AEIDC 707 A STREET, ANCHORAGE, ALASKA, 99501; (907) 279-4523

ARCTIC ENVIRONMENTAL INFORMATION AND DATA CENTER

SUSITNA HYDROELECTRIC PROJECT AQUATIC IMPACT ASSESSMENT: EFFECTS OF PROJECT-RELATED CHANGES IN TEMPERATURE, TURBIDITY, AND STREAM DISCHARGE ON UPPER SUSITNA SALMON RESOURCES DURING JUNE THROUGH SEPTEMBER

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Prepared by:

Arctic Environmental Information and Data Center
University of Alaska
707 A Street
Anchorage, Alaska 99501

Submitted to:

Harza-Ebasco Susitna Joint Venture
711 H Street
Anchorage, Alaska 99501

For:

Alaska Power Authority
334 W. 5th Avenue, Second Floor
Anchorage, Alaska 99501

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The report was prepared by the following
AEIDC staff:

William J. Wilson, Principal Investigator

Charles G. (Mike) Prewitt, Ph.D., Fisheries Biologist
Michael D. Kelly, Fisheries Biologist
Joseph C. LaBelle, Geomorphologist

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INTRODUCTION

This report documents the assessment by the University of Alaska's Arctic Environmental Information and Data Center (AEIDC) of aquatic impacts of the Susitna hydroelectric project as proposed by the Alaska Power Authority (APA). It is based on existing information and analyzed data regarding project-related changes in stream temperature, turbidity, and discharge. Results and discussion are limited to the ice-free months June through September. Material in this report is intended to aid the U.S. Federal Energy Regulatory Commission (FERC) in preparation of the draft and final environmental impact statements which will fulfill project licensing requirements and serve as a basis for continued mitigation and monitoring of project effects.

Information from the license application submitted to FERC (APA 1983a,b,c,d) is restated here only for continuity or as general introductory material. This report focuses on analyses and provides steps toward incorporation of instream flow, temperature, and water quality needs into the final design of the project. Therefore, much detail is referenced to APA (1983a,b,c,d) to avoid restatement.

Other agencies and organizations are responsible for specific steps in the sequential process of aquatic impact analysis and mitigation. These organizations and their respective project responsibilities are:

1. Alaska Department of Fish and Game (ADF&G) Suhydro Study Team--to gather and analyze baseline fishery data and to develop instream flow analytic capabilities.

2. E. Woody Trihey and Associates (EWT)--to assist in study design and field data collection and analysis.
3. Harza-Ebasco Susitna Joint Venture--to provide coordination and engineering support for simulation models used in the instream flow assessment.
4. AEIDC--to develop the necessary simulation modeling system and to conduct the quantitative impact assessment.
5. Woodward-Clyde Consultants--to assist in mitigation planning and study design.
6. R&M Consultants--to assist all study team members in hydrologic and meteorologic data collection and processing and to provide engineering support.

Because studies to date have been largely limited to the Susitna River upstream from Talkeetna, Alaska, a comprehensive evaluation of project effects is not possible. Moreover, the current data base covers only those months when the river is ice-free (June, July, August, and September). Thus, this report addresses only those impacts for which completed assessment data and relationships exist. It is limited in scope to the Susitna River reach above Talkeetna, Alaska, during the months of June, July, August, and September. Its purpose is more to detect potential resource conflicts within the current data base than to fully assess project effects.

DESCRIPTION OF THE SUSITNA PROJECT

GEOGRAPHIC SETTING

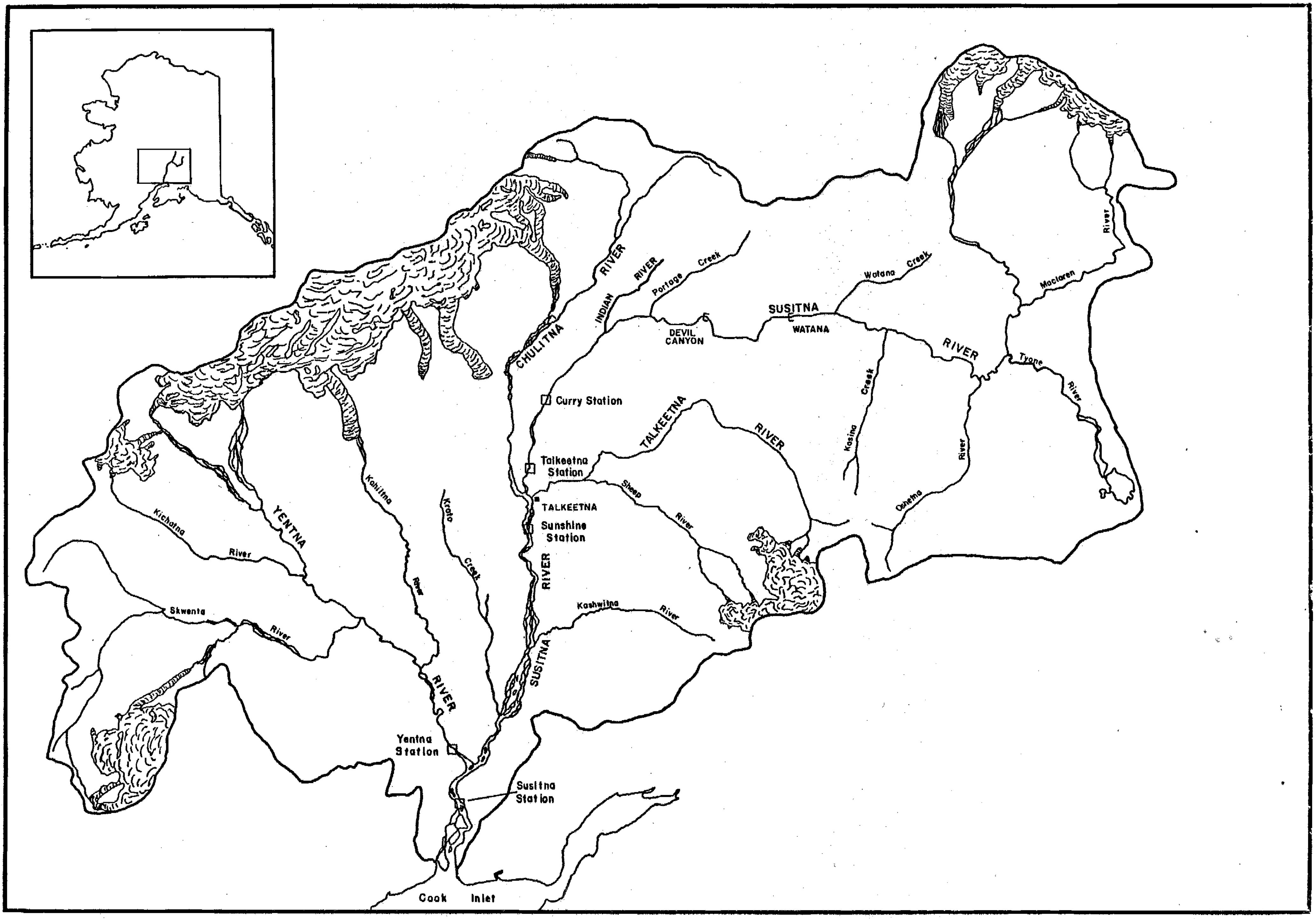
The Susitna River watershed area is 19,600 sq mi, the sixth largest river basin in Alaska. The Susitna flows 320 mi from its origin at Susitna

Glacier to the Cook Inlet estuary. Its basin is bordered by the Alaska Range to the north, the Chulitna and Talkeetna mountains to the west and south, and the northern Talkeetna plateau and Gulkana uplands to the east. This area is largely within the coastal trough of southcentral Alaska, a belt of lowlands extending the length of the Pacific mountain system and interrupted by the Talkeetna, Clearwater, and Wrangell mountains (APA 1983c).

Major Susitna tributaries include the Talkeetna, Chulitna, and Yentna rivers (Figure 1). The Yentna River enters the Susitna at river mile (RM) 28 (28 mi from the Susitna confluence with the Cook Inlet estuary). The Chulitna River rises in the glaciers on the south slope of Mount McKinley and flows south, entering the Susitna near Talkeetna (RM 99). The Talkeetna River rises in the Talkeetna Mountains, flows west, and joins the Susitna near Talkeetna (Bredthauer and Drage 1982).

Tributaries in northern portions of the Susitna basin originate in the glaciers of the eastern Alaska Range. The east and west forks of the Susitna and the McClaren rivers join the mainstem Susitna River above RM 260. Below the glaciers the braided channel traverses a high plateau and continues south to the Oshetna River confluence near RM 233. There it takes a sharp turn west and flows through a steeply cut canyon which contains the Watana (RM 184.4) and Devil Canyon (RM 151.6) damsites. In this predominantly single channel reach the gradient is quite steep, approximately 10 ft/mi (APA 1983a). Below Gold Creek (RM 137) the river alternates between single and multiple channels until the confluence with the Chulitna and Talkeetna rivers (RM 97), below which the Susitna broadens into widely braided channels for 97 miles to Cook Inlet.

Figure 1. Susitna River drainage basin with major tributaries and geographic features.



PROJECT DESCRIPTION

The proposed project consists of two dams to be constructed over a period of about 10 years. The Watana dam would be completed in 1994 at a site 3 mi upstream from Tsusena Creek (RM 183). This development would include an underground powerhouse and 885-ft-high earthfill dam, which would impound a reservoir 48 mi long with a surface area of 38,000 acres and a usable storage capacity of 3.7 million acre feet (maf). The dam would house multiple level intakes and cone valves. Installed generating capacity would be 1020 megawatts (mw), with an estimated average annual energy output of 3460 gigawatt hours (gwh).

The concrete arch Devil Canyon dam would be completed by 2002 at a site 32 mi downstream of the Watana damsite. It would be 645 ft high and would impound a 26-mi-long reservoir with 7,800 surface acres and a storage capacity of 0.36 maf (APA 1983). Installed generating capacity would be about 600 mw, with an average annual energy output of 3450 gwh. Both reservoirs will be drawn down during the high energy demand winter months and filled during the summer months when energy requirements are lowest.

EXPECTED CHANGES IN SUSITNA RIVER DISCHARGE AND TEMPERATURE PATTERNS

The Susitna license application is based on a power production scenario determined by design and feasibility engineers to retain acceptable economics while providing adequate release discharge regimes for downstream aquatic resources (APA 1983a). The term postproject applies to this operating schedule, known as Case "C" (APA 1983a). Case C provides for maximum electrical output during midwinter months (November through April) by storage of water during high-discharge, low-energy demand summer months (June, July, August).

Flow levels were desired that would allow passage of adult salmon into certain spawning areas (in this case, sloughs) above Talkeetna. The license application specified instream flow requirements of 12,000 cubic feet per second (cfs) from August 1 to September 15, six weeks of 1,000 cfs/da increase beginning July 15 and ending August 31, and 1,000 cfs/da decrease beginning September 15. July and September minimum flows were to be 6,000 cfs.

These power and streamflow requirements (as well as certain reservoir drawdown constraints) were optimized by Acres American, Inc. (ACRES), using a simulation model which reflected the estimated project power demands at that time. Other postproject streamflow conditions are expected during the Watana dam filling period and when Watana is full but operating alone before Devil Canyon dam construction. In this report downstream discharges expected during these periods are referred to as the "Watana filling" and "Watana only" flow regimes (Figure 2).

Effects of the expected increases in winter discharge and decreases in summer discharge are the primary concerns of the aquatic impact assessment. Even if project specifications change, the general pattern of winter augmentation and summer reduction will occur if the project is to meet seasonal energy needs within the available water supply. Secondarily, the temperature regime of the Susitna River downstream of the project is expected to change due to release of water from various temperature zones in the reservoirs. With the project, summer stream temperatures will probably be lower and winter temperatures higher than at present, and short-term temperature variation would be expected to decrease (APA 1983a).

Changes in stream discharge and temperature would have direct effects on aquatic life and indirect effects through changes in suspended sediment

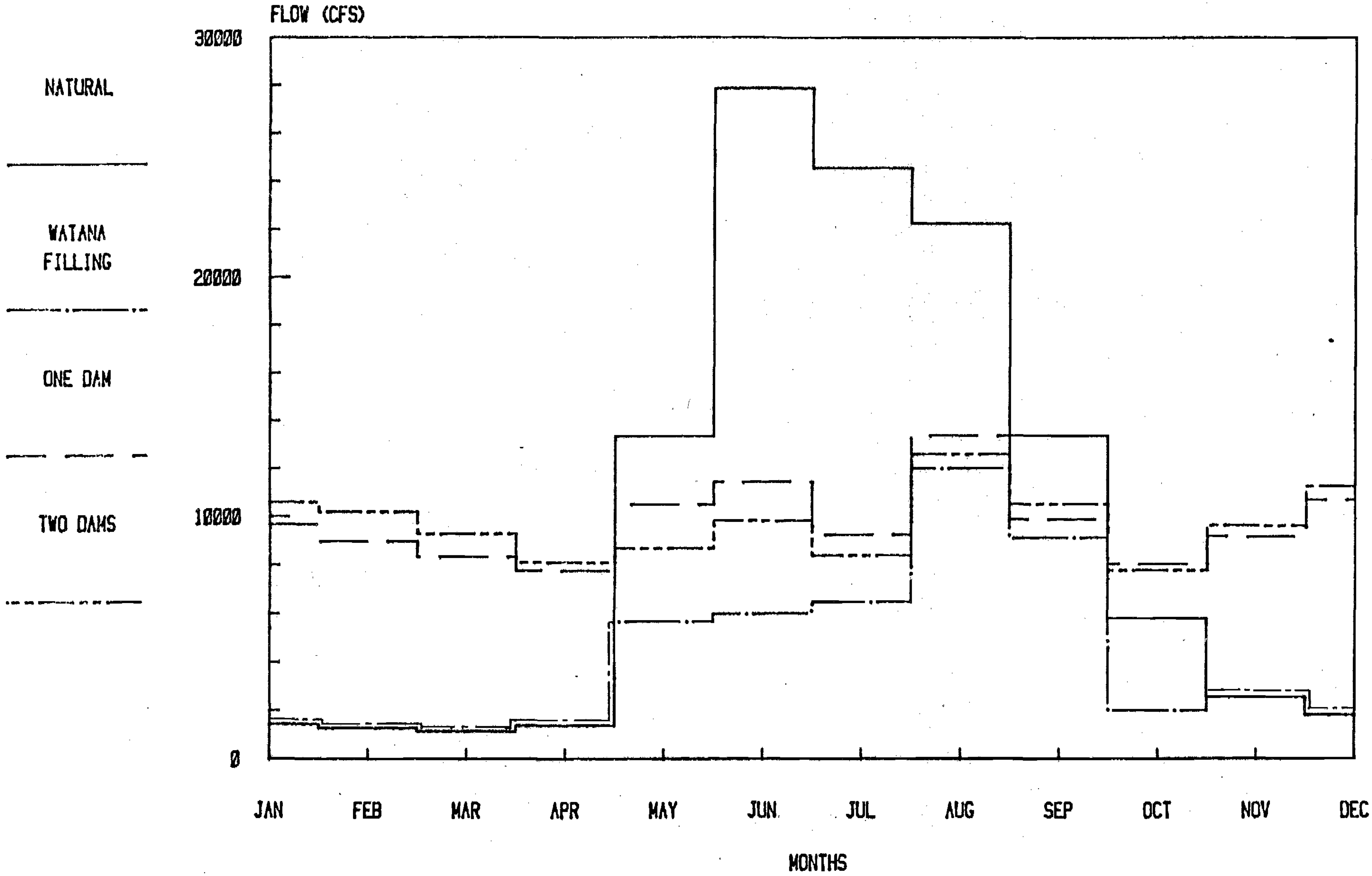


Figure 2. Present, Watana filling, Watana only (one dam), and Watana-Devil Canyon mean monthly discharge under APA Case C.

and turbidity, bedload sediment transport, ice processes, and the geomorphological character of the river basin. Reliable impact assessment must recognize these secondary changes as well as other long-term effects.

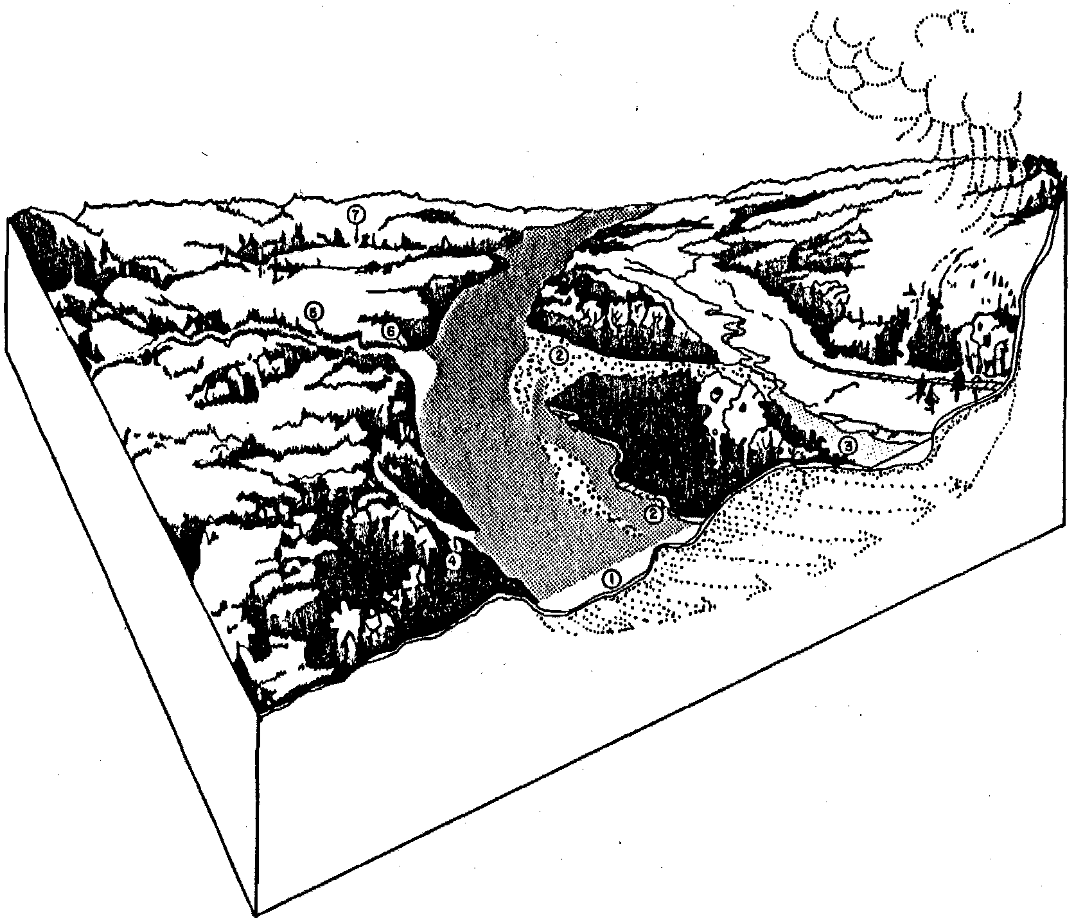
POTENTIALLY AFFECTED AQUATIC RESOURCES

In this report the Susitna River is divided into three major study zones: the Impoundment Zone--Oshetna River (RM 236) to the Devil Canyon damsite (RM 152), the Upper Susitna Zone--Devil Canyon damsite to the Chulitna River confluence (RM 99), and the Lower Susitna Zone--Chulitna River confluence to Cook Inlet estuary. There are seven major habitat types in the Upper Susitna Zone (ADF&G 1983a). These are main channel, side channel, side slough, upland slough, tributary, tributary mouth, and lake (Figure 3). Except for lakes and tributaries, each habitat could be affected by changes in mainstem discharge and temperature.

Seven anadromous and 12 resident species have been formally reported in the Susitna drainage (Appendix A). Of these 19 species, the license application (APA 1983d) listed seven anadromous and six resident fish species as important (Figure 4).

Upper Susitna study emphasis has been placed on salmon because of (1) the relative importance of the Susitna River to salmon production in Upper Cook Inlet (Appendix A) and (2) the likelihood of impacts on certain salmon populations in the Upper Susitna. Expected project effects on habitats normally utilized by certain salmon life stages illustrate current concerns for Upper Susitna aquatic impacts (Figure 5).

The most predictable changes are expected to be in side channel and mainstem reaches nearest the dam(s). Similar changes are expected in side



GENERAL HABITAT CATEGORIES OF THE SUSITNA RIVER

1) **Mainstem Habitat** consists of those portions of the Susitna River that normally convey streamflow throughout the year. Both single and multiple channel reaches are included in this habitat category. Groundwater and tributary inflow appear to be inconsequential contributors to the overall characteristics of mainstem habitat. Mainstem habitat is typically characterized by high water velocities and well-armored streambeds. Substrates generally consist of boulder and cobble size materials with interstitial spaces filled with a grout-like mixture of small gravels and glacial sands. Suspended sediment concentrations and turbidity are high during summer due to the influence of glacial melt-water. Streamflows recede in early fall and the mainstem clears appreciably in October. An ice cover forms on the river in late November or December.

2) **Side Channel Habitat** consists of those portions of the Susitna River that normally convey streamflow during the open water season but become appreciably dewatered during periods of low flow. Side channel habitat may exist either in well-defined overflow channels, or in poorly defined water courses flowing through partially submerged gravel bars and islands along the margins of the mainstem river. Side channel streambed elevations are typically lower than the mean monthly water surface elevations of the mainstem Susitna River observed during June, July, and August. Side channel habitats are characterized by shallower depths, lower velocities, and smaller streambed materials than the adjacent habitat of the mainstem river.

3) **Side Slough Habitat** is located in spring-fed overflow channels between the edge of the floodplain and the mainstem and side channels of the Susitna River and is usually separated from the mainstem and side channels by well-vegetated bars. An exposed alluvial berm often separates the head of the slough from mainstem or side channel flows. The controlling streambed/streambank elevations at the upstream end of the side sloughs are slightly less than the water surface elevations of the mean monthly flows of the mainstem Susitna River observed for June, July, and August. At the intermediate and low-flow periods, the side sloughs convey clear water from small tributaries and/or upwelling groundwater (ADF&G 1981c, 1982b). These clear water inflows are essential contributors to the existence of this habitat type. The water surface elevation of the Susitna River generally causes a backwater to extend well up into the slough from its lower end (ADF&G 1981c, 1982b). Even though this substantial backwater exists, the sloughs function hydraulically very much like small stream systems and several hundred feet of the slough channel often conveys water independent of mainstem backwater effects. At high flows the water surface elevation of the mainstem river is sufficient to overtop the upper end of the slough (ADF&G 1981c, 1982b). Surface water temperatures in the side sloughs during summer months are principally a function of air temperature, solar radiation, and the temperature of the local runoff.

4) **Upland Slough Habitat** differs from the side slough habitat in that the upstream end of the slough is not interconnected with the surface waters of the mainstem Susitna River or its side channels. These sloughs are characterized by the presence of beaver dams and an accumulation of silt covering the substrate resulting from the absence of mainstem scouring flows.

5) **Tributary Habitat** consists of the full complement of hydraulic and morphologic conditions that occur in the tributaries. Their seasonal streamflow, sediment, and thermal regimes reflect the integration of the hydrology, geology, and climate of the tributary drainage. The physical attributes of tributary habitat are not dependent on mainstem conditions.

6) **Tributary Mouth Habitat** extends from the uppermost point in the tributary influenced by mainsteam Susitna River or slough backwater effects to the downstream extent of the tributary plume which extends into the mainstem Susitna River or slough (ADF&G 1981c, 1982b).

7) **Lake Habitat** consists of various lentic environments that occur within the Susitna River drainage. These habitats range from small, shallow, isolated lakes perched on the tundra to larger, deeper lakes which connect to the mainstem Susitna River through well-defined tributary systems. The lakes receive their water from springs, surface runoff, and/or tributaries.

Figure 3. General habitat types in the Upper Susitna River. (ADF&G 1983d)

Figure 4. List of fish species which occur in the Susitna River basin.

Common Name	Scientific Name
Arctic lamprey	*Lampetra japonica* (Martens)
Eulachon (hooligan)*	*Thaleichthys pacificus* (Richardson)
Arctic grayling*	*Thymallus arcticus* (Pallas)
Bering cisco*	*Coregonus laurettae* Bean
Round whitefish*	*Prosopium cylindraceum* (Pallas)
Humpback whitefish	*Coregonus pidschian* (Gmelin)
Rainbow trout*	*Salmo gairdneri* Richardson
Lake trout*	*Salvelinus namaycush* (Walbaum)
Dolly Varden*	*Salvelinus malma* (Walbaum)
Pink (humpback) salmon*	*Oncorhynchus gorbuscha* (Walbaum)
Sockeye (red) salmon*	*Oncorhynchus nerka* (Walbaum)
Chinook (king) salmon*	*Oncorhynchus tshawytscha* (Walbaum)
Coho (silver) salmon*	*Oncorhynchus kisutch* (Walbaum)
Chum (dog) salmon*	*Oncorhynchus keta* (Walbaum)
Northern pike	*Esox lucius* Linnaeus
Longnose sucker	*Catostomus catostomus* (Forster)
Threespine stickleback	*Gasterosteus aculeatus* Linnaeus
Burbot*	*Lota lota* (Linnaeus)
Slimy sculpin	*Cottus cognatus* Richardson

*Species considered important in FERC License Application (APA 1983d)

Figure 5. Upper Susitna habitat types and associated salmon life/stage utilization.

Habitat Type[1]	Salmon Species Chinook	Coho	Sockeye	Pink	Chum
Side channel	R,IM,O	R,IM,O	R,IM,O	IM,O,S,I,R	S,R,I,IM,O
Mainstem	R,IM,O	R,IM,O	R,IM,O	IM,O	S,R,I,IM,O
Tributary mouth	S,I,IM,O	S,I,R,IM,O	IM,O	S,I,IM,O	S,I,IM,O
Side slough	R,IM,O	S,I,R,IM,O	S,R,I,IM,O	S,R,I,IM,O	S,R,I,IM,O
Upland slough	R,O	R	R,O		
Tributary[2]	IM,O,S,R,I	IM,O,S,I,R	IM,O	S,I,IM,O	S,I,IM,O

Source: ADF&G 1983a,b,c.

1. Listed in order of degree of expected project-related habitat change.
2. Assuming no restriction in tributary access.

I = Incubation
IM = Inmigration
S = Spawning
R = Rearing
O = Outmigration

sloughs because of their dependence on relatively high mainstem discharges to either overtop their upper ends or to provide backwater effects which increase the depth and subsequent ease of access into their lower ends.

Side channels and side sloughs are important for spawning chum and sockeye salmon and for rearing of all salmon species, most notably coho, sockeye and chum. Mainstem habitats are primarily migration corridors, with some importance as chum salmon spawning areas. Upland sloughs are primarily juvenile fish rearing areas.

A large number of salmon, especially chinook, utilize two tributaries, Portage Creek and Indian River, far more than other Upper Susitna tributaries (Figure 6, Appendix A). Because of their great importance, special emphasis has been placed on determining access restrictions which might result from perching and scour of these tributary deltas due to reduced postproject summer discharges. Assessment of perching and scour has been addressed by Trihey (1983) and R&M (1982) and will not be further analyzed in this report.

Figure 6. Numbers of salmon by species at various upper Susitna observation points, 1982.

Location/Habitat	Chinook	Coho	SPECIES Pink	Chum	Sockeye
Talkeetna[1] Station (RM 103)	10,884	5,111	73,038	49,118	3,123
Lane Creek[2] (RM 113.6)	47	5	640	11	0
Curry Station[1] (RM 120)	11,307	2,438	58,835	29,413	1,261
Fourth of July[2] Creek (RM 131)	56	4	702	191	0
Indian River[2] (RM 138.6)	1,503	101	738	1,346	0
Portage Creek[2] (RM 148.9)	1,253	88	169	153	0
Sloughs[3]		53	507	2,244	607

Source: ADF&G 1983b

[1] Tag/recapture population estimate

[2] Peak salmon survey counts which do not reflect the total number of salmon but only a population density within index areas

[3] Total slough counts.

EXPECTED UPPER SUSITNA PHYSICAL HABITAT CHANGES

Changes in the physical attributes of Upper Susitna will be assessed in two categories: (1) hydraulic-related habitat, and (2) temperature and turbidity. The hydraulic-related impact issues are: (1) access of spawners to side sloughs and upland sloughs, and (2) rearing in selected tributary mouths, side sloughs, and upland sloughs. Temperature and turbidity impact issues are: (1) temperature effects on migration, spawning, incubation, and rearing; and (2) turbidity effects on riverine fish production, behavior, and protection from predation. These issues are discussed in greater detail in the following section.

HYDRAULIC-RELATED HABITAT

Access and rearing impacts result from effects of main channel discharge changes on the hydraulic parameters (depth, velocity, substrate, and cover) most likely to be affected in side sloughs, upland sloughs, or side channels. Access to side sloughs might be impacted because backwater effect due to main channel stage (water surface elevation) is a function of the discharge in the main Susitna and influences the depth at the mouths of certain sloughs. At certain low discharges water depth at slough mouths is insufficient to provide access into those sloughs by fish inmigrating to spawn. Juvenile salmon rearing might be impacted because the wetted surface area where certain side sloughs, upland sloughs, and tributary mouths meet the mainstem Susitna is a function of stage in the mainstem. Preferences of juvenile salmon for various "zones" within these study sites known as Designated Fish Habitat (DFH) sites, have been determined and related to the surface areas of the zones at various mainstem Susitna discharges. DFH sites were selected for study by ADF&G to represent side and upland slough and tributary mouth locations with documented utilization by juvenile salmon (ADF&G 1983a). DFH rearing suitability changes represent quantifiable relationships between Susitna discharge and juvenile salmon habitat, most notably for chinook and coho.

OTHER PHYSICAL CHANGES--TEMPERATURE AND TURBIDITY

INSTREAM TEMPERATURE

Project-related decreases in June-September stream temperatures may create temperature differentials at tributary confluences, and may change seasonal temperature regimes within various habitat types. The former effect may influence adult salmon inmigration by creating temperature barriers, especially at major confluences. More importantly, juvenile salmon outmigrating from tributaries might encounter colder spring and summer mainstem temperatures, reducing outmigratory stimulus and possibly disrupting timing.

The second temperature effect, expected in slough and possibly side channel habitats, may cause changes in development or growth rates in eggs, fry or juvenile salmon. Because relationships between main channel and side-slough temperatures are poorly known it is not possible to discuss such growth or physiologic effects at this time. With more reliable techniques to relate mainstem and slough temperatures, growth rate changes will probably be assessable using the Susitna-specific temperature-growth information in Wangaard and Burger (1983).

TURBIDITY

Reductions in Susitna River turbidity due to the trapping of sediment in the impoundments may cause changes in riverine primary production due to increased light penetration as well as changes in protective cover for fry and juvenile salmon previously provided by turbid water. Important to completion of this analysis are a determination of the actual Susitna food production systems (allochthanous or autochthanous) and the degree to which rearing salmon depend on turbidity for protection from fish, bird and mammalian predation.

