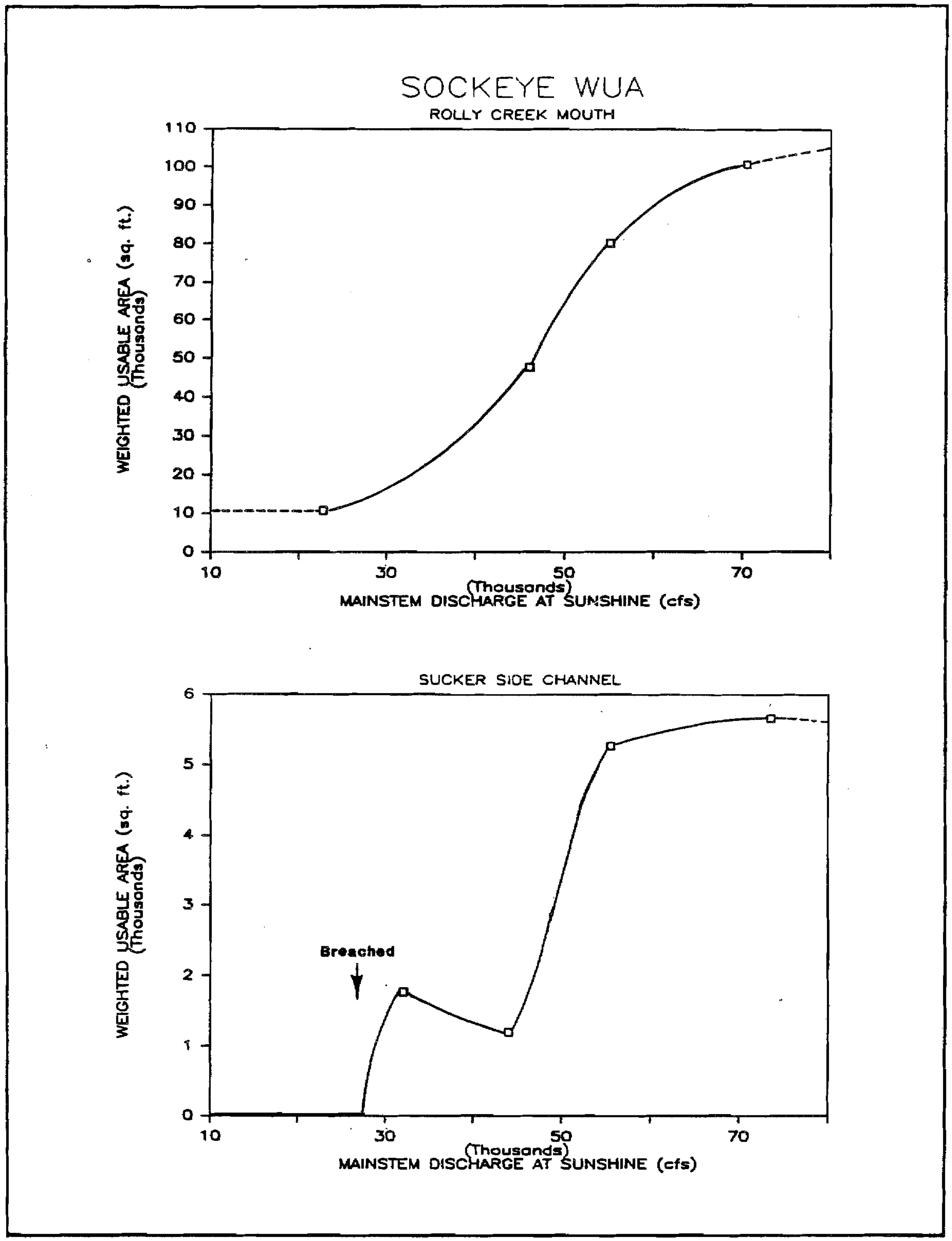


Figure 33. Weighted usable area for juvenile sockeye salmon at Rolly Creek Mouth and Sucker Side Channel study sites as a function of mainstem discharge, 1984.

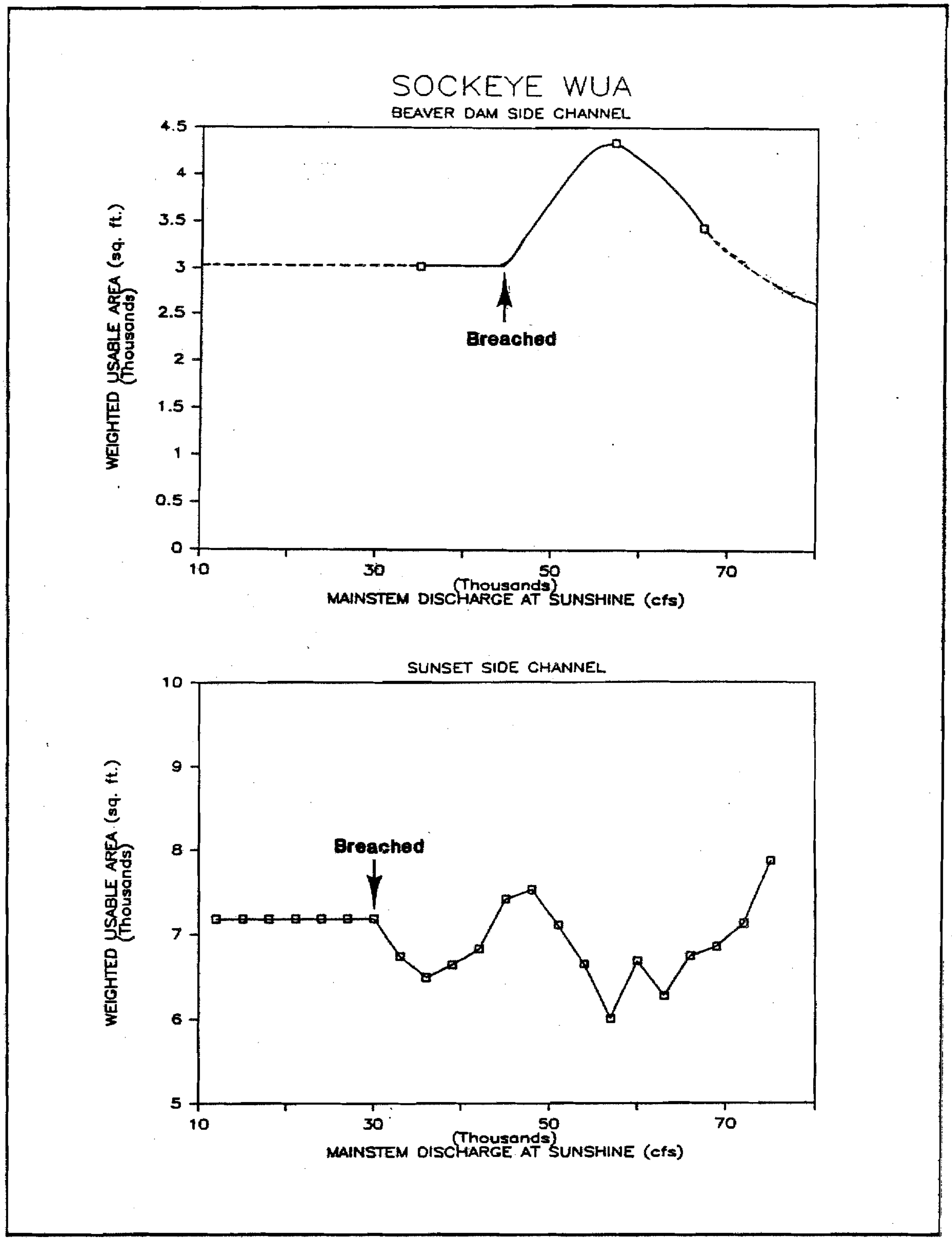


Figure 34. Weighted usable area for juvenile sockeye salmon at the Beaver Dam and Sunset Side Channel study sites as a function of mainstem discharge, 1984.

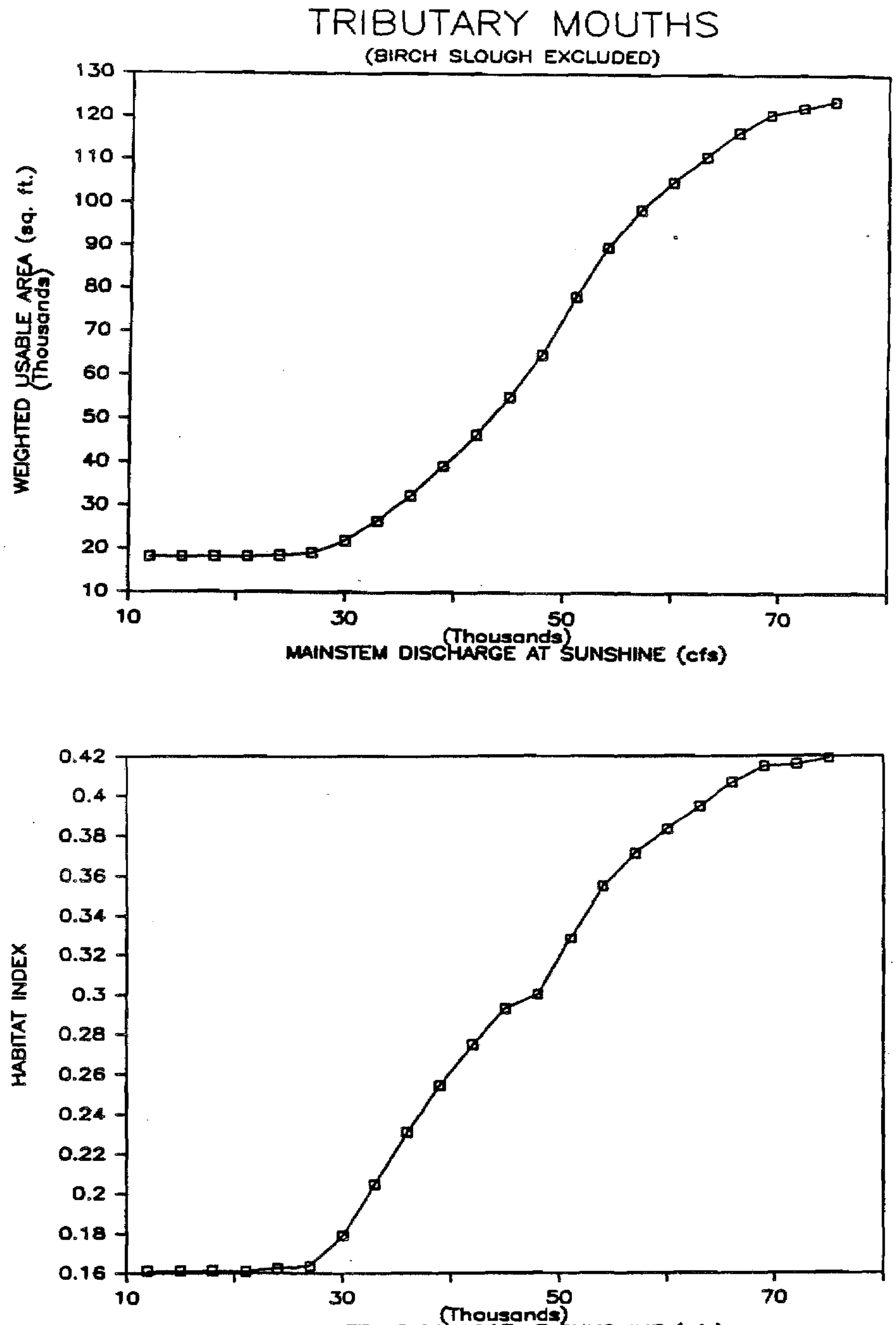


Figure 35. Weighted usable area and habitat indices for juvenile sockeye salmon at tributary mouth study sites on the lower Susitna River as a function of mainstem discharge, 1984.

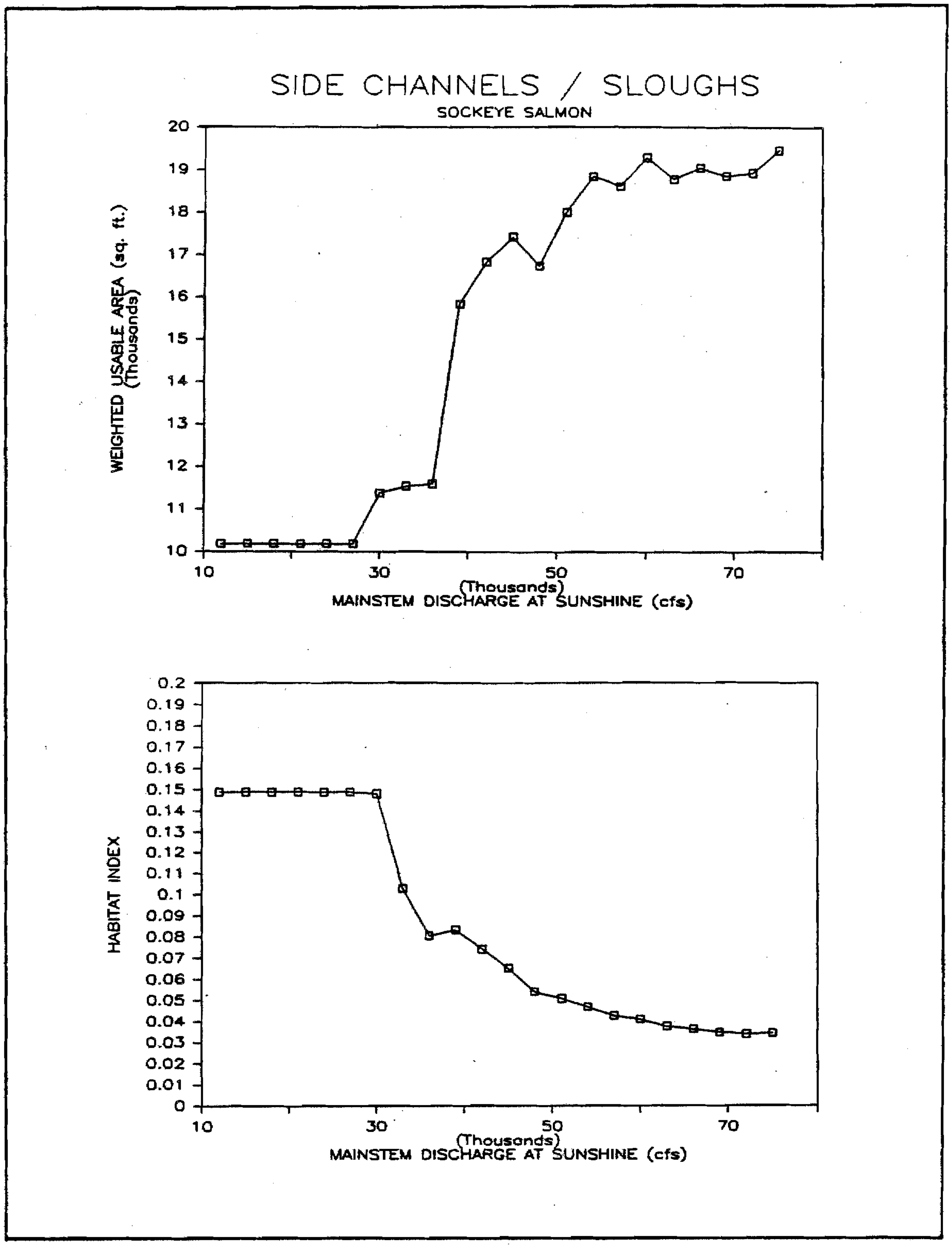


Figure 36. Weighted usable area and habitat indices for juvenile sockeye salmon at side channel and slough study sites on the lower Susitna River as a function of mainstem discharge, 1984.

similar turbidity regimes, being located on the same general location on the river. Use of many of the other side channels is probably limited by turbidity.

The mean seasonal habitat index for sockeye salmon at the four tributary mouths and four side channel sites was calculated for the period from May 15 to October 15, 1984. The mean catch of sockeye salmon juveniles was positively related to the mean habitat index (Figure 37). High turbidities and velocities within the other side channels presumably limited use by sockeye salmon juveniles.

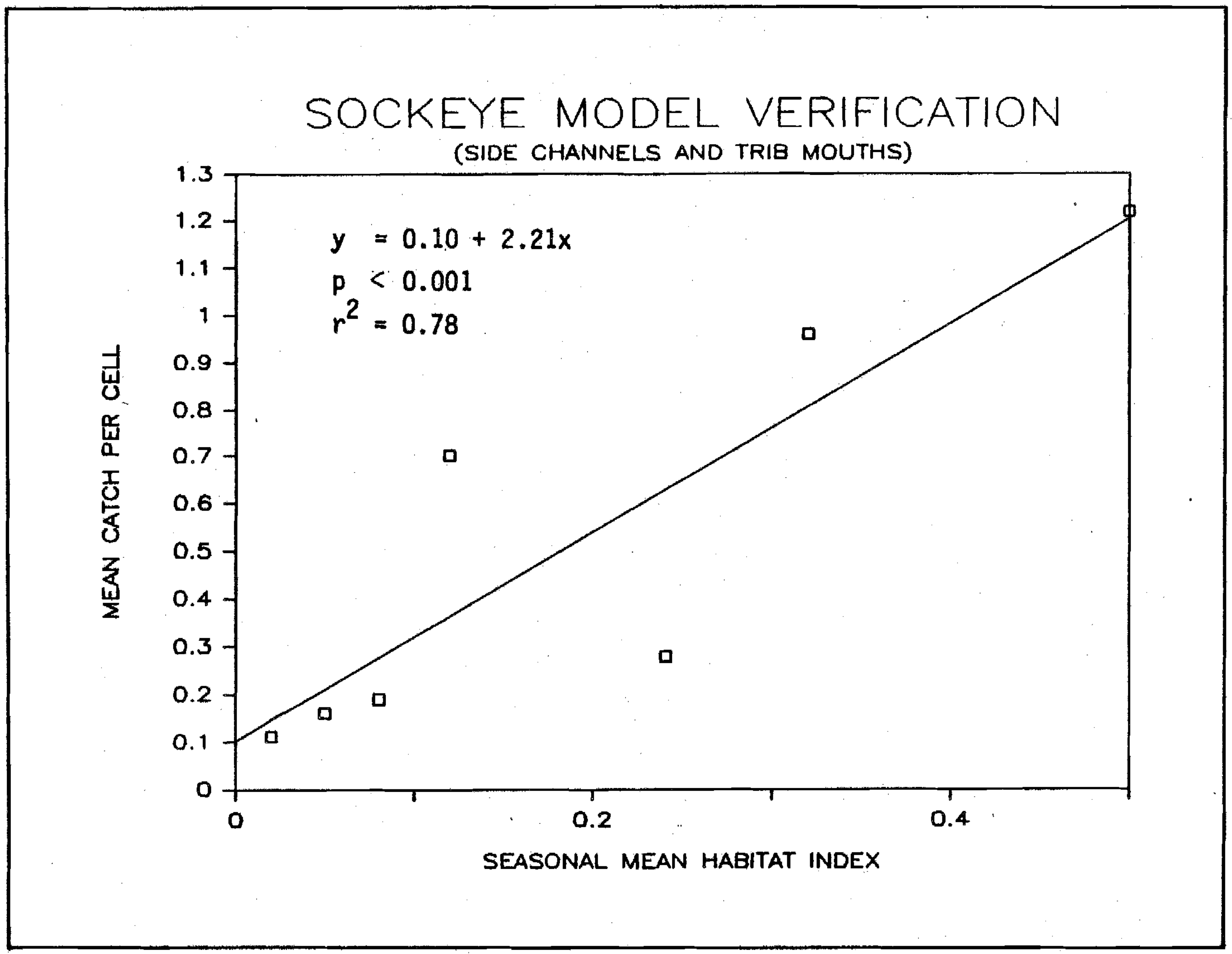


Figure 37. Juvenile sockeye salmon mean catch per cell versus seasonal mean habitat indices at side channel and tributary mouth modelling sites on the lower Susitna River, 1984.

4.0 DISCUSSION

4.1 Chinook Salmon

Chinook salmon were widely distributed throughout tributary mouths and side channels of the lower Susitna River. Densities of juvenile chinook were highest within tributary mouths. This distribution of chinook fry substantiates earlier observations (ADF&G 1981a; Dugan et al. 1983) that densities of chinook are generally highest at tributary mouths. Caswell Creek mouth had the highest CPUE of juvenile chinook salmon in the lower river and appears to be a major rearing or holding area.

Chinook salmon juveniles used side channels for rearing in both the middle and lower Susitna River after moving from tributary natal areas. Redistribution of chinook fry from natal areas to lower density rearing areas has also been observed in the Deshka River (Delaney et al. 1981) and Montana Creek (Riis and Freise 1978). This phenomenon reflects a downstream movement or dispersal of the 0+ age fish (ADF&G 1981c). Most of the 1+ chinook juveniles have outmigrated by August 1.

Use of tributary mouths is limited by the amount of instream cover and suitable velocities. Also, depth may be important to chinook juveniles in tributaries because it probably provides cover in slightly turbid water (10 to 20 NTU) (Appendix A). At Caswell Creek mouth, catches of juvenile chinook were low in September when the mainstem water stage dropped and depths decreased, velocities increased, and amount of cover was reduced.

Use of Susitna River side channels by chinook juveniles for rearing is widespread although it is limited by turbidity in portions of the lower reach. Side channels located in the Talkeetna River plume had much higher use than those located in the more turbid Chulitna River plume or those located further downstream where the water of these two tributaries are mixed. Side channel catch rates of juvenile chinook (in similar habitat) in the middle Susitna River in 1983 were approximately four times higher than those in the lower river in 1984 (Dugan et al. 1984).

Since lower Susitna River side channels are used less by chinook juveniles than middle river side channels, it is not surprising that sloughs are also used less in the lower reach than in the middle reach. As water levels decreased in the fall and side channel heads dewatered, there were very few chinook fry at slough sites in the lower river to take advantage of the lowered turbidity. Also the side sloughs in the lower river contain little cover.

Instream flow effects upon juvenile chinook salmon are related to backwater effects at the tributary mouths and side channel/slough sites and to breaching and side channel flows. When a side slough is not overtopped by the mainstem, access is usually poor and cover is limited.

At tributary mouths, backwater effects increase chinook use significantly because of increases in instream cover and depth and decreases in water velocity. Also, turbid backwater from the mainstem sometimes intrudes into the sites with rapid rises in mainstem stage. Pooled data from three tributary mouths showed major increases in WUA at mainstem discharges greater than 45,000 cfs.

If the study sites had been chosen further upstream in the tributary mouths, WUAs would have begun to increase at a higher discharge, so the 45,000 cfs figure is not absolute. At Birch Creek Slough, for example, there were no measurable effects of backwater to mainstem discharges of 72,000 cfs. In general, increases in mainstem discharge increase the amount of juvenile chinook salmon habitat at tributary mouths. Also, these backwaters may increase access into tributaries where rearing could occur by decreasing water velocities at the mouth.

Within side channel/slough sites, mainstem discharge is very important. When sloughs are breached, the water becomes turbid and cover for the chinook juveniles is improved. High turbidities, however, may also limit use of side channels (Figure 10). High turbidities generally occur from mid-June through September (especially during high discharges), while turbidities are much lower during the rest of the year. Turbidity also varies spatially within the river. Chulitna and Talkeetna river plume effects extend at least 20 miles downriver (Figure 4). Sites located within the Talkeetna River plume have much lower turbidity and higher juvenile chinook salmon use.
Mainstem discharge initially increases chinook WUA within a side channel/slough after it overtops but with further increases in flow, WUA usually remains constant or declines while the proportion of usable chinook habitat declines. The RJHAB model shows a decline in WUA with increasing discharge which is greater than that shown by the IFIM model (Appendix C).

The results obtained by pooling WUA from all modelled sites should not be directly extrapolated to represent the entire lower reach. If the modelling sites would have been chosen randomly, many more large, high velocity side channels with extremely little usable habitat would have been modelled. This study was designed to sample proportionately more side channels with usable habitat which would represent a diversity of channel types in the lower river. The modelled side channels represent a wide range of sizes and shapes of channels with diverse breaching flows, and so these results need to be coupled with a stratification of lower river side channels by breaching discharge and channel size and type. The most important side channel complexes in the lower Susitna River for juvenile chinook salmon rearing are located within the low turbidity plume of the Talkeetna River. Other side channels or side channel complexes should be weighted according to their mean turbidity level.

4.2 Coho Salmon

Juvenile coho salmon in the lower river were found mostly within tributary mouths. Tributaries and tributary mouths were also the most important rearing areas for juvenile coho salmon in the middle Susitna River (Dugan et al. 1984). Upland sloughs were also used by coho salmon for rearing in the middle river, but upland slough habitat is limited in the lower river and was not sampled during this study.

The heavy use of tributary mouths by juvenile coho is due in part to coho in tributary mouths rearing near their natal areas. Their limited use of side channels may be due to their documented tendencies to favor waters with relatively low turbidities. Sigler et al. (1984), for example, found that a larger number of juvenile coho salmon emigrated from experimental laboratory channels with turbidities of 25-50 NTU than from clear water channels. In another laboratory study, Bisson and Bilby (1982) established that coho salmon avoided turbidities exceeding 70 NTU. Turbidities in lower Susitna River side channels during June through August often greatly exceeded 100 NTU.

Use of tributary mouths by juvenile coho varied greatly seasonally and from site to site. Rolly Creek and Beaver Dam Slough CPUE's of coho salmon generally increased from early summer to late fall (Figure 12). This occurrence may be due to both the immigration of coho juveniles and a decrease in site area. The area of Rolly Creek was reduced by approximately 63% from late June and July to September and early October, while the area of Beaver Dam Slough was reduced by approximately 33% between these two time periods. In Birch Creek Slough, on the other hand, a relatively high CPUE occurred in early summer with much smaller values throughout the summer and fall. The relatively high CPUE's in early summer at Birch Creek Slough are probably due to a natal effect. Barrett et al. (1985) reported that Birch Creek has a spawning run of coho salmon.

A comparison of juvenile coho catch rates between tributary mouths and the Talkeetna outmigrant trap (RM 103.0) suggests that a redistribution of juvenile coho into suitable rearing habitat peaks from late July to early August. The catch per hour of age 0+ coho at the Talkeetna outmigrant trap increased during this time period while CPUE's at tributary mouths also changed greatly. Birch Creek Slough, which habitat modelling indicates to be relatively poor coho tributary mouth rearing habitat (Figure 27), shows a reduction in CPUE in late July, following natal emigration, while Caswell Creek, a site evaluated as having relatively good rearing habitat, had increasing CPUE's beginning in late July. A study conducted by Delaney and Wadman (1979) in the Little Susitna River found emigration of emergent fry from natal areas after the end of June.

Instream flow effects of the lower Susitna River upon juvenile coho salmon are limited to the backwater zone effects at tributary mouths because coho juveniles make little use of the side channel/slough sites. Initially, backwater may decrease the amount of habitat slightly as tributary mouths change from free flowing to a backwater zone but then WUA generally increases with mainstem stage as cover is inundated. Also, the backwater can provide access into small tributaries and beaver ponds where rearing and overwintering can occur.

Studies of coho salmon distribution in 1982 by hydraulic zone showed that coho generally preferred free-flowing tributaries over backwater zones (ADF&G 1983). Cover in the free-flowing tributaries is often better than in the backwater areas. For example, Birch Creek Slough generally has poor cover while Birch Creek itself has abundant emergent and aquatic vegetation in which coho were abundant.

4.3 Chum Salmon

The use of minnow trapping during 1981 and 1982 juvenile anadromous studies makes comparisons of lower river catch and CPUE data with 1984 studies difficult because chum salmon are rarely captured in minnow traps. The necessity for very early sampling, almost concurrent with ice-out, becomes important when studying chum salmon juveniles. Their early season movement and short time in the Susitna River system makes detailed conclusions difficult.

The large catches of chum salmon fry in side channels in the lower river contrast with the 1983 distribution data from the middle reach. Dugan et al. (1984) indicated that chum fry CPUE's were greatest at tributaries and side sloughs. The 1983 catch rates, however, reflect the prevalence of natal sloughs in the middle reach, while the lower reach contains few natal side sloughs. Also, side channels in the middle reach were not extensively sampled until July in 1983.

In 1984, chum salmon spawning was observed in several side channel/slough sites where none had been observed previously (Barrett et al. 1985) indicating that under certain conditions, lower river side channels do provide some suitable spawning habitat. Chum salmon fry observed in some of the side channels may be rearing near their natal areas.

The exact stimulus for the outmigration of chum salmon from the Susitna River is not known, but probably reflects a combination of factors (Roth et al. 1984). Mainstem discharge was highly positively correlated with chum salmon CPUE at the Talkeetna outmigrant traps in 1983. The sharp decline in CPUE at the lower river sites from early June (3+ fpc) to late June (1+ fpc) in 1984 followed the peak June discharge on June 17 at Sunshine Station, and the mid-June peak of chum outmigration past the Talkeetna traps.

Since juvenile chum salmon outmigration is mostly completed by mid-July, flow effects are limited to spring and early summer for this species. Juvenile chum salmon used side channels heavily during this time while use of the tributary mouths was limited. Apparently, chum salmon do not move into the tributary mouths as they gradually move downstream and out of the system. Most of the use of side channels for rearing occurs before high turbidities occur.

Use of side channels by juvenile chum salmon is limited by depth and velocity. The presence or lack of instream cover in side channels is not important to juvenile chum (Appendix A). Chum fry were captured primarily in shallow sampling cells (≤ 1.0 ft) which had a relatively low velocity and low to moderate cover. After breaching, side channel WUA's may increase or decrease but the proportion of the area that is suitable generally decreases as velocities and depths become unsuitably large. Turbidities show sharp seasonal increases and some side channels become turbid earlier in the season than others depending upon the turbidity regimes in the Chulitna, Talkeetna, and Susitna rivers.

Since chum salmon side channel WUA's respond very similarly to those of chinook salmon at individual sites, it appears that an analysis of response to changes in mainstem discharge for chinook would also hold for chum salmon. An analysis of flow regimes, would only need to take place through mid-July for chum salmon, however, while chinook salmon fry occur throughout the season in side channels.

4.4 Sockeye Salmon

Tributary mouths were the primary capture sites for sockeye salmon in the lower river. In the middle river, sockeye salmon were captured primarily at side sloughs (Dugan et al. 1984). Side sloughs were the primary spawning areas for sockeye salmon in the middle river, and tributary/lake systems were the major sockeye spawning areas in the lower reach (Barrett et al. 1985). Relatively large catches of juvenile sockeye in the middle river side sloughs were due to fish rearing in their natal areas.

Few sockeye juveniles were captured in early June at modelled JAHS sites. This low incidence was probably due to lack of natal habitat in mainstem influenced areas of the lower river. Outmigrant trap catches at Talkeetna (RM 103.0) and Flathorn (RM 22.4) indicate that sockeye fry were redistributing in the system by the middle of June (Part 1 of this report). The greatest catch per cell of juvenile sockeye occurred at the modelled sites during late June.

The consistently low CPUE's in lower river side channels suggest these areas are of limited value for juvenile sockeye rearing. Possibly these juvenile sockeye catches represent transient populations. Exceptions include Beaver Dam Side Channel and other side channels located in the Talkeetna River plume where lower turbidities allow juveniles to rear. Since turbid glacial lakes are much less productive for sockeye salmon than are clearwater lakes (Lloyd 1985), the productivity of these side channels for sockeye is probably low in comparison to similar clearwater streams.

The larger catches (21 to 101) of sockeye at tributary mouths indicate that these sites are of some value for juvenile sockeye rearing. Beaver Dam Slough had moderate numbers of sockeye present throughout much of the season. Beaver Dam Slough resembled a lake system as it had low velocities, large amounts of cover, and relatively warm temperatures during the open-water season. CPUE's of sockeye fry at Rolly Creek mouth was low until early August. Emergent and aquatic vegetation were profuse at this site during mid-season, making sampling difficult. After late August, CPUE's of sockeye juveniles increased. Although high numbers of these salmon fry were caught late in the season, we do not know if they overwinter.

Instream flow effects upon sockeye salmon rearing occur at both tributary mouths and side channels. Occurrence of sockeye juveniles in side channels appears to be limited by factors such as turbidity and velocity. Juvenile sockeye were captured more than half the times sampled only in four side channel sites in the Talkeetna River plume. Even at these four sites, the number of sockeye fry captured was less than 20 at each, except at Beaver Dam Side Channel where 71 were captured. Typically, WUAs for sockeye increase after overtopping of the side channels but then gradually decrease with further increases in discharge as side channel velocities became unsuitable. Sometimes backwater areas may form at the mouths of side channels (for example, Sucker Side Channel) and modify this relationship somewhat so that WUA may rise with increases in discharge for much longer periods. Generally, the proportion of area that is usable within side channels decreases with flow as velocities become less suitable.

At tributary mouths, the formation of backwater zones has a major effect in increasing WUA for sockeye salmon juveniles. The response of the increase in WUA for sockeye is similar to that of chinook salmon. Access into suitable rearing and overwintering areas may also occur with the increase in backwater or the amount of overtopping. For example, access into potential rearing areas such as Whitsol Lake may be inhibited if Kroto Slough is not overtopped. Also several other small tributaries along the Kroto Slough side channel may be inaccessible if flows are below those required for overtopping.

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APPENDIX A

LOWER SUSITNA RIVER
JUVENILE SALMON REARING SUITABILITY
CRITERIA

INTRODUCTION

Habitat suitability criteria are necessary for evaluating fish habitat using the instream flow incremental methodology (Bovee 1982). The criteria express the value of a habitat variable such as velocity on a zero (unusable) to one (optimum) basis for a given fish species and life stage. The suitability criteria are coupled with the habitat present within a study site to produce estimates of equivalent optimal habitat called weighted usable area (WUA).

Juvenile salmon rearing suitability criteria have been used to model the response of juvenile salmon habitat to variations in mainstem discharge of the middle reach (Chulitna River confluence to Devil Canyon) of the Susitna River (Hale et al. 1984, Marshall et al. 1984). The suitability criteria used in these studies were developed specifically for the middle Susitna River by Suchanek et al. (1984). EWT&A (1985) modified a few of the same suitability criteria for use in impact analysis of chinook salmon rearing in the middle Susitna River.

In 1984, some of the juvenile salmon habitat modeling effort was directed toward evaluating responses of juvenile salmon habitat in the lower Susitna River (below the Chulitna River confluence) to discharge variations. Since habitat data collection techniques used in 1984 were similar to those used during the 1983 studies, suitability criteria specific to the lower reach can be developed. The purpose of this appendix is to verify the applicability of the suitability criteria developed in 1983 by Suchanek et al. (1984) for use in the lower river habitat studies. The general philosophy was to use the 1983 middle river criteria curves for the lower river unless the 1984 studies in the lower river provided evidence for modifications.

METHODS

The field sampling methods used are detailed in Section 2.1 of this report. These methods are very similar to those used during the 1983 studies (Suchanek et al. 1984) and will only be summarized briefly here. Sampling sites included: (1) 20 habitat model sites which were normally sampled twice a month and (2) 31 opportunistic sites which were usually sampled only once.

At each site, 6 ft x 50 ft rectangular cells were sampled for fish and then habitat variables were measured in each cell. Cells were selected randomly at model sites, although sometimes additional selected cells with "good" habitat were also sampled. At opportunistic sites, cells were selected to encompass a variety of habitat conditions within potentially usable habitat. Habitat measurements taken at each cell sampled included a representative depth, mean column velocity, and estimates of primary cover type and percent cover (Appendix Table A-1).

The data collected were examined for suitability criteria development by using the procedures described in Suchanek et al. (1984), with a few modifications.

Suitability was represented by mean catch per cell for chinook and coho salmon and proportional presence (proportion of cells sampled in which

Appendix Table A-1. Percent cover and cover type categories.

Group #	% Cover	Group #	Cover Type
1	0-5%	1	No object cover
2	6-25%	2	Emergent vegetation
3	26-50%	3	Aquatic vegetation
4	51-75%	4	Debris or deadfall
5	76-96%	5	Overhanging riparian vegetation
6	96-100%	6	Undercut banks
		7	Gravel (1" to 3" diameter)
		8	Rubble (3" to 5" diameter)
		9	Cobble (larger than 5" diameter)

fish were captured) was used as the suitability measure for chum and sockeye salmon. Data were pooled by species for analysis. Some data were excluded from analysis by using results from the distribution and abundance analysis (Section 3.2) which indicated factors other than the microhabitat variables of velocity, depth, and cover were greatly affecting distribution. Macrohabitat type and turbidity were two factors which greatly affected distribution and were used as a basis for excluding cells fished. Cells which were excluded from the analysis varied by species and are detailed in the results section. The beach seine and electrofishing data were pooled for analysis because these sampling methods were both thought to be equally as effective given the sampling conditions. Although sampling efficiency varies by gear type and conditions fished, we assumed equal efficiency under all conditions as analysis of sampling efficiency was beyond the scope of this study.

Groupings of habitat variables were identical to those used in 1983. Percent object cover categories 76-95% and 96-100% were pooled because of small sample sizes. Velocity and depth were pooled in groups identical to those used in 1983 with the exception that cells with depths of 0.1 feet were examined separately. In 1983, only two cells with a depth of 0.1 feet were sampled, and therefore insufficient data were available for examination of suitability of this depth.

Comparisons of the 1983 data with the 1984 data were made by plotting the suitability criteria derived in 1983 on the same graph with comparable 1984 data. On the depth and velocity graphs this was done by normalizing the suitability to 1.0 for the 1984 depth or velocity increment with the highest suitability and then plotting the 1983 suitability criteria normalized to the same scale. The 1984 percent cover data were first regressed against catch per cell or proportional presence, and, if significant, the regression line was plotted and the suitability normalized to 1.0 for the highest cover category. The 1984 percent cover suitability line was then plotted on the same graph, by using the normalized 1.0 as the starting point. The suitability of cover type for each species was calculated with the 1984 data using the methods described in Suchanek et al. (1984). The suitabilities calculated were then graphed against the cover type suitabilities calculated in 1983.

Variations in histogram distributions are to be expected on a univariate basis given that percent cover, cover type, velocity, and depth together affect suitabilities of a cell. Therefore, composite weighting factors were calculated for each cell using the 1983 suitability criteria and revised 1984 criteria and then these weighting factors were compared with catch. Composite weighting factors were calculated by multiplying suitability indices for cover type, percent cover, and velocity together. For chinook and coho salmon, Pearson correlation coefficients were calculated between composite weighting factors and catch per cell [transformed by natural log (X + 1)]. Chi-square association tests were run between chum and sockeye proportional presence and composite weighting factor value intervals calculated using the 1984 criteria data. Intervals of composite weighting factors were specified by dividing the data into four groups of approximately equal sizes by value of the composite weighting factor. Pearson correlation coefficients and results of the chi-square analysis were then compared with the same analyses done in 1983. Most of the statistical tests and data manipulations were done with the Statistical Package for the Social Sciences (SPSS) (Nie et al. 1975).

If the fit of the 1984 data to the 1983 suitability criteria did not seem close upon visual inspection, the 1983 criteria were modified. One of the procedures for modification was as follows. If, for example, the 1984 velocity distribution data appeared to match closely the 1983 velocity criteria, the 1983 velocity criteria were input as suitabilities and averaged over each increment of a variable such as depth for which a modification of suitability was desired. These averages were then multiplied by the mean catch of fish per cell divided by the mean suitability. The actual mean catches per cell by depth increment were then divided by the adjusted mean velocity suitability. If this ratio was less than 1.0, this would indicate less use of a depth increment than expected, given the average suitability for velocity. If the ratio was greater than 1.0, the use would be more than expected by adjusting for the effect of velocity. Sometimes this procedure would be effective in taking out variation caused by the other variable. If necessary, this procedure was used to adjust for effects of two or more variables.

If the above procedure was not effective in discounting the extraneous variation, then the criteria were modified using professional judgement. Correlations or chi-square association tests were then calculated between mean catch and calculated composite weighting factors using the modified criteria.

RESULTS

Abundance and distribution data (Section 3.2) have shown that the number juvenile chinook, coho, chum and sockeye salmon was very small at side sloughs in the lower reach. Even sampling cells at sloughs with good habitat failed to have any significant number of fish present in comparison with similar cells at the other macrohabitat types (tributary mouths and side channels). Fish were therefore responding to factors other than the availability of suitable microhabitat in their use of sloughs. For this reason, data collected at sloughs were eliminated from suitability criteria analyses to avoid comparing similar cells with large differences in mean catch.

Chinook Salmon

Chinook salmon suitability criteria were developed for both clear (< 30 NTU) and turbid (> 30 NTU) water in 1983 because the catch in cells without object cover was much greater in turbid water than in clear water (Suchanek et al. 1984). Data collected in the lower river in 1984 have shown that turbidity may limit the distribution of chinook salmon by being too high (Figure 10). Since cells with good habitat were sampled when high turbidity was limiting use by chinook salmon fry, we decided to eliminate sampled cells with turbidities greater than 350 NTU.

After eliminating cells in side sloughs and cells with turbidities greater than 350 NTU, 1155 cells were available for analysis of chinook distribution. Of the 1155 cells, 400 were sampled in water with a turbidity of 30 NTU or less. Mean adjusted catch (catch adjusted to a standard cell size of 300 ft^2) per cell of chinook fry in the 400 clear water cells was 1.3, while mean adjusted catch per cell in the 755 turbid cells was 1.1.

A scatter plot of chinook salmon catch in cells without object cover versus turbidities ranging to 100 NTU was examined. No notable inflections in catches of chinook salmon fry were noted over this range, although gradual increases in catches occurred across the range. It seemed reasonable, therefore, to keep the same 30 NTU breakpoint between high and low turbidity data for this year's analysis.

Clear Water

Correlations among the values of habitat attributes and clear water (< 30 NTU) chinook catch range to 0.32 in absolute value and a number of the correlations are statistically significant (Appendix Table A-2). In addition to these data, partial habitat data were recorded for four additional clear water cells and these additional data are used in subsequent analyses.

Composite weighting factors for all cells sampled were calculated by using the 1983 suitability criteria and also with modification of the velocity criteria as proposed by EWT&A (1985) and then correlated with chinook catch transformed by natural log (x + 1). In clear water, the correlation in 1983 was 0.43 but the correlation with the 1984 data was only 0.31 for the original criteria data and 0.26 with the change in velocity criteria proposed by EWT&A (1985). It was therefore deemed desirable to modify the criteria where large differences in individual criteria were found.

Appendix Table A-2. Kendall correlation coefficients between habitat variables and chinook catch by cell (N=396) for all gear types, in clear water.

	Percent Cover	Cover Type	Velocity	Depth	Chinook
Percent Cover	1.00				
Cover Type	0.08*	1.00			
Velocity	-0.32**	0.04	1.00		
Depth	0.03	-0.08*	-0.04	1.00	
Chinook	0.07	0.09*	-0.09*	0.21**	1.00

* Significantly different from 0 at $p < 0.05$.
** Significantly different from 0 at $p < 0.01$.

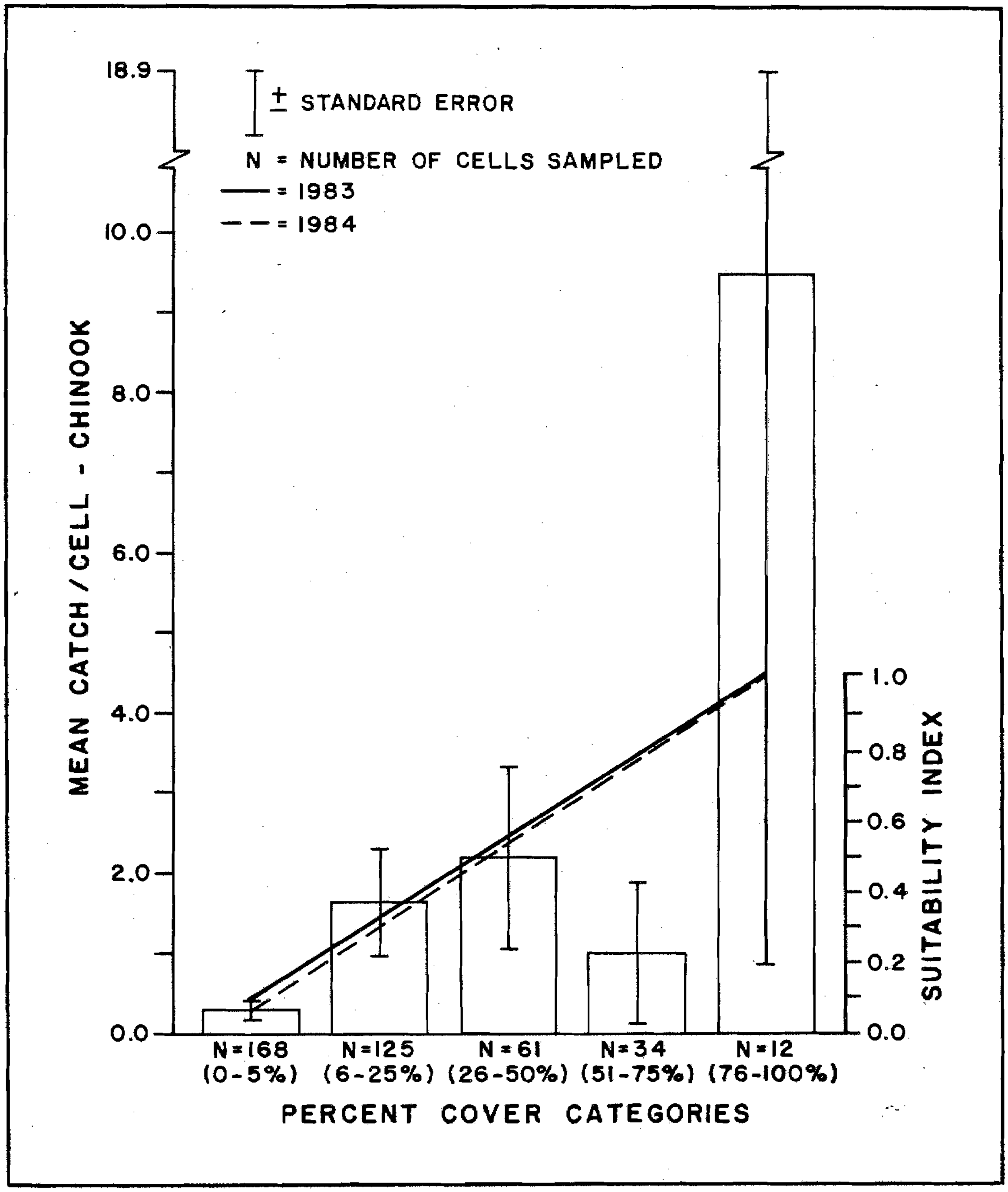
Least squares regressions were run between chinook catch per cell and the percent cover categories in clear water. There was a significant positive regression which is very similar to the suitability line developed in 1983 when the Y axis is normalized to a suitability of one (Appendix Figure A-1). The 1983 suitability criteria was therefore retained as a good estimate of this relationship.

The distribution of mean catch per cell of chinook fry by velocity interval in clear water in 1984 shows that peak catches were made in sampling cells with a velocity ranging from 0.1 to 0.3 fps (Appendix Figure A-2). After normalizing this peak in catch to a suitability of 1.0 and then plotting the 1983 suitability criteria on the same graph, it appears that chinook used lower velocity water in the lower reach than in the middle reach under clear conditions. It was noted that the 1984 clear water distribution of catch by velocity interval was more similar to the 1983 turbid water velocity suitability criteria and therefore the 1983 turbid velocity criteria were plotted against the 1984 data (Appendix Figure A-3). Since the two distributions were similar, the 1983 turbid water velocity criteria were taken as a good estimate of the lower river velocity suitability for chinooks in clear water.

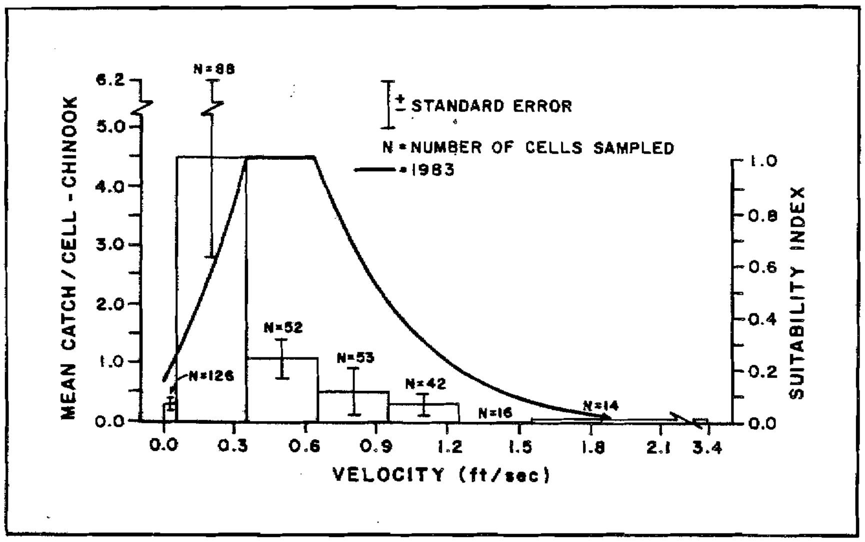
Cover type suitabilities derived in 1984 for juvenile chinook in clear water contrasted sharply with those derived in the middle reach in 1983 (Appendix Figure A-4). Debris was used less by chinook in the lower reach for cover and emergent vegetation was used more. The sample size of the cobble/boulder cover category was only one and therefore this cover type could not be evaluated. Catches in the cells without object cover were also relatively higher in 1984 than in 1983.

Therefore, it appeared that 1983 suitability for cover types would not apply in the lower reach. By adjusting for the effects of velocity and percent cover, better estimates of cover type suitability for the lower river were formulated from the 1984 data (Appendix Figure A-5). Since cobble and boulder sample sizes were low, suitabilities for these cover types were kept proportional in suitability to large gravel as was the case in 1984. Since the "no cover" catches were relatively large because fish were using relatively deep cells without object cover (see next paragraph), we lowered the suitability for no cover cells to 0.10, the suitability found in 1983.
A heavy use of deep, clear water by chinooks was found in 1984 while in 1983 the data suggested a peak in use of cells 1.0 to 1.5 feet deep (Appendix Figure A-6). In 1983, an evaluation of depth found it had little effect on increasing the correlation of fish catch with composite weighting factors using it. Depth was used in the 1983 modelling efforts as having no value if less than 0.14 ft and having a suitability of 1.0 if greater than 0.15 ft. In order to evaluate depth, suitability criteria were fit to the data using professional judgement after first adjusting for mean velocity and percent cover suitability (Appendix Figure A-7).

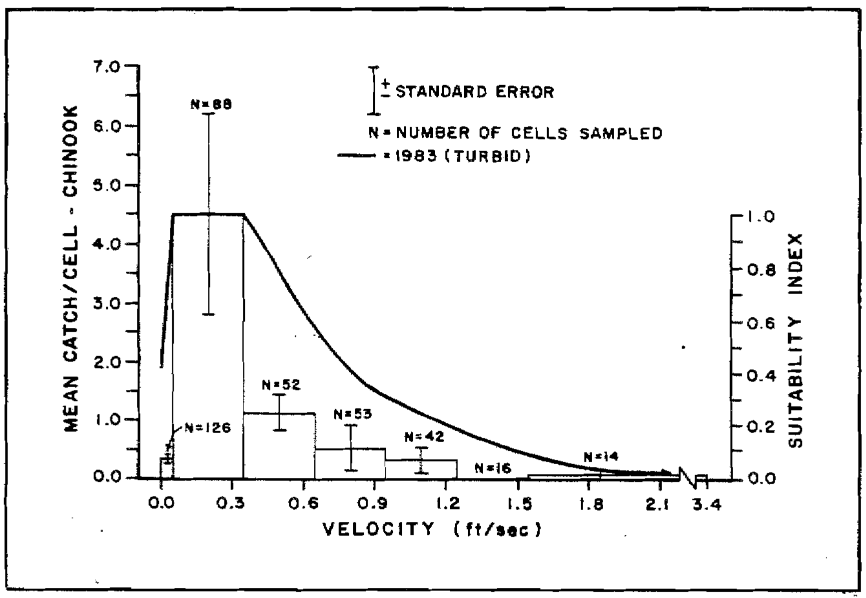
After the modifications to the cover suitability and depth criteria were made, we then correlated transformed chinook catch with the composite



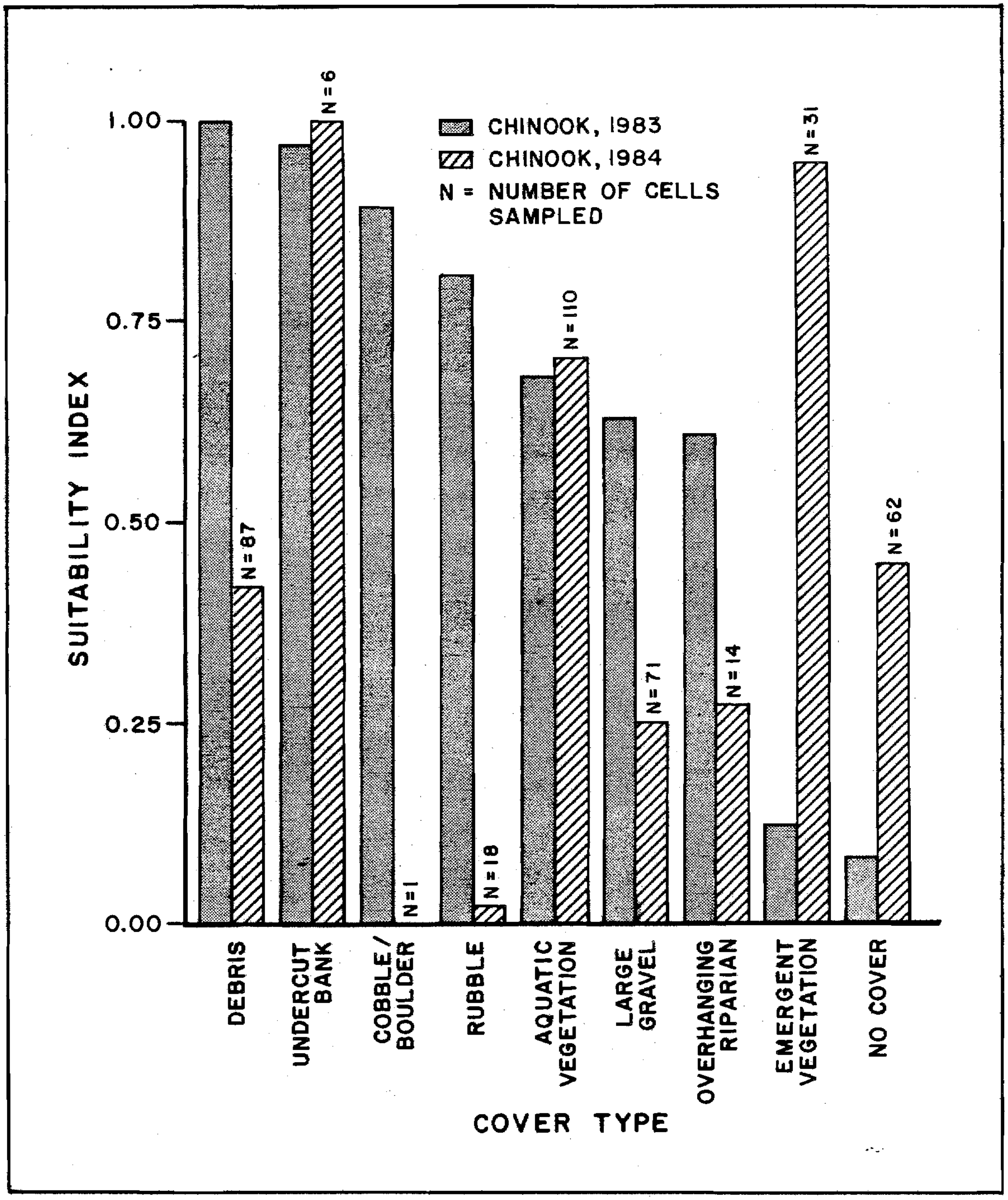
Appendix Figure A-1. Mean catch of juvenile chinook salmon per cell by percent cover category (bars) in clear water of the lower Susitna River, 1984 and comparison of fitted suitability indices (lines) calculated in 1984 and for the middle Susitna River, 1983.



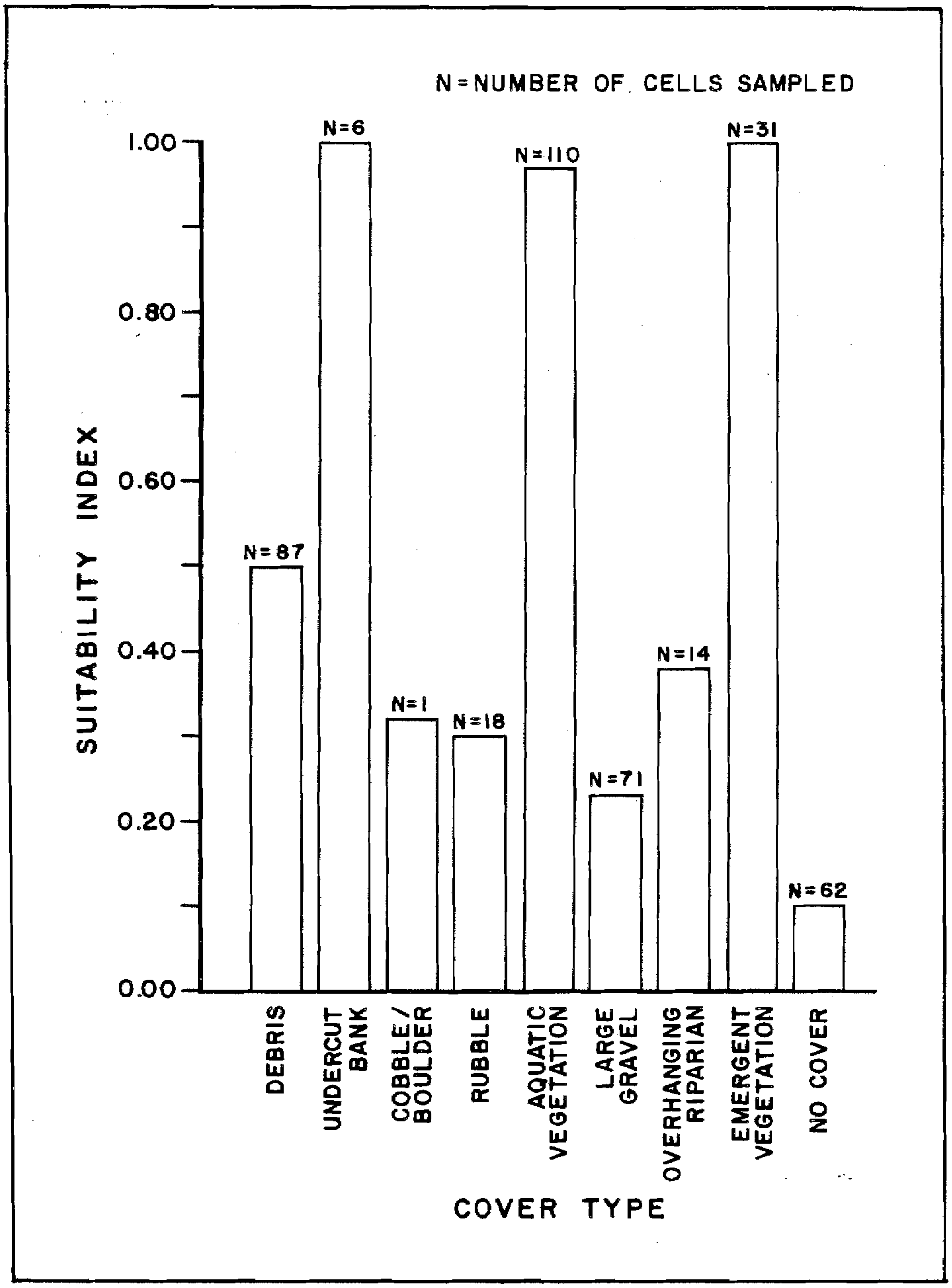
Appendix Figure A-2. Mean catch of juvenile chinook salmon per cell by velocity intervals (bars) in clear water of the lower Susitna River, 1984 and fitted suitability index (line) developed for the middle Susitna River, 1983.



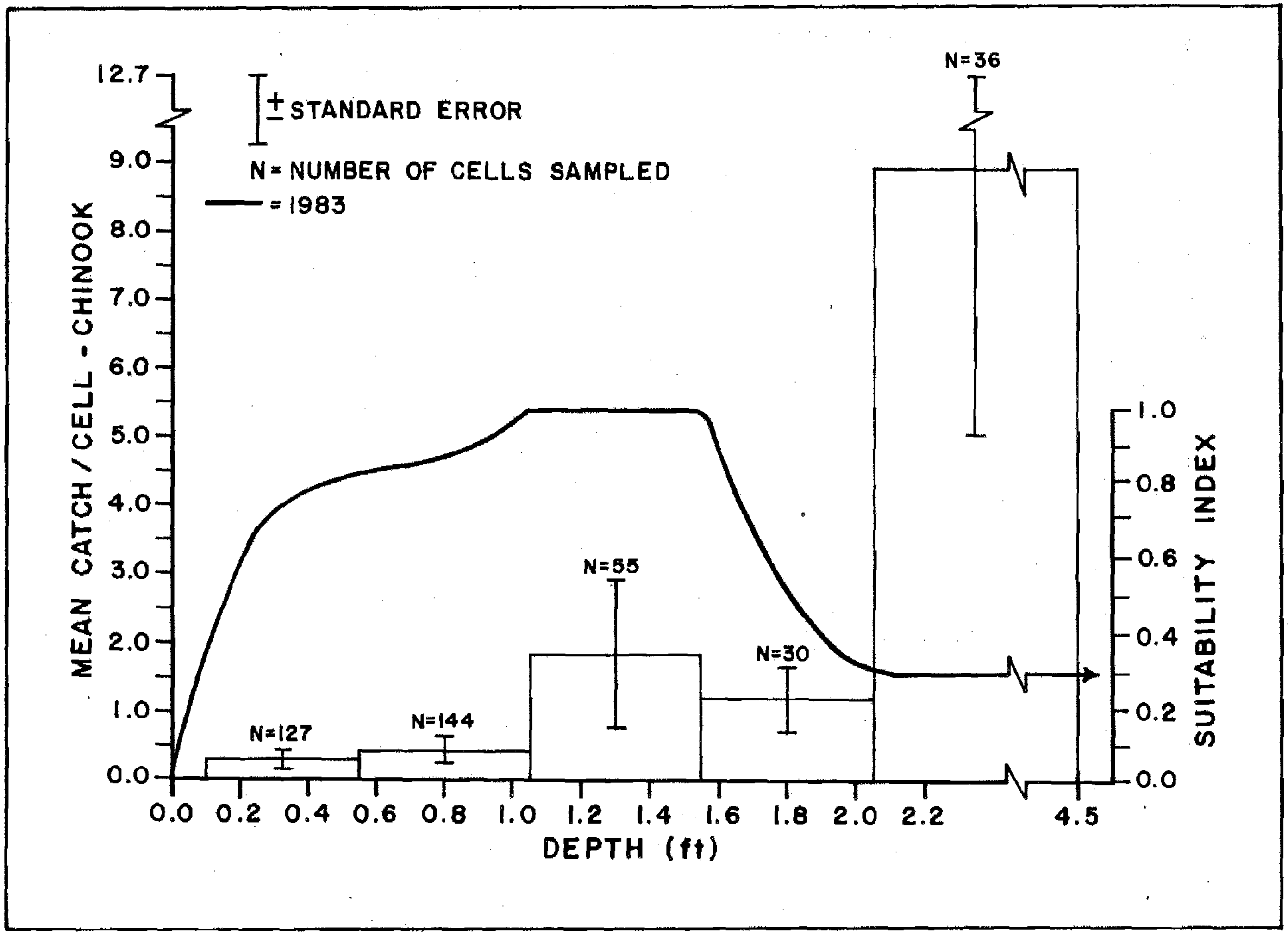
Appendix Figure A-3. Mean catch of juvenile chinook salmon per cell by velocity intervals (bars) in clear water of the lower Susitna River, 1984 and fitted suitability index (line) developed for turbid water in the middle Susitna River, 1983.



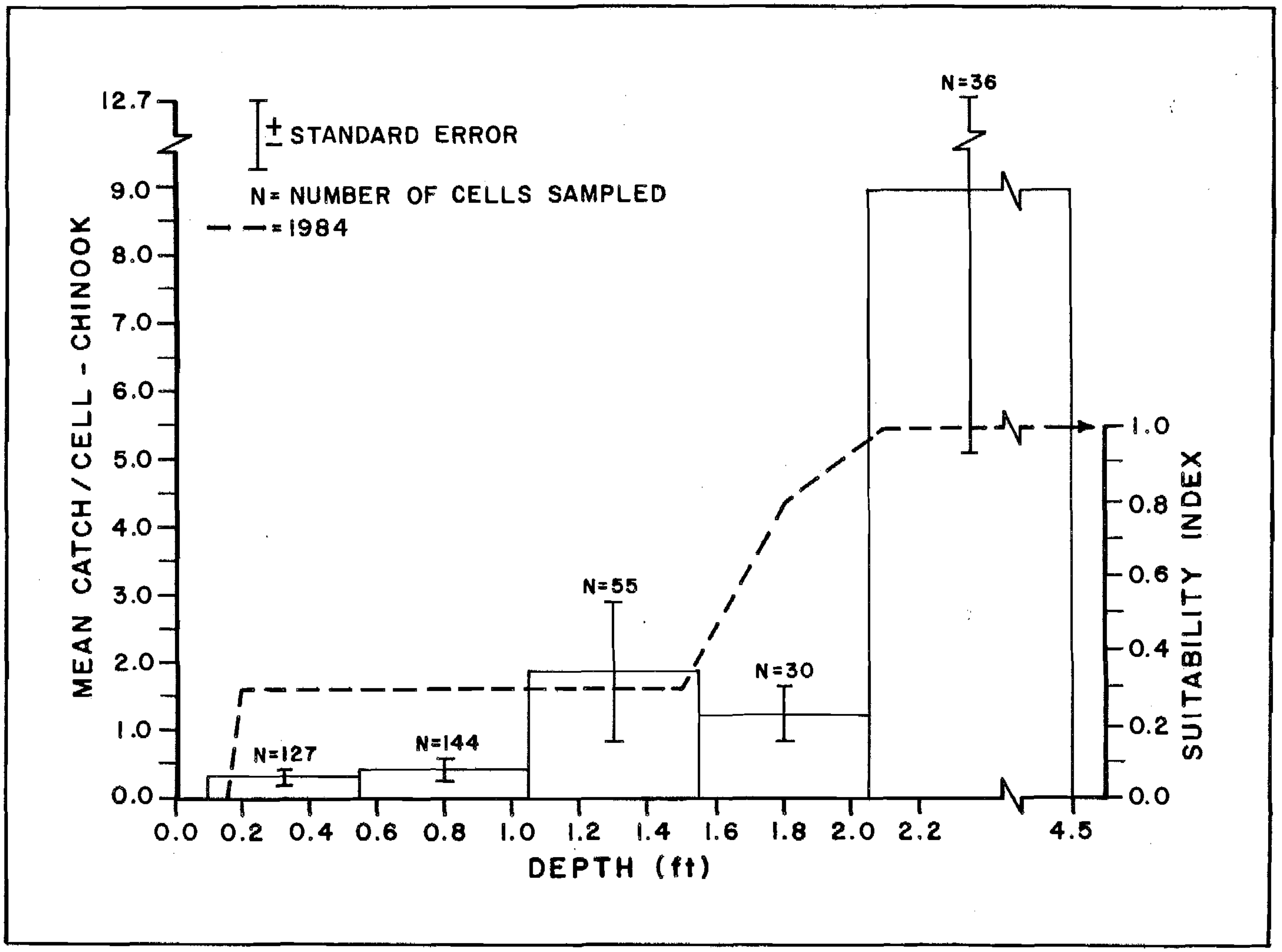
Appendix Figure A-4. Comparison of cover type suitability indices for juvenile chinook salmon in clear water calculated from 1984 lower Susitna River distribution data and 1983 distribution data.



