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Exxon Valdez Oil Spill
Restoration Project Annual Report

Sockeye Salmon Stocking
Solf Lake

Restoration Project 01256B
Annual Report

This annual report has been prepared for peer review as part of the *Exxon Valdez* Oil Spill Trustee Council restoration program for the purpose of assessing project progress. Peer review comments have not been addressed in the annual report.

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Sockeye Salmon Stocking Solf Lake
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Study History: Subsistence resources and services were injured throughout Prince William Sound as a result of the *Exxon Valdez* Oil Spill. This project is the continuing investigation and enhancement of lost subsistence opportunities through the stocking of sockeye salmon (*Oncorhynchus nerka*) in Solf Lake, Herring Bay, in Prince William Sound (PWS). Solf Lake has been recognized as a site for establishing a self-sustaining sockeye salmon population since the 1960's. The lake now provides an excellent opportunity to establish a replacement fishery to benefit subsistence users in western Prince William Sound

Habitat improvements were made in 1978, 1980, and 1981 to provide access to the lake for anadromous fish. The lake was never stocked with juvenal salmon and subsequent investigations suggest that it was fishless, but had adequate habitat to support a sockeye salmon population. There are two phases to this project: Phase 1, which began in FY96, verified the ability of Solf Lake to support a sustainable population of sockeye salmon. Phase 2 will stock the lake with approximately 100,000 sockeye salmon fry annually starting in 1998 and ending in 2001.

Abstract: Prince William Sound Aquaculture Corporation (PWSAC) personnel collected eggs from Coghill brood stock during the fall of 2000 and reared them at the Main Bay facility. This resulted in the release of 116,100 fry into net pens at Solf Lake on May 15, 2001. Limnology investigations were discontinued in 2001 as the Trustee Council felt it was unimportant to the success of the project and discontinued funding for this portion. Smolt out migration was not monitored in 2001. During the 2001 field season Forest Service personnel constructed two weirs at the base of both steep passes to create pools for increased fish access. Solf Lake was monitored on 5 occasions for adult salmon escapements in 2001. No fish were observed in the lake.

Key Words: *Exxon Valdez,* sockeye salmon (*Oncorhynchus nerka*), stocking, fishways, Limnology, Solf Lake, Prince William Sound.

Project Data: *Description of data* - There are three primary sets of digital data developed for this project: (1) The feasibility phase of the study included examination of zooplankton and algal biomass, temperature and light profiles, dissolved oxygen and water chemistry. (2) Modified Hankin and Reeves (1988) stream survey information that incorporates the geophysical and hydrological characteristics of the stream into distinct habitat units. (3) An inventory of fish and macro-invertebrate populations. *Format* - Data sets are in Excel spreadsheets and Word Perfect formats. *Custodian* - Contact Merlyn Schelske at the Glacier Ranger District Office, USDA Forest Service, POB. 129 Girdwood, Alaska 99587. PH. (907) 783-3242, Fax (907) 783-2094, E-mail mschelske@fs.fed.us. *Availability* - copies of data sets are available upon written request.

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EXECUTIVE SUMMARY

Subsistence resources and services were injured throughout Prince William Sound because of the *Exxon Valdez* Oil Spill. This project continues to improve subsistence opportunities through the stocking of sockeye salmon (*Oncorhynchus nerka*) and stream improvements to allow adult salmon passage into Solf Lake, Herring Bay in Prince William Sound (PWS). Solf Lake has been recognized as a site for establishing a self-sustaining sockeye salmon population since the 1960's. The lake now provides an excellent opportunity to establish a fishery to benefit subsistence users in western Prince William Sound.

This 1996 project began as a feasibility assessment. In Fiscal Year 1996 (FY96) the Trustee Council funded project 96256, which was a combined proposal to assess the feasibility of establishing a stocking program at both Columbia and Solf Lakes. Interim reports and a recommendation on the feasibility of these two lakes for stocking were provided to the Trustee Council in the fall of 1996. It was determined that Solf Lake could support stocking levels of as many as 400,000 fry based on the available zooplankton. In April 1995, the proposal for this project was presented to the Prince William Sound Copper River Regional Fisheries Planning Team (RPT) for approval. The Forest Service discussed brood stock source/mixed stock issues and stocking levels with the RPT in 1997 at which time they approved the project but recommended stocking at a lower level. The RPT's recommendation was to stock 100,000 fry to achieve the goal of 10,000 adult fish returning to Solf Lake.

