0011167

SUSITNA HYDROELECTRIC PROJECT

SUPPLEMENTAL RESPONSES

VOLUME I OF III

FERC License & Permitting
Harza-Ebasco Susitna
Joint Venture

LTNO 4532

Enclosure 1

I

Susitna Hydroelectric Project No. 7114
Schedule B, Supplemental Information

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2. Water Use and Quality

Comment 1 (p. E-2-5)

Provide copies of the original photographs, with dates, and an estimate of mainstem flow at Gold Creek when the aerial photographs in Figures E.2.11 to E.2.20 were taken. Provide similar sets of photographs at high, medium, and low flows to document channel stability, wetted surface areas, etc., in future Aquatic Studies.

Response

Copies of the original photos in Figures E.2.11 through E.2.20 (Exhibit E, Volume 5B) are contained in Supplemental Attachment 2-1 as SA 2-1-1 through SA 2-1-16. The photos at a scale of 1":4000' were taken on 24 August 1980 by North Pacific Aerial Survey and represent a mainstem flow at Gold Creek of 18,000 cfs. Photographs of this reach of the river for varying flows (low, middle, and high) will be taken during August-October 1983. Copies of these aerial photographs will be provided to FERC as they are made available.

EXHIBIT E

2. Water Use and Quality

Comment 2 (p. E-2-5, Figure E.2.12 - E.2.20)

Provide complete references to all cross-section data and staff gage data for locations indicated in these figures.

Response

References to Cross-Section Data:

Cross-sections LRX-1 to LRX-6[illegible], including cross-sectional plots and a description of substrate and vegetation present, are contained in: R & M Consultants, Inc. 1981. Susitna Hydroelectric Project Hydrographic Surveys Closeout Report prepared for Acres American Inc. This document is included as part of our response to your request for literature, Exhibit E, Chapter 11.

Additional mainstem cross-sections: LRX nos.: 1, 1.1, 1.2, 2, 2.1, 2.2, 2.3, 3, 3.1, 3.2, 3.3, 3.4, [illegible], 4.1, 4.2, 4.3, 5, 9.1; 10.1, 10.2, 10.3, 18.1, 18.2, 18.3, 19.1, 20.1, 20.2, 25.1, and 28.1 are contained in: R & M Consultants, Inc. 1982. Susitna Hydroelectric Project Hydrographic Surveys Report prepared for Acres American Inc. This information is included in pp. 2-2-4 to 2-2-32.

Cross-sections for sloughs 22, 21, 20, 19, 16, 11, 10, 4th of July Creek, Slough 9, 8A, Lane Creek Slough, Slough 6A and Whiskers Slough are also contained in the above cited 1982 Hydrographic Surveys Report. They are contained in pp. 2-2-33 to 2-2-84.

Cross-sectional data for Portage Creek, Jack Long Creek, Indian River, Gold Creek, unnamed tributary at river mile (RM) 132.0, 4th of July Creek, Sherman Creek, unnamed tributary at RM 123.9, Deadhorse Creek, unnamed tributary at RM 121.0, Little Portage Creek, McKenzie Creek, Lane Creek, Gash Creek, unnamed tributary at RM 110.1, and Whiskers Creek are contained in: R & M Consultants, Inc. 1982. Susitna Hydroelectric Project Analysis. Prepared for Acres American Inc. This is included in pp. 2-2-85 to 2-2-99.

Additional cross-section survey data not illustrated in Figures E.2.12 to E.2.20 were collected by the Alaska Department of Fish and Game (ADF&G) at Sloughs 8A, 9, 16B, 19, and 21. This information is contained in: Alaska Department of Fish and Game. 1981. Susitna Hydroelectric Project, Final Draft Report. Aquatic Habitat and Instream Flow Phase I Final Draft Report. Page E-5-190 and Appendix EE. The FERC staff has a copy of this document.

In the Devil Canyon to Talkeetna reach, ADF&G collected cross-section data in the following sloughs: Whiskers Creek, Lane Creek, 11, 16B, 20, 22, 8A, 9, and 21. This information is presented in: Alaska Department of Fish and Game. 1983. Susitna Hydro Aquatic Studies Phase II Basic Data Report. Figures 4-A-31 to 4-A-39 and Tables 4-E-19 to 4-E-56. The FERC staff also has a copy of this document.

References to Staff Gage Data

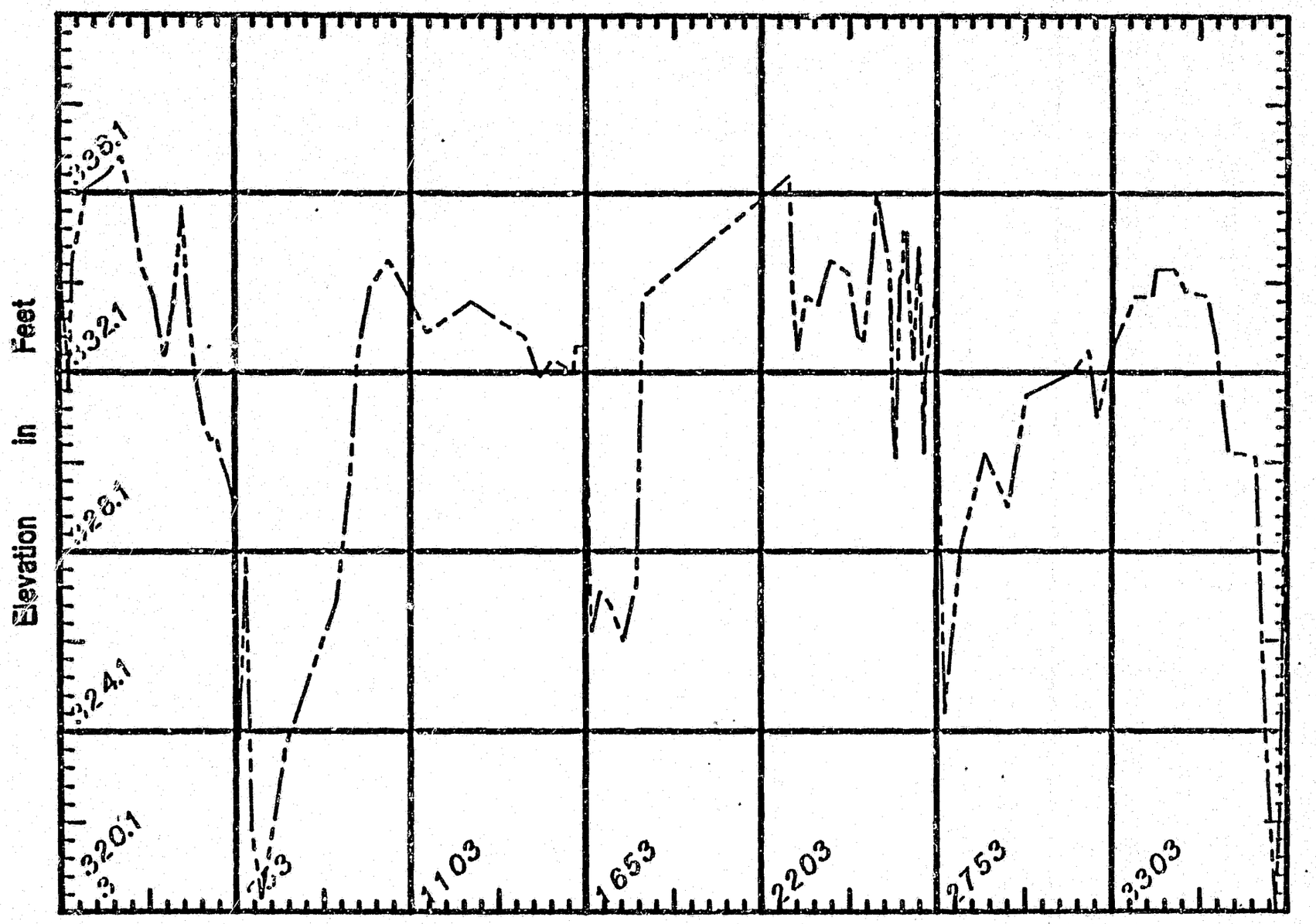
Staff gages were installed and monitored in 1981 and 1982.

Data for 1981 are presented in: Alaska Department of Fish and Game. 1981. Aquatic Habitat and Instream Flow Phase I Final Draft Report. Staff gage locations are shown on pp. E-5-174 to E-5-177, and are included in pp. 2-2-100 to 2-2-104.

Data are listed on pp. ED-1 to ED-27. Crest gage data for 1981 in the mainstem Susitna River are listed in: R & M Consultants Inc. 1982. Susitna Hydroelectric Project Field Data Collection and Processing Volume 3, pp. E-7 to E-19. This is included in pp. 2-2-105 to 2-2-117.

Information on the staff gage sites installed and monitored in 1982 in the Devil Canyon to Talkeetna reach is contained in: Alaska Department of Fish and Game. 1983. Susitna Hydro Aquatic Studies Phase II Basic Data Report. Staff gages at tributaries between Devil Canyon and Talkeetna are shown in Table 4-I-3-3, staff gage data from mainstem Susitna River sites in Table 4-A-2, staff gage data for sloughs upstream of Talkeetna in Table 4-A-3, and staff gage data at the downstream end of Slough 9 in Table 4-II-4-2.

SUSITNA HYDROGRAPHIC SURVEYS



PREPARED BY:

R&M CONSULTANTS, INC.

CROSS-SECTION Number 1

PREPARED FOR:

ACRES

C-8

2-2-4

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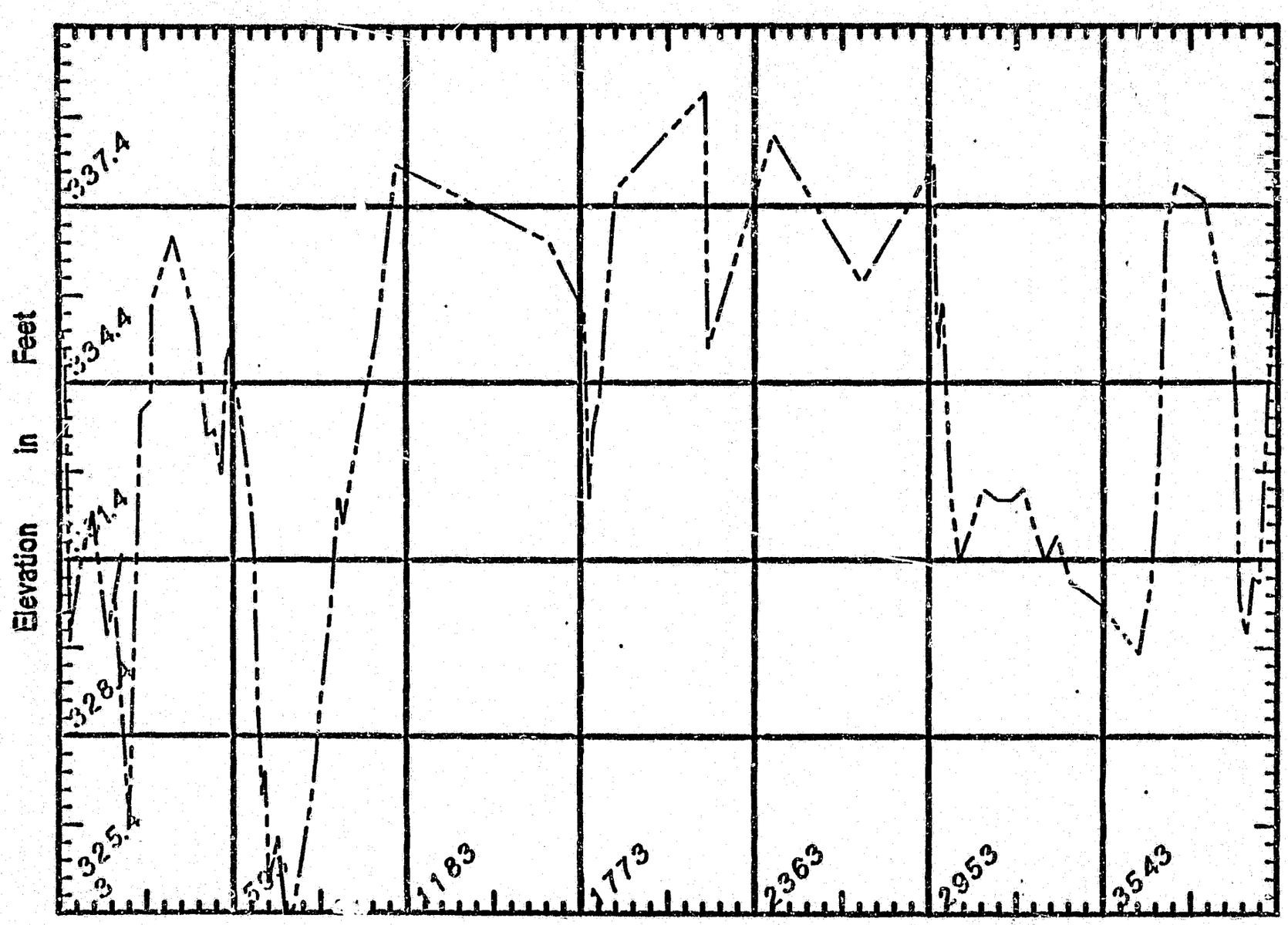

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C-3

2-2-5

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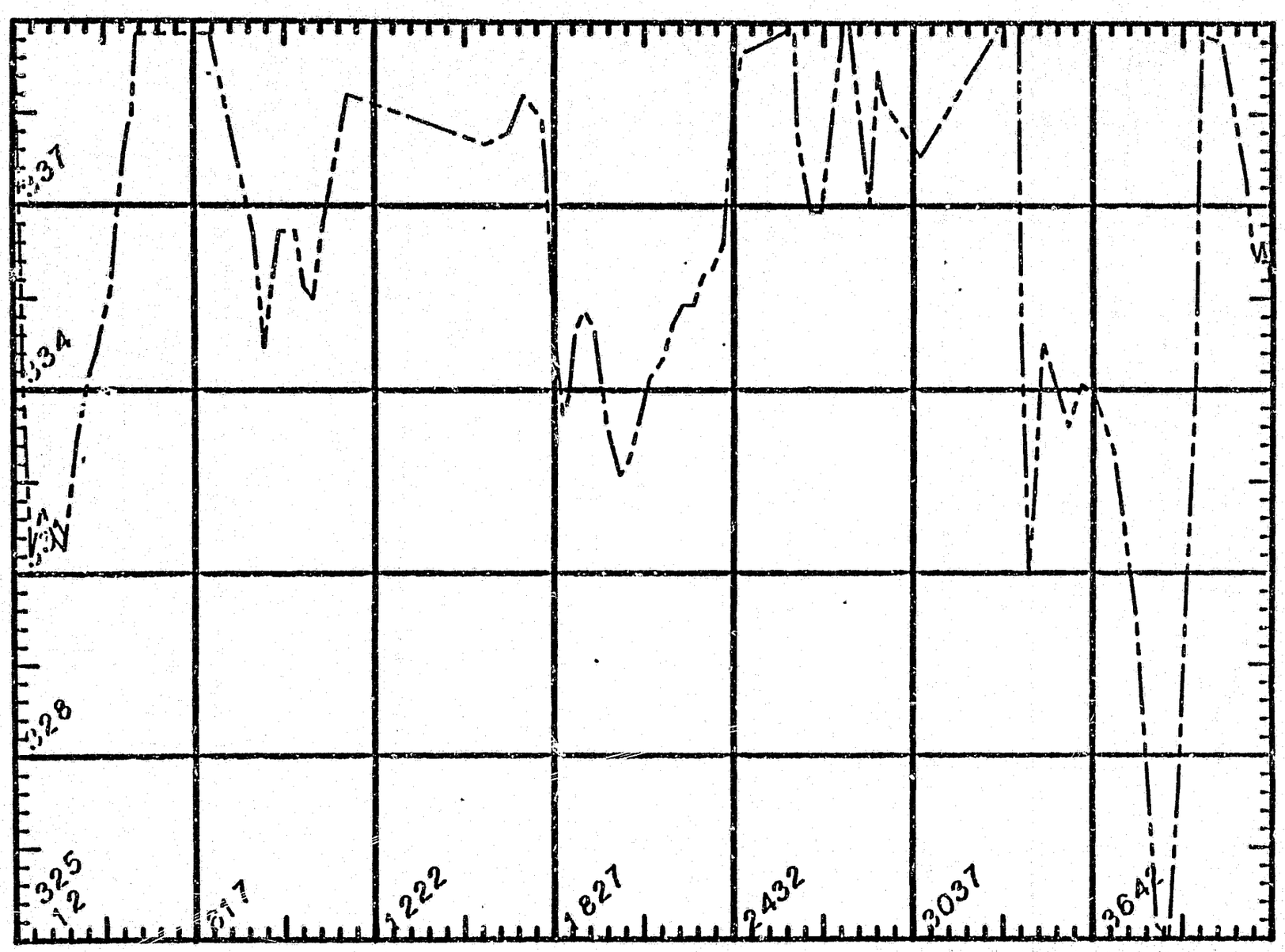

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C-10

6-2-2

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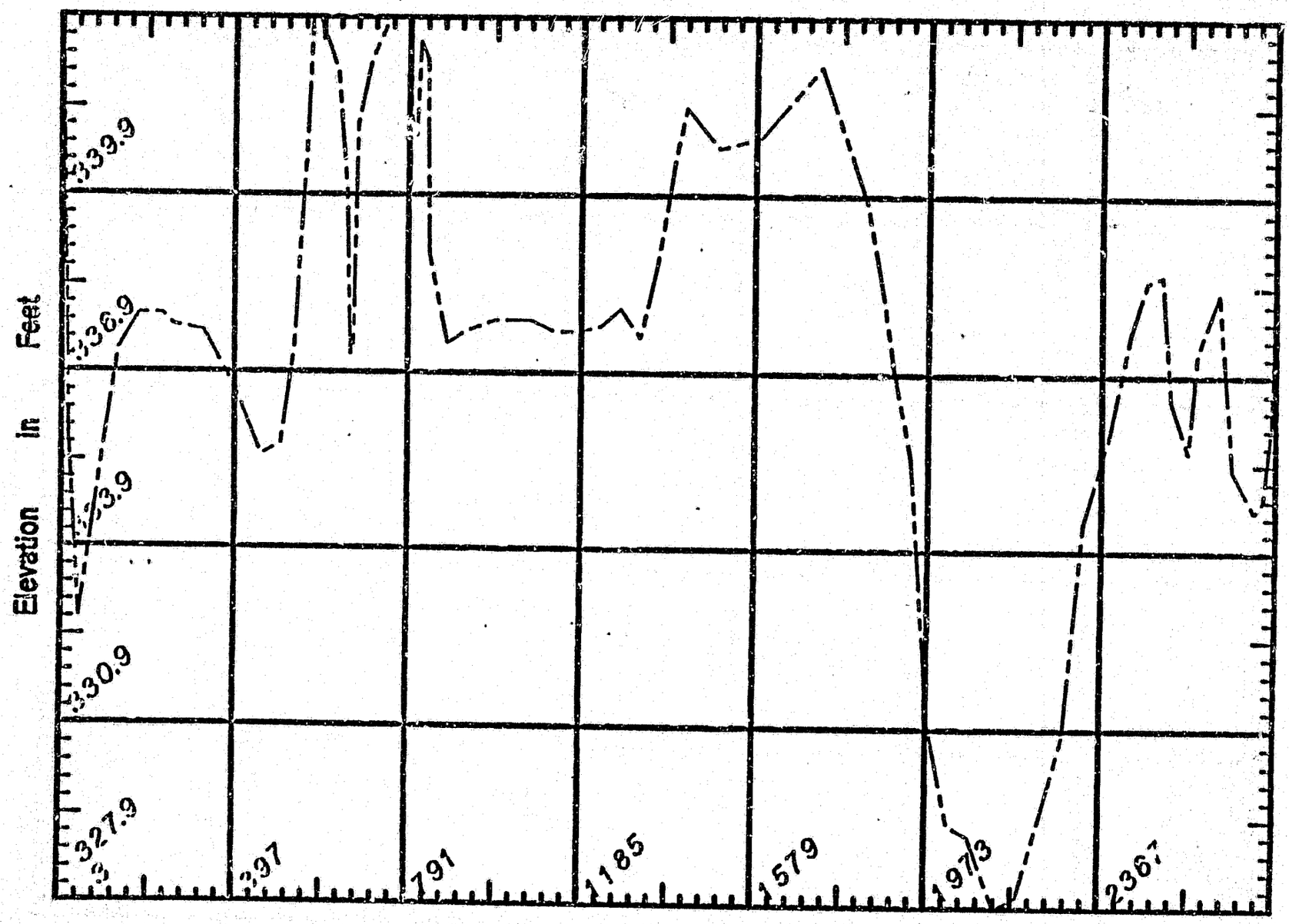

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2-2-7

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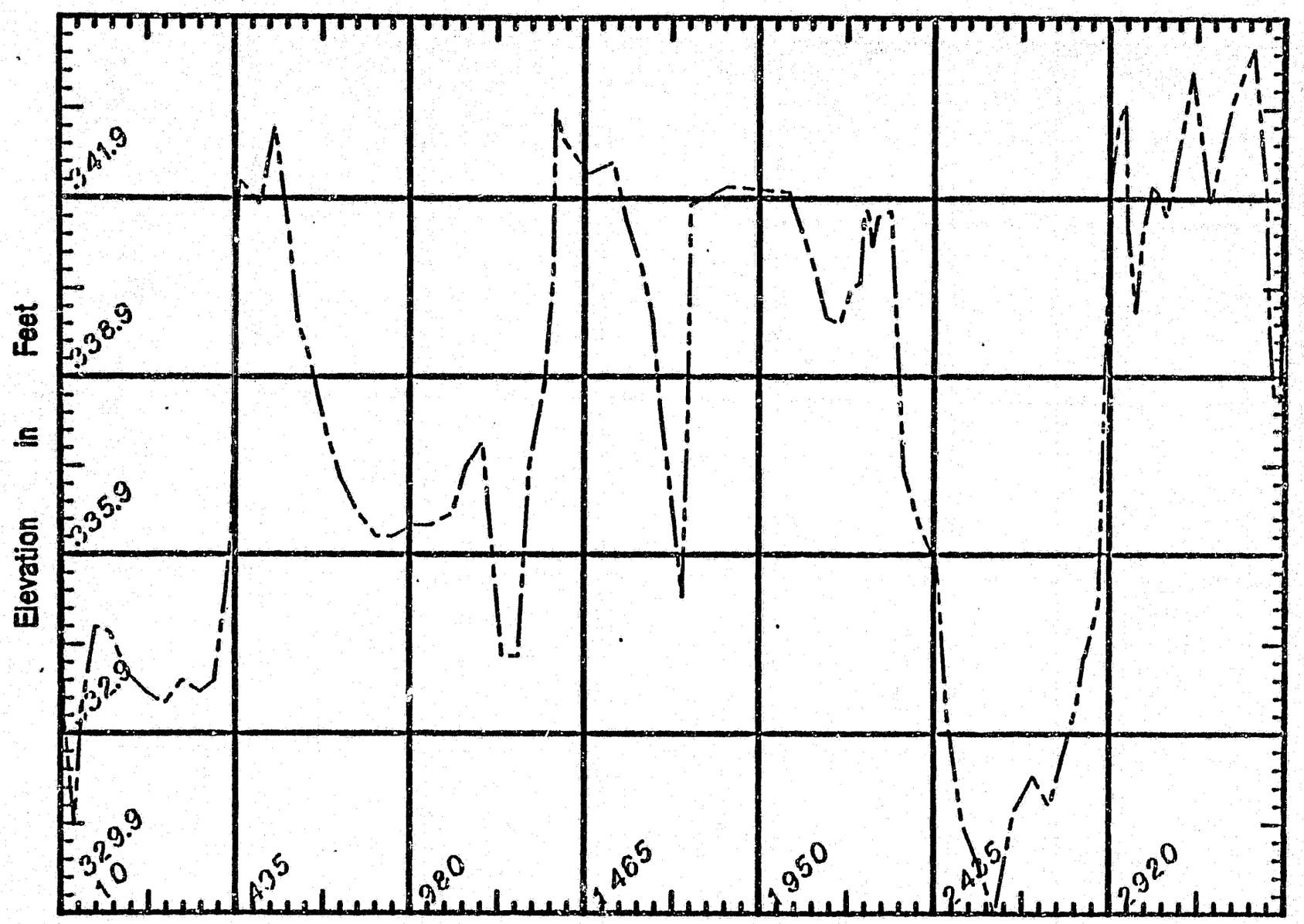

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C-12

2-2-8

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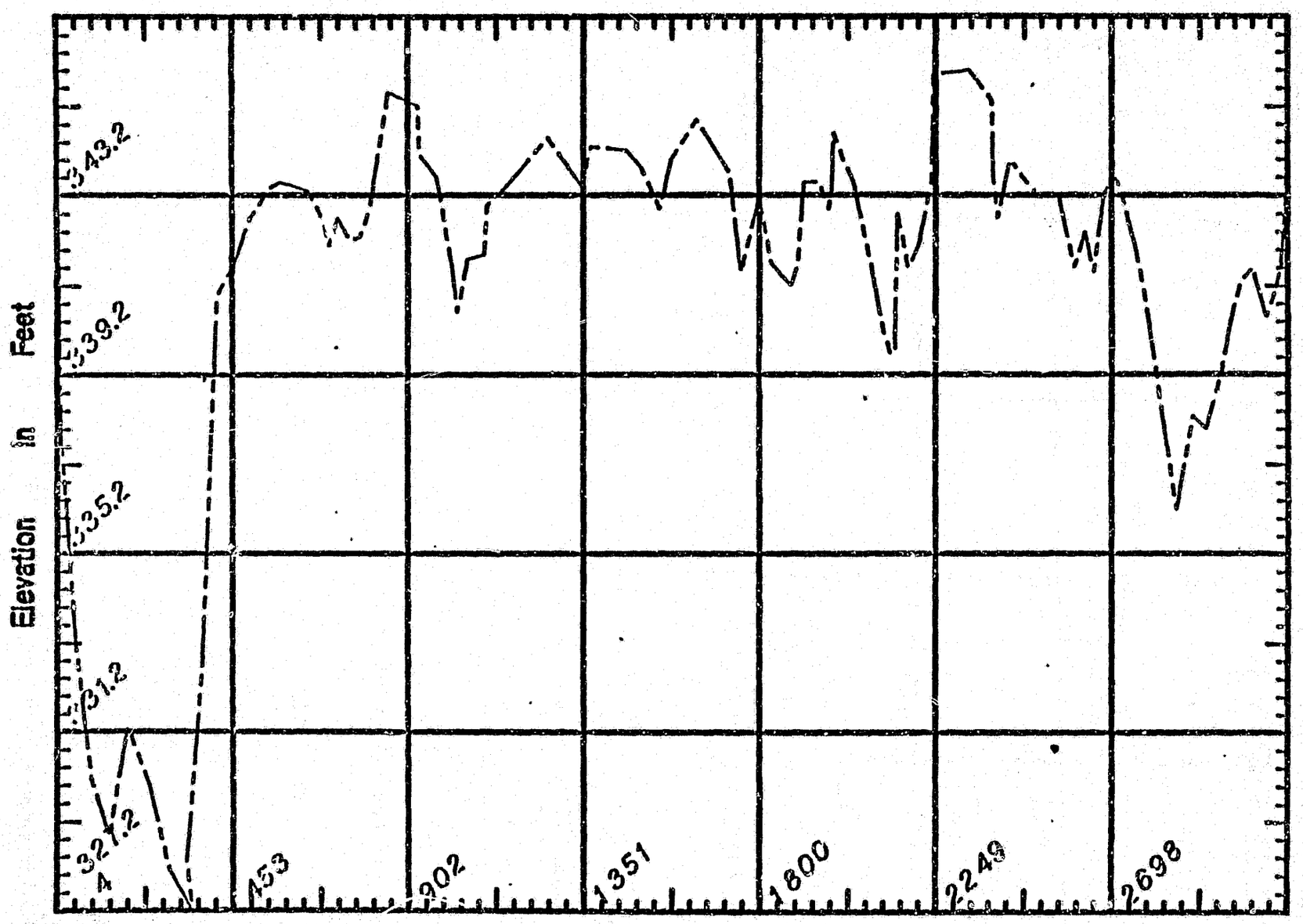

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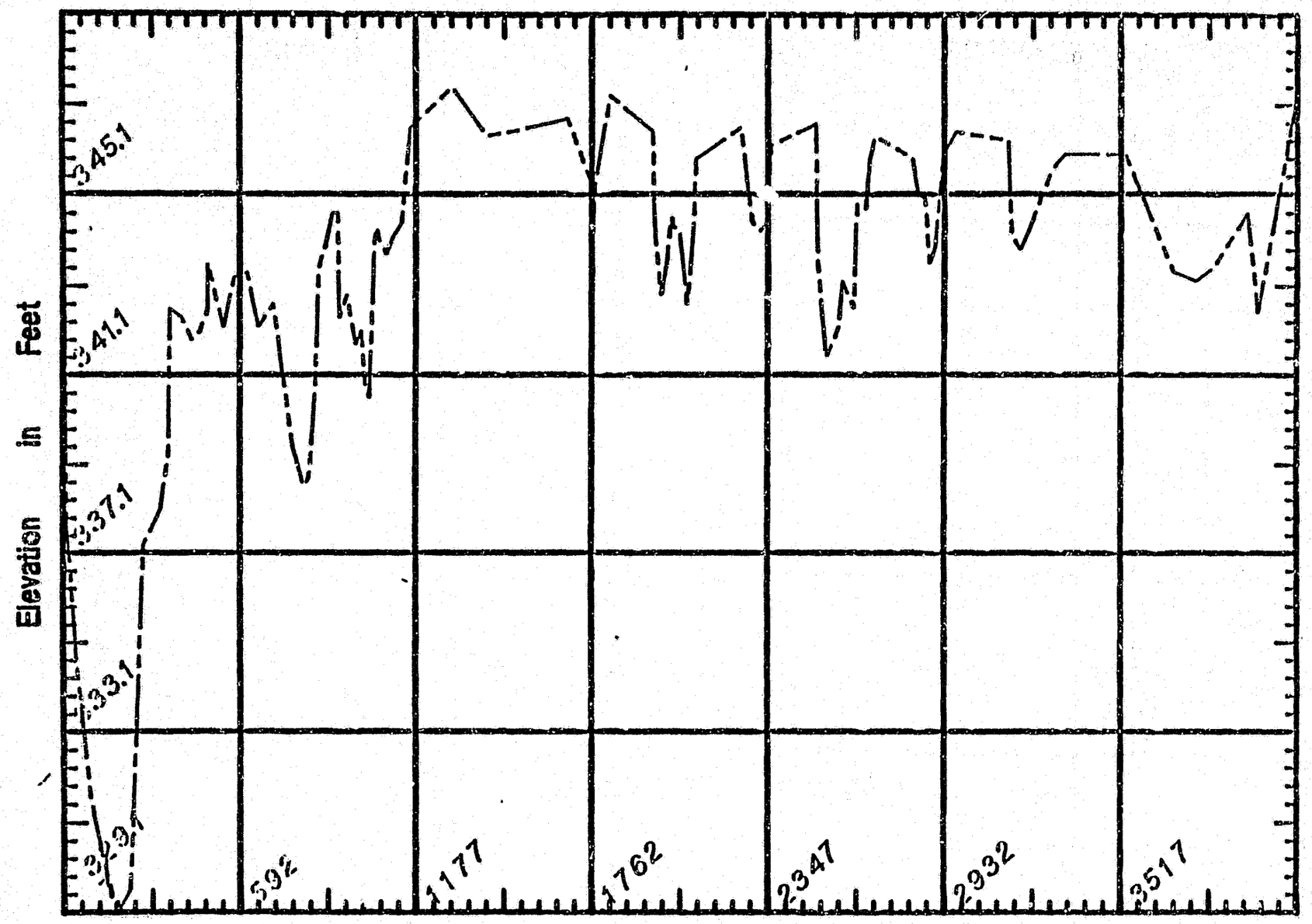

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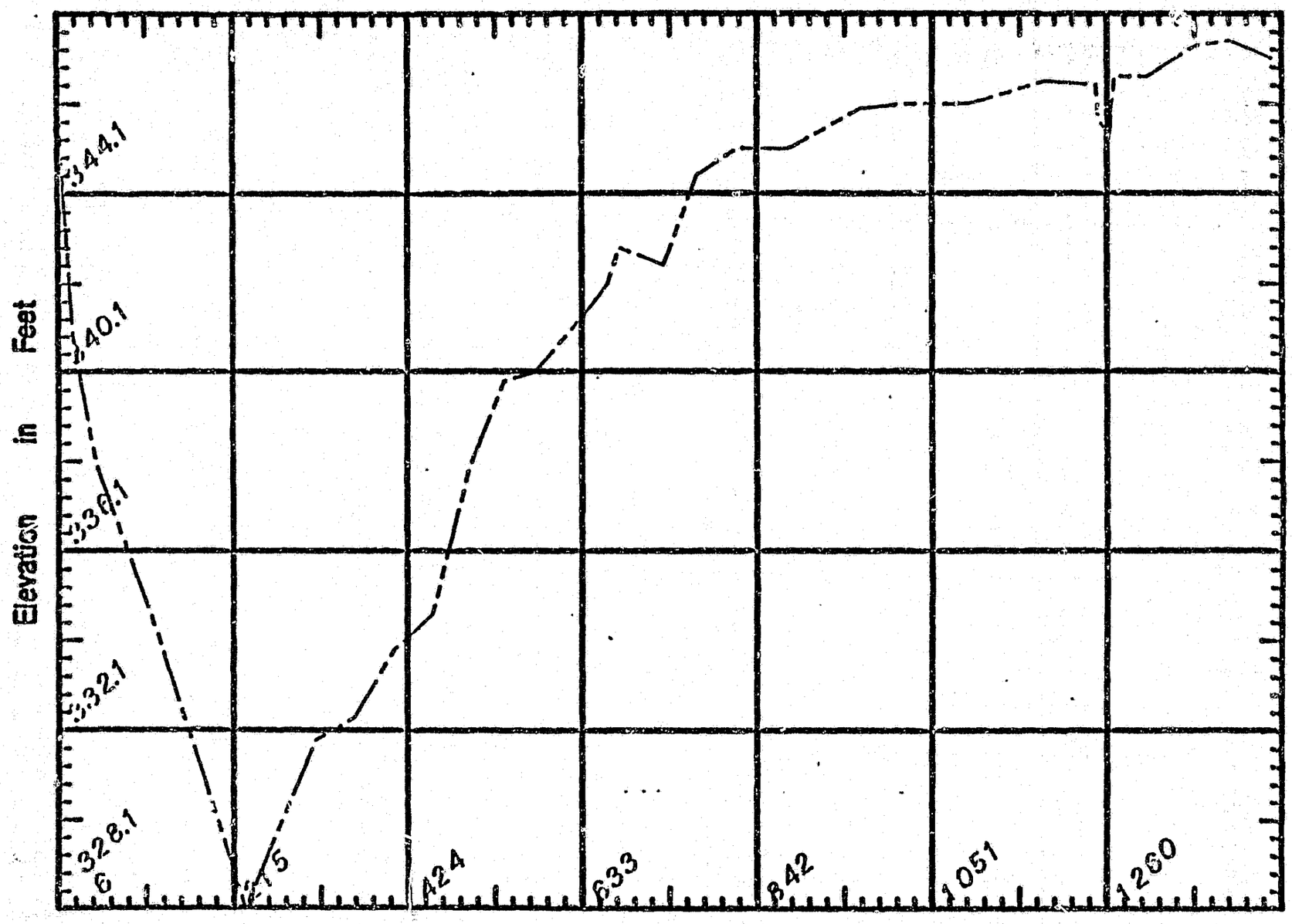

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CROSS-SECTION Number 3

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11-2-2

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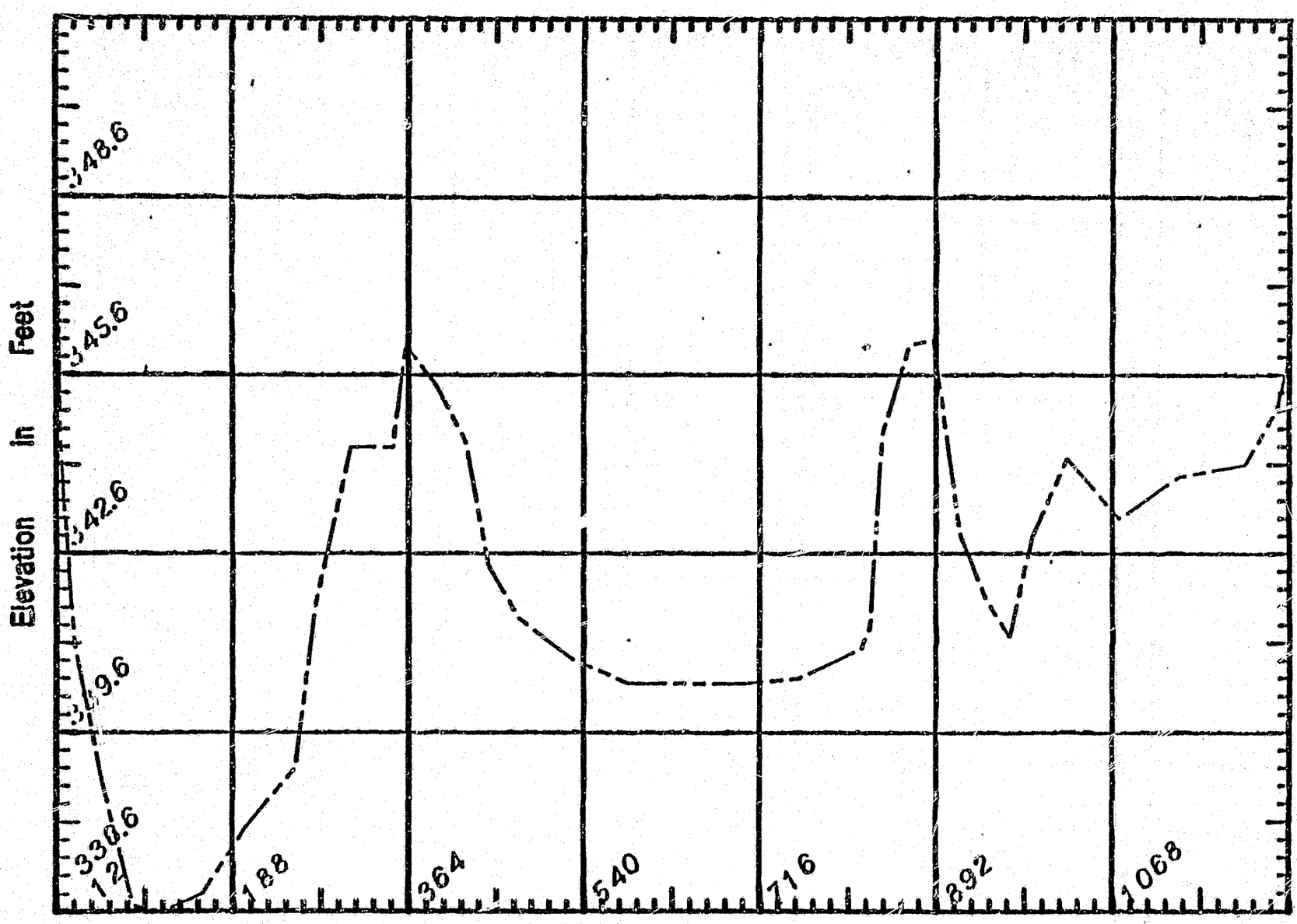

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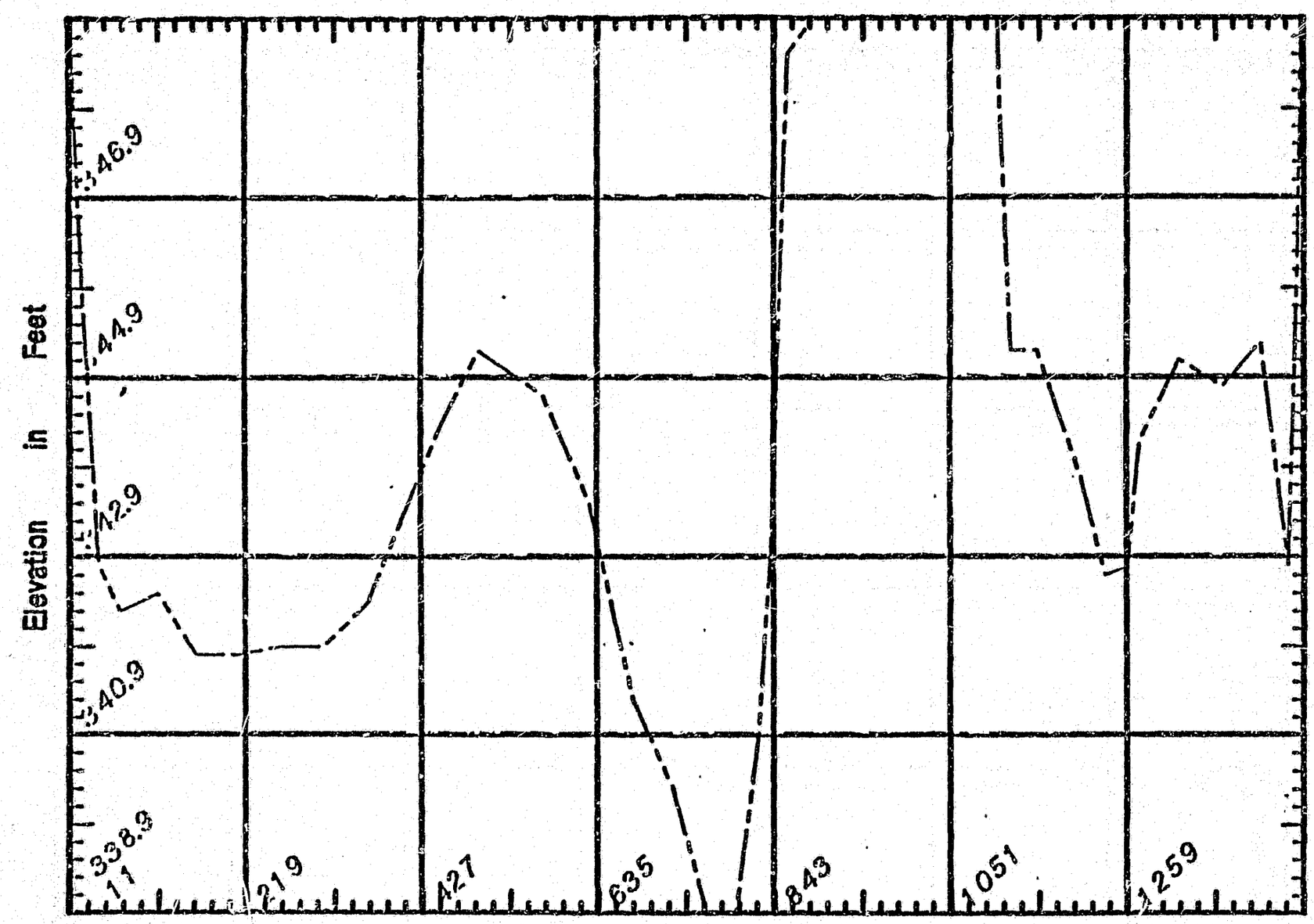

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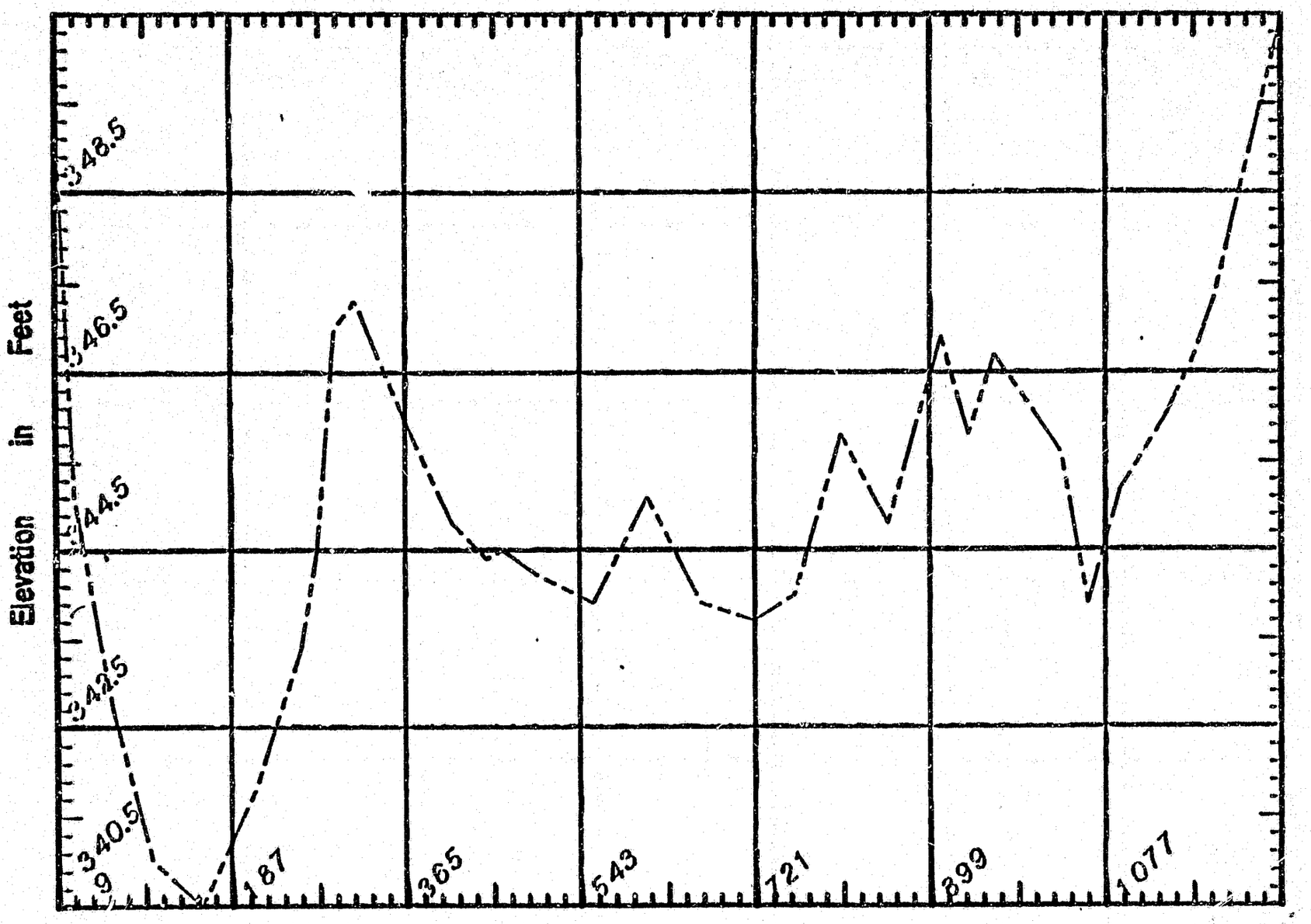

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C-18

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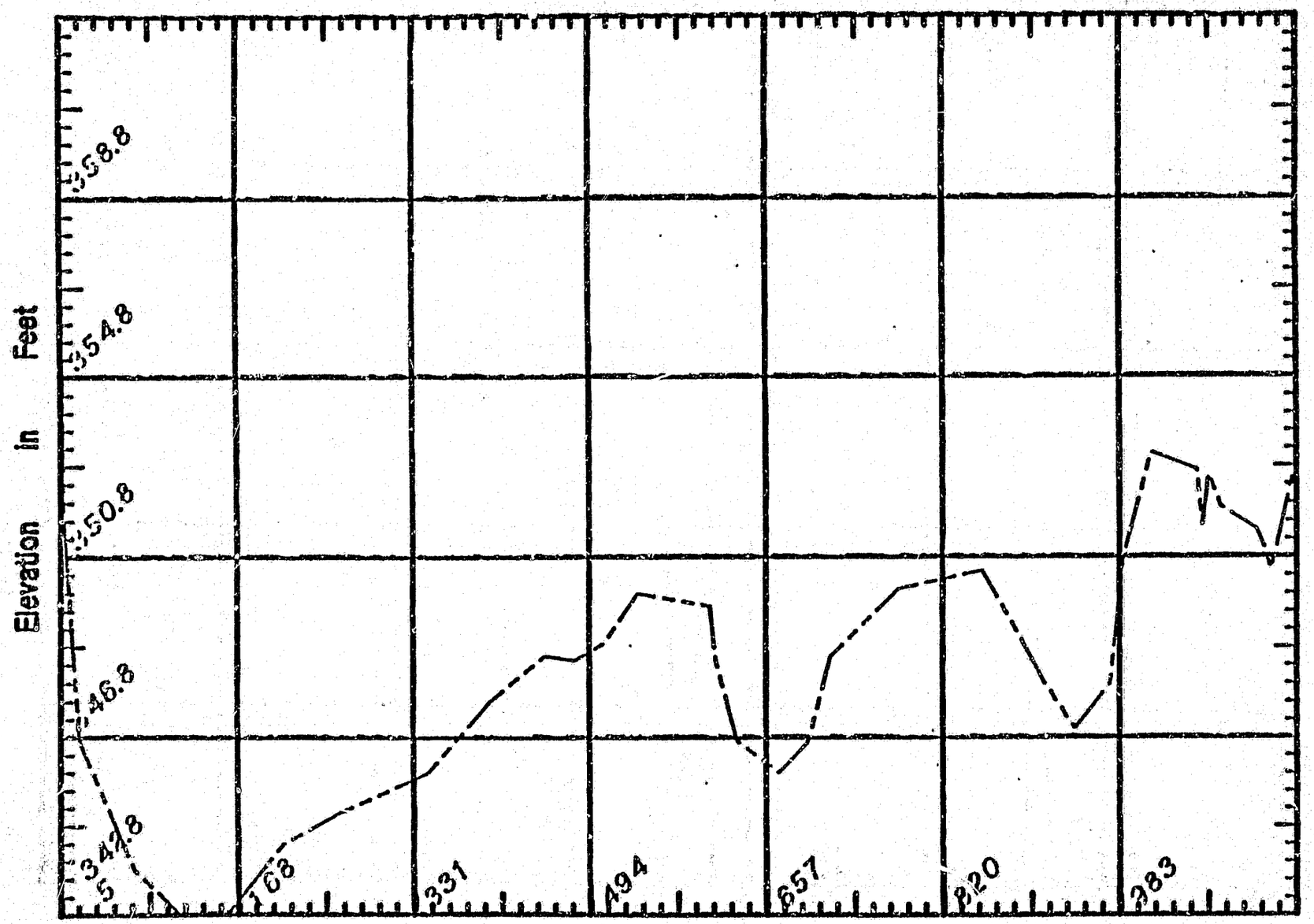

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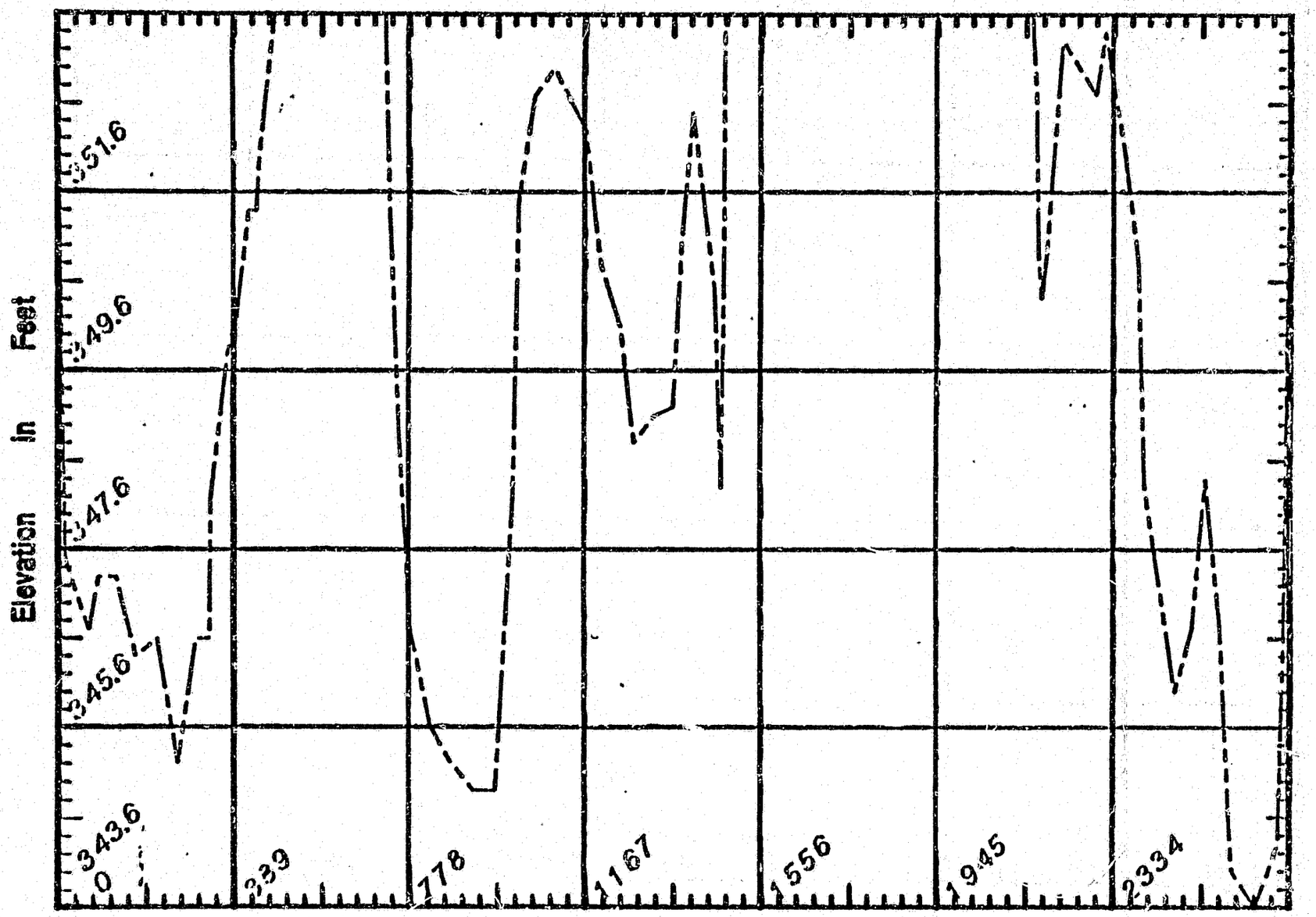

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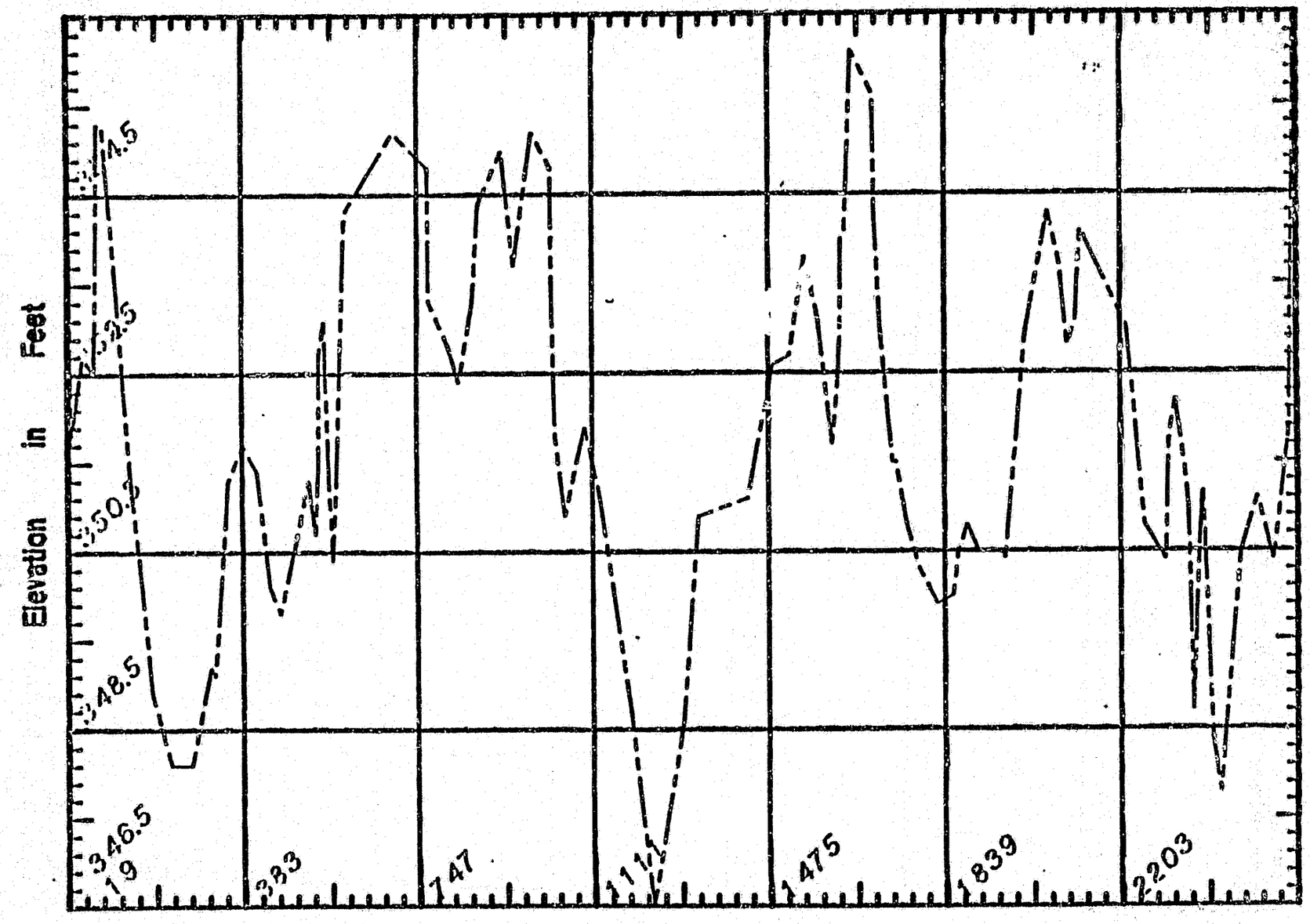

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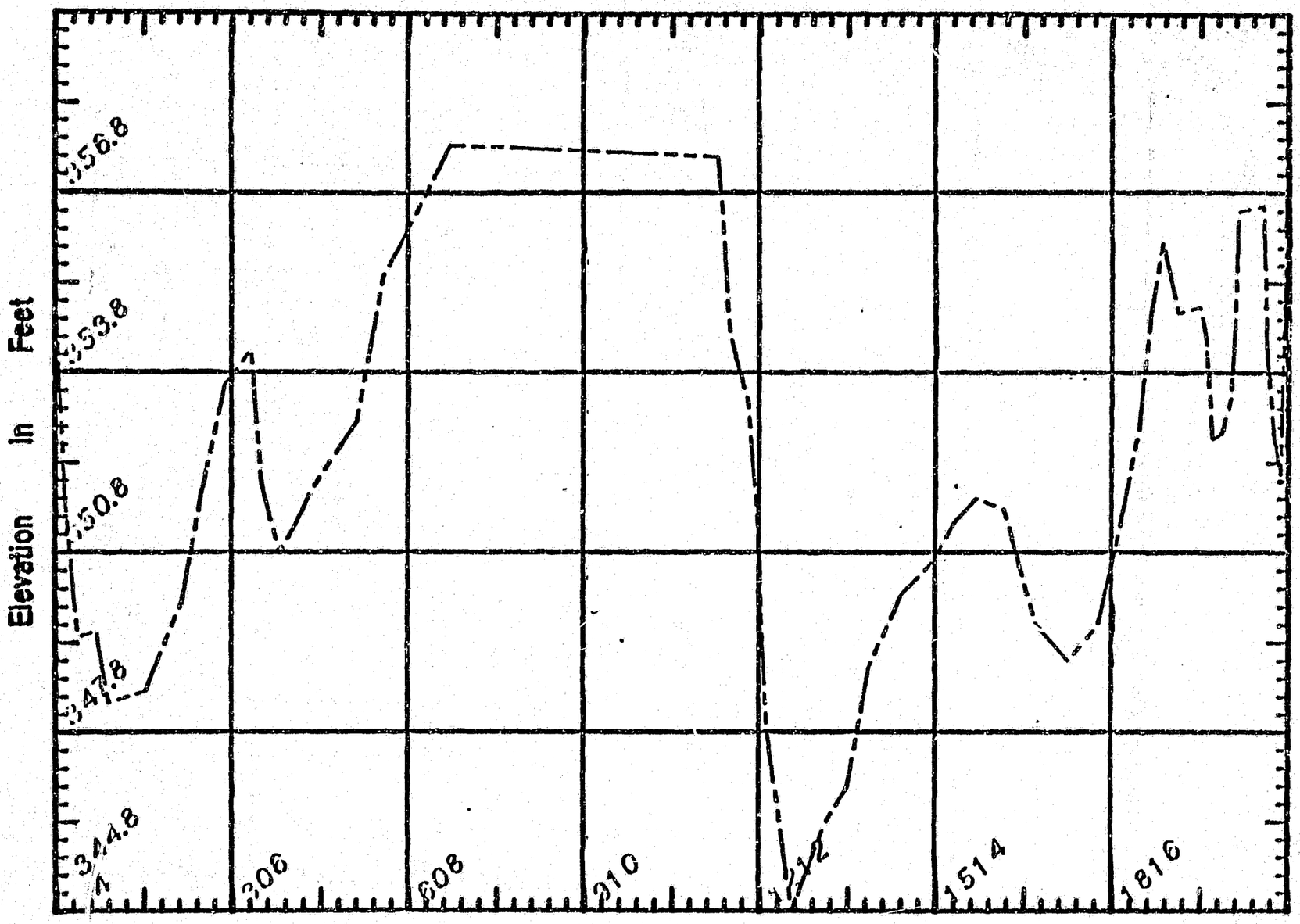

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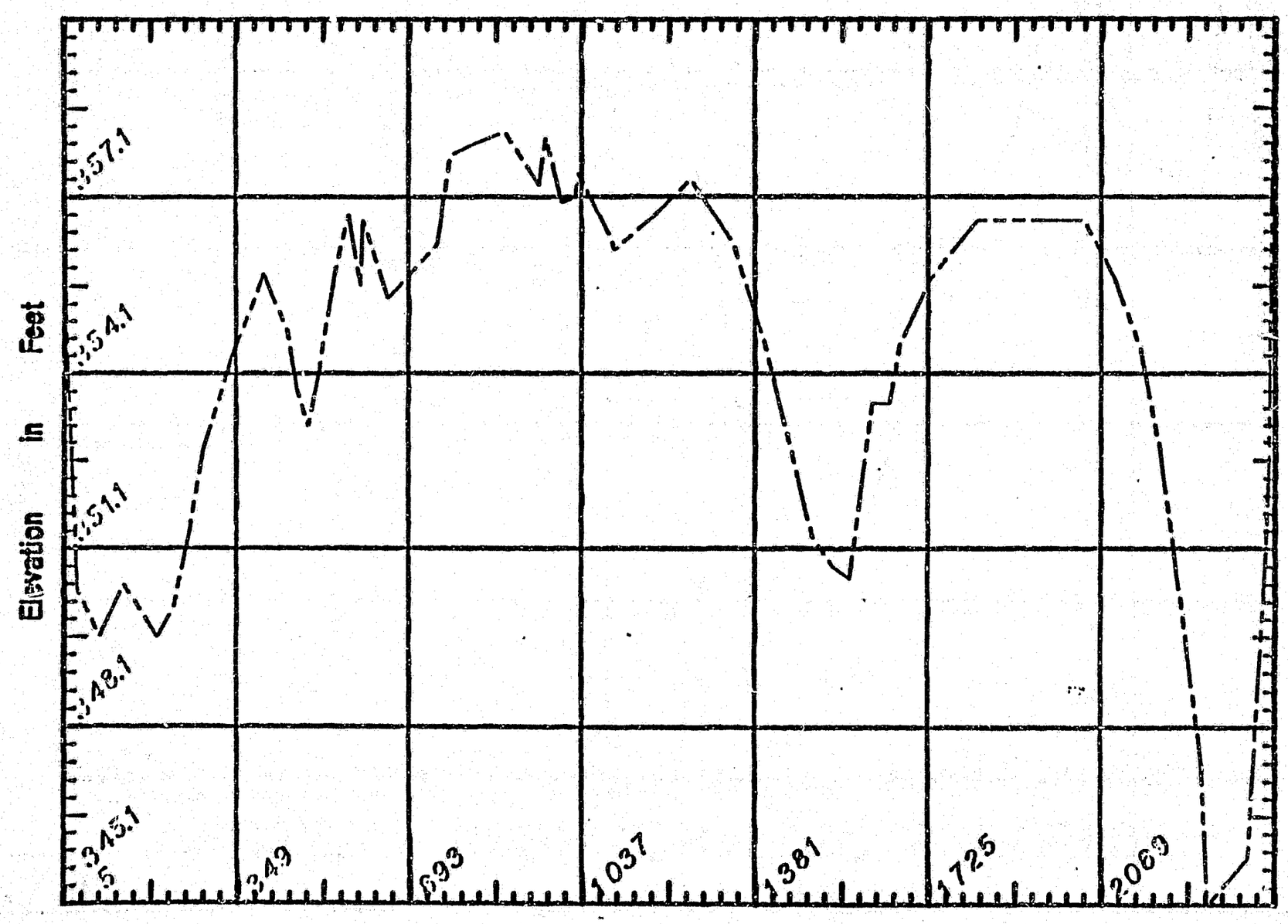

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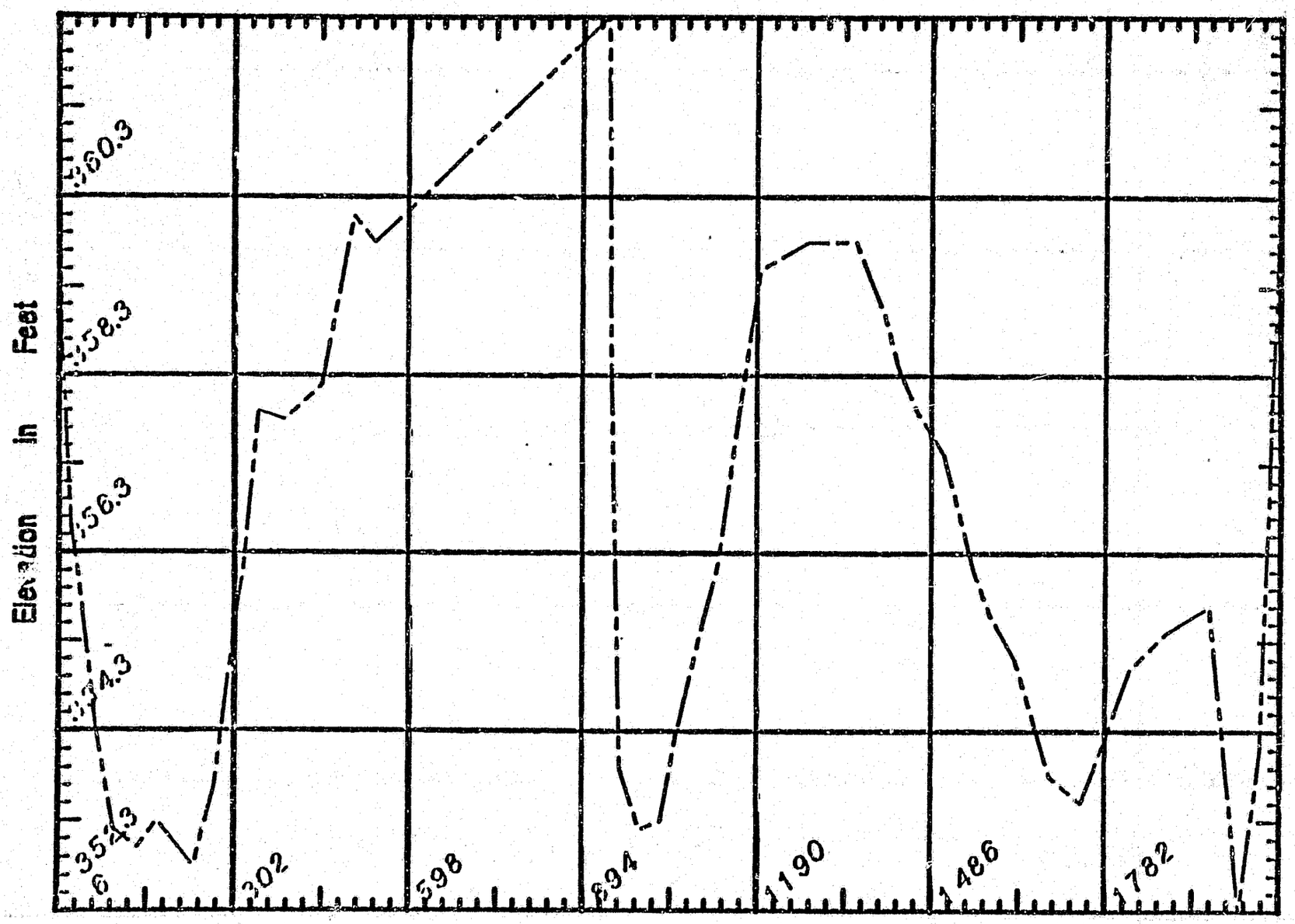

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2-22-20

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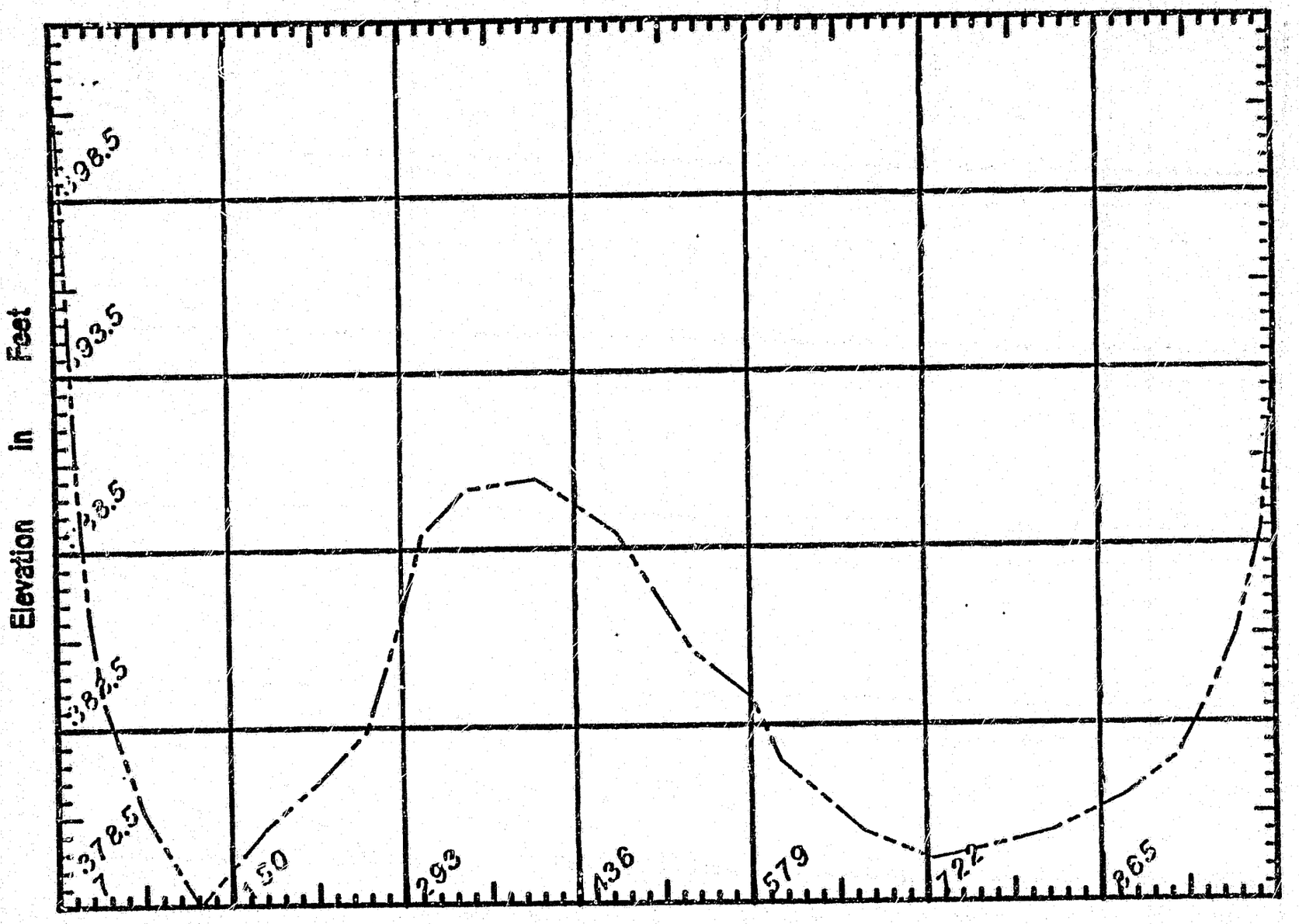

