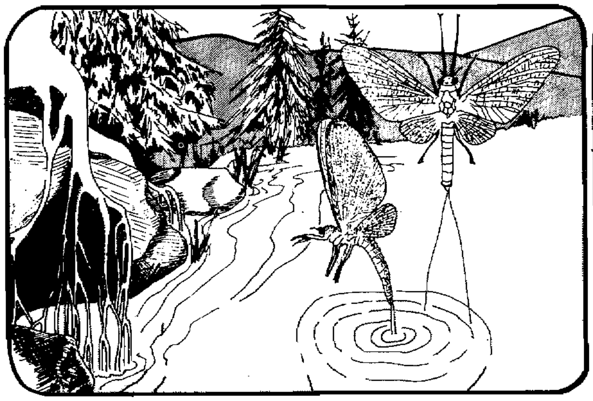

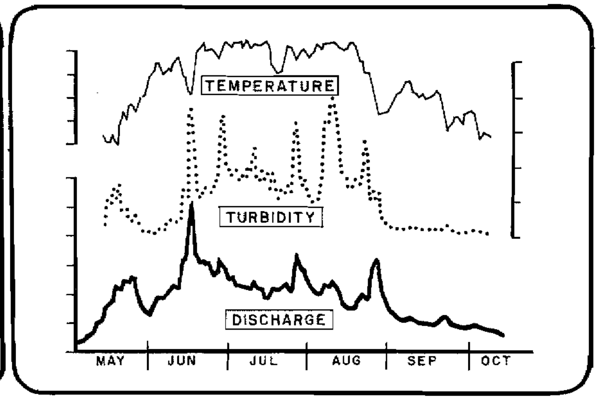

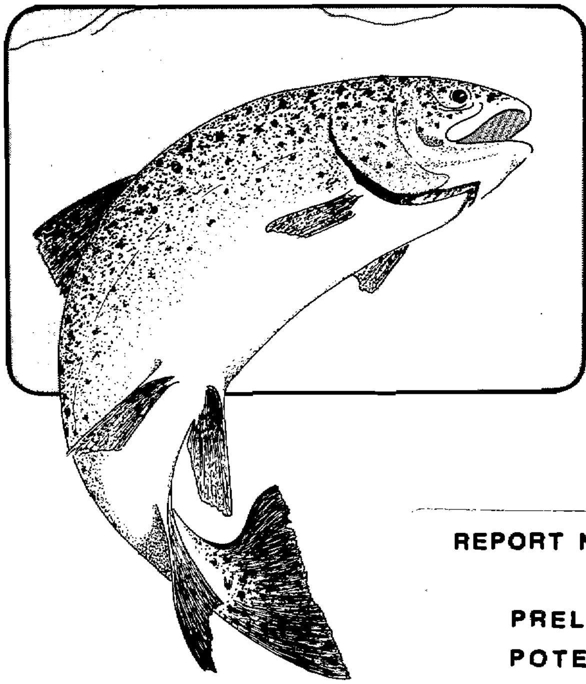

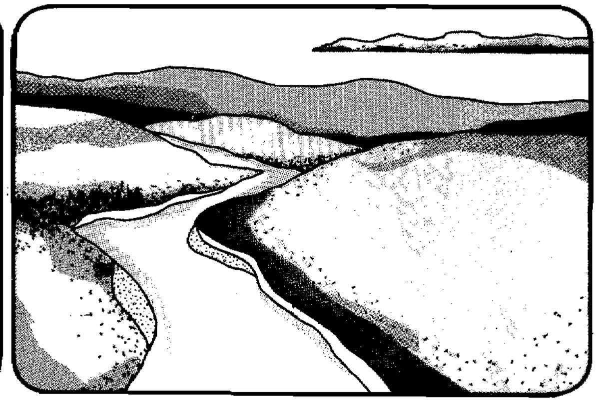

REPORT NO. 10

PRELIMINARY EVALUATIONS OF POTENTIAL FISH MITIGATION SITES IN THE MIDDLE SUSITNA RIVER

ALASKA DEPARTMENT OF FISH AND GAME
SUSITNA HYDRO AQUATIC STUDIES REPORT SERIES

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PRELIMINARY EVALUATIONS OF POTENTIAL FISH MITIGATION SITES IN THE MIDDLE SUSITNA RIVER

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NOVEMBER 1985

PREFACE

This report is one of a series of reports prepared for the Alaska Power Authority (APA) by the Alaska Department of Fish and Game (ADF&G) to provide information to be used in evaluating the feasibility of the proposed Susitna Hydroelectric Project. The ADF&G Susitna River Aquatic Studies Program was initiated in November 1980.

The studies described in this report were conducted in support of mitigation planning being done by ENTRIX, Inc., the primary mitigation contractor. This report includes studies conducted from July 1984 through April 1985 in the middle reach of the Susitna River from Talkeetna (RM 98.0) to the mouth of Devil Canyon (RM 150.0). The study examined general habitat characteristics during the open-water season and site specific incubation conditions during the ice-covered season.

The open-water study examined general habitat characteristics (surface water quality, substrate, upwelling, passage, temperature, salmon spawning, etc.) of 44 slough and side channel sites in order to evaluate their potential to mitigate for adverse effects to salmon spawning and incubation habitats as a result of the proposed hydroelectric project. The ice-covered study examined incubation conditions (surface and intragravel water quality and temperature, and substrate composition) in these sites to further determine their suitability as potential mitigation sites. Each site studied exhibited general conditions (passage, substrate, etc.) that were similar to those found in other sites that proved to be limiting to salmon spawning.

The combined data from these open-water and ice-covered studies will be used by ENTRIX, Inc. to help determine the suitability of habitat types (side slough, upland slough, side channel) and habitat modification methods for mitigation of adverse impacts to salmon spawning and incubation environments as a result of the proposed hydroelectric development.

Questions concerning this report should be directed to:

Alaska Power Authority
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Anchorage, Alaska 99501
Telephone (907) 276-0001

TITLES IN THIS SERIES

Report Number	Title	Publication Date
1	Adult Anadromous Fish Investigations: May - October 1983	April 1984
2	Resident and Juvenile Anadromous Fish Investigations: May - October 1983	July 1984
3	Aquatic Habitat and Instream Flow Investigations: May - October 1983	September 1984
4	Access and Transmission Corridor Aquatic Investigations: May - October 1983	September 1984
5	Winter Aquatic Investigations: September 1983 to May 1984	March 1985
6	Adult Anadromous Fish Investigations: May - October 1984	June 1985
7	Resident and Juvenile Anadromous Fish Investigations: May - October 1984	July 1985
8	Availability of Invertebrate Food Sources for Rearing Juvenile Chinook Salmon in Turbid Susitna River Habitats	July 1985
9	Summary of Salmon Fishery Data for Selected Middle Susitna River Sites	August 1985
10	Preliminary Evaluations of Potential Fish Mitigation Sites in the Middle Susitna River	November 1985

PRELIMINARY EVALUATIONS OF POTENTIAL FISH MITIGATION SITES IN THE MIDDLE SUSITNA RIVER

Report No. 10

by Donald R. Seagren and Robert G. Wilkey

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ABSTRACT

Development of the Susitna Hydroelectric Project is expected to alter the natural seasonal flow regime of the Susitna River downstream of Devil Canyon (RM 152.0). Changes in the natural flow regime of the Susitna River may impact salmon spawning and incubation habitat in the middle reach of the river from Talkeetna (RM 98.0) to Devil Canyon (RM 152.0). This study was conducted by the Alaska Department of Fish and Game during 1984 and 1985 to evaluate potential slough and side channel sites that may be used to mitigate for adverse impacts to salmon spawning and incubation habitat resulting from operation of the hydroelectric project. These evaluations focused on habitat modification as a mitigation alternative to improve fish passage, upwelling, and substrate conditions. Forty-four potential fish mitigation sites were identified during the open-water portion of this study. Of these 44 sites, 23 were side slough habitats, 16 were upland slough habitats, and 5 were side channel habitats. From the initial 44 sites, three representative sites were selected for more detailed evaluations of habitat modification alternatives during the ice-covered season. Baseline information on surface and intragravel water quality, substrate conditions, upwelling sources, and fish passage restrictions were collected during the open-water season. The ice-covered studies evaluated incubation conditions (water quality and substrate) and specific habitat modification techniques which may be applicable for mitigation purposes. Recommendations for specific sites which generally appear to be most suitable for mitigation are presented in the discussion. However, the selection of these sites was based on field observations and limited data, therefore a more detailed evaluation should be conducted to determine if these sites are the most practical sites for mitigation purposes. This study only evaluates the mitigation potential of sites under current habitat conditions and any changes to the habitat that may take place in the future may necessitate a reevaluation of these sites.

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1.0 INTRODUCTION

This report evaluates slough and side channel habitats in the middle reach of the Susitna River to identify potential sites that may be used to mitigate for adverse effects of proposed hydroelectric development on salmon resources in this reach of the river (Figure 1). A limited evaluation of beaver dam removal as a possible mitigation technique is also presented. The report presents data which was collected during open-water (June 30 to October 12, 1984) and ice-covered (November 14, 1984 to May 1, 1985) sampling periods. The information presented in this report is intended primarily to supplement mitigation planning which is being done by ENTRIX, Inc. (Moulton et al. 1984).

1.1 Background

Operation of the Susitna Hydroelectric Project is expected to alter the natural seasonal flow regime of the Susitna River downstream of Devil Canyon (RM 152.0) (Acres 1982). Under the proposed operating scheme the present seasonal flow fluctuations will be altered, resulting in a more stabilized annual flow regime (Acres 1982). Such changes in the natural flow regime of the Susitna River may result in a net loss of presently available salmon spawning habitat due to passage restrictions, reduced upwelling, loss of wetted usable habitat, or other discharge related effects (Moulton et al. 1984; Sautner et al. 1984).

To insure that there is no net loss of fisheries production, the Alaska Power Authority (APA) has supported mitigation measures focusing on maintaining existing habitat or providing replacement habitat of sufficient quality and quantity to maintain the productivity of the present natural populations (Acres 1983). Mitigation alternatives that have been proposed to meet these goals include: 1) altering the discharge release regime of the reservoir during the critical spawning period to provide passage and increased wetted surface area for spawning; 2) mechanically altering the channels of the currently used spawning sites to increase passage and available spawning area; 3) increasing head berm elevation to prevent winter overtopping of currently used spawning sites; or 4) locating replacement habitats that exhibit similar conditions under projected with-project conditions to those currently used for spawning and rearing.

The initial mitigation plan developed for the Susitna Hydroelectric project was presented in Acres (1983). A recent fish mitigation plan for the Susitna River was developed by Woodward-Clyde Consultants (Moulton et al. 1984) that focused on flow release combined with physical modification of habitat as a mitigation alternative. The Woodward-Clyde study focused on four slough habitats (Sloughs 8A, 9, 11 and 21) which have been the focus of other studies relating to this project (Vincent-Lang et al. 1984) and which have traditionally supported the majority of chum and sockeye salmon spawning among slough habitats (Barrett et al. 1984, 1985). Although Moulton et al. (1984) presents a potential fish mitigation plan for these selected sites, there is no assurance of success and there may be other sites which

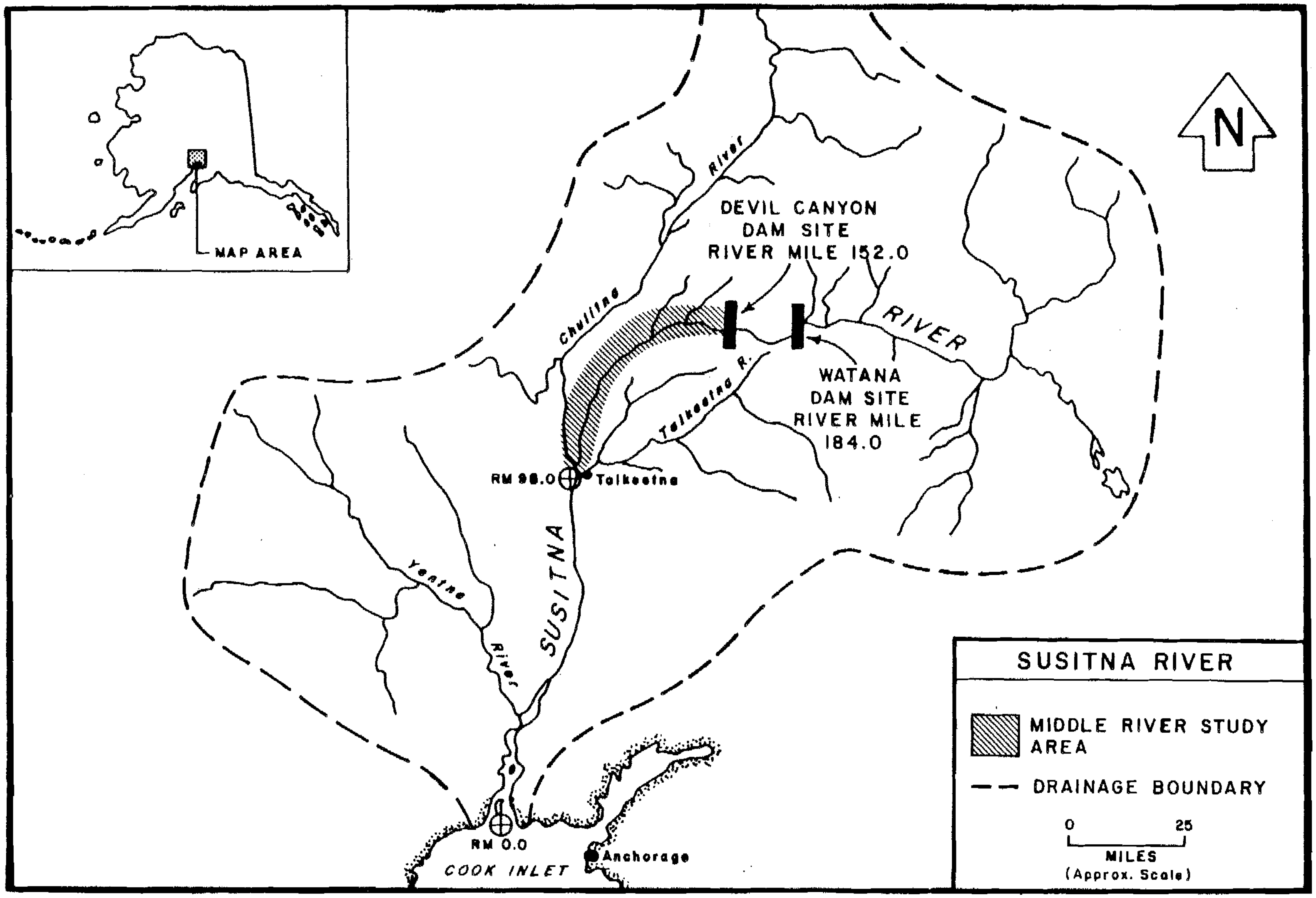


Figure 1. Map of the fish mitigation site study area in the Susitna River basin, 1984-1985.

present feasible mitigation options. For these reasons, baseline evaluations were conducted to identify all potential mitigation sites in the middle Susitna River so that they may be considered in future mitigation planning.

The middle reach of the Susitna River was selected for study because the most significant changes in the existing physical characteristics of aquatic habitats are expected to occur in this reach. Slough and side channel habitats in this reach were selected as the primary focus of study because they are used by several species of salmon for spawning (Figure 2) and appear to provide the greatest potential for mitigation for adverse impacts to salmon spawning habitat resulting from proposed hydroelectric project. The 1984 estimated salmon spawning escapement to the middle reach of the Susitna River was approximately 7,180 chinook salmon, 2,427 sockeye salmon, 27,350 pink salmon, 26,050 chum salmon, and 2,900 coho salmon (Barrett et al. 1985). Side channel and slough habitats presently support approximately 71% of the estimated chum and 100% of the estimated sockeye salmon spawning which presently occurs in the middle reach of the Susitna River (Barrett et al. 1985). For this reason, chum and sockeye salmon are the primary species of interest in this report.

1.2 Objectives

This_ was initiated during July 1984. Initial sampling during the open-water season consisted of a preliminary evaluation of slough and side channel habitats in the middle reach of the Susitna River to identify those sites that may have potential for providing additional salmon spawning habitat under anticipated with-project conditions by using habitat modification techniques. Although these studies evaluated factors limiting to salmon spawning under present-flow condition, the sites which were selected appeared to be suitable for fish mitigation under general with-project flow regime of 9,000 to 12,000 cfs. This flow regime is a composite of Case EV and EVI scenarios that are presently under consideration (Harza-Ebasco 1984). The data will be used in development of the Second Interim Mitigation Report by ENTRIX, Inc. The surveys evaluated general habitat characteristics (substrate composition, water temperature, water quality, upwelling, fish passage) present in each of the sites. Data from these surveys were used to assist in identifying potential sites for habitat modification as an alternative for maintaining naturally occurring salmon populations during operation of the proposed hydroelectric project. Additional sampling was conducted during the ice-covered season to identify specific habitat modification techniques for possible use at the potential mitigation sites to determine the feasibility of implementing such mitigation alternatives.

The present study was specifically designed to supplement previous mitigation plans (Moulton et al. 1984) and to provide additional information to evaluate potential mitigation alternatives by addressing the following objectives:

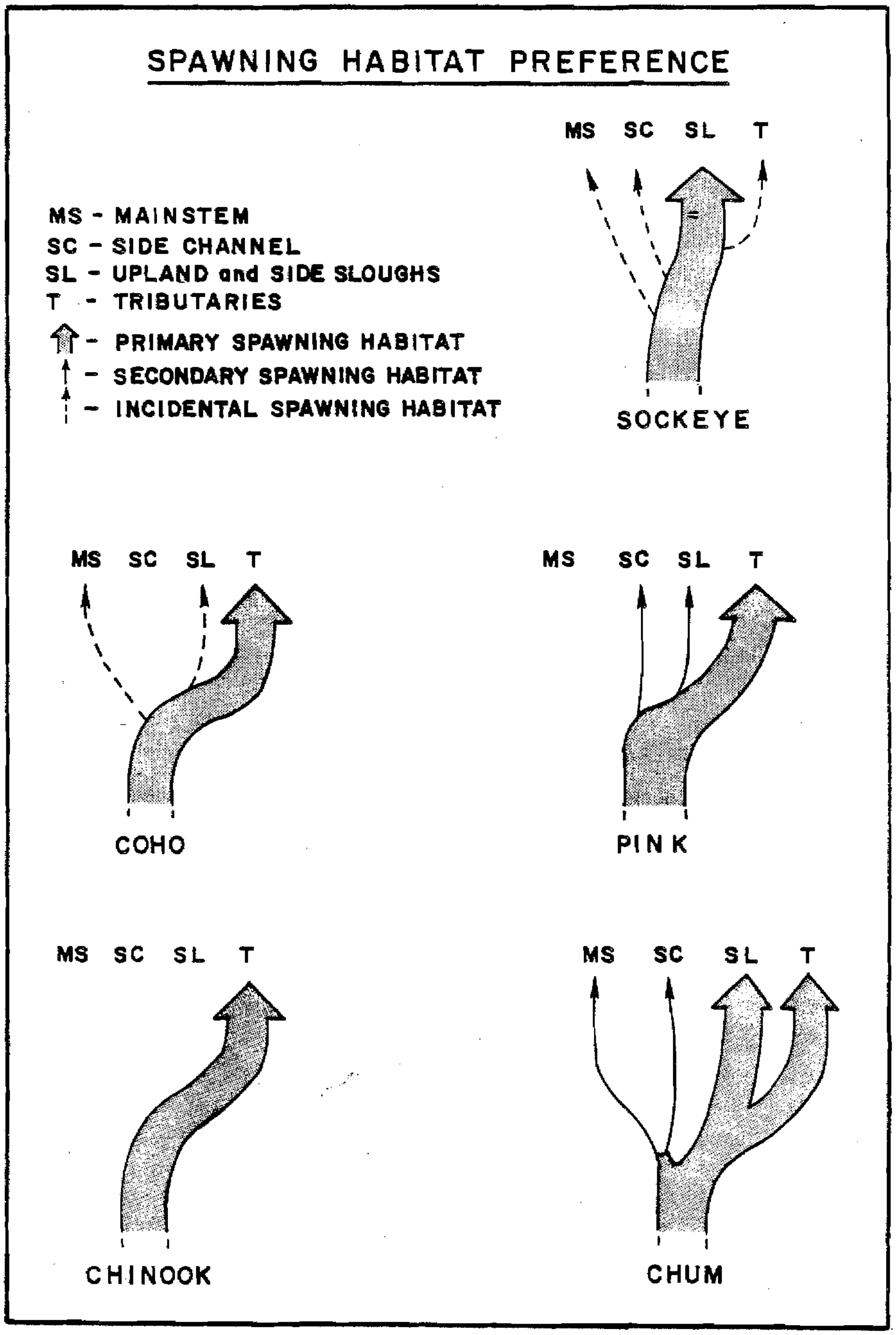


Figure 2. General spawning habitat preference of the five species of salmon utilizing the Susitna River basin (derived from data in Barrett et al. 1984).

1) Evaluate slough and side channel habitats in the middle reach of the Susitna River to identify sites for mitigation of adverse impacts resulting from development of the Susitna Hydroelectric Project.

2) Remove fish passage restrictions (i.e. beaver dams) from selected slough habitats during the salmon spawning period to determine the feasibility of this technique as a mitigation option.

3) Evaluate intragravel conditions at selected potential mitigation sites to determine suitability of the incubation environment for salmon embryos.

4) Evaluate the applicability of physical modification of habitat as a viable mitigation option at selected potential mitigation sites.

2.0 METHODS

The fish mitigation site studies were conducted during the open-water field season (June 30 to October 12, 1984) and the ice-covered field season (November 14, 1984 to May 1, 1985). The open-water studies consisted of a general evaluation of slough and side channel habitats as potential mitigation sites in the middle Susitna River (Figures 3-9). The ice-covered studies were more intensive evaluations of incubation conditions and potential habitat modification techniques at three potential mitigation sites.

2.1 Open-Water Studies

2.1.1 Site Selection

Forty-four sites, considered representative of the habitat types utilized by spawning chum and sockeye salmon in the middle Susitna River, were selected for study during the open-water phase of these studies (Figures 3-9). Sampling sites for this study were selected from locations where salmon spawning ground surveys had been conducted by ADF&G (Barrett et al. 1985). Sampling sites were selected from each habitat type where salmon spawning has been documented (Barrett et al. 1985).

In addition to the regularly surveyed sites, aerial photos taken during March, 1983 were used to locate open leads in the ice cover to identify any potential spawning sites that had not been previously surveyed for spawning activity. Open leads are generally indicative of either upwelling or high water velocities. Ground surveys were later conducted at these sites to determine if upwelling was present. Sites with upwelling were included as potential mitigation sites because chum salmon prefer areas with upwelling for spawning (Kogl 1965; Bakkala 1970; Vining et al. 1985). Selected sites were classified as either side slough, upland slough, or side channel habitats based on definitions presented in Vincent-Lang et al. (1984).

2.1.2 Surface Water Quality and Intragravel Water Temperature

Selected surface water quality parameters (pH, conductivity, dissolved oxygen, and temperature) were measured within each of the study sites to evaluate existing water quality conditions and determine if water quality is presently a limiting factor for salmon spawning and development at any of these sites. Measurements of each water quality parameter were obtained at a minimum of three locations (head, mid-site, and mouth) within each study site. Measurements were obtained during non-breaching mainstem discharges at each study site to more accurately assess water quality conditions at anticipated with-project discharges. Water quality parameters were measured using a Hydrolab model 4041 water quality meter following procedures outlined in ADF&G (1984). Prior to each sampling trip, the meter was calibrated using procedures described in ADF&G (1984).

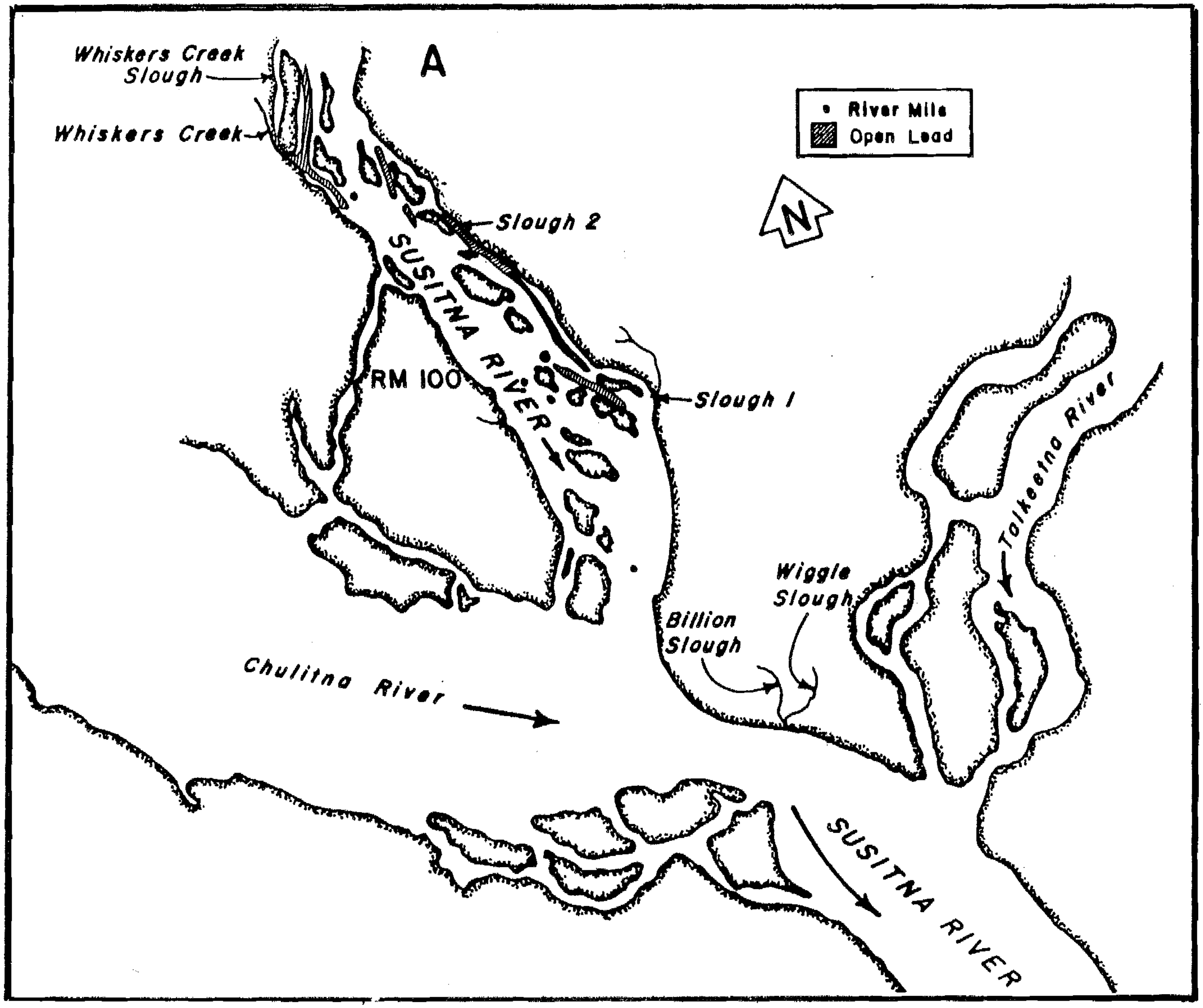


Figure 3. Maps of the middle Susitna River from RM 98.0 to 101.5 showing study sites and open leads.

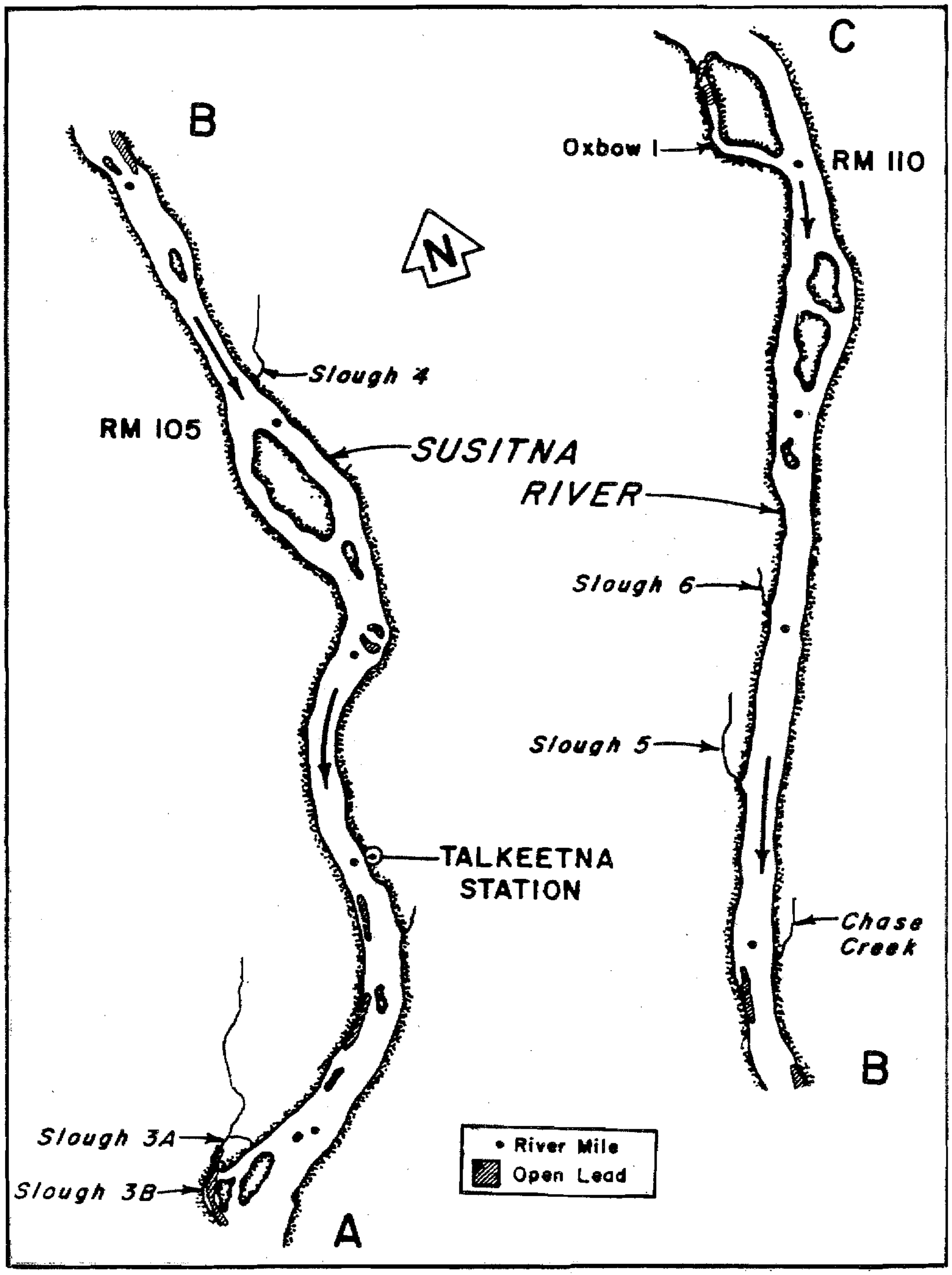


Figure 4. Maps of the middle Susitna River from RM 101.5 to 110.5 showing study sites and open leads.

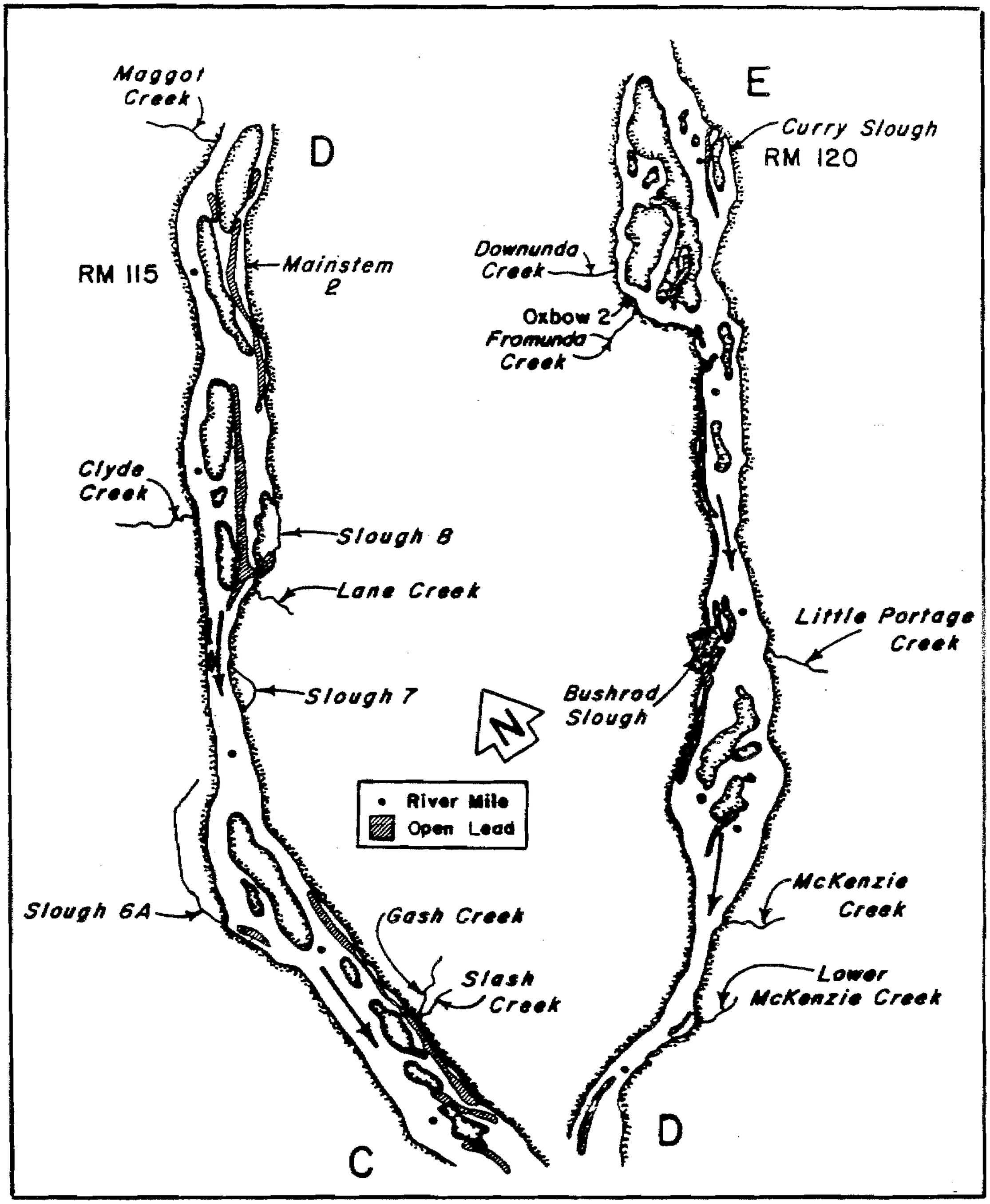


Figure 5. Maps of the middle Susitna River from RM 110.5 to 120.5 showing study sites and open leads.

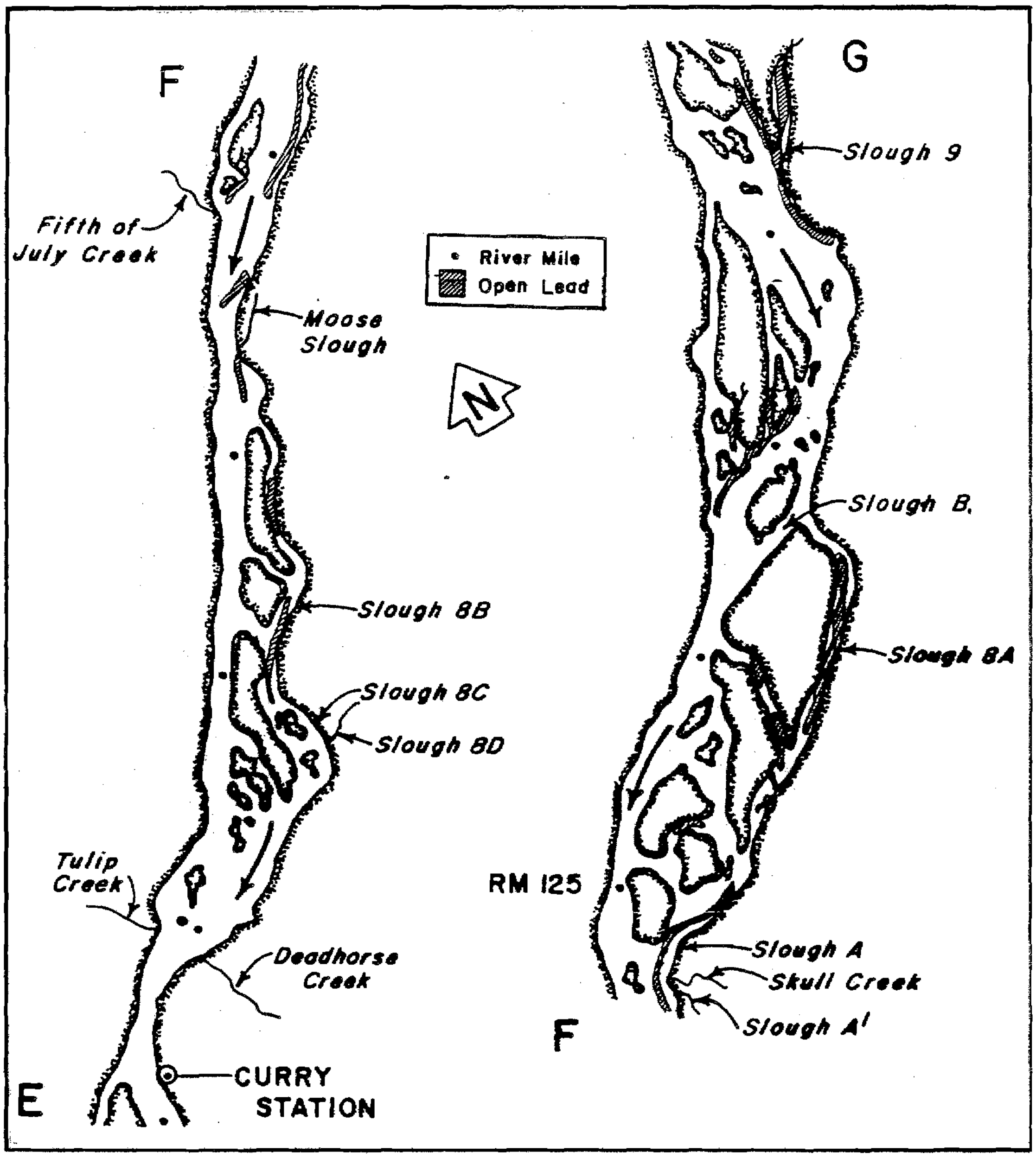


Figure 6. Maps of the middle Susitna River from RM 120.5 to 128.5 showing study sites and open leads.

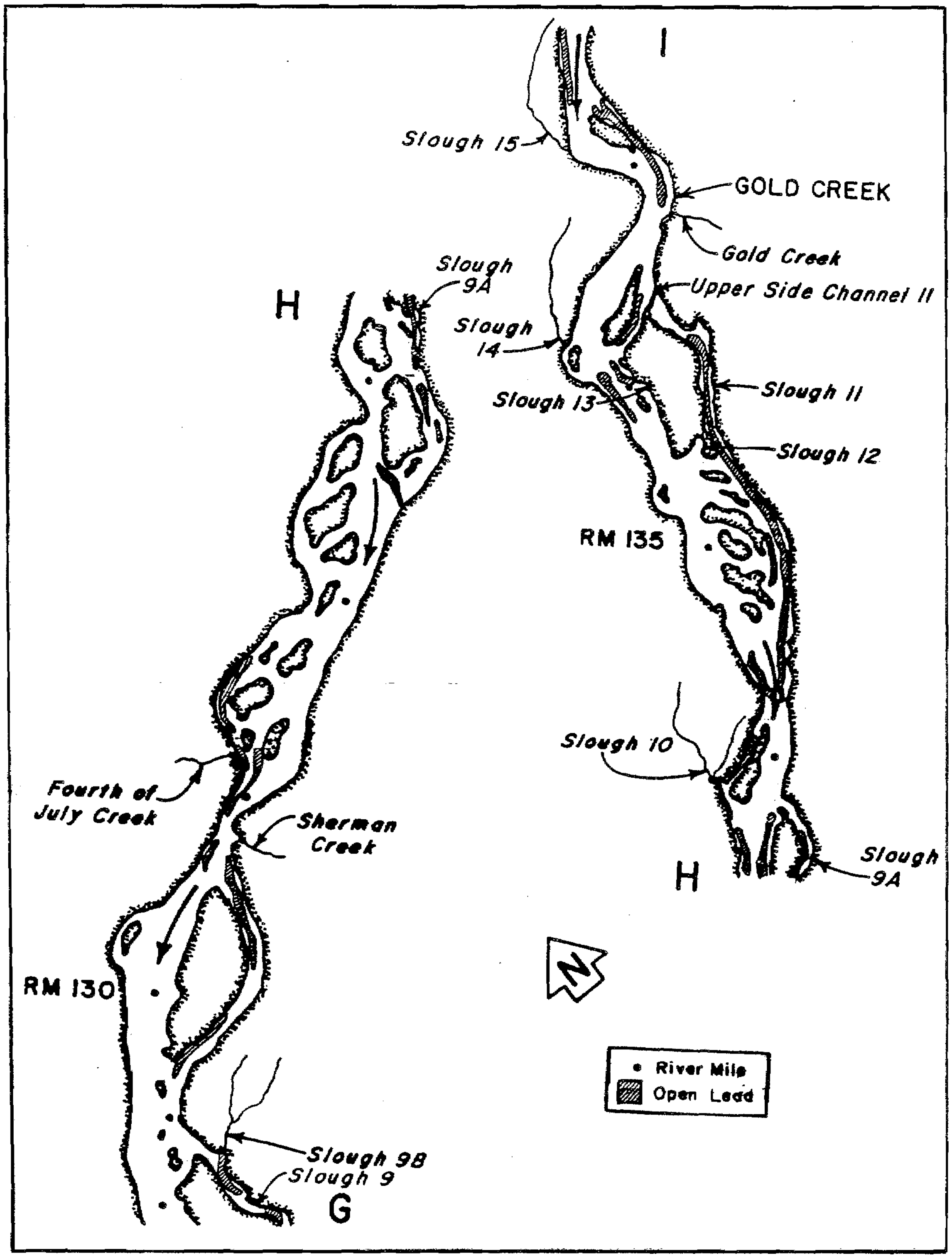


Figure 7. Maps of the middle Susitna River from RM 128.5 to 137.5 showing study sites and open leads.

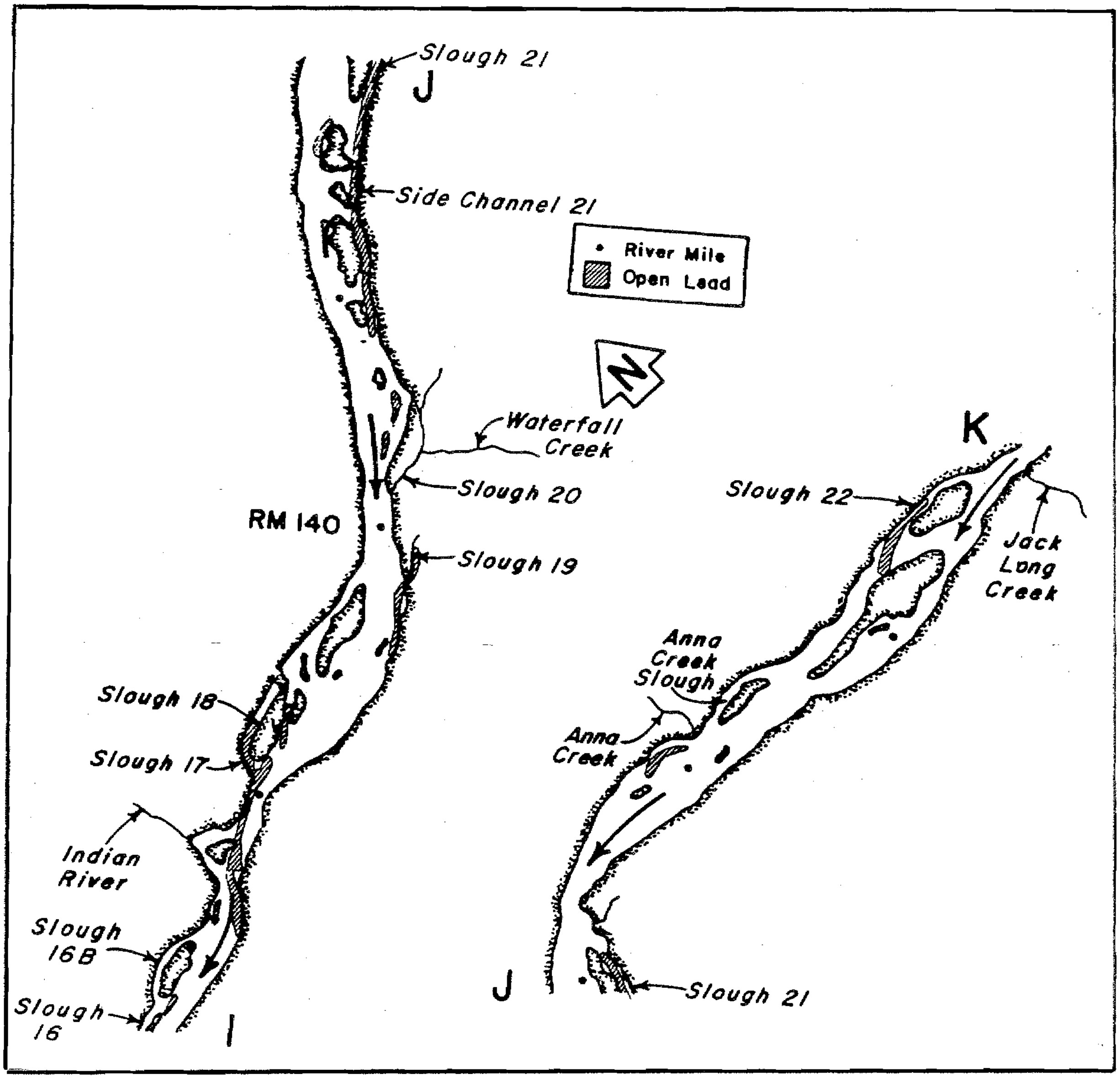


Figure 8. Maps of the middle Susitna River from RM 137.5 to 144.5 showing study sites and open leads.

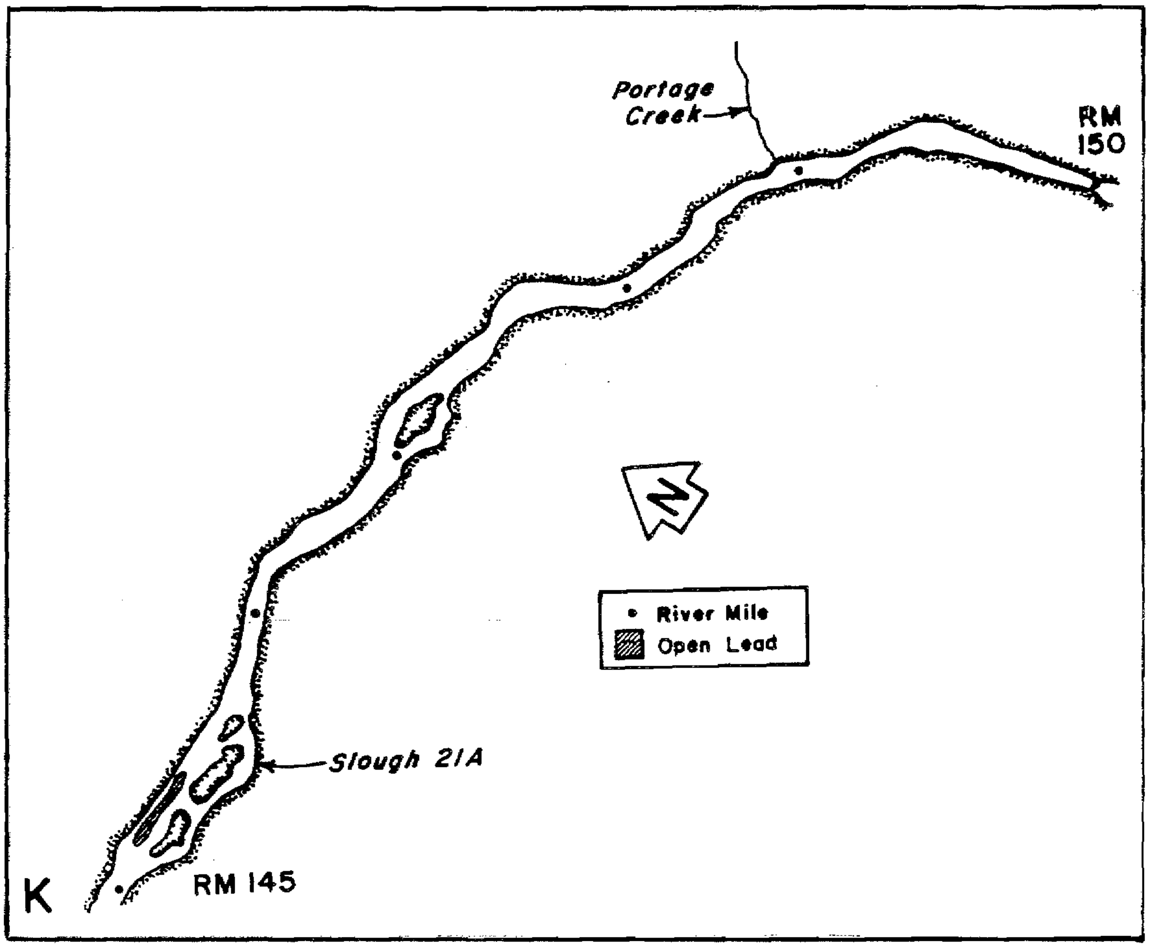


Figure 9. Maps of the middle Susitna River from RM 144.5 to 150.0 showing study sites and open leads.

Sampling frequency of water quality parameters varied because of logistics and time constraints. Originally, each site was to be sampled at least twice during the season, preferably early and late in the season. However, due to the large number of sites, lower required breaching discharges, and equipment problems, some sites were only sampled once. All data were summarized and compared with accepted tolerance ranges for spawning and incubation of salmonid embryos presented in Appendix Table D-1.

Instantaneous intragravel water temperature measurements (°C) were recorded at the same time and sampling location as for surface water quality measurements using a Digisense digital thermistor thermometer, model 8522-10 and Yellow Springs Instruments (YSI) model 419 stainless steel probe. Intragravel water temperature readings were taken at a depth of approximately 10 inches to reflect the approximate depth at which chum salmon eggs incubate (Vining et al. 1985). A depth of 10 inches was chosen because chum salmon were the primary species of interest and this depth allowed us to compare our data with related studies. At some locations, due to substrate composition (size or degree of cementation), the probe could not be inserted to a depth of 10 inches. In these instances, measurements were made as deep as the probe could be inserted into the substrate.

2.1.3 General Substrate Evaluations

Evaluations of the general substrate composition of each of the study sites were made by visual assessment of the dominant substrate types present throughout each study site. This evaluation was based on the substrate size classification scheme presented in Table 1.

Table 1. Substrate classification scheme utilized to evaluate general substrate composition at slough and side channel study sites.

Substrate Code	Substrate Description	Size
SI	silt	very fine
SA	sand	fines
SG	small gravel	¼"-1"
LG	large gravel	1"-3"
RU	rubble	3"-5"
CO	cobble	5"-10"
BO	boulder	greater than 10"

Substrate information was recorded on site maps to provide a general overview of the spatial surface substrate composition of each site. Data from these general substrate evaluations were compared to accepted substrate size ranges for spawning salmonids as reported in Reiser and Bjornn (1979), Lotspeich and Everest (1981), and Vincent-Lang et al. (1984) to provide an index as to the suitability of the substrate at each site for spawning salmon.

2.1.4 Upwelling and Bank Seepage

Upwelling and bank seepage are critical variables that are needed to make habitat suitable for chum salmon spawning and incubation (Vincent-Lang et al. 1984; Vining et al. 1985). Upwelling and bank seepage are key environmental factors affecting survival and development of chum salmon embryos by reducing dewatering and freezing of redds and increasing the rate of exchange of water in the redds to replenish dissolved oxygen and remove metabolic wastes (Kogl 1965; Bakkala 1970; Vining et al. 1985). For these reasons, locating areas of upwelling and bank seepage was important for identifying potential mitigation sites.

Areas of upwelling and bank seepage were located and mapped during foot surveys of each study site. Upwelling was usually apparent as water percolating through the substrate of a site. It was most readily apparent in areas of silt or sand where the flow of water could be easily observed as a bubbling action. In areas of substrate with little silt or sand, upwelling was observed as a current circulating through the water column if the water was calm enough and/or the upwelling strong enough. Bank seepage appeared as a lateral movement of water from the sides of a site. It was also noted where upwelling and/or bank seepage was present at high discharge but disappeared at lower discharges.

Another indicator of upwelling is the presence of open leads during the winter. Aerial photos of the middle Susitna River, taken during March 1983, were used to locate open leads and verify the accuracy of upwelling areas documented during the summer.

2.1.5 Evaluations of Fish Passage Restrictions

Baseline information on fish passage conditions were obtained from previous studies (Trihey 1982; Trihey et al. 1983; Quane et al. 1984; Sautner et al. 1984; Blakely et al. 1985). These baseline data were supplemented with data from a visual inspection of the study sites to denote any fish passage restrictions due to either water depth or the presence of physical barriers such as beaver dams. Passage restrictions due to flow (i.e. depth) were primarily observed at mainstem discharges ranging from 9,000 to 12,000 cfs to determine if the passage restrictions would be a barrier to upstream migration at anticipated project discharges. Physical barriers, primarily beaver dams, were assessed to determine their affect on upstream salmon migration. Dams at several sites were periodically opened during the peak spawning period to observe if migrating salmon would utilize available spawning habitats upstream of the dams.

2.2 Ice-Covered Studies

2.2.1 Site Selection

The selection of ice-covered study sites was made to provide additional information and options that may be considered in development of the Second Interim Mitigation Report by ENTRIX, Inc. (Moulton et al. 1984).

The objectives of the ice-covered season studies were: 1) to provide information on additional sites as options for the present fish mitigation plan; 2) to provide information on potential sites for a pilot mitigation project, and 3) to provide information on potential sites that may provide additional spawning habitat for the 25% of chum salmon not addressed in the present fish mitigation plan (Moulton et al. 1984).

Three of the open-water study sites were selected for more detailed study during the ice-covered season to evaluate incubation conditions and identify possible habitat modification techniques. Study sites were selected utilizing the data collected during the open-water phase of this study. Study sites were selected to be representative of features or problems that exist in other study sites in the middle reach of the Susitna River and also have limited utilization by spawning adult chum or sockeye salmon.

Sites selected for study during the ice-covered season were Bushrod Slough (RM117.9L), Curry Slough (RM119.7R), and Slough 10 (RM133.8L). Each of these sites presently has upwelling and only receives limited use by spawning salmon. Limited numbers of chum salmon were observed spawning at all three sites during 1984.

Bushrod Slough was selected as representative of sites exhibiting fish passage restrictions due to flow at the anticipated project discharges of 9,000-12,000 cfs. Curry Slough was selected as a representative study site exhibiting both substrate and passage restrictions. In addition, Curry Slough was studied as a possible fry release site in conjunction with possible incubation box development. Slough 10 is representative of sites having substrate limitations for spawning salmon.

2.2.2 Surface and Intragravel Water Quality

Surface and intragravel water quality variables were monitored in each study site. Thus a comparison of the site-specific water quality variables against accepted tolerance ranges for incubating salmon (Hale 1981) will give an indication of the suitability of a site for spawning and incubation. The surface and intragravel water quality (pH, conductivity, temperature, and dissolved oxygen) of a spawning area during the winter is important to the incubation of salmon eggs and in the development of embryos and alevins (Vining et al. 1985). Of these four parameters, temperature and dissolved oxygen most directly affect the rate of development, survival rate, and timing of emergence of incubating salmon embryos (Vining et al. 1985).

To monitor intragravel water quality at each study site, 15 polyvinyl chloride (PVC) standpipes were placed in selected locations in each site. The PVC standpipes were virtually identical to those used in previous ADF&G studies (ADF&G 1983; Vining et al. 1985). Based on ideas presented in Terhune (1958) and Woods (1980), the standpipes in this study were modified by placing a collar made of 1 foot by 1 foot plastic

(2 ml thick) around the base of the standpipe to reduce the flow of surface water down the outside of the standpipe (Figure 10). A collar was placed over the pipe after it was driven in the substrate and held in place with rubber bands. The collars were placed directly on the substrate with the edges being buried in the substrate. At several locations, upwelling was observed flowing up the outside of the standpipe after it was driven into the substrate. The flow of upwelling ceased once the collar was in place. It was assumed, based on the upwelling observations, that the reverse would be true in that the collars could be effective in reducing the flow of surface water down the outside of the standpipe, thereby producing more accurate measurements of intragravel water quality.

Instantaneous water quality measurements were collected periodically throughout the winter at each study site both inside and outside the standpipes using procedures described in ADF&G (1983b) and Vining et al. (1985).

A continuous record of surface and intragravel water temperatures was obtained using Omnidata model 2321 two channel temperature recorders (datapods) in a representative locations in each site. These temperature recorders were installed and continuously operated in each winter study site following procedures in ADF&G (1983b), Keklak and Quane (1985), and Keklak and Withrow (1985).

2.2.3 Freeze-Core Substrate Analysis

Two types of substrate sampling methods were considered for evaluating substrate in this study, the McNeil (McNeil and Ahnell 1960) and the freeze-core (Walkotten 1976; Everest et al. 1980). Of these two methods, the freeze-core technique was selected for the following reasons:

1) it allows sub-sampling of the freeze-core at varying increments of depth;

2) it is more versatile, functioning under a wider variety of weather and water conditions;

3) the metal probe of the freeze-core technique provides easier penetration of the large and cemented substrates present at many sites; and,

4) it allows more accurate sampling of sediments less than 0.062 mm (Walkotten 1976).

The only change made in the freeze core system described by Walkotten was the use of steel probes instead of copper. This modification was made because steel probes were more durable.

Freeze core samples were collected at five locations in each of the winter study sites using a single probe freeze-core apparatus as described in Walkotten (1976) (Figure 11). The five substrate sampling

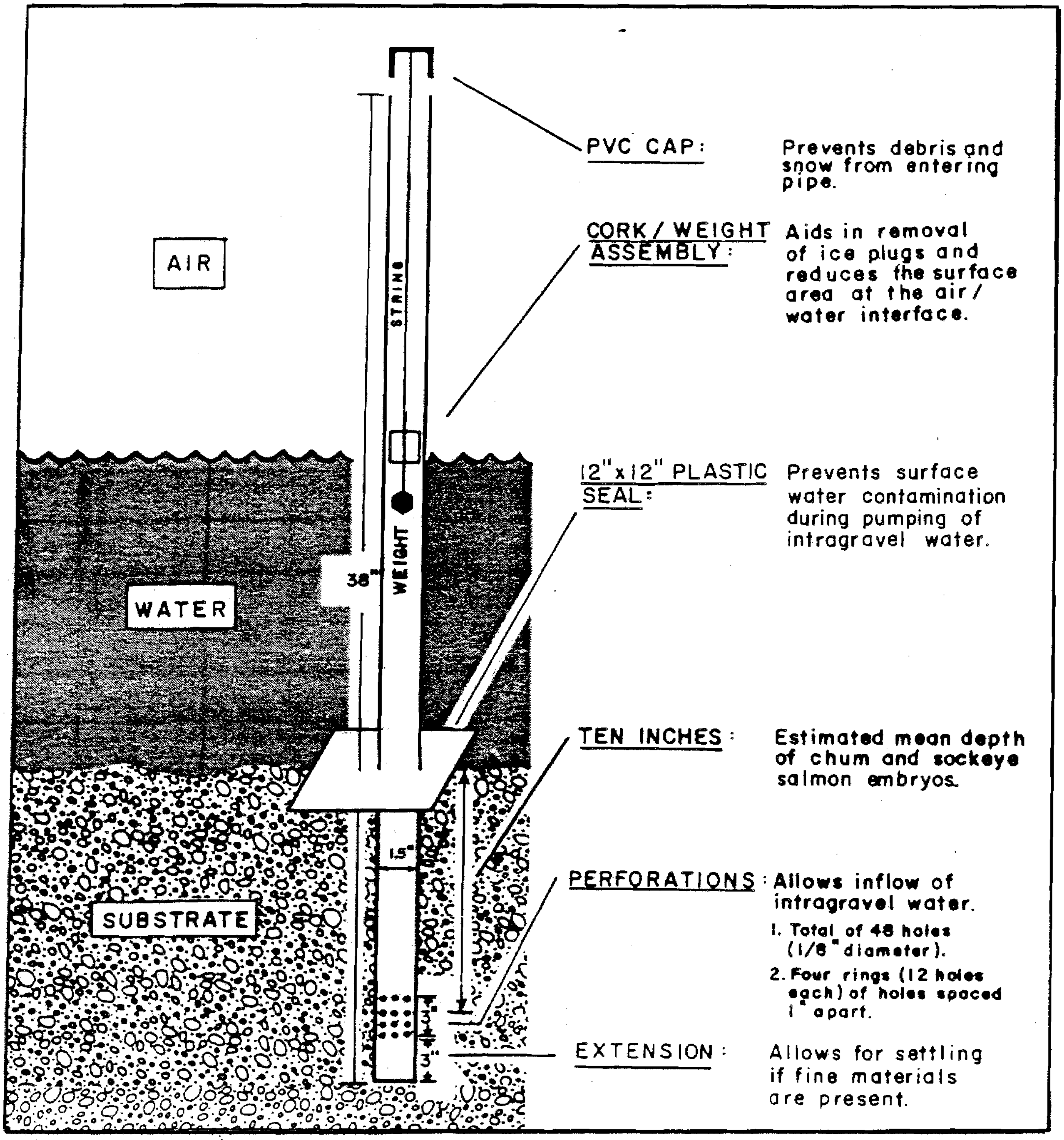


Figure 10. Diagram of a polyvinyl chloride (PVC) standpipe used to evaluate intragravel water conditions in streambeds of salmon spawning habitats in the middle reach of the Susitna River.

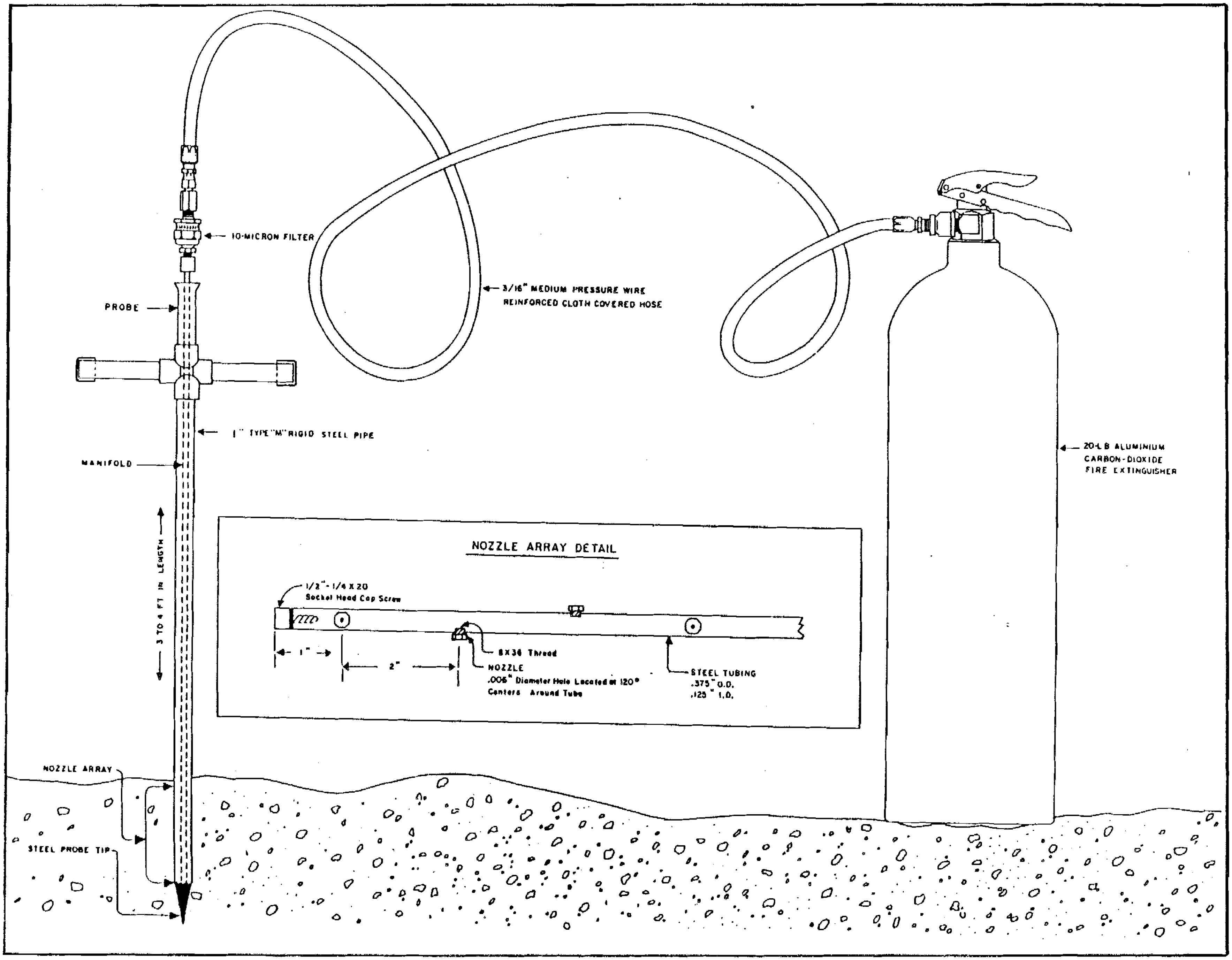


Figure 11. Single probe freeze core apparatus used to sample streambed substrate in the middle reach of the Susitna River, 1985 (adapted form Walkotten 1976).

locations were selected arbitrarily at each site in an attempt to represent all characteristics present in a site. Difficult sampling conditions (frozen substrate, deep snow, etc.) at Curry Slough limited sample collection to two locations at this site. All freeze core samples were collected to a depth of 16 inches. This depth was selected to encompass the average redd depth for all salmon species (Appendix Table D-2).

Through experimentation, the best substrate cores were obtained by discharging a complete 20 lb. tank of CO_2 into the probe for each freeze core sample. This procedure generally took about 10 minutes. Frozen substrate samples were then extracted from the streambed using a tripod and hand operated winch. Cores were thawed using portable propane heaters and split into two samples, the top 8 inches and the bottom 8 inches, to observe differences in composition with depth (Everest et al. 1980; 1981; Scrivener and Brownley 1981). Samples were stored in plastic garbage bags in a freezer prior to analysis.

Frozen freeze core samples were taken to the Alaska Department of Transportation (ADOT) Central Materials Testing Laboratory for analysis. Sieve analysis of the samples followed procedures (T27-82 and T11-82) outlined in the American Association of State Highway and Transportation Officials (1982). A series of seven sieves of the following mesh sizes: 127, 76.2, 25.4, 2.0, 0.84, 0.50, and 0.062 mm were used in the analysis. With the exception of the 0.84 mm sieve, these are the same sizes used in previous ADF&G analyses (Vining et al. 1985). The sieve selection was based on the previous ADF&G studies as well as recommendations from Wendling (1976), Shirazi et al. (1980), Lotspeich and Everest (1981), Everest et al. (1981), and Platts et al. 1983. After sieving, the dry weight of each size class of substrate was measured to the nearest gram and expressed as a percentage of the total weight.

The quality of spawning gravels has traditionally been estimated by determining the percentage of fine grains less than some specified diameter. Harrison (1923) and Phillips et al. (1975) demonstrated that an inverse relationship exists between percent fines and survival. While percent fines provides an index of gravel quality, it is limited because it ignores the textural composition of the remainder of the sample. Other methods, such as the use of geometric mean diameter of particles (Shirazi and Seim 1979), have been proposed to improve on the percent fines method. Used alone, each method has its drawbacks. Further research by Lotspeich and Everest (1981) and Everest et al. (1981) resulted in the development of a quality index that appears to overcome the limitations of other methods. This quality index for gravels can be obtained by dividing geometric mean particle size by the sorting coefficient (a measure of the distribution of grain sizes) in a sample. The resulting number, called the "fredle index," is currently being used for evaluating the reproductive potential of spawning gravel (Lotspeich and Everest 1981, Everest et al. 1981, and Platts et al. 1983).

The fredle index, as used in this study, incorporates the influence of texture on two fundamental properties of spawning gravels - pore size and permeability - that influence survival. Pore size and permeability regulate intragravel water velocity and oxygen transport to incubating salmonid embryos removal of metabolic wastes, and control intragravel movement of alevins. Pore size, rather than porosity, was chosen as a component of the quality index because pore size (and permeability) is directly proportional to mean grain size while porosity has been shown to be independent of grain size. To derive the fredle index, the raw data from textural analysis was entered into a computer program developed by Porter and Rogers (1984). This program provides a concise summary of the indices which describe the textural composition of spawning gravels.

2.2.4 Upwelling and Bank Seepage

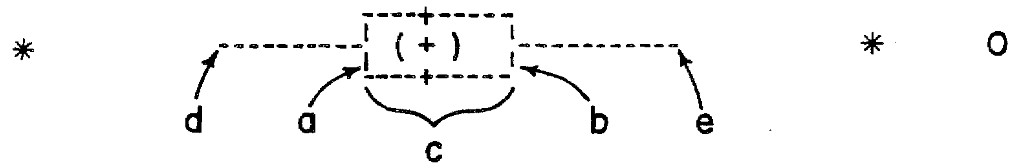
Because of the difficulty in observing and measuring upwelling and bank seepage, no quantitative measurements were made of either. Rather, visual observations were used to note the presence or absence of upwelling and bank seepage both spatially and temporally throughout each of the winter study sites. If upwelling or bank seepage was not visible during the winter, the presence of an open lead in an area where upwelling and/or bank seepage was present during the open-water season served as an indicator of its presence during the winter. These data were then delineated on site maps with the open water upwelling observations to provide a record of upwelling patterns in slough and side channel habitats in the middle Susitna River.

2.3 Interpretation of Figures

Results in this report are shown in two types of figures (box-and-whiskers plots or boxplots and scatter number plots) which warrant a description of symbols used.

Boxplots are used to summarize water temperature, dissolved oxygen, pH, and conductivity data. The format basically follows that used by Velleman and Hoaglin (1981). The boxplots, as presented here, were computer generated by the microcomputer program MINITAB (Ryan et al. 1982). Measured values (i.e., dissolved oxygen, water temperature, etc.) from each study site comprise a data batch, which is ordered from lowest value to highest. Specific symbols used in the boxplot figures of this report are explained in Figure 12.

Scatter number plots are used in a number of figures in this report to summarize water temperature, dissolved oxygen, pH, and conductivity data. Each number in a figure represents the number of occurrences in single integers (1-9) at that point.



Symbol	Representative Term
a, b	lower and upper hinges (about 25 percent of the way in from each end of an ordered batch)
c	H-spread (the difference between the hinges; middle half of the data batch)
d	minimum adjacent value = minimum observed value greater than [lower hinge - (1.5 x H-spread)]
e	maximum adjacent value = maximum observed value less than [upper hinge + (1.5 x H-spread)]
+	median (middle value of the batch)
*	outside value (outside of the adjacent values)
O	far outside value-outside of the following range: lower hinge - (3 x H-spread) upper hinge + (3 x H-spread)
( )	notches (represent approximately a 95 percent confidence limit about the median): $\text{median} \pm 1.58 \times (\text{H-spread})/\sqrt{n}$

Figure 12. Definitions of symbols used in boxplots which summarize water temperature, dissolved oxygen, pH, and conductivity data.

3.0 RESULTS

3.1 Open-Water Studies

Results of open-water studies conducted at 44 potential mitigation sites in the middle reach of the Susitna River from July 31 to October 8, 1984 are presented in the following sections. Of the 44 sites identified, 23 were side sloughs, 16 were upland sloughs, and 5 were side channel habitats. A summary of the selected site characteristics for each of these sites is presented in Table 2.

3.1.1 Instantaneous Surface Water Quality and Intragravel Water Temperature Data

Instantaneous surface water quality and intragravel water temperature measurements recorded at all slough and side channel sites during the open water sampling period are presented in Appendix Table B-1. A comparison of the range and mean of water quality parameters measured in side slough, upland slough, and side channel habitats by sampling period is presented in Figure 13 and Figure 14. Because of the limited number of samples that were collected, only general assumptions can be made regarding differences in water quality between sites. A comparison of the mean water quality parameters over time indicate that there were no major differences between the three habitat types and that water quality is not presently a limiting factor for salmon spawning and development at any of these sites.

3.1.2 General Substrate Evaluations

Substrate composition of slough and side channel study sites, as determined from visual observations, is presented on individual site maps in Appendix A. Side slough habitats tended to have a greater percentage of loose gravel substrates, whereas the substrate composition in side channels was more compacted and generally contained more rubble, cobble, and boulder. Upland sloughs generally have a greater percentage and depth of silt-sand deposits compared to side sloughs.

3.1.3 Upwelling and Bank Seepage

Prior to the open-water season, winter aerial photos of open leads in the ice were studied to try to identify upwelling and bank seepage at prospective study sites. During the open-water season, areas where open leads had been present on winter aerial photographs were checked and all observations of upwelling and bank seepage at side slough, upland slough, and side channel habitats were recorded on site maps (Appendix A). Upwelling and bank seepage are also discussed on a site by site basis in the site description narratives in Appendix A. Sites where upwelling and/or bank seepage has been recorded are summarized in Table 2.

Of the 23 side sloughs surveyed, 18 (78%) exhibited upwelling and/or bank seepage. Fourteen (61%) of the side sloughs surveyed, had open

Table 2. Summary of selected site characteristics of potential mitigation sites surveyed in the middle reach of the Susitna River, 1984.

Site	River Mile[1]	Habitat Type[2]	Salmon Spawning Observed[3]	Open Lead Observed	Upwelling Bank Seepage Observed	Beaver Activity[4]	Passage Restrictions due to Beavers[5]
Slough 1	99.5R	US	X			X	
Slough 2	100.7R	SS	X	X	X	X	
Whiskers Creek Slough	101.2L	SS	X	X	X	X	X
Slough 3B	101.4L	SS	X	X			
Slough 3A	101.9L	US	X	X	X	X	X
Slough 4	105.2R	US				X	X
Slough 5	107.6L	US	X	X		X	X
Slough 6	108.2L	US		X		X	X
Oxbow I	110.1L	SC	X	X			
Slough 6A	112.3L	US		X		X	X
Slough 7	113.2R	SS			X		
Slough 8	113.7R	SS	X	X	X		
Mainstem 2	114.5R	SC	X	X	X		
Bushrod Slough	117.9L	SS	X	X	X		
Curry Slough	119.7R	US	X	X	X		
Slough 8D	121.8R	US	X	X		X	
Slough 8C	121.8R	SS	X		X		
Slough 8B	122.2R	SS	X	X		X	
Moose Slough	123.1R	SS	X		X		
Slough A[1]	124.6R	SS	X		X		
Slough A	124.8R	US	X		X		
Slough 8A	125.3R	SS	X	X	X	X	X
Slough B	126.3R	SS	X		X		
Slough 9	128.3R	SS	X	X	X		
Slough 9B	129.2R	US	X	X	X	X	X
Slough 9A	133.2R	SS	X	X	X	X	
Slough 10	133.8L	US	X	X	X	X	X

Table 2 (Continued).

Site	River Mile[1]	Habitat Type[2]	Salmon Spawning Observed[3]	Open Lead Observed	Upwelling Bank Seepage Observed	Beaver Activity[4]	Passage Restrictions due to Beavers[5]
Side Channel 10	133.8L	SC		X	X		
Slough 11	135.3R	SS	X	X	X		
Slough 12	135.4R	US				X	X
Slough 13	135.5R	SS	X		X		
Upper Side Channel 11	136.0R	SC	X	X	X		
Slough 14	136.0L	US	X	X		X	X
Slough 15	137.2L	SS	X		X	X	X
Slough 16	137.7L	SS	X	X			
Slough 16B	137.9L	SS	X	X			
Slough 17	138.9L	US	X	X	X	X	X
Slough 18	139.1L	US	X			X	
Slough 19	139.8R	US	X	X	X	X	
Slough 20	140.1R	SS	X	X			
Side Channel 21	140.6R	SC	X	X	X		
Slough 21	141.8R	SS	X	X	X		
Slough 22	144.2L	SS	X	X	X		
Slough 21A	145.3R	SS	X		X		

1 Letters idicate left bank (L), right bank (R) or center channel (C) as viewed looking upstream

2 SS - side slough
US - upland slough
SC - side channel

3 Spawning observed at least once during 1981-1984. Appendix Table C-1 presents a more detailed presentation of spawning observations.

4 Beaver activity refers to either a lodge, dam or both.

5 All sites may have passage restrictions due to flow in the 9,000 to 12,000 cfs range.

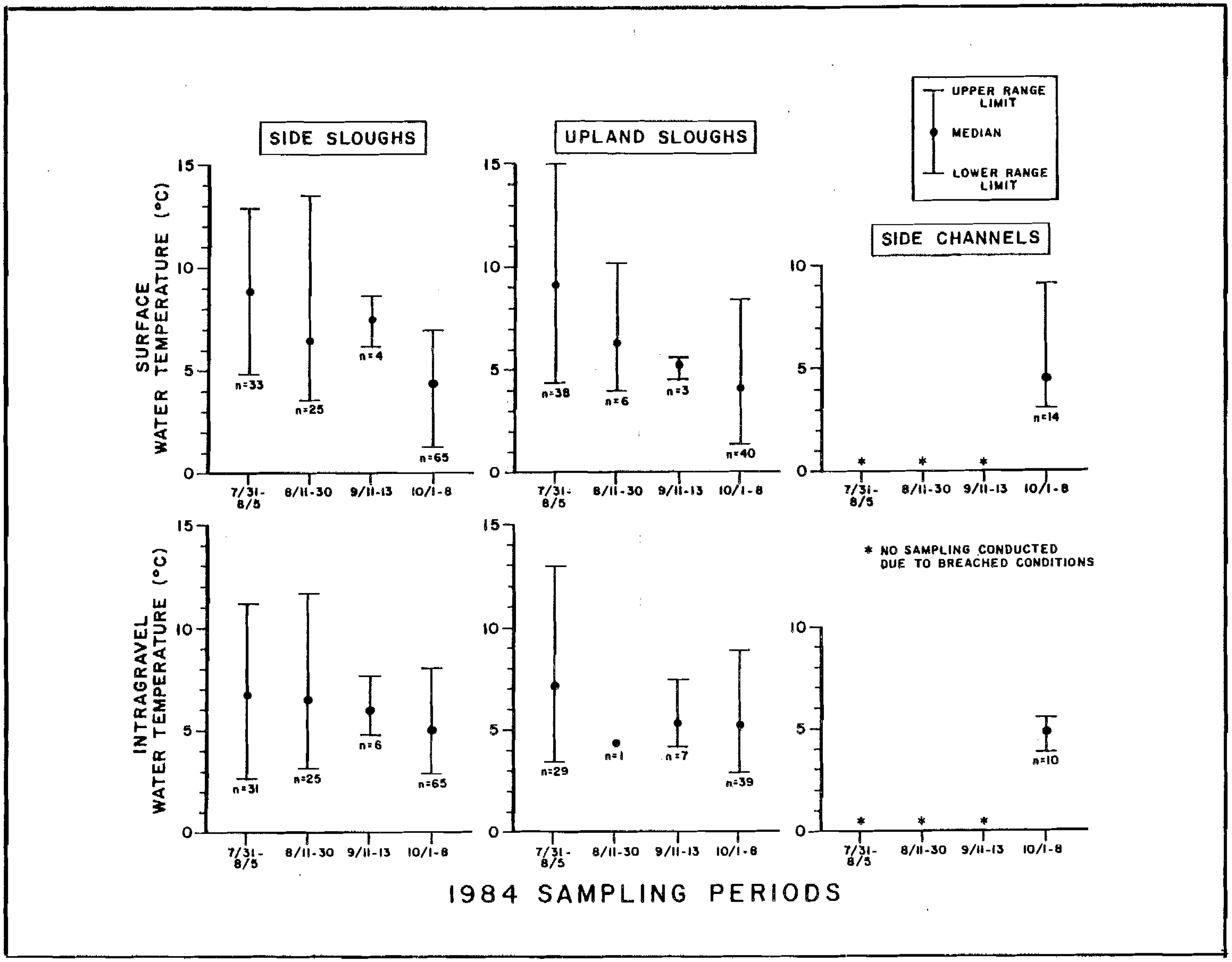


Figure 13. Comparison of the range and mean of instantaneous surface water and intragravel water temperatures measured at side slough, upland slough, and side channel habitats by sampling period, 1984.

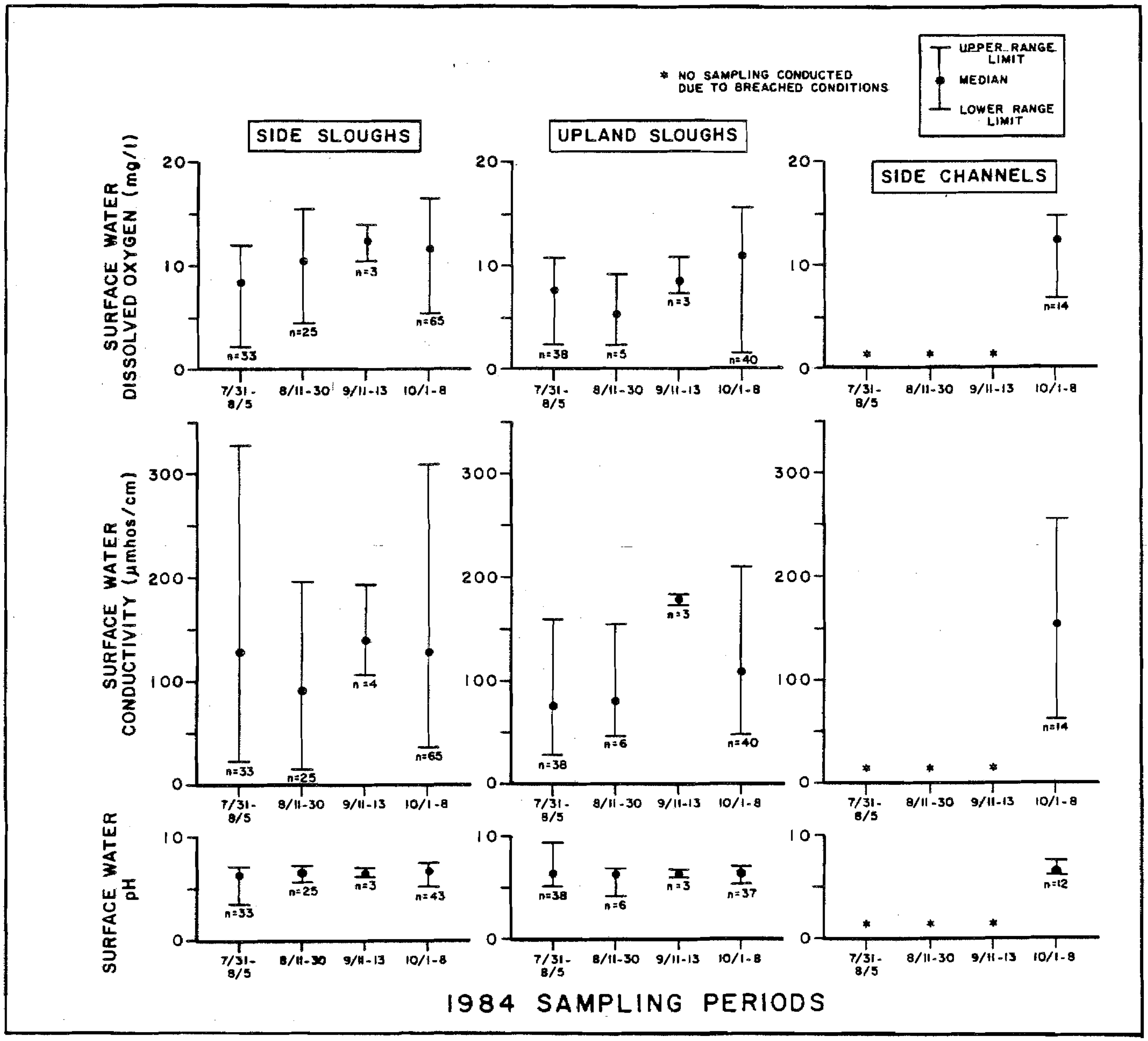


Figure 14. Comparison of the range and mean of dissolved oxygen, conductivity, and pH measured at side slough, upland slough, and side channel habitats by sampling period, 1984.

leads during the winter, which we attribute to upwelling. However, upwelling was not documented at all side sloughs that had open leads. Five side sloughs that had no visible upwelling (3B, 8B, 16, 16B, and 20), had open leads during the winter, indicating that upwelling may be present even though not visible. Also, eight side sloughs (7, 8C, Moose, A', B, 13, 15, and 21A) that exhibited upwelling and/or bank seepage, had no open leads during the winter.

Upwelling was observed in a smaller percentage of upland slough habitats than was observed in side slough habitats. Upwelling and/or bank seepage was observed in seven (44%) of the 16 upland sloughs surveyed. Open leads, an indication of upwelling during the winter, were observed in 11 (69%) of the sites. The only upland slough site that had upwelling but no open lead was Slough A. Upwelling may be present in the four sites that had open leads even though none was observed during the open-water surveys.

Upwelling was observed in 4 of the 5 side channel habitats surveyed during 1984. Only Oxbow I Side Channel had no visible upwelling or bank seepage. All 5 side channels did have open leads during the winter, indicating the possible presence of upwelling in Oxbow I Side Channel. Although upwelling was found at side channel sites, it did not appear to be as strong or extensive as the upwelling found in side slough habitats.

3.1.4 Evaluations of Fish Passage Restrictions

Fish passage restrictions in side slough, upland slough, and side channel habitats can result from restricted flows or physical barriers. Flow related passage restrictions in selected sites have been previously discussed in Trihey (1982), Trihey et al. (1983), Sautner et al. (1984), and Blakely et al. (1985). Field observations indicate that in the 9,000 to 12,000 cfs range, all of the open-water season study sites will likely have flow related passage restrictions. No further detailed analysis of flow-related passage restrictions other than field observations was done for this study. Results of the passage portion of this study focus on physical barriers, primarily beaver dams, that may be easily removed for mitigation purposes. Beaver dams may be barriers to the upstream migration of salmon (Canada 1980). Sites having potential fish passage problems due to beaver activity are summarized in Table 2.

Of the 23 side sloughs surveyed, six (26%) have beaver activity. Of these sites, only two (Sloughs 8A and 15) presently have passage restrictions due to physical barriers resulting from beaver dams. The other four sites (Sloughs 2, Whiskers, 8B, and 9A) have beaver activity associated with them but no passage barriers at present. However, it appeared as if several dams were being constructed in the fall of 1984 at Slough 2. Completion of these dams will likely result in physical barriers to fish passage.

Beaver dams which were opened at two side slough sites during 1984 resulted in successful passage of salmon to areas upstream of the dams. In Slough 8A, a beaver dam constructed during 1983 isolated all previously utilized spawning area upstream of it. During 1984, several dams in Slough 8A were periodically opened to determine if providing passage through the dams would be a possible mitigation alternative. When the dams were opened, the chum, sockeye, and pink salmon that were present, readily migrated through the opening in the dam and utilized the available spawning habitat upstream of the dam. A similar situation occurred on Whiskers Creek, emptying into Whiskers Slough. In this case, coho salmon readily migrated through the dam to upstream spawning areas.

Beavers are present in 14 (88%) of the upland sloughs surveyed. Beaver dams prevent passage of salmon in eleven (69%) of the upland sloughs surveyed. Three upland slough sites (Slough 1, 8D, and 19) have beaver activity, but no dams at present.

Beaver dams in selected upland slough sites were opened to see if chum salmon would utilize newly available or previously utilized spawning habitat. Slough 4 was opened but no adults entered the area above the dam. Due to lack of upwelling and thick silt deposits the newly accessible area was probably unsuitable as a spawning site this year. The dams in Slough 9B were periodically opened to see if chum and sockeye salmon would spawn in a previously utilized area. Both species spawned in Slough 9B prior to the construction of the dams in late 1982. The fish that enter Slough 9B must travel through Slough 9 to reach the mouth. During a high water period, passage was possible through Slough 9 and chum and sockeye salmon readily migrated into the slough. They selected upwelling areas for spawning and removed thick silt deposits, up to 18 inches, to reach the spawning substrate.

At present all passage restrictions located in side channel habitats are flow related. While considerable site-by-site variation exists, side channels dewater appreciably at low mainstem discharges, creating numerous passage restrictions. Backwater affects will influence passage reaches in the mouth area of side channels but generally not those upstream. No beaver activity was observed in any of the side channels surveyed.

3.1.5 Salmon Spawning Utilization

The locations of side slough, upland slough, and side channel habitats which have been utilized by spawning salmon in the middle reach of the Susitna River between 1981 and 1984 are shown on individual site maps in Appendix A. Summary tables of salmon spawning data at individual sites are presented in Table 2 and Appendix Table C-1.

In the middle reach of the Susitna River, side slough habitats are primarily used as spawning areas by chum and sockeye salmon and less frequently by pink salmon. Although chum and sockeye salmon spawn in many different side sloughs in the middle reach, the sites which have consistently had the highest concentrations of spawners are Sloughs 8A, 9, 11, and 21. Pink salmon have been observed spawning in 15 of the 23 side slough sites. They have frequently been observed in other sites but only as milling fish. During the period 1981-1984, the only side slough in which salmon spawning or milling was not reported was Slough 7.

Chum and sockeye salmon are the predominate species which utilize upland sloughs for spawning. Of the 16 upland sloughs studied, salmon spawning has occurred at 12 (75%) of the sites during one or more years in the 1981-1984 time period. Sloughs 1, 5, Curry, and 14 had spawning reported for the first time in 1984. Only two upland sloughs (17 and 19) have had spawning reported in every year. Four of the sixteen upland sloughs studied (Sloughs 4, 6, 6A and 12) had no reported salmon spawning during 1981-1984. These four sloughs have extensive beaver activity and limited spawning area. It should be noted that even though 75% of the upland sloughs have had spawning reported during 1981-1984, only a few have had spawning every year. In addition, because the spawning area is limited in upland sloughs the numbers of fish spawning in upland sloughs is relatively low and their overall contribution to the fishery is low.

Of the 5 side channels surveyed, only Side Channel 10 has no reported salmon spawning. Three milling chum salmon were observed in Side Channel 10 during 1984. Oxbow I had limited chum salmon spawning reported in 1984. The remaining three sites (Mainstem 2, Upper Side Channel 11, and Side Channel 21) have had chum salmon spawning every year between 1981 and 1984. Sockeye and pink salmon have also been observed spawning in Upper Side Channel 11 and Side Channel 21. Coho salmon have been observed milling in Upper Side Channel 11 every year, but have not been observed spawning. Chinook salmon have not been observed in side channel habitats.

3.2 Ice Covered Surveys

Based on the results of the open water surveys three sites were selected for more detailed study to better determine their potential as possible mitigation sites. These studies included an examination of incubation conditions at each site and identification of selected habitat modification techniques that may be used as mitigation alternatives at these sites. The three sites selected, Bushrod Slough (RM 117.9L), Curry Slough (RM 119.7R), and Slough 10 (RM 133.8L) presently have limited salmon spawning activity that may be due to factors such as passage restrictions, substrate limitations, or lack of upwelling.

3.2.1 Physical Characteristics

3.2.1.1 Water Temperature

Water temperature data presented in this section includes instantaneous surface and intragravel water temperatures measured at individual standpipe water quality sampling sites, and continuous surface and intragravel water temperatures measured at each mitigation study site.

3.2.1.1.1 Instantaneous Surface and Intragravel Water Temperature

A comparison of instantaneous surface and intragravel water temperatures measured at standpipes in each slough are presented in Figure 15. The raw data used to develop these figures is presented in Appendix Table E-1. There is a general relationship between winter surface and intragravel water temperatures. This relationship is more evident at Curry Slough than at Slough 10. This is unexpected since Slough 10 has a greater amount of upwelling and the surface and intragravel water temperature ranges are most similar.

A summary of surface and intragravel instantaneous water temperatures for these three sites is presented in Figures 16 and 17. For all three sites, the median values for intragravel water temperatures are higher than for surface water temperatures. Bushrod Slough has the highest median intragravel water temperature and Curry Slough the lowest. Slough 10 has the highest median surface water temperature and Curry Slough the lowest.

3.2.1.1.2 Continuous Surface and Intragravel Water Temperature

Continuous surface and intragravel water temperatures were measured at one location in Bushrod and Curry Sloughs and in two locations (one site in each channel) in Slough 10 (Figures 18, 19, 20, and 21 respectively). A complete presentation of these data are included in Keklak and Withrow (1985). Bushrod and Curry Sloughs experienced a drop in temperatures until early November with surface water warmer than intragravel water. After this time, water temperatures warmed slightly with intragravel temperatures warmer than surface water. In Slough 10, the decrease in water temperature lasted until early December with intragravel water temperatures becoming warmer than surface water in early November. The northeast channel in Slough 10 exhibited more variability in both surface and intragravel water temperatures than was found in the other sites. The ranges of continuous water temperatures, while comparable to the instantaneous data, present a more complete record and better describe the variability of water temperatures in each site.

3.2.1.2 Freeze Core Substrate Analysis

Freeze-core substrate samples collected at Bushrod Slough, Curry Slough, and Slough 10 were analyzed to compute a fredle index. The fredle index is a measure of substrate quality in terms of both pore size and relative permeability, both of which increase as the fredle index increases. This textural analysis verifies the general visual substrate evaluations made during the open-water survey period. The composition of substrate samples collected at these three sites are summarized in Appendix Table F-1.

For all substrate samples obtained in Bushrod Slough, the greatest size percentage, by weight, of substrates fell within the 2.0 mm to 127 mm size class. Only one sample contained particles greater than 127 mm in size. All samples contained some fines less than 0.5 mm in size, whereas only two samples (4A and 2B) contained (34% and 38% respectively) fines of this size class.

