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INSTREAMFLOW RELATIONSHIPS REPORT
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Prepared for:

HARZA-EBASCO SUSITNA JOINT VENTURE

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Field studies and analyses completed by other members of the Aquatic Study Team are also cited within this report. Most visible are numerous references to the Alaska Department of Fish and Game (ADF&G). The ADF&G SuHydro Study Team conducted field studies to determine the seasonal distribution, relative abundance, and habitat requirements of anadromous and selected resident fish populations in the Susitna River.

The University of Alaska, Arctic Environmental Information and Data Center (AEIDC) conducted the instream temperature modeling studies, a key element in this evaluation. Mr. Paul Meyer and Mr. Joe Labelle are recognized for assembling the supporting technical information and drafting portions of the Instream Temperature and Ice Processes section of this report.

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Streamflow Variability section of this report. Mr. Carl Schoch provided technical information and drafted portions of the Instream Temperature and Ice Processes section of this report.

Finally special recognition is given to Milo C. Bell for the flawless insights he provided at the onset of the feasibility studies regarding the issues that would arise as being central to project licensing and his wise counsel concerning their implications to the maintenance and enhancement of salmon resources in the Susitna River Basin.

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I. INTRODUCTION

Instream Flow Relationships Report

The primary purpose of the Instream Flow Relationships Report (IFRR), presented here in draft form, is to present technical information within a hierarchical structure that reflects the relative importance of interactions among physical processes governing the seasonal availability of fish habitats in the Talkeetna-to-Devil Canyon segment of the Susitna River. The IFRR and its associated technical report series should not be construed as an impact assessment document. Rather, these reports describe a variety of natural and with-project relationships among abiotic instream habitat conditions that are necessary to evaluate alternative streamflow and stream temperature regimes, conduct impact analyses, and prepare mitigation plans.

The IFRR is intended to inform a broad spectrum of readers having widely differing educational backgrounds and degrees of familiarity with the proposed project about potentially beneficial or adverse influences the proposed project may have on fluvial processes in the middle Susitna River that control the availability and quality of fish habitat. By meeting this objective, the report will assist the Alaska Power Authority and resource agencies to reach an agreement on an instream flow regime (and associated mitigation plan) that will minimize impacts and possibly enhance existing middle Susitna River fish resources.

The final draft of the IFRR will: (1) identify the most limiting life history phases of fish populations indigenous to the middle Susitna River; (2) identify and rank the most influential habitat variables regulating these life phases; and (3) quantify the responses of these habitat variables to project induced changes in streamflow, stream temperature, suspended sediment and water quality. Other fluvial characteristics such as channel structure, sediment transport, ice processes, turbidity and water chemistry are elements of these three driving variables.

The influence of the project induced changes in stream temperature and water quality will be discussed on a macrohabitat level by habitat type, season, and species. The influence of streamflow on fish habitat will be evaluated on both a macrohabitat and microhabitat level. Site specific habitat responses to instream hydraulics will be identified at the microhabitat level and summarized in the form of flow relationship hydrographs at the macrohabitat level. These hydrographs are intended to describe the composite response of individual study sites by habitat type to changes in mainstem discharge for specific species and life history phases of interest.

This draft is based upon information available in project documents and the status of the IFRR technical report series as of October 1984. Environmental factors that influence the seasonal distribution and relative abundance of fish in the middle river are principally discussed at the macrohabitat level by habitat type. The influence of instream hydraulic conditions on the availability and quality of fish habitat can only be discussed on a quantitative basis for a few side sloughs and side channels. Subjective statements are required at this time to extend these site specific habitat responses to other habitat types within the middle Susitna River. As more technical information becomes available, undocumented discussion will be expanded to encompass such important habitat variables as upwelling, intragravel temperatures and primary production and their relationship to anticipated with-project streamflow, temperature and turbidity regimes.

In this report the three principal freshwater life phases of the Pacific salmon are ranked in their order of importance as determined by existing habitat conditions in the middle river, and the relative importance of several environmental factors in providing suitable habitat for each of these life history phases is identified. To the extent data and technical information are available the response of seasonal habitat conditions to altered streamflow, stream temperature and water quality conditions are also discussed.

Instream Flow Relationships Studies

The Alaska Power Authority submitted a license application to the Federal Energy Regulatory Commission (FERC) for the proposed Susitna Hydroelectric Project on February 18, 1983. Following submission of supplemental information and responses to FERC comments, the application was accepted on July 19, 1983 for review by the FERC. The application was then sent by the FERC to resource agencies for review and comment. This review is now complete, and the FERC is proceeding with preparation of the final environmental impact statement (FEIS). The decision to issue the license is tentatively scheduled to be made by the FERC in 1987, assuming no substantial delays in the licensing process prior to that date. Even though the license application has been accepted by the FERC for review, and preparation of the FEIS has begun, various aquatic or aquatic-related studies are still in progress to assure that the licensing process proceeds on schedule.

In 1982, following two years of preliminary baseline studies, a multi-disciplinary approach to quantify effects of the proposed Susitna Hydroelectric Project on existing fish habitats and identify mitigation options was initiated. As part of this multi-disciplinary effort, a technical report series was planned that would (1) describe the existing fish resources of the Susitna River and identify the seasonal habitat requirements of selected species, and (2) evaluate the effects of alternative project designs and operating scenarios on those physical processes which most influence the seasonal availability of fish habitats in the middle Susitna River. In addition, a summary report, the Instream Flow Relationships Report, would integrate the findings of the technical report series and prioritize the physical processes evaluated in the technical report series and provide quantitative relationships (where possible) and discussions regarding the influences of incremental changes in streamflow, stream temperature, and water quality on fish habitats in the Talkeetna to Devil Canyon reach of the Susitna River on a seasonal basis.

The IFRR technical report series consists of the following:

Technical Report No. 1. Fish Resources and Habitats of the Susitna Basin. This report, being prepared by Woodward-Clyde Consultants, will consolidate information obtained by ADF&G SuHydro on the fish resources and habitats in the Talkeetna-to-Devil Canyon reach of the Susitna River. A draft report utilizing data available through June 1984 was prepared by WCC in November 1984.

Technical Report No. 2. Physical Processes Report. This report, being prepared by R&M Consultants, describes naturally occurring physical processes within the Talkeetna-to-Devil Canyon river reach pertinent to evaluating project effects on riverine fish habitat.

Technical Report No. 3. Water Quality/Limnology Report. This report, being prepared by Harza-Ebasco, will consolidate existing information on water quality for the Susitna River and provide technical level discussions of the potential for with-project bioaccumulation of mercury, adverse effects of nitrogen gas supersaturation, changes in downstream nutrients, and changes in turbidity and suspended sediments. A draft report based on literature reviews and project data available through June 1984 was prepared in November 1984.

Technical Report No. 4. Reservoir and Instream Temperature. This report, prepared by AEIDC, consists of three principal components: (1) reservoir and instream temperature modeling; (2) development of temperature criteria for Susitna River fish stocks by species and life stage; and (3) evaluation of the influences of with-project stream temperatures on existing fish habitats and natural ice processes. A final report describing downstream temperatures associated with various reservoir operating scenarios and an evaluation of these stream temperatures on fish was prepared in October 1984. A draft report addressing the influence of anticipated with-project stream temperatures on natural ice processes was prepared in November 1984.

Technical Report No. 5. Aquatic Habitat Report. This report, being prepared by E. Woody Trihey and Associates, will describe the availability of various types of aquatic habitat in the Talkeetna-to-Devil Canyon river reach as a function of mainstem discharge. A preliminary draft of this report is scheduled for March 1985 with a draft final report prepared in FY86.

Project Setting

The Susitna River is located in Southcentral Alaska between the major population centers of Anchorage and Fairbanks. The Susitna Valley is a transportation corridor and contains both the Alaska Railroad and the Parks Highway. Yet even with these transportation facilities, the basin remains largely undeveloped except for several small communities located in the lower portion of the drainage. Talkeetna, the largest of these communities, has an approximate population of 280 and is located on the east bank of the Susitna River at river mile (RM) 98.

The proposed Susitna Hydroelectric Project consists of two dams scheduled for construction over a period of 15 years. Construction on the first dam, Watana, is scheduled to begin when the FERC license is issued, possibly in 1987, and would be completed in 1994 at a site located approximately 184 river miles upstream from the mouth of the Susitna River. The Watana development would include an 885 ft high earth fill dam, which would impound a 48-mile long, 38,000 acre reservoir with a total storage capacity of 8.6 million acre feet (maf) and a usable storage capacity of 3.7 maf. Multiple level intakes and cone valves would be installed in the dam to control downstream temperatures and dissolved gas concentrations, which otherwise might be harmful to fish resources. An underground powerhouse would contain six generators with an installed capacity of 1020 megawatts (mw), and an estimated average annual energy output of 3460 gigawatt hours (gwh). Maximum possible outflow from the powerhouse at full pool is 21,000 cfs. The cone valves are designed to pass 24,000 cfs at full pool (APA 1983).

The second phase of the proposed development is construction of the 645 foot high concrete arch Devil Canyon dam, which is scheduled for completion by 2002. Devil Canyon dam would be constructed at a site 32 miles downstream of Watana dam and would impound a 26-mile long reservoir with 7,800 surface acres and a usable storage capacity of 0.36 maf. Installed generating capacity would be about 600 mw, with an average annual energy output of 3450 gwh. A multiple level intake structure and cone valves would also be installed in Devil Canyon dam. The maximum possible outflow from the four generators in the powerhouse at full pool is 14,700 cfs. The cone valves at Devil Canyon dam are designed to pass 38,500 cfs. When both dams are operational, Watana Reservoir would be drawn down during the winter when energy demand is high and filled during the summer when energy requirements are lowest. Devil Canyon reservoir would remain relatively full during most of the year with a short period of drawdown in the fall (APA 1983).

The Susitna River is an unregulated glacial river. Middle Susitna River turbidities are commonly between 400 and 500 nephelometric turbidity units (NTUs) in summer and less than 10 NTU in winter. Typical summer flows range from 16,000 to 30,000 cubic feet per second (cfs) while typical winter flows range between 1,000 and 3,000 cfs. A thick ice cover forms on the river during late November and December that persists through mid-May. The drainage area of the Susitna River is approximately 19,600 square miles, which is the sixth largest river basin in Alaska. The Susitna 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. Major tributaries to the Susitna include the Talkeetna, Chulitna, and Yentna Rivers, all of which are glacial streams with characteristic high turbid summer streamflows and ice covered clearwater winter flows. The Yentna River is the largest tributary to the Susitna and adjoins it at RM 28. The Chulitna River originates in the glaciers on the south slope of Mount McKinley and flows south, entering the Susitna River near Talkeetna (RM 99). The Talkeetna River headwaters in the Talkeetna Mountains, flows west, and joins the Susitna near the town of Talkeetna (RM 97). The junction of the Susitna, Chulitna and Talkeetna rivers is often called the three rivers confluence.

The Susitna River originates in the Susitna Glacier in the Alaska Range and follows a disjunct south and west course 320 miles to Cook Inlet (Figure I-1). The Susitna River flows south from the glacier in

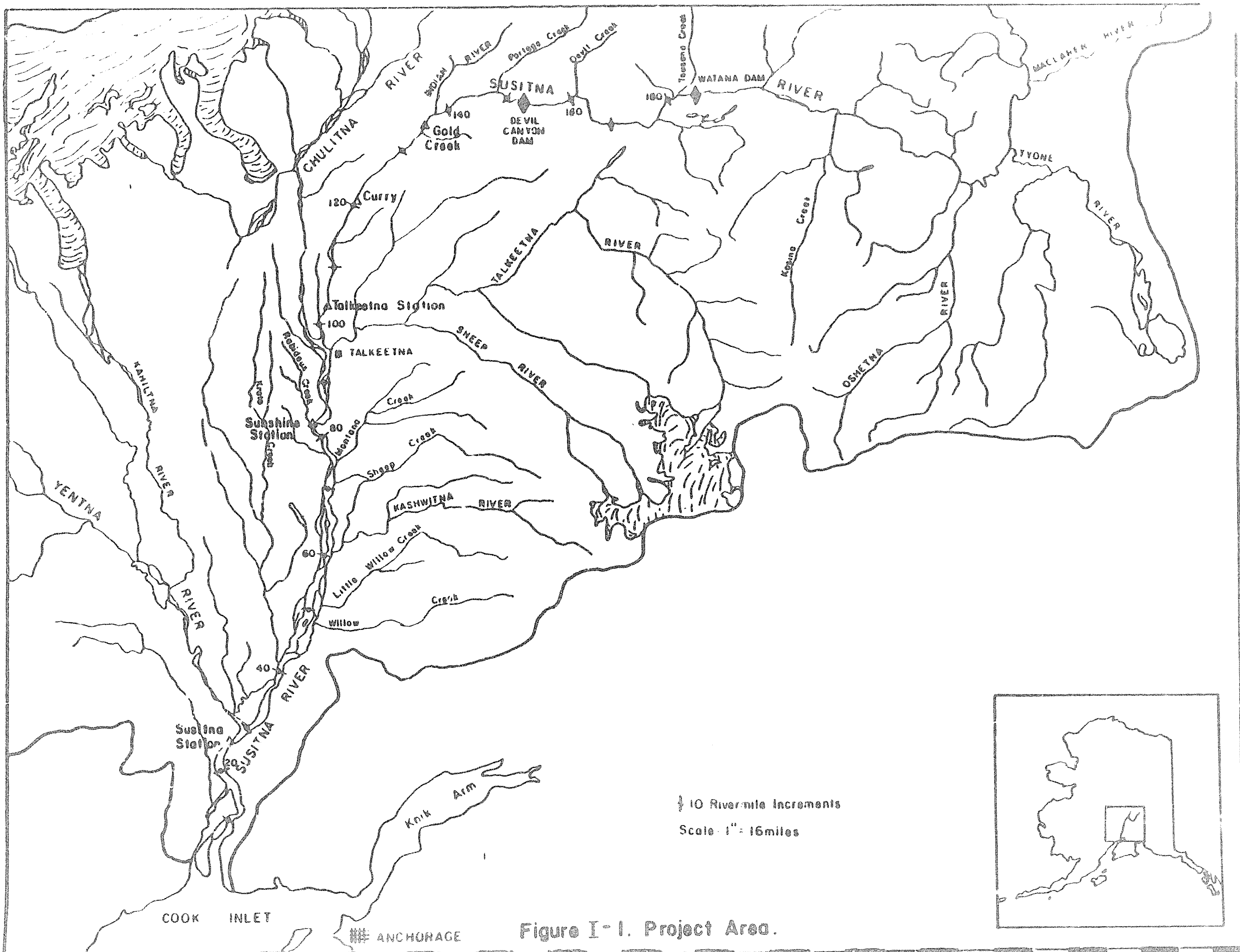

Figure I-1. Project Area.

a braided channel across a broad alluvial fan for approximately 50 miles, then west in a single channel for the next 75 miles through the steep-walled Vee and Devil Canyons. The two proposed Watana (RM 184.4) and Devil Canyon (RM 151.6) dam sites are located in this reach. Downstream of Devil Canyon, the river flows south again through a well defined and relatively stable multiple channel until it meets the Chulitna and Talkeetna Rivers (RM 99). Downstream of the three rivers confluence, the Susitna River valley broadens into a large coastal lowland. In this reach the down valley gradient of the river decreases and it flows through a heavily braided segment for its last 100 miles to the estuary.

Overview of Fish Resources and Project Related Concerns

The Susitna River basin supports populations of both anadromous and resident fish. Commercial or sport fisheries exist for five species of Pacific salmon (chinook, sockeye, coho, chum, and pink), rainbow trout, Arctic grayling, Dolly Varden, and burbot. The commercial fishery intercepts returning sockeye, chum, coho and pink salmon in Cook Inlet. Sport fishing is concentrated in clear water tributaries to the Susitna River for chinook, coho, pink salmon, rainbow trout and Arctic grayling.

Construction and operation of the proposed project will notably reduce streamflows during the summer months and increase them during the winter months, leading to a more uniform annual flow cycle. Stream temperatures and turbidities will be similarly affected. The most pronounced changes in stream temperature and turbidity will likely be observed in mainstem and side channel areas with somewhat lesser effects occurring in peripheral areas. However, reduced summer and increased winter streamflows will have their greatest influence on site-specific depth and velocity conditions in areas peripheral to the mainstem.

The effects that anticipated changes in streamflow, stream temperature and turbidity will have on fish populations inhabiting the Susitna

River depends upon their seasonal habitat requirements and the regulatory control which these habitat components exert upon the population. Some project induced changes in environmental conditions may have no appreciable effect on existing fish populations and their associated habitats, whereas other changes may have dramatic consequences. Thus, in order to understand the possible effects of the proposed project on existing fish populations and identify mitigation opportunities or enhancement potential, it is important to understand the relationships among the naturally occurring physical processes which provide fish habitat in the middle river and how fish populations respond to natural variations in habitat availability.

II. AQUATIC HABITAT MODELING

Approach

The goal of the Alaska Power Authority (APA) in identifying an environmentally acceptable flow regime is the maintainence or enhancement of existing fish resources and levels of production (APA 1982). This goal is consistent with mitigation goals of the U.S. Fish and Wildlife Service (USFWS) and the Alaska Department of Fish and Game (ADF&G) (APA 1982, ADF&G 1982a, USFWS 1981. Although maintenance of naturally occurring fish populations is the ultimate goal, the focus of the Instream Flow Relationships Studies (IFRS) is on describing the response of middle Susitna River fish habitats to incremental changes in mainstem discharge, temperature and water quality.

Fish populations of the Susitna River fluctuate markedly for many reasons. Some of the factors affecting population levels exert their influence outside the river basin. This is particularly true for anadromous species such as Pacific salmon, which spend portions of their life cycles in freshwater estuarine and marine environments. Ocean survival and commercial catches significantly affect the number of salmon returning to spawn in the Susitna River and its tributaries. Within the freshwater environment other factors such as late summer and fall high flows, cold-dry winters, predation, and sport fishing also affect fish populations. In addition, the long-term response of adult fish populations to perturbations either within or outside their freshwater environment is seldom immediately apparent. A time-lag lasting up to several years may occur before an effect, whether beneficial or detrimental, is reflected in an increase or decrease in the reproductive potential of the population.

To avoid many of the uncertainties associated with fluctuating population levels, fish habitat is often used when making decisions regarding hydroelectric development and instream flow releases (Stalnaker and Arnette 1976, Olsen 1979, Trihey 1979). When using fish habitat as the basis for decision making, the direction and magnitude of change in habitat quality and availability are accepted as indicators of population response. This relationship is not necessarily linear, but is generally quantifiable (Wesche 1973, Binns 1979). Instream flow recommendations based on an analysis of fish habitat rather than fish population levels requires exact knowledge of the seasonal habitat requirements of the species and evaluating the characteristic responses of individuals of those species to variations in habitat conditions. In the middle Susitna River the abiotic habitat components of most interest are groundwater upwellings, channel structure, streamflow, temperature, and the water quality of the Susitna River.

Framework for Analysis

Fish habitat is the integrated set of environmental conditions to which a typical individual of a species responds both behaviorally and physiologically. It is generally recognized that temperature, water quality, water depth and velocity, cover or shelter, and streambed material are the most important physical variables affecting the amount or quality of riverine fish habitat (Hynes 1972). Important biological factors include food availability, parasitism or disease, and predation. The principal relationships (linkages) among environmental factors which influence salmon populations within the Talkeetna-to-Devil Canyon segment of the Susitna River are diagrammed in Figure I1-1.

Various approaches exist for evaluation of fluvial systems and their associated fish habitats. The macrohabitat approach to describing riverine ecology and fluvial processes examines a river from its headwaters to its mouth (Burton and Odum 1945, Sheldon 1968, Mackin 1948). Watershed characteristics such as climate, hydrology, geology, topography and vegetative cover (land use) are the principal determinants of basin runoff and erosional processes which become manifest as a river system. The macrohabitat approach focuses on the longitudinal transition in channel morphology, water quality and the biological community which results from the interaction of these watershed characteristics. Based on the natural variability of the system as well as the anticipated project impacts, the 320 mile length of the Susitna River may be divided into four major discrete segments described below. This report is focused specifically on the Middle River, or Talkeetna-to-Devil Canyon, segment of the Susitna River.

1. Upper Basin (RM 320-232). This segment includes the headwater reach of the Susitna River and its associated glaciers and tributary streams above the elevation of the proposed impoundments.

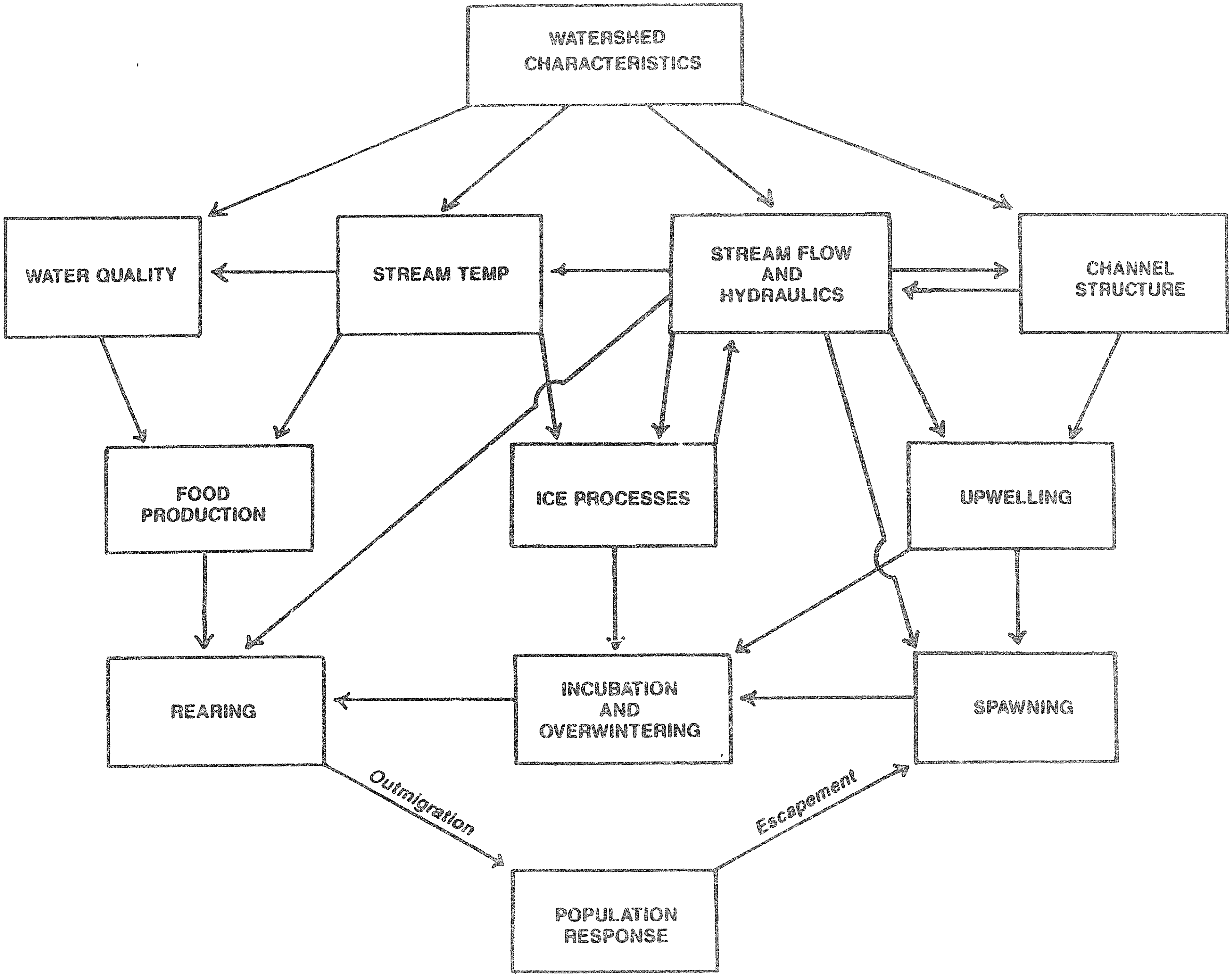

Figure II-1. Primary linkages among habitat components and their relationship to freshwater life phases of salmon within the Talkeetna to Devil Canyon of the Susitna River.

2. The Impoundment Zone (RM 150-232). This segment includes the eighty-mile portion of the Susitna River which will be inundated by the Watana and Devil Canyon impoundments. This single channel reach is characterized by steep gradient, and high velocity. Intermittent islands are found in the reach with significant rapids occurring in Vee Canyon and between Devil Creek and Devil Canyon.

3. The Middle River (RM 99-150). This fifty-mile segment extends from Devil Canyon downstream to the three rivers confluence. It is a relatively stable multiple channel reach with insignificant tributary inflow. Naturally occurring streamflow, stream temperature, and suspended sediment regimes are expected to be significantly altered throughout this river segment by construction and operation of the proposed projects.

4. The Lower River (RM 0-99). This segment extends one hundred miles from the three rivers confluence downstream to the estuary. The river channel is very broad, heavily braided and unstable within this segment. Seasonal changes in streamflow, stream temperature and suspended sediment within this river segment will be attentuated by the unaltered inflow of such major tributaries as the Talkeetna, Chulitna, Deshka and Yentna rivers.

Another method frequently used in riverine ecology studies is to hold macrohabitat conditions constant and examine the relationships between environmental conditions and the distribution and abundance of key species (Everest and Chapman 1977, Bovee 1984, Gore 1978). This method attempts to describe the manner in which individuals of a species respond to changes in site-specific habitat variables such as surface and intragravel water temperatures, substrate composition, depth, velocity, cover, food availability, and predation. Within the structure of our analysis this method is referred to as the microhabitat approach and is reflected in the development of species-specific habitat suitability criteria and numerous site-specific habitat models.

On the microhabitat level, two useful concepts for evaluating the influence of streamflow variations on fish habitat are fixed and variable boundary habitats. The usability of a location within a stream as fish habitat is often disproportionately affected by one or two dominant microhabitat variables. Fixed boundary habitat conditions prevail whenever the quality and location of the most influential microhabitat variable(s) do not significantly respond to changes in streamflow. Microhabitat variables most often associated with fixed boundary situations are upwelling, substrate composition, and object cover. Streamflow variations primarily influence availability of microhabitat within the fixed boundary habitats as when depths become too shallow or velocities too fast for the upwelling, substrate or object cover to be useful to fish. Variable boundary situations prevail whenever the quality and distribution of the most significant microhabitat variable(s) respond directly to streamflow. Depth, velocity, turbidity, and surface water temperature are microhabitat variables often associated with variable boundary habitat conditions in the middle Susitna River. In the case of juvenile salmon, velocity and turbidity are the primary determinants of rearing habitat and, therefore, the location of good rearing areas responds directly to mainstem discharge.

Because of the notable variation and differences in microhabitat conditions within the middle Susitna River, six major habitat types are recognized: mainstem, side channel, side slough, upland slough, tributary and tributary mouth. Habitat type refers to a major portion of the wetted surface area of the river having comparatively similar morphologic, hydrologic and hydraulic characteristics. At some locations, such as major side channels and tributary mouths, a designated habitat type persists over a wide range of mainstem discharge even though its surface area may change significantly. In other instances the habitat classification of a specific area may change from one type to another in response to mainstem discharge (Klinger and Trihey 1984). Such an example is the transformation of some turbid water side channels that exist at typical mid-summer mainstem discharge levels to clear water sloughs at lower mainstem flows.

Habitat categories are used to classify specific areas within the river corridor according to the type of transformation they undergo as mainstem discharge varies. This approach was chosen as the basic framework for extrapolating site-specific habitat responses to the remainder of the middle Susitna River because (1) a significant amount of wetted surface area is expected to be transformed from one habitat type to another as a result of project induced changes in streamflow (Klinger and Trihey 1984); and (2) a large amount of circumstantial evidence exists within the ADF&G SuHydro data base and elsewhere that indicates turbid water channels which transform into clearwater habitats may provide more valuable rearing conditions than those channels that remain turbid.

The statement that clear water may provide better rearing conditions than turbid water is supported by a number of studies comparing growth rates of sockeye juveniles rearing in glacial and clear lakes on the Kenai Peninsula (Koenings & Kyle 1982); naturally stunted chinook salmon juveniles in the Kasilof River (Koenings, pers. comm.); and growth rates among non-salmonid warm water species grown in clear vs. turbid fish ponds elsewhere in the country (Buck 1956). Additional evidence is provided by the Susitna River as well, where 0+ chinook juveniles rearing in clearwater tributaries average approximately 15 percent more growth during the summer than 0+ chinook rearing in turbid side channels (Dana Schmidt, ADF&G, 1984, pers. comm.).

The hierarchical structure of our analysis, proceeding from micro-habitat study sites through habitat categories, to habitat types, and finally macrohabitat level is diagrammed in Figure II-2. The structure of our analysis is similar to the study site to representative reach to river segment logic referenced in other instream

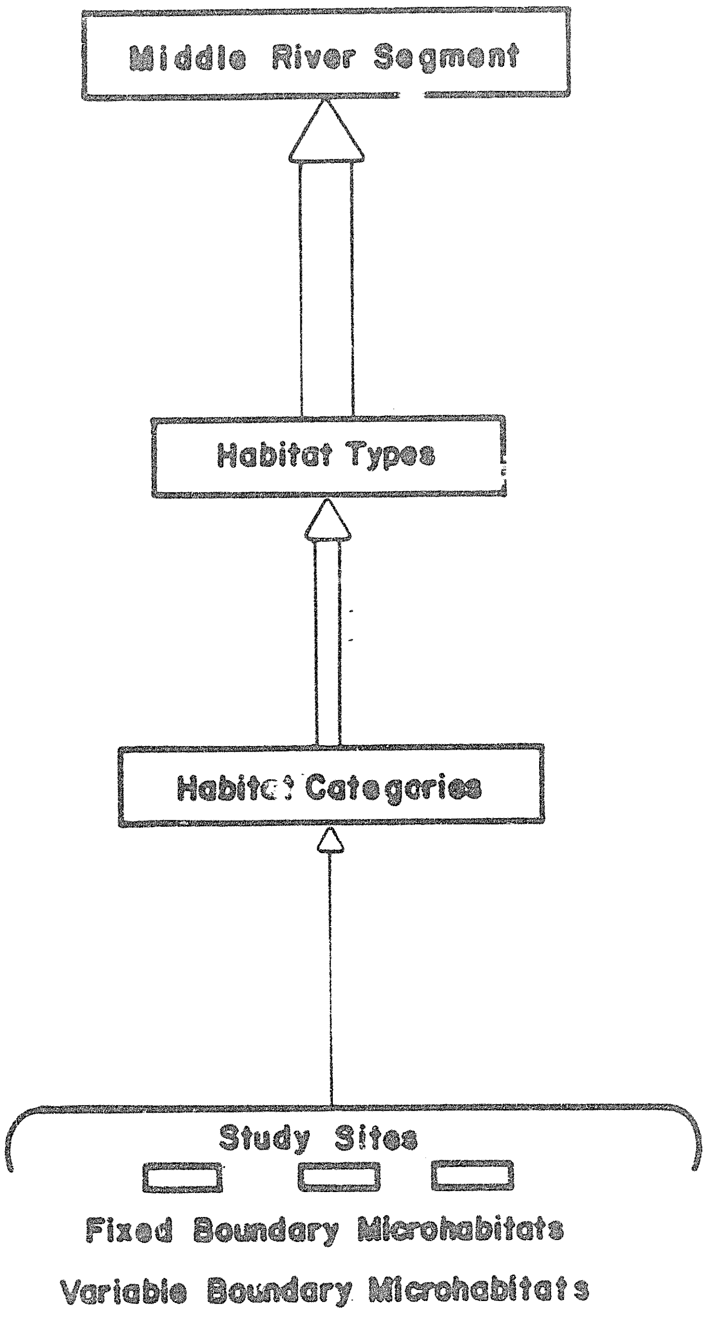

Figure II-2. Hierarchial structure of the relationship analysis.

flow studies and training documents (Bovee and Milhous 1978, Wilson et al. 1981, Bovee 1982).

The basic difference between our methodology and that applied in other instream flow studies is that habitat types and habitat categories have been substituted for river segments and representative reaches. Additionally our methodology uses wetted surface area as the common denominator for extrapolation rather than reach length. Given the spatial diversity and temporal variation of riverine habitat conditions within the Talkeetna-to-Devil Canyon segment of the Susitna River, the structure of our analysis appears more applicable.

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Relationships Model

The purpose of applying the habitat model is to evaluate the response of fish habitat to various changes in physical processes which influence its availability and quality. Thus the primary output functions of the model are habitat availability and quality indices.

Within the structure of our analysis visually discernable characteristics of the riverine environment are used to categorize areas of the river according to habitat type. The structure also recognizes that variations in mainstem discharge affect both the amount and classification of the wetted surface area which exists at any location within the river corridor. Hence a fundamental requirement of our habitat model is that it forecast the amount of surface area which exists within each habitat type at various levels of mainstem discharge.

The total surface area of each habitat type in the middle Susitna River has been estimated at four mainstem discharges ranging from 9,000 to 23,000 cfs using digital measurements on 1 inch = 1000 feet aerial photographs (Klinger and Trihey 1984). Hence the response of specific areas within the middle Susitna River corridor to variations in mainstem discharge can be modeled and their habitat type and surface area forecast for any middle Susitna River discharge between 9,000 and 23,000 cfs. Additional photography has been obtained or is planned that will expand the limits of the surface area model to a range of mainstem discharges from 5,000 cfs to over 30,000 cfs.

At the microhabitat level weighted usable area (WUA) is used as an index to evaluate the influence of site-specific variations in stream flow on the availability of potential fish habitat. WUA is defined as the total surface area of the study site expressed as an equivalent surface area of optimal (preferred) habitat for the lifestage of the particular species being evaluated (Bovee and Milhous 1978). Such site-specific considerations as the presence or absence of upwelling, or highly turbid versus clear water, as well as the depth of flow, mean column velocity, substrate composition and available object cover are determinants of the WUA index in our analysis

The visual distinction between clear and turbid water provides a sufficient basis to locate and estimate the amount of wetted surface area within the middle Susitna River which is directly influenced by the temperature and water quality of the mainstem. The amount of surface area affected is dependent upon the magnitude of the mainstem discharge and can be forecast by the HABAREA model. Seasonal stream temperature and water quality regimes for the mainstem can be superimposed on these forecasts and the relative effects of mainstem discharge on the thermal and water quality characteristics of various locations and habitat types evaluated. A schematic diagram of the functional and structural components of our hierarchical analysis is diagrammed in Figure II-3.

Either directly or indirectly, mainstem discharge influences the spatial dimensions of each middle Susitna River habitat type, as well as its temperature, water quality and hydraulic characteristics. Hence mainstem discharge is the primary driving variable or input function to the habitat model. The partitioning and utilization of the middle Susitna River by fish indicate that different species and life history phases have different habitat requirements and exhibit different microhabitat preferences. Therefore species and lifestage are the second input variable. Season of the year may also be an input variable, but it is implied by specifying the species and life stage.

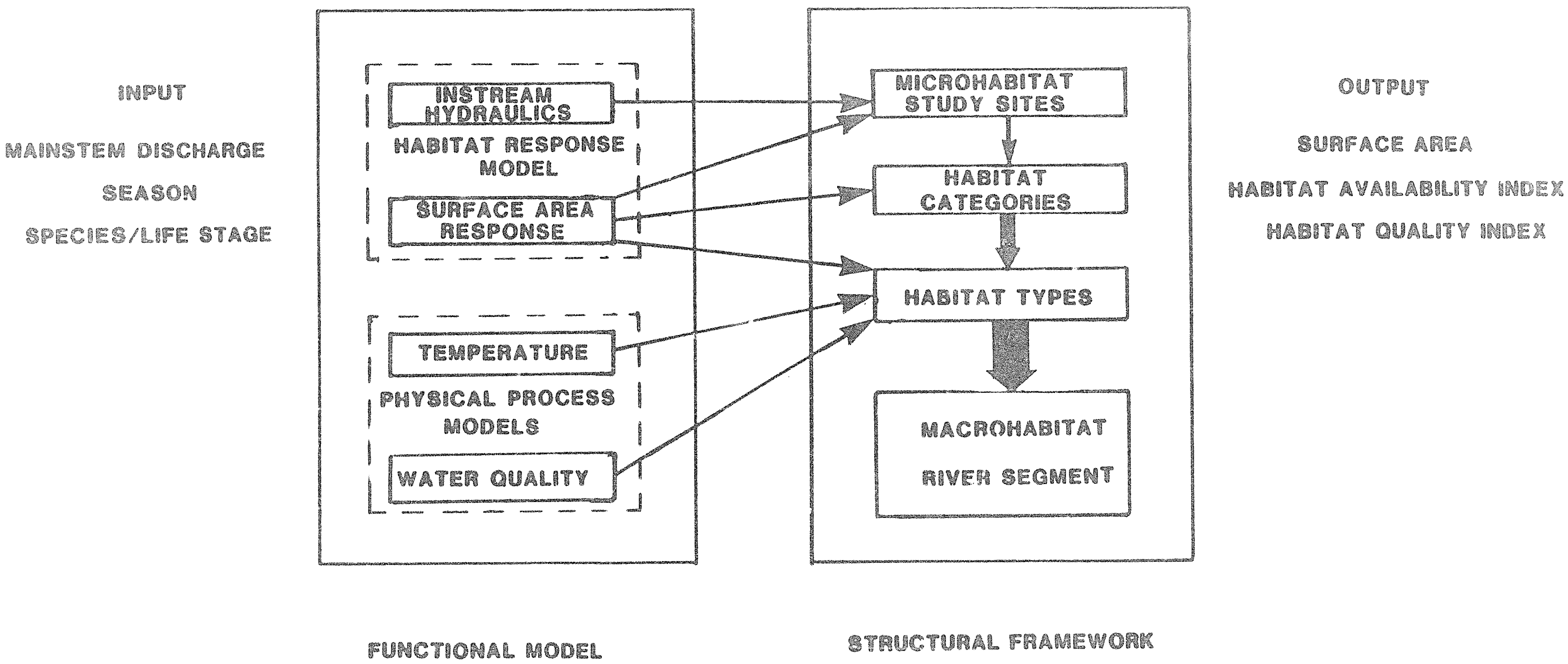

Figure II-3. A schematic diagram of the structural and functional components of the relationship analysis.

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Application

Sufficient data have been obtained and analyzed to apply the aquatic habitat model. Important analyses which have been completed include the identification of seasonal habitat requirements and microhabitat requirements of resident fish and adult and juvenile salmon indigenous to the middle Susitna River. In addition, physical process models have been developed to evaluate stream temperature, ice cover, sediment transport, and site-specific hydraulic conditions for a broad range of streamflow and meteorologic conditions. The surface area response of middle Susitna River habitat types to mainstem discharge has also been estimated.

This information can be used to evaluate the response of fish habitat to seasonal changes in mainstem streamflow, stream temperature and water quality (Figure II-4). The model can thus describe the surface area response of individual habitat types or specific areas to mainstem discharge and forecast the location and amount of area influenced by mainstem temperature and water quality. The model is also structured to evaluate the response of fish habitat to site-specific hydraulic and fixed boundary variables for each habitat category. Hence, the model will provide forecasts of the amount of wetted surface area influenced by streamflow alterations and quantitative indices of habitat availability and quality which can be subjectively applied to estimate the effect of altered streamflow temperature and water quality on macrohabitat fish production. However, the data available at this time will only support limited applications to side slough and side channel habitats.

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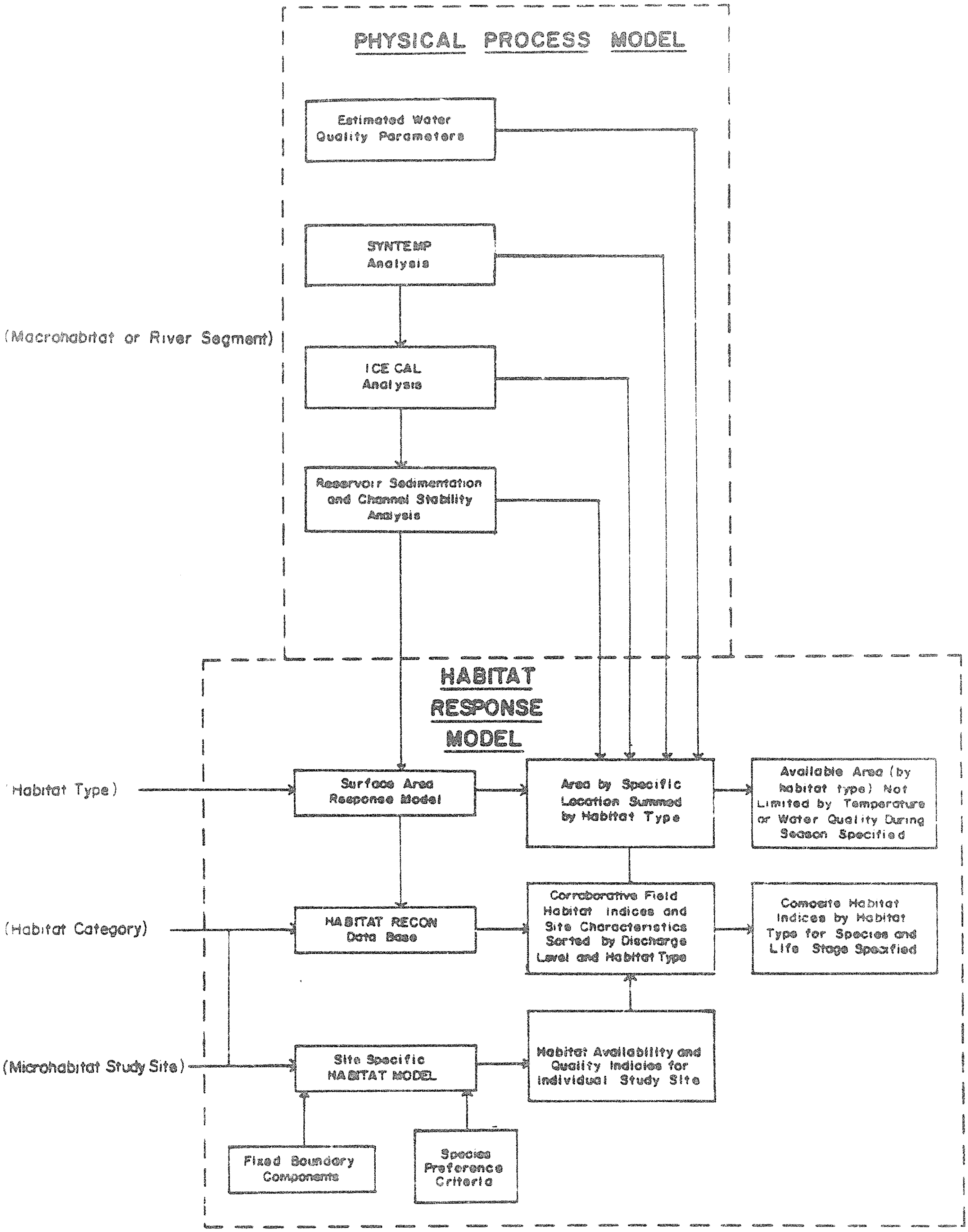


Figure II-4. Schematic diagram showing the integration of physical process and the habitat response components of the Relationships Analysis.

III. FISH RESOURCES AND HABITAT TYPES

Overview of Susitna River Fish Resources

Fish resources in the Susitna River comprise a major portion of the Cook Inlet commercial salmon harvest and provide sport fishing for residents of Anchorage and the surrounding area. Anadromous species that form the base of commercial and sport fisheries include five species of Pacific salmon: chinook, coho, chum, sockeye, and pink. Important resident species found in the Susitna River basin include Arctic grayling, rainbow trout, lake trout, burbot, Dolly Varden, and round whitefish. Scientific and common names of all fish species which inhabit the Susitna River are presented in Table III-1.

Adult Salmon Contribution to Commercial Fishery

With the exception of sockeye and chinook salmon, the majority of the upper Cook Inlet salmon commercial catch originates in the Susitna Basin (ADF&G 1984a). The long-term average annual catch of 3.1 million fish is worth approximately $17.9 million to the commercial fishery (K. Florey, ADF&G, pers. comm. 1984). In recent years commercial fishermen have landed record numbers of salmon in the upper Cook Inlet fishery with over 6.2 million salmon caught in 1982 and over 6.7 million fish landed in 1983 (Table III-2).

The most important species to the upper Cook Inlet commercial fishery is sockeye salmon. In 1984, the sockeye harvest of 2.1 million fish in upper Cook Inlet was valued at $13.5 million (K. Florey, ADF&G, pers. comm. 1984). The estimated contribution of Susitna River sockeye to the commercial fishery is from 10 to 30 percent (ADF&G 1984a). Thus, in 1984 the Susitna River contributed between 210,000 and 630,000 sockeye salmon to the upper Cook Inlet fishery, which represents a worth of between $1.4 million and $4.1 million.

Chum and coho salmon are the second most valuable commercial species. In 1984, the chum salmon salmon harvest of 684,000 fish was valued at

Table III-1. Common and scientific names of fish species recorded from the Susitna Basin.

Scientific Name	Common Name
Petromyzontidae	
Lampetra japonica	Arctic lamprey
Salmonidae	
Coregonus laurettae	Bering cisco
Coregonus pidschian	humpback whitefish
Oncorhynchus gorbuscha	pink salmon
Oncorhynchus keta	chum salmon
Oncorhynchus kisutch	coho salmon
Oncorhynchus nerka	sockeye salmon
Oncorhynchus tshawytscha	chinook salmon
Prosopium cylindraceum	round whitefish
Salmo gairdneri	rainbow trout
Salvelinus malma	Dolly Varden
Salvelinus namaycush	lake trout
Thymallus arcticus	Arctic grayling
Osmeridae	
Thaleichthys pacificus	eulachon
Esocidae	
Esox lucius	northern pike
Catostomidae	
Catostomus catostomus	longnose sucker
Gadidae	
Lota lota	burbot
Gasterosteidae	
Gasterosteus aculeatus	threespine stickleback
Pungitius pungitius	ninespine stickleback
Cottidae	
Cottus spp.	sculpin

Source: ADF&G SuHydro, Anchorage, Alaska.

Table III-2. Commercial catch of upper Cook Inlet salmon in numbers of fish by species, 1954 - 1984.

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	1,834,022
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	19,210	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	4,780	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	544,184	1,233,733	1,049,704
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
1982	20,636	3,237,376	777,132	788,972	1,428,621	6,252,737
1983	20,396	5,003,070	520,831	73,555	1,124,421	6,742,273
1984 (1)	8,800	2,103,000	443,000	623,000	684,000	3,861,800
Average	19,247	1,340,339	263,785	even-1,576,646 odd - 120,416	659,190	3,058,170

(1) ADF&G Preliminary Data, Commercial Fish Division, Anchorage, Alaska

$2.0 million, while the coho salmon harvest of 443,000 fish was worth $1.8 million (K. Florey, ADF&G, pers. comm. 1984). The estimated contribution of Susitna River chum to the upper Cook Inlet commercial fishery is estimated to be 85 percent, while the estimated contribution of Susitna River coho to the fishery is approximately 50 percent (ADF&G 1984a).

Pink salmon is the least valued of the commercial species in upper Cook Inlet. In 1984, the pink salmon harvest of 623,000 fish was worth an estimated $0.5 million (K. Florey, ADF&G, pers. comm. 1984), of which Susitna River pink salmon contributed about 85 percent (ADF&G 1984a).

Since 1964 the upper Cook Inlet commercial salmon fishery has opened in late June to avoid capturing chinook salmon. Thus, most chinook salmon have entered their natal streams when the commercial fishing season opens and their harvest is incidental to the commercial catch. In 1984, the 8,800 chinook harvested in upper Cook Inlet had a commercial value of $0. million (K. Florey, ADF&G, pers. comm. 1984). It is estimated that the Susitna River contribution of chinook salmon was about 10 percent (ADF&G 1984a).

In the last four years (1981-1984) sockeye, chum and coho salmon harvests, which account for over 95 percent of the commercial value in the fishery, have exceeded the long-term average catches for those species (Table III-2). Record catches for coho and chum were recorded in 1982 and for sockeye in 1983.