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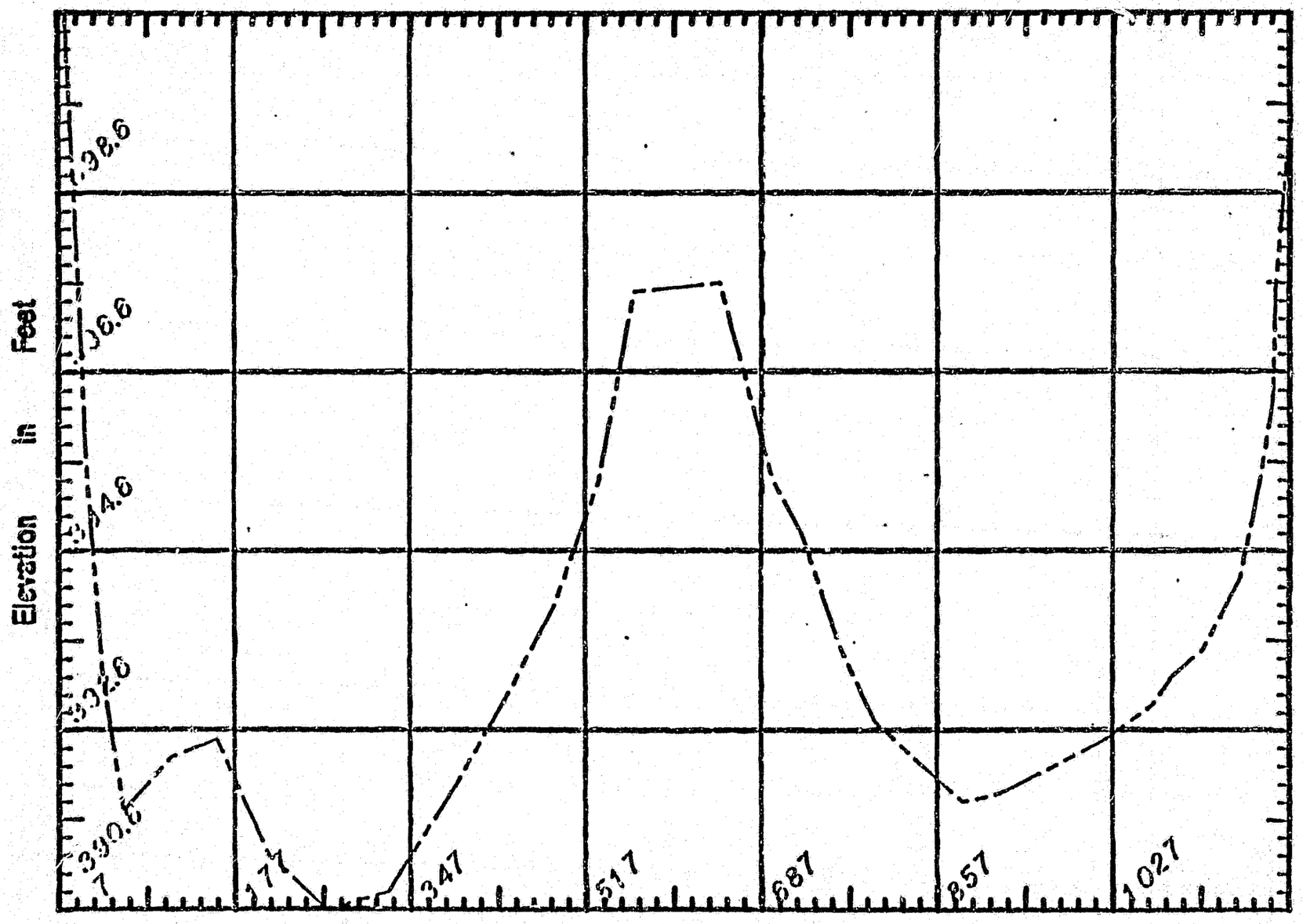

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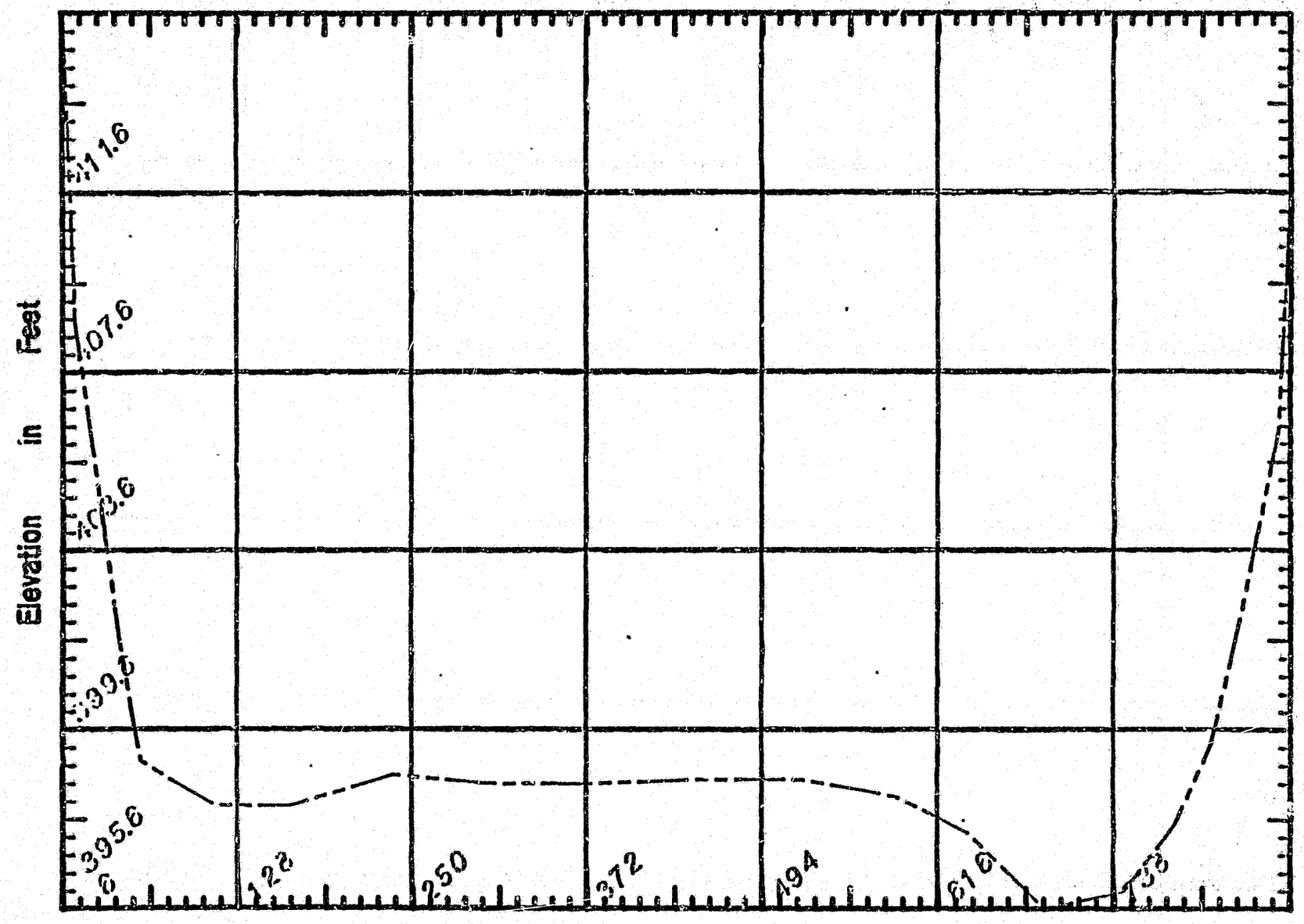
SUSITNA HYDROELECTRIC PROJECT



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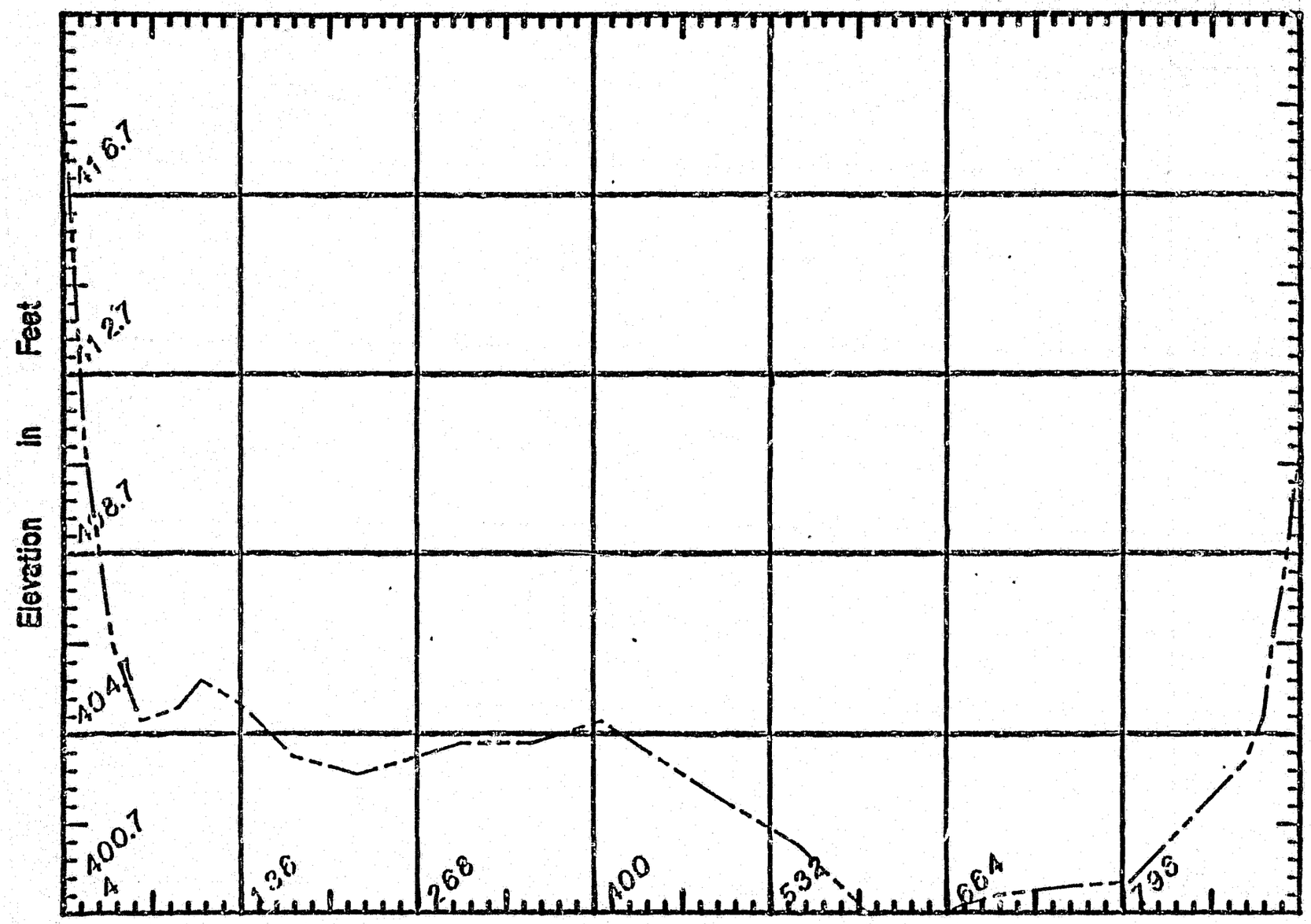

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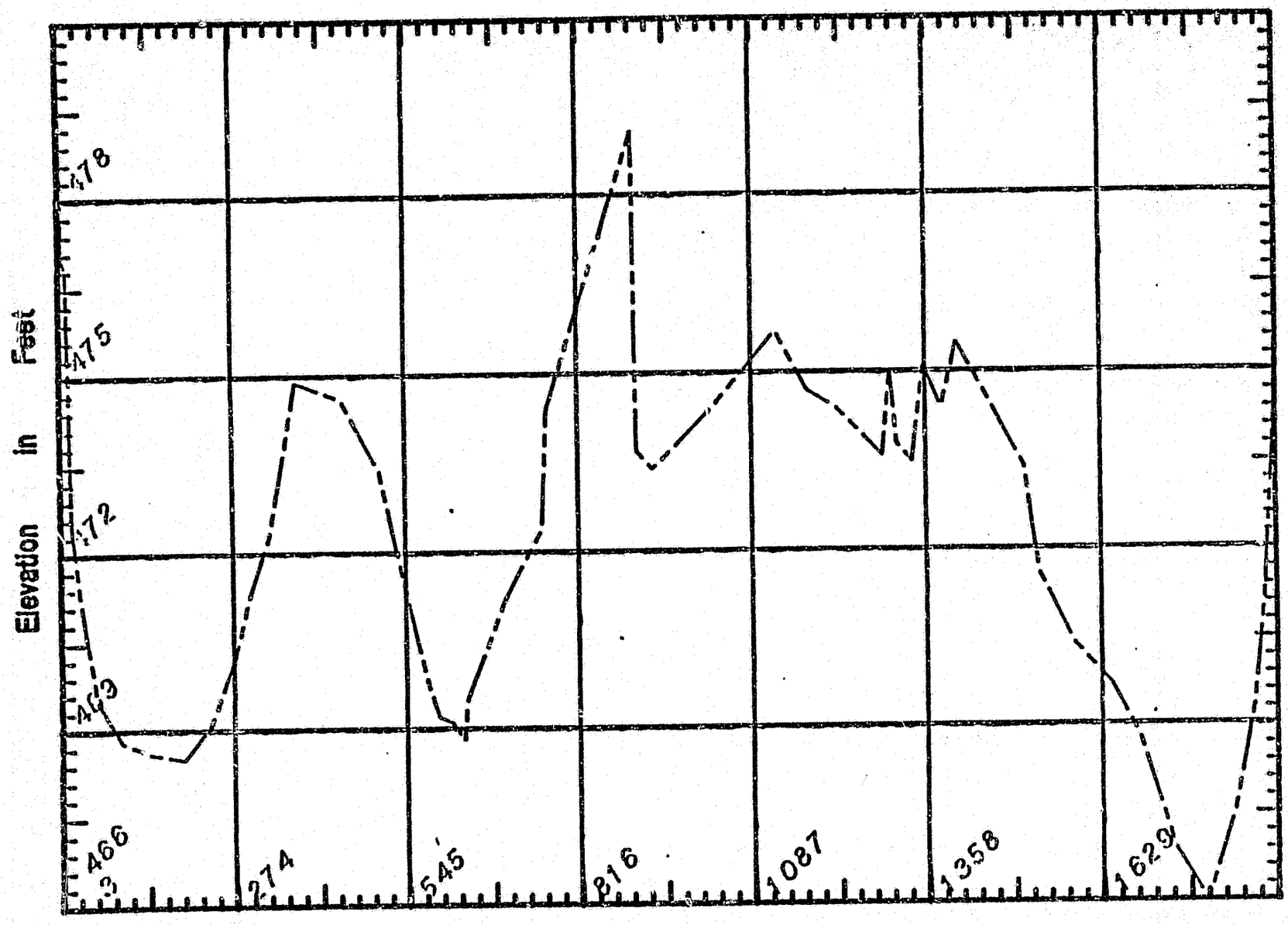

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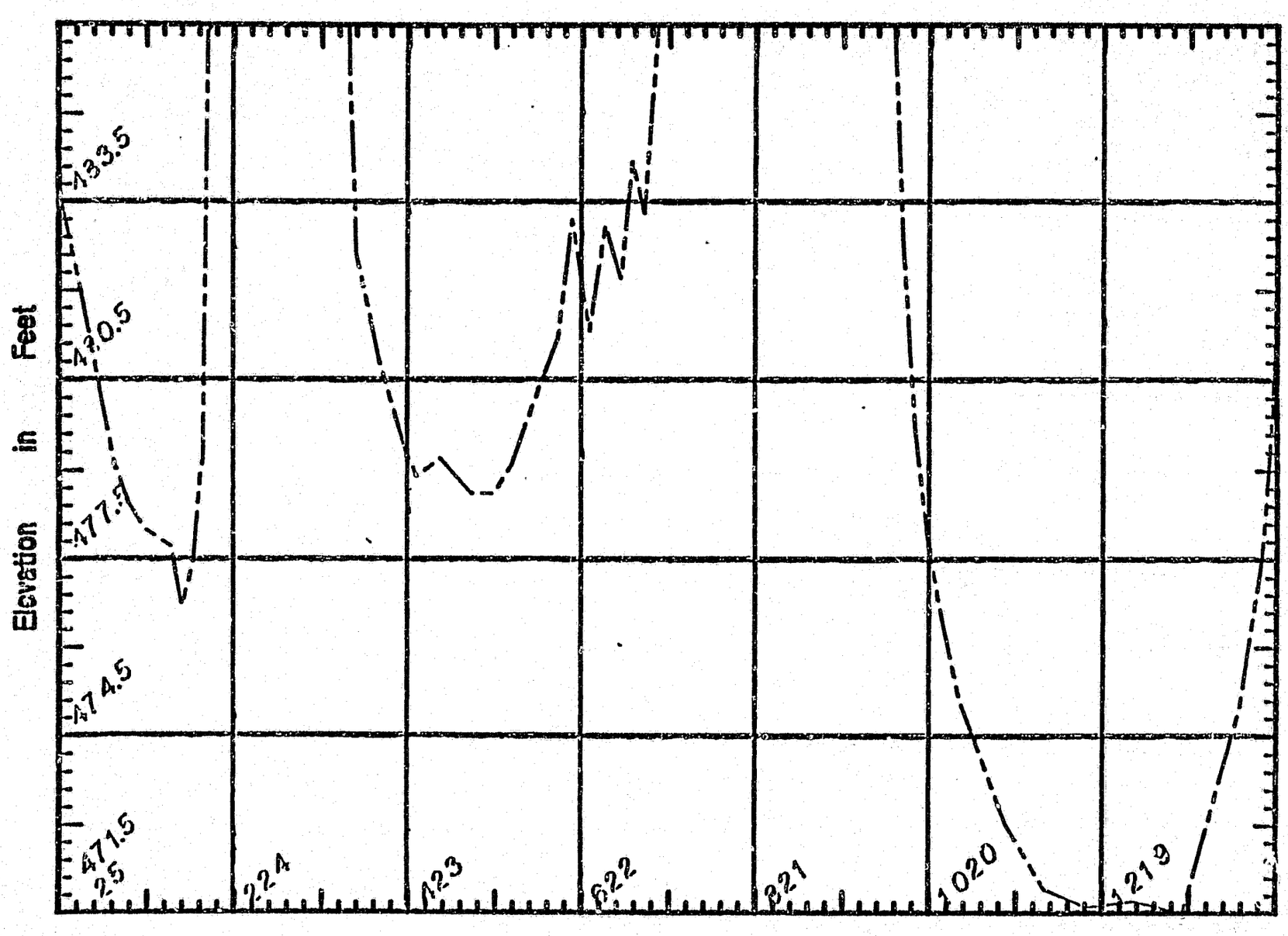
2-2-25

SUSITNA HYDROELECTRIC PROJECT



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ACRES

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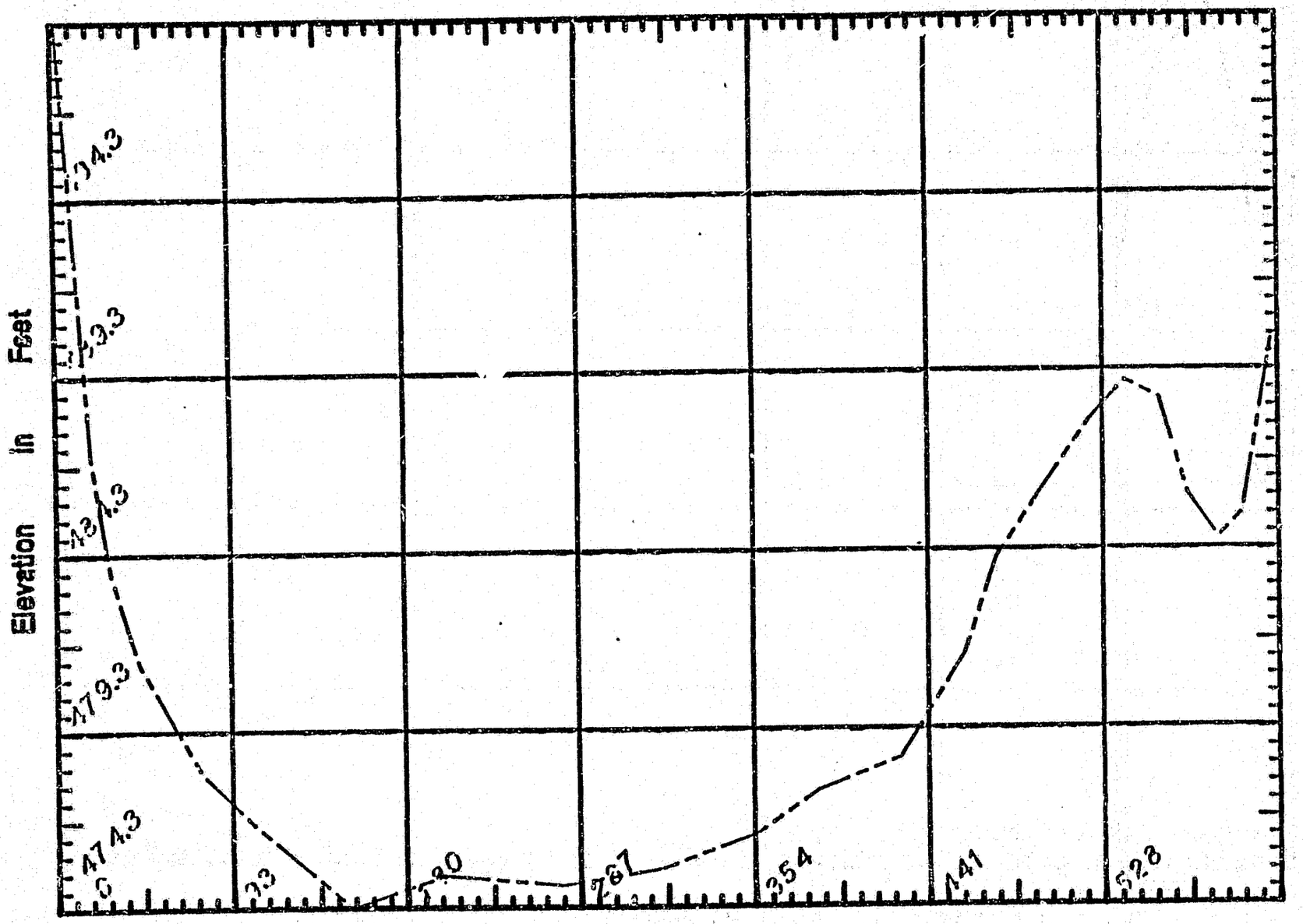
2-2-26

SUSITNA HYDROGRAPHIC SURVEYS



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CROSS-SECTION Number 1 8.3

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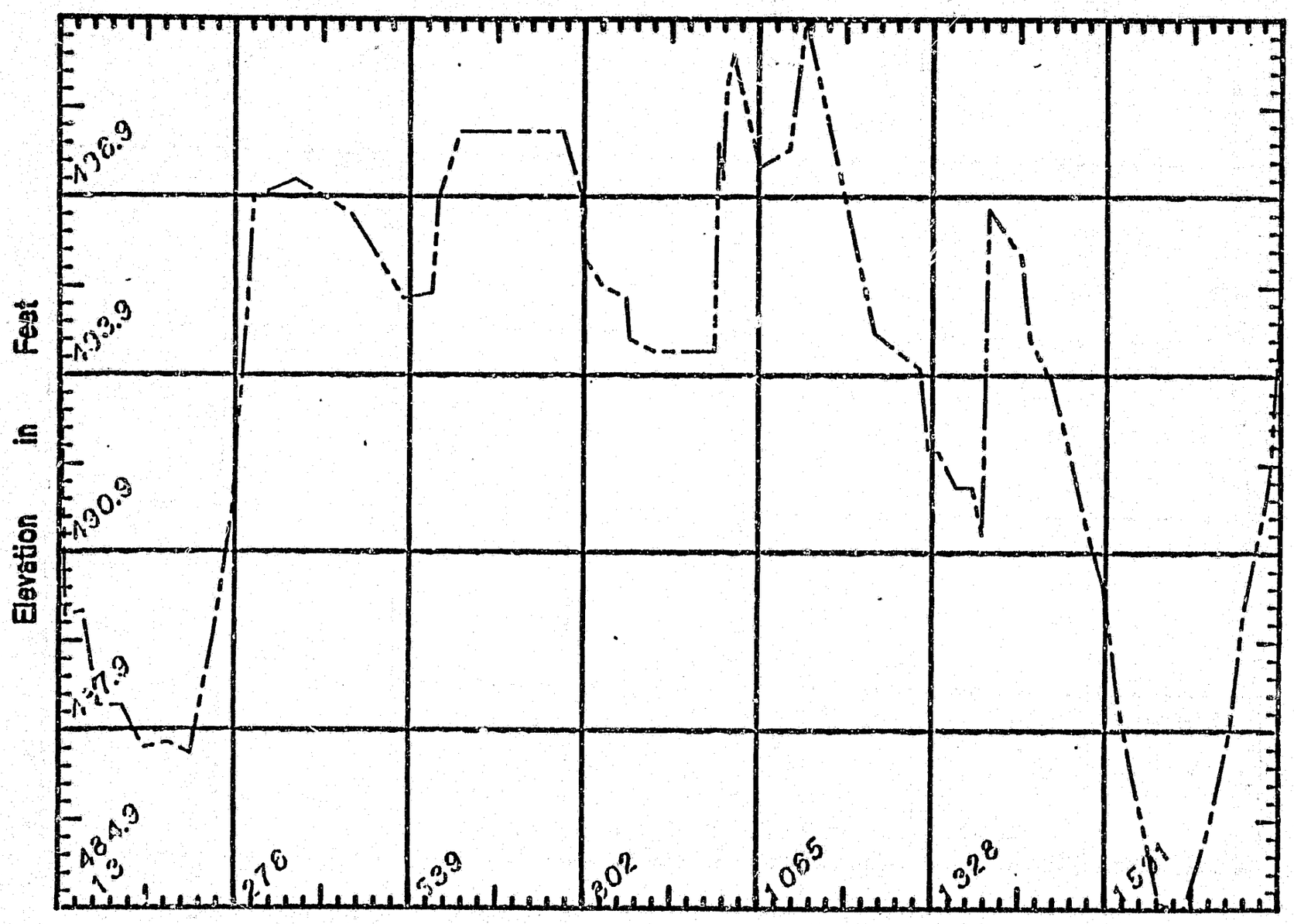
ACRES

C-32

2-2-27

SUSITNA HYDROGRAPHIC SURVEYS



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CROSS-SECTION Number 19.1

PREPARED FOR:

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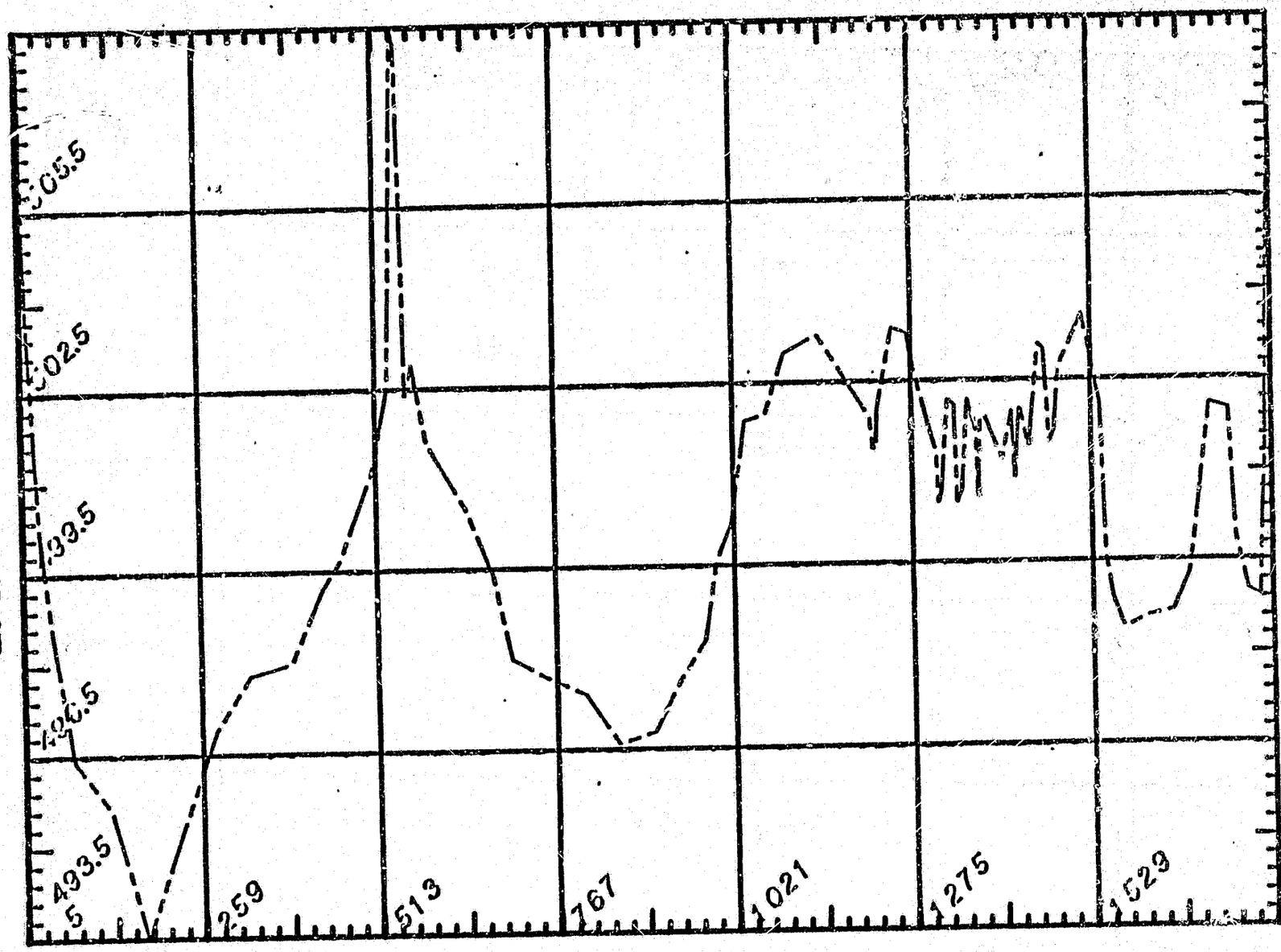
2-2-28

SUSITNA HYDROGRAPHIC SURVEYS



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PREPARED FOR:

ACRES

C-24

2-22-29

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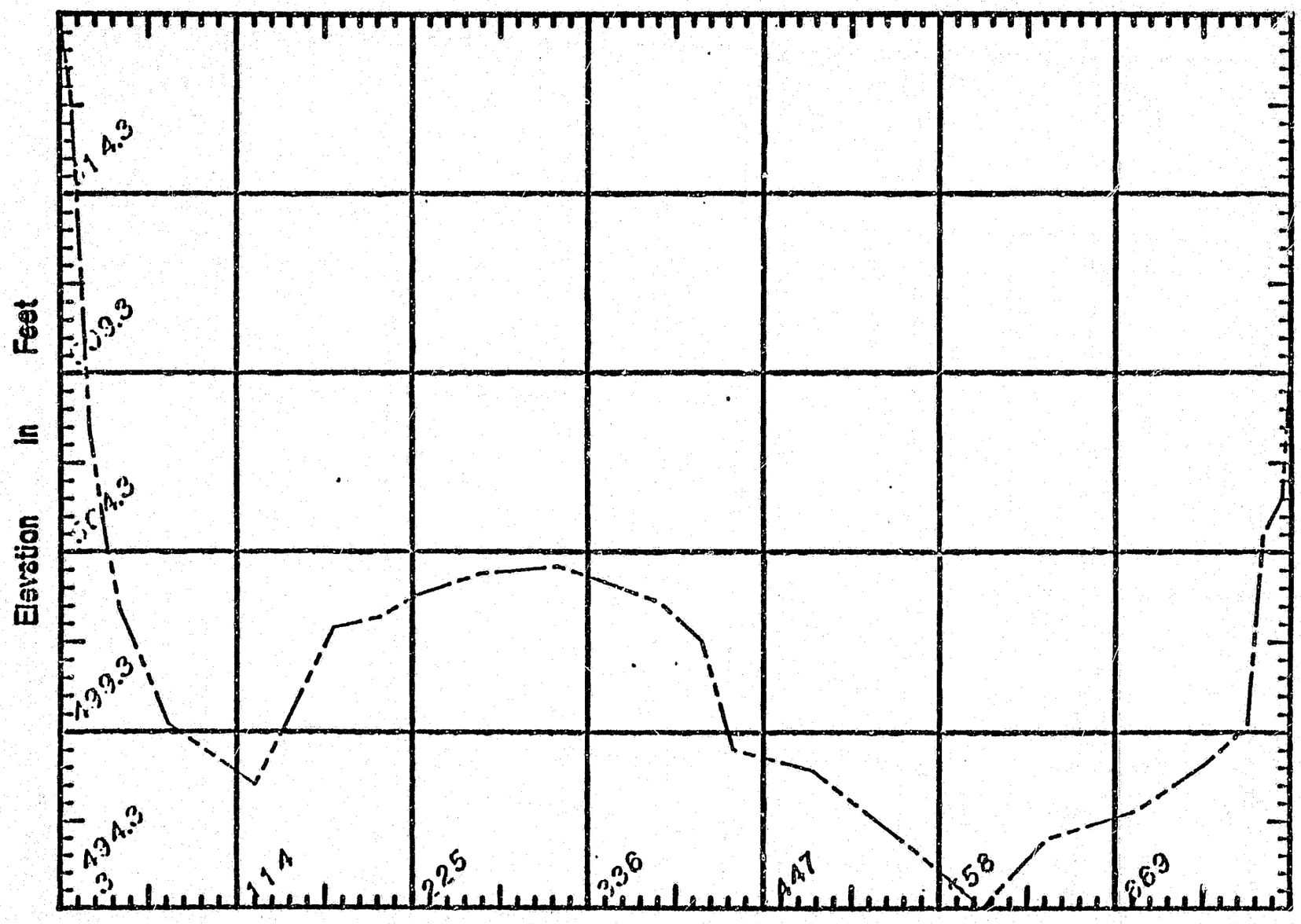

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R&M CONSULTANTS, INC.

PREPARED FOR:

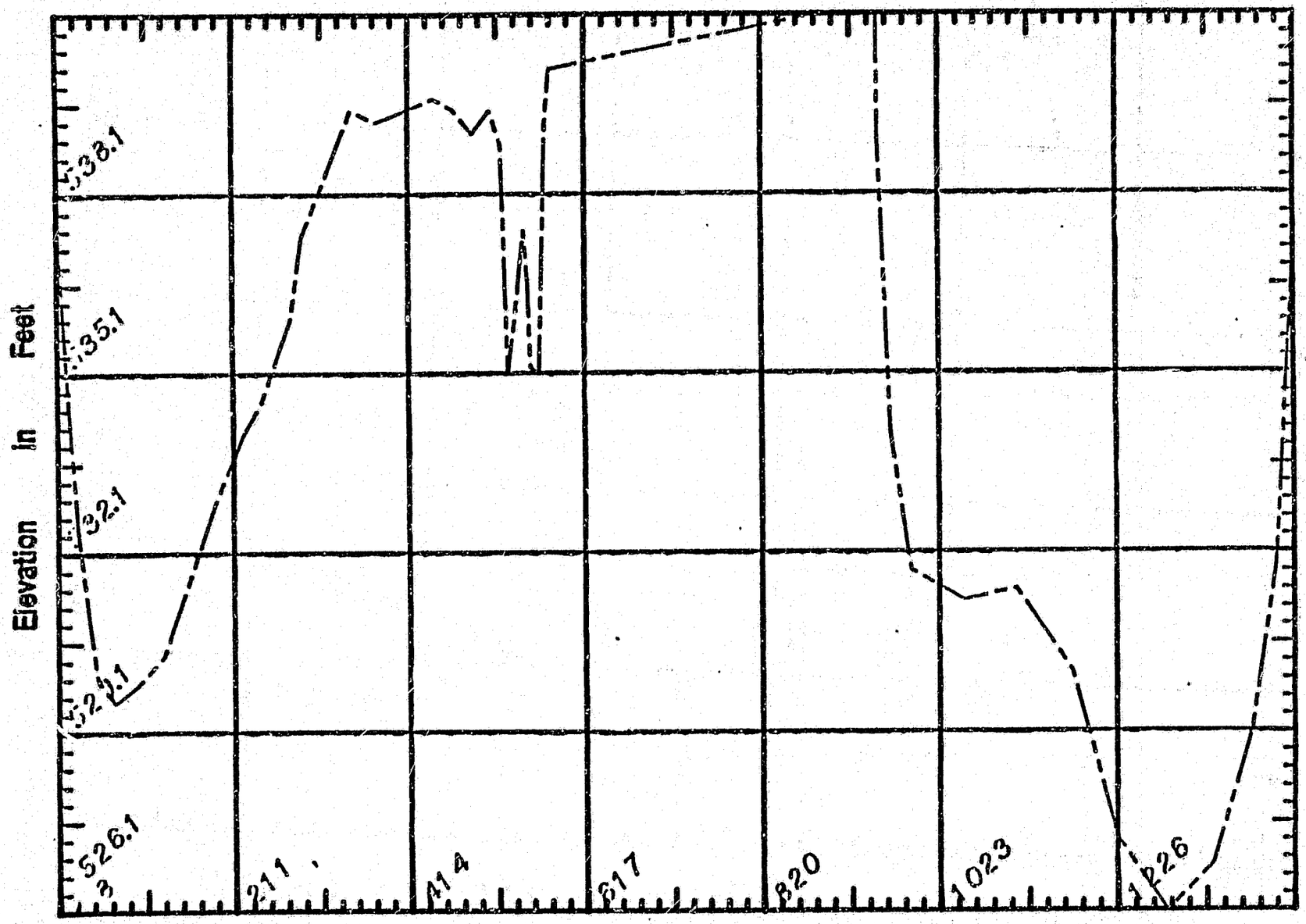
ACRES

CROSS-SECTION Number 20.2

C-35

2-2-30

SUSITNA HYDROGRAPHIC SURVEYS



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R&M CONSULTANTS, INC.

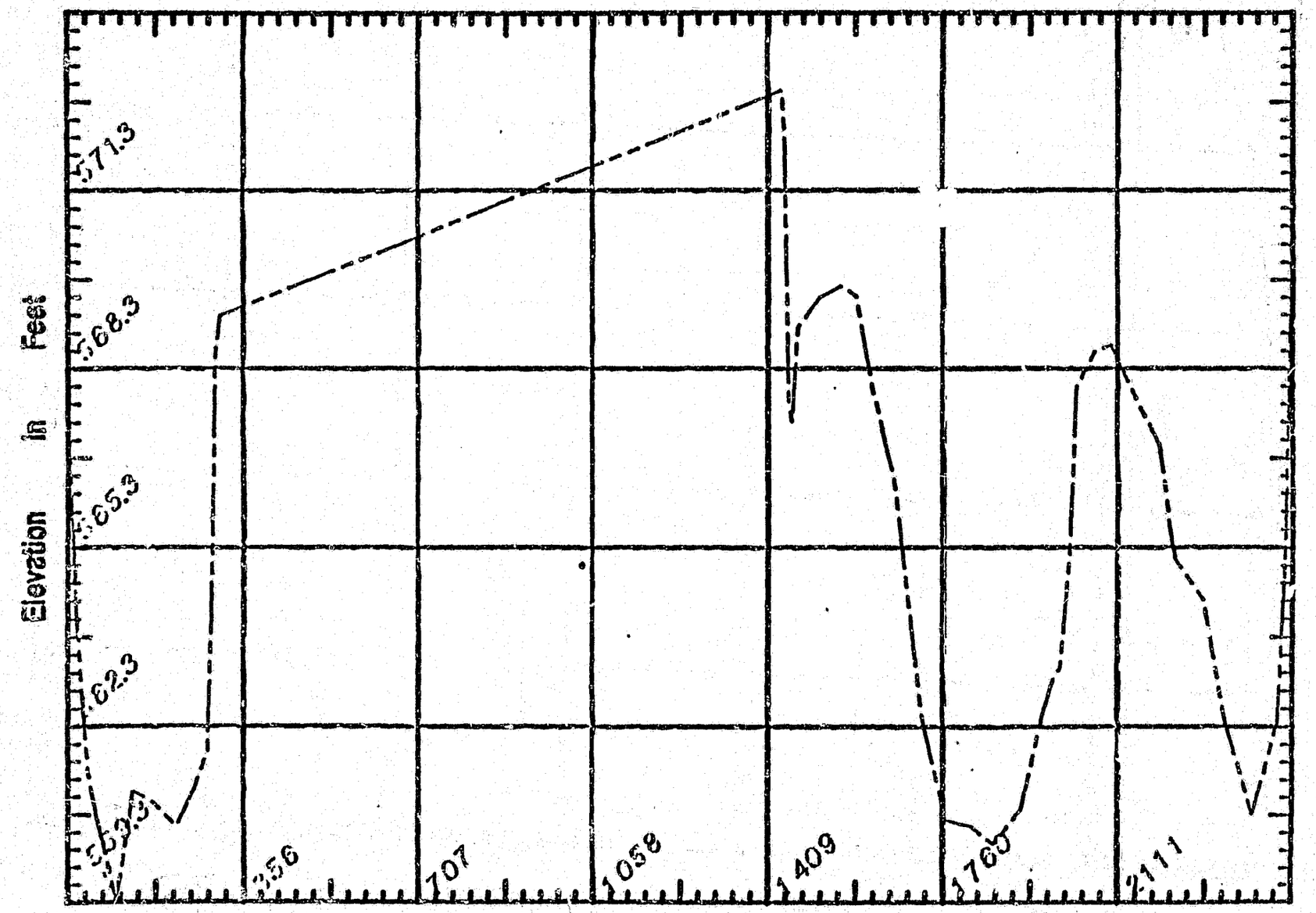
CROSS-SECTION Number 25.1

PREPARED FOR:

ACRES

2-2-3

SUSITNA HYDROGRAPHIC SURVEYS



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R&M CONSULTANTS, INC.

CROSS-SECTION Number 28.1

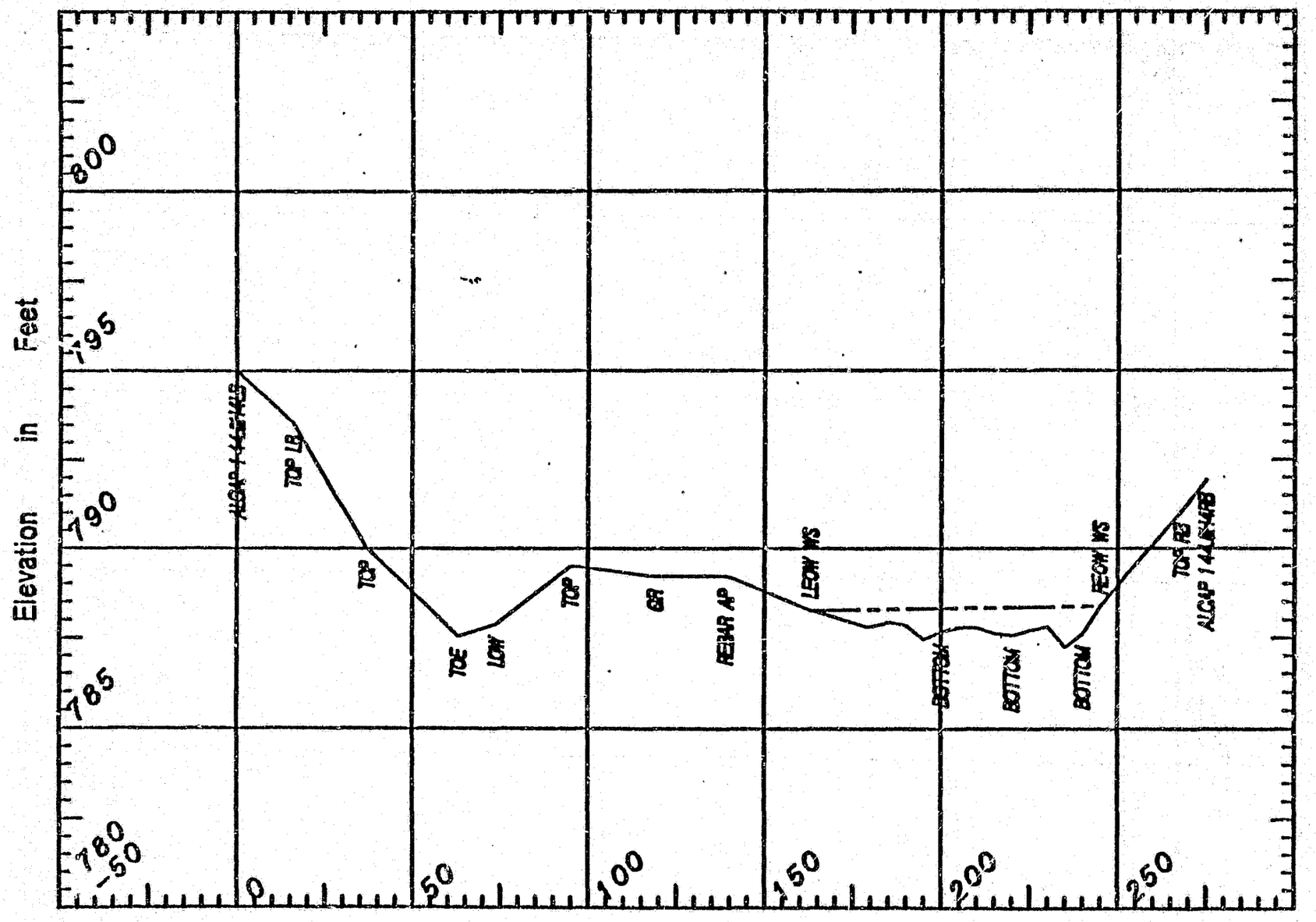
PREPARED FOR:

ACRES

2-2-32

3-3

SUSITNA HYDROGRAPHIC SURVEYS



2-2-33

PREPARED BY:

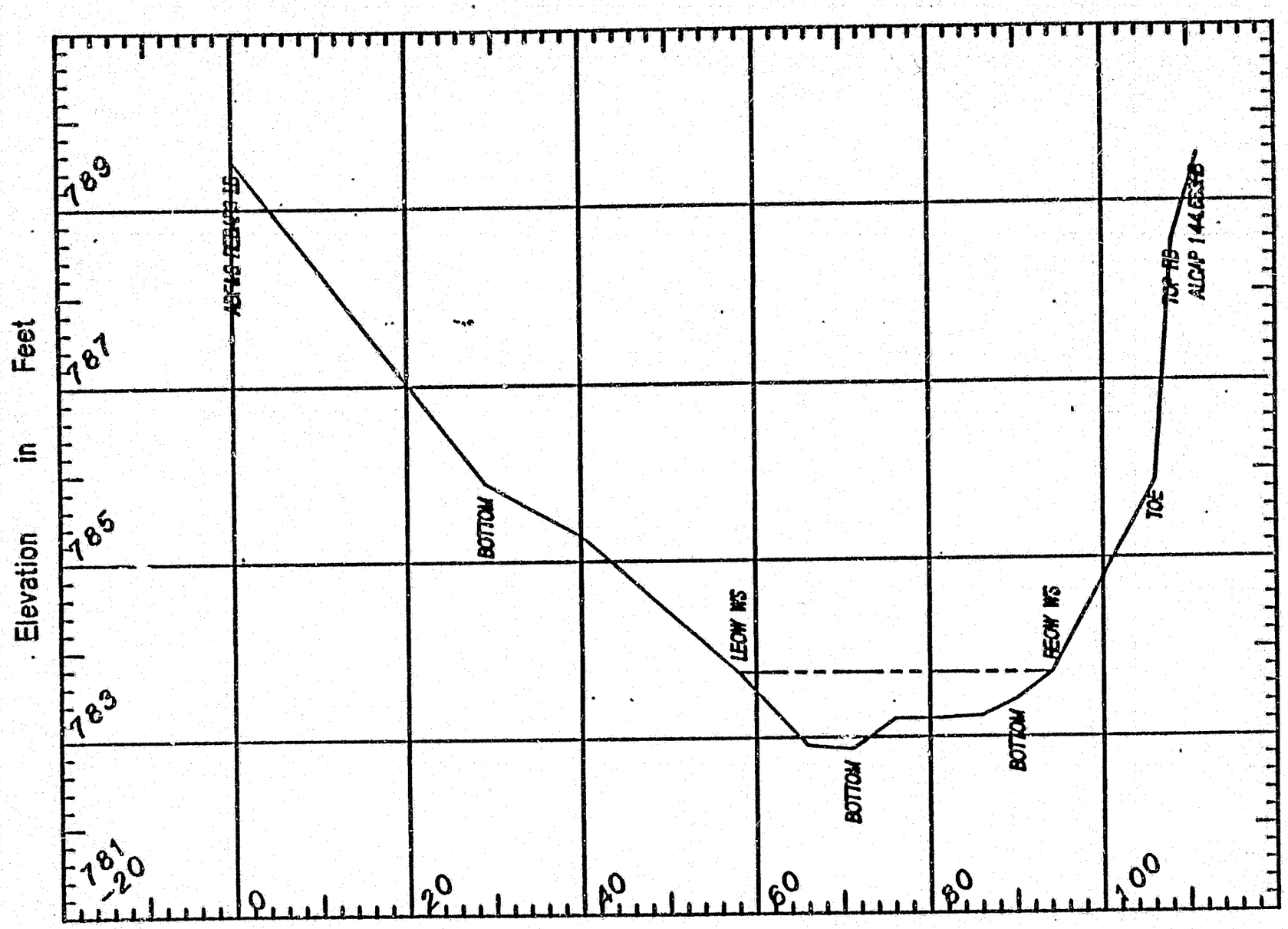
R&M CONSULTANTS, INC.

cross section SL22 144.8H4
Date of Survey: JULY 10, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



2-2-34

PREPARED BY:

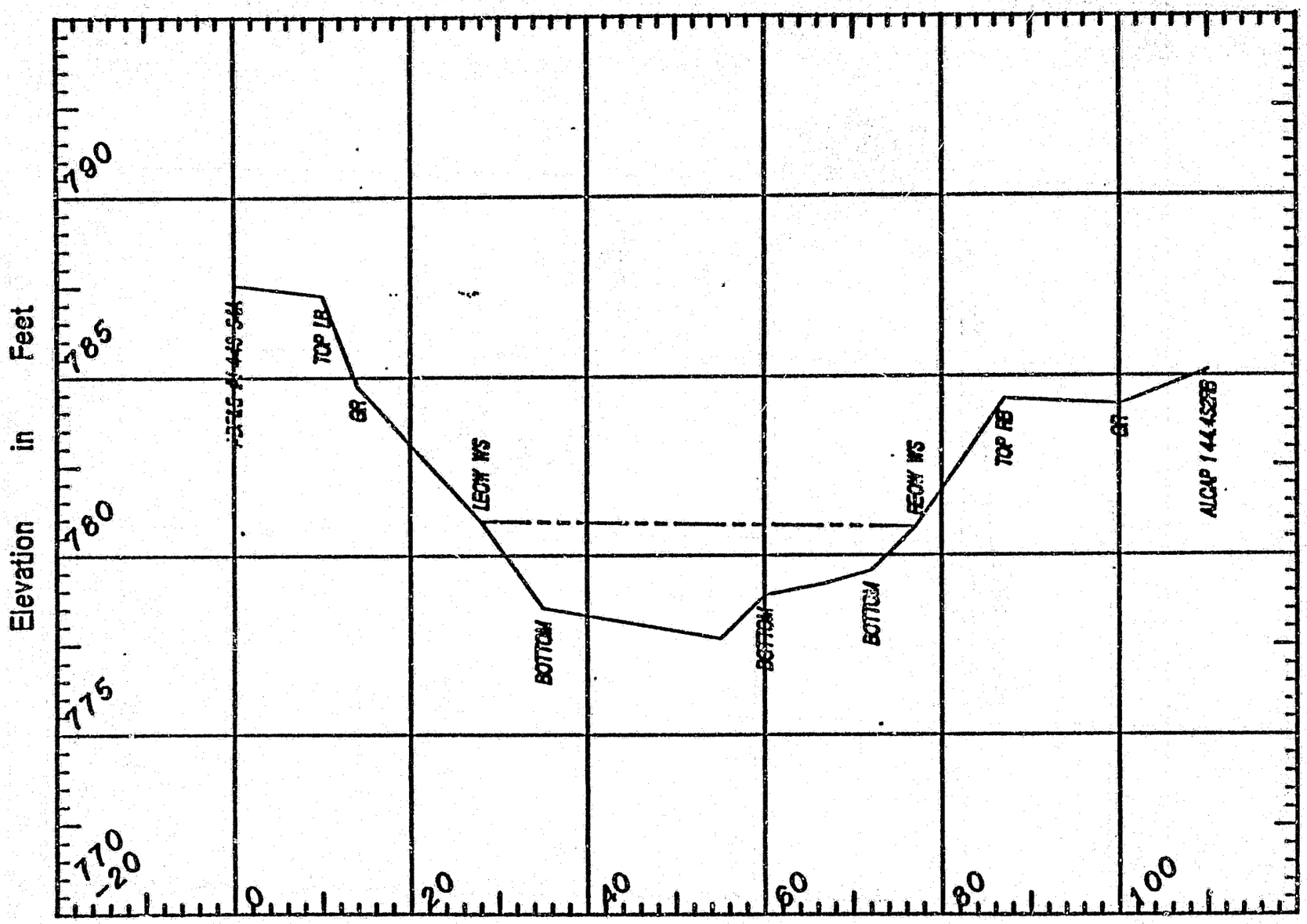
R&M CONSULTANTS, INC.

cross section SL22 144.6S3
Date of Survey: JULY 10, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



2-2-35

PREPARED BY:

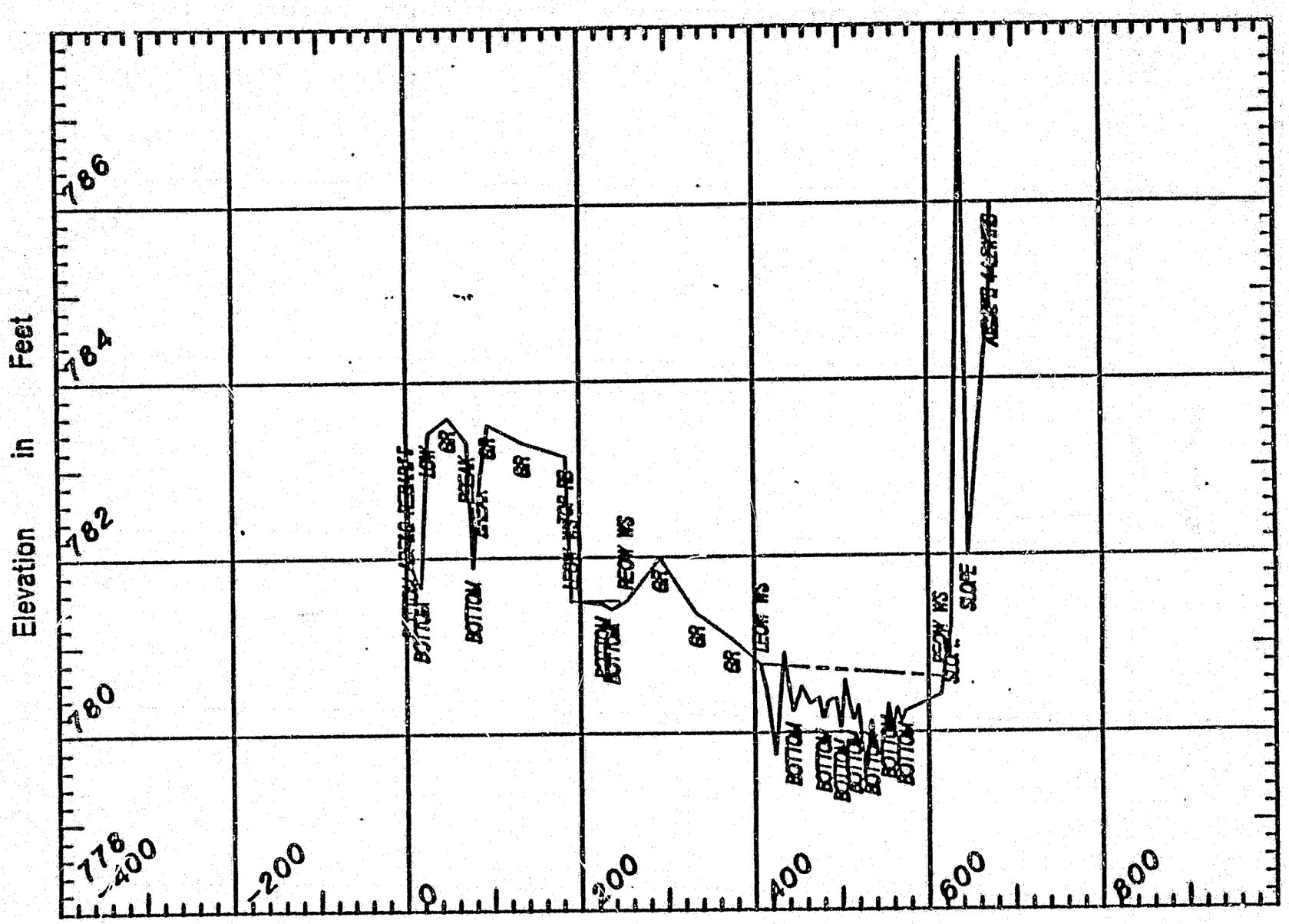
R&M CONSULTANTS, INC.

cross section SL22 144.4S2
Date of Survey: JULY 10, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



2-2-36

PREPARED BY:

R&M CONSULTANTS, INC.

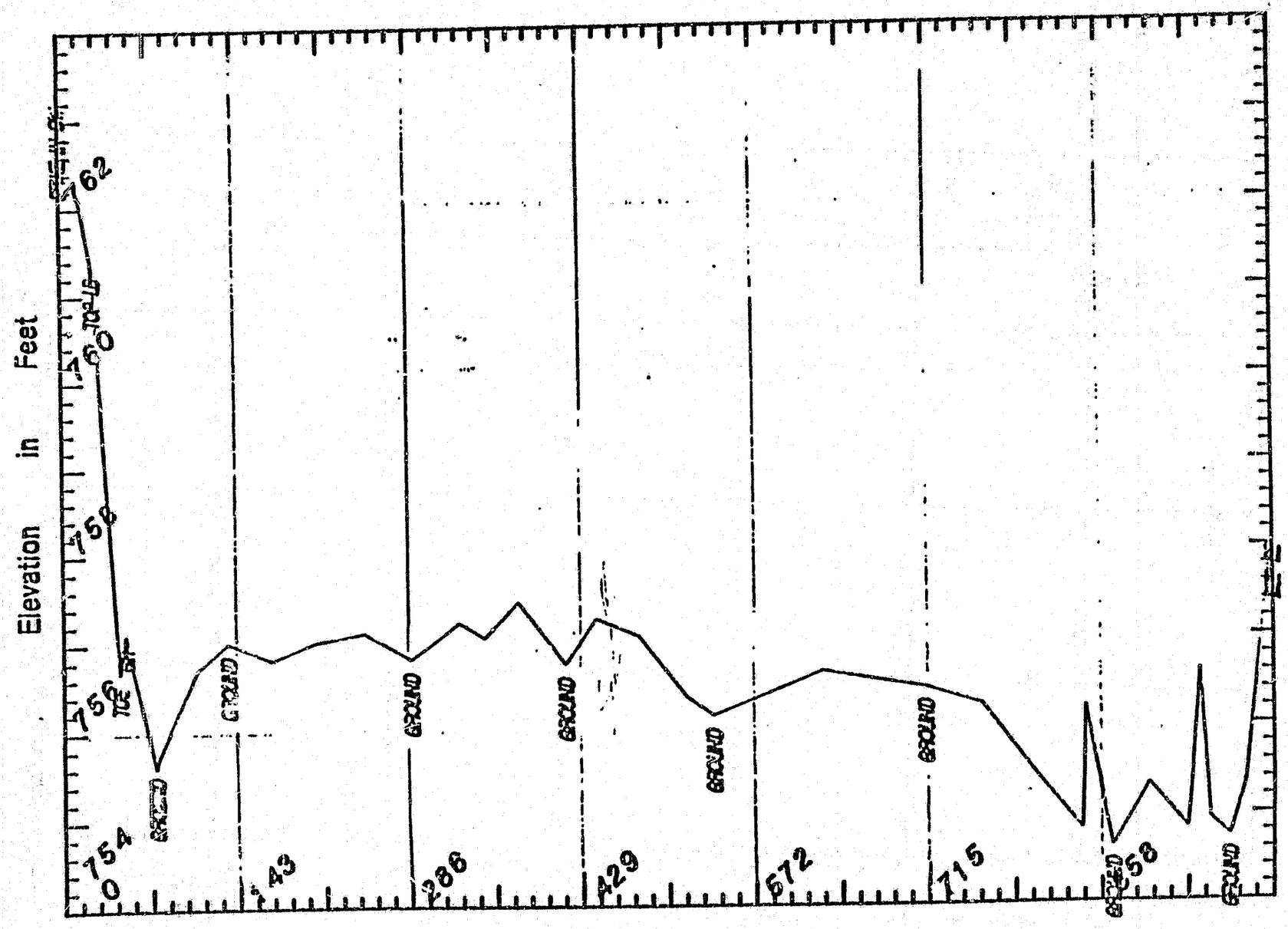
cross section SL22 144.2W1

Date of Survey: JULY 10, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



2-2-37

PREPARED BY:

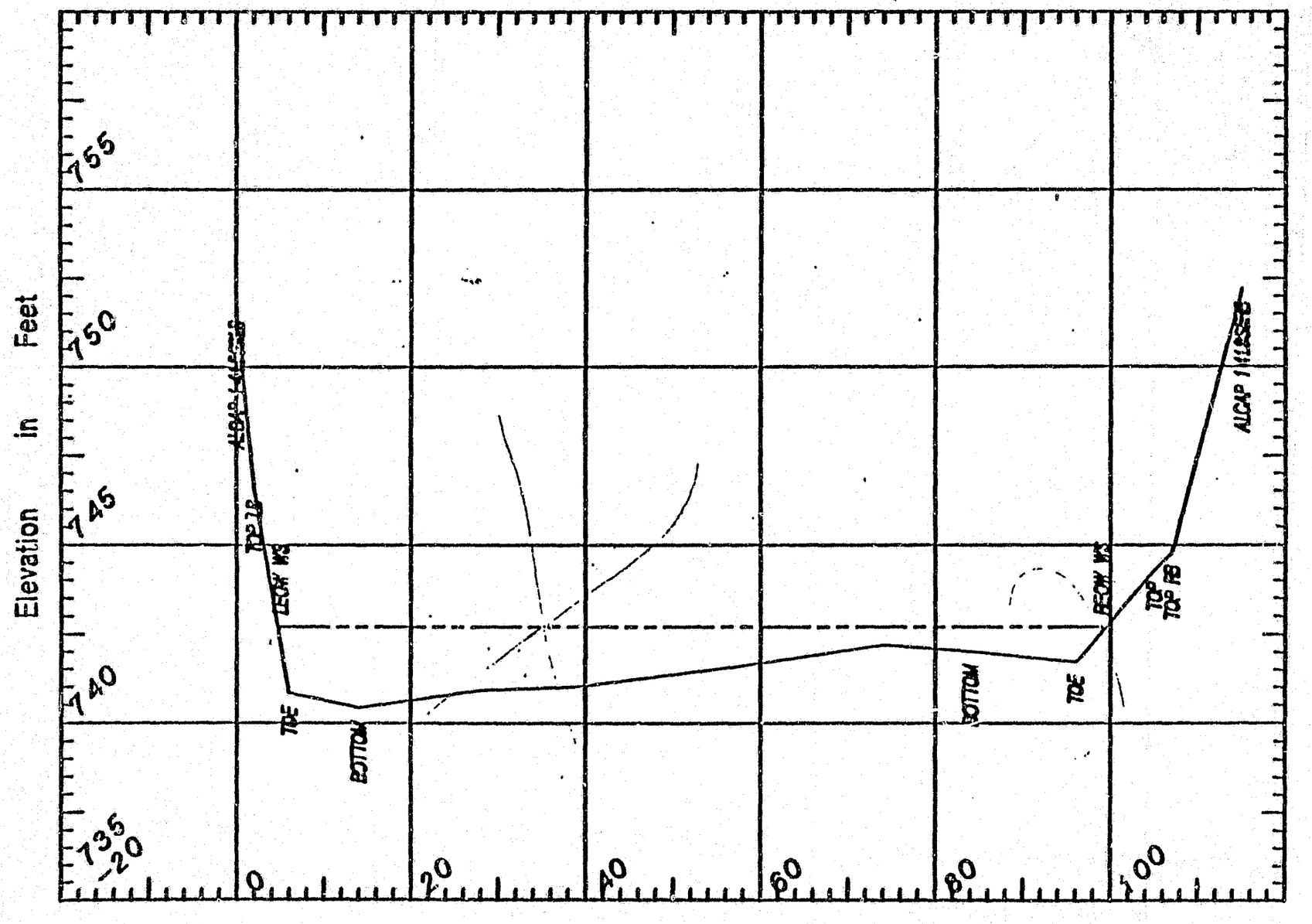
R&M CONSULTANTS, INC.

cross section SL21 1 42.0H9
Date of Survey: JULY 11,1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



2-2-38

PREPARED BY:

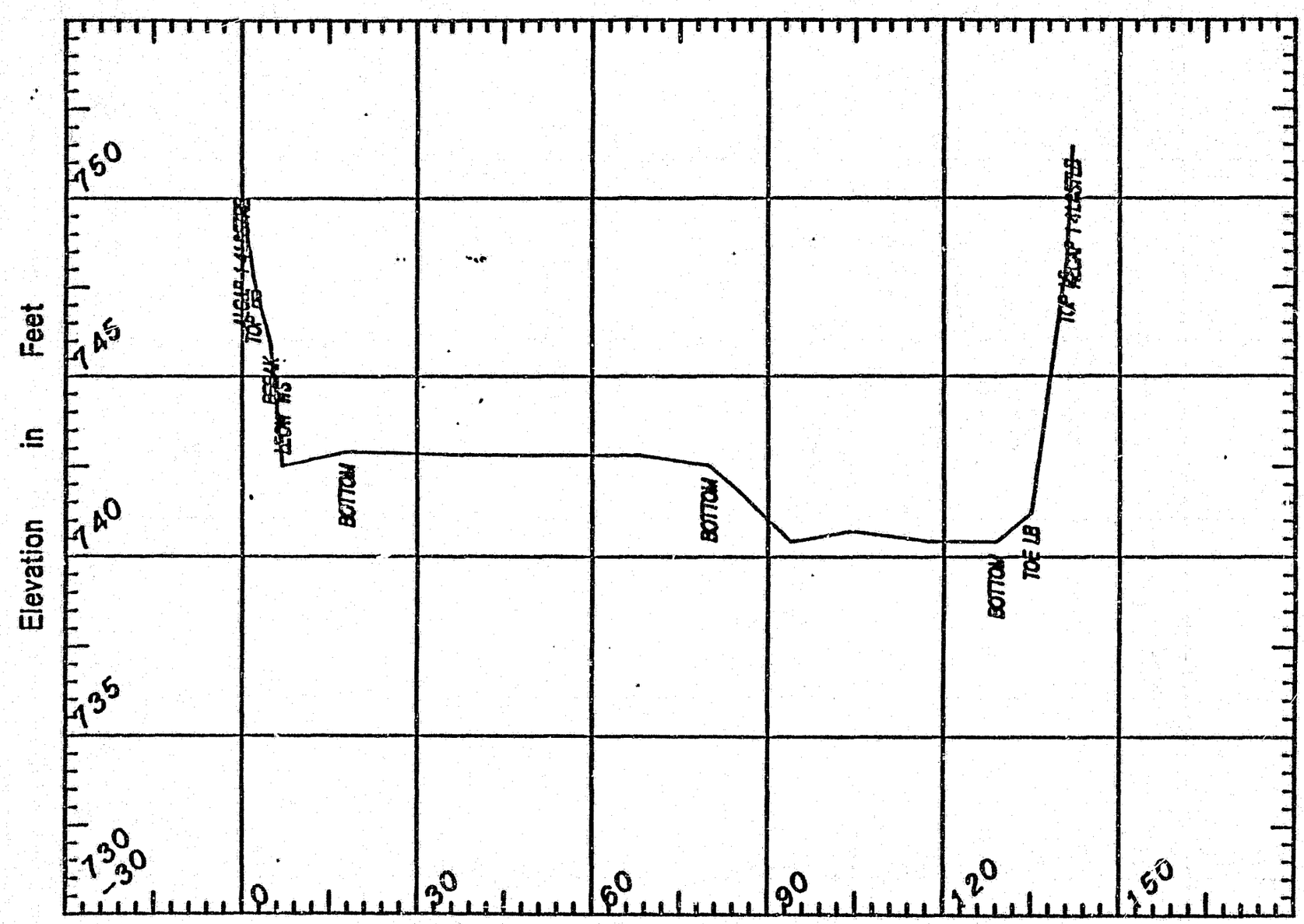
R&M CONSULTANTS, INC.

cross section SL21 141.9S8
Date of Survey: JULY 11, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



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PREPARED BY:

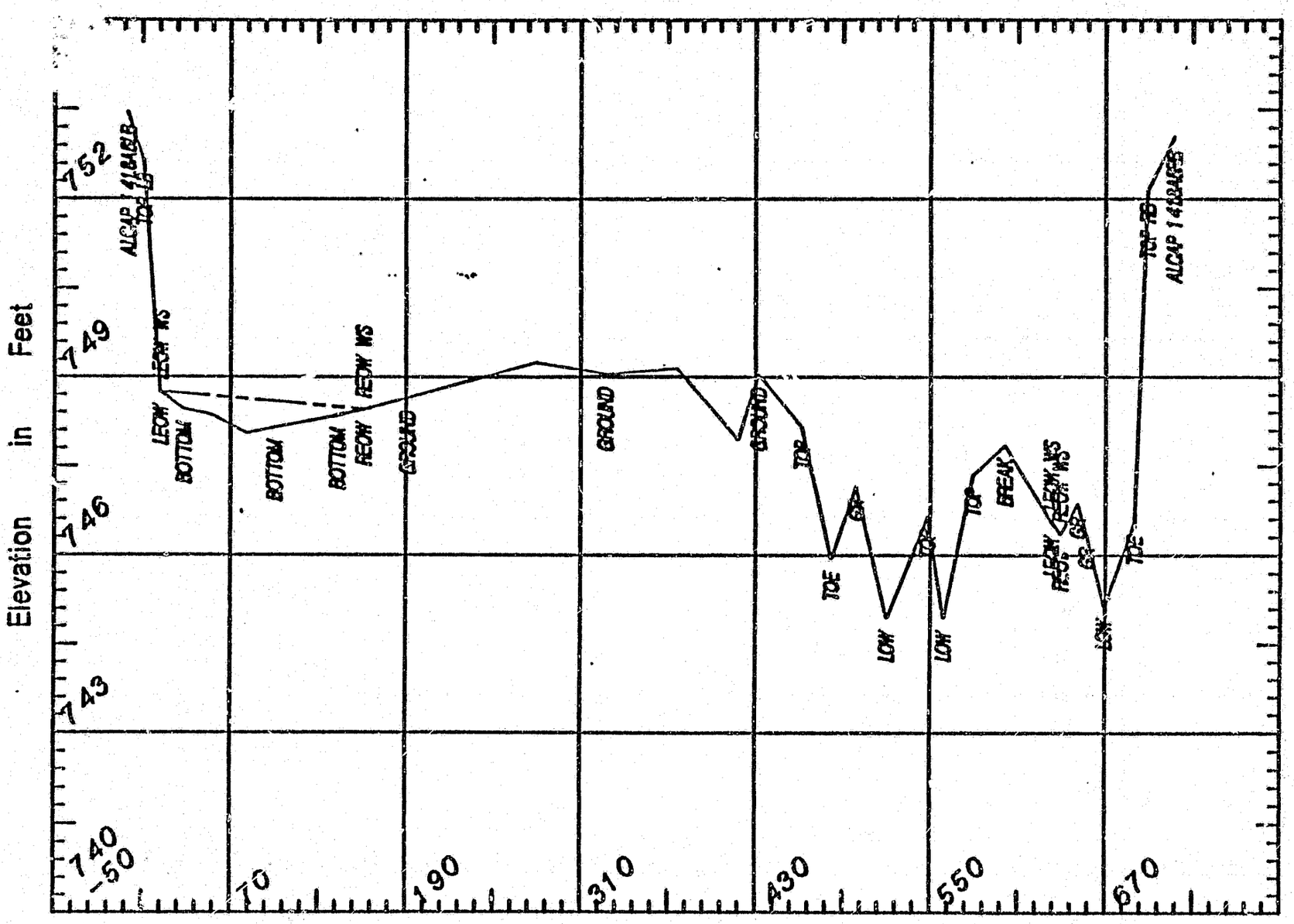
R&M CONSULTANTS, INC.

cross section SL21 1 41.8S7
Date of Survey: JULY 11, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



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PREPARED BY:

R&M CONSULTANTS, INC.

