SUSITNA HYDROELECTRIC PROJECT

FEDERAL ENERGY REGULATORY COMMISSION
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FISH MITIGATION PLAN

WOODWARD-CLYDE
CONSULTANTS

UNDER CONTRACT TO

HARZA-EBASCO
SUSITNA JOINT VENTURE

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FISH MITIGATION PLAN

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Under Contract to
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NOTICE

ANY QUESTIONS OR COMMENTS CONCERNING
THIS REPORT SHOULD BE DIRECTED TO
THE ALASKA POWER AUTHORITY
SUSITNA PROJECT OFFICE

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EXECUTIVE SUMMARY

The approach and the process that will be followed to develop an acceptable mitigation plan for potential impacts of the proposed Susitna Hydroelectric Project are outlined. The goal of the Alaska Power Authority for the project fisheries mitigation is to maintain existing habitat or provide replacement habitat of sufficient quantity and quality to support the productivity of naturally reproducing populations (APA 1983). Two mitigation approaches are proposed to achieve this goal 1) modifications to design, construction or operation of the project; and 2) resource management strategies. The first approach is project specific and emphasizes the avoidance or minimization of adverse impacts. The second approach would employ measures to rectify, reduce or compensate for impacts that cannot be mitigated by the first approach. These approaches are applied to two geographical areas that are expected to be impacted by the project: downstream of the project and the impoundment zone.

Three mitigation options, flow release, habitat modification and artificial propagation are proposed for downstream impacts. These options are directed at impacts to chum and sockeye spawning habitat in sloughs and side channels in the Talkeetna to Devil Canyon reach of the middle Susitna River. A summary discussion is provided on the first option, flow release, as the primary means of mitigating for impacts on chinook juvenile rearing.

Flow releases designed to minimize impacts to chinook juvenile rearing (Case EVI), minimize impacts to chum spawning (Case C), and minimize impacts to both chinook rearing and chum spawning (Case EV), are analyzed for their mitigative potential for chum and sockeye spawning habitat in sloughs and side channels. A qualitative discussion of flow release as the primary option for mitigating impacts to chinook juvenile rearing habitat is presented. The flow releases evaluated partially mitigated for losses of spawning habitat in sloughs and side channels. Habitat modification is proposed to rectify residual impacts.

Habitat modification techniques used in stream enhancement projects in Alaska, Canada and Washington State are evaluated and those with the greatest likelihood of success are applied to seven sloughs and side channels in the middle Susitna River. The modification techniques selected and associated costs for each slough are summarized in Table 1. Artificial propagation in the form of streamside egg boxes is proposed as a mitigation option should higher priority options prove ineffective.

Monitoring studies are proposed to (1) monitor salmon population and production levels to ensure that the predicted level of impact is not being exceeded and (2) evaluate the effectiveness of the project mitigation plan.

In the impoundment area, Arctic grayling is selected as the evaluation species for mitigation because of its abundance in the area, its sensitivity to impacts during all seasons and life stages, and its desirability as a sport fish. Measures to avoid, minimize, rectify or reduce the anticipated loss of spawning and Arctic grayling habitats are considered infeasible (APA 1983). Therefore, measures to compensate for the loss of Arctic grayling habitat are the options considered for impoundment mitigation planning.

1 - INTRODUCTION

1.1 - Approach to Mitigation

The Alaska Power Authority's (APA) goal for Susitna Hydroelectric Project fisheries mitigation is to maintain the productivity of natural reproducing populations (APA 1982). This is consistent with the 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). The APA plans to either maintain existing habitat or provide replacement habitat of sufficient quantity and quality to support this productivity. Where it is not feasible to achieve this goal, APA will compensate for the impact with propagation facilities.

The development of the fish mitigation plan will follow a logical step-by-step process. Figure 1 illustrates this process and identifies the major components (APA 1983). The options proposed to mitigate for impacts of the Susitna Hydroelectric Project will be analyzed according to the hierarchical scheme shown in Figure 2.

Mitigation options proposed are grouped into two broad categories based on different approaches:

- Modifications to design, construction, or operation of the project

- Resource management strategies

The first approach is project specific and emphasizes measures that avoid or minimize adverse impacts according to the Fish and Wildlife Mitigation Policy established by the APA (1982) and coordinating agencies (ADF&G 1982a, USFWS 1981). These measures involve adjusting or adding project features during design and planning so that mitigation becomes a built-in component of project actions.

If impacts cannot be mitigated by the first approach, rectification, reduction or compensation measures will be implemented. This type of mitigation will involve management of the resource rather than adjustments to the project, and will require concurrence of resource management boards or agencies with jurisdiction over resources within the project area.

Mitigation planning for the Susitna Hydroelectric Project has emphasized both approaches. The sequence of option analysis from avoidance through compensation has been applied to each impact issue. If full mitigation can be achieved at a high priority option, lower options may not be considered. In the development of mitigation plans, measures to avoid, minimize, or rectify potential impacts are treated in greatest detail.

Monitoring and maintenance of mitigation features to reduce impacts over time are recognized as integral parts of the mitigation process. The monitoring program is being developed and will be applied to fishery resources and their habitat.

1.2 - Scope

This report presents analyses of mitigation options that can be used in developing an acceptable mitigation plan for impacts resulting from the proposed Susitna Hydroelectric Project. Options are presented for impacts on fish resources and habitats in two areas affected by the project; 1) downstream of proposed dams and 2) the impoundment zone.

Downstream of the proposed project, impacts and mitigation measures for chum and sockeye salmon spawning habitat are evaluated. Several sloughs were selected for detailed analysis in this report; however, the analyses are applicable to other sloughs and side channels in the middle Susitna River where physical impacts are expected to be similar. The selected sites (Sloughs 8A, 9, 9A, 11, 21, Upper Side Channel 11, and Side Channel 21) were the ones most heavily used during the 1981-1983 study period (Barrett et al. 1984). Downstream impacts to chinook salmon rearing and associated mitigation options are qualitatively discussed. As quantified habitat-flow relationships become available for juvenile salmon rearing in 1985, detailed mitigation option analyses will be undertaken.

This report presents alternative project flow regimes as the primary mitigative alternative for chinook juveniles and the partial mitigation for chum spawning. Additional chum salmon spawning mitigation follows one of the following strategies: (1) structural modification to presently utilized side sloughs to maintain production spawning habitat and (2) artificial propagation with stream-side egg boxes to compensate for losses. As stated in the License Application (APA 1983), mitigation can be achieved with either strategy. Final decisions on the strategy to be implemented will be made through discussions with resource managers.

Preliminary mitigation options for impacts to Arctic grayling habitat in the impoundment zone are also presented. An expanded version of mitigation approaches for this area will be prepared in 1985. The mitigation plans for other species/life stages, other project areas, and the applicability of proposed mitigation plans to other phases of the project are subjects of upcoming reports.

1.3 - Selection of Evaluation Species

All three mitigation policies (APA, ADF&G and USFWS) imply that project impacts on the habitats of certain sensitive fish species will be of greater concern than changes in distribution and abundance of less sensitive species. Sensitivity can be related to high human use value as well as susceptibility to change because of project impacts. Statewide policies and management approaches of resource agencies suggest that concern for fish and wildlife species with commercial, subsistence, and other consumptive uses is greater than for species without such value. These species are often numerous, and utilize a wide range of habitats, as well as having high human use value. Such characteristics often result in these species being selected for careful evaluation when their habitats are subjected to alternative uses. By avoiding or minimizing alterations to habitats utilized by these evaluation species, the impacts to other less sensitive species that utilize similar habitats may also be avoided or reduced.

The evaluation species were selected after initial baseline studies and impact assessments had identified the important species and potential impacts on available habitats throughout the year. Mitigation plans were then developed that will reduce impacts on habitat parameters that are expected to control populations of these species.

Based on the aquatic studies baseline reports, impact assessments, and harvest contributions, five species of Pacific salmon (chum, sockeye, chinook, coho, and pink) were identified as evaluation species for the Susitna River downstream from Devil Canyon (APA 1983).

Since the greatest changes in downstream habitats are expected in the reach between Devil Canyon and Talkeetna, fish using that portion of the river were considered to be the most sensitive to project effects. Because of differences in their seasonal habitat requirements, not all salmon species would be equally affected by the proposed project. Of the five species, chum and sockeye salmon appear to be the most vulnerable in this reach, because of their dependence on slough habitats for spawning, incubation and early rearing. Of these two, chum salmon are the dominant species. Chinook and coho salmon are less likely to be impacted by the project because two critical life stages, spawning and incubation, occur in habitats that are not likely to be altered by the project. While some pink salmon spawn in slough habitats in the reach between Devil Canyon and Talkeetna, most of these fish utilize tributary habitats. The mitigation measures proposed to maintain chum salmon productivity should allow sockeye and pink salmon to be maintained as well. The chinook juveniles rear in the river up to two years and coho salmon juveniles up to 3 years prior to out-migration. Much of the coho rearing apparently occurs in clear water areas, such as in sloughs and tributary mouths, with chinook rearing in turbid side channels as well as clear water areas. Replacement habitat that may become available in the mainstem under project flows and the effect of the potential loss of rearing areas in sloughs is the subject of ongoing studies.

The greatest change to resident fish will occur in the impoundment zone. In the impoundment zone, Arctic grayling were selected as the evaluation species because of their abundance in the area, their sensitivity to impacts during all seasons and life stages, and their desirability as a sport fish.

In summary, the evaluation species and life stages selected for the Susitna Hydroelectric Project are:

(A) <u>Devil Canyon to Cook Inlet Reach</u>

PRIMARY

<u>Chum Salmon</u>

- Spawning adults
- Embryos and pre-emergent fry

<u>Chinook Salmon</u>

- Rearing juveniles

SECONDARY

<u>Chum Salmon</u>

- Emergent fry
- Returning adults
- Out-migrant juveniles

<u>Chinook Salmon</u>

- Emergent fry
- Returning adults
- Out-migrant juveniles

Sockeye Salmon

- Spawning adults
- Embryos and pre-emergent fry
- Emergent fry
- Rearing juveniles
- Returning adults
- Out-migrant juveniles

Coho Salmon

- Emergent fry
- Rearing juveniles
- Returning adults
- Out-migrant juveniles

Pink Salmon

- Spawning adults
- Embryos and pre-emergent fry
- Emergent fry
- Returning adults
- Out-migrant juveniles

(B) Impoundment Zone

Arctic Grayling

- Spawning adults
- Incubating embryos
- Rearing
- Overwintering

1.4 - Overview of Selected Evaluation Species in the Middle Susitna River

Fishery 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. The Talkeetna-Devil

Canyon sub-basin provides habitat for annual escapements of approximately 24,100 chum; 9,500 chinook; 2,200 coho; 54,800 even-year pink; 4,400 odd-year pink; and 2,800 sockeye (Table 2).

Most chum salmon above RM 98.6 spawn in either sloughs or tributaries (ADF&G 1981, 1982a; Barrett et al. 1984). About 93 percent of the 10,570 chum salmon counted during peak index surveys were observed in tributaries or sloughs; the remaining 7 percent were observed at mainstem spawning sites (Table 3). In 1983, chum salmon peak index counts in tributaries and sloughs were about equal, while in 1982 and 1981, counts were higher in sloughs (Table 3). Chum salmon peak index counts in middle Susitna River sloughs are presented in Table 4. Eleven of the 33 sloughs surveyed in all three years supported chum salmon spawning in each year. Four of the eleven, Sloughs 8A, 9, 11 and 21, averaged over 200 fish annually for the three years and accounted for about two-thirds of the total chum salmon counted in sloughs. Eighteen chum salmon mainstem spawning sites were identified during 1981-1983 surveys; seven sites were used in two or more of the three years (Barrett et al. 1984). The peak of chum salmon spawning occurred during the last week of August in tributaries, the first week of September in sloughs, and the first two weeks of September at mainstem spawning sites in all three years (ADF&G 1981, 1982a, Barrett et al. 1984).

Juvenile chum salmon expend one to three months rearing. Most juvenile chum are distributed in side sloughs and tributaries, their natal areas. Outmigration is generally complete by mid-July (Schmidt et al. 1984).

Sockeye salmon escapements to the Susitna River system consist of two distinct runs. The first-run sockeye spawn primarily in the Talkeetna River drainage. Second-run sockeye are distributed system-wide. Most second-run sockeye salmon in the Talkeetna-Devil Canyon sub-basin spawn in slough habitat (ADF&G 1981, 1982a, Barrett et al. 1984). Approximately 99 percent of the 2,420 second-run sockeye counted during peak spawner counts were observed in sloughs. The remaining second-run sockeye salmon were in the mainstem and tributaries. One main channel spawning site (RM 138.6-138.9) was identified during the 1981-1983 surveys (ADF&G 1981, 1983, Barrett et al. 1984). Six second-run sockeye were observed in tributaries during the 1981-1983 surveys. All six, however, were considered milling fish that did not spawn in streams (ADF&G 1981, 1982a, Barrett et al. 1984). During spawning surveys in 1981-1983, second-run sockeye were observed in 17 sloughs above RM 98.6 (Table 5). Only 3 of the 17 sloughs contained significant numbers of spawning second-run sockeye in all three years. Sloughs 8A, 11 and 21 accounted for 89 percent of the total slough peak counts in 1981, 95 percent in 1982 and 92 percent in 1983 (Table 5). The peak of spawning occurred between the last week of August and the end of September in all three years (Barrett et al. 1984).

Juvenile sockeye generally rear in upland and side slough habitats. Tributaries and side channels are relatively important for rearing. Most juvenile sockeye leave the Talkeetna-Devil Canyon during their first year of life (Schmidt et al. 1984).

Most coho salmon in the Talkeetna-Devil Canyon sub-basin spawn in tributaries. During spawning ground peak surveys in 1981-1983, over 99 percent of the 1,336 coho salmon counted were observed in tributaries. Only five coho salmon were observed spawning in mainstem and slough habitats (ADF&G 1982a).

Coho juveniles generally spend one to two years rearing in freshwater. Most juveniles are distributed in tributary, upland slough, and side channel slough habitats (Schmidt et al. 1984).

Most pink salmon in the Talkeetna-Devil Canyon sub-basin spawn in tributaries (Barrett et al. 1984). Pink salmon were documented spawning in sloughs in 1981 and 1982 (ADF&G 1981, 1982a). Total slough escapement of pink salmon above RM 98.6 in 1981 was 38 fish in Slough 8 (Table 6). However use of Slough 8 may have been due to Lane Creek flowing into the slough in 1981. Lane Creek changed its course subsequent to the 1981 season and pink salmon were not observed spawning in this slough in 1982 or 1983. In 1982, total pink salmon escapement above RM 98.6 was about 297 fish in seven sloughs (Table 6). Two of the seven sloughs, 11 and 20, accounted for over 80 percent of the pink salmon total escapement in sloughs in 1982. No pink salmon were observed spawning in sloughs in 1983; fish counted in slough habitat during spawning surveys in 1983 were considered milling fish (Barrett et al. 1984). In 1981, the peak of pink salmon spawning in Slough 8 occurred about the last week of August, while in 1982 the peak of pink salmon spawning in sloughs occurred during the first three weeks of August (Barrett et al. 1984). No pink salmon were observed spawning in the mainstem of the Susitna River above RM 98.6 in 1981-1983 (Barrett et al. 1984).

After emergence, juvenile pink move almost immediately downstream to sea with little if any freshwater rearing. Few juvenile pink salmon are observed after July in the middle Susitna River (Schmidt et al. 1984).

Chinook salmon spawn exclusively in tributaries or tributary mouths above RM 98.6 (Barrett et al. 1984). No chinook spawning has been observed in any mainstem, side channel or slough areas.

One to two months after emergence, many juvenile chinook move from their natal tributaries to rearing and overwintering areas (mainstem, side channels, side sloughs, upland sloughs, and tributary mouths). Most juvenile chinook in the Talkeetna-Devil Canyon sub-basin spend one winter in freshwater before going to sea (Schmidt et al. 1984).

2 - DOWNSTREAM MITIGATION

2.1 - Mitigation Options - Historical Perspective

2.1.1 - Flow Release

Flow releases designed to meet instream flow requirements of fishery resources are mitigative measures that have recently been routinely incorporated in project operations. Historically, this was not always the case. As older projects are relicensed, flow-release restrictions are being instituted to protect downstream fish habitat. Instream flow requirements for anadromous species have generally focused on the spawning and incubation life stages as flow needs for these life stages are more easily assessed than for other stages. Minimum and target maximum flows are often required during the spawning season while minimum flows based on the spawning flow are implemented during the periods of incubation and emergence. Recently, ramping rate and amplitude restrictions have been placed in the flow release schedules of several projects to avoid stranding of fry and juveniles during flow fluctuations. A selection of rivers with anadromous fish populations and hydroelectric or flood control projects and associated flow release restrictions is presented in Table 7 to illustrate the evolution of instream flow requirements. Additional mitigation measures (e.g. hatcheries) are also indicated.

2.1.2 - Habitat Modification

On-site habitat modification as a mitigation option for hydroelectric projects has rarely been employed. Habitat modifications as enhancement projects are more commonplace, and the various techniques employed are applicable to the slough and side channel areas of the Susitna River. Examples of mitigation and/or enhancement projects in Alaska, British Columbia and Washington State are presented below.

2.1.2.1 - Alaska

(a) Chilkat River Salmon Enhancement Project

In 1983, the Northern Southeast Regional Aquaculture Association (NSRAA) completed construction of a 1,500-foot spawning channel for chum salmon near Haines, Alaska (Bachen 1984). The channel was located in the floodplain of the Klehini River above the confluence with the Chilkat River. The existing channel had supported chum spawning in previous years. In the construction process native material was excavated from the channel and sorted on site; particles in the size range of 3/4 to 3 inch were returned to the channel. Flow through the channel was supplied by 6-7°C groundwater at a rate of approximately 2.7-5.6 cfs. The channel was divided into three level sections with six-inch drops between sections. Wooden check dams placed at the lower end of each section provided adequate depth for spawning upstream.

During 1983, the first year of operation, 461 chum salmon and 117 coho salmon returned to the channel. Approximately 700 chum salmon had used the channel in previous years. The lower than average utilization may be attributed to the weak escapement in 1983. However, the estimated egg-to-fry survival the following spring was 22-24 percent, 2-3 times greater than the estimated survival in unimproved natural system (Bachen 1984). In 1984, the second year of operation, approximately 1,500 fish had returned to the channel by the end of October.

The channel was designed to accommodate as many as 3000 females assuming uniform distribution of fish at a density of one female/11 square feet.

The channel was constructed at a cost of $125,000 or approximately $37 per square yard. The only scheduled maintenance for the channel is weekly removal of carcasses during the spawning season to prevent increased oxygen demand resulting from decomposition.

Application to Susitna River Mitigation Plan. Chum salmon escapement in the second year was at least 1500 fish, approximately twice its historical use, perhaps due to a large escapement or preferential use of the channel. Increased use of the channel should occur as the first returns arrive in the fourth year of operation. If egg-to-fry survival rate of 22-24 percent (about 2-3 times the estimated survival in unimproved channels) were repeated the second year, the net result would be a 400-600 percent increase in production over historical levels. These results indicate the potential production that can be attained with appropriate habitat modification techniques.

(b) Tern Lake Enhancement Project

The U.S. Forest Service completed a spawning enhancement project on Daves Creek immediately below the outlet of Tern Lake. Prior to construction, the channel geometry and substrate in this reach of the creek provided only marginal habitat for chinook and coho salmon spawning. The channel was restructured and substrate appropriate for chinook salmon spawning added. The pool-riffle sequence was established with notched logs. Following two years of operation, increased use by spawning chinook as well as coho salmon has been reported (Ralph Browning, USFWS, pers. comm., 1984). A two year project evaluation report will be forthcoming by the end of 1984.

Application to Susitna River Mitigation Plan. The Tern Lake project is a recent development and evaluations at this point are preliminary. It does appear that it has met its general objective of providing additional spawning habitat in an area that was only marginally usable earlier; however, overall assessment of the success of the project must await the returns from these spawning areas in 1986. The use of log barriers to establish pools and riffles is a technique that is proposed for various sloughs in the Susitna River.

(c) Williwaw Creek near Portage

Construction of a salmon enhancement project by the U.S. Forest Service and Alaska Department of Transportation is currently underway at Portage Creek. A groundwater-fed spawning channel measuring approximately 3,000 feet in length and 20 feet in width has been designed principally for chum salmon but may be used by all five species of Pacific Salmon that occur in the area. In addition, 4 rearing ponds totaling five acres have been planned. Expected completion date is fall 1985.

2.1.2.2 - Canada

In the late 1970s the Canadian Department of Fisheries and Oceans initiated a program in southern British Columbia to increase chum salmon production by developing new spawning areas or improving existing ones (Lister et al. 1980a). The areas selected for enhancement were located in overflow channels generally separated from the main river except during flood conditions similar to sloughs and side channels of the middle Susitna River under project flows. The source of flow through these areas was generally groundwater.

Among the techniques used to enhance these spawning areas were to 1) provide access into the channels by removing obstructions;

2) lower the bed elevation of the channel to increase groundwater flow, depth, and area available for spawning; 3) install weirs to increase water depth and control gradient; and 4) add suitable spawning gravels where previously lacking.

Chum salmon egg-to-fry survival for seven improved channels after the first year of operation averaged 16.3 percent, approximately twice the average (7.9 percent) documented at six natural spawning areas in British Columbia. Survival at two of the sites, 33.5 and 20.7 percent, exceeded egg-to-fry survival previously reported for chum salmon under natural conditions, and compared favorably with the average (27 percent) achieved at a spawning channel with controlled flow at Big Qualicum River on Vancouver Island. Moreover, one channel that did not support a spawning population of chum salmon in the past received over 1,300 spawners in the first year of operation with a 20 percent egg-to-fry survival.

In channels where sorted gravel was added, both high and low survivals were recorded. The removal of fine material may allow for greater egg deposition; however, the overall survival may have been reduced because of facilitated access to interstitial space by predators. The advantages of sorted gravel may also have been masked by other site specific biological and physical features that affect survival such as density of spawning fish and channel characteristics that determine the gradient and groundwater flow.

Application to Susitna River Mitigation Plan. The Canadian enhancement projects demonstrated that through various habitat modification techniques the production from historical spawned areas can be improved by increasing the amount of suitable spawning habitat and thereby accommodating more spawning pairs and by attaining high egg-to-fry survival rates. As applied to the Susitna River, improvement of habitat quality in selected areas of the middle Susitna River may be used to mitigate for some spawning areas that will be lost.

2.1.2.3 - Washington State

(a) Satsop River Chum Enhancement Projects

In recent years the Washington State Department of Fisheries has undertaken instream chum enhancement projects along the Satsop River to restore chum salmon runs in this area to their historical levels (Dave King, Wash. Dept. Fisheries pers. comm., 1984). Three projects completed to date have involved modifications to old river channels that convey water only during high flow. In two of the channels the silt-sand substrate was excavated to a depth to intercept the water table and replaced with 1/4 to 3 inch leveled gravel. In the third channel, after excavation, the gravel in the channel appeared suitable for spawning and did not require replacement. The channels were graded to an approximate 2 percent gradient and, where necessary, diked off at the upper end to prevent overflow during flood periods.

Although the projects have been in operation only for 1 or 2 years, preliminary evaluations appear promising with egg-to-fry survival ranging from 38 to 78 percent. The highest survival was documented in the channel in which the native gravel was retained. This channel was only a depression before it was modified and had not been used by fish previously. Its dimensions were 7 feet by 500 feet. It received 52 fish its first year of operation. The low density (reduced likelihood of superimposition) and the protection against predation afforded by smaller gravels and sand found in the natural substrate may have contributed to the high survival rate. Dimensions of the remaining channels and densities of spawning fish were: 20 feet by 600 feet with 600 fish and 15 feet by 1,000 feet with 1,000 fish.

The Washington State costs associated with these projects were $15 per square yard for channels with replaced gravels and $11-12 per square yard without replacement. During the construction process some sand and silts were deposited over the replaced gravels and were removed with a gravel cleaning machine at cost of $2-4 per square yard.

Application to Susitna River Mitigation Plan. The Satsop River projects were patterned after the pioneering work of the Canadians in British Columbia and their application to the Susitna River are similar. The egg-to-fry survival from the Washington projects indicates the potential production that can be attained with appropriate habitat modification techniques.

(b) Baker Lake Substitute Spawning Beach

Historically, an estimated 95 percent of the sockeye salmon spawning in the Baker River, Washington system was confined to two beach spawning areas on Baker Lake. Completion of the second Baker Lake Dam resulted in the reservoir inundating the lake shore spawning beds to a depth of 60 feet. Periods of reservoir drawdown also coincided with hatching and fry emergence, with the result that any egg deposition within the elevation range of drawdown would be subject to dewatering or freezing. As a mitigation measure a substitute spawning beach was developed to perpetuate this stock of fish.

Studies done before the dam was built indicated that the spawning areas were associated with entry points of coldwater springs. At average lake levels the temperature of these springs was independent of lake temperatures and varied only a few degrees from the time fish spawned until fry emerged. However, during fall floods when the lake level rose 5 feet or more, the temperature in the spawning areas approximated lake temperature, possibly indicating cessation of flow from the springs due to hydrostatic pressure. Fall reservoir conditions (60 feet of head at the spawning areas) would be likely to effect the same changes. One of the criteria for selecting a site for development of a substitute spawning beach was based on acquiring a water supply with temperature patterns and water chemistry similar to those present in the lake shore spawning grounds. Of the tributary streams entering Baker Lake, only one possessed similar water quality while the others differed markedly. Moreover, this stream did support a small number of spawning sockeye.

Preliminary testing involved a 1,000 square feet beach in which water diverted from the selected stream provided upwelling through the area by means of a timber gridwork. Following the success of the test beach, two 15,000 square feet earthen beach ponds were added. Each accommodates approximately 1,500 adult fish. The source water is supplied through a diffusion system consisting of two, 14-inch supply mains drawing water from a diversion dam, with each main connected to 50 four-inch pipes stationed three feet apart. Water exits each set of 50 pipes through 3/16 inch holes drilled 8 inches apart. The network is covered with 1/4 to 3/4 inch gravel and supplies the entire area with upwelling water. The total flow required for the system is approximately 3.75 cfs. The head differential between the headworks of the dam and the spawning pools is about 3 feet.

The system has operated successfully for many years with excellent egg deposition efficiency and egg-to-fry survival ranging from a low of 35 percent to a high of 89 percent of potential egg deposition.

The success of this project may have been due in large part to selecting a source of water with water quality characteristics similar to those present in the historical spawning grounds.

Application to Susitna River Mitigation Plan. Mitigative measures for the middle Susitna River which propose the use of supplemented water supply will include evaluations of the water quality and temperature profile to insure satisfactory results. The Baker River beach spawning upwelling system described in detail above demonstrates that such a system could be used for those species on the Susitna River, i.e. chum and sockeye salmon, that appear to depend on upwelling for spawning.

(c) Columbia River Spawning Channels

Construction of dams on the Columbia River has been responsible for the inundation and subsequent loss of the historic mainstem spawning grounds for fall chinook. The natural habitat for salmon above Bonneville, the dam farthest downstream, has deteriorated as a result of increased water temperatures, pollution, predation and decreased velocities (Meekin, T.K. 1967). Although these environmental conditions have affected several life stages, loss of suitable habitat for spawning has been the principal concern.

The Washington Department of Fisheries, faced with the decision of how to perpetuate the Columbia River runs, considered two alternatives. The first was to develop fish hatchery programs and the second was to construct artificial spawning channels simulating natural conditions. The Department opted for the second alternative and in 1954 initiated a program to evaluate the physical habitat requirements for spawning chinook salmon so that artificial spawning channels could be constructed to mitigate for the loss of mainstem spawning areas. This resulted in the construction of the McNary Supplemental Spawning Channel in 1957, the first of its kind for the propogation of chinook salmon. The Canadian Department of Fisheries and Oceans had experimented with artificial spawning channels for pink salmon in British Columbia since 1954 and had reported good egg-to-fry survival (Houston and Mackinnon 1957).

The spawning channel program expanded with the completion of five hydroelectric projects above McNary Dam; Chief Joseph Dam in 1957, Priest Rapids in 1960, Rocky Reach in 1961, Wanapum in 1967 and Wells in 1967. Each of these dams incorporated fish passage facilities, except for Chief Joseph Dam which marked the endpoint for upstream migration of anadromous fish. As mitigation for the inundated spawning grounds, spawning channels were also developed at Priest Rapids, Rocky Reach, and Wells Dams.

Evaluations of the performance of each of these channels in maintaining the mainstem chinook stocks were conducted during each year of operation. The results are summarized below.

(i) McNary

The McNary spawning channel consisted of 12 spawning runs measuring 22 by 175 feet with each run separated by a pool. Gravel size ranged from 0.5 to 3 inches. Flow through the channel was 92 cfs. As this was the first spawning channel completed, several important conclusions were derived that were of use in development of subsequent channels (Meekin 1967).

1) It was demonstrated that chinook salmon would voluntarily enter a channel with physical conditions resembling natural ones and spawn.

2) The poor return of marked fish indicated that a self-perpetuating run had not been established.

3) The allocated area of 55 square feet per female was insufficient to support spawning and at least 165 square feet was required.

4) Low egg-to-fry survival resulted from high water temperatures, silt deposition, and superimposition.

5) Attempts to transplant fall chinook indigenous to the upper reaches of the river resulted in excessive pre-spawning mortality.

(ii) Rocky Reach

The Rocky Reach Spawning Channel was constructed as a mitigation facility for loss of chinook salmon spawning grounds resulting from the construction of Rocky Reach Dam. The 1,000-foot long by 32 foot wide spawning channel was designed to accommodate 330 pairs of chinook salmon - the number of fish estimated to spawn historically in the reach inundated by the reservoir. The results of seven years of operation were:

1) High prespawning mortality of adults.

2) Low numbers and small fry production with correspondingly small size and few juveniles released.

3) Extremely low adult returns.

4) High operational costs.

Prespawning mortality resulted from excessive handling combined with high temperatures, which increased the susceptibility to disease. Egg-to-migrant survivals were quite variable over the seven years of operation with three years greater than 40 percent and the other four years less than 10 percent. Factors thought responsible for the low survival included superimposition, predation by juvenile coho, and nitrogen supersaturation (Meekin et al. 1971).

The poor returns of adult fish may have been attributable to low survival during outmigration or perhaps straying of adults, since the channel water was pumped directly from the Columbia; however, significant numbers of marked adults were not observed at upstream dam fish ladders.

In summary, the channel did not fulfill its intended purpose of maintaining a viable run of chinook salmon that historically spawned in the Rocky Reach section of the Columbia.

The channel is presently being used as a coho egg incubation channel and rearing station.

(iii) Priest Rapids

The Priest Rapids Spawning Channel was completed in 1963 as a mitigation measure for the loss of chinook salmon spawning grounds following the construction of Priest Rapids and Wanapum Dams on the Columbia River. The channel was approximately 6,000 ft and designed to accommodate 2,500 pairs of chinook spawners.

The period of channel operation from 1963 to 1967 was characterized by substantial prespawning mortality and poor juvenile production ranging between 5 and 14 percent of the potential egg deposition. The 1967-68 season marked a transition point in the channel operation. For three seasons, production in the channel was consistent, and was greater than 50 percent of egg deposition (Allen 1968). The increased production of the later years was attributed to:

1) Decreased superimposition resulting from reduced number of adults in the channel and their forced dispersion.

2) Lower incidence of disease and elimination of treatments.

3) Maintenance of adequate flows through the entire incubation periods.

4) Negligible introduction of wind-blown sand deposits into the spawning channel.

However, this channel, like the others, suffered from the lack of significant adult return to the facility apparently due to the poor seaward survival of outmigrants and a high rate of straying for returning adults.

(iv) Wells Spawning Channel

The Wells Spawning Channel was designed to accommodate 3,000 female spawners. The spawning channel, measuring 6,000 feet, began operation in 1967. For the first five years of operation, fry production ranged from 48 to 66 percent of egg deposition. Moreover, prespawning mortality was less prevalent in this channel than in some of the older ones. However, this channel, like those that preceded it, was unable to produce fry of a size that would enable them to survive the downstream passage through numerous dams and predator-infested waters. The net result was that self perpetuating runs could not be maintained. In time the facilities were converted to rearing areas for hatchery produced fry.

The overall failure of the Columbia River Spawning Channel program was largely attributable to environmental conditions unique to that system. Several of the channels, particularly Wells, were successful in producing fry from naturally spawning adults. Extraneous factors such as low survival of outmigrants and possible straying of returning adults, however, contributed to the program's eventual demise.

Application to Susitna River Mitigation Plan. The Columbia River Spawning Channels provide evidence that chinook salmon would voluntarily enter and successfully spawn and incubate in an artificially constructed channel if conditions resembling the natural environment were simulated. In addition, the eventual failure of the channels and replacement with artificial incubation facilities and rearing ponds emphasize the importance in developing alternative mitigation options should failure of higher priority measures occur.

2.2 - Development of Mitigation Plan

It is expected that the distribution and abundance of fish species downstream of the proposed Susitna Hydroelectric Project will change as a result of project operation. The impact assessments presented in this report were developed for the maximum power flows (Case P-1) which includes no minimum instream flow requirements, and three proposed project flows (Case C, Case EV, and Case EVI), each with different environmental flow constraints. Case C is designed to provide mitigation for chum spawning in sloughs. Case EV is designed to mitigate for both rearing and spawning habitats. Finally, Case EVI is designed to minimize impacts to rearing habitats. The development of these flow regimes is discussed in Harza-Ebasco (1984b). The general impacts related to all flow regimes are discussed in the following section; specific differences in the degree of impact among the various flow regimes are discussed in subsequent sections. The impact assessments link predicted physical changes with habitat utilization to provide a qualitative statement of impacts likely to result from the Susitna Hydroelectric Project. Impact issues have been identified and ranked by procedures established by the Susitna Hydroelectric Project Fish and Wildlife Mitigation Policy (APA 1982).

2.2.1 - Impact Assessment

2.2.1.1 Spawning Habitat Utilization in Sloughs and Side Channels

The area of spawning habitat utilized within selected sloughs and side channels was estimated by digitizing the actual areas spawned during the 1982, 1983, and 1984 spawning seasons as outlined by ADF&G (unpublished maps of spawning areas). The 1981 data were not used because the high flows and poor visibility during the spawning season precluded definition of spawning areas. The areas outlined by ADF&G indicate general areas of spawning, not the area actually excavated by spawning fish. For example, a circumscribed area of 10,000 square feet may have had 50 spawning pairs of fish widely distributed, while a similar area elsewhere may have accommodated several hundred spawning fish over the course of the season. The areas spawned for all three years were classified as composite or total areas. Composite areas were obtained by superimposing maps of spawned areas for each year and measuring the area spawned one or more times. Total area was the sum of the area spawned in each of the three years. Figure 3 illustrates the difference between composite area and total area. The ratio of the composite areas spawned to the total area used over the three years is presented in Tables 8 through 13 for Sloughs 8A, 9, 9A, 11 and 21 and Side Channel 21 and Upper Side Channel 11. The ratio of the composite area to total area serves as an index of the amount of area repeatedly spawned during the three years. If the same area were used each of the three years the ratio would be .33. Greater values indicate less repeated use of spawning habitat. A value of 1.0 indicates different areas were used in each of the three years.

The composite areas spawned can be considered representative of the potential spawning habitat within the sloughs and side channels evaluated if the following conditions are satisfied:

1) Sufficient numbers of fish annually escaped to the sloughs and side channels to occupy generalized areas of available spawning habitat.

2) Flows during the 1982, 1983, and 1984 spawning periods provided average access and passage conditions to spawning habitat that were representative of the conditions the long term flow record has provided.

3) The periods in which access and passage conditions were provided by the 1982-1984 flows coincided with the availability of spawning fish.

Further evaluation of the above conditions will be undertaken when the flow and escapement records for the 1984 season become available. The fortuitous occurrence of a high 1984 escapement and a period of high flow coincident with the historical beginning of the peak spawning period during the 1984 season should provide a valuable data base for evaluation of conditions that allowed access to and utilization of most of the potential slough and side channel spawning habitat in the middle Susitna River.

2.2.1.2 Project Related Physical Changes in Sloughs and Side Channels

Operation of the Susitna Hydroelectric Project would modify the annual flow and temperature regime of the Susitna River, thus causing physical changes in sloughs and side channels in the middle reach. In general, flows during project operation would be less than natural flows during June, July, August, and September and higher than natural flows in the remaining months as the reservoir is drawn down. Project flows would be relatively constant throughout the year as compared with the natural variability of flows. The project flow regime would cause the following physical changes in sloughs and side channels of the middle Susitna River:

- Reduced backwater effects during summer
- Reduced frequency of breaching during summer

- Reduced groundwater upwelling during summer and in winter upstream of the ice cover
- Increased frequency of winter overtopping in ice-covered areas

Susitna River discharges presented in this report are flows at the Gold Creek gage maintained by the USGS.

(a) Backwater

A backwater area forms at the mouth of a slough or side channel if the stage in the mainstem is greater than the stage of the flow in the slough or side channel at its mouth. If the mainstem stage rises with no change in flow in the slough or side channel, the level of the backwater increases and the aerial extent of backwater influence moves upstream in the slough or side channel. If the mainstem stage drops, then the backwater level also drops and its length is shortened. The drop in mainstem stage can be sufficient to eliminate the backwater completely; the stage and corresponding mainstem discharge at which this occurs varies from site to site. The stage of the backwater may be defined by the mainstem discharge that forms the backwater. Project operation would generally cause a decrease in backwater area and stage during June through September.

(b) Breaching

A slough or side channel breaches when the mainstem flow overtops the upstream end, or head, of the channel. Breaching is directly related to mainstem discharges; as the discharge increases, the stage increases and when stage exceeds the elevation of the top of the berm at the head of the slough or side channel, flow is diverted through the channel. Further increase in stage will cause additional flow to pass through the slough or side channel. Project operation would generally cause a substantial decrease in the amount of time that a slough or side channel would be breached.

(c) Groundwater Upwelling

Groundwater flows out of (upwells from) the bed of a slough or side channel when the elevation of the bed is less than that of the local groundwater level. Studies have been conducted to relate the flow and temperature of the mainstem to upwelling quantity and temperature in sloughs and side channels (APA 1984). Although a complete evaluation of the sources of groundwater was not conducted, the apparent groundwater upwelling component of slough flow was isolated from the surface inflow component and related to mainstem discharge at Sloughs 8A, 9, and 11. Relationships were developed in the form of regression equations for inferred upwelling component as a function of mainstem flows; these were used in making a preliminary analysis of project related changes in the groundwater upwelling component of slough discharge as described in Appendix A.

The temperature of the groundwater upwelling appears to remain relatively constant at a value approximately equal to the mean annual river temperature (APA 1984). A mean annual temperature increase resulting from project operation will probably be reflected as a slight increase in the temperature of groundwater upwelling flow (APA 1984).

Winter flow and ice regimes affect upwelling in the sloughs. As the mainstem forms an ice cover, the stage increases because of backwater effects from frazil ice particles and pans jamming in constricted areas or building up on downstream jams. Thus river stage with an ice cover at low flow may approximate the stage of a much larger flow in the open channel conditions of summer flows, thus changing the hydraulic head that controls groundwater from the river.

The higher project flows in conjunction with increased water temperatures would change the ice processes, and thus upwelling, in the middle Susitna River. Under project operation, the upstream edge of the ice cover would vary from RM 125 to RM 142 depending on meteorologic conditions and the depth (and thus temperature) from which water is withdrawn from the reservoir (Harza-Ebasco 1984b). Upstream of the backwater effects of an ice cover, the stage in the river would decrease relative to the stage experienced under an ice cover formed under natural conditions. According to preliminary upwelling studies, this would result in decreased groundwater upwelling in sloughs and side channels throughout the winter. Downstream of the ice front the increased staging would result in upwelling rates greater than those under natural conditions.