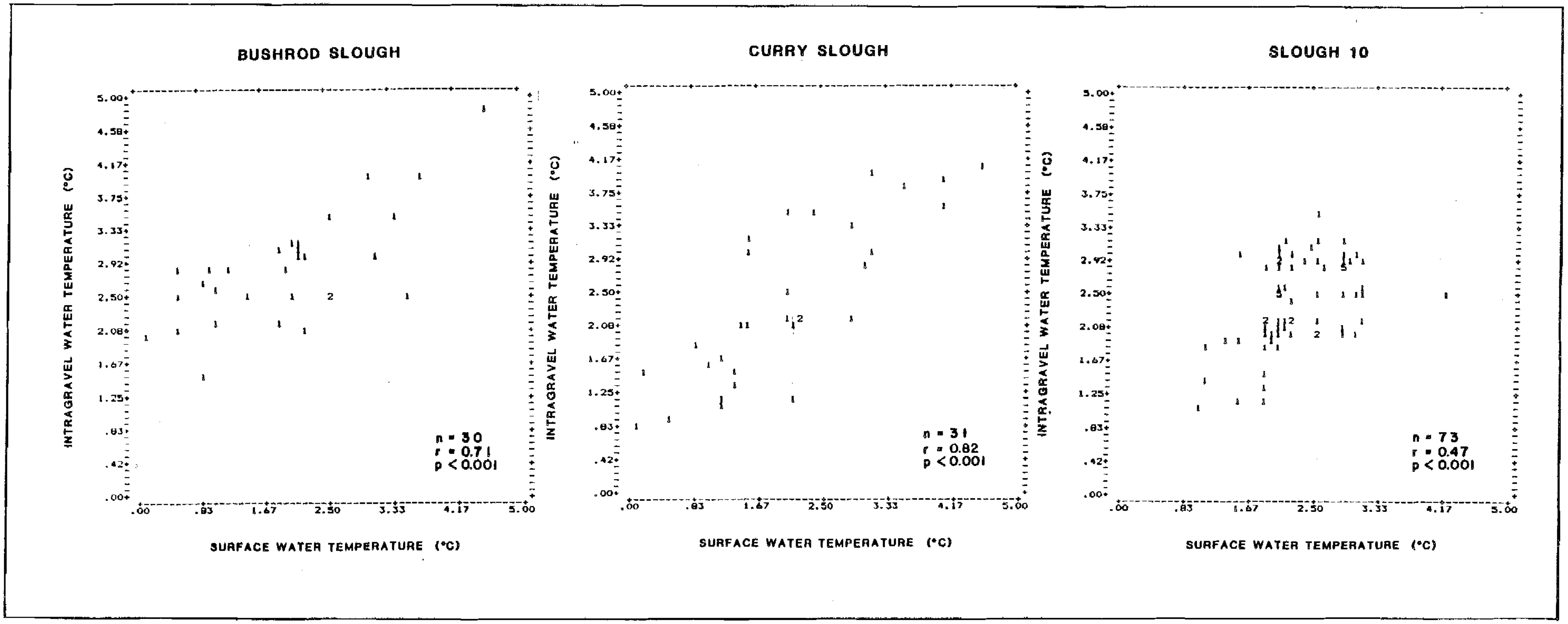


Figure 15. A comparison of instantaneous surface and intragravel water temperature (°C) data measured at standpipes in Bushrod Slough, Curry Slough, and Slough 10 during the ice-covered season, 1984-85.

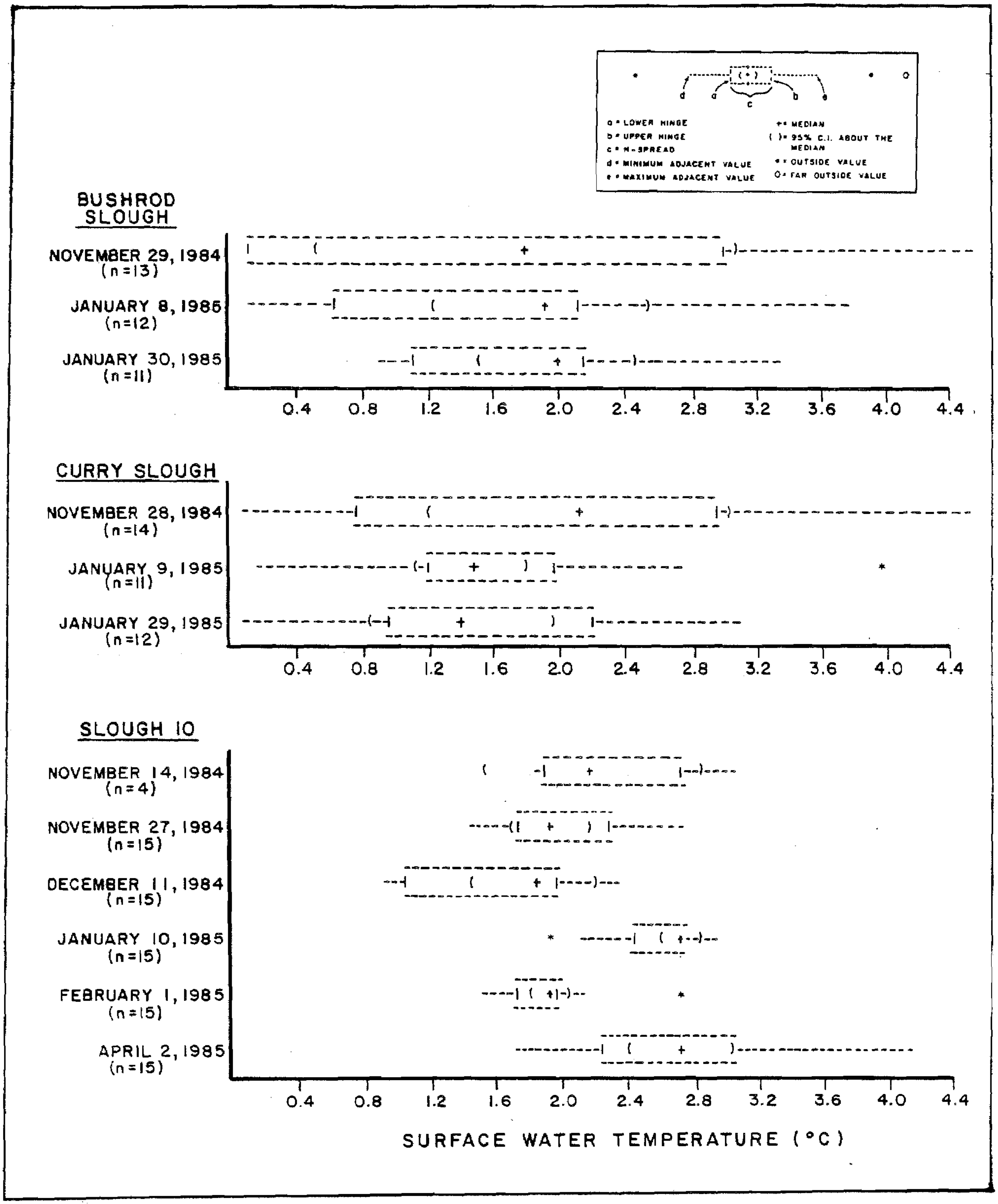


Figure 16. Summary of instantaneous surface water temperature data (°C) measured at standpipes in the middle reach of the Susitna River, by study site and sampling period, ice-covered season 1984-85.

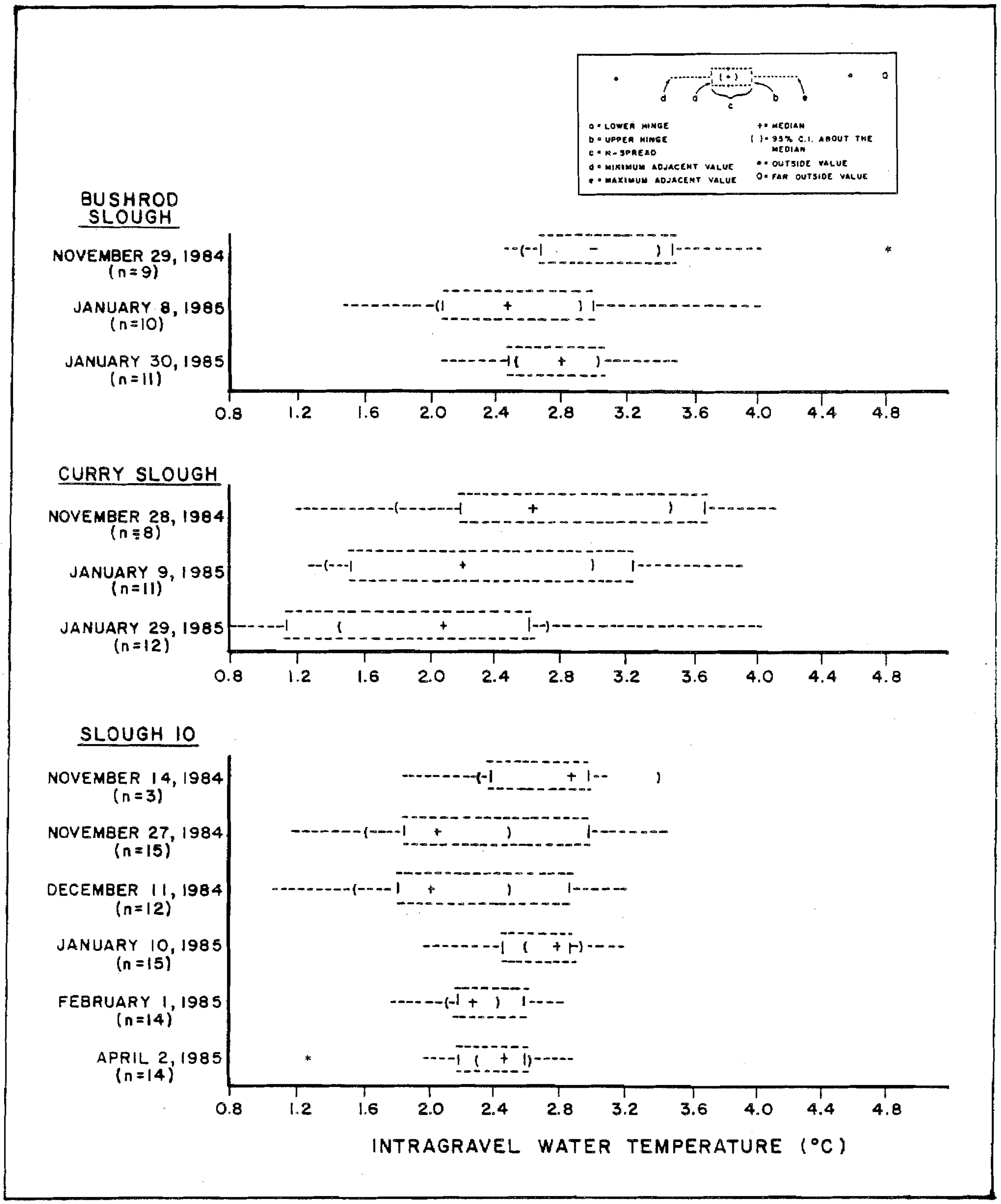


Figure 17. Summary of instantaneous intragravel water temperature data (°C) measured at standpipes in the middle reach of the Susitna River, by study site and sampling period, ice-covered season 1984-85.

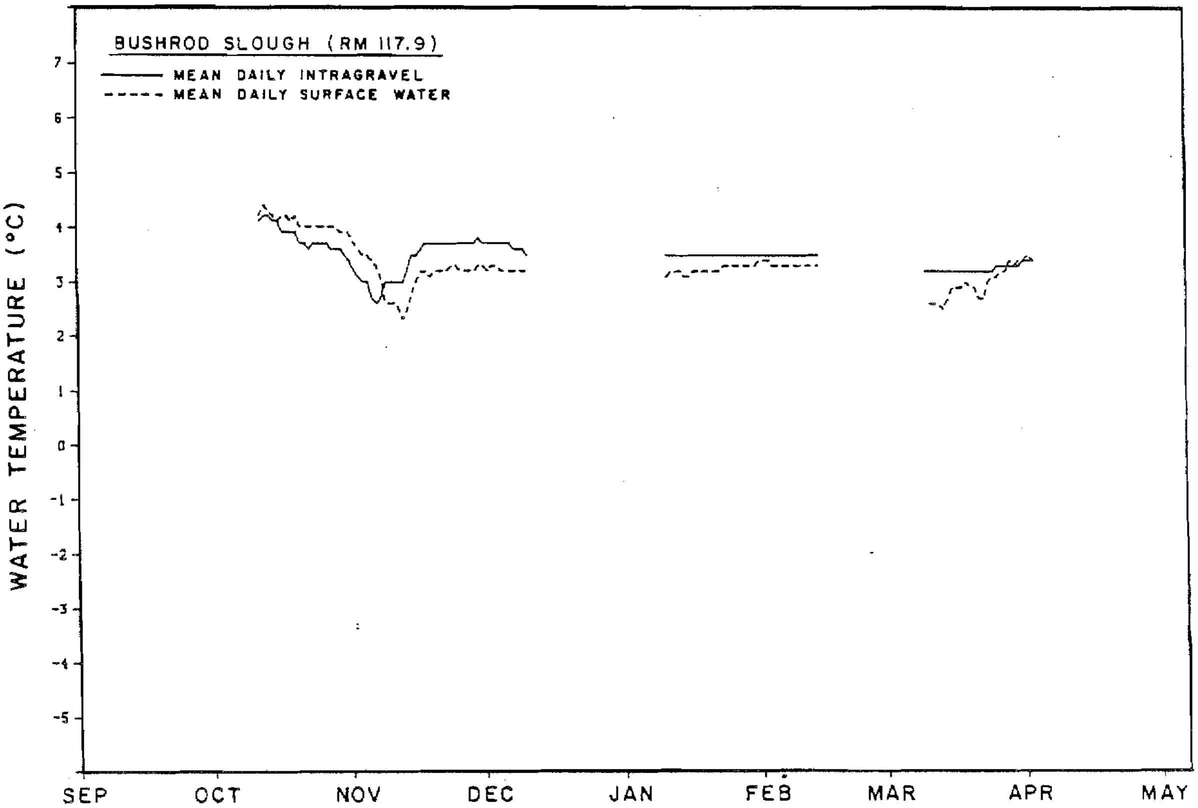


Figure 18. Mean daily intragravel and surface water temperatures (°C) recorded at Bushrod Slough (RM 117.9) during the ice-covered season, 1984-85.

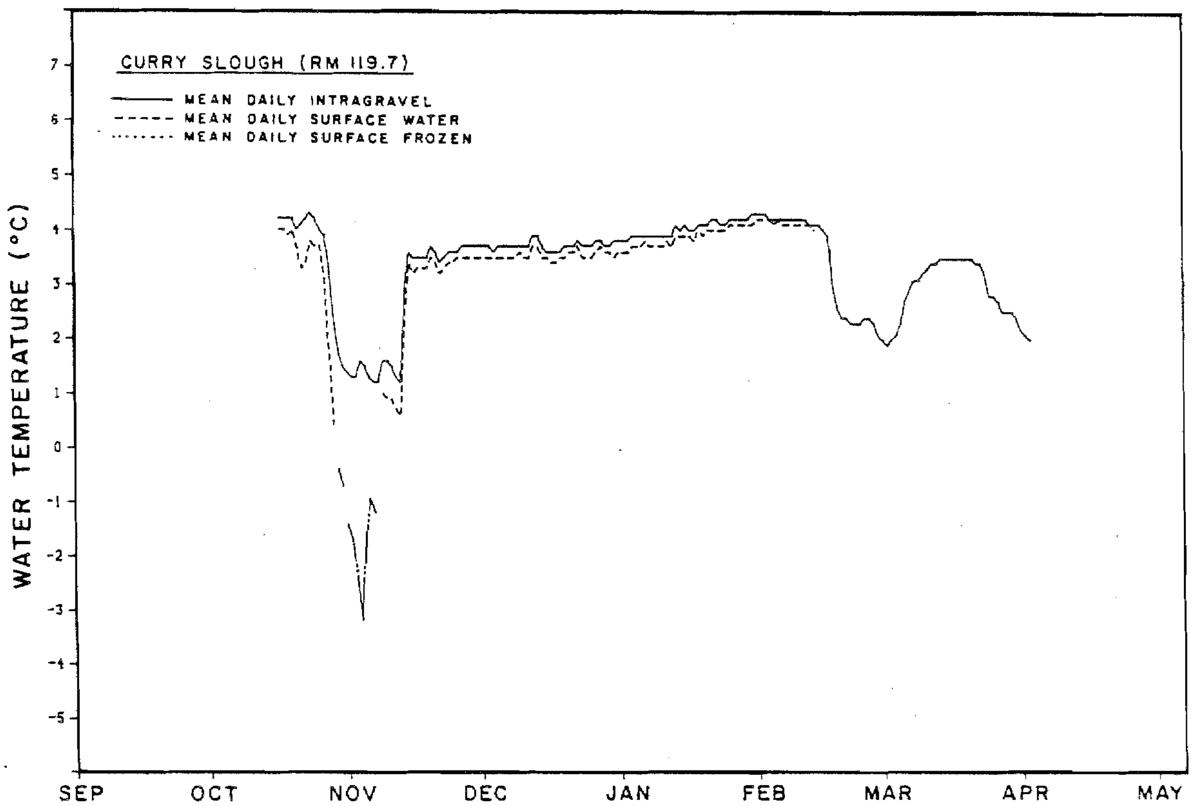


Figure 19. Mean daily intragravel and surface water temperatures (°C) recorded at Curry Slough (RM 119.7) during the ice-covered season, 1984-85.

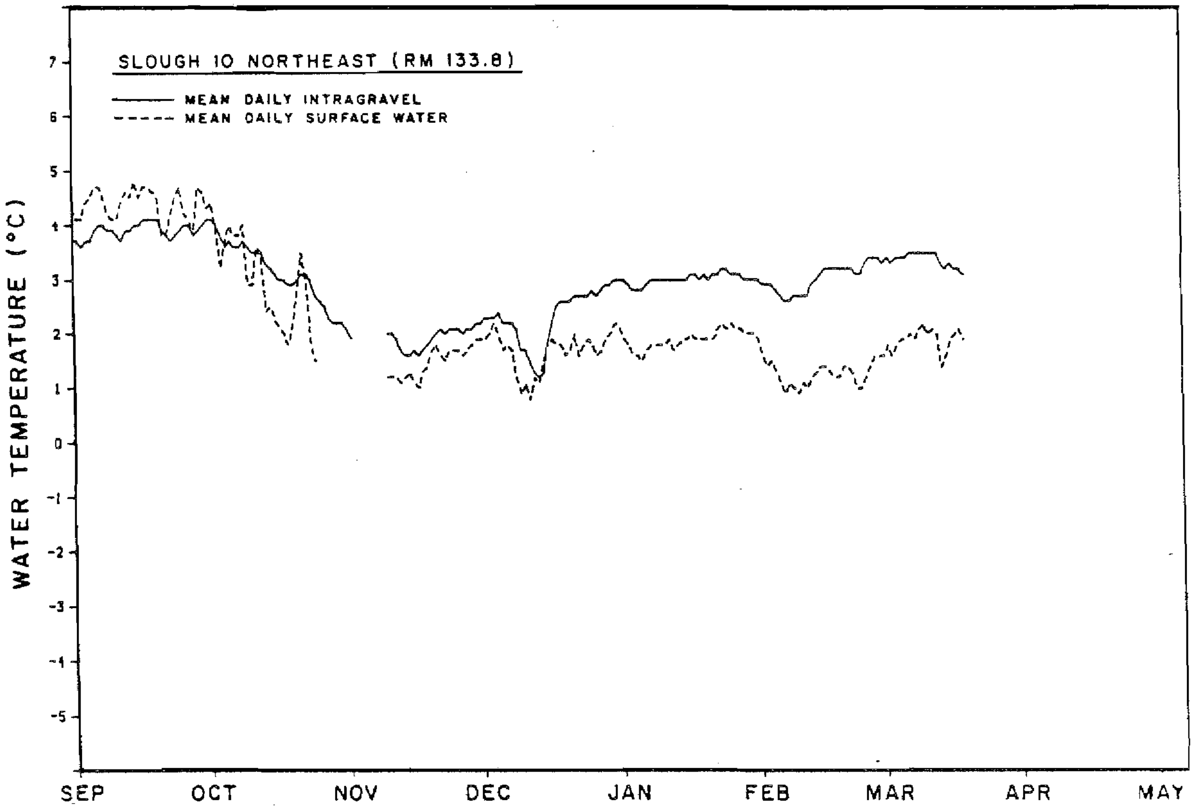


Figure 20. Mean daily intragravel and surface water temperatures (°C) recorded at Slough 10 Northease (RM 113.8) during the ice-covered season, 1984-85.

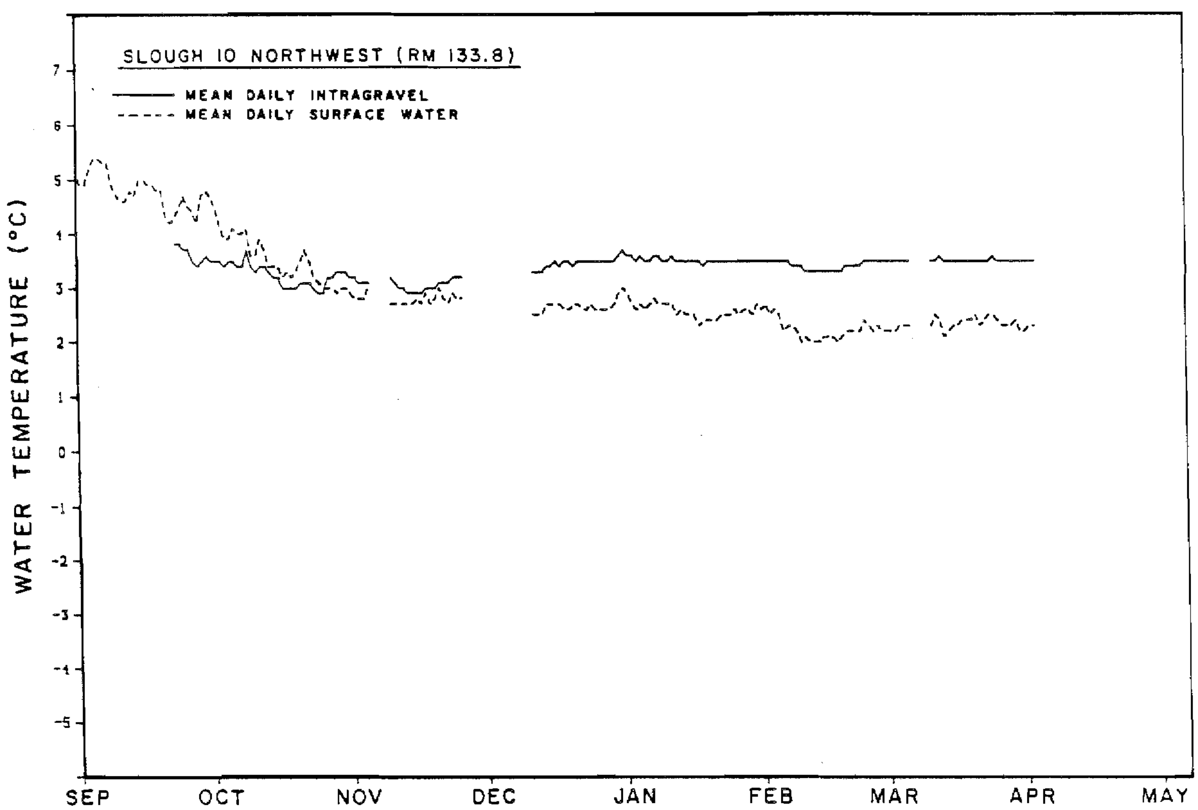


Figure 21. Mean daily intragravel and surface water temperatures (°C) recorded at Slough 10 Northwest (RM 133.8) during the ice-covered season, 1984-85.

A summary of the computed indices of substrate quality for Bushrod Slough is presented in Table 3. For the total sample, Bushrod Slough had a fredle index of about 12.07 with 11.8% of the sample finer than 1.0 mm. The upper eight inches of the samples have a fredle index of about 15.16 with 13.0% finer than 1.0 mm. The lower eight inches of the samples has a fredle index of about 11.13 with 14.8% finer than 1.0 mm. These results indicate that the substrate in Bushrod Slough is of good quality for salmon spawning. However, substrate quality could be improved by removing fines which accumulate in the lower eight inches of the streambed.

Numerous problems were associated with the collection of freeze core samples at Curry Slough. As a result, only two samples were obtained, one each at opposite ends of the main pool. The size composition of the majority of the substrate obtained was between 2.0 mm and 127 mm. The furthest upstream site contained a greater percentage of fine material less than 0.5 mm (Appendix Table F-1). The affect of the fines can be seen in the lower intragravel dissolved oxygen readings at standpipes in this area.

Due to the limited number of samples obtained at Curry Slough no analysis of substrate by depth was conducted. Table 4 summarizes the computed quality indices for Curry Slough. The fredle index is about 7.16 with 17.1% finer than 1.0 mm. These numbers indicate that the quality of spawning substrate is not as good as is found in other sites, such as Bushrod Slough, due to a higher percentage of fines.

In Slough 10, substrate composition shows a preponderance of unsuitable spawning substrate at those sites which were sampled (Appendix Table F-1). The majority of substrate samples collected are less than 0.5 mm in diameter. An exception is sample five, taken in the area where salmon currently spawn. This sample contained very few fines with 78% of the total sample being greater than 127 mm, largely cobble and boulder.

The overall substrate analysis of Slough 10 results in a fredle index of about 18.46 indicating good spawning substrate (Table 5). This index is somewhat misleading because only one sample from the presently used spawning area, contains suitable spawning substrate (Appendix Table F-1). This sample appears to have strongly influenced the fredle index. The large percent of fines less than 1.0 mm in size (78.6%) recorded at this site should result in a smaller fredle index reflecting the apparent poor quality of the spawning substrate. The relatively large geometric mean (27.61) and small sorting coefficient (2.46) appear to be the modifying measurements resulting in the larger fredle index. These two numbers indicate that the sample has large pore spaces that are not completely filled with fines, allowing for intragravel flow and movement of alevins. When the freeze core is divided into two subsamples, this same result is evident, especially in the upper eight inch subsample. The analysis subdividing the freeze core samples in Slough 10, illustrates a decrease in substrate quality with depth. The upper eight inch subsample has a fredle index of about 26.52 with 78.9% finer than 1.0 mm. The lower eight inch subsample has a fredle index of about 0.61

Table 3. Summary of computed substrate quality indices at Bushrod Slough (RM 117.9L)

	Mean	Standard Error of Mean	Sample Size
Total Sample			
Total Sample Weight (g)	1438.94	291.48	5
Geometric Mean Particle Size (mm)	25.56	6.81	5
Sorting Coefficient	2.62	0.40	5
Fredle Index	12.07	4.36	5
Percent Finer Than 1.0 mm	11.77	3.26	5
Upper 8" Subsample			
Total Sample Weight	804.38	179.32	5
Geometric Mean	31.28	10.23	5
Sorting Coefficient	3.20	1.04	5
Fredle Index	15.16	5.28	5
Percent Finer Than 1.0 mm	13.02	6.17	5
Lower 8" Subsample			
Total Sample Weight	634.56	158.36	5
Geometric Mean	21.86	7.98	5
Sorting Coefficient	3.30	1.24	5
Fredle Index	11.13	4.98	5
Percent Finer Than 1.0 mm	14.78	7.50	5

Table 4. Summary of computed substrate quality indices at Curry Slough (RM 119.7R)

	Mean	Standard Error of Mean	Sample Size
Total Sample			
Total Sample Weight	1216.45	711.65	2
Geometric Mean	19.27	7.75	2
Sorting Coefficient	3.90	1.70	2
Fredle Index	7.16	5.11	2
Percent Finer Than 1.0 mm	17.06	6.70	2

Table 5. Summary of computed substrate quality indices at Slough 10 (RM 133.8L).

	Mean	Standard Error of Mean	Sample Size
Total Sample			
Total Sample Weight	212.92	160.67	5
Geometric Mean	27.61	27.46	5
Sorting Coefficient	2.46	0.33	5
Fredle Index	18.46	18.41	5
Percent Finer Than 1.0 mm	78.56	18.92	5
Upper 8" Subsample			
Total Sample Weight	186.34	145.77	5
Geometric Mean	36.91	36.75	5
Sorting Coefficient	2.35	0.35	5
Fredle Index	26.52	26.45	5
Percent Finer Than 1.0 mm	78.98	19.41	5
Lower 8" Subsample			
Total Sample Weight	26.58	14.98	5
Geometric Mean	2.14	2.00	5
Sorting Coefficient	3.28	0.30	5
Fredle Index	0.61	0.56	5
Percent Finer Than 1.0 mm	77.34	15.70	5

with 77.3% finer than 1.0 mm. One of the primary reasons for such a difference in the fredle index between the two samples is the large difference in geometric means; 36.91 for the upper eight inches as compared to 2.14 for the lower eight inches.

3.2.1.3 Upwelling and Bank Seepage

Areas of upwelling and bank seepage are recorded on individual site maps for Bushrod Slough, Curry Slough, and Slough 10 in Appendix A (Appendix Figures A-31, A-35 and A-74, respectively). Upwelling and bank seepage are also discussed in the individual site description narratives in Appendix A.

The lower pool in Bushrod Slough, where the majority of salmon spawning occurred, had visible bank seepage occurring along the left bank during the open-water season. Due to the clean gravel and clear deep water no other upwelling was visible in this pool. This bank seepage ceased to flow with the onset of winter. Most of the spawning occurred along the right bank. In addition, an open lead occurred along this bank indicating that upwelling continued at this site during the winter.

The upper pool of Bushrod Slough, which supported no spawning, had only limited bank seepage along the right bank during the open-water season which appeared to be related to mainstem flows. As the mainstem discharges dropped in the fall, this seepage slowed and then stopped. Consequently, the upper pool dewatered completely and the substrate froze. No open leads were observed in this section of the slough.

Curry Slough primarily consists of two pools separated by a riffle. The water level in the lower pool appears to be related to mainstem flows, creating a backwater at higher discharges. As the mainstem dropped in the fall, this pool dewatered and froze. No upwelling or bank seepage was observed in this pool during the open-water or ice-covered season. The upper pool has limited upwelling and bank seepage in the lower half, during the open-water season, which was not readily apparent during the winter. The upper half of the pool, as well as the riffle separating the head of the pool and the berm at the head, contains the majority of the upwelling and bank seepage. Both upwelling and bank seepage in this area are strong and constant throughout the winter. An open lead was present throughout this area except during the extreme cold experienced in February. Bank seepage in other areas of the slough appears to be intermittent and more dependent on surface runoff than true groundwater.

Upwelling and bank seepage were present throughout Slough 10 during the entire year. The upwelling provides a stable incubation environment as well as keeping the slough ice free. This slough appears to have one of the stronger and more continuous upwellings found in the middle reach of the Susitna River.

3.2.2 Chemical Characteristics

3.2.2.1 Dissolved Oxygen

Comparisons of dissolved oxygen concentrations (mg/l) measured in surface and intragravel water in standpipes in Bushrod Slough, Curry

Slough, and Slough 10 are presented in Figure 22. Similar plots for percent oxygen saturation can be found in Figure 23. The raw data used to construct these plots is presented in Appendix Table E-1. The relationship between surface and intragravel dissolved oxygen levels, indicating an influence of intragravel water and surface water, appears to be strongest in Bushrod Slough and weakest in Slough 10. A weaker relationship (i.e., wider scatter of points) appears at Curry Slough and Slough 10 at low and intermediate measurements than at higher measurements. Median dissolved oxygen values for both surface and intragravel water are lowest in Slough 10 (Figures 24 through 27). Bushrod Slough has the highest median intragravel dissolved oxygen concentration, while Curry Slough has the highest median surface dissolved oxygen concentration. However, due to the dewatering and freezing which occurred in the lower section of Curry Slough the accuracy of the intragravel water measurements from the first three standpipes are suspect. There is a strong probability that surface water influenced the dissolved oxygen measurements in this section of Curry Slough.

3.2.2.2 pH

Comparison of pH levels measured in surface and intragravel waters in Bushrod Slough, Curry Slough, and Slough 10 are presented in Figure 28. Because of sampling problems, the number of pH measurements at Bushrod and Curry Sloughs is approximately half the number obtained at Slough 10. The figures show that there is a relationship, indicating an influence of intragravel water and surface water, between pH values measured in surface and intragravel waters. The relationship appears strongest in Slough 10 and weakest in Curry Slough. Slough 10 has the highest median pH readings for both surface and intragravel water and Curry Slough the lowest (Figure 29 and 30).

3.2.2.3 Conductivity

Scatter plots of the conductivity levels (umhos/cm) in surface and intragravel water in Bushrod Slough, Curry Slough, and Slough 10 are presented in Figure 31. The relationship between surface and intragravel conductivity levels, indicating an influence of intragravel water and surface water, appears strongest (i.e., closer scatter of points) in Bushrod Slough and Slough 10, and weakest (i.e., wider scatter of points) at Curry Slough. In both surface and intragravel waters, Slough 10 has the highest median conductivity value and Curry Slough the lowest (Figure 32 and 33).

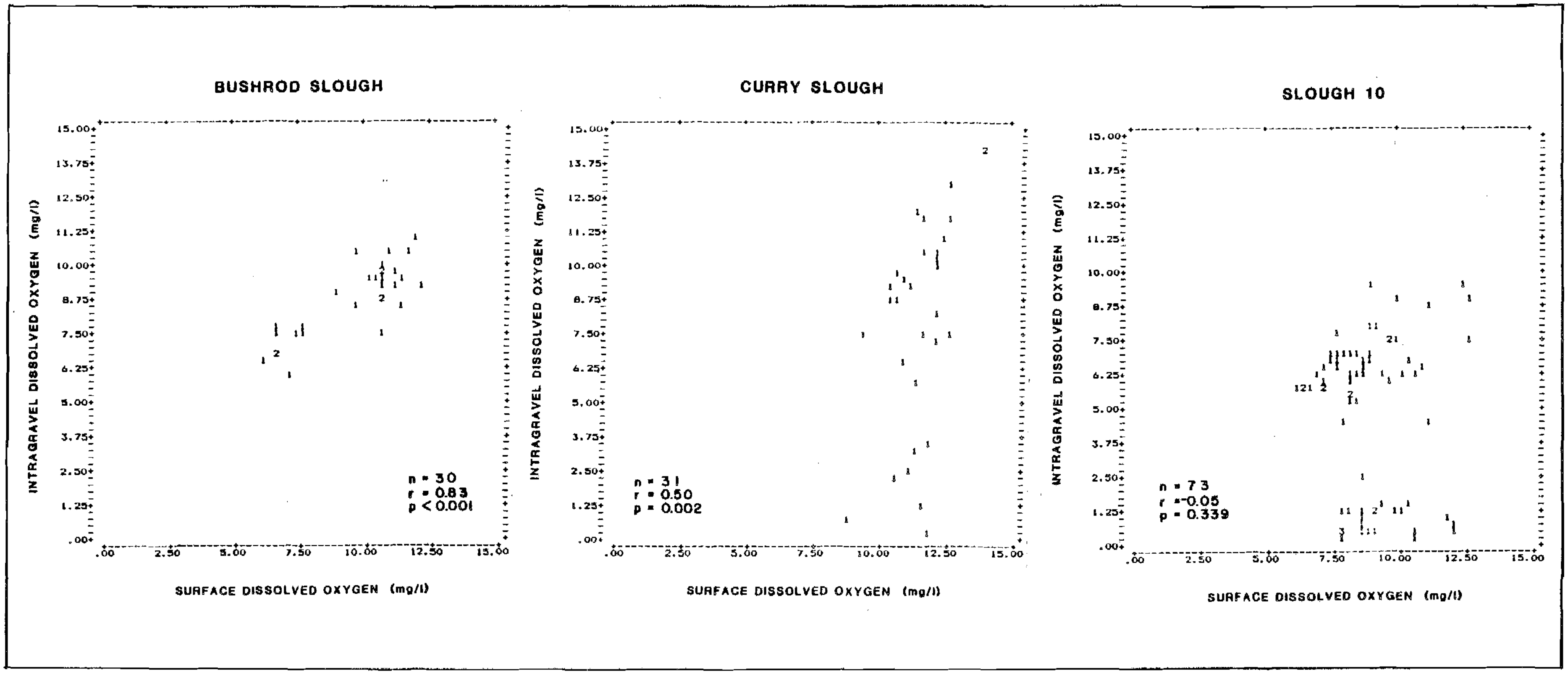


Figure 22. A comparison of surface and intragravel dissolved oxygen concentration (mg/l) data measured at standpipes in Bushrod Slough, Curry Slough, and Slough 10 during the ice-covered season, 1984-85.

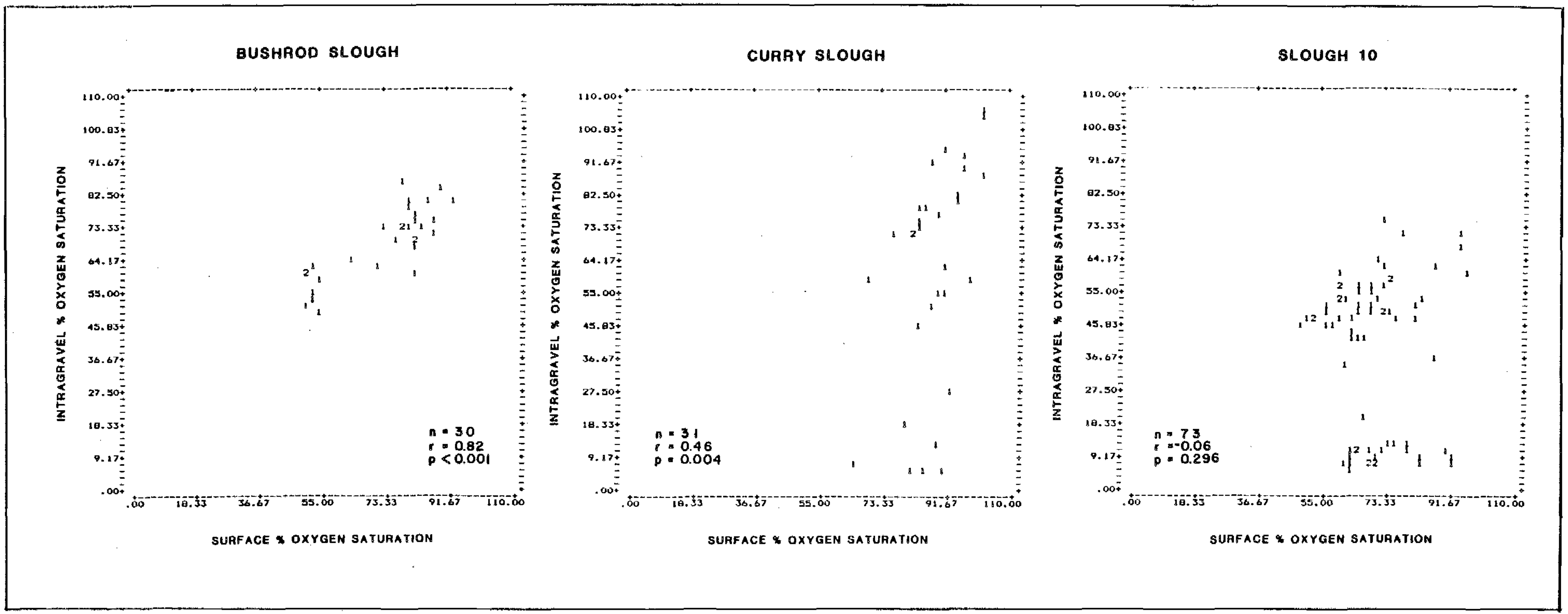


Figure 23. A comparison of surface and intragravel percent oxygen saturation data measured at standpipes in Bushrod Slough, Curry Slough, and Slough 10 during the ice-covered season, 1984-85.

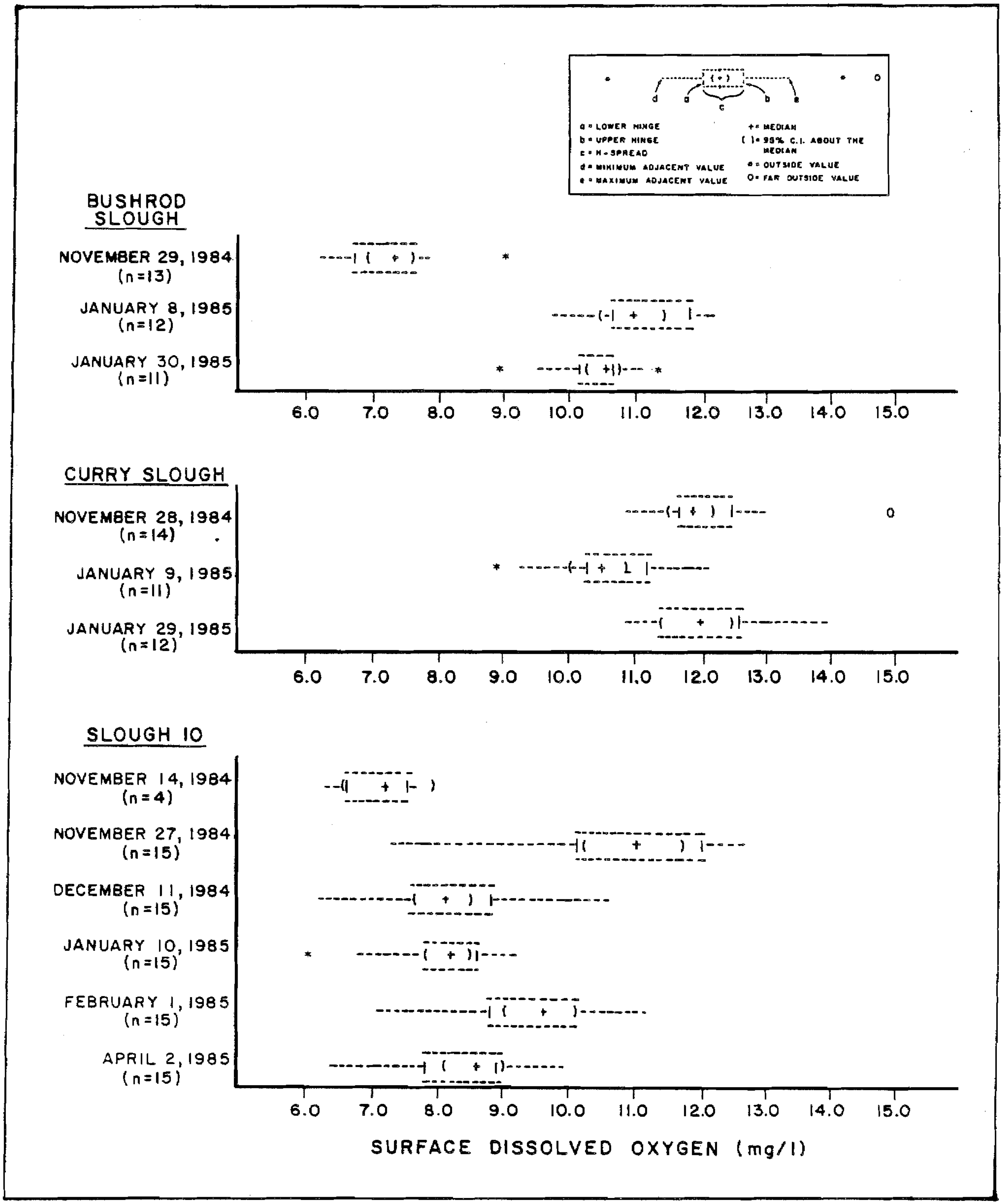


Figure 24. Summary of surface water dissolved oxygen data (mg/l) measured at standpipes in the middle reach of the Susitna River, by study site and sampling period, ice-covered season 1984-85.

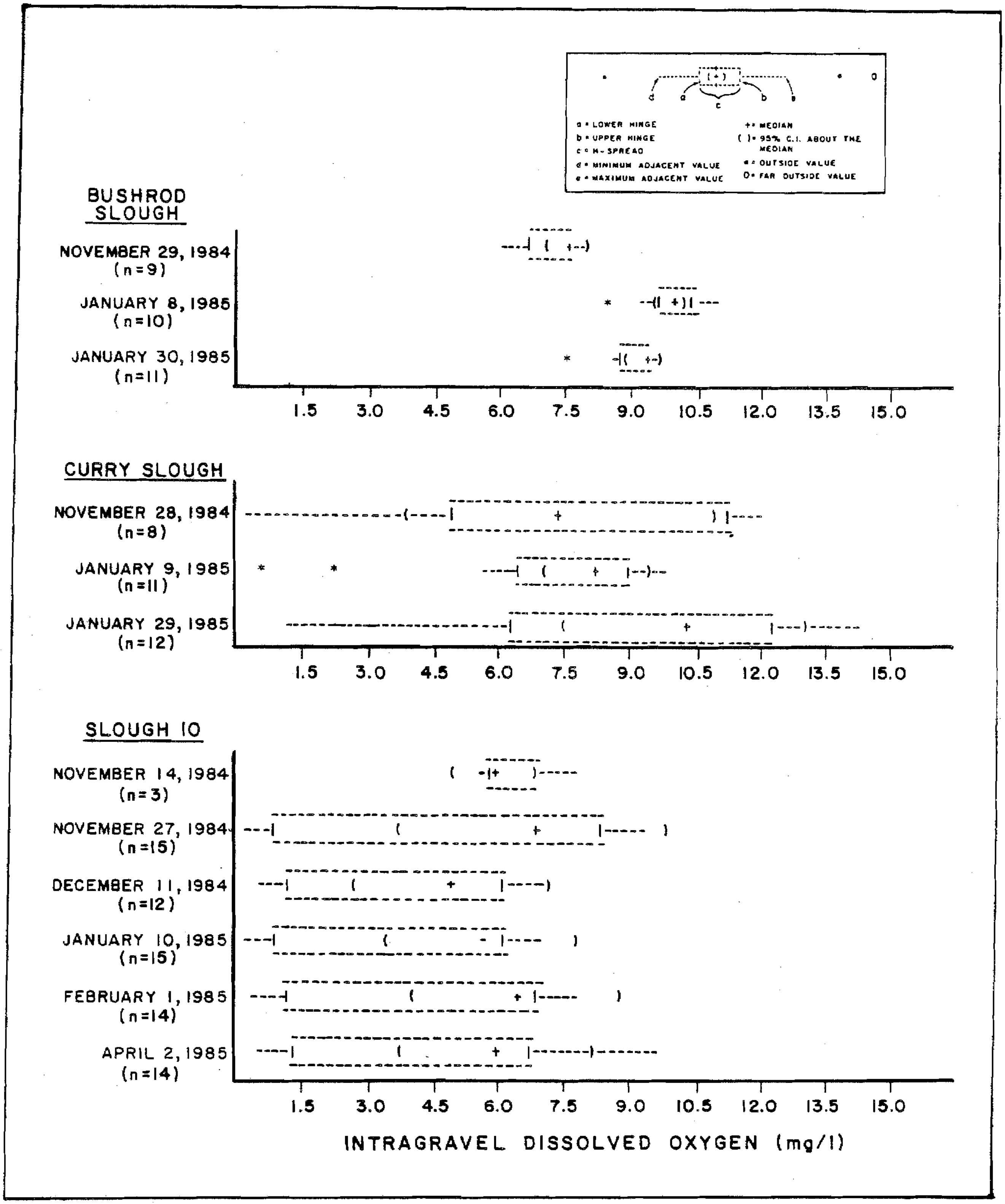


Figure 25. Summary of intragravel water dissolved oxygen data (mg/l) measured at standpipes in the middle reach of the Susitna River, by study site and sampling period, ice-covered season 1984-85.

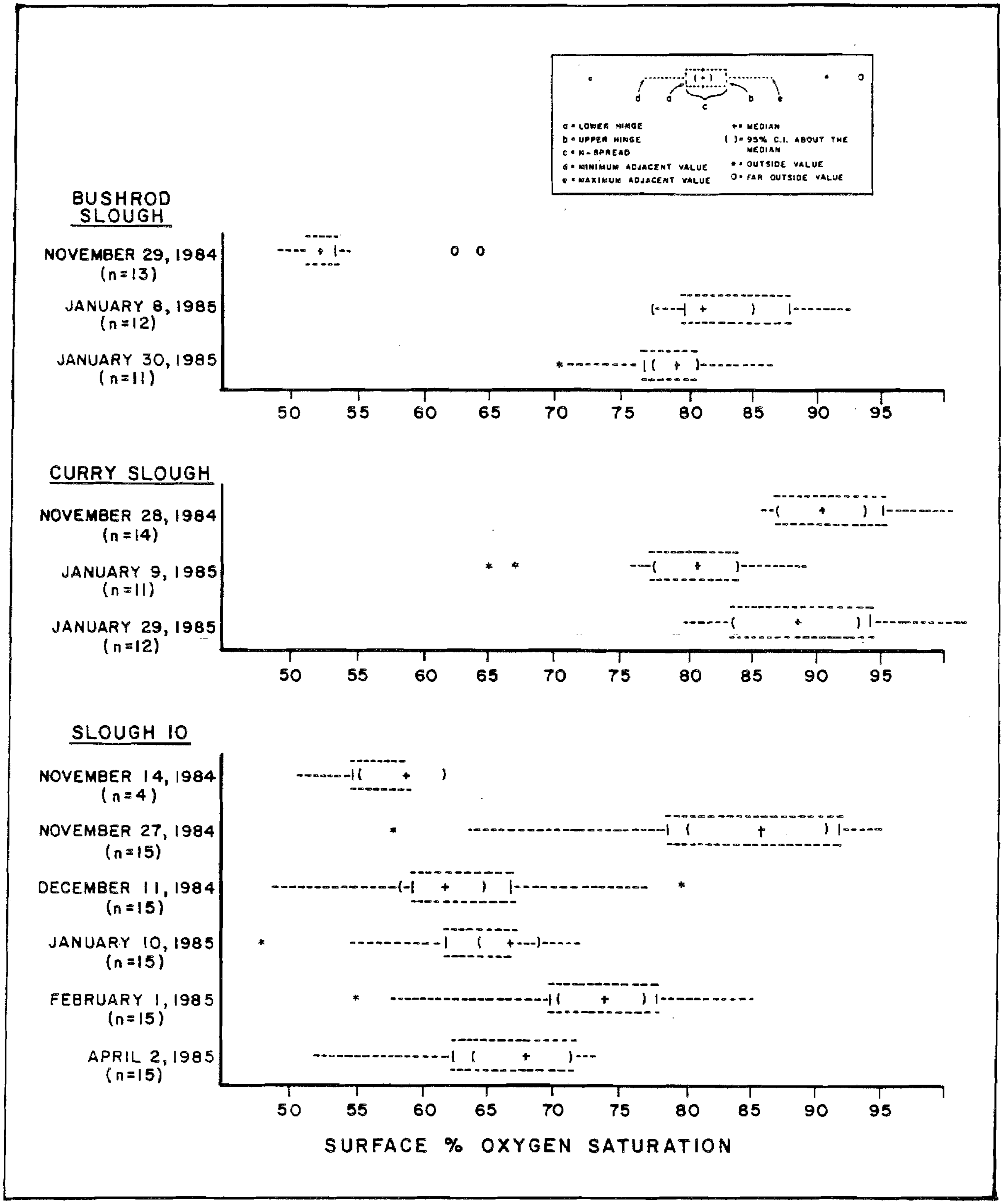


Figure 26. Summary of surface water percent oxygen saturation data measured at standpipes in the middle reach of the Susitna River, by study site and sampling period, ice-covered season 1984-85.

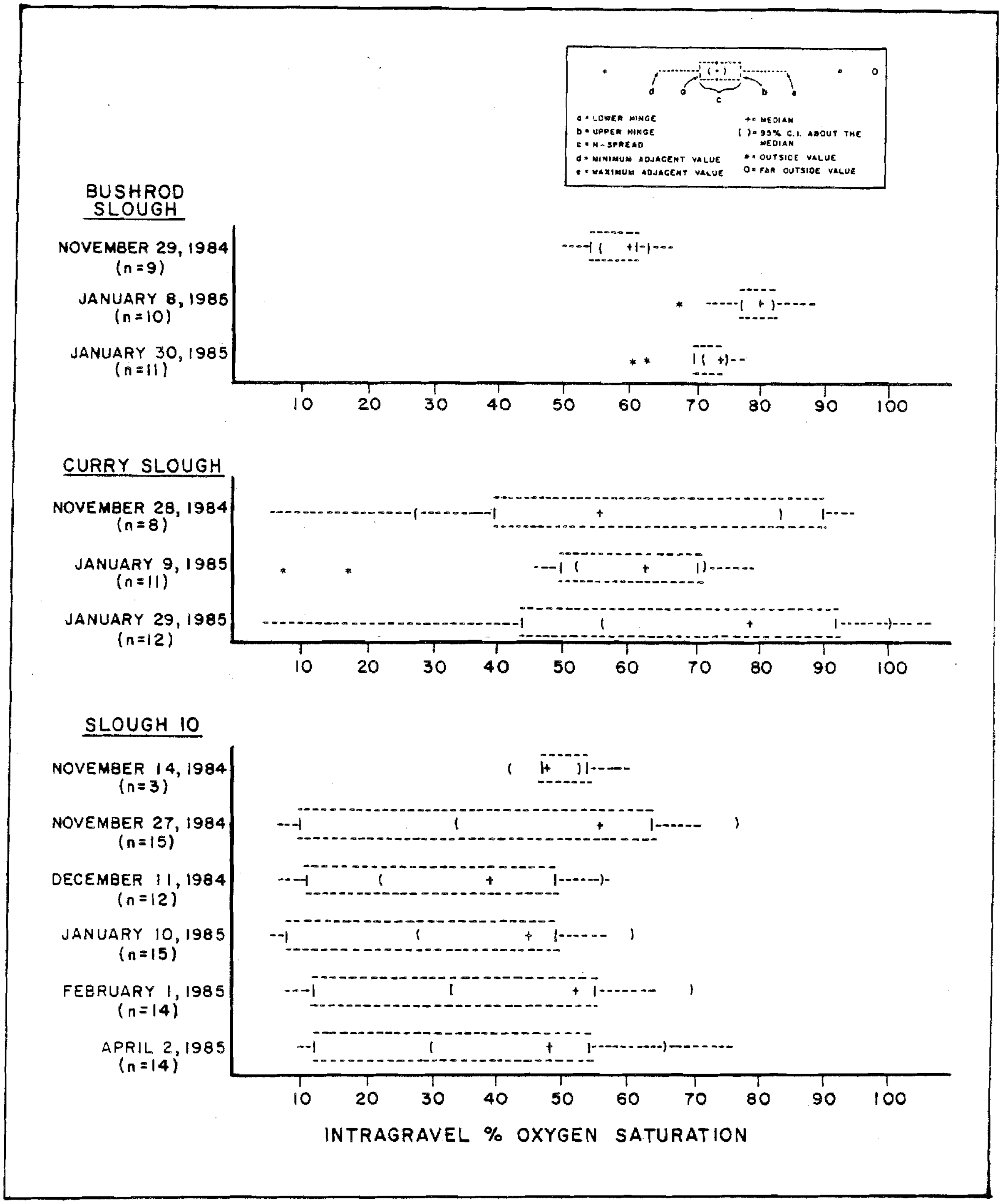


Figure 27. Summary of intragravel water percent oxygen saturation data measured at standpipes in the middle reach of the Susitna River, by study site and sampling period, ice-covered season 1984-85.

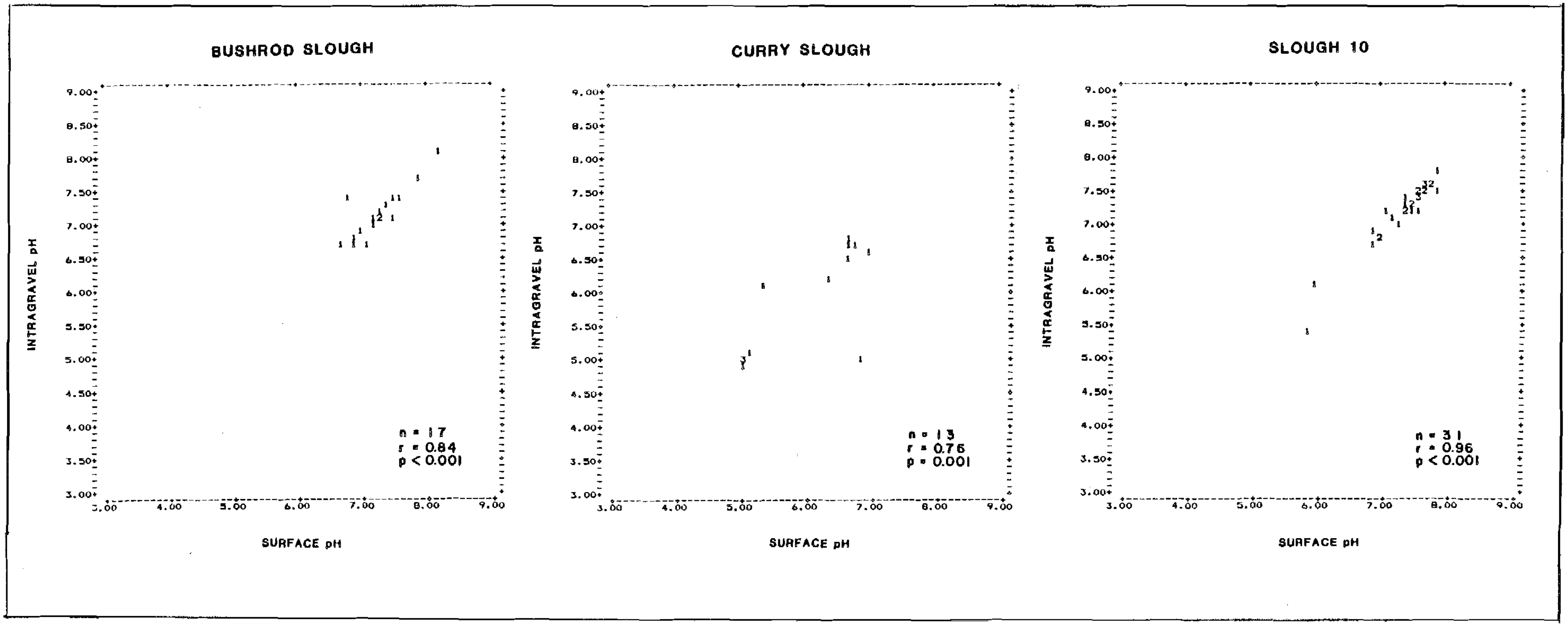


Figure 28. A comparison of surface and intragravel pH data measured at standpipes in Bushrod Slough, Curry Slough, and Slough 10 during the ice-covered season, 1984-85.

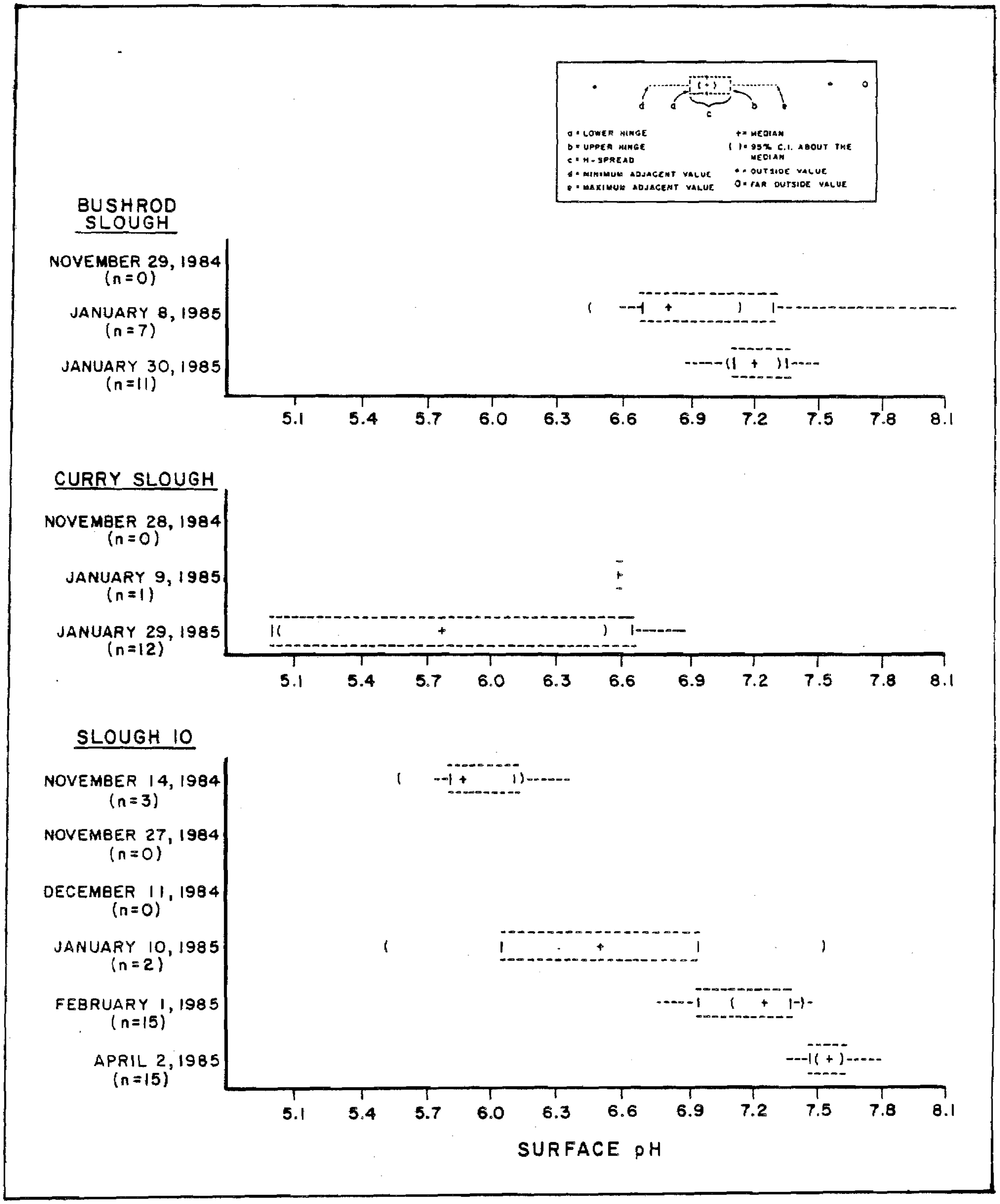


Figure 29. Summary of surface water pH data measured at standpipes in the middle reach of the Susitna River, by study site and sampling period, ice-covered season 1984-85.

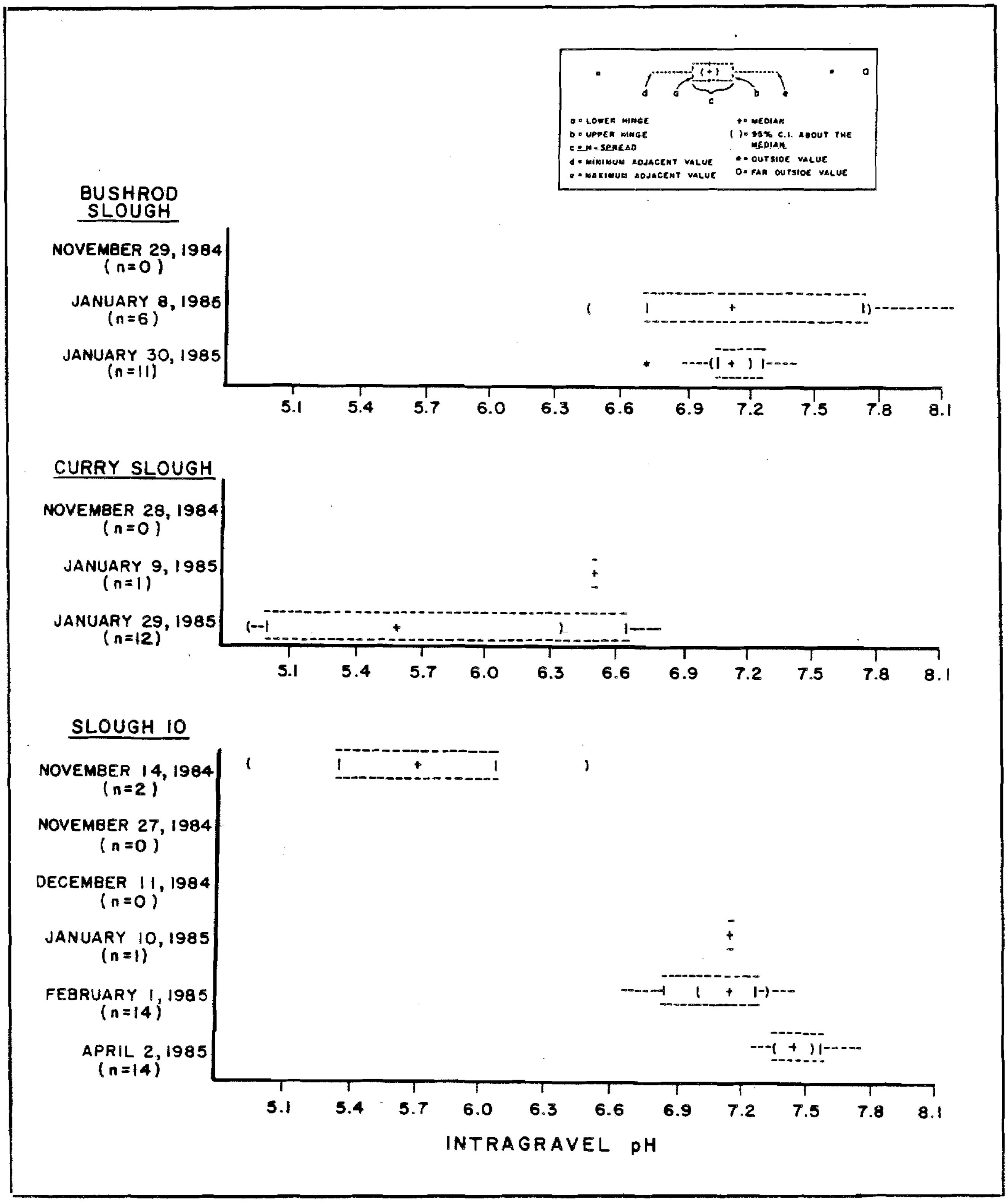


Figure 30. Summary of intragravel water pH data measured at standpipes in the middle reach of the Susitna River, by study site and sampling period, ice-covered season 1984-85.

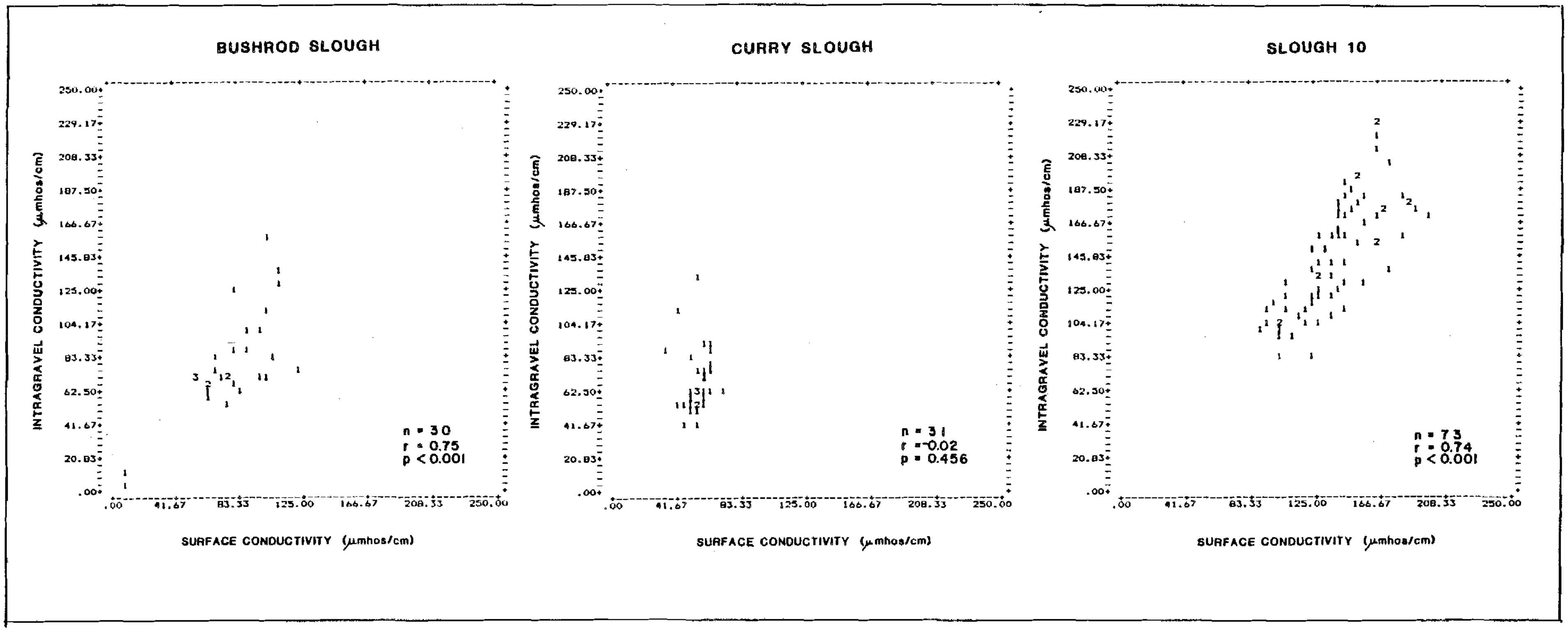


Figure 31. A comparison of surface and intragravel conductivity (umhos/cm) data measured at standpipes in Bushrod Slough, Curry Slough, and Slough 10 during the ice-covered season, 1984-85.

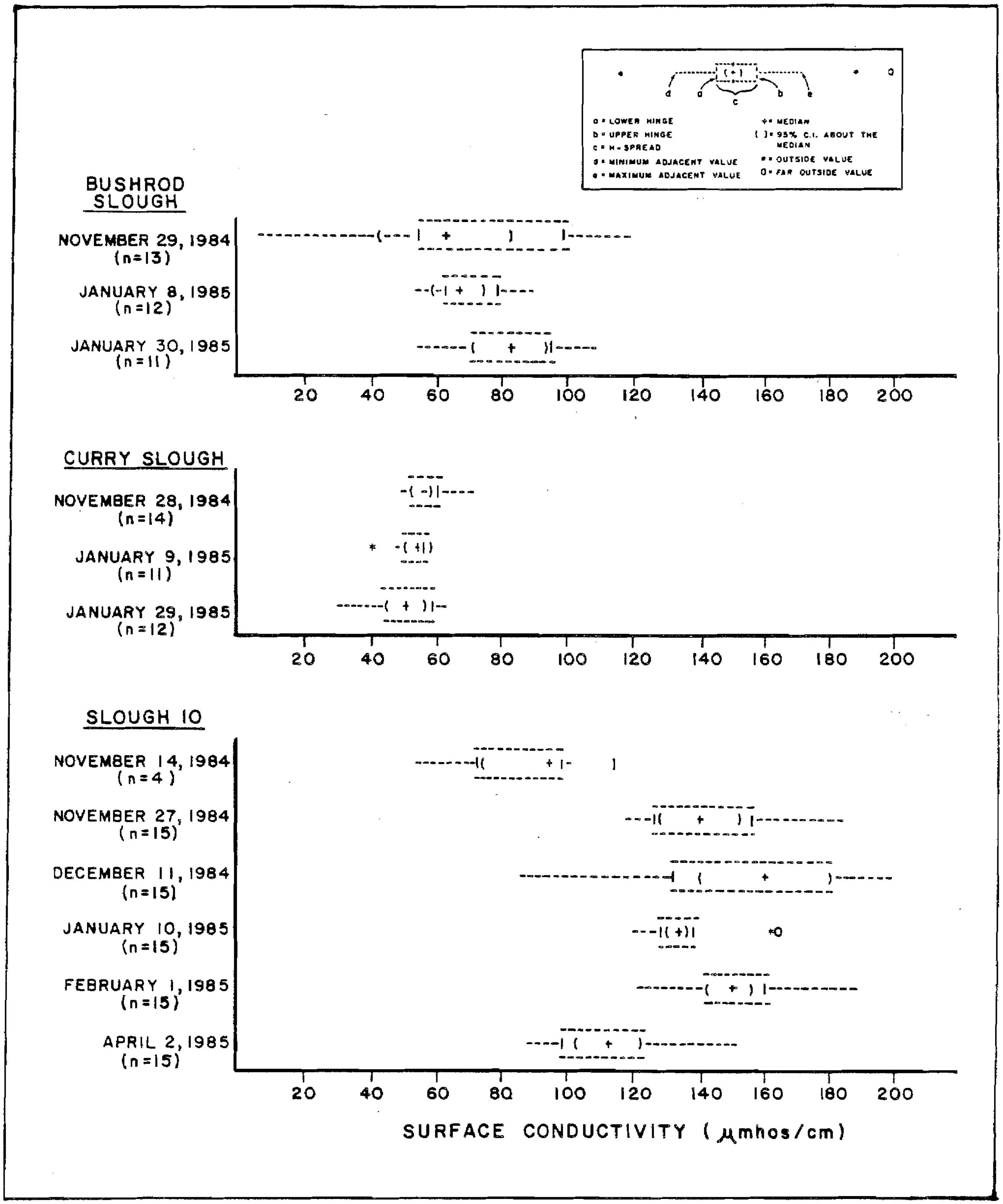


Figure 32. Summary of surface water conductivity data (umhos/cm) measured at standpipes in the middle reach of the Susitna River, by study site and sampling period, ice-covered season 1984-85.

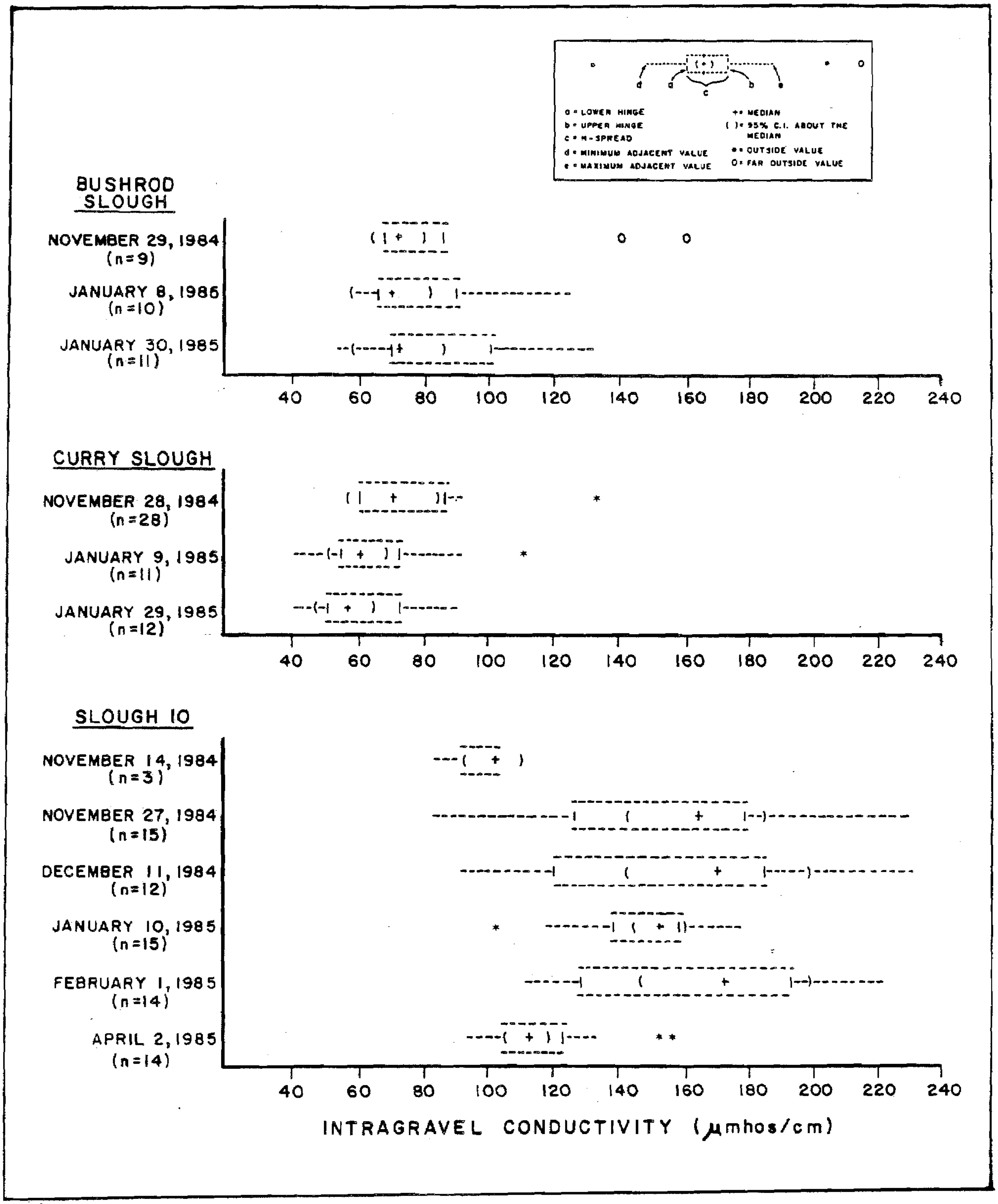


Figure 33. Summary of intragravel water conductivity data (umhos/cm) measured at standpipes in the middle reach of the Susitna River, by study site and sampling period, ice-covered season 1984-85.

4.0 DISCUSSION

4.1 General Evaluations of Potential Mitigation Sites at Side Slough, Upland Slough, and Side Channel Habitats

A discussion of the various potential mitigation sites evaluated during this study is presented in the following sections by habitat type. This discussion focuses on identifying the habitat types most suitable for providing improved salmon spawning habitat by physically modifying the habitat. However, a great degree of variability exists in the physical and biological characteristics between potential mitigation sites within a particular habitat type, making it difficult to identify a specific habitat type as being most suitable for mitigation purposes. While this discussion attempts to identify which habitat types generally appear to be most suitable for mitigation purposes, it should be noted that exceptions occur within each habitat category.

Because of the variables involved in evaluating potential mitigation sites, the suitability of individual sites cannot be ranked based on the available data. Recommendations for specific sites which generally appear to be most suitable for mitigation are presented in this discussion. However, the selection of these sites was based on field observations and limited data, therefore a more detailed evaluation should be conducted to determine if these sites are the most practical sites for mitigation purposes. This determination should include a detailed evaluation of the selected mitigation technique, logistics, physical and biological characteristics of the site as they relate to the salmon species of interest, and a cost/benefit analysis. This study only evaluates the mitigation potential of sites under current habitat conditions and any changes to the habitat that may take place in the future as a result of construction and operation of the proposed hydroelectric project may necessitate a reevaluation of these sites. Further analysis and mitigation planning will be conducted by the primary mitigation contractor (ENTRIX, Inc.).

4.1.1 Side Channel Habitats

In general, side channel habitats exhibit one or more of the following limiting factors: 1) substrates are generally large and well cemented with only limited areas suitable for spawning; 2) upwelling and bank seepage is limited and frequently intermittent, ceasing completely during the ice-covered season; 3) passage into and within the site is a problem in the 9,000 to 12,000 cfs range; 4) sites frequently dewater and freeze in the winter; and 5) frequent overtopping occurs during the winter as the river stages. Due to the numerous limiting factors associated with side channel habitats, it is felt that under current conditions slough habitats provide a more viable option as salmon spawning mitigation sites.

4.1.2 Upland Slough Habitats

Upland slough habitats are located in protected channels that do not overtop either during the open-water or ice-covered periods. The primary limiting factors affecting upland sloughs in regard to mitigation sites are: 1) passage restrictions at the 9,000 to 12,000 cfs range; 2) the presence of thick deposits of silt (unsuitable for salmon spawning) due to the lack of flushing flows; 3) lack of strong continuous upwelling (with the exception of Sloughs 9B, 10, and 17); and 4) extensive beaver activity resulting in passage restrictions due to beaver dams. Although internal passage problems exist in the 9,000 to 12,000 cfs range, passage problems are primarily expected to occur at the mouth of the upland sloughs. The mouths of upland sloughs generally have a silt/sand bar which would restrict passage at lower discharges. Upland sloughs generally act as large backwater areas which eliminates passage problems while at the same time creating substrate problems.

Due to the lack of flow and the backwater effects which occur in upland sloughs, suspended sediments are able to settle out creating thick deposits of silt and sand. The thick silt deposits affect spawning in two ways: 1) by not providing suitable spawning substrate and 2) affecting incubation conditions within the intragravel environment. Most of the upland sloughs examined lack the strong continuous upwelling that would be needed to provide a stable incubation environment. Where spawning occurred in areas of thick silt deposits, such as Slough 9B, strong upwelling was also present to stabilize the incubation environment.

Upland sloughs provide an ideal habitat for beaver colonies. Eighty-eight percent of the upland sloughs surveyed have beaver activity. The primary affect of the beaver activity upon adult salmon is limiting passage to spawning areas by construction of dams.

Of the sixteen upland sloughs surveyed, seven should be considered for further study as mitigation sites (Sloughs 3A, Curry, 8D, 9B, 10, 17, and 19). While each of these sites exhibit one or more of the primary limiting factors, the degree to which they occur is not as great as in other sites. Also, salmon spawning has occurred at each of these sites in at least one previous year. In general, the factors limiting spawning in these sites can be confined to passage and substrate, both of which can be overcome by mechanical habitat alteration. Beaver activity, which is a primary concern in Sloughs 9B, 10, and 17, can be overcome by removal of the beavers or a maintenance program of opening the dams during the spawning period. An additional problem unique to Slough 9B is that passage must be provided through Slough 9 in order for salmon to reach the mouth of Slough 9B.

4.1.3 Side Slough Habitats

Side slough habitats are the most numerous habitat type observed. Of the habitats looked at in this study, side sloughs support the greatest numbers of spawning salmon in the middle reach and appear to be best suited for habitat modification. The primary problems associated with side sloughs are: 1) restricted passage in the 9,000 to 12,000 cfs range; 2) poor substrate conditions; and 3) winter overtopping in some sites. These limiting factors can readily be corrected through mechanical habitat alteration techniques.

Of the 23 side sloughs studied, 12 sites, all presently supporting spawning salmon populations, should be considered for further study as mitigation sites. These sites are Whiskers Slough, Slough 8, Bushrod Slough, and Sloughs 8B, 8A, 9, 9A, 11, 16B, 20, 21, and 22. Sloughs 8A, 9, 11, and 21 have already been addressed in the Fish Mitigation Plan (Moulton et al. 1984). Habitat modifications in the other sites can be readily accomplished to provide increased spawning or, as in the case of Slough 16B, to provide increased spawning and a suitable habitat which would attract spawners annually and allow successful development of their eggs and fry.

4.2 Opening of Beaver Dams to Improve Fish Passage Conditions

Fish passage restrictions, particularly due to beaver dams, occur in upland and side slough habitats in the middle reach of the Susitna River. Possible mitigation options would be to either: 1) remove the beavers and their dams completely; or 2) have a maintenance project to open dams during the spawning season; or 3) upgrade the habitat below the dams.

Beaver dams were periodically opened at selected slough sites during the salmon spawning period to observe whether salmon would utilize previously inaccessible spawning habitat. In all cases except one, fish readily migrated through the dams and utilized spawning habitat above the dams. The one exception was Slough 4, a site previously unutilized by salmon. Spawning salmon were not observed in this site after removal of the dam. Further habitat modification may be necessary to make this site suitable for spawning. Although incubation conditions were not monitored at these sites, it was assumed that spawning would be successful based on previous spawning survey data from these areas (ADF&G 1981, ADF&G 1983a; Barrett et al. 1984). Based on limited data, it appears as if opening or removing dams and removing beavers would be a viable option for providing additional spawning habitat. Of the three options, the most practical appears to be periodically removing the beavers and their dams. Without removing the beavers, it is a somewhat futile effort to attempt to keep dams open to provide passage, since the dams would be rebuilt overnight. When considering mitigation alternatives, this option could be considered in order to increase spawning areas in Sloughs 9 and 9B. Upgrading spawning habitat downstream of the dams may be possible although it may be more expensive and short lived if the beavers extend their range downstream in a site.

4.3 Identification of Habitat Modification Techniques at Selected Slough Sites

The primary purpose of the ice covered studies was to further examine selected sites to identify possible habitat modifications to improve salmon spawning and incubation habitat. The ice-covered studies examined three sites (two upland sloughs and one side slough) that appeared to have high potential as successful mitigation sites. The three sites (Bushrod Slough, Curry Slough, and Slough 10) were selected based on the results of the open-water surveys. These sites are generally representative of each habitat type and exhibit problems limiting salmon spawning that can be found in all habitat types studied.

One of the primary requirements for successful development and survival of salmon embryos is the presence of a suitable incubation environment. Incubating salmon embryos require a constant supply of water which is of suitable temperature, containing sufficient dissolved oxygen, and free of toxic substances. The rate of flow and quality of intragravel water is influenced by the substrate composition. Therefore, the successful development and survival of salmon embryos is directly related to both the physical and chemical characteristics influencing the intragravel water surrounding the developing embryos. The significance of the various parameters on embryo development in the middle Susitna River has been presented in detail in Vining et al. (1985). The incubation habitat should be examined both prior to and after any habitat modification projects designed to improve spawning. This will not only provide additional baseline data on which to make more accurate management decisions, but will also provide a measure of success of the habitat modification techniques by comparing incubation conditions before and after alteration of the habitat.

4.3.1 Bushrod Slough

This site was selected for detailed study because, in the proposed range of project discharges, it exhibits problems that may be expected to occur in other side slough habitats. Initial surveys of this slough indicated generally favorable conditions for salmon spawning and incubation throughout the site even though pink and chum salmon have only been observed spawning at this site during 1984, and then only in the lower pool. The primary problem in Bushrod Slough appears to be two passage reaches located at the mouth and mid-slough. The passage reach at the mouth presents a problem only at flows less than 12,000 cfs. The mid-slough passage reach is unpassable at all discharges below the breaching discharges. Secondary problems in the upper pool are dewatering and limited bank seepage and upwelling.

Bushrod Slough consists of two pools separated by a riffle within well defined banks. The physical size of the pools as well as both surface and intragravel water quality and substrate composition is almost identical in the two pools. The substrate in the upper pool exhibits a slightly higher percentage of fines less than 0.84 mm which appear to be slightly more cemented than the lower pool. Because of such close similarities in the data between the two pools, it was felt that passage or upwelling must be the factors limiting spawning to the lower pool.

It was observed that, during breaching conditions, when passage was possible through the mid-slough riffle, chum salmon did not migrate to the upper pool to spawn. This indicates that although passage is a factor limiting spawning at lower flows, another factor such as limited upwelling may be the controlling factor which limits spawning in the lower pool. The upwelling in the lower pool remained constant throughout the year whereas only limited bank seepage was observed in the upper pool. This seepage in the upper pool occurred along the right bank and appears to be related to mainstem discharge. As the mainstem discharge dropped in the fall, the bank seepage in the upper pool ceased. This pool eventually dewatered completely and froze prior to the river staging. Once the river staged, water was again present throughout the winter but the substrate remained frozen except for the top six inches.

4.3.2 Curry Slough

Curry Slough is a former side channel/side slough of the Susitna River at which a ten foot high berm was built across the head of the site by the Alaska Railroad. This was done to prevent breaching of the site and subsequent erosion of the railroad tracks which run along the right bank of the slough. As a result, there are no breaching discharges to flush accumulated sediments from the site. Backwater effects at high mainstem discharges continually add to the silt accumulation. Chum salmon spawning was first reported at this site during 1984 when a total of eight chum salmon were observed.

This site was included in the detailed study for several reasons. It is indicative of sites having passage and substrate problems which limit spawning.

The lower half of the slough, which dewaters as the mainstem discharge decreases, is the primary area where passage problems occur in the site. This can possibly be overcome by mechanically creating a deeper channel to permit passage of salmon at low mainstem discharges.

The area of primary interest in Curry Slough is the upper two-thirds of the site, consisting of a long-deep pool and a riffle. Once fish negotiate the passage problems at the mouth, they encounter no further passage restrictions until they reach the riffle at the head. Water levels in the pool dropped during the winter but water quantity and quality were still suitable for embryo incubation (Appendix Table E-1). The source of water is constant upwelling and bank seepage that occurs in the riffle area located in the upper 300 feet of the slough. The upwelling supplies water of adequate temperature and quality to allow for successful incubation. When comparing water quality in the three areas of the slough, the riffle area (standpipe 11-15) has the most favorable measurements (Appendix Table E-1).

The main problem appears to be the existing substrate. It is either too large or too fine with thick silt deposits covering the entire slough.

Another potential problem is any undetermined adverse effects of the Alaska Railroad. During the winter, tons of snow are plowed off the railroad tracks into the slough. This may affect the water quality in the slough due to the debris and chemicals associated with the railroad that are mixed in the snow.

The problems which limit spawning in Curry Slough may be overcome by providing passage, relocating the channel away from the railroad tracks, replacing the substrate, and providing a berm at the lower end to maintain pool depth.

4.3.3 Slough 10

Slough 10 is an upland slough that was selected for detailed study because substrate appears to be the primary factor limiting spawning. There are no passage problems at this site except at the mouth at a discharge range less than the expected post project discharges. The lower half of this slough is a large backwater area with thick deposits of silt.

Substrate samples indicate that 78% of all substrates in Slough 10 are less than 1.0 mm. The accumulation of fines is generally uniform throughout the 16-inch sample depth. The fredle index analysis indicates that the lower eight inches is almost all silt. The fredle index is strongly influenced by the sample obtained in the present spawning area, and is therefore somewhat misleading at this site. At present there is only a limited area near the head of the northwest channel that is suitable for spawning. All chum salmon spawning observed in Slough 10 has occurred in this area. As a result, the fish that spawn later are spawning on top of earlier spawner's redds. Because of crowding of eggs in the redds, survival of incubating embryos may not be as good as it might be in an undisturbed redd (McNeil 1969). No spawning has ever been observed in the northeast channel where substrates are primarily silt, cobble, and boulder.

Intragravel water quality throughout the site is generally suitable for spawning. The effects of silt and decaying organic matter on water quality can be observed by comparing the average dissolved oxygen readings in the heavily silted areas (1.1 mg/l) with those with less silt accumulation such as the northeast channel (7.1 mg/l) or the northwest channel spawning area (6.6 mg/l). This clearly illustrates the deleterious effects of excessive silt and decaying organic matter on water quality. It is interesting to note while the northeast channel has higher average dissolved oxygen readings and comparable temperatures, no spawning occurs in this channel. This is most likely due to the substrate composition.

Water quality and temperature are maintained all year by strong and constant upwelling and bank seepage present throughout both channels in Slough 10. Due to the constant upwelling, this is one of the only sites that remains ice free except for periods of extreme cold. Because of the presence of upwelling throughout the slough, one would expect chum salmon to spawn everywhere. However, salmon only spawn in a limited area in Slough 10, which indicates that substrate may be a limiting factor in this case. Alevins were observed in the gravel at Slough 10 in January, earlier than other sites, which may be attributable to the continuous upwelling.

A potential problem in Slough 10, as in other upland sloughs, is the presence of beavers. Beaver activity has eliminated passage to spawning areas used during 1983.

4.4 Conclusions/Recommendations

Conclusions

Recommendations for specific sites which generally appear to be most suitable for mitigation are presented in the discussion. However, the selection of these sites was based on field observations and limited data, therefore a more detailed evaluation should be conducted to determine if these sites are the most practical sites for mitigation purposes. This study only evaluates the mitigation potential of sites under current habitat conditions and any changes to the habitat that may take place in the future as a result of construction and operation of the proposed hydroelectric project may necessitate a reevaluation of these sites.

1. Based on observed conditions in the anticipated minimum mainstem discharge range of 9,000 to 12,000 cfs, side slough habitats appear to present the best probability of success as mitigation sites, using habitat modification techniques, for chum and sockeye salmon in the middle Susitna River.

2. Based on these initial surveys it appears that the removal of fish passage restrictions at selected sites would be a successful mitigation alternative to improve chum and sockeye salmon spawning conditions.

3. Habitat modifications to correct substrate and upwelling limitations would only be applicable at a limited number of sites.

Recommendations

1. Small scale habitat alteration projects should be conducted to demonstrate feasibility of habitat alteration as a mitigation option in the Susitna River.

   For example, Bushrod Slough could be used to test the effects of removing fish passage restrictions, increasing upwelling, and placeing a protective berm at the head of a slough to prevent breaching.

   Curry Slough is a possible site for development of an experimental salmon spawning channel (Moulton et al. 1984). The berm at the head of this site should provide protection to habitat modifications made at this site. The close proximity of the Alaska Railroad tracks would provide good access to this site for equipment and supplies. Another mitigation option that might be considered at Curry Slough is the use of incubation boxes (Roberson and Holder 1983; Moulton et al. 1984) using the existing water system at Curry.

2. A study of incubation conditions should be included in any mitigation plan to insure the success of habitat modification for mitigation purposes.

3. Although chum and sockeye salmon were the primary species of interest in this study, other salmon species may be considered for mitigation purposes if conditions at a specific site appear more favorable to a particular species.

4. Other factors such as engineering, economics, and logistics were not included in this report but should be evaluated when considering other sites selected for habitat modifications.

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8.0 APPENDICES

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APPENDIX A

STUDY SITE DESCRIPTIONS AND SITE MAPS.

Slough 1 (RM 99.5R)

Slough 1 appears to be a remnant side channel functioning as an upland slough approximately 50 feet wide and 1,600 feet long. Under the observed range of discharges, the slough appears to be a long continuous turbid backwater with minimal flow. Beaver activity is prevalent throughout the slough, with a lodge present along the right bank near the mouth but no dams at present. At anticipated project discharges, the present sand bar at the mouth would not restrict fish passage.

The upper 100 to 200 feet of the slough divides into two clear water channels (Appendix Figure A-1). The large gravel - small gravel substrate in this area is covered by a layer of silt and organic debris. Due to the depth of the water and high turbidity, it was not possible to accurately determine substrate composition in the remainder of the slough. It is presumed, based on slough conditions, that the thick layer of silt and organic debris continues throughout this area. The banks are covered with a combination of grasses, shrubs and mixed deciduous-coniferous trees with a ridge paralleling the right bank of the slough. The left bank is low and marshy, and is dissected by canals as a result of beaver activity. No upwelling or bank seepage was observed throughout this site.

In late August, 1984, 24 chum salmon and two sockeye salmon were observed in the upper end of the slough, (Appendix Figure A-2) with some chum salmon spawning being observed at this time.

