APPENDIX B

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

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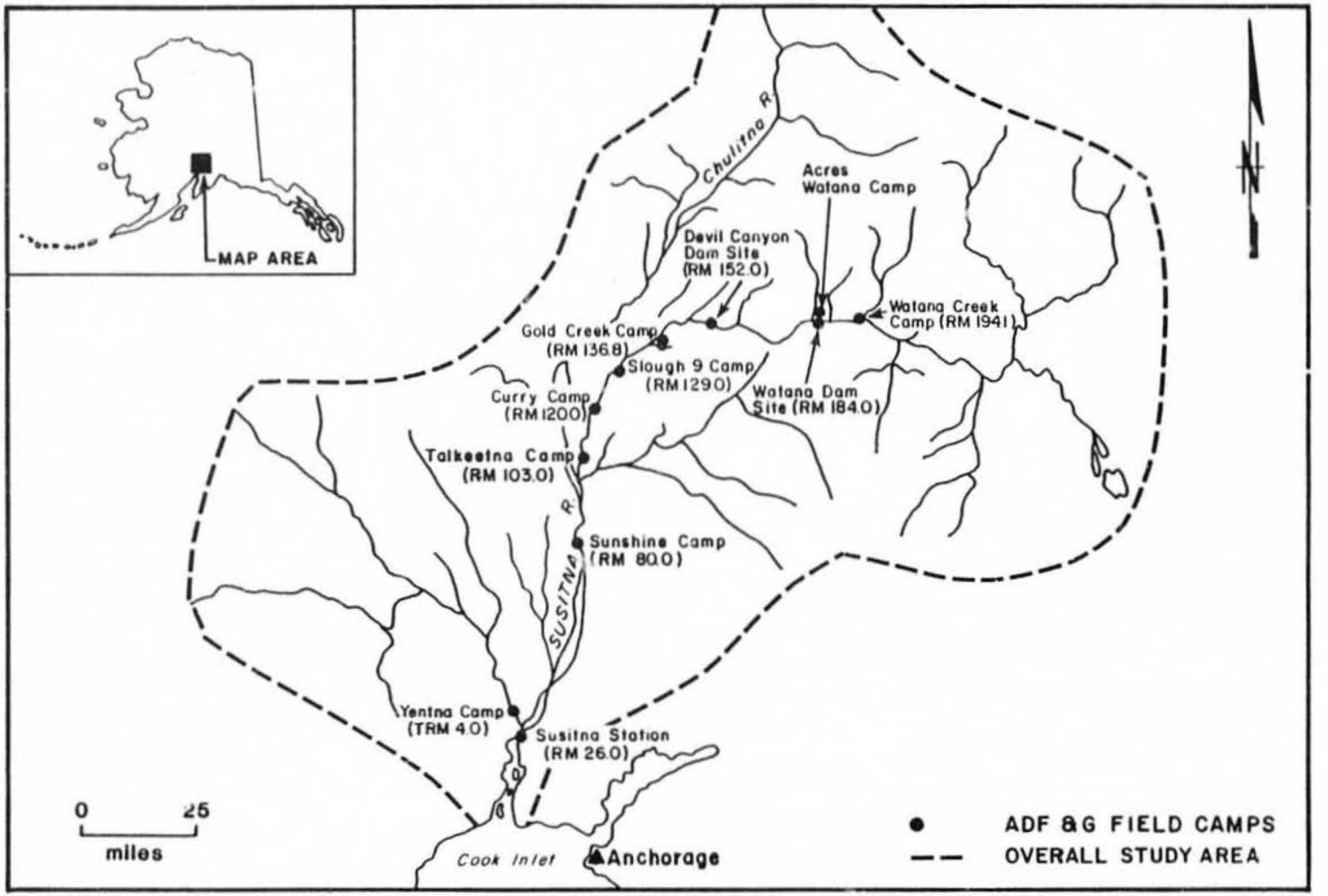
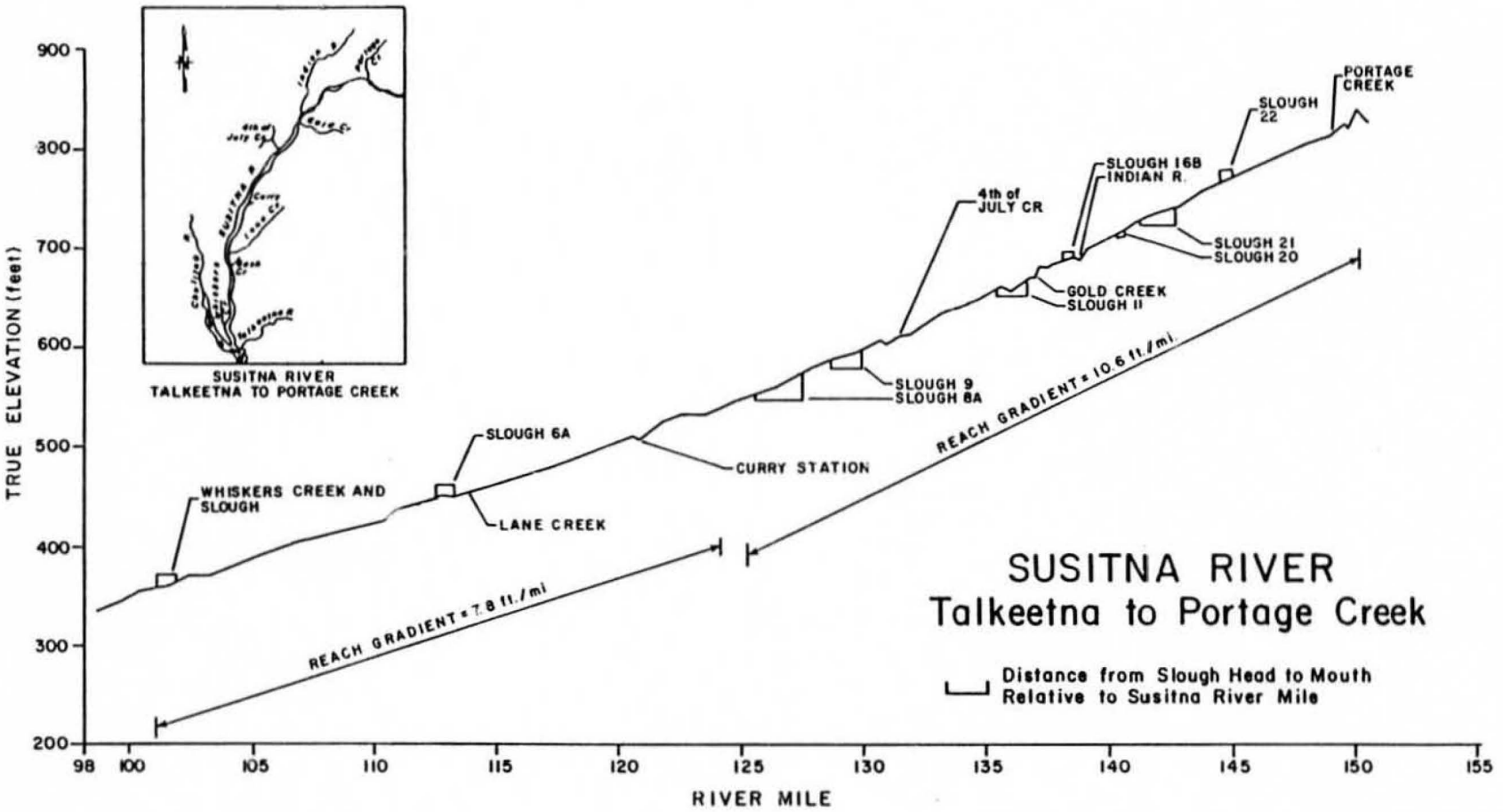
INTRODUCTION

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

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



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



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

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

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

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

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

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

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

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

varies with mainstem discharge. Depth and surface area responses of these backwater areas to various mainstem discharges appears to influence the immigration of adult salmon from the mainstem river into the sloughs.

