SUSITNA
HYDROELECTRIC PROJECT

FEDERAL ENERGY REGULATORY COMMISSION
PROJECT No. 7114

# ASSESSMENT OF ACCESS BY SPAWNING SALMON INTO TRIBUTARIES OF THE LOWER SUSITNA RIVER


PREPARED BY

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UNDER CONTRACT TO

HARZA-EBASCO
SUSITNA JOINT VENTURE


FINAL REPORT


JUNE 1985

DOCUMENT No. 2775


ALASKA POWER AUTHORITY

Document No. 2775
Susitna File No. 4.2.2.1

# SUSITNA HYDROELECTRIC PROJECT

# ASSESSMENT OF ACCESS BY SPAWNING SALMON INTO TRIBUTARIES OF THE LOWER SUSITNA RIVER

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Under Contract To
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Prepared for
Alaska Power Authority

Final Report
June 1985

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## ACKNOWLEDGEMENTS

This study is one of the environmental studies pertaining to the proposed Susitna Hydroelectric Project. Funding was provided by the Alaska Power Authority, and work was conducted under contract to Harza-Ebasco Susitna Joint Venture.

Information regarding the timing of adult salmon migration and the use of lower river tributaries by spawning salmon was obtained from Alaska Department of Fish and Game SuHydro reports summarizing their 1984 and 1985 Adult Anadromous Field Studies. The initial airphoto evaluation of access into the tributaries was done by Carl Schoch. Field data were collected by Stephen Bredthauer, Chip Green and Bill Ashton. Debbie Stephens assisted in data analysis and figure preparation. Stephen Bredthauer and Carl Schoch contributed many useful editorial comments. Orlando Paraoan and Mark Cordery drafted the figures and Barb Estus typed the report.

## 1.0 INTRODUCTION

The proposed Susitna Hydroelectric Project will alter the natural flow regime of the Susitna River by increasing winter flows and decreasing summer flows. Previous studies have evaluated the effects of the proposed Susitna project on the morphologic stability and fish access conditions at tributary mouths and side sloughs within the Talkeetna to Devil Canyon reach of the Susitna River (R&M, 1982; Trihey, 1983; and Sautner et al., 1984).

This report provides an assessment of the potential effects of the with-project streamflow downstream of the Chulitna-Susitna-Talkeetna confluence with regard to: 1) the change in backwater zones at tributary mouths that may be used by adult salmon as holding areas; 2) access by adult salmon into tributaries; and 3) morphologic stability of the tributary mouths. The assessment is based on visual evaluation of aerial photographs, comparisons between anticipated lower river with-project discharges and available U.S.G.S. streamflow data, observations from helicopter overflights and on-site field measurements made during a period of low streamflows.

Section 2 describes the natural flow regime of the lower Susitna River and its tributaries, the timing of upstream salmon migration and a general introduction to concerns with-project streamflow might have on adult salmon access into lower river tributaries, the availability of holding areas and tributary mouth stability. Within this report, the terms backwater zone and holding area are used interchangeably. Section 3 describes the methods used in the analysis, and section 4 summarizes the results of the analysis. Exhibit A presents a location map and aerial photos of each tributary evaluated in this study, a brief description of adult salmon use of each tributary, and an assessment of potential with-project effects at each tributary mouth.





## 2.0 OVERVIEW OF EXISTING SYSTEM

### 2.1 Basin Overview

The Susitna River drainage basin is located in the southcentral region of Alaska. It is bordered on the west and north by the Alaska Range, on the east by the Copper River lowlands and the Talkeetna mountains, and on the south by Cook Inlet (Figure 2.1). The basin covers an area of 19,600 square miles and lies within two climatic zones . The upper basin (that portion upstream of Devil Canyon) is in the continental zone, with the lower basin in the transitional zone. Continental climate is characterized by large diurnal and annual temperature variations, low precipitation, low humidity and mean annual temperatures in the range of 15-25° F. Transitional climate is characterized by diurnal and annual temperature variations moderated by maritime influences, higher precipitation than continental climatic zones and mean annual temperatures in the range of 25-35°F (Hartman and Johnson, 1978). The mountainous areas of both climatic zones typically have higher precipitation values than valley areas.

### 2.2 Fish Resources

Fish resources of the Susitna River contribute significantly to the Cook Inlet commercial salmon harvest and to sport fishing opportunities for residents of the Matanuska-Susitna Borough and Anchorage (Barrett et al, 1984). Five species of Pacific salmon (chinook, chum, sockeye, pink and coho) are important to the commercial and sport fisheries.

The primary salmon spawning areas within the lower Susitna Basin appear to be the clearwater tributaries such as Willow Creek and the Deshka River (Barrett et al, 1984). Timing of the adult salmon migration has varied by species over the past four years, as indicated in Figures 2.2 through 2.5. Typically, chinook reach Sunshine station in early June, followed by sockeye, pink, chum and coho salmon in July and August. The upstream

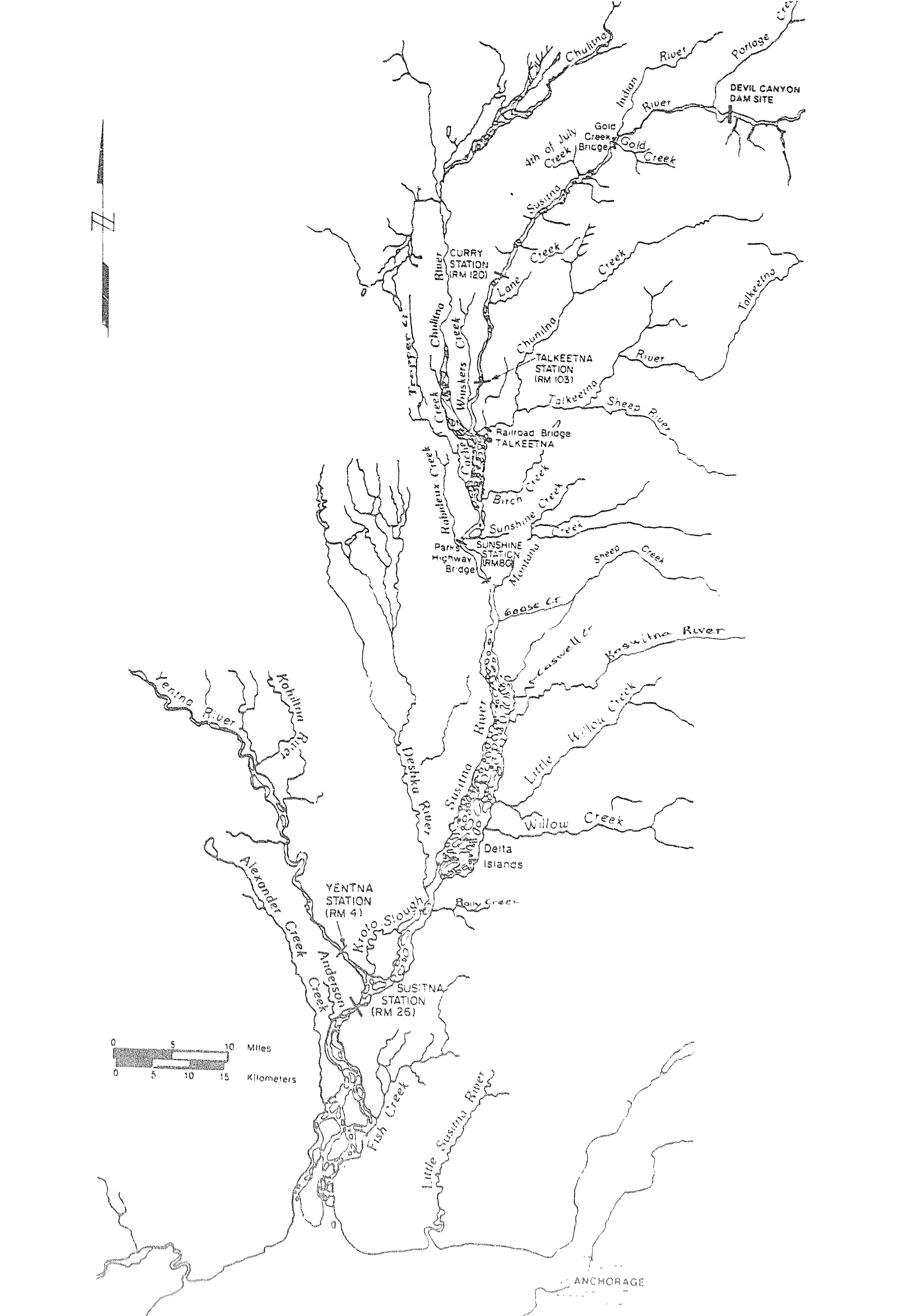


FIGURE 2.1

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SUSITNA RIVER AND MAJOR TRIBUTARIES FROM MOUTH TO DEVIL CANYON

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migration by adult salmon appears to be retarded by mainstem flows above 80,000 cfs at Sunshine (Barrett et al. 1984 and 1985).

Low velocity backwater areas near tributary mouths are often used as holding areas by adult salmon during upstream migration. Pink and chum salmon have been observed spawning in the interface reach of some of the lower river tributaries (Barrett et al, 1985). Tributaries in the lower Susitna River are used for spawning primarily by pink, coho and chum salmon, with some tributaries having runs of chinook and sockeye (Appendix 7, Barrett et al. 1985). During 1984 the greatest numbers of fish were observed in the tributary mouths from late July through August (Appendix 7, Barrett et al, 1985).

## 2.3 Natural Flow Regime and Salmon Migration

### 2.3.1 Mainstem Susitna River

The Talkeetna to Devil Canyon reach of the Susitna River alternates between a single channel and split channel river. At its confluence with the Chulitna River the channel pattern becomes extensively braided due to a reduction in channel gradient and the increased sediment load from the Chulitna River. At the U.S.G.S. Sunshine gage the percentages of annual flow contribution are: the Susitna River 41 percent, the Chulitna River 36 percent, the Talkeetna River 16 percent, and minor tributaries between the three river confluence and the gage 7 percent (Table 2.1). The Sunshine gage (U.S.G.S. 15292780) is approximately 14 miles downstream from the three rivers confluence. During the summer, the Susitna River's average contribution ranges from a high of 49 percent in May to a low of 39 percent in July and August (Table 2.1).

The mean daily flows for 1981 through 1984 for the Susitna River at the Sunshine gage, the Deshka River and Willow Creek are presented in Figures 2.2 through 2.5, along with the timing of salmon





TABLE 2.1

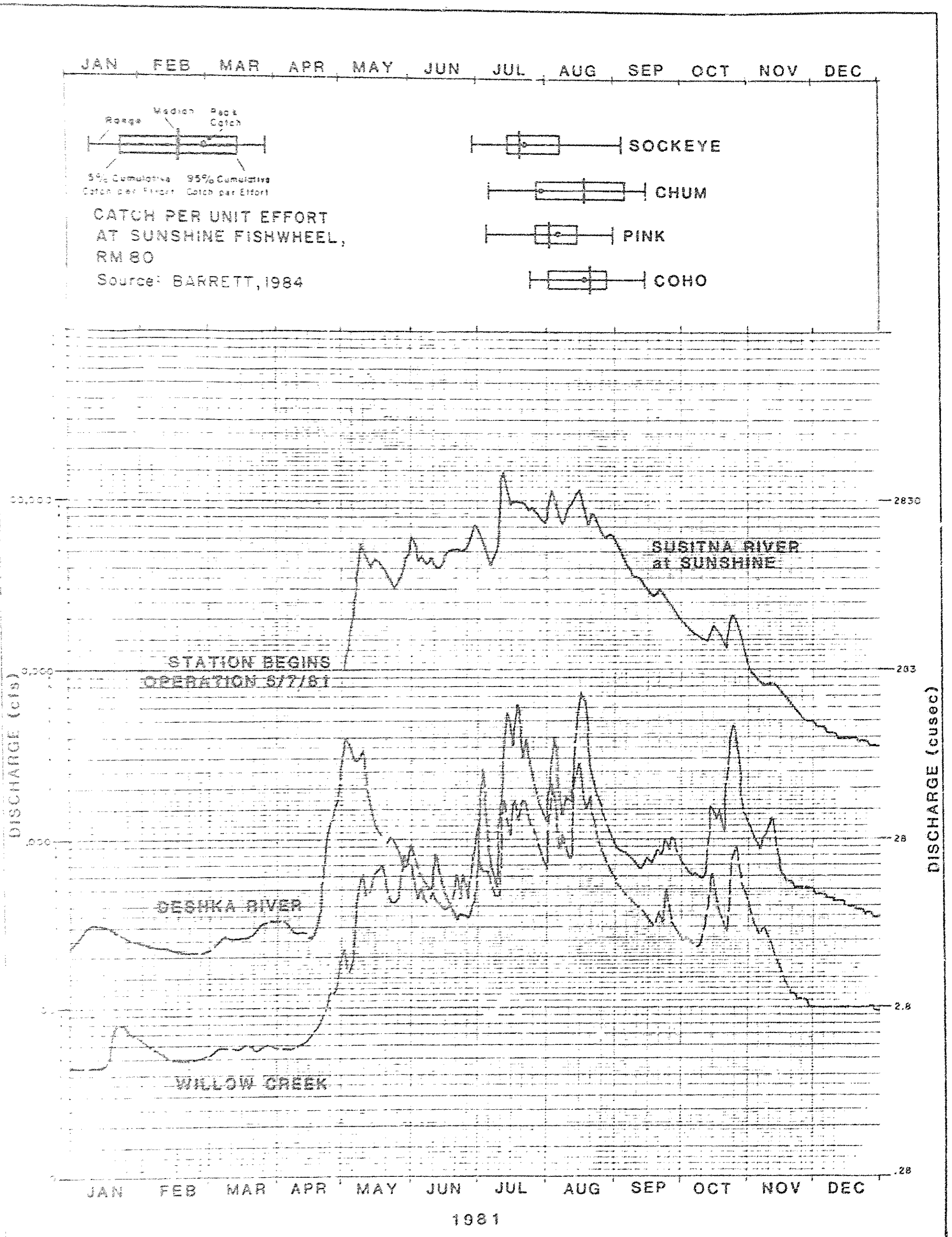
RELATIVE CONTRIBUTION OF FLOWS IN THE LOWER SUSITNA RIVER 1981-1984

| | Flow Contribution by (cfs) (1) | | | | Percent Flow at Sunshine by | | | |
|---|---|---|---|---|---|---|---|---|
| | Chulitna R. nr Talkeetna | Talkeetna R. nr Talkeetna | Susitna R. at Gold Creek | Susitna R. at Sunshine | Chulitna | Talkeetna | Susitna | Other (2) |
| October | 6320 | 3000 | 7550 | 18000 | 35% | 17% | 42% | 6% |
| November | 2560 | 1140 | 3020 | 7200 | 36% | 17% | 42% | 5% |
| December | 1820 | 857 | 2160 | 5070 | 35% | 17% | 43% | 4% |
| January | 1550 | 725 | 2000 | 4540 | 34% | 16% | 44% | 6% |
| February | 1140 | 558 | 1820 | 4160 | 27% | 13% | 44% | 16% |
| March | 1030 | 483 | 1650 | 3620 | 29% | 13% | 45% | 13% |
| April | 1230 | 568 | 1830 | 4180 | 29% | 14% | 44% | 13% |
| May | 8110 | 4100 | 14600 | 30000 | 27% | 14% | 49% | 10% |
| June | 19600 | 9470 | 24200 | 57800 | 34% | 16% | 42% | 8% |
| July | 250 | 11000 | 25700 | 65800 | 38% | 17% | 39% | 4% |
| August | 24800 | 10100 | 24500 | 62500 | 40% | 16% | 39% | 5% |
| September | 12800 | 5400 | 13600 | 33800 | 38% | 16% | 40% | 6% |
| Annual | 8830 | 3960 | 10200 | 24700 | 36% | 16% | 41% | 7% |

(1) Discharge data from U.S.G.S. records up to September, 1984.

Chulitna R. near Talkeetna USGS No. 15292400
Talkeetna R. near Talkeetna USGS No. 15292700
Susitna R. at Gold Creek USGS No. 15292000
Susitna R. at Sunshine USGS No. 15292780

(2) Includes contributing area between Chulitna-Talkeetna-Susitna Confluence and Sunshine.




DISCHARGE DATA FROM USGS (1982, 1983)

FIGURE 2.2

SALMON MIGRATION TIMING AT SUNSHINE AND DISCHARGE FOR SUSITNA RIVER AND SELECTED TRIBUTARIES

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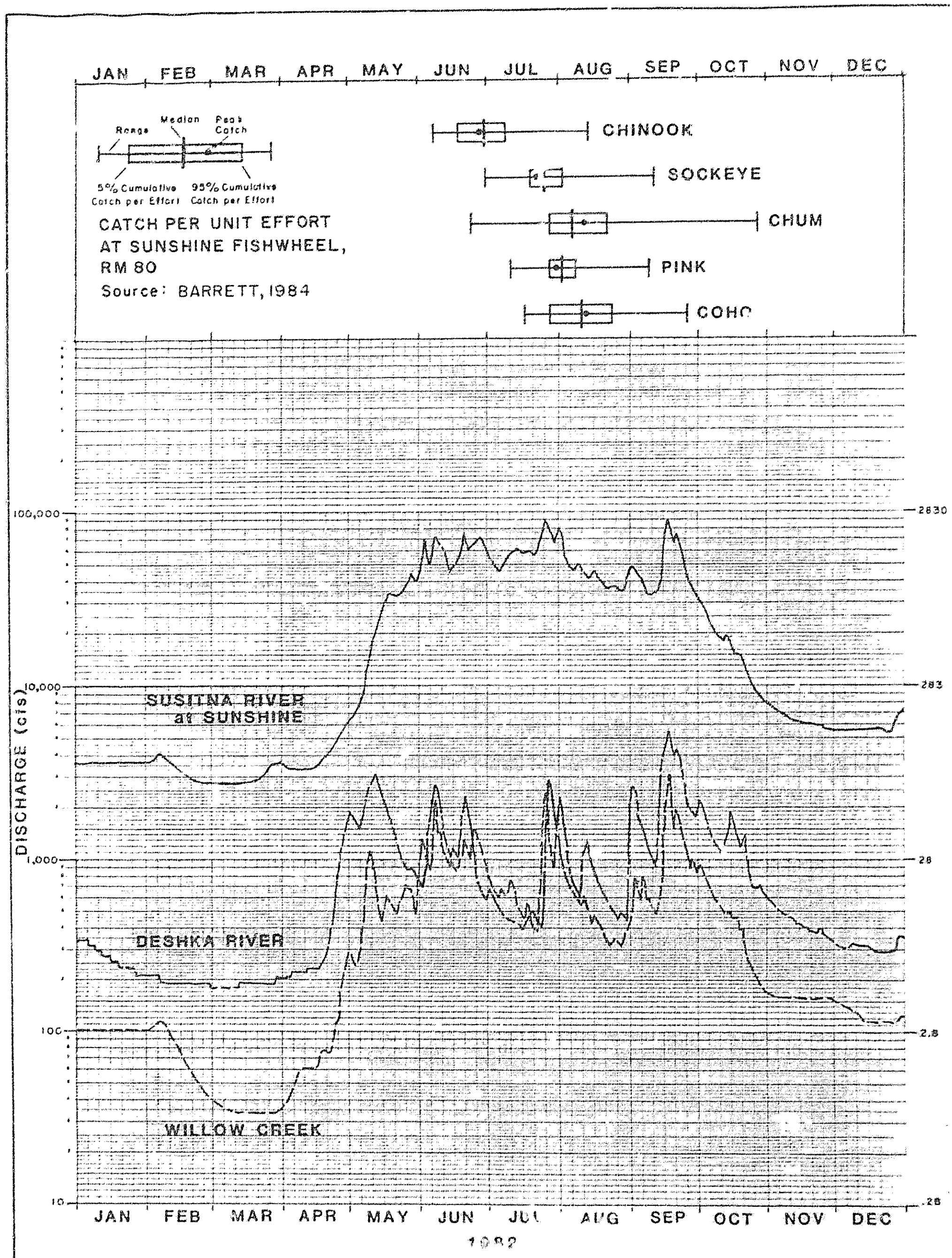


DISCHARGE DATA FROM USGS (1983, 198

FIGURE 2.3

SALMON MIGRAT[illegible] TIMING AT SUNSHINE A[illegible] DISCHARGE FOR SUSITNA RIVE[illegible] SELECTED TRIB[illegible]ARIES

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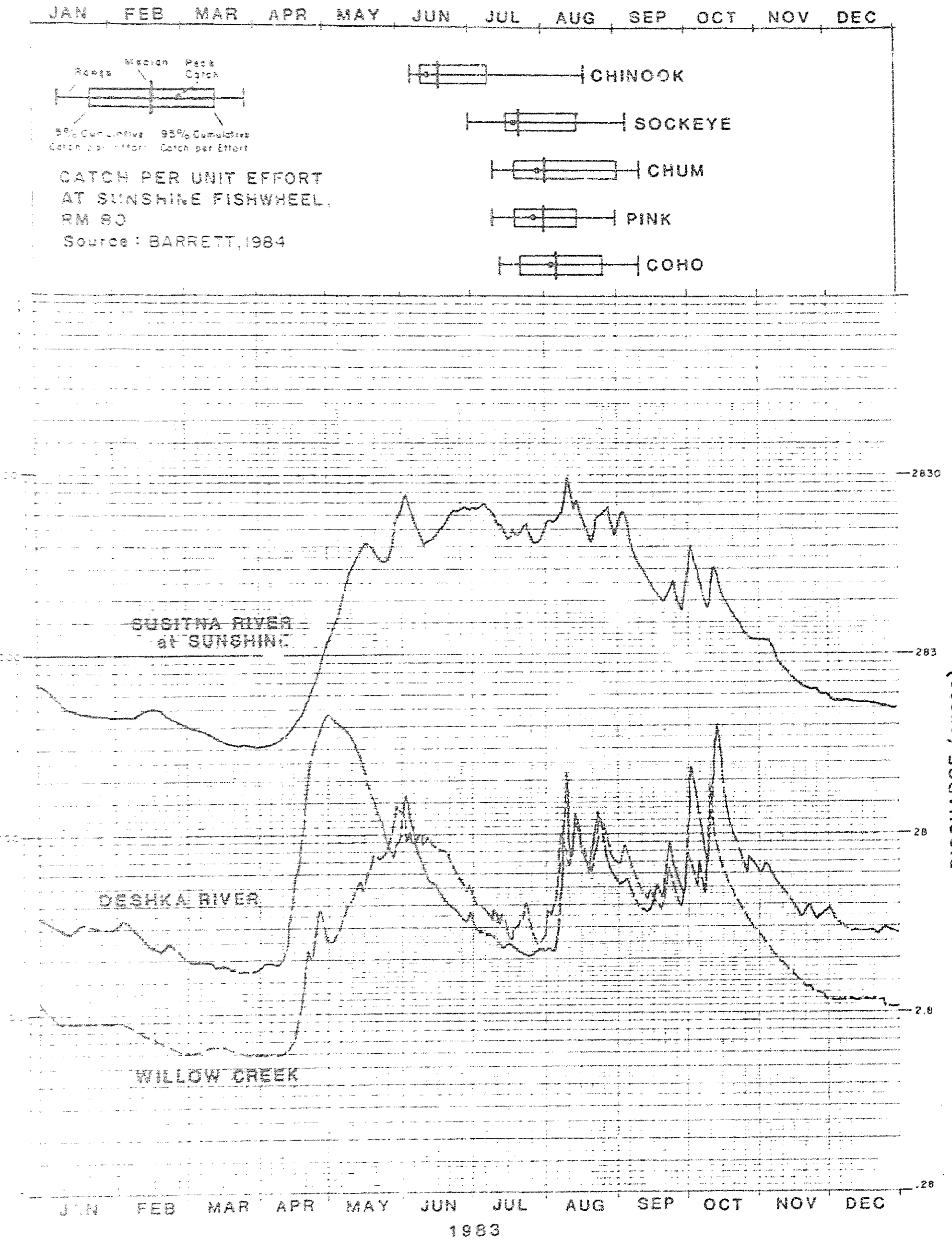


DISCHARGE DATA FROM USGS (1984 & Preliminary Data)