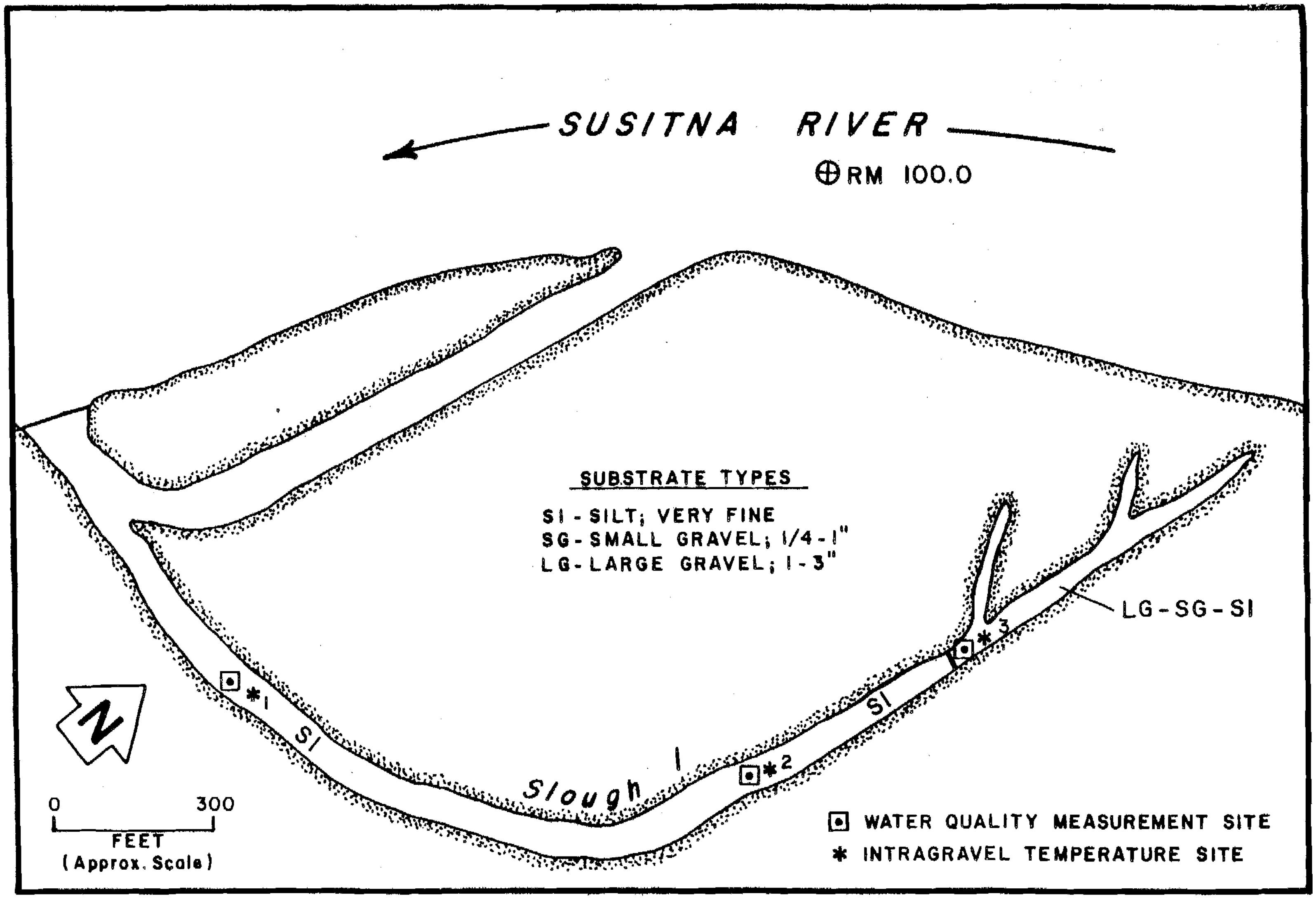
Substrate, lack of upwelling and low flows appear to be the main factors limiting spawning in this site.

Slough 2 (RM 100.7R)

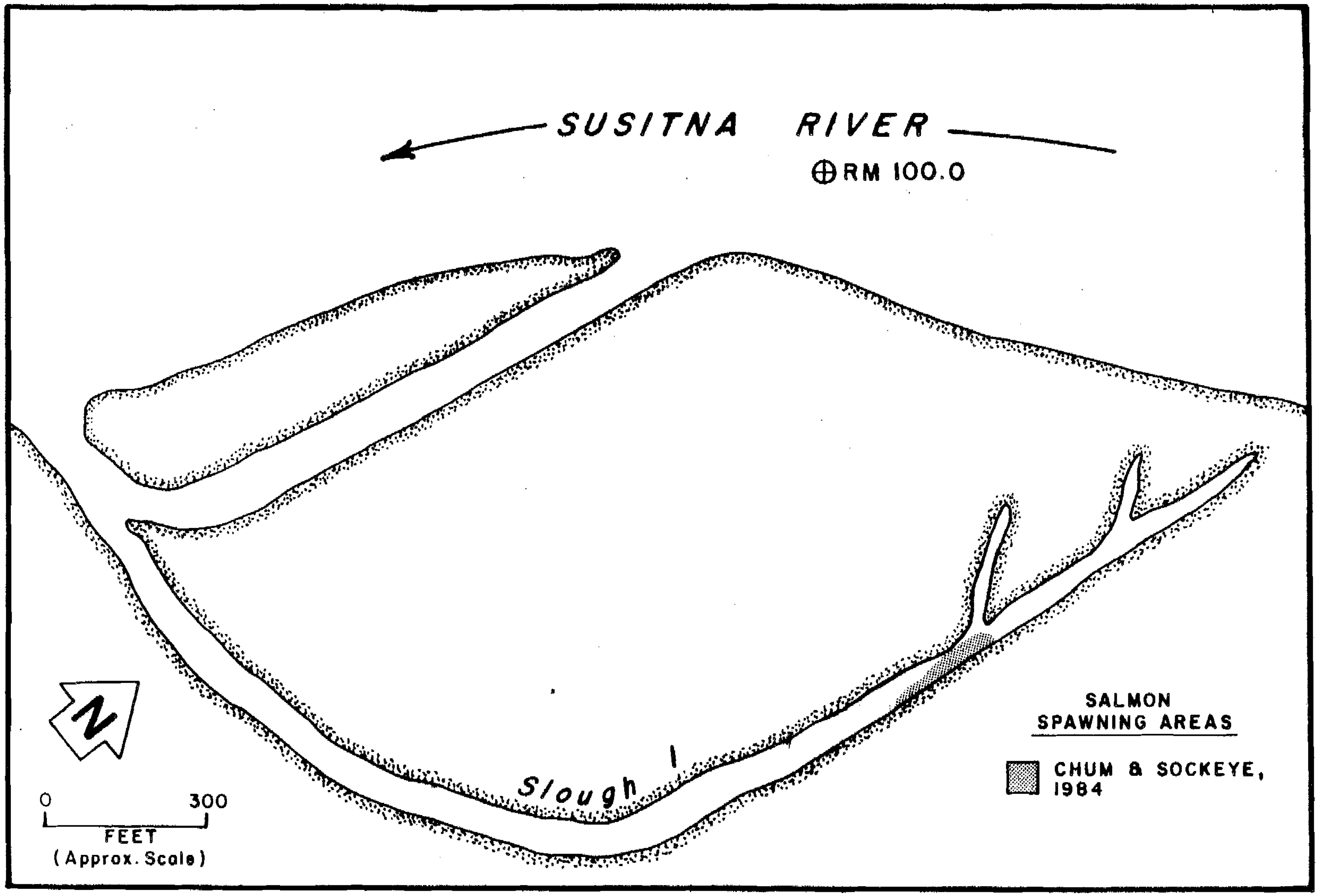
This is an 0.3 mile long bow shaped side slough on the east side of the Susitna River with a backwater area extending 500 feet upstream from the mouth, followed by a pool riffle sequence. A small bog fed creek drains into the right side of the slough near the head of the first pool. Upwelling and bank seepage are present along the left bank of the upper pool and appears to be related to mainstem discharge (Appendix Figure A-3). Upwelling present along the right bank, downstream of the creek, appears to be related to bog drainage.

In the backwater areas silt and sand cover the larger substrate to a depth of approximately one foot. Upstream of the backwater, the two pools have rubble/large gravel substrates interspersed with boulders and silt. The best substrate is along the right bank of the first pool where there are pockets of large gravel/rubble (Appendix Figure A-4). A cobble/boulder berm is present at the head. There are two areas where passage may be restricted, a large sand/silt bar present at the mouth and the 20 foot riffle between the backwater and first pool.

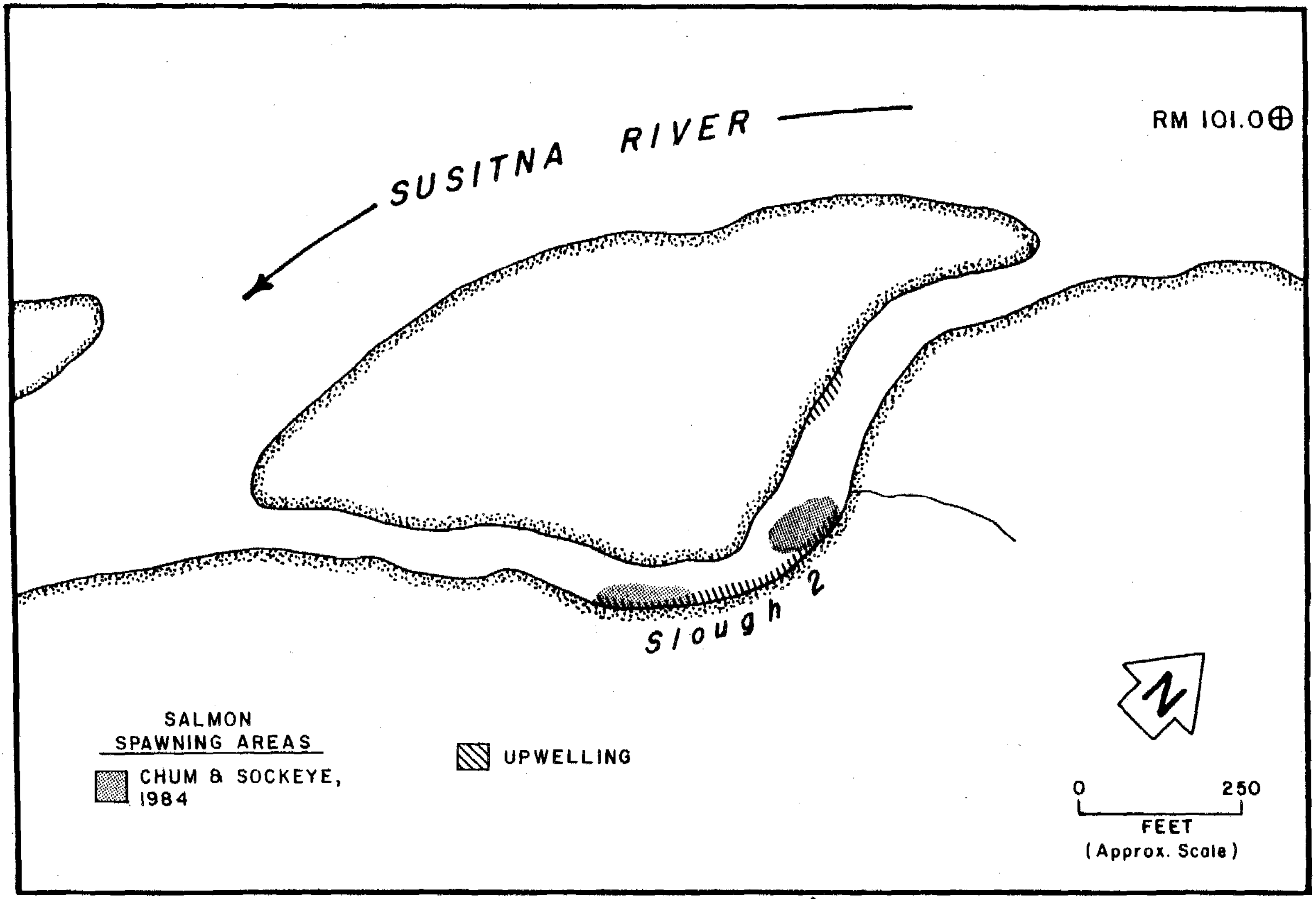
In 1984 chum and sockeye salmon were reported spawning in the backwater area and the first pool. The redds in the first pool were located in an upwelling area downstream of the bog creek along the right bank (Appendix Figure A-3). Fry were observed in both pools.



Appendix Figure A-1. Substrate composition and sampling locations in Slough 1 (RM 99.R).



Appendix Figure A-2. Salmon spawning locations in Slough 1 (RM 99.5R).



Appendix Figure A-3. Upwelling and salmon spawning areas in Slough 2 (RM 100.7R).

The factors that appear to be limiting to spawning are passage into and within the slough, substrate and limited upwelling.

Whiskers Slough (RM 101.2L)

Whiskers Slough is a 0.5 mile long side slough located on the west bank of the Susitna River with the head joining Slough 3B. The confluence of Whiskers Creek is on the left bank, 0.2 miles upstream of the mouth. Breaching of the head occurs at mainstem discharges of 23,000 cfs and greater. Base slough flow is maintained through intragravel flow and flow from Whiskers Creek. Whiskers Slough consists of a 520 foot long by 75 feet wide backwater followed by a series of pools and riffles. The substrate in the backwater is composed of thick deposits of silt/sand with the remainder of the slough being predominately deposits of rubble/large gravel with a layer of silt and some cobble (Appendix Figure A-5). The last 400 feet of the slough at the head is cobble/boulder. Three riffles are present which could inhibit fish passage. A more complete description of passage conditions can be found in Sautner, et al. 1984 and Blakely, et al. 1985.

Evidence of upwelling is present in the upper pools, and bank seepage in the backwater area. The bank seepage along the right bank may be related to mainstem discharge (Appendix Figure A-6). Upwelling was not observed in the backwater due to the turbid water.

Limited spawning occurs downstream of the mouth of Whiskers Creek and in the creek-slough interface (Appendix Figures A-7 and A-8). The majority of spawning in this site occurs in Whiskers Creek. The upper pools, while not utilized for spawning, are rearing areas for salmon fry. Open leads are present in these pools during the winter.

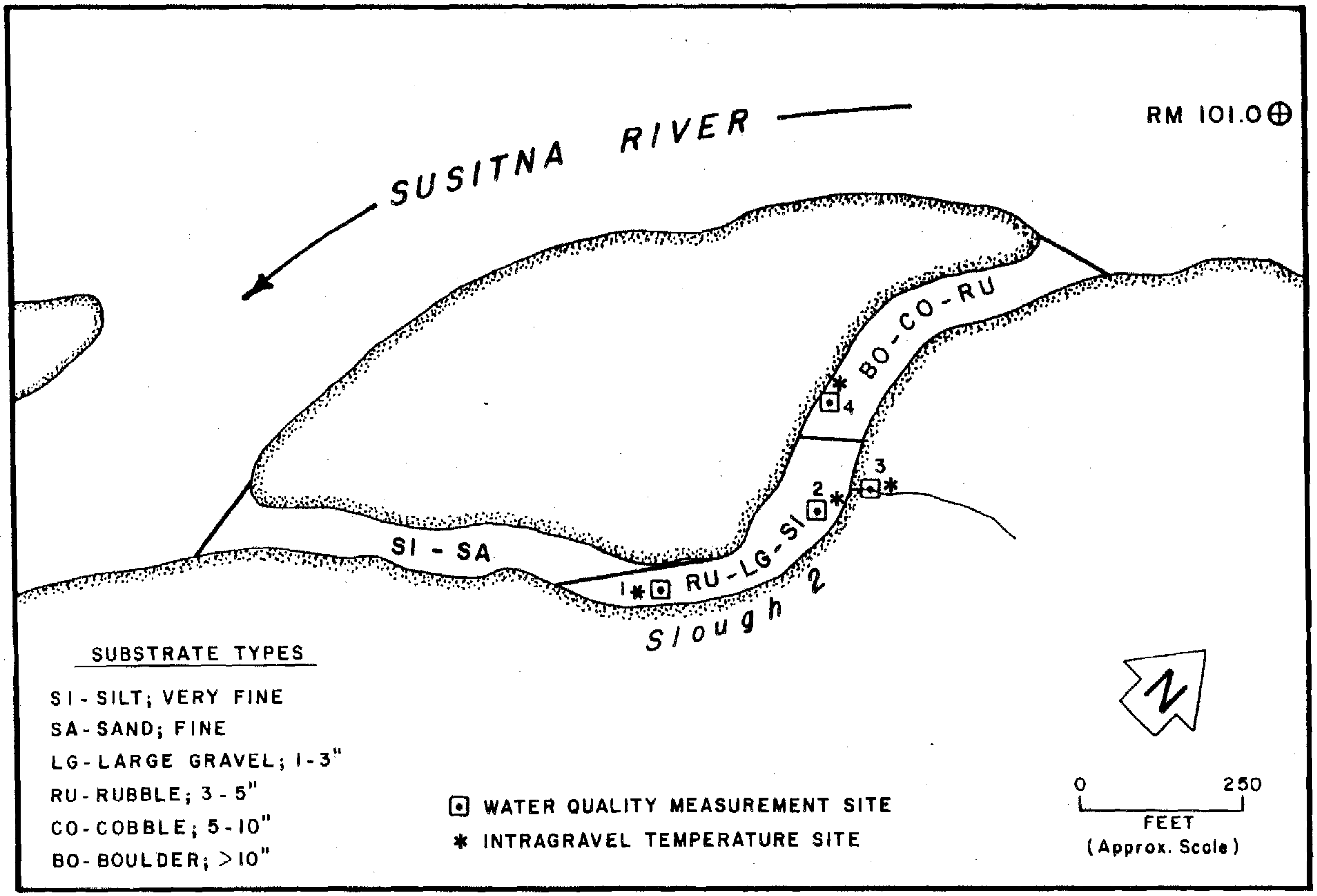
It appears that the primary factors limiting spawning in Whiskers Slough are passage, siltation of the substrate and lack of strong upwelling.

Slough 3B (RM 101.4L)

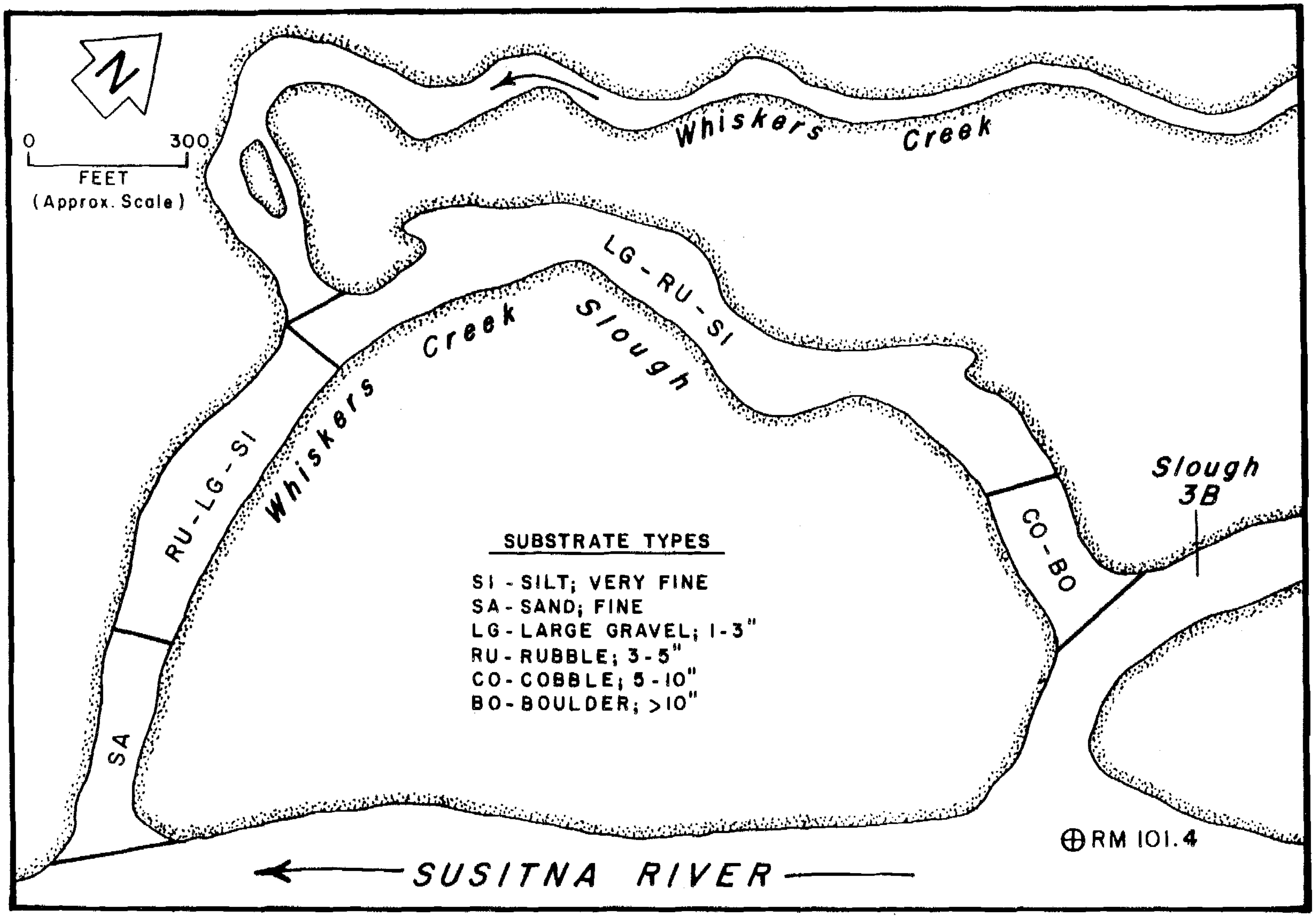
Slough 3B is a 0.3 mile long side slough on the west side of the Susitna River at RM 101.4. The channel is approximately 40 feet wide consisting of two pools separated by a 20 foot riffle, approximately 740 feet above the mouth. The mouth of Slough 3A enters Slough 3B 320 feet from the head (Appendix Figure A-9). Substrate throughout the slough is rubble/cobble overlain by a thin layer of silt (Appendix Figure A-10). In a breached condition, this site appears more like a side channel. In an unbreached state, several riffles are present which may inhibit fish passage. The necessary local flows and/or discharge to alleviate these passage reaches are not known.

The extent of salmon spawning in this slough is shown in Appendix Figure A-11. Barrett et al. 1984 indicated peak counts for chum, sockeye and pink salmon at 56, 20, and 28 fish respectively.

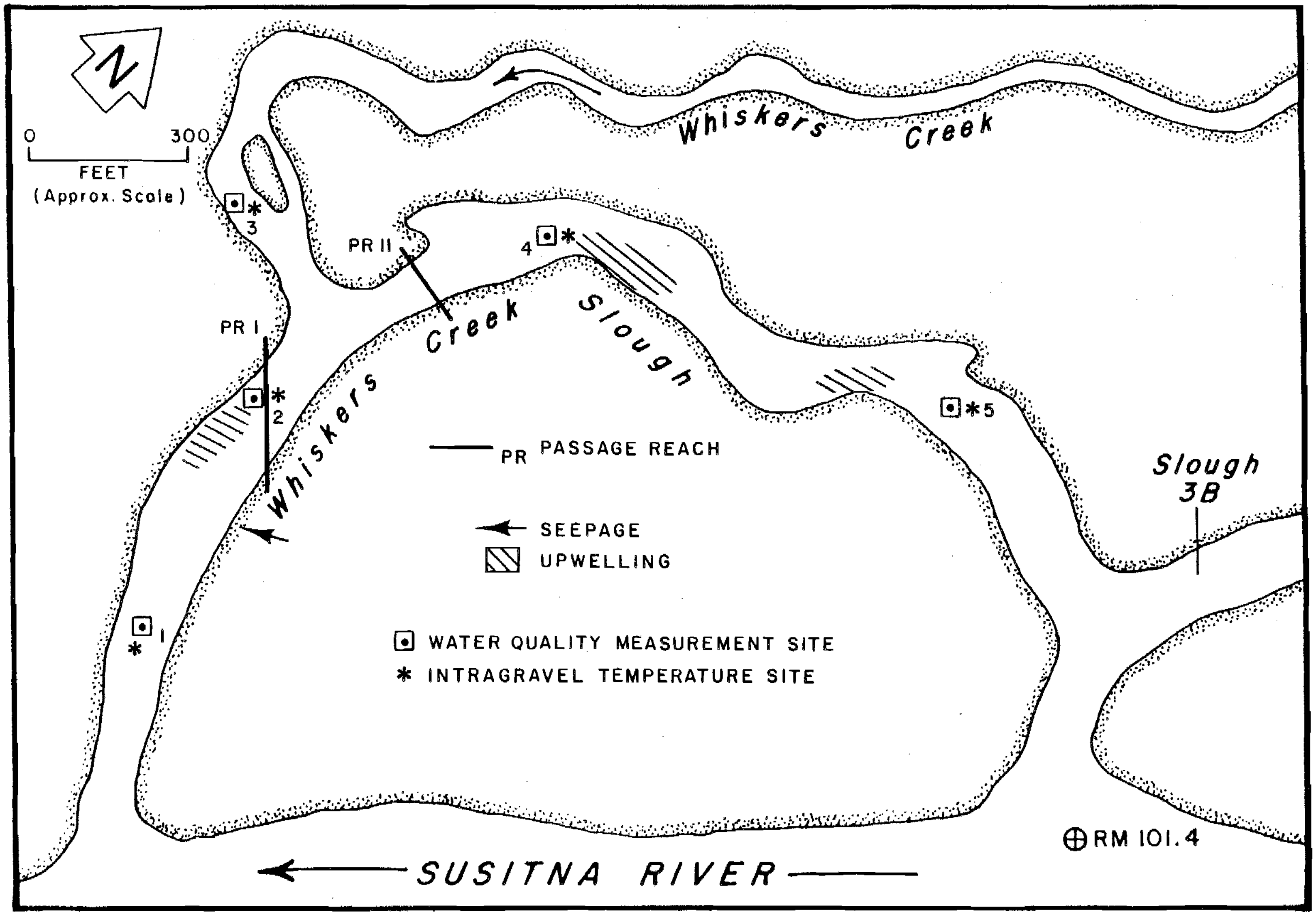
Large substrate and lack of upwelling appear to be the factors limiting spawning in this site.



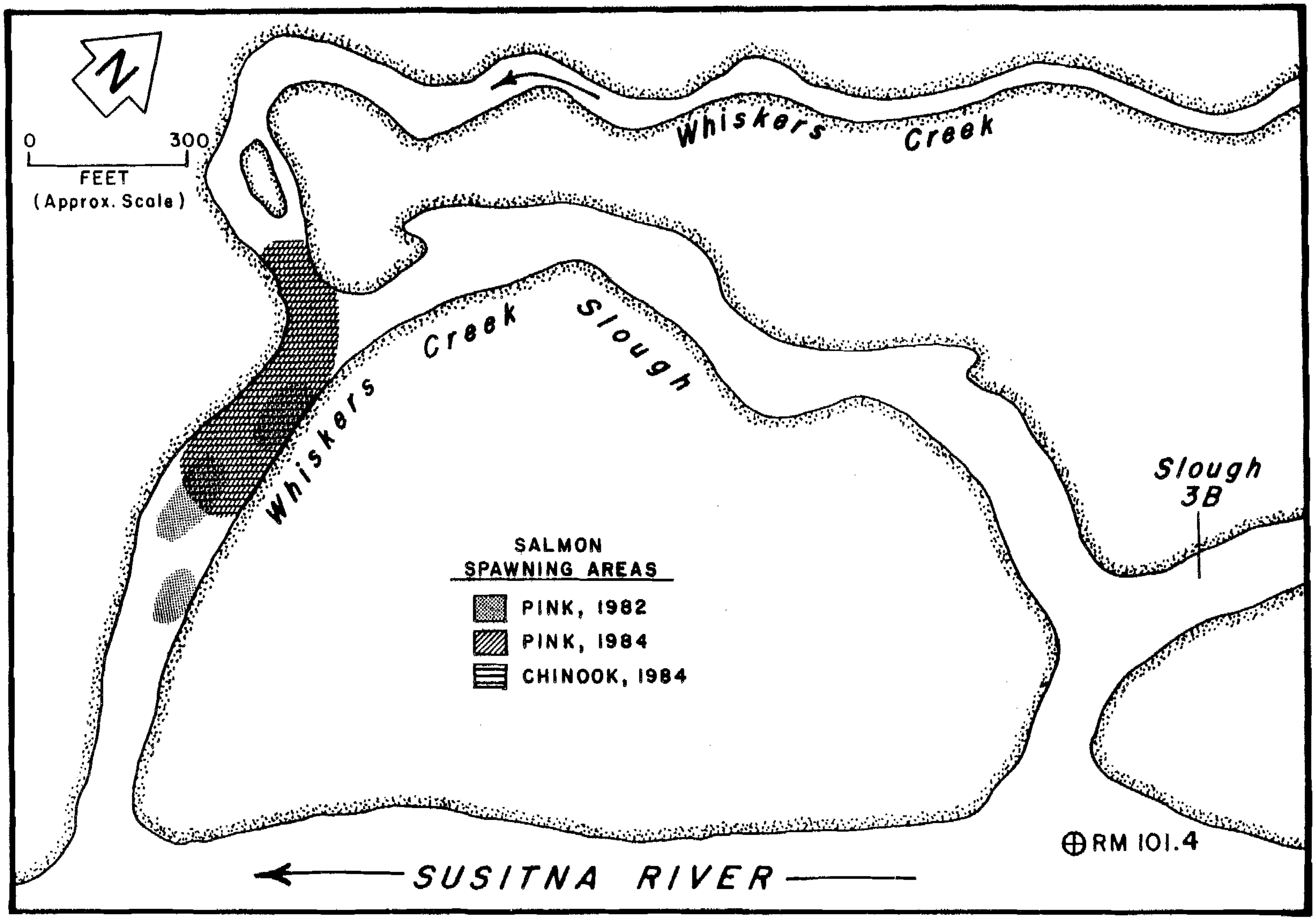
Appendix Figure A-4. Substrate composition and sampling sites in Slough 2 (RM 100.2R).



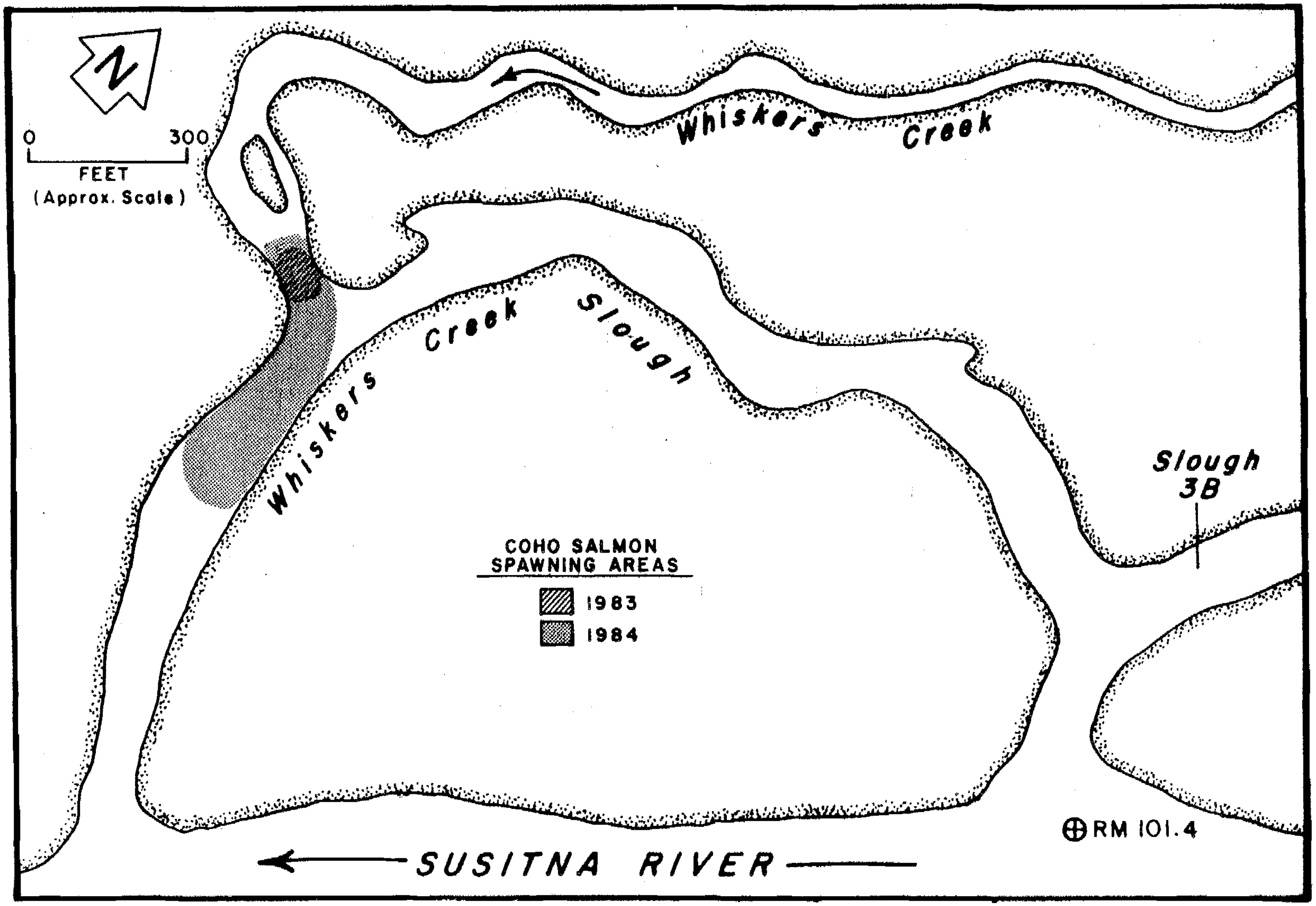
Appendix Figure A-5. Substrate composition of Whiskers Slough (RM 101.2L).



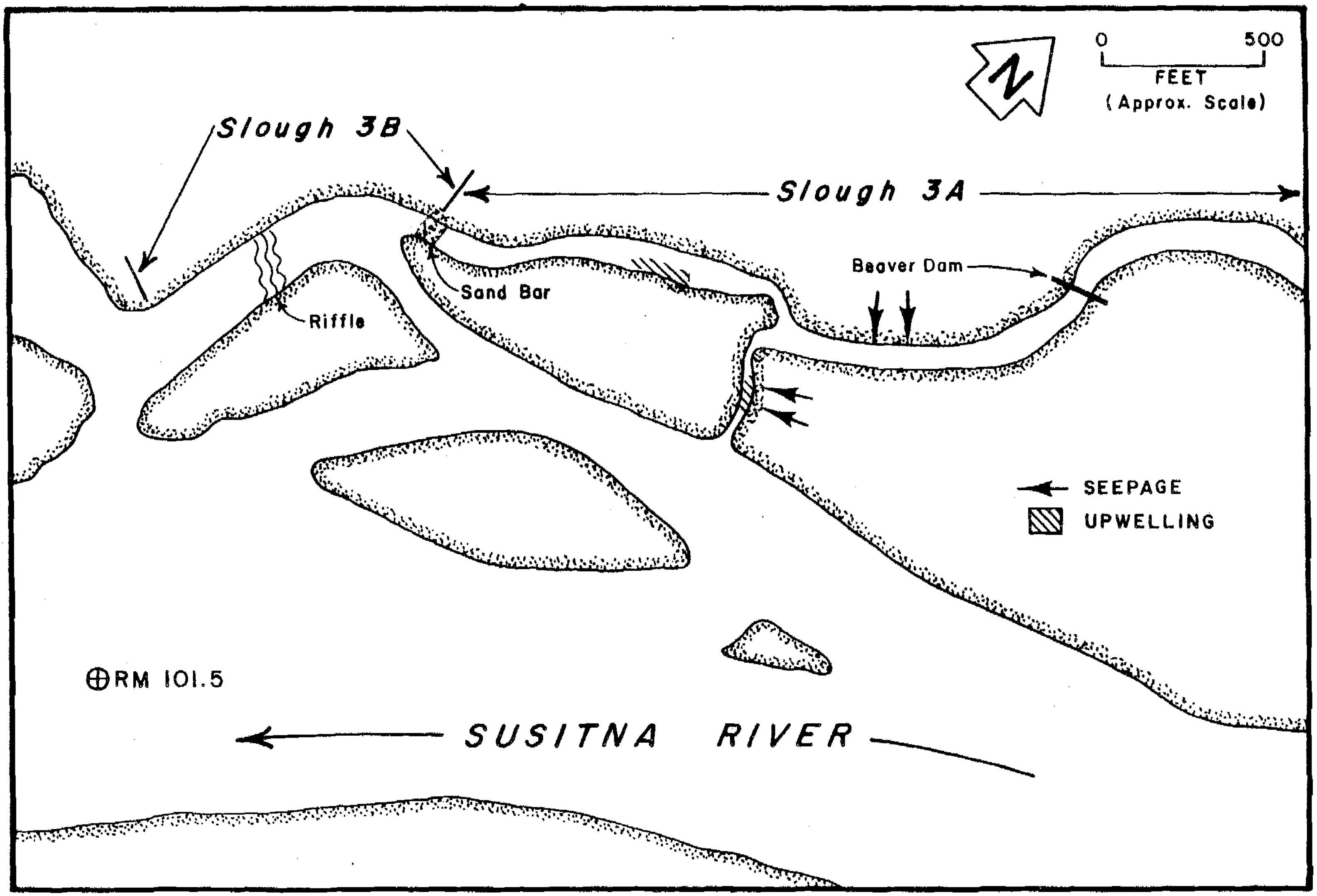
Appendix Figure A-6. Upwelling areas and sampling sites in Whiskers Slough (RM 101.2L).



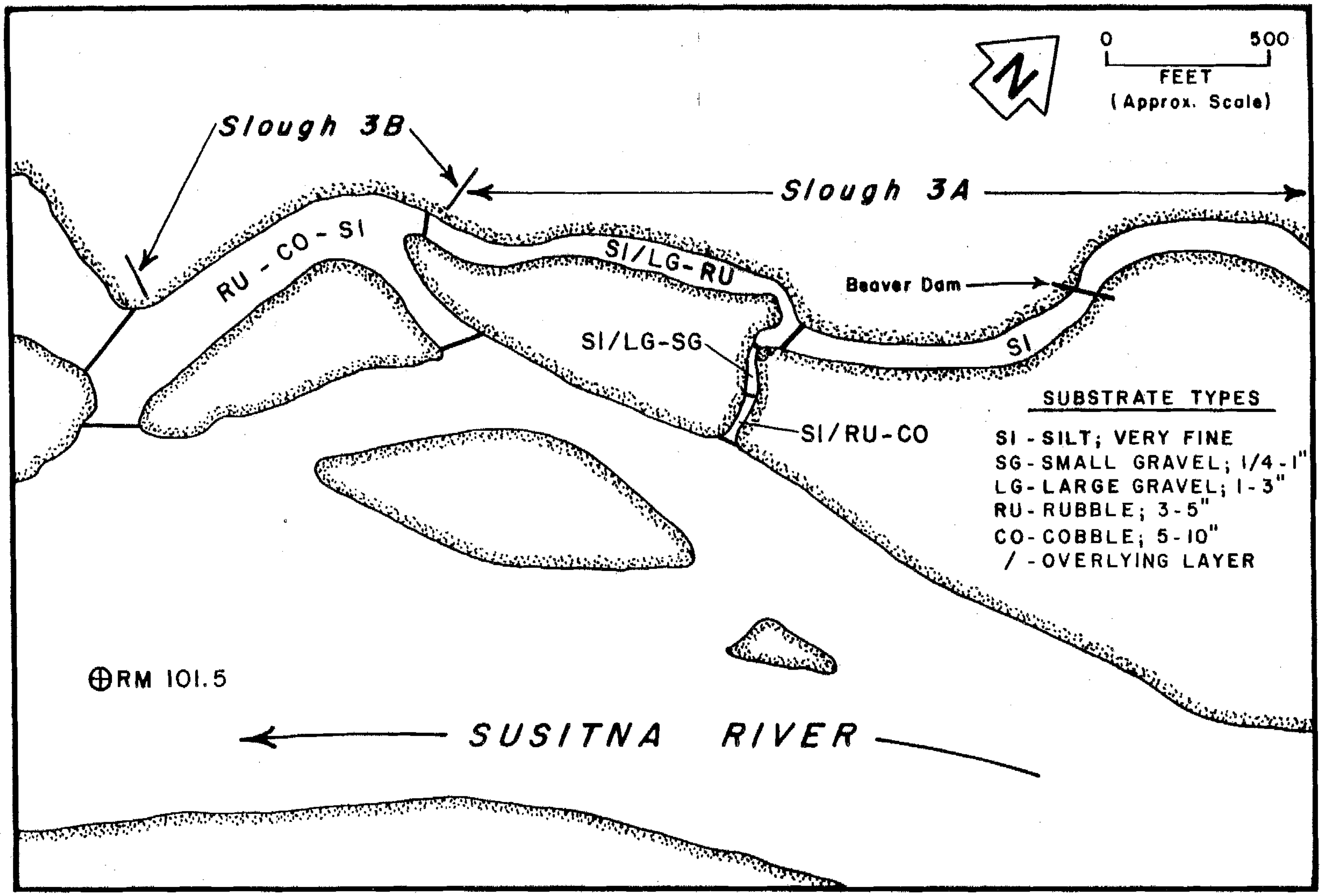
Appendix Figure A-7. Pink and chinook salmon spawning areas in Whiskers Slough (RM 101.2L).



Appendix Figure A-8. Coho salmon spawning areas in Whiskers Slough (RM 101.2L).



Appendix Figure A-9. Channel configuration and upwelling areas in Slough 3B (RM 101.4L) and Slough 3B (RM 101.4L) and Slough 3A (RM 101.9L).



Appendix Figure A-10. Substrate composition of Slough 3B (RM 101.4L) and Slough 3A (RM 101.9L).

Slough 3A (RM 101.9L)

Slough 3A is an upland slough flowing into Slough 3B, originating in a marshy area on the west side of the Susitna River. The backwater area extends approximately 200 feet upstream of the mouth to the confluence of a small left bank tributary draining a bog (Appendix Figure A-9). A thick layer of silt/sand is found in the backwater area. The next 1,000 feet of the slough is a 6 foot wide channel comprised of a series of shallow pools and riffles with rubble-large gravel substrates covered by a thin silt layer (Appendix Figure A-10). Upwelling and bank seepage is present throughout this reach (Appendix Figure A-9).

A 300 feet long and 15 feet wide side channel, 1,200 feet upstream of the mouth, connects Slough 3A with the mainstem. Silt, covering rubble-cobble substrate, predominates in this channel. Upwelling was observed along the right bank near the midpoint of the channel. No fish were observed in this channel. At high discharges, the head of this side channel is breached.

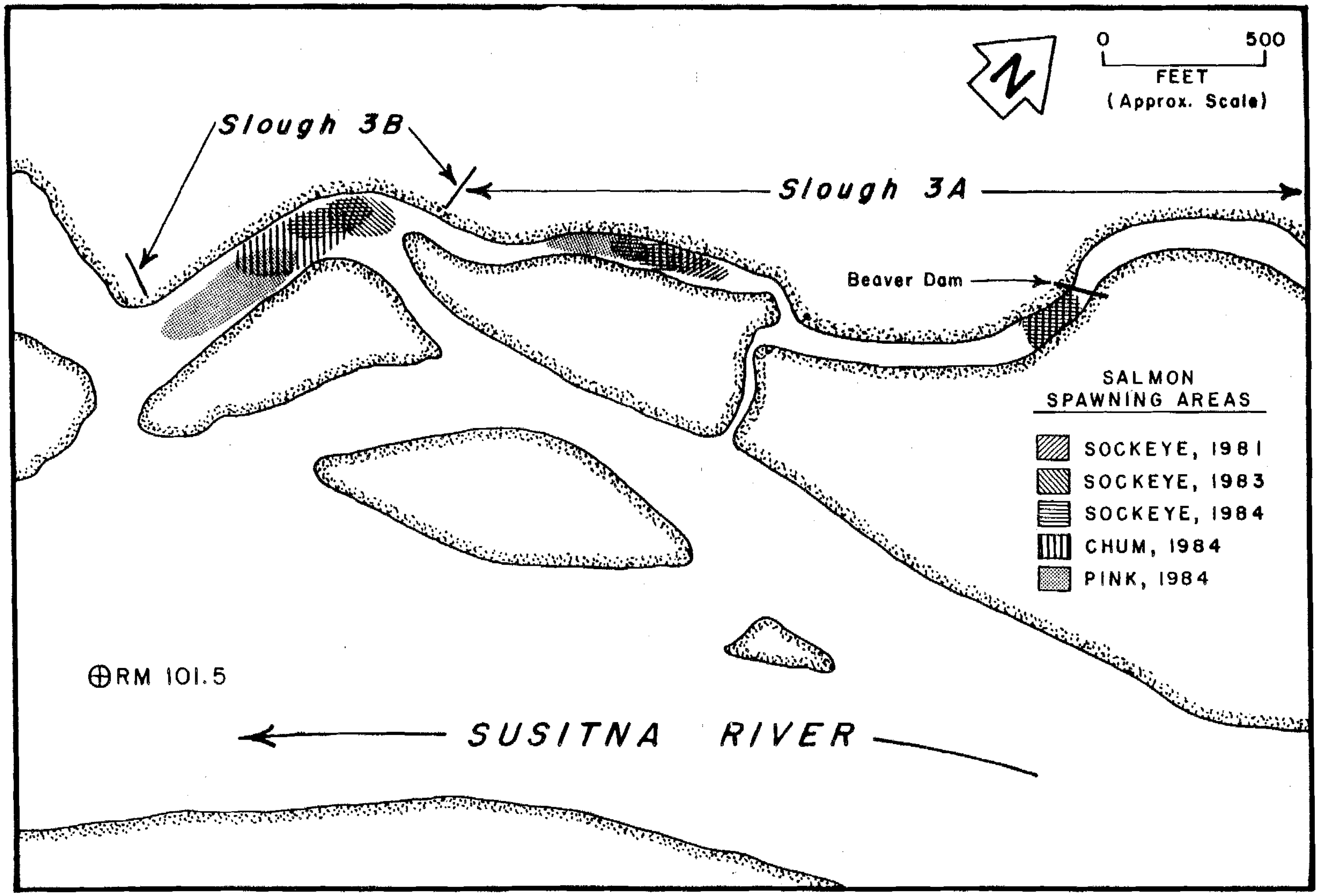
A long pool, which terminates in a beaver dam, is located upstream of the confluence of the slough and side channel. The pool appears almost stagnant with little perceptible flow. Some bank seepage from a bog area is evident along the left bank. Thick silt, organic debris and aquatic vegetation cover the bottom of this pool. The area appeared to be a rearing area as numerous fry were observed, even in the presence of low dissolved oxygen readings (2.5 mg/l).

Upstream of this pool, the slough is a marsh maintained by a series of beaver dams. Chum and sockeye salmon were observed spawning within 50 feet of the base of the first dam. Salmon spawning areas observed during 1984 are presented in Appendix Figure A-11. According to Barrett et al. 1985, the peak survey counts for sockeye, chum, and pink salmon were 11, 17, and 36 respectively.

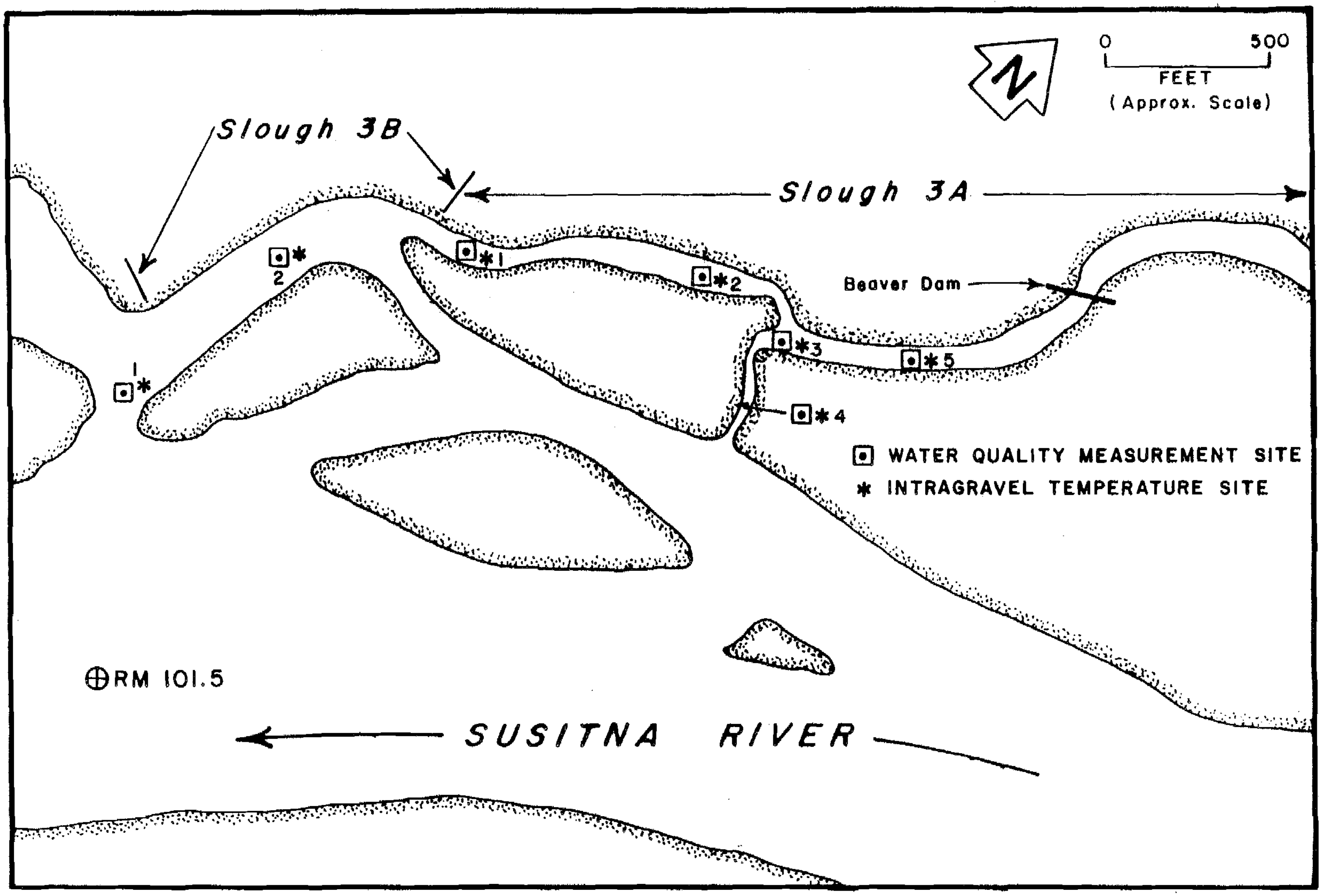
Passage, substrate, and widely fluctuating dissolved oxygen levels in parts of the slough, appear to be the factors limiting spawning.

Slough 4 (RM 105.2R)

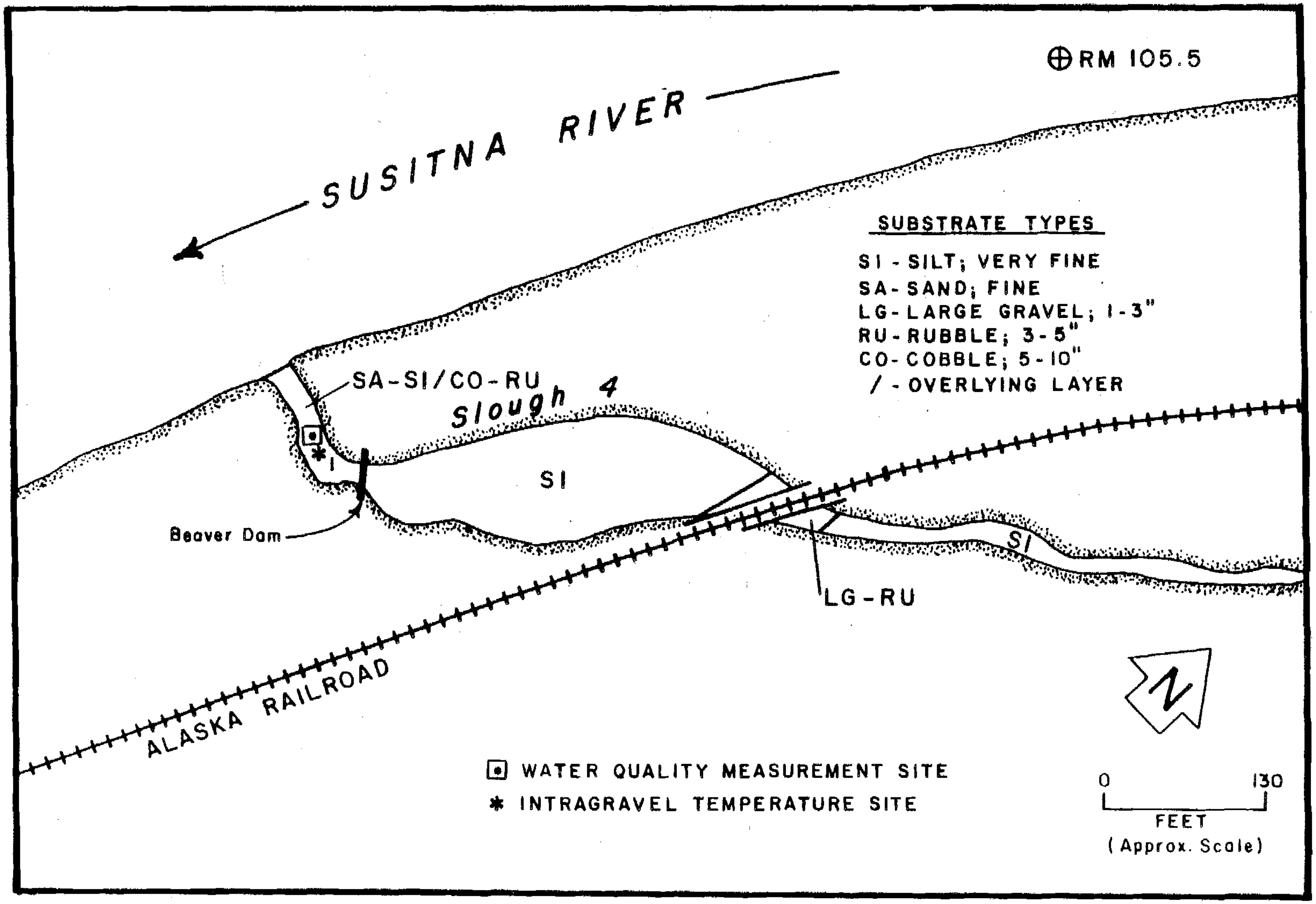
This is an upland slough on the east side of the Susitna River. Prior to the summer of 1984, it consisted of a large beaver pond maintained by a 12 foot high 100 foot long beaver dam 100 feet upstream of the mouth. In 1984, this dam was opened to observe if salmon would utilize the newly available habitat. After removal of the dam and subsequent drainage of the pool, the slough was reduced to a 3 foot wide channel meandering from the mouth to the railroad bridge 1/4 mile upstream. Upstream of the railroad bridge a series of beaver dams and ponds is still present. The observable substrate is silt and sand with large amounts of organic detritus. Large gravel/small gravel substrate is evident in the vicinity of the ARR tracks (Appendix Figure A-13). This may be a natural occurrence or as a result of railroad work. There is no evidence of upwelling or bank seepage in Slough 4. There is no history of any spawning activity due to the beaver dam blocking passage. Salmon fry were observed in a pool at the base of the dam. Upstream of



Appendix Figure A-11. Salmon spawning areas in Slough 3B (RM 101.4L) and Slough 3A (RM 101.9L).



Appendix Figure A-12. Sampling locations in Slough 3B (RM 101.4L) and Slough 3A (RM 101.9L).



Appendix Figure A-13. Channel configuration, substrate composition, and sampling sites in Slough 4 (RM 105.2R).

the dam, only three spine sticklebacks and numerous insect larvae were observed.

Passage, substrate and lack of upwelling appear to be the factors limiting spawning in this site.

Slough 5 (RM 107.6L)

Slough 5 is an upland slough, approximately one mile long, entering the mainstem Susitna River on the west side at RM 107.6 and consisting of a series of long narrow beaver ponds. The first beaver dam, 1,500 feet upstream of the mouth, effectively restricts further upstream migration of fish. Below this dam the slough appears to be a long narrow run with cobble boulder substrate covered by a thin layer of silt. The water is stained brown due to dissolved organic compounds filtered out of the bog, which appears to be the main source of water for this slough. A sand bar at mouth of the slough may prevent passage at lower mainstem discharges (Appendix Figure A-14). There was no evidence of any upwelling or bank seepage in Slough 5, and although there was limited spawning present in 1982 and 1983, none was evident in 1984. Although none were observed, the marshy area may be utilized as a rearing area for juvenile salmon. The aquatic vegetation provides excellent cover.

This slough has numerous deficiencies as a spawning area and should be left as a possible juvenile rearing area.

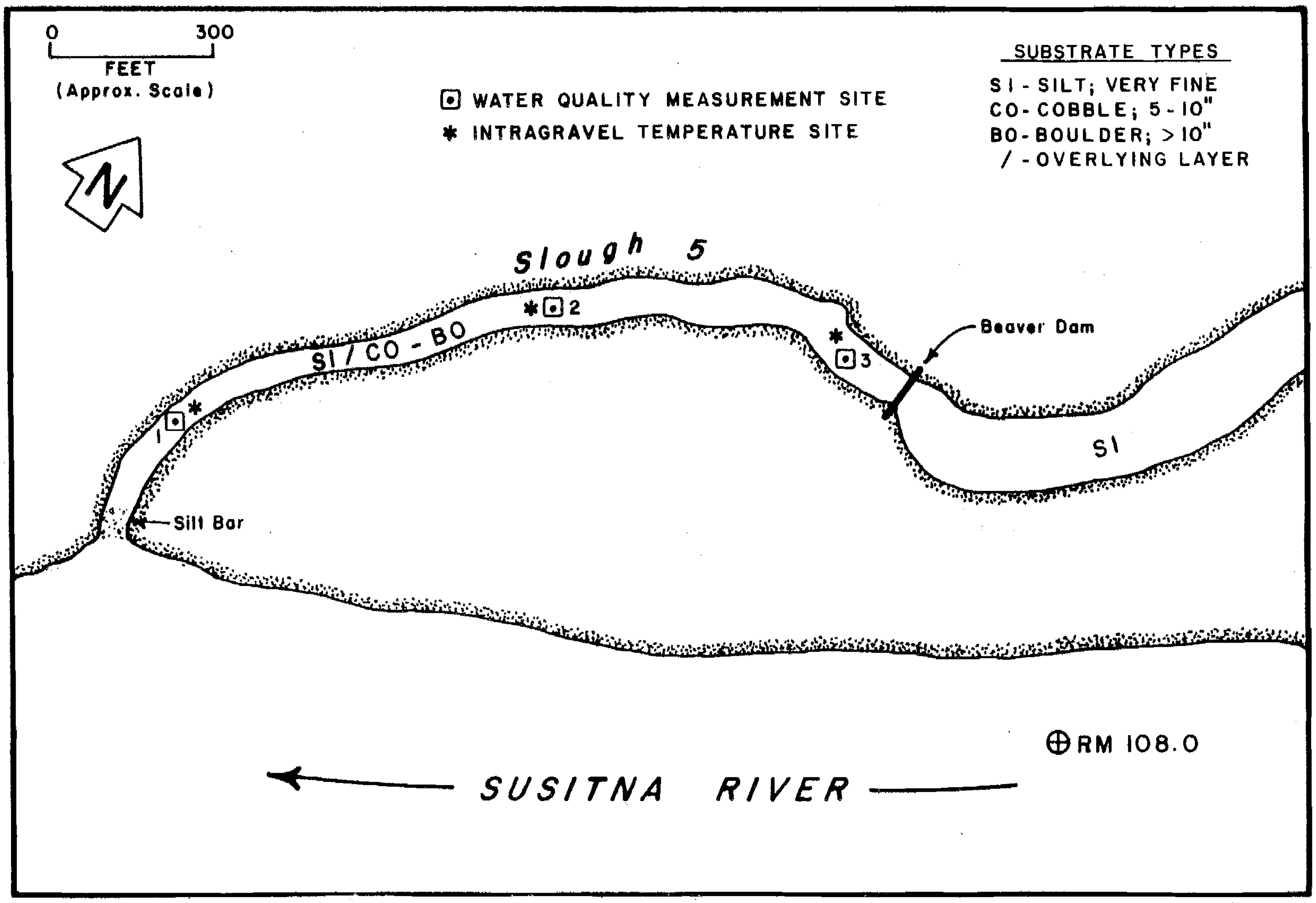
Slough 6 (RM 108.2L)

This is a 1.5 mile long upland slough, originating in a bog with numerous beaver dams and ponds, located on the west side of the Susitna River at RM 108.2. The water is stained brown due to dissolved organic materials. A beaver dam, located seven hundred feet from the mouth, is a complete passage barrier (Appendix Figure A-15). Upstream of this dam is a large and complex series of dams. A backwater area extends approximately 50 feet into the slough, followed by a 200 foot shallow riffle. A straight run extends above the riffle to the beaver dam. Substrate in the backwater is silt/sand while the rest of the slough tends to be cobble/rubble (Appendix Figure A-16). Limited bank seepage was observed along the left bank. Spawning has not been documented in Slough 6.

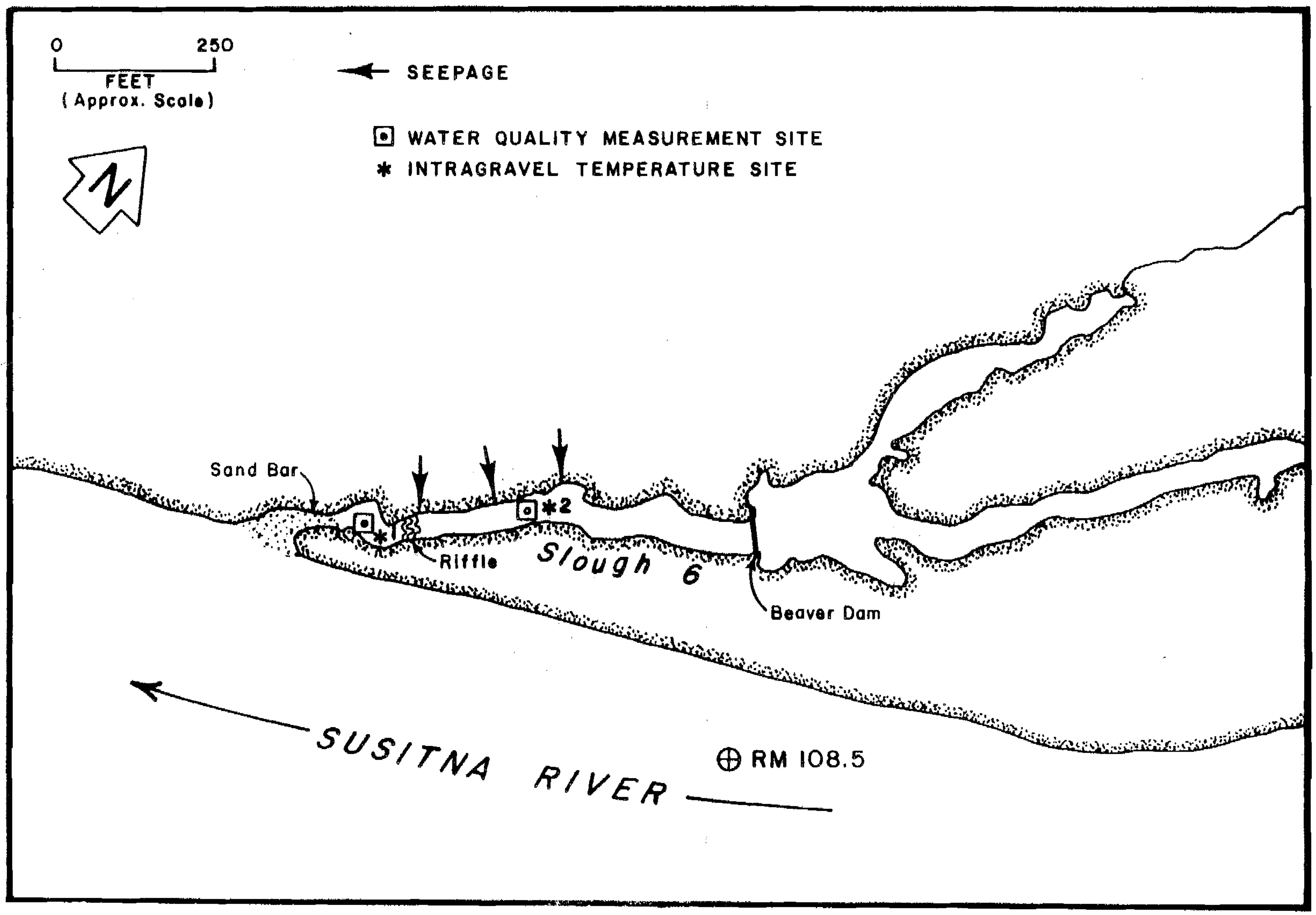
This site has numerous deficiencies as a spawning site and is best maintained as a possible rearing area.

Oxbow I (RM 110.1L)

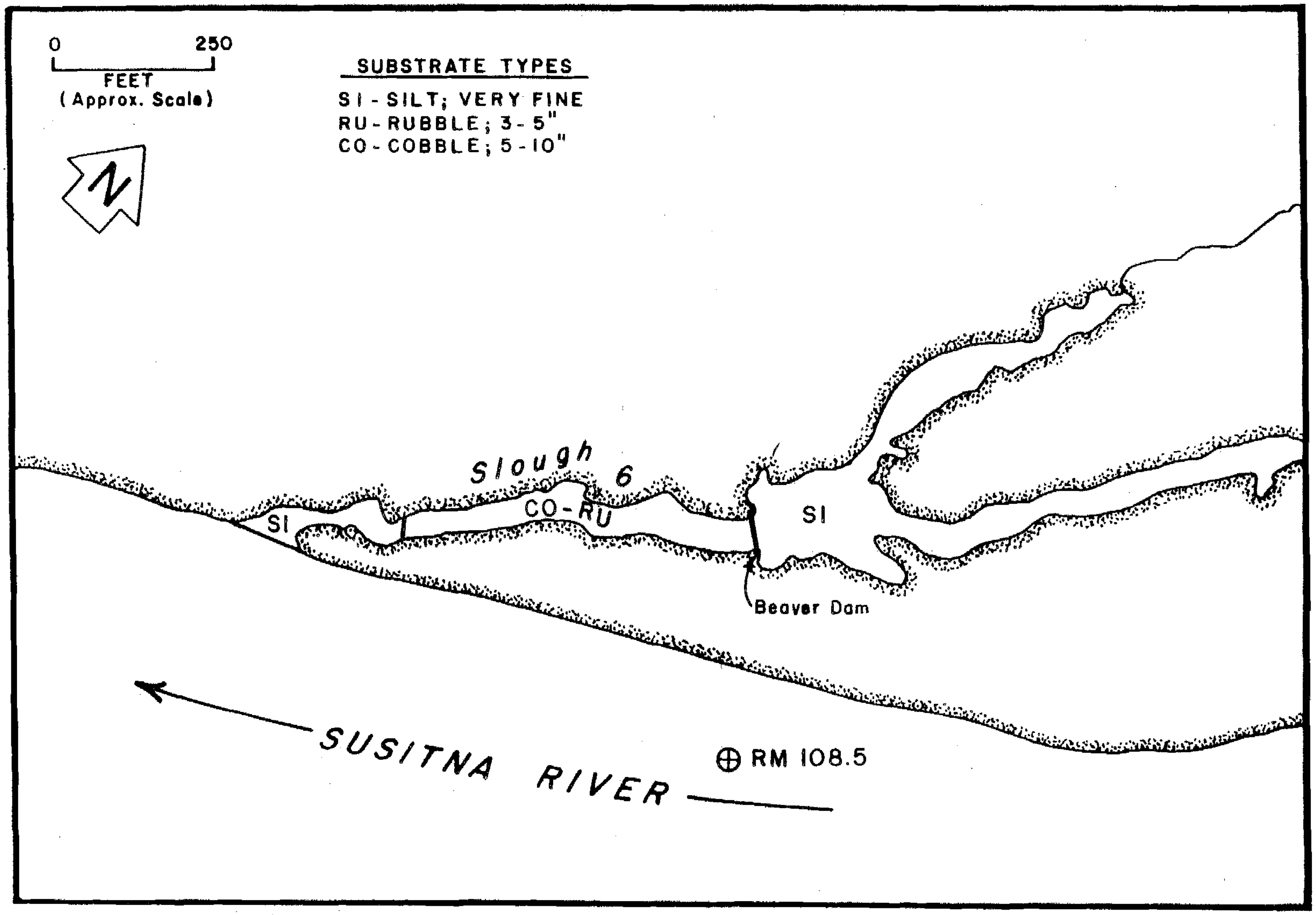
Oxbow I is a 100 foot wide by 0.5 mile long side channel at RM 110.1. A small creek draining a bog, enters the left bank at the midpoint of the slough. In an unbreached condition, three large pools exist in the upper section of the slough and a backwater area in the lower section. Substrates are predominately cobble/boulder. But, areas of large gravel/rubble substrate can be found throughout the site. In the backwater, silt/sand deposits have accumulated up to two feet thick (Appendix Figure A-17). Three riffles are present which may inhibit fish passage, depending on mainstem discharge. The base water source



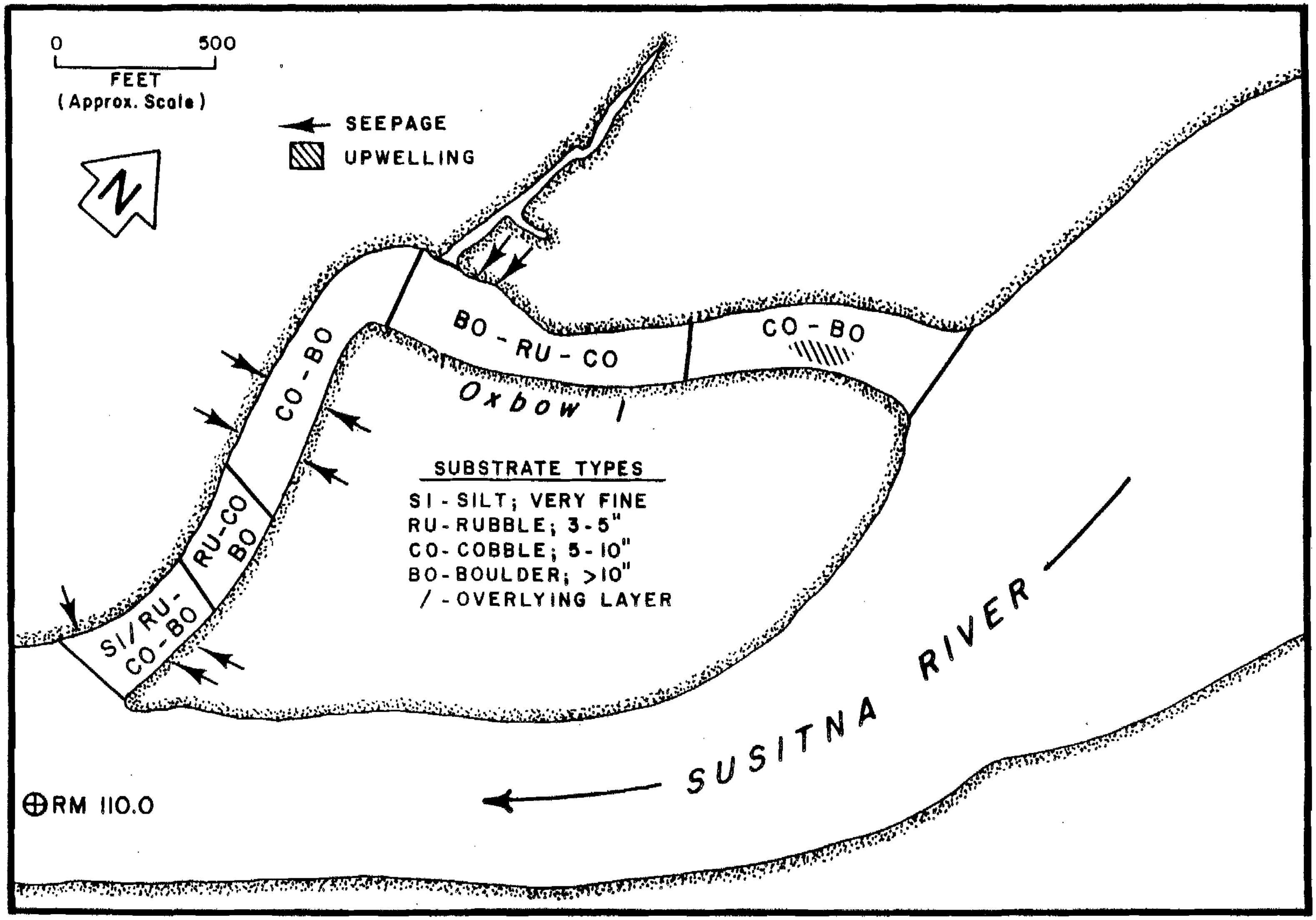
Appendix Figure A-14. Channel configuration, substrate composition, and sampling sites in Slough 5 (RM 107.6L).



Appendix Figure A-15. Channel configuration, bank seepage, and sampling sites in Slough 6 (RM 108.2L).



Appendix Figure A-16. Substrate composition in Slough 6 (RM 108.2L).



Appendix Figure A-17. Upwelling and substrate composition in Oxbow I side channel (RM 110.0L).

appears to be the surface inflow of the small creek and seepage from both banks in the lower portions of the first pool. Mainstem water may also flow intragravelly through the head during unbreached conditions. The pools near the head have open leads during the winter, but no upwelling was observed.

The only recorded spawning in Oxbow I Side Channel occurred in 1984, when chum salmon were observed spawning in the backwater area (Appendix Figure A-18).

Problems inhibiting spawning appear to be passage at low mainstem discharges, substrate and lack of upwelling. Overtopping in winter may inhibit incubation, thereby limiting spawning potential.

Slough 6A (RM 112.3L)

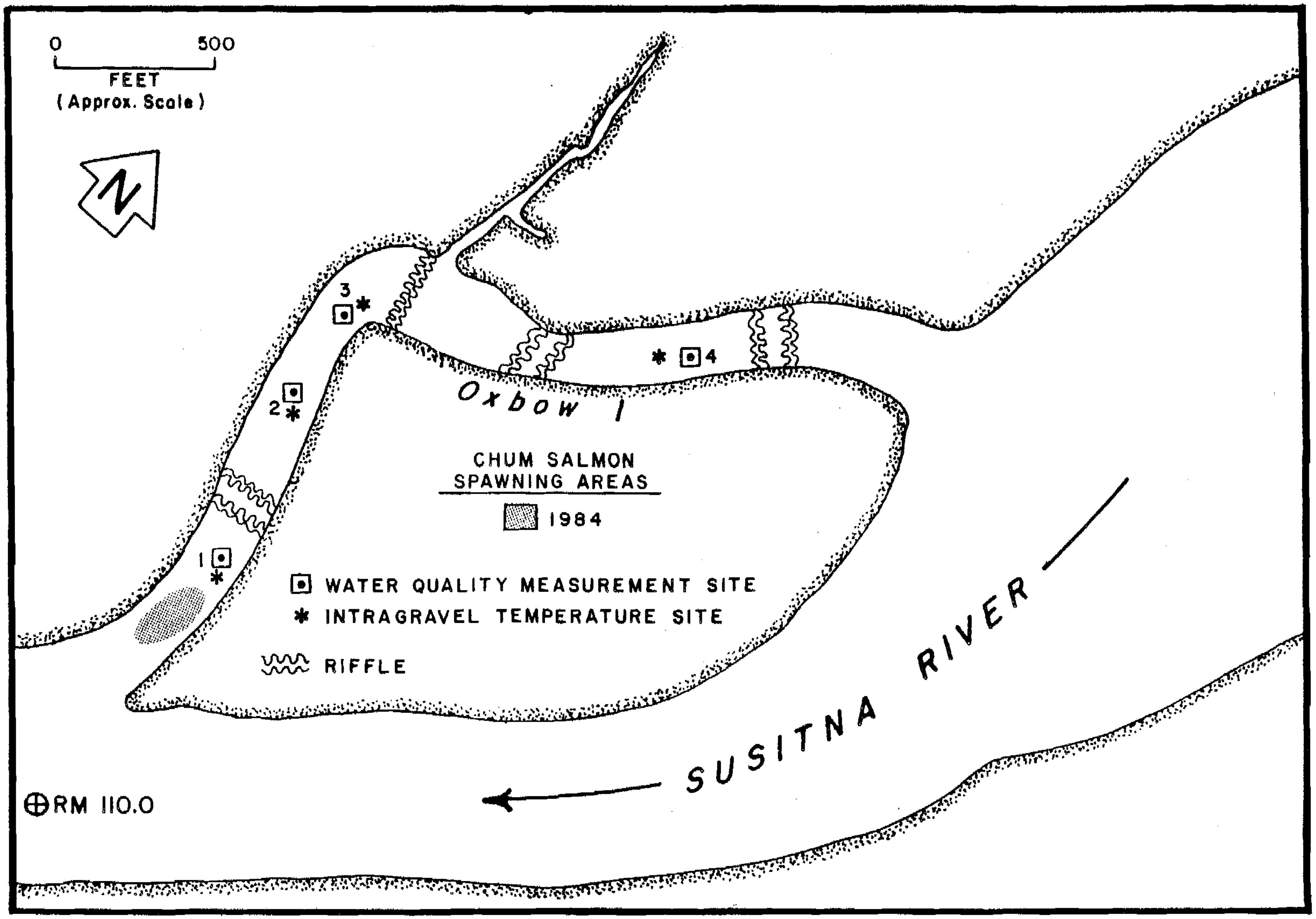
Slough 6A is an upland slough, draining a marshy area, approximately one mile long on the west bank of the Susitna River at RM 112.3. Approximately 1,000 feet upstream of the mouth of the slough, a beaver dam complex acts as a complete passage barrier (Appendix Figure A-19). A tributary enters the slough on the left bank approximately 500 feet upstream of the mouth. The water of both the slough and tributary is stained brown due to dissolved organic compounds. The reach from the mouth to the dam appears to be a backwater with imperceptible flow. The substrate is covered with deep silt/sand and decaying organic matter. Immediately downstream of the dam, the silt thins and cobble/boulder substrate can be seen. Areas of large gravel/rubble substrate can also be observed along the left bank, downstream of the tributary. No spawning was observed in Slough 6A in 1984. Fish observations made in Slough 6A were of milling fish.

Substrate and lack of upwelling appears to be the factors limiting spawning. At present, the site is best left as a possible juvenile rearing area.

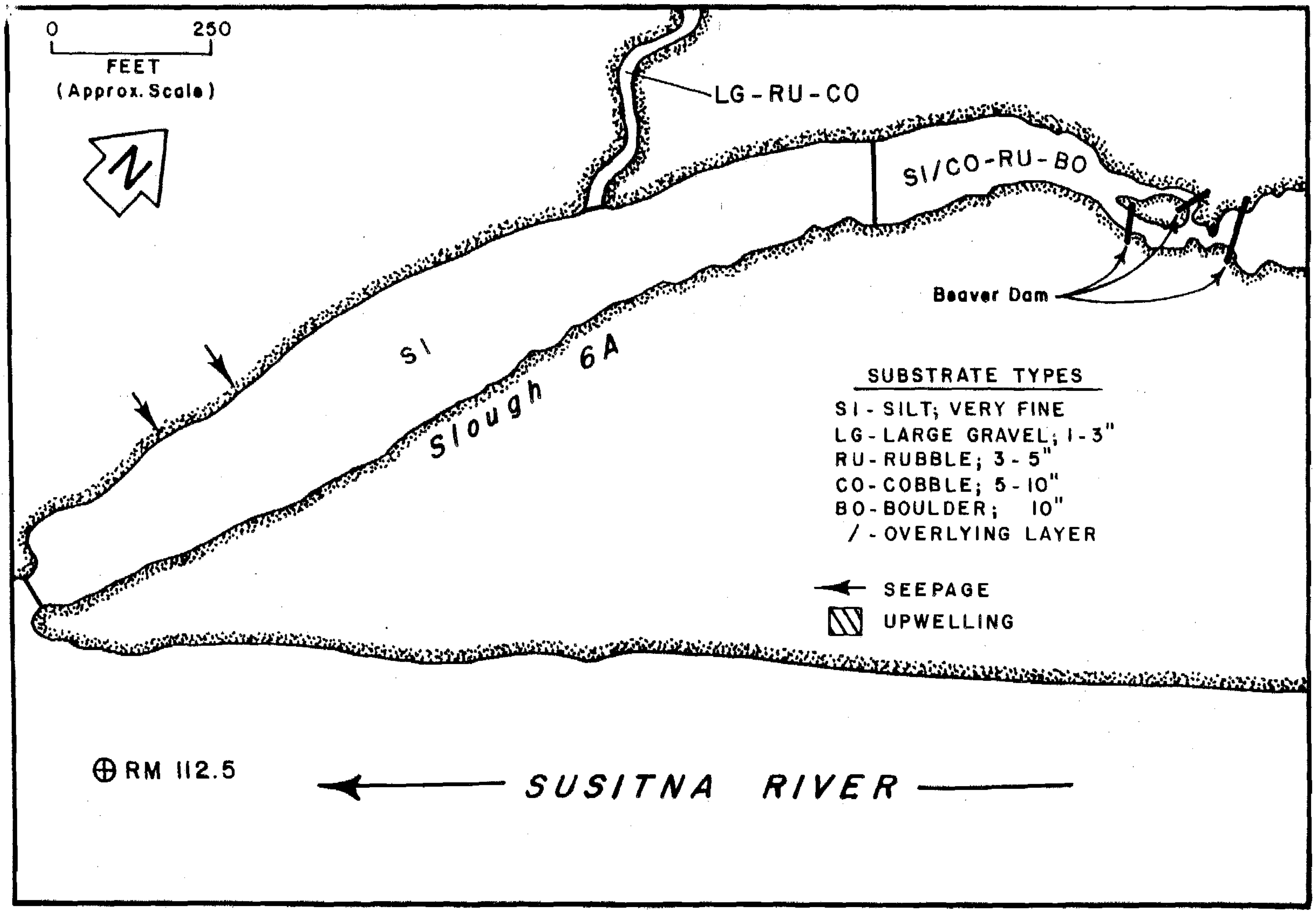
Slough 7 (RM 113.2R)

Slough 7 is a remnant side slough on the east bank of the Susitna River adjacent to the ARR tracks. The slough is approximately 500 feet in length, comprised of two pools separated by a narrow, short channel. A silt/sand bar across the mouth severely restricts passage into the slough at most discharges (Appendix Figure A-21). Silt deposits approximately 4 to 5 feet deep are found in both pools with cobble/boulder deposits located between the two pools and at the head. Limited upwelling occurs along the left bank and is most likely related to mainstem discharges. No documentation of salmon spawning in Slough 7 exists.

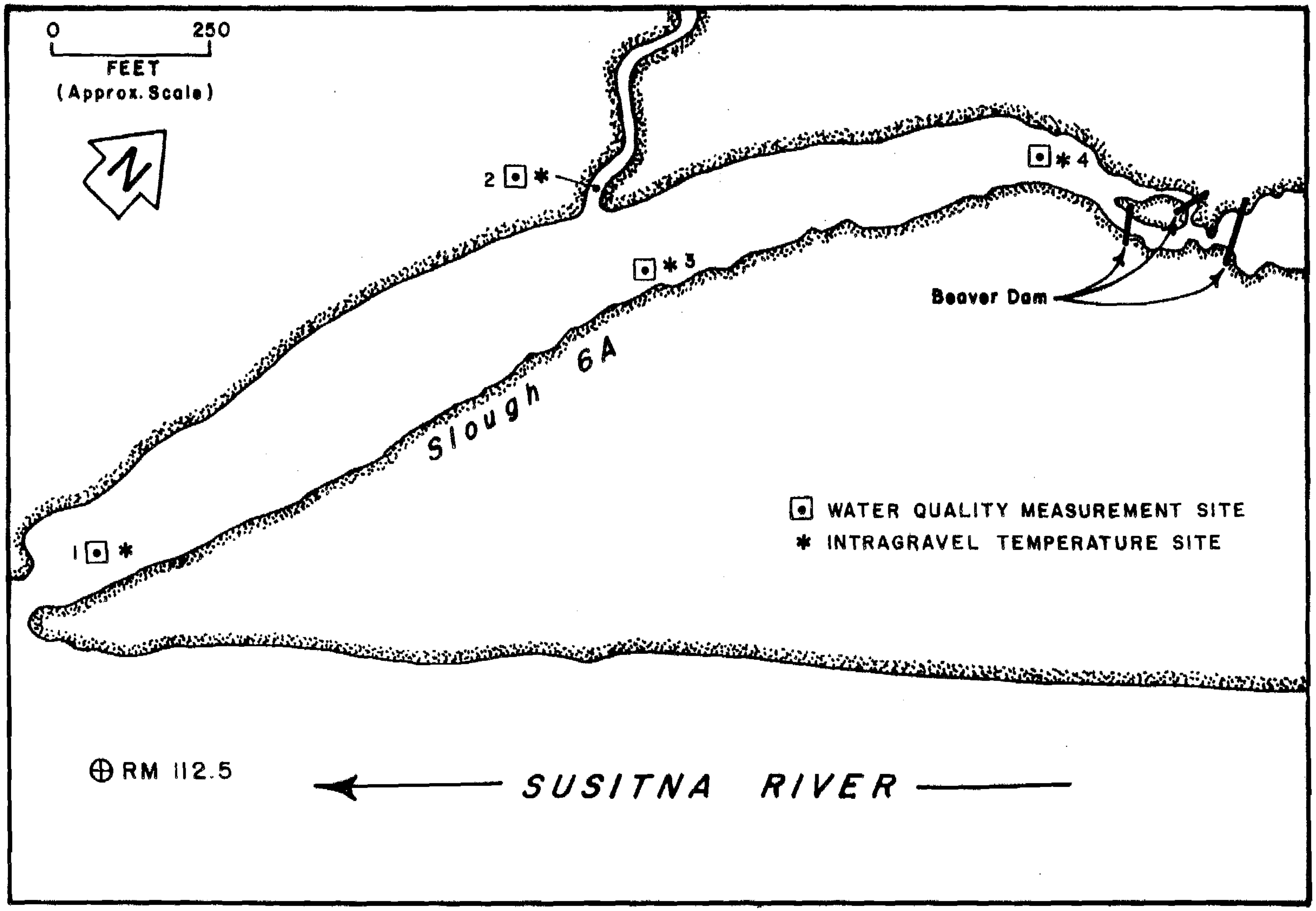
Slough 7 appears to be a remnant slough of little use. Passage, substrate and low pH appear to be limiting any spawning.



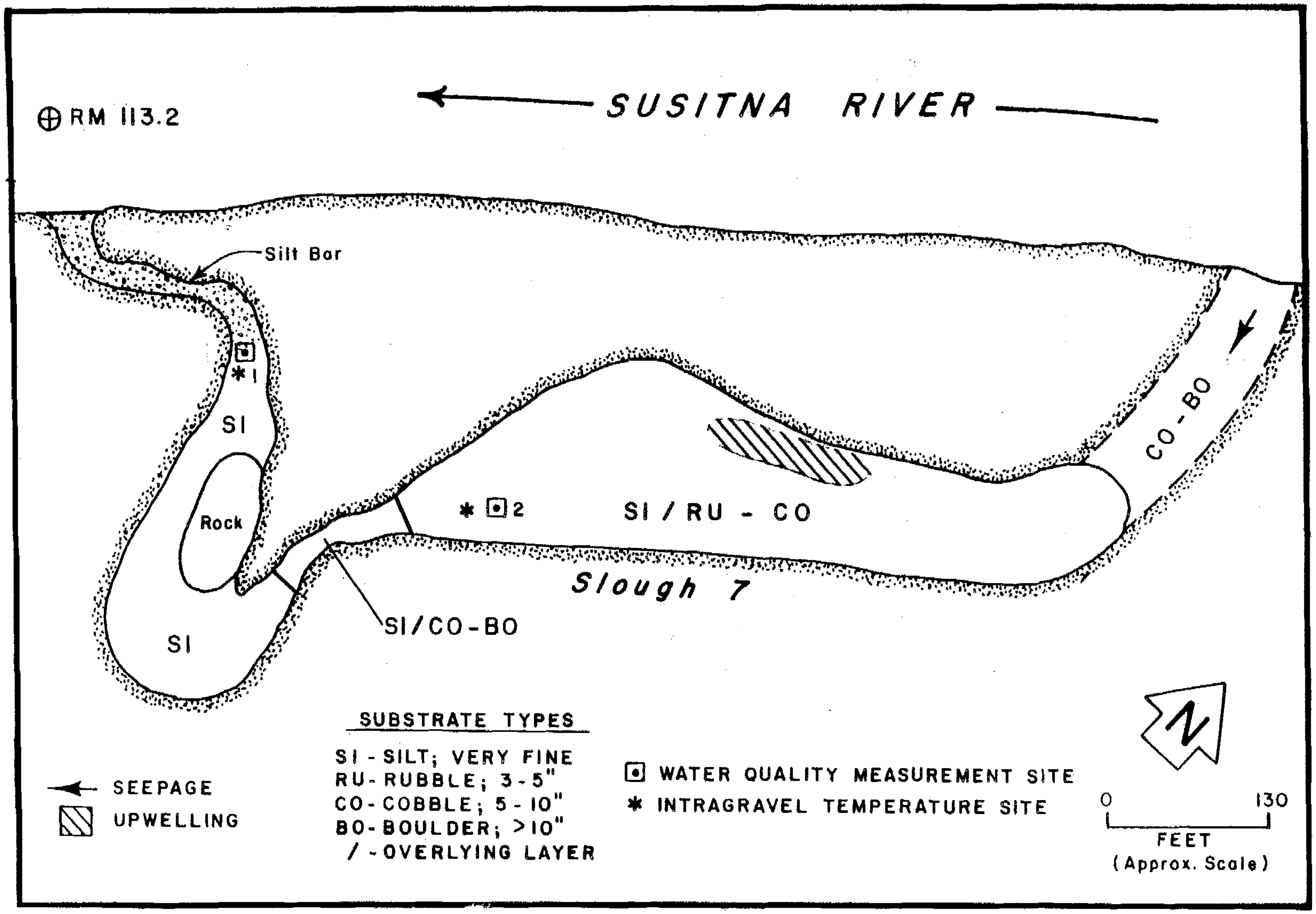
Appendix Figure A-18. Sampling sites and chum salmon spawning areas in Oxbow I side channel (RM 110.0L).



Appendix Figure A-19. Substrate composition and bank seepage areas in Slough 6A (RM 112.3L).



Appendix Figure A-20. Sampling locations in Slough 6A (RM 112.3L).



Appendix Figure A-21. Substrate composition, sampling locations, and upwelling areas in Slough 7 (RM 113.2R).

Slough 8 (RM 113.7R)

Slough 8, also called Lane Creek Slough, is an 0.5 mile long side slough adjacent to the ARR at RM 113.7R. Substrates appear to be rubble/cobble with sections of large gravel/small gravel in the upper reach and thin silt/sand deposits in the lower reach (Appendix Figure A-22). Extensive areas of upwelling along the right bank and surface inputs via a remnant channel from Lane Creek occur in the lower half of the slough (Appendix Figure A-23). A culvert under the Alaska Railroad channels surface runoff into the slough.

A number of riffles exist which could possibly inhibit fish passage. The primary passage barrier at low discharges, appears to be a sand bar at the mouth. Backwater effects, apparently related more to a hydraulic plug caused by the creek discharge than mainstem discharge, will have a modifying effect on this passage reach but not those beyond it.

Spawning occurs in areas associated with pockets of large gravel/rubble substrate as well as having evidence of upwelling (Appendix Figures A-24 and A-25).

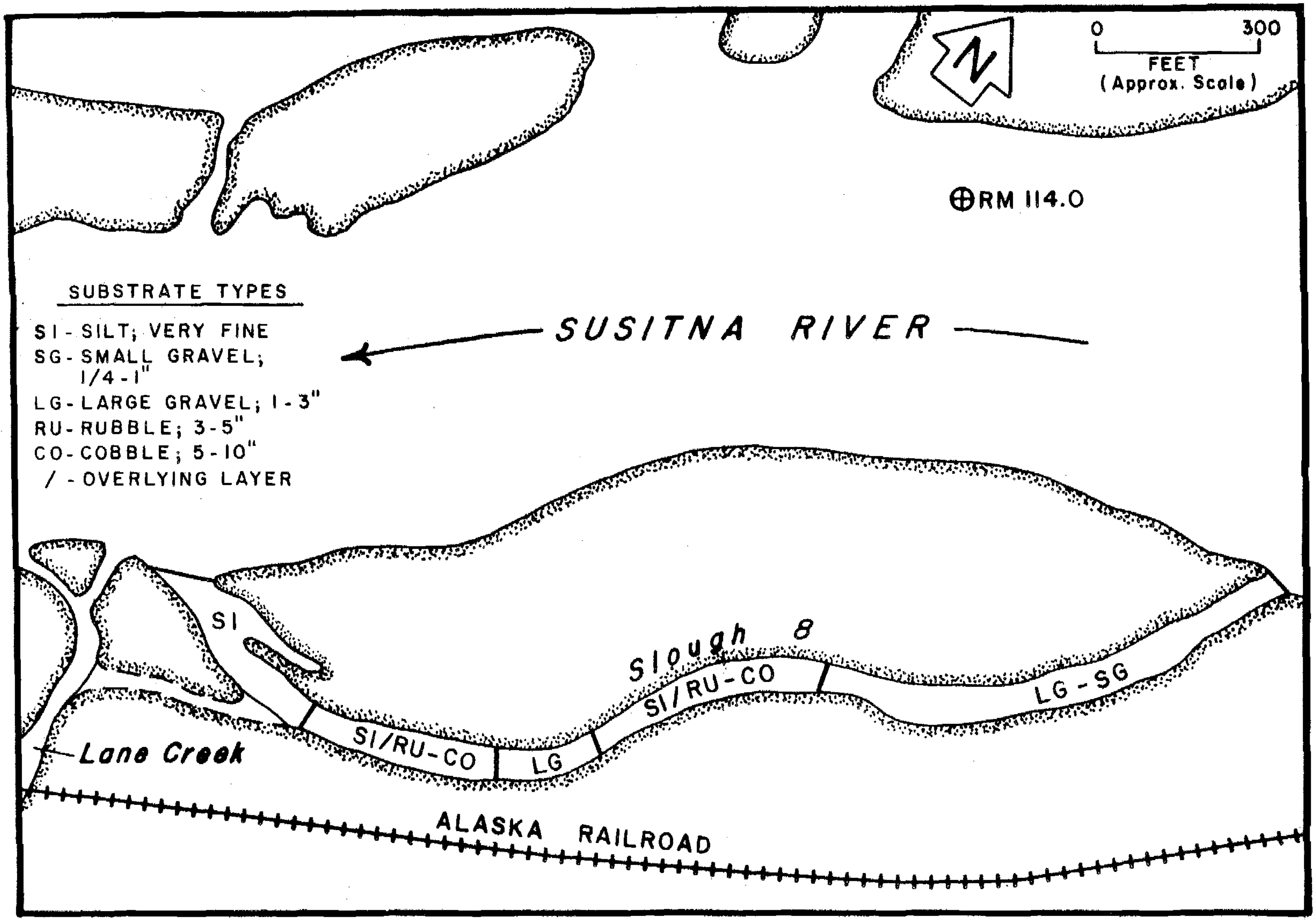
At present, passage and substrate appear to be limiting spawning in this site. Due to strong upwelling and bank seepage, presence of areas of suitable substrate, and its close proximity to the ARR, this would be a good candidate for further study as a mitigation site.

