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APPENDIX D

HYDRAULIC MODELS FOR USE IN ASSESSING THE REARING HABITAT OF JUVENILE SALMON IN SIX SIDE CHANNELS OF THE LOWER SUSITNA RIVER

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ABSTRACT

Six side channels (Island, Mainstem West Bank, Circular, Sauna, Sunset, and Trapper Creek) in the lower reach of the Susitna River were evaluated using an Instream Flow Incremental Methodology (IFIM) physical habitat simulation (PHABSIM) modelling approach to evaluate the effects that site flow and mainstem discharge have on rearing juvenile salmon habitat. These sites were thought to contain potential habitat conditions for rearing juvenile salmon and were chosen to range greatly in size, shape, and overtopping discharge.

Six hydraulic simulation models (either IFG-2 or IFG-4) were calibrated to simulate depths and velocities associated with a range of site-specific flows at these six modelling study sites. Comparisons between

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corresponding sites of simulated and measured depths and velocities indicate that the calibrated models provide reliable estimates of depths and velocities within their recommended calibration ranges.

The recommended calibration ranges over which these models can hydraulically simulate the habitat of rearing juvenile salmon is: Island Side Channel from 35,000 to 70,000 cfs mainstem discharge; Mainstem West Bank Side Channel from 18,000 to 48,000 cfs; Circular Side Channel from 36,000 to 63,000 cfs; Sauna Side Channel from 44,000 to 63,000 cfs; Sunset Side Channel from 32,000 to 67,000 cfs; and Trapper Creek Side Channel from 20,000 to 66,000 cfs.

DRAFT

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF APPENDIX FIGURES

Appendix Figure

LIST OF APPENDIX FIGURES (Continued)

LIST OF APPENDIX FIGURES (Continued)

LIST OF APPENDIX FIGURES (Continued)

LIST OF APPENDIX TABLES

LIST OF APPENDIX TABLES (Continued)

INTRODUCTION

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About 40% of the annual discharge of the lower Susitna River at Park's Highway bridge originates from the mainstem Susitna River above the confluence of the Talkeetna and Chulitna Rivers. Thus, operation of the proposed hydroelectric project will alter the natural flow regime of this lower river reach beyond the normal weekly variations in flow which occur naturally during the open water season.

One of the predominate aquatic habitat types in this lower river reach which maybe affected by such flow alternations are side channels. Side channel areas in this river reach currently provide habitat for rearing juvenile salmon. The quantity and quality of juvenile salmonid rearing habitat in side channels in this river reach is dependent on a multitude of interrelated habitat variables, including water depth and velocity, which are intimately related to mainstem discharge.

This appendix presents results of the physical habitat modelling simulation efforts that Alaska Department of Fish and Game (ADFG) Su Hydro personnel conducted in the open water season of 1984. The objective of the study was to provide calibrated hydraulic simulation models for selected Task 14 lower river juvenile salmon habitat modelling study sites. The approach of the study was to apply a methodology which utilizes water depth and velocity as the dominant hydraulic variables to quantify the responses of rearing habitat to changes in site flow and mainstem discharge. The methodology used was the system developed by the U.S. Fish and Wildlife Service (USF&WS) Instream Flow Group (IFG) using the Instream Flow Incremental Methodology (IFIM) Physical Habitat

Simulation (PHABSIM) modelling system (IFG 1980, Bovee 1982). The calibrated hydraulic simulation models will be utilized to assess how site flows and mainstem discharge affect juvenile salmon rearing habitat in side channel habitats of the lower Susitna River reach.

METHODS

Analytical Approach

The current most accepted methodology used for assessing habitat responses to flow variations is the USFWS, IFIM, PHABSIM modelling system. The IFIM, PHABSIM modelling system is a collection of computer programs used to simulate both the available hydraulic conditions and usable habitat at a study site for a particular species/life phase as a function of flow. It is based on the theory that changes in riverine habitat conditions can be estimated from a sufficient hydraulic and biologic field data base. It is intended for use in those situations where flow regime and channel structure are the major factors influencing river habitat conditions.

The modelling system is based on a three step approach. The first step uses field data to calibrate hydraulic simulation models to forecast anticipated changes in physical habitat variables important for the species/life phase under study as a function of flow. The second step involves the collection and analysis of biological data to determine the behavioral responses of a particular species/life phase to selected physical habitat variables important for the species/life phase under study. This information is used to develop weighted behavioral response criteria curves (e.g., utilization curves, preference curves, or suitability curves). The third step combines information gained in the first two steps to calculate weighted usable area (WUA) indices of habitat usability as a function of flow for the species/life phase under study.

Hydraulic modelling is of central importance to the PHABSIM system. The primary purpose of incorporating hydraulic modelling into the analytical approach is to make the most efficient use of limited field observations to forecast hydraulic attributes of riverine habitat (depths and velocities) under a broad range of unobserved streamflow conditions.

The IFG specifically developed two hydraulic models (IFG-2 and IFG-4) during the late 1970's to assist fisheries biologists in making quantitative evaluations of effects of streamflow alterations on fish habitat. The IFG-2 hydraulic model is a water surface profile program that is based on open channel flow theory and formulae. The IFG-2 model can be used to predict the horizontal distribution of depths and mean column velocities at 100 points along a cross section for a range of streamflows with only one set of field data. The IFG-4 model provides the same type of hydraulic predictions as the IFG-2 model, but it is more strongly based on field observations and empiricism than hydraulic theory and formulae. Although a minimum of two data sets are required for calibrating the IFG-4 model, three are recommended. Either model can be used to forecast depths and velocities occurring in a stream channel over a broad range of streamflow conditions.

The IFG-4 model, which is based upon a greater number of observed sets of field data (i.e. flow levels), generally can be used to model a greater range of flow conditions than the IFG-2 model. Additionally, since the IFG-4 model is more dependent upon observed depths and velocities than the IFG-2 model, predicted depths and velocities can be directly compared with the observed values. This comparison is a useful tool for verifying the models.

Both models are most applicable to streams of moderate size and are based on the assumption that steady flow conditions exist within a rigid stream channel. A stream channel is rigid if it meets the following two criteria: (1) it must not change shape during the period of time over which the calibration data are collected, and (2) it must not change shape while conveying streamflows within the range of those that are to be simulated. Thus a channel may be "rigid" by the above definition, even though it periodically (perhaps seasonally) changes course. Streamflow is defined as "steady" if the depth of flow at a given location in the channel remains constant during the time interval under consideration (Trihey 1980).

In this analysis, all streamflow rates were referenced to the average daily discharge of the Susitna River at the U.S. Geological Survey (USGS) stream gage at Sunshine, Alaska (station number 15292780). This location was selected as the index station primarily because it is the gage located near the center of the river segment that is of greatest interest in this particular analysis. The target mainstem discharge range for data collection was from 12,000 to 75,000 cfs.

species-specific life history requirements. Criteria for application of the representative concept are less restrictive, enabling this concept to be used when only limited biological information is available or when critical habitat conditions cannot be identified with any degree of certainty.

In the critical concept, a study area is selected because one or more of the physical or chemical attributes of the habitat are known to be of critical importance to the fish resource. That is, recognizable physical or chemical characteristics of the watershed hydrology, instream hydraulics, or water quality are known to control species distribution or relative abundance within the study area. Because of this, an evaluation of critical areas will provide a meaningful index of species response in the overall critical study area.

The representative concept acknowledges the importance of physical habitat variables throughout the entire study stream for sustaining fish populations. Thus, under the representative concept approach, study areas are selected for the purpose of quantifying relationships between streamflow and physical habitat conditions important for species/life phase under study at selected key locations (representative reaches) that collectively exemplify the general habitat characteristics of the entire river segment inhabited by the species/life phase under study.

For this study, an adaptation of the representative concept was the approach used to assess how mainstem discharges affect the rearing habitat of juvenile salmon in the side channel habitat of the Kashwitna to Talkeetna reach of the Susitna River. The six specific sites modelled in this study were chosen by ADF&G Su Hydro Resident and Juvenile Anadromous (RJ) project personnel in conjunction with ADF&G Su Hydro Aquatic Habitat and Instream Flow Study (AH) project and E. Woody Trihey and Associates (EWTA) personnel from lower river side channels which met the following basic criteria:

1. The sites were chosen to range greatly in size, shape, and overtopping discharge;

2. The sites were thought to contain potential habitat conditions for rearing juvenile salmon;

3. The sites were judged by AH project and EWTA personnel to be readily modelled using IFG methods;

4. The sites were accessible by boat at normal mainstem discharges during the open-water season; and,

5. The sites were above Kashwitna landing and therefore much easier to sample for logistical purposes.

The six sites chosen for modelling complemented other sites modelled using the RJHAB method. All were side channels as the majority of potential habitat in the lower river is composed of side channel habitat, and much of the other habitat is affected primarily by mainstem backwater which is difficult to model with the IFG model.

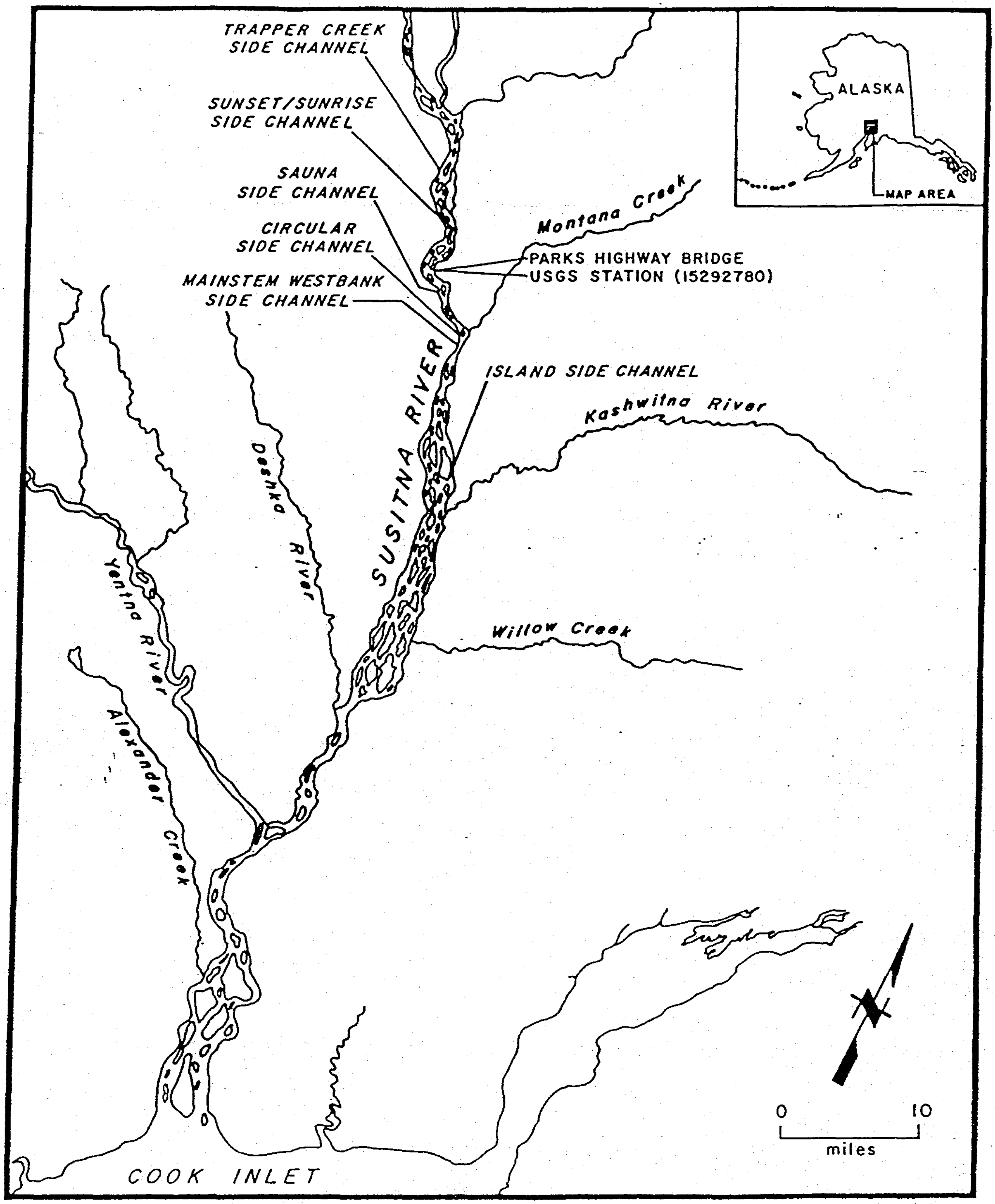
Appendix Figure D-1 shows the location of each of these six study sites selected for study based on the above criteria. The river mile location of each of the six sites is presented in Table D-1.

General Techniques for Data Collection

A study reach was selected for detailed evaluation in each of the six side channel sites. The length of the reach was determined by placing enough transects within the area to adequately represent the major macrohabitat types of the particular side channel area.

Cross sections were located within each study reach following field methods described in Bovee and Milhous (1978) and Trihey and Wegner (1981). Cross sections were located to facilitate collection of hydraulic and channel geometry measurements of importance in evaluating flow effects on salmon rearing habitat. Field data were obtained to describe a representative spectrum of water depth and velocity patterns, cover, and substrate composition at each side channel reach.

The number of cross sections established at the study reaches varied from four to eight. The end points of each cross sections were marked with 30-inch steel rods (headpins) driven approximately 28 inches into the ground. The elevation of each headpin was determined by differential leveling using temporary benchmarks set at assumed elevations of 100.00 feet.



Appendix Figure D-1. Location of the six IFG hydraulic modelling sites in the lower Susitna River.

Appendix Table D-1. The six lower river IFG modelling sites with corresponding river mile location.

Side Channel Site	River Mile
Island Side Channel	63.2
Mainstem West Bank Side Channel	74.4
Circular Side Channel	75.3
Sauna Side Channel	79.8
Sunset Side Channel	86.9
Trapper Creek Side Channel	91.6

Cross section profiles were measured with a level, survey rod, and fiberglass tape. Horizontal distances were recorded to the nearest 1.0 foot and streambed elevations to the nearest 0.1 foot. Water surface elevations at each cross section in the study site were determined to the nearest 0.01 feet by differential leveling or reading staff gages located on the cross section.

Streambed elevations used in the hydraulic models were determined by making a comparison between the surveyed cross section profile and the cross section profiles derived by subtracting the flow depth measurements at each cross section from the surveyed water surface elevation at each calibration flow (Trihey 1980).

A longitudinal streambed profile (thalweg profile) was surveyed and plotted to scale for each modeling site (Quane et al. 1985).

The water surface elevation at which no flow occurs (stage of zero flow) at each cross section in the study site was determined from the streambed profile. If the cross section was not located on a hydraulic control, then the stage of zero flow was assumed equal to that of the control immediately downstream of the cross section.

Discharge measurements were made using a Marsh-McBirney or Price AA velocity meter, topsetting wading rod, and fiberglass tape. Discharge measurements were made using standard field techniques (Buchanan and Somers 1969; Bovee and Milhous 1978; Trihey and Wegner 1981). Depth and velocity measurements at each calibration flow were recorded for the same respective points along the cross sections by referencing all horizontal measurements to the left bank headpin.

Cover and substrate values were also determined for each cell along modelling transects. Methods described in Schmidt et al. (1984) were used to code cover (Appendix Table 2). Substrate categories were classified by visual observation employing the substrate classifications presented in Appendix Table 3. The distribution of various substrate types was indicated on field maps. Substrates were classified using a single or dual code. In those instances that a dual code was used, the first code references the most predominant (i.e., 70% rubble/30% cobble = RU/CO).

General Techniques for Calibration

The calibration procedure for each of the hydraulic models was preceded by field data collection, data reduction, and refining the input data. The field data collection entailed establishing cross sections along which hydraulic data (water surface elevations, depths, and velocities) were obtained at each of the different calibration flows. The data reduction entails determining the streambed and water surface elevations, velocity distribution and stage of zero flow for each cross section; and, determining a mean discharge for all the cross sections in the study site. Refining the input data entailed adjusting the water surface elevations and velocities so that the forecasted data agreed more closely to the observed. A model was considered calibrated when: 1) the majority of predicted water surface profiles were within ±0.05 ft

Table D-2. Percent cover and cover type categories.

Substrate	Code	% Cover	Code
silt, sand (no cover)	1	0-5	.1
emergent vegetation	2	6-25	.2
aquatic vegetation	3	26-50	.3
1-3" gravel	4	51-75	.4
3-5" rubble	5	76-100	.5
5" cobble, boulder	6		
debris	7		
overhanging riparian vegetation	8		
undercut bank	9		

Appendix Table D-3. Substrate classifications.

Substrate	Particle Size	Classification
Silt	Silt	1
		2
Sand	Sand	3
		4
Small Gravel	1/8-1"	5
		6
Large Gravel	1-3"	7
		8
Rubble	3-5"	9
		10
Cobble	5-10"	11
		12
Boulder	10"	13

of the observed elevations and 2) the majority of predicted velocities were within ±0.10 ft/sec of the measured velocities. A calibrated IFG-4 model gives velocity adjustment factors in the range of 0.9 to 1.1, and relatively few velocity prediction errors. The velocity adjustment factor is the ratio of the computed (observed) discharge to the predicted discharge.

An IFG-2 model does not have velocity adjustment factors and must be reviewed with the observed data before its considered calibrated.

General Techniques for Verification

The verification of how well each of these six hydraulic models simulated their respective site flows was performed by hydraulic engineers of EWT&A. The approach they used to assess the quality of each model was based on two levels of criteria. The first was qualitative evaluation of four separate sub-criteria. These sub-criteria were:

1. How well does the model conform to the established IFG and EWT&A guidelines?

2. How well does the extrapolation range of the model conform to the desired range?

3. Are the models appropriate for the species and life stage being considered?

4. How well do the ranges of depth and velocities of the forecasted data conform to the ranges of depth and velocity of the suitability criteria curves being considered based on a "visual" evaluation?

After the first level of qualitative evaluation was performed, an overall rating was given to the various segments of each model. The ratings given were excellent, good, acceptable, and unacceptable. Figures depicting these rating are presented for each site in the results section. The second level in the verification process required a statistical analytical evaluation of the models calibration. It was only performed when the forecast capabilities of either the IFG-2 and IFG-4 model were not given an excellent rating in the level one evaluation. For a detailed explanation of the verification analysis see Appendix Attachment 1.

RESULTS

The results of the physical habitat simulation modelling studies are presented below by study site. The six lower river side channel IFG modelling sites with type of hydraulic model used, dates calibration flows were measured, and corresponding site specific flows and mainstem discharges for the open water period in 1984 are presented in Appendix Table D-4. For each study site, a general site description, a summary of data collected at the study sites, a description of the model calibration procedures used to calibrate the model for the study site, the verification of the model at the study site, and the recommended application of the model for the study site are presented.

Appendix Table D-4. The six lower river side channel IFG modelling sites with type of hydraulic model used, dates calibration flows measured, and corresponding site specific flows and mainstem discharges for the open water period in 1984.

Side Channel Site (RM)	Type of Hydraulic Model	Date Calibration Flow Measured	Site Specific Flow (cfs)	Mainstem Discharge at Sunshine (cfs)
Island Side Channel (63.2)	IFG-2	July 25	338	56,100
Mainstem West Bank (74.4)	IFG-4	September 2	450	32,000
		September 20	310	30,500
		September 25	6	
Circular Side Channel (75.3)	IFG-4	July 24	204	55,200
		August 17	50	42,500
Sauna Side Channel (79.8)	IFG-2	July 23	52	52,000
Sunset Side Channel (86.9)	IFG-4	July 22	496	57,800
		August 17	127	42,500
Trapper Creek Side Channel (91.6)	IFG-4	September 18	16	20,900
		August 16	32	44,000
		July 21	389	57,700

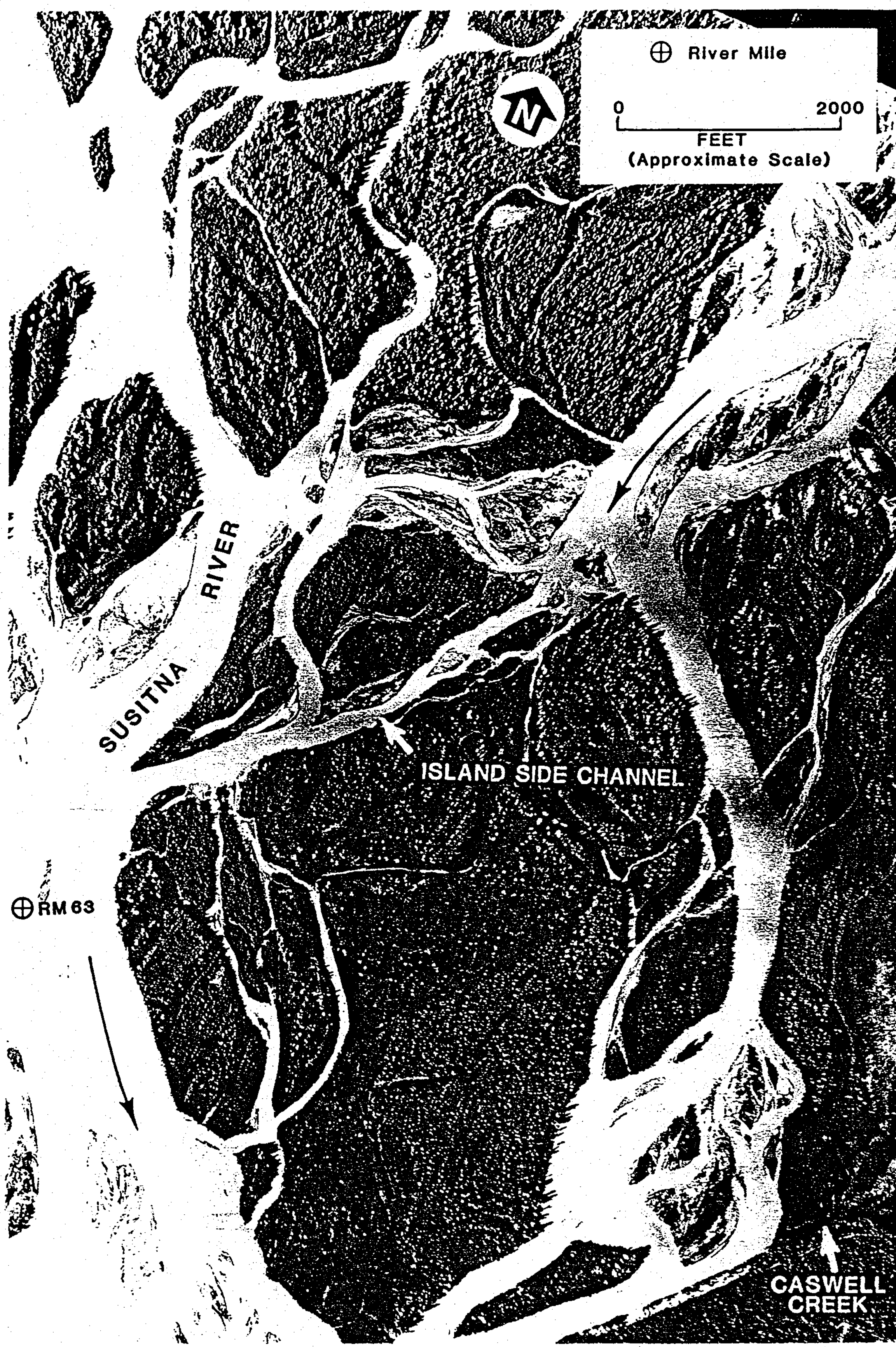
Island Side Channel (RM 63.2)

Site Description

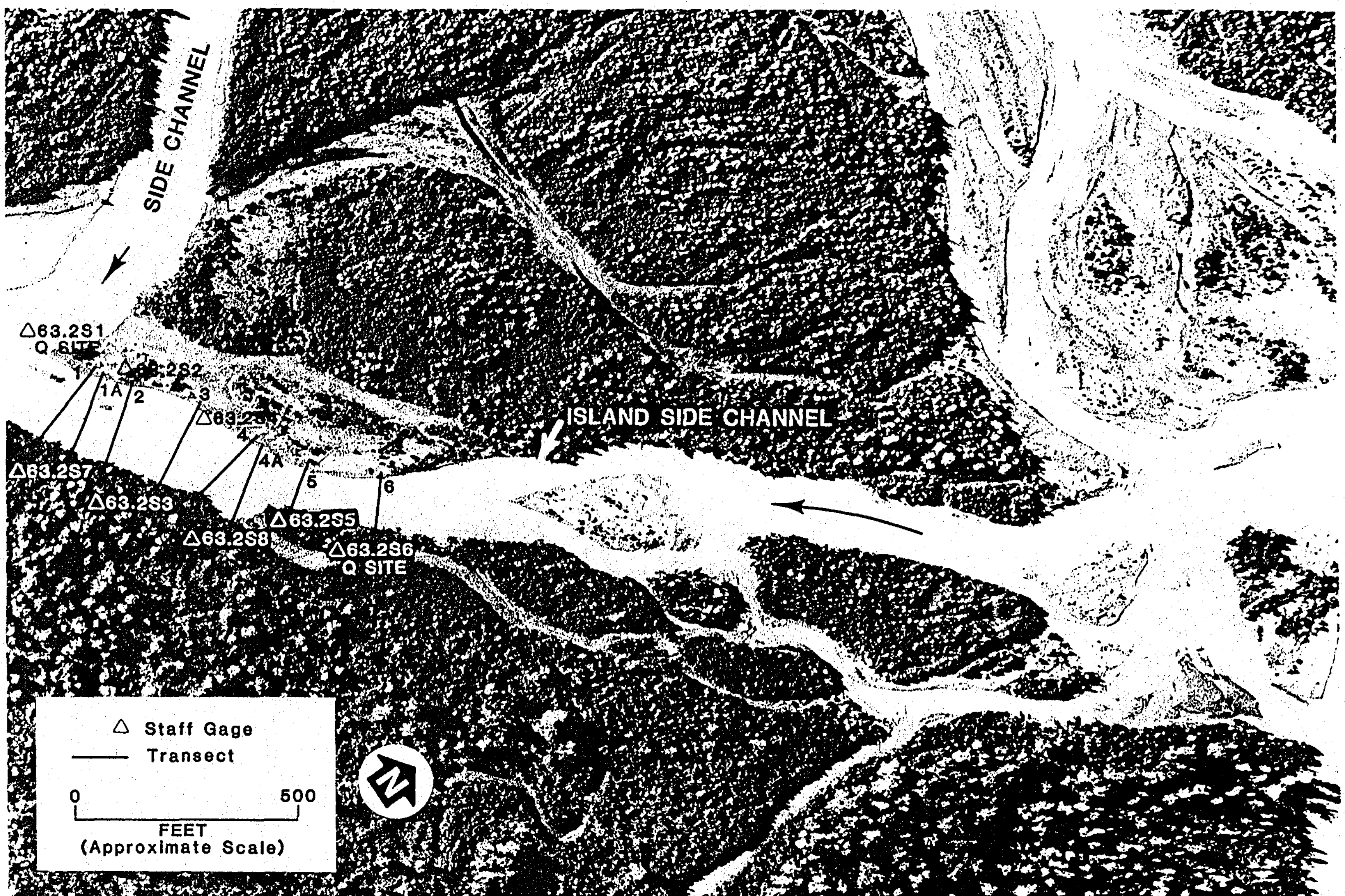
Island Side Channel is located on the east bank of the main channel of the Susitna River at river mile (RM) 63.2 (Appendix Figure D-2). This side channel is located downstream of a braided, vegetated floodplain and is not directly connected to the main channel Susitna River. It is approximately 0.7 miles in length with both the mouth and head portions adjoining side channel networks. Breaching flows in this side channel result from overtopping of the head by an adjoining larger side channel. Prior to breaching, flow in the side channel is greatly reduced with a series of pools remaining (Quane et al. 1985).

The IFG modelling site selected for Island Side Channel during the 1984 open water field season, was 735 feet in length and was located in the lower portion of the side channel (Appendix Figure D-3). The site generally consists of a pool-riffle-pool sequence. Based on assessments by Quane et al. (1985), an area of backwater extends through the study site to a point at least 1,100 feet upstream from the mouth of the side channel at a non-breaching mainstem discharge of 35,000 cfs. During mainstem discharges of 38,000 to 66,700 cfs, the area of backwater extends throughout the study site.

The right bank of the study site is steep, being approximately five feet high, and results from erosional effects. The primary riparian vegetation along this bank is alder. There are also two side pocket areas,



Appendix Figure D-2. Overview of Island Side Channel (RM 63.2).