Solf Lake has two outlets. The western outlet historically provided anadromous fish access to the lake until an earthquake in 1930 uplifted it creating an impassable barrier. At the same time a new outlet on the eastern side of the lake was created, but was blocked by debris from a landslide due to the earthquake. For many years, Dolly Varden (*Salvelinus malma*) was the only recorded species of fish in Solf Lake and it was determined that neither outlet was passable for anadromous salmon. In 1978, the Forest Service removed the barriers from the east channel and created a dam at the western outlet to provide adequate stream flows to the eastern channel, which was intended to provide access for sockeye salmon to the lake. Additional improvements to the eastern outlet and dam were made in 1980 and 1981, but the system was never stocked with juvenal salmon. The old structures at the two outlets of the lake were evaluated in 1997. It was determined that the structures at both outlets required extensive reconstruction. A new diversion weir was completed at the western outlet in 1998 and a design for the fishway in the eastern outlet was completed in August of 1999 and approved by the Forest Service Regional Engineers. Forest Service Crews in 2000 successfully installed the fishway, consisting of two Alaska Steepasses each with concrete headwalls and supports; three intermittent weirs; and a 60-foot long bedrock trench. In 2001 two weirs were constructed at the base of both steep passes to create pools for increased fish access. Construction for the weirs was begun on July 15, 2001 and finished on July 25, 2001.

The fourth stocking of 116,100 Coghill brood stock sockeye salmon fry was successfully completed on June 15, 2001 by Prince William Sound Aquaculture Corporation (PWSAC).

INTRODUCTION

Subsistence use of resources in the EVOS area declined following the spill. Although restoration studies have shown that harvest levels have since returned to pre-spill levels in most oil spill communities, Chenega Bay and Tatitlek are exceptions (Seitz and Fall, 1995; Seitz and Miraglia, 1995). These communities showed reduced harvest levels in 1993/94 and an increased reliance on salmon harvests (Seitz and Fall, 1995; Seitz and Miraglia, 1995). Solf Lake provides an opportunity to establish a large replacement fishery that is easily accessible, approximately 40 miles from Chenega Bay (Figure 1).

Solf Lake is located off Herring Bay on Knight Island. The lake is approximately 40 miles by boat from Chenega Bay and 46 miles from Whittier. The lake is unnamed on USGS maps; however, Nickerson (1978), PWSRPT (1983), Barto and Nelson (1982) all refer to the lake as Solf Lake (ADF&G Stream 690). The lake is described in the Anadromous Waters Catalog as number 226-10-16900-0010 (ADF&G, 1992).

Solf Lake is a clear water lake with a mean depth of 42.5 m and a surface area of approximately 0.61 km^2 (Barto and Nelson, 1982). Based on historical limnological data from the 1980's; stream survey information collected in 1996; and analysis of current limnological data; it is reasonable to expect that the lake is capable of supporting a sustainable sockeye population with an adult return of approximately 10,000 fish. Establishing this fishery would directly benefit subsistence users in western Prince William Sound.

Solf Lake has long been recognized as an opportunity to reestablish a sockeye salmon run in Prince William Sound. According to Nickerson (1978), "This system had historic runs of sockeye salmon. An earthquake in the 1930's caused blockages of the natural outlet resulting in water flowing over an impassable fall." Starting in the early 1970's, various attempts have been made to reestablish sockeye salmon in Solf Lake. For two years in this same period, ADF&G personnel transported adult sockeye salmon from Eshamy River to Solf Lake. Unfortunately, necessary stream improvements had not been completed when the offspring from the transplanted fish returned. In 1978, 1980 and 1981, the USFS implemented improvements to the outlet streams. The work consisted of improving the eastern outlet and partially damming the western outlet. The diversion weir was designed to raise the level of the lake to provide adequate water flow for fish passage at the eastern outlet. The improved eastern outlet channel is less than 100 m in length, with an average gradient of 23 percent (Figure 2). Stocking of the lake never occurred after the improvements due to higher priority projects for both the USFS and ADF&G.