Appendix Figure A-5. Cover type suitability indices for juvenile chinook salmon in clear water calculated from 1984 lower Susitna River distribution data after adjusting for velocity and percent cover.



Appendix Figure A-6. Mean catch of juvenile chinook salmon per cell by depth intervals (bars) in clear water of the lower Susitna River, 1984 and fitted suitability index (line) developed for the middle Susitna River, 1983.



Appendix Figure A-7. Mean catch of juvenile chinook salmon per cell by depth intervals (bars) in clear water of the lower Susitna River, 1984. Suitability index (line) fitted by hand using professional judgement.

weighting factors calculated with the 1983 percent cover criteria and turbid water velocity criteria along with the 1984 lower river cover type and depth suitability criteria. The correlation was 0.61, substantially higher than the original 1983 criteria. If depth was eliminated from the calculations, the correlation dropped to 0.26 and if primary cover type was dropped the correlation dropped to 0.52. Therefore, it seemed reasonable to keep the newly modified cover type and depth criteria as inputs.

Turbid Water

Correlations between the values of habitat attributes and chinook catch in turbid water range to 0.39 in absolute value and a number are statistically significant (Appendix Table A-3). Partial habitat data were recorded for 11 additional turbid cells and these additional data were used in subsequent univariate histograms.

Correlations between composite weighting factors calculated with the 1983 turbid water criteria and 1984 chinook catch was 0.31, while composite weighting factors calculated by incorporating the cover modifications proposed by EWT&A (1985) were correlated with an r-value of 0.26. Comparable correlation with the 1983 data was 0.38. These data again suggested that some modifications could be made, especially given the changes already made in the clear-water cover type suitabilities.

A comparison of 1984 velocity distribution data and the 1983 velocity suitability criteria for chinook salmon showed few differences (Appendix Figure A-8), and therefore the 1983 velocity criteria were accepted as the 1984 criteria curve.

Least squares regressions were run between chinook catch per cell and the percent cover categories in turbid water. There was no significant relationship between catch per cell and percent cover category and mean catch per cell decreased with increases in cover (Appendix Figure A-9). By adjusting for velocity, a slight trend upward was noted over the first three categories. The percent cover criteria developed in 1983 was therefore accepted as reasonable, as increases in the amount of object cover would seem more desirable for fish and sample sizes were very small in the 51-75% and 76-100% cover categories.

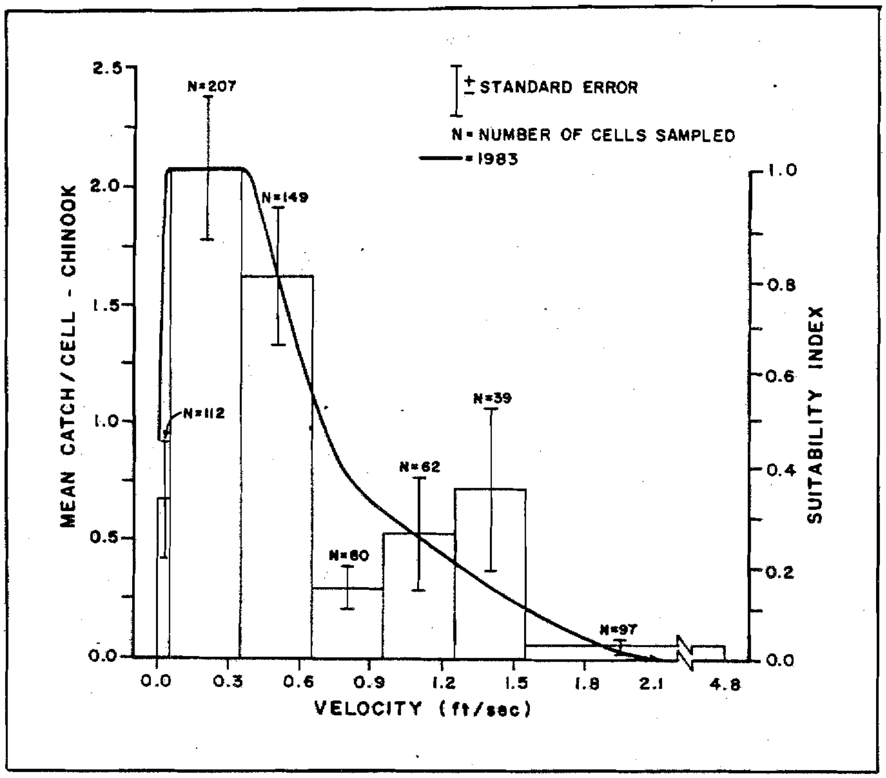
In 1983, cover type for chinook in turbid water was not evaluated. EWT&A (1985) modified the turbid water criteria, however, so that they more closely reflected the clear water criteria developed in 1983. In 1984, mean catches of chinooks in turbid water were highest in the emergent vegetation, rubble, and debris-deadfall categories, but catches were only slightly higher than in the cover category "no cover".

Cover type was evaluated in 1984 by using the method of EWT&A (1985) for calculating turbidity factors from the fitted regressions of percent cover in clear and turbid water and their associated chinook mean catches. Turbidity factors were calculated (Appendix Table A-4) and then applied to the revised lower river cover suitability data. These

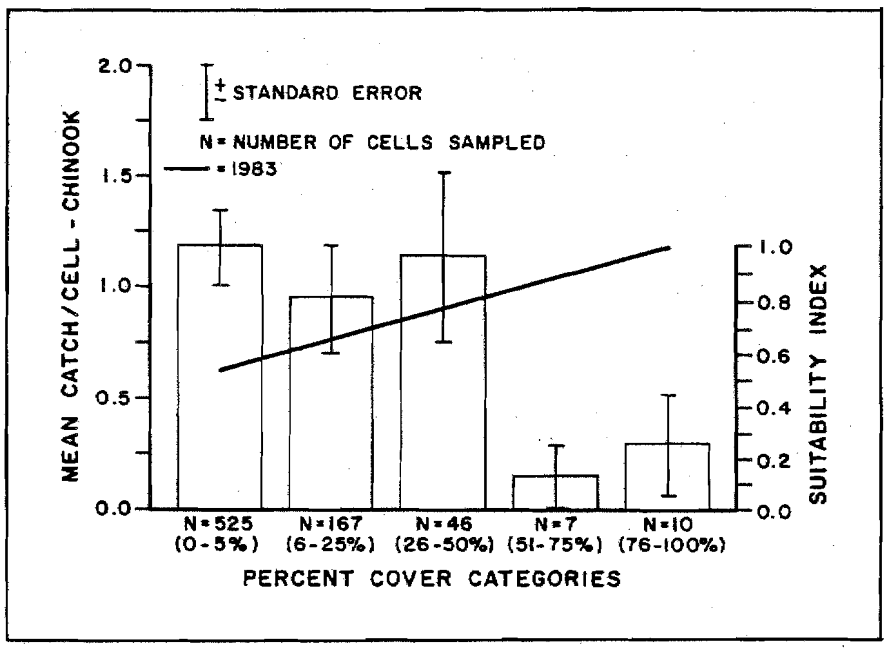
Appendix Table A-3. Kendall correlation coefficients between habitat variables and chinook catch by cell (N=744) for all gear types, in turbid water.

	Percent Cover	Cover Type	Velocity	Depth	Chinook
Percent Cover	1.00				
Cover Type	0.39**	1.00			
Velocity	0.05*	0.16**	1.00		
Depth	0.06*	0.26**	0.21**	1.00	
Chinook	-0.02	0.00	-0.17**	-0.15**	1.00

* Significantly different from 0 at $p < 0.05$.
** Significantly different from 0 at $p < 0.01$.



Appendix Figure A-8. Mean catch of juvenile chinook salmon per cell by velocity intervals (bars) in turbid waters of the lower Susitna River, 1984 and fitted suitability index (line) developed for the middle Susitna River, 1983.



Appendix Figure A-9. Mean catch of juvenile chinook salmon per cell by percent cover category (bars) in turbid water of the lower Susitna River, 1984 and fitted suitability index (line) calculated for the middle Susitna River, 1983.

revised suitabilities were much too low for many categories given observed catches and therefore a suitability of 0.15 was assigned as a minimum for cover type suitability in turbid water based on observed mean catches. Using this method, none of the suitabilities for cover type in conjunction with percent cover in turbid water are greater than 0.40 (Appendix Figure A-10).

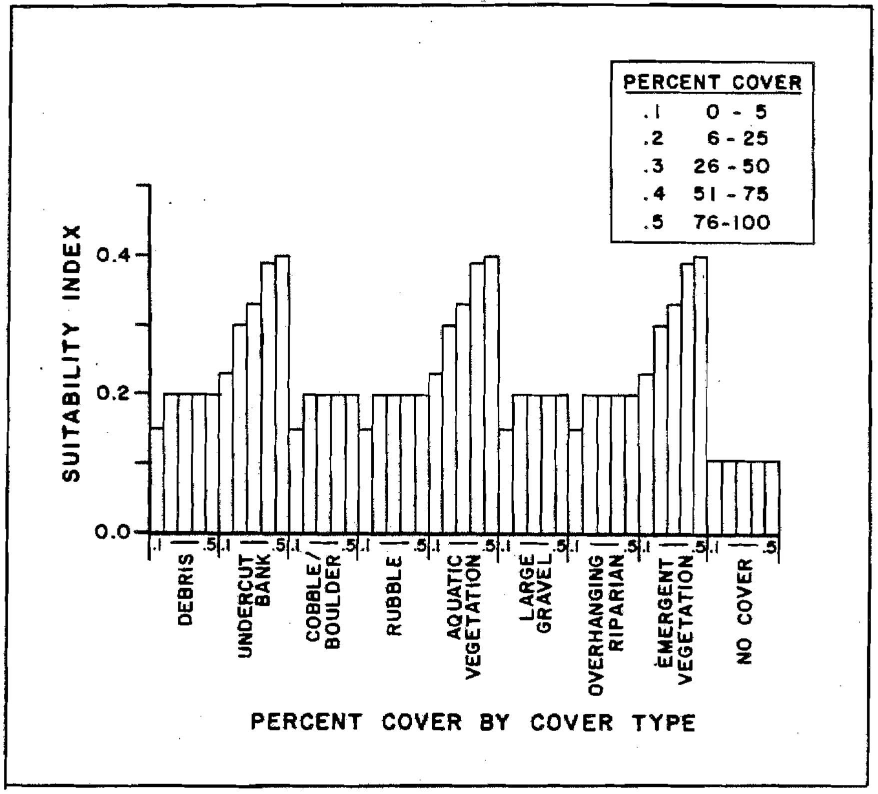
Appendix Table A-4. Calculations of turbidity factors for 1984 lower river data.

Percent Cover	Number of Fish Per Cell (Fitted to a Line) Clear	Turbid	Turbidity Factor
0-5%	0.5	1.1	2.2
6-25%	1.5	1.3	0.9
25-50%	2.5	1.5	0.6
51-75%	3.5	1.7	0.5
76-100%	4.5	1.9	0.4

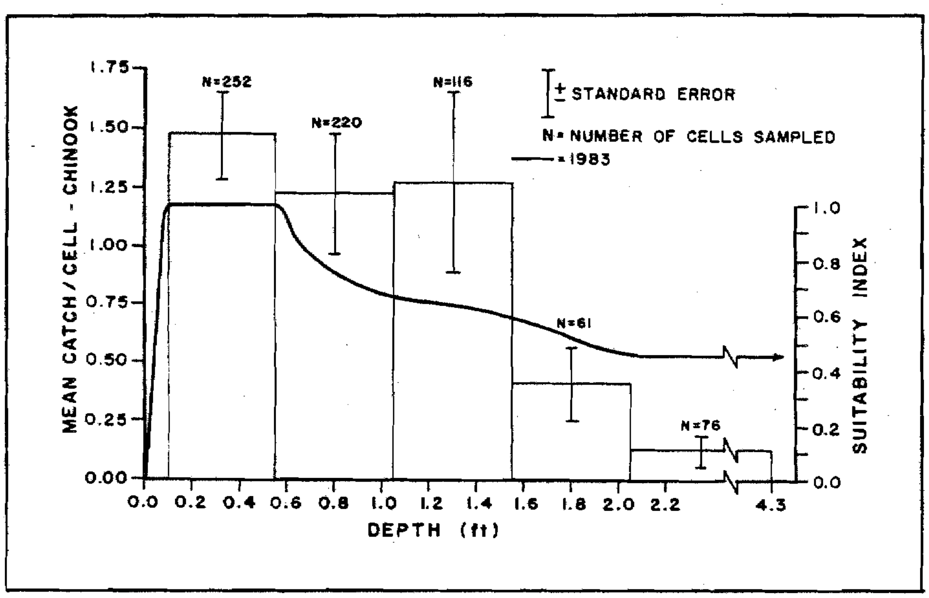
In turbid water, peaks in chinook use were found in water less than 0.5 ft deep in both 1983 and 1984 (Appendix Figure A-11). In 1983, since fitting the depth suitability line to the data did not increase the composite weighting factor much, the depth criteria used for clear water (0 if less than 0.14 ft, 1.0 if greater than 0.15 ft) was used for modelling.

In 1983 there was only one turbid cell sampled with a depth of 0.1 feet and therefore the value of cells with this depth could not be evaluated. For purposes of IFIM modelling, this depth was assigned a suitability of 0, while in the RJHAB model data this depth did not occur. In turbid water, 21 cells of 0.1 feet depth were fished in 1984 and the mean catch was 0.5 chinook juveniles per cell. These data suggest that under turbid conditions the value of 0.1 feet cells is greater than 0. A suitability criteria line was fit to the 1984 turbid water depth data by first adjusting for the effects of velocity (Appendix Figure A-12). The optimum depth ranged from 0.3 to 1.5 feet.

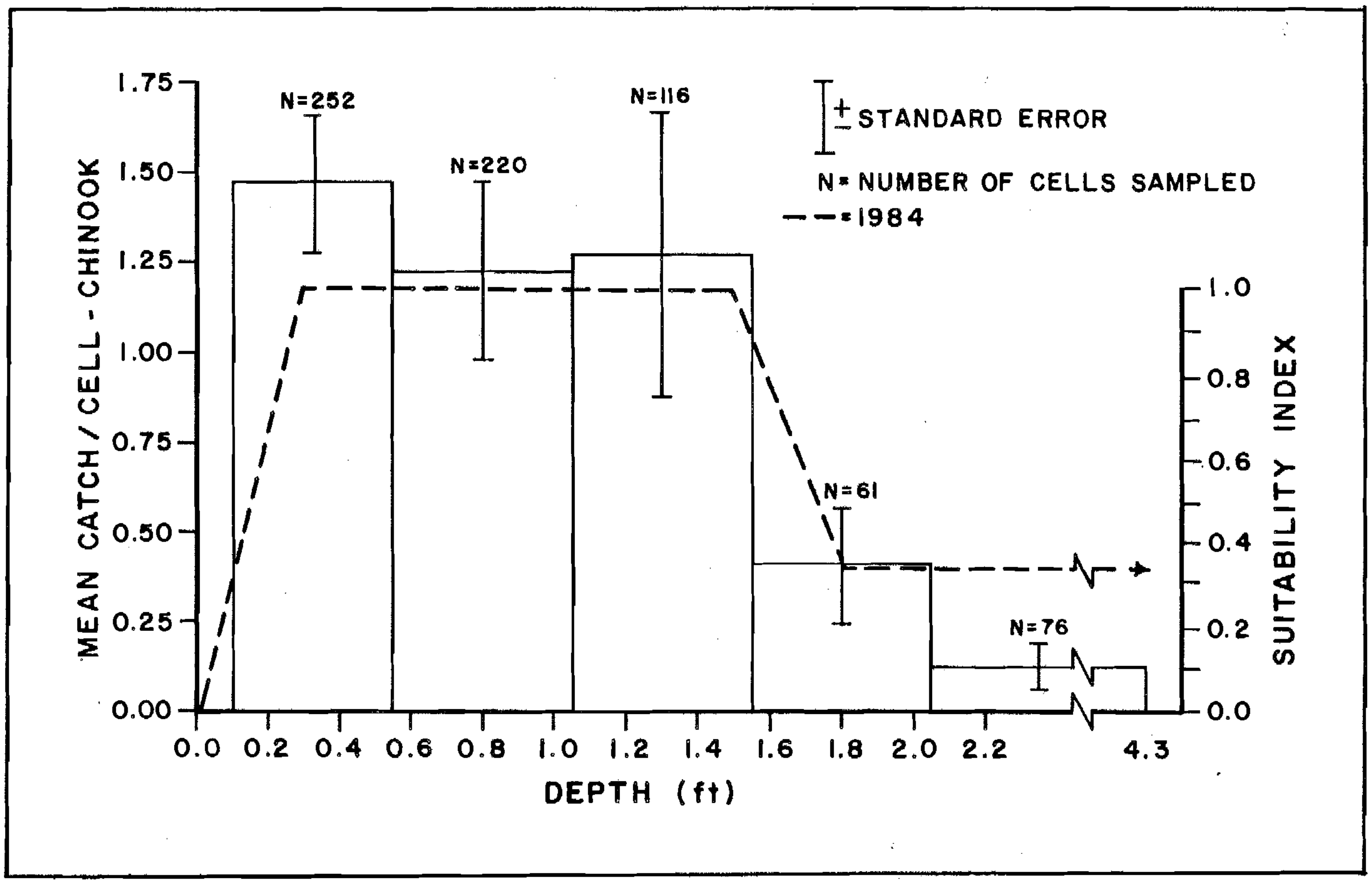
Once all the criteria were modified, correlations were calculated between catch transformed by natural log (x + 1) and the composite weighting factor calculated by multiplying the suitabilities for velocity, cover, and depth together. The correlation was 0.33, and if depth were removed the correlation dropped to 0.28. If cover was removed from calculations of the composite weighting factor, the correlation increased to 0.36. Since instream cover has value as a velocity break in turbid water, it seemed reasonable to keep velocity, cover, and depth in the modelling.



Appendix Figure A-10. Cover type suitability indices for juvenile chinook salmon in turbid water developed from 1984 lower Susitna River chinook turbid water distribution data.



Appendix Figure A-11. Mean catch of juvenile chinook salmon per cell by depth intervals (bars) in turbid water of the lower Susitna River, 1984 and fitted suitability index (line) developed for the middle Susitna River, 1983.



Appendix Figure A-12. Mean catch of juvenile chinook salmon per cell by depth intervals (bars) in turbid water of the lower Susitna River, 1984. Suitability index (line) fitted by hand using professional judgement.

Coho Salmon

Juvenile coho salmon suitability criteria were developed only for clear water in 1983. Very few coho were captured in macrohabitat types other than tributary mouths in the lower reach and therefore only tributary mouth data were used in suitability criteria comparisons. Most of the turbidities in the tributary mouths were less than 30 NTU although on two occasions, turbidities were over 100 NTU.

A total of 345 cells with complete habitat data were sampled in tributary mouths and another 2 cells with partial habitat data were sampled. Mean adjusted catch in the cells sampled was 1.2 fpc. Kendall correlations among the values of habitat attributes and coho catch ranged to 0.43 in absolute value (Appendix Table A-5). Cover type was most highly correlated with coho catch.

The distribution of mean coho catch per cell by velocity interval in 1984 matched quite closely with the suitability criteria derived in 1983 for the middle river (Appendix Figure A-13). The 1983 velocity criteria were therefore chosen as representative for the lower river.

A regression of coho catch to percent cover category was significant (Appendix Figure A-14). When the 1983 and 1984 data were normalized to 1.0 on the Y-axis for the 76-100% category, the 1983 suitability line had a much greater slope, and suitability for 0-5 percent cover in 1983 was 0.12, while in 1984 it was 0.33. After adjusting for the effect of velocity, the distribution of catches by percent cover interval appeared to be more similar to the 1983 distribution and since the sample size in 1983 was larger, the 1983 percent cover suitability relationship was chosen for use in the lower river.

Initial calculations of the suitability of cover type for coho salmon indicated that suitabilities in the lower river were similar to those found in 1983 (Appendix Figure A-15). After adjusting for the effects of velocity and percent cover, these estimates of cover suitability for the cover types were revised for use in the lower river in 1984 (Appendix Figure A-16). Since sample sizes for the three substrate cover types were small, the suitability of 0.10 calculated in 1983 for rubble and boulders was used for these three categories.

The distribution of CPUE's for depth was very different from that found in 1983 (Appendix Figure A-17). By adjusting for the effects of velocity, percent cover, and cover type there still was no trend in depth suitabilities and therefore depth suitability was not changed from that used in 1983.

The correlation between transformed coho catch and the composite weighting factor calculated by multiplying the velocity, cover, and depth suitabilities together was 0.32.

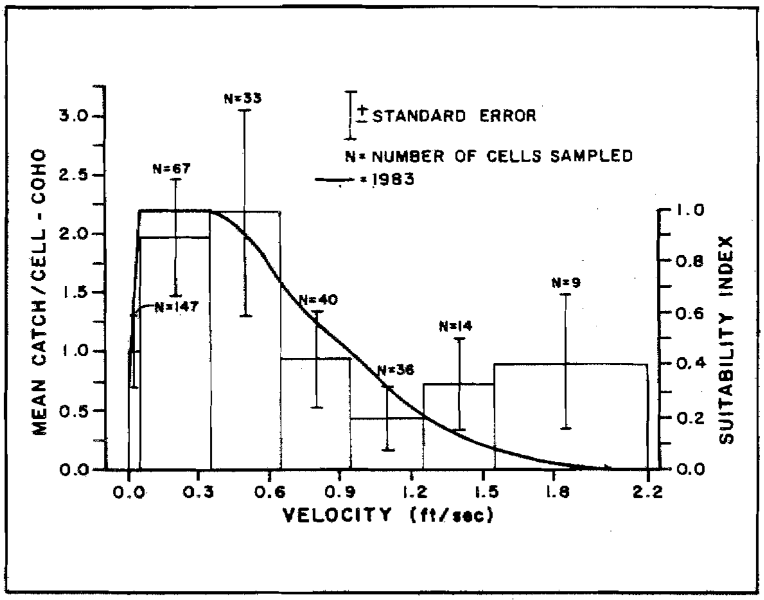
Sockeye Salmon

Juvenile sockeye salmon suitability criteria were developed by pooling data over gear type and turbidity level in 1983. Since abundance and distribution data have indicated that sockeye salmon use of lower river

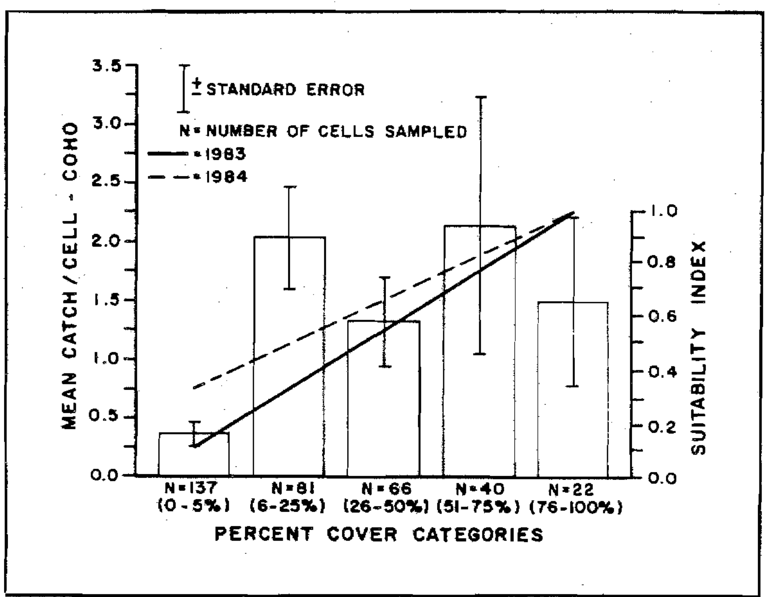
Appendix Table A-5. Kendall correlation coefficients between habitat variables and coho catch by cell (N=345) in clear water.

	Percent Cover	Cover Type	Velocity	Depth
Percent Cover	1.00			
Cover Type	0.05	1.00		
Velocity	-0.43**	0.02	1.00	
Depth	0.05	-0.09*	-0.14**	1.00
Coho	0.09*	0.23**	-0.01	0.05

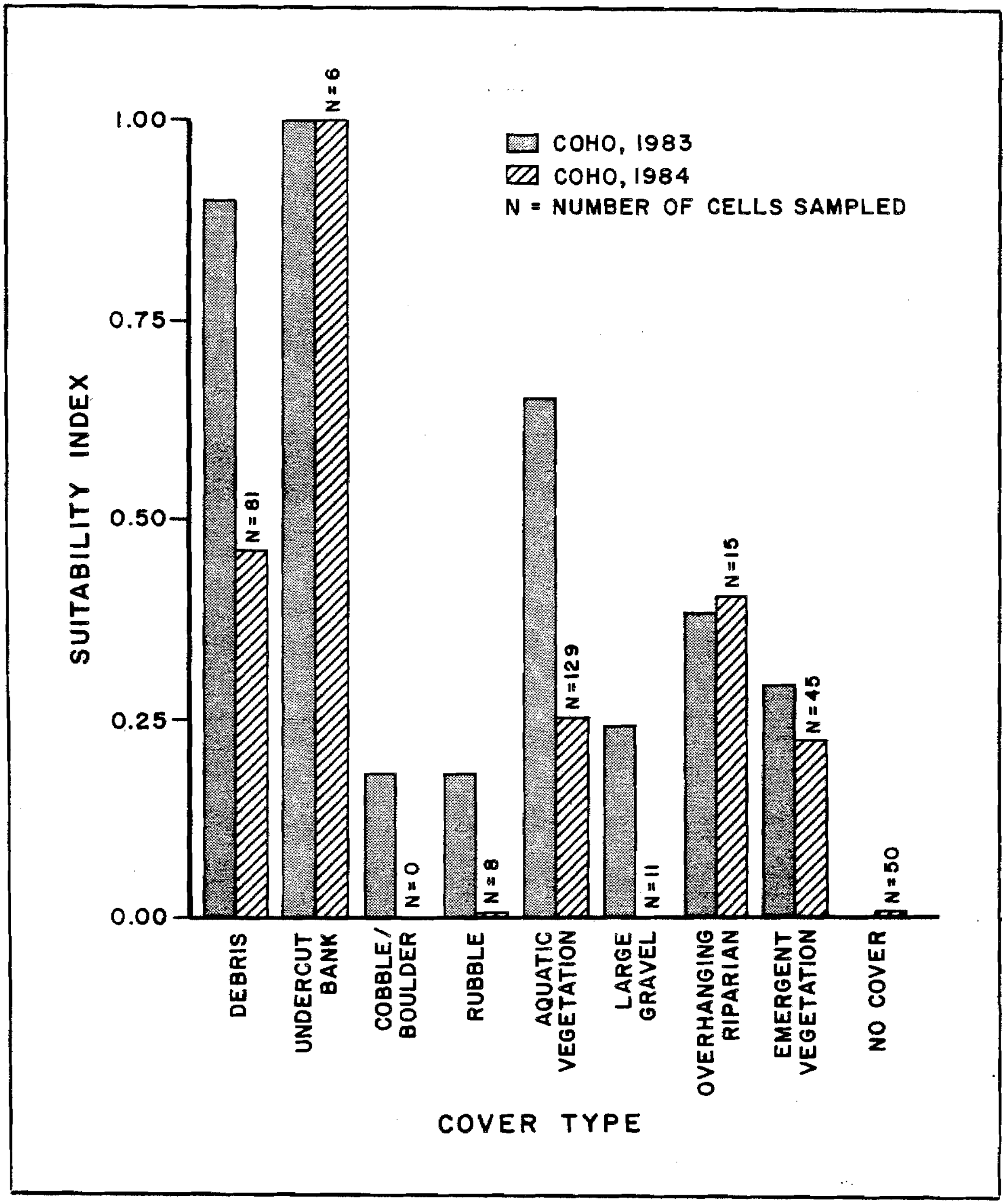
* Significantly different from 0 at $p < 0.05$.
** Significantly different from 0 at $p < 0.01$.



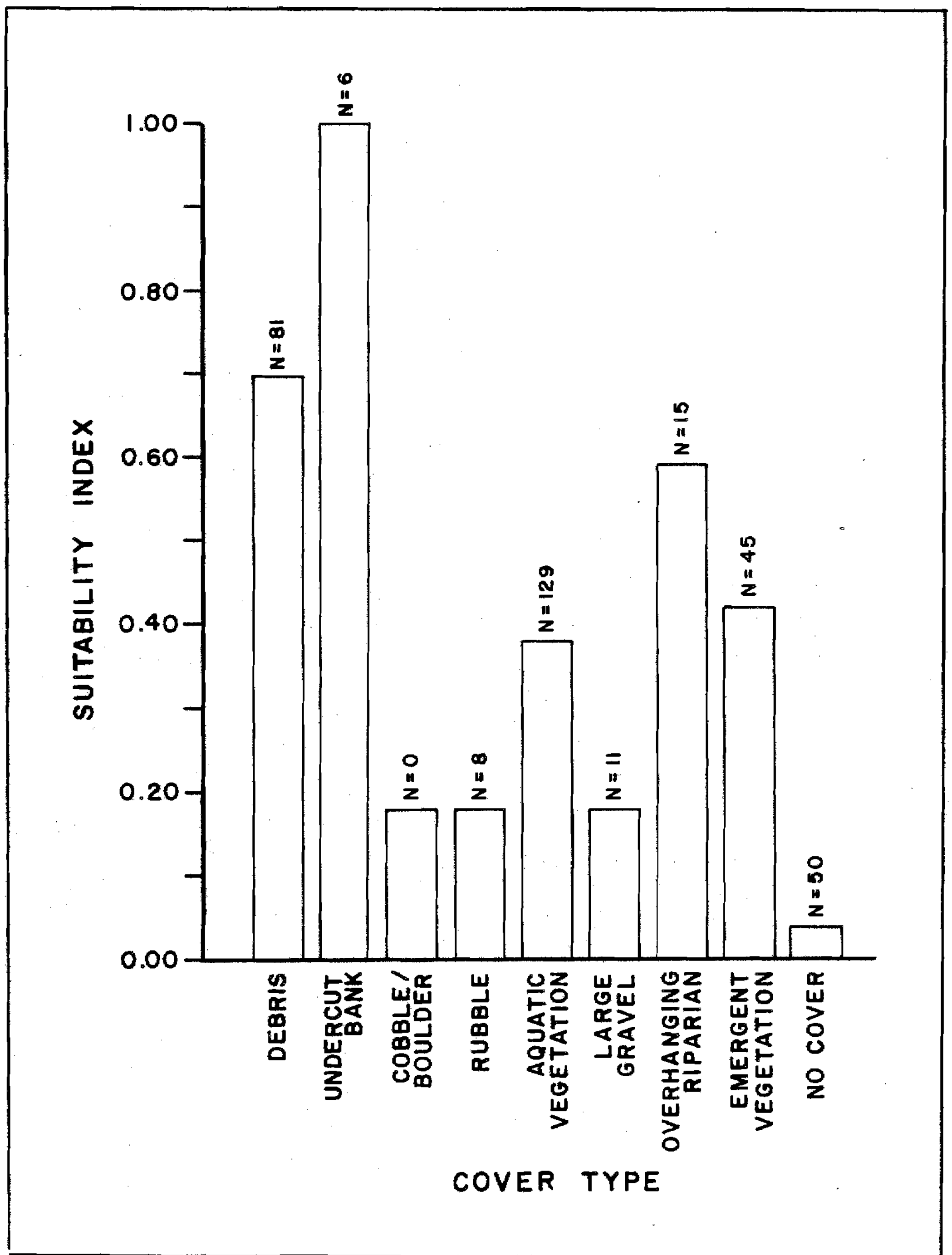
Appendix Figure A-13. Mean catch of juvenile coho salmon per cell by velocity intervals (bars) in the lower Susitna River, 1984 and fitted suitability index (line) developed for the middle Susitna River, 1983.



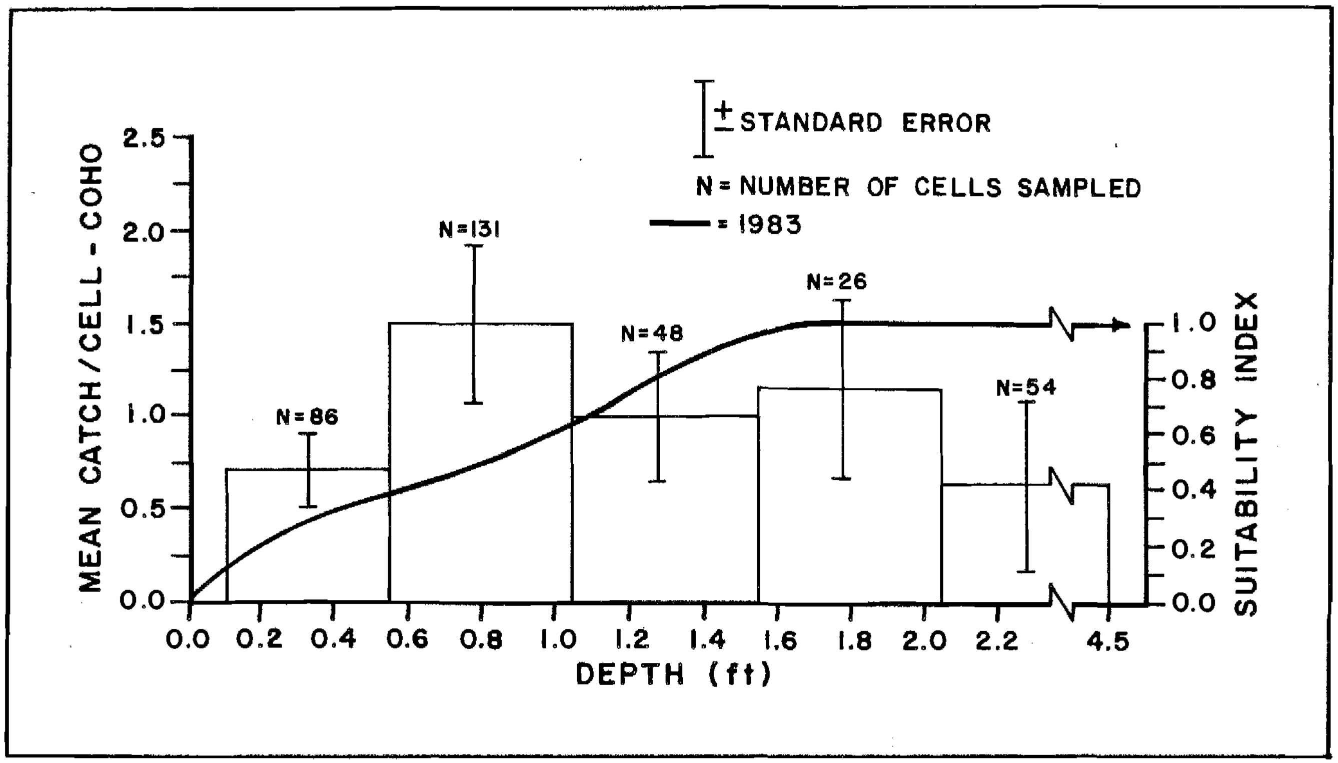
Appendix Figure A-14. Mean catch of juvenile coho salmon per cell by percent cover category (bars) in the lower Susitna River, 1984 and comparison of fitted suitability indices (lines) calculated in 1984 and for the middle Susitna River, 1983.



Appendix Figure A-15. Comparison of cover type suitability indices for juvenile coho salmon calculated from 1984 lower Susitna River distribution data.



Appendix Figure A-16. Cover type suitability indices for juvenile coho salmon developed for the lower Susitna River in 1984.



Appendix Figure A-17. Mean catch of juvenile coho salmon per cell by depth intervals (bars) in clear water of the lower Susitna River, 1984 and fitted suitability index (line) developed for the middle Susitna River, 1983.

side channels is limited by high turbidities (Figure 18), cells with turbidities greater than 250 NTU were eliminated from suitability criteria development.

After cells with turbidities greater than 250 NTU were eliminated, 922 cells with complete habitat data were available for analysis. Sockeye were captured in 117 (12.7%) of these cells. Correlations among the habitat variables ranged to 0.65 in absolute value and velocity was most highly correlated with sockeye catch (Appendix Table A-6). In addition to these cells, partial habitat data were collected at six additional cells and these data are used in subsequent univariate histograms.

The distribution of proportional presence by velocity interval was very similar to that found in 1983 (Appendix Figure A-18). There was no use of velocities greater than 1.2 fps, however, and in 1983 there also was no use of velocities greater than 1.2 fps although sample sizes were smaller. Since these high velocities are not used, the lower river velocity suitability criteria were modified so that velocities greater than 1.2 fps have 0 suitability (Appendix Figure A-18).

Distribution of proportional presence by percent cover categories was similar to that found in 1983 (Appendix Figure A-19). The 1983 suitability relationship was therefore selected for use in 1984.

The distribution of proportional presence by cover type categories was somewhat different than that found in 1983 (Appendix Figure A-20). Suitabilities for the cover types used in the lower river in 1984 will be those developed in 1984 with the following two exceptions. Since sample sizes were small (less than 25) for the cover type categories, undercut banks and overhanging riparian vegetation, the suitabilities calculated in 1983 were averaged with the 1984 suitabilities to give a value intermediate between the two.

No trend was noted in the 1984 depth distribution data and therefore no suitability criteria were fit to these data (Appendix Figure A-21). Of the 20 cells sampled with 0.1 ft depth, fish were sampled in 2 suggesting that this depth does have value. Therefore any depth will be assumed to have a suitability of 1.

Composite weighting factor intervals calculated by multiplying cover and velocity suitabilities together were associated with proportional presence of sockeye salmon (Appendix Table A-7).

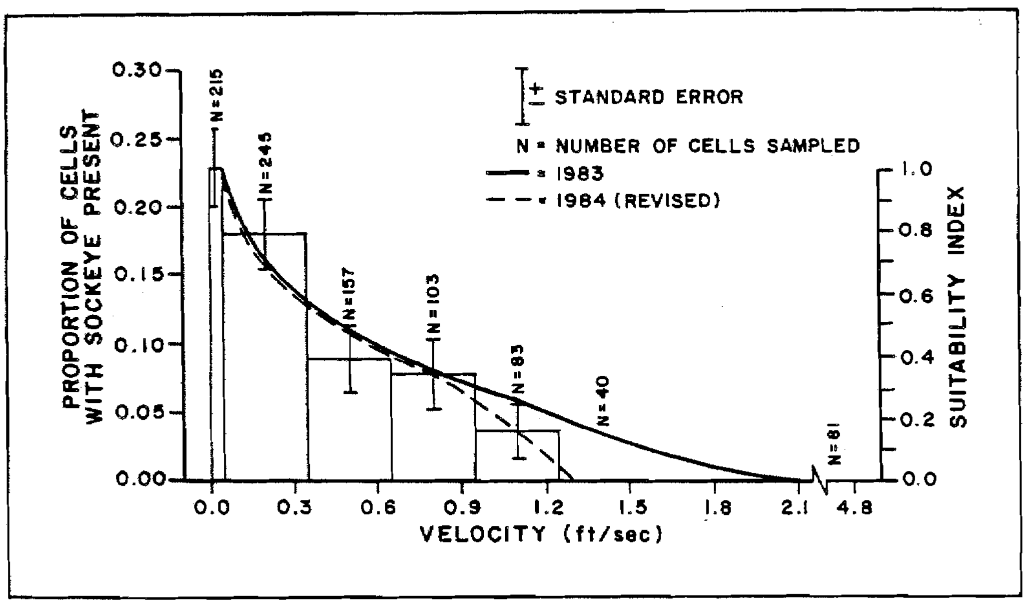
Chum Salmon

Juvenile chum salmon suitability criteria were developed by pooling data over gear type and turbidity in 1983. Abundance and distribution data indicate that chum salmon use of lower river side channels is limited by high turbidities (Figure 15). Cells with turbidities greater than 200 NTU were eliminated from suitability criteria development. Also, since most chum salmon outmigrate before July 16, only data collected before this date were retained for suitability criteria analysis.

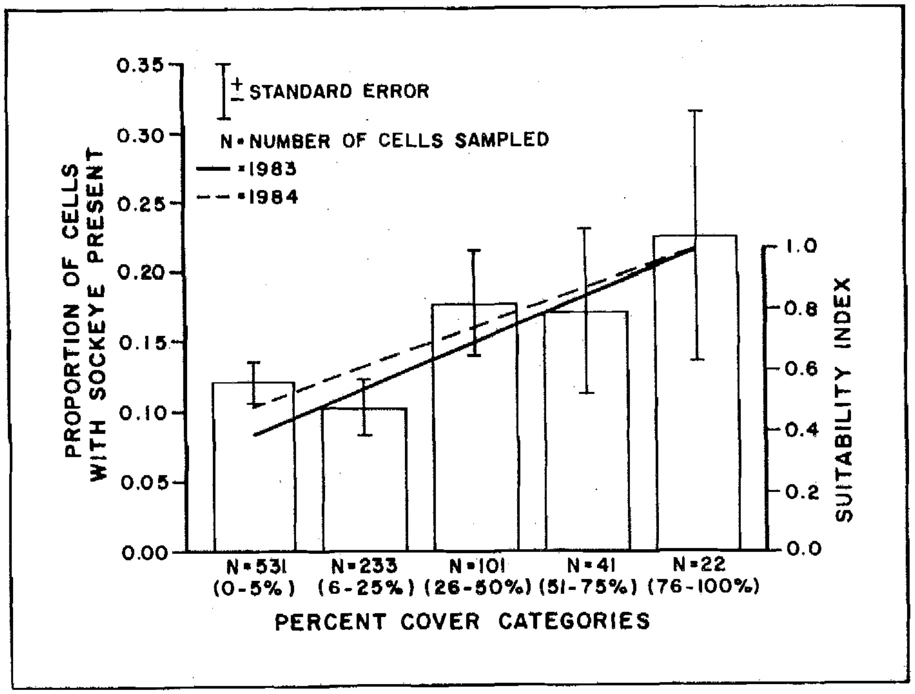
Appendix Table A-6. Kendall correlation coefficients between habitat variables and sockeye catch by cell (N=922).

	Percent Cover	Cover Type	Velocity	Depth
Percent Cover	1.00			
Cover Type	0.30**	1.00		
Velocity	-0.18**	0.65**	1.00	
Depth	0.05*	-0.01	0.07**	1.00
Sockeye	0.04	-0.06*	-0.21**	0.02

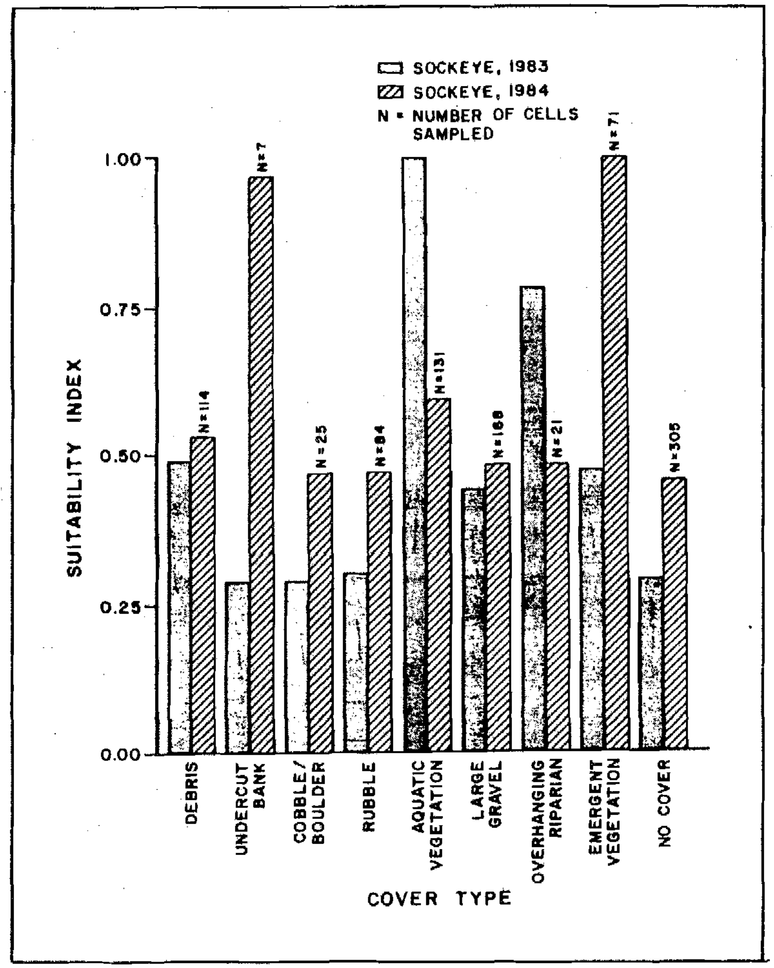
* Significantly different from 0 at $p<0.05$.
** Significantly different from 0 at $p<0.01$.



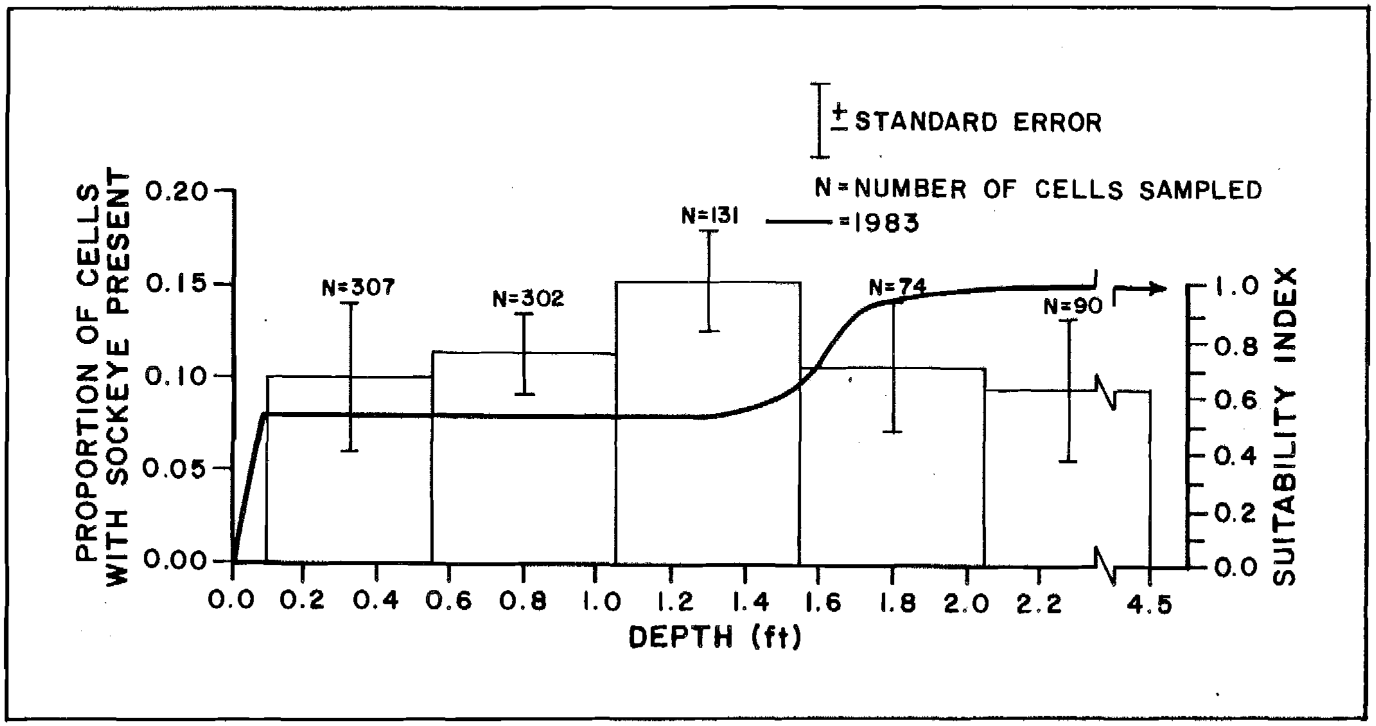
Appendix Figure A-18. Proportion of cells with juvenile sockeye salmon present by velocity intervals (bars) in the lower Susitna River, 1984 and fitted suitability index (line) developed for the middle Susitna River, 1983 and revised in 1984 for the lower Susitna River using professional judgement.



Appendix Figure A-19. Proportion of cells with juvenile sockeye salmon present by percent cover category (bars) in the lower Susitna River, 1984 and comparison of fitted suitability indices (lines) calculated in 1984 and for the middle Susitna River, 1983.



Appendix Figure A-20. Comparison of cover type suitability indices for juvenile sockeye salmon calculated from 1984 lower Susitna River distribution data and 1983 middle Susitna River distribution data.



Appendix Figure A-21. Proportion of cells with juvenile sockeye salmon présent by depth intervals (bars) in the lower Susitna River, 1984 and suitability index (line) developed for the middle Susitna River, 1983.

Appendix Table A-7. Proportional presence of sockeye salmon associated with the composite weighting factor calculated by multiplying velocity and cover suitabilities together.

Composite Weighting Factor Interval	Total Number of Cells	Proportion With Fish Present	Chi-Square
0 - 0.06	244	0.02	$X^2 = 55.3$
0.07 - 0.11	213	0.08	
0.12 - 0.19	228	0.17	$p < 0.001$
0.20 - 1.00	241	0.23	

The number of cells available for analysis of juvenile chum distribution totaled 249 after elimination of the cells outlined above. Chum salmon were captured in 98 (39.4%) of these cells. Correlations among the habitat variables and chum fry catch ranged to 0.32 in absolute value (Appendix Table A-8). Partial habitat data were collected at two additional cells.

The chum salmon distribution by velocity interval in 1984 was similar to 1983 (Appendix Figure A-22). Therefore, the suitability criteria for chum salmon developed in 1983 was selected for use in 1984.

In 1983, the relationship of chum salmon use to percent cover and cover type was the weakest of any of the four species. In 1984, the 0-5% cover category and the "no cover" type had the highest proportional presence within their respective distributions (Appendix Figures A-23 and A-24). These data indicate that chum salmon fry do not orient to cover during rearing. Even when velocity suitability was adjusted for, no real trends in percent cover and cover type utilization were noted, although large gravel and rubble were used slightly more than was the "no cover" type. Since there were no trends, cover type and percent cover will not be used in the 1984 analysis of chum habitat use.

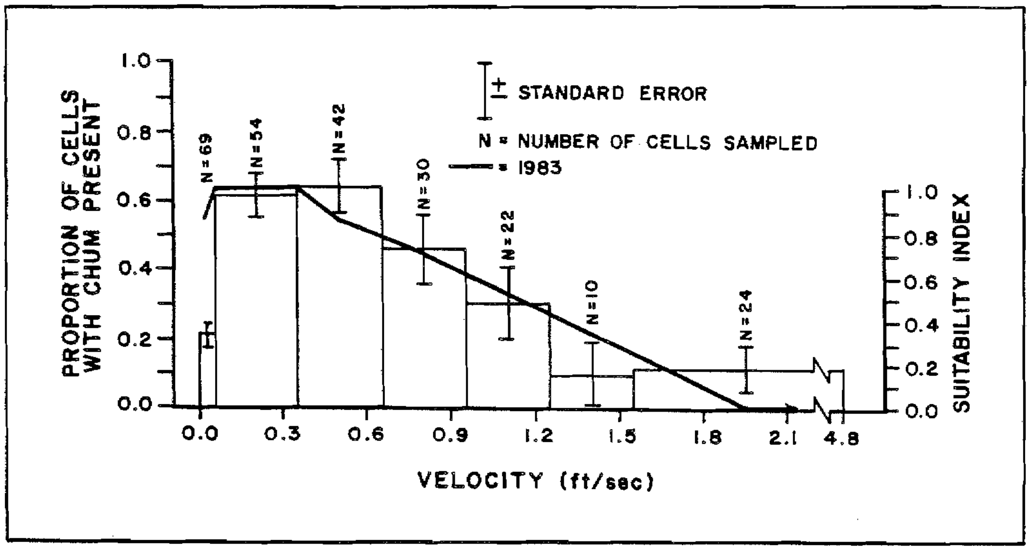
The distribution of chum proportional presence by depth intervals in 1984 was similar to that found in the 1983 studies (Appendix Figure A-25). Since the distributions were similar, the criteria fit in 1983 was used to test for the value of depth in increasing the associations with chum catch. Therefore velocity was first used alone and then with depth to form categories which were associated with chum proportional presence.

Although composite weighting factors calculated by velocity alone and velocity and depth together were both significantly associated with chum proportional presence, the composite weighting factor calculated by depth and velocity together seemed to fit the observed distribution data better (Appendix Table A-9). Therefore both velocity and depth suitability criteria will be used to model chum salmon habitat.

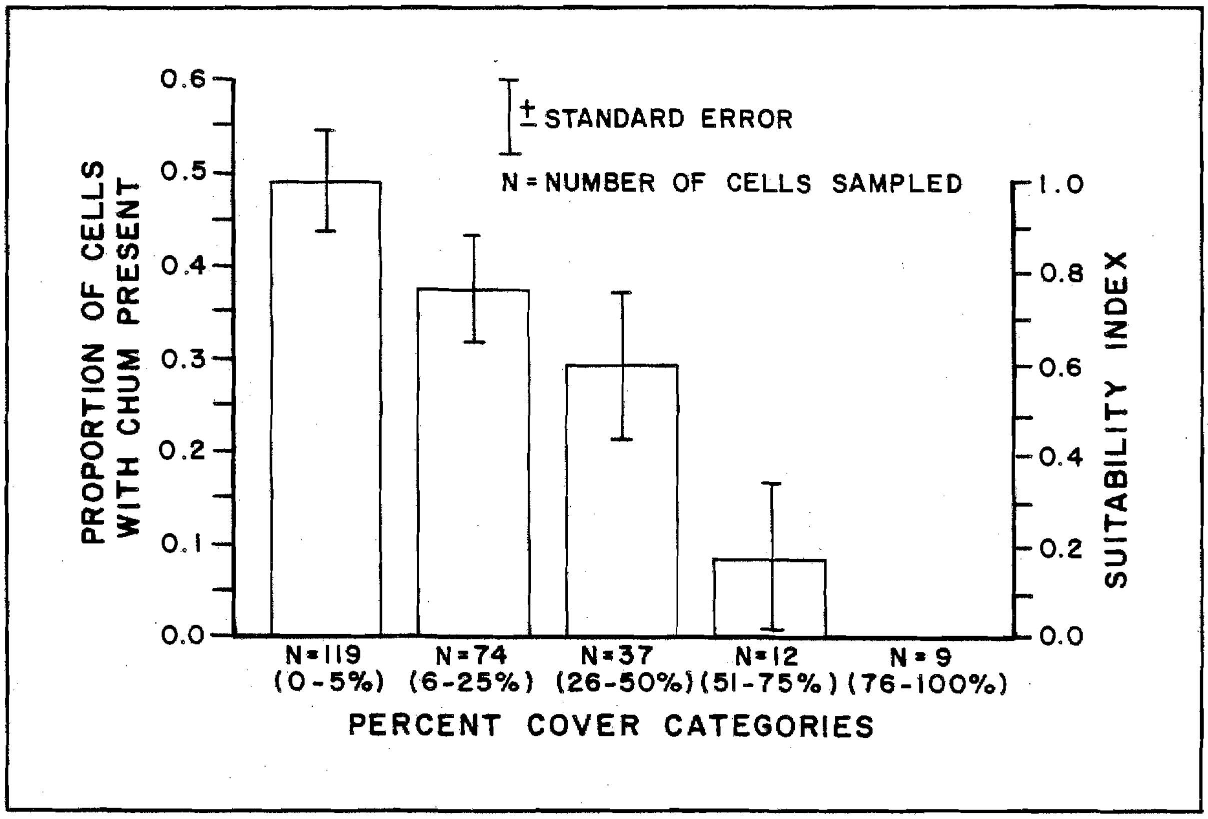
Appendix Table A-8. Kendall correlation coefficients between habitat variables and chum catch by cell (N=249) for all gear types, turbidity below 200 NTU.

	Percent Cover	Cover Type	Velocity	Depth	Chum
Percent Cover	1.00				
Cover Type	0.13**	1.00			
Velocity	-0.25**	0.15**	1.00		
Depth	-0.05	-0.03	0.07	1.00	
Chum	-0.20**	-0.07	-0.04	-0.32**	1.00

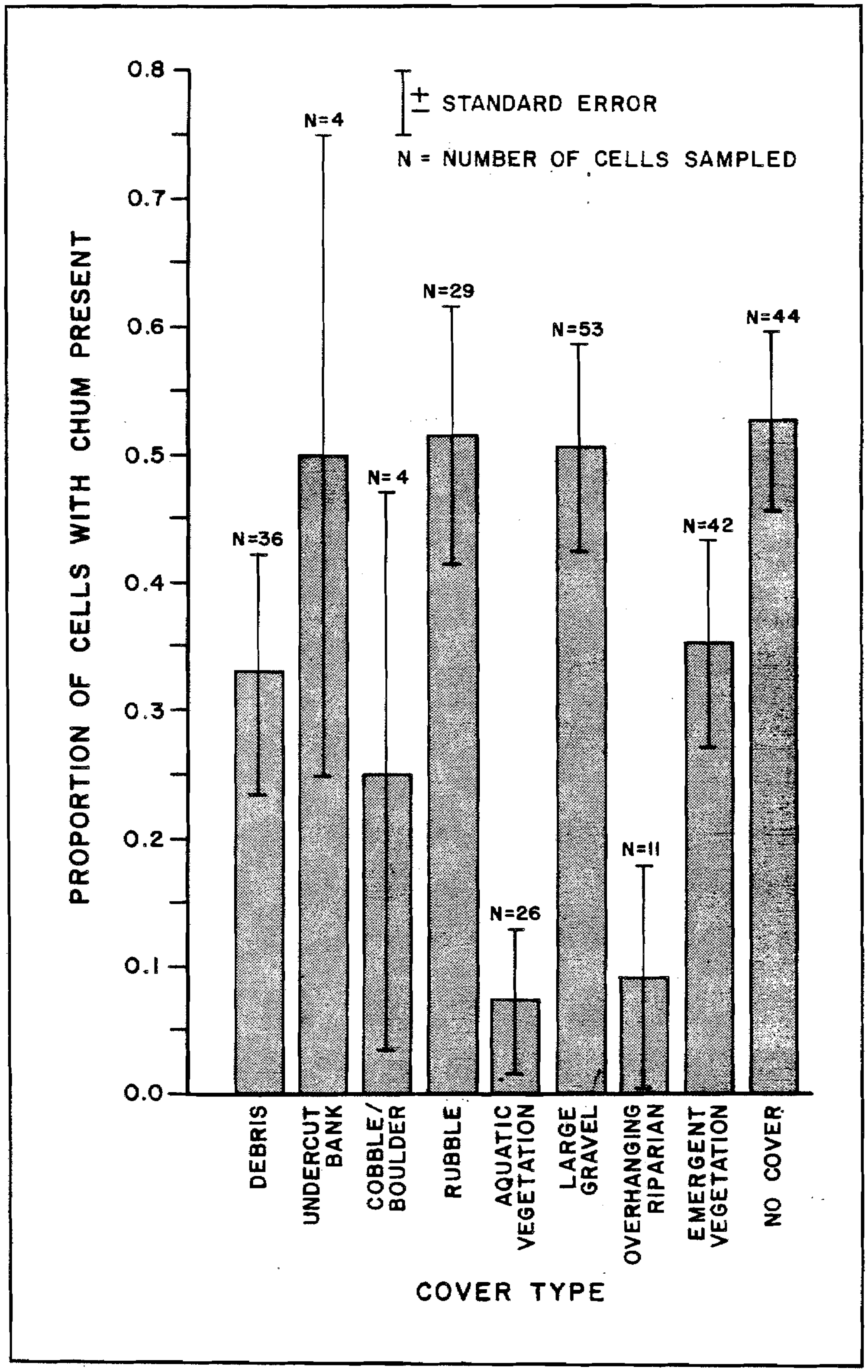
* Significantly different from 0 at $p<0.05$.
** Significantly different from 0 at $p<0.01$.



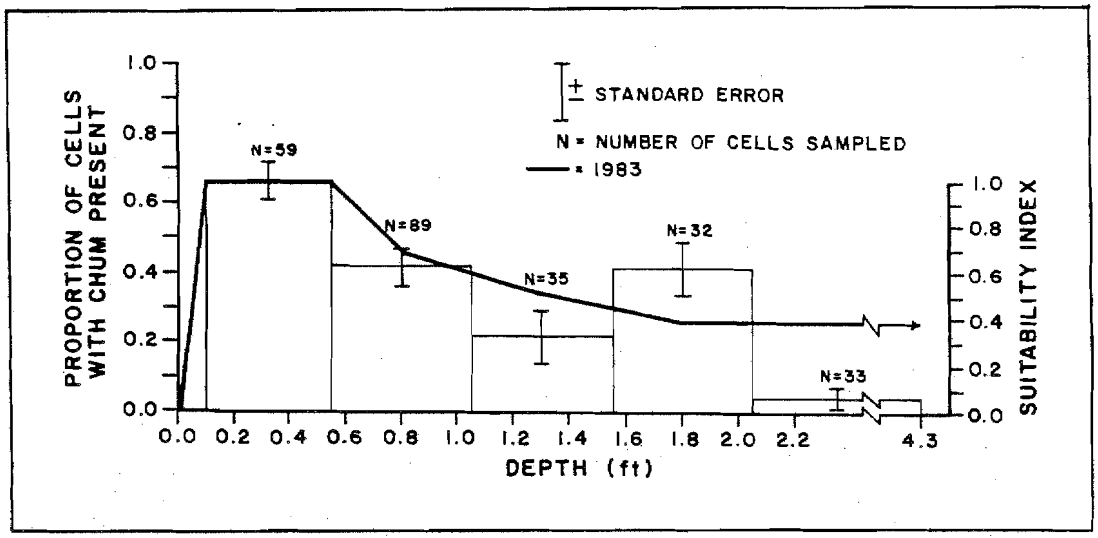
Appendix Figure A-22. Proportion of cells with juvenile chum salmon present by velocity intervals (bars) in the lower Susitna River, 1984 and fitted suitability index (line) developed for the middle Susitna River, 1983.



Appendix Figure A-23. Proportion of cells with juvenile chum salmon present by percent cover category (bars) in the lower Susitna River, 1984 and fitted suitability index (line) calculated for the middle Susitna River, 1983.



Appendix Figure A-24. Proportion of cells with juvenile chum salmon present by cover type (bars) in the lower Susitna River, 1984.



Appendix Figure A-25. Proportion of cells with juvenile chum salmon present by depth intervals (bars) in the lower Susitna River, 1984 and fitted suitability index (line) developed for the middle Susitna River, 1983.

Appendix Table A-9. Proportional presence of chum salmon fry associated with several composite weighting factors.

Composite Weighting Factor Calculation	Composite Weighting Factor Interval	Total Number of Cells	Proportion With Fish Present	Chi-Square
Velocity	0 - 0.55	49	0.20	$\chi^2 = 34.3$
	0.60 - 0.81	51	0.49	$p<0.001$
	0.86	82	0.24	
	0.93 - 1.00	69	0.64	
Velocity*Depth	0 - 0.32	71	0.10	
	0.34 - 0.49	54	0.43	$\chi^2 = 46.8$
	0.50 - 0.73	60	0.42	$p < 0.001$
	0.76 - 1.00	66	0.67	

Summary

A summary table of revisions of the middle river suitability criteria for use in the lower river reveals that about half the criteria were not changed or changed only slightly (Appendix Table A-10). The velocity and percent cover relationships were often not changed while the depth and cover type criteria have often been modified. Point specific values for all the suitability criteria developed for use in the lower river are presented in Appendix Table A-11.

DISCUSSION

Chinook Salmon

The turbid water velocity criteria developed in 1983 were used for both clear and turbid chinook distributions in the lower river in 1984. The reason that there was no shift in velocity optima from clear to turbid water may be due to several factors. In the middle river, substrate is much larger and therefore, juvenile chinooks may find higher velocities because suitable as there is always some substrate cover to hide under or behind. In the lower river, however, very little substrate cover is present and therefore chinook use lower velocity water much more.

In the lower river, cover suitabilities were often somewhat different than in the middle river. Part of this difference may be due to the actual cover in cover type categories being of a different type. For instance, the aquatic vegetation in Caswell Creek, which harbored large numbers of chinook fry, was not present in any of the sampled streams in the middle river. Also the debris cover type in the lower river was often much more silted in than in the middle river and therefore less suitable. The primary cover type is associated with a variety of secondary cover types and it is likely that, on the average, secondary cover types associated with a primary cover type in the lower river are different than the secondary cover types most common in the middle river. If these secondary cover types are more suitable for fish, then they might raise the suitability of the primary cover type.