FIGURE 2.4

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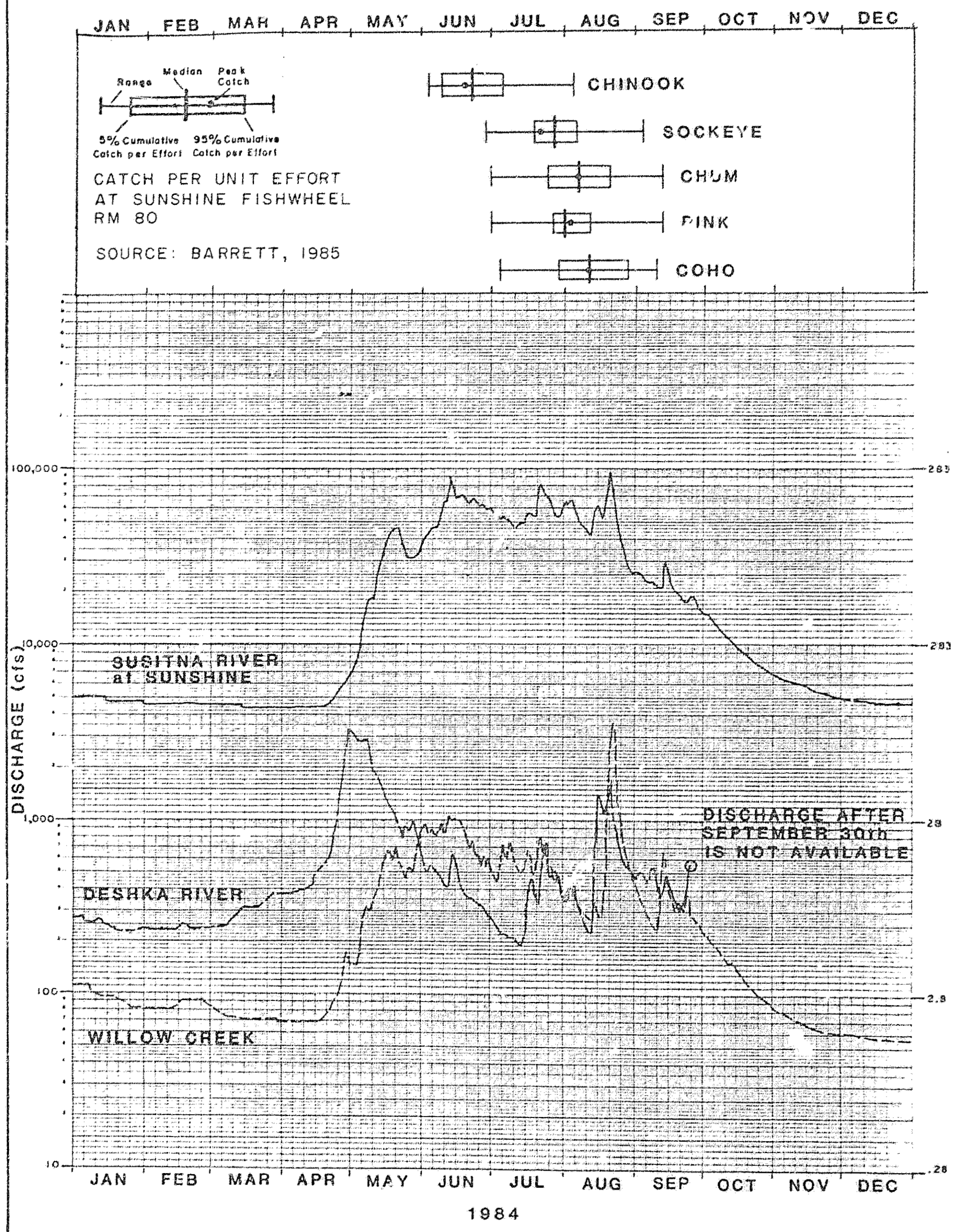
SALMON MIGRATION TIMING AT SUNSHINE AND DISCHARGE FOR SUSITNA RIVER AND SELECTED TRIBUTARIES

PREPARED FOR: HARZA-EBASCO SUSITNA JOINT VENTURE






DISCHARGE DATA FROM USGS (PRELIMINARY DATA)

FIGURE 2.5

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SALMON MIGRATION TIMING AT SUNSHINE AND DISCHARGE FOR SUSITNA RIVER AND SELECTED TRIBUTARIES

PREPARED FOR: HARZA-EBASCO SUSITNA JOINT VENTURE

migrations. The initial rise in mainstem and tributary discharge in the spring results from snowmelt in the lower basin during late April or early May. As snowmelt runoff in the lower basin decreases during late June, streamflow in the mainstem and clearwater tributaries declines. This decline is most pronounced in the tributaries because the largest percentage of their drainage area is at low elevation and snowmelt has generally ended by mid-June. The streamflow contribution to the Lower River mainstem from high elevation snowmelt and glaciers begins in mid-June and increases during July and August. Thus, mainstem flows generally remain high during summer months. Tributary flows decline after the snowmelt season, but may increase due to precipitation. An example of clearwater tributary flow decreasing while the mainstem discharge remains high occurred during June and July 1983 (Figure 2.4).

The influence of glaciers on mainstem discharge is quite apparent below the three rivers confluence. Glaciers cover 10 percent of the basin area above the Sunshine streamgage. Glacier influence is not uniformly apportioned among the three subbasins, however. Only 5 percent of the drainage area which contributes to the Susitna River discharge at Gold Creek is covered by glaciers, whereas 27 percent of the Chulitna and 7 percent of the Talkeetna River basins are covered by glaciers. The large contribution of glacier melt from the Chulitna Basin decreases the relative importance of the middle Susitna River streamflow for maintaining summer baseflow in the lower river.

The Chulitna River contribution to lower river discharges increases from 27% in May to 40% in August whereas middle Susitna River contribution decreases from 49% to 39% (Table 2.1). In addition to the influence from glaciers, summer rainstorms over the Susitna basin also have a significant influence on the percentage contribution of subbasins to the total lower river discharge at Sunshine. By mid-September cool air temperatures at high elevations cause a decrease in the streamflow contribution from glacier melt and increases the importance of fall rain storms in maintaining lower river streamflows.

### 2.3.2 Lower Susitna River Tributaries

Tributaries to the Lower Susitna River generally fall within two classifications: Susitna Basin lowland streams and streams originating in the Talkeetna Mountains. During basin-wide summer storms, the amount of runoff per unit area generally increases as the basin size decreases. Hence, smaller tributaries generally have a more rapid and pronounced response to rainstorms than large tributaries or the mainstem Susitna River.

The Susitna lowlands are covered with birch and white spruce forests on the better drained sites, and with black spruce trees and sphagnum bogs on the poorly drained sites. The area is relatively flat, with low hills to the south and mountains to the west ranging in elevation up to 8,000 feet. Lowland streams such as the Deshka River have relatively flat channel gradients and numerous meanders. Lowland tributary streamflows are not influenced by glacial melt, although snowmelt runoff causes high streamflows in late April to early May. Tributary flow typically declines during the summer, although periodic rainstorms cause short term increases in streamflow. In general, the lakes and bogs in lowland basins retard runoff from summer storms, resulting in attenuated peak flows of extended duration. Streamflow records for the Deshka River near Willow (USGS Station No. 15294100) provides an example of streamflows for a lowland tributary (Figures 2.2 through 2.5).

Watersheds in the Talkeetna Mountains generally possess alpine vegetation above 2,000 feet elevation, with forests of birch and white spruce on better drained sites, and black spruce trees and sphagnum bogs on the poorly drained sites. Stream channels are relatively steep and of low sinuosity in the mountains, but become relatively flat and meandering as they cross the lowlands before entering the Susitna. Snowmelt during May causes high spring streamflows. During summer, streamflows respond to rainstorms which may cause short duration peak flows. In general, tributaries which originate in the Talkeetna Mountains are not buffered by lakes and bogs to the same extent as lowland tributaries. Streamflow records for Willow Creek near Willow (USGS Station No. 15294005) provide an example of a Talkeetna Mountain stream (Figures 2.2 through 2.5).

### 2.3.3 Discussion of 1981-1984 Flows and Salmon Migrations

During 1981 high flow from snowmelt occurred in early May for the Deshka River and mid-May for Willow Creek and the Susitna River at Sunshine (Figure 2.2). The high mainstem flow on June 1, 1981 (Figure 2.2) is an example of a high flow event probably caused by rainfall and snowmelt, lagging behind high flows in the Deshka River and Willow Creek. The annual peak flow for the Susitna River at Sunshine occurred July 11 due to rainfall in the lower basin. This storm also caused high flows on the Deshka River and Willow Creek. High baseflow in the Deshka River and Willow Creek is maintained through July and August by rainfall. The peak catch at the Sunshine fishwheel during 1981 occurred from mid-July to mid-August (Figure 2.2) during a period of high flows on the Susitna due to glacial melt and summer rainstorms. There were two rainstorms during October which caused high runoff from the tributaries as well as the Susitna River.

The influence of snowmelt runoff is evident by mid-April, 1982 in hydrographs for both Willow Creek and the Deshka River. Tributary flows were high in mid-May and remained so probably as the result of rainfall (Figure 2.3). The snowmelt high flow for the Susitna River at Sunshine occurred during mid-to late June with peak flows, probably due to rainfall-related high flows, superimposed on top of



the snowmelt base flow. During the period of peak catches for chum, pink, coho and second run sockeye, there were high flows in both the lower river and the tributaries. During the fall a rainstorm caused the highest flow event of the year for the tributaries and the second highest flow event in the Susitna River for the year at Sunshine.

In 1983 snowmelt caused the Deshka to peak in early May, whereas the snowmelt high flow for Willow Creek and the Susitna River occurred in early June (Figure 2.4). Tributary flows were low during the period of peak catches for chum, pink and second run sockeye salmon (Figure 2.4). A fall rainstorm caused the annual peak flow on Willow Creek and high flows in the Deshka and Susitna Rivers.

Lower basin snowmelt in 1984 caused high flows on the Deshka River in late April - early May, in Willow Creek in mid-to late May and in mid-June on the Susitna River. By mid-July the majority of snowmelt runoff on the Willow Creek basin was finished and summer rains became the dominant cause of high flows. The annual peak flow occurred in mid-August for the Susitna and the tributaries. This year is different from 1981 through 1983 in that there was no high flow from rainfall during September or October.

The chinook migration occurs during June. During this month snowmelt runoff generally causes high flow in the Susitna River, while tributary flow from snowmelt is decreasing. During mid-June rainfall runoff may cause high flows on top of the snowmelt baseflow (see June 1982 as compared to a low rainfall period, late June and early July, 1983). Chum, pink, coho, and second run sockeye salmon migrate from mid-July through August. During 1981, 1982 and 1984, rainfall caused high flows in the tributaries from mid-July through August. July of 1983 was a drier-than-normal month, as indicated by the low July tributary flows

## 2.4 Potential Effects of an Altered Lower River Flow Regime

### 2.4.1 General

The effects of project operation on the flow regime of the lower Susitna River will be dampened by influences of its major tributaries: the Chulitna River (RM 98), the Talkeetna River (RM 97) and the Yentna River (RM 28). Project operation will generally result in increased mainstem discharge during the late fall and winter, lower discharge during the summer, and nearly equal flows in spring and early fall. During extremely dry years, project flows may result in higher-than-natural flow during late summer and early fall (Table 2.2).

Project-induced reductions of mid-summer mainstem discharge may affect adult salmon access into lower Susitna River tributaries by: 1) decreasing the size of backwater areas available to migrating salmon for resting or holding in tributary mouths; 2) decreasing the water depth in the tributary mouth to levels which deny access to adult salmon; and 3) altering the morphologic stability of the tributary mouth or adjoining side channel, thereby potentially inhibiting access into the tributaries during periods of low tributary flow. These possibilities were subjectively evaluated and are discussed in Section 4.

### 2.4.2 Holding Areas

With-project flows are expected to reduce the size and depth of low velocity backwater areas in tributary mouths during the summer. Predicting the magnitude of this reduction is difficult because the size and depth of these backwater a[illegible] respond to both mainstem stage and tributary flow. Tributary flow varies independently of mainstem discharge, so numerous combinations of tributary flow and mainstem discharge are possible. In addition, the magnitude of mainstem or





TABLE 2.2 FLOW DURATION DATA AT SUNSHINE FOR NATURAL AND WATANA/DEVIL CANYON, OPEN-WATER SEASON, CASE EVI

| | Week 32 (May 6 - May 12) | | Week 33 (May 13 - May 19) | | Week 34 (May 20 - May 26) | |
|---|---|---|---|---|---|---|
| Percent | Natural Conditions | 2020 Load | Natural Conditions | 2020 Load | Natural Condition | 2020 Load |
| 0 | 40,800 | 33,100 | 45,500 | 44,600 | 71,200 | 54,500 |
| 25 | 21,400 | 19,000 | 33,000 | 27,000 | 46,700 | 30,700 |
| 50 | 13,000 | 15,400 | 29,300 | 22,500 | 36,100 | 27,900 |
| 75 | 9,460 | 11,300 | 20,900 | 29,900 | 29,900 | 25,000 |
| 90 | 6,330 | 10,100 | 10,200 | 1[illegible],900 | 17,300 | 17,800 |
| 100 | 3,930 | 9,860 | 5,260 | 9,860 | 10,800 | 14,100 |

| | Week 35 (May 27 - June 2) | | Week 36 (June 3 - June 9) | | Week 37 (June 10 - June 16) | |
|---|---|---|---|---|---|---|
| Percent | Natural Conditions | 2020 Load | Natural Conditions | 2020 Load | Natural Conditions | 2020 Load |
| 0 | 77,800 | 50,500 | 160,000 | 96,300 | 121,000 | 79,800 |
| 25 | 61,100 | 43,700 | 68,000 | 48,200 | 76,400 | 54,700 |
| 50 | 48,800 | 37,400 | 54,500 | 37,000 | 61,500 | 45,700 |
| 75 | 38,100 | 29,100 | 45,700 | 32,200 | 51,500 | 38,600 |
| 90 | 29,200 | 23,000 | 37,500 | 29,900 | 41,000 | 32,500 |
| 100 | 23,900 | 20,600 | 28,300 | 23,500 | 37,500 | 29,600 |

| | Week 38 (June 17 - June 23) | | Week 39 (June 24 - June 30) | | Week 40 (July 1 - July 7) | |
|---|---|---|---|---|---|---|
| Percent | Natural Conditions | 2020 Load | Natural Conditions | 2020 Load | Natural Conditions | 2020 Load |
| 0 | 109,000 | 75,500 | 106,000 | 76,200 | 79,200 | 56,700 |
| 25 | 74,100 | 51,000 | 71,100 | 51,900 | 66,000 | 49,100 |
| 50 | 63,600 | 45,600 | 63,800 | 48,200 | 60,900 | 45,800 |
| 75 | 52,100 | 39,800 | 57,300 | 44,000 | 55,900 | 43,200 |
| 90 | 43,100 | 35,100 | 49,200 | 39,900 | 50,200 | 40,600 |
| 100 | 39,300 | 34,200 | 46,700 | 38,800 | 45,400 | 36,600 |

TABLE 2.2 FLOW DURATION DATA AT SUNSHINE FOR NATURAL
AND WATANA/DEVIL CANYON, OPEN-WATER SEASON, CASE EVI
(Continued)

| Percent | Week 41 (July 8 - July [illegible]) Natural Conditions | Week 41 2020 Load | Week 42 (July 15 - July 21) Natural Conditions | Week 42 2020 Load | Week 43 (July 22 - July 28) Natural Conditions | Week 43 2020 Load |
|---|---|---|---|---|---|---|
| 0 | 116,000 | 85,600 | [illegible] | 77,100 | [illegible] | 67,100 |
| 25 | 72,900 | 54,200 | 73,800 | 55,100 | [illegible] | 53,800 |
| 50 | 60,900 | 49,100 | 64,400 | 49,800 | [illegible] | 49,200 |
| 75 | 56,100 | 43,200 | 57,700 | 44,600 | 53,800 | 42,400 |
| 90 | 52,300 | 41,300 | 48,600 | 39,100 | 48,800 | 38,500 |
| 100 | 45,800 | 37,800 | 42,000 | 35,800 | 41,000 | 33,800 |

| Percent | Week 44 (July 29 - August 4) Natural Conditions | Week 44 2020 Load | Week 45 August 5 - August 11) Natural Conditions | Week 45 2020 Load | Week 46 (August 12 - August 18) Natural Conditions | Week 46 2020 Load |
|---|---|---|---|---|---|---|
| 0 | 94,300 | 75,500 | 111,000 | 75,600 | 134,000 | 96,000 |
| 25 | 73,000 | 51,700 | 65,700 | 51,700 | 63,600 | 52,600 |
| 50 | 61,400 | 48,200 | 59,300 | 45,700 | 52,900 | 43,900 |
| 75 | 58,200 | 45,100 | 53,200 | 42,500 | 47,100 | 36,500 |
| 90 | 50,400 | 39,600 | 49,700 | 37,600 | [illegible] | 34,100 |
| 100 | 38,200 | 32,800 | 38,700 | 32,500 | 20,100 | 20,700 |

| Percent | Week 47 (August 19 - August 25) Natural Conditions | Week 47 2020 Load | Week 48 (August 26 - Sept 1) Natural Conditions | Week 48 2020 Load | Week 49 (Sept 2 - Sept 8) Natural Conditions | Week 49 2020 Load |
|---|---|---|---|---|---|---|
| 0 | 111,000 | 62,900 | 87,700 | 61,000 | 60,100 | 60,100 |
| 25 | 58,900 | 48,600 | 52,100 | 40,000 | 45,600 | 39,000 |
| 50 | 51,100 | 42,000 | [illegible] | 35,800 | 35,800 | 32,500 |
| 75 | 43,500 | 35,900 | 35,900 | 31,900 | 31,500 | 28,300 |
| 90 | 38,400 | 29,200 | 30,100 | 28,300 | 25,500 | 22,700 |
| 100 | 16,400 | 18,300 | [illegible] | 18,700 | 18,100 | 19,800 |



R22/2b 6

TABLE 2.2 FLOW DURATION DATA AT SUNSHINE FOR NATURAL
AND WATANA/DEVIL CANYON, OPEN-WATER SEASON
(Continued)

| Percent | Week 50 (Sept 9 - Sept 15) Natural Conditions | Week 50 2020 Load | Week 51 (Sept 16 - Sept 22) Natural Conditions | Week 51 2020 Load | Week 52 (Sept 22 - Sept 30) Natural Conditions | Week 52 2020 Load |
|---|---|---|---|---|---|---|
| 0 | 56,600 | 52,400 | 76,200 | 58,000 | 79,100 | 67,100 |
| 25 | 42,600 | 36,400 | 35,200 | 31,800 | 35,800 | 27,800 |
| 50 | 33,900 | 30,909 | 29,100 | 26,700 | 26,700 | 23,700 |
| 75 | 27,600 | 25,800 | 23,100 | 22,300 | 23,000 | 19,700 |
| 90 | 22,400 | 21,900 | 19,200 | 18,200 | 15,800 | 15,300 |
| 100 | 15,400 | 16,900 | 13,000 | 14,200 | 12,500 | 11,800 |

side channel stage fluctuations depends on the shape of the channel cross-section. For the same incremental decrease in mainstem discharge, the decrease in water surface elevation is generally greater at confined channel sections, such as at the Parks Highway Bridge (the location of the USGS Sunshine streamgage), than at wide, braided channel sections, such as the Delta Islands. Hence the same incremental change in mainstem discharge will have different degrees of influence on backwater (holding) areas in tributary mouths, depending upon local mainstem channel morphology and tributary flow.

### 2.4.3 Tributary Access

Within the lower Susitna River, tributaries enter directly into the mainstem or into side channels. For those tributaries which directly enter the mainstem Susitna, with-project summer flow may adversely affect access conditions into the tributary by reducing depth of flow at the tributary mouth. Access into tributaries adjoining side channels may also be adversely affected if with-project summer flows are insufficient to overtop the upstream berm of the side channel, thereby contributing to significant dewatering of the side channel downstream of the tributary mouth.

### 2.4.4 Tributary Mouth Stability

The persistence and stability of tributary mouths adjoining the mainstem and side channels depend on the magnitude and timing of mainstem and tributary flows and sediment load in both the mainstem and the tributary. Access into the lower river tributaries may be affected by reduced summer mainstem discharges causing low velocity areas near tributary mouths in which suspended sediment (silt and sand) transported by the mainstem might be deposited. It is also possible that sediments transported by the tributary might aggrade near the tributary mouth if mainstem flows are insufficient to



transport them downriver. However, tributary flows could be sufficient to scour the deposited sediment when the mainstem stage later drops.

## 3.0 STUDY PLAN DESIGN AND METHODS

### 3.1 Holding Areas

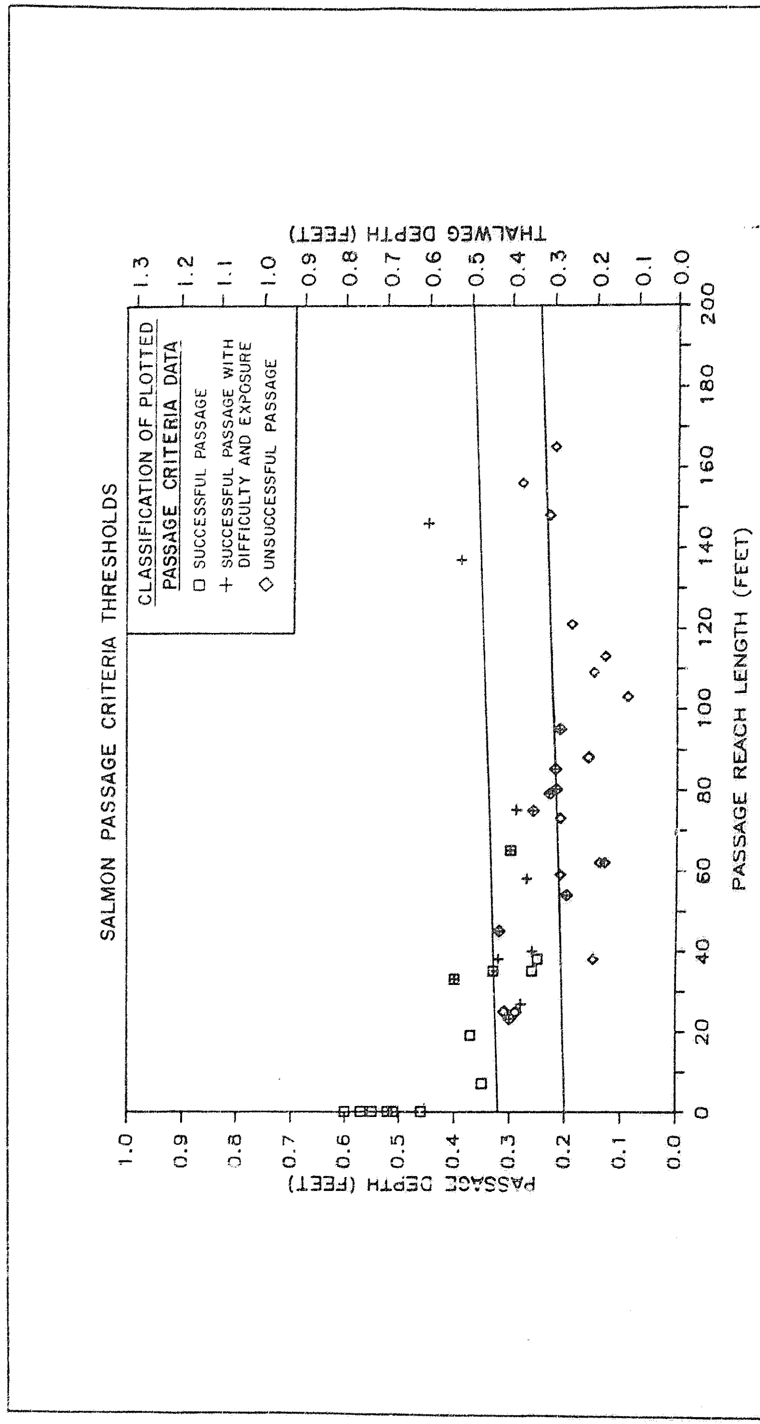
The extent of holding areas is greater in low gradient streams as compared to steep gradient streams. Therefore the analysis concentrated on the effect of with-project flows on low gradient streams. Caswell Creek and Sheep Creek were selected as representative of low gradient streams (Table 3.1). Holding areas at the tributary mouth are affected more by water depth than backwater area. Response curves of water depth to mainstem discharge were developed for these two sites using data collected for this study, ADF&G (1985) and professional judgment. Time series plots of water depth versus 50 percent exceedence weekly natural and with-project flows for Case E-VI (2020 load) were made to identify the degree of change in water depth caused by project flows. Tributary flows occurring during the fall of 1984 when the data was obtained were below average. Hence this evaluation will overestimate the decrease in water depth which would normally occur.

### 3.2 Tributary Access

The ability of fish to pass through a given stream reach is primarily a function of the species of fish and life stage being considered, environmental stresses the fish are exposed to during migration, water depth and velocity in the passage reach, length of the passage reach and availability of resting areas. Passage criteria most often considered are water depth, water velocity and passage reach length (Sautner et al., 1984).