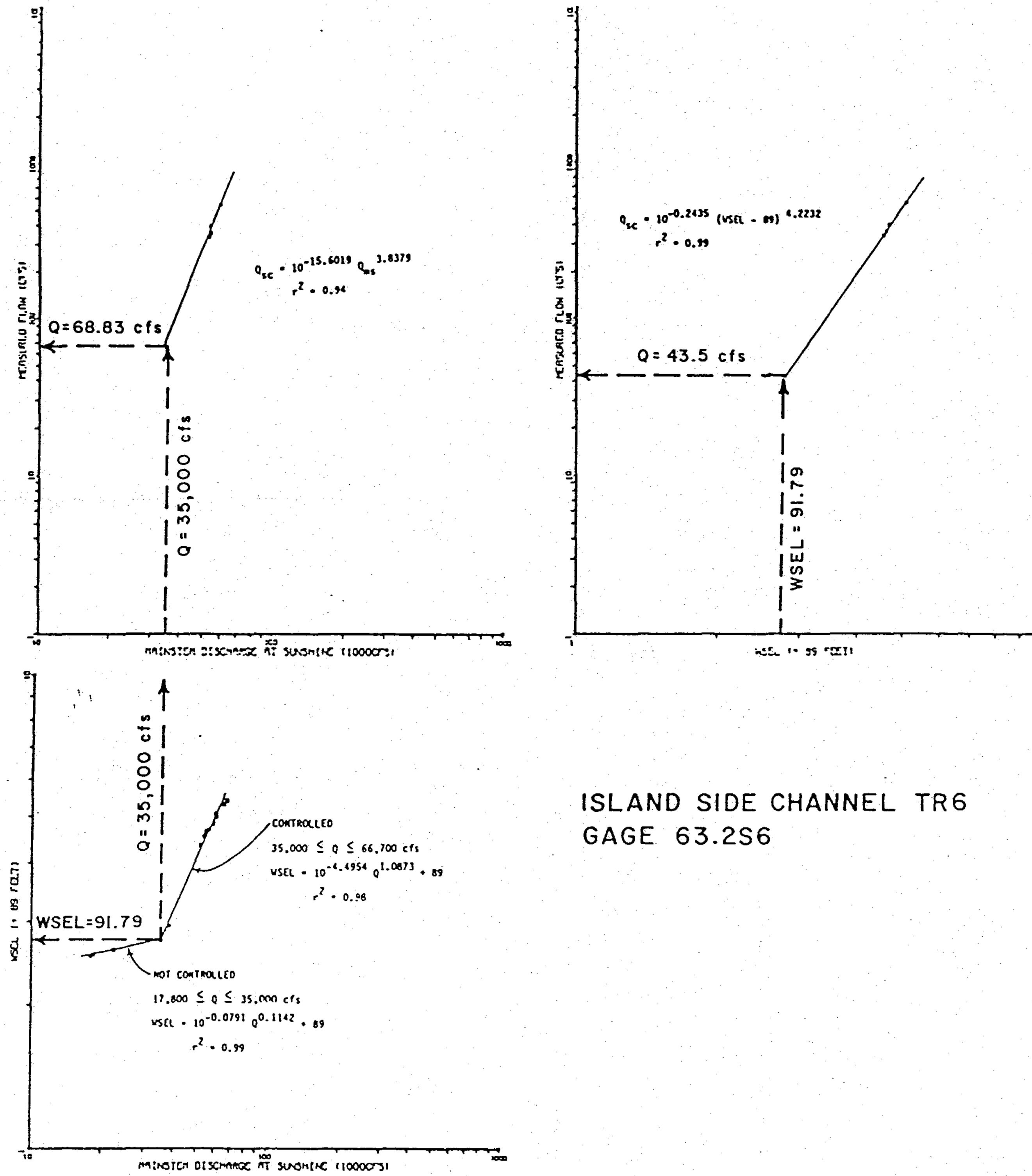
Appendix Figure D-3. Location of Island Side Channel study site (RM 63.2).

along this bank, which during higher site flows (about 400 cfs), become slow velocity slack water areas. In contrast, the left bank of the study site consists largely of a gently sloping depositional bank. The riparian vegetation on this bank is sparse and consists primarily of shrub willow.

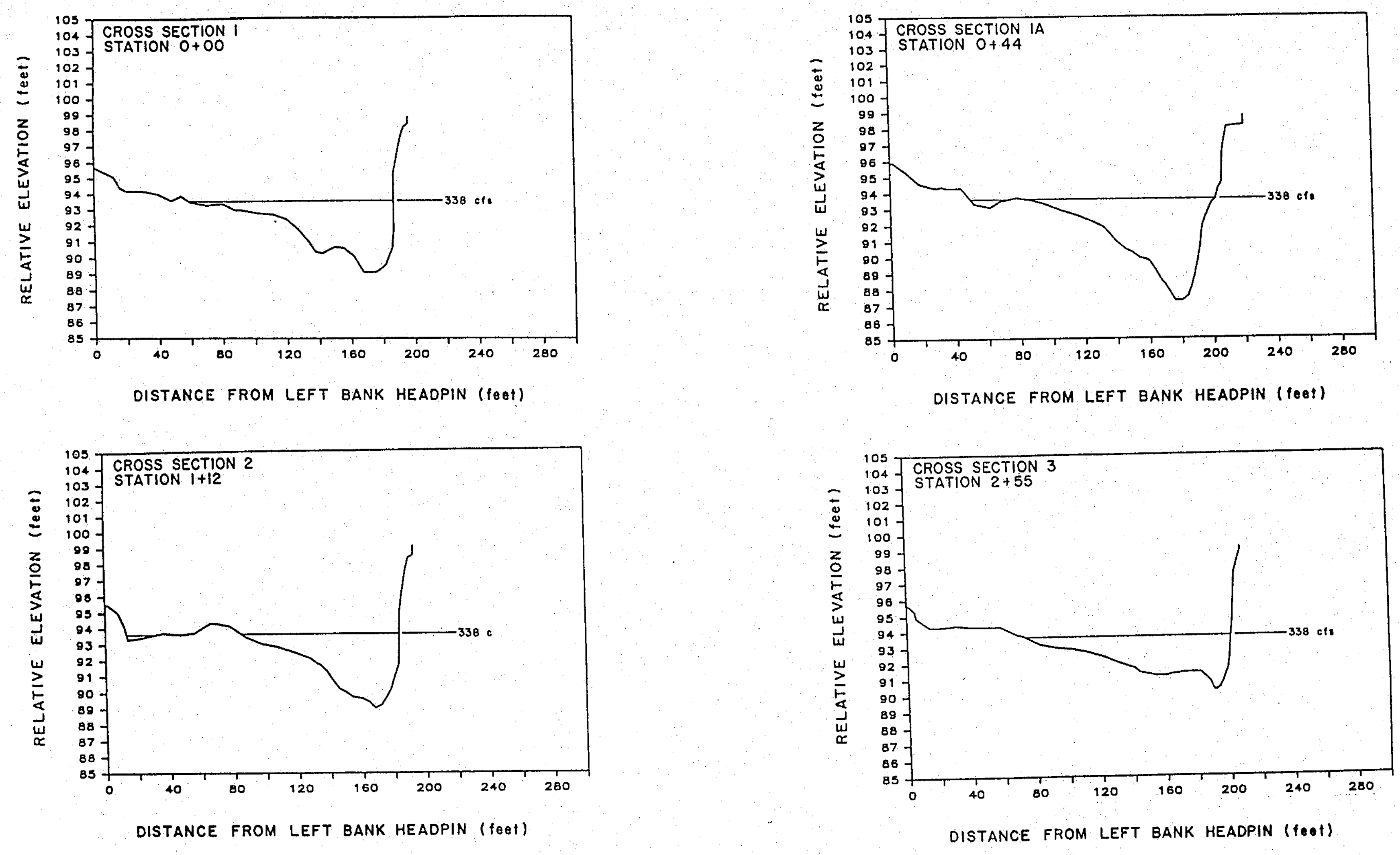
Substrate at the study site consists primarily of gravels, cobbles, and rubbles, with substrate changing to sand and silt in slackwater areas. The thalweg gradient of the side channel is 15.6 ft/mile (Quane et al. 1985). Breaching of Island Side Channel is the result of overtopping of the head by an adjoining side channel. From an evaluation of field observations, aerial photography and the stage/discharge relationship developed for this side channel, an initial breaching discharge has been estimated to occur at 34,000 cfs (Quane et al. 1985).

Based on a review of available rating curves (Appendix Figure D-4) it has been determined that at mainstem discharges exceeding 35,000 cfs, the hydraulics within this side channel become directly controlled by mainstem discharge (Quane et al. 1985). A side channel streamflow estimate of 43.5 cfs has been estimated to occur at a mainstem discharge of 35,000 cfs (Quane et al. 1985).

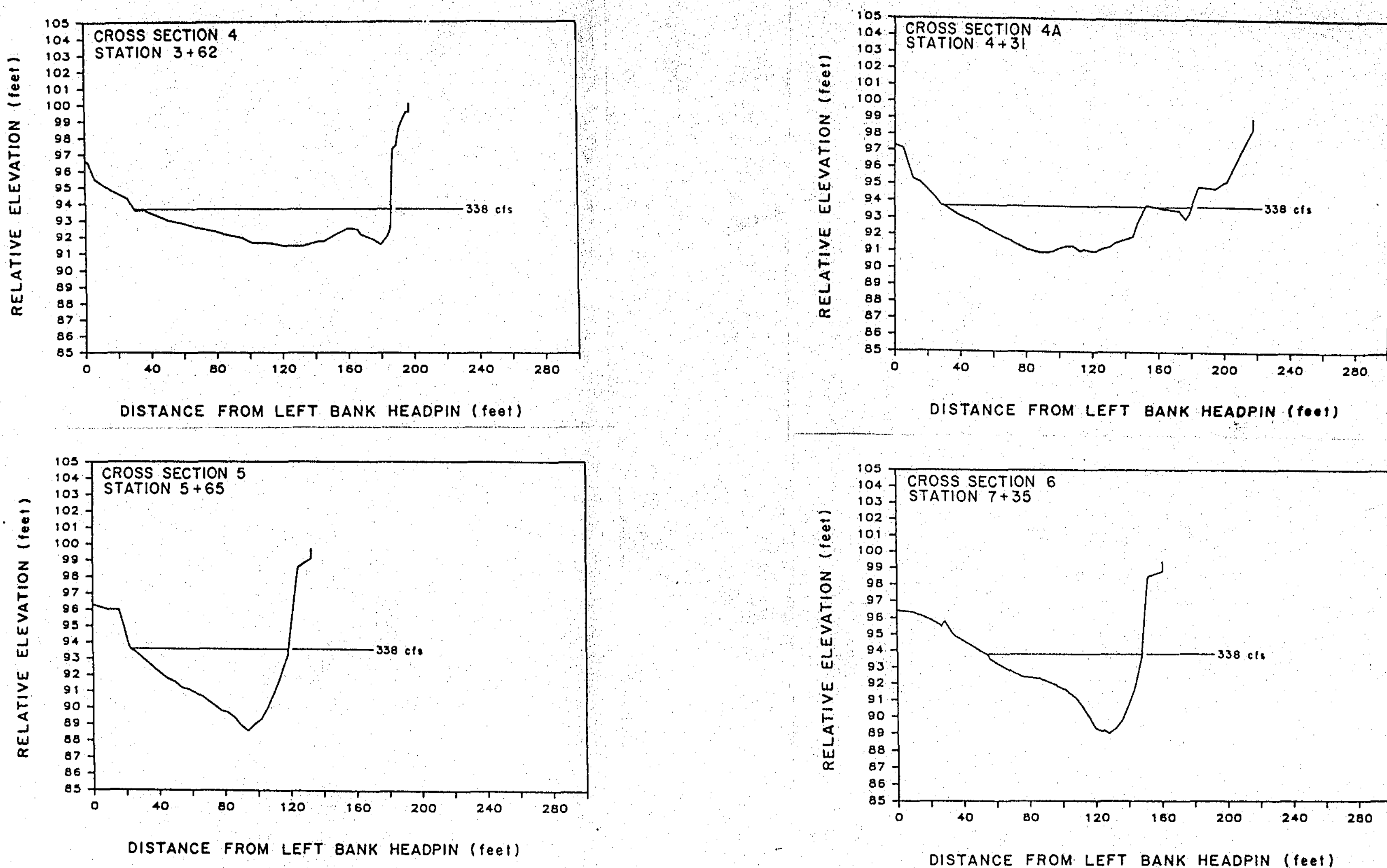
Eight cross sections were surveyed within this site during 1984 to define channel geometry (Appendix Figures D-5 & 6). The upper two transects (5 and 6) were located in primarily pool habitat. Transects 4A and 4 represent primarily riffle habitat in the main portion of the channel. Transect 4A was placed as a partial transect originating from the right hand bank. It represents the larger of the two slack water



Appendix Figure D-4. Comparison of rating curves for Island Side Channel transect 6(Q site) (from Quane et. al. 1985).



Appendix Figure D-5. Cross section of transects 1,1A, 2, and 3 at Island Side Channel (adapted from Quane et. al. 1985).



Appendix Figure D-6. Cross section of transects 4,4A,5, and 6 at Island Side Channel (adapted from Quane et. al. 1985).

areas in this reach. The four downstream most transects are primarily in pool type habitat. Transect 1A was also a partial transect, representing the smaller slack water area along the right bank.

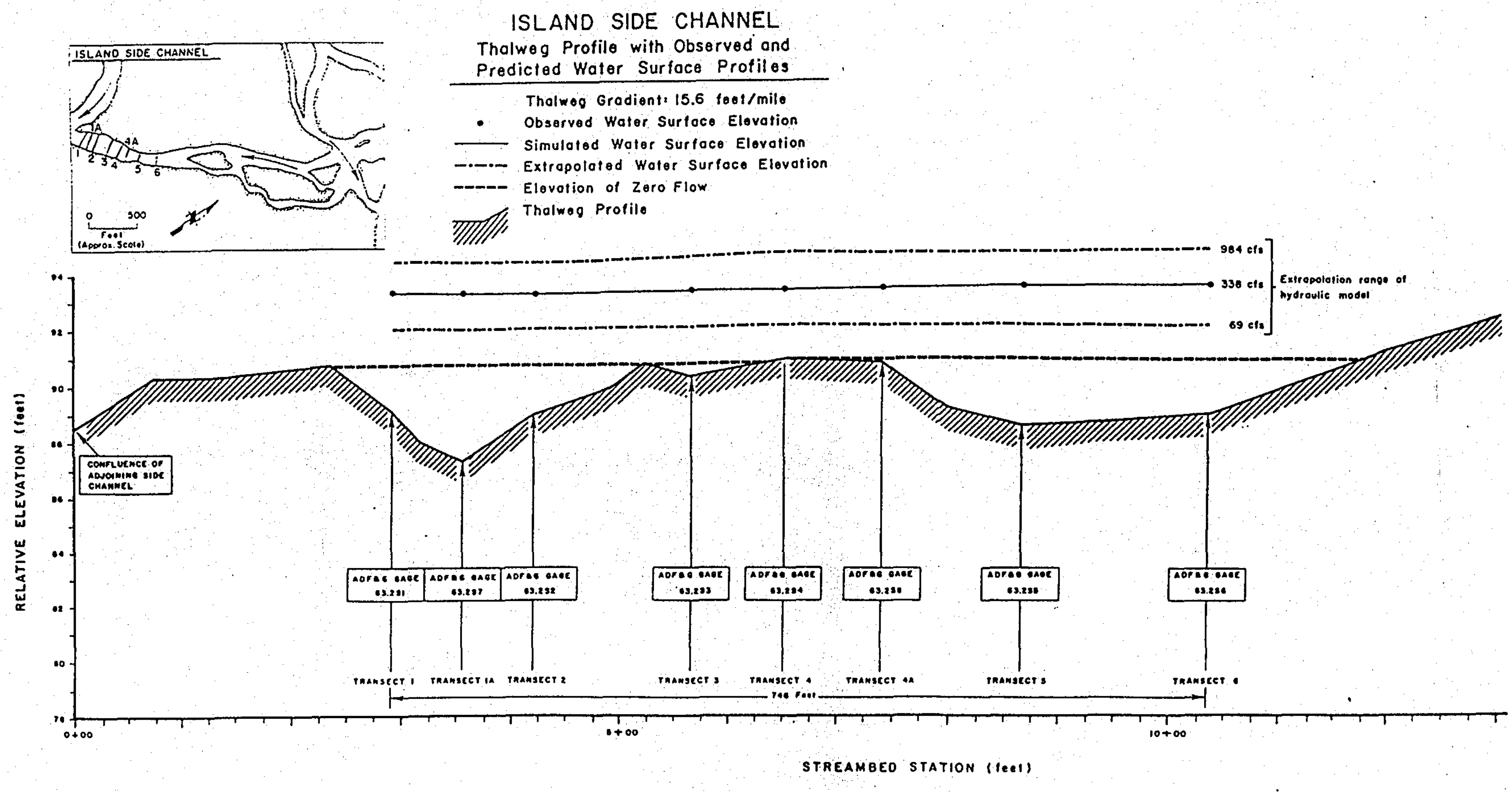
Data Collected

Hydraulic data were collected at a site flow of 338 cfs (Appendix Table D-4). The mean daily discharge for the Susitna River on the date the calibration data were collected at the study site was 56,100 cfs as determined from provisional USGS streamflow data.

Calibration

Calibration data available at the close of 1984 field season was limited to that obtained for a side channel flow of 338 cfs (56,100 cfs mainstem discharge). As a result, an IFG-2 model was used to forecast instream hydraulics based on this single calibration flow. The streambed profile, stages of zero flow, and observed and predicted water surface elevations for this study reach are plotted to scale in Appendix Figure D-7.

The original field water surface elevations (WSEL's) were compared to the model predicted WSEL's for the calibration flow of 338 cfs (Appendix Table D-5). At transect 1A, the original field WSEL was surveyed at 93.46 feet. In examining the WSEL's of transects 1 and 2 (93.33 and 93.41 feet in elevation respectively), it was felt that an error in



Appendix Figure D-7. Comparison of observed and predicted water surface profiles from calibrated model and surveyed thalweg profile at Island Side Channel (adapted from Quane et. al. 1985).

Appendix Table D-5. Comparison of field measured and model predicted water surface elevations at the calibration flow of 338 cfs for Island Side Channel.

Transect	Water Surface Elevation (ft) Field	Model Predicted	Difference
1	93.33	93.33	--
1A	93.46[A]	93.36	0.00
2	93.41	93.36	0.05
3	93.44	93.40	0.04
4	93.48	93.46	0.02
4A	93.52	93.50	0.02
5	93.56	93.53	0.03
6	93.55	93.56	0.01

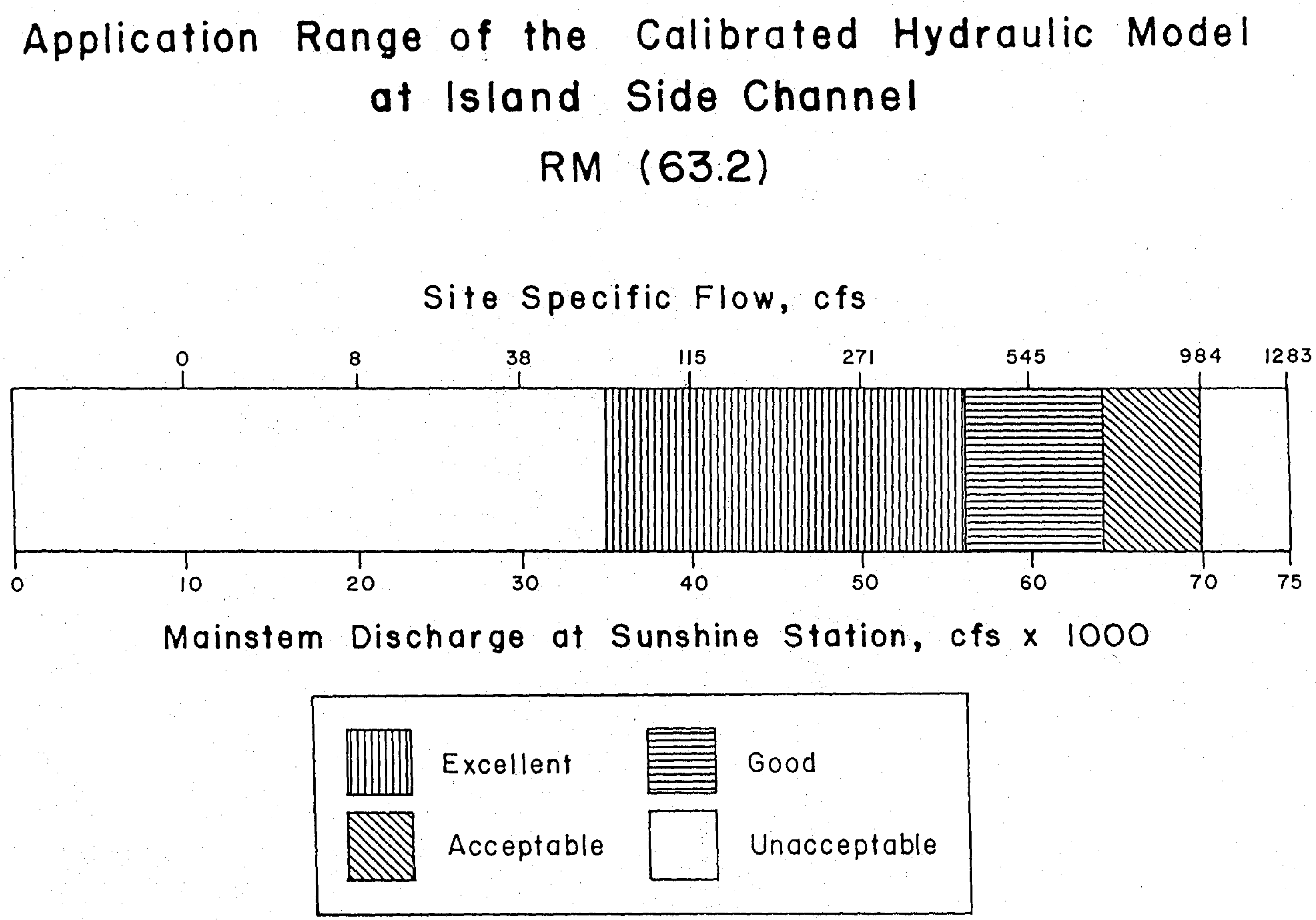
[A] Water surface elevation reduced by 0.1 feet to 93.36 feet.

surveying occurred at transect 1A. As a result, the WSEL for this transect was lowered by 0.1 feet to 93.36 feet. For all other transects, the difference between the field WSEL's and the model predicted WSEL's for the calibration flow were 0.05 ft. or less.

The two partial transects (1A and 4A) which represent slackwater habitat were extended out to the principal velocity filament. In order to complete the data sets for these two partial transects for use in the model, the associated data from transects 1 and 4 were used. At partial transect 1A, the velocities were all negative. In order to use this information in the model, these velocities were treated as positive, as it was felt that the direction of the current would not influence the utilization of this area by juvenile salmon. With respect to the amount of water flowing through this section, it amounted to only 6.5 cfs or about 2% of the flow.

Verification

Based on the first level of verification conducted by EWT&A, the model does an excellent job of simulating hydraulics between 35,000 and 56,000 cfs mainstem discharge (69 and 416 cfs site flow). Above 56,000 cfs, however, the simulated depth and velocity distributions begin to deteriorate in quality. As a result, the model simulations were rated good between 56,000 and 64,000 cfs (416 and 692 cfs site flow), acceptable between 64,000 and 70,000 cfs (692 and 984 cfs site flow), and unacceptable above 70,000 cfs mainstem. Below 35,000 cfs mainstem, insufficient



Appendix Figure D-8. Application range of the calibrated hydraulic model at Island Side Channel.

data was available to evaluate the performance of the model. These ratings are depicted graphically in Appendix Figure D-8.

The second level of the verification has not been performed as of this time.

Application

For habitat simulation modelling purposes, the hydraulic simulation model developed for Island Side Channel can simulate channel flows in the mainstem discharge range of 35,000 to 70,000 cfs.

Mainstem West Bank Side Channel (RM 74.4)

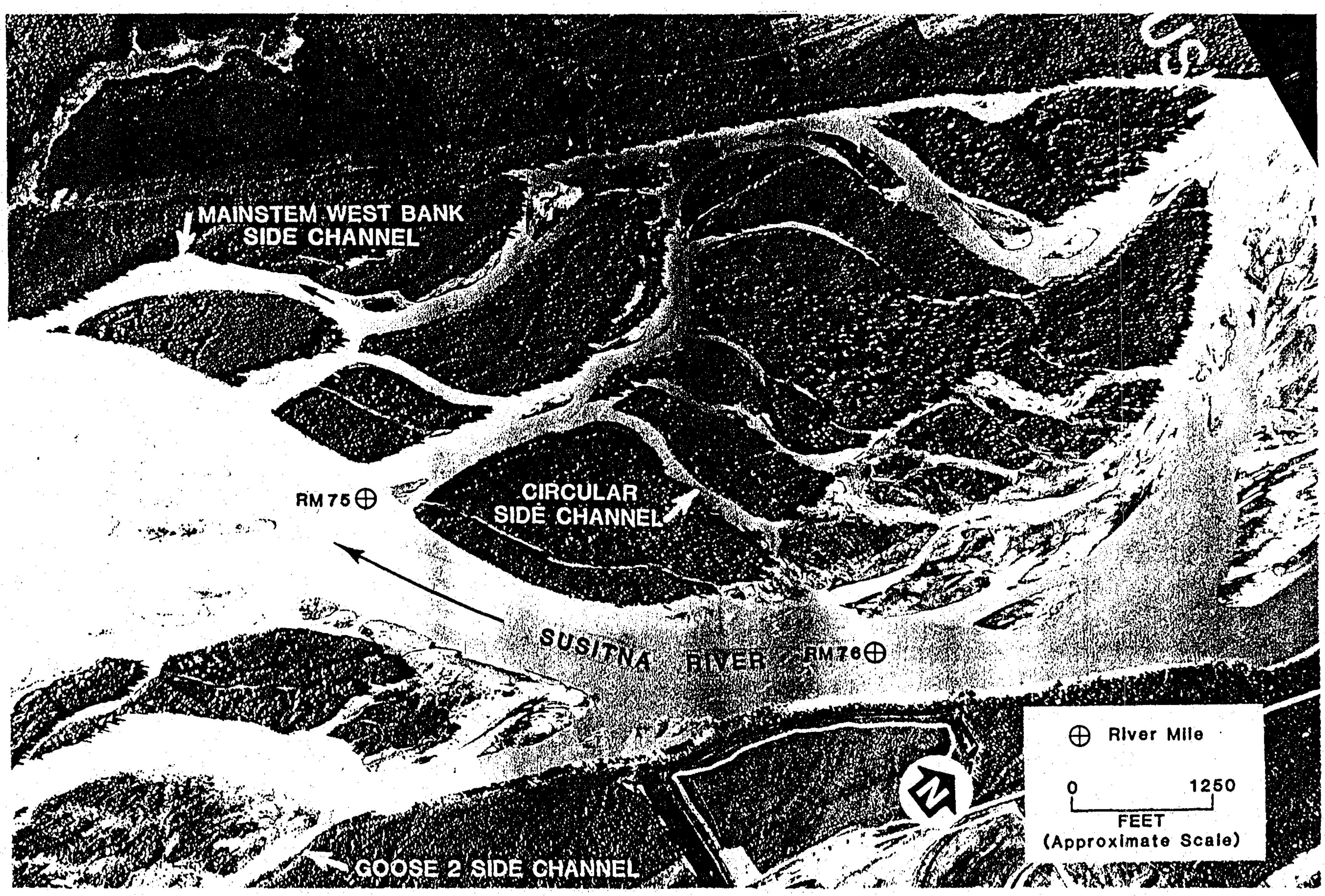
Site Description

Mainstem West Bank Side Channel is located on the west bank of the main channel Susitna River at river mile 74.4 (Appendix Figure D-9). It is approximately 2.2 miles in length. Both the mouth and head of the side channel directly connect to the Susitna River. Two heads, both located approximately 1.5 miles upstream of the study site, connect this side channel to the mainstem (Quane et al. 1985).

The IFG modelling site within this side channel during the 1984 open water field season was 930 feet in length and was located in the lower portion of the side channel (Appendix Figure D-9). The side channel within the study site is confined on the west by a steep bank and on the east by a well vegetated island which separates it from the mainstem. The upper portion of the side channel upstream of the study site is separated from the mainstem by a network of side channels and well vegetated islands. A minor channel is located within the study site on the east bank of the side channel. During nonbreached conditions, the side channel primarily consists of a series of pools and small riffles. Groundwater provides the major contribution of flow prior to breaching of the head (Quane et al 1985).