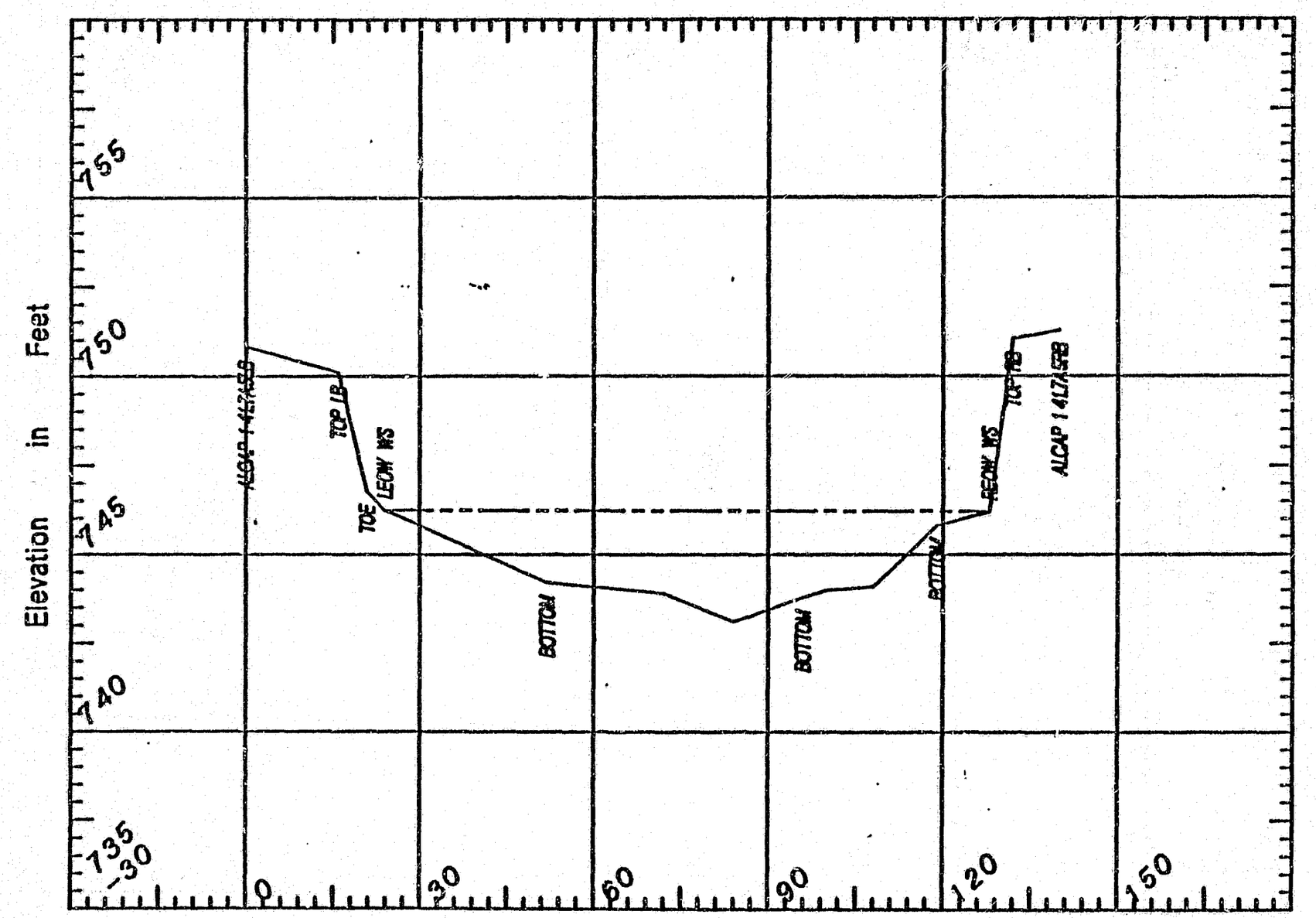
cross section: SL21 1 41.8A6

Date of Survey: JULY 11, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



14-2-2

PREPARED BY:

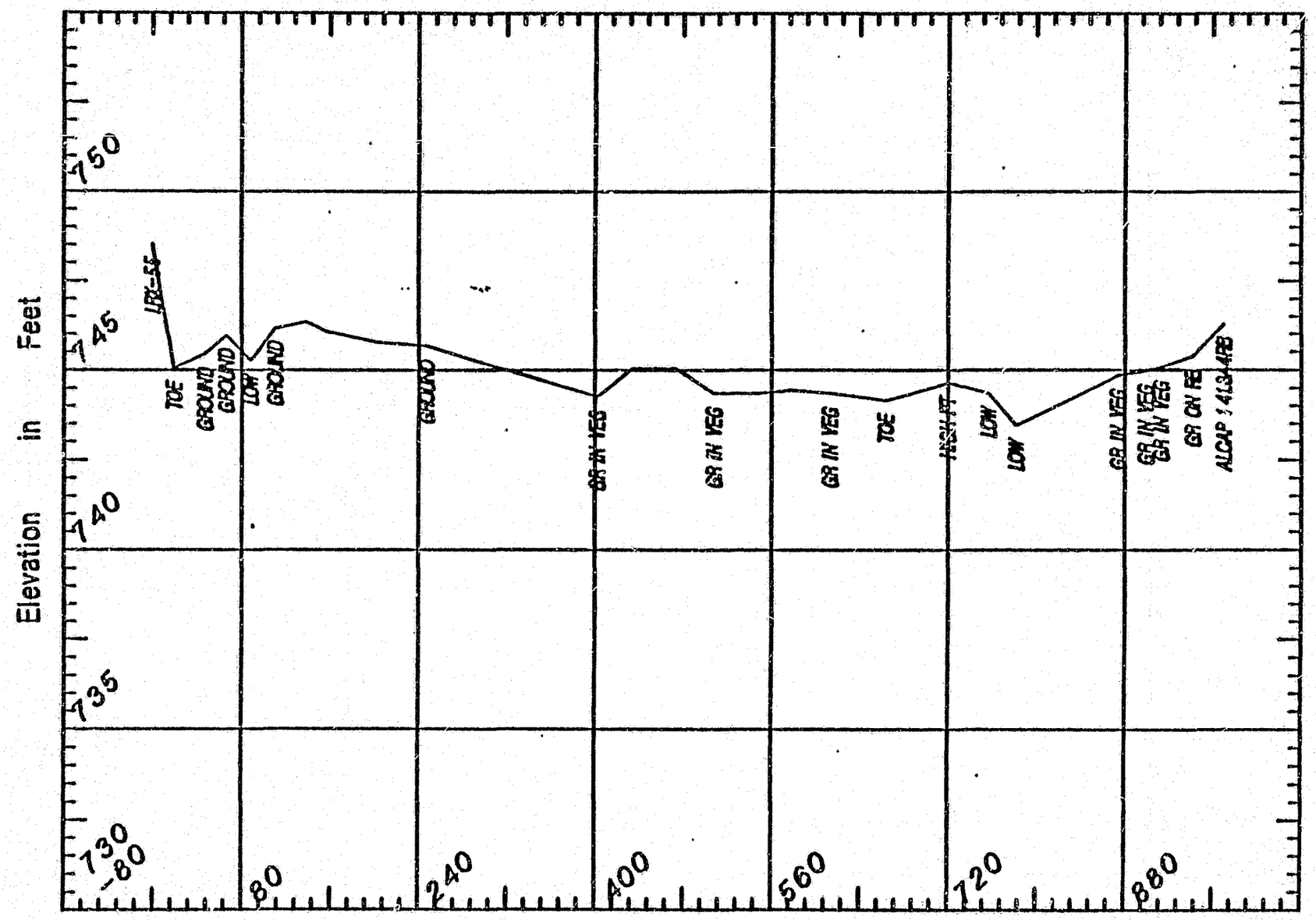
R&M CONSULTANTS, INC.

cross section SL21 1 41.7A5
Date of Survey: JULY 11,1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



24-22

PREPARED BY:

R&M CONSULTANTS, INC.

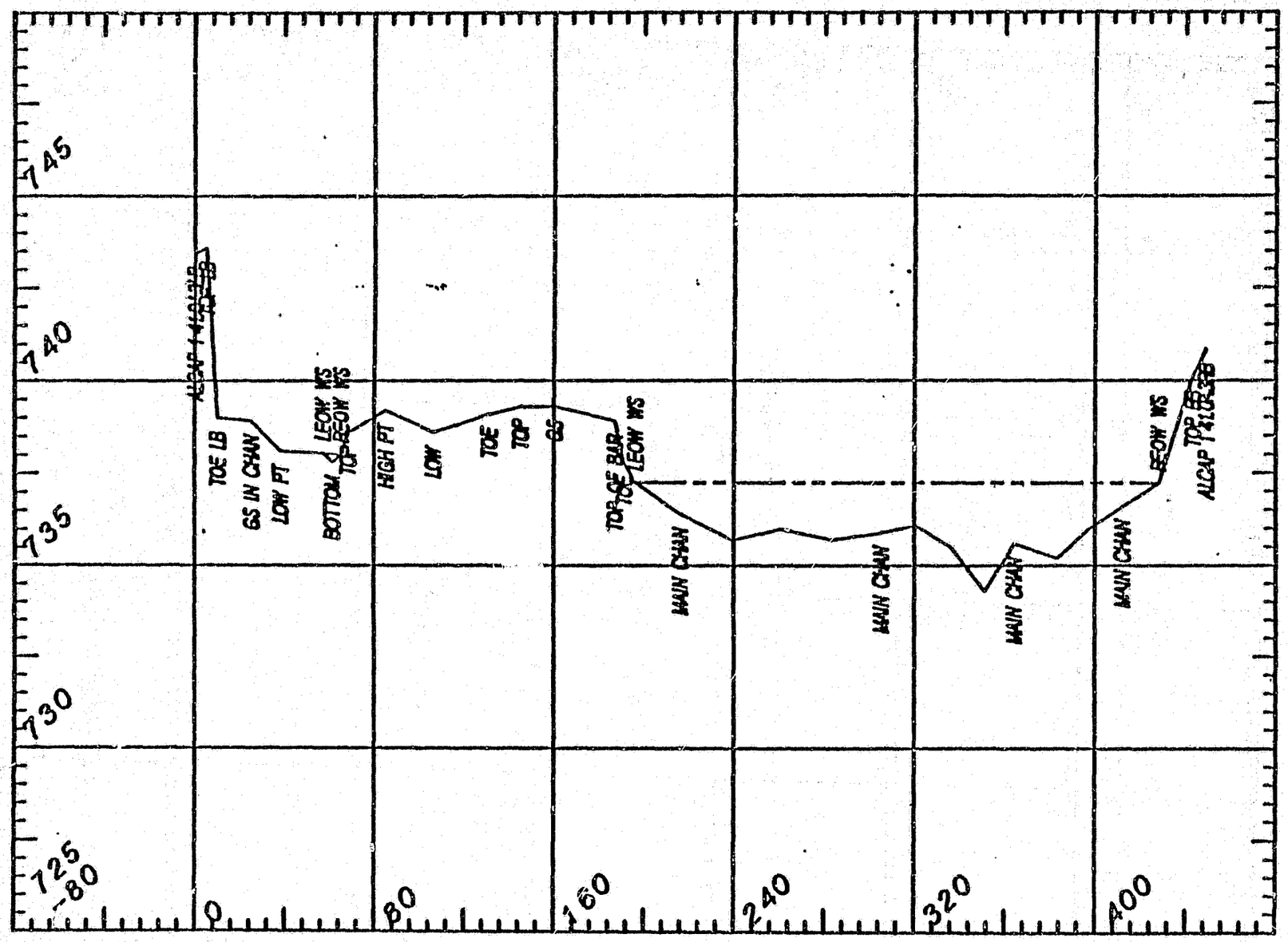
cross section SL21 1 41.3A4

Date of Survey: JULY 12, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



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PREPARED BY:

R&M CONSULTANTS, INC.

cross section SL21 1 41.0A3
Date of Survey: JULY 12, 1982

PREPARED FOR:

ACRES

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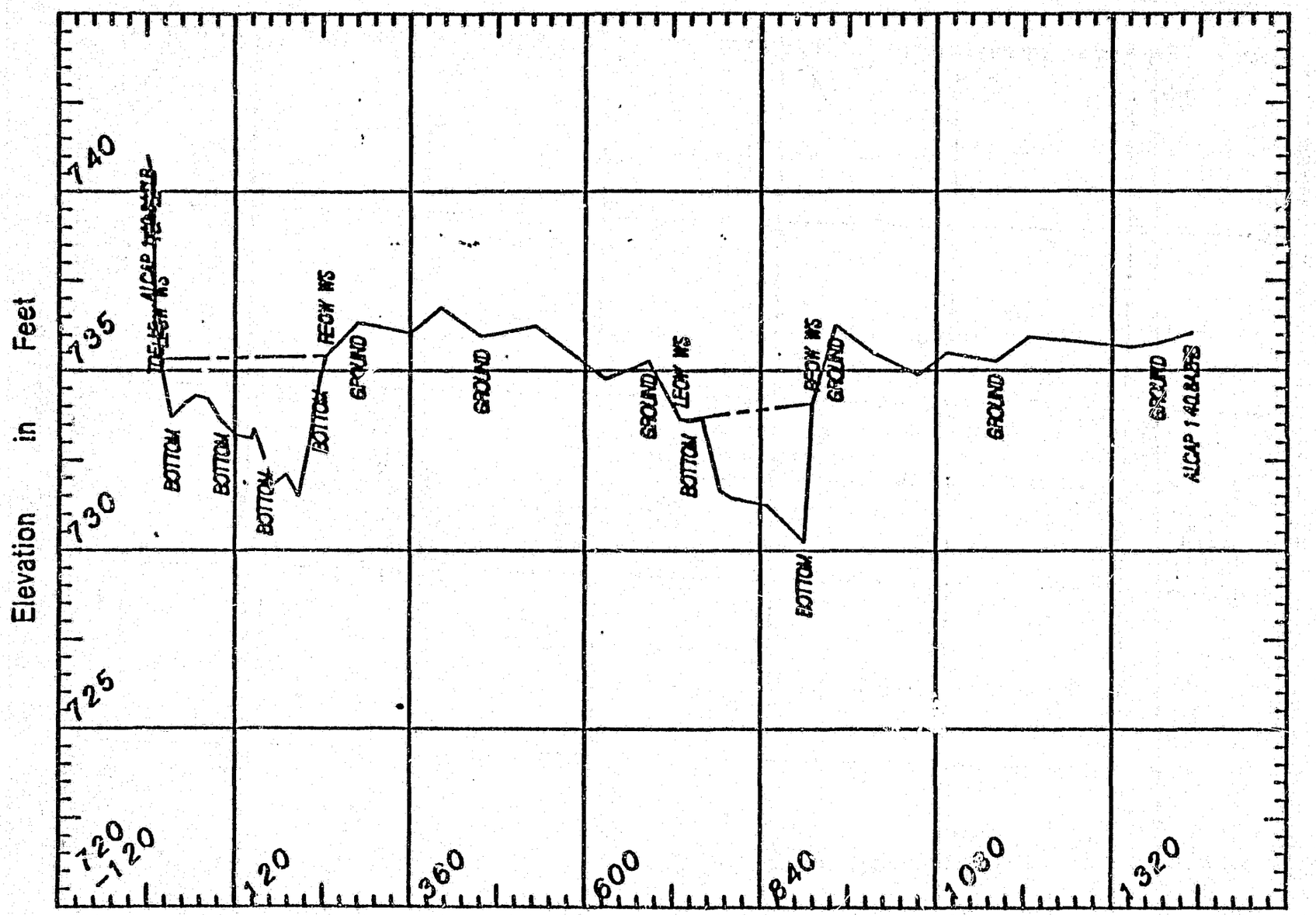


2-2-44

PREPARED BY:

R&M CONSULTANTS, INC.

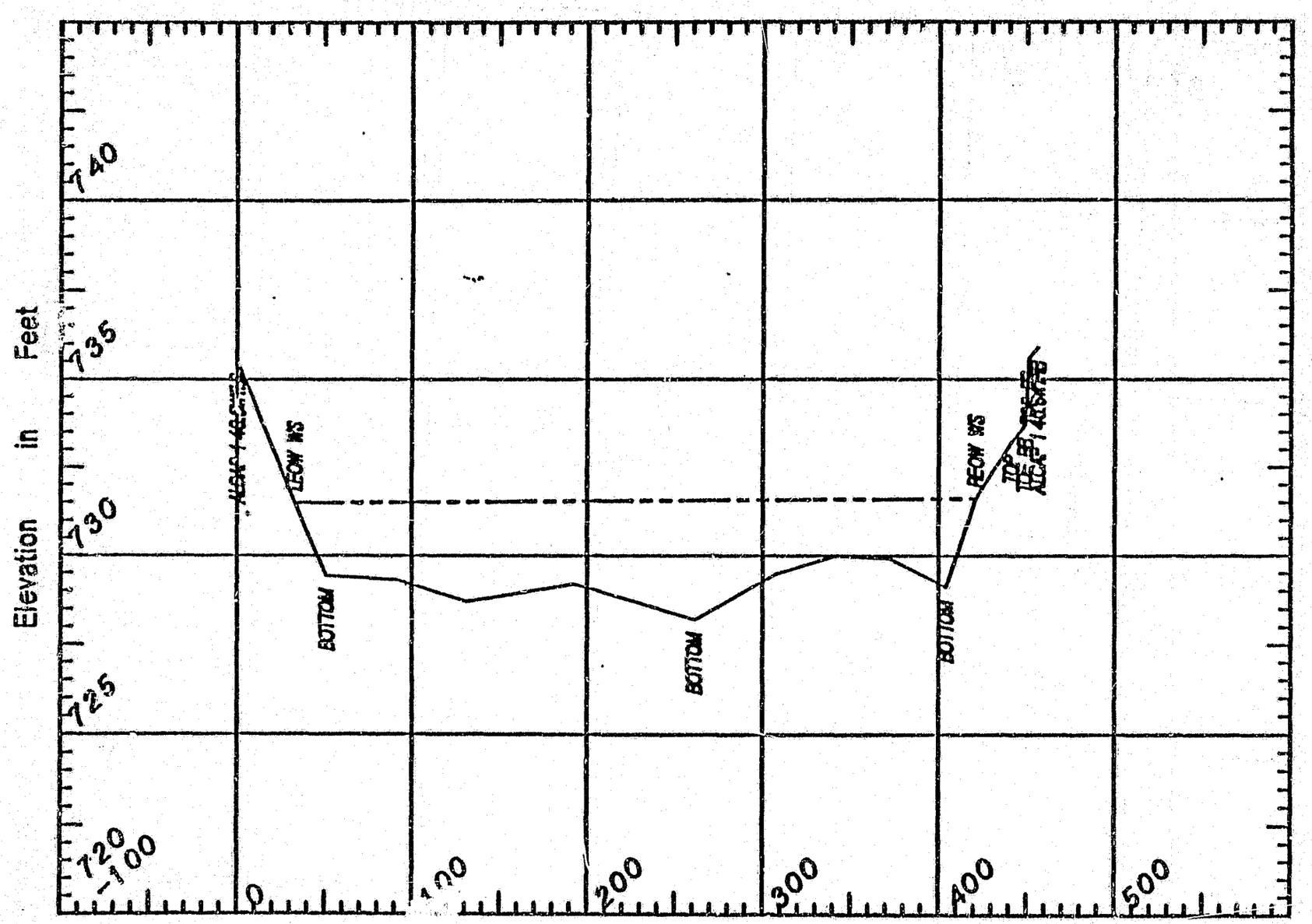
cross section SL21140.8A2

Date of Survey: JULY 12, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



Sh-2-2

PREPARED BY:

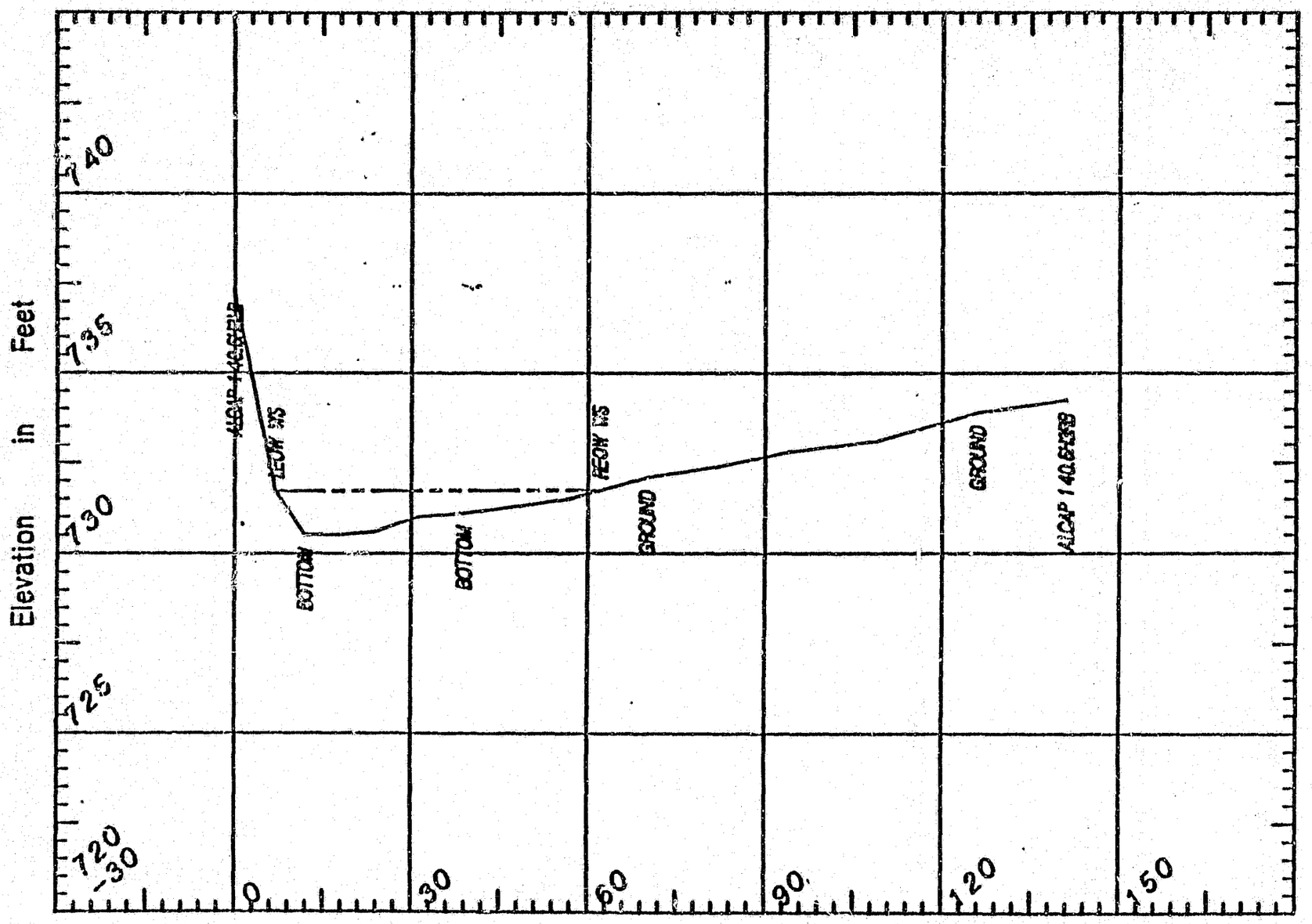
R&M CONSULTANTS, INC.

cross section SL21 1 40.6W1
Date of Survey: JULY 12, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



14-2-2

PREPARED BY:

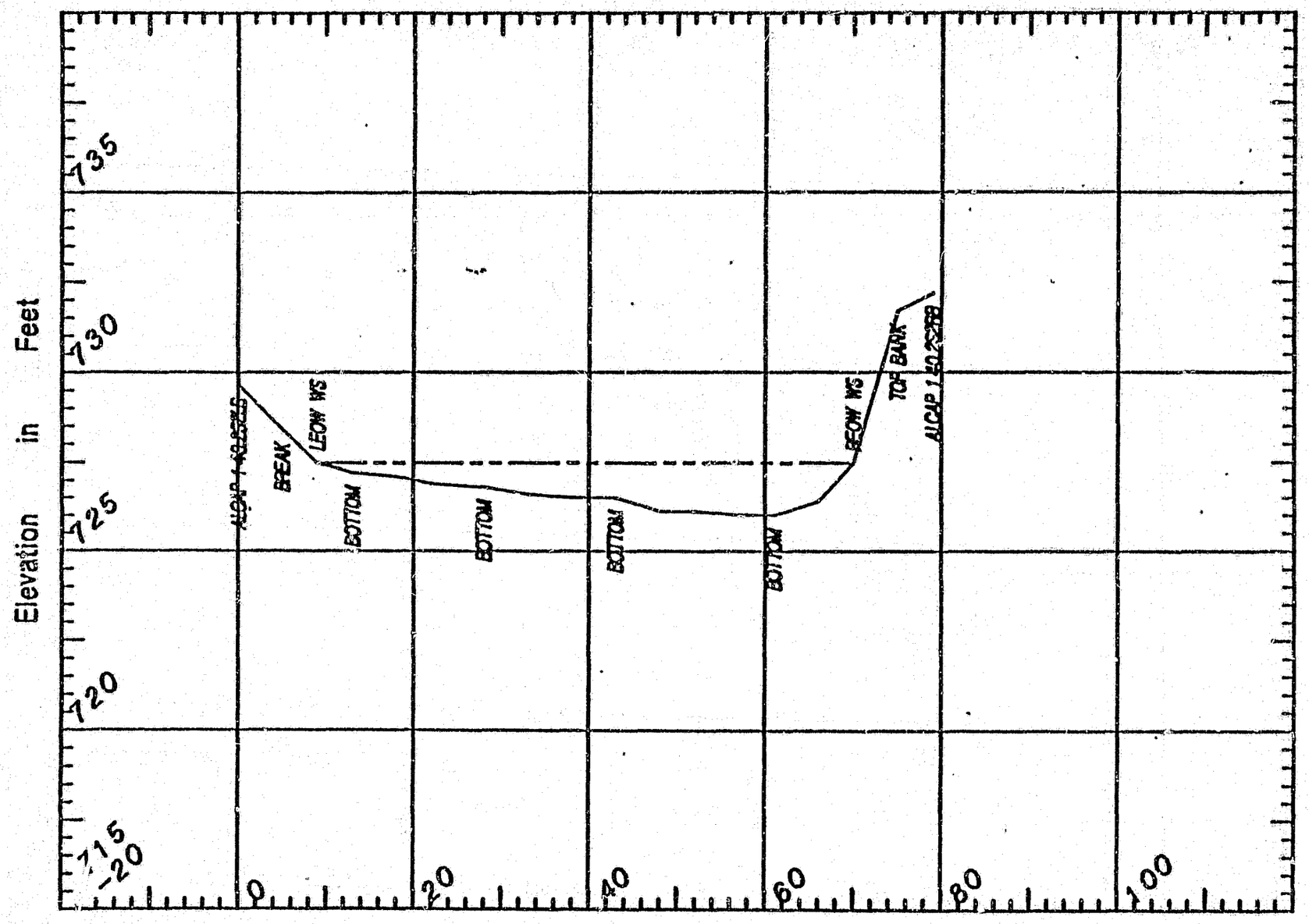
R&M CONSULTANTS, INC.

cross section SL20 140.6H3
Date of Survey: JULY 27, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



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PREPARED BY:

R&M CONSULTANTS, INC.

cross section SL20 1 40.2S2
Date of Survey: JULY 27, 1982

PREPARED FOR:

ACRES

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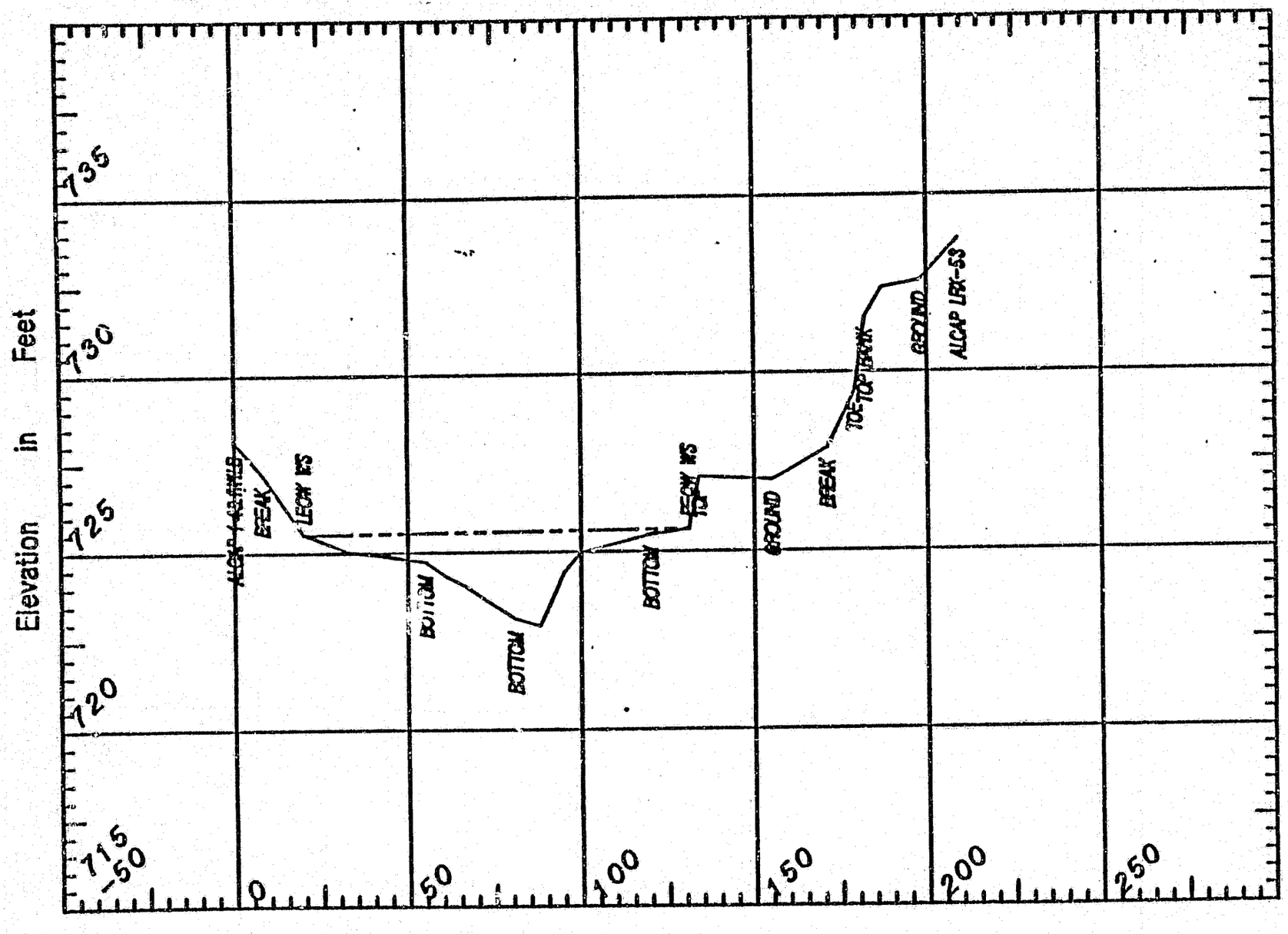


84-2-48

PREPARED BY:

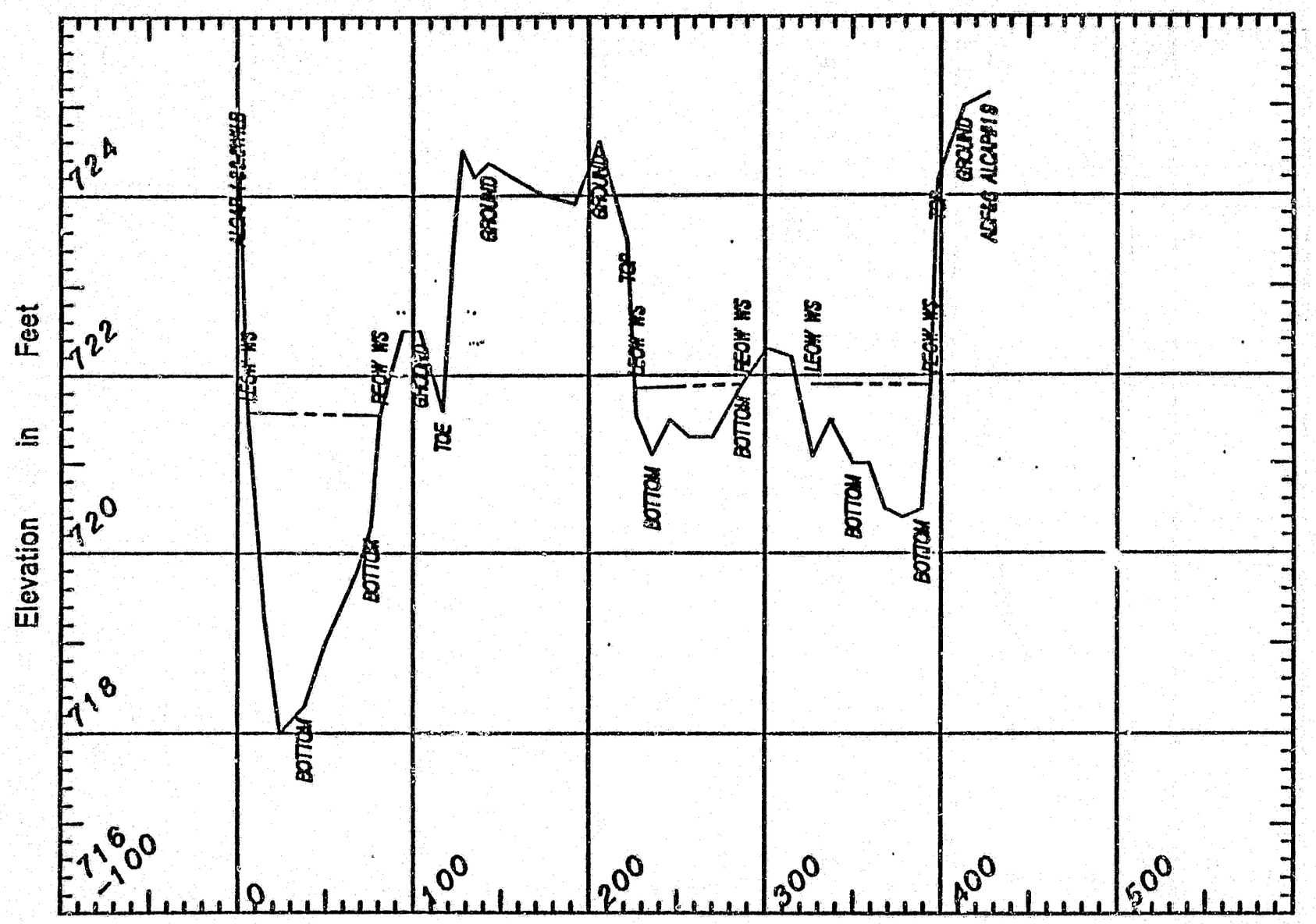
R&M CONSULTANTS, INC.

cross section SL20 1 40.1W1
Date of Survey: JULY 24, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



64-2-7

PREPARED BY:

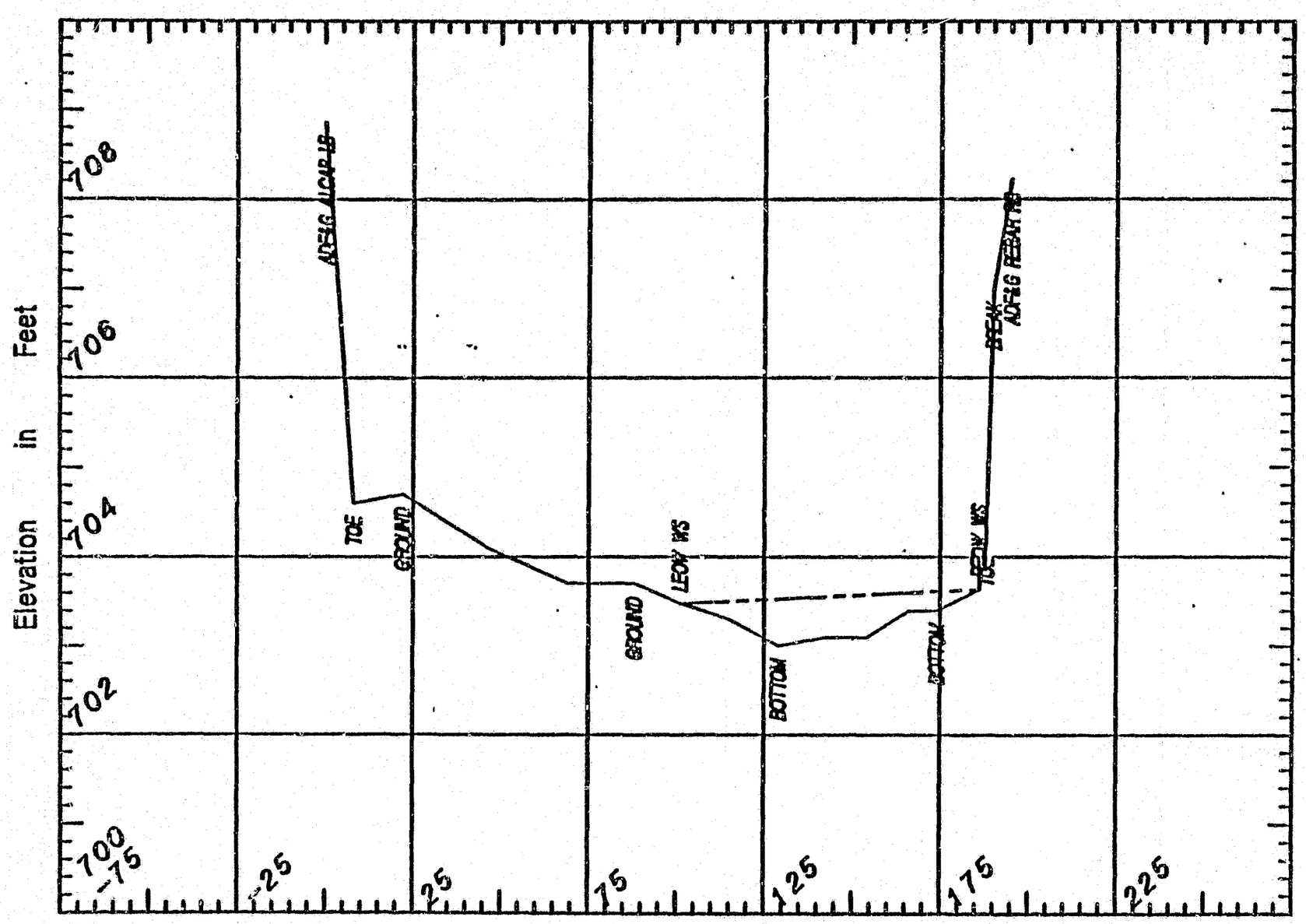
R&M CONSULTANTS, INC.

cross section SL1 9 139.8W1
Date of Survey: JULY 24, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



2-22-50

PREPARED BY:

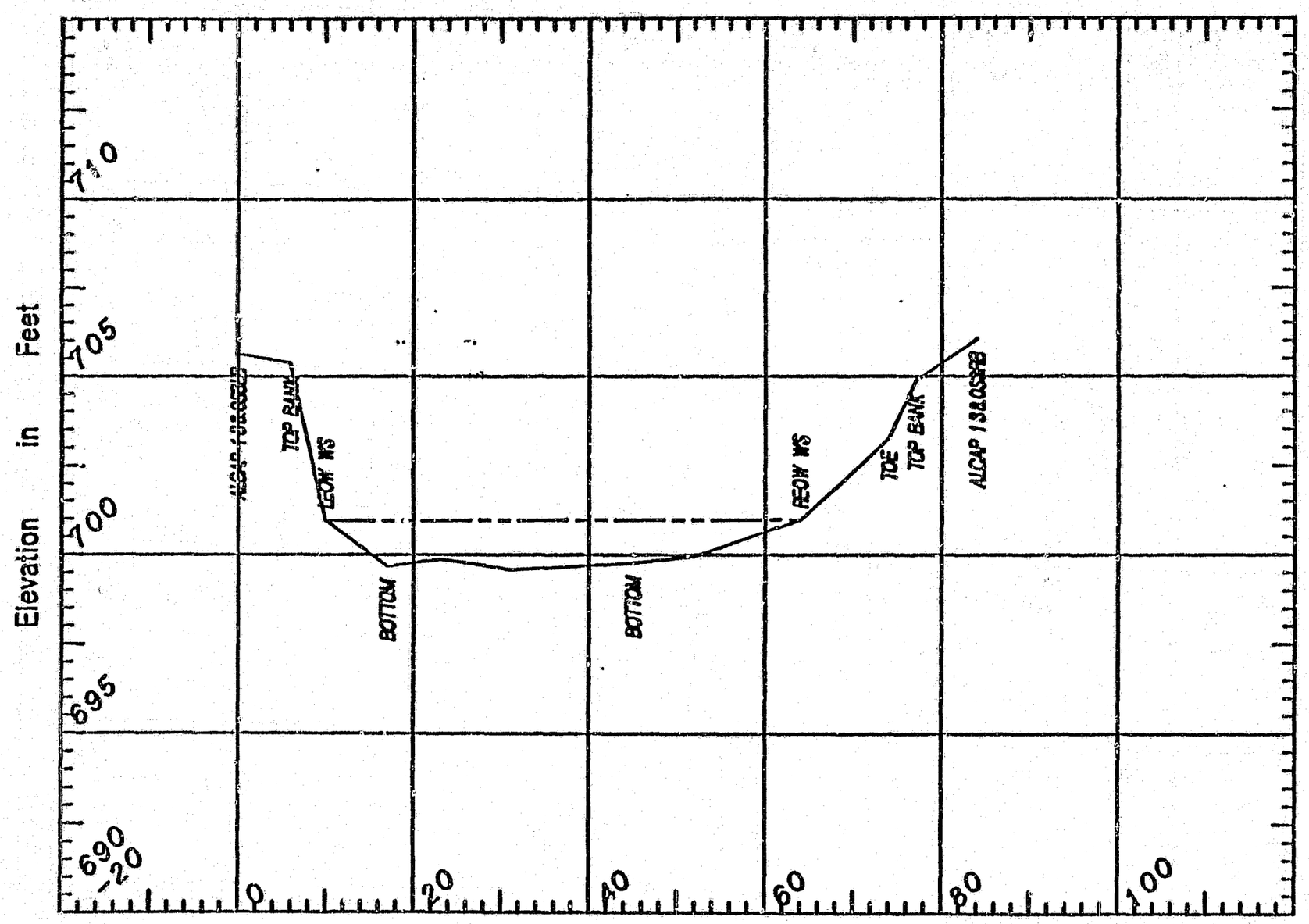
R&M CONSULTANTS, INC.

cross section SL16 138.3H4
Date of Survey: JULY 22, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



15-2-2

PREPARED BY:

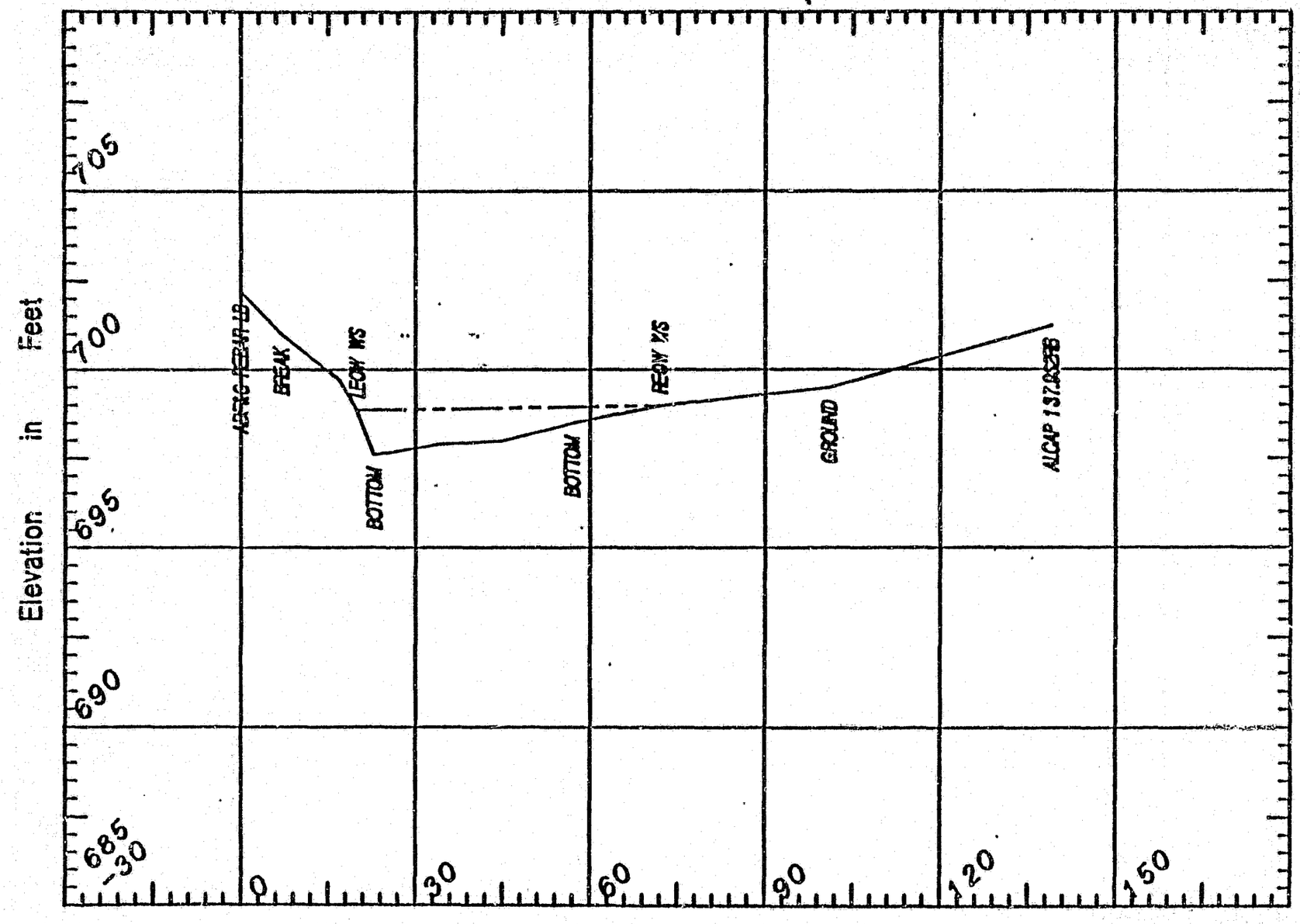
R&M CONSULTANTS, INC.

cross section SL1 6 138.0S3
Date of Survey: JULY 24, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



22-22

PREPARED BY:

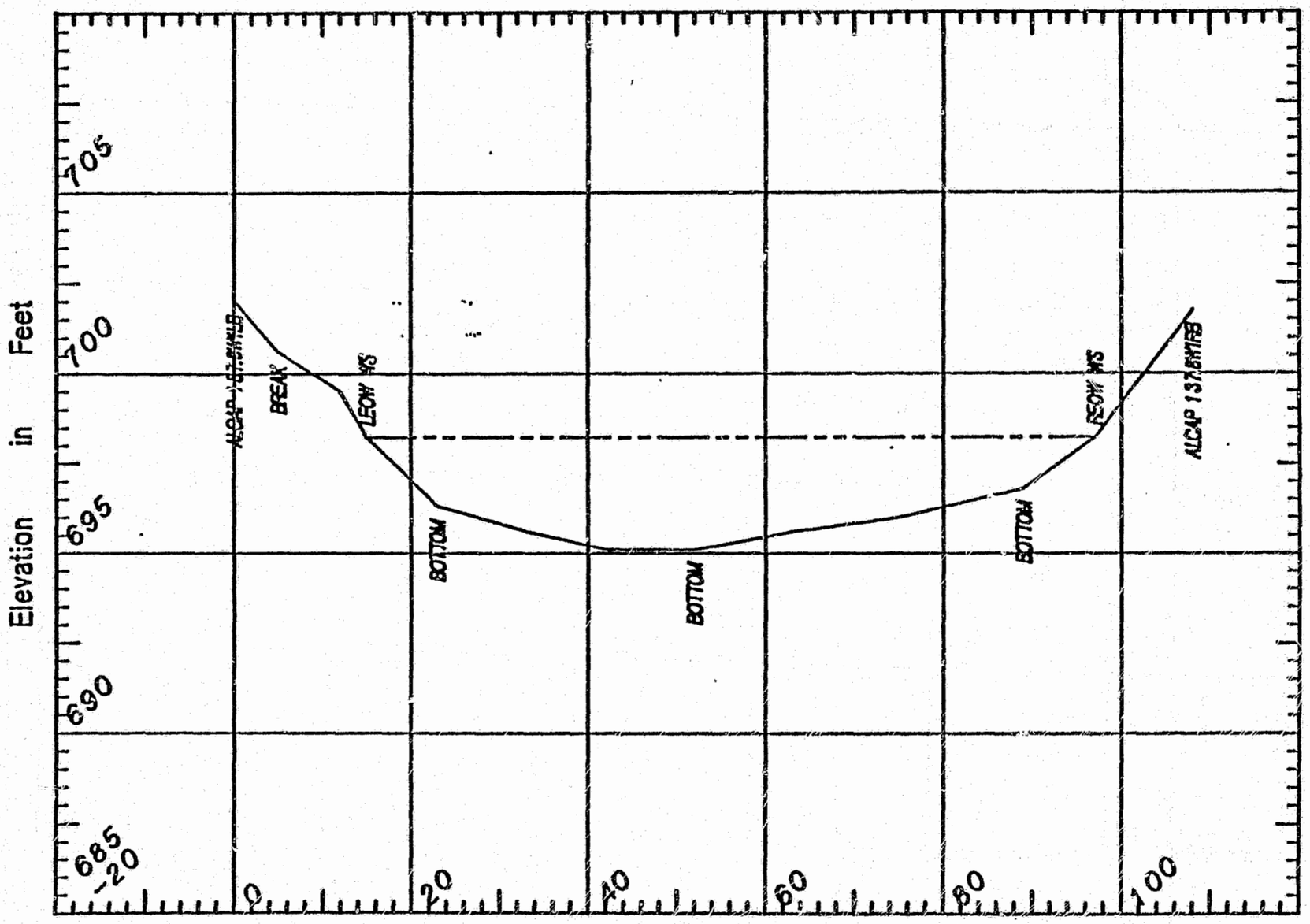
R&M CONSULTANTS, INC.

cross section SL16 137.9S2
Date of Survey: JULY 22, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



2-2-53

PREPARED BY:

R&M CONSULTANTS, INC.

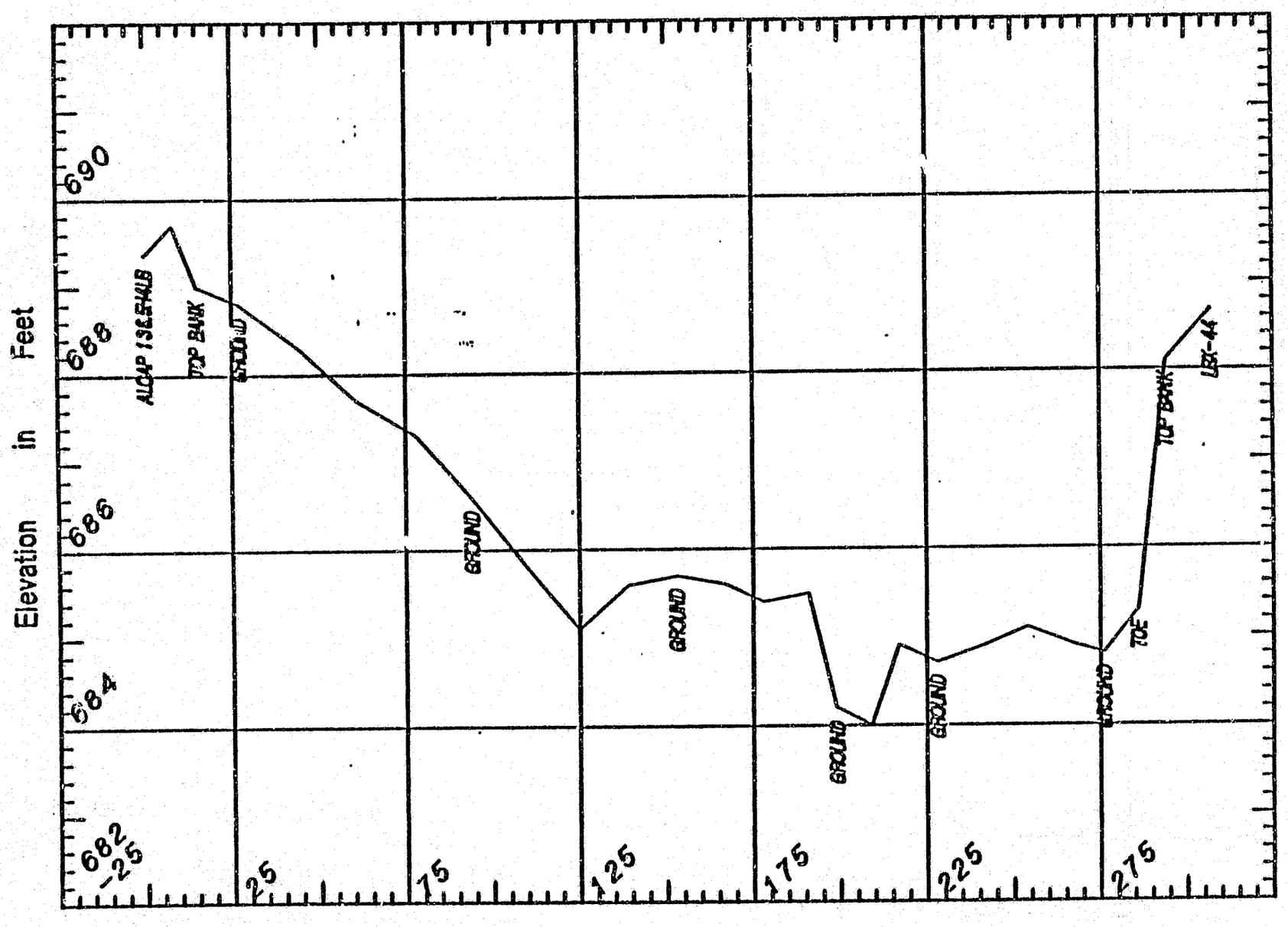
cross section SL16 137.8W1

Date of Survey: JULY 22, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



4-5-2-2

PREPARED BY:

R&M CONSULTANTS, INC.

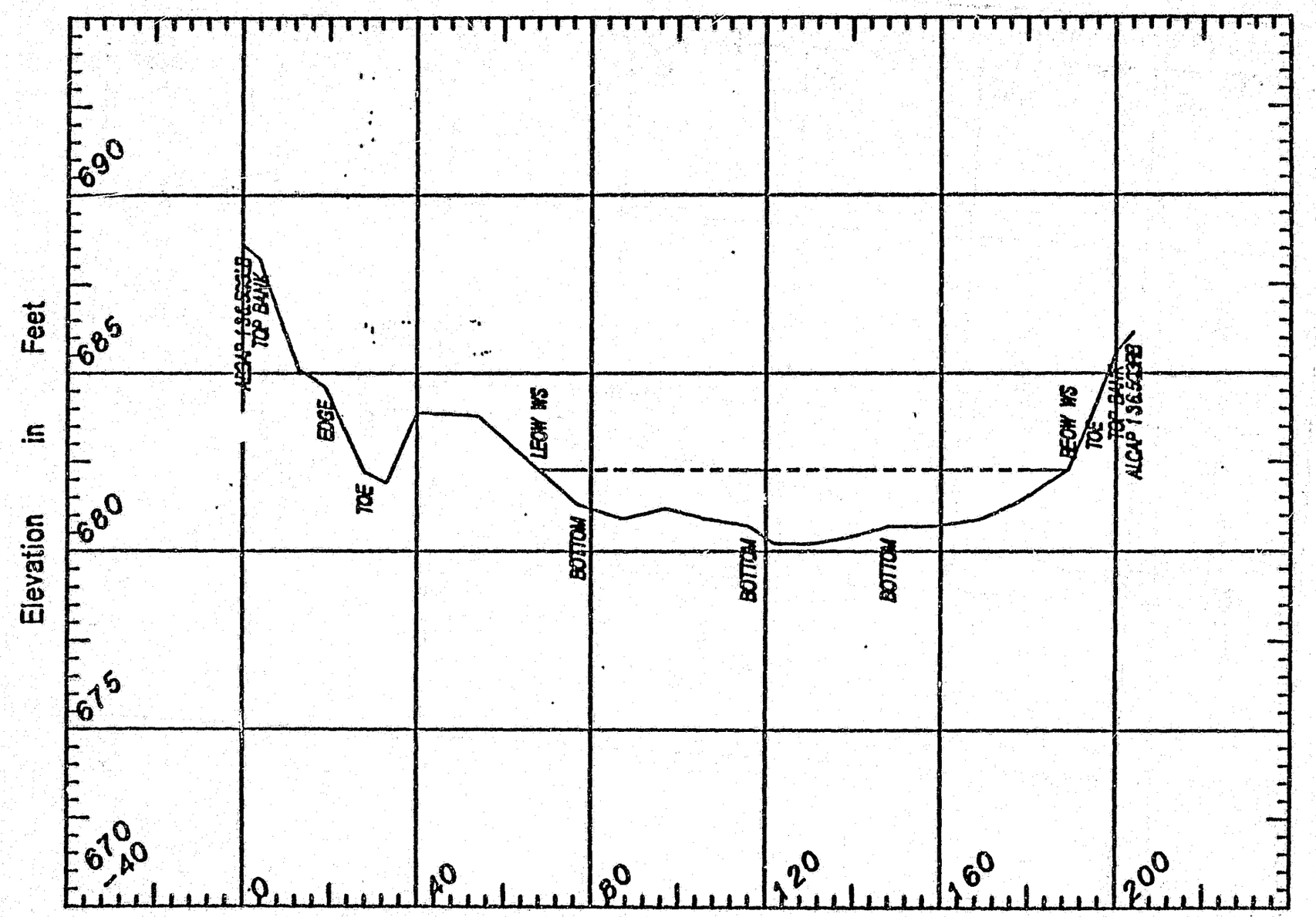
cross section SL11136.5H4

Date of Survey: JULY 28, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



2-2-55

PREPARED BY:

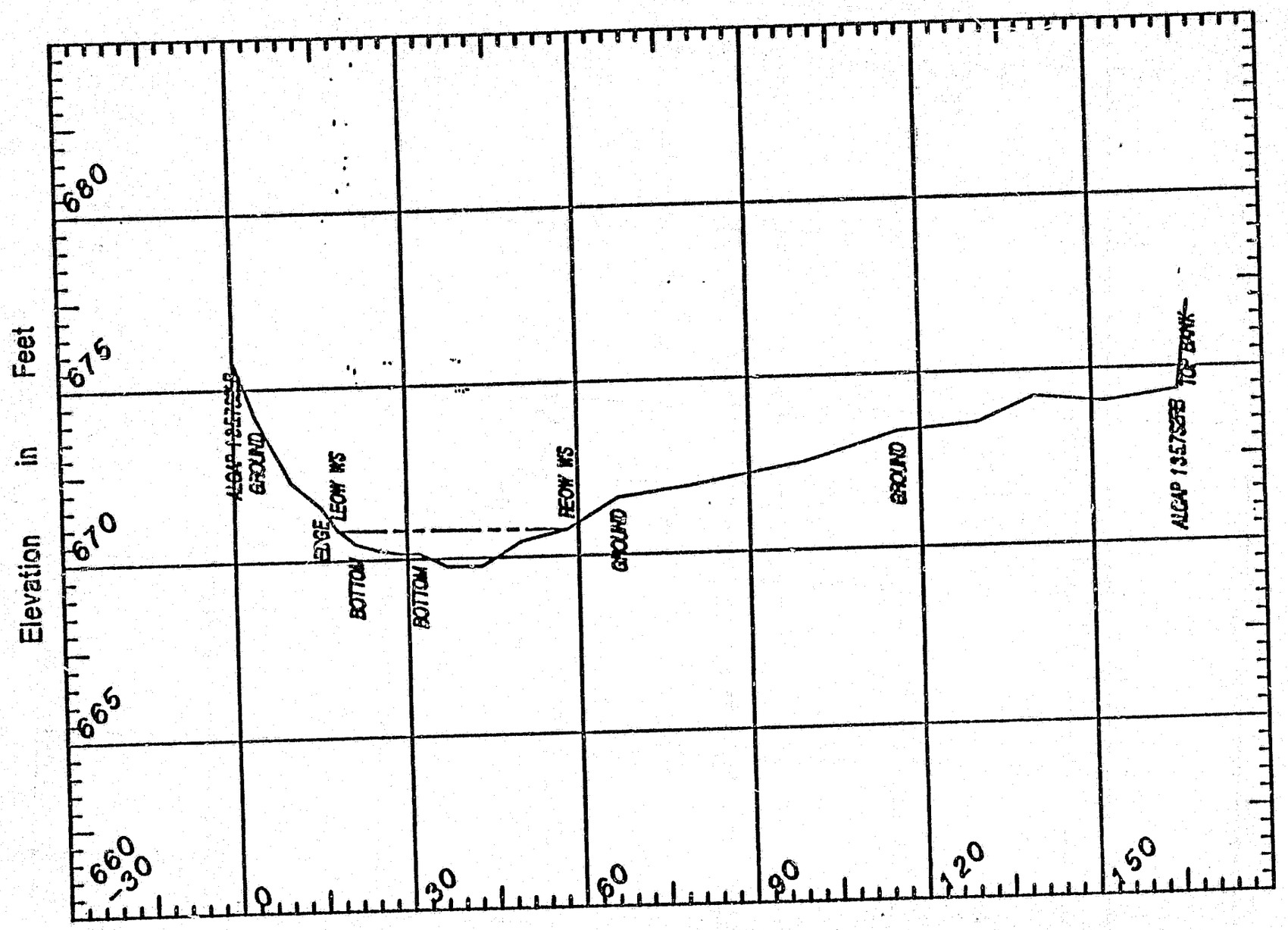
R&M CONSULTANTS, INC.

cross section SL11136.5Q3
Date of Survey: JULY 28, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



2-2-56

PREPARED BY:

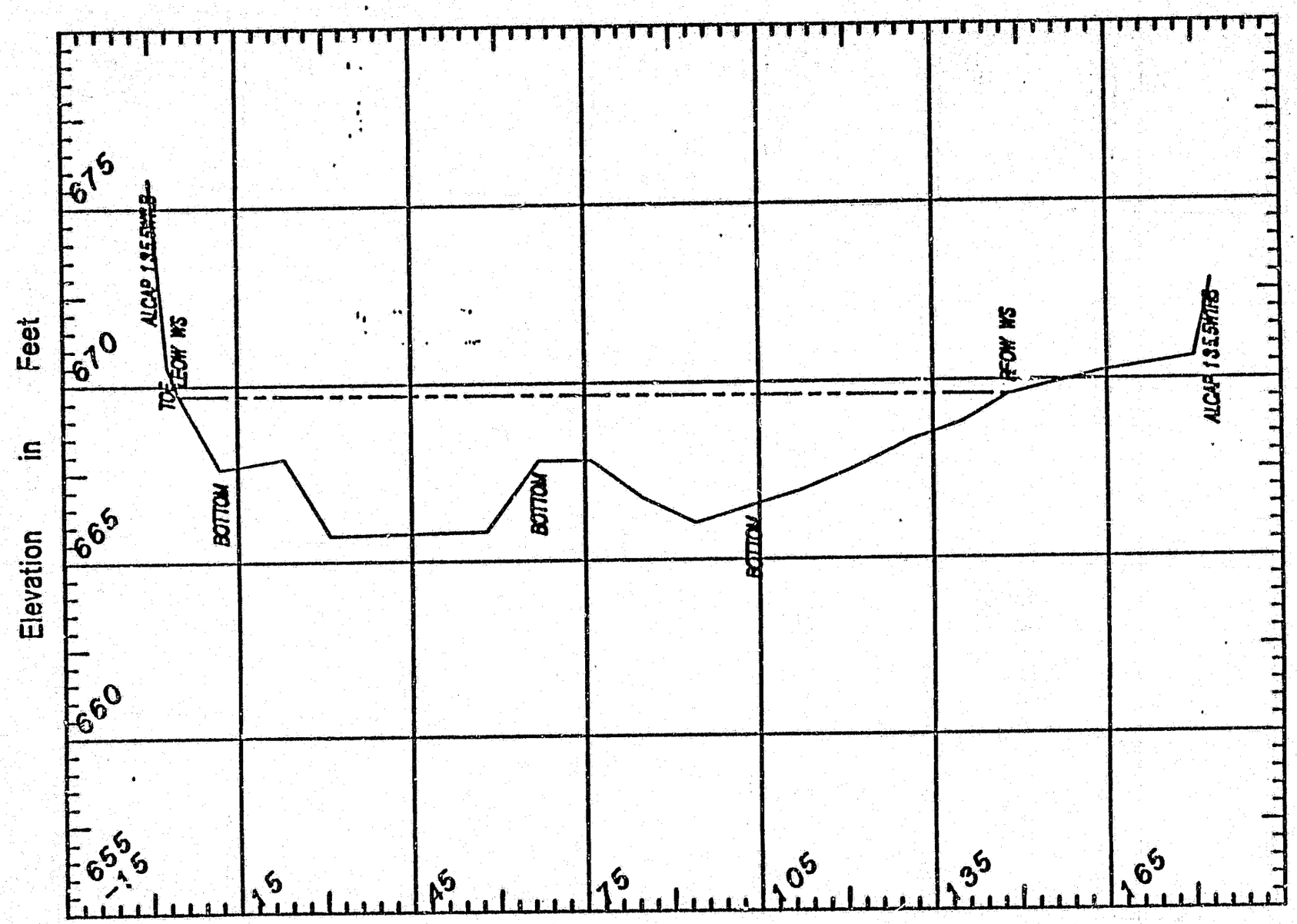
R&M CONSULTANTS, INC.

cross section SL11 135.7S2
Date of Survey: JULY 28, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



2-2-57

PREPARED BY:

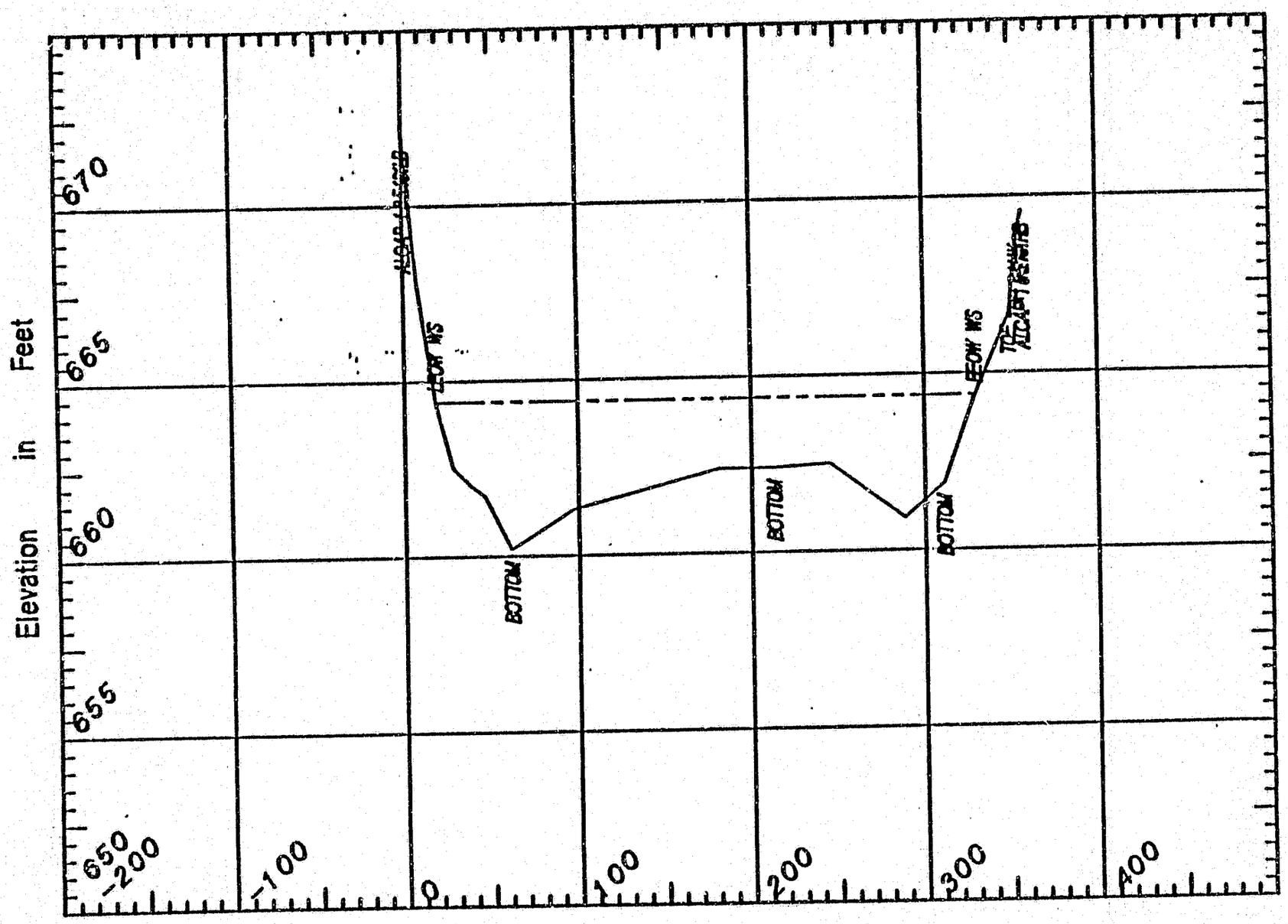
R&M CONSULTANTS, INC.

cross section SL11 135.5W1
Date of Survey: JULY 28, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



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PREPARED BY:

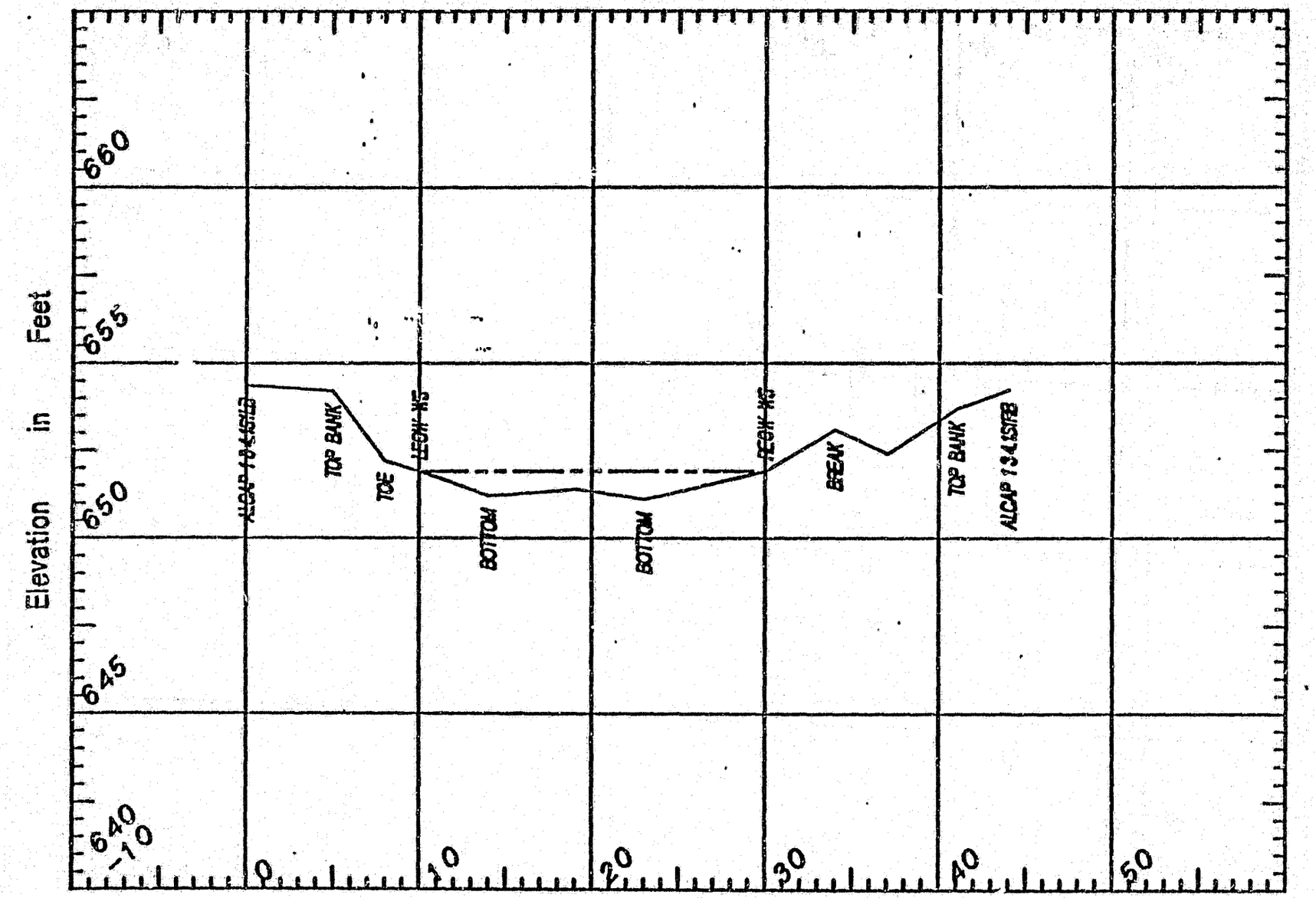
R&M CONSULTANTS, INC.

cross section SL1 1 1 35.1S1
Date of Survey: JULY 29, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



2-2-59

PREPARED BY:

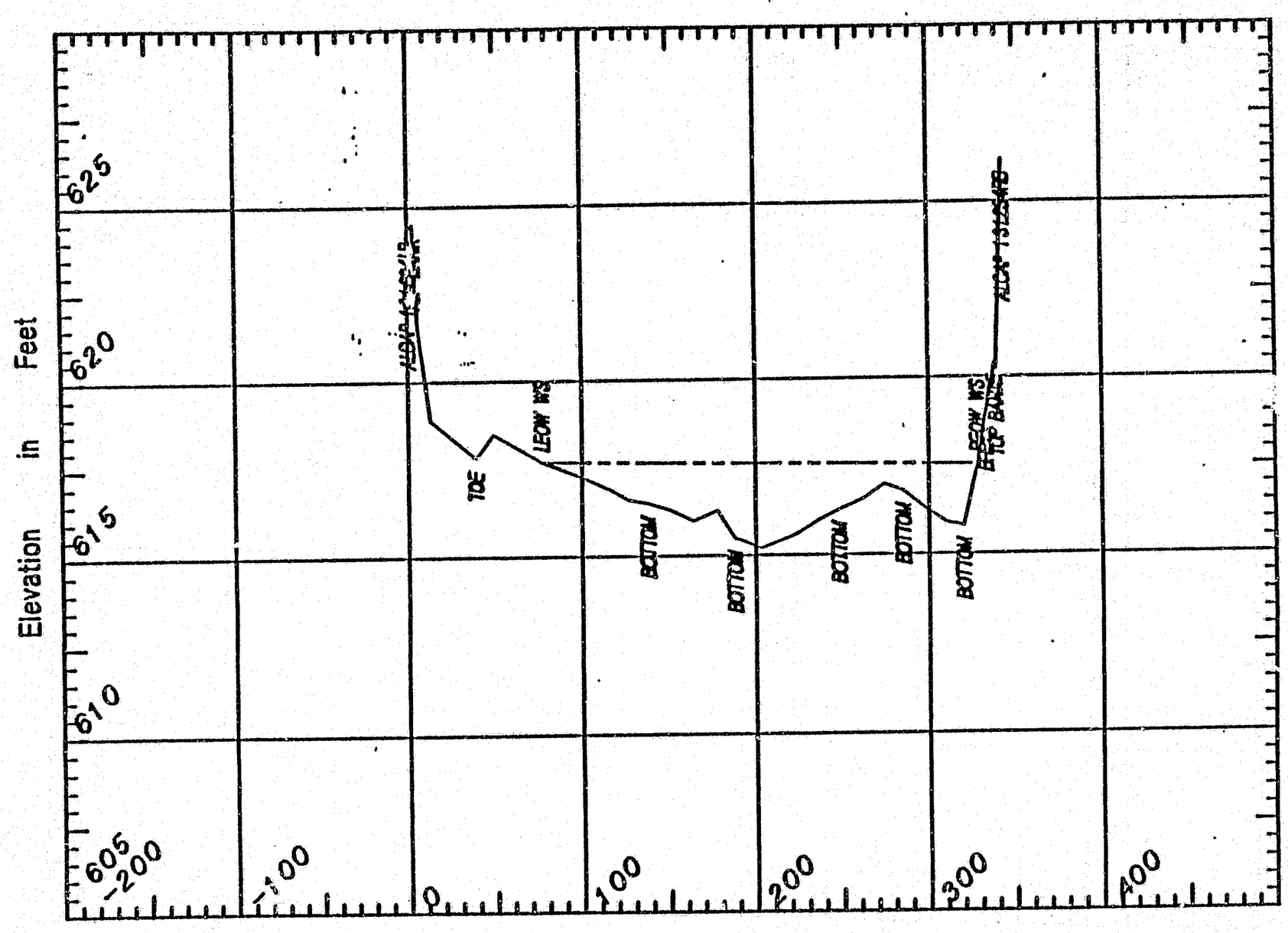
R&M CONSULTANTS, INC.

cross section SL10 134.1S1
Date of Survey: JULY 29, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



2-2-10

PREPARED BY:

R&M CONSULTANTS, INC.