Mainstem Two (RM 114.5R)

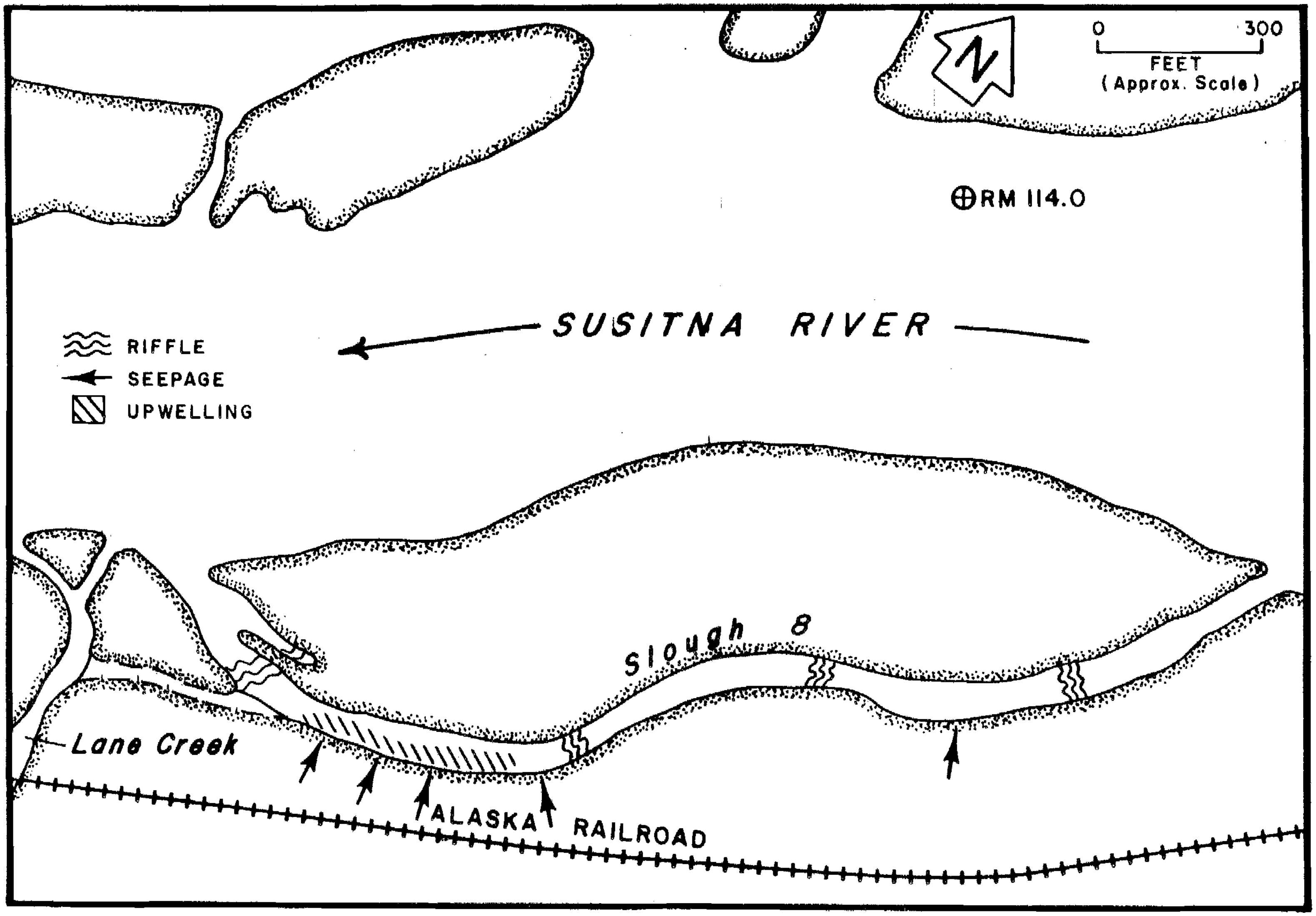
Mainstem Two is a one mile long Y-shaped side channel located one mile upstream of Lane Creek (Appendix Figure A-26). The side channel is separated from the mainstem Susitna River by a large vegetated island. The east and west channels are 4,400 and 2,800 feet long respectively and merge approximately 1,600 feet upstream of the mouth. The east fork has a breaching discharge of 25,000 cfs while the west fork breaches at 16,000 cfs. Downstream of the confluence of the east and west channel, Mainstem Two is a backwater area and a series of pools and riffles throughout both forks upstream. Substrate in the backwater area is deep silt/sand over boulder except in the extreme upper portions where there are pockets of rubble/large gravel (Appendix Figure A-27). The remainder of the side channel has well cemented cobble/boulder substrates with rubble/large gravel substrate in the pool areas. There is moderate bank seepage and upwelling from both banks in the backwater and in the east fork. During unbreached conditions, mainstem water may flow intragravelly through the head of both forks.

Passage to upper spawning areas becomes a problem in an unbreached condition (Appendix Figure A-28). A complete analysis of passage into and within the slough can be found in Blakely et al. 1985 and Sautner et al. 1984. Mainstem Two historically has been a chum salmon spawning habitat. In 1984, the total peak count for the site was 134 fish. The extent of salmon spawning can be seen in Appendix Figure A-29.

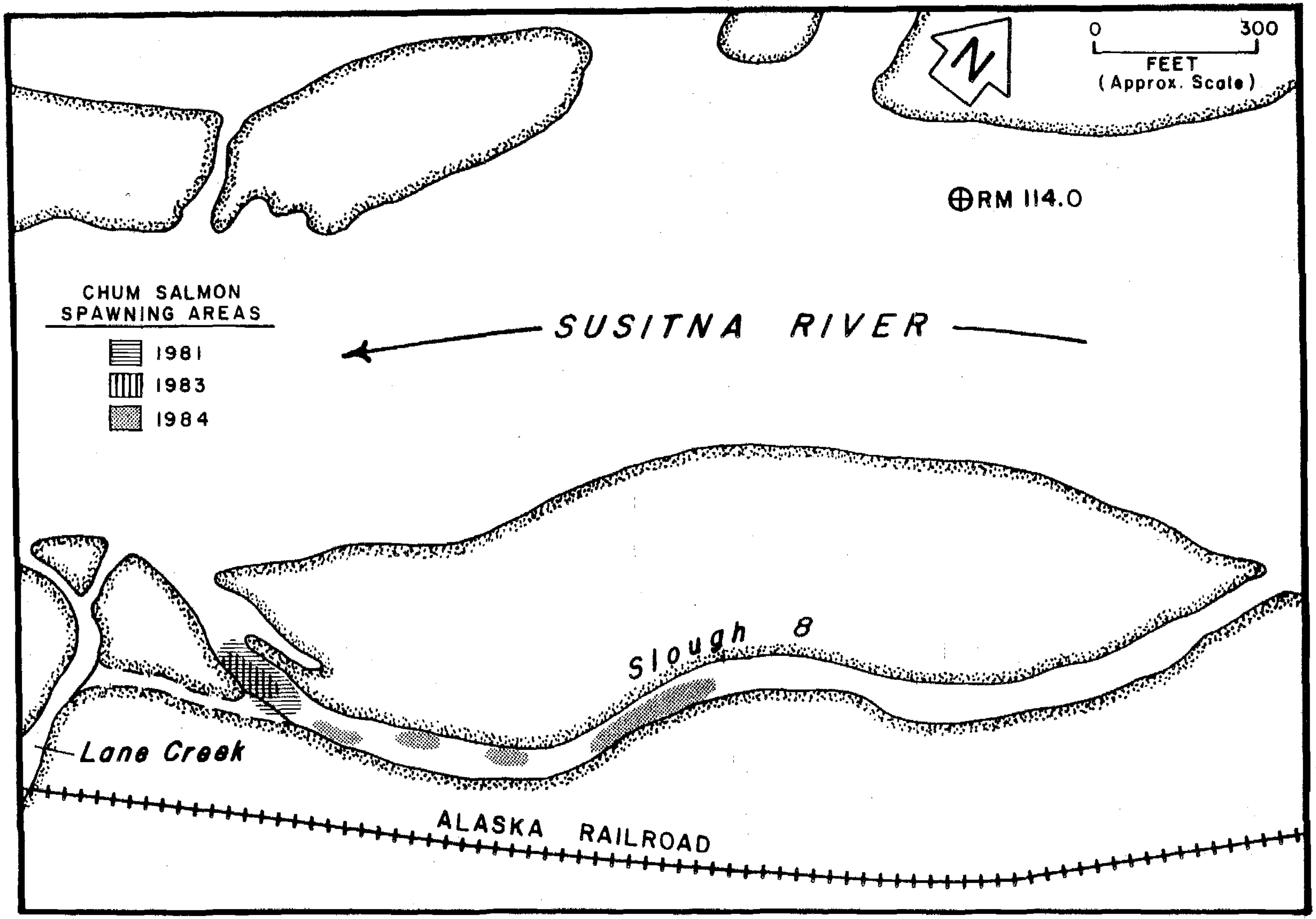
Passage, substrate and dewatering of redds at low mainstem discharges are the primary problems limiting spawning in this site.



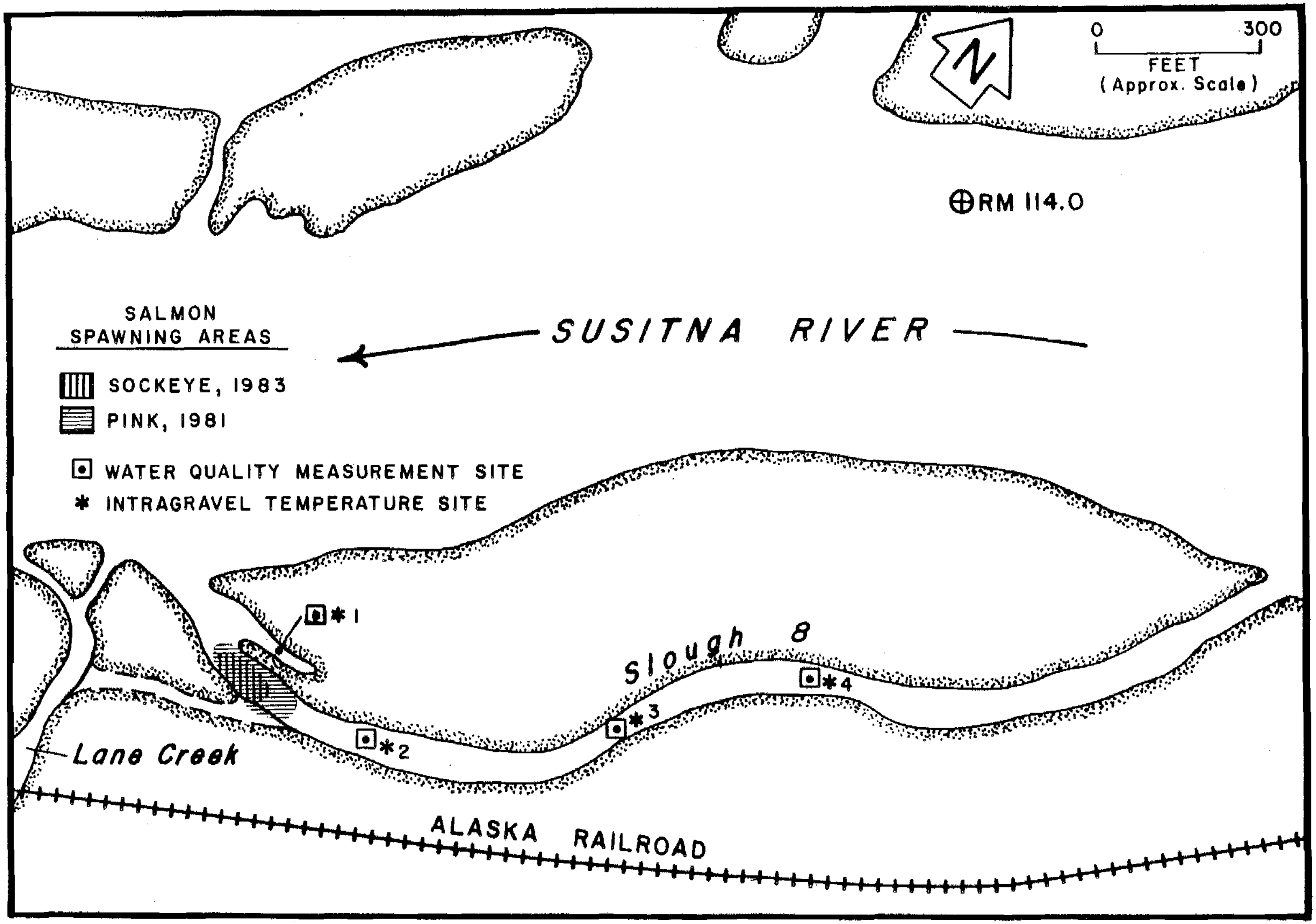
Appendix Figure A-22. Substrate composition of Slough 8 (RM 113.7R).



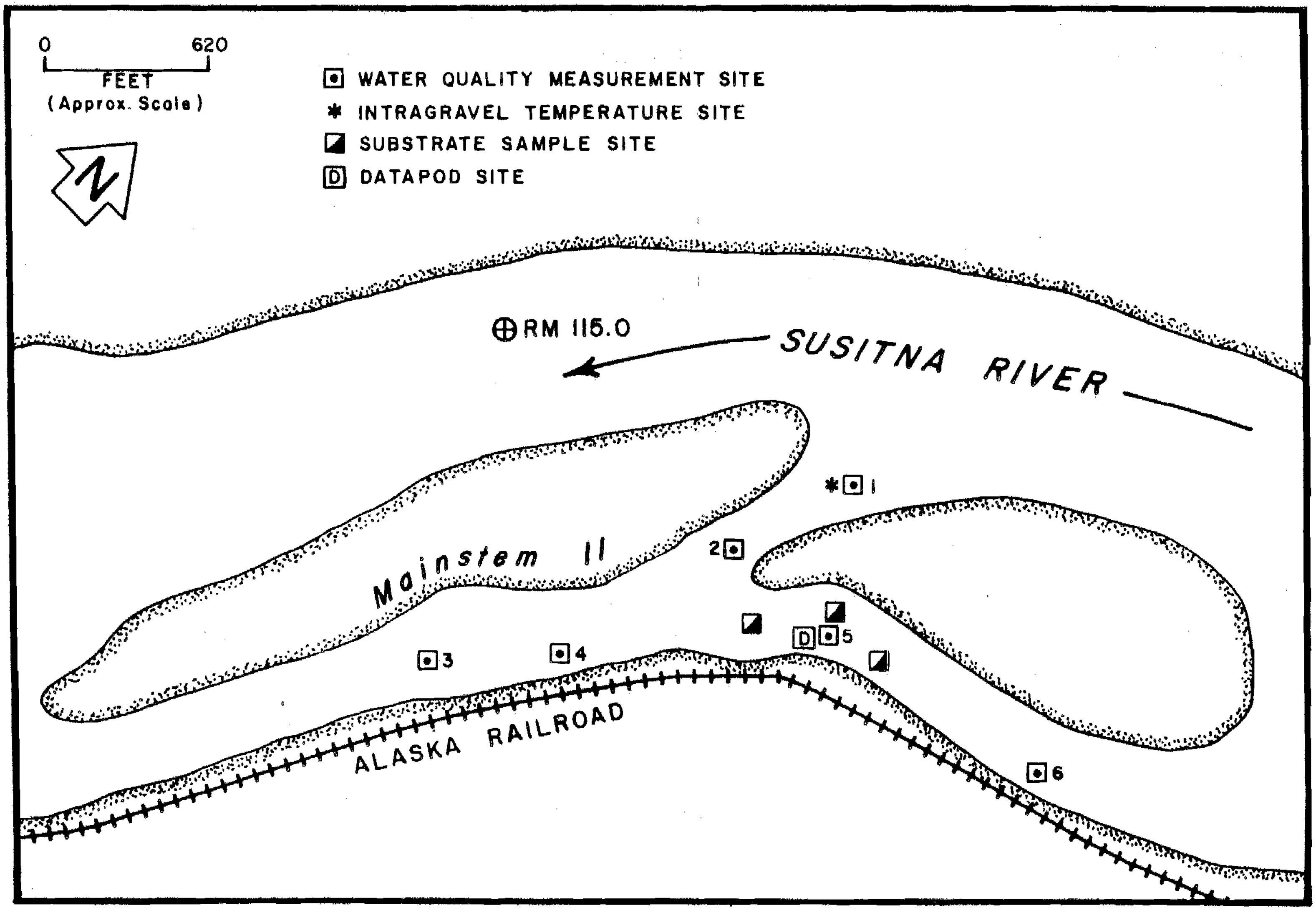
Appendix Figure A-23. Upwelling and bank seepage areas in Slough 8 (RM 113.7R).



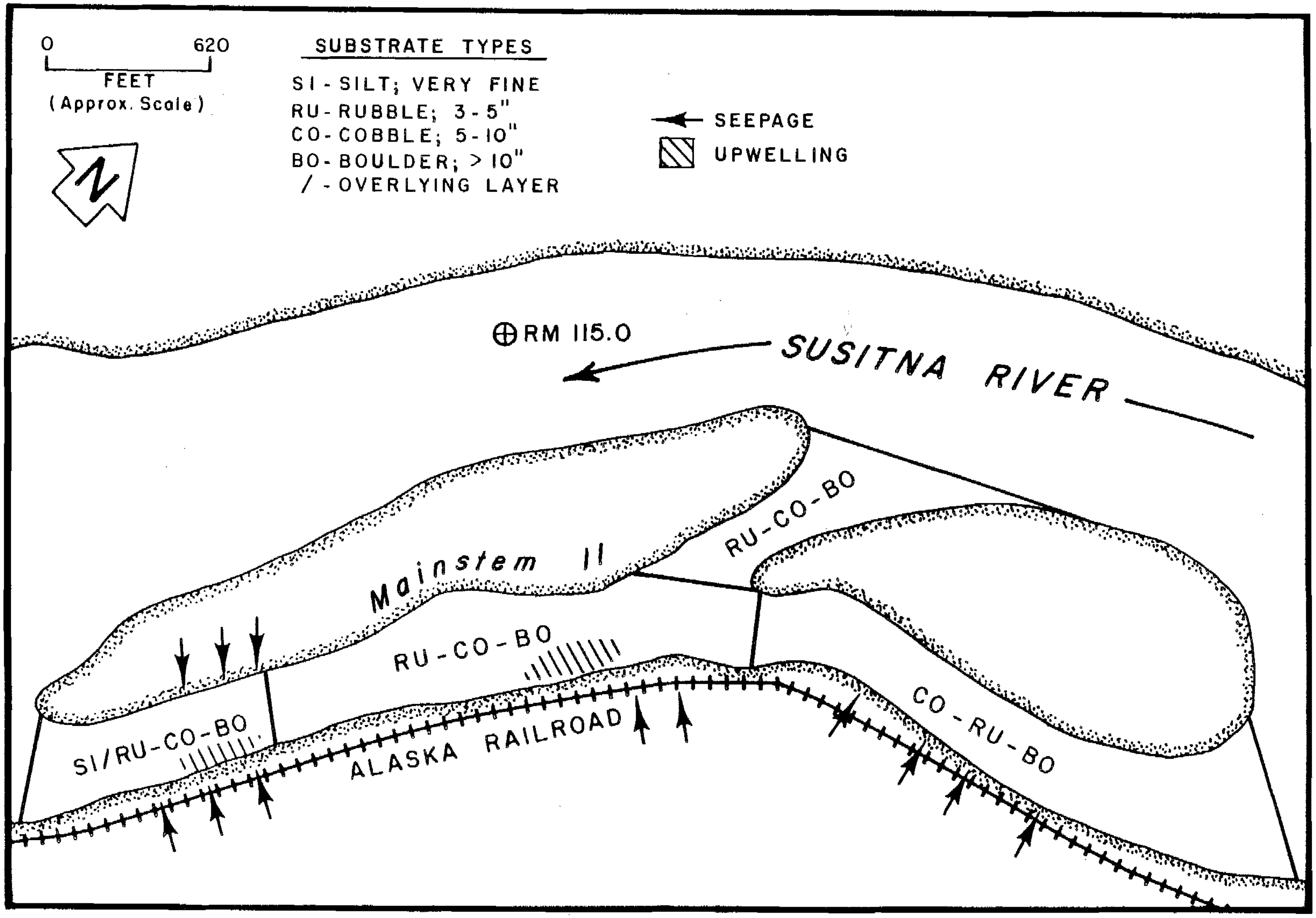
Appendix Figure A-24. Chum salmon spawning areas in Slough 8 (RM 113.7R).



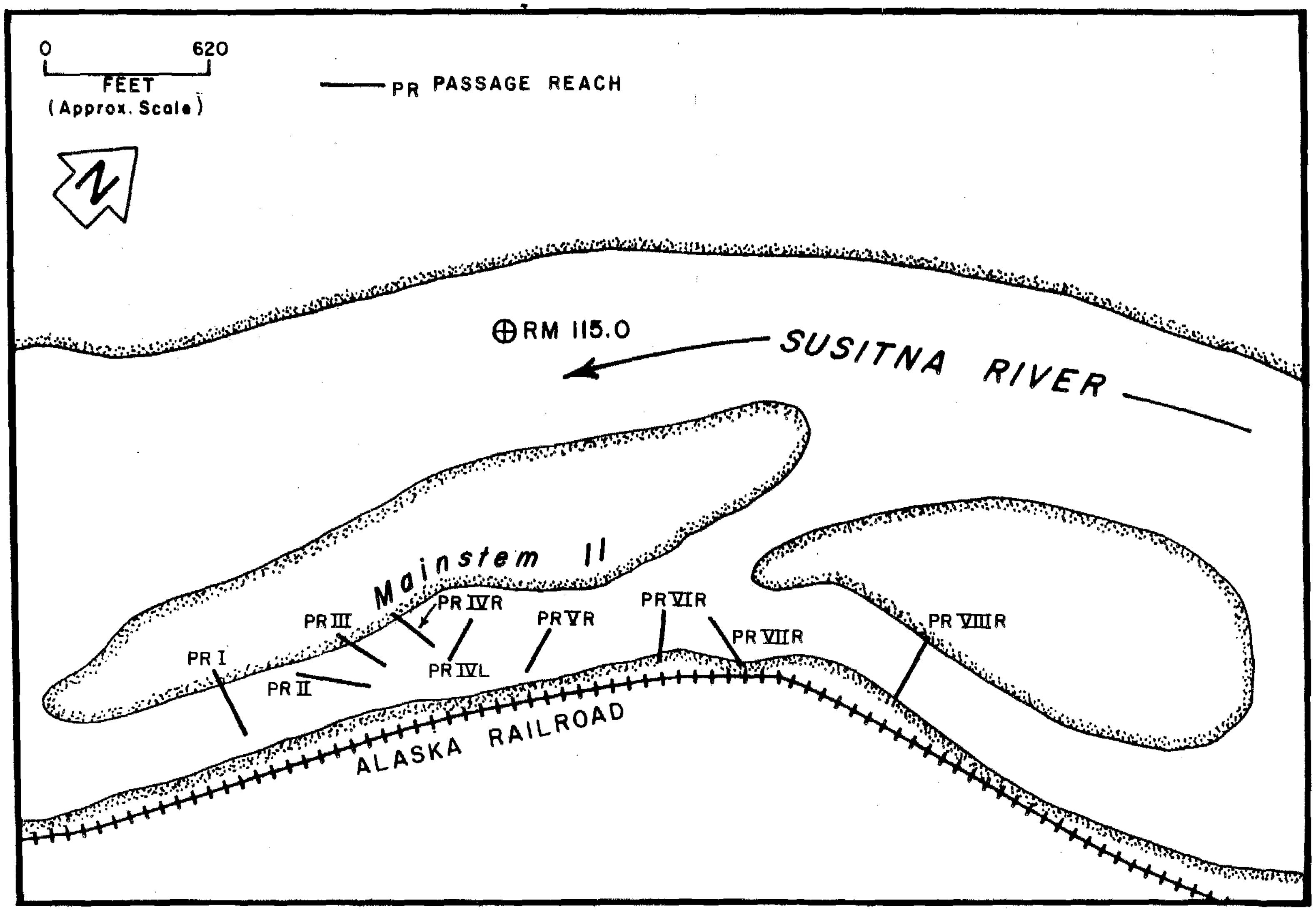
Appendix Figure A-25. Sockeye and pink salmon spawning areas and sampling locations in Slough 8 (RM 113.7R).



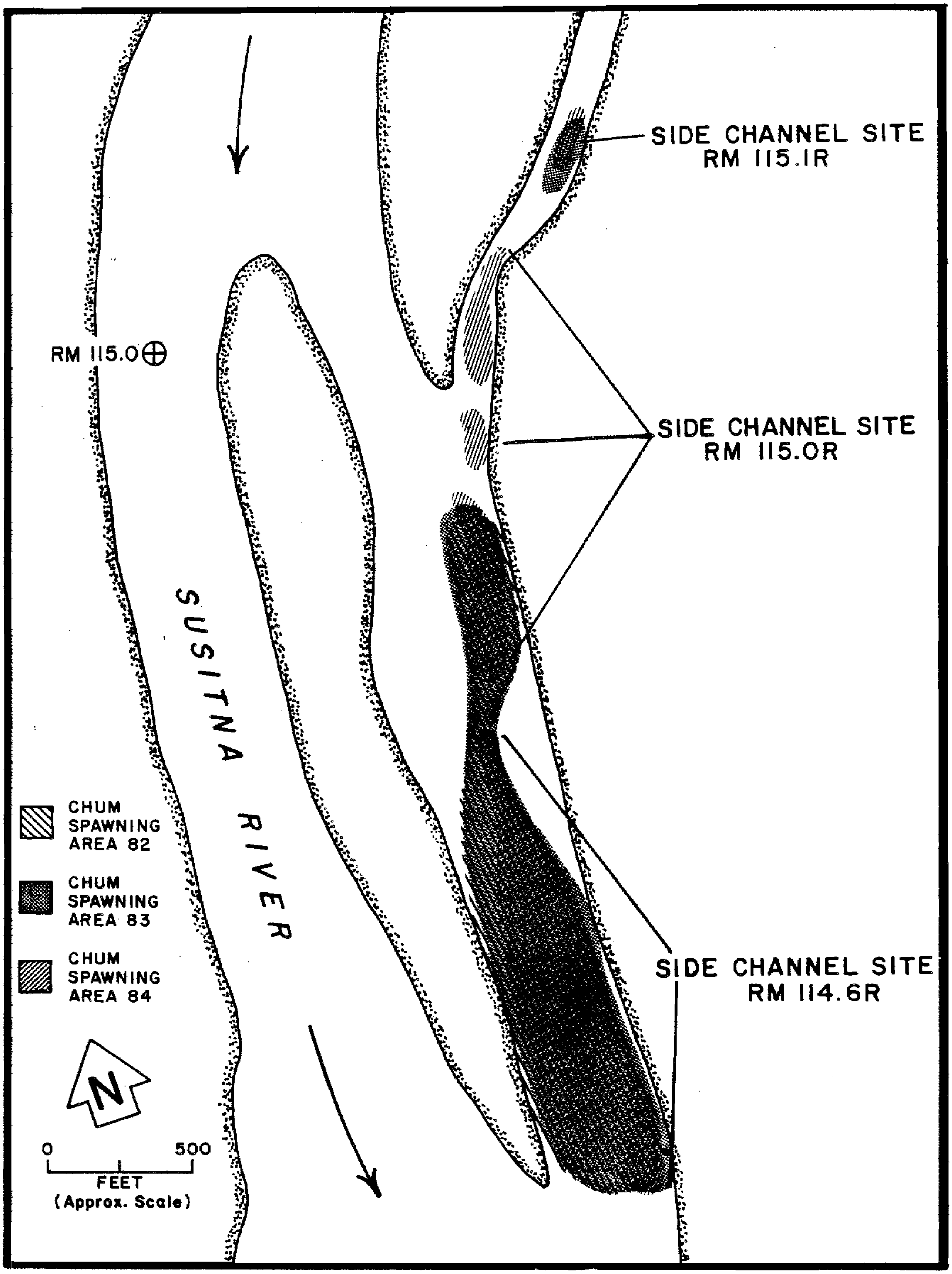
Appendix Figure A-26. Channel geometry and sampling sites in Mainstem Two Side Channel (RM 114.5R).



Appendix Figure A-27. Substrate composition and bank seepage areas in Mainstem Two Side Channel (RM 114.5R).



Appendix Figure A-28. Passage reaches in Mainstem Two Side Channel (RM 114.5R).



Appendix Figure A-29. Chum salmon spawning areas in Mainstem Two Side Channel (RM 114.5R).

Bushrod Slough (RM 117.9L)

This is a 2,000 foot long S-shaped side slough on the west side of the Susitna River at RM 117.9L (Appendix Figure A-30). The slough is composed of a bedrock based backwater area followed by a pool riffle sequence. The head is a cobble-boulder berm. Substrate in both pools is primarily large gravel/rubble with the upper pool containing a greater percentage of silt and having a greater degree of cementation than the lower pool. The riffle between the two pools is primarily well cemented rubble-cobble substrate (Appendix Figure A-31). A small tributary, draining a bog area, enters the left bank at the mouth. Four foot high banks border both sides of the slough.

In the 9,000 cfs to 12,000 cfs range, the backwater is tannin stained to clear, indicating a greater slough influence than mainstem. At mainstem discharges above 12,000 cfs the backwater is turbid. Upwelling and bank seepage seem to be the driving hydraulic force in the slough in an unbreached state (Appendix Figure A-31). The limited right bank upwelling and bank seepage in the upper pool appears more directly related to mainstem discharge than an independent groundwater influence. As mainstem discharge drops in the fall, upwelling stops and the pool will gradually dewater and freeze prior to the river staging. The lower pool is greater than 3 feet deep in places and appears to be maintained by upwelling and bank seepage. While upwelling was only visible along the left bank, it is strongly suspected that it is present along the right bank as is evidenced by the presence of an open lead, temperature data and spawning activity.

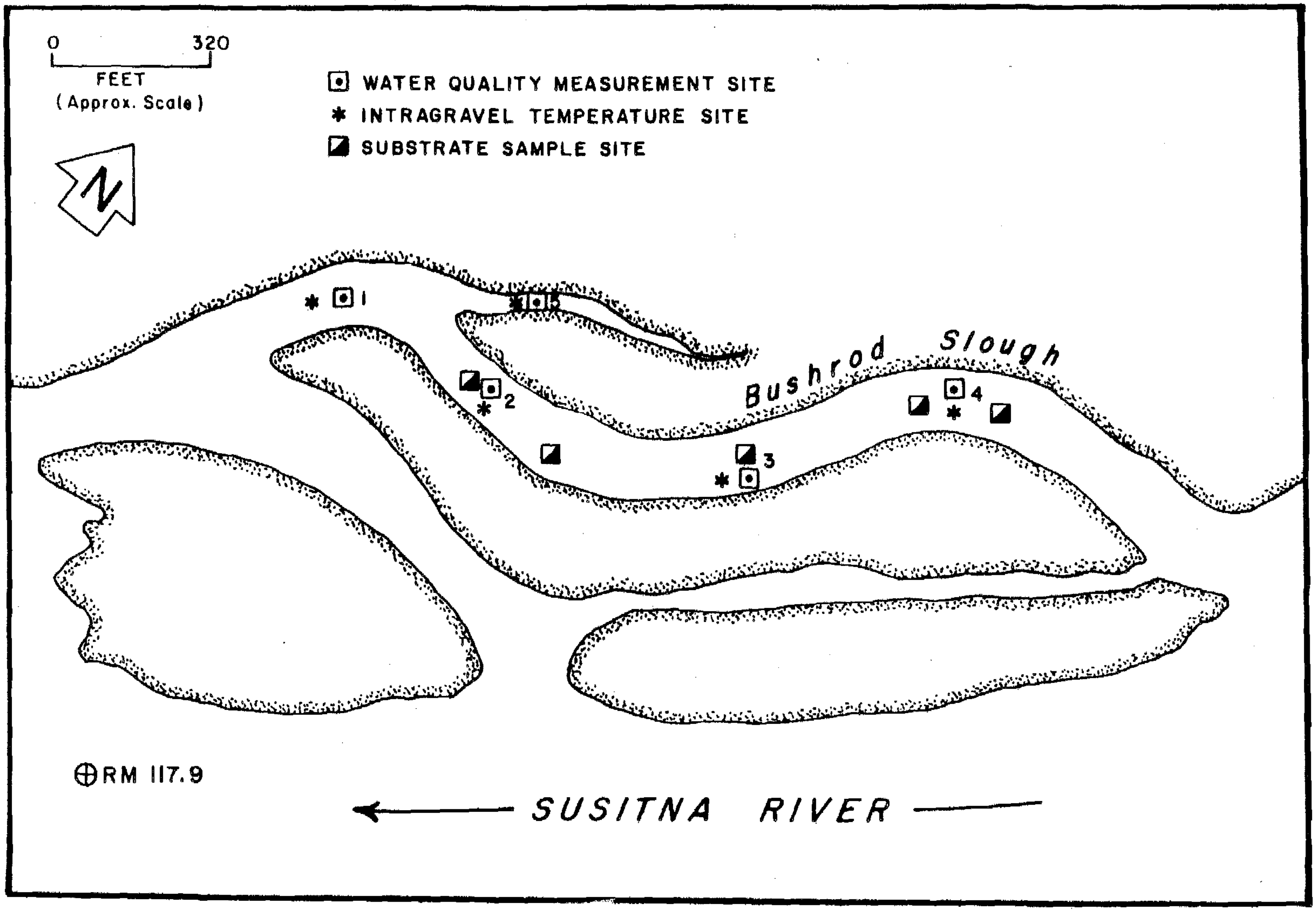
In the 9,000 cfs to 12,000 cfs range, two major passage problems exist, a 50 foot riffle that separates the backwater from the first pool and a 175 foot riffle separating the two pools (Appendix Figure A-32). The passage restriction at the riffle between the two pools is prevalent during unbreached conditions while the passage restriction at the mouth becomes evident only below 12,000 cfs.

According to Barrett et al. 1985, peak counts of 10 pink salmon and 90 chum salmon were observed in the slough. Chum salmon spawned extensively throughout the lower pool and did not utilize the upper pool, even when passage was possible during breached conditions (Appendix Figure A-32). Chum salmon were first observed spawning in this site during 1984. Fry were observed in both pools during 1984. Numerous chum salmon fry, from 1984 spawning, were observed in the lower pool during the spring of 1985.

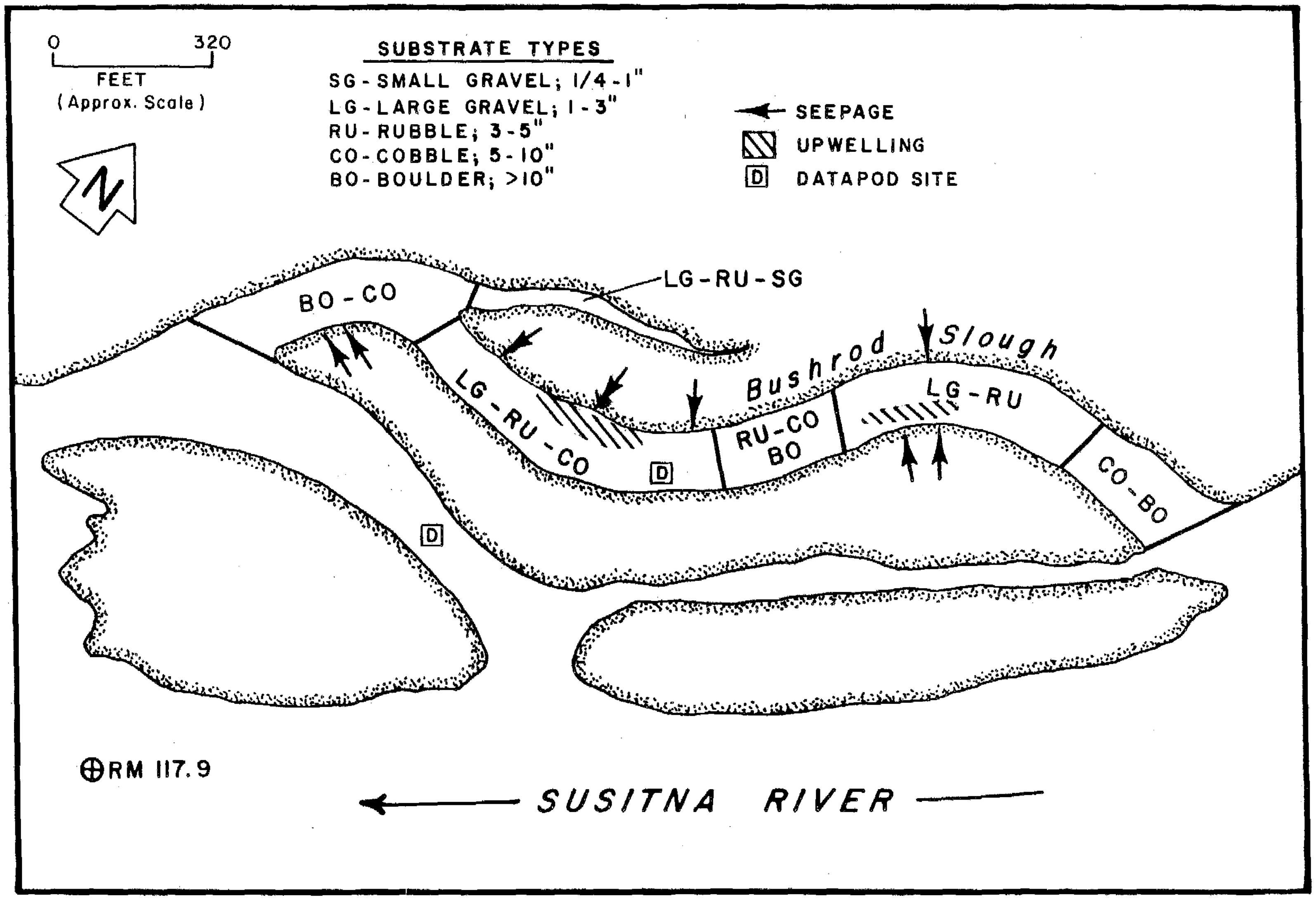
Problems limiting spawning at this site are passage, substrate and limited upwelling in the upper pool.

Curry Slough (RM 119.7R)

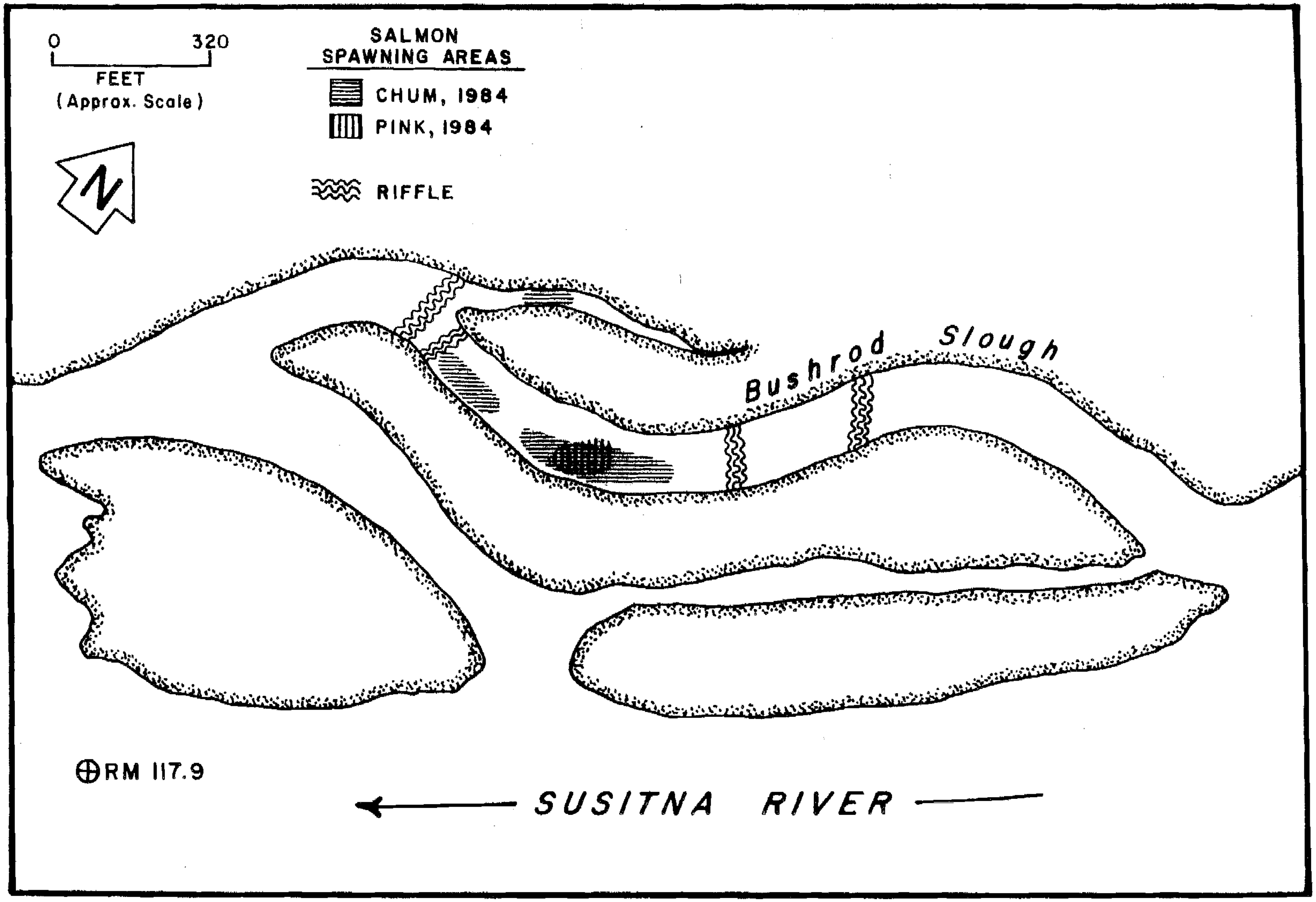
Curry Slough, a former side channel located on the east side of the Susitna River, is approximately two miles downstream of the Alaska Railroad (ARR) Curry Station. The ARR constructed a 10 foot high berm across the head to prevent erosion of the ARR tracks that parallel the right bank of the slough. This berm, which prevents overtopping of the



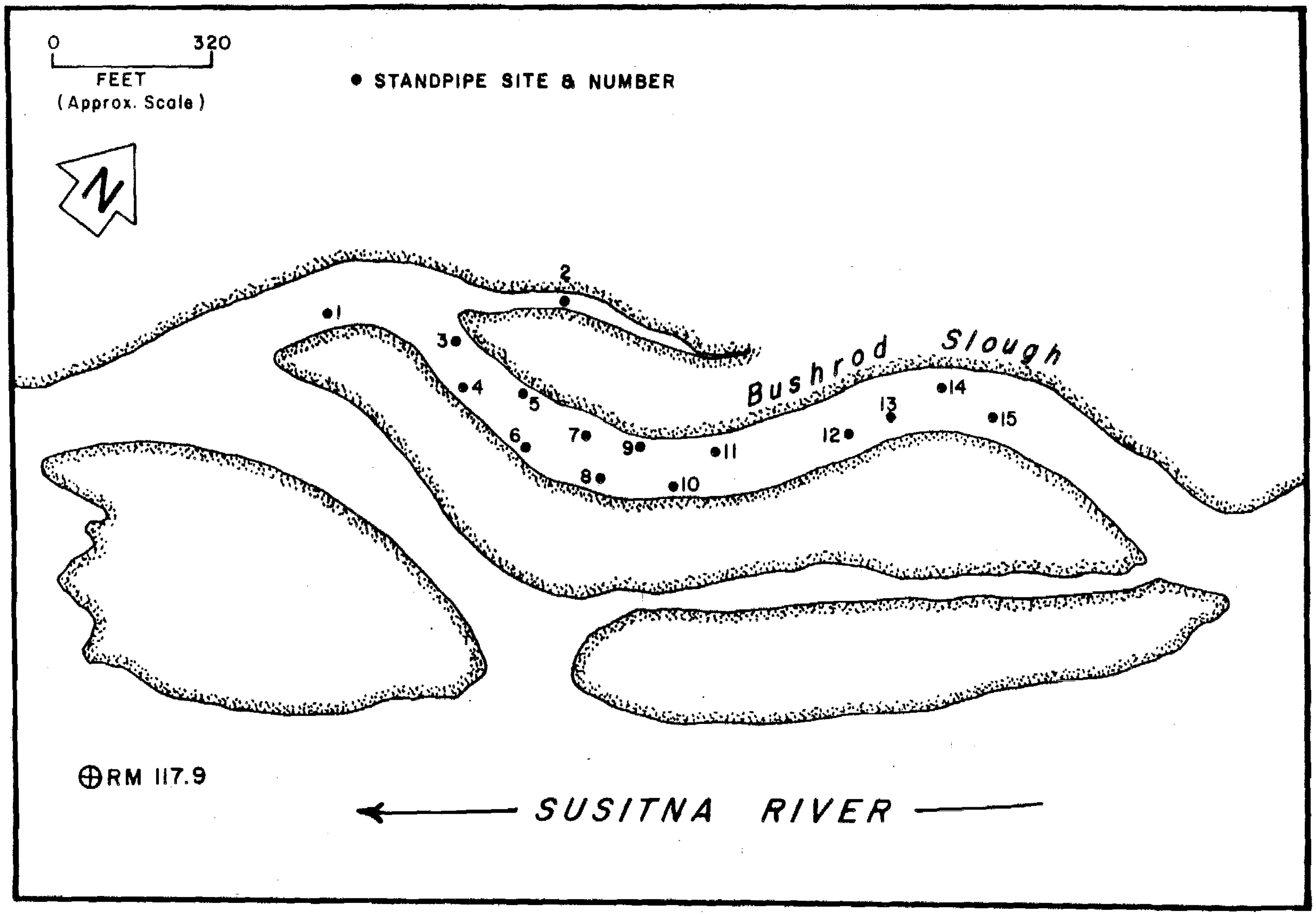
Appendix Figure A-30. Channel geometry and sampling locations in Bushrod Slough (RM 117.9L).



Appendix Figure A-31. Substrate composition and upwelling areas in Bushrod Slough (RM 117.9).



Appendix Figure A-32. Chum and pink salmon spawning areas in Bushrod Slough (RM 117.9).



Appendix Figure A-33. Standpipe locations in Bushrod Slough (RM 117.9L).

head, changed the characteristics of the site to those more closely associated with upland sloughs.

The right bank is a 10 foot high embankment that serves as the roadbed for the ARR. The left bank is a low lying vegetated gravel bar. The slough is a 600 foot long run followed by a 700 foot long pool. Three riffles are present at the mouth, between the run and pool and from the head of the pool to the berm (Appendix Figure A-34). The substrates throughout the site are primarily rubble/cobble covered by a layer of silt that may reach up to two feet thick in places (Appendix Figure A-35).

At low mainstem discharges, the lower run dewaters indicating it may be directly related to changes in mainstem discharges. The pool habitat, which is 3 to 4 feet deep in places, is apparently maintained through upwelling and bank seepage occurring at the head of the slough (Appendix Figure A-35).

During 1984, a peak count of 8 chum salmon were observed in this slough (Barrett et al. 1985). This is the first observed use of this site by chum salmon with two redds resulting (Appendix Figure A-34). Fry have also been observed throughout the site.

Problems limiting spawning in this site are passage (primarily from the mouth to the base of the upper pool) and substrate (large substrate and excessive siltation).

<u>Slough 8C RM 121.8R)</u>

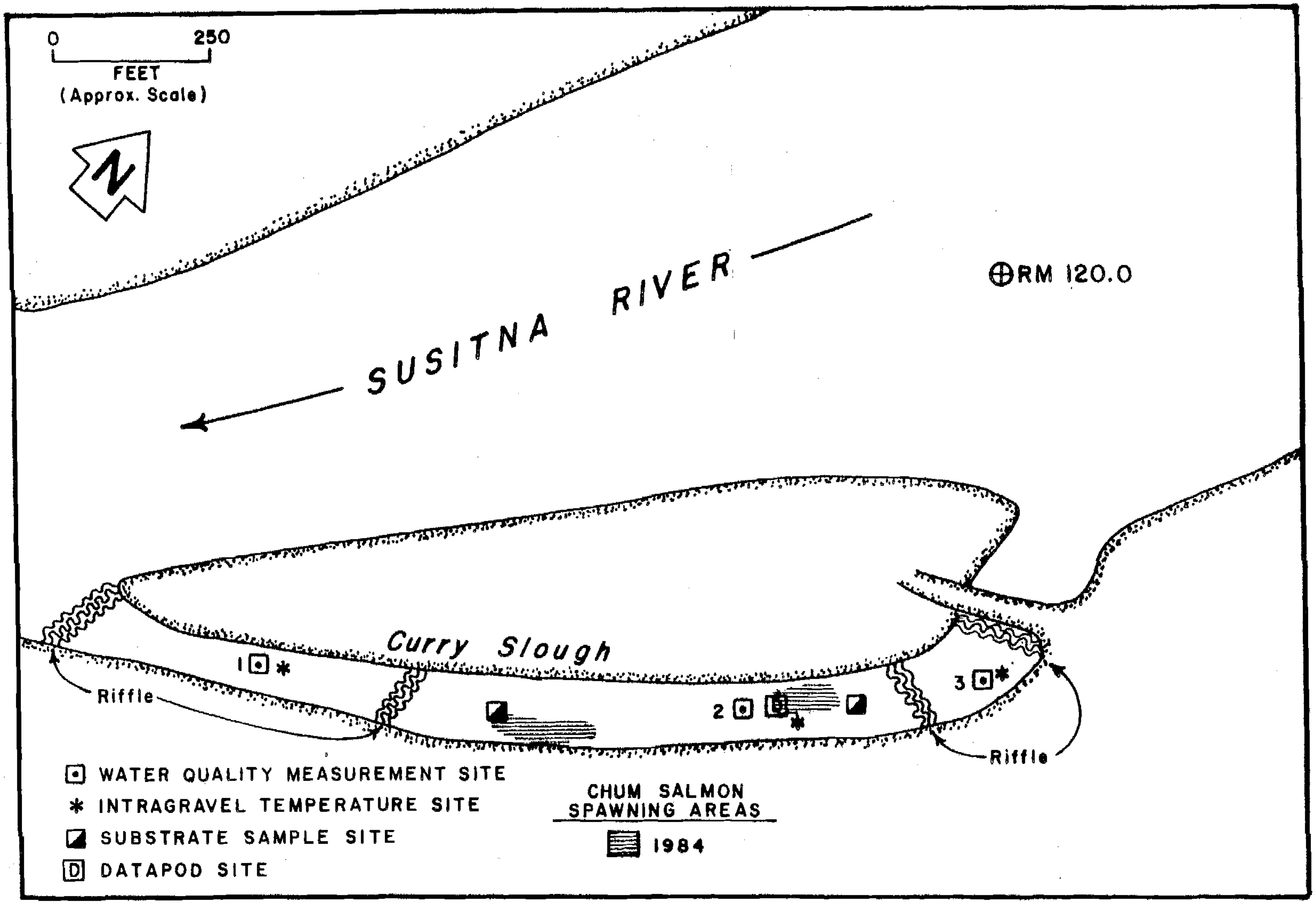
Slough 8C is a 1,600 foot side slough on the east side of the Susitna River with a low lying head that is frequently breached. A small clear water creek enters the right bank of the slough about 300 feet from the head. Upwelling is present in the proximity of this creek as well as in the upper third of the slough (Appendix Figure A-37). The lower half of the slough is a turbid backwater at most discharges. The substrate throughout this slough is a fairly uniform rubble/large gravel covered with a thin layer of sand. Large gravel/small gravel deposits exist in the upper half of the slough. A silt/sand bar becomes evident in the mouth area at low discharges which is the only apparent potential passage problem (Appendix Figure A-38). At this time a 100 foot riffle forms which may be restrictive to passage.

All spawning that has been noted in Slough 8C has been in close relationship to the areas of upwelling (Appendix Figure A-39), primarily in the upper half of the slough. Limited spawning also occurs along the right bank in the lower half.

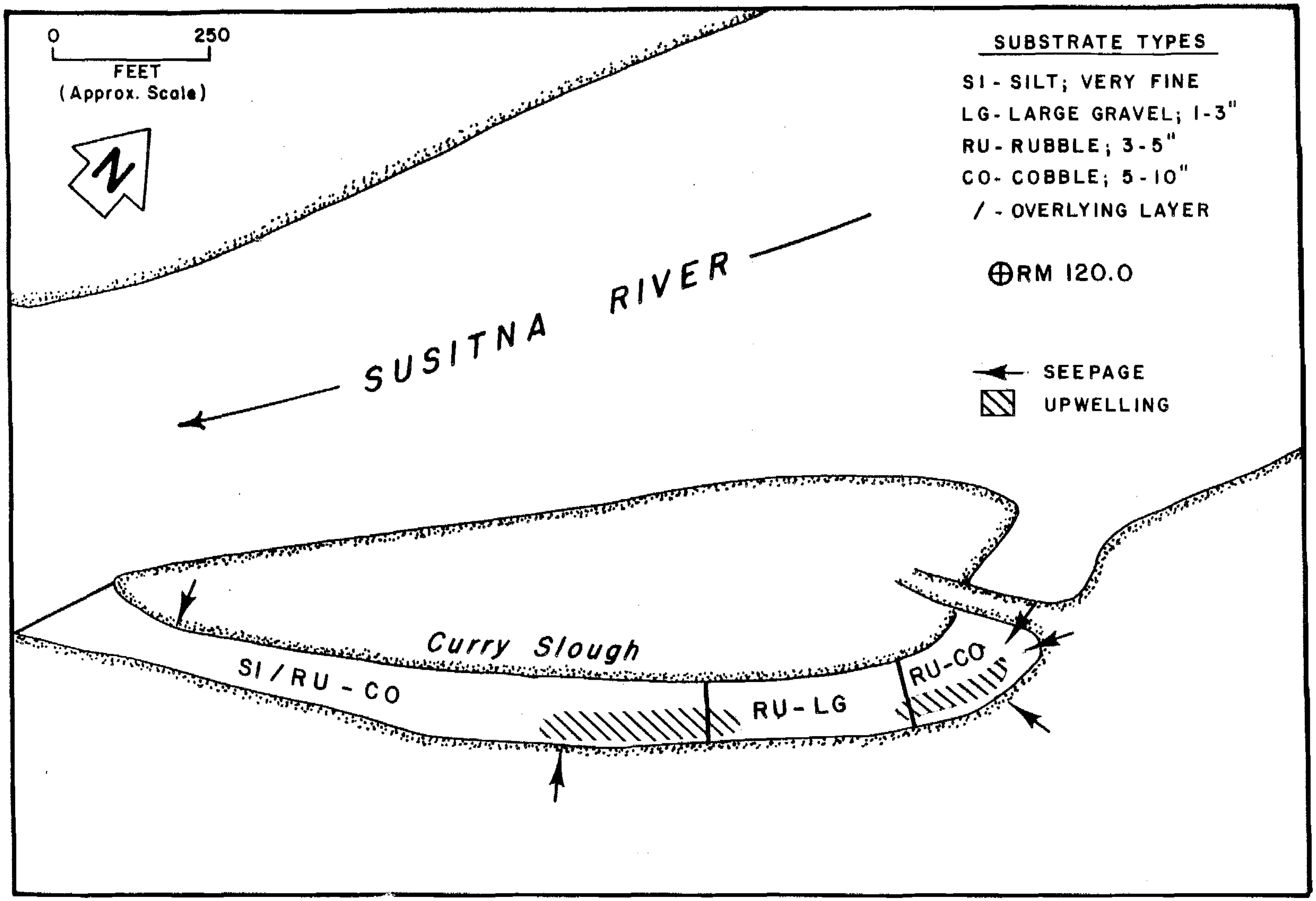
Problems limiting spawning are passage at low discharges, substrate, and limited upwelling.

<u>Slough 8D (RM 121.8R)</u>

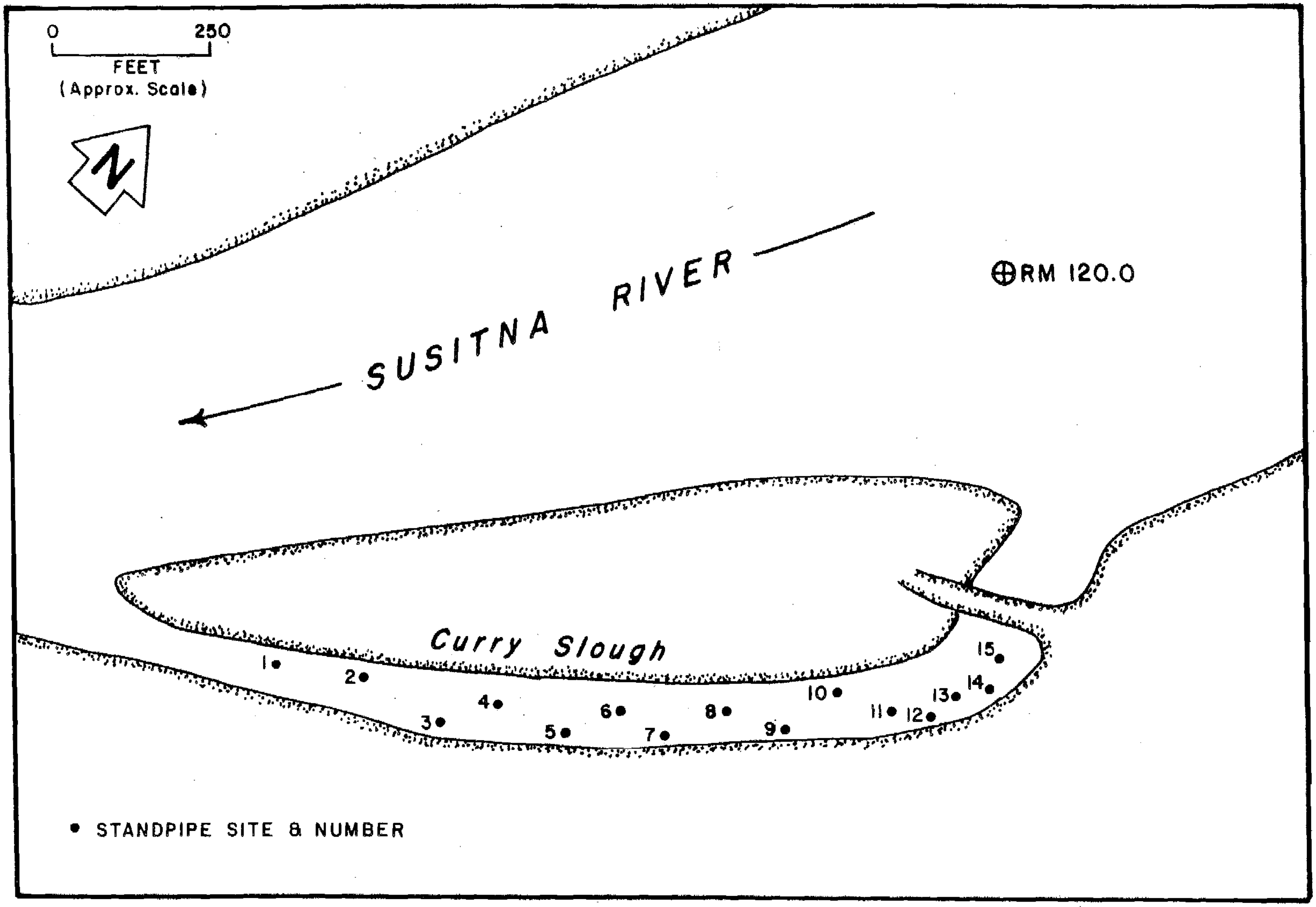
This upland slough enters the mainstem Susitna River immediately downstream of the mouth of Slough 8C. It runs roughly parallel to the



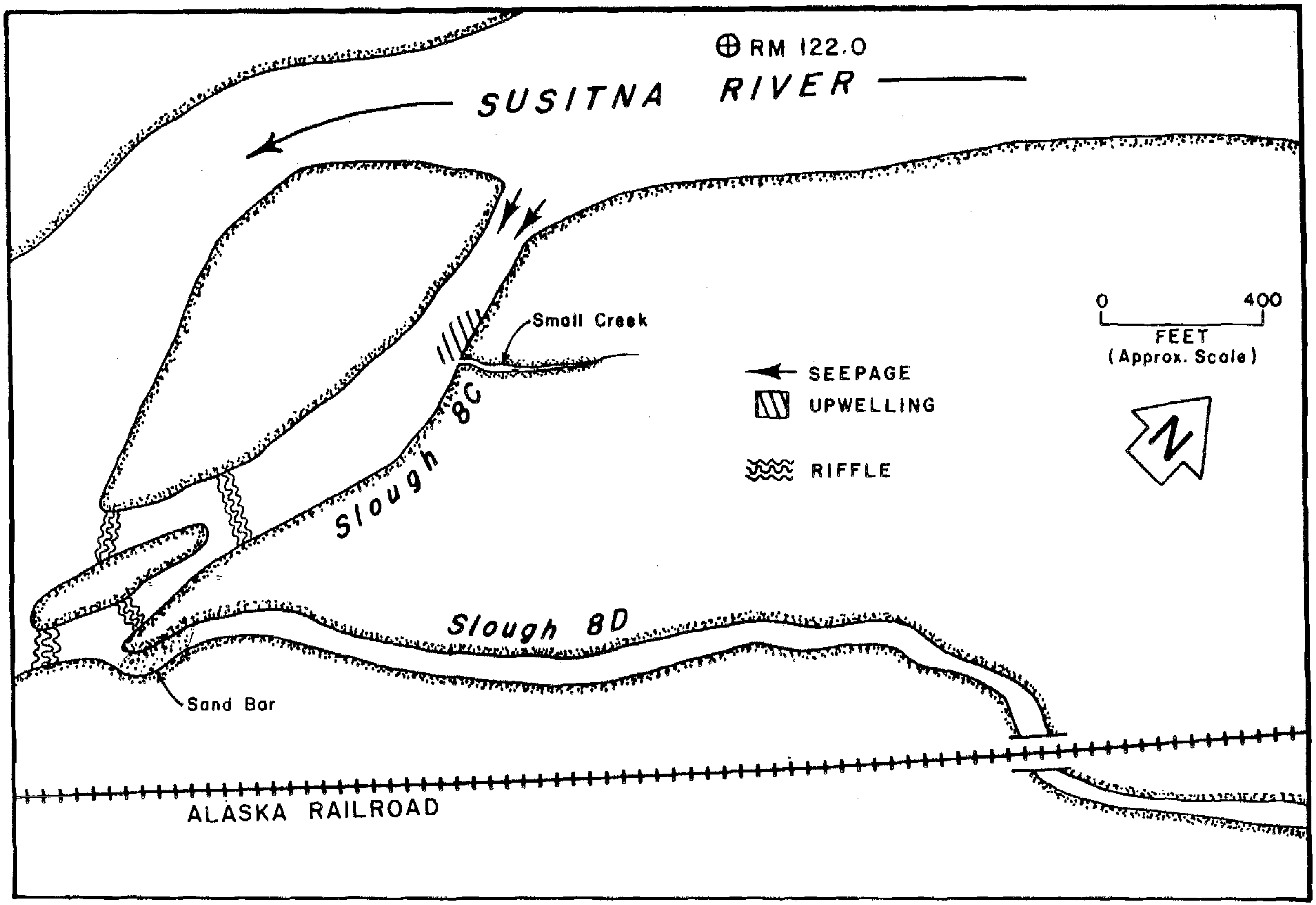
Appendix Figure A-34. Channel geometry, sampling locations, and chum salmon spawning areas in Curry Slough (RM 119.7R).



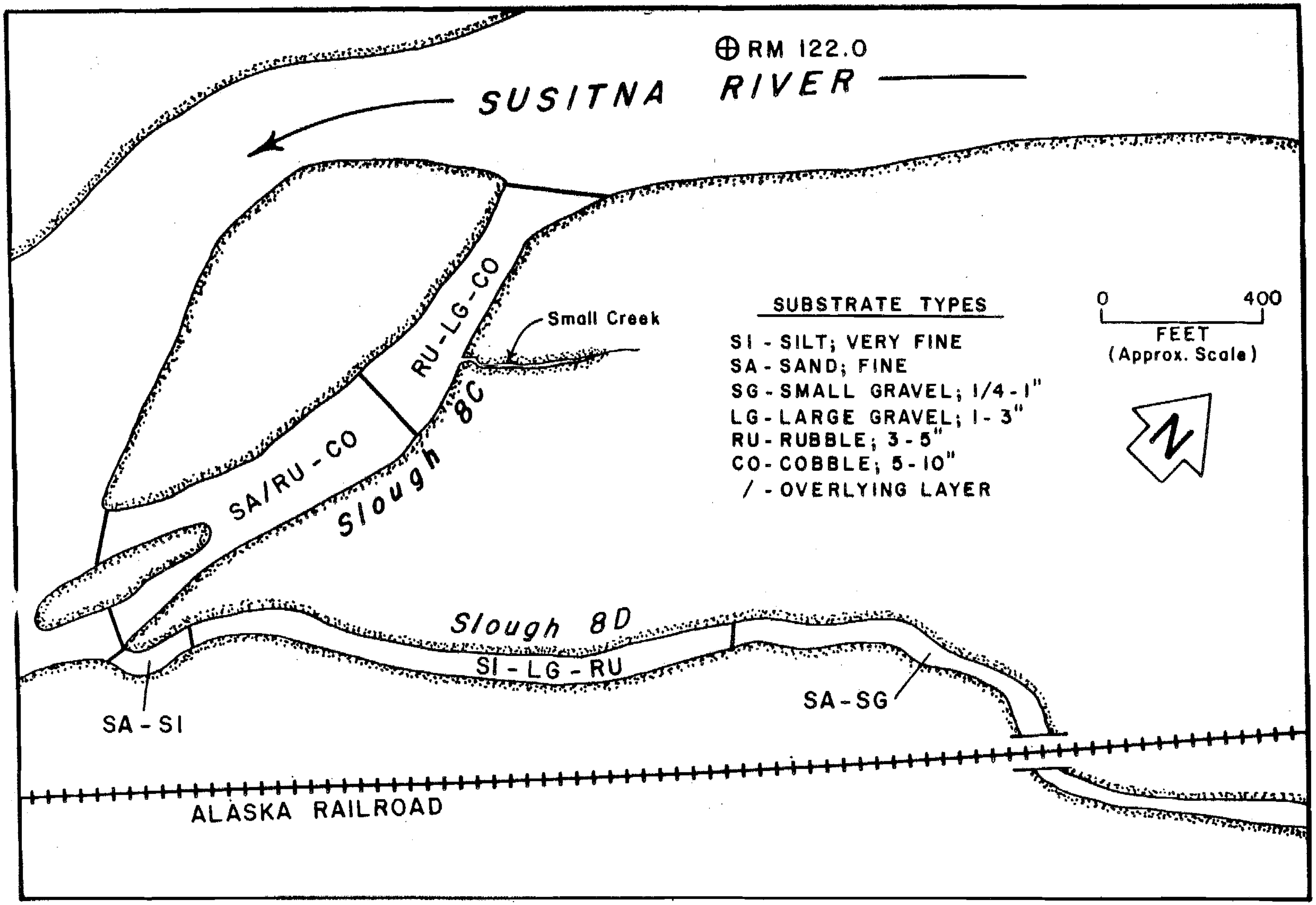
Appendix Figure A-35. Substrate composition and upwelling areas in Curry Slough (RM 119.7R).



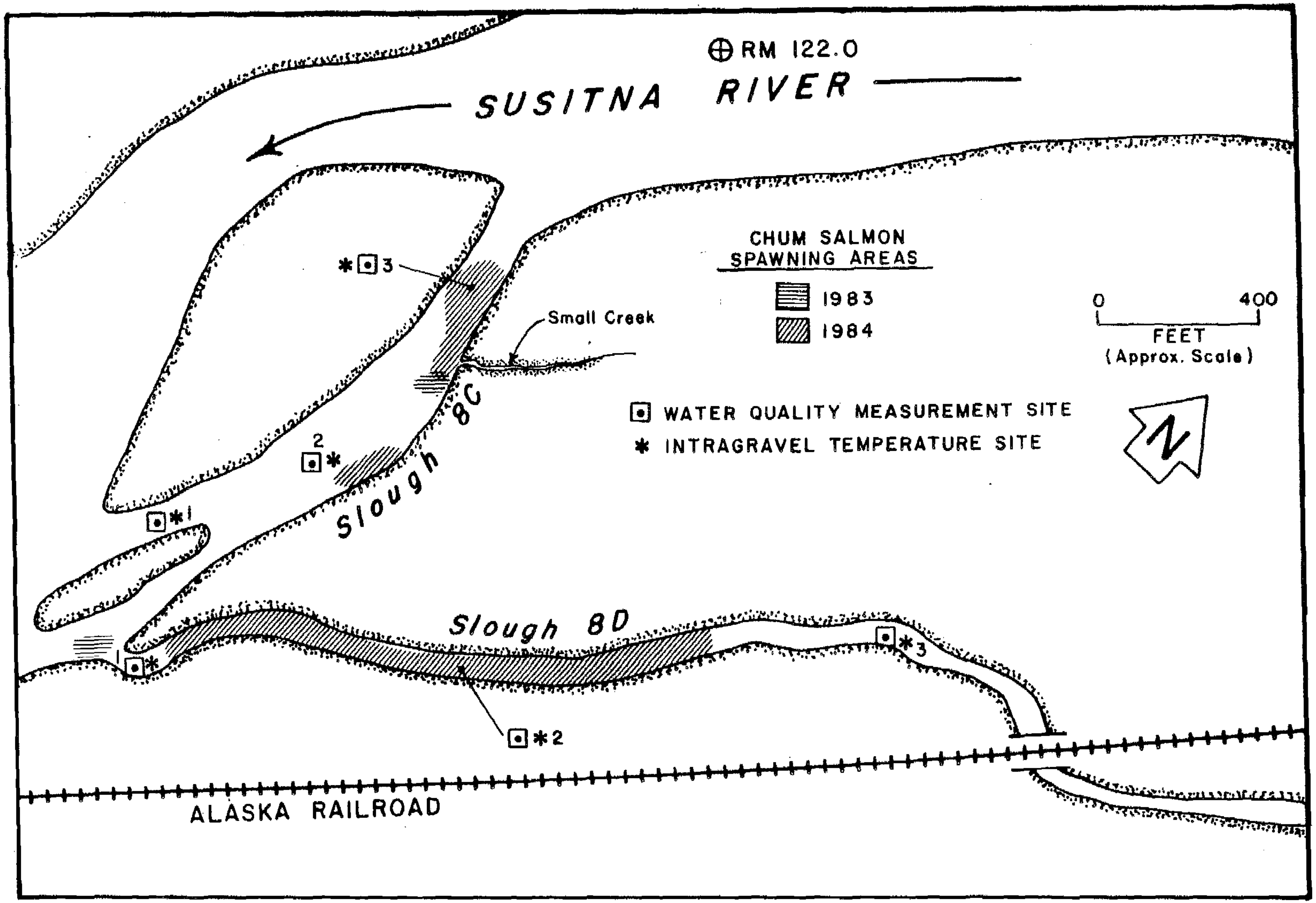
Appendix Figure A-36. Standpipe locations in Curry Slough (RM 119.7R).



Appendix Figure A-37. Channel geometry and upwelling areas in Slough 8C (RM 121.8R) and Slough 8D (RM 121.8R).



Appendix Figure A-38. Substrate composition in Slough 8C (RM 121.8R) and Slough 8D (RM 121.8R).



Appendix Figure A-39. Chum salmon spawning areas and sampling locations in Slough 8C (RM 121.8R) and Slough 8D (RM 121.8R).

Alaska Railroad for approximately 0.4 miles before crossing the tracks (Appendix Figure A-37). The channel is approximately 15 feet wide, with thickly vegetated banks providing good cover for juvenile fish. Many fry were observed in Slough 8D during the open water surveys.

Substrates are large gravel/rubble/small gravel with some silt and sand accumulations, especially at the mouth (Appendix Figure A-38). The sand bar at the mouth causes fish passage problems at low mainstem discharges. The lower half of the slough was the primary chum salmon spawning area in 1984 (Appendix Figure A-39). Although upwelling wasn't observed in this site, it is probable that it is present as open leads were observed during the winter.

Problems limiting spawning at this site are minor passage restrictions at the mouth during low discharges and possible substrate.

Slough 8B (RM 122.2R)

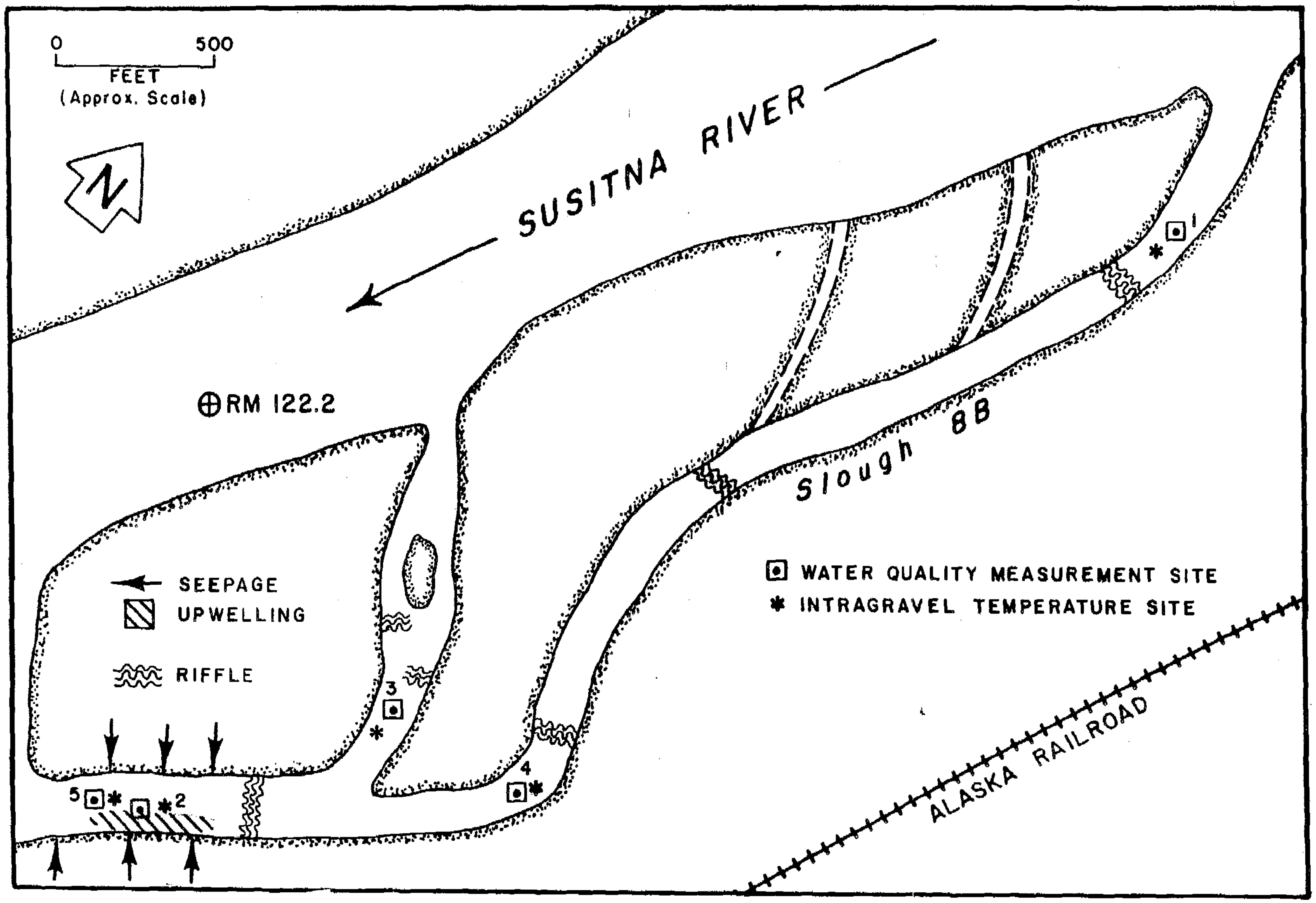
This is a 1.6 mile side slough beginning at RM 122.2 on the east side of the Susitna River. Intermittent side channels connect the slough with the mainstem. Breaching discharges for these channels have not been determined. The only observed upwelling or bank seepage was found in the backwater area of the mouth (Appendix Figure A-40) but may be present in other areas of the slough, as evidenced by open leads in the winter. Observations of upwelling were hindered by turbid water or lack of silt to mark water movement. Generally, downstream of the confluence of the two channels, substrate is predominately silt over rubble/cobble, while the right channel is rubble/cobble/large gravel (Appendix Figure A-41). Passage restrictions are numerous throughout the slough. Large areas of Slough 8B are used for spawning by chum and pink salmon (Appendix Figure A-42).

Passage appears to be the primary limiting factor to spawning in this slough.

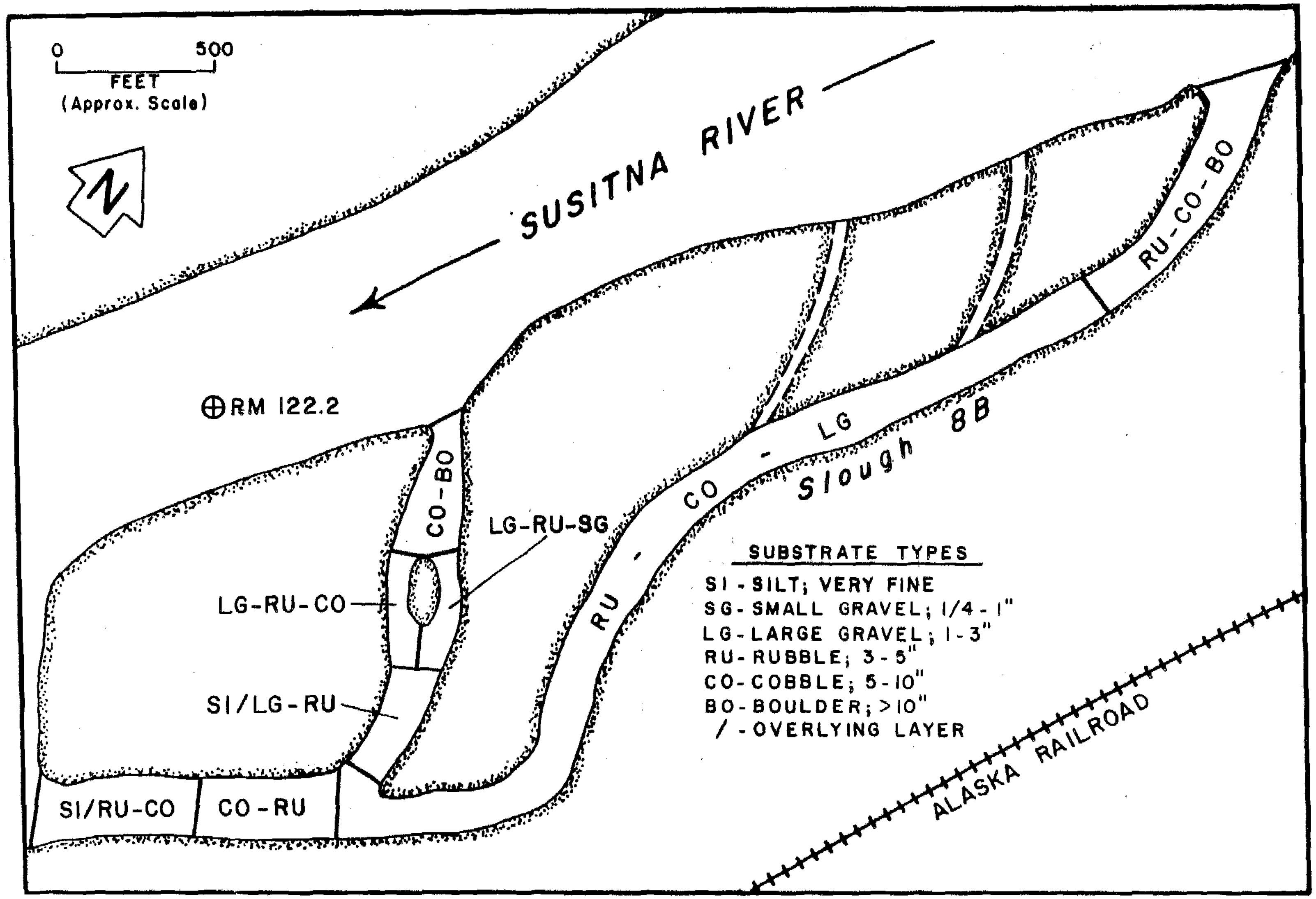
Moose Slough (RM 123.1R)

Moose Slough, a 2,000 foot long side slough, is located two-tenths of a mile upstream of the head of Slough 8B. It is a narrow channel with a backwater in the lower one-half and a run in the upper one-half. Deep accumulations of silt and sand occur in the backwater area. The upper section is large gravel/rubble with some cobble occurring, primarily in riffles (Appendix Figure A-43). A low gravel bar separates the slough from the mainstem on the left bank.

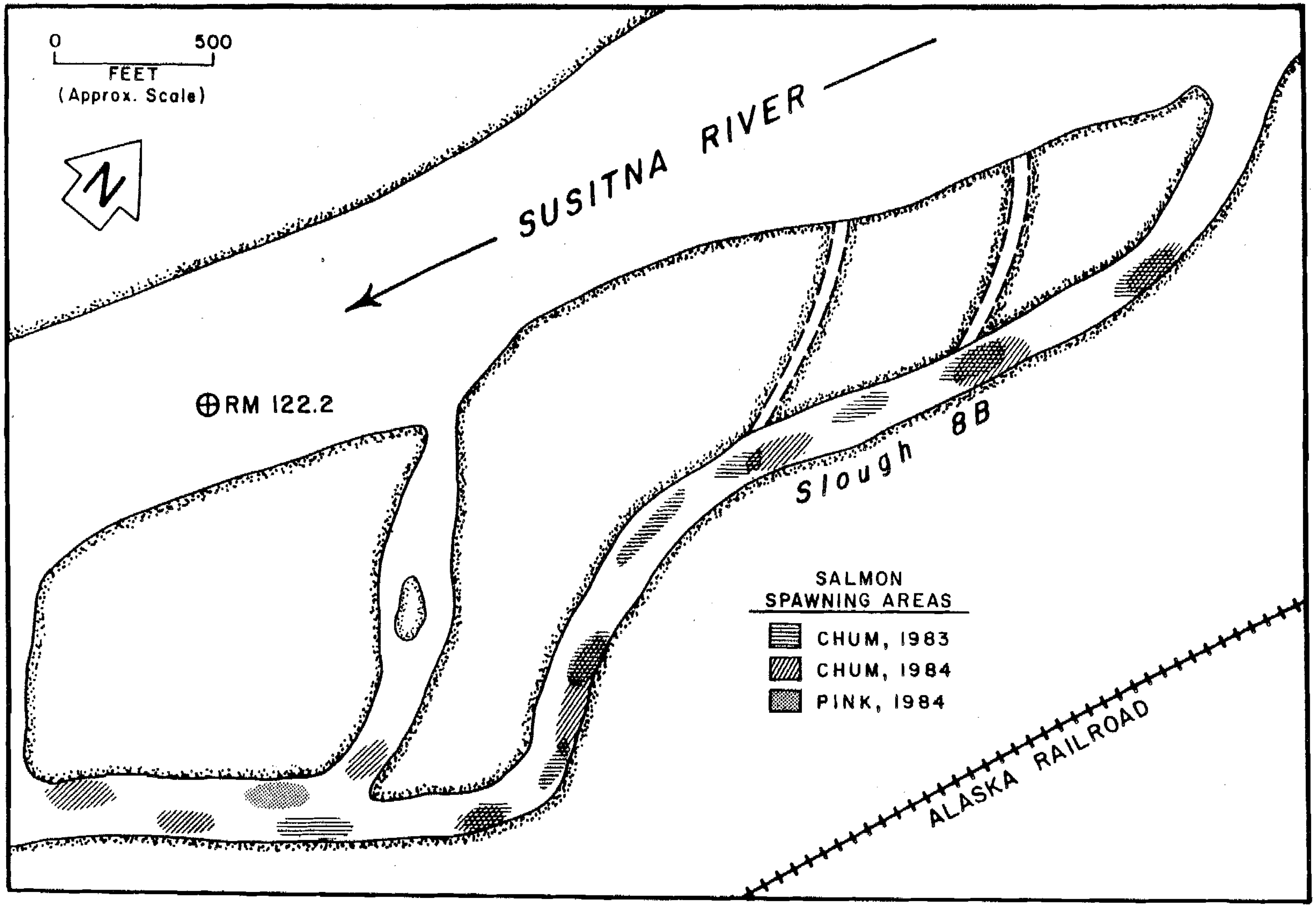
Extensive upwelling and bank seepage occurs throughout this slough (Appendix Figure A-44). The left bank upwelling appears to be the result of mainstem intragravel flow, while that on the right bank is probably independent of mainstem effects. At low mainstem discharges, the channel dewaters except for isolated pools and a small backwater area, creating passage problems for fish. The majority of spawning occurs at the upper end of the backwater and upstream (Appendix Figures A-45 and A-46).



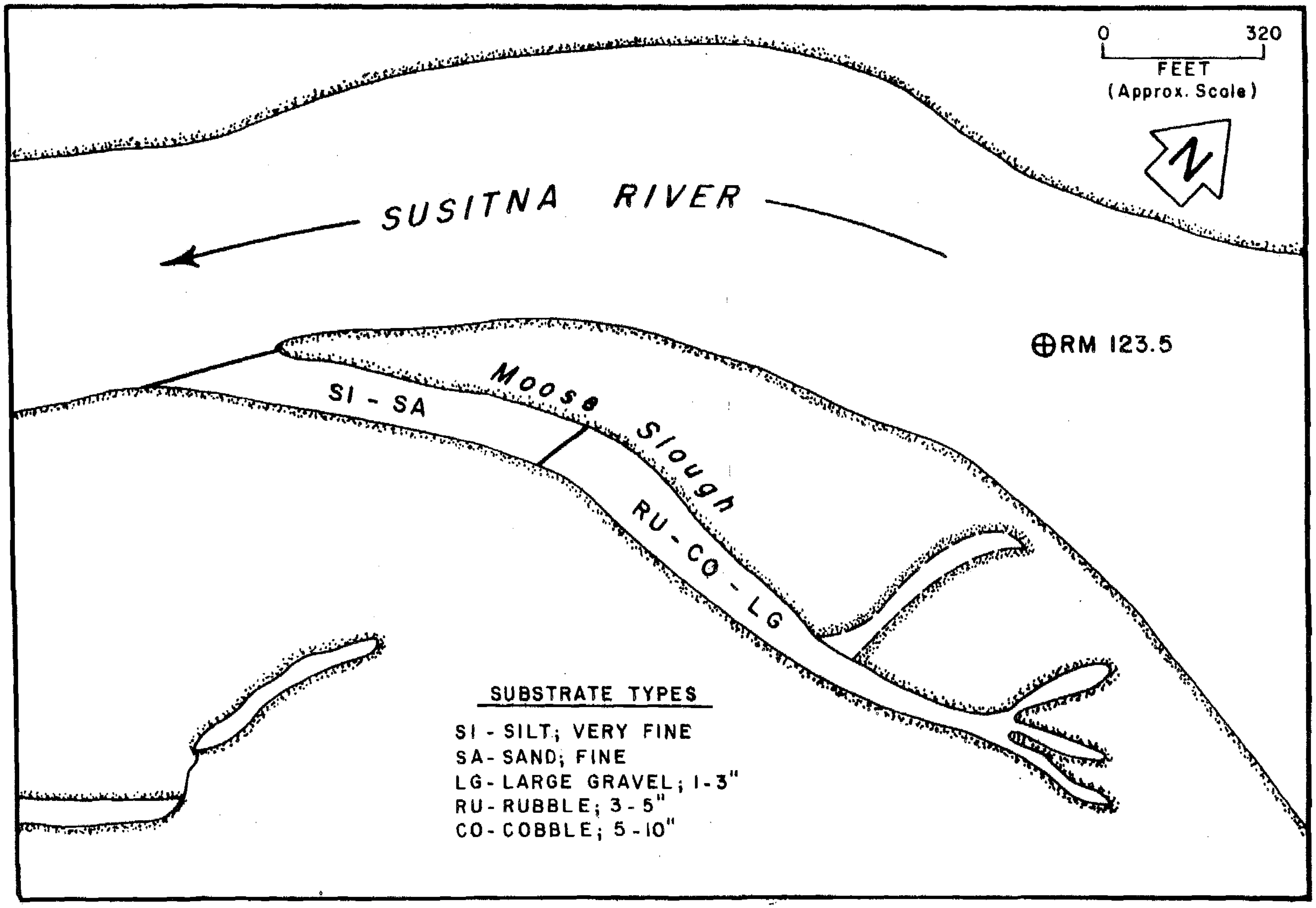
Appendix Figure A-40. Channel geometry, upwelling areas, and sampling locations in Slough 8B (RM 122.2R).



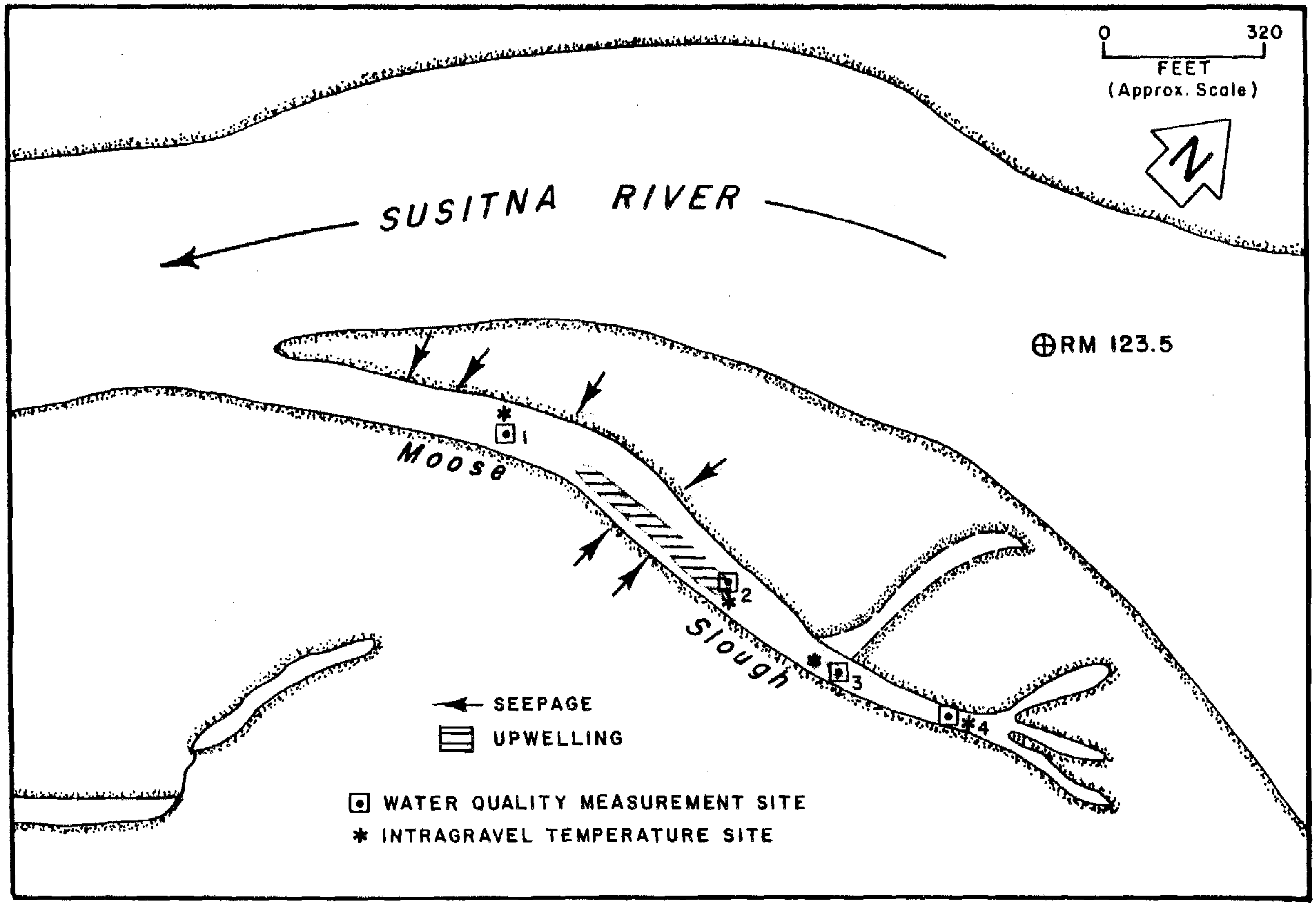
Appendix Figure A-41. Substrate composition in Slough 8B (RM 122.2R).