Passage criteria for adult chum salmon (Figure 3.1) which describe passage ability as a function of depth and reach length have been developed by ADF&G Su Hydro (Blakely et al., 1985). These criteria of chum salmon spawning in side sloughs of the middle Susitna River are based on field observations, literature, review, and professional judgement.






Revised passage criteria thresholds for successful and unsuccessful passage conditions of chum salmon within sloughs and side channels in the middle Susitna River (After Blakely et al., 1985)

FIGURE 3.1

PREPARED BY: R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS HYDROLOGISTS SURVEYORS

PREPARED FOR: HARZA-EBASCO SUSITNA JOINT VENTURE

TABLE 3.1. LOWER SUSITNA RIVER TRIBUTARIES EVALUATED DURING 1984

| Tributary | River Mile | Gradient of Stream is Relatively |
|---|---|---|
| Alexander Creek | 9.1 | Low |
| Deshka River | 40.6 | Low |
| Willow Creek | 49.1 | Steep |
| Little Willow Creek | 50.5 | Steep |
| Kashwitna River | 61.0 | Steep |
| Caswell Creek | 64.0 | Low |
| Sheep Creek | 66.1 | Low |
| Goose Creek | 72.0 | Steep |
| Montana Creek | 77.0 | Steep |
| Rabideux Creek | 83.1 | Low |
| Sunshine Creek | 85.1 | Low |
| B[illegible]ch Creek | 89.2 | Low |
| Trapper Creek | 91.5 | Low |

Passage criteria selected for evaluating access by adult salmon into lower river tributaries are those published by Thompson (1972) and applied by Trihey (1983) to tributaries of the middle Susitna River (Table 3.2). Thompson's criteria were selected over the ADF&G criteria because it is slightly more conservative (requires greater depth) than the ADF&G criteria and because it can be applied without reach length measurements. Both these considerations were preferred for this evaluation of access into lower river tributaries as less field data would be required and interpretation of the limited data base would be conservative. If passage conditions were determined to be marginal using Thompson's 0.6 ft depth criteria, then successful passage would likely be determined were additional field measurements obtained and the ADF&G criteria applied.



The procedures used for evaluating tributary access in the lower Susitna River included an initial review of aerial photography to identify potential passage conditions at the tributary mouth, followed by field reconnaissance to check the results of the airphoto assessment and to obtain representative depth measurements in the shallowest portions of the channel during low flow conditions.

TABLE 3.2. DEPTH AND VELOCITY CRITERIA FOR SUCCESSFUL UPSTREAM MIGRATION OF ADULT SALMON (FROM THOMPSON, 1972)

| Fish Species | Minimum Depth (ft) | Maximum Velocity (fps) |
|---|---|---|
| Chinook salmon | 0.8 | 8 |
| Coho salmon | 0.6 | 8 |
| Chum salmon | 0.6 | 8 |
| Pink salmon | 0.6 | 7 |
| Sockeye salmon | 0.6 | 7 |

The lowest with-project average weekly flows estimated for the period June 3 to September 22 is 26,700 cfs at Sunshine (2020 load) (Harza-Ebasco, 1984). Aerial photography obtained September 16, 1983 at a mainstem discharge of 21,100 cfs as reported at Sunshine was selected for the initial airphoto assessment and as the photo base for this report. These photographs show passage conditions at tributary mouths which generally will be moderated by with-project mainstem flows in excess of 21,100 cfs, by mid-summer tributary flows increased by rainstorm runoff events, or a combination of the two. The photos were examined for sand bars or shallow riffle areas that might block the continuous flow of water from tributary mouths through adjoining side channels leading to the mainstem. Tributaries with potential access problems were identified for follow-up aerial reconnaissance and on-site field measurements at a mainstem discharge near 21,000 cfs.

The field reconnaissance was conducted on September 13, 18, 19 and 27, 1984, a period of low mainstem and tributary flow (Sunshine discharge ranged from 18,300 to 22,700). Therefore, the site-specific depth measurements represent anticipated worst case passage conditions for Case E-VI project flows.

### 3.3 Tributary Mouth Stability

Field reconnaissance of tributary mouths provided a basis for estimating their present morphologic stability and the extent which with-project flows might affect their present condition. In addition, aerial photographs of the tributary mouths, obtained on July 3, 1951, at various dates during 1962 and 1963, on August 24, 1980 and on September 16, 1983, were examined to determine what, if any, changes occurred during the 1951 to 1983 period. The stability of tributary mouths which exhibited no change from 1951 to 1983 is considered good, the stability of those which exhibited some change is considered fair and the stability of those which changed significantly since 1951 is considered poor.

The stability of a tributary mouth at with-project flows was evaluated by considering the effect of reduced mainstem discharge on the morphology of the mouth, the potential for aggradation within the tributary near the mouth and the possibility of perching to occur. Tributaries were evaluated to determine if the reduction in mainstem flows would lower the mainstem water surface elevation below the tributary mouth. For the purpose of fish access, channel stability is defined as the persistence of the width/depth ratio over time. This is a function of the tributary flow, channel gradient and local bed material.



## 4.0 RESULTS AND CONCLUSIONS

### 4.1 General

Thirteen tributaries to the lower Susitna River were evaluated. Site specific assessments are presented in Exhibit A. These include oblique and vertical air photos of the tributary mouth at low flow and an air photo mosaic showing channel morphology of the confluence area.

Based on the evaluations provided in Exhibit A, it can be concluded that passage for adult salmon is not presently restricted at any of the locations evaluated, and is unlikely to become a problem for with-project flows similar to Case E-VI. These findings are summarized in Table 4.1 and discussed in the following subsections by topic.

### 4.2 Holding Areas

Project effects on the extent of backwater areas will vary depending on the season, precipitation, the channel gradient and location of the tributary mouth (in a side channel or the mainstem). The mainstem channel cross-section geometry will determine the amount the mainstem stage drops for a specified decrease in flow. For example, the lowest median average weekly flow at Sunshine during the four week period June 3 to June 30 drops from 54,500 cfs under natural conditions to 37,000 cfs under with-project conditions (2020 load) (Harza-Ebasco, 1984). This change in streamflow causes a decrease in stage of 1.7 feet at the USGS Sunshine gage, whereas at Willow Creek (RM 49.1) and Caswell Creek (RM 64.0) the decrease in channel stage for the same decrease in flow are 0.7 and 1.3 feet, respectively. At 21,100 cfs with low tributary flows, the upstream extent of backwater is slight or nonexistent at each study site except the Deshka River.

The reduction in surface area backwater zones is primarily due to a reduction in the length that the backwater extends up the tributary. Due

## TABLE 4.1. SUMMARY OF POTENTIAL EFFECTS ON WITH-PROJECT FLOWS ON TRIBUTARIES OF THE LOWER SUSITNA RIVER

| | | Tributary Mouth in | | | Summary of Adult Salmon Usage of Stream Interface Reach 1984(1) | | Passage Conditions Near Tributary Mouth | | Effects of With-Project Flows On: Fish Access Into Tributaries at 21,100 cfs (2) | | On Backwater Areas (3) | | Morphologic Stability of Tributary Mouth (4) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tributary | River Mile | Side Channel | Mainstem | Breahing Discharge at Sunshine (cfs) | Passage | Spawning | Water Depth (ft) | Discharge at Sunshine (cfs) | Possible Problem | No Problem | Moderate Change | Slight Change | Present | With-Project |
| Alexander Cr | 9.1 | X | | --- | Not Surveyed | | -- | -- | | X | X | | Good | Good |
| Deshka R. | 40.6 | | X | --- | Ch S P Co | -- | -- | -- | | X | X | | Fair | Fair |
| Willow Cr | 49.1 | X | | <13,900 | S P Ch Co | P Ch | 2.8 | 18,300 | | X | | X | Good | Good |
| L Willow Cr | 50.5 | X | | 58,000 | Ck S P Ch Co | P | 1.5 | 18,300 | | X | X | | Good | Good |
| Kashwitna R | 61.0 | X | | --- | P Ch | -- | -- | -- | | X | | X | Fair | Fair |
| Caswell Cr | 64.0 | X | | 35,000 | Ck S P Ch | P Ch | 0.8 | 21,100 | X | | X | | Fair | Fair/Good |
| Sheep Cr | 66.1 | X | | <13,900 | S P Ch Co | P | 3.0 | 18,300 | | X | X | | Good | Good |
| Goose Cr | 72.0 | X | | 21,000 | Ck S P Ch Co | P | 0.4 | -- | X | | | X | Fair | Fair/Good |
| Montana Cr | 77.0 | | X | 35,000 | Ck P Ch Co | P Ch | 1.1 | 18,300 | X | | | X | Poor | Poor/Fair |
| Rabideux Cr | 83.1 | | X | --- | Ck S P Ch | -- | -- | -- | | X | X | | Fair | Good |
| Sunshine Cr | 85.1 | X | | < 13,900 | Ck S P Ch | P Ch | 1.5 | 28,400 | | X | X | | Good | Good |
| Birch Cr | 89.2 | | X | 54,100 | Ck S P Ch Co | P | -- | -- | | X | X | | Fair | Fair/Good |
| Trapper Cr | 91.5 | X | | 44,000 | Ck S P Ch Co | P Ch | 0.6 | 20,900 | X | | X | | Fair | Fair |

Definitions:

1 The interface reach is first third mile from mouth up the tributary. Source Barrett, et al., 1985. Ck = chinook, S = sockeye, P = pink, Ch = chum, and Co = coho.

2 Possible Problem - There is the potential for access problems depending on low tributary flows, debris jams or channel changes.

No Problem - No problem with access currently exists.

3 Moderate Change - The extent of backwater area could be moderately reduced by with-project flows during June and July.

Slight Change - The extent of backwater area could be slightly reduced by with-project flows during June and July

4 Good - No change in tributary mouth morphology since 1951.

Fair - Some change in tributary mouth morphology since 1951.

Poor - Change in tributary mouth morphology from 1951 to present.

to reduced mainstem stage, the interface between tributary flow and backwater will occur further downstream in the tributary than it presently does. This effectively increases the length of tributary habitat and reduces the length of backwater.

During field reconnaissance in 1984 it was observed for low gradient streams such as Caswell Creek that the tributary streambanks near the tributary mouth are generally steep and the channel relatively deep. Therefore the reduction in mainstem stage at tributary mouths is not expected to significantly change the top width or surface area of holding areas at tributary mouths. The major effect of with-project flows on these holding areas will be their depth.

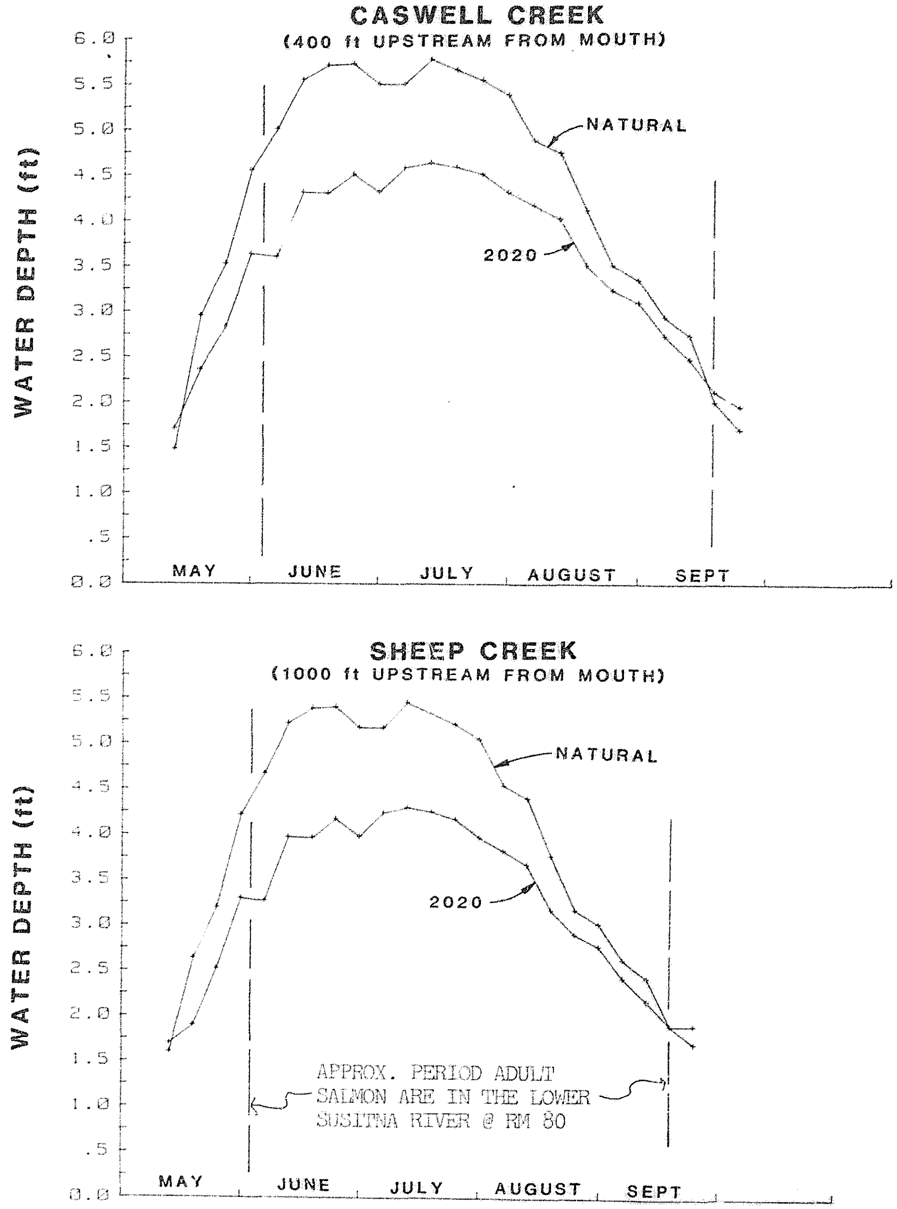
The estimated decrease in water depth for the holding area at the mouth of Caswell Creek measured approximately 400 feet upstream from the mouth from natural to with-project (2020 load) flows is from 5.7 feet to 4.5 feet the last week in June (Figure 4.1). During the last week in August the estimated decrease is from 4.1 feet to 3.5 feet (Figure 4.1). For the holding area at Sheep Creek, approximately 1000 feet upstream from the mouth, the estimated decrease in water depth is from 5.4 feet to 4.0 feet the last week in June (Figure 4.1). During the last week in August the estimated decrease is from 3.8 feet to 3.2 feet (Figure 4.1).

Based on a comparison with depth criteria for spawning chinook and coho salmon developed for tributary streams in the middle Susitna River (Estes and Lang, 1984) it does not appear that one foot reduction at these tributary mouths would adversely affect their utility as holding areas.

## 4.3 Tributary Access

Although high velocities have been reported to impede or block the upstream migration of spawning salmon in other streams, field observations of entrance conditions at several lower river tributaries indicate that it is unlikely for velocity barriers to exist (Exhibit A). Thus the ease with






COMPARISON OF HOLDING AREA WATER DEPTHS IN CASWELL CREEK AND SHEEP CREEK FOR NATURAL AND WITH-PROJECT (2020 LOAD) 50% EXCEEDENCE WEEKLY DISCHARGE AND AVERAGE SALMON MIGRATION TIMING AT SUNSHINE

PREPARED BY: R&M CONSULTANTS, INC.

**FIGURE 4.1**

PREPARED FOR: HARZA-EBASCO SUSITNA JOINT VENTURE

which spawning salmon can enter lower river tributaries is soley a function of depth (and channel stability).

Goose Creek and Trapper Creek were the only tributaries with minimum water depths at or below Thompson's criteria at 21,100 cfs (Table 4.1). Both creeks flow into side channels prior to reaching the mainstem. At 21,100 cfs the berms at the head of the side channels are unbreached. Water depths in the side channels are therefore dependent on tributary flows. The head of the Goose Creek side channel breaches at approximately 22,000 cfs. During project operation (2020 load) this discharge is exceeded 100 percent of the time from May 13th to September 30th (Figure 4.2). Based on field observations the minimum water depths in the side channel while breached will exceed 0.8 feet.

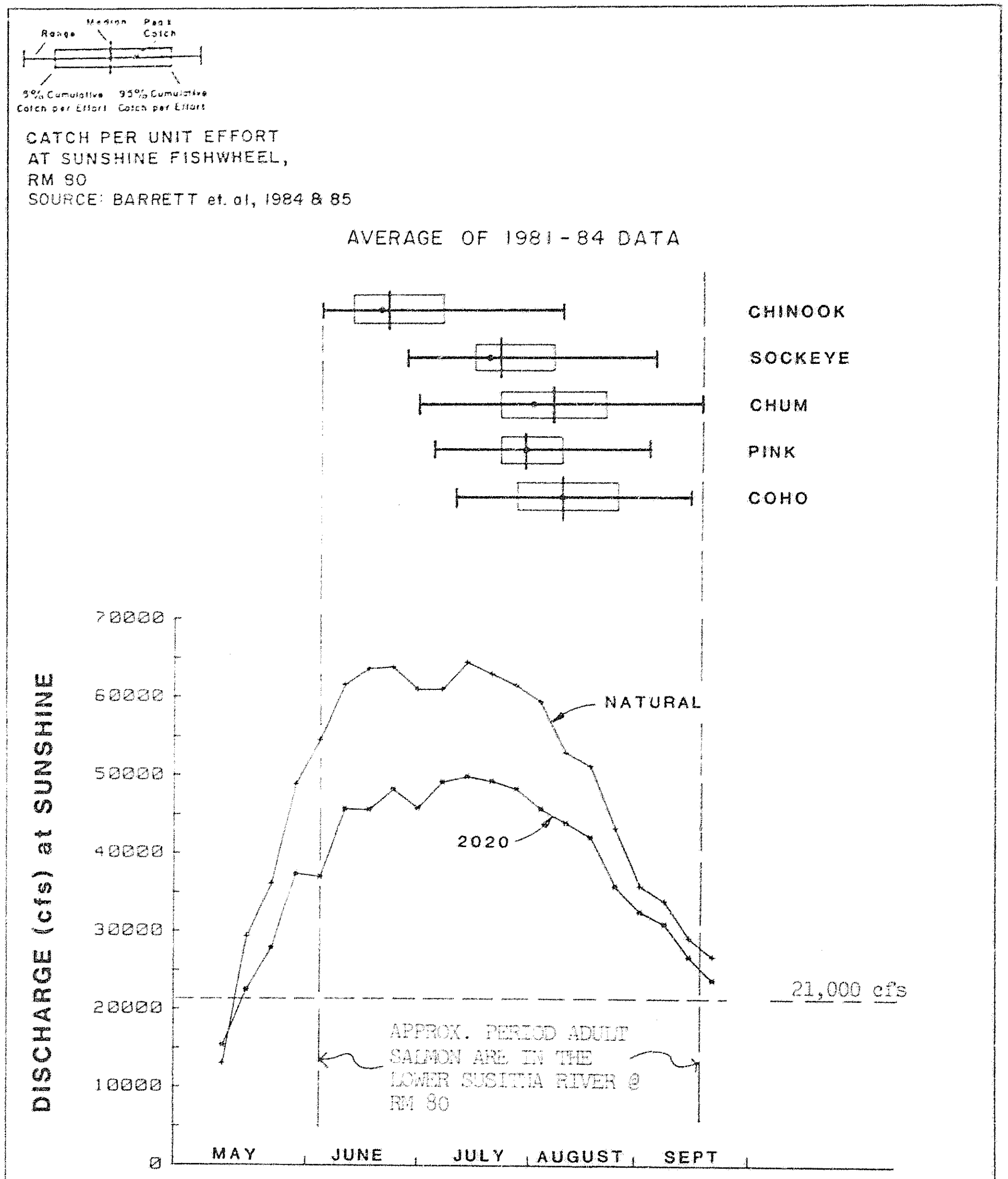
Trapper Creek side channel breaches at approximately 44,000 cfs. During project operation (2020 load) this discharge is exceeded 50 percent of the time from June 10th to August 11th (Figure 4.2). Based on field observations, the minimum water depth at 23,000 cfs (the lowest median weekly with-project flow during the period adult salmon are migrating through the area) will equal or exceed 0.8 feet.

4.4 Tributary Mouth Stability

Currently only the tributary mouth at Montana Creek is morphologically unstable. Since 1951 the side channel complex upstream of Montana Creek has increased in size and became more stable. The creek mouth continues to shift location from year to year. The general effect of with-project flows will be to reduce the frequency of the mainstem channel forming flows, thereby slightly increasing the stability of the side channel complex and the creek mouth.

Sediment deposition within relatively low gradient lowland streams presently occurs in the backwater area within the tributary mouth. During project operation, with reduced backwater areas, deposition will occur closer to






COMPARISON OF NATURAL AND WITH-PROJECT (2020 LOAD) 50% EXCEEDENCE WEEKLY DISCHARGE AND AVERAGE MIGRATION TIMING AT SUNSHINE

PREPARED BY: R&M CONSULTANTS, INC.

FIGURE 4.2

PREPARED FOR: HARZA-EBASCO SUSITNA JOINT VENTURE

the mouth. Since tributary flow will not be affected by project operation the present tributary sediment transport capacity will remain unaffected. Therefore the amount of deposition is not expected to change substantially because of project operation.

At 21,100 cfs with low tributary flows, all of the tributaries had a continuous water course with no steep riffle sections from the tributary to the mainstem/side channel. This indicates that no perching of tributaries would occur due to project operation.



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# EXHIBIT A EVALUATION OF SELECTED LOWER SUSITNA RIVER TRIBUTARIES

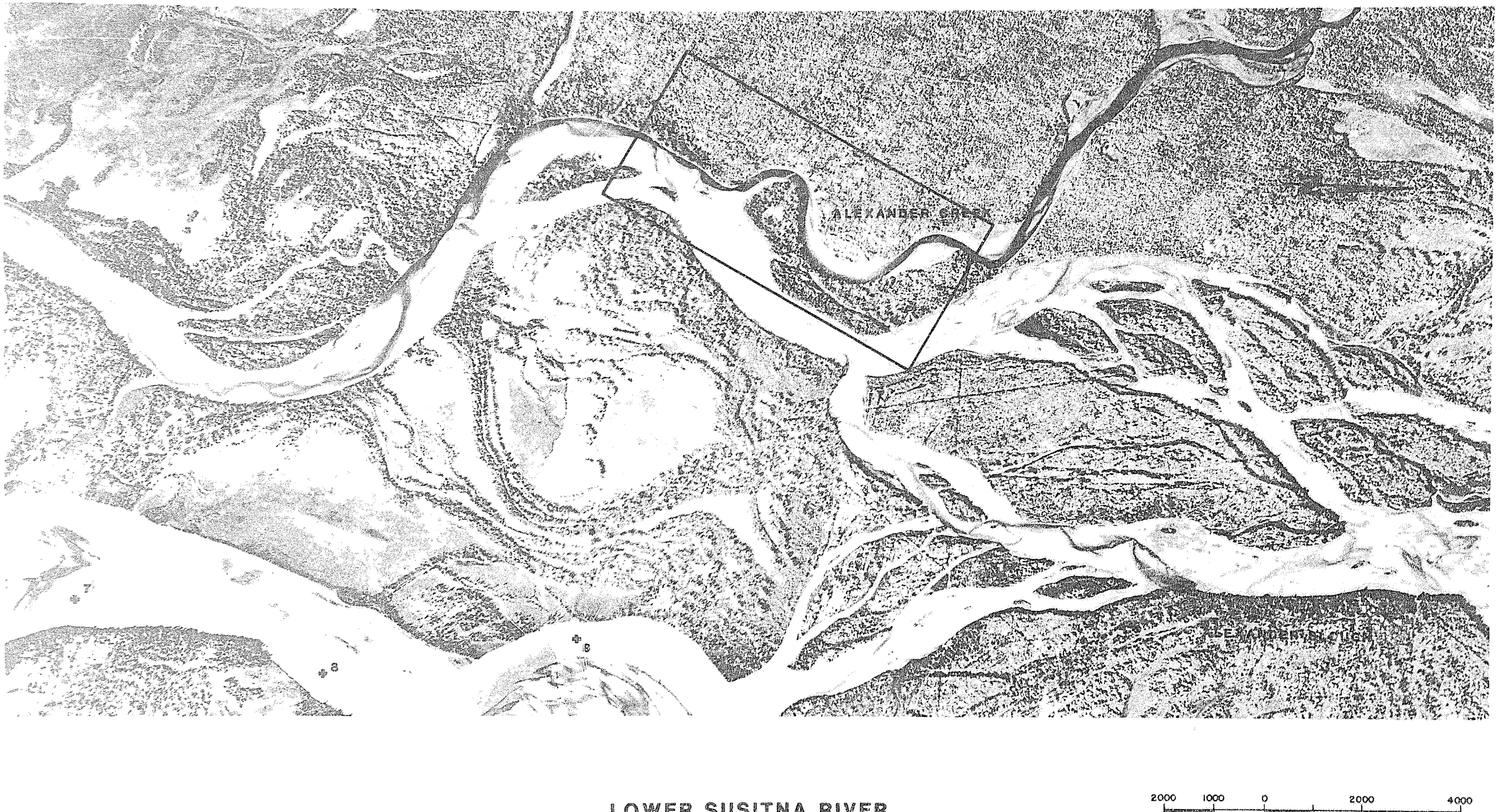
The following are descriptions of the hydrology and use by salmon of selected lower Susitna River tributaries. These descriptions are based on initial aerial photo evaluation of access field data collected to confirm the evaluation, and analysis of the potential effect of with-project flows on backwater areas, tributary access and morphologic stability of the tributary mouth. The fish utilization of the tributary mouths for spawning or passage is from "Appendix 7 - Adult Salmon Lower Susitna River Spawning Surveys," by Levesque and Seagren (Barrett, et al. 1985). Depths reported for tributaries are passage depths where cross-sections were measured and maximum depth where only spot measurements were made. Passage depth is the average of the mean depth and the maximum depth (Sautner, et al., 1984). Aerial photographs (at 1" = 500') of each study site are provided for a flow at Sunshine of 21,100 cfs except for Caswell and Sheep Creeks, where the lowest flow at which aerial photography is available is at 59,100 cfs. The tributaries are given in upstream order. Tributary locations are marked on the lower Susitna River aerial mosaics (at 1"=2000') showing the channel morphology of the confluence area.