Importance of Timing

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

Importance of Access

Positive rheotactic migration of salmon from the Susitna River into natal tributary and slough spawning areas is dependent upon adequate water velocities and depths which will allow passage. When access is

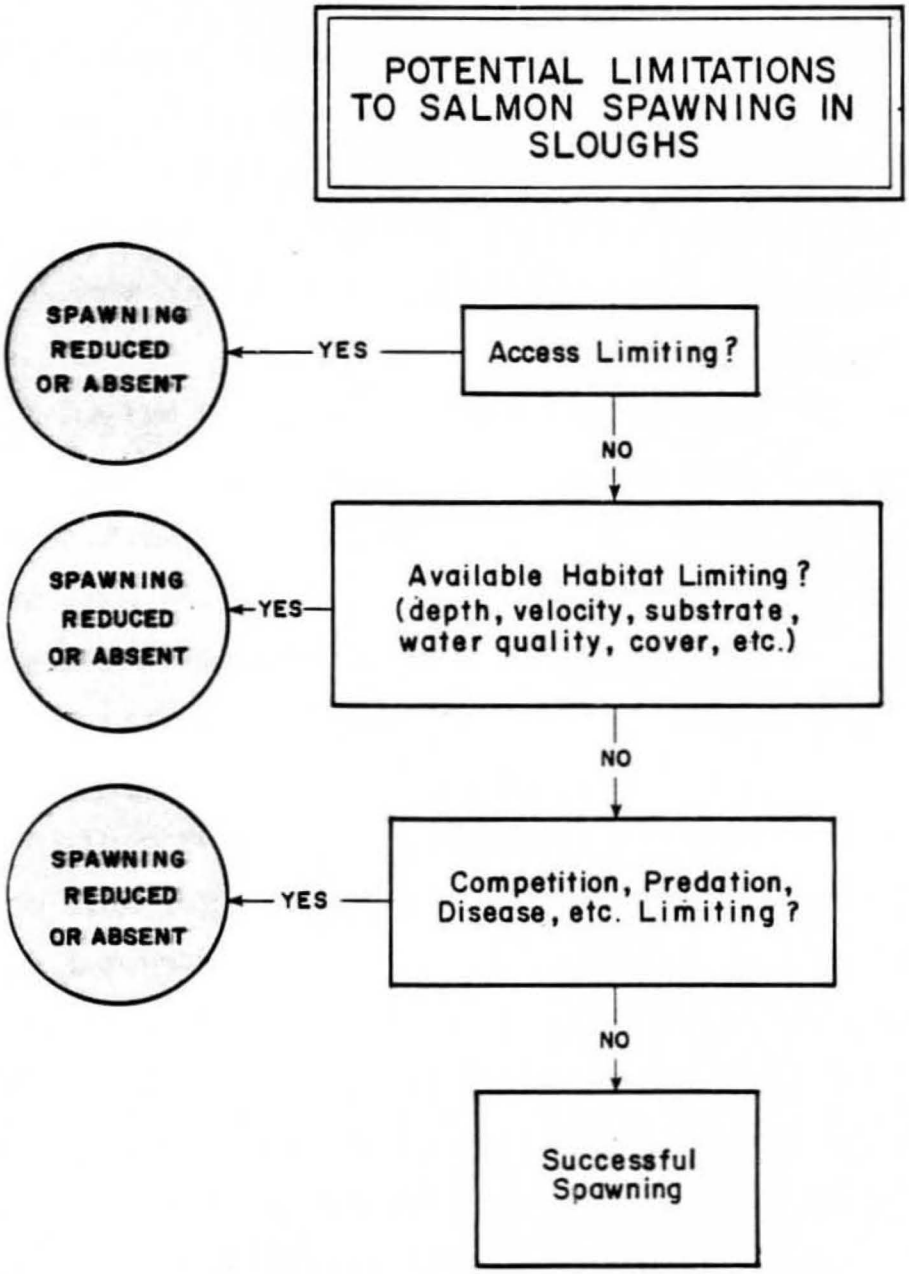
denied into a spawning area, all habitat above the impass is unavailable for use by adult salmon (Appendix Figure B-3).

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

METHODS

Timing of Upstream Migration

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



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

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

Timing of Movement into Sloughs and Tributaries

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

Slough Access Conditions

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

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

Method one

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

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

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

Thalwegs

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

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

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

Staff gages

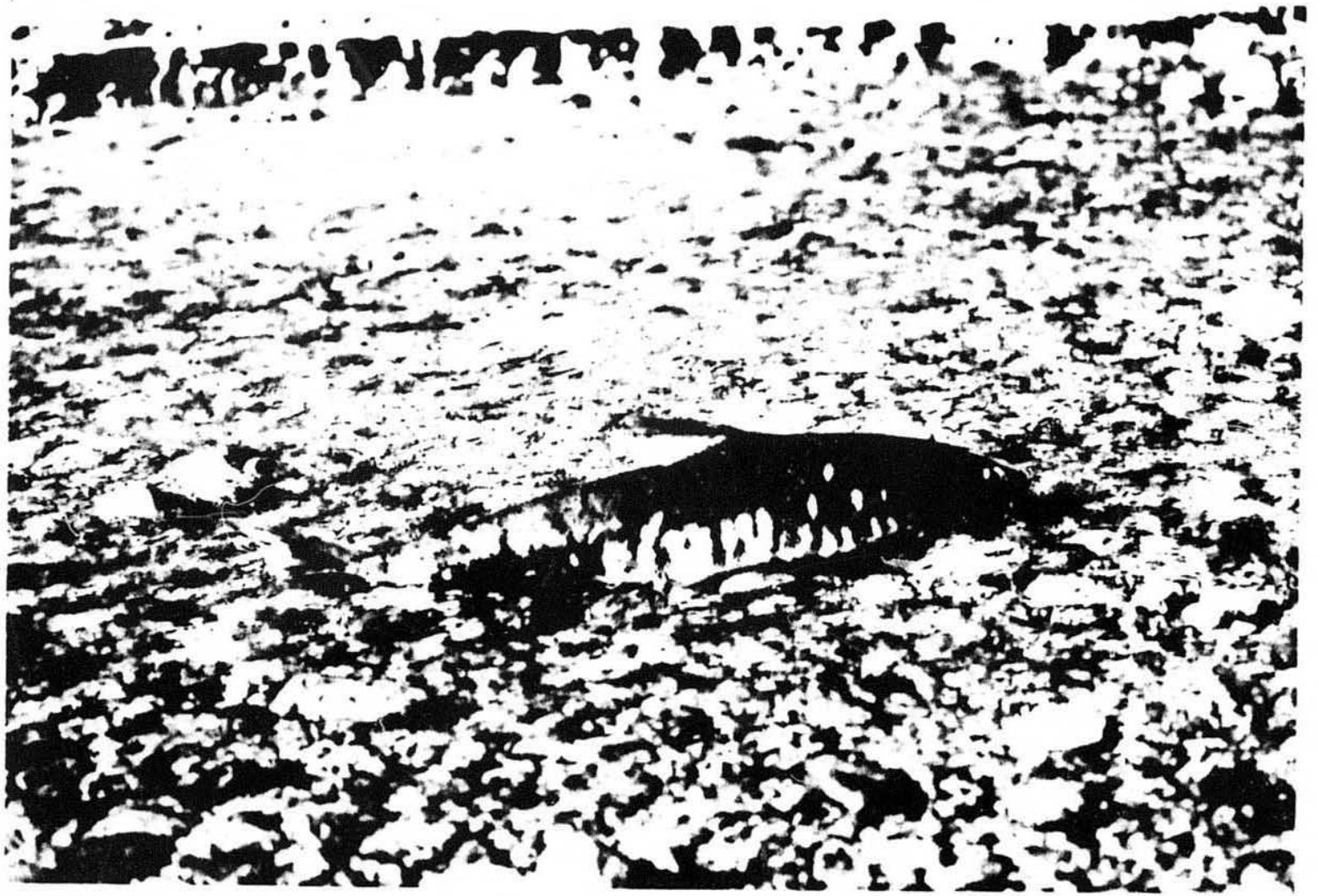
Sites for staff gage installations at the mouths of sloughs were selected in order to evaluate the influence of mainstem discharge on water depth in fish passage reaches within the slough mouth. An assumed elevation, which was referenced to a temporary bench mark (TBM), was determined for each staff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