Sport Fishing

The Susitna River, along with many of its tributaries, provides a multi-species sport fishery easily accessible from Anchorage and other Cook Inlet communities. Since 1978, the Susitna River and its tributaries have accounted for an annual average of 127,100 angler days of sport fishing effort (Mills 1979, 1980, 1981, 1982, 1983, 1984). This represents approximately 13 percent of the 1977-1983 annual average of 1.0 million total angler days for the Southcentral region. Most of the sport fishing in the Susitna Basin occurs in the lower Susitna River from the Deshka River (RM 40.5) upstream to the Parks Highway (RM 84).

Most sport fishing activity occurs in tributaries and at tributary mouths, while the mainstem receives less fishing pressure. Coho and chinook salmon are most preferred by sport anglers in the Susitna River. In addition many pink salmon are taken during even-year runs. The annual sport harvest of coho salmon in the Susitna River is significant when compared to the estimated total coho escapement. In 1983, almost one of every five coho salmon entering the Susitna River was caught by sport anglers (Table III-3). The annual harvest of chinook salmon in the Susitna River has increased from 2,850 fish in 1978 to 12,420 fish in 1983 (Table III-4). During this period, the contribution of the Susitna River chinook sport harvest to the Southcentral Alaska chinook sport harvest has increased from 11 to 22 percent.

Rainbow trout and Arctic grayling sport fishing occurs primarily near the mouths and in the lower reaches of Fourth of July Creek, Indian River and Portage Creek. River boat service out of Talkeetna provides access for some anglers to the salmon, trout and grayling fishing areas in the middle reach of the Susitna River.

Subsistence Fishing

Subsistence harvests within the Susitna Basin are unquantified even though salmon provide an important resource for Susitna Basin residents. The village of Tyonek, approximately 30 miles (50 km) southwest of the Susitna River mouth, is supported primarily by subsistence fishing on Susitna River chinook stocks. The annual Tyonek subsistence harvest has averaged 2,000 chinook, 250 sockeye and 80 coho per year from 1980 through 1983 (ADF&G 1984b).

Table III-3. Summary of commercial and sport harvest on Susitna River basin adult salmon returns.

	Commercial Harvest						Sport Harvest	
Species	Upper Cook Inlet Harvest[1]	Estimated Percent Susitna[2] Mean	Range	Estimated Susitna Harvest	Estimated Susitna Escapement[3]	Estimated Total Run	Susitna Basin Sport Harvest[4]	Percent of Escapement
Sockeye								
81	1,443,000	20	(10-30)	288,600	287,000	575,600	1,283	0.4
82	3,237,000	20	(10-30)	647,400	279,000	926,400	2,205	0.8
83	5,003,000	10	(10-30)	500,300	185,000	685,300	5,537	3.0
Pink								
81	128,000	85		108,800	127,000	235,800	8,660	6.8
82	789,000	85		670,650	1,318,000	1,988,650	16,822	1.3
83	74,000	85		62,900	150,000	212,900	4,656	3.1
Chum								
81	843,000	85		716,550	297,000	1,013,550	4,207	1.4
82	1,429,000	85		1,214,650	481,000	1,695,650	6,843	1.4
83	1,124,000	85		955,400	290,000	1,245,400	5,233	1.8
Coho								
81	494,000	50		247,000	68,000	315,000	9,391	13.8
82	777,000	50		388,500	148,000	536,500	16,664	11.3
83	521,000	50		260,500	45,000	305,500	8,425	18.7
Chinook								
81	11,500	10		1,150	---	---	7,576	---
82	20,600	10		2,060	---	---	10,521	---
83	20,400	10		2,040	---	---	12,420	---

1 Source: ADF&G Commercial Fisheries Division

2 B. Barrett, ADF&G Su Hydro, February 15, 1984 Workshop Presentation

3 Yentna Station + Sunshine Station estimated escapement + 5% for sockeye[2]
+ 48% for pink[2]
+ 5% for chum[2]
+ 85% for coho[2]

4 Mills 1982, 1983, 1984

Table III-4. Sport fish harvest for Southcentral Alaska and Susitna Basin in numbers of fish by species, 1978-1983.

Year	Arctic Grayling		Rainbow Trout		Pink Salmon		Coho Salmon		Chinook Salmon		Chum Salmon		Sockeye Salmon	
	South-central	Susitna Basin	South-central	Susitna Basin	South-central	Susitna Basin	South-central	Susitna Basin	South-central	Susitna Basin	South-central	Susitna Basin	South-central	Susitna Basin
1978	47,866	13,532	107,243	14,925	143,483	55,418	81,990	15,072	26,415	2,843	23,755	15,667	118,299	845
1979	70,316	13,342	129,815	18,354	63,366	12,516	93,234	12,893	34,009	6,910	8,126	4,072	77,655	1,586
1980	69,462	22,083	126,686	15,488	153,794	56,621	127,958	16,499	24,155	7,389	8,660	4,759	105,914	1,304
1981	63,695	21,216	149,460	13,757	64,163	8,660	95,376	9,391	35,822	7,576	7,810	4,207	76,533	1,283
1982	60,972	18,860	142,579	16,979	105,961	16,822	136,153	16,664	46,266	10,521	13,497	6,843	128,015	2,205
1983	56,896	20,235	141,663	16,500	47,264	4,656	87,935	8,425	57,094	12,420	11,043	5,233	170,799	5,537
Average	61,535	18,211	132,908	16,000	134,413 (even) 58,264 (odd)	42,954 (even) 8,611 (odd)	103,774	13,157	37,294	7,943	12,149	6,797	112,869	2,128

Source: Mills (1979-1984)

Relative Abundance of Adult Salmon by Sub-Basin

Major salmon-producing tributaries to the Susitna River include the Yentna River drainage (RM 28), the Chulitna River drainage (RM 98.6) and the Talkeetna River drainage (RM 97.1). Numerous other smaller tributaries also contribute to the salmon production of the Susitna River. Salmon escapements can be estimated for four major sub-basins of the Susitna River (Figure III-1):

- o the lower Susitna River sub-basin;
- o the Yentna River sub-basin;
- o the Talkeetna-Chulitna sub-basin; and
- o the Talkeetna-Devil Canyon sub-basin.

Lower Susitna River Sub-basin

The lower Susitna River sub-basin includes the Susitna River and all of its adjoining tributary drainages within the eighty-mile reach from Cook Inlet to Sunshine Station with the exception of the Yentna River drainage (RM 28). Escapement estimates for the lower Susitna sub-basin are inferred by subtracting the ADF&G escapements for Yentna Station [Tributary Mile (TRM) 04] and Sunshine Station (RM 80) from the total Susitna River escapements estimated by ADF&G (1984a). Because total escapement estimates are based in part on professional judgment, the description of escapements to the lower Susitna River sub-basin provided in Table III-5 should be viewed as approximations.

During even numbered years, when pink salmon runs are large, approximately 500,000 salmon spawn in the lower Susitna sub-basin. This represents about 24 percent of the estimated 2.1 million salmon in the Susitna River basin during even numbered years.

The lower Susitna River sub-basin also provides important habitat for coho salmon. About 46 percent of the annual coho escapement spawn in this sub-basin. The annual sockeye and chum escapements to this sub-basin account for approximately 5 percent of the total annual

Table III-5. Susitna River average annual salmon escapement by sub-basin and species

Sub-basin	Sockeye[1] Number	Sockeye[1] % of Total	Chum[2] Number	Chum[2] % of Total	Coho[2] Number	Coho[2] % of Total	Pink[3] Number	Pink[3] % of Total	Chinook[4] Number	Chinook[4] % of Total	Sub-basin Total Number	Sub-basin Total % of Total
Lower Susitna[5] (RM 0 to 80)	11,900	5	17,000	5	39,900	46	Even 427,400 Odd 44,800	32 33	---	---	Even 496,200 Odd 113,600	24 12
Yentna[6] (RM 28)	119,200	48	19,500	5	20,000	23	Even 447,300 Odd 48,400	34 35	---	---	Even 606,000 Odd 207,100	29 23
Talkeetna-Chulitna[7] (RM 80 to 98.6)	116,000	46	295,600	83	24,700	28	Even 338,400 Odd 40,600	30 29	62,000	---	Even 886,700 Odd 538,900	43 60
Talkeetna-Devil Canyon[8] (RM 98.6 to 152)	2,800	1	24,100	7	2,200	3	Even 54,800 Odd 4,400	4 3	9,500	---	Even 93,400 Odd 43,000	4 4
Total Susitna	249,900	100	356,200	100	86,800	100	Even 1,267,900 Odd 138,200	100	---	---	Even 2,082,300 Odd 43,000	100 100

1 1981-83 average of ADF&G second-run sockeye escapements (ADF&G 1984a)
2 1981-83 average of ADF&G escapement estimates (ADF&G 1984a)
3 Even year 1982 only; odd year 1981 and 1983 average (ADF&G 1984a)
4 1982-83 average of ADF&G escapement estimates (ADF&G 1984a)
5 Lower Susitna sub-basin equals total Susitna basin escapement minus Yentna and Sunshine escapements
6 Yentna sub-basin escapement equals Yentna Station (TRM 04) escapement (ADF&G 1984a)
7 Talkeetna-Chulitna sub-basin escapement equals Sunshine Station (RM 80) escapement minus Talkeetna-Devil Canyon sub-basin escapement
8 Talkeetna-Devil Canyon sub-basin escapement equals Talkeetna Station (RM 103) escapement minus milling fish that return downstream. Milling rates: sockeye 30%, chum 40%, pink 25%, chinook 25%, coho 40% (ADF&G 1984a)
9 Total Susitna basin escapement equals Yentna Station (TRM 04) escapement plus Sunshine Station (RM 80) escapement plus: 5% for sockeye, 48% for pink, 5% for chum, 85% for coho (ADF&G 1984a)

sockeye and chum escapements in the Susitna River basin. The estimated annual chinook escapement to this sub-basin is unknown but several major chinook-producing tributaries, including the Deshka River, Alexander Creek, Montana Creek, and Willow Creek, occur in this reach.

Yentna River Sub-basin

The Yentna River sub-basin includes the entire length of the Yentna River (RM 28) and all of its tributary drainages. Escapement estimates for this sub-basin are based on ADF&G apportioned sonar counts at Yentna Station (TRM 04).

The Yentna sub-basin provides important pink salmon spawning habitat with approximately 600,000 salmon entering the sub-basin during even years. This comprises about 29 percent of the estimated 2.1 million even-year salmon escapement for the Susitna Basin.

The annual sockeye escapement into the Yentna sub-basin is also significant, accounting for 48 percent of the estimated annual Susitna Basin sockeye escapement of 250,000 fish. About 23 percent of the annual coho escapement enter this sub-basin. The annual escapement of chum salmon into the Yentna sub-basin is about 5 percent of the total escapement to the Susitna Basin.

Talkeetna-Chulitna Sub-basin

The Talkeetna-Chulitna sub-basin includes both the Talkeetna and Chulitna River drainages, and that portion of the Susitna River and its tributaries upstream from Sunshine Station (RM 80) to the three rivers confluence. Escapement estimates for this sub-basin are derived by subtracting the estimated escapements for the Talkeetna-Devil Canyon sub-basin from ADF&G escapements at Sunshine Station.

The Talkeetna-Chulitna sub-basin has an estimated 886,700 salmon entering the sub-basin during even years, which comprises about 43 percent of the estimated even-year Susitna Basin escapement of 2.1 million salmon. The odd-year salmon escapement to this sub-basin accounts for 60 percent of the odd-year salmon escapement to the Susitna Basin. Thus, the Talkeetna-Chulitna sub-basin is the most important salmon-producing sub-basin in the Susitna River.

The Talkeetna-Chulitna sub-basin provides significant spawning habitat for two important commercial species: sockeye and chum salmon. Approximately 83 percent of the estimated annual Susitna Basin chum escapement and 46 percent of the total annual Susitna River sockeye escapement enter the Talkeetna-Chulitna sub-basin. About 29 percent of the even-year pink escapement and 28 percent of the annual coho escapement enter this sub-basin. The estimated annual chinook escapement to this sub-basin is 62,000 fish.

Talkeetna-Devil Canyon Sub-basin

The Talkeetna-Devil Canyon sub-basin consists of the fifty mile segment of the Susitna River between the three rivers confluence and Devil Canyon including all tributary drainages. Escapement estimates for this sub-basin are based on ADF&G population estimates at Talkeetna Station (RM 103), which have been reduced to account for milling fish that return downstream to spawn below Talkeetna Station. Milling rates estimated by ADF&G (1984a) are: 30 percent for sockeye, 40 percent for chum, 40 percent for coho, 25 percent for pink and 25 percent for chinook. These statistics are based on the total numbers of fish counted at Talkeetna Station.

Approximately 93,400 salmon enter the Talkeetna-Devil Canyon sub-basin during even years. This is approximately 4 percent of the estimated 2.1 million salmon entering the Susitna Basin in even years.

Excluding even-year pink salmon, chum and chinook are the most abundant salmon species in this sub-basin. The annual chum escapement to the Talkeetna-Devil Canyon sub-basin accounts for about 7 percent of the estimated annual Susitna Basin chum escapement of 356,200 fish. The estimated annual chinook escapement to this sub-basin is 9,500 fish, however, the contribution to the Susitna Basin chinook escapement cannot be estimated because the total Susitna River chinook escapement is unknown. The annual sockeye, coho and pink salmon escapements to this sub-basin account for less than five percent of the total escapements for each species to the Susitna Basin.

Relative Abundance and Timing of Juvenile Salmon and Resident Species

Juvenile Salmon

The relative abundance of juvenile salmon in sub-basins of the Susitna River can only be approximated because:

- population estimates of outmigrating juvenile salmon have been done only for chum and sockeye salmon in the Talkeetna-Devil Canyon sub-basin;

- catch per unit effort data are available from smolt traps in the Talkeetna-Dev . Canyon sub-basin, but comparable data are unavailable from other sub-basins; and

- the downstream redistribution of rearing chinook, sockeye and coho juveniles results in movement between sub-basins.

Therefore, the following discussion is based pri ily on inference and professional judgment.

Chum salmon rear in the middle Susitna River for one to three months, while pink salmon spend little time in this reach (ADF&G 1984c). Because of this short freshwater residence time, it is expected that after emergence the relative abundance of juve le chum and pink would reflect the sub-basin adult spawner relative oundance. This assumes that fecundities and egg-to-emergent fry survival rates are not significantly different between sub-basins. Thus, it is expected that most juvenile chum would rear in the Talkeetna-Chulitna sub-basin, whereas juvenile pink relative abundance would be evenly divided among the Lower Susitna, the Yentna and the Talkeetna-Chulitna sub-basins. This is based on the relative abundance of adult chum and pink salmon presented in Table III-5. As chum and pink smolts begin to outmigrate, the relative abundance in the lower Susitna River would increase in comparison to the relative abundance in other sub-basins until outmigration is completed. The outmigration of juvenile chum from the middle Susitna River extends from May through July, whereas most juvenile pink salmon leave this reach of river by June (ADF&G 1984c). Outmigration timing of pink and chum juveniles is positively correlated with mainstem discharges (ADF&G 1984c).

Chinook, sockeye and coho salmon rear from one to three years in the Susitna River (ADF&G 1984c). Because of the longer freshwater residence time, the downstream redistribution of juvenile chinook, sockeye and coho from the Talkeetna-Devil Canyon sub-basin and possible redistribution of juvenile salmon in other sub-basins, it is less likely that the relative abundance of outmigrating chinook, sockeye and coho smolts from sub-basins reflects the relative abundance of adult spawners. In the Talkeetna-Devil Canyon sub-basin, it is expected that the sockeye smolt abundance relative to adult spawners would be less than sub-basins where rearing conditions are more favorable.

Age 0+ juveniles of chinook, coho and sockeye salmon move downstream out of the middle Susitna River throughout the summer with peak movements occurring in June, July and August (ADF&G 1984c). Chinook, coho and sockeye juveniles that remain in the middle Susitna River utilize rearing habitats until September and October when they move to overwintering habitats. Age 1+ chinook, coho and sockeye and age 2+ coho outmigrate from the middle Susitna River primarily in June (ADF&G 1984c).

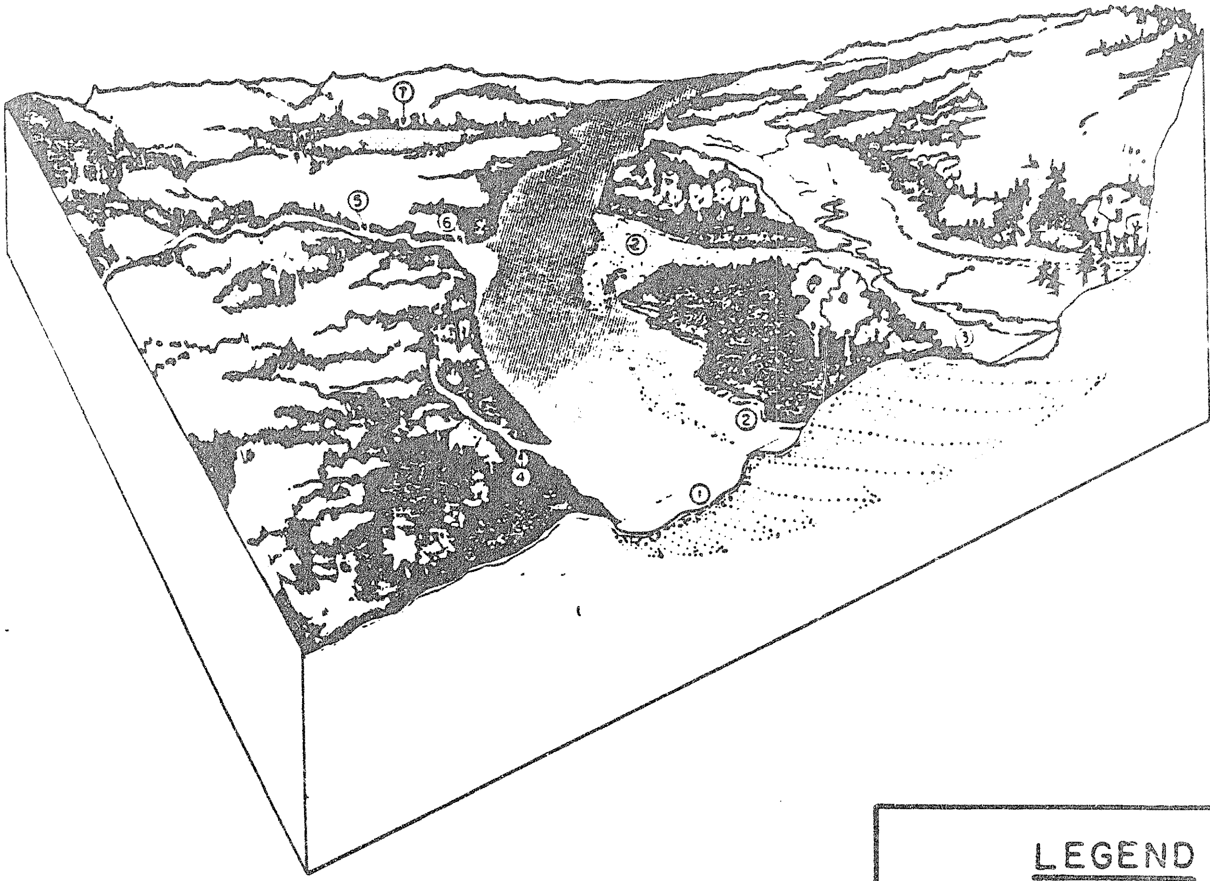
Resident species such as rainbow trout and Arctic grayling primarily use aquatic habitats within the middle Susitna River during all phases of their life cycle. However, movements between sub-basins may be significant for some resident species such as Dolly Varden, round whitefish, and humpback whitefish (ADF&G 1984c).

Identification and Utilization of Habitat Types

Fish habitat is the integrated set of environmental conditions to which a particular species/life phase responds both behaviorally and physiologically. Temperature, water quality, streamflow, and channel structure are among the most important abiotic environmental factors affecting the amount and quality of lotic (riverine) fish habitat. Important biological factors include food availability, parasitism or disease, and predation.

The complex of primary, secondary and overflow channels that exists within the Talkeetna-to-Devil Canyon segment of the Susitna River provides a great diversity of habitat conditions.

Six major aquatic habitat types, having comparatively similar morphologic, hydrologic and hydraulic characteristics, have been identified within the Talkeetna-to-Devil Canyon reach of the Susitna River: mainstem, side channel, side slough, upland slough, tributary, and tributary mouth (Figure III-2) (ADF&G 1983c). Within these aquatic habitat types, varying amounts and qualities of fish habitat may exist within the same habitat type depending upon site-specific thermal, water quality, channel structure and hydraulic conditions. Differentiation of aquatic habitat types is useful for evaluating the seasonal utilization patterns and habitat preferences of the fish species/life stages which inhabit the middle Susitna River as well as determining the influence of seasonal variations in streamflow on the availability of potential aquatic habitat. The seasonal utilization of the middle Susitna River habitat types by fish is primarily dependent upon the abiotic conditions they offer the species and life stage under consideration. Abiotic habitat conditions are primarily influenced by streamflow, stream temperature and water quality which in the middle Susitna River vary markedly among habitat types and also change with the season of the year (ADF&G 1983c).



LEGEND

1. Mainstem Habitat
2. Side Channel Habitat
3. Side Slough Habitat
4. Upland Slogh Habitat
5. Tributary Habitat
6. Tributary Mouth Habitat

Note: A more detailed description of these habitat types can be found in Section III-D of this report.

Figure III - 1. General habitat types of the Susitna River.

Mainstem Habitat

Mainstem habitat is defined as those portions of the Susitna River which normally convey the largest amount of streamflow throughout the year. Both single and multiple channel reaches, as well as poorly defined water courses flowing through partially vegetated gravel bars or islands, are included in this aquatic habitat category.

Mainstem habitats are thought to be predominantly used as migrational corridors by adult and juvenile salmon during summer. Isolated observations of chum salmon spawning at upwelling sites along shoreline margins have been reported (ADF&G 1982a). Also, mainstem habitats are utilized by several resident species; most notably Arctic grayling, burbot, longnose sucker, rainbow trout and whitefish.

Turbid, high-velocity, sediment-laden summer streamflows and low, cold, ice-covered, clearwater winter flows are characteristic of this habitat type. Channels are relatively stable, high gradient and well armored with cobbles and boulders. Interstitial spaces between these large streambed particles are generally filled with a grout-like mixture of small gravels and glacial sands. Isolated deposits of small cobbles and gravels exist, however they are usually unstable.

Groundwater upwellings and clearwater tributary inflow appear to be inconsequential determinants of the overall characteristics of mainstem habitat except during winter when they dominate mainstem water quality conditions.

Side Channel Habitats

Side channel habitat is found in those portions of the river which normally convey streamflow during the summer, but become appreciably dewatered during periods of low flow. For convenience of classification and analysis, side channels are defined as conveying less than 10 percent of the total flow passing a given location in the river. Side channel habitat may exist in well-defined channels, or in poorly defined water courses flowing through submerged gravel islands or along shoreline or mid-channel margins of mainstem habitat.

Juvenile chinook appear to make the most extensive use of side channel habitats, particularly during July and August (ADF&G 1984c). A limited amount of chum salmon spawning also occurs in side channel habitats where upwelling is present and velocities and substrate composition are suitable (ADF&G 1984d). Resident species, such as burbot and whitefish, also utilize side channel habitats.

In general, the turbidity, suspended sediment and thermal characteristics of side channel habitats reflect mainstem conditions. The exception is in quiescent areas, where suspended sediment concentrations are less. Side channel habitats are characterized by shallower depths, lower velocities and smaller streambed materials than mainstem habitats. However, side channel velocities and substrate composition often provide suboptimal habitat conditions for both adult and juvenile fish.

The presence or absence of clearwater inflow, such as groundwater upwellings or tributaries, is not considered a critical component in the designation of side channel habitat. However, a strong positive correlation exists between the location of such clearwater inflows and the location of chum salmon spawning sites that exist within side channel habitats (ADF&G 1984d). In addition, tributary and groundwater inflow prevents some side channel habitat from becoming completely dewatered when mainstem flows recede in September and October. These clearwater areas are suspected of being important for primary production prior to the formation of a winter ice cover.

Side Slough Habitats

With the exception of the clearwater tributaries, side slough habitats are probably the most productive of all the middle Susitna River aquatic habitat types. Side slough habitats typically exist in overflow channels, which originate from riverine physical processes such as flood events or ice gouging. Clearwater inflows from local runoff and/or upwelling are components of this aquatic habitat type. Periodic overtopping by high mainstem discharge events is the most distinguishing characteristic of side slough habitat (ADF&G 1983c).

A non-vegetated alluvial berm connects the head of the slough to the mainstem or a side channel. A well vegetated gravel bar or island parallels the slough separating it from the mainstem (or side channel). During intermediate and low-flow periods, mainstem water surface elevations are insufficient to overtop the alluvial berm at the upstream end (head) of the slough. However, the mainstem stage is often sufficient at the downstream end (mouth) of the slough to cause a backwater effect to extend a few hundred feet upstream into the slough (Trihey 1982).

Approximately 80 percent of all middle Susitna River chum salmon spawning in non-tributary habitats and essentially all sockeye salmon spawning occurs in side slough habitat (ADF&G 1981, 1982a, 1984a). In early spring, large numbers of juvenile chum and sockeye salmon can be found in side sloughs. During summer, moderate numbers of juvenile coho and chinook make use of side-slough habitats, with chinook densities increasing during the fall-winter transition (ADF&G 1984b). Small numbers of resident species are also present throughout the year.

Considerable variation in water chemistry has been documented among side sloughs and is principally a function of local runoff patterns and basin characteristics when the side sloughs are not overtopped. Once overtopped, side sloughs display the water quality characteristics of the mainstem (ADF&G 1982b). Presumably side sloughs provide better habitat for aquatic organisms than mainstem or side channel areas largely because side sloughs convey turbid water less frequently than other channels and contain warmer water year round.

During periods of high mainstem discharge, the water surface elevation of the mainstem is often sufficient to overtop the alluvial berms at the heads of some sloughs. When this occurs, discharge through the side slough increases markedly as water in the slough is replaced with turbid mainstem flow. Such overtopping events affect the thermal, water quality and hydraulic conditions of side slough habitat (ADF&G 1982b). Depending upon their severity, overtopping events may flush organic material and fine sediments from the side slough, or totally rework the channel geometry and substrate composition.

Streambed materials in side slough habitats tend to be a heterogeneous mixture of coarse sands, gravels and cobbles often overlain by fine glacial sands in quiescent areas. Perhaps because of the upwelling or the less frequent conveyance of mainstem water, streambed materials in side slough habitats do not appear to be as cemented or grouted as similar size particles would be in side channel habitats.

When side sloughs are not overtopped, surface water temperatures respond independently of mainstem temperatures (ADF&G 1982b). Surface water temperatures in side sloughs are strongly influenced by upwelling groundwater. In many instances during winter, the thermal effect of the upwelling water is sufficient to maintain relatively ice free conditions in the side sloughs throughout winter (Trihey 1982, ADF&G 1983a).

Upland Slough Habitats

Upland slough habitats are clearwater systems which exist in relic side channels or overflow channels. They differ from side slough habitats in several ways. The most apparent reason for many of these differences is because the elevation of the upstream berm, which separates these habitats from adjacent mainstem or side channels, is sufficient to prevent overtopping in all but the most extreme flood or ice jam events. Upland sloughs typically possess well vegetated streambanks which are often quite steep, near zero flow velocities, and sand or silt streambeds. Active or abandoned beaver dams and food caches are commonly observed in upland slough habitats.

Upwelling is often present in upland sloughs, however, little spawning occurs in these habitats (ADF&G 1984a). The most extensive use is by juvenile sockeye and coho salmon (ADF&G 1984c).

The primary influence of the mainstem or side channel flow adjacent to the upland slough is to regulate its depth by backwater effects. The water surface elevation of the adjacent mainstem or side channel often controls the water surface elevation at the mouth of the upland slough. Depending upon the rate at which the mainstem water surface elevation responds to storm events relative to the response of local runoff into the upland slough, turbid mainstem water may or may not enter the slough. The rapid increase in mainstem water surface elevations and suspended sediment concentrations in association with peak flow events is suspected of being a primary transport mechanism of fine sediments into the backwater areas of upland sloughs. Local surface water inflow and bank erosion may be major contributors of sediments in reaches upstream of backwater areas and beaver dams.

Tributary Habitat

Tributary habitats reflect the integration of its watershed characteristics and are independent of mainstem flow, temperature and sediment regimes. Middle Susitna River tributary streams convey clear water throughout the year which originates from snowmelt, rainfall runoff or groundwater base flow.

Tributaries to the middle Susitna River provide the only reported spawning of chinook salmon, and nearly all the coho and pink salmon spawning that occurs in this river segment (ADF&G 1984a). Approximately half the chum salmon escapement to the middle Susitna River also spawn in tributary habitat. Pink salmon juveniles outmigrate shortly after emergence and juvenile chum leave within one to two months, but a large percentage of emergent chinook and coho remain in tributary streams for several months following emergence (ADF&G 1984c). Resident species such as Arctic grayling and rainbow trout also greatly depend on tributary streams for spawning and rearing habitat.

Tributary Mouth Habitat

Tributary mouth habitat refers to that portion of the tributary which adjoins the Susitna River. The areal extent of this habitat responds to changes in mainstem discharge. By definition, this habitat extends from the uppermost point in the tributary influenced by mainstem backwater effects to the downstream extent of its clearwater plume.

This habitat type is an important feeding station for juvenile chinook and resident fish (ADF&G 1982a). Tributary mouth habitat associated with the larger tributaries within the middle Susitna River also provides significant spawning habitat for pink and chum salmon (ADF&G 1984a).

Selection of Evaluation Species

Selection of evaluation species followed the guidelines and policies of the Alaska Power Authority, Alaska Department of Fish and Game and U.S. Fish and Wildlife Service which imply that species with commercial, subsistence and recreational uses are given high priority. The habitats of those species that are likely to be significantly influenced by the project are of the greatest concern. The primary species and life stages selected for evaluation were chum salmon spawning adults and incubating embryos, and chinook salmon rearing juveniles (Woodward-Clyde Consultants 1984). These species/life stages depend on side slough and side channel habitats, which are expected to be significantly affected by project operation. The following discussion provides a synopsis of the baseline data used in the selection of evaluation species.

Surveys of spawning adult salmon conducted during 1981-83 by the Alaska Department of Fish and Game (ADF&G 1984a) indicate that tributaries and side sloughs are the primary spawning areas for the five species of Pacific salmon that occur in the middle reach of the Susitna River (Figure III-2). Comparatively small numbers of fish spawn in mainstem, side channel, upland slough and tributary mouth habitats.

Chum and sockeye are the most abundant of the four species that spawn in non-tributary habitats in the Talkeetna-to-Devil Canyon reach of the Susitna River (ADF&G 1984a). The estimated number of chum salmon spawning in non-tributary habitats within the middle Susitna River averaged 4,200 fish per year for the 1981-83 period of record (ADF&G 1984a). Approximately 1,600 sockeye per year spawned exclusively in slough habitat during the same period. A few pink salmon utilize side channels and side sloughs for spawning during even-numbered years (ADF&G 1984a). Similarly, only a few coho salmon spawn in non-tributary habitats of the Susitna River (ADF&G 1984a).

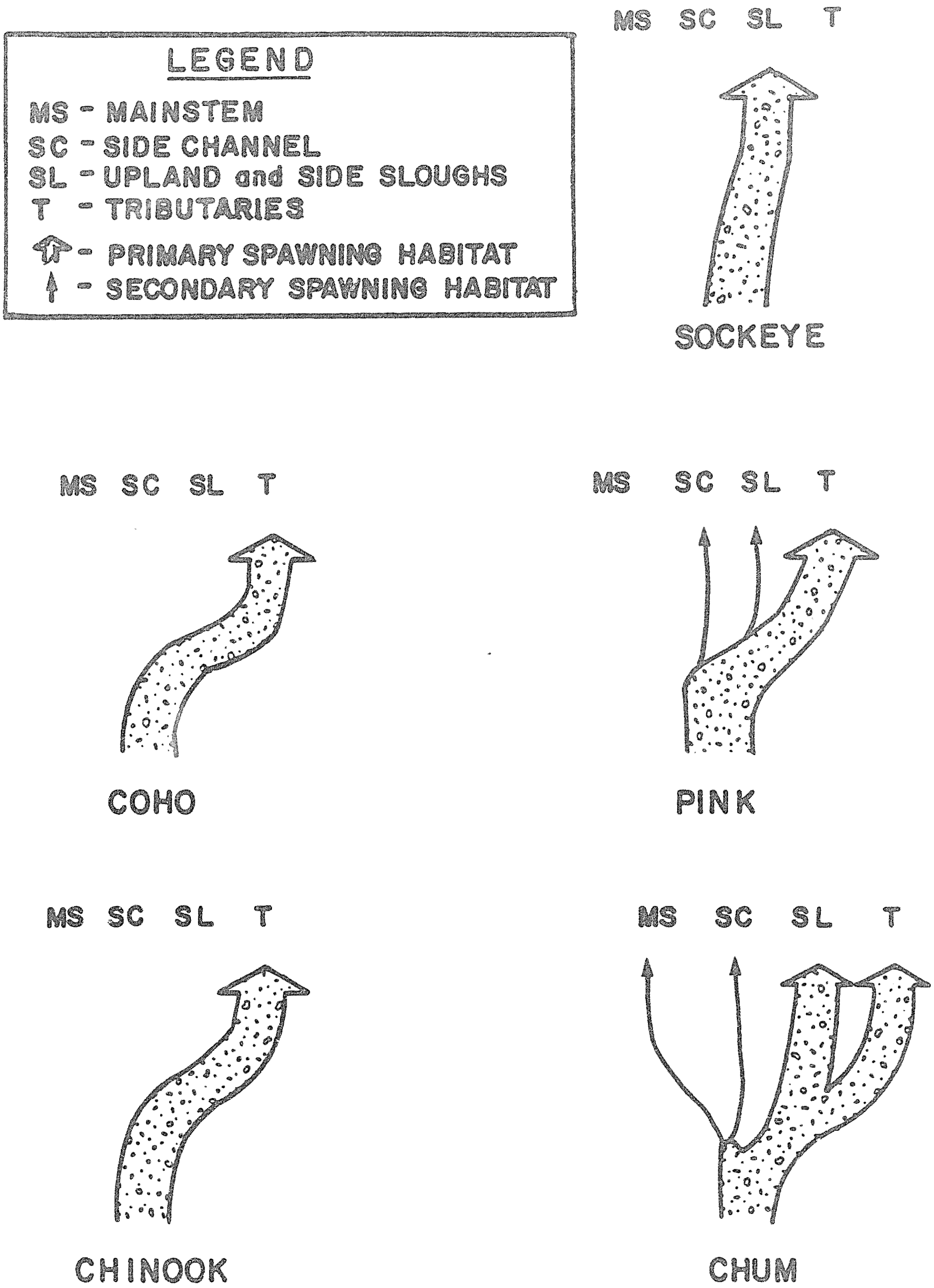


Figure III-2. Relative distribution of salmon spawning within different habitat types of the middle Susitna River. (ADF&G 1984c).

Approximately 80 percent of all chum salmon spawning in non-tributary habitats within the middle Susitna River occurs in side slough habitats, with Sloughs 21, 11, 9, 9A and 8A accounting for 75 percent of the annual slough spawning (ADF&G 1981, 1982, 1984a). Extensive surveys of side channel and mainstem areas have documented comparatively few spawning areas (ADF&G 1981, 1982, 1984a); however, these habitats are often characterized by highly turbid water in which spawning fish or their redds are difficult to detect, possibly causing an underestimation of their value as spawning habitat.

Within the Talkeetna-to-Devil Canyon reach, spawning sockeye salmon are distributed among eleven sloughs, with Sloughs 11, 8A, and 21 accounting for more than 95 percent of the spawning on a yearly basis (ADF&G 1984a). In 1983, 11 sockeye salmon were observed spawning alongside 56 chum salmon in the mainstem approximately 0.5 miles upstream of the mouth of the Indian River (ADF&G 1984a). This is the only recorded occurrence of sockeye salmon spawning in middle Susitna River areas other than slough habitats.

Chum and sockeye salmon spawning areas commonly overlap at all of the locations where sockeye spawning has been observed (ADF&G 1984a). This overlap is likely a result of similar timing and habitat requirements (ADF&G 1984a and d). Because chum salmon appear to be more constrained by passage restrictions and low water depth during spawning than sockeye salmon, the initial evaluation and analysis of flow relationships on existing salmon spawning in the middle Susitna River is on chum salmon with the assumption that sockeye salmon will respond similarly.

Depending upon the season of the year, rearing habitat for juvenile salmon is provided in varying degrees by all aquatic habitat types found within the middle Susitna River. Among the non-tributary habitats, juvenile salmon densities are highest in side and upland sloughs and side channel areas (Figure III-3). Extensive sampling for juveniles has not been conducted in mainstem habitats, largely due to sampling gear inefficiency in typically deep, fast, turbid waters.

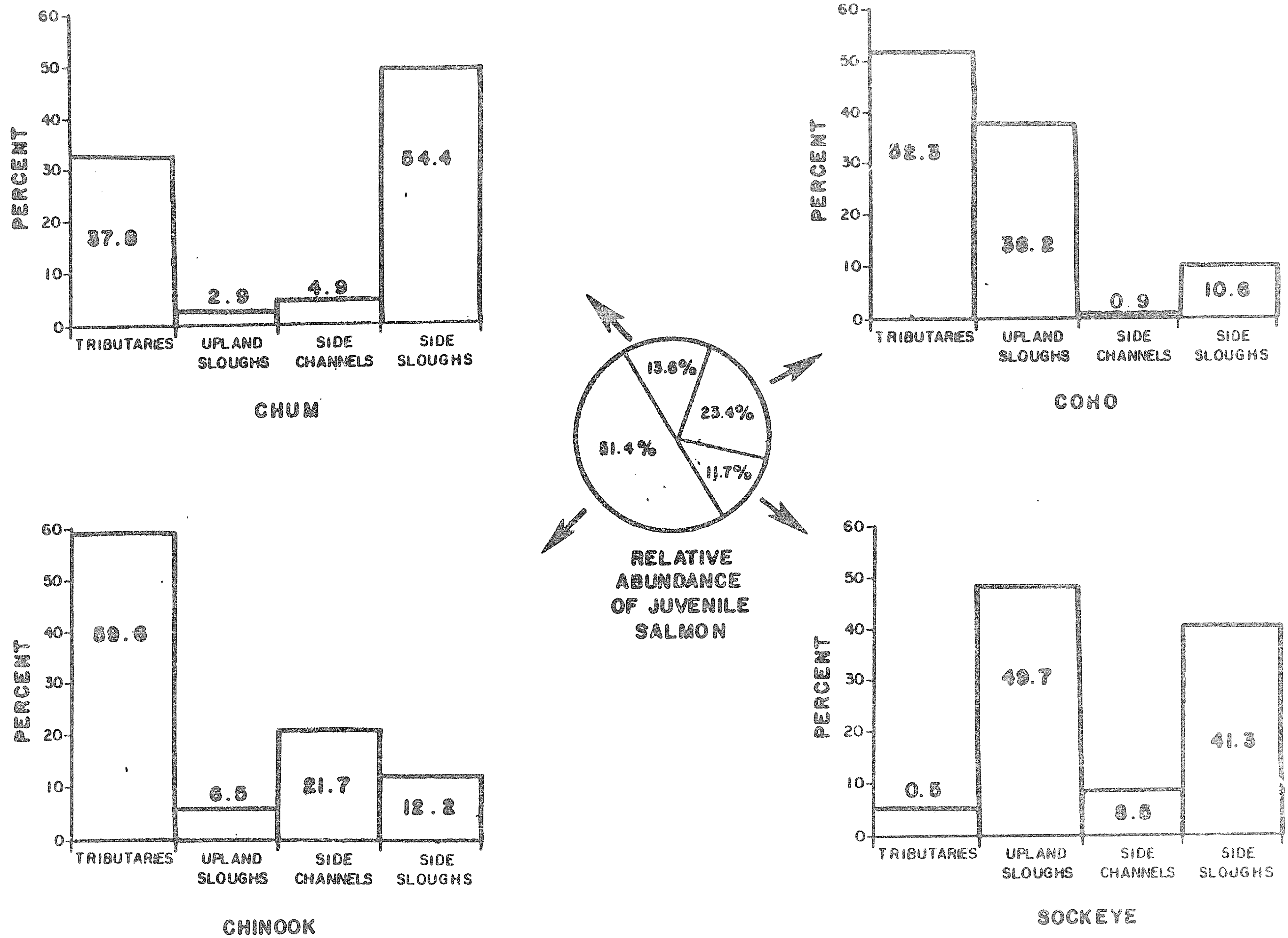


Figure III-3. Relative abundance and distribution of juvenile salmon within different habitat types of the middle Susitna River (ADF&G 1984c).

Little utilization of these habitats is expected except in the lateral margins that have low velocities.

Coho salmon juveniles are most abundant in tributary and upland slough habitats. In general, these habitats do not respond significantly to variations in mainstem discharge (Klinger and Trihey 1984). Sockeye juveniles, although relatively few in number, make extensive use of upland slough and side slough habitats within the middle Susitna River. In contrast, juvenile chum and chinook salmon are quite abundant in the middle Susitna River and are most numerous in side slough and side channel habitats (ADF&G 1984c). These habitats respond markedly to variations in mainstem discharge (Klinger and Trihey 1984). For this reason, these two species, chinook and chum, have been selected for evaluating rearing conditions for juvenile salmon within the middle Susitna River.

Based on the information available from resident fish studies, resident fish have not been selected for evaluation in the middle Susitna River. Project-induced changes to middle Susitna River habitats are not expected to significantly affect important resident fish populations including rainbow trout, Arctic grayling and burbot. These populations are low and appear to be limited by factors other than those associated with mainstem discharge.

With the exception of burbot, important resident species on the middle Susitna River are mainly associated with tributary habitats. Both rainbow trout and Arctic grayling are important sport species in the basin. The spawning and rearing for these two species occur almost exclusively in tributary and tributary mouth habitats. Some individuals of both species use mainstem habitats for overwintering.

The availability of spawning and rearing habitats appears to limit the present population of rainbow trout (ADF&G 1984c). Few rearing fish have been captured in habitat types other than tributaries associated with lakes. Since the proposed project will have little effect on tributary habitat, no change is predicted for rainbow trout populations.

Arctic grayling are also closely associated with tributary habitats. The major limiting factor for these fish is probably rearing habitat (ADF&G 1984c). Some small Arctic grayling are found in mainstem habitats, but these fish are probably excluded from better quality rearing areas in the tributaries by territorial displacement by larger juveniles.

Few burbot are found in the middle reach of the Susitna River (ADF&G 1984c). Burbot are found almost exclusively in mainstem and side channel habitats, as they appear to prefer turbid habitats. Although turbidity levels will be reduced under project conditions, low numbers of burbot are still expected to occupy mainstem habitats. Mainstem turbidities are expected to be greater than 30 NTUs under project conditions. This level will still cause light extinction quickly, allowing burbot to occupy depths greater than 3 ft (estimated euphotic zone, see Section IV). Burbot populations are likely limited by food supply (ADF&G 1984c). The production of other resident species is important to maintaining burbot populations in the middle Susitna River. Since significant changes to these populations are not expected, burbot population levels are not likely to change significantly.

As the habitat relationships analysis continues, additional fish may be included in the evaluation species list. Overwintering rainbow trout and rearing juvenile grayling may be appropriate candidates. Other species whose populations may be influenced by project conditions will also be considered for evaluation species status. Species/life stages such as chum, chinook and pink salmon spawning will be evaluated in side channel and mainstem habitats. All of these species currently spawn primarily in habitats other than the mainstem and side channels of the middle Susitna River. The physical characteristics of mainstem and side channel habitats in this reach are expected to approach those in other Alaskan river systems utilized by these species under possible with-project streamflow, water temperature and water quality regimes.

IV. WATERSHED CHARACTERISTICS AND PHYSICAL PROCESSES INFLUENCING MIDDLE RIVER HABITATS

Watershed Characteristics

Basin Overview

Tributaries in the upper portions of the Susitna River drainage basin originate in the glaciers of the Alaska Range, which is dominated by Mount Deborah (12,339 feet), Mount Hayes (13,823 feet), and Mount Moffitt (13,020 feet). Other peaks average 7,000 to 9,000 feet in altitude. Tributaries in the eastern portion of the basin originate in the Copper River lowland and in the Talkeetna Mountains, with elevations averaging 6,000 to 7,000 feet and decreasing northward and westward. To the northwest, the mountains form a broad, rolling glacially-scoured upland dissected by deep glaciated valleys. Between these ranges and Cook Inlet is the Susitna lowlands, a broad basin increasing in elevation from sea level to 500 feet, with local relief of 50 to 250 feet (Figure IV-1).

The drainage basin lies in a zone of discontinuous permafrost. In the mountainous areas, discontinuous permafrost is generally present. In the lowlands and upland areas below 3,000 feet, there are isolated masses of permafrost in areas with fine-grained deposits. The basin geology consists largely of extensive unconsolidated deposits derived from glaciers. Glacial moraines and gravels fill U-shaped valleys in the upland areas. Gravelly till and outwash in the lowlands and on upland slopes are overlain by shallow to moderately deep silty soils. Windblown silt covers upland areas. Steep upper slopes have shallow, gravelly and loamy deposits with many bedrock exposures. On the south flank of the Alaska Range and south-facing slopes of the Talkeetna Mountains, soils are well-drained, dark, and gravelly to loamy. Poorly drained, gravelly and stony loams with permafrost are present on northfacing slopes of foothills, moraines, and valley bottoms. Water erosion is moderate on low slopes and severe on steep slopes.

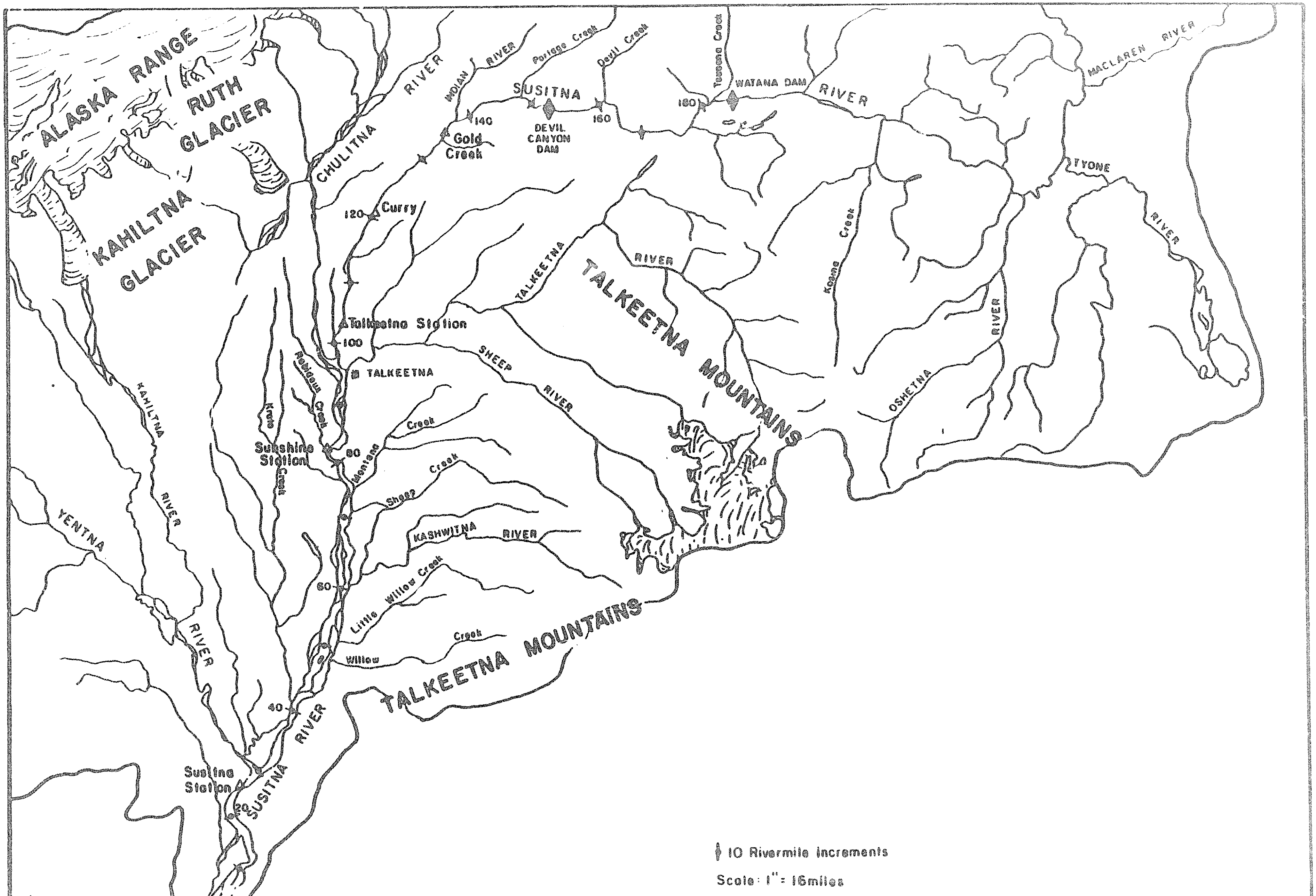


Figure IV-1. Stream network within the Susitna River Basin.