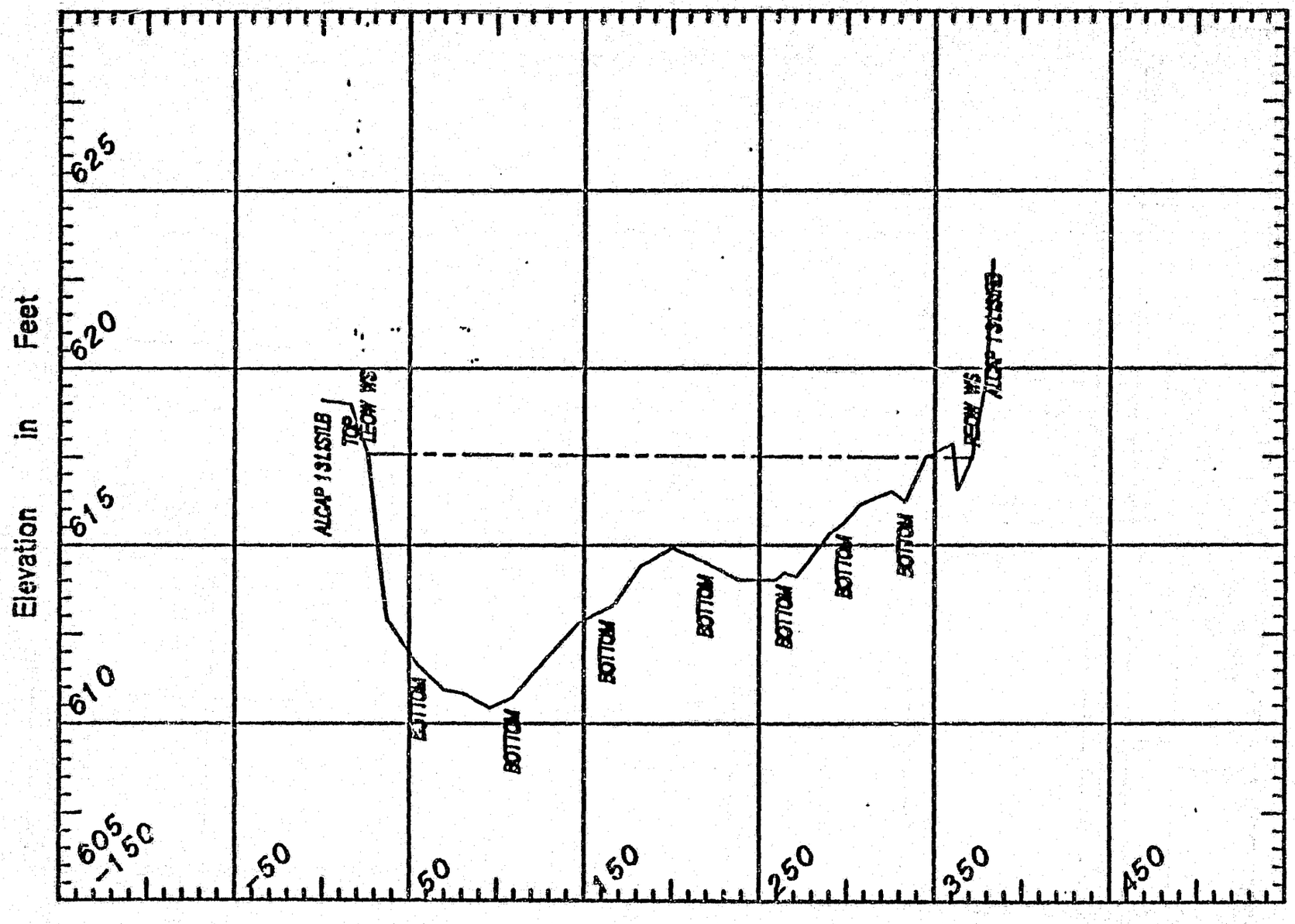
cross section 4TH OF JULY 131.2S4

Date of Survey: AUGUST 3, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



19-2-2

PREPARED BY:

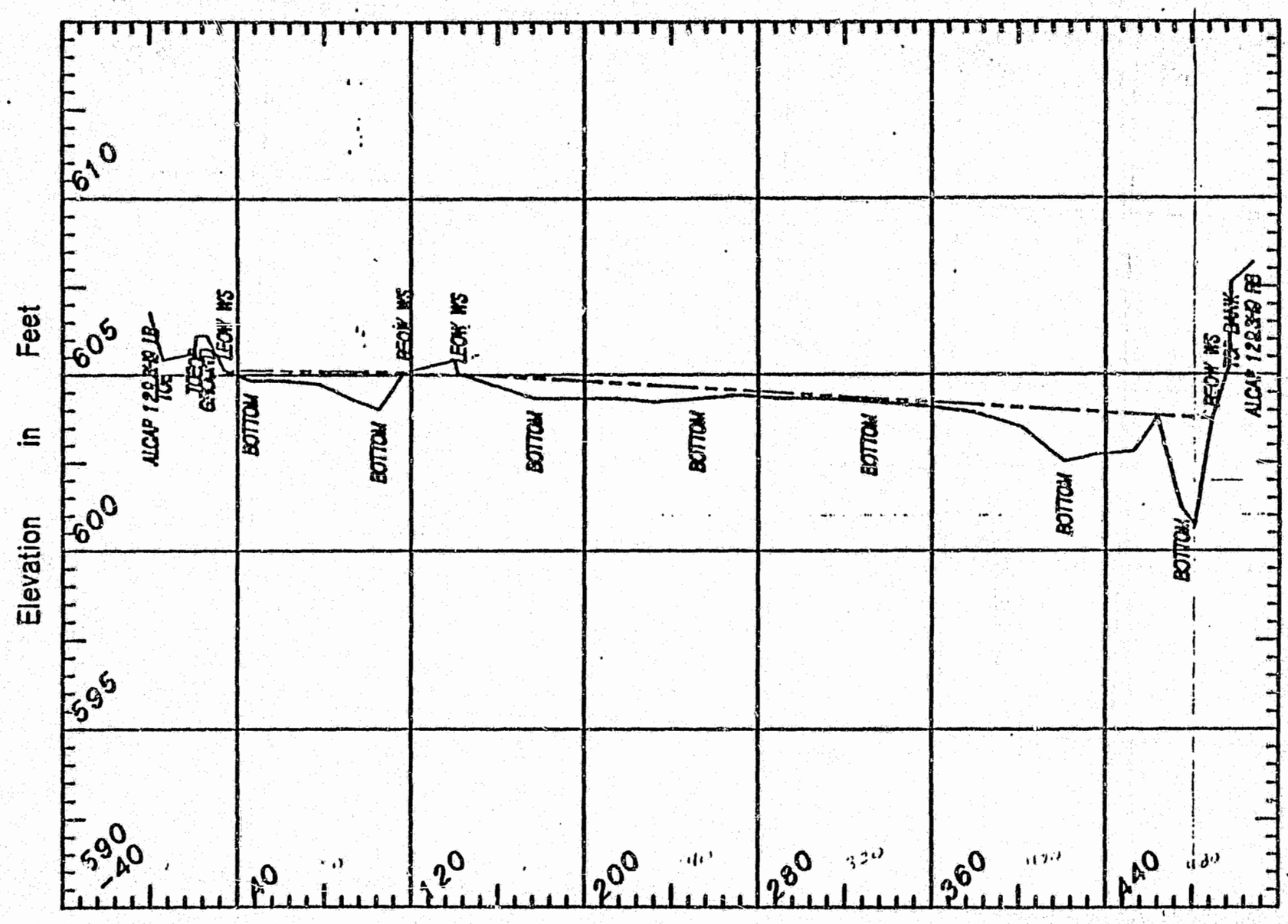
R&M CONSULTANTS, INC.

cross section 4TH OF JULY 131.1S1
Date of Survey: JULY 30, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



29-2-2

PREPARED BY:

R&M CONSULTANTS, INC.

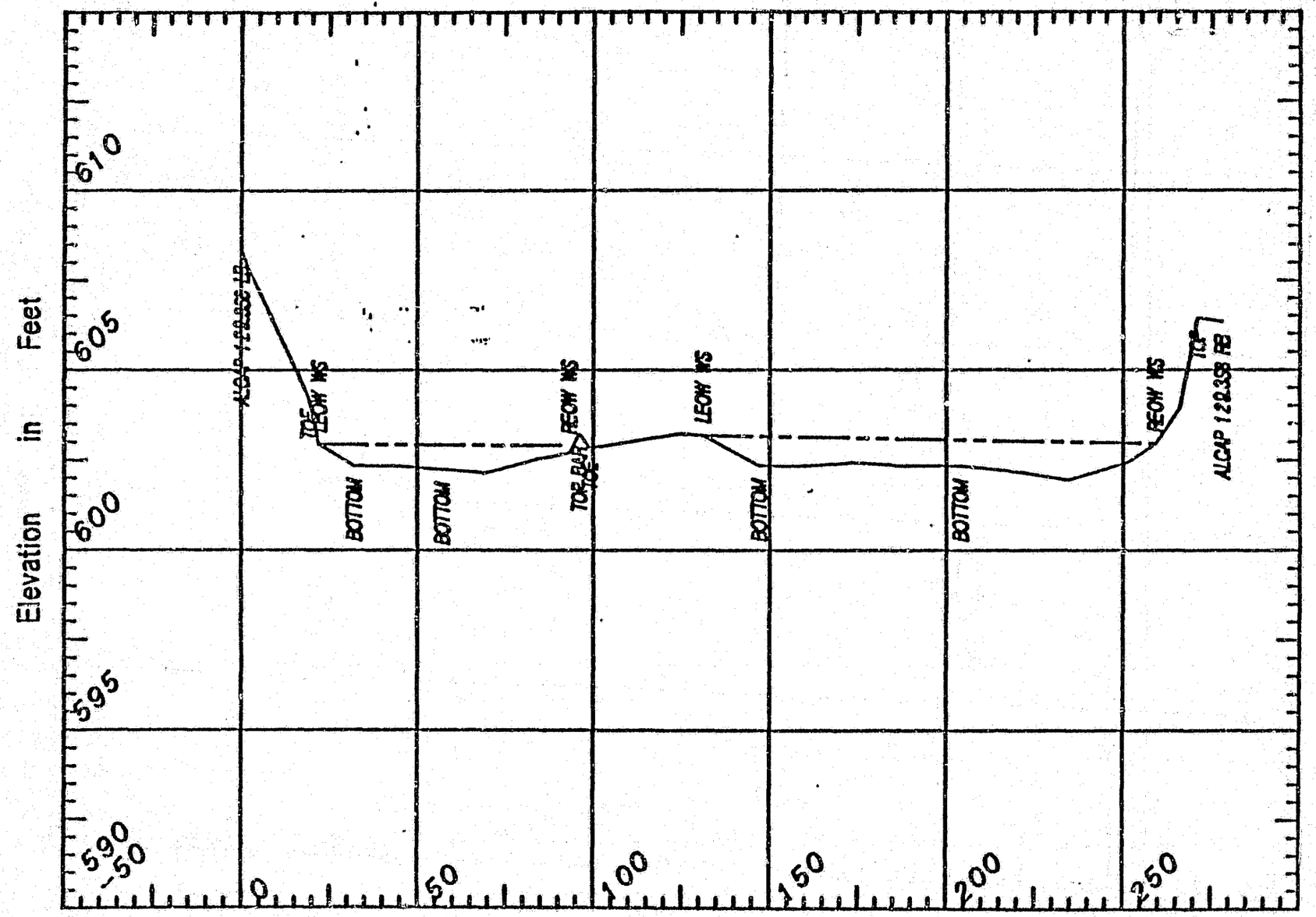
cross section SLOUGH 9 129.3H9
Date of Survey: AUGUST 1, 1982

Q_{tot} = 36,400 cfs

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



2-2-83

PREPARED BY:

R&M CONSULTANTS, INC.

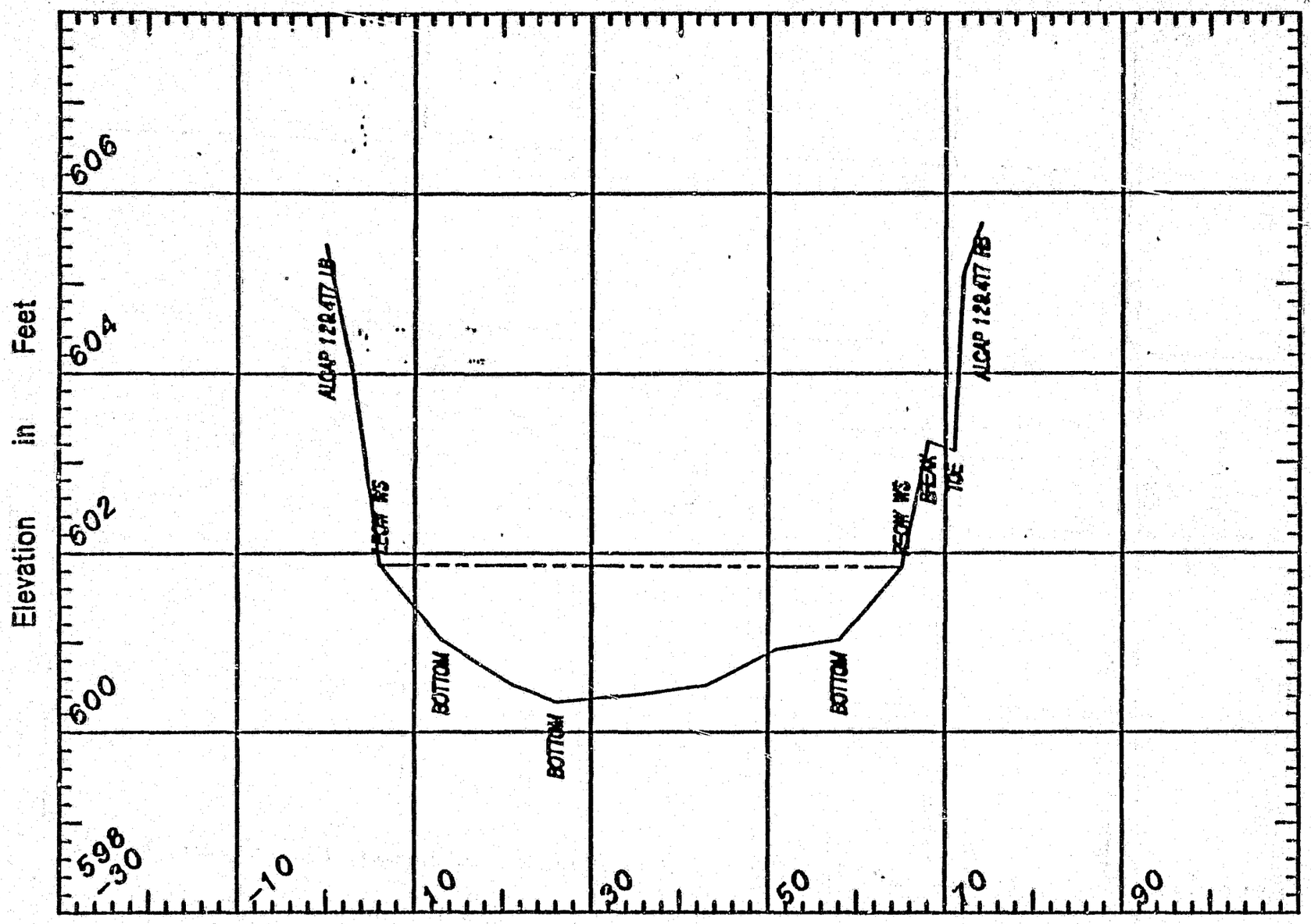
cross section SLOUGH 9 129.3S8

Date of Survey: AUGUST 1, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



2-2-84

PREPARED BY:

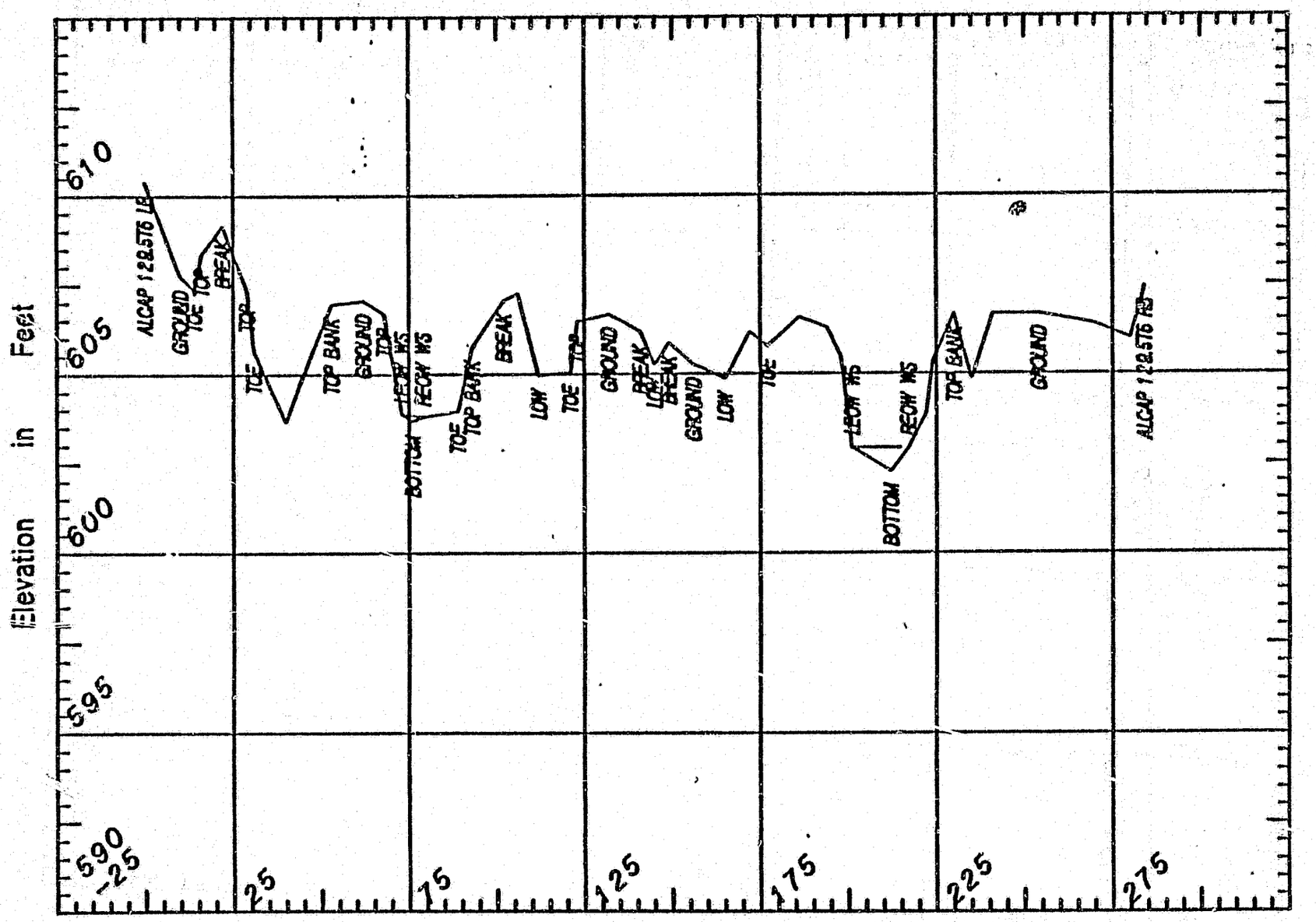
R&M CONSULTANTS, INC.

cross section SLOUGH 9 129.4T7
Date of Survey: AUGUST 1, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



59-22-2

PREPARED BY:

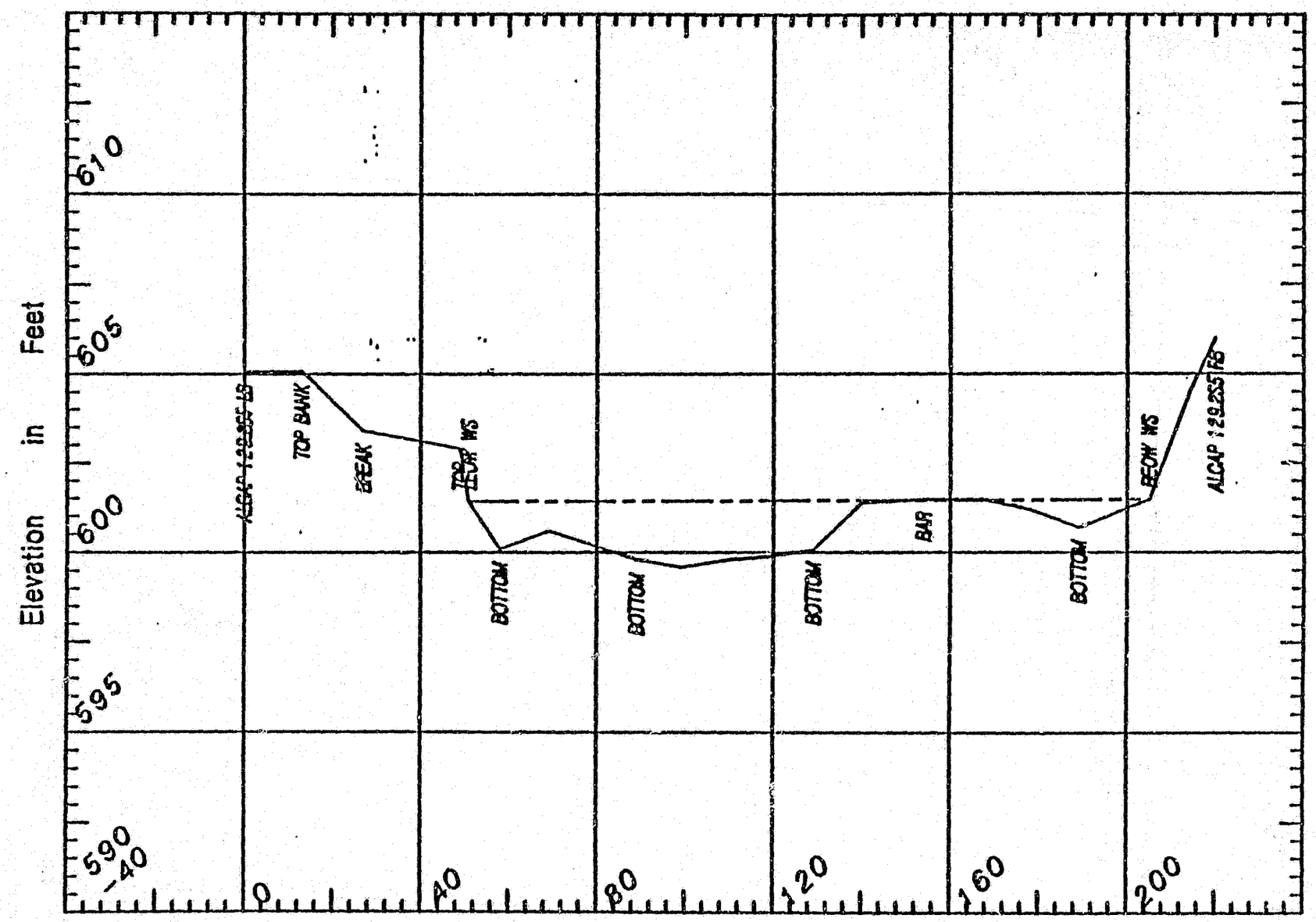
R&M CONSULTANTS, INC.

cross section SLOUGH 9 129.5T6
Date of Survey: AUGUST 1, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



2-2-66

PREPARED BY:

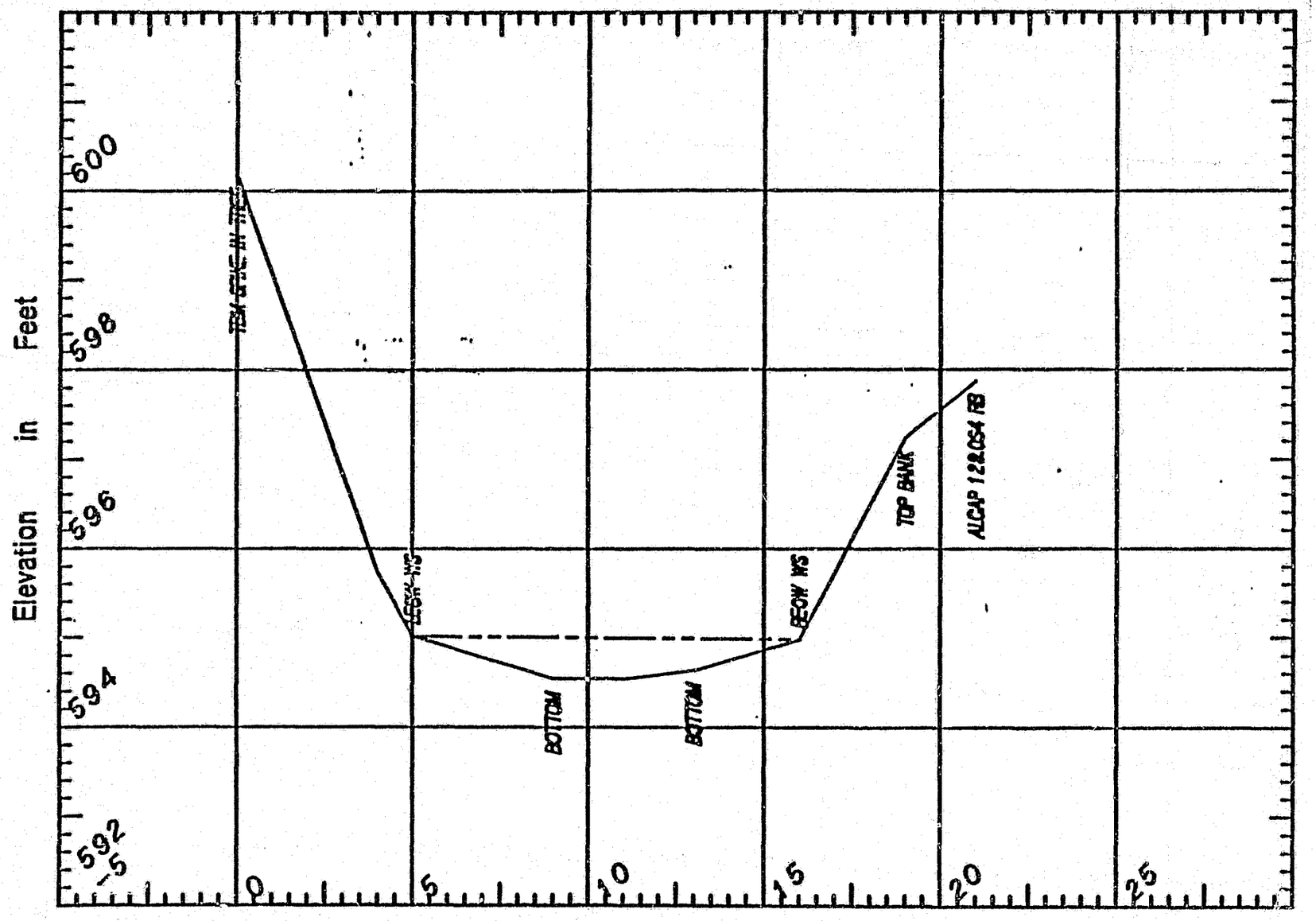
R&M CONSULTANTS, INC.

cross section SLOUGH 9 129.2S5
Date of Survey: AUGUST 1, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



2-2-17

PREPARED BY:

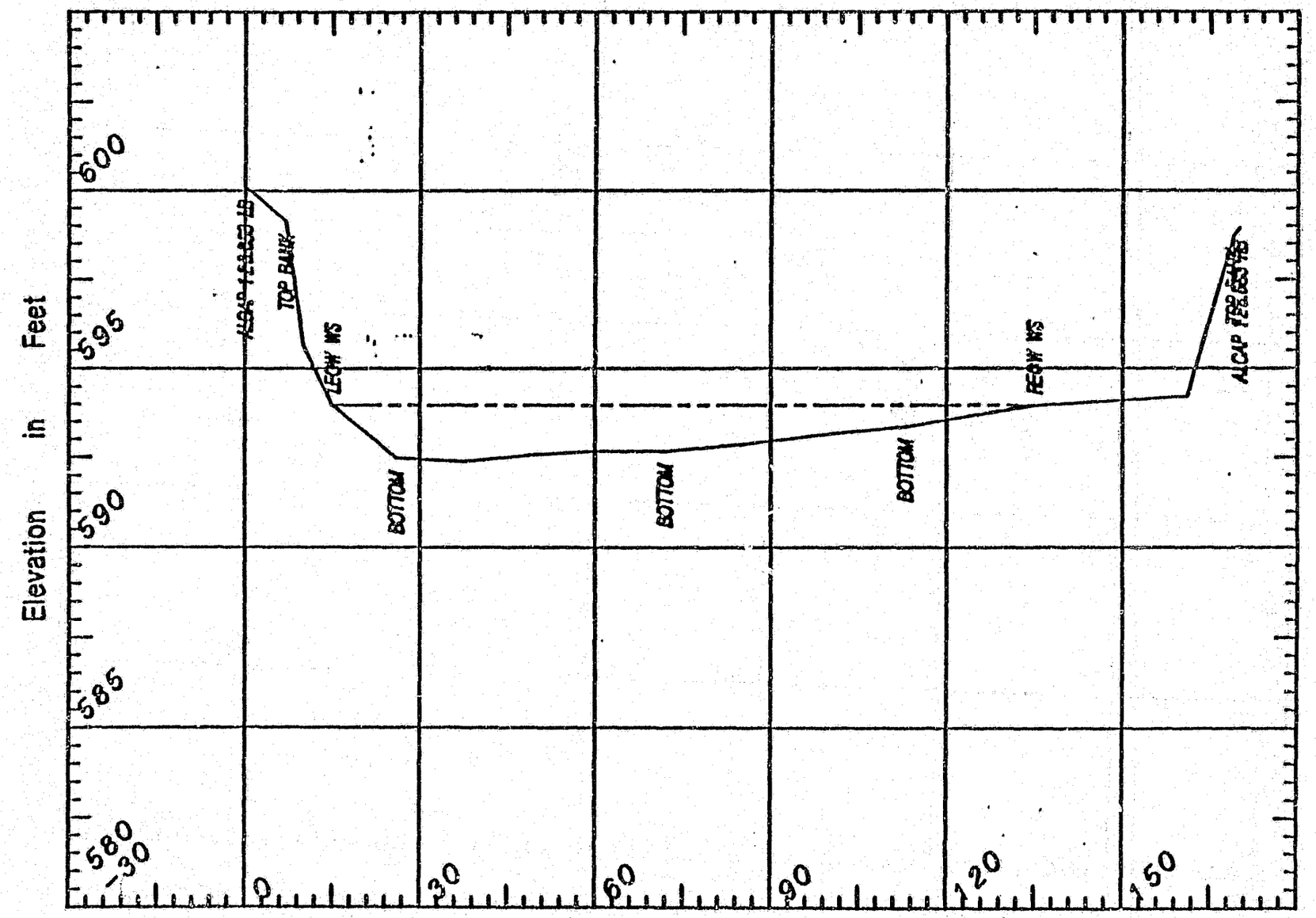
R&M CONSULTANTS, INC.

cross section SLOUGH 9 129.0S4
Date of Survey: AUGUST 1,1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



2-2-108

PREPARED BY:

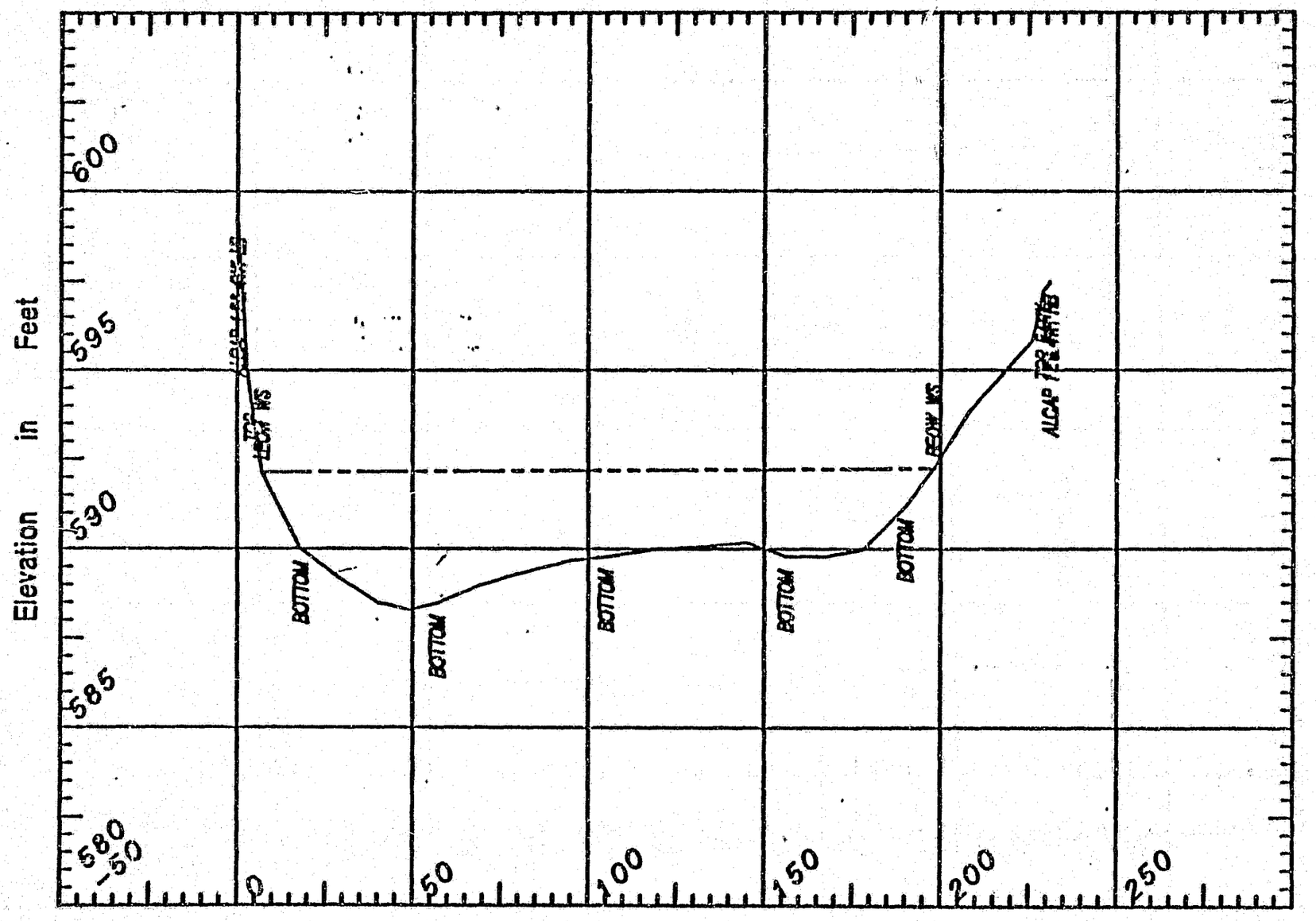
R&M CONSULTANTS, INC.

cross section SLOUGH 9 128.8S3
Date of Survey: AUGUST 1, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



69-2-27

PREPARED BY:

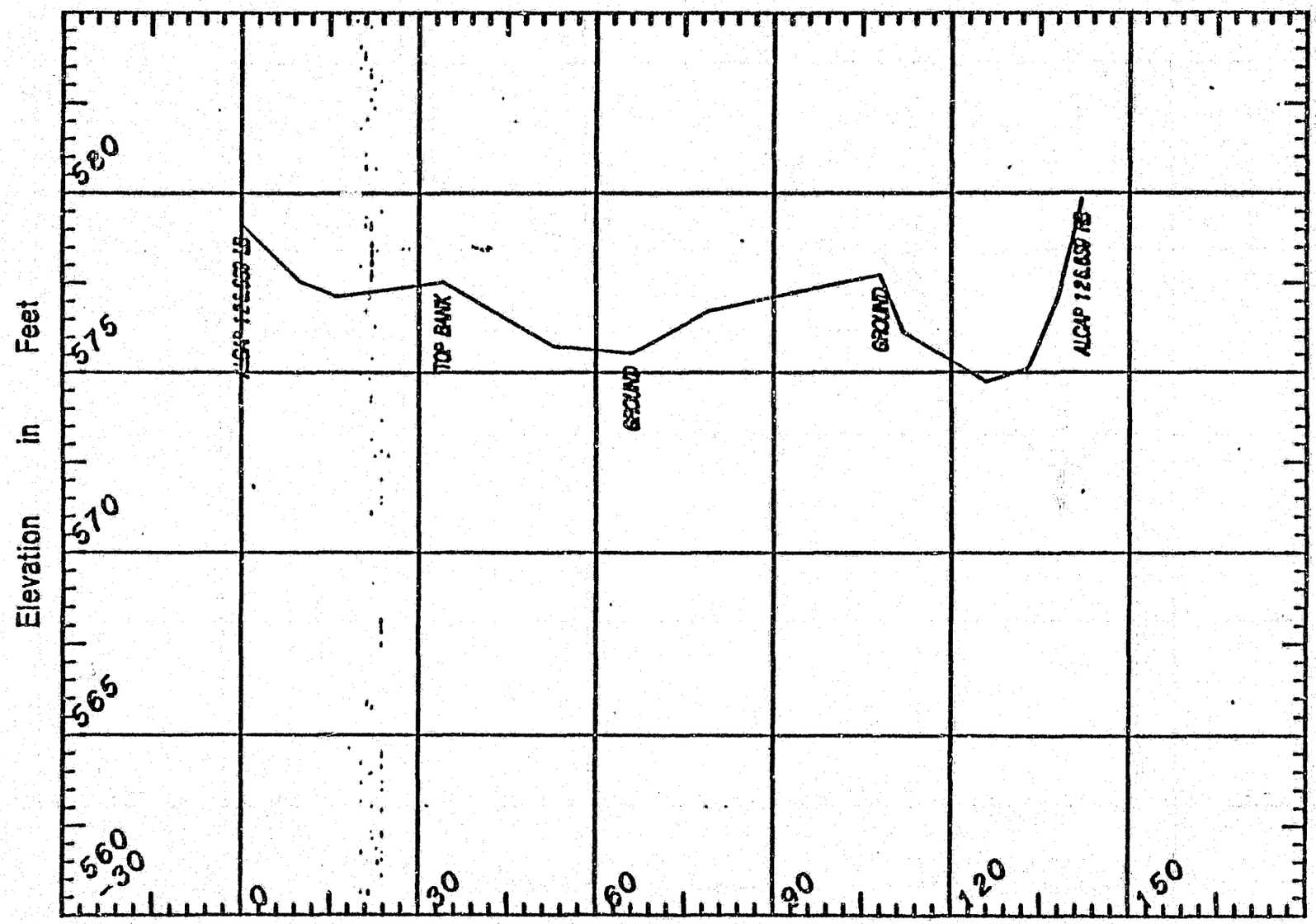
R&M CONSULTANTS, INC.

cross section SLOUGH 9 128.4W1
Date of Survey: AUGUST 2, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



B-80

2-2-70

PREPARED BY:

R&M CONSULTANTS, INC.

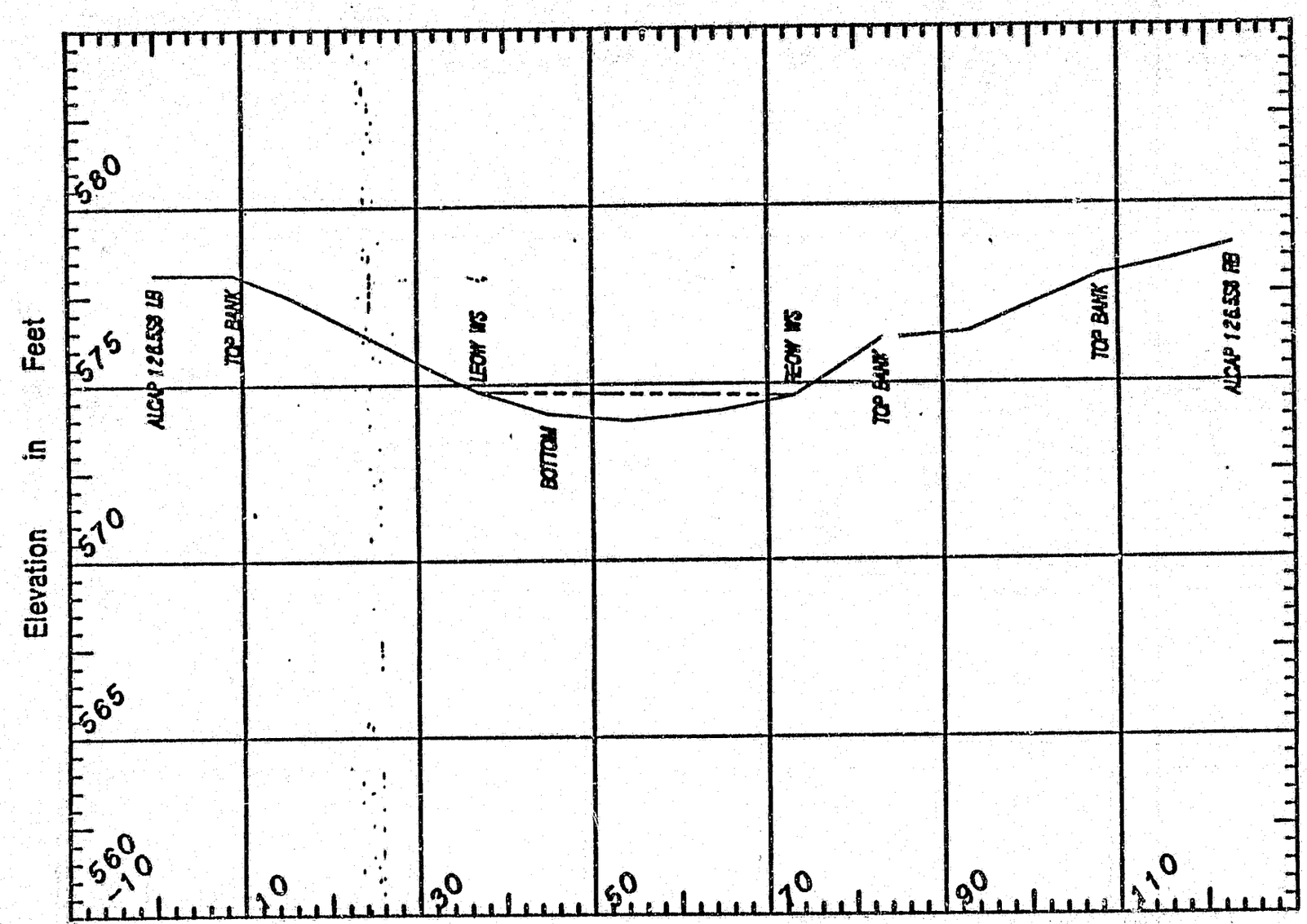
cross section SLOUGH 8 126.6S9

Date of Survey AUGUST 4, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



B-82

2-22-71

PREPARED BY:

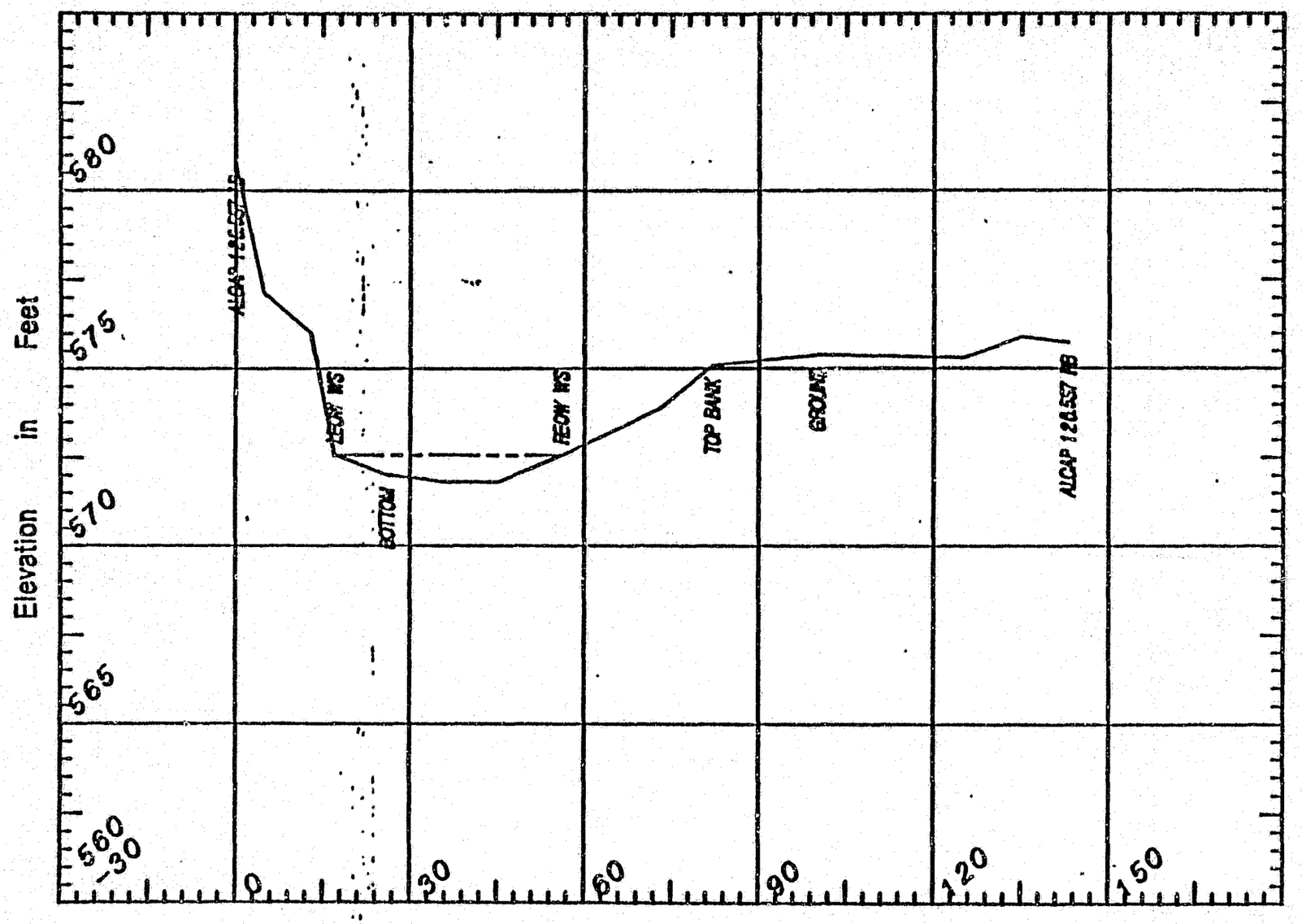
R&M CONSULTANTS, INC.

cross section SLOUGH 8 126.5S8
Date of Survey: AUGUST 4, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



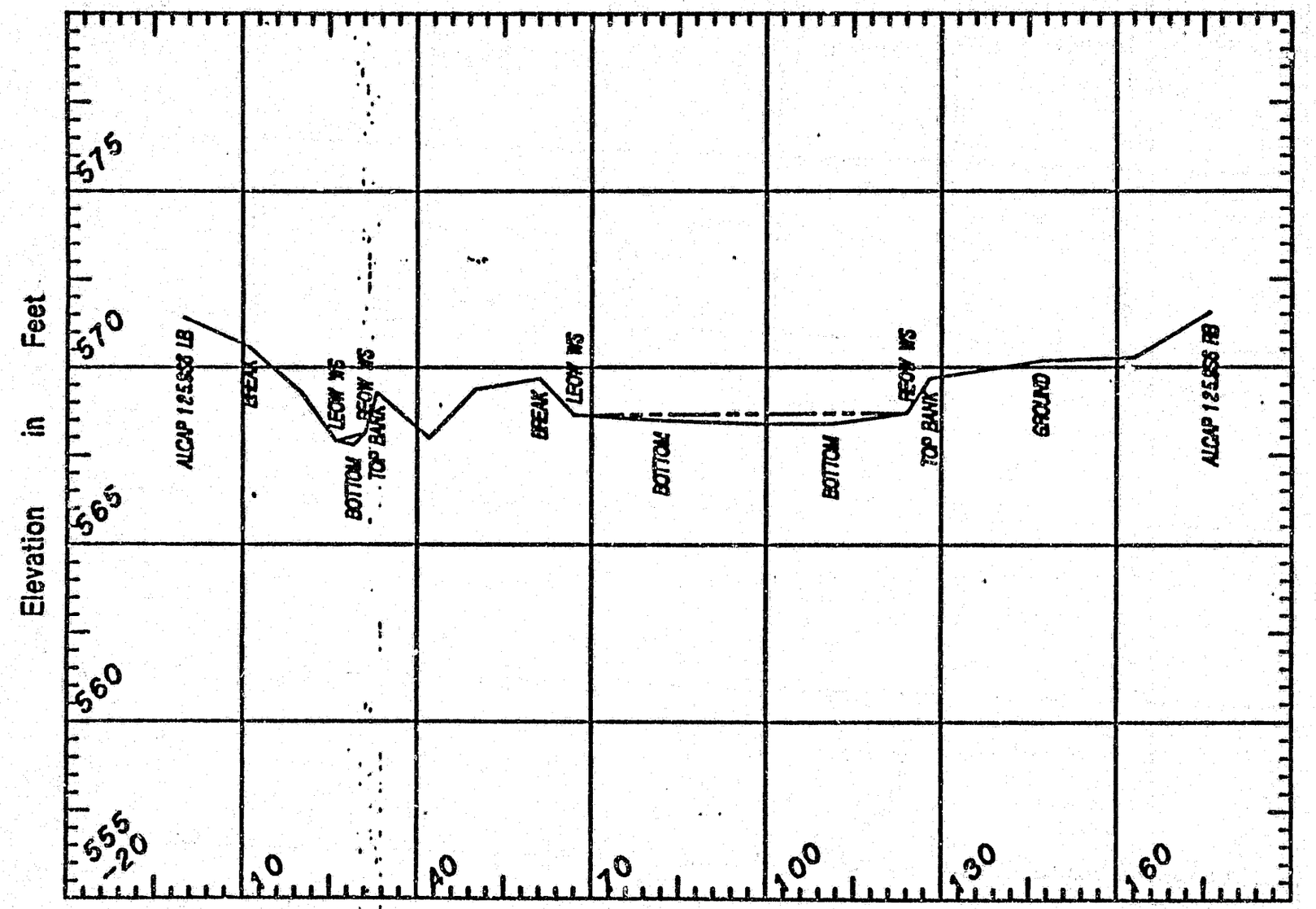
cross section SLOUGH 8 126.5S7
Date of Survey: AUGUST 4, 1982

PREPARED BY: R&M CONSULTANTS, INC.

PREPARED FOR: ACRES

2-2-72

SUSITNA HYDROGRAPHIC SURVEYS



B-86

2-2-73

PREPARED BY:

R&M CONSULTANTS, INC.

cross section SLOUGH 8 125.9S6

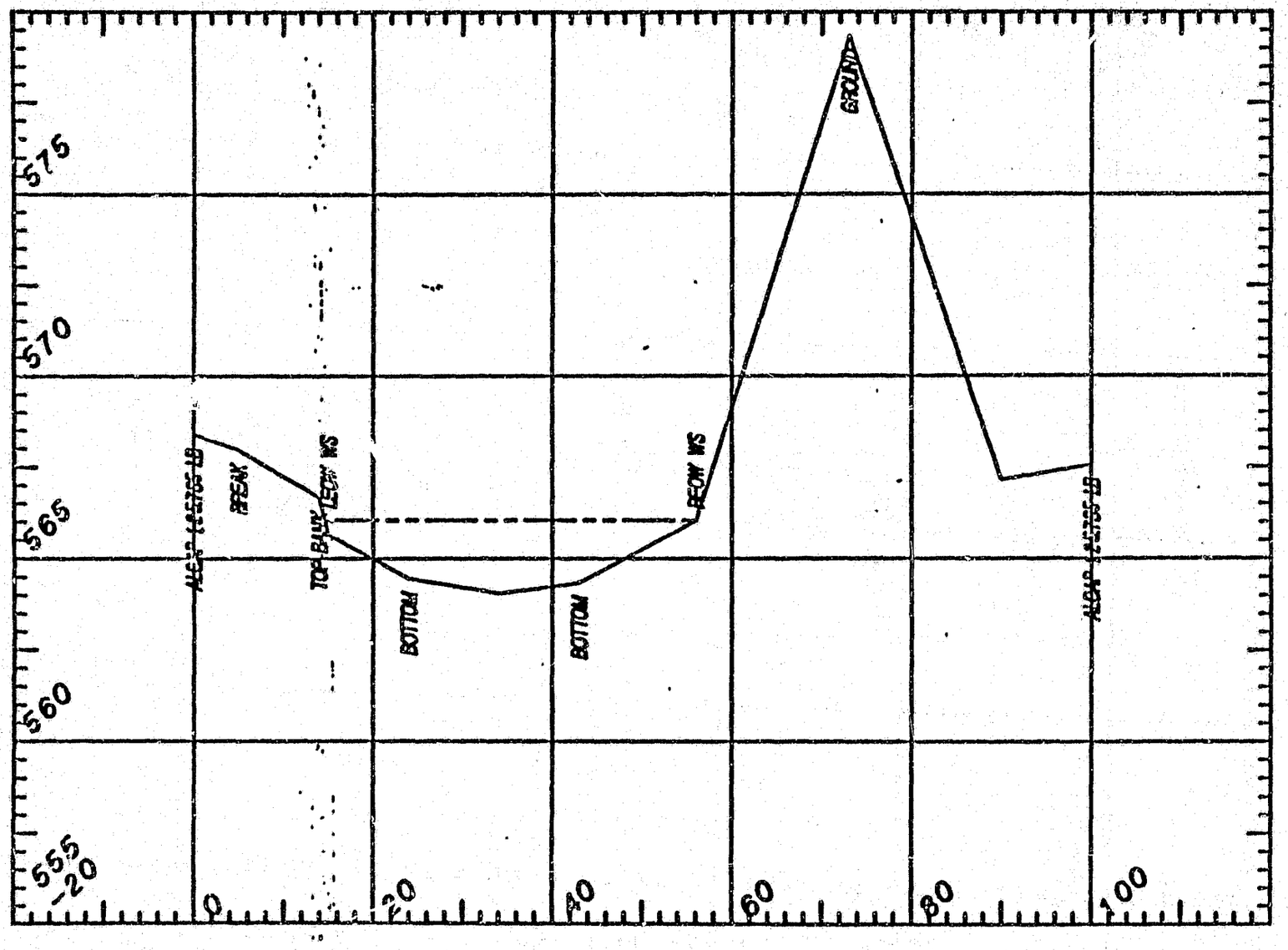
Date of Survey: AUGUST 4, 1982

PREPARED FOR:

ACRES

B-88

SUSITNA HYDROGRAPHIC SURVEYS



2-22-74

PREPARED BY:

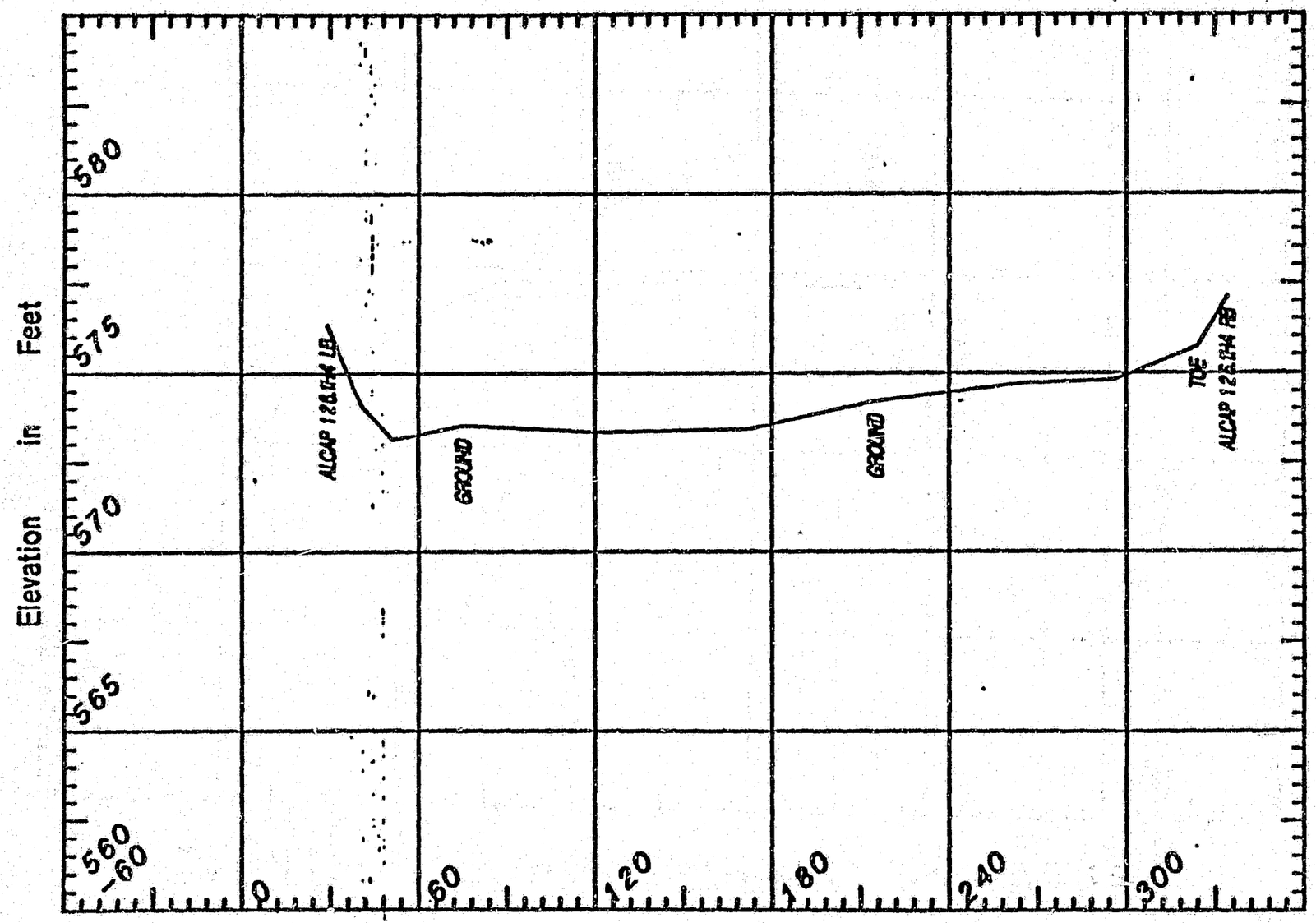
R&M CONSULTANTS, INC.

cross section SLOUGH 8 125.7S5
Date of Survey: AUGUST 4, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



B-90

2-2-75

PREPARED BY:

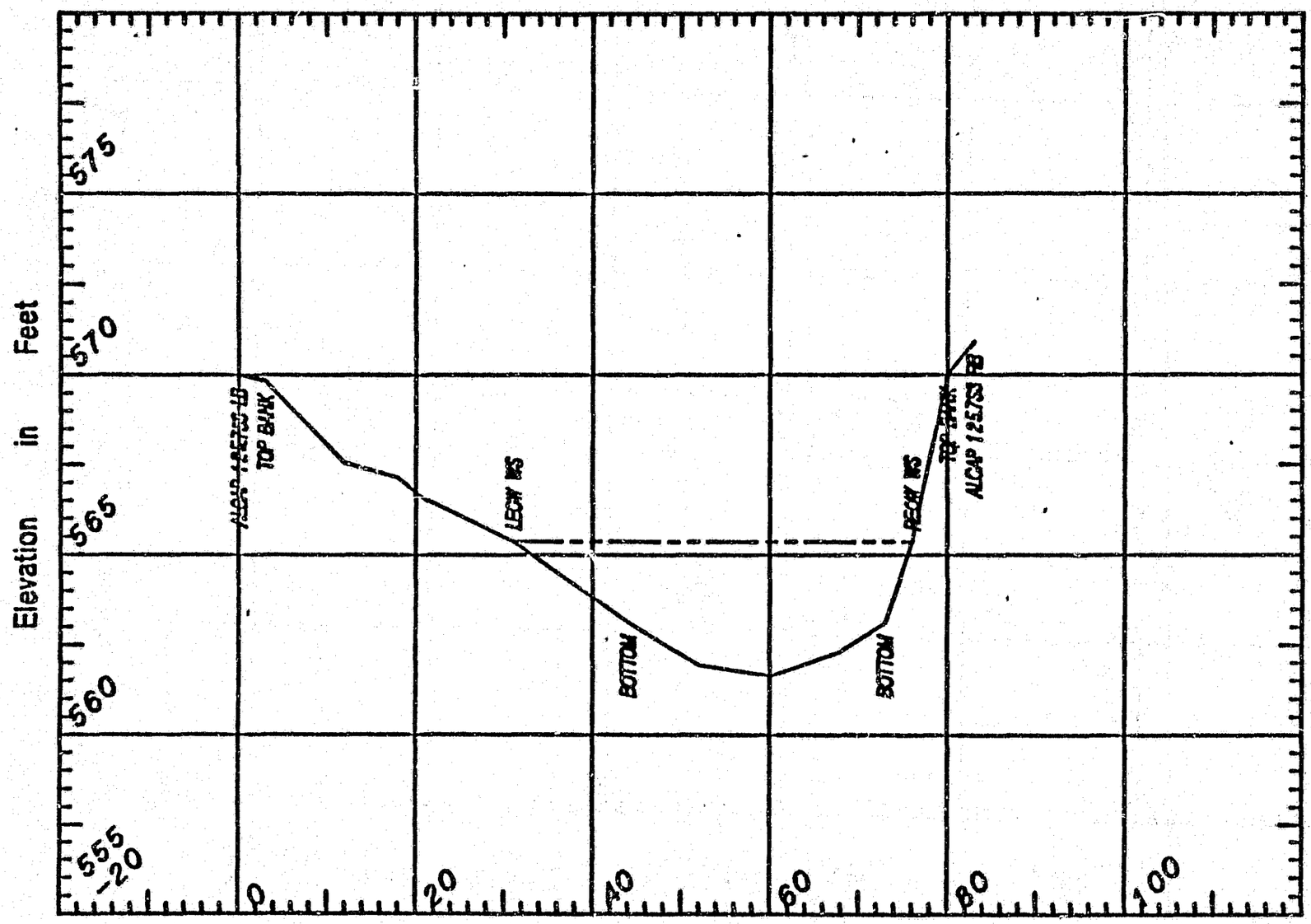
R&M CONSULTANTS, INC.

cross section SLOUGH 8 126.1H4
Date of Survey: AUGUST 4, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



2-2-76

PREPARED BY:

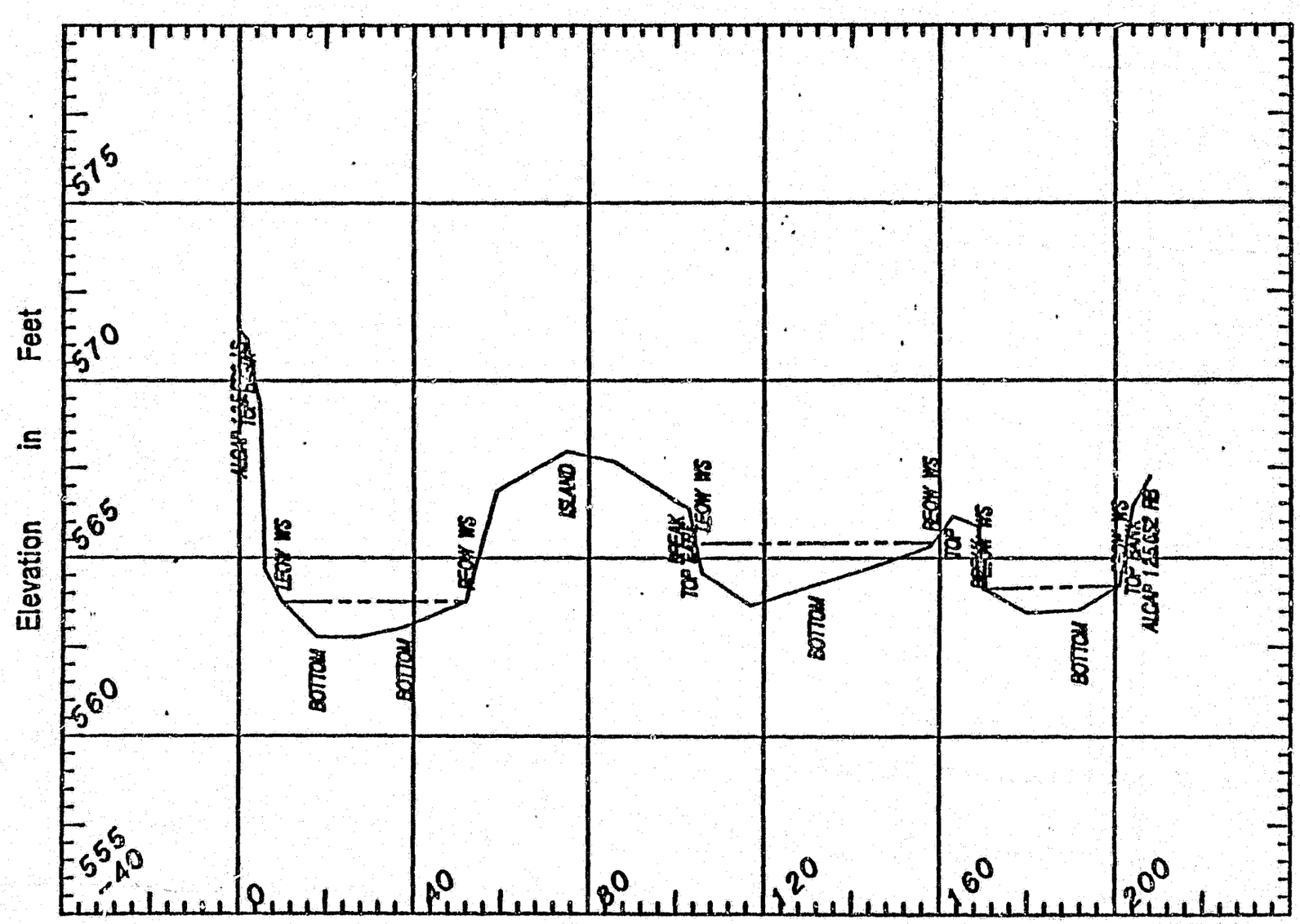
R&M CONSULTANTS, INC.

cross section SLOUGH 8 125.7S3
Date of Survey: AUGUST 4, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



B-94

2-2-17

PREPARED BY:

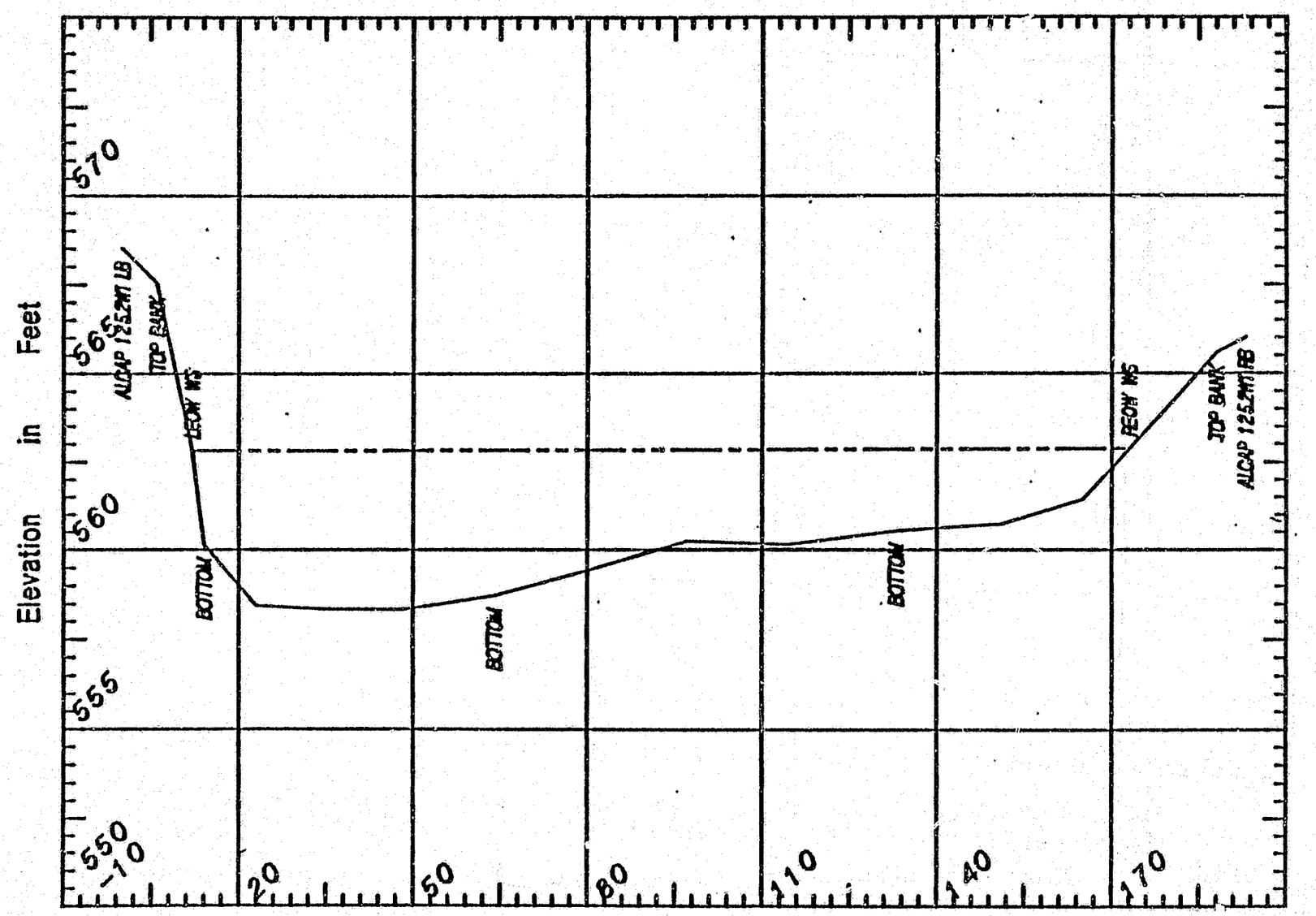
R&M CONSULTANTS, INC.

cross section SLOUGH 8 125.6S2
Date of Survey: AUGUST 4, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



B-96

2-2-78

PREPARED BY:

R&M CONSULTANTS, INC.