ASSESSMENT METHODS

This section documents methods used to resolve the physical habitat impact issues described in the last section. Methods for assessment of tributary access in the Upper Susitna are presented in Trihey (1983) and R&M (1982).

As stated previously, physical habitat assessment capabilities are currently confined to the Upper Susitna during the ice-free season. They allow assessment of spawner access to side sloughs, rearing at DFH sites, and the effects of project-related temperature and turbidity. Temperature and turbidity effects will be assessed individually and predicted postproject discharge patterns will be assessed against requirements for salmon access and rearing to determine potential conflicts between potential monthly discharge requests for these two salmon activities and feasible project operations.

INSTREAM TEMPERATURE

Monthly stream temperature predictions are available for (1) the Watana filling period during warm, normal, and cool meteorologic periods, and (2) the Watana only and Watana plus Devil Canyon operations as predicted for meteorology which occurred during 1981 (AEIDC 1983b). The assessment method involves the determination of temperature preferences of various salmon life history stages (inmigration, spawning, incubation, rearing, and outmigration) drawn from literature and from specific Susitna river studies. These preferences are then compared by life stage to present and postproject temperatures predicted for June, July, August, and September using the SNTEMP instream temperature model (AEIDC 1983a). Two analyses were performed. First, we assessed the effects of the second year of the Watana filling schedule with a release temperature of 4 °C. This temperature might occur because of the necessity to release cold hypolimnetic water when reservoir surface elevations were not at levels which would allow use of the upper level release structures. In APA (1983a,d) it was suspected that such cold water temperatures in the second summer might extend far downstream and cause a temperature "barrier" at the confluence with warmer Chulitna-Talkeetna river waters. It was proposed that the temperature barrier might inhibit continuation of migration up the Susitna River by salmon which milled at the zone of the major confluences.

The SNTEMP model (AEIDC 1983a) was used to simulate the downstream temperature profile with an initial Watana release temperature of 4 °C under meteorologic conditions from warm (1977), normal (1980), and cold (1970) summer seasons. This provided three downstream temperature patterns expected to span the range of possible Watana-filling temperature effects. Detailed description of the SNTEMP model is available in AEIDC (1983c), and methods used to simulate the various temperature patterns are found in AEIDC (1983a). At several fish habitat locations along the Susitna River, the resulting predicted stream temperatures were assessed for suitability to various salmon life stages. At the Susitna-Chulitna-Talkeetna confluence, we examined the differential between Susitna and confluence water to determine the likelihood of a temperature barrier.

Analysis of actual Watana or Watana-Devil Canyon operation temperatures was quite limited due to the lack of DYRESM reservoir temperature model results. Currently, DYRESM reservoir temperature profiles are available only for meteorologic conditions measured in 1981. These reservoir temperature profiles were used as initial condition temperatures in the SNTEMP model to simulate downstream temperature during Watana only and Watana-Devil Canyon June through September operations.

In summary, temperature simulations were of (1) summer (June-September) release temperatures of 4 °C to simulate conditions during the second year of Watana filling and (2) monthly summer temperatures under 1981 meteorologic conditions for both Watana only and Watana-Devil Canyon operations.

TURBIDITY

As with temperature, effects of changes in turbidity were evaluated by comparisons of fish turbidity preferences or tolerances (from literature sources) with predicted postproject turbidity levels. Postproject turbidity levels were drawn from Peratrovich, Nottingham, and Drage (1982), and general literature sources were used to determine effects of certain turbidity levels on production, predation, and distribution of Pacific salmon and related species.

HYDRAULIC-RELATED HABITAT ANALYSIS USING AN ITERATIVE ASSESSMENT PROCESS

The analysis of hydraulic habitat versus postproject flow regimes was to identify potential conflicts between project operations and downstream discharge requirements for (1) salmon access into upper Susitna sloughs, and (2) juvenile salmon rearing at the DFH sites described in ADF&G (1983a). As such, the analysis was of discharge effects only; the other physical habitat effects (temperature, turbidity, and dissolved gas) were to be considered separately.

The objective was to examine a range of potential project operations bounded either by the discharge requirements implied by ADF&G habitat relationships, or by the range of pre- and postproject discharges. These specified project operations were evaluated in terms of both long-term fishery benefits and project economics.

To accomplish this objective only the reservoir operations model and the access and DFH site habitat relationships described in ADF&G (1983a) were required. Water balancing (accounting for downstream accretions of inflow) was not used in the analysis because mean monthly discharges in the Upper Susitna were not believed to be greatly affected by monthly tributary or groundwater inflow, and because some discharge balancing between the Devil Canyon dam and Gold Creek was done automatically by the reservoir operation model.

RESERVOIR OPERATION MODEL

The current reservoir operation model simulates monthly discharge patterns for a 32-year forecast period under the assumption that future inflows to the Susitna reservoirs will be the same as those which occurred above Watana and Devil Canyon damsites during the past 32 years. Given this historic water supply estimate, the reservoir operation model applies operating criteria (monthly power generation requirement, monthly minimum water elevations, maximum powerhouse release discharges, maximum drawdown level and downstream flow requirement) to predict average release discharge, power production, and reservoir elevation for each month of the 32 years in the water supply data base.

The model operating logic prioritizes downstream discharge demands to the extent that within all other constraints, reservoir operations will meet these demands. This feature provides a link between downstream fishery discharge demands and the power production requirements of the reservoirs. Reservoir operation model ouput is in the form of 12-month x 32-year matrices (summarized for June, July, August, and September in Appendix B) for both predicted mean monthly discharge and average monthly energy production (in gwh), providing the basis for 32-year comparisons between habitat and energy production benefits. Such time-series analyses provide benefits in assessing long-term changes in variation and recurrence of both low and high discharge or habitat conditions (Trihey 1981; AEIDC 1983b).

HABITAT RELATIONSHIPS

ADF&G (1983a) access and rearing habitat relationships were used to evaluate salmon access and rearing for the 12 x 32 discharge matrices from the reservoir operation model. The access relationship is essentially depth related and it defines mainstem discharges at which certain depth criteria (either 0.3 or 0.5 ft depending on the available data at a given slough) were met in the studied side sloughs. The 0.5 ft depth criterion was applied to sloughs with less quantitative data bases to provide conservative estimates of discharge requirements. Stage (water surface elevation) versus discharge models were used to determine stage at a given mainstem Susitna discharge. This predicted stage was imposed on a profile of the deepest channel line (thalweg) of the slough bed to determine access depth. If the 0.3 or 0.5 ft depth criteria were met at a given discharge for a length of less than 100 ft, access was assured "without difficulty." If the access depths existed for 100 ft or more, the condition was described as "acute." If the access depths were not available, or if they persisted for a distance greater than 100 ft, access was assumed to be blocked. We interpreted the ADF&G access criteria conservatively, assuming that no fish would pass at discharges below the "acute" levels.

Calculation of Habitat Index (HI) is described in ADF&G (1983a) Appendix E. Rearing HI relationships were proportions of variously preferred hydraulic zones within the DFH sites at various mainstem discharges. Basically, HI is the ratio between the catch-per-unit effort (CPUE) of juvenile salmon in the standing water zone (H1) within the DFH to the CPUE in an adjacent moving water zone (H2). The H1:H2 CPUE ratio was adjusted to range between zero and one and served as a fixed-value Zone Quality Index (ZQI) for the DFH site. The ZQI for a given DFH site was multiplied by the surface areas of the respective (H1 or H2) zones at a given discharge to produce the HI or Habitat Index of the site with respect to the zone (H1 or H2) in question. HI is suitable to evaluate rearing versus discharge effects within a given DFH site, but is limited in ability to assess the suitability of a single discharge at several different DFH sites. Using the HI versus discharge relationship it was possible to evaluate each monthly discharge in a pre- or postproject 12 x 32 discharge matrix to create a 12 x 32 HI matrix. The 12 x 32 HI matrix allowed quantification of rearing habitat at various exceedence levels or recurrence intervals to quantify long-term habitat effects associated with various downstream demands.

For both access and rearing it was necessary to determine the sites to be assessed, the critical time period, and the range of discharges to be evaluated. Appropriate access and rearing sites were selected based on numbers of salmon at the study site and degree of influence of main-channel discharge on the habitat conditions at that slough.

Assessment time period was determined using published accounts of salmon numbers during one-week periods throughout the summer months. In the case of access, one month was selected as most important for use in the monthly reservoir operation simulations. This month was determined by noting the month with highest levels of fish inmigration activity. In contrast to the access timing, which was well documented through frequent actual observation, rearing timing was only broadly defined; therefore, rearing was evaluated during the period corresponding to the ADF&G rearing habitat relationship study period (June through September).

Upper Susitna access discharge requirements were examined using the ADF&G access relationships (ADF&G 1983a, Appendix B), assuming that discharges less than the "acute" access discharge allowed essentially no passage into the slough, and that the discharge associated with the "no difficulty" evaluation offered no passage restrictions.

Access conditions at various sloughs were evaluated at discharges only up to 25,000 cfs because access requirements in all major sloughs appeared to be met at discharges of 20,000 cfs.

Because relative rearing utilization among all DFH sites was not available, it was not known which DFH sites were most important. Because of this, and because HI values were probably not comparable among sites, no attempt was made to conduct a site-by-site evaluation of discharge. On the assumption that larger HI values implied greater potential rearing utilization, a composite rearing relationship was compiled using the sum of the upper Susitna HI values. It must be stressed that this summation is simply a method of obtaining one habitat value for each of an incremental series of discharges; the actual rearing analysis should be based on completed rearing relationships which account for all species in all habitat types used for rearing.

Because calculated HI values were for a narrower range of discharges (12,500-27,500 cfs) than either pre- or postproject regimes, they were extrapolated to an HI of 0 at 6,000 cfs; HI values between 27,500 and 45,000 cfs were extrapolated using a linear regression of the HI versus flow values between 12,500 and 27,500 cfs. Those above 45,000 cfs were given the 45,000 cfs HI value. This step was performed only to allow an evaluation of all discharges expected to occur, and violates stated assumptions expressed in ADF&G (1983c) regarding use of the HI values in actual analyses. The resulting rearing assessment is, therefore, demonstrational only and is presented only to document how future analyses will be performed.

From examination of both access and rearing relationships a series of potential monthly flow request cases was developed and input as downstream demand in the monthly reservoir operation model. The model was run to determine effects of these potential requests on energy production and to produce the flow regimes which would result. The 12 x 32 discharge matrices were then analyzed to determine (1) ability of the project to meet various access requests, (2) long-term effects on composite rearing HI, and (3) power production associated with each of the discharge request series.

Long-term rearing effects of the various operation schedules were quantified by first converting predicted monthly discharges into HI values using the rearing HI versus discharge relationship. This resulted in a 12 x 32 discharge matrix, of which the 32 predicted HI's for the June through September period were analyzed. A computer program was used to order lists of the 32-predicted discharges and the 32 HI values calculated for these discharges from the composite rearing HI relationship. For demonstration purposes, the 20th, 50th, and 80th percentile exceedence HI values were evaluated to assess effects upon low, medium, and high HI values, respectively.

RESULTS AND DISCUSSION

INSTREAM TEMPERATURE

PACIFIC SALMON TEMPERATURE PREFERENCES

Pacific salmon are cold-adapted fish which have specific temperature range requirements for each of their life history phases. Water temperature influences salmon migration, reproduction, incubation, growth, survival, swimming ability, and the ability to withstand disease (Reiser and Bjornn 1979). Salmon body temperature changes with change in water temperature as do the rates of various physiological processes of fish (Warren 1971). However, poikilotherms adapted to low temperatures can maintain body function at lower temperatures than can warm-adapted fish (Warren 1971). Through adaptation fish can keep body functions at a fairly constant level independent of environmental temperature within the range of tolerances (Precht 1958). It is this tolerance range that we will identify in this section based on a review of selected literature and an evaluation of Susitna-specific data.

A review of literature dealing with the temperature tolerances of Pacific salmon was conducted, and the relevant information was then organized by life phase for each of the five salmon species (Figure 7). This review indicated that (1) tolerances vary greatly by species, life stage, and geographic setting, and (2) comparatively little is known about the specific temperature tolerances of salmon in freshwater systems above 60° N latitude.

Since these published data are not specific to the Susitna drainage, they must be interpreted in order to arrive at preliminary temperature tolerance ranges. These ranges should not be considered as final evaluation criteria

Figure 7. Observed temperature ranges for various life stages of Pacific salmon.

SPECIES OF FISH	LIFE STAGE	SOURCE	TEMPERATURE RANGE °C MIGRATION	SPAWNING	INCUBATION	REARING
Chum	Adult	Bell 1973	8.3-15.6	7.2-12.8		
		Bell 1983	1.5			
		ADF&G 1980	5.0-12.8			
		Mattson & Hobart 1962	4.4-19.4			
		McNeil & Bailey 1975		7.0-13.0		
		Wilson 1981		6.5-12.5		
		Neave 1966		4.0-16.0		
	Juvenile	Trasky 1974	5.0- 7.0			
		Sano 1966	6.0-10.0			
		Bell 1973	6.7-13.3			11.2-15.7
		McNeil & Bailey 1975				4.4-15.7
		Wilson 1979	5.0-7.0			
	Egg/Alevin	Bell 1973			4.4-13.3	
		McNeil 1966			0 -15.0	
		Merritt & Raymond 1982			0.2-10.0	
		Sano 1966			4	
		McNeil & Bailey 1975			4.4	
		Kogl 1965			0.5-4.5	
		Francisco 1977			0.4-6.7	
Coho	Adult	Bell 1973	7.2-15.6	4.4- 9.5		
		Bell 1983	4			
		McNeil & Bailey 1975		7.0-13.0		
	Juvenile	Cederholm & Scarlet 1982	6			
		Bustard & Narver 1975	7			
		Bell 1973				11.8-14.6
		McNeil & Bailey 1975				4.4-15.7
	Egg/Alevin	Bell 1973			4.4-13.3	

Note: Single temperature values are lower observed thresholds.

Figure 7. (Cont'd) Observed temperature ranges for various life stages of Pacific salmon.

SPECIES OF FISH	LIFE STAGE	SOURCE	TEMPERATURE RANGE °C MIGRATION	SPAWNING	INCUBATION	REARING
Pink	Adult	Bell 1973	7.2-15.6	7.2-12.8		
		Bell 1983	5			
		McNeil & Bailey 1975		7.0-13		
		Sheridan 1962		7.2-18.4		
	Juvenile	Bell 1973				5.6-14.6
		McNeil & Bailey 1975				4.4-15.7
		Wilson 1979	5.0-7.0			
	Egg/Alevin	Bell 1973			4.4-13.3	
		Bailey & Evans 1971			4.5	
		Combs 1965			0.5- 5.5	
Sockeye	Adult	Bell 1973	7.2-15.6	10.6-12.2		
		Bell 1983	2.5			
		McNeil & Bailey 1975		7.0-13.0		
	Juvenile	McCart 1967	5.0-17.0			
		Raleigh 1971	4.5			
		Bell 1973				11.2-14.6
		McNeil & Bailey 1975				4.4-15.7
		Fried & Laner 1981	4.0- 7.0			
		Bucher 1981	4.4-17.8			
	Egg/Alevin	Bell 1973			4.4-13.3	
Chinook	Adult	Bell 1973	3.3-13.9	5.6-13.9		
		Bell 1983	4			
		McNeil & Bailey 1975		7.0-13.0		
	Juvenile	Raymond 1979	7			
		Bell 1973				7.3-14.6
		McNeil & Bailey 1975				4.4-15.7
	Egg/Alevin	Bell 1973			5.0-14.4	

Note: Single temperature values are lower observed thresholds.

for Susitna River salmon stocks. We expect to modify these temperature tolerance criteria, especially as more Susitna-specific data are evaluated.

Literature reports and Susitna-specific data on temperature ranges are organized by salmon life phase. Life phases potentially affected by temperature in the Susitna River are adult inmigration, adult spawning, embryo incubation, juvenile rearing, and fry/smolt outmigration.

Adult Inmigration

Adult Pacific salmon have been reported to migrate into freshwater systems in water temperatures which range from 1.5 to 19.4 °C (Figure 7). The reported temperatures at which natural migration occurs vary between species and location, but appear to be influenced by latitude. In general, average annual freshwater temperatures are progressively cooler with increasing latitude (Wetzel 1975). At latitudes above 55° N inmigrating chinook, coho, sockeye, and chum salmon have been observed at temperatures as low as 4° C or colder (Bell 1983).

Reiser and Bjornn (1979) report that unusual stream temperatures can also lead to other factors, such as disease outbreaks in migrating fish, which can alter timing of migration. Temperatures above the upper tolerance range have been reported to stop the migration of fish (Bell 1973). Adult salmon moving through the Portage Creek to Talkeetna reach experience natural water temperatures ranging from 2.5 to 15.7 °C during the chinook inimgration, 4.0 to 14.6 °C during the coho inmigration, and 5.0 to 15.7 °C during the pink, chum, and sockeye inmigration (ADF&G 1983d).

Adult Spawning

Spawning of adult Pacific salmon has been reported to occur in water temperatures which range from 4.0 to 18.4 °C (Figure 7), although the preferred temperature range for all five species is reported by McNeil and Bailey (1975) as 7 to 13 °C. Chum salmon have been observed spawning in Upper Susitna mainstem habitats at temperatures which are much colder, ranging from 3.3 to 7.0 °C (ADF&G 1983b).

Embryo Incubation

Compared with the other salmon life phases, incubation rates of salmon embryos are perhaps most directly influenced by water temperature. Generally, the lower and upper temperature limits for successful initial incubation of salmon eggs are 4.5 and 14.5 °C, respectively (Reiser and Bjornn 1979). In laboratory studies conducted in Washington (Combs 1965) and from a literature review conducted by Bams (1967), salmon eggs are reportedly vulnerable to temperature stress before closure of the blastopore, which occurs at about 140 accumulated Centigrade temperature units. A temperature unit is one degree above freezing experienced by developing fish embryos per day. After the period of initial sensitivity to low temperatures has passed (approximately 30 days), embryos and alevins can tolerate temperatures near 0 °C (McNeil and Bailey 1975). From his work on Sunshine Creek in southeast Alaska, Merrell (1962) suggested that pink salmon egg survival may be related to water temperatures during spawning. McNeil (1969) further examined Sunshine Creek data and discussed the relationship between initial incubation temperature and survival. Eggs exposed to cooler spawning temperature experienced greater incubation mortality than eggs which began incubation at warmer temperatures. Abnormal embryonic development could occur if, during initial stages of development, embryos are exposed to temperatures below 6 °C (Bailey 1983). Bailey and Evans (1971) reported an increase in mortalities for pink salmon when initial incubation water temperatures were below 4.5 °C, and complete mortality occurred when water temperatures were held below 2 °C during this initial incubation period. Increases in embryo mortalities and alevin abnormalities were shown to occur when average temperatures were maintained at a level less than 3.4 °C during experimental lab tests of developing Susitna chum and sockeye salmon embryos (Wangaard and Burger 1983). It appears that a complete loss of all incubating salmon eggs will not occur if the reduced water temperatures occur after closure of the embryonic blastopore.

Juvenile Rearing

Water temperature has a profound effect on immature fish metabolism, growth, food capture, swimming performance, and disease resistance. It appears that juvenile salmonids tolerate a fairly wide range of water temperatures (Figure 7). Generally, the acceptable temperature range is between 4.4 and 15.7 °C. However, rearing juvenile salmonids have been observed in side sloughs in the upper Susitna River where June through September water temperatures were between 2.4 and 15.5 °C (ADF&G 1983d), a slightly wider range.

According to literature reviewed to date, normal juvenile salmon activity has not been observed at water temperatures lower than 4.4 °C. However, this collective experience is primarily for the northwest United States and Southeast Alaska. At lower water temperatures, fish tend to be less active and spend more time resting in secluded covered habitats (Chapman and Bjornn 1969). In Carnation Creek, British Columbia, Bustard and Narver

(1975) reported that at water temperatures above 7 °C most fish were active and feeding. As water temperatures decreased below 7 °C coho salmon moved into deeper water or closer to objects providing cover. In Grant Creek near Seward, Alaska, observed juvenile salmonids were inactive and inhabiting the cover afforded by streambed cobble and large gravel substrates at 1.0 to 4.5 °C water temperatures (AEIDC 1982).

Fry/Smolt Outmigration

Water temperature change may serve as a stimulus for smolt outmigration (Sano 1966). Juvenile chinook salmon outmigrations from the Salmon River, Idaho have been related to sudden rises in water temperature (Raymond 1979). The critical temperature triggering this movement appeared to be 7 °C and outmigrations were slowed when water temperatures dropped below 7 °C. Low temperatures seemed to slow the rate of outmigrations for coho salmon in the Clearwater River, Washington, and only minor movement was noted below 6 °C (Cederholm and Scarlet 1982). Juvenile chinook and coho salmon have been observed to stop outmigrating when water temperature falls below 7° C (Raymond 1979; Cederholm and Scarlet 1982; Bustard and Narver 1975).

In the Susitna River, salmon smolt outmigration from overwintering areas and pink and chum salmon fry outmigration from natal habitats is not well defined. Currently no specific data are available for pink fry outmigration timing. Outmigrating chum fry occur in the river mainstem from late May to mid-August, peaking in June. During May river temperatures generally range from just above freezing to 6 to 7 °C. River ice breakup generally occurs during a large part of the initial chum salmon fry outmigration period.

Coho, chinook and sockeye smolts appear to outmigrate during the period June through September. Specific smolt outmigration timing data for sockeye are not currently available but rather are combined with data on general fry and juvenile movement patterns from ADF&G's Talkeetna Station outmigrant trap. These data illustrate chinook outmigration occurs in June to mid-July, while coho outmigration appears to occur throughout June to September. According to reported 1982 Susitna River data (ADF&G 1983d), June river temperatures normally range from 2.5 to 9.0 °C. During July water temperatures range from 5.0 to 15.7 °C, while during August mainstem water temperatures were warmest, ranging from 8.2 to 14.6 °C. In September 4.0 to 10.0 °C was the range for mainstem water temperatures in the Devil Canyon to Talkeetna reach.

Susitna Temperature Impact Assessment Criteria

The existing literature concerning the various salmon life stage preferences is primarily for latitudes below 60 °N. These reported temperature ranges have been evaluated with respect to available observed temperatures in the Susitna River in order to develop preliminary temperature criteria that can then be related to the stream temperature predictions reported by AEIDC (1983a). The preliminary salmon temperature criteria utilized in the remainder of this section are provided in Figure 8.

In order to prepare preliminary thermal impact assessment criteria, we considered both literature and observed Susitna temperature ranges. Susitna temperature values have not been correlated to actual fish activities in every case. Some subjectivity was involved on our part in those situations. We utlized mean Susitna temperature values for those months where minimum temperatures were felt to be too low and anomalous.

Figure 8. Preliminary salmon temperature tolerance criteria for use in Susitna thermal impact assessment.

Salmon Life Phase	Temperature Tolerance Criteria (°C) Literature Reports	Susitna[1] Observed Surface Water Temperature	Preliminary Impact Assessmen[t] Criteria
Adult Inmigration			
Chinook	4.0-13.9	2.5-15.7	4.0-16.0
Coho	4.0-15.6	4.0-14.6	4.0-16.0
Sockeye	5.0-15.6	5.0-15.7	4.0-16.0
Pink	1.5-19.4	5.0-15.7	4.0-16.0
Chum	2.5-15.6	5.0-15.7	4.0-16.0
Adult Spawning			
Chinook	5.6-13.9	5.5-11.5	5.5-12.0
Coho	4.4-13.0	3.0-9.5	3.0-12.0
Sockeye	7.0-13.0	3.1-9.2	3.0-12.0
Pink	7.0-18.4	3.1-9.2	3.0-12.0
Chum	4.0-16.0	3.1-9.2	3.0-12.0
Embryo Incubation[2]			
Chinook	5.0-14.4	0.0-12.0	
Coho	4.4-13.3	0.0-12.0	
Sockeye	4.4-13.3	0.5-12.5	4
Pink	0.5-13.3	0.0-12.0	
Chum	0.0-15.0	0.0-12.0	
Juvenile Rearing			
Chinook	4.4-15.7	2.5-15.7	2.5-16.0[5]
Coho	4.4-15.7	2.5-15.7	2.5-16.0
Sockeye	4.4-15.7	2.5-15.7	2.5-16.0
Pink	4.4-15.7	2.5-15.7	2.5-16.0
Chum	4.4-15.7	2.5-15.7	2.5-16.0
Fry/Smolt Outmigration			
Chinook	>7	2.5-15.7	5.0-16.0
Coho	>6	2.5-15.7	5.0-16.0
Sockeye	4.5-17.0	2.5-15.7	5.0-16.0
Pink	5.0-7.0	0.5- 9.0[3]	5.0-16.0
Chum	5.0-13.3	2.5-15.7	5.0-16.0

[1]In many cases, very limited data exist with which to compile these temperature ranges.

[2]Embryo incubation is more rapid at high temperatures, slower at cooler temperatures. Range indicates tolerance only; timing of hatching, button-up, and ultimately outmigration depends on quantity of accumulated temperature units. Susitna observed temperature data are from surface water measurements; no correlation has been made for any relationships between surface and intragravel water temperatures.

[3]Assumes pink fry outmigrate in May.

[4]Accumulated °C temperature units should be determined for each species as criteria for incubation.

[5]Rearing includes feeding, growth, and general movement between habitats. Specific temperature criteria for winter months may be different pending review of winter data from ADF&G. Separate overwintering criteria may be required in order to adequately address thermal impact.

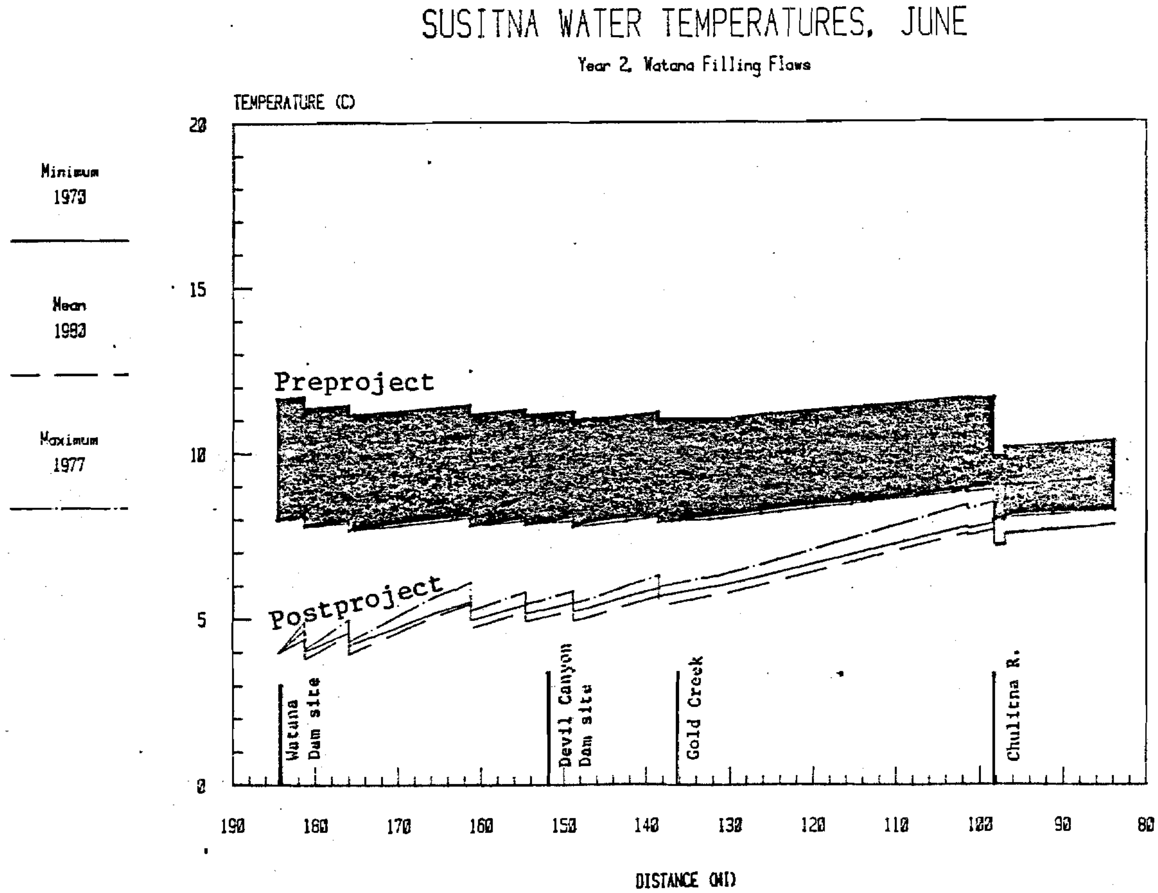
EFFECT OF PROJECT-RELATED WATER TEMPERATURE CHANGES ON SALMON

In this section pre- and postproject temperature regimes in the Devil Canyon to Talkeetna reach for the months of June through September are evaluated with respect to the various life stage temperature tolerance criteria established in the previous section. Three scenarios are examined: (1) natural versus the second year of Watana reservoir filling (during year one essentially the preproject thermal conditions will be extant, and during year three the thermal conditions will be the same as Watana operational), (2) natural versus Watana dam operation, and (3) natural versus combined operation of the Watana and Devil Canyon dams. During Watana filling (Figure 9), postproject temperatures will be 4 °C at the dam and will warm to nearly preproject conditions at the Chulitna confluence for June, July, and August simulations. September conditions appear to be essentially the same pre- and postproject with slightly cooler postproject releases at the dam. A 15-year simulation period for preproject conditions is shown. During operation (Figures 10 and 11) postproject temperatures gradually approach preproject conditions with increasing distance downstream from the dams. Only 1981 hydrologic and meteorologic conditions are compared.

Adult Inmigration

The most apparent project-related change in Susitna River water temperature will occur in the mainstem and side channels since these habitats will be directly affected by change in river discharge. Since these habitats are primarily used by adults as migration corridors (ADF&G 1983b) the principal potential thermal impact will be on the adults returning to spawning grounds. The Upper Susitna inmigration period for chinook is late June to mid-July; pink and sockeye salmon inmigrate from late July through August;

Figure 9. Pre- and postproject longitudinal Susitna River mainstem temperature profiles, Watana dam to Sunshine: second year Watana reservoir filling.