(d) Winter Overtopping

The stage increase during ice cover formation (winter staging) was described briefly in the previous section in relation to the reduced upwelling at locations upstream from the ice front. With project flows higher than natural flows during winter, the staging effect would be higher during project operation downstream from the ice front. Thus, the probability of breaching caused by ice staging at and downstream from the ice front would also be greater. Under natural conditions, the staging effects occasionally cause slough and side channel overtopping. When an ice cover forms, shore ice develops causing flow restrictions (R&M Consultants, Inc. 1983). The shore ice may act as a barrier to contain the flow and prevent the mainstem from overtopping the slough berms (Figure 4). However, under higher mainstem discharges, the probability of overtopping would increase. Figures 5 through 9, derived from ice cover prediction modeling (Harza-Ebasco 1984a), may be used to predict possible overtopping events under natural and project winter flow regimes at Sloughs 8A, 9, 9A, 11 and 21. They do not, however, identify the probability or duration of actual events which are dependent on other factors besides mainstem stage.

2.2.1.3 Relationship Between Physical Changes and Available Habitat in Sloughs and Side Channels

The physical changes associated with project flows as discussed in Section 2.2.1.2 would either 1) directly affect the quantity and quality of spawning and incubation habitat by reducing the area that satisfies the physical requirements of these life stages or 2) indirectly affect the availability of spawning habitat by restricting access to those areas.

(a) Direct Effects

(i) Reduced Backwater

Backwater effects in the area of the slough mouth under natural conditions provide greater depths in the affected zone than would be provided by local slough flow. Project flows would substantially reduce the backwater zone in some sloughs resulting in a decrease in the surface area with suitable spawning depths and a loss of spawning habitat at the slough mouth. The degree of loss would be dependent on the relative spatial distribution of available spawning habitat under natural and project conditions.

(ii) Reduced Frequency of Breaching Flows

Breaching flows also provide additional spawning habitat within the slough and side channels by increasing the amount of area with suitable spawning depths. Project flows would substantially reduce the frequency of breaching flows and thus decrease the potential spawning habitat. The amount of habitat lost would be dependent on the site specific frequency of breaching flows under natural conditions. Spawning habitat provided at breached conditions in sites with relatively high breaching discharges (low frequency of occurrence) is generally of insufficient duration for fish to effectively utilize; if such habitat were used, it would likely result in dewatering and freezing of the embryo. Spawning habitat provided under breached conditions in channels with relatively low breaching discharges (high frequency of occurrence) can be effectively utilized; embryos have a higher probability of remaining wetted and unfrozen at such sites. The infrequent breached conditions under project flows would result in a loss of this spawning habitat. The quantity of habitat loss would depend on the relative spatial distribution of available spawning habitat under natural and project conditions.

(iii) Reduced Upwelling

Reduced mainstem flows during the spawning season would also decrease the amount of upwelling in the slough. Chum salmon prefer to spawn in areas with upwelling flow (Vincent-Lang 1984). The reduction in the rate of upwelling would reduce the quality and quantity of available spawning habitat. Winter flows, although higher than natural, would result in reduced upwelling in sloughs upstream of the ice cover because the staging effects during ice formation would no longer occur. A decrease in the rate of upwelling in winter may decrease the quality of incubation habitat.

(iv) Increased Frequency of Winter Overtopping

Project winter flows would be higher than flows under natural conditions. Thus, the probability of breaching caused by ice staging at, and downstream from, the ice front would also be greater. Under natural conditions, the staging effects occasionally cause slough overtopping.

For those sloughs which are overtopped, the influx of near freezing water and subsequent ice formation would result in retarded development of embryos and delayed emergence timing (ADF&G 1983b).

(b) Indirect Effects

Project mainstem discharges during the August-September spawning season would reduce the channel depths in sloughs and side channels. The depth at any location in a slough or side channel is a function of the cumulative effect of backwater, breaching, and local flow in the channel. Local flow is generated by surface inflow (surface runoff and tributary inflow) and groundwater upwelling.

The influence of mainstem discharge on backwater, breaching, and groundwater upwelling was introduced previously. Variations in surface inflow are not dependent on the mainstem discharge directly, even though there is some correlation through their mutual dependence on precipitation. The shallow depths at various locations in sloughs and side channels would result in restricted passage of adult fish and a loss of otherwise available spawning habitat. Criteria that have been developed for evaluation of fish passage are a function of flow depth and length over which the depth remains shallow. Reaches within sloughs and side channels that have inadequate depth for successful passage are referred to as passage reaches (Sautner et al. 1984).

Decrease in slough or side channel depth resulting from project operation is also dependent on the location within the slough or side channel. Relative changes in depth generally decrease in the downstream direction for a given channel configuration as surface inflow and groundwater upwelling accumulate through the site.

Assessment of the relative impacts of project operation on passage conditions can be accomplished by identifying how often a certain depth occurs under natural and project conditions. For example, specified depth for successful passage at a passage reach located near the mouth of a slough may be reached 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 can be obtained from the flow duration curve for the period of interest. An approximation of the frequency of surface flow can be obtained from a precipitation duration curve, which is related to the surface flow through a runoff coefficient. If it is assumed, to be conservative, that the backwater, breaching, and precipitation events are coincident, then in the example above, the frequency that the specified depth is equalled or exceeded is 80 percent, corresponding with the frequency due to backwater. The evaluations of project effects can address the frequencies corresponding to project operation, which may be 0 percent of the time due to backwater only, 0 percent of the time due to breaching only, and 35 percent of the time if average groundwater were supplemented by the unaffected surface inflow. Thus, the effects of the project for the passage reach in this example is reduction in the percent of time that a specified depth for successful passage is equalled or exceeded from 80 percent to 35 percent. This relative change is fairly typical of the change that may occur to a passage reach near the mouth of a slough or side channel, while a change from 10 percent to 8 percent may be more typical of a passage reach located farther upstream in the site.

A recurrence interval curve for the peak flow during the spawning season (August 20 - September 20) was developed to assess the importance of high flow events in providing suitable passage conditions (Figure 10). For example, the exceedance probability of a flow of 19,000 cfs is 29 percent on a flow duration curve, yet the recurrence of that flow during the spawning season is approximately three out of four years. The occurrence of a high flow coincident with peak escapement timing to sloughs would produce maximum passage benefits. Peak flows during the August 20 - September 20 period generally clustered around the first part of the period, August historically having higher flows. Peak escapements to sloughs also have occurred during the early part of the period for the 1981-1983 seasons. Recurrence interval analysis will be refined in upcoming reports following a detailed examination of fish wheel catches, flow records, and escapement timing to sloughs for the 1981-1984 seasons.

Analyses in Appendix A provide results indicating project influence on passage reaches in selected sloughs and side channels of the middle Susitna River.

2.2.2 - Mitigation Options

For the middle section of the Susitna River, altered flows would affect the fish populations. Under natural conditions, mainstem discharges are high in late May, June, July, August, and early September and decrease during September and October to low flows throughout the winter (Figure 11). Hydroelectric power is desired primarily during winter and water is retained during summer to fill the reservoir. Flows under project operation would be much more uniform throughout the year and thus would necessarily be higher in the winter and lower in the summer than natural flows.

Three levels of mitigation options are proposed for potential impacts on fish populations in the middle Susitna River resulting from project operation; these are flow release, habitat modification, and artificial propagation. The purpose of flow release is to avoid or minimize the impacts by maintaining an acceptable amount of suitable habitat for limiting species/life stages which cannot be economically maintained using other techniques. The purpose of habitat modification is to rectify or reduce the impacts remaining after implementation of the flow release mitigation. This will be accomplished through modification of existing habitats to maintain or enhance the natural productivity of the habitat. The purpose of artificial propagation is to compensate for losses which cannot be economically mitigated for by flow release and habitat modification.

also as a last resort if other means fail. See page 80

2.2.2.1 - Flow Release

(a) Impact Issue

The proposed hydroelectric development on the Susitna River is for power production. To maximize power and energy benefits, the discharge downstream of the dams would follow Case P-1 (Harza-Ebasco 1984a). This schedule of flows varies greatly from the natural mean monthly flows recorded at Gold Creek (Figure 11, Table 14).

Case P-1 flows average 9,700 cfs during both the winter (October through April) and summer (May through September) periods (Harza-Ebasco 1984a). During winter, mean flows will gradually increase to a maximum of approximately 12,000 cfs in December, followed by a gradual decrease through the rest of the winter. Mean December flow can be as high as 14,000 cfs in some years. Minimum monthly mean flows would rarely be less than 7,000 cfs during the winter period (Harza-Ebasco 1984a).

Summer flows would exhibit more variability around the mean of 9,700 cfs. During high flow years, mean flow in May, June, and July could approach 20,000 cfs while mean flow in August and September could be greater than 20,000 cfs (Harza-Ebasco 1984a). In low flow years, the flow could be 4,500 cfs for extended periods. Summer flow would be less than 7,000 cfs about 30 percent of the time (Harza-Ebasco 1984a).

The comparatively low flows during August and September would restrict movement of adult salmon into and within sloughs. At a mainstem discharge of 6,000 cfs under Case P-1, backwater effects at the slough mouths would be negligible, breaching of the sloughs would rarely occur, and the upwelling component of local flow would be less than that at natural flows. Project flows would also reduce the spawning habitat available due to reduced backwater, breaching, and groundwater upwelling effects. Project flow in the mainstem during winter can cause reduced upwelling upstream of the ice front and increased potential for overtopping downstream of the ice front.

Juvenile salmon rearing habitat would be reduced under Case P-1 flows during both summer and winter months. Flows of 4,500 cfs in summer months would result in a substantial loss of the mainstem and side-channel rearing habitat presently used by chinook juveniles (Harza-Ebasco 1984a). Juvenile overwintering habitat may also be adversely affected under Case P-1 flows; the increased winter mainstem stage would overtop the sloughs more frequently in ice-covered areas and may result in displacement or mortality of juveniles. On-going instream flow-juvenile rearing habitat studies will allow for a quantitative assessment of potential flow-related impacts to these habitats.

(b) Mitigation

Of the project flow schedules which have been identified (Harza-Ebasco 1984a), three mitigation flow schedules are discussed to reduce the adverse impacts of Case P-1. Case C, previously selected as the primary environmental flow case presented in the License Application, is intended to partially mitigate impacts to spawning adult salmon. Case EV is designed to reduce both spawning and rearing habitat impacts. The Alaska Power Authority's designated flow case, Case EVI, is selected primarily to reduce loss of chinook rearing habitat (Harza-Ebasco 1984a).

(i) Case C

The environmental flow components of Case C are designed to maintain suitable conditions for the upstream migration of adult salmon during the summer and to increase access to side sloughs by chum salmon for spawning during August and September as compared to Case P-1 (Harza-Ebasco 1984a). Mainstem flows in August and September are constrained to provide a minimum of 12,000 cfs (Figure 12). No maximum flow constraints throughout the year are established.

In comparison to Case P-1 flows, Case C will improve the frequency of salmon passage into sloughs and side channels in August and September. A mainstem discharge of 12,000 cfs under the Case C flow schedule will increase the backwater effects in slough mouths. Breaching of some side channels would occur at this flow. The local flow in side sloughs would also increase due to upwelling related to mainstem discharge.

However, the lack of a constraining maximum flow adversely affects rearing and overwintering habitat as well as incubating conditions. The low mainstem flows of 6,000 cfs in summer months prior to August under Case C would result in the loss of most of the existing chinook juvenile habitat currently in use (Harza-Ebasco 1984a). The potential magnitude of these adverse impacts prompted the identification of more detailed and refined environmental flow schedules (Harza-Ebasco 1984a).

(ii) Case EV

Case EV flow constraints are designed to minimize the losses of the existing chum salmon slough spawning habitat and chinook salmon side channel rearing habitat.

Spawning habitat will be partially preserved by mainstem flows which are constrained to a minimum of 12,000 cfs during August and early September when chum salmon are migrating and spawning in sloughs of the middle Susitna River (Figure 13). Case P-1 flows are projected to approach 6,000 cfs during this time. A mainstem discharge of 12,000 cfs will create backwater effects increasing the frequency of passage in the mouths of some sloughs and side channels. Breaching would occur in some side channels. However, greater mainstem flows are required to breach the sloughs containing the majority of the spawning habitat in the middle Susitna River (Sloughs 8A, 9, 9A, 11 and 21).

Local slough flows are anticipated to increase for Case EV in comparison to local flows under Case P-1. Based on current information (APA 1984), it is estimated that Case EV flows would increase slough flows by 0.5 cfs in Sloughs 8A, 9 and 11 and by 4 cfs in Slough 21. However, local flows would be less than local flows under natural conditions.

Case EV scheduled flows include a two-day period in August when the mainstem discharge will approach 18,000 cfs in order to improve access to chum salmon spawning habitat; the higher flow will increase breaching in some sloughs and backwater effects in most. At 18,000 cfs, breaching will not substantially ameliorate salmon passage in the sloughs of primary spawning importance (Sloughs 8A, 9, 9A, 11 and 21). Backwater effects may provide passage through an additional passage reach upstream of the reaches passable due to backwater effects at 12,000 cfs.

Local flow during the fall spiking flow of 18,000 cfs is anticipated to remain approximately at the levels of the local slough flow at a mainstem discharge of 12,000 cfs. The short duration of the higher flow and the probable unsaturated condition of the substrate above the 12,000 cfs mainstem stage may result in delayed and damped response of the local flow to the mainstem discharge increase.

The Case EV minimum mainstem discharge of 9,000 cfs (Harza-Ebasco 1984a) would maintain much of the rearing habitat currently in use by chinook juveniles during the summer months. The minimum discharge would occur 55 percent of the time, although the predicted average flow during the summer period would be 11,400 cfs (Harza-Ebasco 1984a). The spiking flows may cause displacement of chinook juveniles; however, the increased mainstem flow stability may improve the overall quality of the remaining rearing habitat under Case EV (Harza-Ebasco 1984a).

Winter flows under Case EV, in comparison to Case P-1, would decrease the frequency of breaching flows downstream of the ice cover and reduce the amount of upwelling upstream of the ice cover. The maximum winter discharges of 16,000 cfs would assist in maintaining viable incubation habitat within the sloughs; winter overtopping under Case EV will occur more frequently than under natural conditions downstream of the ice front. Upstream of the ice front under Case EV, the decreased mainstem stage from Case P-1 may result in reduced upwelling. Both cases will result in decreased upwelling upstream o the ice front as compared to natural conditions.

Case EV flows are designed to minimize loss of chum spawning habitat and chinook rearing habitat; however, additional measures would be necessary to mitigate for residual impacts. Additional mitigation also would be necessary for Case EV winter flows.

(iii) Case EVI

Case EVI is designed to minimize loss of existing chinook salmon side channel rearing habitat in all years except low flow years (Harza-Ebasco 1984a). Spawning habitat is not specifically considered in the establishment of minimum and maximum mainstem discharge constraints. The minimum discharge constraint for Case EVI is greater than natural discharges in the winter months and less than natural discharges in the summer months (Figure 14). The maximum constrained discharge is greater than the mean monthly natural discharge throughout the year (Figure 16). The simulated mean monthly discharges for Case EVI (Figure 15) are considerably greater than the minimum constrained discharge. The constraining bounds represent discharges which could be reached during low or high flow years.

Under Case EVI, minimum flows during the critical period of chum salmon migration and spawning in August and September will be increased above the Case P-1 projected flows of 6,000 cfs to 9,000 cfs. For Sloughs 9 and 11, a mainstem discharge increase from 6,000 cfs to 9,000 cfs is estimated to increase slough flow by 1 cfs over the former, based on currently available analyses (APA 1984). In Sloughs 8A, 9A and 21 the Case EVI flows are anticipated to also increase the local flow slightly.

The higher mainstem flows will increase the discharge in the sloughs through increased groundwater contributions to local flow. This will increase fish passage efficiency. The local flows will be lower than local flows under natural conditions in the August to September period. The frequency of passage will become less than the natural frequency of passage. The higher Case EVI flows will have a negligible effect on the backwater at the slough mouths and the flows will not be high enough to breach the sloughs of primary importance to fish production (Sloughs 8A, 9, 9A, 11 and 21).

why ?

Case EVI mainstem discharges are less than the natural discharges during the summer and fall. The lack of breaching flows and backwater effects will still lower the efficiency of fish passage in sloughs. Local flow in the sloughs will also be lower than natural conditions. Case EVI will partially mitigate for impacts on chum salmon and will minimize impacts on chinook rearing habitat, nevertheless, adverse impacts on side slough spawning and incubation will occur. Mitigation in addition to flow release will be necessary for the late summer, fall, and winter.

2.2.2.2 - Habitat Modification

(a) Impact Issue

Residual impacts to the amount of spawning and incubation habitat available to chum salmon in sloughs and side channels of the middle Susitna River will persist after implementation of the Case EVI or Case EV flow release. Case C flow releases during the spawning season are similar to the base flows of Case EV and will not be discussed to avoid redundancy. Partial or complete loss of these habitats, when compared with natural conditions, will result from:

- Reduced backwater effects
- Reduced frequency of breaching flows
- Reduced upwelling during spawning and incubation
- Passage restriction
- Increased frequency of winter overtopping in ice-covered areas

(b) Mitigation Measures

A number of mitigation measures are presented in this section that can be used singly or in combination to minimize identified impacts. Table 15 shows the relationship between the mitigation measures and the impact for which they are designed.

(i) Channel Width Modifications

Channeling slough flow will improve fish access through passage reaches by contracting the width of the channel and deepening the channel. This technique is especially useful in modifying short, wide passage reaches. Wing deflectors extending out from the channel bank or rock gabions restructuring the cross section of the natural channel may be used to contract the flow width (Bell 1973).

In determining the modified width for the channel, a maximum velocity criteria of 8 fps was used to permit fish access through the reach (Bell 1973).

- Wing Deflectors

Wing deflectors are used to divert the flow in a channel. Two wing deflectors placed on opposite banks will funnel the flow from a wider to a narrower cross section as shown in Figure 18. The narrowed channel is designed to provide fish passage at the minimum flow. At higher flows, the wing deflectors are inundated; fill between the banks and the wing deflector walls is sized to prevent scouring at higher discharges. Fill will typically be composed of large cobbles available at the sloughs.

Wing deflector walls are constructed either of rock or gabions formed of wire mesh and filled with cobbles. Another alternative is the use of 12-inch-diameter timbers, anchored to the banks and channel bed. A wing deflector costs $31,000 when constructed of rock, approximately $24,000 when constructed with gabions, and $22,000 if timber logs available on site are used. For sites where timber is not available, a log wing deflector would cost $23,000. Estimates are based on a typical passage reach of approximately 200 feet for a slough on the middle Susitna River (Figure 17).

- Rock Gabion Channel

Reshaping the original cross section of the channel with rock gabions is an alternative method of channelizing the slough flow. The channel is excavated and gabions are used to establish the new configuration. The new channel shape is designed to maximize depth at minimum flows; at higher discharges, the gabions prevent scouring of the channel banks. Figure 18 illustrates a typical cross section for a reshaped passage reach. For long passage reaches, resting areas are created by widening the channel between the rock gabions forming the minimum discharge channel. The gabions are provided throughout the length of the passage reach and protected upstream by riprap or wing wall gabions. The gabion banks extend higher than the height of the maximum slough discharge to prevent collapse from erosion.

The gabions composing the channel banks prevent scouring of the banks; the channel will be more stable than a similar channel modified by wing deflectors. For passage reaches with greatly varying discharges, the added stability of the rock gabion channel is an advantage. The cost of constructing the gabion channel is approximately $60,000 for a typical passage reach 200 feet in length.

(ii) Channel Barriers

Fish access through passage reaches is also improved by creating a series of pools. Barriers are placed to break the flow on long, steep passage reaches and create pools between obstacles. Fish passage over the obstacles is accomplished if sufficient steps of decreased barrier height are provided to permit surmounting the original barrier (Bell 1973).

Channel barriers are used on long slopes to create fish resting pools, as shown in Figure 19. These barriers with heights of 10 inches to 14 inches act as weirs, with a section of decreased height to improve fish passage between pools. The barriers are constructed of various materials. Concrete highway curbs anchored to the bed with rebar (Figure 19) or cobbles and boulders placed to create a sill may be used. Logs may also be attached to the banks and anchored securely to the bed to prevent movement at high discharges. Gabions shaped as shown in Figure 19 may also be used (Lister et al. 1980b).

Channels are constrained in width to form effective pools. For a wide channel, channel widths are modified where a pool and weir structure is desired.

Estimates of costs per barrier on the basis of a two barrier system are listed below. Each slope will require more than one barrier to create a series of pools. As more barriers are built on a site, the cost per barrier will decrease because of the economies of scale; the major cost involved in the construction of the barrier is the cost of transporting the equipment needed.

Barrier	Cost/Barrier
Concrete highway curbs	$12,000
Rock sill	$16,000
Gabions	$12,000
Anchored logs available on site	$11,000
Anchored logs not available on site	$12,000

(iii) Passage Provided by Flow Augmentation

With lower mainstem discharges, less groundwater may percolate into the sloughs, resulting in decreased slough discharge (APA 1984). Passage reaches negotiable at natural flows might become impassable under project conditions. In order to augment the slough flow, a piping system can be designed to transport water from the mainstem or other sources to affected passage reaches.

The sloughs of primary interest, including 8A, 9, 9A, 11, and 21, were considered in evaluating the feasibility of a piping system at a mainstem discharge of 9,000 cfs. This corresponds to the minimum spawning period mainstem discharge for Case EVI flows. The system feasibility was also considered at a mainstem discharge of 12,000 cfs corresponding to the minimum discharge for Case EV during the August to September period.

For Sloughs 8A and 9A, the mainstem elevations at 9,000 and 12,000 cfs would produce insufficient head between the mainstem stage and the critical passage reaches to provide sufficient flow to provide passage. Flows corresponding to the site-specific overtopping discharges are necessary to produce the required head for the required flow.

At Slough 9, a 9,000 cfs mainstem discharge would provide sufficient head for 1 cfs through a piped system. A collection tank (Figure 20) 20 feet from the main channel would collect mainstem water. The collector was designed to be located 20 feet from the mainstem in order to provide erosion protection and a filtration system for the water. A 1-foot-diameter corrugated metal pipe would deliver the water 2,800 feet to the upstream end of Passage Reach (PR) V, as shown in Figure 21. At a mainstem discharge of 17,000 cfs, the system would provide approximately 1.5 cfs. The system would provide a maximum of 3 cfs prior to berm overtopping. The amount of flow provided by the system seems to be uneconomical when the alternative options available at Slough 9 are considered. The installation of piping system is not recommended due to the cost of the system and the large number of mitigative measures feasible.

For Slough 11, mainstem discharges of 9,000 cfs or 12,000 cfs could provide sufficient head for a flow of 1 cfs from a collector through a 1-foot-diameter pipe for delivery to PR V, a distance of 3,200 feet from the slough head (Figure 22). The installation of a piping system into Slough 11 is not recommended; the quantity of water supplied is low. Alternative mitigation options exist which could accomplish a similar reduction in negative impacts with reduced monetary costs.

A mainstem discharge of 9,000 cfs would be necessary at Slough 21 for a local flow of 1 cfs from a similar sized collector through a 1,700-foot-long, 0.75-foot-diameter pipe (Figure 23). A mainstem discharge of 12,000 cfs will not significantly increase the flow through the system. A maximum of 2 cfs would flow through the system just prior to overtopping. The shorter distance from the mainstem to the pipe outlet and the smaller pipe required in the system increase desirability of the installation of such a system. Although the addition of local flow would increase the frequency of passage and improve spawning habitat throughout Slough 21 and Side Channel 21, alternative mitigative measures accomplishing the same goal are more cost-effective.

Estimated construction costs total $120,000 for the backhoe installation of the collector and piping system in Slough 9, $120,000 for the system in Slough 11 and $134,000 for the system in Slough 21.

(iv) Gated Water Supply System

In the absence of large flows in sloughs and side channels, debris buildup, siltation, and algal growth may create passage restrictions and decrease available spawning habitat. Side sloughs and side channels are breached under natural conditions with a frequency from 1 to 4 years. The large breaching flows remove obstacles caused by debris and scour the channel bed. Flows of 50 cfs or greater may be required for the removal of debris and channel scouring. Under project conditions, breaching of the sloughs and side channels will occur less frequently in spring and summer months and may not provide sufficient flushing of the channel. A gated pipeline extending under the berm at the head of a slough or side channel could provide large quantities of flow under unbreached conditions.

The gated water supply system consists of a 3 ft diameter corrugated pipe with a gate valve structure. The pipe intake is protected by a riprap cover to prevent the entrainment of fish and debris. The riprap will stabilize the bank of the berm at the intake by preventing scour. Large riprap at the outlet will create turbulent conditions for improved air entrainment and the dissipation of energy to prevent excessive channel bed erosion. The gate valve structure will enable the manual opening of the pipe to allow large flows into the channel. In order to provide the suggested 50 cfs of slough flow, the pipe system will be operated at a high mainstem discharge. To prevent the influx of turbid water during chum spawning or near-freezing water during incubation, the pipe gate valve will remain closed during the fall and winter months.

A gated water supply system to provide a minimum of 50 cfs is feasible at a given mainstem discharge if the head difference between the mainstem elevation and the slough bed is large enough to drive water through the required pipe length. A 3 ft head difference will deliver 50 cfs through a 4500 ft or less pipe length. A 1 ft head difference requires a pipe length of less than 1300 ft. Given the head difference and pipe length requirements, a gated water supply system is feasible at Sloughs 9, 11, and 21. The estimated cost of a system with a pipe length of 2500 ft is $100,000.

(v) Upwelling Augmentation

A system providing supplementary upwelling would maintain or increase spawning habitat in the sloughs during low mainstem discharges. The mainstem and nearby tributaries were evaluated as possible sources of upwelling water. The mainstem as an upwelling water source could not be used at numerous sites because of the low hydraulic head at low mainstem flows.

For sloughs with tributaries, the tributary could provide the water and the hydraulic head for an upwelling system, as shown in Figure 24. The critical period for induced upwelling would be during the project's projected low mainstem discharge period in August and September. Under natural conditions, it is assumed, based on the relationships provided in APA (1984), that upwelling increases during this period because of the high mainstem discharges. Selection of spawning sites has been shown to be related to the presence of upwelling at a site; therefore, upwelling needs to be maintained under project flows to maintain spawning habitat.

Under natural conditions, the mainstem stage and upwelling decrease from September until ice formation in November to December. Similarly, a tributary supplied upwelling system would also have decreasing discharges during this period. Reduction in a piped water supply would not become substantial until mid-October, when project discharges increase. Upwelling under project operation is likely to be greater than upwelling under natural conditions from September to December.

Upwelling during winter (December to March) will decrease for sloughs upstream of the ice cover and increase for sloughs downstream of the ice front, relative to the natural conditions. The upwelling provided by a tributary driven system may prove inadequate during this period upstream of the ice front.

In the spring, tributary flows increase with the melting of snow and ice. By April, the tributary flows would be sufficient to provide upwelling from the piping system. Upwelling thus would be provided continuously throughout the year. Under natural conditions, upwelling is greatest from June through September and December through April.

Temperatures of the upwelling flows from the piped system would correspond to the temperatures of the tributary flows. Water will flow through the system as long as the water temperatures are above 0°C. Freezing water will not be released in the spawning gravels, as flow will cease in the system at freezing temperatures.

Estimated cost of the system is $210,000 for a 300-foot main pipe and 200-foot reaches of cross pipe, spaced at 5-foot intervals for upwelling. A system with a longer main pipe could be built to tap Gold Creek water for Slough 11. Until more refined values are available quantifying the extent of the reduction in upwelling, the system will not be recommended for installation in any slough.

(v) Slough Excavation

Mechanical excavation of certain reaches of sloughs would improve fish passage and fish habitat within the sloughs. At slough mouths, excavation would provide fish access when backwaters are negligible during low mainstem discharges. Mechanical excavation can be used to facilitate passage within sloughs by channelizing the flow or deepening the thalweg profile at the passage reach.

On a larger scale, mechanical excavation to lower the profile of the entire slough could increase the amount of upwelling in the slough. A greater head between the mainstem and the slough bed would result in additional local flow in the slough.

An additional benefit of the excavation process would be the opportunity to improve the substrate in the slough. Replacement of poor substrate with suitable spawning gravels would provide additional spawning habitat. Sorting of the existing substrate will be undertaken to remove unsuitable particle sizes. The excavation process would be designed to develop additional spawning and rearing habitat.

An estimate of the cost to excavate a typical slough mouth in the middle portion of the Susitna River is $26,000. An estimate of the cost to lower a typical slough profile by 2 feet for a length of 2,000 feet in the middle section of the Susitna River is $34,000.

(vi) Development of New Spawning Habitat

In order to provide the conditions that chum salmon prefer for spawning, existing pools in sloughs would be modified. Chum salmon prefer to spawn at upwelling sites (ADF&G 1983a). A weir structure that is permeable at the base and impermeable elsewhere could be erected in a pool to produce a head difference between the upstream and downstream sides. Such a weir would cause water to flow through the spawning gravels placed at the base of the structure (Figure 25).

A notch in the top of the structure facilitates fish passage between pools. The notch is designed for a minimum slough discharge of 2 cfs; this discharge corresponds to a typical low discharge in the sloughs along the middle section of the Susitna River.

The structure is securely embedded, anchored to the channel walls and bed, and riprapped to prevent erosion during high flows.

The weir can be constructed of timber posts 10 inches in diameter, reinforced with 2 x 4 inch cross bracing and faced with impermeable material, as in Figure 26. Gravel materials are piled on each side of the weir; the gravel provides stability to the structure in addition to providing spawning habitat. Only fine silts present in the gravel base will be eroded by the 2 fps water velocities over the weir. The spawning gravels would have a maximum angle of 10° with the channel bed to prevent downstream displacement caused by females digging redds during spawning.

Rock gabions can also be used to construct the weir shown in Figure 27. Sheets of plywood in the center of the structure impede flow through the gabions. Spawning gravels provide habitat at the base of the structure. A notch is provided for fish passage at low flows.

A rock structure with an impermeable core can be built as in Figure 28. Plywood sheets anchored with reinforcing rebars are adequate for use as a core.

The decision as to the materials used for the weir structure will be made during the design phase of the project based on the cost, durability, and aesthetics of the various structures.

The cost estimate of the three structures is based on a 20-foot channel width and a 3-foot natural pool depth. Economies of scale are considerable if more than one structure is built at a site.

Structure	Cost/Weir
Timber pile weir	$32,000
Rock gabion weir	$32,000
Rock weir	$45,000

(vii) Prevention of Slough Overtopping

Project flows are higher than natural discharges in the winter. Ice staging at these discharges will result in an increase in mainstem stage and increase the probability of overtopping of sloughs downstream of the ice cover front.

An influx of cold mainstem water into the incubating area of the Slough 8A in 1982 caused adverse impacts (ADF&G 1983b). To prevent overtopping, the height of the slough berms is increased as shown in Figure 31.

29 or 30?

Cost estimates per berm range from $24,000 to $161,000 depending on the slough need configurations.

(c) Site Specific Impacts and Mitigations

Site-specific habitat modification measures are proposed for Sloughs 8A, 9, 9A, 11 and 21 and Upper Side Channel 11 and Side Channel 21. Collectively, the mean peak spawning counts to these sites comprised 72 percent of the mean total peak counts to sloughs for 1981, 1982, and 1983 (ADF&G 1984a). The modification techniques suggested for these selected sites are applicable to the remaining sloughs and side channels supporting spawning chum salmon in the middle Susitna River. The proposed measures would be similar given a Case EVI or Case EV flow scenario. Cost estimates for these sites are summarized in Table 1.

(i) Slough 8A

- Relative Utilization

During the 1981-1983 studies, the mean peak counts of chum salmon and sockeye salmon in Slough 8A were 331 (range: 37-620) and 104 (range: 67-177). The mean estimated total escapements to the slough were 553 chum (range: 112-1062) and 152 sockeye (range: 131-195) (ADF&G 1984a). Slough 8A mean chum escapements comprised 15.7 percent of the total escapement to sloughs in the middle Susitna River. The approximate percentage distribution of chum salmon during the 1984 spawning season is shown in Figure 30 (Seagren 1984 memo).

- Impact Mechanism

. Backwater

Spawning habitat that is dependent on backwater effects for providing suitable spawning depths would be lost because of project effects. An estimated spawning area of 103,000 square feet is affected by the backwater zone of natural flows. The portion of this area would become unsuitable for spawning at Case EVI project flows would be greater than that of the Case EV flows.

. Breaching

The exceedence probabilities associated with natural breaching flows 27,000 and 33,000 cfs are 7 percent for the northwest channel and 2 percent for the northeast channel (Sautner et al. 1984). The recurrence intervals for flows sufficient to breach the respective channels are approximately 2.1 and 7 years (Figure 10). These relatively low exceedance probabilities indicate that the importance of breaching lies in providing successful passage rather than increasing the potential spawning habitat by increasing the area with suitable spawning depths. Neither the Case EVI or Case EV minimum project flows would be of sufficient magnitude to provide breaching conditions.

- <u>Groundwater Upwelling</u>

Groundwater reductions at the various passage reaches under Case EVI would range from 60 to 62 percent during the spawning season. Case EV reductions would range from 29 to 50 percent (Appendix A, Tables A5-A13).

- <u>Winter Flows</u>

Overtopping of Slough 8A is predicted for several combinations of year specific climatologic data, operational regimes, and demand schedules (Harza-Ebasco 1984b).

- <u>Passage Restrictions</u>

Under Case EVI flows, the frequency of successful passage conditions will decrease at passage reaches (PR's) I and II from natural levels of 79 and 48 percent to project levels of 25 and 16 percent. For PR's III to IX the decrease will range from 1 to 3 percent (Table 16). Case EV flows would increase the frequency of successful passage above natural conditions to 100 percent in PR I. At PR II a decrease will occur from 48 to 18 percent. At the remaining PR's, decreases would be 1 or 2 percent. The 18,000 cfs spike proposed for Case EV would temporarily provide frequencies of successful passage greater than those under natural conditions. These decreases in frequencies of successful passage may, over time, result in a loss of potential spawning habitat. Historically spawned areas are presented in Table 8.

- Mitigation

Passage through PR's I and II is provided under natural conditions by backwater effects from a high mainstem discharge. With Case EVI flows, access through these passage reaches will be provided in an alternative manner to maintain the 103,000 square feet of fish habitat available within the slough. Benefits that may accrue from the Case EV 18,000 cfs spike would depend on its occurrence relative to escapement timing and other factors contributing to frequency of passage.

The maximum channel bed elevation of the PR I will be reduced to ease fish passage into the slough. Flow in PR II will be channeled to increase the depth at the expected lower slough flow. Adding wing deflectors to narrow the channel and remove boulders from the channel will improve passage through PR II. Other passage reaches may be improved by excavating a deeper channel through the reach. Passage and improvement of spawning habitat in the west channel will be evaluated as 1984 data become available. Slough 8A passage evaluations are complicated by the presence of several beaver dams. Measures to provide passage through these structures will be undertaken with the approval of appropriate Fish and Game management agencies.

Winter overtopping sometimes occurs at Slough 8A under natural conditions (R&M Consultants 1983). Under Case EVI, the frequency of winter overtopping is predicted to increase (Harza-Ebasco 1984b). Increasing the elevation of the berm at the head of each fork of the slough will prevent overtopping by near-freezing waters. The height of the northeast fork berm will be increased by 9 feet; approximately 250 feet of berm is required. The northwest fork berm will be increased four feet for a length of 250 feet.

The capital costs associated with each of the mitigation measures and the annual operating and maintenance costs based on semi-annual inspections and periodic repairs of mitigation measures for Slough 8A are shown below and in Figure 30:

Mitigation Measure	Number Proposed	Capital Costs	Annual Operating & Maint. Costs
Slough mouth excavation	1	26,000	5,000
Wing deflector	1	24,000	1,500
Excavate passage reaches	6	10,000	2,000
Protective slough berms	2	61,000	15,000
Total		$121,000	$4,00

(ii) Slough 9

- Relative Utilization

During the 1981-1983 studies, the mean peak counts of chum salmon and sockeye salmon in Slough 9 (including 9B) were 295 (range: 175-358) and 33 (range: 2-91). The mean estimated total escapements to the slough were 563 chum (range: 430-645) and 81 sockeye (range: 0-230) (ADF&G 1984a). Slough 9 mean chum escapements comprised 11.6 percent of the total mean escapement to sloughs in the middle Susitna River. The approximate percentage distribution of chum salmon during the 1984 spawning season is shown in Figure 31 (Seagren 1984, memo).

- Impact Mechanism

  . Backwater

  Backwater effects provided potential spawning area during the study period 1982-1984 and a small portion of that area was spawned only in 1983. The lower portion of this slough has since silted in and the channel has changed its course, thus precluding spawning in this area.

  . Breaching

  The exceedance probability associated with breaching discharges of 19,000 cfs during the spawning period is 29 percent (Sautner et al. 1984). The recurrence interval for 19,000 cfs is about 1.3 years (Figure 10). It is probable that the breaching flows are providing the depth required for spawning in some areas and that these areas would become unspawnable at project flows. However, the extent of these areas appear minimal when the wetted perimeter boundaries at a flow of 9,000 cfs are overlaid on outlines of spawned areas from 1982-1984. Neither Case EVI nor Case V project flows would be of sufficient magnitude to provide breaching conditions.

- Reduced Groundwater Upwelling

Case EVI would reduce groundwater upwelling at each of the passage reaches by approximately 40 percent during the spawning season. Case EV reductions would amount to approximately 20 percent (Appendix A, Tables A14-A18).

- Winter Flows

The upstream extent of the ice cover is projected to progress beyond Slough 9 for several combinations of selected meteorologic data, operation regimes, and demand schedules. Based on the simulations completed to date, there is a moderate probability of annual overtopping of the slough (Harza-Ebasco 1984b).

- Passage Restrictions

Based on mainstem discharge-groundwater relationships and slough flow analysis, Case EVI flows will result in reductions in the frequency of successful passage conditions at PR's I, III, IV and V. Successful passage at PR I would be reduced from 100 to 47 percent. At PR's III and IV, passage under natural conditions occurs 18 and 17 percent of the time as compared to 15 percent and 14 percent under project flows (Table 17). At PR V, natural occurrences of 29 percent will change to 0 percent passage under project flows. The reduction in opportunities of passage at PR's III and IV may also result in loss of some spawning habitat. Case EV flows would result in decreases of successful PR III and IV of only 1 to 2 percent and decreases from 29 to no passage at PR V. The general area of spawning above PR V that would become inaccessible at Case EVI and Case EV flows amounts to approximately 5,300 square feet (Table 9).

- Mitigation

Passage through the downstream section of Slough 9 is currently difficult because of silt deposited during the 1983-1984 season. Removal of this silt will expose the spawning gravels and increase the habitat in the downstream region of the slough. The slough mouth would be excavated to increase the frequency of passage through PR I under the Case EVI flow regime.

Based on the relationship between mainstem flow and slough flow presented in APA (1984), PR's III and IV are greatly affected by a reduction in natural discharges. At discharges corresponding to Case EVI the frequency of passage through these reaches will be increased by excavating a deeper channel and channelizing the available local flow. Larger cobbles and boulders will be removed from the channel to improve the spawning habitat. Other efforts to improve spawning habitat in the pool region between PR's IV and V include construction of a rock weir to increase available spawning habitat.

Upstream from PR V, spawning habitat is available under natural conditions. Under project conditions, based on the currently available slough flow analysis, fish would not be able to reach this habitat. A pool and weir structure will be constructed to enable fish to access the natural pool habitat available upstream of PR V. A series of 20 weirs composed of anchored logs will allow salmon to access an additional 1,000 ft of Slough 9.

Slough 9 is expected to be overtopped more frequently in winter by the increased ice stage caused by project flows (Harza-Ebasco 1984a). An overtopping-prevention berm 8 feet high and 375 feet long will be placed at the head of the slough to maintain the suitability of incubation habitat within the slough. In addition, the berm would prevent the deposition of sands and silts as it currently occurs.

The capital costs associated with each of the mitigation measures the estimated annual operating and maintenance costs for all measures based on semi-annual inspections and periodic repair of mitigation measures for Slough 9 are shown below and in Figure 31:

Mitigation Measure	Number Proposed	Capital Costs	Annual Operating & Maint. Costs
Slough mouth excavation	1	26,000	
Rock weir	1	37,000	
Protective slough berm	1	59,000	
Log barriers	20	30,000	
Passage reach excavation	2	7,000	
Total		$250,000	$4,000

(iii) Slough 9A

- Relative Utilization

During the 1981-1983 studies, the mean peak count of chum salmon in Slough 9A was 135 (range:105-182) while the mean estimated total escapement to the slough was 152 chum (range 86-231) (Barrett et al.