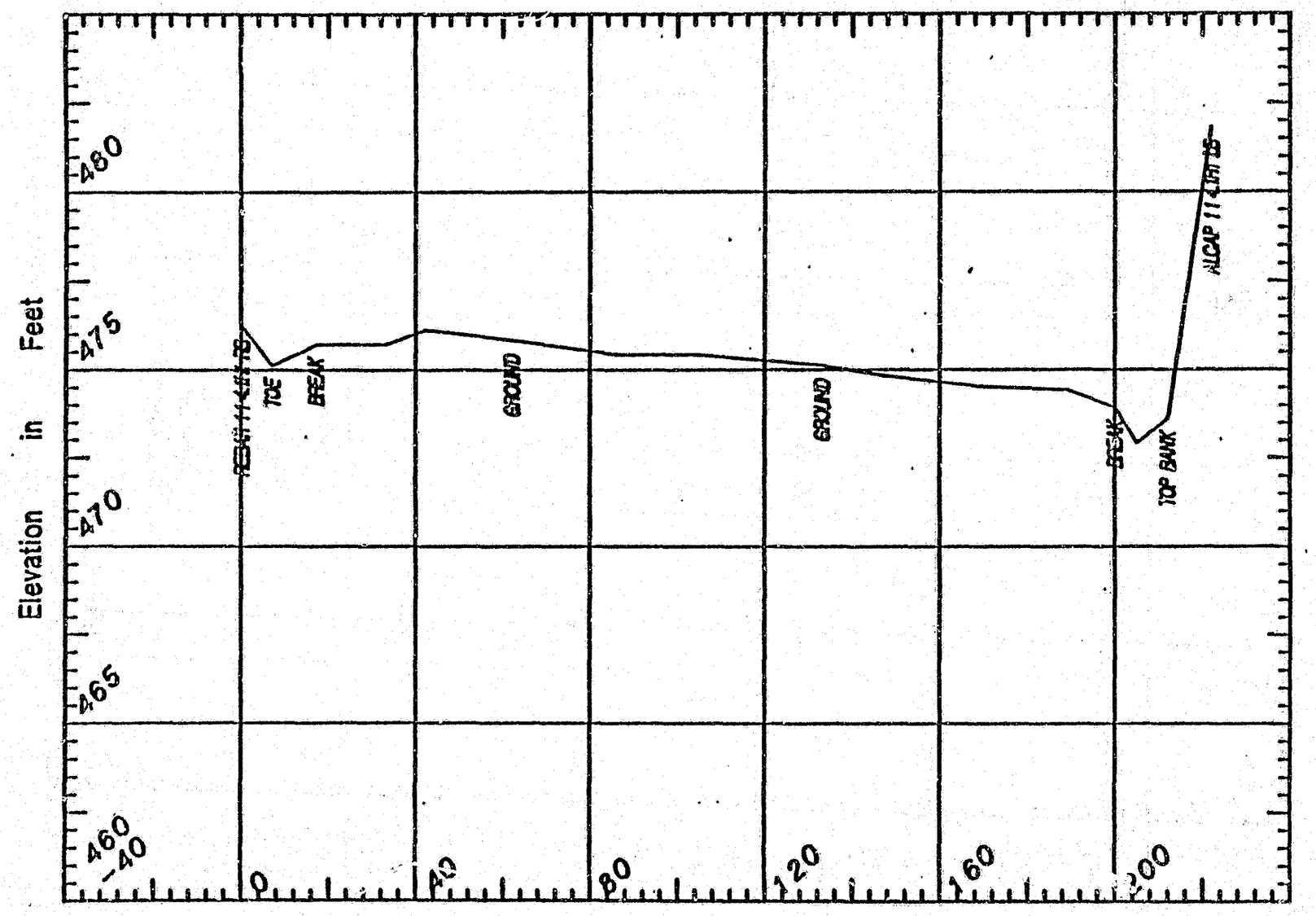
cross section SLOUGH 8 125.2W1

Date of Survey: AUGUST 4, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



B-98

2-2-79

PREPARED BY:

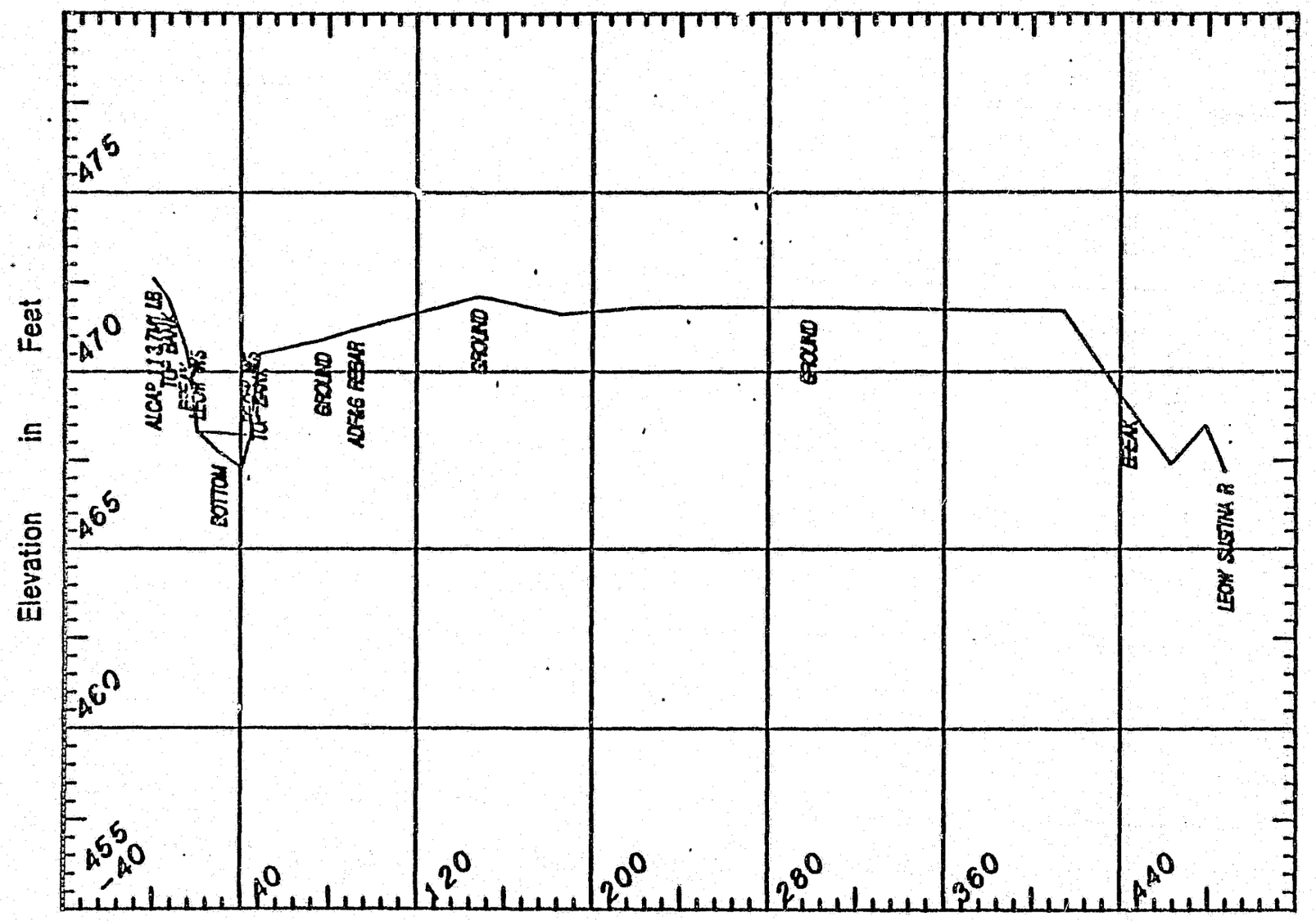
R&M CONSULTANTS, INC.

cross section LANE CR SLOUGH 1 1 4.1H1
Date of Survey: AUGUST 16, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



B-100

2-22-80

PREPARED BY:

R&M CONSULTANTS, INC.

cross section LANE CR SLOUGH 113.7M1
Date of Survey: AUGUST 24, 1982

PREPARED FOR:

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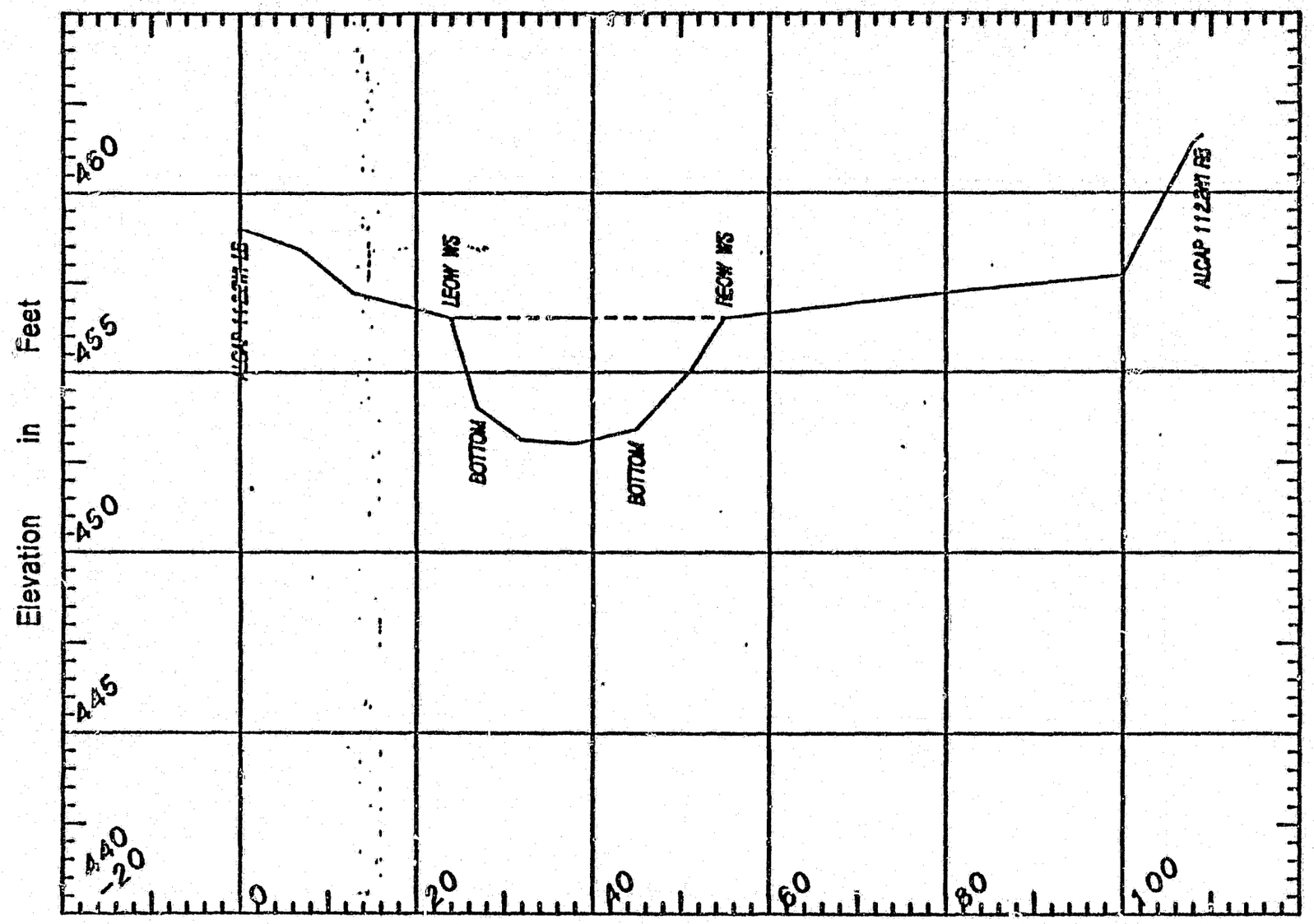
SUSITNA HYDROGRAPHIC SURVEYS



B-102

2-2-82

PREPARED BY:

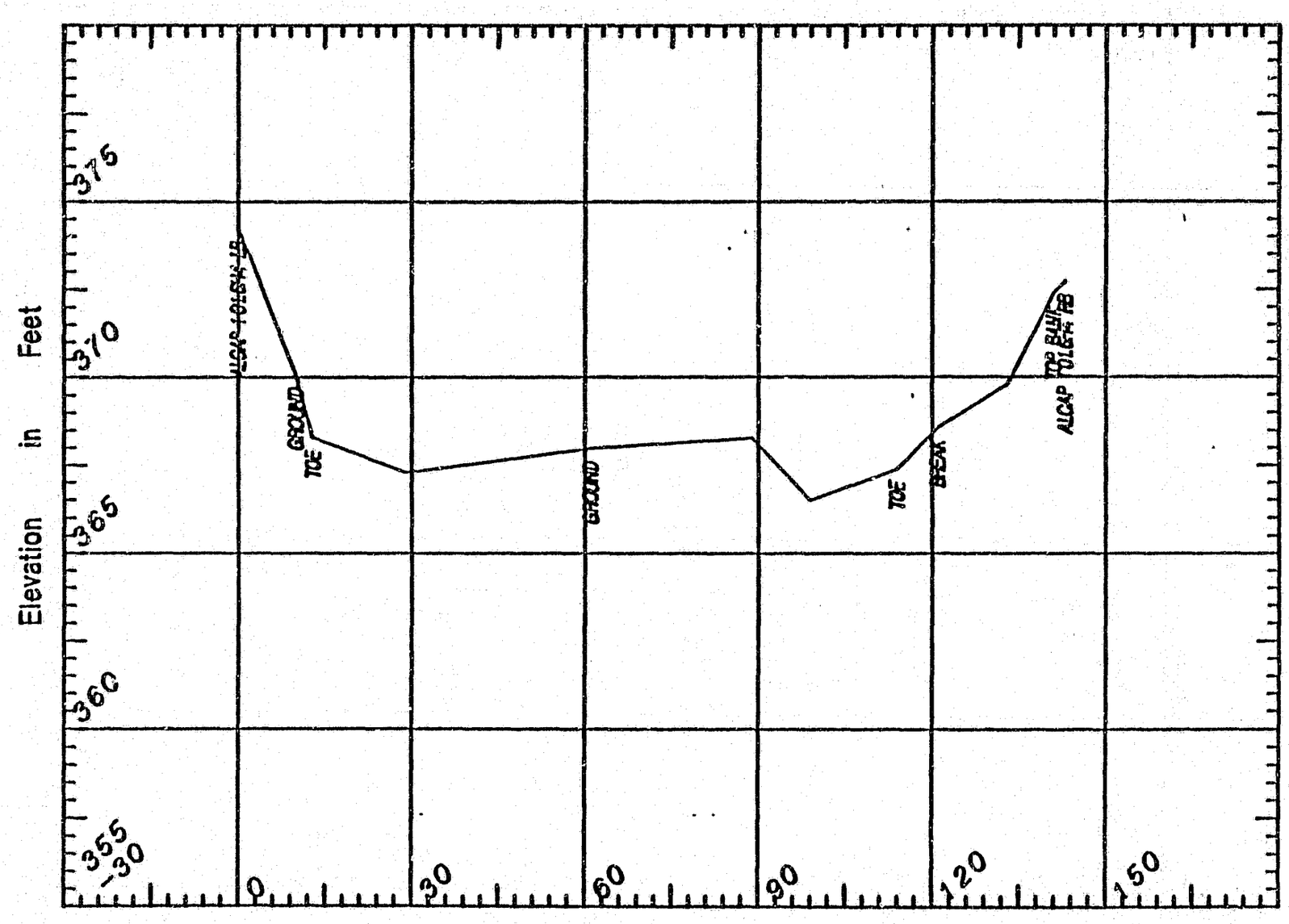
R&M CONSULTANTS, INC.

cross section SLOUGH 6A 1122W1
Date of Survey: SEPTEMBER 2, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



B-104

2-22-82

PREPARED BY:

R&M CONSULTANTS, INC.

cross section WHISKERS 101.6H4
Date of Survey: AUGUST 11, 1982

PREPARED FOR:

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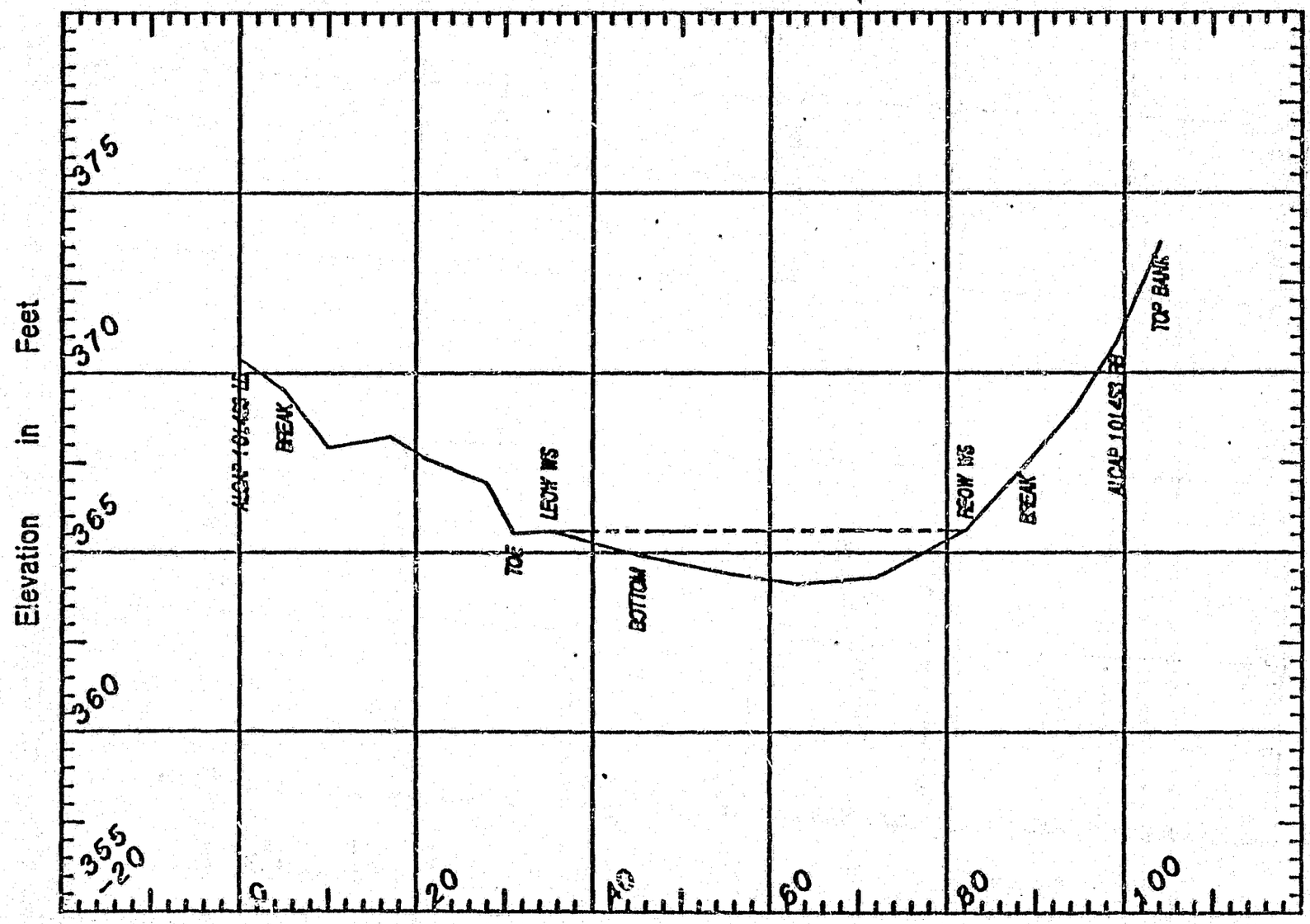
SUSITNA HYDROGRAPHIC SURVEYS



B-106

2-2-83

PREPARED BY:

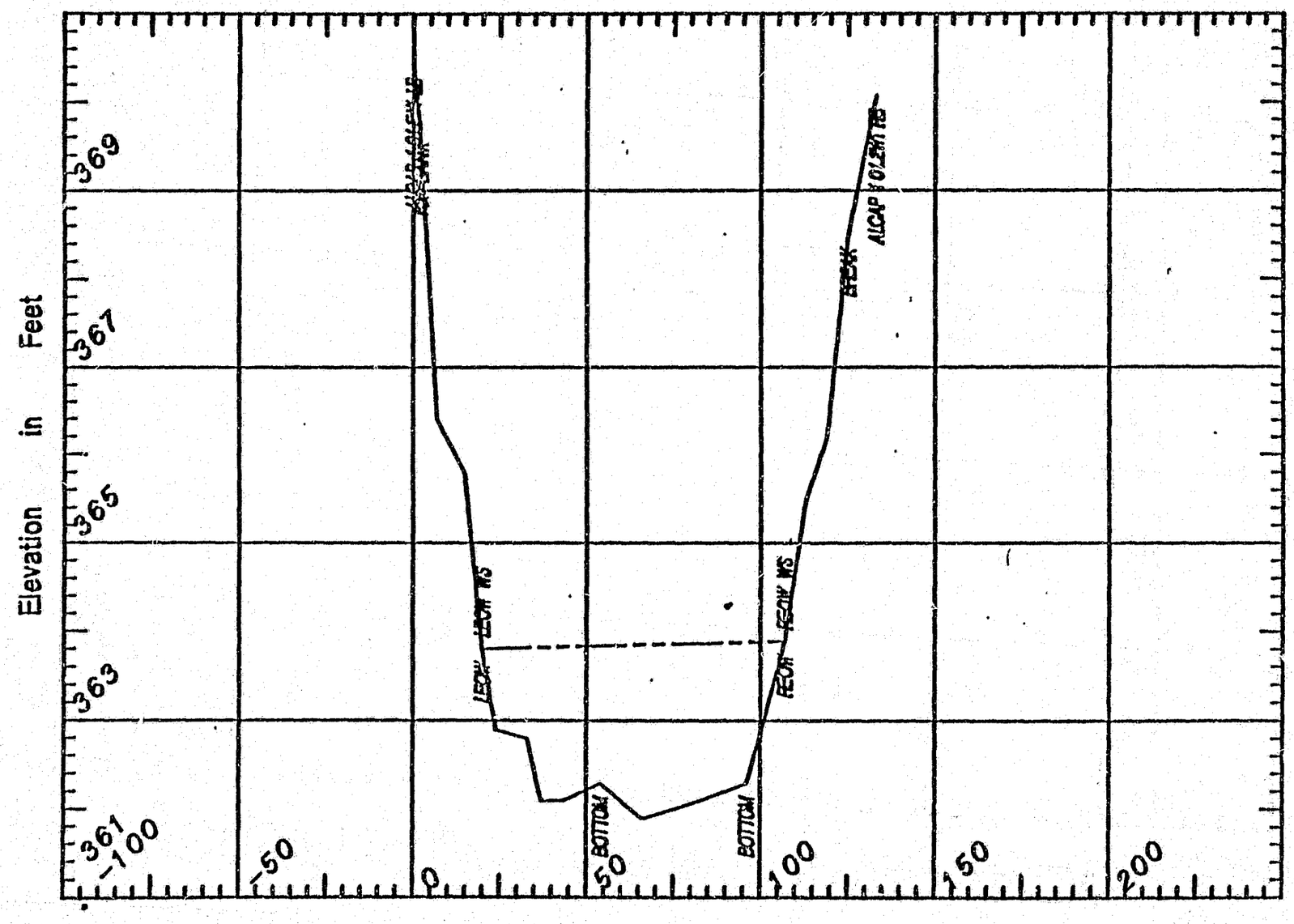
R&M CONSULTANTS, INC.

cross section WHISKERS 101,453
Date of Survey: AUGUST 11, 1982

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



B-108

78-2-7

PREPARED BY:

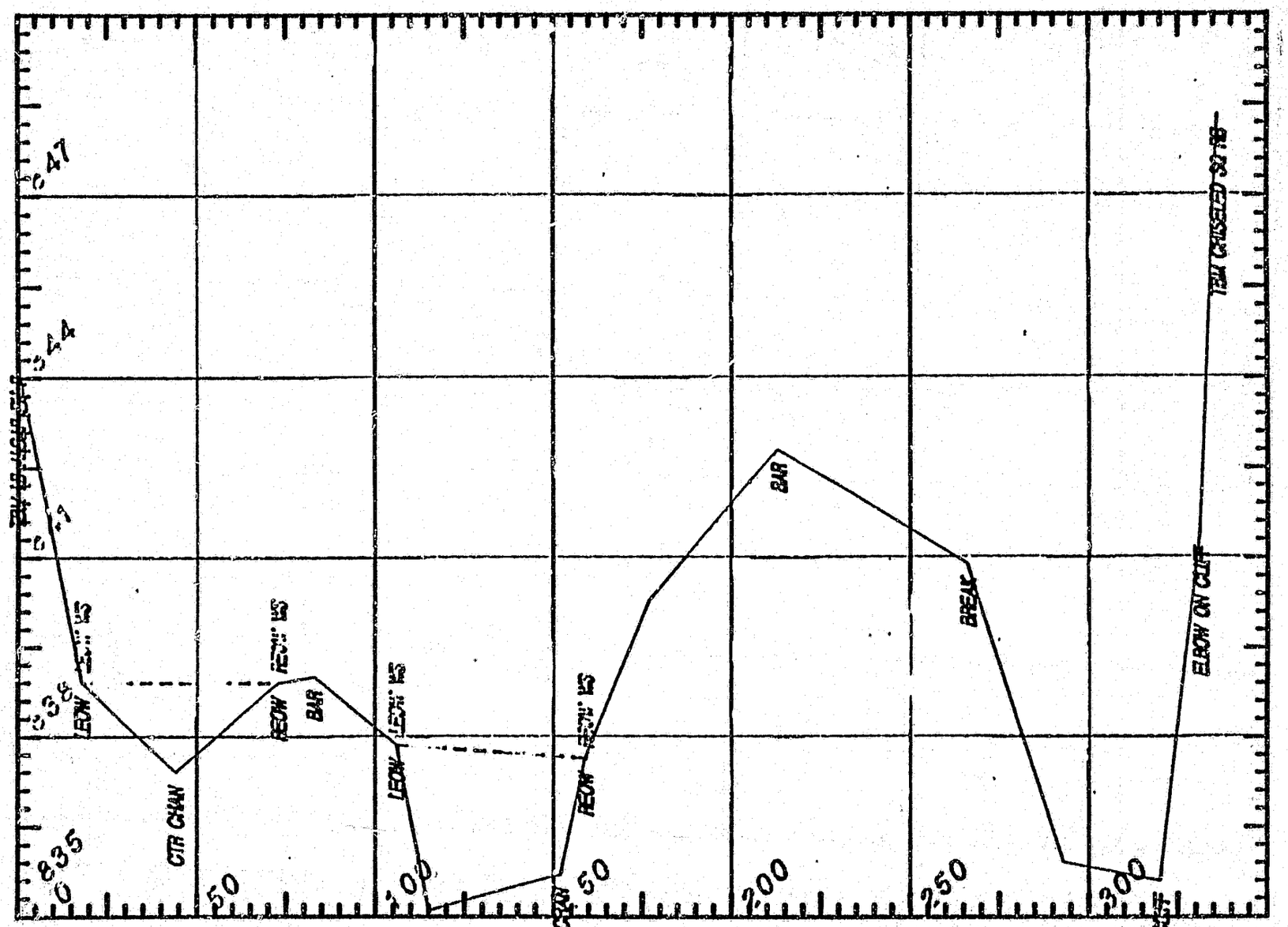
R&M CONSULTANTS, INC.

cross section WHISKERS 101.2W1

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



A-4

2-2-85

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MOUTH OF PORTAGE CREEK X-SEC

PREPARED FOR:

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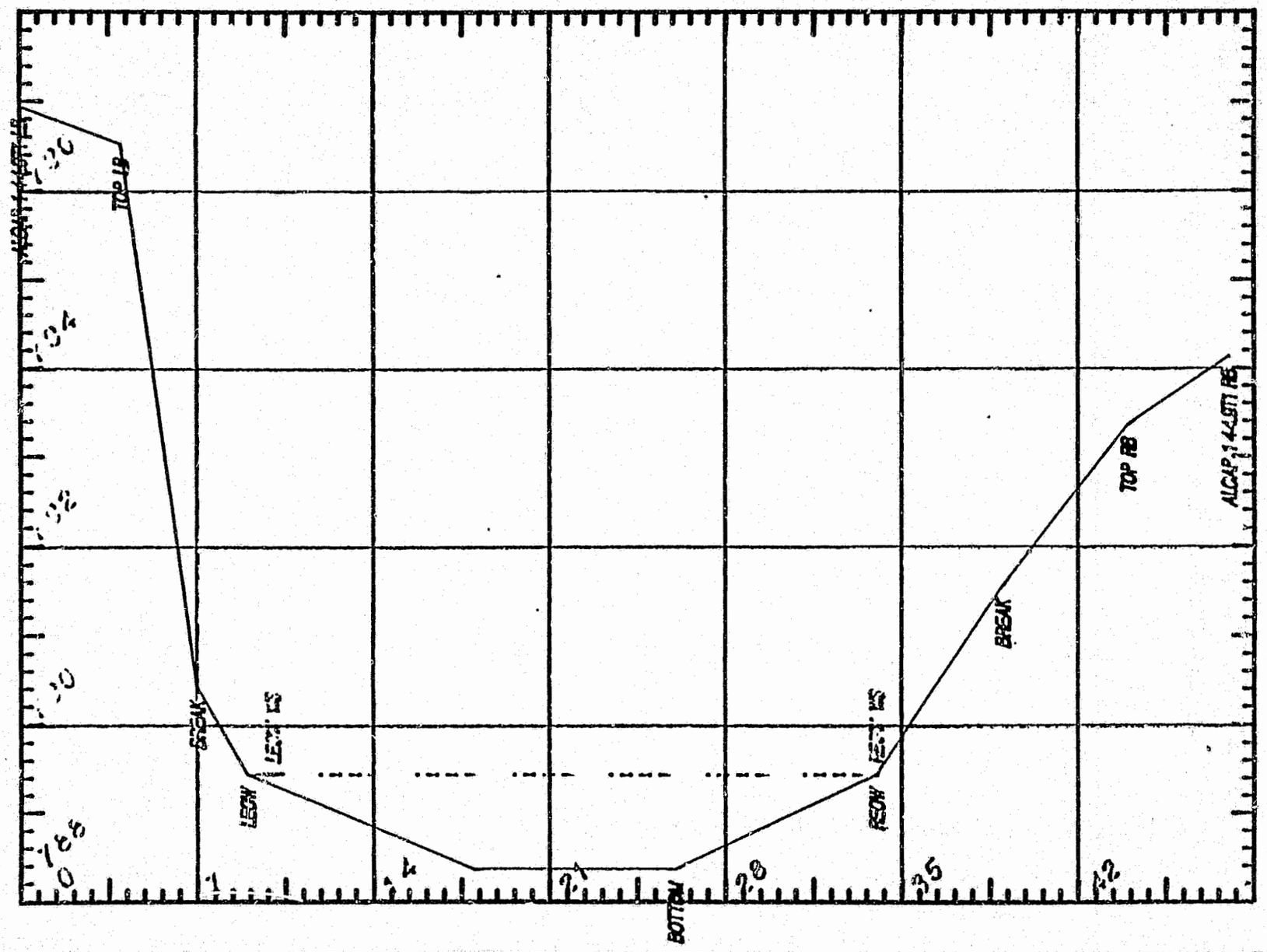
SUSITNA HYDROGRAPHIC SURVEYS



A-7

2-2-84

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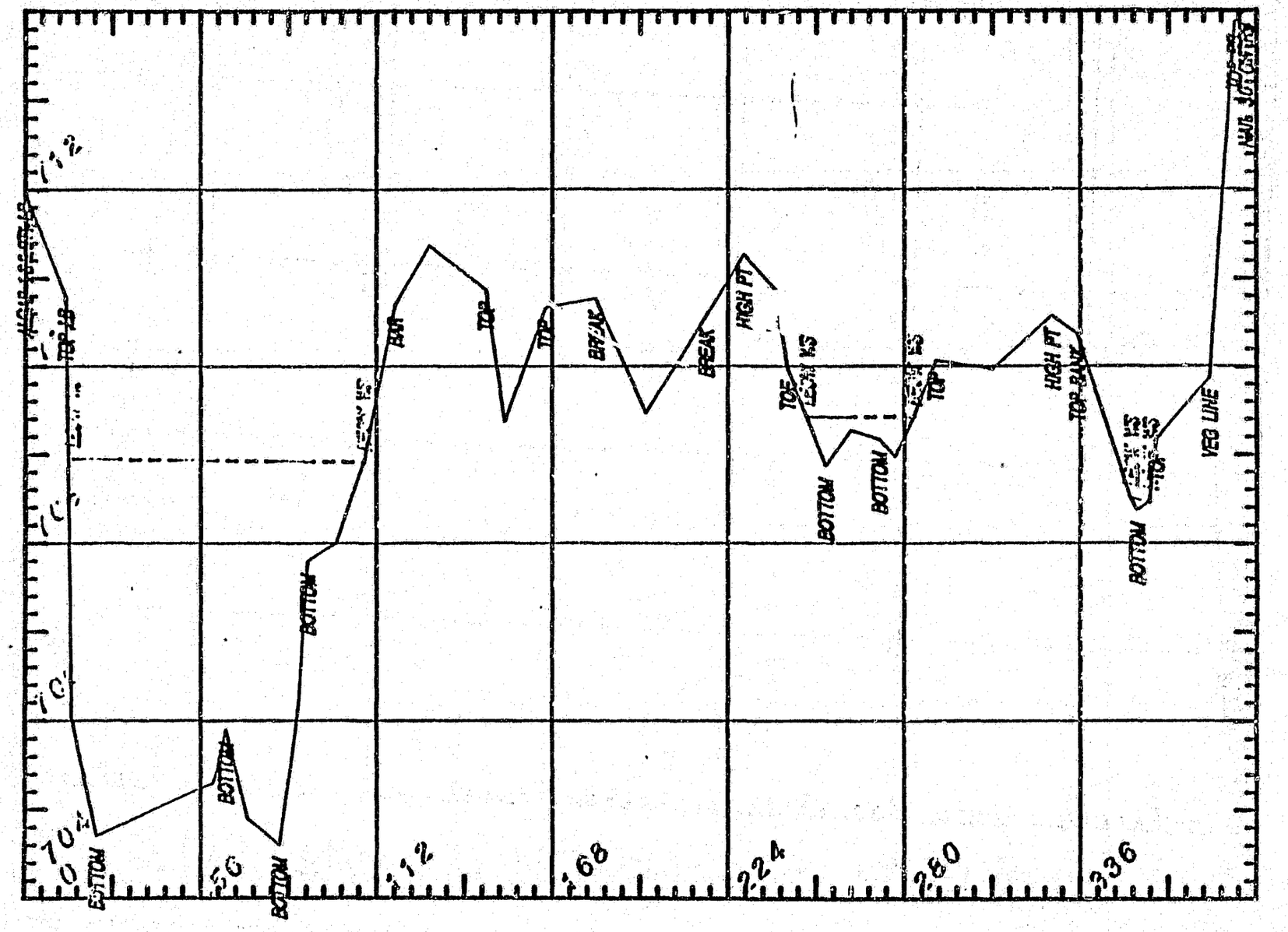
R&M CONSULTANTS, INC.

MOUTH JACKLONG CREEK X-SEC

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS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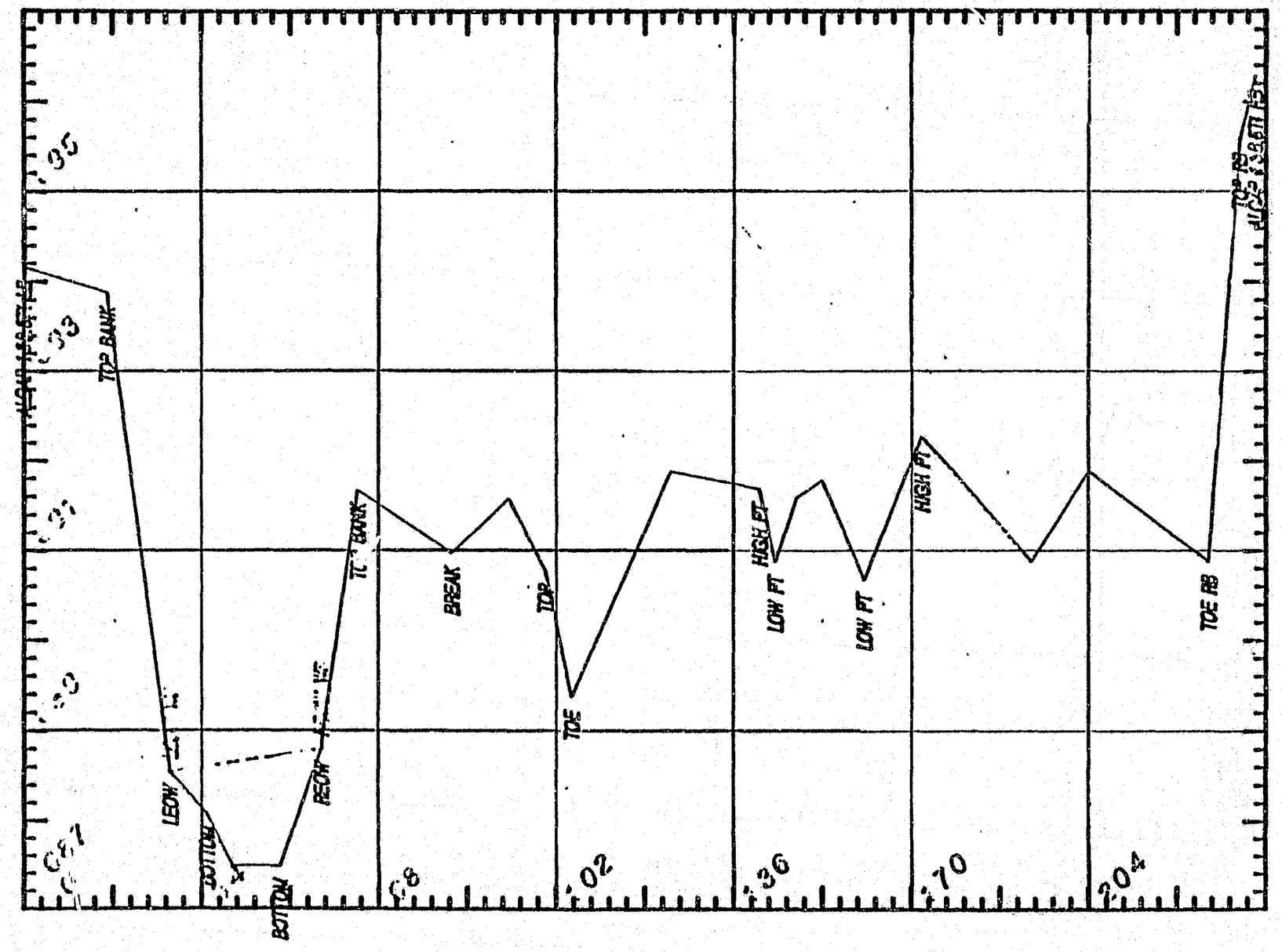
BOTTOM

SUSITNA HYDROGRAPHIC SURVEYS



A-13

2-22-88

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R&M CONSULTANTS, INC.

MOUTH GOLD CREEK X-SEC

PREPARED FOR:

ACRES

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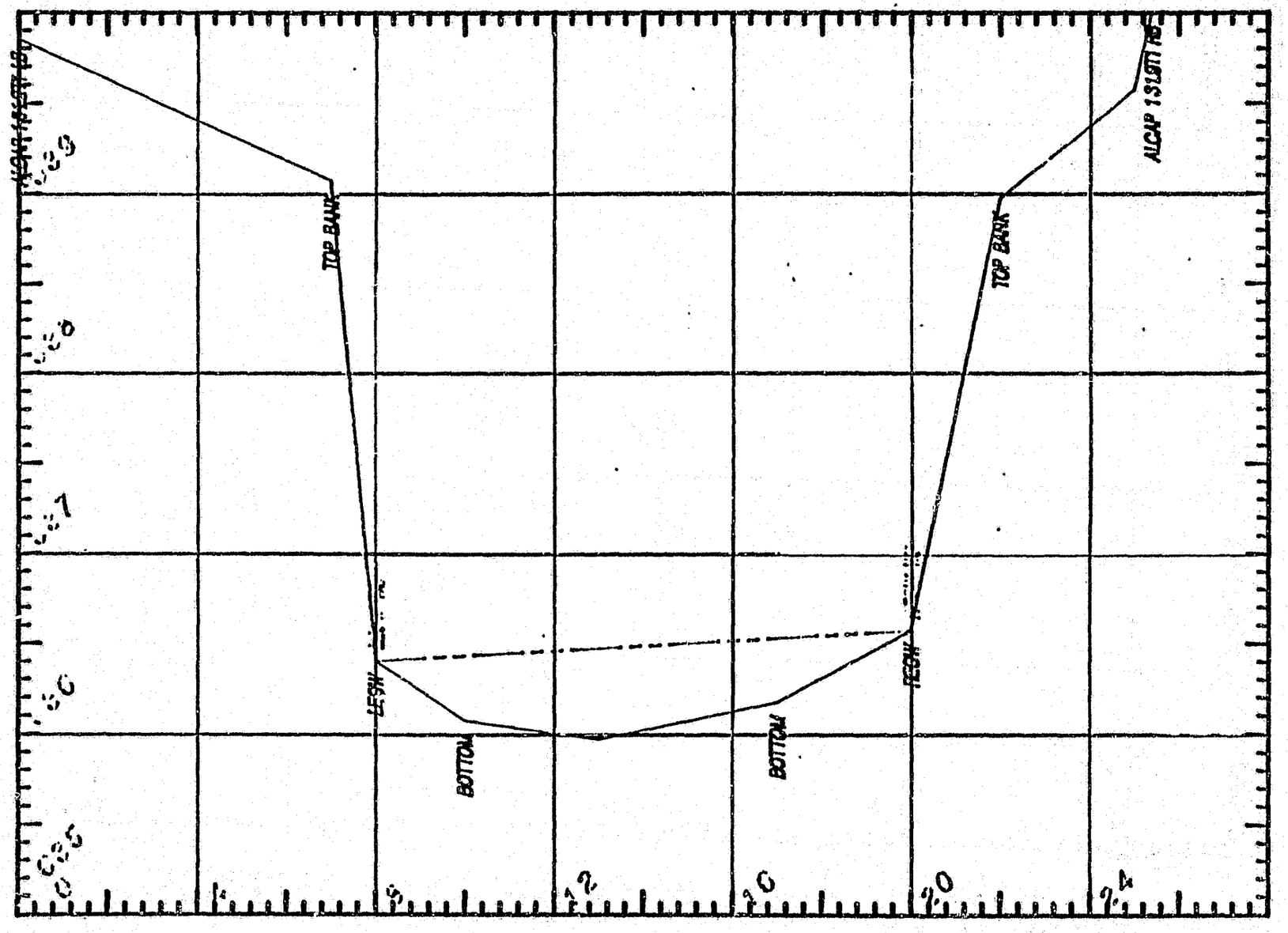

A-16

2-27-89

PREPARED BY:

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TRIBUTARY AT RM 132.0 X-SEC

PREPARED FOR:

ACRES

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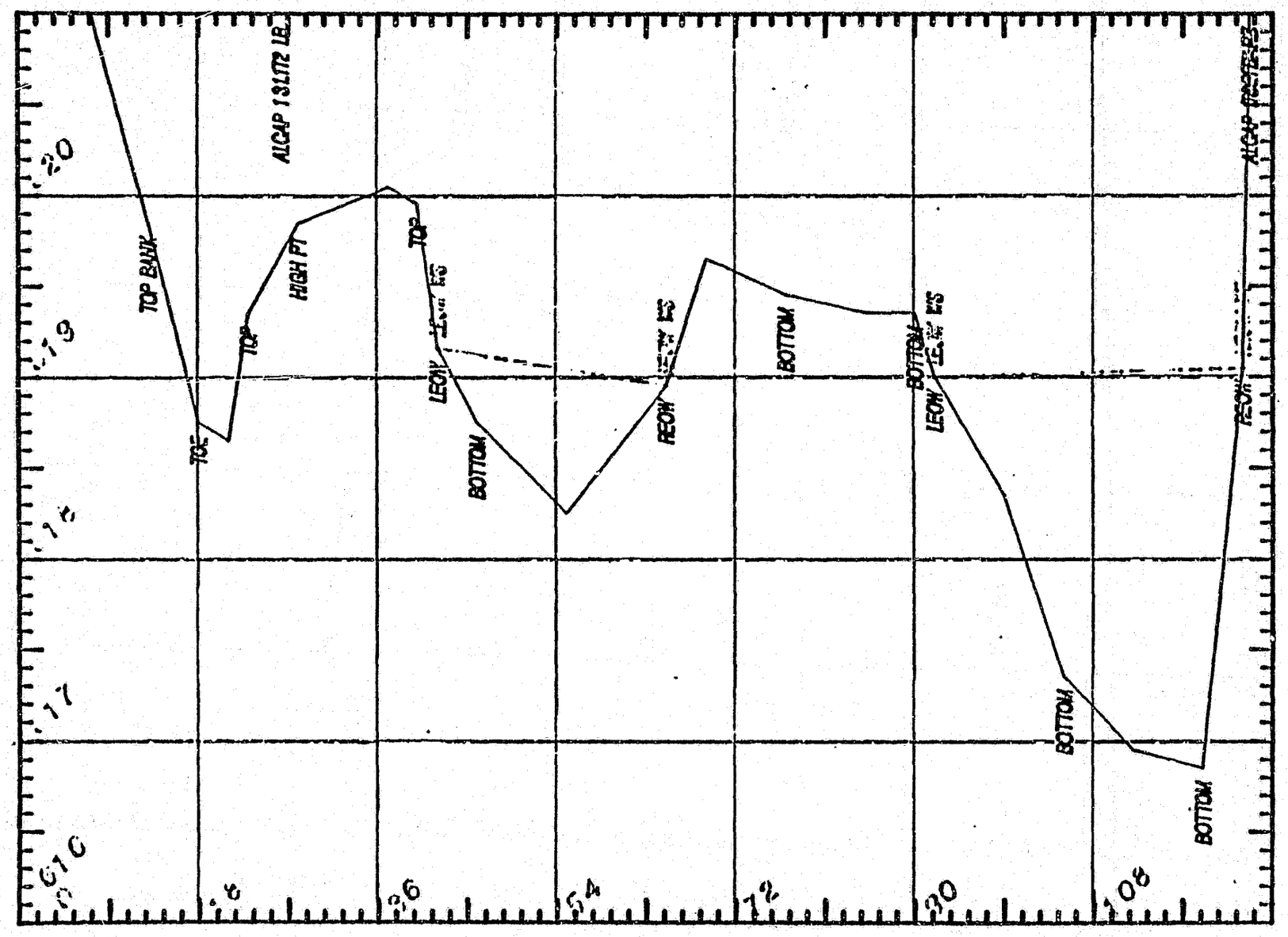


A-19

2-2-90

PREPARED BY:

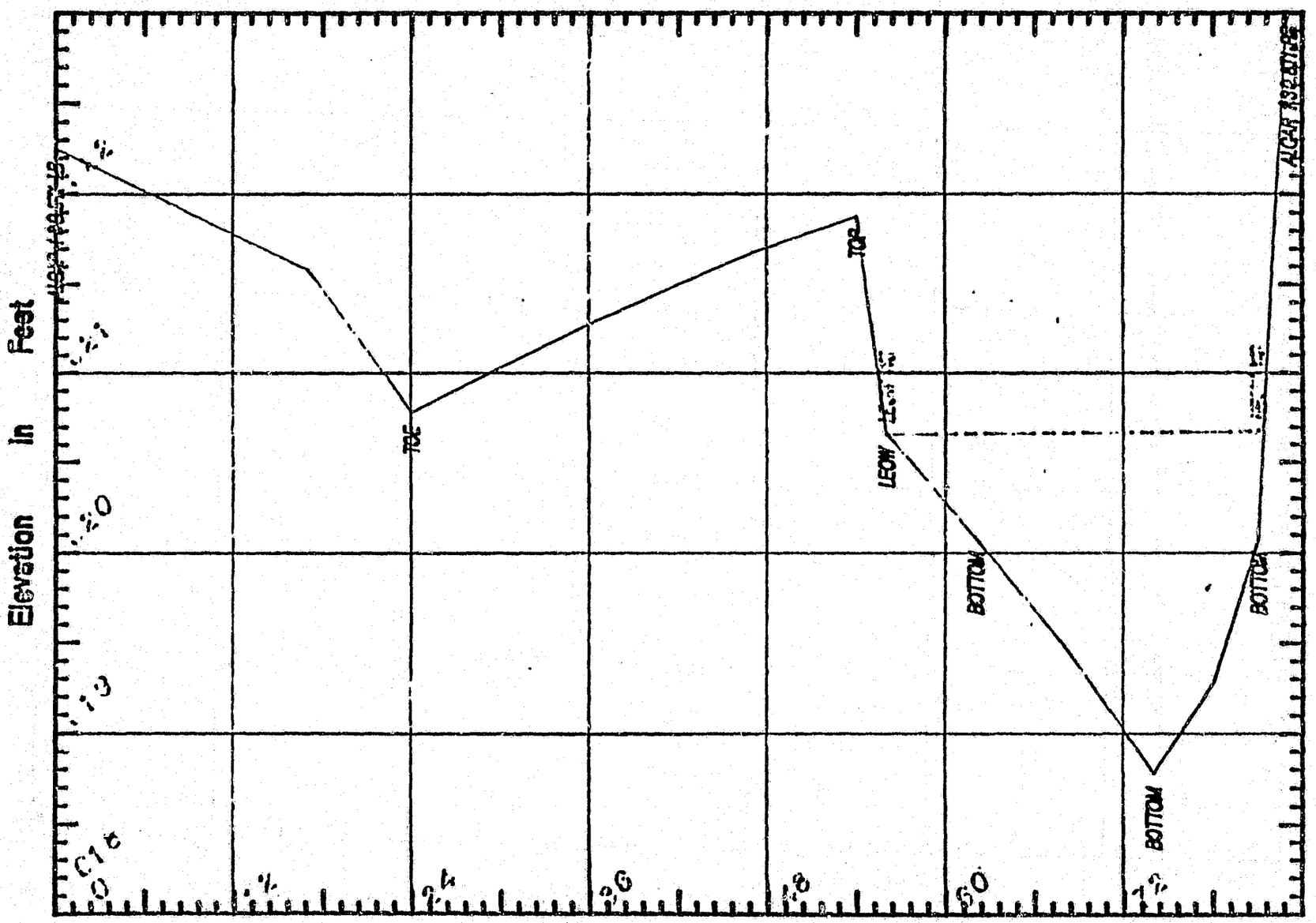
R&M CONSULTANTS, INC.

4TH OF JULY CREEK MOUTH X-SEC

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



A-22

2-2-91

PREPARED BY:

R&M CONSULTANTS, INC.

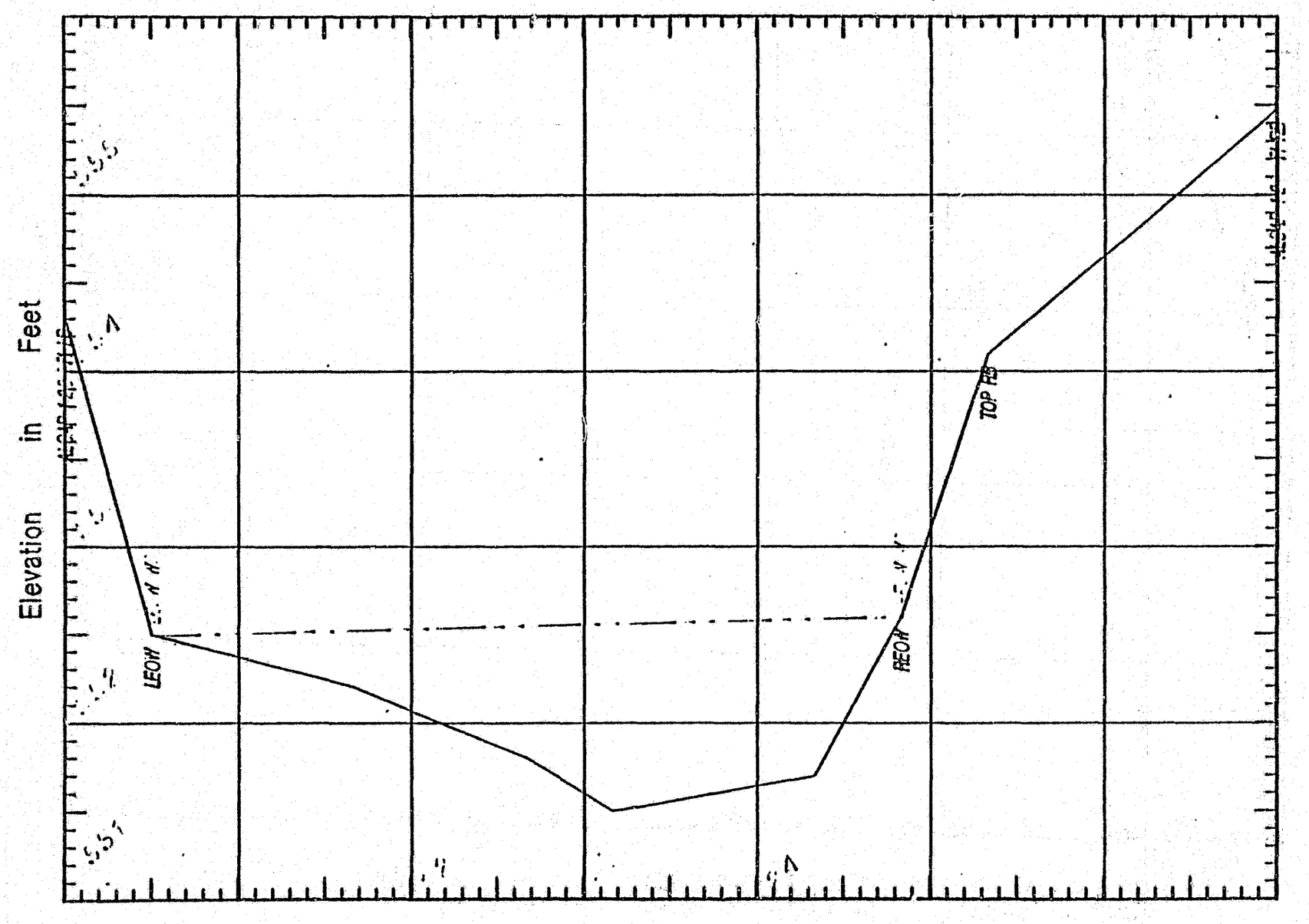
PREPARED FOR:

ACRES

MOUTH SHERMAN CREEK X-SEC

Date of Survey: JULY 30,1982

SUSITNA HYDROGRAPHIC SURVEYS



A-34

2-2-92

PREPARED BY:

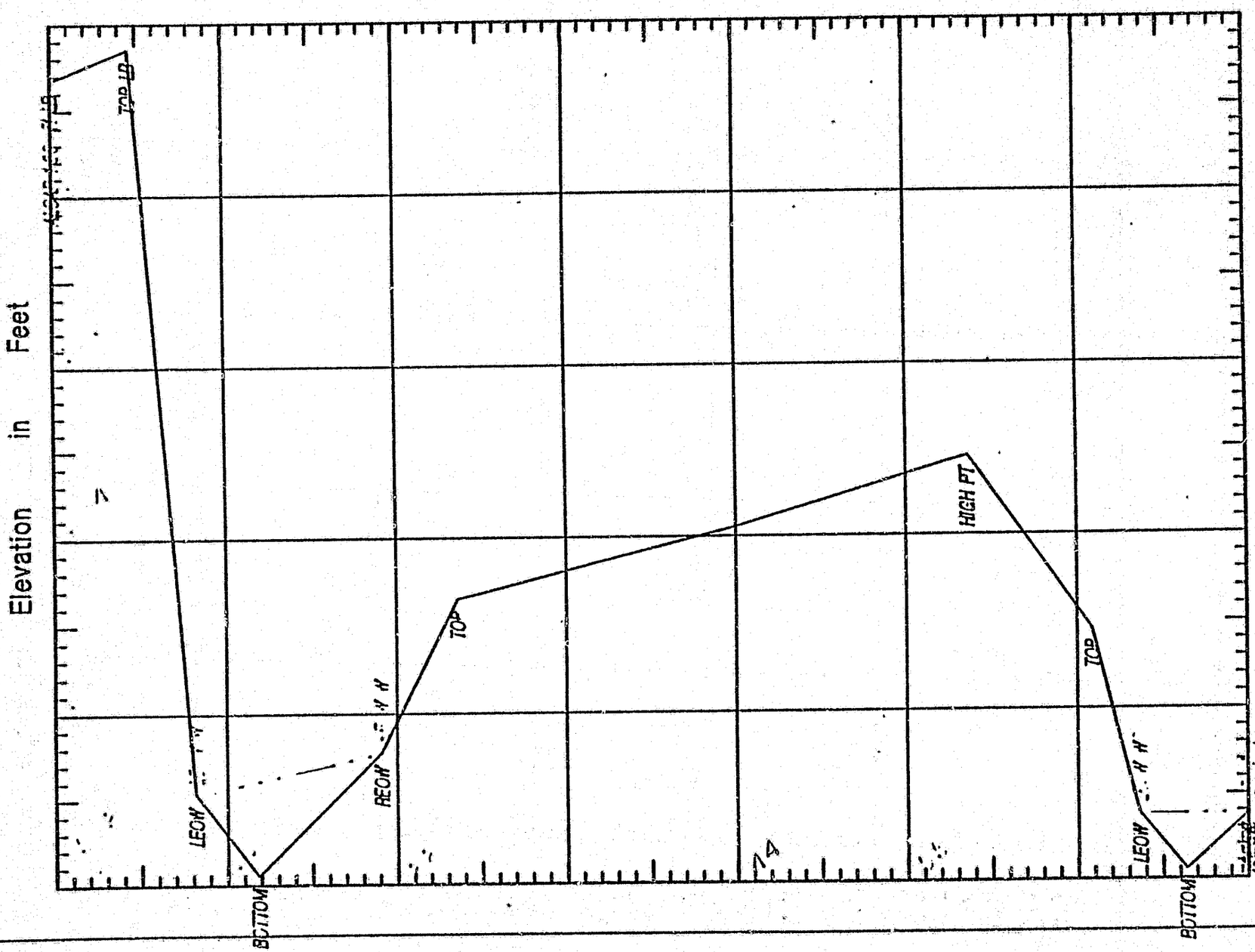
R&M CONSULTANTS, INC.

TRIBUTARY AT RM 123.9 X-SEC

PREPARED FOR.

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



A-37

2-22-93

PREPARED BY:

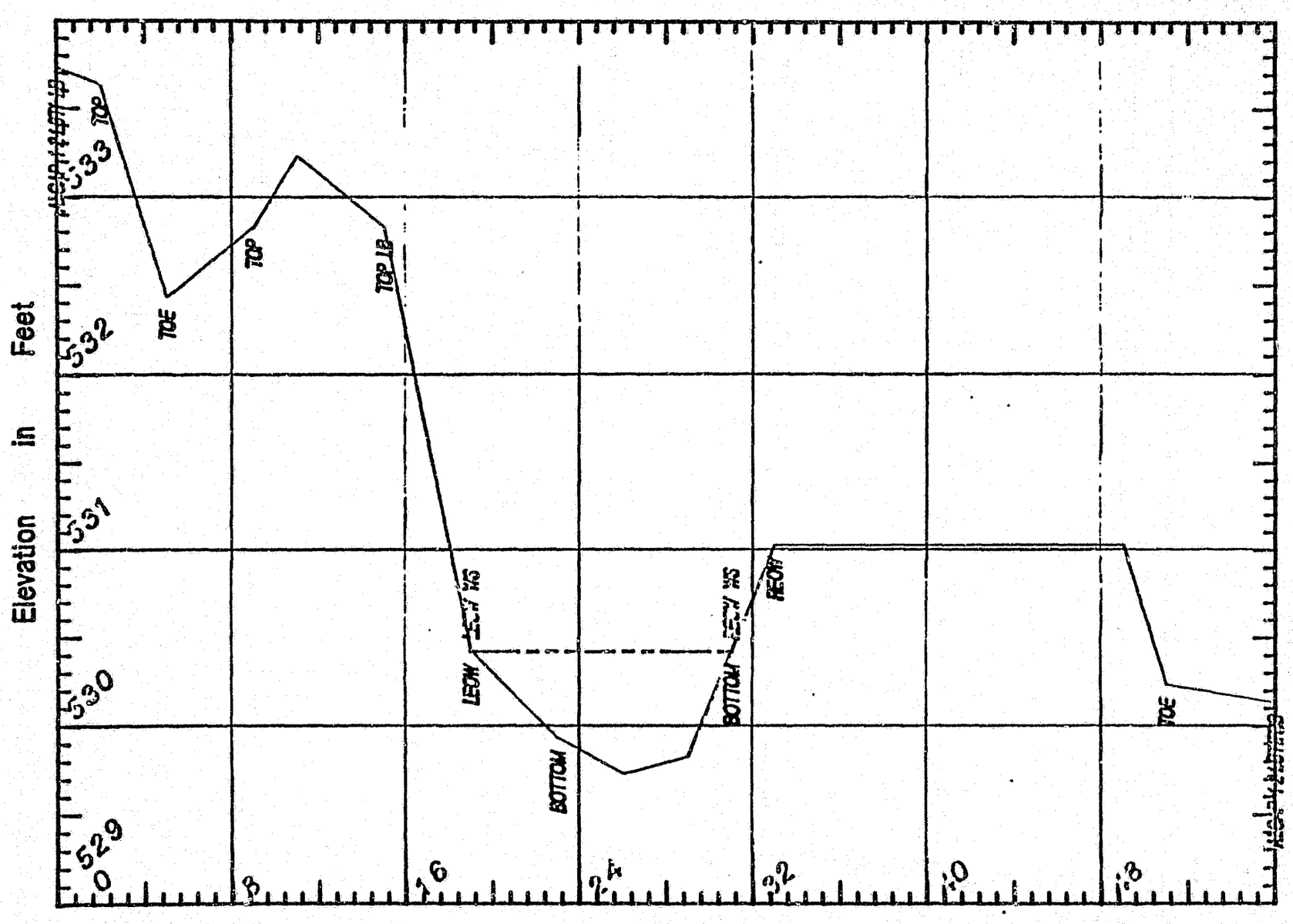
R&M CONSULTANTS, INC.

DEADHORSE CREEK MOUTH X-SEC

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



A-40

4-22-94

PREPARED BY:

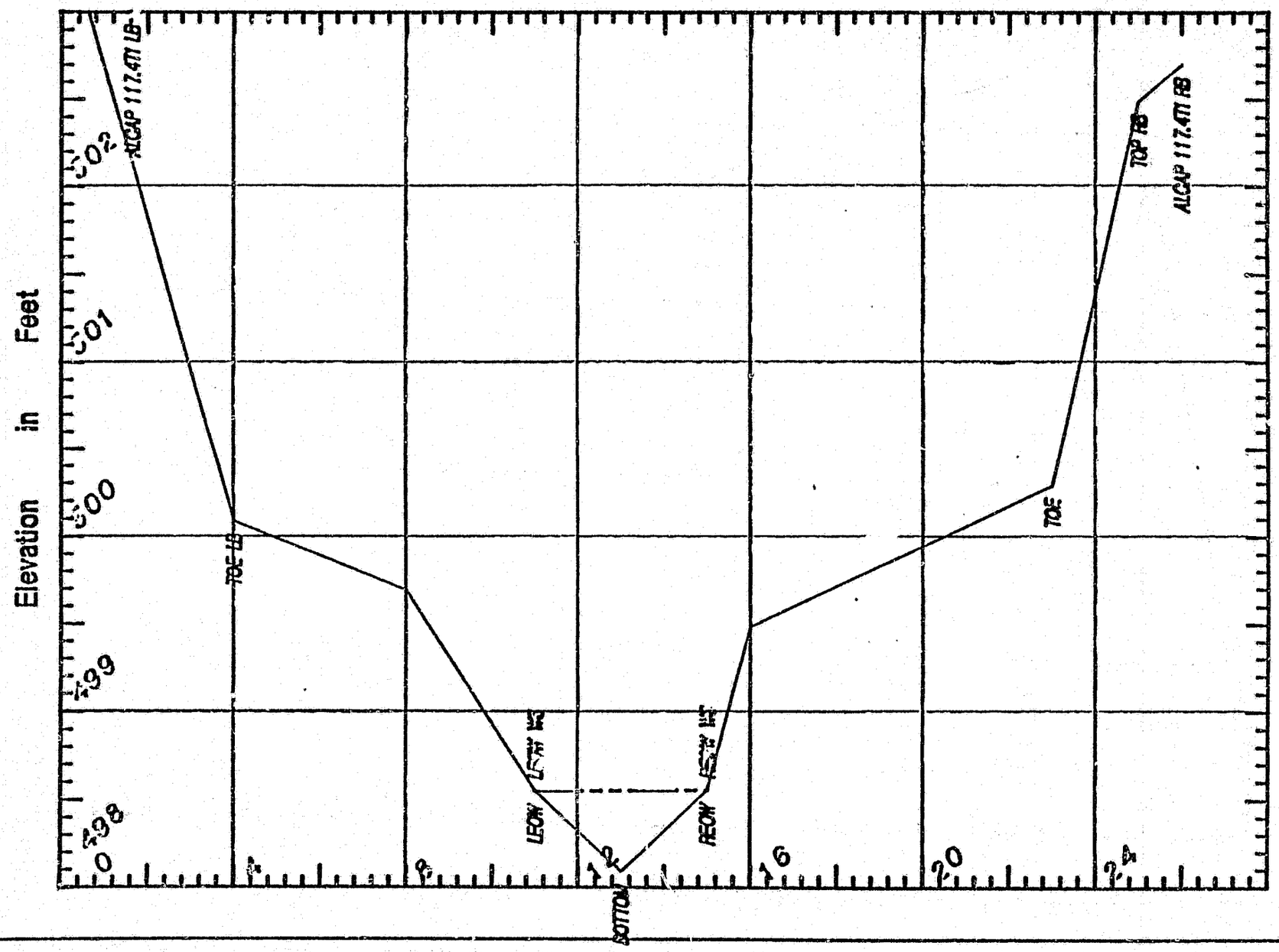
R&M CONSULTANTS, INC.

TRIBUTARY AT RM 121.0 MOUTH X-SEC

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



A-43

2-22-95

PREPARED BY:

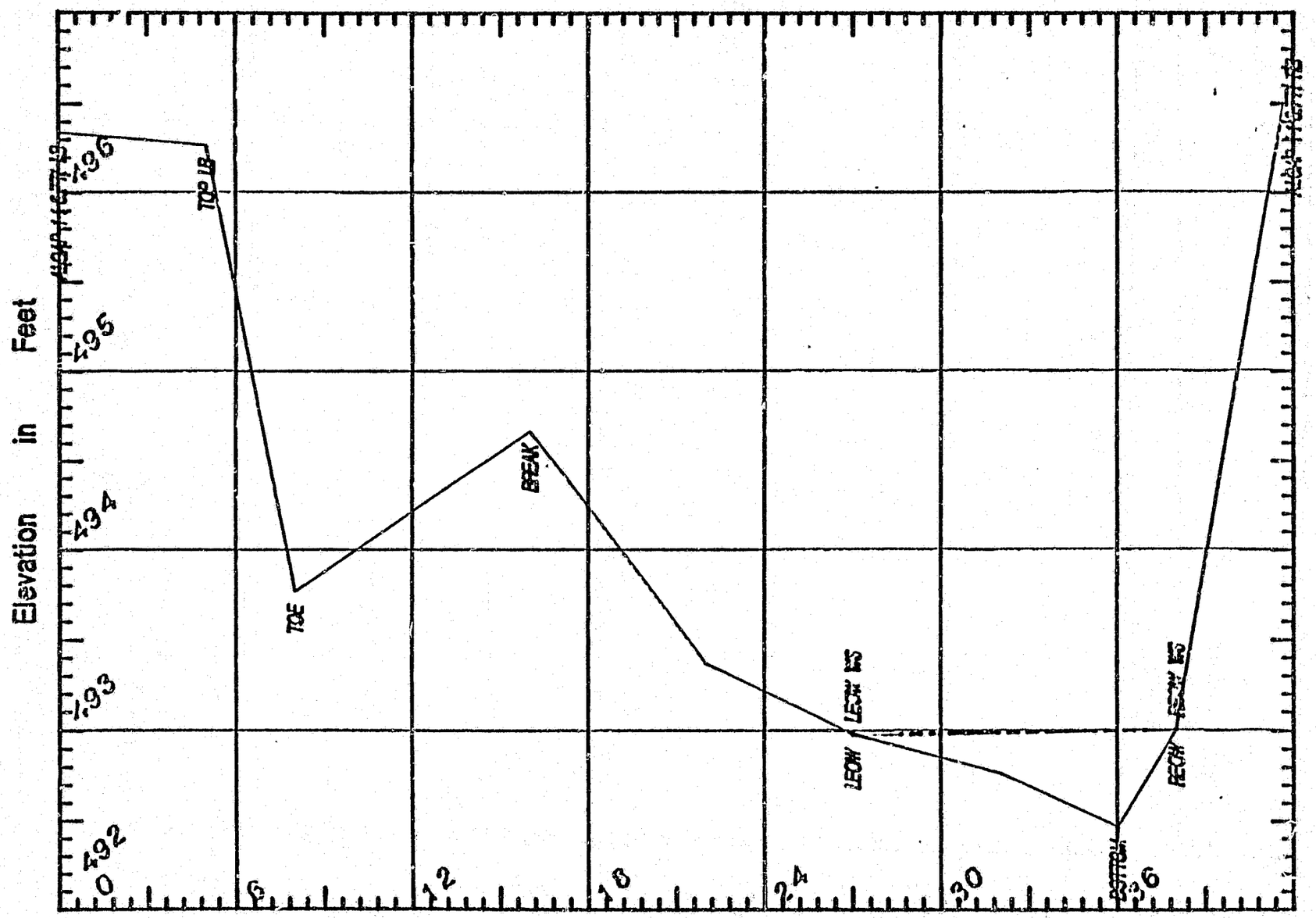
R&M CONSULTANTS, INC.

LITTLE PORTAGE CREEK MOUTH X-SEC

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



A-46

96-2-2

PREPARED BY:

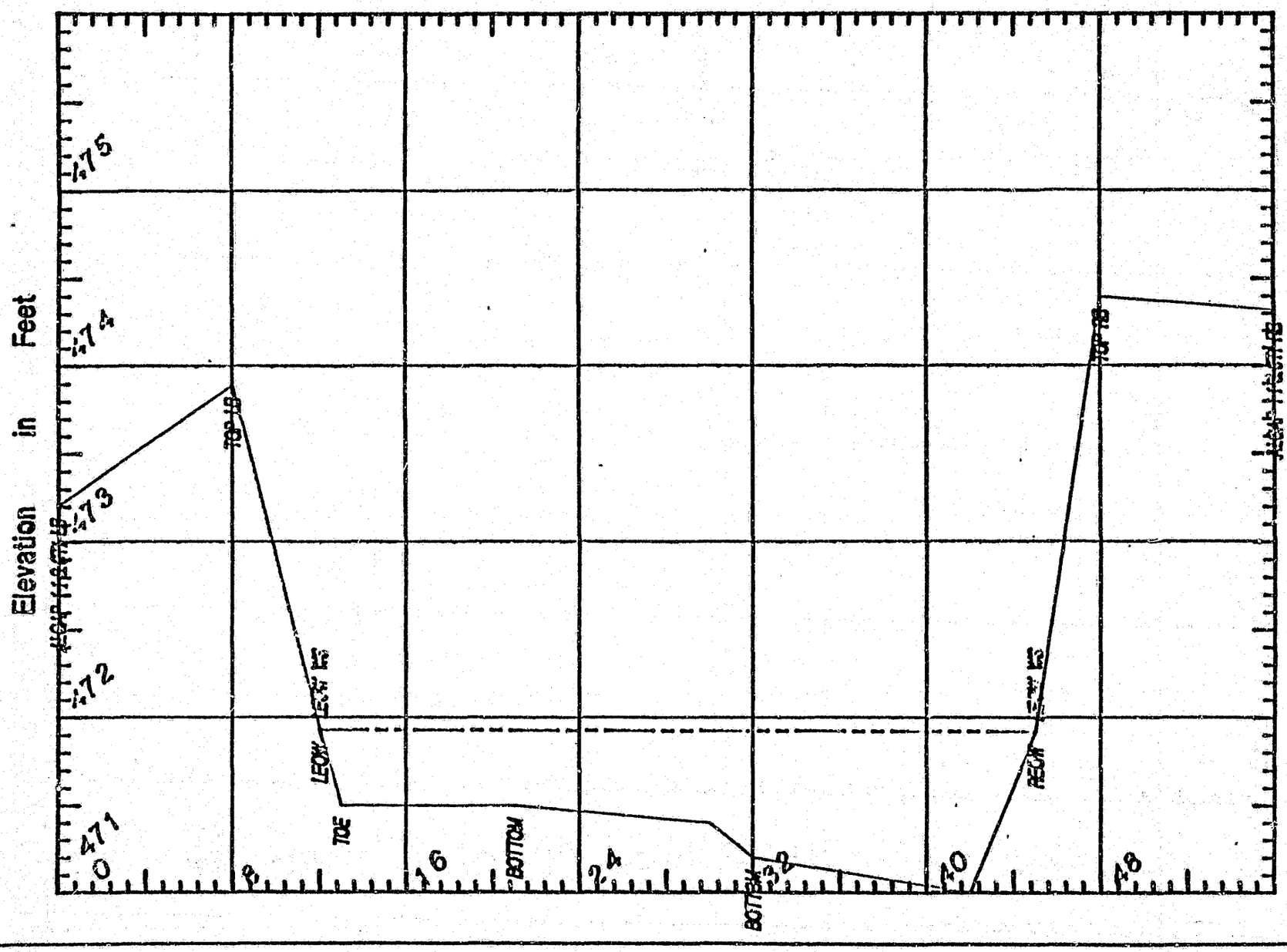
R&M CONSULTANTS, INC.