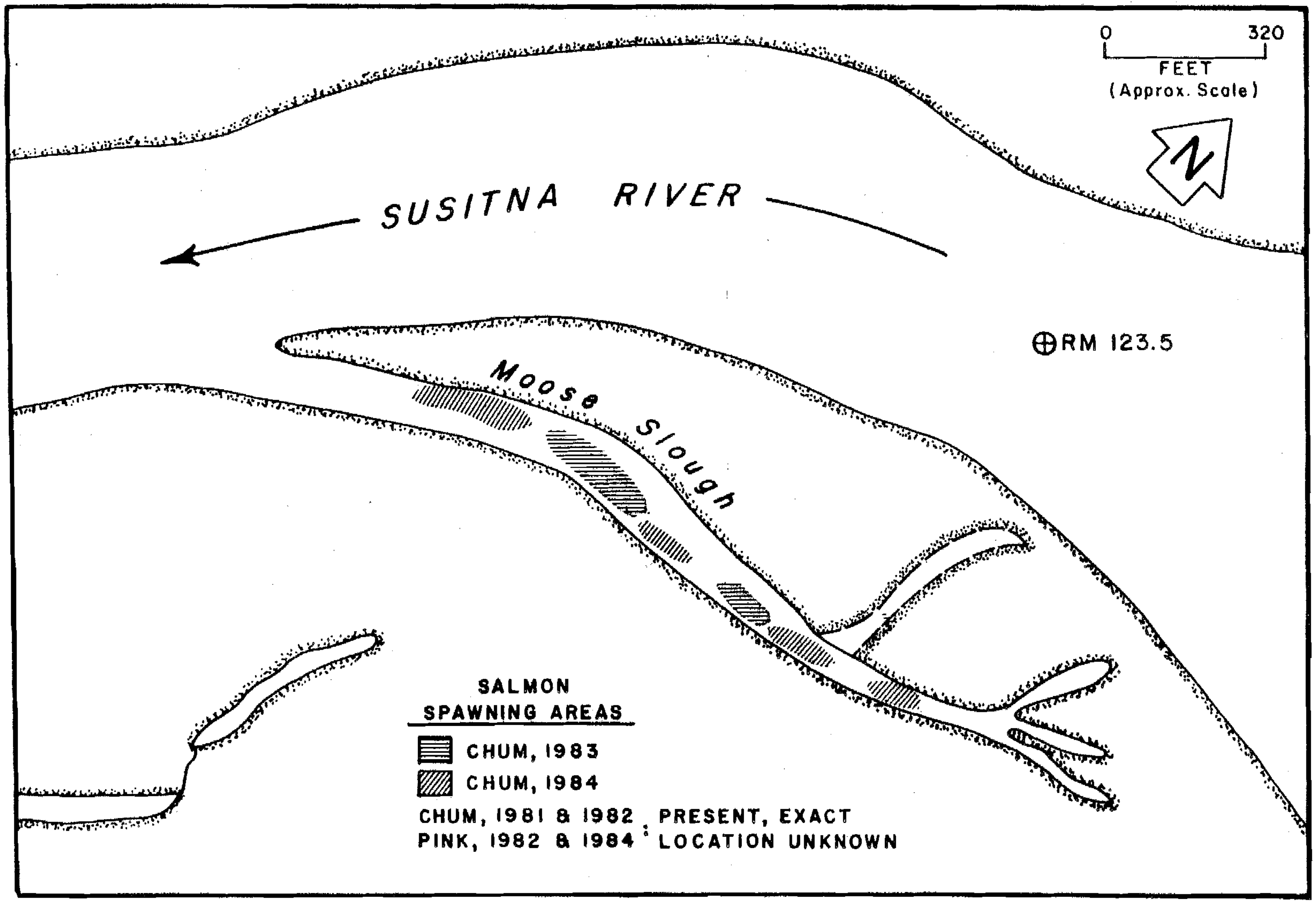
Appendix Figure A-42. Spawning areas in Slough 8B (RM 122.2R)



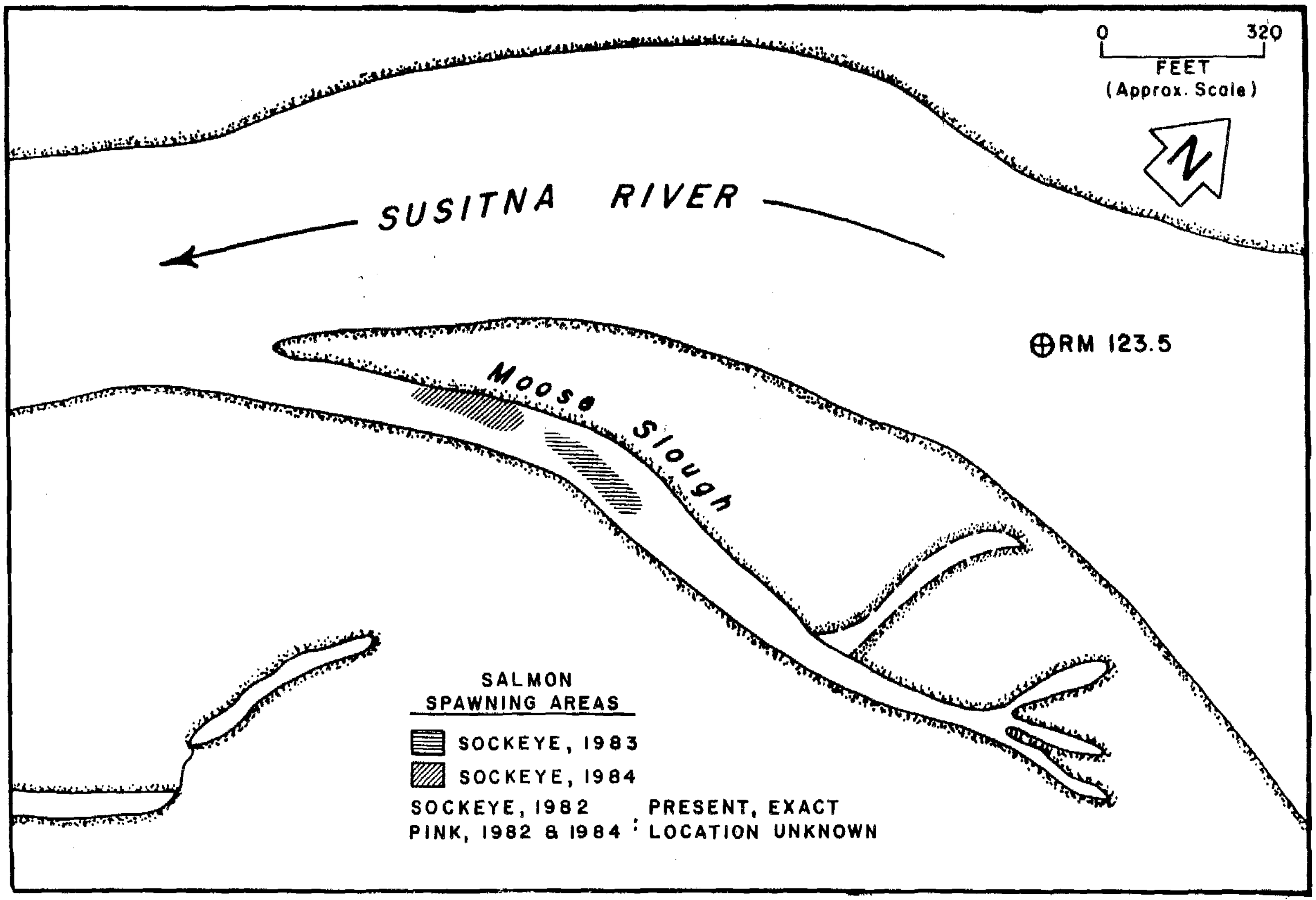
Appendix Figure A-43. Substrate composition in Moose Slough (RM 123.1R).



Appendix Figure A-44. Upwelling and bank seepage areas in Moose Slough (RM 123.1R).



Appendix Figure A-45. Chum salmon spawning areas in Moose Slough (RM 123.1R).



Appendix Figure A-46. Sockeye salmon spawning areas in Moose Slough (RM 123.1R).

Passage and silt/sand substrate are the main problems limiting spawning at this site.

Slough A[1] (RM 124.6R)

This is a 450 foot long slough at RM 124.6, immediately downstream of Skull Creek, on the east side of the Susitna River. The Alaska Railroad runs parallel to the right bank, crossing Skull Creek near the slough head. The berm on the south side of Skull Creek acts as the upper limit of Slough A[1]. There is an intermittent side channel that connects the slough to the mainstem along the left bank at the head. Water from Skull Creek flows intragravelly through the berm into the head of the slough in substantial quantities. Upwelling can be seen in the area of the side channel and is probably the result of mainstem intragravel flow. Upwelling and bank seepage occur along both banks throughout the majority of the slough (Appendix Figure A-47). Upwelling and bank seepage occurring along the left bank is probably mainstem in origin, while that along the right bank is likely due to intragravel groundwater flow and surface runoff.

Substrate in the upper half of the slough is rubble/cobble with large gravel while the lower half is large gravel/rubble. The lower backwater area also has a thick layer of silt and sand (Appendix Figure A-47). Salmon utilized all areas of this slough for spawning with a preference for the upper silt free areas (Appendix Figures A-48 and A-49).

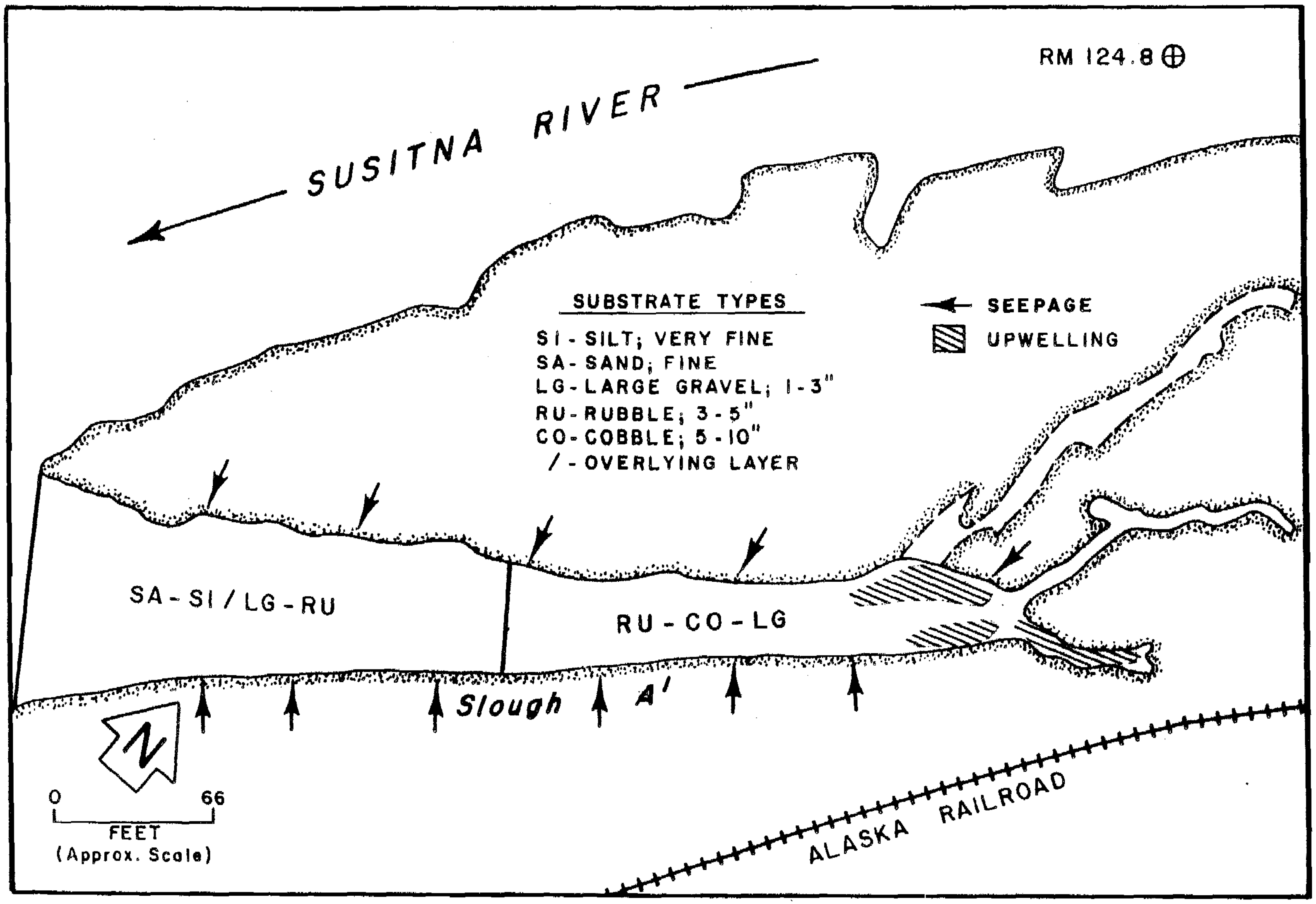
Limiting factors at this site are minor passage problems at low discharges, silt/sand deposits throughout the slough and the small physical size of the site.

Slough A (RM 124.8R)

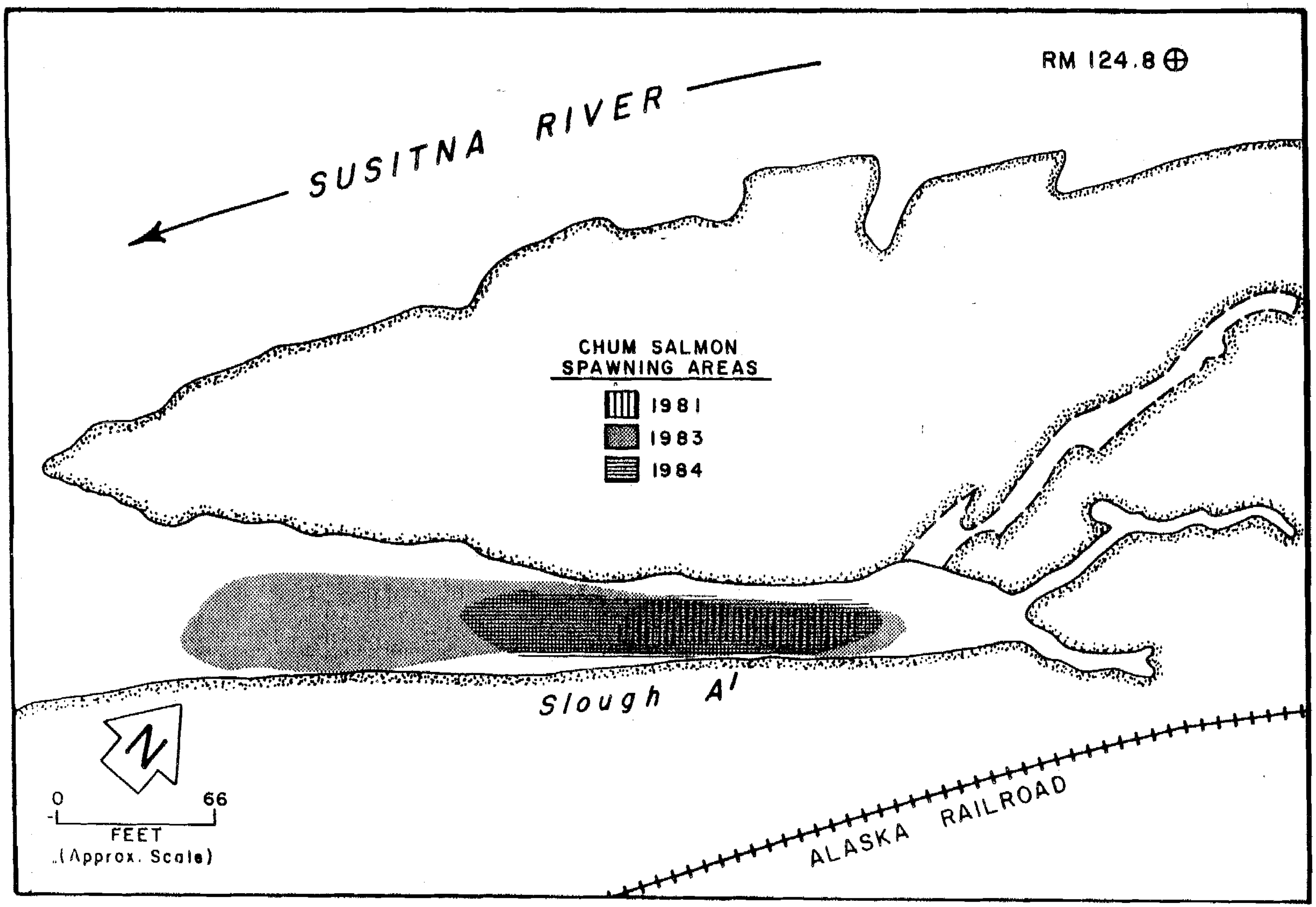
Slough A is a 350 feet long upland slough on the east side of the Susitna River, immediately upstream of Skull Creek. The ARR parallels the right bank of the slough. The first 100 feet consists of a two-foot wide shallow run with large gravel/small gravel substrate covered with approximately eight inches of sand followed by a riffle. Above this riffle there is a 20 x 150 foot pool with deep silt and sand overlying the rubble/cobble substrate. A 100 foot long narrow, shallow run comprises the upper reach of the slough (Appendix Figure A-50). The entire lower section is a barrier to fish.

Upwelling and bank seepage flow out of the berm adjacent to Skull Creek as well as along the right bank of the pool. This seepage is most likely the result of surface runoff and intragravel flow of groundwater. Limited chum salmon spawning was observed only during 1981 (Appendix Figure 51).

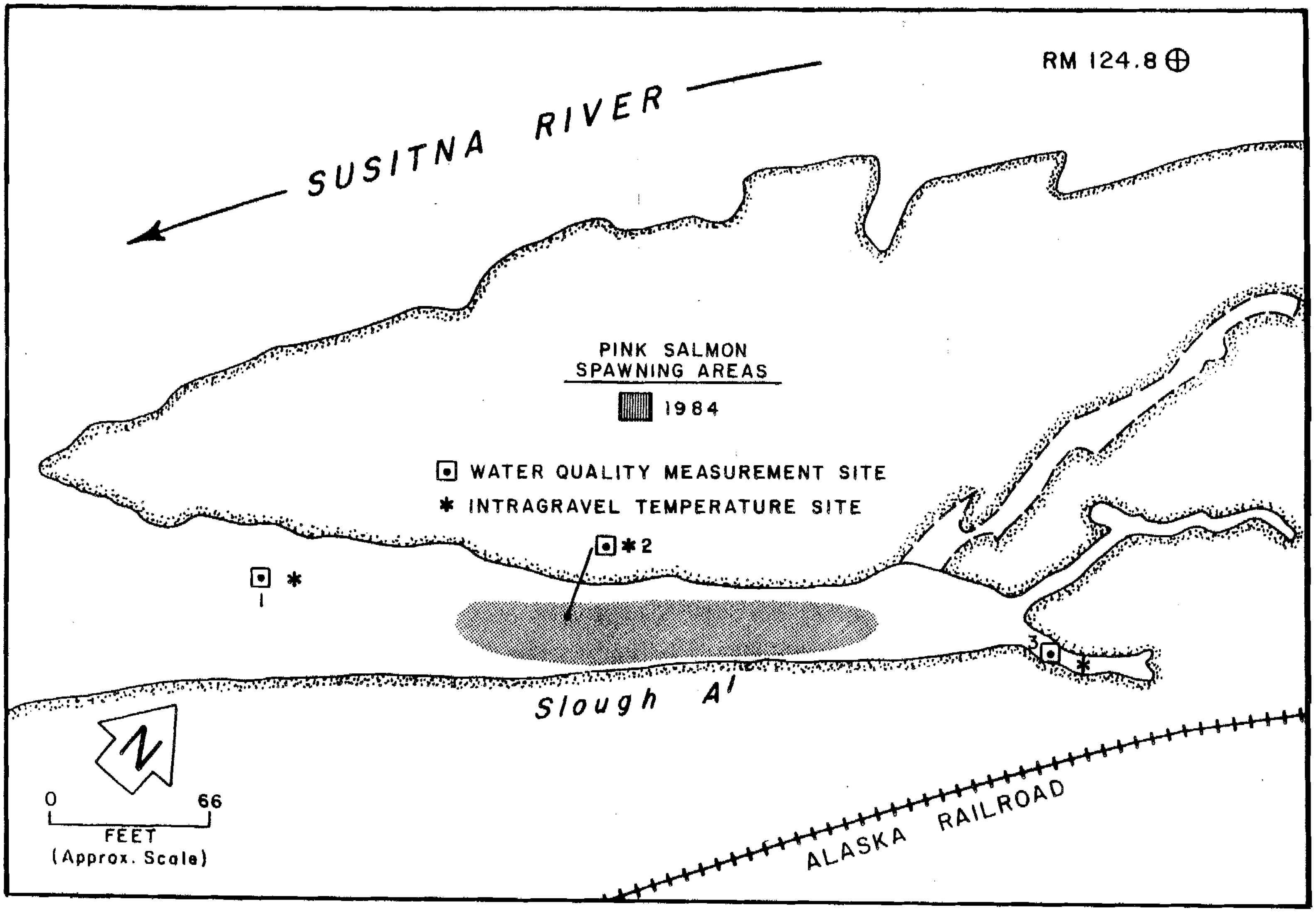
Passage and substrate as well as the physical size of the slough, are the factors limiting spawning.



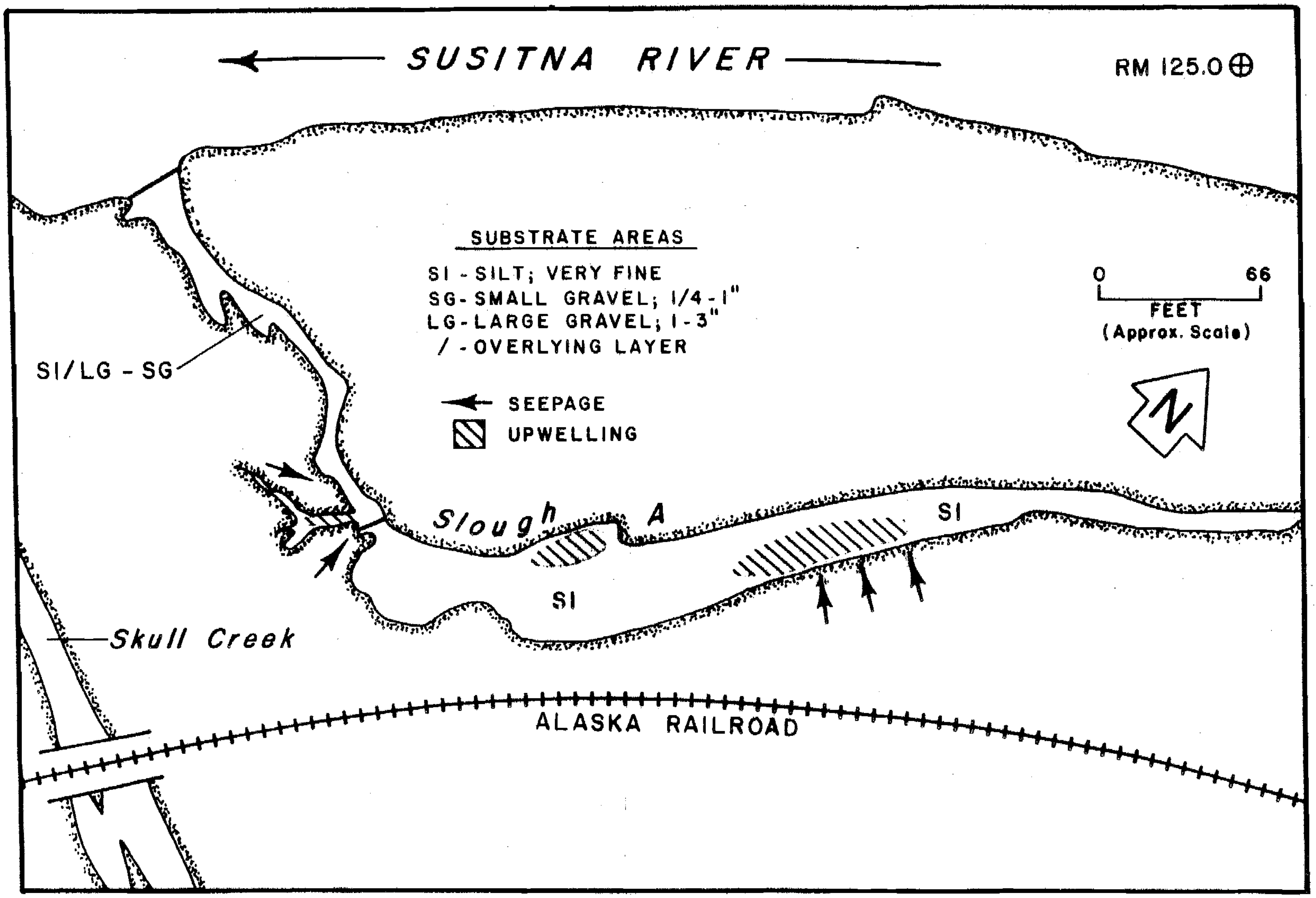
Appendix Figure A-47. Substrate composition and upwelling areas in Slough A[1] (RM 124.6R).



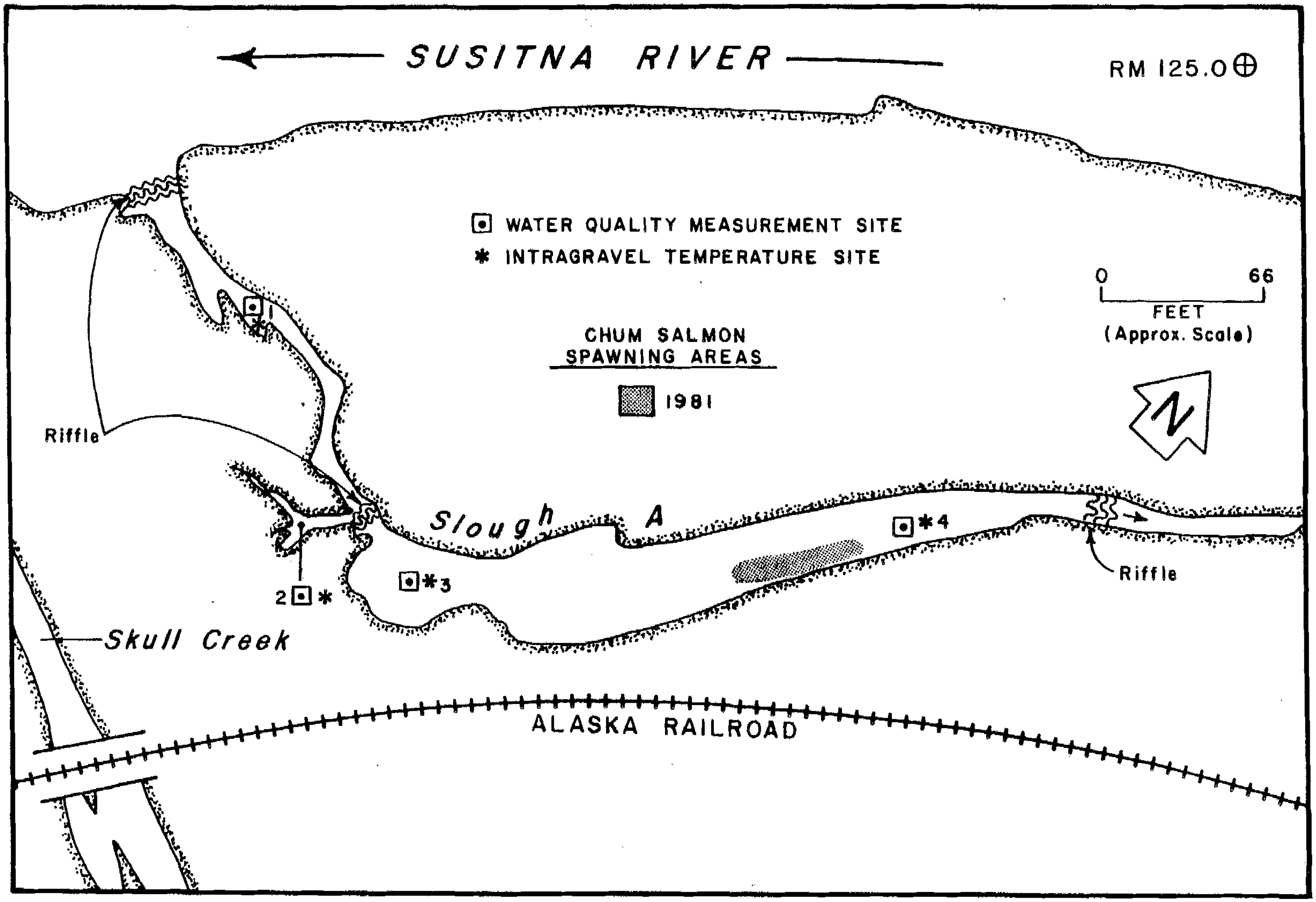
Appendix Figure A-48. Chum salmon spawning areas in Slough A^1 (RM 124.6R).



Appendix Figure A-49. Pink salmon spawning areas in Slough A[1] (RM 124.6R).



Appendix Figure A-50. Substrate composition and upwelling areas in Slough A (RM 124.8R).



Appendix Figure A-51. Chum salmon spawning areas and sampling locations in Slough A (RM 124.8R).

Slough 8A (RM 125.3R)

This 2.0 mile long side slough is separated from the mainstem of the Susitna River by a large vegetated gravel bar. Two principal channels, with breaching discharges of 27,400 cubic feet per second (cfs) for the northwest channel and 33,000 cfs for the northeast channel, connect Slough 8A with the Susitna River (Appendix Figure A-52). Local surface runoff and groundwater maintain the base slough flow in an unbreached condition.

At mainstem discharges between 20,000 and 30,000 cfs, a backwater area extends approximately 1,000 feet into the slough. Above the backwater area is a 100-300 ft riffle that terminates in a large beaver dam. The northwest channel flows into a large pool behind the beaver dam.

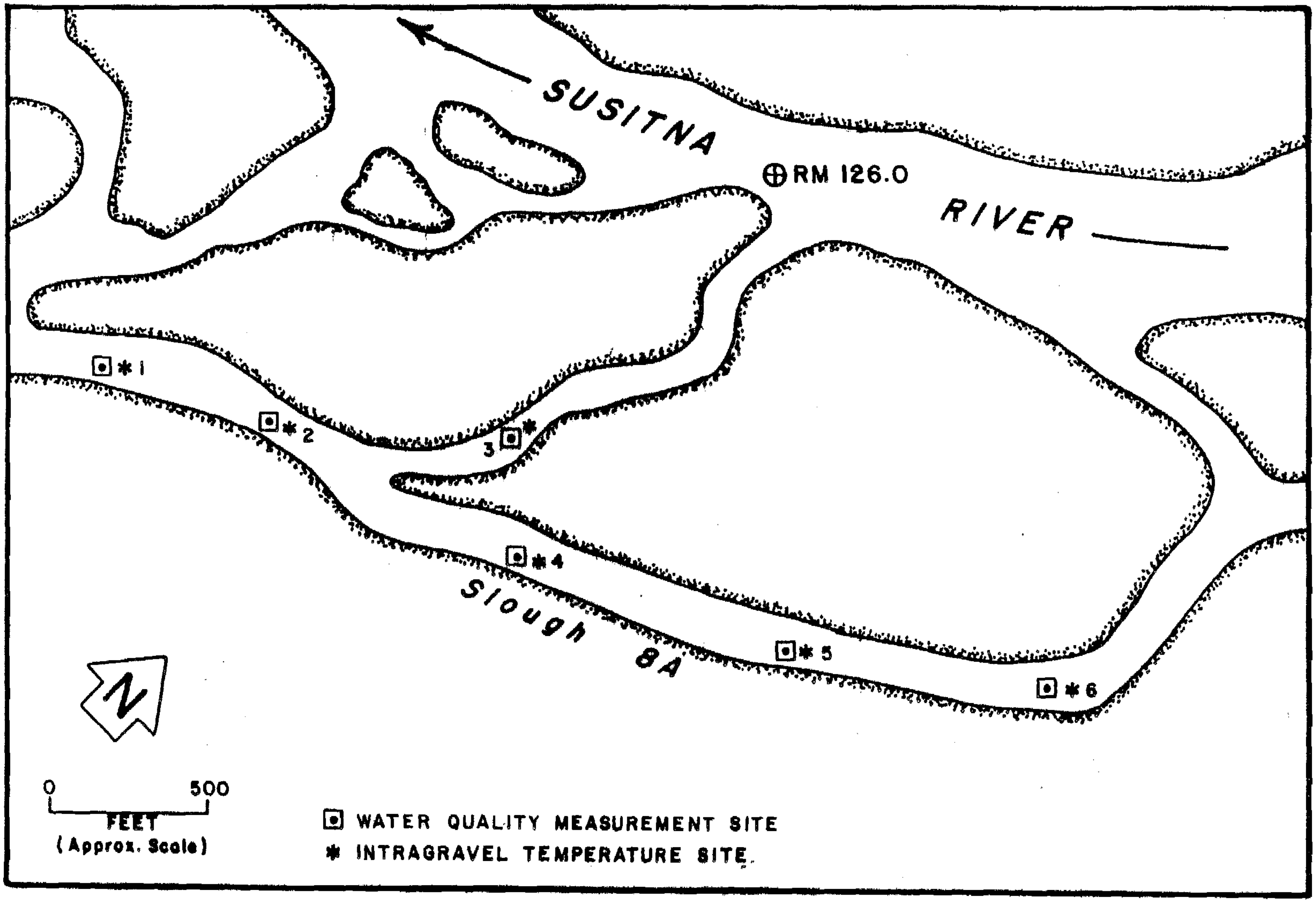
Channel alignment is straight, with a gentle bend near the head of the slough. Substrate in the lower half of the slough is predominantly large gravel and rubble and cobble and boulder in the upper half of the slough. Deposits of fine silt/sand are found in the pools and in the backwater area near the mouth (Appendix Figure A-53). A total of eleven passage reaches have been found in this site, the lower four of which can be accessed due to backwater effects at mainstem discharges ranging from 7,700 to 25,000 cfs (Appendix Figure A-54). Breaching occurs before backwater effects can be noticed on the upper passage reaches. Slough 8A is an important spawning channel for chum and sockeye salmon (Appendix Figures A-55, A-56 and A-57). In 1984 this site accounted for 12.1 and 13.8 percent of the chum and sockeye salmon slough spawning with peak counts of 917 and 128 fish respectively (Barrett et al. 1985).

Passage, either depth related or due to beaver dams, appears to be the primary factor limiting spawning in this site. Passage at this site has been more thoroughly discussed in Blakely et al. 1985 and Sautner et al. 1984.

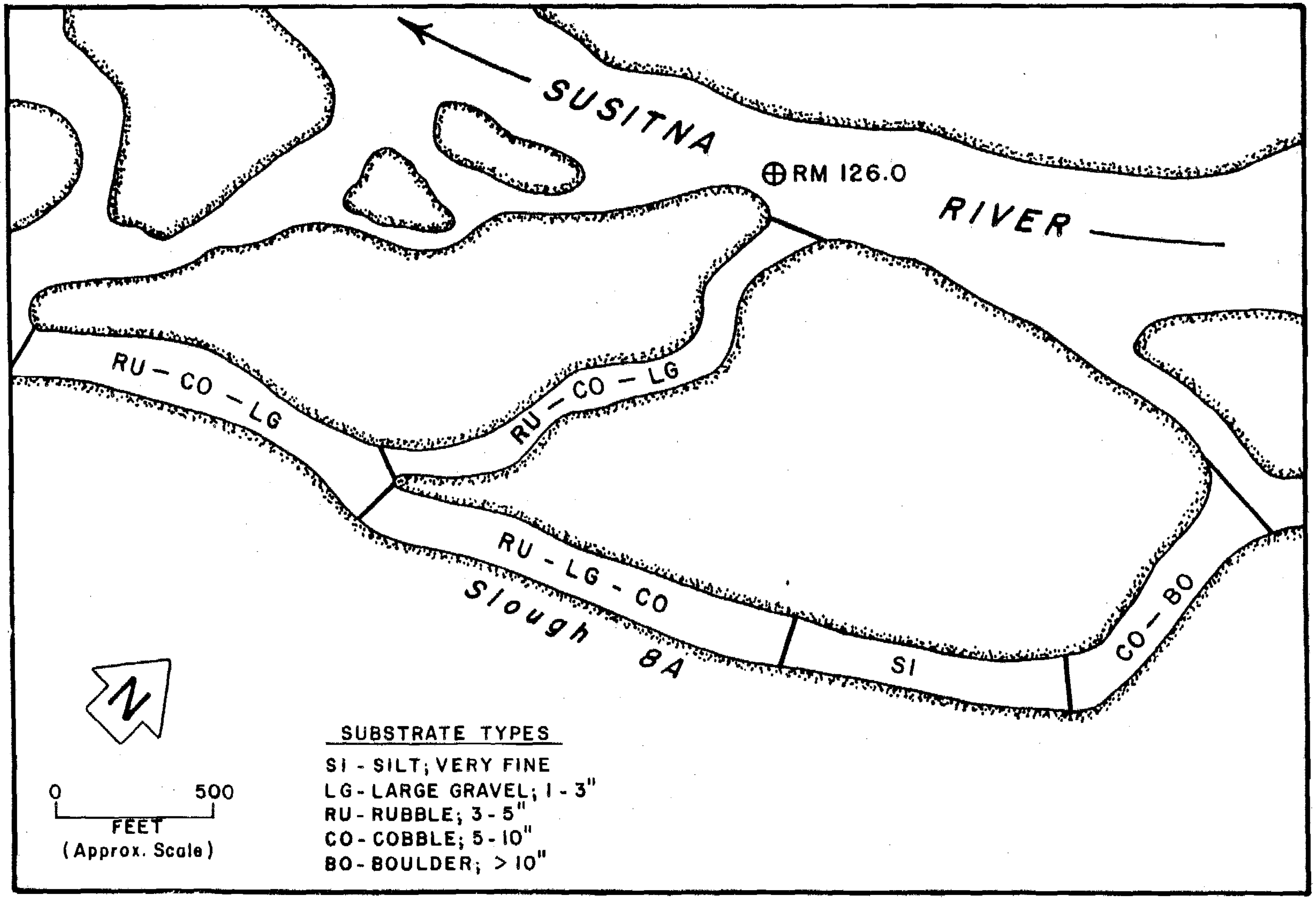
Slough B (RM 126.3R)

This is a side slough, approximately 2,000 feet long, located on the east side of the Susitna River at the head of Slough 8A. The slough has a straight channel that is separated from the mainstem by a large vegetated gravel bar. The first third of the slough is a backwater area. The middle of the slough is a large pool, while the upper end is a divided channel with pool-riffle sequence (Appendix Figure A-58). Substrates are primarily rubble/cobble with occasional patches of large gravel with sand/silt deposits overlying the coarser substrate in the backwater area and first pool (Appendix Figure A-58).

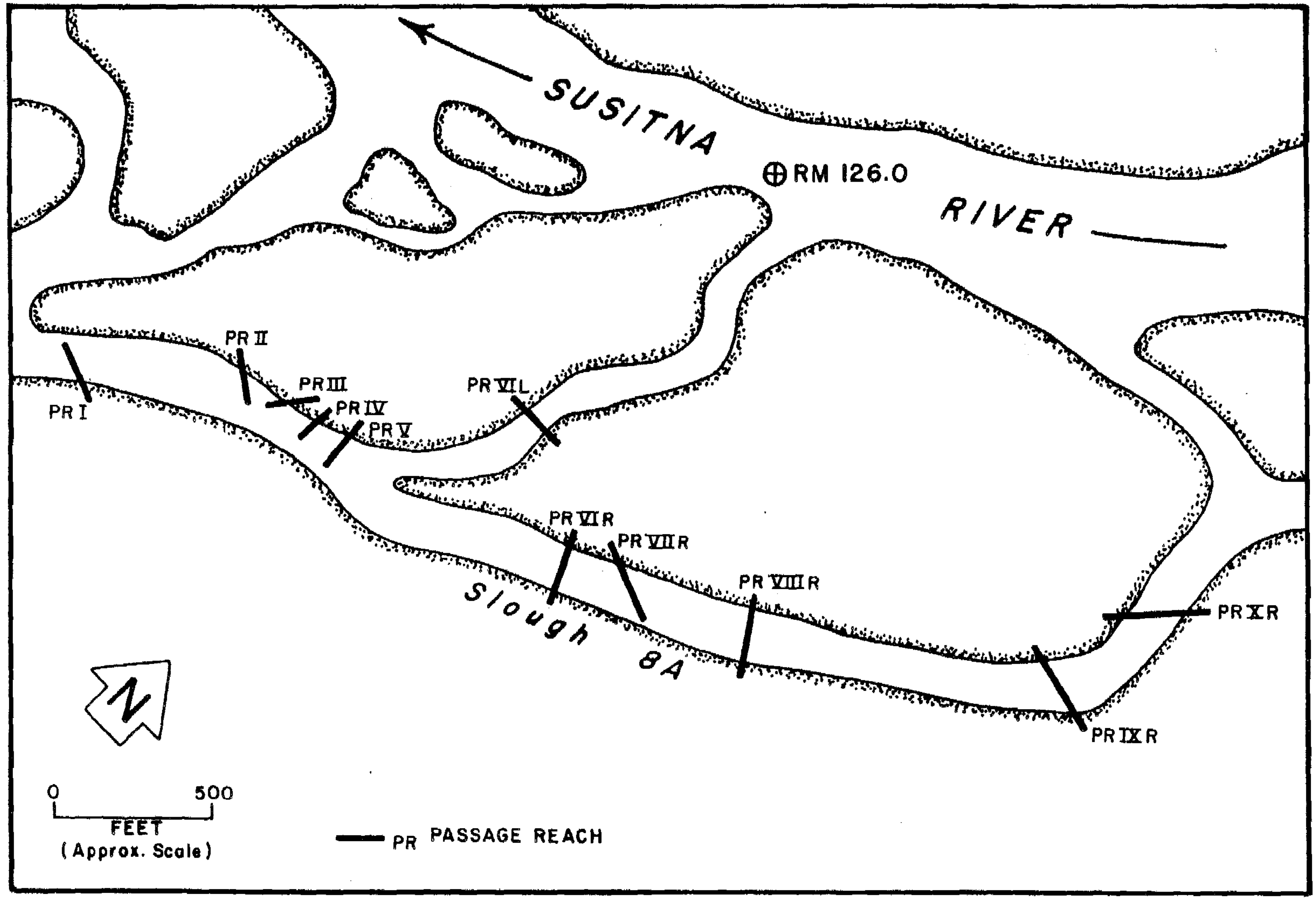
In an unbreached condition, water flows intragravelly through the head from a side channel located upstream. While no upwelling was observed, limited bank seepage from the right bank and heavy bank seepage from the left bank was present. The latter is likely mainstem related. Chum and sockeye salmon spawning is evident in the slough (Appendix Figures A-59 and A-60). A 20 foot long riffle, separating the backwater and pool habitats, is the major passage restriction at lower discharges. The riffle -pool area near the head also exhibits passage problems at low discharges.



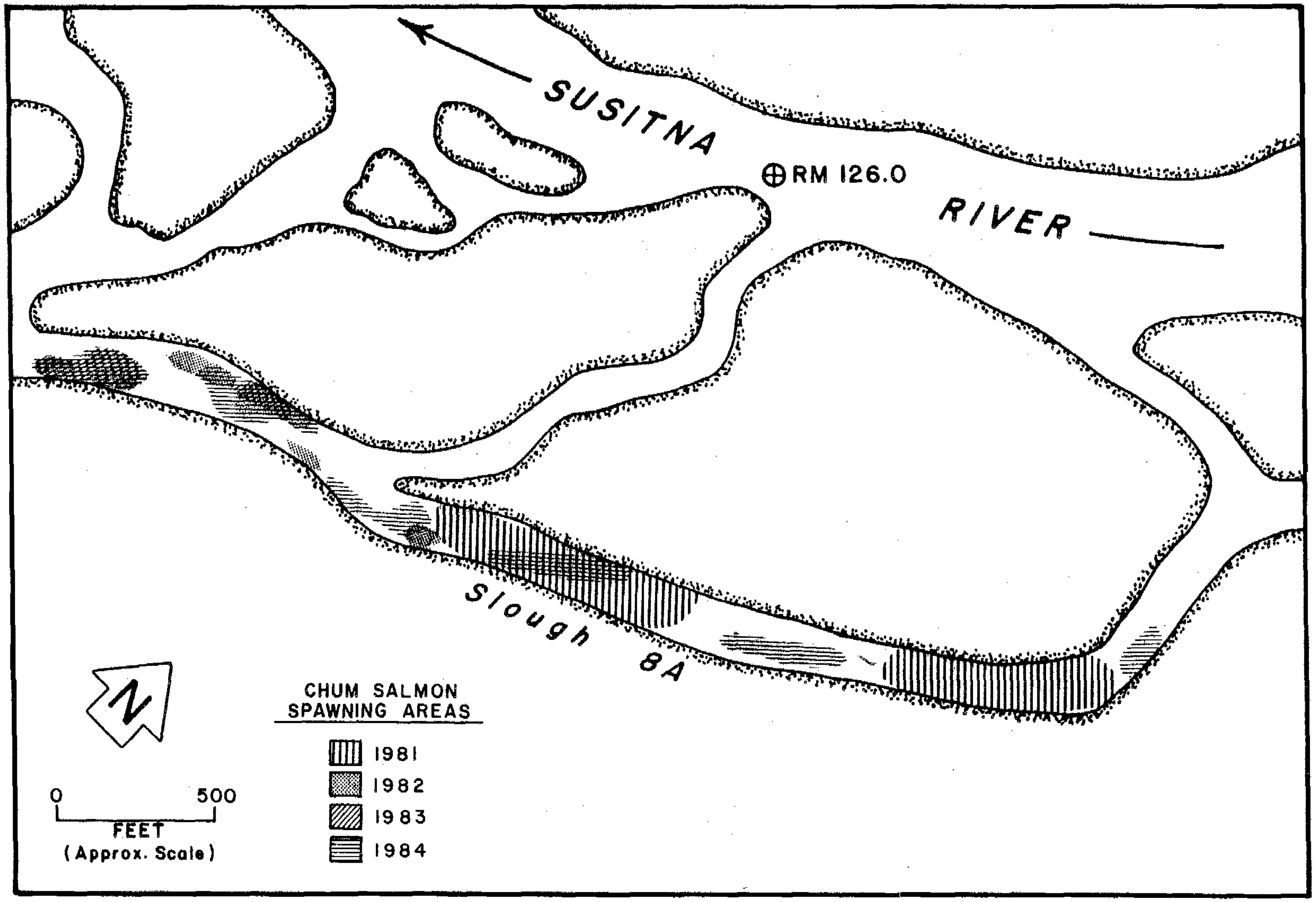
Appendix Figure A-52. Channel geometry and sampling locations in Slough 8A (RM 125.3R).



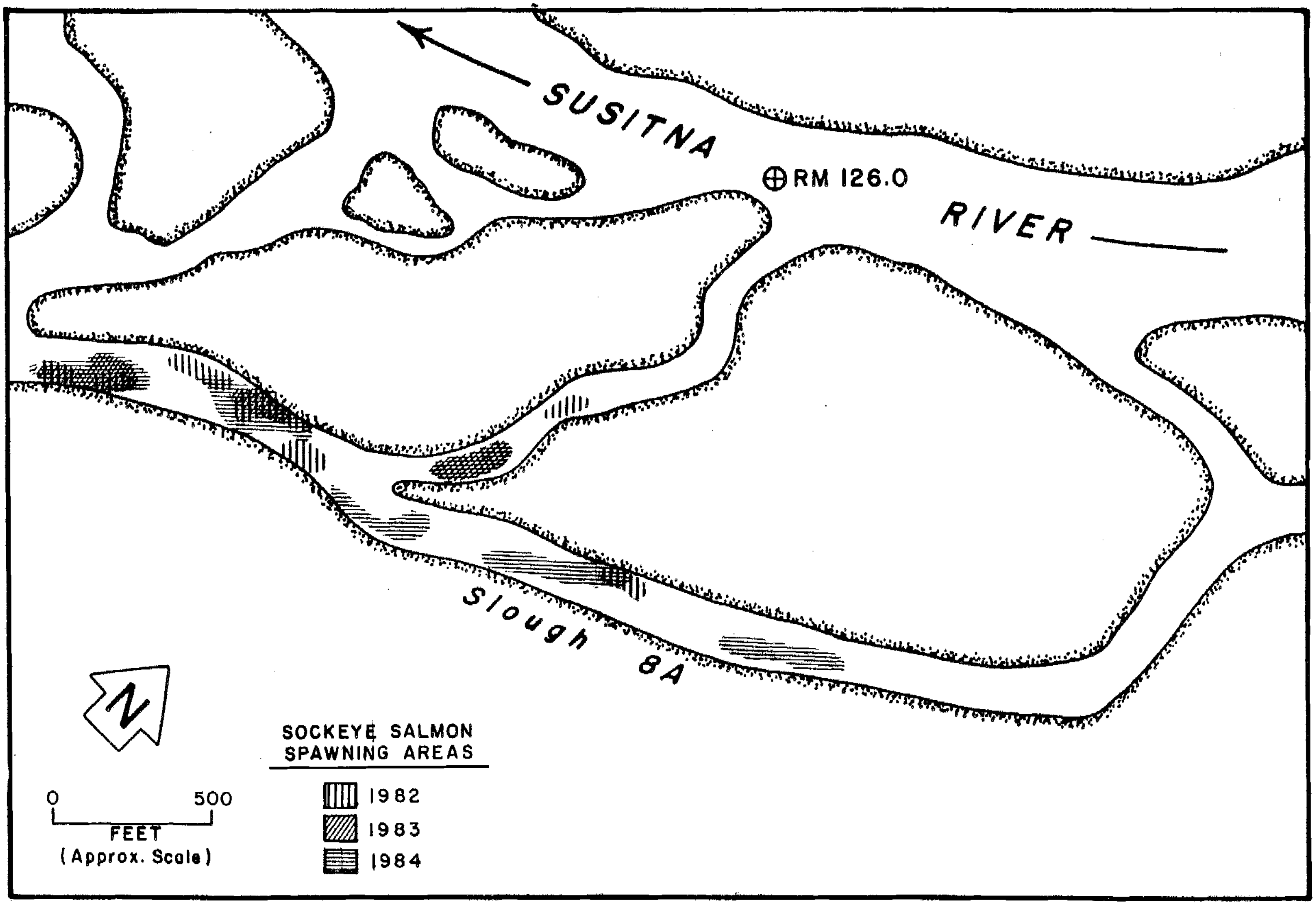
Appendix Figure A-53. Substrate composition in Slough 8A (RM 125.3R).



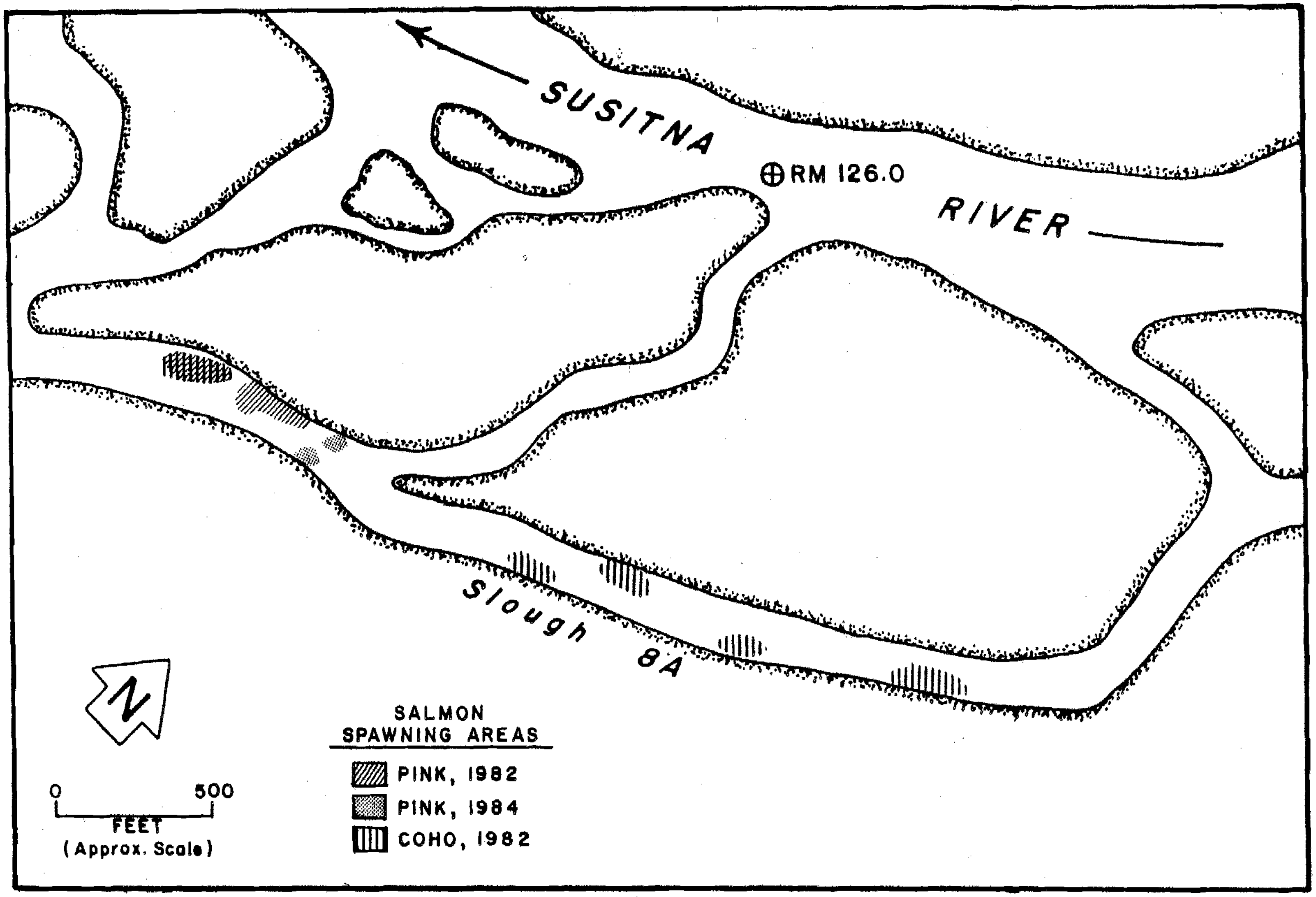
Appendix Figure A-54. Passage reach locations in Slough 8A (RM 125.3R).



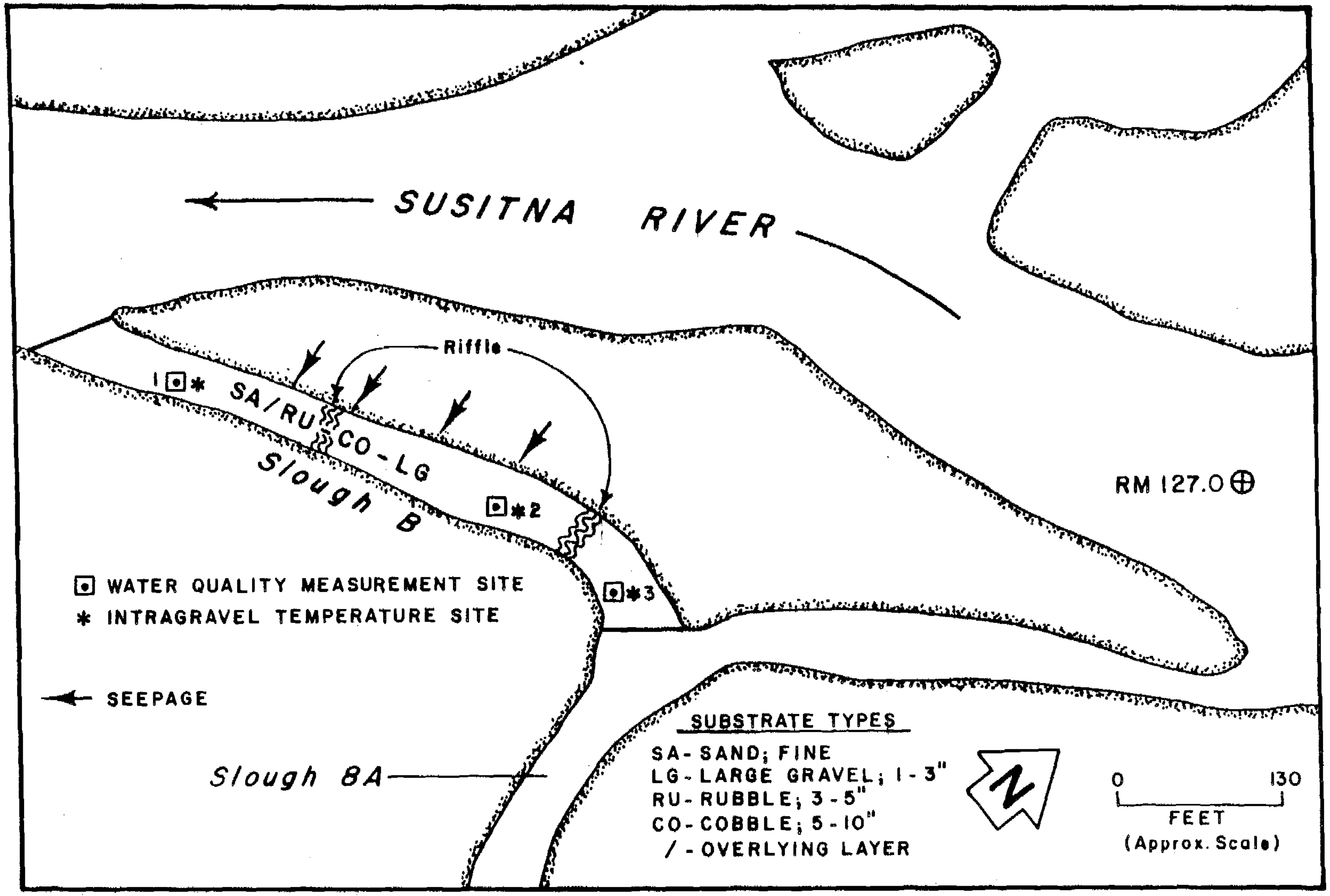
Appendix Figure A-55. Chum salmon spawning areas in Slough 8A (RM 125.3R).



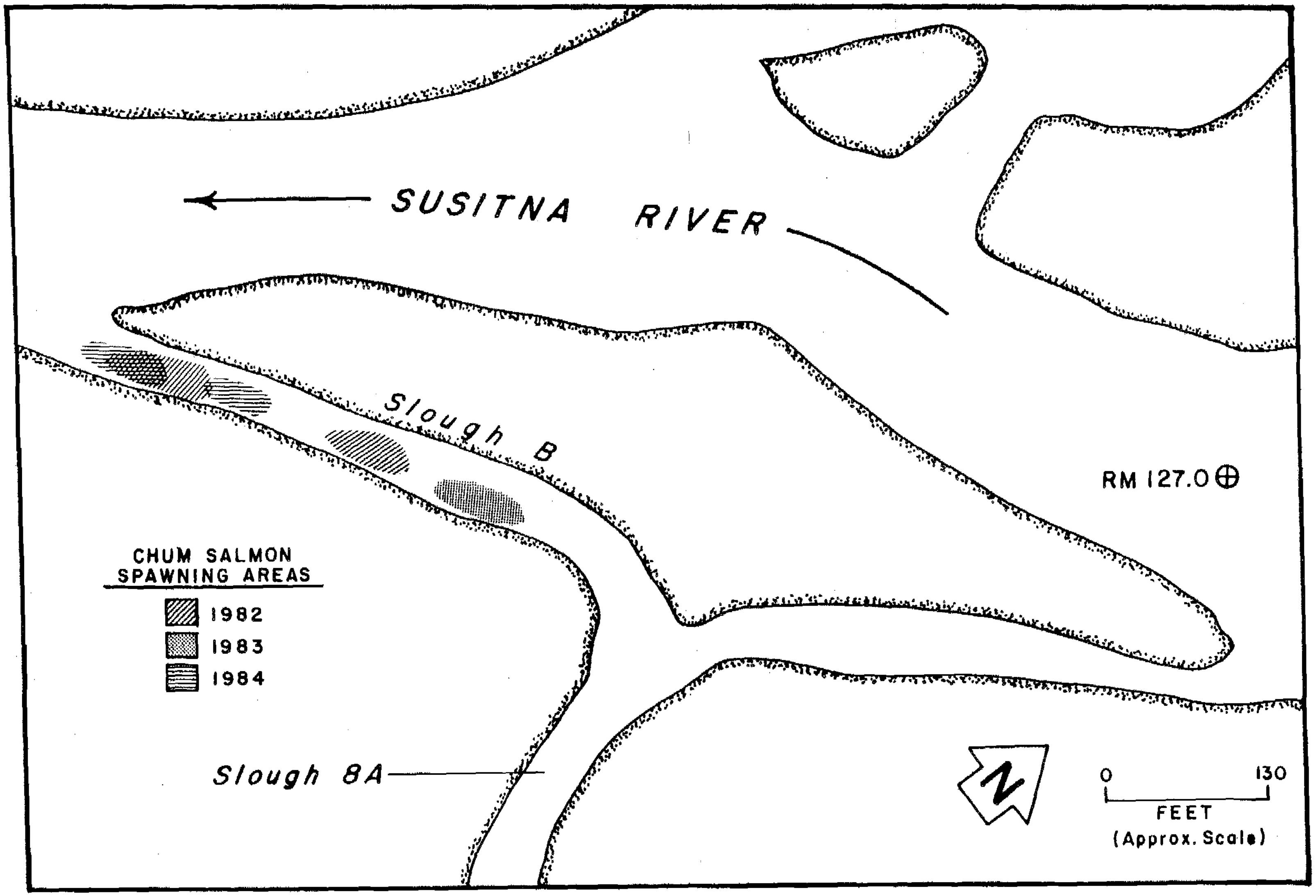
Appendix Figure A-56. Sockeye salmon spawning areas in Slough 8A (RM 125.3R).



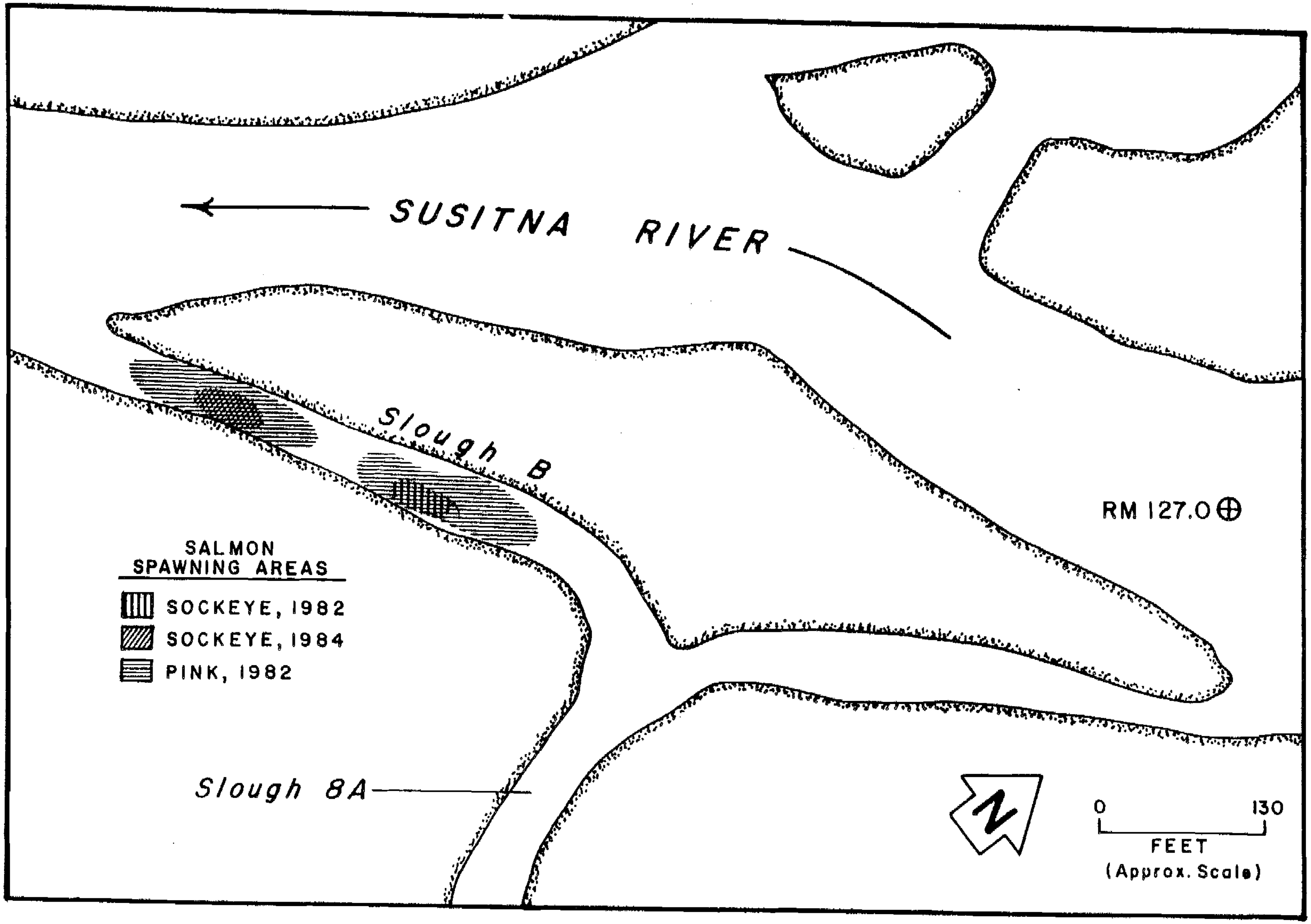
Appendix Figure A-57. Pink and coho salmon spawning areas in Slough 8A (RM 125.3R).



Appendix Figure A-58. Substrate composition, bank seepage, and sampling locations in Slough B (RM 126.3R).



Appendix Figure A-59. Chum salmon spawning areas in Slough B (RM 126.3R).



Appendix Figure A-60. Sockeye and pink salmon spawning areas in Slough B (RM 126.3R).

Factors limiting spawning at this site are passage, substrate, and lack of upwelling.

Slough 9 (RM 128.3R)

Slough 9 is a 1.2 mile long side slough on the east side of the Susitna River. Base slough flow is maintained by upwelling and two small creeks that enter the slough at approximately 0.2 and 0.75 miles upstream of the mouth (Appendix Figure A-61). When breaching occurs at mainstem discharges exceeding 16,000 cfs, slough flows become turbid and rapidly increase from less than 10 cfs to approximately 100 cfs or higher.

The slough channel has several gentle bends that occur throughout the site. A right angle bend occurs near the second creek where the slough turns from east to south after coming in contact with rip-rap along the Alaska Railroad which parallels the right bank of the slough. Substrate composition in the lower two-thirds of the slough is predominantly gravel and rubble covered by a four to five-inch thick layer of sand. Substrate in the upper one third of the slough is exposed cobble and boulder in riffles with sand deposits in pool areas (Appendix Figure A-62).

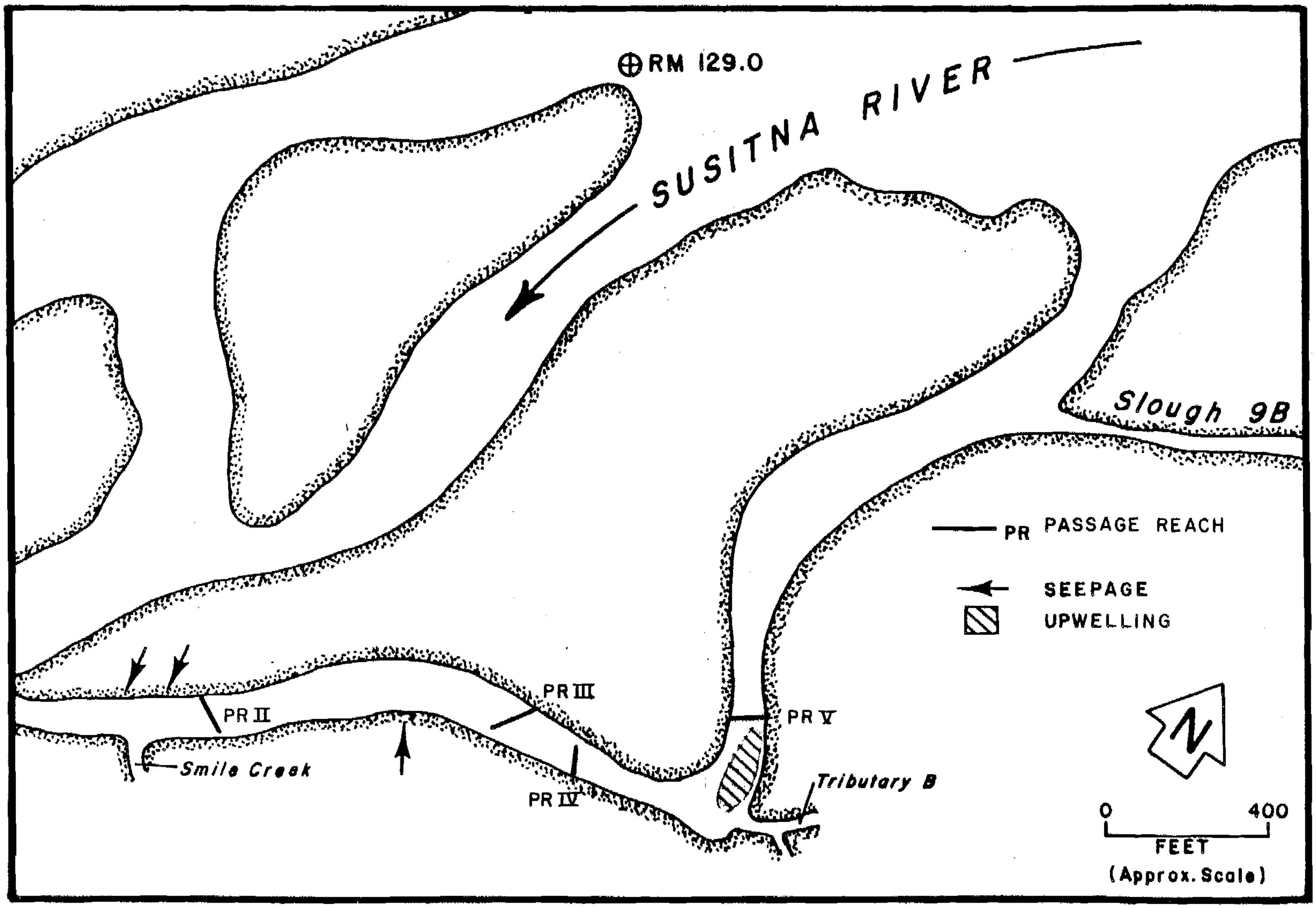
Passage can be a problem, with five passage reaches being described by Blakely et al. 1985 and Sautner et al. 1984 (Appendix Figure A-61). Slough 9 is an important chum salmon spawning site, with extensive spawning activity occurring throughout the slough (Appendix Figures A-63 and A-64). In 1984 this site had a peak count of 350 chum salmon accounting for 4.6 percent of the total slough spawning escapement (Barrett et al. 1985).

Factors influencing spawning at this site are passage and substrate. Dewatering of the upper half of the slough during unbreached conditions also affects the extent of spawning.

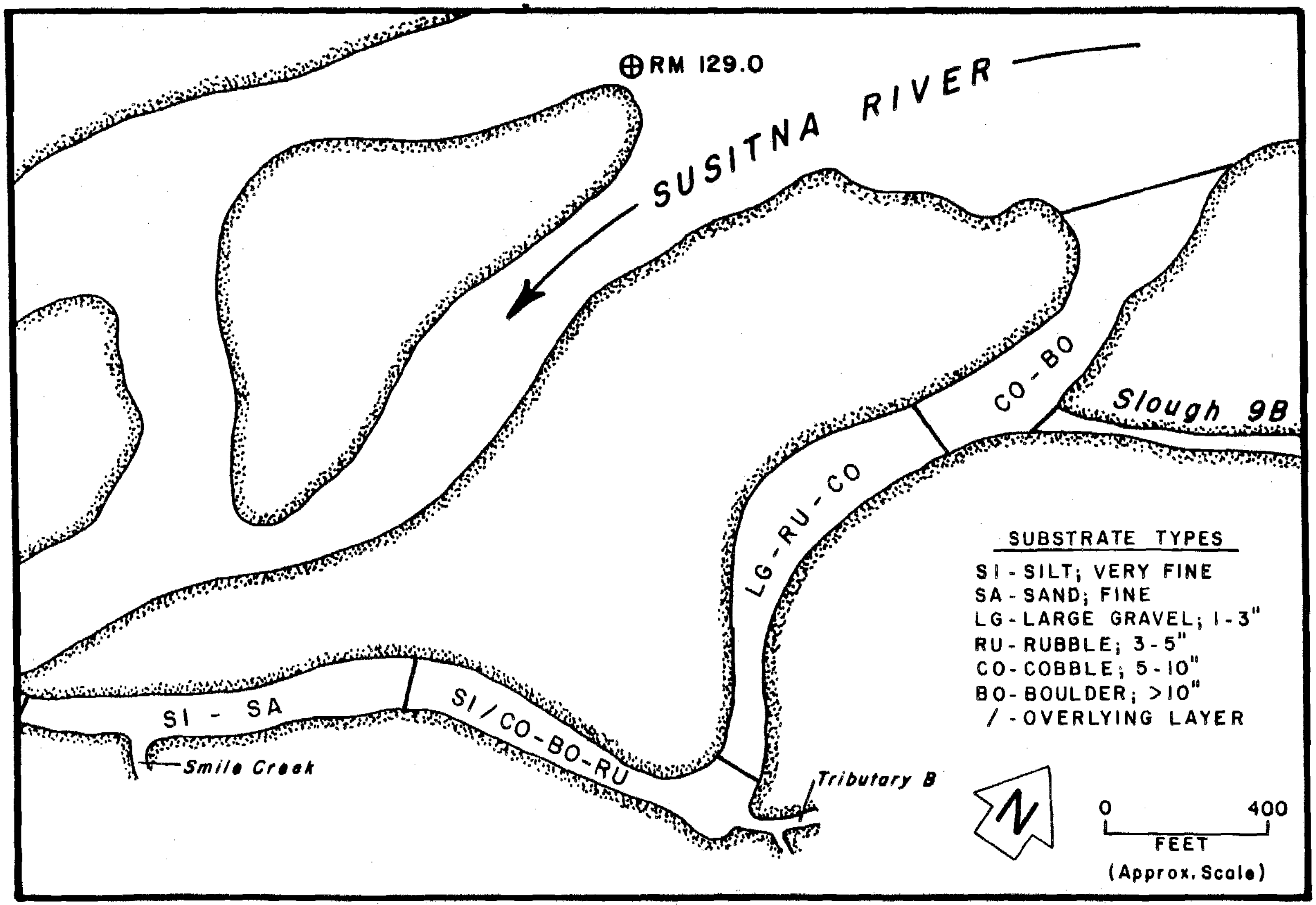
Slough 9B (RM 129.2R)

Slough 9B is located inside Slough 9, about 1,000 feet downstream of the head along the right bank. The overall length of this upland slough is 1,750 feet. The channel forks 1,250 feet from the mouth, forming two narrow riffle areas. Downstream of this point, the slough is a long pool, 3 to 4 feet deep. Thickly vegetated banks occur throughout the slough. The slough has little flow due to the extensive beaver activity. As a result, a thick silt layer with decaying organic matter overlies large gravel/rubble substrate. Strong upwelling occurs throughout the slough, especially along the left bank (Appendix Figure A-65). Salmon selected these upwelling areas for spawning, digging through 18 inches or more of silt to reach the useable substrate.

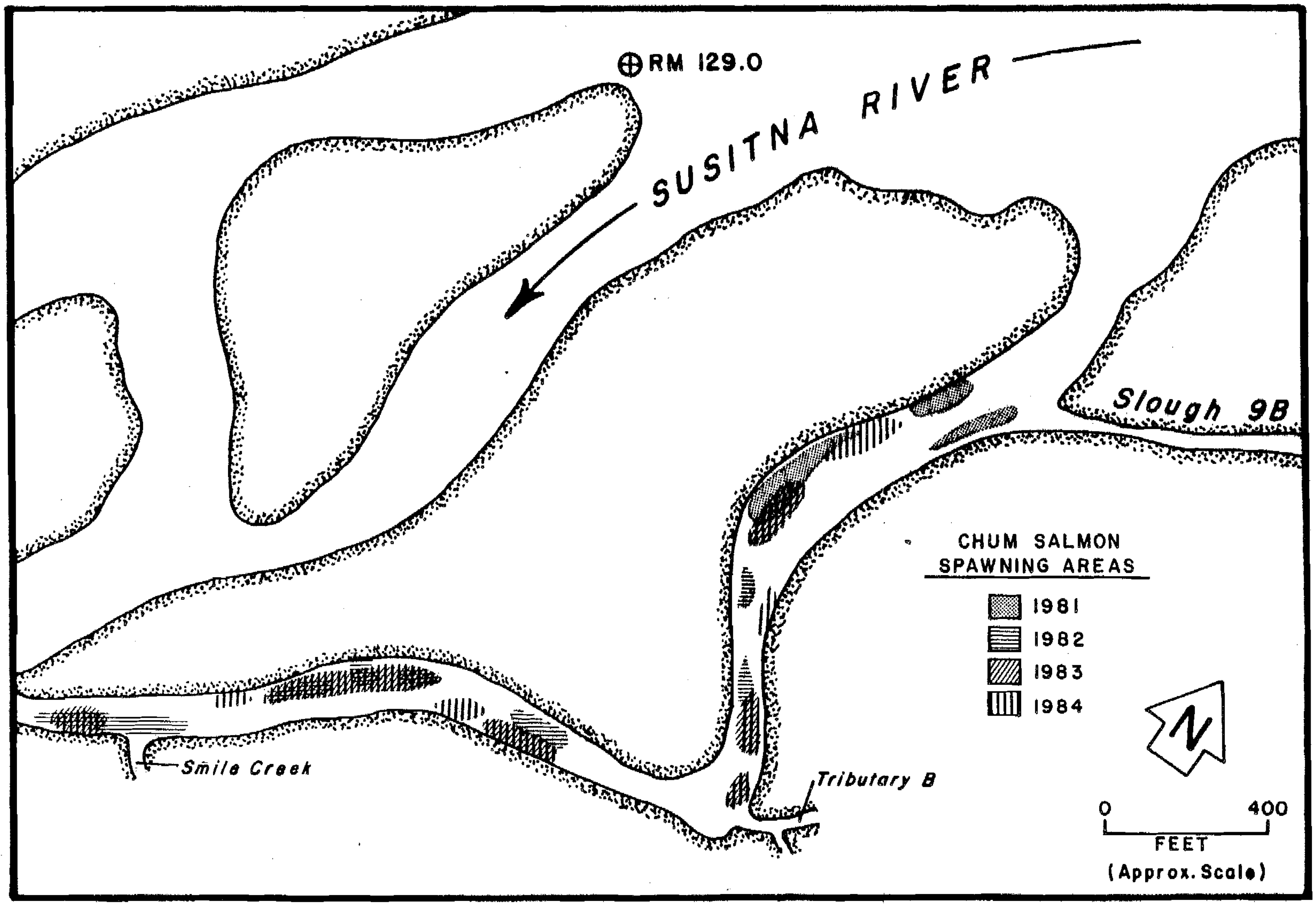
Access to this site is provided through Slough 9, which can be a problem when passage in Slough 9 is restricted. Two large beaver dams, at the mouth and 1,250 feet upstream of the mouth, were built in late 1982, resulting in completely blocking passage to this slough for spawning salmon since the fall of that year. Numerous smaller dams occur in the



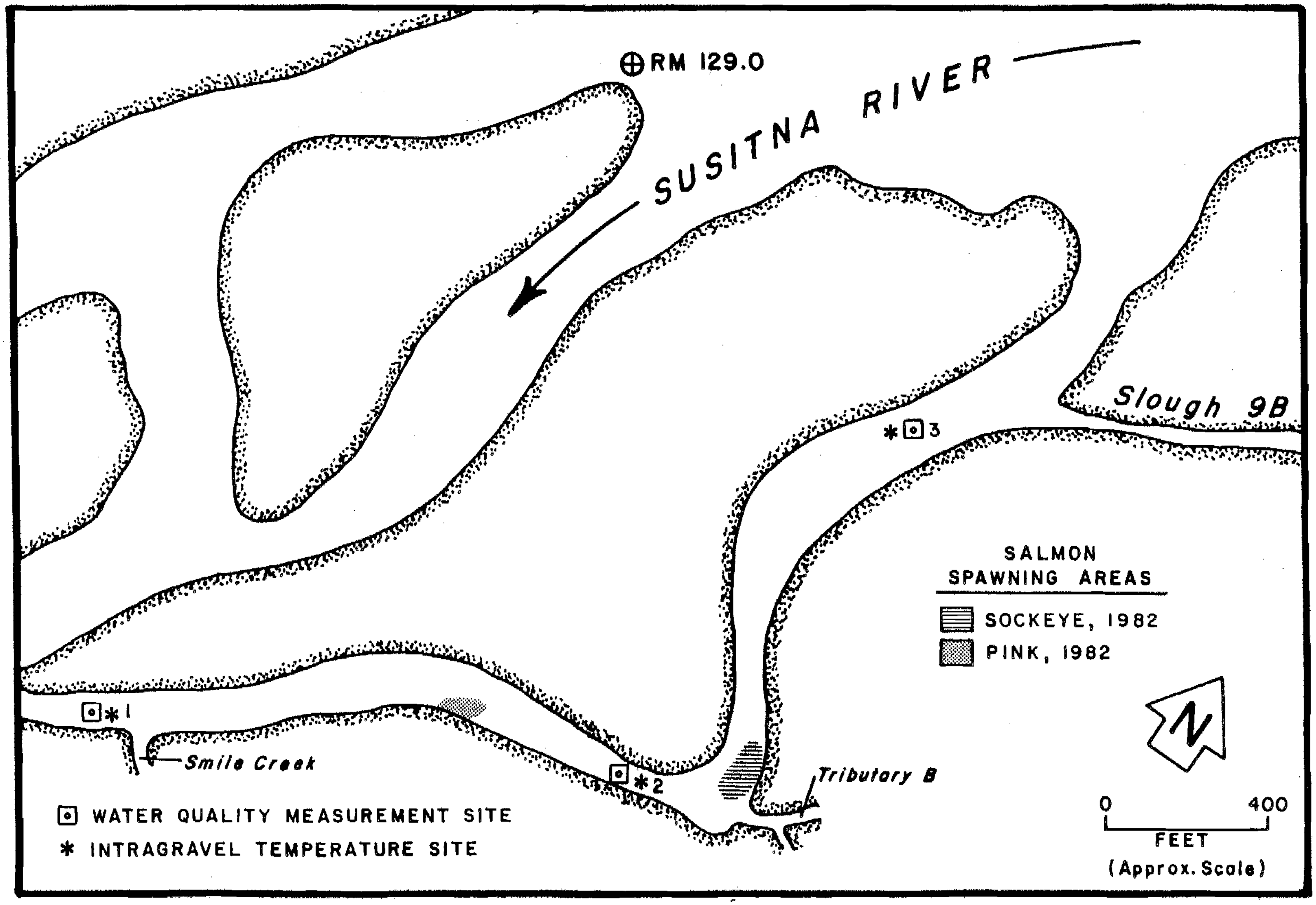
Appendix Figure A-61. Upwelling areas and passage reaches in Slough 9 (RM 128.3R).



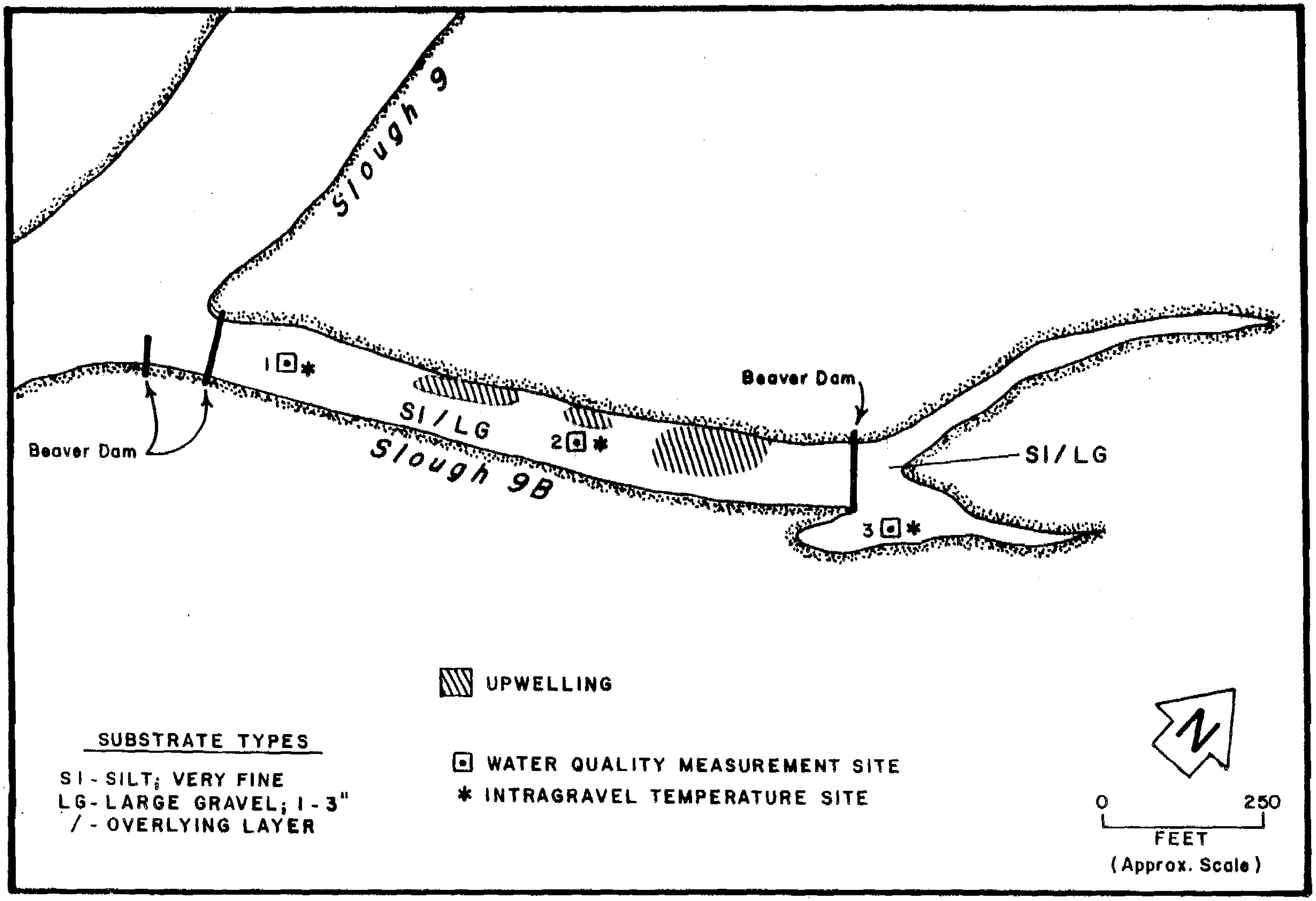
Appendix Figure A-62. Substrate composition in Slough 9 (RM 128.3R).



Appendix Figure A-63. Chum salmon spawning areas in Slough 9 (RM 128.3R).



Appendix Figure A-64. Sockeye and pink salmon spawning areas in Slough 9 (RM 128.3R).



Appendix Figure A-65. Substrate composition and upwelling areas in Slough 9B (RM 129.2R).

channels upstream of the second major dam. In 1984, ADF&G personnel created temporary openings in both dams to provide passage into the slough. Chum and sockeye salmon moved into the slough and spawned during a period of high water which provided passage through Slough 9 (Appendix Figures A-66 and A-67). Numerous fry (up to 6 inches in length) were observed in the slough prior to opening the dam at the mouth. They immediately migrated downstream when the dam at the mouth of the slough was opened.

Factors limiting salmon spawning in this slough are passage (through Slough 9 and into Slough 9B) and substrate. Both passage into Slough 9B and the substrate problems can be directly related to the extensive beaver activity throughout the site.

Slough 9A (RM 133.2R)

This is approximately an 0.6 mile long by 50 feet wide , side slough on the east bank of the Susitna River, separated from the mainstem by a long vegetated island. Breaching occurs at mainstem discharges greater than 12,000 cfs, creating one long run. Below 12,000 cfs, the wetted area develops into a series of pools and riffles. Ten passage reaches occur at various discharge levels and are discussed at length in Blakely et al. 1985 and Sautner et al. 1984 (Appendix Figure A-68).

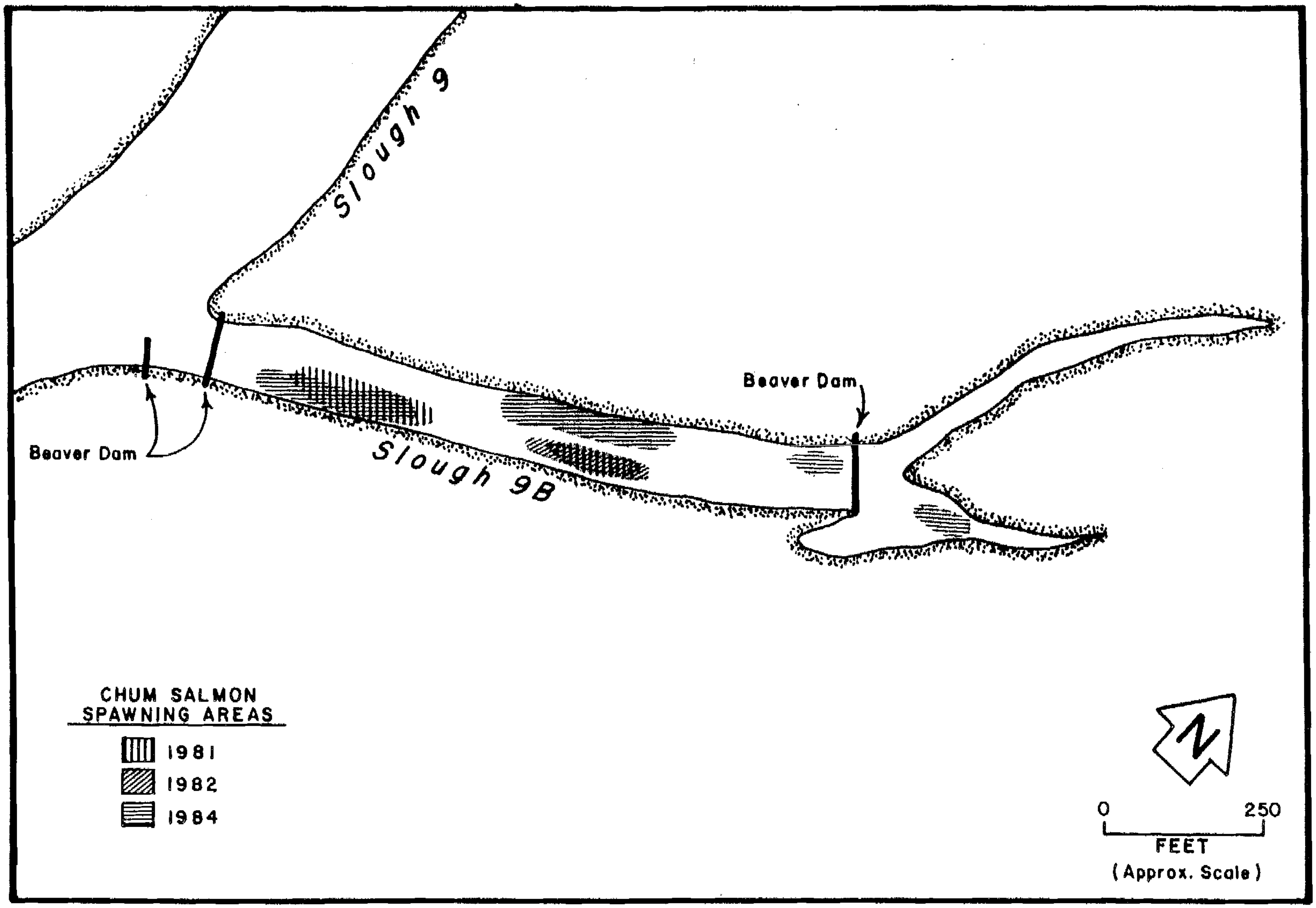
There appears to be good bank seepage and upwelling along the entire length of the slough (Appendix Figure A-68). Mainstem influence is probably the driving force along the left bank, while runoff from the mountains influences the right bank. Substrate composition in the slough is predominately rubble/cobble. Areas of large gravel exist in pool areas throughout the slough while cobble/boulder predominates in the riffle habitats (Appendix Figure A-69).

Chum and sockeye salmon spawn in Slough 9A (Appendix Figure A-70 and 71) with a peak 1984 chum salmon count of 303 fish or 4.6 percent of the total slough escapement. A channel on the right bank at the head is also heavily utilized for spawning. This channel has good substrate throughout most of its length with upwelling and bank seepage. Fry were observed in pools throughout the slough.

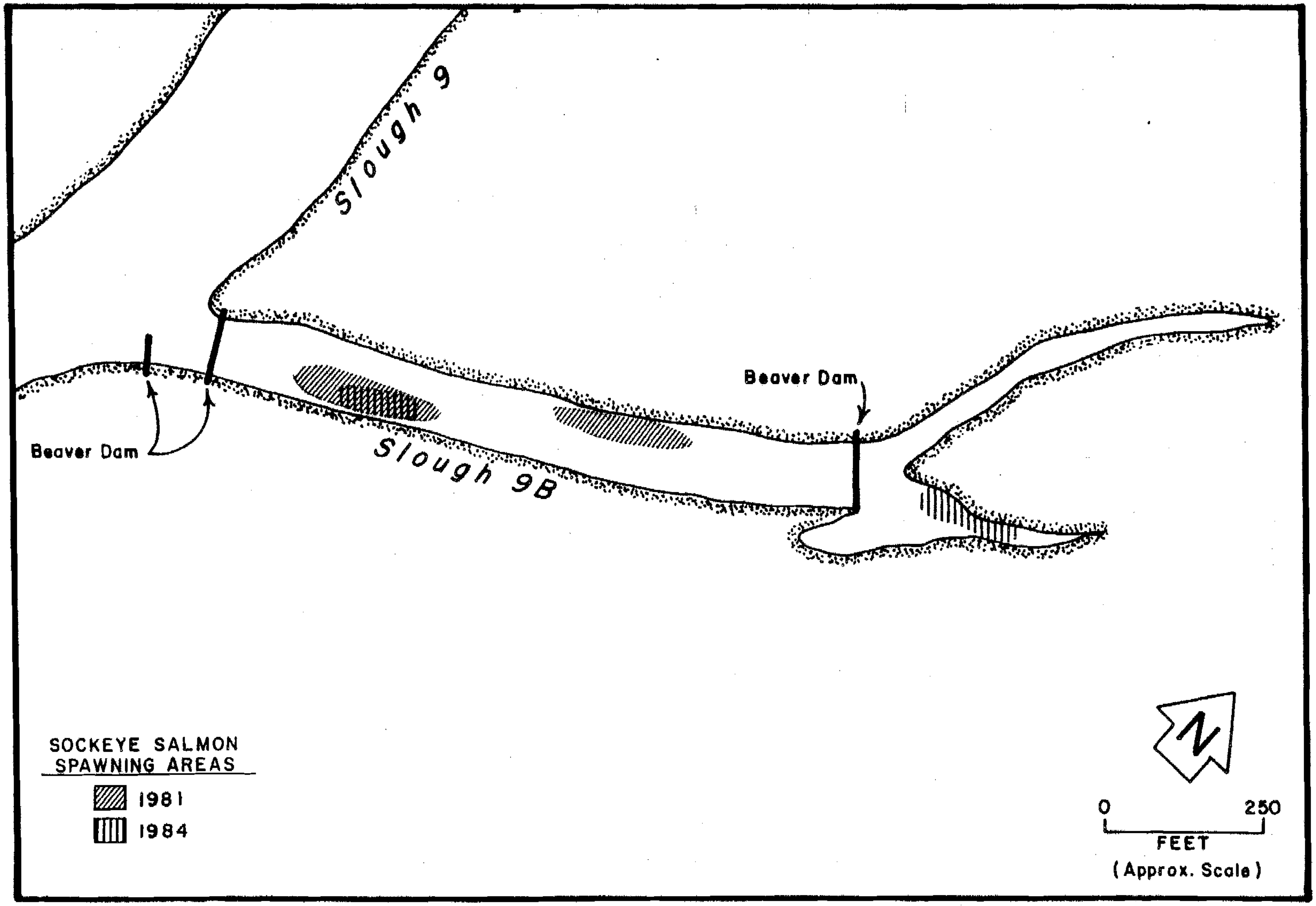
Spawning habitat improvements include removing passage barriers and minor substrate replacement.