1984). Slough 9A mean chum escapement comprised 6.4 percent of the total escapement to sloughs in the middle Susitna River. The approximate percentage distribution of chum salmon during the 1984 spawning season is shown in Figure 32 (Seagren 1984, memo).

- Impact Mechanism

  - Backwater

    Evaluation of backwater effects are not applicable to this slough because breaching conditions prevail for the majority of the spawning season.

  - Breaching

    The breaching discharge for Slough 9A has not been established but appears to be around 12,000 cfs with an exceedance probability of 71 percent (Sautner et al. 1984). The recurrence interval for 12,000 cfs is approximately 1.05 years. Field observations during September 1984 indicated that the gravel surface of some areas spawned earlier in the season under breached conditions were dewatered. Survival from these areas is unknown. Estimates of the spawning area lost under Case EVI will be obtained by overlaying the boundaries of the wetted surface area at 9,000 cfs onto the spawned areas delineated for the 1982-1984 seasons. The base flow of 12,000 cfs for Case EV may provide breaching flows and a flow spike of 18,000 cfs most certainly would.

- Groundwater Upwelling

Groundwater upwelling reductions at the various passage reaches in Slough 9A under Case EVI would range from 30-48 percent for the various passage reaches during the spawning season. Case EV reductions would range from 13-24 percent (Appendix A, Table A19-A28).

- Winter Flows

Simulation of the upstream extent of ice cover for several combinations of operating regimes, demand schedules and meteorologic conditions for selected years indicated that there is a probability of the slough overtopping on an annual basis (Harza-Ebasco 1984b).

- Passage Restrictions

Under natural conditions, PR's I-IX can be successfully negotiated by chum salmon 100 percent of the time (Table 18). Five out of these nine passage reaches are anticipated to provide successful passage condition 3 to 32 percent of the time under Case EVI flows. Of the five passage reaches, PR III is considered to be of greatest concern since access to substantial amounts of historically spawned areas can be achieved if passage through this reach is facilitated (Table 10). Breaching conditions resulting from Case EV flows would provide passage 100 percent of the time.

- Mitigation

Spawning habitat in Slough 9A is primarily accessed during breaching flows under natural conditions. Under Case EVI scheduled discharges, the habitat will be retained by lowering the slough profile until depths suitable for spawning are obtained.

While the slough profile is being excavated, the large cobbles and boulders will be removed to improve access between the series of pools that exist along the thalweg. Removal of the large cobbles and boulders will provide additional spawning habitat to that presently existing within the side channels.

Slough 9A breaches at a relatively low natural mainstem discharge and protection from winter overtopping under project conditions will be supplied. The berm at the head of the slough will be heightened 10 feet for a length of 150 feet to prevent winter overtopping if the ice front is predicted to extend upstream of this slough more frequently than once every ten years.

The capital costs associated with each of the mitigation measures and the estimated annual operating and maintenance costs for all measures based on semi-annual inspections and periodic repairs for Slough 9A are shown below and in Figure 32:

Mitigation Measure	Number Proposed	Capital Costs	Annual Operating & Maint. Costs
Protective slough berm	1	$42,000	
Excavation of slough	1	76,000	
Total		$118,000	$4,000

(iv) Slough 11

- Relative Utilization

During the 1981-1983 studies, the mean peak counts of chum salmon and sockeye salmon in Slough 11 and Upper Side Channel 11 were 369 (range: 238-459) and 532 (range:248-893). The mean estimated total escapements to the slough were 957 chum (range: 674-1,119) and 1,128 sockeye (range: 564-1,620) (Barrett et al. 1984a). Slough 11 and Upper Side Channel 11 mean chum escapement comprised 17.6 percent of the total escapement to sloughs in the middle Susitna River. The approximate percentage distribution of chum salmon during the 1984 spawning season for Slough 11 and Upper Side Channel 11 is shown in Figure 33 (Seagren 1984, memo).

- Impact Mechanism

. Backwater

The backwater at the slough mouth affects approximately 50,000 square feet of area that has been spawned in the past. Overlying the boundaries of the wetted surface area at 9,000 cfs indicates that approximately 20 percent of that spawned area would be dewatered during Case EVI operations. Less habitat would be lost under Case EV flows. For purposes of mitigation, this dewatered area will be considered lost habitat. Additional habitat with the wetted perimeter at 9,000 cfs may be unsuitable for spawning due to insufficient depth and would also be considered lost habitat.

- Breaching

The exceedance probabilities associated with natural breaching discharges of 42,000 cfs is one percent (Sautner et al. 1984). The recurrence interval for this flow is about once every eleven years (Figure 10). Based on this low frequency of occurrence, the contribution of breaching conditions in providing access and passage or in increasing the spawnable area within the slough is negligible. Neither Case EVI, Case C or Case EV would provide breaching flows.

- Groundwater Upwelling

Groundwater reductions at the passage reaches in Slough 11 under Case EVI would range from 20-25 percent during the spawning season. Corresponding reductions for Case EV range from 13-19 percent (Appendix A, Tables A29-A33).

- Winter Flows

Simulations of ice cover progressing have indicated that the front will proceed as far as Slough 11 generally in the coldest years (Harza-Ebasco 1984b). The probability of the slough overtopping on a yearly basis is therefore low.

- Restricted Access

Under natural conditions, PR's I-III provide successful passage 70, 43 and 12 percent of the time, principally through the groundwater contribution to local slough flow (Table 19).

Passage reaches IV and V provide adequate passage conditions only during infrequent breaching conditions, which occur one percent of the time. Based on currently available information, project flows of 9,000 cfs will reduce the groundwater input to the extent that passage will be restricted across all passage reaches (APA 1984). Case V flows will provide additional groundwater to the slough and result in frequencies of passage for PR I, II and III of 60, 20, and 5 percent. The Case EV spike would be of such short duration that contributions to groundwater would be minimal. The spawning areas that will be affected are shown in Table 11.

- Mitigation

The passage reaches in Slough 11 will require channelization in order to increase the depth of flow in the reaches and provide passage.

A channel will be excavated through the silty materials at the slough mouth and the banks of the channel stabilized with rock gabions. The stabilized channel will extend 1,200 feet upstream in the slough and modify PR's I and II. Passage through 300 feet of PR III will be facilitated by construction of wing deflectors made from rock gabions.

A channel will be excavated at PR IV. A pool and weir structure will be constructed in the excavated channel which will improve fish passage upstream. Ten weirs will be needed for 500 feet of slough channel.

Under natural flows, backwater effects provide 50,000 square feet of fish spawning habitat at the slough mouth. Under project conditions, this spawning area will be partially replaced with rock weirs placed in pools between PR's II and III and PR's III and IV.

Under project conditions the slough may experience winter overtopping. Current analysis of ice processes indicates a low frequency of overtopping; however should refined analysis show a higher probability, the berm at the head of the slough will be heightened five feet for a length of 250 feet to prevent this occurrence.

The capital costs associated with each of the mitigation measures and the estimated annual operating and maintenance costs for all measures based on semi-annual inspections and periodic maintenance for Slough 11 are shown below and in Figure 33:

Mitigation Measure	Number Proposed	Capital Costs	Annual Operating & Maint. Costs
Wing deflector	1	24,000	
Weirs	2	61,000	
Bank stabilization	1	25,000	
Slough excavation	1	26,000	
Log barriers	15	24,000	
Protective berm	1	150,000	
Total		$310,000	$4,000

(v) Upper Side Channel 11

- Relative Utilization

(see Slough 11)

- Impact Mechamism

. Backwater Effects

The backwater at the side channel mouth affects a large portion of the area that has been spawned in the past. Overlaying the boundaries of the wetted surface area at 9,000 cfs indicate that dewatering of spawned area would be minimal. However, the depths at 9,000 cfs may be unsuitable for spawning.

. Breaching

The exceedance probability associated with the controlling breaching discharge of 16,000 cfs is 45 percent (Sautner et al. 1984). The recurrence interval for this breaching discharge is 1.06 years (Figure 10). This relatively high frequency of occurrence indicates that breaching flows are instrumental in providing access and passage and increasing the spawnable area in the side channel.

. Groundwater Upwelling

Mainstem discharge - groundwater upwelling relationship have not been developed for this side channel.

. Winter Flows

Similar to Slough 11 the probability of the side channel overtopping on a yearly basis is low to moderate.

. Restricted Access

Under natural conditions PR's I-III provide successful passage 100, 45 and 45 percent of the time. Case EVI and EV would eliminate successful passage conditions at all the PRs, principally through reduction in breaching flows (Table 20). Historically spawned area that would be lost are shown in Table 12.

- Mitigation

The majority of the spawning area in this side channel occurs below PR II and much of this could be retained under Case EVI or EV flows. Access to spawning areas above PR II will require excavation of the channel. The measure, accompanied with replacement of spawning gravels would provide more spawning habitat than currently exists.

Prevention of overtopping in the winter and during spring runoff will be accomplished by constructing a berm at the head of the side channel parallel to the flow. The berm would be 10 feet high and 1,000 feet in length.

The capitals costs associated with each of the mitigation measures and the estimated annual operating and maintenance costs based on semi-annual inspections and periodic repair of the meausres for Upper Side Channel 11 are shown below and in Figure 33:

Mitigation Measure	Number Proposed	Capital Costs	Annual Operating & Maint. Costs
Channel excavation	1	$ 26,000	
Protective slough berm	1	161,000	
Total		$187,000	$4,000

(vi) Slough 21

- Relative Utilization

During the 1981-1983 studies, the mean peak counts of chum salmon and sockeye salmon in Slough 21 and Side Channel 21 were 443 (range: 274-736) and 96 (range 38-197). The mean estimated total escapements to the slough were 958 chum (range: 481-1737) and 148 sockeye (range: 63-294) (Barrett et al. 1984). Slough 21 and Side Channel 21 mean chum escapements comprised 21.1 percent of the total escapement to sloughs in the middle Susitna River. The approximate percentage distribution of chum salmon during the 1984 spawning season for Slough 21 and Side Channel 21 is shown in Figure 34 (Seagren 1984, memo).

- Impact Mechanism

. Backwater

Spawning areas in the mouth of the slough do not appear to be dependent on backwater. Areas that were spawned under natural flows should remain spawnable under Cases EVI and EV.

. Breaching

The exceedance probabability associated with the controlling breaching discharge of 25,000 cfs for the left channel is 10 percent (Sautner et al. 1984). The recurrence interval for breaching flows through the left channel is 1.7 years (Figure 10). Breaching provides access and passage within the slough, but does not appreciably increase spawnable area. Neither Case EVI nor Case EV would provide breaching conditions.

- Groundwater Upwelling

Case EVI would reduce groundwater upwelling at the various passage reaches by approximately 77 percent during the spawning season. Case EV reductions would be approximately 38 percent (Appendix A, Tables A31-A39).

- Winter Flows

The ice front is predicted as far upstream as Slough 21 only during the coldest of years (Harza-Ebasco 1984b). The probability of the slough overtopping is very low.

- Restricted Access

PR's I, IIL, and IIR provide suitable passage conditions 100, 25 and 20 percent of the time under natural flow. Case EVI flows will reduce the frequency at PR' s I, IIL and IIR to 6, 0, and 1 percent, primarily as a result of reduced groundwater flow (Table 21). The frequency of passage for Case EV and Case EVI flows would be 100, 0, and 2 percent for PR's I, IIL and IIR. The restriction at PR IIL will eliminate the spawnable area above this point (Table 13). If passage were facilitated, much of the historically spawned area will not be of sufficient depth for use under project flows.

- Mitigation

Passage through Side Channel 21 is necessary prior to entry into Slough 21. Modification of passages reaches within Side Channel 21 is needed to permit fish access to the habitat in Slough 21.

Passage through Slough 21 will be ameliorated by the excavation of the channel profile. A 2 foot drop in the elevation of the profile corresponds to the mainstem stage reduction from natural conditions to Case EVI conditions. Large cobbles and boulders will be removed and used to stabilize the banks and channelize the flow.

After the large cobbles and boulders in the upper portion of the slough are removed, sorted gravel would be provided to increase the available spawning habitat.

The capital cost associated with the mitigation measure and the annual operating and maintenance costs based on semi-annual inspections and periodic repair for Slough 21 are shown below and in Figure 34:

Mitigation Measure	Number Proposed	Capital Costs	Annual Operating & Maint. Costs
Excavation of slough	1	$34,000	
Total		$34,000	$4,000

(vii) Side Channel 21

- Relative Utilization

(see Slough 21)

- Impact Mechanism

. Backwater

Evaluation of backwater effects on availability of spawning habitat are not applicable in light of the low breaching discharges.

. Breaching

A series of channels enter Side Channel 21 (SC21) along its length and each breaches at a different mainstem discharge (Figure 34). The uppermost channel, A6, has a breaching discharge of 24,000 cfs with an associated frequency of occurrence of 12 percent (Sautner et al. 1984). The recurrence interval for 24,000 cfs is 1.65 years (Figure 10. Spawning areas between the entry point of this channel into SC21 and next downstream channel, A5, are limited primarily by the depth provided by local flow and not breaching.

The exceedance probability of 71 percent and recurrence interval of 1.05 years associated with breaching discharges of 12,000 cfs at the A5 channel indicates that mainstem overflow into the side channel provided the required depths for much of the spawned area downstream from this point during the 1982-1984 seasons. This was confirmed by field observations of the channel at unbreached conditions in September, 1984 when areas spawned previously in the season were observed to be dewatered. Case EVI would not provide proposed breaching conditions while the 12,000 cfs provided by Case EV may cause the lower entry channel to breach.

. <u>Groundwater Upwelling</u>

Reductions in groundwater upwelling for Case EVI and Case EV would be 77 and 38 percent for the various passage reaches in Side Channel 21 (Appendix A, Tables A40-A49).

. <u>Winter Flows</u>

Similar to Slough 21, the ice front is only projected to reach Side Channel 21 in the coldest years. The probability of overtopping is low, although the side channel would overtop before the slough.

. <u>Restricted Access</u>

Under natural conditions, the frequencies of suitable passage conditions range from 71-100 percent for PR's I-X (Table 22). Under Case EVI conditions, successful passage conditions will be available about 30 percent of the time at PR's I-IV and one percent or less at PR's V-IX, based on current analysis. The majority of the spawning occurs above PR V and these areas would have restricted access (Table 13). Case EV should provide passage through all reaches 100 percent of the time.

- <u>Mitigation</u>

At project flows, the lack of breaching flows will impact fish passage within Side Channel 21. The frequency of fish passage will be increased by channelizing the local flow.

Passage reaches I-V will be improved by excavating a channel through the most restrictive sections of each passage reach.

Passage reaches upstream of PR V will be channelized with rock wing deflectors at the passage reaches. The flow through 2,500 feet of channel will be channelized with wing deflectors. Large cobbles and boulders will be removed to improve the frequency of fish passage through the reaches. Marginal spawning substrate in the upstream side channels will be replaced with sorted gravels to increase the available spawning habitat.

Winter overtopping of the berms along the length of Side Channel 21 is not anticipated since the ice front on the Sustina River is estimated to be downstream (Harza-Ebasco 1984b).

The capital costs associated with each of the mitigation measures and the annual operating and maintenance costs based on semi-annual inspections and periodic repair for Side Channel 21 are shown below and in Figure 34:

Mitigation Measure	Number Proposed	Capital Costs	Annual Operating & Maint. Costs
Excavation of channel	1	$45,000	
Wing deflectors for bank stabilization	6	240,000	
Total		$285,000	$5,000

(d) Development of New Spawning Areas

Case EVI and EV flows during the spawning season will reduce the mainstem flows from a median level of 15,000 cfs for the August 20-September 20 period to minimum required flows of 9,000 and 12,000 cfs. This reduction will result in the transformation of many side channels to sloughs. Areas in which spawning was limited by high velocity under natural conditions may become suitable for spawning assuming other physical habitat requirements are satisfied.

Habitat modifications to these new areas may prove more cost-effective than the measures required to maintain the production in some of the existing sloughs and side channels.

Substrate may be unsatisfactory either because the particle size distribution is outside the preferred range for spawning or the substrate is of appropriate size but has become embedded with sands and silts under the natural flow regimes. Modification measures that would be taken to remedy these conditions would be replacement of inappropriate substrate with suitable spawning gravel and scarifying the embedded substrate particles to remove the sand and silts.

Preliminary screening of candidate mainstem and side channel sites is currently underway. Site selection and monitoring of physical variables are critical steps in assessing the potential success of proposed replacement spawning areas. A list of mainstem and side channel sites at which physical variables are presently being monitored is presented in Table 23. Evaluations of the potential of these sites to provide additional spawning habitat will be made as data become available.

2.2.2.3 - Artificial Propagation

An alternative means to achieve the mitigation goal of maintaining chum salmon production is through artificial propagation. Mitigation by artificial propagation would be considered if other mitigation measures are ineffective. The artificial propagation method selected for mitigation for salmon spawning habitat losses in the middle Susitna River is stream-side egg incubation boxes. The emergent fry would be returned to the sloughs for rearing and/or migration. Egg boxes with gravity fed water systems are well suited for remote-site installation because they are cost effective and require little maintenance.

(a) Design and Operation of Egg Box

A stream-side egg incubation box similar to that used extensively on the Gulkana River in Alaska for artificial propagation of sockeye salmon would be used. The egg box is a 4 ft x 4 ft x 8 ft gravel-filled upwelling box capable of incubating 500,000 eggs. The box would be insulated to protect against freezing.

In each egg box 500,000 green eggs (those just-fertilized) are placed on the gravel surface and incubated. At hatching the alevins fall or migrate into gravel interstitial spaces and reside there until the yolk-sac has been absorbed, at which time they emerge from the gravel and leave the box. Survival from green egg to emergent fry has averaged 85 percent (Roberson ADF&G, pers. comm., 1984).

(b) Site Selection Criteria

The primary concern in siting the egg boxes is the availability of a dependable water source. The water should be sediment free, meet water quality standards and be gravity-fed to the egg boxes. The latter is of primary concern due to the low reliability and high cost of pumping water. Other criteria are access to the site and proximity to a slough for juvenile release and adult return. Curry Station (RM 120) appears to satisfy the above criteria for site location.

(i) Water Supply

Curry Station has an existing gravity-fed surface water system. Using an existing system is more economical than developing a new one. The system at Curry was built in the 1930's as a water supply for the railway construction camp. It consists of an impoundment structure and pipeline which draws water year round. Before an egg box program is implemented, detailed flow rates, temperature and water quality data would need to be obtained. Information on the seasonal temperature variation of the water source will be used to predict the emergence timing of fry and to select the proper brood stock.

(ii) Slough Proximity

Another aspect of site location is the proximity to a slough. The slough will be utilized in two ways. First, emergent fry from the egg boxes will be released directly into the slough for additional rearing and/or migration. Second, the slough will serve as an adult return area and will facilitate procurement of the brood stock. Curry Slough is approximately 4,000 feet downstream from Curry Station and can be utilized, although it may need some modifications to make it suitable.

(iii) Site Access

Curry Station is easily accessible by helicopter and rail. The close proximity of the railway will facilitate movement of materials and equipment to the site.

(b) Brood Stock

The initial selection of brood stock will depend on the temperature profile of the water source. It appears that the existing water source is colder than intergravel temperatures to which incubating eggs are exposed. This may cause the fry produced from egg box to emerge later than native fry. If this delay exceeds the natural variation in emergence timing for native fry, the tributary spawning chum in the middle Susitna River, or another stock of earlier-spawning chum, will be selected to allow the egg box fish to emerge at the estimated escapement to the sloughs in the Talkeetna to Devil Canyon reach of the Susitna River, approximately the same time as native fry.

The donor stock will be utilized for the first five years of the project since Susitna chum predominantly return at 4 and 5 years of age. After the initial 5 year introduction period the returning adults will serve as the brood stock. To mitigate for the loss of 4,200 chum, approximately 700,000 eggs (250 females) will be needed for egg box incubation. This figure is based on maintaining the 4,200 chum escapement using the following assumptions: 1.1:1 male to female ratio (Barrett et al. 1984), a 15 percent egg-to-fry survival (Schmidt et al. 1984), a fecundity of 2,850 eggs per female, and a 0.7 percent fry to adult return (including harvest) (Barrick et al. 1983). Excess returns to the egg box facility will be allowed to spawn naturally in adjacent sloughs. To insure genetic diversity of the artificially propagated stock, eggs from each female will be fertilized with the gametes of several males.

(c) Alternatives for Development

There are two alternatives for the Curry Station egg box site. The first is a plan to establish the egg box site at Curry Slough and the second is a plan for development of the egg box site at Curry Station.

(i) Curry Slough Development

Establishing the egg box site at Curry Slough will require the water source presently at Curry Station (approximately 4,000 feet upstream) to be piped to Curry Slough. This will entail burying (to safeguard against freezing and physical damage) approximately 4,000 feet of 6-inch diameter pipe. The egg boxes will be set up near the downstream end of Curry Slough and emergent fry will be released directly into the slough from the egg boxes. The slough will be appropriately sloped to facilitate downstream migration of fry and to ensure that returning adults have access to the slough. The advantage of locating the boxes adjacent to the slough, is that the emergent fry can be released without being handled. Fry will be released into the slough to allow for acclimation and/or rearing before seaward migration. Releasing newly emerged fry directly into the mainstem would not allow for acclimation and orientation. The costs for this option are outlined in Appendix B and summarized below:

Mitigation Measure	Number Proposed	Capital Costs	Annual Operating & Maint. Costs
Artificial propagation	2	$450,000	$50,000
Total		$450,000	$50,000

(ii) Curry Station Development

The Curry Station development consists of installing the egg boxes near the outfall of the existing water system. This will require a minimal amount of pipe, which can be installed above ground if insulated pipe is used. Newly emergent fry will be collected in two 18-foot-diameter x 4 foot deep above-ground rearing ponds. Fry will be transported daily to Curry Slough and released. This installation has the disadvantage of extensive handling of fry. The costs for this option are outlined in Appendix B and summarized below:

Mitigation Measure	Number Proposed	Capital Costs	Annual Operating & Maint. Costs
Artificial propagation	2	$81,000	$35,000
Total		$81,000	$35,000

2.2.3 - Monitoring Studies

Monitoring studies are recognized as an essential projects mitigation feature that provides for a reduction of impacts over time (APA 1982). Operational monitoring will be conducted to (1) monitor salmon population and production levels to ensure that the predicted level of impact is not being exceeded, and (2) evaluate the effectiveness of the project mitigation plan.

2.2.3.1 - Impact Monitoring of Salmon Populations

Salmon populations in the Devil Canyon to Talkeetna reach will be monitored to assess whether populations maintain historical levels during the operation phase. Monitoring will consist of enumerating returning adults that pass Sunshine and Curry Stations and monitoring smolt out-migration from the reach. Adults will be enumerated using the fishwheel tag/recapture program currently being used in the baseline studies. The smolt out-migration will be evaluated using a smolt trap program to the one conducted during the 1982 to 1984 baseline studies program.

The results of these studies will be used to evaluate changes in the population size, species composition or changes in stream use patterns of the five Pacific salmon species. Results of the mitigation monitoring described in the following section will be used to assess the cause of changes.

2.2.3.2 - Mitigation Monitoring

Mitigation features to be monitored for evaluation of the level of mitigation being achieved include:

- Slough modification
- Replacement habitats
- Egg boxes

The monitoring activity will include evaluating the operation and maintenance procedures to ensure that the facilities are operating effectively. If a mitigation feature is not meeting the intended level of effectiveness, modifications to the mitigation feature will be made to increase its effectiveness.

(a) Monitoring Slough Modifications

The various measures incorporated for slough habitat maintenance will be monitored to assess whether they are meeting their intended function and are operating properly. Methods used to evaluate the slough mitigation features will be consistent with methods currently being used to assess baseline conditions of the parameters to be monitored.

Mitigation features designed to allow adult salmon passage into and within the sloughs will be annually inspected after breakup to identify and conduct needed repairs prior to the adult return. Annual monitoring of returning adults will allow identification of additional passage problems. Appropriate corrective actions will be taken.

Modifications to sloughs designed to maintain spawning areas will be annually inspected prior to the spawning season to verify that the area contains suitable spawning conditions such as upwelling, amount of flow, depth of water, and suitable substrate. Areas that become overly silted will be cleaned. If slough flows diminish so that spawning is no longer possible, appropriate corrective actions will be taken.

The number of spawning adults returning to the sloughs will be monitored annually to measure changes in distribution to assess if the combination of minimum flow and slough modifications is maintaining natural production. This monitoring will also serve to assess whether the capacity of the modified areas is being exceeded. Appropriate remedial actions will be taken when spawning sites are inadequate.

Fry production will be monitored annually to evaluate incubation success. Fry monitoring will include an assessment of out-migration timing and success.

The annual slough monitoring will include an evaluation of general slough conditions including vegetative encroachment, beaver occupation, and general condition of the spawning and rearing areas. Appropriate remedial actions will be performed to maintain slough productivity.

Representative sloughs will be monitored for temperature and slough flow. Monitoring of the physical processes will be continued until slough conditions stabilize under the regulated flow regime. This monitoring will be used in part to assess whether further modifications to the physical habitat must be made to maintain slough productivity.

(b) Monitoring Replacement Habitats

Replacement habitats which develop as a result of the lower and more stable project mainstem flows during the spawning season will be monitored to quantify use of these areas by adult salmon. Monitoring methodology will be similar to that currently used to evaluate spawning habitats and will include standard physical and chemical measurements as well as biological analyses.

(c) Monitoring of Artificial Propagation

Stream-side egg boxes, if utilized, will be monitored to evaluate their effectiveness in producing the number of returning chum salmon for which they were designed.

3 - IMPOUNDMENT MITIGATION

3.1 - Introduction and Background

The primary long-term impact associated with the filling of the Watana and Devil Canyon reservoirs is the loss of clear-water tributary habitat (APA 1983). The tributary habitat that will be inundated currently supports a population of Arctic grayling, estimated in 1982 to be at least 16,300 fish. Aquatic habitats within the reservoirs are not expected to support a significant grayling population.

In the impoundment area, Arctic grayling was selected as the evaluation species for mitigation because of its abundance in the area, its sensitivity to impacts during all seasons and life stages, and its desirability as a sport fish. Measures to avoid, minimize, rectify or reduce the anticipated loss of spawning and Arctic grayling habitats are considered infeasible (APA 1983). Therefore, measures to compensate for the loss of Arctic grayling habitat are the options being considered for impoundment mitigation planning.

Impoundment mitigation options to compensate for lost Arctic grayling habitat were outlined in Exhibit E, Federal Energy Regulatory Commission License Application (APA 1983) and included: (1) funding of research on Arctic grayling propagation technology; (2) hatchery propagation of Arctic grayling and the subsequent stocking of the reared fish (i.e. fingerling); (3) stocking of hatchery-reared rainbow trout if Arctic grayling propagation proved to be technically infeasible; and (4) the introduction of rainbow trout into the Devil Canyon reservoir. Agency comments on the hatchery-rearing of Arctic grayling were generally negative and concluded that grayling production in Alaska must be considered experimental and compensation must be judged as speculative (ADF&G 1983c). Reasons for this position were: (1) the lack of a reliable egg source; (2) low survival from the green egg to fry stage; (3) unsuccessful attempts to rear grayling fry to fingerling in hatcheries; and (4) the inability to evaluate survival of stocked fry because of their small size.

3.2 - Mitigation Options

In the draft EIS, the FERC staff recommended that kokanee be considered for stocking in the impoundment reservoirs (FERC 1984). Stocked kokanee would: (1) provide sport fishing opportunities and (2) fill a niche in the reservoirs as a pelagic forage fish species. An evaluation of this alternative will also be presented in the April 1985 report. Rainbow trout and Arctic grayling are evaluated below.

3.2.1 - Rainbow Trout

Rainbow trout is the species being considered for primary compensation for lost Arctic grayling habitat. A rainbow trout propagation and a stocking program has documented success in Alaska and there is a high demand for the species by sport anglers.

It appears that Devil Canyon reservoir may be too turbid to successfully grow rainbow trout to a desired size. Turbidity levels in Devil Canyon reservoir are expected to be in the range of 40-50 NTUs with light penetrating about one meter into the water column (T. Stewart, Harza-Ebasco, pers. comm. 1984). Primary production in Devil Canyon reservoir is expected to be low as a result of the turbidity levels. Because the success of a stocking program of rainbow trout in Devil Canyon reservoir is uncertain, the reservoir's ~~limnology and resident fish populations before initiating a stocking program for any species.~~

Sport fishing opportunities would be available to a larger number of people if fish were stocked near population centers. Additionally, stocking sites can be chosen that will have a higher probability of success than Devil Canyon reservoir. Rainbow trout have been successfully stocked in numerous lakes in the Matanuska-Susitna Valley area (L. Engel, ADF&G, Palmer, pers. comm. 1984). Case histories, cost analyses and stocking areas for a rainbow trout stocking program will be discussed in the impoundment mitigation plan scheduled for 1985.

3.2.2 - Arctic Grayling

Arctic grayling stocking is desirable because of "in-kind" replacement for lost spawning and rearing habitat. In 1984, significant progress was made in Arctic grayling propagation technology. About 100,000 grayling fingerling (approximately 50 to 60 mm) were reared at Clear Hatchery (D. Parks, ADF&G Hatchery Manager, Clear, Alaska, pers. comm. 1984). Feeding experiments with various kinds of commercial feeds, automatic feeders, and increased light intensity are factors that were thought to be important in the successful rearing of grayling fingerling. The survival rate was about 70 percent from emergent sac-fry to 2 gram fingerling for one experimental group, which is about seven times greater than previous survival rates for emergent sac-fry to fingerling.

Because significant progress in Arctic grayling propagation technology is being made and the desirability of "in-kind" replacement, grayling is still considered a primary candidate species for compensation. The impoundment mitigation plan scheduled for April 1985 will discuss propagation technology for Arctic grayling and examine areas that need further research, such as brood stock development, commercial feeds, vitamin deficiencies, disease problems, stocking evaluation, stocking areas.

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4 - REFERENCES

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TABLES

Table 1. Summary of estimated costs for habitat modification measures in selected sloughs and side channels.

	Slough 8A		Slough 9		Slough 9A		Slough 11		USC 11		Slough 21		Side Channel 21		Total	
	Capital Costs	O&M	Capital Costs	O&M	Capital Costs	O&M	Capital Costs	O&M	Capital Costs	O&M	Capital Costs	O&M	Capital Costs	O&M	Capital Costs	O&M
Slough Mouth Excavation	26,000		26,000												52,000	
Wing Deflector	24,000						24,000						240,000		288,000	
Passage Reach Excavations	10,000		7,000												17,000	
Protective Berm	61,000		59,000		42,000		24,000		161,000						347,000	
Log Barriers			30,000				24,000								54,000	
Bank Stabilization							25,000								25,000	
Rock Weir			37,000				61,000								98,000	
Total Slough Excavations					76,000		26,000		26,000		34,000		45,000		207,000	
Total	121,000	4,000	159,000	4,000	118,000	4,000	184,000	4,000	187,000	4,000	34,000	5,000	285,000	5,000	1,088,000	30,000

Table 2. 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] % 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	---	---
Yentna[6] (RM 28)	119,200	48	19,500	5	20,000	23	Even 447,300 Odd 48,400	34 35	---	---
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	---
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	---
Total Susitna	249,900	100	356,200	100	86,800	100	Even 1,267,900 Odd 138,200	100	---	---

1 1981-83 average of ADF&G second-run sockeye escapements
2 1981-83 average of ADF&G escapement estimates
3 Even year 1982 only; odd year 1981 and 1983 average; from ADF&G escapement estimates
4 1982-83 average of ADF&G escapement estimates
5 Lower Susitna sub-basin equals total Susitna basin escapement minus Yentna and Sunshine escapements
6 Yentna sub-basin escapement from ADF&G estimates at Yentna Station (TRM 04)
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% (Barrett 1984)
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 (Barrett 1984)

Table 3. Chum salmon peak index counts by habitat type above RM 98.6, 1981-1983.

Habitat Type	1981	1982	1983	3-Year Average
Mainstem[1]	16	550	219	262
Streams	241	1,737	1,500	1,159
Sloughs[2]	2,596	2,244	1,467	2,102
Total	2,853	4,531	3,186	3,523

Source: ADF&G 1981a, 1982a, Barrett et al. 1984

1 Includes main channel and side channel habitats

2 Includes upland slough and side slough habitats

Table 4. Chum salmon peak index counts in sloughs above RM 98.6, 1981-83.

Slough	River Mile	1981	1982	1983	3-Year Average
1	99.6	6	0	0	2
2	100.2	27	0	49	25
3B	101.4	0	0	3	1
3A	101.9	0	0	0	0
4	105.2	0	0	0	0
5	107.6	0	2	1	1
6	108.2	0	0	0	0
6A	112.3	11	2	6	6
7	113.2	0	0	0	0
8	113.7	302	0	0	101
8D	121.8	0	23	1	8
8C	121.9	0	48	4	17
8B	122.2	1	80	104	62
Moose	123.5	167	23	68	86
A'	124.6	140	0	77	72
A	124.7	34	0	2	12
8A	125.1	620	336	37	331
B	126.3	--	58	7	--
9	128.3	260	300	169	243
9B	129.2	90	5	0	32
9A	133.8	182	118	105	135
10	133.8	0	2	1	1
11	135.3	411	459	238	369
12	135.4	0	0	0	0
13	135.9	4	0	4	3
14	135.9	0	0	0	0
15	137.2	1	1	2	1
16	137.3	3	0	0	1
17	138.9	38	21	90	50
18	139.1	0	0	0	0
19	139.7	3	0	3	2
20	140.0	14	30	63	36
21	141.1	274	736	319	443
22	144.5	--	--	114	---
21A	144.3	8	0	0	3
Total		2,596	2,244	1,467	2,102[1]

Source: ADF&G 1981a, 1982a, Barrett et al. 1984

[1] Three-year average of totals

Table 5. Second-run sockeye salmon peak survey counts in sloughs above RM 98.6, 1981-1983.

Slough	River Mile	1981	1982	1983
3B	101.4	1	0	5
3A	101.9	7	0	0
6A	112.3	1	0	0
8C	121.9	0	2	0
8B	122.2	0	5	0
Moose	123.5	0	8	22
8A	125.1	177	68	66
B	126.3	0	8	2
9	128.3	10	5	2
9B	129.2	81	1	0
9A	133.8	2	1	1
10	133.8	0	0	1
11	135.3	893	456	248
17	138.9	6	0	6
19	139.7	23	0	5
20	140.1	2	0	0
21	141.1	38	53	197
Total		1,241	607	555

Source: ADF&G 1981a, 1982a, Barrett et al. 1984

Table 6. Pink salmon total slough escapement above RM 98.6, 1981-1983.

Slough	River Mile	1981	1982	1983
8	113.7	38	0	0
Moose	123.5	0	2	0
8A	125.1	0	5	0
B	126.3	0	18	0
9	128.3	0	18	0
11	135.3	0	170	0
20	140.0	0	75	0
21	141.1	0	9	0
Total		38	297	0

Source: Barrett et al. 1984

Table 7. Selected rivers with hydroelectric projects and associated mitigations for anadromous fish species.

Terror Lake, AK

Average Discharge:	Pre-project 279 cfs, post-project 181 cfs.
Species:	Pink, chum and coho salmon, Dolly Varden.
Projects:	Alaska Power Authority - diversion dam for hydroelectric project.
Mitigation:	Instream flow requirements and monitoring program.

Tyee Creek, AK

Species:	Intertidal spawning pink and chum salmon.
Projects:	Alaska Power Authority - diversion dam for hydroelectric projects may eliminate flow to Tyee Creek.
Mitigation:	Spawning gravels were added to the tailrace area as replacement spawning habitat.

Blue Lake, AK

Species:	Pink, chum and coho salmon, Dolly Varden.
Projects:	City of Sitka, diversion dam
Mitigation:	Instream flow requirements.

Ketchikan Creek, AK

Species:	Natural and hatchery runs of chinook, pink, coho and chum salmon.
Projects:	Ketchikan Public Utility, dam and powerhouse
Mitigation:	Instream flow requirements

Solomon Creek, AK

Species:	Chum, pink, and coho salmon.
Projects:	Alaska Light and Power, dam and powerhouse.
Mitigation:	Instream flow requirements and flow fluctuation restrictions to prevent deposition of fines during high flow period.

Table 7 (Continued)

Skagit River, WA

Average Discharge:	15,190 cfs (below Baker River). Below City of Seattle project average discharge 4282 cfs to Baker River.
Species:	Summer chinook, fall chinook, sockeye, pink, coho and chum salmon, steelhead; spring, summer and fall chinook (main river and tributary spawning). Pinks and chums (main river spawning and tributary spawning). Steelhead (mainstem and tributary spawning).
Projects:	Three City of Seattle projects (1 large, 1 medium, 1 small storage reservoirs, all with power plants).
Mitigation:	Minimum flows for prevention of juvenile stranding. Ramping rate restrictions. Augmentation from a hatchery at Marblemount. These features were not in operation when the City of Seattle began operations and resulted from a voluntary agreement between the City of Seattle and state agencies.

Baker River, WA

Average Discharge:	2,520 cfs
Species:	River had spring chinook, sockeye, coho and steelhead. Now has only sockeye and coho.
Projects:	Puget Sound Power & Light Company (2 dams & 2 powerhouses)
Mitigation:	Fish are trapped below lower dam and hauled above the upper dam. Traps are used in the lakes for collection and downstream passage.

Sultan River, WA

Average Discharge:	775 cfs
Species:	Coho and steelhead present.
Projects:	City of Everett - water supply. Snohomish County P.U.D. (1 dam and 1 powerhouse).
Mitigation:	None for many years. Now has a flow control program.

Table 7 (Continued)

<u>Tolt River, WA</u>	
Average Discharge:	575 cfs
Species:	Pink, coho, fall chinook and chum salmon, fall chinook and steelhead trout
Projects:	Diversion dam. City of Seattle - water supply.
Mitigation:	Has minimum flow control regulation
<u>Cedar River, WA</u>	
Average Discharge:	684 cfs
Species:	Sockeye, steelhead, chinook
Projects:	City of Seattle - water supply and small powerhouse
Mitigation:	Flow control regulation implemented, plus a new hatchery.
<u>Green River, WA</u>	
Average Discharge:	1,270 cfs
Species:	Summer and fall chinook and steelhead (Many years ago had pink and chum runs.)
Projects:	City of Tacoma - water supply (diversion of flow)
Mitigation:	Has minimum flow release regulation for fisheries.
<u>White River, WA</u>	
Average Discharge:	1,372 cfs
Species:	Spring chinook and steelhead (small coho run)
Projects:	Corps of Engineers - flood control. Puget Sound Power & Light Company - diversion of flow with lake storage.
Mitigation:	Has minimum flow release. Screen diversion. Issue resolution continuing

Table 7 (Continued)

Nisqually River, WA

Average Discharge: 1,695 cfs

Species: Spring and fall chinook, pink, coho and chum salmon

Projects: City of Tacoma (2 powerhouses and 1 storage dam). City of Centralia - diversion of flow.

Mitigation: Instream flow requirements for salmon. City built a hatchery (about 1916) which was not used and is now gone.

Elwha River, WA

Average Discharge: 1,450 cfs

Species: Summer chinook, pink, coho and summer and winter steelhead

Projects: Rayonier Pulp and Washington Pulp and Paper (2 dams, 2 power plants and 1 storage reservoir behind upper powerhouse).

Mitigation: No mitigation initially (1914) at lower dam. Leakage has kept fish runs below the lower dam alive. Now has rearing pond and Indian hatchery to help support salmon runs. National Parks Service plans to reopen area above upper dam for anadromous stocks.

Wynoochee River, WA

Average Discharge: 750 cfs (above the dam)

Species: Coho, chum and steelhead

Projects: Corps of Engineers dam (flood control and water supply). A power plant and a hatchery are now planned.

Mitigation: Flow release based on river cross sectional work.

Cowlitz River, WA

Average Discharge: 9,330 cfs

Species: Spring chinook, fall chinook and coho salmon and steelhead trout

Projects: City of Tacoma (1 large storage basin and 2 power plants)

Mitigation: Flow regulation required in license. Now has two hatcheries.