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

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

Fish passage criteria

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



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

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

Method two

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

Stage

Data from cross sections, staff gages, and rating curves for slough stage/ mainstem discharges (ADF&G 1983b: Appendix 4-A) were combined

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

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

Fish passage criterion

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

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

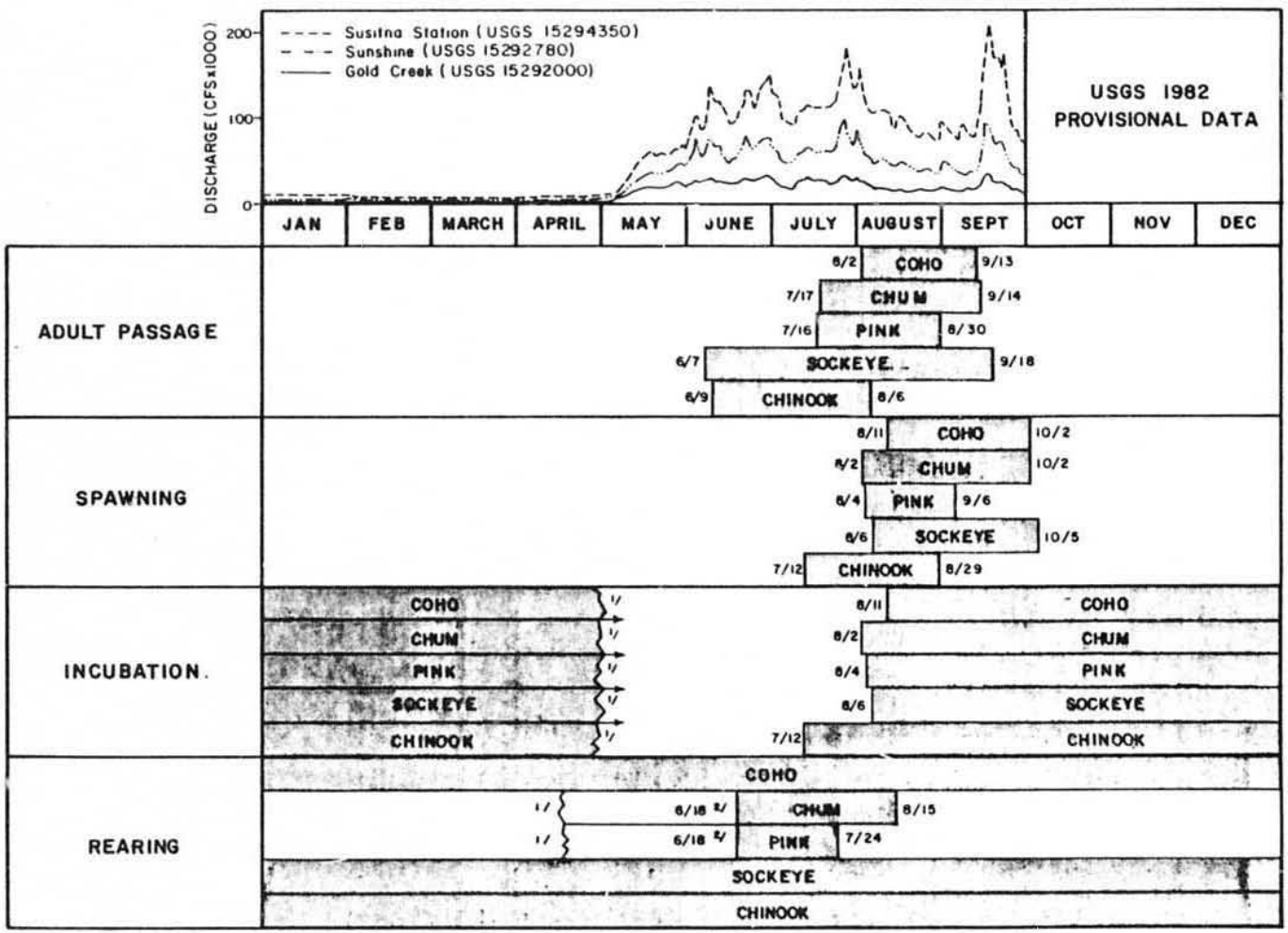
Thus, for this second approach to passage analysis, mainstem flows resulting in an average minimum water depth less than 0.5 ft at the slough mouth were considered acute and those providing depths of 0.5 ft or greater were considered unrestricted.

RESULTS

Timing of Upstream Migration

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

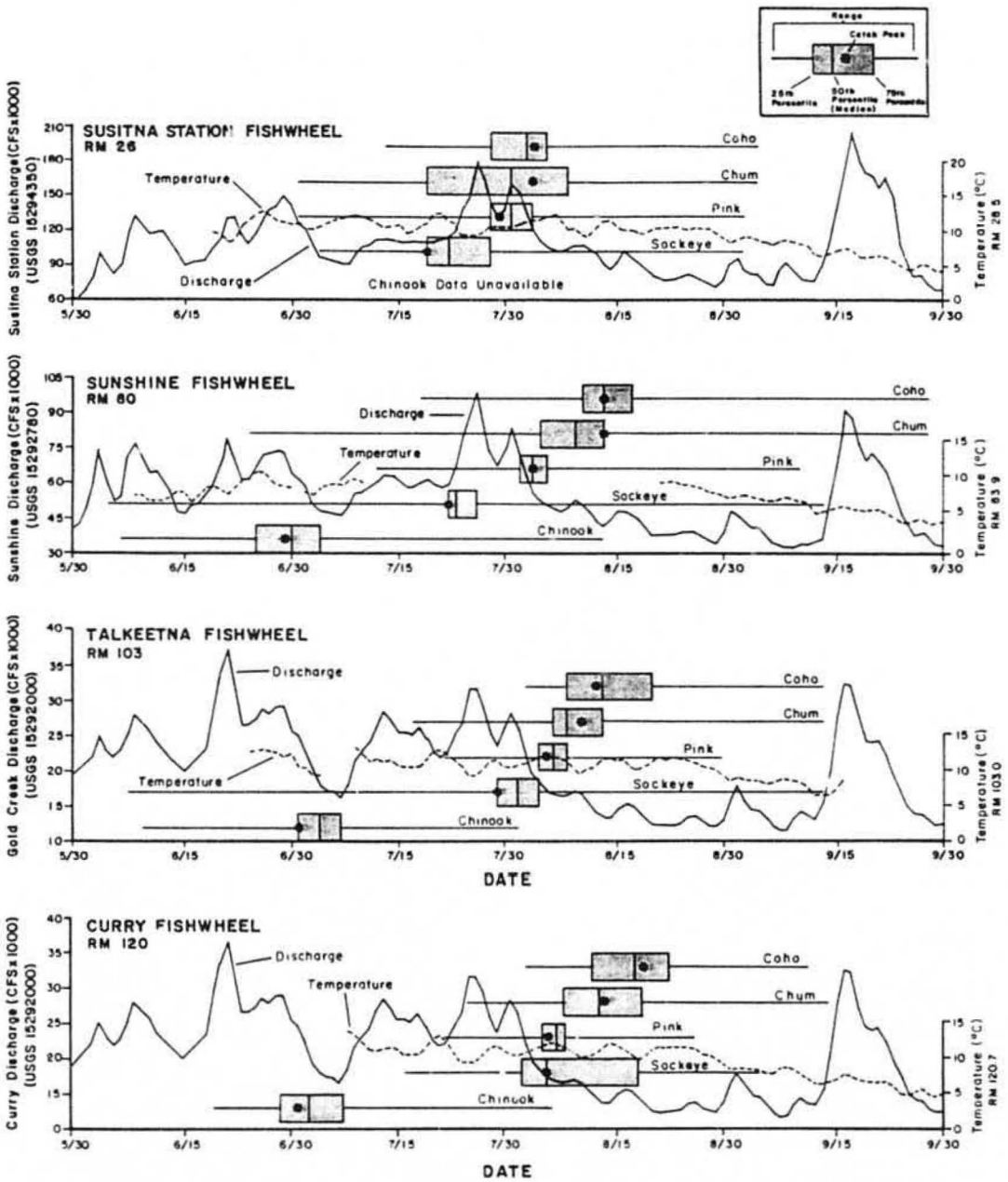
Because there appears to be an inverse relationship between discharge and temperature (Appendix Figure B-5) it is not possible to distinguish their separate effects on upstream movements of salmon. Both of these variables undoubtedly affect a host of other physical and chemical