Most notable in the analysis of chinook suitability criteria was the effect of depth upon the distribution of chinook salmon. In the lower river, chinook salmon found deep, water much more suitable than in the middle river (Appendix Figure A-7). This is probably due to the tributaries in the lower river having a turbidity of approximately 10 to 20 NTU and therefore depth might have a cover value in deeper waters. In the middle river, much of the data were collected in Portage Creek, Indian River, and other areas where the turbidity was usually less than 5 NTU and depth would not provide cover at depths which can be sampled. Sometimes juvenile salmon thought to be chinook fry could be seen feeding on the surface in tributary mouths such as Rolly Creek where depths were greater than 5.0 ft.

In turbid water, on the other hand, depths greater than 1.5 ft were less suitable than shallower cells (Appendix Figure A-11). This trend was

Appendix Table A-10. Summary of revisions of 1983 middle river juvenile salmon criteria for use in the lower Susitna River, 1984.

Species	Velocity	Percent Cover	Cover Type	Depth
Chinook (clear)	Turbid chinook criteria developed in 1983 used	Same as 1983	Modified	Modified
Chinook (turbid)	Same as 1983	Same as 1983	Modified	Modified
Coho	Same as 1983	Same as 1983	Modified	Same as 1983
Sockeye	Modified Slightly	Same as 1983	Modified Slightly	Modified Slightly
Chum	Same as 1983	Modified (Set to 1.0)	Modified (Set to 1.0)	Modified

Appendix Table A-11. Suitability indices for juvenile salmon for velocity, depth, and cover in the lower Susitna River, 1984.

VELOCITY

Chinook		Coho		Sockeye		Chum	
Velocity (ft/sec)	Suitability	Velocity (ft/sec)	Suitability	Velocity (ft/sec)	Suitability	Velocity (ft/sec)	Suitability
0.00	0.42	0.00	0.29	0.00	1.00	0.00	0.86
0.05	1.00	0.05	1.00	0.05	1.00	0.05	1.00
0.35	1.00	0.35	1.00	0.20	0.71	0.35	1.00
0.50	0.80	0.50	0.88	0.50	0.48	0.50	0.87
0.80	0.38	0.80	0.55	0.80	0.35	0.80	0.70
1.10	0.25	1.10	0.32	1.10	0.14	1.10	0.56
1.40	0.15	1.40	0.12	1.30	0.00	1.40	0.37
1.70	0.07	1.70	0.04			1.70	0.15
2.00	0.02	2.00	0.01			2.00	0.03
2.30	0.01	2.10	0.00			2.10	0.00
2.60	0.00						

DEPTH

Chinook (turbid)		Chinook (clear)		Coho		Sockeye		Chum	
Depth (ft)	Suitability	Depth (ft)	Suitability	Depth (ft)	Suitability	Depth (ft)	Suitability	Depth (ft)	Suitability
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.10	0.29	0.15	0.00	0.14	0.00	0.10	1.00	0.10	1.00
0.30	1.00	0.20	0.25	0.15	1.00	10.00	1.00	0.50	1.00
1.50	1.00	1.50	0.25	10.00	1.00			0.80	0.68
1.80	0.33	1.80	0.80					1.30	0.50
10.00	0.33	2.10	1.00					1.80	0.38
		10.00	1.00					10.00	0.38

Appendix Table A-11 (Continued)

Cover Type	Percent Cover	Chinook (turbid)	Chinook (clear)	Coho	Sockeye	Chum
No cover	0-5%	0.15	0.01	0.00	0.18	1.00
Emergent Vegetation	0-5%	0.23	0.11	0.05	0.39	1.00
	6-25%	0.30	0.33	0.14	0.54	1.00
	26-50%	0.33	0.55	0.24	0.70	1.00
	51-75%	0.39	0.78	0.33	0.85	1.00
	76-100%	0.40	1.00	0.42	1.00	1.00
Aquatic Vegetation	0-5%	0.23	0.10	0.04	0.23	1.00
	6-25%	0.30	0.32	0.13	0.32	1.00
	26-50%	0.33	0.53	0.21	0.41	1.00
	51-75%	0.39	0.76	0.30	0.50	1.00
	76-100%	0.40	0.97	0.38	0.59	1.00
Debris or Deadfall	0-5%	0.15	0.05	0.08	0.21	1.00
	6-25%	0.20	0.17	0.24	0.29	1.00
	26-50%	0.20	0.28	0.39	0.37	1.00
	51-75%	0.20	0.39	0.55	0.45	1.00
	76-100%	0.20	0.50	0.70	0.53	1.00
Overhanging Riparian Vegetation	0-5%	0.15	0.04	0.07	0.25	1.00
	6-25%	0.20	0.13	0.20	0.34	1.00
	26-50%	0.20	0.21	0.33	0.44	1.00
	51-75%	0.20	0.30	0.46	0.54	1.00
	76-100%	0.20	0.38	0.59	0.63	1.00
Undercut Banks	0-5%	0.23	0.11	0.12	0.25	1.00
	6-25%	0.30	0.33	0.34	0.34	1.00
	26-50%	0.33	0.55	0.56	0.44	1.00
	51-75%	0.39	0.78	0.78	0.54	1.00
	76-100%	0.40	1.00	1.00	0.63	1.00

Appendix Table A-11 (Continued)

Cover Type	Percent Cover	Chinook (turbid)	Chinook (clear)	Coho	Sockeye	Chum
Large Gravel (1-3")	0-5%	0.15	0.02	0.02	0.18	1.00
	6-25%	0.20	0.08	0.06	0.24	1.00
	26-50%	0.20	0.13	0.10	0.32	1.00
	51-75%	0.20	0.18	0.14	0.38	1.00
	76-100%	0.20	0.23	0.18	0.45	1.00
Rubble (3-5")	0-5%	0.15	0.03	0.02	0.18	1.00
	6-25%	0.20	0.10	0.06	0.24	1.00
	26-50%	0.20	0.17	0.10	0.32	1.00
	51-75%	0.20	0.23	0.14	0.38	1.00
	76-100%	0.20	0.30	0.18	0.45	1.00
Cobble or Boulder (> 5")	0-5%	0.15	0.03	0.02	0.18	1.00
	6-25%	0.20	0.11	0.06	0.24	1.00
	26-50%	0.20	0.18	0.10	0.32	1.00
	51-75%	0.20	0.25	0.14	0.38	1.00
	76-100%	0.20	0.32	0.18	0.45	1.00

also found in 1983 although discounted at the time. This difference may be due to fish reacting to high suspended solid concentrations by staying near the surface (Wallen 1951 as cited in Beauchamp et al. 1983). It also could be due to fish not being able to feed at depths where there is very little light, whereas in shallower water a greater amount of light may enable fish to feed.

Coho Salmon

The suitability criteria developed for coho salmon juveniles in the middle river were modified only slightly in cover suitability for use in the lower reach. The fit of the data to the composite weighting factor was not very high (r=0.32) however, which suggests that coho respond to other factors than those studied. These factors include food supply or seasonal movements.

Sockeye Salmon

Since sockeye normally rear in lakes (Morrow 1980), it is not surprising that velocity is one of the most important variables affecting their distribution. In both the lower and middle Susitna river, no sockeye were captured in cells with velocities greater than 1.2 ft/sec. The highest catches of sockeye in the lower river were made at Beaver Dam Slough, which is a backwater site with minimal velocity.

Instream cover also has an effect on juvenile sockeye salmon distribution and it appears they use turbidity as cover (Section 3.2.4). In lakes which are turbid due to glacial input, however, production of sockeye smolts on an area basis is much smaller than that of clear lakes (Lloyd 1985). Deep water in the clear lakes would provide cover while in the Susitna, depths of 10 feet or more are infrequently found, and therefore turbidity would be used as cover. Cover type suitabilities were somewhat different in the lower reach than in the middle reach, perhaps due to differences in the primary or secondary cover type within the categories between the two reaches.

Chum Salmon

Chum salmon, in contrast to the other species, did not show any positive response to the presence of cover. The response shown, which is a negative one, is probably partly a function of gear efficiency. They did respond to velocity and depth, however. The lack of relationship with cover may partly be a function of schooling behavior which reduces the need for cover. It is also possible that since chum fry rear in fresh water for only a short period, they usually are searching for food instead of hiding in cover.

The reason for the heavier use of shallower depths by chum juveniles found in both years not known. It could be due to a use of shallow depths and low velocities in side channels where some of the suspended solids may settle out. Perhaps these areas also are somewhat warmer than adjacent areas because the sunlight strikes the substrate and is absorbed heating the water above.

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APPENDIX B

MODELLED SITE TURBIDITIES, JUVENILE
SALMON CATCHES, AREAS, SIDE CHANNEL FLOWS,
WEIGHTED USABLE AREAS, AND HABITAT INDICES

This appendix is a compilation of data arranged into a number of graphs and tables. The first three tables (Appendix Tables B-1, B-2, and B-3) present: modelled side channel turbidities; modelled site catches and CPUE's of juvenile salmon; and lengths of RJHAB model sites; respectively. Appendix Table B-4 presents modelled side channel flows as a function of mainstem discharge at 3,000 cfs increments.

Next weighted usable areas and habitat indices are presented by species in the following order:

Chinook Salmon

Tabulation of weighted usable areas and habitat indices for 18 sites (Appendix Table B-5).

Graphs of weighted usable area versus mainstem discharge for sites not presented in Section 3.3:

Caswell Creek Mouth	(Appendix Figure B-1)
Beaver Dam Slough	(Appendix Figure B-1)
Hooligan Side Channel	(Appendix Figure B-2)
Bearbait Side Channel	(Appendix Figure B-2)
Last Chance Side Channel	(Appendix Figure B-3)
Rustic Wilderness Side Channel	(Appendix Figure B-3)
Island Side Channel	(Appendix Figure B-4)
Mainstem West Bank	(Appendix Figure B-4)
Goose 2 Side Channel	(Appendix Figure B-5)
Circular Side Channel	(Appendix Figure B-5)
Sauna Side Channel	(Appendix Figure B-6)
Bearbait Side Channel	(Appendix Figure B-6)
Sunset Side Channel	(Appendix Figure B-7)
Sunrise Side Channel	(Appendix Figure B-7)
Trapper Creek Side Channel	(Appendix Figure B-8)

Coho Salmon

Tabulation of weighted usable areas and habitat indices for three sites (Appendix Table B-6).

Chum Salmon

Tabulation of weighted usable areas and habitat indices for 15 sites (Appendix Table B-7).

Graphs of weighted usable area versus mainstem discharge for sites not presented in Section 3.3:

Hooligan Side Channel	(Appendix Figure B-9)
Kroto Slough Head	(Appendix Figure B-9)
Bearbait Side Channel	(Appendix Figure B-10)
Island Side Channel	(Appendix Figure B-10)
Mainstem West Bank	(Appendix Figure B-11)
Goose 2 Side Channel	(Appendix Figure B-11)
Circular Side Channel	(Appendix Figure B-12)
Sauna Side Channel	(Appendix Figure B-12)
Sucker Side Channel	(Appendix Figure B-13)
Beaver Dam Side Channel	(Appendix Figure B-13)
Sunrise Side Channel	(Appendix Figure B-14)

Sockeye Salmon

Tabulation of weighted usable areas and habitat indices for seven sites (Appendix Table B-8).

Graphs of weighted usable area versus mainstem discharge for sites not presented in Section 3.3:

Caswell Creek Mouth	(Appendix Figure B-15)
Beaver Dam Slough	(Appendix Figure B-15)
Sunrise Side Channel	(Appendix Figure B-16)

Appendix Table B-1. Turbidities within modelled side channels of the lower Susitna River, June through August, 1984. Values within parentheses were calculated by inputting the overall mean for all the side channels during a given two week period.

Site	June 1-15	June 16-30	July 1-15	July 16-30	Aug 1-15	Aug 16-30[1]	Mean
West Bank Lateral Side Channels							
Kroto Side Channel	(64)	394	(369)	272,704	784	126	388
Bear Bait Side Channel	(64)	392	284	312	328	142	254
Mainstem West Bank	(64)	(227)	(369)	368	324	324	279
Sauna Side Channel	120	(227)	496	364	244	156,256	266
Trapper Side Channel	96	576	940	470	306	608	499
Middle Side Channels							
Hooligan Side Channel	(64)	365	288	296	704	544	377
Last Chance Side Channel	(64)	(227)	296	672	352	576	365
Island Side Channel	55	126	334	336	228	(209)	215
Circular Side Channel	89	122	592	288	216	78,304	241
Sucker Side Channel	26	64	276	118	292	44,163	140
Sunrise Side Channel	18	112	180	88	280	44,124	121
East Bank Lateral Side Channels							
Rustic Wilderness Side Channel	(64)	120	130	160	196	38	118
Goose Side Channel	41	140	384	300	188	64,244	194
Sunset Side Channel	(64)	(227)	(369)	114	100	41,146	152
Beaver Dam Side Channel	(64)	90	224	134	170	150	139
OVERALL MEAN	64	227	369	312	314	209	

[1] Two turbidities are given in this column for six sites because there were two sampling trips during this two week period in the Sunshine area. Turbidities were dropping rapidly in late August and so turbidities taken on the first late August trip were much higher than those taken during the second trip in late August.

Appendix Table B-2. Catch and catch per cell (CPUE) of juvenile salmon within lower Susitna River sampling sites, 1984. Cells have been standardized to an area of 300 ft^2.

Site	No. of cells sampled	Chinook catch	Coho catch	Chum catch	Sockeye catch	Chinook CPUE	Coho CPUE	Chum CPUE	Sockeye CPUE
Hooligan Side Channel	77	21	0	78	3	0.27	0.00	1.01	0.04
Eagles Nest Side Channel	30	5	0	0	0	0.17	0.00	0.00	0.00
Kroto Slough Head	56.5	4	0	1	2	0.07	0.00	0.02	0.04
Rolly Creek Mouth	91	53	39	2	87	0.58	0.43	0.02	0.96
Bearbait Side Channel	49.4	4	0	3	0	0.08	0.00	0.06	0.00
Last Chance Side Channel	50	0	0	1	0	0.00	0.00	0.02	0.00
Rustic Wilderness Side Channel	65	55	1	11	0	0.85	0.02	0.17	0.00
Caswell Creek Mouth	74	419	245	0	21	5.66	3.31	0.00	0.28
Island Side Channel	82	39	1	74	2	0.48	0.01	0.90	0.02
Mainstem West Bank	45	7	0	0	1	0.16	0.00	0.00	0.02
Goose 2 Side Channel	82	74	1	30	2	0.90	0.01	0.37	0.02
Circular Side Channel	88	28	0	114	6	0.32	0.00	1.30	0.07
Sauna Side Channel	44	3	0	41	5	0.07	0.00	0.93	0.11
Sucker Side Channel	77.1	23	0	112	15	0.30	0.00	1.45	0.19
Beaver Dam Slough	83	14	67	0	101	0.17	0.81	0.00	1.22
Beaver Dam Side Channel	102	153	9	23	71	1.50	0.09	0.23	0.70
Sunset Side Channel	73.5	121	0	0	12	1.65	0.00	0.00	0.16
Sunrise Side Channel	73	120	1	43	8	1.64	0.01	0.59	0.11
Birch Creek Slough	96	23	71	45	29	0.24	0.74	0.47	0.30
Trapper Creek Side Channel	96	43	2	20	4	0.45	0.02	0.21	0.04
SUBTOTAL	1434.5	1209	437	598	369	0.84	0.30	0.42	0.26
Opportunistic sites	163.7	249	5	10	43	1.52	0.03	0.06	0.26
TOTAL	1598.2	1458	442	608	412	0.91	0.28	0.38	0.26

Appendix Table B-3. Lengths of RJHAB model sites in the lower Susitna River, 1984.

Site	Length (feet)
Hooligan Side Channel	1377
Eagle's Nest Side Channel	490
Kroto Slough Head	748
Rolly Creek Mouth	1437
Bearbait Side Channel	496
Last Chance Side Channel	961
Rustic Wilderness Side Channel	1169
Caswell Creek Mouth	712
Island Side Channel	769
Goose 2 Side Channel	1030
Sucker Side Channel	658
Beaver Dam Slough	436
Beaver Dam Side Channel	608
Sunrise Side Channel	1003
Birch Creek Slough	841
Trapper Creek Side Channel	968

Appendix Table B-4. Side channel flows at the 15 modelled side channels in the lower Susitna River as a function of mainstem discharge, 1984. Flows calculated from rating curves presented in Quane et al. (1985).

MAINSTEM DISCHARGE	HOOLIGAN S. C. SITE AREA	HOOLIGAN S. C. FLOW	KROTO SLOUGH HEAD SITE AREA	KROTO SLOUGH HEAD FLOW	BEARBAIT SIDE CHANNEL SITE AREA	BEARBAIT SIDE CHANNEL FLOW	LAST CHANCE S. C. SITE AREA	LAST CHANCE S. C. FLOW	RUSTIC WILDERNESS S. C. SITE AREA	RUSTIC WILDERNESS S. C. FLOW
12000	63400	0	48200	0	3100	0	17500	0	4800	0
15000	63400	0	48200	0	3100	0	17500	0	4800	0
18000	63400	0	48200	0	3100	0	17500	0	4800	0
21000	63400	0	48200	0	3100	0	17500	0	31900	54
24000	79800	50	48200	0	3100	0	20000	1	49500	76
27000	86900	72	48200	0	3100	0	22000	3	60700	103
30000	90800	100	48200	0	3100	0	27000	5	69700	134
33000	96500	135	48200	0	3100	0	34000	8	76800	171
36000	104800	178	50000	<5 a	5700	33	46500	13	83300	213
39000	113700	229	67900	74	10800	48	70000	21	89900	261
42000	122900	288	77500	98	14600	67	81000	31	97000	315
45000	131300	358	86800	128	17900	93	91000	46	104000	375
48000	141200	439	95100	163	21100	125	94000	67	109000	442
51000	152000	531	102200	206	23800	166	96300	95	114000	516
54000	163000	636	106700	255	26400	217	98500	131	117400	596
57000	174100	753	110200	314	29000	279	100200	178	119200	684
60000	186800	885	113500	381	31500	354	101800	238	120700	779
63000	200800	1032	116600	459	33900	445	103200	314	121700	b
66000	213300	1194	119000	547	36300	552	104400	408	122200	b
69000	226000	1373	120100	648	38300	b	105500	526	122700	b
72000	239000	1570	121000	761	40000	b	106300	669	123000	b
75000	250900	1785	121400	889	41500	b	107000	844	123500	b

a = Flow estimated
b = Rating curve not available
c = IFIM model rated unacceptable at this site flow
d = Modelled at flow of 6 cfs for IFIM
e = Modelled at flow of 5 cfs for IFIM
f = These flows are approximate because they are heavily influenced by Cache Creek flow

Appendix Table B-4. Continued.

MAINSTEM DISCHARGE	ISLAND SIDE CHANNEL SITE AREA	ISLAND SIDE CHANNEL FLOW	MAINSTEM WEST BANK SITE AREA	MAINSTEM WEST BANK FLOW	GOOSE 2 SIDE CHANNEL SITE AREA	GOOSE 2 SIDE CHANNEL FLOW	CIRCULAR SIDE CHANNEL SITE AREA	CIRCULAR SIDE CHANNEL FLOW	SAUNA SIDE CHANNEL SITE AREA	SAUNA SIDE CHANNEL FLOW
12000	31500	<1 d	61603	<1 d	0	0	59464	<1 d	42093	<1 e
15000	31500	<1 d	61603	<1 d	0	0	59464	<1 d	42093	<1 e
18000	31500	<1 d	61603	<1 d	0	0	59464	<1 d	42093	<1 e
21000	31500	<1 d	73426	19	0	0	59464	<1 d	42093	<1 e
24000	31500	<1 d	80904	53	0	0	59464	<1 d	42093	<1 e
27000	31500	<1 d	93353	134	0	0	59464	<1 d	42093	<1 e
30000	31500	<1 d	108613	307	9600	<5 a	59464	<1 d	42093	<1 e
33000	31500	<1 d	114738	470	21500	24	59464	<1 d	42093	<1 e
36000	39200	69	117696	559	34300	32	71590	27	42093	<1 e
39000	45300	94	120505	657	47800	41	76534	38	49127	21 c
42000	51000	126	123397	762	61400	52	80557	54	49758	25 c
45000	58500	166	129211	874	72000	65	85140	73	50289	29
48000	65500	215	133649	995	81400	81	92944	98	50889	34
51000	72000	273	136885	1123 c	87800	98	102530	129	51451	39
54000	79400	342	140761	1260 c	93200	118	113323	167	52011	44
57000	86700	424	144269	1404 c	97100	141	125753	213	52676	50
60000	93100	520	147899	1555 c	99900	166	134218	268	53294	56
63000	99800	631	151842	1715 c	102000	195	143575	334	54275	63
66000	106200	758	154205	1882 c	103200	226	150869	412 c	55184	70 c
69000	111900	904	156425	2057 c	104200	261	154657	503 c	56053	77 c
72000	118200	1070 c	158522	2241 c	104800	300	157074	610 c	57142	85 c
75000	123300	1256 c	160818	2431 c	105100	342	159211	733 c	61018	93 c

a = Flow estimated
b = Rating curve not available
c = IFIM model rated unacceptable at this site flow
d = Modelled at flow of 6 cfs for IFIM
e = Modelled at flow of 5 cfs for IFIM
f = These flows are approximate because they are heavily influenced by Cache Creek flow

Appendix Table B-4. Continued.

MAINSTEM DISCHARGE	SUCKER SIDE CHANNEL SITE AREA	SUCKER SIDE CHANNEL FLOW	BEAVER DAM SIDE CHANNEL SITE AREA	BEAVER DAM SIDE CHANNEL FLOW	SUNSET SIDE CHANNEL SITE AREA	SUNSET SIDE CHANNEL FLOW	SUNRISE SIDE CHANNEL SITE AREA	SUNRISE SIDE CHANNEL FLOW	TRAPPER CREEK S. C. SITE AREA	TRAPPER CREEK S. C. FLOW
12000	0	0	18900	<1	49562	1 e	0	0	73300	9 f
15000	0	0	18900	<1	49562	1 e	0	0	73300	12 f
18000	0	0	18900	<1	49562	1 e	0	0	73300	14 f
21000	0	0	18900	<1	49562	1 e	0	0	73300	16 f
24000	0	0	18900	<1	49562	1 e	0	0	73300	18 f
27000	0	0	18900	<1	49562	1 e	0	0	73300	20 f
30000	8500	13	18900	<1	49562	1 e	0	0	73300	22 f
33000	14900	18	18900	<1	78488	47	0	0	73300	24 f
36000	16900	24	18900	<1	89472	68	19000	19	73300	26 f
39000	19400	31	18900	<1	97943	96	53900	29	73300	28 f
42000	23600	39	18900	<1	106320	132	78500	41	73300	30 f
45000	29600	48	18900	<1	122338	178	97100	58	77600	39
48000	37100	59	22400	7	135476	235	115400	79	91200	72
51000	46600	71	28000	11	149248	305	131100	106	108100	129
54000	57900	86	32600	18	165990	390	146900	139	123300	221
57000	66900	101	35700	29	173483	492	160600	181	137700	370
60000	71300	119	38000	45	188419	614	175600	233	151200	564
63000	73900	139	39600	68	194419	757	192000	295	158000	683
66000	75900	161	40800	101	203000	925	207300	370	163100	819
69000	77300	185	41500	148	206972	1119 c	221400	459	166900	975 c
72000	78100	211	41900	213	210728	1345 c	229000	564	170700	1151 c
75000	78300	240	42100	302	215861	1603 c	233300	688	173500	1351 c

a = Flow estimated
b = Rating curve not available
c = IFIM model rated unacceptable at this site flow
d = Modelled at flow of 6 cfs for IFIM
e = Modelled at flow of 5 cfs for IFIM
f = These flows are approximate because they are heavily influenced by Cache Creek flow

Appendix Table B-5. Weighted usable areas and habitat indices for juvenile chinook salmon in lower Susitna River model sites, 1984.

ROLLY CREEK MOUTH

MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	84900	3900	0.05
15000	84900	3900	0.05
18000	84900	3900	0.05
21000	84900	3900	0.05
24000	85300	3900	0.05
27000	88300	3900	0.04
30000	93200	3900	0.04
33000	99800	4100	0.04
36000	108900	4200	0.04
39000	121000	4300	0.04
42000	135000	4400	0.03
45000	152600	4500	0.03
48000	178500	7300	0.04
51000	198800	14100	0.07
54000	213000	20100	0.09
57000	223200	23400	0.10
60000	229800	25800	0.11
63000	235000	28000	0.12
66000	238700	30000	0.13
69000	241600	31500	0.13
72000	243200	32800	0.13
75000	243600	33500	0.14

CASWELL CREEK MOUTH

MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	16200	800	0.05
15000	16200	800	0.05
18000	16200	800	0.05
21000	16200	800	0.05
24000	16200	800	0.05
27000	16300	800	0.05
30000	16700	1100	0.07
33000	17300	1600	0.09
36000	18000	2200	0.12
39000	18900	2700	0.14
42000	19800	3200	0.16
45000	21000	3700	0.18
48000	21800	4200	0.19
51000	22700	4700	0.21
54000	23700	5200	0.22
57000	24600	5700	0.23
60000	25500	6200	0.24
63000	26300	6700	0.25
66000	27200	7200	0.26
69000	27900	7600	0.27
72000	28900	8000	0.28
75000	29700	8400	0.28

BEAVER DAM SLOUGH

MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	11600	1300	0.11
15000	11600	1300	0.11
18000	11600	1300	0.11
21000	11700	1300	0.11
24000	11900	1300	0.11
27000	12200	1300	0.11
30000	12500	1300	0.10
33000	13000	1300	0.10
36000	13400	1300	0.10
39000	13900	1400	0.10
42000	14400	1500	0.10
45000	15000	1800	0.12
48000	15700	2100	0.13
51000	16300	2600	0.16
54000	16800	3000	0.18
57000	17600	3700	0.21
60000	18500	4200	0.23
63000	19700	4600	0.23
66000	20800	4800	0.23
69000	21600	5000	0.23
72000	22100	5100	0.23
75000	22600	5200	0.23

HOOLIGAN SIDE CHANNEL

MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	63400	500	0.01
15000	63400	500	0.01
18000	63400	500	0.01
21000	63400	500	0.01
24000	79800	7600	0.10
27000	86900	7200	0.08
30000	90800	6700	0.07
33000	96500	6100	0.06
36000	104800	5500	0.05
39000	113700	4900	0.04
42000	122900	4200	0.03
45000	131300	3600	0.03
48000	141200	2900	0.02
51000	152000	2200	0.01
54000	163000	2000	0.01
57000	174100	2000	0.01
60000	186800	1900	0.01
63000	200800	1800	0.01
66000	213300	1800	0.01
69000	226000	1800	0.01
72000	239000	1800	0.01
75000	250900	1800	0.01

KROTO SLOUGH HEAD

MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	48200	100	.00
15000	48200	100	.00
18000	48200	100	.00
21000	48200	100	.00
24000	48200	100	.00
27000	48200	100	.00
30000	48200	100	.00
33000	48200	100	.00
36000	50000	2000	0.04
39000	67900	4800	0.07
42000	77500	6200	0.08
45000	86800	7300	0.08
48000	95100	8100	0.09
51000	102200	7900	0.08
54000	106700	6900	0.06
57000	110200	6000	0.05
60000	113500	5100	0.04
63000	116600	4300	0.04
66000	119000	3400	0.03
69000	120100	2900	0.02
72000	121000	2500	0.02
75000	121400	2200	0.02

BEARBAIT SIDE CHANNEL

MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	3100	20	0.01
15000	3100	20	0.01
18000	3100	20	0.01
21000	3100	20	0.01
24000	3100	20	0.01
27000	3100	20	0.01
30000	3100	20	0.01
33000	3100	20	0.01
36000	5700	200	0.04
39000	10800	350	0.03
42000	14600	530	0.04
45000	17900	650	0.04
48000	21100	720	0.03
51000	23800	790	0.03
54000	26400	800	0.03
57000	29000	750	0.03
60000	31500	700	0.02
63000	33900	650	0.02
66000	36300	610	0.02
69000	38300	590	0.02
72000	40000	570	0.01
75000	41500	560	0.01

Appendix Table B-5. Continued.

LAST CHANCE S. C.

MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	17500	110	0.01
15000	17500	110	0.01
18000	17500	110	0.01
21000	17500	110	0.01
24000	20000	1200	0.06
27000	22000	1320	0.06
30000	27000	1370	0.05
33000	34000	1400	0.04
36000	46500	1420	0.03
39000	70000	1440	0.02
42000	81000	1470	0.02
45000	91000	1500	0.02
48000	94000	1610	0.02
51000	96300	2050	0.02
54000	98500	2560	0.03
57000	100200	2620	0.03
60000	101800	2540	0.02
63000	103200	2460	0.02
66000	104400	2350	0.02
69000	105500	2240	0.02
72000	106300	2100	0.02
75000	107000	1900	0.02

RUSTIC WILDERNESS S. C.

MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	4800	30	0.01
15000	4800	30	0.01
18000	4800	30	0.01
21000	31900	4800	0.15
24000	49500	5100	0.10
27000	60700	4300	0.07
30000	69700	3700	0.05
33000	76800	3000	0.04
36000	83300	2400	0.03
39000	89900	1900	0.02
42000	97000	1500	0.02
45000	104000	1200	0.01
48000	109000	900	0.01
51000	114000	700	0.01
54000	117400	500	.00
57000	119200	500	.00
60000	120700	600	.00
63000	121700	600	.00
66000	122200	600	.00
69000	122700	700	0.01
72000	123000	700	0.01
75000	123500	800	0.01

ISLAND SIDE CHANNEL

MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	31500	400	0.01
15000	31500	400	0.01
18000	31500	400	0.01
21000	31500	400	0.01
24000	31500	400	0.01
27000	31500	400	0.01
30000	31500	400	0.01
33000	31500	400	0.01
36000	39200	3500	0.09
39000	45300	4800	0.11
42000	51000	4100	0.08
45000	58500	3400	0.06
48000	65500	2900	0.04
51000	72000	2400	0.03
54000	79400	2100	0.03
57000	86700	1800	0.02
60000	93100	1700	0.02
63000	99800	1800	0.02
66000	106200	2100	0.02
69000	111900	2400	0.02
72000	118200	2600	0.02
75000	123300	2700	0.02

MAINSTEM WEST BANK

MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	61603	1082	0.02
15000	61603	1082	0.02
18000	61603	1082	0.02
21000	73426	10041	0.14
24000	80904	8325	0.10
27000	93353	5224	0.06
30000	108613	4045	0.04
33000	114738	3959	0.03
36000	117696	3861	0.03
39000	120505	3775	0.03
42000	123397	3855	0.03
45000	129211	4113	0.03
48000	133649	4630	0.03
51000	136885	5080	0.04
54000	140761	5554	0.04
57000	144269	6217	0.04
60000	147899	6728	0.05
63000	151842	7092	0.05
66000	154205	7598	0.05
69000	156425	7913	0.05
72000	158522	8078	0.05
75000	160818	8438	0.05

GOOSE 2 SIDE CHANNEL

MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	0	0	0.00
15000	0	0	0.00
18000	0	0	0.00
21000	0	0	0.00
24000	0	0	0.00
27000	0	0	0.00
30000	9600	1500	0.16
33000	21500	2900	0.13
36000	34300	4000	0.12
39000	47800	5100	0.11
42000	61400	6100	0.10
45000	72000	6900	0.10
48000	81400	7000	0.09
51000	87800	6700	0.08
54000	93200	6000	0.06
57000	97100	4600	0.05
60000	99900	3100	0.03
63000	102000	2700	0.03
66000	103200	2400	0.02
69000	104200	2100	0.02
72000	104800	1800	0.02
75000	105100	1600	0.02

CIRCULAR SIDE CHANNEL

MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	59464	747	0.01
15000	59464	747	0.01
18000	59464	747	0.01
21000	59464	747	0.01
24000	59464	747	0.01
27000	59464	747	0.01
30000	59464	747	0.01
33000	59464	747	0.01
36000	71590	8717	0.12
39000	76534	8404	0.11
42000	80557	8013	0.10
45000	85140	7472	0.09
48000	92944	7077	0.08
51000	102530	6998	0.07
54000	113323	6999	0.06
57000	125753	6634	0.05
60000	134218	6516	0.05
63000	143575	6906	0.05
66000	150869	7926	0.05
69000	154657	8561	0.06
72000	157074	8840	0.06
75000	159211	8854	0.06

Appendix Table B-5. Continued.

SAUNA SIDE CHANNEL

MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	42093	165	.00
15000	42093	165	.00
18000	42093	165	.00
21000	42093	165	.00
24000	42093	165	.00
27000	42093	165	.00
30000	42093	165	.00
33000	42093	165	.00
36000	42093	165	.00
39000	49127	5759	0.12
42000	49758	5740	0.12
45000	50289	5503	0.11
48000	50889	4980	0.10
51000	51451	4470	0.09
54000	52011	4046	0.08
57000	52678	3645	0.07
60000	53294	3365	0.06
63000	54275	3116	0.06
66000	55184	2947	0.05
69000	56053	2757	0.05
72000	57142	2678	0.05
75000	61018	2714	0.04

SUCKER SIDE CHANNEL

MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	0	0	0.00
15000	0	0	0.00
18000	0	0	0.00
21000	0	0	0.00
24000	0	0	0.00
27000	0	0	ERR
30000	8500	1060	0.12
33000	14900	1600	0.11
36000	16900	1570	0.09
39000	19400	1510	0.08
42000	23600	1450	0.06
45000	29600	1550	0.05
48000	37100	2070	0.06
51000	46600	2940	0.06
54000	57900	4230	0.07
57000	66900	4680	0.07
60000	71300	4490	0.06
63000	73900	4230	0.06
66000	75900	3940	0.05
69000	77300	3610	0.05
72000	78100	3270	0.04
75000	78300	3010	0.04

BEAVER DAM SIDE CHANNEL

MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	18900	50	.00
15000	18900	50	.00
18000	18900	50	.00
21000	18900	50	.00
24000	18900	50	.00
27000	18900	50	.00
30000	18900	50	.00
33000	18900	50	.00
36000	18900	50	.00
39000	18900	50	.00
42000	18900	50	.00
45000	18900	50	.00
48000	22400	820	0.04
51000	28000	2370	0.08
54000	32600	3560	0.11
57000	35700	3840	0.11
60000	38000	3570	0.09
63000	39600	3060	0.08
66000	40800	2510	0.06
69000	41500	2260	0.05
72000	41900	2100	0.05
75000	42100	2000	0.05

SUNSET SIDE CHANNEL

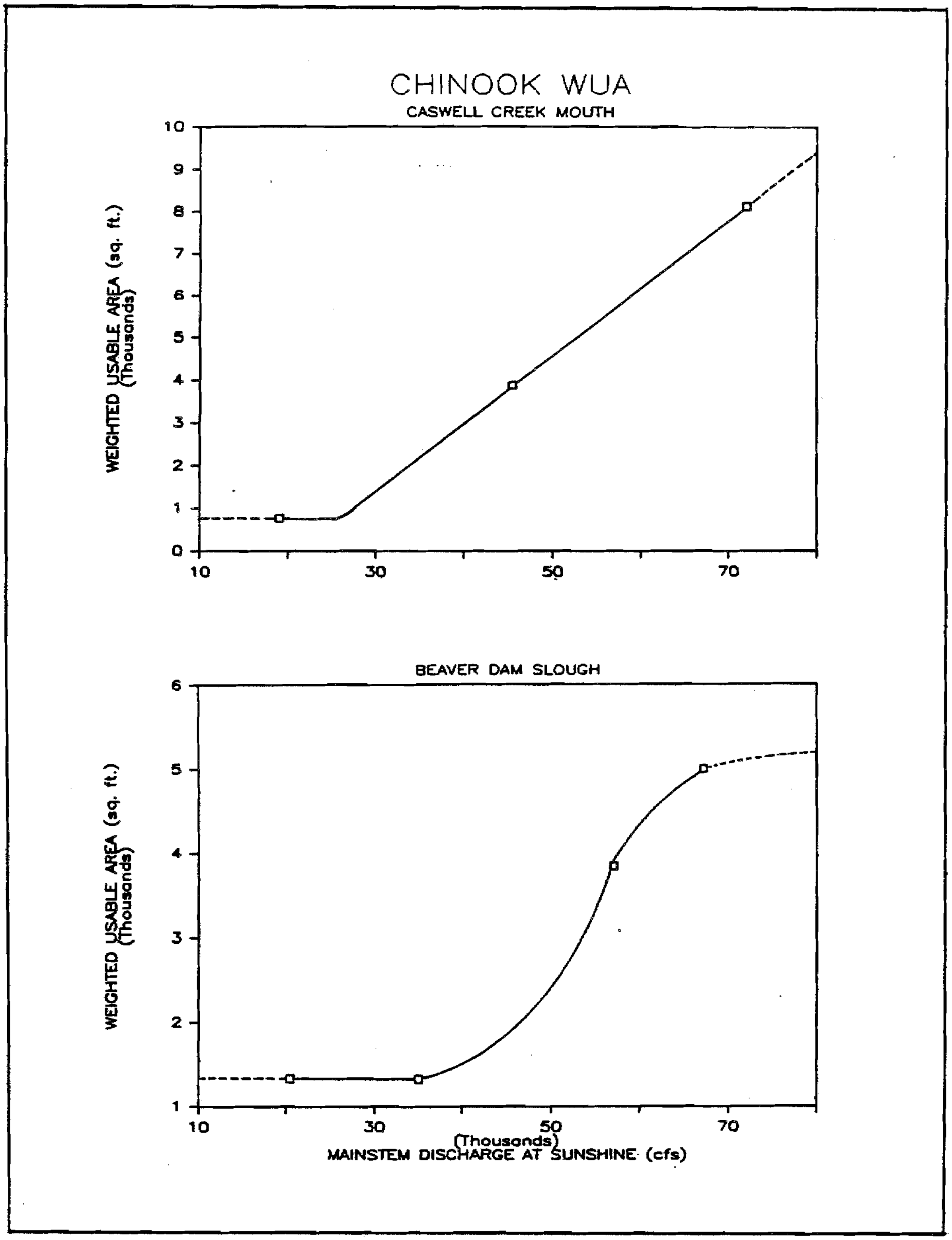
MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	49562	568	0.01
15000	49562	568	0.01
18000	49562	568	0.01
21000	49562	568	0.01
24000	49562	568	0.01
27000	49562	568	0.01
30000	49562	568	0.01
33000	78488	4378	0.06
36000	89472	4420	0.05
39000	97943	4630	0.05
42000	106320	4984	0.05
45000	122338	5436	0.04
48000	135476	5846	0.04
51000	149248	5868	0.04
54000	165990	5768	0.03
57000	173483	5487	0.03
60000	188419	5931	0.03
63000	194419	6000	0.03
66000	203000	6231	0.03
69000	206972	6263	0.03
72000	210728	6157	0.03
75000	215861	5848	0.03

SUNRISE SIDE CHANNEL

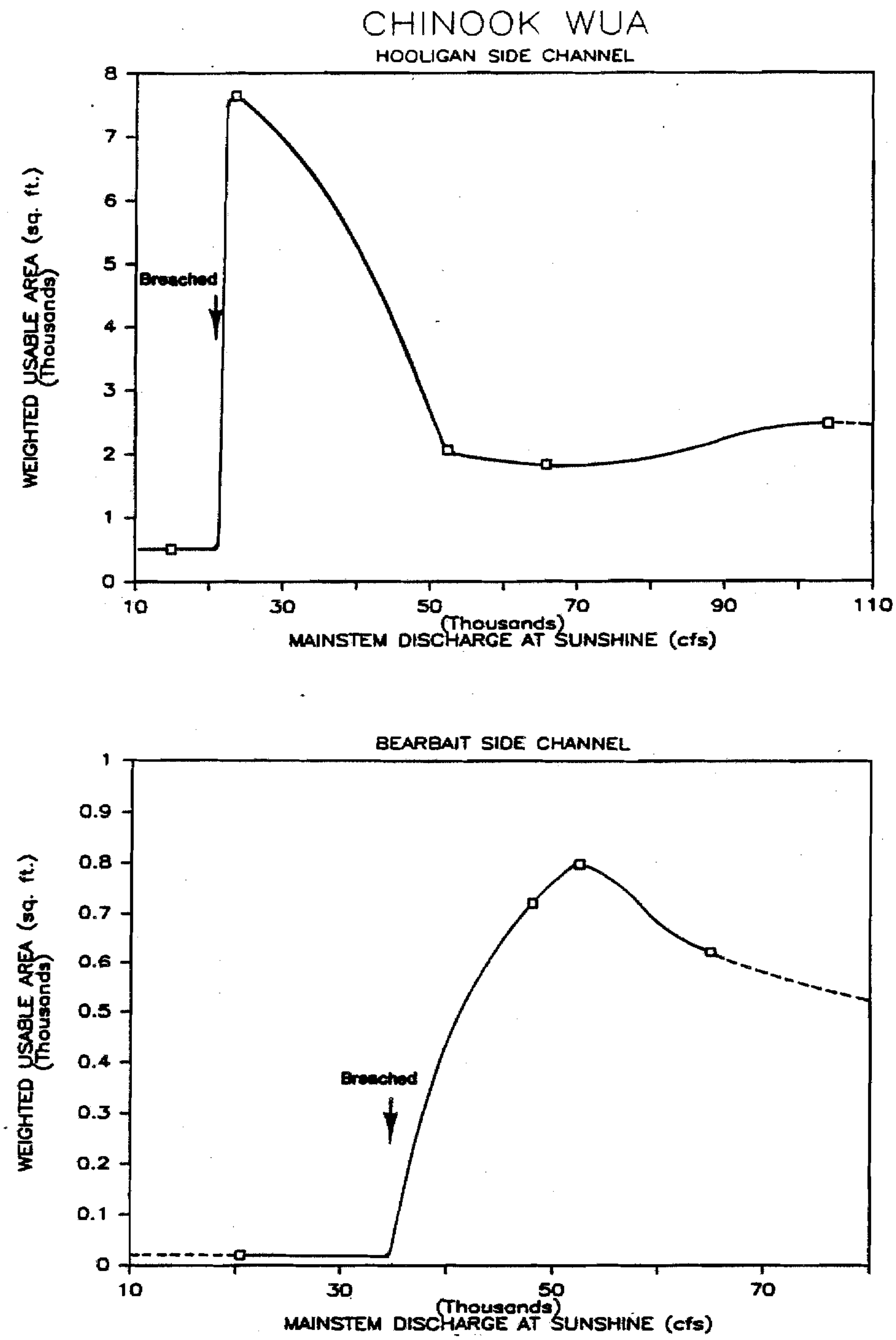
MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	0	0	0.00
15000	0	0	0.00
18000	0	0	0.00
21000	0	0	0.00
24000	0	0	0.00
27000	0	0	0.00
30000	0	0	0.00
33000	0	0	0.00
36000	19000	610	0.03
39000	53900	3250	0.06
42000	78500	5660	0.07
45000	97100	6090	0.06
48000	115400	4270	0.04
51000	131100	3820	0.03
54000	146900	3540	0.02
57000	160600	3250	0.02
60000	175600	3180	0.02
63000	192000	3460	0.02
66000	207300	3760	0.02
69000	221400	4080	0.02
72000	229000	4190	0.02
75000	233300	4210	0.02

TRAPPER CREEK S. C.

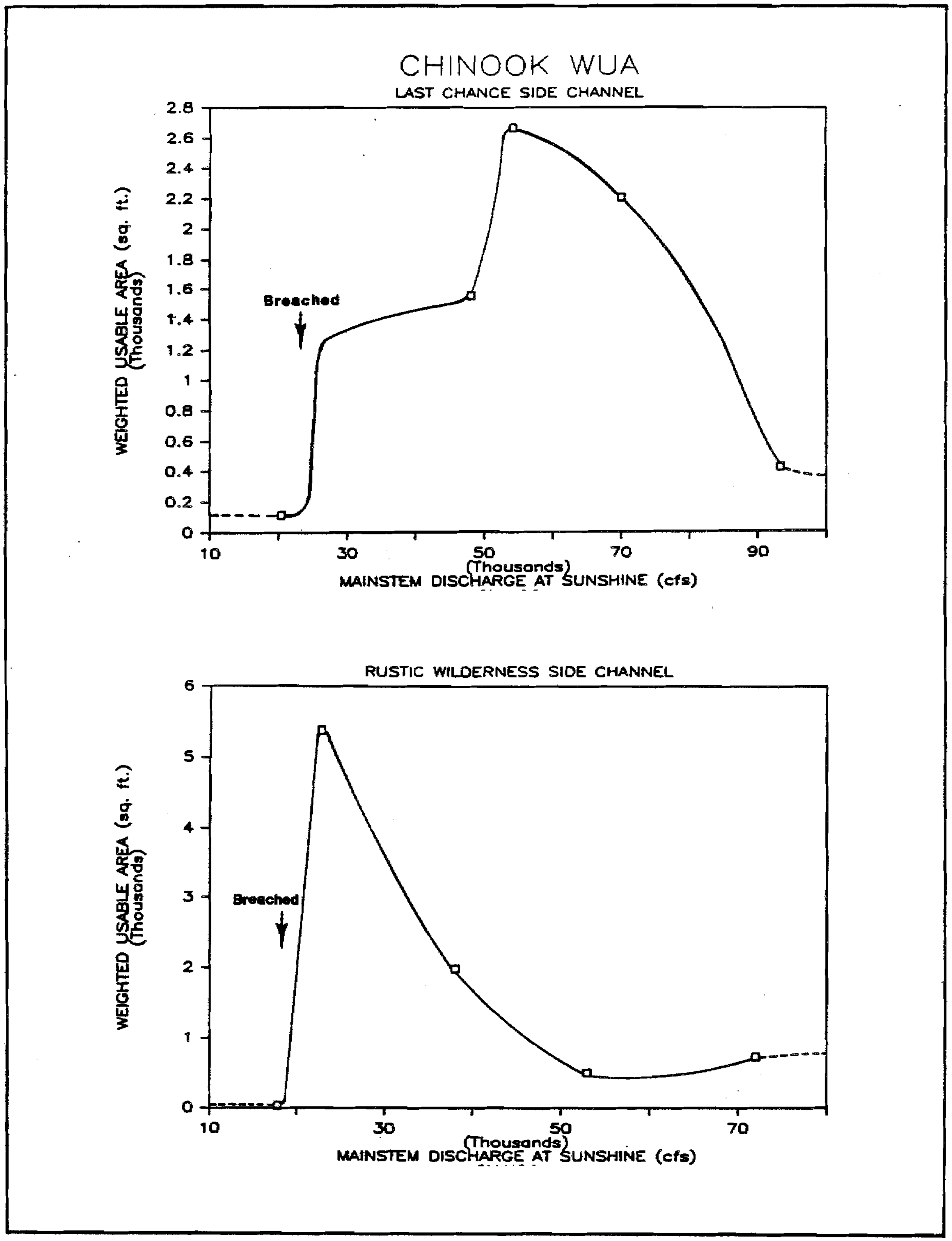
MAINSTEM DISCHARGE	SITE AREA	CHINOOK WUA	CHINOOK H. I.
12000	73300	1100	0.02
15000	73300	1100	0.02
18000	73300	1100	0.02
21000	73300	1100	0.02
24000	73300	1100	0.02
27000	73300	1100	0.02
30000	73300	1100	0.02
33000	73300	1100	0.02
36000	73300	1100	0.02
39000	73300	1100	0.02
42000	73300	1100	0.02
45000	77600	9300	0.12
48000	91200	9000	0.10
51000	108100	7500	0.07
54000	123300	5600	0.05
57000	137700	2900	0.02
60000	151200	1300	0.01
63000	158000	1330	0.01
66000	163100	1360	0.01
69000	166900	1390	0.01
72000	170700	1400	0.01
75000	173500	1400	0.01



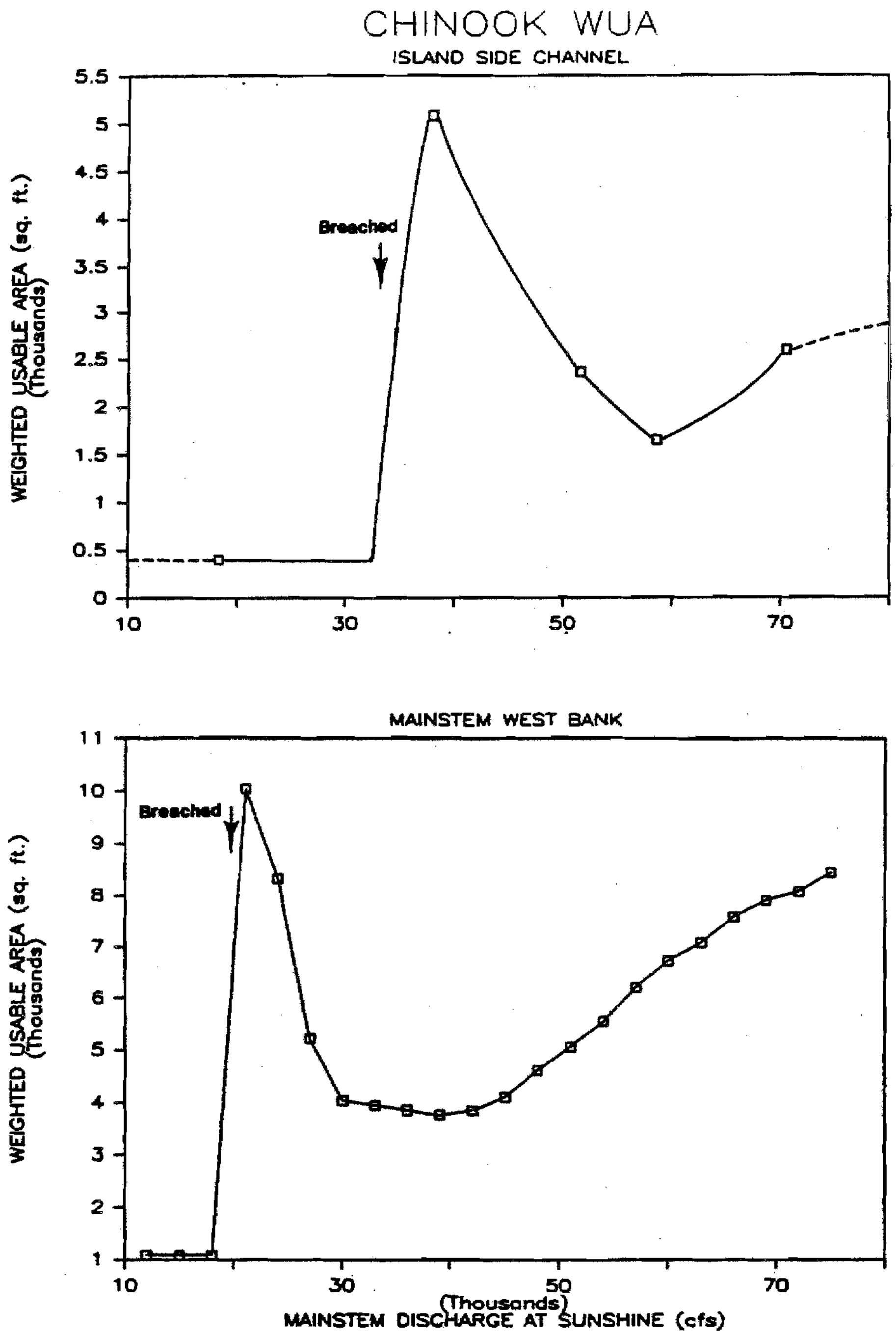
Appendix Figure B-1. Weighted usable area for juvenile chinook salmon at Caswell Creek and Beaver Dam tributary study sites as a function of mainstem discharge.



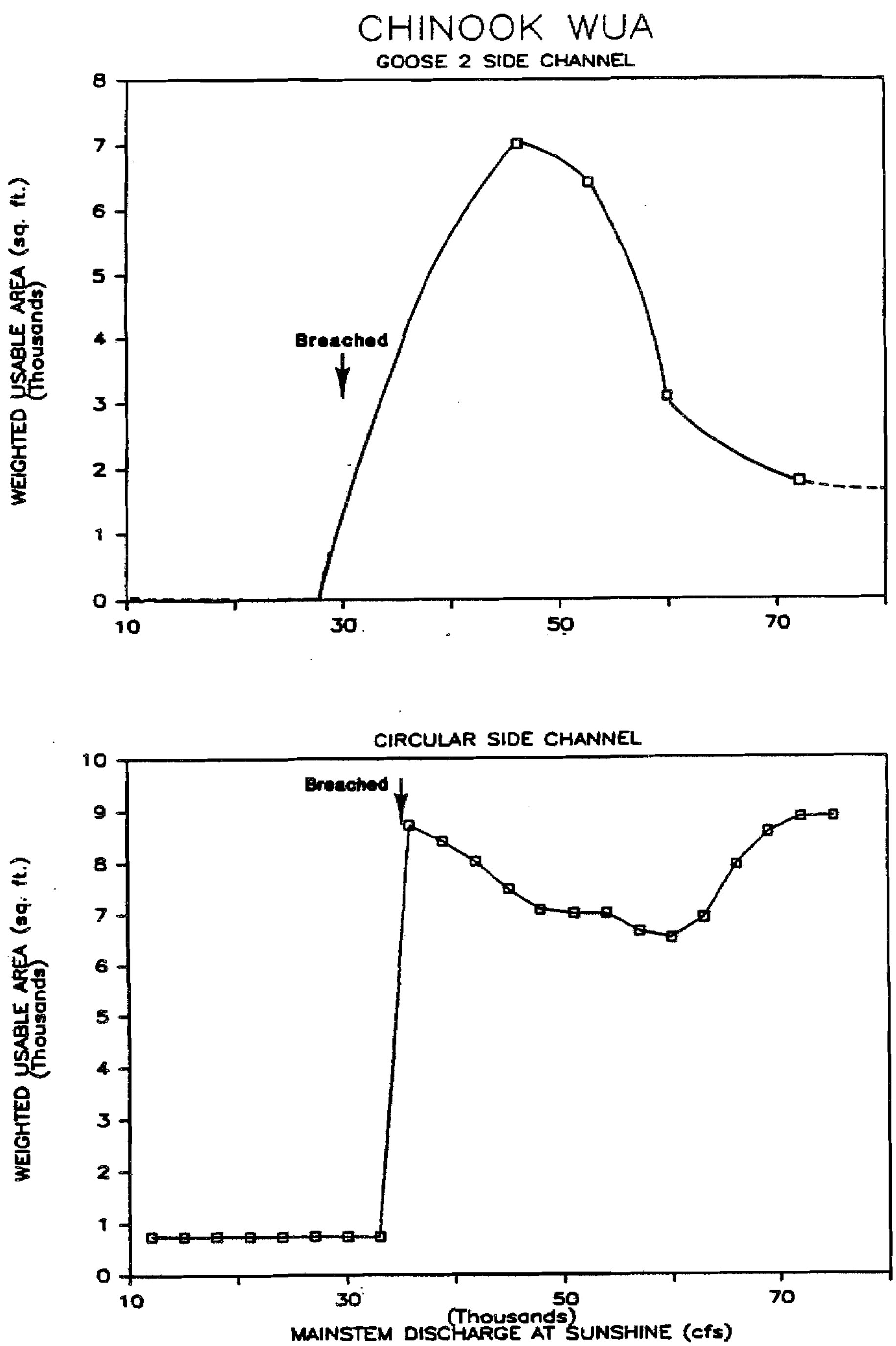
Appendix Figure B-2. Weighted usable area for juvenile chinook salmon at the Hooligan and Bearbait Side Channel study sites as a function of mainstem discharge.



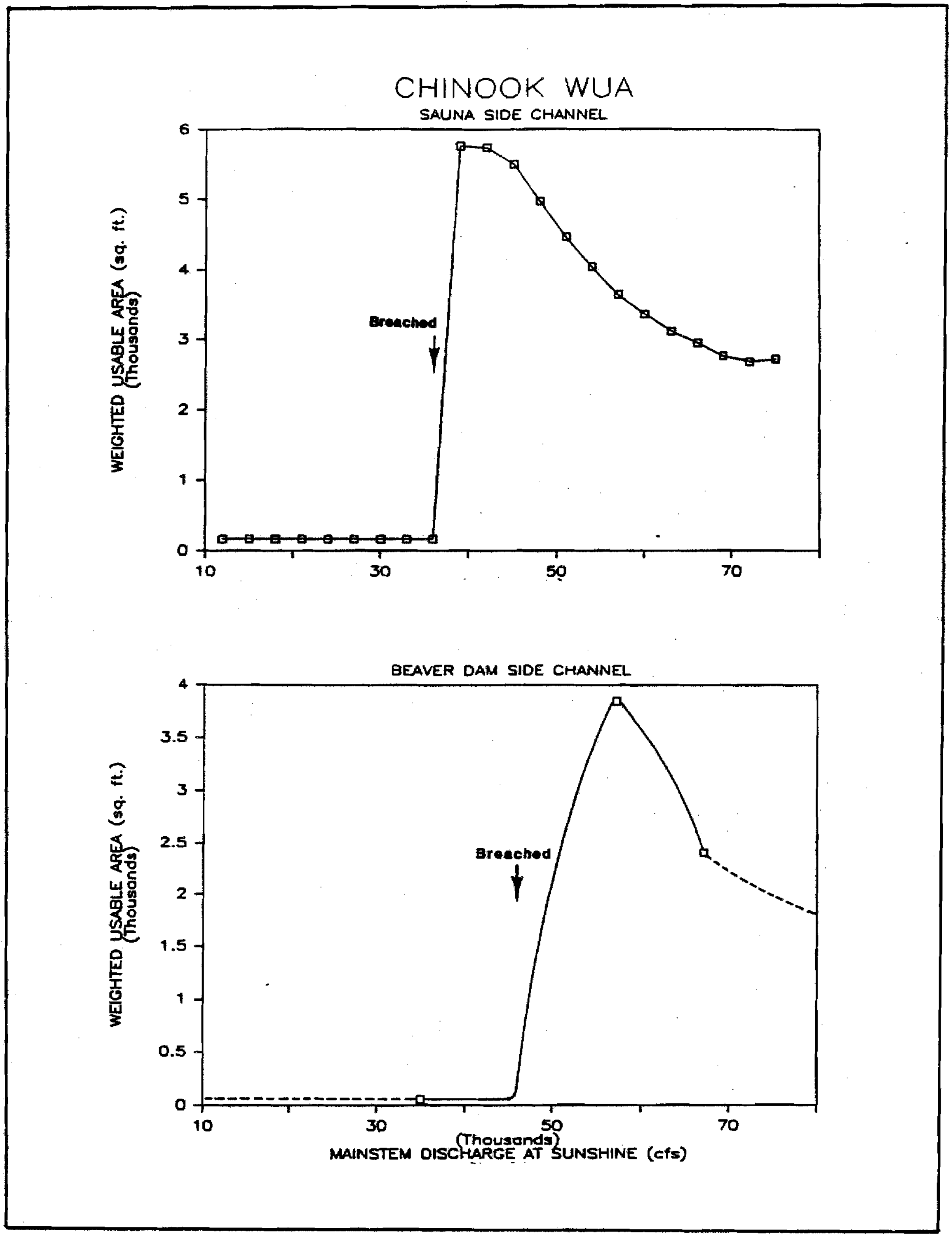
Appendix Figure B-3. Weighted usable area for juvenile chinook salmon at Last Chance and Rustic Wilderness Side Channel study sites as a function of mainstem discharge.



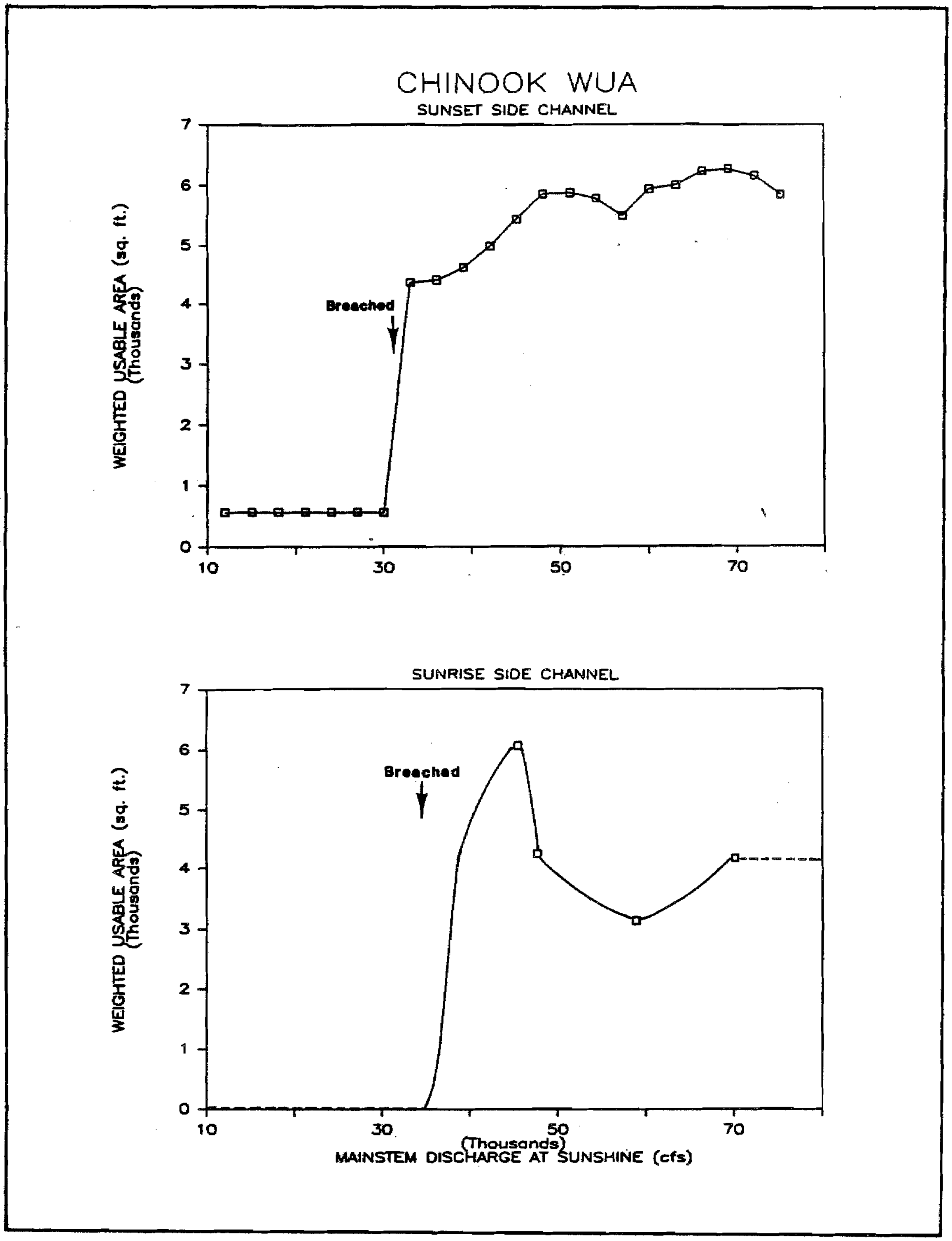
Appendix Figure B-4. Weighted usable area for juvenile chinook salmon at the Island Channel and Mainstem West Bank study sites as a function of mainstem discharge.



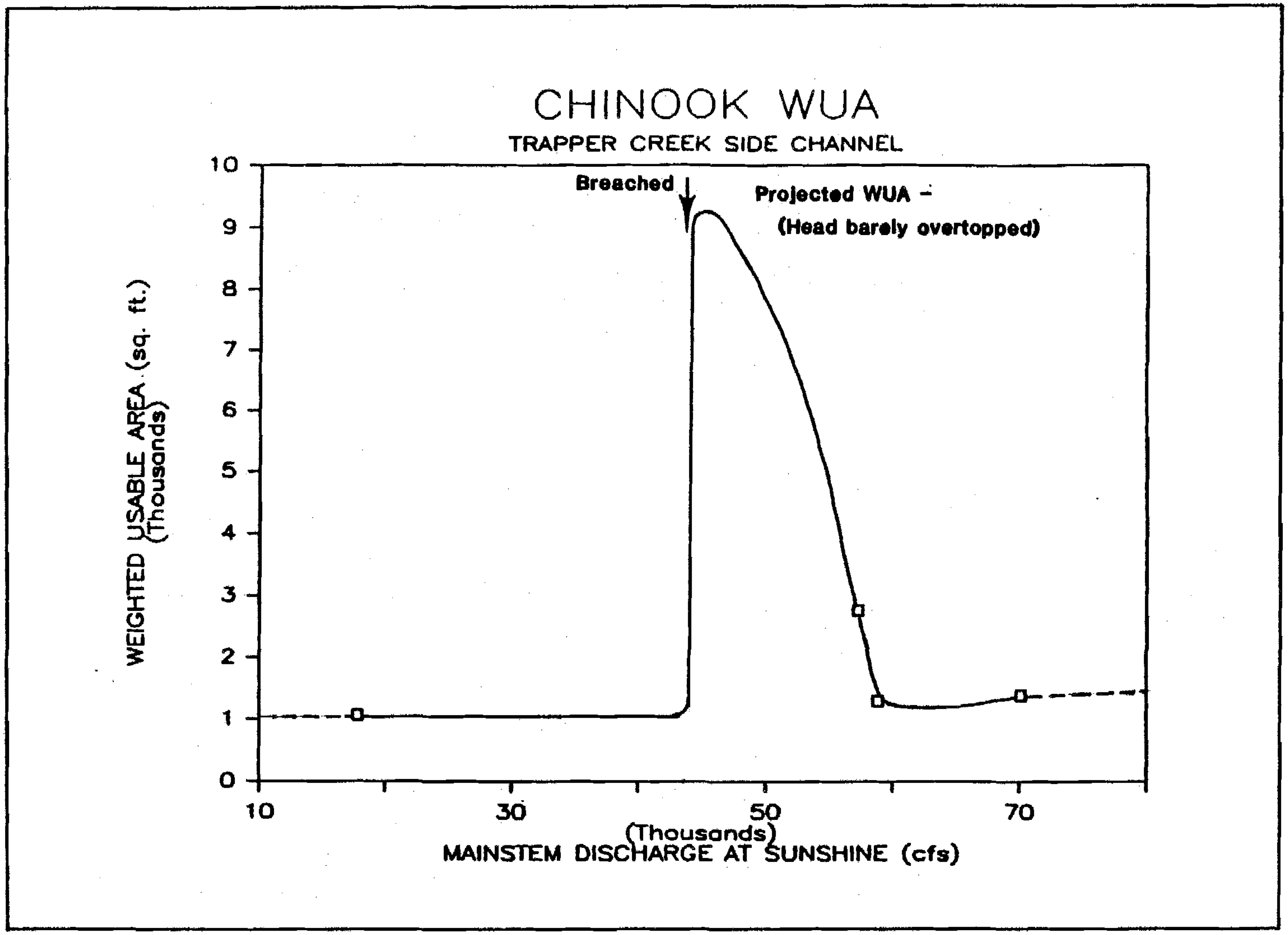
Appendix Figure B-5. Weighted usable area for juvenile chinook salmon at the Goose 2 and Circular Side Channel study sites as a function of mainstem discharge.