Table 7 (Continued)

<u>Lewis River, WA</u>

Average Discharge:	4,897 cfs
Species:	Spring chinook, fall chinook and coho salmon and steelhead
Projects:	Three major dams and powerhouses.
Mitigation:	Has flow regulation below lower dam. Initially a hatchery for spring chinook was constructed and operated. Flow control used to maintain fall chinook runs.

<u>Big White Salmon River, WA</u>

Average Discharge:	1,075 cfs
Species:	Fall chinook. Very limited area for spawning below dam.
Projects:	Pacific Power and Light - Condit Dam
Mitigation:	Fish are taken and eggs shipped to a hatchery for artificial propagation. Early fish ladder failed, rebuilt and failed again. Site of first attempt to brail fish above a dam.

<u>Upper Columbia River, WA</u>

Average Discharge:	(Grand Coulee Dam) 64,800 cfs
Mitigation:	Three hatcheries built to perpetuate runs which went above dam.

<u>Snake River, ID</u>

Average Discharge:	20,650 cfs
Species:	Spring and late summer chinook and steelhead. (Had at one time a run of coho.)
Projects:	Idaho Power Company - Hells Canyon Dam (lowest of three dams)
Mitigation:	Flow regulation and hatchery at Brownlee. Fish are trapped at Hells Canyon for artificial propagation. There are minimum flow requirements and ramping rate limitations.

Table 7 (Continued)

<u>North Santiam River, OR</u>

Average Discharge:	3,367 cfs.
Species:	Spring chinook. There is main stream spawning.
Project:	Has 1 large storage reservoir and power plant and 1 reregulation pool and power plant (Corps of Engineers).
Mitigation:	Adults trapped for egg collection and hatchery rearing.

<u>Clackamas River, OR</u>

Average Discharge:	3,636 cfs.
Species:	Spring chinook
Projects:	Portland General Electric Company - 3 plants
Mitigation:	Have fishways and partial screening.

<u>Deschutes River, OR</u>

Average Discharge:	830 cfs
Species:	Spring and fall chinook and spring and summer steelhead
Projects:	Pelton Dam - Portland General Electric Company
Mitigation:	Hatchery. Has a fishway which has problems associated with seasonal flow changes.

Table 8. Area spawned between passage reaches within Slough 8A for 1982, 1983 and 1984. The ratio of the composite to the total area spawned for all years and percent distribution of spawning fish in 1984 are also shown.

Passage[1] Reaches	Area Spawned (ft^2) 1982	1983	1984	Percent[2] Distribution 1984	Composite Area 1982-1984	Composite/ Total
Mouth - I	1,800	11,000	17,100	5	26,200	0.88
I-II	20,900	9,700	90,600	↓	93,800	0.77
II-III	3,800	2,600	36,200	60	36,800	0.86
III-IV	5,700	12,000	96,500	↓	102,200	0.89
IV-V	0	0	10,700	20	10,700	1.0
V-VI	0	0	9,600	↓	9,600	1.0
VI-VII	3,900	0	11,200	5	13,700	0.91
VII-VIII	7,700	0	500	↓	8,100	0.99
VIII-IX	0	0	200		200	1.0
IX-head	0	0	4,900		4,900	1.0

[1] As designated in Sautner et al. 1984

[2] Seagren 1984, memo

Table 9. Area spawned between passage reaches within Slough 9 for 1982, 1983 and 1984. The ratio of the composite to the total area spawned for all years and percent distribution of spawning fish in 1984 are also shown.

Passage Reaches[1]	Area Spawned (ft^2) 1982	1983	1984	Percent Distribution[2] 1984	Composite Area 1982-1984	Composite/ Total
Mouth - II	17,200	4,700	0		21,800	.99
II-III	21,500	25,300	24,300	60	41,500	0.58
III-IV	7,000	4,000	4,900	↓	10,700	0.67
IV-V	7,700	3,200	3,800	8	8,100	0.55
V-head	33,000	6,800	31,500	32	50,500	.71

1 As designated in Sautner et al. 1984

2 Seagren 1984, memo

Table 10. Area spawned between passage reaches within Slough 9A for 1982, 1983 and 1984. The ratio of the composite to the total area spawned for all years and percent distribution of spawning fish in 1984 are also shown.

Passage[1] Reaches	Area Spawned (ft^2) 1982	1983	1984	Percent[2] Distribution 1984	Composite Area 1982-1984	Composite/ Total
Mouth - I	4,500	3,900	0	50	4,800	0.57
I-II	1,300	8,200	2,200	↓	15,700	0.67
II-III	4,500	4,800	1,600	↓	6,100	0.56
III-IV	10,700	4,600	5,500	↓	11,400	0.55
IV-V	20,600	13,200	11,800	↓	28,400	0.62
V-VI	9,000	10,000	11,500	10	18,300	0.60
VI-VII	13,000	2,800	1,700	10	15,200	0.87
VII-VIII	7,400	6,400	6,100	↓	13,100	0.66
VIII-IX	0	2,500	3,800	10	6,300	1.00
IX-X	8,600	5,800	12,600		12,500	0.46
X-head	9,400	0	5,800	20	10,200	9.67

1 As designated in Sautner et al. 1984

2 Seagren, 1984, memo

Table 11. Area spawned between passage reaches within Slough 11 for 1982, 1983 and 1984. The ratio of the composite to the total area spawned for all years and percent distribution of spawning fish in 1984 are also shown.

Passage Reaches[1]	Area Spawned (ft^2) 1982	1983	1984	Percent Distribution[2] 1984	Composite Area 1982-1984	Composite/ Total
Mouth - I	23,500	43,600	33,300	10	76,900	0.77
I-II	12,400	18,300	22,200	15	30,400	0.57
II-III	24,000	7,700	37,600	40	54,100	0.78
III-IV	5,900	8,000	5,200	5	77,000	0.69
IV-V	5,800	8,000	10,400	25	12,000	0.50
V-head	24,000	4,700	14,100	5	33,400	0.78

[1] As designated in Sautner et al. 1984

[2] Seagren 1984, memo

Table 12. Area spawned between passage reaches within Upper Side Channel 11 for 1982, 1983 and 1984. The ratio of the composite to the total area spawned for all years and percent distribution of spawning fish in 1984 are also shown.

Passage Reaches[1]	Area Spawned (ft^2) 1982	1983	1984	Percent[2] Distribution 1984	Composite Area 1982-1984	Composite/ Total
Mouth - I	12,100	40,600	24,500	60	48,200	0.62
I-II	12,300	21,800	8,200	↓	25,700	0.61
II-III	12,300	11,300	23,400	40	35,700	0.76
III-IV	0	5,500	6,100		6,100	0.53

1 As designated in Sautner et al. 1984

2 Seagren 1984, memo

Table 13. Area spawned between passage reaches within Slough 21 Complex for 1982, 1983 and 1984. The ratio of the composite to the total area spawned for all years and percent distribution of spawning fish in 1984 are also shown.

Passage Reaches[1]	Area Spawned (ft^2) 1982	1983	1984	Percent[2] Distribution 1984	Composite Area 1982-1984	Composite/ Total
Side Channel 21						
Mouth - I	0	0	0		0	0
I-II	0	0	0		0	0
II-III	0	5,900	2,800		8,700	1.0
III-IV	0	4,100	2,700	20	4,800	0.71
IV-V	20,000	27,400	67,800	15	75,000	0.65
V-VI	1,000	11,300	6,300		12,600	0.67
VI-VII	4,000	0	0		4,000	1.0
VII-VIII	0	0	300		300	1.0
VIII-IX	12,000	0	1,400		13,300	0.99
IX-X	35,700	9,600	82,400		95,600	0.75
X-SL21/PRI	20,700	27,500	42,600	40	49,800	0.55
I - IIC & IIR						
Slough 21	6,100	32,000	26,600	25	36,900	0.57
IIL	0	1,700	0		1,700	1.0
IIR	7,700	15,600	7,300		21,300	0.70

1 As designated in Sautner et al. 1984

2 Seagren 1984, memo

Table 14. Mean monthly discharges at Gold Creek for natural conditions and Case P-1.

Month	Natural (cfs)	Case P-1 (cfs)
January	1,440	10,900
February	1,210	9,200
March	1,090	7,900
April	1,340	7,300
May	13,400	8,800
June	28,150	10,500
July	23,990	8,900
August	21,950	9,800
September	13,770	10,900
October	5,580	10,200
November	2,430	10,600
December	1,750	12,100

Table 15. Relationship between mitigation alternatives and the impacts for which they are applicable.

Mitigation alter-natives/impact issue	Inadequate passage	Loss of physical habitat	Loss of upwelling	Winter overtopping of slough berm
channel width modification	P			
channel barrier construction	P			
Flow augmentation	P	P	S	
Upwelling augmentation	S	S	P	
Slough excavation	P	P	P	
creating spawning habitat in pools		P	S	
Increase berm height				P

P = primary effect

S = secondary effect

Table 16. Condition which provides successful passage most frequently and approximate percent of time that passage is successful during the period 20 August - 20 September at Slough 8A.

Passage Reach	Natural		Project 12,000 cfs		Project 9,000 cfs		Project 8,000 cfs		All Project Flows With Mitigation	
	Cond.	Occurrence (%)	Cond.	Occurrence (%)	Cond.	Occurrence (%)	Cond.	Occurrence (%)	Cond.	Occurrence (%)
I	BW	100	BW	100	SW/GW	34	SW/GW	32	SW/GW	100
II	BW	48	SW/GW	22	SW/GW	20	SW/GW	20	SW/GW	100
III	SW/GW	25	SW/GW	22	SW/GW	20	SW/GW	20	SW/GW	100
IV	SW/GW	14	SW/GW	12	SW/GW	10	SW/GW	10	SW/GW	100
V	SW/GW	13	SW/GW	11	SW/GW	9	SW/GW	9	SW/GW	100
VI	SW/GW	14	SW/GW	13	SW/GW	12	SW/GW	12	SW/GW	100
VII	SW/GW	13	SW/GW	13	SW/GW	11	SW/GW	11	SW/GW	100
VIII	SW/GW	6	SW/GW	6	SW/GW	5	SW/GW	4	SW/GW	100
IX	BR	2	---	0	---	0	---	0	SW/GW	0

BW is backwater condition which neglects the effect of local flow

BR is breaching condition which represents controlling discharge through the slough

SW/GW is surface water and groundwater condition with a median natural flow or minimum project flow controlling groundwater levels and surface water related to precipitation events.

Appendix B contains an explanation of the derivation of the percent exceedance values

Table 17. Condition which provides successful passage most frequently and approximate percent of time that passage is successful during the period 20 August - 20 September at Slough 9.

Passage Reach	Natural		Project 12,000 cfs		Project 9,000 cfs		Project 8,000 cfs		All Project Flows With Mitigation	
	Cond.	Occurrence (%)	Cond.	Occurrence (%)	Cond.	Occurrence (%)	Cond.	Occurrence (%)	Cond.	Occurrence (%)
I	SW/GW	100	SW/GW	100	SW/GW	47	SW/GW	44	SW/GW	100
II	SW/GW	100	SW/GW	100	SW/GW	100	SW/GW	100	SW/GW	100
III	SW/GW	18	SW/GW	16	SW/GW	15	SW/GW	14	SW/GW	100
IV	SW/GW	17	SW/GW	16	SW/GW	14	SW/GW	14	SW/GW	100
V	BR	29	---	0	---	0	---	0	SW/GW	100

BW is backwater condition which neglects the effect of local flow

BR is breaching condition which represents controlling discharge through the slough

SW/GW is surface water and groundwater condition with a median natural flow or minimum project flow controlling groundwater levels and surface water related to precipitation events.

Appendix B contains an explanation of the derivation of the percent exceedance values

Table 18. Condition which provides successful passage most frequently and approximate percent of time that passage is successful during the period 20 August - 20 September at Slough 9A.

Passage Reach	Natural		Project 12,000 cfs		Project 9,000 cfs		Project 8,000 cfs		All Project Flows With Mitigation	
	Cond.	Occurrence (%)	Cond.	Occurrence (%)	Cond.	Occurrence (%)	Cond.	Occurrence (%)	Cond.	Occurrence (%)
I	SW/GW	100	SW/GW	100	SW/GW	100	SW/GW	100	SW/GW	100
II	SW/GW	100	SW/GW	100	SW/GW	100	SW/GW	41	SW/GW	100
III	SW/GW	100	SW/GW	100	SW/GW	32	SW/GW	14	SW/GW	100
IV	SW/GW	100	SW/GW	100	SW/GW	100	SW/GW	100	SW/GW	100
V	SW/GW	100	SW/GW	100	SW/GW	100	SW/GW	20	SW/GW	100
VI	SW/GW	100	BR	100	SW/GW	24	SW/GW	14	SW/GW	100
VII	SW/GW	100	BR	100	SW/GW	10	SW/GW	7	SW/GW	100
VIII	SW/GW	100	BR	100	SW/GW	6	SW/GW	3	SW/GW	100
IX	SW/GW	100	SW/GW	100	SW/GW	3	SW/GW	2	SW/GW	0
X	---	0	---	0	---	0	---	0	SW/GW	0

BW is backwater condition which neglects the effect of local flow

BR is breaching condition which represents controlling discharge through the slough

SW/GW is surface water and groundwater condition with a median natural flow or minimum project flow controlling groundwater levels and surface water related to precipitation events.

Appendix B contains an explanation of the derivation of the percent exceedance values

Table 19. Condition which provides successful passage most frequently and approximate percent of time that passage is successful during the period 20 August - 20 September at Slough 11.

Passage Reach	Natural		Project 12,000 cfs		Project 9,000 cfs		Project 8,000 cfs		All Project Flows With Mitigation	
	Cond.	Occurrence (%)	Cond.	Occurrence (%)	Cond.	Occurrence (%)	Cond.	Occurrence (%)	Cond.	Occurrence (%)
I	SW/GW	70	SW/GW	60	---	0	---	0	SW/GW	100
II	SW/GW	43	---	20	---	0	---	0	SW/GW	100
III	SW/GW	12	---	5	---	0	---	0	SW/GW	100
IV	BR	1	---	0	---	0	---	0	SW/GW	100
V	BR	1	---	0	---	0	---	0	SW/GW	100

BW is backwater condition which neglects the effect of local flow

BR is breaching condition which represents controlling discharge through the slough

SW/GW is surface water and groundwater condition with a median natural flow or minimum project flow controlling groundwater levels and surface water related to precipitation events.

Appendix B contains an explanation of the derivation of the percent exceedance values

Table 20. Condition which provides successful passage most frequently and approximate percent of time that passage is successful during the period 20 August - 20 September at Upper Side Channel 11.

Passage Reach	Natural Cond.	Natural Occurrence (%)	Project 12,000 cfs Cond.	Project 12,000 cfs Occurrence (%)	Project 9,000 cfs Cond.	Project 9,000 cfs Occurrence (%)	Project 8,000 cfs Cond.	Project 8,000 cfs Occurrence (%)	All Project Flows With Mitigation Cond.	All Project Flows With Mitigation Occurrence (%)
I	SW/GW	100	---	0	---	0	---	0	SW/GW	100
II	BR	45	---	0	---	0	---	0	SW/GW	100
III	BR	45	---	0	---	0	---	0	SW/GW	100

BW is backwater condition which neglects the effect of local flow

BR is breaching condition which represents controlling discharge through the slough

SW/GW is surface water and groundwater condition with a median natural flow or minimum project flow controlling groundwater levels and surface water related to precipitation events.

Appendix B contains an explanation of the derivation of the percent exceedance values

Table 21. Condition which provides successful passage most frequently and approximate percent of time that passage is successful during the period 20 August - 20 September at Slough 21.

Passage Reach	Natural		Project 12,000 cfs		Project 9,000 cfs		Project 8,000 cfs		All Project Flows With Mitigation	
	Cond.	Occurrence (%)	Cond.	Occurrence (%)	Cond.	Occurrence (%)	Cond.	Occurrence (%)	Cond.	Occurrence (%)
I	SW/GW	100	SW/GW	100	SW/GW	6	SW/GW	4	SW/GW	100
IIL	SW/GW	10	---	0	---	0	---	0	SW/GW	0
IIR	SW/GW	4	SW/GW	2	SW/GW	1	SW/GW	1	SW/GW	100

BW is backwater condition which neglects the effect of local flow

BR is breaching condition which represents controlling discharge through the slough

SW/GW is surface water and groundwater condition with a median natural flow or minimum project flow controlling groundwater levels and surface water related to precipitation events.

Appendix B contains an explanation of the derivation of the percent exceedance values

Table 22. Condition which provides successful passage most frequently and approximate percent of time that passage is successful during the period 20 August - 20 September at Side Channel 21.

Passage Reach	Natural Cond.	Natural Occurrence (%)	Project 12,000 cfs Cond.	Project 12,000 cfs Occurrence (%)	Project 9,000 cfs Cond.	Project 9,000 cfs Occurrence (%)	Project 8,000 cfs Cond.	Project 8,000 cfs Occurrence (%)	All Project Flows With Mitigation Cond.	All Project Flows With Mitigation Occurrence (%)
I	SW/GW	100	BR	100	SW/GW	28	SW/GW	24	SW/GW	100
II	SW/GW	100	BR	100	SW/GW	28	SW/GW	24	SW/GW	100
III	SW/GW	100	BR	100	SW/GW	31	SW/GW	26	SW/GW	100
IV	SW/GW	100	BR	100	SW/GW	31	SW/GW	26	SW/GW	100
V	BR	71	BR	100	SW/GW	1	SW/GW	0.5	SW/GW	100
VI	BR	71	BR	100	SW/GW	0.5	---	0	SW/GW	100
VII	BR	71	BR	100	SW/GW	0.5	---	0	SW/GW	100
VIII	BR	71	BR	100	SW/GW	0.5	---	0	SW/GW	100
IX	BR	71	BR	100	SW/GW	0.5	---	0	SW/GW	100
X	SW/GW	100	SW/GW	100	SW/GW	9	SW/GW	5	SW/GW	100

BW is backwater condition which neglects the effect of local flow

BR is breaching condition which represents controlling discharge through the slough

SW/GW is surface water and groundwater condition with a median natural flow or minimum project flow controlling groundwater levels and surface water related to precipitation events.

Appendix B contains an explanation of the derivation of the percent exceedance values

Table 23. Candidate sites for development of replacement spawning habitat.

RM*	Site Location	Historical Spawning Use
110.1 L	Mouth of Oxbow I	chum
115.0 R	Mainstem 2, right channel	chum
117.9 L	Channel outside of Bushrod	
118.9 L	Downstream of Oxbow II mouth	chum
127.1 L or C	Complex Downstream of mouth SL 9	
129.8 R	Right side of side channel at head of SL 9	chum
131.3 L	Upstream of 4th of July Creek	chum
132.9 R	Downstream of mouth of SL 9A	chum
137.5 L	Downstream of mouth of SL 16	
139.0 L	Between mouth of SL 17 and 18	chum, sockeye
143.2 L	Upstream of intertie	chum

* L Left side of channel looking upstream

C Center of channel

R Right side of channel looking upstream

FIGURES

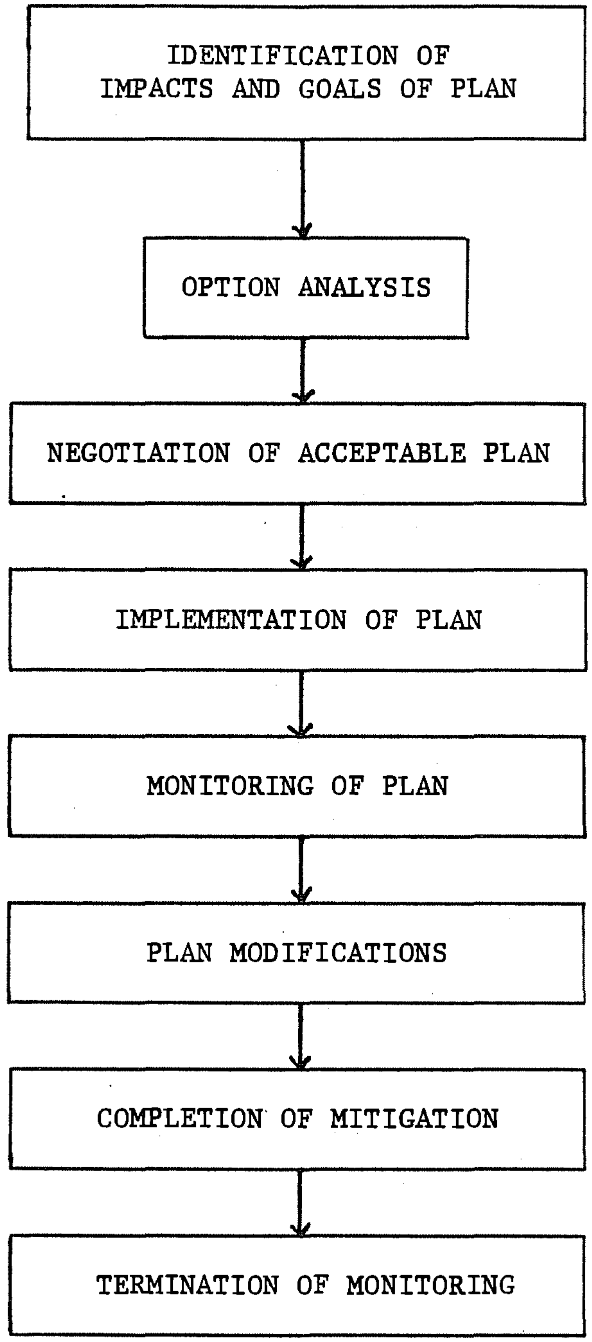

FIGURE 1 MITIGATION PLAN DEVELOPMENT AND IMPLEMENTATION

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SUSITNA HYDROELECTRIC PROJECT

Woodward-Clyde Consultants

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SUSITNA JOINT VENTURE

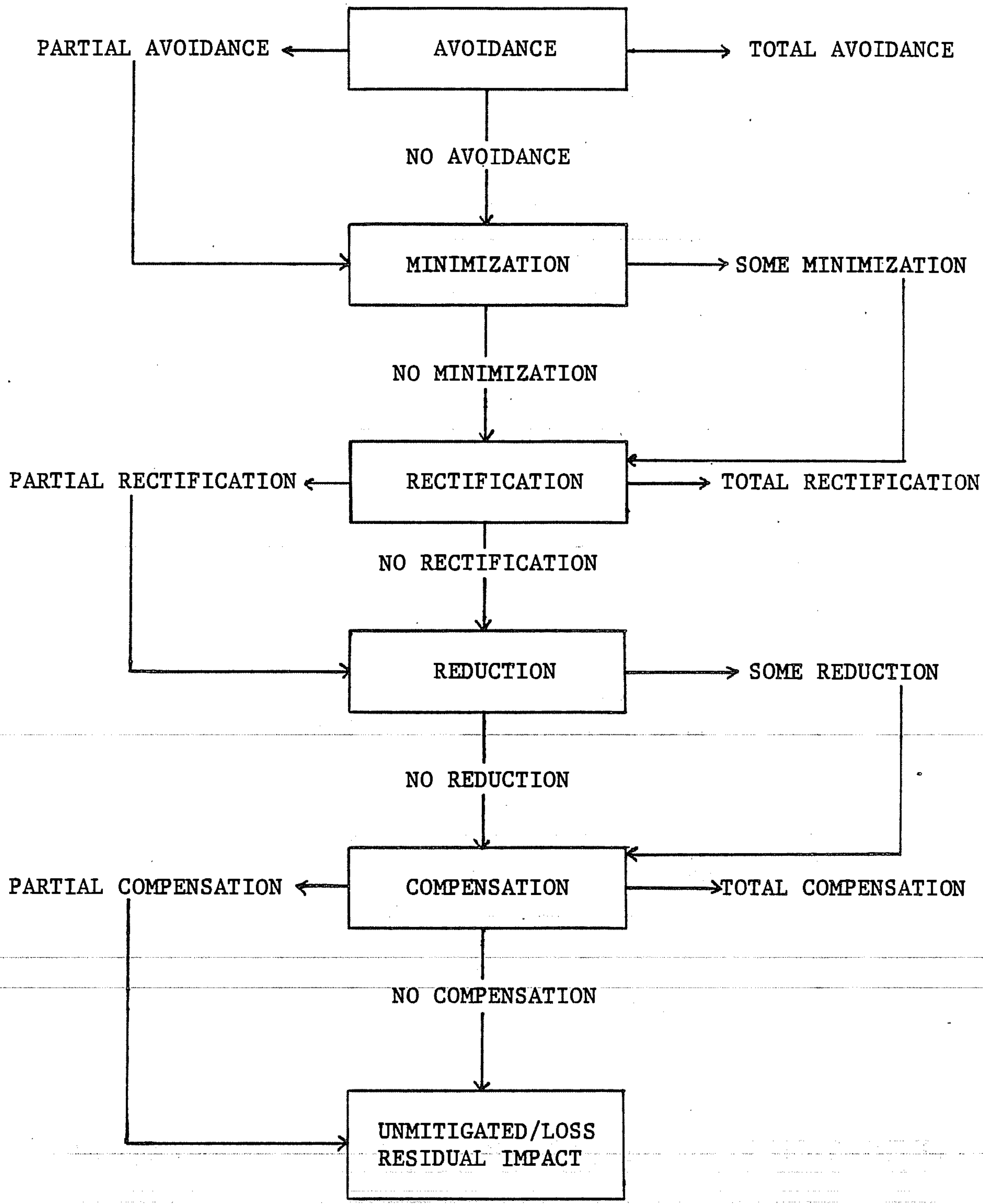

FIGURE 2 OPTION ANALYSIS

ALASKA POWER AUTHORITY SUSITNA HYDROELECTRIC PROJECT	
Woodward-Clyde Consultants	HARZA-EBASCO SUSITNA JOINT VENTURE

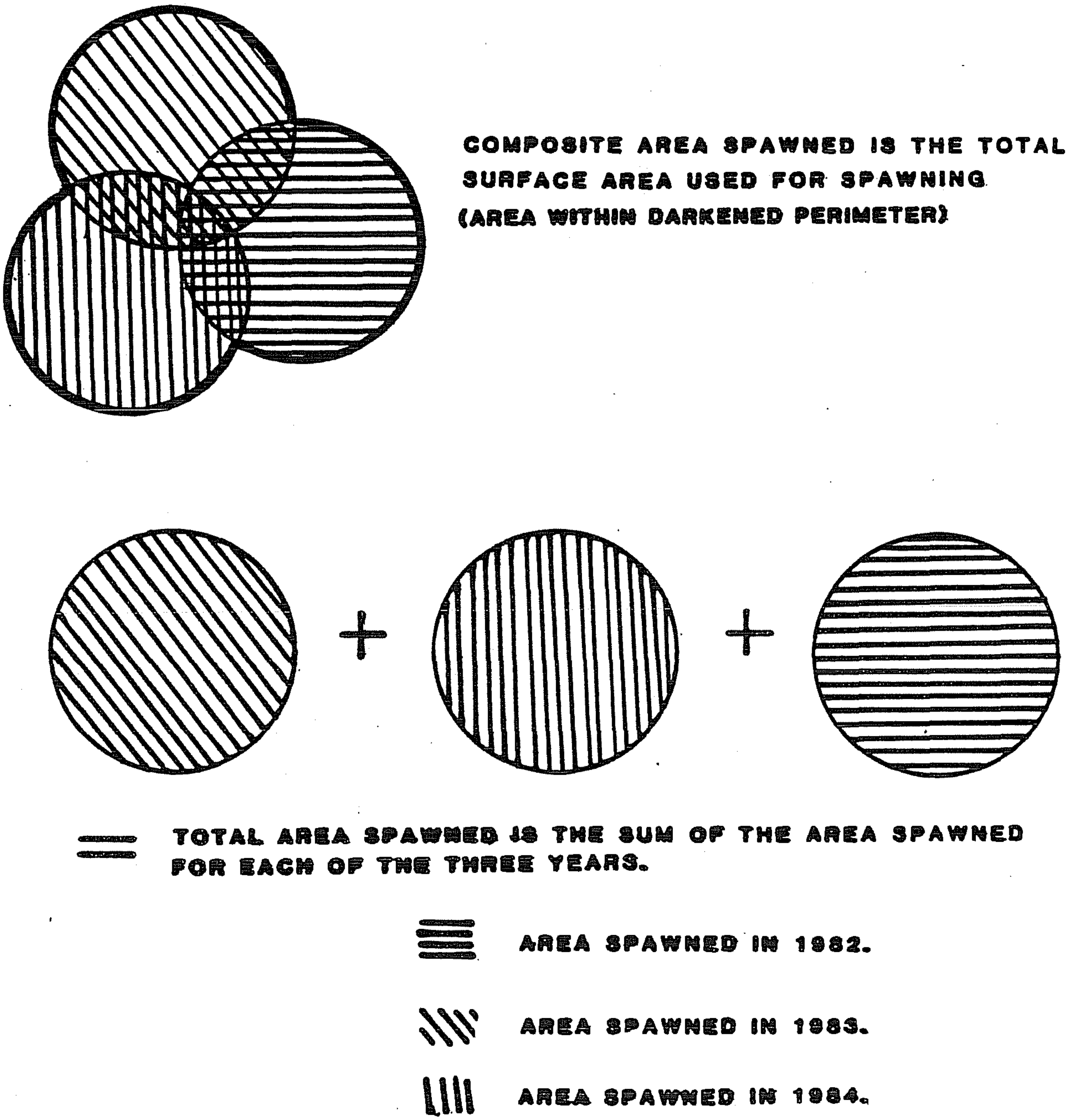

FIGURE 3 SCHEMATIC DIAGRAM ILLUSTRATING DIFFERENCE BETWEEN COMPOSITE AREA AND TOTAL AREA SPAWNED.

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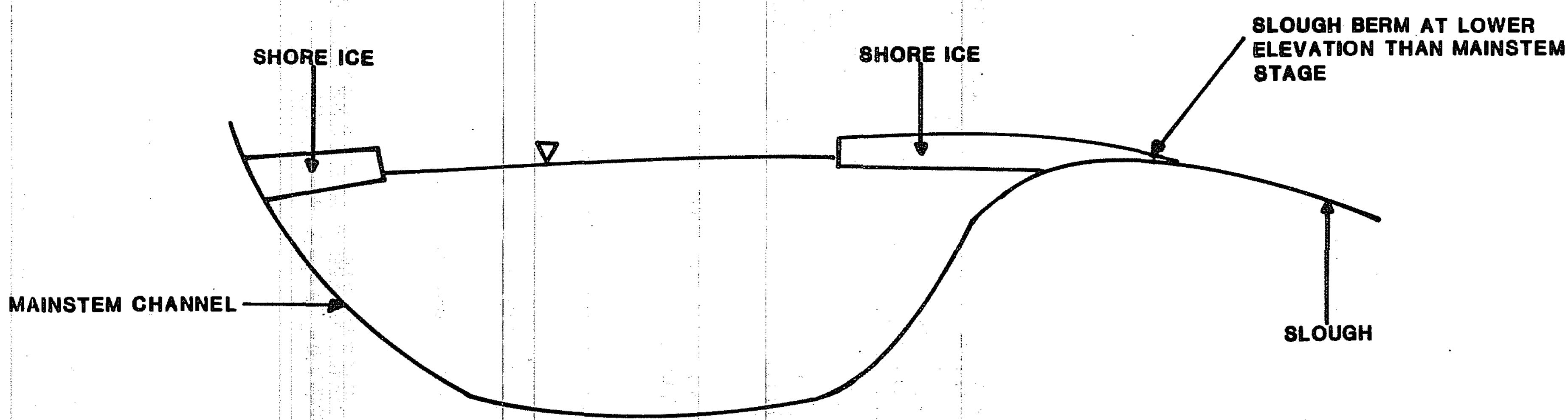

FIGURE 4 SHORE ICE BUILDUP WITHOUT OVERTOPPING

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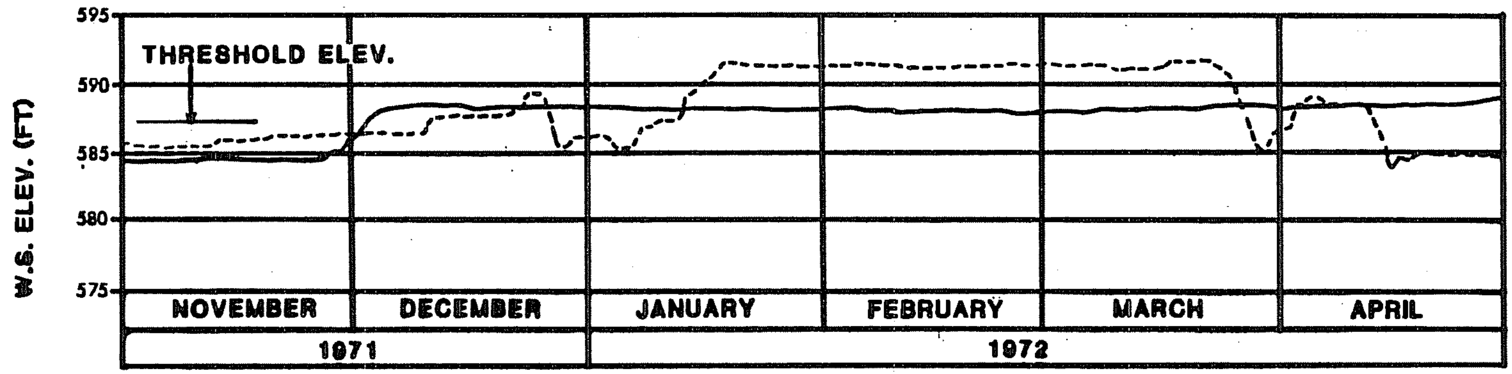
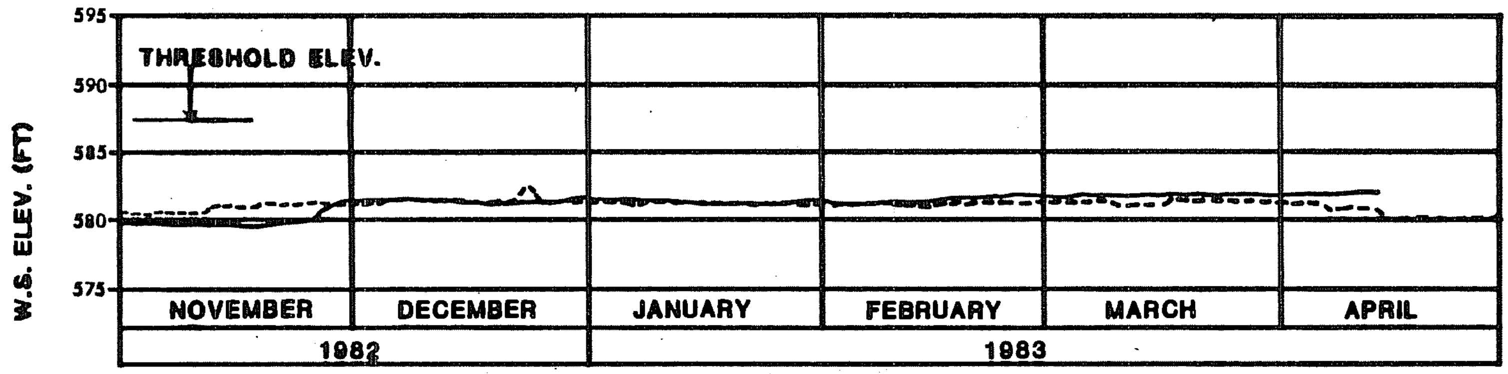


WEATHER PERIOD 1 NOV 71 - 30 APR 72 (COLD WINTER)



WEATHER PERIOD 1 NOV 82 - 30 APR 83 (AVERAGE WINTER)

LEGEND

—— NATURAL FLOW AND WEATHER

---- WATANA 1996 FLOW AND NATURAL WEATHER

REF: HARZA-EBASCO SUSITNA JOINT VENTURE. 1984. INSTREAM ICE SIMULATION STUDY. DRAFT REPORT PREPARED FOR ALASKA POWER AUTHORITY FOR SUSITNA HYDROELECTRIC PROJECT. SEPTEMBER.

FIGURE 5 PREDICTED WINTER MAINSTEM STAGES FOR NATURAL AND PROJECT FLOWS NEAR THE HEAD OF SLOUGH 8A

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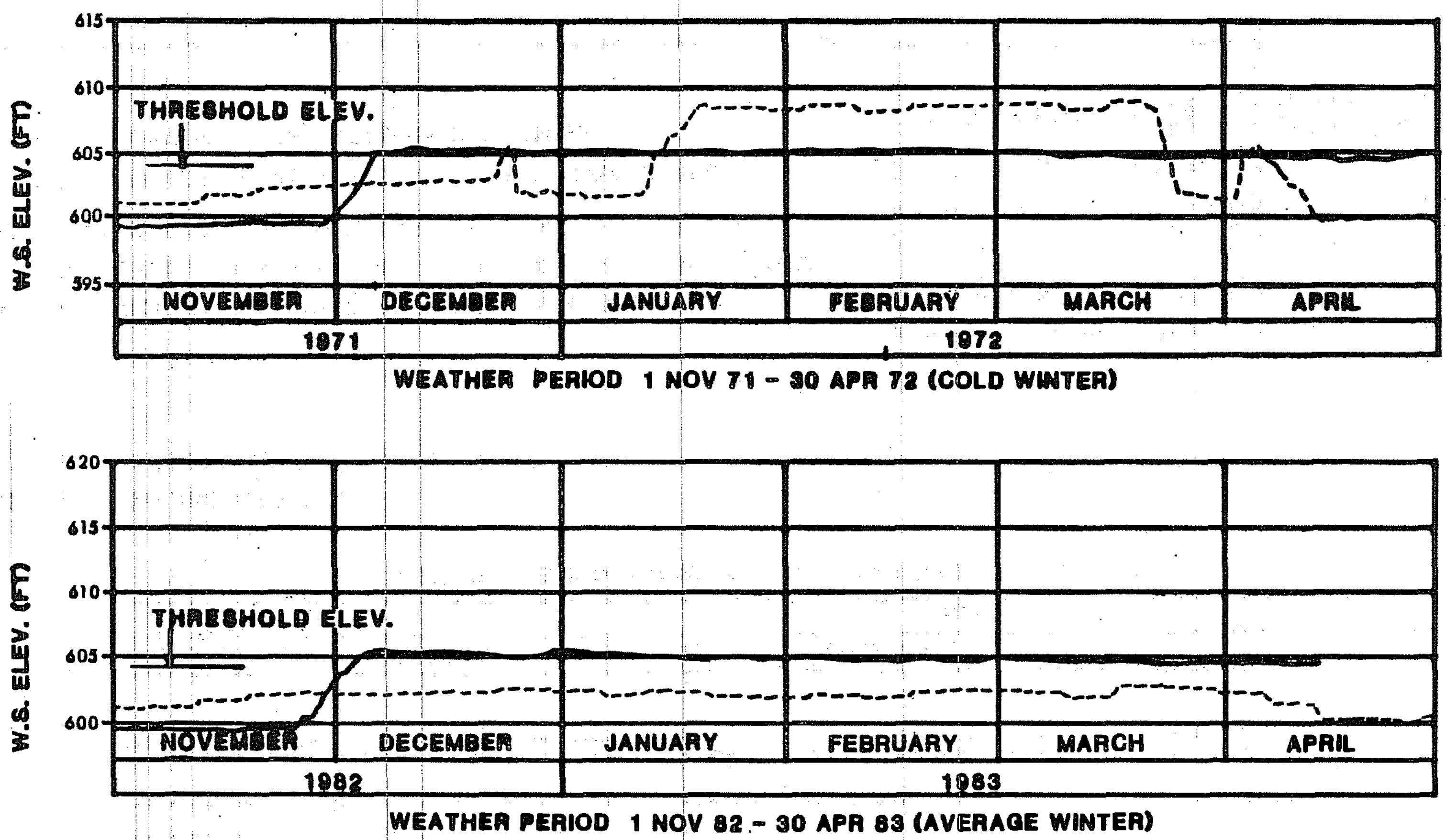

LEGEND

—— NATURAL FLOW AND WEATHER

---- WATANA 1996 FLOW AND NATURAL WEATHER

REF: HARZA-EBASCO SUSITNA JOINT VENTURE. 1984. INSTREAM ICE SIMULATION STUDY. DRAFT REPORT PREPARED FOR ALASKA POWER AUTHORITY FOR SUSITNA HYDROELECTRIC PROJECT. SEPTEMBER.