ADF&G surveyed Solf Lake in 1985/1986 as part of a lake investigation study. The results of this survey, which included attempts to capture fish, suggest that the lake may be fishless (Pellissier and Somerville, 1987). However 1996 minnow trapping by USFS crews indicated a larger population of Dolly Varden than has been previously observed, but still not significant. These results are also supported by the composition and biomass of the zooplankton populations, which were sampled in 1986. The Pellissier and Somerville (1987) survey also documented that water was flowing through the western outlet due to an incomplete seal by the diversion weir. Three minor barriers to fish passage were identified in the eastern channel. The report also suggested that if all the water passing under the dam at the western outlet was stopped these barriers might disappear.

ADF&G recommends stocking based on their zooplankton studies and added that the instability of the macrozooplankton community in barren lakes when faced with predation necessitates stocking programs based on a conservative approach. Close evaluation and experimenting with stocking strategies will ameliorate significant impacts to the macrozooplankton community. Major reasons for the disparity of response to stocking barren lakes include; inherent low productivity of these lakes; macro zooplankton abundance, composition, and ability to adapt to predation; stocking density; lake morphology and variability in the indirect effects of predation in individual lakes. Based on limnological information the stocking levels at Solf Lake could be as high as 400,000 fry. While Solf Lake is most likely capable of supporting stocking at this level, it was decided to take a more conservative approach to stocking.

Based on the available spawning area, it was estimated that Solf Lake could sustain a run of approximately 10,000 sockeye salmon. An escapement goal of approximately 4,500 fish would be required to fully seed the system without depleting the zooplankton populations, leaving 5,500 sockeye available for harvest. Consequently, we recommended stocking at the 100,000 fry level to meet the objective of the stated desired return, with the assumption that there will be a high fry to adult survival during the stocking phase of the project.

The eastern outlet, to the lake required reconstruction of the "irrigation type" control dam; this work was completed in 1997. An engineered survey of the western outlet and suitable dam design was also completed in 1997, and in 1998 installation of the new diversion weir at the western outlet was completed. In 1999 Forest Service Engineers surveyed the eastern outlet and designed a fishway that that would provide sockeye salmon passage into Solf Lake, the Regional Office approved the design in January of 2000.

OBJECTIVES

Phase 1. Feasibility phase. The four components to this objective are:

1. Determine if Solf Lake can sustain a population of sockeye salmon (completed).
2. Determine appropriate stocking levels (completed).
3. Coordinate with PWSAC and Main Bay Hatchery to establish an appropriate brood stock and the necessary logistics to begin a stocking program (completed).
4. Evaluate existing habitat improvement structures to ensure adequate conditions for adult migration (completed).

Phase 2. Implementation phase. There are three objectives to this phase:

1. Design and construct necessary improvements to the outlet channel and dam to ensure adequate passage for adult salmon migration (completed).
2. Stock Solf Lake with sockeye salmon to produce a self-sustaining population that can provide an adequate subsistence harvest (ongoing).
3. Monitor zooplankton and smolt out-migration to ensure appropriate stocking levels (discontinued in 2001).

METHODS

In general, project 00256B involved the installation of a fishway at the eastern outlet of Solf Lake, stocking of juvenal sockeye salmon, and limnology and water quality sampling.

Part 1. Types of improvements needed to provide access for returning salmon:

ADF&G personnel visited Solf Lake as part of a PWS lake investigation project in 1985 (Pellissier and Somerville, 1987). Three minor barriers to fish migration were identified in the outlet channel. These barriers were height and velocity barriers that ranged in size from 1.5 to 2.5 meters. The barriers may potentially be removed through the creation of plunge pools or by installing Steep Passes. The report also suggested that the barriers might not exist if more water were in the eastern outlet channel, which could be achieved by repairing the diversion weir at the western outlet.

The eastern outlet to the lake required reconstruction of the "irrigation type" control weir; this work was completed in 1997. During the 1998 field season Forest Service personnel completed the installation of the diversion weir at the lakes western outlet, EVOS Project 98256b.
The fishway in the eastern outlet was completed in the summer of 2000 and was designed to provide sockeye salmon passage into Solf Lake. The design called for two Alaska Steep Passes one 30 feet, another 40 feet in length, installed at a 22% slope. Each Steep Pass requires a concrete head wall and support piers. The upper pass spills into an excavated section of bedrock forming a watertight trench. Additionally, step pools will be created by the installation of intermittent notched concrete weirs, to further facilitate fish passage.