MACKENZIE CREEK MOUTH X-SEC

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



A-49

2-2-97

PREPARED BY:

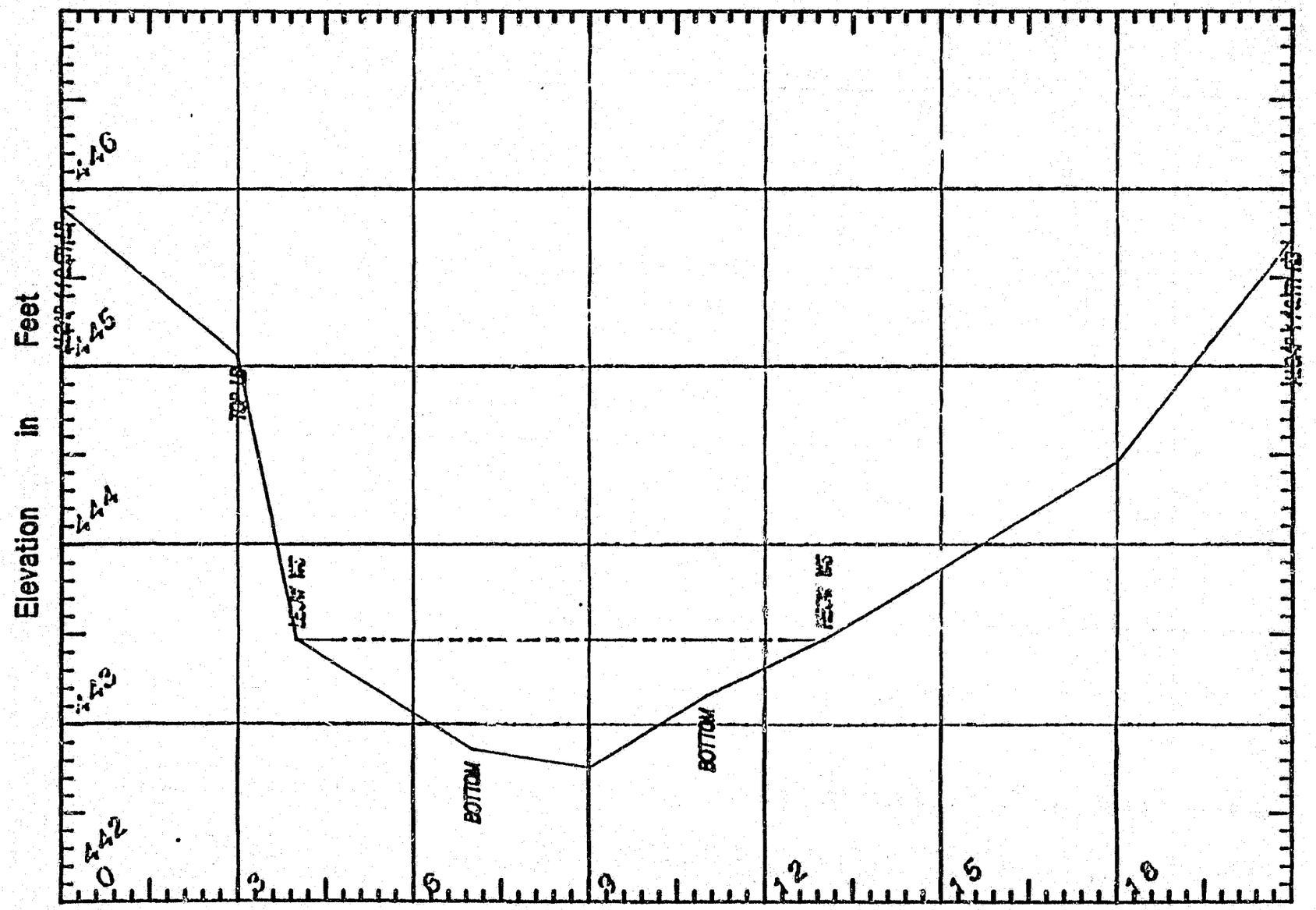
R&M CONSULTANTS, INC.

LANE CREEK MOUTH X-SEC

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



A-53

21-2-98

PREPARED BY:

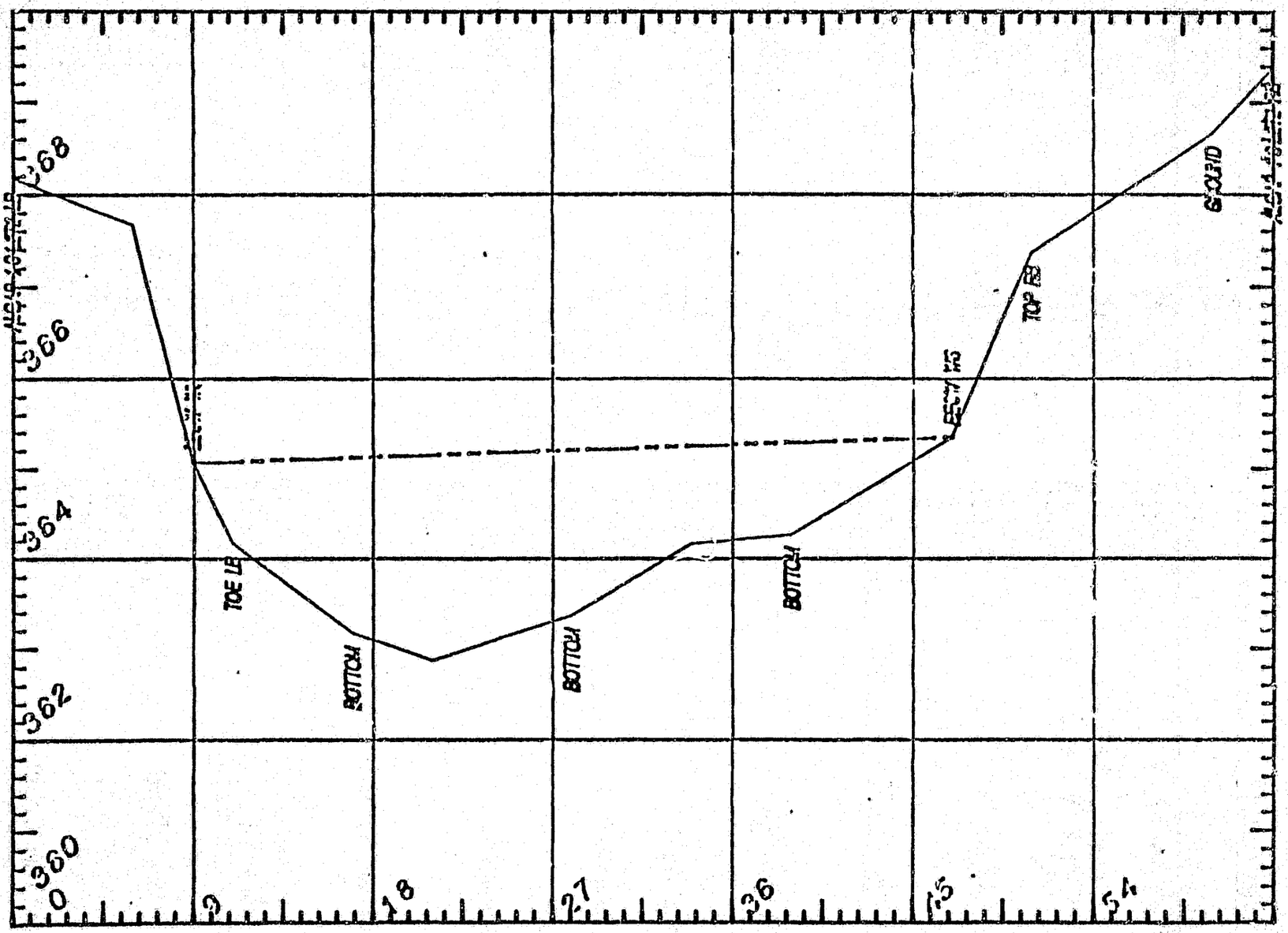
R&M CONSULTANTS, INC.

TRIBUTARY AT RM 110.1 X-SEC MOUTH

PREPARED FOR:

ACRES

SUSITNA HYDROGRAPHIC SURVEYS



A-56

2-2-79

PREPARED BY:

R&M CONSULTANTS, INC.

WHISKERS CREEK X-SEC MOUTH

PREPARED FOR:

ACRES

Table E.5.5. Location of staff gages installed in the Susitna River drainage. Summer 1981.

LOCATION	STAFF GAGE #	RIVER MILE	GEOGRAPHIC CODE
Fish Creek	YE011A	7.0	15N07W27AAC
Alexander Creek Site A	YE021B	10.1	15N07W06DCA
	YE021A		
Alexander Creek Site B	YE031A	10.1	16N07W32CCB
Alexander Creek Site C	YE041A	10.1	16N07W30ACD
	YE041B		
	YE042A		
Anderson Creek	YE051B	23.8	17N07W29DDD
	YE051A		
	YE052A		
Kroto Slough Mouth	YE061A	30.1	17N07W01DBC
	YE061B		
	YE061C		
	YE061D		
Mid-Kroto Slough	YE071A	36.3	18N06W16BBC
	YE071B		
	YE072A		
Mainstem Slough	YE081A	31.0	17N06W05CAB
	YE082A		
	YE083A		
	YE081B		
	YE082B		
	YE083A		
Deshka River Site A	YE091A	40.6	19N06W35BDA
	YE091B		
	YE092A		
	YE092B		
Deshka River Site B	YE101A	40.6	19N06W26BCB
	YE101B		
	YE101C		
	YE101D		
Deshka River Site C	YE111A	40.6	19N06W14BCA
	YE111B		
	YE112A		
Lower Delta Island	YE121A	44.0	19N05W19ACB
	YE122A	44.0	19N05W19ADC
	YE123A	45.0	19N05W17BCD
	YE124A	45.0	19N05W17BCB
Little Willow Creek	YE131A	50.5	29N05W27AAD
	YE132A	50.5	29N05W23CBC
	YE133A	50.5	29N05W27BAC
Rustic Wilderness	SU011A	58.1	21N05W25CBD
	SU011B		
	SU011C		
Kashwitna River	SU021A	61.0	21N05W13AAA
	SU022A		

2-2-100

Table E.5.5. Location of staff gages installed in the Susitna River drainage. Summer 1981

LOCATION	STAFF GAGE #	RIVER MILE	GEOGRAPHIC CODE
Fish Creek	YE011A	7.0	15N07W27AAC
Alexander Creek Site A	YE021B	10.1	15N07W06DCA
	YE021A		
Alexander Creek Site B	YE031A	10.1	16N07W32CCB
Alexander Creek Site C	YE041A	10.1	16N07W30ACD
	YE041B		
	YE042A		
Anderson Creek	YE051B	23.8	17N07W29DDD
	YE051A		
	YE052A		
Kroto Slough Mouth	YE061A	30.1	17N07W01DBC
	YE061B		
	YE061C		
	YE061D		
Mid-Kroto Slough	YE071A	36.3	18N06W16BBC
	YE071B		
	YE072A		
Mainstem Slough	YE081A	31.0	17N06W05CAB
	YE082A		
	YE083A		
	YE081B		
	YE082B		
	YE083A		
Deshka River Site A	YE091A	40.6	19N06W35BDA
	YE091B		
	YE092A		
	YE092B		
Deshka River Site B	YE101A	40.6	19N06W26BCB
	YE101B		
	YE101C		
	YE101D		
Deshka River Site C	YE111A	40.6	19N06W14BCA
	YE111B		
	YE112A		
Lower Delta Island	YE121A	44.0	19N05W19ACB
	YE122A	44.0	19N05W19ADC
	YE123A	45.0	19N05W17BCD
	YE124A	45.0	19N05W17BCB
Little Willow Creek	YE131A	50.5	29N05W27AAD
	YE132A	50.5	29N05W23CBC
	YE133A	50.5	29N05W27BAC
Rustic Wilderness	SU011A	58.1	21N05W25CBD
	SU011B		
	SU011C		
Kashwitna River	SU021A	61.0	21N05W13AAA
	SU022A		

Table E.5.5 (Continued)

LOCATION	STAFF GAGE #	RIVER MILE	GEOGRAPHIC CODE
Caswell Creek	SU031A SU031B SU031C	63.0	21N04W06BDD
Slough West Bank	SU041A SU041B SU041C	65.6	22N05W27ADC
Sheep Creek Slough	SU051A SU051B	66.1	22N04W30BAB
Goose Creek (Lower) 1	SU061A SU061B	72.0	23N04W31BBC
Goose Creek (Lower) 2	SU071A SU072A SU073A SU072B SU073B SU073C	73.1	23N04W30BBB
Mainstem West Bank	SU081A SU081B SU081C	74.4	23N05W13BCC
Montana Creek	SU091A SU092A SU093A	77.0	23N04W07ABA
Rabideux Creek	SU101A	83.1	23N05W16DDA
Mainstem 1	TA011A TA011B	84.0	24N05W10DCC
Sunshine Creek	TA021A TA021B	85.7	24N05W14AAB
Birch Creek Slough	TA031A TA031B	88.4	25N05W25DCC
Birch Creek	TA041A TA041B	89.2	25N05W25ABD
Cache Creek Slough	TA051A TA051B	95.5	26N05W35ADC
Whiskers Creek Slough	TA071A TA071B TA072A	101.2	26N05W03ADB
Whiskers Creek	TA081A TA081B	101.4	26N05W03AAC
Slough 6A	TA091A TA091B TA092A	112.3	28N05W13CAC
Lane Creek	TA101A TA102A TA103A TA103B TA103C TA104A	113.6	28N05W12ADD
Mainstem 2	TA111A TA111B	114.4	28N04W06CAB

2-2-102

Table E.5.5 (Continued)

LOCATION	STAFF GAGE #	RIVER MILE	GEOGRAPHIC CODE
Mainstem Susitna - Curry	GC011A GC011B	120.7	29N04W10BCD
Susitna Side Channel	GC021A GC021B	121.6	29N04W11BBB
Mainstem Susitna - Gravel Bar	GC031A GC031B GC031C	123.8	30N04W26DDD
Slough 8A	GC041A GC042A	125.3	30N03W30BCD
Fourth of July Creek	GC051A GC051B GC052A GC052B	131.1	30N03W03DAC
Slough 10	GC061A GC061B GC061C GC061D	133.8	31N03W36AAC
Slough 11	GC071A GC072A GC071B	135.3	31N02W19DDD
Mainstem Susitna - Inside Bend	GC081A GC081B GC081C	136.9	31N02W17CDA
Indian River	GC091A GC091B GC091C GC091D GC092A GC092B GC092C GC092D	138.6	31N02W09CDA
Slough 20	GC101A GC101B GC101C GC102A GC102B	140.1	31N02W11BBC
Mainstem Susitna - Island	GC111A GC112A GC112B GC112C GC112D	146.9	32N10W27DBC
Portage Creek	GC121A GC121B GC121C GC121D GC121E GC122A GC122B GC122C GC123A	148.8	32N01W25CDB

2-2-103

Table E.5.5 (Continued)

LOCATION	STAFF GAGE #	RIVER MILE	GEOGRAPHIC CODE
Sunshine Base Camp			
Fishwheel EB 1	SB011A SB012A SB012B	79.0	24N05W36BDC
Fishwheel EB 2	SB021A	81.0	24N05W25BAD
Fishwheel WB 2	SB031A	81.0	24N05W26BAA
Fishwheel WB 3	SB041A	81.0	24N05W23CCA
Talkeetna Base Camp			
East Bank Sonar	TB011A	101.0	27N05W26DDA
Upper East Fishwheel	TB021A	101.0	27N05W26DDD
Upper West Fishwheel	TB031A	101.0	27N05W26DAC
Lower East Fishwheel	TB041A	101.0	27N05W35AAA
Lower West Fishwheel	TB051A	101.0	27N05W35AAB
West Bank Sonar	TB061A	101.0	27N05W26DDB
Curry Base			
In Front of Camp	CB011A CB011B CB011C CB011D	120.0	27N04W16DBA
Lower East Fishwheel	CB021A CB021B	120.0	29N04W16DBD
West Bank Fishwheel	CB031A	120.0	29N04W10BCC

2-2-104

ATTACHMENT E.2

STREAMFLOW (PARTIAL)

K&E LOGARITHMIC • 2 X 3 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7323

FIGURE E.2.1
STAGE-DISCHARGE RATING CURVE
SUSITNA RIVER NEAR DEADMAN CREEK
CREST STAGE RECORDER
(U.R.X. 101)

ELEVATION (M.S.L.)

1517
1516
1515
1514
1513
1512
1511
1510
1509
1508

8-3-81
7-30-80
7-12-81
6-1-81
9-3-81
9-16-81
9-6-80
11-13-80
11-2-81

1,000 2 3 4 5 6 7 8 9 10,000 2 3 4 5 6 7 8 9 100,00

C.F.S.)*

* Q = (QWATANA)(0.969)

E-8

901-2-106

K·E LOGARITHMIC • 2 X 3 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7323

FIGURE E.2.2
STAGE DISCHARGE RATING CURVE
SUSITNA RIVER AT WATANA DAM
SITE CREST STAGE RECORDER
(URX - 10613)

1472
1462
1461
1460
1459
1458
1457
1456
1455
1454
1453

8-3-81
7-12-81
6-1-81
7-30-80
9-3-81
9-16-81
9-6-80
11-2-81
10-31-80
11-13-80

1 2 3 4 5 6 7 8 9 1,000 2 3 4 5 6 7 8 9 10,000 2 3 4 5 6 7 8 9 100,000

Q (CFS)*

2-2-107

K+E LOGARITHMIC 3 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7323

FIGURE E.2.3
STAGE-DISCHARGE RATING CURVE
SUSITNA RIVER AT WATANA STAFF GAGE
(APPROX. 1 MILE D/S OF PROPOSED DAMSITE
AND 1000 FT. U/S OF URX-109)

ELEVATION (M.S.L.)

1452
1451
1450
1449
1448
1447
1446
1445
1444
1443
1442

6-10-81
6-3-81
SAME POINT

6-1-81

7-28-81
8-5-81
SAME POINT

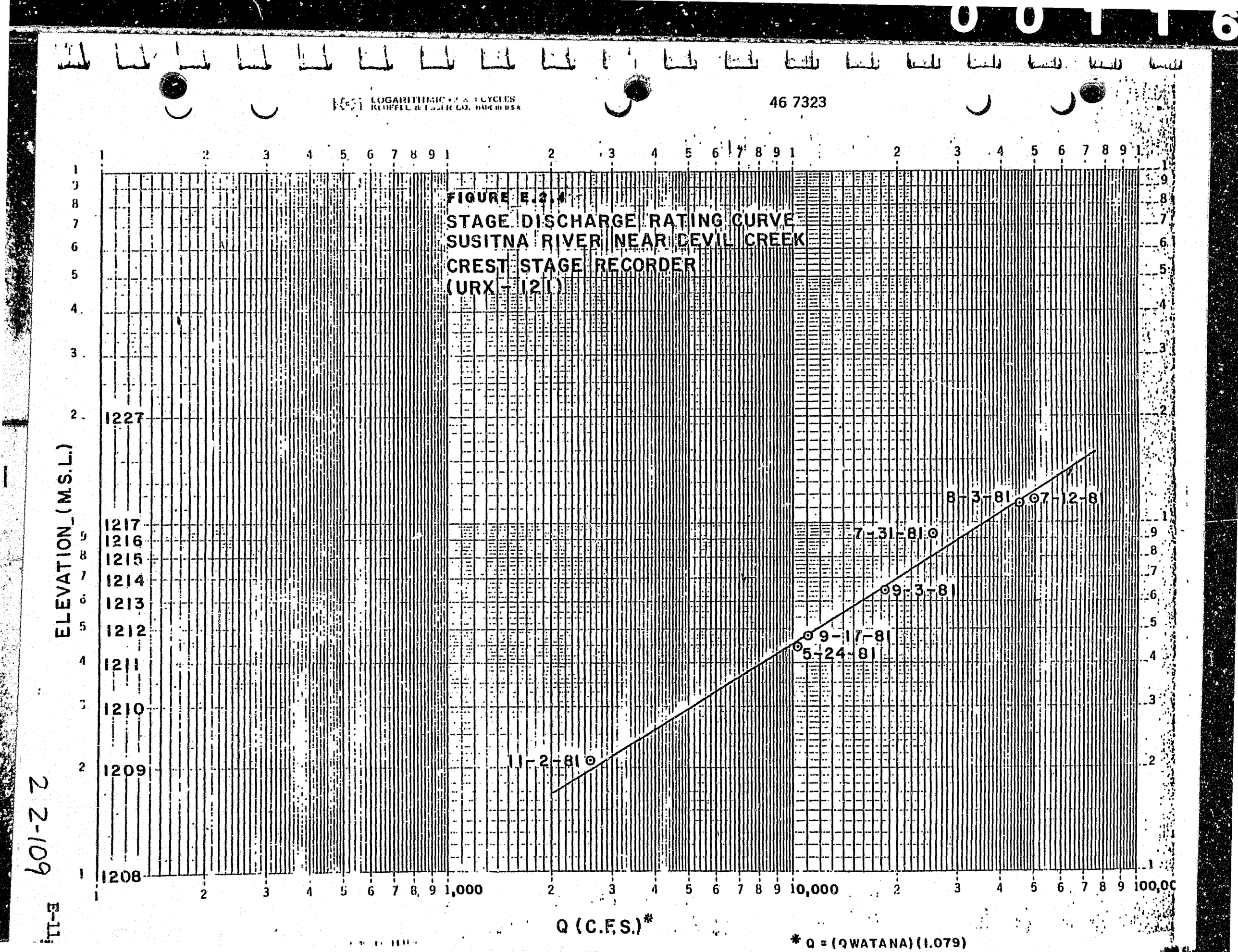
8-13-81

100 1000 10,000 100,000

Q=(C.F.S.) Q=QWATANA

E-10

801-2-2



LOGARITHMIC 2 X 3 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 7323
FIGURE E.2.4
STAGE DISCHARGE RATING CURVE
SUSITNA RIVER NEAR DEVIL CREEK
CREST STAGE RECORDER
(URX - 121)
ELEVATION (M.S.L.)
1227
1217
1216
1215
1214
1213
1212
1211
1210
1209
1208
8-3-81
7-12-81
7-31-81
9-3-81
9-17-81
5-24-81
11-2-81
1,000
10,000
100,000
Q (C.F.S.)*
* Q = (QWATANA)(1.079)

2 2-109

LOGARITHMIC 2 X 1 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7323

FIGURE E.2.5
STAGE DISCHARGE RATING CURVE
SUSITNA RIVER AT DEVIL CANYON UPPER
CREST STAGE RECORDER
(APPROX. 1.5 MILES U/S OF D.C. DAMSITE)

ELEVATION (MSL)

960
951
950
949
948
947
946
945
944
943
942
941

8-2-81
7-12-81
7-29-80
7-31-80
5-31-81
9-3-81
9-17-81
9-6-80
10-14-80
11-19-80

1,000
10,000
100,000

Q (CFS)*

* Q = (Q GOLD CR.) (0.933)

011-2-2

E-12

K+E LOGARITHMIC • 2 X 3 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7323

FIGURE E.2.8

STAGE DISCHARGE PRELIMINARY RATING CURVE
SUSITNA RIVER AT DEVIL CANYON STAFF GAUGE
LRX-68

NOTE: DISCHARGE AT THE DEVIL CANYON STAFF GAUGE ARE DRAINAGE AREA PRORATED FROM GOLD CREEK STREAM FLOW DATA.

ELEVATION (M.S.L.)

859
858
857
856
855
854
853
852
851
850

8-12-81
7-27-81
8-6-81
6-2-81
5-31-81
5-14-81
5-8-81
6-19-81
5-24-81
5-21-81

THE RELIABILITY OF THIS READING IS IN DOUBT

10,000 100,000

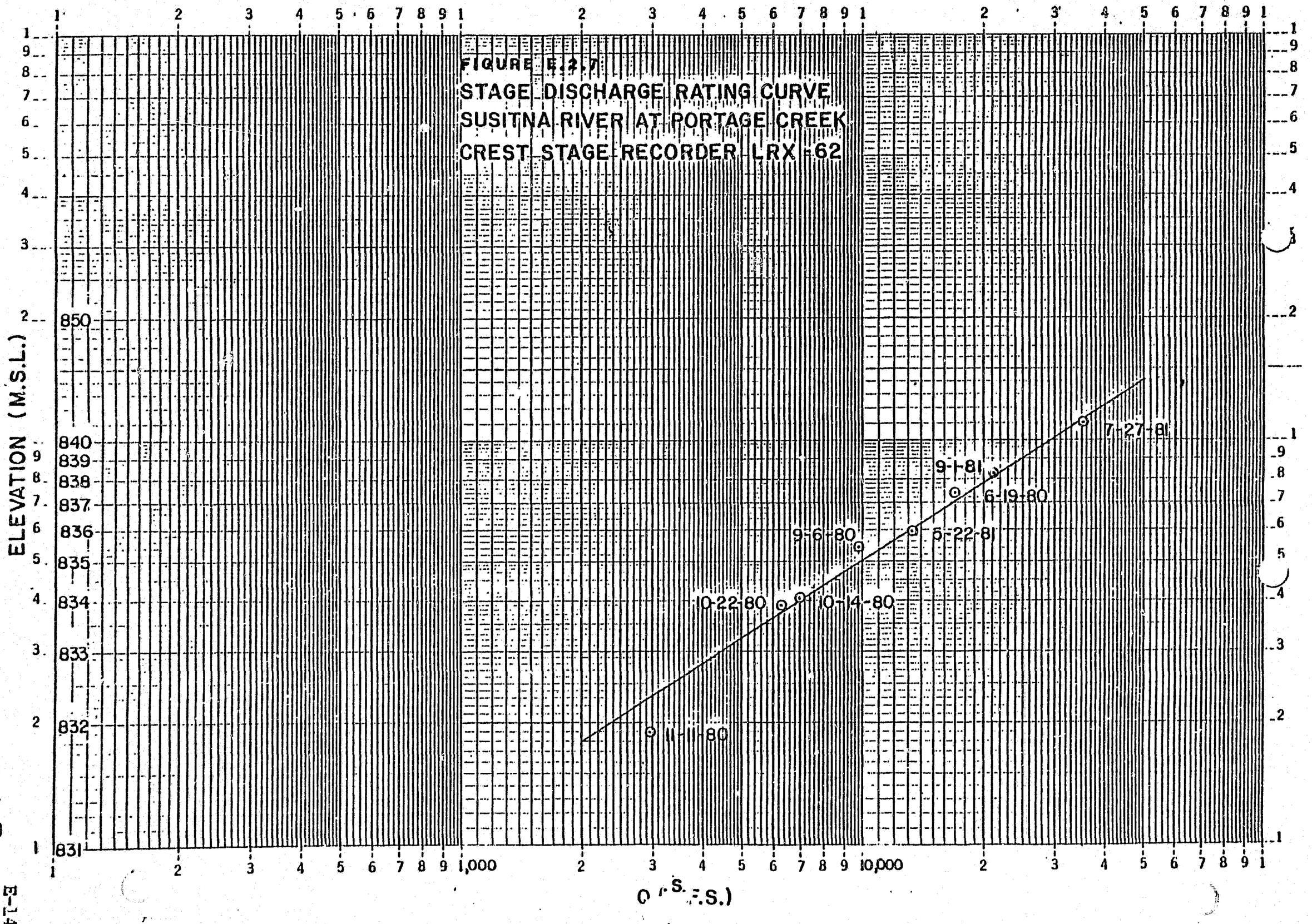
Q (C.F.S.)

111-2-2

E-13

K&E LOGARITHMIC 2 X 3 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 7323

FIGURE E.2.7
STAGE DISCHARGE RATING CURVE
SUSITNA RIVER AT PORTAGE CREEK
CREST STAGE RECORDER LRX-62

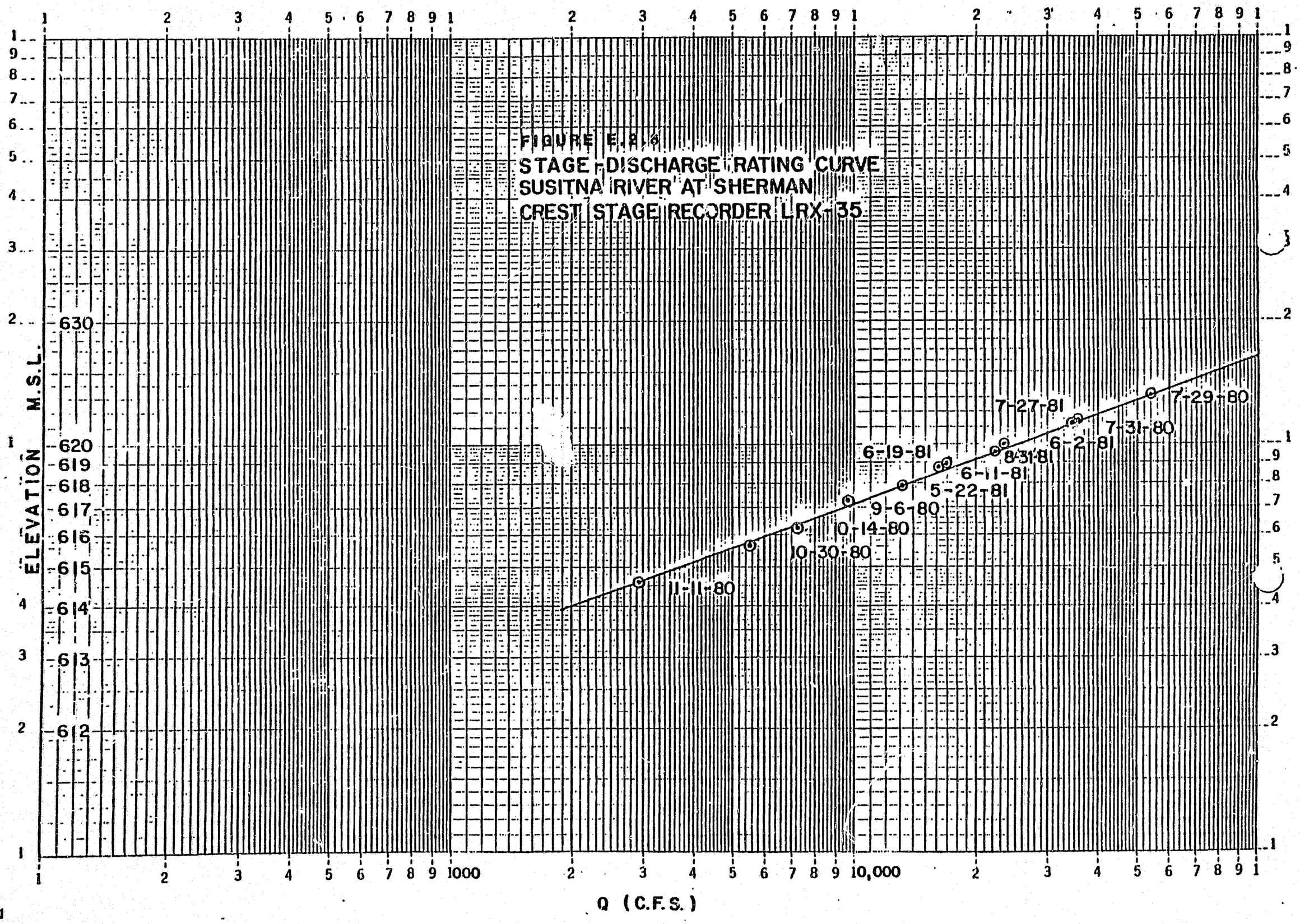


2-2-112

K&E LOGARITHMIC 2 X 3 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7323

FIGURE E.8.6
STAGE-DISCHARGE RATING CURVE
SUSITNA RIVER AT SHERMAN
CREST STAGE RECORDER LRX-35



2-2-113

E-15

K&E LOGARITHMIC • 2 X 3 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7323

FIGURE E.2.9

STAGE DISCHARGE RATING CURVE

SUSITNA RIVER AT SECTION 25

CREST STAGE RECORDER LRX-28

ELEVATION (M.S.L.)

560
559
558
557
556
555
554
553
552
551

11-7-80
10-14-80
9-6-80
8-31-81
6-19-81
6-2-81
7-31-80
7-27-81
7-29-80

Q (C.F.S.)

1 2 3 4 5 6 7 8 9 1,000 2 3 4 5 6 7 8 9 10,000 2 3 4 5 6 7 8 9 1

2-11-4

FIGURE E.2.10

STAGE DISCHARGE RATING CURVE
SUSITNA RIVER AT CURRY
CREST STAGE RECORDER LRX-24

528
527
526
525
524
523
522
521
520
519

7-29-80
7-27-81
7-31-80
8-31-81
6-19-81
5-22-80
9-6-80
10-14-80
11-8-80

1,000
10,000

Q (C.F.S.)

S11-2-2

FIGURE E.2.11
STAGE DISCHARGE RATING CURVE
SUSITNA RIVER AT CHASE
CREST STAGE RECORDER LRX-9

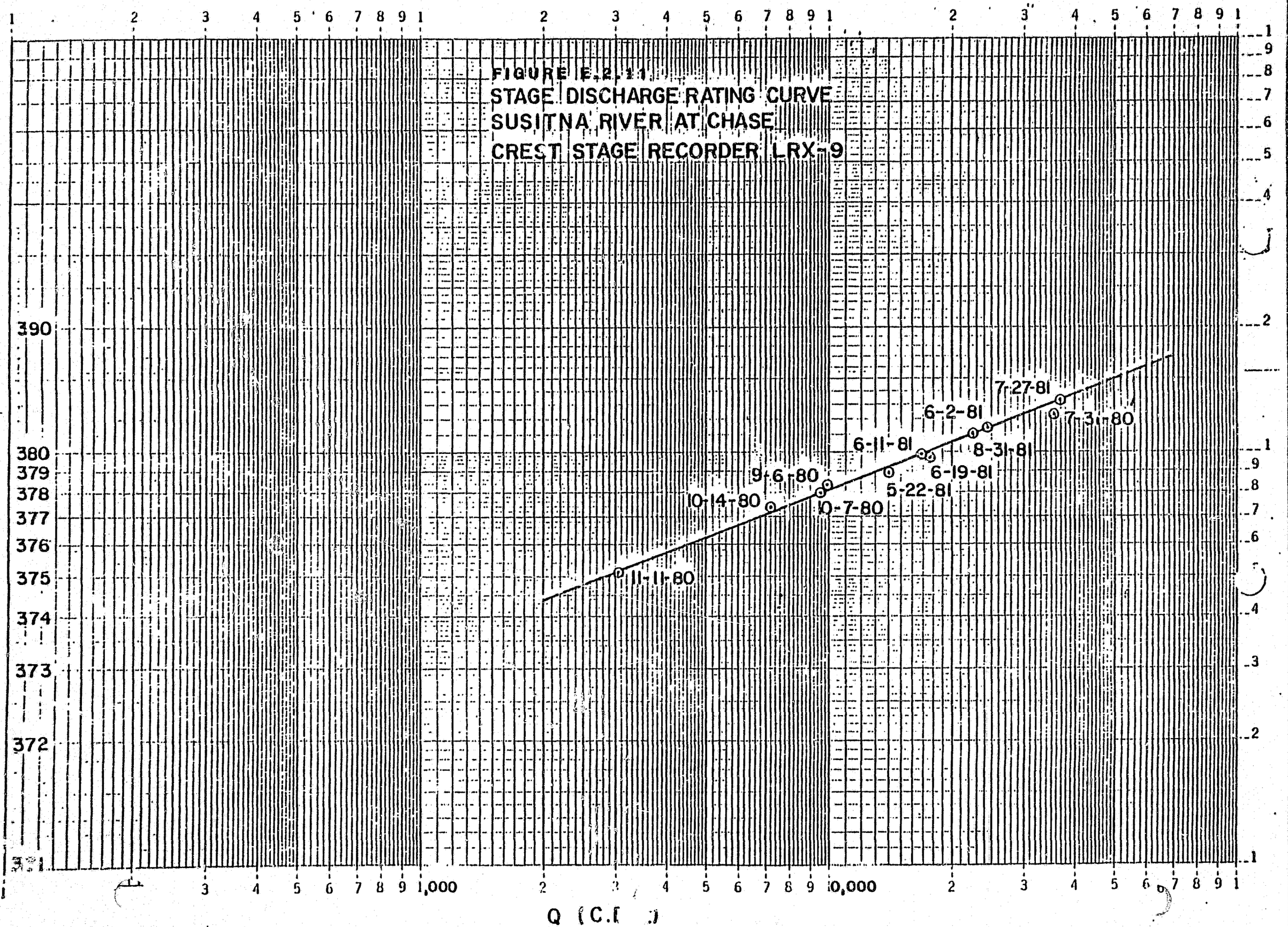


FIGURE E.2.12
STAGE DISCHARGE RATING CURVE
SUSITNA RIVER AT CHULITNA CONFLUENCE
CREST STAGE RECORDER LRX - 4

360
350
349
348
347
346
345
344
343
342

7-27-81
7-29-80
6-2-81
7-31-80
6-11-81
8-31-81
6-19-81
10-4-80
5-22-81
9-6-80
10-14-80

1 2 3 4 5 6 7 8 9 1,000 2 3 4 5 6 7 8 9 10,000 2 3 4 5 6 7 8 9 1

1 9 8 7 6 5 4 3 2 1

Q (CFS)

2-2-117

EXHIBIT E

2. Water Use and Quality

Comment 3 (p. E-2-17, para.1)

Provide stage-discharge diagrams for all gaging stations on both mainstem and tributaries.

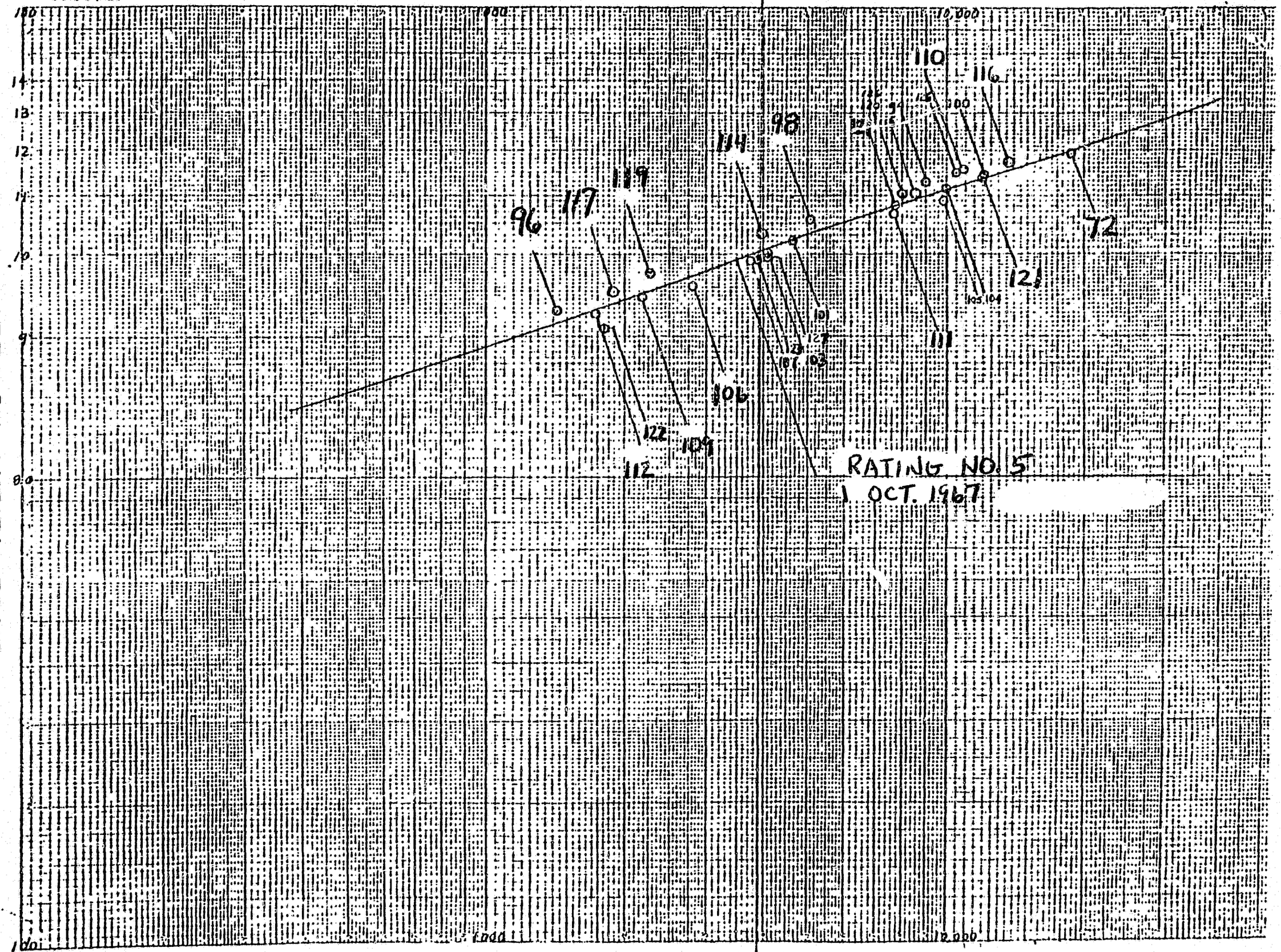
Response

The stage-discharge diagrams for the continuous gaging stations on the mainstem Susitna River and its tributaries are attached. These stations include:

Six Mainstem Stations	River Mile
Denali	290.7
Cantwell (Vee Canyon)	223.0
Watana	182.1
Gold Creek	136.6
Sunshine	83.8
Susitna Station	25.7

Ten Tributary Stations	
Maclaren River near Paxson	259.9
Portage Creek	148.8
Indian River	138.5
Chulitna River near Talkeetna	98.5
Talkeetna River near Talkeetna	97.2
Willow Creek near Willow	48.5
Deception Creek near Willow	48.5
Deshka River near Willow	40.5
Skwentna River near Skwentna	27.5
Yentna River near Susitna Station	27.5

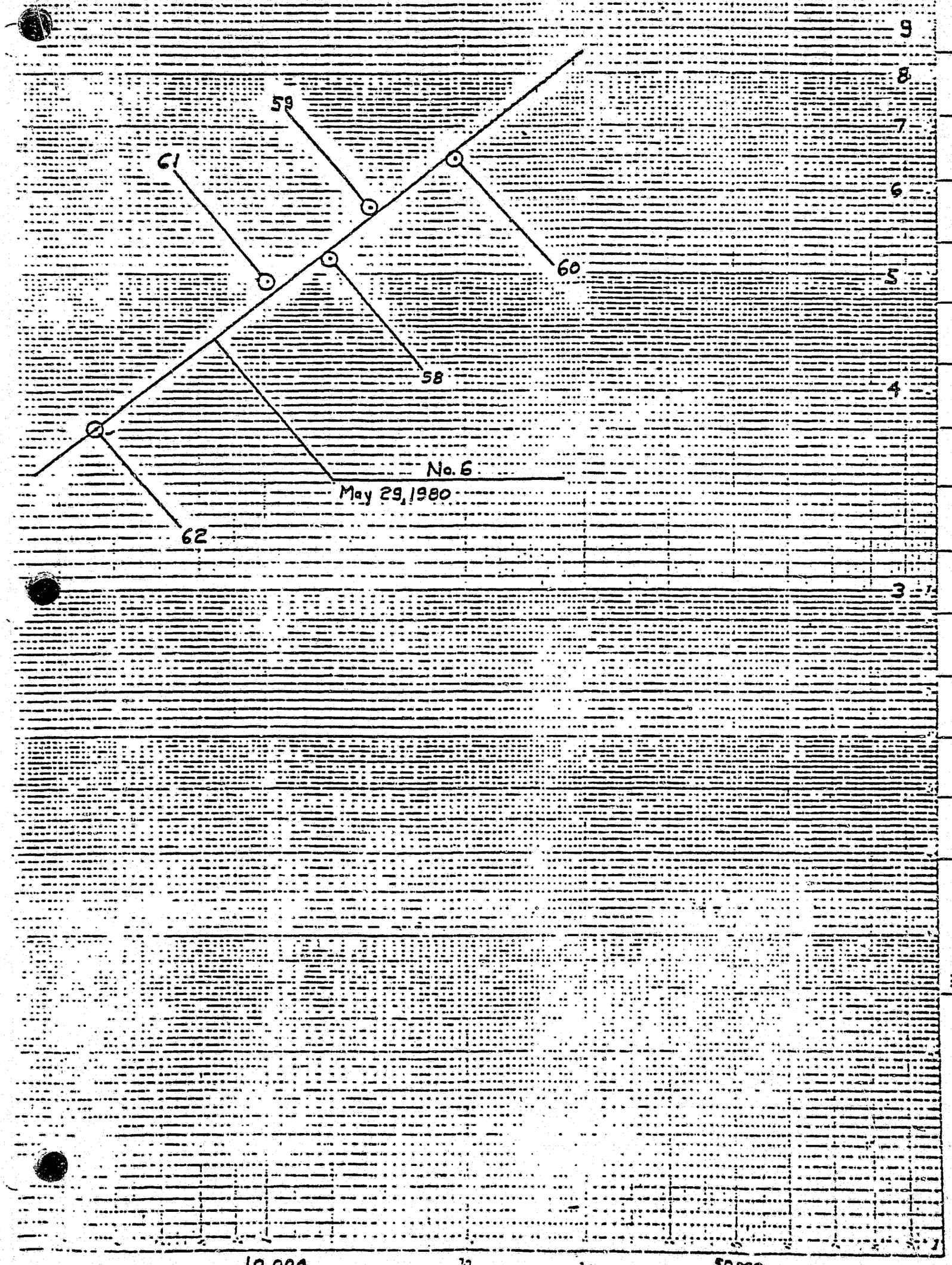
9-279 G (REV. 11-65)



SUSITNA RIVER ... DENALI

2-3-2.

SUSITNA RIVER NEAR CANTWELL



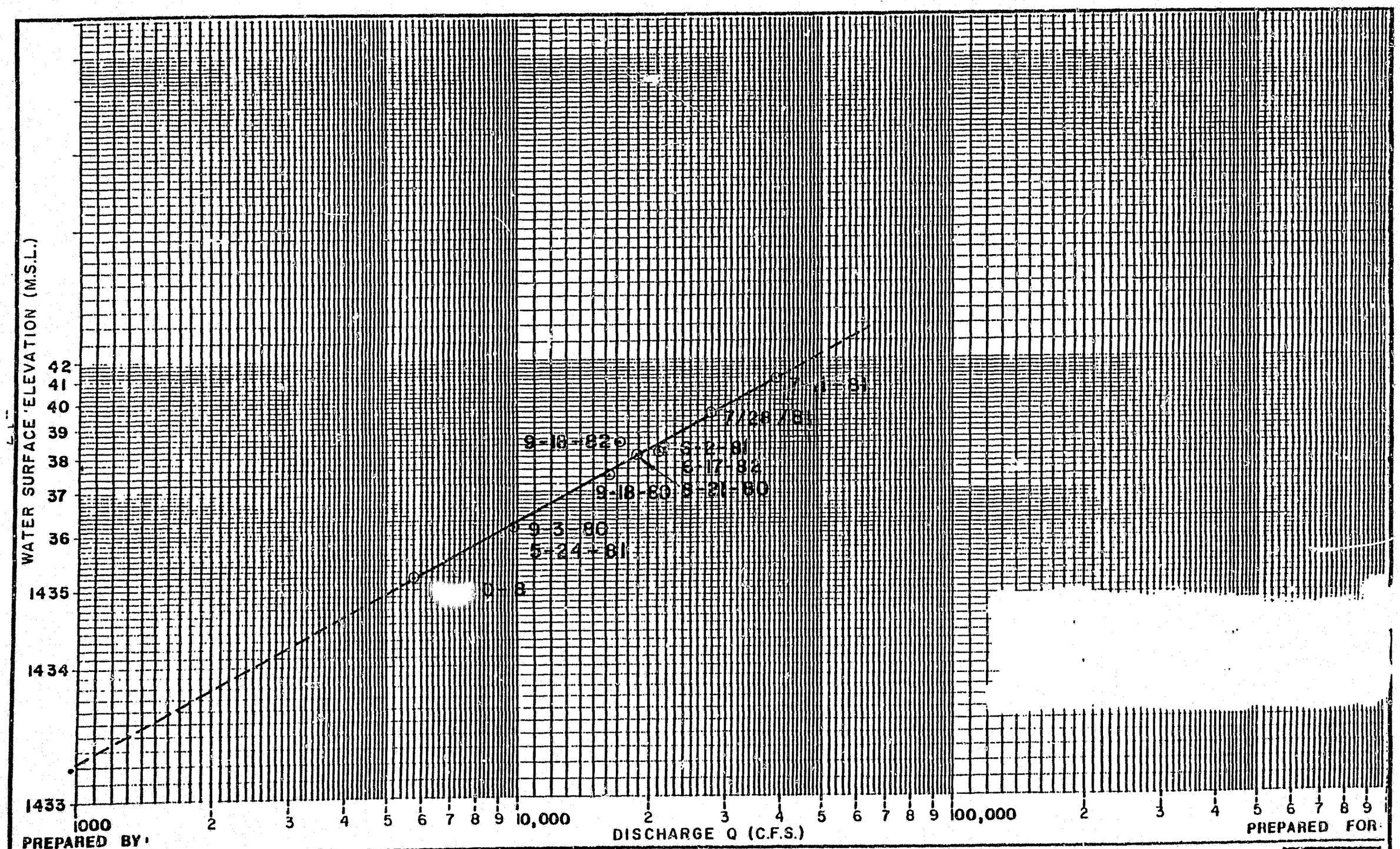
Water year	1980	1981
Mean. Nos.	58-61	62
Mean not plotted	None	
Max G. H.	8.27	
Min G. H.		

Curve approved by:

Office Engineer.

District Engineer

2-3-3



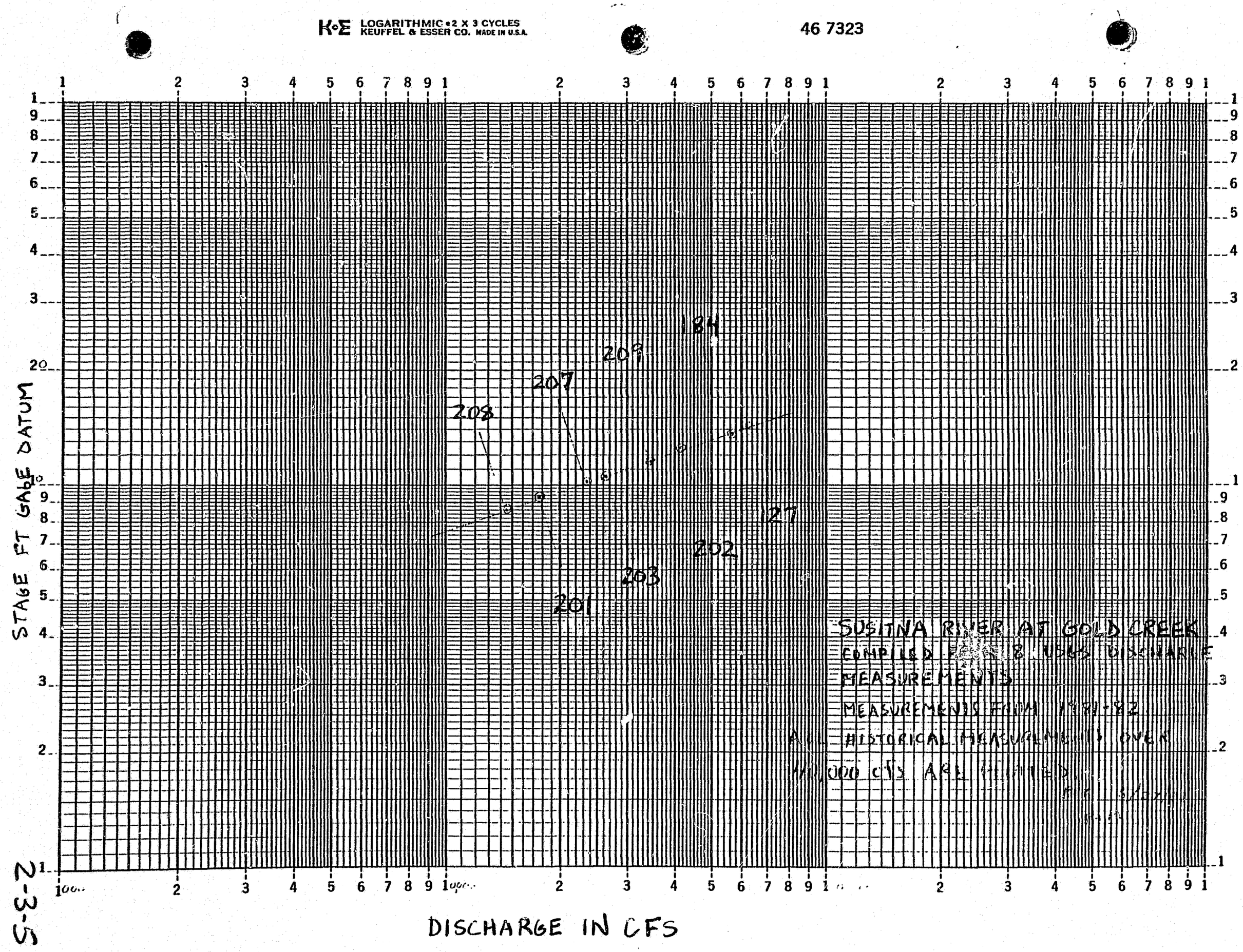
R&M CONSULTANTS, INC.

2-3-4

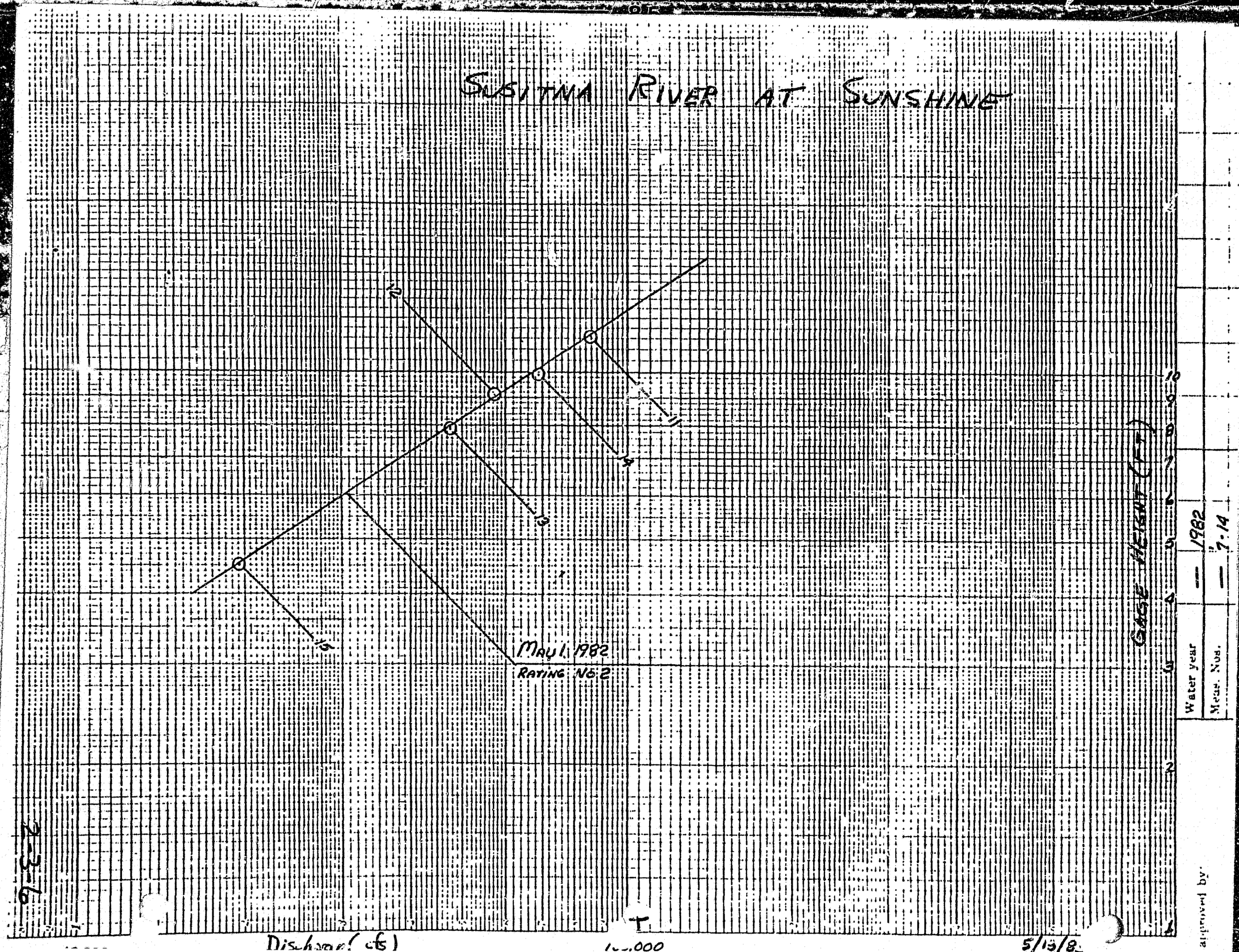
STAGE DISCHARGE RATING CURVE
SUSITNA RIVER NEAR WATANA

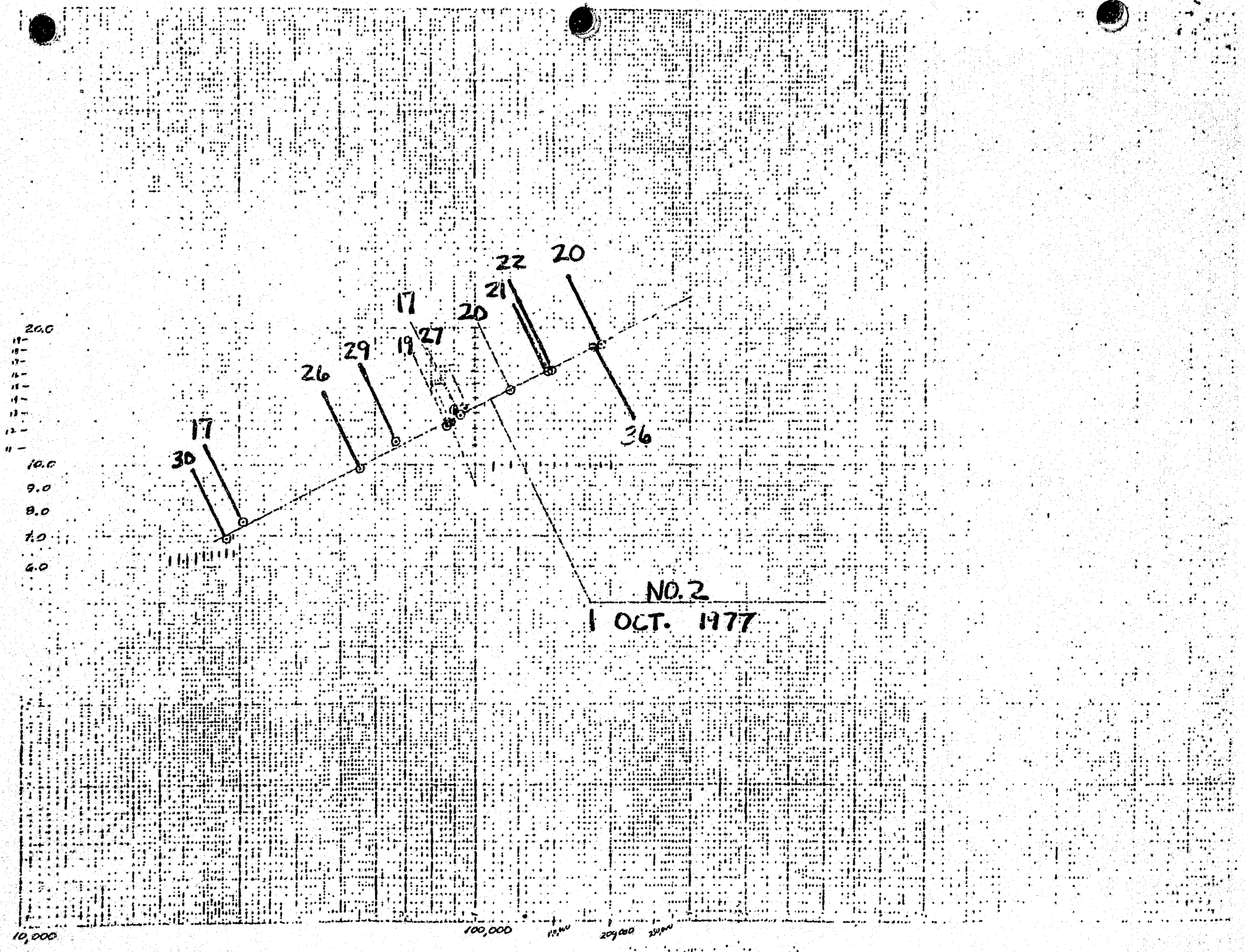
Figure 2.1.1

ACRES


K+E LOGARITHMIC • 2 X 3 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 7323
STAGE FT GAGE DATUM
DISCHARGE IN CFS
184
209
207
208
127
202
203
201
SUSITNA RIVER AT GOLD CREEK
COMPILED FROM 8 USGS DISCHARGE
MEASUREMENTS
MEASUREMENTS FROM 1981-82
ALL HISTORICAL MEASUREMENTS OVER
40,000 CFS ARE PLOTTED

2-3-5


SUSITNA RIVER AT SUNSHINE
12
11
14
13
15
MAY 1, 1982
RATING NO 2
GAGE HEIGHT (FT)
10
9
8
7
6
5
4
3
2
1
Water year — 1982
Meas. Nos. — 7-14
Discharge (cfs)
100,000
5/13/8
2-3-6



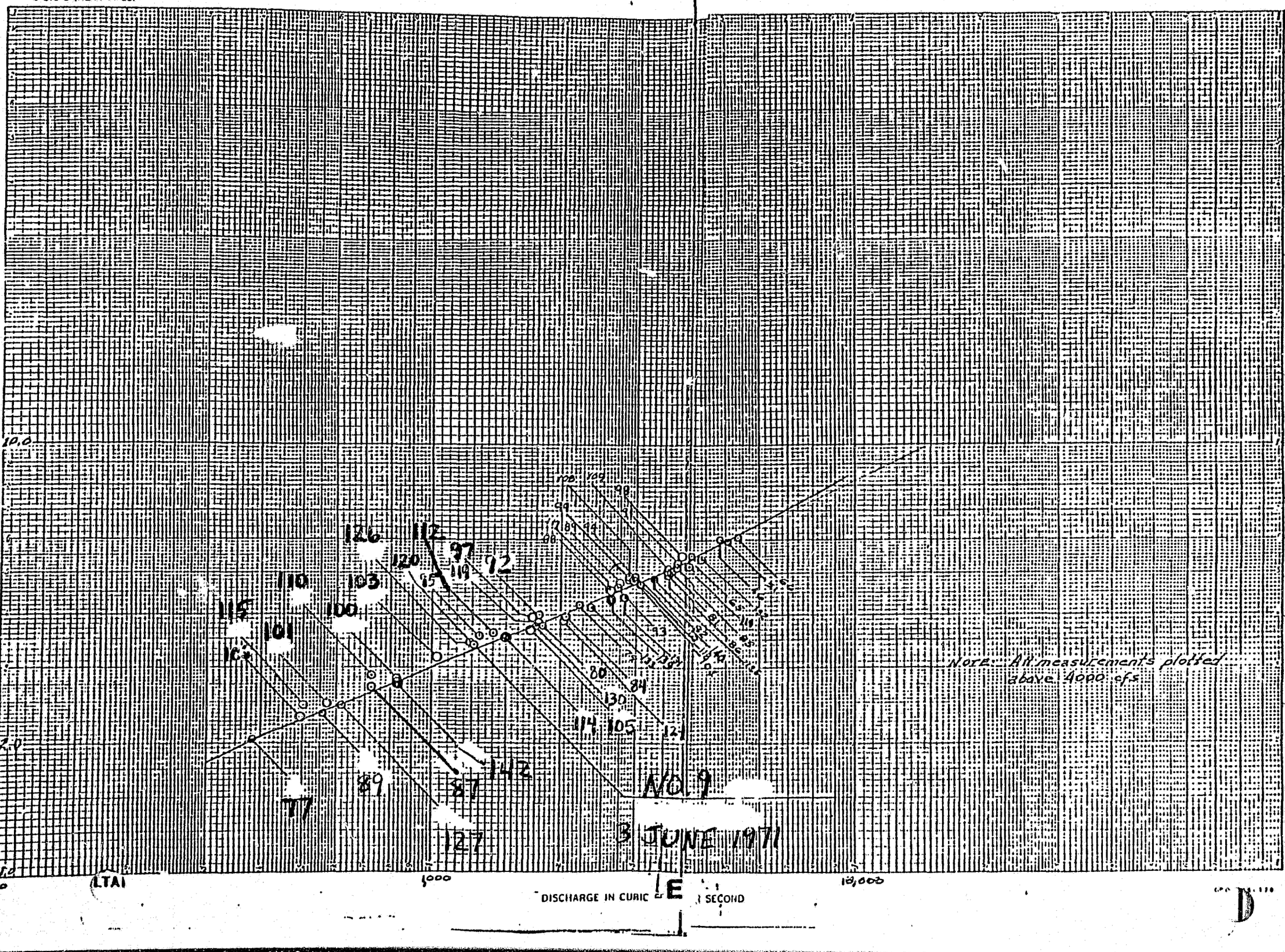
2-3.7

SUSITNA STATION

Maclaren R. near Paxson

UNITED STATES DEPARTMENT OF THE INTERIOR GEOLOGICAL SURVEY (WATER RESOURCES DIVISION) RATING CU E FOR... Sta. No. 65

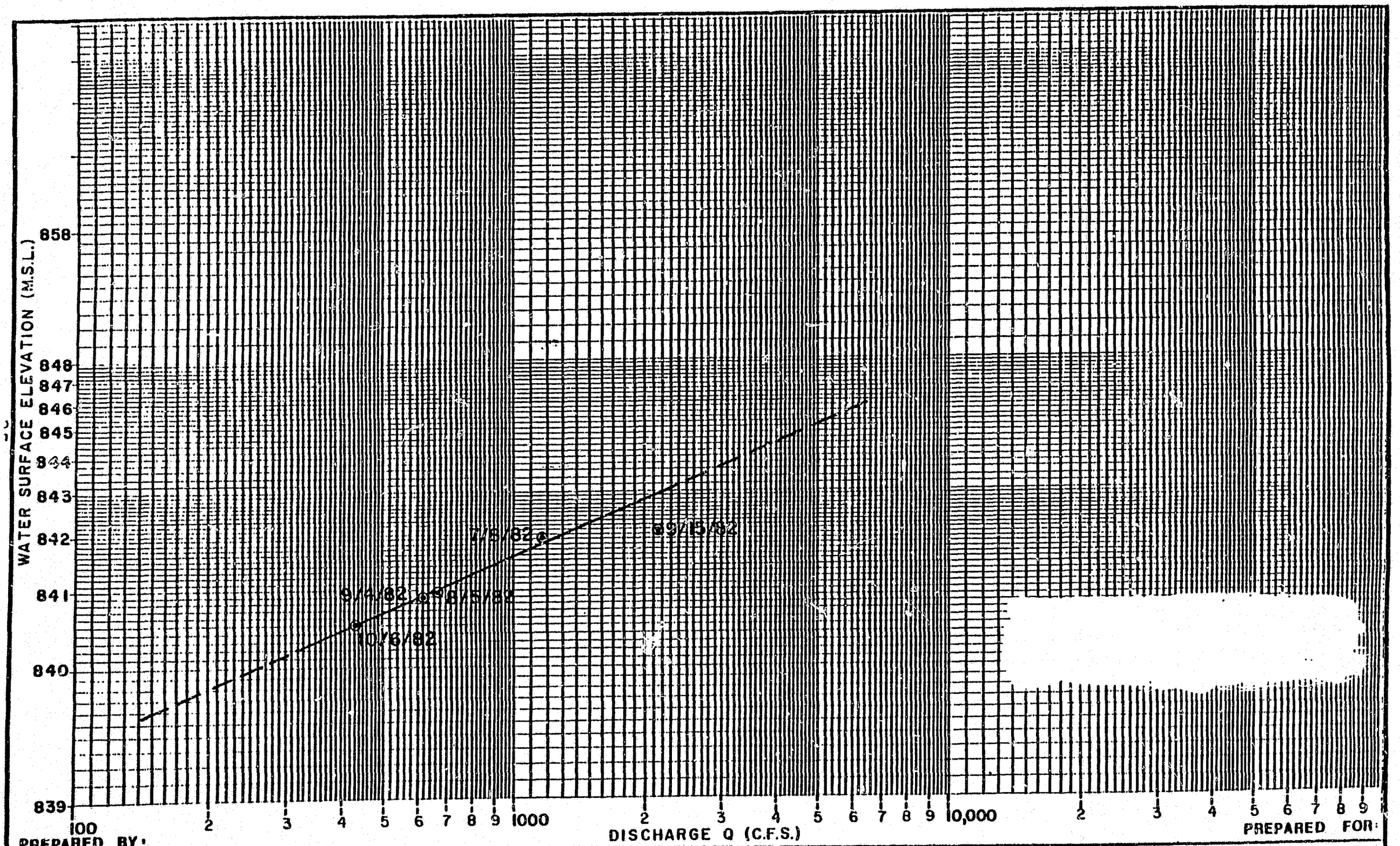
9-279-G (REV. 11-65)



Water year	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Meas. Nos.	80	81,82	83-87	88,89	90-95	96-100	101-106	107-110	111-115	116-120	121-126	127-134	135-142
Meas. not plotted	Most	-	-	-	90	96	102	107	111	116	121-125	128-129	135-138
Max. [illegible]	7.34	8.24	7.14	6.21	5.70	6.67	5.85	6.12	5.42		6.53	6.57	

Curve approved by: Office Engineer

2-3-8



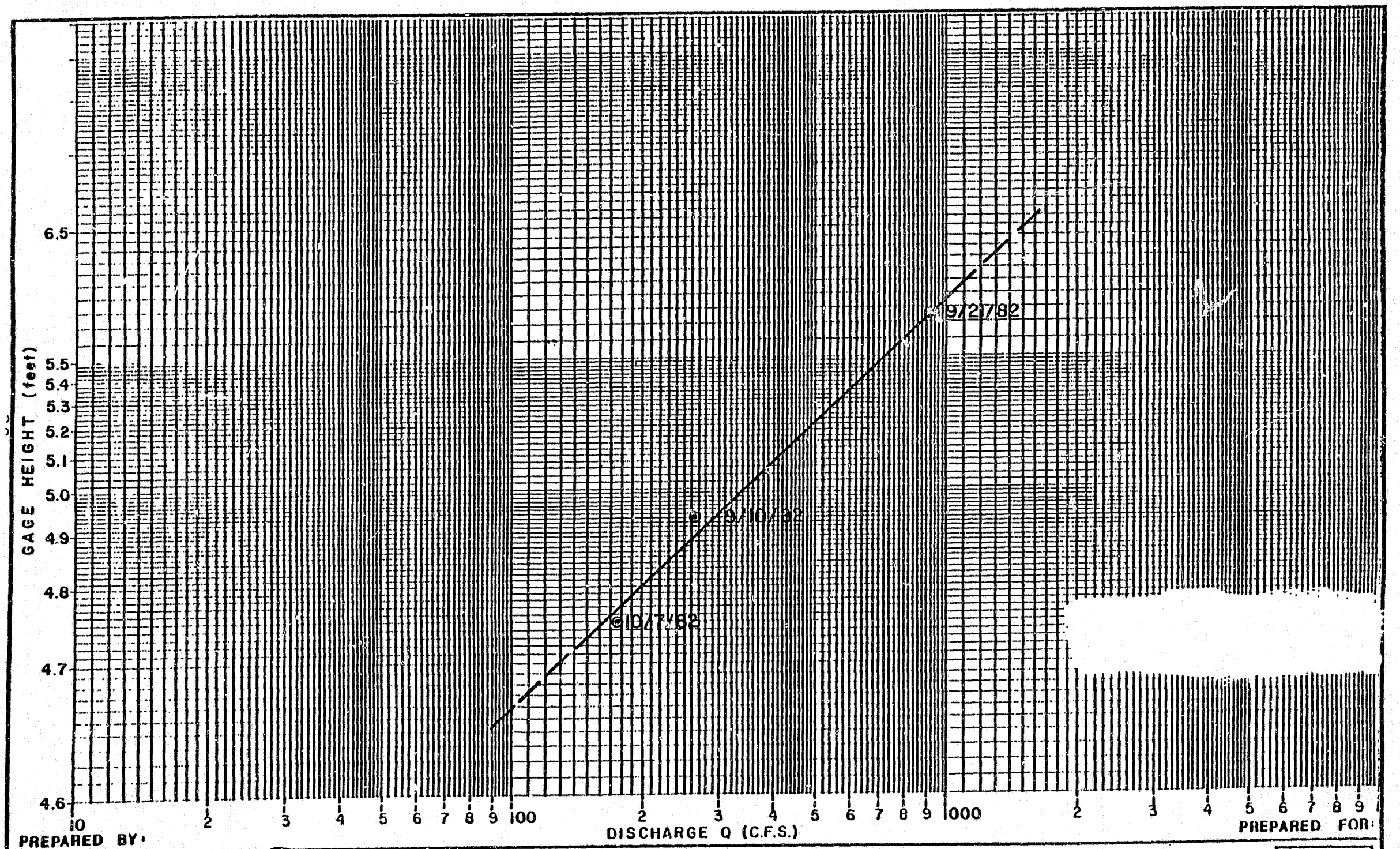
R&M CONSULTANTS, INC.