FIGURE 6 PREDICTED WINTER MAINSTEM STAGES FOR NATURAL AND PROJECT FLOWS NEAR THE HEAD OF SLOUGH 9

ALASKA POWER AUTHORITY

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Woodward-Clyde Consultants

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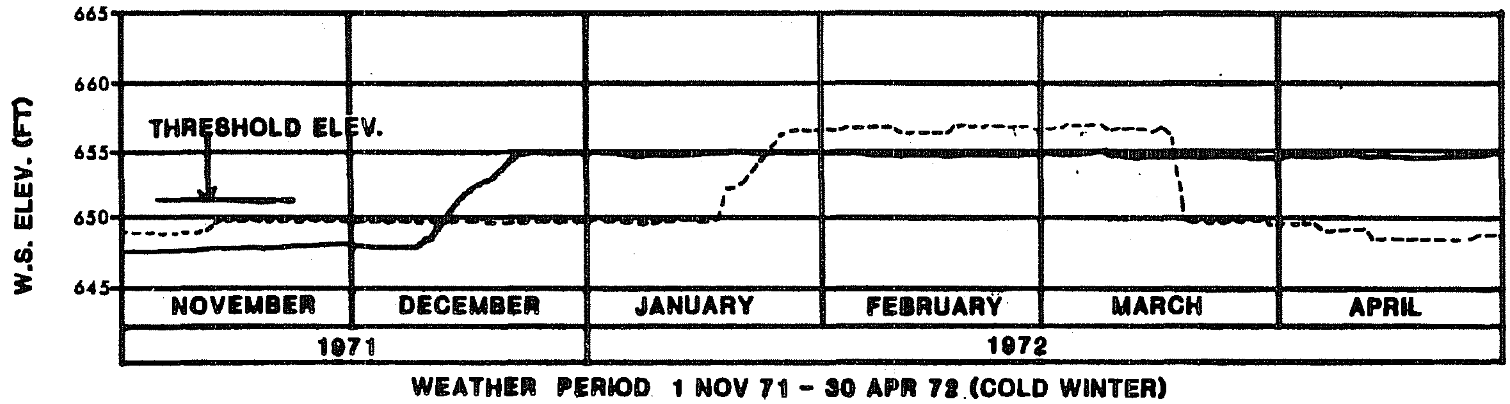
SUSITNA JOINT VENTURE



LEGEND

—— NATURAL FLOW AND WEATHER

---- WATANA 1996 FLOW AND NATURAL WEATHER

REF: HARZA-EBASCO SUSITNA JOINT VENTURE. 1984. INSTREAM ICE SIMULATION STUDY. DRAFT REPORT PREPARED FOR ALASKA POWER AUTHORITY FOR SUSITNA HYDROELECTRIC PROJECT. SEPTEMBER.

FIGURE 7 PREDICTED WINTER MAINSTEM STAGES FOR NATURAL AND PROJECT FLOWS NEAR THE HEAD OF SLOUGH 9A

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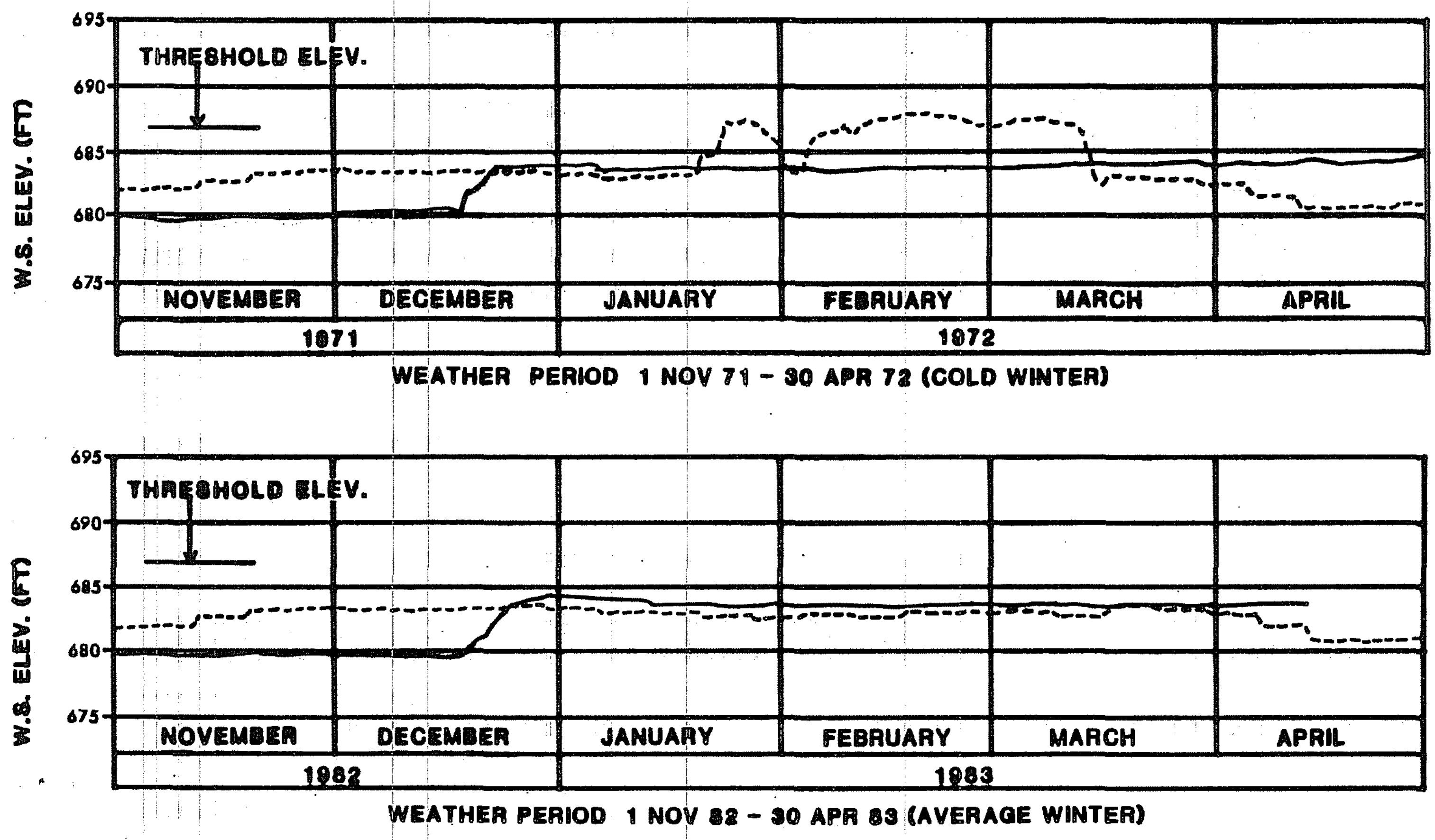

LEGEND

—— NATURAL FLOW AND WEATHER

---- WATANA 1996 FLOW AND NATURAL WEATHER

REF: HARZA-EBASCO SUSITNA JOINT VENTURE. 1984. INSTREAM ICE SIMULATION STUDY. DRAFT REPORT PREPARED FOR ALASKA POWER AUTHORITY FOR SUSITNA HYDROELECTRIC PROJECT. SEPTEMBER.

FIGURE 8 PREDICTED WINTER MAINSTEM STAGES FOR NATURAL AND PROJECT FLOWS NEAR THE HEAD OF SLOUGH 11

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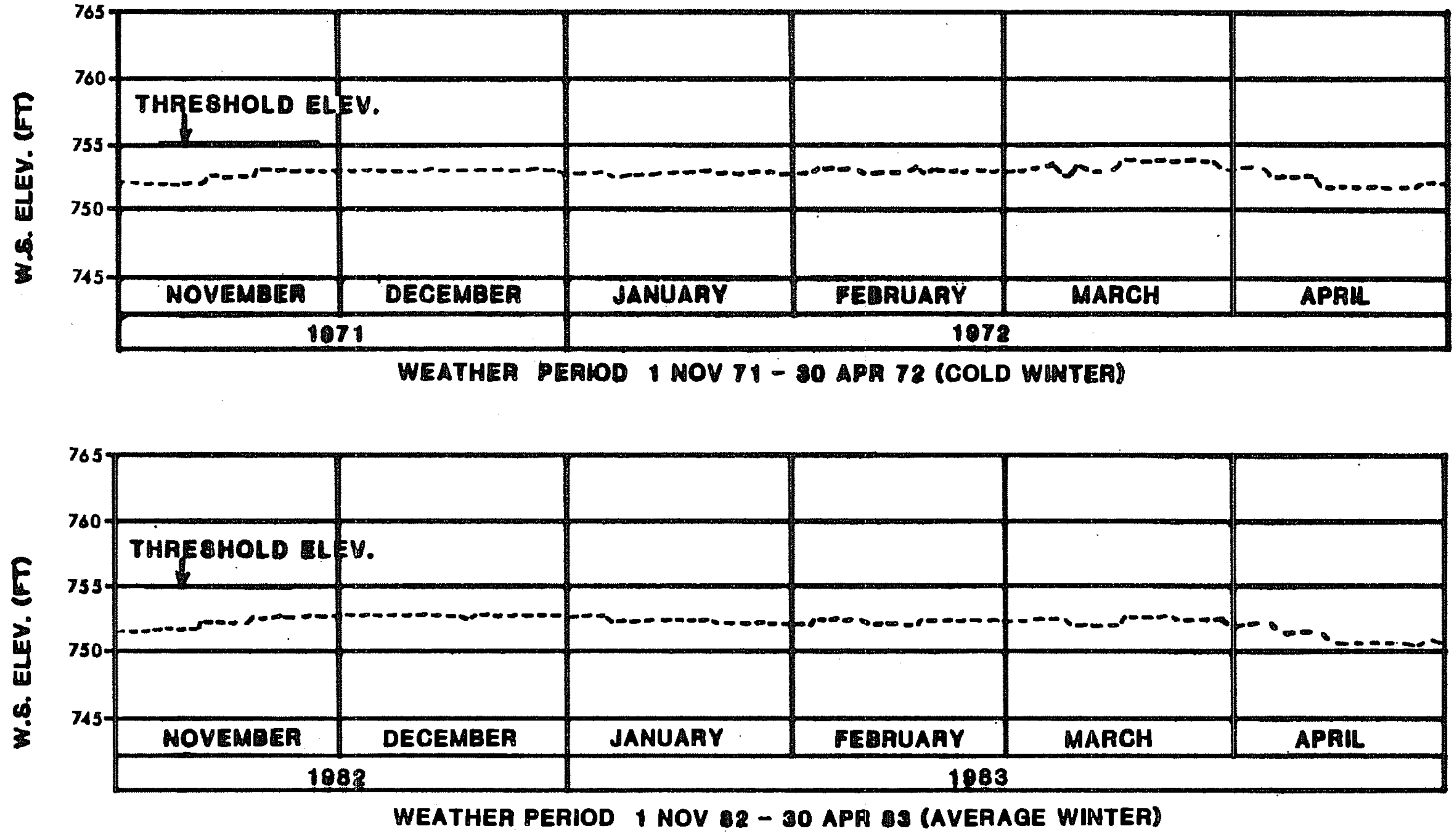

LEGEND

—— NATURAL FLOW AND WEATHER

---- WATANA 1996 FLOW AND NATURAL WEATHER

REF: HARZA-EBASCO SUSITNA JOINT VENTURE. 1984. INSTREAM ICE SIMULATION STUDY. DRAFT REPORT PREPARED FOR ALASKA POWER AUTHORITY FOR SUSITNA HYDROELECTRIC PROJECT. SEPTEMBER.

FIGURE 9 PREDICTED WINTER MAINSTEM STAGES FOR NATURAL AND PROJECT FLOWS NEAR THE HEAD OF SLOUGH 21

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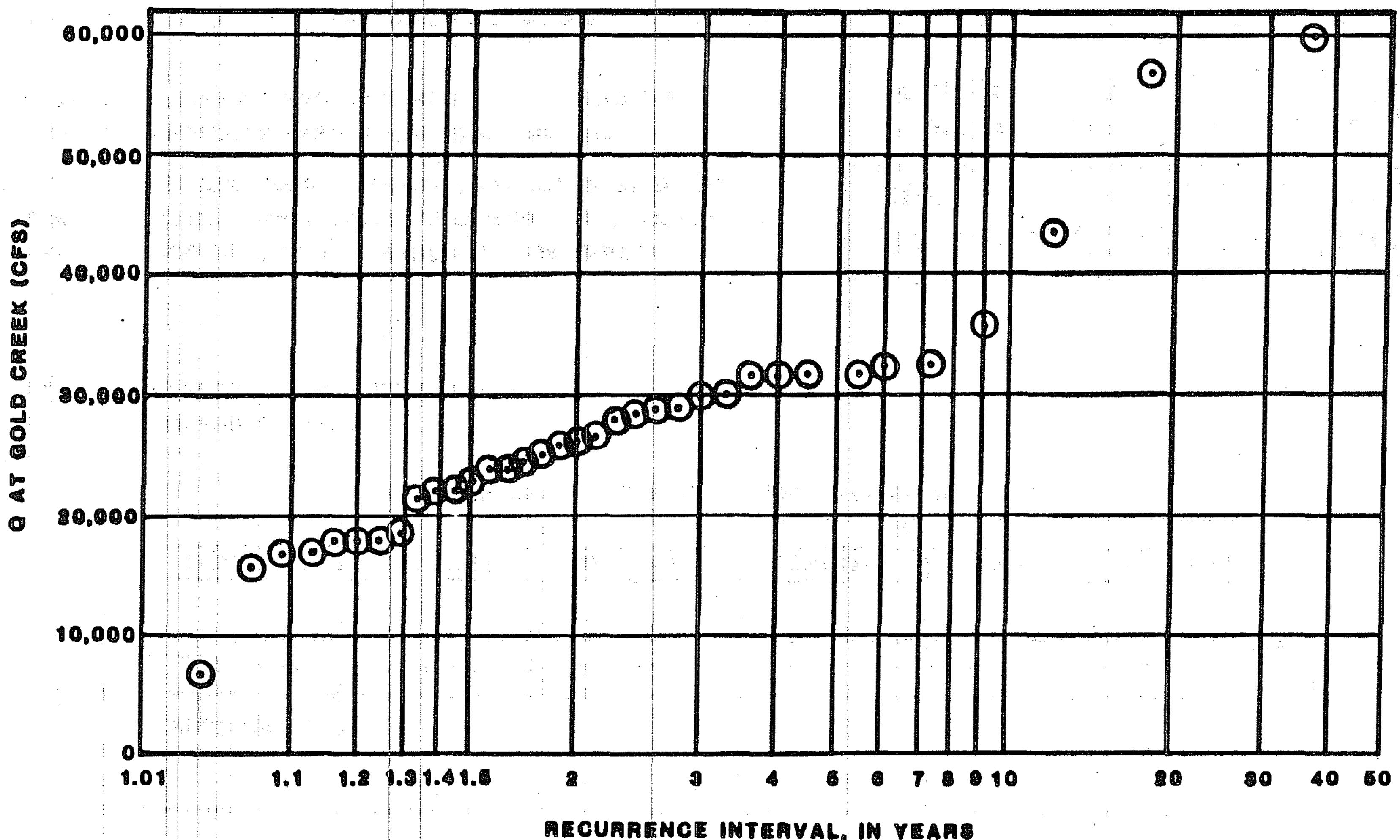

FIGURE 10 RECURRENCE INTERVAL OF THE PEAK DISCHARGE AT GOLD CREEK DURING AUGUST 20-SEPTEMBER 20 FROM 1950 TO 1984

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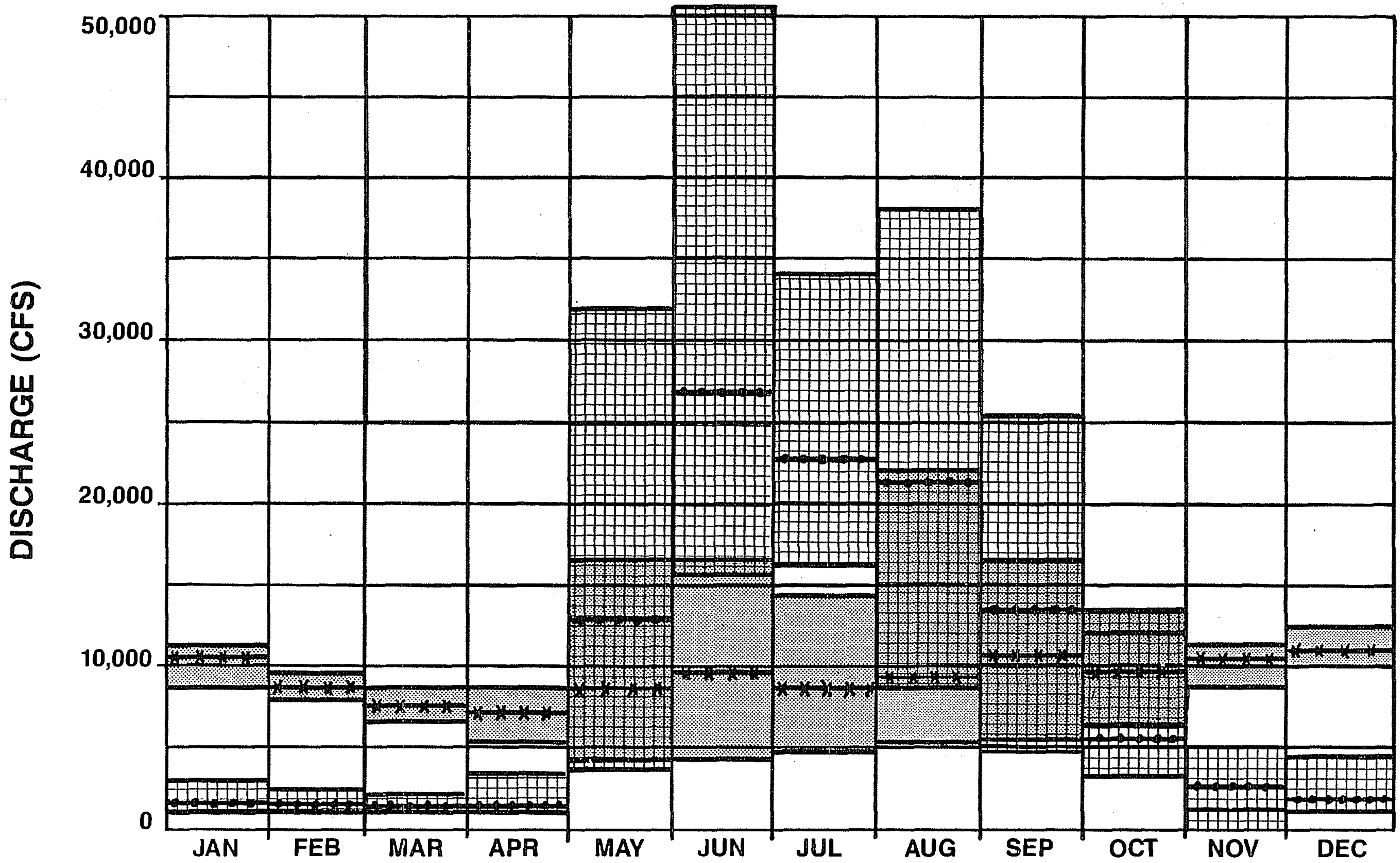

FIGURE 11

SIMULATED MINIMUM, MAXIMUM AND MEAN MONTHLY DISCHARGES FOR MAXIMUM POWER CASE P-1 COMPARED WITH MINIMUM, MAXIMUM AND MEAN MONTHLY DISCHARGES FOR NATURAL CONDITIONS.

- AREA WITHIN THE BOUNDS OF THE SIMULATED MINIMUM AND MAXIMUM MONTHLY DISCHARGES FOR CASE P-1.
- AREA WITHIN THE BOUNDS OF THE MINIMUM AND MAXIMUM MONTHLY DISCHARGES FOR NATURAL CONDITIONS FOR 33 YEARS OF RECORD.
- NATURAL MEAN MONTHLY DISCHARGE.
- SIMULATED MEAN MONTHLY DISCHARGE FOR CASE P-1.

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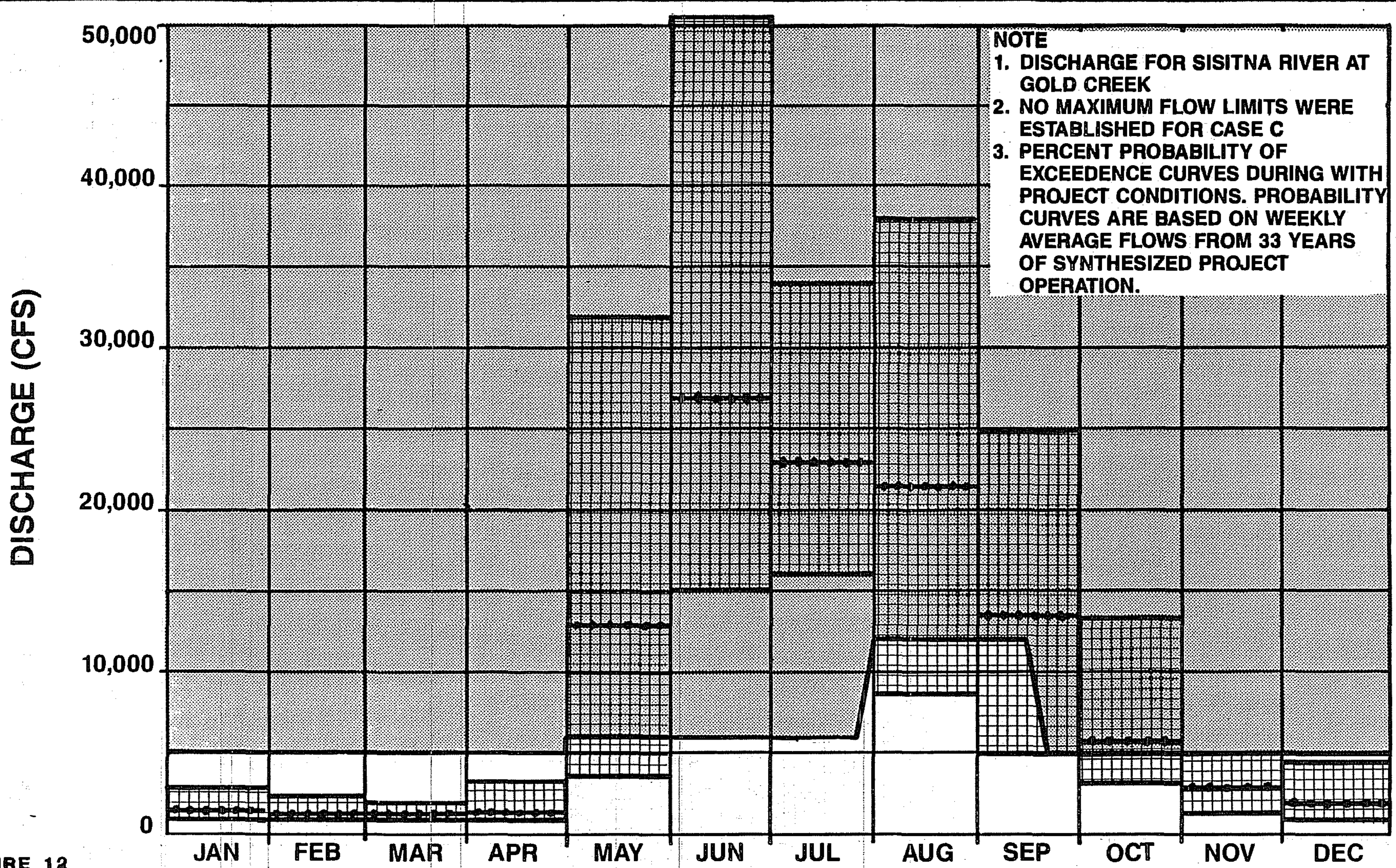

FIGURE 12

MINIMUM AND MAXIMUM WEEKLY DISCHARGES FOR CASE C FLOWS COMPARED WITH MINIMUM, MAXIMUM AND MEAN MONTHLY DISCHARGES FOR NATURAL CONDITIONS.

AREA WITHIN THE BOUNDS OF CASE C INSTREAM FLOW REQUIREMENTS.

AREA WITHIN THE BOUNDS OF THE MINIMUM AND MAXIMUM MONTHLY DISCHARGES FOR NATURAL CONDITIONS FOR 33 YEARS OF RECORD.

NATURAL MEAN MONTHLY DISCHARGES.

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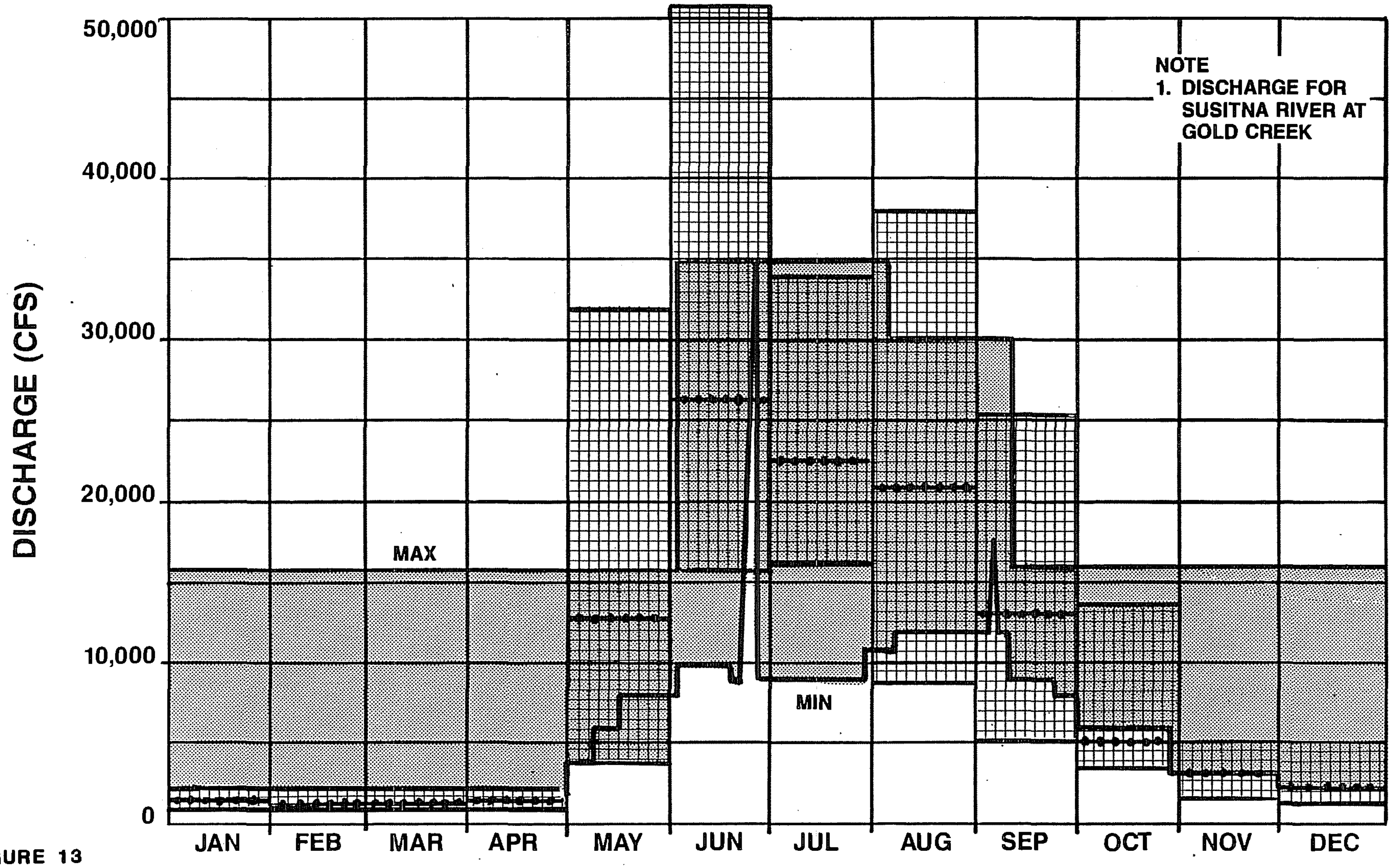

FIGURE 13

MINIMUM AND MAXIMUM WEEKLY DISCHARGES FOR CASE EV FLOWS COMPARED WITH MINIMUM, MAXIMUM AND MEAN MONTHLY DISCHARGES FOR NATURAL CONDITIONS.

AREA WITHIN THE BOUNDS OF CASE EV INSTREAM FLOW REQUIREMENTS.

AREA WITHIN THE BOUNDS OF THE MINIMUM AND MAXIMUM MONTHLY DISCHARGES FOR NATURAL CONDITIONS FOR 33 YEARS OF RECORD.

NATURAL MEAN MONTHLY DISCHARGES.

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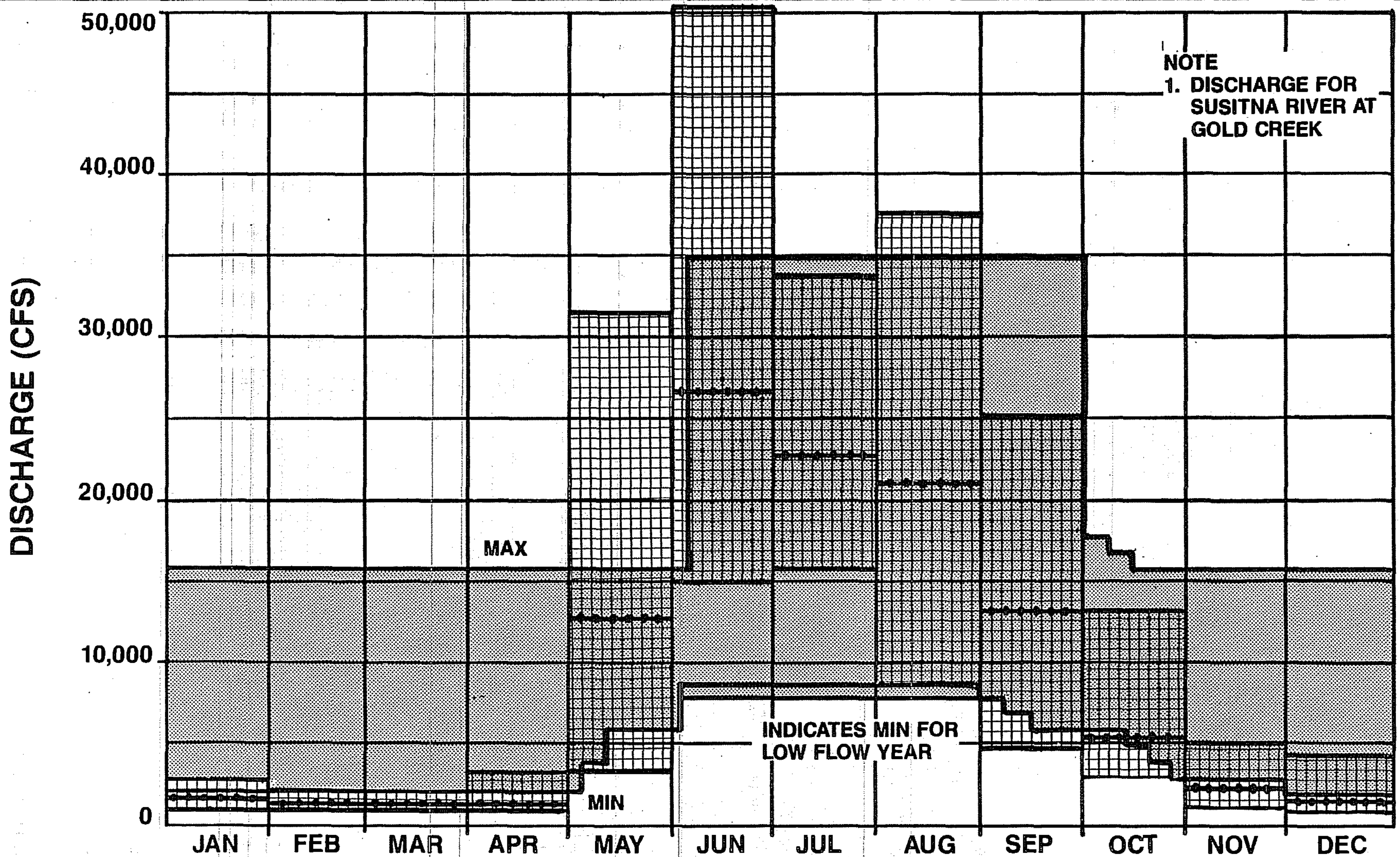

FIGURE 14

MINIMUM AND MAXIMUM WEEKLY DISCHARGES FOR CASE EV1 FLOWS COMPARED WITH MINIMUM, MAXIMUM AND MEAN MONTHLY DISCHARGES FOR NATURAL CONDITIONS.

AREA WITHIN THE BOUNDS OF CASE EVI INSTREAM FLOW REQUIREMENTS.

AREA WITHIN THE BOUNDS OF THE MINIMUM AND MAXIMUM MONTHLY DISCHARGES FOR NATURAL CONDITIONS FOR 33 YEARS OF RECORD.

NATURAL MEAN MONTHLY DISCHARGES.

ALASKA POWER AUTHORITY
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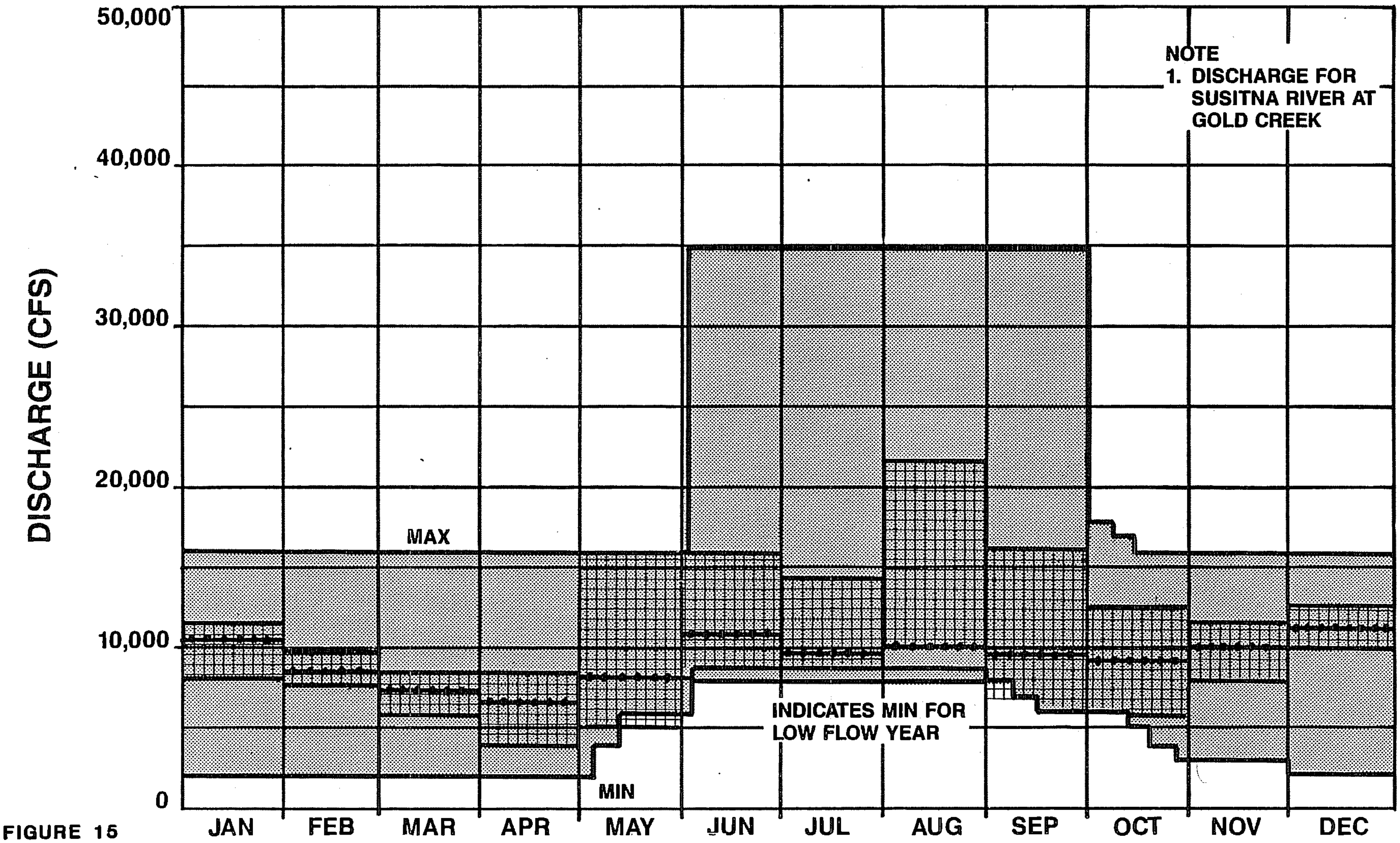

FIGURE 15

SIMULATED MINIMUM, MAXIMUM AND MEAN MONTHLY DISCHARGES COMPARED WITH MINIMUM AND MAXIMUM WEEKLY DISCHARGES FOR CASE EV1 INSTREAM FLOW REQUIREMENTS.

AREA WITHIN THE BOUNDS OF CASE EVI INSTREAM FLOW REQUIREMENTS.

AREA WITHIN THE BOUNDS OF THE SIMULATED MINIMUM AND MAXIMUM MONTHLY DISCHARGES FOR CASE EV1.

SIMULATED MEAN MONTHLY DISCHARGE FOR CASE EV1.