Vegetation above the tree line in steep, rocky soils is predominantly alpine tundra. Well-drained upland soils support white spruce and grasses, whereas poorly drained valley bottom soils support muskeg.

The upper drainage basin is in the continental climatic zone, and the lower drainage basin is in the transitional climatic zone. Due to the maritime influence and the lower elevations, temperatures are more moderate and precipitation is less in the lower basin than that in the upper basin. Storms which affect the area generally cross the Chugach Range from the Gulf of Alaska or come from the North Pacific or southern Bering Sea across the Alaska Range which is west of the upper Susitna Basin. The heaviest precipitation generally falls on the windward side of these mountains leaving the upper basin in somewhat of a precipitation shadow except for the higher peaks of the Talkeetna Mountains and the southern slopes of the Alaska Range. Therefore, precipitation is much heavier in the higher elevations than in the valleys.

Basin Hydrology

The Susitna River is typical of unregulated northern glacial rivers, with relatively high turbid streamflow during summer and low clearwater flow during winter. Sources of water influent to the Susitna River can be classified as: glacial melt, tributary inflow, non-point surface runoff, and groundwater inflow. The relative importance of each of these contributions to the mainstem discharge at Gold Creek varies seasonally (Figure IV-2). Snowmelt runoff and spring rainfall cause a rapid rise in streamflows during late May and early June. Over half of the annual floods occur during this period.

Figure IV-2. Estimated percent contribution to flow at Gold Creek.

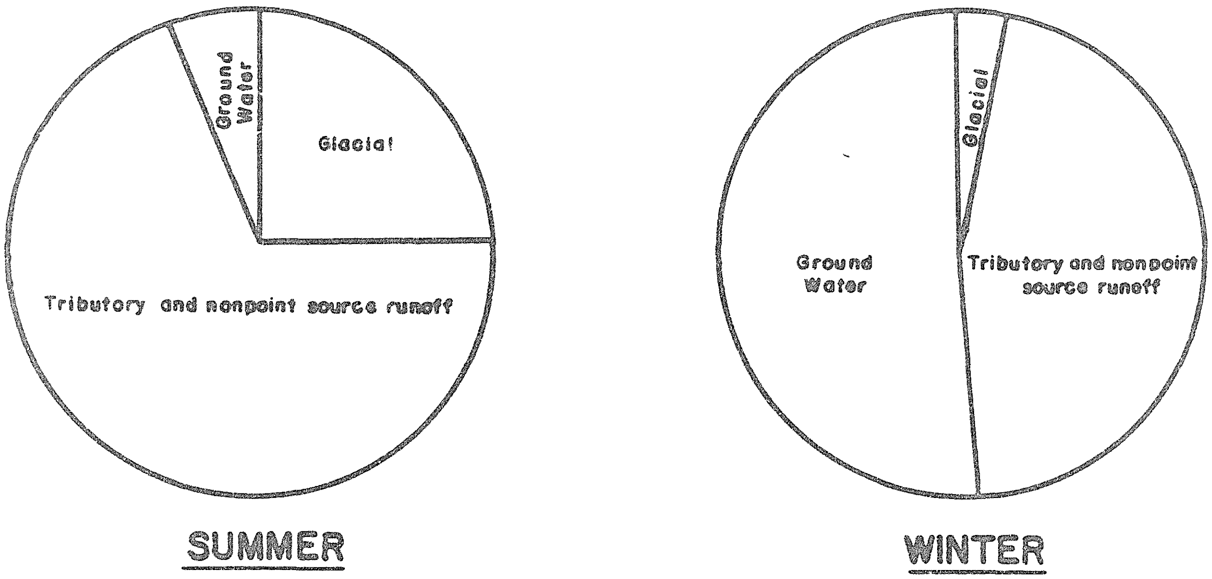


Figure IV-2

The glaciated portions of the upper Susitna Basin play a significant role in shaping the annual hydrograph for the Susitna River at Gold Creek (USGS stream gage station 15292000). Located on the southern slopes of the Alaska Range, these glaciated regions receive the greatest amount of precipitation that falls in the basin. The glaciers, covering about 290 square miles, act as reservoirs maintaining moderately high streamflows throughout the summer. Valley walls in those portions of the upper basin not covered by glaciers, consist of steep bedrock exposures or shallow soil systems. Rapid runoff originates from the glaciers and upper basin whenever rainstorms occur, typically in late summer and early fall. Many annual peak flow events have occurred during August. Approximately 87 percent of the total annual flow of the middle Susitna River occurs from May through September; over 60 percent occurs during June, July and August (Table IV-1). R&M Consultants and Harrison (1981) state that "roughly 38 percent of the streamflow at Gold Creek originates above the gaging stations on the MacLaren River near Paxson and on the Susitna River near Denali..." Thus less than 38 percent of the annual middle Susitna River can be attributed to glacial melt.

Table IV-1. Summary of monthly streamflow statistics for the Susitna River at Gold Creek (Scully et al. 1978).

Month	Monthly Flow (cfs)		
	Maximum	Mean	Minimum
January	2,452	1,463	724
February	2,028	1,243	723
March	1,900	1,123	713
April	2,650	1,377	745
May	21,890	13,277	3,745
June	50,580	27,658	15,500
July	34,400	24,383	16,100
August	38,538	21,996	8,879
September	21,240	13,175	5,093
October	8,212	5,757	3,124
November	4,192	2,568	1,215
December	3,264	1,793	866
Average	16,445	9,651	4,785

As air temperatures drop during fall, glacial melt subsides and streamflows decrease. By November, streamflows have decreased to approximately one tenth of midsummer values. An ice cover, which generally persists until mid-May, forms on the middle Susitna River during November and December. During winter, flow in the Susitna River is maintained by the Tyone River which drains Lake Louise, Susitna Lake and Tyone Lake, and by groundwater inflow to several smaller tributaries and to the Susitna River itself. Although groundwater inflow is thought to remain fairly constant throughout the year, its relative importance increases during winter as inflows from glacial melt and non-point runoff cease.

Streamflow Variability

Peak flows for the Susitna River normally occur during June in association with the snowmelt flood. Rainstorms may also cause floods during late summer. Most annual peak flows occur during June or August (Table IV-2). Snowmelt floods are generally 3 to 5 days in duration, whereas late summer flood peaks are often single day events with higher peak flows than June peaks.

Table IV-2 Percent distribution and duration of annual peak flow events for the Susitna River at Gold Creek 1950-198? (R&M Consultants 1981).

Month	Percent
May	9
June	55
July	9
August	24
September	3

Little difference exists among monthly ratios for the 1-, 3-, and 7-day low flows to their respective monthly flows during June-September (R&M Consultants 1981). Flow is relatively stable during the summer, with occasional sudden increases as the basin responds to the highly variable, and sometimes erratic, precipitation patterns. Susitna River streamflows show the most variation early in May and late in October, periods commonly associated with spring breakup and the onset of freeze up. From November through April, low air temperatures cause surface water in the basin to freeze, and stable but gradually declining groundwater inflow and baseflow from headwater lakes maintain mainstem streamflow.

The natural flow regime of the middle Susitna River streamflows will be significantly altered by project operatio (Figure IV-3). With-project streamflows will generally be less than existing streamflows from May through August as water is being stored in the reservoirs for release during the winter. Variability in the middle Susitna River will be caused primarily by tributary inflow and releases from the reservoirs. Floods will also be reduced in frequency and magnitude

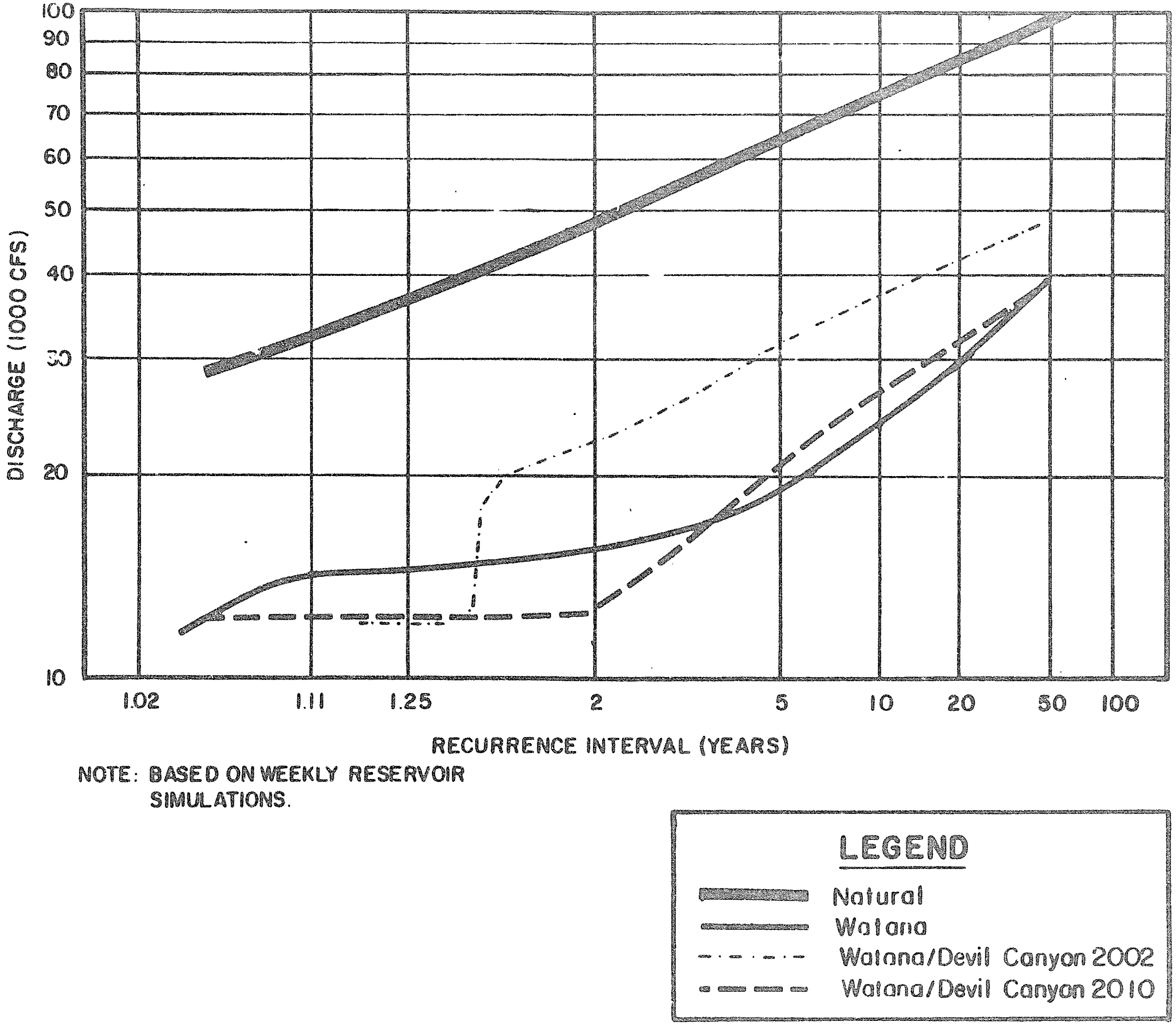


Figure IV-3. Comparison between natural and anticipated with-project annual flood frequency curves for the middle Susitna River. (Source: Alaska Power Authority 1983) generally occurring in late summer when the reservoirs are full and water must occasionally be released.

With-project streamflow during September is expected to be less variable but similar to the long term average monthly natural flow. Flows from October through April will be greater in magnitude and more variable than natural streamflows. Daily fluctuations in streamflow are expected to occur throughout winter as the project responds to meet changes in the daily and weekly load. However, these fluctuations are not expected to exceed ±10 percent the base discharge for the day (W. Dyok, Harza-Ebasco, 1984, pers. comm.).

Influence of Streamflow on Habitat

Mainstem and Side Channel Habitat. The large amount of water that is conveyed during the summer in steep mainstem and side channel water courses results in inhospitable conditions for fish. Mainstem and side channel gradients within the middle Susitna River are on the order of 8-14 ft/mile (R&M Consultants 1982a). Although flood peaks seldom exceed twice the long term average monthly flow for the month in which they occur (R&M Consultants 1981), the average monthly flows for June, July, and August are nearly 2.5 times the average annual discharge of 9700 cfs/day (Scully et al. 1978). As a result of the steep channel gradient, mid-channel velocities are often in the range of seven to nine feet per second (fps) for normal mid-summer streamflow conditions. Velocities of 14 to 15 fps have been measured by the USGS at the Gold Creek stream gage station in association with 62,000 to 65,000 cfs flood flows (L. Leveene, USGS, 1984, pers. comm.).

As a result of being subjected to persistently high velocities, streambed materials in mainstem and side channel habitats typically range in size from cobbles (5 inches) to boulders (10 inches or larger) (R&M Consultants 1982a). Isolated deposits of smaller streambed materials, including sand, also exist within the mainstem and side channels, but only at protected locations. These smaller streambed materials are generally unstable and transient (R&M Consultants 1982).

High summer streamflows characteristic of the Middle Susitna River are not considered to be beneficial to salmon production in mainstem or side channel habitats. As stated above, high streamflows during summer tend to transport spawning gravels out of these habitats. In those locations where salmon have spawned, high streamflows may wash out the redds or deposit sediments over them. Juvenile salmon in middle Susitna River habitats are also displaced downstream by high flows (ADF&G 1984c).

Low seasonal streamflows can also be undesirable. During spawning, low streamflows may restrict fish access to spawning areas or result in shallow depths at potential spawning locations. Thus, the available spawning habitat may be reduced. Low streamflows during incubation may cause dewatering of redds, low dissolved oxygen levels, high temperatures, or, during the winter, freezing of embryos (Hale 1981). Low seasonal streamflows may also adversely influence juvenile salmon rearing by restricting fish access to streambank cover or dewatering rearing habitats.

Side Slough Habitat. Side sloughs are overflow channels along the floodplain margin that convey clear water originating from small tributaries and/or upwelling groundwater. A non-vegetated alluvial berm connects the head of the slough to the mainstem or a side channel. A well-vegetated gravel bar or island parallels the slough, separating it from the mainstem (or side channel). During intermediate and low-flow periods, mainstem water surface elevations are insufficient to overtop the alluvial berm at the upstream end (head) of the slough. However, mainstem stage is often sufficient at the downstream end (mouth) of the slough to cause a backwater to extend a few hundred feet upstream into the slough.

During high mainstem discharges, the water surface elevation of the mainstem is often sufficient to overtop the alluvial berm at the head of many of the sloughs, depending on the stage achieved by the high flow and the elevation of the berm. When this occurs, discharge through the side slough increases markedly as water in the slough is replaced with turbid mainstem flow. Such overtopping affects the thermal, water quality and hydraulic properties within the clear water slough. Overtopping during late August and early September provides unrestricted passage by adult salmon to spawning areas within the sloughs. Overtopping during early summer flushes organic material and fine sediments from the side sloughs, but in some instances transports large amounts of sand into the slough. The turbidity associated with the overtopping flows provides cover for juvenile chinook salmon and allows them to utilize habitat that was previously unavailable (ADF&G 1984c).

The influence of overtopping on various physical conditions will be discussed in subsequent sections of this report. However, prior to those discussions, it is important to recognize the dominant influence of streamflow variability in determining the timing, frequency and duration of overtopping events (Table IV-3).

Upwelling

Water which rises from the streambed has been recognized as strongly influencing the spawning behavior of chum and sockeye salmon in Alaska (Kogl 1965, Wilson et al. 1981, Koski 1975, ADF&G 1984d). This water is commonly referred to as "upwelling" by fisheries biologists because of its characteristic flow direction into the stream channel.

Downwelling and intergravel flow are two other types of subsurface flow which occur in stream channels that are important to maintaining aquatic life in streambed materials (Figure IV-4). However these two types of flow differ from upwelling in both their flow direction and origin. As the term implies, downwelling flows from the stream into the streambed and is generally thought to be in a near vertical

Table IV-3. Number of times breached for duration indicated based on analysis of Gold Creek record 1950-1984.

Breaching Flow (cfs)	1 day	2 days	3 days	4-5 days	5-10 days	>10 days	Total days
			June 3 through June 16				
12,000	0	0	0	0	0	33	459
16,000	1	2	2	2	3	27	412
19,000	3	2	2	0	4	23	357
23,000	5	4	3	1	12	13	300
25,000	0	4	3	3	13	10	263
27,000	3	6	2	3	11	8	218
33,000	3	3	5	3	6	3	118
35,000	1	5	4	3	6	1	94
40,000	0	3	2	2	3	1	55
42,000	2	0	1	3	2	1	46
			August 12 through September 8				
12,000	2	1	2	0	1	35	826
16,000	4	3	6	5	7	25	628
19,000	2	4	6	9	13	15	431
23,000	7	6	8	4	7	6	224
25,000	3	7	3	3	6	3	141
27,000	3	3	2	3	3	3	99
33,000	1	0	1	2	3	1	46
35,000	0	0	1	3	2	1	42
40,000	1	2	1	1	3	0	31
42,000	0	1	1	2	2	0	26

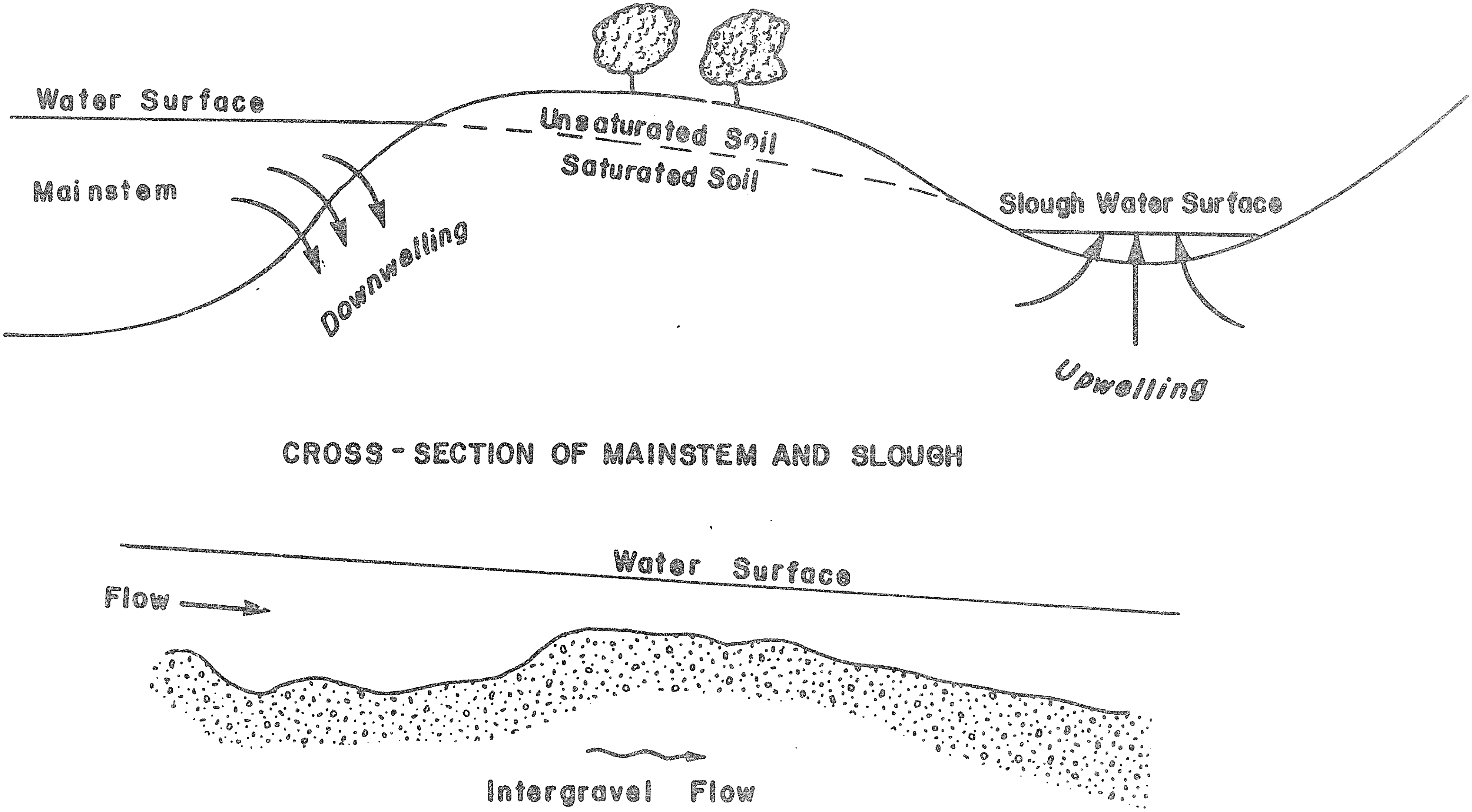


Figure IV-4. Upwelling downwelling and intergravel flow.

direction. Intergravel flow is generally considered to be flow in streambed gravels parallel to the down valley gradient of the channel.

Because the water flowing in the stream channel provides both the source and driving mechanism for downwelling and intergravel flow these two types of subsurface flow generally have temperatures and water chemistry very similar to the surface water. Upwelling, however, generally has temperature and chemical composition characteristics differing from the water flowing above the streambed. As this groundwater flows through the soil from its source to its upwelling location, its thermal and water chemistry properties become defined by the soil properties.

Broadly defined, groundwater is the hydrologic term for water occurring beneath the land surface. Groundwater exists in saturated and unsaturated soil zones. The interface between these two zones is called the water table. The plan shape and slope of the water table is determined by the subsurface geologic structure and type of soil material present. The elevation of the water table at any point is primarily a function of water supply.

Water supply for groundwater consists of precipitation and adjacent surface water bodies. Precipitation infiltrates into the soil, flows through the unsaturated zone as "interflow", and reaches the saturated zone. Because of this increased water supply, the groundwater table rises in elevation. Sometimes excess water appears along streambanks, rock outcrops, or steep hillsides as bank seepage.

During periods of drought caused by lack of precipitation or cold air temperatures freezing precipitation (snow) and shallow subsurface interflow, the elevation of the water table declines because of a shortage of available water supply.

In river valleys like that of the middle Susitna River, where the underlying materials are alluvial deposits of glacial outwash (R&M Consultants 1982d), the groundwater flow patterns may be quite complex. The general slope of the water table is similar to the valley slope. The mountains or hills which parallel the river form the boundary of the alluvial deposits of the larger, original glacial river which also flowed down valley in approximately the same direction. Hence, in the middle Susitna River, regional groundwater is generally thought to be flowing down valley and slightly to the east (R&M Consultants 1982d). Wherever the water table intersects the streambed, upwelling is likely to exist.

The groundwater table elevation, as determined by the structural geology and the corresponding relationship between the sources of groundwater flow, will control upwelling. Downwelling flows will occur if the surface water level in the channel is higher than the groundwater table elevation. Upwelling flows will occur when the elevation of the groundwater table exceeds the water surface elevation in the channel. Upwelling may also occur in a manner similar to pipe flow. A lense of coarse sediments permitting groundwater flow may be flanked by deposits of finer sediments that prohibit groundwater flow. Flow may thus become concentrated in the flow-conducting lense. When the lense intersects a channel, the flow is released from between the flanking deposits and upwelling may result. Piped groundwater flow may occur under the berms at the heads of side sloughs and elsewhere as long as the required geologic conditions are present and a source, such as the mainstem, exists for the quantities of water transported.

In addition to the influence of subsurface alluvial deposits on the location and rate of upwelling water, water supply is also important. In the river valley the most persistent water supply is the river itself. Through downwelling, the river supplies water to the groundwater. At some down valley location, the groundwater will yield this water as upwelling. In the middle Susitna River, much of this upwelling appears to be along the east bank.

Because the water table rises and falls seasonally and across years in response to water supply, upwellings can be both persistent and intermittent. They also may have rather stable or variable flow rates depending upon fluctuations in the local groundwater table.

The groundwater system can be divided into two components: a regional component driven by the down valley gradient and a temporal component influenced by changes in mainstem stage and precipitation infiltration. The regional groundwater component is constant throughout the year and corresponds to the minimum groundwater levels observed under natural conditions. These minimum groundwater conditions appear to occur during the late fall period of low mainstem discharge and reduced precipitation infiltration due to freezing conditions. The temporal groundwater component augments the regional groundwater component. When the mainstem stage is high, the mainstem may supply downwelling flows which increase the groundwater table elevation. Precipitation infiltrating the soil may also serve as a source for the groundwater. The raised elevation of the groundwater table due to the temporal component results in increased areal extents and rates of upwelling flows. Thus, the fluctuations of the groundwater table due to the temporal component variations, which are induced by changes in river stage and precipitation, will have a pronounced effect on upwelling.

The groundwater table appears to reach a minimum elevation in the late October to early November period; upwelling flows will correspondingly reach a minimum rate and areal extent. The temporal groundwater component will be reduced as the mainstem stage lowers and infiltration of precipitation ceases due to freezing temperatures. The remaining upwelling flows will be supplied by the regional groundwater component. At sites where upwelling is continuously provided by the regional groundwater component, viable habitat will be maintained; high mortality is suspected at sites where upwelling is reduced to the reduction in temporal upwelling. As ice formation increases the mainstem stage, the temporal groundwater component will again augment the regional groundwater component and increase upwelling rates and areal extents.

Under with-project conditions, upwelling flows may not be reduced to the extent of upwelling flows experienced under natural conditions during the late fall period. The mainstem stage is anticipated to be maintained at a higher elevation during project operation than under natural conditions in the late fall. The temporal groundwater components will therefore continue to augment the regional component in the late October to early November period. Habitat dewatered or frozen as the temporal groundwater component is reduced under natural conditions may become viable throughout the year as the temporal groundwater component is maintained by higher with-project mainstem stages. The magnitude of the increase in viable habitat is unquantified and is likely to remain so until determined through a monitoring program.

Biological Importance of Upwelling. Upwelling is one of the most important habitat variables influencing the selection of spawning sites by chum and sockeye salmon in the middle Susitna River (ADF&G 1984d). In addition, upwelling flows contribute to local flow in sloughs and side channels and facilitate fish passage.

Incubation appears to be the life stage most critically affected by upwelling in the middle Susitna River. Chum and sockeye salmon embryos, and embryos of other species spawned in the area of upwelling flows, benefit from the upwelling flows. During incubation, upwelling provides for successful development of embryos, principally because of its thermal characteristics. It also ensures the oxygenation of embryos and alevins and inhibits the clogging of streambed material by fine particulates.

Upwelling flows appear to reach a minimum immediately prior to ice staging when mainstem discharges range from 3,000 to 5,000 cfs. During this period upwelling flows are considered to originate exclusively from the regional groundwater component of upwelling. These low mainstem discharges and minimum upwelling flows probably limit the incubation success of embryos that were spawned under higher mainstem and upwelling flows. Many embryos are likely dewatered and frozen. Therefore, the viable incubation habitat is probably that which is effective during this transition period of low upwelling flows.

Mainstem discharges that are higher than the 3,000 to 5,000 cfs would likely increase the upwelling flows in sloughs above natural conditions. Thus, a stable flow regime throughout the spawning and incubation period would probably increase the viable incubation habitat because embryos would develop under upwelling flows similar to those at spawning.

Groundwater upwelling also appears to be an important factor influencing the winter distribution of juvenile salmon and resident fish. Upwelling flows may comprise the predominant source of water in sloughs when runoff from precipitation ceases due to freezing. A constant water flow in sloughs and side channels provides overwintering habitat for juvenile sockeye, chinook, and coho salmon and resident species. The water temperature of sloughs and side channels is usually higher than mainstem waters because of upwelling waters. Warmer temperatures apparently attract overwintering fish and may reduce their winter mortality (ADF&G 1984c).

Sediment Transport Processes

In this section, sediment transport is used generically to include all the physical processes which result in the movement of bed and suspended load. Bed load is defined as that portion of the solid mass being transported within 0.3 ft of the channel bottom. Suspended load refers to that portion of the solid mass present in the water column above 0.3 ft from the channel bottom.

It is well documented that the results of sediment transport processes, such as streambed stability and composition, are important descriptors of aquatic habitat. McNeil (1964) has observed that streambed stability can influence the success of salmonid egg incubation. Several researchers have shown that substrate composition influences the survival of eggs to fry in salmonid populations (McNeil and Ahnell 1964, McNeil 1965, Cooper 1965, Phillips et al. 1975). The suitability of aquatic habitat for rearing is also influenced by substrate composition.

On a macrohabitat level, the channels of the middle Susitna River are quite stable given the range of streamflows and ice conditions to which they are subjected. Review of aerial photography taken over an approximate 35 year period (from 1949-51 to 1977-80) indicates the plan form of the middle Susitna River has changed little (AEIDC 1984a). Although many non-vegetated gravel bars have appeared, and some peripheral areas have changed, a preponderance of channels and habitats appear unchanged over this period.

Channel Stability of Habitat Types

Six habitat types have been identified in the middle Susitna River: mainstem, side channel, side slough, tributary, tributary mouth, and upland slough. Each habitat type can be characterized by the relative influence that specific sediment transport processes have on their formation and maintenance (Table IV-4).

Table IV-4. Sediment transport processes and components and their relative importance in the formation and maintenance of habitat.

Habitat Type	Sediment Load Components: Suspended	Sediment Load Components: Bed	Sediment Transport Processes: High Flow Events	Ice Jams During Breakup	Mechanical Scour by Ice Blocks	Anchor Ice Processes	Shore Ice Processes
Mainstem and Large Side Channels	Secondary	Primary	Primary	Secondary	Secondary	Minor	Minor
Side Channels and Side Sloughs	Primary	Secondary	Primary	Primary	Secondary	Minor	Minor
Tributary and Tributary Mouth	Minor	Primary	Primary	Minor	Minor	Minor	Minor
Upland Slough	Secondary	Minor	Secondary	Minor	Minor	Minor	Minor

Mainstem and Large Side Channels. The plan form of the middle Susitna River appears to be shaped by ice processes, whereas the size of its channels are a result of hydrologic processes. Hydrologic events, or more specifically floods, are probably the dominant channel forming process whereas normal summer streamflows represent the primary sediment transport process. Channel forming discharges are usually those which occur only once every several years. High discharges cause high velocities with the capacity to erode and transport significant quantities of substrate from the bed and banks of the channel. These high discharges would change the shape of the channel, but likely occur only once in 20 years or more. Discharges occurring more frequently, such as the mean annual flood or bankfull discharge, would reshape the channel to reflect the hydraulic conditions associated with this lower, but more frequent, discharge. Some local changes in bed geometry would likely occur, but these persistent lower floods are unlikely to reform the channel to its original condition.

Streambed material in the mainstem and large side channels is of sufficient size to resist erosion or transport by flood flows less than 35,000 cfs. The cobbles and boulders constitute an armor layer which has developed as a result of previous flood events transporting smaller substrate sizes downstream. The cobbles and boulders remain as a well graded protective layer for the more heterogeneous underlying materials. High discharges would have the capacity to erode the armor layer and transport underlying streambed materials downstream, but a new armor layer would likely develop as the flood recedes and cobbles and boulders eroded from upstream locations are redeposited. The entire bed elevation of the middle Susitna River may decrease during these events since the sands and gravels eroded from the materials underlying the armor coat would likely not redeposit. Evidence of such long-term channel degradation has been documented through analysis of aerial photography (AEIDC 1984a).

Resistance of large substrate in the middle Susitna River to erosion is increased by the cementing characteristics of the fine sands and silts which fill interstitial spaces between them. Although the flow is relatively clear in the winter, high concentrations of fine glacial sand and silt are transported through the middle Susitna River throughout the summer. Some of these fine materials are deposited or washed into the armor layer. The stability of the streambed allows these fine silts to accumulate and completely fill the voids between the armor layer. This prevents water from flowing through voids surrounding larger streambed materials, greatly strengthening the armor layer to erosion. If water could flow through the voids, the erodibility of sediment particles would increase.

Several different ice processes also influence the shape and character of mainstem and large side channel habitats: 1) mechanical scour by block ice, 2) scour caused by ice jams during breakup, 3) sediment transport by uprooted anchor ice, and 4) scour and sediment transport by shore ice. In comparison to sediment transport processes associated with high streamflows, ice scour either of the first two processes is of secondary importance. The last two are only of minor importance.

Mechanical scour by block ice is primarily a spring breakup phenomenon. As large ice floes are moved downstream, tremendous potential exists for direct interaction between block ice and streambanks or channel bottoms. Suspended sediment samples collected in late May or early June following breakup typically contain large percentages of sand, which may indicate stream channel or bank scour (Knott and Lipscomb 1983). Bank erosion by ice-block abrasion may be severe (Knott and Lipscomb 1983).

Ice jams during breakup cause local staging and flow constrictions which increase flow velocities and scour potential. High velocity flow directed towards a channel bottom or bank can result in severe local scour. The sudden release of an ice jam can also cause significant scour potential in the form of a flood wave conveying large blocks of ice.

Anchor ice also contributes to sediment transport. During anchor ice formation, suspended sediments are filtered by ice crystals and incorporated into the ice structure (see Ice section). Bed materials are also encased in ice, serving to anchor the ice mass to the channel bottom. In the fall during anchor ice formation, the bonding of anchor ice masses to the channel bottom is sensitive to increases in temperature and direct solar radiation. If the bond is partially reduced by melting, flow momentum and/or buoyant forces may be sufficient to uproot the ice mass. This results in the downstream transport of sediments and streambed particles frozen into the ice mass. Scour of anchor ice during freezeup by changes in local flow velocities or contact with floating ice blocks may also contribute to this process.

Shore ice contributes to sediment transport by directly scouring channel margins and also by encasing and uprooting bed materials and the shoreline vegetation. The denudation of shoreline vegetation indirectly serves to increase sediment transport by increasing the susceptibility of the shoreline to scour by high flow events. Although the relative contribution of sediment transport by shore ice is thought to be minor, the process can significantly influence the character of fish habitats along the channel margin.

Side Channels and Side Sloughs. Of the sediment transport processes described in the previous section, two have dominant roles in the formation and maintenance of side sloughs and side channels. These are: 1) high flow events, and 2) ice jams during breakup. Mechanical scour by block ice, anchor ice processes, and shore ice processes are less active in these habitats.

Side sloughs and side channels are generally stable channels. Their size and shape imply that they were formed by high flows. The frequency of high flows through side sloughs and side channels is generally low, but it varies significantly between sites. This process may be important in maintaining and flushing fine sediments from these habitats. Some sites have formed as a result of ice jams. An ice jam can raise the upstream water level causing flow to divert around the main channel, thereby developing a new channel. Slough 11 apparently formed when an ice jam developed at the railroad bridge at Gold Creek in 1976.

Sediment transported into side sloughs and side channels is primarily from three sources: 1) mainstem, 2) tributary, and 3) overland flow. Of these sources, the mainstem probably dominates. The sediment transported into these habitats is characteristically fine. Overtopping flows from the mainstem, which spill over the gravel berm at the upstream end of these sites, originate in the upper part of the water column and thus typically contain fine particle sizes only. These materials deposit in pools within the channel or in the backwater that is often present at the mouth of the channel.

Tributary and Tributary Mouths. Of the sediment transport processes described in the previous sections, high flow events have the dominant role in shaping tributary mouths. Most tributaries in the middle Susitna River are steep gradient systems with a capacity to transport large quantities of sediment during flood events.

When a rainstorm causing a flood is widespread, the Susitna River would likely have a high discharge concurrent with, or soon after, the high discharge in the tributary. Most sediments carried by the tributary will be transported downstream by the Susitna River. However, during localized storms, a tributary may flood while the Susitna River remains relatively low. In such cases, the delta at the mouth of a tributary may build up with large deposits of gravels and cobbles. The delta may extend well out into the Susitna River mainstem. Subsequent high discharges in the Susitna River will erode the delta away.

Upland Sloughs. Upland slough habitats are largely isolated from mainstem sediment transport processes. The exception is in the vicinity of the slough mouths, where mainstem flow may intrude as a backwater during periods of high mainstem discharge. Suspended sediments may settle out in these backwater areas and contribute to slough sedimentation.

With-Project Sediment Transport and Channel Stability

Sediment transport processes would change with project operation (Table IV-5). The operation of a reservoir will alter the natural hydrologic regime of the middle Susitna River. High erosive discharges will occur less frequently and with reduced magnitudes. This will result in less frequent breaching of side sloughs and side channels. Sediment transport by hydrologic processes will be reduced throughout the middle Susitna River system. Channel stability will be increased. Sedimentation and encroachment of streambank vegetation will be more likely to occur in side channels and side sloughs.

Less frequent and lower flood events in the Susitna River would allow tributary deltas to enlarge over their natural size. However, tributary mouths are best analyzed individually. Local characteristics, such as orientation to mainstem flow and tributary gradient, greatly influence delta formation processes. The above is a generalized scenario which may be characteristic of many tributaries in the middle Susitna River.

Reduced flood peaks and frequency associated with project operation would reduce sediment transport into upland slough mouths via backwater intrusion. Ice processes do not significantly influence sediment transport in upland sloughs.

Both Watana and Devil Canyon reservoirs will trap nearly all sediments sand size and larger. Project discharges will also carry lower concentrations of fine silts, but the concentration will be more uniform throughout the year. Such low concentrations may not cause cementing of the armor layer, but the lower flood regime may not be sufficient to disturb streambed materials and remove the fine sediments which presently fill interstitial spaces between coarse sands and fine gravels.

The assessment of with-project ice processes resulting in sediment transport is dependent on project design and operation. For this

Table IV-5. With-project influence on sediment transfer processes and sediment loading.

Habitat Type	Sediment Load Components: Suspended	Sediment Load Components: Bed	Sediment Transport Processes: High Flow Events	Ice Jams During Breakup	Mechanical Scour by Ice Blocks	Anchor Ice Processes	Shore Ice Processes
Mainstem and Large Side Channels	Reduced	Reduced	Reduced Magnitude and Frequency	Milder, Less Frequent[1] Reduced[2]	Reduced[1] Reduced[2]	Minimal[1] Reduced[2]	Increased Reduced[2]
Side Channels and Side Sloughs	Reduced	Reduced	Reduced Magnitude and Frequency	Milder, Less Frequent[1] Reduced[2]	Increased Reduced[2]	Increased[1] Reduced[2]	Increased Reduced[2]
Tributary and Tributary Mouth	Reduced	Reduced	Reduced Magnitude and Frequency	Minimal[1] Reduced[2]	Reduced[1] Reduced[2]	None[1] Reduced[2]	None[1] Reduced[2]
Upland Slough	Reduced	Reduced	Reduced Magnitude and Frequency	Milder, Less Frequent[1] Reduced[2]	Reduced[1] Reduced[2]	Increased[1] Reduced[2]	Reduced[1] Reduced[2]

[1] Project thermal operating regime is reservoir inflow temperature matching.

[2] Project thermal operating regime is warm-water release throughout winter.

reason, this assessment will proceed based on two possible project thermal operating regimes: 1) reservoir inflow temperature matching, and 2) winter-long warm-water releases.

Reservoir Inflow Temperature Matching. Ice jams may still occur in the mainstem but will be reduced in frequency and magnitude. There will be a greater tendency for the ice cover to melt in place because of warmer than natural stream temperatures during April and increased project flow stability. This will result in less mainstem and side channel scour and less frequent diversions of mainstem flow through side slough habitats. The sediment transport capacity due to ice jams will be reduced. The channel stability of mainstem, side channel, and side slough habitats will be increased.

Mechanical scour by block ice will also be less severe than natural levels in most habitats. This process occurs primarily during breakup. Reduced project discharges will provide less energy to drive ice blocks forcefully into channel banks and bottoms. In some side sloughs with low overtopping discharges, mechanical scour by block ice may be increased. Project flows will be higher during the winter and the breaching of some side sloughs may result.

Project influence on anchor ice sediment transport processes is expected to be minimal. The principal influence will be to delay anchor ice formation by one to two months. There may be some increase in sediment transport in those side sloughs and side channels that will be breached by project discharge levels during periods of ice cover.

Sediment transport by shore ice processes will probably be increased from natural levels. The increased elevation forecast for a with-project ice cover would result in a substantial amount of vegetated shoreline being frozen into the with-project ice cover. However, lower and more stable project discharges during summer would likely minimize streambank scour along channel margins.

Warm-water Releases. If a warm-water release throughout winter could prevent a solid ice cover forming on the mainstem, the sediment transport capacity would be reduced for all ice processes. Mainstem, side channel, and side slough habitats will become extremely stable. Sensitive side slough habitats with low overtopping discharges will not be subjected to increased sediment transport by anchor ice, shore ice, or mechanical scour by block ice, as with reservoir inflow temperature matching.

Tributary mouth and upland slough habitats will have the same with-project channel stability as for reservoir inflow temperature matching.

Instream Water Quality and Limnology

Baseline Condition

Water quality encompasses numerous physical and chemical characteristics, including the temperature, density, conductivity, and clarity of the water, as well as the composition and concentration of all the dissolved and particulate matter it contains. Water quality greatly influences fish habitat quality by virtue of its direct effects on fish physiology and behavior and because it largely governs the type and amount of aquatic food organisms available to support fish growth.

Each of the aquatic habitat types associated with the middle Susitna River differs not only in terms of its morphology and hydraulics, but also in the basic pattern of its water quality regime. Therefore, the relative importance of a habitat type to fish may change in response to seasonal change in either streamflow or water quality. In the middle Susitna River, turbidity is an influential and visually detectable water quality parameter that may be used to classify the six aquatic habitat types into two distinct groups during the open water season: clear water or turbid water. Thus, it is useful to 1) examine the water quality characteristics of both clear and turbid water aquatic habitats; 2) identify how the water quality of these aquatic habitat types changes on a seasonal basis; and 3) determine how these seasonal changes in turn influence the quality of the aquatic habitat types.

Highly turbid water accounts for the greatest amount of wetted surface area in the middle Susitna River from June to September (Klinger and Trihey 1984). During this period, when surface runoff and glacial melting are greatest, total dissolved solids, conductivity, alkalinity, hardness, pH, and the concentrations of the dominant anions and most cations tend to be at their lowest levels of the year, while stream temperature, turbidity, true color, chemical oxygen demand, total suspended solids, total phosphorus, and the total concentrations of a variety of trace metals are at their highest values for the year (Table IV-6). Average nitrate-nitrogen concentrations remain relatively constant throughout the year with greater variation during the summer as discharge fluctuates.

The basic water chemistry of the clear water flow of the middle Susitna River in winter, and of certain groundwater fed habitat types throughout the year can be generalized from an evaluation of the water quality record for the Susitna River at Gold Creek during winter. Surface water flow throughout the basin is low and the concentration of suspended sediment and the trace metals, and phosphorous associated with it, is also low or below detection limits. During winter months, middle Susitna River discharge is comprised almost entirely of outflow from the Tyone River System (lakes Louise, Susitna, and Tyone) and groundwater inflow to tributaries and the mainstem itself. Groundwater spends a greater amount of time in contact with the soil and underlying rocks of the watershed than surface runoff or glacial meltwater and thus contains more dissolved substances.

The specific water quality characteristics of clear or turbid water flowing through a given channel may differ from the general descriptions provided above, depending on local variations in the amount of local surface runoff or the composition and distribution of rocks, soils, and vegetation. Nonetheless, a generalized seasonal water quality regime unique to each habitat type seems to prevail, and having knowledge of it provides useful insight into the direct and indirect role water quality plays as a component of fish habitat within the Talkeetna to Devil Canyon segment of the Susitna River.

Mainstem and Side Channel Habitats

A comparison of the summer and winter water quality record for the Susitna River at Gold Creek (Table IV-6) reveals a seasonal contrast in the water quality conditions of the mainstem and its associated side channels. During winter almost all the flowing water is covered

Table IV-6. Mean baseline water quality characteristics for middle Susitna River at Gold Creek under (a) turbid summer (June-August) conditions and (b) clear, winter (November-April) conditions.

Parameter (Symbol or Abbreviation)	Turbid (summer)	Clear (Winter)
Total Suspended Solids (TSS)	1,000 mg l^{-1}	5
Turbidity	450 NTU	<1
Total Dissolved Solids (TDS)	90 mg l^{-1}	150
Conductivity	145 (μmhos cm^{-1}, 25°C)	240
pH	7.3 pH units	7.5
Alkalinity	50 mg l^{-1} as $CaCO_3$	73
Hardness	62 mg l^{-1} as $CaCO_3$	96
Sulfate (SO_4^{-2})	14 mg l^{-1}	20
Chloride (Cl^-)	5.6 mg l^{-1}	22
Dissolved Calcium (Ca^{+2})	19 mg l^{-1}	29
Dissolved Magnesium (Mg^{+2})	3.0 mg l^{-1}	5.5
Sodium (Na^+)	4.2 mg l^{-1}	11.5
Dissolved Potassium (K^+)	2.2 mg l^{-1}	2.2
Dissolved Oxygen (DO)	11.5 mg l^{-1}	13.9
DO (% Saturation)	102%	98%
Chemical Oxygen Demand (COD)	11 mg l^{-1}	9
Total Organic Carbon (TOC)	2.5 mg l^{-1}	2.2
True Color	15 pcu	5
Total Phosphorous	120 μg l^{-1}	30
Nitrate-nitrogen as N (NO_3-N)	0.15 mg l^{-1}	0.15
Total Recoverable Cadmium [Cd(t)]	2.0 μg l^{-1}	---
Total Recoverable Copper [Cu(t)]	70 μg l^{-1}	<5
Total Recoverable Iron [Fe(t)]	14,000 μg l^{-1}	<100
Total Recoverable Lead [Pb(t)]	55 μg l^{-1}	<10
Total Recoverable Mercury [Hg(t)]	0.30 μg l^{-1}	0.10
Total Recoverable Nickel [Ni(t)]	30 μg l^{-1}	2
Total Recoverable Zinc [Zn(t)]	70 μg l^{-1}	10

Source: R&M Consultants 1981

with ice and snow, however high velocity areas and small isolated areas of warm (3-4°C) groundwater upwelling maintain a few scattered open leads.

A winter-spring transition algal bloom probably occurs at open leads along the mainstem and side channel margins or at mid-channel shoals and riffle areas (Hynes 1970). The amount of surface area potentially involved in this process suggests that this mainstem contribution to autochthonous production may be substantial.

During spring break-up, stream flow rapidly increases during May from approximately 5,000 cfs to 20,000 cfs, while suspended sediment concentrations fluctuate considerably (9 - 1,670 mg l^{-1}), but average approximately 360 mg l^{-1} (Peratrovich et al. 1982). Most of the benthic production that occurred during the winter-spring transition is likely dislodged and swept downstream. A portion of this material may follow the natural flow path along the mainstem margin and into peripheral overflow channels and sloughs. Thus high spring flows may redistribute fish food organisms and retain some of the winter-spring transition organic production. At prevailing springtime turbidities (50 to 100 NTU), the mainstem margin and side channels apparently continue to support a low to moderate level of primary production wherever velocity is not limiting. The euphotic zone at this time is estimated to extend to an average depth between 1.2 and 3.5 ft (Van Nieuwenhuyse 1984).