Appendix Figure B-6. Weighted usable area for juvenile chinook salmon at the Sauna and Beaver Dam Side Channel study sites as a function of mainstem discharge.



Appendix Figure B-7. Weighted usable area for juvenile chinook salmon at the Sunset and Sunrise Side Channel study sites as a function of mainstem discharge.



Appendix Figure B-8. Weighted usable area for juvenile chinook salmon at the Trapper Creek Side Channel study site as a function of mainstem discharge.

Appendix Table B-6. Weighted usable areas and habitat indices for juvenile coho salmon in lower Susitna River model sites, 1984.

ROLLY CREEK MOUTH				CASWELL CREEK MOUTH				BEAVER DAM SLOUGH			
MAINSTEM DISCHARGE	SITE AREA	COHO WUA	COHO H. I.	MAINSTEM DISCHARGE	SITE AREA	COHO WUA	COHO H. I.	MAINSTEM DISCHARGE	SITE AREA	COHO WUA	COHO H. I.
12000	84900	7900	0.09	12000	16200	1350	0.08	12000	11600	1700	0.15
15000	84900	7900	0.09	15000	16200	1350	0.08	15000	11600	1700	0.15
18000	84900	7900	0.09	18000	16200	1350	0.08	18000	11600	1700	0.15
21000	84900	7900	0.09	21000	16200	1350	0.08	21000	11700	1700	0.15
24000	85300	7900	0.09	24000	16200	1350	0.08	24000	11900	1700	0.14
27000	88300	7700	0.09	27000	16300	1500	0.09	27000	12200	1700	0.14
30000	93200	7500	0.08	30000	16700	1700	0.10	30000	12500	1700	0.14
33000	99800	7100	0.07	33000	17300	2000	0.12	33000	13000	1700	0.13
36000	108900	6800	0.06	36000	18000	2300	0.13	36000	13400	1700	0.13
39000	121000	6400	0.05	39000	18900	2500	0.13	39000	13900	1700	0.12
42000	135000	5900	0.04	42000	19800	2800	0.14	42000	14400	1670	0.12
45000	152600	5500	0.04	45000	21000	3000	0.14	45000	15000	1650	0.11
48000	178500	5600	0.03	48000	21800	3200	0.15	48000	15700	1610	0.10
51000	198800	7300	0.04	51000	22700	3400	0.15	51000	16300	1540	0.09
54000	213000	9200	0.04	54000	23700	3600	0.15	54000	16800	1480	0.09
57000	223200	10100	0.05	57000	24600	3800	0.15	57000	17600	1430	0.08
60000	229800	10700	0.05	60000	25500	4000	0.16	60000	18500	1480	0.08
63000	235000	11200	0.05	63000	26300	4300	0.16	63000	19700	1540	0.08
66000	238700	11700	0.05	66000	27200	4400	0.16	66000	20800	1630	0.08
69000	241600	12000	0.05	69000	27900	4700	0.17	69000	21600	1740	0.08
72000	243200	12300	0.05	72000	28900	4900	0.17	72000	22100	1780	0.08
75000	243600	12500	0.05	75000	29700	5100	0.17	75000	22600	1810	0.08

Appendix Table B-7. Weighted usable areas and habitat indices for juvenile chum salmon in lower Susitna River model sites, 1984.

HOOLIGAN SIDE CHANNEL				KROTO SLOUGH HEAD				BEARBAIT SIDE CHANNEL			
MAINSTEM DISCHARGE	SITE AREA	CHUM WUA	CHUM H. I.	MAINSTEM DISCHARGE	SITE AREA	CHUM WUA	CHUM H. I.	MAINSTEM DISCHARGE	SITE AREA	CHUM WUA	CHUM H. I.
12000	63400	28500	0.45	12000	48200	39600	0.82	12000	3100	1300	0.42
15000	63400	28500	0.45	15000	48200	39600	0.82	15000	3100	1300	0.42
18000	63400	28500	0.45	18000	48200	39600	0.82	18000	3100	1300	0.42
21000	63400	28500	0.45	21000	48200	39600	0.82	21000	3100	1300	0.42
24000	79800	47900	0.60	24000	48200	39600	0.82	24000	3100	1300	0.42
27000	86900	46700	0.54	27000	48200	39600	0.82	27000	3100	1300	0.42
30000	90800	44000	0.48	30000	48200	39600	0.82	30000	3100	1300	0.42
33000	96500	41700	0.43	33000	48200	39600	0.82	33000	3100	1300	0.42
36000	104800	38400	0.37	36000	50000	39600	0.79	36000	5700	1400	0.25
39000	113700	34700	0.31	39000	67900	42000	0.62	39000	10800	1900	0.18
42000	122900	30300	0.25	42000	77500	44500	0.57	42000	14600	2600	0.18
45000	131300	26100	0.20	45000	86800	46100	0.53	45000	17900	3300	0.18
48000	141200	21900	0.16	48000	95100	47600	0.50	48000	21100	4100	0.19
51000	152000	18900	0.12	51000	102200	46500	0.45	51000	23800	5300	0.22
54000	163000	18100	0.11	54000	106700	42300	0.40	54000	26400	5700	0.22
57000	174100	17600	0.10	57000	110200	38300	0.35	57000	29000	5500	0.19
60000	186800	17200	0.09	60000	113500	34400	0.30	60000	31500	5100	0.16
63000	200800	16900	0.08	63000	116600	29700	0.25	63000	33900	4700	0.14
66000	213300	16700	0.08	66000	119000	24100	0.20	66000	36300	4400	0.12
69000	226000	16400	0.07	69000	120100	19800	0.16	69000	38300	4200	0.11
72000	239000	16100	0.07	72000	121000	17800	0.15	72000	40000	4100	0.10
75000	250900	15800	0.06	75000	121400	15200	0.13	75000	41500	4000	0.10

Appendix Table B-7. Continued.

LAST CHANCE S. C.

MAINSTEM DISCHARGE	SITE AREA	CHUM WUA	CHUM H. I.
12000	17500	11500	0.66
15000	17500	11500	0.66
18000	17500	11500	0.66
21000	17500	11500	0.66
24000	20000	11500	0.58
27000	22000	11500	0.52
30000	27000	11500	0.43
33000	34000	11500	0.34
36000	46500	11500	0.25
39000	70000	11500	0.16
42000	81000	11500	0.14
45000	91000	11500	0.13
48000	94000	11700	0.12
51000	96300	15100	0.16
54000	98500	20200	0.21
57000	100200	19500	0.19
60000	101800	18000	0.18
63000	103200	16200	0.16
66000	104400	13600	0.13
69000	105500	10500	0.10
72000	106300	8800	0.08
75000	107000	7600	0.07

RUSTIC WILDERNESS S. C.

MAINSTEM DISCHARGE	SITE AREA	CHUM WUA	CHUM H. I.
12000	4800	3600	0.75
15000	4800	3600	0.75
18000	4800	3600	0.75
21000	31900	30800	0.97
24000	49500	32500	0.66
27000	60700	27600	0.45
30000	69700	22700	0.33
33000	76800	18100	0.24
36000	83300	13700	0.16
39000	89900	10600	0.12
42000	97000	8800	0.09
45000	104000	7400	0.07
48000	109000	5800	0.05
51000	114000	4200	0.04
54000	117400	3300	0.03
57000	119200	3000	0.03
60000	120700	3000	0.02
63000	121700	3000	0.02
66000	122200	3000	0.02
69000	122700	3000	0.02
72000	123000	3000	0.02
75000	123500	3000	0.02

ISLAND SIDE CHANNEL

MAINSTEM DISCHARGE	SITE AREA	CHUM WUA	CHUM H. I.
12000	31500	19300	0.61
15000	31500	19300	0.61
18000	31500	19300	0.61
21000	31500	19300	0.61
24000	31500	19300	0.61
27000	31500	19300	0.61
30000	31500	19300	0.61
33000	31500	19300	0.61
36000	39200	28100	0.72
39000	45300	28800	0.64
42000	51000	25800	0.51
45000	58500	22700	0.39
48000	65500	19700	0.30
51000	72000	17400	0.24
54000	79400	15100	0.19
57000	86700	13200	0.15
60000	93100	12400	0.13
63000	99800	12700	0.13
66000	106200	13000	0.12
69000	111900	13300	0.12
72000	118200	13600	0.12
75000	123300	13600	0.11

MAINSTEM WEST BANK

MAINSTEM DISCHARGE	SITE AREA	CHUM WUA	CHUM H. I.
12000	61603	47090	0.76
15000	61603	47090	0.76
18000	61603	47090	0.76
21000	73426	53955	0.73
24000	80904	43289	0.54
27000	93353	31606	0.34
30000	108613	27151	0.25
33000	114738	23420	0.20
36000	117696	21782	0.19
39000	120505	21096	0.18
42000	123397	21218	0.17
45000	129211	22389	0.17
48000	133649	26770	0.20
51000	136885	27661	0.20
54000	140761	30382	0.22
57000	144269	31815	0.22
60000	147899	33950	0.23
63000	151842	35953	0.24
66000	154205	36489	0.24
69000	156425	36211	0.23
72000	158522	37029	0.23
75000	160818	36809	0.23

GOOSE 2 SIDE CHANNEL

MAINSTEM DISCHARGE	SITE AREA	CHUM WUA	CHUM H. I.
12000	0	0	0.00
15000	0	0	0.00
18000	0	0	0.00
21000	0	0	0.00
24000	0	0	0.00
27000	0	0	0.00
30000	9600	4900	0.51
33000	21500	11000	0.51
36000	34300	17400	0.51
39000	47800	25500	0.53
42000	61400	31800	0.52
45000	72000	37900	0.53
48000	81400	41600	0.51
51000	87800	42600	0.49
54000	93200	40700	0.44
57000	97100	33400	0.34
60000	99900	24000	0.24
63000	102000	18600	0.18
66000	103200	13800	0.13
69000	104200	10400	0.10
72000	104800	8300	0.08
75000	105100	7400	0.07

CIRCULAR SIDE CHANNEL

MAINSTEM DISCHARGE	SITE AREA	CHUM WUA	CHUM H. I.
12000	59464	46109	0.78
15000	59464	46109	0.78
18000	59464	46109	0.78
21000	59464	46109	0.78
24000	59464	46109	0.78
27000	59464	46109	0.78
30000	59464	46109	0.78
33000	59464	46109	0.78
36000	71590	44495	0.62
39000	76534	44606	0.58
42000	80557	42269	0.52
45000	85140	42176	0.50
48000	92944	43074	0.46
51000	102530	45026	0.44
54000	113323	50073	0.44
57000	125753	50248	0.40
60000	134218	46305	0.34
63000	143575	49339	0.34
66000	150869	49565	0.33
69000	154657	50346	0.33
72000	157074	48491	0.31
75000	159211	46797	0.29

Appendix Table B-7. Continued.

SAUNA SIDE CHANNEL

MAINSTEM DISCHARGE	SITE AREA	CHUM WUA	CHUM H. I.
12000	42093	31754	0.75
15000	42093	31754	0.75
18000	42093	31754	0.75
21000	42093	31754	0.75
24000	42093	31754	0.75
27000	42093	31754	0.75
30000	42093	31754	0.75
33000	42093	31754	0.75
36000	42093	31754	0.75
39000	49127	27307	0.56
42000	49758	26413	0.53
45000	50289	25204	0.50
48000	50889	23670	0.47
51000	51451	22565	0.44
54000	52011	21836	0.42
57000	52678	21381	0.41
60000	53294	20990	0.39
63000	54275	20669	0.38
66000	55184	20938	0.38
69000	56053	21017	0.37
72000	57142	21153	0.37
75000	61018	23075	0.38

SUCKER SIDE CHANNEL

MAINSTEM DISCHARGE	SITE AREA	CHUM WUA	CHUM H. I.
12000	0	0	0.00
15000	0	0	0.00
18000	0	0	0.00
21000	0	0	0.00
24000	0	0	0.00
27000	0	0	ERR
30000	8500	7300	0.86
33000	14900	11800	0.79
36000	16900	12700	0.75
39000	19400	13200	0.68
42000	23600	13400	0.57
45000	29600	14300	0.48
48000	37100	19900	0.54
51000	46600	27700	0.59
54000	57900	33700	0.58
57000	66900	34400	0.51
60000	71300	32900	0.46
63000	73900	30800	0.42
66000	75900	28200	0.37
69000	77300	25000	0.32
72000	78100	21800	0.28
75000	78300	19200	0.25

BEAVER DAM SIDE CHANNEL

MAINSTEM DISCHARGE	SITE AREA	CHUM WUA	CHUM H. I.
12000	18900	11900	0.63
15000	18900	11900	0.63
18000	18900	11900	0.63
21000	18900	11900	0.63
24000	18900	11900	0.63
27000	18900	11900	0.63
30000	18900	11900	0.63
33000	18900	11900	0.63
36000	18900	11900	0.63
39000	18900	11900	0.63
42000	18900	11900	0.63
45000	18900	11900	0.63
48000	22400	13200	0.59
51000	28000	15700	0.56
54000	32600	17500	0.54
57000	35700	18800	0.53
60000	38000	18200	0.48
63000	39600	16400	0.41
66000	40800	14000	0.34
69000	41500	12100	0.29
72000	41900	11300	0.27
75000	42100	10700	0.25

SUNSET SIDE CHANNEL

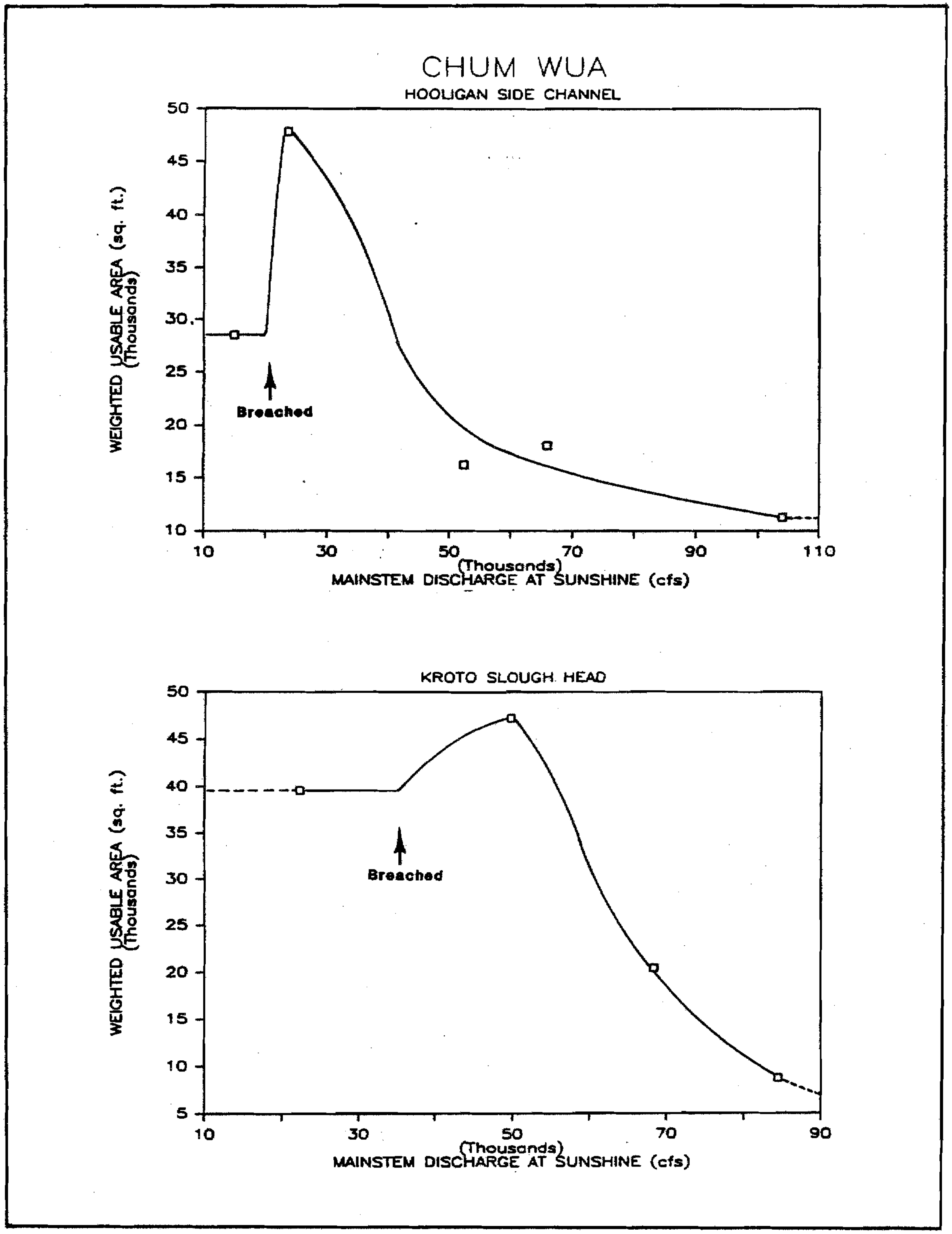
MAINSTEM DISCHARGE	SITE AREA	CHUM WUA	CHUM H. I.
12000	49562	27135	0.55
15000	49562	27135	0.55
18000	49562	27135	0.55
21000	49562	27135	0.55
24000	49562	27135	0.55
27000	49562	27135	0.55
30000	49562	27135	0.55
33000	78488	34059	0.43
36000	89472	34808	0.39
39000	97943	37649	0.38
42000	106320	39888	0.38
45000	122338	46376	0.38
48000	135476	51185	0.38
51000	149248	52671	0.35
54000	165990	53786	0.32
57000	173483	48410	0.28
60000	188419	50093	0.27
63000	194419	43299	0.22
66000	203000	41715	0.21
69000	206972	37100	0.18
72000	210728	33481	0.16
75000	215861	32949	0.15

SUNRISE SIDE CHANNEL

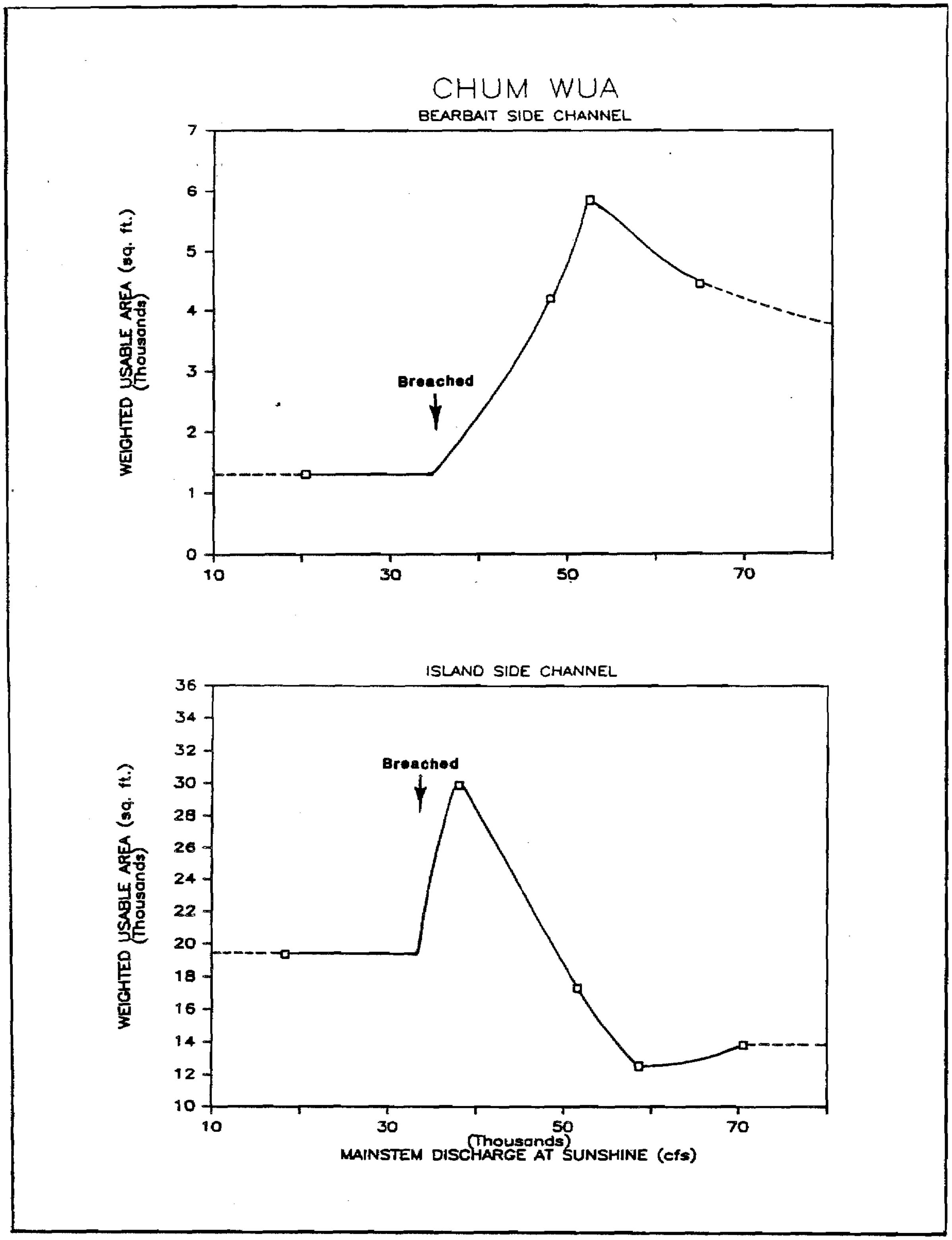
MAINSTEM DISCHARGE	SITE AREA	CHUM WUA	CHUM H. I.
12000	0	0	0.00
15000	0	0	0.00
18000	0	0	0.00
21000	0	0	0.00
24000	0	0	0.00
27000	0	0	0.00
30000	0	0	0.00
33000	0	0	0.00
36000	19000	6200	0.33
39000	53900	32400	0.60
42000	78500	46400	0.59
45000	97100	49700	0.51
48000	115400	44500	0.39
51000	131100	37500	0.29
54000	146900	31100	0.21
57000	160600	26600	0.17
60000	175600	25200	0.14
63000	192000	25300	0.13
66000	207300	26200	0.13
69000	221400	27700	0.13
72000	229000	28500	0.12
75000	233300	29000	0.12

TRAPPER CREEK S. C.

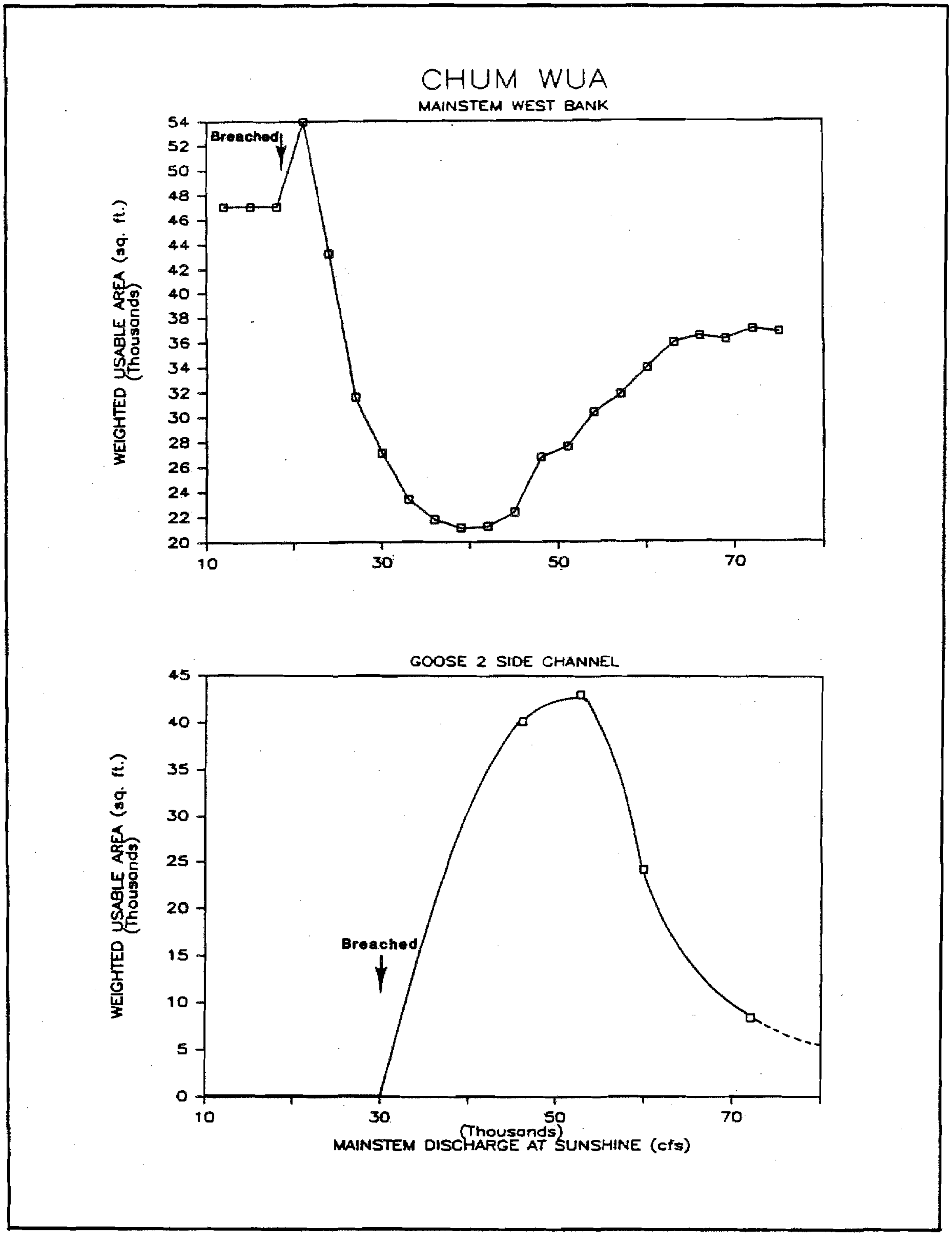
MAINSTEM DISCHARGE	SITE AREA	CHUM WUA	CHUM H. I.
12000	73300	45400	0.62
15000	73300	45400	0.62
18000	73300	45400	0.62
21000	73300	45400	0.62
24000	73300	45400	0.62
27000	73300	45400	0.62
30000	73300	45400	0.62
33000	73300	45400	0.62
36000	73300	45400	0.62
39000	73300	45400	0.62
42000	73300	45400	0.62
45000	77600	44800	0.58
48000	91200	41200	0.45
51000	108100	34600	0.32
54000	123300	27500	0.22
57000	137700	19500	0.14
60000	151200	10700	0.07
63000	158000	10200	0.06
66000	163100	10000	0.06
69000	166900	9800	0.06
72000	170700	9600	0.06
75000	173500	9500	0.05



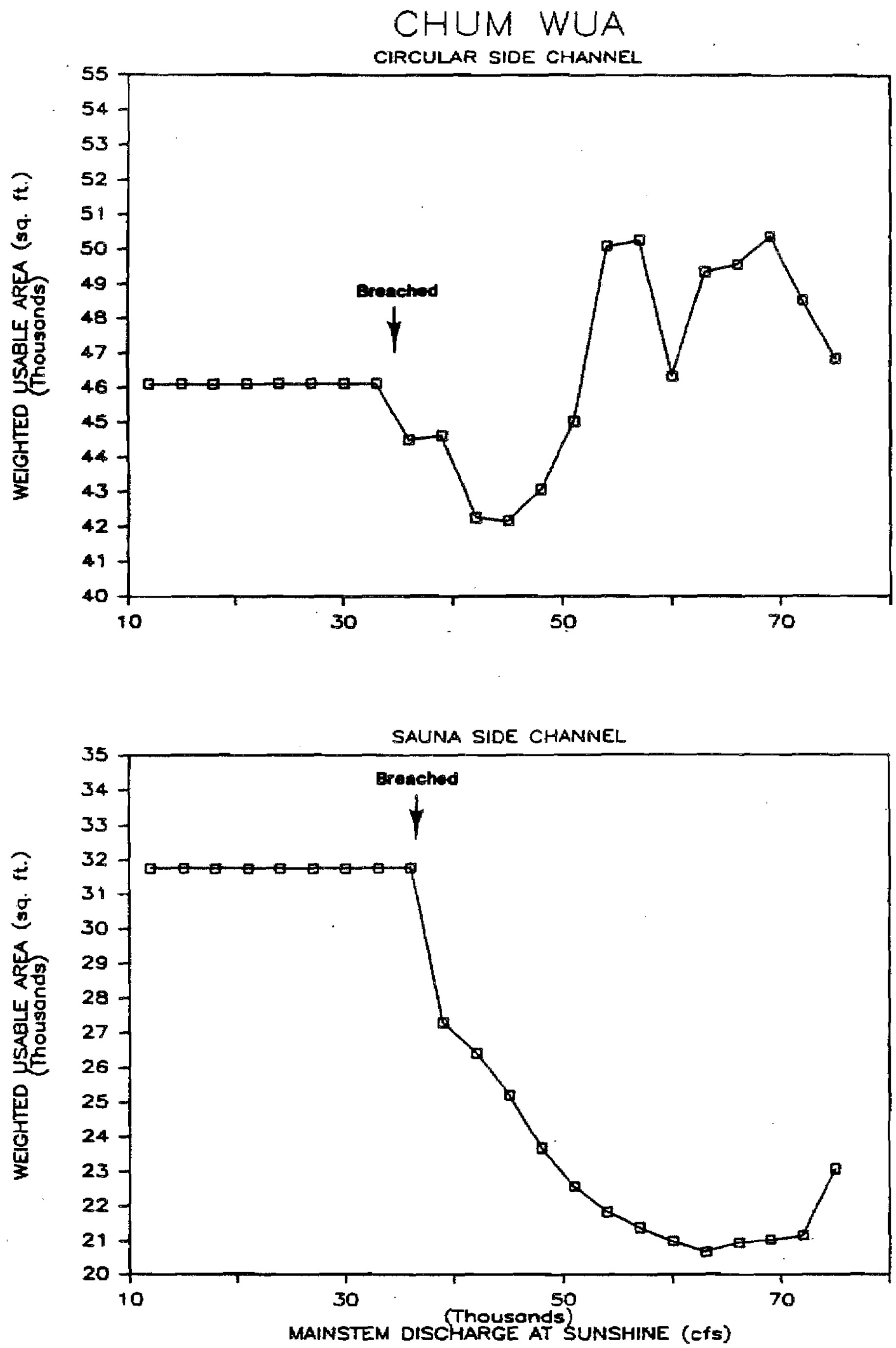
Appendix Figure B-9. Weighted usable area for juvenile chum salmon at the Hooligan Side Channel and Kroto Slough Head study sites as a function of mainstem discharge.



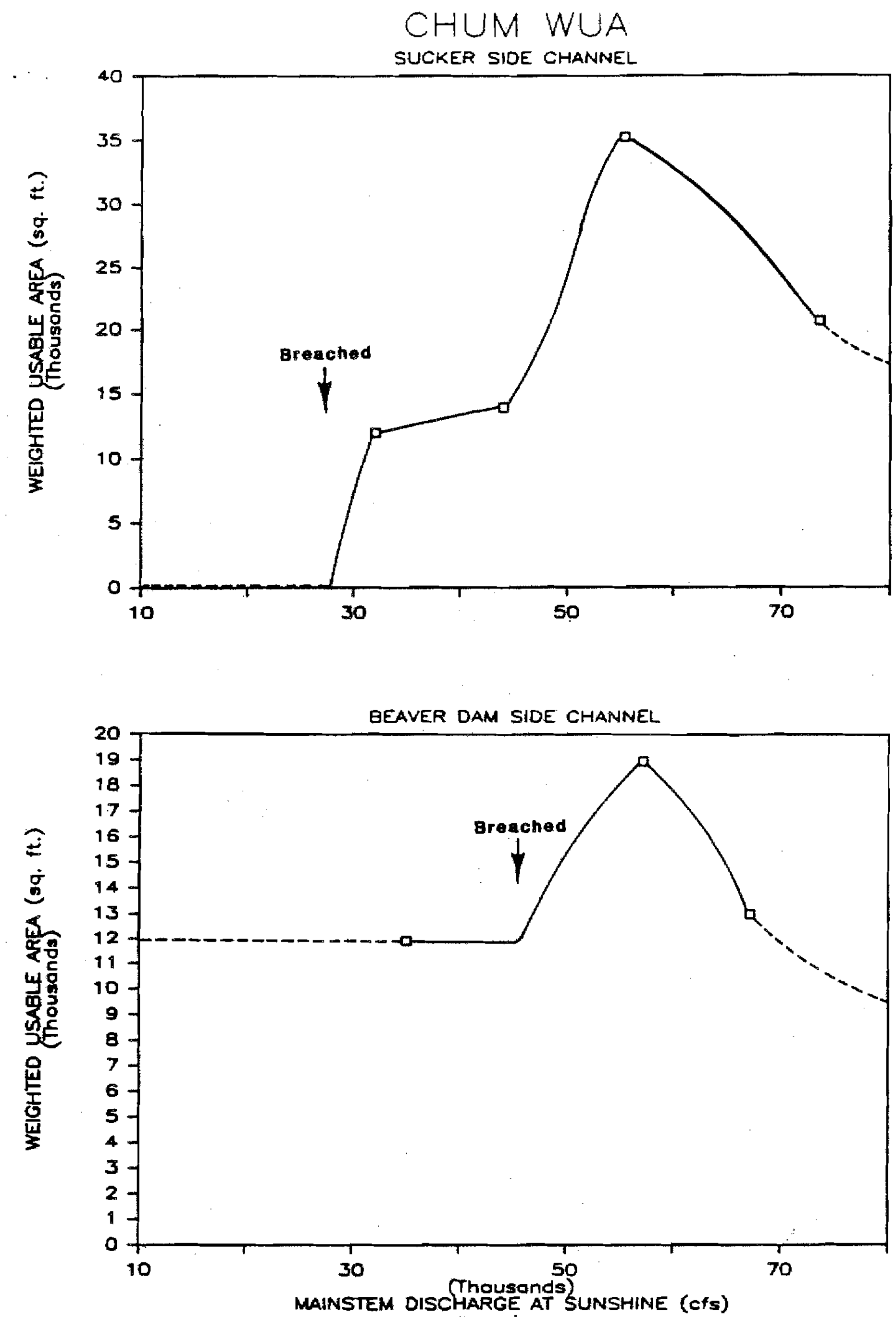
Appendix Figure B-10. Weighted usable area for juvenile chum salmon at Bearbait and Island Side Channel study sites as a function of mainstem discharge.



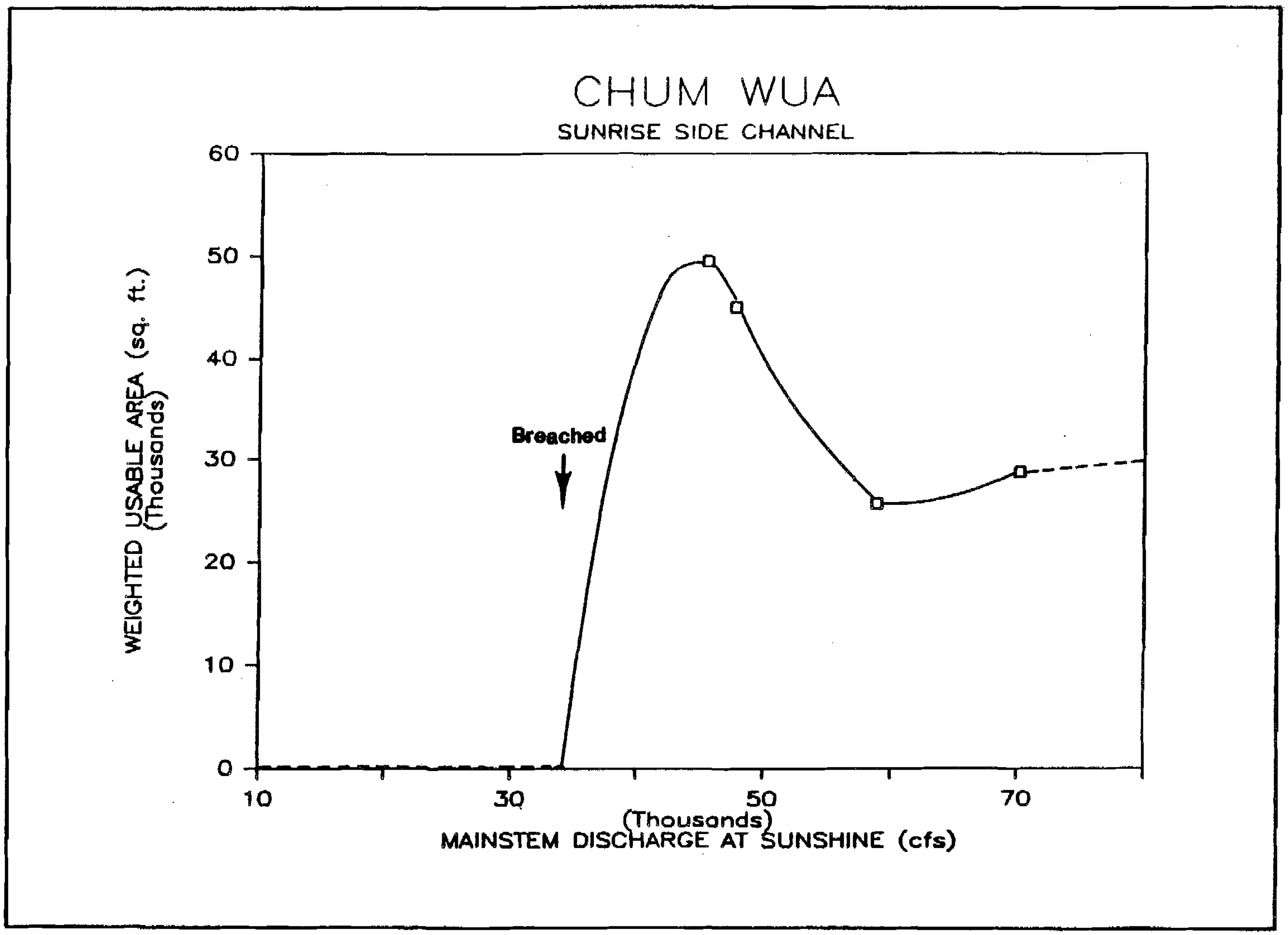
Appendix Figure B-11. Weighted usable area for juvenile chum salmon at the Mainstem West Bank and Goose 2 Side Channel study sites as a function of mainstem discharge.



Appendix Figure B-12. Weighted usable area for juvenile chum salmon at the Circular and Sauna Side Channel study sites as a function of mainstem discharge.



Appendix Figure B-13. Weighted usable area for juvenile chum salmon at the Sucker and Beaver Dam Side Channel study sites as a function of mainstem discharge.



Appendix Figure B-14. Weighted usable area for juvenile chum salmon at the Sunrise Side Channel study site as a function of mainstem discharge.

Appendix Table B-8. Weighted usable areas and habitat indices for juvenile sockeye salmon in lower Susitna River model sites, 1984.

ROLLY CREEK MOUTH

MAINSTEM DISCHARGE	SITE AREA	SOCKEYE WUA	SOCKEYE H. I.
12000	84900	10600	0.12
15000	84900	10600	0.12
18000	84900	10600	0.12
21000	84900	10600	0.12
24000	85300	10600	0.12
27000	88300	11000	0.12
30000	93200	13400	0.14
33000	99800	17600	0.18
36000	108900	22800	0.21
39000	121000	28900	0.24
42000	135000	35500	0.26
45000	152600	43400	0.28
48000	178500	52100	0.29
51000	198800	64400	0.32
54000	213000	75300	0.35
57000	223200	82800	0.37
60000	229800	88200	0.38
63000	235000	93000	0.40
66000	238700	97200	0.41
69000	241600	99900	0.41
72000	243200	100700	0.41
75000	243600	101500	0.42

CASWELL CREEK MOUTH

MAINSTEM DISCHARGE	SITE AREA	SOCKEYE WUA	SOCKEYE H. I.
12000	16200	1350	0.08
15000	16200	1350	0.08
18000	16200	1350	0.08
21000	16200	1350	0.08
24000	16200	1600	0.10
27000	16300	1700	0.10
30000	16700	1900	0.11
33000	17300	2300	0.13
36000	18000	2600	0.14
39000	18900	3100	0.16
42000	19800	3700	0.19
45000	21000	4300	0.20
48000	21800	5000	0.23
51000	22700	5700	0.25
54000	23700	6400	0.27
57000	24600	7200	0.29
60000	25500	7900	0.31
63000	26300	8600	0.33
66000	27200	9200	0.34
69000	27900	10000	0.36
72000	28900	10600	0.37
75000	29700	11400	0.38

BEAVER DAM SLOUGH

MAINSTEM DISCHARGE	SITE AREA	SOCKEYE WUA	SOCKEYE H. I.
12000	11600	6200	0.53
15000	11600	6200	0.53
18000	11600	6200	0.53
21000	11700	6200	0.53
24000	11900	6200	0.52
27000	12200	6400	0.52
30000	12500	6600	0.53
33000	13000	6700	0.52
36000	13400	7000	0.52
39000	13900	7100	0.51
42000	14400	7300	0.51
45000	15000	7500	0.50
48000	15700	7700	0.49
51000	16300	8000	0.49
54000	16800	8200	0.49
57000	17600	8600	0.49
60000	18500	8900	0.48
63000	19700	9400	0.48
66000	20800	10200	0.49
69000	21600	10800	0.50
72000	22100	11000	0.50
75000	22600	11000	0.49

SUCKER SIDE CHANNEL

MAINSTEM DISCHARGE	SITE AREA	SOCKEYE WUA	SOCKEYE H. I.
12000	0	0	0.00
15000	0	0	0.00
18000	0	0	0.00
21000	0	0	0.00
24000	0	0	0.00
27000	0	0	ERR
30000	8500	1200	0.14
33000	14900	1800	0.12
36000	16900	1700	0.10
39000	19400	1500	0.08
42000	23600	1200	0.05
45000	29600	1200	0.04
48000	37100	2600	0.07
51000	46600	4000	0.09
54000	57900	5000	0.09
57000	66900	5300	0.08
60000	71300	5400	0.08
63000	73900	5500	0.07
66000	75900	5600	0.07
69000	77300	5600	0.07
72000	78100	5600	0.07
75000	78300	5600	0.07

BEAVER DAM SIDE CHANNEL

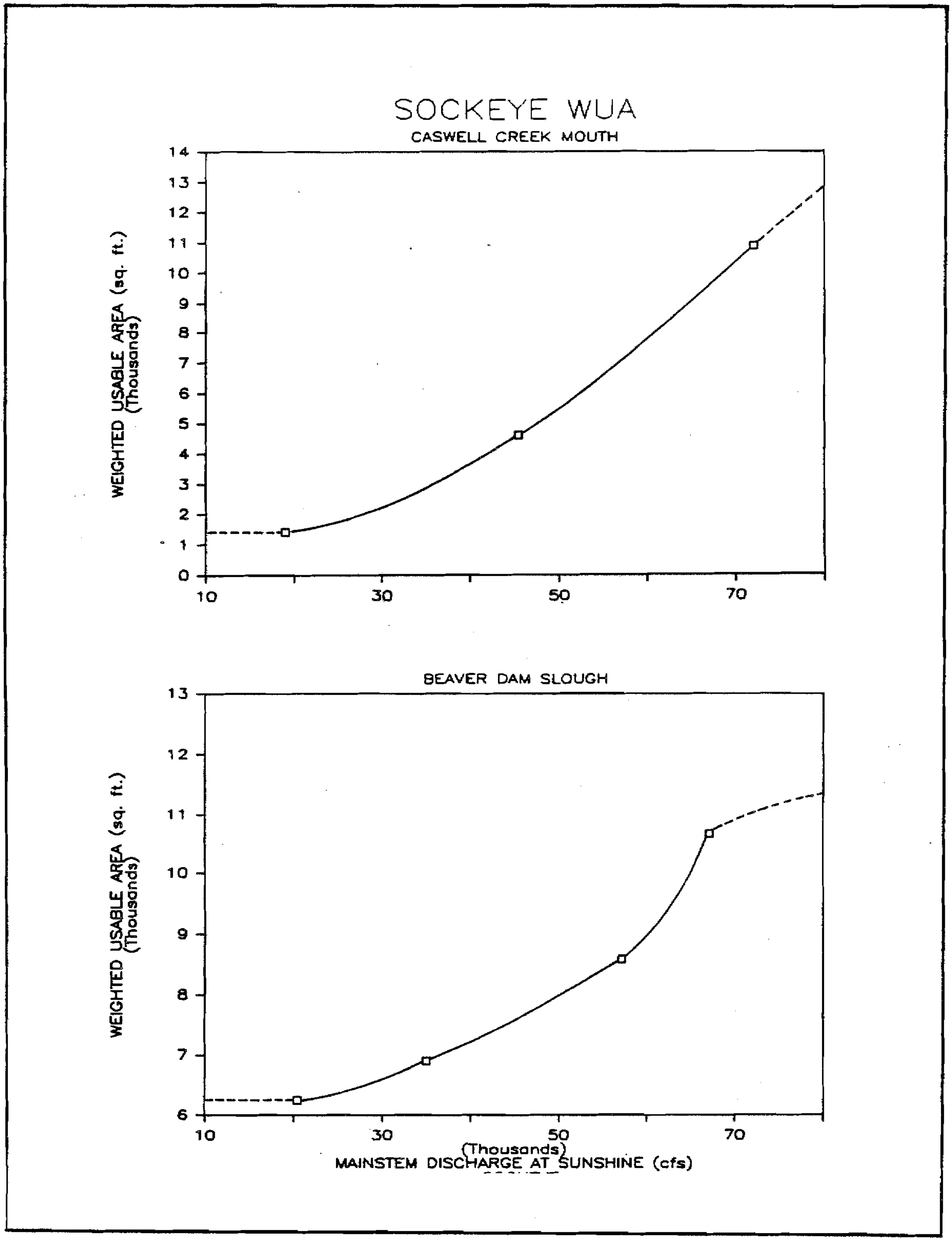
MAINSTEM DISCHARGE	SITE AREA	SOCKEYE WUA	SOCKEYE H. I.
12000	18900	3000	0.16
15000	18900	3000	0.16
18000	18900	3000	0.16
21000	18900	3000	0.16
24000	18900	3000	0.16
27000	18900	3000	0.16
30000	18900	3000	0.16
33000	18900	3000	0.16
36000	18900	3000	0.16
39000	18900	3000	0.16
42000	18900	3000	0.16
45000	18900	3000	0.16
48000	22400	3200	0.14
51000	28000	3700	0.13
54000	32600	4100	0.13
57000	35700	4300	0.12
60000	38000	4200	0.11
63000	39600	3900	0.10
66000	40800	3600	0.09
69000	41500	3200	0.08
72000	41900	3000	0.07
75000	42100	2800	0.07

SUNSET SIDE CHANNEL

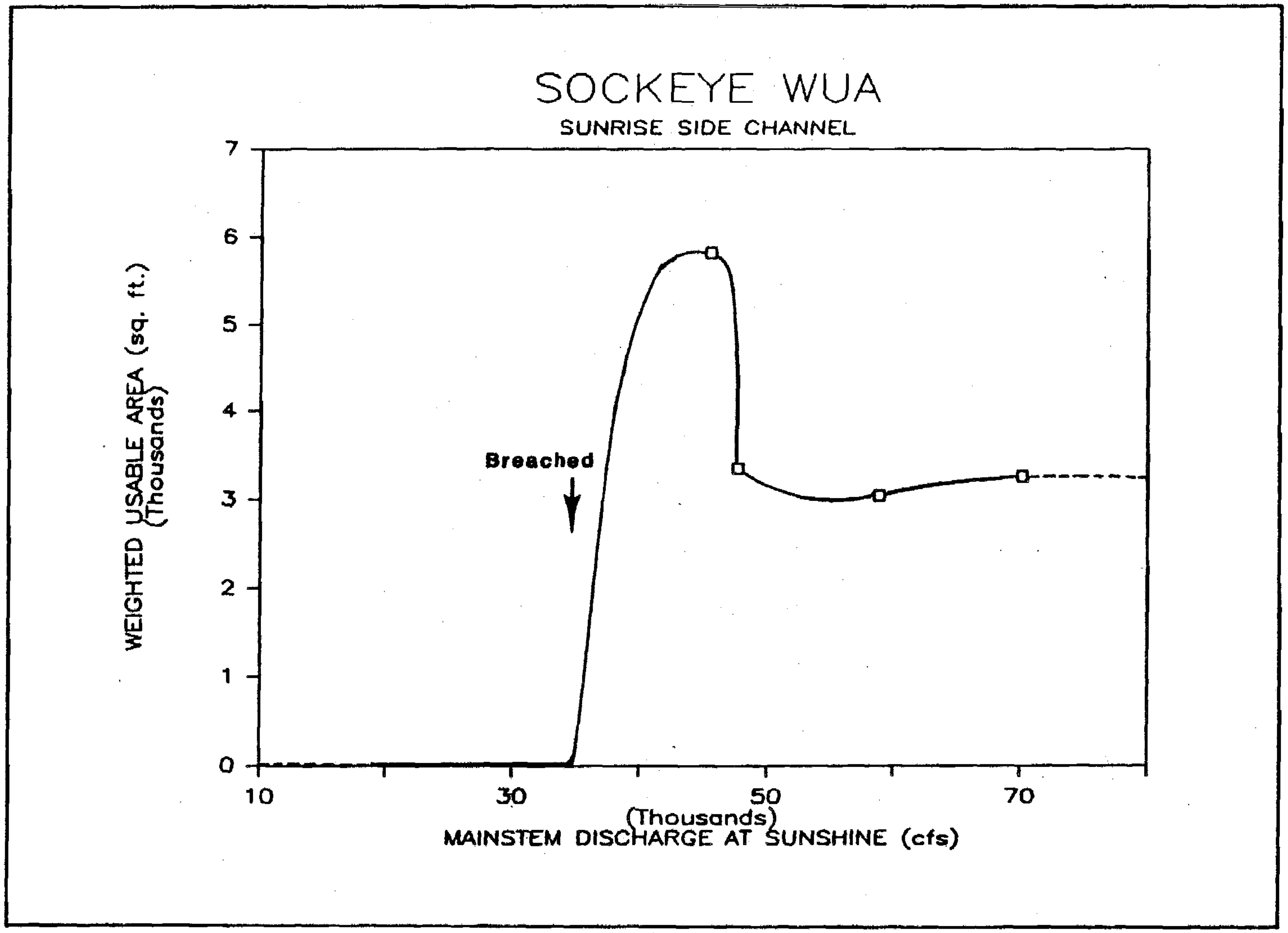
MAINSTEM DISCHARGE	SITE AREA	SOCKEYE WUA	SOCKEYE H. I.
12000	49562	7182	0.14
15000	49562	7182	0.14
18000	49562	7182	0.14
21000	49562	7182	0.14
24000	49562	7182	0.14
27000	49562	7182	0.14
30000	49562	7182	0.14
33000	78488	6738	0.09
36000	89472	6493	0.07
39000	97943	6639	0.07
42000	106320	6828	0.06
45000	122338	7412	0.06
48000	135476	7529	0.06
51000	149248	7108	0.05
54000	165990	6643	0.04
57000	173483	6006	0.03
60000	188419	6682	0.04
63000	194419	6275	0.03
66000	203000	6740	0.03
69000	206972	6850	0.03
72000	210728	7124	0.03
75000	215861	7861	0.04

SUNRISE SIDE CHANNEL

MAINSTEM DISCHARGE	SITE AREA	SOCKEYE WUA	SOCKEYE H. I.
12000	0	0	0.00
15000	0	0	0.00
18000	0	0	0.00
21000	0	0	0.00
24000	0	0	0.00
27000	0	0	0.00
30000	0	0	0.00
33000	0	0	0.00
36000	19000	400	0.02
39000	53900	4700	0.09
42000	78500	5800	0.07
45000	97100	5800	0.06
48000	115400	3400	0.03
51000	131100	3200	0.02
54000	146900	3100	0.02
57000	160600	3000	0.02
60000	175600	3000	0.02
63000	192000	3100	0.02
66000	207300	3100	0.01
69000	221400	3200	0.01
72000	229000	3200	0.01
75000	233300	3200	0.01



Appendix Figure B-15. Weighted usable area for juvenile sockeye salmon at Caswell Creek and Beaver Dam tributary study sites as a function of mainstem discharge.



Appendix Figure B-16. Weighted usable area for juvenile sockeye salmon at Sunrise Side Channel study site as a function of mainstem discharge.

APPENDIX C

COMPARISON OF THE IFIM AND RJHAB MODELLING TECHNIQUES AT TWO SELECTED SITES

INTRODUCTION

In 1983, two techniques were used to model the effects of mainstem discharge on juvenile salmon habitat within the middle Susitna River. The Instream Flow Incremental Methodology (IFIM) (Bovee 1982) was used at seven sites (Hale et al. 1984) and the RJHAB habitat model developed in Marshall et al. (1984) was used to model six other sites. Since studies of the effects of mainstem discharge on juvenile salmon habitat within the lower Susitna River were begun in 1984, it was desirable to compare these two modelling methods. Both methods were used, therefore, at the same transects within two sites to compare results from the two techniques.

METHODS

Trapper Creek Side Channel (RM 91.6) and Island Side Channel (RM 63.2) were selected as sampling sites for this comparative study because they represent two different channel types of the lower Susitna River. Trapper Creek Side Channel is a simple straight channel. Island Side Channel is a more complex, winding channel. Further descriptions and photos of these two sites are contained in Quane et al. (1985).

Descriptions of the two modelling techniques will not be presented here. Detailed descriptions of the IFIM are presented in Appendix D of this report and Bovee (1982), and summarized in Section 2.0 of this report. The original RJHAB model was first developed and described in Marshall et al. (1984) and modifications were described in Section 2.0 of this report.

Both techniques entail taking depth, velocity, and cover or substrate measurements spaced at intervals across transects running at right angles to the channel. Hydraulic models which have been developed for use in the IFIM include the IFG-2 model which is based on open channel flow theory and one set of field data and the IFG-4 model which is based more strongly on field data as three sets of field measurements are recommended (Milhous et al. 1981). Fewer measurements are taken for each RJHAB field data set than for the IFIM models but up to seven data sets are taken. No hydraulic model is developed by the RJHAB and the model runs on a spreadsheet with a microcomputer. The IFIM models can generate estimates of equivalent optimum habitat called weighted usable areas (WUA's) with any flow within their calibration range, while the RJHAB model only calculates WUA's at discharges for which measurements are taken. Therefore, it is necessary to interpolate between point measurements generated by the RJHAB model. The RJHAB model does have the advantage of being able to run in areas heavily influenced by mainstem backwater or sloughs with flows less than 5 cfs. The measurements and data analysis for the RJHAB model were taken by different investigators than those who took the IFIM measurements and analyzed them.

The RJHAB model uses measurements at an additional upper transect within each of the sites. This upper area was very similar to lower sections of the site, and therefore would not change comparability of the two methods. The IFIM presents results of the analysis on the basis of a 1000 foot reach, while the RJHAB model presents WUA's for the site. Therefore, the length of each site as used in the RJHAB model was calculated and WUA's were adjusted to the basis of a 1000 foot reach.

At Island Side Channel, two additional partial transects were put in for IFIM analysis of the site (see Appendix D), and no RJHAB measurements were taken at these transects. A trial run which minimized the effect of these two additional transects showed only very minor changes in WUA.

RESULTS

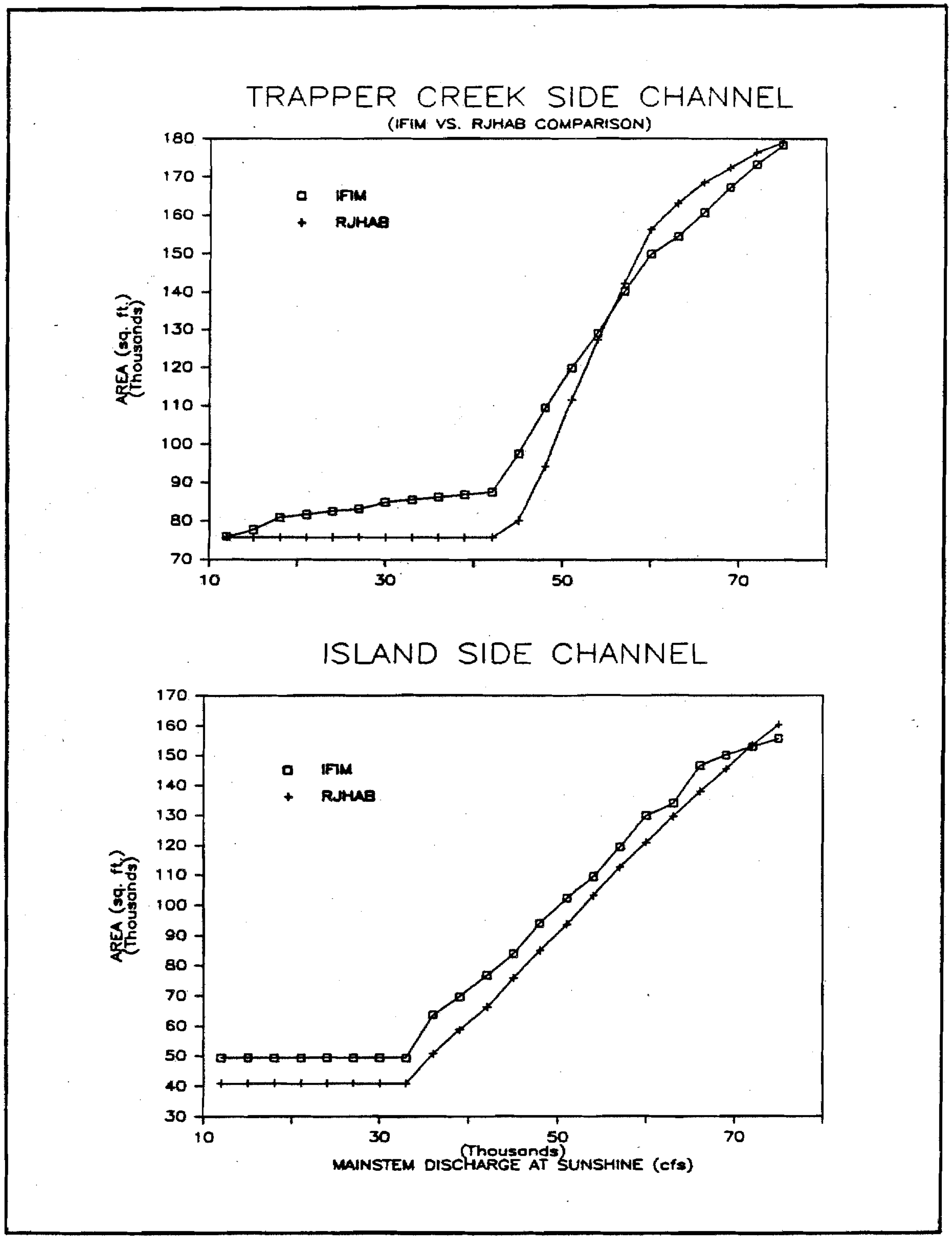
An IFG-2 IFIM model was run at Island Side Channel and hydraulic data were collected at a side channel flow of 338 cfs (Appendix D). At Trapper Creek Side Channel, hydraulic data for an IFG-4 IFIM model were collected at flows of 16, 32, and 389 cfs. Habitat data for the RJHAB model were collected four times at Trapper Creek Side Channel and five times at Island Side Channel and the RJHAB models at both sites were evaluated as "good" (Table 6).

The modelled response of area at the Trapper Creek and Island side channel sites to changes in discharge was almost identical for both the IFIM and RJHAB modelling techniques (Appendix Figure C-1). Differences in areas below the overtopping flow at Island Side Channel are probably due to the IFIM not being able to model flows below 5 cfs while the RJHAB WUA was measured at a flow of less than one cfs. Other differences are readily attributable to sampling error. Since juvenile chinook and chum salmon are the two salmon species which make the heaviest use of side channels for rearing, only WUA results from these two species will be presented here.

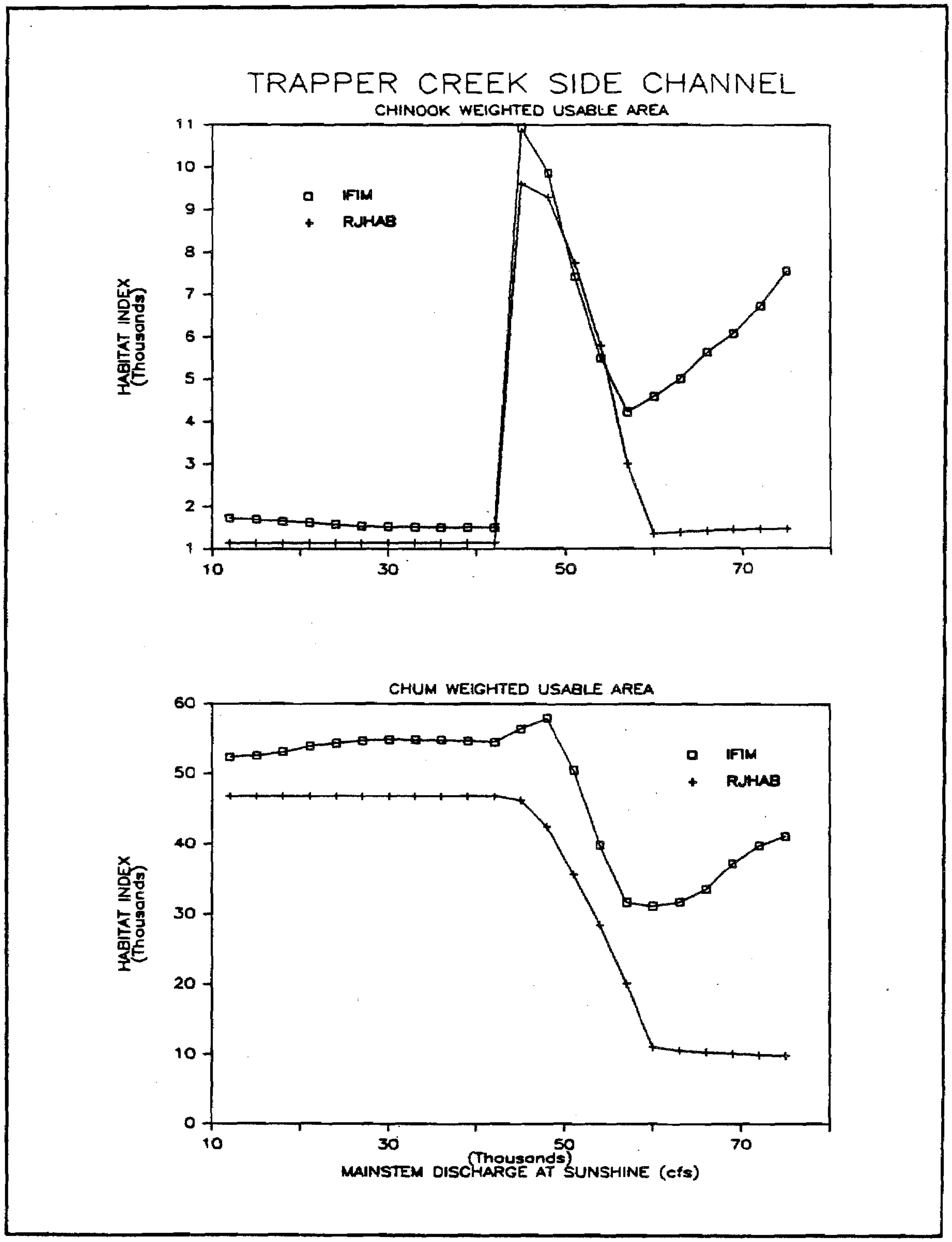
At Trapper Creek Side Channel, the shape of the WUA curves for both species were basically the same for both modelling methods (Appendix Figure C-2). The RJHAB model appears to consistently underestimate the amount of WUA in comparison to the IFIM model. The underestimation of WUA by the RJHAB model leads to smaller habitat indices although the shapes of the habitat index curves are similar for both techniques (Appendix Figure C-3).

At Island Side Channel, on the other hand, WUAs from the two modelling methods do not compare closely (Appendix Figure C-4). The chinook and chum WUA response curves look more similar to each other than do the modelling techniques. Peaks in WUA for the RJHAB model occur at approximately 40,000 cfs while the IFIM model predicts a peak WUA at approximately 60,000 cfs. The IFIM model does predict a chinook salmon WUA of 6,230 ft^2 to 6,600 ft^2 at side channel flows of 6 to 11 cfs which corresponds to the peak in the RJHAB model where a measurement was taken at a side channel flow of approximately 10 cfs.