Breaching of Mainstem West Bank Side Channel occurs as the result of overtopping by the mainstem of at least one of the two side channel heads located approximately 1.5 miles upstream of the study site. The

D-31



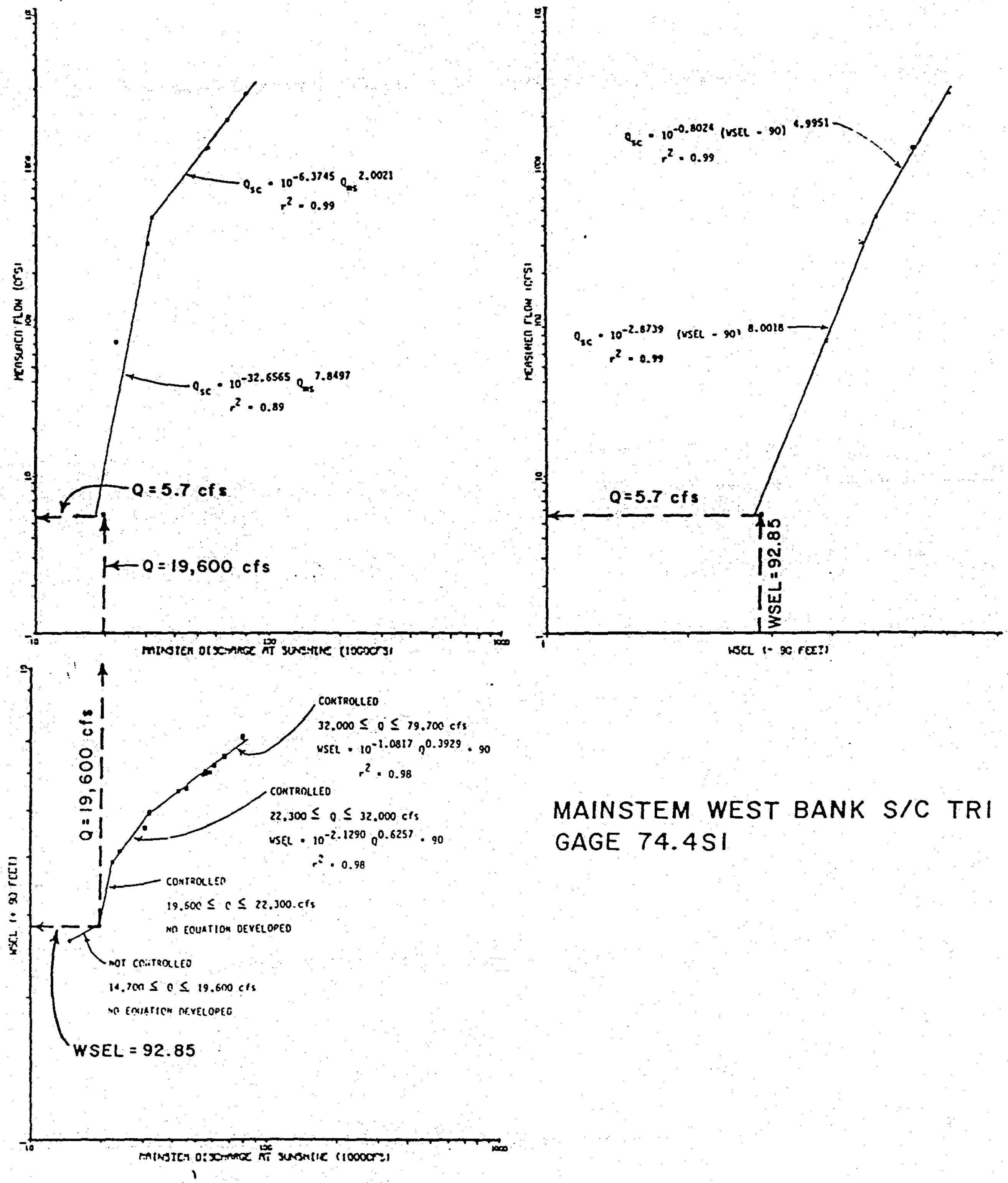
Appendix Figure D-9. Overview of Mainstem West Bank Side Channel (RM 74.4).

side channel has been estimated to be initially breached at a mainstem discharge of 19,000 cfs (Quane et al. 1985).

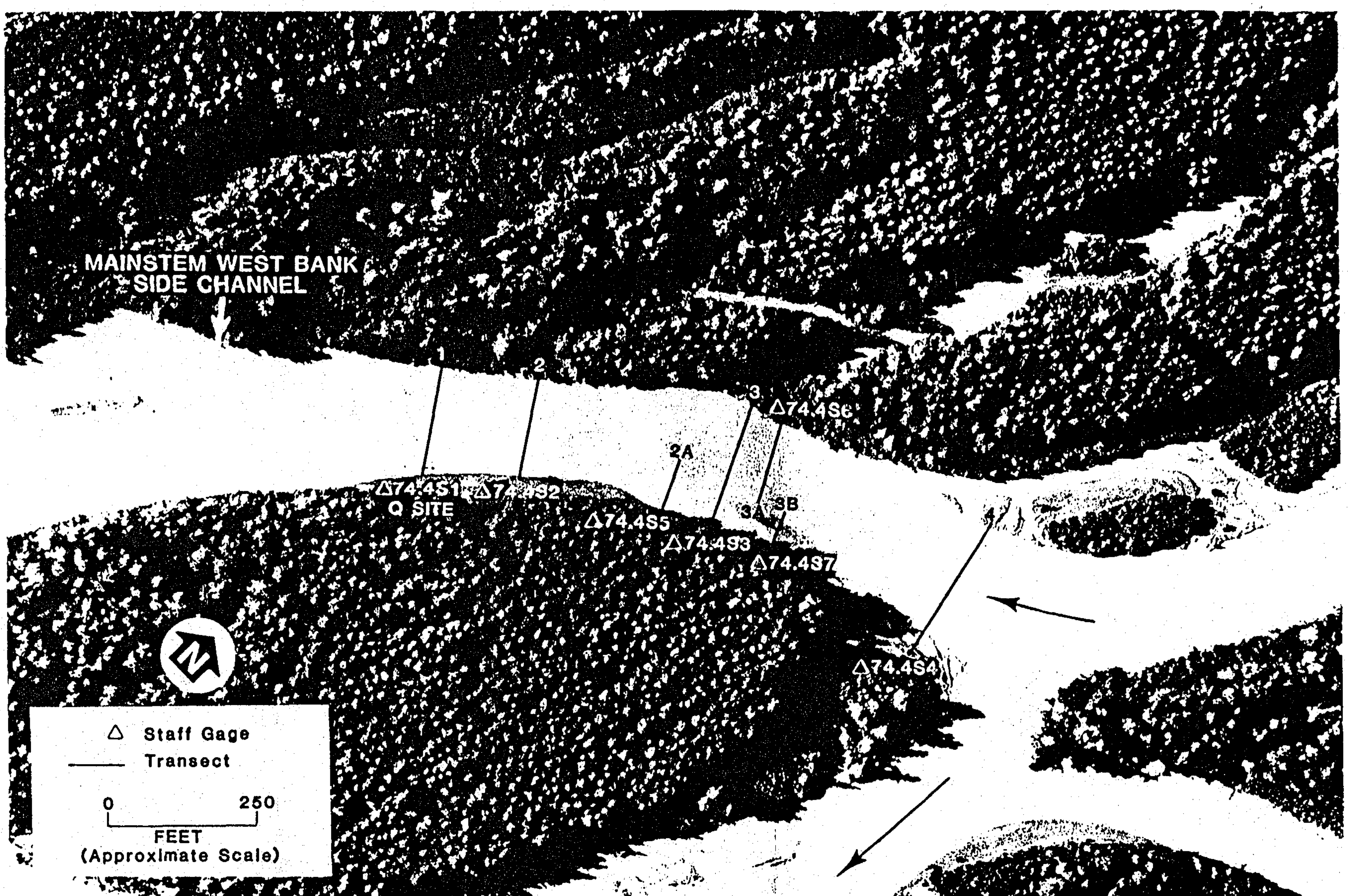
Based on a review by Quane et al. (1985) of the stage versus mainstem discharge rating curve (Appendix Figure D-10), it has been determined that at mainstem discharges greater than 19,600 cfs, the hydraulics within this side channel are directly controlled by mainstem discharge. The site flow that occurs at 19,600 cfs was measured to be 5.7 cfs.

Located within this study site were five transects (1, 2, 3, 3A, 4) in the main channel and three transects (2A, 3 in part, 3B) in a minor side channel from which hydraulic information was gathered (Appendix Figure D-11). The corresponding cross sections are presented in Appendix Figure D-12 & 13.

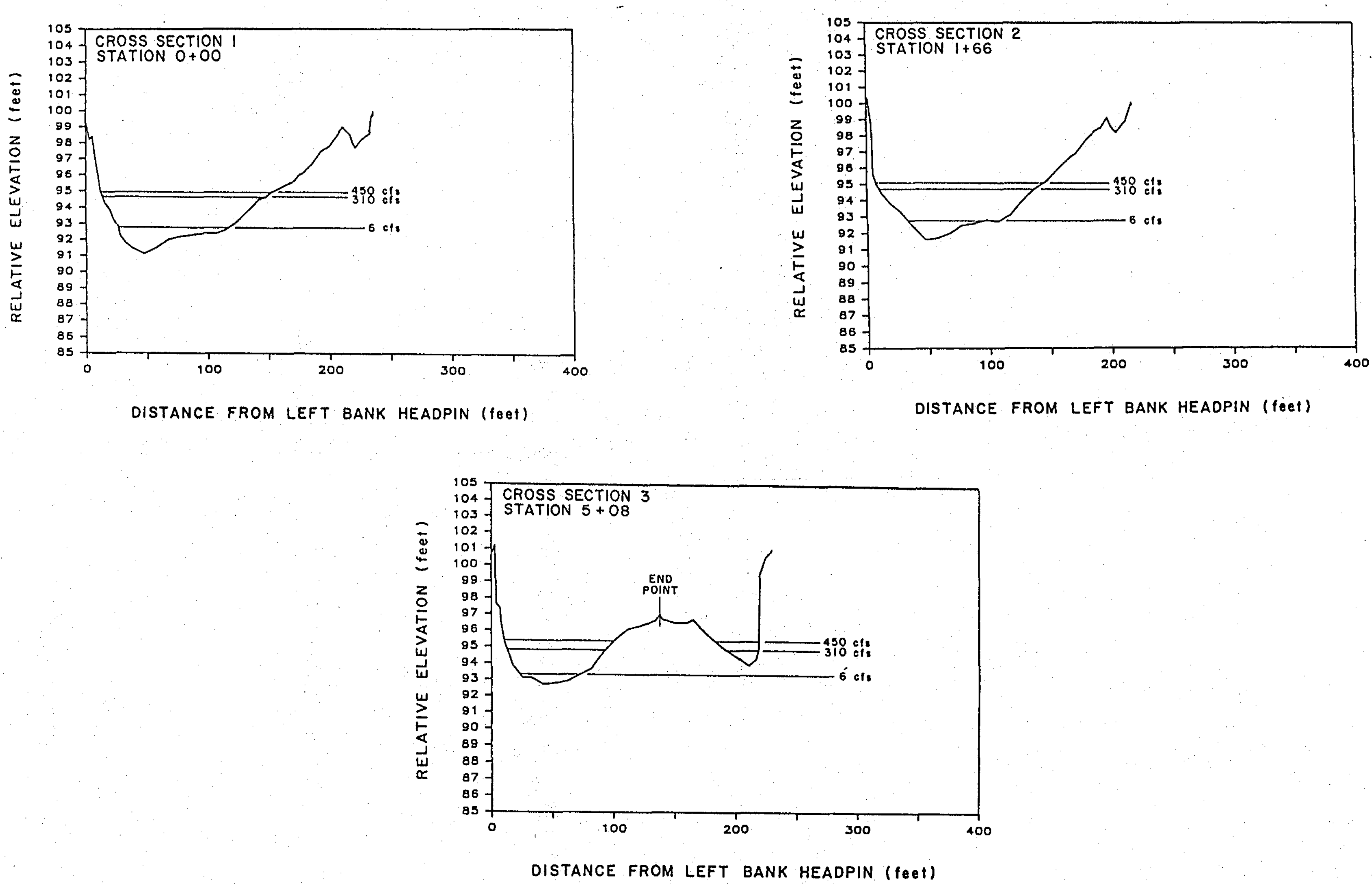
The lower two transects (1 & 2) bisect primarily pool-run type habitat where the banks are gently sloping on both sides. On the upper three transects (3, 3A, & 4) the left bank consisted of an erosional bank and was primarily bordered by alder. For modelling purposes, transects 3 and 3A were ended on a finger-like gravel bar on the right bank which longitudinally bisected the site with the main channel on the left and a minor channel on the right which was free flowing at high flows, backwater at median flows, and dry at low flows. This bar began downstream from transect 4 and ended between transects 2 and 3. Transect 3A was placed in order to obtain a better representation of the slow water debris-strewn habitat along the left hand bank. The main



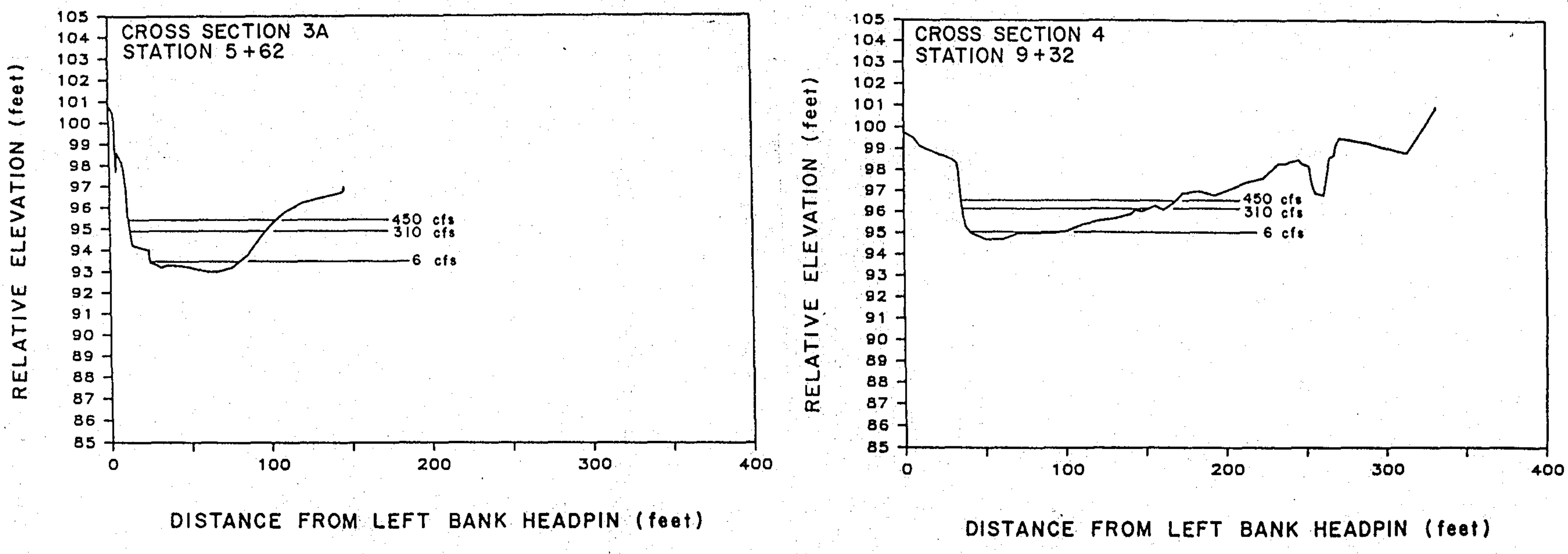
Appendix Figure D-10. Comparison of rating curves for Mainstem West Bank Side Channel transect 1(Q site) (from Quane et. al. 1985).



Appendix Figure D-11. Location of Mainstem West Bank Side Channel study site (RM 74.4).



Appendix Figure D-12. Cross section of transects 1,2,and 3 at Mainstem West Bank Side Channel (adapted from Quane et. al. 1985).



Appendix Figure D-13. Cross section of transects 3A and 4 at Mainstem West Bank Side Channel (adapted from Quane et. al. 1985).

channel habitat of these three transects (3, 3A, & 4) consisted of run-riffle type habitat.

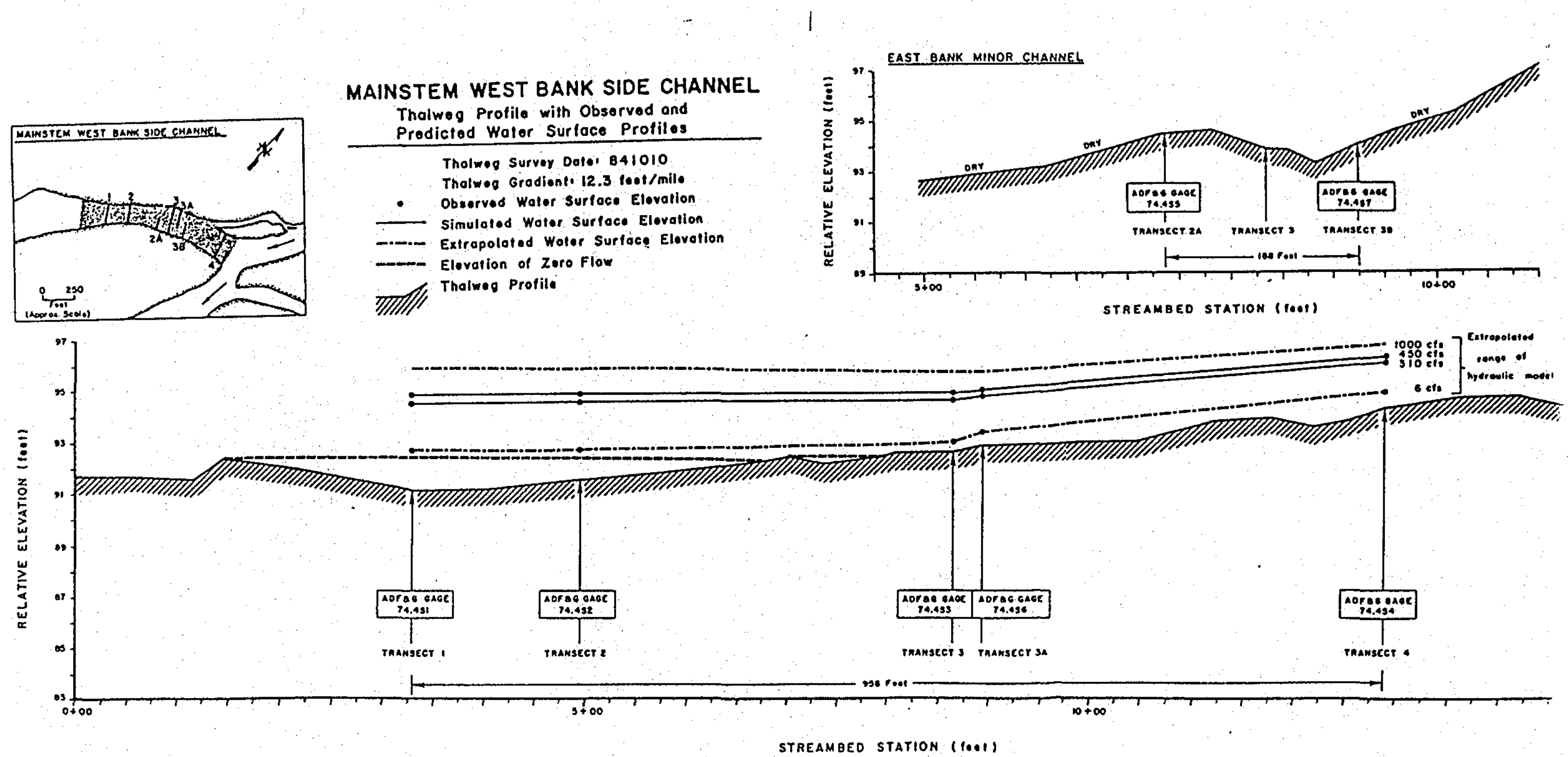
Substrate at this site primarily consisted of rubble and cobble. The thalweg gradient of the side channel is approximately 12.3 ft/mile (Quane et al. 1985).

Data Collected

Hydraulic data were collected for model calibration at three discharges: 6, 310, and 450 cfs (Appendix Table D-4). Mean daily discharges for the Susitna River on the dates that calibration data were collected of this study site were 19,600; 30,500, and 32,000 cfs, representively as determined from provisional USGS streamflow data.

Calibration

Calibration data available at the close of the 1984 field season included data collected for side channel flows of 6, 310, and 450 cfs. Based on these data, an IFG-4 model was used to forecast instream hydraulics. The streambed profile, stage of zero flow, and observed and predicted water surface elevations for the study reach are plotted to scale in Appendix Figure D-14. All three data sets were used to predict hydraulic information for side channel flows of 6 to 2,431 cfs (mainstem discharges of 18,000 to 75,000 cfs).



Appendix Figure D-14. Comparison of observed and predicted water surface profiles from calibrated model and surveyed thalweg at Mainstem West Bank Side Channel (adapted from Quane et. al. 1985).

To evaluate the performance of the hydraulic model, observed and predicted water surface elevations, discharges, and velocity adjustment factors were compared (Appendix Table D-6). The 15 sets of observed and predicted WSEL's for the five transects of the 3 calibration flows were all within ± 0.02 ft. of each other except for 2 sets which were within ± 0.10 feet of each other. All the observed and predicted discharges were within 10% of each other and all velocity adjustment factors were within the good range of 0.9 to 1.1. Additionally, the stage information of the model was compared to available rating curves (Appendix Figure D-10).

To represent the slackwater debris area along the left bank of the upper portion of this study site, a partial transect (3A) was placed about 60 feet upstream from transect 3. In order to complete this data set for transect 3A for use in the model, the velocity information from transect 3 for the two site flows of 310 and 450 cfs were incorporated into transect 3A cross sectional area and water surface elevations. After incorporating this information into transect 3A, the discharge for the 310 cfs site flow, however, did not fall within 10% of the respective discharge that was calculated at the discharge transect. As a result, velocities for the 310 cfs site flow were adjusted upward by 17%.

At the low flow measurement of 6 cfs, the velocity measurements were made completely across transect 3A. The discharge calculated at this site was 18% higher than calculated at the discharge transect. The velocities at this transect were therefore reduced by 15%.

Appendix Table D-6. Comparison between observed and predicted water surface elevations, discharges, and velocities for 1984 Mainstem West Bank side channel hydraulic model.

Streambed Station	Water Surface Elevation		Discharge		Velocity Adjustment Factor
(ft)	Observed (ft)	Predicted (ft)	Observed (cfs)	Predicted (cfs)	
0+00	92.85	92.86	6.0	6.3	1.005
1+66	92.86	92.87	6.9	7.2	.991
5+08	93.25	93.26	6.9	7.2	1.004
5+62	93.51	93.52	5.8	6.1	.996
9+32	95.06	95.06	5.1	5.4	1.013
			Qo = 6.0	Qp = 6.0	
0+00	94.62	94.61	312.8	315.7	1.030
1+66	94.64	94.64	301.3	307.5	1.024
5+08	94.85	94.86	306.4	318.2	1.007
5+62	94.93	94.99	292.8	288.6	.993
			Qo = 301.0	Qp = 308.0	
0+00	94.97	94.98	460.4	457.0	.974
1+66	95.00	95.00	446.1	438.2	.975
5+08	95.19	95.18	470.6	455.2	.994
5+62	95.29	95.23	409.6	415.3	1.001
9+32	96.54	96.45	473.9	451.9	.969
			Qo = 452.0	Qp = 444.0	

Qo is the mean observed calibration discharge.

Qp is the mean predicted calibration discharge.

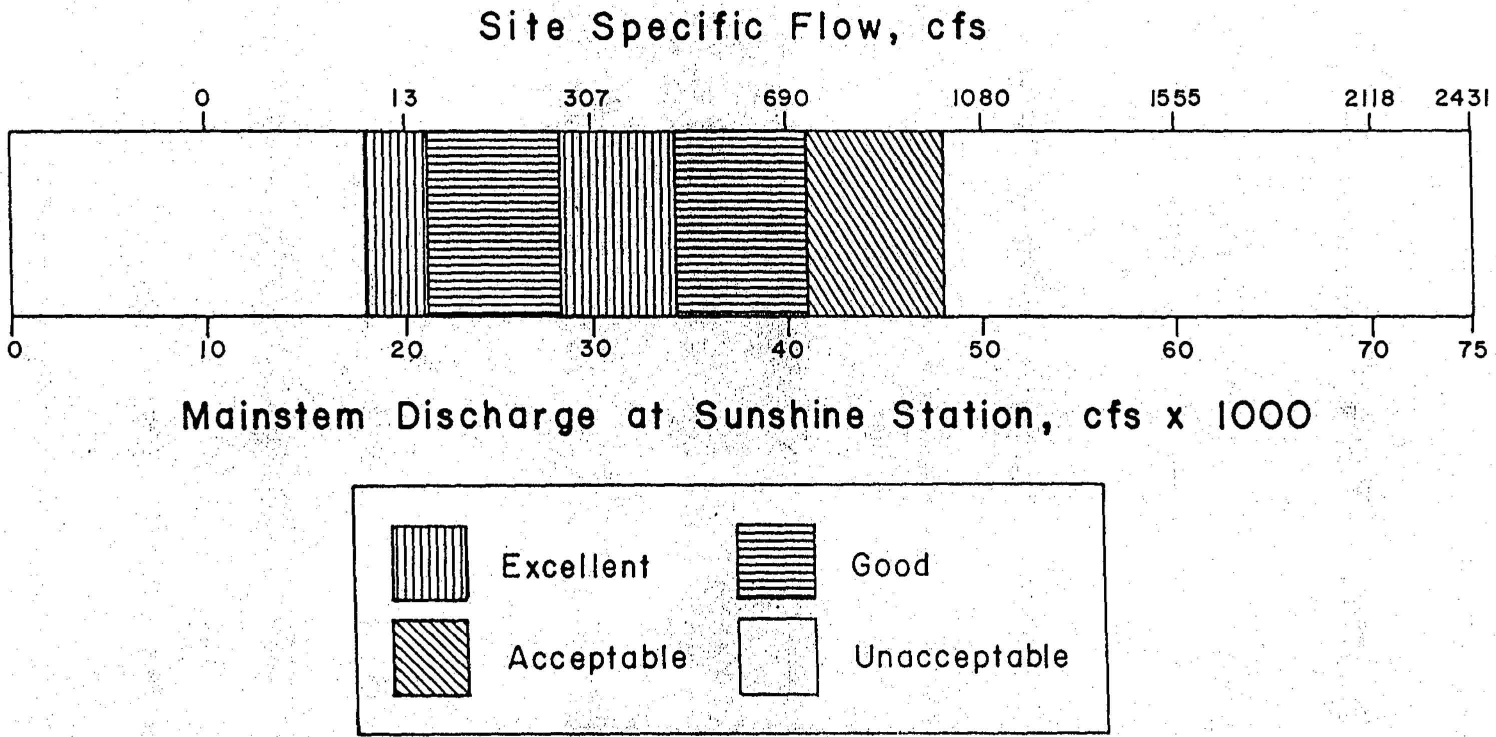
At transect 4 the water surface elevations were not similar across the transect at the 6 cfs flow measurement. Therefore, a weighted average water surface elevation was calculated for this transect.

At higher site flows several small low velocity side channel/backwater areas existed. It was felt that this habitat, which was not represented in the IFG-4 analysis, would be an important area to assess. Because of this, three transects were placed across one of these minor side channels. These transects were to be used to hand calculate the habitat in this area. However, because this side channel area is so small compared to the total area being modelled using the IFG-4, it was felt that including this area in the total weighted usable area calculations would not truly reflect the value of this habitat. For this reason, hand calculations of these areas were not done.

Verification

Based on the first level of verification by EWT&A, the model does an excellent job of simulating channel hydraulics between 18,000 and 21,000 cfs mainstem discharge (6 and 20 cfs site flow) (Appendix Figure D-15). Above 21,000 cfs, simulated water surface profiles deviate somewhat from field observations. As a result, the model was rated good between 21,000 and 28,000 cfs mainstem discharge (20 and 200 cfs site flow), and between 28,000 and 34,000 cfs mainstem discharge (200 and 500 cfs site flow) the model again was rated excellent. Two calibration data sets were collected within this range. Above 34,000 cfs, the quality of the

Application Range of the Calibrated Hydraulic Model at Mainstem West Bank RM (74.4)



Appendix Figure D-15. Application range of the calibrated hydraulic model at Mainstem West Bank Side Channel.

hydraulic simulations begins to deteriorate as the slope of the site flow versus WSEL relationship flattens as a result of channel geometry. The deviation between the regression line developed within the model and that of the rating curve developed independently for the site increases with discharge until the model simulations are no longer acceptable. The model simulations were rated good between 34,000 and 41,000 cfs (500 and 727 cfs site flow), acceptable between 41,000 and 48,000 cfs (727 and 1000 cfs site flow), and unacceptable above 48,000 cfs mainstem discharge.

Overall, the model simulations were rated excellent between 18,000 and 21,000 cfs (6 and 20 cfs) and 28,000 and 34,000 cfs (200 and 500 cfs), good between 21,000 and 28,000 cfs (20 and 200 cfs) and 34,000 and 41,000 (500 and 727 cfs). They were acceptable between 41,000 and 48,000 cfs (727 and 1,000 cfs) and unacceptable over 48,000 cfs.

As of this time, the second level of the verification has not been performed.

Application

For habitat simulation modelling purposes, the hydraulic simulation model developed for Mainstem West Bank Side Channel can simulate channel flows in the mainstem discharge range of 18,000 to 48,000 cfs.