1/ EMERGENCE DATA NOT AVAILABLE AT TIME OF PREPARATION

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

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



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

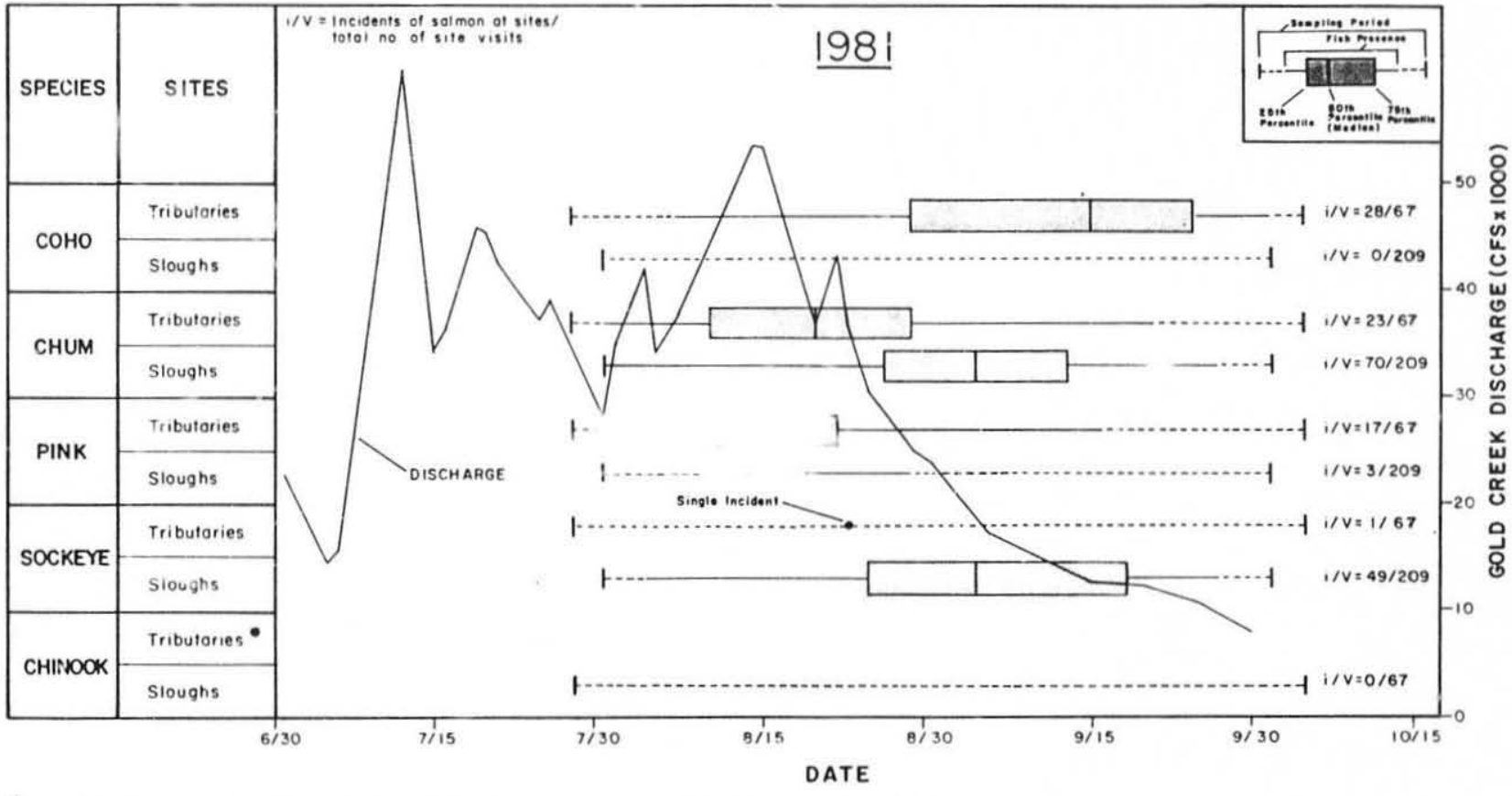
variables, many of which may be affecting salmon migration. In spite of these interpretative limitations it is important to establish the range of conditions encountered by adult salmon during migration. In 1982, salmon migrated up the Susitna River when surface water temperatures ranged between 7 and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