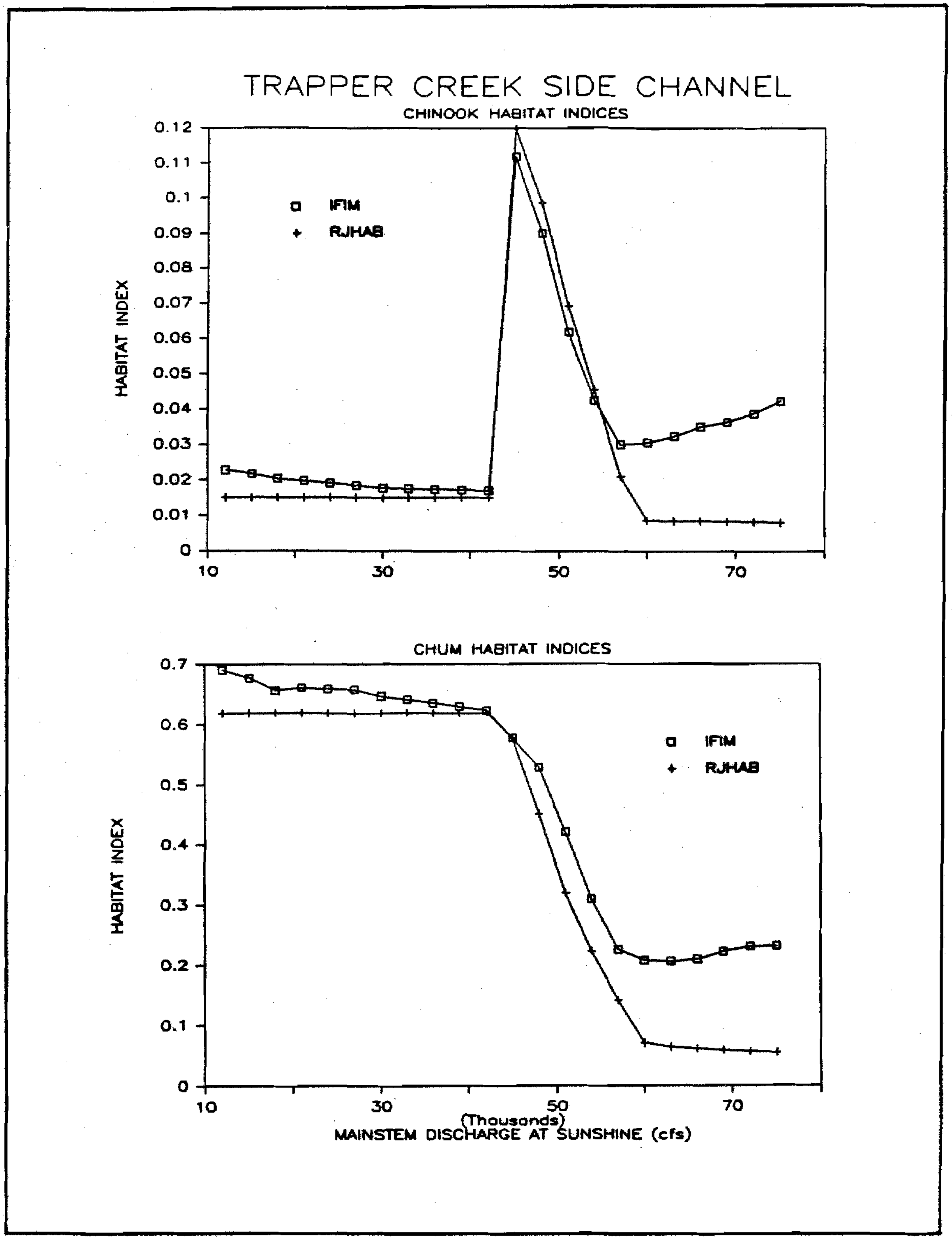
When habitat indices are calculated for both methods at Island Side Channel, differences between the two techniques appear smaller (Appendix Figure C-5). The RJHAB model shows a peak habitat index for chinook salmon at approximately 39,000 cfs which the IFIM model would also show at side channel flows of 6 to 11 cfs. Chum habitat indices for both



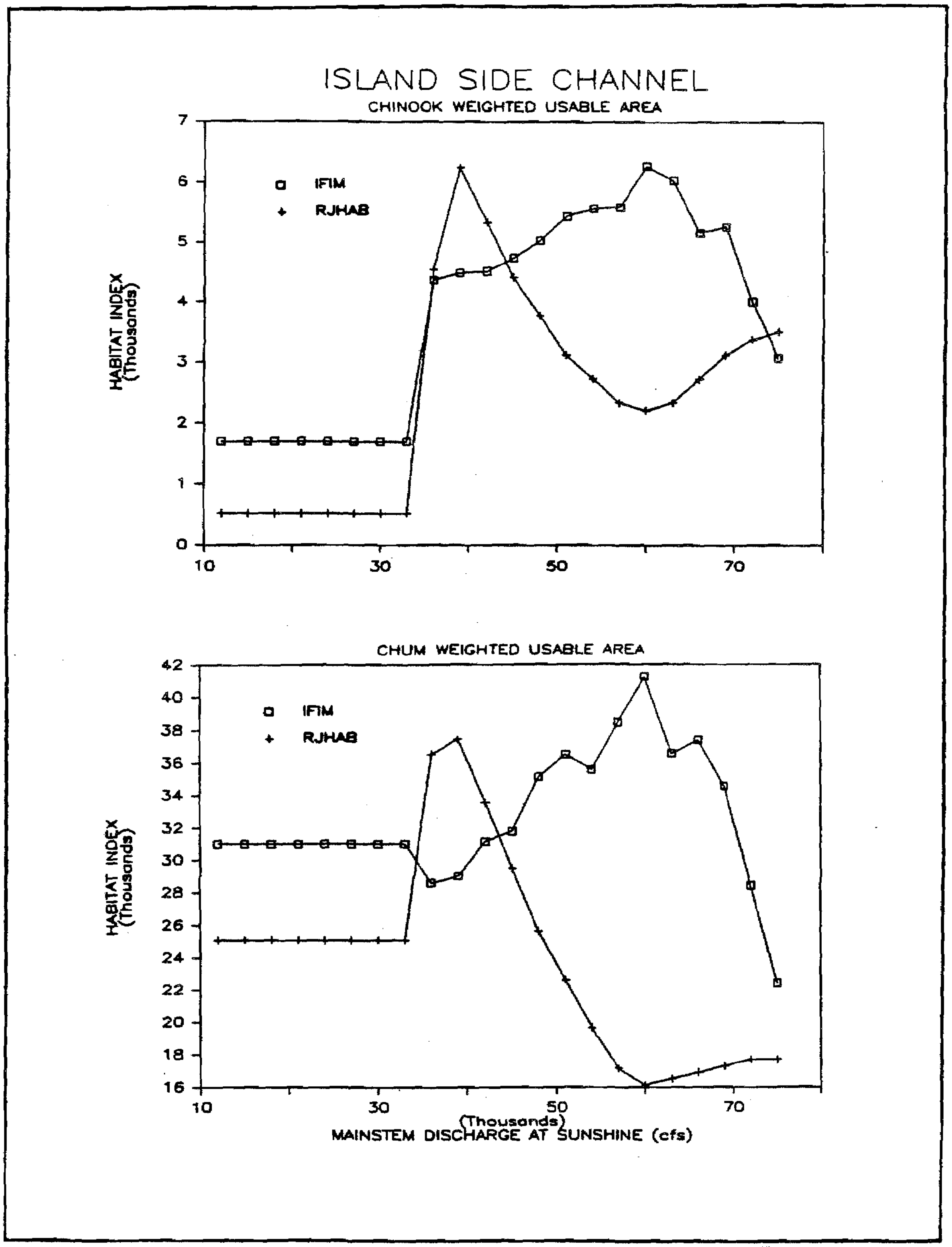
Appendix Figure C-1. Comparison of site areas calculated with the RJHAB and IFIM modelling techniques for the Trapper Creek and Island Side Channel study sites.



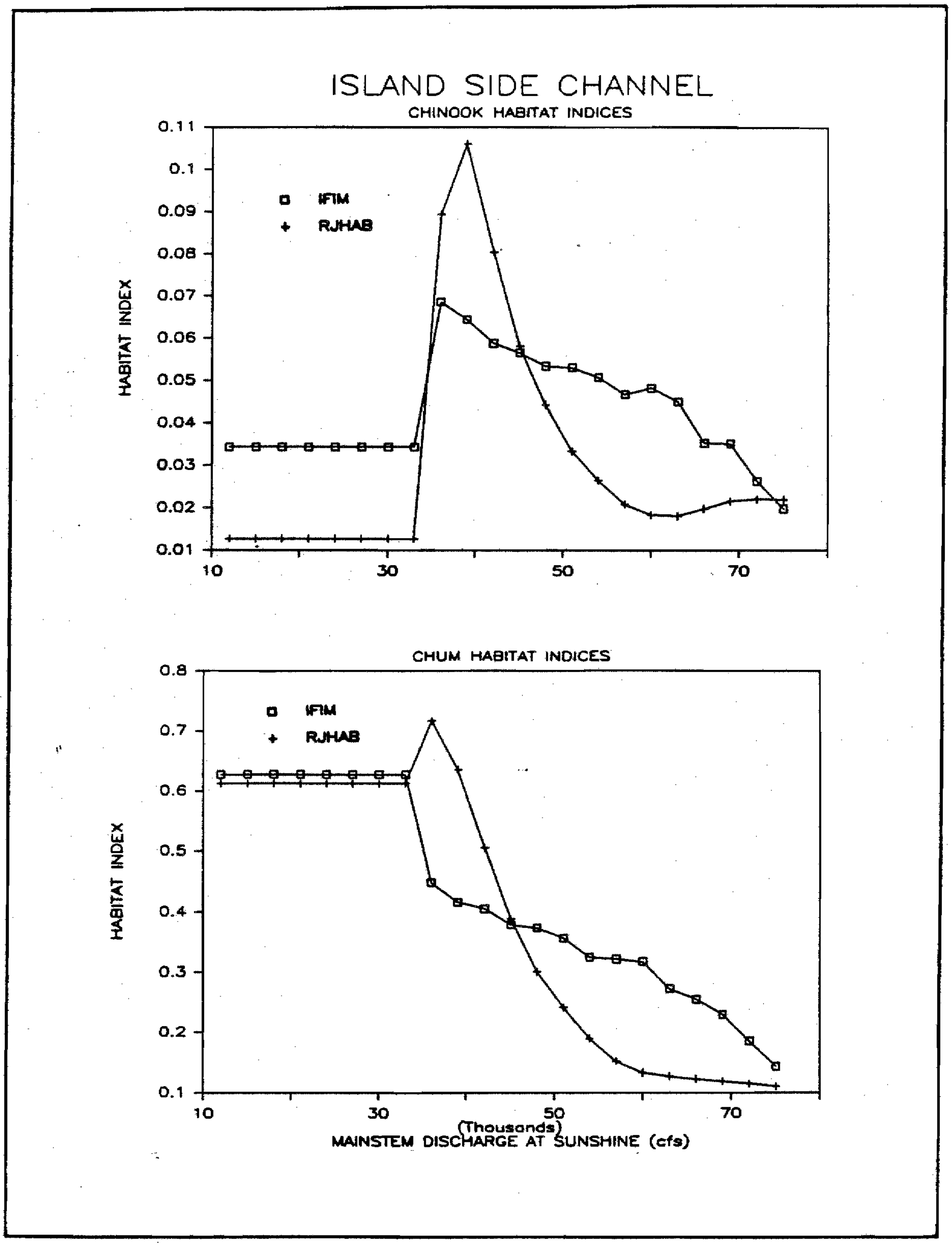
Appendix Figure C-2. Comparison of weighted usable areas calculated with the RJHAB and IFIM modelling techniques for juvenile chinook and chum salmon at Trapper Creek Side Channel, 1984.



Appendix Figure C-3. Comparison of habitat indices calculated with the RJHAB and IFIM modelling techniques for juvenile chinook salmon at Trapper Creek Side Channel, 1984.



Appendix Figure C-4. Comparison of weighted usable areas calculated with the RJHAB and IFIM modelling techniques for juvenile chinook and chum salmon at Island Side Channel, 1984.



Appendix Figure C-5. Comparison of habitat indices calculated with the RJHAB and IFIM modelling techniques for juvenile chinook and chum salmon at Island Side Channel, 1984.

techniques decrease after overtopping although the RJHAB habitat indices drop off more steeply.

DISCUSSION

The two modelling methods compared very favorably at calculating areas within the two sites. The shape of the chum and chinook WUA and habitat index responses at Trapper Creek Side Channel were very similar. The RJHAB model consistently underestimated WUA in comparison to the IFIM model. This is probably due to the RJHAB model not taking into account the area between the shoreline cell and the cell located one-third of the way across the channel. This area was often marginal habitat with barely suitable velocities.

At Island Side Channel, large differences in WUA can also be attributed, in part, to the RJHAB model not taking into account peripheral marginal habitat more than six feet from shore. This difference is also reflected in the habitat indices where the proportion of usable area drops off more quickly for the RJHAB model. The differences in WUA below the overtopping flow can be attributed to the fact that the IFIM model does not run at flows less than five cfs while actual flows at discharges below the overtopping one are less than one cfs (Quane et al. 1985).

The effects of sampling errors in data collection on WUA estimates from both the RJHAB and IFIM techniques are unknown. Since many more measurements are taken for the IFIM, it should be less susceptible to sampling errors. Because only one IFIM measurement was taken at Island Side Channel at a flow of 338 cfs, however, the reliability of modelling flows as small as 5 cfs is unknown. It seems reasonable to assume that an IFG-4 model at Island Side Channel would have given somewhat different results than did the IFG-2 model. The RJHAB model works well in situations where the primary effect of discharge is due to backwater and the IFIM model cannot be used or works poorly.

In summary, the RJHAB model generally gives lower WUA estimates than does the IFIM methodology. Also peaks in WUA are often narrower for the RJHAB model. Both models show the same general trends in the habitat indices for chum and chinook salmon although the RJHAB model is more sensitive to increases in velocity and depth which decrease the habitat indices more quickly. Since the habitat indices for both sites calculated using both techniques are not appreciably different, analysis of trends and optimal flows by use of habitat indices would lead to similar conclusions using both methods. Comparisons of the IFIM with other instream flow methodologies have also shown differences in output, and no one method has yet been proven best (Annear and Conder 1984).

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APPENDIX D

HYDRAULIC MODELS FOR USE IN ASSESSING THE REARING HABITAT OF JUVENILE SALMON IN SIX SIDE CHANNELS OF THE LOWER SUSITNA RIVER

APPENDIX D

HYDRAULIC MODELS FOR USE IN ASSESSING THE REARING HABITAT OF JUVENILE SALMON IN SIX SIDE CHANNELS OF THE LOWER SUSITNA RIVER

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ABSTRACT

Six side channels (Island, Mainstem West Bank, Circular, Sauna, Sunset, and Trapper Creek) in the lower reach of the Susitna River were evaluated using an Instream Flow Incremental Methodology (IFIM) physical habitat simulation (PHABSIM) modelling approach to describe the effects that site flow and mainstem discharge have on rearing juvenile salmon habitat. These sites were thought to contain potential habitat for rearing juvenile salmon and were chosen to range greatly in size, shape, and overtopping discharge.

Six hydraulic simulation models (either IFG-2 or IFG-4) were calibrated to simulate depths and velocities associated with a range of site-specific flows at the six modelling study sites. Comparisons between corresponding sites of simulated and measured depths and velocities indicated that the models provide reliable estimates of depths and velocities within their recommended calibration ranges.

The recommended of ranges of mainstem Susitna River discharge over which these models can hydraulically simulate the habitat of rearing juvenile salmon are: Island Side Channel from 35,000 to 70,000 cfs mainstem discharge; Mainstem West Bank Side Channel from 18,000 to 48,000 cfs; Circular Side Channel from 36,000 to 63,000 cfs; Sauna Side Channel from 44,000 to 63,000 cfs; Sunset Side Channel from 32,000 to 67,000 cfs; and Trapper Creek Side Channel from 20,000 to 66,000 cfs.

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INTRODUCTION

About 40% of the annual discharge of the lower Susitna River at the Parks Highway bridge originates from the mainstem Susitna River above the confluence of the Talkeetna and Chulitna Rivers (Acres 1982). Thus, operation of the proposed hydroelectric project will alter the natural flow regime of this lower river reach beyond the normal variations in flow which occur naturally during the open-water season.

One of the predominant aquatic habitat types in this lower river reach which may be affected by such flow alterations are side channels. Side channel areas in this river reach currently provide habitat for rearing juvenile salmon. The quantity and quality of juvenile salmonid rearing habitat in side channels in this river reach is dependent on a multitude of interrelated habitat variables, including water depth and velocity, which are intimately related to mainstem discharge.

This appendix presents results of the physical habitat modelling simulation efforts that Alaska Department of Fish and Game (ADF&G) Su Hydro personnel conducted during the open-water season of 1984. The objective of the study was to provide calibrated hydraulic simulation models for selected lower river juvenile salmon habitat modelling study sites. The approach of the study was to apply a methodology which used water depth and velocity as the dominant hydraulic variables to quantify the responses of rearing habitat to changes in site flow and mainstem discharge. The methodology used was the system developed by the U.S. Fish and Wildlife Service (USF&WS) Instream Flow Group (IFG) called the Instream Flow Incremental Methodology (IFIM) Physical Habitat Simulation (PHABSIM) modelling system (IFG 1980, Bovee 1982). The calibrated hydraulic simulation models will be utilized to assess how site flows and mainstem discharge affect juvenile salmon rearing habitat in side channels of the lower Susitna River.

METHODS

Analytical Approach

A common methodology used for assessing habitat responses to flow variations is the IFIM, PHABSIM modelling system. The IFIM, PHABSIM modelling system is a collection of computer programs used to simulate both the available hydraulic conditions and usable habitat at a study site for a particular species/life phase as a function of flow. It is based on the theory that changes in riverine habitat conditions can be estimated from a sufficient hydraulic and biological field data base. It is intended for use in those situations where flow regime and channel structure are the major factors influencing river habitat conditions.

The modelling system is based on a three step approach. The first step uses field data to calibrate hydraulic simulation models to forecast anticipated changes in physical habitat variables important for the species/life phase under study as a function of flow. The second step involves the collection and analysis of biological data to determine the behavioral responses of a particular species/life phase to important physical habitat variables. This information is used to develop weighted behavioral response criteria curves (e.g., utilization curves, preference curves, or suitability curves). The third step combines information gained in the first two steps to calculate weighted usable area (WUA) indices of habitat usability as a function of flow for the species/life phase under study.

Hydraulic modelling is of central importance to the PHABSIM system. The primary purpose of incorporating hydraulic modelling into the analytical approach is to make the most efficient use of limited field observations to forecast hydraulic attributes of riverine habitat (depths and velocities) under a broad range of unobserved streamflow conditions.

The IFG developed two hydraulic models (IFG-2 and IFG-4) during the late 1970's to assist fisheries biologists in making quantitative evaluations of effects of streamflow alterations on fish habitat. The IFG-2 hydraulic model is a water surface profile program that is based on open channel flow theory and formulae. The IFG-2 model can be used to predict the horizontal distribution of depths and mean column velocities at 100 points along a cross section for a range of streamflows with only one set of field data. The IFG-4 model provides the same type of hydraulic predictions as the IFG-2 model, but it is more strongly based on field observations and empiricism than hydraulic theory and formulae. Although a minimum of two data sets are required for calibrating the IFG-4 model, three are recommended. Either model can be used to forecast depths and velocities occurring in a stream channel over a broad range of streamflow conditions.

The IFG-4 model, which is based upon a greater number of observed sets of field data (i.e. flow levels), generally can be used to model a greater range of flow conditions than the IFG-2 model. Additionally, since the IFG-4 model is more dependent upon observed depths and velocities than the IFG-2 model, predicted depths and velocities can be directly compared with the observed values. This comparison is a useful tool for verifying the models.

Both models are most applicable to streams of moderate size and are based on the assumption that steady flow conditions exist within a rigid stream channel. A stream channel is rigid if it meets the following two criteria: (1) it must not change shape during the period of time over which the calibration data are collected, and (2) it must not change shape while conveying streamflows within the range of those that are to be simulated. Thus a channel may be "rigid" by the above definition, even though it periodically (perhaps seasonally) changes course. Streamflow is defined as "steady" if the depth of flow at a given location in the channel remains constant during the time interval under consideration (Trihey 1980).

In this analysis, all streamflow rates were referenced to the average daily discharge of the Susitna River at the U.S. Geological Survey (USGS) stream gage at Sunshine, Alaska (station number 15292780). This location was selected as the index station primarily because it is the gage located near the center of the river segment that is of greatest interest in this particular analysis. The target mainstem discharge range for data collection was from 12,000 to 75,000 cfs.

Site specific streamflow data collected during 1984 provided the basis for correlating flow through the various study sites to the average daily streamflow of the Susitna River at the Sunshine gage. Detailed site specific channel geometry and hydraulic measurements provided the necessary data base to calibrate hydraulic models for each study site.

Information for two other physical habitat variables, substrate and cover, were also collected. Substrate was not incorporated into the models at this time, but cover, an important variable in assessing the habitat quality for most rearing salmon juveniles, was.

These data and hydraulic models make up the physical habitat component of the PHABSIM analysis. For a given discharge of the Susitna River at Sunshine, the flow through each study site can be determined and site specific hydraulic conditions (velocity and depth) can be predicted. The results based on velocity, depth, and cover may be used to forecast the effects of mainstem discharge on the weighted usable area for juvenile rearing salmonids of these modelled side channel habitats.

Study Site Selection

Two basic approaches are commonly used for selecting study sites to be evaluated using the IFIM PHABSIM modelling system: the critical and representative concepts (Bovee and Milhous 1978; Trihey 1979; Bovee 1982). Application of the critical concept requires knowledge of a stream's hydrology, water chemistry, and channel geometry in addition to rather extensive knowledge of fish distribution, relative abundance, and species-specific life history requirements. Criteria for application of the representative concept are less restrictive, enabling this concept to be used when only limited biological information is available or when critical habitat conditions cannot be identified with any degree of certainty.

In the critical concept, a study area is selected because one or more of the physical or chemical attributes of the habitat are known to be of critical importance to the fish resource. That is, recognizable physical or chemical characteristics of the watershed hydrology, instream hydraulics, or water quality are known to control species distribution or relative abundance within the study area. Because of this, an evaluation of critical areas will provide a meaningful index of species response in the overall critical study area.

The representative reach concept acknowledges the importance of physical habitat variables throughout the entire study stream for sustaining fish populations. Thus, under this approach, study areas are selected for the purpose of quantifying relationships between streamflow and physical habitat conditions important for the species/life phase under study at selected locations (representative reaches) that collectively exemplify the general habitat characteristics of the entire river segment.

For this study, an adaptation of the representative concept was the approach used to assess how mainstem discharges affect the rearing habitat of juvenile salmon in side channel complexes. The six lower river IFG study sites are most representative, morphologically, of intermediate side channels and of the habitat type designation, secondary side channel as described by Ashton and Klinger-Kingsley (1985). The results from these six IFIM-PHABSIM models are probably most applicable to these types of areas in segments I and II of the lower Susitna River. This segmentation of the lower river is also described in Ashton and Klinger-Kingsley (1985). The six study sites were chosen by ADF&G Su Hydro Resident and Juvenile Anadromous (RJ) project personnel in conjunction with ADF&G Su Hydro Aquatic Habitat and Instream Flow Study (AH) project and E. Woody Trihey and Associates (EWT&A) personnel from lower river side channels which met the following basic criteria:

1. The sites were chosen to range greatly in size, shape, and overtopping discharge;

2. The sites were thought to contain potential habitat conditions for rearing juvenile salmon;

3. The sites were judged by AH project and EWT&A personnel to be readily modelled using the IFIM methodology;

4. The sites were accessible by boat at normal mainstem discharges during the open-water season; and,

5. The sites were above Kashwitna landing and therefore much easier to sample for logistical purposes.

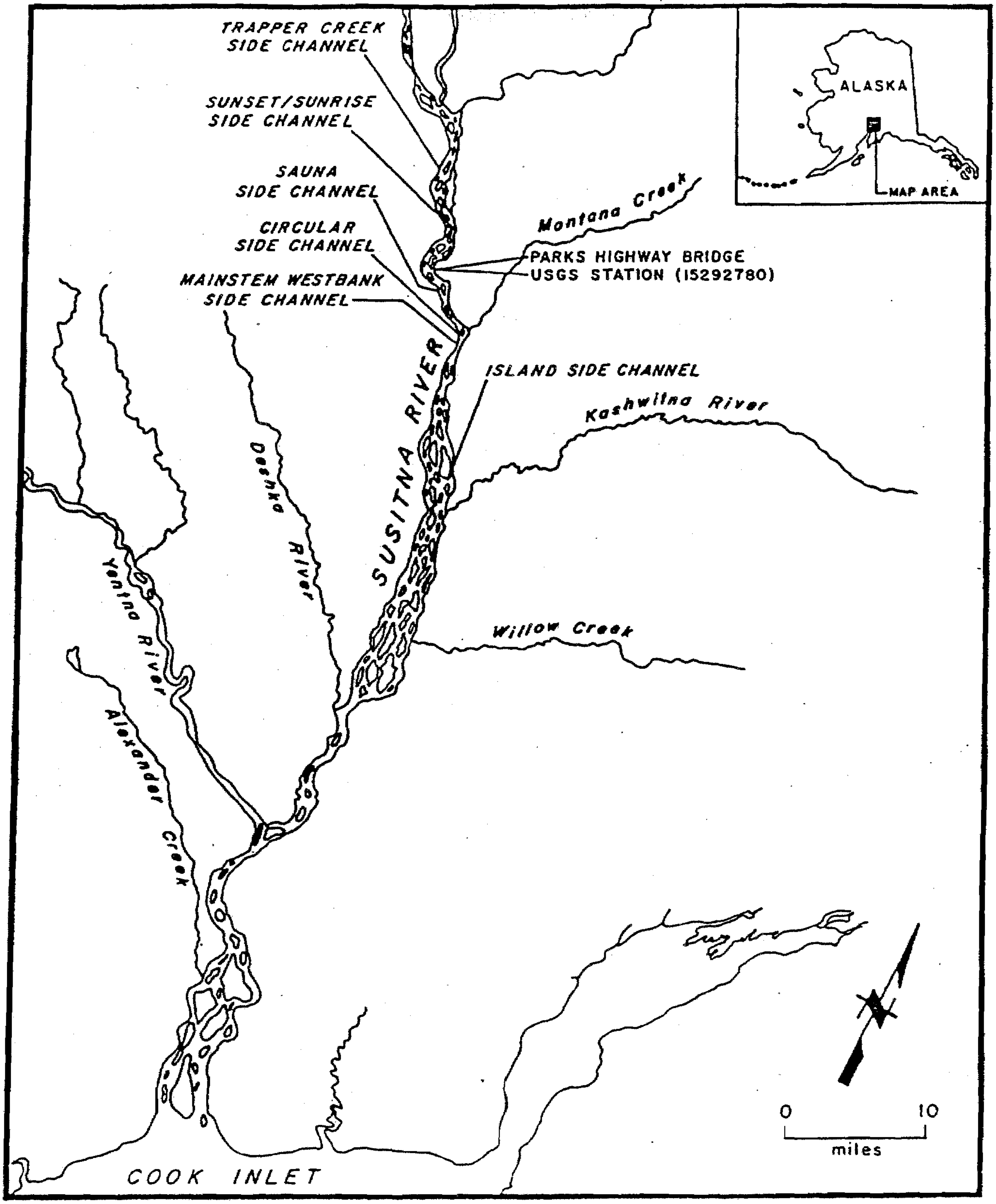
The six sites chosen for modelling complemented other sites modelled using another habitat model (see main text). All of the six sites were side channels, the majority of potential habitat in the lower river is composed of this habitat. Much of the other habitat is difficult to model with the IFIM methodology because it is affected primarily by mainstem backwater. Appendix Figure D-1 shows the location of each of the six sites selected for study, the corresponding river mile location is presented in Appendix Table D-1.

General Techniques for Data Collection

A study reach was selected for detailed evaluation in each of the six side channel sites. The length of the reach was determined by placing enough transects within the area to adequately represent the major macrohabitat types of the particular side channel area.

Transects were located within each study reach following field methods described in Bovee and Milhous (1978) and Trihey and Wegner (1981), and were located to facilitate collection of hydraulic and channel geometry measurements of importance in evaluating flow effects on salmon rearing habitat. Field data were obtained to describe a representative spectrum of water depth and velocity patterns, cover, and substrate composition at each side channel reach.

The number of transects established at the study reaches varied from four to eight. The end points of each transect were marked with 30-inch steel rods (headpins) driven approximately 28 inches into the ground. The elevation of each headpin was determined by differential



Appendix Figure D-1. Location of the six IFG hydraulic modelling sites in the lower Susitna River.

Appendix Table D-1. The six lower river IFG modelling sites with corresponding river mile location.

Side Channel Site	River Mile
Island Side Channel	63.2
Mainstem West Bank Side Channel	74.4
Circular Side Channel	75.3
Sauna Side Channel	79.8
Sunset Side Channel	86.9
Trapper Creek Side Channel	91.6

leveling using temporary benchmarks set at assumed elevations of 100.00 feet.

Cross section profiles at each transect were measured with a level, survey rod, and fiberglass tape. Horizontal distances were recorded to the nearest 1.0 foot and streambed elevations to the nearest 0.1 foot. Water surface elevations at each cross section in the study site were determined to the nearest 0.01 foot by differential leveling or by reading staff gages located on the cross section.

Streambed elevations used in the hydraulic models were determined by making a comparison between the surveyed cross section profile and the cross section profiles derived by subtracting the flow depth measurements at each cross section from the surveyed water surface elevation at each calibration flow (Trihey 1980).

A longitudinal streambed profile (thalweg profile) was surveyed and plotted to scale for each modelling site (Quane et al. 1985).

The water surface elevation at which no flow occurs (stage of zero flow) at each cross section in the study site was determined from the streambed profile. If the cross section was not located on a hydraulic control, then the stage of zero flow was assumed equal to that of the control immediately downstream of the cross section.

Discharge measurements were made using a Marsh-McBirney or Price AA velocity meter, topsetting wading rod, and fiberglass tape. Discharge measurements were made using standard field techniques (Buchanan and Somers 1969; Bovee and Milhous 1978; Trihey and Wegner 1981). Depth and velocity measurements at each calibration flow were recorded for the same respective points along the cross sections by referencing all horizontal measurements to the left bank headpin.

Cover and substrate values were also determined for each cell along modelling transects. Methods described in Suchanek et al. (1985) were used to code cover (Appendix Table D-2). Substrate categories were classified by visual observation employing the substrate classifications presented in Appendix Table D-3. The distribution of various substrate types was indicated on field maps. Substrates were classified using a single or dual code. In those instances that a dual code was used, the first code references the most predominant (i.e., 70% rubble/30% cobble = 9/11).

General Techniques for Calibration

The calibration procedure for each of the hydraulic models was preceded by field data collection, data reduction, and refining the input data. The field data collection entailed establishing cross sections along which hydraulic data (water surface elevations, depths, and velocities) were obtained at each of the different calibration flows. The data reduction entailed determining the streambed and water surface elevations, velocity distribution, the stage of zero flow for each cross section, and determining a mean discharge for all the cross sections in the study site. A model was considered calibrated when: 1) the

Appendix Table D-2. Percent cover and cover type categories.

Cover Type	Code	% Cover	Code
silt, sand (no cover)	1	0-5	.1
emergent vegetation	2	6-25	.2
aquatic vegetation	3	26-50	.3
1-3" gravel	4	51-75	.4
3-5" rubble	5	76-100	.5
5" cobble, boulder	6		
debris	7		
overhanging riparian vegetation	8		
undercut bank	9		

Appendix Table D-3. Substrate classifications.

Substrate Type	Particle Size	Classification
Silt	Silt	1
		2
Sand	Sand	3
		4
Small Gravel	1/8-1"	5
		6
Large Gravel	1-3"	7
		8
Rubble	3-5"	9
		10
Cobble	5-10"	11
		12
Boulder	10"	13

majority of predicted water surface profiles were within ±0.05 ft of the observed elevations and 2) the majority of predicted velocities were within ±0.10 ft/sec of the measured velocities. A calibrated IFG-4 model gives velocity adjustment factors in the range of 0.9 to 1.1, and relatively few velocity prediction errors. The velocity adjustment factor is the ratio of the computed (observed) discharge to the predicted discharge.

An IFG-2 model does not have velocity adjustment factors and is reviewed with the observed data before it is considered calibrated.

For a more detailed explanation of the general techniques used for calibrating the IFG-2 and IFG-4 models in the lower river see Hilliard et al. (1985).

General Techniques for Verification

The verification of how well each of these six hydraulic models simulated their respective site flows was performed by the hydraulic engineers at EWT&A. The approach used to assess the quality of each model was based on two levels of criteria. The first was a qualitative evaluation of four separate sub-criteria. These sub-criteria were:

1. How well does the model conform to the IFG (Main 1978 and Milhous et al. 1984) and EWT&A (Hilliard 1985) guidelines?

2. How well does the extrapolation range of the model conform to the desired range?

3. Are the models appropriate for the species and life stage being considered?

4. How well do the ranges of depth and velocities of the forecasted data conform to the ranges of depth and velocity of the suitability criteria curves being considered based on a "visual" evaluation?

After the first level of qualitative evaluation was performed, an overall rating was given to the various segments of each model. The ratings given were excellent, good, acceptable, and unacceptable. Figures depicting these rating are presented for each site in the results section. The second level of the verification process required a statistical analysis to evaluate the models calibration. It was only performed when the forecast capabilities of either the IFG-2 and IFG-4 model were not given an excellent rating in the level one evaluation. For a detailed explanation of the verification analysis see Hilliard (1985).

RESULTS

The results of the physical habitat simulation modelling studies are presented below by study site. The six lower river side channel IFG modelling sites with type of hydraulic model used, dates calibration flows were measured, and corresponding site specific flows and mainstem discharges for the open-water period in 1984 are presented in Appendix Table D-4. The following items are presented for each study site: (1) a general site description, (2) a summary of data collected, (3) a description of procedures used to calibrate the model, (4) the verification of the model, and (5) the recommended application of the model for each study site.

Appendix Table D-4. The six lower river side channel IFG modelling sites with type of hydraulic model used, dates calibration flows measured, and corresponding site specific flows and mainstem discharges for the open water period in 1984.

Side Channel Site (RM)	Type of Hydraulic Model	Date Calibration Flow Measured	Site Specific Flow (cfs)	Mainstem Discharge at Sunshine[a] (cfs)
Island Side Channel (63.2)	IFG-2	July 25	338	56,100
Mainstem West Bank (74.4)	IFG-4	September 2	450	32,000
		September 20	310	30,500
		September 25	6	19,600
Circular Side Channel (75.3)	IFG-4	July 24	204	55,200
		August 17	50	42,500
Sauna Side Channel (79.8)	IFG-2	July 23	52	52,000
Sunset Side Channel (86.9)	IFG-4	July 22	496	57,800
		August 17	127	42,500
Trapper Creek Side Channel (91.6)	IFG-4	September 18	16	20,900
		August 16	32	44,000
		July 21	389	57,700

[a] Mainstem discharge determined from provisional USGS streamflow data from the stream gage at Sunshine, Alaska (station number 15292780).

Island Side Channel (RM 63.2)

Site Description

Island Side Channel is located on the east bank of the main channel of the Susitna River at river mile (RM) 63.2 (Appendix Figure D-2). This side channel is located downstream of a braided, vegetated floodplain and is not directly connected to the main channel Susitna River. It is approximately 0.7 miles in length with both the mouth and head portions adjoining side channel networks. Breaching flows in this side channel result from overtopping of the head by an adjoining larger side channel. Prior to breaching, flow in the side channel is small with a series of pools remaining (Quane et al. 1985).

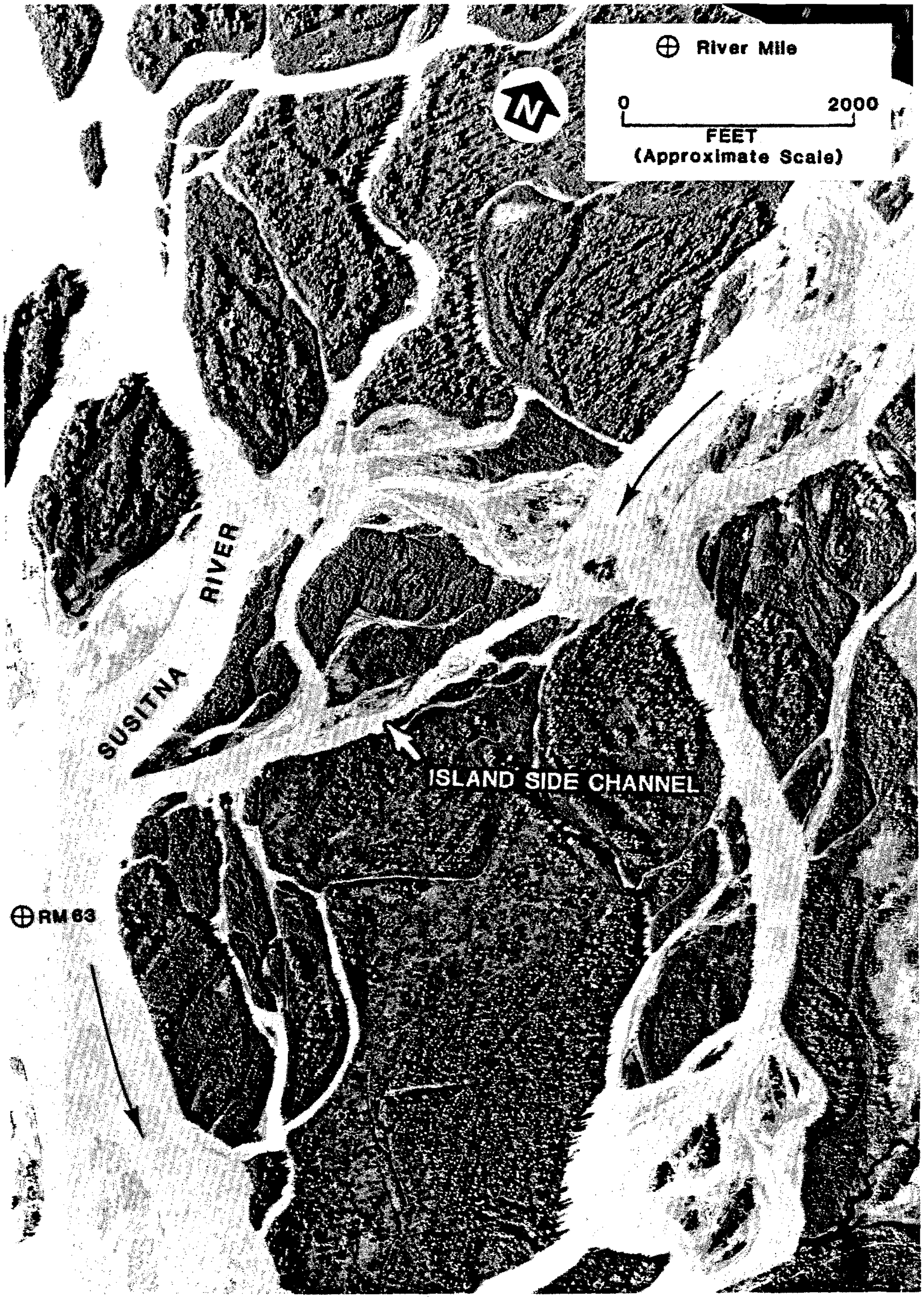
The IFG modelling site at Island Side Channel was 735 feet long and located in the lower portion of the side channel (Appendix Figure D-3). The site generally consists of a pool-riffle-pool sequence. Based on assessments by Quane et al. (1985), an area of backwater extends through the study site to a point at least 1,100 feet upstream from the mouth of the side channel at a non-breaching mainstem discharge of 35,000 cfs. During mainstem discharges of 38,000 to 66,700 cfs, the area of backwater extends throughout the study site.

The right bank of the study site is about five feet high, and the bank is steep due to the effects of erosion. The primary riparian vegetation along this bank is alder. There are two side pocket areas along this bank, which become slack water areas during higher site flows (400 cfs). In contrast, the left bank of the study site is a gently sloping depositional bank. The riparian vegetation on this bank is sparse consisting primarily of shrub willow.

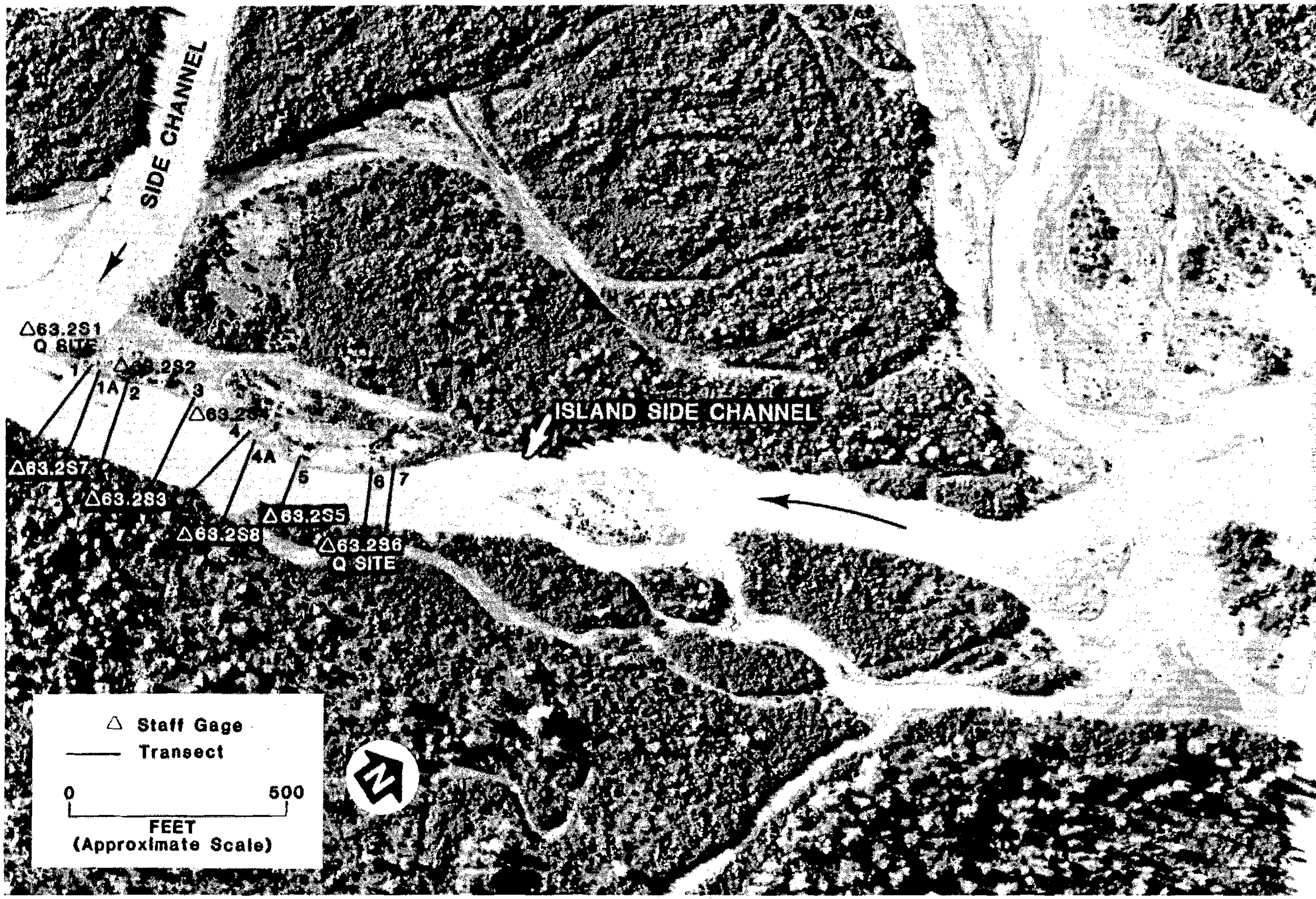
Substrate at the study site consists primarily of gravels and rubbles, with substrate changing to sand and silt in slackwater areas. The thalweg gradient of the side channel is 15.6 ft/mile (Quane et al. 1985). From an evaluation of field observations, aerial photography, and the stage/discharge relationship developed for this side channel, an initial breaching has been estimated to occur at a discharge of 34,000 cfs (Quane et al. 1985).

Based on a review of available rating curves (Appendix Figure D-4) it was determined that the hydraulics within this side channel are directly controlled by mainstem discharges exceeding 35,000 cfs (Quane et al. 1985). A side channel streamflow of 43.5 cfs has been estimated to occur at a mainstem discharge of 35,000 cfs (Quane et al. 1985).

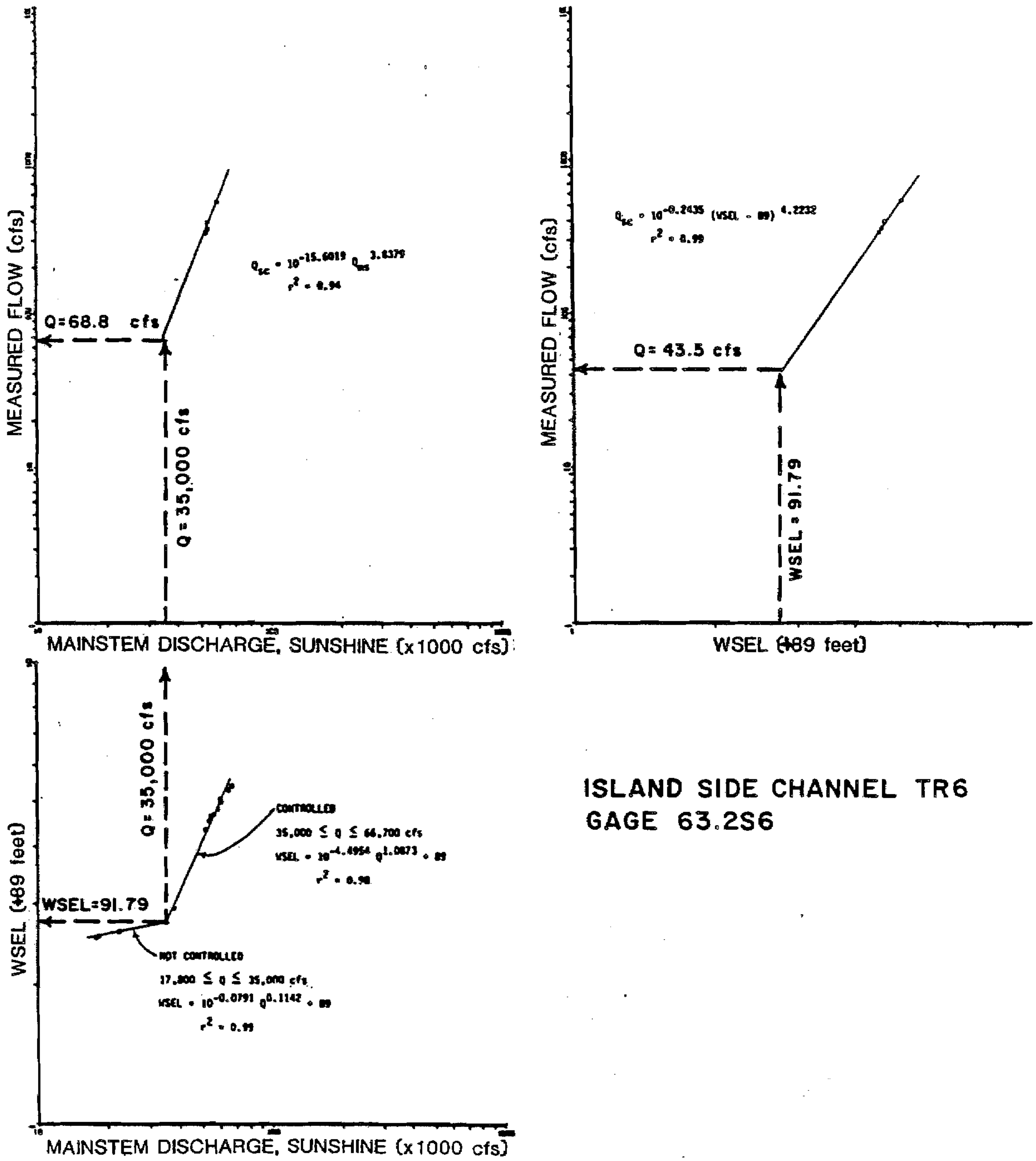
Eight cross sections were surveyed within this site during 1984 to define channel geometry (Appendix Figures D-5 & D-6). The upper two transects (5 and 6) were primarily located in pool habitat. Transects 4A and 4 primarily represent riffle habitat in the main portion of the channel. Transect 4A was placed as a partial transect originating from the right bank. It represents the larger of the two slack water areas in this reach. The four downstream most transects are primarily in pool type habitat. Transect 1A was also a partial transect, representing the smaller slack water area along the right bank.



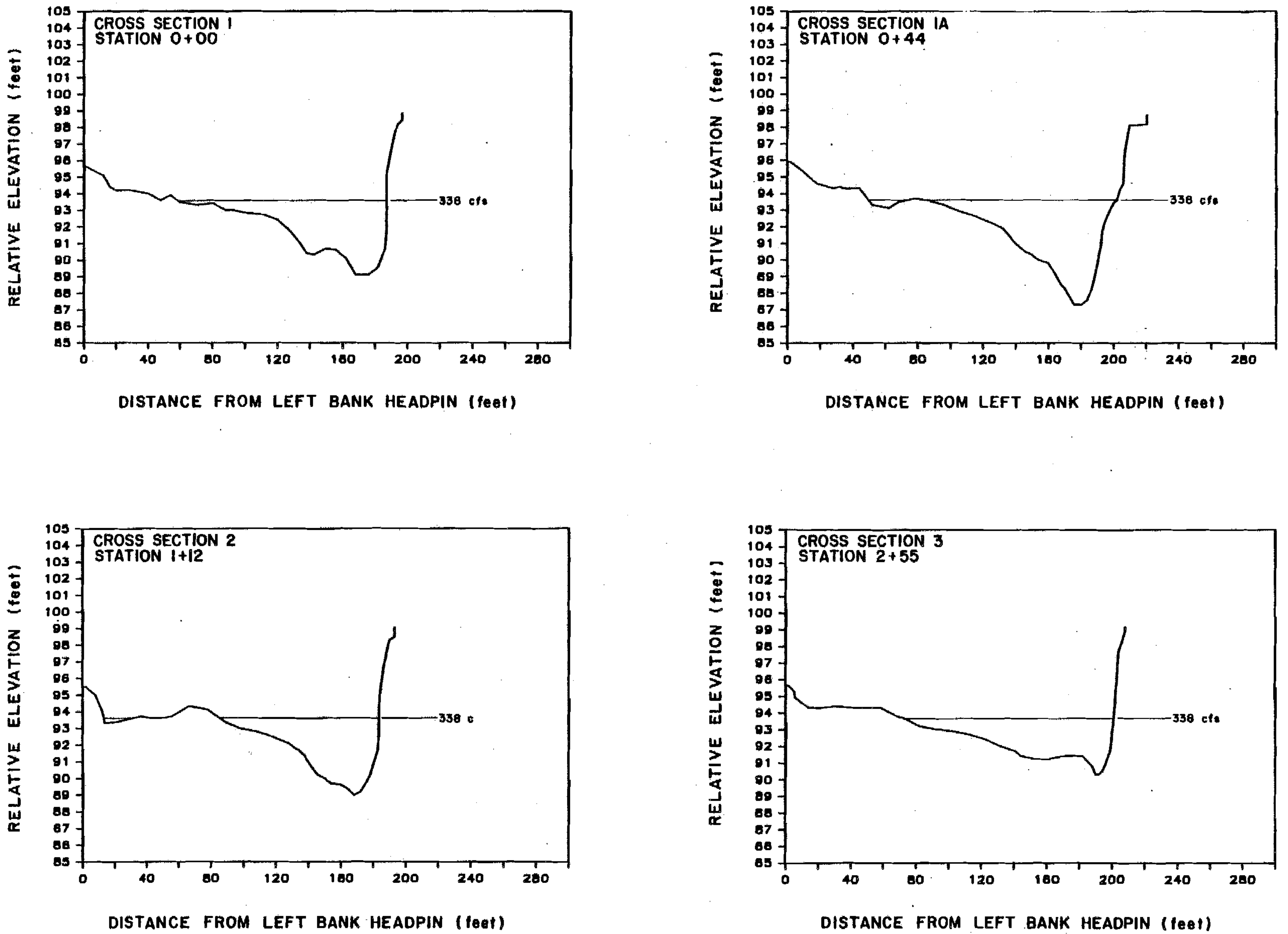
Appendix Figure D-2. Overview of Island Side Channel (RM 63.2).



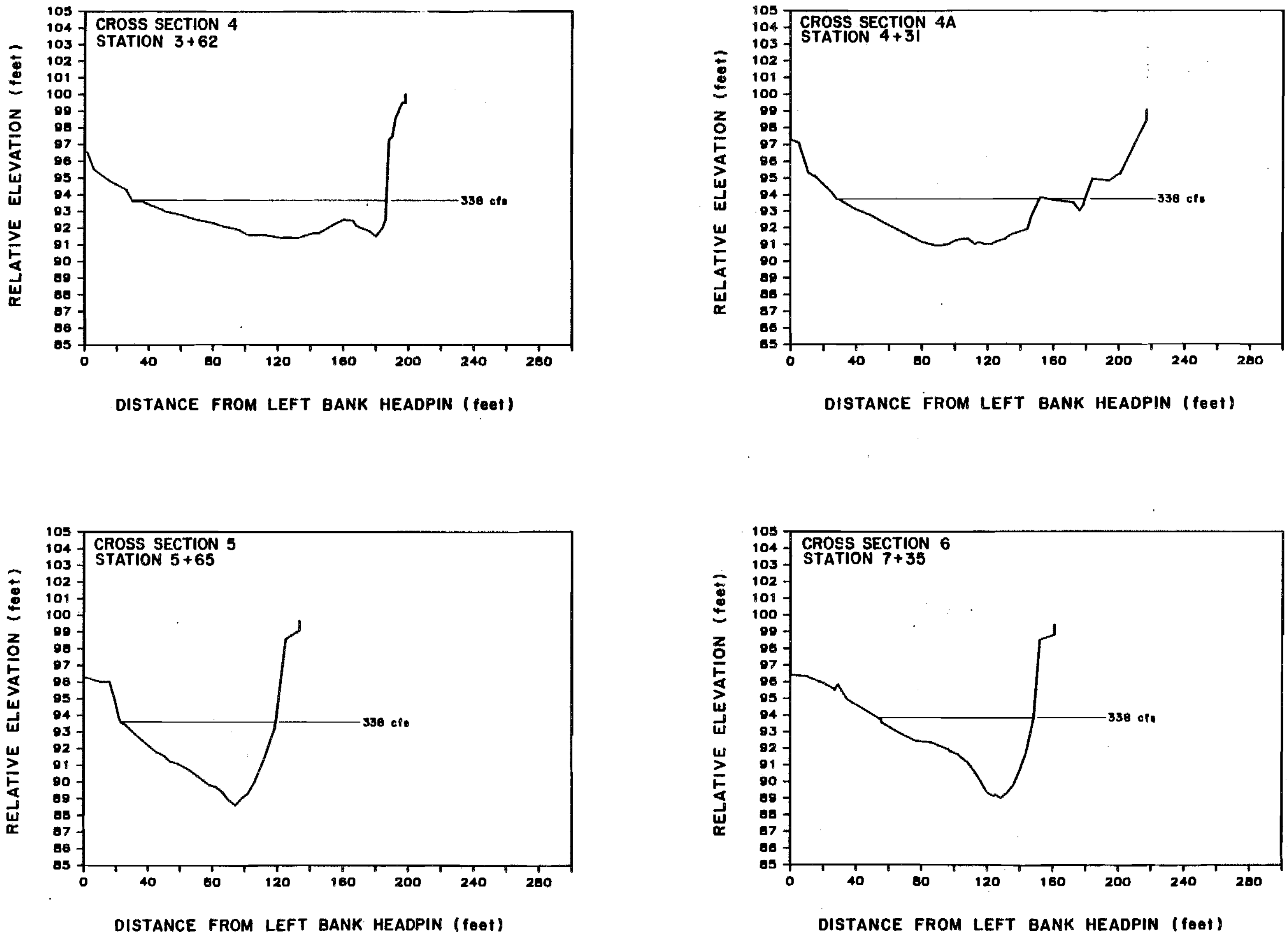
Appendix Figure D-3. Location of Island Side Channel study site (RM 63.2).



Appendix Figure D-4. Comparison of rating curves for Island Side Channel transect 6(Q site) (from Quane et. al. 1985).



Appendix Figure D-5. Cross section of transects 1, 1A, 2, and 3 at Island Side Channel (adapted from Quane et al. 1985).



Appendix Figure D-6. Cross section of transects 4, 4A, 5, and 6 at Island Side Channel (adapted from Quane et al. 1985).

Calibration

Calibration data available at the close of 1984 field season were limited to that obtained for a side channel flow of 338 cfs (56,100 cfs mainstem discharge) (Appendix Table D-4). As a result, an IFG-2 model was used to forecast instream hydraulics based on this single calibration flow. The streambed profile, stages of zero flow, and observed and predicted water surface elevations for this study reach are plotted to scale in Appendix Figure D-7.

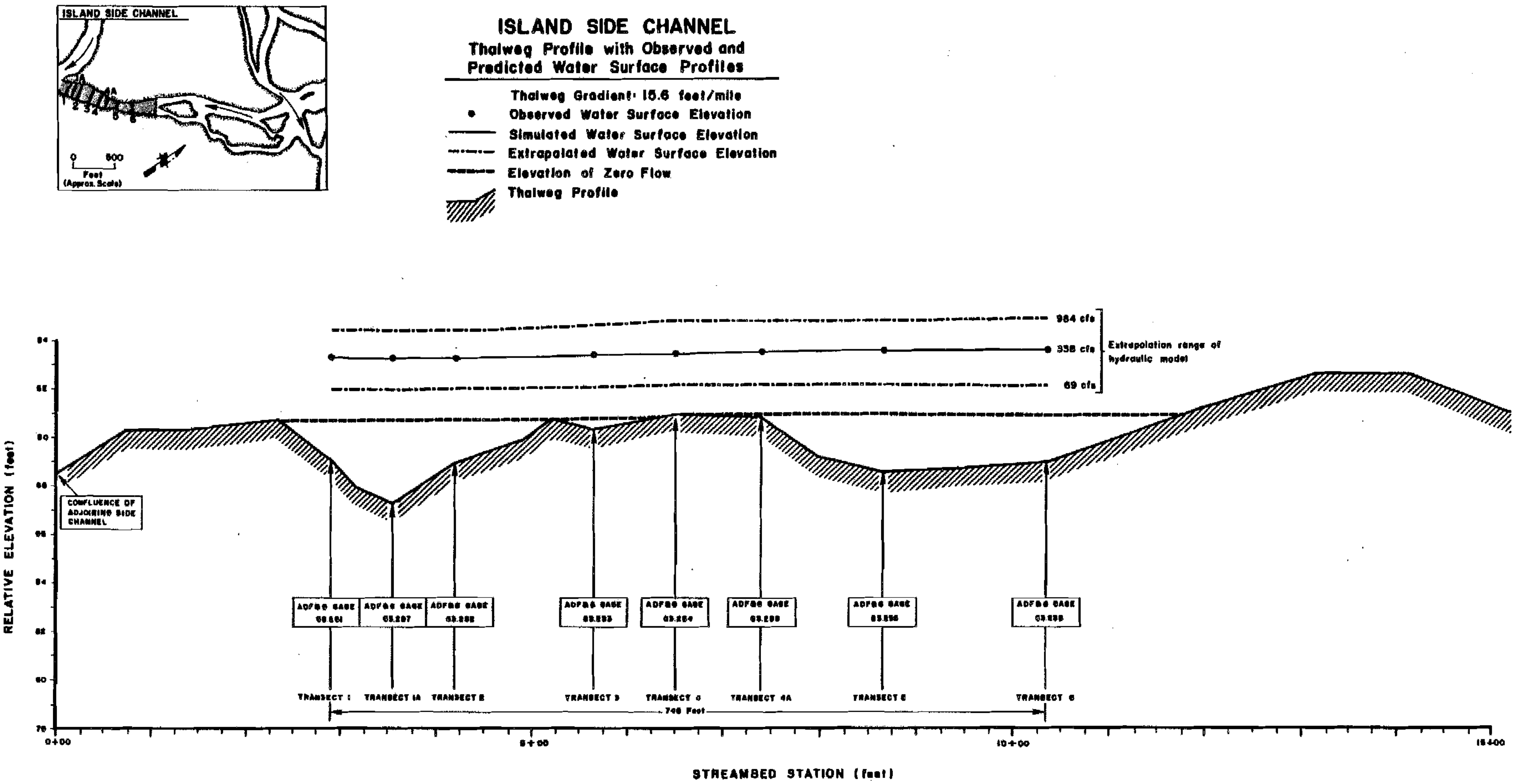
The original field water surface elevations (WSEL's) were compared to the model predicted WSEL's for the calibration flow of 338 cfs (Appendix Table D-5). At transect 1A, the original field WSEL was surveyed at 93.46 feet. In examining the WSEL's of transects 1 and 2 (93.33 and 93.41 feet in elevation respectively), it was felt that an error in surveying occurred at transect 1A. As a result, the WSEL for this transect was lowered by 0.1 feet to 93.36 feet. For all other transects, the difference between the field WSEL's and the model predicted WSEL's for the calibration flow were 0.05 ft. or less.

The two partial transects (1A and 4A) which represent slackwater habitat were extended out to the principal velocity corridor. This corridor is where most of the flow in the channel occurs. In order to complete the data sets for these two partial transects for use in the model, the associated data from transects 1 and 4 were used. At partial transect 1A, the velocities were all negative. In order to use this information in the model, these velocities were treated as positive, as it was felt that the direction of the current would not influence the utilization of this area by juvenile salmon. Only 6.5 cfs or about 2% of the water flowed through this section.

Verification

Based on the first level of verification conducted by EWT&A, the model does an excellent job of simulating hydraulics between 35,000 and 56,000 cfs mainstem discharge (69 and 416 cfs site flow) (Appendix Figure D-8). Above 56,000 cfs, however, the simulated depth and velocity distributions begin to deteriorate in quality. As a result, the model simulations were rated good between 56,000 and 64,000 cfs (416 and 692 cfs site flow), acceptable between 64,000 and 70,000 cfs (692 and 984 cfs site flow), and unacceptable above 70,000 cfs mainstem. Below 35,000 cfs mainstem, the site flow was less than 5 cfs, and the model does not simulate accurately below 5 cfs.

The velocity profiles produced by the IFG-2 hydraulic model for the two flows, 338 and 520 cfs, are compared to their associated observed velocities at two transects (Appendix Figures D-9 & D-10). The observed and predicted velocities are in good agreement for both flows at transect 1. At transect 6 there is also good agreement between the observed and predicted velocities at the 338 cfs flow. But at the 520 cfs flow, from 85 to 140 feet, there is notable differences between the observed and predicted values.



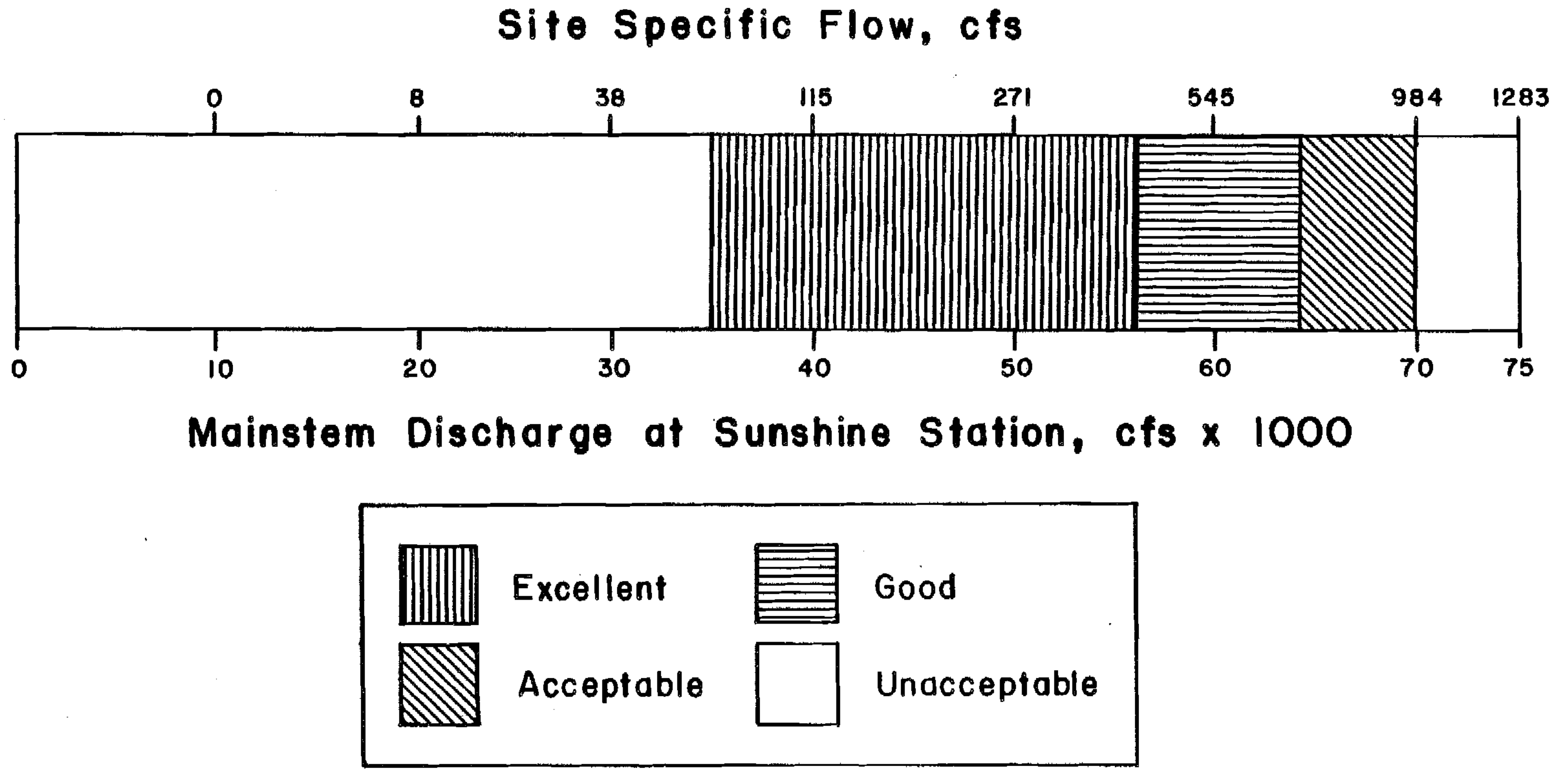
Appendix Figure D-7. Comparison of observed and predicted water surface profiles from calibrated model and surveyed thalweg profile at Island Side Channel (adapted from Quane et al. 1985).

Appendix Table D-5. Comparison of field measured and model predicted water surface elevations at the calibration flow of 338 cfs for Island Side Channel.