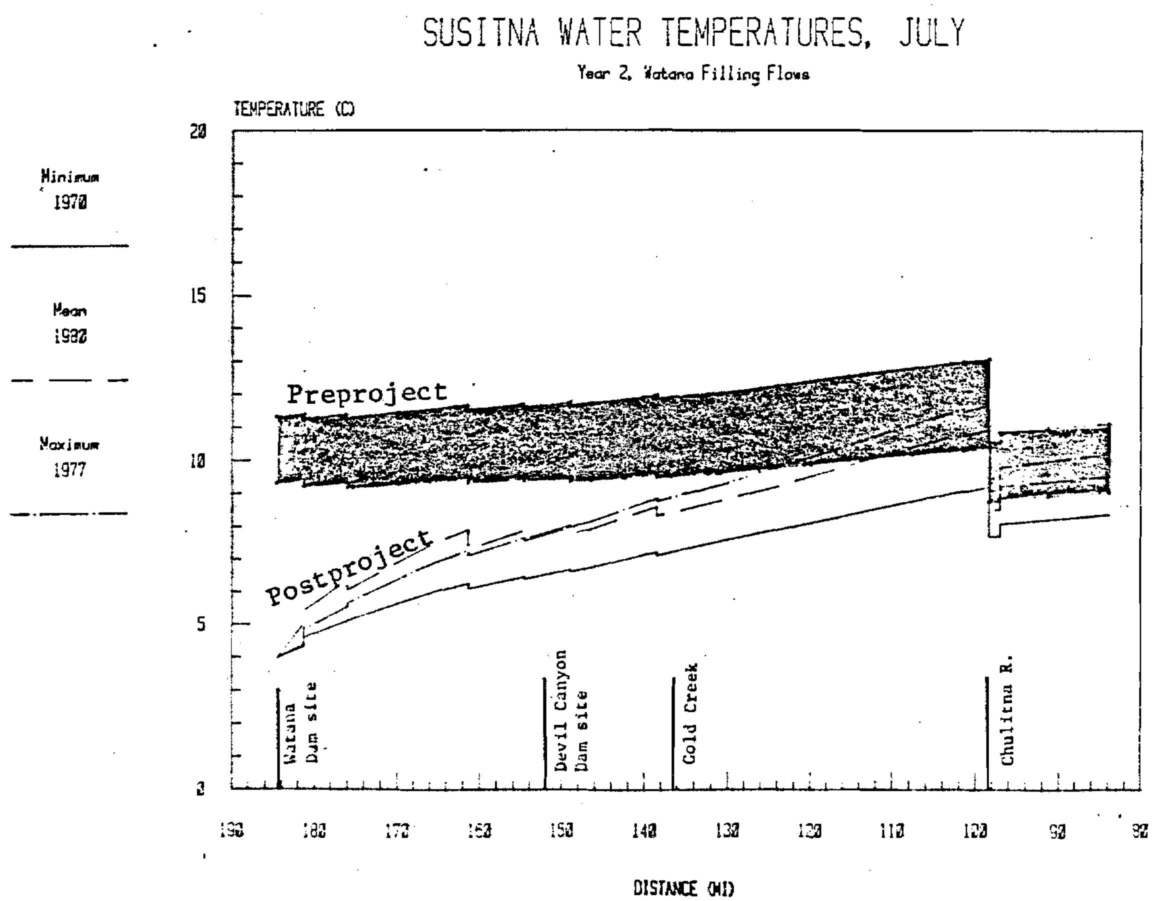
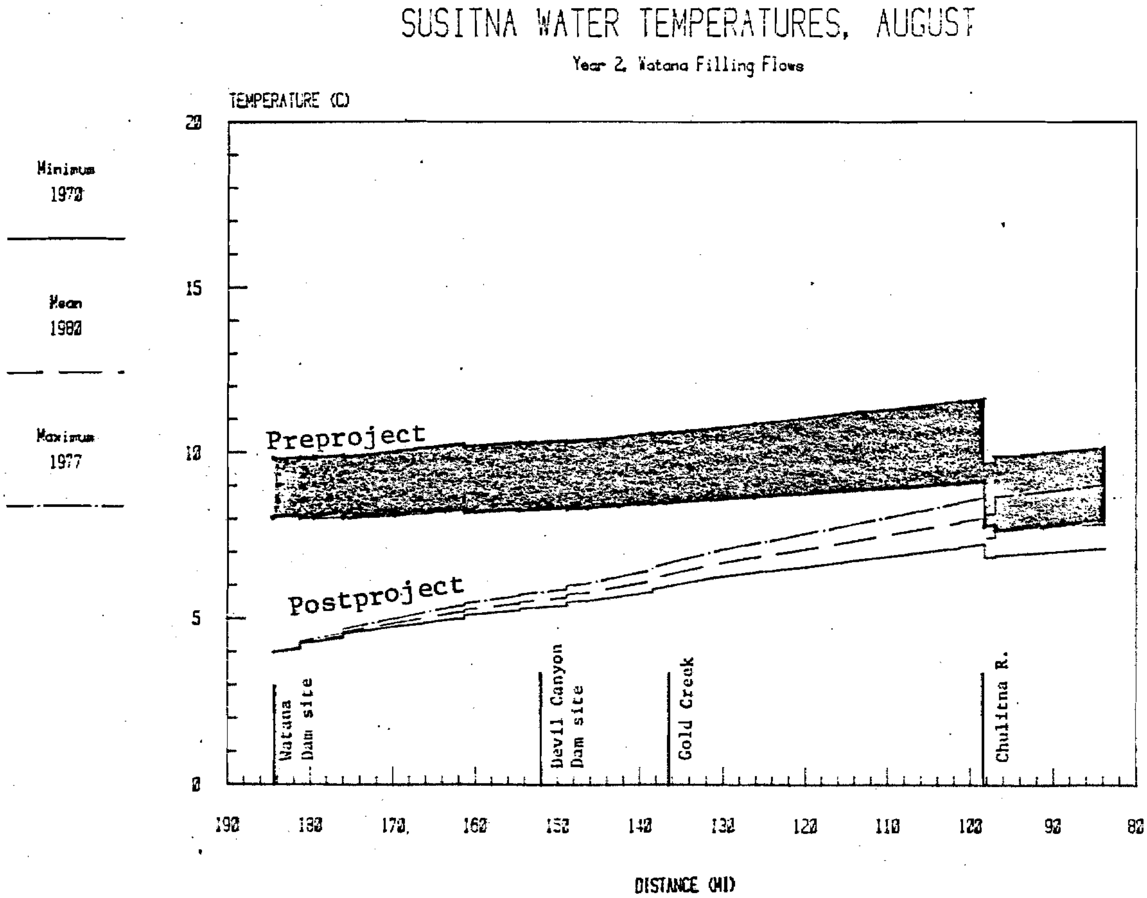


Figure 9 (continued). Pre- and postproject longitudinal Susitna River mainstem temperature profiles, Watana dam to Sunshine: second year Watana reservoir filling.



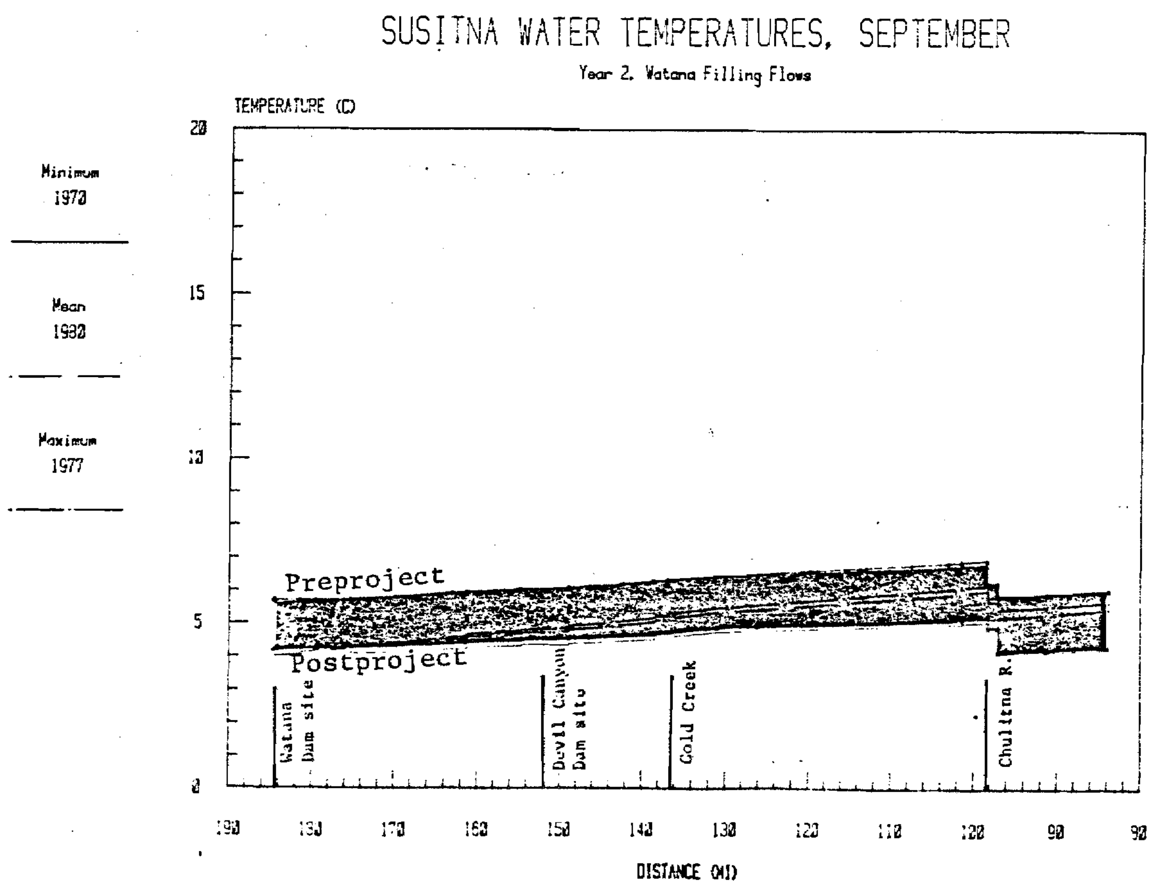
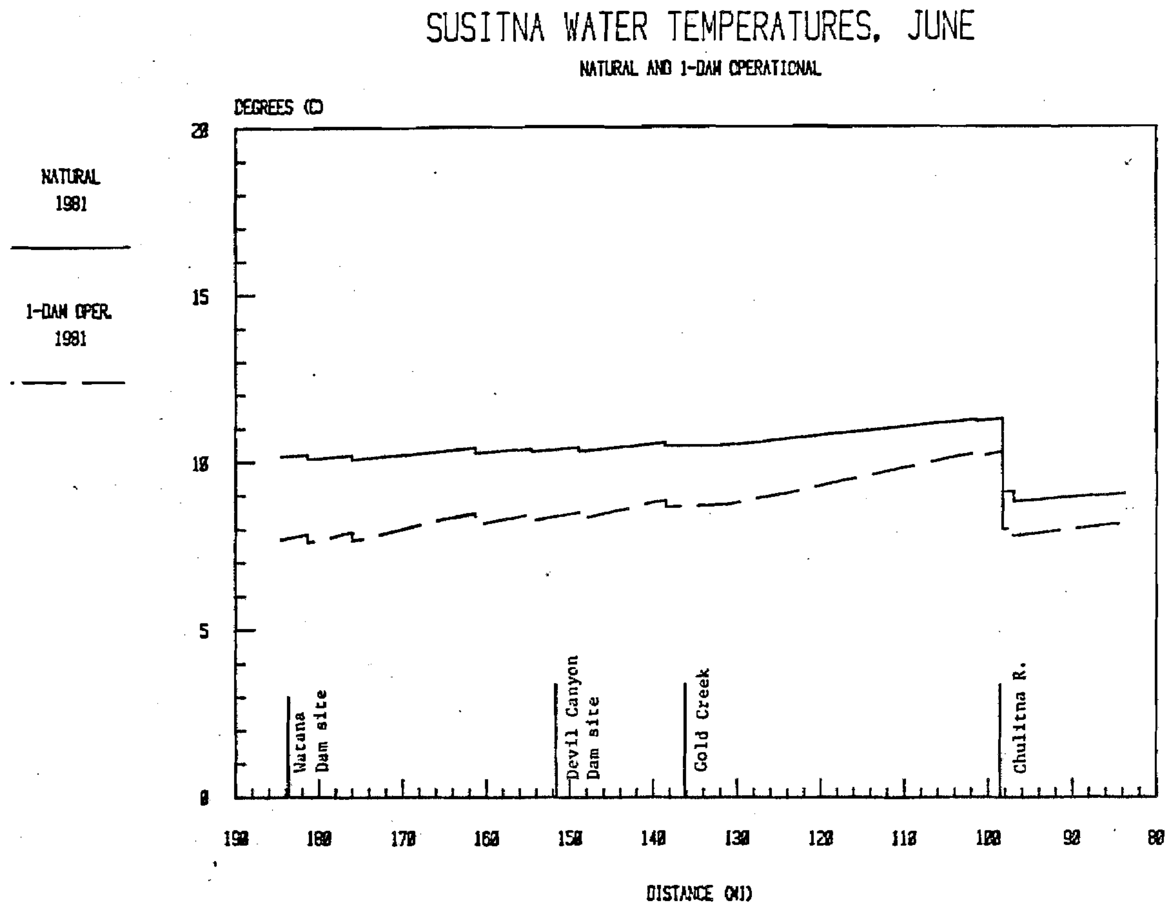


Figure 10. Pre- and postproject longitudinal Susitna River mainstem temperature profiles, Watana dam to Sunshine: Watana dam operational.



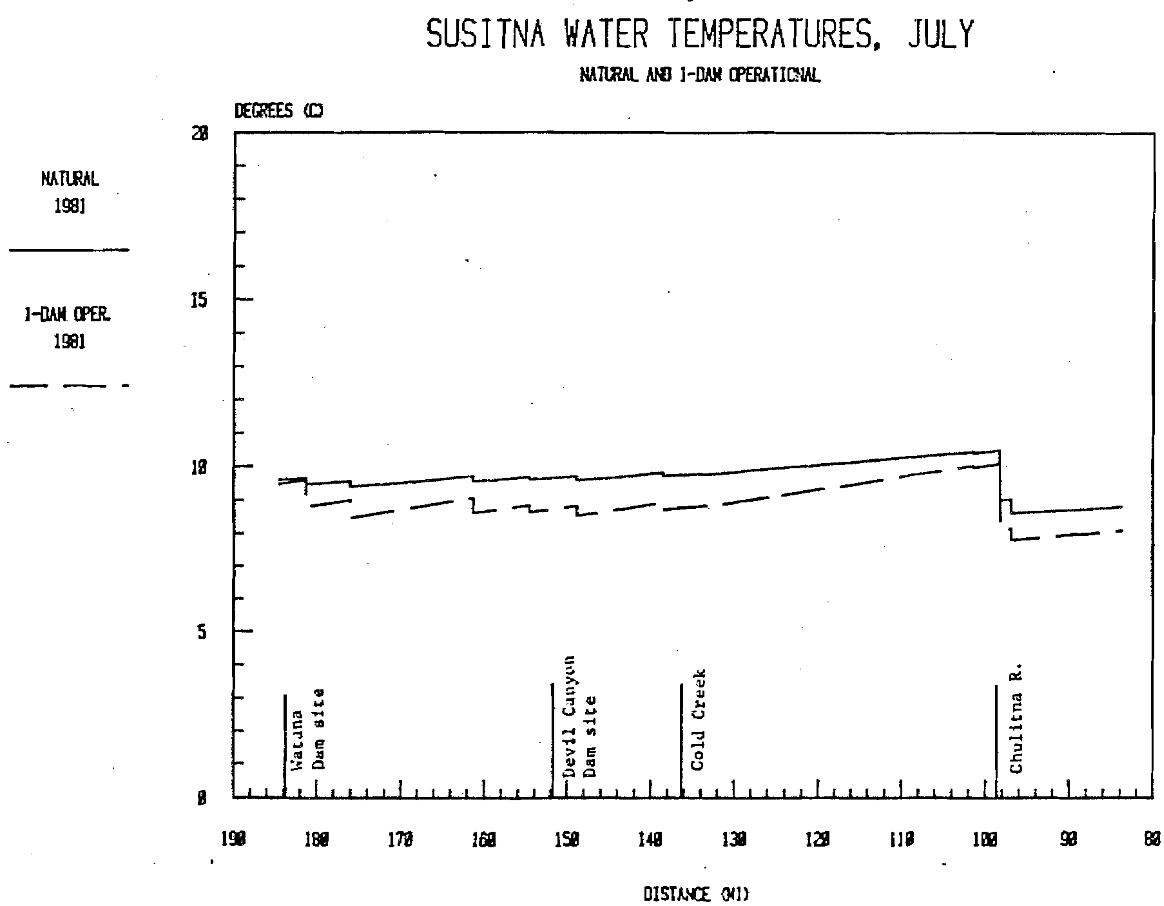
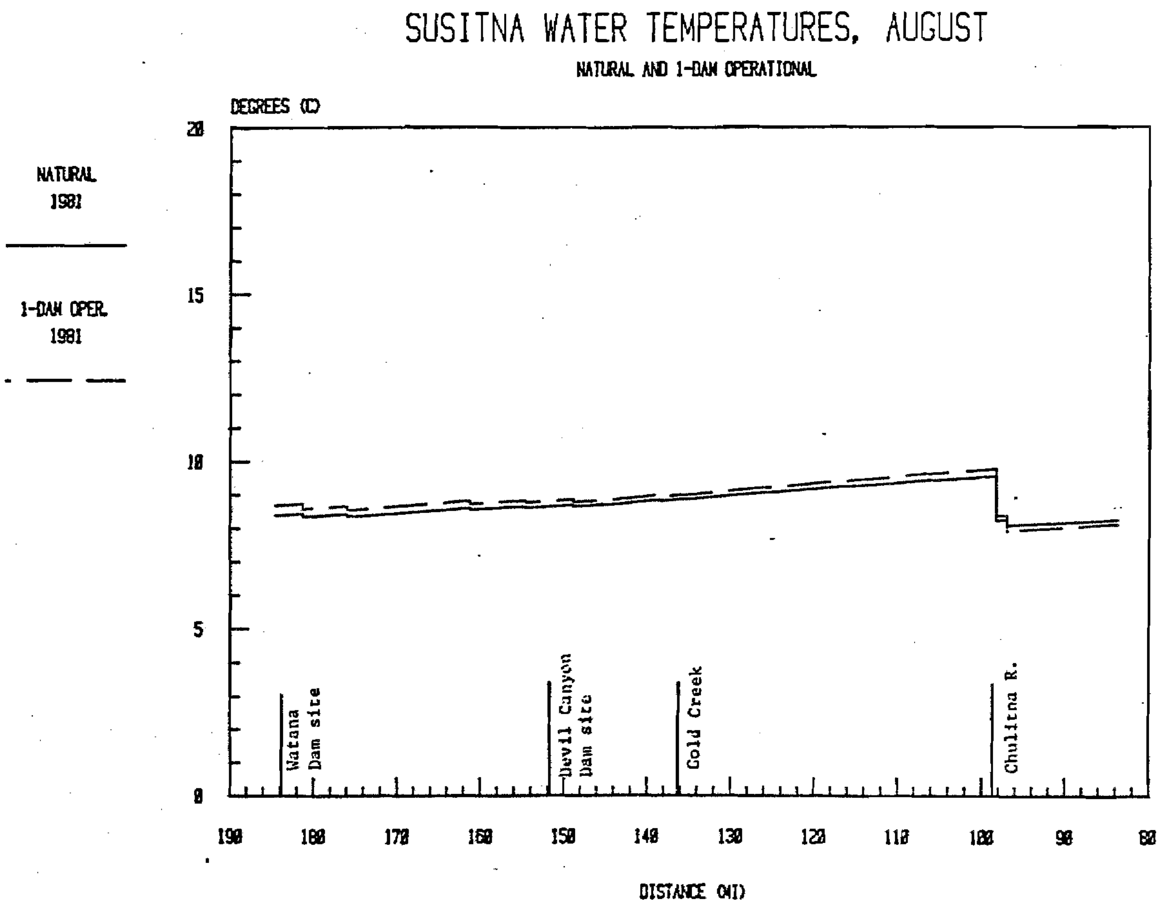


Figure 10 (continued). Pre- and postproject longitudinal Susitna River mainstem temperature profiles, Watana dam to Sunshine: Watana dam operational.



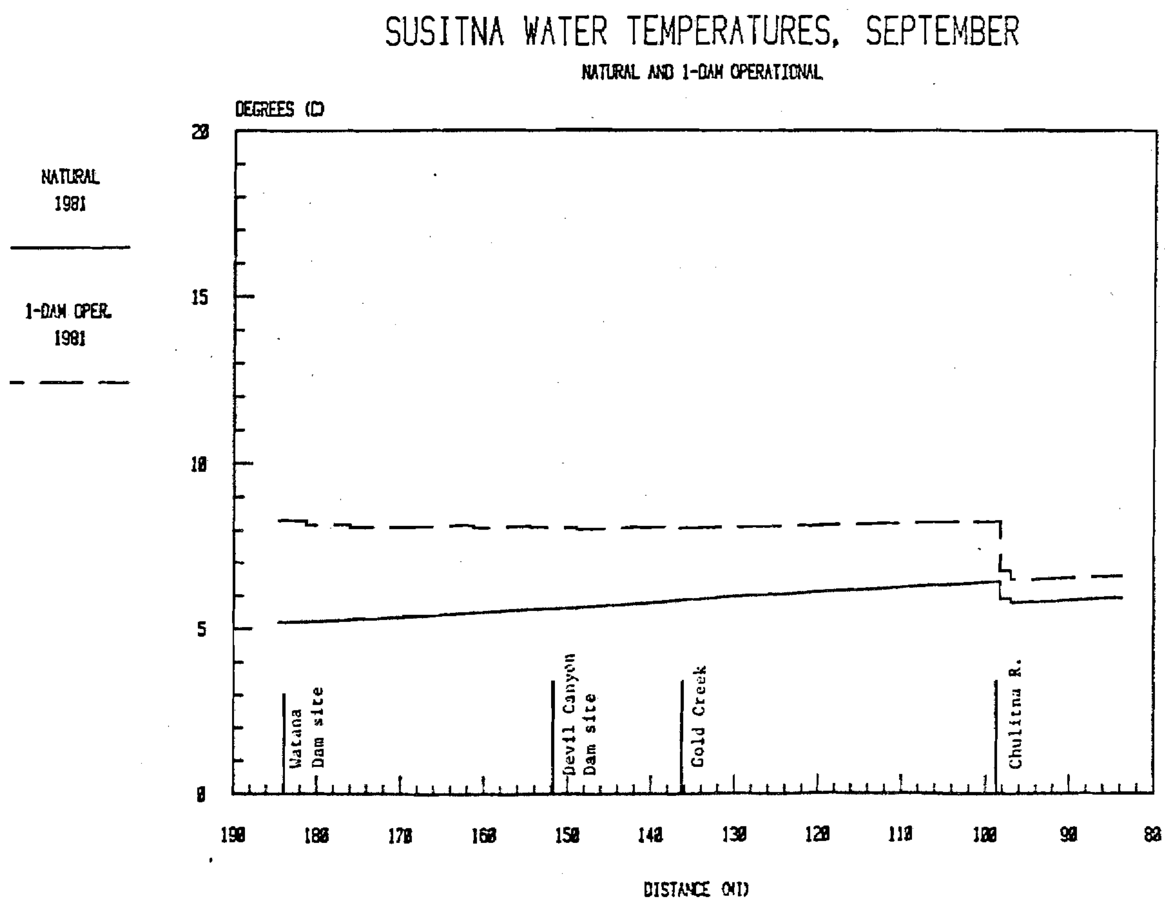
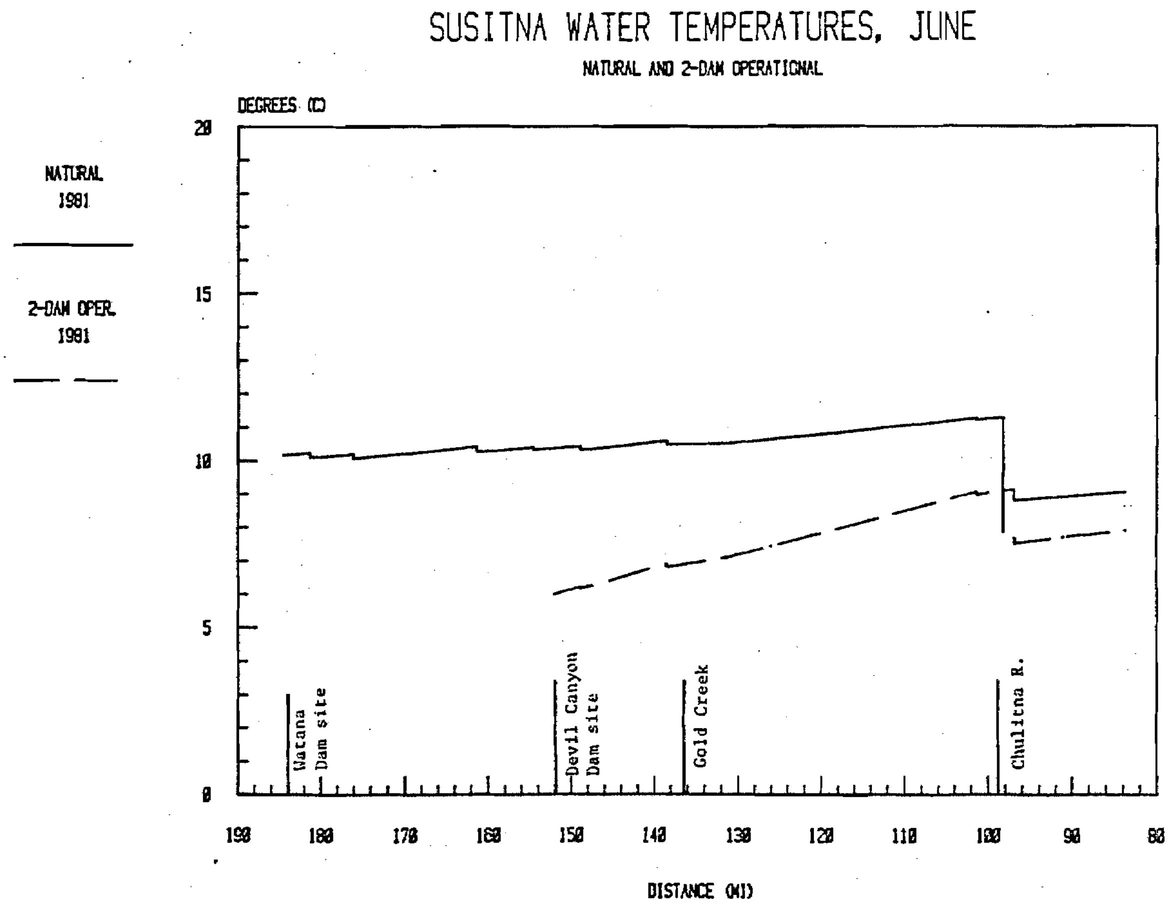


Figure 11. Pre- and postproject longitudinal Susitna River mainstem temperature profiles, Watana or Devil Canyon to Sunshine: Watana and Devil canyon dams operational.