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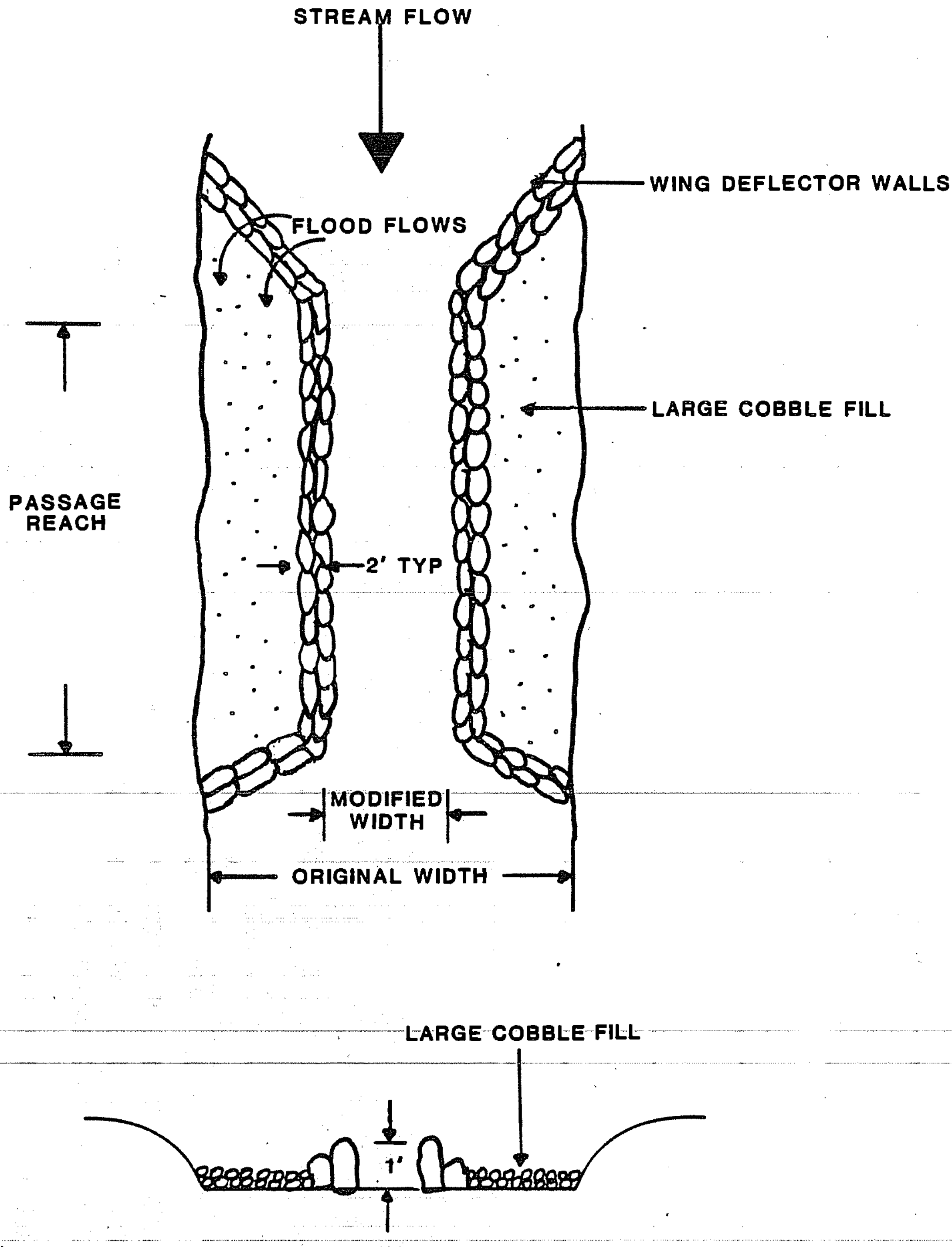

FIGURE 16 WING DEFLECTOR

NOT TO SCALE

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SUSITNA HYDROELECTRIC PROJECT

Woodward-Clyde Consultants

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SUSITNA JOINT VENTURE

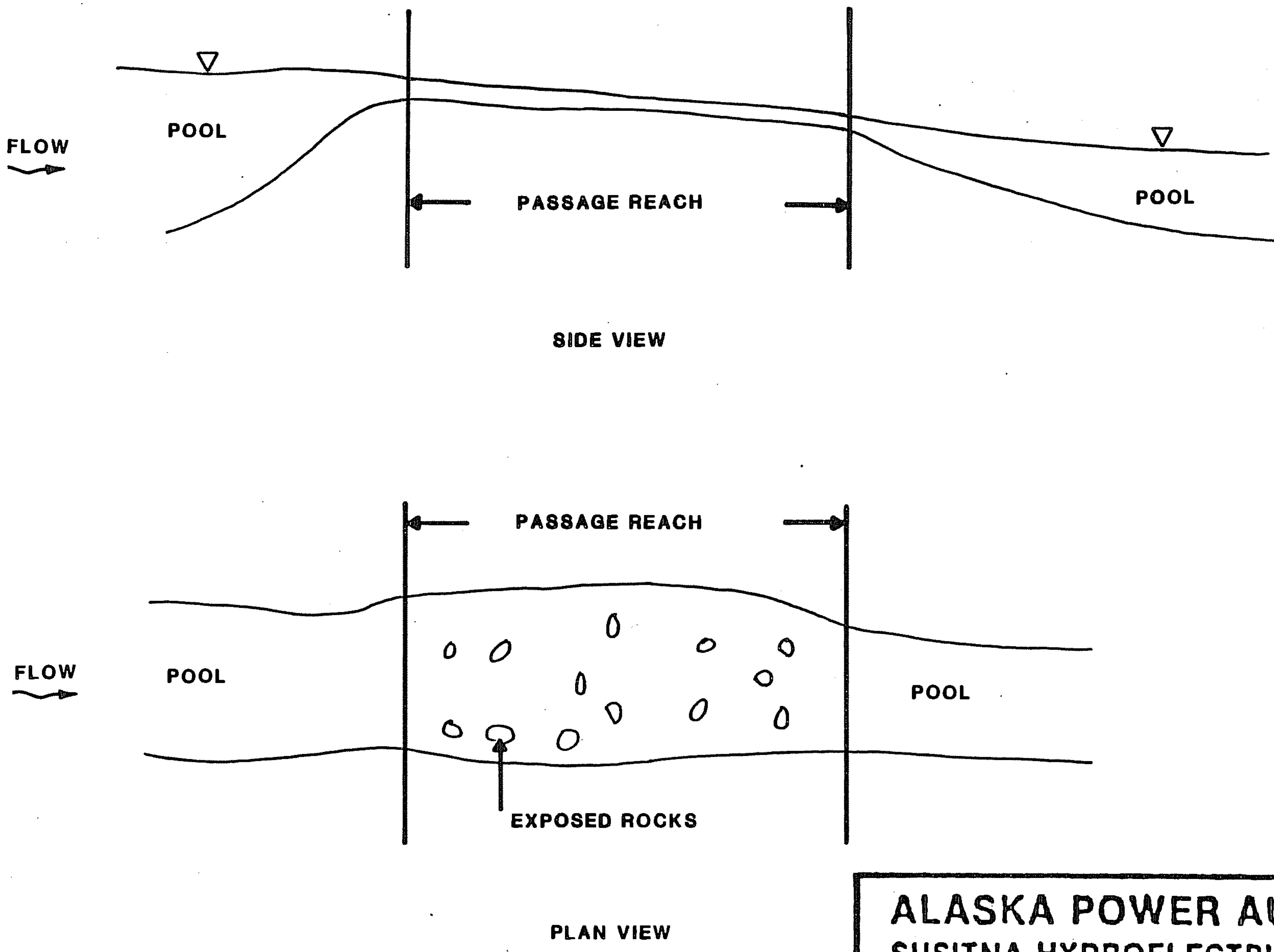

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FIGURE 17 TYPICAL PASSAGE REACH OF SLOUGH ALONG MIDDLE SECTION OF THE SUSITNA RIVER

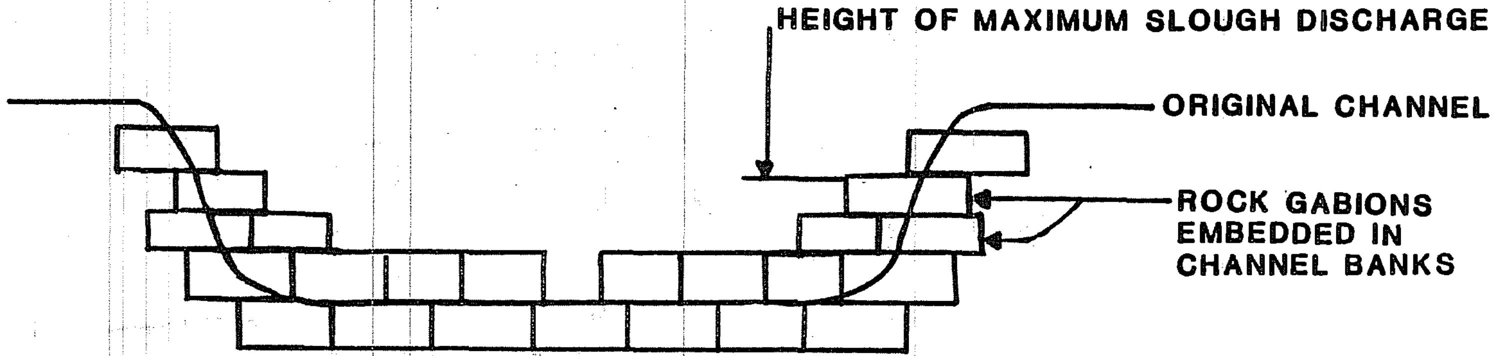

FIGURE 18 **ROCK GABION CHANNEL**

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SUSITNA HYDROELECTRIC PROJECT

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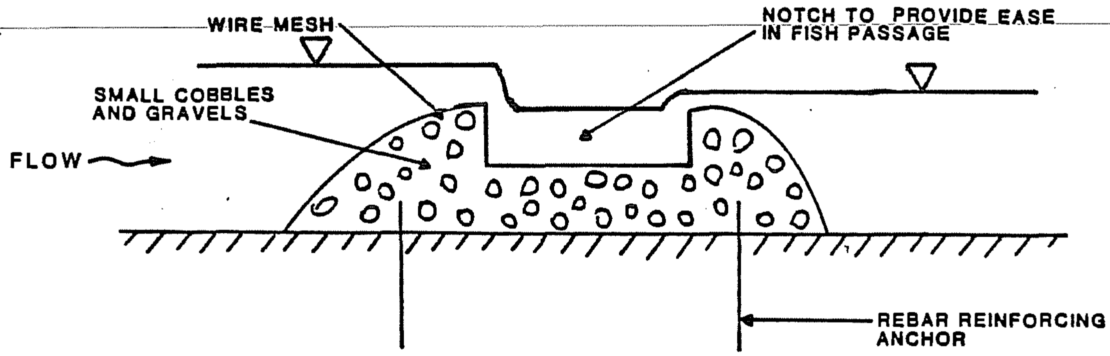
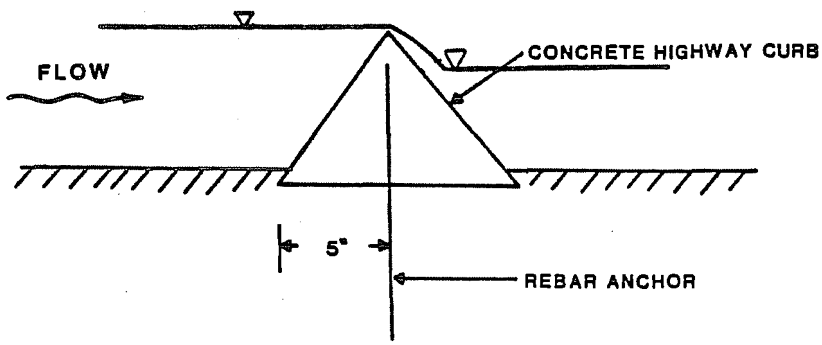
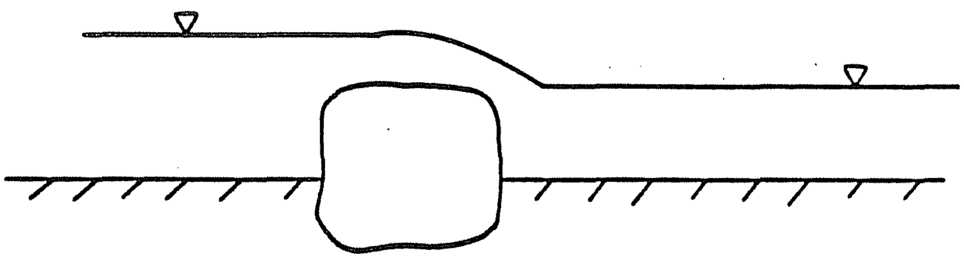
SUSITNA JOINT VENTURE



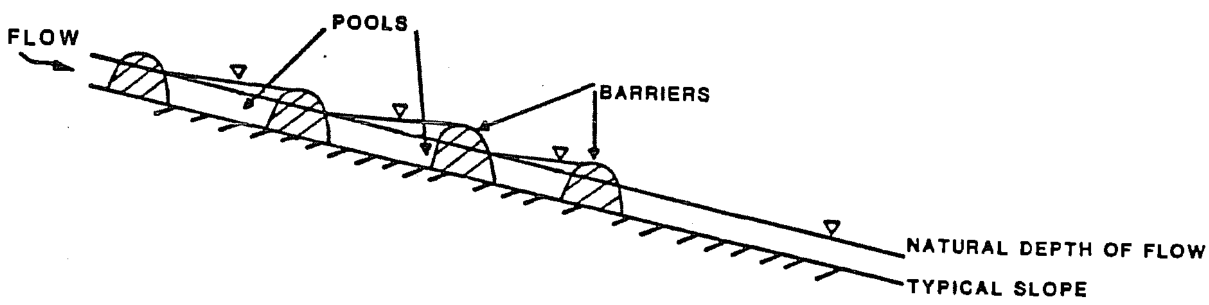
GABION BARRIER



HIGHWAY CURB BARRIER



ROCK SILL BARRIER



POOL AND WEIR STRUCTURE CREATION OF POOLS BETWEEN BARRIERS

FIGURE 19 **GABION BARRIER**
HIGHWAY CURB BARRIER
ROCK SILL BARRIER
POOL AND WEIR STRUCTURE
NOT TO SCALE

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

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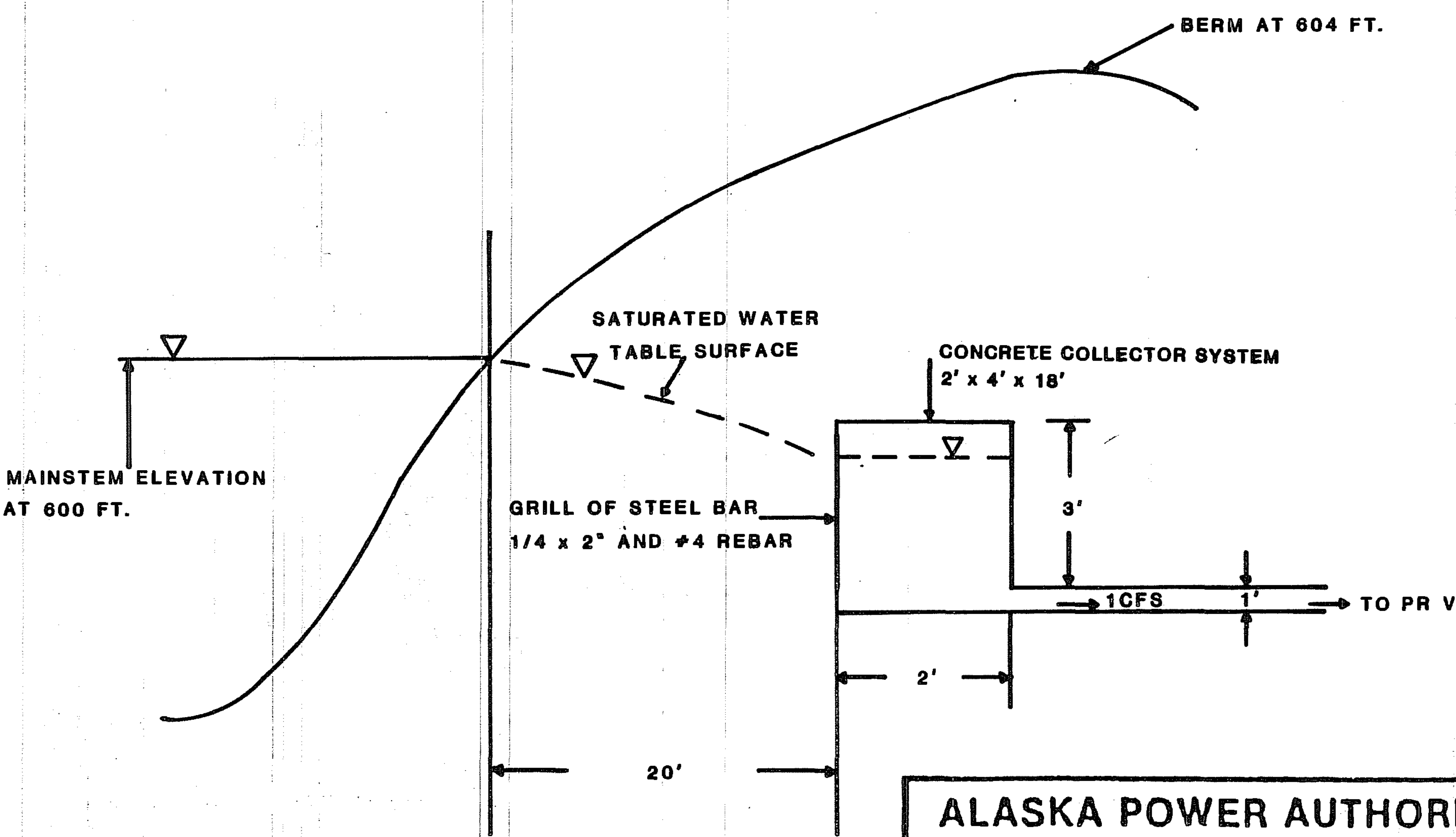

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FIGURE 20 COLLECTOR SYSTEM AT SLOUGH 9

NOT TO SCALE

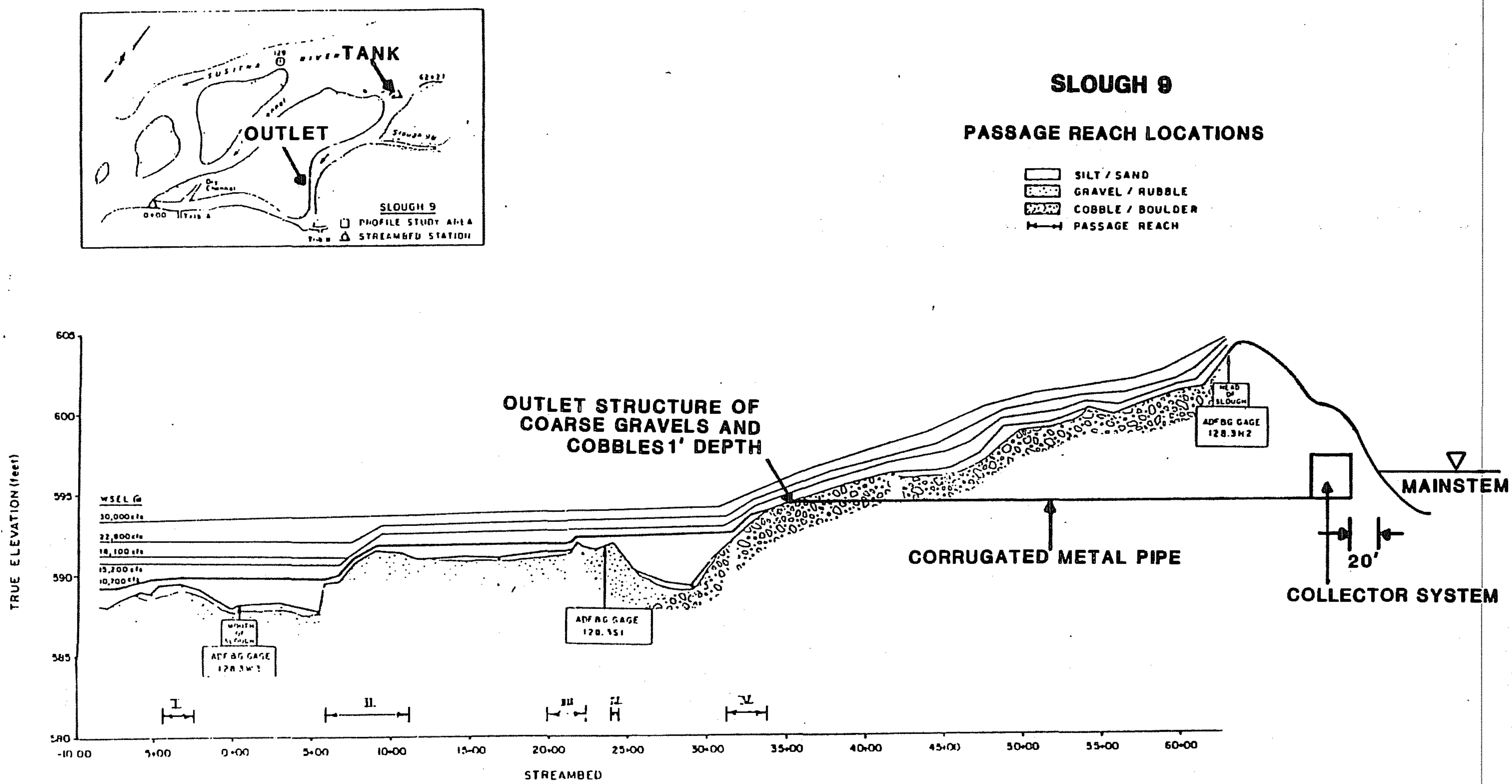

FIGURE 21 THALWEG PROFILE OF SLOUGH 9

SOURCE SAUTNER ET AL, 1984

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

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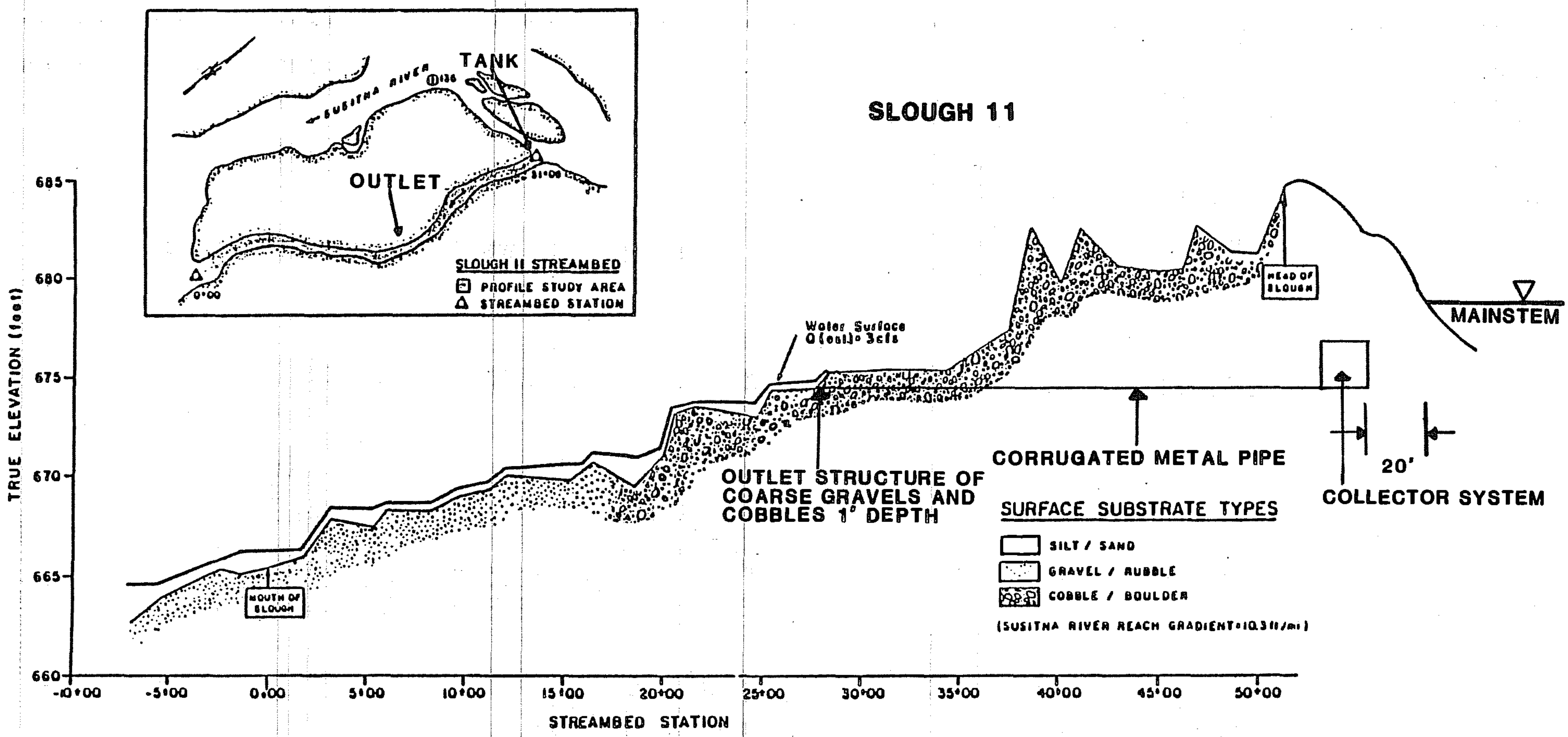

FIGURE 22 THALWEG PROFILE OF SLOUGH 11

SOURCE SAUTNER ET AL, 1984

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

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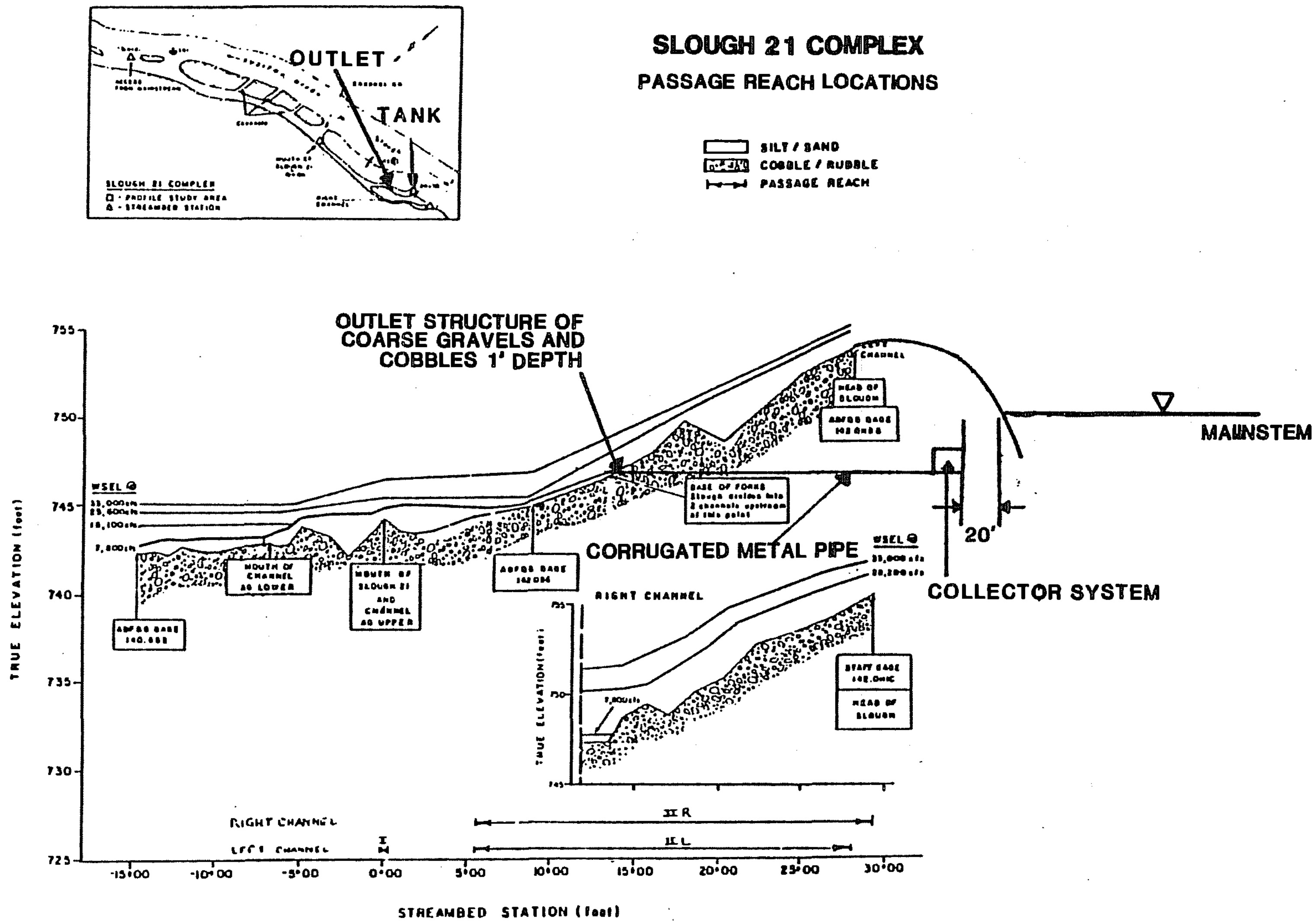

FIGURE 23 THALWEG PROFILE OF SLOUGH 21

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SUSITNA JOINT VENTURE

SOURCE SAUTNER ET AL, 1984

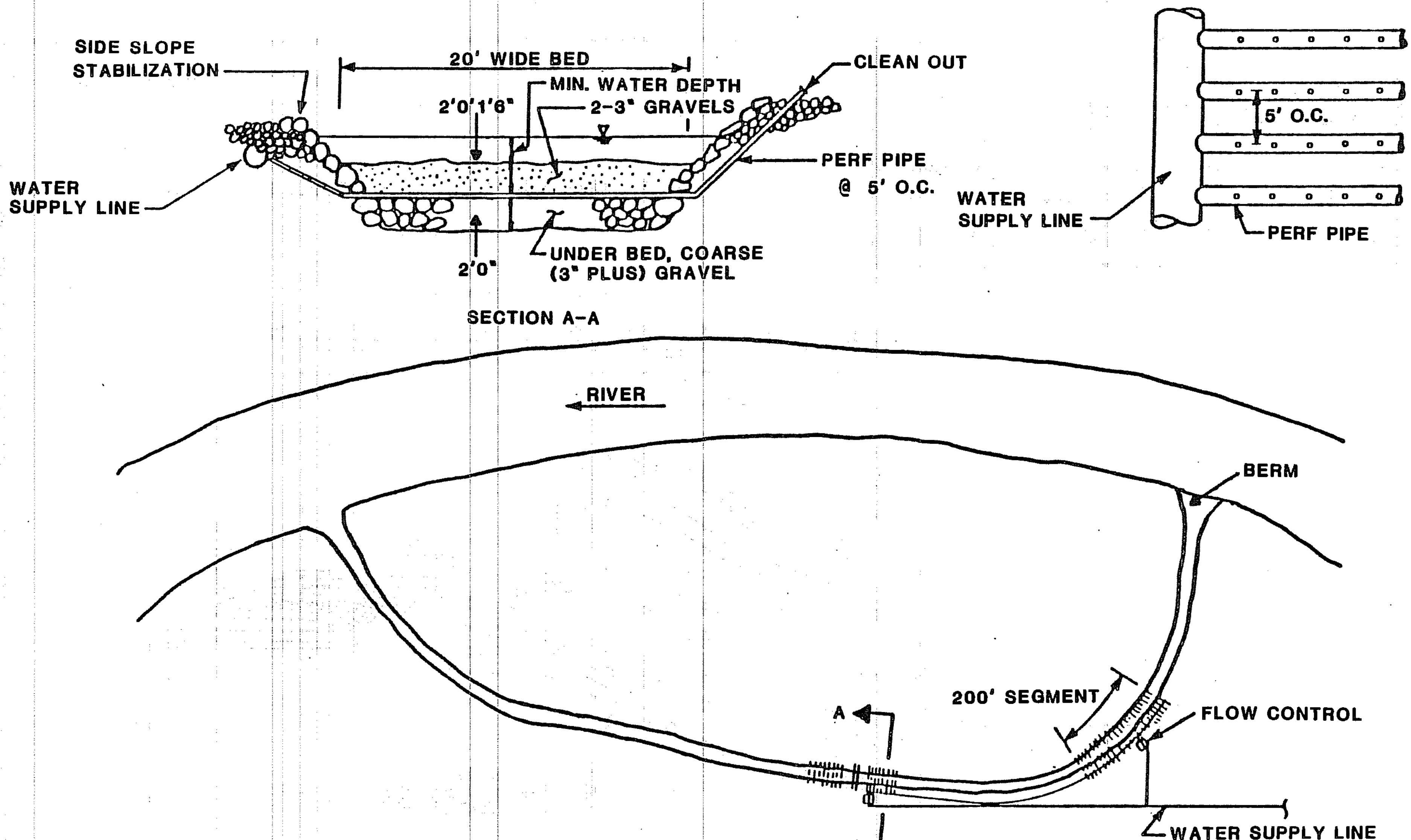

FIGURE 24 SUSITNA RIVER FISHERY MITIGATION INDUCED UPWELLING USING TRIBUTARY WATER SUPPLY

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

Woodward-Clyde Consultants

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SUSITNA JOINT VENTURE

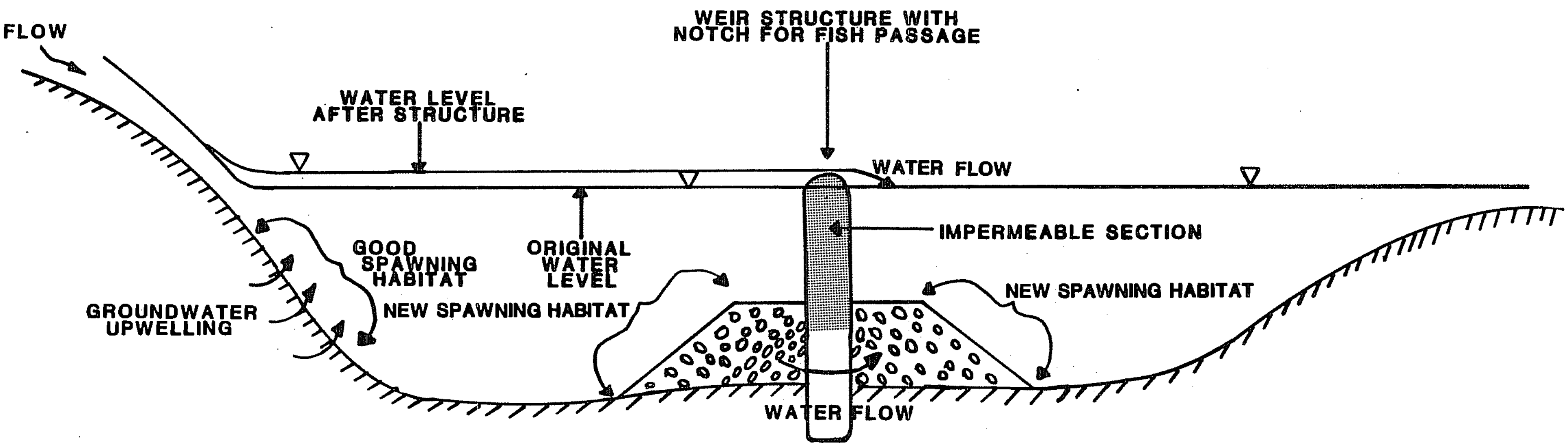


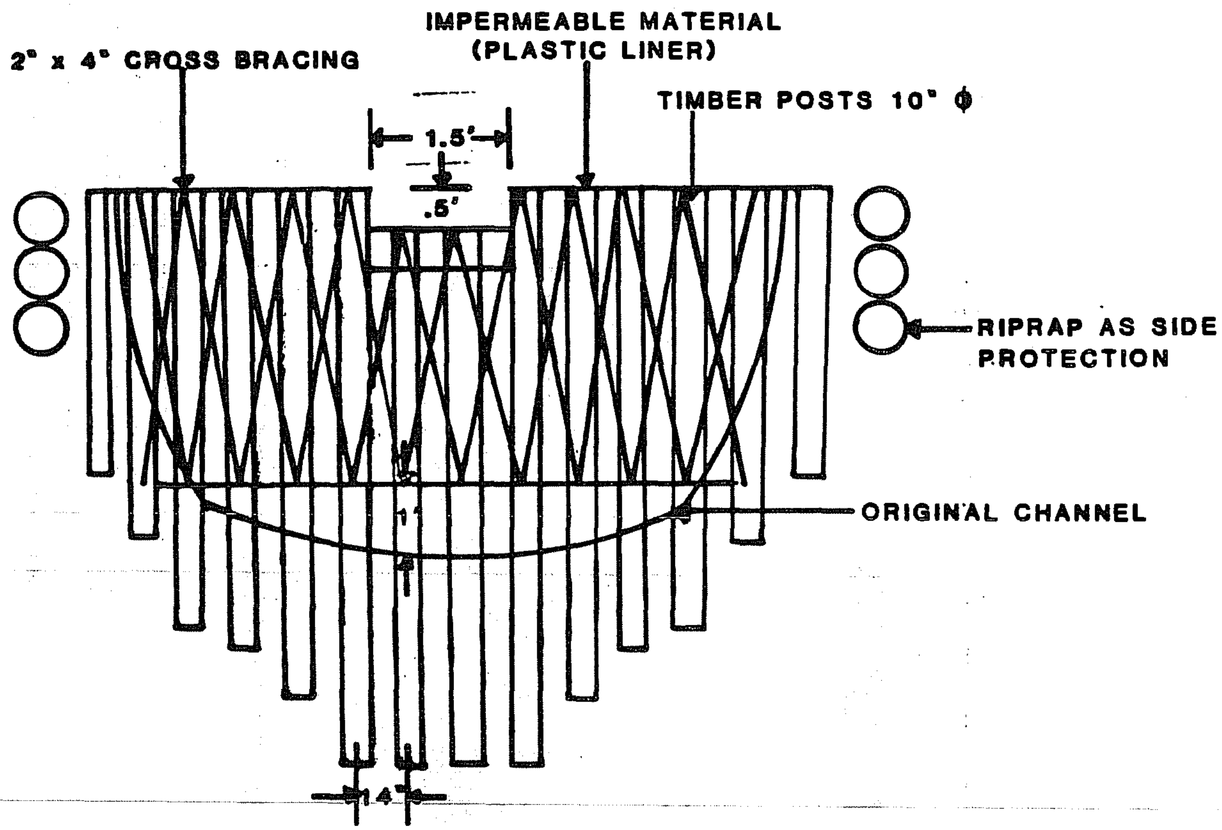
FIGURE 25 WEIR TO INCREASE SPAWNING HABITAT

NOT TO SCALE

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

Woodward-Clyde Consultants

HARZA-EBASCO
SUSITNA JOINT VENTURE



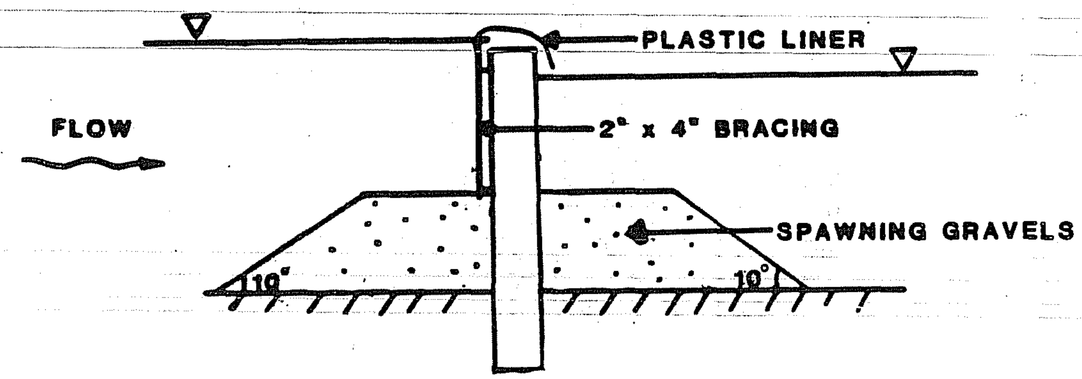


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FIGURE 26 TIMBER POST WEIR

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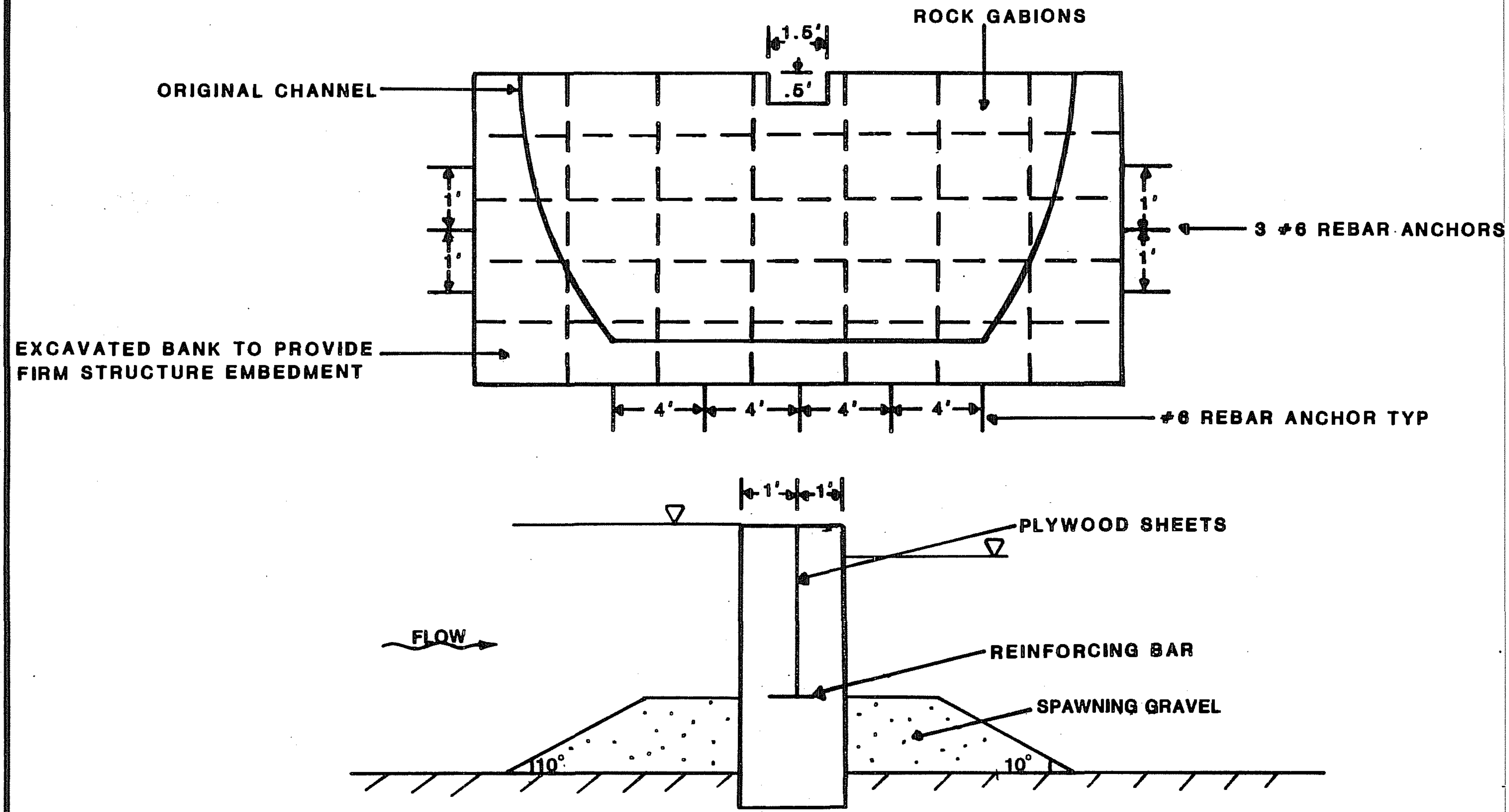