Part 2. Methods to implement a stocking program at Solf Lake:

Interagency Coordination (1997 to Present): Close coordination between the USFS, ADF&G, PWSAC and the PWS/CR RPT are mandatory for the success of this project. Prince William Sound is a complex ecosystem and the potential stocking of Solf Lake needs to be considered in perspective with the overall management of the Sound. Interagency coordination has occurred in 1996 through 2000 to identify appropriate brood stocks, determine appropriate stocking levels, meet hatchery-related requirements, and to address mixed-stock fisheries issues.

Stocking Program (1998 to 2002): Appropriate stocking levels and strategies will be determined in coordination with ADF&G, PWS/CR RPT and PWSAC using all available data. Sockeye fry will be short-term reared at the Main Bay Hatchery and transported to the lake for release. The Eyak and Coghill stocks are identified in the PWS/CR Phase 3 Comprehensive Salmon Plan (PWSRPT, 1993) as potential stocks for Solf Lake. Stocking began in 1998 with Eyak stocks and was switched to Coghill stocks in 1999, 2000, and 2001. Since neither Eyak nor Coghill sockeye salmon stocks eggs will not be available at the Main Bay Hatchery in 2001 stocking of Solf Lake will not occur in the spring 2002.

The success of the stocking program was monitored through sampling of the fish population using hydroacoustic surveys in 1999 and 2000. Escapements are monitored annual for returning adults. Previous fry stocked at Solf Lake were marked with half-length coded wire tags; the fry released in 2000 and 2001 were thermally marked with a specific otolith sequence. Returning adults will be enumerated at a weir on the eastern outlet stream, scales, tags and otolith will be

collected along with sex ratio information for analysis.

Part 3. Collection methods of biological, physical and morphological information at Solf Lake:

Limnological Sampling (2001): No funding for limnological sampling was provided in 2001 as the Oil Spill Trustee Council felt it was unimportant to determine the success of this project.

Sustainable Sockeye Returns: Future estimates of adult returns to Solf Lake are based on the available spawning area times a redd density of one redd per 6.7 m^2 and a fecundity of 2,000 eggs / gravid female, and a 1:1 sex ratio. Survival rates assume a 10% egg to fry survival, a 15% fry to smolt survival and a 15% smolt to adult return.

Smolt out-migration: Smolt counts were not conducted by ADF&G in 2001.

RESULTS

Personnel from the Main Bay Hatchery successfully collected 122,700 green eggs from Coghill brood stock in fall of 2000 and reared them at their Main Bay facility. Overall, survival of green eggs to released fry was 94.6%. This resulted in the release of 116,100, 0.53 gram fry into Solf Lake on June 15, 2001. Of the total number of fry released into Solf Lake all were marked with a thermal otolith mark sequence of 1:1.3,2.4+3.2.

The expected return from the release of the BY01 MBH/Coghill stock sockeye to Solf Lake is expected to be 4,400. Approximately 60% of these should return as four-year-olds in 2005. The remaining 40% may return as five-year-old in 2006.

In 2001 Forest Service personnel constructed a holding pen as to PWSAC specifications to let fry get acclimated to Solf Lake. The holding pen was constructed and placed on the south side of the lake 50 yards from an incoming stream and in 15 feet of water.

Sockeye fry were flown into Solf Lake on 6/15/2001 from Main Bay Hatchery in two deliveries via floatplane and placed in holding pen. Fish arrived in good condition with only six fish found as mortalities that evening. The fish were not fed the first day of arrival to Solf Lake.

The morning of 6/16/2001 the fish were given 6 cups of the provided feed, which they took slowly. The fish appeared in good condition with approximately 50 fish swimming erratically and several mortalities. That evening 17 mortalities were removed from the holding pen. At this time the fish were dispersed throughout the holding pen with a fair number near the surface.

On 6/17/2001 the fish were given 10 cups of feed and then released as to PWSAC recommendations. Approximately 1500 more fish were observed as mortalities at the bottom of

the holding pen. The total number of mortality reached approximately 5000. At release many fish were swimming erratically. It was also noted that approximately 25 fish had physical abnormalities related to redness and bulging of the eyes.

On three separate occasions within a week of fry release small groups of 50 to 200 were observed near the outlets of Solf Lake. No observation was made of fry leaving the lake.