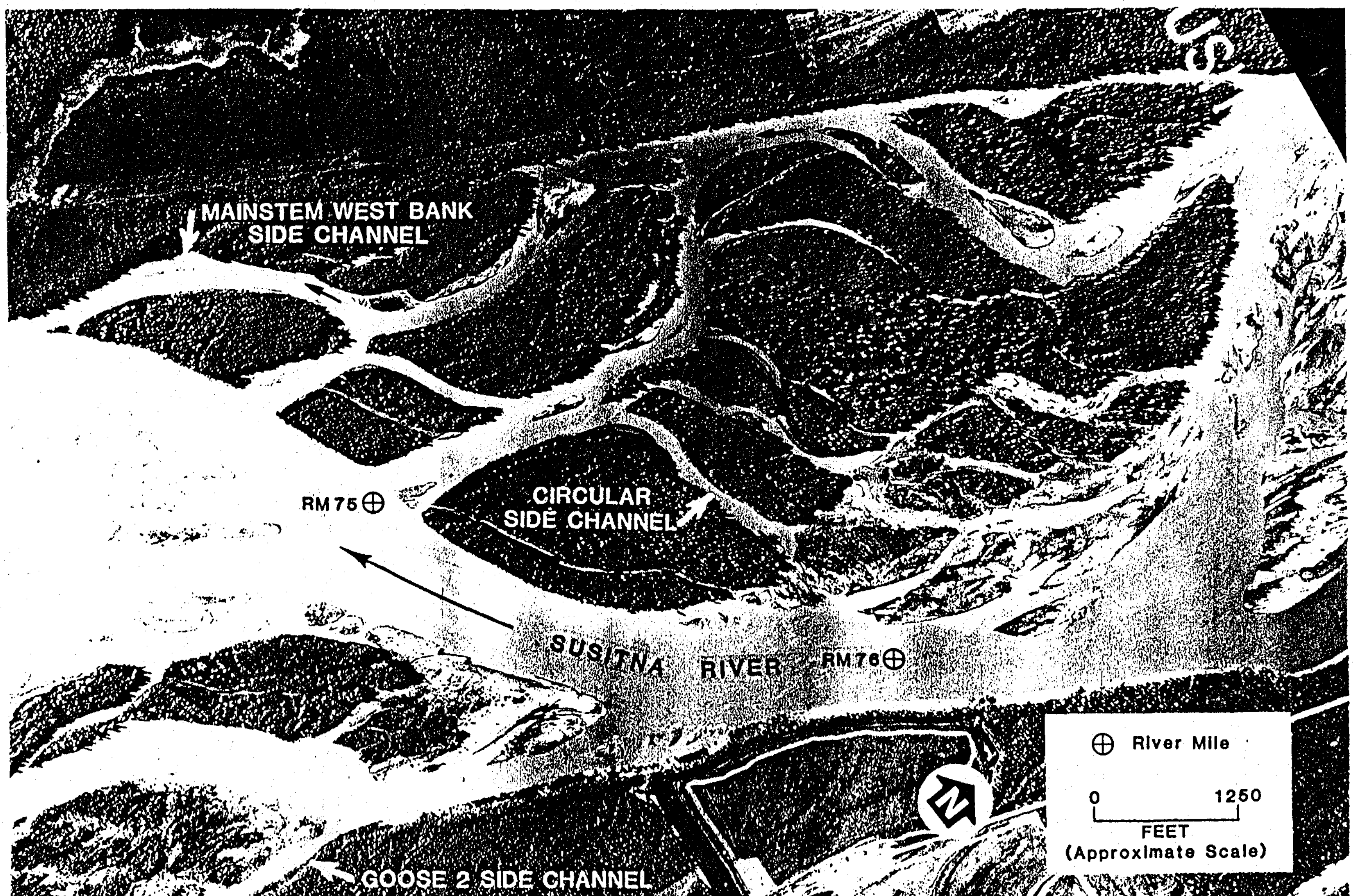
Circular Side Channel (RM 75.3)

Site Description

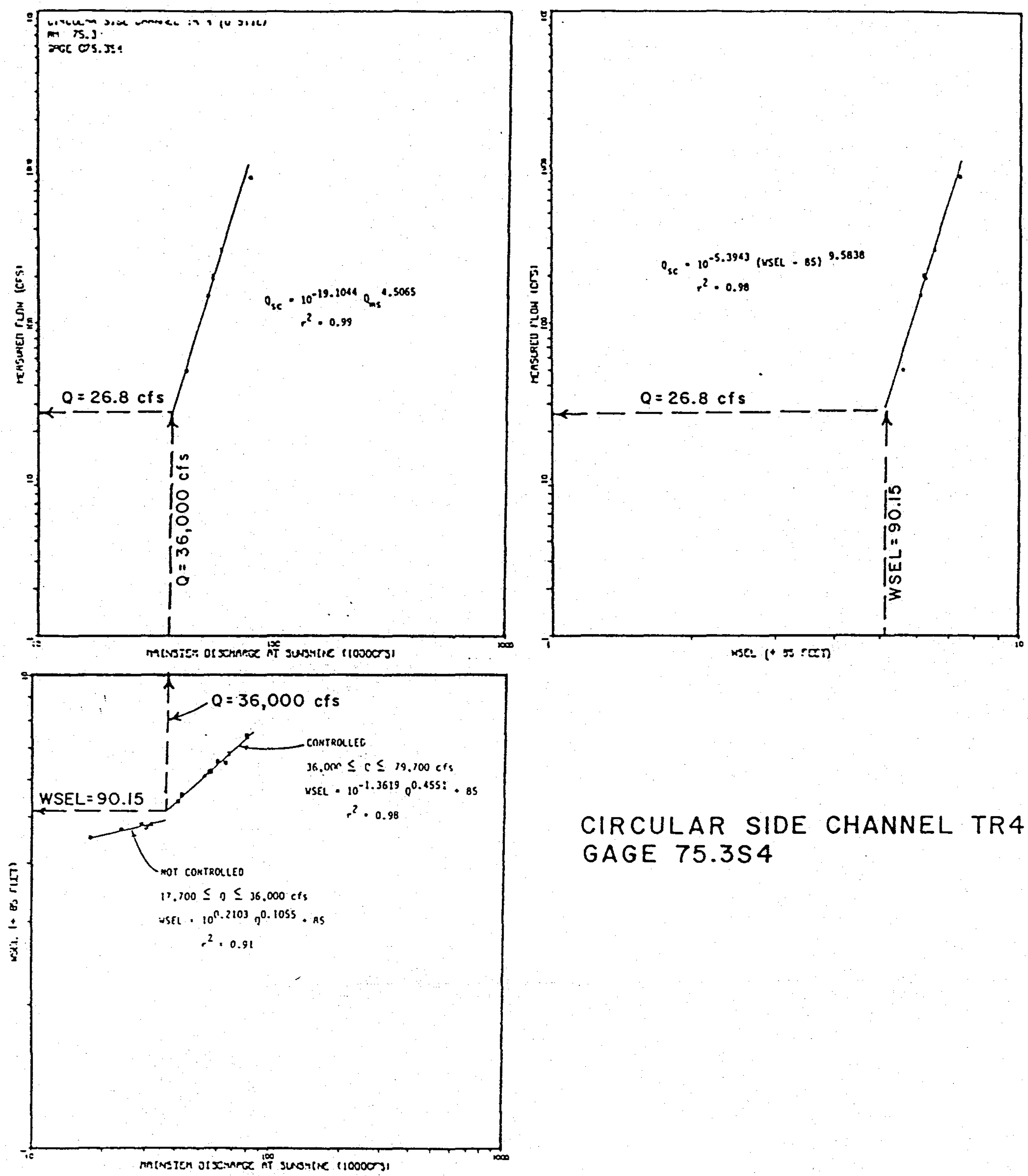
Circular Side Channel is located on the west bank of the Susitna River at river mile 75.3 (Appendix Figure D-16). It is approximately 0.9 miles long and is separated from the mainstem by a large well vegetated island. Both the mouth and head of this side channel are connected to the mainstem Susitna River. An extensive backwater area has been observed to occur in the lower portion of the study site. A network of small channels at the head provide mainstem flow into the site after breaching. Prior to breaching, flow is greatly reduced and the channel is composed of large pools connected by small riffles (Quane et al. 1985).

Breaching of Circular Side Channel is the result of direct overtopping of the head by the mainstem Susitna River, and has been estimated to be initially breached at a mainstem discharge of 36,000 cfs (Quane et al. 1985). It has been determined that the hydraulics within this side channel become governed by mainstem discharge at mean daily mainstem discharge exceeding 36,000 cfs. The site flow that occurs at this mainstem discharge has been estimated to be 26.8 cfs (Appendix Figure D-17) (Quane et al. 1985).

Based on assessments by Quane et al. (1985), backwater has not been observed to occur during non-breaching mainstem discharges. At breaching mainstem discharges of 55,200 to 66,700 cfs, however, an area of



Appendix Figure D-16. Overview of Circular Side Channel (RM 75.3).



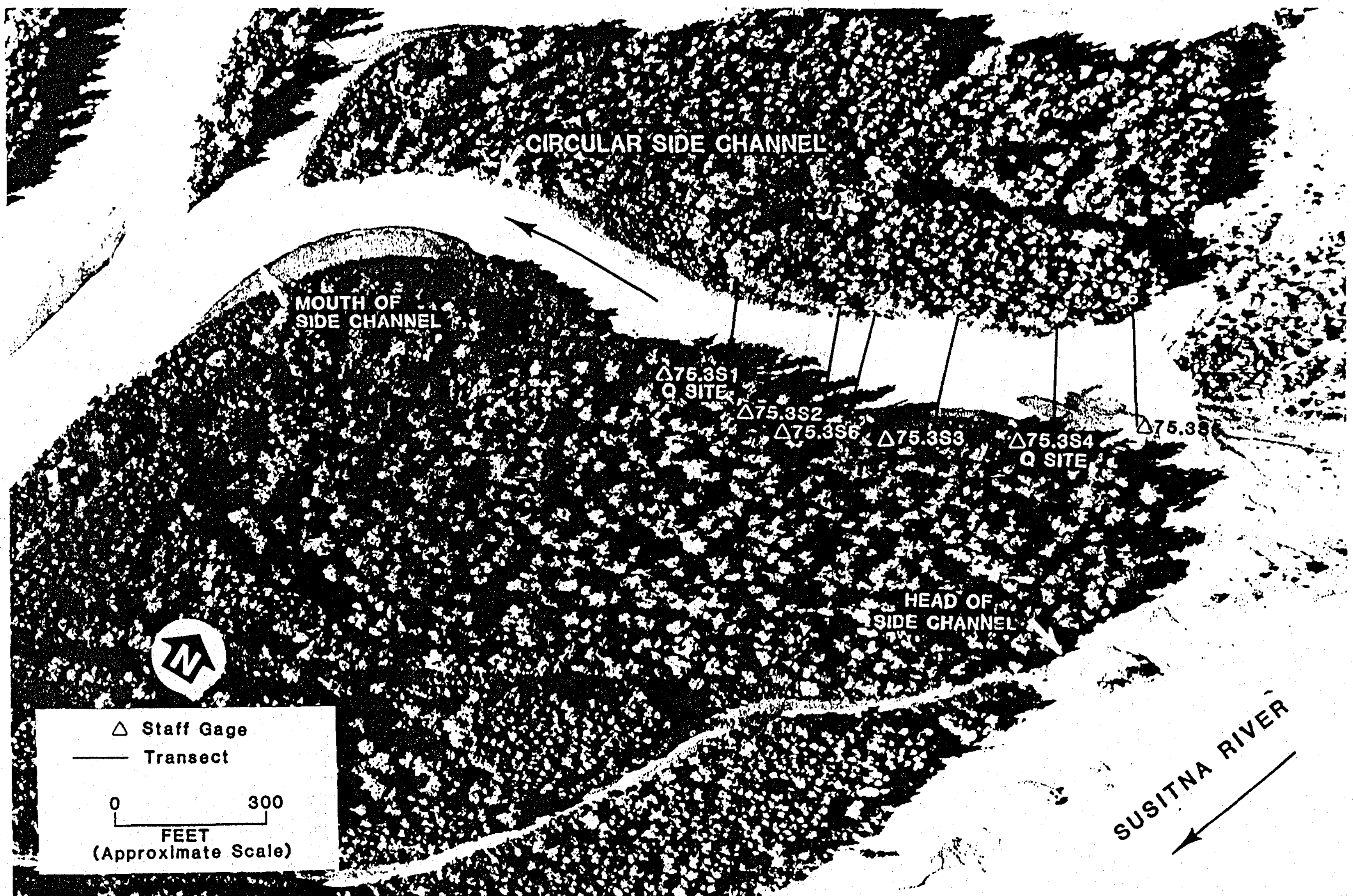
Appendix Figure D-17. Comparison of rating curves for Circular Side Channel transect 4 (from Quane et. al. 1985).

backwater was found to occur upstream to a point approximately 90 feet above transect 2A. At a mainstem discharge of 42,500 cfs, backwater has been determined to extend slightly past transect 2.

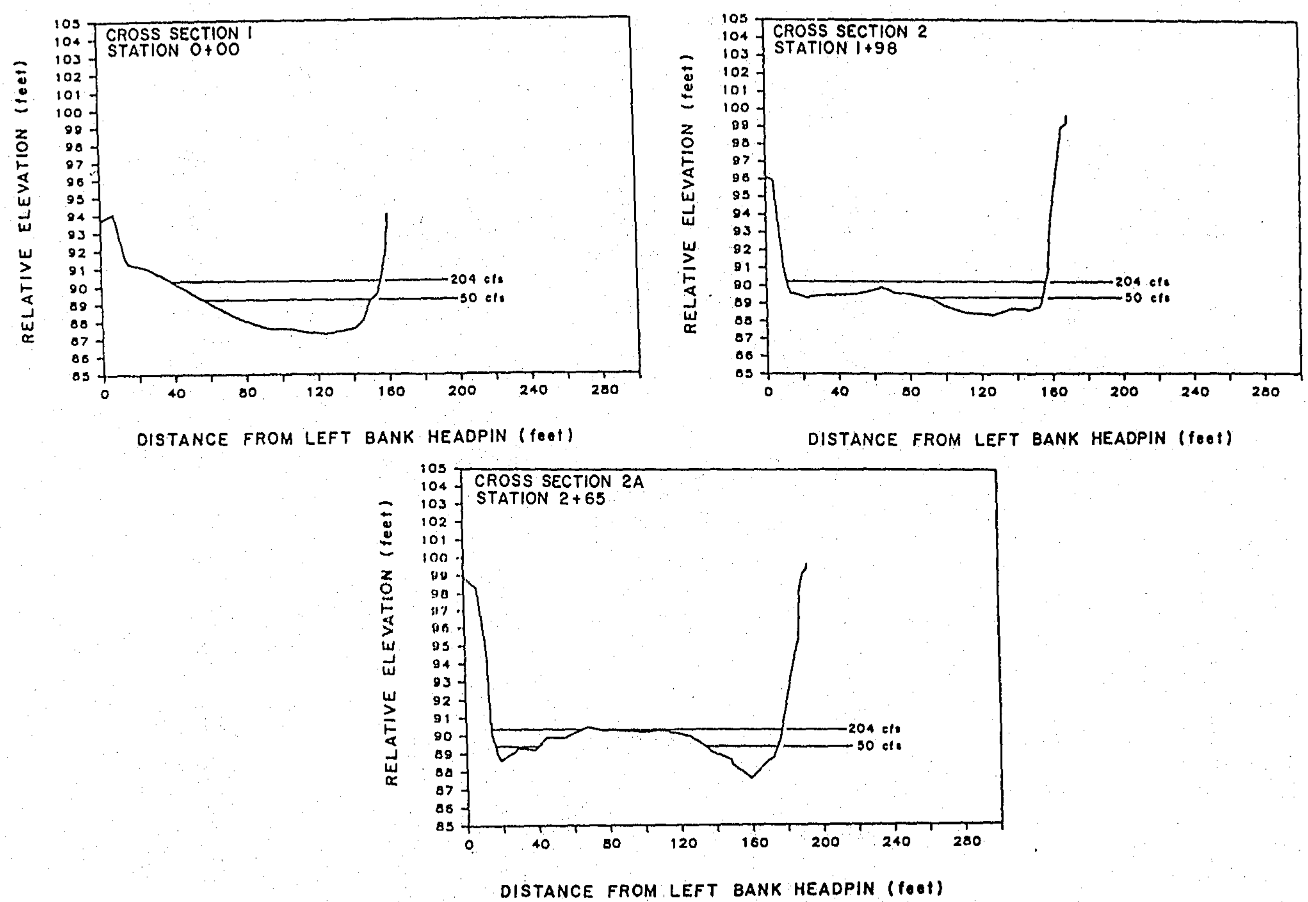
The IFG modelling study site within Circular Side Channel was 820 feet in length and was located in the upper half of the side channel (Appendix Figure D-18). The thalweg gradient of this study site is 14.3 ft/mile (Quane et al. 1985). Riparian vegetation along both banks of this study site consists mostly of alder and cottonwood. Substrate within the lower reaches of the study site consisted predominately of silts, sands, and gravels changing to rubbles at the upper reaches. Six transects from which hydraulic information was gathered for the model were located within this study site (Appendix D-18). The channel is relatively straight and the cross sections are generally box shaped in configuration (Appendix Figures 19 & 20). Transects 1 and 2 were located in shallow pool habitat, created by the backwater. Transect 2A was located in transitional habitat which became run-like habitat at higher flows. Transect 3 was located in riffle habitat. Transect 4 was located in a run area at the end of a pool area which transect 5 also bisects.

Data Collected

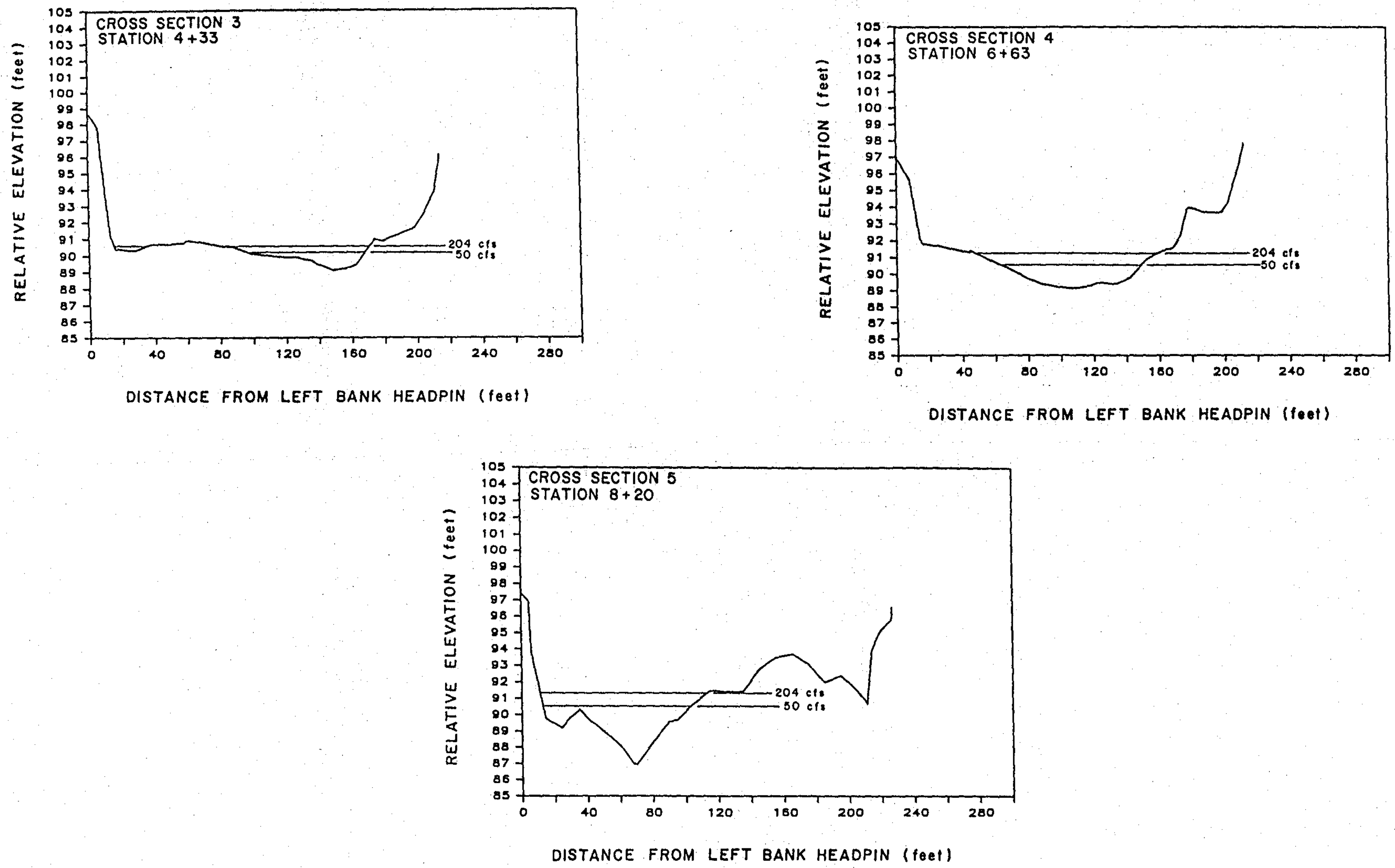
Hydraulic data were collected at two calibration discharges: 50 and 204 cfs (Appendix Table D-4). Mean daily discharges for the Susitna River on the dates that calibration data were collected at the Circular



Appendix Figure D-18. Location of Circular Side Channel study site (RM 75.3).



Appendix Figure D-19. Cross section of transects 1,2, and 2A at Circular Side Channel (adapted from Quane et. al. 1985).



Appendix Figure D-20. Cross section of transects 3,4, and 5 at Circular Side Channel.

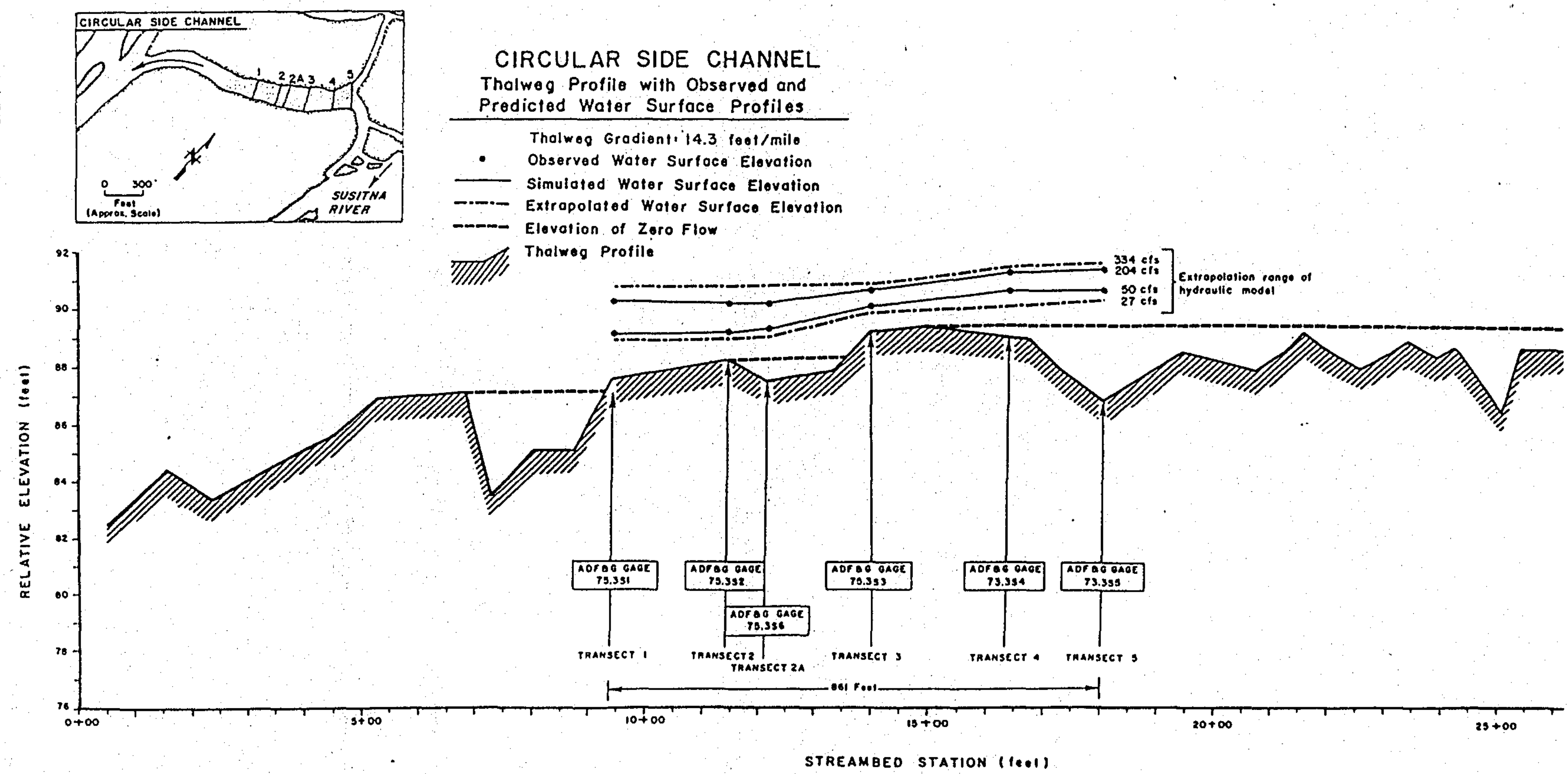
Side Channel study site were 42,500 and 55,200 cfs as determined from provisional USGS streamflow data.

Calibration

Calibration data were available at the close of the 1984 field season for side channel flows of 50 and 204 cfs. An IFG-4 model was used to forecast instream hydraulics based on these two calibration flows. The streambed profile, stages of zero flow, and observed and predicted water surface elevations for the study reach are plotted to scale in Appendix Figure D-21. The two data sets were used to predict hydraulic information from side channel flows of 6 to 733 cfs (mainstem discharges of 25,500 to 75,000 cfs).

To evaluate the performance of the hydraulic model, observed and predicted water surface elevations, discharges, and velocity adjustment factors were compared (Appendix Table D-7). Because of the 2 calibration flows only a 2 point rating curve was formulated. In evaluating the performance of the model, observed and predicted WSEL's and discharges were the same because of this rating curve. Velocity adjustment factors were all within the good range of 0.9 to 1.1. Additionally, the stage information of the model was compared to the rating curves established by Quane et al. 1985 (Appendix Figure D-17).

At the high flow measurement of 204 cfs, the original field measured discharge at transect 2 was 34% lower than that calculated at the discharge transect. In order to use this information in the model, the



Appendix Figure D-21. Comparison of observed and predicted water surface profiles from calibrated model and surveyed thalweg profile at Circular Side Channel (adapted from Quane et. al. 1985).

Appendix Table D-7. Comparison between observed and predicted water surface elevations, discharges, and velocities for 1984 Circular Side Channel hydraulic model.

Streambed Station (ft)	Water Surface Elevation Observed (ft)	Water Surface Elevation Predicted (ft)	Discharge Observed (cfs)	Discharge Predicted (cfs)	Velocity Adjustment Factor
0+00	89.28	89.28	44.4	44.4	1.000
1+98	89.30	89.30	47.9	47.9	.998
2+65	89.41	89.41	56.0	56.0	1.000
4+33	90.20	90.20	43.7	43.7	1.000
6+63	90.60	90.60	50.9	50.9	.997
8+20	90.62	90.63	53.6	53.6	1.000
			Qo = 49.0	Qp = 49.0	
0+00	90.29	90.29	202.8	202.8	.998
1+98	90.27	90.27	203.1	203.1	.987
2+65	90.31	90.31	198.4	198.4	.999
4+33	90.66	90.66	176.9	176.9	.998
6+63	91.29	91.29	199.9	199.9	1.000
8+20	91.32	91.32	194.2	194.2	1.000
			Qo = 196.0	Qp = 196.0	

Qo is the mean observed calibration discharge.

Qp is the mean predicted calibration discharage.

individual velocity measurements were all adjusted upwards by 52%. Why there was such a large discrepancy between flows at this particular transect when the four other transect flow measurements were within 9% of the discharge transect measurement is unknown.

At transect 5 there was a change in the channel cross section from when the actual cross section survey was done and when the two calibration flows were made. Between the cross section survey of September 5, 1985, and the two calibration flow measurements July 24 and August 17, 1984, a flood event occurred on August 26, 1984. After this flood, the right side of the channel at transect 5 was scoured out. In order to avoid violating one of the underlying assumptions of the model, (i.e.,that a rigid stream channel exists) the cross section determined from the two calibration flows was used in the model.

During the 50 cfs calibration flow measurement a water surface elevation was not surveyed for transect 5. In order to obtain a water surface elevation for the model, a value was calculated from the average of the depth measurements added to the corresponding cross section elevations of the 50 cfs flow measurement.