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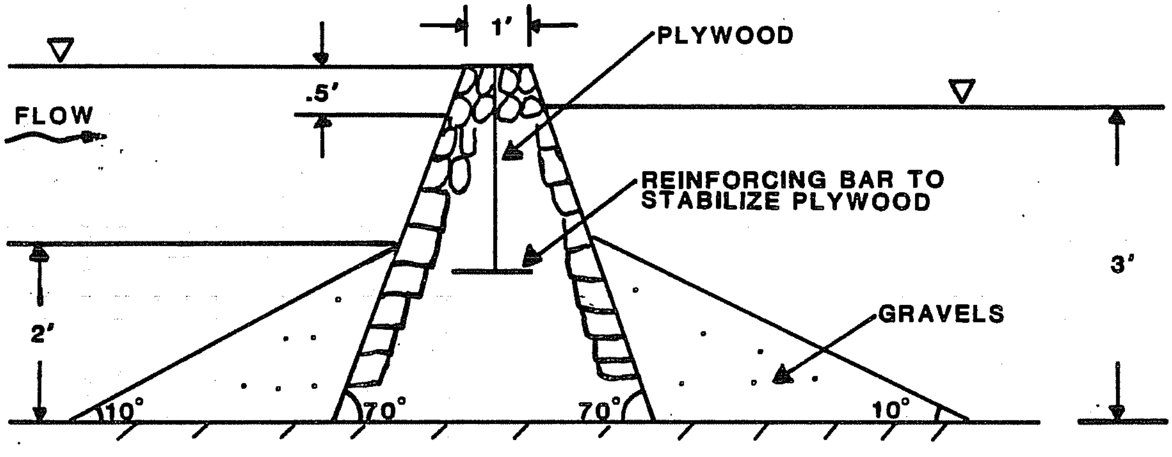
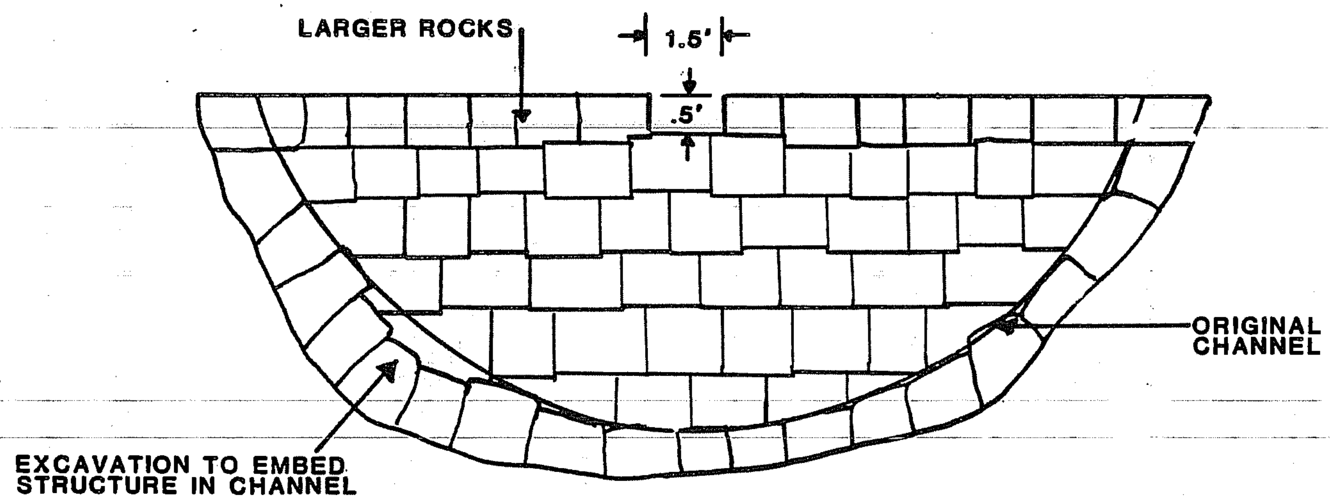
FIGURE 27 ROCK GABION WEIR

NOT TO SCALE



SIDEVIEW



CROSS-SECTION

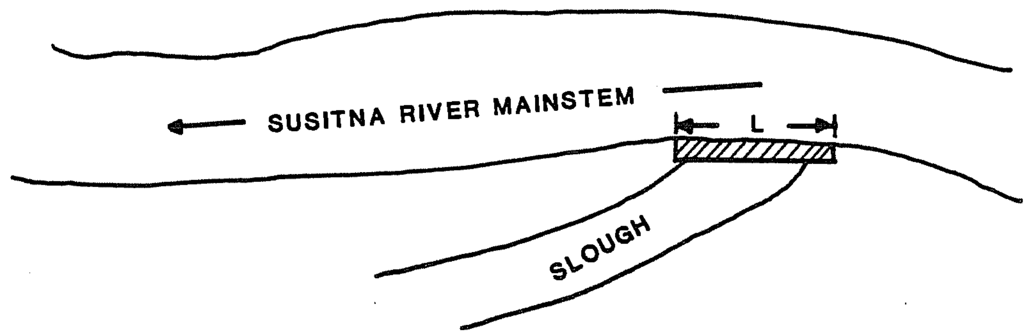
FIGURE 28 ROCK WEIR

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

Woodward-Clyde Consultants

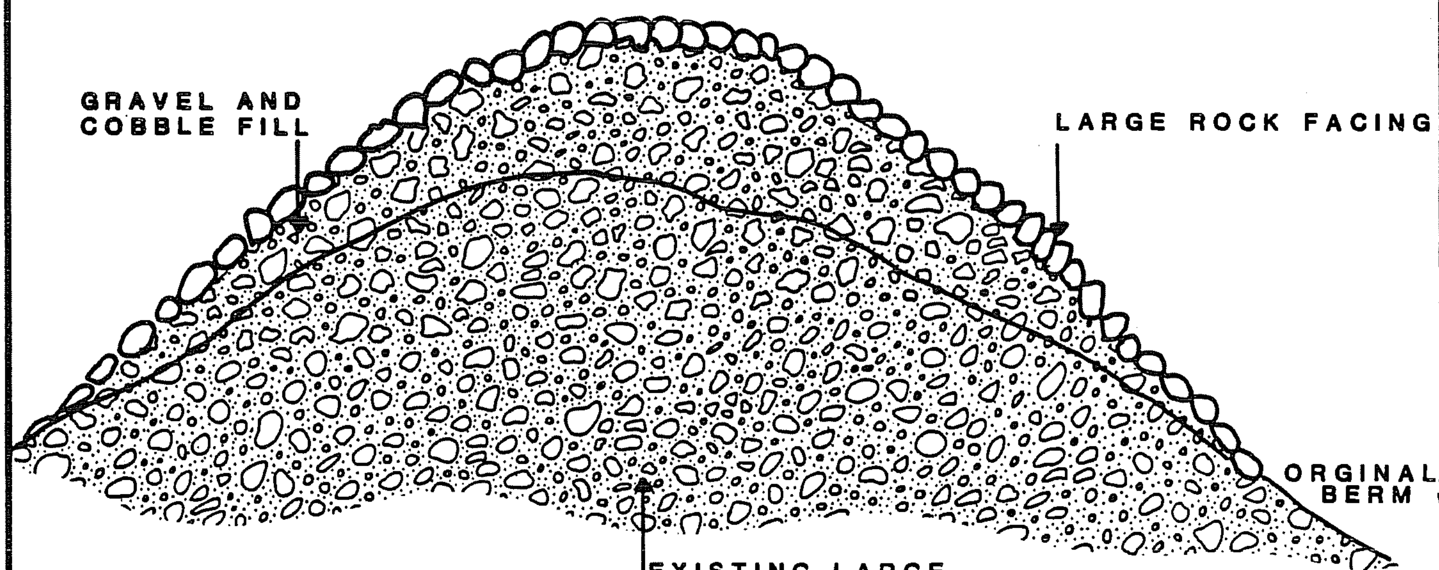
HARZA-EBASCO
SUSITNA JOINT VENTURE

NOT TO SCALE



PLAN VIEW

L=LENGTH OF BERM



CROSS SECTIONAL VIEW

FIGURE 29 **BERM DESIGN TO PREVENT OVERTOPPING**

ALASKA POWER AUTHORITY
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NOT TO SCALE

FIGURE 30 LOCATIONS OF MITIGATION MEASURES AND PERCENT DISTRIBUTION OF SPAWNING CHUM SALMON DURING 1984 IN SLOUGH 8A.

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FIGURE 3[illegible] LOCATIONS OF MITIGATION MEASURES AND PERCENT DISTRIBUTION OF SPAWNING CHUM SALMON DURING 1984 IN SLOUGH 9.

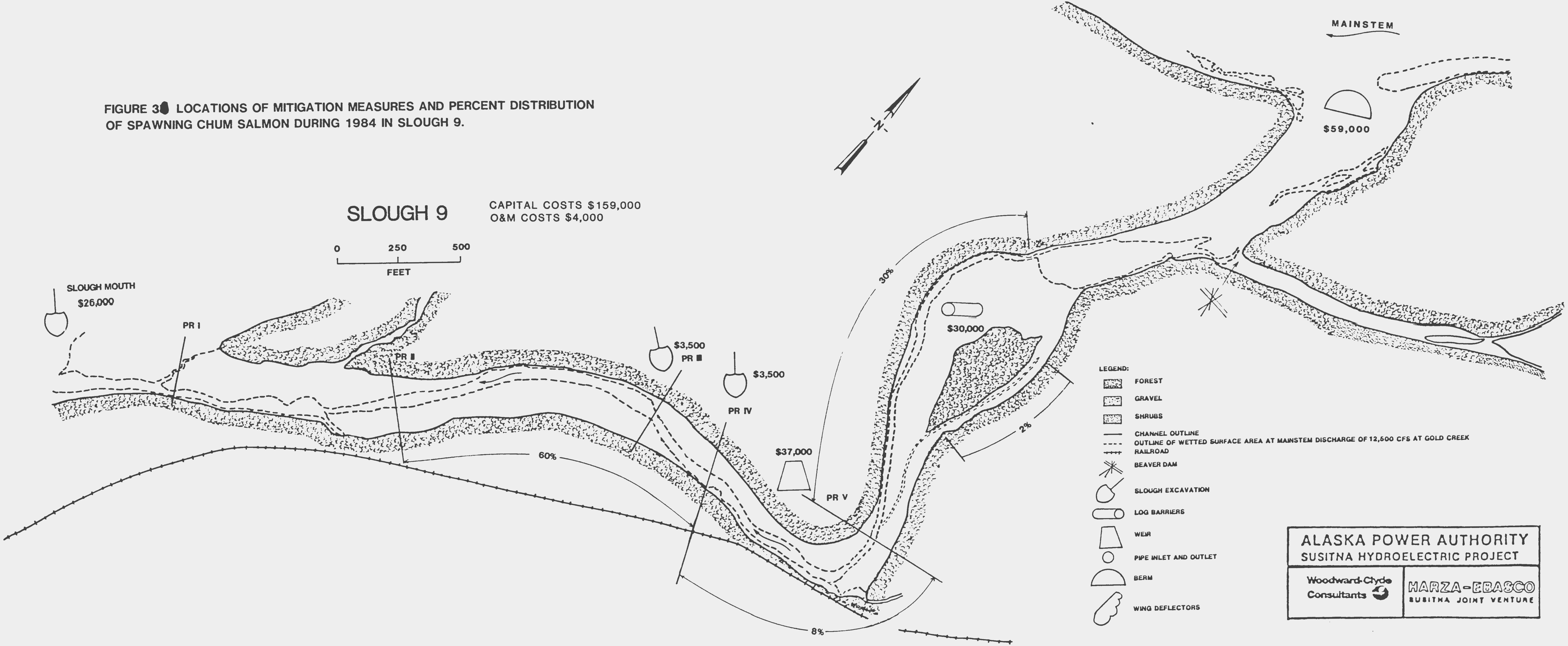
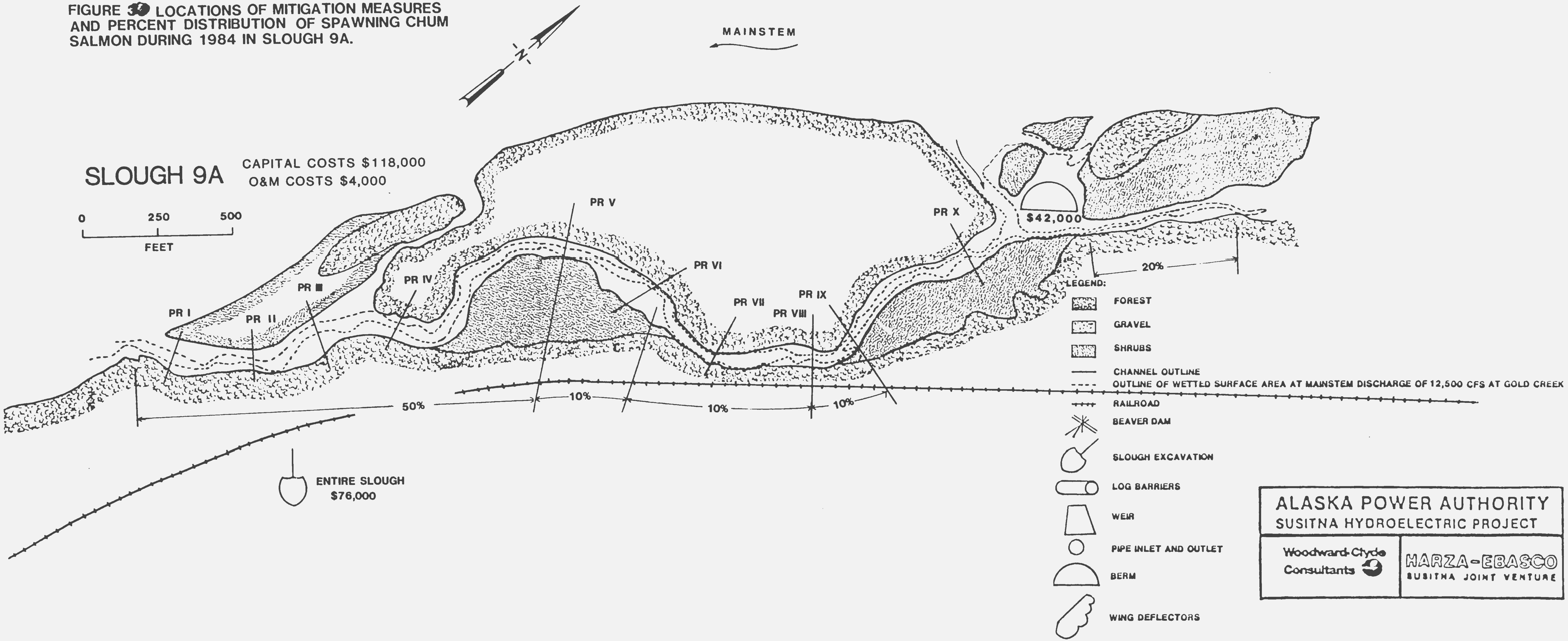


FIGURE 3[illegible] LOCATIONS OF MITIGATION MEASURES AND PERCENT DISTRIBUTION OF SPAWNING CHUM SALMON DURING 1984 IN SLOUGH 9A.



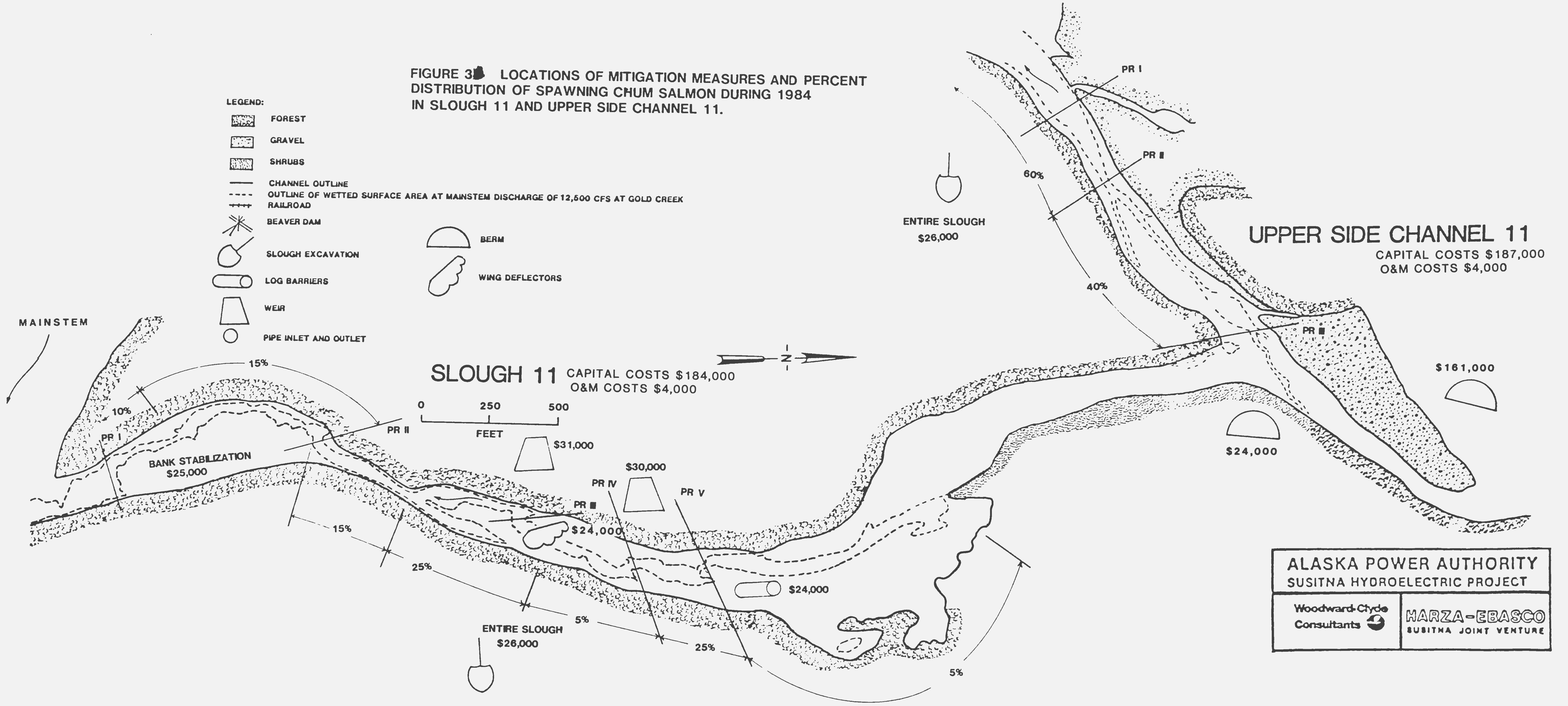


FIGURE 3[illegible] LOCATIONS OF MITIGATION MEASURES AND PERCENT DISTRIBUTION OF SPAWNING CHUM SALMON DURING 1984 IN SLOUGH 11 AND UPPER SIDE CHANNEL 11.

FIGURE 3[illegible] LOCATIONS OF MITIGATION MEASURES AND PERCENT DISTRIBUTION OF SPAWNING CHUM SALMON DURING 1984 IN SLOUGH 21 AND LOWER SIDE CHANNEL 21.

APPENDIX A

APPENDIX A

Passage Reach Flow Evaluation

APPENDIX A

Passage Reach Flow Evaluation

A previous analysis estimated the required local flow for successful fish passage through the passage reaches of the sloughs along the middle section of the Susitna River (Sautner et al. 1984c). In order to evaluate the available local flow in Sloughs 8A, 9, 9A, 11 and 21 in comparison to the required local flows, an analysis of the local flow sources for each slough was conducted. Local flow is composed of groundwater upwelling and surface inflow. A primary component of groundwater upwelling is related to the mainstem discharge (APA 1984).

The relationships developed for the apparent groundwater upwelling component of slough flow at the R&M gage site within the slough versus mainstem discharge measured at Gold Creek are listed below (APA 1984 and pers. comm. B. Bates?).

Slough	Regression Equation	r^2
8A	S = -.10 + .00017G	.53
9	S = -.62 + .00039G	.82
11	S = 1.43 + .000087G	.63
21	S = -7.55 + .00105G	.542

S = slough flow (cfs)

G = mainstem discharge at Gold Creek (cfs)

The limitations and applications of these equations are discussed in the following paragraphs.

Use of the regression equation developed for Slough 8A appears to be a relatively accurate method of determining slough flows for given mainstem flows. The equation was developed for the period from 3 July to 30 October 1984 excluding the 23 August to 28 August period of high runoff. Passage is critical in August and September; the data used to calculate the regression equation represents these mouths. However, the equation does not separate slough flow into tributary inflow and groundwater inflow; the tributary inflow component is assumed to be small at low mainstem discharges.

For Slough 9, the regression equation was developed for the period from 8 September to 30 October 1984 corresponding to the period of non-overtopped flows. The slough flow estimated using the equation includes tributary inflow and groundwater inflow. In order to be able to predict the groundwater slough flow, an alternate equation was developed. Slough flow versus mainstem discharge data for 1982, 1983, and 1984 were plotted (Figure A1). Using a slope for the regression line approximating the slope developed for Slough 8A which was assumed to be the slough most similar to Slough 9, a line was drawn through the values corresponding to the lowest slough flows. A minimum groundwater component for the slough was chosen to be 1 cfs, which is about 75 percent of the minimum recorded flow. Using these lines as shown in Figure A1, the groundwater flow at the gage was obtained for various mainstem discharges.

The regression equation for Slough 11 flow appeared to be a fairly accurate means of predicting slough flows corresponding to mainstem discharges. It was based on data collected from 25 May to 27 October 1983 and from 1 June to 30 October 1984.

At Slough 21, the correlation value of 0.542 for the slough flow versus mainstem flow relationship is consistent with the poor slough discharge predictions at low mainstem discharges. Data from 10 August to 22 October 1982 was used to develop the equation. A minimum base flow was estimated to be 75 percent of the minimum slough discharge recorded; at low mainstem discharges, i.e. <8,300 cfs, the base flow component of the local flow is assumed to be constant at 1.2 cfs.

With these limitations in mind, the regression equations were used to estimate the apparent groundwater upwelling component of local flow at the R&M gage site in a slough given a mainstem discharge. In order to obtain the upwelling component of local flow at other points within the slough, the amounts of upwelling throughout the slough were estimated in terms of percent of the gage flow using aerial photographs, observations by R&M personnel (R&M Consultants, Inc. 1982), and measured upwelling values (APA 1984 and Moulton & Rundquist 1984). The percentage values (Tables A1-A4) were applied to the calculated flow at the gage resulting in estimates of the upwelling component of local flow at points corresponding to passage reaches in the slough (Figures A2-A5). For Slough 9A, measured upwelling values were correlated with mainstem discharge to yield the upwelling component of local flow at the passage reaches. For Upper Side Channel 11, the base flows corresponding to selected mainstem discharges were estimated at each passage reach (Sautner et al. 1984c and ADF&G 1984). Side Channel 21 was assumed to be a hydraulic extension of Slough 21.

A comparison between required local flow and estimated available upwelling component of local flow was made at each passage reach (Tables A5 to A50). An evaluation was conducted of how much of the time the local flow requirements could be satisfied by groundwater flow alone. The required local flow was input to the relationship between slough flow and mainstem discharge to obtain the required mainstem discharge. The flow duration curve developed for the period 20 August to 20 September (Sautner et al. 1984c) for the mainstem discharge was used to evaluate the percent occurrence of these flows under natural conditions.

For project conditions, the minimum instream flow requirement for each project flow case was compared to the mainstem discharge estimated to be necessary to produce upwelling flows sufficient for passage. If the minimum instream flow requirement was greater than the estimated mainstem discharge, a value of 100 percent was assigned to the percent occurrence of successful passage with groundwater alone. Alternatively, a value of 0 percent occurrence was assigned if the minimum instream flow requirement was less than the estimated mainstem discharge. Use of minimum instream flow requirements in the analysis addresses potential impacts during low to average flow years compared with median natural flows. Project effects during high flow years would be less.

A combination of surface water and groundwater sources was analyzed. The groundwater component of the local flow was determined from the regression equation based on selected mainstem discharges. For natural slough flows, the mainstem discharge of 50 percent occurrence equalling 15,000 cfs was chosen as the basis for groundwater flows. Project flows were assumed constant at the minimum required flows of 8,000 cfs or 9,000 cfs for Case EVI and 12,000 cfs for Cases C and EV. Also, for Case EV, the effect of a spike of mainstem discharge of 18,000 cfs during spawning was evaluated. If the higher mainstem discharge increased the frequency of passage over that available for the minimum requirements of 12,000 cfs, this was indicated in Tables A5 to A50. Project effects during high flow years would be less. The percent of time that tributary inflow was sufficient to supplement groundwater in order to provide the required flow for passage was based on an estimate of the contributing basin area, an assumed runoff percentage of 40 percent, and precipitation duration curves for Talkeetna for the period of 1972 to 1981 (Tables A5 to A50). The percent occurrence of successful passage for passage reaches affected by backwater and breaching was previously analyzed (Sautner et al. 1984c).

The final value selected for each passage reach was the largest percent successful passage occurrence value of those calculated (Tables A5 to A50). Passage reaches impacted by a decrease in mainstem flow are identified by significant decreases in percents occurrence between natural and project flows. Any additive effects of accumulation of percent occurrences were assumed negligible.

Table A1. Percent groundwater relative to gage flow at passage reaches in Slough 8A.

Passage Reach	Percent of Groundwater Relative to Gage Flow
I	103
II	101
III	101
IV	60
V	52
VI	43
VII	35
VIII	25
IX	15

Table A2. Percent groundwater relative to gage flow at passage reaches in Slough 9.

Passage Reach	Percent of Groundwater Relative to Gage Flow
I	124
II	117
III	100
IV	95
V	77

Table A3. Percent groundwater relative to gage flow at passage reaches in Slough 11.

Passage Reach	Percent of Groundwater Relative to Gage Flow
I	145
II	127
III	102
IV	97
V	65

Table A4. Percent groundwater relative to gage flow at passage reaches in Slough 21 and Side Channel 21.

Passage Reach	Percent of Groundwater Relative to Gage Flow
Slough 21	
I	122
IIL	35
IIR	39
Side Channel 21	
I	221
II	219
III	214
IV	214
V	212
VI	210
VII	205
VIII	201
IX	200
X	153

Table A5. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Slough 8A for Passage Reach I.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
<u>Groundwater & Surface water</u>				
Required flow (cfs)	2	2	2	2
Groundwater baseflow (cfs) corresponding to specified mainstem flow	2.6	2.0	1.4	1.3
Surface water necessary for passage (cfs)	0.0	0.0	0.6	0.7
Amount of ppt needed for basin area of 1.36 mile^2 (in)	0.0	0.0	.01	.01
% Exceeded based on total daily ppt and groundwater	100	100	34	32
<u>Breaching</u> % exceeded for controlling discharge of 27,000 cfs	7	0	0	0
<u>Backwater</u> % exceeded for mainstem discharge of <10,600 cfs	79	100	0	0
Maximum % exceeded	100	100[b]	34	32

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will assist passage through PR I by backwater effects

Table A6. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Slough 8A for Passage Reach II.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	4[c]	4	4	4
Groundwater baseflow (cfs) corresponding to specified mainstem flow	2.5	1.9	1.4	1.3
Surface water necessary for passage (cfs)	1.5	2.1	2.6	2.7
Amount of ppt needed for basin area of 1.36 mile^2 (in)	.03	.04	.04	.05
% Exceeded based on total daily ppt and groundwater	25	22	20	20
Breaching % exceeded for controlling discharge of 27,000 cfs	7	0	0	0
Backwater % exceeded for mainstem discharge of 15,600 cfs	48	0	0	0
Maximum % exceeded	48	22[b]	20	20

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will assist passage through PR II by backwater effects

c Required flow estimated assuming that required flow at upstream PR is sufficient for passage at downstream PR

Table A7. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Slough 8A for Passage Reach III.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	4	4	4	4
Groundwater baseflow (cfs) corresponding to specified mainstem flow	2.5	1.9	1.4	1.3
Surface water necessary for passage (cfs)	1.5	2.1	2.6	2.7
Amount of ppt needed for basin area of 1.36 $mile^2$ (in)	.03	.04	.04	.05
% Exceeded based on total daily ppt and groundwater	25	22	20	20
Breaching % exceeded for controlling discharge of 27,000 cfs	7	0	0	0
Backwater % exceeded for mainstem discharge of d cfs	d	d	d	d
Maximum % exceeded	25	22	20	20

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will not assist passage through PR III

d Breaching occurs prior to backwater effects

Table A8. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Slough 8A for Passage Reach IV.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	5[c]	5	5	5
Groundwater baseflow (cfs) corresponding to specified mainstem flow	1.5	1.1	.8	.8
Surface water necessary for passage (cfs)	3.5	3.9	4.2	4.2
Amount of ppt needed for basin area of 1.09 $mile^2$ (in)	.07	.08	.09	.09
% Exceeded based on total daily ppt and groundwater	14	12	10	10
Breaching % exceeded for controlling discharge of 33,000 cfs	2	0	0	0
Backwater % exceeded for mainstem discharge of d cfs	d	d	d	d
Maximum % exceeded	14	12[b]	10	10

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18,000 cfs will not assist passage through PR IV

c Required flow estimated assuming that required flow at upstream PR is sufficient for passage at downstream PR

d Breaching occurs prior to backwater effects

Table A9. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Slough 8A for Passage Reach V.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	5	5	5	5
Groundwater baseflow (cfs) corresponding to specified mainstem flow	1.3	1.0	.7	.7
Surface water necessary for passage (cfs)	3.7	4.0	4.3	4.3
Amount of ppt needed for basin area of 1.09 mile^2 (in)	.08	.08	.09	.09
% Exceeded based on total daily ppt and groundwater	13	11	9	9
Breaching % exceeded for controlling discharge of 33,000 cfs	2	0	0	0
Backwater % exceeded for mainstem discharge of d cfs	d	d	d	d
Maximum % exceeded	13	11	9	9

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18,000 cfs will not assist passage through PR V

d Breaching occurs prior to backwater effects

Table A10. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Slough 8A for Passage Reach VI.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	4	4	4	4
Groundwater baseflow (cfs) corresponding to specified mainstem flow	1.1	.8	.6	.6
Surface water necessary for passage (cfs)	2.9	3.2	3.4	3.4
Amount of ppt needed for basin area of 0.96 mile^2 (in)	.07	.08	.08	.08
% Exceeded based on total daily ppt and groundwater	14	13	12	12
Breaching % exceeded for controlling discharge of 33,000 cfs	2	0	0	0
Backwater % exceeded for mainstem discharge of d cfs	d	d	d	d
Maximum % exceeded	14	13[b]	12	12

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will not assist passage through PR VI

c Required flow estimated assuming that required flow at upstream PR is sufficient for passage at downstream PR

d Breaching occurs prior to backwater effects

Table A11. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Slough 8A for Passage Reach VII.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	4[c]	4	4	4
Groundwater baseflow (cfs) corresponding to specified mainstem flow	.9	.7	.5	.5
Surface water necessary for passage (cfs)	3.1	3.3	3.5	3.5
Amount of ppt needed for basin area of .96 $mile^2$ (in)	.08	.08	.08	.08
% Exceeded based on total daily ppt and groundwater	13	13	11	11
Breaching % exceeded for controlling discharge of 33,000 cfs	2	0	0	0
Backwater % exceeded for mainstem discharge of d cfs	d	d	d	d
Maximum % exceeded	13	13	11	11

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will not assist passage through PR VII

c Required flow estimated assuming that required flow at upstream PR is sufficient for passage at downstream PR

d Breaching occurs prior to backwater effects

Table A12. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Slough 8A for Passage Reach VIII.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	4	4	4	4
Groundwater baseflow (cfs) corresponding to specified mainstem flow	.6	.5	.4	.3
Surface water necessary for passage (cfs)	3.4	3.5	3.6	3.7
Amount of ppt needed for basin area of .55 mile^2 (in)	.14	.15	.15	.16
% Exceeded based on total daily ppt and groundwater	6	6	5	4
Breaching % exceeded for controlling discharge of 33,000 cfs	2	0	0	0
Backwater % exceeded for mainstem discharge of d cfs	d	d	d	d
Maximum % exceeded	6	6[b]	5	4

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will not assist passage through PR VIII

d Breaching occurs prior to backwater effects

Table A13. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Slough 8A for Passage Reach IX.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	4	4	4	4
Groundwater baseflow (cfs) corresponding to specified mainstem flow	.4	.3	.2	.2
Surface water necessary for passage (cfs)	3.6	3.7	3.8	3.8
Amount of ppt needed for basin area of 0 mile^2 (in)	e	e	e	e
% Exceeded based on total daily ppt and groundwater	0	0	0	0
Breaching % exceeded for controlling discharge of 33,000 cfs	2	0	0	0
Backwater % exceeded for mainstem discharge of d cfs	d	d	d	d
Maximum % exceeded	2	0[b]	0	0

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will not assist passage through PR IX

d Breaching occurs prior to backwater effects

e Not possible, basin area is insufficient to provide surface runoff

Table A14. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Slough 9 for Passage Reach I.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	2	2	2	2
Groundwater baseflow (cfs) corresponding to specified mainstem flow	2.6	2.1	1.6	1.5
Surface water necessary for passage (cfs)	0	0	.4	.5
Amount of ppt needed for basin area of 2.99 mile^2 (in)	0	0	.003	.004
% Exceeded based on total daily ppt and groundwater	100	100	47	44
Breaching % exceeded for controlling discharge of 19,000 cfs	29	0	0	0
Backwater % exceeded for mainstem discharge of <12,200 cfs	70	0	0	0
Maximum % exceeded	100	100[b]	47	44

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will assist passage through PR I by backwater effects

Table A15. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Slough 9 for Passage Reach II.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	1	1	1	1
Groundwater baseflow (cfs) corresponding to specified mainstem flow	2.5	2.0	1.5	1.4
Surface water necessary for passage (cfs)	0	0	0	0
Amount of ppt needed for basin area of 1.73 mile^2 (in)	0	0	0	0
% Exceeded based on total daily ppt and groundwater	100	100	100	100
Breaching % exceeded for controlling discharge of 19,000 cfs	29	0	0	0
Backwater % exceeded for mainstem discharge of d cfs	d	d	d	d
Maximum % exceeded	100	100[c]	100	100

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will not assist passage through PR II

d Breaching occurs prior to backwater effects

Table A16. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Slough 9 for Passage Reach III.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	6	6	6	6
Groundwater baseflow (cfs) corresponding to specified mainstem flow	2.1	1.7	1.3	1.2
Surface water necessary for passage (cfs)	3.9	4.3	4.7	4.8
Amount of ppt needed for basin area of 1.73 mile^2 (in)	.05	.06	.06	.06
% Exceeded based on total daily ppt and groundwater	18	16	15	14
Breaching % exceeded for controlling discharge of 19,000 cfs	29	0	0	0
Backwater % exceeded for mainstem discharge of d cfs	d	d	d	d
Maximum % exceeded	29	16[b]	15	14

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will not assist passage through PR III

d Breaching occurs prior to backwater effects

Table A17. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Slough 9 for Passage Reach IV.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	6[c]	6	6	6
Groundwater baseflow (cfs) corresponding to specified mainstem flow	2.0	1.6	1.2	1.1
Surface water necessary for passage (cfs)	4.0	4.4	4.8	4.9
Amount of ppt needed for basin area of 1.73 $mile^2$ (in)	.05	.06	.06	.07
% Exceeded based on total daily ppt and groundwater	17	16	14	14
Breaching % exceeded for controlling discharge of 19,000 cfs	29	0	0	0
Backwater % exceeded for mainstem discharge of d cfs	d	d	d	d
Maximum % exceeded	29	16[b]	14	14

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will not assist passage through PR IV

c Required flow estimated assuming that required flow at downstream PR is sufficient for passage at upstream PR

d Breaching occurs prior to backwater effects

Table A18. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Slough 9 for Passage Reach V.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	6[c]	6	6	6
Groundwater baseflow (cfs) corresponding to specified mainstem flow	1.6	1.3	1.0	0.9
Surface water necessary for passage (cfs)	4.4	4.7	5	5.1
Amount of ppt needed for basin area of 0 mile^2 (in)	e	e	e	e
% Exceeded based on total daily ppt and groundwater	0	0	0	0
Breaching % exceeded for controlling discharge of 19,000 cfs	29	0	0	0
Backwater % exceeded for mainstem discharge of d cfs	d	d	d	d
Maximum % exceeded	29	0[b]	0	0

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will not assist passage through PR V

c Required flow estimated assuming that required flow at downstream PR is sufficient for passage at upstream PR

d Breaching occurs prior to backwater effects

e Not possible; basin area is insufficient to provide surface runoff

Table A19. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Slough 9A for Passage Reach I.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	1	1	1	1
Groundwater baseflow (cfs) corresponding to specified mainstem flow	4	3.5	3.1	3.0
Surface water necessary for passage (cfs)	0	0	0	0
Amount of ppt needed for basin area of 2.27 $mile^2$ (in)	0	0	0	0
% Exceeded based on total daily ppt and groundwater	100	100	100	100
Breaching % exceeded for controlling discharge of f cfs	f	f	f	f
Backwater % exceeded for mainstem discharge of f cfs	f	f	f	f
Maximum % exceeded	100	100	100	100

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will not assist passage through PR I according to existing data

f No data available

Table A20. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Slough 9A for Passage Reach II.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	3	3	3	3
Groundwater baseflow (cfs) corresponding to specified mainstem flow	3.9	3.4	3.0	2.5
Surface water necessary for passage (cfs)	0	0	0	.5
Amount of ppt needed for basin area of 2.27 $mile^2$ (in)	0	0	0	.005
% Exceeded based on total daily ppt and groundwater	100	100	100	41
Breaching % exceeded for controlling discharge of f cfs	f	f	f	f
Backwater % exceeded for mainstem discharge of f cfs	f	f	f	f
Maximum % exceeded	100	100[b]	100	41

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will not assist passage through PR II according to existing data

f No data available

Table A21. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Slough 9A for Passage Reach III.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	3	3	3	3
Groundwater baseflow (cfs) corresponding to specified mainstem flow	3.7	3.2	2.8	2.0
Surface water necessary for passage (cfs)	0	0	.2	1.0
Amount of ppt needed for basin area of .35 $mile^2$ (in)	0	0	.01	.07
% Exceeded based on total daily ppt and groundwater	100	100	32	14
Breaching % exceeded for controlling discharge of f cfs	f	f	f	f
Backwater % exceeded for mainstem discharge of f cfs	f	f	f	f
Maximum % exceeded	100	100[b]	32	14