2-3-9

STAGE DISCHARGE RATING CURVE
PORTAGE CREEK

Figure 2.2.1

ACRES



R&M CONSULTANTS, INC.

2-3-10

STAGE DISCHARGE RATING CURVE

INDIAN RIVER

Figure 2.2.4

ARCHIVES

UNITED STATES DEPARTMENT OF THE INTERIOR GEOLOGICAL SURVEY (WATER RESOURCES DIVISION)

9-275 C (REV. 11-67)

RATING CURVE FOR, ... Sta. No. 2...

CHULITNA R. NEAR TALKEETNA

GAGE HEIGHT IN FEET

NO. 6

1 OCT. 1967 to 30 SEPT. 1971

NO. 7

1 OCT. 1981

All measurements over 30,000 cfs plotted

DISCHARGE IN CUBIC FEET PER SECOND

10,000

100,000

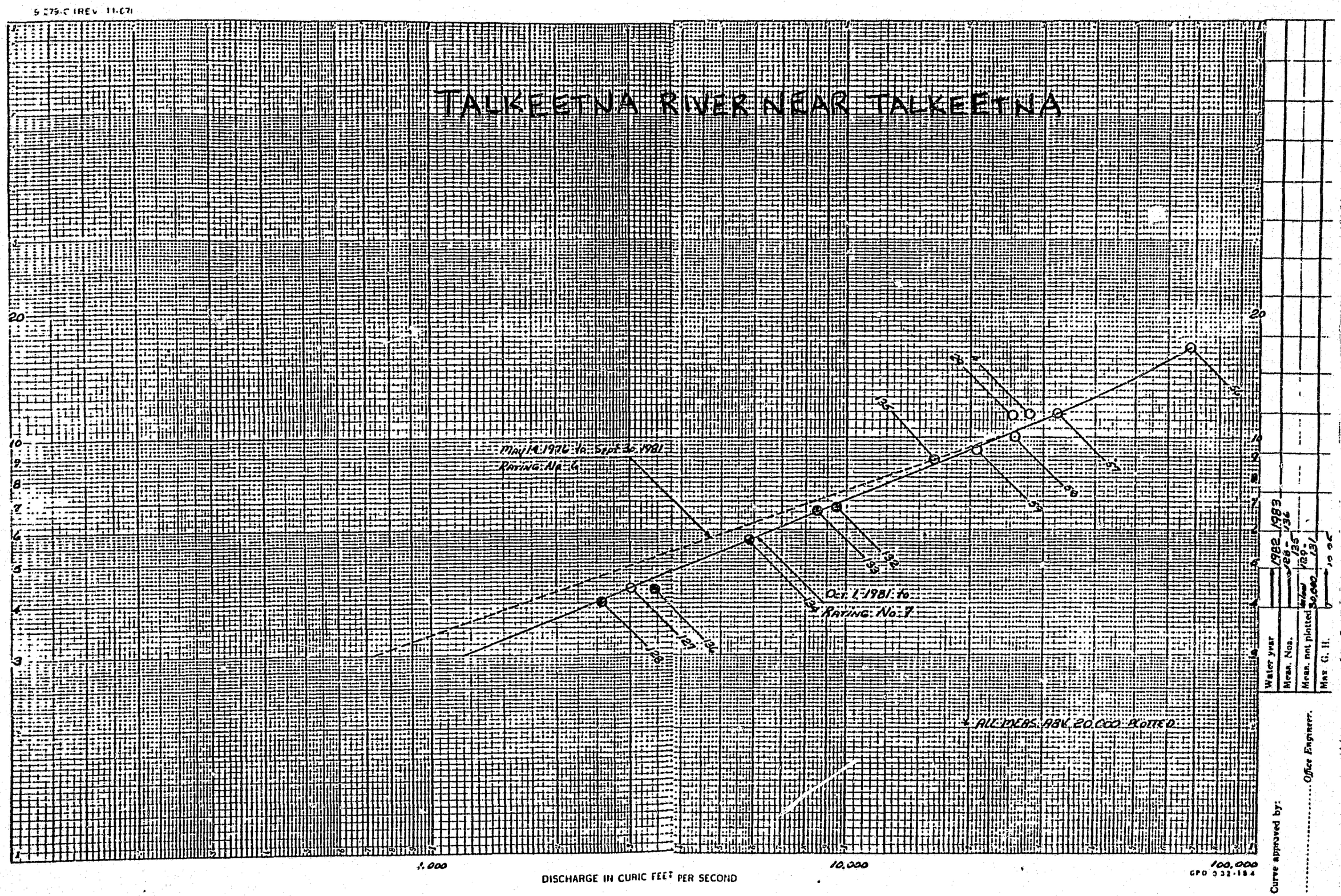
Water year	1972	1980	1981	1982	1983
Meas. nos.	—	-103	104-109	110-118	119-124
Meas. not plotted			Most		125-

Curve approved by ..... Office Engineer

2-3-11

UNITED STATES DEPARTMENT OF THE INTERIOR GEOLOGICAL SURVEY (WATER RESOURCES DIVISION) RATING CURVE FOR ..... Stn. No. 4

9-279-C (REV. 11-67)



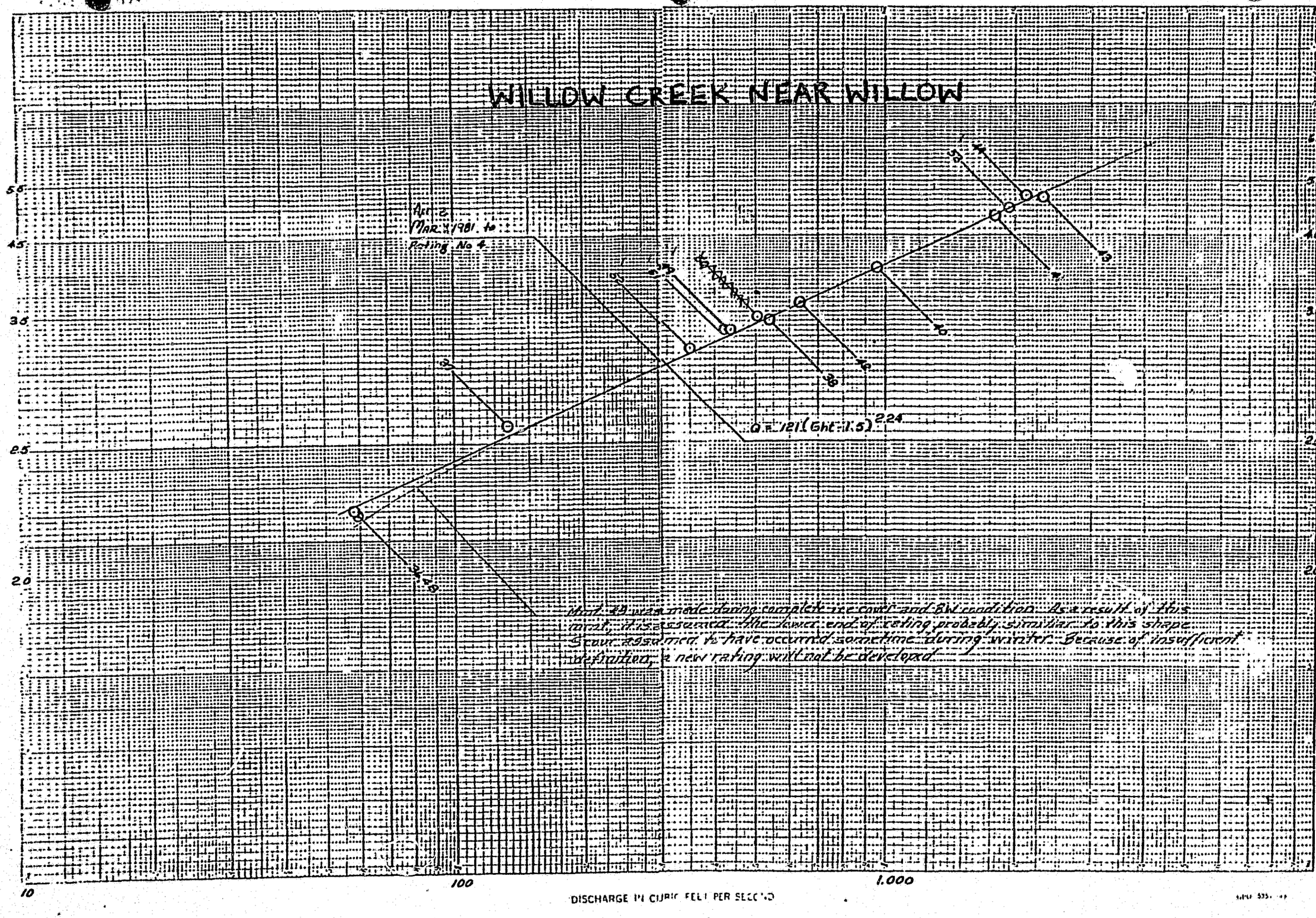
Curve approved by:

.....Office Engineer.

GPO 332-184

2-3-17

UNITED STATES DEPARTMENT OF THE INTERIOR GEOLOGICAL SURVEY WATER RESOURCES DIVISION CURVE FILE Stn. No. 25



Water year	1981	1982
Meas. Nos.	32-44	45-53
Meas. not plotted	32-35	45-49,50
Max G. H.	5.97	6.39

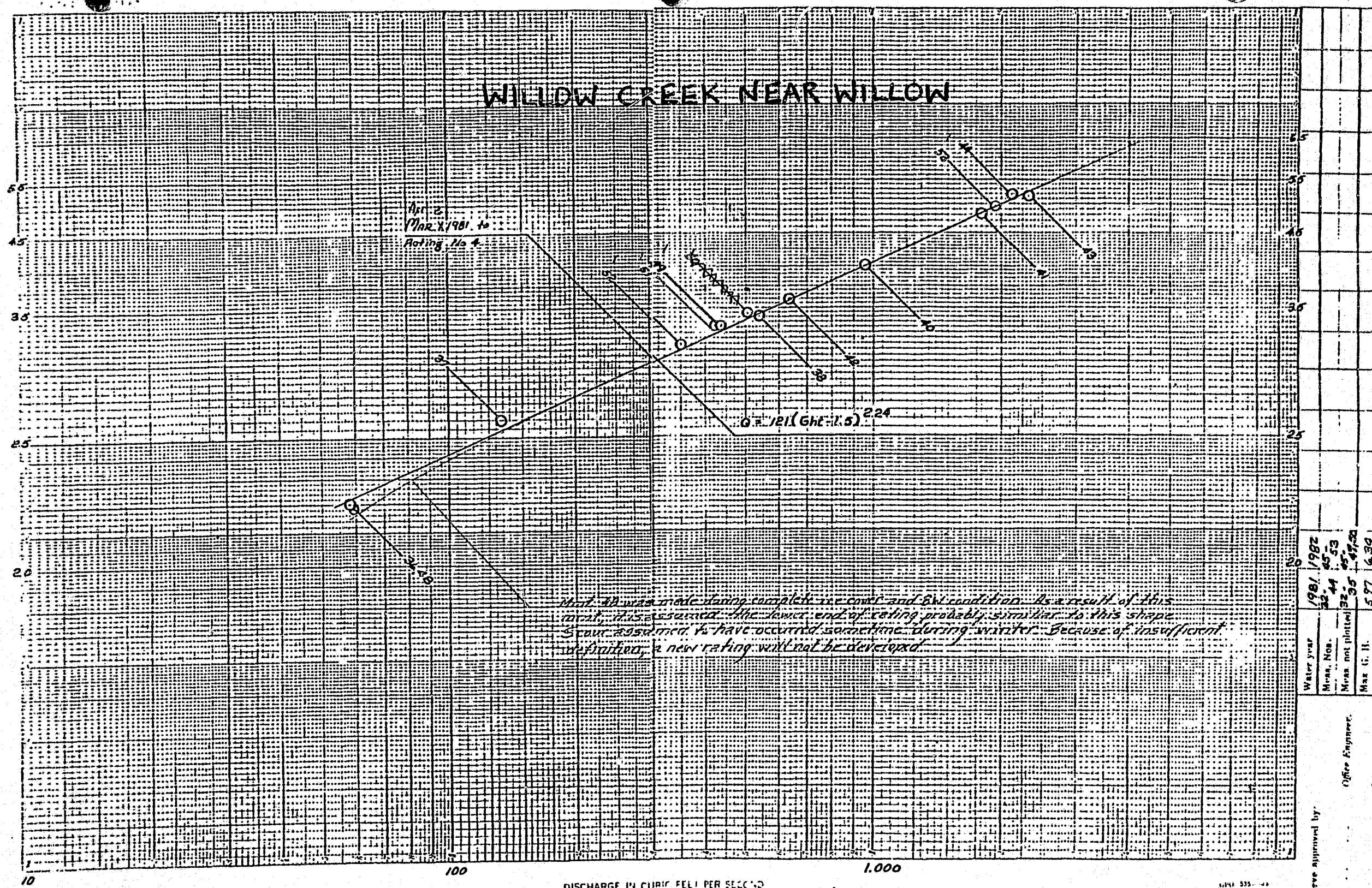
Curve approved by:

Office Engineer

2-3-13

UNITED STATES DEPARTMENT OF THE INTERIOR GEOLOGICAL SURVEY WATER RESOURCES DIVISION CURVE FILE

Stn. No. 25



Water year	1981	1982
Meas. Nos.	32-44	45-53
Meas. not plotted	32-35	45-47,50
Max G. H.	5.97	6.39

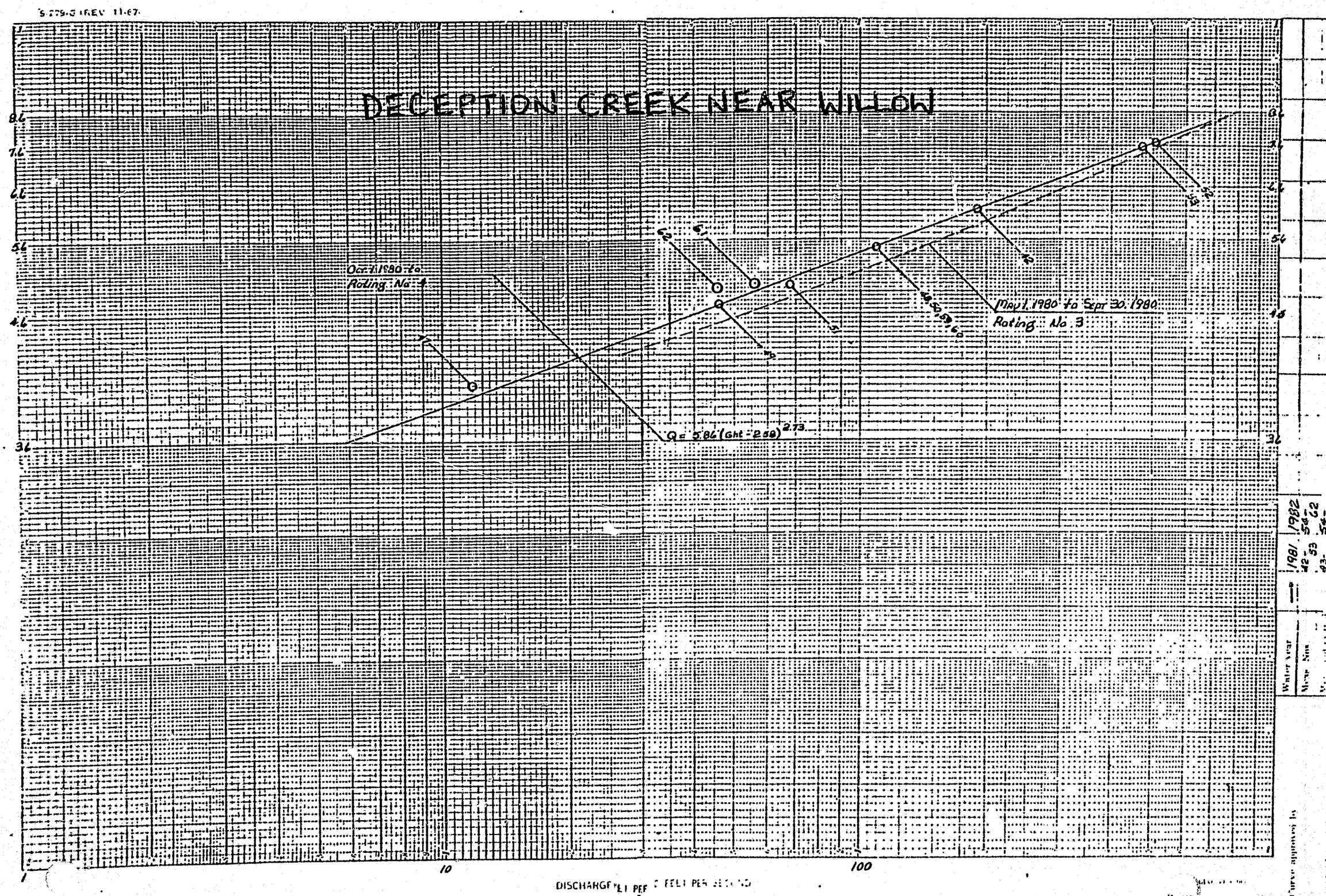
Curve approved by:

Office Engineer.

2-3-13

UNITED STATES DEPARTMENT OF THE INTERIOR GEOLOGICAL SURVEY (WATER RESOURCES DIVISION RATING CURVE FOR ..... Sta. N

9-279-3 (REV. 11-67)



2-3-14

UNITED STATES DEPARTMENT OF THE INTERIOR GEOLOGICAL SURVEY (WATER RESOURCES DIVISION) RATING CURVE FOR.... Sta. No. 152

9-279-G (REV. 11-67)

DESHKA RIVER NEAR WILLOW

RATING NO. 1
17 AUG. 1978

GAGE HEIGHT IN FEET

DISCHARGE IN CUBIC FEET PER SECOND

Water year	1978	1979	1980	1981	1982
Meas. Nos.	2-3	4-12	13-16	17-23	24-28
Meas. not plotted	1	4-6	14	17-18	24-25
Max G. H.			F.11	7.23	

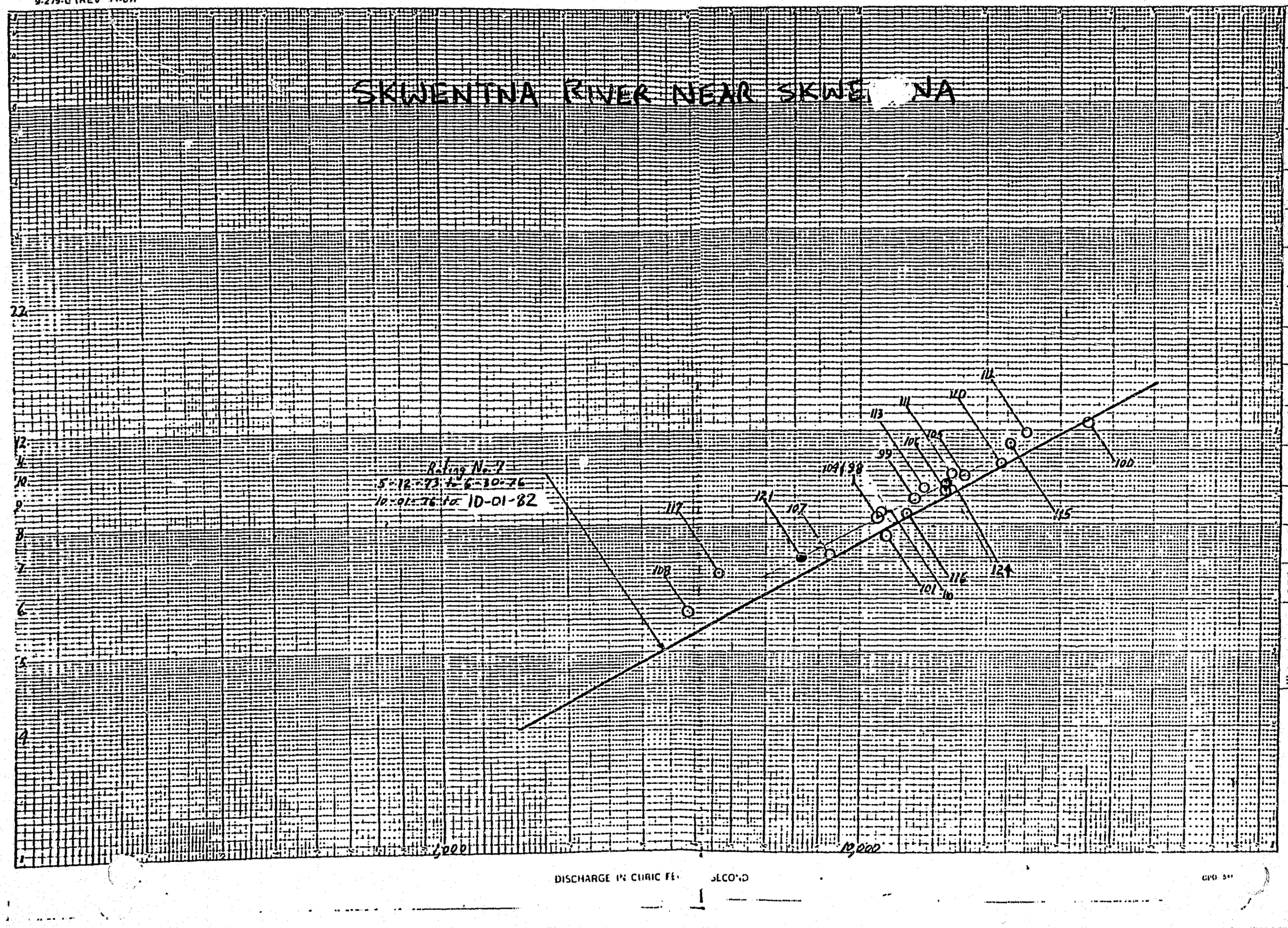
Curve approved by ..... Office Engineer.

..... District Engineer

23-15

UNITED STATES DEPARTMENT OF THE INTERIOR GEOLOGICAL SURVEY (WATER RESOURCES DIVISION) RATING CURVE FOR.... Sta. No. 15[illegible]

9-279-G (REV 11-67)



Water year	1976	1977	1978	1979	1980	1981	1982	1983
Mean Nos.	-98	99-101	102-107	100-112	113-116	117-121	122-124	125
Mean not plotted	must	—	102-103	109	114	116-119	122-123	125
Max G. H.	—	15.09	11.14	13.64	14.76	12.36	14.27	—

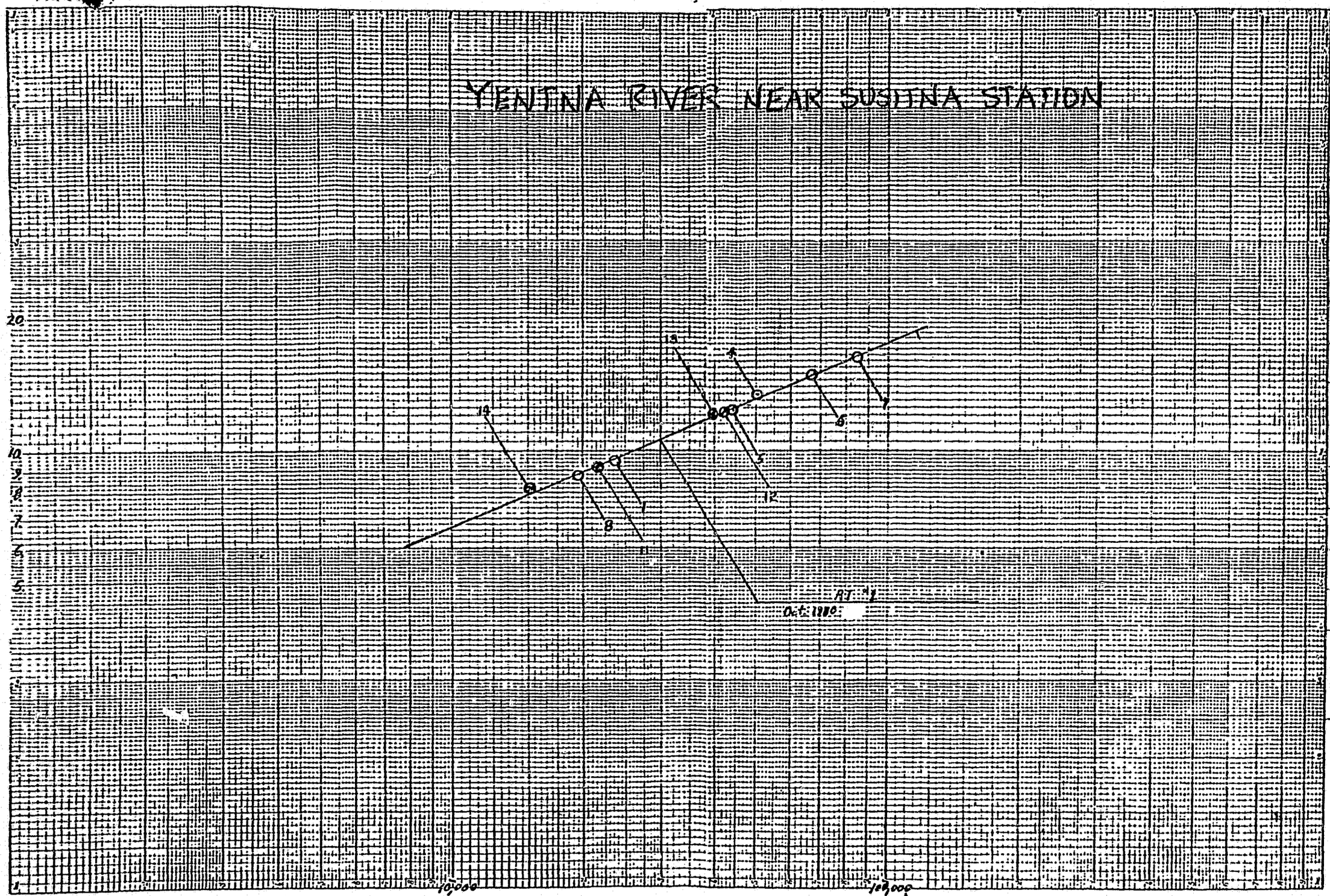
Curve approved by

Office Engineer

2-3-16

UNITED STATES DEPARTMENT OF THE INTERIOR GEOLOGICAL SURVEY (WATER RESOURCES DIVISION) RATING CURVE FOR..... Sta. No. 152

9-279-G (1-57)



Water year	1981	1982
Meas. Nos.	1-8	9-13
Meas. not plotted	2-3	9-10
Max G. H.	13.61	
Min G. H.		

Curve approved by:

..... Office Engineer.

..... District Engineer

GPO 535-068

2-3-17

2. Water Use and Quality

Comment 4 (p. E-2-17, para. 5)

Provide data used to prepare Figure E.2.66 and a detailed discussion (including input data) of this use of HEC-2.

Response

The data used to prepare the stage-discharge diagram on Figure E.2.66 were obtained during 1982. This information is contained in Table 1 (taken from "Preliminary Assessment of Access by Spawning Salmon to Side Slough Habitat above Talkeetna," Trihey, 1982, and from Table 4II-4-2 of Alaska Department of Fish and Game. 1983. Susitna Hydro Aquatic Studies Phase II Basic Data Report, Volume 4, Part II).

The reference made on p. E-2-17 to the use of the HEC-2 analysis for determination of the backwater profiles presented in Figure E.2.65 is incorrect. The water surface profiles for mainstem discharges of 12,500 cfs and 22,500 cfs were based on field observations taken on August 24, 1982, with a slough flow of approximately 3 cfs and on August 2, 1982, with a slough flow of 20 cfs, respectively.

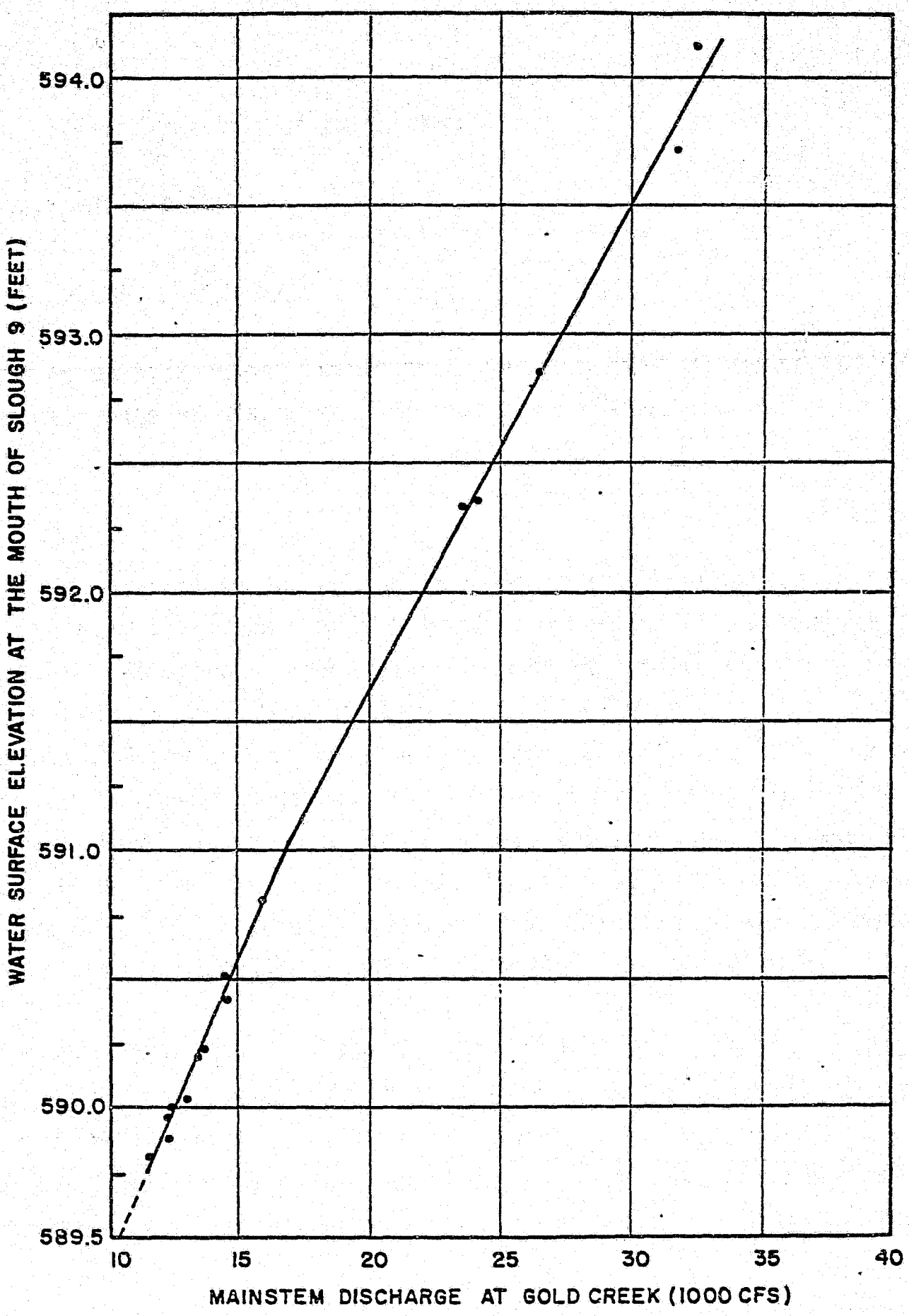
TABLE 1

Comparison of water surface elevations (WSEL) at the entrance to Slough 9 and the average daily mainstem discharge at Gold Creek, 1982.

Date	WSEL[a] (ft)	Gold Creek Discharge (cfs)	Date	WSEL (ft)	Gold Creek Discharge (cfs)
8/24/82	590.03	12,500	9/05/82	590.16	13,600
8/25/82	590.19	13,400	9/06/82	589.91	12,200
8/26/82	590.24	13,600	9/07/82	589.84	11,700
8/27/82	590.04	12,900	9/16/82	594.09	32,500
8/28/82	589.98	12,400	9/17/82	593.71	32,000
8/29/82	589.91	12,200	9/18/82	592.86	26,800
9/02/82	590.82	16,000	9/19/82	592.37	24,100
9/03/82	590.51	14,600	9/20/82	592.36	24,000
9/04/82	590.42	14,400	9/29/82	589.98	12,400

[a]ADF&G gages 129.2 W1A and W1B.

The water surface profiles for mainstem flows of 16,000 and 18,000 cfs were determined by using Figure E.2.66 (attached) to obtain the water surface elevation at the gage location. Since pools existed upstream of the gage location at flows of 12,500 cfs and 22,500 cfs, it was assumed that pools also existed at 16,000 and 18,000 cfs. Hence, the water surfaces at the intermediate flows were drawn in as a horizontal surface upstream until they intersected with the water surface profile for a flow of 12,500 cfs at the upstream end of the pool.



OBSERVED WATER SURFACE ELEVATIONS AT MOUTH OF SLOUGH 9 FOR ASSOCIATED MAINSTEM DISCHARGES AT GOLD CREEK

DATA SOURCE : ADF & G 1982

FIGURE E.2.66

2. Water Use and Quality

Comment 5 (p. E-2-20, para. 1)

Provide data on particle size distribution for suspended sediments collected over the annual range of discharges for the Susitna River.

Response

Susitna River discharges at Gold Creek are least turbid in winter (p. 2-5-2 attached) and most turbid during the months corresponding to maximum discharge (p. 2-5-3 attached, taken from Peratrovich, Nottingham and Drage, Inc., 1982). Winter turbidity is less than 20 NTU's, while turbidity in May, June, July, August, and September may exceed 1,000 NTU's. The size distribution of suspended sediments during the periods of maximum riverine turbidity have been analyzed as shown on p. 2-5-4 attached (taken from Peratrovich, Nottingham and Drage, Inc., 1982). Susitna River suspended sediments are 15-20% (by weight) smaller than 2 microns (mean diameter), 25-35% smaller than 10 microns and 95-100% smaller than 500 microns.

Tables from the Water Quality Annual Reports of 1980, 1981, and 1982 by R & M Consultants, Inc., (pp. 2-5-5 to 2-5-44 attached) contain data describing the turbidity particle size distribution. Suspended sediment size distributions from four sampling locations on the Susitna River during different months and different years are shown on pp. 2-5-45 to 2-5-51 attached.

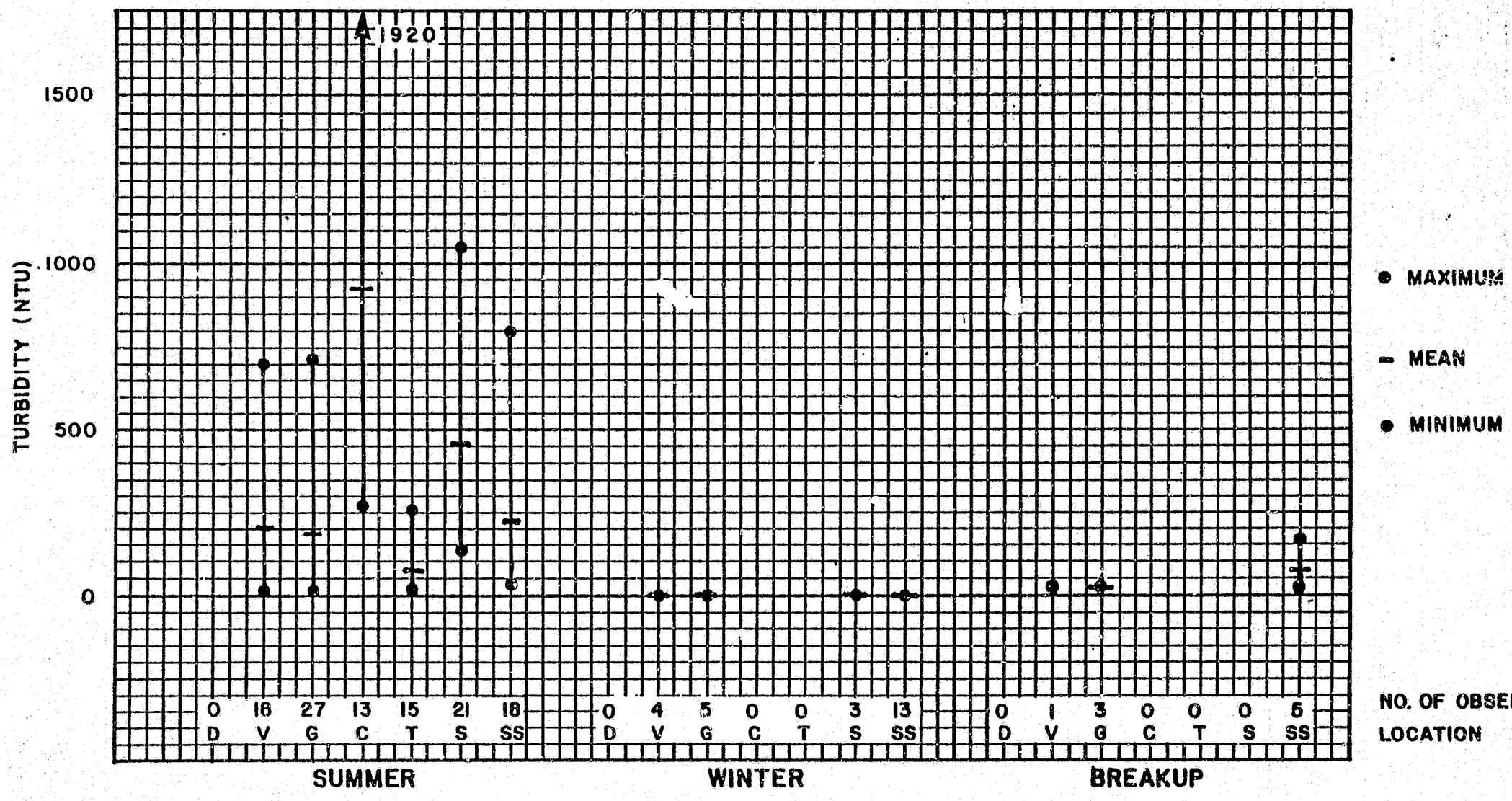
References

Peratrovich, Nottingham and Drage, Inc. and Ian P.G. Hutchinson, 1982. Susitna Reservoir Sedimentation and Water Clarity Study. Prepared for Acres American Inc., Anchorage, Alaska, 35 pp.

R & M Consultants, Inc. 1980. Susitna Hydroelectric Project Water Quality Report. Prepared for Acres American, Inc., Anchorage, Alaska.

R & M Consultants, Inc. 1981. Susitna Hydroelectric Project Water Quality Report. Prepared for Acres American, Inc., Anchorage, Alaska.

R & M Consultants, Inc. 1982. Susitna Hydroelectric Project Water Quality Report. Prepared for Acres American, Inc., Anchorage, Alaska.



NOTES:

I.A. CRITERION: SHALL NOT EXCEED 25 NTU ABOVE NATURAL CONDITIONS (ADEC 1979).

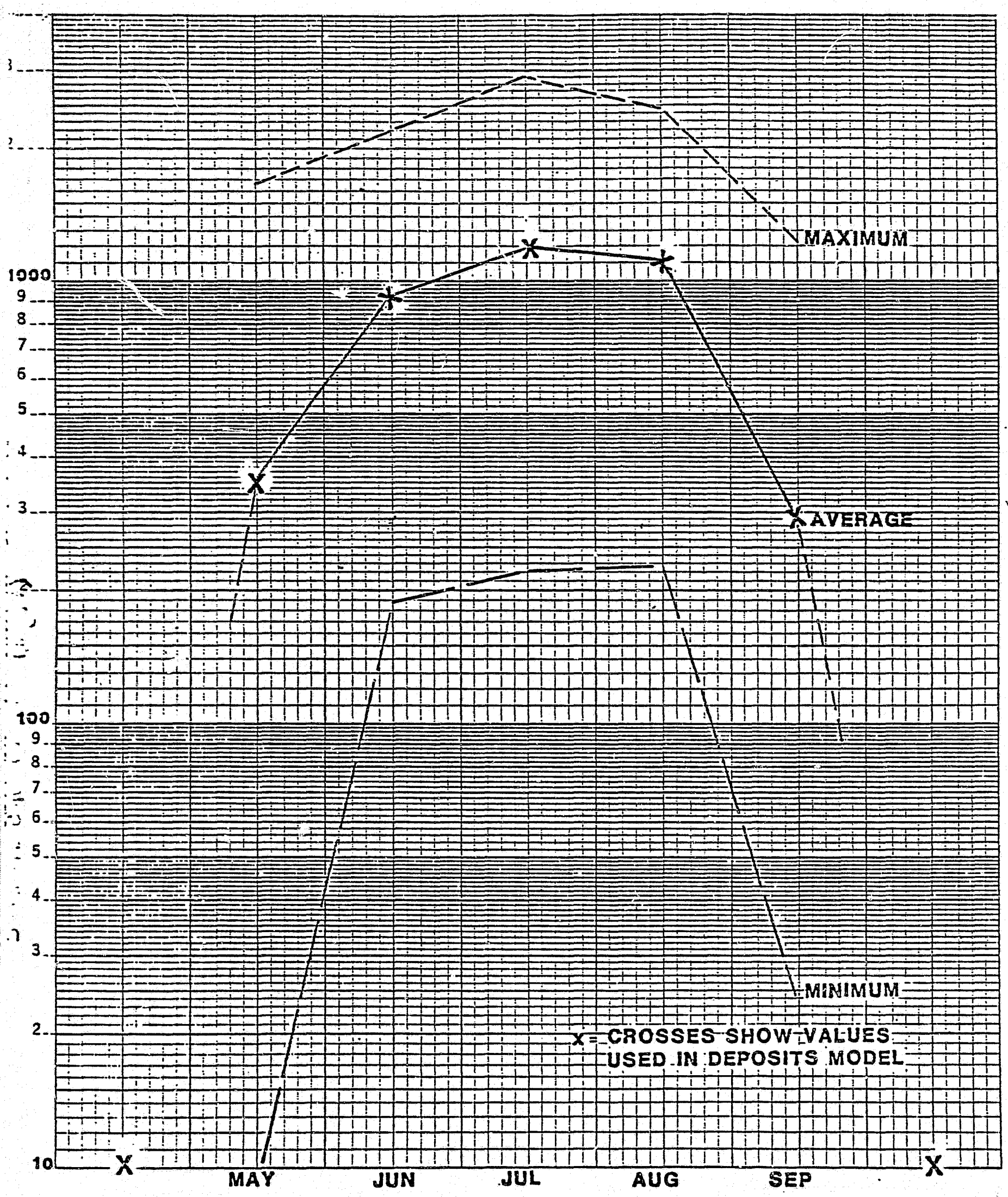
I.B. ESTABLISHED TO PREVENT THE REDUCTION OF THE COMPENSATION POINT FOR PHOTOSYNTHETIC ACTIVITY, WHICH MAY HAVE ADVERSE EFFECTS ON AQUATIC LIFE.

2-51-2

DATA SUMMARY - TURBIDITY

SOURCE: USGS AND R&M

FIGURE E.2.81



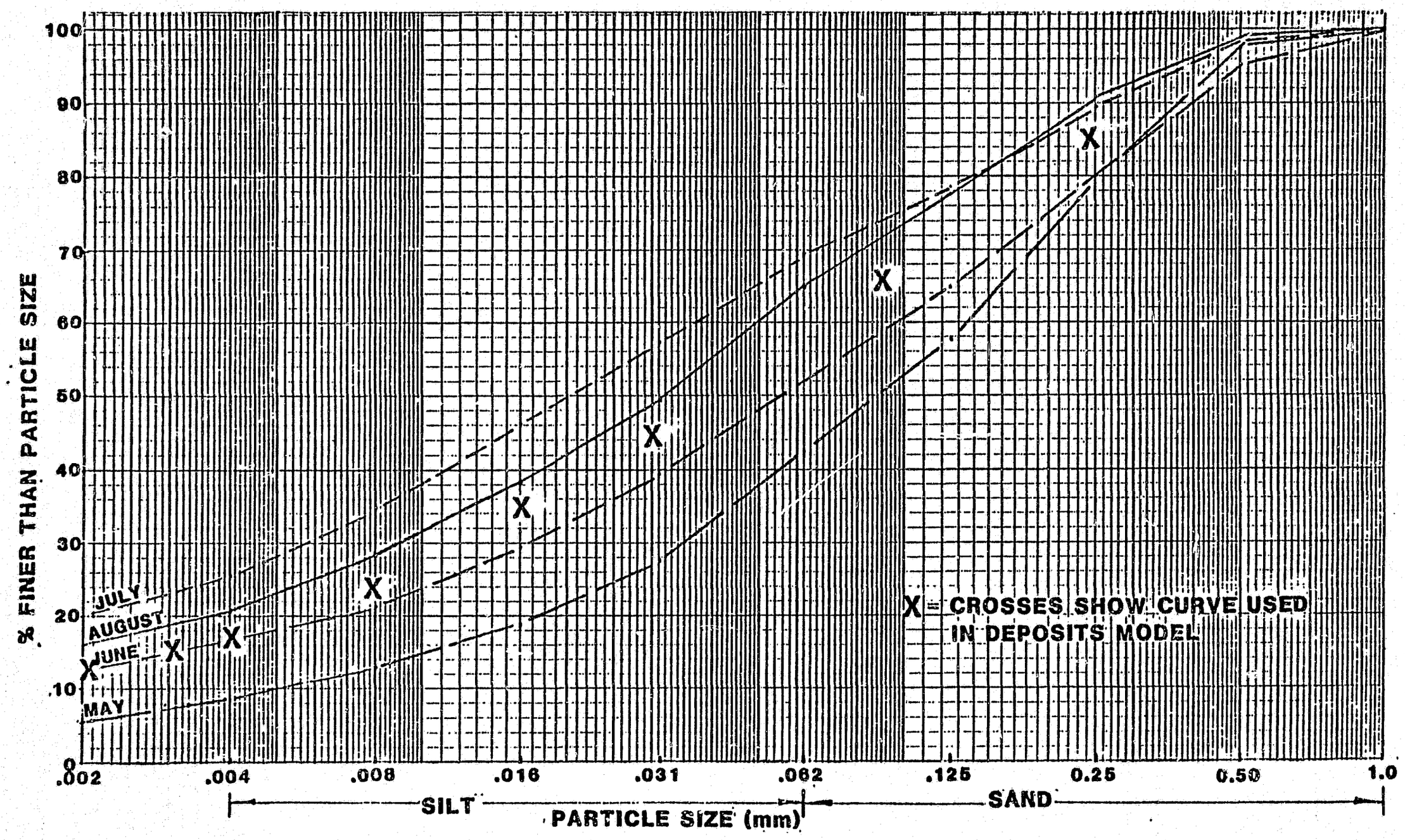
SUSITNA RIVER AT GOLD CREEK SEDIMENT CONCENTRATION-SUMMER VALUES ONLY (1952-1981)*

*DOES NOT INCLUDE 1981 USGS DATA-

FIGURE 5.1

PERATROVICH, NOTTINGHAM & DRAGE, INC.
ENGINEERING CONSULTANTS

2-5-3



4-5-2

SUSITNA RIVER AT GOLD CREEK
AVERAGE MONTHLY PARTICLE SIZE DISTRIBUTION

FIGURE 5.2

PERATROVICH, NOTTINGHAM & DRAGE, INC.
ENGINEERING CONSULTANTS

SUSITNA HYDROELECTRIC PROJECT

WATER QUALITY ANNUAL REPORT 1980

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Alaska Power Authority
334 W. 5th Ave.
Anchorage, Alaska 99501

APRIL 1981

PREPARED BY:

R&M CONSULTANTS, INC.

PREPARED FOR:

ALASKA POWER AUTHORITY

2-5-5

TABLE 2

SUSPENDED SEDIMENT ANALYSIS - September 5, 1980
SUSITNA RIVER NEAR CANTWELL (VEE CANYON SITE)

SIZE, Microns	COUNT/sq mm - %		
	SAMPLE 4	SAMPLE 9	SAMPLE 14
<1-5	3207-99.57	2335-98.52	1779-97.21
5-10	7 - 0.22	23-0.97	26 - 1.42
10-20	4 - 0.12	6-0.25	12 - 0.66
20-50	1 - 0.03	1-0.04	7 - 0.38
>50	2 - 0.06	5-0.22	6 - 0.33

SAMPLE NO.	DATE/TIME	STATION*	INT. TIME	Milligrams/Liter SUSPENDED SOLIDS
1	9-5-80 5:15 p.m.	0 + 15	49 sec	33
2	9-5-80 5:26 p.m.	0 + 35	42 sec	36
3	9-5-80 5:30 p.m.	0 + 55	42 sec	35
4	9-5-80 5:35 p.m.	0 + 75	42 sec	54
5	9-5-80 5:45 p.m.	0 + 95	40 sec	63
6	9-5-80 5:50 p.m.	1 + 15	44 sec	36
7	9-5-80 5:55 p.m.	1 + 35	44 sec	68
8	9-5-80 6:00 p.m.	1 + 55	44 sec	62
9	9-5-80 6:05 p.m.	1 + 75	52 sec	74
10	9-5-80 6:08 p.m.	1 + 95	52 sec	68
11	9-5-80 6:10 p.m.	2 + 15	48 sec	73
12	9-5-80 6:13 p.m.	2 + 35	42 sec	72
13	9-5-80 6:15 p.m.	2 + 55	48 sec	78
14	9-5-80 6:20 p.m.	2 + 75	48 sec	84
15	9-5-80 6:25 p.m.	2 + 95	50 sec	67
16	9-5-80 6:30 p.m.	3 + 15	48 sec	82
17	9-5-80 6:35 p.m.	3 + 35	51 sec	53
18	9-5-80 6:45 p.m.	3 + 55	80 sec	56

* Right Bank (edge of water) is at Station 0+05.
Left Bank (edge of water) is at Station 3+85.

susi4/d

2-5-6

TABLE 3

SUSPENDED SEDIMENT ANALYSIS - September 17, 1980
SUSITNA RIVER NEAR CANTWELL (VEE CANYON SITE)

Sample No.	SAMPLE DESCRIPTION	Particle Size Distribution, Microns				
		≤5	5-10	10-20	20-50	>50
3	Sta 0+70, 9-17-80, 5:46 p.m.	98.53	0.96	0.30	0.15	0.06
8	Sta 1+70, 9-17-80, 6:11 p.m.	98.83	0.44	0.23	0.10	0.40
13	Sta 2+70, 9-17-80, 6:19 p.m.	99.19	0.30	0.10	0.07	0.34

SAMPLE NO.	DATE/TIME	STATION*	INT. TIME	Milligrams/Liter SUSPENDED SOLIDS
1	9-17-80 5:30 p.m.	0 + 30	30 sec	167
2	9-17-80 5:39 p.m.	0 + 50	50 sec	170
3	9-17-80 5:46 p.m.	0 + 70	55 sec	174
4	9-17-80 5:48 p.m.	0 + 90	55 sec	185
5	9-17-80 5:51 p.m.	1 + 10	55 sec	196
6	9-17-80 6:06 p.m.	1 + 30	36 sec	425
7	9-17-80 6:09 p.m.	1 + 50	36 sec	325
8	9-17-80 6:11 p.m.	1 + 70	30 sec	331
9	9-17-80 6:13 p.m.	1 + 90	30 sec	218
10	9-17-80 6:14 p.m.	2 + 10	30 sec	201
11	9-17-80 6:16 p.m.	2 + 30	30 sec	513
12	9-17-80 6:18 p.m.	2 + 50	30 sec	169
13	9-17-80 6:19 p.m.	2 + 70	30 sec	436
14	9-17-80 6:21 p.m.	2 + 90	35 sec	418
15	9-17-80 6:23 p.m.	3 + 10	35 sec	591
16	9-17-80 6:24 p.m.	3 + 30	35 sec	322
17	9-17-80 6:26 p.m.	3 + 50	40 sec	342
18	9-17-80 6:30 p.m.	3 + 70	45 sec	163
19	9-17-80 6:35 p.m.	3 + 85	60 sec	300

* Right edge of water is at Station 0+00.
Left edge of water is at Station 4+00.

2-5-7

WATER QUALITY ANNUAL REPORT
TABLE 4

Suspended Sediment Analysis - October 18, 1980
Susitna River Near Cantwell (Vee Canyon Site)

Size Microns	Particle Site Distribution-% Sample 3	Sample 6	Sample 9
< 5	77.0	82.6	79.5
5-10	12.7	8.1	15.5
10-20	5.4	4.5	3.2
20-50	4.4	4.2	1.2
> 50	0.5	0.6	0.6
	100.0%	100.0%	100.0%

Sample No.	Date/Time	Station*	Int. Time	Milligrams/Liter Suspended Solids
1	10-18-80/12:30 p.m.	0+07	120 sec.	6.0
2	10-18-80/12:35 p.m.	0+36	90 sec.	6.6
3	10-18-80/12:40 p.m.	0+70	75 sec.	4.8
4	10-18-80/12:43 p.m.	1+05	60 sec.	4.2
5	10-18-80/12:49 p.m.	1+38	60 sec.	4.6
6	10-18-80/12:51 p.m.	1+74	60 sec.	6.3
7	10-18-80/12:55 p.m.	2+07	72 sec.	4.4
8	10-18-80/12:59 p.m.	2+38	72 sec.	5.0
9	10-18-80/1:02 p.m.	2+73	72 sec.	7.7
10	10-18-80/1:06 p.m.	3+08	80 sec.	7.4
11	10-18-80/1:10 p.m.	3+39	80 sec.	5.8

* Right edge of water is at Station 0+00.
Left edge of water is at Station 3+78.

2-5-8

WATER QUALITY ANNUAL REPORT
TABLE 5

Suspended Sediment Analysis - January 13, 1981
Susitna River Near Cantwell (Vee Canyon Site)

Particle Size Distribution
Sample No. 11

Size, Microns	Count/Sq. mm	%
< 10	1600	98.7
10-20	15	0.9
20-50	5	0.3
50-100	2	0.1
>100	0	0.
		100.0%

Sample No.	Date/Time	Station	Int. Time	Milligrams/Liter Suspended Solids
10	1-13-81/2:20 p.m.	Left bank	40 sec.	0.1
11	1-13-81/2:30 p.m.	Center	40 sec.	1.0
12	1-13-81/2:35 p.m.	Right bank	54 sec.	1.7

2-5-9

WATER QUALITY ANNUAL REPORT
TABLE 7

Suspended Sediment Analysis - October 16, 1980
Susitna River at Gold Creek

---------- Particle Size Distribution-% ----------

Size Microns	Sample 2	Sample 5	Sample 8
< 5	77.4	78.1	74.1
5-10	13.2	11.6	13.4
10-20	5.6	7.4	6.4
20-50	3.3	2.3	5.7
>50	0.5	0.6	0.4
	100.0%	100.0%	100.0%

Sample No.	Date/Time	Station*	Int. Time	Milligrams/Liter Suspended Solids
1	10-16-80/4:22 p.m.	12+45	120 sec.	8.4
2	10-16-80/4:28 p.m.	12+76	90 sec.	9.0
3	10-16-80/4:34 p.m.	13+11	54 sec.	9.2
4	10-16-80/4:40 p.m.	13+46	40 sec.	7.2
5	10-16-80/4:43 p.m.	13+81	48 sec.	11.0
6	10-16-80/4:48 p.m.	14+16	49 sec.	8.0
7	10-16-80/4:54 p.m.	14+51	60 sec.	7.8
8	10-16-80/5:01 p.m.	14+86	68 sec.	8.0
9	10-16-80/5:05 p.m.	15+21	100 sec.	1.2

* Left edge of water is at Station 12+01.
Right edge of water is at Station 15+64.

2-5-10

WATER QUALITY ANNUAL REPORT
TABLE 8

Suspended Sediment Analysis - January 14, 1981
Susitna River at Gold Creek

Particle Size Distribution
Sample No. 4

Size, Microns	Count/Sq. mm	%
< 10	96	80.0
10-20	9	7.5
20-50	11	9.2
50-100	3	2.5
>100	1	0.8*
		100.0%

Sample No.	Date/Time	Station*	Int. Time	Milligrams/Liter Suspended Solids
4	1-14-81/3:00 p.m.	Left bank	55 sec.	0.4
5	1-14-81/3:15 p.m.	Center	70 sec.	10.6
6	1-14-81/3:35 p.m.	Right bank	120 sec.	10.4

* There were a few specimens of fibrous material approximately 1000 microns in length.

2-5-11

SUSITNA HYDROELECTRIC PROJECT

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2:109

2-5-12

TABLE 3.3
R&M CONSULTANTS, INC.
SUSPENDED SEDIMENT ANALYSIS
SUSITNA RIVER AT VEE CANYON

Date: September 5, 1980
Water Temperature: 5.3°C
Instantaneous Discharge: 5,040 c.f.s.

REW: 00+05
LEW: 03+85

Sample No.	Time	Station	Sediment (mg/l.)
1	5:15 pm	00+15	33
2		00+35	36
3		00+55	35
4		00+75	54
5		00+95	63
6		01+15	36
7		01+35	68
8		01+55	62
9		01+75	74
10		01+95	68
11		02+15	73
12		02+35	72
13		02+55	78
14		02+75	84
15		02+95	67
16		03+15	82
17		03+35	53
18	6:45 pm	03+55	56
			Average 61

Particle Distribution
% by Size

Size (Microns)	Sample: 4	Sample: 9	Sample: 14	Average
5	99.57	98.52	97.21	98.43
5-10	0.22	0.97	1.42	0.87
10-20	0.12	0.25	0.66	0.34
20-50	0.03	0.04	0.38	0.15
50	0.06	0.22	0.33	0.20

Suspended Sediment Discharge (Tons/Day): 827

2-5-13

TABLE 3.4
R&M CONSULTANTS, INC.
SUSPENDED SEDIMENT ANALYSIS
SUSITNA RIVER AT VEE CANYON

Date: September 17, 1980
Water Temperature: 5.9°C
Instantaneous Discharge: 14,200 c.f.s.

REW: 00+00
LEW: 04+00

Sample No.	Time	Station	Sediment (mg/l.)
1	5:30 pm	00+30	167
2		00+50	170
3		00+70	174
4		00+90	185
5		01+10	196
6		01+30	425
7		01+50	325
8		01+70	331
9		01+90	218
10		02+10	201
11		02+30	513
12		02+50	169
13		02+70	436
14		02+90	418
15		03+10	591
16		03+30	322
17		03+50	342
18		03+70	163
19	6:35 pm	03+85	300
			Average 297

Particle Distribution
% by Size

Size (Microns)	Sample: 3	Sample: 8	Sample: 13	Average
5	98.53	98.83	99.19	98.85
5-10	0.96	0.44	0.30	0.57
10-20	0.30	0.23	0.10	0.21
20-50	0.15	0.10	0.07	0.11
50	0.06	0.40	0.34	0.27

Suspended Sediment Discharge (Tons/Day): 11,345

2-5-14.

TABLE 3.5
R&M CONSULTANTS, INC.
SUSPENDED SEDIMENT ANALYSIS
SUSITNA RIVER AT VEE CANYON

Date: October 18, 1980
Water Temperature: 0.0°C
Instantaneous Discharge: 5,000 c.f.s.

REW: 00+00
LEW: 03+78

Sample No.	Time	Station	Sediment (mg/l.)
1	12:30 pm	00+07	6.0
2		00+36	6.6
3		00+70	4.8
4		01+05	4.2
5		01+38	4.6
6		01+74	6.3
7		02+07	4.4
8		02+38	5.0
9		02+73	7.7
10		03+08	7.4
11	1:15 pm	03+39	5.8
		Average	5.7

Particle Distribution
% by Size

Size (Microns)	Sample: 3	Sample: 6	Sample: 9	Average
5	77.0	82.6	79.5	79.7
5-10	12.7	8.1	15.5	12.1
10-20	5.4	4.5	3.2	4.4
20-50	4.4	4.2	1.2	3.3
50	0.5	0.6	0.6	0.6

Suspended Sediment Discharge (Tons/Day): 77

2-5-15

TABLE 3.6
R&M CONSULTANTS, INC.
SUSPENDED SEDIMENT ANALYSIS
SUSITNA RIVER AT GOLD CREEK

Date: October 16, 1980
Water Temperature: 0.0°C
Instantaneous Discharge: 7,000 c.f.s.

REW: 12+01
LEW: 15+74

Sample No.	Time	Station	Sediment (mg/l.)
1	4:22 pm	12+45	8.4
2		12+76	9.0
3		13+11	9.2
4		13+46	7.2
5		13+81	11.0
6		14+16	8.0
7		14+51	7.8
8		14+86	8.0
9	5:30 pm	15+21	1.2
		Average	7.8

Particle Distribution
% by Size

Size (Microns)	Sample: 2	Sample: 5	Sample: 8	Average
5	77.4	78.1	74.1	76.5
5-10	13.2	11.6	13.4	12.7
10-20	5.6	7.4	6.4	6.5
20-50	3.3	2.3	5.7	3.8
50	0.5	0.6	0.4	0.5

Suspended Sediment Discharge (Tons/Day): 147

2-5-16

TABLE 4.5

R&M CONSULTANTS, INC.

SUSPENDED SEDIMENT ANALYSIS

SUSITNA RIVER AT VEE CANYON

Date: January 13, 1981

Water Temperature: 0.1°C

Instantaneous Discharge: 5000 c.f.s.

Sample No.	Time	Station	Sediment (mg/l.)
10	2:20 p.m.	Left Bank	0.1
11	2:30 p.m.	Center	1.0
12	2:35 p.m.	Right Bank	1.7
		Average	0.93

Particle Distribution
% by Size

Size (Microns)	Sample: 11	Sample:	Sample:	Average
< 10	98.7			98.7
10-20	0.9			0.9
25-50	0.3			0.3
50-100	0.1			0.1
>100	0.0			0.0

Suspended Sediment Discharge (Tons/Day): 12

2-5-17

TABLE 4.6
R&M CONSULTANTS, INC.
SUSPENDED SEDIMENT ANALYSIS
SUSITNA RIVER AT VEE CANYON

Date: May 20, 1981
Water Temperature: 6.5°C
Instantaneous Discharge: 9810 c.f.s.

REW: 00+05
LEW: 04+00

Sample No.	Time	Station	Sediment (mg/l.)
1	4:34 p.m.	00+50	150
2		00+75	130
3		01+00	120
4		01+25	120
5		01+50	140
6		01+75	120
7		02+00	130
8		02+25	130
9		02+50	120
10		02+75	140
11		03+00	140
12		03+25	130
13		03+50	150
14	5:25 p.m.	03+75	130
		Average	132

Particle Distribution
% by Size

Size (Microns)	Sample: 4	Sample: 8	Sample: 11	Average
<10	97.42	97.77	97.78	97.66
10-20	1.74	1.69	1.54	1.66
20-50	0.72	0.46	0.47	0.55
50-100	0.10	0.08	0.19	0.12
>100	0.02	0.00	0.02	0.10

Suspended Sediment Discharge (Tons/Day): 3,483

TABLE 4.7

R&M CONSULTANTS, INC.

SUSPENDED SEDIMENT ANALYSIS

SUSITNA RIVER AT VEE CANYON

Date: June 18, 1981 REW: 04+25

Water Temperature: 11.9°C LEW: 00+00

Instantaneous Discharge: 11,600 c.f.s.

Sample No.	Time	Station	Sediment (mg/l.)
1	2:30 p.m.	00+50	300
2		00+75	310
3		01+00	310
4		01+25	300
5		01+50	310
6		01+75	300
7		02+00	300
8		02+25	310
9		02+50	340
10		02+75	320
11		03+00	340
12		03+25	320
13		03+50	320
14	3:15 p.m.	03+75	350
		Average	316

Particle Distribution
% by Size

Size (Microns)	Sample: 4	Sample: 8	Sample: 11	Average
<10	97.88	98.49	99.05	98.51
10-20	1.70	1.19	0.62	1.17
20-50	0.39	0.25	0.23	0.29
50-100	0.03	0.06	0.08	0.06
>100	0.00	0.01	0.02	0.01

Suspended Sediment Discharge (Tons/Day): 9,860

2-5-19

TABLE 4.8

R&M CONSULTANTS, INC.

SUSPENDED SEDIMENT ANALYSIS

SUSITNA RIVER AT VEE CANYON

Date: June 30, 1981 REW: 04+00

Water Temperature: 7.9°C LEW: 00+00

Instantaneous Discharge: 13,700 c.f.s.

Sample No.	Time	Station	Sediment (mg/l.)
1	6:00 p.m.	00+15	140
2		00+40	160
3		00+80	195
4		01+20	180
5		01+60	160
6		02+00	200
7		02+40	180
8		02+80	190
9		03+20	160
10	6:30 p.m.	03+60	150
		Average	172

Particle Distribution
% by Size

Size (Microns)	Sample: 3	Sample: 6	Sample: 9	Average
<10	98.26	97.14	97.95	97.78
10-20	1.48	2.55	1.90	1.98
20-50	0.23	0.22	0.11	0.19
50-100	0.01	0.08	0.01	0.03
>100	0.02	0.01	0.03	0.02

Suspended Sediment Discharge (Tons/Day): 6,339

2-5-20

TABLE 4.9

R&M CONSULTANTS, INC.

SUSPENDED SEDIMENT ANALYSIS

SUSITNA RIVER AT VEE CANYON

Date: August 2, 1981 REW: 04+15

Water Temperature: 8.1°C LEW: 00+00

Instantaneous Discharge: 26,375 c.f.s.

Sample No.	Time	Station	Sediment (mg/l.)
1	4:00 p.m.	00+15	600
2		00+40	710
3		00+80	905
4		01+20	850
5		01+60	840
6		02+00	930
7		02+40	960
8		02+80	860
9		03+20	840
10	4:45 p.m.	03+60	830
		Average	839

Particle Distribution
% by Size

Size (Microns)	Sample: 3	Sample: 6	Sample: 9	Average
<10	91.82	93.22	94.90	93.31
10-20	6.02	4.85	4.04	4.97
20-50	1.77	1.62	0.93	1.44
50-100	0.26	0.26	0.07	0.20
>100	0.13	0.05	0.06	0.08

Suspended Sediment Discharge (Tons/Day): 59,526

2-5-21

TABLE 4.10

R&M CONSULTANTS, INC.

SUSPENDED SEDIMENT ANALYSIS

SUSITNA RIVER AT VEE CANYON

Date: August 3, 1981 REW: 04+15

Water Temperature: 8.1°C LEW: 00+00

Instantaneous Discharge: 29,420 c.f.s.

Sample No.	Time	Station	Sediment (mg/l.)
1	8:00 a.m.	00+15	805
2		00+40	860
3		00+80	705
4		01+20	705
5		01+60	770
6		02+00	790
7		02+40	750
8		02+80	760
9		03+20	725
10	8:45 a.m.	03+60	680
		Average	755

Particle Distribution
% by Size

Size (Microns)	Sample: 3	Sample: 6	Sample: 9	Average
<10	95.54	95.59	94.54	95.22
10-20	3.39	3.35	3.64	3.46
20-50	0.92	0.91	1.42	1.08
50-100	0.08	0.08	0.29	0.15
>10	0.07	0.07	0.11	0.08

Suspended Sediment Discharge (Tons/Day): 59,750

2-5-22

TABLE 4.11

R&M CONSULTANTS, INC.

SUSPENDED SEDIMENT ANALYSIS

SUSITNA RIVER AT VEE CANYON

Date: August 3, 1981

Water Temperature: 9.8°C

Instantaneous Discharge: 28,000 c.f.s.

REW: 04+15

LEW: 00+00

Sample No.	Time	Station	Sediment (mg/l.)
1	2:30 p.m.	00+15	730
2		00+40	545
3		00+80	590
4		01+20	510
5		01+60	720
6		02+00	670
7		02+40	550
8		02+80	595
9		03+20	570
10	3:15 p.m.	03+60	675
		Average	616

Particle Distribution
% by Size

Size (Microns)	Sample: 3	Sample: 6	Sample: 9	Average
<10	93.69	95.55	95.32	94.85
10-20	5.02	3.60	3.59	4.07
20-50	1.03	0.69	0.82	0.85
50-100	0.21	0.13	0.21	0.18
>100	0.05	0.03	0.06	0.05

Suspended Sediment Discharge (Tons/Day): 46,400

2-5-23

TABLE 4.12
R&M CONSULTANTS, INC.
SUSPENDED SEDIMENT ANALYSIS
SUSITNA RIVER AT VEE CANYON

Date: September 15, 1981
Water Temperature: 5.9°C
Instantaneous Discharge: 7790 c.f.s.

REW: 04+10
LEW: 00+00

Sample No.	Time	Station	Sediment (mg/l.)
1	12:45 p.m.	00+40	54
2		00+80	50
3		01+20	44
4		01+60	43
5		02+00	49
6		02+40	46
7		02+80	62
8		03+20	32
9	1:30 p.m.	03+60	44
		Average	47

Particle Distribution
% by Size

Size (Microns)	Sample: 3	Sample: 6	Sample: 9	Average
<10	97.60	97.53	96.90	97.34
10-20	1.65	2.03	2.61	2.10
20-50	0.47	0.28	0.26	0.34
50-100	0.06	0.04	0.04	0.05
100-250	0.10	0.07	0.12	0.10
250-500	0.12	0.00	0.07	0.08
>500	0.00	0.00	0.00	0.00

Suspended Sediment Discharge (Tons/Day): 985

susi9/j

2-5-24

TABLE 4.13

R&M CONSULTANTS, INC.

SUSPENDED SEDIMENT ANALYSIS

SUSITNA RIVER AT GOLD CREEK

Date: January 14, 1981

Water Temperature: 0.3°C

Instantaneous Discharge: NA

Sample No.	Time	Station	Sediment (mg/l.)
4	1500	Left Bank	4.1
5	1515	Center	10.6
6	1535	Right Bank	10.4
		Average	8.4

Particle Distribution
% by Size

Size (Microns)	Sample: 4	Sample:	Sample:	Average
<10	80.0			80.0
10-20	7.5			7.5
20-50	9.2			9.2
50-100	2.5			2.5
>100	0.8			0.8

Suspended Sediment Discharge (Tons/Day): NA

(4)

2-5-25

TABLE 4.14

R&M CONSULTANTS, INC.

SUSPENDED SEDIMENT ANALYSIS

SUSITNA RIVER AT GOLD CREEK

Date: May 27, 1981 REW: 04+34

Water Temperature: 10.5°C LEW: 00+56

Instantaneous Discharge: 14,400 c.f.s.

Sample No.	Time	Station	Sediment (mg/l.)
1	4:11 p.m.	00+90	73
2		01+18	71
3		01+46	64
4		01+74	69
5		02+02	71
6		02+30	75
7		02+58	69
8		02+86	68
9		03+14	64
10		03+42	51
11		03+70	53
12	4:40 p.m.	03+98	49
			Average 65

Particle Distribution
% by Size

Size (Microns)	Sample: 4	Sample: 7	Sample: 10	Average
<10	97.94	97.29	97.94	97.72
10-20	1.62	2.23	1.62	1.82
20-50	0.36	0.46	0.36	0.36
50-100	0.05	0.02	0.05	0.04
>100	0.03	0.00	0.03	0.02

Suspended Sediment Discharge (Tons/Day): 2,520

2-5-26

TABLE 4.15
R&M CONSULTANTS, INC.
SUSPENDED SEDIMENT ANALYSIS
SUSITNA RIVER AT GOLD CREEK

Date: June 17, 1981
Water Temperature: 12.8°C
Instantaneous Discharge: 17,700 c.f.s.

REW: 04+13
LEW: 00+00

Sample No.	Time	Station	Sediment (mg/l.)
1	4:30 p.m.	00+50	160
2		00+78	180
3		01+06	150
4		01+34	150
5		01+62	180
6		01+90	160
7		02+18	150
8		02+46	150
9		02+74	140
10		03+02	150
11		03+30	130
12	5:10 p.m.	03+58	110
			Average 151

Particle Distribution
% by Size

Size (Microns)	Sample: 4	Sample: 8	Sample: 11	Average
< 10	98.24	98.32	97.76	98.11
10-20	1.64	1.25	2.15	1.68
20-50	0.06	0.30	0.06	0.14
50-100	0.06	0.10	0.03	0.06
>100	0.00	0.03	0.00	0.01

Suspended Sediment Discharge (Tons/Day): 7,190

2-5-27

TABLE 4.16
R&M CONSULTANTS, INC.
SUSPENDED SEDIMENT ANALYSIS
SUSITNA RIVER AT GOLD CREEK

Date: June 30, 1981
Water Temperature: 7.3°C
Instantaneous Discharge: 24,550 c.f.s.