Verification

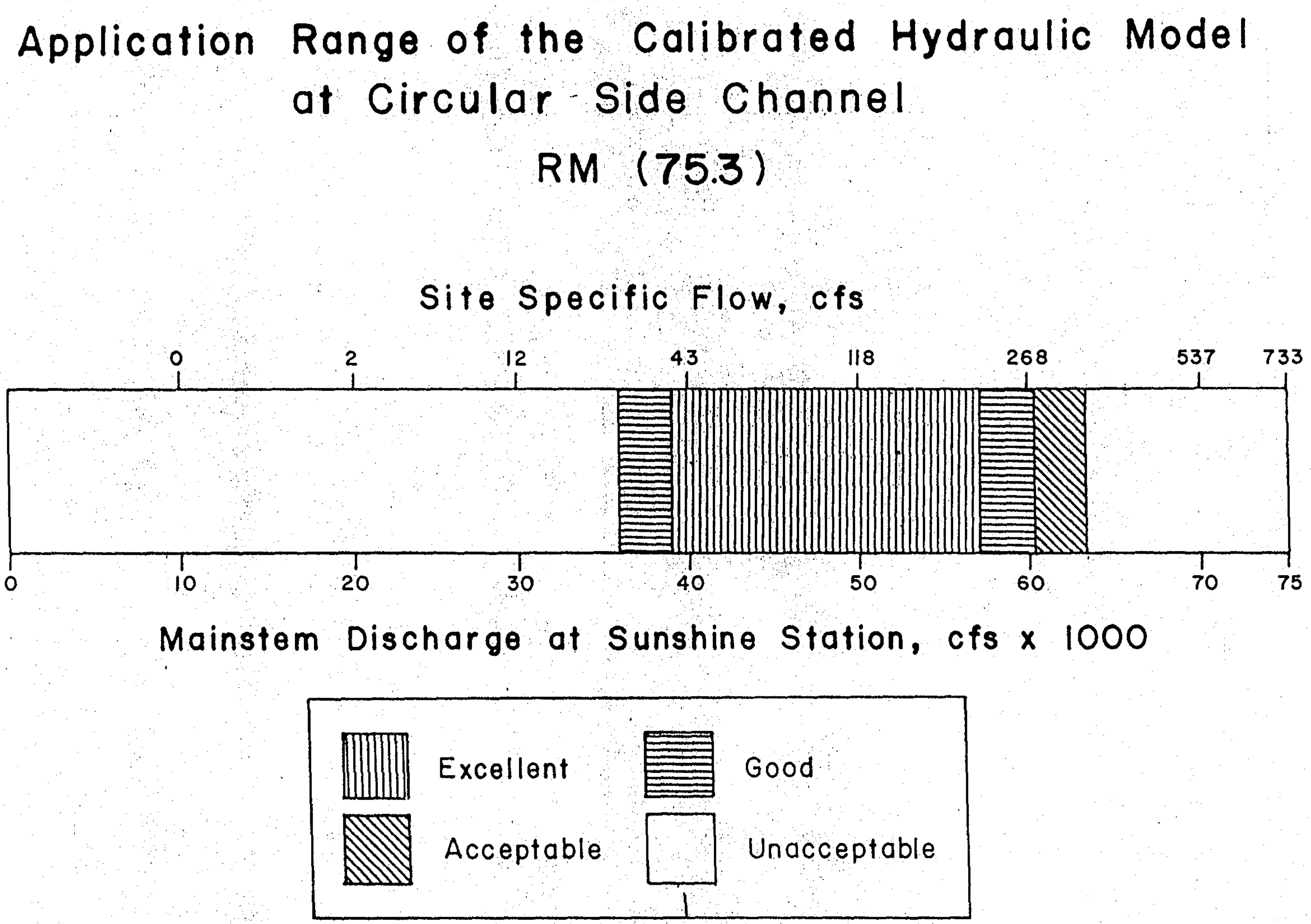
Based on the first level of verification by EWT&A, the model does an excellent job of simulating channel hydraulics between 39,000 and 57,000 cfs, mainstem discharge (38 and 213 cfs site flow) (Appendix Figure

D-22). Above 57,000 cfs, the simulated depth and velocity distributions begin to deteriorate in quality. The model simulations were therefore rated good between 57,000 and 60,000 cfs (213 and 268 cfs site flow), acceptable between 60,000 and 63,000 cfs (268 and 334 cfs site flow), and unacceptable above 63,000 cfs mainstem discharge (Appendix Figure D-22). Below 39,000 cfs, the model simulations were also rated less than excellent as forecasted velocity and depth distributions deteriorated in quality. The model simulations were rated good between 36,000 and 39,000 cfs mainstem discharge (27 and 38 cfs site flow) (Appendix Figure D-22). Below 36,000 cfs mainstem (controlling discharge), insufficient information is available to evaluate the model.

The second level of the verification has not been performed as of this time.

Application

For habitat simulation modelling purposes, the hydraulic simulation model developed for Circular Side Channel can simulate channel flows in the mainstem discharge range of 36,000 to 63,000 cfs.



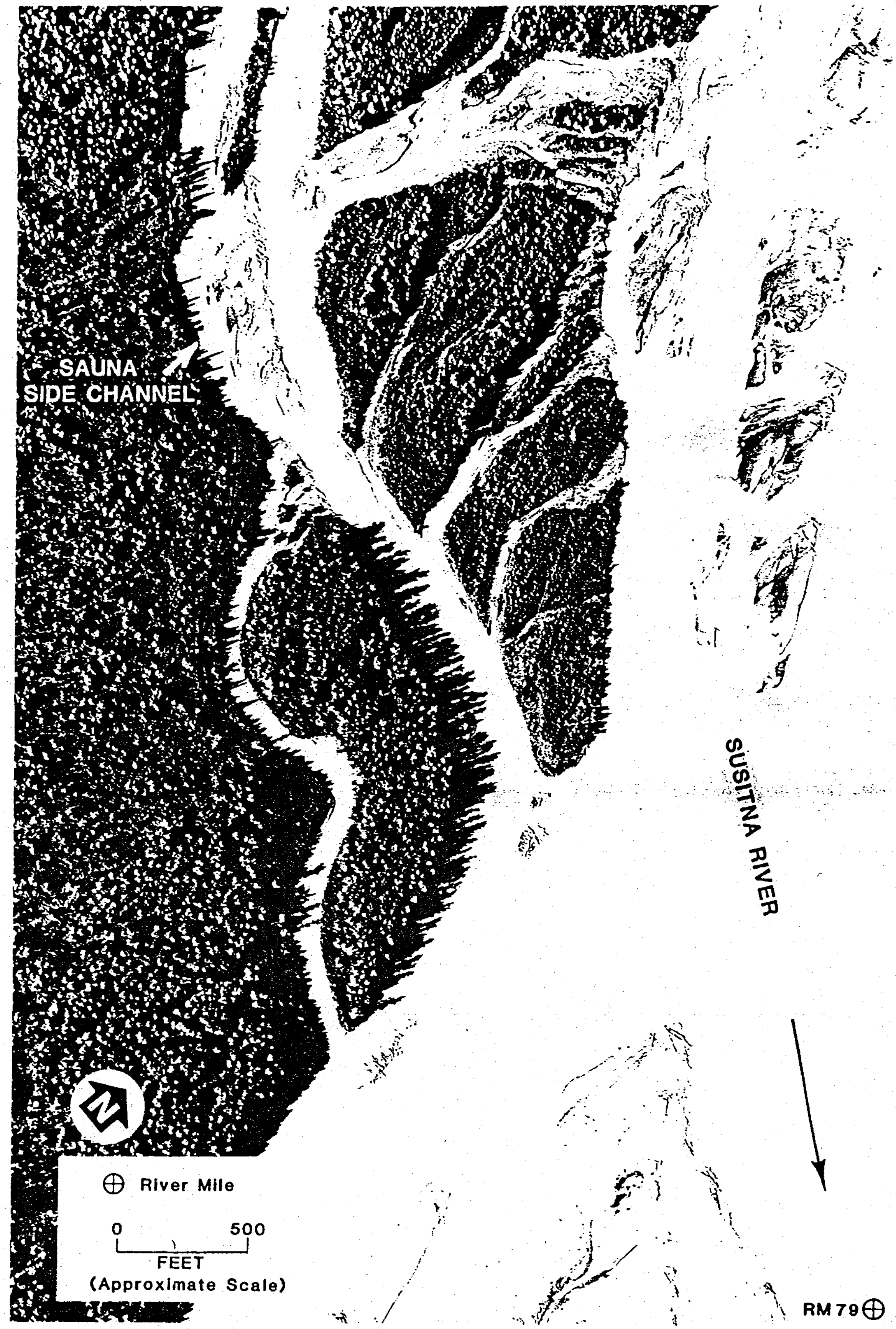
Appendix Figure D-22. Application range of the calibrated hydraulic model at Circular Side Channel.

Sauna Side Channel (RM 79.8)

Site Description

Sauna Side Channel is located on the west bank of the Susitna River at river mile 79.8 (Appendix Figure D-23). It is approximately 0.2 miles long. Both the mouth and head of the side channel are connected to a larger side channel of the mainstem Susitna River. For the most part, the side channel is confined on the west side by a high bank and on the east by a large sparsely vegetated gravel bar. A smaller side channel enters just below the head of Sauna Side Channel on its west bank. This side channel conducts flow to the study site during high mainstem discharges, but dewaters before the head of Sauna Side Channel becomes unbreached. Breaching flows result from overtopping of the side channel that adjoins the head on the east bank of Sauna Side Channel. Prior to breaching, the channel is composed of two large interconnected pools whose water levels are maintained from ground water seepage originating from the vicinity of the head. An extensive log jam exists at the head of Sauna Side Channel that likely influences the flow into this side channel.

Based on assessments by Quane et al. 1985 breaching of Sauna Side Channel is the result of overtopping of the head of the side channel by the adjoining side channel. Based on field observations and stage/discharge relationships, the mainstem discharge estimated to initially breach Sauna Side Channel was 37,000 cfs. A controlling discharge of 38,000 cfs was determined for this side channel also based



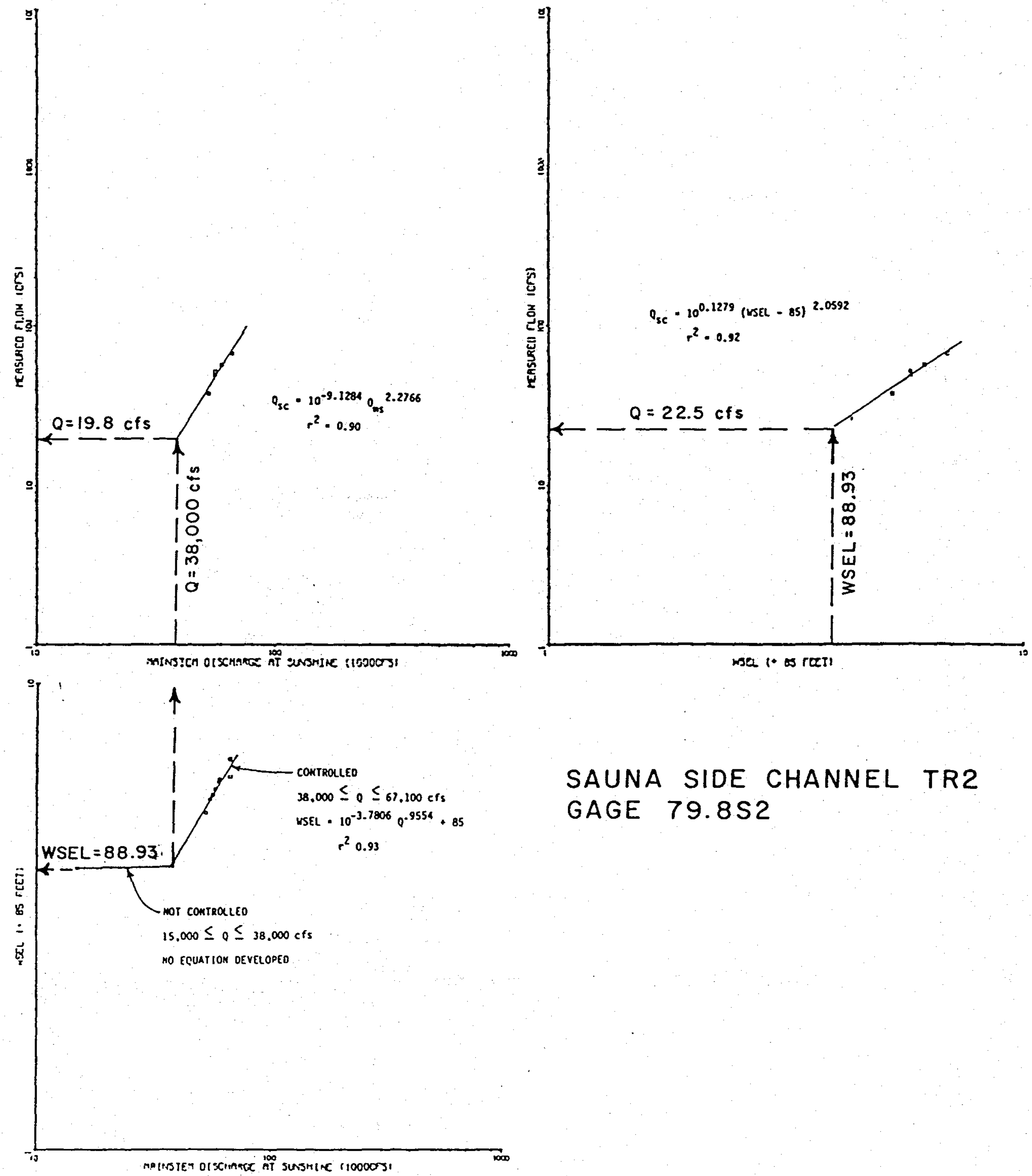
Appendix Figure D-23. Overview of Sauna Side Channel (RM 79.8).

on this stage/discharge relationship. A side channel flow of 22.5 cfs has been estimated to occur at the 38,000 cfs mainstem discharge as derived from the stage versus streamflow rating curve (Appendix Figure D-24). Based on a review of the 1984 stage data and thalweg elevations by Quane et al (1985), it has been determined that backwater does not occur in Sauna Side Channel during non-breaching mainstem discharges. During breaching discharges of 54,600 to 56,700 cfs, however, the area of backwater was observed to occur throughout the Sauna Side Channel study site. The IFG modelling site within this side channel during the 1984 open water field season was 480 feet in length and located approximately 2,000 feet from the mouth of the side channel (Appendix Figures D-23 & 25). The thalweg gradient at this site is 10.4 ft/mile (Quane et al. 1985) with substrates throughout this site consisting primarily of sands and silts. The water is slow moving with velocities usually less than 1.0 ft/sec. The left bank at this site is a erosional bank with a height exceeding five feet. Riparian vegetation along this bank consists of alder and birch, in contrast, the left bank is a depositional bank with no riparian vegetation.

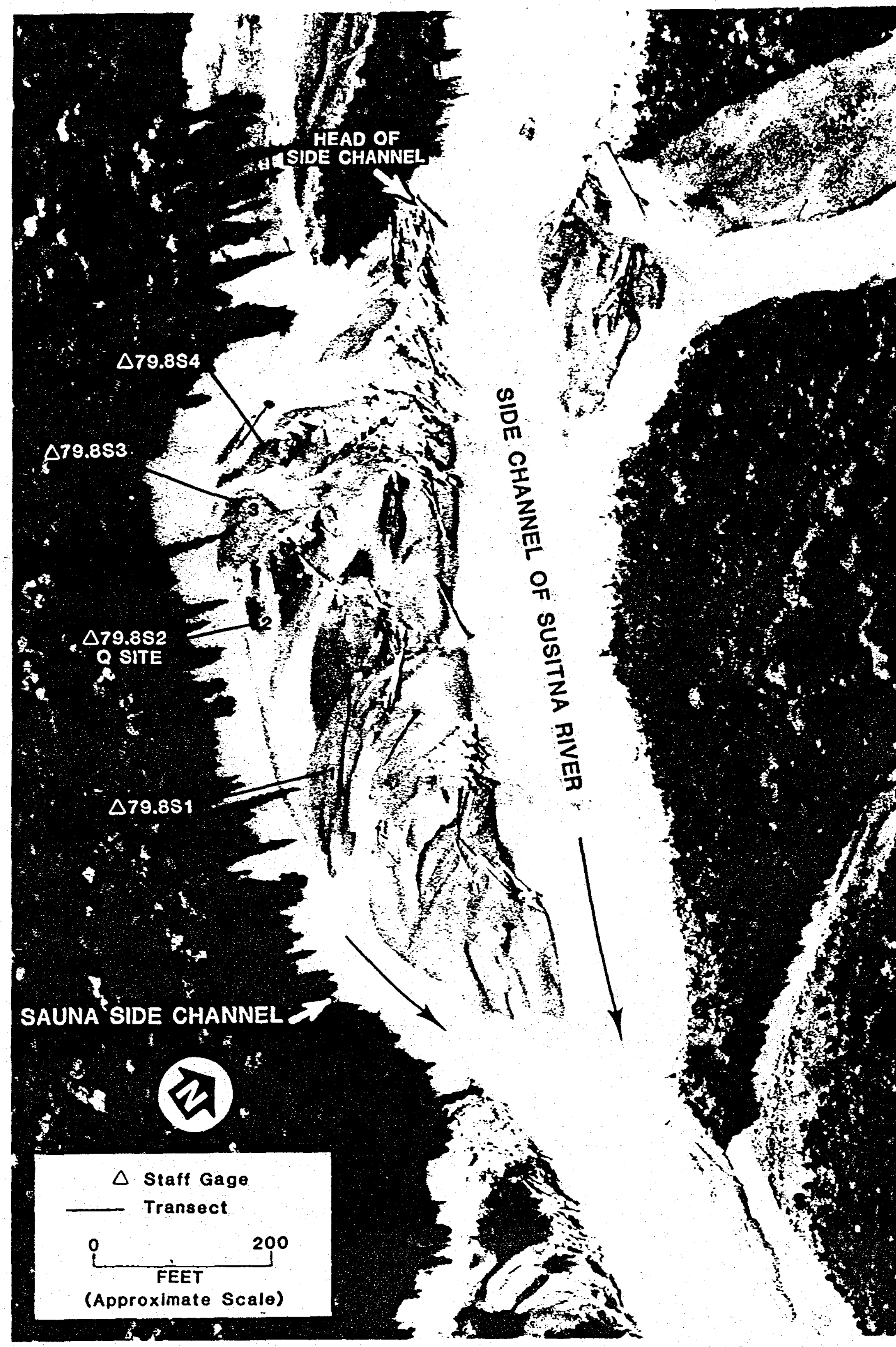
Four transects were located within this study site (Appendix Figure D-26) . Transects 1 and 2 were located in shallow pool habitat whereas transects 3 and 4 were located in deeper pools.

Data Collected

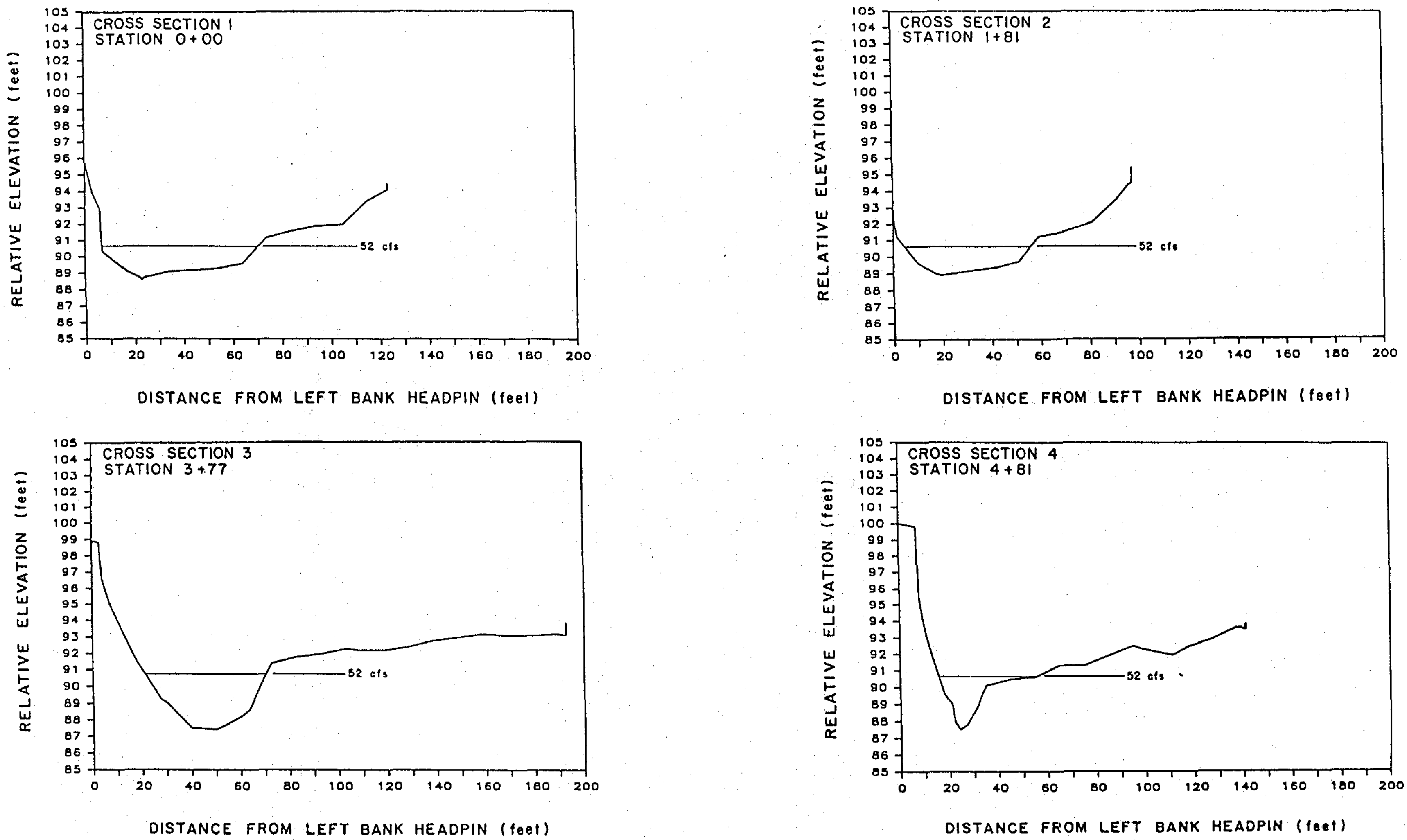
Hydraulic data were collected at a calibration discharge of 52 cfs (Appendix Table D-4). The mean daily discharge for the Susitna River on



Appendix Figure D-24. Comparison of rating curves from Sauna Side Channel transect 2 (from Quane et. al. 1985).



Appendix Figure D-25. Location of Sauna Side Channel study site (RM 79.8).



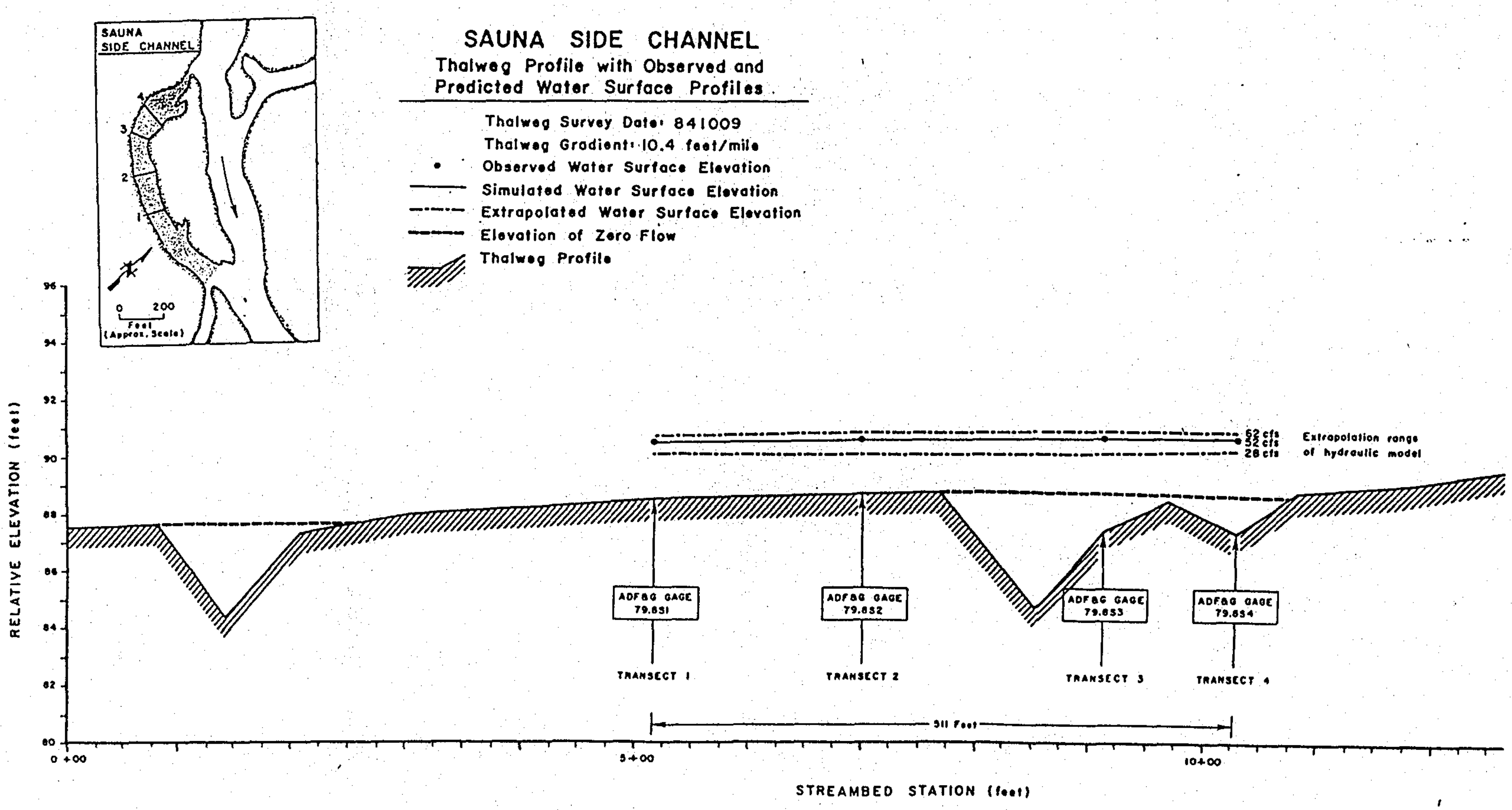
Appendix Figure D-26. Cross section of transects 1,2,3,and 4 at Sauna Side Channel (adapted from Quane et. al. 1985).

the date that the calibration data were collected at the Sauna Side Channel study site was determined to be 52,000 cfs, based on provisional USGS streamflow data.

Calibration

Calibration data available at the close of the 1984 field season consisted of that for a side channel flow of 52 cfs. Based on this calibration flow, an IFG-2 model was used to forecast instream hydraulics of this study site. The streambed profile, stage of zero flow, and observed and predicted water surface elevations for the study reach are plotted to scale in Appendix Figure D-27. This data set was used to predict hydraulic information from side channel flows of 5 to 93 cfs (mainstem discharges of 21,000 to 75,000 cfs). To evaluate the performance of the hydraulic model field observed and model predicted water surface elevations were compared (Appendix Table D-8). Additionally, the stage information of the model was compared to the rating curves established by Quane et al. (1985) (Appendix Figure D-24).

It was difficult to hydraulically calibrate this site as only very limited field data were available. A site flow WSEL rating curve could only be developed for transect 2 (Appendix Figure D-24). The IFG-2 model is essentially a water surface profile model and a critical variable for calibrating it, is the water surface elevations of simulated flows. Data, however, is only available for transect 2 and not for any of the other three transects. The actual velocity measurements from other measured field flows at the discharge transect, however, can be



Appendix Figure D-27. Comparison of observed and predicted water surface profiles from calibrated model and surveyed thalweg profile at Sauna Side Channel (adapted from Quane et. al. 1985).

Appendix Table D-8. Comparison of field measured and model predicted water surface elevations at the calibration flow of 52 cfs for Sauna Side Channel.

	Water Surface Elevation (ft)		
Transect	Original Field	Modified Field*	Model Predicted
1	90.70	90.60	90.61
2	90.71	90.61	90.62
3	90.72	90.62	90.63
4	90.69	90.59	90.63

* Field water surface elevations were reduced by 0.1 feet.

used to compare to the model predicted velocities for those same flows. At the discharge measurement for transect 2, however, there were only two flows that were far enough away from the 52 cfs measurement to be able to do this (38 and 68 cfs). Thus, the information available to hydraulically calibrate the IFG-2 model for this site consists of the water surface elevations and velocity measurements for all four transects at the calibrating flow of 52 cfs and water surface elevations and velocities for the two other site flows of 38 and 68 cfs at transect 2.

Overall, the site is hydraulically quite homogenous being influenced to a great deal by backwater (i.e., all predicted velocities were less than 1.0 ft/sec). The effects of the backwater seem more pronounced at the 68 cfs flow. From the field data, the observed top width is greater by 20 feet, the water surface elevation is 0.93 feet higher and the average velocity is 0.20 ft/sec slower than predicted by the model (Appendix Table D-9). At the 38 cfs flow the effect seems to have reversed, with the observed widths being similar, the WSEL 0.08 feet lower, and the average velocity 0.09 ft/sec faster than predicted by the model (Appendix Table D-9).

In the calibration process, the original field WSEL was reduced by 0.1 feet. This adjustment was made in order to obtain water surface elevations that agreed more closely at the lower site flows. It was felt that this adjustment would make the model, in terms of predictability, more sensitive at the lower site flows. By reducing the WSEL of transect 1 by 0.1 feet, the difference between the WSEL of the field

Appendix Table D-9. The effects of the backwater at Sauna Side Channel, information obtained from transect 2.