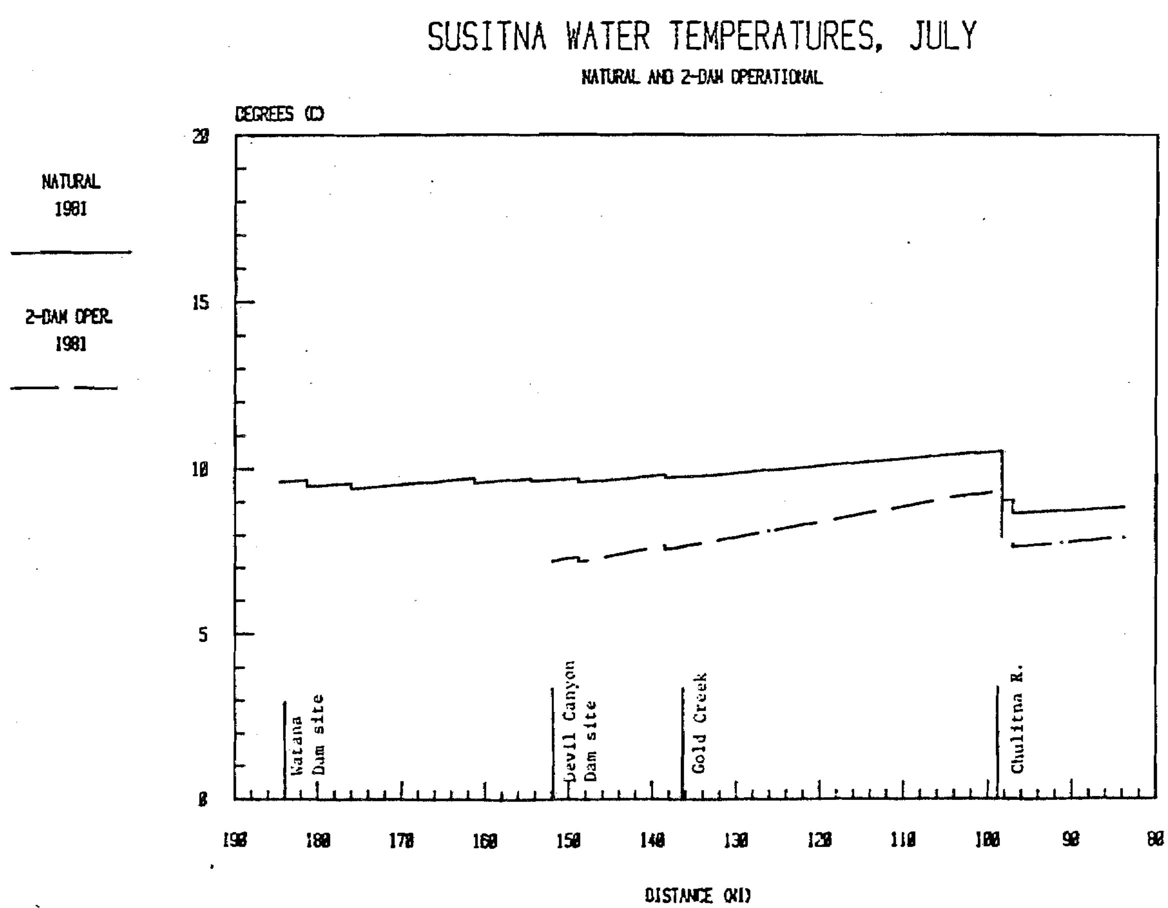
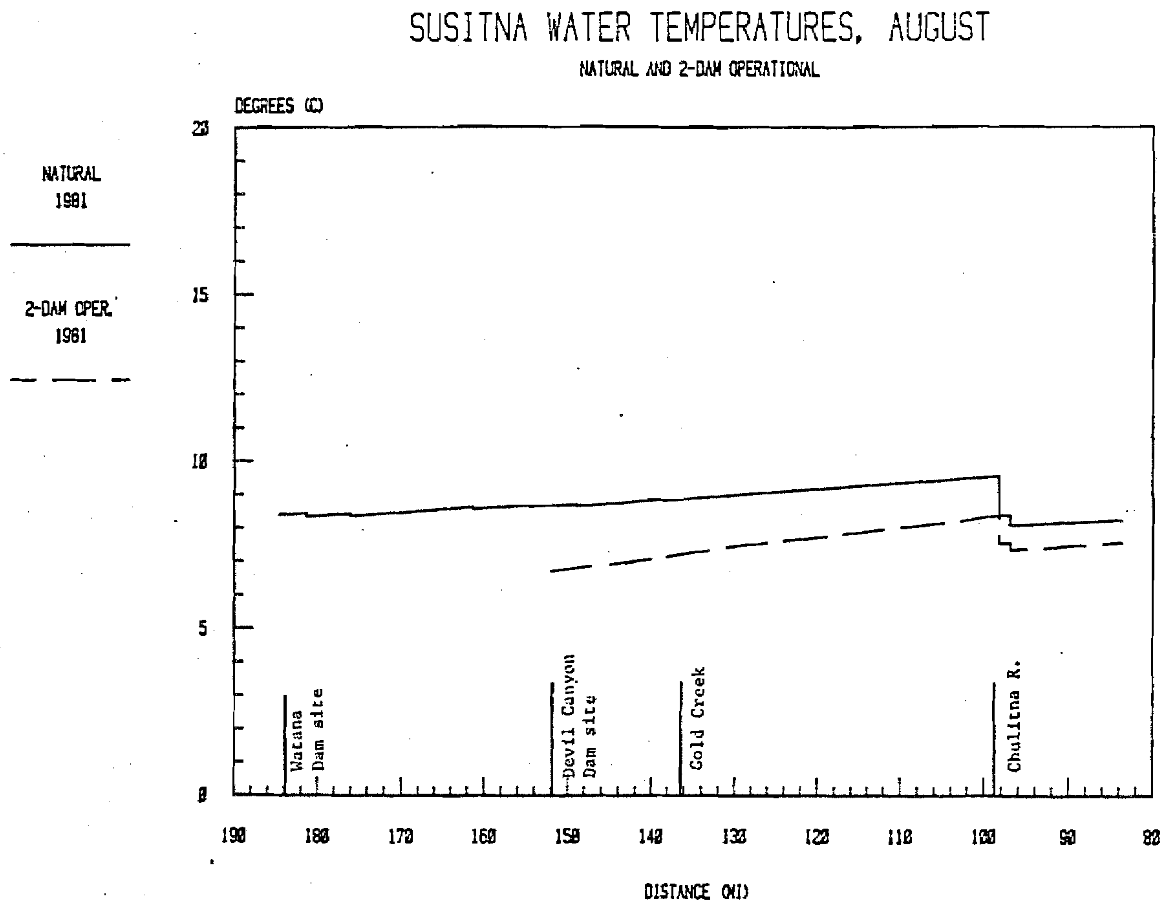
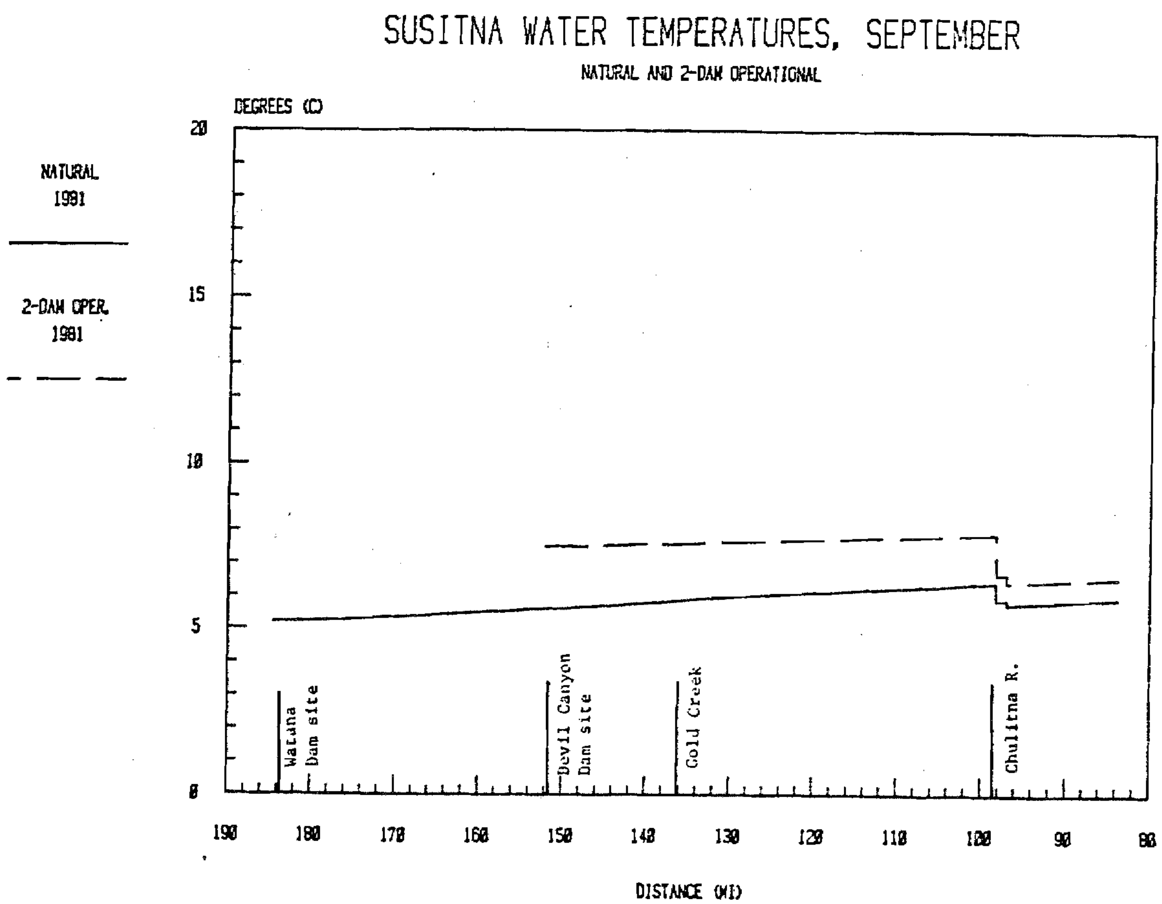


Figure 11 (continued). Pre- and postproject longitudinal Susitna River mainstem temperature profiles, Watana or Devil Canyon to Sunshine: Watana and Devil Canyon dams operational.





and chum and coho inmigrate from late July through early September (ADF&G 1983b).

For the three postproject impact scenarios examined in this report, the following summarizes the significant postproject thermal impact issues for adult inmigrating salmon during June through September using a 1981 meteorological data set for reservoir outlet temperature simulations: (a) reduced water temperatures from Watana to Sunshine during June through August for Watana filling year 2; (b) reduced water temperatures from Watana to Sunshine during June and July and increased water temperatures in this reach during September for Watana dam operation; and (c) reduced water temperatures from Devil Canyon to Sunshine during June through August and increased water temperatures in this reach during September for the combined operation of the Watana and Devil Canyon dams. These scenarios are applicable to all phases of salmon life history in the Upper Susitna River.

During the second year of Watana reservoir filling, June river temperatures at the Chulitna confluence are predicted to range from 6 to 8.1 °C (Figure 12). A temperature gradient of gradually cooler water is expected to be observed extending upstream of the confluence, reaching 4.2 to 6.5 °C at Portage Creek. The natural range from Devil Canyon to Talkeetna is 7.2 to 9.9 °C, a fairly constant temperature regime. Under project conditions, fish will be exposed to water that is 1 °C cooler at the confluence and is 3 to 4.5 °C cooler at Portage Creek. The only salmon entering the Upper Susitna during June are chinook, the majority of which pass Talkeetna during the last week of June and first two weeks of July (ADF&G 1983b).

July temperatures during the second year of filling will range from 7.6 to 9.1 °C at the Chulitna confluence to 6.3 to 8 °C at Portage Creek.

Figure 12. Monthly temperature ranges for mainstem Susitna River, Watana to Sunshine, for natural conditions and three project-related scenarios; June.

Location (River Mile)	Range of simulated monthly preproject temperatures[1] C	Simulated Project-Related Scenario: Watana filling, year #2 range of simulated mean monthly temperatures[1] C	Simulated Project-Related Scenario: Watana only operational[2] temperatures C	Simulated Project-Related Scenario: 2-dam operational[2] temperatures C
Watana (184.5)	7.5-11.6	4.0	7.7	6.0
Devil Canyon (148.8)	7.3-11.2	4.2-6.5	8.5	6.2
Gold Creek (136.8)	7.2-11.0	4.4-7.1	8.7	6.9
Chulitna Confluence (98.2)	7.2-9.9	6.1-8.1	8.0	7.6
Sunshine (83.8)	7.2-10.3	6.5-9.3	8.2	7.9

[1] Based on a 15-year period of simulation, 1968 through 1982

[2] Simulations using 1981 hydrologic and meteorologic conditions and results of DYRESM reservoir temperature model for same period.

Figure 12 (continued). Monthly temperature ranges for mainstem Susitna River, Watana to Sunshine, for natural conditions and three project-related scenarios; July.

Location (River Mile)	Range of simulated monthly preproject temperatures[1] C	Simulated Project-Related Scenario		
		Watana filling, year #2 range of simulated mean monthly temperatures[1] C	Watana only operational temperatures[2] C	2-dam operational temperatures[2] C
Watana (184.5)	9.3-11.3	4.0	9.5	7.2
Devil Canyon (148.8)	9.5-11.8	6.3-8.0	8.8	7.4
Gold Creek (136.8)	9.5-11.9	7.0-8.9	8.8	7.6
Chulitna Confluenc (98.2)	8.7-10.6	7.6-9.1	8.1	7.9
Sunshine (83.8)	8.9-11.2	8.2-10.3	8.1	7.9

[1]Based on a 15-year period of simulation, 1968 through 1982

[2]Simulations using 1981 hydrologic and meteorologic conditions and results of DYRESM reservoir temperature model for same period.

Figure 12 (continued). Monthly temperature ranges for mainstem Susitna River, Watana to Sunshine, for natural conditions and three project-related scenarios; August.

Location (River Mile)	Range of simulated monthly preproject temperatures[1] C	Simulated Project-Related Scenario: Watana filling, year #2 range of simulated mean monthly temperatures[1] C	Watana only operational temperatures[2] C	2-dam operational temperatures[2] C
Watana (184.5)	7.5-10.1	4.0	8.7	6.7
Devil Canyon (148.8)	7.9-10.4	5.2-6.2	8.9	6.8
Gold Creek (136.8)	8.1-10.6	5.7-7.1	9.0	7.2
Chulitna Confluence (98.2)	7.5-9.7	6.5-8.2	8.2	7.5
Sunshine (83.8)	7.5-10.2	6.7-9.1	8.1	7.6

[1] Based on a 15-year period of simulation, 1968 through 1982

[2] Simulations using 1981 hydrologic and meteorologic conditions and results of DYRESM reservoir temperature model for same period.

Figure 12 (continued). Monthly temperature ranges for mainstem Susitna River, Watana to Sunshine, for natural conditions and three project-related scenarios; September.

Location (River Mile)	Range of simulated monthly preproject temperatures[1] C	Simulated Project-Related Scenario: Watana filling, year #2 range of simulated mean monthly temperatures[1] C	Watana only operational temperatures[2] C	2-dam operational temperatures[2] C
Watana (184.5)	4.1-6.1	4.0	8.3	7.5
Devil Canyon (148.8)	4.4-6.6	4.3-5.0	8.1	7.5
Gold Creek (136.8)	4.6-6.8	4.4-5.4	8.1	7.6
Chulitna Confluence (98.2)	4.7-6.6	4.6-6.1	6.7	6.6
Sunshine (83.8)	3.9-6.6	3.8-6.2	6.6	6.6

[1]Based on a 15-year period of simulation, 1968 through 1982

[2]Simulations using 1981 hydrologic and meteorologic conditions and results of DYRESM reservoir temperature model for same period.

Compared to the natural temperatures of 8.7 to 10.6 °C and 9.5 to 11.8 °C at Chulitna and Portage, respectively, all five species of adult salmon will inmigrate through the Chulitna confluence in slightly cooler conditions (1 to 1.5 °C cooler) and at Portage Creek confluence in cooler water (3 °C cooler).

August temperatures during the second year of filling are predicted to be 6.5 to 8.2 °C at the confluence and 5.2 to 6.2 °C at Portage Creek, in comparison to the natural conditions as of 7.5 to 9.7 °C at Chulitna and 7.9 to 10.4 °C at Portage. Chinook salmon will have nearly completed their spawning inmigration by August, but the other four species will be present in the mainstem while moving toward spawning grounds. These fish will be exposed to water at the confluence which will be 1.0 °C cooler and to water temperatures at Portage Creek which will be 2.5 to 4 °C cooler than natural.

September temperature ranges do not appear to be significantly different between filling and preproject conditions. Also, most mainstem adult salmon migration has been completed by September.

In conclusion, the temperature regime during the second year of filling will create conditions which are expected to be cooler than preproject for June, July, and August, but within the preliminary temperature tolerance criteria for adult salmon migrating to spawning habitat. The lower mainstem temperatures (5.2 to 8 °C) predicted for July and August at Portage Creek are lower than the preproject temperature range of 7.3 to 11.8 °C but are within the preliminary criteria established for migrating adult salmon. Also, this lower temperature range falls within the natural 4.5 to 11.5 °C temperature range observed in Portage Creek during July 1982 (ADF&G 1983d). Based on present knowledge, we conclude that this colder mainstem water during June, July, and August for a Watana filling scenario should not significantly impact adult salmon migration.

Postproject water temperatures under a one-dam scenario will be slightly (1.5 °C) warmer than natural conditions in September and slightly (0.5 °C) cooler in July (Figure 12). During other months little change is expected. Using a similar analytical process for the operational scenarios as used in the filling scenario, we conclude that under a one-dam scenario the temperature profiles for June through September in the upper river do not differ enough from natural conditions to interfere with adult salmon migration. Under the two-dam scenario the temperature profiles for June in the upper river indicate that at Portage Creek water temperature will be 1 °C cooler with no difference downstream. In July we expect 1 to 2 °C cooler water in the reach, while in August the mainstem will be 1 °C cooler in the upper part of the reach with no difference at the confluence. September water temperatures will be the same at the confluence and 1 to 2 °C warmer in the upper reach. These conditions do not exceed the tolerance criteria, and we believe that both operational scenarios will have no effect on adult inmigrating salmon.

Adult Spawning

The same thermal impact issues as previously identified for adult inmigration will occur for the spawning period; i.e., project-induced water temperatures will be cooler June through August for the second year of Watana filling, cooler June and July and warmer in September for Watana dam operational, and cooler June through August and warmer in September for Watana and Devil Canyon dams operational (Figure 12). However, this section deals only with identifiable thermal impacts associated with changes in mainstem thermal properties. Thus, only mainstem, side channel, and tributary confluence areas are addressed with respect to thermal change because these habitats are known to be influenced directly by changes in dam discharge. In the case of tributary confluence zones, it is difficult to predict biological impact due to the lack of temperature information on the mixing zone and the degree to which mainstem temperature change would be reflected in the tributary plume.

Chum salmon have been positively identified as utilizing mainstem habitats for spawning (ADF&G 1983b). In this case, nine sites in the Upper Susitna reach have been observed. Only one site in this reach has been utilized by spawning coho salmon (ADF&G 1983b). Chum and coho spawn during the September period and would, therefore, experience slightly warmer temperatures under the one- and two-dam operational scenarios. However, all predicted postproject temperatures for September are within the spawning criteria for chum and coho salmon. Based upon present knowledge, we conclude, therefore, that the predicted water temperature regimes associated with all three scenarios will not inhibit salmon spawning in mainstem and side channel habitats.

Embryo Incubation

The same thermal impact issues as previously identified for adult spawning will occur for the initial incubation period; i.e., project-related water temperatures will be cooler from June through August for the second year of Watana filling, cooler June and July and warmer in September for the second year of Watana filling and Watana dam operational, and cooler June through August and warmer in September for Watana and Devil Canyon dams operational (Figure 12). According to ADF&G (1983b), chum salmon spawn in several mainstem locations, and coho salmon were observed spawning in 1981 at one mainstem site. Thus, only chum and coho salmon embryos would be affected by project-related water temperature change, and both species spawn principally in September. Since Watana filling water temperatures will essentially be the same as natural conditions, no effects on the initial incubation period are expected. For the one- and two-dam scenarios, however, developing chum and coho eggs will experience warmer temperatures during the month of September. The effects of warmer incubation water cannot be fully addressed until the thermal regime of the remainder of the incubation period, probably through April or May, is evaluated. If the September warming trend continues into other months of the incubation period, significant development rate changes may occur.

Juvenile Rearing

The same thermal impact issues as previously identified will occur for the open water rearing period; i.e., project-related water temperatures will be cooler June through August for Watana filling, cooler June and July and warmer in September for Watana dam operational, and cooler June through August and warmer in September for Watana and Devil Canyon dams operational (Figure 12). Chum, sockeye, chinook and coho fry and/or juveniles rear in some mainstem or side channel habitats throughout June and July; most chum fry move out of this reach by July 15 (ADF&G 1983c). Coho, sockeye, and chinook can be found in these mainstem or side channel habitats in August and September as well.

In the Watana filling scenario, mainstem temperatures below Portage Creek to the Chulitna confluence will range from 4.2 to 8.1 °C in June, 6.3 to 9.1 °C in July, 5.2 to 8.2 °C in August, and 4.3 to 6.1 °C in September (Figure 12). These temperatures represent changes from natural conditions of approximately 3 °C cooler in June, approximately 2.5 °C cooler in July and

August, and only slightly (0.5 °C) cooler in September. All postproject temperature ranges fall within the preliminary temperature criteria for juvenile rearing.

In the Watana only scenario, postproject mainstem temperatures will differ from natural conditions by 0.5 °C cooler in July and 1.5 °C warmer in September. During June and August postproject temperatures fall within the range of natural conditions. In the two-dam scenario, postproject June temperatures will be approximately 1 °C cooler near Portage, but no significant differences are expected near the Chulitna confluence. July conditions will be 1 to 2 °C cooler, and in August a similar 1 °C cooler condition will exist in only the upper part of the reach. September temperatures will be warmer than preproject, at or 1 °C above the upper limit of the natural range. All postproject temperatures fall within the preliminary criteria for juvenile rearing.

We conclude based on this analysis that no temperature-related impact on rearing salmon is readily apparent. However, during certain cases, particularly for the Watana filling scenario, water up to 2.5 to 3 °C cooler than natural conditions may retard juvenile salmon growth rates since these colder conditions would persist for three months. Similarly, the September predictions show warming trends which may enhance juvenile salmon growth rates. Temperature change may also affect food availability, indirectly impacting rearing fish. In order to fully evaluate these consequences, however, thermal impact assessment must consider the remainder of the year since juveniles are present year-round. Also, temperature conditions in months other than June through September may either exacerbate or ameliorate these effects.

Fry/Smolt Outmigration

The same thermal impact issues as previously identified will occur for the outmigration period; i.e., project-induced water temperatures will be cooler June through August for Watana filling, cooler June and July and warmer in September for Watana dam operational, and cooler June through August and warmer in September for Watana and Devil Canyon dams operational (Figure 12).

Pink salmon fry outmigrate in May and June, while chum fry outmigrate from late May to mid-July (ADF&G 1983c). Chinook smolts outmigrate in June and July while coho outmigrate throughout June through September. The majority of sockeye outmigrate by the end of July.

In the second year of Watana filling, mainstem temperatures will range from 4.2 to 8.1 °C in June and 6.3 to 9.1 °C in July. In the lower portion of the Devil Canyon to Talkeetna reach these project-related temperatures are within the preliminary criteria. However, from Gold Creek to Portage, June temperatures can fall slightly below the criteria and will expose outmigrating salmon to temperatures which are colder than normal. During July and August all predicted temperature ranges are cooler than preproject but fall within the outmigration criteria. Slightly cooler project-related temperatures will also occur in September. Even though the predicted temperatures fall near to or within the preliminary criteria, postproject temperatures will be 2.5 to 3 °C cooler than natural conditions during June through August. Also, a gradient of gradually cooler water will be exhibited from the upper to the lower segments of the Devil Canyon to Talkeetna reach. Thus fry or smolts outmigrating from tributaries or sloughs in the upper part of the reach will confront colder water than fish leaving from habitats further downstream such as Lane, Chase, and Whiskers creeks.

In the operational scenarios, both slight cooling and slight warming conditions will be present (outlined in previous section). Thus, outmigrating salmon will move out of their rearing habitats through mainstem waters which are generally cooler than preproject conditions in June through August, and through warmer water in September.

We believe that during Watana filling, June outmigrants will confront mainstem temperatures as cool as approximately 4 °C which is considerably cooler than the lower threshold for chinook and coho discussed by Raymond (1979), Cederholm and Scarlet (1982), and Bustard and Narver (1975). In this case June outmigrating chinook and coho salmon could avoid the mainstem and delay outmigration until July when temperatures warm. However, concern exists for September outmigrating chinook and coho during the Watana filling scenario when temperatures again will cool below 5 °C (Figure 12).

In the two operational scenarios, based upon present knowledge we do not believe that the postproject mainstem temperature regime will adversely affect salmon outmigration.

TURBIDITY

The term turbidity expresses an optical property of water that causes light to scatter (APHA 1971). Matter suspended in water such as clay, silt, organic and inorganic particles, plankton, and other microscopic organisms causes turbidity--the higher the intensity of scattered light, the higher the turbidity. Turbidity readings are reported in Nephelometric Turbidity Units (NTU), considered comparable to the Formazin Turbidity Units (FTU) and Jackson Turbidity Units (JTU) previously used (EPA 1974).

The level of turbidity can influence the amount and type of aquatic life in a stream by affecting the amount of light transmitted, which in turn is related to photosynthesis. Decreased light penetration in turbid streams can inhibit the establishment and maintenance of autotrophic plants, which may in turn effectively limit stream production (Ruttner 1963). Major changes in bottom habitats can result from increased sediment deposition during turbid conditions. Deposited sediments can eliminate invertebrate habitat by filling the interstices of bottom substrates and may also cover fish spawning sites and interfere with oxygen exchange for immobile fish life stages (Walburg et al. 1981).

Turbidity below reservoirs is influenced by sedimentation within the reservoir, density currents, discharge depth from the dam, and the inflow from surface runoff and tributary additions. Tailwaters are usually less turbid than reservoir inflow, particularly below deep release reservoirs (Walburg et al. 1981).

The Susitna River typically is clear during winter. Turbidity values measured by the U.S. Geological Survey in January and April 1982 were 1.1 NTU or less at Gold Creek (APA 1983a). Turbidity increases as snow melts and breakup commences, peaking during the summer when glaciers melt and contribute particulates. Summer turbidities averaged 271 with a maximum of 728 NTU at Chase (RM 103) during 1982 (Figure 13). Fish catches could be affected above 30 NTU as visual references are lost (Bell 1973).

During construction of the Watana facility, suspended sediment concentrations and turbidity levels could be expected to increase within the impoundment area and for some distance downstream of the dam. This would result from the construction activities within and immediately adjacent to the river. A 4 percent increase in suspended sediment load could be expected during the summer construction period (APA 1983a). An increase of 4 percent in area baseline levels probably could not be detected and would have

Figure 13. Turbidity and suspended sediment measurements, Chase (RM 103) 1982.

DATE	TURBIDITY[1] (NTU)	SUSPENDED SEDIMENT[2] (mg/l)
6/3	140	769
6/8	130	547
6/15	94	170
6/22	74	426
6/30	376	392
7/8	132	156
7/14	728	729
7/21	316	232
7/28	300	464
8/4	352	377
8/10	364	282
8/18	304	275
8/25	244	221
8/31	188	252
9/19	328	439
Average	271	382

[1] R&M Consultants analysis

[2] Preliminary unpublished USGS data

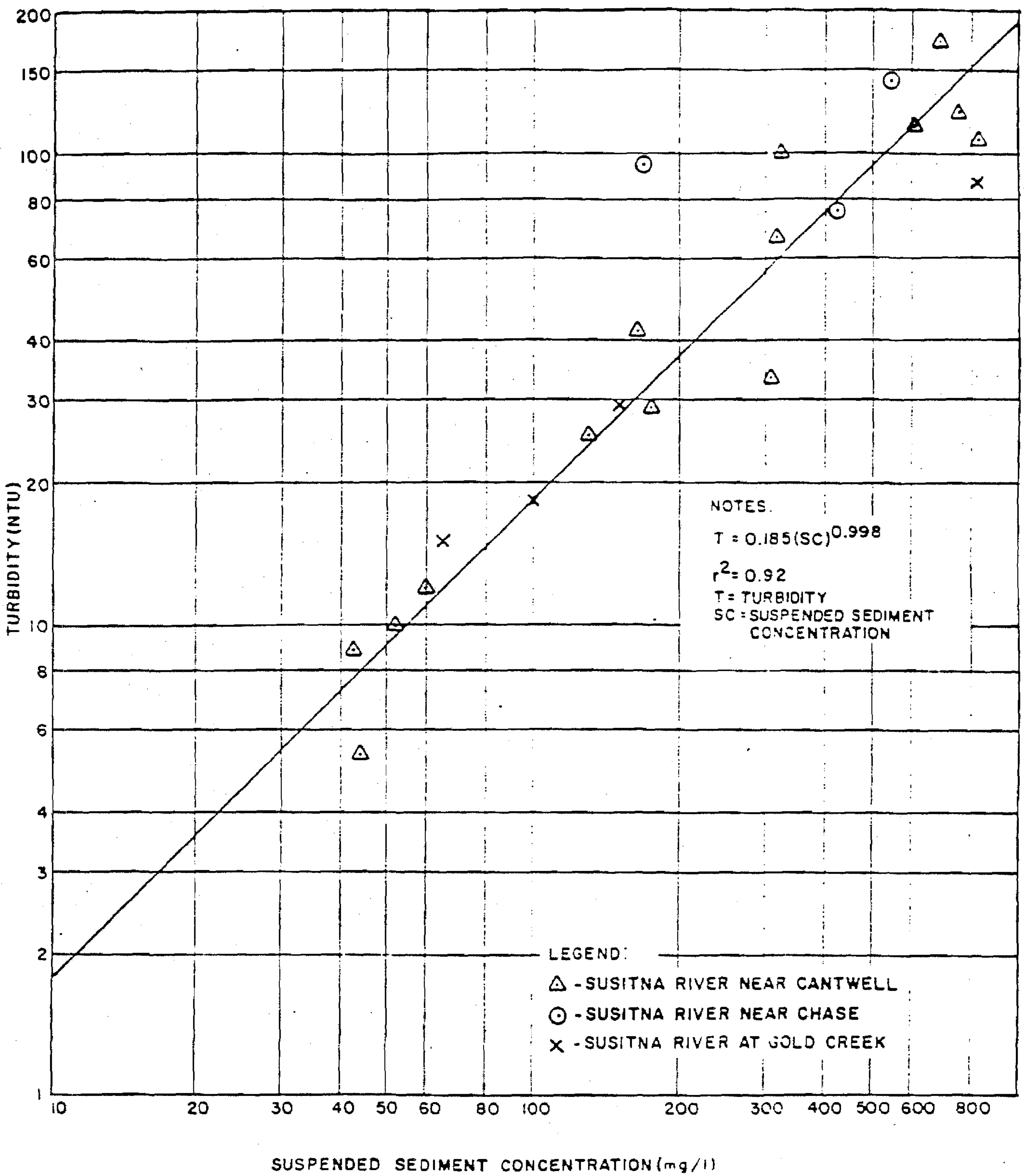
little effect on vertical illumination. Construction of the Devil Canyon facility could be expected to similarly affect turbidity and siltation but would be of much smaller magnitude.

As the reservoir is filled, larger suspended sediment particles would settle; thus reservoir turbidity would decrease during the filling process. During the first year and part of the second year of filling, water would be passed through the low-level outlet. As a consequence, more suspended particles could be expected to pass through the reservoir during the early stages of filling than would be expected during operation (APA 1983a). Maximum suspended particle sizes passing downstream would decrease from about 500 microns to about 5 microns as filling progressed (APA 1983a). Approximately 80 percent of the suspended sediment could be expected to settle in the Watana reservoir as filling nears completion (APA 1983a).

During operation of the Watana dam, reservoir turbidity levels range from 10 to 50 NTU. Peratrovich, Nottingham, and Drage (1982) determined this turbidity range by using the DEPOSITS model to predict outlet suspended sediment concentration and by then applying a regression equation developed between turbidity and suspended sediment concentration (Figure 14). Estimated downstream summer turbidity levels range from 20 to 50 NTU, and winter estimates from 10 to 20 NTU (APA 1983a).

The Watana reservoir, acting as a sediment trap, would reduce the quantity of suspended sediment entering a Devil Canyon reservoir by about 80 percent. As reservoir filling progressed, the Devil Canyon reservoir would provide additional settling capability with a slight decrease in suspended sediment and turbidity downstream. This settling could be expected to be small because of the small sizes of the particles entering the reservoir from Watana and the relatively short water retention time of the

Figure 14. Suspended sediment vs. turbidity at Upper Susitna River stations, 1982. (From Peratrovich et al. 1982)



Devil Canyon reservoir (APA 1983a). Thus, suspended sediment and turbidity levels occurring downstream of Devil Canyon would be only slightly reduced from those at the outflow from Watana. Clearwater tributary inflow downstream of the dams would further dilute the suspended sediment and turbidity levels in the Watana-to-Talkeetna reach.

Streamflow stability combined with reduced turbidity can enhance algal and macrophytic growth and provide additional food and microhabitat diversification for chironomids, oligochaetes, and mollusks (Ward 1976a). This more stable environment generally results in a less diverse fauna with higher standing crops (Ward 1976b). The present high flows and turbid water conditions in the mainstem Susitna River depress levels of primary productivity in this section of river. Though there would be a significant decrease in summer turbidity levels with the project, it might not allow enough light penetration to significantly increase primary production in the mainstem. Primary food production is generally lowered above turbidity levels of 25 NTU (Bell 1973). If project turbidity levels were in the lower end of the 20 to 50 NTU range predicted by Peratrovich, Nottingham, and Drage (1982), vertical illumination and productivity could be enhanced. If project turbidity levels were in the upper predicted range, however, increased vertical illumination and corresponding productivity in the mainstem might be negligible. More refinement of the 20 to 50 NTU prediction is necessary before a conclusion can be reached on the potential for increased productivity in the mainstem Susitna River due to increased vertical illumination from lower turbidity levels.

Another turbidity concern, cover, is very important to rearing and migrating salmonids, for this is when juvenile salmon are most vulnerable to predation from other fish, birds, and animals. Two types of cover are generally found in aquatic systems--overhead and submerged. Overhead cover includes riparian vegetation, turbid water, logs, or undercut banks. Submerged cover includes the stream substrate, aquatic vegetation, logs, and large rocks (Reiser and Bjornn 1979). In relatively short, clear rivers, juvenile chum salmon outmigrate mainly at night (Neave 1955). There is little darkness during the peak time of juvenile salmon outmigration from the Susitna River, and turbidity is important in providing cover (ADF&G 1983a).