Timing of Movement into Sloughs and Tributaries

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

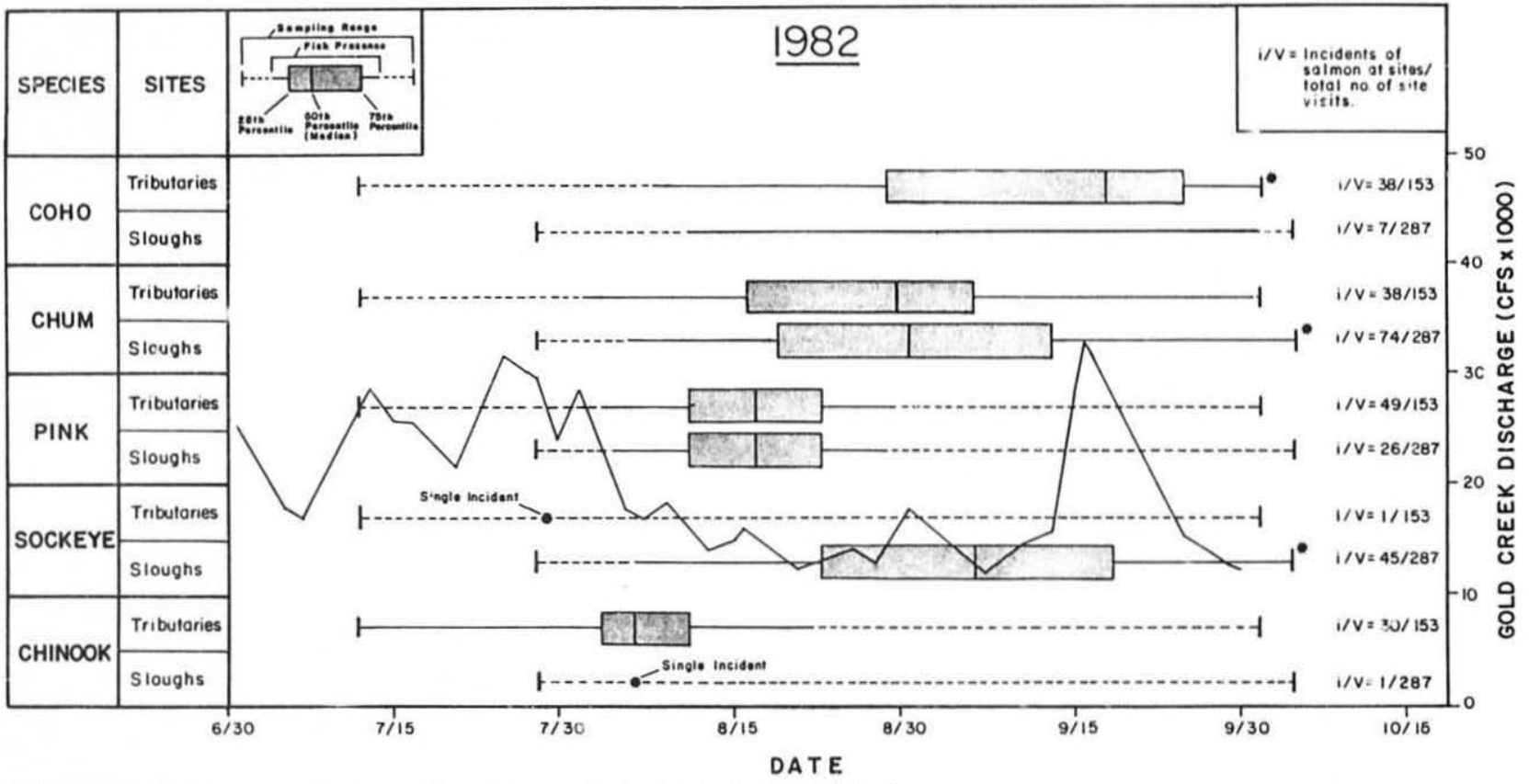
The median dates of arrival for a species in sloughs and tributaries were similar in 1981 and 1982 (Appendix Figures B-6 and B-7). The largest difference for any species in median arrival time between the two years was less than 10 days. This difference is relatively small in light of the large differences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

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



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

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



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

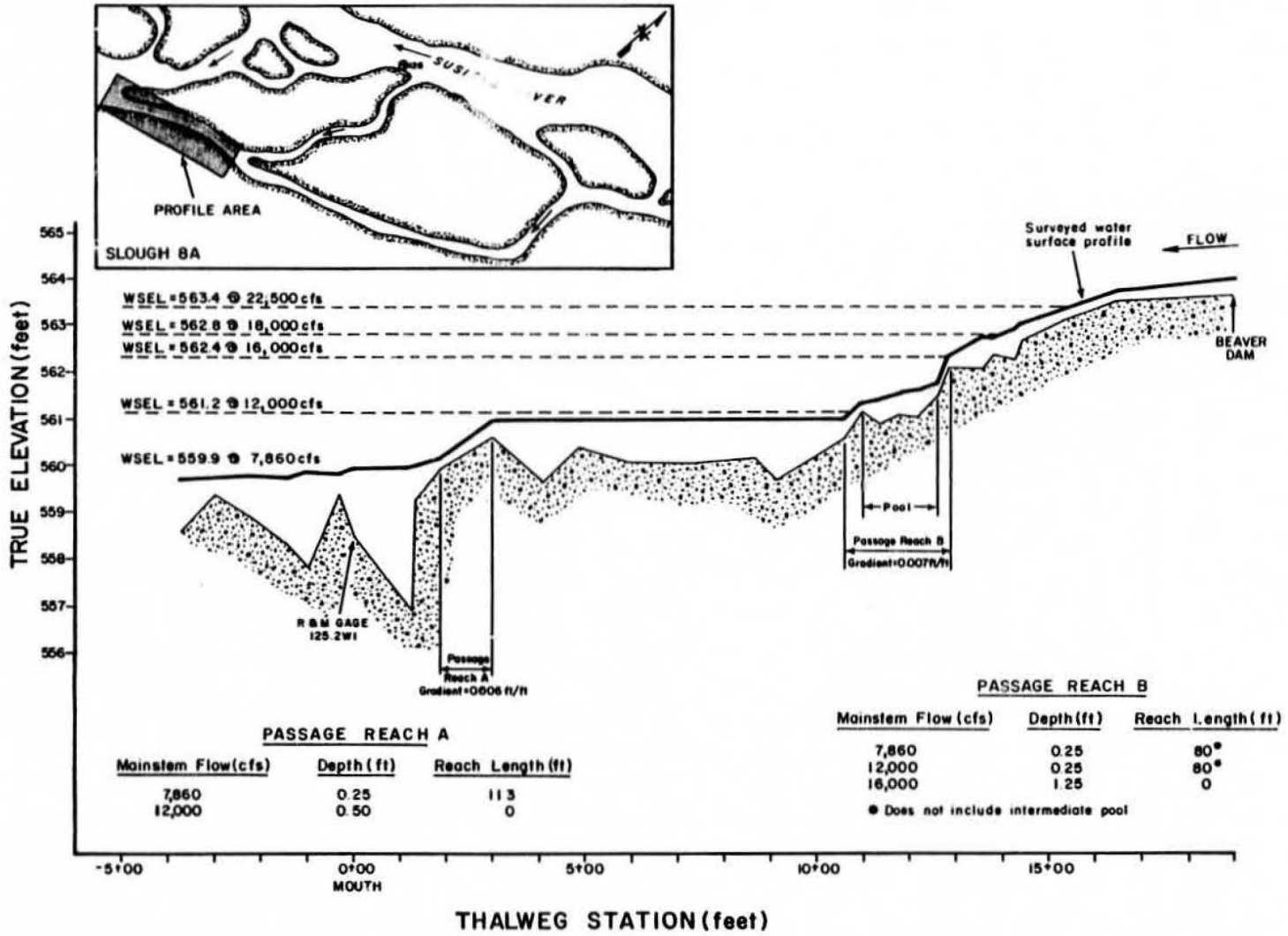
Appendix Figure B-7. Comparison of periodicity of live salmon (ADF&G 1983b: Volume 2) in tributaries (RM 101.4 - 161.0) and sloughs (RM 99.6 - 144.3) with discharge (USGS 1982) at Gold Creek (USGS #15292000), Susitna River, Alaska.