In summer, mainstem flows are at their highest levels. The total surface area available for primary production is limited by high turbidities that reduce the depth of useful light penetration to less than 0.5 ft (Van Nieuwenhuyse 1984). Many of the insect species are in the egg stage or in early instar phases at this time (T. Hansen, Harza-Ebasco, 1984, pers. comm.). Juvenile fish migrating out of their natal tributaries move to low velocity rearing habitats, which seem to be concentrated in peripheral areas of the mainstem and side channels, and side slough, and upland slough aquatic habitats (ADF&G 1984c).

Largely because of its water quality (especially its high suspended sediment concentration), the principal function of mainstem habitat during the summer months is to provide a transportation corridor for inmigrating spawning salmon and outmigrating smolts. Mainstem water quality also has a significant influence on the seasonal water quality regime of side slough habitats, when overtopping of side slough occurs.

Field observations made in 1984 by EWT&A suggested that during a typical autumn transition period, a second pulse of primary production often occurs in the mainstem, dominated this time by green filamentous algae rather than diatoms. This second bloom, induced in part by moderating stream flows, but mostly by a notable reduction in turbidity levels to less than 20 NTU, probably exceeds the winter-spring transition bloom in terms of biomass produced and surface area affected. The depth of the euphotic zone at turbidities of 20 NTU approximates 5 ft (Van Nieuwenhuyse 1984). This fall-winter period of abundance stops at freezeup. Some of this production is dislodged and swept away or frozen in place.

Side Slough Habitat

Side sloughs present a unique seasonal pattern of streamflow and water quality that is important to many fish species inhabiting the middle Susitna River. Side slough habitat consists of clear water maintained by groundwater upwelling or local surface runoff in overflow channels. One distinguishing characteristic of side slough habitat is the periodic overtopping of the upstream end of the slough by high mainstem discharge levels that temporarily transforms the side slough to side channel habitat.

In winter, side sloughs contain numerous open leads maintained by upwelling groundwater (ADF&G 1983a). Thus they provide intragravel habitat for incubating embryos and overwintering opportunities for resident and juvenile anadromous fish.

During the winter-spring transition period, surface water temperatures exceed intragravel water temperatures during the day (Trihey 1982, ADF&G 1983a). Chum, sockeye and pink fry emerge from natal areas within the sloughs during this transition and primary production rates probably increase at this time.

Because side sloughs are located along the lateral portions of the flood plain, spring breakup in the sloughs is generally less spectacular than it is in either the tributaries or mainstem and side channel habitats. The most significant changes in side slough water quality occur during the summer. Side sloughs are connected at their upstream end to the mainstem or side channels by head berms of various elevations. As mainstem discharge increases side sloughs are inundated with turbid mainstem water. The lower the elevation of this upstream berm the more drastic and frequent are these overtoppings. During each overtopping, the side slough water quality and temperature are dominated by the characteristics of the mainstem.

Sloughs are also subject to turbid backwater effects at their downstream juncture with the mainstem or a side channel (mouths). Much of the suspended sediment load carried in by the mainstem water settles in the backwater and thus presents a substrate different from that found farther upstream in the sloughs.

Field observations by EWT&A suggest that some of the sediment carried through sloughs seems to become part of an organic matrix of unknown composition (probably involving bacteria, fungi, and other microbes) which in turn is usually covered by a layer of pennate diatoms. This benthic community, which covers most streambed material greater than 2 to 3 inches in diameter, can be observed throughout the system in mainstem and side channel habitats as well. It is possible that the phosphorus associated with the sediment plays some role in making this possible and studies (Stanford, Univ. of Montana, pers. comm. 1984) elsewhere indicate that as much as 6 percent or more of this sediment-bound total phosphorus can become biologically available --

perhaps to the diatoms. This might help explain how primary producers can still maintain a viable presence even under highly turbid conditions.

During late September and early October, 1984 fall-winter transitional algal blooms were observed by EWT&A in most side sloughs and thus probably occur every year. The 1984 bloom was characterized by dense mats of filamentous green algae growing on gravel substrate of one inch in diameter up to the largest cobble.

Upland Slough Habitat

Upland slough habitat is distinguished from side slough habitat by the lack of overtopping of the upstream slough end by high mainstem discharges. Thus, groundwater upwelling and local runoff dominate the water quality characteristics of upland slough habitats except at the slough mouths, which are influenced by turbid backwater effects from the mainstem.

Tributary and Tributary Mouth Habitats

As for all other aquatic habitat types, the seasonal water quality pattern displayed by the tributaries is closely linked to their annual flow regimes. This pattern is of considerable interest since it is in the tributaries--most notably Portage Creek, Indian River, and Fourth of July Creek--where most of the fish production originates (ADF&G 1981, 1982, 1984a). These streams provide spawning, rearing, and overwintering habitat that either does not exist, or only exists in limited amounts in other habitat types. Tributaries, in effect, may represent the most productive of the aquatic habitats in the middle Susitna River. The ionic composition of tributary water likely conforms to the hydrologic principle that the soils of a stream basin generally govern the quantity and the quality of the solids contained in the water flowing from it. The moderate concentrations of macronutrients (phosphorus and nitrogen) that prevail in these streams probably represent only that which leaks from the internal cycling taking place in the soils of the local watershed.

In winter, tributary flow is minimal and is comprised of groundwater rising up through the deeper portions of the ice-constricted stream channel. Since much of the winter mainstem flow is comprised of contributions made by groundwater and tributary sources, tributary water chemistry is probably similar to the winter water chemistry characteristics of the mainstem (Table IV-6). Thus, the water quality characteristics of tributaries during winter reflect a well-buffered, well-oxygenated environment for embryo incubation and adult and juvenile overwintering.

During the four to six week transition between winter and the onset of the spring freshet, portions of the ice and snow cover on the tributary melt away. Water temperatures may increase slightly and a pulse of primary production probably occurs in response to a lengthening photoperiod (Hynes 1970). The ability of light to reach the algal community is assisted by absence of leaf cover on stream bank vegetation and presence of candle ice that effectively transmits light (Jacqueline LaPerriere, pers. comm. 1984). The emergence of some fish species and many insects is apparently timed to occur during this brief early-spring interlude of plentiful food and relatively tranquil stream flows.

Typically, by mid-May air temperatures have increased to 8°C and the spring freshet has filled the tributary channel with runoff from melting snow. Ice redistributes much of the cobble substrate and flushes out organic and inorganic debris as well as much of the benthic community (Hynes 1970). This erosion causes an increase in suspended sediment concentration and turbidity. Likewise, color, total organic carbon, and chemical oxygen demand, increase substantially, while, as in the mainstem, the inflow of surface runoff dilutes winter concentrations of dissolved solids. It is likely that the spring freshet serves as a functional reset mechanism for the system, in effect, cleansing it in preparation for the ecological events to follow.

Typical water quality in tributaries during the summer (June to mid-September) probably approximates the winter condition except for lesser concentrations of dissolved solids (Hynes 1970). Summer stream temperatures are warmer and fluctuate diurnally. This background condition is frequently punctuated by storm runoff events.

Summer is the season when juvenile fish are most active. Rearing is supported primarily by the growth and recruitment taking place within the aquatic insect community (especially chironomids). The carrying capacity of tributaries, however, does not appear adequate to support the large numbers of rearing juveniles, so many juveniles outmigrate at this time to continue their development elsewhere (ADF&G 1984c).

During late September and early October a second transition period occurs as streamflow, photoperiod, and temperature gradually decline. Algal biomass and productivity are probably at their annual peak as is the standing crop of benthic macroinvertebrates (Hynes 1970). The algal mat is not only a food source for a variety of insect larvae and nymphs, but serves as microhabitat for many aquatic organisms including juvenile fish. The leaves shed from riparian vegetation may provide further microhabitat and insect food substrate.

By late October, surface water temperatures are 0°C and an ice cover begins to form. Unstable border ice and anchor ice probably dislodge a substantial portion of the benthic community causing it to be swept downstream. Much of what remains of this community may be frozen in place as the ice cover formation continues. Freezeup is usually complete by late November or early December when the winter phase of the annual cycle begins once again.

With-Project Relationships

Temperature and suspended sediment seasonally influence aquatic habitat types in the middle Susitna River and therefore are important in the distribution and production of fish. It is also evident that these water quality parameters will be directly affected by construction and operation of the proposed project (AEIDC 1984?, Peratrovich et al. 1982). Stream temperature is discussed in Section IV D of this report, hence the following discussion focuses on suspended sediment and turbidity.

The downstream water quality regime will change as a result of project operation. The reservoir(s) is expected to trap approximately 70 to 95 percent of the total volume of sediments that are annually transported through the middle Susitna River (R&M Consultants 1982, Harza-Ebasco 1984a). The sediment remaining in suspension and released downstream year round will consist predominantly of fine particles (<5μ in diameter) (APA 1983), which create a turbidity far greater in proportion to their mass than larger particles. Estimates for the expected concentration of total suspended solids released from the reservoir(s) year round range from 0 to 345 mg l^{-1}, with the expected average between 30 and 200 mg l^{-1} (Peratrovich et al. 1982). Concentrations of this magnitude will likely result in year round turbidities ranging between 60 and 600 NTU (Peratrovich et al. 1982) with corresponding euphotic zone depths of approximately 3 and 0.4 ft (Van Nieuwenhuyse 1984).

A reduction in suspended sediment levels in the middle reach of the Susitna River would likely result in existing sediments and find sands in streambed materials to be transported downstream (Harza-Ebasco 1984a). Additionally, if short term peak flow events disturbed streambed materials and cleared the interstitial spaces of fine sediments, the hydraulic connection between surface and subsurface flow would probably improve. These conditions, in turn, would be expected to increase the success rate for mainstem and side channel spawning by salmon and the colonization rates of periphyton and benthic invertebrates during the summer.

Primary production in the middle reach of the Susitna River presently appears to be concentrated in the spring and fall periods of low turbidities. Constant, year-round turbidity levels in the range of 60 to 600 NTU would likely reduce the level of primary production during these transition periods.

Instream Temperature and Ice Processes

Instream Temperature Criteria

Within the range of temperatures encountered in northern river systems, increases in stream temperature generally cause an increase in the rate of chemical reactions, primary production, and cycling of allochthonous food sources. The fish inhabitants of the river system adjust their body temperatures to match the temperature of the water. As temperatures increase, rates of digestion, circulation and respiration increase. Thus, there is an overall increase in the rate of energy input, nutrient cycling and energy use as the river system warms.

Each species of fish is physiologically adapted to survive within a tolerance range of stream temperature. Within this tolerance range there is a narrower range of "preferred" temperatures at which metabolism and growth rates of individuals are most efficient. Outside the tolerance range are upper and lower incipient lethal limits.

The preferred temperature range for adult salmon in the middle Susitna River ranges from 6 to 12°C (AEIDC 1984b). Juvenile salmon prefer slightly warmer temperatures for rearing, generally ranging from 7 to 14°C (Table IV-7). These temperatures are consistent with the preferred temperature range of 7 to 13°C reported by McNeil and Bailey (1975) for Pacific salmon. The preferred temperature range for incubation is generally between 4 and 10°C although chum salmon embryos successfully incubate in temperatures between 2 and 8°C.

The time required for embryo incubation is directly related to stream temperature. Development rates increase with rising stream temperature up to approximately 14°C. Above this, further temperature increases are considered detrimental. Salmon embryos are also vulnerable to cold temperatures until they have accumulated

Table IV-7. Preliminary stream temperature criteria for Pacific salmon developed from literature sources for application to the Susitna River.

Species	Life Phase	Temperature Range (°C) Tolerance	Preferred
Chum	Adult Migration	1.5-18.0	6.0-13.0
	Spawning	1.0-14.0	6.0-13.0
	Incubation[1]	0-12.0	2.0-8.0
	Rearing	1.5-16.0	5.0-15.0
	Smolt Migration	3.0-13.0	5.0-12.0
Sockeye	Adult Migration	2.5-16.0	6.0-12.0
	Spawning	4.0-14.0	6.0-12.0
	Incubation[1]	0-14.0	4.5-8.0
	Rearing	2.0-16.0	7.0-14.0
	Smolt Migration	4.0-18.0	5.0-12.0
Pink	Adult Migration	5.0-18.0	7.0-13.0
	Spawning	7.0-18.0	8.0-13.0
	Incubation[1]	0-13.0	4.0-10.0
	Smolt Migration	4.0-13.0	5.0-12.0
Chinook	Adult Migration	2.0-16.0	7.0-13.0
	Spawning	5.0-14.0	7.0-12.0
	Incubation[1]	0-16.0	4.0-12.0
	Rearing	2.0-16.0	7.0-14.0
	Smolt Migration	4.0-16.0	7.0-14.0
Coho	Adult Migration	2.0-18.0	6.0-11.0
	Spawning	2.0-17.0	6.0-13.0
	Incubation[1]	0-14.0	4.0-10.0
	Smolt Migration	2.0-16.0	6.0-12.0

[1] Embryo incubation or development rate increases as temperature rises. Accumulated temperature units or days to emergence should be determined for each species for incubation. See Figure IV-D-1

Source: AEIDC 1984b

approximately 140 centigrade temperature units (CTU's)[1]. After this initial period of sensitivity to cold temperatures has passed, incubating embryos can tolerate temperatures near 0°C.

Table IV-8 provides a comparison between the number of CTU's that resulted in 50 percent hatching and 50 percent emergence of chum salmon alevins under both field and laboratory environments. The number of temperature units that resulted in 50 percent hatching and 50 percent emergence of chum and sockeye alevins at selected middle Susitna River sloughs appear similar to that required by Alaskan stocks of these species under controlled conditions. Collectively these data indicate that 400 to 500 CTU's can be used as an index for 50 percent hatching of chum and sockeye eggs.

A simplified way of forecasting emergence time using the information provided in Table IV-8 and other pertinent data from the literature was developed by AEIDC (1984b). The relationship between mean incubation temperature and development rate for chum and sockeye embryos is presented in the form of a nomograph (Figure IV-5).

This nomograph can be used to forecast the date of 50 percent emergence given the spawning date and the mean daily intragravel water temperature for the incubation period. A straight line projected from the spawning date on the left axis through the mean incubation temperature on the middle axis identifies the date of emergence on the right axis.

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[1] A centigrade temperature unit is the index used to measure the influences of temperature on embryonic development and is defined as one 24 hour period 1°C above freezing (0°C). Hence stream temperatures between 4 and 5°C would provide 140 centigrade temperature units in about one month.

Table IV-8. Comparison of accumulated centigrade temperature units (CTU's) needed to produce 50 percent hatching of chum salmon eggs and 50 percent emergence of chum salmon alevins at selected sites on the Susitna River with those required under controlled incubating environments elsewhere in Alaska.

Location	Brood Year	CTU's required for 50% Hatching	CTU's required for 50% Emergence[1]
Susitna River - Slough 8A	1982	539	---[2]
Susitna River - Slough 11	1982	501	232
Susitna River - Slough 21 Mouth	1982	534	283
Clear Hatchery[3]	1977	420	313
Clear Hatchery[3]	1978	455	393
Eklutna Hatchery[4]	1981	802	209
USFWS Laboratory - Anchorage[5]	1982	306	---
USFWS Laboratory - Anchorage[5]	1982	448	---
USFWS Laboratory - Anchorage[5]	1982	489	---
USFWS Laboratory - Anchorage[5]	1982	472	---

1 Calculated from the time of 50 percent hatching to the time of 50 percent emergence

2 No emergence had occurred as of April 20

3 Raymond (1981)

4 Loren Waldron, Eklutna Hatchery, personal communication

5 Adapted from Waangard and Burger (1983)

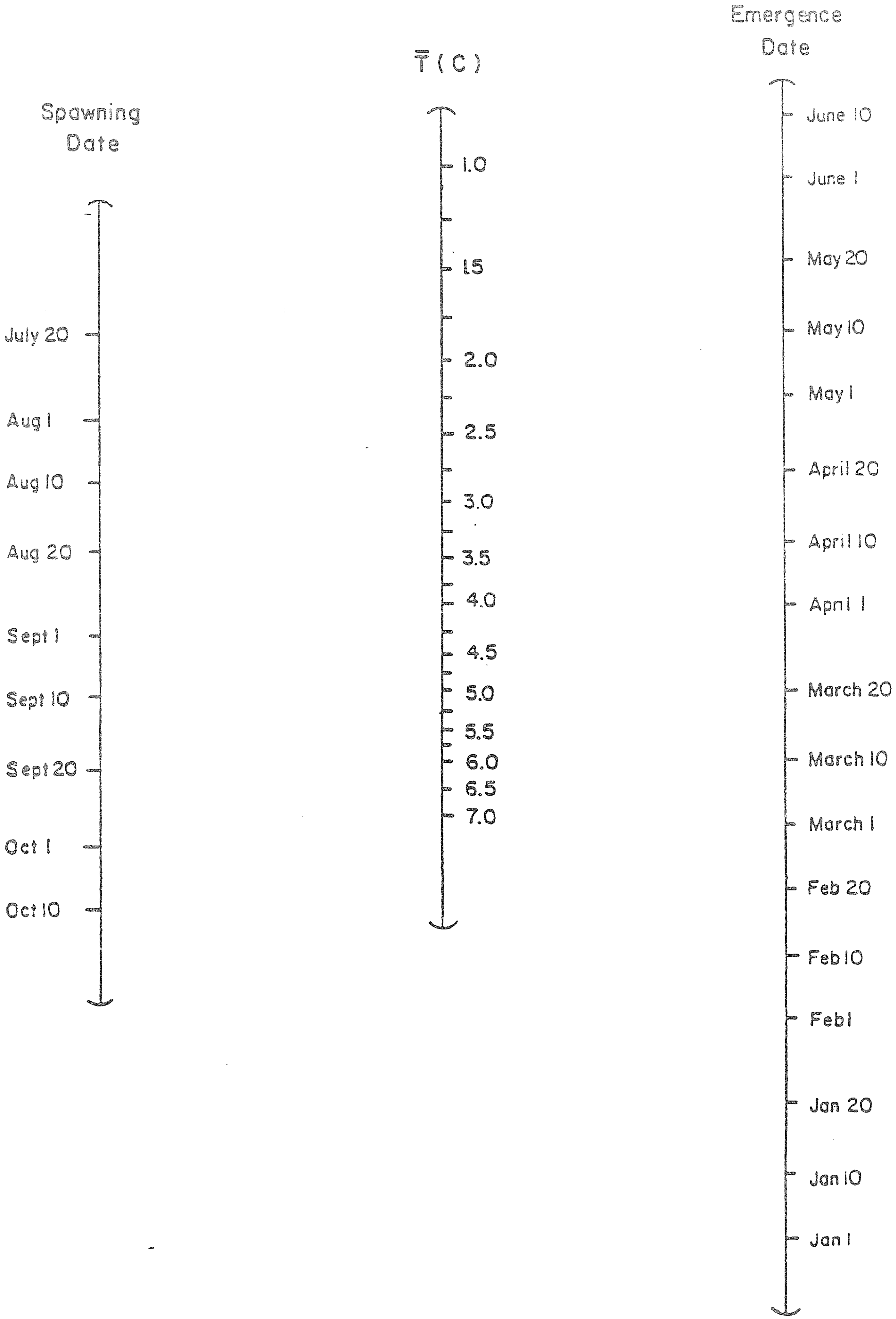

Figure IV-5. Chum salmon spawning time versus mean incubation temperature nomograph. (Source: AEIDC 1984b).

Instream Temperature Processes

Stream temperature in northern rivers responds primarily to the seasonal variation of the local climate and hydrologic conditions. Heat transfer between the atmosphere and an open water surface principally occurs through convection, evaporation/condensation and radiation. Heat transfer by convection and evaporation/condensation responds directly to wind speed and the temperature differential across the air-water interface. Radiative heat transfer consists of two types: shortwave and longwave radiation. Both short- and longwave radiation are significantly influenced by basin topography, percent cloud cover, and surrounding vegetation. At higher latitudes incoming shortwave radiation is highly variable because of seasonal differences in the solar azimuth which influences the intensity of the shortwave radiation per unit area and the length of the daylight period.

Cooling or warming of the river by the processes described above will not be altered by the construction or operation of the proposed project. However, the amount and temperature of water influent to a river also affects its temperature. Construction and operation of the proposed Susitna Project will substantially alter these existing seasonal relationships by the redistribution of the available water supply and its associated heat energy through the year.

Sources of water influent to the Susitna River are classified as: glacial melt, tributary inflow, non-point surface runoff, and groundwater inflow. The relative importance of each of these to mainstem flow and temperature at Gold Creek varies seasonally.

Tributary and non-point surface runoff increase during snow melt periods and in response to rainstorms, and glacial melt water is predominantly a summer phenomena. Groundwater inflow, however, appears to remain fairly constant throughout the year. Hence its relative importance increases during winter as inflows from glacial melt and non-point runoff cease. Tributary inflows themselves diminish to base levels maintained by groundwater inflow from their sub-basins. The temperature of influent groundwater remains near 3 to 4°C throughout the year (ADF&G 1983a). Glacial melt water at the headwaters of the Susitna River is near 0°C but it is warmed by the heat transfer processes described earlier as it flows downstream. Temperature of tributary waters are generally cooler than the temperature of the mainstem, especially during May and June when most of their streamflow consists of snow melt (Figure IV-6. Tributary water temperatures determine surface water temperatures at tributary mouths. Tributary flows characteristically hug the mainstem shoreline after converging with the Susitna River forming a plume that may extend several hundred feet downstream.

Mainstem water temperatures normally range from zero during the November-April period to 11 or 12°C from late June to mid-July. Water temperatures increase rapidly during May but gradually decrease during September and October. Water temperatures in side channels follow mainstem temperatures except in side channel areas which do not convey mainstem water during periods of low flow. Except when overtopped by mainstem flow, surface water temperatures in side sloughs are independent of mainstem water temperatures even though both may occasionally be the same temperature (Table IV-9).

Sloughs receive nearly all of their clear water flow from local runoff and groundwater inflow. Due to their relatively large surface areas in comparison to their depth and flow rate, sloughs are quicker to warm and cool. Hence daily fluctuations in side slough surface water temperatures are more exaggerated than for mainstem or side channel water temperatures (ADF&G 1984f). When sloughs receive substantial inflow from snowmelt or rainfall runoff, their surface water temperatures will reflect the temperature of that runoff. During winter, slough flow is primarily maintained by upwelling which

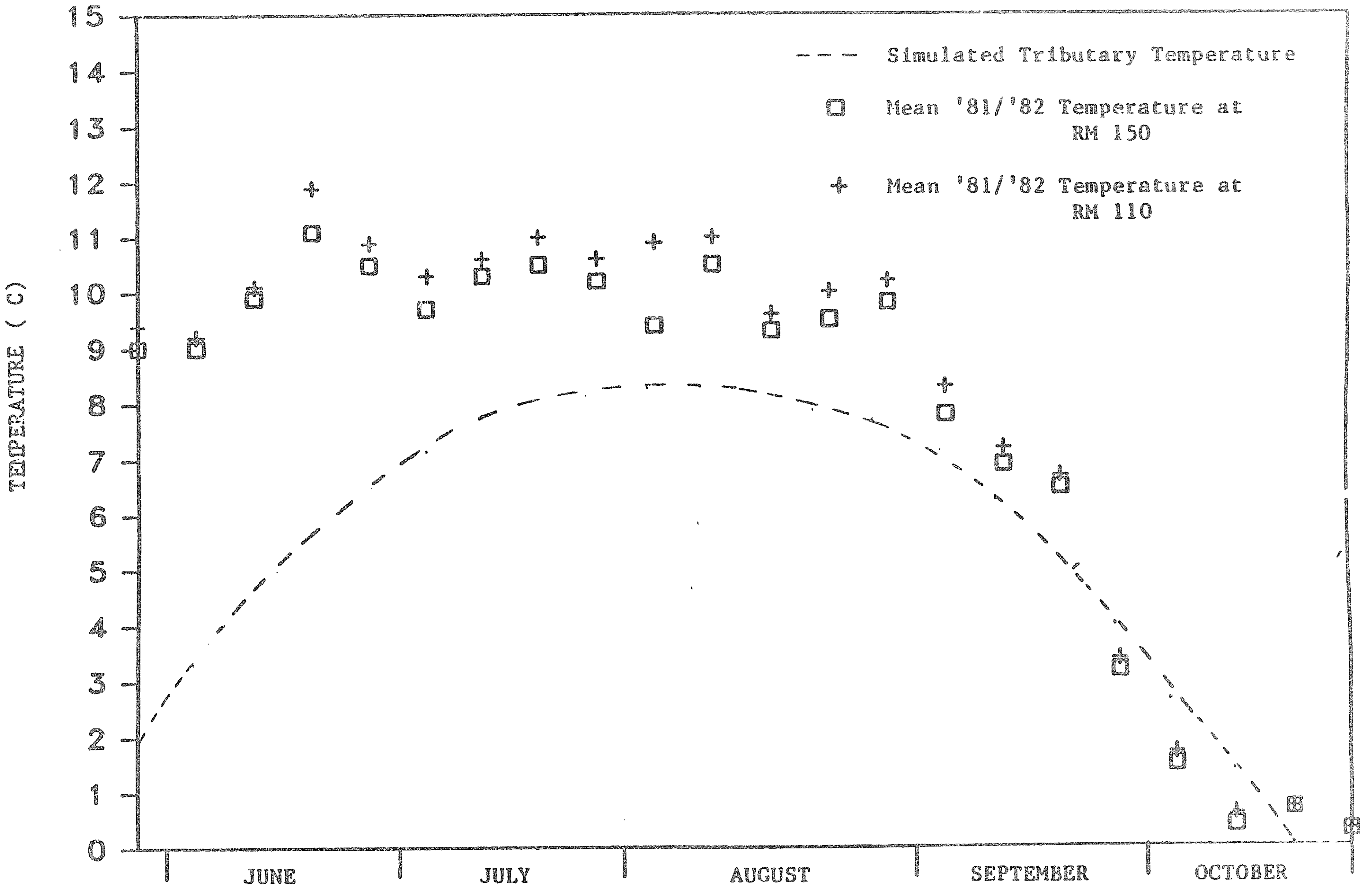

Figure IV-6. Comparison between average weekly stream temperatures for the Susitna River and its tributaries. (Adapted from AEIDC 1984b).

Table IV-9. Comparison between measured surface water temperatures (degrees C) in side sloughs and simulated mainstem temperatures

Location	RM	1982			1982					1983				
		Feb	Mar	Apr	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Slough 8A Mouth	125.4					6.5	2.4	1.7		0	0	0.4	1.3	
Slough 8A Upper	126.4					5.8	4.4					2.5	3.8	3.3
Slough 9	128.7				8.9	5.9	2.3						3.8	4.7
Slough 11	135.7		2.5	3.1		3.3	3.1	2.9	2.9	2.9	2.9	3.0	3.5	6.0
Slough 21	141.8	1.6	1.9	3.1			2.2	1.1	0.8					
Mainstem														
LRX 29	126.1	0.0	0.0	2.9	10.9	6.5	0.6	0.0	0.0	0.0	0.0	0.0	3.0	---
LRX 53	140.2	0.0	0.0	2.5	10.8	6.4	0.6	0.0	0.0	0.0	0.0	0.0	2.6	---

Note: Mainstem temperatures are simulated without an ice cover and warm earlier in the spring than what naturally occurs. Thus the April mainstem temperatures are probably warmer than what would occur.

Source: ADF&G 1983.

possesses very stable temperatures around 3°C (ADF&G 1983). Surface water temperatures are significantly influenced by the thermal quality of the upwellings; often remaining above 0°C throughout most of the winter. Surface water temperatures typically reach 5 or 6°C in quiescent areas within side sloughs by mid April; approximately one month before similar temperatures are available in mainstem and side channel areas.

Occasionally side sloughs are overtopped by mainstem water during staging at freezeup which severely disrupts the relationship between intragravel and surface water temperatures. Once overtopped, the small volume of relatively warm slough water, which serves to buffer submerged upwelling areas from extreme cold, is immediately replaced by a large volume of 0°C water and slush ice. As the overtopped condition persists the warming influence of the upwelling is diminished and intragravel water temperatures decrease from 3 or 4°C to near zero (ADF&G 1983).

A similar condition occurs during spring breakup when large volumes of near zero degree mainstem water may flow through side sloughs flushing them of their substantially warmer surface water. Although little data are available for this period, intragravel water temperatures are not suspected to be as adversely affected by overtopping events during breakup as they are by overtopping during freeze up.

With-Project Temperature Conditions. Construction and operation of Watana dam will directly affect seasonal water temperatures by redistributing streamflow and its associated heat content throughout the year. Those portions of the Susitna River most affected by with-project stream temperatures will be mainstem and side channel areas that convey water released from the reservoir. With-project summer flows are expected to be lower and winter flows higher than naturally occurring streamflows. It is anticipated that stream temperatures will be similarly affected but not to the same degree as streamflow. Addition of Devil Canyon reservoir would amplify the deviation in both summer and winter with-project stream temperatures from naturally occurring mainstem temperatures at any given location within the middle Susitna River (Table IV-10). In effect, the addition of Devil Canyon Reservoir results in naturally occurring stream temperatures being affected further downstream.

Table IV-10. Simulated middle Susitna River mean summer mainstem temperatures[1] for natural, Watana only, and Watana/Devil Canyon conditions.

	RM 150	RM 130	RM 100
Natural	8.4	8.5	9.0
Watana only (1996 Demand)	7.4	7.5	8.5
Watana/Devil Canyon[2] (2002 Demand)	6.4	6.8	7.9

[1] Average of four May-September stream temperature simulations using meteorologic and hydrologic conditions associated with the summers of 1971, 1974, 1981 and 1982.

[2] With increased load demand in later years of operation, less frequent use of the Devil Canyon cone values would result in slightly warmer mean summer temperatures (AEIDC 1984b).

Project design and operation has a notable influence on the temperature and flow rate of water discharged from the dam(s). Within the anticipated operating range of the project, the temperature of the reservoir outflow has a greater influence on downstream water temperatures than flow rate. Table IV-11 displays the simulated downstream temperatures for two situations: the water week 34, where the downstream release temperatures are equal but release rate differ, and water week 45 where release rates are equal but their temperatures differ. The weekly simulation period is the same within each example thereby eliminating downstream temperature differences resulting from climatic influences. The 1.8°C temperature difference shown in the second case results in a much greater downstream temperature difference than that resulting from 810 cfs flow decrease (13 percent decrease in flow) shown in the first case.

The most notable effect of project construction and operation on natural stream temperatures is delaying the temperature rise during early summer and extending warm stream temperatures into fall

Table IV-11. Downstream temperatures (°C) resulting from differences in summer reservoir release flows and temperatures.

		Water Week 34 (May 20 - 26, 1981)		Water Week 45 (August 5 - 11, 1974)	
		Dam Release: 6080 cfs Temp: 3.9°C	5270 cfs 3.9°C	Dam Release: 10,950 cfs Temp: 8.1°C	10,950 cfs 9.9°C
Lower River Cross Section	River Mile	2002 Demand	2020 Demand	2002 Demand	2020 Demand
68	150	4.5	4.5	8.2	9.9
53	140	4.9	5.0	8.5	10.1
33	130	5.4	5.5	8.6	10.1
23	120	6.0	6.1	9.0	10.4
13	110	6.5	6.7	9.4	10.7
3	99	7.1	7.3	9.8	11.0

(Figure IV-7). As with mid-summer stream temperatures, the temperature of the middle Susitna River during winter is directly influenced by climate and project operation. The location at which 0°C water occurs downstream from the dam, and consequently the maximum upstream extent of the ice front, is controlled by annual winter climate. However its location also varies in response to reservoir outflow temperature and to a lesser flow rate.

Due to the occurrence of warmer stream temperatures during fall, ice front development on the middle Susitna River is expected to be delayed from two to seven weeks (Harza-Ebasco 1984b). In addition, the location of the ice front under with-project conditions is not expected to extend as far upstream as it does under natural conditions. Among the variables influencing winter stream temperature, basin meteorology is the most significant.

Short periods of -15 to -25°C air temperature increase the cooling rate of water downstream from the dams and result in the production of frazil ice. There is a rapid upstream progression of the ice front during these periods (Gemperline 1984). Table IV-12 provides an example of the influence winter air temperature has on simulated downstream water temperatures.

The second most important variable, and one over which project design and operation has some degree of control, is the temperature of the reservoir outflow. The amount of water being released from the reservoir also influences winter stream temperature but it is not as significant a variable as outflow temperature or basin climate. Table IV-13 displays downstream temperatures for two cases: (1) where dam release temperatures are the same but flow volumes change (in this case a 59 percent increase) and (2) where dam release flows are relatively constant (note: actually a 11 percent increase) and release temperatures differ. As in the previous example for summer releases, the differences in release temperatures result in the greatest downstream temperature differences.

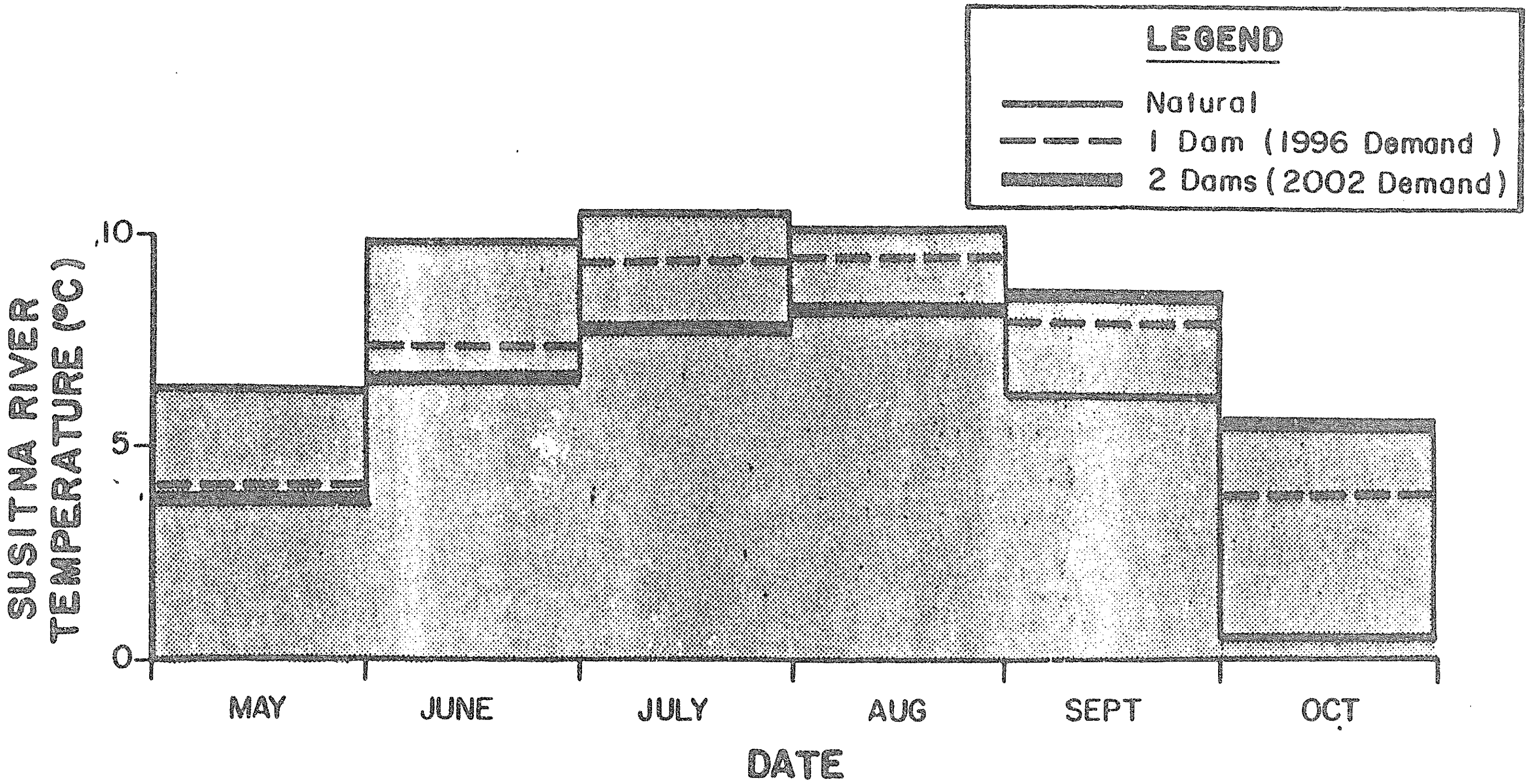

Figure IV-7. Comparison of simulated natural and with-project monthly temperatures of the Susitna River at R.M. 130 for the one and two dam scenarios (Source: AEIDC 1984b).

Table IV-12. Comparison between simulated downstream water temperatures for constant reservoir outflow conditions and different air temperatures.

Lower River Cross Section	River Mile	Water Week 8 (Nov. 19-26, 1981) Dam Release: 7,590 cfs Release Temp: 1.9°C Air Temp: (Talkeetna) -11.6°C	Water Week 18 (Jan. 28-Feb. 3, 1983) Dam Release: 7,600 cfs Release Temp: 1.9°C Air Temp: (Talkeetna) -3.4°C
68	150	1.8	1.9
53	140	1.3	1.6
33	130	0.6	1.2
23	120	0	.8
13	110	0	.5
3	99	0	0

Note: Both simulations are for Devil Canyon dam, 2002 Demand.

Table IV-13. Downstream temperatures (°C) resulting from differences in winter reservoir release flows and temperatures.

Lower River Cross Section	River Mile	Water Week 9 (Nov. 26 - Dec. 2 1970)		Water Week 22 (Feb. 25 - March 3, 1982)	
		Dam Release: 7770 cfs Temp: 1.3 °C	12,370 cfs 1.3°C	Dam Release: 7190 cfs Temp: 2.8°C	8000 cfs 1.7°C
		2002 Demand	2020 Demand	2002 Demand	2020 Demand
68	150	1.3	1.3	2.7	1.7
53	140	0.7	0.9	2.2	1.2
33	130	0	0.4	1.5	0.7
23	120	0	0	0.8	0.1
13	110	0	0	0.2	0
3	99	0	0	0	0

Ice Processes

The most important factors affecting freezeup of the Susitna River are air and water temperature, instream hydraulics, ice supply, and channel morphology. Breakup is primarily influenced by antecedant snowpack conditions, air temperature and spring rainfall. The upper Susitna River is commonly subjected to freezing air temperature by mid-September, and slush ice has been observed in the Talkeetna-to-Devil Canyon reach as early as late September. Initial phases of ice cover deterioration commonly begin by mid-April with ice out on the middle Susitna River generally being complete by mid-May (R&M Consultants 1983).

Figure IV-8 presents a generic flowchart which diagrams the ice forming process on the Talkeetna-to-Devil-Canyon reach of the Susitna River based on a recognition of pertinent climatic and physical factors. In order to understand the flow chart and subsequent discussions in this text, brief definitions have been adopted from R&M (1983) for the most common types of ice found in the middle reach of the Susitna River.

- Frazil - Individual crystals of ice generally believed to form when water becomes supercooled.

- Frazil Slush - Frazil ice crystals have strong cohesive properties and tend to agglomerate into loosely packed clusters that resemble slush. The slush eventually gains sufficient mass and buoyancy to counteract the flow turbulence and float on the water surface.

- Snow Slush - Similar to frazil slush but formed by loosely packed snow particles in the stream.

- Black Ice - Black ice initially forms as individual crystals on the water surface in near zero velocity areas in rivers and underneath an existing ice cover. These crystals

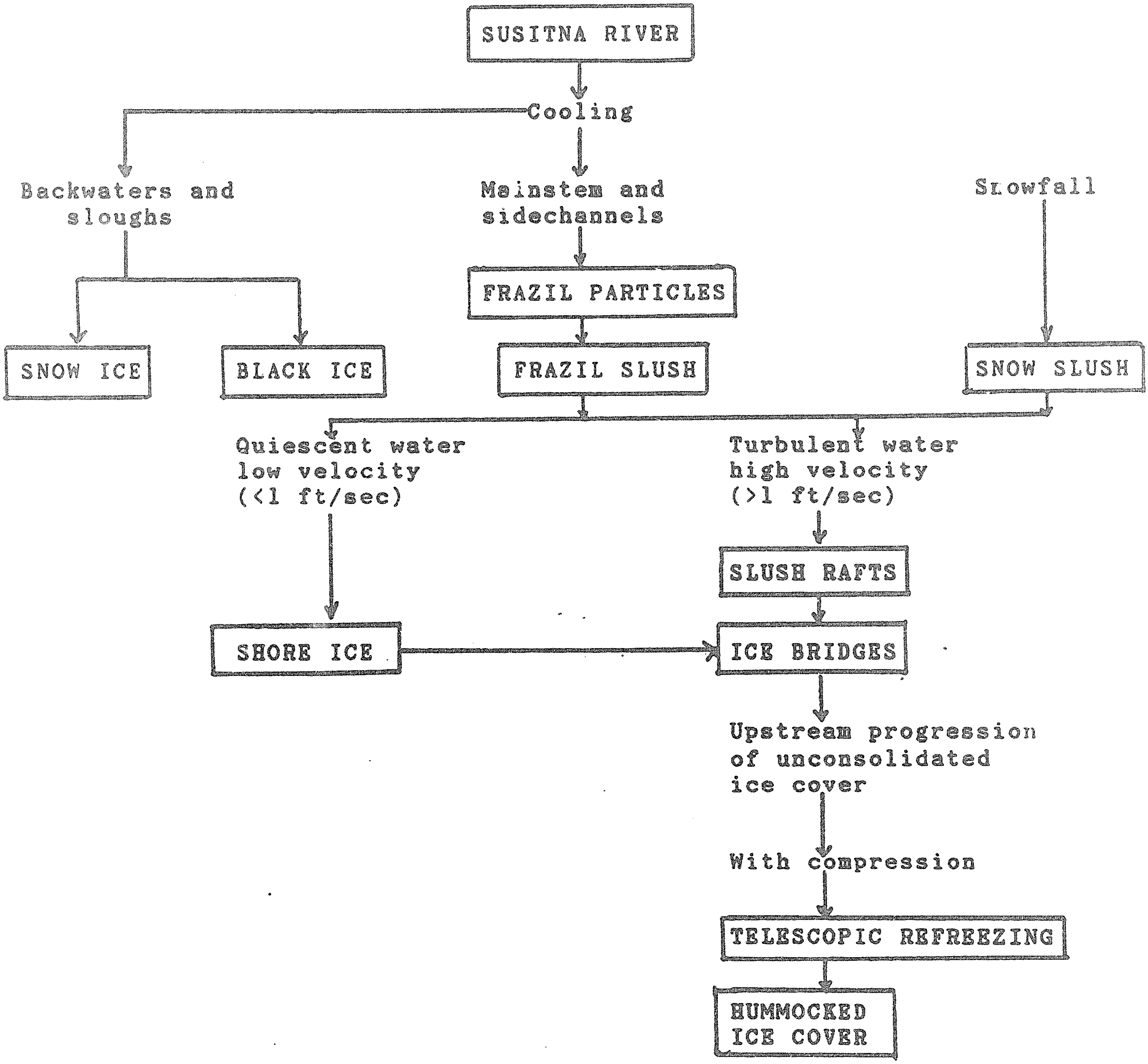

FIGURE IV-8. Flowchart of gneral ice forming processes on the middle reach of the Susitna River.

develop in an orderly arrangement resulting in a compact structure which is far stronger than slush ice covers. Black ice developing in the absence of frazil crystals is characteristically translucent. This type of ice often grows into clear layers several feet thick under the Susitna slush ice cover.

- Shore Ice or Border Ice - This forms along flow margins as a result of slush ice drifting into low velocity areas and freezing against the channel bed.

- Ice Bridges - These generally form when shore ice grows out from the banks to such an extent that a local water surface constriction results. Large volumes of slush ice may not be able to negotiate this constriction at the same rate as the water velocity. An accumulation of slush subsequently occurs at the constriction which may freeze into a continuous solid ice cover or bridge. This ice bridge usually prevents slush rafts from continuing downstream and therefore an upstream accumulation or progression of ice is initiated.

- Hummocked Ice - This is the most common form of ice cover on the Susitna mainstem and side channel areas. Essentially it is formed by continuous accumulation of slush rafts that progressively build up behind ice bridges causing the ice cover to migrate upstream during freezeup.

Freezeup

Frazil Ice Generation. Most river ice covers are formed as a result of the formation and concentration of frazil ice. When river water becomes slightly supercooled (0°C), frazil crystals begin to form, usually by nucleation. Fine suspended sediments in the water during freezeup season may be the nucleating agent in the Susitna River. Frazil crystals initially form principally as small discoid crystals only a few millimeters in diameter. These grow rapidly to larger size and begin to accumulate as frazil slush masses, often contributed to by snowfall into the river which forms floating snow slush. The combined slush usually breaks up in turbulence into individual slush floes that continue drifting downriver until stopped by jamming at river constrictions (Ashton 1978; Michel 1971; Ostercamp 1978).

Frazil ice generally first appears in the river between Denali and Vee Canyon by mid-September. This ice drifts downriver, often accumulating into loosely-bonded slush floes, until it melts away or exits into Cook Inlet. During freezeup, generally about 80 percent of the ice passing Talkeetna into the lower river is produced in the upper Susitna River, while the remaining 20 percent is produced in the Talkeetna and Chulitna Rivers. Below the Yentna confluence, usually more than 50 percent of the ice is produced by the Yentna River.

Talkeetna to Gold Creek. The leading edge of the lower Susitna River ice cover usually arrives at the confluence of the Susitna and Chulitna Rivers (RM 99) between early November and early December (Table IV-14). The rate of upstream progression is significantly slower on the middle reach of the Susitna River.

The ice front progression rate decreases as the ice front moves upriver. In 1982, the progression rate slowed from an average of 3.5 miles per day near the confluence to 0.05 miles per day by the time it reached Gold Creek (RM 136). This is probably due to the increase in gradient moving upriver and to the reduction in frazil ice generation in the upper Susitna River as it develops a continuous ice cover. The upper Susitna River freezes over by border ice growth and intermediate bridging before the advancing leading edge reaches Gold Creek.

Local groundwater levels are often raised when the leading edge approaches. This is probably due to staging effects raising the water level in the mainstem, which then is propagated through the permeable river sediments into surrounding sloughs and side channels.

Table IV-14. Summary of freeze up observations for several locations within the Talkeetna to Devil Canyon reach of the Susitna River. Source: R&M Consultants 1980-81, 1982, 1983, 1984.

Location	River Mile	1980-1981	1981-1982	1982-1983	1983-1984
Ice Bridge or Ice Front At					
Susitna-Chulitna confluence		Nov. 29	Nov. 18	Nov. 5	Dec. 8
Leading Edge Near					
Gold Creek		Dec. 12	Dec. 31	Dec. 27	Jan. 5
Approximate Freezing Dates at					
Susitna Chulitna					
Confluence	98.6		Mid-Nov.	Nov. 5	Dec. 9
"	103.3			Nov. 8	
"	104.3	Dec. 1			
"	106.2			Nov. 9	
"	108.0	Dec. 2			
"	112.9	Dec. 3			
Lane Creek	113.7			Nov. 15	
McKenzie Creek	116.7			Nov. 18	
"	118.8	Dec. 5			
Curry	120.7			Nov. 20	Dec. 21
Slough 8	124.5			Nov. 20	
"	126.5	Dec. 8			
"	127.0		Mid-Dec.	Nov. 22	
Slough 9	128.3			Nov. 29	
"	130.9			Dec. 1	Jan. 5
Slough 11	135.3			Dec. 6	
Gold Creek	136.6	Dec. 12	Early Jan.	Jan. 14	Jan. 15
Portage Creek	148.9			Dec. 23	

Source: R&M Consultants

Many sloughs fail to form a continuous ice cover all winter due to upwelling of relatively warm (1-3°C) groundwater (Trihey 1982, ADF&G 1983a). However, ice does form along slough margins, restricting the open water area to a narrow, open lead. Some sloughs that do form ice covers after being inundated with mainstem water and ice later melt out because of the groundwater thermal influence. These leads often then remain open all winter.

As slush ice accumulates against the leading edge, it consolidates from time to time through compression and thickening. Staging accompanies this process, which sometimes lifts the ice cover and allows it lateral movement, often extending the ice from bank to bank.

Water flowing under the ice cover throughout the winter often causes frictional erosion of the underside of the ice, opening leads in the cover. This usually occurs rapidly after the initial stabilization of a slush ice cover. These leads usually slowly freeze over with a secondary ice cover, and most leads are closed by March.