Slough 10 (RM 133.8L)

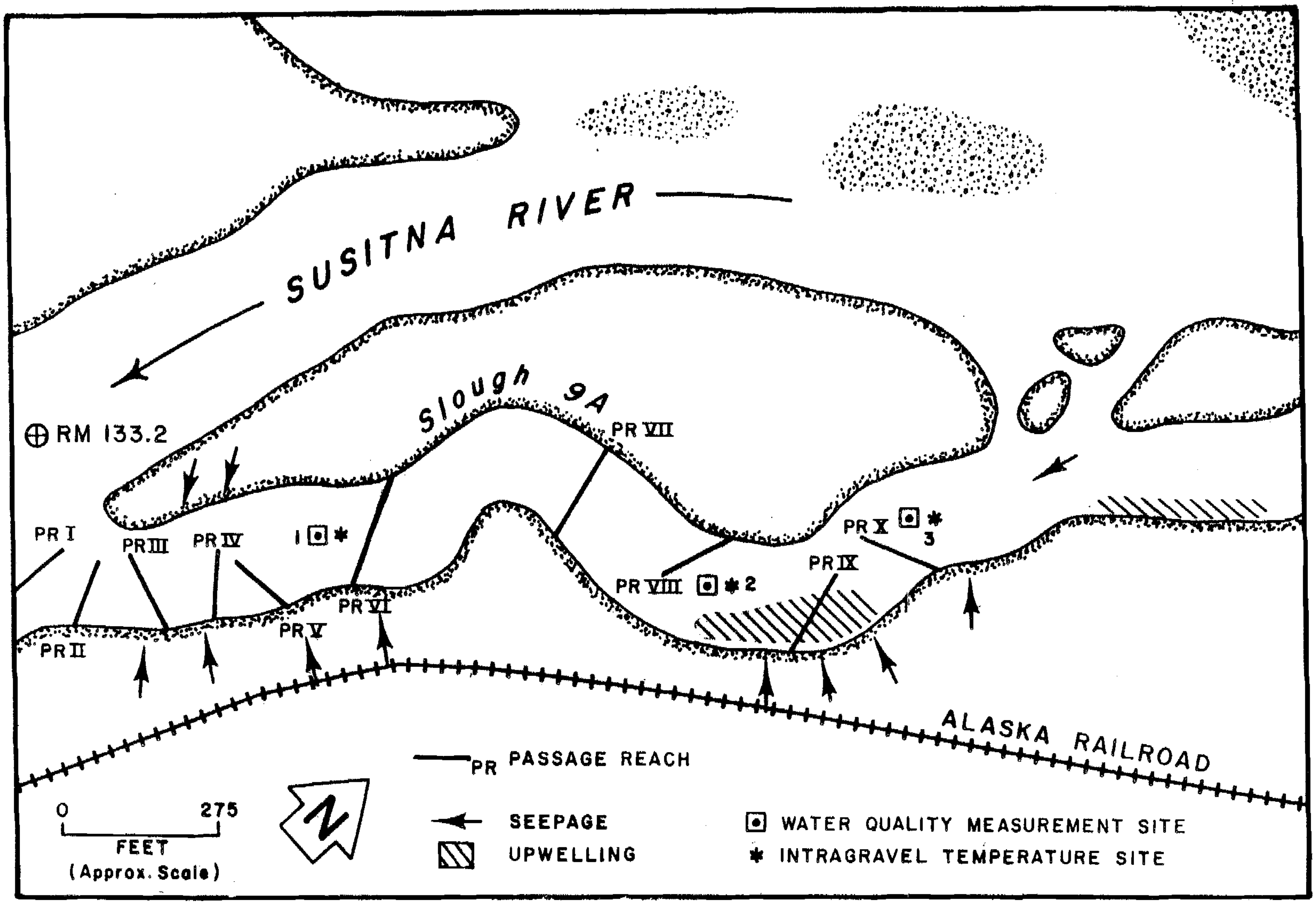
This site is an upland slough on the west side of the Susitna River consisting of two channels that diverge 250 feet upstream of the mouth. The left channel extends approximately 3,000 feet in a northerly direction ending in a series of beaver dams and ponds, while the right channel extends 1,500 feet in an easterly direction. The area below the junction of the two channels is primarily a backwater. The left channel consists of a long run with an occasional riffle and pool while the right channel is a run/riffle area (Appendix Figure A-72). Substrate



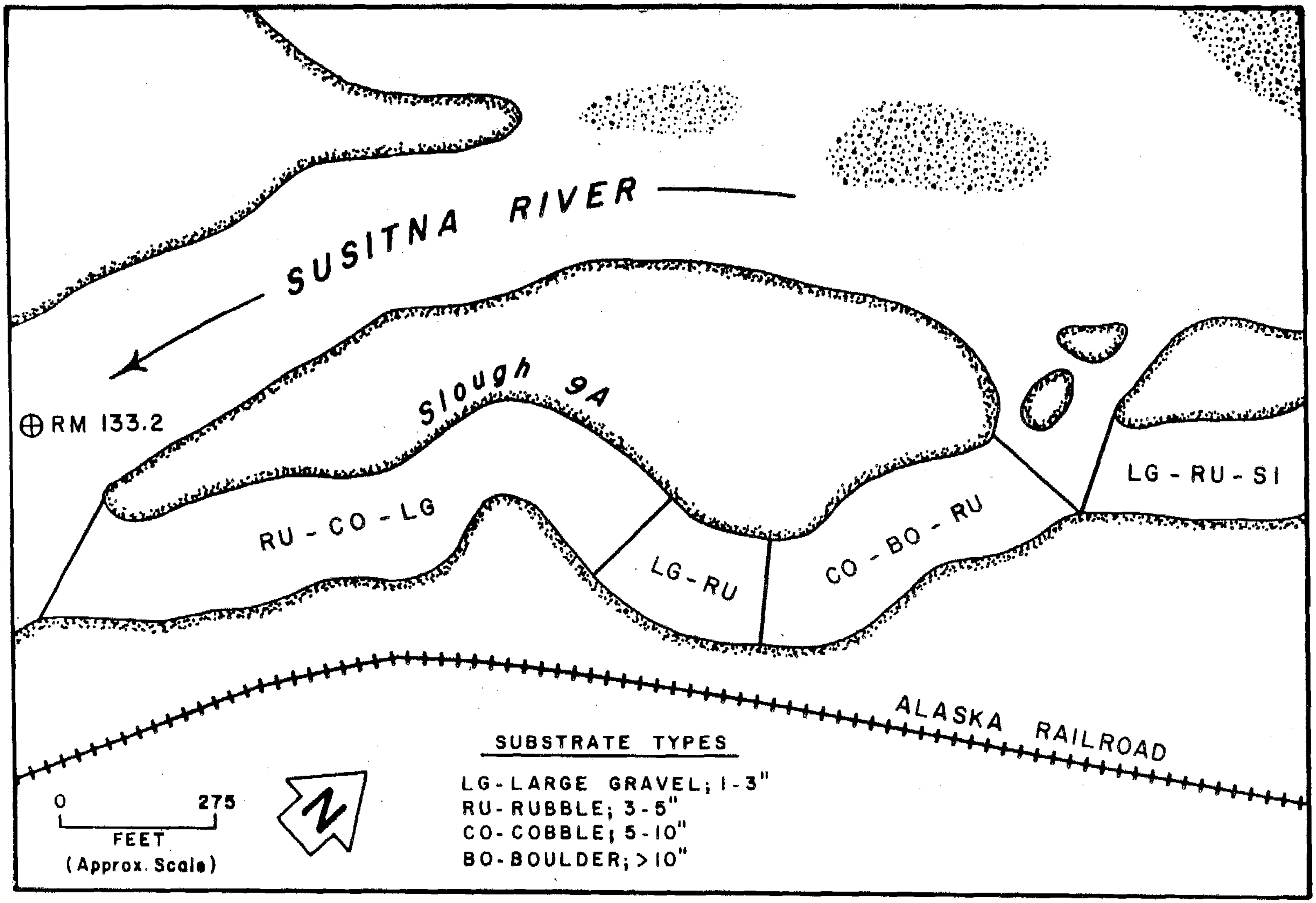
Appendix Figure A-66. Chum salmon spawning areas in Slough 9B (RM 129.2R).



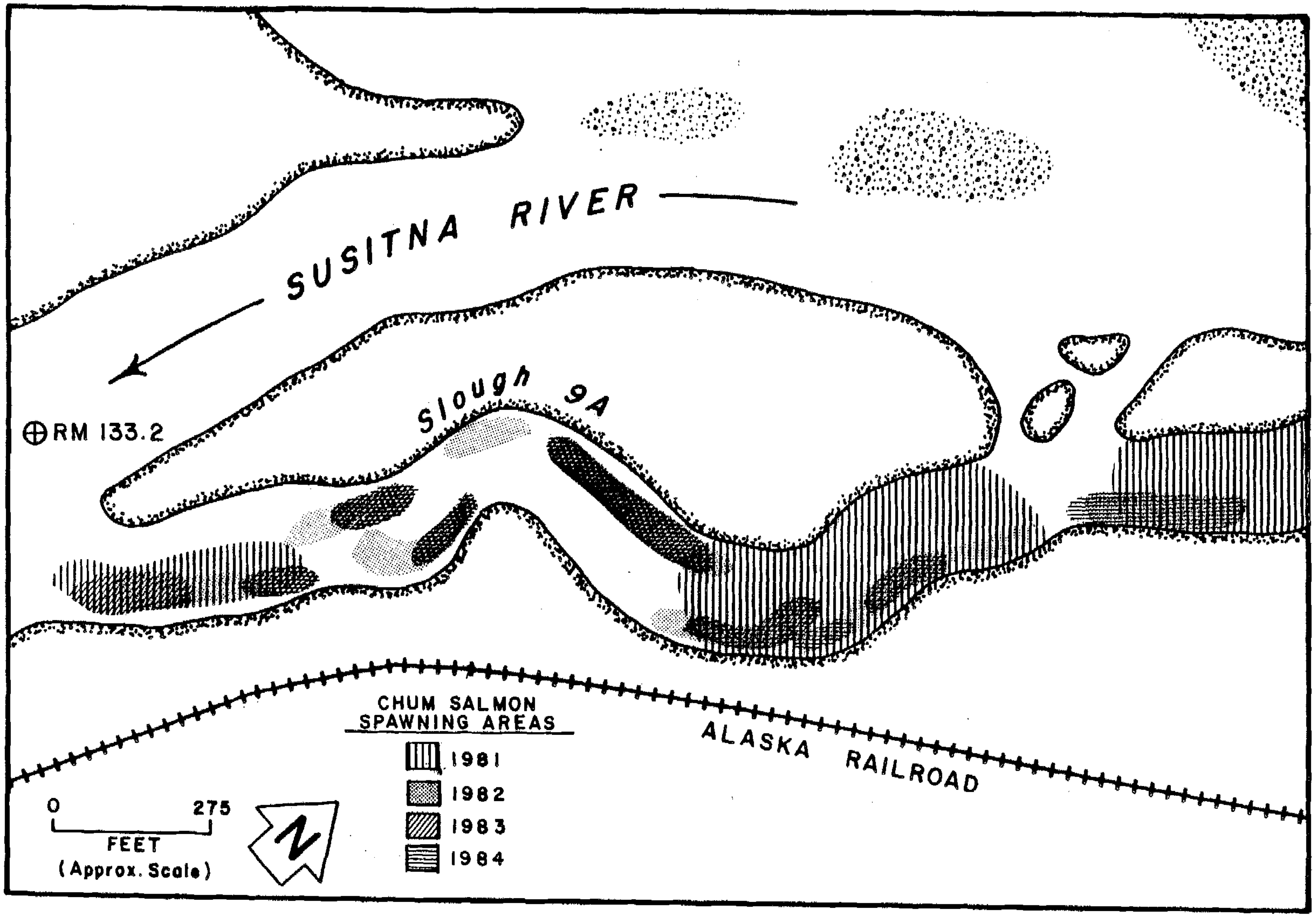
Appendix Figure A-67. Sockeye salmon spawning areas in Slough 9B (RM 129.2R).



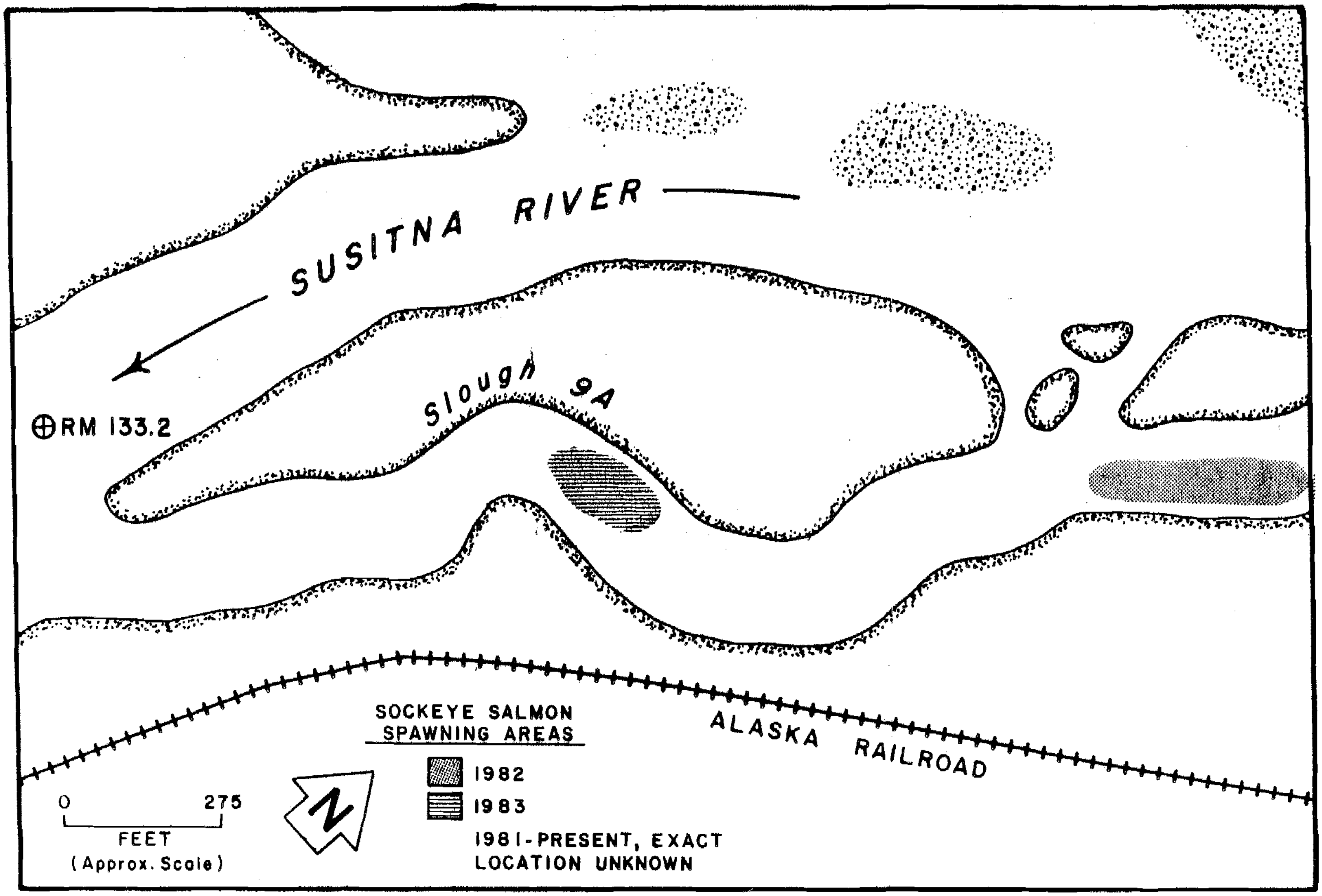
Appendix Figure A-68. Passage reaches and upwelling areas in Slough 9A (RM 133.2R).



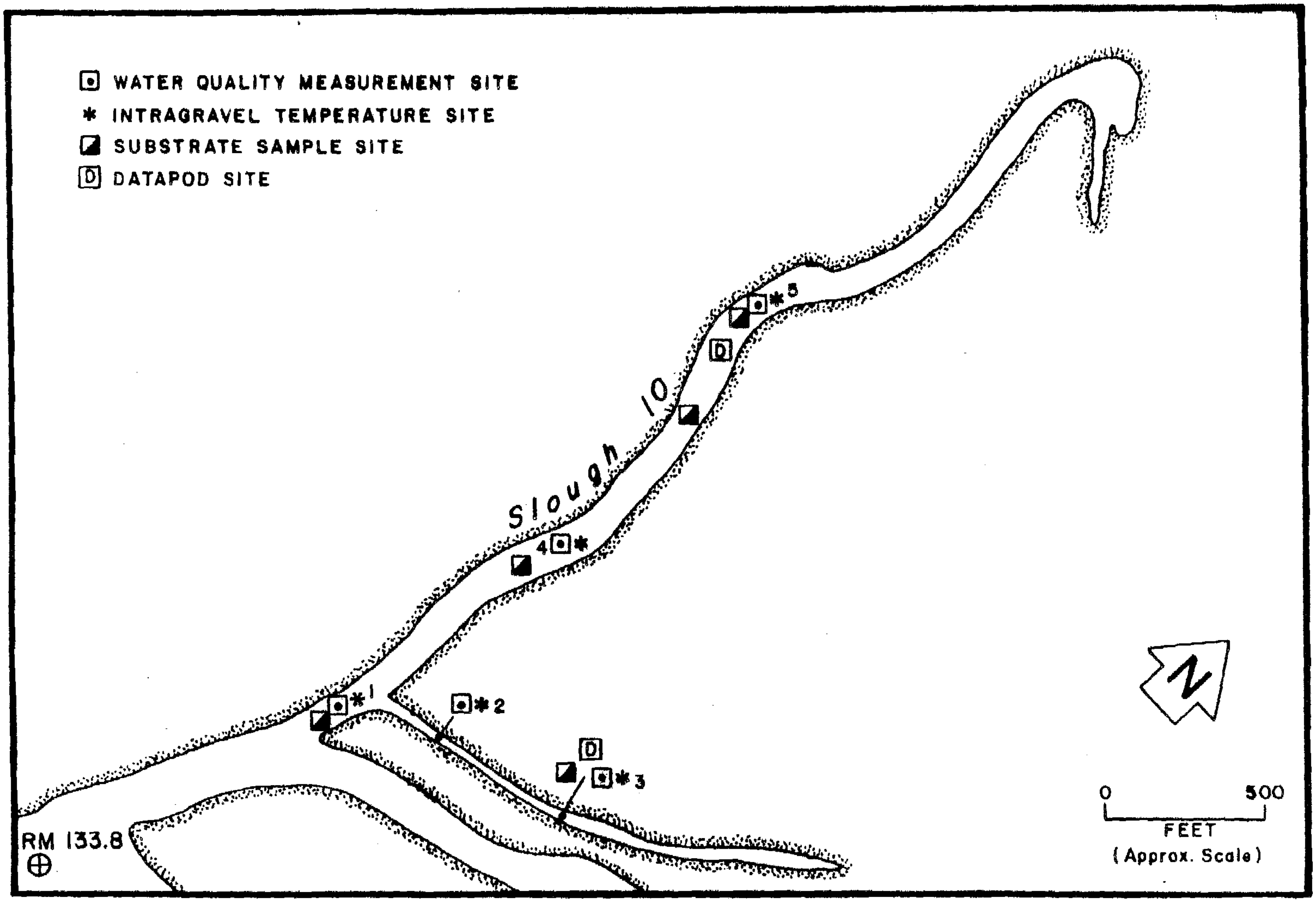
Appendix Figure A-69. Substrate composition in Slough 9A (RM 133.2R).



Appendix Figure A-70. Chum salmon spawning areas in Slough 9A (RM 133.2R).



Appendix Figure A-71. Sockeye salmon spawning areas in Slough 9A (RM 133.2R).



Appendix Figure A-72. Channel geometry and sampling locations in Slough 10 (RM 133.8L).

through most of the slough, except the right fork and upper reaches of the left fork, is composed of a deep silt layer over cobble/boulder. The right channel is predominately cobble/boulder covered by thin sand deposits. The upper reaches of the left channel is primarily rubble/cobble substrate with very little sand or silt (Appendix Figure A-73). The slough is maintained by water draining from the bog and beaver ponds at the head as well as the very extensive upwelling and bank seepage occurring throughout the slough (Appendix Figure A-74). Chum salmon have been observed spawning in this slough since 1982 (Appendix Figure A-75).

It appears that substrate is the primary factor limiting spawning.

Slough 11 (RM 135.3R)

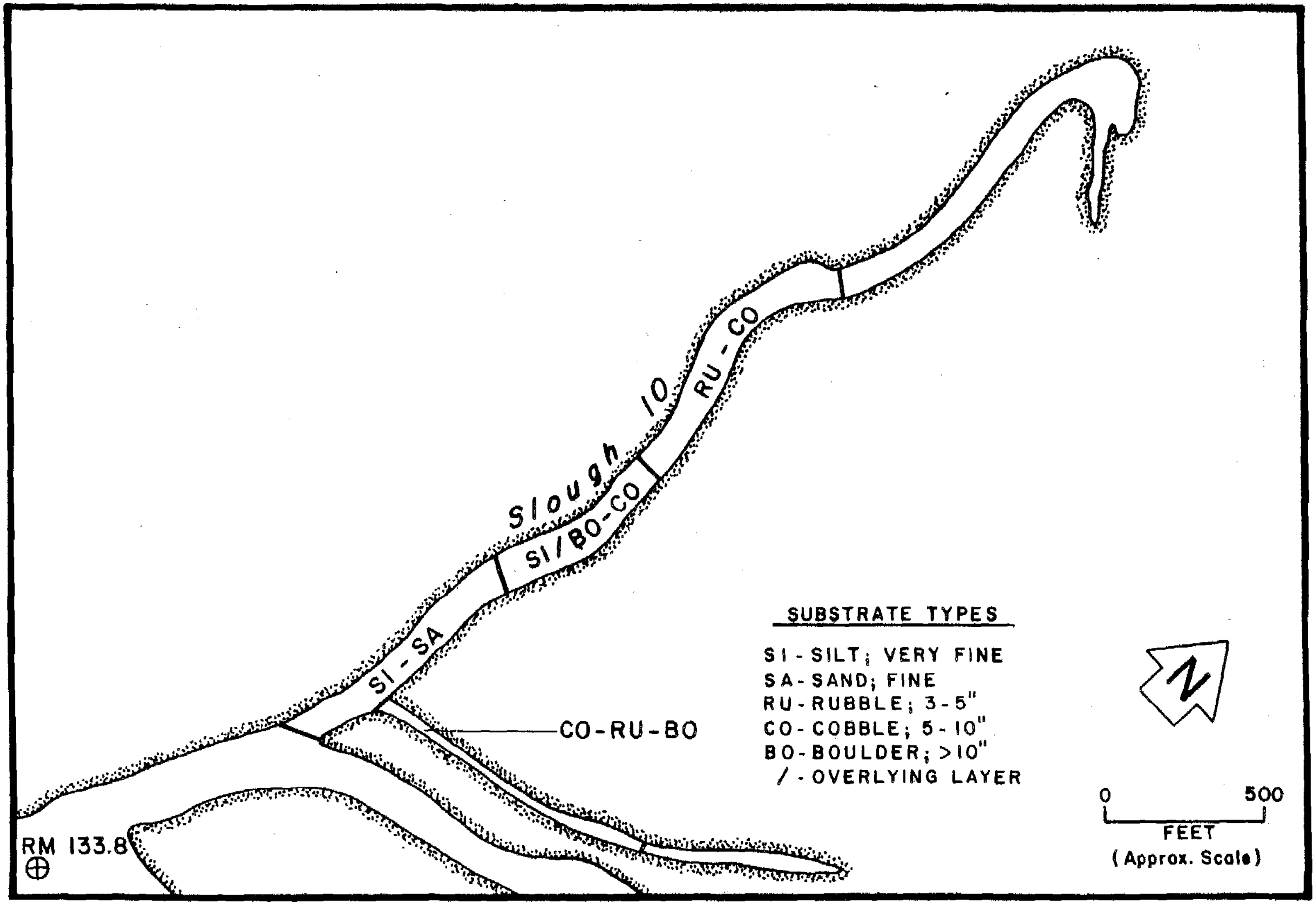
Slough 11 is an important spawning site for chum and sockeye salmon (Appendix Figures A-77 and A-78) as well as pink salmon (Appendix Figure A-79). It is responsible for 21.3 percent of the chum salmon and 61.0 percent of the sockeye salmon total slough distribution (Barrett et al. 1985). It consists of a 0.9 mile side slough beginning at RM 135.3 with access via Lower Side Channel 11. The head is situated in the middle of Upper Side Channel 11. The breaching discharge of the head is estimated at 42,000 cfs. Base slough flow is maintained by extensive upwelling and bank seepage (Appendix Figure A-80). The wetted area consists of a series of pools and riffles. Seven passage reaches have been defined by Blakely et al. 1985 and Sautner et al. 1984 (Appendix Figure A-80). The lower two are readily overcome by backwater effects at mainstem discharges of 19,400 cfs and greater.

There is a large degree of variability in the substrate in this slough (Appendix Figure A-81). The riffles and the head are predominately rubble/cobble/boulder. The pools, which are the major spawning areas, are large gravel/rubble covered by a thin layer of silt. The backwater area consists of thick silt/sand deposits overlying cobble/boulder substrate.

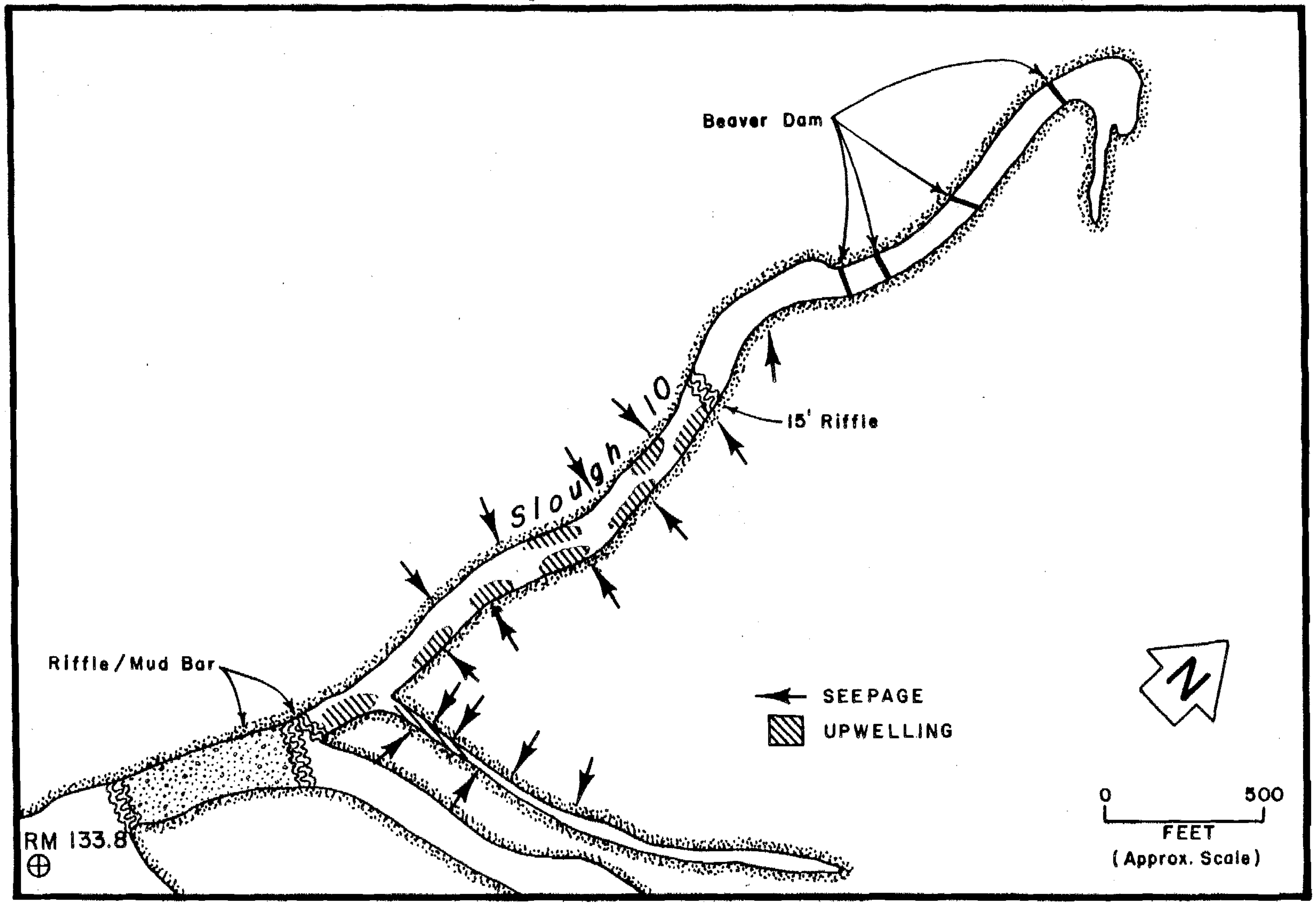
Fry have been observed throughput the slough. Passage is a primary factor inhibiting spawning in this site. Minor substrate cleaning and replacement may also be necessary to improve spawning conditions.

Slough 12 (RM 135.4R)

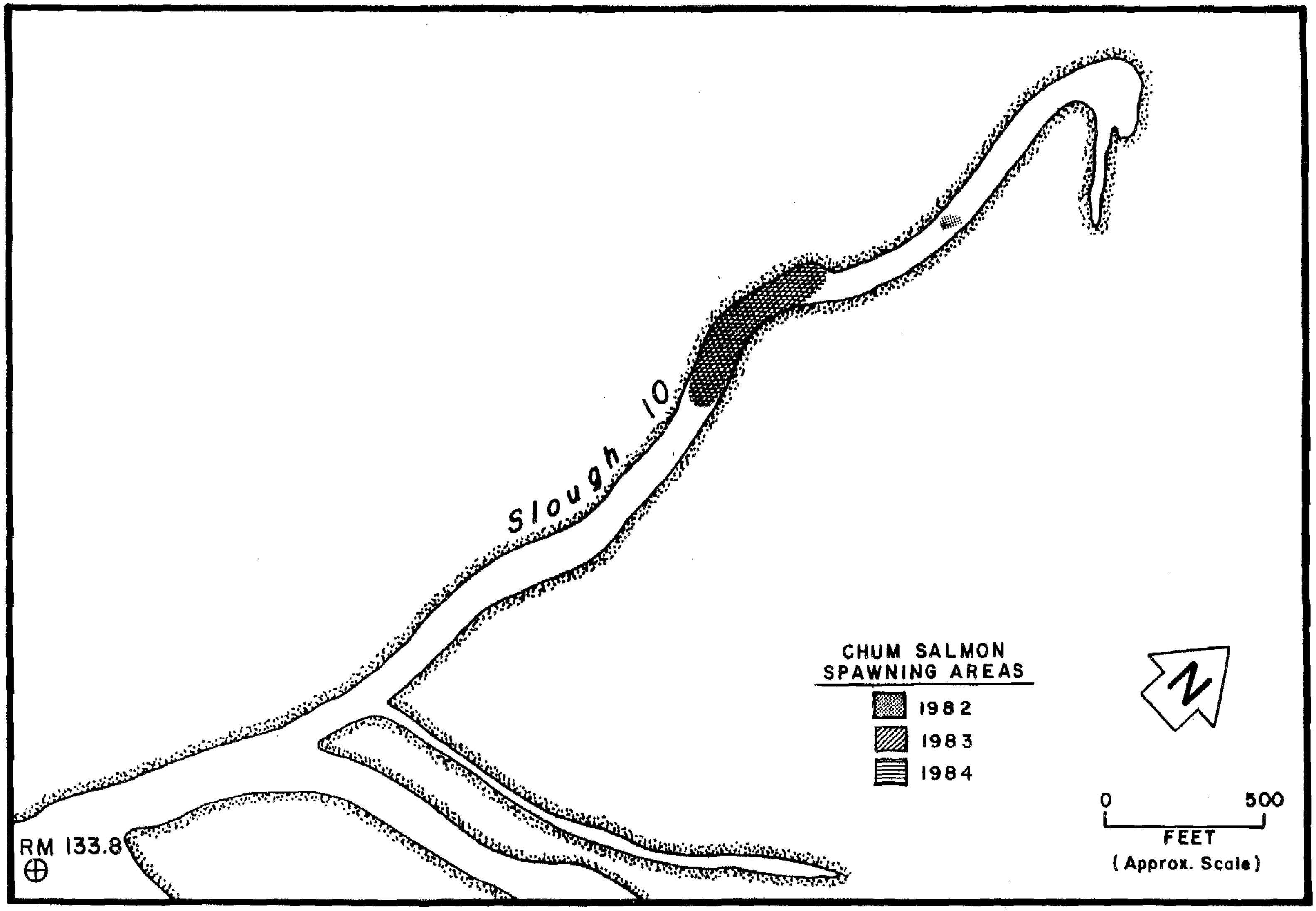
Slough 12 is a 0.3 mile long former side slough that has had its head filled in and overgrown with vegetation. This upland slough originating in a bog between Sloughs 11 and 13 is now primarily beaver habitat. It empties into the side channel above the mouth of Slough 11 at RM 135.4. A small creek drains into the right side of the slough approximately 600 feet upstream of the mouth. Below the creek the wetted area consists of a backwater area and short riffle followed by a long deep pool. Beaver activity is prevalent throughout the slough. A vegetated sand bar at



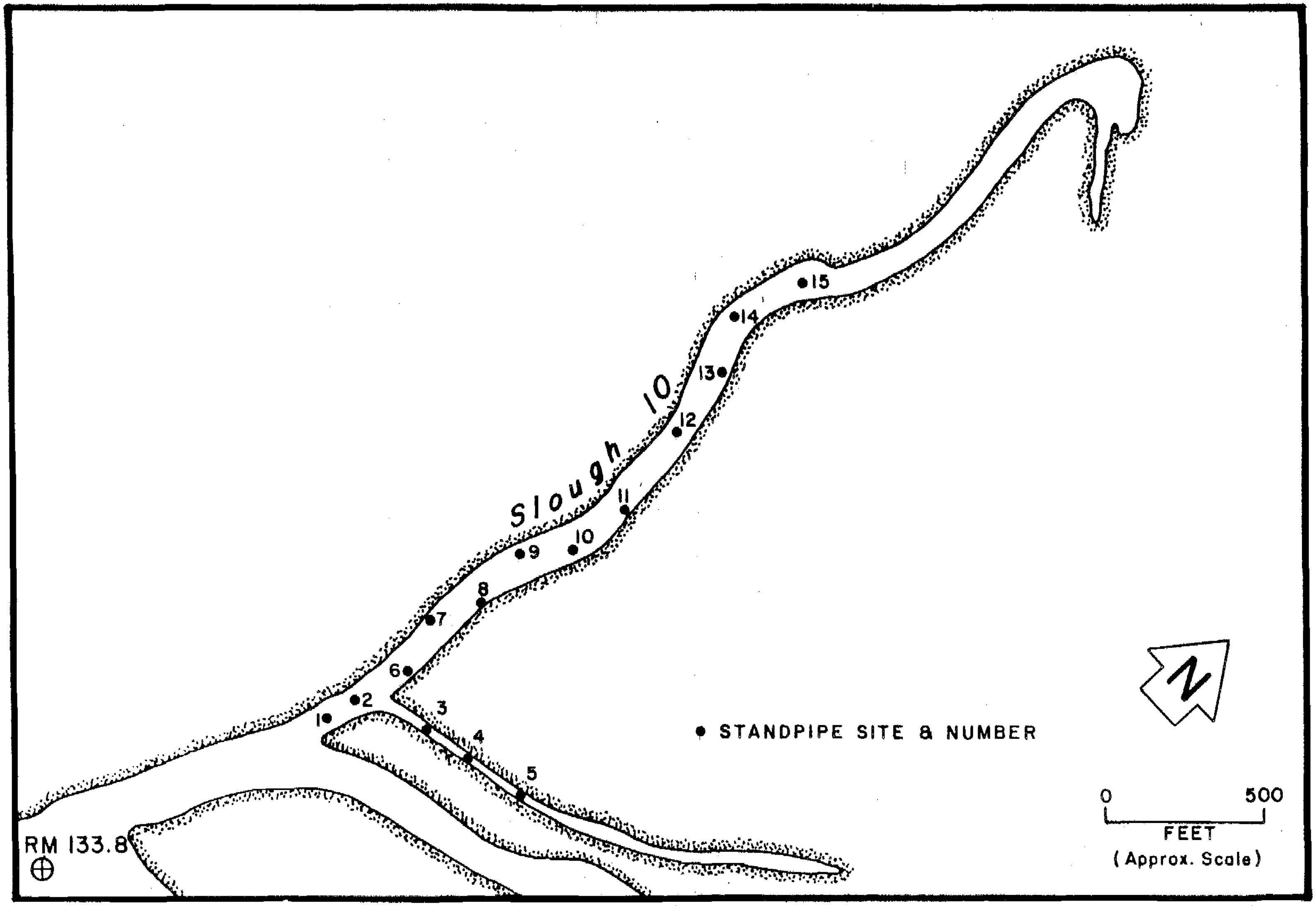
Appendix Figure A-73. Substrate composition in Slough 10 (RM 133.8L).



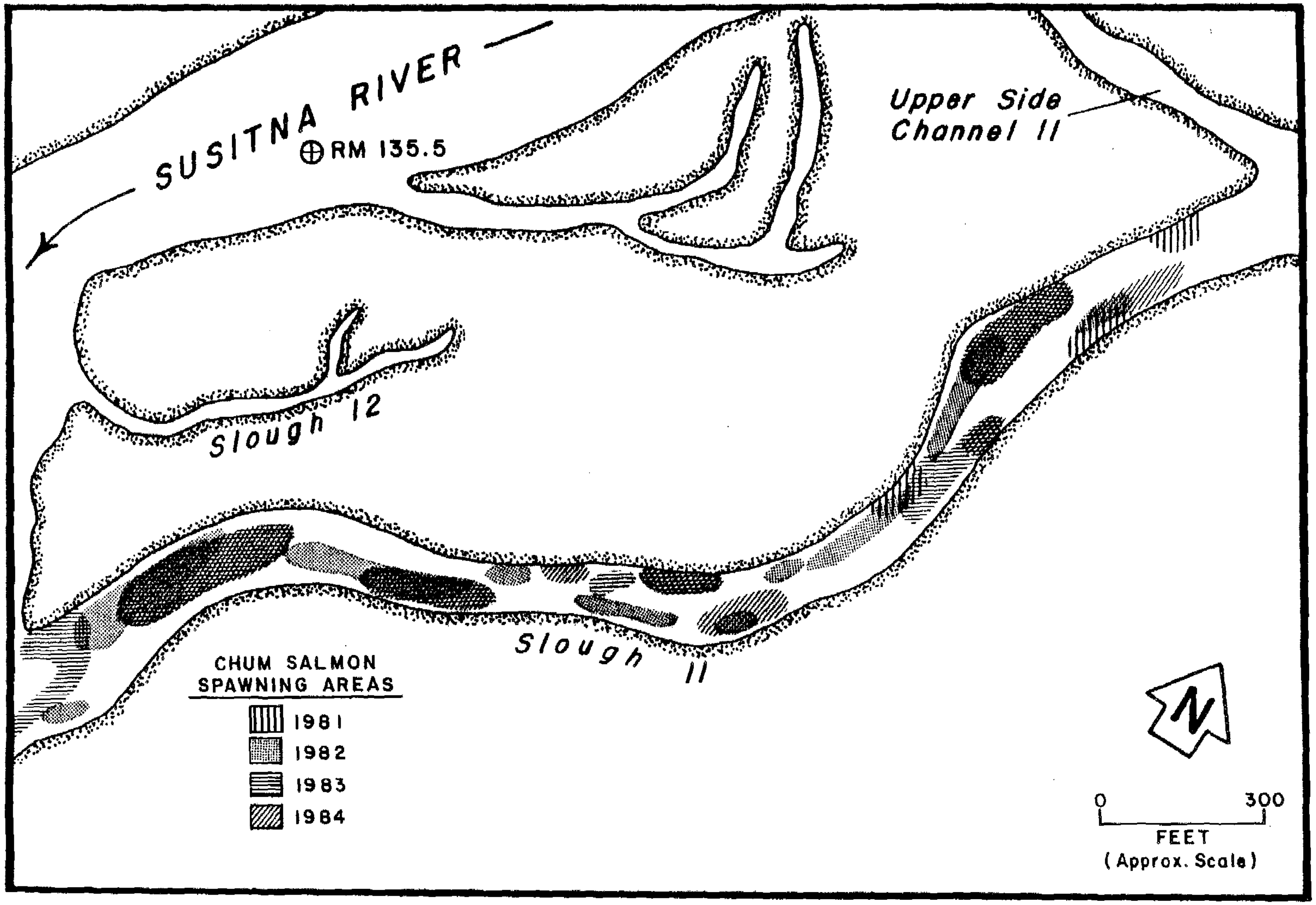
Appendix Figure A-74. Upwelling and bank seepage in Slough 10 (RM 133.8L).



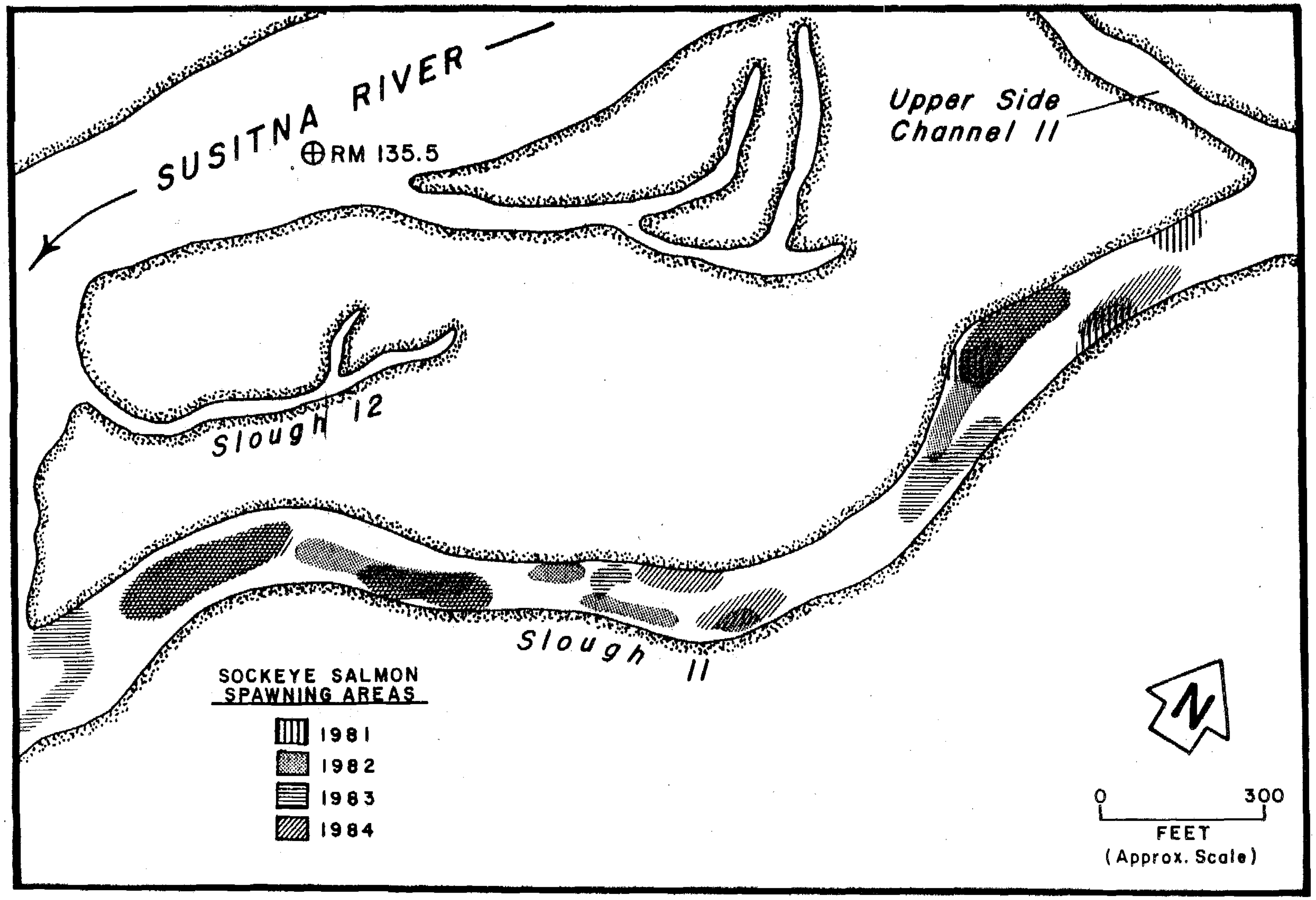
Appendix Figure A-75. Chum salmon spawning areas in Slough 10 (RM 133.8L).



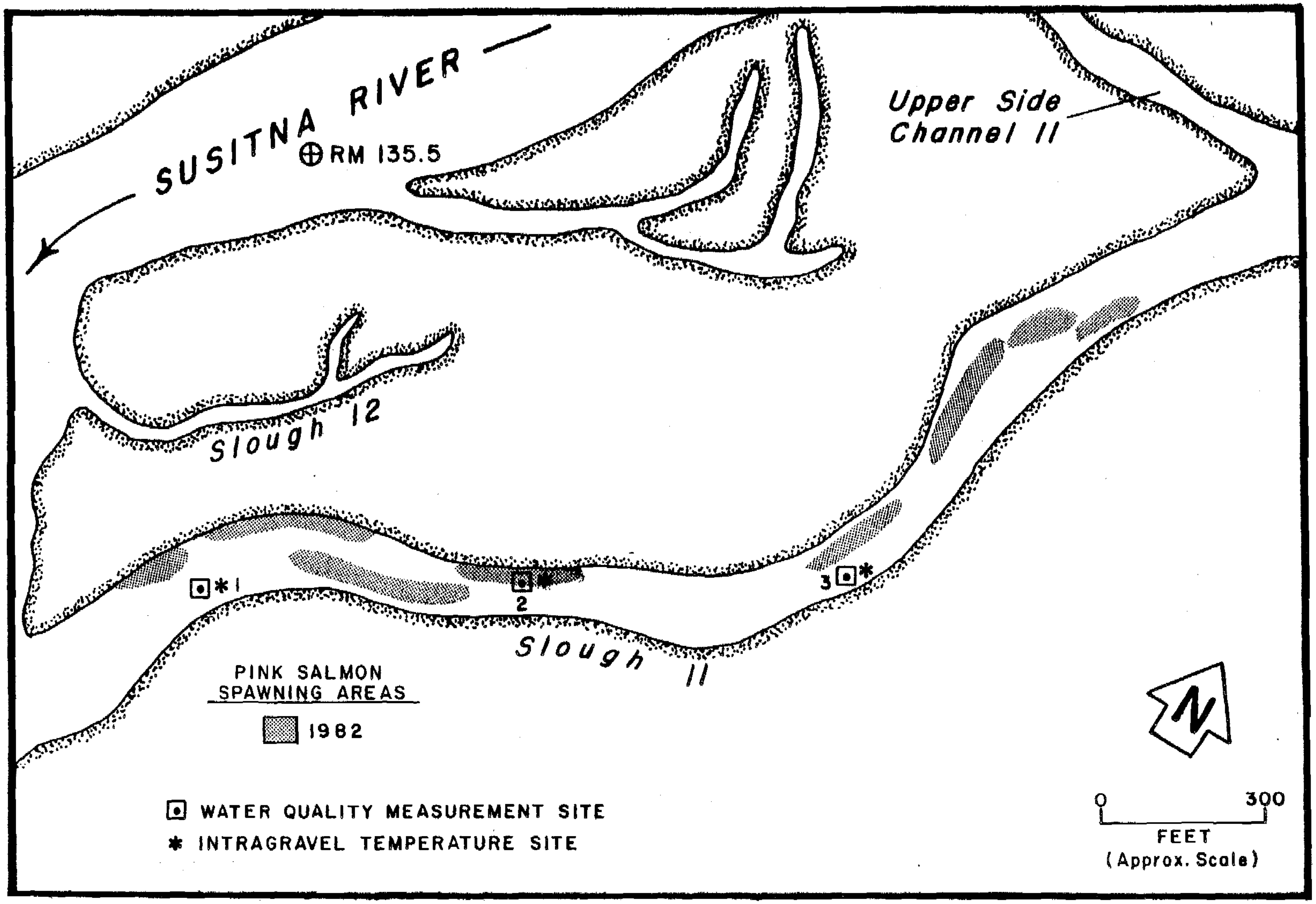
Appendix Figure A-76. Standpipe locations in Slough 10 (RM 133.8L).



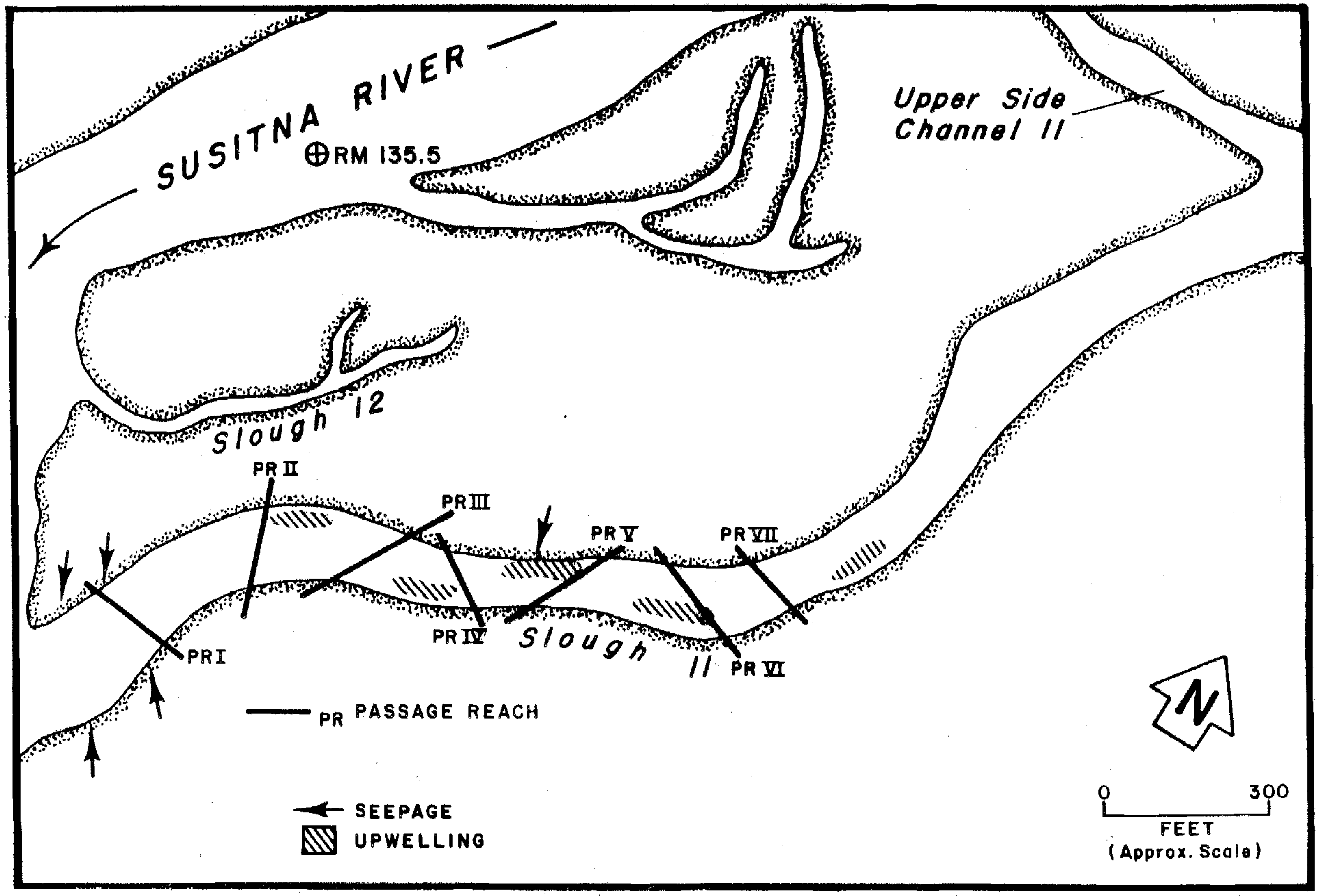
Appendix Figure A-77. Chum salmon spawning areas in Slough 11 (RM 135.3R).



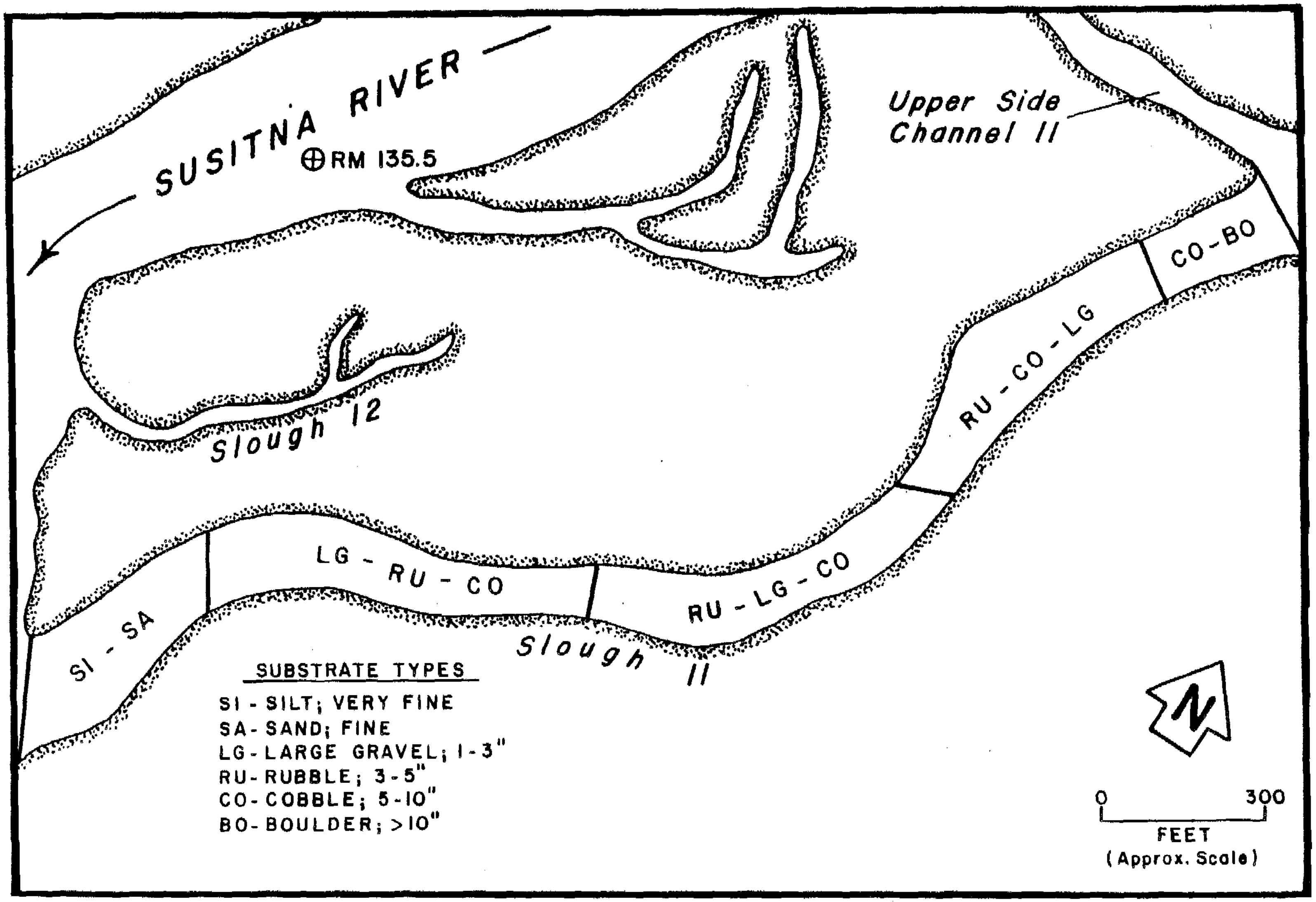
Appendix Figure A-78. Sockeye salmon spawning areas in Slough 11 (RM 135.3R).



Appendix Figure A-79. Pink salmon spawning areas in Slough 11 (RM 135.3R).



Appendix Figure A-80. Passage reach locations and upwelling areas in Slough 11 (RM 135.3R).



Appendix Figure A-81. Substrate composition in Slough 11 (RM 135.3R).

the mouth severely limits passage to this site except at high mainstem discharges (Appendix Figure A-82).

Deep silt substrates are found throughout the channel except in the riffle area where rubble/cobble predominate (Appendix Figure A-83). Littoral and riparian vegetation flourish in and along the pool. No spawning has ever been recorded nor was upwelling or bank seepage evident in this site. During winter it was frozen over, indicating an absence of upwelling.

Because of numerous problems associated with this site (passage, substrate, flow, upwelling, beaver activity), modifications to this site to improve spawning habitat would be extensive.

Slough 13 (RM 135.5R)

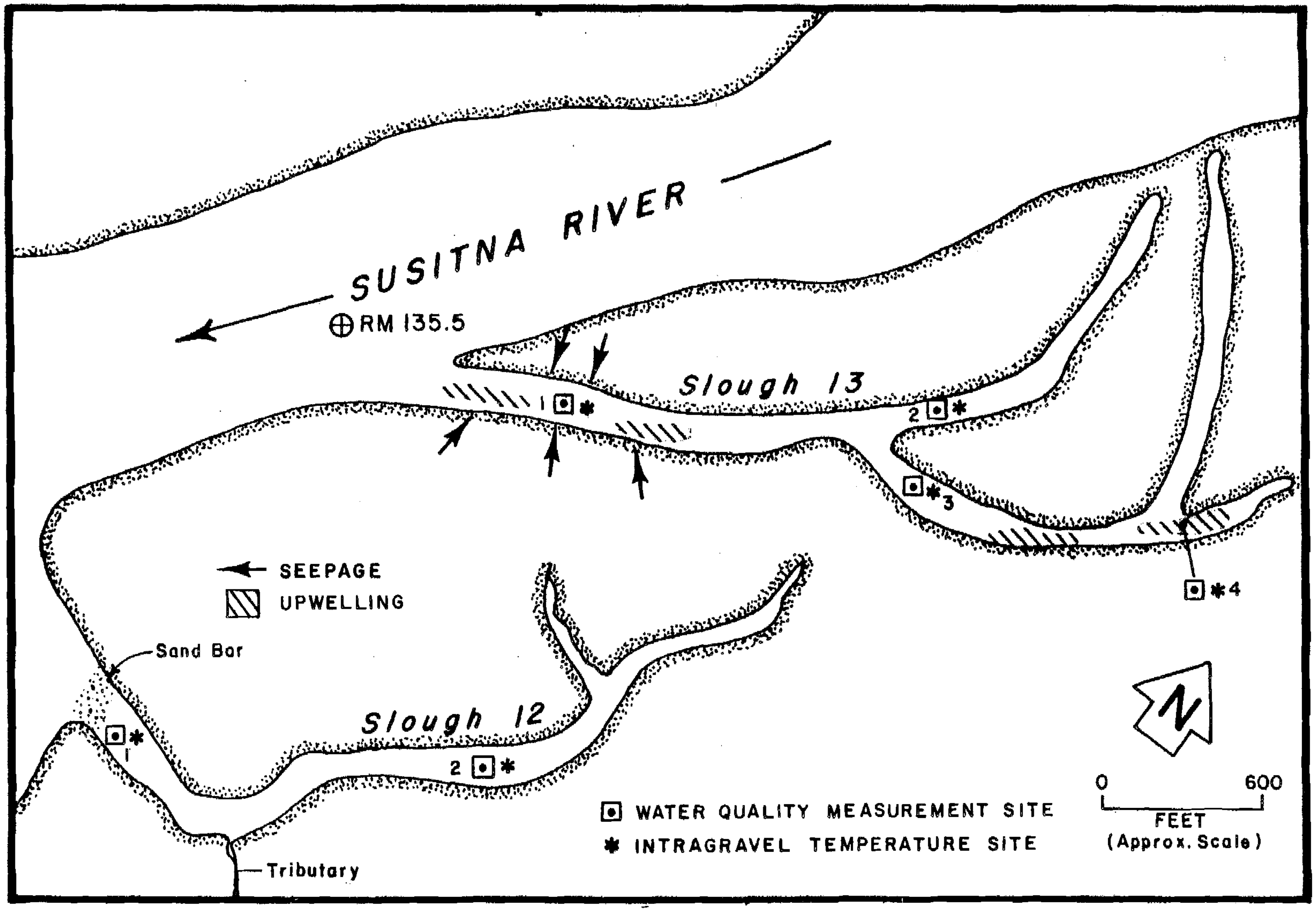
Slough 13 is a 0.5 mile long side slough on the east side of the Susitna River located immediately upstream of Slough 12 at RM 135.4. Two low lying heads join the slough to the mainstem with breaching appearing to be a frequent occurrence. In an unbreached condition, the slough is maintained by upwelling, bank seepage and intragravel flow from the mainstem (Appendix Figure A-82). Substrates in this slough are primarily rubble/large gravel in most areas. Silt and sand deposits accumulate in pools throughout the slough, reaching depths of one foot or greater (Appendix Figure A-83). For the most part, the wetted area is a riffle/run/pool system. Passage problems exist in the riffles during unbreached conditions when the majority of the site dewaters.

Chum salmon have been observed spawning in the upper reaches of this slough (Appendix Figure A-84). Historically, this is not an important slough spawning area. A limited number of fry were observed in a small tributary along the right bank near the head. Extensive work would be needed to improve and maintain the spawning habitat in this slough. It is not considered a prime mitigation candidate.

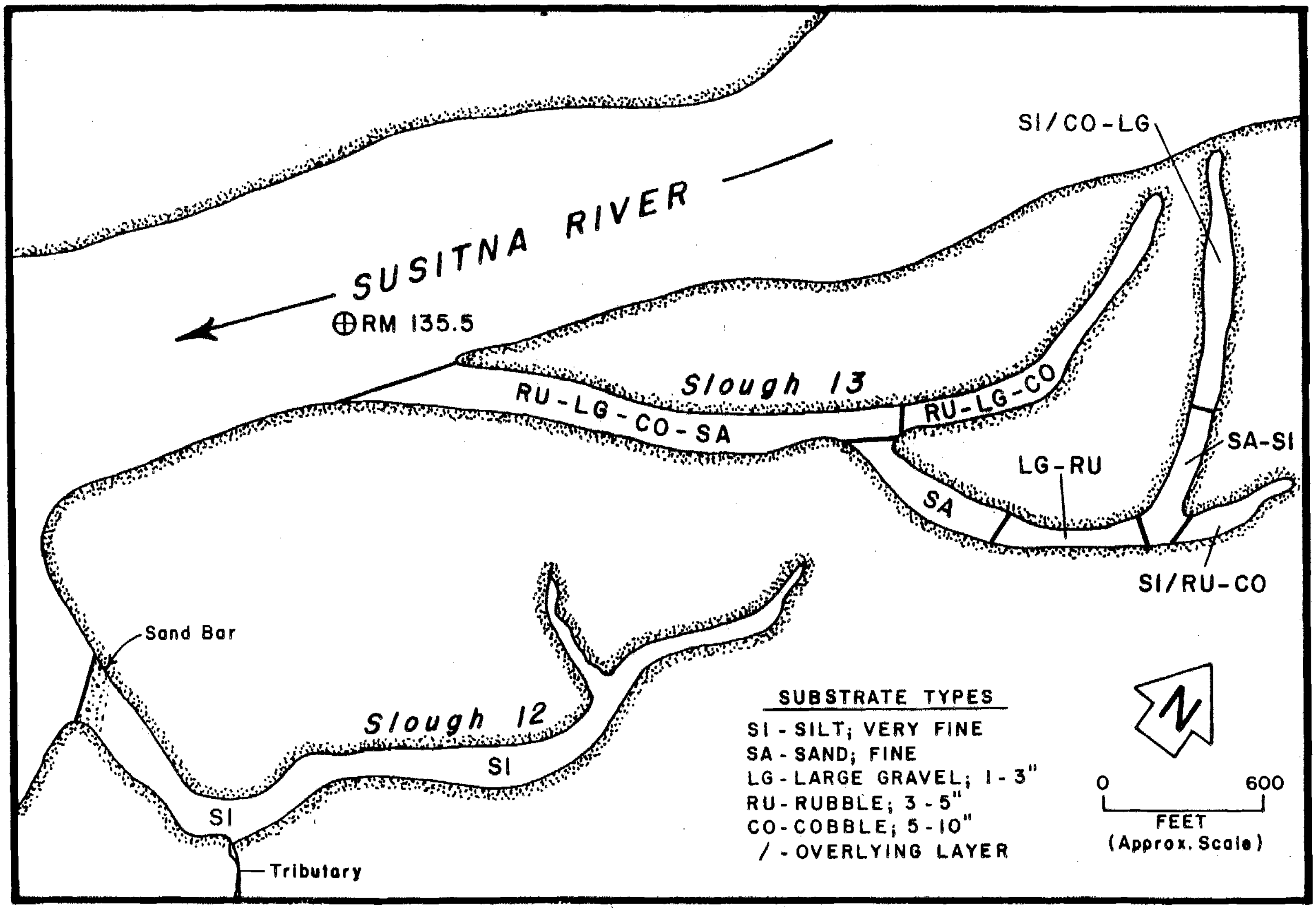
Upper Side Channel 11 (RM 136.0R)

Upper Side Channel 11 (RM 136.0R), located on the east bank of the Susitna River, is a single straight channel approximately 0.4 miles in length that is separated from the mainstem by a well vegetated island (Appendix Figure A-85). Approximately 1,400 feet upstream from the mouth, Upper Side Channel 11 is connected with the head of Slough 11 along the right bank. Channel morphology is rectangular, sloping gently on both sides to vegetated banks. Breaching occurs at mainstem discharges greater than 16,000 cubic feet per second. In an unbreached condition, base flow in the side channel is maintained by upwelling and bank seepage along both banks, primarily in the lower third of the slough (Appendix Figure A-86). The side channel is a backwater followed by riffle pool sequence.

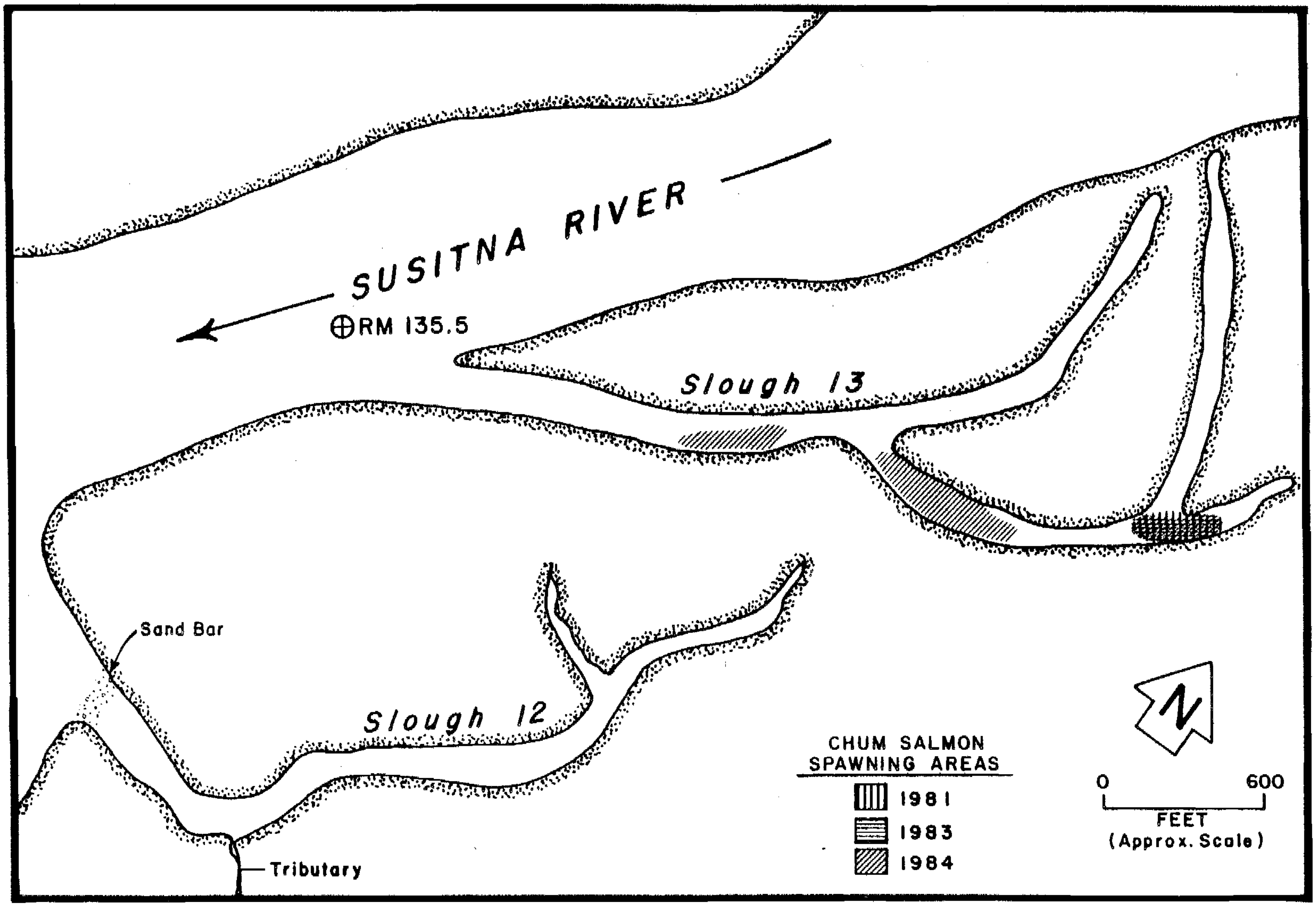
The backwater area in Upper Side Channel 11 extends approximately 450 to 500 feet into the side channel with corresponding mainstem discharges of 11,400 to 31,700 cfs. Above the backwater area, Upper Side Channel 11 consists of a series of long riffles and pools. Silt and sand deposits



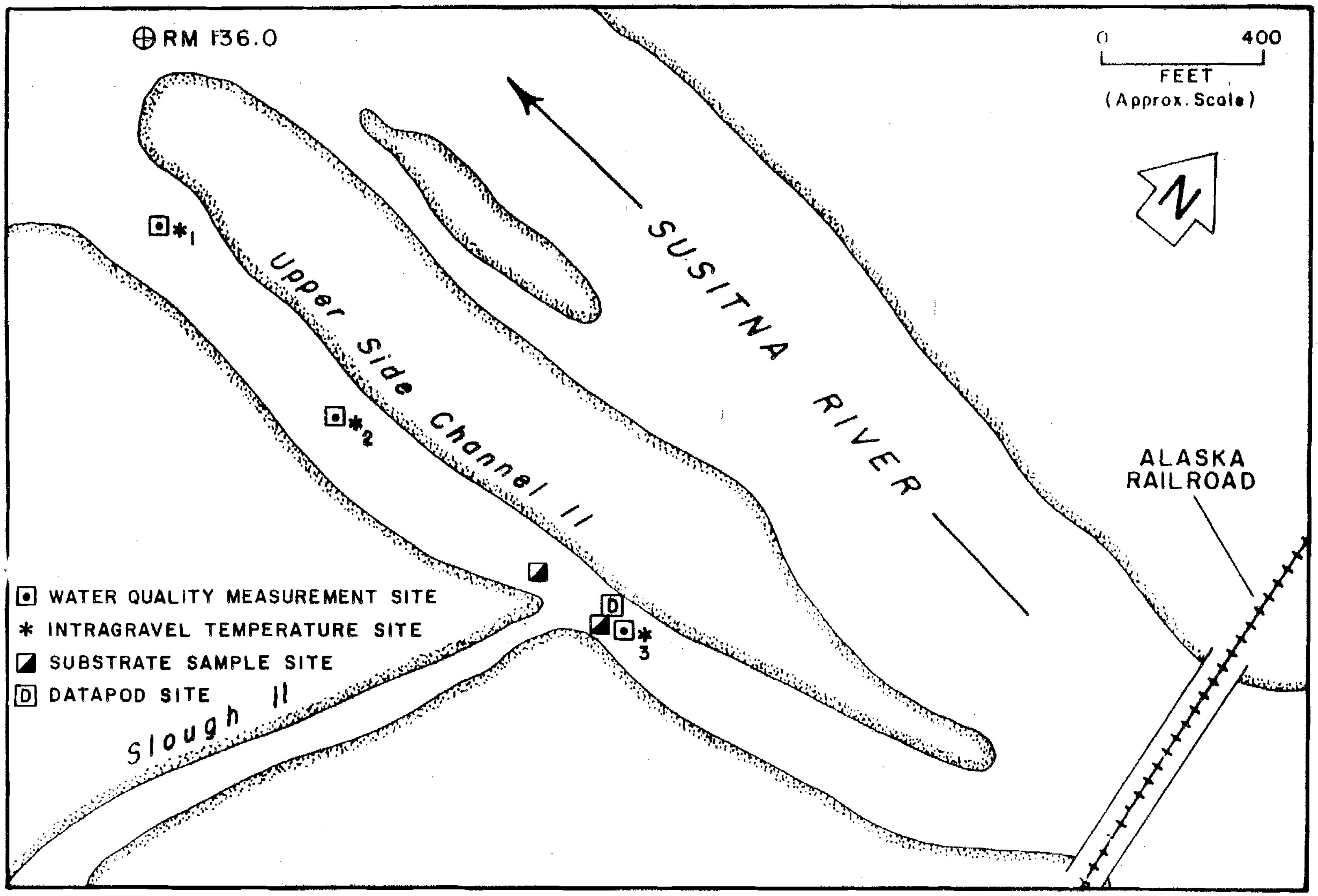
Appendix Figure A-82. Upwellng areas and sampling sites in Slough 12 (RM 135.4R) and Slough 13 (RM 135.5R).



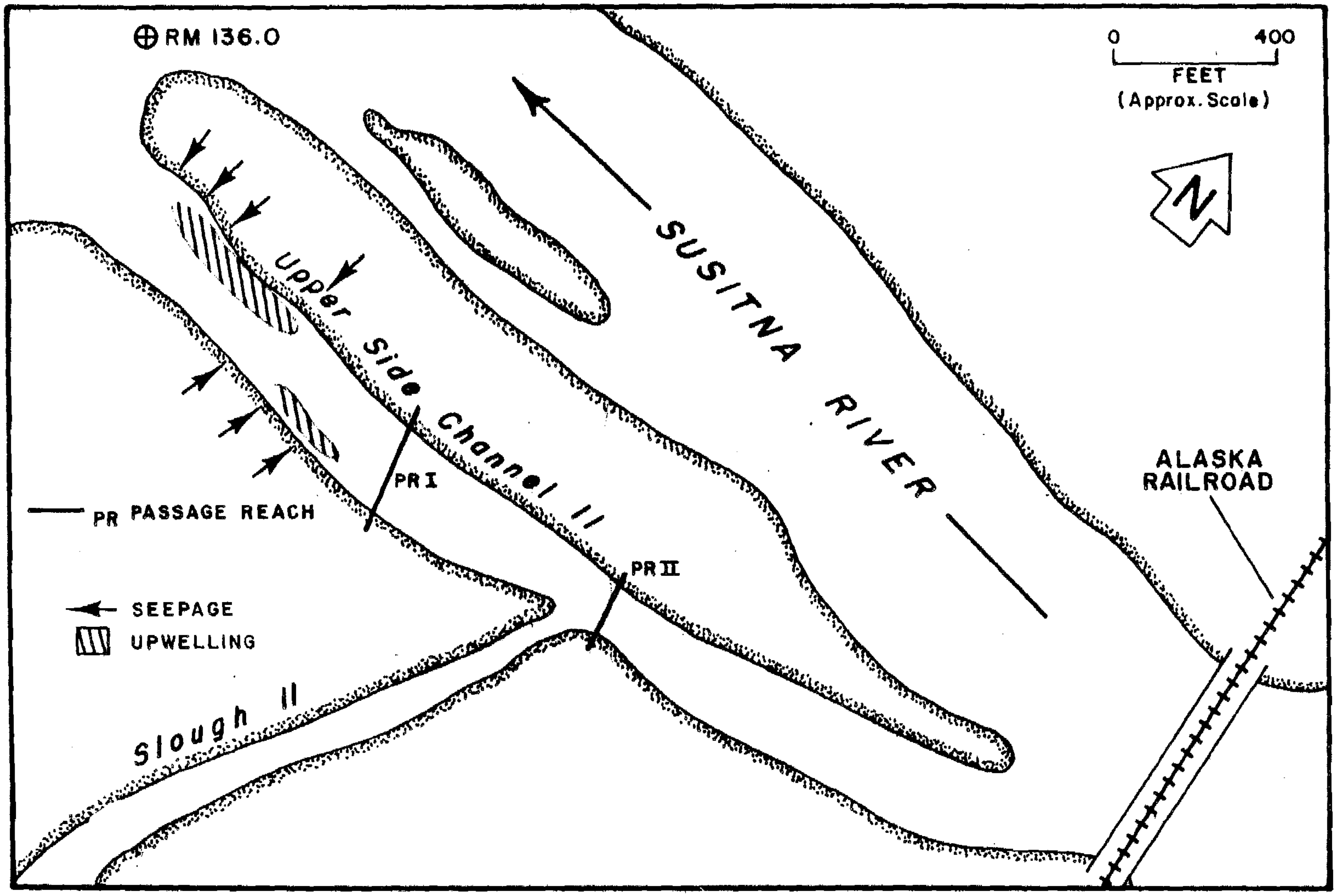
Appendix Figure A-83. Substrate composition in Slough 12 (RM 135.4R) and Slough 13 (RM 135.5R).



Appendix Figure A-84. Chum salmon spawning areas in Slough 13 (RM 135.5R).



Appendix Figure A-85. Channel geometry and sampling sites in Upper Side Channel 11 (RM 136.0R).



Appendix Figure A-86. Passage reaches and upwelling areas in Upper Side Channel 11 (RM 136.0R).

occur in the backwater and pool areas with cobble and boulder substrate predominating in the riffle areas (Appendix Figure A-87). The gradient of Upper Side Channel 11 is approximately 23.6 ft/mi with the corresponding mainstem gradient of 16 ft/mi.

Two passage reaches have been identified in this site (Appendix Figure A-86). Except for the one occurring in the backwater (PRI), breaching discharges are required for successful passage (Blakely et al. 1985 and Sautner et al. 1984). Chum salmon spawning occurs primarily in the backwater area. When passage is possible, spawning will also occur in two pools near the middle of the side channel (Appendix Figure A-88). Factors limiting spawning in this site are substrate and passage.

Slough 14 (RM 136.0L)

This upland slough is an expansive swampy area consisting of a series of beaver dams and ponds located directly across the river from the mouth of Upper Side Channel 11 (Appendix Figure A-89). The first dam is 50 feet from the mouth. Below this is a fairly straight run with rubble/cobble substrate covered by silt. The channel is narrow, approximately 15 feet wide, and heavily vegetated on both banks. Several large beaver ponds, about six to eight feet deep, exist throughout this slough. The substrate in the ponds is covered by a thick layer of decaying organic material and silt.

The beaver dams act as complete barriers to fish passage. Although the area below the first dam may be suitable for limited spawning, no spawning activity has been recorded. No fry were observed in the slough. Little flow is apparent in the slough. The water is stained due to decaying organic matter.

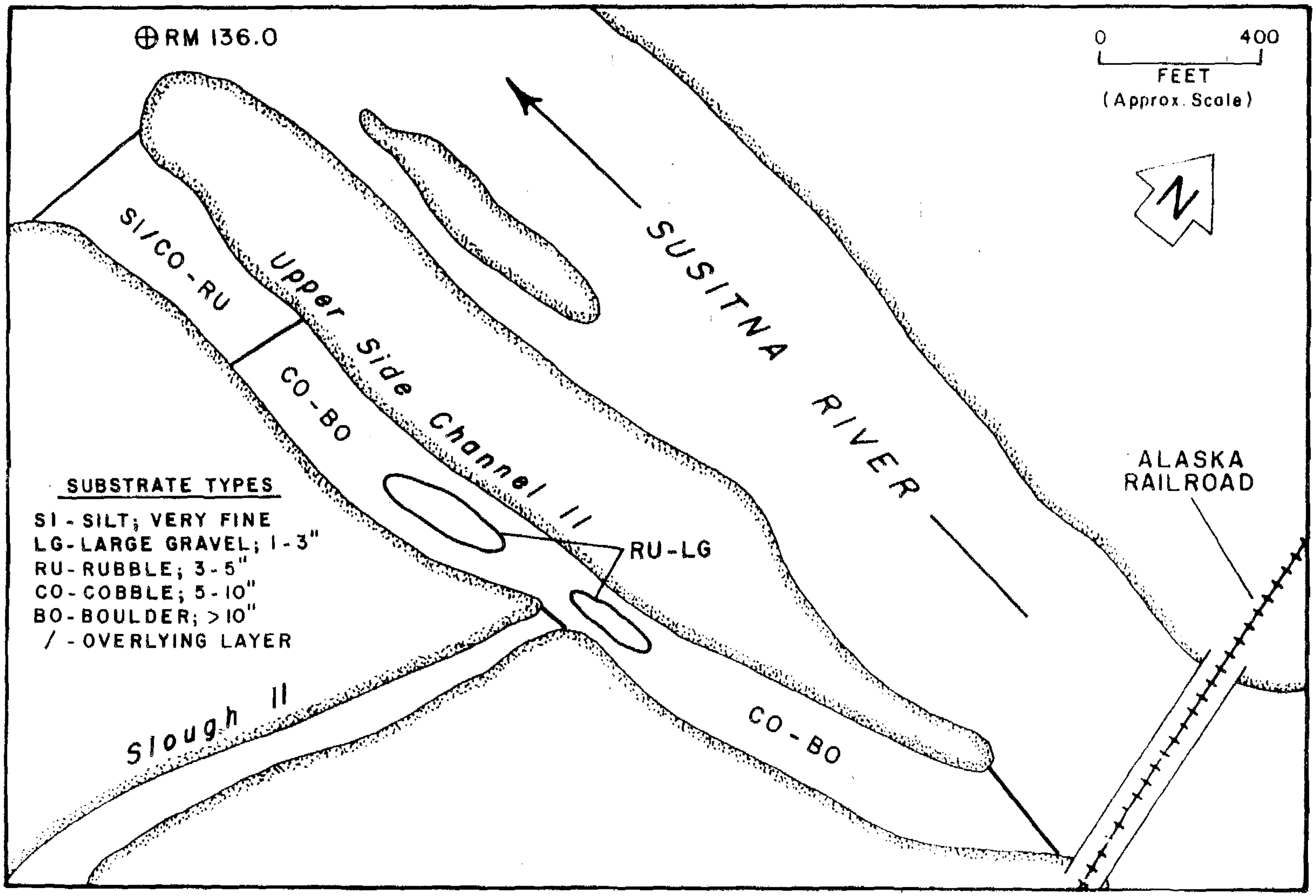
Passage, substrate and possibly low dissolved oxygen during the winter are the limiting factors to spawning in this site.

Slough 15 (RM 137.2L)

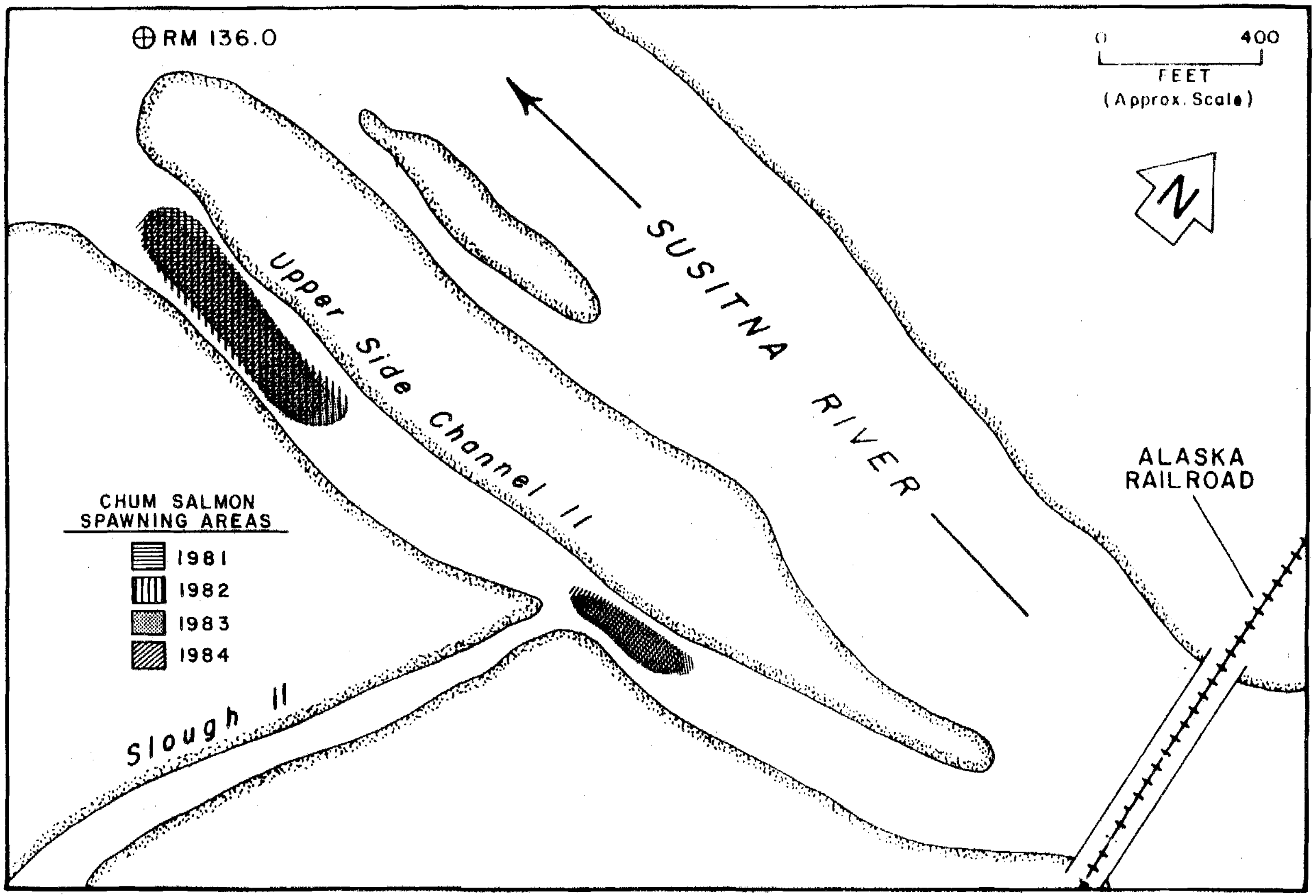
Slough 15 is a winding side slough, approximately one half mile long, with high, stable, vegetated banks located on the west side of the Susitna River, approximately one half mile upstream of the ARR Gold Creek bridge. A beaver dam 300 feet upstream of the mouth as well as one at the head, has made this slough a long beaver pond totally inaccessible to fish (Appendix Figure A-90).

Large gravel/rubble substrates predominate in the lower half of the slough with cobble/boulder predominating in the upper half. The majority of the slough is covered with silt/sand substrate varying in depth from 2 to 18 inches (Appendix Figure A-91).

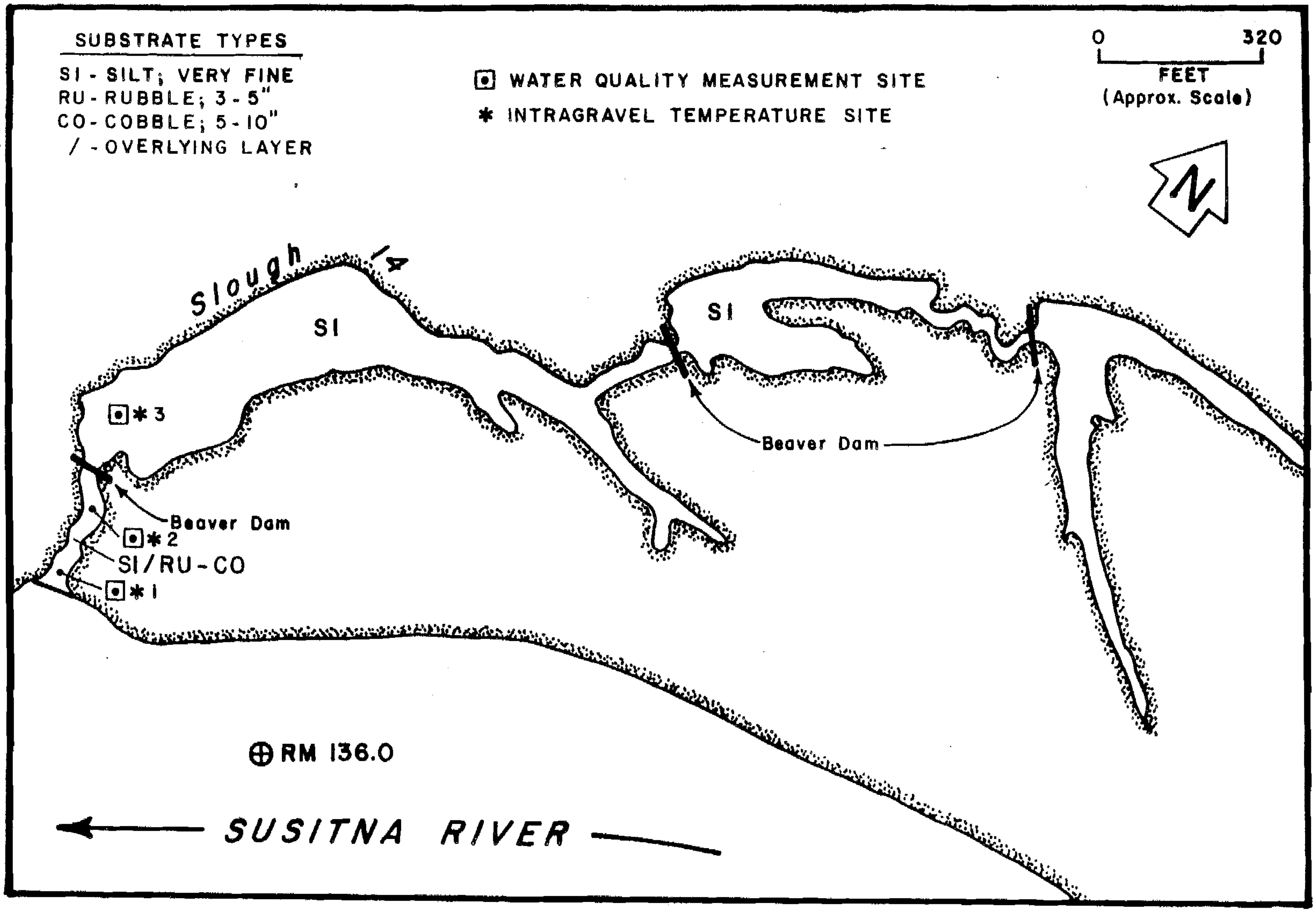
The area below the first beaver dam is either a backwater or riffle, depending on the mainstem discharge. The head is a cobble/boulder riffle dropping sharply from the beaver dam to the mouth of Slough 16. Due to the beaver dams altering the water surface elevation in the slough, water runs out both the mouth and the head. Limited upwelling



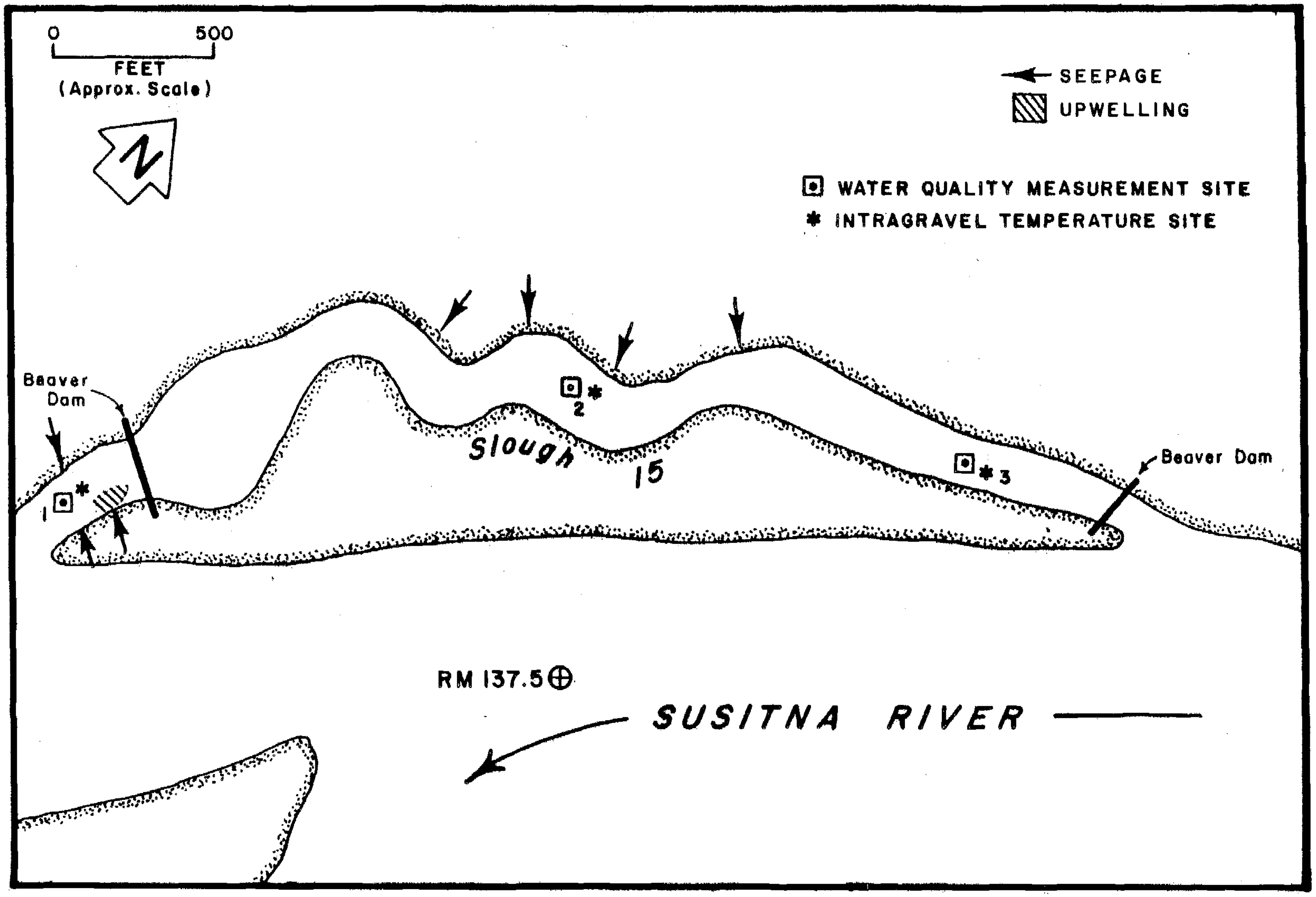
Appendix Figure A-87. Substrate composition of Upper Side Channel 11 (RM 136.0R).