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

Slough Access Conditions

Slough 8A

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



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

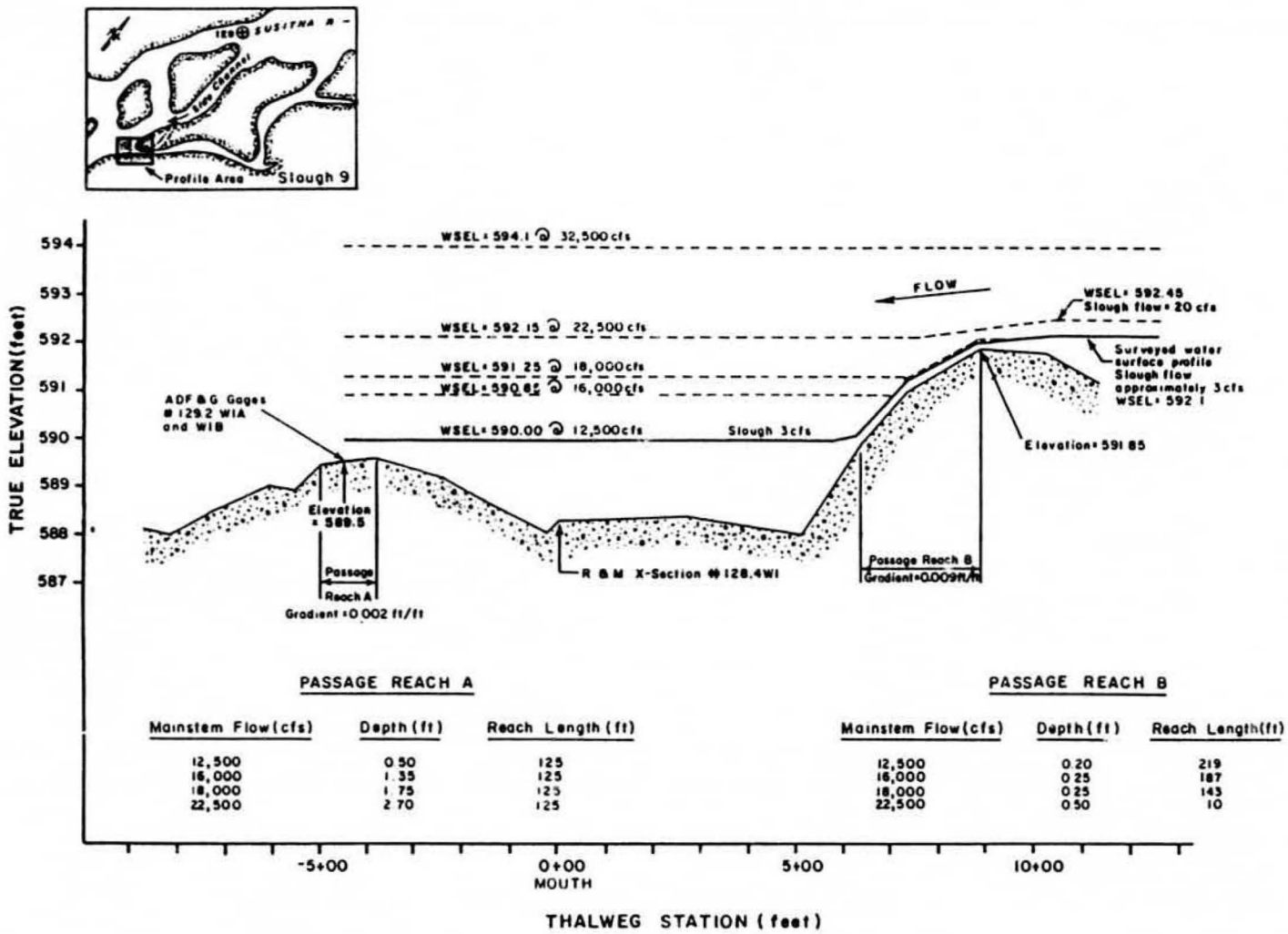
Slough 9

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

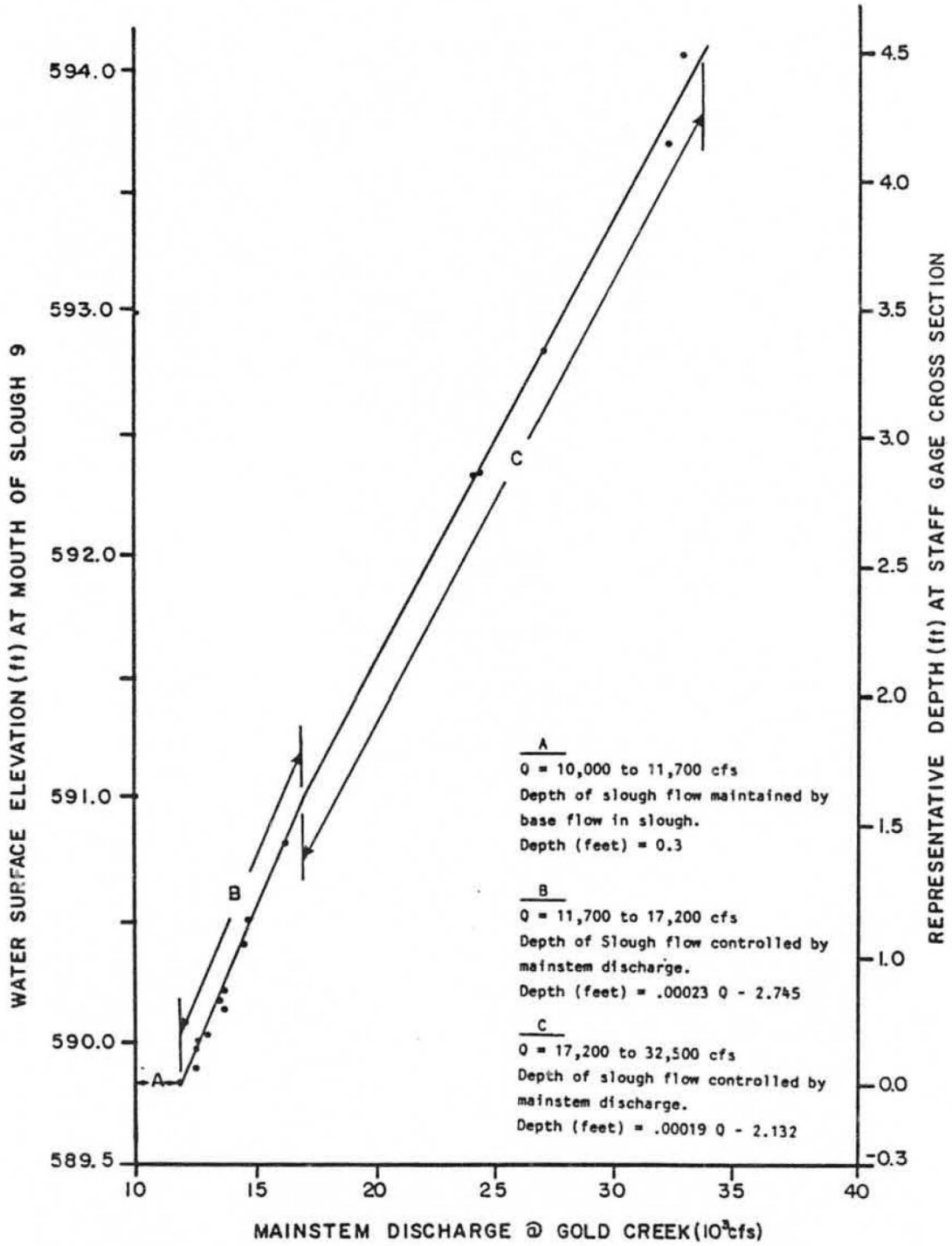
Passage Reach B is located approximately 700 ft above the slough mouth and unlike Passage Reach A, poses different degrees of access difficulties under varying mainstem discharges. At 18,000 cfs, the average depth is 0.25 ft and the reach extends for a distance of 143 ft. As mainstem discharges increase,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