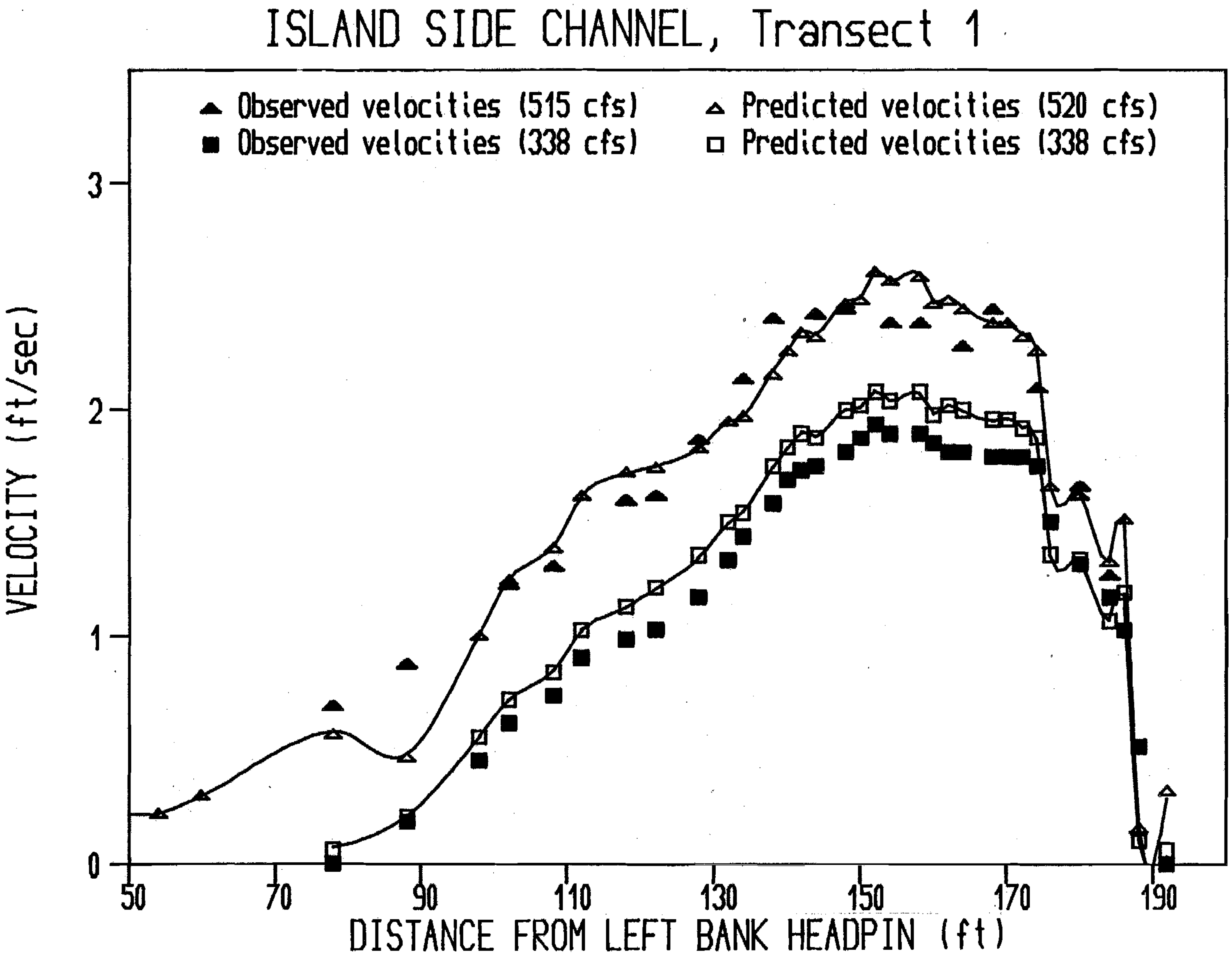
Transect	Water Surface Elevation (ft) Field	Model Predicted	Difference
1	93.33	93.33	--
1A	93.46[a]	93.36	0.00
2	93.41	93.36	0.05
3	93.44	93.40	0.04
4	93.48	93.46	0.02
4A	93.52	93.50	0.02
5	93.56	93.53	0.03
6	93.55	93.56	0.01

[a] Water surface elevation reduced by 0.1 feet to 93.36 feet.

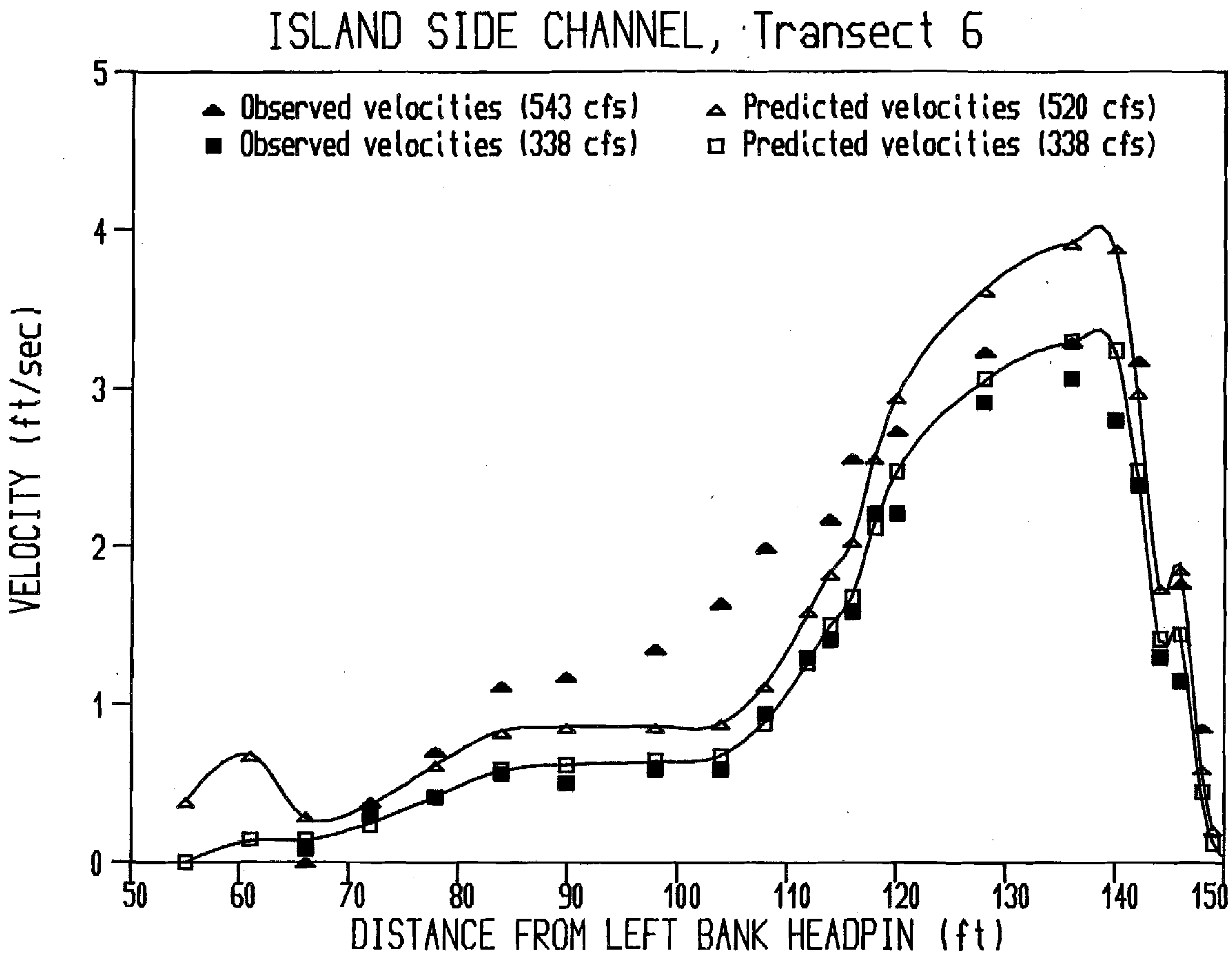
Application Range of the Calibrated Hydraulic Model at Island Side Channel RM (63.2)



Appendix Figure D-8. Application range of the calibrated hydraulic model at Island Side Channel.



Appendix Figure D-9. Comparison of observed and predicted velocities from the IFG-2 hydraulic model at Island Side Channel, using two flows at the transect 1 discharge site.



Appendix Figure D-10. Comparison of observed and predicted velocities from the IFG-2 hydraulic model at Island Side Channel, using two flows at the transect 6 discharge site.

Application

For habitat simulation modelling purposes, the hydraulic simulation model developed for Island Side Channel can simulate channel flows in the mainstem discharge range of 35,000 to 70,000 cfs.

Mainstem West Bank Side Channel (RM 74.4)

Site Description

Mainstem West Bank Side Channel is located on the west bank of the main channel Susitna River at river mile 74.4 (Appendix Figure D-12). It is approximately 2.2 miles in length. The mouth and two heads of this side channel connect directly with the Susitna River.

The IFG modelling site in the lower portion of this side channel was 930 feet long (Appendix Figure D-11). The study site is confined on the west by a steep bank and on the east by a well vegetated island. The portion of the side channel upstream of the study site is separated from the mainstem by a network of side channels and well vegetated islands. A minor channel is located within the study site on the east bank of the side channel. During nonbreached conditions, the side channel primarily consists of a series of pools and small riffles. Groundwater provides the major contribution of flow prior to breaching of the head (Quane et al. 1985).

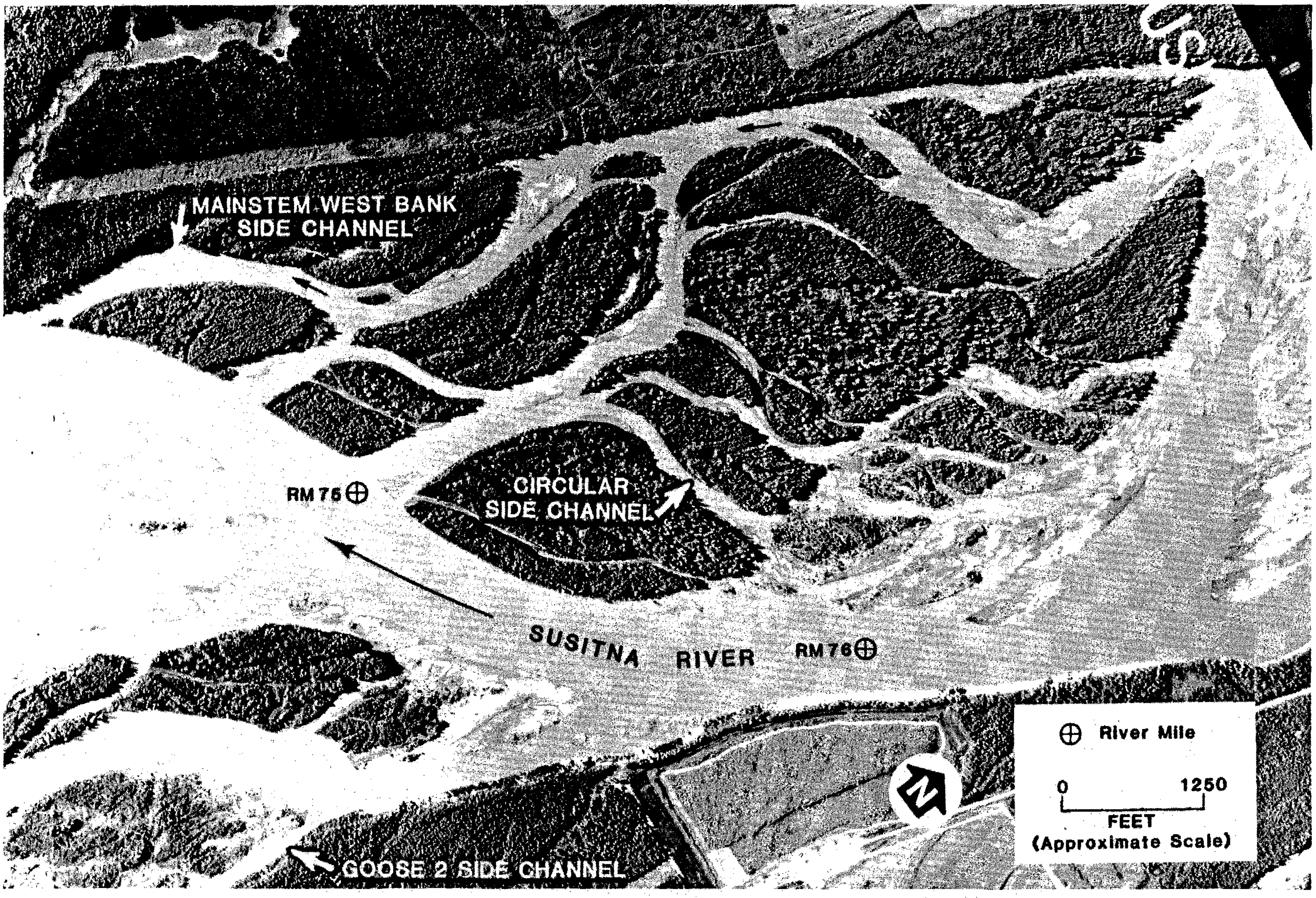
The two heads are both located approximately 1.5 miles upstream of the study site (Quane et al. 1985). Breaching of Mainstem West Bank Side Channel occurs when the mainstem overtops either of the two side channel heads. The side channel has been estimated to be initially breached at a mainstem discharge of 19,000 cfs (Quane et al. 1985).

Based on a review by Quane et al. (1985) of the stage versus mainstem discharge rating curve (Appendix Figure D-13), it has been determined that at mainstem discharges greater than 19,600 cfs, the hydraulics within this side channel are directly controlled by mainstem discharge. The site flow that occurs at 19,600 cfs was measured to be 5.7 cfs.

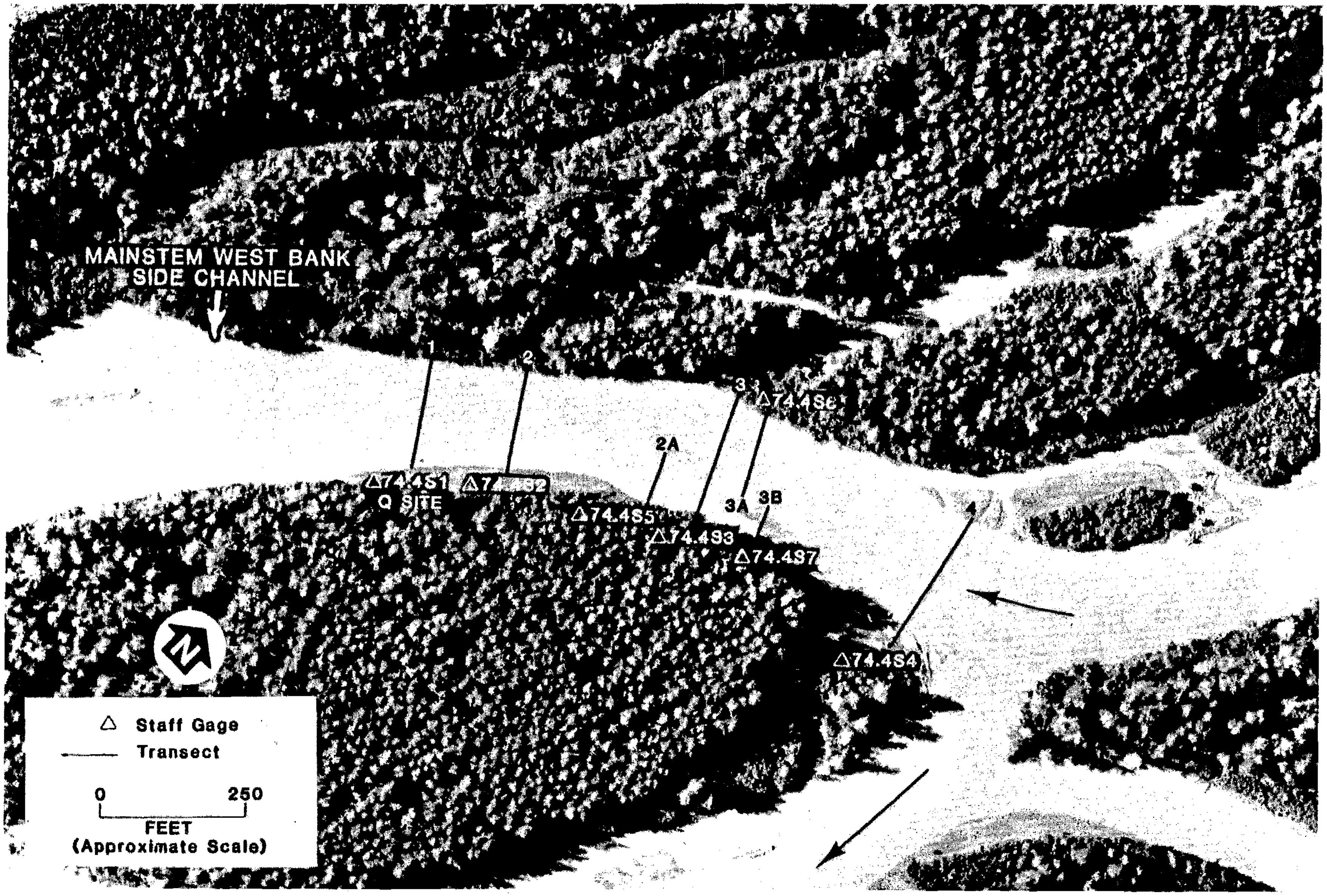
Hydraulic information was gathered from five transects (1, 2, 3, 3A, 4) in the main channel and three transects (2A, 3 in part, 3B) in a minor side channel of this study site (Appendix Figure D-12). The corresponding cross sections are presented in Appendix Figure D-14 & D-15.

The two lower transects (1 & 2) bisect primarily pool and run habitat, the banks are gently sloping on both sides. On the upper three transects (3, 3A, & 4) the left bank consisted of an erosional bank and was primarily bordered by alder. For modelling purposes, transects 3 and 3A were ended on a finger-like gravel bar on the right bank which longitudinally bisected the site with the main channel on the left and a minor channel on the right which was free flowing at high flows, backwater at median flows, and dry at low flows. This bar began downstream from transect 4 and ended between transects 2 and 3. Transect 3A was placed in order to obtain a better representation of the slow water debris-strewn habitat along the left bank. The main channel habitat of these three transects (3, 3A, & 4) consisted of run and riffle habitat.

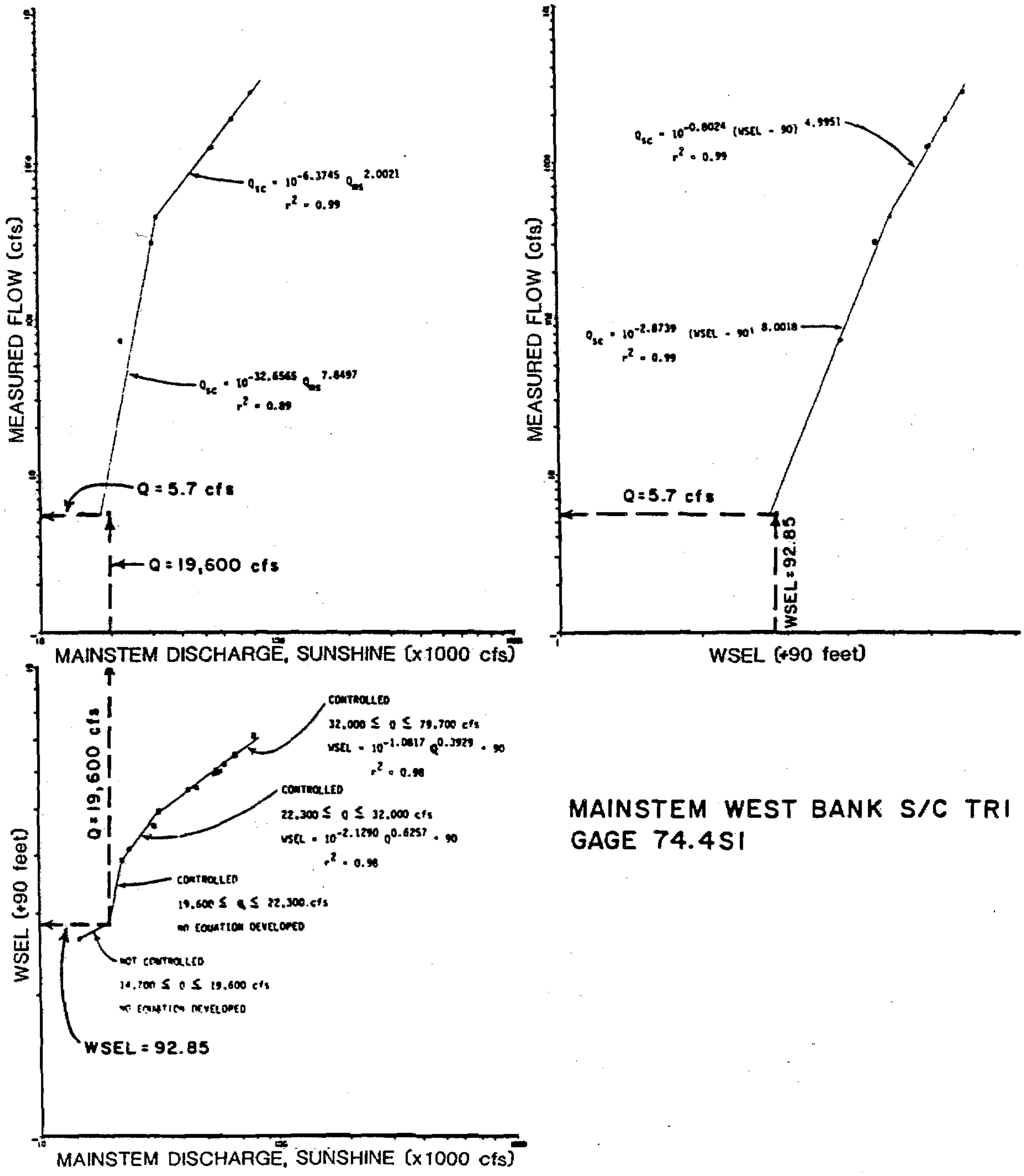
Substrate at this site primarily consisted of rubble and cobble. The thalweg gradient of the side channel is approximately 12.3 ft/mile (Quane et al. 1985).



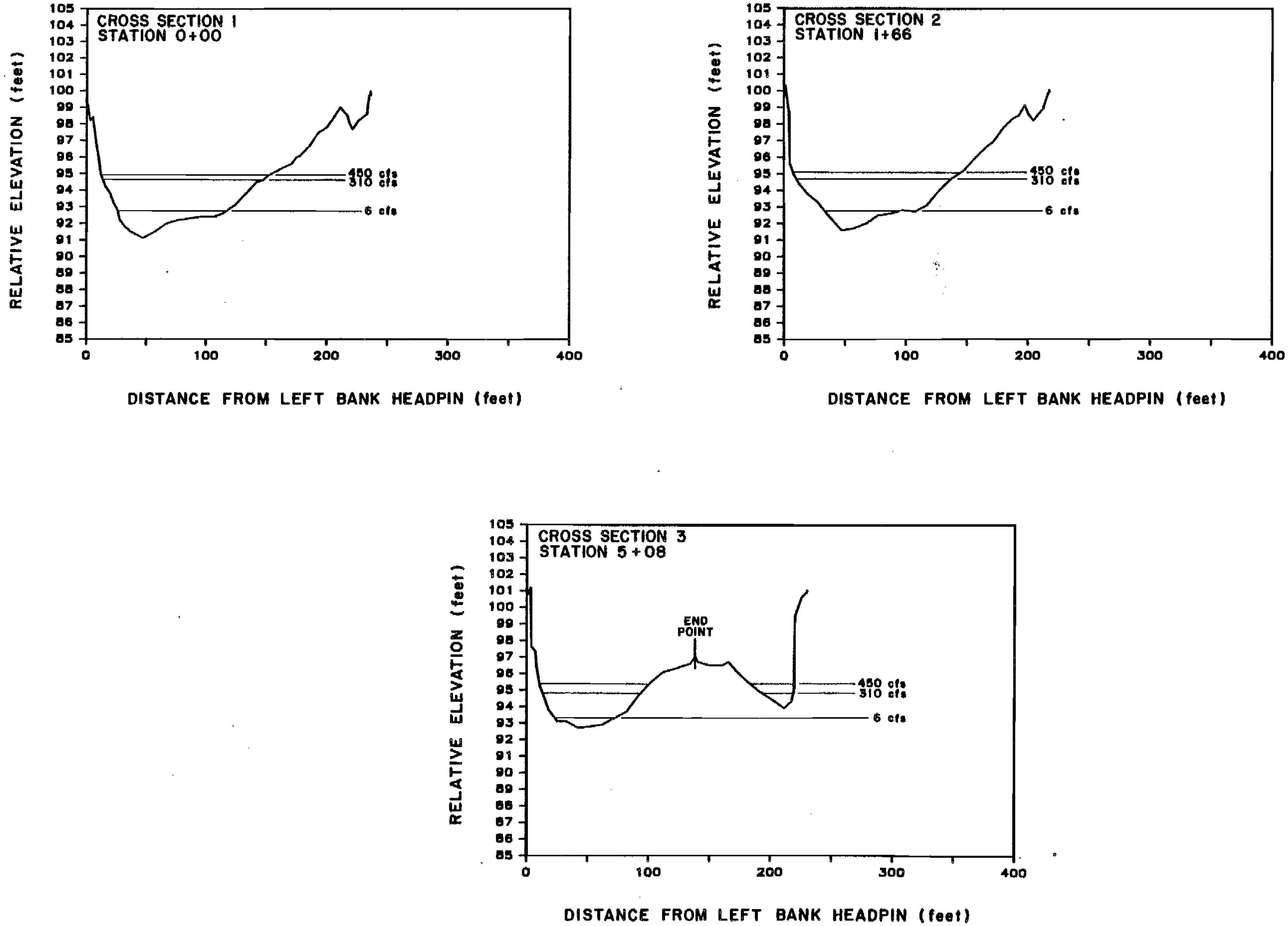
Appendix Figure D-11. Overview of Mainstem West Bank Side Channel (RM 74.4).



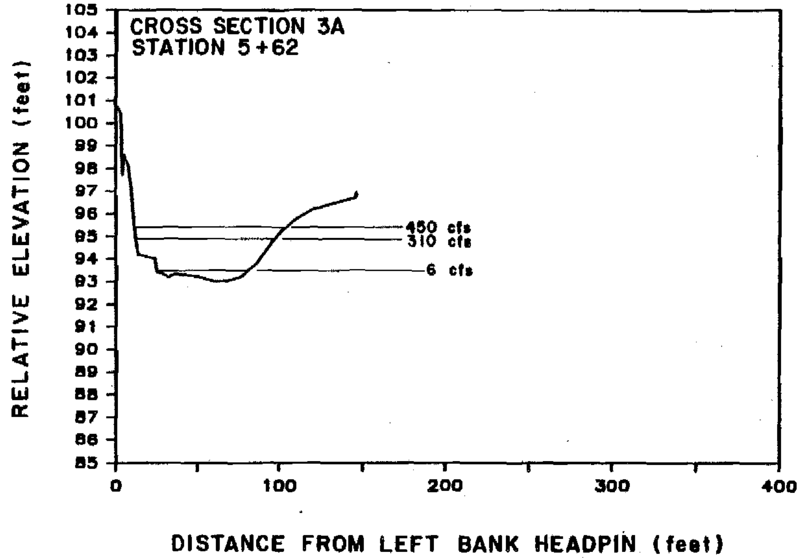
Appendix Figure D-12. Location of Mainstem West Bank Side Channel study site (RM 74.4).

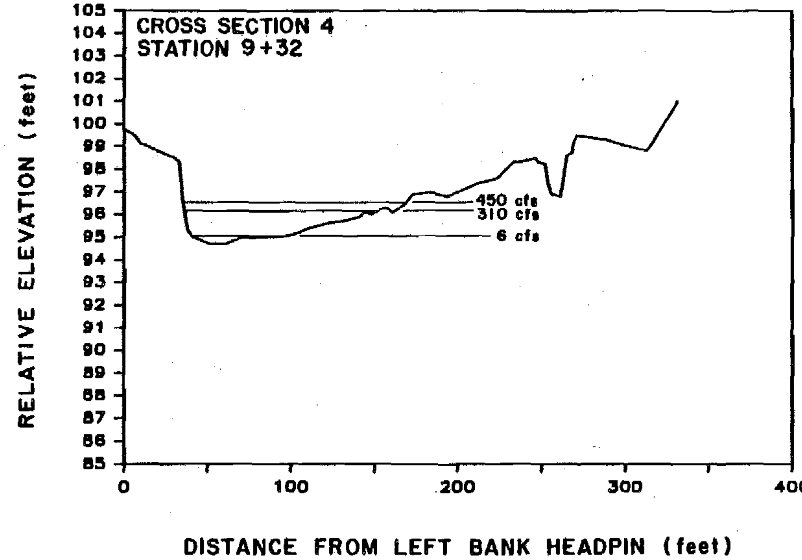


Appendix Figure D-13. Comparison of rating curves for Mainstem West Bank Side Channel transect 1(Q site) (from Quane et. al. 1985).



Appendix Figure D-14. Cross section of transects 1, 2, and 3 at Mainstem West Bank Side Channel (adapted from Quane et al. 1985).





Appendix Figure D-15. Cross section of transects 3A and 4 at Mainstem West Bank Side Channel (adapted from Quane et al. 1985).

Calibration

Hydraulic data were collected for model calibration at three site flows: 6, 310, and 450 cfs, the corresponding mean daily discharges for the Susitna River were 19,600 cfs, 30,500 cfs, and 32,000 cfs, respectively (Appendix Table D-4). Based on these data, an IFG-4 model was used to forecast instream hydraulics. The streambed profile, stage of zero flow, and observed and predicted water surface elevations for the study reach are plotted to scale in Appendix Figure D-16. All three data sets were used to predict hydraulic information for side channel flows of 6 to 2,431 cfs (mainstem discharges of 18,000 to 75,000 cfs).

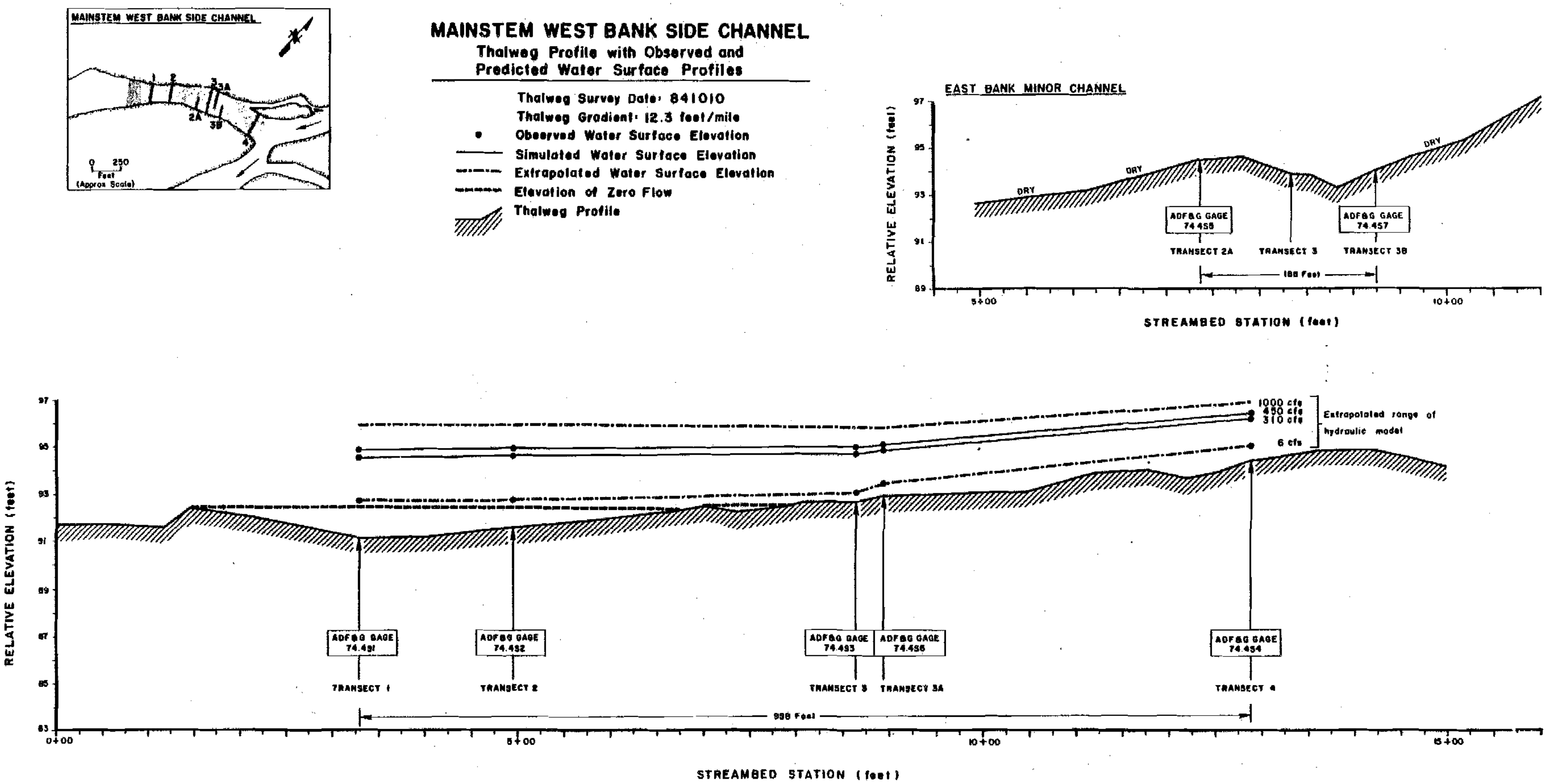
To evaluate the performance of the hydraulic model, observed and predicted water surface elevations, discharges, and velocity adjustment factors were compared (Appendix Table D-6). The 15 sets of observed and predicted WSEL's for the five transects of the 3 calibration flows were all within ± 0.02 ft. of each other except for 2 sets which were within ± 0.10 feet of each other. All the observed and predicted discharges were within 10% of each other and all velocity adjustment factors were within the good range of 0.9 to 1.1. Additionally, the stage information of the model was compared to available rating curves (Appendix Figure D-13).

Transect (3A) was placed about 60 feet upstream from transect 3 to represent the slackwater debris area along the left bank of the upper portion of this study site. In order to complete this data set for transect 3A for use in the model, the velocity information from transect 3 for the two site flows of 310 and 450 cfs were incorporated into transect 3A cross sectional area and water surface elevations. After incorporating this information into transect 3A, the discharge for the 310 cfs site flow, however, did not fall within 10% of the respective discharge that was calculated at the discharge transect. As a result, velocities for the 310 cfs site flow were adjusted upward by 17%.

At the low flow measurement of 6 cfs, the velocity measurements were made completely across transect 3A. The discharge calculated at this site was 18% higher than calculated at the discharge transect. The velocities at this transect were therefore reduced by 15%.

At transect 4 the water surface elevations were not similar across the transect at the 6 cfs flow measurement. Therefore, a weighted average water surface elevation was calculated for this transect.

At higher site flows several small side channel/backwater areas existed which were not represented in the IFG-4 analysis. In order to evaluate this potential habitat several transects were placed across one of these areas, weighted usable area was to be determined by hand calculations. However, this was not done because it was determined that this side channel habitat was so small compared to the total area being hydraulically modelled that it would not affect the total weighted usable area response.



Appendix Figure D-16. Comparison of observed and predicted water surface profiles from calibrated model and surveyed thalweg at Mainstem West Bank Side Channel (adapted from Quane et al. 1985).

Appendix Table D-6. Comparison between observed and predicted water surface elevations, discharges, and velocities for 1984 Mainstem West Bank side channel hydraulic model.

Streambed Station (ft)	Water Surface Elevation Observed (ft)	Water Surface Elevation Predicted (ft)	Discharge Observed (cfs)	Discharge Predicted (cfs)	Velocity Adjustment Factor
0+00	92.85	92.86	6.0	6.3	1.005
1+66	92.86	92.87	6.9	7.2	.991
5+08	93.25	93.26	6.9	7.2	1.004
5+62	93.51	93.52	5.8	6.1	.996
9+32	95.06	95.06	5.1	5.4	1.013
			Qo = 6.0	Qp = 6.0	
0+00	94.62	94.61	312.8	315.7	1.030
1+66	94.64	94.64	301.3	307.5	1.024
5+08	94.85	94.86	306.4	318.2	1.007
5+62	94.93	94.99	292.8	288.6	.993
			Qo = 301.0	Qp = 308.0	
0+00	94.97	94.98	460.4	457.0	.974
1+66	95.00	95.00	446.1	438.2	.975
5+08	95.19	95.18	470.6	455.2	.994
5+62	95.29	95.23	409.6	415.3	1.001
9+32	96.54	96.45	473.9	451.9	.969
			Qo = 452.0	Qp = 444.0	

Qo is the mean observed calibration discharge.

Qp is the mean predicted calibration discharge.

Verification

Based on the first level of verification by EWT&A, the model does an excellent job of simulating channel hydraulics between 18,000 and 21,000 cfs mainstem discharge (6 and 20 cfs site flow) (Appendix Figure D-17). Above 21,000 cfs, simulated water surface profiles deviate somewhat from field observations. As a result, the model was rated good between 21,000 and 28,000 cfs mainstem discharge (20 and 200 cfs site flow), and between 28,000 and 34,000 cfs mainstem discharge (200 and 500 cfs site flow) the model again was rated excellent. Two calibration data sets were collected within this range. Above 34,000 cfs, the quality of the hydraulic simulations begins to deteriorate as the slope of the site flow versus WSEL relationship flattens as a result of channel geometry. The deviation between the regression line developed within the model and that of the rating curve developed independently for the site increases with discharge until the model simulations are no longer acceptable. The model simulations were rated good between 34,000 and 41,000 cfs (500 and 727 cfs site flow), acceptable between 41,000 and 48,000 cfs (727 and 1000 cfs site flow), and unacceptable above 48,000 cfs mainstem discharge.

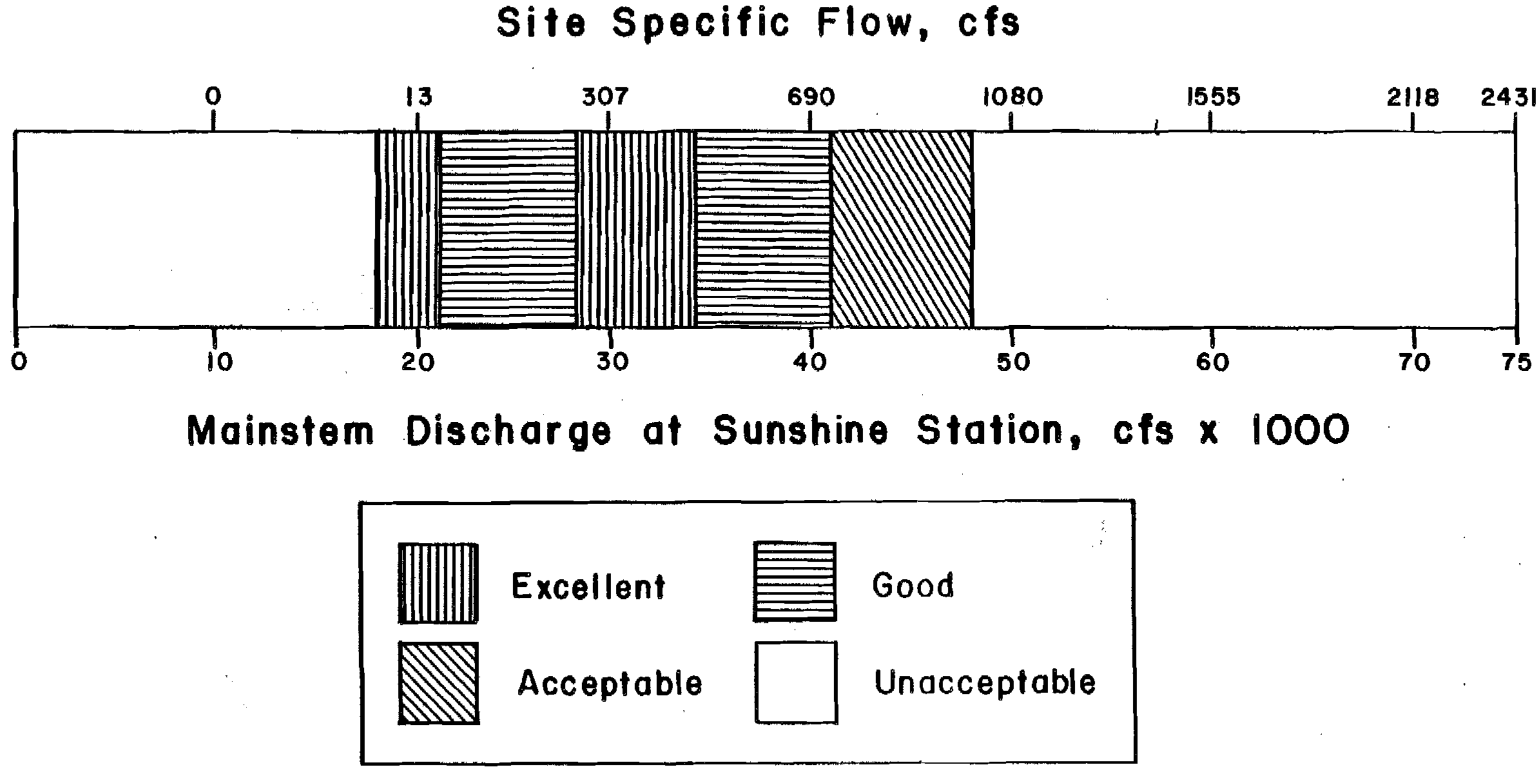
At the second level of verification there is good agreement between the predicted and observed values of depth and velocity (Appendix Figure D-18). At the higher velocities (> 2.5 ft/sec) they begin to spread apart though. In Appendix Table D-7 the results of the statistical tests are shown. There is again good agreement shown between the observed and predicted values for both velocity and depth. The index of agreement (d) is almost one, the total root mean square error (RMSE) is largely composed of the unsystematic RMSE, and the y-intercept (a) is close to zero with a slope (b) of almost one.

Application

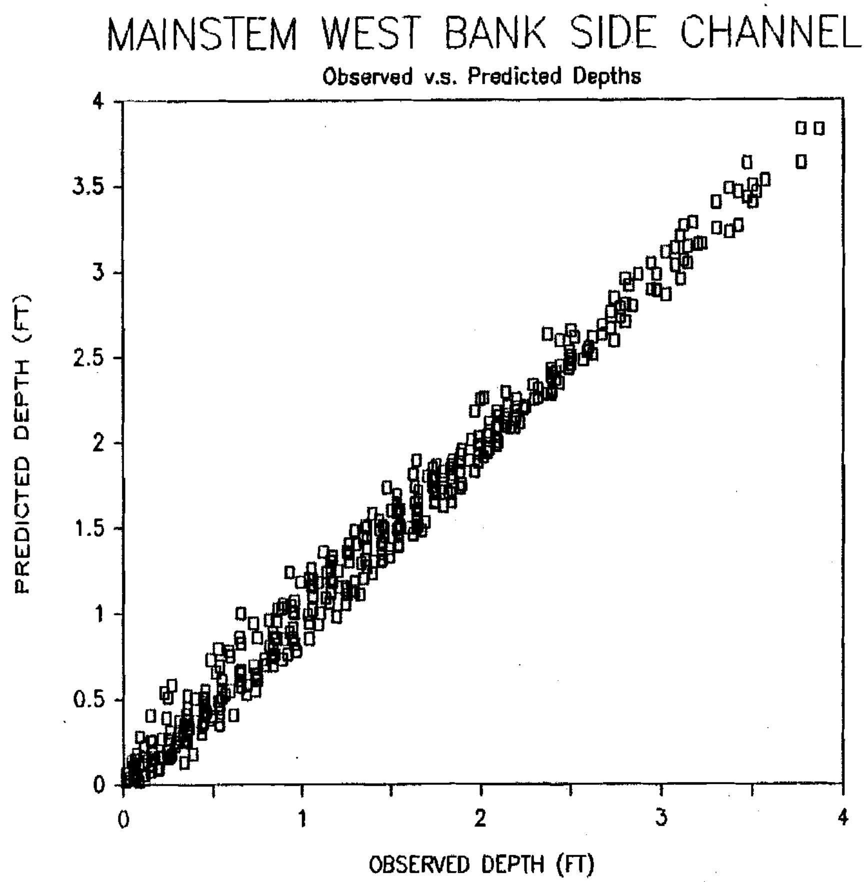
For habitat simulation modelling purposes, the hydraulic simulation model developed for Mainstem West Bank Side Channel can simulate channel flows in the mainstem discharge range of 18,000 to 48,000 cfs.

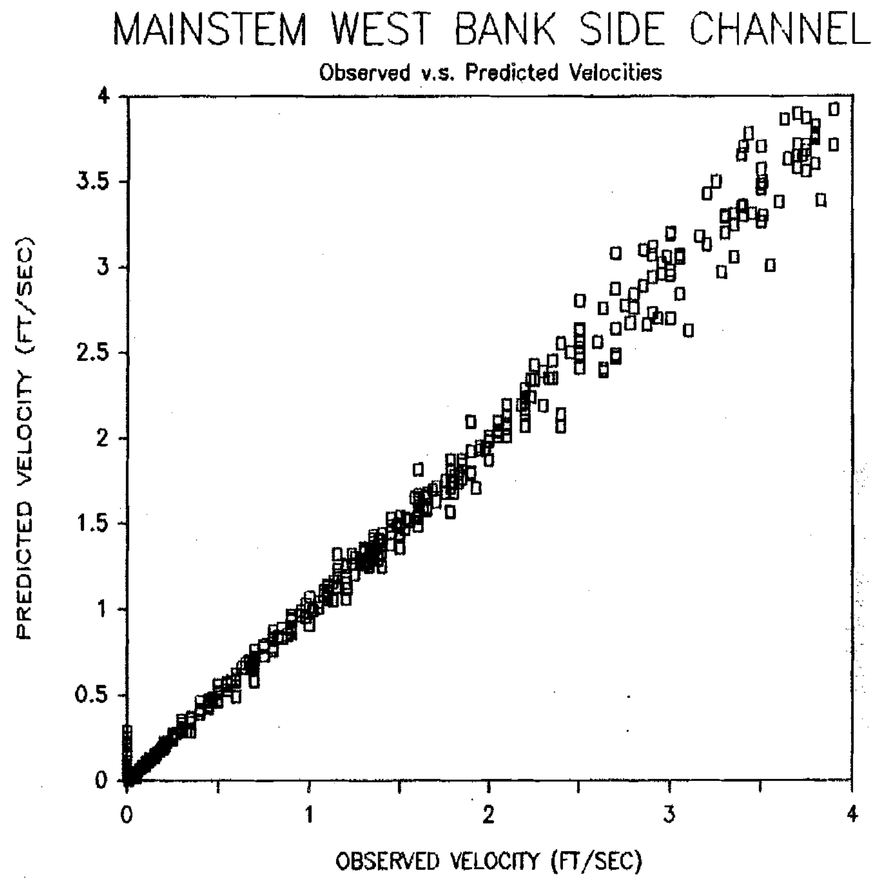
Application Range of the Calibrated Hydraulic Model at Mainstem West Bank

RM (74.4)



Appendix Figure D-17. Application range of the calibrated hydraulic model at Mainstem West Bank Side Channel.





Appendix Figure D-18. Scatterplots of observed and predicted depths and velocities from the calibrated IFG-4 hydraulic model at Mainstem West Bank Side Channel.

Appendix Table D-7. The statistical results used to evaluate the predictive ability of the four lower river IFG-4 hydraulic models.

Side Channel Site		N	$\bar{O}$	$\bar{P}$	Std. O	Std. P	a	b	Total RMSE	Syst RMSE	Unst RMSE	d
Mainstem	Depth	476	1.3813	1.3802	0.8602	0.8552	0.0121	0.9959	0.1013	0.0	0.1005	0.9969
West Bank	Velocity	476	1.4305	1.4367	1.5643	1.5641	0.0114	0.9910	0.1123	0.0	0.1122	0.9979
Circular	Depth	432	1.2200	1.2153	0.6147	0.6048	0.0244	0.9761	0.1392	0.0173	0.1378	0.9919
	Velocity	432	0.9080	0.9091	0.5001	0.4898	0.0127	0.9872	0.0499	0.0	0.049	0.9987
Sunset	Depth	666	1.6615	1.6580	1.8477	1.8406	0.0078	0.9935	0.1305	0.0	.1300	0.9976
	Velocity	666	1.3182	1.3230	0.8626	0.8513	0.0146	0.9926	0.0388	0.0	.0374	0.9995
Trapper	Depth	406	0.9417	0.9417	0.4027	0.3977	0.0128	0.9863	0.0773	0.0	0.0768	0.9962
Creek	Velocity	406	1.0642	1.0712	1.0583	1.0501	0.0136	0.9937	0.0718	0.0	0.0714	0.9987

N = number of observations.

O, P = mean of observed and predicted values.

Std. O, Std. P = standard deviation of observed and predicted values.

a, b = y-intercept and slope of least squares regression between O and P.

RMSE = root mean square error: total, systematic, and unsystematic.

d = index of agreement.

For the use and a discussion of these statistics see Wilmott (1981).

Circular Side Channel (RM 75.3)

Site Description

Circular Side Channel is located on the west bank of the Susitna River at river mile 75.3 (Appendix Figure D-19). It is approximately 0.9 miles long and is separated from the mainstem by a large well vegetated island. An extensive backwater area occurs in the lower portion of the study site. A network of small channels at the head provide mainstem flow into the site after breaching. Prior to breaching, flow is greatly reduced and the channel is composed of large pools connected by small riffles (Quane et al. 1985).

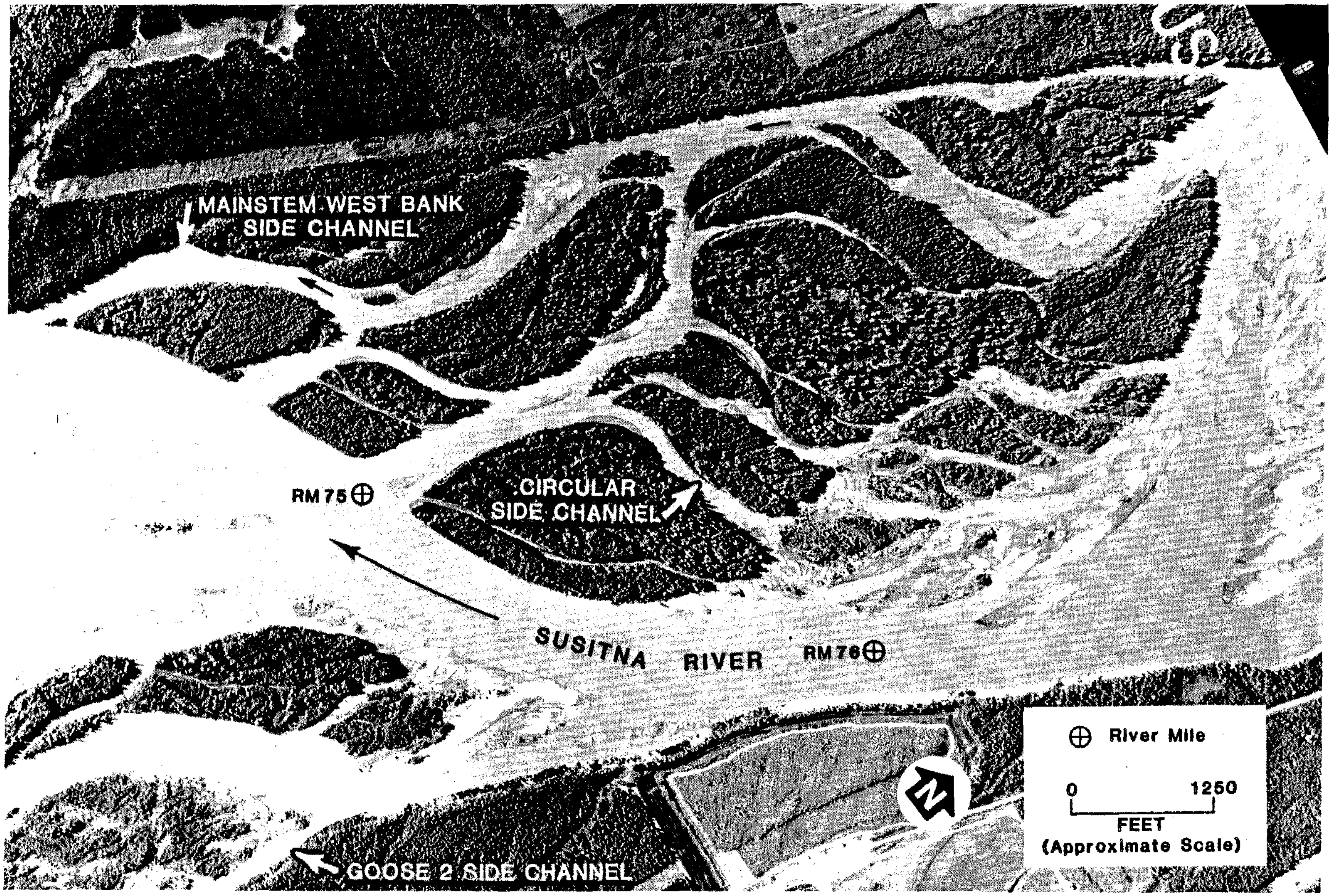
Breaching of Circular Side Channel has been estimated to occur at a mainstem discharge of 36,000 cfs (Quane et al. 1985). It has been determined that the hydraulics within this side channel are governed by mainstem discharge at mainstem discharges exceeding 36,000 cfs. The site flow that occurs at this mainstem discharge is estimated to be 26.8 cfs (Appendix Figure D-20) (Quane et al. 1985).

Based on assessments by Quane et al. (1985), backwater does not occur during non-breaching mainstem discharges. At breaching mainstem discharges of 55,200 to 66,700 cfs, however, an area of backwater was found to occur upstream to a point approximately 90 feet above transect 2A. At a mainstem discharge of 42,500 cfs, backwater has been determined to extend slightly past transect 2.

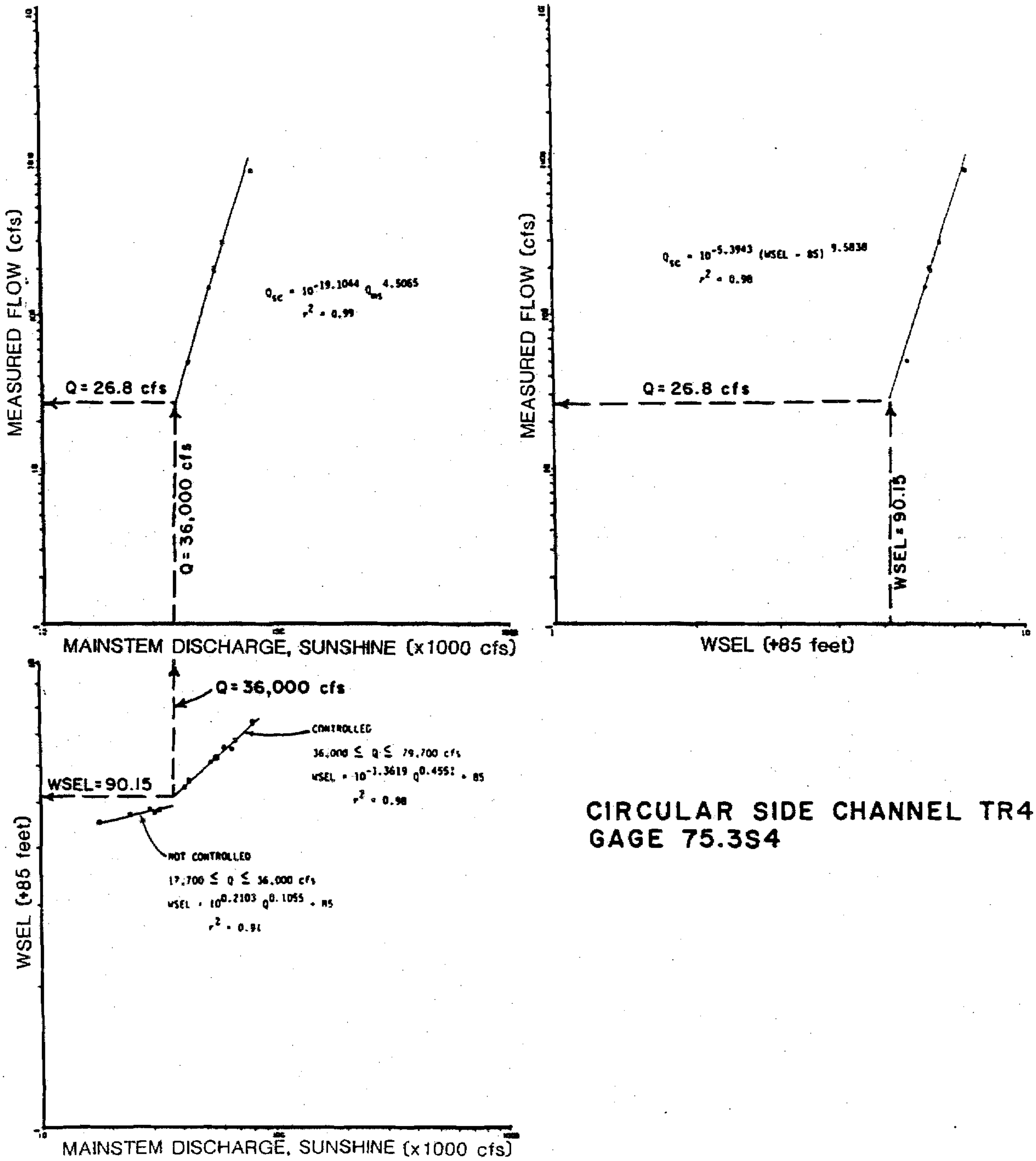
The IFG modelling study site in the upper half of Circular Side Channel is 820 feet (Appendix Figure D-21). The thalweg gradient of this study site is 14.3 ft/mile (Quane et al. 1985). Riparian vegetation along both banks consists mostly of alder and cottonwood. Substrate within the lower reaches of the Circular Side Channel site consisted predominately of silts, sands, and gravels changing to rubbles at the upper reaches. Hydraulic information was gathered from six transects established at this study site (Appendix Figure D-21). The channel is relatively straight and the cross sections are generally box shaped in configuration (Appendix Figures D-22 & D-23). Transects 1 and 2 were located in shallow backwater. Transect 2A was located in a transitional area which became run habitat at higher flows. Transect 3 was located in riffle habitat. Transect 4 was located in run habitat at the end of a pool, transect 5 bisected this pool.

Calibration

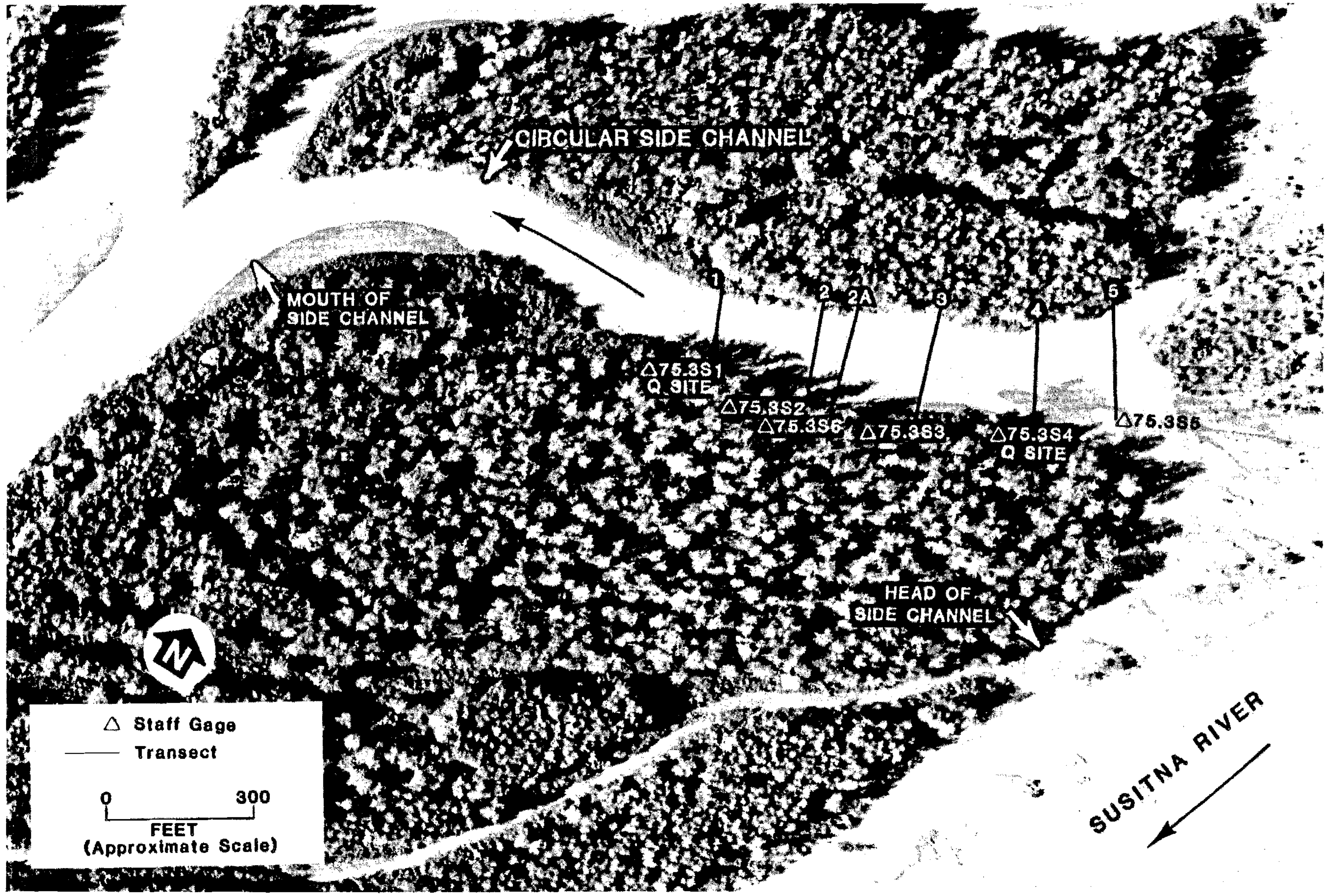
Hydraulic data were collected at two calibration flows: 50 and 204 cfs (Appendix Table D-4). Mean daily discharges for the Susitna River on the dates that calibration data were collected at the Circular Side Channel study site were 42,500 and 55,200 cfs. An IFG-4 model was used to forecast instream hydraulics based on these two calibration flows. The streambed profile, stages of zero flow, and observed and predicted water surface elevations for the study reach are plotted to scale in Appendix Figure D-24. The two data sets were used to predict hydraulic information from side channel flows of 6 to 733 cfs (mainstem discharges of 25,500 to 75,000 cfs).



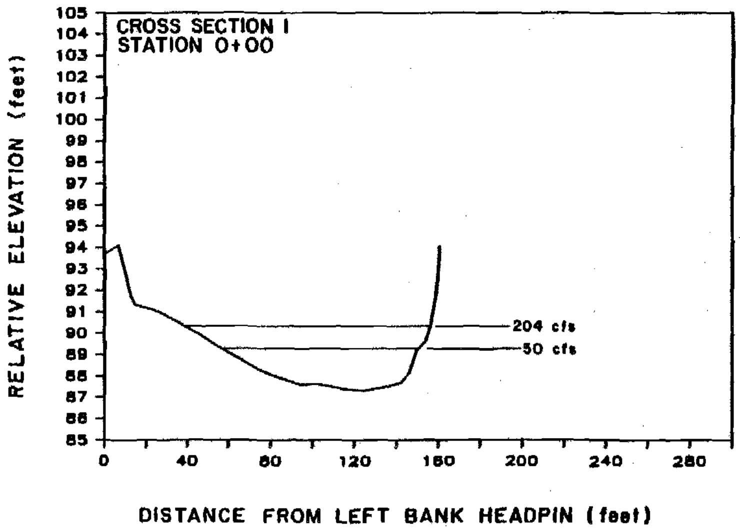
Appendix Figure D-19. Overview of Circular Side Channel (RM 75.3).

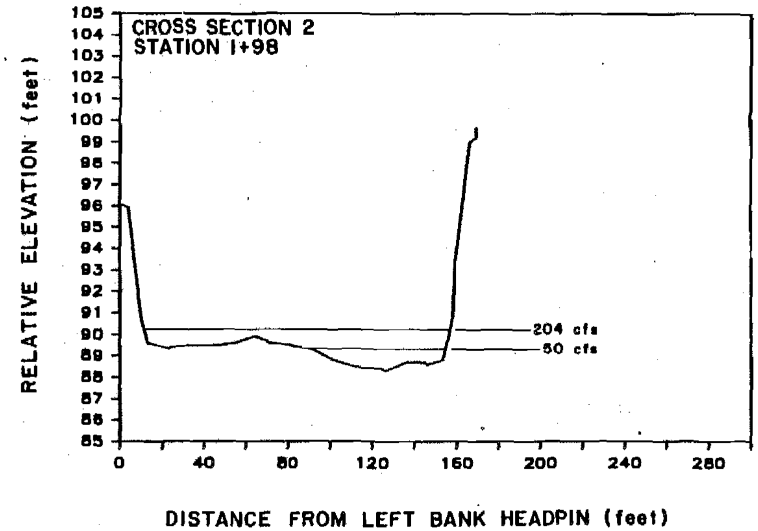


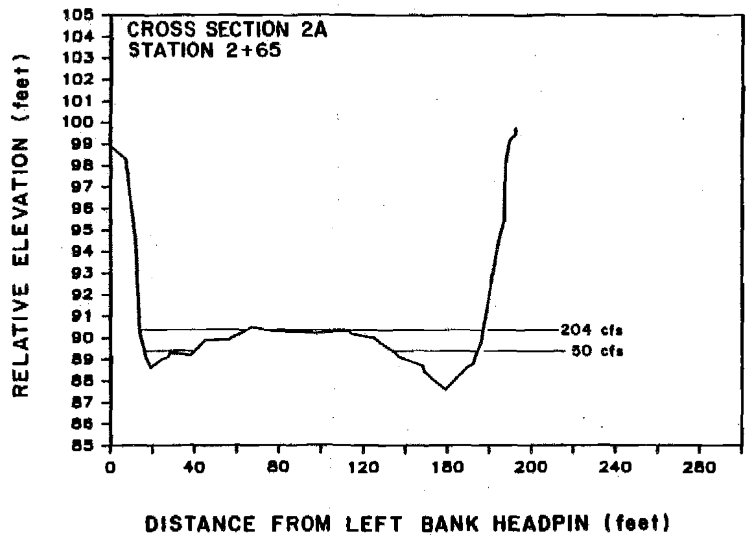
Appendix Figure D-20. Comparison of rating curves for Circular Side Channel Transect 4 (from Quane et. al. 1985).