Site Flow (cfs)	Original WSEL (ft)		Modified WSEL (ft)		Top Width (ft)		Average Velocity (ft/sec)	
	Field	Model	Field	Model	Field	Model	Field	Model
68	91.85	91.06	91.85	90.92	77.0	55.0	0.32	0.52
52[A]	90.71[B]	90.74	90.61[C]	90.62	53.5	53.0	0.53	0.49
38	90.24	90.42	90.24	90.32	50.5	52.0	0.51	0.42

[A] Calibration flow

[B] Original field WSEL input into model

[C] Field WSEL reduced by 0.1 ft

and the model at the 38 cfs site flow was reduced from 0.18 feet, when the calibration discharge WSEL was 90.71, to 0.08 feet, when the calibration discharge WSEL was 90.61 feet (Appendix Table D-9).

As a result of a flood on August 26, sediments were deposited in the study site resulting in changes in all the cross sections derived from the calibration flow on July 23. As a result, the cross sections obtained during the September 15 survey were used in the model until the water's edge of the calibration flow was reached when then the cross section from the calibration flow was used.

When measuring the velocities and depths at each of the transects, the discharge calculated at transect 4 was 16% lower than the 52 cfs site flow calculated at the discharge transect. In order to utilize this information in the model, the velocities were adjusted upwards by 16%.

There was not a stage-site flow rating curve developed for transect 1. When inputting other flows into the model, the IFG-2 requires either the associated WSEL for this flow or the slope. Because the WSEL could not be obtained for these other flows at this transect, a slope value of 0.00005 was input instead. This value was generated by the model from transect 1 at the calibration flow of 52 cfs.

Verification

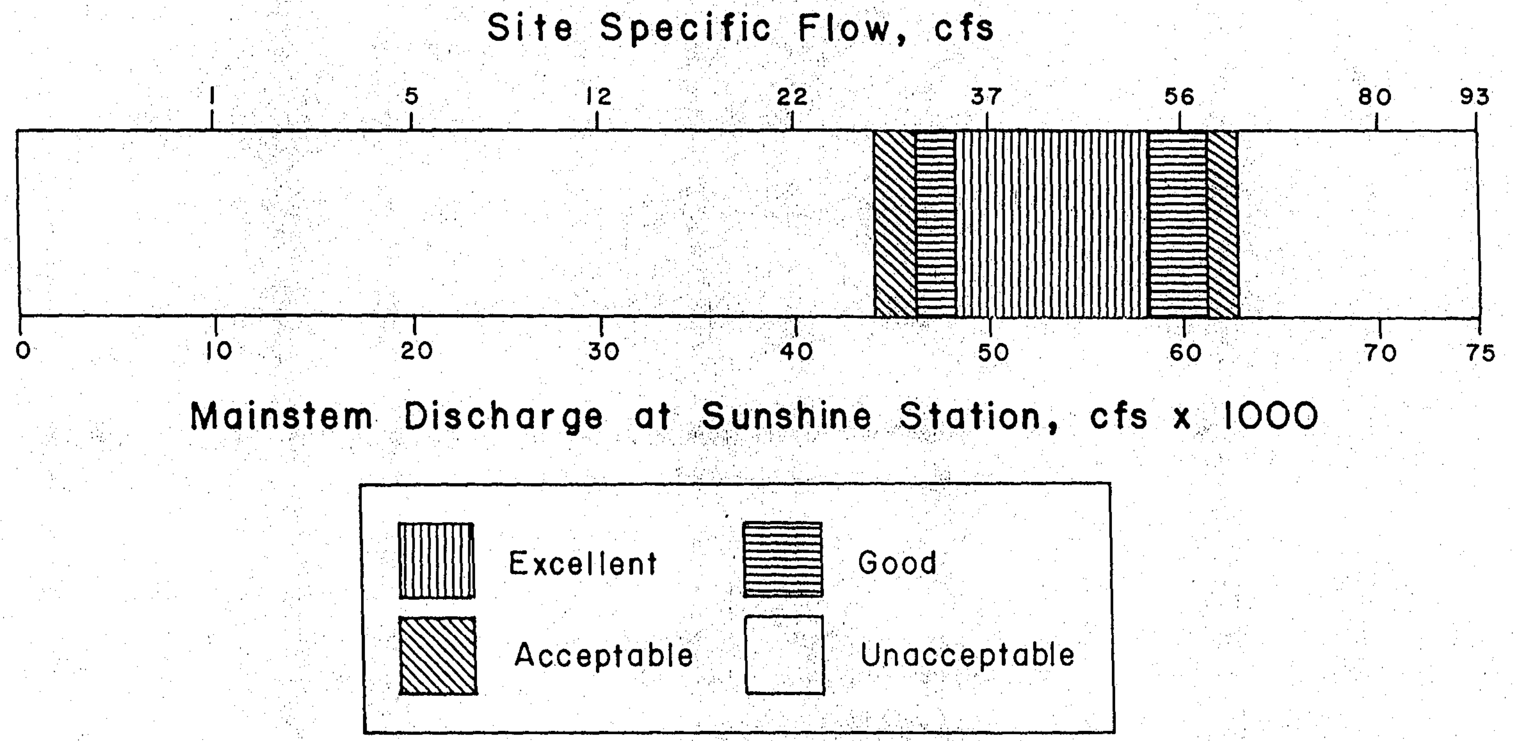
The dominant influence of backwater on channel hydraulics makes the site a poor candidate for application of IFG-2 modeling techniques. However, because only one data set was collected, application of the IFG-4 hydraulic model was not an option.

Based on the first level of verification by EWT&A, the IFG-2 model for this site does an excellent job of simulating channel hydraulics between 48,000 cfs and 58,000 cfs mainstem discharge (34 to 52 cfs site flow) (Appendix Figure D-28). Within this range, predicted WSEL's, depths, and velocities are in close agreement with field information (evaluated at 38 cfs by discharge measurement made by Quane et al (1985). The predictive capability of the model within this range provides evidence that the backwater influence within the study site is lessening with decreasing discharge.

Below 48,000 cfs mainstem, there is increasing disagreement between the WSEL's predicted by the model and those extrapolated from the rating curve. At 23 cfs site flow, the difference in predicted WSEL between model and rating curve equation has increased to approximately one foot at transects 1 and 2. Although there is evidence that suggests that the model may be a more accurate predictor of WSEL's than the rating curve equations below 48,000 cfs mainstem, insufficient information exists to resolve the difference with confidence. Since depths become shallow within this range, predictive errors in WSEL can result in significant errors in predicted depths and velocities. For this reason, the recommended extrapolation range is limited below 48,000 cfs.

Above 48,000 cfs mainstem, there is increasing, disagreement between the WSEL's predicted by the model and those observed in the field. One of

Application Range of the Calibrated Hydraulic Model at Sauna Side Channel RM (79.8)



Appendix Figure D-28. Application range of the calibrated hydraulic model at Sauna Side Channel.

the premises of the hydraulic theory that is the basis of the IFG-2 model is that the water surface profile of the study reach is controlled by its slope. This premise is violated when the water surface profile is influenced by mainstem backwater. From examination of discharge measurements made at 48 and 68 cfs it is apparent that the influence of backwater is increasing with stage above 58,000 cfs mainstem.

Overall, the recommended extrapolation range is limited above 58,000 cfs. The model simulations were rated excellent between 48,000 and 58,000 mainstem discharge (34 to 52 cfs site flow). Good between 46,000 and 48,000 (31 to 34 cfs) and from 58,000 to 60,000 cfs (52 to 58 cfs). Acceptable between 44,000 and 46,000 cfs (28 to 31 cfs) and 60,000 to 63,000 cfs (58 to 62 cfs). The model was rated unacceptable below 44,000 cfs and above 63,000 cfs mainstem discharge (Appendix Figure D-28).

The second level of the verification procedure has not been performed as of this time.

Application

For habitat simulation modelling purposes the hydraulic simulation model developed for Sauna Side Channel can simulate channel flows in the mainstem discharge range of 44,000 to 63,000 cfs.

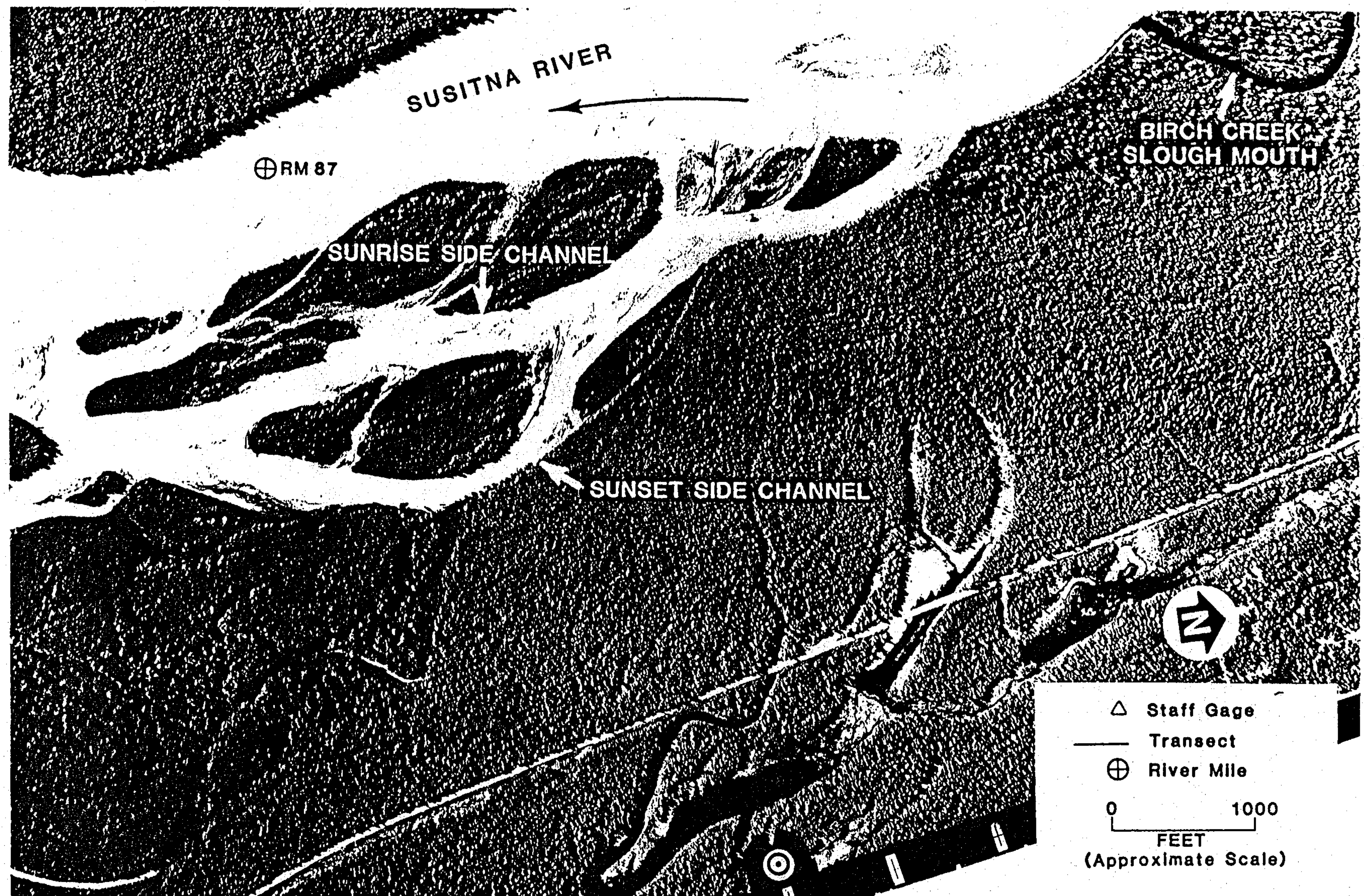
Sunset Side Channel (RM 86.9)

Site Description

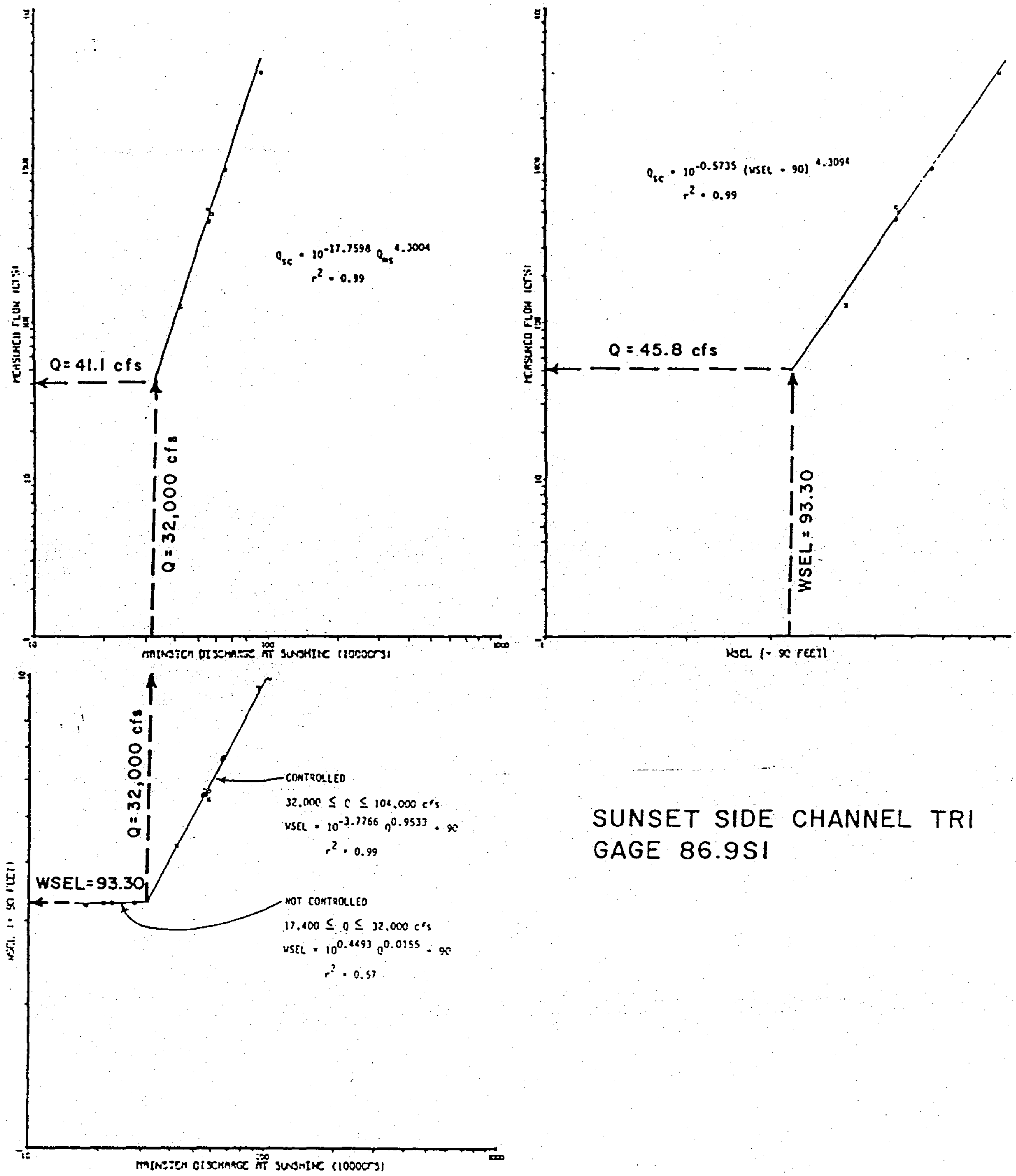
Sunset Side Channel is located on the east bank of the Susitna River at river mile 86.9 (Appendix Figure D-29). It is approximately 1.1 miles in length and is separated from the main channel Susitna River on the west by a network of vegetated islands and side channels. The channel is confined on the east by a high cut bank. Prior to breaching, the side channel is composed of a sequence of pools and riffles. During this period, flow is maintained in the main channel by groundwater seepage and upwelling. Subsequent to breaching, flows up to 3,900 cfs have been measured (Quane et al 1985).

Breaching of Sunset Side Channel results from the direct overtopping of the head of the side channel by the mainstem Susitna River. Based on assessments by Quane et al. 1985 the side channel has been estimated to be initially breached at 31,000 cfs and controlled at a mainstem discharge of 32,000 cfs. The associated site flow has been estimated to be 45.8 cfs (Appendix Figure D-30). This compares to an estimated flow of 41.1 cfs derived from the flow versus mainstem discharge rating curve presented in Appendix Figure D-30 (Quane et al. 1985).

Based on assessments by Quane et al. (1985) a backwater area does not occur in this side channel during unbreached conditions. But at breaching mainstem discharges ranging from 56,000-66,700 cfs, an area of



Appendix Figure D-29. Overview of Sunset Side Channel (RM 86.4).

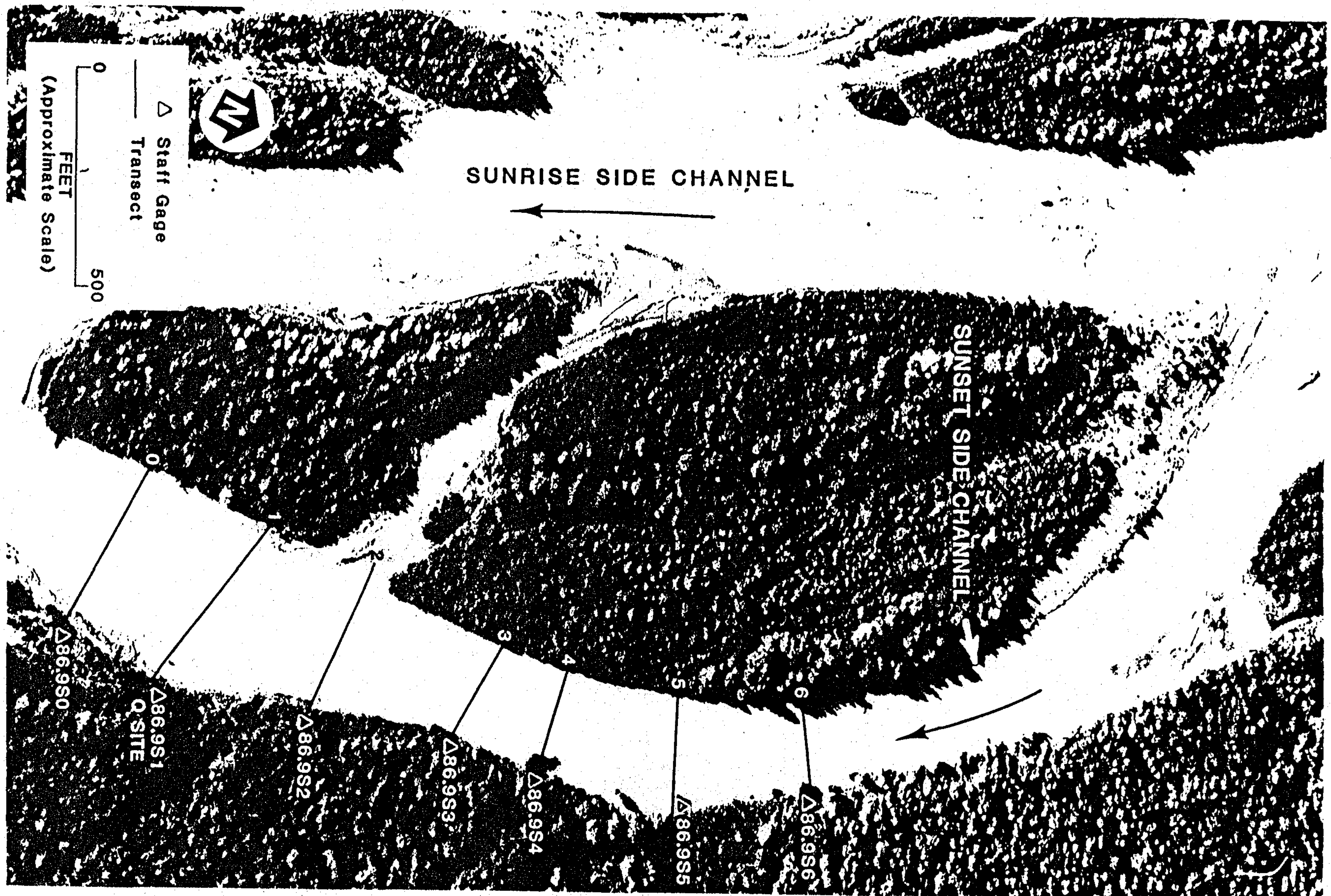


Appendix Figure D-30. Comparison of rating curves from Sunset Side Channel at transect 1 (from Quane et. al. 1985).

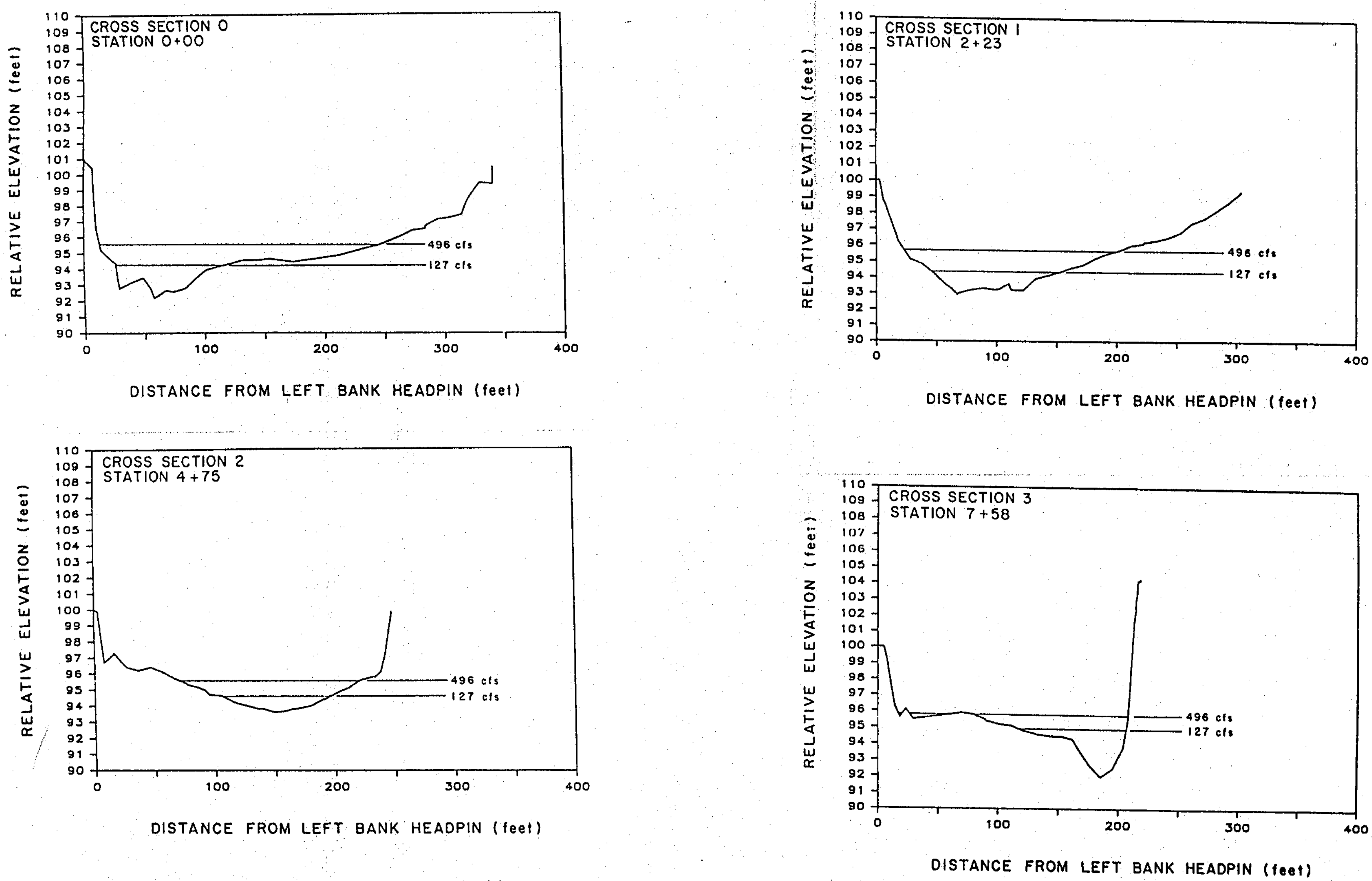
backwater was observed to extend upstream approximately 1,100 feet to a point between transects 1 and 2.

The IFG modelling site within Sunset Side Channel during the 1984 open water field season was located in the lower portion of the side channel and was 1410 feet in length (Appendix Figures D-29 & 31). Seven transects from which hydraulic information was collected were located within this study site (Appendix Figures D-32 & 33). The channel within the study site has a gradual bend. The right bank from transects 2 to 6 is erosional in nature becoming less steep and depositional in nature at transects 0 and 1. On the left bank from transects 2 to 6 is primarily depositional in nature becoming steep and erosional in the areas of transects 0 and 1. At the transect 2 on the left bank a small side channel area enters through which water was never observed running (Appendix Figure D-31). The thalweg gradient within the study site is 9.5 ft/mile (Quane et al. 1985). Riparian vegetation along the right bank is primary birch and spruce whereas on the left bank it is alder.

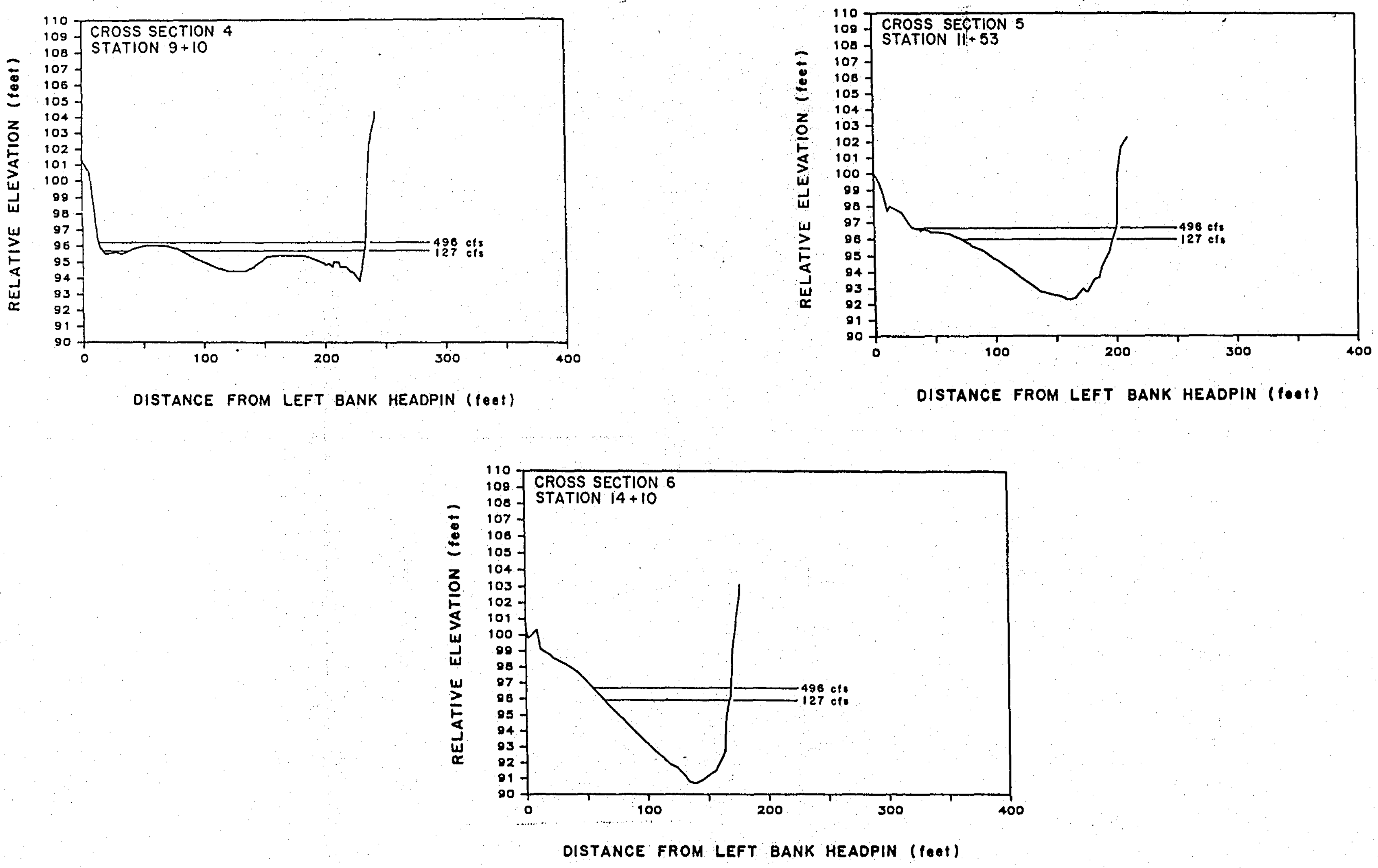
Transect 0 is located in shallow pool type habitat and has substrates of sand and small gravels. At transects 1 (the discharge site) and 2, the primary habitat type is run, and the substrate is small gravel. At transect 3, the habitat changes to run- shallow pool habitat, with the predominate substrates being small and large gravels. The hydraulic control for transects 5 and 6 is transect 4. This transect represents riffle habitat, with substrates composed mostly of small and large gravels. Transects 5 and 6 are located in deep pool habitat, with substrates being composed of mostly small and large gravels.



Appendix Figure D-31. Location of Sunset Side Channel study site (RM 86.9).



Appendix Figure D-32. Cross section of transects 0,1,2, and 3 at Sunset Side Channel (adapted from Quane et. al. 1985).