## Alexander Creek

Alexander Creek (Figure A-1 and A-2) originates in the Susitna lowlands and flows southeast to the Susitna River. The creek is a popular fishing stream although fish use of Alexander Creek is not reported in Appendix 7 (Barrett, et al. 1985). Year-round residents live just upstream from the confluence with the Susitna River (Photo A-1). The flow regime is similar to the Deshka River (Figures 2.2 through 2.5), except that flow from Alexander Lake will result in a higher baseflow during dry summers and during the winter. The water depth at 21,100 cfs (at Sunshine) is in excess of 0.6 feet from Cook Inlet up the west channel to Alexander Creek. Potential fish access is up this side channel or up the east channel and through a slough (RM 6) to the west channel. The flow contribution from the Yentna River will buffer the affect of with-project flows on the morphologic stability of the tributary mouth and fish access into the tributary. There are no with-project flow related changes expected.

PHOTO A-1

Looking upstream at the mouth of Alexander Creek (RM 9.1). In the foreground is Alexander Slough flowing from right to left. Photo taken 9/11/84 discharge at Sunshine 23,600 cfs, discharge at Susitna Station 51,400 cfs.




DATE OF PHOTOGRAPHY: SEPTEMBER 16, 1983

LOWER SUSITNA RIVER

DISCHARGE AT SUNSHINE: 21,100 cfs

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ENGINEERS GEOLOGISTS HYDROLOGISTS SURVEYORS

EWT&A

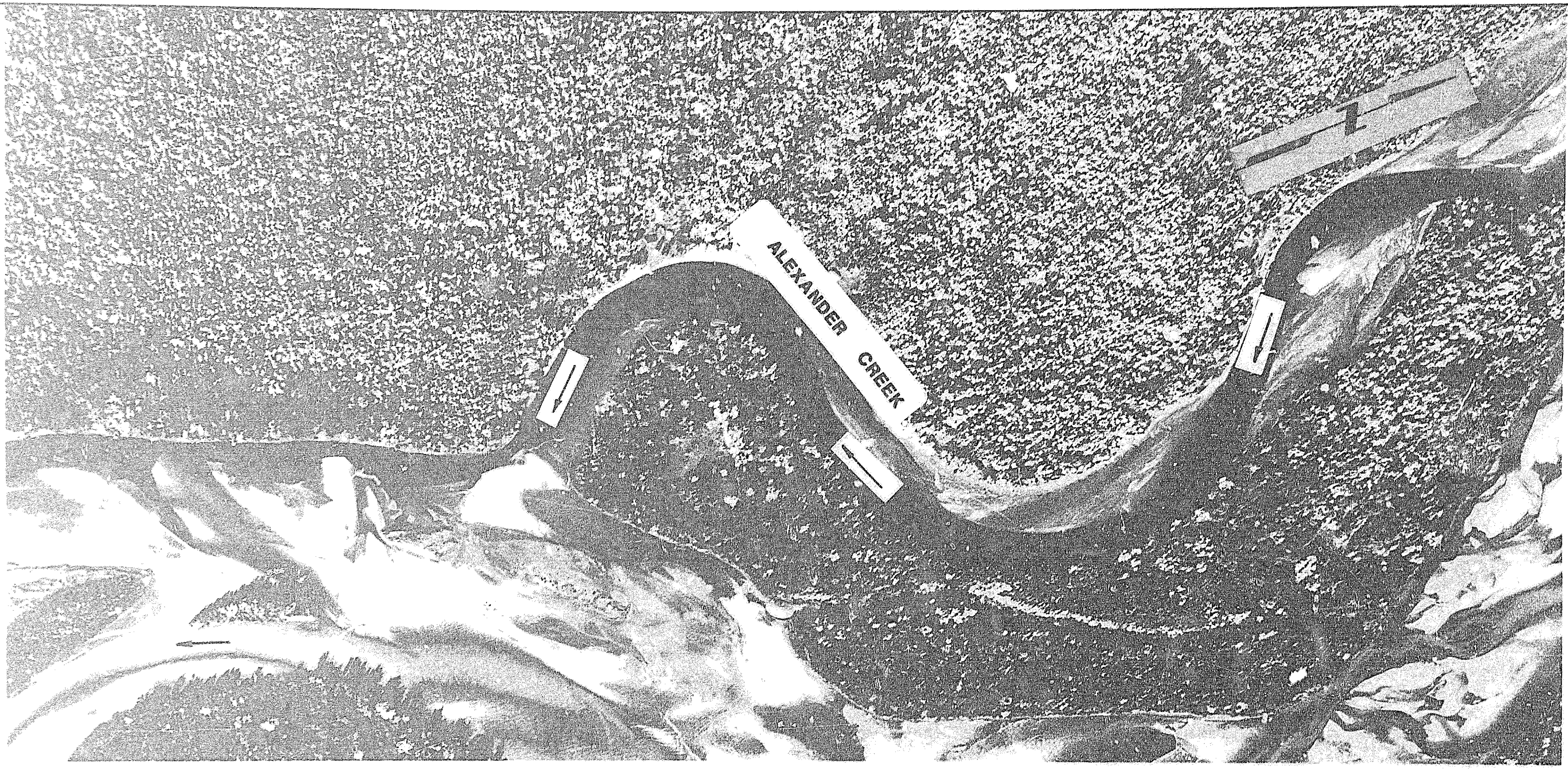
LOCATION OF ALEXANDER CREEK

FIGURE A-1

PREPARED FOR:

HARZA-EBASCO

SUSITNA JOINT VENTURE

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DATE OF PHOTOGRAPHY: SEPT. 16th, 1983

SCALE: 1" = 500'

DISCHARGE at SUNSHINE: 21,100cfs

# ALEXANDER CREEK

FIGURE A-2

PREPARED FOR:

HARZA-EBASCO

SUSITNA JOINT VENTURE

Deshka River

The Deshka River originates in the Susitna lowlands and flows southeast to the Susitna River (Figure A-3). Chinook, sockeye, pink, chum and coho salmon spawn in the upstream habitats. After the Yentna River, the Deshka River is the second largest tributary below Talkeetna. Since October 1978, the USGS has maintained a continuous recording discharge station 7.9 miles upstream on the Deshka River from its confluence with the Susitna River (Figures 2.2 through 2.5). There is sufficient depth to allow fish access at 21,100 cfs. Backwater extended approximately 6,000 feet upstream from the confluence while the mainstem discharge was 33,600 cfs. Island A (Figure A-4) has actively increased in size since 1951, although recently it has started eroding.

With-project flows will decrease the size of the backwater zone. The reduction in size, however, depends on many factors primarily mainstem stage and magnitude of tributary flow and the decreased backwater area will not affect access. The tributary mouth may become more stable because of slightly lower peak mainstem flows. The erosion rate of Island A may decrease.

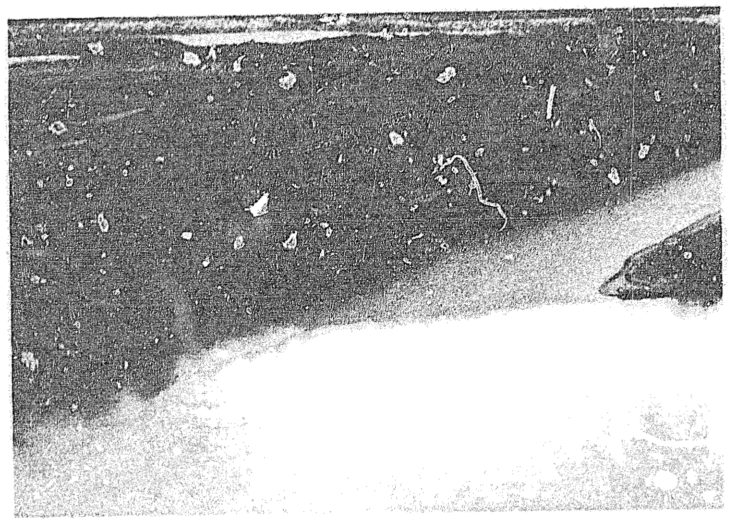

PHOTO A-2

Looking upstream at the mouth of the Deshka River (RM 40.6). The Susitna River mainstem flows from right to left in the foreground. Photo taken 8/31/84, discharge at Sunshine 38,000 cfs.


## LOWER SUSITNA RIVER

**DISCHARGE AT SUNSHINE: 21,100 cfs**

DATE OF PHOTOGRAPHY: SEPTEMBER 16, 1983

2000 1000 0 2000 4000

SCALE IN FEET

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EWT&A

## LOCATION OF DESHKA RIVER

FIGURE A-3

PREPARED FOR:

HARZA-EBASCO

SUSITNA JOINT VENTURE


PREPARED BY

R&M CONSULTANTS, INC.

DATE OF PHOTOGRAPHY: SEPT. 16th, 1983

SCALE: 1" = 500'

DISCHARGE at SUNSHINE: 21,100 cfs

# DESHKA RIVER

FIGURE A-4

PREPARED FOR:

HARZA-EBASCO

SUSITNA JOINT VENTURE

R22/2 35

Willow Creek

Willow Creek originates in the Talkeetna Mountains and flows west through the Susitna lowlands to the Susitna River (Figure A-5). Pink and chum salmon were observed spawning in the tributary just upstream of the mouth of Willow Creek in 1984 (Barrett et al, 1985). Chinook, sockeye, pink, chum and coho salmon spawn in the upstream habitats. Since June 1978, the USGS has maintained a continuous recording discharge station on Willow Creek approximately 15 miles upstream from its confluence with the Susitna River (Figures 2.2 through 2.5). The confluence of two of the mouths of Willow Creek with the side channel are shown on Photo A-3. Water depths at 21,100 cfs are sufficient to allow passage from the mainstem into Willow Creek. At a flow of 17,800 cfs, the passage depth was 2.8 feet and 1.9 feet at cross-sections A and B, respectively (Figure A-6). These cross-sections are at or near the shallowest depth in the reach. The mean velocity was 2.4 per second for an average depth of 2.8 feet at A, and 3.0 fps for the maximum depth of 2.2 feet at B. The substrate ranged from sand to sandy gravel at both A and B. The mouth has been generally morphologically stable since 1951.

With-project flows will cause reduced backwater zones but will not affect access. With-project flows should not change the present stability of the tributary mouth.

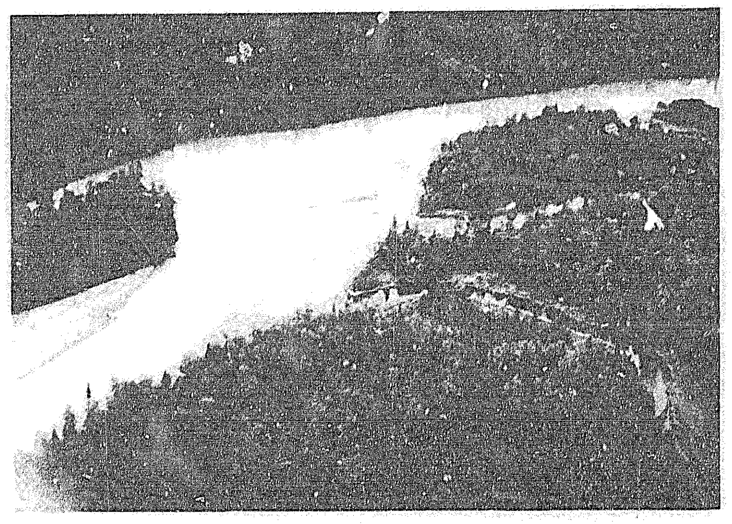

PHOTO A-3

Looking upstream at Willow Creek confluence (RM 49.1). Willow Creek flows from lower right to the center of the photo. Photo taken 8/31/84, discharge at Sunshine 38,000 cfs.

LOWER SUSITNA RIVER

DISCHARGE AT SUNSHINE: 21,100 cfs

DATE OF PHOTOGRAPHY: SEPTEMBER 16, 1983

2000 1000 0 2000 4000

SCALE IN FEET

PREPARED BY:

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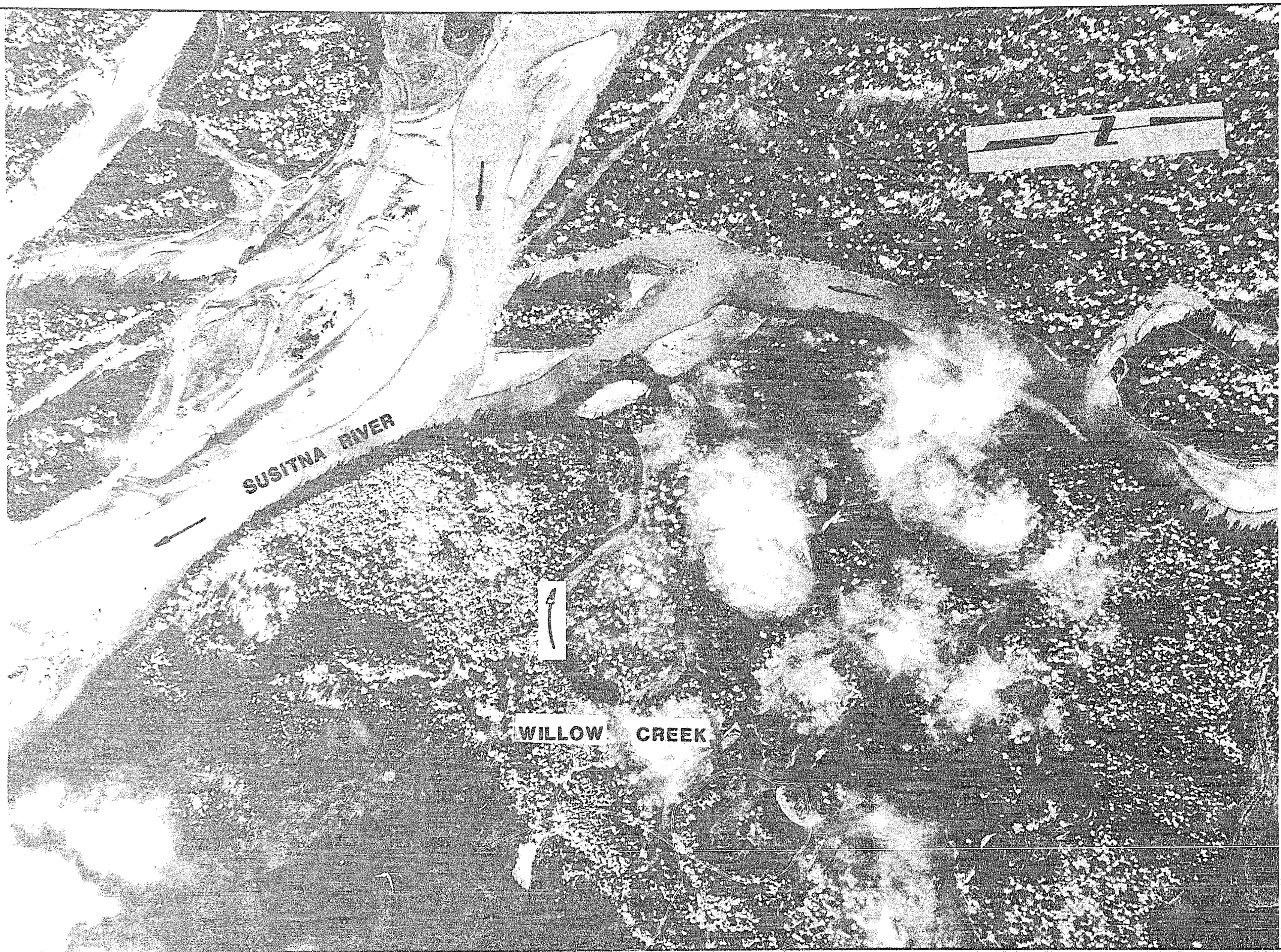
## LOCATION OF WILLOW CREEK & LITTLE WILLOW CREEK SIDE CHANNEL

FIGURE A-5

PREPARED FOR:

HARZA-EBASCO

SUSITNA JOINT VENTURE




EWT&A

PREPARED BY
R&M CONSULTANTS, INC.

DATE OF PHOTOGRAPHY: SEPT. 16th, 1983
SCALE: 1" = 500'
DISCHARGE at SUNSHINE: 21,100 cfs

# WILLOW CREEK

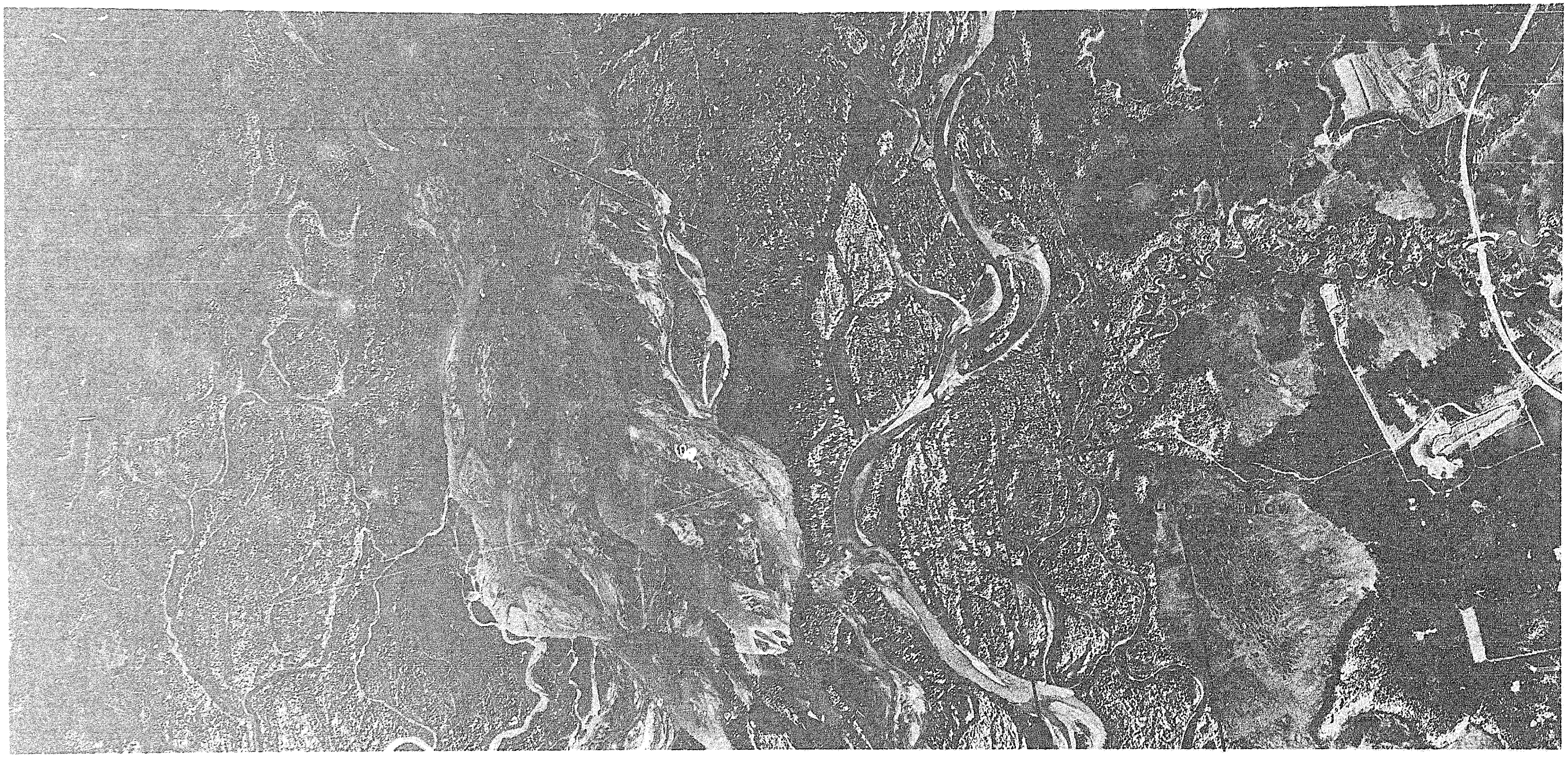
FIGURE A-6

PREPARED FOR:
HARZA-EBASCO
SUSITNA JOINT VENTURE

## Little Willow Creek

Little Willow Creek originates in the Talkeetna Mountains and flows west through the Susitna lowlands to the Susitna River (Figures A-7 and A-8). Pink salmon were observed near point A during 1984 (Barrett et al, 1985). Chinook, sockeye, pink, chum and coho salmon spawn in the upstream habitats. The flow regime is similar to that of Willow Creek (Figures 2.2 through 2.5). Water depths for a mainstem flow of 21,100 cfs are sufficient to allow passage from the mainstem to Little Willow Creek. Access to Little Willow Creek is through a side channel from the Susitna River. At a flow of 17,800 cfs there were no shallow riffles which would impede the passage of fish through the side channel. At a flow of 17,800 cfs, the passage depth was 1.5 feet at cross-section A (Figure A-8) and the mean velocity was 2.0 feet per second at the maximum depth 1.6 feet. The substrate was a silty sand with some gravel covered with a layer of silt-clay. The mouth has been generally morphologically stable since 1951. The extent of backwater at 23,600, 38,000 and 52,000 cfs are marked in Figure A-8.

With-project flows may cause reduced backwater zones, but will not affect access. With-project flows should not affect the present stability of the tributary mouth.



LOWER SUSITNA RIVER

DISCHARGE AT SUNSHINE: 21,100 cfs

DATE OF PHOTOGRAPHY: SEPTEMBER 16, 1983

2000 1000 0 2000 4000

SCALE IN FEET

PREPARED BY

R&M CONSULTANTS, INC.