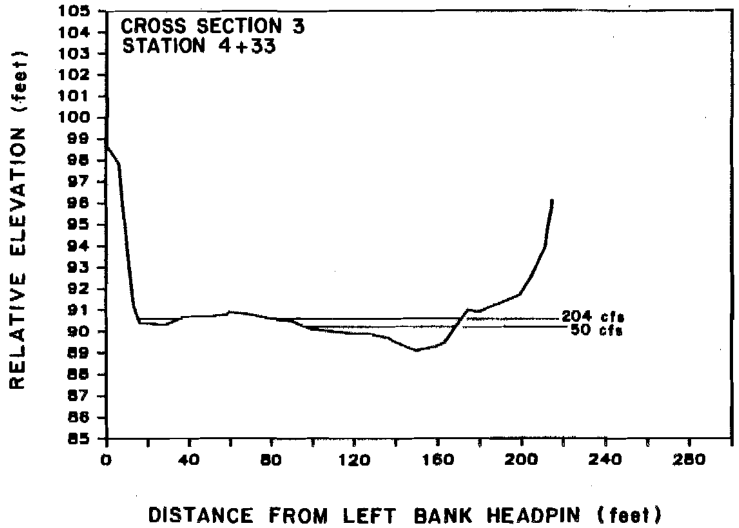
Appendix Figure D-21. Location of Circular Side Channel study site (RM 75.3).

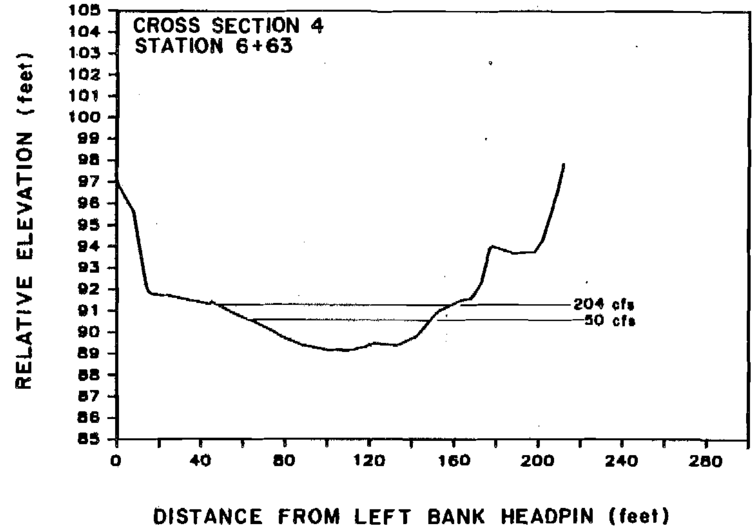


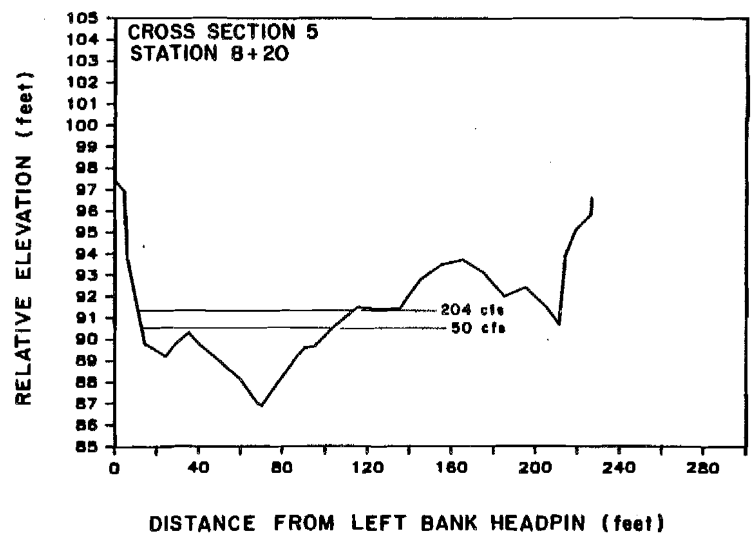




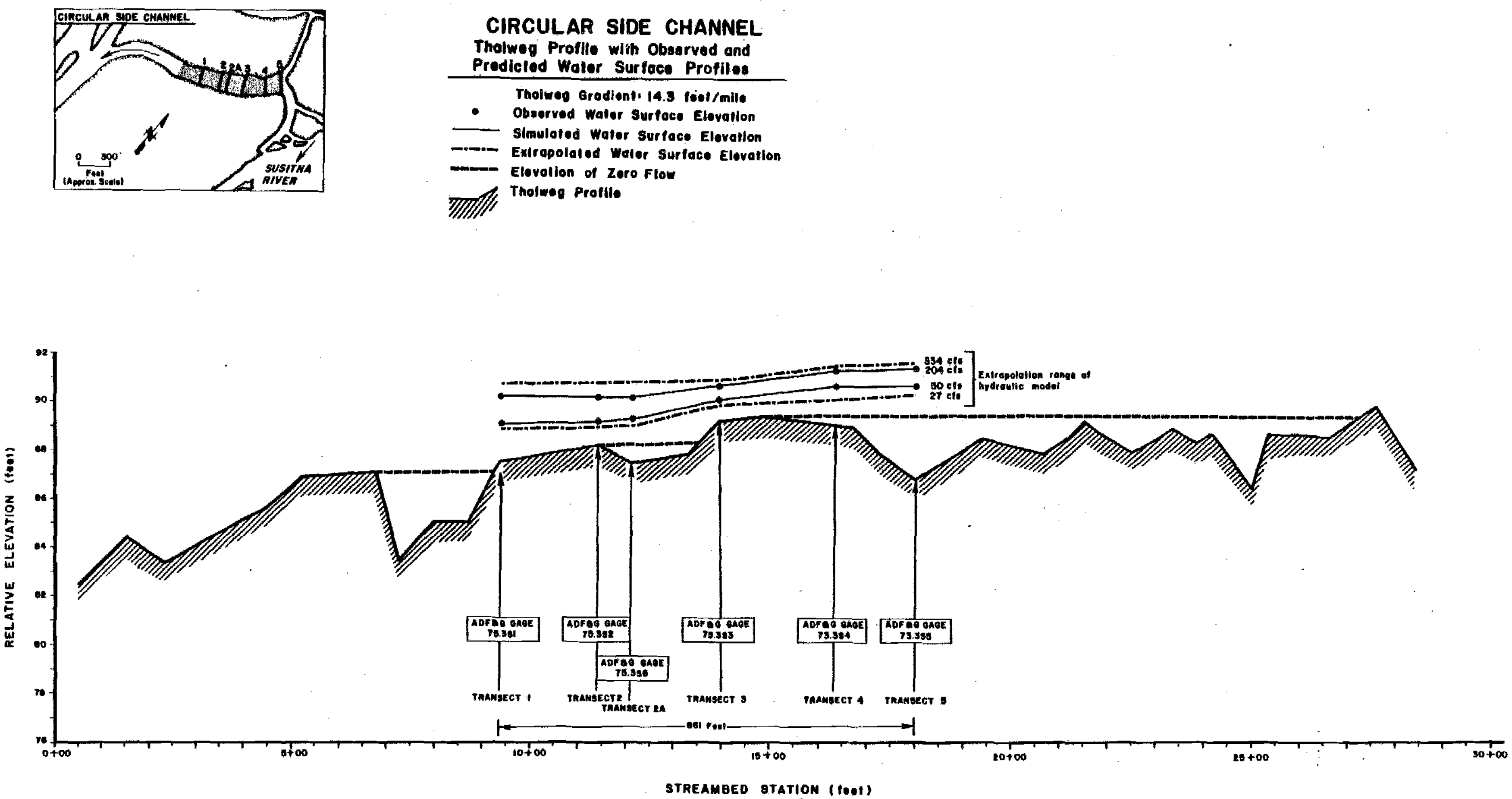
Appendix Figure D-22. Cross section of transects 1, 2, and 2A at Circular Side Channel (adapted from Quane et al. 1985).







Appendix Figure D-23. Cross section of transects 3, 4, and 5 at Circular Side Channel.



Appendix Figure D-24. Comparison of observed and predicted water surface profiles from calibrated model and surveyed thalweg profile at Circular Side Channel (adapted from Quane et al. 1985).

To evaluate the performance of the hydraulic model, observed and predicted water surface elevations, discharges, and velocity adjustment factors were compared (Appendix Table D-8). Because of the 2 calibration flows only a 2 point rating curve was formulated. In evaluating the performance of the model, observed and predicted WSEL's and discharges were the same because of this rating curve. Velocity adjustment factors were all within the good range of 0.9 to 1.1. Additionally, the stage information of the model was compared to the rating curves established by Quane et al. 1985 (Appendix Figure D-20).

At the high flow measurement of 204 cfs, the original field measured discharge at transect 2 was 34% lower than that calculated at the discharge transect. In order to use this information in the model, the individual velocity measurements were all adjusted upwards by 52%. Why there was such a large discrepancy between flows at this particular transect when the four other transect flow measurements were within 9% of the discharge transect measurement is unknown.

At transect 5 there was a change in the channel cross section from when the actual cross section survey was done and when the two calibration flows were made. Between the cross section survey of September 5, 1985, and the two calibration flow measurements July 24 and August 17, 1984, a flood event occurred on August 26, 1984. After this flood, the right side of the channel at transect 5 was scoured out. In order to avoid violating one of the underlying assumptions of the model, (i.e.,that a rigid stream channel exists) the cross section determined from the two calibration flows was used in the model.

During the 50 cfs calibration flow measurement a water surface elevation was not surveyed for transect 5. In order to obtain a water surface elevation for the model, a value was calculated from the average of the depth measurements added to the corresponding cross section elevations of the 50 cfs flow measurement.

Verification

Based on the first level of verification by EWT&A, the model does an excellent job of simulating channel hydraulics between 39,000 and 57,000 cfs, mainstem discharge (38 and 213 cfs site flow). Above 57,000 cfs, the simulated depth and velocity distributions begin to deteriorate in quality. The model simulations were therefore rated good between 57,000 and 60,000 cfs (213 and 268 cfs site flow), acceptable between 60,000 and 63,000 cfs (268 and 334 cfs site flow), and unacceptable above 63,000 cfs mainstem discharge. Below 39,000 cfs, the model simulations were also rated less than excellent as forecasted velocity and depth distributions deteriorated in quality. The model simulations were rated good between 36,000 and 39,000 cfs mainstem discharge (27 and 38 cfs site flow) (Appendix Figure D-25). Below 36,000 cfs mainstem (controlling discharge), insufficient information is available to evaluate the model.

At the second level of verification there is excellent agreement between the observed and predicted velocities and good agreement between the

Appendix Table D-8. Comparison between observed and predicted water surface elevations, discharges, and velocities for 1984 Circular Side Channel hydraulic model.

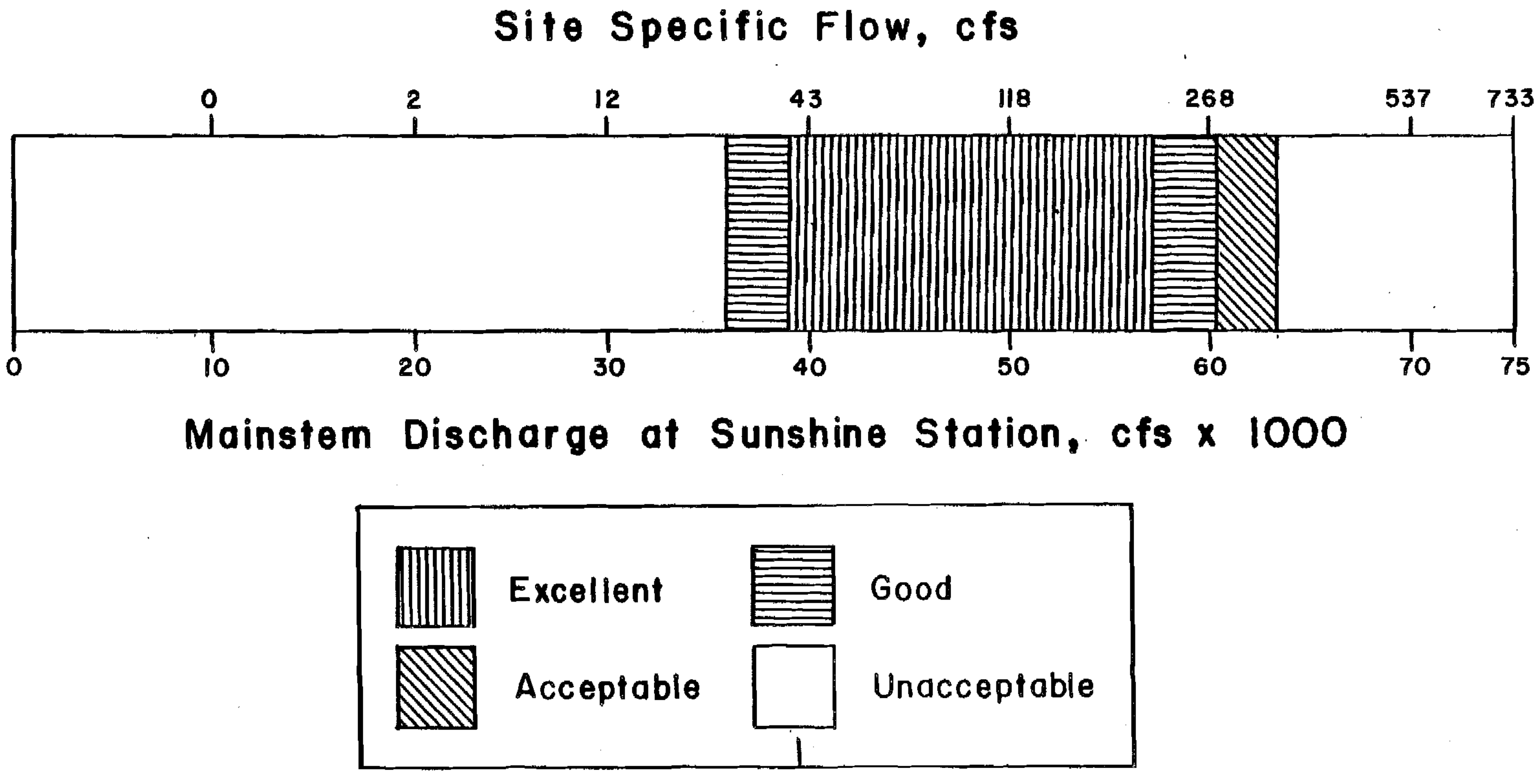
Streambed Station (ft)	Water Surface Elevation Observed (ft)	Water Surface Elevation Predicted (ft)	Discharge Observed (cfs)	Discharge Predicted (cfs)	Velocity Adjustment Factor
0+00	89.28	89.28	44.4	44.4	1.000
1+98	89.30	89.30	47.9	47.9	.998
2+65	89.41	89.41	56.0	56.0	1.000
4+33	90.20	90.20	43.7	43.7	1.000
6+63	90.60	90.60	50.9	50.9	.997
8+20	90.62	90.63	53.6	53.6	1.000
			Qo = 49.0	Qp = 49.0	
0+00	90.29	90.29	202.8	202.8	.998
1+98	90.27	90.27	203.1	203.1	.987
2+65	90.31	90.31	198.4	198.4	.999
4+33	90.66	90.66	176.9	176.9	.998
6+63	91.29	91.29	199.9	199.9	1.000
8+20	91.32	91.32	194.2	194.2	1.000
			Qo = 196.0	Qp = 196.0	

Qo is the mean observed calibration discharge.

Qp is the mean predicted calibration discharage.

Application Range of the Calibrated Hydraulic Model at Circular Side Channel

RM (75.3)

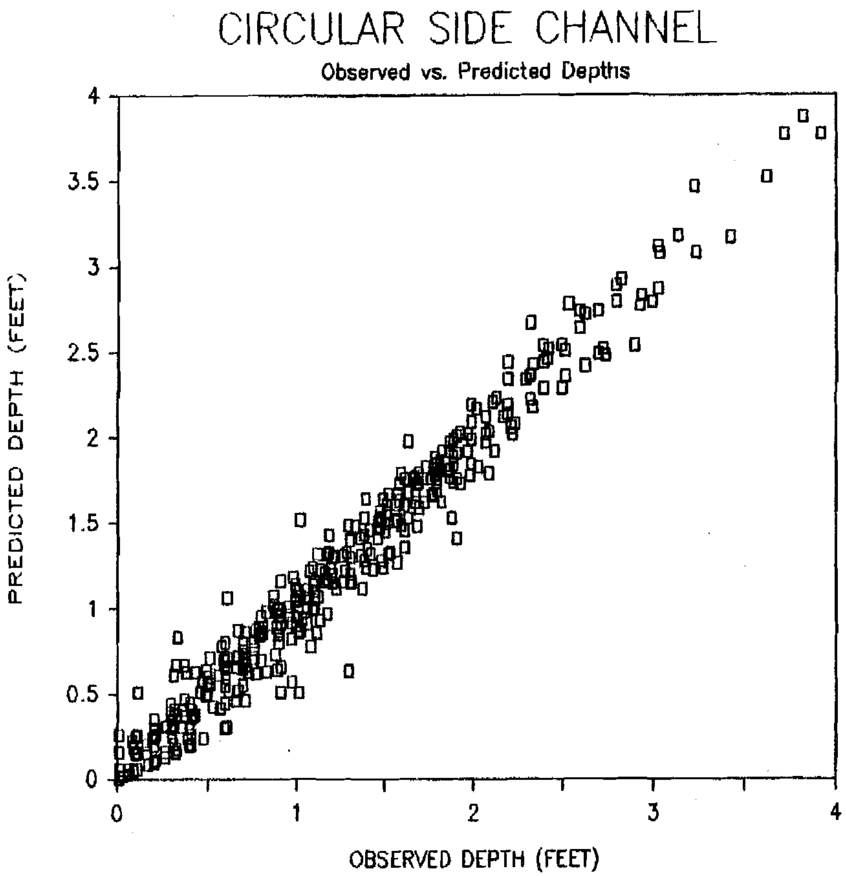


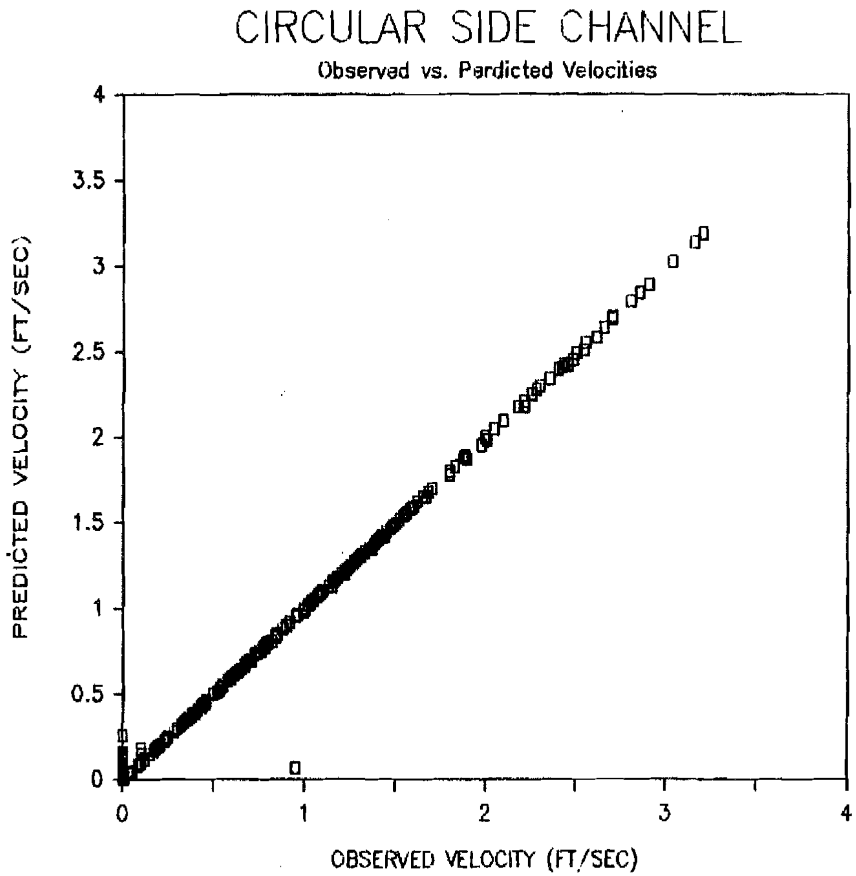
Appendix Figure D-25. Application range of the calibrated hydraulic model at Circular Side Channel.

observed and predicted depths (Appendix Figure D-26). The results of the statistical tests also indicate good agreement between the predicted and observed values for both velocity and depth (Appendix Table D-7). The index of agreement is near one, the total RMSE is mostly composed of the unsystematic RMSE, and the y-intercept is close to zero with a slope of almost one.

Application

For habitat simulation modelling purposes, the hydraulic simulation model developed for Circular Side Channel can simulate channel flows in the mainstem discharge range of 36,000 to 63,000 cfs.





Appendix Figure D-26. Scatterplots of observed and predicted depths and velocities from the calibrated IFG-4 hydraulic model at Circular Side Channel.

Sauna Side Channel (RM 79.8)

Site Description

Sauna Side Channel is located on the west bank of the Susitna River at river mile 79.8 (Appendix Figure D-27). It is approximately 0.2 miles long. Both the mouth and head of the side channel are connected to a larger side channel of the mainstem Susitna River. For the most part, the side channel is confined on the west side by a high bank and on the east by a large sparsely vegetated gravel bar. A smaller side channel enters just below the head of Sauna Side Channel on its west bank. This side channel conducts flow to the study site during high mainstem discharges, but dewaters before the head of Sauna Side Channel becomes unbreached. Breaching flows result from overtopping of the side channel that adjoins the head on the east bank of Sauna Side Channel. Prior to breaching, the channel is composed of two large interconnected pools whose water levels are maintained from ground water seepage originating from the vicinity of the head. An extensive log jam at the head of Sauna Side Channel influences the flow into this side channel.

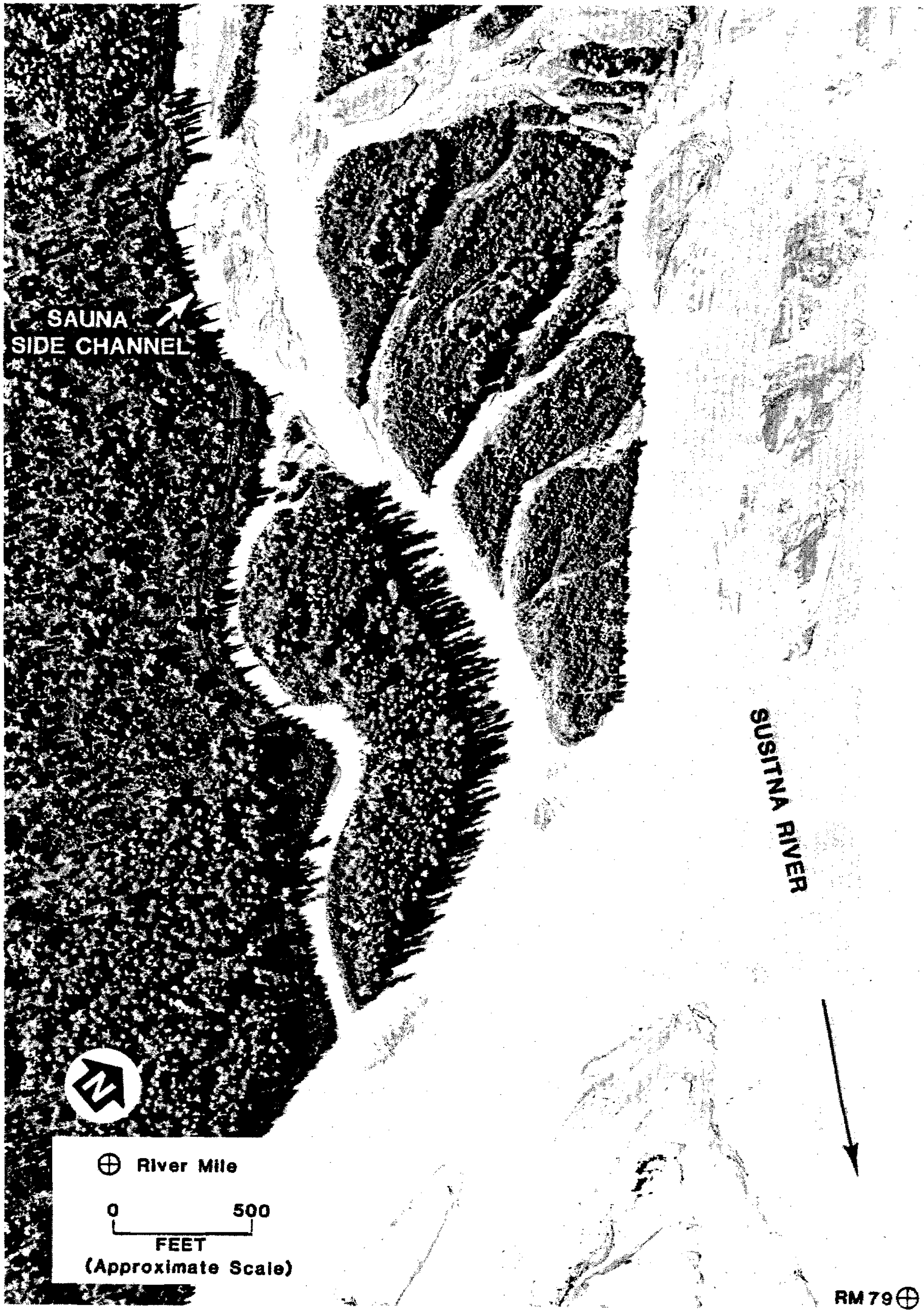
Based on field observations and stage/discharge relationships, the mainstem discharge estimated to initially breach Sauna Side Channel was 37,000 cfs (Quane et al. 1985). A controlling discharge of 38,000 cfs was determined for this side channel also based on this stage/discharge relationship. A side channel flow of 22.5 cfs was estimated to occur at the 38,000 cfs mainstem discharge as derived from the stage versus streamflow rating curve (Appendix Figure D-28). Quane et al. (1985) determined that backwater does not occur in Sauna Side Channel during non-breaching mainstem discharges. During breaching discharges of 54,600 to 56,700 cfs, however, backwater was observed to occur throughout the Sauna Side Channel study site.

The IFG modelling site, located approximately 2,000 feet from the mouth of this side channel, was 480 feet long (Appendix Figure D-29). The thalweg gradient at this site is 10.4 ft/mile (Quane et al. 1985). Substrates throughout this site consist primarily of sands and silts. The water is slow moving with velocities usually less than 1.0 ft/sec. The left bank at the site is an erosional bank with a height exceeding five feet; riparian vegetation along this bank consists of alder and birch. In contrast, the left bank is a depositional bank with no riparian vegetation.

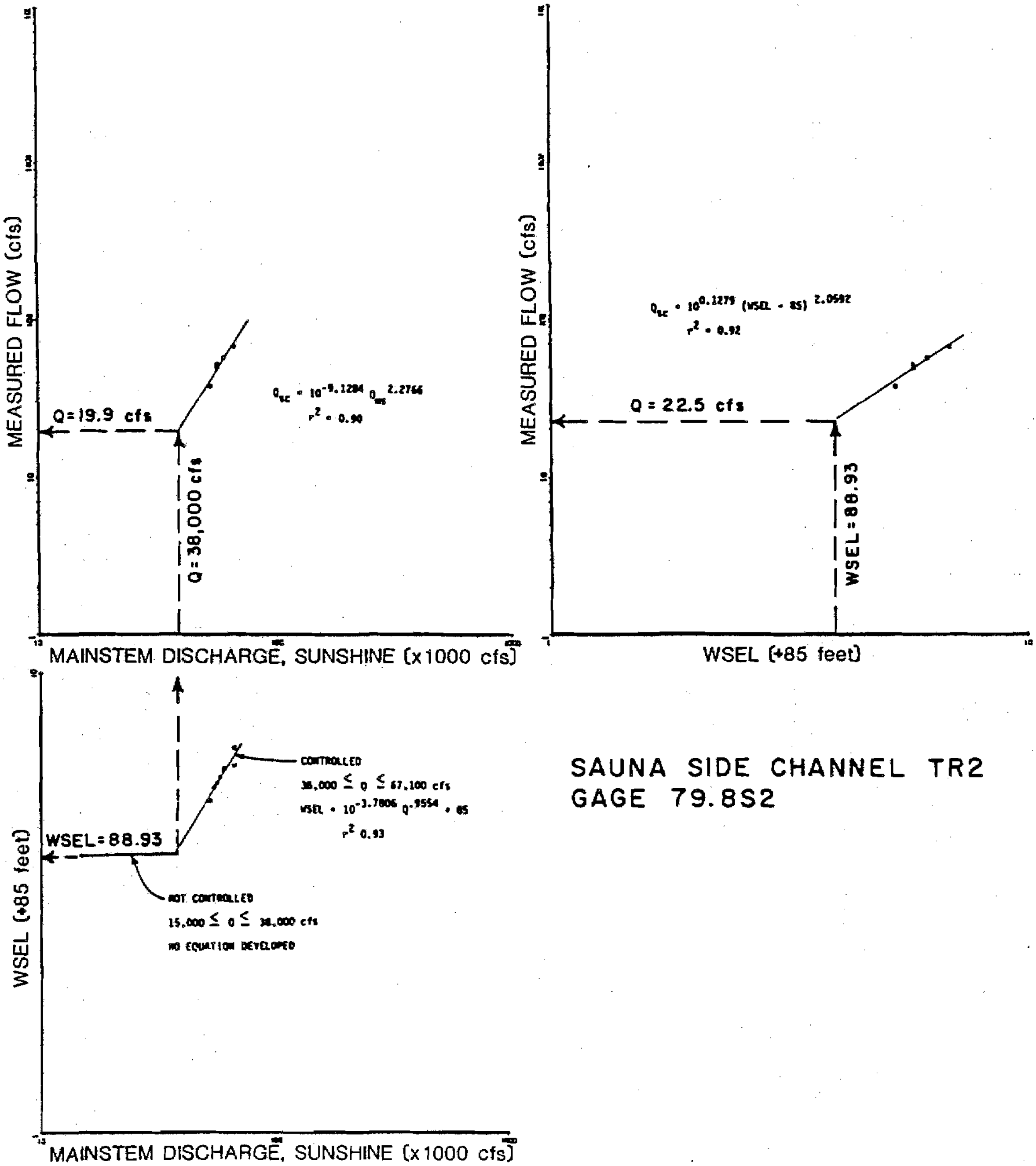
Four transects were located within this study site (Appendix Figure D-30) . Transects 1 and 2 were located in shallow pool habitat whereas transects 3 and 4 were located in deeper pools.

Calibration

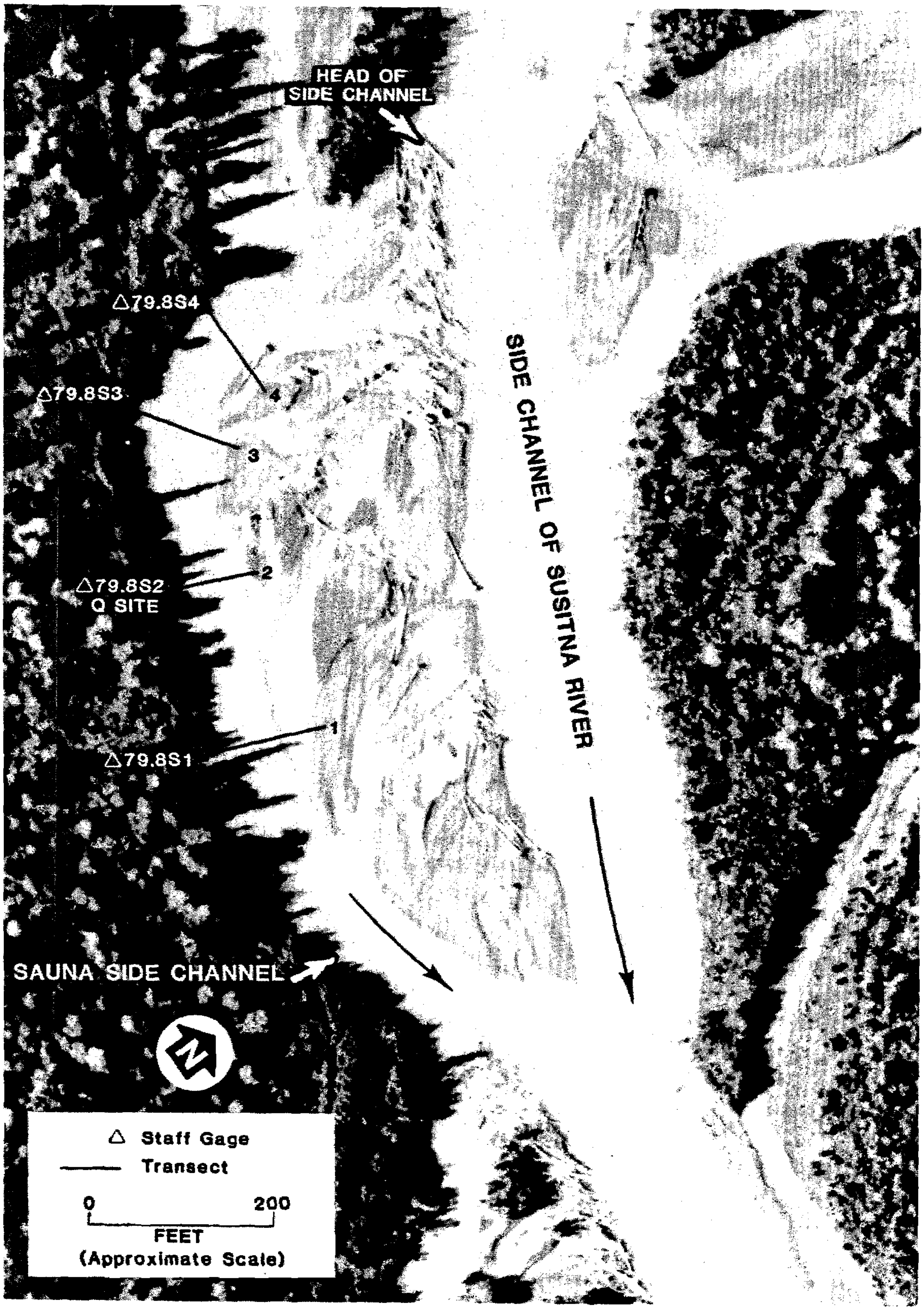
Hydraulic data were collected at a calibration flow of 52 cfs corresponding to a mainstem discharge of 52,000 cfs (Appendix Table D-4). Based on this single calibration flow, an IFG-2 model was used to forecast instream hydraulics of this study site. The streambed profile, stage of zero flow, and observed and predicted water surface elevations for the study reach are plotted in Appendix Figure D-31. This data set



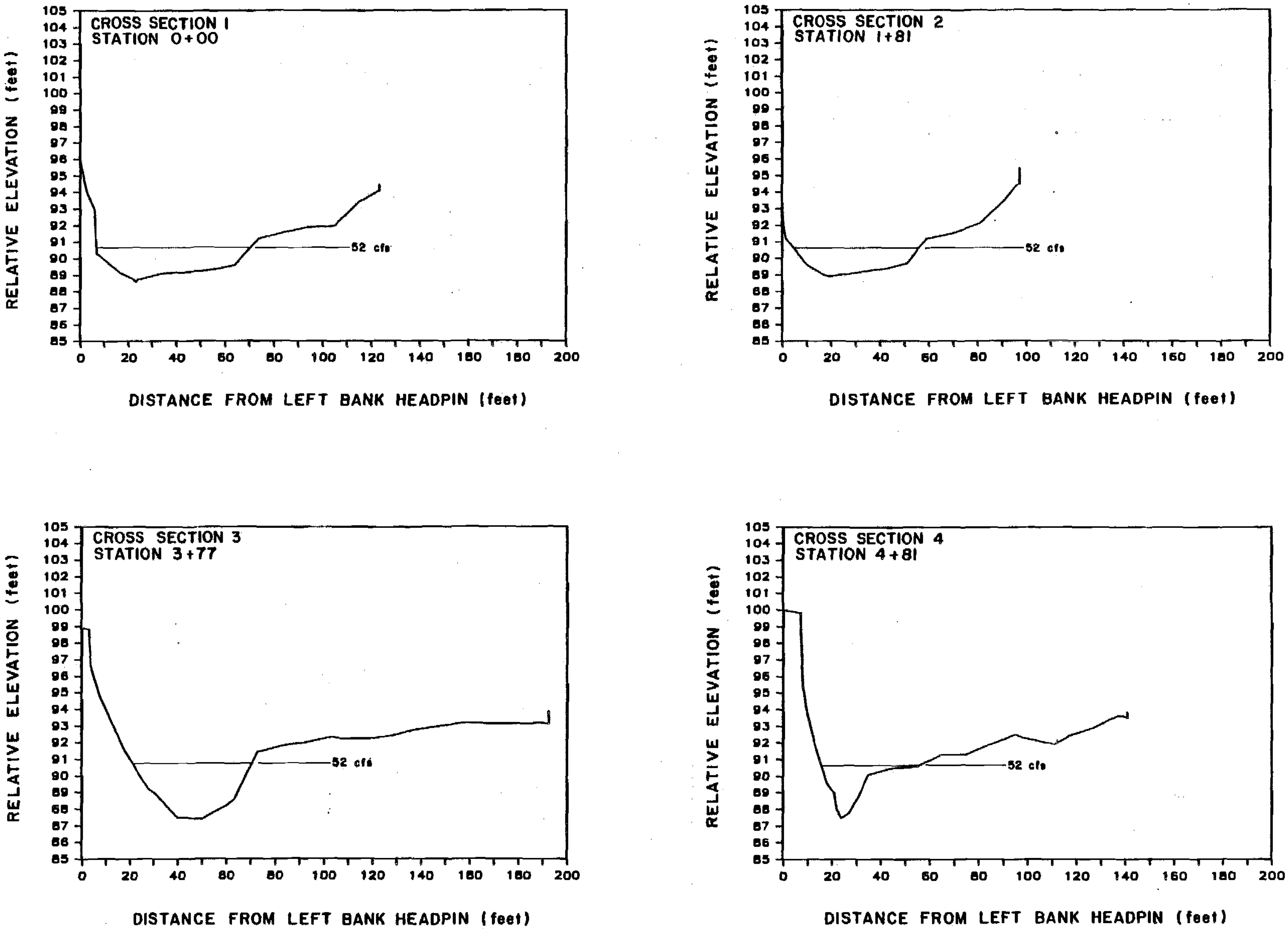
Appendix Figure D-27. Overview of Sauna Side Channel (RM 79.8).



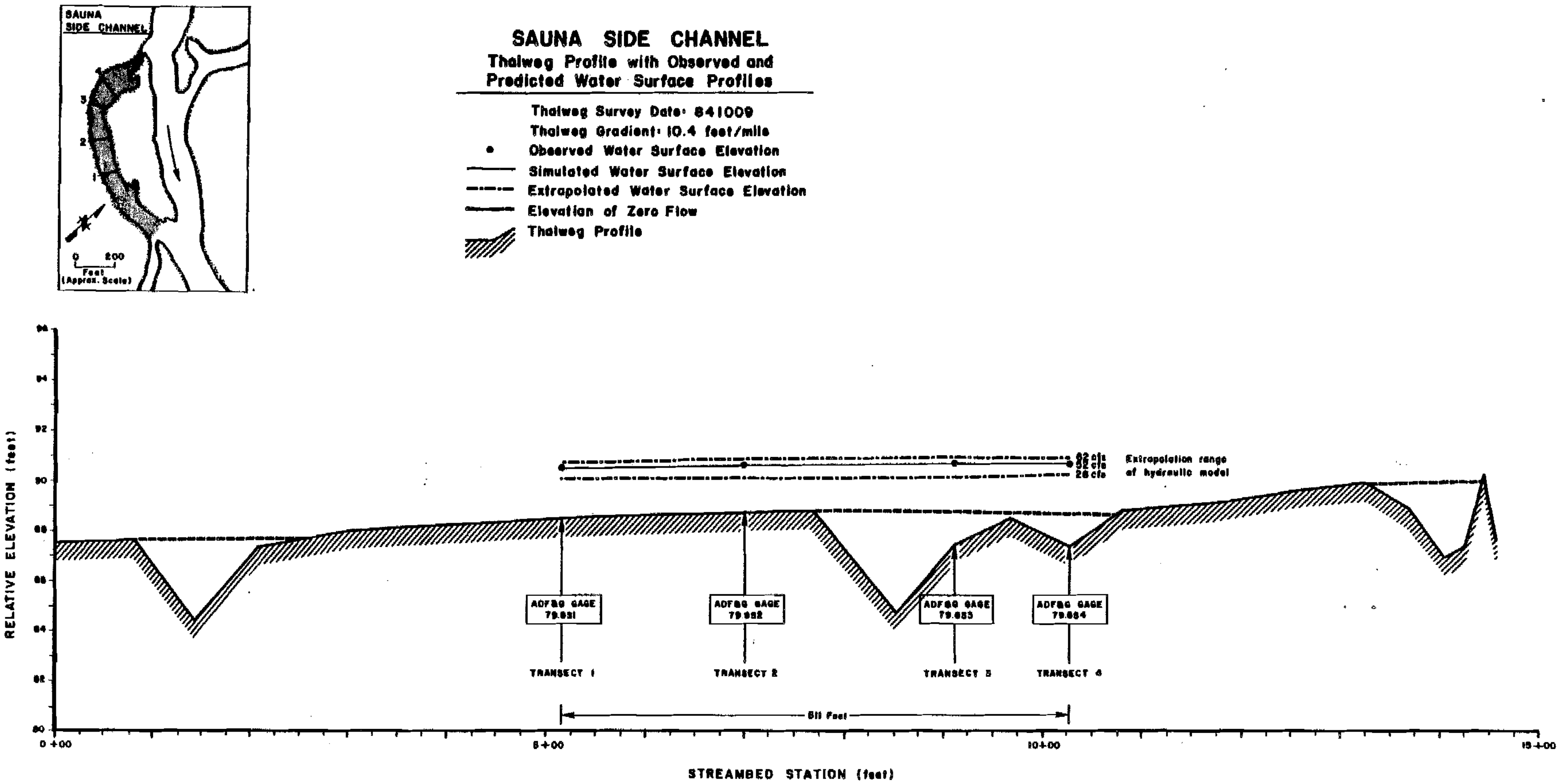
Appendix Figure D-28. Comparison of rating curves from Sauna Side Channel transect 2 (from Quane et. at. 1985).



Appendix Figure D-29. Location of Sauna Side Channel study site (RM 79.8).



Appendix Figure D-30. Cross section of transects 1, 2, 3, and 4 at Sauna Side Channel (adapted from Quane et al. 1985).



Appendix Figure D-31. Comparison of observed and predicted water surface profiles from calibrated model and surveyed thalweg profile at Sauna Side Channel (adapted from Quane et al. 1985).

was used to predict hydraulic information from side channel flows of 5 to 93 cfs (mainstem discharges of 21,000 to 75,000 cfs). To evaluate the performance of the hydraulic model, observed and predicted water surface elevations were compared (Appendix Table D-9). Additionally, the stage information of the model was compared to the rating curves established by Quane et al. (1985) (Appendix Figure D-28).

It was difficult to calibrate hydraulic information at this site because very limited field data were available. A site flow versus WSEL rating curve could only be developed for transect 2 (Appendix Figure D-28). The IFG-2 model is essentially a water surface profile model and a critical variable for calibrating it, is the water surface elevations of simulated flows. Data, however, is only available for transect 2 and not for any of the other three transects. The actual velocity measurements from other measured flows at the discharge transect, however, can be compared to the model predicted velocities for those same flows. At the discharge measurement for transect 2, however, there were only two flows that were far enough away from the 52 cfs measurement to be usable (38 and 68 cfs). Thus, the information available to hydraulically calibrate the IFG-2 model for this site consists of the water surface elevations and velocity measurements for all four transects at the calibrating flow of 52 cfs, and water surface elevations and velocities for the two other site flows of 38 and 68 cfs at transect 2.

This site is influenced by backwater and the effects are more pronounced at the 68 cfs flow. From the field data, the observed top width is greater by 20 feet, the water surface elevation is 0.93 feet higher, and the average velocity is 0.20 ft/sec slower than predicted by the model. At the 38 cfs flow, the effect seems to have reversed, with the observed widths being similar, the WSEL 0.08 feet lower, and the average velocity 0.09 ft/sec faster than predicted by the model (Appendix Table D-10).

In the calibration process, the original field WSEL was reduced by 0.1 feet. This adjustment was made in order to obtain water surface elevations that agreed more closely to the lower site flows. It was felt that this adjustment would make the model, in terms of predictability, more sensitive at the lower site flows. By reducing the WSEL of transect 1 by 0.1 feet, the difference between the field and the model WSEL at the 38 cfs flow was reduced from 0.18 feet, when the calibration discharge WSEL was 90.71, to 0.08 feet, when the calibration discharge WSEL was 90.61 feet (Appendix Table D-10).

As a result of a flood on August 26, sediments were deposited in the study site resulting in changes in all the cross sections derived from the calibration flow on July 23. As a result, the cross sections obtained during the September 15 survey were used in the model until the water's edge of the calibration flow was reached, then the cross sections from the calibration flow were used.

When measuring the velocities and depths at each of the transects, the discharge calculated at transect 4 was 16% lower than the 52 cfs site flow calculated at the discharge transect. In order to utilize this information in the model, the velocities were adjusted upwards by 16%.

Appendix Table D-9. Comparison of field measured and model predicted water surface elevations at the calibration flow of 52 cfs for Sauna Side Channel.

	Water Surface Elevation (ft)		
Transect	Original Field	Modified Field*	Model Predicted
1	90.70	90.60	90.61
2	90.71	90.61	90.62
3	90.72	90.62	90.63
4	90.69	90.59	90.63

* Field water surface elevations were reduced by 0.1 feet.

Appendix Table D-10. The effects of the backwater at Sauna Side Channel, information obtained from transect 2.

Site Flow (cfs)	Original WSEL (ft)		Modified WSEL (ft)		Top Width (ft)		Average Velocity (ft/sec)	
	Field	Model	Field	Model	Field	Model	Field	Model
68	91.85	91.06	91.85	90.92	77.0	55.0	0.32	0.52
52[a]	90.71[b]	90.74	90.61[c]	90.62	53.5	53.0	0.53	0.49
38	90.24	90.42	90.24	90.32	50.5	52.0	0.51	0.42

[a] Calibration flow

[b] Original field WSEL input into model

[c] Field WSEL reduced by 0.1 ft

No stage-site flow rating curve was developed for transect 1. When inputting other flows into the model, the IFG-2 requires either the associated WSEL for this flow or the slope. Because the WSEL could not be obtained for other flows at this transect, a slope value of 0.00005 was input instead. This value was generated by the model from transect 1 at the calibration flow of 52 cfs.

Verification

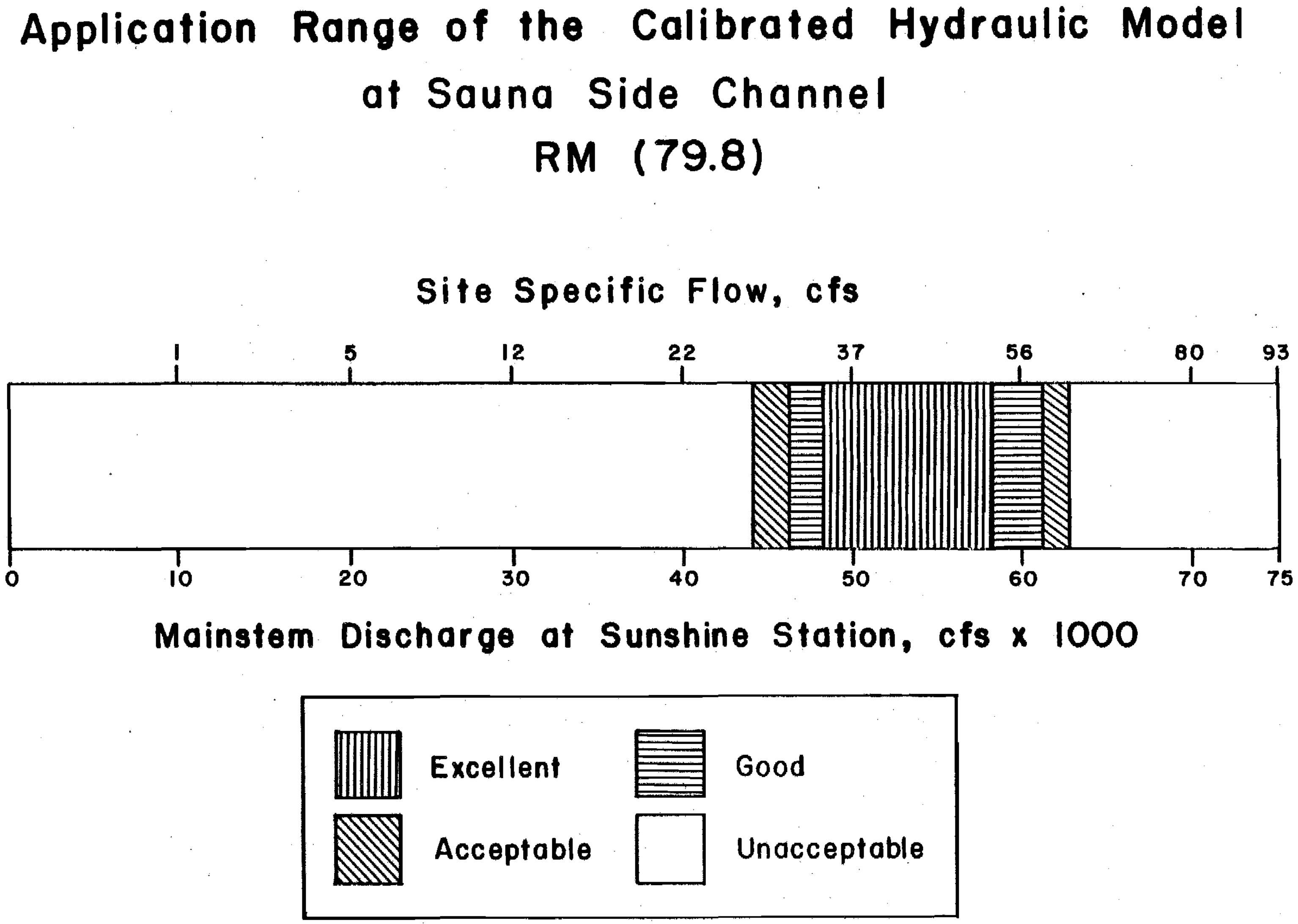
The dominant influence of backwater on channel hydraulics makes the site a poor candidate for application of IFG-2 modeling techniques. However, because only one data set was collected, application of the IFG-4 hydraulic model was not possible.

Based on the first level of verification by EWT&A, the IFG-2 model for this site does an excellent job of simulating channel hydraulics between 48,000 cfs and 58,000 cfs mainstem discharge (34 to 52 cfs site flow) (Appendix Figure D-32). Within this range, predicted WSEL's, depths, and velocities are in close agreement with field information (evaluated at 38 cfs by discharge measurement made by Quane et al. (1985). The predictive capability of the model within this range provides evidence that the backwater influence within the study site is lessening with decreasing discharge.

Below 48,000 cfs mainstem, there is increasing disagreement between the WSEL's predicted by the model and those extrapolated from the rating curve. At a 23 cfs site flow, the difference in predicted WSEL between model and rating curve equation has increased to approximately one foot at transects 1 and 2. Although there is evidence that suggests that the model may be a more accurate predictor of WSEL's than the rating curve equations below 48,000 cfs mainstem, insufficient information exists to resolve the difference with confidence. Since depths become shallow within this range, predictive errors in WSEL can result in significant errors in predicted depths and velocities. For this reason, the recommended extrapolation range is limited below 48,000 cfs.

Above a 48,000 cfs mainstem discharge, there is increasing, disagreement between the WSEL's predicted by the model and those observed in the field. One of the premises of the hydraulic theory that is the basis of the IFG-2 model is that the water surface profile of the study reach is controlled by its slope. This premise is violated when the water surface profile is influenced by mainstem backwater. From examination of discharge measurements made at 48 and 68 cfs it is apparent that the influence of backwater is increasing with stage above 58,000 cfs mainstem.

Overall, the recommended extrapolation range is limited above 58,000 cfs. The model simulations were rated excellent between 48,000 and 58,000 mainstem discharge (34 to 52 cfs site flow). Good between 46,000 and 48,000 (31 to 34 cfs) and from 58,000 to 60,000 cfs (52 to 58 cfs). Acceptable between 44,000 and 46,000 cfs (28 to 31 cfs) and 60,000 to 63,000 cfs (58 to 62 cfs). The model was rated unacceptable below 44,000 cfs and above 63,000 cfs mainstem discharge (Appendix Figure D-32).

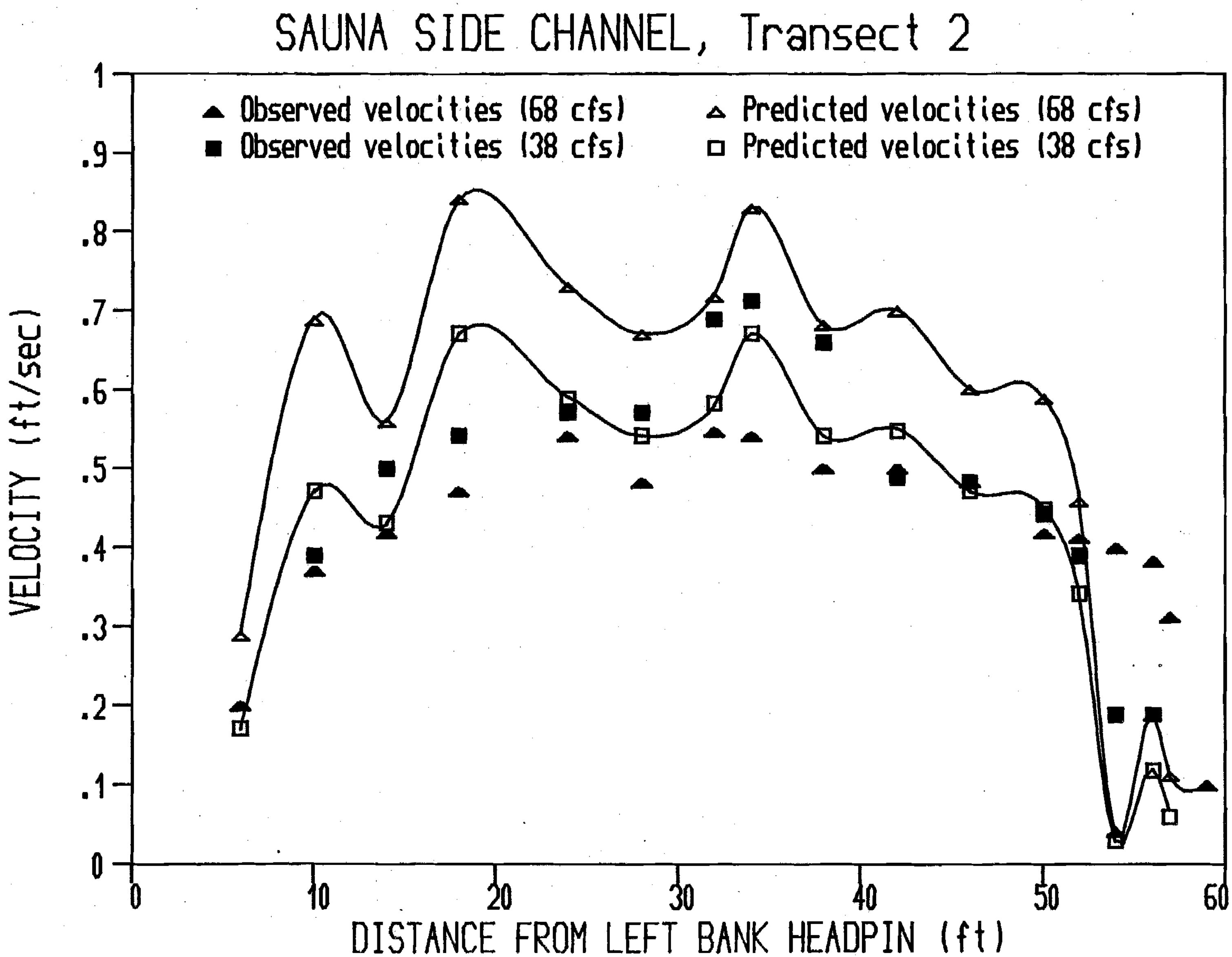


Appendix Figure D-32. Application range of the calibrated hydraulic model at Sauna Side Channel.

The velocity profiles produced by the IFG-2 model at transect 2 were compared to the observed velocities at flows of 38 and 68 cfs (Appendix Figure D-33). Because this site is primarily a backwater area and the IFG-2 hydraulic model is not a backwater model it was thought that calibrating the model to more accurately predict at the lower flows would be more critical than at the higher flows. Thus at the 38 cfs flow there is found a better correspondence between the observed and predicted velocities. At the 68 cfs flow the backwater becomes more apparent. A majority of the observed velocities are lower than the predicted velocities and many of these values are lower than individual 38 cfs flow velocities. Because of the overall low velocities, 1.0 ft/sec, it was felt that this was the best compromise in applying this model to the Sauna Side Channel site.

Application

For habitat simulation modelling purposes the hydraulic simulation model developed for Sauna Side Channel can simulate channel flows in the mainstem discharge range of 44,000 to 63,000 cfs.



Appendix Figure D-33. Comparison of observed and predicted velocities from the IFG-2 hydraulic model at Sauna Side Channel using two flows at the discharge transect.

Sunset Side Channel (RM 86.9)

Site Description

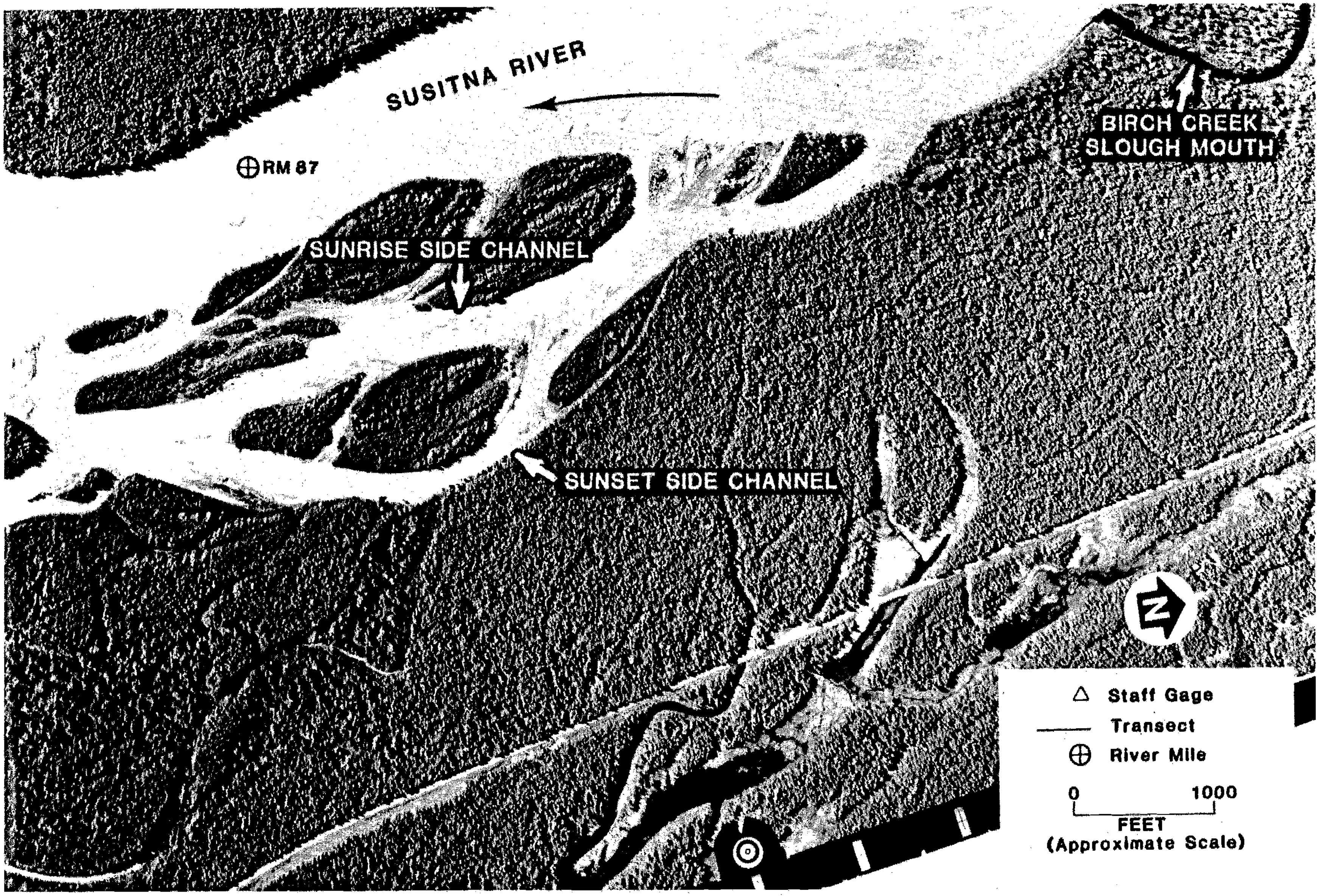
Sunset Side Channel is located on the east bank of the Susitna River at river mile 86.9 (Appendix Figure D-34). It is approximately 1.1 miles long and is separated from the main channel of the Susitna River on the west by a network of vegetated islands and side channels. The channel is confined on the east by a high cut bank. Prior to breaching, the side channel is composed of a sequence of pools and riffles. During this period, flow is maintained in the main channel by groundwater seepage and upwelling. After breaching, flows up to 3,900 cfs have been measured (Quane et al. 1985).

Breaching of Sunset Side Channel results from the direct overtopping of the head of the side channel by the mainstem Susitna River. Based on assessments by Quane et al. (1985) the side channel initially breached at 31,000 cfs and controlled at a mainstem discharge of 32,000 cfs. The associated site flow at the controlling discharge has been estimated to be 45.8 cfs while a flow of 41.1 cfs is derived from the flow versus mainstem discharge rating curve (Appendix Figure D-35).

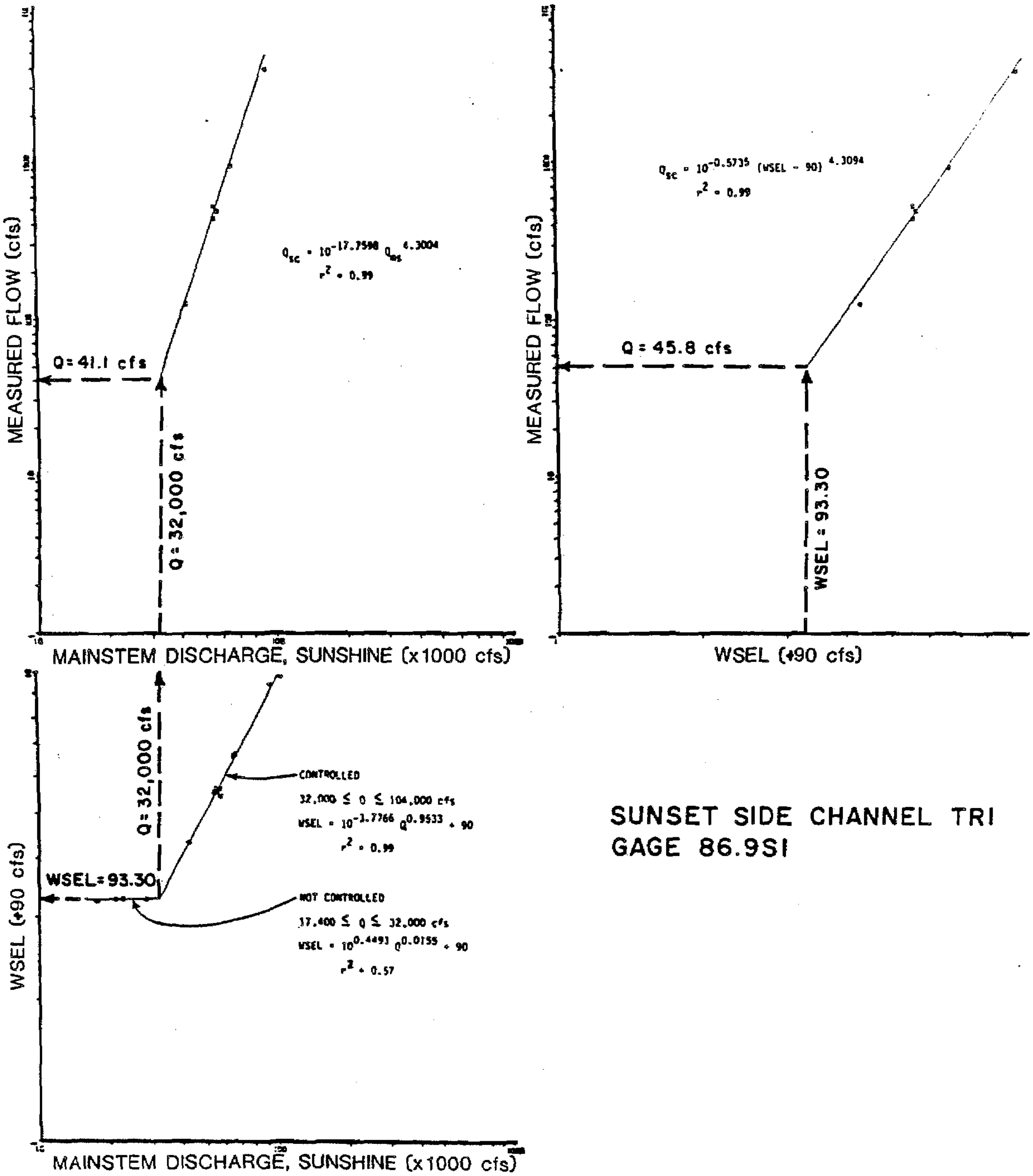
Based on assessments by Quane et al. (1985) a backwater area does not occur in this side channel during unbreached conditions. But at breaching mainstem discharges ranging from 56,000-66,700 cfs, an area of backwater was observed to extend upstream approximately 1,100 feet to a point between transects 1 and 2.