Appendix Figure D-33. Cross section of transects 4,5, and 6 at Sunset Side Channel (adapted from Quane et. al. 1985).

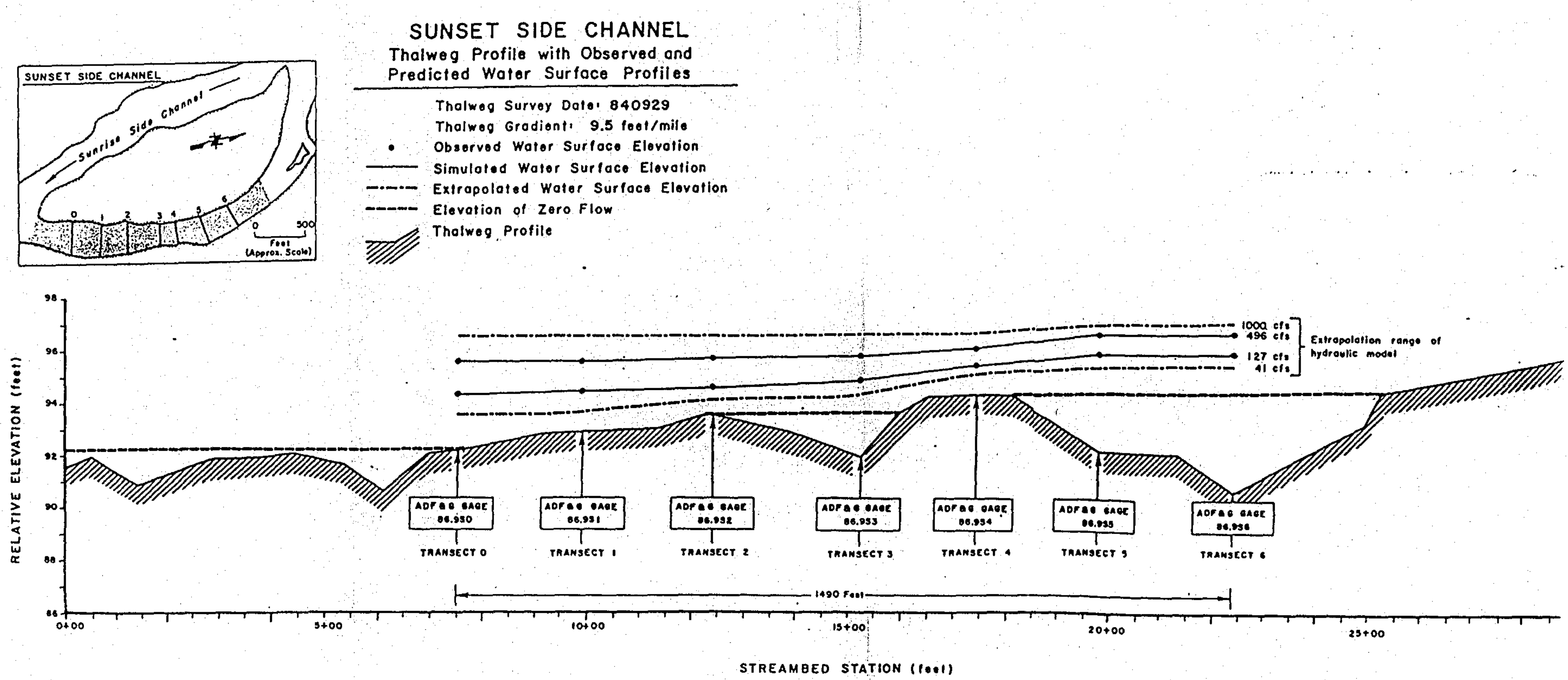
Data Collected

Hydraulic data were collected at two calibration discharges: 127 and 496 cfs (Appendix Table D-4). Mean daily discharges for the Susitna River on the dates that calibration data were collected at the Sunset Site Channel study site were 42,500 and 57,800 cfs, respectively as determined from provisional USGS streamflow data.

Calibration

Calibration data were available at the close of the 1984 field season for side channel flows of 127 and 496 cfs. Based on these two calibration flows, an IFG-4 model was used to forecast instream hydraulics at this study site. The streambed profile, stage of zero flow, and observed and predicted water surface elevations for the study reach are plotted to scale in Appendix Figure D-34. Both calibration data sets were used to predict hydraulic information from side channel flows of 7 to 1,603 cfs (mainstem discharges of 21,000 to 75,000 cfs).

To evaluate the performance of the hydraulic model, observed and predicted water surface elevations, discharges, and velocity adjustment factors were compared (Appendix Table D-10). The hydraulic model at Sunset Side Channel is similar to Circular Side Channel. Because of the 2 calibration flows, only a 2 point rating curve was formulated. In evaluating the performance of the model, observed and predicted WSEL's and discharges were the same because of this rating curve. Velocity



Appendix Figure D-34. Comparison of observed and predicted water surface profiles from calibrated model and surveyed thalweg profile at Sunset Side Channel (adapted from Quane et. al. 1985).

Appendix Table D-10. Comparison between observed and predicted water surface elevations, discharges, and velocities for 1984 Sunset Side Channel hydraulic model.

Streambed Station	Water Surface Elevation		Discharge		Velocity Adjustment Factor
(ft)	Observed (ft)	Predicted (ft)	Observed (cfs)	Predicted (cfs)	
0+00	94.27	94.27	132.7	132.4	1.000
2+23	94.34	94.34	131.7	131.3	.999
4+75	94.69	94.69	133.6	133.3	1.000
7+58	94.97	94.97	127.2	126.9	.998
9+10	95.54	95.54	136.4	136.3	1.000
11+53	95.98	95.98	125.5	125.2	.999
14+10	95.97	95.97	129.9	129.6	
			Qo = 131.0	Qp = 131.0	
0+00	95.62	95.62	462.3	462.3	1.000
2+23	95.67	95.67	500.0	500.0	.999
4+75	95.75	95.75	504.6	504.6	1.000
7+58	95.87	95.87	438.1	438.1	1.000
9+10	96.18	96.18	507.2	507.2	.993
11+53	96.64	96.64	469.9	469.9	.999
14+10	96.63	96.63	492.0	492.0	1.000
			Qo = 482.0	Qp = 482.0	

Qo is the mean observed calibration discharge.

Qp is the mean predicted calibration discharge.

adjustment factors were all within the good range of 0.9 to 1.1. Additionally, the stage information of the model was compared to the rating curves established by Quane et al. (1985) (Appendix Figure D-30).

In the model, the stages of zero flow are not the same as those determined from the thalweg survey by Quane et al. 1985 (Appendix Table D-11). The stage of zero flow values, input into the model, were derived from the thalweg points of the model input cross sections of transects 0, 1, 2, and 4. The reason for this change in thalweg elevations is likely the result of the flood event. All the points used in the model were from measurements made before the flood, whereas the Quane et al. (1985) thalweg survey was done after the flood event.

At transect 6, the velocities at the high calibration flow measurement (496 cfs) were adjusted upwards by 15% and at the low calibration flow measurement (127 cfs) adjusted downwards by 21%. Because this transect bisects a deep pool with eddies, it is difficult to obtain an accurate discharge measurement. The eddy effect was much more pronounced at the high calibration flow measurement, as there was a section of about 40 feet in which the velocities were negative. Because of its depth and slow velocities this area was considered as valuable habitat for rearing juvenile salmon. In order to facilitate using these negative velocity values in the model these measurements were treated as positive.

At transect 3 there was a difference in WSEL's at the 127 cfs calibration flow. WSEL at the left bank was 95.03 feet whereas at the right bank it was 94.90 feet. As the staff gage WSEL was 94.93 feet and the

Appendix Table D-11. Differences between stages of zero flow input into the model and Quane et al. (1985) thalweg survey at Sunset Side Channel.

Transect	Stage of Zero Flow (ft)	
	Model Input	Thalweg Survey
0	92.30	92.50
1	92.60	93.00
2	93.40	93.60
3	93.40	93.60
4	94.20	94.40
5	94.20	94.40
6	94.20	94.40

majority of flow occurred along this right side a WSEL of 94.93 feet was used in the model.

At transect 4 there was a large discrepancy (0.54 ft) in WSEL's across the transect at the calibration flow of 127 cfs. This was because the section of the channel where a majority of the flow occurred was higher in elevation and separated by a gravel berm from a lower elevation minor channel where the staff gage was located. In order to utilize this cross section in the model, the channel cross section of the minor channel was elevated upwards by 0.6 feet.

At a section of transect 3 the individual velocity measurements for the 127 cfs site flow were greater than the corresponding velocity measurements at the higher 496 cfs site flow. If these original values were to be used in the model, the simulated velocities would decrease with increasing site flows. This realistically does not occur. In order to amend this situation, the velocities were adjusted such that the relationship would simulate a positive increase in velocities with corresponding increases in site flow.

Verification

Based on the first level of verification by EWT&A, the model does an excellent job of simulating channel hydraulics between 50,000 and 61,000 cfs, mainstem discharge(275 and 649 cfs site flow) (Appendix Figure 35). Above 61,000 cfs, the simulated depth and velocity distributions begin to deteriorate in quality. The model simulations were rated good between 61,000 and 64,500 cfs (649 and 850 cfs site flow), acceptable between 64,500 and 67,000 cfs (850 and 1,000 cfs site flow), and unacceptable above 67,000 cfs mainstem discharge (Appendix Figure D-35). Below 50,000 cfs, the model simulations were also rated less than excellent, primarily because of reduced effectiveness in predicting water surface profiles as compared to field observations. The model simulations were rated good between 38,000 and 50,000 cfs (89 and 275 cfs site flow), acceptable between 32,000 and 38,000 cfs (41 and 89 cfs site flow), and unacceptable below 32,000 cfs mainstem discharge (Appendix Figure D-35).

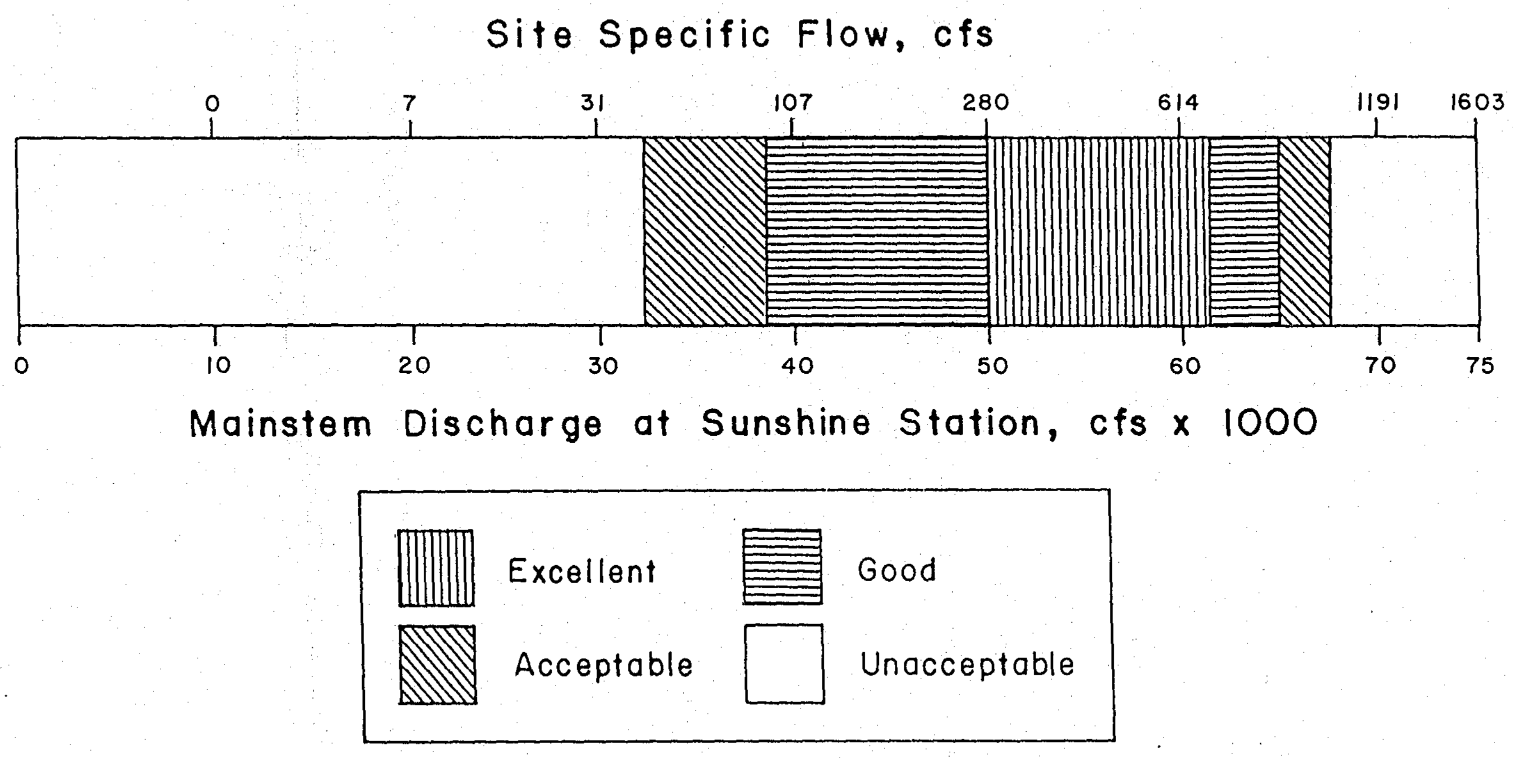
Overall, the model simulations were rated excellent between 50,000 and 61,000 cfs (275 and 649 cfs) and good from 38,000 to 50,000 cfs (89 to 275 cfs) and from 61,000 to 64,500 cfs (649 to 850 cfs). They were acceptable between 32,000 and 38,000 cfs (41 and 89 cfs) and between 64,500 and 67,000 cfs (850 and 1,000 cfs), and became unacceptable at mainstem discharges below 32,000 cfs and above 67,000 cfs.

The second level of verification has not been performed as of this time.

Application

For habitat simulation modelling purposes the hydraulic simulation model developed for Sunset Side Channel can simulate channel flows in the mainstem discharge range of 32,000 to 67,000 cfs.

Application Range of the Calibrated Hydraulic Model
at Sunset Side Channel
RM (86.9)



Appendix Figure D-35. Application range of calibrated hydraulic model at Sunset Side Channel.

Trapper Creek Side Channel (RM 91.6)

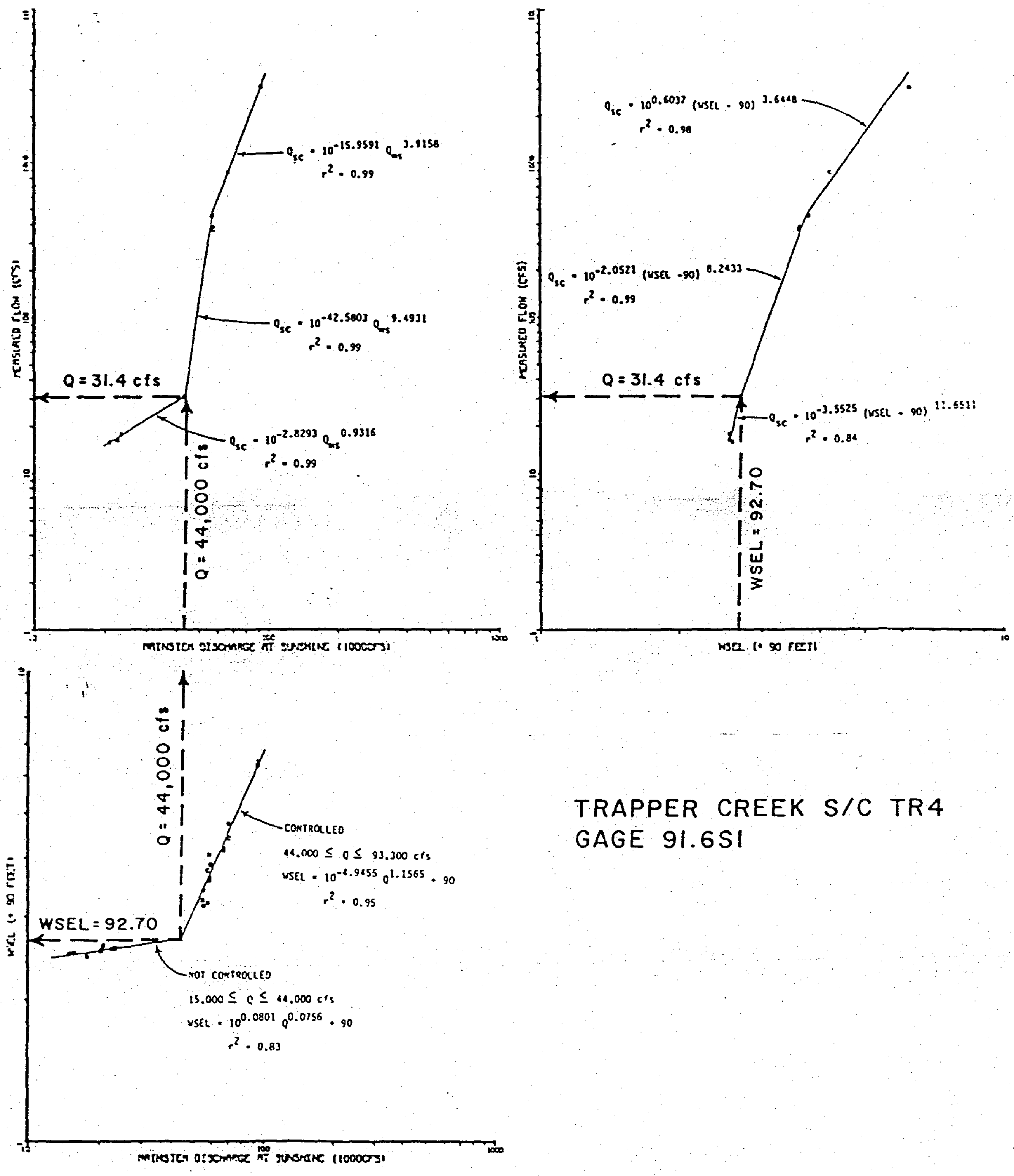
Site Description

Trapper Creek Side Channel is located on the west bank of the Susitna River and is approximately 5.0 miles in length (Appendix Figure D-36). It has a relatively uniform, broad, and flat bottomed alluvial channel which is fed by multiple heads. It is separated from the mainstem Susitna River by a complex of sand bars, small channels, and vegetated islands. The head portion of this side channel is located in a complex of small channels and vegetated islands making it difficult to identify the origin of breaching flows (Quane et al. 1985).

During unbreached conditions flows in Trapper Creek Side Channel are principally due to Cache Creek and groundwater occurring in the upper reaches of the side channel. Breaching of Trapper Creek Side Channel is the result of the direct overtopping of the multiple heads of the side channel by the mainstem Susitna River. Based on assessments by Quane et al. (1985), the channel is estimated to be initially breached at a mainstem discharge of 43,000 cfs. Based on the comparison of the stage versus mainstem discharge rating curve for transect 4 (Appendix Figure D-37) by Quane et al. 1985, a discharge of 44,000 cfs was selected as the controlling breaching discharge. This mainstem discharge corresponds to a streamflow measurement of 31.4 cfs.

Based on assessments of backwater by Quane et al. (1985), an area of backwater has not been observed during other breaching and nonbreaching

Appendix Figure D-36. Overview of Trapper Creek Side Channel (RM 91.6).



Appendix Figure D-37. Comparison of rating curves from Trapper Creek Side Channel transect 4 (from Quane et. al. 1985).

mainstem discharges. But at mainstem discharges ranging from 15,700 to 22,700 cfs, pooling was observed at transects 1, 2, and 3 which resulted from the control located about 370 feet downstream from transect 1.

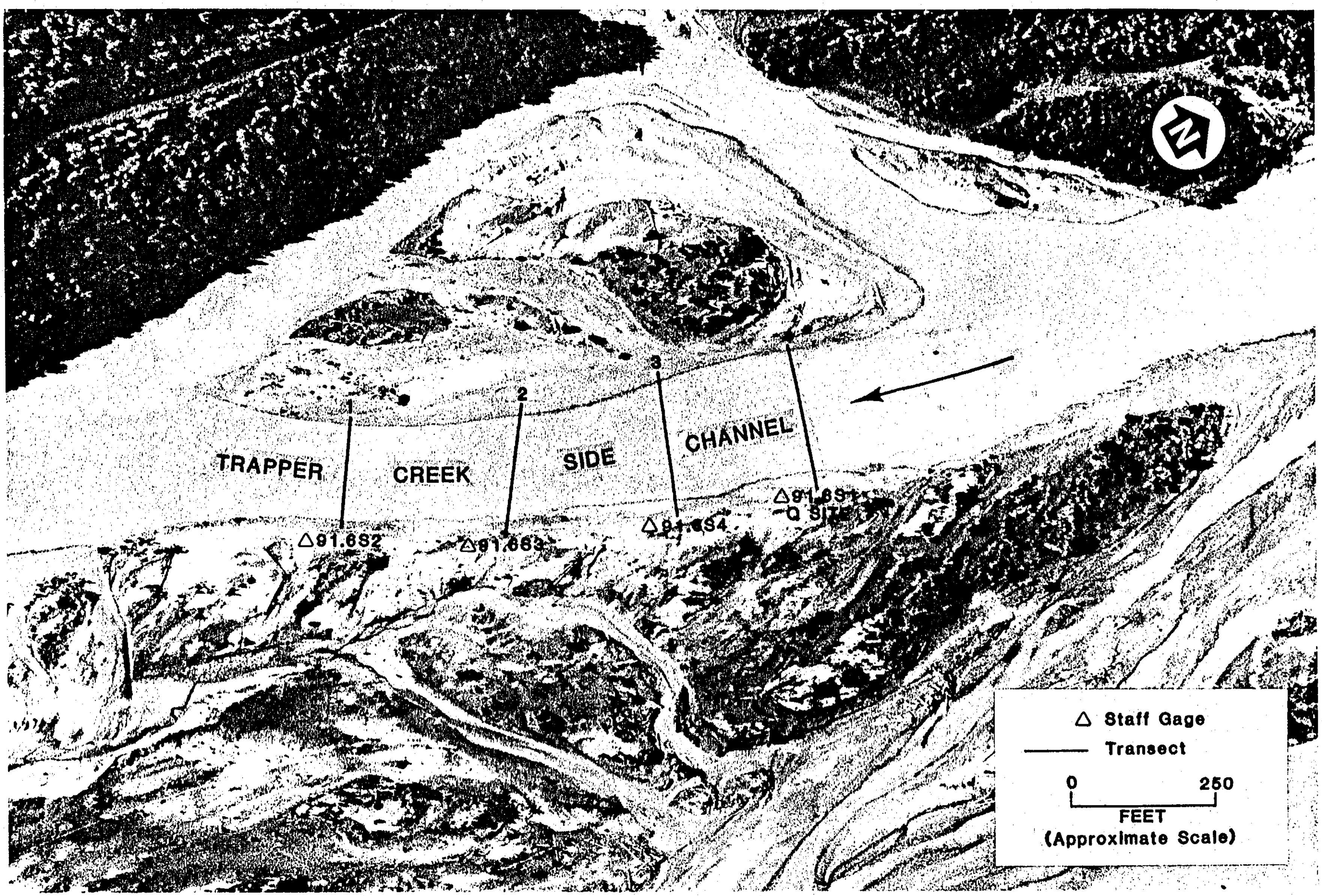
The IFG modelling site selected for Trapper Creek Side Channel during the 1984 open water field season was 790 feet in length and was located in the lower portion of the side channel in a broad open channel area (Appendix Figures D-36 and D-38). Four cross sections were surveyed within this area to define channel geometry (Appendix Figure D-39). The upper two transects were situated in a run, whereas the lower two transects were in a backwater pool influenced by a downstream control. Substrate within the study consisted primarily of cobbles and gravels with some sand at the first transect. The thalweg gradient of the side channel is 12.1 ft/mile (Quane et al. 1985).

Data Collected

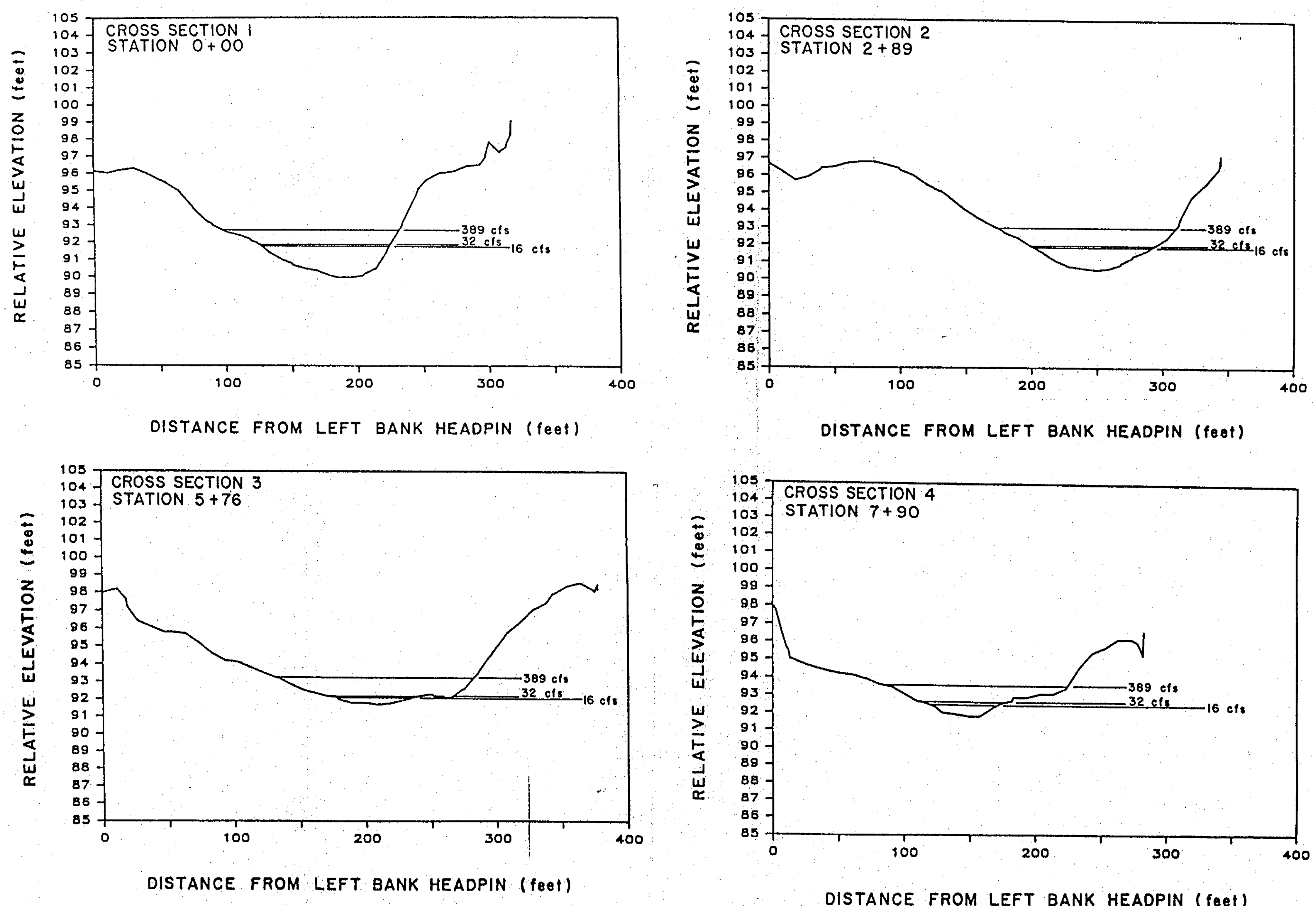
Hydraulic data were collected at three calibration discharges: 16, 32, and 389 cfs (Appendix Table D-4). Mean daily discharges for the Susitna River on the dates that calibration data were collected at the Trapper Creek study site were 20,900; 44,000; and 57,700 cfs respectively as determined from provisional USGS streamflow data.

Calibration

Calibration data were available at the close of the 1984 field season for side channel flows of 16, 32, and 389 cfs. Based on these



Appendix Figure D-38. Location of Trapper Creek Side Channel study site (RM 91.6).