The slush ice front progression from the Susitna/Chulitna confluence generally terminates in the vicinity of Gold Creek , about 35 to 40 miles upstream from the confluence, by December or early January.

Gold Creek to Devil Canyon. Freezeup occurs gradually in the reach from Gold Creek (RM 136) to Devil Canyon (RM 150), with a complete ice cover in place much later than in the reach below Gold Creek, usually not until March (R&M Consultants 1983). The ice front does not generally progress beyond the vicinity of Gold Creek because of the lack of frazil ice input after the upper river freezes over. Also, ice is late in forming here because of the relatively high velocities in this reach, caused by the steeper gradient and single-channel characteristics of the reach.

Wide border ice layers build out from shore throughout the freezeup season, narrowing the open water channel in the mainstem and frequently forming ice bridges across the river, separated by open leads. In the open water areas, frazil ice adheres easily to any object it contacts within the river flow, such as rocks and gravel on the channel bottom, forming anchor ice. Anchor ice may form into low dams in the stream bed, especially in areas narrowed by border ice, increasing local water turbulence which may increase frazil generation. Slight backwater areas are sometimes induced due to a general raising of the effective channel bottom, affecting flow distribution between channels and causing overflow onto border ice. Within the backwater area, slush ice may freeze in a thin layer from bank to bank.

Little staging occurs in this reach during freezeup, and sloughs and side channels are generally not breached at their upper ends. They usually remain open all winter due to groundwater inflow. Open leads occur in the mainstem , especially in high velocity areas between ice bridges, but few new leads open after the formation of the initial ice cover. There is minimal ice cover sag in this reach.

Ice Cover at the Peak of Development. Once the initial ice cover forms it remains quite dynamic, either thickening or eroding. Slush ice adheres to the underside of the ice cover in low velocity areas and becomes bonded by low temperatures. The ice cover becomes most stable at its height of maturity, generally in March (R&M Consultants 1983). The only open water at that time is in the numerous leads that persist over turbulent areas and areas of groundwater upwelling, and little frazil slush is generated.

Breakup. Under natural conditions, the Susitna River ice cover disintegrates in the spring by a progression beginning with a slow, gradual deterioration of the ice and ending with a dramatic breakup drive accompanied by ice jams, flooding, and erosion (R&M Consultants 1983). The duration of the breakup period depends on the intensity of solar radiation, air temperatures, and precipitation.

A pre-breakup period occurs as snowmelt begins in the area, usually by early April. Snowmelt begins first at the lower elevations near the Susitna River mouth and slowly works northward up the river. By late

April, snow has usually disappeared on the river south of Talkeetna and snowmelt is proceeding into the reach above the Susitna/Chulitna confluence. Tributaries to the lower river have usually broken out in their lower elevations, and open water exists at their confluences with the Susitna River. Increased flows from the tributaries erode the Susitna ice cover for considerable distances downstream from their confluences.

As water levels in the river begin to rise and fluctuate with spring snowmelt and precipitation, overflow often occurs onto the ice since the rigid and impermeable ice cover fails to respond quickly enough to these changes. Standing water appears in sags and depressions on the ice cover. This standing water reduces the albedo, or reflectivity, of the ice surface, and open leads quickly appear in these depressions. As the water level rises and erodes the ice cover, ice becomes undercut and collapses into the open leads, drifting to their downstream ends and accumulating in small ice jams. In this way, leads become steadily wider and longer. This process is especially notable in the reach from Talkeetna-to-Devil Canyon; in the wide, low-gradient river below Talkeetna open leads occur less frequently and extensive overflow of mainstem water onto the ice cover is the first indicator of rising water levels.

The disintegration of the ice cover into individual fragments or floes and the drift of these floes downstream and out of the river is called the breakup drive. The natural spring breakup drive is largely associated with rapid flow increases, due to precipitation and snowmelt, that lift and fracture the ice surface. When the river discharge becomes high enough to break and move the ice sheet, the breakup drive begins. Its intensity is dependent upon meteorological conditions during the pre-breakup period.

Major ice jams generally occur in shallow reaches with a narrow confining thalweg channel along one bank, or at sharp river bends. Major jams are commonly found adjacent to side channels or sloughs, and may have played a part in forming them through catastrophic overflow and scouring at some time in the past. This is known to have happened at Slough 11 in 1976, as reported by local residents in the area, when a large ice jam overflow event altered a previously-existing small upland slough into a major side slough.

Breakup ice jams commonly cause rapid, local stage increases that continue rising until either the jam releases or the adjacent sloughs or side channels become flooded. While the jam holds, flow and large amounts of ice are diverted into side channels or sloughs, rapidly eroding away large sections of riverbank and often pushing ice well up into the trees.

Generally, the final destruction of the ice cover occurs in early to mid-May when a series of ice jams break in succession, adding their mass and momentum to the next jam downstream. This continues until the river is swept clean of ice except for stranded ice floes along shore. Ice that has been pushed well up onto banks above the water level may last for several weeks before melting away in place.

Effects of With-Project Instream Temperatures on Susitna River Ice Processes.

ICECAL modeling runs show that operation of the Susitna River Hydroelectric Project would have significant effects on the ice processes of the Susitna River, especially in the Talkeetna to Devil Canyon reach, due to changes in flows and water temperatures in the river below the dams. Generally, winter flows would be several times greater than they are under natural winter conditions, and winter water temperatures would be 0.4 C to 6.4 C where they are normally 0°C immediately below the dams (AEIDC 1984b). The ICECAL computer model developed by Harza-Ebasco Susitna Joint Venture was used to simulate river ice conditions under various scenarios of project operations, with Watana operating alone and in conjunction with Devil Canyon dam, under varying power demand situations, and with differing climatic conditions (Harza-Ebasco 1984c).

With-Project Simulations, Freezeup. Frazil ice that is generated in the upper river area, principally in the Vee Canyon and Denali areas, normally drifts downstream into the lower and middle reaches of the Susitna River and provides the source for initial ice bridging and subsequent ice cover formation for most of the those reaches. With Watana dam and reservoir in place, this frazil would be trapped in the reservoir and be prevented from reaching its normal destinations. Consequently, freezeup of the river below the dam would be delayed. Later, with the construction of Devil Canyon dam and reservoir, most of the frazil-generating rapids within Devil Canyon would be inundated, further reducing frazil production reaching the middle and lower river reaches, and further delaying river freezeup.

Arrival of the ice front at the Yentna River mouth usually occurs in late October or early November under natural conditions. This timing is not expected to be significantly altered with-project in spite of the reduced frazil input from the upper Susitna River because the ice contributions from the Yentna River and other major tributaries would remain the same. Based on this, November 1 was used by ICECAL as a representative date for the passage of the ice front by the Yentna River mouth. However, reduced frazil input would slow the advance rate of the leading edge. These effects would combine with the higher winter flows and warmer water temperatures to produce a delay of initial freezeup at the Susitna/Chulitna confluence ranging from about 2 to 5 weeks with Watana operating alone to 4 to 6 weeks with Watana and Devil Canyon operating together (Table IV-15).

The warmer water temperatures released from the dams would not cool to the freezing level for a number of miles and would prevent ice from forming all winter there, except for some border ice attached to shore. The maximum upriver extent of ice cover progression below the project, with Watana operating alone, would vary from RM 124 to RM 142 depending on winter climate and operational scenario. Similarly, with both Watana and Devil Canyon operating, the maximum ice cover extent would be from RM 123 to RM 137. The ice front would reach its maximum position between mid-December and late March for Watana alone and

Table IV-15. ICECAL simulated ice front progression and meltout dates (Harza-Ebasco Susitna Joint Venture, 1984c).

	Starting Date at Chulitna Confluence	Melt-out Date	Maximum Upstream Extent (River Mile)
Natural Conditions			
1971-72	Nov. 5	---	137[N]
1976-77	Dec. 8	---	137[N]
1981-82	Nov. 18	May10-15[B]	137[N]
1982-83	Nov. 5	May 10[B]	137[N]
Watana Only - 1996 Demand			
1971-72	Nov. 28	May 15[E]	140
1976-77	Dec. 25	May 3[E]	137
1981-82	Dec. 28	April 3	137
1982-83	Dec. 12	March 20	127
1971-72[W]	Dec. 17	March 27	127
Watana Only - 2001 Demand			
1971-72	Nov. 28	May 15[E]	142
1982-83	Dec. 19	March 16	124
Both Dams - 2002 Demand			
1971-72	Dec. 2	May 3[E]	137
1976-77	Jan. 10	April 20	126
1981-82	Dec. 30	March 12	124
1982-83	Dec. 22	March 20	123
Both Dams - 2020 Demand			
1971-72	Dec. 3	April 15	133
1982-83	Dec. 14	March 12	127

Legend:
- B - Observed natural break up.
- E - Melt-out date is extrapolated from results when occurring beyond April 30
- N - Ice cover for natural conditions extends upstream of Gold Creek (River Mile 137) by means of lateral ice bridging.
- I - Computed ice front progression upstream of Gold Creek (River Mile 137) is approximation only. Observations indicate closure of river by lateral ice in this reach for natural conditions.

Notes:
1. "Case C" instream flow requirements are assumed for with-project simulations.
2. 1971-72[W] simulation assumes warm, 4°C reservoir releases. All other with-project simulations assume an "inflow-matching" temperature policy.

mid-January to mid-March for Watana and Devil Canyon together, but would fluctuate considerably in position for the rest of the winter depending on prevailing air temperatures.

Under natural conditions, secondary ice bridges may form between the Susitna/Chulitna confluence and Gold Creek before the ice front progression in the middle Susitna River has reached Gold Creek. With the project in place these conditions may not occur, and ICECAL simulations are based only on the initiation of one ice bridge at RM 9 in November and the subsequent ice cover development on the lower river. ICECAL assumes only one leading edge progression above the confluence.

Increases in winter discharges in the river below the dams would cause staging levels during freezeup to be significantly higher than natural. In that reach, where the ice cover forms, staging is expected to be 2 to 7 feet higher than normal with Watana operating alone, while with both dams operational, stages should be about 1 to 6 feet higher than normal. Downstream from the ice front, more sloughs and side channels would be overtopped more frequently (Table IV-16).

Winter discharges would be higher than normal but no freezeup staging would occur upstream from the ice front's maximum position and water levels in that reach would be 1 to 3 feet lower than natural freezeup staging levels with Watana operating alone, and 1 to 5 feet lower with both dams operating. Therefore, no sloughs should be overtopped. However, lack of freezeup staging in this reach of the river may prevent or reduce groundwater upwelling in the sloughs. Natural freezeup staging causes approximately the same hydraulic head to exist between the mainstem and adjacent sloughs as occurs during summer. With the project in place and no freezeup staging occurring, the hydraulic head would be reduced.

Since the ice edge would not advance as far, or as rapidly, during project operations as during natural conditions, more areas of open water would exist, and they would remain longer than usual. This

Table IV-16. Occurrences where with-project[1] maximum river stages are higher than natural conditions.

Slough or Side Channel	River Mile	Watana Only Operating[2]	Watana and Devil Canyon Operating[2]
Whiskers	101.5	6/6	6/6
Cash Creek	112.0	6/6	5/6
6A	112.3	6/6	5/6
8	114.1	6/6	6/6
MSII	115.5	6/6	6/6
MSII	115.9	6/6	6/6
Curry	120.0	6/6	3/6
Moose	123.5	6/6	4/6
8A West	126.1	5/6	4/6
8A East	127.1	4/6	2/6
9	129.3	4/6	2/6
9 u/s	130.6	3/6	0/6
4th July	131.8	3/6	2/6
9A	133.7	3/6	1/6
10 u/s	134.3	4/6	1/6
11 d/s	135.3	3/6	0/6
11	136.5	4/6	2/6

Notes:

1 "Case C" instream flow requirements and "inflow-matching" reservoir release temperatures are assumed for with-project simulations.

2 For example, 4/6 means that 4 of the 6 with-project simulations resulted in a higher maximum river stage than the natural conditions for corresponding winters.

Source: Harza-Ebasco Susitna Joint Venture, 1984a could cause the incidence of more anchor ice during cold periods. This might cause the formation of slight backwater areas because of the general raising of the channel bottom, possibly affecting flow distribution between channels with low berms.

Where an ice cover forms, the maximum total ice thickness with Watana operating alone are expected to be generally similar to natural ice thickness. With both dams operating, maximum total ice thickness should be about 1 to 2 feet less than natural ice thickness.

With-Project Simulations, Breakup. Breakup processes are expected to be different in the Susitna River below the project, especially in the Talkeetna to Devil Canyon reach. Since the maximum upstream extent of the ice cover below the dams would be somewhere between RM 124 and RM 142, there would be no continuous ice cover between this area and the damsite, and consequently no breakup or meltout in that reach. Any border ice attached to shore would probably slowly melt away in place; occasional pieces of border ice might break away from shore and float downstream. Ice in the river reach above the project would break up normally, but would not drift into this area as it normally does because it would be trapped in the reservoirs.

The normal spring breakup drive is usually brought on by rapid flow increases that lift and fracture the ice cover. The proposed project reservoirs would regulate such seasonal flows, yielding a more steady flow regime and resulting in a slow meltout of the ice cover in place.

The warmer-than-normal water temperatures released from the project would cause the upstream end of the ice cover to begin to decay earlier in the season than normal. Gradual spring meltout with Watana operating alone is predicted to be 4 to 6 weeks earlier than normal, and 7 to 8 weeks earlier than normal with both dams operating. By May, flow levels in the river would be significantly reduced as the project begins to store incoming flows from upstream. The result is expected to be that breakup drive processes that now normally occur in the middle Susitna River area would be effectively eliminated.

Instead, a slow and steady meltout of river ice in this reach would probably occur. Since there would be no extensive volume of broken ice floating downstream and accumulating against the unbroken ice cover, ice jamming in the middle Susitna River would usually not occur or would be substantially reduced in severity. This would eliminate or substantially reduce river staging and flooding normally associated with ice jams, thereby eliminating or greatly reducing the overtopping of berms and the flooding of side sloughs.

In the lower river below the Susitna/Chulitna confluence, breakup would approximate natural conditions due to the substantial flow contributions from major tributaries. Ice thicknesses in this reach, however, may be somewhat thicker than normal because of the higher Susitna River winter flows from the project.

Environmental Effects

Ice jams during breakup commonly cause rapid and pronounced increases in local water surface elevations. The water continues to rise until either the jam releases or the rising water can spill out of the mainstem into adjacent side channels or sloughs. This may cause sections of riverbank to be eroded. Ice scars have been documented on trees in some localized areas as high as 10 feet above the stream bank. The sediment transport associated with these events can raise or lower the elevation of berms at the upstream end of sloughs. Ice floes left stranded in channels and sloughs during breakup can deposit a layer of silt as they melt.

Ice processes in the mainstem river are important in maintaining the character of the slough habitat. Besides reworking substrates and flushing debris and beaver dams from the sloughs that could otherwise be potential barriers to upstream migrants, ice processes are also considered important for maintaining the groundwater upwelling in the side sloughs during winter months. This is critical in maintaining the incubation of salmon eggs as described previously in the sediment transport (Section IV-B). The increased stage associated with a winter ice cover on the Susitna makes it possible for approximately the same hydraulic head to exist between the mainstem and an adjacent side slough during periods of low winter flow as that which exists during normal summer. The river stage observed during mid-winter 1981-82 associated with the ice cover formation on the Susitna River appeared very similar to the water surface elevation associated with summer discharges of 18,000 to 19,000 cfs. The alluvial deposits that form gravel bars and islands between the mainstem river and side sloughs are highly permeable, making it possible for water from the river to flow downgradient through the alluvium and into the sloughs. Thus the increased stage associated with an ice cover on the river may provide an important driving mechanism for maintaining the upwelling in the side sloughs throughout the winter.

Ice processes may also have negative impacts on fisheries habitat. Ice scouring can remove redds. Mainstem water entering the slough near an ice jam can expose juvenile fish and incubating eggs to near zero degree water, causing mortality. The removal of substrate by anchor ice, scouring or flooding can greatly effect cover availability for rearing fishes. Freezing processes, such as anchor ice, can also encase many types of cover, making it useless to juvenile fish. Benthic organisms and small fish can also be displaced by sudden fluctuations in flow caused by ice jams.

V. INFLUENCE OF STREAMFLOW AND INSTREAM HYDRAULICS ON MIDDLE RIVER HABITATS

Habitat Types and Categories

As used in this document, habitat type refers to portions of the riverine environment having visually distinguishable morphologic, hydrologic and hydraulic characteristics which are comparatively similar. Habitat types used here are not defined by biological criteria. Rather, they are based on explicit hydraulic and turbidity considerations. Thus, both high and low value fish habitat may exist within the same habitat type. The relative value of one habitat type over another is derived from seasonal fish utilization and densities within the middle Susitna River. Six major riverine habitat types have been identified within the Talkeetna-to-Devil Canyon reach of the Susitna River: mainstem, side channel, side slough, upland slough, tributary, and tributary mouth.

The total surface area of each habitat type in the Talkeetna-to-Devil Canyon reach has been estimated for mainstem discharges ranging from 9,000 to 23,000 cfs at Gold Creek (USGS gage 15292000) using digital measurements on 1 inch = 1,000 feet aerial photographs (Klinger and Trihey 1984).

Surface areas of clearwater habitat types, such as upland sloughs, tributaries and tributåry mouths, collectively represent approximately one percent of the total wetted surface area within the middle Susitna River (Klinger and Trihey 1984). The surface areas of these habitat types exhibit little response to mainstem discharge (Figure V-1). At times their surface areas may respond more to seasonal runoff and local precipitation than to variations in mainstem discharge.

Comparatively large differences exist regarding the magnitude and rate of response of mainstem, side channel, and side slough surface areas

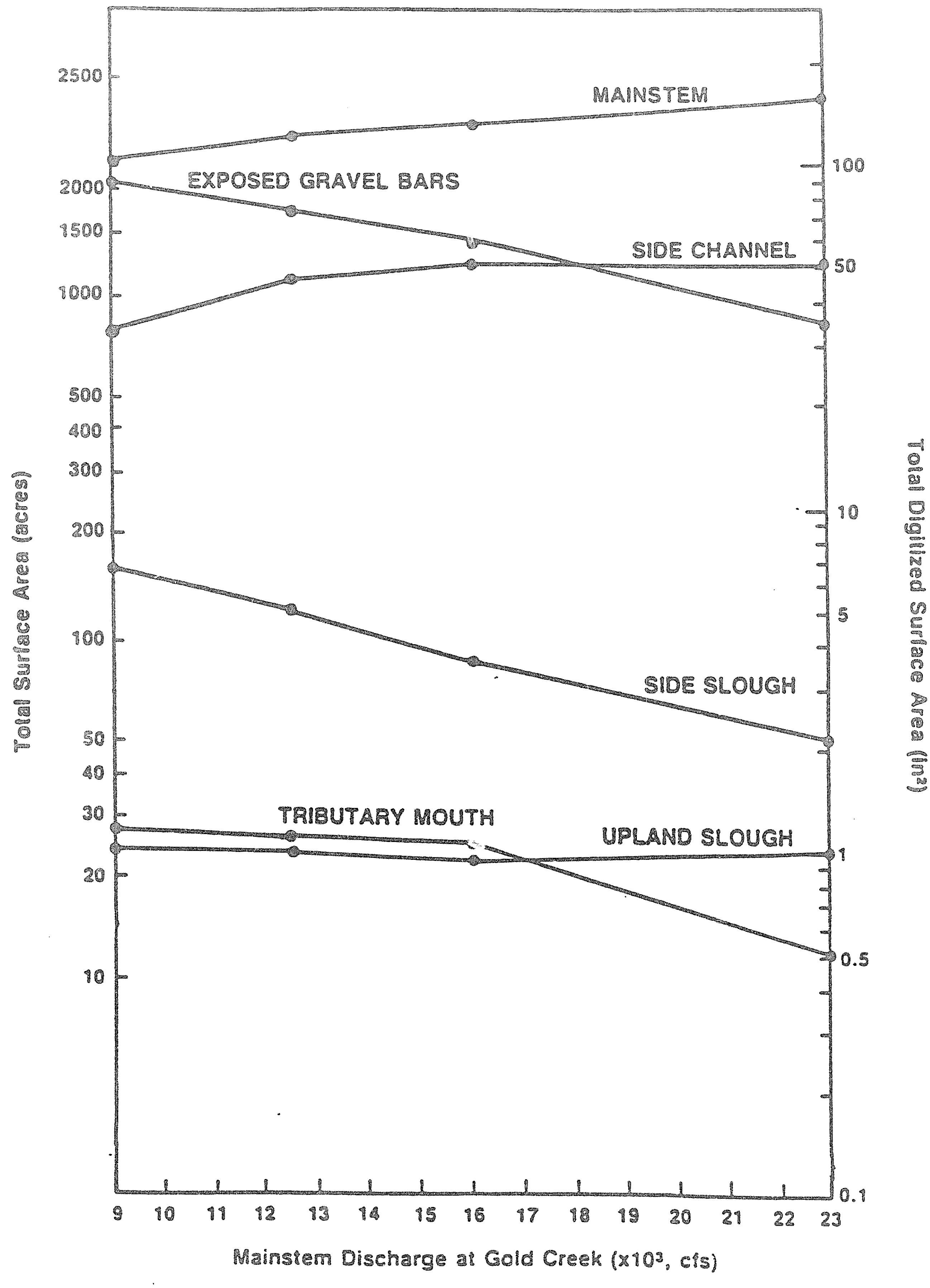

Figure V-1. Surface area responses to mainstem discharge in the Talkeetna-to-Devil Canyon reach of the Susitna River (RM 101 to 149).

to mainstem discharges. At 9,000 cfs, mainstem and side channel surface areas are approximately 37 percent less than their combined surface area at 23,000 cfs. But, side slough surface area is nearly 200 percent greater at the lower discharge. As a result, the total surface area of clearwater habitat types within the river corridor represents 8.2 percent of the total wetted surface area at 9,000 cfs whereas less than 2 percent of the total wetted surface area consisted of clearwater habitat types at 23,000 cfs.

Subreaches of the middle Susitna River possess various amounts of each habitat type. The diversity of habitat types within subreaches of the middle Susitna River is directly related to the complexity of the channel and mainstem discharge. The greatest diversity occurs from RM 113 to 138 in the Lane Creek-to-Gold Creek subreach (Klinger and Trihey 1984). This river segment is characterized by a stable multiple channel pattern and numerous partially vegetated gravel bars. The least diversity occurs in the single channel segments between RM 103 and RM 109, and upstream of RM 145. These subreaches consist almost entirely of mainstem habitat regardless of discharge.

For some specific areas within the middle Susitna River corridor, such as major side channels and tributary mouths, a designated habitat type persists over a wide range of mainstem discharge even though its surface area and habitat quality may change significantly. In other instances, the classification of specific areas may change from one habitat type to another in response to mainstem discharge (Klinger and Trihey 1984). Such an example is the transformation of some turbid water side channels at 23,000 cfs to clear water side sloughs at lower mainstem flows. An important characteristic of these sites, with regard to their value as fish habitat, appears to be the frequency, duration, and time of year they exist as one habitat type or the other (ADF&G 1984d).

Closely related to habitat transformation is the concept of variable boundary habitats (i.e. microhabitat location changes with discharge). Within the middle Susitna River, rearing habitat is an example of a variable boundary habitat, particularly in mainstem and side channel areas where the combination of low-velocity flow and turbidity appear to be the dominant microhabitat variables. As discharge changes, the spatial distribution of turbid, low-velocity conditions suitable for rearing fish also changes within the river corridor.

Rather than track the spatial movement of suitable variable boundary habitats, the transformations and changes in habitat suitability were monitored at specific areas of the river in response to incremental changes in streamflow. This provides a systematic framework for analyzing riverine habitat. A specific area is defined as any location within the middle Susitna River corridor with a designated perimeter that contains a portion of the non-mainstem surface area. The total surface area of all specific areas equals the total non-mainstem surface area. Specific areas are classified by habitat type and their wetted surface areas measured on aerial photography at several mainstem discharges. Specific areas frequently contain individual side channels, side sloughs, or upland sloughs. Occasionally a large side channel or slough was subdivided into two or more specific areas.

A significant amount of wetted surface area is expected to be transformed from one habitat type to another as a result of project-induced changes in streamflow (Klinger and Trihey 1984). This approach was chosen as the basic framework for the extrapolation methodology because it focuses on the dynamic change in the system and allows examination of the system as flows change from a summer mainstem discharge of 23,000 cfs to a lower discharge level. Habitat transformations are referenced from a mainstem discharge of 23,000 cfs at Gold Creek because 23,000 cfs is a typical mid-summer discharge (APA 1983) and continuous overlapping aerial photography was available.

Nine habitat categories are used to describe the transformation of specific areas from one habitat type to another as mainstem discharge decreases below 23,000 cfs (Table V-1). Figure V-2 presents a flow chart of the possible habitat transformations that may occur as

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Table V-1. Descri-tion of Habitat Categories

Category 0 - Tributary and tributary mouth habitats which persist as tributary or tributary mouth habitat at a mainstem discharge less than 23,000 cfs.

Category I - Side slough and upland slough habitats at 23,000 cfs which persist as the same habitat type at lower mainstem discharges

Category II - Side channel habitats which transform to clearwater habitat at a mainstem discharge less than 23,000 cfs, and possess sufficient upwelling to maintain an open lead throughout winter.

Category III - Side channel habitats which transform to clearwater habitat at a mainstem discharge less than 23,000 cfs but do not possess sufficient upwelling to maintain an open lead throughout winter.

Category IV - Side channel areas which persist as side channel habitat at a mainstem discharge less than 23,000 cfs.

Category V - Mainstem or side channel shoals which transform into distinct side channels at a mainstem discharge less than 23,000 cfs.

Category VI - Mainstem or side channel shoals which become appreciably dewatered but persist as shoals at a mainstem discharge less than 23,000 cfs.

Category VII - Mainstem or side channel shoals which transform to side slough habitat at a mainstem discharge less than 23,000 cfs, and possess sufficient upwelling to maintain an open lead throughout winter.

Category VIII - Mainstem or side channel shoals which transform to clearwater habitat at a mainstem discharge less than 23,000 cfs but do not possess sufficient upwelling to maintain an open lead throughout winter.

Category IX - Any water course which is wetted at 23,000 cfs but becomes dewatered at a lower mainstem discharge.

Category X - Mainstem habitats which persist as mainstem habitat at a mainstem discharge less than 23,000 cfs.

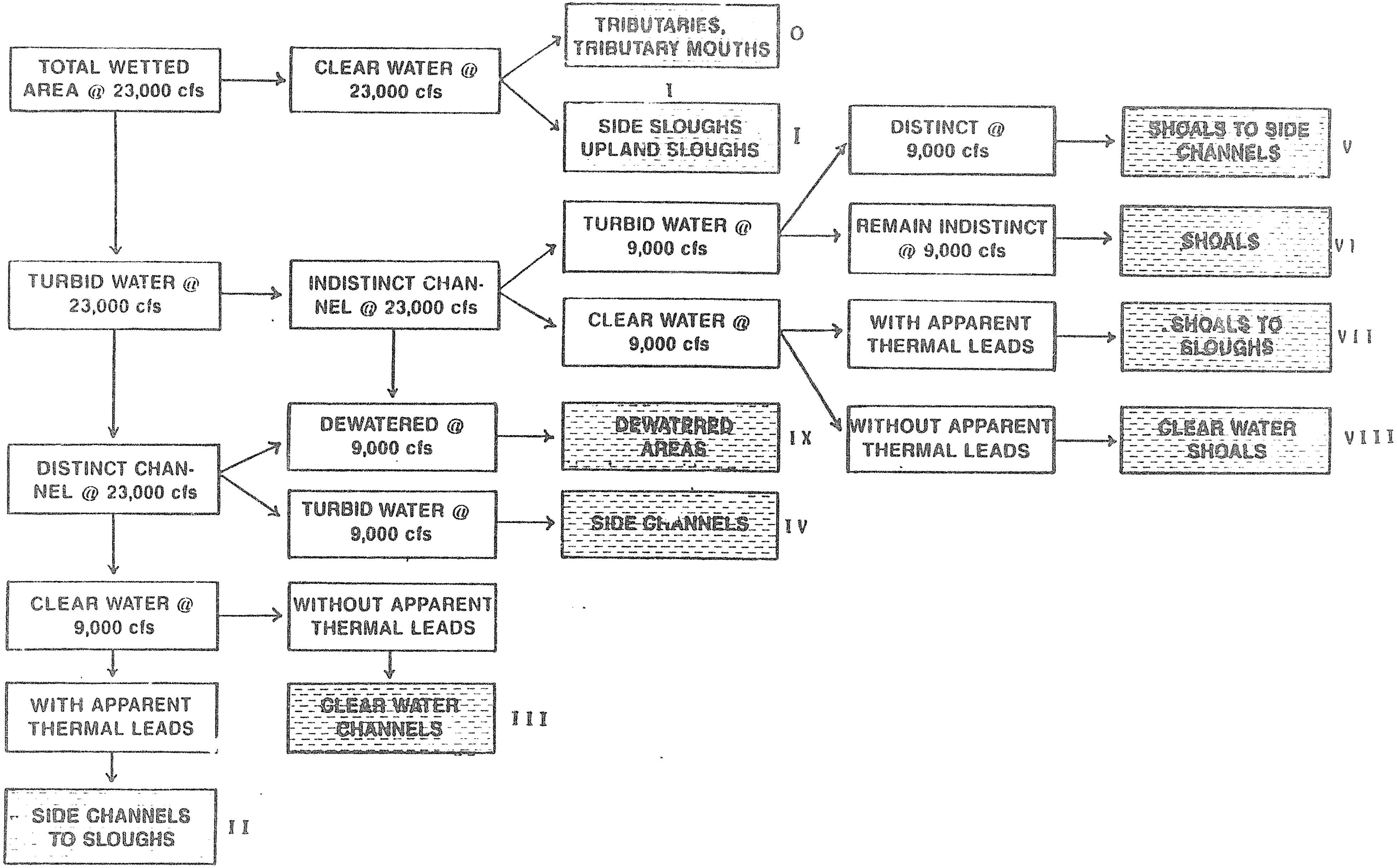

Figure V-2. Flowchart describing possible habitat transformation that may occur with decreases in mainstem discharge.

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mainstem discharge decreases from 23,000 cfs to 9,000 cfs. Any middle Susitna River flow of interest lower than 23,000 cfs for which aerial photography exists can be substituted for the 9,000 cfs discharge level.

When the habitat transformations at all 167 of the specific areas delineated in the middle Susitna River are summarized, a ready illustration of overall riverine habitat behavior with decreasing mainstem discharge is obtained (Table V-2). This analysis is directly applicable to the assessment of project effects on middle Susitna River fisheries habitats.

Inspection of the relative numbers of specific areas in the various categories at several mainstem reference flows reveals some interesting trends (Figure V-3). With decreasing mainstem discharge, there is a notable decrease in the number of side channel sites (Category IV), and an increase in side sloughs (Category II). There is also an increase in dewatered areas (Category IX), which indicates the loss of potential habitat for fish. The implications associated with the decrease in side channel and the increase in side slough habitat types to fish are less obvious. Although it is possible to generally characterize some of the attributes of the specific areas that belong in these categories, a more refined analysis of microhabitat variables (e.g., depth, velocity, substrate, etc.) is necessary to fully assess the capability of a riverine habitat to support fish.

Table V-2. Number of specific areas classified in each habitat category for seven mainstem discharges.

Habitat Category	18000	16000	12500	10600	9000	7400	5100
1	32	32	32	32	32	32	32
2	10	15	24	25	27	33	33
3	5	6	10	10	13	12	15
4	52	47	36	35	28	23	23
5	4	4	7	9	11	10	11
6	21	21	17	11	7	7	6
7	2	2	3	5	5	4	4
8	2	2	3	4	6	5	3
9	6	6	8	9	13	18	20
10	33	32	27	27	25	23	20
Total	167	167	167	167	167	167	167

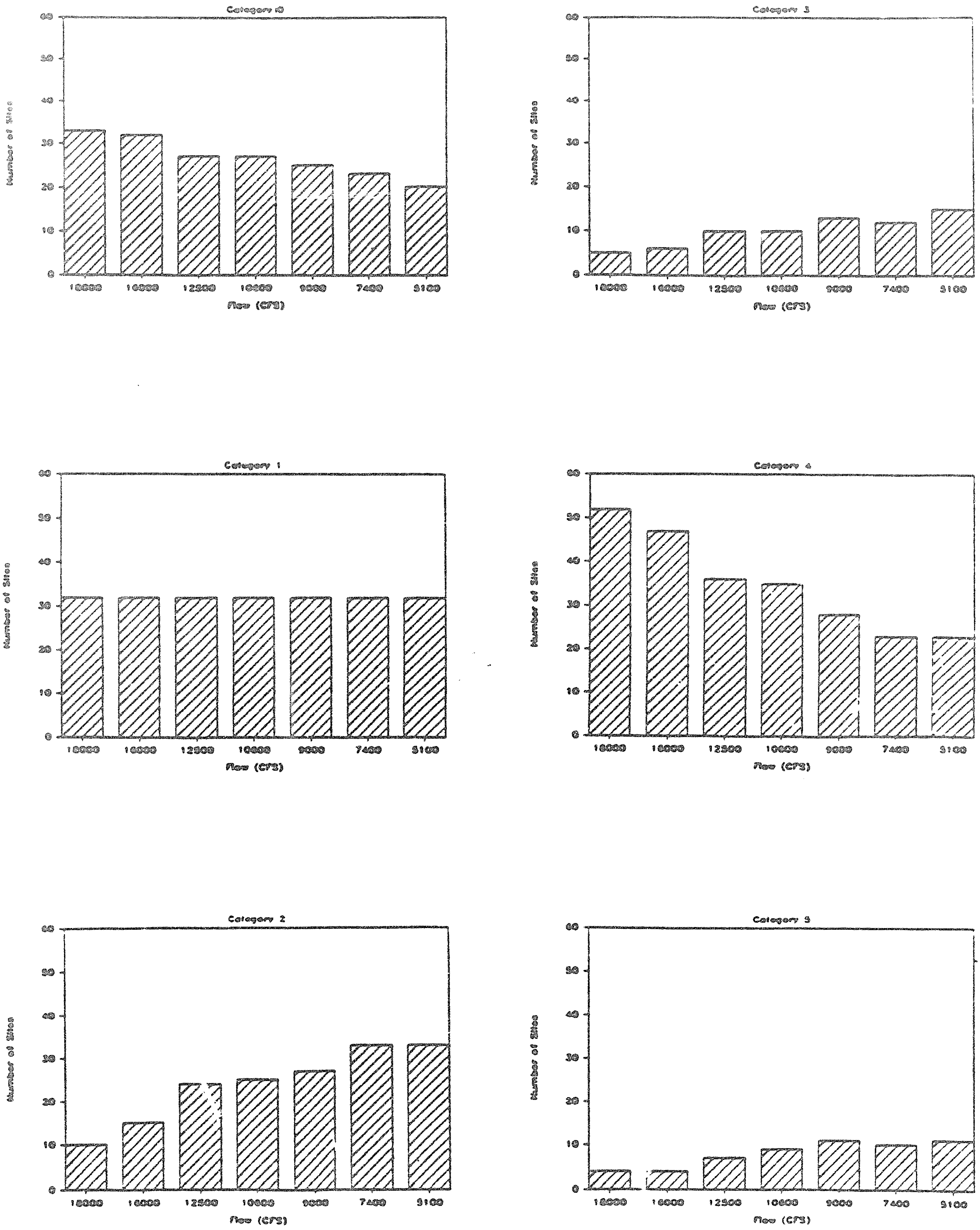


Figure V-3. Number of specific areas classified in each habitat category for various Gold Creek mainstem discharge.

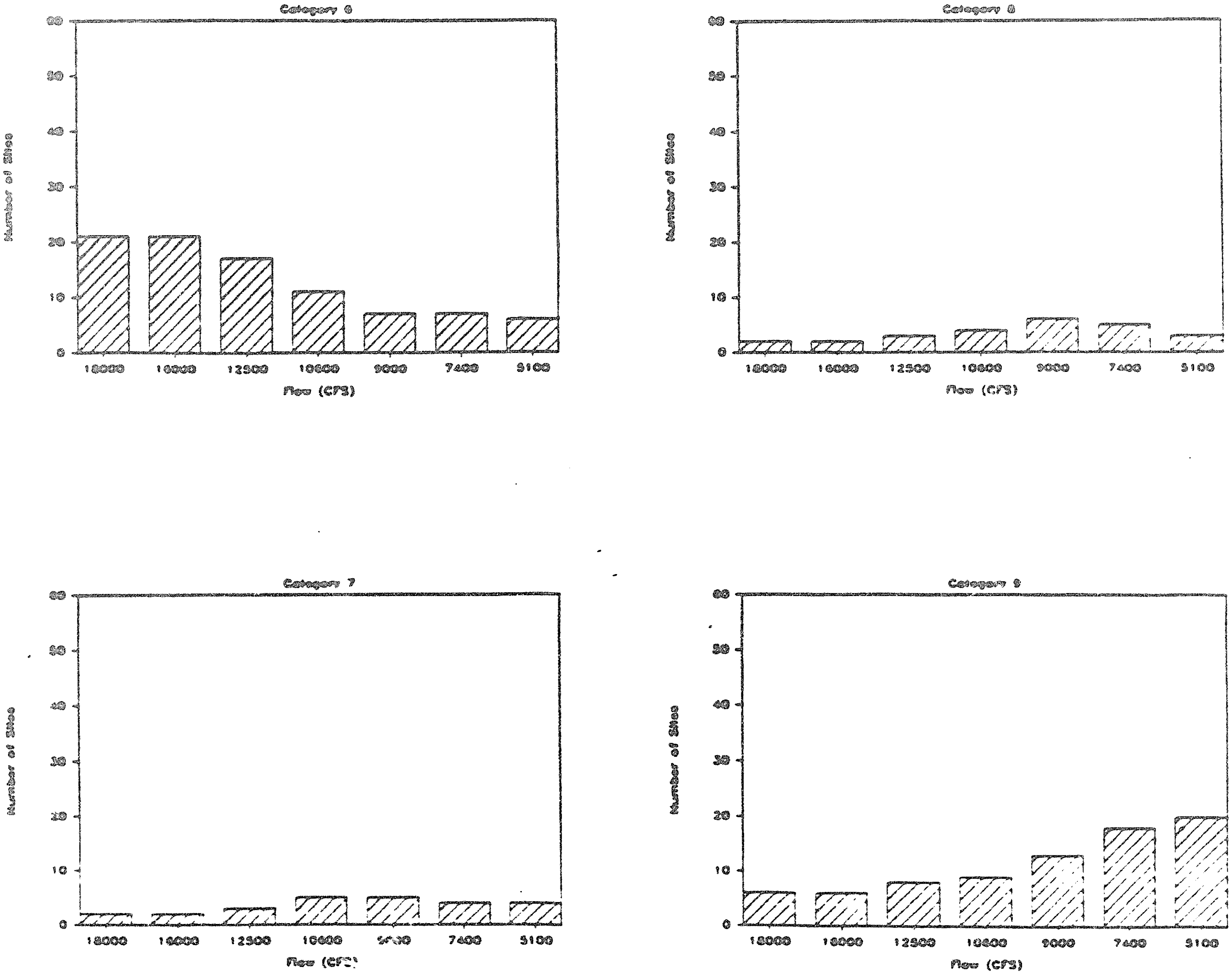


Figure V-3 continued. Number of specific areas classified in each habitat category for various Gold Creek mainstem discharge.

Passage

Fish passage is defined as the movement of fish from one location to another. The ability to move freely into and out of habitats on a seasonal basis is important in maintaining fish populations. For anadromous species, adults move upstream into spawning areas and juveniles move from natal areas to rearing habitat and finally outmigrate to marine environments. Restriction of passage conditions can inhibit or eliminate utilization of even high quality habitat. Three levels of difficulty are defined for fish passage in the middle Susitna River (ADF&G 1984e):

1. Successful passage - movement to another location is unrestricted.

2. Difficult passage - movement to another location is possible, but it requires strenuous effort and exposure to atmospheric drying or predation.

3. Unsuccessful passage - movement to another location is not possible.

These three levels define the relative level of difficulty that most fish of the same species/life stage have with passage even though certain individuals may have a greater or lesser degree of success than the majority of fish (ADF&G 1984e).

Passage reaches (PR) are sub-sections of stream channel with hydraulic or morphologic characteristics that impede the movement of fish. The length of a passage reach is based on the length of stream channel having such characteristics (Figure V-4); the nonuniformity of natural stream beds necessitates some averaging of characteristics when evaluating the reach length.

Physical parameters that cause passage restrictions include shallow depth of flow, high flow velocity, and barriers such as debris or

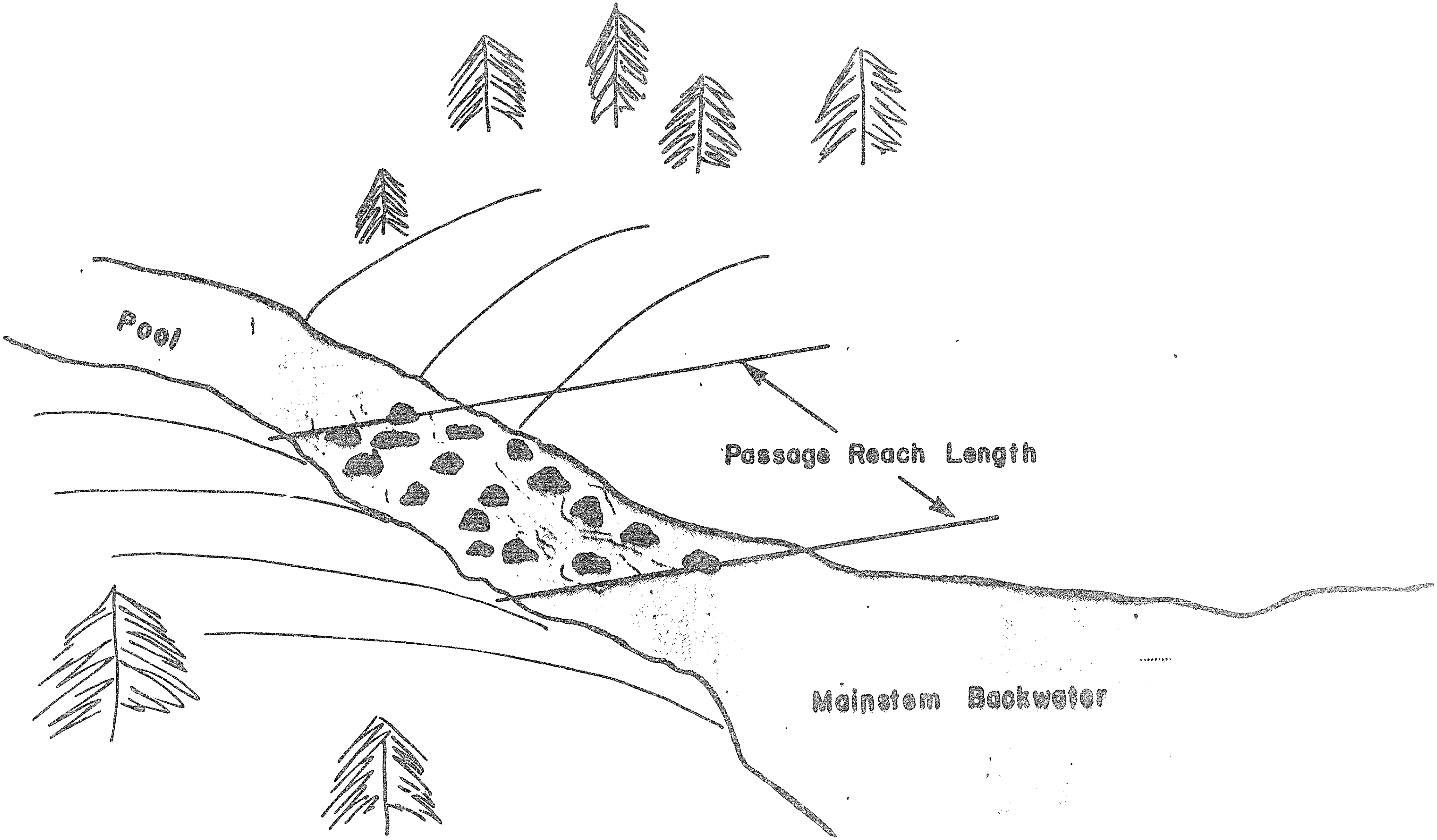


Figure V-4. Typical passage reach configuration.

beaver dams. Passage criteria for chum salmon, based on flow depth and flow velocity, have been developed (ADF&G 1984e, Thompson 1972). If the reach over which these parameters are limiting is long, passage would be more difficult, since the swimming speed of salmon and their ability to navigate through shallow depths decreases with increasing reach length (Bell 1973). Limited resting areas in a passage reach also makes passage more difficult.

Affected Life Stages. Although the adult and juvenile migration and rearing life stages of the anadromous and resident species in the middle Susitna River involve movement from one location to another and thus are potentially affected by passage, adult chum salmon migration is the species/life stage with the greatest potential to be affected by passage restrictions. Adult chum salmon show less ability than other salmonid species to surmount obstacles (Bell 1973, Scott and Crossman 1973). Adult chinook salmon also have potential for being affected by passage restrictions due to their large size. Depth criteria for chinook salmon is greater than for other salmon species (Thompson 1972). Adult coho, sockeye, and pink salmon could be affected by passage restrictions if the conditions were difficult or unsuccessful for chum or chinook; thus, the analysis of passage conditions for chum or chinook salmon is conservatively taken as being representative of coho, sockeye, and pink salmon. Resident adult trout typically have shallower minimum depth criteria for passage than salmon and thus would not be restricted by depth as often as salmon would be, but the maximum velocity criteria for trout is lower than that for salmon (Thompson 1972).

Parameters affecting passage of juvenile resident and anadromous species into, out of, and within their rearing habitats include shallow flow depth and high velocities. The most restrictive conditions for juvenile passage would be entrapment, where pools containing juveniles become isolated when surface flows reduce to zero. High velocities (<2.0 fps) in channels with few interstitial spaces between streambed particles or few cobbles and boulders to provide low velocity resting areas would also be difficult passage reaches for juveniles.

Passage of outmigrating smolt would have similar criteria to those of juveniles. Entrapment would be most critical, as their downstream direction of migration reduces the importance of velocity as a passage criteria parameter.

Mainstem Habitats. The parameter with the greatest potential to restrict passage within mainstem habitats is velocity. The mainstem is used as a migration corridor by adult, juvenile, and smolt salmonids. Mean channel velocities ranging from 5 to 9 fps are commonly associated with typical midsummer flows (R&M Consultants 1982b). Shoreline velocities and velocities near the channel bottom are generally well below the maximum velocity criteria developed by Thompson (1972) of 8 fps for adult salmon, but occasionally very near the maximum velocity criteria of 4 fps for trout. An analysis of the timing of adult salmon migration indicates that discharges at Gold Creek ranging from 12,000 to 60,800 cfs did not appear to affect adult salmon migration to sloughs and side channel entrances (ADF&G 1984e). Water depth is sufficient for successful passage at mainstem discharges within the natural range; barriers such as debris dams do not exist in the mainstem of the middle Susitna River.

Side Channel Habitats. Side channel habitats may be used for migration by adult, juvenile, and juvenile salmonids. Some side channels are used by chum and sockeye salmon for spawning; successful adult passage conditions are needed for successful spawning.

Passage conditions in side channel habitats are similar to those of mainstem habitats during much of the open water season. During breaching, velocity is the parameter with the greatest potential for affecting fish passage. Depth would be sufficient for successful passage.

At lower mainstem discharges, the depth at the head of side channels becomes the most significant parameter affecting passage. As the water surface elevation in the mainstem decreases to a level below that required for breaching, the head of the side channel becomes exposed, preventing passage through that reach and potentially trapping fish in downstream pools. Many side channels receive inflow from groundwater or tributary sources along their length. As flow accumulates along the slough, passage is first provided for by juveniles and outmigrating smolts due to their shallow minimum depth requirements. If sufficient flow accumulates, adult passage could become successful. Backwater from the mainstem may be sufficient to provide for successful passage through lower passage reaches in a side channel.