The IFG modelling site within Sunset Side Channel was located in the lower portion of the side channel and was 1410 feet long (Appendix Figure D-36). Hydraulic information was collected from seven transects within this study site (Appendix Figures D-37 & D-38). The channel within the study site has a gradual bend. The right bank from transects 2 to 6 is erosional, becoming less steep and depositional at transects 0 and 1. On the left bank, transects 2 through 6 are primarily depositional in nature. In the areas of transects 0 and 1, the left bank becomes steep and erosional. At transect 2 on the left bank a small dewatered channel enters but water was never observed running in it (Appendix Figure D-36). The thalweg gradient within the study site is 9.5 ft/mile (Quane et al. 1985). Riparian vegetation along the right bank is primarily birch and spruce, whereas on the left bank it is alder.

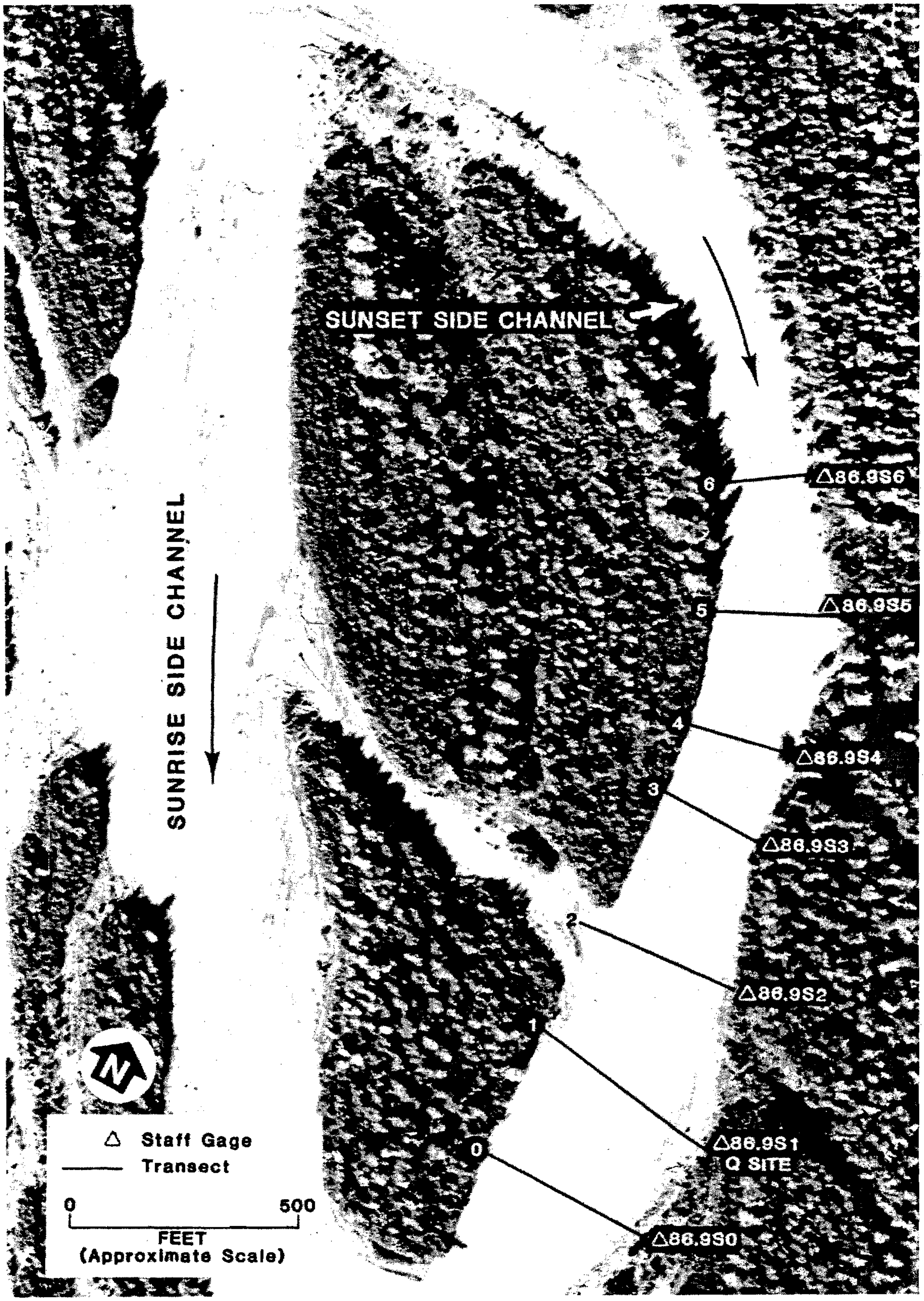
Transect 0 is located in a shallow pool habitat and has a substrate of sand and small gravel. Transects 1 (the discharge site) and 2 are primarily run habitat, and the substrate is small gravel. At transect 3, the habitat changes to run and shallow pool habitat, the predominant substrate is small and large gravel. The hydraulic control for transects 5 and 6 is transect 4. This transect represents riffle habitat, with substrates composed mostly of small and large gravels. Transects 5 and 6 are located in deep pool habitat, with small and large gravel substrate.



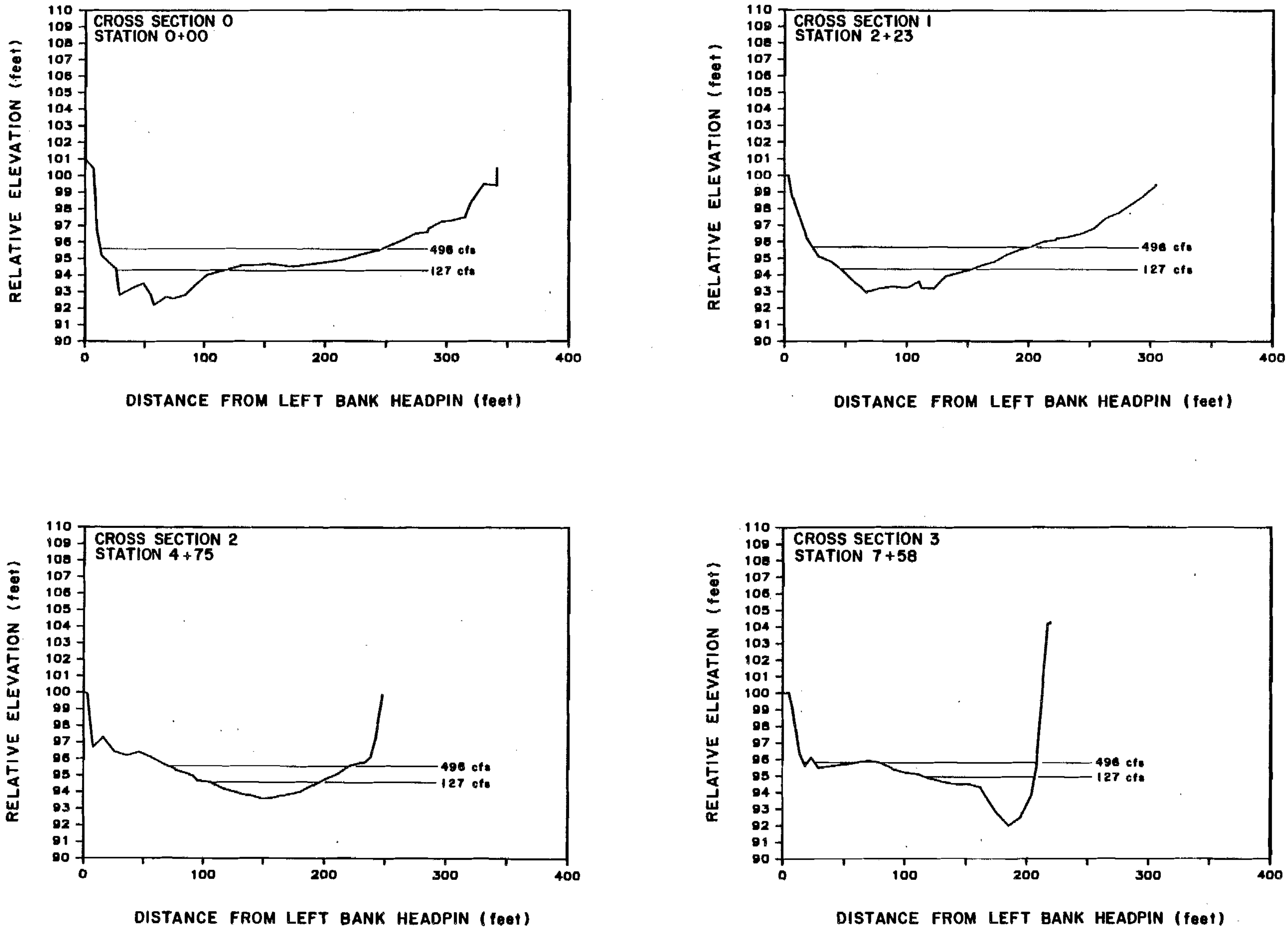
Appendix Figure D-34. Overview of Sunset Side Channel (RM 86.4).



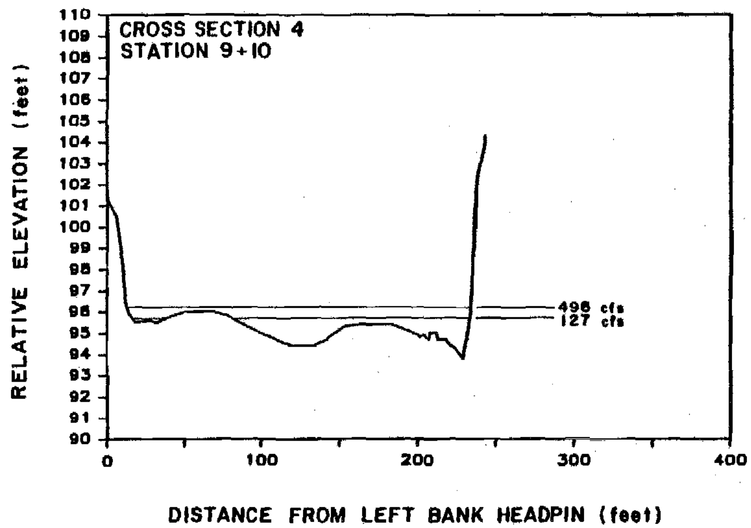
Appendix Fugure D-35. Comparison of rating curves from Sunset Side Channel at transect 1 (from Quane et. al. 1985).

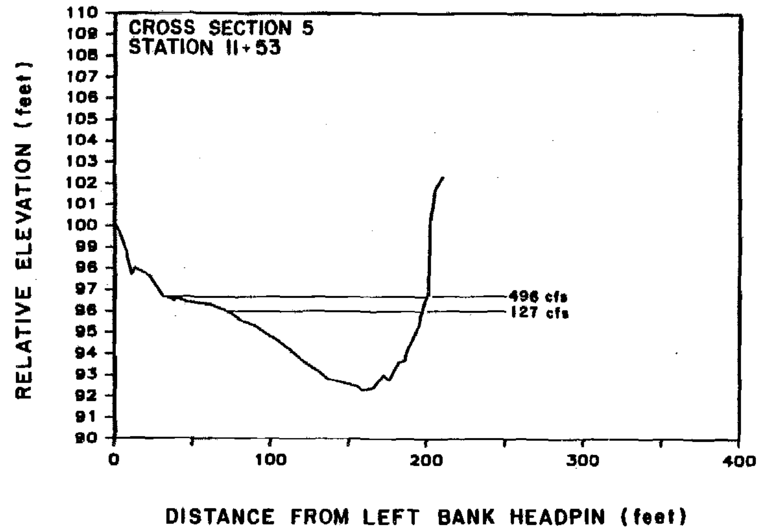


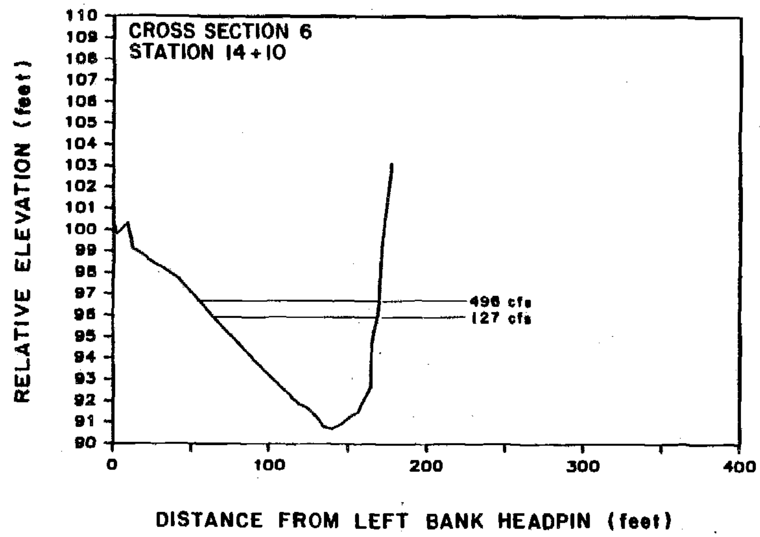
Appendix Figure D-36. Location of Sunset Side Channel study site (RM 86.9).



Appendix Figure D-37. Cross section of transects 0, 1, 2, and 3 at Sunset Side Channel (adapted from Quane et al. 1985).







Appendix Figure D-38. Cross section of transects 4, 5, and 6 at Sunset Side Channel (adapted from Quane et al. 1985).

Calibration

Hydraulic data were collected at two calibration flows: 127 and 496 cfs (Appendix Table D-4). Mean daily discharges for the Susitna River on the dates that calibration data were collected at the Sunset Site Channel study site were 42,500 and 57,800 cfs, respectively. Based on these two calibration flows, an IFG-4 model was used to forecast instream hydraulics at this study site. The streambed profile, stage of zero flow, and observed and predicted water surface elevations for the study reach are plotted to scale in Appendix Figure D-39. Both calibration data sets were used to predict hydraulic information from side channel flows of 7 to 1,603 cfs (mainstem discharges of 21,000 to 75,000 cfs).

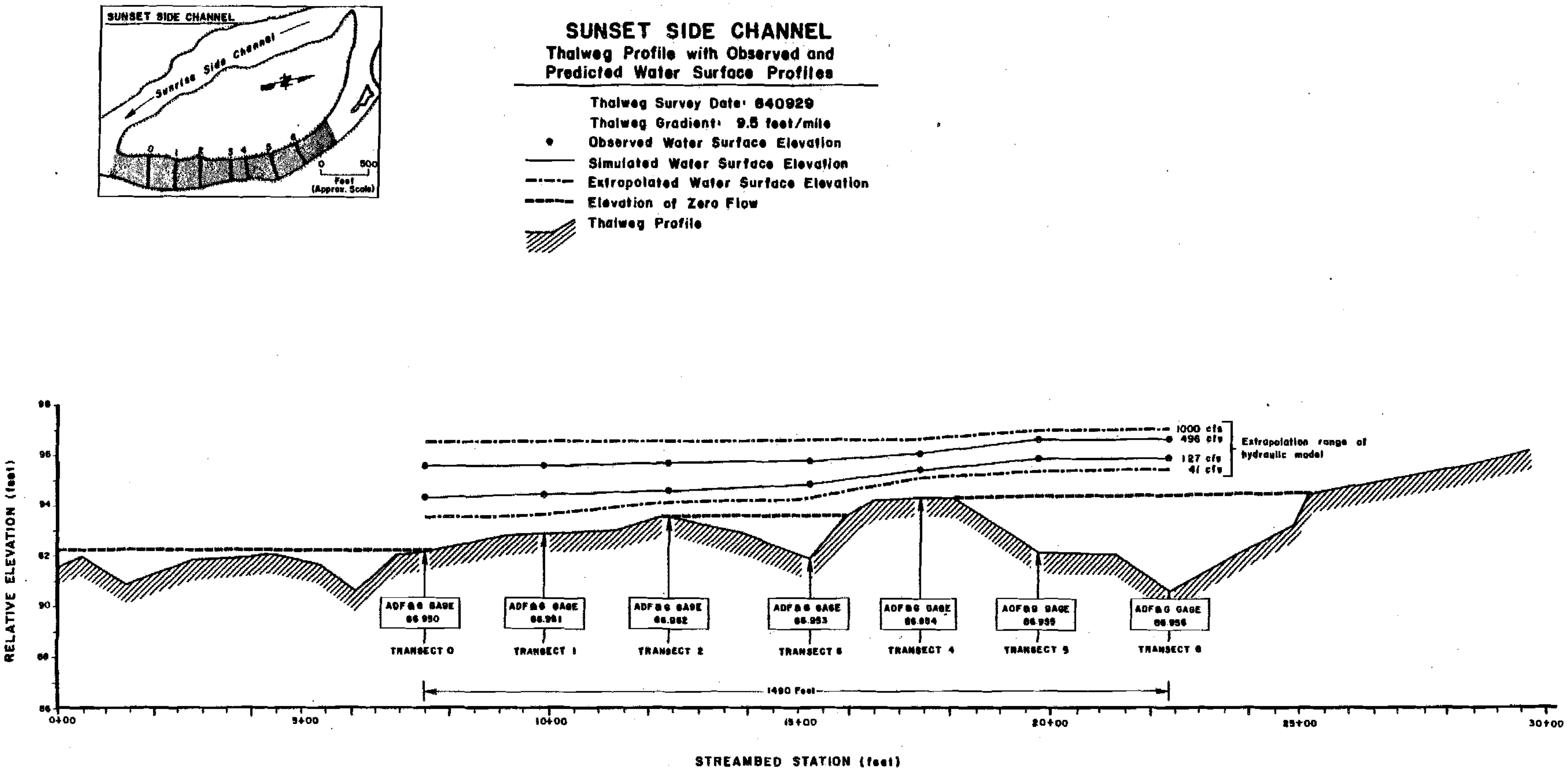
To evaluate the performance of the hydraulic model, observed and predicted water surface elevations, discharges, and velocity adjustment factors were compared (Appendix Table D-11). The hydraulic model at Sunset Side Channel is similar to Circular Side Channel. Because of the 2 calibration flows, only a 2 point rating curve was formulated. In evaluating the performance of the model, observed and predicted WSEL's and discharges were the same because of this rating curve. Velocity adjustment factors were all within the good range of 0.9 to 1.1. Additionally, the stage information of the model was compared to the rating curves established by Quane et al. (1985) (Appendix Figure D-35).

In the model, the stages of zero flow are not the same as those determined from the thalweg survey by Quane et al. 1985 (Appendix Table D-12). The stage of zero flow values, input into the model, were derived from the thalweg points of the model input cross sections of transects 0, 1, 2, and 4. The reason for this change in thalweg elevations is likely the result of the flood event. All the points used in the model were from measurements made before the flood, whereas the Quane et al. (1985) thalweg survey was done after the flood event.

At transect 6, the velocities at the high calibration flow measurement (496 cfs) were adjusted upwards by 15% and at the low calibration flow measurement (127 cfs) adjusted downwards by 21%. Because this transect bisects a deep pool with eddies, it is difficult to obtain an accurate discharge measurement. The eddy effect was much more pronounced at the high calibration flow measurement, as there was about a 40 foot a section in which the velocities were negative. Because of its depth and slow velocities, this area was considered valuable habitat for rearing juvenile salmon. In order to facilitate using these negative velocity values in the model these measurements were treated as positive.

At transect 3, there was a difference in WSEL's at the 127 cfs calibration flow. WSEL at the left bank was 95.03 feet, whereas at the right bank it was 94.90 feet. As the staff gage WSEL was 94.93 feet and the majority of flow occurred along this right side, a WSEL of 94.93 feet was used in the model.

At transect 4, there was a large discrepancy (0.54 ft) in WSEL's across the transect at the calibration flow of 127 cfs. This occurred because



Appendix Figure D-39. Comparison of observed and predicted water surface profiles from calibrated model and surveyed thalweg profile at Sunset Side Channel (adapted from Quane et al. 1985).

Appendix Table D-11. Comparison between observed and predicted water surface elevations, discharges, and velocities for 1984 Sunset Side Channel hydraulic model.

Streambed Station	Water Surface Elevation		Discharge		Velocity Adjustment Factor
(ft)	Observed (ft)	Predicted (ft)	Observed (cfs)	Predicted (cfs)	
0+00	94.27	94.27	132.7	132.4	1.000
2+23	94.34	94.34	131.7	131.3	.999
4+75	94.69	94.69	133.6	133.3	1.000
7+58	94.97	94.97	127.2	126.9	.998
9+10	95.54	95.54	136.4	136.3	1.000
11+53	95.98	95.98	125.5	125.2	.999
14+10	95.97	95.97	129.9	129.6	
			Qo = 131.0	Qp = 131.0	
0+00	95.62	95.62	462.3	462.3	1.000
2+23	95.67	95.67	500.0	500.0	.999
4+75	95.75	95.75	504.6	504.6	1.000
7+58	95.87	95.87	438.1	438.1	1.000
9+10	96.18	96.18	507.2	507.2	.993
11+53	96.64	96.64	469.9	469.9	.999
14+10	96.63	96.63	492.0	492.0	1.000
			Qo = 482.0	Qp = 482.0	

Qo is the mean observed calibration discharge.

Qp is the mean predicted calibration discharge.

Appendix Table D-12. Differences between stages of zero flow input into the model and Quane et al. (1985) thalweg survey at Sunset Side Channel.

Transect	Stage of Zero Flow (ft)	
	Model Input	Thalweg Survey
0	92.30	92.50
1	92.60	93.00
2	93.40	93.60
3	93.40	93.60
4	94.20	94.40
5	94.20	94.40
6	94.20	94.40

the section of the channel where a majority of the flow occurred was higher in elevation and separated by a gravel berm from a lower elevation minor channel where the staff gage was located. In order to utilize this cross section in the model, the channel cross section of the minor channel was elevated upwards by 0.6 feet.

At a section of transect 3, because of channel configuration, the individual velocity measurements for the 127 cfs site flow were greater than the corresponding velocity measurements at the higher 496 cfs site flow. If these original values were to be used in the model the simulated velocities would decrease with increasing site flows rather than increase as expected under normal circumstances. In order to amend this situation, the velocities were adjusted such that the relationship would simulate a positive increase in velocities with corresponding increases in site flow.

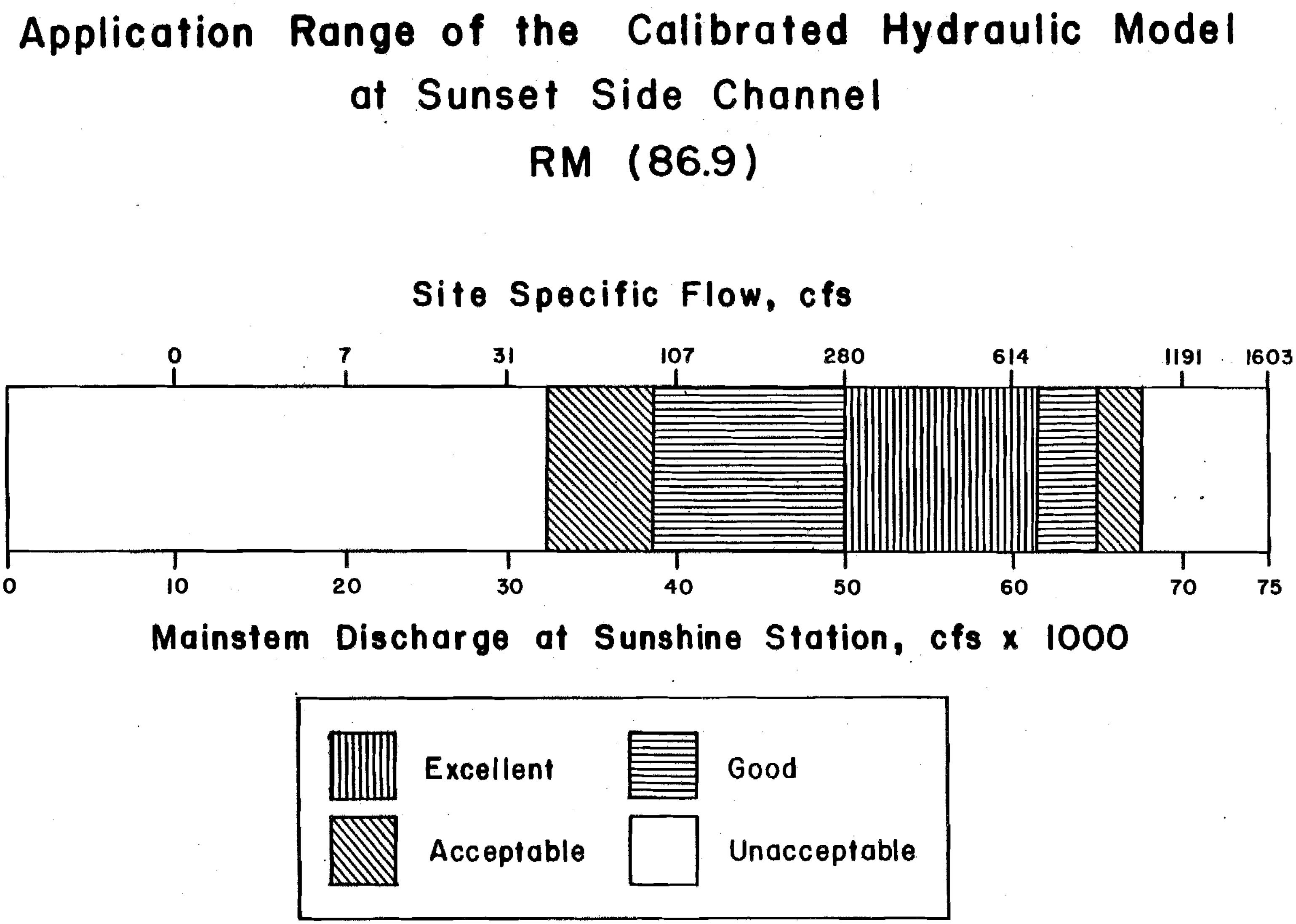
Verification

Based on the first level of verification by EWT&A, the model does an excellent job of simulating channel hydraulics between 50,000 and 61,000 cfs, mainstem discharge(275 and 649 cfs site flow). Above 61,000 cfs, the realiability of the simulated depth and velocity distributions begin to decrease. The model simulations were rated good between 61,000 and 64,500 cfs (649 and 850 cfs site flow), acceptable between 64,500 and 67,000 cfs (850 and 1,000 cfs site flow), and unacceptable above 67,000 cfs mainstem discharge. Below 50,000 cfs, the model simulations were also rated less than excellent, primarily because of reduced effectiveness in predicting water surface profiles as compared to field observations. The model simulations were rated good between 38,000 and 50,000 cfs (89 and 275 cfs site flow), acceptable between 32,000 and 38,000 cfs (41 and 89 cfs site flow), and unacceptable below 32,000 cfs mainstem discharge (Appendix Figure D-40).

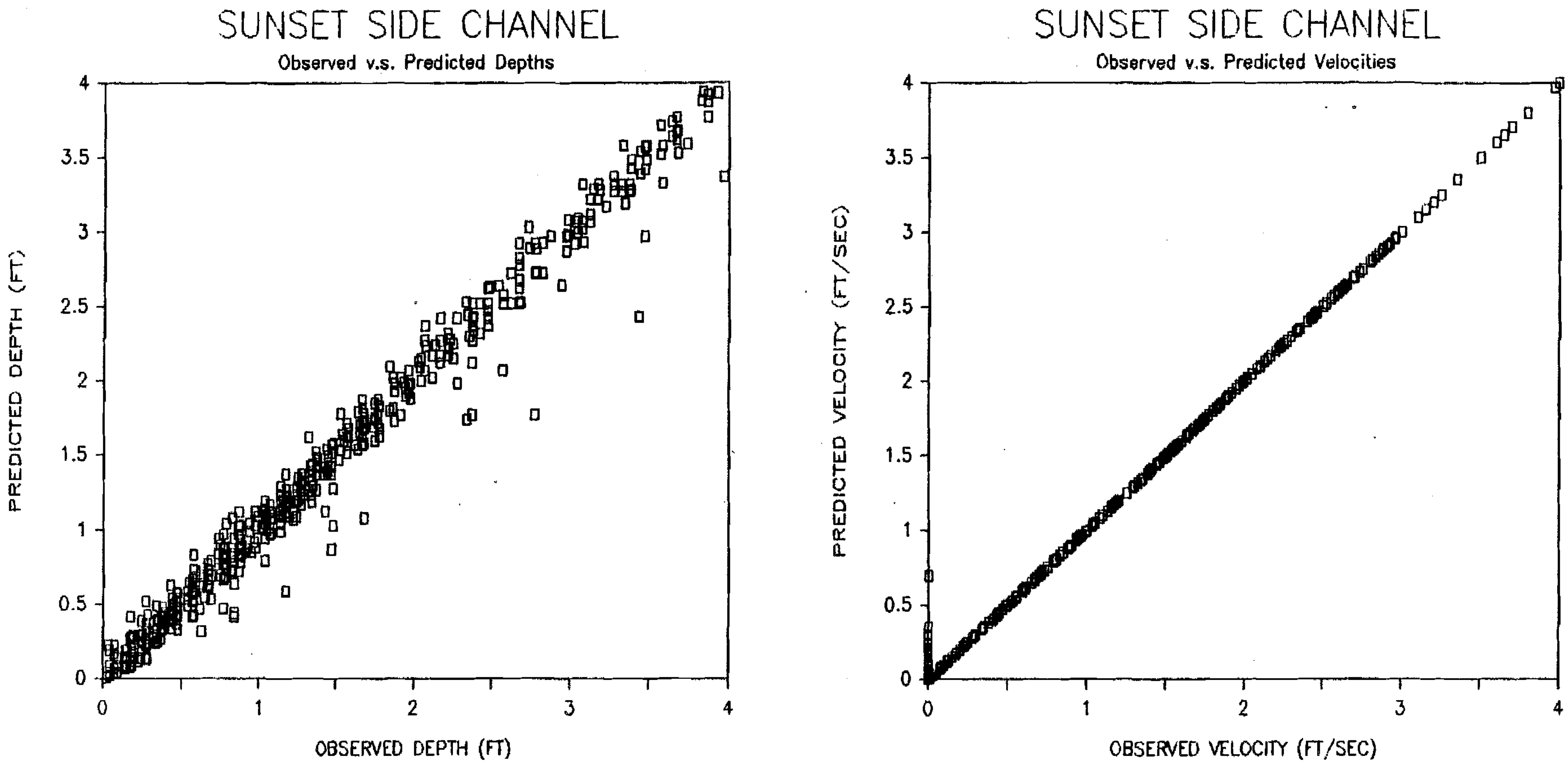
At the second level of verification there is excellent agreement for velocity and good agreement for depth between observed and predicted values (Appendix Figure D-41). For a small number of depths there is a deviation away from the expected one to one relationship and this maybe attributable to the adjustments in the channel cross section at transect 4. The statistical tests show good agreement between these predicted and observed values (Appendix Table D-7). The index of agreement is almost one, the total RMSE is mostly composed of the unsystematic RMSE, and the y-intercept is essentially zero with a slope of 0.99.

Application

For habitat simulation modelling purposes the hydraulic simulation model developed for Sunset Side Channel can simulate channel flows in the mainstem discharge range of 32,000 to 67,000 cfs.



Appendix Figure D-40. Application range of calibrated hydraulic model at Sunset Side Channel.



Appendix Figure D-41. Scatterplots of observed and predicted depths and velocities from the calibrated IFG-4 hydraulic model at Sunset Side Channel.

Trapper Creek Side Channel (RM 91.6)

Site Description

Trapper Creek Side Channel is located on the west bank of the Susitna River and is approximately 5.0 miles long (Appendix Figure D-42). It has a relatively uniform, broad, and flat bottomed alluvial channel which is fed by multiple heads. It is separated from the mainstem Susitna River by a complex of sand bars, small channels, and vegetated islands. The head portion of this side channel is located in a complex of small channels and vegetated islands making it difficult to identify the origin of breaching flows (Quane et al. 1985).

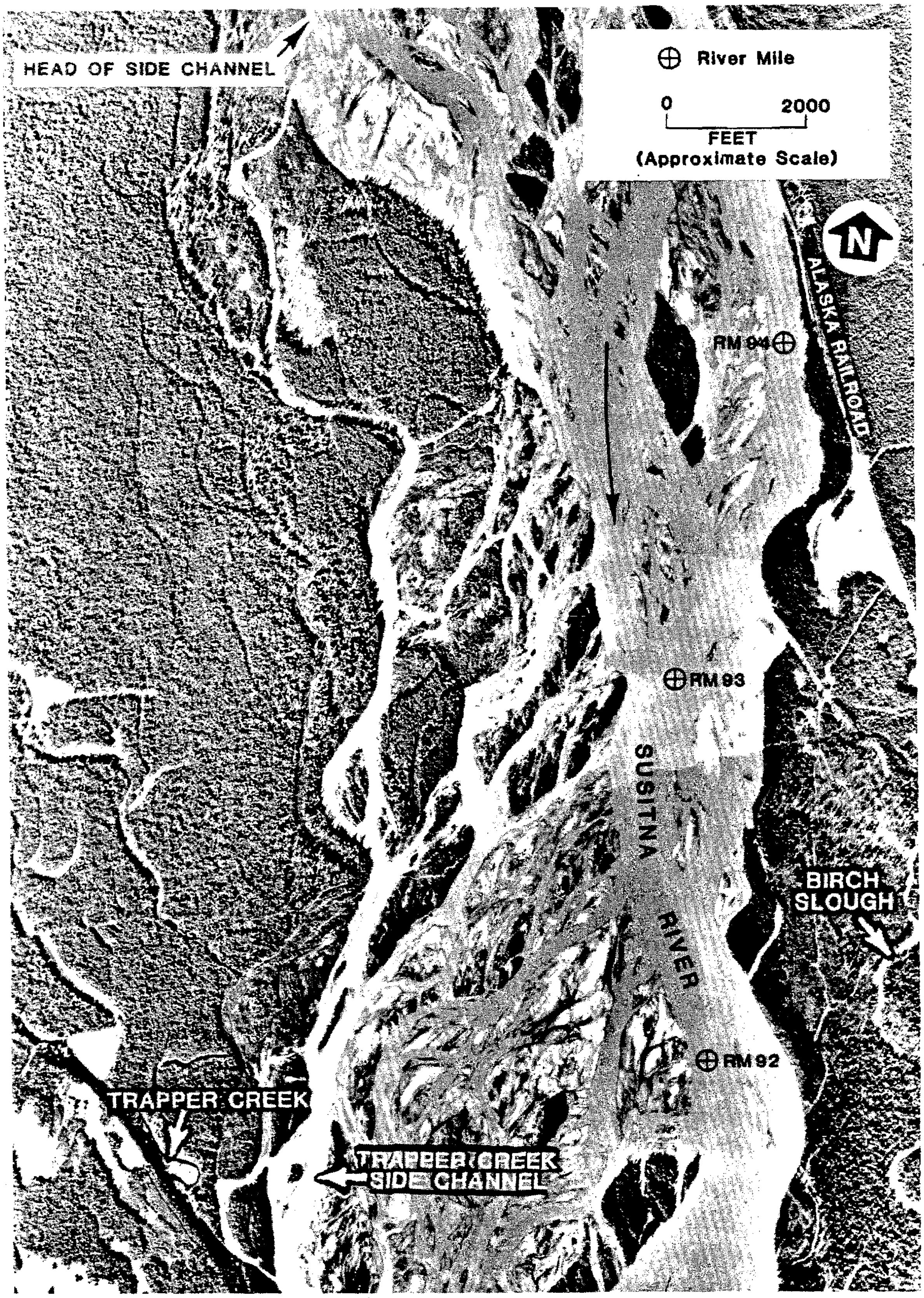
During unbreached conditions, flows in Trapper Creek Side Channel are principally due to Cache Creek and groundwater from the upper reaches of the side channel. Breaching of Trapper Creek Side Channel is the result of the direct overtopping of the multiple heads of the side channel by the mainstem Susitna River. Based on assessments by Quane et al. (1985), the channel is estimated to be initially breached at a mainstem discharge of 43,000 cfs. Based on the comparison of the stage versus mainstem discharge rating curve for transect 4 (Appendix Figure D-43) by Quane et al. 1985, a discharge of 44,000 cfs was selected as the controlling breaching discharge. This mainstem discharge corresponds to a streamflow measurement of 31.4 cfs.

Based on assessments by Quane et al. (1985), backwater has not been observed. But at mainstem discharges ranging from 15,700 to 22,700 cfs, pooling was observed at transects 1, 2, and 3 which resulted from the control located about 370 feet downstream from transect 1.

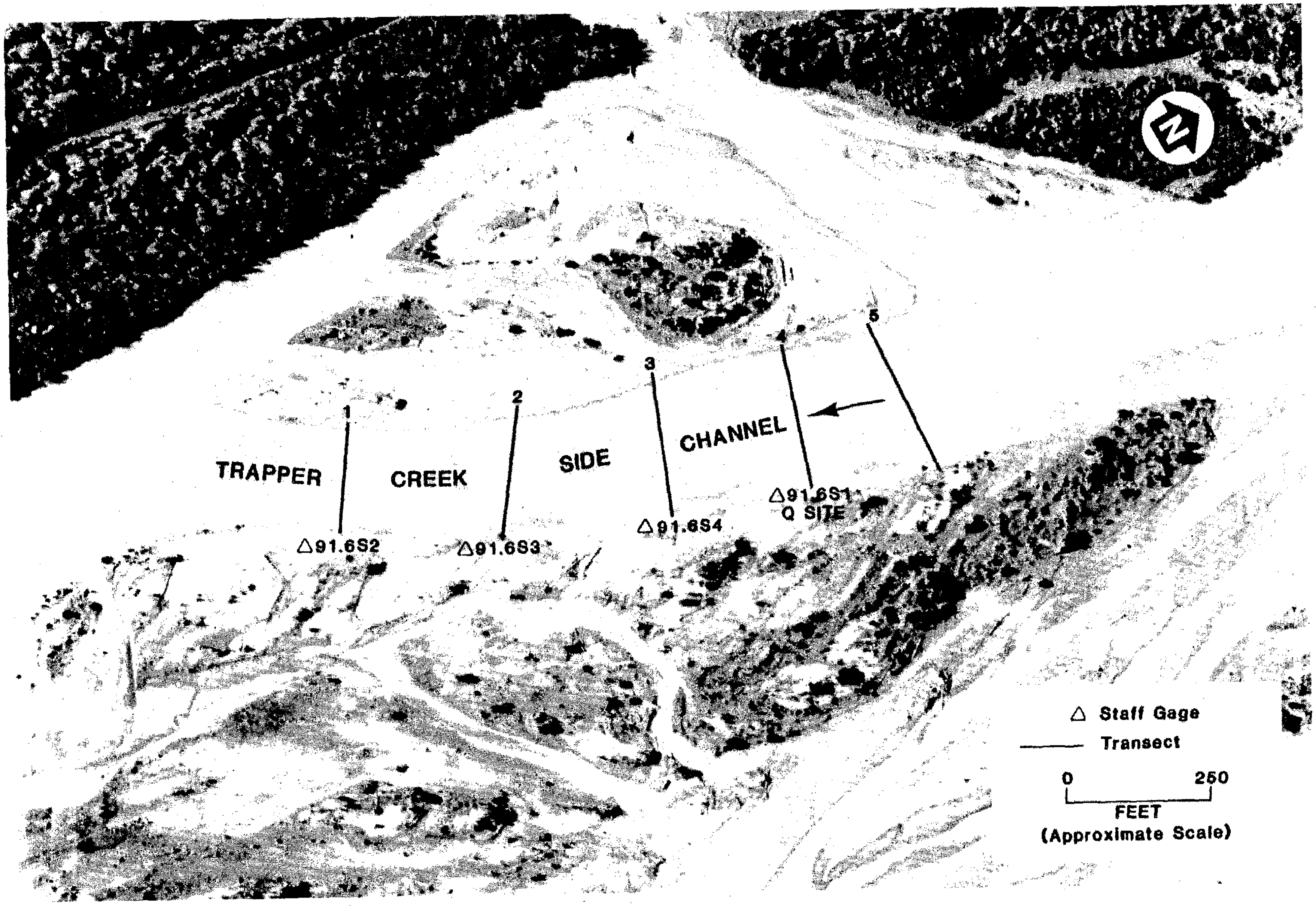
The 790 foot long IFG modelling site at Trapper Creek Side Channel was located in the lower portion of the side channel in a broad open channel area (Appendix Figure D-44). Four cross sections were surveyed within this area to define channel geometry (Appendix Figure D-45). The upper two transects were situated in a run, whereas the lower two transects were in a pool influenced by a downstream control. Substrate consisted primarily of rubble and gravels with some sand at the first transect. The thalweg gradient of the side channel is 12.1 ft/mile (Quane et al. 1985).

Calibration

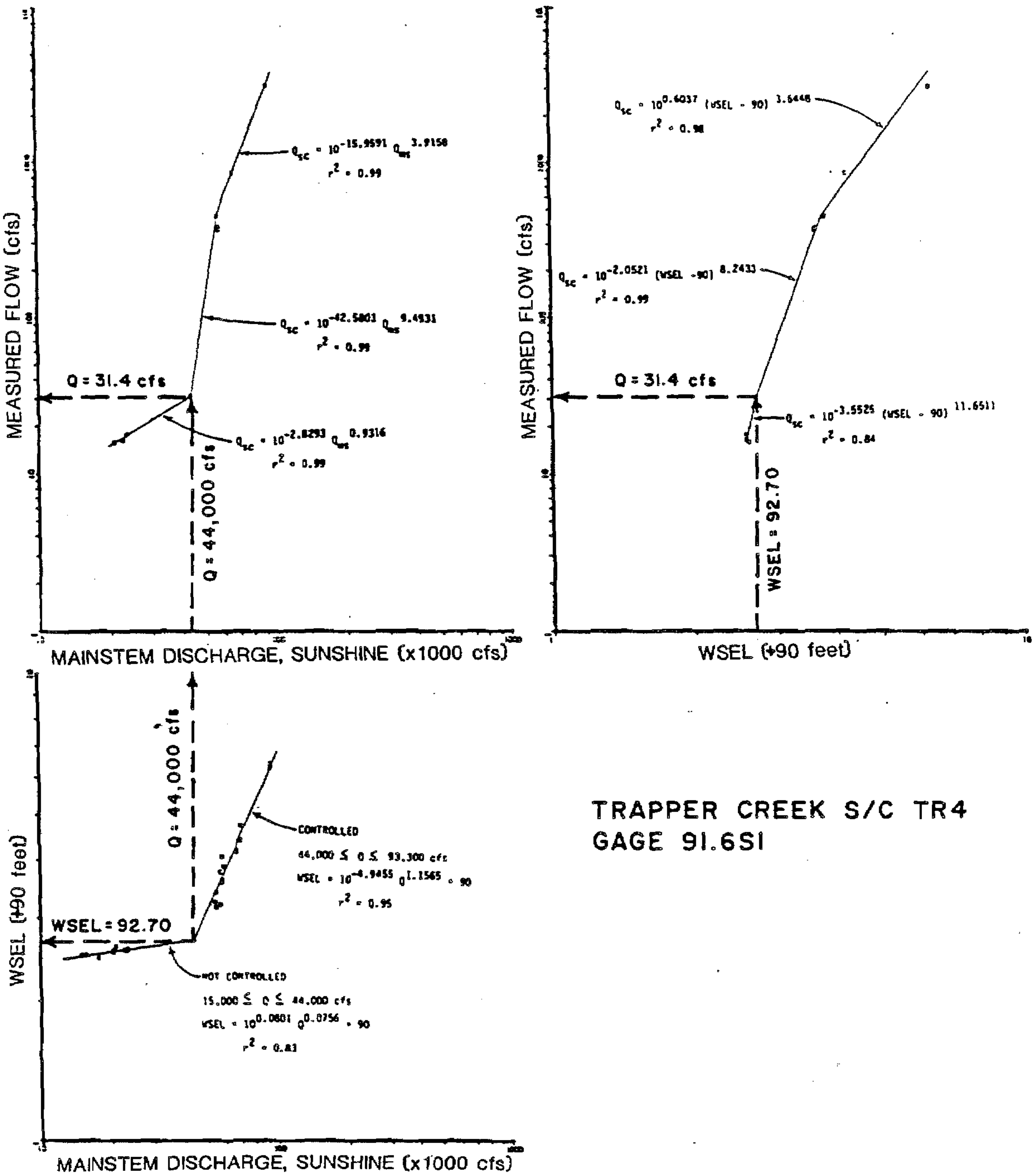
Hydraulic data were collected at three calibration flows: 16, 32, and 389 cfs (Appendix Table D-4). Mean daily discharges for the Susitna River on the dates that calibration data were collected at the Trapper Creek study site were 20,900 cfs, 44,000 cfs, and 57,700 cfs respectively. Based on these calibration flows an IFG-4 model was used to forecast instream hydraulics for this study site. The streambed profile, stages of zero flow, and observed and predicted water surface elevations for the study reach are plotted to scale in Appendix Figure D-46. All three data sets were used to predict hydraulic information for side channel flows from 9 to 1,351 cfs (mainstem discharges of 12,000 to 75,000 cfs).



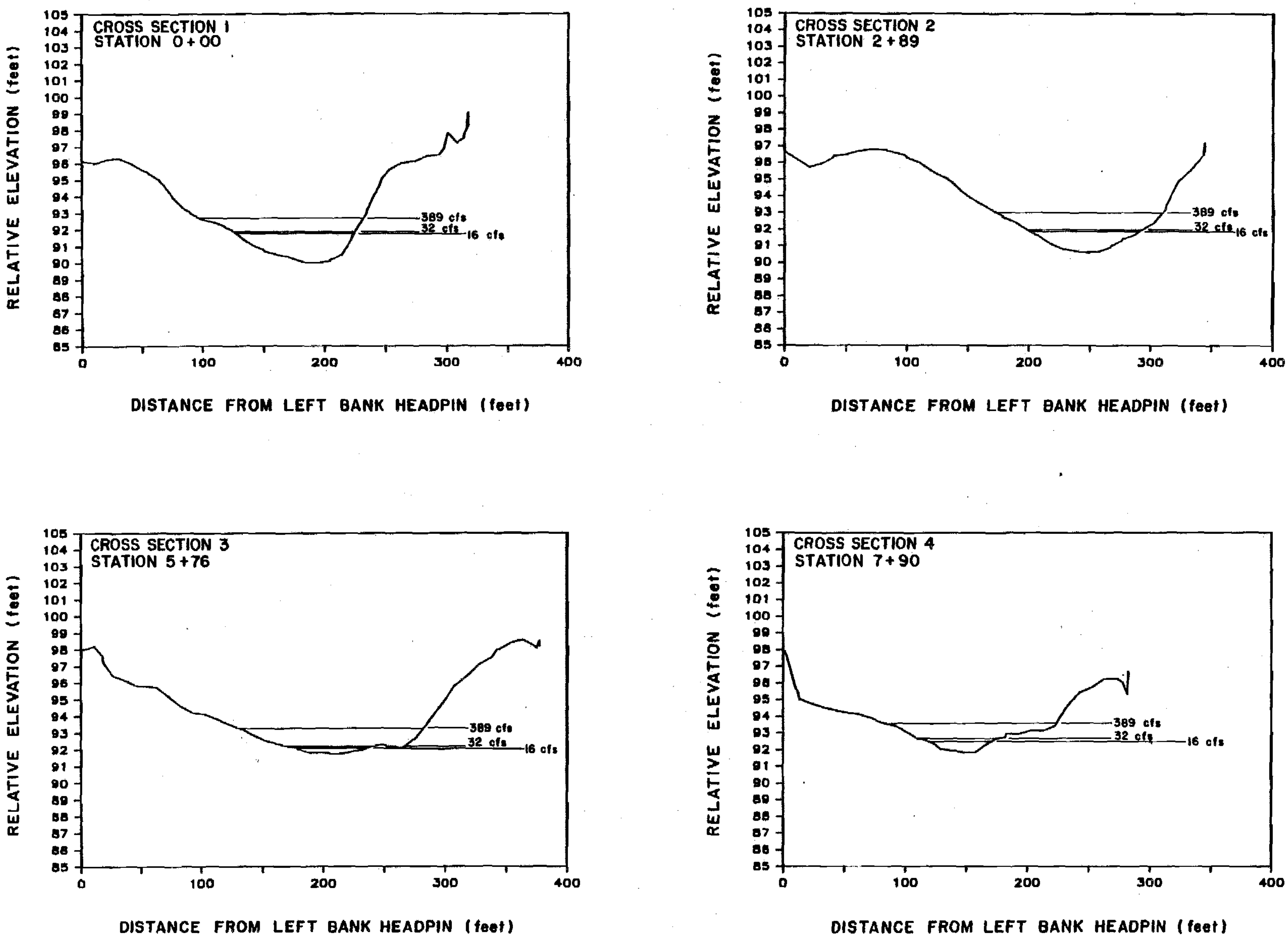
Appendix Figure D-42. Overview of Trapper Creek Side Channel (RM 91.6).



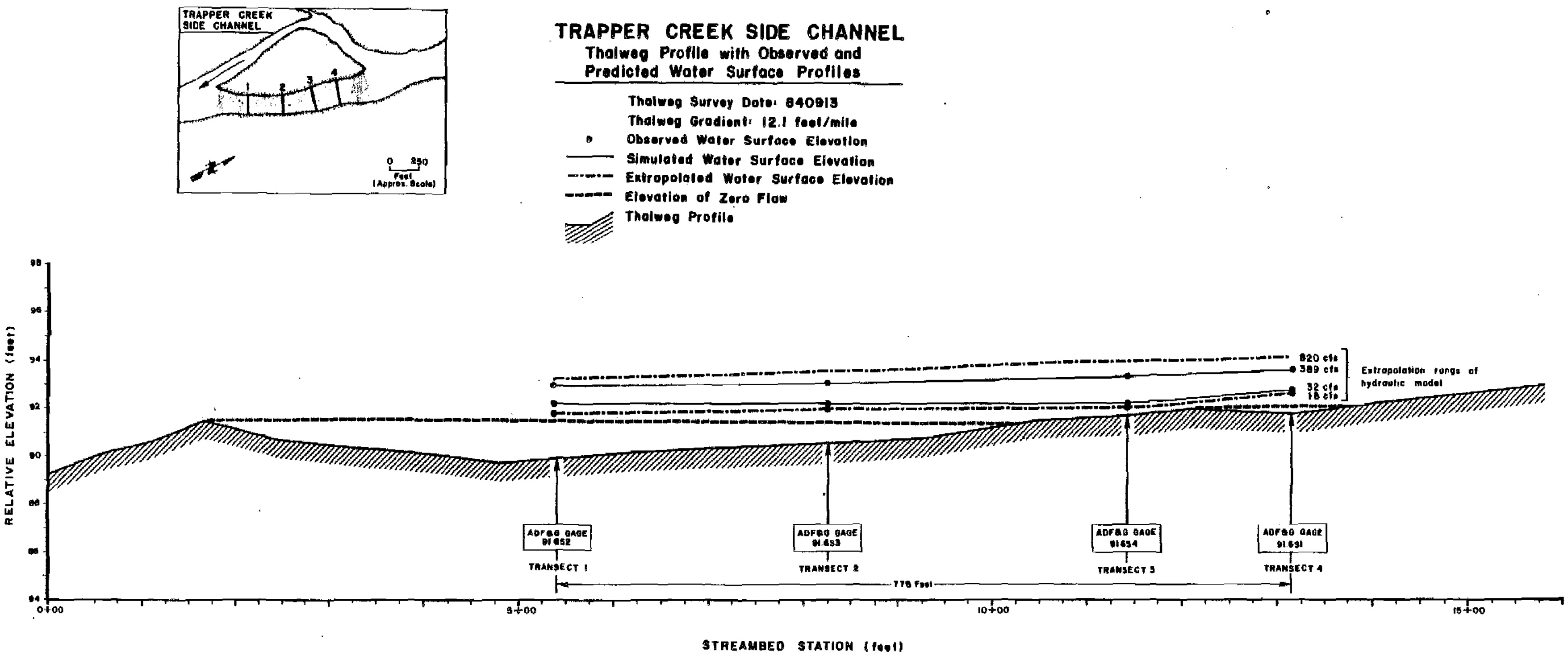
Appendix Figure D-44. Location of Trapper Creek Side Channel study site (RM 91.6).



Appendix Figure D-43. Comparison of rating curves from Trapper Creek Side Channel transect 4 (from Quane et. al. 1985).



Appendix Figure D-45. Cross section of transects 1, 2, 3, and 4 at Trapper Creek Side Channel (adapted from Quane et al. 1985).



Appendix Figure D-46. Comparison of observed and predicted water surface profiles from calibrated model and surveyed thalweg profile for Trapper Creek Side Channel (adapted from Quane et al. 1985).

To evaluate the performance of the hydraulic model, observed and predicted water surface elevations, discharges, and velocity adjustment factors were compared (Appendix Table D-13). Of the 12 sets of observed and predicted WSEL's, six sets were within ±0.02 feet of each other and the other six sets were within ±0.05 feet of each other. All the observed and predicted discharges were within 10% of each other except for one set in which there was an 11% difference. All velocity adjustment factors were within the good range of 0.9 to 1.1. Additionally, the stage information of the model was compared to the rating curves established by Quane et al. (1985) (Appendix Figure D-43).

Between the time that the first two calibration flows (389 and 32 cfs) were made and the last calibration flow of 16 cfs was made, the channel cross section at transect 1 was scoured by a flood event. In order to utilize this information in the model, the cross section determined from the survey and the 16 cfs flow measurement were used, and the WSEL's of the two calibration flows (389 and 32 cfs) were then reduced by 0.37 feet.

Transect 1 was determined to be a poor site for measuring discharge because it was a pool area affected by a downstream control. The velocities for the 32 cfs calibration flow were therefore adjusted upwards by 27%, and at the 16 cfs calibration flow were also adjusted upwards by 20%.

Verification

Based on the first level of verification by EWT&A the model does a good job of simulating channel hydraulics between 20,000 cfs and 54,000 cfs mainstem discharge (15 and 220 cfs site flow) (Appendix Figure D-47). There are sufficient deviations in water surface elevation and discharge between predicted and observed values within this range to preclude attainment of the excellent rating. This occurs because the model is approximating a portion of the rating curve described by two adjoining linear relationships with a single line.

Between 54,000 cfs and 58,000 cfs mainstem (220 and 460 cfs site flow) the model does an excellent job of simulating channel hydraulics. Beyond 58,000 cfs mainstem, the quality of the simulations begins to deteriorate as the slope of the stage/discharge relationship for the site flattens with a change in channel geometry. The deviation between the regression line developed within the model and that of the rating curve increases with discharge until the model simulations are no longer acceptable. The model simulations were rated good between 58,000 cfs and 61,000 cfs (460 and 600 cfs site flow), acceptable between 61,000 cfs and 66,000 cfs (600 and 820 cfs site flow), and unacceptable above 66,000 cfs mainstem (Appendix Figure D-47).

At the second level of verification there is good agreement between the observed and predicted values for velocity and depth (Appendix Figure D-48). The statistical tests also show good agreement between the predicted and observed values (Appendix Table D-7). The index of agreement is 0.99, the total RMSE is largely composed of the unsystematic RMSE, and the y-intercept is almost zero with a slope near one.

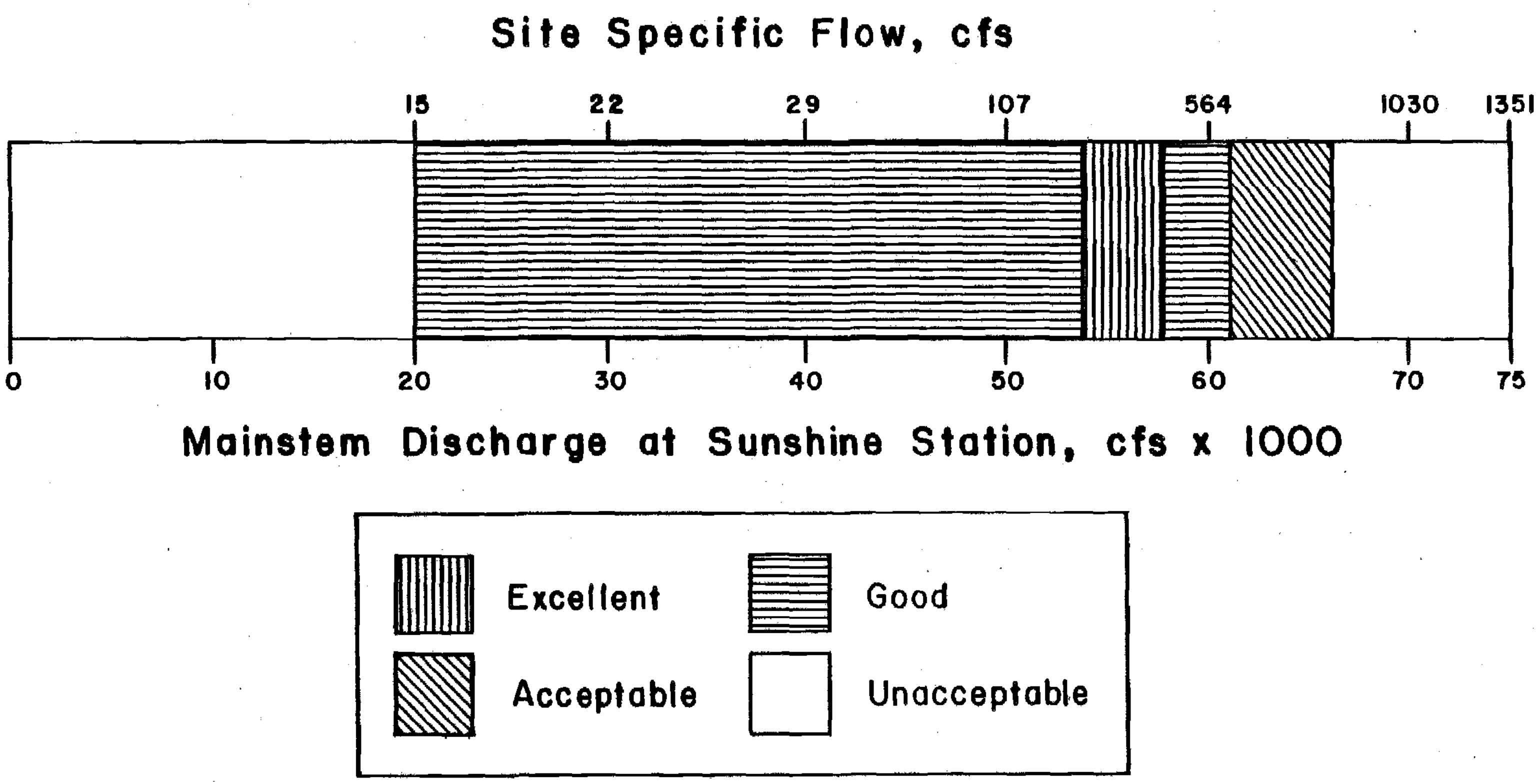
Appendix Table D-13. Comparison between observed and predicted water surface elevations, discharges, and velocities for 1984 Trapper Creek Side Channel hydraulic model.

Streambed Station (ft)	Water Surface Elevation Observed (ft)	Water Surface Elevation Predicted (ft)	Discharge Observed (cfs)	Discharge Predicted (cfs)	Velocity Adjustment Factor
0+00	91.94	91.90	15.4	15.1	.985
2+89	91.94	91.91	15.5	14.1	.962
5+76	92.18	92.14	16.7	15.6	.995
7+90	92.56	92.56	15.1	15.1	.976
			Qo = 16.0	Qp = 15.0	
0+00	91.97	92.92	30.1	30.8	1.041
2+89	92.00	92.04	26.0	28.9	1.033
5+76	92.24	92.29	29.6	31.8	1.043
7+90	92.70	92.70	30.2	30.2	1.042
			Qo = 29.0	Qp = 30.0	
0+00	92.75	92.74	397.8	397.3	.980
2+89	93.00	92.99	392.3	387.9	.995
5+76	93.32	93.31	413.4	410.7	.994
7+90	93.58	83.58	367.2	367.2	.997
			Qo = 393.0	Qp = 391.00	

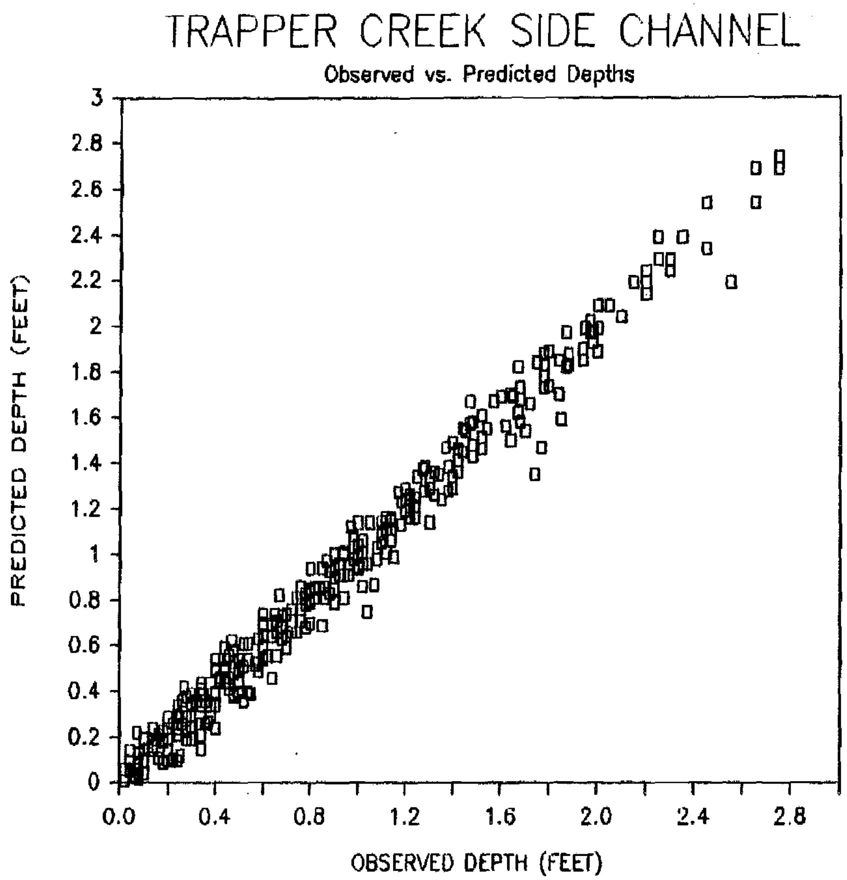
Qo is the mean observed calibration discharge.

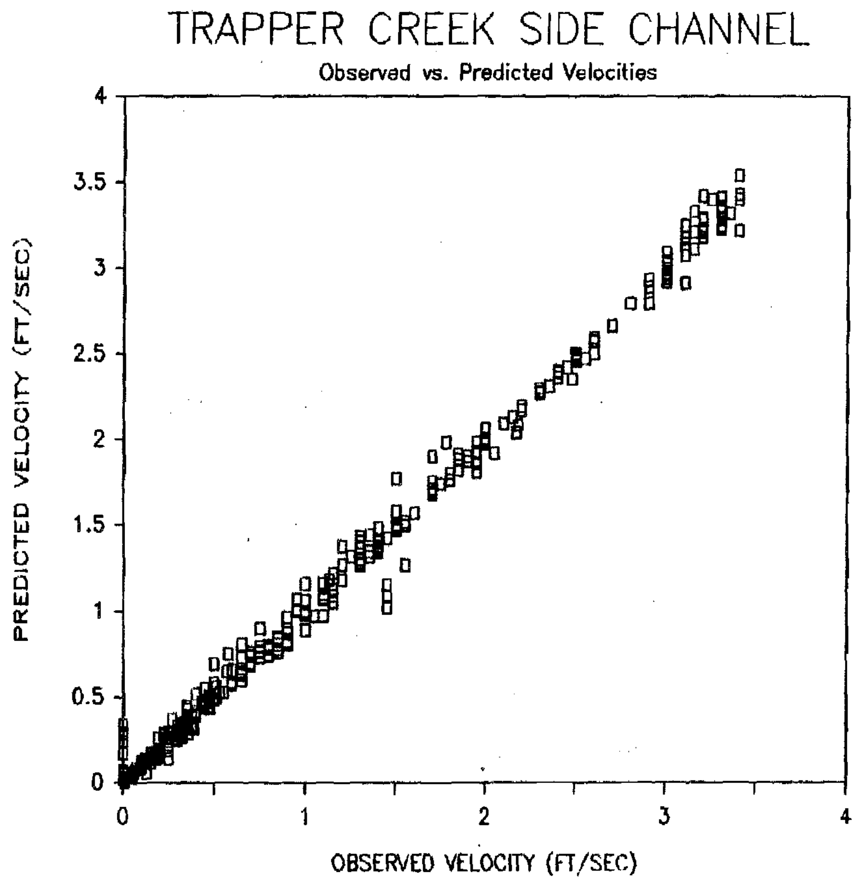
Qp is the mean predicted calibration discharge.

Application Range of the Calibrated Hydraulic Model at Trapper Creek Side Channel RM (91.6)



Appendix Figure D-47. Application range of the calibrated hydraulic model at Trapper Creek Side Channel.





Appendix Figure D-48. Scatterplots of observed and predicted depths and velocities from the calibrated IFG-4 model at Trapper Creek Side Channel.

Application

For habitat simulation modelling purposes the hydraulic simulation model developed for Trapper Creek Side Channel can simulate channel flows in the mainstem discharge range of 20,000 to 66,000 cfs.

SUMMARY

A summary of the range of mainstem discharges that the hydraulic models can simulate for the rearing habitats of salmon at the six lower river IFG modelling sites is presented in Appendix Table D-14.

Appendix Table D-14. Summarization of the range of mainstem discharges that the hydraulic models can simulate for the rearing habitats of salmon at the six lower river IFG modelling sites.

Site (RM)	Mainstem Discharge Range (cfs)
Island Side Channel (63.2)	35,000 to 70,000
Mainstem West Bank (74.4)	18,000 to 48,000
Circular Side Channel (75.3)	36,000 to 63,000
Sauna Side Channel (79.8)	44,000 to 63,000
Sunset Side Channel (86.9)	32,000 to 67,000
Trapper Creek Side Channel (91.6)	20,000 to 66,000

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