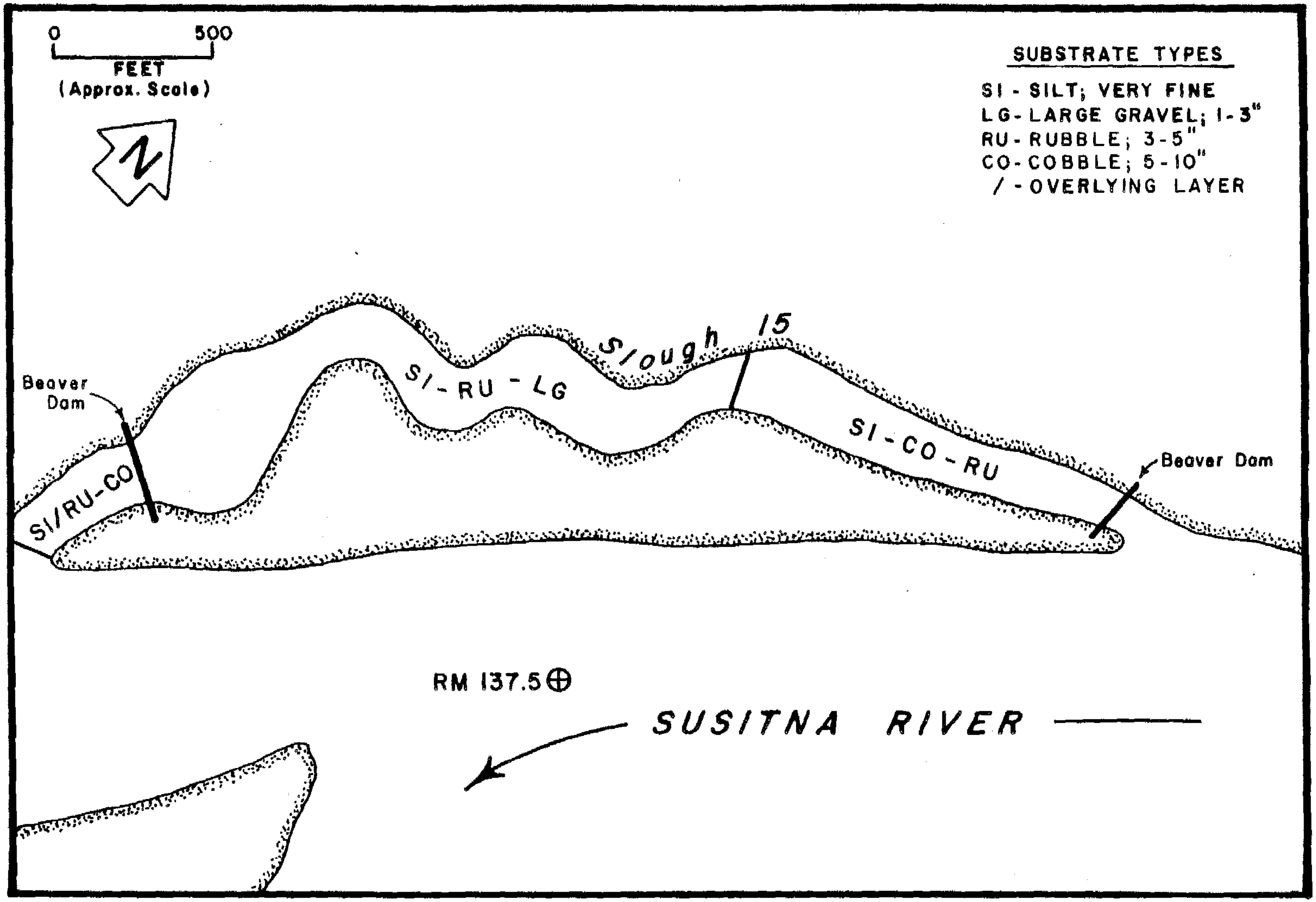
Appendix Figure A-88. Chum salmon spawning areas in Upper Side Channel 11 (RM 136.0R).



Appendix Figure A-89. Channel geometry, substrate composition, and sampling sites in Slough 14 (RM 136.0L).



Appendix Figure A-90. Channel geometry, sampling site, and upwelling areas in Slough 15 (RM 137.2L).



Appendix Figure A-91. Substrate composition in Slough 15 (RM 137.2L).

and bank seepage is present, primarily along the left bank near mid slough (Appendix Figure A-90). The water is stained brown indicating a marsh or bog origin.

Limited spawning by chum and pink salmon occurred in the mouth area during 1984 (Appendix Figure A-92). The mouth area is consistently used as a milling area by chum, pink, sockeye, and coho salmon. No fry were seen throughout the slough.

Major factors limiting spawning are passage (primarily due to beaver activity), substrate, and possibly low flows.

Slough 16 (RM 137.7L)

Immediately upstream of the head of Slough 15 is Slough 16 at RM 137.7. This is a 1,100 foot long, bow shaped side slough on the west bank of the Susitna River. Channel morphology is rectangular with gently sloping banks on both sides. Substrate in this site is a uniform mixture of large gravel, rubble and sand (Appendix Figure A-93). The head of this slough is adjacent to the mouth of Slough 16B and portions of the water running out of the mouth of Slough 16B enters Slough 16. No upwelling or bank seepage has been recorded at this site. Limited chum salmon spawning has occurred with a peak count of 15 chum salmon recorded by ADF&G personnel in 1984, accounting for 0.2 percent of the total slough spawning (Appendix Figure A-94).

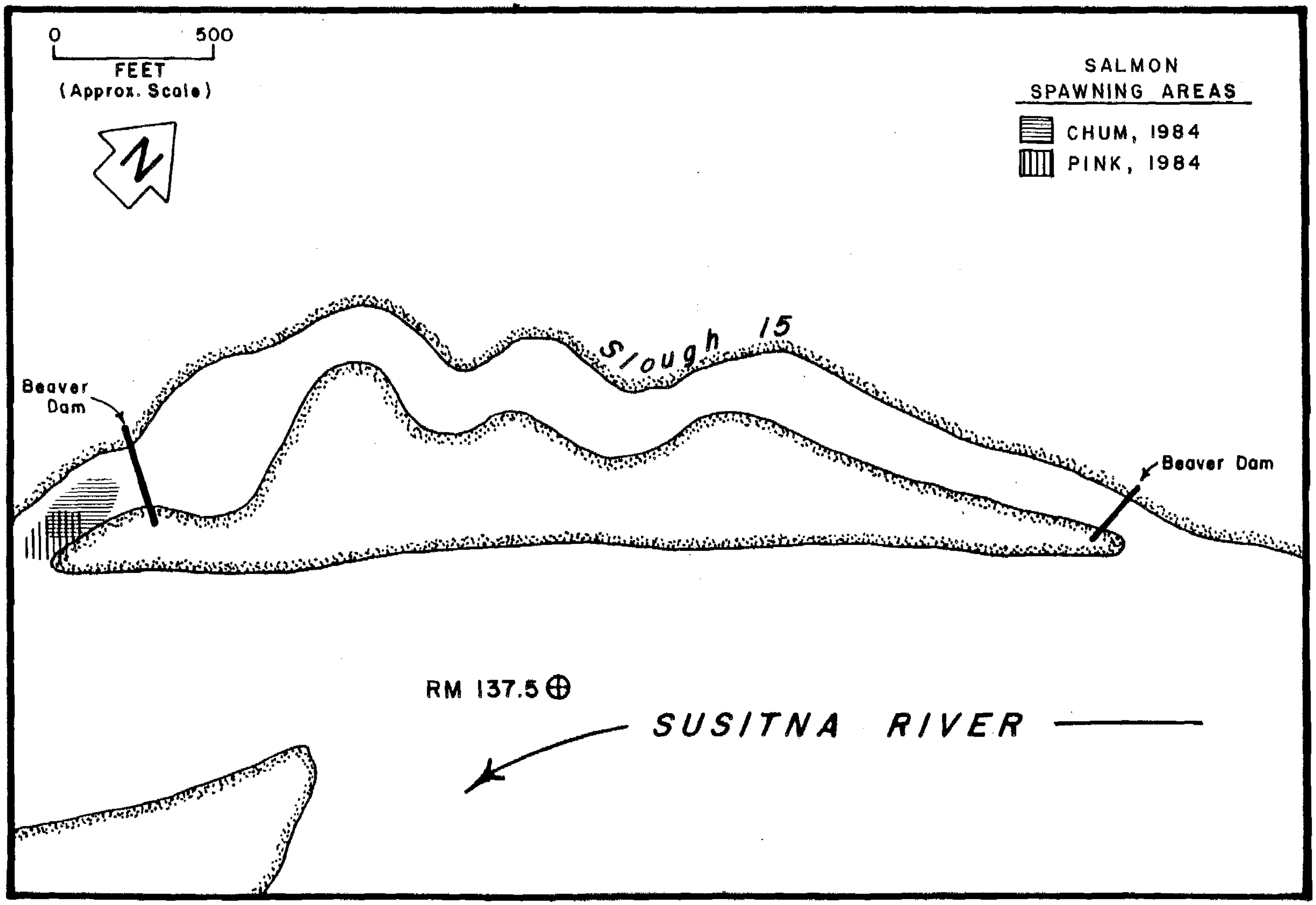
Passage and to some extent substrate are limiting to spawning in this site.

Slough 16B (RM 137.9L)

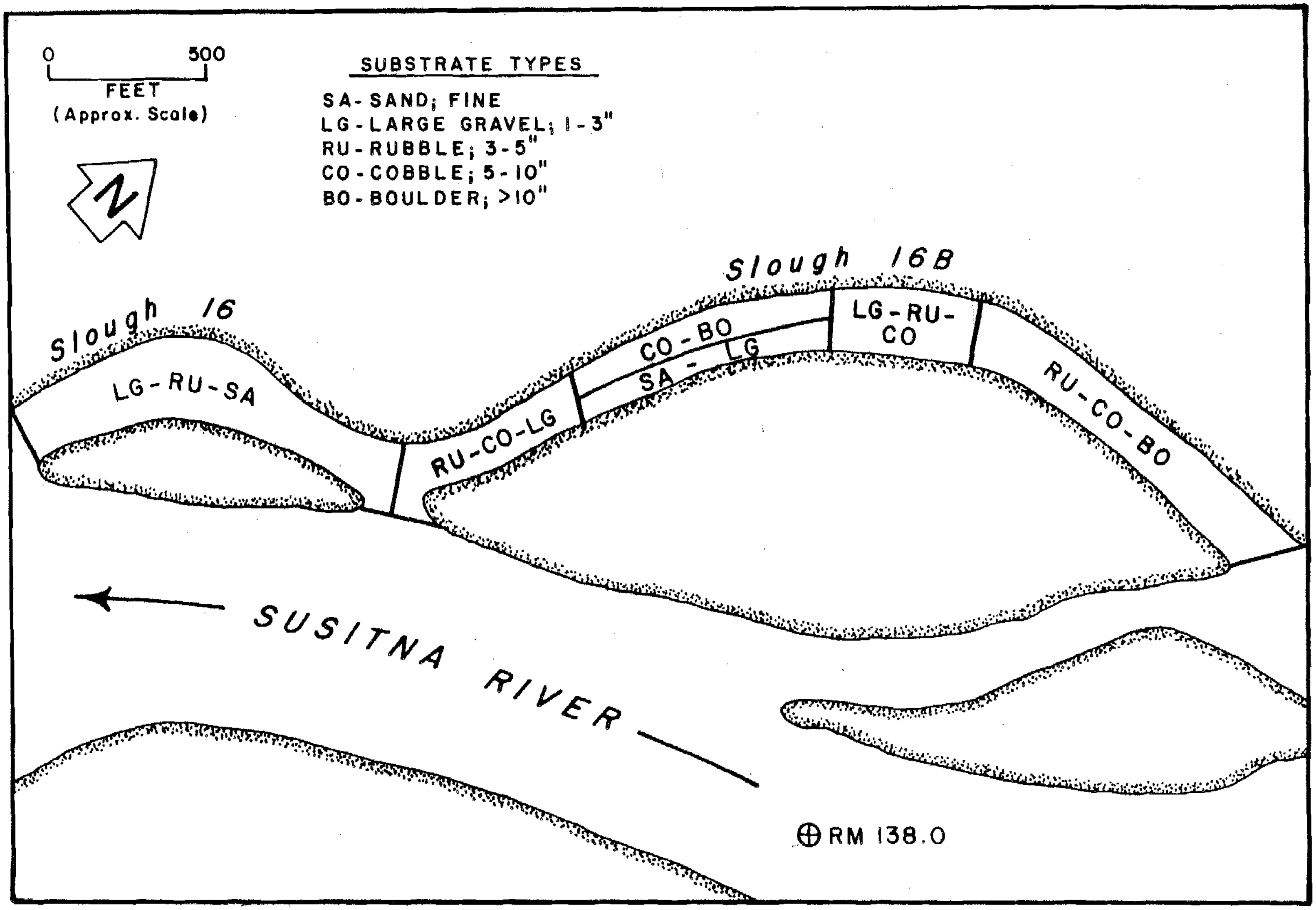
This is a 2,000 foot long bow shaped side slough, located on the west bank of the Susitna River adjacent to the head of Slough 16. The 0.4 mile channel is separated from the mainstem by a large vegetated island. Breaching discharge is 23,000 cfs. Below the breaching discharge, the slough becomes a series of shallow pools separated by long riffles with the upper third of the slough dewatering and becoming a cobble/boulder berm. Rubble and large gravel predominate in the wetted areas, while cobble/rubble can be found along the banks and occasionally in the riffles (Appendix Figure A-93). These gravels and cobbles are relatively free of any silt or sand deposits except in a small pool at the mouth.

No evidence of upwelling or bank seepage was observed in Slough 16B. One chum salmon redd, the first observed spawning in this site since 1982, was observed in a pool at the mouth of Slough 16B in 1984 (Appendix Figure A-94).

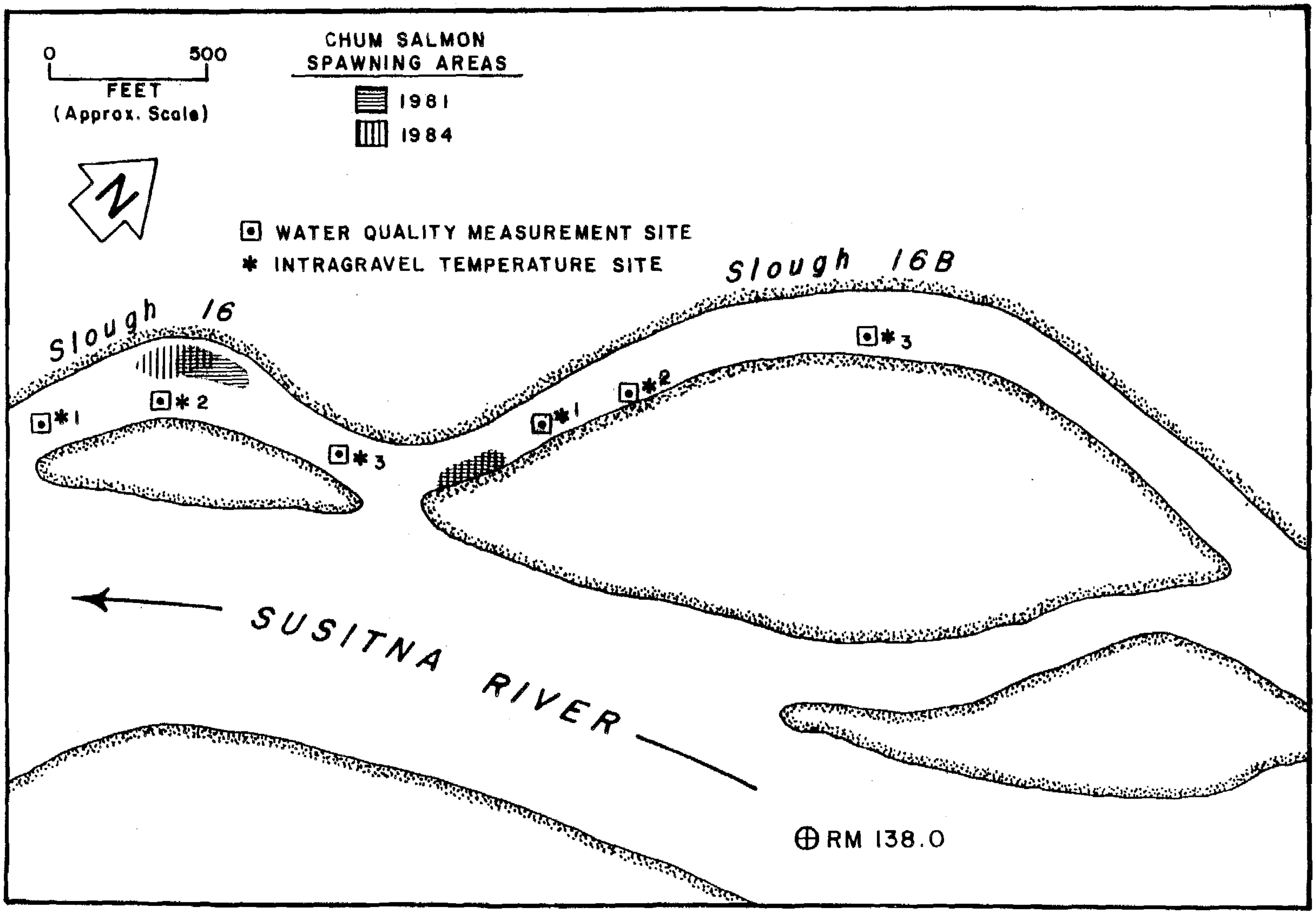
Slough 16B has good substrate throughout the site. The problem limiting spawning appears to be water quantity in an unbreached state, which in turn affects passage into and through the site. Due to lack of water and no apparent upwelling the site most likely freezes during the winter.



Appendix Figure A-92. Chum and pink salmon spawning areas in Slough 15 (RM 137.2L).



Appendix Figure A-93. Substrate composition of Slough 16 (RM 137.7L) and Slough 16B (RM 137.9L).



Appendix Figure A-94. Chum salmon spawning areas and sampling locations in Slough 16 (RM 137.7L) and Slough 16B (RM 137.9L).

Slough 17 (RM 138.9L)

This is a reasonably productive upland slough located on the west bank of the Susitna River. This is a former side slough/side channel that has had the head gradually fill in and revegetate so that it no longer breaches. Beavers have claimed the majority of the slough for their use with a series of three beaver dams, beginning 800 feet upstream from the mouth, which are total barriers to fish passage. A long forked pond with silt substrate is located upstream of the dams (Appendix Figure A-95). The major area of interest however, is below the dams. This is a 600-700 foot run over primarily large gravel/rubble substrate with silt and sand accumulating in most areas due to frequent backwater affects. The right bank is a gently sloping mud bank with sparse vegetation. The left side is a cut bank with overhanging vegetation. Upwelling and bank seepage are extensive in this reach, especially along the left bank (Appendix Figure A-96). Sockeye and chum salmon spawn in this slough including at least one instance of spawning beyond the first two dams (Appendix Figures A-97 and A-98). Surveys conducted in 1984, showed peak counts of 66 chum salmon and 16 sockeye salmon for 0.9 and 1.7 percent of the total slough distribution respectively.

This site exhibits promise for being more productive but only through extensive habitat manipulation including beaver control, removal of beaver dams, substrate cleaning or replacement, and possible flow augmentation to keep substrate clean and provide passage.

Slough 18 (RM 139.1L)

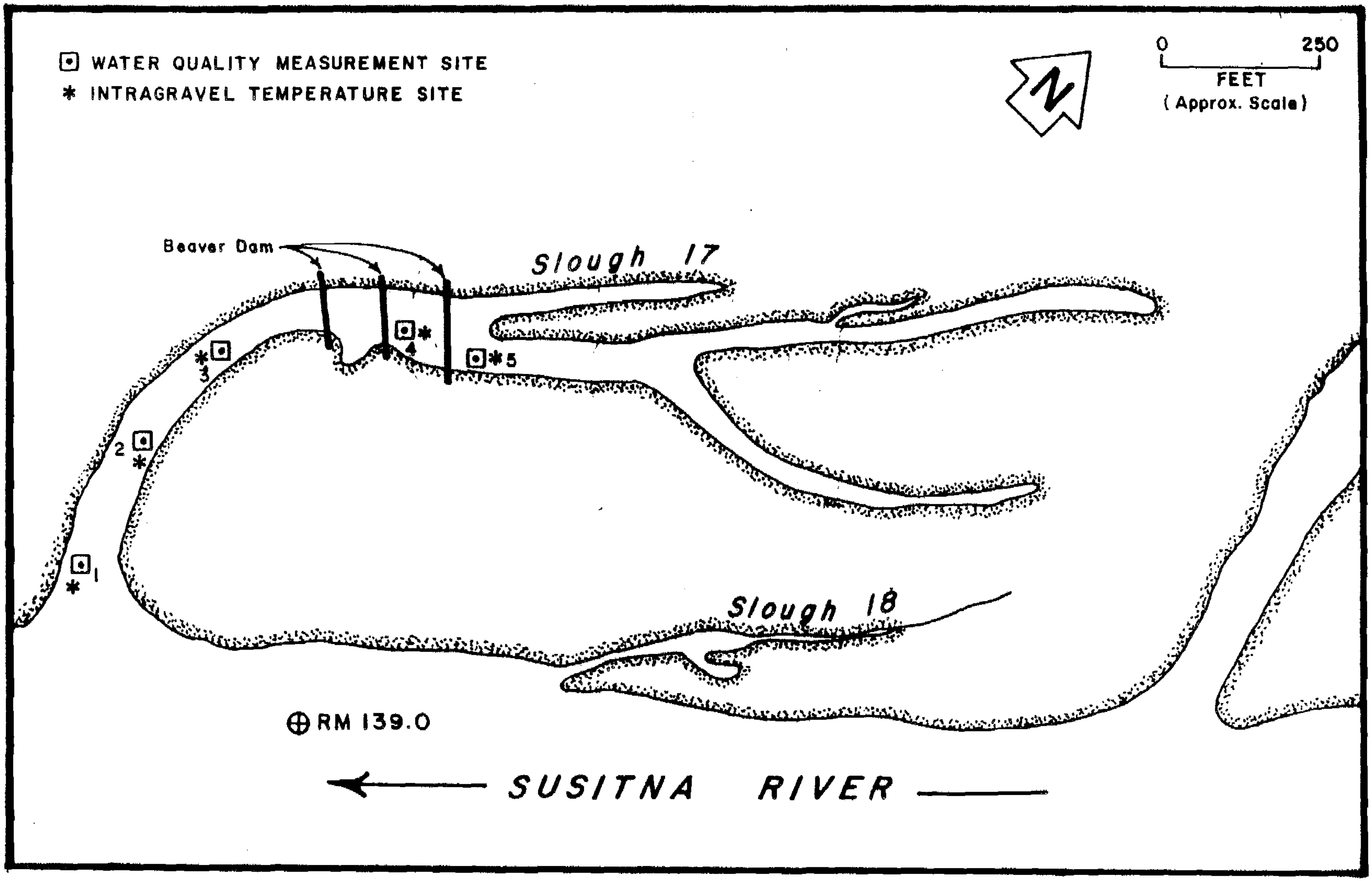
This small upland slough drains a bog area adjacent to Slough 17. The total length is approximately 800 feet, which consists of a narrow channel with two small adjacent pools (Appendix Figure A-99). The banks are heavily vegetated and littoral vegetation persists all along the slough. Substrate is thick silt over an unknown base. No upwelling or bank seepage was observed.

The first observed spawning, located in the two pools in the middle of the slough, was in 1984. (Appendix Figure A-99). A peak count of eleven chum salmon were observed in these areas. Limited numbers of fry were observed throughout the two pools. There is evidence of beaver activity in the channel upstream of the two pools.

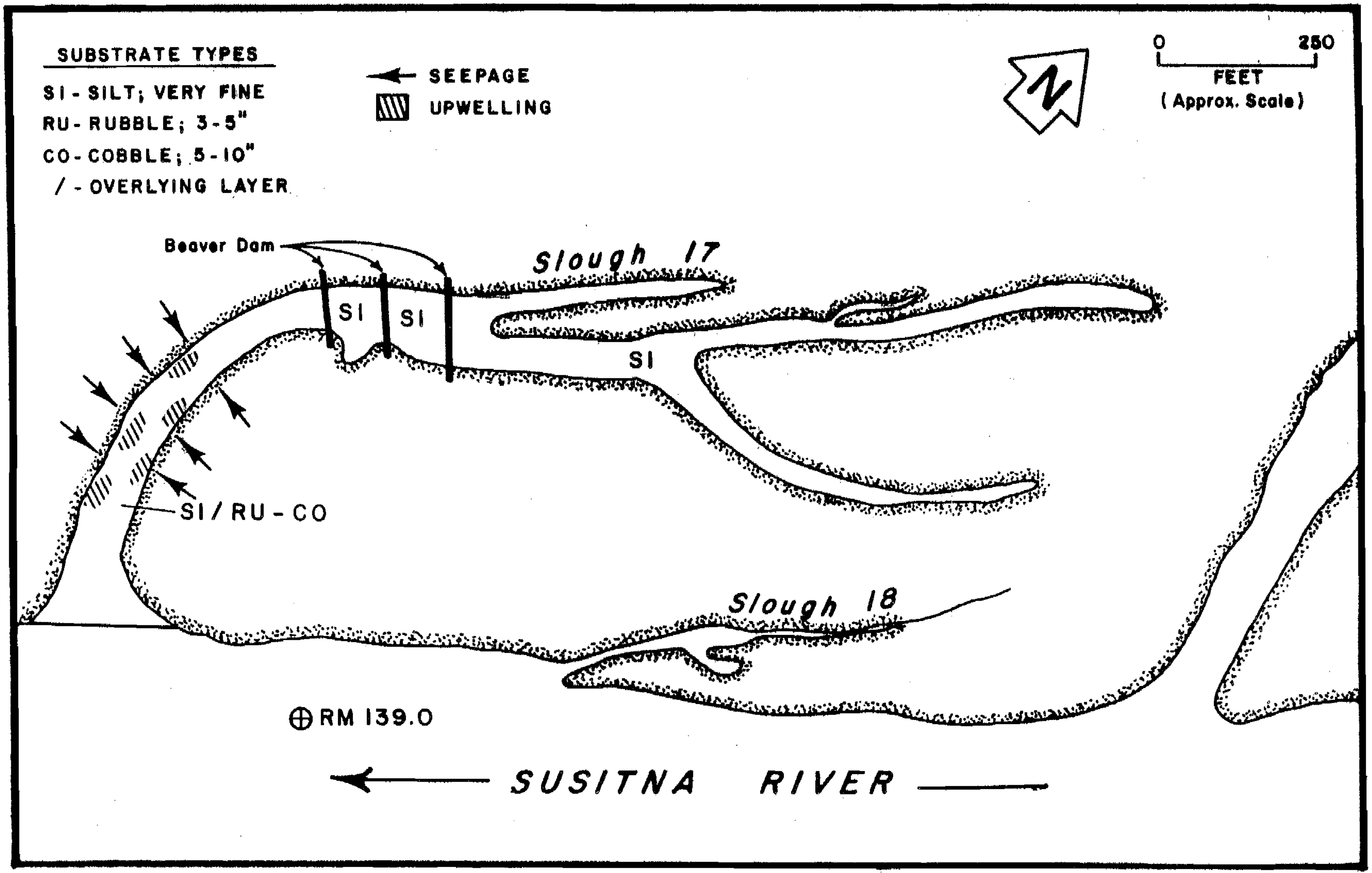
Limitations to spawning in this site are passage into and within the slough, substrate and water flow.

Slough 19 (RM 139.8R)

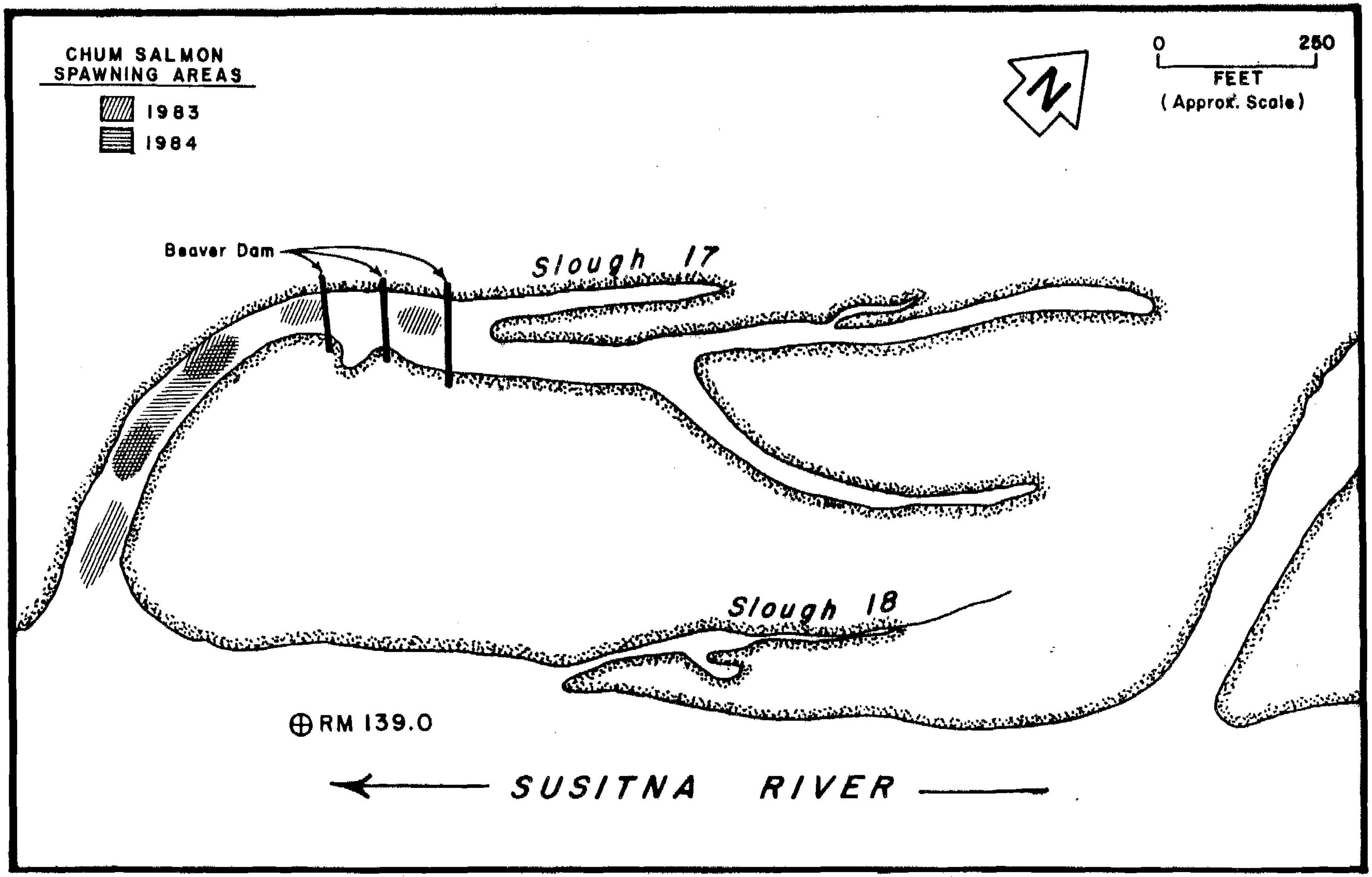
This is a 1,000 foot long upland slough located on the east bank of the Susitna River. A former side slough, the head of this site has been filled in and revegetated. A side channel connects the slough to the mainstem Susitna River (Appendix Figure A-100). The substrate consists of approximately six inches of silt over large gravel and rubble. The shallow pool, at the mouth, is rimmed by littoral vegetation and a beaver lodge is found along the left bank. Above the pool, the channel



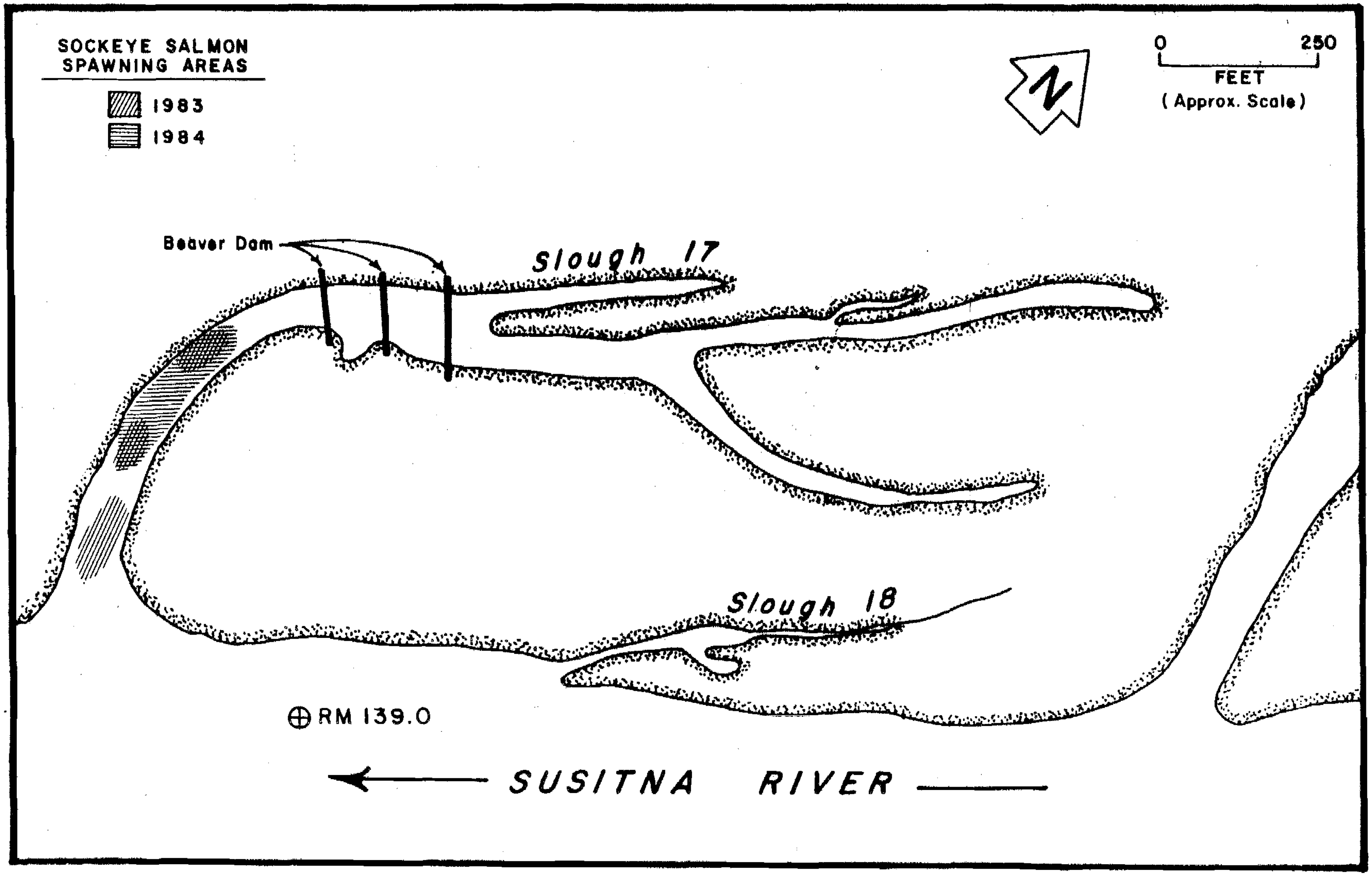
Appendix Figure A-95. Channel geometry and sampling sites in Slough 17 (RM 138.9L).



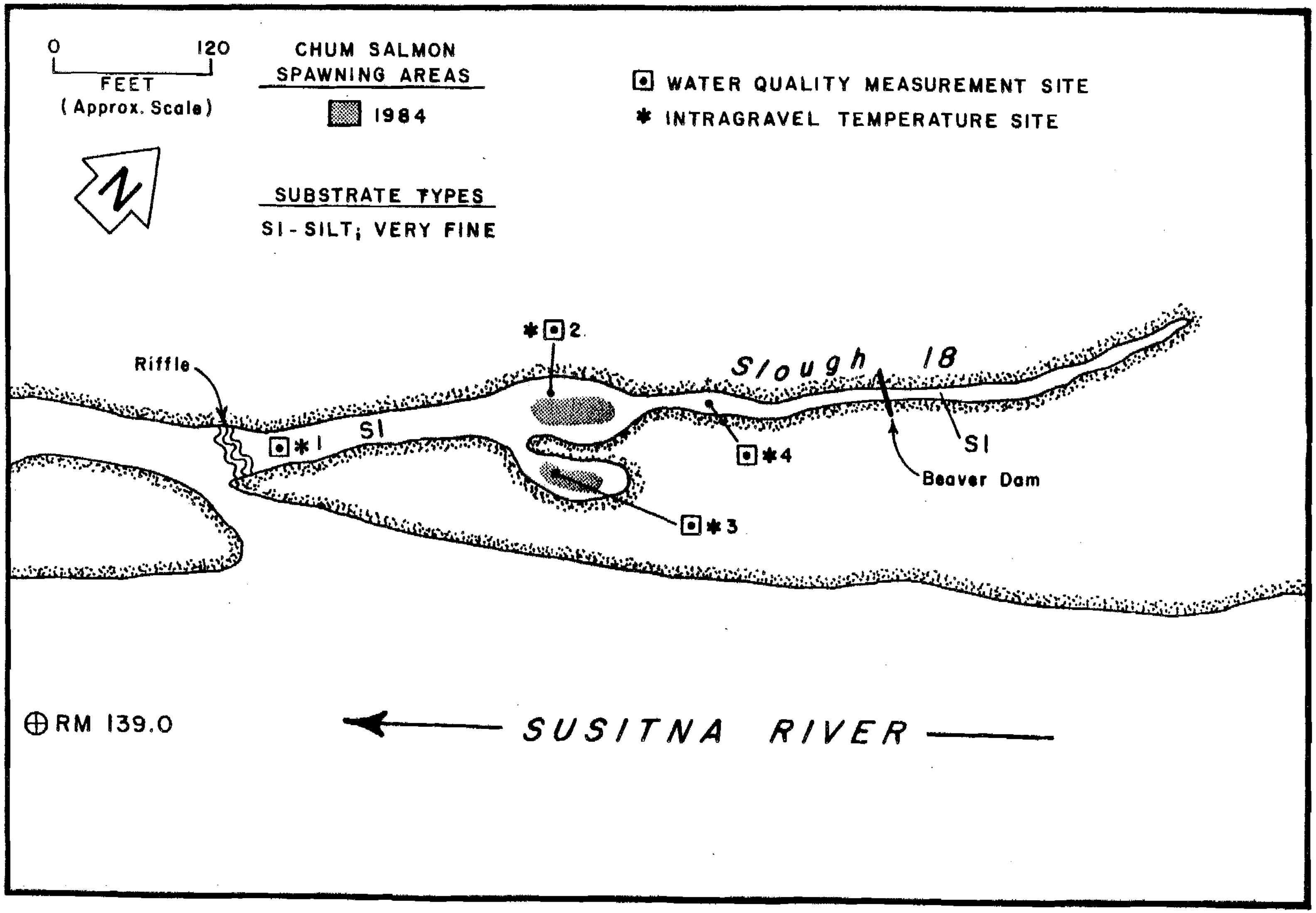
Appendix Figure A-96. Substrate composition and upwelling areas in Slough 17 (RM 138.9L).



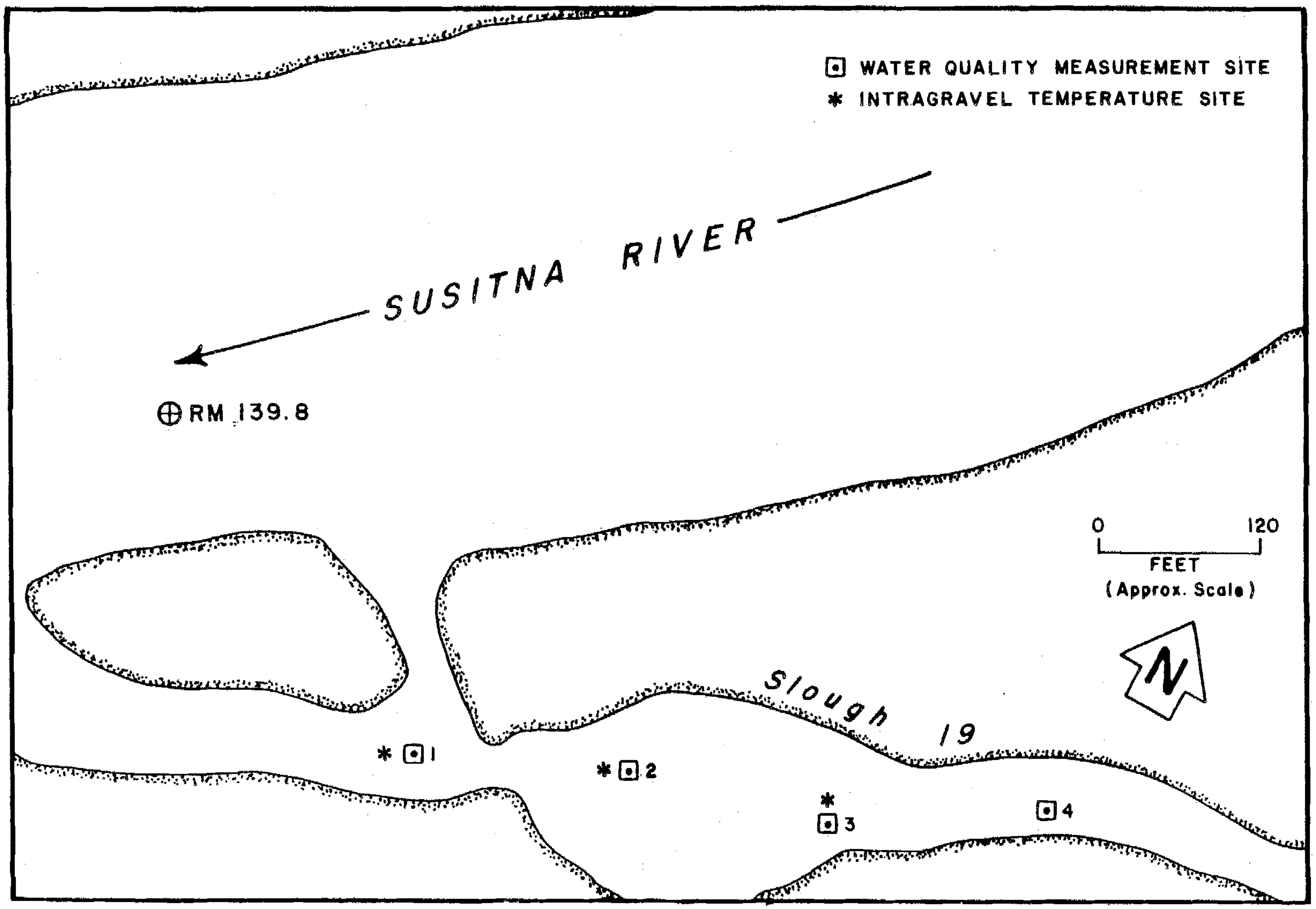
Appendix Figure A-97. Chum salmon spawning areas in Slough 17 (RM 138.9L).



Appendix Figure A-98. Sockeye salmon spawning areas in Slough 17 (RM 138.9L).



Appendix Figure A-99. Substrate composition and spawning areas in Slough 18 (RM 139.1L).



Appendix Figure A-100. Channel geometry and sampling locations in Slough 19 (RM 139.8R).

narrows and substrate changes to rubble/cobble/boulder. In the side channel, cobble/boulder predominates except for a pool at the junction of the side channel and the slough where large gravel and rubble can be found (Appendix Figure A-101).

Upwelling and bank seepage is found in the lower reach of the slough. At low mainstem discharges, water is clearer and upwelling and bank seepage can be found in the side channel downstream of the slough (Appendix Figure A-102). Both sockeye and chum salmon utilize this slough for spawning (Appendix Figures A-103 and A-104). Fry are present in the slough, particularly in the pool at the mouth.

Factors limiting spawning at this site are substrate and passage at low mainstem discharges.

Slough 20 (RM 140.1R)

Slough 20, located on the south bank of the Susitna River, is a single channel side slough approximately 0.5 miles long. The slough is separated from the mainstem Susitna River by a large vegetated island. Two tributaries flow into Slough 20 on the right bank. Waterfall Creek enters approximately 1,500 feet upstream from the mouth, and a small unnamed tributary enters near the head of the slough.

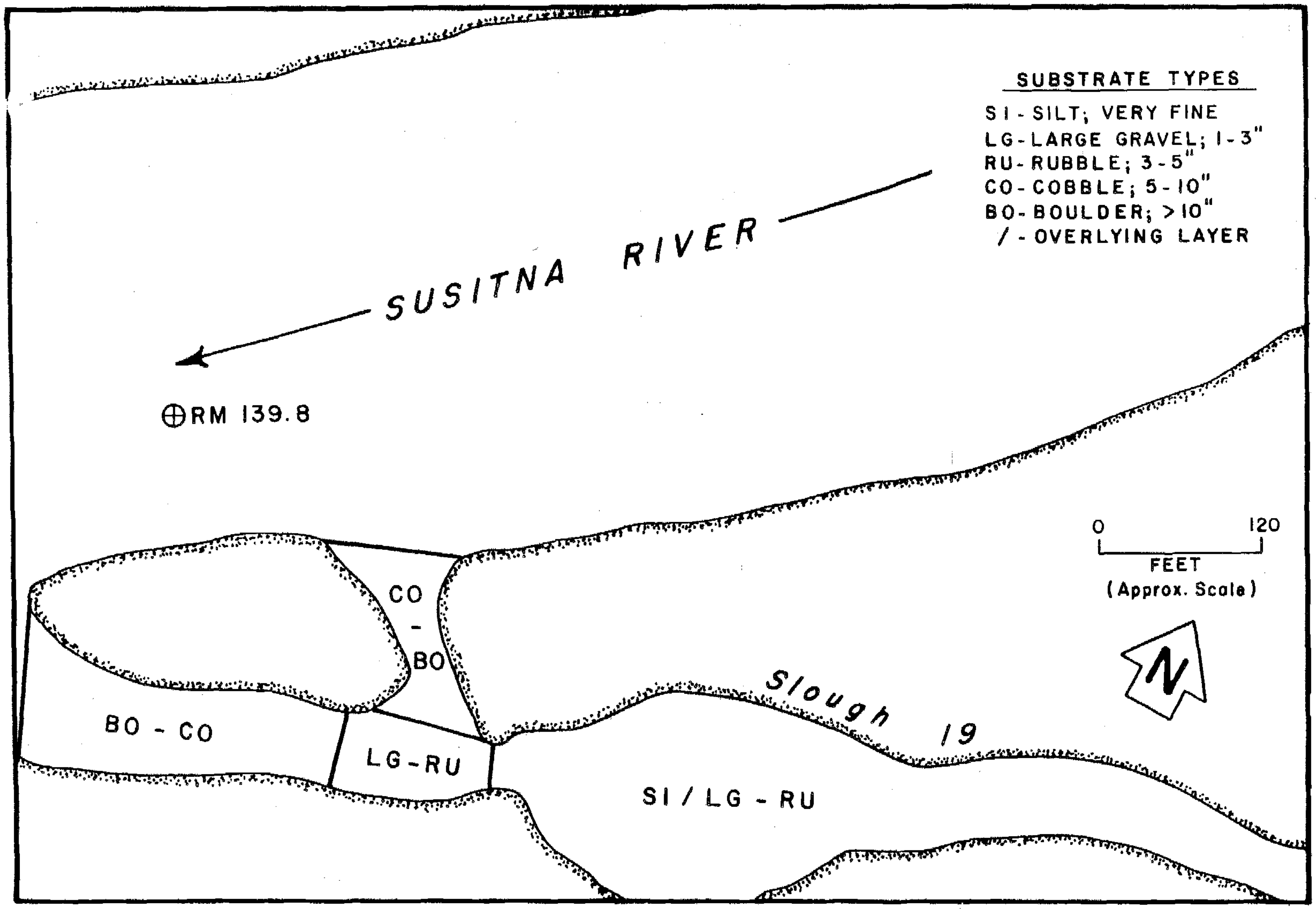
At mainstem discharges exceeding 8,480 cfs, the backwater area extends approximately 300 feet into the slough with silt and sand predominating. Above the backwater area, Slough 20 consists of a series of pools and riffles. Substrate is composed of gravel/rubble with areas of cobble/boulder at the head. Pools contain deposits of silt and sand. The 250 feet run downstream of Waterfall Creek contains substrate of compacted angular shale that is different from what was found in the rest of the slough (Appendix Figure A-105). It is assumed that the presence of the shale was due to the erosion and deposition of Waterfall Creek. The gradient of Slough 20 is 13.5 ft/mi with a corresponding mainstem gradient of 13.4 ft/mi. Six passage reaches have been described in Blakely et al. 1985 and Sautner et al. 1984 (Appendix Figure A-106).

Spawning in Slough 20 occurs primarily in the first 900 feet of the slough with pink and chum salmon the primary salmon species (Appendix Figures A-106 and A-107). Peak counts of 280 chum and 85 pink salmon were recorded, accounting for 3.7 and 8.0 percent respectively of the total slough spawning for each species.

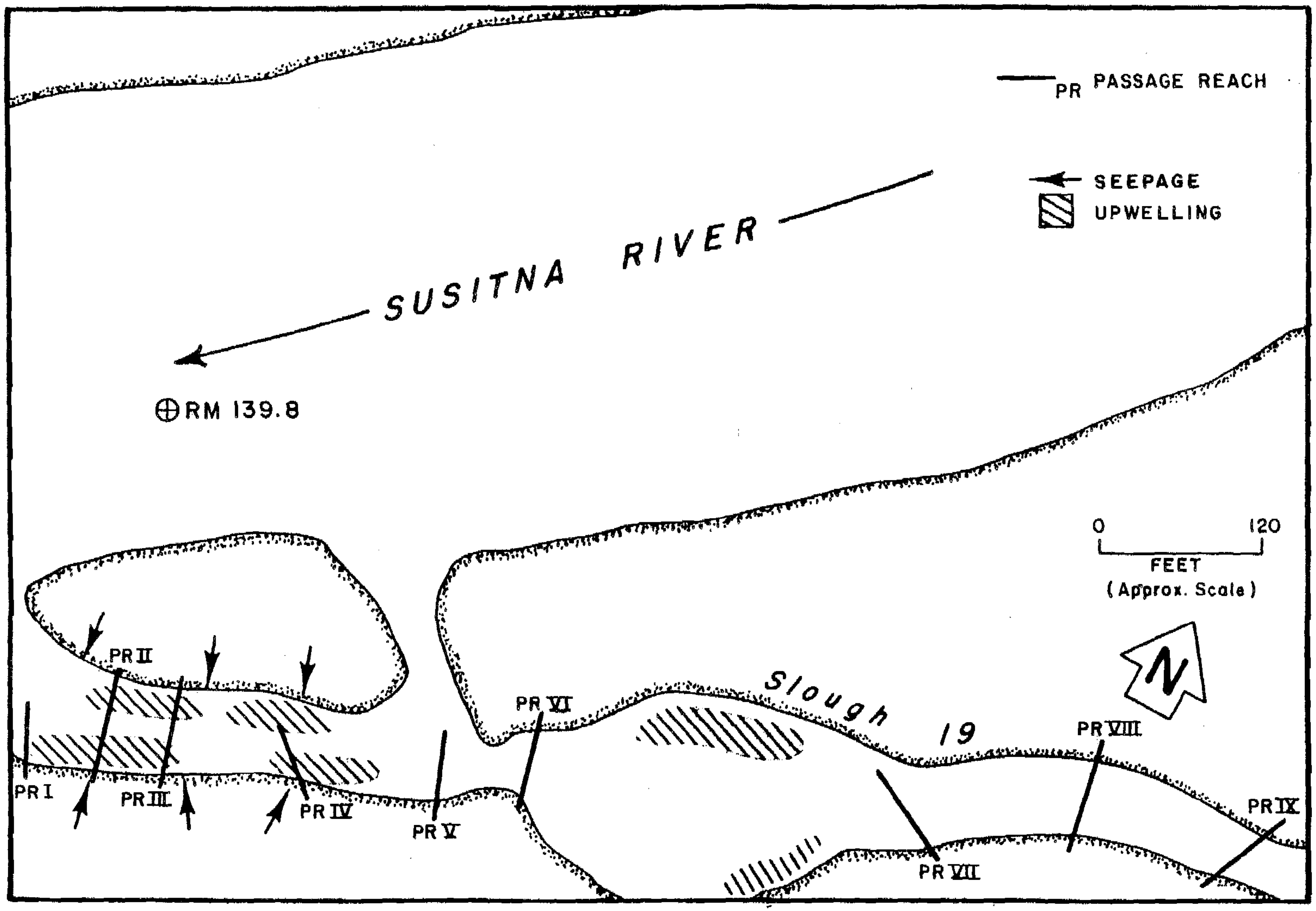
Problems limiting spawning in this site are passage at low mainstem discharges, dewatering of the upper 900 feet of the site and some substrate limitations.

Side Channel 21 (RM 140.6R)

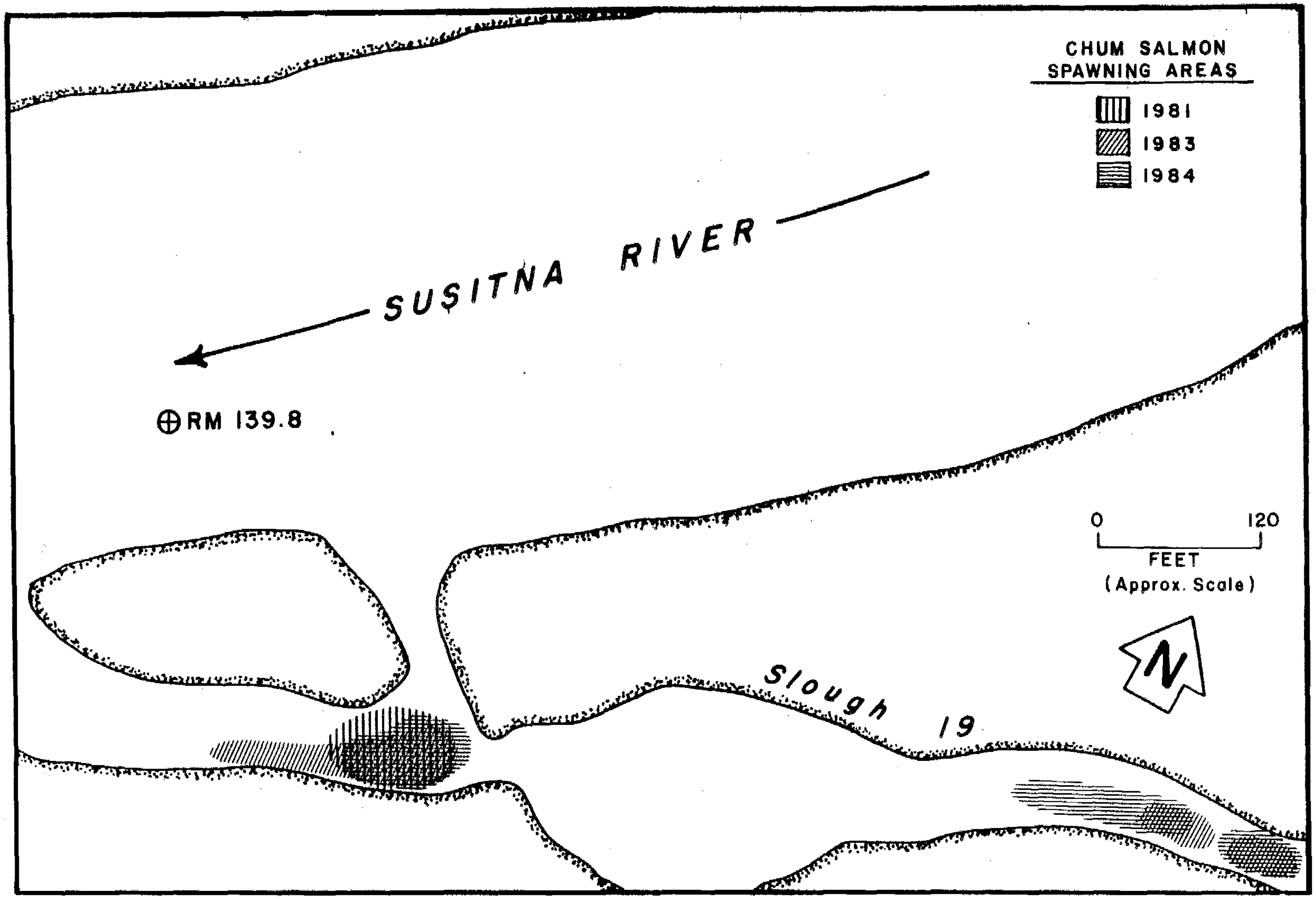
Side Channel 21 is a relatively straight, single channel, approximately 0.9 mi long, located on the south bank of the Susitna River. It is separated from the mainstem by a series of well vegetated islands and gravel bars (Appendix Figure A-108). Several intermittent channels



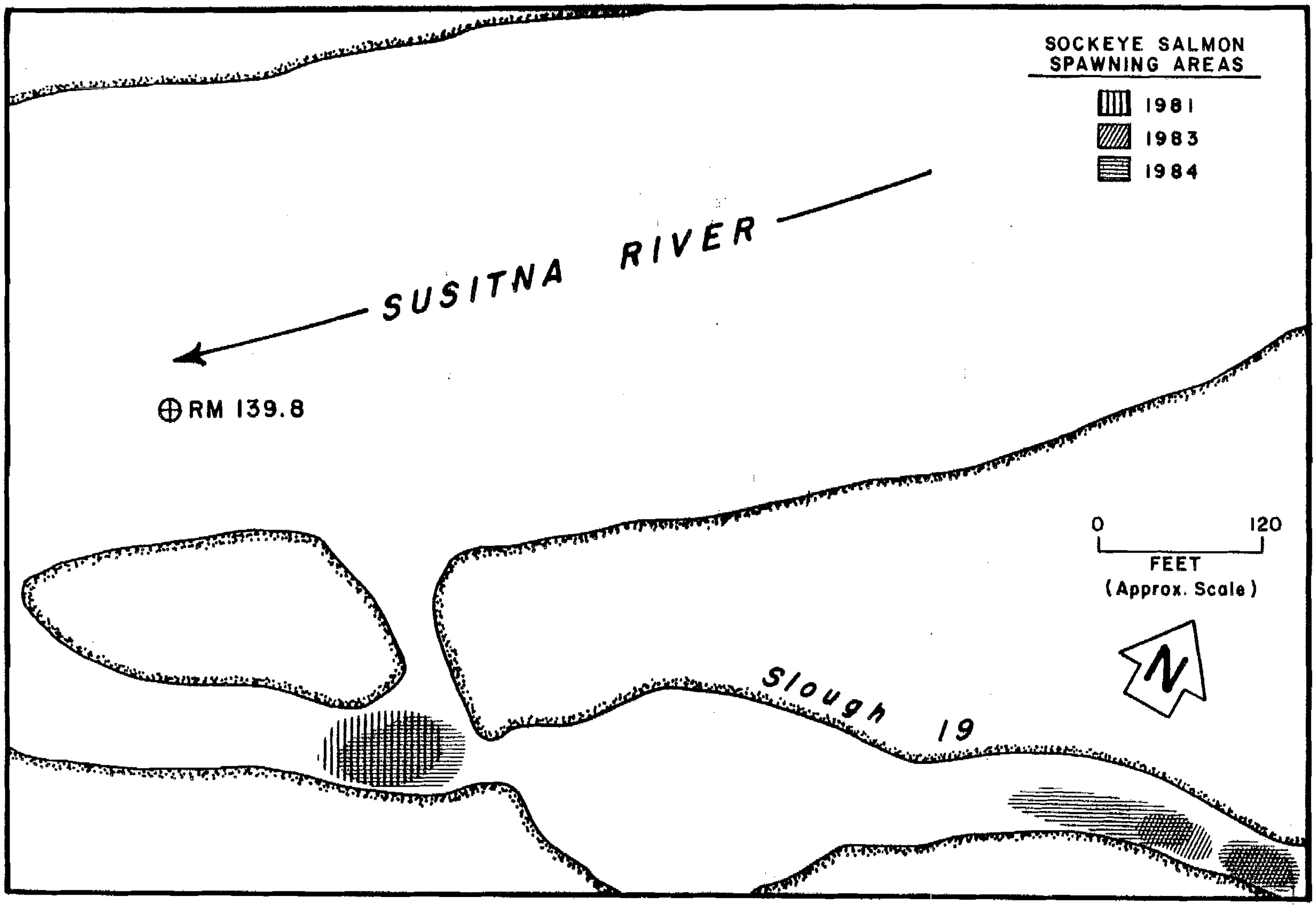
Appendix Figure A-101. Substrate composition in Slough 19 (RM 139.8R).



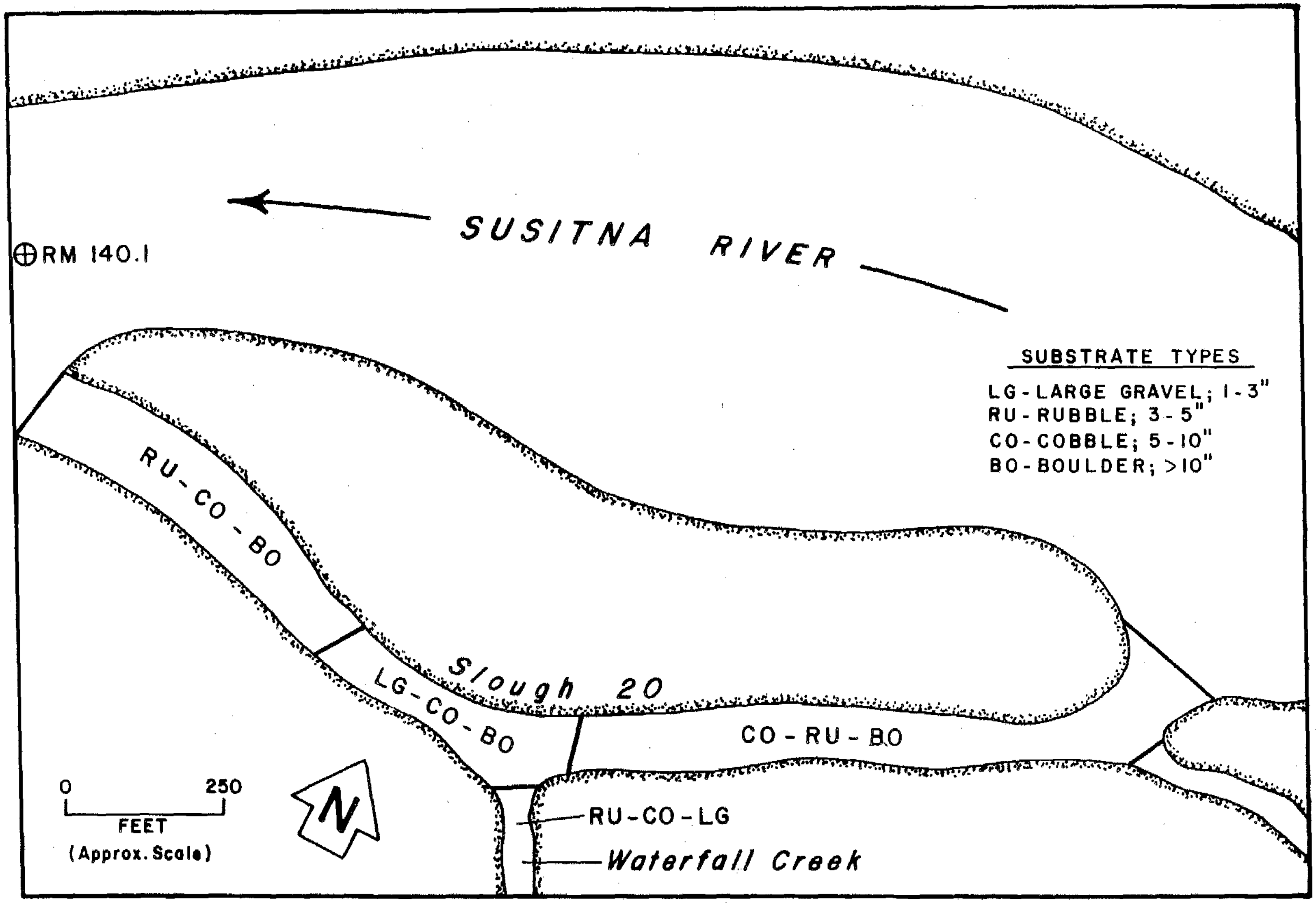
Appendix Figure A-102. Passage reaches and upwelling areas in Slough 19 (RM 139.8R).



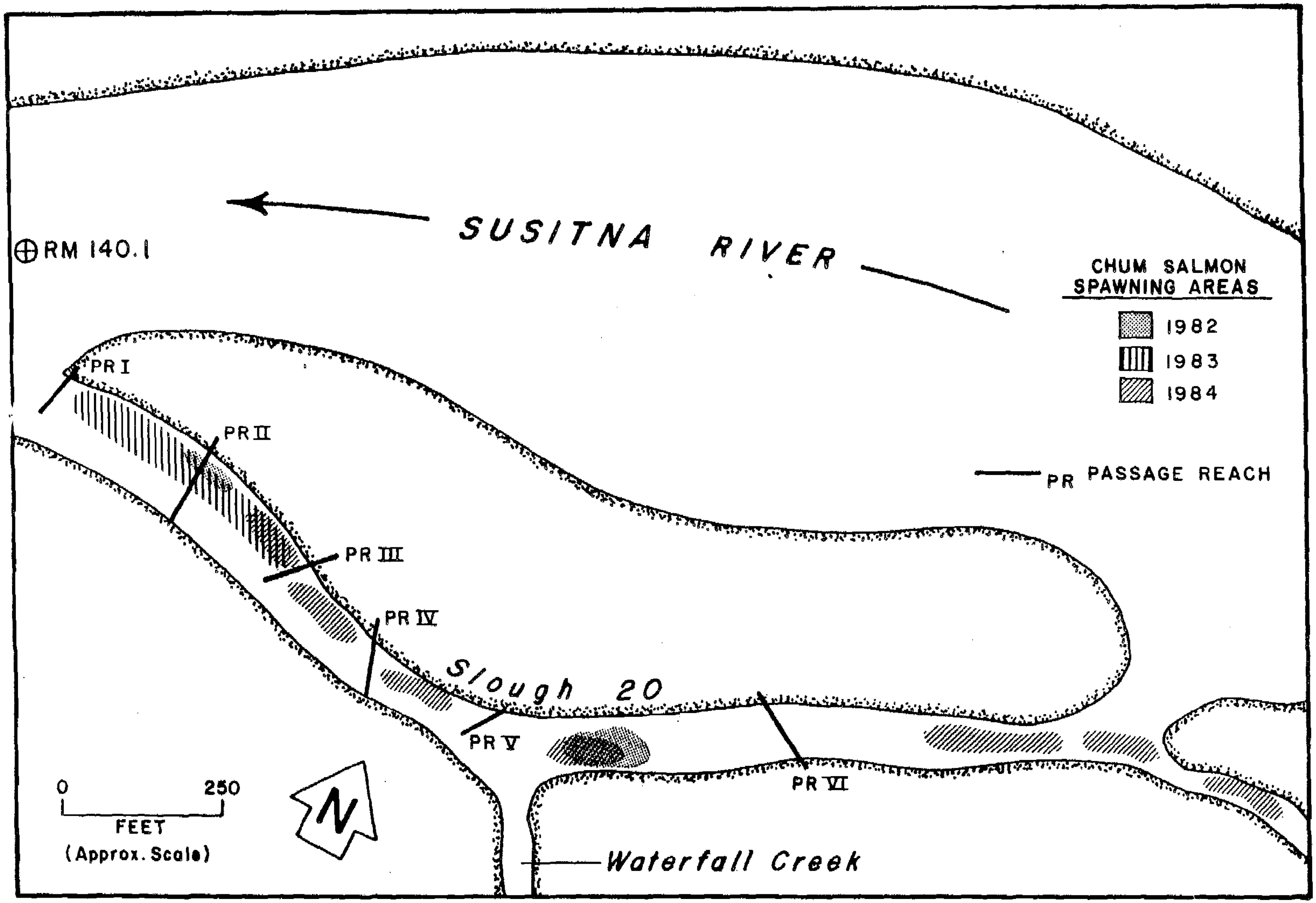
Appendix Figure A-103. Chum salmon spawning areas in Slough 19 (RM 139.8R).



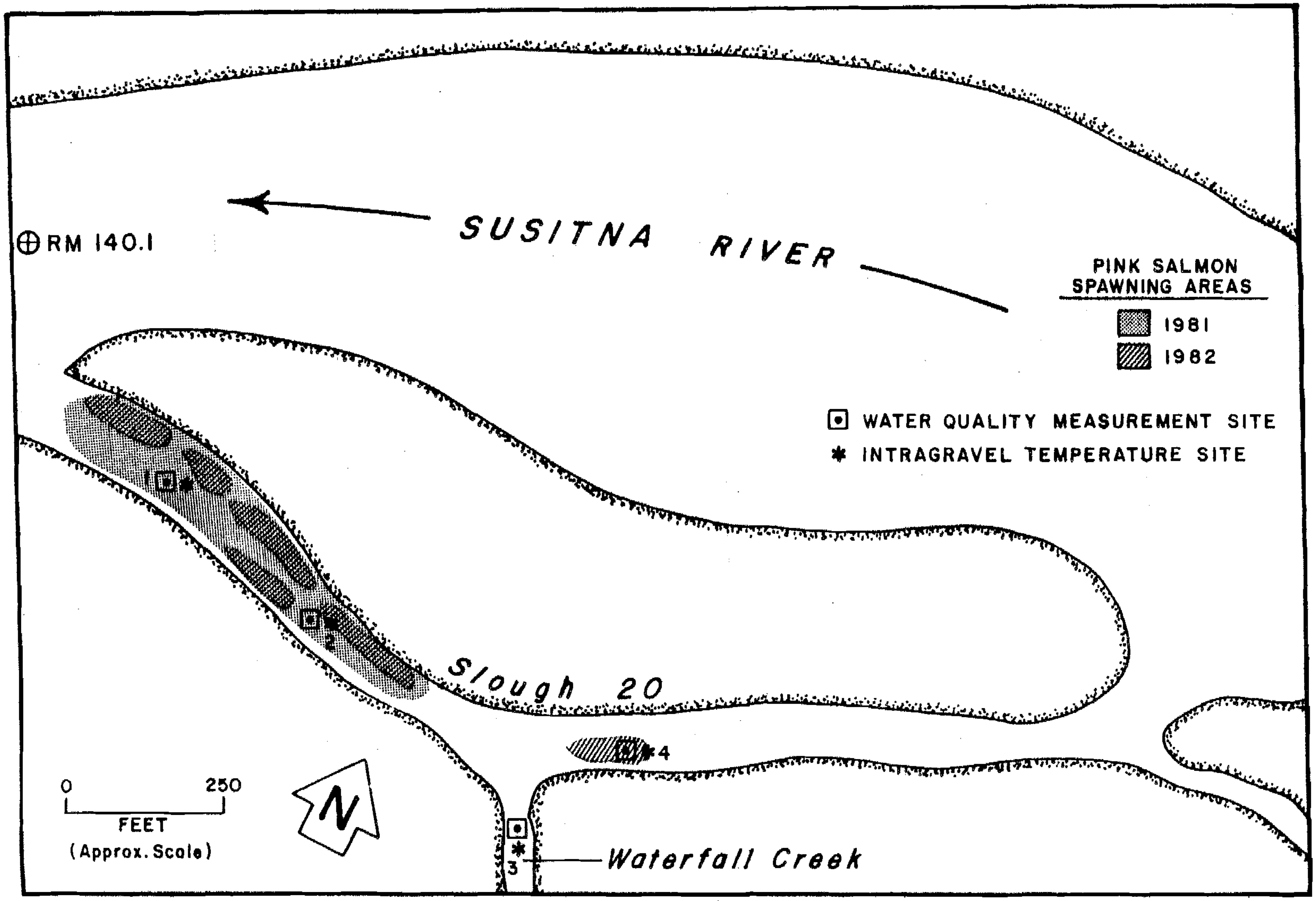
Appendix Figure A-104. Sockeye salmon spawning areas in Slough 19 (RM 139.8R).



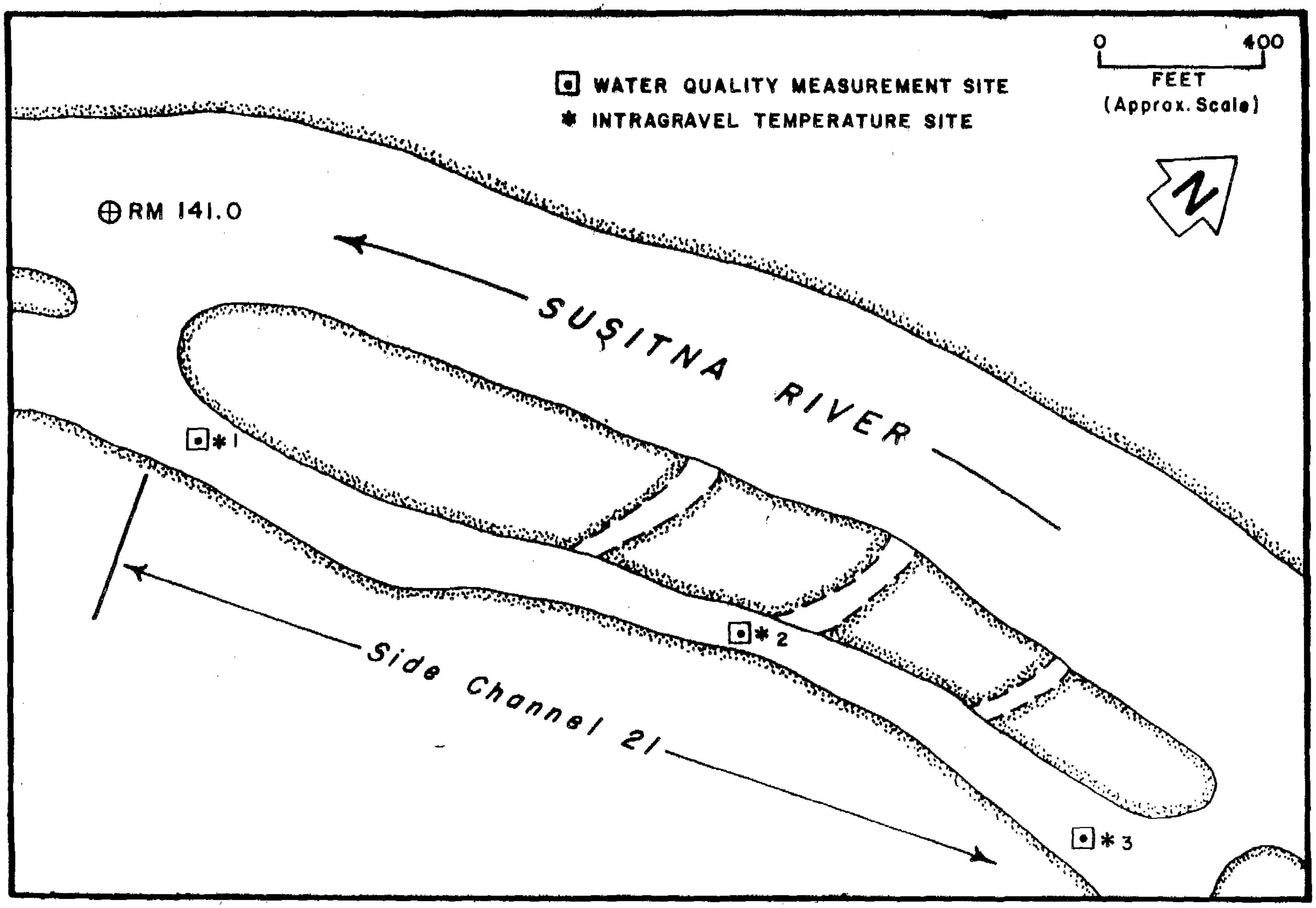
Appendix Figure A-105. Substrate composition in Slough 20 (RM 140.1R).



Appendix Figure A-106. Chum salmon spawning areas in Slough 20 (RM 140.1R).



Appendix Figure A-107. Pink salmon spawning areas in Slough 20 (RM 140.1R).



Appendix Figure A-108. Channel geometry and sampling sites in Side Channel 21 (RM 140.6R).

connect the side channel with the mainstem. The mouth of Slough 21 flows directly into the upper portion of Side Channel 21. Pools are located in the mouth and head areas. The backwater area extends approximately 1,500 feet into the side channel at mainstem discharges exceeding 16,000 cfs. Substrate composition in Side Channel 21 is predominantly cobble/boulder with silt/sand deposits in the mouth and pool areas (Appendix Figure A-109). The gradient of Side Channel 21 is 12.4 ft/mi with the corresponding mainstem gradient of 16.6 ft/mi.

A total of nine passage reaches have been identified in this site and are discussed in detail by Blakely et al. 1985 (Appendix Figure A-110). Peak counts of 17 sockeye and 48 chum salmon were recorded accounting for 52 and 3.7 percent respectively of the total mainstem and side channel spawning. In general Side Channel 21, as part of the Slough 21 complex, is vitally important to sockeye and chum spawning activity both as a passage corridor to Slough 21 and as a spawning habitat (Appendix Figure A-111). Upwelling and bank seepage is limited and appears to be somewhat intermittent.

Factors limiting spawning activity in this site are substrate and passage.

Slough 21 (RM 141.8R)

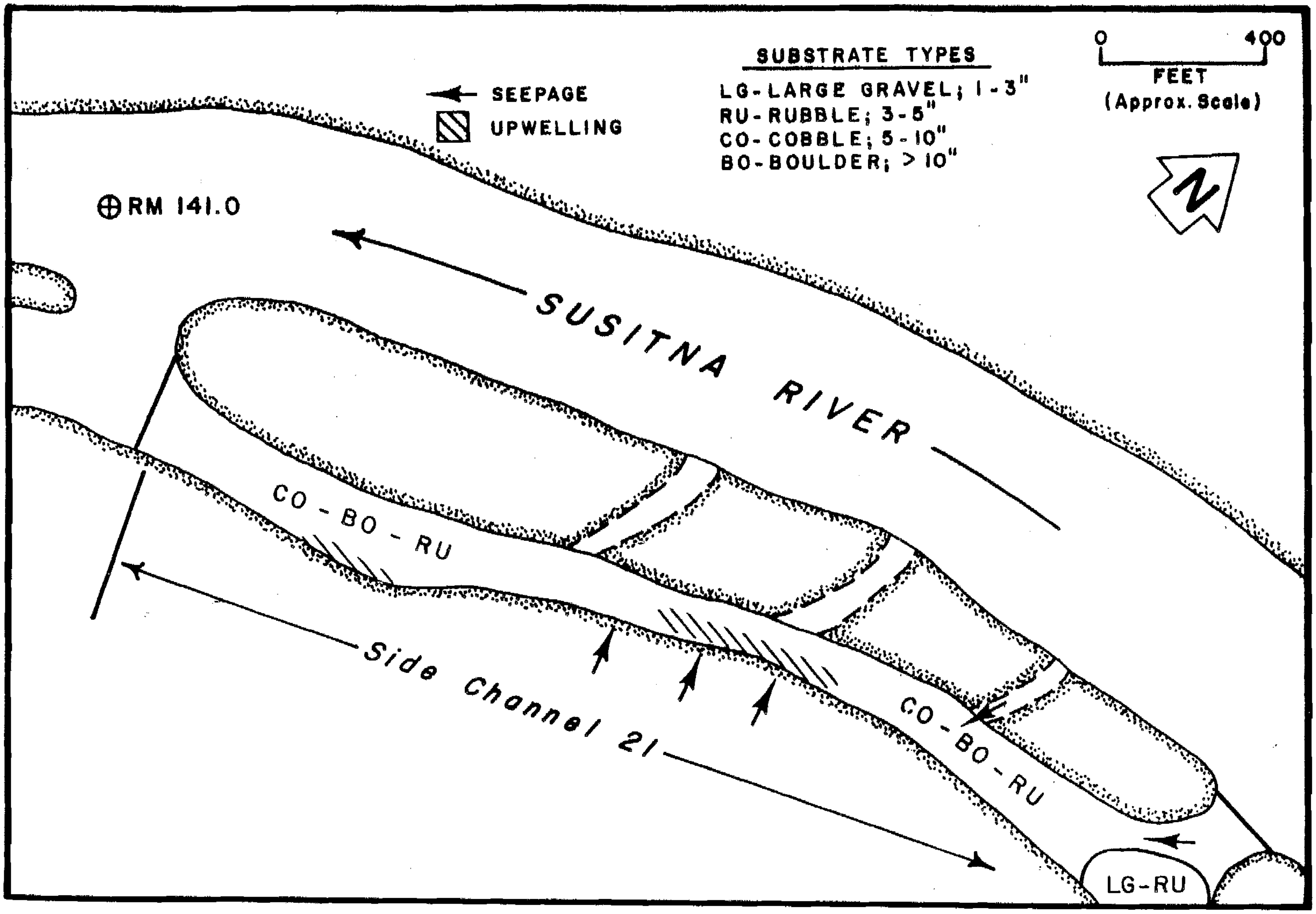
Slough 21 located on the south bank of the Susitna River, is approximately 3,000 feet long and is separated from the mainstem by a large vegetated gravel bar. Approximately 1,500 feet upstream from the mouth, Slough 21 divides into two forks: a northwest (left) channel and a northeast (right) channel. The mouth of Slough 21 flows directly into the head of Side Channel 21 where a pool is formed (Appendix Figure A-112). No backwater has been observed in Slough 21. Cobble and boulder with silt/sand deposits in the pool areas are the predominant substrate types found in Slough 21 (Appendix Figure A-113). The gradient of Slough 21 is 22.9 ft/mi, with a corresponding mainstem gradient of 12.1 ft/mi. Passage problems exist in this site but the overriding control of fish movement into Slough 21 is passage within Side Channel 21. Four passage reaches have been identified in this slough as are found in Blakely et al. 1985 and Sautner et al. 1984 (Appendix Figure A-114).

Slough 21 is one of the three major spawning sloughs for sockeye and chum salmon on the Susitna River (Appendix Figure A-114). According to Barrett et al. 1985 it accounted for 13.2 percent of the sockeye and 31.2 percent of the chum salmon slough spawning with peak survey counts of 122 and 2,354 fish respectively. Over the past four years (1981-1984) Slough 21 has been responsible for 12.3 percent of the sockeye and 25.7 percent of the chum salmon slough spawning.

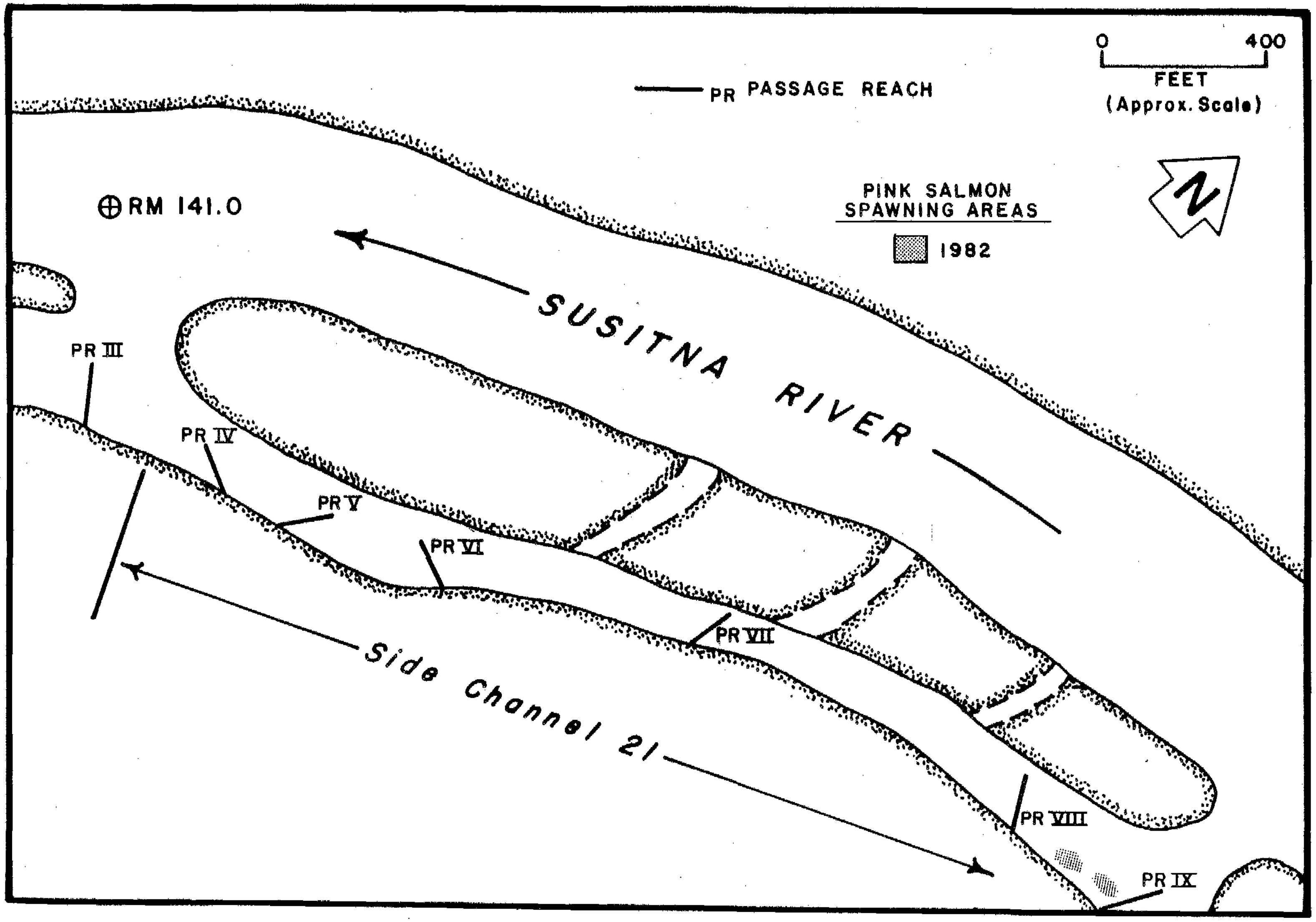
Factors limiting spawning in this site are passage and substrate.

Slough 22 (RM 144.2L)

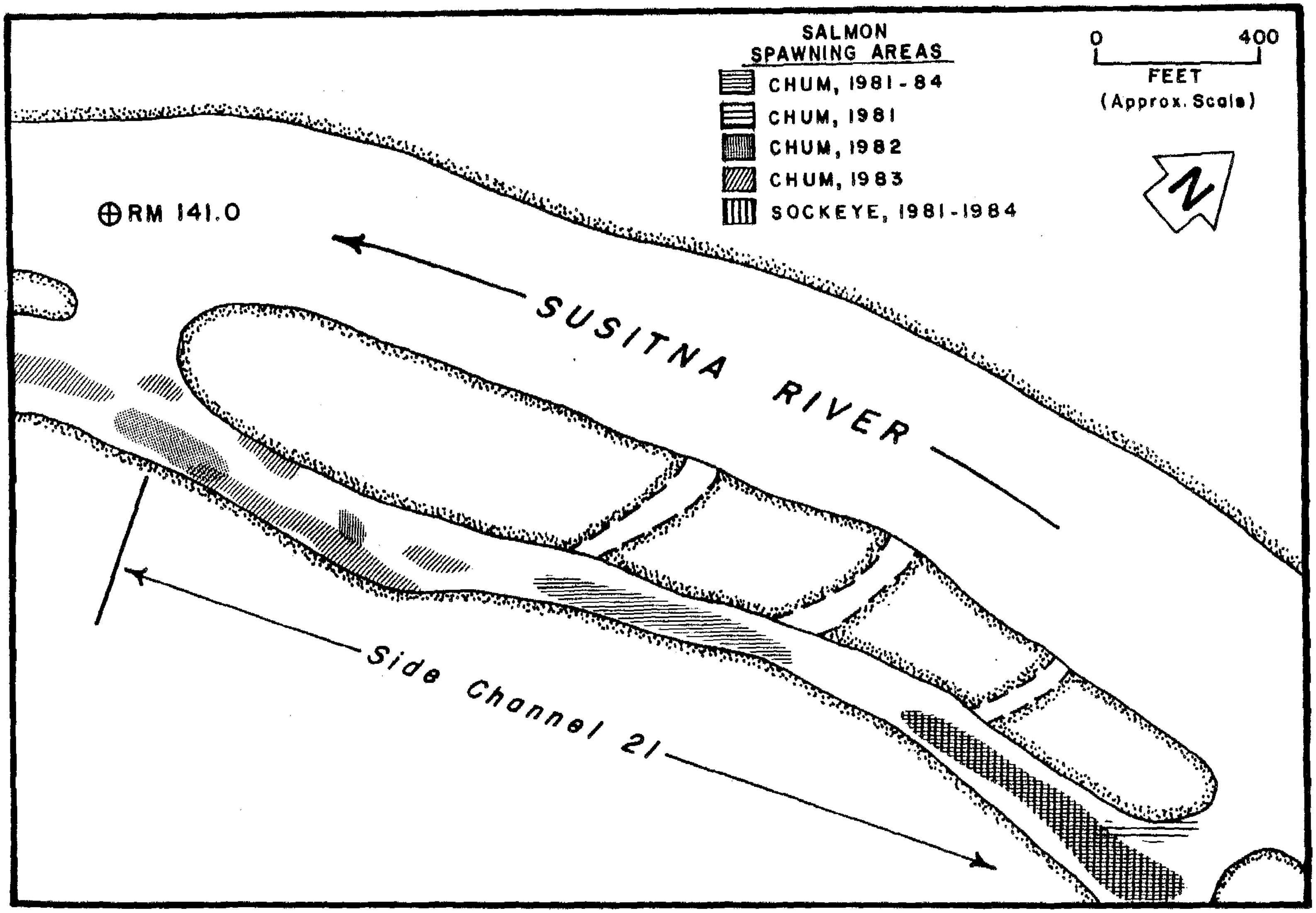
Slough 22 is a 0.5 mile long side slough located on the north bank of the Susitna River at RM 144.2. A clear water tributary entering along



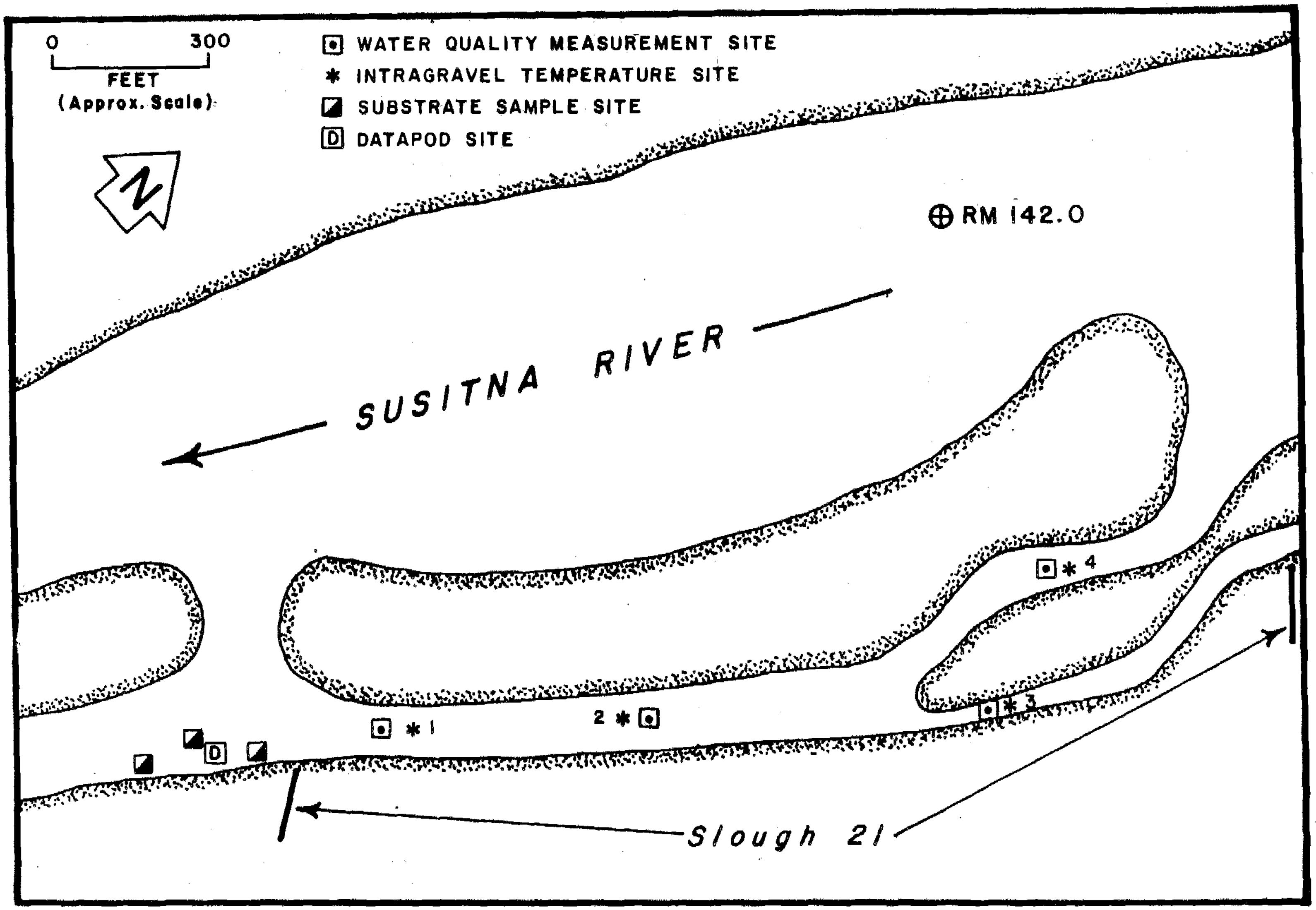
Appendix Figure A-109. Substrate composition and upwelling areas in Side Channel 21 (RM 140.6R).