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will not assist passage through PR III according to existing data

f No data available

Table A22. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Slough 9A for Passage Reach IV.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	1	1	1	1
Groundwater baseflow (cfs) corresponding to specified mainstem flow	3.4	2.9	2.5	1.9
Surface water necessary for passage (cfs)	0	0	0	0
Amount of ppt needed for basin area of .35 mile^2 (in)	0	0	0	0
% Exceeded based on total daily ppt and groundwater	100	100	100	100
Breaching % exceeded for controlling discharge of f cfs	f	f	f	f
Backwater % exceeded for mainstem discharge of f cfs	f	f	f	f
Maximum % exceeded	100	100[b]	100	100

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will not assist passage through PR IV according to existing data

f No data available

Table A23. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Slough 9A for Passage Reach V.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	2[c]	2	2	2
Groundwater baseflow (cfs) corresponding to specified mainstem flow	2.9	2.4	2.0	1.6
Surface water necessary for passage (cfs)	0	0	0	.4
Amount of ppt needed for basin area of .21 $mile^2$ (in)	0	0	0	.04
% Exceeded based on total daily ppt and groundwater	100	100	100	20
Breaching % exceeded for controlling discharge of f cfs	f	f	f	f
Backwater % exceeded for mainstem discharge of f cfs	f	f	f	f
Maximum % exceeded	100	100[b]	100	20

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will not assist passage through PR V according to existing data

c Required flow estimated assuming that required flow at upstream PR is sufficient for passage at downstream PR

f No data available

Table A24. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Slough 9A for Passage Reach VI.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	2[c]	2	2	2
Groundwater baseflow (cfs) corresponding to specified mainstem flow	2.7	2.2	1.8	1.5
Surface water necessary for passage (cfs)	0	0	.2	.5
Amount of ppt needed for basin area of .17 mile^2 (in)	0	0	.03	.06
% Exceeded based on total daily ppt and groundwater	100	100	24	14
Breaching % exceeded for controlling discharge of f cfs	f	f	f	f
Backwater % exceeded for mainstem discharge of f cfs	f	f	f	f
Maximum % exceeded	100	100[b]	24	14

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will not assist passage through PR VI according to existing data

c Required flow estimated assuming that required flow at upstream PR is sufficient for passage at downstream PR

f No data available

Table A25. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Slough 9A for Passage Reach VII.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	2[c]	2	2	2
Groundwater baseflow (cfs) corresponding to specified mainstem flow	2.4	1.9	1.5	1.3
Surface water necessary for passage (cfs)	0	.1	.5	.7
Amount of ppt needed for basin area of .13 mile^2 (in)	0	.02	.09	.13
% Exceeded based on total daily ppt and groundwater	100	40	10	7
Breaching % exceeded for controlling discharge of f cfs	f	f	f	f
Backwater % exceeded for mainstem discharge of f cfs	f	f	f	f
Maximum % exceeded	100	40[b]	10	7

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will not assist passage through PR VII according to existing data

c Required flow estimated assuming that required flow at upstream PR is sufficient for passage at downstream PR

f No data available

Table A26. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Slough 9A for Passage Reach VIII.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	2[c]	2	2	2
Groundwater baseflow (cfs) corresponding to specified mainstem flow	2.3	1.8	1.4	1.2
Surface water necessary for passage (cfs)	0	.2	.6	.8
Amount of ppt needed for basin area of .10 mile^2 (in)	0	.05	14	.19
% Exceeded based on total daily ppt and groundwater	100	31	6	3
Breaching % exceeded for controlling discharge of f cfs	f	f	f	f
Backwater % exceeded for mainstem discharge of f cfs	f	f	f	f
Maximum % exceeded	100	31[b]	6	3

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will not assist passage through PR VIII according to existing data

c Required flow estimated assuming that required flow at upstream PR is sufficient for passage at downstream PR

f No data available

Table A27. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Slough 9A for Passage Reach IX.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	2	2	2	2
Groundwater baseflow (cfs) corresponding to specified mainstem flow	2.1	1.6	1.3	1.1
Surface water necessary for passage (cfs)	0	.4	.7	.9
Amount of ppt needed for basin area of .08 mile^2 (in)	0	.12	.20	.25
% Exceeded based on total daily ppt and groundwater	100	24	3	2
Breaching % exceeded for controlling discharge of f cfs	f	f	f	f
Backwater % exceeded for mainstem discharge of f cfs	f	f	f	f
Maximum % exceeded	100	24[b]	3	2

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will not assist passage through PR IX according to existing data

f No data available

Table A28. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Slough 9A for Passage Reach X.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	3	3	3	3
Groundwater baseflow (cfs) corresponding to specified mainstem flow	0	0	0	0
Surface water necessary for passage (cfs)	3	3	3	3
Amount of ppt needed for basin area of .02 $mile^2$ (in)	e	e	e	e
% Exceeded based on total daily ppt and groundwater	0	0	0	0
Breaching % exceeded for controlling discharge of f cfs	f	f	f	f
Backwater % exceeded for mainstem discharge of f cfs	f	f	f	f
Maximum % exceeded	0	0[b]	0	0

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will not assist passage through PR X according to existing data

e Not possible, basin area is insufficient to provide surface runoff

f No data available

Table A29. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Slough 11 for Passage Reach I.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
<u>Groundwater & Surface water</u>				
Required flow (cfs)	4	4	4	4
Groundwater baseflow (cfs) corresponding to specified mainstem flow	4.0	3.6	3.2	3.0
Surface water necessary for passage (cfs)	0	.4	.8	1.0
Amount of ppt needed for basin area of 0 mile^2 (in)	e	e	e	e
% Exceeded based on total daily ppt and groundwater	70	50	0	0
<u>Breaching</u> % exceeded for controlling discharge of 42,000 cfs	1	0	0	0
<u>Backwater</u> % exceeded for mainstem discharge of 16,200 cfs	44	0	0	0
Maximum % exceeded	50	45[b]	0	0

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will assist passage through PR I by backwater effects

e Not possible, basin area is insufficient to provide surface runoff

Table A30. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Slough 11 for Passage Reach II.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	4	4	4	4
Groundwater baseflow (cfs) corresponding to specified mainstem flow	3.5	3.2	2.8	2.7
Surface water necessary for passage (cfs)	.5	.8	1.2	1.3
Amount of ppt needed for basin area of 0 mile^2 (in)	e	e	e	e
% Exceeded based on total daily ppt and groundwater	30	18	0	0
Breaching % exceeded for controlling discharge of 42,000 cfs	1	0	0	0
Backwater % exceeded for mainstem discharge of 33,100 cfs	2	0	0	0
Maximum % exceeded	30	18[b]	0	0

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will not assist passage through PR II

e Not possible, basin area is insufficient to provide surface runoff

Table A31. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Slough 11 for Passage Reach III.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	4	4	4	4
Groundwater baseflow (cfs) corresponding to specified mainstem flow	2.8	2.5	2.2	2.1
Surface water necessary for passage (cfs)	1.2	1.5	1.8	1.9
Amount of ppt needed for basin area of 0 mile^2 (in)	e	e	e	e
% Exceeded based on total daily ppt and groundwater	10	5	0	0
Breaching % exceeded for controlling discharge of 42,000 cfs	1	0	0	0
Backwater % exceeded for mainstem discharge of 39,600 cfs	1	0	0	0
Maximum % exceeded	10	5[b]	0	0

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will not assist passage through PR III

e Not possible, basin area is insufficient to provide surface runoff

Table A32. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Slough 11 for Passage Reach IV.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	8	8	8	8
Groundwater baseflow (cfs) corresponding to specified mainstem flow	2.6	2.4	2.1	2.0
Surface water necessary for passage (cfs)	5.4	5.6	5.9	6.0
Amount of ppt needed for basin area of 0 $mile^2$ (in)	e	e	e	e
% Exceeded based on total daily ppt and groundwater	0	0	0	0
Breaching % exceeded for controlling discharge of 42,000 cfs	1	0	0	0
Backwater % exceeded for mainstem discharge of d cfs	d	d	d	d
Maximum % exceeded	1	0	0	0

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will not assist passage through PR IV

d Breaching occurs prior to backwater effects

e Not possible, basin area is insufficient to provide surface runoff

Table A33. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Slough 11 for Passage Reach V.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	4	4	4	4
Groundwater baseflow (cfs) corresponding to specified mainstem flow	1.7	1.6	1.4	1.4
Surface water necessary for passage (cfs)	2.3	2.4	2.6	2.6
Amount of ppt needed for basin area of 0 mile^2 (in)	e	e	e	e
% Exceeded based on total daily ppt and groundwater	0	0	0	0
Breaching % exceeded for controlling discharge of 42,000 cfs	1	0	0	0
Backwater % exceeded for mainstem discharge of d cfs	d	d	d	d
Maximum % exceeded	1	0[b]	0	0

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will not assist passage through PR V

d Breaching occurs prior to backwater effects

e Not possible, basin area is insufficient to provide surface runoff

Table A34. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Upper Side Channel 11 for Passage Reach I.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	6	6	6	6
Groundwater baseflow (cfs) corresponding to specified mainstem flow	6	5	5	5
Surface water necessary for passage (cfs)	0	1	1	1
Amount of ppt needed for basin area of 0 $mile^2$ (in)	e	e	e	e
% Exceeded based on total daily ppt and groundwater	50	0	0	0
Breaching % exceeded for controlling discharge of 16,000 cfs	45	0	0	0
Backwater % exceeded for mainstem discharge of 12,400 cfs	68	0	0	0
Maximum % exceeded	68	0[b]	0	0

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will assist passage through PR I by breaching effects

d Breaching occurs prior to backwater effects

Table A35. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Upper Side Channel 11 for Passage Reach II.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	12	12	12	12
Groundwater baseflow (cfs) corresponding to specified mainstem flow	6	5	5	5
Surface water necessary for passage (cfs)	6	7	7	7
Amount of ppt needed for basin area of 0 $mile^2$ (in)	e	e	e	e
% Exceeded based on total daily ppt and groundwater	0	0	0	0
Breaching % exceeded for controlling discharge of 16,000 cfs	45	0	0	0
Backwater % exceeded for mainstem discharge of d cfs	d	d	d	d
Maximum % exceeded	45	0[b]	0	0

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will assist passage through PR II by breaching effects

d Breaching occurs prior to backwater effects

e Not possible; basin area is insufficient to provide surface runoff

Table A36. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Upper Side Channel 11 for Passage Reach III.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	12[c]	12	12	12
Groundwater baseflow (cfs) corresponding to specified mainstem flow	3	2	2	2
Surface water necessary for passage (cfs)	9	10	10	10
Amount of ppt needed for basin area of 0 mile^2 (in)	e	e	e	e
% Exceeded based on total daily ppt and groundwater	0	0	0	0
Breaching % exceeded for controlling discharge of 16,000 cfs	45	0	0	0
Backwater % exceeded for mainstem discharge of d cfs	d	d	d	d
Maximum % exceeded	45	0[b]	0	0

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will assist passage through PR III by breaching effects

c Required flow estimated assuming that required flow at downstream PR is sufficient for passage at upstream PR

d Breaching occurs prior to backwater effects

e Not possible; basin area is insufficient to provide surface runoff

Table A37. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Slough 21 for Passage Reach I.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	5	5	5	5
Groundwater baseflow (cfs) corresponding to specified mainstem flow	10	6.2	2.3	1.1
Surface water necessary for passage (cfs)	0	0	2.7	4.9
Amount of ppt needed for basin area of .52 mile^2 (in)	0	0	.12	.22
% Exceeded based on total daily ppt and groundwater	100	100	6	4
Breaching % exceeded for controlling discharge of 25,000 cfs	10	0	0	0
Backwater % exceeded for mainstem discharge of d cfs	d	d	d	d
Maximum % exceeded	100	100[b]	6	4

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will not assist passage through PR I

d Breaching occurs prior to backwater effects

Table A38. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Slough 21 for Passage Reach IIL.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	5	5	5	5
Groundwater baseflow (cfs) corresponding to specified mainstem flow	2.9	1.8	0.7	0.3
Surface water necessary for passage (cfs)	2.1	3.2	4.3	4.7
Amount of ppt needed for basin area of 0 mile^2 (in)	e	e	e	e
% Exceeded based on total daily ppt and groundwater	0	0	0	0
Breaching % exceeded for controlling discharge of 25,000 cfs	10	0	0	0
Backwater % exceeded for mainstem discharge of d cfs	d	d	d	d
Maximum % exceeded	10	0[b]	0	0

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will not assist passage through PR IIL

d Breaching occurs prior to backwater effects

e Not possible; basin area is insufficient to provide surface runoff

Table A39. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Slough 21 for Passage Reach IIR.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	5	5	5	5
Groundwater baseflow (cfs) corresponding to specified mainstem flow	3.2	2.0	0.7	0.4
Surface water necessary for passage (cfs)	1.8	3.0	4.3	4.6
Amount of ppt needed for basin area of .26 mile^2 (in)	.16	.27	.39	.41
% Exceeded based on total daily ppt and groundwater	4	2	1	1
Breaching % exceeded for controlling discharge of f cfs	f	f	f	f
Backwater % exceeded for mainstem discharge of f cfs	f	f	f	f
Maximum % exceeded	4	2[b]	1	1

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will not assist passage through PR IIR

f No data available

Table A40. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Side Channel 21 for Passage Reach I.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	8[c]	8	8	8
Groundwater baseflow (cfs) corresponding to specified mainstem flow	18.1	11.3	4.2	2.0
Surface water necessary for passage (cfs)	0	0	3.8	6.0
Amount of ppt needed for basin area of 5.03 mile^2 (in)	0	0	.02	.03
% Exceeded based on total daily ppt and groundwater	100	100	28	24
Breaching % exceeded for controlling discharge of 12,000 cfs	71	100	0	0
Backwater % exceeded for mainstem discharge of 12,000 cfs	71	100	0	0
Maximum % exceeded	100	100[b]	28	24

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will assist passage through PR I by breaching effects

c Required flow estimated assuming that required flow at upstream PR is sufficient for passage at downstream PR

Table A41. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Side Channel 21 for Passage Reach II.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	8	8	8	8
Groundwater baseflow (cfs) corresponding to specified mainstem flow	18.0	11.2	4.2	2.0
Surface water necessary for passage (cfs)	0	0	3.8	6.0
Amount of ppt needed for basin area of 5.03 $mile^2$ (in)	0	0	.02	.03
% Exceeded based on total daily ppt and groundwater	100	100	28	24
Breaching % exceeded for controlling discharge of 12,000 cfs	71	100	0	0
Backwater % exceeded for mainstem discharge of d cfs	d	d	d	d
Maximum % exceeded	100	100[b]	28	24

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will assist passage through PR II by breaching effects

d Breaching occurs prior to backwater effects

Table A42. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Side Channel 21 for Passage Reach III.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	7[c]	7	7	7
Groundwater baseflow (cfs) corresponding to specified mainstem flow	17.5	10.9	4.1	1.9
Surface water necessary for passage (cfs)	0	0	2.9	5.1
Amount of ppt needed for basin area of 5.03 mile^2 (in)	0	0	.01	.02
% Exceeded based on total daily ppt and groundwater	100	100	31	26
Breaching % exceeded for controlling discharge of 12,000 cfs	71	100	0	0
Backwater % exceeded for mainstem discharge of d cfs	d	d	d	d
Maximum % exceeded	100	100[b]	31	26

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will assist passage through PR III by breaching effects

c Required flow estimated assuming that required flow at upstream PR is sufficient for passage at downstream PR

d Breaching occurs prior to backwater effects

Table A43. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Side Channel 21 for Passage Reach IV.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	7	7	7	7
Groundwater baseflow (cfs) corresponding to specified mainstem flow	17.5	10.9	4.1	1.9
Surface water necessary for passage (cfs)	0	0	2.9	5.1
Amount of ppt needed for basin area of 5.03 mile^2 (in)	0	0	.01	.02
% Exceeded based on total daily ppt and groundwater	100	100	31	26
Breaching % exceeded for controlling discharge of 12,000 cfs	71	100	0	0
Backwater % exceeded for mainstem discharge of d cfs	d	d	d	d
Maximum % exceeded	100	100[b]	31	26

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will assist passage through PR IV by breaching effects

d Breaching occurs prior to backwater effects

Table A44. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Side Channel 21 for Passage Reach V.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	18	18	18	18
Groundwater baseflow (cfs) corresponding to specified mainstem flow	17.4	10.8	4.0	1.9
Surface water necessary for passage (cfs)	0.6	7.2	14.0	16.1
Amount of ppt needed for basin area of .52 mile^2 (in)	.03	.32	.63	.73
% Exceeded based on total daily ppt and groundwater	24	2	1	.5
Breaching % exceeded for controlling discharge of 12,000 cfs	71	100	0	0
Backwater % exceeded for mainstem discharge of d cfs	d	d	d	d
Maximum % exceeded	71	100[b]	1	.5

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will assist passage through PR V by breaching effects

d Breaching occurs prior to backwater effects

Table A45. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Side Channel 21 for Passage Reach VI.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	20[c]	20	20	20
Groundwater baseflow (cfs) corresponding to specified mainstem flow	17.2	10.7	4.0	1.9
Surface water necessary for passage (cfs)	2.8	9.3	16.0	18.1
Amount of ppt needed for basin area of .52 $mile^2$ (in)	.13	.42	.72	.81
% Exceeded based on total daily ppt and groundwater	7	1	.5	0
Breaching % exceeded for controlling discharge of 12,000 cfs	71	100	0	0
Backwater % exceeded for mainstem discharge of d cfs	d	d	d	d
Maximum % exceeded	71	100[b]	.5	0

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will assist passage through PR VI by breaching effects

c Required flow estimated assuming that required flow at upstream PR is sufficient for passage at downstream PR

d Breaching occurs prior to backwater effects

Table A46. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Side Channel 21 for Passage Reach VII.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	20[c]	20	20	20
Groundwater baseflow (cfs) corresponding to specified mainstem flow	16.8	10.4	3.9	1.8
Surface water necessary for passage (cfs)	3.2	9.6	16.1	18.2
Amount of ppt needed for basin area of .52 mile^2 (in)	.14	.43	.73	.82
% Exceeded based on total daily ppt and groundwater	6	1	.5	0
Breaching % exceeded for controlling discharge of 12,000 cfs	71	100	0	0
Backwater % exceeded for mainstem discharge of d cfs	d	d	d	d
Maximum % exceeded	71	100[b]	.5	0

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will assist passage through PR VII by breaching effects

c Required flow estimated assuming that required flow at upstream PR is sufficient for passage at downstream PR

d Breaching occurs prior to backwater effects

Table A47. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Side Channel 21 for Passage Reach VIII.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	20[c]	20	20	20
Groundwater baseflow (cfs) corresponding to specified mainstem flow	16.5	10.2	3.8	1.8
Surface water necessary for passage (cfs)	3.5	9.8	16.2	18.2
Amount of ppt needed for basin area of .52 mile^2 (in)	.16	.44	.73	.82
% Exceeded based on total daily ppt and groundwater	4	1	.5	0
Breaching % exceeded for controlling discharge of 16,000 cfs	71	100	0	0
Backwater % exceeded for mainstem discharge of d cfs	d	d	d	d
Maximum % exceeded	71	100[b]	.5	0

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will assist passage through PR VIII by breaching effects

c Required flow estimated assuming that required flow at upstream PR is sufficient for passage at downstream PR

d Breaching occurs prior to backwater effects

Table A48. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Side Channel 21 for Passage Reach IX.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	20	20	20	20
Groundwater baseflow (cfs) corresponding to specified mainstem flow	16.4	10.2	3.8	1.8
Surface water necessary for passage (cfs)	3.6	9.8	16.2	18.2
Amount of ppt needed for basin area of .52 mile^2 (in)	.16	.44	.73	.82
% Exceeded based on total daily ppt and groundwater	4	1	.5	0
Breaching % exceeded for controlling discharge of 12,000 cfs	71	100	0	0
Backwater % exceeded for mainstem discharge of d cfs	d	d	d	d
Maximum % exceeded	71	100[b]	.5	0

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will assist passage through PR IX by breaching effects

d Breaching occurs prior to backwater effects

Table A49. Required flow, passage reach flows and percent exceedance of successful passage due to groundwater and surface water discharges, breaching flows and backwater effects for the period of 20 August to 20 September at Side Channel 21 for Passage Reach X.

	Mainstem flow at Gold Creek (cfs)			
	Natural[a]	12000	9000	8000
Groundwater & Surface water				
Required flow (cfs)	5[c]	5	5	5
Groundwater baseflow (cfs) corresponding to specified mainstem flow	12.5	7.8	2.9	1.4
Surface water necessary for passage (cfs)	0	0	2.1	3.6
Amount of ppt needed for basin area of .52 mile^2 (in)	0	0	.09	.16
% Exceeded based on total daily ppt and groundwater	100	100	9	5
Breaching % exceeded for controlling discharge of 24,000 cfs	12	0	0	0
Backwater % exceeded for mainstem discharge of d cfs	d	d	d	d
Maximum % exceeded	100	100[b]	9	5

a Natural flows identified by 50 percent exceedance mainstem discharge of 15,000 cfs (Sautner et al. 1984c)

b For Case EV, the mainstem discharge period of 18000 cfs will not assist passage through PR X

c Required flow estimated assuming that required flow at upstream PR is sufficient for passage at downstream PR

d Breaching occurs prior to backwater effects

FIGURES

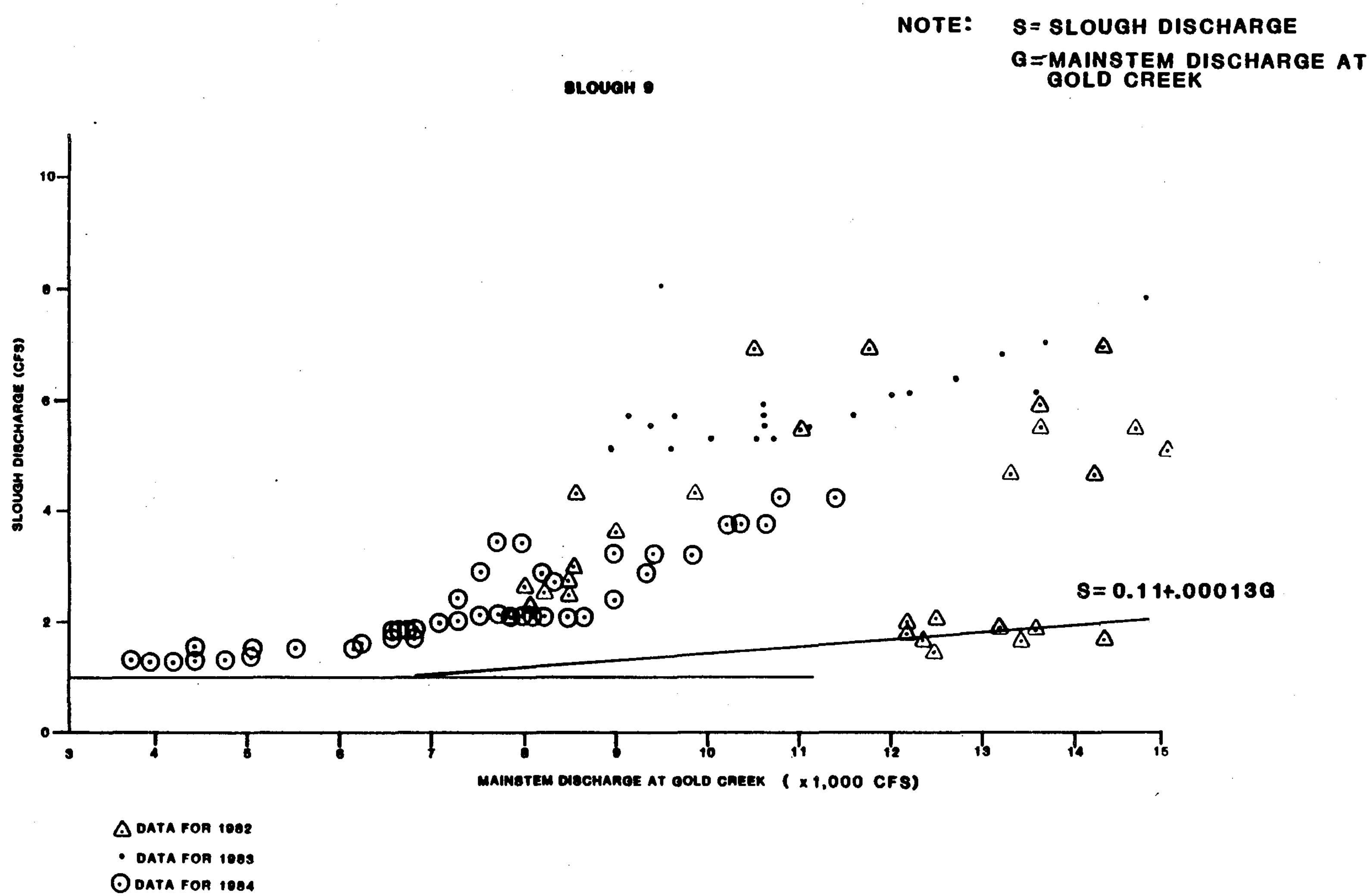


FIGURE A1. IDENTIFICATION OF RELATIONSHIP BETWEEN SLOUGH DISCHARGE AND MAINSTEM DISCHARGE FOR SLOUGH 9.

SOURCE R&M CONSULTANTS, 1982, 1983, 1984

ALASKA POWER AUTHORITY
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Woodward-Clyde Consultants

HARZA-EBASCO
SUSITNA JOINT VENTURE

FIGURE A2. PERCENT GROUNDWATER FLOW RELATIVE TO GAGE FLOW FOR SLOUGH 8A

FIGURE A3. PERCENT GROUNDWATER FLOW RELATIVE TO GAGE FLOW FOR SLOUGH 9

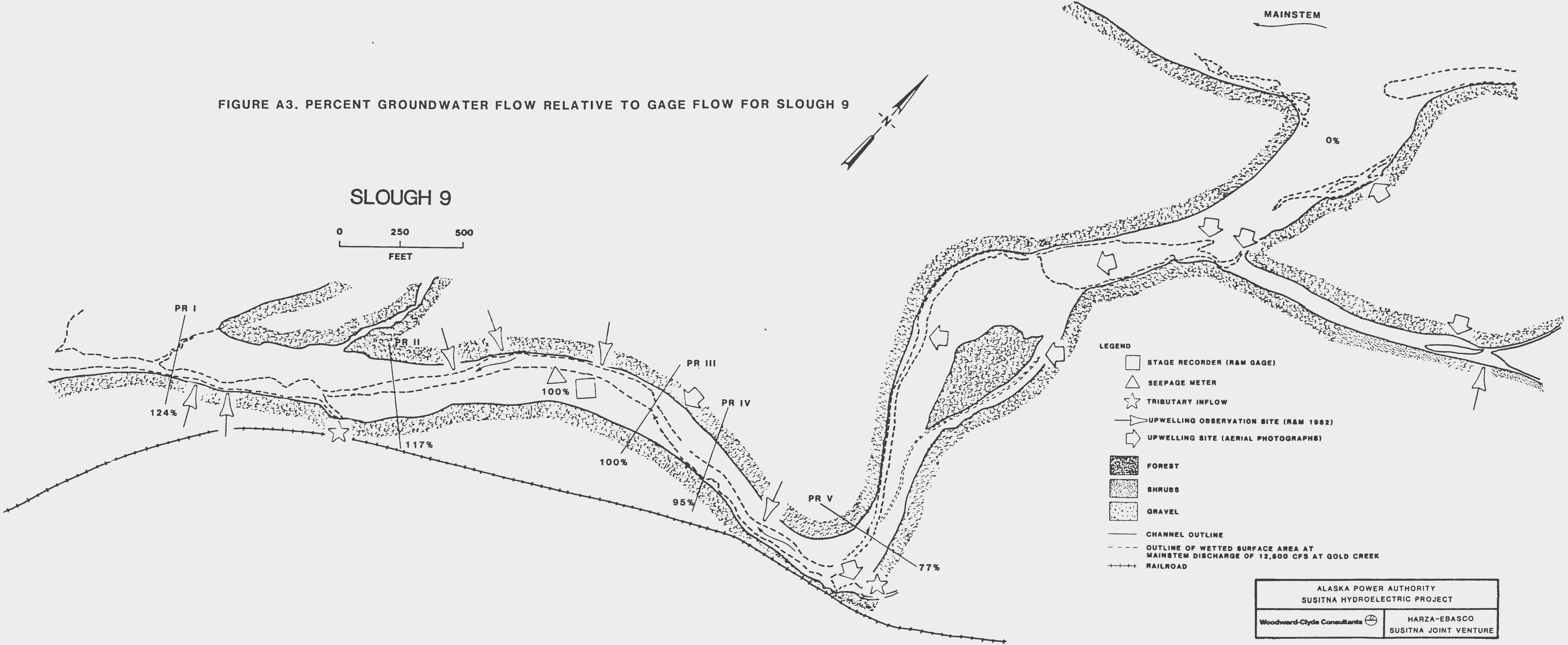

FIGURE A4. PERCENT GROUNDWATER FLOW RELATIVE TO GAGE FLOW FOR SLOUGH 11

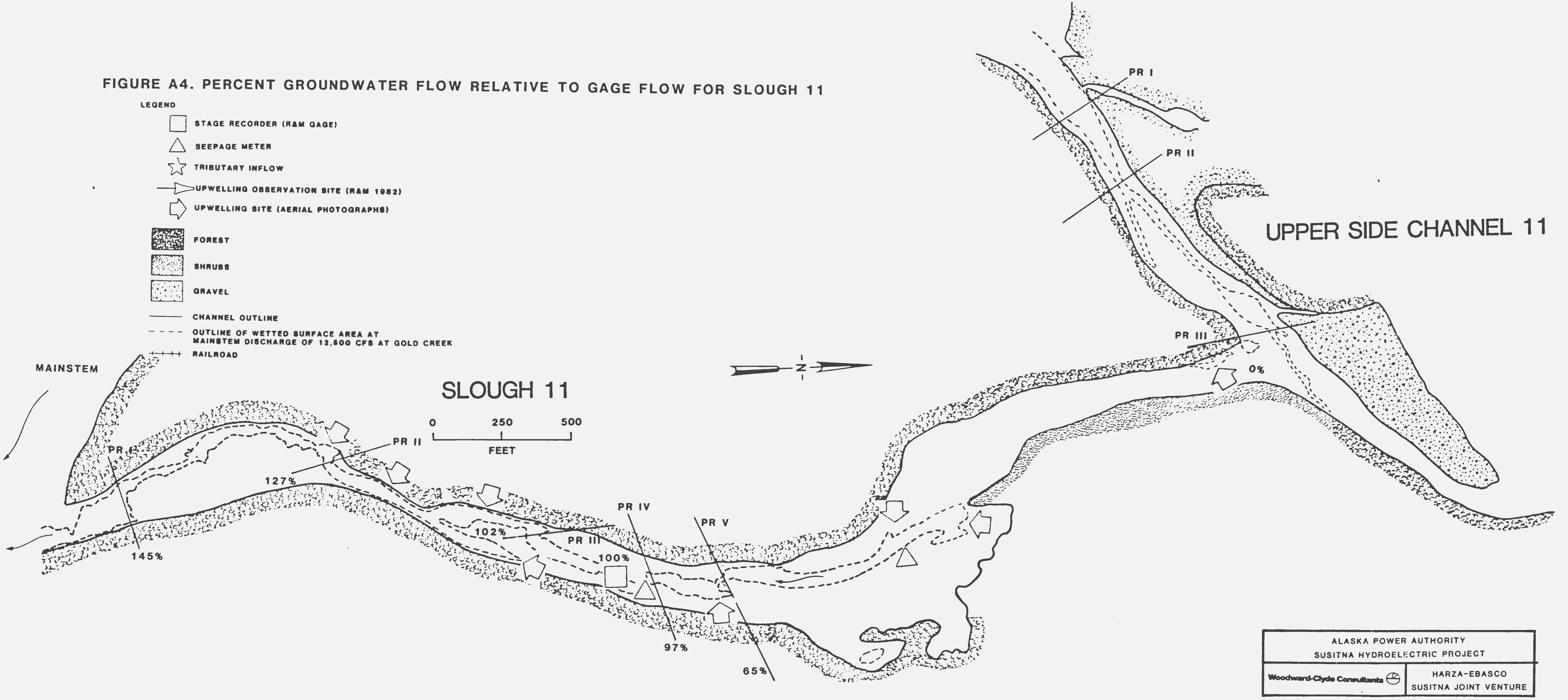

FIGURE A5. PERCENT GROUNDWATER FLOW RELATIVE TO GAGE FLOW FOR SLOUGH 21 AND SIDE CHANNEL 21

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APPENDIX B

APPENDIX B

Detailed Mitigation Costs

APPENDIX B

Detailed Mitigation Costs

This appendix presents the preliminary costs for the various mitigation measures presented in Chapter 3. A major cost is that for mobilizing equipment, materials and men to the sites. These costs are based on using the Alaska Railroad to transport much of the equipment and materials. Details regarding timing and cost associated with loading and unloading the railroad cars have not been evaluated.

Side Channel 21 and Slough 21 do not have access to the railroad or other land transportation during the summer construction season. Three alternatives exist to mobilize equipment to this site.

1) Helicopter: Advantages include timing, speed and scheduling. Disadvantages include high cost and limited equipment size.

2) Barge: Advantages include lower costs, and ability to schedule and operate efficiently. Disadvantage of shallow draft in river that may limit equipment size.

3) Mobilizing during winter: Advantage includes low cost of getting large equipment and supplies into work site by transport over river ice. Disadvantages are posed by long lead time to mobilize materials and tying up equipment for one year before demobilization could be completed.

Costs in this section for Slough and Side Channel 21 are based on the assumption that river conditions are such that barges may be operated to the site.

Slough 8A

1 Slough Mouth Excavation		
Labor	6,000	
Equipment	8,000	
Mobilization/Demobilization	7,000	
Engineering/Management	5,000	
Total		$ 26,000
1 Wing Deflector 300 ft		
Labor	5,000	
Equipment/Materials	9,000	
Mobilization/Demobilization	5,000	
Engineering/Management	5,000	
Total		$ 24,000
Excavation of 6 Passage Reaches 1,400 ft		
Labor	2,000	
Equipment/Materials	3,000	
Mobilization/Demobilization	2,000	
Engineering/Management	3,000	
Total		$ 10,000
Buildup of 2 Slough Berms		
Labor	37,000	
Equipment/Materials	11,000	
Mobilization/Demobilization	5,000	
Engineering/Management	8,000	
Total		$ 61,000
TOTAL INITIAL COSTS OF MITIGATION MEASURES FOR SLOUGH 8A		$121,000
AVERAGE ANNUAL OPERATING AND MAINTENANCE COSTS		$ 4,000

Slough 9

1 Rock Weir		
Labor	9,000	
Equipment/Materials	14,000	
Mobilization/Demobilization	8,000	
Engineering/Management	6,000	
Total		$37,000
1 Buildup of Slough Berm		
Labor	36,000	
Equipment/Materials	10,000	
Mobilization/Demobilization	5,000	
Engineering/Management	8,000	
Total		$59,000
20 Log Barriers 1,000 ft		
Labor	20,000	
Equipment/Materials	2,000	
Mobilization/Demobilization	2,000	
Engineering/Management	6,000	
Total		$30,000
Excavation of 2 Passage Reaches 300 ft		
Labor	2,000	
Equipment/Materials	1,000	
Mobilization/Demobilization	2,000	
Engineering/Management	2,000	
Total		$7,000
1 Slough Mouth Excavation		
Labor	6,000	
Equipment	8,000	
Mobilization/Demobilization	7,000	
Engineering/Management	5,000	
Total		$26,000

TOTAL INITIAL COSTS OF MITIGATION MEASURES FOR SLOUGH 9 $159,000

AVERAGE ANNUAL OPERATING AND MAINTENANCE COSTS $ 4,000

Slough 9A

1 Buildup of Slough Berm		
Labor	23,000	
Equipment/Materials	7,000	
Mobilization/Demobilization	5,000	
Engineering/Management	7,000	
Total		$42,000
Excavation of Entire Slough		
Labor	6,000	
Equipment/Materials	7,000	
Mobilization/Demobilization	5,000	
Gravel Processing	55,000	
Engineering/Management	3,000	
Total		$76,000

TOTAL INITIAL COSTS OF MITIGATION MEASURES FOR SLOUGH 9A $118,000

AVERAGE ANNUAL OPERATING AND MAINTENANCE COSTS $ 4,000

Slough 11

2 Weirs		
Labor	18,000	
Equipment/Materials	28,000	
Mobilization/Demobilization	8,000	
Engineering/Management	7,000	
Total		$61,000
Bank Stabilization 1,200 ft		
Labor	8,000	
Equipment/Materials	7,000	
Mobilization/Demobilization	5,000	
Engineering/Management	5,000	
Total		$25,000
Slough Excavation		
Labor	6,000	
Equipment/Materials	7,000	
Mobilization/Demobilization	5,000	
Gravel Processing	5,000	
Engineering/Management	3,000	
Total		$26,000
10 Log Barriers 500 ft		
Labor	15,000	
Equipment/Materials	2,000	
Mobilization/Demobilization	2,000	
Engineering/Management	5,000	
Total		$24,000
1 Wing Deflector 300 ft		
Labor	5,000	
Equipment/Materials	9,000	
Mobilization/Demobilization	5,000	
Engineering/Management	5,000	
Total		$24,000
1 Buildup of Protective Berm		
Labor	10,000	
Equipment	5,000	
Mobilization/Demobilization	5,000	
Engineering/Management	4,000	
Total		$24,000

TOTAL INITIAL COSTS OF MITIGATION FOR SLOUGH 11 $184,000

AVERAGE ANNUAL OPERATING AND MAINTENANCE COSTS $ 4,000

Upper Side Channel 11

Excavation of Channel		
Labor	6,000	
Equipment/Materials	7,000	
Mobilization/Demobilization	5,000	
Gravel Processing	5,000	
Engineering/Management	3,000	
Total		$26,000
Buildup of Protective Berm		
Labor	100,000	
Equipment/Materials	44,000	
Mobilization/Demobilization	5,000	
Engineering/Management	12,000	
Total		$161,000
TOTAL INITIAL COSTS OF MITIGATION FOR SIDE CHANNEL 11		$187,000
AVERAGE ANNUAL OPERATING AND MAINTENANCE COSTS		$ 4,000

Side Channel 21

Excavation of Channel		
Labor	8,000	
Equipment/Materials	9,000	
Mobilization/Demobilization	11,000	
Gravel Processing	8,000	
Engineering/Management	9,000	
Total		$45,000
6 Wing Deflectors Bank Stabilization 250 ft		
Labor	70,000	
Equipment/Materials	65,000	
Mobilization/Demobilization	20,000	
Oversize Material Removal	35,000	
Engineering/Management	50,000	
Total		$240,000

TOTAL INITIAL COSTS OF MITIGATION MEASURES FOR SIDE CHANNEL 21 — $285,000

AVERAGE ANNUAL OPERATING AND MAINTENANCE COSTS — $ 5,000

Slough 21

Excavation to Lower Slough Profile

Labor	5,000	
Equipment/Materials	6,000	
Mobilization/Demobilization	5,000	
Oversize Substrate Removal	10,000	
Engineering/Management	8,000	
Total		$34,000

TOTAL INITIAL COSTS OF MITIGATION MEASURES FOR SLOUGH 21	$34,000
AVERAGE ANNUAL OPERATING AND MAINTENANCE COSTS	$ 5,000

Curry Slough

Curry Slough Development
Propagation System

Labor	135,000	
Equipment/Materials	80,000	
Pipe	100,000	
Gravel Processing	30,000	
Mobilization/Demobilization	35,000	
Engineering/Management	70,000	
Total		$450,000

AVERAGE ANNUAL OPERATING AND MAINTENANCE COSTS $ 50,000

Curry Station Development
Propagation System

Labor	15,000	
Equipment Materials	35,000	
Gravel Processing	8,000	
MobilizationDemobilization	10,000	
Engineering/Management	13,000	
Total		$ 81,000

AVERAGE ANNUAL OPERATING AND MAINTENANCE COSTS $ 35,000

TOTAL INITIAL COSTS OF MITIGATION MEASURES $531,000