If the project turbidity levels are in the upper range predicted by Peratrovich, Nottingham, and Drage (1982), sufficient turbid water should remain in the mainstem and side channels to provide cover for outmigrating juvenile fish. Project turbidity levels in the lower predicted range could increase the river clarity to a point where outmigratory fish become more vulnerable to predation.

HYDRAULIC-RELATED HABITAT ANALYSIS

ACCESS

Selection of Side Sloughs for Access Assessment

Results presented in ADF&G (1983a) Appendix B present final discharge versus access relationships for sloughs 6A, 8A, 9, 11, 16B, 20, 21, 22, and Whiskers Creek slough (Figure 15). Of these, chum salmon were noted as medium or high abundance in sloughs 8A, 9, 11, and 21; sockeye salmon had medium or high abundance in sloughs 8A, 11, and 21. Whiskers Creek slough and slough 6A were not extensively used by either pink or chum salmon but acute access discharges were not expected to be problematical, and were not included in access assessment. Slough 20 was used moderately by pink salmon and only slightly by chum salmon; it was included because it appeared to be influenced by mainstem discharge. Sloughs 16B and 22 were not

Figure 15. Discharge versus access relationships for Upper Susitna side sloughs and relative utilization by three salmon species (See Figure A 8, Appendix A).

Slough	ACCESS Acute	Unrestricted	PEAK ESCAPEMENT COUNTS Sockeye 1981	Sockeye 1982	Pink[1] 1982	Chum 1981	Chum 1982
Whiskers Creek	8,000 cfs	10,000 cfs	0	0	138	0	0
6A	--	8,000 cfs	0	0	35	11	2
8A	7,860 cfs	12,500 cfs	177	68	28	620	336
9	18,000 cfs	20,000 cfs	6	10	12	260	300
11	--	6,700 cfs	214	893	131	411	459
16B	18,000 cfs	26,400 cfs	0	0	0	0	0
20	20,000 cfs	21,500 cfs	2	0	64	14	30
21	20,000 cfs	23,000 cfs	38	53	64	274	736
22	20,000 cfs	22,500 cfs	0	0	0	0	0

[1] 1982 data only as even year runs dominate in the Susitna

-- Data unavailable

apparently utilized by salmon. Therefore, access requirements were to be considered at sloughs 8A, 9, 11, 20, and 21, with emphasis on sloughs 8A and 11 because of their apparently high importance to chum and sockeye salmon.

Selection of the Assessment Time Period

Escapement survey counts (ADF&G 1983b) for chum salmon into sloughs 8A, 9, 11, and 21 indicate initial passage into these sloughs beginning August 6, 1982 and as early as August 7, 1981 (Figure 16). In both years peak slough counts occurred in the first week of September, except at slough 11 where peak counts were reached as late as September 13.

Access was assumed to be a problem only during the ascending limb of the escapement curve. The descending limb occurred after most fish had accessed the slough and begun to spawn and die. The period beginning August 16 and lasting until approximately September 5 was considered to encompass most flow-related access concerns for chum salmon. When using the monthly reservoir operation model, access flows were specified for the month of August.

At slough 11, a large influx of sockeye in the September 1 through September 13 period of 1981 suggested selection of a later access assessment time period than was chosen for chum salmon (Figure 17). However, the 1982 sockeye escapement dates more closely paralleled those for chum salmon (Figure 17) in both 1981 and 1982, indicating that the same assessment period might at least initially be selected for both species. If further data indicate that sockeye spawn or arrive at the spawning beds significantly later than chum salmon or that perhaps there are two escapement peaks, the assessment

Figure 16. Weekly chum salmon escapement to four Upper Susitna sloughs. (From ADF&G 1983b)

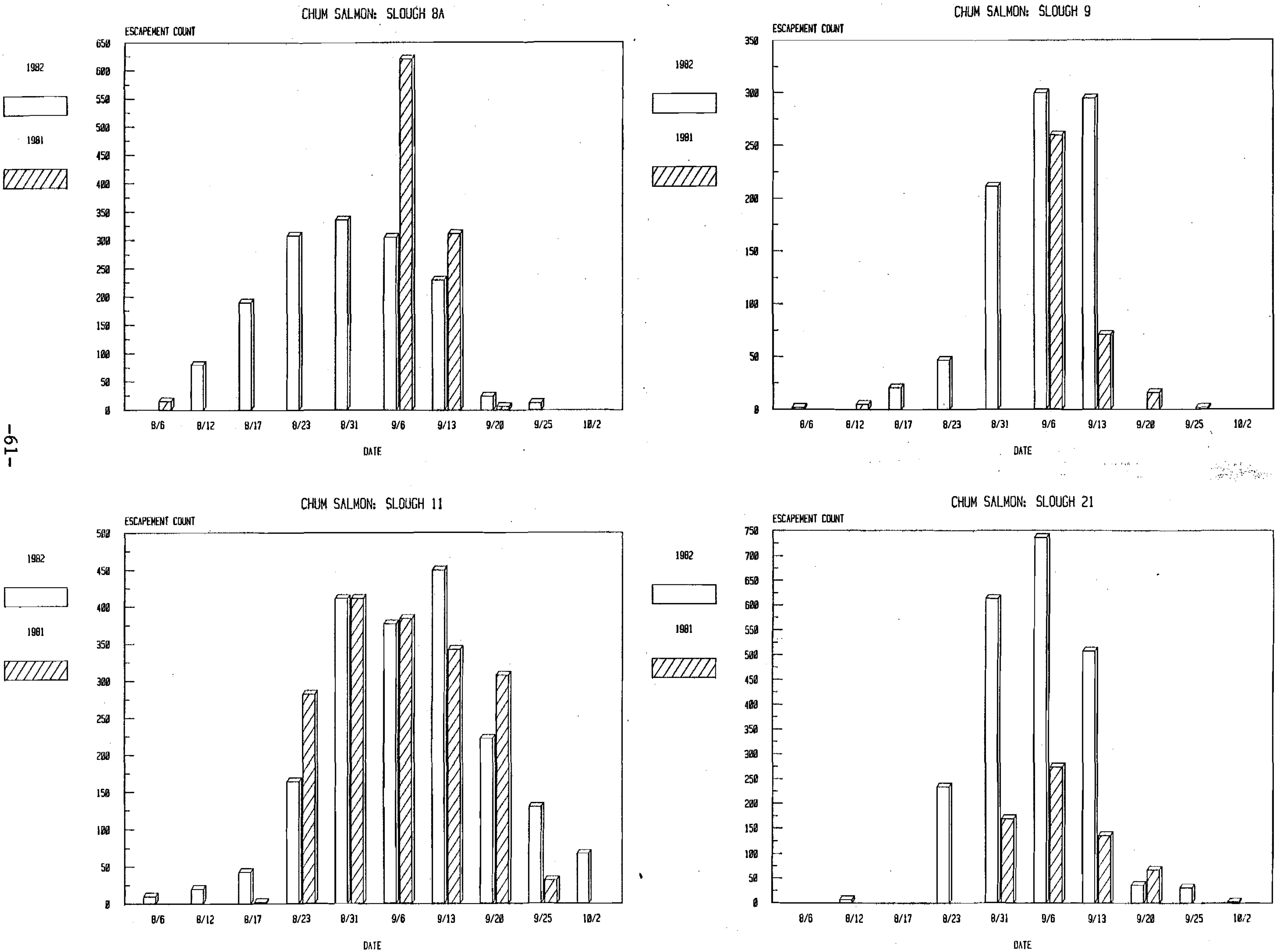
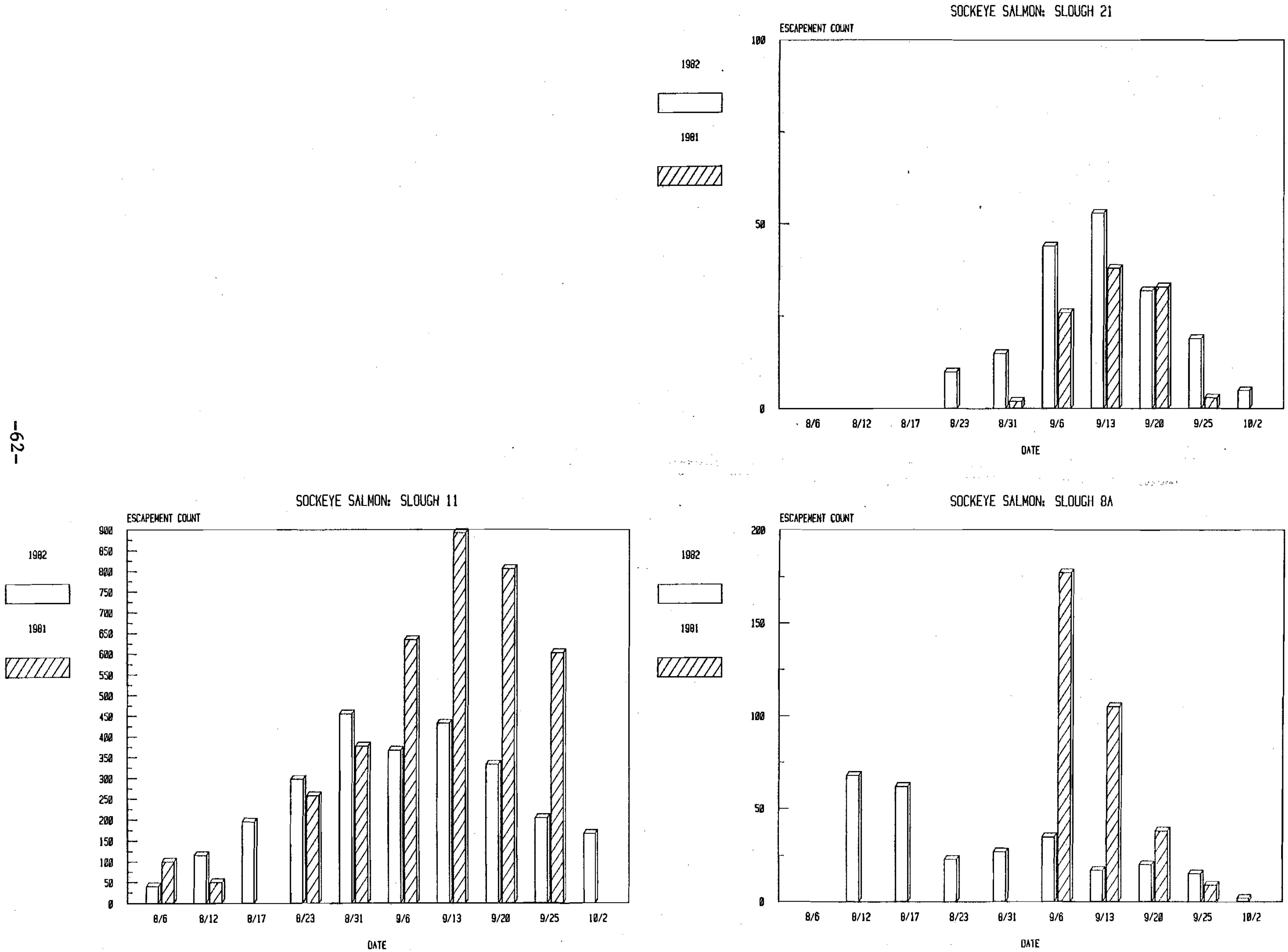


Figure 17. Weekly sockeye salmon escapement to three Upper Susitna River sloughs. (From ADF&G 1983b)



period may be extended or a separate, later access period used for sockeye salmon.

Access Discharge Requirements

Results from ADF&G (1983a) Appendix B suggest that sloughs 8A and 11 account for more than 80 percent of the potentially affected slough spawning sockeye salmon and as much as half of the chum salmon. Their acute access discharge requirements of less than 8,000 cfs, however, occur at flows significantly below those expected during the summer reservoir operation period. Sloughs 9, 20, and 21 required minimum access flows of at least 19,000 cfs, a level well above the current operation specifications. Therefore, August discharges of 12,000 cfs would provide fully adequate access conditions for the two sloughs with the highest relative utilization. Only by providing discharges of 20,000 cfs would access be assured in the remaining sloughs. Therefore, intermediate discharge levels (14,000, 16,000, and 18,000 cfs) were not expected to increase access conditions above those at 12,000 cfs. They were included to determine the August flow level which might cause a conflict with feasible reservoir operations.

REARING

Habitat and River Reach Selection

Relative utilization of Upper Susitna juvenile salmon rearing sites was higher in sloughs 6A and 8A than in the remaining DFH sites (ADF&G 1983a, Appendix E). Relative utilization of the reaches upstream and downstream of Talkeetna differed significantly on a monthly basis between June and September (Figures 18 through 20). Coho salmon were much more abundant in Lower Susitna DFH sites in June, July, and August than in Upper Susitna

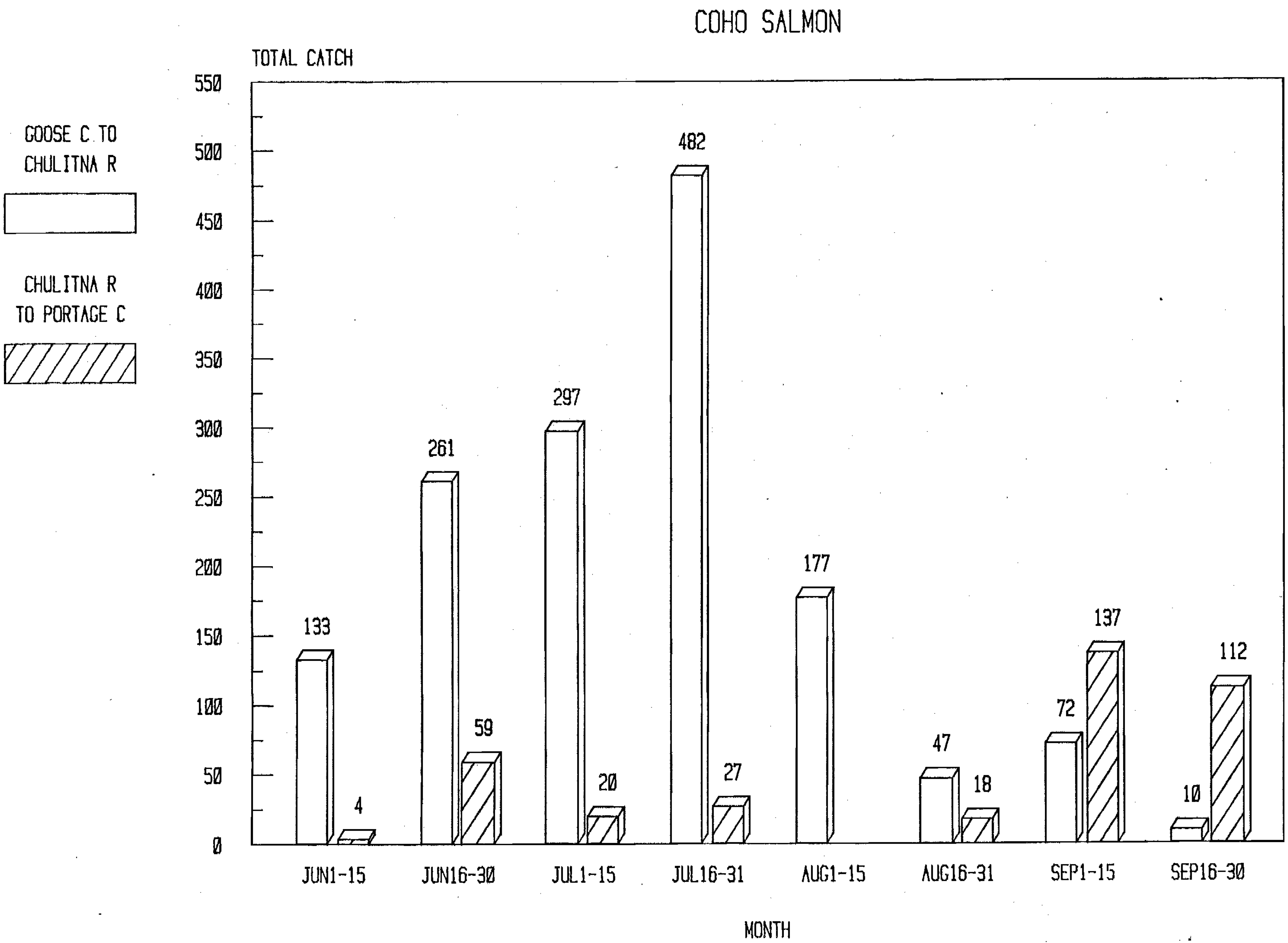


Figure 18. Relative utilization by two week period of Lower and Upper Susitna DFH sites by coho salmon. (ADF&G 1983c)

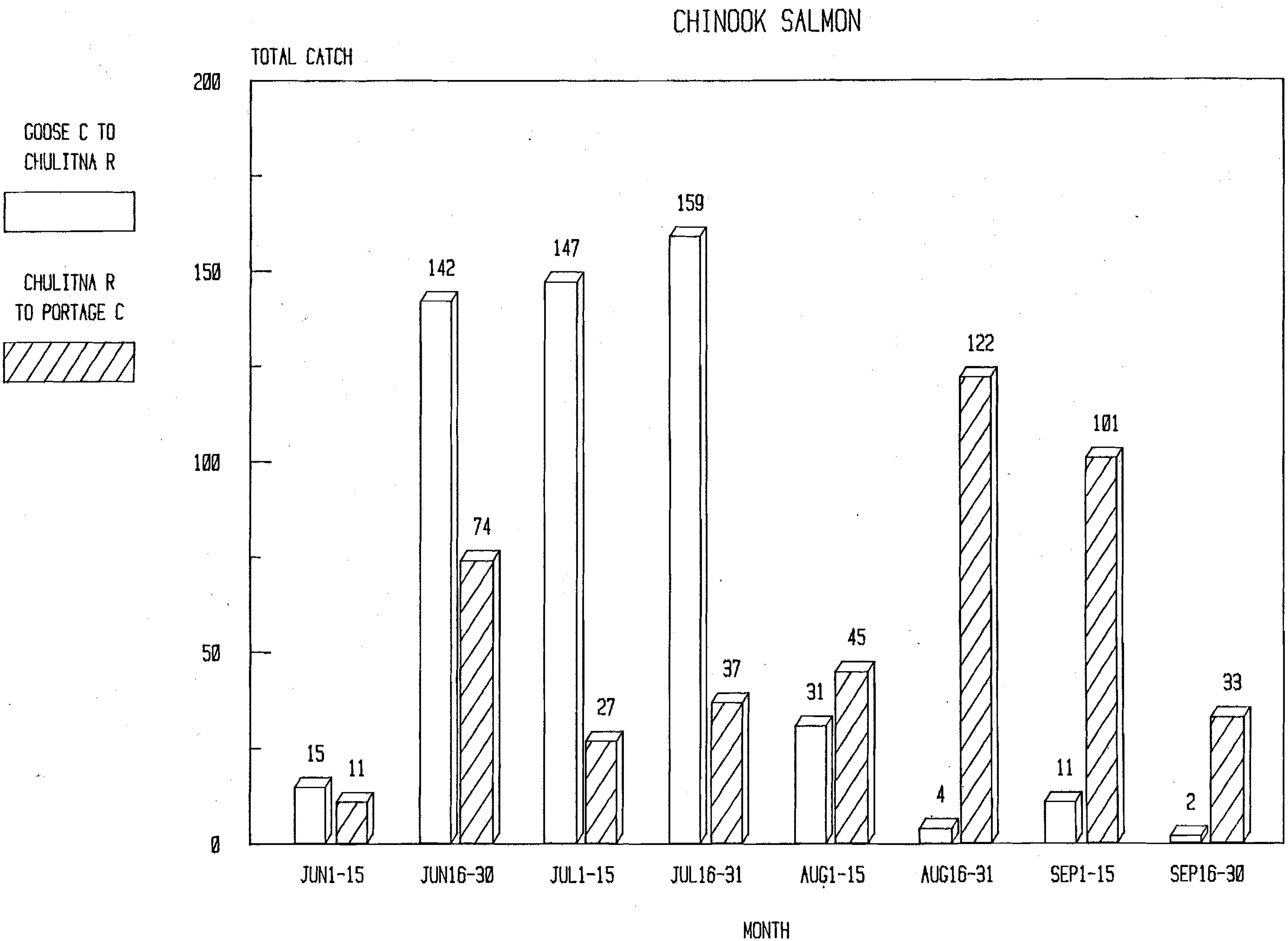


Figure 19. Relative utilization by two week period of Lower and Upper Susitna DFH sites by chinook salmon. (ADF&G 1983c)

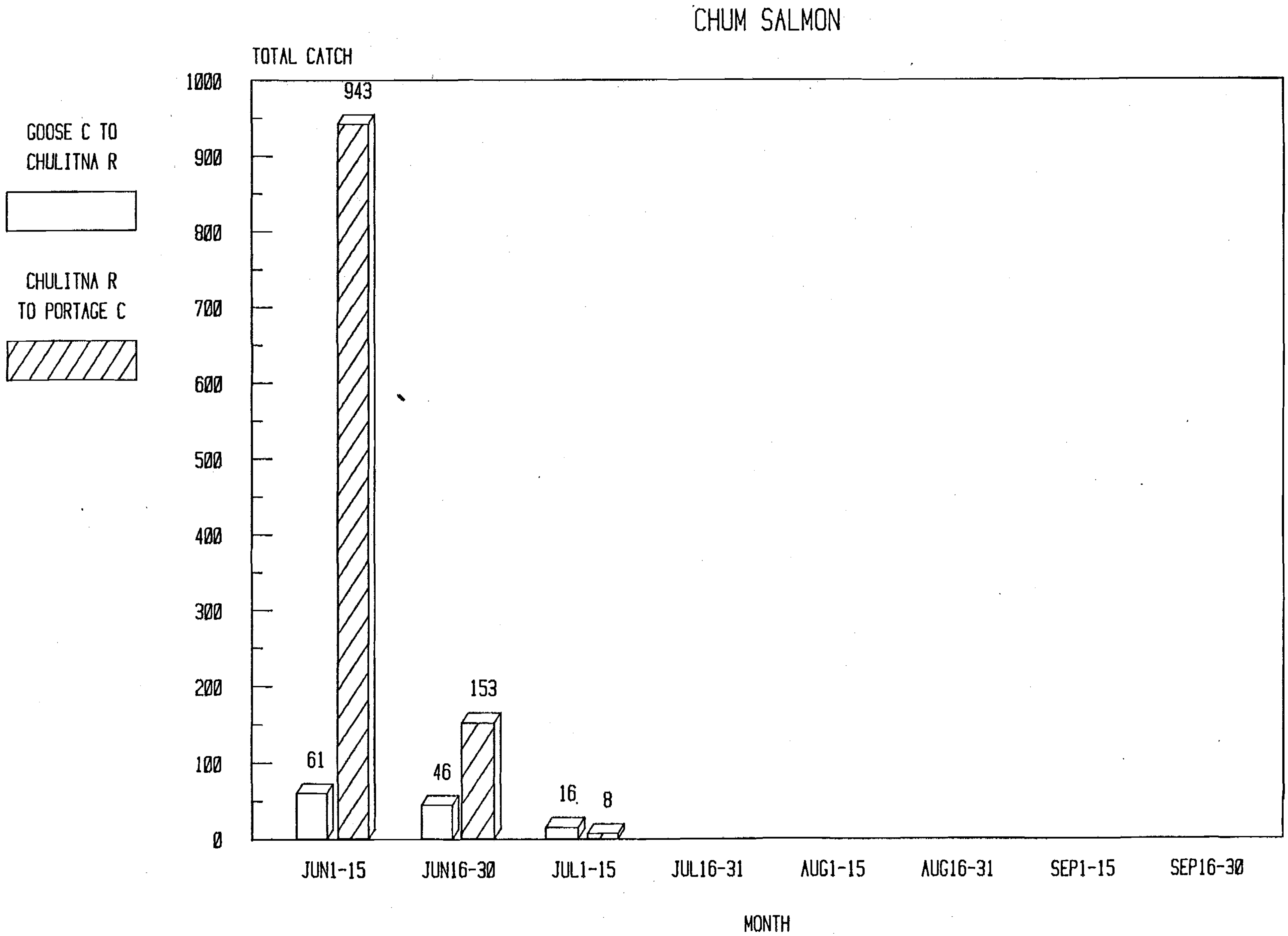


Figure 20. Relative utilization by two week period of Lower and Upper Susitna DFH sites by chum salmon (ADF&G 1983c)

sites. Relative abundance of coho shifted to Upper Susitna sites in September (Figure 18). Similarly, juvenile chinook salmon were more abundant in Lower Susitna sloughs in June and July, becoming relatively more abundant in Upper Susitna sites during August and September (Figure 19). These estimates are based on catch figures not corrected for effort, and, therefore, may only be indicative of relative abundance.

Chum salmon juvenile catches were consistently higher in Upper Susitna sites throughout the summer (Figure 20). This abundance was consistently influenced by very large catches in slough 6A (ADF&G 1983c). Clearly, juvenile chum salmon remained in most river reaches only during June and July and had completed outmigration from the river system by early August. Most Upper Susitna chum salmon rearing occurred in slough 6A; however, the rearing habitat of slough 6A was not considered sensitive to changes in mainstem discharge.

Assessment Time Period Selection

Though rearing was evident in all DFH sites during all summer months, Lower Susitna juvenile catches were higher in June, July, and August, and Upper Susitna rearing catches were higher during August and September. Within the Upper Susitna scope of this report, rearing effects were assessed for all summer months (June through September) with emphasis on effects in August and September.

Upper Susitna Rearing Discharge Requirements

Upper Susitna rearing HI versus discharge relationships indicated that the site with the largest habitat area (6A) was relatively insensitive to changes in discharge (Figure 21). Two sites with lower habitat values (Lane

Figure 21. Habitat index (HI) versus discharge (Q) relationships for Upper Susitna study sites (from ADF&G 1983a).

Q	WHISKERS CREEK AND SLOUGH (Chinook)	LANE CREEK AND SLOUGH 8 (Coho)	SLOUGH 8A (Sockeye)	SLOUGH 19 (Sockeye)	SLOUGH 6A (Chum)	LANE CREEK AND SLOUGH 8 (Chum)
12,500	87	19	119	12	128	10
15,000	92	21	124	14	129	12
17,500	96	22	129	6	131	15
20,000	101	23	134	7	132	17
22,500	105	24	139	7	134	18
25,000	109	15	144	9	135	36
27,500	110	10	149	9	137	36

Creek and slough 19) were similarly insensitive to mainstem discharge changes or lost HI value with increasing discharge. Only sloughs 8 and 8A gained significantly in HI as discharge increased.

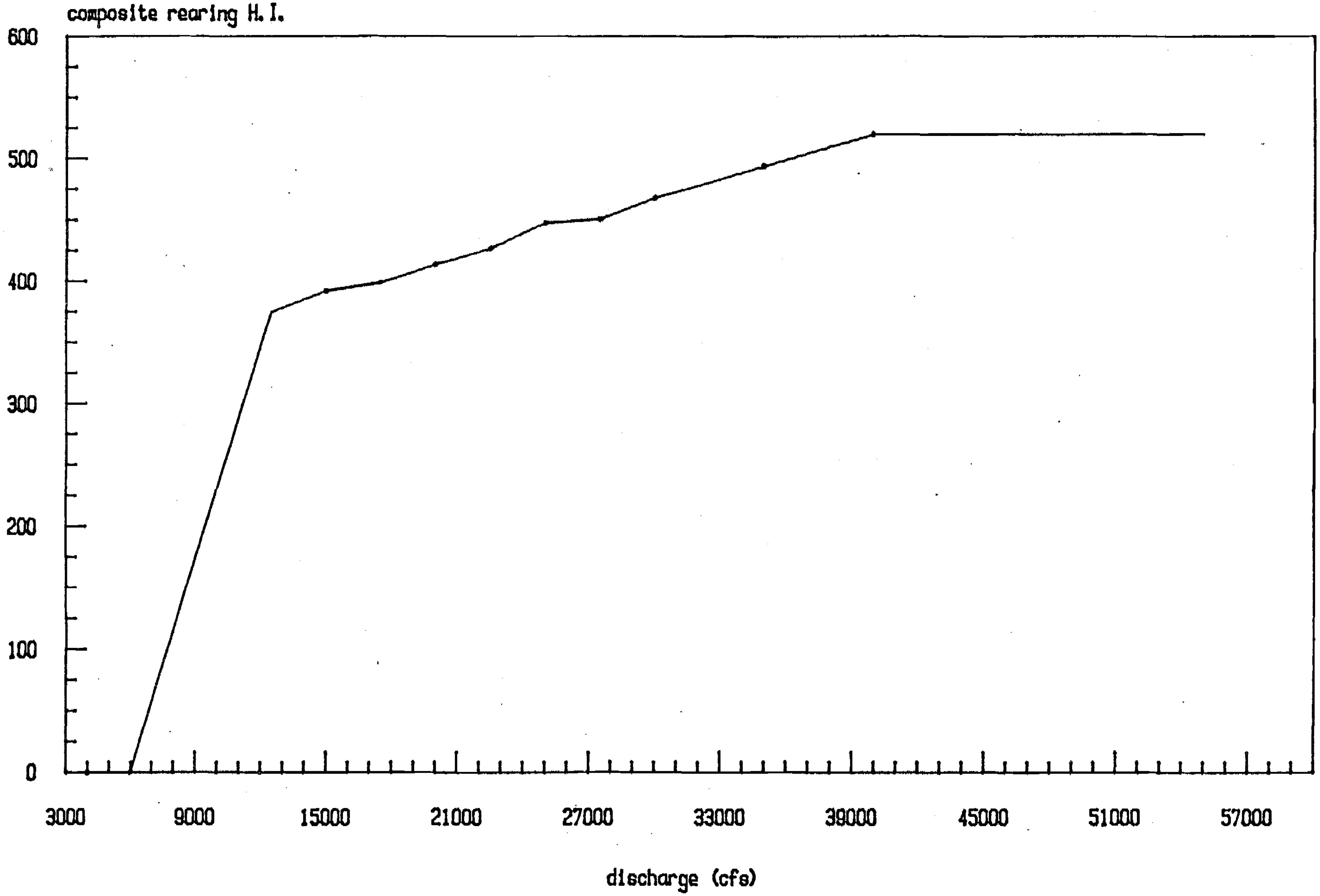
To produce a single, composite discharge versus HI relationship, it was assumed that sites with the greatest HI offered the greatest available habitat, an assumption supported by the relative catch records from ADF&G basic data reports (ADF&G 1983c). It seemed appropriate to sum the HI values for each discharge level to produce a composite HI within which sites with the greatest HI had the most influence. As mentioned before, however, this step was taken only to compile the HI values and had no relevance to actual interspecies effects. The resulting curve retained the essential characteristics of the two sites with the greatest HI value and the highest documented juvenile salmon utilization.

The demonstrational Upper Susitna rearing relationship (Figure 22) depicts a rather noncritical relationship within the range of flows for which rearing HI was computed. Within the 6,000 to 12,500 cfs range, however, composite HI changed rapidly as flow increased due to the extrapolation to zero at 6,000 cfs. This extrapolation was considered extremely conservative, but was concurred with in personal communication with Dana Schmidt, ADF&G.