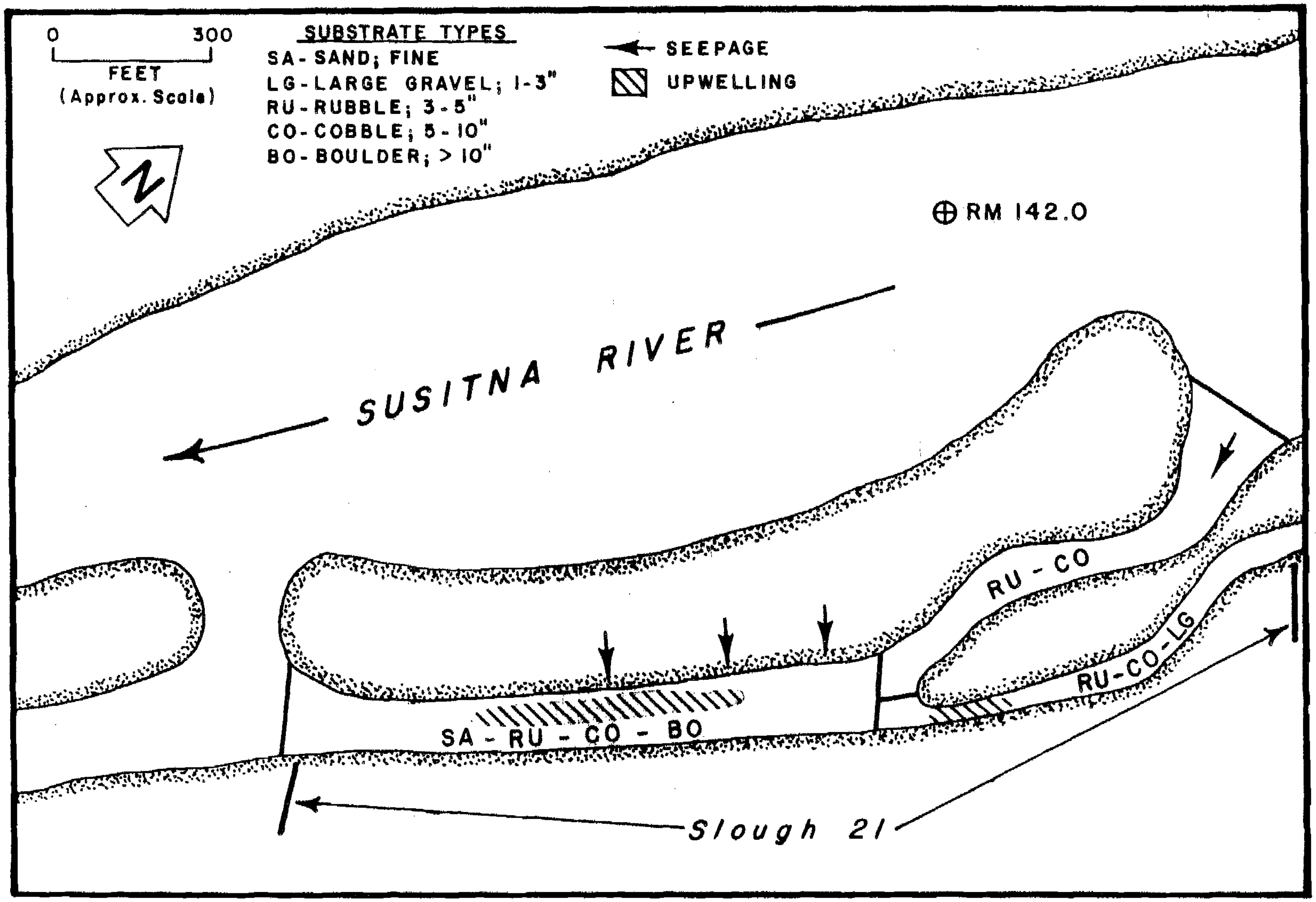
Appendix Figure A-110. Passage reaches and pink salmon spawning areas in Side Channel 21 (RM 140.6R).



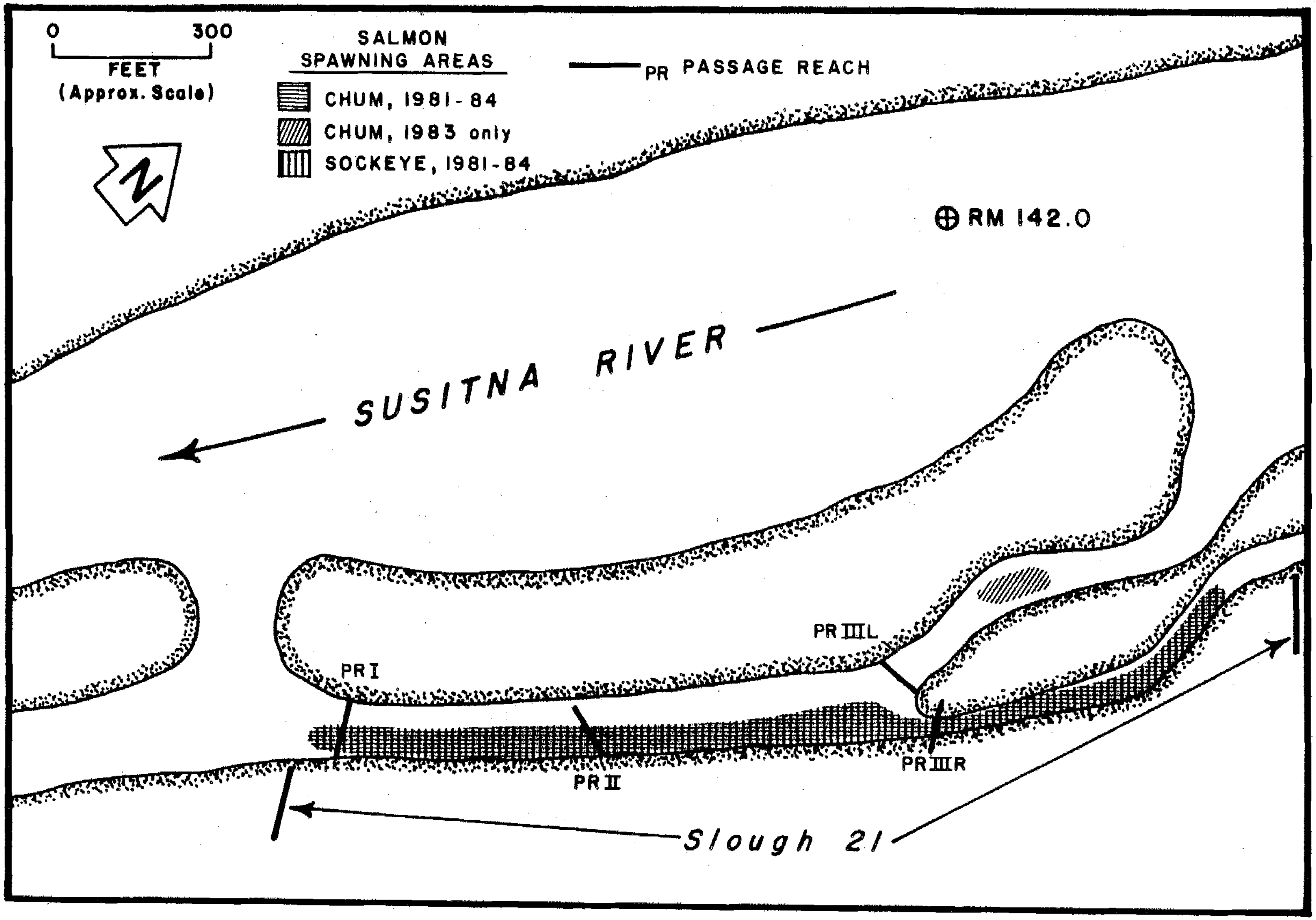
Appendix Figure A-111. Chum and sockeye salmon spawning areas in Side Channel 21 (RM 140.6R).



Appendix Figure A-112. Channel geometry and sampling sites in Slough 21 (RM 141.8R).



Appendix Figure A-113. Substrate composition and upwelling areas in Slough 21 (RM 141.8R).



Appendix Figure A-114. Chum and sockeye salmon spawning areas in Slough 21 (RM 141.8R).

the left bank approximately 600 feet below the head is the weakest and most seasonal of two tributaries and may be mainstem related. The second tributary, draining a bog area, enters about 1,000 feet below the head. It is tannin stained and flows constantly all year. Upwelling and bank seepage are evident in the middle reach and along the left bank in the mouth area (Appendix Figure A-115).

Boulder/cobble substrate predominates in most areas, especially in the upper half where during unbreached conditions, the area is characterized by a shallow pool followed by a long riffle (Appendix Figure A-116). The lower half contains two deep pools that are separated by a riffle. The lower pool sometimes exhibits backwater characteristics and has boulder/cobble substrate covered by silt. The upper pool has large gravel/rubble substrates with a thin layer of silt.

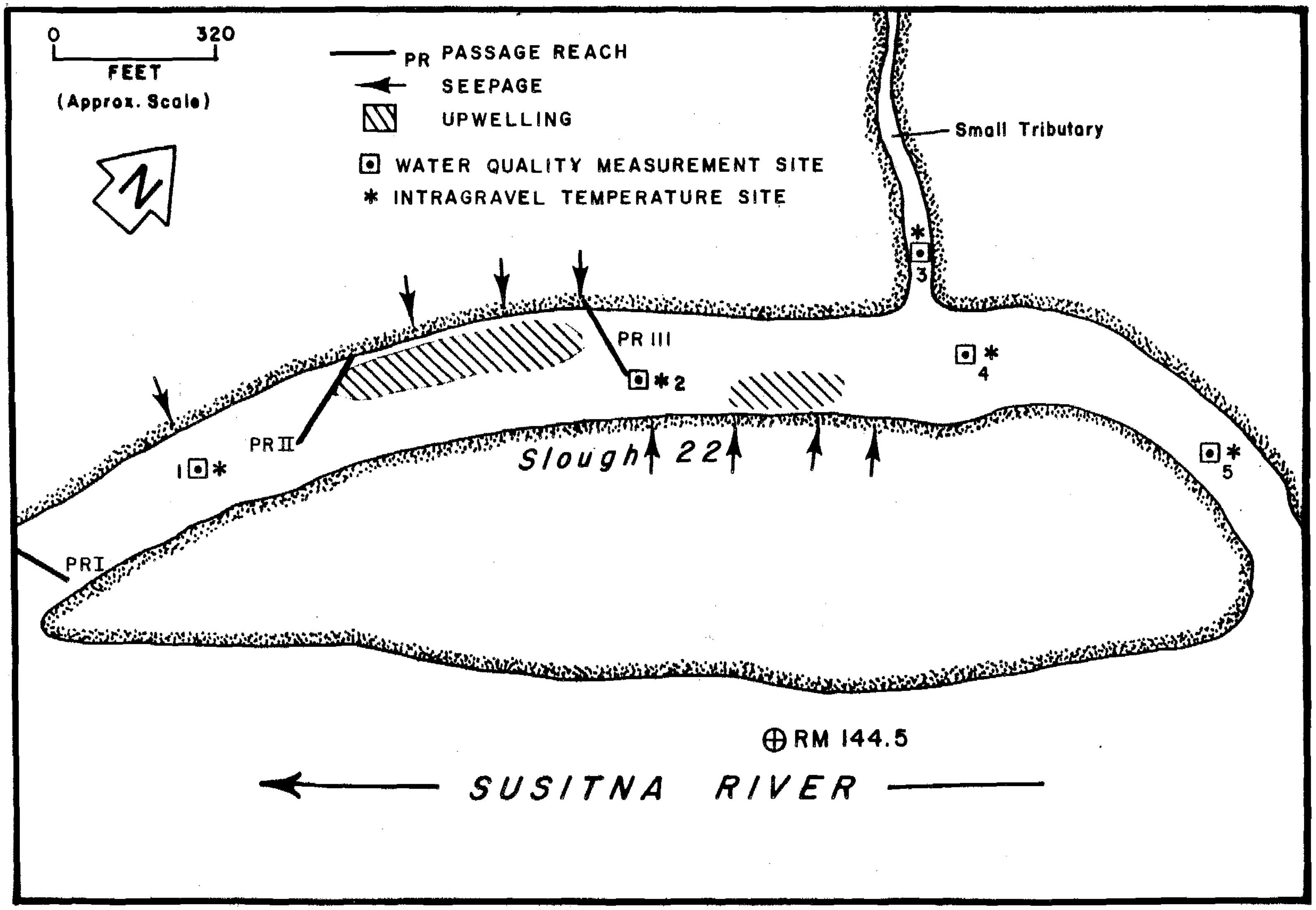
There are three passage reaches in this slough that can be restrictive to fish passage in an unbreached condition as is found in Blakely et al. 1985 and Sautner et al. 1984 (Appendix Figure A-115). Chum and sockeye salmon spawned in this slough during 1983 and 1984 with the majority of spawning centered around the upper half of the second pool (Appendix Figure A-117). This pool has good upwelling as well as large gravel/rubble substrate. Fry are present throughout the site.

Factors limiting spawning in this site are passage, substrate and limited upwelling.

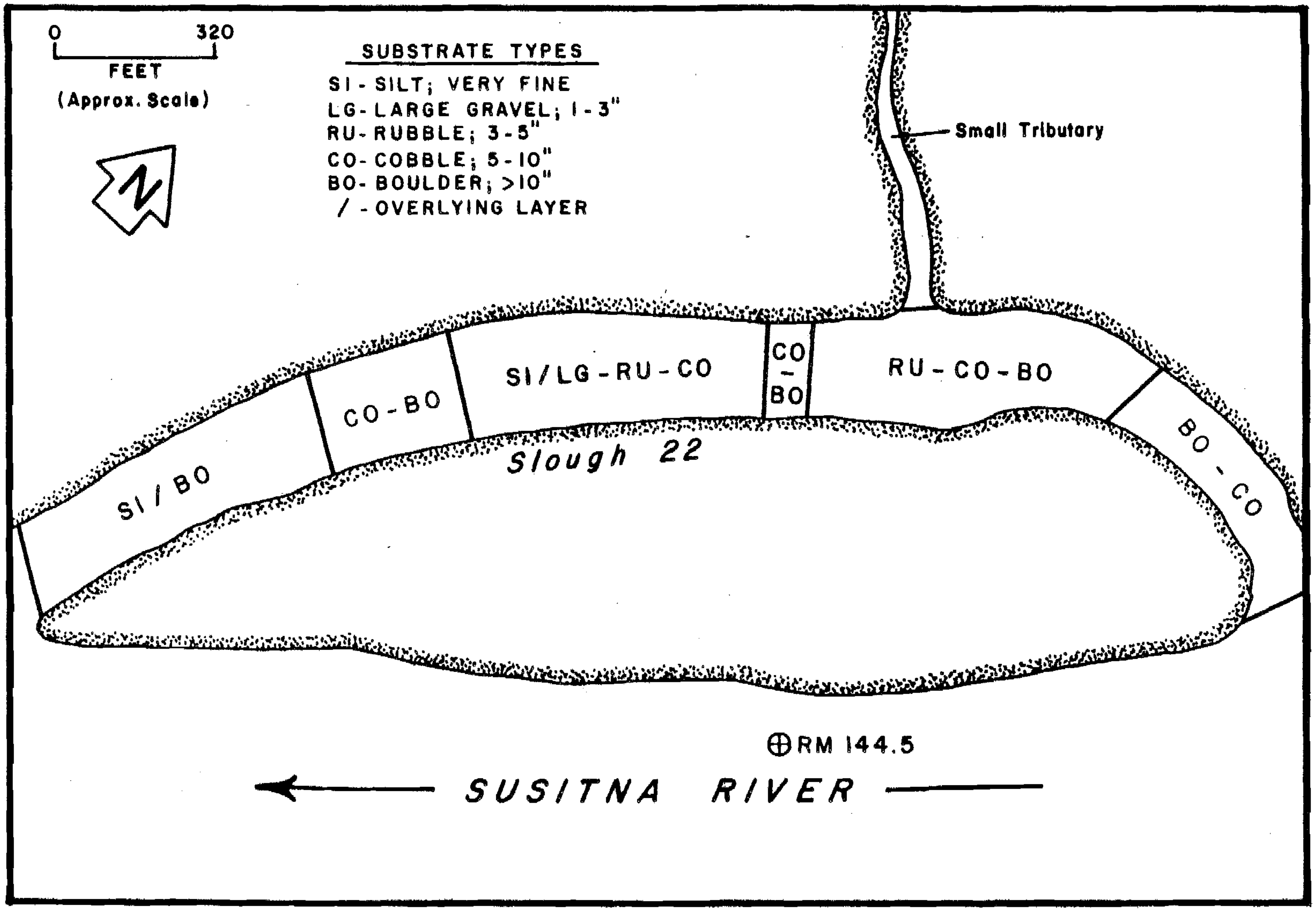
Slough 21A (RM 145.3R)

This is a 0.75 mile side slough located on the east bank of the Susitna River at RM 145.3 with a small stream entering the slough about 0.2 miles below the head (Appendix Figure A-118). The only observed bank seepage and upwelling in this slough appears at and slightly downstream of this inlet stream (Appendix Figure A-119). This upwelling was weak and stopped completely in late fall. Channel geometry is mainly rectangular in the upper reaches tending toward parabolic in the lower reaches. In general, cobble/boulder substrates predominate with pockets of rubble/cobble or small gravel/large gravel (Appendix Figure A-120). This slough has numerous passage problems, and dewaters completely at low mainstem discharges. During 1984, chum salmon spawning was observed in the upwelling area below the inlet stream and in the mouth area (Appendix Figure A-121). Fry were observed in isolated pools that later dewatered completely.

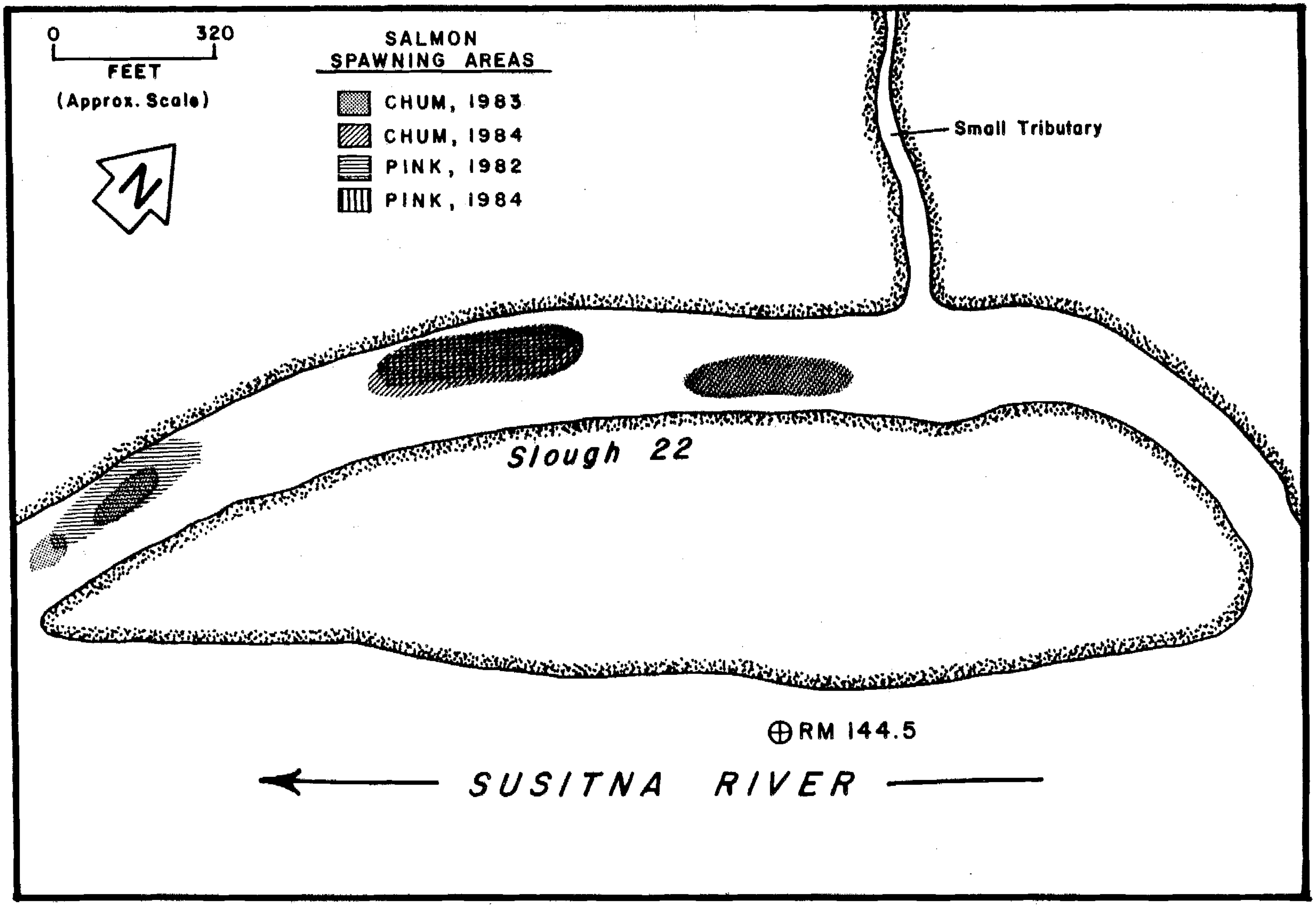
Problems limiting spawning in this site are passage, substrate, and dewatering of the slough.



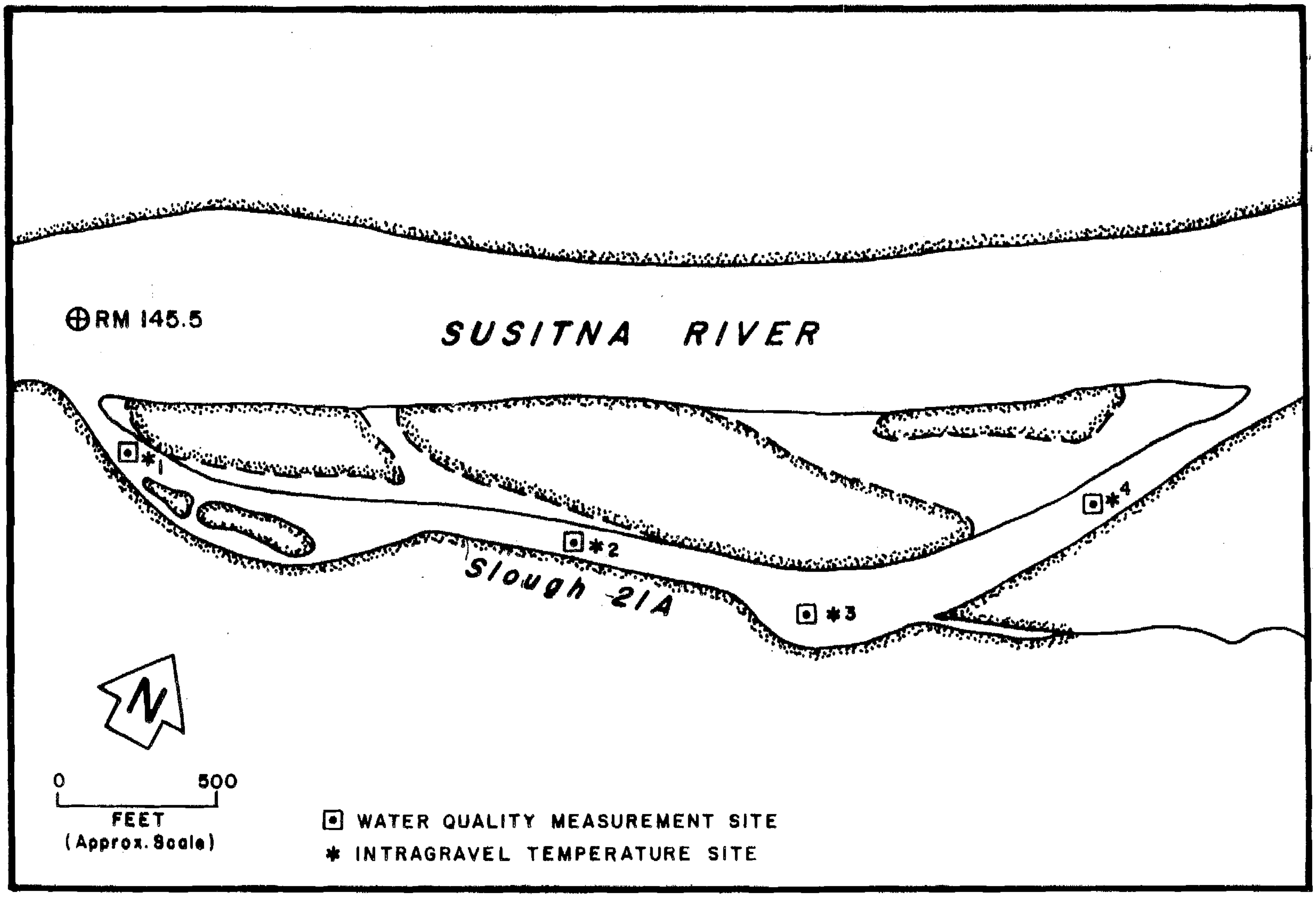
Appendix Figure A-115. Upwelling areas, passage reaches, and sampling sites in Slough 22 (RM 144.2L).



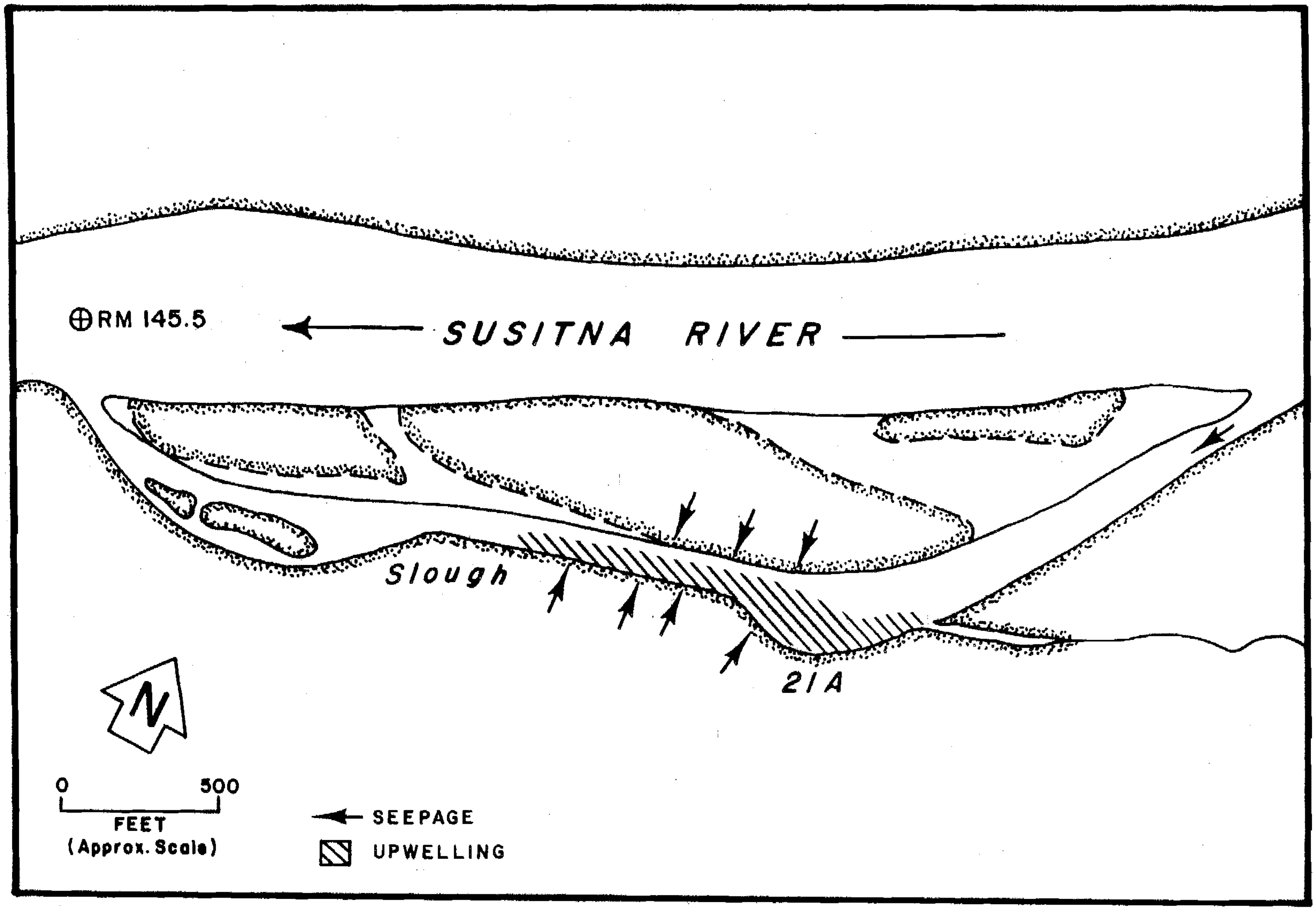
Appendix Figure A-116. Substrate composition in Slough 22 (RM 144.2L).



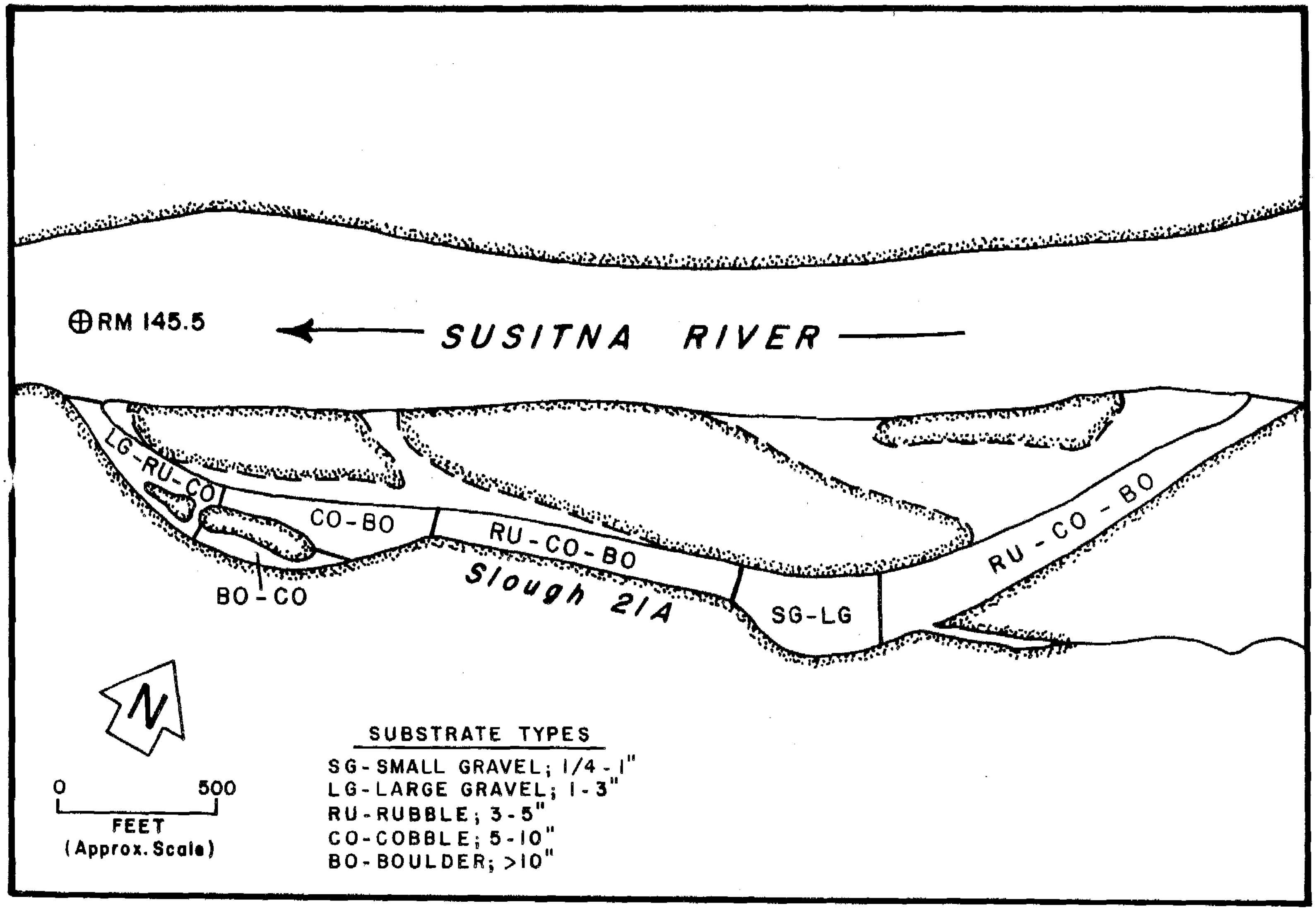
Appendix Figure A-117. Chum and pink salmon spawning areas in Slough 22 (RM 144.2L).



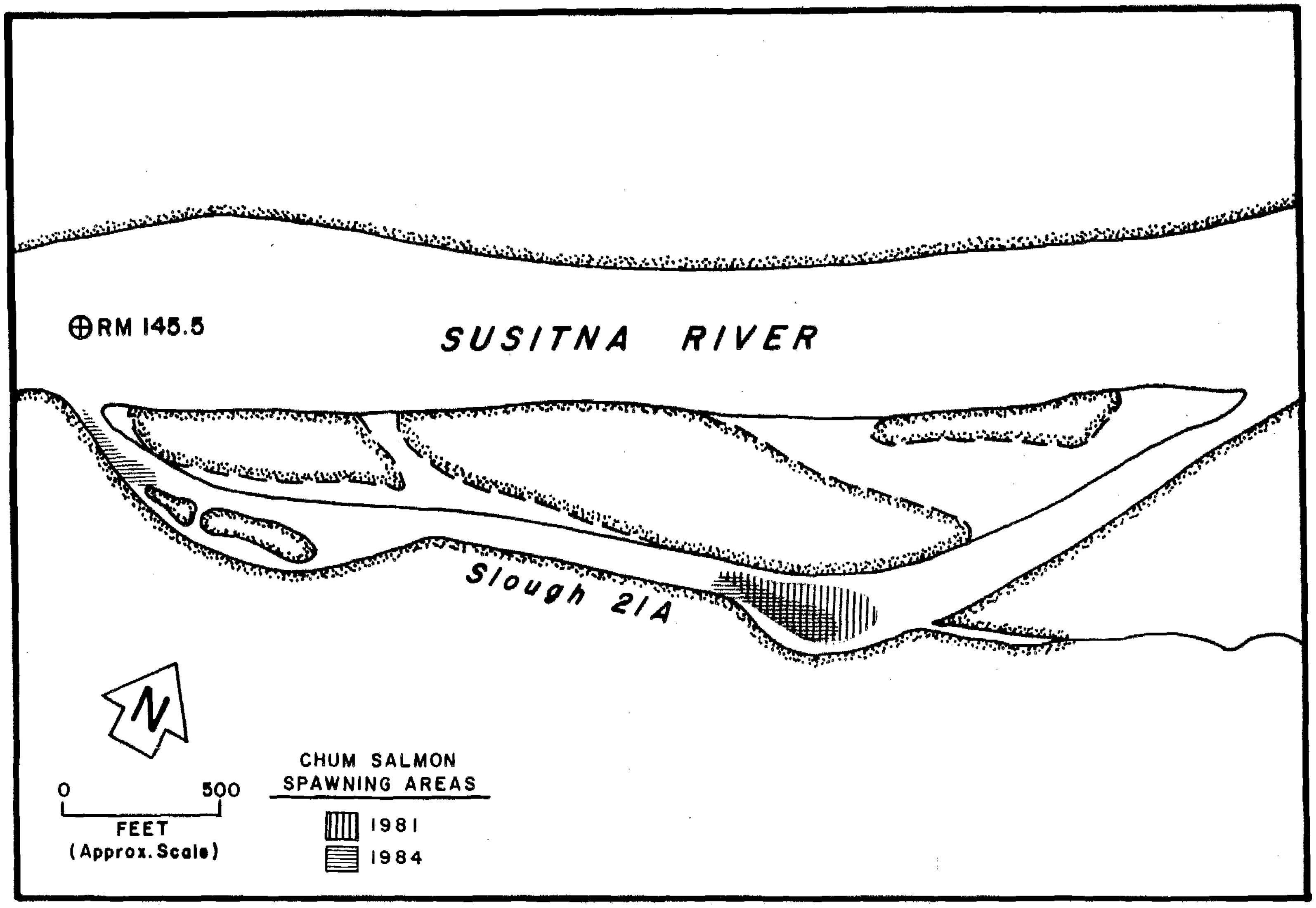
Appendix Figure A-118. Channel geometry and sampling sites in Slough 21A (RM 145.3R).



Appendix Figure A-119. Upwelling and bank seepage areas in Slough 21A (RM 145.3R).



Appendix Figure A-120. Substrate composition in Slough 21A (RM 145.3R).



Appendix Figure A-121. Chum salmon spawning areas in Slough 21A (RM 145.3R).

APPENDIX B

GENERAL SURFACE WATER QUALITY AND

INTRAGRAVEL TEMPERATURE DATA.

Appendix Table B-1. General surface water quality measurements and intragravel water temperatures in selected sloughs and side channels in the middle reach of the Susitna River, 1984.

Site (River Mile)	Date Sampled	Sample Location	Surface Water Quality Temperature (°C)	Surface Water Quality Dissolved Oxygen (mg/l)	Surface Water Quality Conductivity (field) (umhos/cm)	Surface Water Quality pH	Intragravel Water Temperature (°C)	Discharge at Gold Creek (cfs)
Slough 1 (99.5R)	8-5-84	Mouth	11.4	7.1	132	6.4	-	21,100
		Middle	11.4	7.5	115	6.3	-	
		Head	9.1	5.9	111	6.0	-	
Slough 2 (100.7R)	8-5-84	Mouth	6.2	6.6	179	6.1	5.4	21,100
		Middle	6.2	5.9	175	6.3	6.1	
		Tributary	8.9	5.8	168	6.2	7.2	
		Head	9.6	2.1	329	6.2	6.9	
Whiskers Creek Slough (101.2L)	8-15-84	Mouth	13.5	11.0	26	6.9	11.6	
		Middle	12.1	10.6	21	6.4	11.7	
		Whiskers Creek	11.8	11.1	17	6.8	11.2	
		Middle	11.9	8.4	67	6.5	10.5	
		Head	7.5	4.6	61	6.8	8.5	
Slough 3B (101.4L)	8-15-84	Mouth	11.6	7.5	70	7.0	10.1	15,100
		Middle	10.7	7.6	64	6.8	10.5	
Slough 3A (101.9L)	8-5-84	Mouth	13.3	7.9	160	6.6	9.6	21,100
		Middle	12.4	6.1	112	6.1	11.4	
		Middle	6.8	2.5	78	6.3	5.6	
		Middle	7.4	5.5	68	5.9	6.4	
		Head	7.4	5.9	69	6.1	6.4	
	8-15-84	Mouth	5.2	2.5	82	6.7	-	15,100
		Middle	6.2	5.4	72	6.7	-	
		Middle	5.7	4.4	56	6.7	-	
		Head	6.3	4.9	68	6.6	-	
Slough 4 (105.2R)	8-15-84	Mouth	4.0	-	48	4.2	4.4	15,100

Appendix Table B-1 (Continued).

Site (River Mile)	Date Sampled	Sample Location	Surface Water Quality: Temperature (°C)	Dissolved Oxygen (mg/l)	Conductivity (field) (umhos/cm)	pH	Intragravel Water Temperature (°C)	Discharge at Gold Creek (cfs)
Slough 5	8-4-84	Mouth	14.7	8.4	81	6.3	-	20,000
(107.6L)		Middle	15.0	7.9	67	6.3	-	
	10-8-84	Mouth	4.1	10.5	90	6.1	6.3	6,600
		Middle	4.9	11.7	83	6.2	5.5	
		Head	4.9	11.2	71	6.5	5.3	
Slough 6	8-4-84	Mouth	14.9	8.6	30	6.1	-	20,000
(108.2L)	10-8-84	Mouth	4.0	13.1	56	6.2	5.5	6,600
		Middle	4.0	12.6	55	6.2	4.8	
Oxbow I								
Side Channel	10-8-84	Mouth	3.3	10.6	176	6.2	5.2	6,600
(110.1L)		Middle	3.1	9.9	128	6.2	4.6	
		Middle	3.5	11.5	107	6.3	4.7	
		Head	3.2	6.9	62	6.1	5.0	
Slough 6A	8-3-84	Mouth	12.3	8.1	43	6.2	-	20,400
(112.3L)		Middle	13.6	8.5	45	6.1	-	
	10-8-84	Mouth	2.9	13.0	61	6.3	5.1	6,600
		Middle	2.7	13.8	53	6.5	4.0	
		Middle	3.6	12.1	90	6.3	5.2	
		Head	5.1	1.7	182	6.2	5.9	
Slough 7	8-3-84	Mouth	10.4	5.5	99	6.0	7.9	20,400
(113.2R)		Middle	11.4	6.9	94	3.7	7.5	
	10-6-84	Mouth	6.4	13.8	71	6.5	5.7	6,780
		Middle	5.3	10.6	69	6.4	6.3	
Slough 8	8-3-84	Mouth	9.6	9.7	60	6.5	-	20,400
(113.7R)		Middle	8.8	8.1	69	6.2	4.5	
		Head	9.4	6.3	86	5.8	4.4	
	10-6-84	Mouth	5.3	11.8	76	6.2	5.0	6,780
		Middle	5.1	13.7	73	6.3	4.4	
		Middle	5.1	9.5	88	6.3	4.2	
		Head	5.0	8.8	90	5.2	4.6	

Appendix Table B-1 (Continued).

Site (River Mile)	Date Sampled	Sample Location	Surface Water Quality: Temperature (°C)	Surface Water Quality: Dissolved Oxygen (mg/l)	Surface Water Quality: Conductivity (field) (umhos/cm)	Surface Water Quality: pH	Intragravel Water Temperature (°C)	Discharge at Gold Creek (cfs)
Mainstem 2 Side Channel (114.5R)	10-5-84	Middle	3.2	14.2	117	-	-	7,080
		Middle	4.8	14.3	114	6.7	-	
		Head R	3.5	14.4	139	-	-	
		Head L	3.2	14.8	149	6.3	4.7	
		Head L	3.5	14.9	173	6.3	-	
Bushrod Slough (117.9L)	8-3-84	Mouth	7.5	10.0	29	6.3	4.5	20,400
		Middle	7.1	9.6	97	6.4	5.4	
		Middle	7.6	7.9	109	6.3	7.2	
		Head	7.3	9.0	105	6.4	6.4	
	10-5-85	Mouth	2.9	13.4	191	-	4.5	7,080
		Middle	2.5	12.5	84	-	4.0	
		Middle	2.5	11.6	109	-	4.0	
		Head	3.3	11.2	93	-	5.1	
		Trib	5.2	9.6	62	-	6.1	
Curry Slough (119.7R)	8-3-84	Mouth	6.5	10.7	53	6.2	6.1	20,400
		Middle	5.9	10.0	51	6.1	7.3	
		Head	5.4	9.7	51	5.9	5.3	
	10-5-84	Mouth	2.5	15.7	54	6.3	3.3	7,080
		Middle	1.4	14.8	56	-	5.1	
		Head	2.4	14.2	58	-	4.6	
Slough 8C (121.8R)	8-16-84	Mouth	9.4	8.1	115	6.9	9.4	14,500
		Middle	6.9	7.2	92	7.0	7.0	
		Head	8.1	7.3	111	7.0	7.7	
	8-28-84	Mouth	3.6	9.9	77	5.7	3.9	21,000
	9-13-84	Mouth	6.2	-	107	-	6.4	9,000
		Middle	-	-	-	-	5.1	
		Head	-	-	-	-	4.8	
	10-4-84	Mouth	5.0	8.9	104	-	5.1	7,380
		Middle	4.2	9.2	65	6.7	3.4	
		Head	6.1	11.2	101	6.8	6.1	
Slough 8D (121.8R)	8-2-84	Mouth	8.5	10.9	34	6.3	7.0	22,000
		Middle	8.5	10.5	33	6.2	8.4	
		Head	8.1	10.6	29	5.1	6.2	
	10-4-85	Mouth	5.2	14.0	50	-	5.4	7,380
		Middle	6.1	13.7	49	6.8	5.2	

Appendix Table B-1 (Continued).

Site (River Mile)	Date Sampled	Sample Location	Surface Water Quality: Temperature (°C)	Dissolved Oxygen (mg/l)	Conductivity (field) (umhos/cm)	pH	Intragravel Water Temperature (°C)	Discharge at Gold Creek (cfs)
Slough 8B (122.2R)	8-13-84	Mouth	5.2	6.3	182	5.8	4.1	17,600
	10-4-84	Mouth	4.3	13.4	128	-	4.3	7,380
		Middle	4.0	13.4	132	-	5.9	
		Middle	5.3	10.4	123	-	5.7	
		Head	3.2	10.5	172	-	4.0	
Moose Slough (123.1R)	8-2-84	Mouth	8.8	7.8	200	6.3	8.8	22,000
		Middle	8.7	7.0	182	6.7	9.2	
		Head	11.0	6.6	157	5.7	11.2	
	10-4-84	Mouth	5.8	13.8	216	-	4.2	7,380
		Middle	3.7	14.2	212	-	4.5	
		Middle	5.1	11.6	212	-	5.9	
		Head	7.0	6.3	181	-	7.6	
Slough A' (124.6R)	8-2-84	Mouth	9.1	9.2	87	7.1	5.5	22,000
		Head	9.1	9.3	71	6.8	4.8	
	10-4-85	Middle	2.4	14.7	117	-	3.3	7,380
		Middle	4.3	13.6	115	-	5.3	
		Head	4.4	12.7	114	-	5.8	
Skull Creek	8-2-84	Mouth	8.7	11.5	63	6.9	9.2	22,000
		Mouth	8.7	11.9	60	7.0	9.3	
	10-4-85	Mouth	2.6	15.1	117	-	3.5	
		Middle	2.5	14.8	118	-	3.4	
Slough A (124.8R)	8-2-84	Mouth	9.5	8.2	79	6.0	7.8	22,000
		Middle	8.7	10.2	66	6.5	8.9	
		Middle	9.5	7.1	90	6.2	9.6	
		Head	9.2	6.9	86	5.9	7.3	
	10-4-84	Mouth	3.3	11.8	109	5.3	5.8	7,380
		Head	2.5	13.2	106	5.9	6.6	
Slough 8A (125.3R)	10-4-85	Mouth	2.0	14.6	132	6.7	2.9	7,380
		Middle	3.0	12.8	127	6.7	5.1	
		Middle	2.0	7.1	230	6.4	4.0	
		Middle	1.3	12.3	104	6.8	3.6	
		Head	1.4	13.4	94	6.8	3.8	

Appendix Table B-1 (Continued).

Site (River Mile)	Date Sampled	Sample Location	Surface Water Quality: Temperature (°C)	Dissolved Oxygen (mg/l)	Conductivity (field) (umhos/cm)	pH	Intragravel Water Temperature (°C)	Discharge at Gold Creek (cfs)
Slough B	8-2-84	Mouth	9.8	10.1	165	6.9	8.8	22,000
(126.3R)		Middle	10.1	9.9	159	6.7	6.3	
		Middle	10.6	10.7	139	6.9	10.4	
		Head	6.3	7.4	243	6.5	4.1	
	10-4-84	Mouth	5.7	12.1	294	6.0	4.2	7,380
		Middle	3.6	12.8	310	-	5.9	
		Head	3.1	13.2	262	-	4.7	
Slough 9	9-12-84	Mouth	8.7	12.6	193	6.3	7.7	9,000
(128.3R)		Middle	7.0	10.5	130	6.2	5.3	
		Head	8.1	14.0	130	6.8	6.8	
	10-3-84	Mouth	5.3	13.4	96	6.7	5.6	7,680
		Head	5.8	10.7	120	6.7	4.5	
Slough 9B	8-11-84	Mouth	10.2	9.1	157	6.9	-	22,500
(129.2R)	9-12-84	Mouth	5.6	10.4	183	6.2	7.5	9,080
		Middle	4.6	7.9	180	6.2	5.3	
		Head	4.5	7.5	174	6.4	5.4	
	10-3-84	Mouth	5.6	10.6	163	6.6	6.6	7,680
		Middle	5.3	9.6	162	6.9	5.4	
		Head	5.0	8.4	162	6.5	5.0	
Slough 9A	10-3-84	Mouth	4.3	15.1	183	6.6	5.2	7,680
(133.2R)		Middle	4.0	12.9	189	6.8	4.0	
		Head	4.7	11.7	207	6.6	4.1	
Slough 10	10-3-84	Mouth	2.7	11.3	183	6.7	4.3	7,680
(133.8L)		Middle	2.6	11.8	210	6.8	3.3	
		Middle	2.6	12.0	205	6.8	3.4	
		Middle	2.8	10.4	158	6.8	3.7	
		Head	2.9	9.8	148	6.8	3.5	
Slough 11	10-2-84	Mouth	5.0	13.3	235	7.0	4.7	7,980
(135.3R)		Middle	5.0	13.5	237	7.0	5.1	
		Head	4.4	12.6	238	6.9	4.6	
Slough 12	8-1-84	Mouth	13.0	9.0	113	6.6	11.6	23,400
(135.4R)	10-2-84	Mouth	7.4	12.3	158	6.8	6.8	7,980
		Middle	6.8	11.1	130	7.0	6.8	

Appendix Table B-1 (Continued).

Site (River Mile)	Date Sampled	Sample Location	Surface Water Quality Temperature (°C)	Dissolved Oxygen (mg/l)	Conductivity (field) (umhos/cm)	pH	Intragravel Water Temperature (°C)	Discharge at Gold Creek (cfs)
Slough 13 (135.5R)	8-1-84	Mouth	12.9	10.9	68	7.0	10.7	23,400
		Middle	4.8	8.9	174	6.9	4.5	
		Middle	5.6	10.0	184	6.9	6.6	
		Head	5.7	10.9	194	7.0	5.9	
Upper Side Channel 11 (136.0R)	10-2-84	Mouth	6.6	12.2	165	6.7	5.6	7,980
		Middle	6.6	9.7	198	6.5	3.9	
		Head	9.1	14.1	257	6.7	5.5	
Slough 14 (136.0L)	8-1-84	Mouth	10.9	8.5	35	6.0	8.8	23,400
		Middle	12.6	5.3	71	6.0	10.0	
	10-2-84	Mouth	6.4	10.6	44	6.5	8.9	7,980
		Middle	8.4	4.3	76	6.3	8.6	
		Head	6.9	7.3	72	6.7	7.3	
Slough 15 (137.2L)	8-1-84	Mouth	10.7	5.7	90	6.3	6.6	23,400
		Middle	10.6	9.0	23	6.2	11.2	
		Head	10.4	8.6	28	6.0	-	
	10-2-84	Mouth	5.9	9.9	37	6.2	6.2	7,980
		Middle	6.8	9.2	56	6.6	6.2	
Slough 16 (137.7L)	10-2-84	Mouth	6.2	7.8	51	6.6	7.0	7,980
		Middle	5.6	5.6	52	6.1	5.2	
		Head	5.3	13.5	56	6.6	5.3	
Slough 16B (137.9L)	10-2-84	Mouth	4.7	12.0	56	6.5	8.0	7,980
		Middle	5.7	10.8	56	6.6	5.4	
		Head	5.0	9.6	61	6.4	5.8	
Slough 17 (138.9L)	8-1-84	Mouth	4.8	8.4	57	6.1	5.3	23,400
		Middle	4.4	8.8	53	6.0	3.5	
		Middle	6.9	7.0	61	6.0	7.6	
		Middle	12.0	3.6	67	5.8	13.0	
		Head	4.8	8.3	57	6.2	5.0	
	9-11-84	Mouth	-	-	-	-	5.0	9,330
		Middle	-	-	-	-	5.1	
		Middle	-	-	-	-	-	
		Middle	-	-	-	-	4.9	
		Head	-	-	-	-	4.2	

Appendix Table B-1 (Continued).

Site (River Mile)	Date Sampled	Sample Location	Surface Water Quality: Temperature (°C)	Surface Water Quality: Dissolved Oxygen (mg/l)	Surface Water Quality: Conductivity (field) (umhos/cm)	Surface Water Quality: pH	Intragravel Water Temperature (°C)	Discharge at Gold Creek (cfs)
Slough 17 (138.9L)	10-2-84	Mouth	3.3	12.1	76	5.4	4.1	7,980
		Middle	3.7	5.8	125	6.7	3.6	
		Middle	3.3	11.4	74	6.0	3.0	
		Middle	3.4	10.3	72	6.0	3.0	
		Head	3.6	10.0	76	6.1	4.3	
Slough 18 (139.1L)	7-31-84	Mouth	7.5	8.6	109	6.4	5.8	25,300
		Middle	7.8	7.6	142	6.2	7.4	
		Middle	6.6	8.6	85	6.3	4.7	
		Head	6.1	9.0	78	6.3	4.0	
	10-2-84	Middle	4.7	7.8	171	6.4	5.4	7,980
		Middle	5.5	10.5	142	6.3	6.0	
Slough 19 (139.8R)	7-31-84	Mouth	5.4	5.8	113	9.4	-	25,300
		Middle	6.9	6.2	113	9.1	3.8	
		Head	5.1	6.2	106	9.0	4.8	
	10-1-84	Mouth	4.3	12.1	158	6.4	6.2	7,830
		Middle	5.2	12.2	151	6.6	5.9	
		Middle	4.7	11.2	161	6.8	5.8	
		Head	2.7	9.2	48	7.0	-	
Slough 20 (140.1R)	8-30-84	Mouth	4.6	14.4	73	6.9	4.2	15,300
		Middle	4.2	14.4	72	6.8	4.0	
		Waterfall Creek	3.7	15.3	75	7.2	4.0	
		Head	4.9	13.1	54	7.0	4.6	
	10-1-84	Mouth	5.5	13.9	97	6.4	6.5	7,830
		Middle	4.8	13.6	98	7.5	6.0	
		Waterfall Creek	4.6	14.7	98	7.4	6.0	
		Head	4.6	13.9	95	7.5	6.0	
Side Channel 21 (140.6R)	10-1-84	Middle	4.7	14.6	177	7.6	5.2	7,830
		Head	4.2	12.1	196	7.4	4.3	

Appendix Table B-1 (Continued).

Site (River Mile)	Date Sampled	Sample Location	Surface Water Quality: Temperature (°C)	Surface Water Quality: Dissolved Oxygen (mg/l)	Surface Water Quality: Conductivity (field) (umhos/cm)	Surface Water Quality: pH	Intragravel Water Temperature (°C)	Discharge at Gold Creek (cfs)
Slough 21 (141.8R)	8-30-84	Mouth	4.6	11.3	197	6.7	3.6	15,300
		Middle	4.3	11.3	192	6.6	3.5	
		Middle	4.5	10.0	195	6.6	3.2	
		Head	4.1	9.9	196	6.7	3.3	
	10-1-84	Mouth	6.1	16.6	152	7.6	6.0	7,830
		Middle	3.5	12.8	195	7.2	4.2	
		Middle	3.5	10.1	197	7.2	4.1	
		Head	3.6	12.8	199	7.2	4.1	
Slough 22 (144.2L)	8-30-84	Mouth	4.5	12.0	88	5.9	4.8	15,300
		Middle	4.8	11.9	78	6.1	3.7	
		Middle	5.5	13.9	36	6.3	5.8	
		Middle	5.8	13.6	31	6.8	6.0	
		Head	5.4	13.1	101	6.4	5.8	
	10-1-84	Mouth	4.9	9.9	162	7.1	6.5	7,830
		Middle	4.1	8.6	122	7.1	5.0	
		Middle	5.4	13.1	68	7.2	6.3	
		Middle	5.9	12.7	69	7.1	6.7	
		Head	3.7	8.8	109	7.0	4.9	
Slough 21A (145.3R)	7-31-84	Mouth	10.8	11.5	113	7.0	11.2	25,300
		Middle	10.4	10.8	119	6.1	2.7	
		Middle	8.1	10.5	129	6.1	3.9	
		Head	9.9	12.0	146	6.3	5.2	
	10-1-84	Mouth	3.1	9.5	183	6.9	5.5	7,830

APPENDIX C

SALMON SPAWNING DISTRIBUTION DATA.

Appendix Table C-1. Salmon spawning distribution in the middle reach of the Susitna River, 1981 - 1984 (adapted from Barrett et al. 1985).

	1981					1982					1983					1984				
Site (River Mile)	Chinook	Sockeye	Pink	Chum	Coho	Chinook	Sockeye	Pink	Chum	Coho	Chinook	Sockeye	Pink	Chum	Coho	Chinook	Sockeye	Pink	Chum	Coho
Slough 1 (99.5R)				M													X		X	
Slough 2 (100.7R)				X										X			X	M	X	
Wiskers (101.2L)								X								X		X		X
Slough 3B (101.4L)		X		X								X		X			X	X	X	
Slough 3A (101.9L)		X	M														X	X	X	
Slough 4 (105.2R)																				
Slough 5 (107.6L)									M								X	X		
Slough 6 (108.2L)				M					M					M						
Oxbow I (110.1L)																			X	
Slough 6A (112.3L)		M		M				M	M	M				M	M					
Slough 7 (113.2R)																				
Slough 8 (113.7R)			X	X													X		X	

X - Spawning observed

M - Milling observed, no spawning observed

Appendix Table C-1 (Continued).

Site (River Mile)	1981 Chinook	1981 Sockeye	1981 Pink	1981 Chum	1981 Coho	1982 Chinook	1982 Sockeye	1982 Pink	1982 Chum	1982 Coho	1983 Chinook	1983 Sockeye	1983 Pink	1983 Chum	1983 Coho	1984 Chinook	1984 Sockeye	1984 Pink	1984 Chum	1984 Coho
Mainstem II (114.5R)				X					X					X					X	
Bushrod (117.9L)																		X	X	
Curry (119.7R)																			X	
Slough 8D (121.8R)			X	X					X										X	
Slough 8C (121.8R)							M		X					X				M	X	
Slough 8B (122.2R)							X		X					X			X	X	X	
Moose (123.1R)		X	M	X			X	M	X			X	M	X			X	X	X	M
Slough A' (124.6R)				X										X				X	X	
Slough A (124.8R)			M	X									M						X	
Slough 8A (125.3R)		X	X	X			X	X	X	X		X	M	X	M		X	X	X	
Slough B (126.3R)							X	X	X			X		X			X		X	
Slough 9 (128.3R)		X		X			X	X	X			X		X			X	M	X	

X - Spawning observed

M - Milling observed, no spawning observed

Appendix Table C-1 (Continued).

Site (River Mile)	1981 Chinook	1981 Sockeye	1981 Pink	1981 Chum	1981 Coho	1982 Chinook	1982 Sockeye	1982 Pink	1982 Chum	1982 Coho	1983 Chinook	1983 Sockeye	1983 Pink	1983 Chum	1983 Coho	1984 Chinook	1984 Sockeye	1984 Pink	1984 Chum	1984 Coho
Slough 9B (129.2R)		X		X			X		X								X		X	
Slough & S.C. 10 (133.8L)				M					X			M		X					X	M
Slough 9A (133.2R)		X		X			X		X			X		X					X	
Slough 11 (135.3R)		X	X	X	M		X	X	X	M		X	X	X	M		X	X	X	
USC 11 (136.0R)		X	X	X	M		X	X	X	M		X		X	M				X	M
Slough 12 (135.4R)																				
Slough 13 (135.5R)				M										M					X	
Slough 14 (136.0L)																			X	
Slough 15 (137.2L)								M	M	M			M	M	X		X	X	X	M
Slough 16 (137.7L)				X															X	
Slough 16B (137.9L)				X																
Slough 17 (138.9L)		X		X	M		X		X	M		X		X	M		X	M	X	

X - Spawning observed

M - Milling observed, no spawning observed

Appendix Table C-1 (Continued).

Site (River Mile)	1981 Chinook	1981 Sockeye	1981 Pink	1981 Chum	1981 Coho	1982 Chinook	1982 Sockeye	1982 Pink	1982 Chum	1982 Coho	1983 Chinook	1983 Sockeye	1983 Pink	1983 Chum	1983 Coho	1984 Chinook	1984 Sockeye	1984 Pink	1984 Chum	1984 Coho
Slough 18 (139.1L)									X										X	
Slough 19 (139.8R)		X		X			X	M				X	M	X			X		X	
Slough 20 (140.1R)		M	X	X				X	X				M	X				X	X	
Slough & S.C. 21 (140.6R)		X		X			X	X	X			X	M	X			X	X	X	
Slough 22 (144.2L)														X			X		X	
Slough 21A (145.3R)				X															X	

X - Spawning observed

M - Milling observed, no spawning observed

APPENDIX D

SELECTED PHYSICAL AND CHEMICAL REQUIREMENTS FOR VARIOUS LIFE STAGES OF SALMON SPECIES.

Appendix Table D-1. Water temperature, dissolved oxygen, pH and substrate requirements for various life stages of salmon species.

Life Stage	Species	Parameter	Observed Values	Remarks	Location	Reference
Upstream Migration	Chum	Water Temperature (°C)	4.4 - 19.4	total range	Traitors River	Mattson & Hobart (1962)
			8.9 - 14.4	range during peak migration		
			5.0 - 12.8	range during upstream migration	Tributaries of Kuskokwim River	ADF & G (1980a)
			10.0 - 16.7	during peak of upstream migration	Anvik River	Trasky (1974)
			8.3 - 21.1	range for the species		Bell (1973)
			10.1	optimum value		
			0.0 25.6	lower and upper lethal limit		
Spawning	Chum	Water Temperature (°C)	6.5 - 12.5		Terror & Kizhuyak Rivers	Wilson et al. (1981)
			13	most spawning	Sashin Creek	McNeil (1964)
			2.5	inhibited spawning behavior	Big Bear Creek, Washington	Schroder (1973)
			1.8 - 8.2		Sakhalin, USSR	Rukhlov (1969a)
			5.0 - 6.0	most spawning	South Kuril Island, USSR	Ivankov & Andreyev (1971)
			7.2 - 12.9	suggested criteria for species		Bell (1973)
			9.5 - 12.8	mean temperatures, summer chum	Amur River, USSR	Soin (1954)
			9.0 - 10.0	summer chum	Amur River, USSR	Sano (1966)
			ca. 6.0	autumn chum		
			2.0 - 9.0	bottom water	Iski River, USSR	Smirnov (1947)

Appendix Table D-1 (Continued).

Life Stage	Species	Parameter	Observed Values	Remarks	Location	Reference
Spawning	Chinook	Water Temperature (°C) (cont'd)	3.3 - 13.3	range for species		Bell (1973)
	Pink		7.2 - 15.6	range for species		Bell (1973)
	Coho		7.2 - 15.6	range for species		Bell (1973)
	Sockeye		7.2 - 15.6	range for species		Bell (1973)
Spawning	Chum	Substrate Particle Size	gravel 2 - 3 cm in diam., also use coarser stones and bedrock		Alaska	Morrow (1980)
			covered with small boulders			
			gravel mostly 1.27 - 127.0 cm with variable amount fines	spawning grounds	Delta River	Francisco (1976)
			stones 1.3 - 13.0 cm, coarse sand, fine sand and silt		Hooknose Creek,	Hunter (1959) British Colombia
			gravel I 2.69 cm (98%)	gravel sizes II and III selected by 75% of spawning females; gravel I selected by 20%, gravel IV selected by 5%	Big Beef Creek	Duker (1977)
			gravel II 1.35 - 7.61 cm (97%)			
			gravel III 0.67 - 2.69 cm (96%)			
			gravel IV 0.02 - 0.67 cm (96%)			

Appendix Table D-1 (Continued).

Life Stage	Species	Parameter	Observed Values	Remarks	Location	Reference
Spawning	Chum	Substrate Particle Size (cont'd)	1.3 - 10.2 cm	substrate size criteria for species		Bell (1973)
			gravel mixed with small amount of silt		Amur River,	Soin (1954) USSR
			"sand" (0.8 - 52.8%, av. 12.0 - 12.7%)		spawning grounds	Sakhalin Rukhlov (1969b)
			"gravel" (10.0 - 50.1%, avg. 33.0 - 45.9%)			
			"shingle" (6.0 - 84.1%, avg. 41.4 - 44.4%)			
			"sand" (14 - 22%)	decreased survival to emergence	Sakhalin	Rukhlov (1969b)
			0.5 cm (25%), 0.6 - 3.0 cm (45%), 3.1 cm (30%)		Northern Japan	Sano (1959, cited by Bakkala, 1970)
			particles 0.5 cm (always 20%)	spawning grounds	Memu River, Japan	Sano & Nagasawa (1958)
			particles 3.0 cm (25 - 53%)			
	Chinook		1.3 - 10.2 cm	subsize criteria for species		Bell (1973)
	Pink		1.3 - 10.2 cm	subsize criteria for species		Bell (1973)
	Coho		1.3 - 10.2 cm	subsize criteria for species		Bell (1973)
	Sockeye		1.3 - 10.2 cm	subsize criteria for species		Bell (1973)

Appendix Table D-1 (Continued).

Life Stage	Species	Parameter	Observed Values	Remarks	Location	Reference
Intragravel Development	Chum	Water Temperature, (°C)	0.5 - 4.5		Chena River	Kogl (1965)
			2.0 - 4.2 3.6 - 4.5	higher mortality at lower range	Clear hatchery	Raymond (1981)
			2.0 - 4.5	emergence delayed beyond that of wild fry incubated at 3.9°C		
			0.2 - 10.0		Noatak River	Merritt & Raymond (in prep.)
			0.0 - 4.0	probe 20.3 cm deep	Olsen Creek	Bailey (1964)
			0.4 - 6.7		Delta River	Francisco (1977)
			4.4 - 13.3	suggested criteria for species		Bell (1973)
			4.4	lowest temp. prior to closure of blastopore (Pacific salmon), can go as low as 0°C and still have good survival.		McNeil & Bailey (1975)
			3.5 - 5.0	range, fertilization to emergence	Bira River, USSR	Disler (1951)
			3.9 - 4.9 2.4 - 3.0	egg stage alevin stage	Bolshaia River, USSR	Semko (1954, cited by Sano, 1966)
	Chinook		5.0 - 14.4	suggested criteria for species		Bell (1973)
	Pink		4.4 - 13.3	suggested criteria for species		Bell (1973)
	Coho		4.4 - 13.3	suggested criteria for species		Bell (1973)
	Sockeye		4.4 - 13.3	suggested criteria for species		Bell (1973)

Appendix Table D-1 (Continued).

Life Stage	Species	Parameter	Observed Values	Remarks	Location	Reference
Intragravel Development	Chum	Substrate Particle Size	fines 0.0833 cm (12.7%)	poor quality substrate	Prince William	Thorsteinson (1965) Sound
			silt and sand (6%), 15 cm (81%), 15 cm (13%)		redds lower Columbia River	tributaries of Burner (1951)
			5.1 - 10.2 cm 1.0 - 3.8 cm	greater survival to emergence in larger gravel	Robertson Creek, British Columbia	Dill & Northcote (1970)
			sand, 0.0105 - 0.3327 cm (ca. 5 - 50%)	lower survival to emergence and smaller fry at higher percentages	Big Beef Creek, Washington	Koski (1975)
			mostly 0.2 - 1.0 cm, some particles 2.0 cm	redds - also, redds had less of the 0.025 - 0.1 cm fractions, but more sand and mud than spawning gravel	Sakhalin	Rukhlov (1969a)
			"sand"(1.8 - 30.0%), avg. 10.0 - 13.5%)	redds	Sakhalin	Rukhlov (1969b)
			"gravel"(13.4 - 60.0%, avg. 33.5 - 40.3%)			
			"shingle" (13.7 - 75.9%, avg. 39.2 - 53.0%)			
			10 cm (0.0 - 50.0%, avg. 0.7 - 9.5%)			
	Chinook		14% 6", 80% 6" 6% silt-sand	redds	Tributaries of lower Columbia River	Burner (1951)

Appendix Table D-1 (Continued).

Life Stage	Species	Parameter	Observed Values	Remarks	Location	Reference
Intragravel Development	Coho		10% 6",85% 6" 5% silt-sand	redds	Tributaries of lower Columbia River	Burner (1951)
	Sockeye		0.5% 6", 92% 6" 7.5% silt-sand	redds	Tributaries of lower Columbia River	Burner (1951)
	Chum	Dissolved Oxygen, mg/l	2.0	good survival of eggs and alevins (strong flow of groundwater)	Chena River	Kogl (1965)
			0.6 - 3.0 2.8 - 6.5 2.1 - 4.1	low survival high survival smaller alevins produced at lower end of range		
			0.0 - 12.7 5.4 - 8.9	annual range September and November	Twelvemile Creek Indian Creek	McNeil (1962)
			1.77 - 6.80	July - September, lowest caused by long dry period	Traitors River	Mattson et al. (1964)
			3.6 - 8.3	upper intertidal area July - September, low percent survival at low end of range	Olsen Creek	Bailey (1964)
			2.0 5.0 8.0	lethal limit for eggs low desirable	British Columbia	Wickett (1957)
			2.0	good survival of eggs and and alevins as long as there is a strong ground water outflow	Amur River, USSR	Levanidov (1954)
			6.0 - 8.0	most favorable level for entire development period of embryos and larvae at 4-8°C	N. Okhotsk, USSR	Lukina (1973)

Appendix Table D-1 (Continued).

Life Stage	Species	Parameter	Observed Values	Remarks	Location	Reference
Intragravel Development	Chum	Dissolved Oxygen, mg/l	3.0 - 4.0	lowest value in redds	Bira River, USSR	Disler (1951)
			0.72	critical value at 0 days		Wickett (1954)
			1.67	critical value at 5 days		
			1.14	critical value at 12 days		
			3.70	critical value at 85 days		
			0.4 - 1.4	50% lethal limit for incubating chum		Alderice (1958)
	All Species		7.0 or 90% sat.		Hatchery criteria	ADF & G (1983)
	Chum	pH	6.5	intragravel	Chena River	Kogl (1965)
			"slightly acidic"	intragravel	Amur River, USSR	Levanidov (1954)
			6.3 - 6.5	intragravel		Kobayashi (1968)
	All Species		5.0 - 9.0	Range		Doudoruff (1957)
			6.0 - 8.0	Preferred range		Bailey (1975)
			6.5 - 8.0	Hatchery criteria		ADF & G (1983)
Emergence and Downstream Migration	Chum	Water Temperature (°C)	3.0 - 5.5	emergence and out-migration	Delta River	Raymond (1981)
			5.0 - 7.0	range during peak of fry outmigration	Salcha River	Trasky (1974)
			6.7 - 13.3	preferred range for species		Bell (1973)
			8.0 - 10.0	preferred temp (over the range 5.2 - 19.0 °C)	Amur River, USSR	Levanidov (1954)
			15.0	survive		

Appendix Table D-1 (Continued).

Life Stage	Species	Parameter	Observed Values	Remarks	Location	Reference
Emergence and Downstream Migration	Chum	Water Temperature (°C)	4.5 - 5.5	outmigration	Bolshaia River, USSR	Semko (1954, cited by Sano, 1966)
			7.3 - 23.8	preferred range		Dill & Northcote (1970)
	Chinook		25.0 - 15.0	upper lethal limit and optimum		Bams (1967)
			7.4 - 25.1	preferred range		Dill & Northcote (1970)
	Pink		NA - 23.9	preferred range		Dill & Northcote (1970)
	Coho		6.4 - 25.0	preferred range		Dill & Northcote (1970)
	Sockeye		6.7 - 24.4	preferred range		Dill & Northcote (1970)

Appendix Table D-2. Literature review of salmon redd depths by species in Alaska and the Pacific Northwest.

Life Stage	Species	Redd Depth (cm)	Remarks	Location	References
Spawning	Chinook	greater than 35		Alaska	Morrow, J.E. (1980)
		30.5		Canada	Scott and Crossman (1973)
	Sockeye	25		Frazer River, B.C. Canada	Cooper (1965)
		up to 40		Alaska	Morrow, J.E. (1980)
		5.1 - 10.2	Kokanee	Canada	Scott and Crossman (1973)
		20 - 25		Iliamna Lake, Alaska	Olsen, J.C. (1968)
	Pink	17.8 - 25.4		Southeast, Alaska (Hollis area)	McNeil (1962)
		7.62 - 38.1		Southeast, Alaska (Hollis area)	McNeil and Ahnell (1964)
		25		Frazer Rivdr, B.C. Canada	Cooper (1965)
		up to 45.7		Alaska	Morrow, J.E. (1980)
		up to 45.7		Alaska/Canada	Krueger, S. (1981)
		up to 45.7		Canada	Scott and Crossman (1973)
	Chum	15 - 30		Alaska	Bakkala (1970)
		8 - 43			Hale (1981)
		20 - 40		Noatak River, Kotzebue Sound, Alaska	Merritt, M.F. and J.A. Raymond (1982)

Appendix Table D-2. Continued.

Life Stage	Species	Redd Depth (cm)	Remarks	Location	References
Spawning	Chum	20 - 30		Susitna River, Alaska	Roth, Kent (pers. comm.) (1984)
		up to 40		Alaska	Morrow, J.E. (1980)
		40.6		Washington	Scott and Crossman (1973)
	Coho	20 - 25		Alaska	Morrow, J.E. (1980)
		25		Oregon coastal streams	Ringler N.H. and J.D. Hall (1975)

APPENDIX E

WINTER WATER QUALITY DATA.

Appendix Table E-1. Intragravel and surface water quality data collected at standpipe locations at Bushrod Slough (RM 117.9L), Curry Slough (RM 119.7R) and Slough 10 (RM 139.8L) from November 1984 to May 1985, Susitina River, Alaska.

				Intragravel Water					Surface Water				
		Sampling			DO					DO			
Site (River Mile)	Standpipe No.	Date (y/m/d)	Time	Temp. (C)	(mg/l)	%Sat.	pH	Conductivity (umhos/cm)	Temp. (C)	(mg/l)	%Sat.	pH	Conductivity (umhos/cm)
Bushrod Slough (117.9L)	001	841129	1418	—	—	—	—	—	—	—	—	—	—
	002	841129	1418	4.8	7.8	65	—	68	4.5	7.5	62	—	64
	003	841129	1418	3.0	7.8	62	—	85	3.1	6.4	51	—	103
	004	841129	1418	4.0	6.7	55	—	77	3.0	6.6	52	—	119
	005	841129	1418	2.5	6.8	53	—	5	2.5	6.6	51	—	7
	006	841129	1418	3.5	6.1	49	—	139	2.5	6.9	53	—	107
	007	841129	1418	2.5	6.6	52	—	160	3.5	6.1	49	—	100
	008	841129	1418	3.1	7.6	60	—	72	1.8	6.5	50	—	56
	009	841129	1418	2.8	7.6	60	—	69	0.5	7.6	50	—	94
	010	841129	1418	2.7	7.6	59	—	12	0.8	7.3	54	—	9
	011	841129	1418	—	—	—	—	—	—	—	—	—	—
	012	841129	1418	—	—	—	—	—	0.1	7.7	52	—	53
	013	841129	1418	—	—	—	—	—	0.1	7.2	52	—	57
	014	841129	1418	—	—	—	—	—	0.1	7.2	52	—	63
	015	841129	1418	—	—	—	—	—	0.1	8.9	64	—	93
	001	850108	1420	—	—	—	—	—	2.0	10.4	80	6.7	68
	002	850108	1420	4.0	10.4	87	8.1	63	3.7	9.6	77	8.1	64
	003	850108	1420	2.0	9.2	71	7.4	89	0.1	11.9	87	6.7	80
	004	850108	1420	3.2	9.8	80	7.7	65	2.1	10.9	84	7.8	80
	005	850108	1420	2.8	9.8	77	6.8	89	1.9	10.6	81	6.8	89
	006	850108	1420	3.0	8.4	67	6.7	124	2.1	11.2	81	6.6	80
	007	850108	1420	2.5	10.4	81	6.7	84	2.5	11.6	91	6.8	67
	008	850108	1420	2.1	10.4	81	—	71	0.5	10.8	79	—	55
	009	850108	1420	2.5	10.0	78	—	68	0.5	10.6	79	—	62
	010	850108	1420	1.5	10.9	85	—	69	0.8	11.8	88	—	74
	011	850108	1420	—	—	—	—	—	1.9	12.0	92	—	68
	012	850108	1420	—	—	—	—	—	—	—	—	—	—
	013	850108	1420	—	—	—	—	—	—	—	—	—	—
	014	850108	1420	2.2	9.7	76	—	57	1.8	10.4	80	—	63
	015	850108	1420	—	—	—	—	—	—	—	—	—	—
	001	850130	1300	—	—	—	—	—	—	—	—	—	—
	002	850130	1300	3.5	9.1	73	6.7	76	3.3	8.8	71	7.0	68
	003	850130	1300	2.1	9.5	73	6.9	98	2.2	9.9	77	6.9	89
	004	850130	1300	3.2	8.8	70	7.2	72	2.0	10.4	80	7.2	98
	005	850130	1300	2.5	8.7	69	7.0	114	2.0	10.5	80	7.1	98
	006	850130	1300	3.1	7.6	60	7.1	129	2.1	10.5	81	7.2	107
	007	850130	1300	2.5	9.3	73	7.1	102	1.4	10.9	82	7.2	95
	008	850130	1300	2.8	9.3	74	7.1	61	0.9	10.4	77	7.1	83
	009	850130	1300	2.8	9.4	74	7.3	69	1.2	10.5	79	7.3	55
	010	850130	1300	2.6	9.4	70	7.4	70	1.0	10.2	76	7.5	74

Appendix Table E-1. (Continued).

Site (River mile)	Standpipe No.	Sampling Date (y/m/d)	Sampling Time	Intragravel Water Temp. (C)	Intragravel Water DO (mg/l)	Intragravel Water DO %Sat.	Intragravel Water pH	Intragravel Water Conductivity (umhos/cm)	Surface Water Temp. (C)	Surface Water DO (mg/l)	Surface Water DO %Sat.	Surface Water pH	Surface Water Conductivity (umhos/cm)
Bushrod Slough (continued)	011	850130	1300	3.0	9.6	76	7.4	72	2.2	11.2	86	7.4	71
	012	850130	1300	—	—	—	—	—	—	—	—	—	—
	013	850130	1300	—	—	—	—	—	—	—	—	—	—
	014	850130	1300	2.2	8.6	62	7.1	53	1.0	9.4	70	7.4	74
	015	850130	1300	—	—	—	—	—	—	—	—	—	—
Curry Slough (119.7R)	001	841128	1300	—	—	—	—	—	0.8	11.8	87	—	54
	002	841128	1300	—	—	—	—	—	0.9	11.8	87	—	56
	003	841128	1300	—	—	—	—	—	0.5	12.9	94	—	56
	004	841128	1300	—	—	—	—	—	0.1	12.4	89	—	130
	005	841128	1300	1.2	7.4	55	—	92	2.1	11.5	88	—	62
	006	841128	1300	—	—	—	—	—	0.1	14.8	108	—	174
	007	841128	1300	2.2	3.6	28	—	80	2.8	11.7	91	—	61
	008	841128	1300	—	—	—	—	—	—	—	—	—	—
	009	841128	1300	2.2	0.3	6	—	133	2.2	11.8	90	—	53
	010	841128	1300	—	—	—	—	—	2.5	12.4	95	—	61
	011	841128	1300	2.5	12.0	92	—	61	2.0	11.3	86	—	71
	012	841128	1300	3.8	6.4	52	—	82	3.5	10.8	86	—	51
	013	841128	1300	3.6	11.0	88	—	64	4.0	12.3	100	—	58
	014	841128	1300	4.1	11.7	94	—	63	4.5	11.6	95	—	53
	015	841128	1300	2.8	7.5	58	—	61	3.0	12.6	98	—	53
	001	850109	—	1.3	8.3	63	6.5	77	1.3	12.0	89	6.6	58
	002	850109	—	1.5	7.3	55	—	69	1.3	12.0	89	—	58
	003	850109	—	—	—	—	—	—	—	—	—	—	—
	004	850109	—	1.7	9.3	71	—	59	1.2	10.2	76	—	59
	005	850109	—	—	—	—	—	—	—	—	—	—	—
	006	850109	—	—	—	—	—	—	—	—	—	—	—
	007	850109	—	2.2	2.3	18	—	92	2.0	10.4	79	—	57
	008	850109	—	1.5	7.6	58	—	42	0.2	9.2	67	—	53
	009	850109	—	1.6	0.7	8	—	112	1.0	8.8	65	—	41
	010	850109	—	—	—	—	—	—	—	—	—	—	—
	011	850109	—	3.0	9.3	74	—	55	1.5	11.0	82	—	58
	012	850109	—	3.5	8.8	71	—	54	2.0	10.3	80	—	50
	013	850109	—	3.3	8.7	71	—	61	2.8	10.4	81	—	56
	014	850109	—	3.9	9.8	79	—	62	4.0	10.5	85	—	50
	015	850109	—	3.2	5.7	46	—	55	1.5	11.2	83	—	56
	001	850129	1530	1.2	14.2	104	5.0	64	1.2	13.8	101	5.0	64
	002	850129	1530	1.1	14.3	106	5.1	74	1.2	13.7	100	5.1	64
	003	850129	1530	—	—	—	—	—	—	—	—	—	—
	004	850129	1530	0.8	12.9	95	5.0	56	0.1	12.5	89	5.0	42
	005	850129	1530	2.1	3.2	6	4.9	89	1.5	11.2	84	5.0	64
	006	850129	1530	—	—	—	—	—	—	—	—	—	—
	007	850129	1530	2.2	1.3	12	5.0	89	2.2	11.6	88	5.0	32
	008	850129	1530	0.9	10.6	78	5.0	41	0.5	11.5	83	6.8	47

Appendix Table E-1. (Continued).

Site (River mile)	Standpipe No.	Sampling Date (y/m/d)	Sampling Time	Intragravel Water Temp. (C)	Intragravel Water DO (mg/l)	Intragravel Water DO %Sat.	Intragravel Water pH	Intragravel Water Conductivity (umhos/cm)	Surface Water Temp. (C)	Surface Water DO (mg/l)	Surface Water DO %Sat.	Surface Water pH	Surface Water Conductivity (umhos/cm)
Curry Slough (continued)	009	850129	1530	1.8	2.6	5	6.1	75	0.8	10.9	80	5.3	56
	010	850129	1530	—	—	—	—	—	—	—	—	—	—
	011	850129	1530	2.1	10.1	77	6.7	53	1.4	11.9	88	6.7	55
	012	850129	1530	3.5	9.5	76	6.6	51	2.3	10.8	83	6.9	53
	013	850129	1530	3.0	10.3	80	6.8	52	3.1	11.9	93	6.6	48
	014	850129	1530	4.0	10.4	83	6.7	58	3.1	11.9	93	6.6	52
	015	850129	1530	2.1	11.7	89	6.2	53	2.1	12.6	95	6.3	46
Slough 10 (133.8L)	001	841114	1436	—	—	—	—	—	—	—	—	—	—
	002	841114	1436	—	—	—	—	—	—	—	—	—	—
	003	841114	1436	—	—	—	—	—	—	—	—	—	—
	004	841114	1436	—	—	—	—	—	—	—	—	—	—
	005	841114	1436	—	—	—	—	—	—	—	—	—	—
	006	841114	1436	—	—	—	—	—	—	—	—	—	—
	007	841114	1436	—	—	—	—	—	—	—	—	—	—
	008	841114	1436	—	—	—	—	—	—	—	—	—	—
	009	841114	1436	—	—	—	—	—	—	—	—	—	—
	010	841114	1436	—	—	—	—	—	—	—	—	—	—
	011	841114	1436	—	—	—	—	—	—	—	—	—	—
	012	841114	1436	—	—	—	—	—	2.5	7.5	59	—	56
	013	841114	1436	1.9	7.8	60	—	104	1.9	7.6	59	6.4	93
	014	841114	1436	2.9	5.8	47	6.1	85	3.1	6.3	51	5.9	101
	015	841114	1436	3.1	6.0	48	5.4	103	2.0	7.0	59	5.8	98
	001	841127	1216	2.0	0.6	7	—	230	1.8	12.0	92	—	162
	002	841127	1216	1.5	0.8	9	—	165	1.8	12.0	92	—	153
	003	841127	1216	3.0	7.5	60	—	179	1.5	12.5	95	—	185
	004	841127	1216	1.2	9.0	68	—	169	1.8	12.4	94	—	162
	005	841127	1216	1.2	9.4	71	—	138	1.5	12.2	94	—	172
	006	841127	1216	1.8	1.0	11	—	183	2.0	11.7	90	—	143
	007	841127	1216	2.1	6.2	48	—	158	1.8	10.5	81	—	142
	008	841127	1216	2.0	4.6	36	—	169	2.2	11.0	86	—	142
	009	841127	1216	2.2	0.6	9	—	181	2.2	10.5	82	—	138
	010	841127	1216	2.5	0.3	8	—	179	2.5	10.4	82	—	149
	011	841127	1216	3.0	8.7	63	—	122	2.2	11.0	86	—	122
	012	841127	1216	3.2	8.1	65	—	134	2.5	8.8	70	—	123
	013	841127	1216	2.1	9.1	71	—	121	2.8	9.8	77	—	123
	014	841127	1216	3.5	6.9	56	—	85	2.5	7.3	58	—	119
	015	841127	1216	3.0	7.0	56	—	107	2.0	8.3	64	—	134
	001	841211	1300	1.1	1.3	11	—	230	1.0	9.0	68	—	162
	002	841211	1300	1.4	1.3	11	—	182	1.1	8.6	65	—	156

Appendix Table E-1. (Continued).

Site (River mile)	Standpipe No.	Sampling Date (y/m/d)	Sampling Time	Intragravel Water Temp. (C)	Intragravel Water DO (mg/l)	Intragravel Water DO %Sat.	Intragravel Water pH	Intragravel Water Conductivity (umhos/cm)	Surface Water Temp. (C)	Surface Water DO (mg/l)	Surface Water DO %Sat.	Surface Water pH	Surface Water Conductivity (umhos/cm)
Slough 10 (continued)	003	841211	1300	—	—	—	—	—	1.0	10.2	77	—	199
	004	841211	1300	—	—	—	—	—	1.1	9.8	74	—	193
	005	841211	1300	1.8	6.7	52	—	180	1.1	8.6	65	—	184
	006	841211	1300	1.9	1.2	11	—	188	1.3	8.1	62	—	146
	007	841211	1300	1.9	5.6	44	—	158	1.5	8.1	62	—	178
	008	841211	1300	2.0	4.4	35	—	205	1.9	7.8	60	—	170
	009	841211	1300	2.1	2.5	20	—	169	2.0	8.5	66	—	196
	010	841211	1300	2.1	0.6	7	—	174	2.1	7.7	60	—	165
	011	841211	1300	—	—	—	—	—	1.9	10.5	80	—	147
	012	841211	1300	2.9	6.7	53	—	130	2.3	7.3	58	—	106
	013	841211	1300	3.1	7.1	57	—	115	2.4	7.5	59	—	120
	014	841211	1300	3.2	5.8	47	—	94	2.1	6.2	49	—	108
	015	841211	1300	2.9	5.8	46	—	100	2.0	7.1	56	—	87
	001	850110	1300	2.2	1.1	8	7.2	158	2.5	8.5	67	7.0	137
	002	850110	1300	2.0	0.5	7	—	169	2.5	8.6	67	6.1	139
	003	850110	1300	2.8	6.2	49	—	155	2.2	9.2	72	—	163
	004	850110	1300	2.5	6.6	52	—	154	2.0	8.6	67	—	164
	005	850110	1300	2.9	6.9	55	—	173	2.0	8.7	67	—	166
	006	850110	1300	2.8	0.7	9	—	177	2.8	8.6	69	—	139
	007	850110	1300	2.8	5.3	42	—	160	2.8	8.3	66	—	135
	008	850110	1300	2.5	5.4	43	—	161	2.8	8.1	65	—	137
	009	850110	1300	2.9	0.4	7	—	142	2.9	7.8	62	—	133
	010	850110	1300	2.8	0.3	6	—	151	2.8	7.8	62	—	128
	011	850110	1300	3.0	6.3	50	—	150	2.8	8.2	71	—	122
	012	850110	1300	3.0	6.2	49	—	138	3.0	6.8	55	—	121
	013	850110	1300	3.2	6.9	56	—	134	2.8	7.8	67	—	134
	014	850110	1300	2.8	5.7	45	—	104	2.8	6.0	48	—	125
	015	850110	1300	2.0	5.7	45	—	119	2.5	7.0	55	—	133
	001	850201	1130	2.2	1.4	13	6.9	221	1.8	10.2	78	6.8	162
	002	850201	1130	2.2	1.2	12	7.1	213	2.0	9.8	76	7.1	161
	003	850201	1130	2.8	6.6	53	7.5	174	1.8	10.7	82	7.5	189
	004	850201	1130	1.8	6.7	52	7.4	183	1.8	10.2	80	7.5	180
	005	850201	1130	—	—	—	—	—	1.6	11.1	85	7.4	181
	006	850201	1130	2.0	1.2	11	7.2	143	2.0	10.0	78	7.5	143
	007	850201	1130	2.5	6.1	48	7.2	193	2.0	9.6	75	7.3	143
	008	850201	1130	2.2	7.4	58	7.3	174	1.8	9.6	74	7.3	144
	009	850201	1130	2.2	0.5	8	7.4	195	2.1	8.9	70	7.3	151
	010	850201	1130	2.4	0.6	8	7.2	194	2.2	8.8	70	7.4	151
	011	850201	1130	2.5	7.4	58	7.2	114	2.0	9.5	74	7.3	143
	012	850201	1130	2.2	7.0	55	7.0	142	2.2	8.1	64	7.2	124

Appendix Table E-1. (Continued).

Site (River mile)	Standpipe No.	Sampling Date (y/m/d)	Sampling Time	Intragravel Water Temp. (C)	Intragravel Water DO (mg/l)	Intragravel Water DO %Sat.	Intragravel Water pH	Intragravel Water Conductivity (umhos/cm)	Surface Water Temp. (C)	Surface Water DO (mg/l)	Surface Water DO %Sat.	Surface Water pH	Surface Water Conductivity (umhos/cm)
Slough 10 (continued)	013	850201	1130	2.8	7.9	63	6.8	130	2.8	9.1	72	6.9	156
	014	850201	1130	2.6	6.5	52	6.8	126	2.0	7.1	55	6.9	139
	015	850201	1130	2.8	6.6	53	6.7	130	2.0	7.4	58	6.8	143
	001	850402	1240	2.0	1.3	11	7.6	116	3.0	9.0	72	7.7	95
	002	850402	1240	2.0	1.4	12	7.5	111	2.8	9.2	73	7.6	90
	003	850402	1240	2.5	6.3	50	7.5	105	2.0	9.9	73	7.5	98
	004	850402	1240	1.3	7.5	57	7.6	106	1.8	9.8	71	7.6	117
	005	850402	1240	2.6	6.2	50	7.6	154	2.1	8.6	68	7.6	151
	006	850402	1240	—	—	—	—	—	3.2	8.9	72	7.6	129
	007	850402	1240	2.5	9.6	76	7.5	158	3.1	8.8	71	7.6	124
	008	850402	1240	2.2	6.3	50	7.6	124	3.1	8.1	65	7.7	125
	009	850402	1240	2.5	1.2	11	7.8	132	4.2	7.8	65	7.8	124
	010	850402	1240	2.5	0.6	10	7.5	114	3.0	7.7	62	7.8	117
	011	850402	1240	2.6	6.8	54	7.4	119	3.1	8.7	70	7.5	103
	012	850402	1240	2.9	5.9	47	7.6	112	2.8	7.9	63	7.6	104
	013	850402	1240	2.9	6.8	54	7.4	107	2.5	7.6	61	7.5	114
	014	850402	1240	2.8	5.8	47	7.3	96	2.6	6.4	52	7.4	101
	015	850402	1240	2.5	5.3	42	7.3	102	2.0	7.9	62	7.4	98

APPENDIX F

FREEZE CORE SUBSTRATE DATA.

Appendix Table F-1. Substrate composition of samples collected using a freeze core sampler at three selected sloughs: March 1985 to April 1985, Susitna River, Alaska.

Site (River mile)	Area	Sampling Date (y/m/d)	Total Dry wt. (g)	>127 Dry wt. (g)	>127 % Tot.	127-76.2 Dry wt. (g)	127-76.2 % Tot.	76.2-25.4 Dry wt. (g)	76.2-25.4 % Tot.	25.4-2.0 Dry wt. (g)	25.4-2.0 % Tot.	2.0-0.84 Dry wt. (g)	2.0-0.84 % Tot.	0.84-0.5 Dry wt. (g)	0.84-0.5 % Tot.	0.5-0.062 Dry wt. (g)	0.5-0.062 % Tot.	<0.062 Dry wt. (g)	<0.062 % Tot.
BUSHROD SLOUGH (117.9L)	1A	850410	10300	0	0	4055	39	4886	47	530	5	262	3	92	1	387	4	88	1
	2A	850410	12522	3959	32	3351	27	2147	17	2242	18	253	2	73	1	415	3	82	1
	3A	850410	5555	0	0	0	0	2207	40	2363	43	319	6	84	2	498	9	84	2
	4A	850410	2460	0	0	0	0	334	14	1123	46	109	4	60	2	743	30	91	4
	5A	850410	9382	0	0	3626	39	3598	38	1525	16	223	2	104	1	238	3	68	1
	1B	850410	9371	0	0	3284	35	2929	31	2217	24	250	3	134	1	443	5	114	1
	2B	850410	4308	0	0	0	0	933	22	1321	31	164	4	237	6	1550	36	103	2
	3B	850410	4033	0	0	0	0	2221	55	1375	34	205	5	49	1	152	4	31	1
	4B	850410	3095	0	0	0	0	279	9	2282	74	213	7	118	4	184	6	19	1
	5B	850410	10921	0	0	5823	53	3124	29	1364	12	200	2	128	1	253	2	29	0
CURRY SLOUGH (119.7R)	3A	850328	9926	0	0	2974	30	3799	38	1805	18	148	1	53	1	710	7	437	4
	5A	850328	2273	0	0	1287	57	169	7	70	3	4	0	2	0	456	20	285	13
	3B	850328	9355	0	0	3813	41	2856	31	1769	19	161	2	171	2	517	6	68	1
	5B	850328	2775	0	0	0	0	1432	52	846	30	48	2	14	1	350	13	85	3
SLOUGH 10 (133.8L)	1A	850327	449	0	0	0	0	0	0	1	0	2	0	5	1	213	47	228	51
	2A	850327	214	0	0	0	0	0	0	0	0	0	0	1	0	105	49	108	50
	3A	850327	598	0	0	0	0	0	0	2	0	5	1	26	4	510	85	55	9
	4A	850327	367	0	0	0	0	0	0	16	4	2	1	5	1	242	66	102	28
	5A	850327	7689	6750	88	0	0	359	5	446	6	30	0	15	0	89	1	0	0
	1B	850327	114	0	0	0	0	0	0	0	0	1	1	0	0	34	30	79	69
	2B	850327	42	0	0	0	0	0	0	8	19	2	5	1	2	13	31	18	43
	3B	850327	158	0	0	0	0	0	0	5	3	1	1	2	1	82	52	68	43
	4B	850327	156	0	0	0	0	0	0	2	1	2	1	3	2	87	56	62	40
	5B	850327	859	0	0	0	0	306	36	357	42	61	7	28	3	98	11	9	1

Substrate size classes (mm)