Side Slough Habitats. Side sloughs are utilized by chum and sockeye salmon for spawning. Thus, successful spawning in sloughs relies on successful passage into and within the sloughs. Successful spawning would lead to the need for successful passage conditions for outmigrating smolts. Juvenile salmon also use sloughs for rearing.

Side slough habitats have similar passage characteristics to side channel habitats except breaching is less frequent. Thus, the depth restrictions described for unbreached side channel sites would apply to side slough habitats more frequently during the spawning season.

Passage into and within side slough sites is provided by breaching, backwater, or local flow conditions. Even in side slough sites, breaching is relatively frequent during the spawning season under natural flow regimes. Backwater provides for passage through the first and sometimes second passage reaches upstream of the slough mouth during much of the spawning season. Slough flow, when increased by rainstorm runoff from the local area may provide for passage of adults through some reaches.

Upland Slough Habitats. As with side sloughs, upland sloughs are utilized by adult salmon for immigration and spawning and juvenile salmon for rearing, and salmon smolts for outmigration. Passage into, within, or out of upland sloughs relies primarily on backwater and local flow, since breaching is an infrequent event.

Tributary Habitats. Tributary habitats are utilized primarily by adult chinook, coho, and chum salmon for spawning, coho juvenile for rearing, and chinook, coho, and chum salmon for smolt outmigration. Passage into or out of tributary habitats could be affected by reduced mainstem flows of the project. Studies have identified that most tributaries will adjust to the new mainstem elevations through a degradation process (R&M 1982c, Trihey 1983).

Passage and Habitat Availability

The relationship between habitat availability and passage conditions under natural conditions is assessed by identifying how often the depth required for passage is available. As introduced earlier the depth at passage reaches in a slough or side channel is a function of the cumulative effect of backwater, breaching, and local flow in the channel.

Analysis of escapement timing to sloughs and flow history during the 1981-1982 spawning season provides the information necessary to delineate the period in which combinations of backwater, breaching, and local flow are most important for passage.

Escapement Timing. Selection of the period from August 12 through September 8 for chum salmon passage into and within sloughs and side channels of the middle Susitna River is based on chum migration timing in the mainstem at Curry Station (RM 120) and the dates of first and peak counts in six sloughs that contain the majority of slough-spawning chum salmon in the middle Susitna River. These sloughs (8A, 9, 9A, 11, 20 and 21) are located between RM 125 and 142.

The peak of the chum salmon run passes Curry Station during the first two weeks of August (ADF&G 1981, 1982a, 1984a). Since the average migration speed of chum salmon ranges between 4.5 miles per day (mpd) and 7.7 mpd (ADF&G 1981, 1982a, 1984a), most chum salmon would be expected to cover the 5 to 22 miles from Curry Station to the six sloughs mentioned in one to five days. Therefore, chum salmon are expected to be abundant in the six sloughs during the first three weeks of August.

The dates that chum salmon were first observed in Sloughs 8A, 9, 9A, 11, 20 and 21 have ranged from August 4 to September 11, while the dates of peak counts at these six sloughs have ranged from August 18 to September 20 (ADF&G 1981, 1982a, 1984a). Thus the period of August 12 through September 8 covers the first observations of chum salmon in sloughs and most of the period of peak counts.

The slough utilization by chum salmon is one to two weeks later than the predicted dates based on migration timing in the mainstem. Factors that may explain this difference, either singly or together, are: (1) stock differences; (2) milling behavior; (3) slough observation conditions; and (4) passage conditions.

Stock Differences. The dates of first and peak counts in tributaries are one to two weeks earlier than in sloughs (ADF&G 1981, 1982a, 1984a). Hence, the first part of the run passing Curry Station may be a separate stock destined primarily for tributaries.

Milling Behavior. Fish may mill in the mainstem near the mouths of sloughs before entering the sloughs to spawn.

Slough Observation Conditions. When sloughs are overtopped by turbid, high velocity mainstem water, observation conditions deteriorate. Poor observation conditions may result in fish utilization remaining undetected until the slough water clears.

Passage Conditions. Passage conditions, which are influenced by breaching, backwater, and local flow (ADF&G 1984e), may delay passage of chum salmon into and within sloughs in some years. For example, in 1982, mainstem discharge at Gold Creek was below 20,000 cfs from early August to mid-September, which reduced backwater and breaching influences and may have restricted chum passage into sloughs. A rainstorm event from August 29 to September 3 increased local flows, which appeared to provide successful passage conditions at most sites. All sloughs (9, 9A, 11, 20 and 21) except Slough 8A contained peak numbers of chum salmon between August 30 and September 6 (ADF&G 1982a).

Frequency of Passage

Passage conditions can be further evaluated by establishing how often the depth required for passage occurs under natural or proposed project flows and what condition (breaching, backwater, or local flow) is responsible for passage. For example, the specified depth for successful passage at a passage reach located near the mouth of a slough may be equalled or exceeded 80 percent of the time due to backwater only, 20 percent of the time due to breaching only, and 40 percent of the time if an average groundwater flow were supplemented by surface inflow. Since backwater, breaching, and groundwater upwelling are functions of mainstem discharge, the frequency of a certain depth being equalled or exceeded is obtained from a flow frequency analysis for the period of interest. Analysis of the contribution of local flow (surface flow and groundwater upwelling) to passage conditions will be completed as 1984 field data become available.

Breaching flows occur relatively frequently at sloughs and side channels under natural conditions. The frequency of overtopping was evaluated at selected sloughs and side channels (Table V-3). This table presents the number of years each site was breached at least one day during the evaluation period. The frequency of years that individual sloughs and side channels breach varies according to their

Table V-3. Frequency of breaching flows at selected sloughs and side channels.

Site	Controlling Discharge (cfs)	Frequency (%)	Years Occurred (out of 35)
Slough 8A	27,000	28	10
	33,000	6	--
Slough 9	19,000	9	3'
Slough 11	42,000	1	5
Upper Side Channel 11	16,000	97	34
Side Channel 21	12,000	97	34
Slough 21	25,000	43	15

breaching flow. For example, the frequency of years for breaching flows at Slough 21 (25,000 cfs), Slough 9 (17,000 cfs), and the lower portion of Side Channel 21 (12,000 cfs), are 47, 91, and 97 percent. Although the number of years in which at least one breaching event occurred was similar for Slough 9 and Side Channel 21, the average number of breached days per year for Slough 9 (13.9) was about half that of Side Channel 21 (24.3). Associated with the decrease in frequency of years at Slough 21 is a decrease in the average number of days breached (8.3). The importance of multiple event breaching flows for passage at a site depends on their timing within the spawning season. Several closely clustered events may be less beneficial to passage than a few well spaced overtoppings. Figure V-5 presents a frequency analysis of the percent of years that a flow is equalled or exceeded at least once during the period 12 August to 8 September. The 50 percent occurrence flow is approximately 22,500 cfs. From this analysis, it can be concluded that channels with breaching flows below 22,500 cfs will be breached, on the average, once every two years.

The backwater associated with mainstem discharge under natural conditions provides passage through passage reaches in the mouths of some sloughs. In Slough 8A, for example, a mainstem discharge of 10,600 cfs is required to produce the backwater required for successful passage at Passage Reach I. This discharge occurred in 97 percent of the last 35 years. At Passage Reach II a mainstem discharge of 15,600 is needed, which also occurred 97 percent of the time (Figure V-6). However, the average number of days per year that passage was provided PR I and PR II during the August 12 - September 8 period were 25.6 and 18.5.

Under anticipated project flows, naturally occurring mainstem flow to breach sites or cause the backwater effects necessary for passage will in general be significantly reduced during the spawning season. The importance of local flow in compensating for some of these reductions in passage conditions will be described in the final draft of this report.

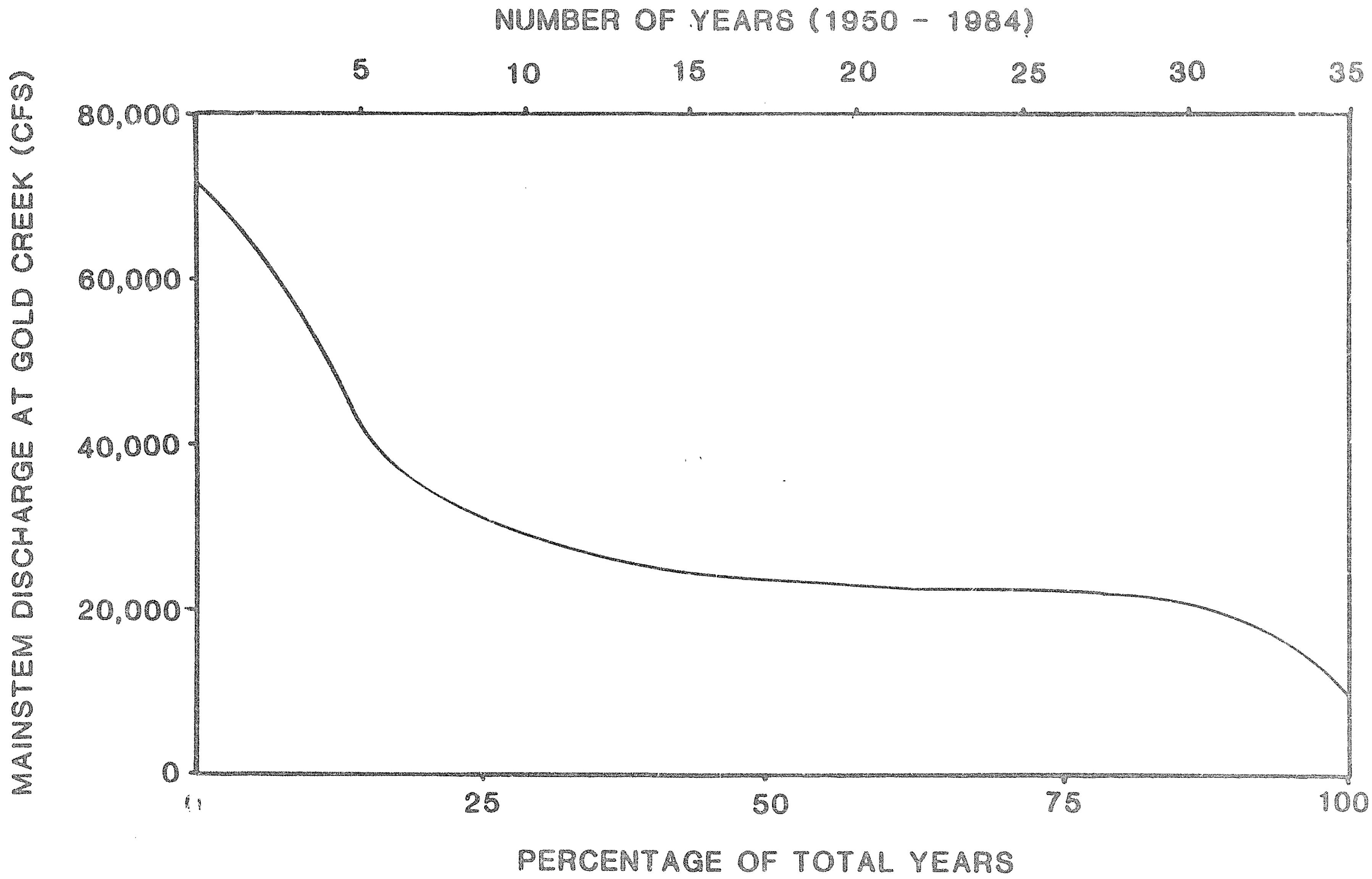


Figure V-5. Breaching flow occurance during 12 August to 8 September based on Susitna River Discharge Period 1950-1984.

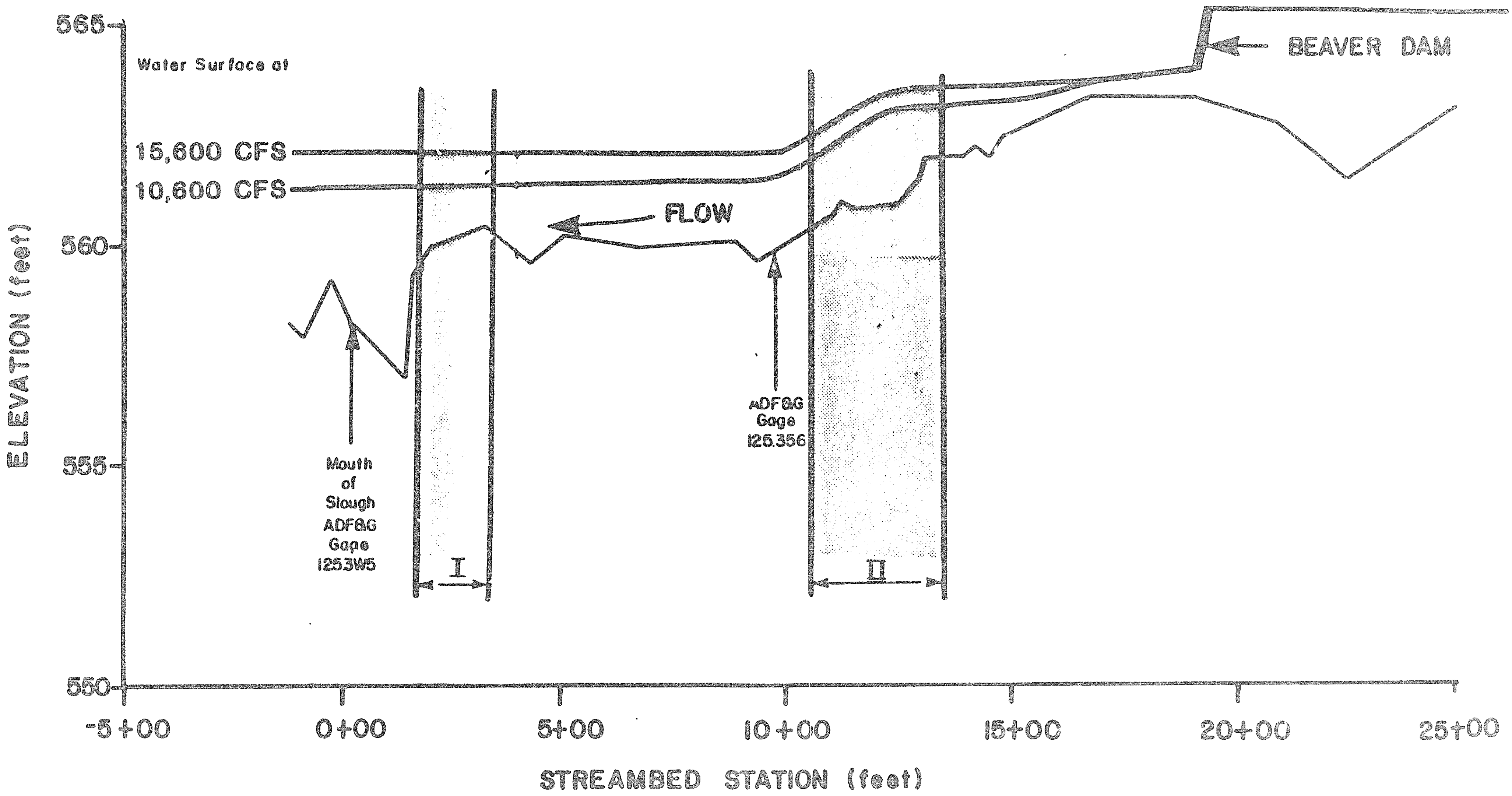


Figure V-6 Thalwag profile of Slough 8A.

Microhabitat Response to Instream Hydraulics

Depth and velocity of flow respond to variations in streamflow, affecting the availability and quality of fish habitat. The effect of streamflow variations on the availability of spawning and rearing habitat has been modeled at several side slough and side channel study sites (ADF&G 1984c ADF&G 1984d). This modeling process used computer software developed by the USFWS Instream Flow and Aquatic Systems Group (Bovee and Milhous 1978, Bovee 1982, Milhous et al. 1984).

Spatial distribution of depths and velocities within a study site were simulated at several different site-specific flows using the IFG-4 and IFG-2 hydraulic models. Using the simulated depths and velocities in combination with numeric descriptors for other microhabitat variables (upwelling, cover, and substrate), physical habitat at the study site can be described as a function of streamflow. The numeric description of upwelling, depth, velocity, substrate and cover available to fish at various flow levels are then compared to weighting factors representing their suitability to fish. These weighting factors are obtained from habitat suitability criteria for each species and life stage being evaluated. An index of habitat availability called Weighted Usable Area (WUA) is calculated by this modeling process. Because several of the microhabitat variables used respond to streamflow variations, weighted usable area may be considered a streamflow dependent habitat availability index.

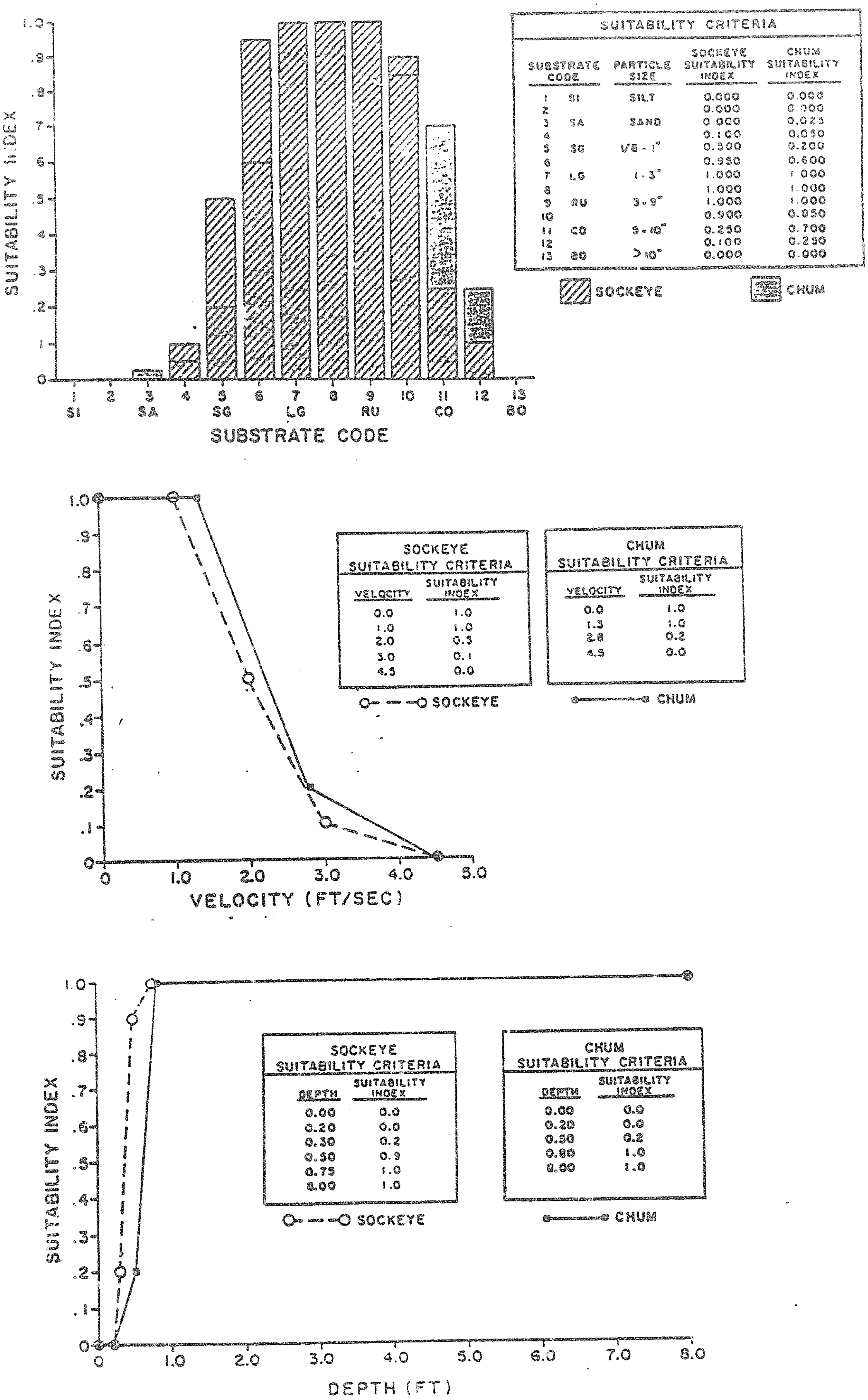
Spawning Salmon

Microhabitat Preferences. The influence streamflow variations may have on spawning habitat is generally evaluated using three microhabitat variables: depth, velocity and substrate (Bovee 1982, Wesche and Reckard 1980). However, a fourth variable, upwelling, is also considered important for successful chum and sockeye salmon spawning in the middle Susitna River habitats (ADF&G 1984d). Upwelling has also been identified as an important habitat component for spawning chum salmon at other locations in Alaska (Kogl 1965, Koski 1975, Wilson et al. 1981, Hale 1981).

Of the four microhabitat variables used in the modeling processes, upwelling appears to be the most important variable influencing the selection of redd sites by spawning chum and sockeye salmon. Spawning is commonly observed at upwelling sites in side slough and side channel areas possessing a relatively broad range of depths, velocities and substrate sizes. However, other portions of these same habitats but possessing similar depth, velocities, and substrate sizes without upwelling are not used by spawning salmon (ADF&G 1984d). Because of this strong preference evident in field observations, a binary criterion was used for this microhabitat variable. Habitat suitability criteria for upwelling assigns optimal suitability to areas with upwelling and non-suitability to areas without upwelling.

In regard to its overall influence on the quality of spawning habitat substrate could rank second to upwelling in importance. However, the substrate criteria developed by ADF&G for chum and sockeye salmon spawning in side slough and side channel habitats assigns optimal suitability to streambed material sizes from one to nine inches (Figure V-7, Part A). This range includes much larger particle sizes than are commonly cited in the literature as being suitable for spawning chum and sockeye salmon. Literature values typically range from coarse sands to five-inch material; with 1/4 to three inches being the most suitable size range (Hale 1981).

This discrepancy between the ADF&G criteria and the literature is probably related to the dominant influence upwelling has on the selection of redd sites. Apparently, such a small amount of good quality spawning substrate exists in middle Susitna River habitats that both chum and sockeye salmon use whatever streambed material sizes are associated with the upwellings. Another consideration is that salmon recorded as spawning in large substrate sizes (>6 inches) may actually have been excavating their redds in smaller streambed particles surrounding the cobbles and boulders.



SUITABILITY CRITERIA

SUBSTRATE CODE		PARTICLE SIZE	SOCKEYE SUITABILITY INDEX	CHUM SUITABILITY INDEX
1	SI	SILT	0.000	0.000
2			0.000	0.000
3	SA	SAND	0.000	0.025
4			0.100	0.050
5	SG	1/8 - 1"	0.500	0.200
6			0.950	0.600
7	LG	1 - 3"	1.000	1.000
8			1.000	1.000
9	RU	3 - 5"	1.000	1.000
10			0.900	0.850
11	CO	5 - 10"	0.250	0.700
12			0.100	0.250
13	BO	> 10"	0.000	0.000

SOCKEYE SUITABILITY CRITERIA

VELOCITY	SUITABILITY INDEX
0.0	1.0
1.0	1.0
2.0	0.5
3.0	0.1
4.5	0.0

CHUM SUITABILITY CRITERIA

VELOCITY	SUITABILITY INDEX
0.0	1.0
1.3	1.0
2.8	0.2
4.5	0.0

SOCKEYE SUITABILITY CRITERIA

DEPTH	SUITABILITY INDEX
0.00	0.0
0.20	0.0
0.30	0.2
0.50	0.9
0.75	1.0
8.00	1.0

CHUM SUITABILITY CRITERIA

DEPTH	SUITABILITY INDEX
0.00	0.0
0.20	0.0
0.50	0.2
0.80	1.0
8.00	1.0

Figure V-7. Habitat suitability criteria for slough spawning chum and sockeye salmon.

In comparison to streambed particle sizes identified in the literature as spawning substrate, the overall quality of substrate in side slough and side channel habitats for spawning salmon is quite low. The predominant substrate type in side sloughs consists of sands and silts in low velocity areas or large gravels and small cobbles intermixed with large cobbles and small boulders in free flowing reaches (ADF&G 1982b). Since the substrate composition is often similar within and between side slough spawning areas (ADF&G 1982b, 1984d) and spawning salmon use a broad range of particle sizes in the middle Susitna River, substrate composition does not appear to have much influence on the selection of redd sites or when compared to the other microhabitat variables. The limited influence of streambed material size on slough-spawning chum and sockeye salmon is evident in the broad range of particle sizes identified as being optimal (ADF&G 1984d).

Velocity is often considered one of the most important microhabitat variables affecting spawning salmon (Thompson 1974, Wilson et al. 1980, Bjornn et al. 1981). The habitat suitability criteria developed by ADF&G for both spawning chum and sockeye salmon assigns optimal suitabilities to velocities less than 1.3 fps (Refer Figure V-7, Part B). As the mean column velocity at the spawning site increases above 1.0 fps, suitability declines more rapidly for sockeye than for chum. Microhabitat areas with mean column velocities exceeding 4.5 fps are considered unusable by both species.

The ADF&G criteria assign slightly lower suitabilities to velocities between 2 and 3 fps than criteria available in the literature (Bovee 1978, Wilson et al. 1981, Estes et al. 1980, Hale 1981). This discrepancy may exist because most data used to develop velocity suitability criteria for spawning and sockeye salmon in the middle Susitna River were collected in side slough habitats that characteristically have a narrow range of low velocities. Habitat suitability criteria developed by other investigators in Alaska were based on data principally collected in higher velocity habitats of other river systems. The velocity suitability criteria developed by ADF&G for chum and sockeye spawners are considered most applicable to sites possessing slough-like velocities. Velocity criteria from the literature are considered more applicable to evaluating microhabitat preferences of spawning chum salmon in the mainstem and side channels of the middle Susitna River.

Habitat suitability criteria for depth indicate that depths in excess of 0.8 feet provide optimal spawning depths for chum and sockeye salmon (Figure V-7, Part C). This depth is slightly more conservative but consistent with the 0.6 foot depths used elsewhere (Smith 1973, Thompson 1972). Microhabitat areas with depths less than 0.8 feet provide suboptimal spawning conditions and depths of 0.2 feet or less are unusable. These minimum depth criteria are consistent with values presented by others as minimum depth requirements for spawning chum salmon (Kogl 1965, Wilson et al. 1981).

Habitat Availability. WUA indices (habitat response curves) have been developed by ADF&G for spawning chum and sockeye salmon at seven side slough and side channel locations. Both chum and sockeye salmon have been observed spawning within four of these study sites or in their immediate vicinity (ADF&G 1984a,d). Although minor differences occur between the habitat response curves for spawning chum and sockeye salmon at each of these four study sites, they are, in general, quite similar (Figure V-8). The minor differences that exist between the habitat response curves for these two species are attributable to differences between depth and velocity suitability criteria. A slightly higher suitability is assigned to depths between 0.2 and 0.8 feet for sockeye whereas a slightly higher suitability is assigned to velocities in excess of 1 fps for chum salmon.

Except for a few isolated observations, all sockeye salmon spawning in the middle Susitna River has occurred in side sloughs that are also utilized by chum salmon. The timing and spawning habitat requirements of sockeye salmon are also similar to chum salmon (ADF&G 1984d). In addition chum salmon spawners are both more numerous and widespread than sockeye spawners in middle Susitna River habitats. Thus the analysis will focus on the response of chum salmon spawning habitats

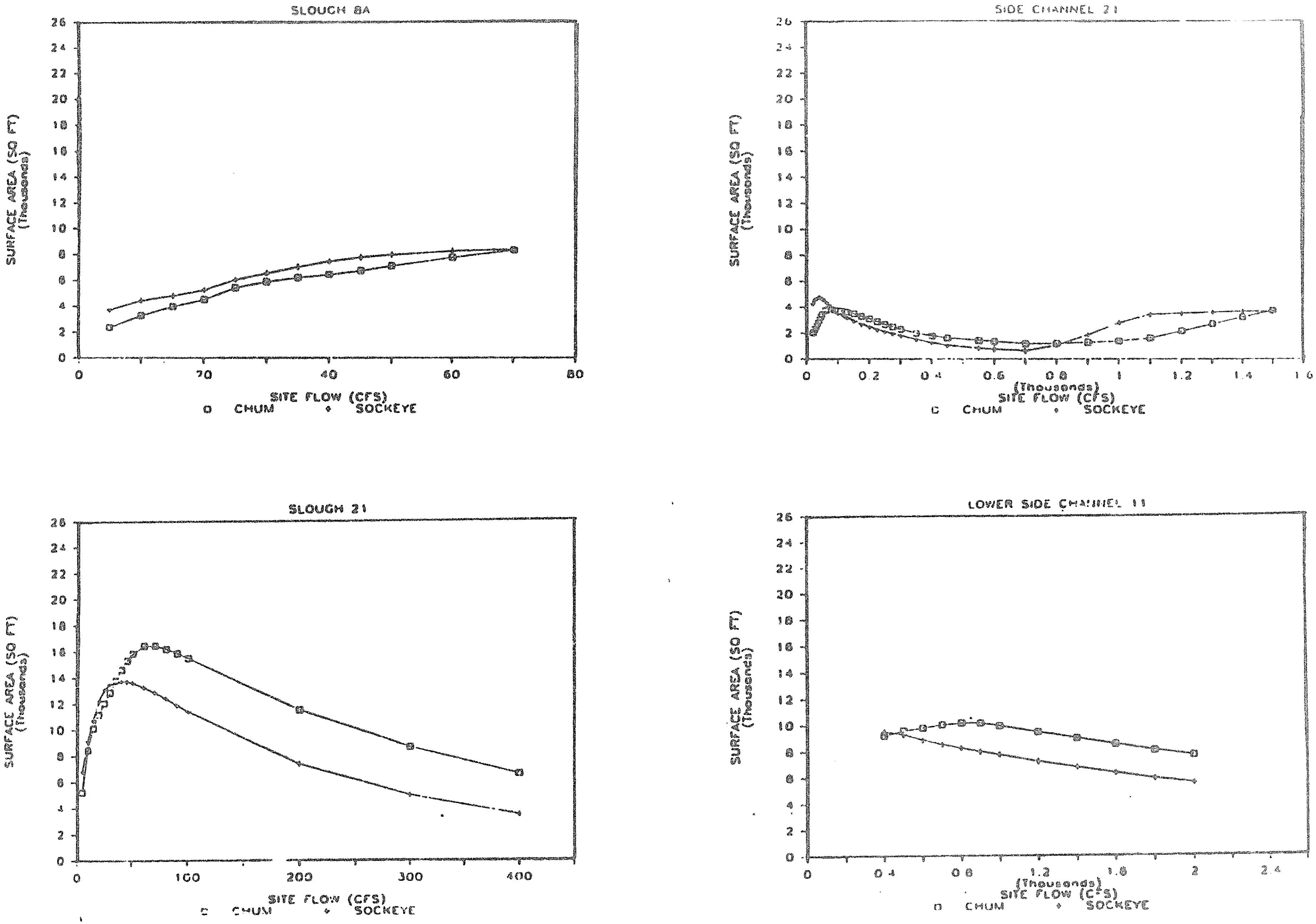


Figure V-8. Comparison of WUA responses to site flow for spawning chum and sockeye salmon at four middle Susitna River study sites. (Adapted from ADF&G 1984 d).

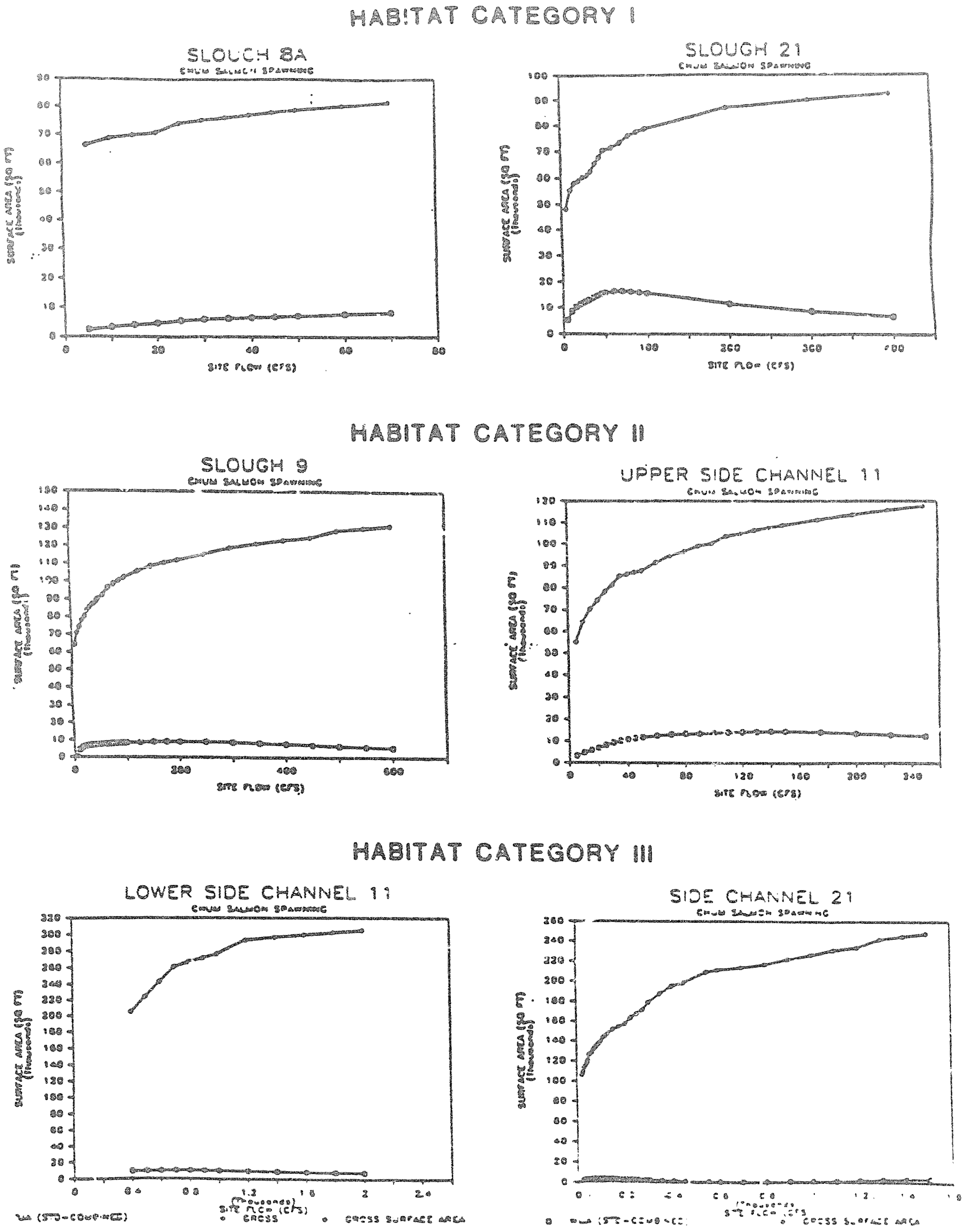


Figure V-9. Total surface area and WUA index for spawning chum salmon at Habitat Category I, II, and III study sites. (Adapted from ADF&G 1984d).

and use those WUA indices to also estimate the response of sockeye salmon spawning habitats.

Response curves for total surface area and weighted usable area for spawning chum salmon are presented by habitat category in Figure V-9. Habitat Category I contains those areas that exist as clearwater side slough habitats at mainstem discharges of 23,000 cfs and less. Category II sites convey turbid mainstem water at 23,000 cfs but become clearwater side slough habitats at a lower discharge. Habitat Category III refers to side channels that continue to carry turbid water. Of most interest in Figure V-9 is the relatively low WUA indices forecast at all sites in comparison to total surface area. The magnitude of this difference underscores the inappropriateness of using wetted surface area as a measure of spawning habitat.

The other notable feature in these graphs for Category I and II is the location of optimal WUA values. The highest value occurs at a relatively high discharge after the slough is overtopped by mainstem flows. The habitat response curves for these two categories generally increase rapidly as the channel is overtopped and then levels off, either slightly increasing or decreasing with site discharge. In Habitat Category III sites, the WUA is not closely related to flow in the site for the discharges analyzed. WUA values remain relatively constant as flow increases. The shape of the WUA function relative to change in gross area indicates the stability of the habitat. The magnitude of the WUA function is controlled by fixed habitat attributes, upwelling and substrate while the slope WUA reflects the depth and velocity distribution or variable habitat attributes.

The maximum amount of spawning habitat potentially available at any site under noted conditions is determined by the total surface area of the upwelling. The total surface area of upwellings at the Side Slough 21 and Upper Side Channel 11 study sites were increased by 16 and 53 respectively and WUA recalculated. By arbitrarily increasing the percentage of the total surface area of the upwelling at these sites WUA increased at both sites without a notable change occurring in the shape of the habitat response curve for either site (Figure V-10). This demonstrates that a general increase or decrease in the amount of upwelling will affect the availability of spawning habitat to approximately the same degree over a broad range of site flows. Other microhabitat variables that are important to spawning salmon in the middle Susitna River (depth and velocity) principally determine the accessibility and quality of upwelling areas.

The habitat response curve for Slough 21 peaks when the mainstem discharge is approximately 28,500 cfs, the respones curve for Upper Side Channel 11 peaks when the mainstem discharge is near 23,000 cfs (Figure V-11). At these discharge levels, the alluvial berm at the upstream end of each site is overtopped and the site specific flows are approximately 70 cfs in Slough 21 and 150 cfs in Upper Side Channel 11 (ADF&G 1984d). Base flow at both sites is approximately 5 cfs whenever the mainstem discharge is less than that required to overtop their upstream berms (ADF&G 1984d). The depth of flow over upwelling areas forecast by hydraulic models of these sites indicate that depths typically range less than 0.5 feet at base flow but increase to 1.0 feet or greater when overtopped (Figure V-12). Velocities respond similarly to overtopping typically increasing from the 0 to 0.5 fps range to approximately 1.5 fps (Figure V-13).

Comparison of depths and velocities associated with baseflow and controlled flow conditions with habitat suitability criteria presented earlier for spawning chum salmon (Refer Figure V-7) indicates the rapid increase in WUA indices for Slough 21 and Upper Side Channel 11 evident in Figure V-11 is attributable to an increase of depth over upwelling areas (Figures V-12 and 13). The gradual decrease in WUA indices at higher site flows is due to mean column velocities over upwelling areas exceeding the 0 to 1.3 fps optimum range established for slough spawners. The importance of depth adversely influencing the availability of spawning habitat at Category I and II sites under non-breached conditions is important to recognize. The analysis presented earlier regarding the influence of overtopping events on providing adequate passage depths within these sites for adult salmon

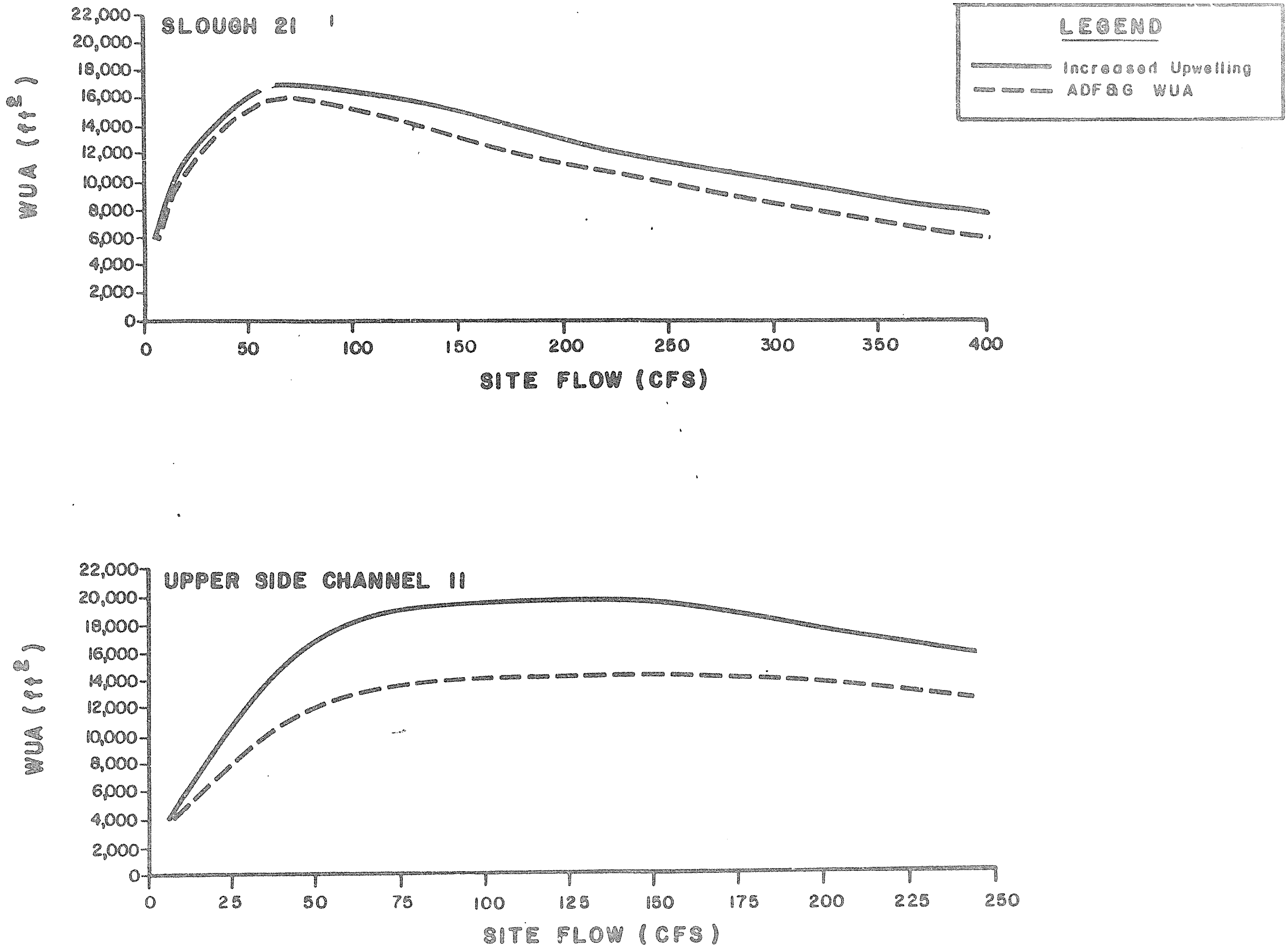


Figure V-10. Simulated influence of increased upwelling on WUA for spawning chum salmon at Slough 21 and Upper Side Channel 11.

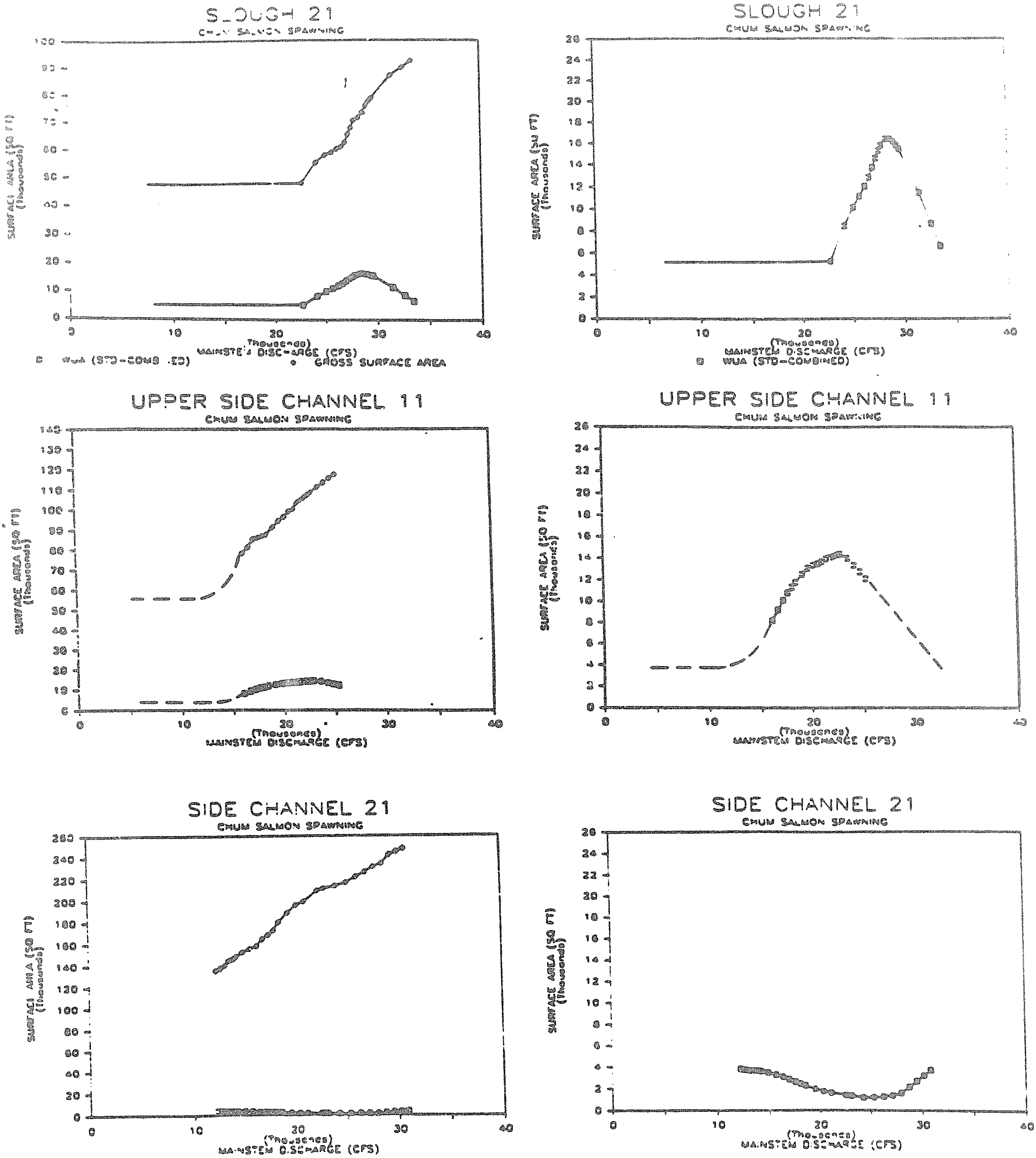


Figure V-11. Surface area and WUA responses to mainstem discharge Habitat Category I, II, and III spawning sites. (Adapted from ADF&G 1984c).