SELECTION OF DOWNSTREAM DEMAND CASES

Based on the access and rearing relationships, a matrix of potential monthly discharge requests was constructed to demonstrate effects of varying discharge requests both on power production and access and rearing. The objective was to permute a range of potential monthly discharge requests

Figure 22. Composite Upper Susitna rearing HI vs. Susitna discharge.
(Compiled from ADF&G 1983a)



for rearing against those for access in order to determine which combinations were most economically feasible and which provided the most habitat benefit.

In each case, a range of rearing discharges was specified for June, July, August, and September (Figure 23). Potential access requests were specified for the month of August only. Note that these discharge ranges did not duplicate those in the FERC license application although one case, DS1, was similar.

Three levels of June and July rearing discharges were analyzed--6,000, 10,000, and 14,000 cfs. The 6,000 cfs lower limit in June and July was selected because it was the lowest level for which an HI value was currently estimated. A minimum of 8,000 cfs was specified for September to provide for salmon access into sloughs and to reflect the higher September power demand. The two higher levels (10,000 and 14,000 cfs) were chosen as significantly large incremental increases, and because 14,000 was well within the range of computed HI values.

The August discharge range reflected the range of potential access discharge requests. The 12,000 cfs minimum was the level used in the license application and was thought to be adequate for access to sloughs 11 and 8A. The 20,000 cfs maximum was the discharge at which access to the remaining selected sloughs was provided and above which little additional access benefit appeared to be gained. An additional case (Case DSA) was included to illustrate habitat and power generation effects when no discharge constraints were applied (downstream flow demand equal to zero).

RESERVOIR OPERATION MODEL SET-UP

Operating parameters of the reservoir operation model were different from those used in the license application in four areas: first, year 2010

Figure 23. Matrix of twelve potential discharge requests for access (August) and DFH site rearing (June-July-September) as input to the reservoir operation model. (License Application flow requirements illustrated for comparison)

	POTENTIAL MINIMUM FLOWS AT GOLD CREEK (cfs)[1]				
Case	Oct-Apr	May	Jun-Jul	Aug	Sep
DSA		No flow constraints			
DS1	5,000	6,000	6,000	12,000	8,000
DS2	5,000	6,000	6,000	14,000	8,000
DS3	5,000	6,000	6,000	16,000	8,000
DS4	5,000	6,000	6,000	18,000	8,000
DS5	5,000	6,000	6,000	20,000	8,000
DS6	5,000	6,000	10,000	12,000	10,000
DS7	5,000	6,000	10,000	14,000	10,000
DS8	5,000	6,000	10,000	16,000	10,000
DS9	5,000	6,000	10,000	18,000	10,000
DS10	5,000	6,000	10,000	20,000	10,000
DS11	5,000	6,000	14,000	14,000	14,000

License Application Case	Oct-Apr	May-Jun	Jul	Aug	Sep
A	5,000	4,000	4,000	6,000	5,000
A1	5,000	5,000	5,100	8,000	6,500
A2	5,000	5,000	5,320	10,000	7,670
C	5,000	6,000	6,480	12,000	9,300
C1	5,000	6,000	6,530	14,000	10,450
C2	5,000	6,000	6,920	16,000	11,620
D	5,000	6,000	7,260	11,620	13,170

[1] Minimum flow requirements are incrementally tested for June, July, August and September. Proposed minimum flows for October through May do not test flow requirements.

power demand was lowered from 7,791 gwh to 5,945 gwh to reflect the most recent Alaska Department of Revenue (ADOR) load estimates; second, the maximum drawdown for Devil Canyon reservoir was raised to 100 ft from 50 ft, and third, the rule curve (set of monthly target operational reservoir elevations) was changed for several months (Figure 24). Fourth, the natural hydrologic record was used (a modified record was used in the license application). The model retained the Watana maximum water surface elevation (wsel) of 2185 ft and the Devil Canyon maximum wsel of 1,455 ft used in the license application.

ENERGY PRODUCTION OF DOWNSTREAM DEMAND CASES

All energy simulations produced less energy than the system energy demand of 5,945 gwh. However, as releases during the normal storage months of June, July, and August increased, energy production decreased. This is because the high summer releases resulted in lower reservoir elevations and less available energy during the high-demand winter months, most notably in drier years. For Case DSA (no downstream discharge requirement) energy production was 166 gwh less than the 5,945 gwh demand; the DS1 through DS5 case series resulted in higher energy production levels than the DS6 through DS10 case series. On an average annual basis DS1 produced 99 gwh less than Case DSA and the DS5 case August requirement for 20,000 cfs produced 258 gwh less energy than Case DSA. Using an order of magnitude estimate of $80,000 per gwh (i.e., $0.08 per kwh), the difference in energy benefits between DS5 and DSA would be about $21,000,000 on an annual basis for the energy demand considered.

The DS6 to DS10 case series (June, July, September discharge requirement of 10,000 cfs) resulted in greater losses in average annual energy (Figure 24). Maximum energy production from this series (Case DS6)

Figure 24. Average and firm (monthly minimum) energy outputs and mean with-project discharges for the DS1-5, DS6-10, and DS5-11 case series (see note).

	Avg Annual Energy (GWH)	Firm Energy (GWH)	Mean with-project flows (cfs) Aug	Dec	Jun
DSA	5,779	5,554	18,370	9,220	8,910
DS1	5,680	5,407	19,420	9,100	8,930
DS2	5,651	5,356	19,920	9,050	8,940
DS3	5,609	5,312	20,540	8,900	8,970
DS4	5,569	5,282	21,300	8,890	8,960
DS5	5,521	5,159	22,230	8,760	8,940
DS6	5,520	5,165	19,120	8,830	10,140
DS7	5,486	5,011	19,690	8,699	10,166
DS8	5,459	4,858	20,340	8,600	10,170
DS9	5,429	4,705	21,080	8,500	10,170
DS10	5,399	4,519	22,010	8,400	10,170
DS11	5,287	4,097	18,370	9,220	14,000

Note: All runs made with ADOR demand = 5,945 GWH (2,010)
Watana drawdown = 120'
Devil Canyon drawdown = 100'
Rule curve (Watana monthly target reservoir elevations)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
2,180	2,170	2,158	2,147	2,138	2,129	2,120	2,140	2,160	2,175	2,185	2,185

was 259 gwh less than Case DSA target, and minimum production (Case DS10 or 20,000 cfs August demand) resulted in 380 gwh less than Case DSA or an annual loss of $30,000,000 with the given energy demand.

Raising the June, July, September level to 14,000 cfs and setting the August request also at 14,000 cfs (Case DS11) resulted in an average annual energy production of 492 gwh less than Case DSA; as potential August requests were incremented to 16,000 and 18,000 cfs, the average energy production and firm energy decreased significantly. At these demand levels, the reservoir operation rule curve had to be modified to permit production to be calculated because of violations of downstream flows and firm energies. Clearly, energy production dropped significantly when June, July, September demands of 14,000 cfs were coupled with August demands higher than 14,000 cfs.

EFFECTS ON ACCESS AND REARING

Potential August flow requests between 12,000 and 20,000 cfs could be consistently met if June-July-September requests were less than or equal to 10,000 cfs (case series DS1-5 and DS6-10, Appendix B). If June-July-September requests were 14,000 cfs, August requests of 14,000 to 18,000 cfs could be met only at a great expense in energy production; if energy production were to be optimized, the August demand would not be consistently available. Access was not assessed for these flow cases because the energy losses appeared to be economically unjustifiable.

June, July and September rearing habitat associated with the 6,000 cfs base case showed significant (greater than 20%) losses in HI relative to present values, primarily in the very low habitat values (those exceeded 80 percent of the time). The greatest losses were in June, followed by those in

September. July postproject habitat reductions were smaller, though still significant (Figure 25). The June, July, September discharges under the DS1-DS5 Cases were mostly at power production levels (7,000 to 8,000 cfs). In this range, the rearing HI versus discharge line was quite steep in its trend toward zero HI at 6,000 cfs (Appendix B). DS1-DS5 August HI values did not vary significantly from present values primarily because of the 12,000 to 20,000 cfs discharges already provided for access in that month.

Substantially improved June, July, and September rearing HI values were afforded by the DS6-DS10 series relative to the DS1-DS5 series. This gain was primarily in the lower habitat values and occurred because the minimum discharges of 10,000 cfs were closer to the discharge (12,500 cfs) at which rearing HI no longer increased rapidly with increasing flow. In the DH6-10 case-series (Figure 26), HI values were quite stable because the 10,000 cfs request level was generally larger than discharges required to meet summer power needs, and was met by nonpower releases. For each such occurrence, the result was prediction of a 10,000 cfs discharge (the specified downstream demand). Similar consistencies would be expected in actual project operations.

With the DS11 case (14,000 cfs for June, July, August, and September), rearing HI increased significantly again, to values much closer to those calculated for present flows. It can be assumed that large demands such as 16,000 and 18,000 cfs would produce higher HI with higher discharge requests because of the positive HI versus discharge habitat relationship.

August and September juvenile catches appeared to be higher in the Upper Susitna than in the Lower Susitna. Because suitable August rearing discharge levels were probably assured through the access requirement, the

Figure 25. Composite DFH site rearing HI for present DS1-DS5 case series in $ft^2/1000$, 20th, 50th and 80th exceedence percentiles of 32-year postproject discharges.

		COMPOSITE HABITAT INDEX		
CASE		20th Percentile	50th Percentile	80th Percentile
Present	June	483	453	418
	July	452	434	416
	August	444	419	409
	September	397	380	254
DS1	June	297	258	190
	July	406	309	196
	August	436	416	382
	September	397	378	214
DS2	June	297	258	198
	July	408	308	193
	August	436	416	385
	September	397	378	214
DS3	June	297	258	196
	July	410	343	195
	August	436	416	395
	September	397	378	214
DS4	June	294	257	196
	July	410	364	195
	August	437	417	402
	September	397	378	214
DS5	June	290	257	196
	July	410	378	193
	August	437	417	414
	September	397	378	214

Figure 26. Composite DFH site rearing HI for DS6-DS11 case series in $ft^2/1000$, 20th, 50th and 80th exceedence percentiles of 32-year postproject discharges.

CASE		COMPOSITE HABITAT INDEX 20th Percentile	50th Percentile	80th Percentile
DS6	June	289	286	286
	July	413	333	286
	August	436	410	357
	September	397	378	286
DS7	June	287	286	286
	July	413	360	286
	August	436	411	385
	September	397	378	286
DS8	June	287	286	286
	July	413	360	286
	August	436	411	395
	September	397	378	286
DS9	June	287	286	286
	July	413	360	286
	August	436	411	402
	September	395	378	286
DS10	June	287	286	286
	July	413	341	286
	August	428	414	414
	September	393	369	286
DS11	June	385	385	385
	July	393	385	385
	August	419	390	385
	September	394	385	385

September HI values were examined closely. June HI was also examined because it changed considerably with the different case series. Only the lower recurrence September habitat values were affected by project operations (Figure 27). June HI at the the 50th and 80th percentiles was affected by project operations (Figure 26). Increased June and September discharges resulted in highly significant gains in rearing habitat. Regulation of flows brought September habitat at the 80th percentile exceedence level from 214 to as much as 385 composite HI units with almost identical gains for June. It is probably important to determine whether these low or medium HI values might be potentially population-limiting. If so, certain project operations might offer significant improvement in rearing habitat.

These rearing results should be viewed as strictly demonstrational and intentionally conservative. They may serve to point out potential conflicts and benefits but should not be construed as any level of project impact assessment. Project discharges and habitat analyses will certainly change as discharge requirements are developed for other life stages and activities, and project design specifications change.

Figure 27. June and September DFH composite HI for all case-series in $ft^2/1000$, 20th, 50th, and 80th percentiles of 32-year postproject discharges.

Percentile	20		50		80	
	June	September	June	September	June	September
Present	483	397	453	380	418	254
DS1-5	297	397	258	378	193	214
DS6-DS10	287	397	286	378	286	286
DS11	385	394	385	385	385	385
DSA	298	397	258	378	191	243

CONCLUSIONS

TEMPERATURE

Temperature impact assessment involved comparison of published ranges of tolerance by various salmonids with observed conditions in the Susitna basin. Based on these data, preliminary temperature impact assessment criteria were developed. Temperature model predictions for Watana reservoir filling, Watana dam operation, and Watana-Devil Canyon dam operations were then evaluated in light of the preliminary criteria.

Using this methodology, no significant impact on adult salmon inmigration and spawning can be demonstrated for any project development scenario. During the initial salmon embryo incubation period for mainstem spawning chum and coho salmon, warmer project-related September conditions may accelerate embryo development.

By strict comparison with the preliminary criteria, no impact is apparent for any species of rearing juvenile salmon. However, warm conditions in the one- and two-dam September period, and cooler water, particularly with the Watana reservoir filling scenario, could affect fish behavior and physiology. Until postproject temperature regimes for the remainder of the year are examined, no definite conclusions can be drawn.

During the June coho and chinook salmon outmigration, mainstem temperature conditions for the Watana reservoir filling scenario will be colder than preproject. It is possible that outmigrants may delay movement until waters warm in July.

TURBIDITY

The impacts of change in suspended sediment levels was examined by evaluating available literature reports on relationships between salmon biology and turbidity. This information was factored into an analysis of predictions of postproject turbidity levels from the DEPOSITS model and observed natural Susitna River turbidity levels.

Project-related turbidity levels in the mainstem Susitna River will be reduced permanently. Summer turbidity will be decreased to 20 to 50 NTU enhancing productivity in the lower end of this range because of increased vertical illumination. Predicted postproject turbidity levels, although much lower than natural conditions, should still be sufficiently high in the mainstem and side channels to provide cover for juvenile salmonids.

HYDRAULIC AND HABITAT ANALYSIS

All conclusions regarding the results from the reservoir operation model must be reviewed with knowledge that, because of changes in the load forecast, release discharges were significantly different from those presented as Schedule C in the license application. Discharges similar to those analyzed in the report are found in Table E2.58 in the license application (APA 1983a) The analysis in our report reflects the most current view of future energy requirements.

An Upper Susitna access discharge request of either 12,000 or 20,000 cfs for August could be consistently provided within the present water supply. Some energy production and project economy would be sacrificed in meeting a 20,000 cfs August request. Increments of August discharge above 12,000 cfs did not significantly change release discharge or subsequent habitat values in the remaining summer months. An element of future project design should be to determine whether such releases and their additional fishery benefits are required.

Rearing relationships for the most utilized DFH sites were not strongly sensitive to discharge changes within the range of flows for which ADF&G calculated HI values. Because this range was narrower than the range of either pre- or postproject discharges, the HI versus discharge curve was extended through extrapolation. The resulting analysis was, therefore, presented only to demonstrate the assessment approach. The rapid losses in HI below 12,500 cfs were probably artificial because of the extrapolation to zero HI at 6,000 cfs. The demonstration HI versus discharge curve was conservative, and, as mentioned repeatedly before, only used to demonstrate the assessment approach. If such a rearing relationship actually existed, it would seem prudent to retain June, July, and September discharges at as high a level as possible. June through September discharge requests above 14,000 cfs would probably be unfeasible, but requests between 6,000 and 10,000 cfs would offer increased habitat with each discharge increment. Perhaps most fruitful would be analysis of different request levels for each summer month instead of the single summer-long levels currently considered, especially considering that relative rearing utilization changes during the summer months in both the Upper and Lower Susitna. With the present capabilities, it is possible to conclude that there would be clear resource benefit-power production conflict if summer-long discharges over 14,000 cfs were determined critical for fishery habitat maintenance. Operational flexibility appears to be available within the reduced power demand estimates currently envisioned, however, and it will be very beneficial to examine a variety of operational alternatives.

REFINEMENT OF ANALYSES

In order to improve and extend the aquatic impact assessment of the proposed Susitna Hydroelectric Project, AEIDC will conduct the following.

TEMPERATURE

1. Thermal impact assessment for fish embryo incubation and juvenile rearing will be extended to other ice-free periods and to the ice-covered season.
2. Temperature variation dampened out in mean monthly values will be more realistic in weekly simulation. Weekly, and perhaps during some periods daily, temperature model predictions will be examined for selected fish species and life phases.
3. Additional reservoir temperature simulations (DYRESM) for years of extreme (warm or cold) natural water temperatures are required from Harza-Ebasco in order to identify ranges of downstream temperatures from project operation. River temperature modeling based on these new ranges of thermal input will be conducted by AEIDC and the downstream impacts on fish species and life phases identified.
4. AEIDC will continue efforts to correlate the natural thermal regimes of the Susitna River with various fish life phases in order to improve the preliminary temperature tolerance criteria.
5. An examination of alternate postproject flow regimes will be conducted to determine the frequency of side slough overtopping and the consequences of mainstem thermal conditions on slough fish.

6. The relationship between mainstem and side slough thermal regimes will be quantified or dismissed. This effort will be assisted by contributions from the ADF&G intragravel water studies and the Harza-Ebasco mainstem versus side slough groundwater investigations.

TURBIDITY

1. Refinement of the DEPOSITS Model predictions for downstream turbidity levels is required from Harza-Ebasco to adequately assess impact. The current predictions of 20 to 50 NTU is too broad a range.
2. Turbidity predictions for winter conditions will be evaluated and impacts on overwintering fish determined.

HABITAT RELATIONSHIPS AND ITERATIVE ASSESSMENT APPROACH

1. Habitat relationships for remaining critical salmon life stages (side slough, side channel and mainstem spawning and incubation, and side channel rearing) will be finalized by ADF&G.
2. Winter season data allowing predictions of physical habitat, ice processes and fishery responses will be collected and compiled by ADF&G.
3. AEIDC will proceed with linking simulation models and relationships to allow rapid analyses of responses to changes in project design parameters.
4. AEIDC's computer-based facility to assess numerous potential project operations will be utilized to examine a comprehensive array of potential monthly flow requests. These data will be used as input

to the reservoir operation model. It is highly likely that more operational constraints will arise as downstream discharge requests are made for more months as more habitat relationships become available. The output in terms of energy production and habitat value will be valuable to demonstrate an inclusive array of potential project effect conflicts.

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APPENDIX A

SUSITNA RIVER DRAINAGE SALMON RESOURCE

SUSITNA RIVER DRAINAGE FISHERY RESOURCE

Nineteen species of fish have been captured by ADF&G Su Hydro in the Susitna drainage (ADF&G 1983a, 1981c; APA 1983) (Figure A1). Seven of these are anadromous and 12 are resident species. The occurrence of these species by study reach (the Impoundment Zone from the Oshetna River (RM 236) downstream to Devil Canyon (RM 152), the Upper Zone from Devil Canyon to the confluence of the Susitna and Chulitna rivers (RM 98), and the Lower Zone from the confluence to Cook Inlet (RM 0) (APA 1983)) is shown in Figure A2. This Appendix reviews the total salmon resource with a species by species account for the five Pacific salmon concentrating on what is known of their life histories above the Chulitna confluence.

SALMON FISHERY RESOURCE

Anadromous species form the basis of commercial and noncommercial fishing in Upper Cook Inlet. Five species of salmon (chinook, coho, chum, sockeye, and pink) are harvested as they migrate to their stream of origin. The Kenai, Kasilof, Susitna, and Crescent rivers are the region's major salmon spawning systems.

The number of each salmon species annually returning to the inlet varies. Largest returns are of dominant-year pink salmon. Economically, sockeye are the most valuable species harvested, followed by chum, pink (even years), coho, pink (odd years), and chinook (Ruesch and Browning 1982). Historical commercial catch data (Figure A3) depicts the fluctuations in harvest over the past 30 years.

Figure A1. List of common and scientific names of fish found to date by ADF&G Su Hydro in the Susitna River basin.

Arctic lamprey	Lampetra japonica (Martens)
Eulachon (hooligan)	Thaleichthys pacificus (Richardson)
Arctic grayling	Thymallus arcticus (Pallas)
Bering cisco	Coregonus laurettae Bean
Round whitefish	Prosopium cylindraceum (Pallas)
Humpback whitefish	Coregonus pidschian (Gmelin)
Rainbow trout	Salmo gairdneri Richardson
Lake trout	Salvelinus namaycush (Walbaum)
Dolly Varden	Salvelinus malma (Walbaum)
Pink (humpback) salmon	Oncorhynchus gorbuscha (Walbaum)
Sockeye (red) salmon	Oncorhynchus nerka (Walbaum)
Chinook (king) salmon	Oncorhynchus tshawytscha (Walbaum)
Coho (silver) salmon	Oncorhynchus kisutch (Walbaum)
Chum (dog) salmon	Oncorhynchus keta (Walbaum)
Northern pike	Esox lucius Linnaeus
Longnose sucker	Catostomus catostomus (Forster)
Threespine stickleback	Gasterosteus aculeatus Linnaeus
Burbot	Lota lota (Linnaeus)
Slimy sculpin	Cottus cognatus Richardson

Figure A2. Susitna River drainage basin fish species by study zones.

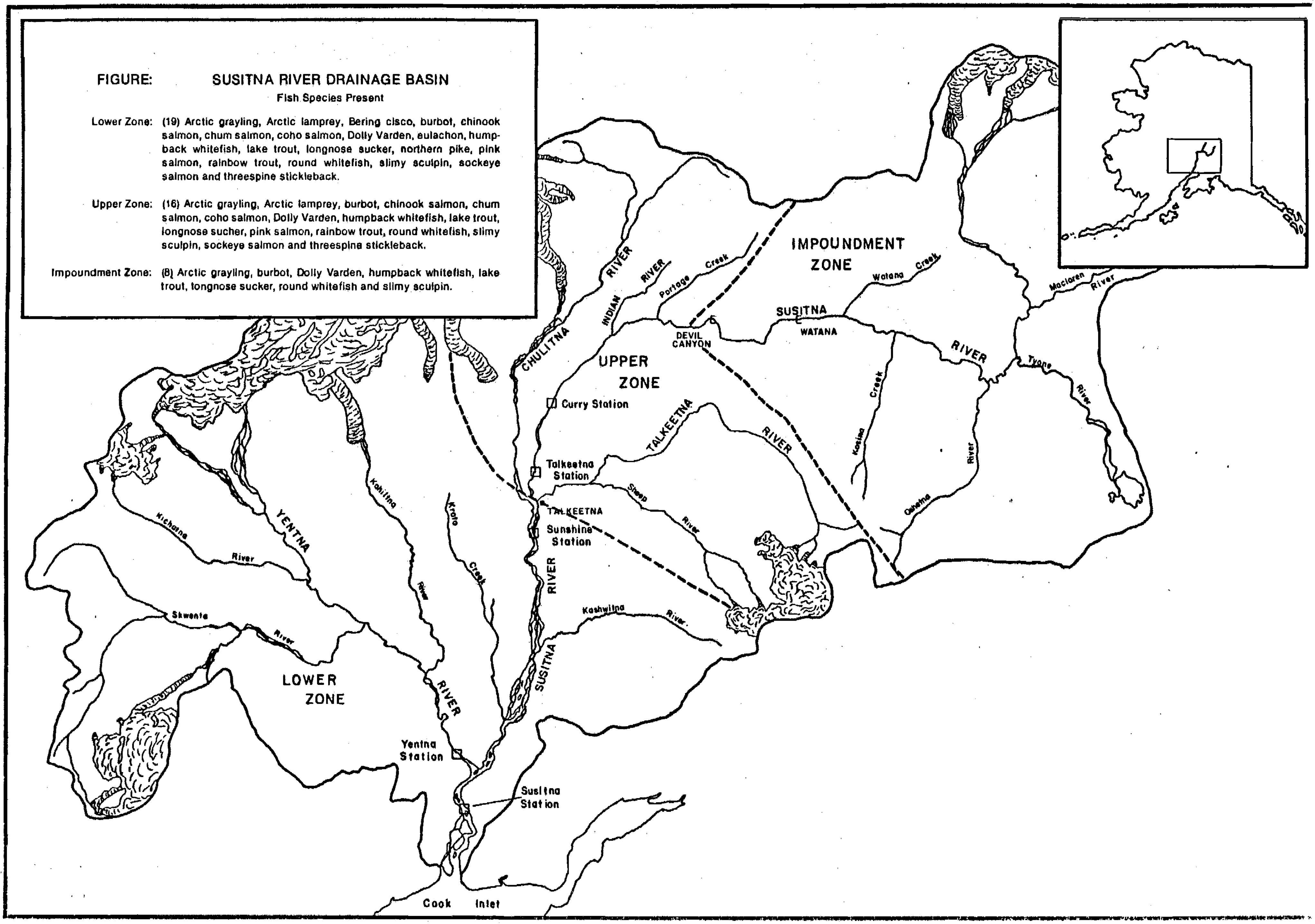


Figure A3. Commercial salmon catch for Upper Cook Inlet 1954-1982

Year	Chinook	Sockeye	Coho	Pink	Chum	Total
1954	63,780	1,207,046	321,525	2,189,307	510,068	4,291,726
1955	45,926	1,027,528	170,777	101,680	248,343	1,594,254
1956	64,977	1,258,789	198,189	1,595,375	782,051	3,899,381
1957	42,158	643,712	125,434	21,228	1,001,470	1,834,002
1958	22,727	477,392	239,765	1,648,548	471,697	2,860,129
1959	32,651	612,676	106,312	12,527	300,319	1,064,485
1960	27,512	923,314	311,461	1,411,605	659,997	3,333,889
1961	19,737	1,162,303	117,778	34,017	349,628	1,683,463
1962	20,210	1,147,573	350,324	2,711,689	970,582	5,200,378
1963	17,536	942,980	197,140	30,436	387,027	1,575,119
1964	4,531	970,055	452,654	3,231,961	1,079,084	5,738,285
1965	9,741	1,412,350	153,619	23,963	316,444	1,916,117
1966	9,541	1,851,990	289,690	2,006,580	531,825	4,689,626
1967	7,859	1,380,062	177,729	32,229	296,037	1,894,716
1968	4,536	1,104,904	470,450	2,278,197	1,119,114	4,977,201
1969	12,398	692,254	100,952	33,422	269,855	1,108,881
1970	8,348	731,214	275,296	813,895	775,167	2,603,920
1971	19,765	636,303	100,636	35,624	327,029	1,119,357
1972	16,086	879,824	80,933	628,580	630,148	2,235,571
1973	5,194	670,025	104,420	326,184	667,573	1,773,396
1974	6,596	497,185	200,125	483,730	396,840	1,584,476
1975	4,790	684,818	227,372	336,359	951,796	2,205,135
1976	10,867	1,664,150	208,710	1,256,744	469,807	3,610,278
1977	14,792	2,054,020	192,975	554,184	1,233,733	4,049,704
1978	17,303	2,622,487	219,234	1,687,092	571,925	5,118,041
1979	13,738	924,415	265,166	72,982	650,357	1,926,658
1980	12,497	1,584,392	283,623	1,871,058	387,078	4,138,648
1981	11,548	1,443,294	494,073	127,857	842,849	2,919,621
Average	19,548	1,114,408	229,684	even-1,701,026 odd- 124,459	614,384	2,891,894
1982[1]	20,636	3,237,376	777,132	788,972	1,428,621	6,252,737

[1]Preliminary data

SOURCE: Ruesch and Browning 1982

The tributary streams of the Susitna River provide a multi-species recreational fishery. In 1981, over 95,000 angler days were spent catching more the 30,000 salmon in the Susitna Basin (Mills 1982). The majority of these fish were caught in the Lower Susitna tributaries and no specific catch numbers are reported by Mills (1982) for Upper Susitna tributaries.

The Susitna River drainage is the largest watershed in upper Cook Inlet and is considered to be the inlet's largest salmon-producing system. The exact contribution of the Susitna River to the fishery is unknown because spawning and rearing areas are so numerous that data on salmon-producing systems are few, and migration time of mixed stocks overlaps in Cook Inlet harvest areas.

ADF&G has attempted to assess total inlet production to determine the contribution of Susitna fish to the Upper Cook Inlet fishery. The total number of adult salmon migrating into freshwater spawning habitat has been enumerated by sonar, weir or tower monitoring. Air and ground surveys were used for peak counts. Tributary stream counts only index population density by species within observed areas, not total number of spawning salmon. Turbid water and poor weather conditions often precluded surveys from being conducted or allow only for partial counts. Side-scan sonar counters are used to monitor escapement in the Kenai, Kasilof, Crescent, and Susitna rivers by ADF&G, Division of Commercial Fisheries. Additional escapement information has been gathered for the Susitna by ADF&G Susitna hydro studies by sonar and tag/recapture operations.

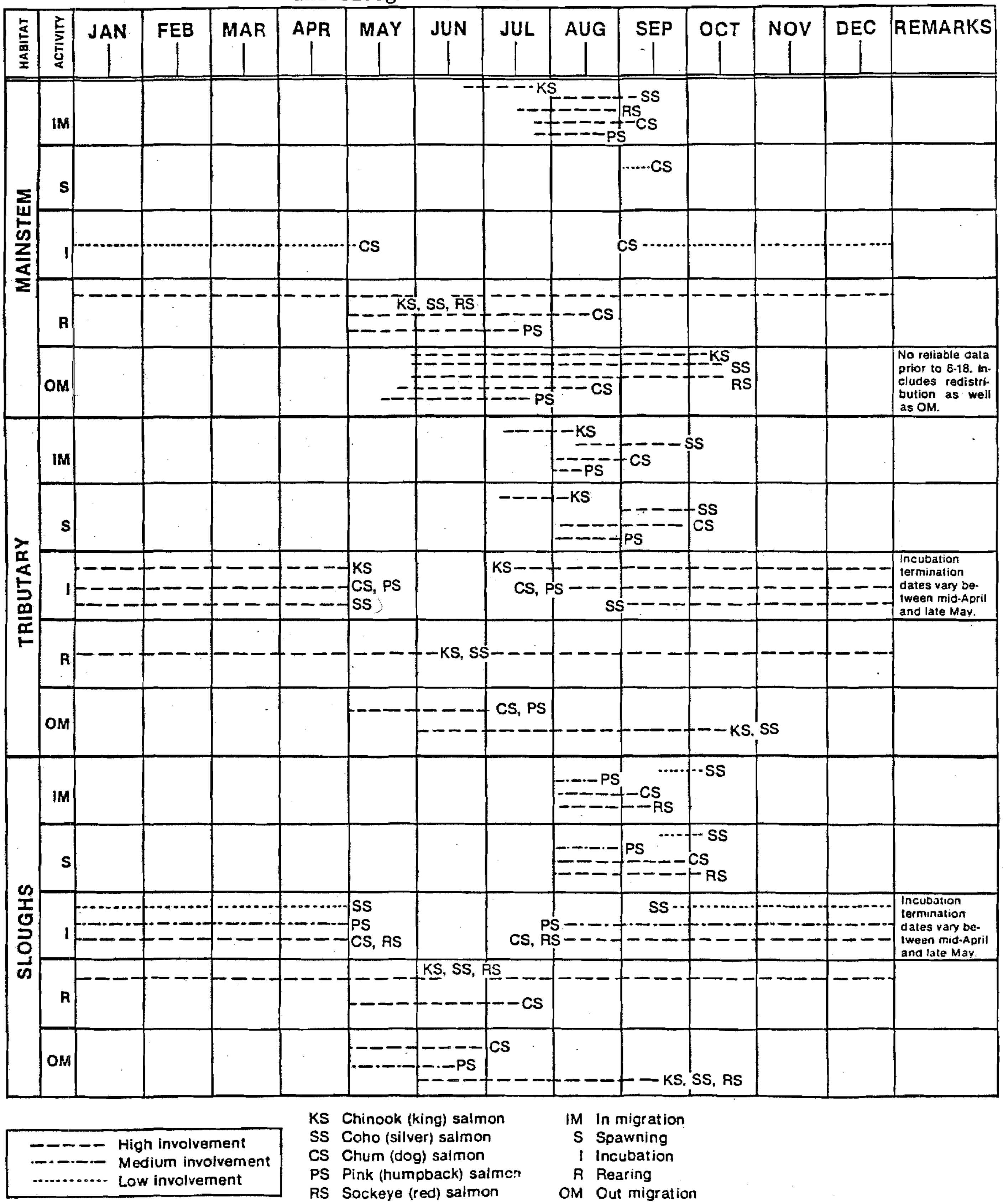
To better evaluate the feasibility of the proposed Susitna hydroelectric project, ADF&G has studied the aquatic resource in the Susitna River upstream of the Chulitna confluence since 1974. Adult salmon abundance above the Chulitna River confluence has been determined by tag and recovery programs in 1974, -75, -77, -81, and -82 (Barrett 1974; Riis 1977; ADF&G 1976, 1978, 1981b, 1983b). An intensive investigation was started in 1981 when ADF&G established five escapement monitoring stations at Susitna, Yentna, Sunshine, Talkeetna, and Curry (Figure A2). Side-scan sonar counters were used at all but the Curry Station, and fishwheels were installed at all five. Because of the suspected inaccuracy of counts due to siting problems, Susitna station counts are considered invalid (ADF&G 1983b). All fishwheel-intercepted salmon at Sunshine, Talkeetna, and Curry Stations were tagged in order to conduct a Peterson population estimate. Intensive juvenile anadromous studies in the Upper Susitna were also started in 1981. Figure A4 provides provisional periodicity for the various life stages of salmon between Talkeetna and Devil Canyon.