A small number of (3-6) Dolly Varden were observed feeding on the sockeye fry, which had escaped the holding pen, and upon release from the holding pen.

Forest Service Engineers completed and approved a fishway design in January of 2000. The design provides sockeye salmon moderately difficult passage into Solf Lake during anticipated low flow periods of 10 cfs and at any tide stage. The design called for two Alaska Steep Passes, one 30 feet, the other 40 feet in length installed at a 22% slope. Each Steep Pass required a concrete head wall and support piers anchored into bedrock. The upper Steep Pass spills into an excavated section of bedrock that forms a 60-foot long watertight trench. Installation of three notched concrete weirs anchored into bedrock creates intermittent step pools; facilitating fish passage during periods of low stream flow, see figure 6. Forest Service personnel completed construction of the Steep Pass in 2000 with two weirs remaining to be completed.

In 2001 construction of two weirs was finished completing the Steep Pass. Weirs were placed at the bottom of both Steep Passes to create pools and facilitate fish passage through the Steep Passes.

Five escapement surveys were conducted in Solf Lake in 2001 for adult salmon. Four chum salmon (*Oncorhynchu keta)* and 25 pink salmon (*Oncorynchus gorbuscha)* observed below the Steep Pass in inter-tidal areas. No adult salmon were observed in the lake. 2001 Should have been the first year for returning sockeye salmon from stocking efforts in 1998.

DISCUSSION and CONCLUSIONS

Fishless lakes are susceptible to overgrazing by large numbers of obligate planktivores, i.e. sockeye fry, resulting in steep declines in macrozooplankton numbers and biomass. Diet selectivity studies for rearing sockeye fry have shown that fry presented with a wide choice of food items tend to select for cladoceran and large calanoid forms. Although sockeye fry do graze on *Cyclops*, it is not actively selected. Thus, in Solf Lake, we would expect the large, red pigmented, and therefore, highly visible *Diaptomus*, to be an indicator species of excessive grazing pressure and a guide to gauge stocking levels.

In 2001 stocking procedures include retention of sockeye fry in temporary holding pen near the lakes inlet streams for three days. A two-week period was anticipated to allow time for fry to acclimate and for observation of possible mortalities. After only a couple days it was observed that fish were becoming stressed and upon consultation with PWSAC it was advised to release them from the holding pens.

Forest Service crews observe several small groups of fry, usually numbering 50 to 200 at the

outlets of Solf Lake these fry were not seen leaving the lake. Three to six Dolly Varden were observed feeding on fry that had escaped the holding pens or upon release. Depensatory mortality to fry from predation by Dolly Varden may be a factor but is unknown. If there were only three to six Dolly Varden observed around the holding pens mortality would be insignificant. The population of Dolly Varden in the lake is unknown and could be significant resulting in a substantial mortality to sockeye fry.

Cook Inlet Aquaculture Association (CIAA) has documented age-0 sockeye salmon smolts emigrating from their lake stocking programs; from 1990-1995, estimates of age-0 smolt emigrating Chelatna Lake (Susitna River basin) have ranged from less than 1% to 62% of the total outmigration (Fandrei 1995), and in Bear Lake (Seward) age-0 smolt estimates for 1990-1994 have ranged from less than 1%, up to 98% in one year (Hetrick and Prochazka 1998). If the age-0 out migration in 1999 accounted for a high percentage of the fry population then the ocean mortality may have been at a high rate resulting in undetectable numbers of returning adults.

With the discontinuing of limnology sampling we will not know whether it is due to freshwater conditions (e.g.,limited prey availability) or something in the oceanic environment. This is one reason Alaska Department of Fish and Game makes limnology sampling a requirement when a stocking program is initiated. The Trustee Council didn't feel the need for this aspect of the project for funding in 2001 to determine the success of the Steep Pass. The Council felt the success of the fishway would be judged on its ability to pass adult sockeye into Solf Lake. If stocking is continued in 2003 limnology sampling will likely be implemented again.