ENGINEERS GEOLOGISTS HYDROLOGISTS SURVEYORS

EWT&A

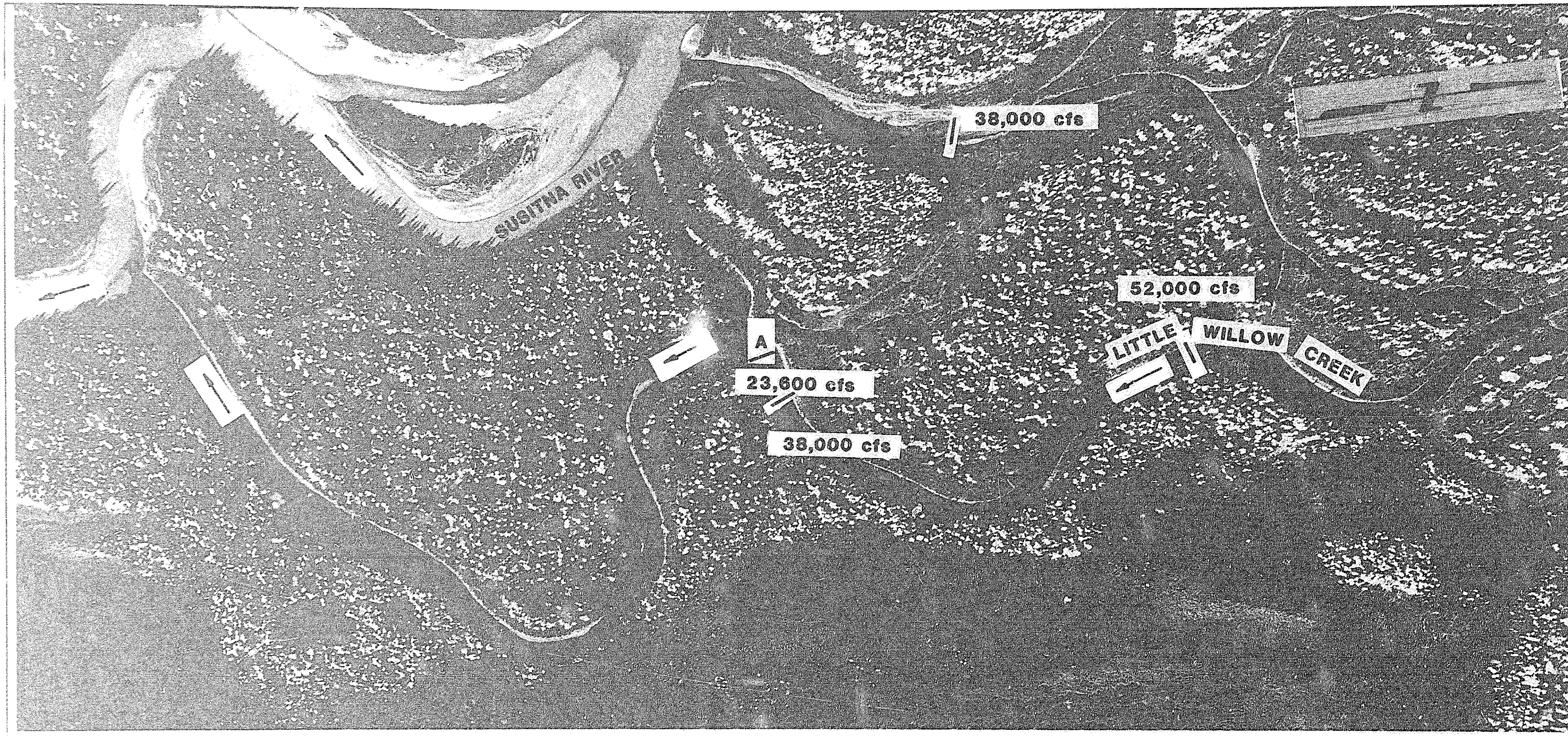
LOCATION OF LITTLE WILLOW CREEK

FIGURE A-7

PREPARED FOR:

HARZA-EBASCO

SUSITNA JOINT VENTURE




PREPARED BY:

R&M CONSULTANTS, INC.

ENGINEERS GEOLOGISTS HYDROLOGISTS SURVEYORS

DATE OF PHOTOGRAPHY: SEPT. 16th, 1983

SCALE: 1" = 500'

DISCHARGE at SUNSHINE: 21,100 cfs

# LITTLE WILLOW CREEK

FIGURE A-8

PREPARED FOR:

HARZA-EBASCO

SUSITNA JOINT VENTURE

Kashwitna River

The Kashwitna River originates in the Talkeetna Mountains and flows west through the Susitna lowlands to the Susitna River (Figure A-9). Chinook, pink, chum and coho salmon spawn in upstream habitats. Glacier melt in the headwaters results in a higher baseflow during July and August than on other east bank tributaries without glaciers The river responds to summer rains in a manner similar to Willow Creek. Fish access is through a side channel from the mainstem (Figure A-10). This channel provides access from the Kashwitna River to the mainstem (Photo A-4).

With-project flows will decrease the size of the backwater zone. The reduction in size depends on many factors, primarily mainstem stage and magnitude of tributary flow. The bar to the west of the boat ramp has been increasing in size since 1951. The rate of growth of the bar may decrease under with-project flows.

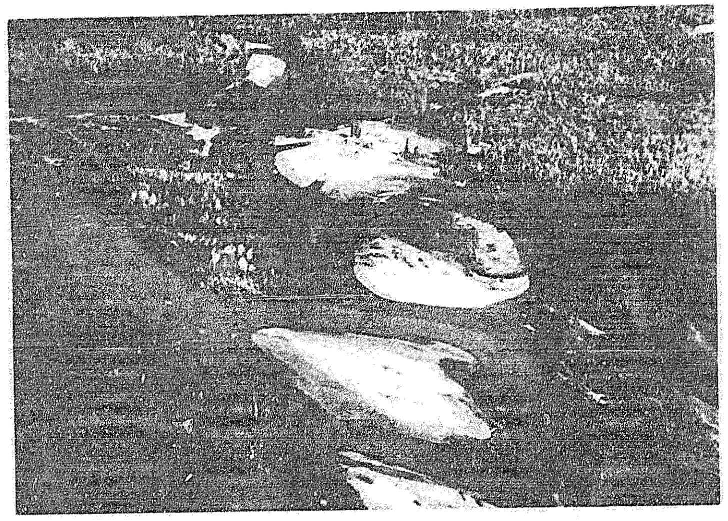
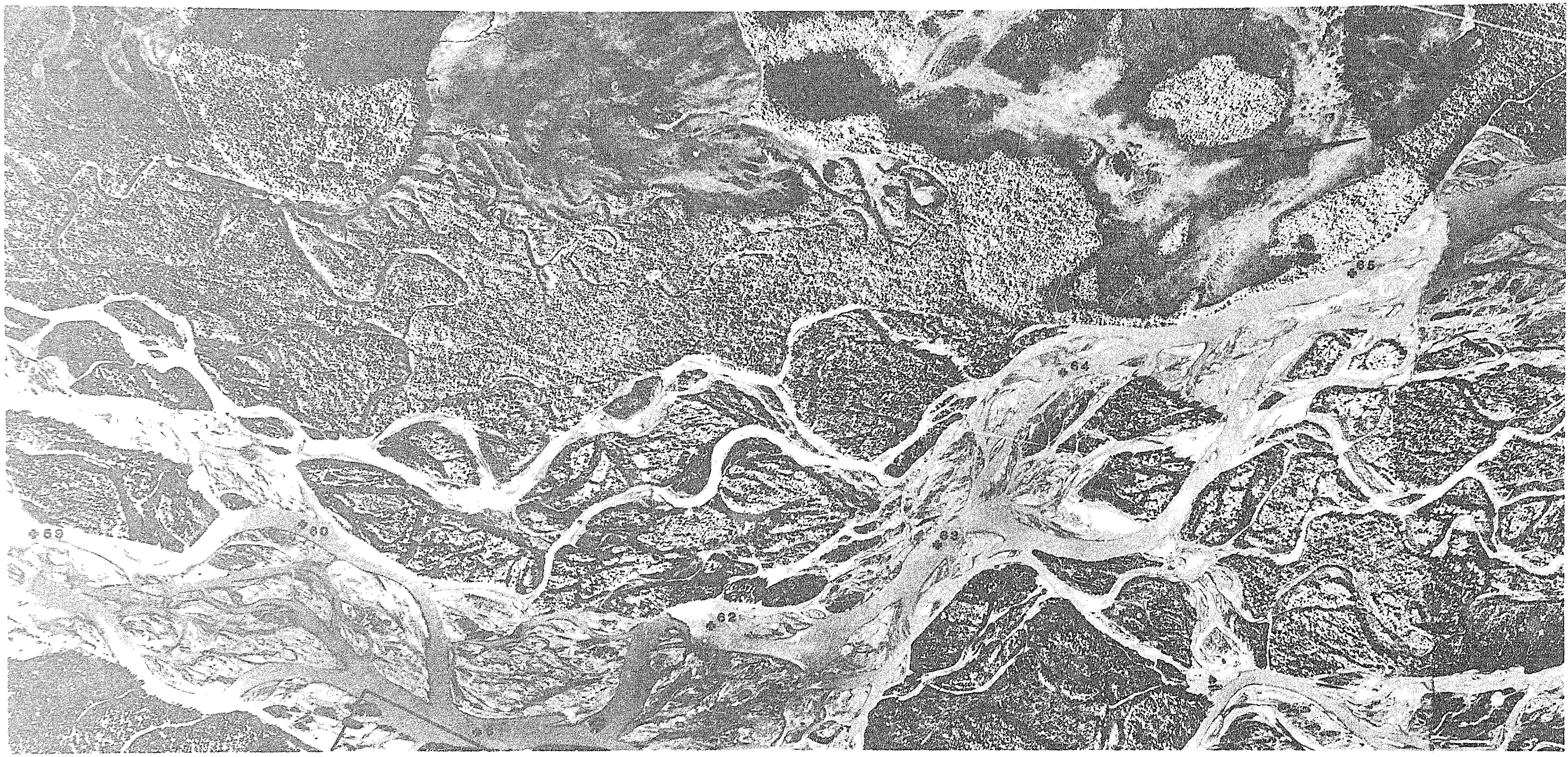


PHOTO A-4

Looking upstream at the Kashwitna River (RM 61.0). Susitna Landing boat ramp is on the gravel bar in the top center to lower right. Photo taken 9/11/84, discharge at Sunshine 23,600 cfs.




KASHWITNA RIVER

## LOWER SUSITNA RIVER

DISCHARGE AT SUNSHINE: 21,100 cfs

DATE OF PHOTOGRAPHY: SEPTEMBER 16, 1983

2000 1000 0 2000 4000

SCALE IN FEET

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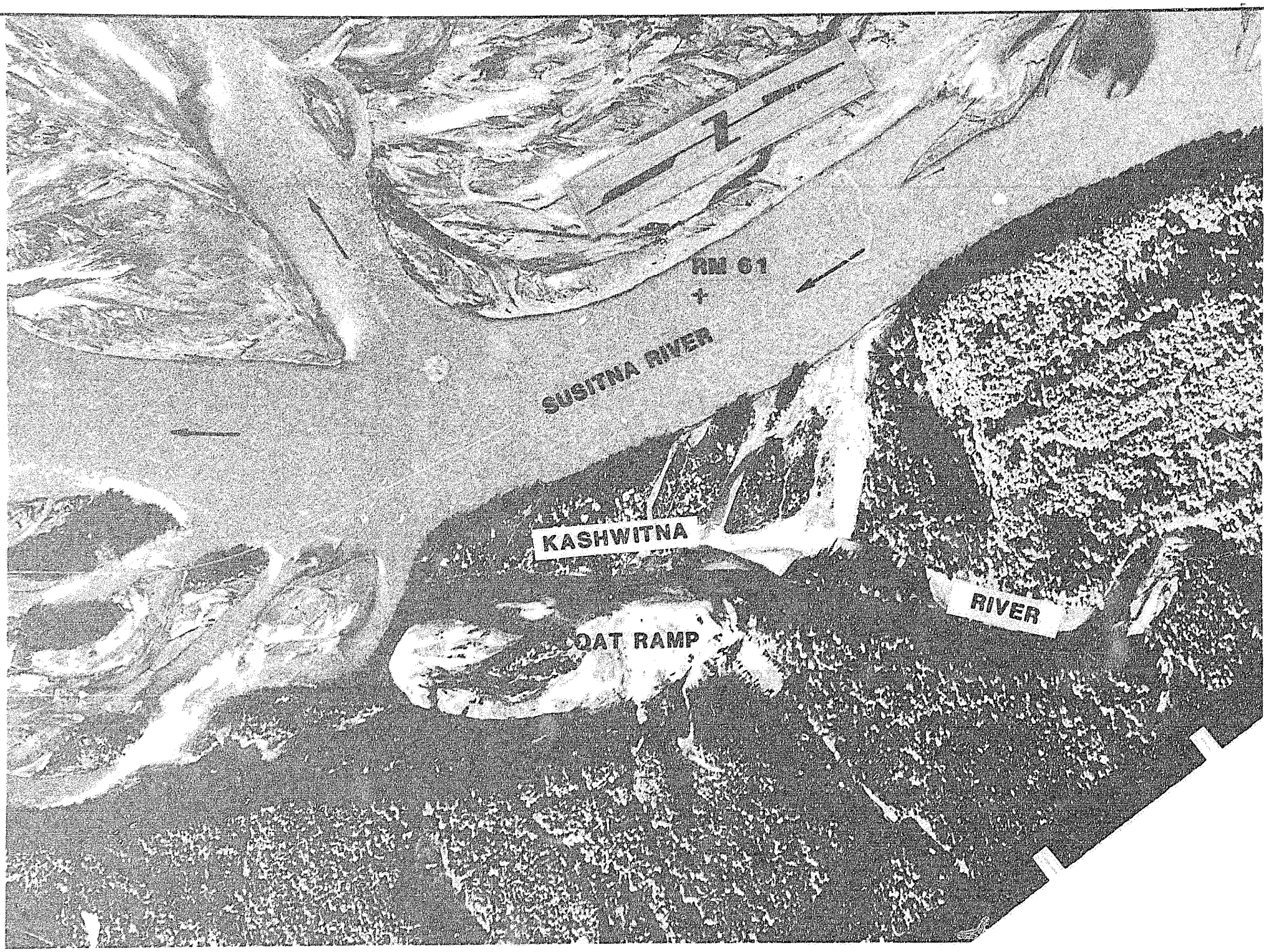
## LOCATION OF KASHWITNA RIVER

FIGURE A-9

PREPARED FOR:

HARZA-EBASCO

SUSITNA JOINT VENTURE

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DATE OF PHOTOGRAPHY: SEPT. 16th, 1983
SCALE: 1" = 500'
DISCHARGE at SUNSHINE: 21,100 cfs

# KASHWITNA RIVER

FIGURE A-10

PREPARED FOR:
HARZA-EBASCO
SUSITNA JOINT VENTURE

Caswell Creek

The headwaters of Caswell Creek are in the Susitna River lowlands in the Caswell Lake area (Figure A-11). Pink and chum salmon were observed spawning in the tributary just upstream of the mouth. Chinook, sockeye, pink, chum and coho salmon spawn in upstream habitats. Caswell Creek has lower peak flows after rainfall events than does Deshka River or Willow Creek due to the influence of lakes in the basin. Baseflow during the winter and during dry summers would be relatively higher due to the influence of Caswell Lake.

Channel A (Figure A-12) is dewatered at approximately 35,000 cfs thereby extending the tributary mouth approximately 800 feet to the southwest (Photo A-5). The low water mouth is a mobile bed of silt and sand which changes with each high flow event. During our site visit (September 27, 1984, 17,800 cfs) there was a water depth of 0.2 to 0.4 feet for a length of 10 to 20 feet at the mouth. Water velocities were low, 0.2 to 0.6 fps. There could be difficulty in passage due to shallow depths at 17,800 cfs. At 21,100 cfs there would be sufficient depths and velocities to ensure passage.

With-project flows will affect the extent of backwater up Caswell Creek. However, the area which would change would be 600 to 800 feet upstream from the tributary mouth. The stability of the tributary mouth would not be affected by with-project flows. The shape of the side channel immediately downstream of the tributary mouth changes with each high flow and will continue to change shape under with-project conditions.

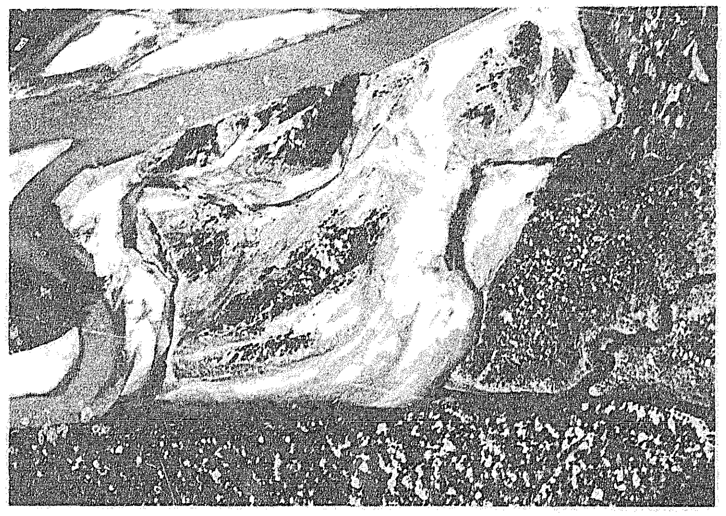
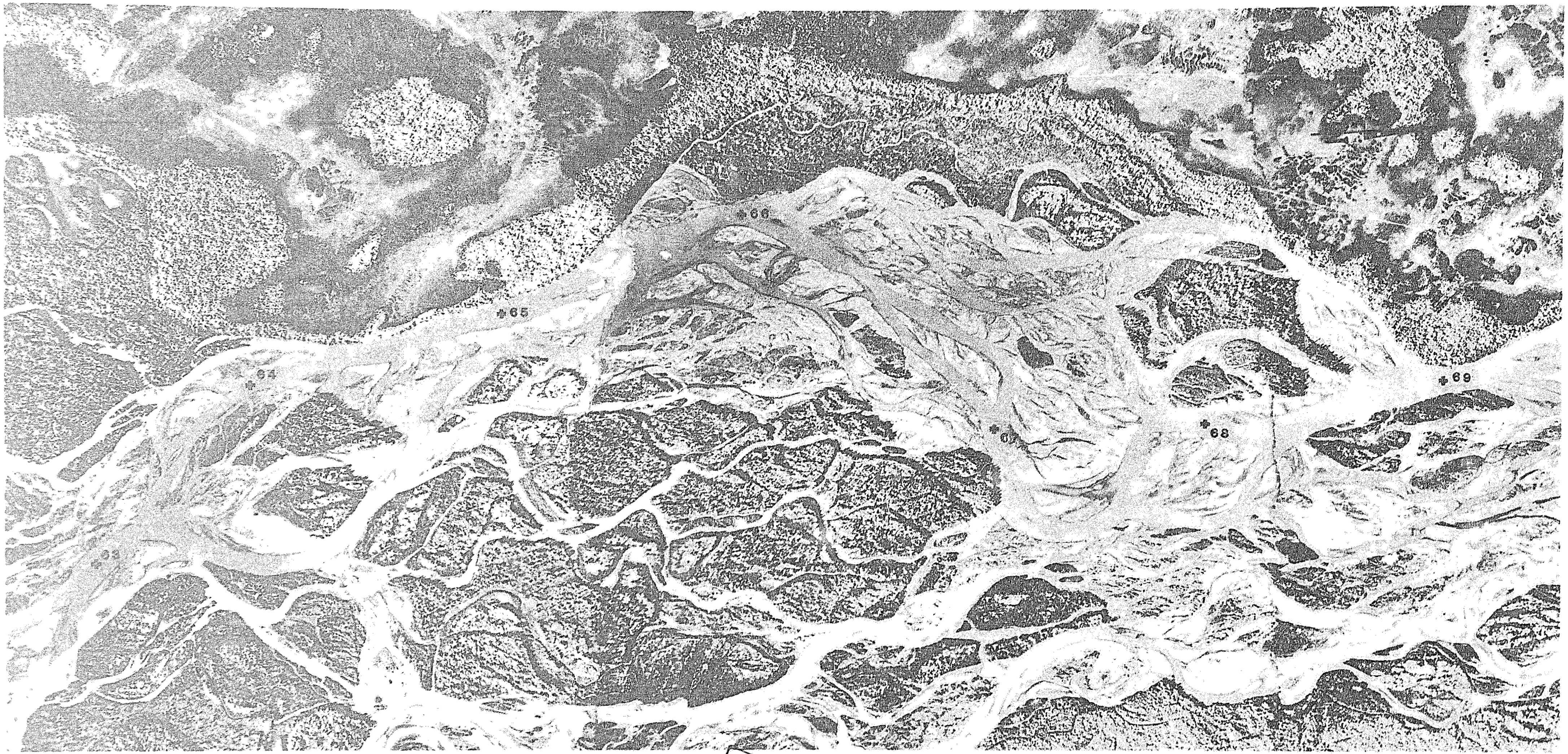


PHOTO A-5

Caswell Creek (RM 64.0) flows from right to left. This photo shows the side channel below the creek mouth. Photo taken 9/11/84, discharge at Sunshine 23,600 cfs.




SHEEP CREEK

CASWELL CREEK

## LOWER SUSITNA RIVER

DISCHARGE AT SUNSHINE: 21,100 cfs

DATE OF PHOTOGRAPHY: SEPTEMBER 16, 1983

2000 1000 0 2000 4000

SCALE IN FEET

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**LOCATION OF CASWELL CREEK & SHEEP CREEK**

FIGURE A-11

PREPARED FOR:

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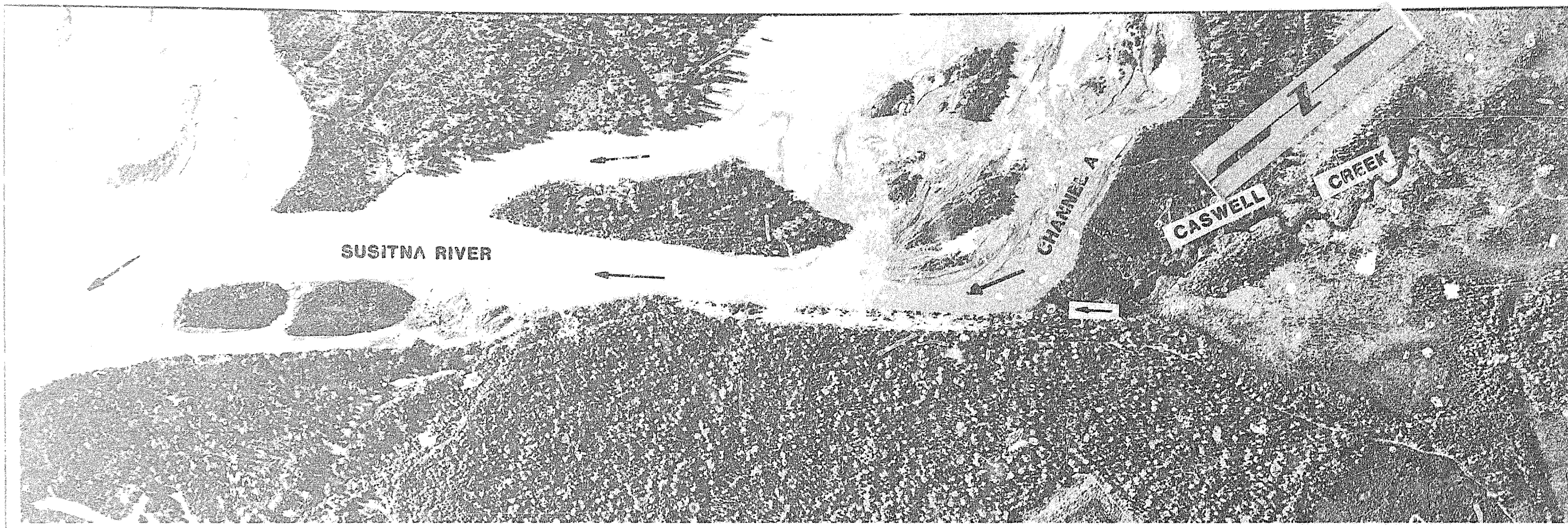
SUSITNA JOINT VENTURE

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PREPARED BY

R&M CONSULTANTS, INC.

DATE OF PHOTOGRAPHY: AUG. 27th, 1983

SCALE: 1" = 500'

DISCHARGE at SUNSHINE: 59,100 cfs

# CASWELL CREEK

FIGURE A-12

PREPARED FOR:

HARZA-EBASCO

SUSITNA JOINT VENTURE

## Sheep Creek

Sheep Creek originates in the Talkeetna Mountains and flows west through the Susitna River lowlands to the Susitna River. Pink salmon were observed to spawn just upstream of the tributary mouth. Chinook, sockeye, pink, chum and coho spawn in upstream habitats. As Sheep Creek leaves the mountains, a secondary channel flows to Goose Creek. The percentage of water going to Goose Creek varies, depending on natural channel shifting and man-made diversions at the confluence of the two creeks. The flow regime is similar to Willow Creek (Figures 2.2 through 2.5). The small area of glaciers in the headwaters will maintain a marginally higher baseflow during July and August than that at Willow Creek.

The aerial photo (Figure A-13) is 59,100 cfs, as the area was not covered in the 21,100 cfs photography. At 21,100 cfs there is a continuous water course in the side channel downstream from Sheep Creek (Photo A-8). Backwater in the tributary occurs at mainstem discharges above 23,000 cfs (Photo A-6 and Figure A-13). At 52,000 cfs the backwater zone extends approximately 5,000 feet up Sheep Creek. The extent of backwater for three different flows at Sunshine are marked in Figure A-13.

The effect of with-project flows will be limited to reduced backwater zones, and will not affect access or morphologic stability of the tributary mouth.