Between the Chulitna River confluence (RM 98.5) and Chinook Creek (RM 156.8) in Devil Canyon are 18 tributaries and 34 sloughs that provide potential fish habitat (Figure A5). Chum and sockeye salmon are the principal species utilizing slough habitats for spawning, and 82 percent of the peak slough escapement counts for chum and sockeye in 1981 and 1982 occurred in just four of these 34 sloughs--8A, 9, 11, and 21. Ninety-two percent of the sockeye, 70 percent of the chum, and 44 percent of the slough spawning pink salmon were counted in these four sloughs (ADF&G 1981b; 1983b).

A small number of pink salmon use the sloughs for spawning. Adult coho and chinook salmon rarely spawn in sloughs and primarily use slough habitat for juvenile rearing. Sloughs 6A, 8A, 10, 11, and 20 are most used for rearing (ADF&G 1981a, 1983a).

Escapement survey counts in the tributary streams do not reflect the total number of spawning salmon, only the relative population density by species within the surveyed index areas. These index areas range in length from 0.25

Figure A4. Provisional phenology and habitat utilization of upper Susitna River salmon in mainstem, tributary, and slough habitats.



1. Based primarily on ADF&G field data.

Sources: ADF&G 1976, 1978, 1981a, 1981b, 1983a, 1983b; Barrett 1974; Riis 1977; Morrow 1980.

Figure A5. Upper Susitna River map showing important hanbitat and geographic features between RM 100 and RM 153.

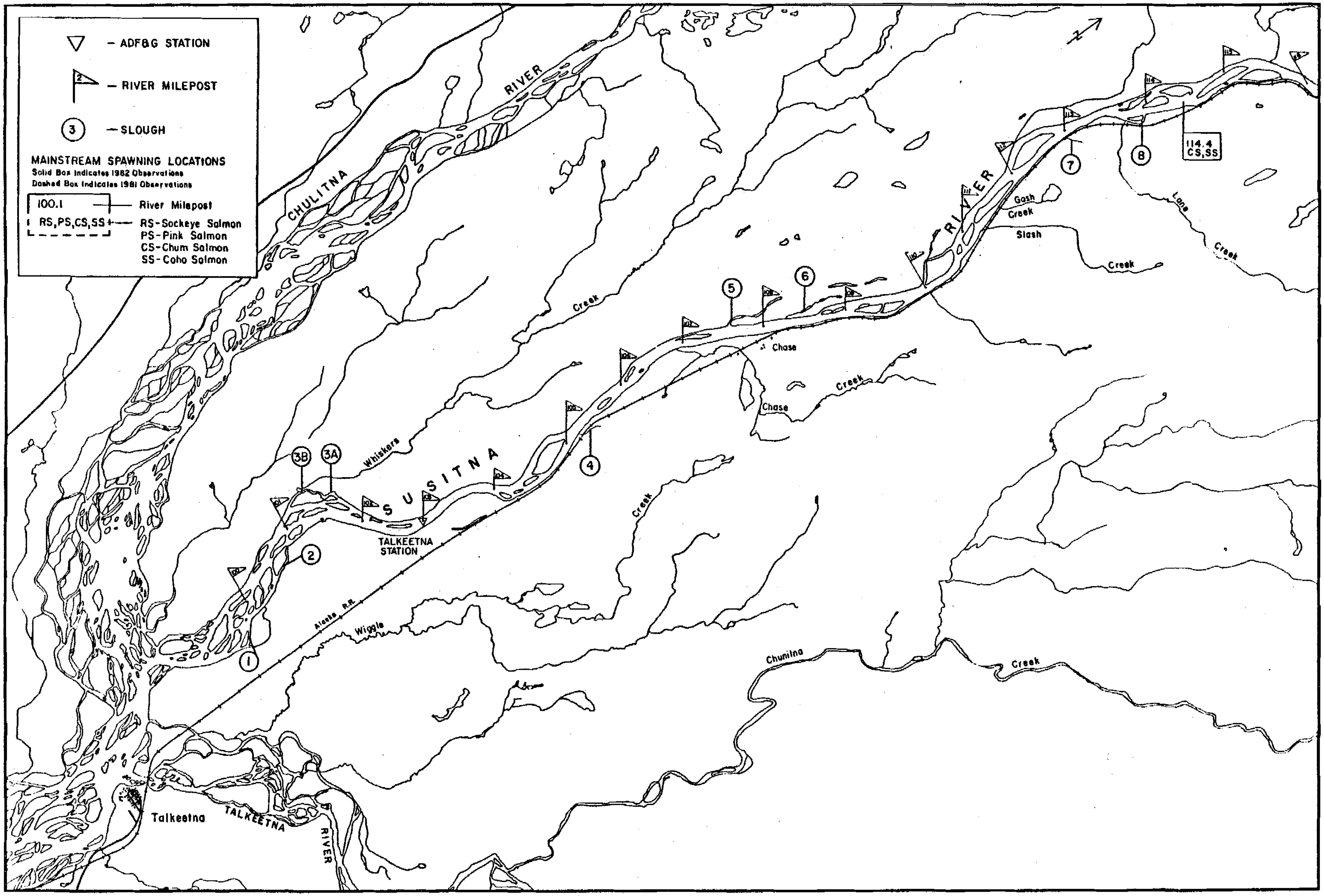


Figure A5 (continued). Upper Susitna River map showing important habitat and geographic features between RM 100 and RM 153.

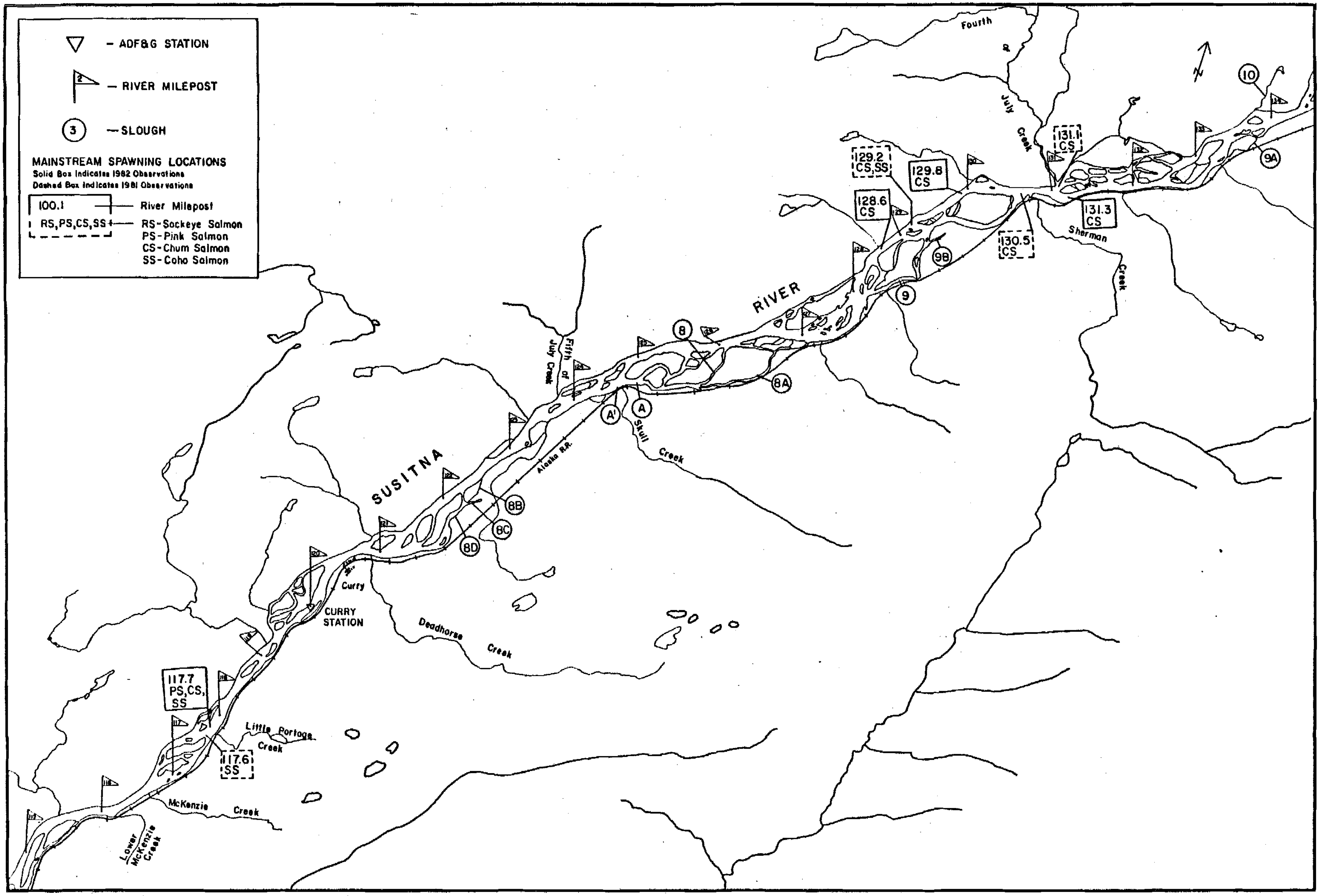
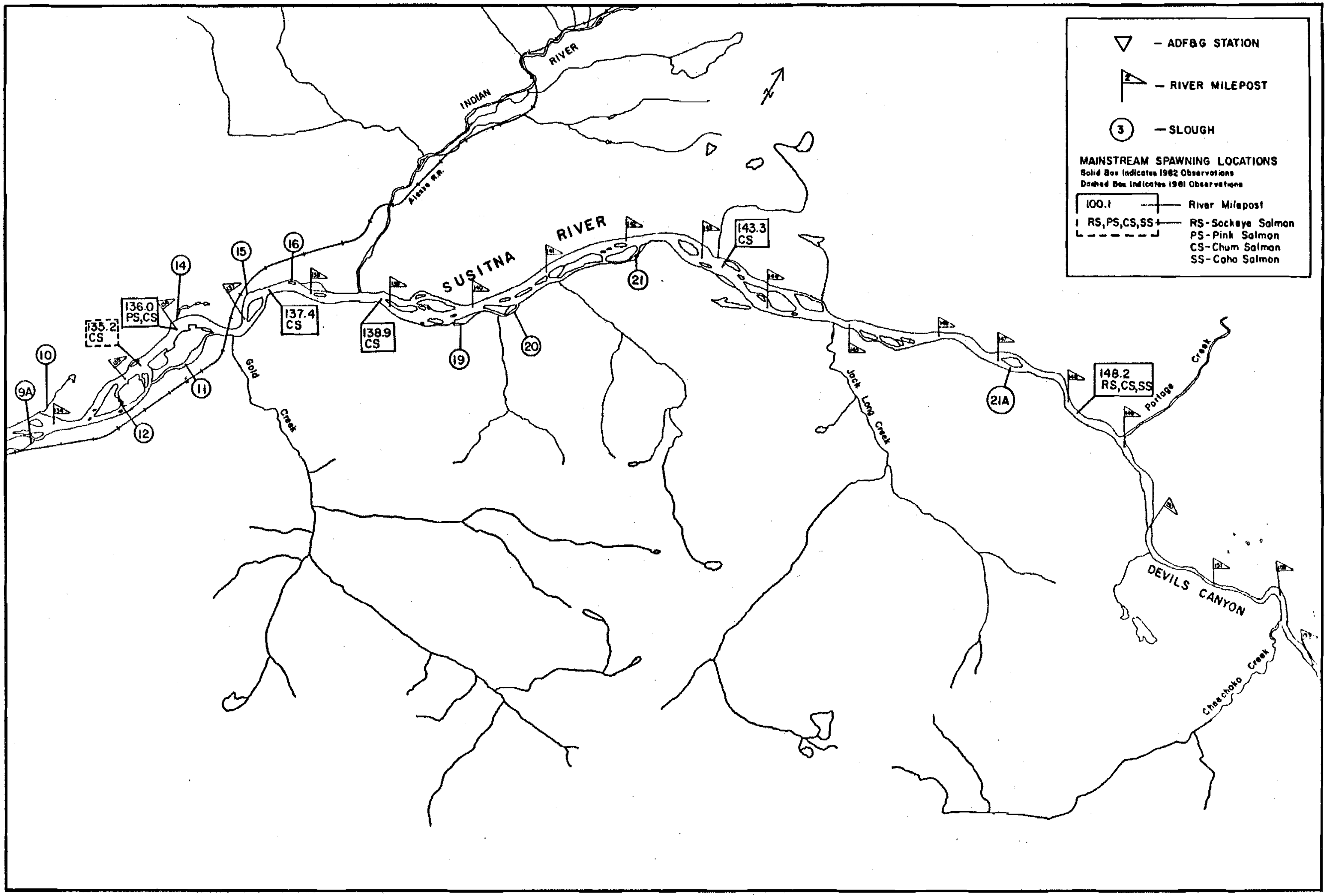


Figure A5 (continued). Upper Susitna River map showing important habitat and geographic features between RM 100 and RM 153.



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to 15 miles. Of the 8 tributaries in the Upper Susitna Zone, Indian River (RM 138.6), Portage Creek (RM 148.9), and, possibly, Whiskers (RM 101.4), Lane (RM 113.6), and Fourth of July (RM 131.0) creeks contain the bulk of the tributary escapement for chinook, coho, pink, and chum salmon (Figure A6).

ADF&G conducted mainstem spawning surveys in 1981 and 1982 using portable and boat-mounted electroshockers, examining 317 and 1,211 sites, respectively (ADF&G 1983b). In 1981, 12 mainstem spawning sites were observed between RM 68.3 and 135.2, of which six were above the Chulitna River confluence. Eighty-five chum salmon were observed at 10 of these sites, and nine coho were observed in three sites. In 1982, 11 mainstem spawning sites were documented between RM 114.4 and RM 148.2. Five hundred and sixty-five chum salmon were observed in 10 sites and one sockeye at one site.

SOCKEYE SALMON

The commercial sockeye harvest has averaged approximately 1.1 million fish in Upper Cook Inlet since 1954 (Figure A3). The estimated 1981 and 1982 catches were 1.44 and 3.24 million, respectively. The 1982 catch was the highest in the 29 years of record. In 1979 and 1980 19 to 23 percent of the Upper Cook Inlet run originated from the Susitna River (Logan 1981).

The Susitna River sockeye salmon escapement for 1981 and 1982 can be approximated by the summation of the Yentna River and Sunshine Station escapement counts (Figure A6). This count does not include escapements to tributaries other than the Yentna downstream of RM 77; however, these tributaries produce comparatively few sockeye. Using these estimates, the minimum sockeye escapement to the Susitna River was 272,000 in 1981 and 265,000 in 1982. Based on ADF&G Peterson population estimates for 1981 and 1982, ADF&G escapement counts above Curry were 2,800 and 1,300,

Figure A6. Peak salmon survey counts above Talkeetna for Susitna River tributary streams,

STREAM	SURVEY DISTANCE	Coho				Chinook						
YEAR		74	76	81	82	75	76	77	78	79	81	82
Whisker's Creek (RM 101.4)	0.25	27		70	176	22	8					
Chase Creek (RM 106.9)	0.25	40		80	36							15
Slash Creek (RM 111.2)	0.75				6							
Gash Creek (RM 111.6)	1.0			141	74							
Lane Creek (RM 113.6)	0.5			3	5						40	47
Lower McKenzie (RM 116.2)	1.5			56	133							
McKenzie Creek (RM 116.7)	0.25											
Little Portage (RM 117.7)	0.25				8							
Fifth of July (RM 123.7)	0.25											3
Skull Creek (RM 124.7)	0.25											
Sherman Creek (RM 130.8)	0.25											3
Fourth of July (RM 131.0)	0.25	26	17	1	4	1	14					56
Gold Creek (RM 136.7)	0.25				1							21
Indian River (RM 138.6)	15.0	64	30	85	101	10	537	393	114	285	422	1053
Jack Long (RM 144.5)	0.25				1							2
Portage Creek (RM 148.9)	15.0	150	100	22	88	29	702	374	140	140	659	1253
Cheechako Creek (RM 152.5)	3.0											16
Chinook Creek (RM 156.8)	2.0											4
TOTAL		307	147	458	633	62	1261	767	254	425	1121	2473

Figure A6 (continued). Peak salmon survey counts above Talkeetna for Susitna River tributary streams.

STREAM	SURVEY DISTANCE	Chum						Sockeye					
YEAR		74	75	76	77	81	82	74	75	76	77	81	82
Whisker's Creek (RM 101.4)	0.25					1							
Chase Creek (RM 106.9)	0.25					1							
Slash Creek (RM 111.2)	0.75												
Gash Creek (RM 111.6)	1.0												
Lane Creek (RM 113.6)	0.5		3		2	76	11						
Lower McKenzie (RM 116.2)	1.5					14						1	
McKenzie Creek (RM 116.7)	0.25								46				
Little Portage (RM 117.7)	0.25						31						
Fifth of July (RM 123.7)	0.25												
Skull Creek (RM 124.7)	0.25					10	1						
Sherman Creek (RM 130.8)	0.25					9							
Fourth of July (RM 131.0)	0.25	594		78	11	90	191		1				
Gold Creek (RM136.7)	0.25												
Indian River (RM 138.6)	15.0	531	70	134	776	40	1346		1	2	1		
Jack Long (RM 144.5)	0.25						3						
Portage Creek (RM 148.9)	15.0	276		300			153						
Cheechako Creek (RM 152.5)	3.0												
Chinook Creek (RM 156.8)	2.0												
TOTAL		1401	73	512	789	241	1736	1	48	2	1	1	

Figure A6 (continued). Peak salmon survey counts above Talkeetna for Susitna River tributary streams.

STREAM	SURVEY DISTANCE	Pink					
YEAR		74	75	76	77	81	82
Whisker's Creek (RM 101.4)	0.25			75		1	138
Chase Creek (RM 106.9)	0.25			50		38	107
Slash Creek (RM 111.2)	0.75						
Gash Creek (RM 111.6)	1.0						
Lane Creek (RM 113.6)	0.5	82	106		1103	291	640
Lower McKenzie (RM 116.2)	1.5						23
McKenzie Creek (RM 116.7)	0.25						17
Little Portage (RM 117.7)	0.25						140
Fifth of July (RM 123.7)	0.25					2	113
Skull Creek (RM 124.7)	0.25					8	12
Sherman Creek (RM 130.8)	0.25					6	24
Fourth of July (RM 131.0)	0.25	159	148	4000	612	29	702
Gold Creek (RM 136.7)	0.25			32			11
Indian River (RM 138.6)	15.0	577	321	5000	1611	2	738
Jack Long (RM 144.5)	0.25					1	
Portage Creek (RM 148.9)	15.0	218		3000			169
Cheechako Creek (RM 152.5)	3.0						21
Chinook Creek (RM 156.8)	2.0						
TOTAL		1036	575	12157	3326	378	2855

Source: Barrett 1974, Riis 1977
ADF&G 1976, 1978, 1981b, 1983b

respectively (Figure A7). Thus 0.5 to 1.0 percent of the Susitna 1981 and 1982 sockeye escapement spawn in the upper river sloughs.

Sockeye salmon age composition analyses in 1981 and 1982 indicated that the majority of the fish was age 5_2 (five years old with two years in fresh water) followed by age 4_2 fish. At Susitna Station in 1981 age 5_2 and 4_2 fish comprised 83.4 and 8.4 percent of the escapement sample, respectively, whereas in 1982 age 5_2 and 4_2 fish comprised 65.8 and 22.4 percent of the run (ADF&G 1983b).

Sockeye salmon begin their upstream spawning migration in early July and have reached the Upper Susitna River by late August. In 1981 the first sockeye was captured on July 4 at Susitna Station and the last on August 22 at Curry Station. In 1982 the migration began on July 18 and was over on August 28, and peaked at Curry Station around August 5. Peak spawning occurred during the last week of August and first three weeks of September (ADF&G 1981b, 1983b).

Rivers in which sockeye spawn usually have lakes in their systems. Spawning occurs in inlet and outlet streams and along the gravel shoals of lakes. No mainstem Susitna spawning was observed for sockeye in 1981 or 1982. Most sockeye escapement above the Yentna confluence is bound for spawning areas in the Talkeetna and Chulitna rivers. In the Upper Susitna River sockeye appear to be the species most heavily dependent on slough habitat for spawning. Approximately 90 percent of the total sockeye escapement observed between 1974-82 for the Upper Susitna spawned in sloughs 8A, 9, 11, and 21, with more than 70 percent of this escapement occurring in slough 11 (Figure A8).

Hatching occurs during the period January to March, and fry emerge from the gravel between April and June. Fry move into lakes for rearing in

Figure A7. Susitna River escapements by species and sampling location, 1981 & 1982

Sampling Location	River Mile	Escapement[1] Chinook[2] 1981	Chinook[2] 1982	Sockeye 1981	Sockeye 1982	Pinks 1981	Pinks 1982	Chum 1981	Chum 1982	Coho 1981	Coho 1982	Total[3] 1981	Total[3] 1982
Yentna Station	04	--	--	139401	113847	36053	447257	19765	27830	17017	34089	212236	623023
Sunshine Station	80	--	52847	133489	151485	49501	443198	262851	430442	19841	45735	465682	1123707
Talkeetna Station	103	--	10884	4809	3123	2335	73038	20835	49118	3306	5111	31285	141274
Curry Station	120	--	11307	2804	1261	1041	58835	13068	29413	1146	2438	18059	103254
Total[4]	--	--	--	272890	265332	85554	890455	282616	458272	36858	79824	677918	1746730

1. Escapement numbers were derived from tag/recapture population estimates with the exception of the Yentna Station escapements which are represented by sonar counts.

2. Stations were not operating during entire chinook migration and escapements are not available.

3. Total escapement minus chinook counts for 1981 and Yentna Station 1982.

4. Susitna River drainage escapement (Yentna Station and Sunshine Station) minus chinook counts and escapement into other tributaries downstream of RM 77.

Source: ADF&G 1981b, 1983b

Figure A8. Peak slough escapement counts above Talkeetna.

Slough No.	River Mile	Chum 1974	Chum 1975	Chum 1976	Chum 1977	Chum 1981	Chum 1982	Sockeye 1974	Sockeye 1975	Sockeye 1976	Sockeye 1977	Sockeye 1981	Sockeye 1982	Pink 1976	Pink 1977	Pink 1981	Pink 1982	Coho 1982
1	99.6					6												
2	100.4					27												
3B	101.4		50						15			7				1		
3A	101.9											1						
Talkeetna St.	103.0																	
4	105.2																	
5	107.2						2											
6	108.2	1																
6A	112.3					11	2					1					35	35
7	113.2																	
8	113.7					302										25		
Curry St.	120.0																	
8D	121.8						23											
8C	121.9						48						2					
8B	122.2					1	80				2		5					
Moose	123.5					167	23						8				8	
A1	124.6					140												
A	124.7					34										2		
8A	125.1				51	620	336				70	177	68				28	4
B	126.3						58						8				32	
9	128.3	511	181		36	260	300	8			6	10	5				12	
9B	129.2					90	5					81	1					
9A	133.3					182	118					2	1					
10	133.8				2		2											
11	135.3	33		66	116	411	459	79	84	78	214	893	456	1			131	
12	135.4																	
13	135.7		1			4												
14	135.9	2																
15	137.2		1			1	1			1							132	14
16	137.3	2	12		4	3									13			
17	138.9	24				38	21					6						
18	139.1																	
19	139.7	4				3		3		32	8	23					1	
20	140.1	107		2	28	14	30		20			2					64	
21	141.0	668	250	30	304	274	736	13	75	23		38	53				64	
21A	145.5					8												
Total		1352	495	98	541	2596	2244	103	194	134	300	1241	607	1	13	28	507	53

Source: Barrett 1974, Riis 1977.
ADF&G 1976, 78, 81b, 83b.

most systems. In the Upper Susitna, there are no lakes for sockeye rearing, and fry appear to leave this reach of river in their first summer between June and August (ADF&G 1983a).

CHUM SALMON

Historically. the average annual commercial catch for Upper Cook Inlet chum salmon has been approximately 614,000 fish (Figure A4). Estimated 1981 and 1982 catches were 843,000 and 1,430,000, respectively, the highest in the 29 years of record. Assuming a 2.2:1 harvest to escapement ratio (Friese 1975), the average total escapement would be about 900,000 fish and total escapement for 1981 and 1982 would be 1.2 to 2.1 million, respectively. The Susitna drainage and the Chinitna Bay streams are the major chum salmon producers.

Susitna River escapement for chum salmon can be estimated by summing the Yentna Station and Sunshine Station escapements (Figure A7). This escapement estimate was 283,000 in 1981 and 458,000 in 1982. This will be an underestimate, however, as it does not include escapement to tributaries downstream of RM 77 except for the Yentna. Chum salmon age composition analysis in 1981 and 1982 indicates that most (88 percent) fish were age 4_1, followed by 5_1 and 3_1 fish.

Chum salmon in the Susitna River begin their upstream spawning migration in mid-July and reach the upper river by late August. In 1981 the migration began on July 10 at Susitna Station and ended on September 2 at Curry Station, and in 1982 began on July 19 and ended on August 26. The migration reached its midpoint between August 12 and 17 at Curry Station. Peak spawning occurred between mid-August and mid- September (ADF&G 1983b).

Chum salmon spawning usually occurs in or near areas in the Upper Susitna with upwellings of groundwater (ADF&G 1983c). The majority of spawners appear to be distributed between the sloughs and tributaries with only a small fraction using mainstem areas for spawning. Approximately 70 percent of the slough escapement occurred in 8A, 9, 11, and 21. More chum salmon spawn in sloughs than any other species. 1981 and 1982 peak slough escapements were 2,596 and 2,244, respectively (Figure A7). Estimates of chum salmon spawning in sloughs upstream from Talkeetna during 1981 and 1982 were 3,526 and 3,674, respectively (APA 1983).

By far the most important tributary for chum salmon spawning in the Upper River is Indian River, where more than 1,300 fish were counted in the 15-mile index area in 1982 (Figure A6). Fourth of July Creek and Portage Creek are also significant chum salmon tributaries. Escapements at Curry for 1981 and 1982 were estimated at 13,000 and 29,000, respectively (ADF&G 1983b), which represents between four and six percent of the total Susitna escapement.

Upper Susitna River fry usually emerge in April or May and rear in the river for a short period before outmigrating. Peak outmigration from the upper Susitna in 1982 occurred by late June (ADF&G 1983a).

PINK SALMON

The commercial pink salmon harvest has averaged approximately 1.7 million during even years and 125,000 during odd years in Upper Cook Inlet since 1954 (Figure A4). The estimated 1981 and 1982 catches were 127,857 and 788,972, respectively.

Pink salmon have a two-year life cycle that results in two distinct stocks occurring in a system. The stocks are referred to as "odd" or "even" year on the basis of the year in which adults spawn. Even year runs dominate in the Susitna drainage. The 1981 and 1982 Susitna River pink salmon escapements were 85,500 and 890,500 fish, respectively (ADF&G 1983b). These estimates do not include escapement to rivers downstream of RM 77 excluding the Yentna River. These systems are significant producers of pink salmon and, therefore, these estimated escapements are low. A very large escapement occurred in 1982 that was probably due to a low commercial fishery effort for this species.

Pink salmon in the Susitna drainage begin their upstream migration in mid- July and have reached the Upper River spawning areas by mid-August. The 1981 migration began on July 18 at Susitna Station and ended on August 21 at Curry Station. The 1982 migration began on July 23 and ended on August 13. The migration peak at Curry Station was August 5 to 8, and peak spawning occurred in mid- to late August (ADF&G 1983b).

Most pink salmon in the Upper Susitna spawn in tributaries. Indian River, Portage Creek, Lane Creek, and Fourth of July creeks all support significant runs of pink salmon. In 1976 more than 12,000 pinks were counted in these tributaries (Figure A6). Additionally, a small number of pinks (507 in 1982) spawn in about 10 different sloughs (Figure A7).

Curry Station escapement was 1,041 and 58,835 pink salmon in 1981 and 1982, respectively (ADF&G 1983b). Depending on the year, the upper Susitna represents approximately one to seven percent of the total Susitna escapement. Average pink salmon escapement numbers are difficult to establish because of the large variance between odd- and even- year runs. Pink fry emerge from the gravels in the spring (April to June) and immediately begin migrating downstream to feeding areas in salt water, spending almost no time rearing in fresh water.

COHO SALMON

The present average annual commercial catch for coho in Upper Cook Inlet is about 230,000 fish (Figure A4). The estimated 1981 and 1982 catches were 494,000 and 777,000, respectively. The 1982 catch was the largest in the 29 years of record.