Slough 11

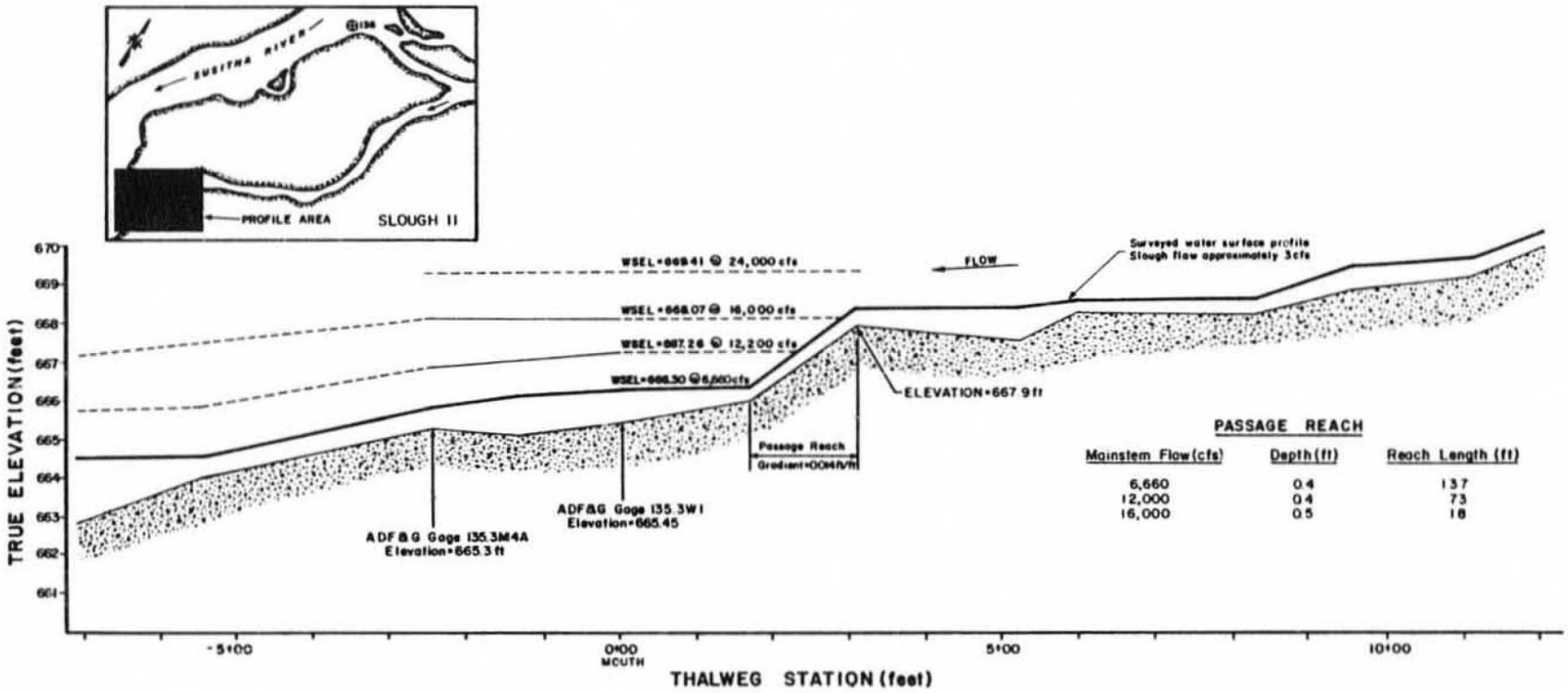
Access conditions for adult chum salmon in the lower reach of Slough 11 are illustrated for four mainstem discharges ranging from 6,660 to 24,000 cfs (Appendix Figure B-11). A single reach, located approxi-



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



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



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

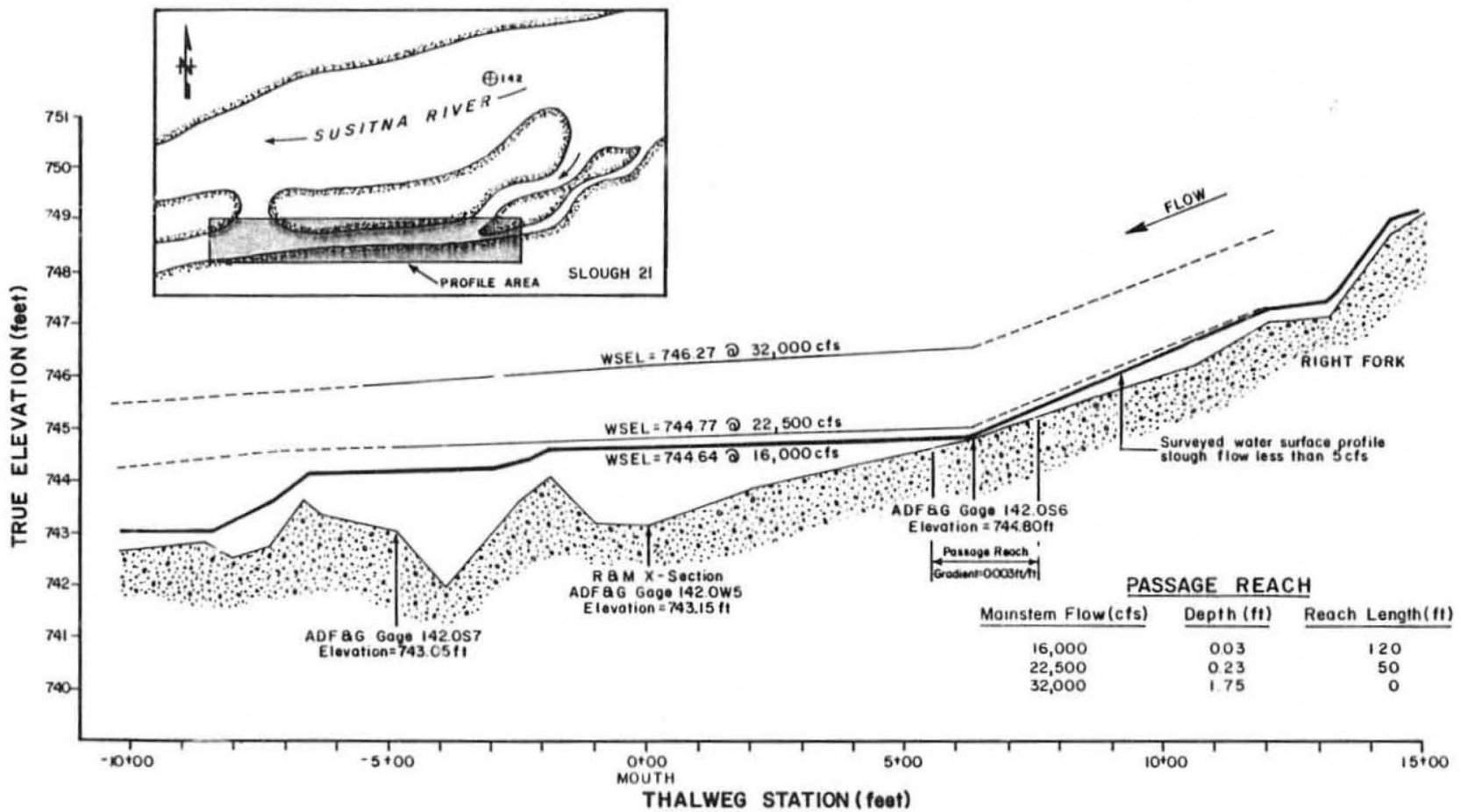
mately 200 ft above the slough mouth, was identified as potentially restrictive to fish passage. However at a mainstem discharge of 6,660 cfs the minimum depth for this passage reach is 0.4 ft for 137 feet. This is not considered to be acutely restrictive to passage of adult chum salmon. However, because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

Slough 21*

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

---

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



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

Other sloughs

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

DISCUSSION

General

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

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

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

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

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

-- Data unavailable.