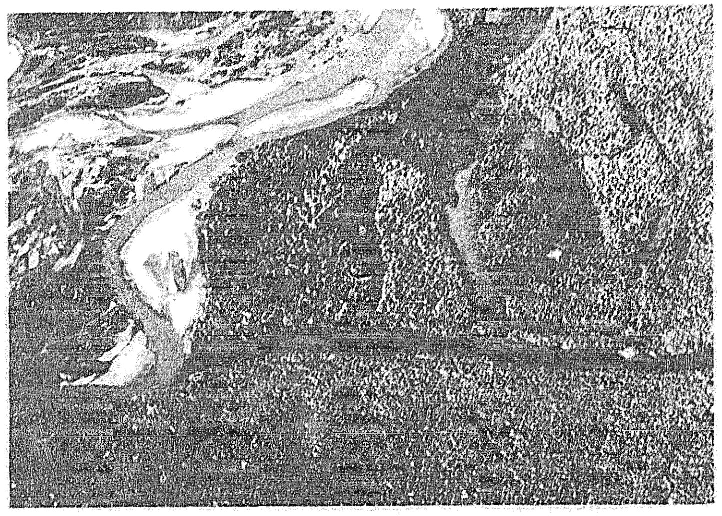
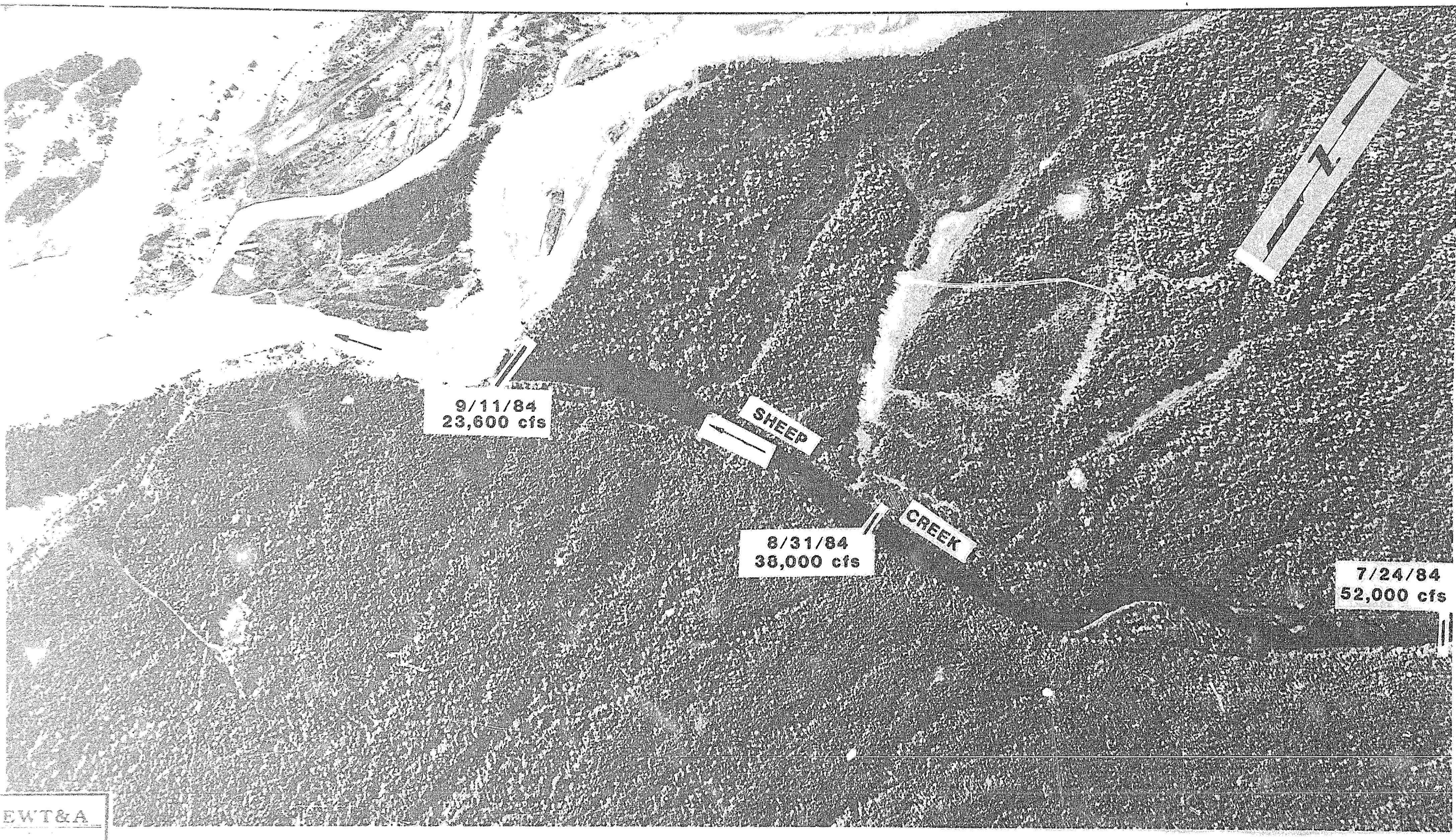


PHOTO A-6

Sheep Creek (RM 66.1) flows from right to left. Sheep Creek side channel flows from top to lower left. Photo taken 9/11/84, discharge at Sunshine 23,600 cfs.




PREPARED BY

R&M CONSULTANTS, INC.

DATE OF PHOTOGRAPHY: AUG. 27th, 1983

SCALE: 1" = 500'

DISCHARGE at SUNSHINE: 59,100 cfs

# SHEEP CREEK

FIGURE A-13

PREPARED FOR:

HARZA-EBASCO

SUSITNA JOINT VENTURE

## Goose Creek

Goose Creek originates in the foothills of the Talkeetna Mountains and flows west through the Susitna River lowlands to the Susitna River (Figure A-14 and A-15). Pink salmon were observed to spawn near the tributary mouth. Chinook, sockeye, pink, chum and coho salmon spawn in upstream habitats. The channel starts at the point where Sheep Creek leaves the mountains. The percentage of water entering Goose Creek from Sheep Creek varies, depending on natural channel shifting and man made diversion. The flow regime is similar to Willow Creek (Figures 2.2 through 2.5). Near its mouth, Goose Creek splits into four main channels, with two flowing into the mainstem of the Susitna River and two flowing into a side channel (Photo A-7). The side channel overtops at approximately 22,000 cfs. The actual overtopping flow varies from year to year due to channel changes and debris accumulating at the head of the side channel. When the side channel is overtopped, there is sufficient water depth and low water velocities to ensure fish passage into Goose Creek. Water depths and velocities were measured in the side channel downstream of the tributary mouth when the berm was not overtopped. At cross-section A (Figure A-15) the critical section had a water depth of 1.0 feet, a velocity of 4.6 fps and a reach length of 20 feet. Section B (Figure A-16) had a critical section water depth of 1.2 feet, a velocity of 4.6 fps and a reach length of 20 feet. The discharge in the side channel was 39 cfs during these measurements. The shallowest water depth, 0.4 feet, was at Section C (Figure A-19), with a water velocity of 0.9 fps and a reach length of 50 feet. The tributary mouth has changed considerably since 1951 due to bedload moving down Goose Creek and elevating the old mouth where it joins a side channel at point A (Figure A-18). From point A water flows both to the north and to the southwest. The event which caused the change in the mouth appears to have been a log jam which diverted flow into another channel.

During project operation Sunshine flows will exceed 22,000 cfs 50 percent of the time from May 13th to September 30th. Since most of the adult inmigration occurs during the period when the side channel berm is overtopped (June 3 to September 8), there is little chance of fish passage problems. The slight change in stage with with-project flows will slightly alter the backwater in the channels flowing into the mainstem, but s[illegible] not severely affect potential holding areas. With-project flows sh[illegible] affect the stability of the tributary m[illegible].

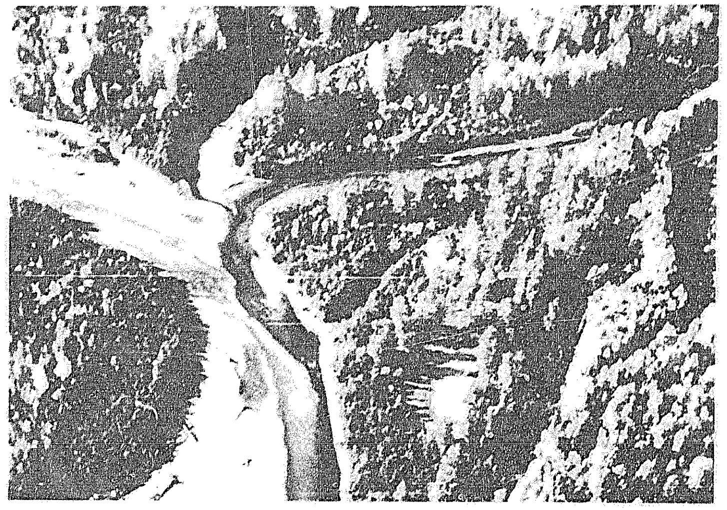
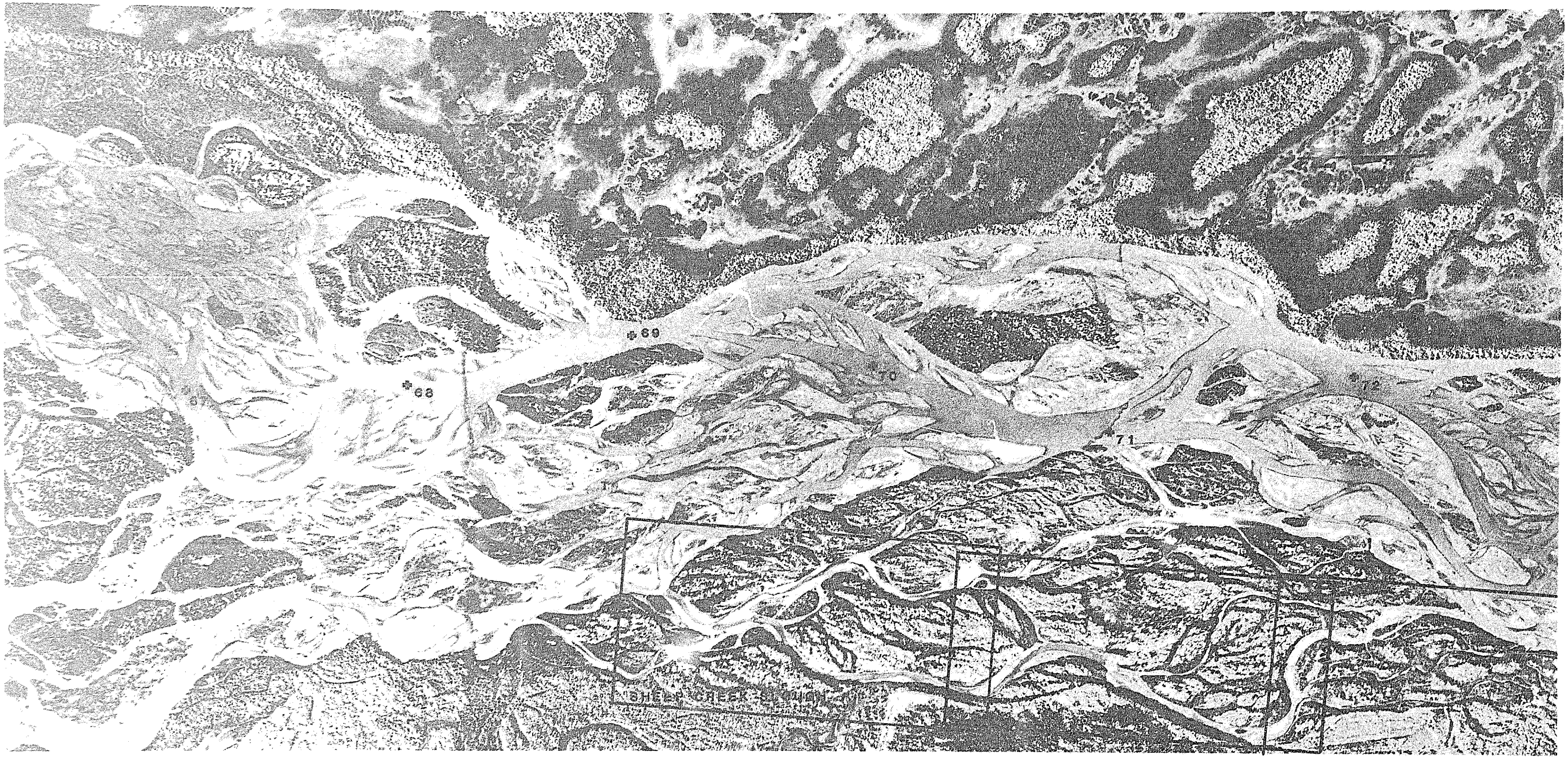


PHOTO A-7

Looking upstream at the confluence of Goose Creek and Goose Creek side channel (RM 72.0). Goose Creek flows from top right towards bottom center. The side channel was barely overtopped at 23,600 cfs, at Sunshine on 9/11/84.




DATE OF PHOTOGRAPHY: SEPTEMBER 16, 1983

LOWER SUSITNA RIVER

DISCHARGE AT SUNSHINE: 21,100 cfs

PREPARED BY:

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LOCATION OF GOOSE CREEK

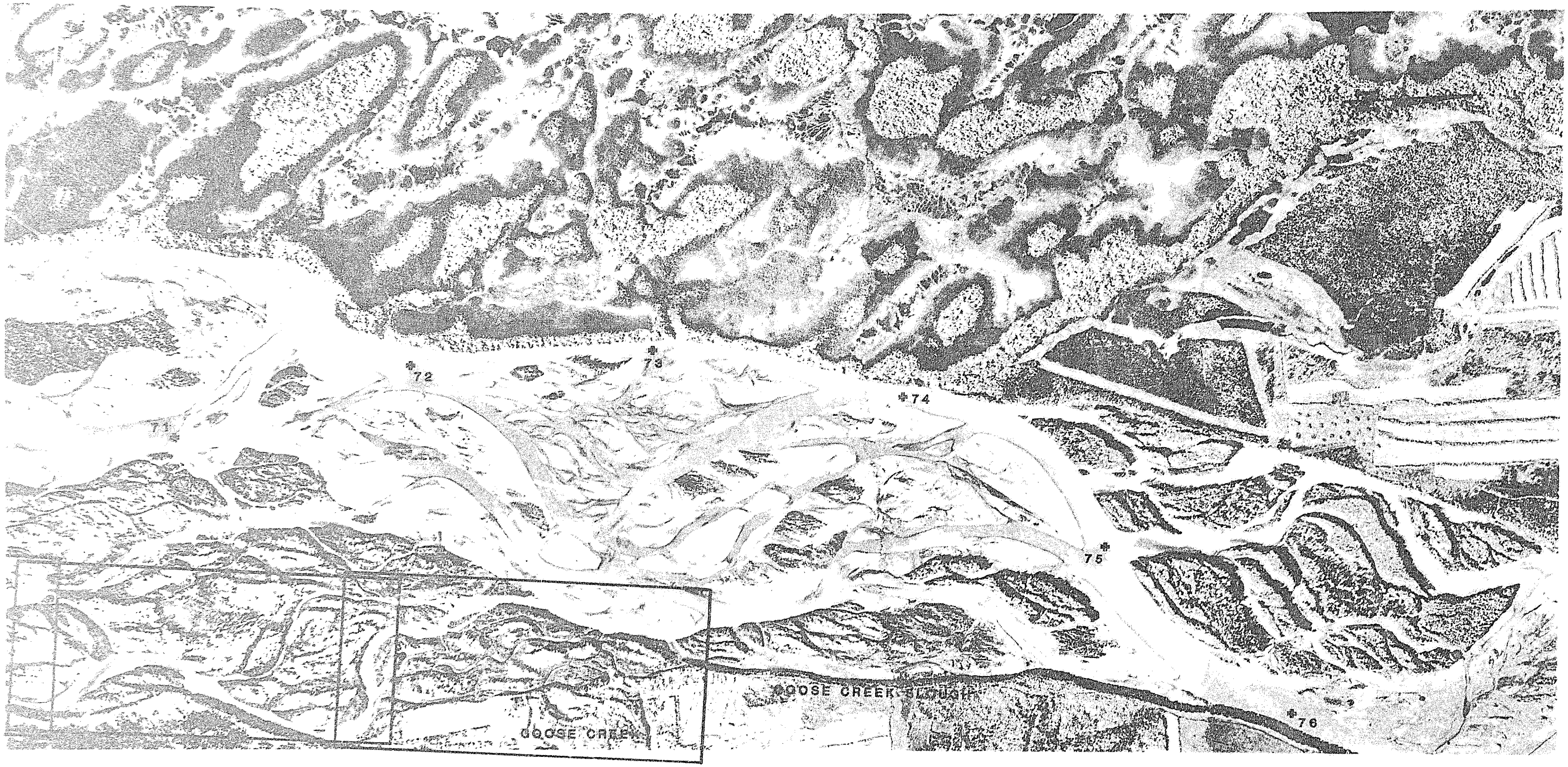
1 of 2

FIGURE A-14

PREPARED FOR:

HARZA-EBASCO

SUSITNA JOINT VENTURE




2000 1000 0 2000 4000
SCALE IN FEET

DATE OF PHOTOGRAPHY: SEPTEMBER 16, 1983

## LOWER SUSITNA RIVER

DISCHARGE AT SUNSHINE: 21,100 cfs

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## LOCATION OF GOOSE CREEK

2 of 2

FIGURE A-15

PREPARED FOR:

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SUSITNA JOINT VENTURE


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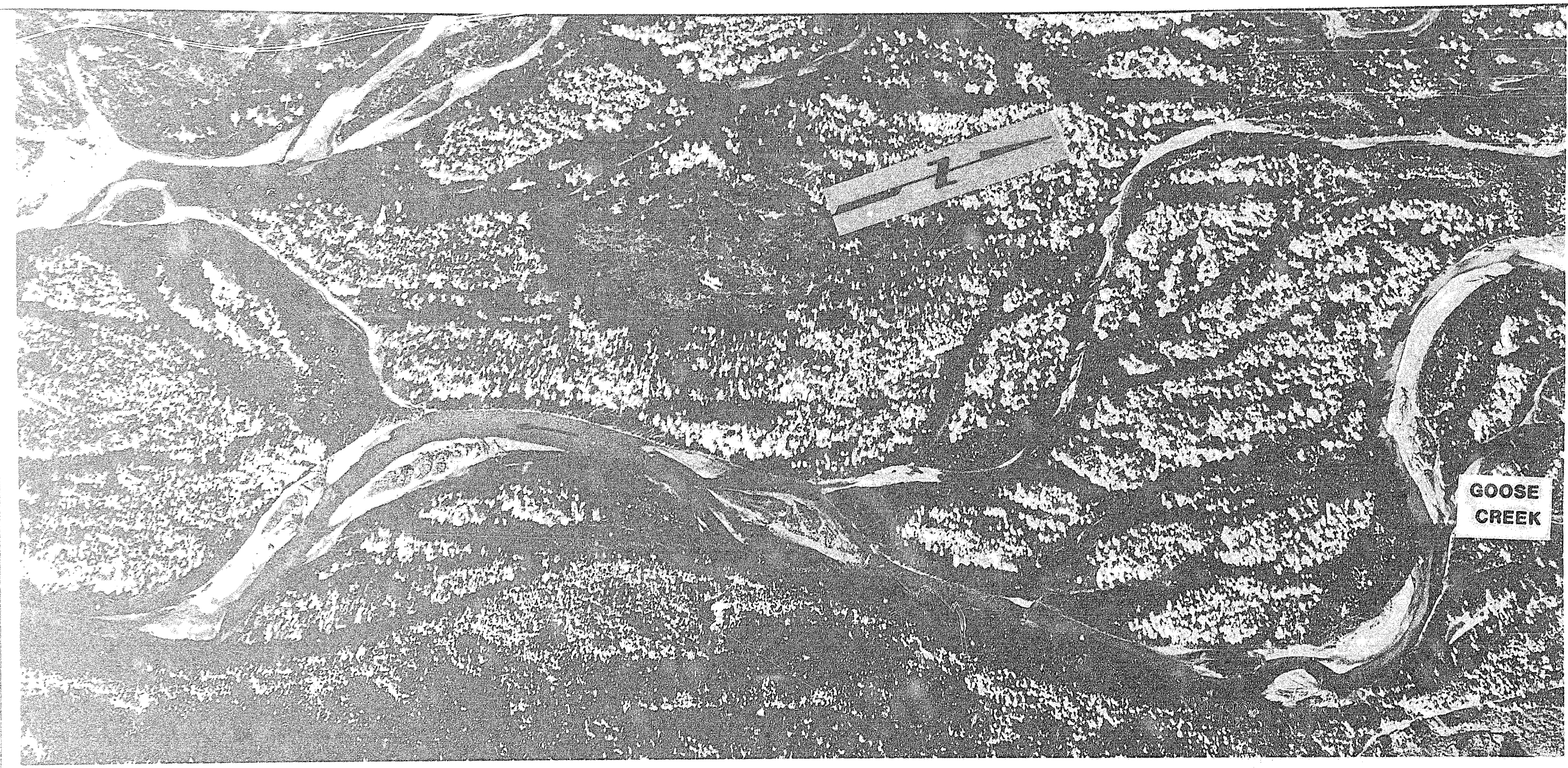
DATE OF PHOTOGRAPHY: SEPT. 16th, 1983
SCALE: 1" = 500'
DISCHARGE at SUNSHINE: 21,100 cfs

# GOOSE CREEK A

FIGURE A-16

PREPARED FOR:

HARZA-EBASCO
SUSITNA JOINT VENTURE

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SCALE: 1" = 500'

DISCHARGE at SUNSHINE: 21,100 cfs

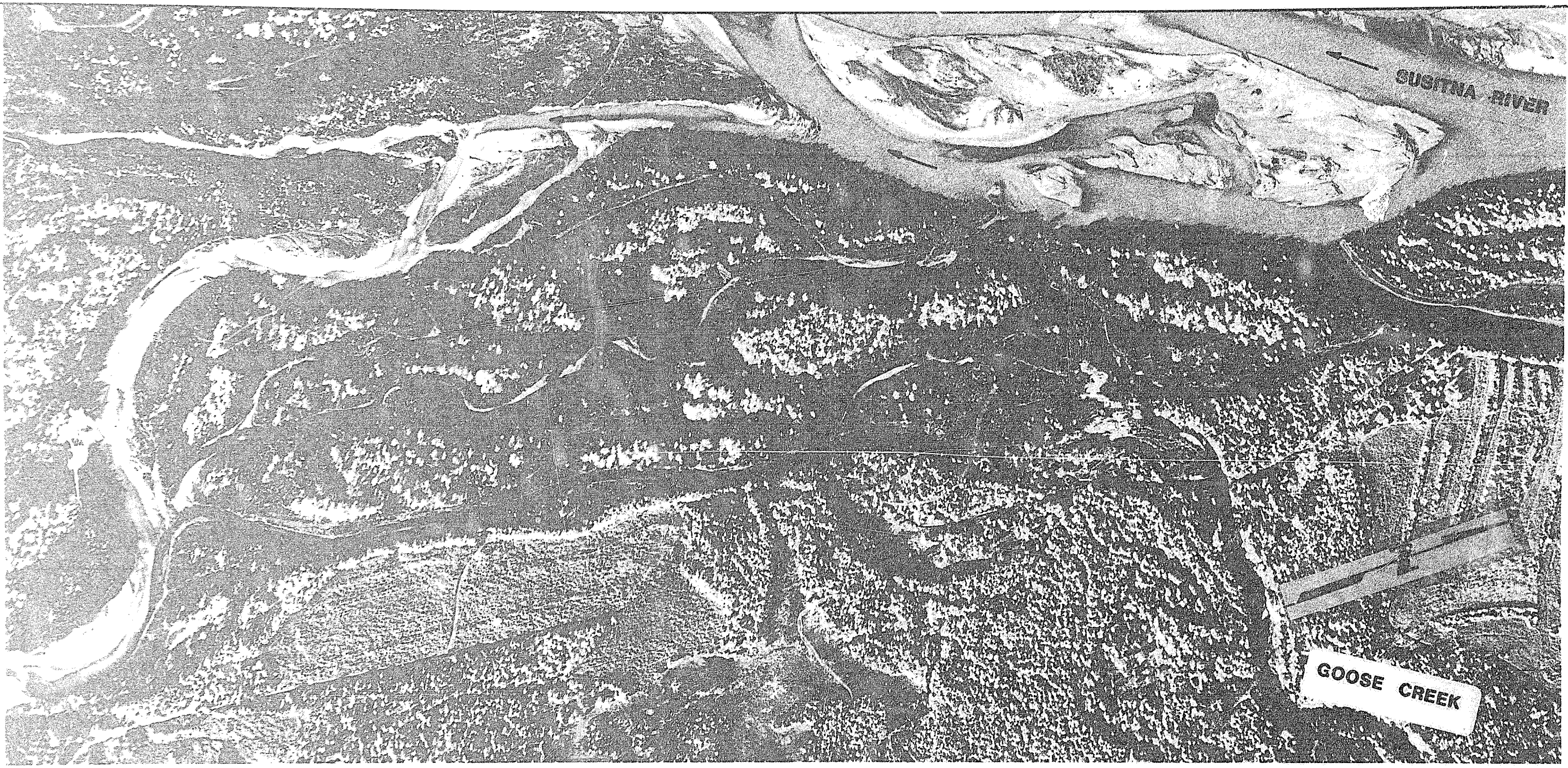
# GOOSE CREEK B

FIGURE A-17

PREPARED FOR:

HARZA-EBASCO

SUSITNA JOINT VENTURE

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DATE OF PHOTOGRAPHY: SEPT. 16th, 1983

SCALE: 1" = 500'

DISCHARGE at SUNSHINE: 21,100 cfs

# GOOSE CREEK C

FIGURE A-18

PREPARED FOR:

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SUSITNA JOINT VENTURE

## Montana Creek

Montana Creek originates in the Talkeetna Mountains and flows west through the Susitna lowlands to the Susitna River (Figure A-19). Pink and chum salmon were observed spawning just upstream from the tributary mouth. Chinook and coho salmon spawn in upstream habitats. The flow regime is similar to that of Willow Creek (Figures 2.2 through 2.5). Water depths during 21,100 cfs are sufficient to allow passage from the mainstem to Montana Creek. Montana Creek has a relatively steep gradient, with essentially no backwater zone at mainstem flows of up to 38,000 cfs, and with approximately 600 feet of backwater at 52,000 cfs. The side channels entering Montana Creek from the north are overtopped between 38,000 cfs and 52,000 cfs. During the past 30 years the sandbars at the confluence of Montana Creek and the Susitna River have become more vegetated and morphologically stable. However, the morphology of the channel between measurement sites A and B and the confluence change each year (Figure A-20 and Photo A-8). At point A and B the water depth and velocity were 1.8 feet and 3.1 fps, and 1.2 feet and 2.8 fps, respectively. At point C the water depth and velocity were 1.3 feet and 7.1 fps, while at point D they were 1.1 feet and 3.2 fps.