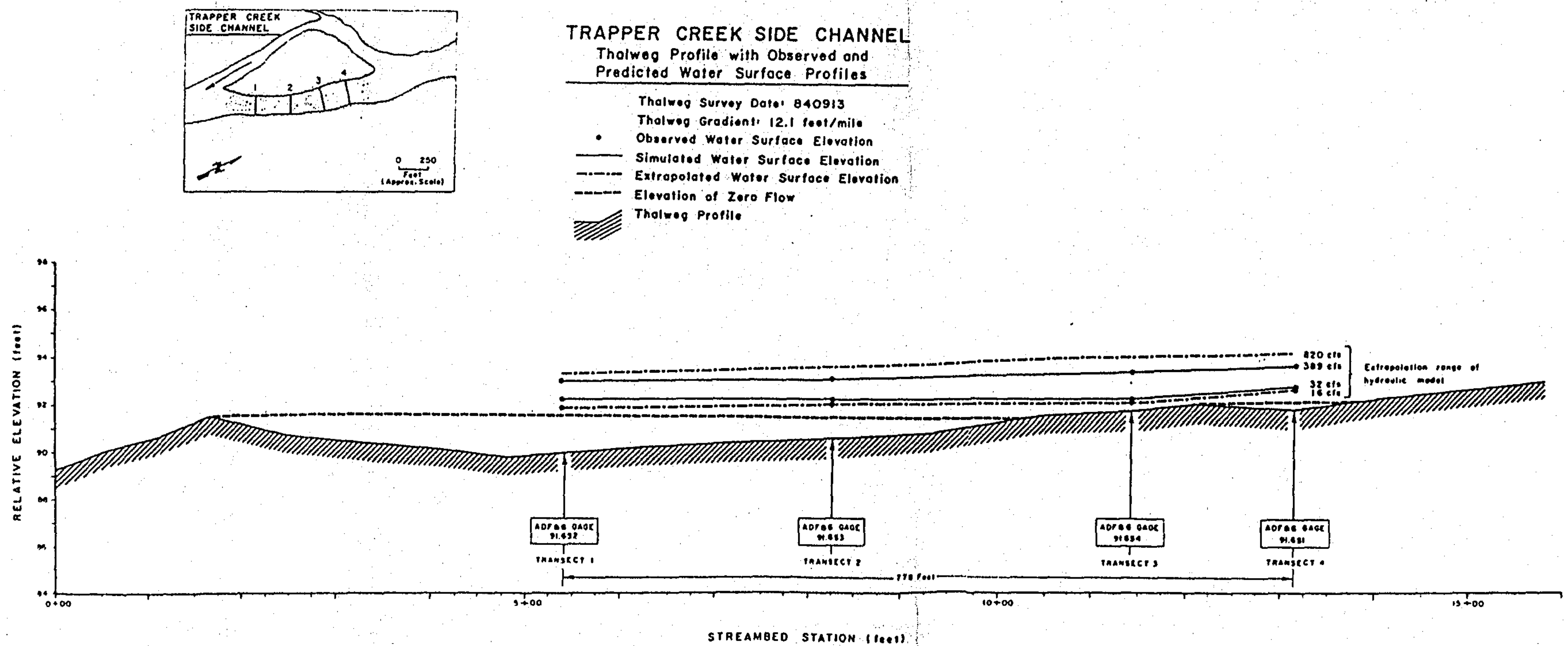


Appendix Figure D-39. Cross section of transects 1,2,3, and 4 at Trapper Creek Side Channel (adapted from Quane et. al. 1985).

calibration flows an IFG-4 model was used to forecast instream hydraulics for this study site. The streambed profile, stages of zero flow, and observed and predicted water surface elevations for the study reach are plotted to scale in Appendix Figure D-40. All three data sets were used to predict hydraulic information for side channel flows from 9 to 1,351 cfs (mainstem discharges of 12,000 to 75,000 cfs).

To evaluate the performance of the hydraulic model, observed and predicted water surface elevations, discharges, and velocity adjustment factors were compared (Appendix Table D-12). Of the 12 sets of observed and predicted WSEL's, six sets were within ±0.02 feet of each other and the other six sets were within ±0.05 feet of each other. All the observed and predicted discharges were within 10% of each other except for one set in which there was an 11% difference. All velocity adjustment factors were within the good range of 0.9 to 1.1. Additionally, the stage information of the model was compared to the rating curves established by Quane et al. (1985) (Appendix Figure D-37).

Between the time period when the first two calibration flows (389 and 32 cfs) were made and the last calibration flow of 16 cfs was made the channel cross section at transect 1 was scoured by a flood event. In order to utilize this information in the model the cross section determined from the survey and the 16 cfs flow measurement were used, the WSEL's of the two calibration flows (389 and 32 cfs) were then reduced by 0.37 feet.



Appendix Figure D-40. Comparison of observed and predicted water surface profiles from calibrated model and surveyed thalweg profile for Trapper Creek Side Channel (adapted from Quane et. al. 1985).

Appendix Table D-12. Comparison between observed and predicted water surface elevations, discharges, and velocities for 1984 Trapper Creek Side Channel hydraulic model.

Streambed Station (ft)	Water Surface Elevation Observed (ft)	Water Surface Elevation Predicted (ft)	Discharge Observed (cfs)	Discharge Predicted (cfs)	Velocity Adjustment Factor
0+00	91.94	91.90	15.4	15.1	.985
2+89	91.94	91.91	15.5	14.1	.962
5+76	92.18	92.14	16.7	15.6	.995
7+90	92.56	92.56	15.1	15.1	.976
			Qo = 16.0	Qp = 15.0	
0+00	91.97	92.92	30.1	30.8	1.041
2+89	92.00	92.04	26.0	28.9	1.033
5+76	92.24	92.29	29.6	31.8	1.043
7+90	92.70	92.70	30.2	30.2	1.042
			Qo = 29.0	Qp = 30.0	
0+00	92.75	92.74	397.8	397.3	.980
2+89	93.00	92.99	392.3	387.9	.995
5+76	93.32	93.31	413.4	410.7	.994
7+90	93.58	83.58	367.2	367.2	.997
			Qo = 393.0	Qp = 391.00	

Qo is the mean observed calibration discharge.

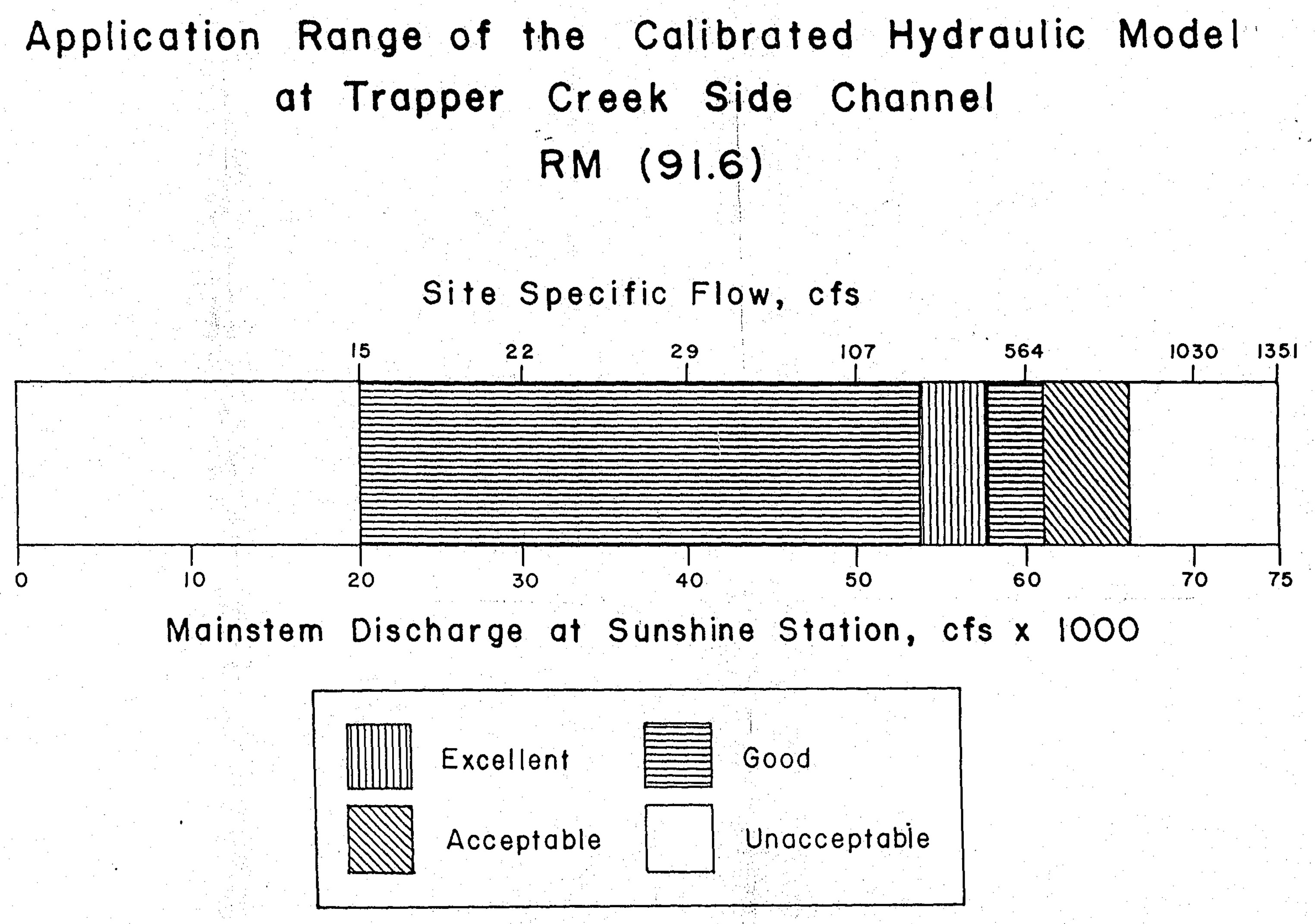
Qp is the mean predicted calibration discharge.

Transect 1 was determined to be a poor site for measuring discharge as it was a pool area affected by a downstream control. The velocities for the 32 cfs calibration flow were therefore adjusted upwards by 27% and for the 16 cfs calibration flow by 20%.

Verification

Based on the first level of verification by EWT&A the model does a good job of simulating channel hydraulics between 20,000 cfs and 54,000 cfs mainstem discharge (15 and 220 cfs site flow) (Appendix Figure D-41). There are sufficient deviations in water surface elevation and discharge between predicted and observed values within this range to preclude attainment of the excellent rating. This is because the model is approximating a portion of the rating curve described by two adjoining linear relationships with a single line.

Between 54,000 cfs and 58,000 cfs mainstem (220 and 460 cfs site flow) the model does an excellent job of simulating channel hydraulics. Beyond 58,000 cfs mainstem, the quality of the simulations begins to deteriorate as the slope of the stage/discharge relationship for the site flattens with a change in channel geometry. The deviation between the regression line developed within the model and that of the rating curve increases with discharge until the model simulations are no longer acceptable. The model simulations were rated good between 58,000 cfs and 61,000 cfs (460 and 600 cfs site flow), acceptable between 61,000 cfs and 66,000 cfs (600 and 820 cfs site flow), and unacceptable above 66,000 cfs mainstem (Appendix Figure D-41).



Appendix Figure D-41. Application range of the calibrated hydraulic model at Trapper Creek Side Channel.

D-97

The second level of the verification has not been performed as of this time.

Overall, the model simulations were rated excellent from 54,000 to 58,000 cfs (220 to 460 cfs) and good from 20,000 to 54,000 (15 to 220 cfs) and from 58,000 to 61,000 cfs (460 to 600 cfs). They were acceptable from 61,000 to 66,000 cfs (600 to 820 cfs), the simulations became unacceptable below 20,000 cfs and above 66,000 cfs.

Application

For habitat simulation modelling purposes the hydraulic simulation model developed for Trapper Creek Side Channel can simulate channel flows in the mainstem discharge range of 20,000 to 66,000 cfs.

SUMMARY

Island Side Channel (RM 63.2)

An IFG-2 hydraulic model was used to hydraulically simulate site flows of this study site based on one field measured flow of 338 cfs was. The calibrated IFG-2 model simulated site flows excellently in the mainstem discharge range of 35,000 to 56,000 cfs and good in the range of 56,000 to 64,000 cfs. The acceptable range was from 64,000 to 70,000 cfs. For habitat simulation modelling purposes the Island Side Channel hydraulic model can simulate channel flows in the mainstem discharge range of 35,000 to 70,000 cfs.

Mainstem West Bank Side Channel (RM 74.4)

An IFG-4 hydraulic model was used to hydraulically simulate site flows at this study site based on field measured flows of 6, 310, and 450 cfs from which simulated flows were based. The IFG-4 model developed for this site simulated site flows excellently in the mainstem discharge range of 18,000 to 21,000 cfs and from 28,000 to 34,000 cfs. It predicted good in the range of 21,000 to 28,000 cfs and from 34,000 to 41,000 cfs. The acceptable range was from 41,000 to 48,000 cfs. For habitat simulation modelling purposes the Mainstem West Bank Side Channel hydraulic model can simulate channel flows in the mainstem discharge range of 18,000 to 48,000 cfs.

Circular Side Channel (RM 75.3)

An IFG-4 hydraulic model was used to hydraulically simulate site flows at this study site based on field measured flows of 50 and 204 cfs from which simulated flows were based. The IFG-4 model simulated site flows excellently in the mainstem discharge range of 39,000 to 57,000 cfs. It predicted good in the range of 36,000 to 39,000 cfs and from 57,000 to 60,000 cfs. The acceptable range was from 60,000 to 63,000 cfs. For habitat simulation modelling purposes the Circular Side Channel hydraulic model can simulate channel flows in the mainstem discharge range of 36,000 to 63,000 cfs.

Sauna Side Channel (RM 79.8)

An IFG-2 hydraulic model was used to hydraulically simulate site flows at this study site based on one field measured flow of 52 cfs from which simulated flows were based. The IFG-2 model simulated site flows excellently in the mainstem discharge range of 48,000 to 58,000 cfs and good in the range of 46,000 to 48,000 cfs and from 58,000 to 61,000 cfs. The acceptable range was from 44,000 to 46,000 cfs and from 61,000 to 63,000 cfs. For habitat simulation modelling purposes the Sauna Side Channel hydraulic model can simulate channel flows in the mainstem discharge range of 44,000 to 63,000 cfs.

Sunset Side Channel (RM 87.0)

An IFG-4 hydraulic model was used to hydraulically simulate channel flows at this study site based on field measured flows of 127 and 496 cfs from which simulated site flows were based on. The IFG-4 model simulated site flows excellently in the mainstem discharge range of 50,000 to 61,000 cfs. It predicted good in the range of 38,000 to 50,000 cfs and from 61,000 to 64,500 cfs. The acceptable range was from 32,000 to 38,000 cfs and from 64,500 to 67,000 cfs. For habitat simulation modelling purposes the Sunset Side Channel hydraulic model can simulate channel flows in the mainstem discharge range of 32,000 to 67,000 cfs.

Trapper Creek Side Channel (RM 91.6)

An IFG-4 hydraulic model was used to hydraulically simulate channel flows at this study site based on field measured flows of 16, 32, and 389 cfs from which simulated flows were based. The IFG-4 model simulated site flows excellently in the mainstem discharge range of 54,000 to 58,000 cfs. It predicted good in the range of 20,000 to 54,000 cfs and from 58,000 to 61,000 cfs. The acceptable range was from 61,000 to 66,000 cfs. For habitat simulation modelling purposes the Trapper Creek Side Channel hydraulic model can simulate channel flows in the mainstem discharge range of 20,000 to 66,000 cfs.

ACKNOWLEDGEMENTS

The authors express their appreciation to the following for their assistance in preparing this report:

-- The other ADF&G Su Hydro Aquatic Studies Program staff who provided their support to this study. For collection of field data: Fred Metzler, Pat Morrow, Isaac Queral, Glenn Freeman, and John McConnaughey. To Paul Suchanek for collection of the cover information used in assessing the weighted usable areas of the models. In reduction of the data, making the many computer runs, and helping prepare this appendix: Fred Metzler, Mary Shiffer, Dan Kingsley, and Kathy Dugan. To Tim Quane, Pat Morrow, and Isaac Queral for use of much of their findings and figures from Task 36 support technical report - Hydrological Investigations at Selected Lower Susitna River Study Sites. To the editors: Doug Vincent-Lang, Tim Quane and Paul Suchanek. For the cartography on the final figures: Carol Hepler and Rox Ann Peterson.

-- To E.W. Trihey and Associates particularly Bob Aaserude and Diane Hilliard for the valuable expertise in the collection of data, the calibration, and the verification of the hydraulic models. It is felt that Bob Aaserude's involvement in the preparing of this appendix deserves an authorship.

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Appendix Attachment 1

Technical Memorandum
Extrapolation Limits of the 1984 Middle River IFG Models

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Technical Memorandum

Extrapolation Limits of the 1984 Middle River IFG Models

by

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E. Woody Trihey and Associates

April 8, 1985

D-106

The 1984 middle river IFG hydraulic models have been calibrated and their extrapolation ranges evaluated. The IFG-4 models were calibrated using both the IFG and EWT&A guidelines. The IFG-2 models were calibrated using a variable Manning's n approach. With an increase in the depth of flow, there is a corresponding decrease in Manning's n values. The depth and velocity information collected at each site was classified as either calibration or shoreline data. The calibration data was collected across the entire cross section. Shoreline data were collected from each bank out into the channel until either the depth or velocity was limiting to field personnel. Site-specific flow values, as determined by either the water surface elevation versus site flow or site flow versus mainstem discharge relationships are presented for mainstem discharges from 5,000 to 35,000 cfs. Within this range of mainstem discharges, several study sites transform from clear water side sloughs to turbid water side channels to mainstem channels. Baseline flows have been estimated for the sites when they are not controlled by the mainstem.

The quality of each model was based on two levels of criteria. The level one criteria is a qualitative evaluation of four separate criteria. The models were given a numeric rating of compliance for each criteria whenever possible. When it was not possible to routinely assign a numeric rating through a comparison of model performance with criteria, a numeric rating was assigned based on professional judgment. Application of professional judgment requires: an understanding of open channel hydraulics, familiarity with the study site, experience with the models, and knowledge of how the model will be used in the habitat analysis.

Numeric ratings for each of the four criteria are 2, 1, or 0. The models received a rating depending on how well they met the criteria. By summing the individual ratings, an overall rating was calculated for each model. Using the overall rating, models were evaluated according to the following scale:

Excellent	8
Good	7
Acceptable	5-6
Unacceptable	<5; or zero for any evaluation category

The level two criteria are based on analytical approach and will only be made when a model is not considered excellent in the level one evaluation.

LEVEL ONE EVALUATION FOR IFG MODELS

1. How well does the model conform to the IFG and EWT&A calibration guidelines?

Compare predicted depths and velocities for calibration flows with observed field data.

Are the velocity profiles realistic?

Are there more than a few outliers for the extrapolated flows?

Do the predicted discharges agree with the discharges measured in the field (IFG-4 model only) for each transect?

Are the predicted water surface elevations for a broad range of discharges coincident with the rating curves for each site?

Plot the water surface profiles, stage of zero flow, and thalweg. Are they reasonable? To be reasonable, the water must flow downhill; an increase in discharge should cause the pool riffle sequence to drown out and the water surface profile to become more uniform in gradient; a decrease in discharge should cause the water surface profile to more acutely reflect changes in stream bed gradient and riffle pool profiles.

2 = A model that can forecast both water surface elevations and velocities accurately.

1 = A model that can define water surface elevations and velocities accurately at the calibration flows but may not be able to reliably define both WSEL and velocities for the extrapolated flows.

0 = A model that can not reproduce depths or velocities accurately at the calibration flow or throughout the extrapolation range.

2. How well does the extrapolation range of the model conform to the desired range?

The first assumption made in this evaluation is that the rating curves (site flow versus mainstem discharge and water surface elevations versus mainstem discharge for the site are accurate. The ability to evaluate the forecasting capabilities improve with an increase in number of transects which have well-defined rating curves. By reviewing aerial photography and incorporating field experience, determine if there are dramatic changes in the channel geometry or local flow patterns (such as other channels becoming overtopped at higher mainstem discharges) that may cause a significant change in the site flow versus mainstem discharge relationship above the range of available data. The number of hydraulic models required to describe the full spectrum of hydraulics in the site can be determined from this analysis (one for each straight-line portion of the site flow versus mainstem discharge plot). Low flow models should be able to describe the baseline flow conditions. High flow models describe the breached conditions and can be checked by comparing the water surface profiles and velocities with observed data.

2 = A model that can accurately define both water surface elevations and velocities accurately.

1 = A model that can describe either velocities or water surface profiles accurately.

0 = The model can't describe depth and velocity for the defined range.

3. Are the models appropriate for the species and life stage being considered?

Cross sections should be located to accurately define cover, substrate, or other habitat parameters which are of importance to the species and/or life stage of interest. Study sites set up for a particular species or life stage may not accurately represent the habitat conditions for a second species or life stage.

Hydraulic models for juveniles should accurately define low velocity areas (<0.8 ft/sec), but need not be as accurate when velocities exceed 2 fps. Depth needs only to be approximate above 0.15 feet, and is of little consequence in steep-sided channels where an error will not cause a notable change in top width.

Hydraulic models for adults should accurately define velocities up to 2 ft/sec, and depths up to 1.0 feet.

2 = A model that provides sufficient precision in hydraulic forecasts to be applied to evaluation of adult and juvenile life phases with an equal level of confidence.

1 = The model provides a higher level of precision for evaluation of either adult or juvenile life phase. The greatest accuracy of the model is for the life phase for which it was originally established but resulting hydraulic forecasts are sufficiently accurate to be acceptable for other life phases. Had the study site been laid out differently, additional data collected or a separate hydraulic model calibrated, an excellent rating would have been possible.

0 = Insufficient data were collected to calibrate the model in the flow range of interest for the species/life stages to be evaluated.

4. How well do the ranges of depth and velocities of the forecasted data conform to the ranges of depth and velocity of the suitability criteria curves being considered based on a "visual" evaluation?

Do the predicted hydraulic variables associated with a high percent error fall within the a, b, or c limits of the suitability curves?

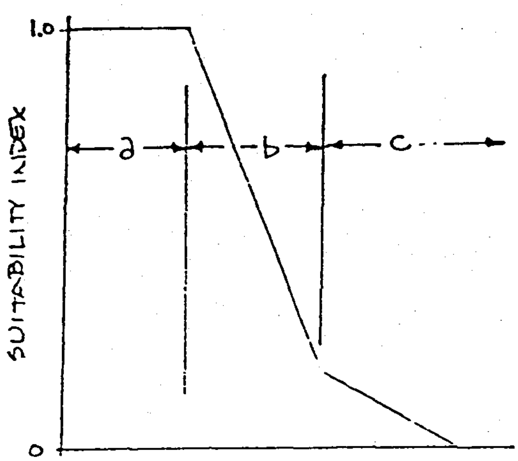


FIGURE 1.

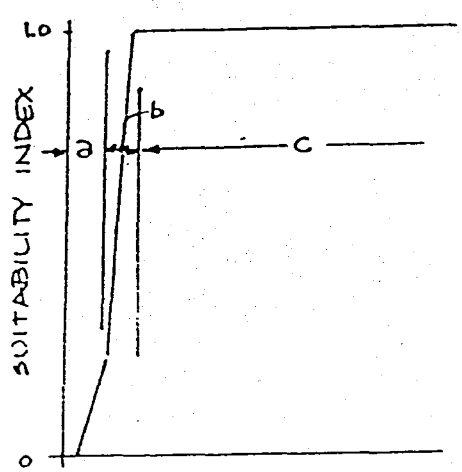


FIGURE 2.

Even though the model is not accurately reproducing depths or velocities from a hydraulic viewpoint, the predicted suitability indices could fall within a range that is not sensitive to errors in one of these indices.

The calibrated model is linked with the habitat model and weighted usable area versus site flow plots are developed. Are the WUA projections continuing on the same trend beyond the extrapolation range or is there a change in the trend?

When there is a change in the WUA versus site flow relationship similar to Figure 4, an upper limit should be established at the low point in the curve.

FIGURE 3.

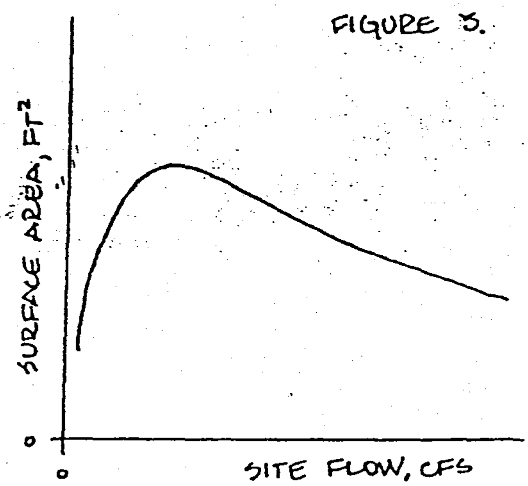
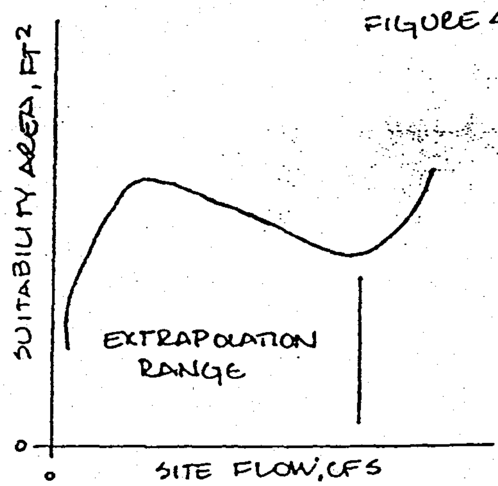


FIGURE 4.



2 = An accurate description of all ranges of depths and velocities present in the study site.

1 = Forecasting capabilities of the model are adequate when it accurately describes two of the three ranges of the suitability curve.

0 = When one or no ranges of the suitability curve are described accurately.

LEVEL TWO EVALUATION FOR IFG MODELS

Use of the level two criteria requires an analytical approach and should be applied when the forecast capabilities of either the IFG-2 and IFG-4 model are not given an excellent rating in the level one evaluation. These techniques can be incorporated as an additional step in the calbration procedure for future studies. The best method of evaluating the predictive capabilities of the hydraulic models is to collect an additional data set at each cross section that is not used in the calibration procedure and compare it to the model predictions. The test could not be applied, however, because of the limited field data that were available. All data sets that were collected were used to calibrate the models.

The analytical procedure presented has been suggested for use in geographic models which face similar problems in evaluating the differences between observed and predicted data. To date, this is the most appropriate method to use in place of collecting an additional data set.

A visual comparison is made between scatter plots of the observed and predicted depths and velocities at all cross sections for each calibration flow. The standard USGS discharge measurement procedure requires at least 20 - 25 verticals where depth and velocity data are collected. For a particular channel the verticals at higher flows are spaced further apart than at low flows. Because a cell-by-cell comparison is made for the IFG-4 model, velocities must be assigned to the same cells at the same flows. The velocities are interpolated between adjacent cells for the high flows and used as input for the model. The IFG-4 model with two or more flows generally has a larger number of verticals than the IFG-2 model suggesting this method of evaluation is more appropriate for the IFG-4 model. Scatterplot evaluations provide a qualitative assessment of the forecast capabilities of the model. A quantitative assessment can be made by computing several statistics which describe the differences between observed and predicted values (Willmott 1981). Pearson's Product-Moment Correlation Coefficient (r), Coefficient of Determination (r2), the slope (b) and intercept (a) of a least squares regression between observed and predicted values are reported as the reliable measures of a model's predictive capabilities. Willmott has suggested computing additional statistics to better evaluate the predictive capability of the model. These variables include the systematic and unsystematic components of the root mean square error

$$RMSE_S = [N^{-1}\sum_{i=1}^{N}((a + bO_i) - O_i)^2]^{0.5}$$

and

$$RMSE_U = [N^{-1}\sum_{i=1}^{N}(P_i - (a + bO_i))^2]^{0.5}$$

as well as the total root mean square error

$$RMSE = [N^{-1}\sum_{i=1}^{N}(P_i - O_i)^2]^{0.5}$$

where:

i = 1,2,........n (sample size of the number of predicted cells)

O = Observed or field measured data

P = Model predicted data.

An index of agreement (d) may also be calculated to determine the degree to which a model's predictions are error free. The index of agreement is computed by

$$d = 1 - \frac{\sum_{i=1}^{N} (P_i - O_i)^2}{\sum_{i=1}^{N} [P_i - O + O_i - O]^2}$$

The value of d varies between 0.0 and 1.0 where a computed value of 1.0 indicates perfect agreement between the observed and predicted observations, and 0.0 denotes complete disagreement.

A visual comparison can be made of the observed and predicted velocity distribution plots for the IFG-2 models, where much of the data is along the shorelines only. In general, the cells in the IFG-2 model do not coincide with verticals where field measurements were made, but rather with distinct changes in channel geometry, roughness, or habitat suitability. A representative velocity distribution "shape" was developed for each cross section, using the calibration flow data, which typically extended the full width of the channel. Where only shoreline data was available, the shape of the velocity profile was modeled after either a similar cross section at the site where a complete data set was available, or by simply developing a shape based on the channel geometry (i.e., the highest velocities should correspond to the deepest portion of the channel). This is a reliable method, since cross-sectional area and discharge are fixed and therefore the average channel velocity is defined.

Operating the IFG-2 model at discharges other than the calibration flow produces velocity profiles similar in shape to that of the calibration flow. When inconsistencies between field data and predicted velocities occurred at high flows, a second model was developed. Generally, the high flow model predicts velocity profiles that are steeper near the water's edge than the corresponding low flow models.

The level two analyses are nearly complete and will be included in the draft report. Each of the models were evaluated and rated using chinook juvenile rearing criteria. A separate evaluation using the chum spawning criteria will be discussed in a later memorandum after upwelling information is collected. A summary of the application ranges of the calibrated models with their associated ratings is presented in Figure 1. The hydraulic relationships used in the calibration effort are listed in the Appendix tables and should be used in the habitat modeling and flow duration analysis.

SITE-SPECIFIC EVALUATIONS

The specific evaluations of the middle river sites are not given because they are not applicable to the lower river study.