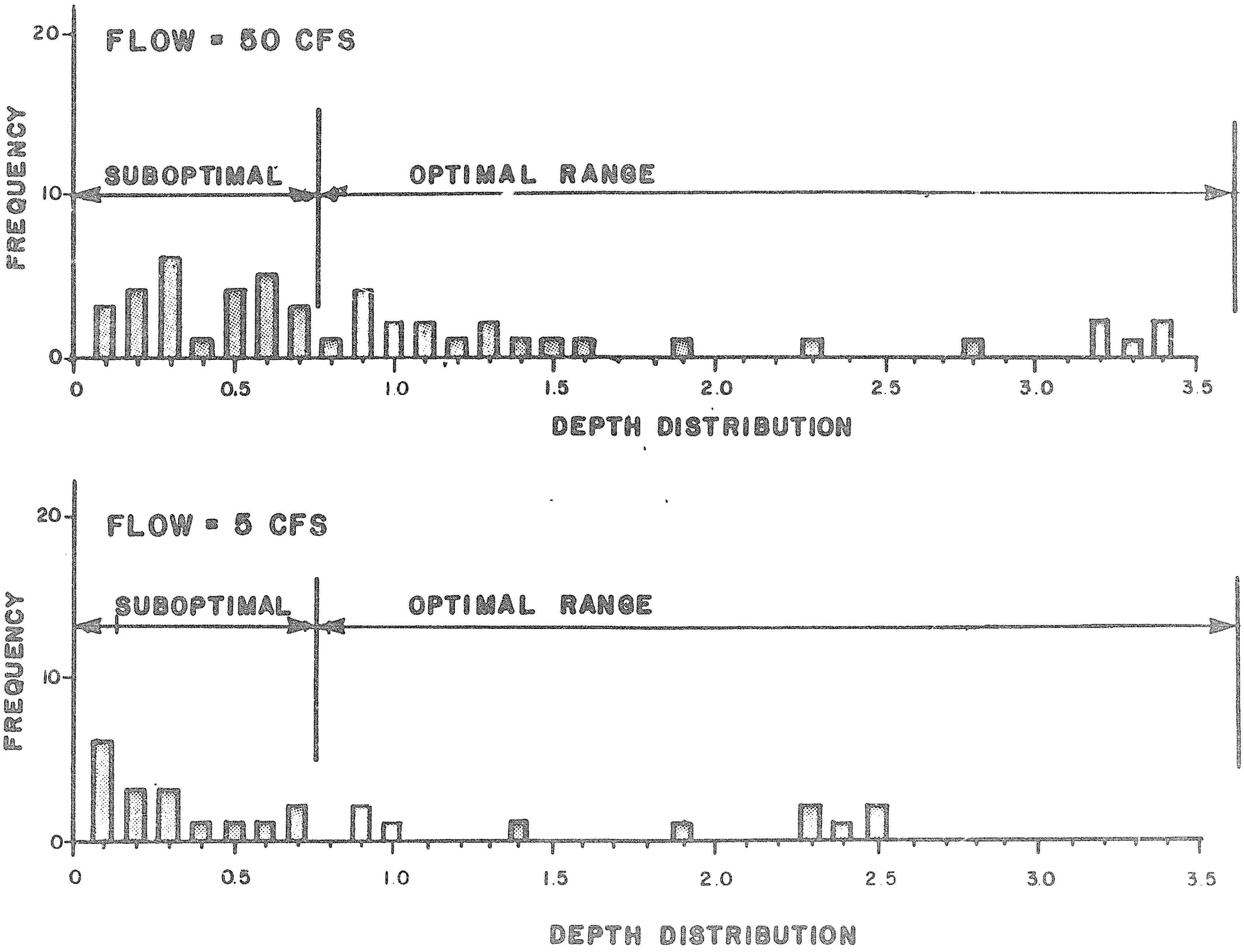


Figure V-12. Frequency distribution of cell depth over upwelling areas in Upper Side Channel 11 at site flow of 5 and 50 cfs.

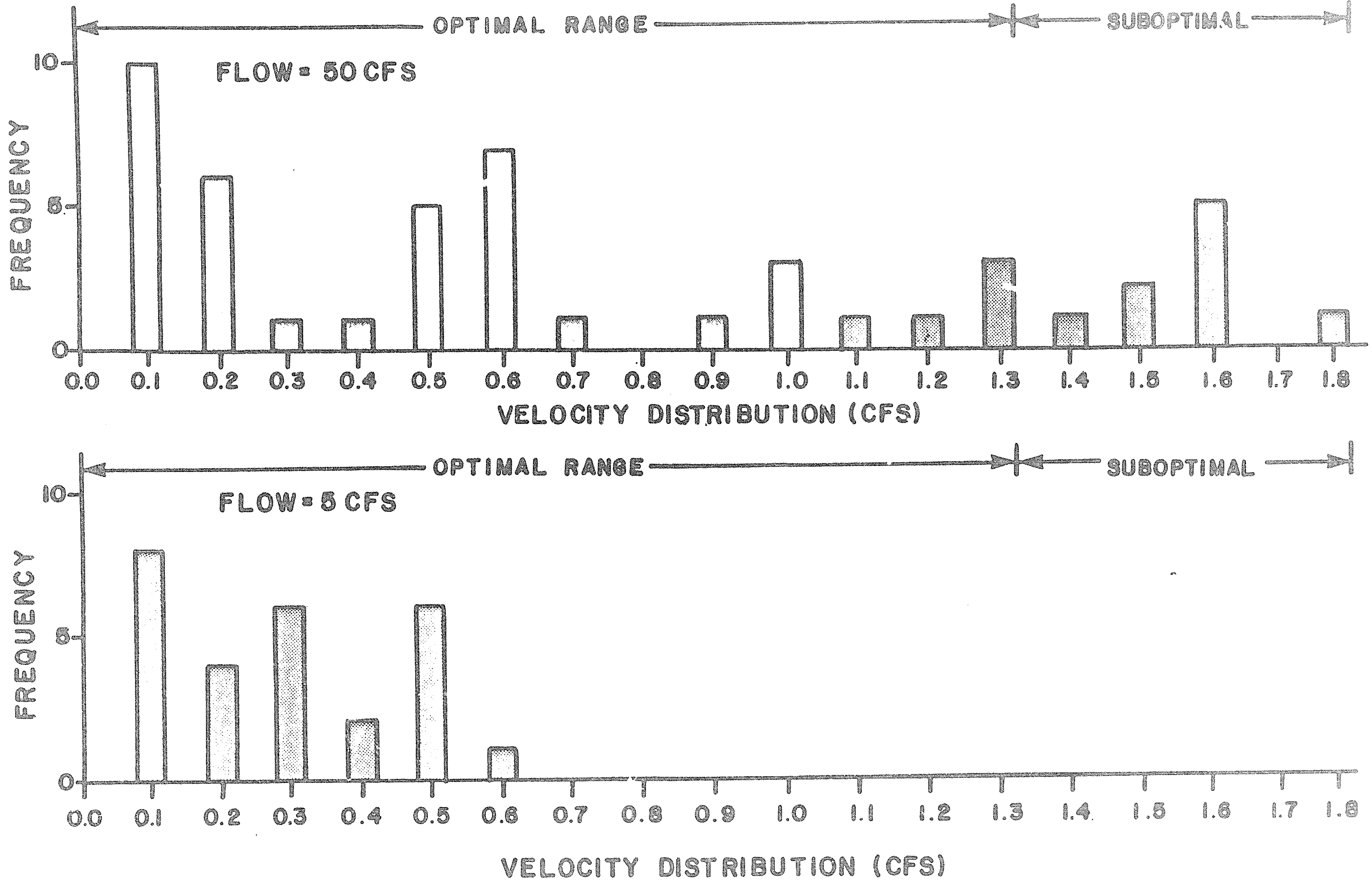


Figure V-13. Frequency distribution of cell velocity over upwelling areas in Upper Side Channel 11 at site flows 5 and 50 cfs.

is also applicable in estimating the importance of breaching flows on the availability of spawning habitat.

Side sloughs provide a relatively stable amount of habitat for spawning chum salmon. The habitat stability results from the base flow conditions which are present during much of the spawning season. Figure V-14 presents flow duration and habitat duration curves for three habitat categories. Each habitat duration curve was constructed from daily habitat values derived from daily flows at the site. Site flows were determined from mainstem flow at Gold Creek using the regression equations presented by ADF&G (1984d).

Slough 21 provides an example of a category I habitat which is quite stable. The habitat duration curve indicates that the habitat value equalled or exceeded 90 percent of the time is nearly the same as that equalled or exceeded 10 percent of the time. The higher habitat values are associated with breaching flows as discussed previously.

Habitat category II sites are also relatively stable. Upper side channel 11 has a flat habitat duration curve from 100 to 50 percent equalled or exceeded. Higher habitat values associated with breached conditions occur more frequently than in category I.

Rearing Salmon

Microhabitat Preferences. Extensive field studies have been conducted by ADF&G to determine the seasonal movement and habitat requirements of juvenile chinook, chum, coho and sockeye salmon in the middle Susitna River (ADF&G 1984b). Juvenile coho salmon rear predominantly in tributary and upland slough habitats. The low numbers of sockeye juveniles rearing in the middle Susitna River are most commonly found in upland slough habitats. Juvenile chum and chinook salmon are the most abundant salmon species that rear in side slough and side channel habitats. By early summer (mid June) most juvenile chum salmon have outmigrated from middle Susitna River habitats, and a large inmigration of chinook fry is occurring from natal tributaries. These

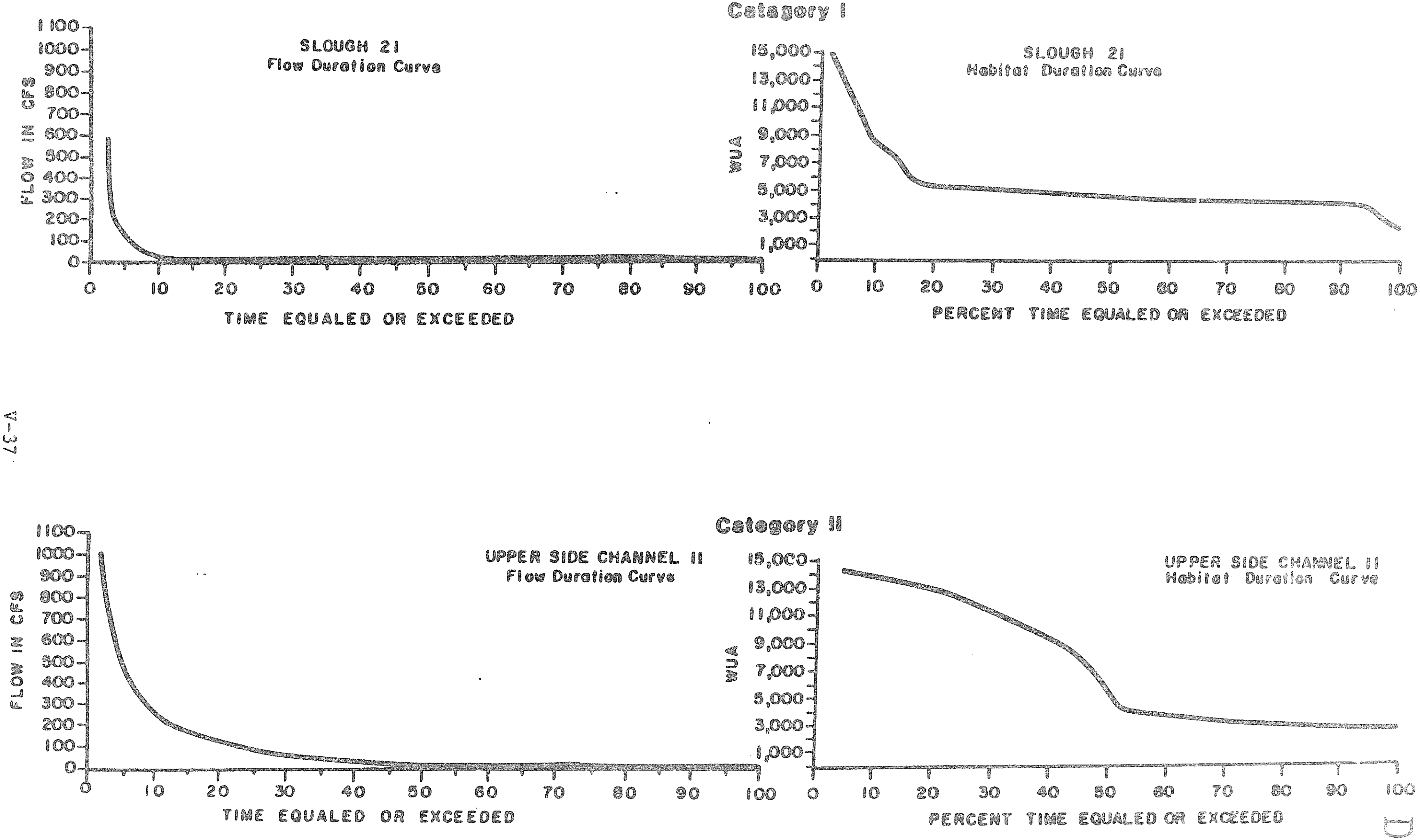


Figure V-14. Flow and habitat duration curves for spawning chum salmon by habitat categories.

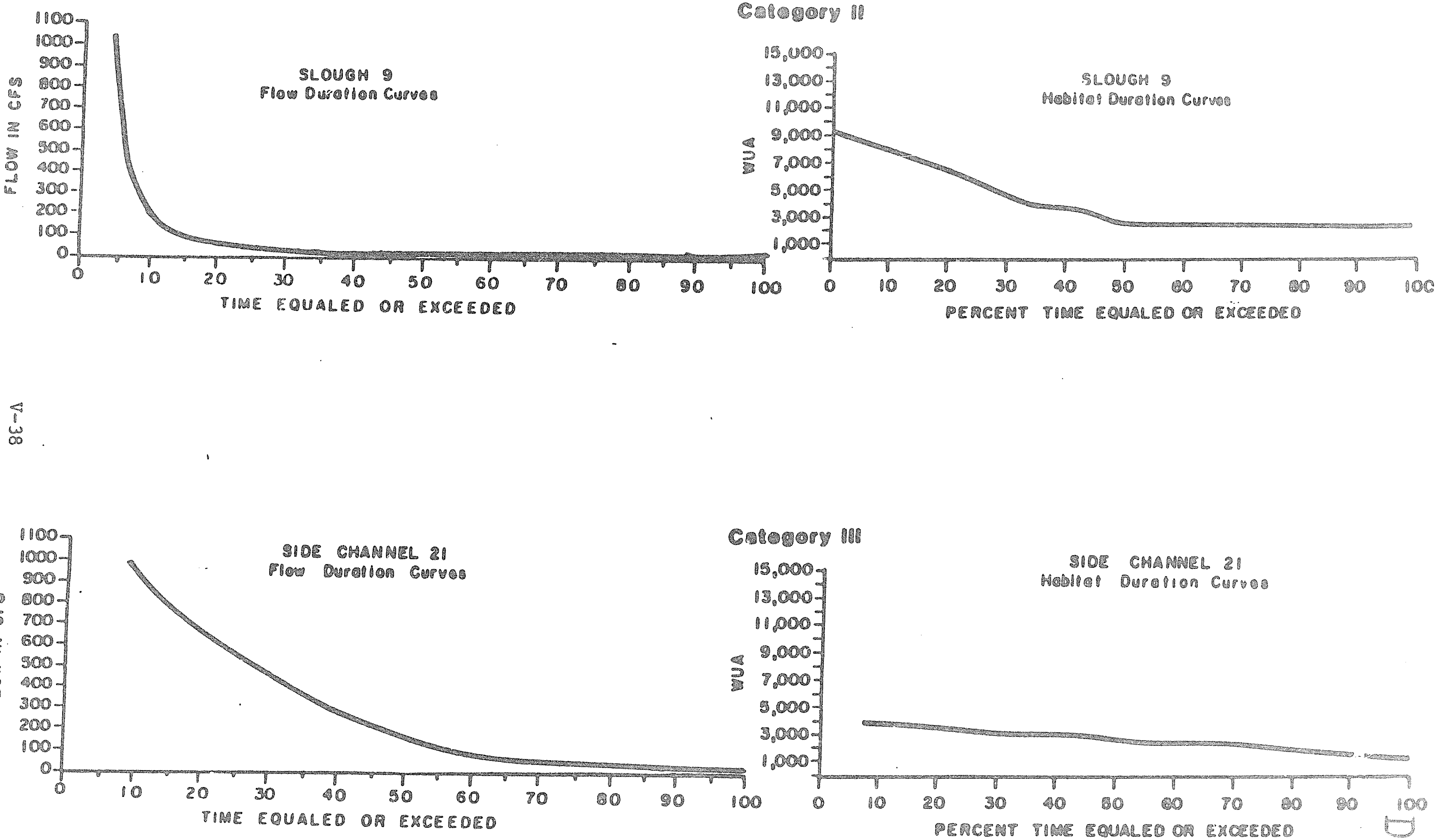


Figure V-14 (cont'd). Flow and habitat duration curves for spawning chum salmon by habitat categories.

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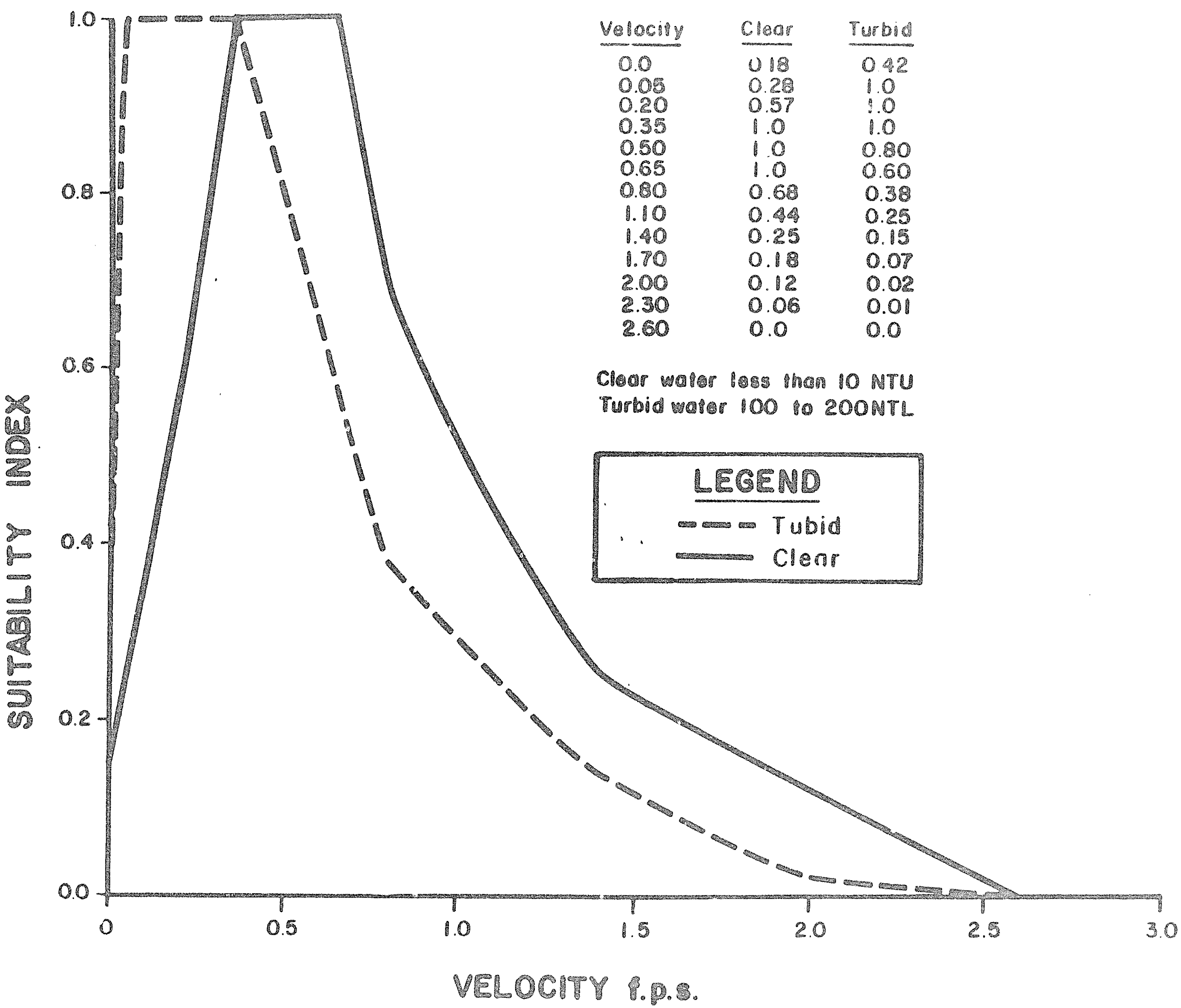
immature chinook redistribute into side channels and side sloughs during the remainder of the summer. With the onset of fall and colder mainstem and side channel water temperatures, chinook juveniles move into the upwelling areas associated with side slough habitats to overwinter (ADF&G 1984).

Rearing habitat is commonly evaluated using three variables: depth, velocity, and cover (Bovee 1982 and Wesche and Reckard 1980). Habitat suitability criteria have been developed by ADF&G to describe the preferences of juvenile chum and chinook salmon for these microhabitat variables. Habitat suitability criteria developed by ADF&G indicate that water depths exceeding 0.15 feet provide optimal conditions for rearing chinook (ADF&G 1984b). This compares well with Burger et al. (1981) who found chinook using depths greater than 0.2 feet up to 10 feet.

Cover is used by juvenile salmon as a means of avoiding predation and obtaining protection from unfavorable water velocities. Instream objects, such as submerged macrophytes, large substrate, organic debris, and undercut banks provide both types of shelter for juvenile salmon (Burger et al. 1981, Bustard and Narver 1975, Bjornn 1971, and Cederholm and Koski 1977). One significant result of the ADF&G field studies is the use of turbidity by juvenile chinook as cover. Juvenile chinook were commonly found in low-velocity turbid water (100-200 NTU) without object cover but were rarely observed in low-velocity, clearwater (under 10 NTU) without object cover. The influence of turbidity on the distribution of juvenile chinook in side channel habitats was so pronounced that habitat suitability criteria for velocity and object cover were developed by ADF&G for both clear and turbid water conditions (Figures 15 and 16).

These criteria curves assign optimal suitability values to velocities between 0.05 and 0.35 fps for turbid water, and between 0.35 and 0.65 fps for clear water. The Susitna River criteria for juvenile chinook in clear water differ from velocity criteria developed in other Alaska studies (Burger et al. 1981, Bechtel 1983) and those used



Velocity	Clear	Turbid
0.0	0.18	0.42
0.05	0.28	1.0
0.20	0.57	1.0
0.35	1.0	1.0
0.50	1.0	0.80
0.65	1.0	0.60
0.80	0.68	0.38
1.10	0.44	0.25
1.40	0.25	0.15
1.70	0.18	0.07
2.00	0.12	0.02
2.30	0.06	0.01
2.60	0.0	0.0

Figure V-15. Velocity criteria for juvenile Chinook in clear and turbid water.

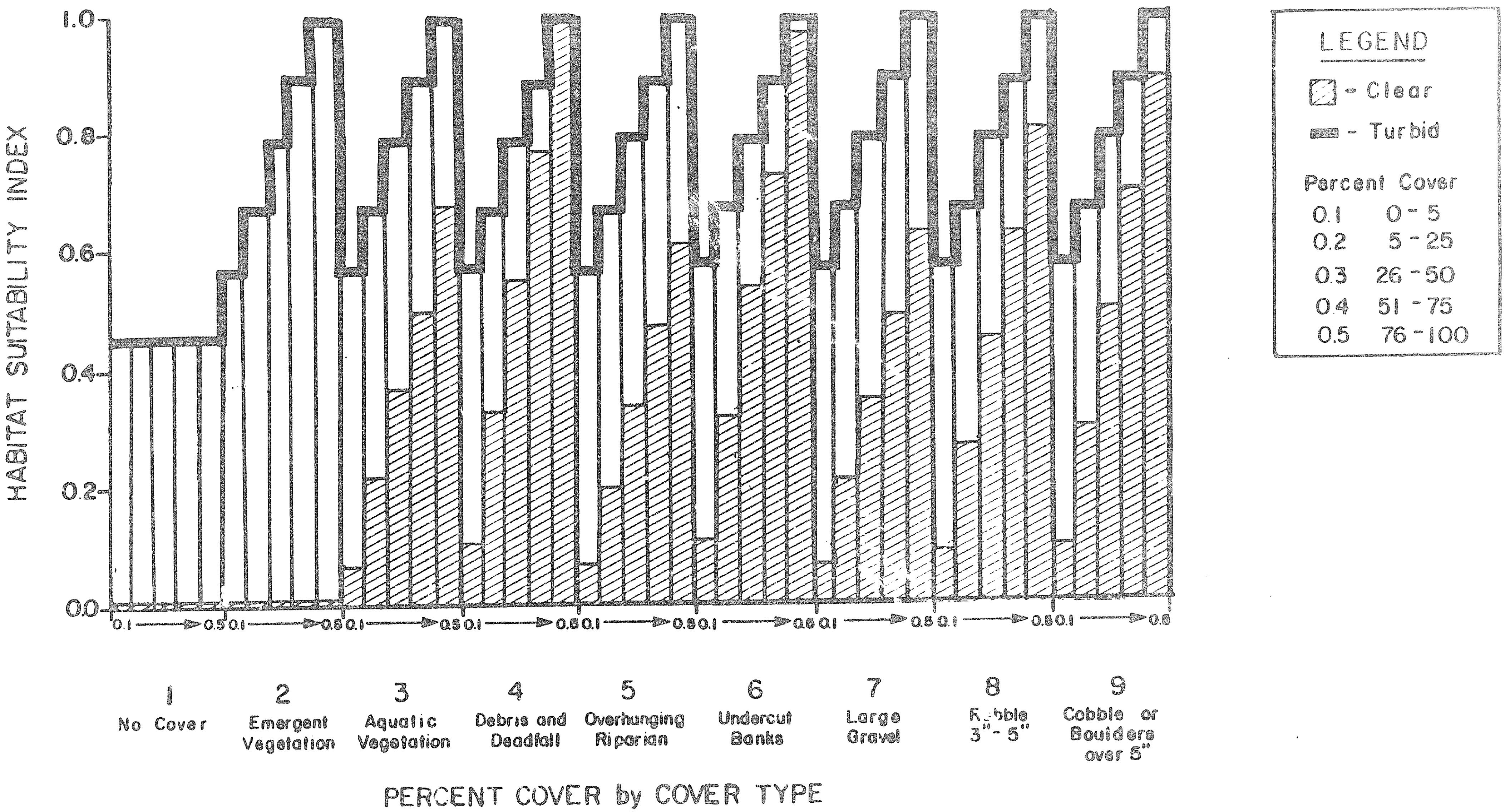


Figure V-16. ADF&G cover criteria for juvenile chinook in clear and turbid water.

by the IFG (Nelson pers. comm. 1984). Literature values typically indicate optimal velocities for juvenile chinook in clear water are less than 0.5 fps. The criteria presented by both Burger et al. and Bechtel (Figure 17) can be considered comparable to ADF&G's criteria for juvenile chinook insofar as the Burger and Bechtel criteria were developed for juvenile chinook (under 100 mm) rearing in large glacial rivers in Alaska. Although the chinook criteria from the literature were developed from data collected in clear water (less than 30 NTU), they are more similar to the Susitna River velocity criteria for turbid water (100-200 NTU). The apparent reason for this discrepancy is the difference in field methods used by ADF&G and the other investigators.

Mean column velocities were measured by both ADF&G and other investigators to develop habitat suitability curves for juvenile chinook. However, the location at which the mean column velocity was measured relative to the apparent locations of juvenile chinook were quite different. ADF&G reported the mean column velocity at the midpoint of a 6 foot by 50 foot cell (mid-cell velocity) regardless of the location that juvenile fish may have occupied within. The velocity criteria developed by Burger and Bechtel are based on mean column velocities measured in the immediate vicinity of individual fish observations or captures (point velocities).

Assuming that immature fish in clear water are more likely to be found along stream banks (where lower velocities and cover are generally more available), the practice of measuring mid-cell velocities a minimum distance of 3 feet (one half the width of the ADF&G sample cell) from the streambank would result in slightly higher mean column velocities being measured than if point velocities had been measured. Hence it is understandable that the 0.35 to 0.65 fps velocity range selected by ADF&G as being optimal for juvenile chinook is slightly higher than the 0 to 0.5 fps velocity range selected by other investigators.

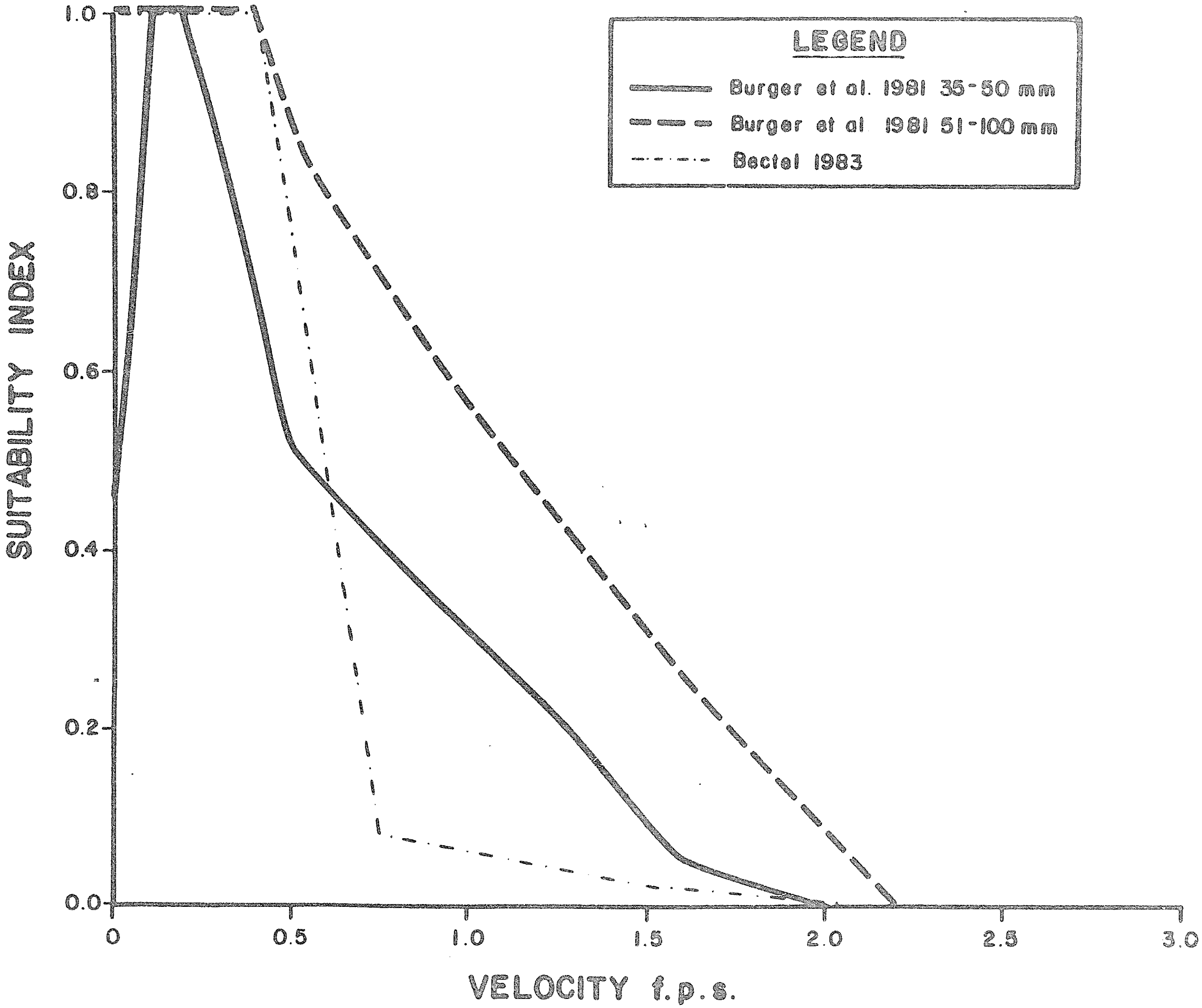


Figure V-17. Velocity suitability criteria for juvenile chinook in the Kenai and Chakachamna rivers; Alaska. (Source: Burger et al. 1981 and Bectel 1983).

In turbid water (100-200 NTU) it appears that juvenile chinook do not orient along the streambank or associate with object cover to the same degree they do in clear water (ADF&G 1984c). Rather, they are randomly distributed in low velocity areas with little or no object cover. In these low-velocity turbid areas, it is quite likely that mid-cell velocities meausred 3 feet from the streambank differ little from point velocities measured in microhabitats along the shoreline that would be inhabited by juvenile chinook in a clearwater stream. Therefore, it is not surprising that the 0 to 0.4 fps velocity range selected by ADF&G as being optimum for juvenile chinook in turbid water differs little from the 0 to 0.5 fps velocity range selected by other investigators using point velocity measurements rather than mid-cell velocities as their data base.

It can be inferred from the ADF&G habitat suitability criteria that in low-velocity water (<0.4 fps) where juvenile chinook do not require protection from water currents, they are more likely to be found within the water column away from object cover if the water is turbid (100 to 200 NTU) than if it is clear (less than 10 NTU). At velocities greater than 0.4 fps, the distribution of juvenile chinook in turbid water will likely become more strongly influenced by velocity, and when velocities exceed 1.0 fps, object cover is probably as important to juvenile chinook in turbid water as it is to them in clear water. However, since these young fish do not appear to orient well in turbid water, they cannot make use of object cover that may be available and are therefore redistributed in microhabitats by velocity currents.

Whenever mainstem discharge recedes sufficiently for turbid water in small side channel areas to clea~, juvenile chinook redistribute from low-velocity turbid water pools to clear water riffles near the upstream end of the site. In these clearwater riffle areas object cover appears important, and juvenile chinook are most commonly found among streambed particles or near organic debris regardless of the velocities present (ADF&G 1984c). Based on the preceding discussions of habitat suitability criteria and the behavior of juvenile chinook, it appears that velocity and cover are the two most important abiotic microhabitat variables influencing juvenile chinook rearing habitat. Of the two cover appears most influential.

Although offering no protection from velocity, turbid water appears to provide juvenile chinook adequate concealment from their prey and predators that they make extensive use of turbid (100-200 NTU) low-velocity areas (<0.4 fps). In clear water juveniles generally seek concealment within interstitial spaces among streambed particles. Utilization of these interstitial spaces also provides sufficient protection from velocity that they are frequently found during daylight in riffle areas possessing velocities between 0.35 and 0.65 fps (ADF&G 1984c).

The difference in velocity ranges utilized by juvenile chinook in clear and turbid water is thought to be most strongly influenced by food and cover availability. Given the high suspended sediment concentrations that presently exist in side channel habitats, interstitial spaces between streambed particles are generally filled with fine glacial sands in most areas where velocities of 0.4 fps or less would exist at moderate to high mainstem discharges. At low mainstem discharges when water at the site clears the most likely place to find interstitial spaces between streambed particles not filled with fine sediments and a good food supply is in riffle areas that were subjected to relatively high velocities when the site was breached. Generally these types of riffle areas occur at the head of the site.

Based on this logic the following modifications have been made to the ADF&G habitat suitability criteria for juvenile chinook. The cover and depth criteria developed by ADF&G for chinook in clear water have been adopted. However the ADF&G velocity criteria for both clear and turbid water have been combined such that the optimal or preferred velocity range extends from 0.05 fps to 0.65 fps for clearwater situations. As velocity increases above 0.65 fps the habitat suitability decreases in accord with the ADF&G clear water criteria.

This approach incorporates the response of juvenile chinook to low-velocity flow observed by other investigators at locations where better object cover was available than in low velocity middle Susitna River habitats. The importance of object cover in providing both concealment and protection from velocity is expressed in the clearwater cover criteria developed by ADF&G for middle Susitna River habitats. Whenever the water is turbid, the ADF&G depth and turbid water velocity criteria are applied in conjunction with a modification of the ADF&G turbid water cover criteria.

The ADF&G cover criteria for turbid water were modified by multiplying the clear water percent cover suitability values for each cover type by a turbidity factor. This turbidity factor is the mean catch per cell in turbid water divided by the mean catch per cell in clear water for corresponding percent cover categories (Table V-4).

Table V-4. Calculation of turbidity factors for determination of the influence of turbidity on clear water cover criteria for juvenile chinook salmon.

Percent Cover	Number of Fish Per Cell		Turbidity Factor
	Clear	Turbid	
0-5%	.8	3.5	4.38
6-25%	2.5	4.2	1.68
26-50%	4.0	4.8	1.20
51-75%	5.7	5.5	.96
76-100%	7.2	6.0	0.83

Source: ADF&G 1984c

Application of these turbidity factors to the ADF&G clear water cover criteria increases the suitability of percent cover categories under turbid water conditions if 50 percent or less object cover is present but decreases suitability if more than 50 percent object cover is present (Figure V-18). The decrease in suitability of the higher percent cover categories in turbid water conditions may be attributed in part, to the inability of juveniles to orient themselves and fully utilize the available cover. Because the turbid water suitability

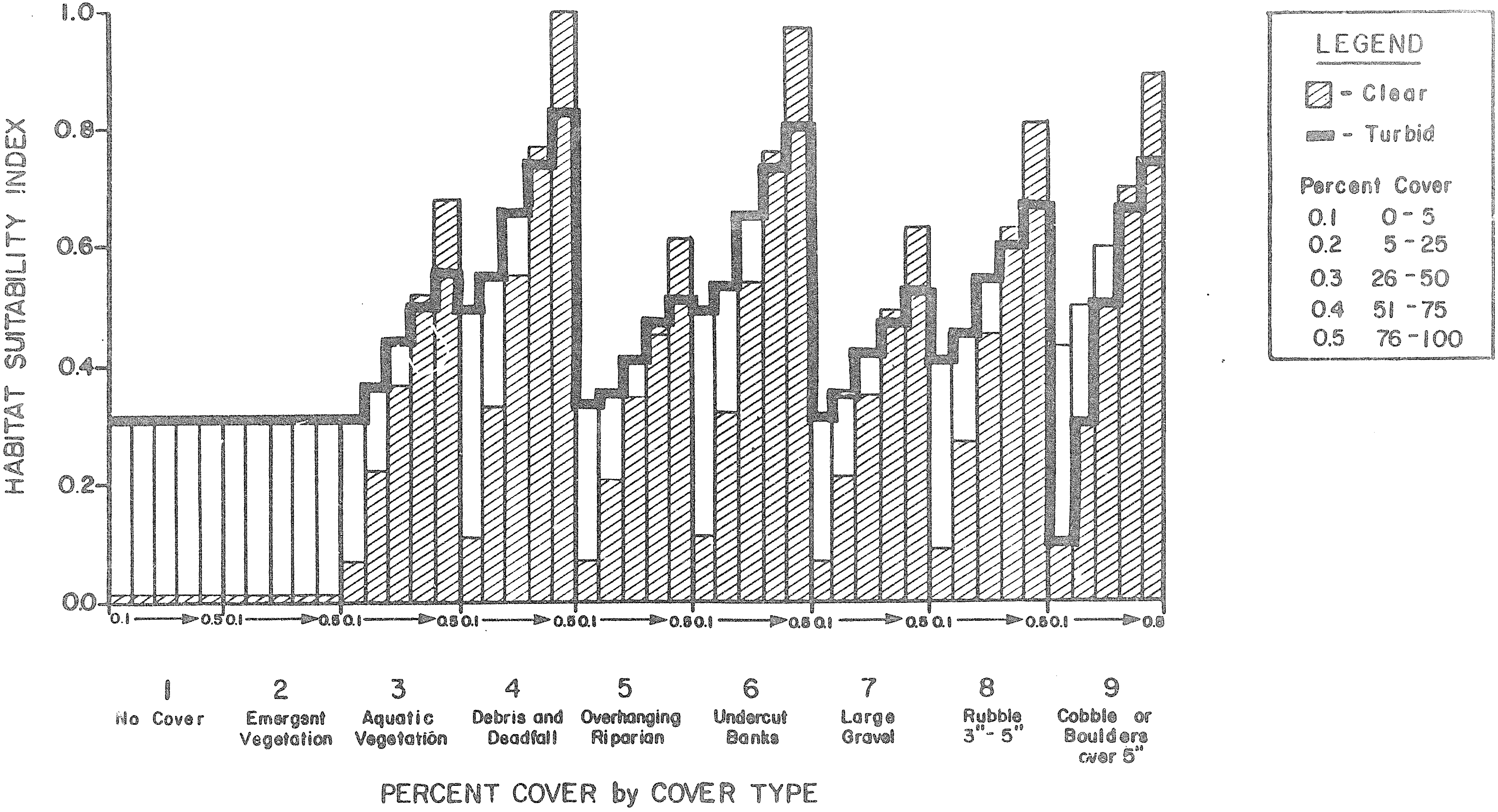


Figure V-18. Revised cover criteria for juvenile chinook in clear and turbid water.

values calculated for the no-cover type were unrealistically low (approximately 0.04) a more appropriate value, 0.30, was arbitrarily chosen that is similar to the majority of calculated values in the 0 to 5 percent cover categories for other cover types. By applying the above criteria it is felt that a rearing habitat model can be developed that can reliably respond to a broader range of with-project conditions by making use of species-specific behavior in addition to microhabitat preferences of chinook juveniles.

Habitat Availability. WUA indices forecast for juvenile chinook rearing at Side Channel 21 and Upper Side Channel 11 using ADF&G criteria and the modified velocity criteria are compared in Figure V-19. Increasing the range of low velocities suitable for juvenile chinook in clear water at these study sites did not substantially increase WUA indices above those previously forecast by ADF&G. This is attributable to the importance of cover to juvenile chinook in clear water and the poor cover conditions associated with low-velocity areas in these sites under natural conditions. The most notable changes although slight, occurred at the very low discharges (5-10 cfs) where low-velocity water is more likely associated with larger substrates in the mid-channel zone. WUA indices forecast for juvenile chinook using cover criteria for low and high turbidity conditions are presented in Figure V-20. Identical habitat response curves are forecast for low turbidity conditions because the ADF&G clear water cover criteria is used in both models. However, application of the modified turbid water cover criteria results in approximately a 25 percent reduction in WUA indices from the ADF&G forecasts.

Under project operation, the larger sediments (sands and silts) that are currently transported by the river are expected to settle out in the reservoirs. Without continual recruitment of these sediments into habitats downstream of the reservoirs it is anticipated that the finer material presently filling interstitial spaces among larger streambed particles will be gradually removed. The effect of an increase in cover suitability resulting from the removal of fine sediments from

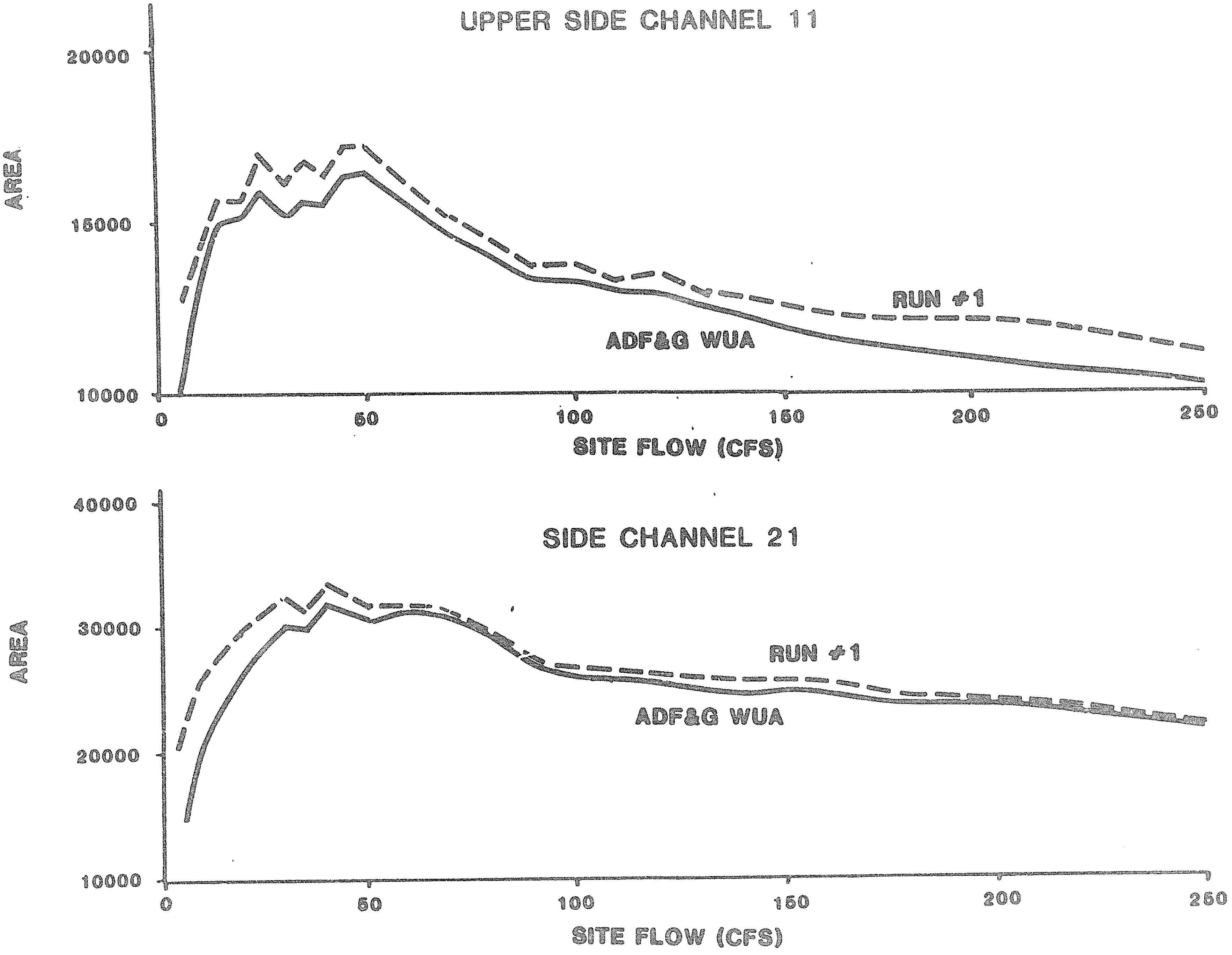


Figure V-19. Comparison between WUA forecasts useing ADF&G low turbidity velocity criteria and modified low turbidity velocity criteria.

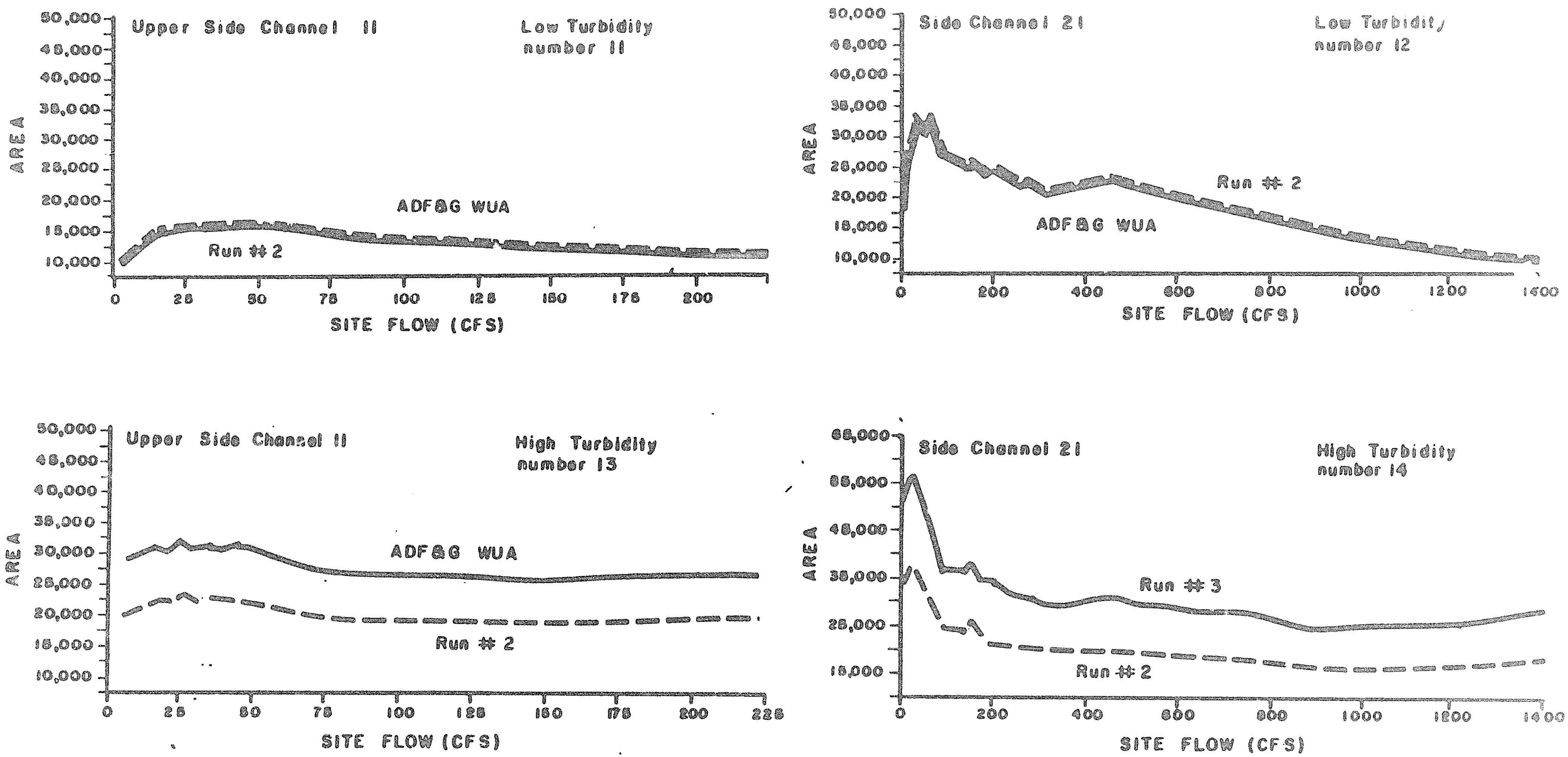


FIGURE V-20. COMPARISON BETWEEN WUA FORECASTS USING ADF&G AND MODIFIED COVER CRITERIA FOR JUVENILE CHINOOK.

interstitial voids was simulated by upgrading all recorded percent cover categories at two study sites by one category and recalculating WUA indices for juvenile chinook. This simulation resulted in increased WUA indices at Upper Side Channel 11 and Side Channel 21 of approximately 60 percent depending on the suitability criteria applied (Figure V-21).