The effect of with-project flows will be limited to slightly reduced backwater zones, and will not affect access. With-project flows will probably cause deposition of the Montana Creek bedload closer to the confluence with the mainstem, whereas now the bedload is deposited further upstream. High flows in Montana Creek will be able to move the deposited material out of the mouth even though it is deposited further down the channel

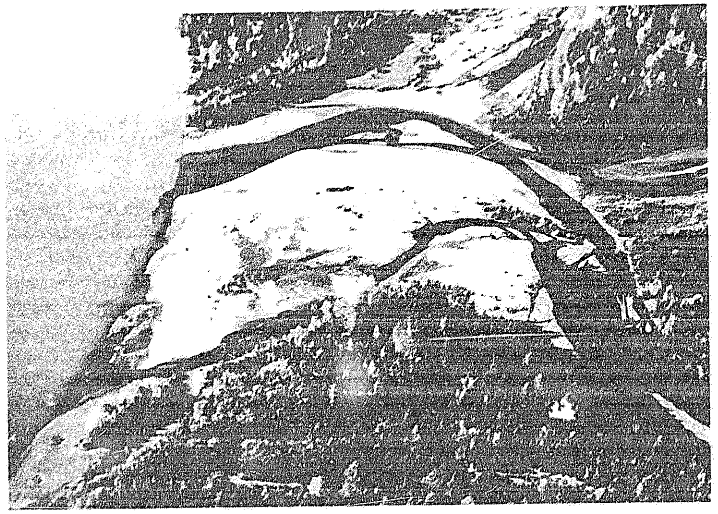
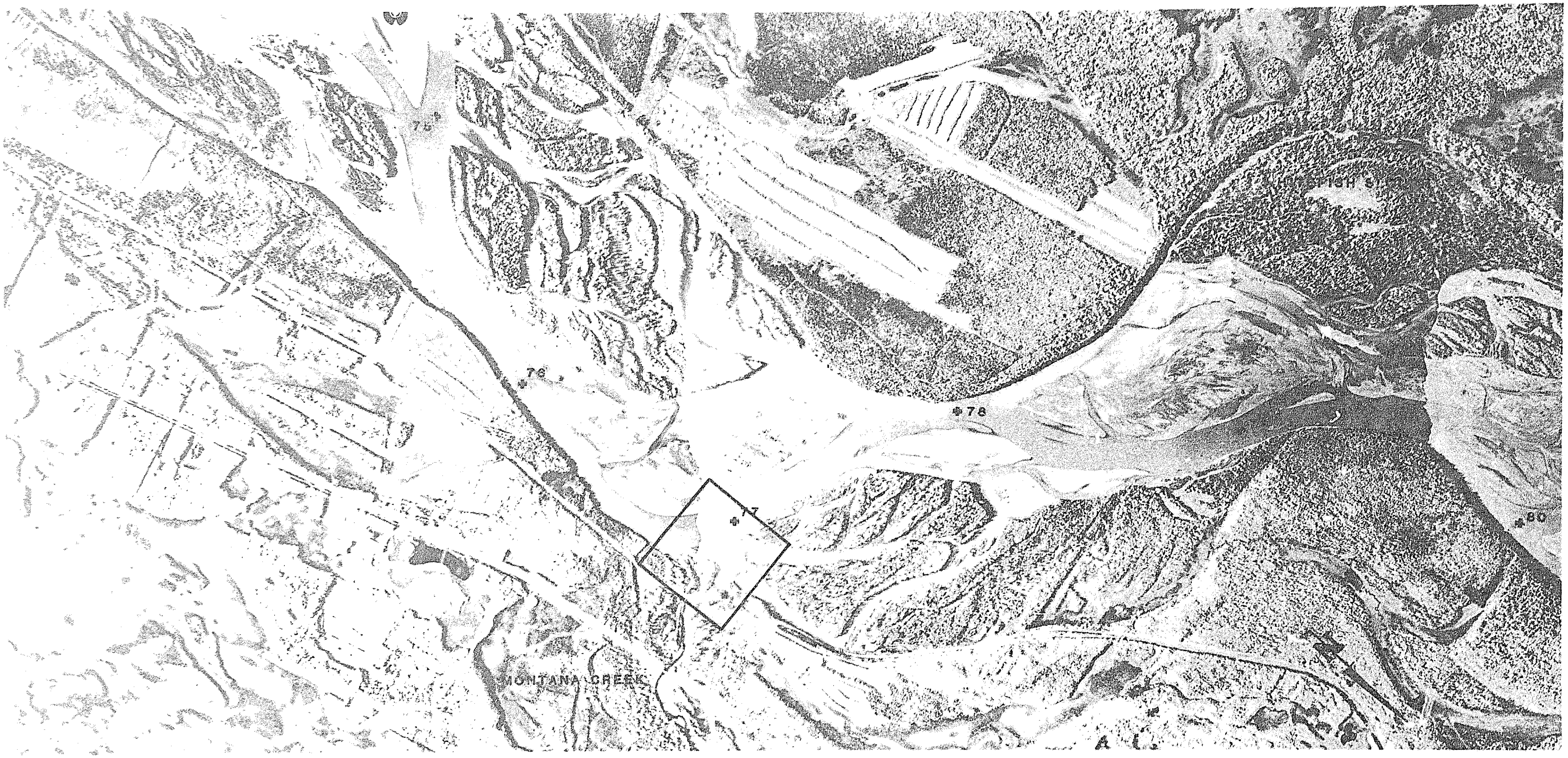


PHOTO A-8

Montana Creek (RM 77.0) flows from right to left center. The Susitna River mainstem flows from upper left to lower left. Photo taken 9/11/84, discharge at Sunshine 23,600 cfs.




2000 1000 0 2000 4000

SCALE IN FEET

LOWER SUSITNA RIVER

DISCHARGE AT SUNSHINE: 21,100 cfs

DATE OF PHOTOGRAPHY: SEPTEMBER 16, 1983

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FIGURE A-19

LOCATION OF MONTANA CREEK

PREPARED FOR:

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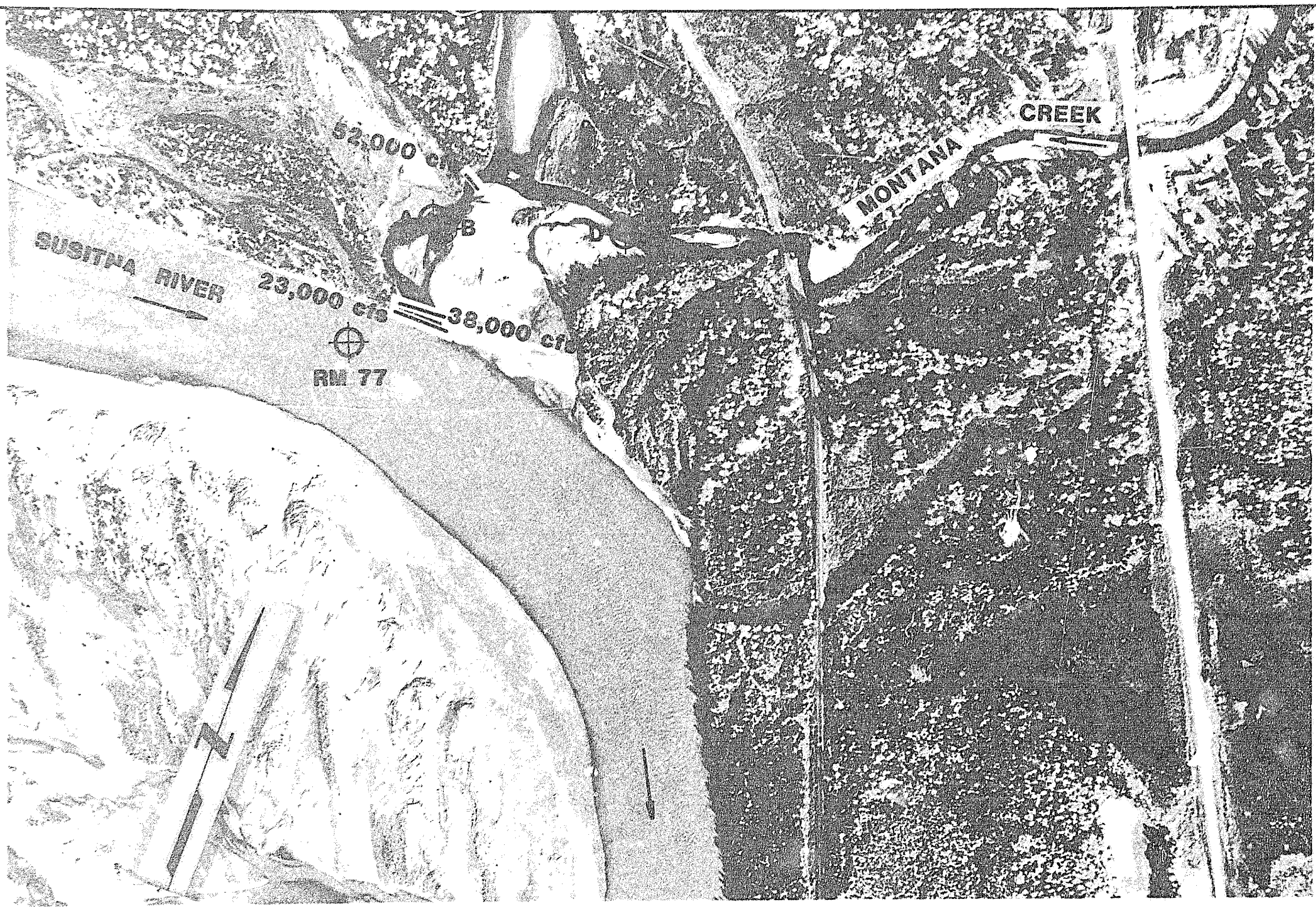
SUSITNA JOINT VENTURE

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DATE OF PHOTOGRAPHY: SEPT. 16th, 1983

SCALE: 1" = 500'

DISCHARGE at SUNSHINE: 2[illegible],100cfs

# MONTANA CREEK

FIGURE A-20

PREPARED FOR:

HARZA-EBASCO

SUSITNA JOINT VENTURE

## Rabideux Creek

Rabideux Creek originates in the Susitna lowlands and flows southeast to the Susitna River (Figure A-21). Chinook, sockeye, pink, chum and coho salmon spawn in upstream habitats. The flow regime is similar to that of the Deshka River (Figures 2.2 through 2.5). At 21,100 cfs passage appears feasible. There is one reach that may provide problems. The bar at the mouth changes shape year to year, depending on the high flows from Rabideux Creek (Figure A-22 and Photo A-9). The confluence with the Susitna River has been morphologically stable since 1951.

The effect of with-project flows will be limited to reducing the backwater zones and will not affect access or morphologic stability of the tributary mouth.



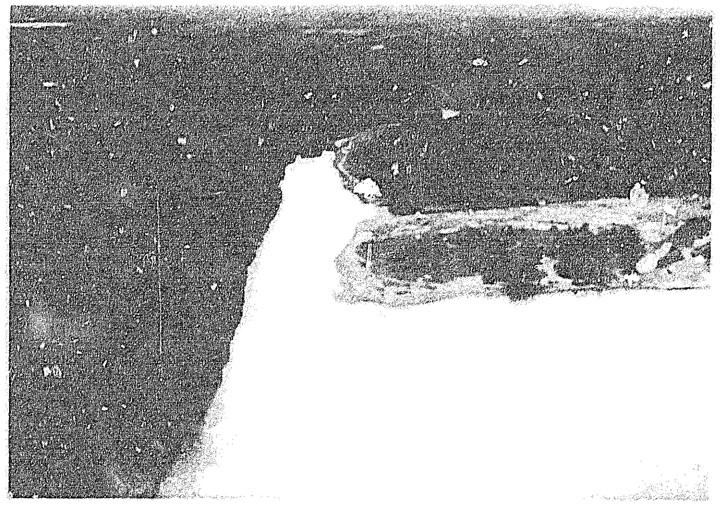
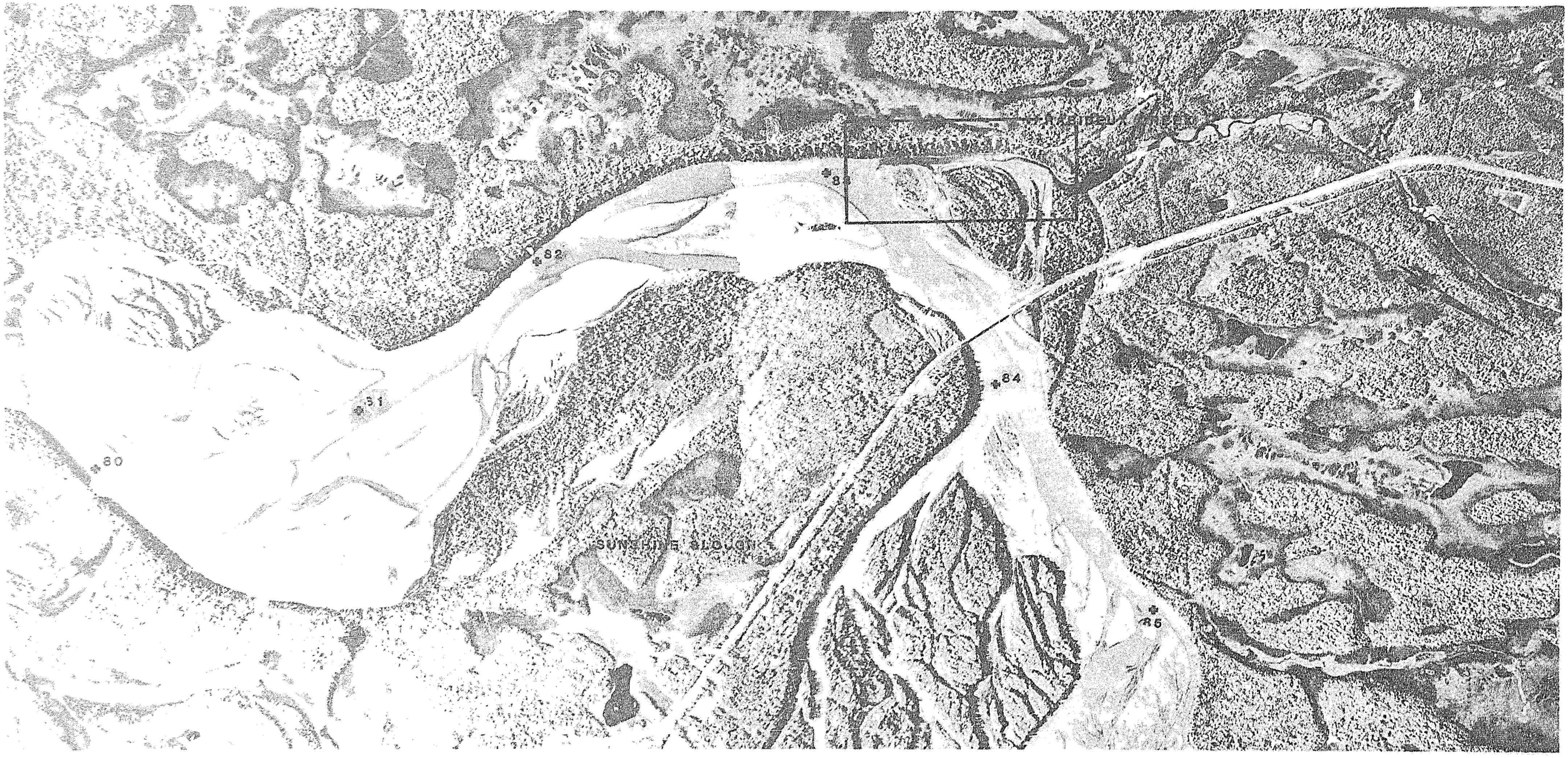


PHOTO A-9

Looking upstream at Rabideux Creek (RM 83.1). The Susitna River mainstem flows from center right to bottom center. Photo taken 8/31/84, discharge at Sunshine 38,000 cfs.




DATE OF PHOTOGRAPHY: SEPTEMBER 16, 1983

**LOWER SUSITNA RIVER**

DISCHARGE AT SUNSHINE: 21,100 cfs

2000 1000 0 2000 4000

SCALE IN FEET

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**LOCATION OF RABIDEUX CREEK**

FIGURE A-21

PREPARED FOR:

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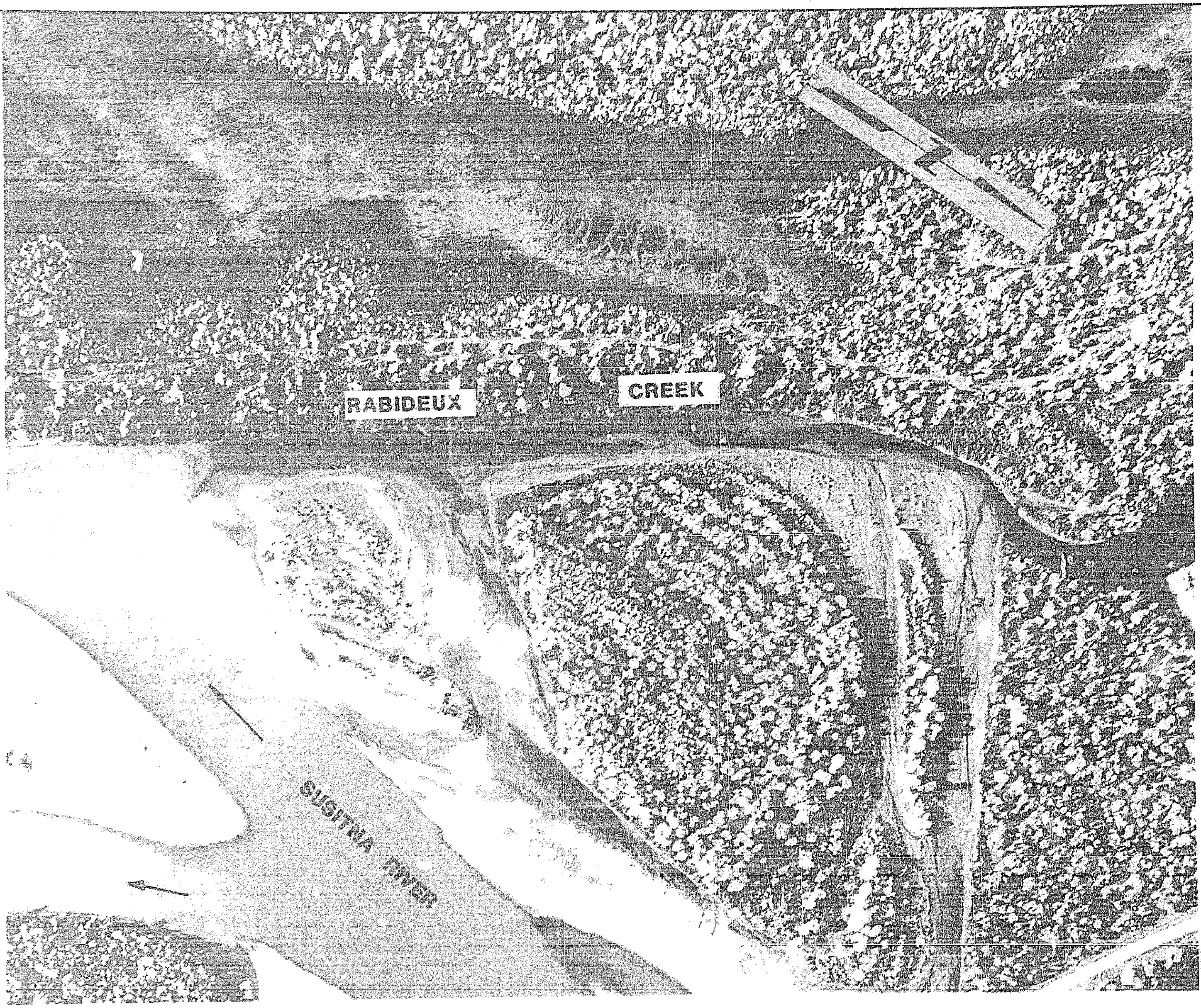
SUSITNA JOINT VENTURE

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DATE OF PHOTOGRAPHY: SEPT. 16th, 1983

SCALE: 1" = 500'

DISCHARGE at SUNSHINE: 21,100 cfs

# RABIDEUX CREEK

FIGURE A-22

PREPARED FOR:

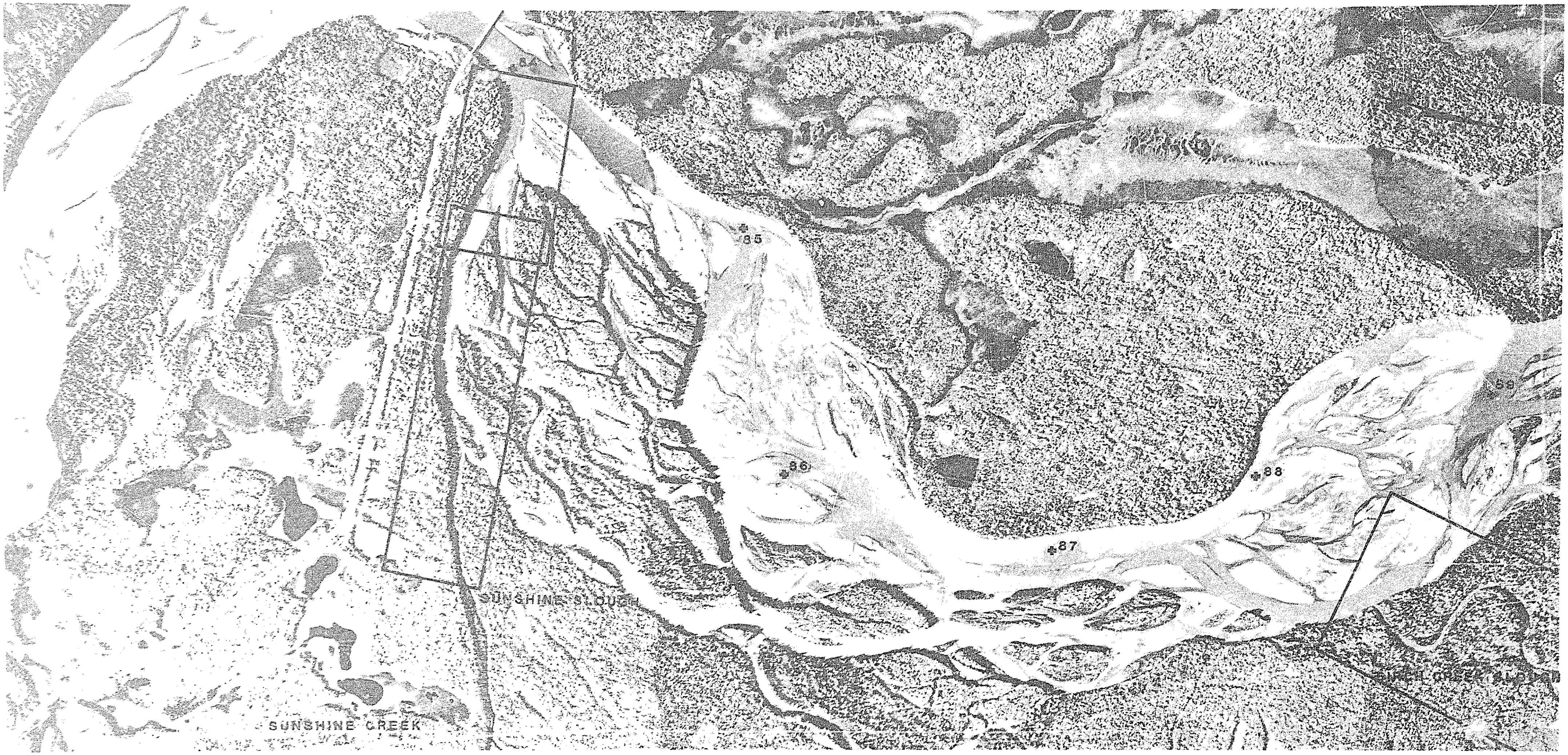
HARZA-EBASCO

SUSITNA JOINT VENTURE

## Sunshine Creek

Sunshine Creek originates in the Susitna River lowlands and flows southwest to the Susitna River (Figure A-23). Pink and chum salmon were observed spawning just upstream of the tributary mouth during 1984. Chinook, sockeye, pink, chum and coho spawn in the upstream habitats. The flow regime is similar to that of the Deshka River (Figures 2.2 through 2.5). The effect of the many lakes in the basin is to flatten out the peak flows from rainfall events and to maintain a relatively higher baseflow, as compared to a basin without lakes. At a mainstem flow of 21,100 cfs, the mouth of Sunshine Creek extends down a side channel to Sunshine Slough (from point A to point B, Figure A-24 and A-25). During the site visit of September 19, 1984, 1.5 feet was the minimum depth in the low water channel from the mainstem Susitna River to the mouth of Sunshine Creek.