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

Timing

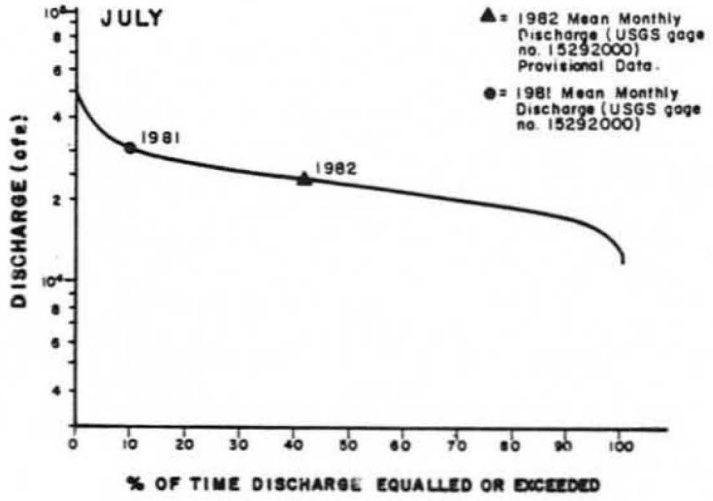
The timing of peak movements of salmon generally corresponded with stable or declining mainstem discharges and stable or increasing water temperatures. However, because there appears to be an inverse relationship between water temperature and discharge level in the mainstem Susitna River it is not possible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

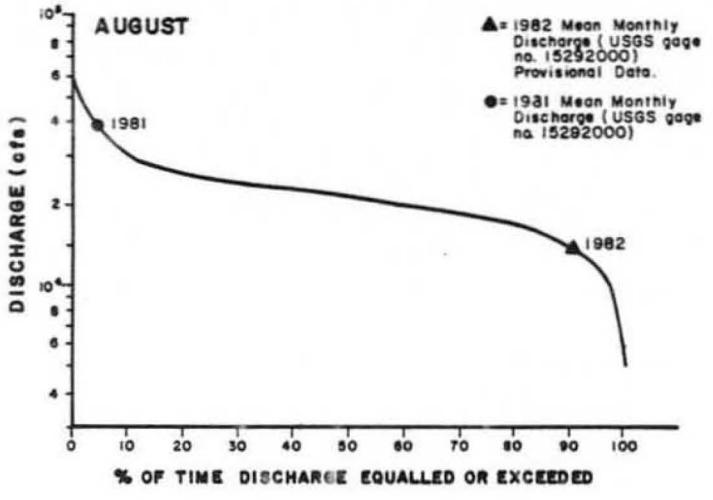
During upstream migration of salmon in 1982, temperatures ranged from 7 to 12°C in the Susitna River. These values are in the lower range of temperatures reported by Bell (1973) for species in other areas of North America: fall chinook salmon (10.6 - 19.4°C), chum salmon (8.3 - 15.6°C), coho salmon (7.2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

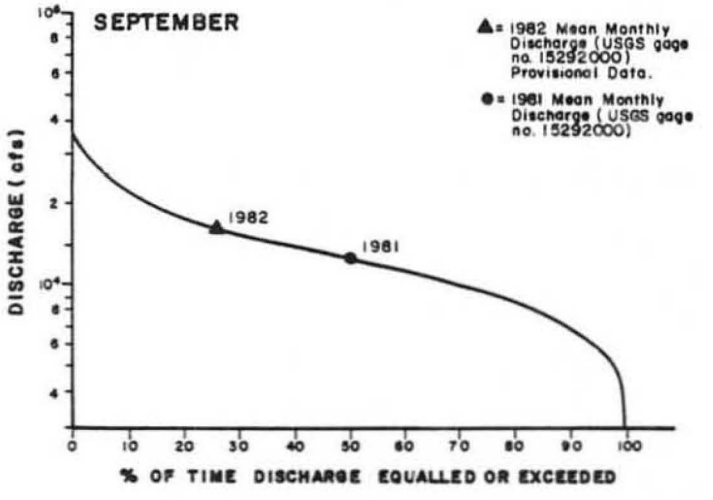
Compared to a 30 year average, mainstem discharge levels (at Gold Creek) for 1982 were relatively low and levels in 1981 were relatively high (Appendix Figure B-13). This basic difference was particularly large during August when chum salmon were entering sloughs to spawn. However, despite this dramatic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

Slough Access Conditions

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







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

Slough 8A

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

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

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

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

* 1982 slough discharges are averages of several transect measurements.

Slough 9

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

Slough 11

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

Slough 21

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

Other sloughs

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

Combined sloughs

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

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

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

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

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

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

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

-- Data unavailable.

Additional evidence for access problems

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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Appendix B: Timing and Passage of Adult Salmon in the Mainstream Susitna River and Access into Selected Sloughs Upstream of the Chulitna River Confluence

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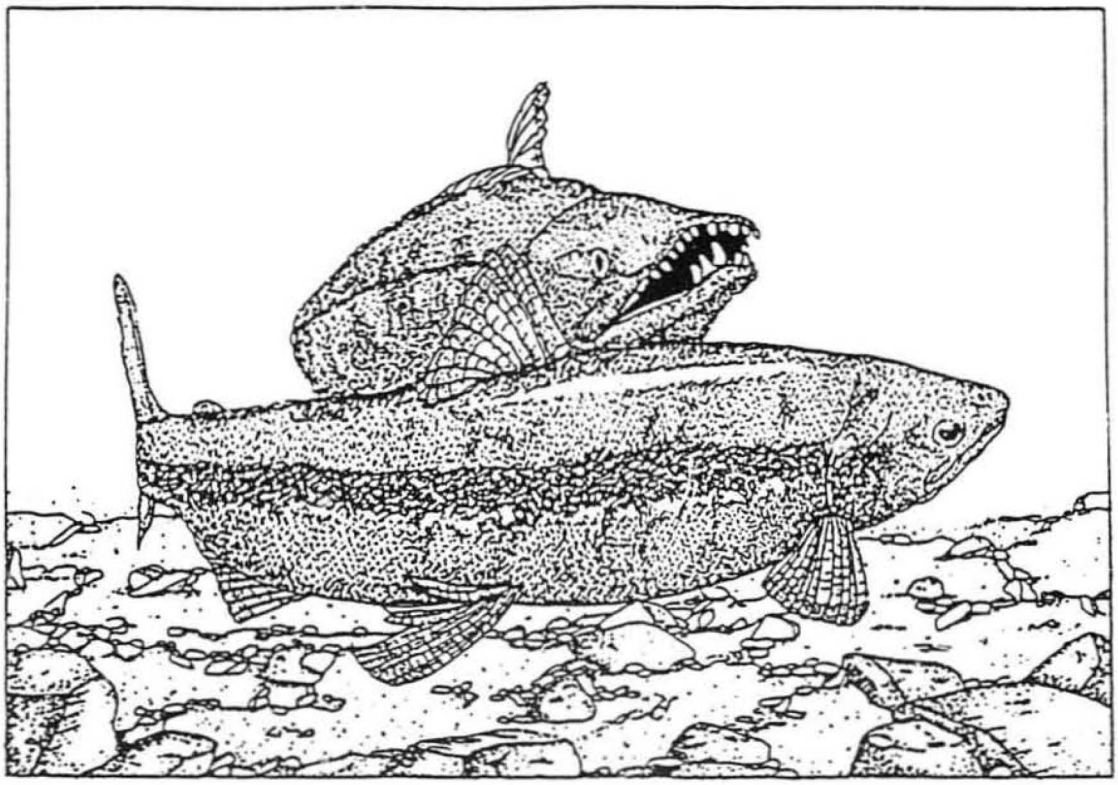

SUSITNA HYDRO AQUATIC STUDIES
PHASE II REPORT

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

— APPENDICES —

by

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1983