Rearing habitat for juvenile chinook under low and high turbidity conditions was modeled using a combination of the revised clear water velocity criteria, modified high turbidity cover criteria and ADF&G criteria for depth, velocity and cover (Table V-5). WUA indices

Table V-5. Habitat suitability criteria used in revised model to forecast WUA for juvenile chinook salmon under low and high turbidities.

Low Turbidity (>30 NTU)	High turbidity (100-200 NTU)
ADF&G Depth Criteria	ADF&G Depth Criteria
ADF&G Cover Criteria	Modified Cover Criteria
Revised Velocity Criteria	ADF&G Velocity Criteria

forecast for juvenile chinook salmon at Side Channel 21 and Upper Side Channel 11 using the ADF&G and revised rearing habitat criteria are compared to total surface area in Figure V-22 as functions of mainstem discharge. The upstream berms at these sites can be overtopped at mainstem discharges of 9,200 cfs and 13,000 cfs, respectively. Hence low turbidity conditions exist at the Side Channel 21 site whenever the mainstem discharge is less than 9,200 cfs, and high turbidities prevail whenever the mainstem discharge exceeds 9,200 cfs. The same relationship between mainstem discharge and turbidity conditions exists for Upper Side Channel 11 except the threshold discharge is 13,000 cfs.

The general shape of habitat response curve sfor juvenile chinook is determined primarily by the interaction between cover availability and suitable velocities. Of these, cover seems to be the more important variable determining the absolute amount of rearing habitat available.

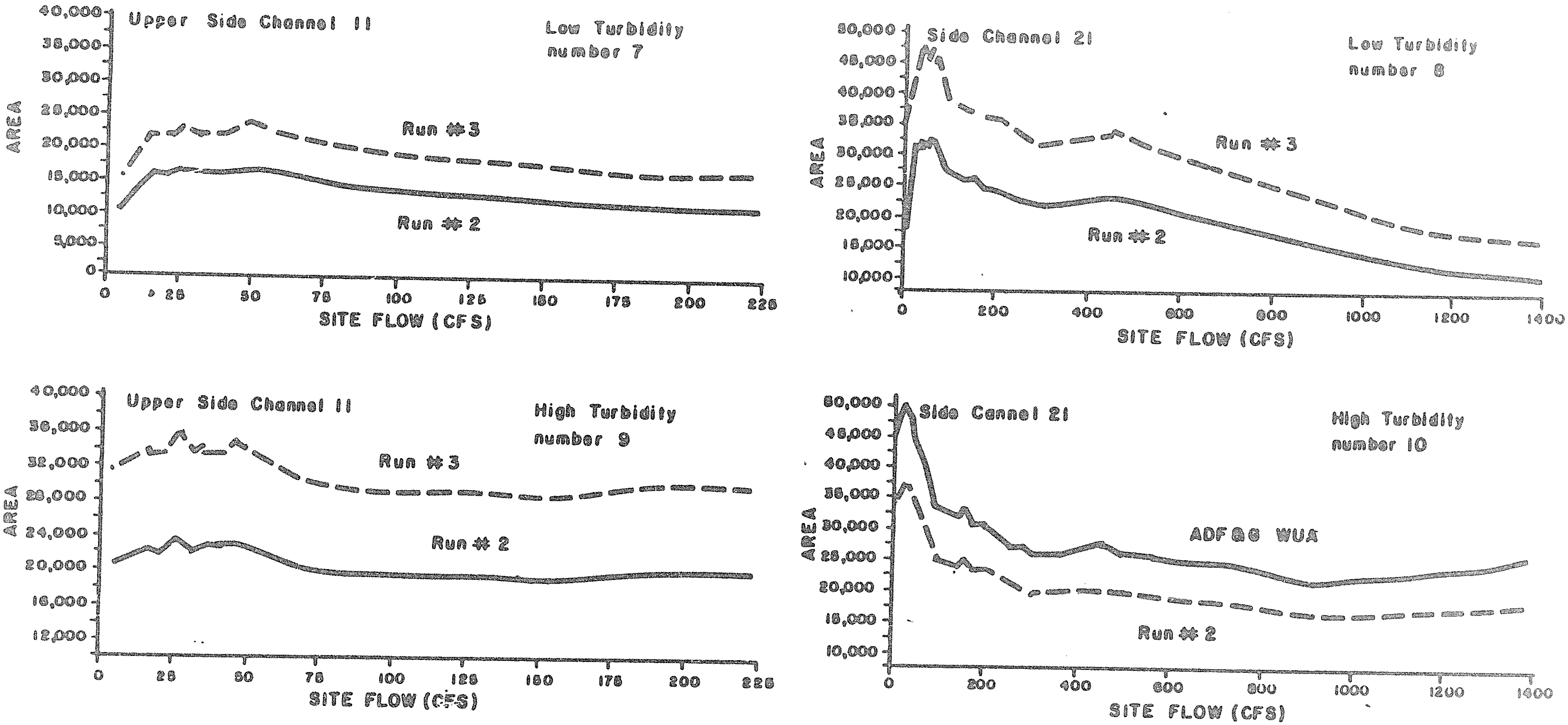


FIGURE V-21. SIMULATED EFFECT OF REDUCING FINE SEDIMENT DEPOSITION AT TWO STUDY SITES.

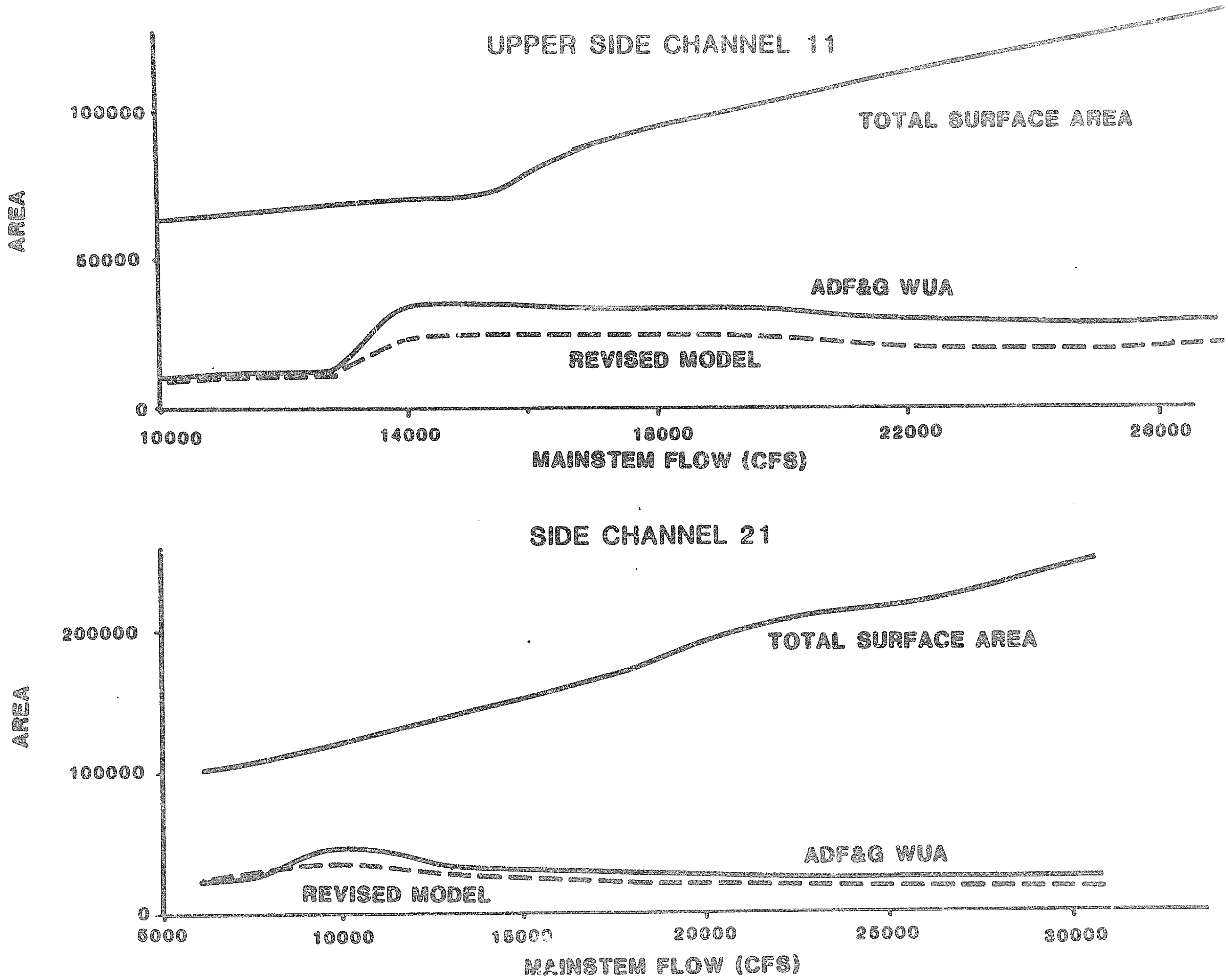


Figure V-22. Comparison between WUA forecasts using ADF&G and revised rearing habitat model.

Because chinook salmon in the middle Susitna River are capable of using naturally occurring turbidity levels as a form of cover, increases in WUA caused by breaching of a study site respond directly to an increase in wetted surface area possessing suitable velocities.

The initial increase in WUA indices depicted in Figure V-19 is attributable to the influence of turbidity on improving otherwise poor cover conditions at these sites. Subsequent increases in WUA result from increases in wetted surface area with suitable velocities for juvenile chinook. Turbidity has a lesser effect on increasing WUA indices at the Side Channel 21 site than the Upper Side Channel 11 site because less favorable velocities exist at the Side Channel 21 site. This trend for habitat Category III sites to possess less favorable rearing velocities than habitat Category I or II sites is suspected to be widespread in the middle Susitna River.

The relationship between weighted usable area and wetted surface area is plotted as a flow dependent percentage in Figure V-23. At higher mainstem discharges a lesser percentage of the total wetted surface area is available as rearing habitat. This is attributable to wetted areas with suitable velocities for rearing fish becoming available at a lesser rate that increases in wetted surface area; a common occurrence in steep gradient channels. The most efficient use of streamflow to provide rearing habitat occurs at lower mainstem discharges where a greater percentage of the total wetted surface area is associated with suitable velocities for rearing fish.

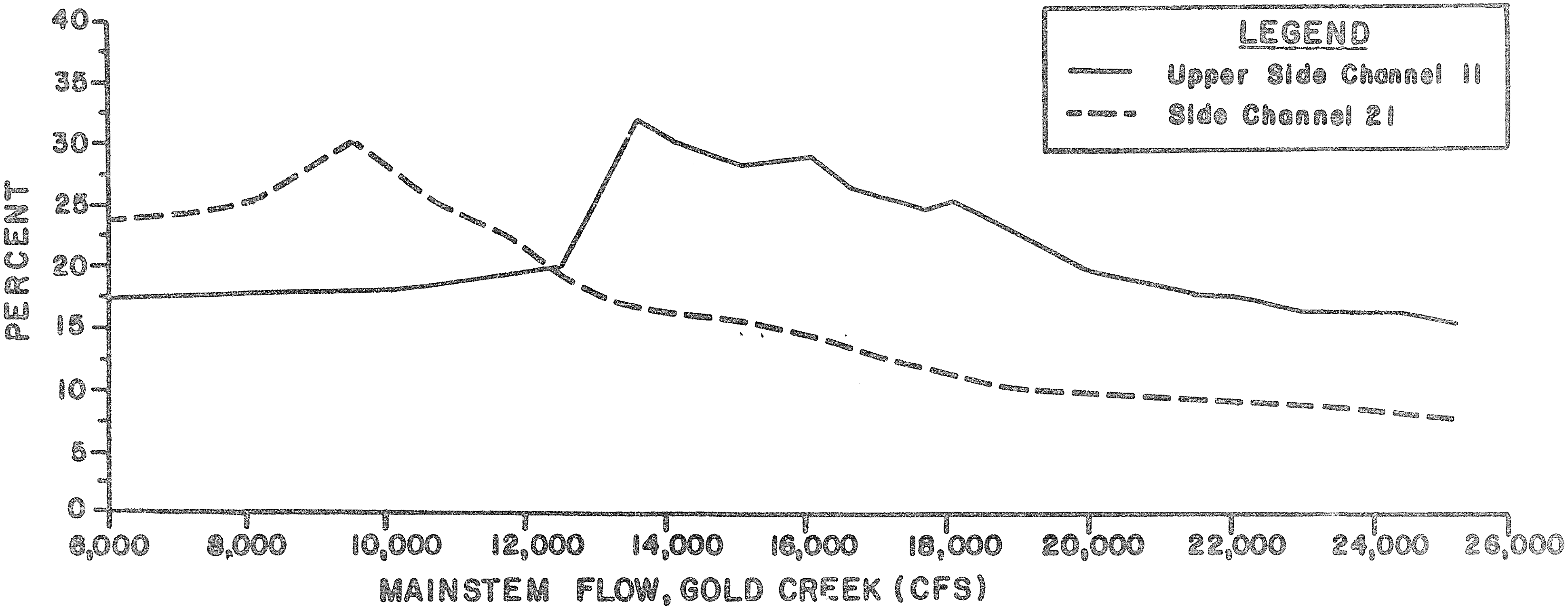


Figure V-23. Percent of total wetted surface area providing WUA for rearing chinook at Side Channel 21 and Upper Side Channel 11.

VI. INTEGRATION OF HABITAT COMPONENTS

Physical Processes Influencing Middle Susitna River Habitat Components

The primary environmental factors at the macrohabitat level which influence fish habitat in the middle Susitna River are water supply, air temperature, and channel morphology. Of these water supply and air temperature vary both seasonally and annually (AEIDC 1984b) whereas channel morphology is considered constant (R&M Consultants 1982a, AEIDC 1984a). The relationships between air temperature and water supply determine the seasonal response of middle Susitna River flow, water temperature and water quality. Annual variations in basin precipitation and climate account for year to year fluctuations in these three primary habitat components. Glaciers, which cover approximately 290 square miles of the upper Susitna Basin, as well as three large lakes in the Tyone River drainage have a moderating influence on streamflow variability during summer. Because glacial flow results in high turbidity and suspended sediment concentrations in summer, the water quality of the middle Susitna River changes markedly with the seasons.

The streamflow and thermal regime with associated water quality (turbidity and suspended sediment) characteristics are the driving variables which control the availability of habitat in the middle Susitna River . As discussed in Section IV, seasonal changes in these driving variables significantly influence the seasonal the characteristics and utility of middle Susitna River habitats. These seasonal changes in physical components of middle Susitna River habitats are also attended by seasonal changes in biological activities and habitat utilization patterns.

The climatologic, geologic, and topographic characteristics of the watershed determine the channel pattern and channel structure of the river as well as seasonal and daily variations in streamflow, stream temperature and water quality. Among the many watershed characteristics affecting these three driving variables, air temperature and water supply are most important. Air temperature regulates seasonal changes in streamflow patterns; precipitation governs its variability. Streamflow, stream temperature, and water quality either directly or indirectly control the seasonal availability and quality of fish habitat in the middle Susitna River.

Of the three, streamflow is most important because it is directly related in varying degrees to all physical processes influencing fish habitat in the middle Susitna River. High streamflows reshape channel geometry, which at lower discharge levels controls site specific hydraulic conditions. Summer streamflows transport large amounts of suspended sediment, which cause high turbidities and generally degrade water quality. The relatively poor quality of mainstem and side channel habitat in summer is caused by high suspended sediment concentrations. The suspended sediment load is considered limiting to the colonization of streambed materials by algae and aquatic insects which generally provide an important food source for fish.

Streamflows and stream temperatures during winter play an integral role in middle Susitna River ice processes, which directly affect channel structure, shoreline stability and the general quality of winter fish habitat. River ice affects instream hydraulic conditions; most notably constricting the channel, reducing velocity and increasing river stage (Harza-Ebasco 1984c). This increase in water surface elevation during winter has both positive and negative effects on fish habitat. Higher water surface elevations during winter appear important for raising local groundwater tables within the river corridor thereby maintaining upwellings in slough and side channel areas throughout winter (R&M Consultants 1982d, Harza-Ebasco 1984d). These upwellings provide a source of relatively warm water (2-3°C) throughout winter (Trihey 1982, ADF&G 1983) essential for the successful incubation of salmon eggs and that can also be used by overwintering fish. However, if river stage increases above the streambed elevation at the upstream end of the slough or side channel then near 0°C water from the mainstem will flow through these channels greatly reducing the thermal effect of upwelling areas and their value as winter habitat (ADF&G 1983).

Seasonal Habitat Utilization

Mainstem and side channel habitats are predominantly used as migrational corridors by adult and juvenile salmon. Adult inmigration begins in late May and extends to mid-September. Juvenile outmigration occurs May through July. A limited amount of chum salmon spawning occurs at upwelling areas along shoreline margins in these habitats (ADF&G 1984a) and chinook juveniles use low-velocity areas for rearing (ADF&G 1984c).

Side slough habitats provide important spawning, rearing, and overwintering habitat. One prominent physical feature of this habitat is upwelling groundwater, which maintains clearwater flow in these habitats during periods of low mainstem discharge. Approximately half of the chum salmon (5,000) and all of the sockeye salmon (1,500) that spawn in the middle Susitna River depend upon side slough habitats (ADF&G 1984a). Most chum and sockeye spawning activity occurs between mid-August and mid-September. Upwelling attracts spawning salmon and provides good incubation conditions, which result in high survival rates (ADF&G 1984c). Fry begin to emerge in late April and rear near these natal spawning areas until June (ADF&G 1984c). Chum fry outmigrate in June and early July to marine habitats while sockeye juveniles generally move into accessible upland slough habitats to rear. Juvenile chinook follow spawning salmon into side slough habitats in August and overwinter near upwelling areas until late spring when they begin their outmigration to marine habitats.

Upland sloughs provide rearing and overwintering habitats for juvenile sockeye, coho and chinook salmon (ADF&G 1984c). Some spawning by chum salmon also occurs in this habitat but it is fairly restricted (ADF&G 1984a). Sockeye fry rear in upland slough habitats throughout the summer but apparently leave the middle Susitna River prior freezeup (ADF&G 1984c).

Tributary mouth habitats provide important areas for spawning, rearing and overwintering. Pink, chum, and chinook salmon have been observed spawning in tributary mouth habitats in mid-August (ADF&G 1984a). Juvenile chinook and coho salmon occupy these habitats for both rearing and overwintering (ADF&G 1984c).

Evaluation Periods and Species

Both the biological activities and the physical processes vary seasonally. In order to integrate the physical processes and biological activities to evaluate seasonal changes in habitat we divided the year into four segments. The four segments were established on the basis of timing of the four principal life stages of the freshwater residency of salmon: Spawning, incubation, overwintering, and summer rearing. (Figure VI-1). Although these periods overlap, the habitats occupied by overlapping life stages and the physical requirements differ sufficiently to warrant separate analysis. To facilitate the analysis of the effects of streamflow on habitat, the biological activities were defined in water weeks (Table VI-1). Water weeks begin October 1 and consist of 51 consecutive 7-day periods. The fifty-second week (September 23-30) contains eight days and February 29 is omitted.

Table VI-1. Simplified periodicity chart.

Species	Life stage	Activity period	Water Weeks
Chum	Spawning	August 12 to September 15	45 through 50
Chum	Incubation	August 12 to March 24	46 through 25
Chinook	Overwintering	September 16 to May 19	51 through 33
Chinook	Summer rearing	May 20 to September 15	34 through 50

Seasonal habitat requirements are species and life stage specific. Evaluation species have been selected on the basis of their importance to commercial and sport fisheries and potential impacts project construction and operation might have on their habitats (APA 1983). The primary evaluation species and life stages for natural conditions are chum salmon spawning and incubation, and juvenile chinook salmon

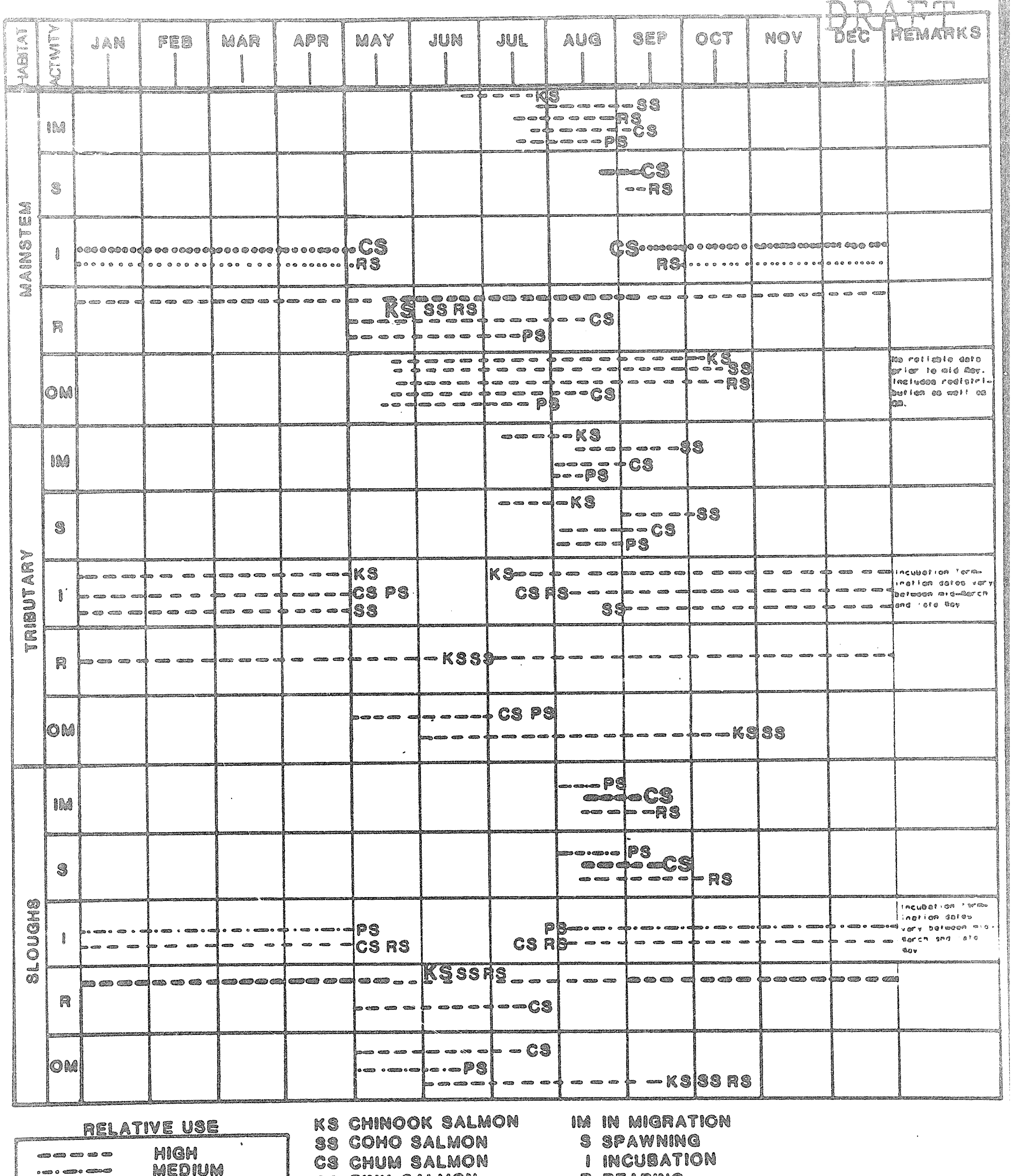


FIGURE VI-1. PHENOLOGY AND HABITAT UTILIZATION OF MIDDLE SUSITNA RIVER SALMON IN MAINSTEM, TRIBUTARY, AND SLOUGH HABITATS.

ADAPTED FROM AEIDC 1984c

rearing (Woodward-Clyde 1984). These species and life stages were selected because they greatly depend on slough and side channel habitats that will be significantly alter by project operation.

Influence of Physical Habitat Components

Spawning and incubation are associated with fixed boundary habitat conditions, while rearing and overwintering generally occur under variable boundary conditions. Fixed boundary conditions are more closely associated with localized structural features of the channel like substrate or upwelling, whereas variable boundary habitats are more strongly influenced by transient hydraulic conditions within the channel, such as depth, velocity and turbidity. Both the quality and location of variable boundary habitats respond to changes in streamflow; only the quality of fixed boundary habitats respond.

Availability of spawning and incubation habitat appears quite limited throughout the middle Susitna River. The presence of upwelling water is the most important microhabitat variable influencing the selection of spawning areas by chum salmon and it significantly affects egg-to-fry survival rates(ADF&G 1984c, 1984b). Table VI-2, Parts A and B summarize the influences of existing physical habitat components on spawning and incubation in each habitat type.

Use of mainstem habitats by spawning chum salmon is limited by several factors. Velocities between 5 and 9 fps (Harza-Ebasco 1984e) preclude spawning in many mainstem areas and substrates are generally large and well-cemented with silts and sands (R&M Consultants 1982e, ADF&G 1983b). Upwelling areas within side channels are used by spawning salmon but to a limited degree. Side channel habitats generally have low quality substrate and are also limited by velocity except in isolated locations along streambank margins. During the spawning season mainstem discharge is usually adequate to provide adult spawners access to upwelling areas in side channel habitats (Harza-Ebasco 1984f, Klinger and Trihey 1984). Exclusive of the major clearwater tributaries, spawning most frequently occurs in side slough

Table VI-2. Evaluation of the relative degree[1] of influence physical habitat components exert on the suitability of middle Susitna River habitat types.

Habitat Parameters*	Mainstem	Side Channel	Side Slough	Upland Slough	Tributary Mouth
PART A			Spawning (August 12 - September 15)		
Mainstem flow	-3	-2	+2	0	-1
Upwelling	+3	+3	+3	+3	+3
Substrate composition	-3	-2	+1	-2	+2
Suspended sediment	-1	-1	0	0	0
Turbidity	0	0	0	0	0
Water Chemistry	0	0	0	0	0
Water Temperature	0	0	0	0	0
Index value	-4	-2	+6	+1	+4
PART B			Incubation (August 12 - March 24)		
Mainstem flow	-3	-2	+2	0	-1
Upwelling	+1	+2	+3	+3	+2
Substrate composition	-1	-1	+1	-1	+1
Suspended sediment	-1	-1	0	0	0
Turbidity	0	0	0	0	0
Water chemistry	0	0	0	0	0
Water temperature	-3	-3	+2	+2	-2
Ice processes	-2	-2	-1	0	-2
Index value	-9	-7	+7	+4	-2
PART C			Overwintering (September 16 - May 19)		
Mainstem flow	-2	-3	+2	+2	+1
Upwelling	+1	+1	+3	+2	+1
Substrate composition	-2	-2	+2	-1	+2
Suspended sediment	0	0	0	0	0
Turbidity	0	0	0	0	0
Food availability	0	0	0	0	0
Water chemistry	0	0	0	0	0
Water temperature	-2	-2	+2	+2	+1
Ice processes	-2	-3	-1	0	-2
Index value	-7	-9	+8	+5	+3
PART D			Summer Rearing (May 20 - September 15)		
Mainstem flow	-3	-2	+2	+3	-2
Upwelling	0	+1	+2	+2	+1
Substrate composition	-2	-2	+2	+1	+2
Suspended sediment	-3	-2	-1	0	0
Turbidity	+1	+1	+1	+2	+2
Food availability	-2	-2	+2	+2	+3
Water chemistry	0	0	0	0	0
Water temperature	0	0	-1	0	0
Index value	-9	-6	+7	+10	+6

1 Evaluation scale
- +3 extremely beneficial
- +2 moderately beneficial
- +1 slightly beneficial
- 0 no effect
- -1 slightly detrimental
- -2 moderately detrimental
- -3 extremely detrimental

* Typical conditions for the habitat type during the season evaluated.

habitats where upwelling is prevalent and other physical habitat conditions are suitable (ADF&G a and d). Seldom in side slough habitats does velocity or substrate composition limit spawning conditions. Often, however, side slough habitats are limited by depth. Passage problems exclude spawning salmon from using upstream reaches and shallow depths reduce the quality of accessible upwelling areas. Breaching flows, which appear to be important for passage and the short term improvement of spawning conditions, frequently occur in side sloughs (Section V).

Both incubation and overwintering conditions are adversely influenced by naturally occurring cold water temperatures, winter ice conditions and low streamflows (Table VI-2, Part B and Part C). Due to the presence of upwelling groundwater throughout winter (Trihey 1982, ADF&G 1983a), incubation conditions in slough habitats are generally favorable and result in high egg-to-fry survival rates; up to 35 percent in 1983-1984 (ADF&G 1984b). Many sloughs have ice-free areas but ice covers do form over deeper pools and at the slough mouths. Overwinter conditions in sloughs are relatively good. Pool habitats generally provide adequate depth, water temperatures are warm, and small fish can occupy interstitial spaces between the larger substrate materials.

At times sloughs are overtopped by mainstem flows during winter. These overtopping events are caused by ice cover formation (see Section IV). The influx of cold mainstem water into side slough habitats reduces intragravel water temperatures and adversely affects incubation rates and embryo growth. Overtopping events also adversely affect overwintering habitat as water temperatures drop to near zero. Anchor ice may form on the streambed freezing embryos and small fish. Such overtopping events do not appear to be common under natural conditions at the most productive slough habitats.

The influence of cold water temperatures is most adverse in mainstem and side channel habitats where near 0°C water temperatures exist for approximately seven months. In addition, a thick ice cover (4-6 ft) forms over these habitats during winter (R&M Consultants 1983). Although a thick ice cover can serve to insulate the underlying streambed from subfreezing air temperatures, its formation and break-up also appear to have substantial detrimental effects.

Shorefast and slush ice form along channel margins freezing the streambed and filling the low-velocity areas where fish might over-winter with ice. Upwelling exists in mainstem and side channel areas but its thermal value is significantly reduced due to the large volume of 0°C water in these channels. Velocities in much of the mainstem are excessive for overwintering habitat since fish would have to expend energy to maintain position. Portions of mainstem and side channel habitats possessing large bed elements that would provide velocity barriers generally have interstitial spaces filled with densely packed glacial sand; thereby preventing small fish from burrowing into the streambed.

Summer rearing habitat for chinook juveniles is found in tributary and tributary mouth habitats, side channels and side sloughs. Most rearing fish were captured in tributary habitats; side channels had the next highest abundance (ADF&G 1984c). Much of the main channel and large side channels contain areas with high velocities and high suspended sediments not suitable for small fish (Table VI-2, Part D). Although turbidity is used by juvenile chinook for cover, high turbidity also limits light penetration and reduces primary production levels in these habitats. Low primary production results in a low aquatic food base for rearing fish. Thus turbidity has both beneficial and detrimental effects on rearing habitat. Side channel habitats that fluctuate between clear and turbid in response to streamflow variations or that have a clearwater input would appear to provide better rearing habitats than areas that remain turbid throughout summer. While the area is clear, primary production rates would be high, stimulating production of benthic prey items. Under turbid conditions, the young chinook could move into these areas and feed without unduly exposing themselves to predation. However, if rearing areas remain turbid continuously, aquatic food production would likely be poor. Turbid areas with clear water inflow would also provide good rearing habitat. Food predation occurring in clearwater areas would be transported into turbid side channels with better cover.

Substrate in many mainstem and side channels has glacial fines filling interstitial spaces reducing cover value of large substrate. Stream temperature is generally positively correlated with growth. Surface water temperatures in mainstem and side channel habitats are typically warmer than those in slough and tributary habitats during much of the summer.

Rearing areas in mainstem and side channel habitats are located in low-velocity areas along the lateral margins, in backwater areas, or behind velocity barriers. Depths less than 2 ft are most commonly associated with mild-gradient shorelines. In these areas, streamflow fluctuations can cause large changes in wetted area. Low-velocity area generally increases as discharge decreases.

In contrast to mainstem and side channel habitats, clearwater habitats such as side sloughs and upland sloughs provide a much better food base and physical environment for juvenile fish if sufficient cover is present. Although their water temperatures in most of the channel are generally cooler (10°C) than would exist under ideal conditions (12-14°C) they are quite suitable. Unless the slough is overtopped and conveying a large amount of mainstem water, velocities in most of the channel are generally within the tolerance range for juvenile fish.

Given natural streamflow, stream temperature, and water quality conditions, the most stressful period for fish within the middle Susitna River appears to occur during winter (Table VI-3). High streamflows, suspended sediment concentrations and turbidities during summer appear to have a significant adverse influence on mainstem and side channel habitats when compared to adjacent clearwater habitats. The limited amount (surface area) of spawning habitat that exists in five side sloughs (21, 11, 9, 9A and 8A) accounts for approximately 95

Table VI-3. Tabulation of habitat and evaluation period indices for the middle Susitna River.

Period	Mainstem	Side Channel	Side Slough	Upland Slough	Tributary Mouth	Evaluation Period Index
Spawning	-4	-2	+6	+1	+4	+5
Incubation	-9	-7	+7	+4	-2	-7
Overwintering	-7	-9	+8	+5	+3	-16
Summer Rearing	-9	-6	+7	+10	+6	+8
Habitat Index	-29	-24	+28	+20	+13	

percent of the sockeye, and 75 percent of the chum salmon spawning in non-tributary habitats within the middle Susitna River. Therefore, improvement of incubation/overwintering conditions; reduction of high summer streamflows, suspended sediment concentrations and turbidities; and maintenance or enhancement of existing clearwater spawning habitats appear to be three reasonable goals to pursue when establishing instream flow requirements for the middle Susitna River.

Inherent Project Influences and Degrees of Control

The most notable project induced changes at the macrohabitat level will be alteration of natural streamflow, stream temperature and sediment transport regimens (Figure VI-2). These anticipated changes in turn cause changes on stream channel stability, upwelling, turbidity, and winter ice conditions. Understanding project induced changes in these habitat components and degree of control associated with project operations will provide a basis for estimating the potential habitat conditions for spawning, rearing, and overwintering in the middle Susitna River. Some changes in habitat components are inherent in construction and operation of the project. Others we can choose or influence through operation, facility design or location.

Inherent with-Project Relationships

With-project summer streamflows are expected to be approximately one half naturally occurring average monthly values whereas winter flows are estimated to increase five fold (APA 1983). Overall there will be less variability in the annual flow cycle and a marked reduction in flood peaks, resulting in more stable middle Susitna River flows. Since mid-summer streamflows will be lower and winter flows higher, a notable difference will exist regarding site specific hydraulic conditions in peripheral habitats. Many areas will be dewatered that presently convey streamflow during summer whereas the opposite trend will prevail during winter. Mid-channel areas will also experience a change in hydraulic conditions that will affect the amount and quality of fish habitat relative to present levels.

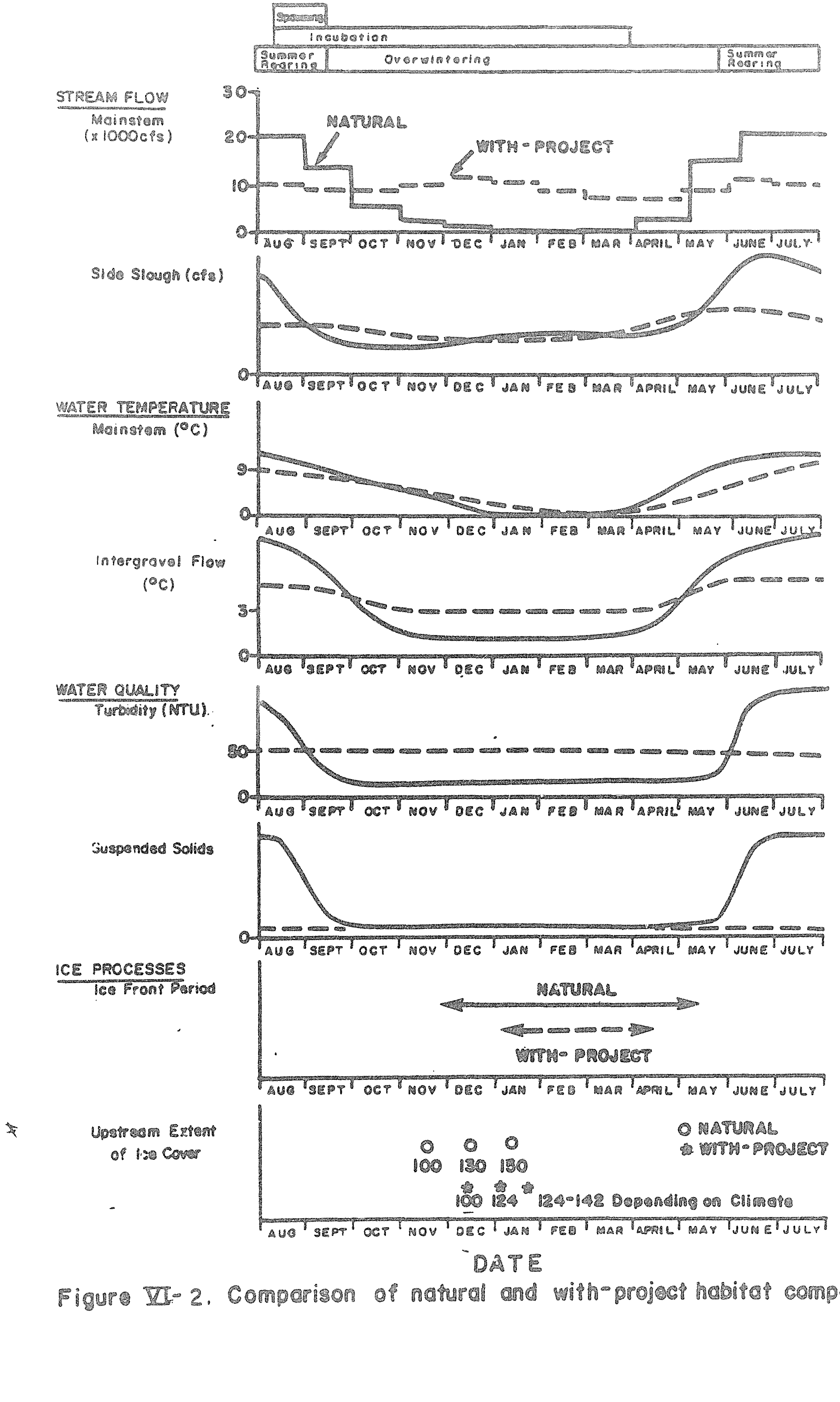


Figure VI-2. Comparison of natural and with-project habitat components.

The 8.6 million acre-foot impoundment behind the proposed Watana dam will effectively trap nearly all the sand and larger size materials currently being transported downstream from upstream sources (R&M 1982f, Harza-Ebasco 1984a).

In addition, the time required for water from the Susitna Glacier to reach Talkeetna will be greatly increased. Detention time for Watana Reservoir is estimated to be 1.6 years (APA 1983), thus downstream water quality will be affected by limnological processes occurring in the reservoirs. It is hypothesized, for example, that the Watana reservoir will contain turbid glacier melt water throughout the year. Hence downstream flows are expected to change from highly turbid in summer and clear in winter to moderately turbid all year (Peratovich et al. 1982).

Downstream temperature is also expected to be altered by the large impoundments. The reservoirs will attenuate existing mid-summer stream temperatures and store solar energy during summer for redistribution during fall and winter months. This will promote warmer stream temperatures in the fall probably delay freeze-up (AEIDC 1984b, Harza-Ebasco 1984c).

Anticipated instream water quality and temperature are important to flow negotiations in that with-projects conditions may either alter or provide mitigative opportunities being considered. Although it is necessary to evaluate the influence of project design and operation on with-project water quality and temperature conditions, it must be recognized that certain unavoidable conditions (project effects) may exist over which project design and operation has limited control.

However, in many situations design and operation of the proposed Susitna project will afford varying degrees of control over the streamflow, stream temperatures and water quality of the middle Susitna River. The degree of control that might exist over these macrohabitat conditions will in turn influence other important habitat components at the microhabitat level (Figure VI-3).

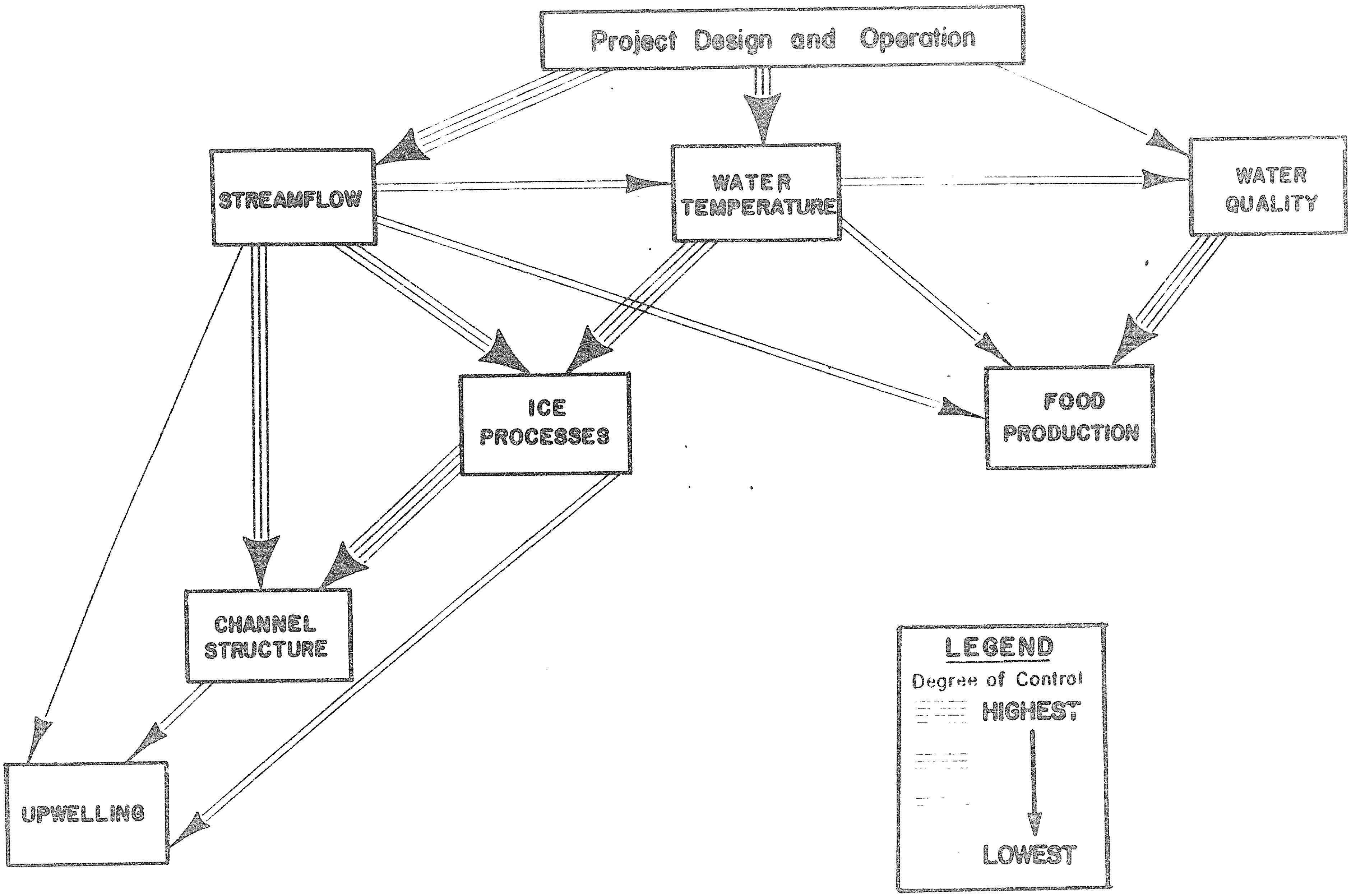


Figure VI-3. Ranking of habitat component in accord with the degree of control project design and operation might provide them.

Control over with-Project Relationships

The degree of control that project design and operation can exert over macrohabitat conditions in the middle Susitna River is strongly influenced by basic laws of physics governing energy transfer and the seasonal changes in air temperature. The influence of mainstem discharge, temperature and water quality on middle Susitna River fish habitat is also highly dependent upon the location of affected habitats with respect to the dam site(s) and the mainstem channel. The further downstream from the project, the less influence project operation has on streamflow (Harza-Ebasco 1984f); stream temperature (AEIDC 1984b); and presumably, water quality. It is also evident that aquatic habitats peripheral to the mainstem are most sensitive to dewatering by variations in mainstem discharge (EWT&A 1984, ADF&G 1984d) whereas habitats directly associated with the mainstem are most significantly influenced by variations in mainstem temperature and water quality (ADF&G 1982b).

Therefore the nature and degree of change that may be intentionally caused by project design and operation is bounded by watershed characteristics and physical laws of science as well as project economics. Some unavoidable effects of project construction may be beneficial to middle Susitna River fish habitats. Most notably is the entrapment of nearly all suspended sediment currently being transported by the middle Susitna River. Reduction in mid-summer suspended sediment concentrations is expected to result in more hospitable habitat conditions for invertebrates and immature fish that typically inhabit streambed materials. Associated with the reduction in suspended sediments, will likely be a reduction in mid-summer turbidities, which may improve the depth of light penetration and stimulate algal growth on a more stable and coarse graded streambed.

Mainstem turbidities are also expected to remain higher than natural throughout winter. At present it is not known whether project design or operation could significantly control downstream turbidities. Nor has the effect of the project induced change in natural turbidity levels been estimated. However, overwintering fish are thought to primarily use low velocity lateral habitats, such as sloughs, slough mouths or tributary mouths. It is likely that the high winter flows will increase upwelling and thus may increase the amount of clear-water, low velocity habitat in the winter. The actual gain in habitat, if any, would depend on the upstream extent of the ice fronts and the effects of staging on slough habitats.

With-project stream temperatures are expected to be cooler in summer and warmer in winter. Project design and operation can exert a moderate degree of control over middle Susitna River temperatures (AEIDC 1984). The most important season in which to evaluate the degree of control project design and operation has over middle Susitna River temperatures is winter. Cold stream temperatures and associated ice processes appear to be the habitat component most limiting existing fish populations (Table VI-2). Hence the increase of stream temperatures throughout winter would likely result in improved overwintering conditions in mainstem and side channel habitats. Surface and groundwater temperatures in slough habitats may also increase slightly. Were mainstem and side channel temperatures sufficient to prevent formation of an ice cover, it is expected that terrestrial vegetation would stabilize along shorelines and partially vegetated gravel bars. This change would likely improve summer rearing conditions due to greater availability of terrestrial insects and shoreline cover.

Lack of winter ice cover would also greatly reduce the adverse effects currently associated with the naturally occurring overtopping of side slough spawning habitats. Lack of an ice cover would reduce staging and therefore the frequency at which side slough habitats are overtopped. In addition those channels which convey water warmer than 0°C may provide improved overwintering and incubation conditions. Project operation can provide a high degree of control over streamflow in the middle Susitna River (Harza-Ebasco 1984f). Summer flow could be regulated to provide relatively stable depths and velocities or intentionally fluctuated to flush undesirable sediment from the streambed. Streamflow fluctuations during fall could assist adult salmon gain access to side slough spawning habitats (ADF&G 1984e, WCC 1984 Mitigation). During winter, higher than natural, but stable, streamflows would likely improve overwintering conditions in mainstem and side channel habitats. However, the inflow of colder mainstem water could adversely affect incubation and overwintering conditions in side slough habitats if mainstem water surface elevations associated with higher winter streamflows were sufficient to cause recurrent mid-winter breaching events.

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ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

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