The effect of with-project flows will be to reduce the magnitude of flood flows causing morphologic changes in Sunshine Slough. The slough would tend to become more stable. The extent of the backwater area may be reduced by with-project flows, but this would not affect access conditions. The tributary mouth has been relatively stable since 1951, and should not be affected by with-project flows.




## LOWER SUSITNA RIVER

DISCHARGE AT SUNSHINE: 21,100 cfs

DATE OF PHOTOGRAPHY: SEPTEMBER 16, 1983

2000 1000 0 2000 4000

SCALE IN FEET

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LOCATION OF SUNSHINE CREEK & BIRCH CREEK

FIGURE A-23

PREPARED FOR:

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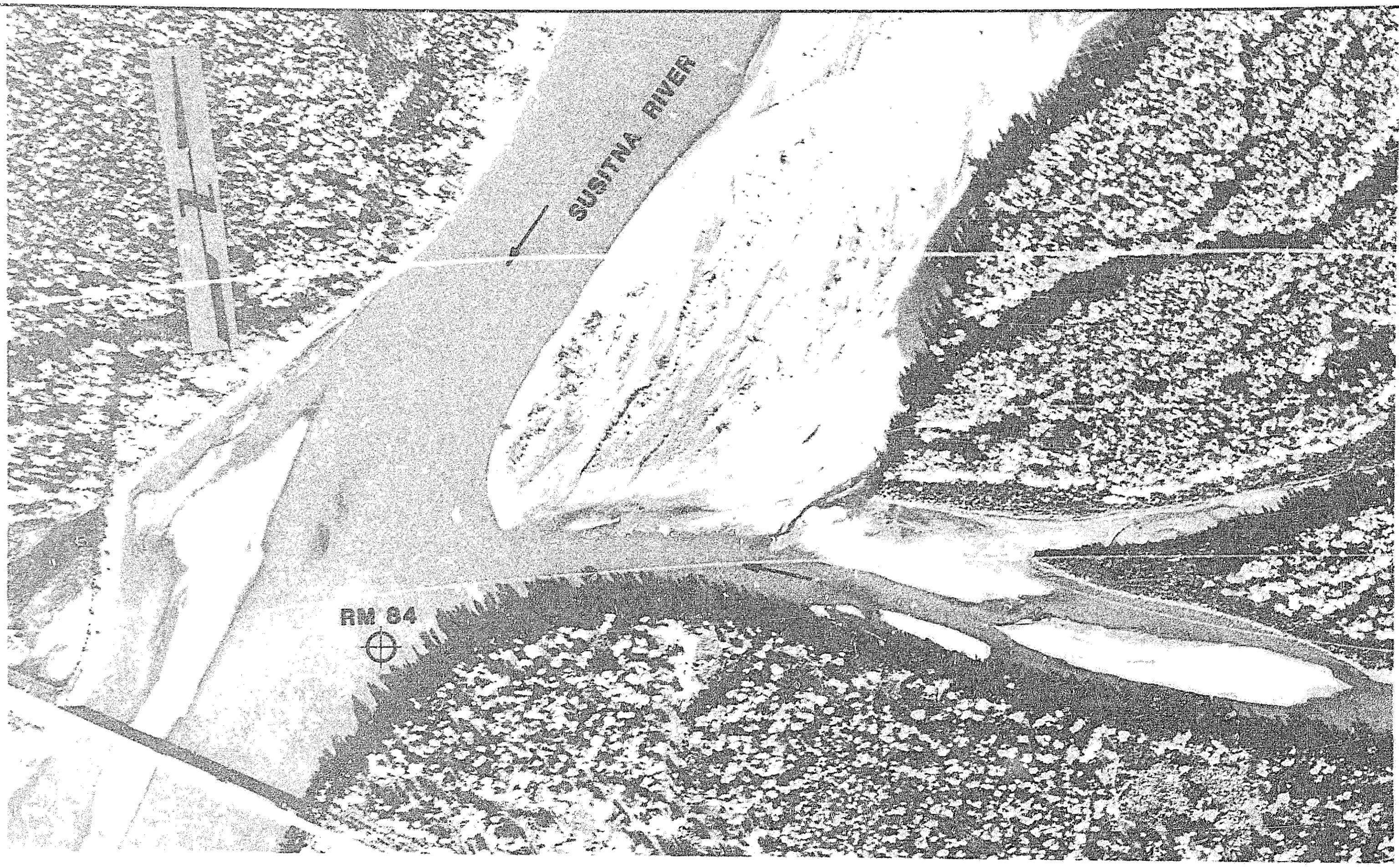
SUSITNA JOINT VENTURE

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DATE OF PHOTOGRAPHY: SEPT. 16th, 1983

SCALE: 1"= 500'

DISCHARGE at SUNSHINE: 21,100 cfs

# SUNSHINE CREEK A

FIGURE A-24

PREPARED FOR:

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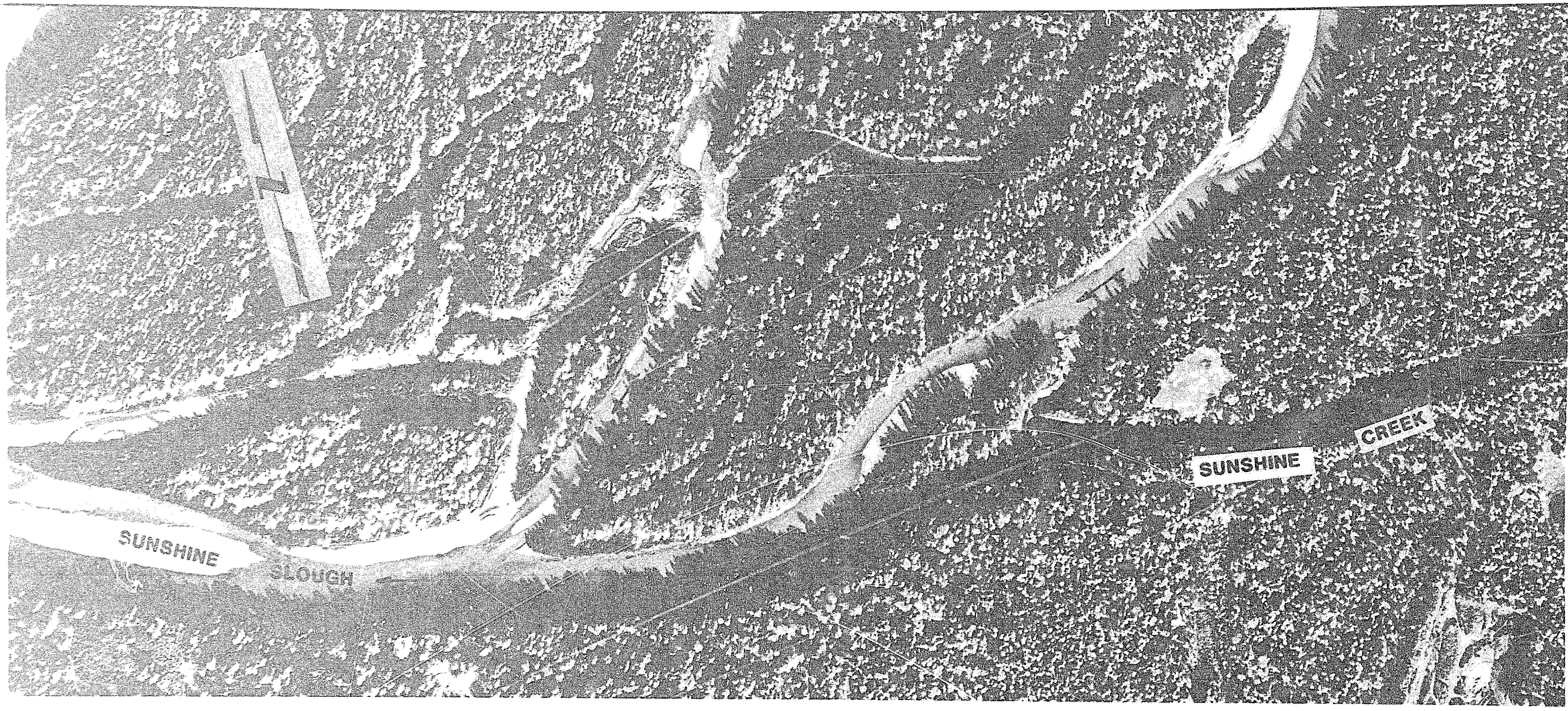
SUSITNA JOINT VENTURE

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DATE OF PHOTOGRAPHY: SEPT. 16th, 1983

SCALE: 1" = 500'

DISCHARGE at SUNSHINE: 21,100cfs

# SUNSHINE CREEK B

FIGURE A-25

PREPARED FOR:

HARZA-EBASCO

SUSITNA JOINT VENTURE

## Birch Creek

Birch Creek originates in the Susitna River lowlands and flows southwest to the Susitna River (Figure A-23 and A-26). Pink salmon were observed spawning near the mouth of Birch Creek and in Birch Creek Slough below the confluence in 1984. Chinook, sockeye, pink, chum and coho salmon spawn in upstream habitats. The flow regime is similar to that of the Deshka River (Figures 2.2 through 2.5). The effect of the many lakes in the basin, especially Fish Lake, is to flatten out the peak flows from rainfall events and to maintain a relative high baseflow, as compared to a basin without lakes. Birch Creek (Figure A-27) flows into Birch Creek Slough, which flows into one of the mainstem channels (Photo A-10). Birch Creek Slough has sufficient water for fish access at 21,100 cfs.

The extent of the backwater area in Birch Creek Slough may be reduced at with-project flows, but this would not affect access conditions. Between 1951 and 1974 an island between the mouth of Birch Creek Slough and the mainstem Susitna has eroded away. Since 1974 the tributary mouth has been relatively stable and should not be affected by with-project flows.



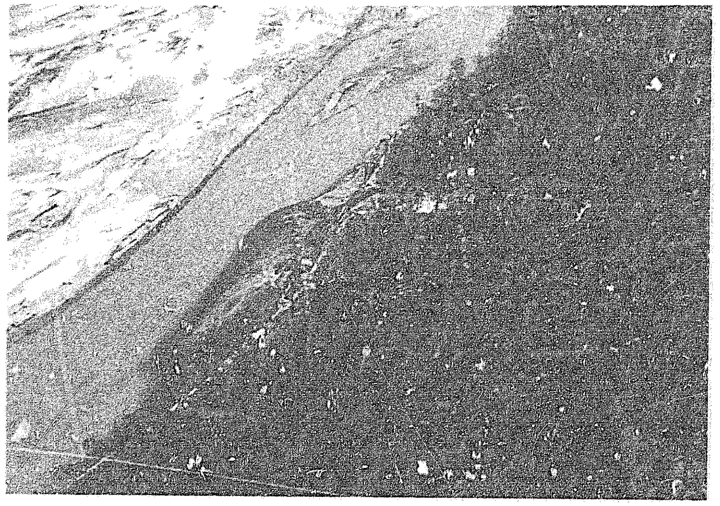

PHOTO A-10

Looking upstream with Birch Creek Slough (RM 89.2) flowing from center right to center. Photo taken 9/11/84, discharge at Sunshine 23,600 cfs.


2000 1000 0 2000 4000

SCALE IN FEET

## LOWER SUSITNA RIVER

DISCHARGE AT SUNSHINE: 21,100 cfs

DATE OF PHOTOGRAPHY: SEPTEMBER 16, 1983

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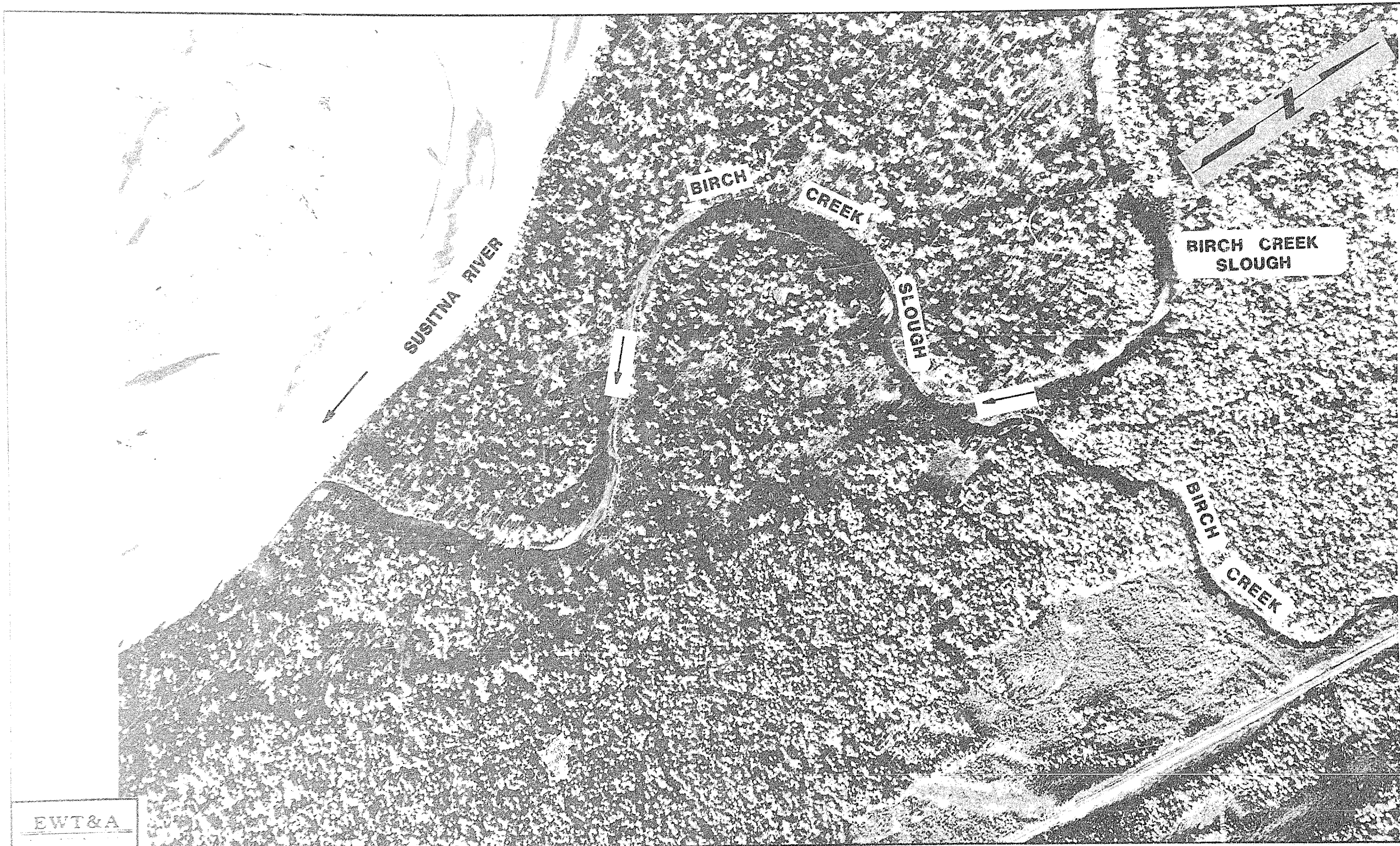
LOCATION OF TRAPPER CREEK & BIRCH CREEK

FIGURE A-26

PREPARED FOR:

HARZA-EBASCO

SUSITNA JOINT VENTURE

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PREPARED BY

R&M CONSULTANTS, INC.

DATE OF PHOTOGRAPHY: SEPT. 16th, 1983

SCALE: 1" = 500'

DISCHARGE at SUNSHINE: 21,100cfs

# BIRCH CREEK

FIGURE A-27

PREPARED FOR:

HARZA-EBASCO

SUSITNA JOINT VENTURE

## Trapper Creek

Trapper Creek originates in the Susitna lowlands and flows southeast to the Susitna River (Figure A-26). Pink and chum salmon were observed spawning just upstream of the tributary mouth during 1984. Chinook, sockeye, pink, chum and coho salmon spawn in upstream habitats. The flow regime is similar to that of the Deshka River, but has a smaller magnitude of flow (Figures 2.2 through 2.5). At 21,100 cfs, Trapper Creek extends down a side channel to the mainstem Susitna River. The channel is transitory, with its shape and water depth varying from year to year, depending on the magnitude of the peak flow that year. Comparing Figure A-28 with Photo A-13 shows how the channel changed shape from 1983 to 1984. During the field visit of September 18 1984, the channel shape was different from that shown in the aerial photo. Minimum depths in the low water channel varied between 0.4 and 0.6 feet. At 20,900 cfs fish were observed accessing both Trapper Creek and the ADF&G IFIM Trapper Creek study site (Figure A-28). Since 1951 the main channel of the Susitna River has shifted from the west side to the east side of the flood plain, increasing the length of the side channel from the mouth of Trapper Creek to the Susitna River.

The effect of with-project flows will be to reduce the magnitude of the flood flows causing morphologic changes in the channel downstream of Trapper Creek. The channel would tend to become relatively more stable and the vegetation may encroach on the channel. The backwater zones will be reduced by with-project flows, but this should not affect access conditions.



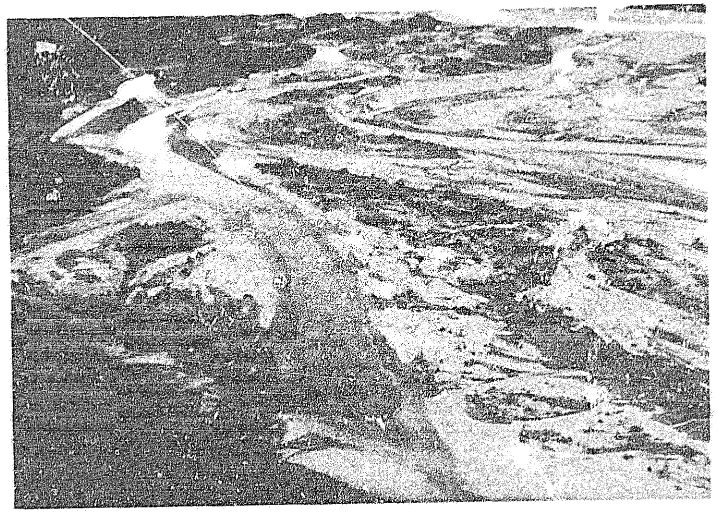
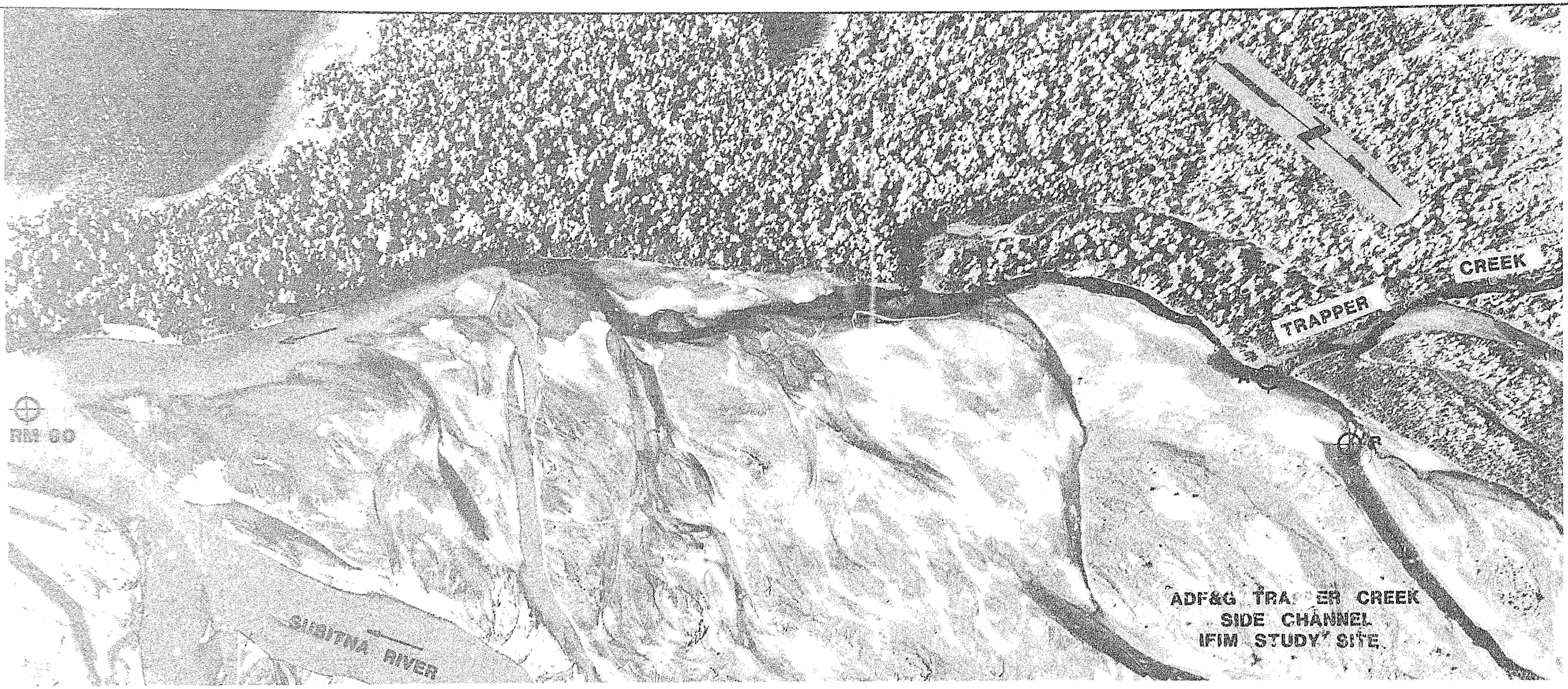


PHOTO A-11

Looking upstream at Trapper Creek Side Channel ADF&G IFIM Study Site, Trapper Creek (RM 91.5) flows from center left to bottom center. Photo taken 8/31/84, discharge at Sunshine 38,000 cfs.

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PREPARED BY:

R&M CONSULTANTS, INC.

ENGINEERS GEOLOGISTS HYDROLOGISTS SURVEYORS

DATE OF PHOTOGRAPHY: SEPT. 16th, 1983

SCALE: 1" = 500'

DISCHARGE at SUNSHINE: 21,100cfs

# TRAPPER CREEK

FIGURE A-28

PREPARED FOR:

HARZA-EBASCO

SUSITNA JO