Escapement data for coho salmon in Cook Inlet are sparse. Major populations are found in the Susitna and Kenai river systems. Estimated escapement of coho in the Susitna River was 37,000 in 1981 and 80,000 in 1982 (Figure A7). This does not include escapements to tributaries downstream of RM 77 except for the Yentna River. These lower river tributaries produce significant numbers of coho salmon, so these escapement estimates are low.

Age class composition estimates (based on scale analysis) indicate that in 1981 and 1982 four-year-old (4_3) coho salmon were most abundant followed by three-year-olds (3_2) (ADF&G 1983b).

Peak coho salmon migration into the Susitna River occurs in mid-July and early August. In 1981 the migration began at Susitna Station on July 23 and ended at Curry Station on September 2. In 1982 the migration began on July 19 and ended on September 5. The migration peak at Curry Station was August 18 and August 23 in 1981 and 1982, respectively (ADF&G 1983b). Peak spawning occurred during the second and third weeks of September in 1981 and between the second week in September and the first week in October for 1982 (ADF&G 1983b).

Except for occasional fish found in sloughs and mainstem habitats, coho salmon in the Upper Susitna spawn in tributaries. Of the 18 accessible Upper Susitna tributaries coho have been observed spawning in 12 (Figure A6). Coho salmon are found spawning in smaller numbers in many places as opposed to large numbers in a few places. Whiskers Creek, Chase Creek, Lower

McKenzie Creek, Gash Creek, Portage Creek, and Indian River all contain populations of coho salmon.

Population estimates for the Susitna River above Talkeetna in 1981 and 1982 were 3,300 and 5,111, respectively (ADF&G 1983b) which would be approximately six to nine percent of the total Susitna River escapement. This estimate could be high, however, due to missing escapement data for tributaries downstream of RM 77.

Upon emergence in the spring (April-June), the fry generally rear in areas with cover, low velocities, and moderate water temperatures. During winter and spring (November-May), juvenile coho salmon are most frequently found at tributary mouth sites downstream from Talkeetna and in mainstem and slough sites upstream of Talkeetna. During summer and fall (June-September), juvenile fish occurred most frequently at tributary mouths (ADF&G 1981a, 1983a). Three age groups of juvenile coho salmon (2+, 1+, 0+) were collected at various habitat locations between Devil Canyon and Cook Inlet (ADF&G 1983a). The predominant age group for smolts in the Susitna River is age 2+, followed by age 1+. Peak smolt outmigration occurred in June in 1981 and 1982 (ADF&G 1981a, 1983a).

CHINOOK SALMON

The present average annual commercial catch in Upper Cook Inlet is about 19,000 fish (Figure A3), though for the last 10 years it has dropped to 12,000 or 13,000 fish. The 1982 commercial catch of nearly 21,000 fish represents a considerable increase over more recent years.

The Susitna drainage is believed to account for the majority of harvested Cook Inlet chinook salmon with the Kenai, Kasilof, Ninilchik and Anchor rivers and Deep Creek providing additional runs. Escapement to the Susitna River in recent years has ranged from 100,000 to 115,000 fish, peaking at about 125,000 chinook in 1977 (Logan 1981).

Age 3, 4, 5, and 6 fish are common in the Susitna River. At Sunshine Station in 1981 the escapement sample was 25.6 percent age 3_2, 30.5 percent age 4_2, 21.8 percent age 5_2, and 16.6 percent age 6_2 fish. In 1982, 14.8 percent of the fish sample was age 3_2, 27.2 percent age 4_2, 20.5 percent age 5_2, and 36.1 percent age 6_2 (ADF&G 1983b).

In the Susitna River, adult chinook begin their upstream migration in late May and ends in mid-July. In 1981 the migration began at Sunshine Station on June 22 and ended at Curry Station on July 24. In 1982 the migration began on June 18 and ended on July 19, peaking between June 24 and July 3 (ADF&G 1983b). Most chinook in the Susitna River system spawn in tributaries in July and early August. The most important spawning tributary in the Susitna system is Kroto Creek (Deshka River) and other spawning tributaries include Alexander Creek, Willow Creek, Chunilna (Clear) Creek, Chulitna River, Peters Creek, Lake Creek, Talachulitna River, Prairie Creek, Montana Creek, Indian River, and Portage Creek (ADF&G 1981b, 1983b).

Of the 18 accessible Upper Susitna tributaries, chinook spawn in 11 of them. However, almost the entire escapement in the Upper Susitna River for chinook salmon occurs in just two tributary streams--Indian River and Portage Creek (Figure A6). The chinook salmon escapement above Talkeetna in 1982 was approximately 11,000 fish, about 80 percent higher than in 1981 and above the mean average for years 1976 through 1981 (ADF&G 1983b).

Chinook eggs incubate in the gravel through winter and emerge the following spring (April-June) and become free-swimming feeding fry. Scale analysis shows that most Susitna River chinook remain in fresh water for one year and smolt in their second year of life (ADF&G 1983a). Clearwater sloughs also provide some summer rearing habitat. During fall most juvenile chinook migrate from tributaries into mainstem and slough sites to overwinter. This migration is apparently due to icing and lower tributary flows (ADF&G 1981a). Tributary mouths appear to provide important rearing habitat during the summer.

Two age groups of juvenile chinook salmon (1+, 0+) are present between Devil Canyon and Cook Inlet until August after which most of the smolts have emigrated. Outmigration occurs between mid June and September (ADF&G 1983a).

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APPENDIX B

Appendix B. Postproject Gold Creek discharges for Cases DS1-DS10, and DSA (June-September only).

CASE DS1

YEAR	MONTH JUN	JUL	AUG	SEP
1950	7,978.4	7,871.4	12,000.0	8,000.0
1951	7,332.5	7,411.6	13,599.1	21,240.0
1952	10,361.5	8,443.3	20,397.2	14,480.0
1953	9,776.2	10,399.7	20,610.0	15,270.0
1954	9,753.9	7,811.3	22,006.7	12,920.0
1955	9,213.4	11,318.6	25,750.0	14,290.0
1956	10,008.7	22,533.1	24,530.0	18,330.0
1957	9,125.4	10,639.2	20,540.0	19,800.0
1958	8,224.4	8,651.1	22,540.0	8,000.0
1959	9,218.1	8,611.7	28,375.9	16,920.0
1960	7,330.5	7,899.7	17,153.5	20,510.0
1961	10,347.4	16,004.2	22,100.0	13,370.0
1962	10,882.1	25,850.0	23,550.0	15,890.0
1963	9,420.1	23,338.5	23,670.0	12,320.0
1964	11,088.9	20,149.8	16,440.0	9,571.0
1965	8,874.0	11,038.5	21,120.0	19,350.0
1966	10,626.6	8,033.7	19,392.1	11,750.0
1967	9,054.6	15,521.4	32,620.0	16,870.0
1968	9,774.2	18,723.7	17,170.0	8,816.0
1969	6,137.5	6,000.0	12,000.0	8,000.0
1970	8,199.8	7,933.7	12,000.0	8,000.0
1971	6,000.0	6,282.3	12,000.0	8,000.0
1972	10,561.0	21,327.2	19,290.0	12,400.0
1973	8,494.1	6,779.8	13,979.8	9,074.0
1974	7,896.3	7,458.9	12,000.0	8,000.0
1975	9,631.9	17,449.2	18,090.0	16,310.0
1976	8,805.1	6,807.4	12,185.5	8,000.0
1977	10,327.6	15,726.3	19,240.0	12,640.0
1978	6,958.7	7,297.6	12,000.0	8,000.0
1979	6,951.8	14,885.3	20,460.0	10,770.0
1980	10,047.9	19,808.5	20,960.0	13,280.0
1981	7,483.6	18,468.4	37,870.0	13,790.0
1982	8,960.5	9,955.8	15,274.0	17,807.0

Appendix B (Continued). Postproject Gold Creek discharges for Cases DS1-DS10, and DSA (June-September only).

CASE DS2

	MONTH			
YEAR	JUN	JUL	AUG	SEP
1950	7,976.8	7,870.3	14,000.0	8,000.0
1951	7,333.8	7,412.4	14,000.0	20,666.7
1952	10,358.9	8,441.2	20,842.2	14,480.0
1953	9,775.0	10,623.9	20,610.0	15,270.0
1954	9,751.5	78,09.3	22,385.2	12,920.0
1955	9,211.1	11,675.3	25,750.0	14,290.0
1956	10,006.3	23,018.5	24,530.0	18,330.0
1957	9,123.1	10,986.2	20,540.0	19,800.0
1958	8,224.4	8,651.1	22,540.0	8,000.0
1959	9,215.8	8,610.0	28,724.3	16,920.0
1960	7,327.5	7,897.6	17,502.9	20,510.0
1961	10,347.4	16,004.2	22,100.0	13,370.0
1962	11,238.3	25,850.0	23,550.0	15,890.0
1963	9,418.9	23,559.5	23,670.0	12,320.0
1964	11,034.0	20,543.1	16,440.0	9,571.0
1965	8,871.6	11,386.1	21,120.0	19,350.0
1966	10,626.0	8,033.2	19,484.3	11,750.0
1967	9,052.7	15,868.1	32,620.0	16,870.0
1968	9,772.4	19,069.8	17,170.0	8,816.0
1969	6,042.8	6,000.0	14,000.0	8,000.0
1970	8,079.0	7,836.8	14,000.0	8,000.0
1971	6,055.4	6,795.6	14,000.0	8,000.0
1972	10,599.9	21,549.1	19,290.0	12,400.0
1973	8,472.3	6,776.8	14,514.5	9,074.0
1974	7,892.3	7,456.0	14,000.0	8,000.0
1975	9,631.9	17,449.3	18,090.0	16,310.0
1976	8,802.7	6,805.4	14,000.0	8,000.0
1977	10,326.0	16,072.4	19,240.0	12,640.0
1978	6,958.7	7,297.6	14,000.0	8,000.0
1979	6,949.5	15,232.7	20,460.0	10,770.0
1980	10,047.9	19,808.5	20,960.0	13,280.0
1981	7,483.6	18,468.4	37,870.0	13,790.0
1982	8,959.3	10,176.9	15,274.0	17,807.0

Appendix B (Continued). Postproject Gold Creek discharges for Cases DS1-DS10, and DSA (June-September only).

CASE DS3

YEAR	MONTH JUN	JUL	AUG	SEP
1950	7,971.6	7,866.6	16,000.0	8,000.0
1951	7,328.7	7,408.7	16,000.0	19,220.5
1952	10,343.2	9,152.5	20,920.0	14,480.0
1953	9,773.0	11,023.3	20,610.0	15,270.0
1954	9,747.6	7,806.0	23,012.7	12,920.0
1955	9,211.1	11,675.3	25,750.0	14,290.0
1956	10,002.2	23,834.9	24,530.0	18,330.0
1957	9,119.6	11,610.2	20,540.0	19,800.0
1958	8,224.4	8,651.1	22,540.0	8,000.0
1959	9,212.0	8,607.0	29,351.0	16,920.0
1960	7,323.2	7,894.7	18,017.5	20,510.0
1961	10,347.4	16,004.2	22,100.0	13,370.0
1962	11,879.6	25,850.0	23,550.0	15,890.0
1963	9,416.8	23,960.9	23,670.0	12,320.0
1964	10,935.1	21,254.8	16,440.0	9,571.0
1965	8,867.4	12,011.9	21,120.0	19,350.0
1966	10,622.5	8,030.0	20,112.3	11,750.0
1967	9,049.2	16,492.3	32,620.0	16,870.0
1968	9,770.9	19,363.2	17,170.0	8,816.0
1969	6,798.5	6,000.0	16,000.0	8,000.0
1970	7,962.6	7,687.1	16,000.0	8,000.0
1971	6,000.0	6,279.8	16,000.0	8,000.0
1972	10,559.8	21,589.1	19,290.0	12,400.0
1973	8,489.8	6,776.5	16,000.0	8,000.0
1974	7,885.2	7,450.8	16,000.0	8,000.0
1975	9,628.3	18,138.9	18,090.0	16,310.0
1976	8,798.4	6,801.8	16,000.0	8,000.0
1977	10,322.9	16,695.4	19,240.0	12,640.0
1978	6,958.7	7,297.6	16,000.0	8,000.0
1979	6,945.2	15,858.1	20,460.0	10,770.0
1980	10,047.9	19,808.5	20,960.0	13,280.0
1981	7,483.6	18,468.4	37,870.0	13,790.0
1982	8,958.2	10,362.9	16,000.0	17,056.8

Appendix B (Continued). Postproject Gold Creek discharges for Cases DS1-DS10, and DSA (June-September only).

CASE DS4

YEAR	MONTH			
	JUN	JUL	AUG	SEP
1950	7,966.1	7,862.7	18,000.0	8,000.0
1951	7,328.4	7,408.4	18,000.0	17,195.4
1952	10,236.7	9,919.0	20,920.0	14,480.0
1953	9,770.8	11,455.4	20,610.0	15,270.0
1954	9,743.7	7,802.5	23,688.6	12,920.0
1955	9,207.6	12,193.7	25,750.0	14,290.0
1956	9,998.8	24,507.1	24,530.0	18,330.0
1957	9,115.9	12,282.5	20,540.0	19,800.0
1958	8,224.4	8,651.1	22,540.0	8,000.0
1959	9,207.0	8,603.7	30,027.4	16,920.0
1960	7,319.8	7,892.4	18,453.3	20,510.0
1961	10,347.4	16,004.2	22,100.0	13,370.0
1962	11,985.9	25,850.0	23,550.0	15,890.0
1963	9,414.5	24,393.2	23,670.0	12,320.0
1964	10,828.4	22,021.6	18,000.0	8,000.0
1965	8,862.7	12,686.2	21,120.0	19,350.0
1966	10,618.7	8,026.6	20,788.5	11,750.0
1967	9,045.5	17,165.0	32,620.0	16,870.0
1968	9,770.9	19,363.2	18,000.0	8,000.0
1969	6,833.6	6,000.0	18,000.0	8,000.0
1970	7,781.5	7,513.6	18,000.0	8,000.0
1971	6,000.0	6,280.6	18,000.0	8,000.0
1972	10,559.4	21,678.3	19,290.0	12,400.0
1973	8,487.1	6,773.9	18,000.0	8,000.0
1974	7,880.1	7,447.1	18,000.0	8,000.0
1975	9,628.1	18,175.3	18,090.0	16,310.0
1976	8,793.8	6,797.9	18,000.0	8,000.0
1977	10,319.7	17,368.7	19,240.0	12,640.0
1978	6,958.7	7,297.6	18,000.0	8,000.0
1979	6,940.7	16,532.0	20,460.0	10,770.0
1980	10,047.9	19,808.5	20,960.0	13,280.0
1981	7,483.6	18,468.4	37,870.0	13,790.0
1982	8,958.2	10,362.9	18,000.0	14,990.1

Appendix B (Continued). Postproject Gold Creek discharges for Cases DS1-DS10, and DSA (June-September only).

CASE DS5

YEAR	MONTH JUN	JUL	AUG	SEP
1950	7,959.5	7,858.0	20,000.0	8,000.0
1951	7,324.5	7,405.8	20,000.0	15,636.8
1952	10,108.7	10,840.7	20,920.0	14,480.0
1953	9,770.4	11,538.6	20,610.0	15,270.0
1954	9,739.4	7,798.3	24,500.9	12,920.0
1955	9,202.2	13,001.6	25,750.0	14,290.0
1956	9,994.8	25,315.4	24,530.0	18,330.0
1957	9,112.2	12,951.0	20,540.0	19,800.0
1958	8,224.4	8,651.1	22,540.0	8,000.0
1959	9,201.6	8,599.8	30,837.9	16,920.0
1960	7,319.3	7,892.1	20,000.0	18,980.8
1961	10,347.4	16,004.2	22,100.0	13,370.0
1962	11,985.9	25,850.0	23,550.0	15,890.0
1963	9,411.7	24,912.1	23,670.0	12,320.0
1964	10,700.6	22,943.5	20,000.0	8,000.0
1965	8,857.4	13,494.8	21,120.0	19,350.0
1966	10,616.7	8,024.8	21,140.5	11,750.0
1967	9,041.0	17,971.8	32,620.0	16,870.0
1968	9,770.9	19,363.2	20,000.0	8,000.0
1969	6,826.3	6,373.3	20,000.0	8,000.0
1970	7,577.7	7,307.3	20,000.0	8,000.0
1971	6,000.0	6,297.7	20,000.0	8,000.0
1972	10,559.4	21,678.3	20,000.0	11,666.3
1973	8,481.3	6,769.2	20,000.0	8,000.0
1974	7,874.0	7,442.6	20,000.0	8,000.0
1975	9,625.6	18,657.2	20,000.0	14,336.3
1976	8,787.9	6,793.0	20,000.0	8,000.0
1977	10,319.3	17,451.5	20,000.0	11,854.7
1978	6,958.7	7,297.6	20,000.0	8,000.0
1979	6,942.9	16,206.1	20,460.0	10,770.0
1980	10,047.9	19,808.5	20,960.0	13,280.0
1981	7,483.6	18,468.4	37,870.0	13,790.0
1982	8,958.2	10,362.9	20,000.0	12,923.5

Appendix B (Continued). Postproject Gold Creek discharges for Cases DS1-DS10, and DSA (June-September only).

CASE DS6

	MONTH			
YEAR	JUN	JUL	AUG	SEP
1950	10,000.0	10,000.0	12,000.0	10,000.0
1951	10,000.0	10,000.0	12,000.0	20,973.0
1952	10,099.2	10,909.0	20,920.0	14,480.0
1953	10,000.0	11,316.4	20,610.0	15,270.0
1954	10,000.0	10,000.0	22,106.5	12,920.0
1955	10,000.0	12,279.3	25,750.0	14,290.0
1956	10,000.0	25,369.7	24,530.0	18,330.0
1957	10,000.0	12,091.8	20,540.0	19,800.0
1958	10,000.0	10,000.0	19,472.8	10,000.0
1959	10,000.0	10,000.0	28,724.7	16,920.0
1960	10,000.0	10,000.0	13,818.0	20,510.0
1961	10,347.4	16,004.2	22,100.0	13,370.0
1962	11,985.9	25,850.0	23,550.0	15,890.0
1963	10,000.0	24,349.4	23,670.0	12,320.0
1964	10,754.9	22,950.0	16,440.0	10,000.0
1965	10,000.0	12,451.0	21,120.0	19,350.0
1966	10,616.7	10,000.0	19,165.3	11,750.0
1967	10,000.0	17,103.4	32,620.0	16,870.0
1968	10,000.0	19,141.5	17,170.0	10,000.0
1969	10,000.0	10,000.0	12,000.0	10,000.0
1970	10,000.0	10,000.0	12,000.0	10,000.0
1971	10,000.0	10,000.0	12,000.0	10,000.0
1972	10,559.4	21,678.3	19,290.0	12,400.0
1973	10,000.0	10,000.0	12,000.0	10,000.0
1974	10,000.0	10,000.0	12,000.0	10,000.0
1975	10,000.0	20,092.8	18,090.0	16,310.0
1976	10,000.0	10,000.0	12,000.0	10,000.0
1977	10,319.3	17,451.5	19,240.0	12,640.0
1978	10,000.0	10,000.0	12,000.0	10,000.0
1979	10,000.0	13,843.3	20,460.0	10,770.0
1980	10,047.9	19,808.5	20,960.0	13,280.0
1981	10,000.0	16,033.2	37,870.0	13,790.0
1982	10,000.0	10,000.0	14,628.7	17,807.0

Appendix B (Continued). Postproject Gold Creek discharges for Cases DS1-DS10, and DSA (June-September only).

CASE DS7

YEAR	MONTH			
	JUN	JUL	AUG	SEP
1950	10,000.0	10,000.0	14,000.0	10,000.0
1951	10,000.0	10,000.0	14,000.0	19,561.4
1952	10,031.0	11,559.8	20,920.0	14,480.0
1953	10,000.0	11,316.4	20,610.0	15,270.0
1954	10,000.0	10,000.0	22,631.2	12,920.0
1955	10,000.0	12,279.3	25,750.0	14,290.0
1956	10,000.0	26,084.3	24,530.0	18,330.0
1957	10,000.0	12,091.8	20,540.0	19,800.0
1958	10,000.0	10,000.0	19,472.8	10,000.0
1959	10,000.0	10,000.0	29,003.2	16,920.0
1960	10,000.0	10,000.0	14,000.0	20,332.0
1961	10,347.4	16,004.2	22,100.0	13,370.0
1962	11,985.9	25,850.0	23,550.0	15,890.0
1963	10,000.0	24,349.4	23,670.0	12,320.0
1964	11,575.3	22,950.0	16,440.0	10,000.0
1965	10,000.0	12,643.6	21,120.0	19,350.0
1966	10,616.7	10,000.0	19,165.3	11,750.0
1967	10,000.0	17,144.4	32,620.0	16,870.0
1968	10,000.0	19,141.5	17,170.0	10,000.0
1969	10,000.0	10,000.0	14,000.0	10,000.0
1970	10,000.0	10,000.0	14,000.0	10,000.0
1971	10,000.0	10,000.0	14,000.0	10,000.0
1972	10,559.4	21,678.3	19,290.0	12,400.0
1973	10,000.0	10,000.0	14,000.0	10,000.0
1974	10,000.0	10,000.0	14,000.0	10,000.0
1975	10,000.0	20,116.9	18,090.0	16,310.0
1976	10,000.0	10,000.0	14,000.0	10,000.0
1977	10,319.3	17,451.5	19,240.0	12,640.0
1978	10,000.0	10,000.0	14,000.0	10,000.0
1979	10,000.0	13,519.7	20,460.0	10,770.0
1980	10,047.9	19,808.5	20,960.0	13,280.0
1981	10,000.0	16,033.2	37,870.0	13,790.0
1982	10,000.0	10,000.0	14,628.7	17,807.0

Appendix B (Continued). Postproject Gold Creek discharges for Cases DS1-DS10, and DSA (June-September only).

CASE DS8

YEAR	MONTH JUN	JUL	AUG	SEP
1950	10,000.0	10,000.0	16,000.0	10,000.0
1951	10,000.0	10,000.0	16,000.0	17,397.0
1952	10,031.0	11,559.8	20,920.0	14,480.0
1953	10,000.0	11,316.4	20,610.0	15,270.0
1954	10,000.0	10,000.0	22,631.2	12,920.0
1955	10,000.0	12,279.3	25,750.0	14,290.0
1956	10,000.0	26,084.3	25,530.0	18,330.0
1957	10,000.0	12,091.8	20,540.0	19,800.0
1958	10,000.0	10,000.0	19,472.8	10,000.0
1959	10,000.0	10,000.0	29,003.2	16,920.0
1960	10,000.0	10,000.0	16,000.0	18,255.3
1961	10,347.4	16,004.2	22,100.0	13,370.0
1962	11,985.9	25,850.0	23,550.0	15,890.0
1963	10,000.0	24,349.4	23,670.0	12,320.0
1964	11,767.4	22,950.0	16,440.0	10,000.0
1965	10,000.0	12,643.6	21,120.0	19,350.0
1966	10,616.7	10,000.0	19,165.3	11,750.0
1967	10,000.0	17,144.4	32,620.0	16,870.0
1968	10,000.0	19,141.5	17,170.0	10,000.0
1969	10,000.0	10,000.0	16,000.0	10,000.0
1970	10,000.0	10,000.0	16,000.0	10,000.0
1971	10,000.0	10,000.0	16,000.0	10,000.0
1972	10,559.4	21,678.3	19,290.0	12,400.0
1973	10,000.0	10,000.0	16,000.0	10,000.0
1974	10,000.0	10,000.0	16,000.0	10,000.0
1975	10,000.0	20,116.9	18,090.0	16,310.0
1976	10,000.0	10,000.0	16,000.0	10,000.0
1977	10,319.3	17,451.5	19,240.0	12,640.0
1978	10,000.0	10,000.0	16,000.0	10,000.0
1979	10,000.0	13,242.5	20,460.0	10,770.0
1980	10,047.9	19,808.5	20,960.0	13,280.0
1981	10,000.0	16,033.2	37,870.0	13,790.0
1982	10,000.0	10,000.0	16,000.0	16,390.0

Appendix B (Continued). Postproject Gold Creek discharges for Cases DS1-DS10, and DSA (June-September only).

CASE DS9

YEAR	JUN	JUL	AUG	SEP
		MONTH		
1950	10,000.0	10,000.0	18,000.0	10000.0
1951	10,000.0	10,000.0	18,000.0	14,962.9
1952	10,031.0	11,559.8	20,920.0	14,480.0
1953	10,000.0	11,316.4	20,610.0	15,270.0
1954	10,000.0	10,000.0	22,631.2	12,920.0
1955	10,000.0	12,279.3	25,750.0	14,290.0
1956	10,000.0	26,084.3	24,530.0	18,330.0
1957	10,000.0	12,091.8	20,540.0	19,800.0
1958	10,000.0	10,000.0	19,472.8	10,000.0
1959	10,000.0	10,000.0	29,003.2	16,920.0
1960	10,000.0	10,000.0	18,000.0	16,188.6
1961	10,347.4	16,004.2	22,100.0	13,370.0
1962	11,985.9	25,850.0	23,550.0	15,890.0
1963	10,000.0	24,349.4	23,670.0	12,320.0
1964	11,767.4	22,950.0	18,000.0	10,000.0
1965	10,000.0	12,643.6	21,120.0	19,350.0
1966	10,616.7	10,000.0	19,165.3	11,750.0
1967	10,000.0	17,144.4	32,620.0	16,870.0
1968	10,000.0	19,141.5	18,000.0	10,000.0
1969	10,000.0	10,000.0	18,000.0	10,000.0
1970	10,000.0	10,000.0	18,000.0	10,000.0
1971	10,000.0	10,000.0	18,000.0	10,000.0
1972	18,559.4	21,678.3	19,290.0	12,400.0
1973	10,000.0	10,000.0	18,000.0	10,000.0
1974	10,000.0	10,000.0	18,000.0	10,000.0
1975	10,000.0	20,010.9	18,090.0	16,310.0
1976	10,000.0	10,000.0	18,000.0	10,000.0
1977	10,319.3	17,451.5	19,240.0	12,640.0
1978	10,000.0	10,000.0	18,000.0	10,000.0
1979	10,000.0	12,929.0	20,460.0	10,770.0
1980	10,047.9	19,808.5	20,960.0	13,280.0
1981	10,000.0	16,033.2	37,870.0	13,790.0
1982	10,000.0	10,000.0	18,000.0	14,323.3

Appendix B (Continued). Postproject Gold Creek discharges for Cases DS1-DS10, and DSA (June-September only).

CASE DS10

YEAR	MONTH JUN	JUL	AUG	SEP
1950	10,000.0	10,000.0	20,000.0	10,000.0
1951	10,000.0	10,000.0	20,000.0	13,674.9
1952	10,031.0	11,559.8	20,920.0	14,480.0
1953	10,000.0	11,316.4	20,610.0	15,270.0
1954	10,000.0	10,000.0	22,631.2	12,920.0
1955	10,000.0	12,279.3	25,750.0	14,290.0
1956	10,000.0	26,084.3	24,530.0	18,330.0
1957	10,000.0	12,091.8	20,540.0	19,800.0
1958	10,000.0	10,000.0	20,000.0	10,000.0
1959	10,000.0	10,000.0	29,003.2	16,920.0
1960	10,000.0	10,000.0	20,000.0	14,122.0
1961	10,347.4	16,004.2	22,100.0	13,370.0
1962	11,985.9	25,850.0	23,550.0	15,890.0
1963	10,000.0	24,349.4	23,670.0	12,320.0
1964	11,767.4	22,950.0	20,000.0	10,000.0
1965	10,000.0	12,643.6	21,120.0	19,350.0
1966	10,616.7	10,000.0	20,000.0	10,887.4
1967	10,000.0	17,144.4	32,620.0	16,870.0
1968	10,000.0	19,141.5	20,000.0	10,000.0
1969	10,000.0	10,000.0	20,000.0	10,000.0
1970	10,000.0	10,000.0	20,000.0	10,000.0
1971	10,000.0	10,000.0	20,000.0	10,000.0
1972	10,559.4	21,678.3	20,000.0	11,666.3
1973	10,000.0	10,000.0	20,000.0	10,000.0
1974	10,000.0	10,000.0	20,000.0	10,000.0
1975	10,000.0	20,116.9	20,000.0	14,336.3
1976	10,000.0	10,000.0	20,000.0	10,000.0
1977	10,319.3	17,451.5	20,000.0	11,854.7
1978	10,000.0	10,000.0	20,000.0	10,000.0
1979	10,000.0	13,637.2	20,460.0	10,770.0
1980	10,047.9	19,808.5	20,960.0	13,280.0
1981	10,000.0	16,033.2	37,870.0	13,790.0
1982	10,000.0	10,000.0	20,000.0	12,256.6

Appendix B (Continued). Postproject Gold Creek discharges for Cases DS1-DS10, and DSA (June-September only).

CASE DSA

YEAR	MONTH			
	JUN	JUL	AUG	SEP
1950	7,709.1	7,878.4	8,775.6	8,301.0
1951	7,345.4	7,420.5	12,095.9	21,240.0
1952	10,371.5	8,451.5	18,734.2	14,480.0
1953	9,782.3	9,217.0	20,610.0	15,270.0
1954	9,766.0	7,821.0	20,141.1	12,920.0
1955	9,225.6	9,495.5	25,750.0	14,290.0
1956	10,019.5	20,387.0	24,530.0	18,330.0
1957	9,134.0	9,347.3	20,540.0	19,800.0
1958	8,226.1	8,423.4	22,540.0	7,550.0
1959	9,231.7	8,621.7	26,353.6	16,920.0
1960	7,341.5	7,907.2	15,853.1	20,510.0
1961	10,347.6	15,970.9	22,100.0	13,370.0
1962	10,757.8	24,686.6	23,550.0	15,890.0
1963	9,426.0	22,237.2	23,670.0	12,320.0
1964	11,132.7	18,233.9	16,440.0	9,571.0
1965	8,885.0	9,465.4	21,120.0	19,350.0
1966	10,633.0	8,039.5	18,251.4	11,750.0
1967	9,069.3	13,108.6	32,620.0	16,870.0
1968	9,780.8	17,435.3	17,170.0	8,816.0
1969	6,493.3	6,045.4	6,130.4	6,433.3
1970	8,533.0	8,267.6	8,039.5	7,218.3
1971	4,558.6	7,218.7	8,851.6	10,894.8
1972	10,564.8	20,502.8	19,290.0	12,400.0
1973	8,510.0	6,792.4	11,793.3	9,074.0
1974	7,920.7	7,476.9	7,574.0	7,492.4
1975	9,641.3	15,772.6	18,090.0	16,310.0
1976	8,812.5	6,813.6	11,113.7	6,881.0
1977	10,334.8	14,249.8	19,240.0	12,640.0
1978	6,962.4	7,300.2	10,806.1	8,607.0
1979	6,966.3	13,093.6	20,460.0	10,770.0
1980	10,048.4	19,717.8	20,960.0	13,280.0
1981	7,483.6	18,468.4	37,870.0	13,790.0
1982	8,965.9	9,125.8	15,274.0	17,807.0