The Regional Forest Service Engineer and the Trustee Council approved the final design for the fishway to be installed in 2000 in the spring of the same year. The constructed fishway varied only slightly from the approved design in location and orientation of the Steep Passes and concrete headwalls. Construction specifications detailed in the final design were adhered to the greatest extent possible. Excavation of the 60-foot trench through bedrock went extremely well, primarily due to the expertise of the Forest Service Blasters and construction crew. Because the integrity of the bedrock was maintained during trench construction and a watertight seal created, a concrete liner was not required. An as-built survey is planned in 2002 and should be available for inclusion in the final report.

Both the diversion weir at the western outlet and the control structure on the eastern outlet has been successfully completed and are working properly. During the 2001 field season both structures were inspected for serviceability. After a full 4 years of exposure to the rigorous weather of Prince William Sound the structures remain operational showing little sign of wear.

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Figure 1. Location Map.

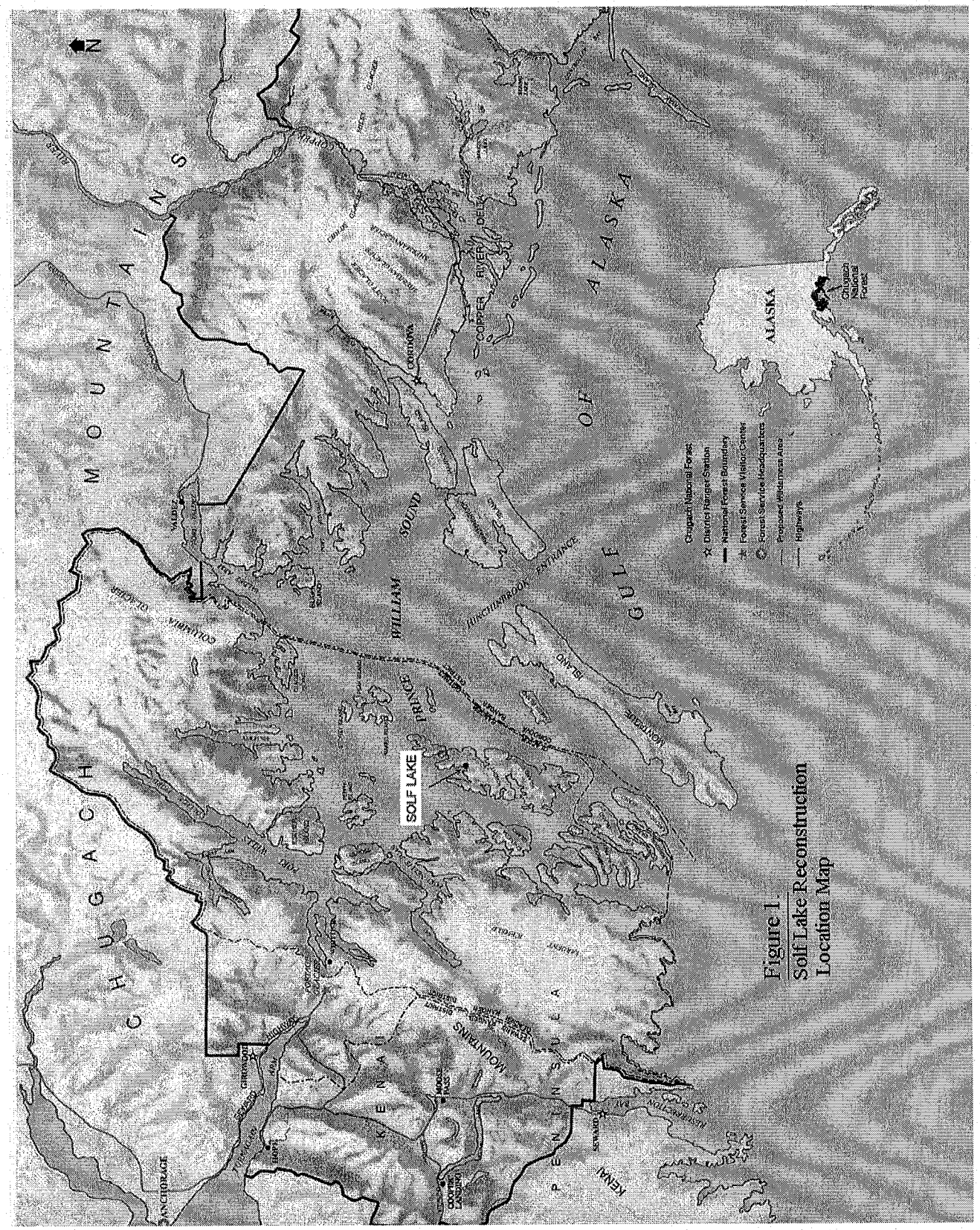

Figure 1.
Solf Lake Reconstruction
Location Map

Figure 2. Site Plan

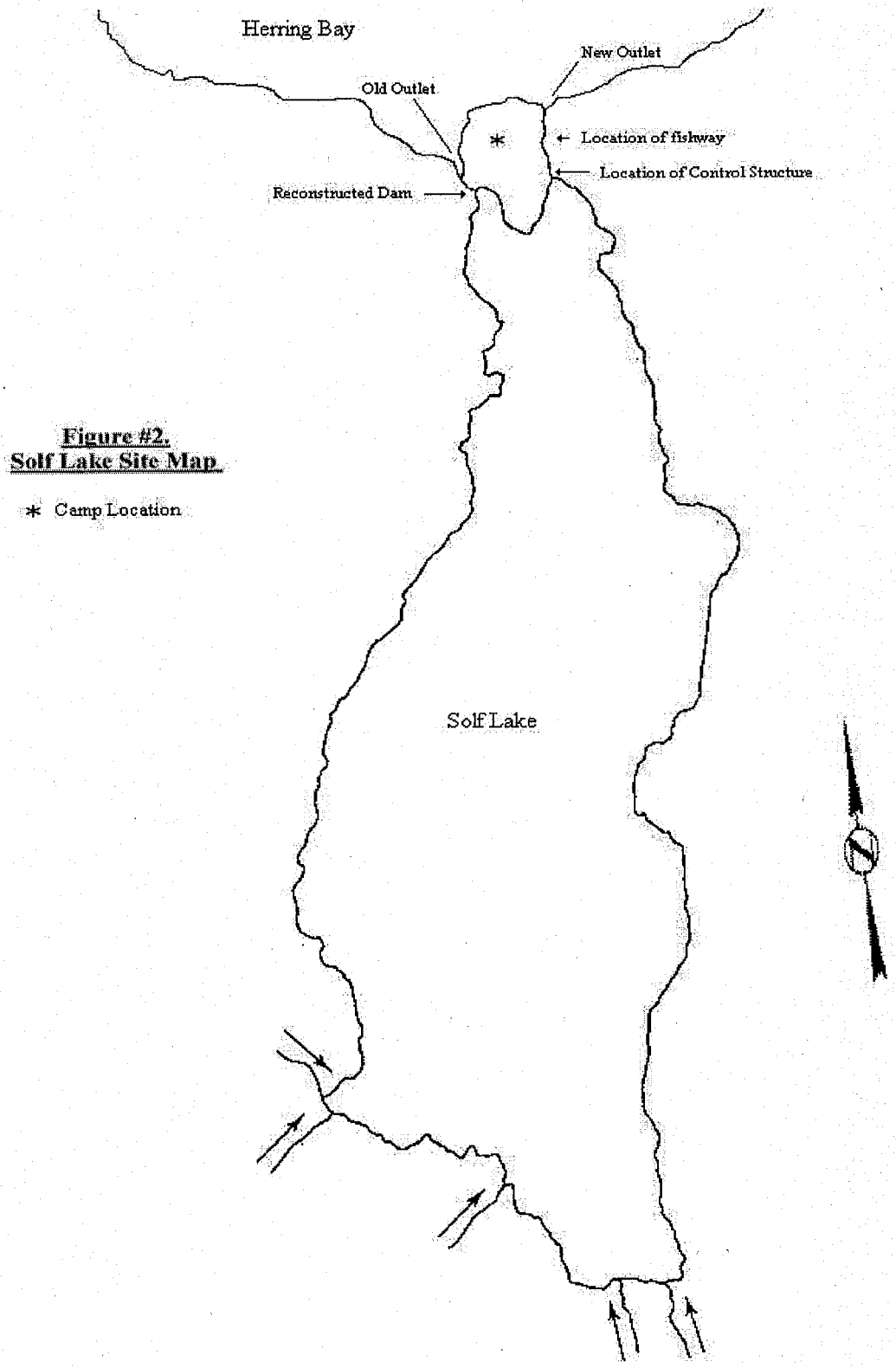

Figure 6. Plan View Solf Fishway.