REW: 04+14
LEW: 00+00

Sample No.	Time	Station	Sediment (mg/l.)
1	8:00 a.m.	00+84	230
2		01+26	190
3		01+68	190
4		02+10	210
5		02+52	180
6		02+94	160
7		03+36	150
8		03+78	160
9	10:00 a.m.	04+20	150
		Average	180

Particle Distribution
% by Size

Size (Microns)	Sample: 2	Sample: 5	Sample: 8	Average
<10	97.85	96.28	95.64	96.59
10-20	1.97	3.34	3.85	3.05
20-50	0.16	0.36	0.48	0.33
50-100	0.01	0.01	0.01	0.01
100-250	0.01	0.01	0.01	0.01
250-500	0	0	0.01	0
>500	0	0	0	0

Suspended Sediment Discharge (Tons/Day): 12,060

2-5-28

TABLE 4.17

R&M CONSULTANTS, INC.

SUSPENDED SEDIMENT ANALYSIS

SUSITNA RIVER AT GOLD CREEK

Date: July 1, 1981

Water Temperature: 8.6°C

Instantaneous Discharge: 21,900 c.f.s

REW: 03+90

LEW: 00+00

Sample No.	Time	Station	Sediment (mg/l.)
1	1:00 a.m.	00+40	100
2		00+70	100
3		01+00	100
4		01+30	110
5		01+60	100
6		01+90	110
7		02+20	105
8		02+50	110
9		02+80	94
10		03+10	99
11	1:45 a.m.	03+40	74
		Average	100

Particle Distribution
% by Size

Size (Microns)	Sample: 3	Sample: 6	Sample: 9	Average
<10	97.04	97.73	96.82	97.20
10-20	2.74	1.81	2.87	2.47
20-50	0.19	0.33	0.28	0.27
50-100	0.02	0.04	0.01	0.02
>100	0.01	0.09	0.02	0.04

Suspended Sediment Discharge (Tons/Day): 5,900

susi9/j

2-5-29

TABLE 4.18

R&M CONSULTANTS, INC.

SUSPENDED SEDIMENT ANALYSIS

SUSITNA RIVER AT GOLD CREEK

Date: August 2, 1981 REW: 04+20

Water Temperature: 9.2°C LEW: 00+00

Instantaneous Discharge: 51,000 c.f.s.

Sample No.	Time	Station	Sediment (mg/l.)
1	12:00 noon	01+12	260
2		01+40	250
3		01+68	380
4		01+96	270
5		02+24	300
6		02+80	450
7		03+08	750
8		03+36	640
9		03+92	450
10	1:00 p.m.	04+20	450
		Average	420

Particle Distribution
% by Size

Size (Microns)	Sample: 2	Sample: 5	Sample: 8	Average
< 10	98.39	97.56	97.90	97.95
10-20	1.08	1.63	1.60	1.44
20-50	0.34	0.55	0.29	0.39
50-100	0.05	0.04	0.01	0.03
100-250	0.12	0.15	0.16	0.14
250-500	0.01	0.05	0.03	0.03
>500	0.01	0.02	0.01	0.01

Suspended Sediment Discharge (Tons/Day): 57,600

2-5-30

TABLE 4.19

R&M CONSULTANTS, INC.

SUSPENDED SEDIMENT ANALYSIS

SUSITNA RIVER AT GOLD CREEK

Date: August 3, 1981

Water Temperature: 9.2°C

Instantaneous Discharge: 46,000 c.f.s.

REW: 04+20

LEW: 00+00

Sample No.	Time	Station	Sediment (mg/l.)
1	12:40 p.m.	01+12	850
2		01+40	1200
3		01+68	900
4		01+96	850
5		02+24	770
6		02+80	875
7		03+08	780
8		03+36	720
9		03+92	560
10	1:15 p.m.	04+20	600
			Average 810

Particle Distribution
% by Size

Size (Microns)	Sample: 2	Sample: 5	Sample: 8	Average
<10	97.90	97.05	97.59	97.51
10-20	1.52	1.93	0.64	1.36
20-50	0.41	0.61	0.58	0.53
50-100	0.04	0.19	0.04	0.09
100-250	0.12	0.17	0.10	0.13
250-500	0.12	0.04	0.04	0.03
>500	0.00	0.01	0.01	0.01

Suspended Sediment Discharge (Tons/Day): 100,000

2-5-31

TABLE 4.20

R&M CONSULTANTS, INC.

SUSPENDED SEDIMENT ANALYSIS

SUSITNA RIVER AT GOLD CREEK

Date: September 14, 1981 REW: 03+78

Water Temperature: 6.8°C LEW: 00+00

Instantaneous Discharge: 12,600 c.f.s.

Sample No.	Time	Station	Sediment (mg/l.)
1	1:00 p.m.	00+84	45
2		01+12	75
3		01+40	94
4		01+48	112
5		01+96	84
6		02+24	47
7		02+52	67
8		02+80	42
9		03+08	72
10	1:30 p.m.	03+36	47
		Average	69

Particle Distribution
% by Size

Size (Microns)	Sample: 2	Sample: 5	Sample: 8	Average
<10	97.60	96.51	97.16	97.09
10-20	1.63	2.85	2.18	2.22
20-50	0.39	0.44	0.60	0.48
50-100	0.18	0.01	0.03	0.07
100-250	0.13	0.16	0.01	0.10
250-500	0.07	0.02	0.01	0.03
>500	0.00	0.01	0.01	0.01

Suspended Sediment Discharge (Tons/Day): 2,340

2-5-32

0 0 1 1 6

SUSITNA HYDROELECTRIC PROJECT

1982

WATER QUALITY

ANNUAL REPORT

LIBRARY COPY

DECEMBER 1982

PROPERTY OF:
Alaska Power Authority
334 W. 5th Ave.
Anchorage, Alaska 99501

PREPARED BY:
R&M CONSULTANTS, INC.

PREPARED FOR:
ACRES

ALASKA POWER AUTHORITY

2-5-33

r16/t4

ATTACHMENT D

PARTICLE SIZE AND CONCENTRATION ANALYSIS
OF LAKE AND RIVER SEDIMENTS FROM ALASKA

2-5-34

PARTICLE DATA LABORATORIES, LTD.

115 Hahn Street • Elmhurst, Illinois 60126 • (312) 832-5658

September 14, 1982

R & M Consultants Inc.
5024 Cordova
Box 6087
Anchorage Alaska 99502

Attention: Mr. Brett Jokela

Subject: Particle Size and Concentration Analysis of Lake and River Sediments From Alaska

PDL Project: I-6849

Gentlemen:

Introduction

Seventeen samples of lake and river water were received for a standard electronic particle size and concentration analysis via the Elzone computerized particle size analyzer.

Four samples were subjected to a density gradient analysis to determine the relative density of distribution of the minerals present.

A petrographic analysis was conducted on four samples via polarized light microscopy to determine the relative quantities of the various minerals present. All microscope observations and density determinations were conducted by Mr. M. Bayard.

Results

The results of the petrographic analysis are listed below in Table I. All samples are similar in mineral content except that the lake water has a smaller average partice size distribution than the river water. We would expect this because of sedimentation effects present in the lake water.

Table I
Petrographic Analysis of Susitna River and Eklutna Lake Water Samples

Mineral	Percentile
Augite	5 to 10
Quartz	15
Diatoms	15

2-5-35

Table I

Petrographic Analysis of Susitna River and Eklutna Lake Water Samples

Mineral	Percentile
Muscovite	15 to 20
Mixed Feldspars	25 to 30
Iron Oxides	10 - 15
Illmenite	about 5
Calcite	1 - 2

Table 2

Density Distributions

Sample	Composition Percentage	Density Range
Susitna River Depth Integrated Sampled August 17, 1982	60%	2.7 - 2.9
	15%	2.9 - 3.2
	25%	2.6 - 2.7
Eklutna Lake 2 Jul 82, STA 8, 45M	80%	2.80 - 2.84
	10%	2.90
	10%	2.48 - 2.55
Eklutna Lake 2 Jul 82, STA 8, 5M	70%	2.85 - 2.90
	15%	2.90 - 3.05
	15%	2.65 - 2.85
Eklutna Lake 2 Jul 82, STA 8, 15M	70%	2.74 - 2.80
	25%	<2.74
	5%	2.8 - 3.0

2-5-36

Table 3 summarizes the concentration and size distribution data for each of the required samples. It should be noted that these sample were dispersed in a 4% by weight sodium pyrophosphate electrolyte and ultrasonically treated so as to eliminate an agglomeration that may have occurred between original sampling, transport and final analysis.

Your data appears in two formats:

1) Frequency Data

2) Volume or Mass Data

The frequency data is analagous to a microscope count in which several hundred particles are sized and tabulated by their projected diameters. Standard fine particle mathematics are then used to calculate the various statistical parameters. In an electronic analysis we typically count between 50 thousand and 100 thousand particles per sample.

At your request, we have performed a concentration analysis for each sample. This additional analysis is included with each particle size distribution run. Due to the limitations of the technology, the lowest size measurable is a function of the largest size present in the sample (dynamic range). This limitation in one form or another is present in every type of electronic particle size analysis. The data is reported on the basis of counts/liter of sample over some indicated range. This range must be considered when evaluating data. Since all data is in permanent magnetic storage, it could be possible to normalize data about some common reference point at a later date.

The mass data is analagous to a sieve analysis in which the results are expressed as a weight percent greater than or equal to an indicated sieve (micron size).

Concluding Remarks

Due to the vacation schedule of Mr. Bayard and the arrival of your samples, no photographic work could be completed at this time. Upon his return on September 27, your project will be his primary concern.

If you have any questions regarding data or techniques involved in acquiring your results, please do not hesitate to contact us at Particle Data Laboratories.

Respectfully submitted,

Richard Karuhn/lk

Richard Karuhn
Director

RK/lk

2-5-37

September 14, 1982
R & M Consultants, Inc.
PDL Project I-6849

Table 3

Concentration and Particle Size Summary

Sample I.D.	Counts/Liter	Mass Median Size	Count Median Size
1. Susitna River 8/17/82 Depth Integrated	76,814,800	16.67	2.89
2. Lake Inlet 50 Ft. Upstream	34,216,000	46.25	3.44
3. Lake Inlet Creek Mouth	129,360,000	25.46	2.89
4. 18 Jun 82, STA 11, 20M	84,783,000	12.83	1.93
5. 17 Jun 82, STA 4, 24M	60,946,000	3.68	1.53
6. 18 Jun 82, STA 9, 14M	51,786,000	3.10	1.53
7. 17 June 82, STA 4, 19M	104,788,000	3.56	1.53
8. Lake Inlet Surface 200 Ft. into Lake	71,148,000	4.86	1.82
9. 15 Jul 82, STA 9, 1M	129,180,000	3.10	1.53
10. 15 Jul 82, STA 11, 1M	52,254,000	4.09	1.60
11. 15 Jul 82, STA 9, 14M	188,495,000	2.70	1.53
12. 15 Jul 82, STA 11, 28M	19,034,000	33.34	1.59
13. 2 Jul 82, STA 8, 5M	145,691,000	3.56	1.76
14. 2 Jul 82, STA 10, 5M	229,996,000	3.10	1.76
15. 2 Jul 82, STA 8, 15M	191,151,000	3.32	1.68
16. 2 Jul 82, STA 14, 5M	126,603,000	3.32	1.76
17. 2 Jul 82, STA 8,45M	284,282,000	3.95	1.76

2-5-38

CONCENTRATION ANALYSIS BY COMPUTERIZED ELZONE METHOD

R & M CONSULTANTS, INC.

SAMPLE I.D. :SUSTINA RIVER DEAPTH INTEGRETED RM 232 BY USGS - Sampled 8/17/82

COUNTS/LITER:768149000(0.96-23.84 MICRONS RANGE)

TABULATION

DATA ID 6849 DATE 9 SEP
SIZE-NORMALIZED COUNT DISTRIBUTION
TOTAL = 768149

CHNL	SIZE	COUNT	CHNL	SIZE	COUNT	CHNL	SIZE	COUNT
18	.95	93	50	2.89	23333	82	8.76	1958
19	.99	47	51	2.99	24496	83	9.07	1612
20	1.02	165	52	3.10	21988	84	9.39	1246
21	1.06	3138	53	3.21	21931	85	9.72	1113
22	1.10	6105	54	3.32	21779	86	10.06	1092
23	1.13	7069	55	3.44	19824	87	10.42	959
24	1.17	6536	56	3.56	18018	88	10.79	891
25	1.22	6872	57	3.68	19199	89	11.17	728
26	1.26	6915	58	3.81	16353	90	11.56	834
27	1.30	7364	59	3.95	15741	91	11.97	499
28	1.35	7553	60	4.09	14761	92	12.39	734
29	1.40	8969	61	4.23	12780	93	12.83	458
30	1.45	8780	62	4.38	11792	94	13.28	478
31	1.50	9592	63	4.54	10915	95	13.75	441
32	1.55	10462	64	4.70	9014	96	14.23	353
33	1.60	10649	65	4.86	10284	97	14.74	306
34	1.66	11539	66	5.03	8917	98	15.26	348
35	1.72	12945	67	5.21	8027	99	15.79	191
36	1.78	14664	68	5.39	7311	100	16.35	178
37	1.84	14944	69	5.58	7053	101	16.93	186
38	1.91	14931	70	5.78	6538	102	17.52	138
39	1.97	17636	71	5.98	5269	103	18.14	137
40	2.04	18526	72	6.20	5101	104	18.78	85
41	2.12	18392	73	6.41	4017	105	19.44	83
42	2.19	19363	74	6.64	4086	106	20.13	93
43	2.27	21562	75	6.87	3738	107	20.84	38
44	2.35	20977	76	7.12	3488	108	21.57	57
45	2.43	22920	77	7.37	3072	109	22.34	33
46	2.52	23553	78	7.63	2778	110	23.12	29
47	2.60	25011	79	7.90	2313	111	23.94	52
48	2.70	23971	80	8.18	2096			
49	2.79	23455	81	8.46	2089			

2-5-39

PARTICLE SIZE ANALYSIS BY ELZONE METHOD - PARTICLE DATA LABORATORIES,LDT.
115 HAHN STREET - ELMHURST,IL. 60126 - TELEPHONE:(312)832-5658

CLIENT: R & M CONSULTANTS, INC. 9 SEP 82 :DATE
SAMPLE: SUSTINA RIVER DEAPTH INTEGATED 6849 : JOB NUMBER
Sampled 8/17/82

VOLUME (MASS) DISTRIBUTION FROM DISPLAY AREA: 4

INDICES

VOLUME MODE = 17.32 MEDIAN = 16.67 MICRONS AND LARGER

GEOMETRIC VOLUME MEAN = 15.85 +/- 15.72 (99.21%) SKEWNESS = -.09

ARITHMETIC VOLUME MEAN = 19.56 +/- 12.19 (62.33%) SKEWNESS = .18

FOR PLOTTING PROBABILITY ON LOG PAPER:

PERCENTILE: 00.1% OF VOLUME IS AT 64.15 MICRONS AND LARGER
PERCENTILE: 01.0% OF VOLUME IS AT 55.00 MICRONS AND LARGER
PERCENTILE: 06.0% OF VOLUME IS AT 42.00 MICRONS AND LARGER
PERCENTILE: 22.0% OF VOLUME IS AT 27.50 MICRONS AND LARGER
PERCENTILE: 50.0% OF VOLUME IS AT 16.67 MICRONS AND LARGER
PERCENTILE: 78.0% OF VOLUME IS AT 9.72 MICRONS AND LARGER
PERCENTILE: 94.0% OF VOLUME IS AT 4.68 MICRONS AND LARGER
PERCENTILE: 99.0% OF VOLUME IS AT 2.63 MICRONS AND LARGER
PERCENTILE: 99.9% OF VOLUME IS AT 1.65 MICRONS AND LARGER

COUNT (FREQUENCY) DISTRIBUTION FROM DISPLAY AREA: 5

INDICES

COUNT MODE = 2.79 MEDIAN = 2.99 MICRONS AND LARGER

GEOMETRIC COUNT MEAN = 3.11 +/- 2.69 (86.59%) SKEWNESS = .12

ARITHMETIC COUNT MEAN = 3.87 +/- 3.30 (85.06%) SKEWNESS = .33

FOR PLOTTING PROBABILITY ON LOG PAPER:

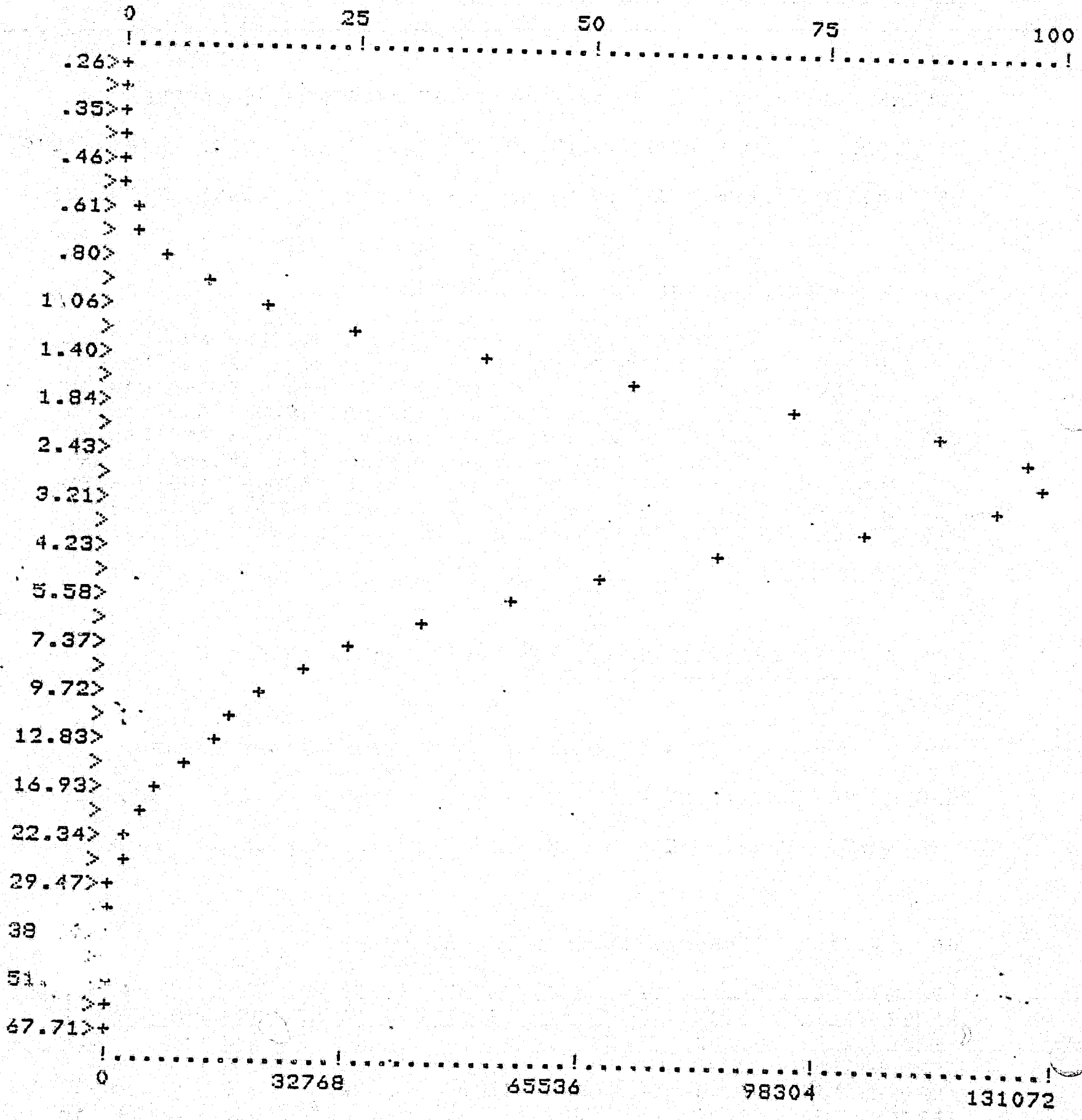
PERCENTILE: 00.1% OF COUNT IS AT 31.59 MICRONS AND LARGER
PERCENTILE: 01.0% OF COUNT IS AT 16.93 MICRONS AND LARGER
PERCENTILE: 06.0% OF COUNT IS AT 9.07 MICRONS AND LARGER
PERCENTILE: 22.0% OF COUNT IS AT 4.86 MICRONS AND LARGER
PERCENTILE: 50.0% OF COUNT IS AT 2.99 MICRONS AND LARGER
PERCENTILE: 78.0% OF COUNT IS AT 1.97 MICRONS AND LARGER
PERCENTILE: 94.0% OF COUNT IS AT 1.30 MICRONS AND LARGER
PERCENTILE: 99.0% OF COUNT IS AT .86 MICRONS AND LARGER
PERCENTILE: 99.9% OF COUNT IS AT .61 MICRONS AND LARGER

2-5-40

PARTICLE SIZE ANALYSIS BY ELZONE METHOD - PARTICLE DATA LABORATORIES,LDT.
115 HAHN STREET - ELMHURST,IL. 60126 - TELEPHONE:(312)832-5658

CLIENT: R & M CONSULTANTS, INC. 9 SEP 82 :DATE
SAMPLE: SUSTINA RIVER DEAPTH INTEGATED 6849 : JOB NUMBER
PARTICLE SIZE VS. COUNT (+) AND % OF COUNT LARGER THAN SIZE (*)

GRAPH - FROM : TO : - SKIP: ? = 1



2-5-41

PARTICLE SIZE ANALYSIS BY ELZONE METHOD - PARTICLE DATA LABORATORIES,LDT.
115 HAHN STREET - ELMHURST,IL. 60126 - TELEPHONE:(312)832-5658

CLIENT: R & M CONSULTANTS, INC. 9 SEP 82 :DATE
SAMPLE: SUSTINA RIVER DEAPTH INTEGATED 6849 : JOB NUMBER
8/19/82

"TOTAL IN TABULATION= TOTAL COUNT OR VOLUME IN ANALYSIS
TABULATION

DATA ID 6849 DATE 9 SEP
SIZE-NORMALIZED COUNT DISTRIBUTION
TOTAL = 2562671

CHNL	SIZE	COUNT	CHNL	SIZE	COUNT	CHNL	SIZE	COUNT
17	.26	2	44	1.72	83684	71	11.17	16695
18	.28	2	45	1.84	95044	72	11.97	15209
19	.30	7	46	1.97	104955	73	12.83	13726
20	.33	13	47	2.12	113761	74	13.75	12011
21	.35	20	48	2.27	121048	75	14.74	10339
22	.37	36	49	2.43	126674	76	15.79	8576
23	.40	61	50	2.60	129700	77	16.93	7061
24	.43	108	51	2.79	130000	78	18.14	5749
25	.46	189	52	2.99	127922	79	19.44	4613
26	.49	310	53	3.21	123576	80	20.84	3629
27	.53	494	54	3.44	116384	81	22.34	2848
28	.57	771	55	3.68	104605	82	23.94	2198
29	.61	1219	56	3.95	93646	83	25.66	1700
30	.65	1894	57	4.23	83757	84	27.50	1287
31	.70	2802	58	4.54	75163	85	29.47	970
32	.75	4057	59	4.86	67722	86	31.59	740
33	.80	5752	60	5.21	61104	87	33.85	552
34	.86	8211	61	5.58	55593	88	36.28	408
35	.92	11483	62	5.98	49383	89	38.89	292
36	.99	15408	63	6.41	42748	90	41.68	207
37	1.06	20258	64	6.87	36863	91	44.67	148
38	1.13	26118	65	7.37	32648	92	47.88	100
39	1.22	33615	66	7.90	29119	93	51.31	66
40	1.30	42359	67	8.46	25859	94	55.00	38
41	1.40	51554	68	9.07	23078	95	58.94	18
42	1.50	61548	69	9.72	20520	96	63.17	8
43	1.60	72106	70	10.42	18528	97	67.71	2

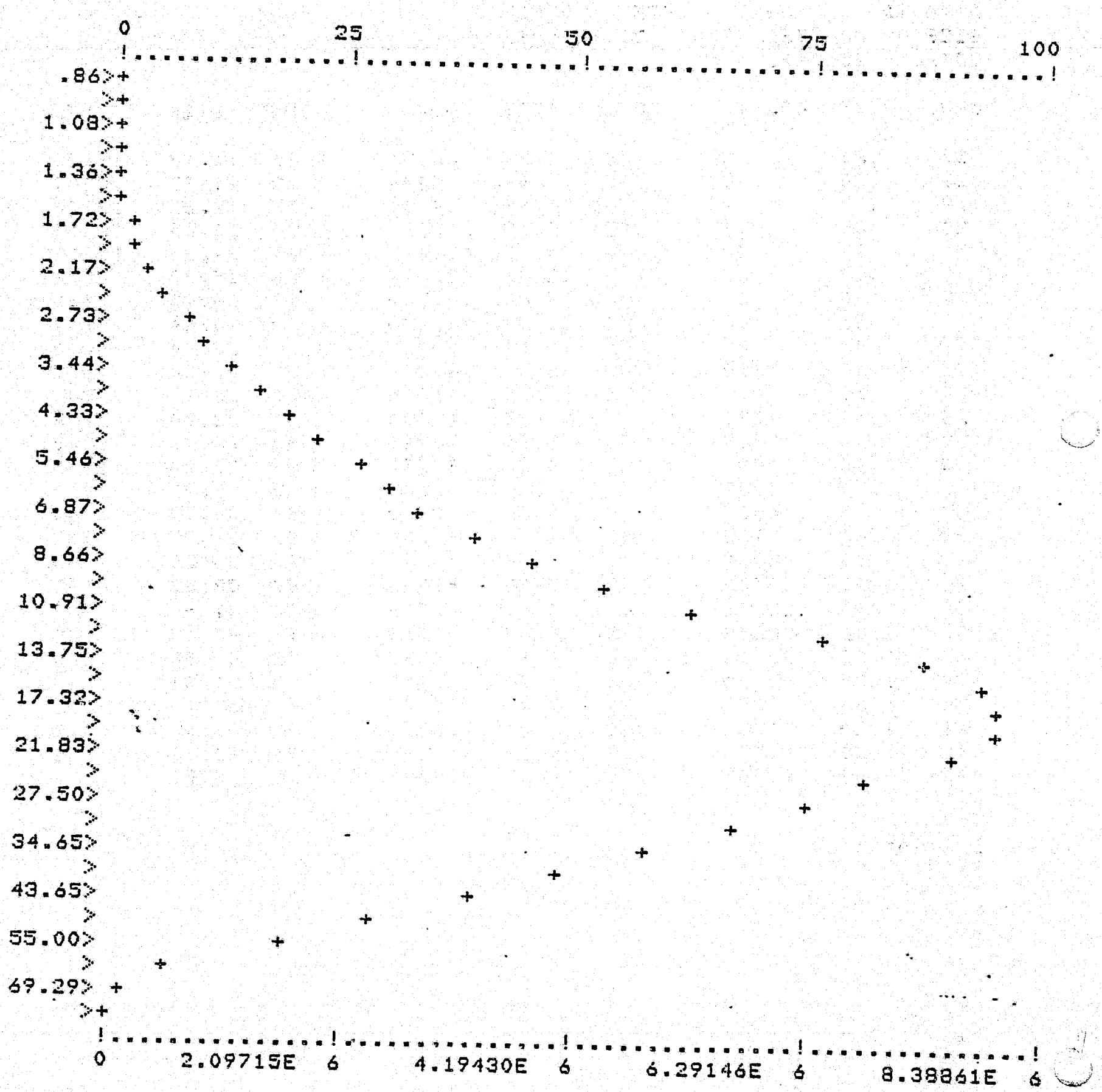
DISPLAY AREA: 4

2-5-42

PARTICLE SIZE ANALYSIS BY ELZONE METHOD - PARTICLE DATA LABORATORIES,LDT.
115 HAHN STREET - ELMHURST,IL. 60126 - TELEPHONE:(312)832-5658

CLIENT: R & M CONSULTANTS, INC. 9 SEP 82 :DATE
SAMPLE: SUSTINA RIVER DEAPTH INTEGATED 6849 : JOB NUMBER
PARTICLE SIZE VS. VOLUME (+) AND % OF VOLUME LARGER THAN SIZE (*)

GRAPH - FROM : TO : - SKIP: ? = 2



2-5-43

PARTICLE SIZE ANALYSIS BY ELZONE METHOD - PARTICLE DATA LABORATORIES,LDT.
115 HAHN STREET - ELMHURST,IL. 60126 - TELEPHONE:(312)832-5658

CLIENT: R & M CONSULTANTS, INC. 9 SEP 82 :DATE
SAMPLE: SUSTINA RIVER DEAPTH INTEGATED 6849 : JOB NUMBER
8/17/82

"TOTAL IN TABULATION= TOTAL COUNT OR VOLUME IN ANALYSIS TABULATION

DATA ID 6849 DATE 9 SEP
SIZE-NORMALIZED VOLUME DISTRIBUTION
TOTAL =37958937

CHNL	SIZE	VOLUME	CHNL	SIZE	VOLUME	CHNL	SIZE	VOLUME
12	.93	28	51	4.17	1461136	90	18.71	7937483
13	.96	83	52	4.33	1520464	91	19.44	7947236
14	1.00	132	53	4.50	1615831	92	20.21	7853900
15	1.04	2710	54	4.68	1716951	93	21.00	7727175
16	1.08	8325	55	4.86	1819602	94	21.83	7575461
17	1.13	12435	56	5.05	1954195	95	22.68	7281022
18	1.17	13461	57	5.25	2037958	96	23.57	7090060
19	1.22	15742	58	5.46	2198857	97	24.50	6872016
20	1.26	18071	59	5.67	2326588	98	25.46	6659054
21	1.31	21502	60	5.89	2469201	99	26.46	6419549
22	1.36	26292	61	6.12	2517390	100	27.50	6266254
23	1.42	32378	62	6.36	2603621	101	28.58	5990698
24	1.47	37812	63	6.61	2697760	102	29.70	5842865
25	1.53	46650	64	6.87	2795345	103	30.87	5579647
26	1.59	54497	65	7.14	2921287	104	32.08	5327950
27	1.65	65754	66	7.42	3138735	105	33.34	5071671
28	1.72	84213	67	7.72	3262085	106	34.65	4798201
29	1.79	107601	68	8.02	3439966	107	36.01	4543890
30	1.86	122573	69	8.33	3578517	108	37.42	4221621
31	1.93	146675	70	8.66	3773250	109	38.89	3998038
32	2.00	186290	71	9.00	3985998	110	40.41	3737836
33	2.08	213372	72	9.35	4175116	111	42.00	3487012
34	2.17	246935	73	9.72	4400951	112	43.65	3262757
35	2.25	305980	74	10.10	4720822	113	45.36	2854257
36	2.34	342995	75	10.50	4994368	114	47.15	2620499
37	2.43	419729	76	10.91	5259312	115	49.00	2346607
38	2.53	492249	77	11.34	5592651	116	50.92	2132528
39	2.63	573849	78	11.79	5915794	117	52.92	1741967
40	2.73	618739	79	12.25	6386353	118	55.00	1511037
41	2.84	682656	80	12.73	6673118	119	57.16	1180547
42	2.95	785169	81	13.23	7060864	120	59.40	843250
43	3.06	836380	82	13.75	7290997	121	61.73	532023
44	3.18	902038	83	14.29	7671742	122	64.15	296192
45	3.31	1004350	84	14.85	7876144	123	66.67	164476
46	3.44	1033747	85	15.43	7874619	124	69.29	99567
47	3.57	1153894	86	16.04	7906484	125	72.01	21072
48	3.71	1238607	87	16.67	7987280	126	74.84	6287
49	3.86	1305394	88	17.32	8000000	127	77.78	12678
50	4.01	1386599	89	18.00	7928014	128	80.83	9282

2-5-44

SUSPENDED SEDIMENT SIZE DISTRIBUTIONS
FOR THE SUSITNA RIVER AT:

1) MACLAREN RIVER NEAR PAXON

2) DENALI

3) CANTWELL (VEE CANYON)

4) GOLD CREEK

2-5-45

AT 5

Madison River at Paxson

Date	Instantaneous Flow (cfs)	% Exceedance	Sol. Conc. (mg/l)	Susp. Sed. Disch. (tons/day)	Susp. Sed. Fall Diameter % Finer Than .002 mm	.004 mm	.008 mm	.016 mm	.031 mm	Susp. Sed. Size Diameter % Finer Than .062 mm	.125 mm	.250 mm	.500 mm	1
6/15/58	3,800	4	710	7,290	17	23	30	40	51	67	80	95	100	1
7/15/58	3,110	10	596	5,010	13	19	25	35	46	67	84	96	100	1
7/16/59	1,220	24	214	1,050	—	—	—	—	—	38	61	89	99	1
5/20/59	2,050	22	524	2,900	18	25	35	42	52	65	77	91	98	1
6/15/60	1,940	22	190	995	—	—	—	—	—	60	67	85	98	1
7/5/60	2,510	17	767	5,200	20	29	37	46	58	72	80	92	99	1
8/2/60	2,270	20	565	3,460	12	19	27	38	50	73	81	94	99	1
7/5/61	2,410	12	292	2,290	12	17	28	36	42	52	63	85	98	1
8/2/61	3640	5	1,630	16,000	23	30	42	55	70	75	87	95	99	1
6/26/62	3,520	6	489	4,650	17	24	34	43	54	66	80	95	99	1
7/27/62	3,220	9	1,190	10,300	12	19	33	47	61	78	88	95	99	1
7/	3,780	4	807	8,240	—	5	13	22	40	67	83	90	99	1
6/ 64	5,070	1	760	10,400	10	20	25	40	49	55	73	88	96	1
7/10/64	3,720	15	350	3,520	19	24	34	42	53	62	74	88	97	1
8/12/64	1,130	30	89	272	—	—	—	—	—	52	58	73	89	1
7/30/65	2,640	15	550	3,920	24	30	39	45	54	63	72	81	94	9
7/6/65	2,810	13	240	5,620	26	36	45	57	67	74	82	89	97	1
10/2/65	724	35	98	192	—	—	—	—	—	45	54	82	100	1
7/3/66	2,160	21	551	3,210	18	25	33	42	49	54	61	71	84	1
8/24/66	3,390	18	448	3,890	—	—	—	—	—	55	72	88	98	1
9/30/66	624	37	25	42	—	—	—	—	—	46	52	88	100	1
6/16/67	3,620	5	649	6,340	12	18	27	40	54	68	84	88	98	9
7/22/67	4,030	3	677	7,370	13	18	25	36	45	57	73	95	99	1
8/16/67	5,320	0.5	1,040	14,900	7	10	15	19	24	31	39	48	76	10
7/29/74	2,720	14	856	6,290	15	21	29	38	49	63	80	92	99	1
7/25/75	2,900	12	446	3490	11	16	23	32	43	—	—	—	99	1

2-5-46

H-5

2-5-47

Susitna River at Denali

Date	Instantaneous Flow (cfs)	% Flow Exceedance	Sed. Conc. (mg/l)	Susp. Sed. Disch. (tons/day)	Susp. Sed. Fall Diameter % Finer Than .002 mm	.004 mm	.008 mm	.016 mm	.031 mm	Susp. Sed. Sieve Diameter % Finer Than .062 mm	.125 mm	.250 mm	.500 mm
6/1/58	6,770	10	2,620	62,000	20	28	35	43	50	63	75	86	93
7/21/58	6,760	11	2,420	56,000	10	14	18	26	35	50	63	80	96
8/28/58	3,860	27	832	8,670	14	21	24	32	40	52	66	88	99
7/19/59	5,610	21	592	8,970	12	14	21	27	34	47	61	82	93
8/12/59	6640	17	1,400	25,100	15	21	27	38	51	67	79	93	100
5/16/59	1,970	36	438	2,330	-	-	-	-	-	44	52	81	98
6/5/60	4,290	25	924	10,700	22	28	39	48	60	68	78	93	100
7/5/60	8,560	10	1,270	29,400	17	22	29	37	47	66	79	91	97
8/23/60	6,250	19	1,070	18,100	17	20	25	34	44	62	75	94	100
7/5/61	8,070	12	1,550	33,800	11	11	15	24	29	38	49	64	83
8/23/61	11,800	3	3,830	90,200	10	16	24	37	56	68	88	92	98
6/25/62	11,300	3	1,580	48,200	18	25	35	46	56	68	79	93	100
7/27/62	10,600	5	1,900	54,500	5	9	18	27	39	52	64	76	87
9/19/62	2,280	34	355	2,190	9	13	17	22	28	36	46	65	73
7/3/63	12,200	2	1,190	39,200	14	19	23	32	41	54	72	91	99
6/19/64	11,300	3	1,600	48,800	14	17	23	31	38	52	68	89	99
7/10/64	9,290	8	1,300	32,600	10	14	20	25	33	50	70	88	98
9/21/64	2,140	35	590	3,410	-	-	-	-	-	16	20	34	56
5/27/65	4,140	25	570	6,370	-	-	-	-	-	32	58	90	99
7/30/65	7,320	15	1,400	27,700	12	16	20	29	37	46	52	62	73
9/6/65	7,000	16	1,440	27,200	12	15	21	30	47	66	80	95	100
10/3/65	2,090	35	1,340	7,840	2	3	4	4	5	6	9	26	66
5/24/66	2,810	31	1,070	8,120	2	3	6	14	28	33	70	92	99
7/3/66	6680	17	1,690	30,500	10	14	19	24	28	34	42	58	77
8/24/66	8,210	12	887	19,700	4	8	14	20	29	40	60	90	99
5/23/68	5,840	20	1,190	12,800	1	3	8	15	32	51	70	95	100
7/4/68	9,110	8	886	21,800	18	22	30	39	49	61	75	93	100
8/20/68	7,890	13	1,030	22,000	16	22	30	40	52	66	77	91	100
10/1/68	963	44	85	221	-	-	-	-	-	55	69	98	100
7/29/74	9,020	9	1,630	39,700	21	26	37	49	61	70	81	93	99
8/30/74	12,100	2	5,690	186,000	27	37	48	58	65	71	76	81	90
9/22/74	4,660	24	960	12,100	12	17	23	31	42	54	62	77	86
6/29/75	10,000	6	998	26,900	12	17	24	33	46	64	82	94	99

A5

Susitna River at Denali

Date	Instantaneous Flow (cfs)	90 Flow Exceedance	Susp. Sed. Conc. (mg/l)	Susp. Sed. Discharge (tons/day)	Susp. Sed. Fall Diameter % Finer Than .062 mm	.104 mm	.165 mm	.316 mm	.631 mm	Susp. Sed. Sieve Diameter % Finer Than .062 mm	.125 mm	.250 mm	.500 mm
9/[illegible]/75	3,750	26	231	2,360	—	—	—	—	—	39	56	81	98
5/[illegible]/76	2,180	35	195	1,150	13	15	21	30	45	61	67	87	98
7/15/76	5,700	4	1,960	57,700	16	23	32	43	56	69	79	87	91
8/27/76	7,660	13	757	15,700	16	21	29	38	48	60	73	85	94
9/27/76	1,720	38	155	724	—	—	—	—	—	38	54	79	98
6/1/77	3,970	26	630	6,750	2	6	10	16	27	44	61	78	90
7/8/77	5,590	11	1,510	35,000	7	11	18	33	49	57	63	72	86
8/11/77	13,700	1	1,420	52,500	9	16	23	33	47	65	80	93	99
9/26/77	1,840	37	124	633	—	—	—	—	—	32	47	73	98
6/29/79	7,100	16	640	12,300	14	18	22	28	35	43	61	78	96
8/27/79	8,050	12	734	16,000	20	25	32	41	50	61	72	87	98
9/[illegible]/79	4,100	26	165	1,830	—	—	—	—	—	54	67	84	98
[illegible]/80	1,570	39	102	432	5	5	6	7	8	9	29	37	84
6/24/80	4,900	23	302	4,000	17	23	30	36	44	54	64	84	99
5/19/81	4060	26	575	6,300	12	14	20	27	38	54	63	77	89
6/24/81	9,270	8	822	20,600	-	28	37	47	58	67	72	90	99
7/21/81	14,200	1	893	34,200	—	26	33	42	52	60	72	88	97
8/25/81	7,100	16	350	6,710	16	22	28	34	39	43	50	73	94

2-5-48

#5

2-5-49

Susitna River at Gintwell (Vee Canyon)

Date	Instantaneous Flow (cfs)	% Excedance	Sed. Conc. (mg/l)	Susp. Sed. Disch. (tons/day)	Susp. Sed. Fall Diameter % Finer Than .002 mm	.004 mm	.008 mm	.016 mm	.031 mm	Susp. Sed. Sieve Diameter % Finer Than .062 mm	.125 mm	.250 mm	.500 mm
7/6/62	23,100	4	2,590	161,000	18	23	31	39	49	63	77	90	96
7/16/62	14,200	18	814	32,500	20	24	32	38	48	58	69	86	97
7/11/63	12,000	22	219	7,100	4	10	17	23	30	38	57	84	98
6/3/63	15,000	17	408	16,500	10	11	13	20	25	39	54	83	97
7/8/63	26,000	3	2,745	146,000	9	11	15	22	35	54	70	84	96
7/25/63	22,000	5	1,300	77,200	9	12	17	24	34	50	67	86	95
9/4/63	12,500	22	770	26,600	20	23	32	43	55	61	70	88	98
9/30/63	6,600	34	116	2,070	12	15	22	27	36	44	54	78	97
6/2/64	40,500	0.1	1,600	175,000	—	—	—	—	—	38	56	75	93
7/20/64	16,800	13	720	32,700	16	19	28	37	45	55	65	87	98
9/10/64	5,250	37	200	2,840	—	—	—	—	—	43	51	72	94
7/16/65	22,300	5	1,200	72,300	17	22	32	38	49	60	73	84	96
7/17/66	12,300	22	896	29,800	15	22	31	39	51	57	64	82	94
8/22/66	10,500	27	380	10,800	9	12	17	22	29	38	52	75	97
9/29/66	4,700	38	68	863	—	—	—	—	—	36	40	74	100
6/7/67	14,200	19	417	16,000	5	8	13	17	25	37	58	83	98
6/20/67	20,800	6	1,240	69,700	18	23	32	41	51	63	77	91	100
7/18/67	13,500	21	681	24,800	12	19	28	37	46	62	71	87	98
8/23/67	16,100	14	798	34,700	12	16	23	30	37	48	66	89	97
9/21/67	7,480	32	159	3,210	12	18	23	28	33	37	48	76	94
6/8/68	15,600	16	388	16,300	—	—	—	—	—	35	52	83	99
7/24/68	18,200	10	1,240	61,000	17	24	32	45	58	71	79	91	99
5/15/69	8,670	30	726	17,000	—	—	—	—	—	38	63	81	97
6/24/69	15,800	15	1,860	79,400	23	31	36	50	62	73	83	92	99
7/24/69	10,600	27	713	20,400	11	17	25	33	43	56	71	88	99
5/26/70	11,400	25	661	20,300	5	8	—	20	—	48	59	79	95
7/17/70	10,900	26	632	18,600	13	18	—	32	—	51	63	83	96
8/11/70	12,500	23	542	18,300	12	18	22	28	35	50	68	88	98
9/12/70	7,040	33	236	4,490	9	15	—	21	—	42	53	76	97
7/12/71	17,200	12	1,360	63,200	23	32	36	46	58	69	79	91	98
8/17/71	17,100	12	942	43,500	20	24	33	44	54	66	82	96	100
8/10/72	14,400	18	1,040	40,400	14	22	27	36	49	65	74	86	97

2-5-50

Susitna River at Gold Creek

Date	Instantaneous Flow (cfs)	% Annual Flow Exceedance	Sed. Conc. (mg/l)	Susp. Sed. Discharge (tons/day)	Susp. Sed. Fall Diameter % Finer Than .002 mm	.004 mm	.008 mm	.016 mm	.031 mm	Susp. Sed. Size Diameter % finer than .062 mm	.125 mm	.250 mm	.500 mm
7/10/53	21,700	18	1610	94,300	16	24	32	44	71	77	85	94	100
8/6/53	21,700	18	1910	112,000	15	23	35	44	56	81	90	96	99
6/22/54	33,600	4	492	43,700	7	9	13	19	27	45	62	82	96
7/14/55	22,400	17	621	37,600	23	28	38	49	59	74	86	95	99
7/28/55	29,000	7	2620	205,000	15	20	28	39	55	72	86	96	100
8/8/55	19,100	22	800	41,300	17	23	28	39	48	67	80	92	99
8/18/55	13,500	32	250	9,110	21	26	35	43	52	68	83	96	100
8/31/55	23,000	15	445	27,600	-	27	29	34	38	54	73	88	97
9/25/55	10,100	36	33	900	-	-	-	-	-	98	99	100	100
5/22/56	31,300	5	674	57,000	-	11	15	19	26	43	62	87	99
6/3/57	33,400	4	548	49,400	14	16	17	24	30	47	62	84	98
6/[illegible]/57	29,300	7	1,470	116,000	24	33	40	53	67	83	90	97	100
/57	25,500	11	2,180	150,000	18	25	32	47	65	83	91	97	100
7/10/57	20,200	20	1,000	54,500	29	34	44	56	70	84	91	97	100
8/12/57	17,700	26	1,200	57,300	20	27	38	50	63	81	90	96	100
8/17/57	21,600	18	2,200	128,000	14	20	28	42	59	72	88	96	100
8/29/57	23,500	14	2,400	152,000	13	17	22	31	45	63	82	95	100
9/6/57	16,700	27	582	26,200	19	24	28	38	47	64	77	99	99
6/16/62	53,000	0.2	1,400	197,000	11	13	16	25	34	60	77	92	99
7/6/62	25,200	11	852	58,000	30	42	56	69	77	81	86	96	100
7/16/62	21,700	18	334	19,600	19	27	38	52	64	77	81	95	99
9/11/62	14,400	31	107	4,160	-	20	27	37	50	59	69	87	97
7/5/74	15,800	29	573	24,400	19	25	33	44	55	65	75	86	97
9/17/74	9,850	36	385	10,200	20	33	48	66	79	86	92	97	100
5/19/75	19,400	22	660	34,600	4	6	9	13	21	34	52	78	98
6/20/75	35,500	3	574	55,000	5	8	11	18	32	47	60	76	93
7/17/75	28,100	8	1,130	85,700	19	28	39	53	66	77	85	92	99
7/25/75	15,300	29	225	9,300	-	-	-	-	-	71	81	95	100
9/2[illegible]/75	15,500	29	56	2,340	-	-	-	-	-	43	56	76	93
5/12/76	14,200	31	365	14,000	9	11	15	21	34	48	52	68	99
6/9/76	24,700	12	401	26,700	6	6	9	12	17	24	28	40	81
7/7/76	14,600	31	221	8,710	-	-	-	-	-	67	76	84	96
8/19/76	18,600	24	454	22,800	13	17	24	33	43	54	65	81	98

Susitna River at Gold Creek

Date	Instantaneous Flow (cfs)	% Flow Exceedance	Sed. Conc. (mg/l)	Susp. Sed. Disch. (tons/day)	Susp. Sed. Fall Diameter % Finer Than .002 mm	.004 mm	.008 mm	.016 mm	.031 mm	Susp. Sed. Sieve Diameter % Finer Than .062 mm	.125 mm	.250 mm	.500 mm
5/10/77	3,760	48	120	1,220	-	-	-	-	-	44	64	87	99
5/18/77	14,200	21	1,110	42,600	7	9	17	27	44	63	74	90	99
6/14/77	52,500	0.2	915	128,000	2	4	6	11	22	40	62	84	97
7/28/77	21,000	20	344	20,300	14	19	29	44	54	70	80	92	99
5/10/77	20,000	21	656	35,400	13	19	27	39	52	65	74	86	95
5/17/72	19,700	21	498	26,300	4	5	8	11	17	29	49	78	96
5/8/78	19,000	23	938	48,100	16	19	29	41	54	67	77	88	97
7/10/29	25,700	11	627	43,500	16	21	27	34	40	47	56	72	91
5/14/80	14,400	31	1,010	39,300	-	11	16	23	32	43	55	73	93
7/2/80	34,100	3	318	29,300	21	23	28	34	41	49	61	80	97
5/27/21	15,400	29	164	7,040	8	10	14	19	26	37	51	79	98
6/23/81	17,800	25	327	15,700	26	37	46	57	64	70	77	86	9
7/21/81	42,500	1	680	78,000	-	17	23	31	39	49	58	80	97
8/27/81	26,600	10	158	11,300	7	10	21	27	36	49	64	86	100

2-5-51

2. Water Use and Quality

Comment 6 (p. E-2-28, para. 4)

Provide data on the contribution of organic matter to suspended sediment concentrations at each sampling station in the Susitna River on a seasonal basis.

Response

Suspended organic matter is technically measured as particulate organic carbon (POC) in samples from aquatic environments. Total organic carbon (TOC) in aquatic environments is composed of both particulate (POC) and dissolved (DOC) fractions. The particulate (POC) fraction of (TOC) in lotic environments such as the Susitna River may be expected to vary from 10-15 percent of the TOC (Wetzel, 1975). Measurements of TOC in the Susitna River range from 1 to 10 mg/1 (U.S. Geological Survey data summary by R&M Consultants, Inc., 1982. Task 3-Hydrology, Water Quality Annual Report), therefore POC estimates in the Susitna River potentially range from at least 0.1 to 1.5 mg/1.

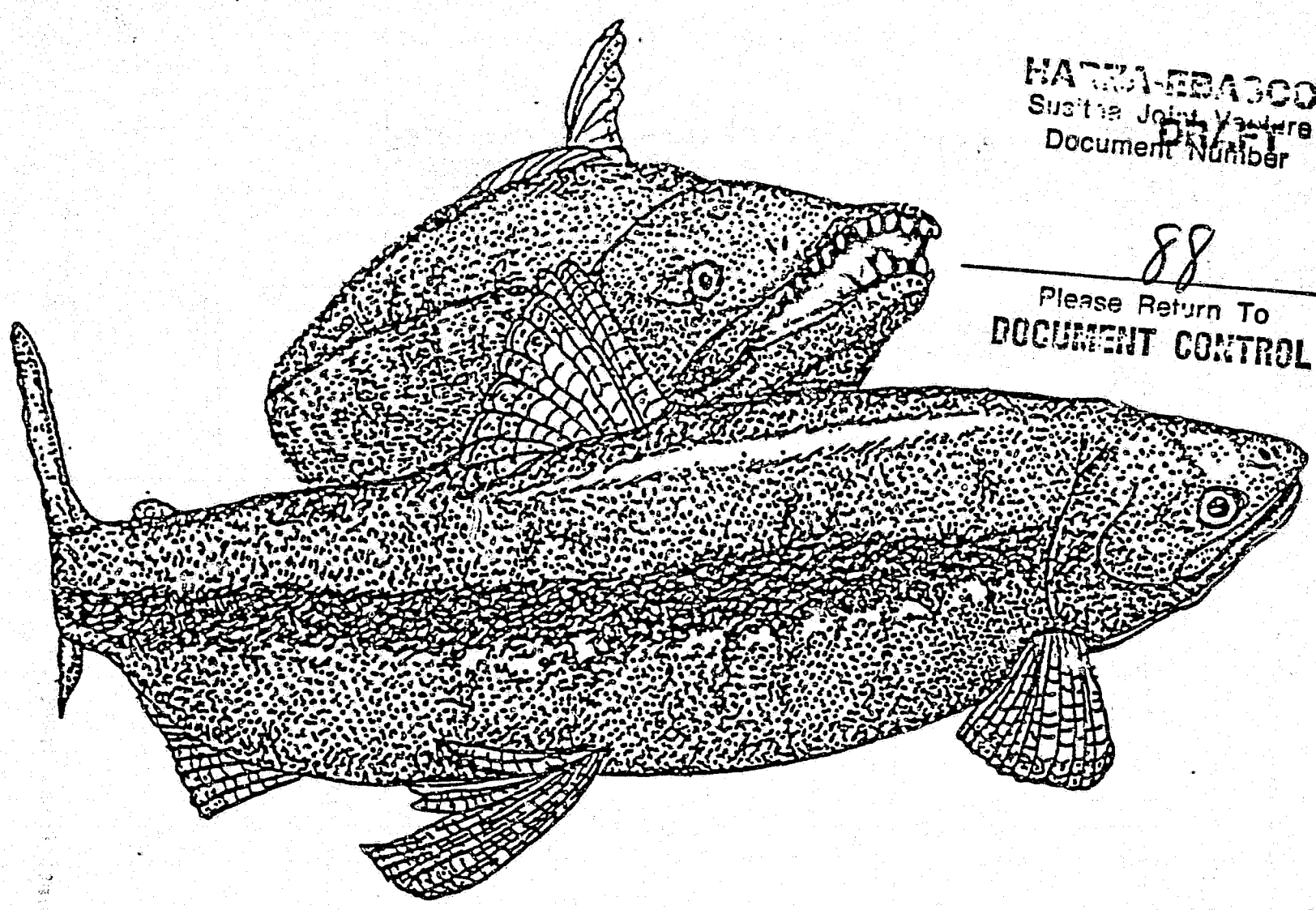
Two measurements of POC exist for the Susitna River at Gold Creek (see attached data summary from Susitna Hydro Aquatic Studies Phase II - Basic Data Report Volume 4, Appendix 4-D-6). There were on 23 June, 1981 (POC = 0.9 mg/1) and 30 March, 1982 (POC = 0.1 mg/1). No additional measurements of POC in the Susitna River main channel exist to our knowledge. Additional measurements of POC concentration exist for selected sloughs. These data are also presented on the attached data summary from Susitna Hydro Aquatic Studies Phase II - Basic Data Report.

References

(1) R&M Consultants, Inc. 1982. Task 3 - Hydrology. Water Quality Annual Report. Anchorage, Alaska.

(2) Alaska Department of Fish and Game, 1983. Susitna Hydro Aquatic Studies Phase II Basic Data Report. Volume 4. Aquatic Habitat and Instream Flow Studies, 1982, Appendix 4-D-6, Page 4-D-78.

(3) Wetzel, R. G. 1975. Limnology. W. B. Saunders, Co., Philadelphia. 743 pp.



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PHASE II BASIC DATA REPORT

Volume 4. Aquatic Habitat and Instream Flow Studies, 1982.

Appendices D - J

-by-

ALASKA DEPARTMENT OF FISH AND GAME
Susitna Hydro Aquatic Studies
2207 Spenard Road
Anchorage, Alaska 99503
1983

2-6-3

Appendix Table 4-D-6. Summary of provisional water quality data for sloughs 8A, 9, 16B, 19, 21, and mainstem Susitna River at Gold Creek, collected by ADF&G and USGS in June, July, and September, 1981, and in January and February, 1982.

Parameter	Date[a]	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Physical and Field Parameters[b]							
*Water Temperature °C	June	15.5	14.2	14.0	5.5	10.7	12.4
	July	11.2	10.9	9.0	9.8	11.3	10.5
	September	3.5	5.6	4.8	1.8	2.4	0.4
	January	0.5	0.5	1.5	2.0	1.5	0.0
	March	0.5	0.5	2.0	1.0	1.5	0.0
Air Temperature °C	June	21.0	20.1	---	---	23.0	---
	July	16.0	14.0	15.5	---	---	---
	September	8.0	7.5	---	3.0	---	---
	January	---	---	---	---	---	---
	March	---	---	---	---	-11.0	---
Streamflow (discharge) cfs	June	6.4	2.9	0.7	0.2	3.2	1,780.0
	July	551.0	714.0	503.0	0.0	142.0	42,500.0
	September	2.8	1.5	0.3	<0.1	0.43	8,540.0
	January	---	---	---	---	---	---
	March	---	---	---	---	---	1,520.0
*Specific Conductance (field) umho/cm	June	140	145	71	146	226	---
	July	117	124	72	127	130	119
	September	135	113	64	150	205	172
	January	193	121	59	148	221	260
	March	142	143	59	129	196	266

[a]Sloughs and mainstem Susitna River were sampled on 2 or 3 consecutive days in each month (except January) as follows.

	8A	9	16B	19	21	Susitna River at Gold Creek
June	25	24	23	23	24	23
July	21	21	22	22	22	21
September	30	30	28	29	29	28
January	20	20	20	20	20	20
March	31	30	30	30	30	30

[b]Parameters marked with an * are averages of transect point measurements (see methods).

--- indicates data not available.

Appendix Table 4-D-6 (Continued).

Parameter	Date	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Nutrients - Cont'd							
Phosphorus, total mg/l P	June	0.05	0.01	0.01	0.01	<0.01	0.12
	July	0.27	0.48	0.14	0.01	0.38	0.02
	September	<0.01	<0.01	<0.01	<0.01	<0.01	0.02
	January	<0.01	<0.01	<0.01	0.02	0.01	0.01
	March	0.01	0.01	0.01	0.01	0.01	0.01
Phosphorus, total mg/l PO_4	June	0.2	<0.1	<0.1	<0.1	<0.1	0.4
	July	0.8	1.5	0.4	<0.1	1.2	0.1
	September	---	---	---	---	---	0.1
	January	---	---	---	0.1	<0.1	0.1
	March	<0.1	<0.1	<0.1	<0.1	<0.1	---
Phosphorus, dissolved mg/l P	June	0.03	0.01	0.01	0.01	<0.01	0.02
	July	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	September	0.01	<0.01	<0.01	<0.01	<0.01	0.01
	January	<0.01	<0.01	<0.01	0.02	0.04	0.01
	March	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Carbon, dissolved organic mg/l C	June	1.9	2.1	1.4	1.3	2.0	2.8
	July	13.0	9.0	3.3	6.2	6.0	18.0
	September	1.5	1.7	1.9	2.2	1.1	---
	January	1.4	1.3	0.5	0.7	0.5	---
	March	1.4	0.7	0.7	1.4	1.1	1.6
Carbon, total suspended organics mg/l C	June	---	0.2	---	0.2	0.2	0.9
	July	0.2	0.5	0.0	0.0	0.3	---
	September	0.1	0.1	0.1	0.1	0.1	---
	January	0.0	0.0	0.0	0.0	0.0	---
	March	0.0	0.0	0.0	0.1	0.1	0.1
Trace Metals							
Arsenic, total ug/l As	June	1	1	1	2	2	6
	July	2	5	4	1	5	7
	September	2	1	1	2	2	---
	January	2	2	1	2	2	---
	March	1	1	2	1	2	2

EXHIBIT E

2. Water Use and Quality

Comment 7 (p. E-2-28, para. 4)

The discussion presented here suggests the existence of data (10/mg/L, 2620 mg/L, 5690 mg/L) beyond that given in Table E.2.20. Provide these data.

Response

The additional data for suspended sediment concentrations referred to on p. E-2-28, para. 4, comes from data gathered and reported by the U.S. Geological Survey 1982 Water Quality Annual Report (December 1982) by R & M Consultants, Inc.; Tables 2.4 through 2.11. Pertinent sections of this report are enclosed.

TABLE 2.4

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: R&M CONSULTANTS, INC.
Station: VEE CANYON 1980 - 1982
Elevation: 1900 FT.

Field Parameters (1)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Dissolved Oxygen	12.6/14.5/10.4	9.7/10.7/10.4	11.9/13.1/10.4	7/4/1	7/4/1
Percent Saturation	110/104/83	84/84/83	101/98/83	7/4/1	7/4/1
pH, pH Units	7.9/7.6/6.6	7.0/6.0/6.6	7.6/7.1/6.6	10/4/1	10/4/1
Conductivity, umhos/cm @ 25°C	171/333/100	103/130/100	129/212/100	9/4/1	9/4/1
Temperature, °C	11.9/0.1/6.5	5.3/-0.1/6.5	7.7/0.0/6.5	10/4/1	10/4/1
Free Carbon Dioxide (2)	4.5/20.0/-	1.7/5.5/-	3.0/10.3/-	7/3/0	7/3/0
Alkalinity, as $CaCO_3$	81/99/-	41/57/-	61/81/-	7/3/0	7/3/0
Settleable Solids, ml/l	1.0/-/-	0.1/-/-	0.7/-/-	4/0/0	10/3/1
Laboratory Parameters (1)(3)					
Ammonia Nitrogen	.27/.26/.13	.09/.09/.13	.16/.19/.13	6/2/1	9/4/1
Organic Nitrogen	.63/.85/.34	.22/.08/.34	.49/.40/.34	8/3/1	9/3/1
Kjeldahl Nitrogen	.79/.85/.47	.26/.17/.47	.60/.52/.47	9/4/1	9/4/1
Nitrate Nitrogen	.19/.30/-	.09/.30/-	.14/.30/-	5/1/0	10/4/1
Nitrite Nitrogen	-/.01/-	-/.01/-	-/.01/-	0/1/0	9/4/1
Total Nitrogen	.92/.85/.47	.39/.17/.47	.61/.52/.47	9/3/1	9/3/1
Ortho-Phosphate	.05/.02/-	.03/.02/-	.04/.02/-	2/2/0	9/4/1
Total Phosphorus	.49/.07/-	.03/.02/-	.14/.05/-	6/2/0	10/4/1

s3/1

TABLE 2.4 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: R&M CONSULTANTS, INC.
Station: VEE CANYON 1980 - 1982
Elevation: 1900 FT.

Laboratory Parameters (1) (3) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Alkalinity, as $CaCO_3$	60/66/-	40/66/-	48/66/-	4/1/0	4/1/0
Chemical Oxygen Demand	39/13/8	8/6/8	20/10/8	8/4/1	8/4/1
Chloride	11/18/4.5	3/16/4.5	6.7/17.5/4.5	7/4/1	10/4/1
Conductivity, umhos/cm @ 25°C	150/190/-	150/190/-	150/190/-	1/1/0	1/1/0
True Color, Color Units	175/30/15	5/5/15	70/15/15	9/4/1	9/4/1
Hardness, as $CaCO_3$ (4)	76/122/40	49/78/40	58/103/40	10/4/1	10/4/1
Sulfate	9/18/4	2/11/4	6/14/4	10/4/1	10/4/1
Total Dissolved Solids	170/157/100	38/115/100	98/141/100	10/4/1	10/4/1
Total Suspended Solids	1150/14/93	25/0.6/93	358/6.0/93	10/4/1	10/4/1
Turbidity, NTU	720/2.5/25	8.7/.35/25	156/1.3/25	14/4/1	14/4/1
Uranium	-/-/-	-/-/-	-/-/-	0/0/0	5/2/0
Radioactivity, Gross Alpha, pCi/l	-/-/-	-/-/-	11.6 ± 0.6/ 10.3 ± 0.6/-	1/1/0	1/1/0
Total Organic Carbon	-/2/-	-/2/-	-/2/-	0/1/0	0/1/0
Total Inorganic Carbon	-/2/-	-/2/-	-/2/-	0/1/0	0/1/0
Organic Chemicals					
Endrin	-/-/-	-/-/-	-/-/-	0/0/0	3/1/0
Lindane	-/-/-	-/-/-	-/-/-	0/0/0	3/1/0

3-7-2

TABLE 2.4 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: R&M CONSULTANTS, INC.
Station: VEE CANYON 1980 - 1982
Elevation: 1900 FT.

Laboratory Parameters (1) (3) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Methoxychlor	-/-/-	-/-/-	-/-/-	0/0/0	3/1/0
Toxaphene	-/-/-	-/-/-	-/-/-	0/0/0	3/1/0
2, 4-D	-/-/-	-/-/-	-/-/-	0/0/0	3/1/0
2, 4, 5-TP Silvex	-/-/-	-/-/-	-/-/-	0/0/0	3/1/0
Elements (Dissolved)					
Ag, Silver	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1
Al, Aluminum	2.2/.18/-	1.6/.18/-	1.4/.18/-	3/1/0	10/3/1
As, Arsenic	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1
Au, Gold	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1
B, Boron	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1
Ba, Barium	.12/-/-	.07/-/-	.10/-/-	7/0/0	10/3/1
Bi, Bismuth	.19/-/-	.19/-/-	.19/-/-	1/0/0	10/3/1
Ca, Calcium	23/41/13	13/25/13	18/33/13	10/4/1	10/4/1
Cd, Cadmium	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1
Co, Cobalt	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1
Cr, Chromium	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1
Cu, Copper	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1
Fe, Iron	4.0/.37/.08	.05/.37/.08	1.1/.37/.08	9/1/1	10/3/1
Hg, Mercury	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1

h-t-2

TABLE 2.4 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: R&M CONSULTANTS, INC.
Station: VEE CANYON 1980 - 1982
Elevation: 1900 FT.

Laboratory Parameters (1) (3) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
K, Potassium	5.0/9.0/1.6	1.7/2.0/1.6	2.3/5.2/1.6	9/3/1	10/4/1
Mg, Magnesium	3.4/7.6/1.7	1.2/3.8/1.7	2.4/5.2/1.7	10/4/1	10/4/1
Mn, Manganese	.10/-/-	.07/-/-	.09/-/-	2/0/0	10/3/0
Mo, Molybdenum	-/-/-	-/-/-	-/-/-	0/0/0	10/3/0
Na, Sodium	5.1/12.0/2.0	2.4/6.3/2.0	3.4/8.0/2.0	10/4/1	10/4/1
Ni, Nickel	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1
Pb, Lead	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1
Pt, Platinum	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1
Sb, Antimony	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1
Se, Selenium	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1
Si, Silicon	6.9/5.0/1.7	2.0/3.7/1.7	3.5/4.5/1.7	10/4/1	10/4/1
Sn, Tin	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1
Sr, Strontium	.08/.13/-	.05/.06/-	.06/.10/-	9/3/0	10/3/1
Ti, Titanium	.24/-/-	.13/-/-	.18/-/-	3/0/0	10/3/1
W, Tungsten	-/.4/-	-/.4/-	-/.4/-	0/1/0	10/3/1
V, Vanadium	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1
Zn, Zinc	.07/-/-	.07/-/-	.07/-/-	1/0/0	10/3/1
Zr, Zirconium	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1

(1) Table values are mg/l unless noted otherwise.

(2) All values for free CO_2 determined from nomograph on p. 297 of Standard Method, 14th edition.

(3) Samples for all parameters except chemical oxygen demand, dissolved and suspended solids, and turbidity were filtered.

(4) Hardness calculated by R&M personnel.

2-24-2

s3/u26

TABLE 2.5

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: R&M CONSULTANTS, INC.
Station: GOLD CREEK 1980 - 1982
Elevation: 676.5 FT.

Field Parameters (1)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Dissolved Oxygen	12.8/14.1/11.5	8.6/13.3/11.2	11.2/13.8/11.4	10/3/2	10/3/2
Percent Saturation	110/101/102	81/100/101	101/101/102	9/3/2	9/3/2
pH, pH Units	7.8/7.8/6.7	6.8/7.1/6.4	7.3/7.4/6.5	8/3/2	8/3/2
Conductivity, umhos/cm @ 25°C	183/249/106	75/84/105	128/179/106	15/5/2	15/5/2
Temperature, °C	12.8/0.8/10.5	6.8/0.0/10.3	9.8/0.2/10.4	15/5/2	15/5/2
Free Carbon Dioxide (2)	8.6/20/-	2.1/3.2/-	4.4/10.7/-	5/3/0	5/3/0
Alkalinity, as $CaCO_3$	64/74/-	25/46/-	44/65/-	5/3/0	5/3/0
Settleable Solids, ml/l	0.6/-/-	0.1/-/-	0.4/-/-	7/3/2	7/3/2
Laboratory Parameters (1)(3)					
Ammonia Nitrogen	.21/.52/.08	.02/.32/.08	.09/.42/.08	11/2/1	14/4/2
Organic Nitrogen	.74/.81/.34	.05/.34/.27	.49/.54/.31	10/3/2	10/3/2
Kjeldahl Nitrogen	4.8/.99/.35	.06/.66/.34	.87/.82/.35	11/3/2	14/5/2
Nitrate Nitrogen	.86/.34/-	.14/.12/-	.32/.21/-	10/3/0	16/5/2
Nitrite Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	14/4/2
Total Nitrogen	5.66/1.34/0.35	.35/.66/.34	1.22/1.00/.35	11/4/2	11/4/2
Ortho-Phosphate	.10/.02/-	.01/.02/-	.04/.02/-	3/1/0	16/3/2
Total Phosphorus	.43/.02/.08	.01/.01/.08	.12/.02/.08	10/2/1	16/5/2

4-1-2

TABLE 2.5 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: R&M CONSULTANTS, INC.
Station: GOLD CREEK 1980 - 1982
Elevation: 676.5 FT.

Laboratory Parameters (1) (3) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Alkalinity, as $CaCO_3$	36/57/-	28/57/-	32/57/-	2/1/0	2/1/0
Chemical Oxygen Demand	24/16/12	1.3/2/8	10.9/8.4/10	14/5/2	16/5/2
Chloride	14/29/10	4/9/6	7.3/19/8	10/5/2	12/5/2
Conductivity, umhos/cm @ 25°C	37/165/-	37/165/-	37/165/-	2/1/0	2/1/0
True Color, Color Units	110/40/15	5/10/10	50/20/10	7/3/2	7/3/2
Hardness, as $CaCO_3$(4)	97/121/43	31/67/43	50/87/43	11/5/2	11/5/2
Sulfate	14.8/17/6	1.0/9.5/5	6.7/13.6/5.5	16/5/2	16/5/2
Total Dissolved Solids	103/188/90	63/100/87	86/135/89	16/5/2	16/5/2
TSS → Total Suspended Solids	1255/8/56	56/1/49	268/6/53	16/5/2	16/5/2
Turbidity, NTU	728/1.2/19	14/0.3/15	199/0.8/17	22/3/2	22/3/2
Uranium	-/-/-	-/-/-	-/-/-	0/0/0	4/2/0
Radioactivity, Gross Alpha, pCi/l	5.5/2.0/-	2.6/2.0/-	4.1/2.0/-	2/1/0	2/1/0
Total Organic Carbon	3.8/1.0/-	1.4/1.0/-	23/1.0/-	8/1/0	8/1/0
Total Inorganic Carbon	12/4/-	8.6/4/-	10.5/4/-	8/1/0	8/1/0
Organic Chemicals					
Endrin	-/-/-	-/-/-	-/-/-	0/0/0	3/1/0
Lindane	-/-/-	-/-/-	-/-/-	0/0/0	3/1/0

8-7-2

s3/u28

TABLE 2.5 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: R&M CONSULTANTS, INC.
Station: GOLD CREEK 1980 - 1982
Elevation: 676.5 FT.

Laboratory Parameters (1) (3) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Methoxychlor	-/-/-	-/-/-	-/-/-	0/0/0	3/1/0
Toxaphene	-/-/-	-/-/-	-/-/-	0/0/0	3/1/0
2, 4-D	-/-/-	-/-/-	-/-/-	0/0/0	3/1/0
2, 4, 5-TP Silvex	-/-/-	-/-/-	-/-/-	0/0/0	3/1/0
Elements (Dissolved)					
Ag, Silver	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Al, Aluminum	.70/.18/-	.08/.18/-	.39/.18/-	2/1/0	6/3/2
As, Arsenic	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Au, Gold	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
B, Boron	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Ba, Barium	.11/.05/.07	.06/.05/.05	.09/.05/.06	7/1/2	7/3/2
Bi, Bismuth	.19/.07/-	.19/.07/-	.19/.07/-	1/1/0	7/3/2
Ca, Calcium	33.5/34.4/14	10/21/14	16.0/26.5/14	12/5/2	12/5/2
Cd, Cadmium	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Co, Cobalt	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Cr, Chromium	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Cu, Copper	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Fe, Iron	2.3/.35/.07	.07/.35/.07	.77/.35/.07	6/1/1	7/3/2
Hg, Mercury	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2

TABLE 2.5 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: R&M CONSULTANTS, INC.
Station: GOLD CREEK 1980 - 1982
Elevation: 676.5

Laboratory Parameters (1) (3) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
K, Potassium	2.0/2.7/1.9	0.9/1.2/1.8	1.6/2.1/1.9	12/4/2	12/4/2
Mg, Magnesium	3.1/10.0/2.0	1.2/3.2/2.0	2.2/4.9/2.0	12/5/2	12/5/2
Mn, Manganese	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Mo, Molybdenum	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Na, Sodium	10.2/21.1/4.1	2.8/7.4/3.9	5.1/11.7/4.0	12/5/2	12/5/2
Ni, Nickel	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Pb, Lead	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Pt, Platinum	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Sb, Antimony	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Se, Selenium	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Si, Silicon	5.9/5.0/2.5	2.6/3.9/2.4	3.5/4.4/2.5	7/3/2	7/3/2
Sn, Tin	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Sr, Strontium	.09/.19/.07	.06/.10/.06	.07/.13/.07	4/3/2	7/3/2
Ti, Titanium	.14/-/-	.11/-/-	.13/-/-	2/0/0	7/3/2
W, Tungsten	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
V, Vanadium	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Zn, Zinc	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Zr, Zirconium	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2

01-7-2

s3/

(1) Table values are mg/l unless noted otherwise.

(2) All values for free CO2 determined from nomograph on p. 297 of Standard Method, 14th edition.

(3) Samples for all parameters except chemical oxygen demand, dissolved and suspended solids, and turbidity were filtered.

(4) Hardness calculated by R&M personnel.

2-7-11

TABLE 2.6

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: NR. DENALI 1957 - 1982
Elevation: 2440 FT.

Field Parameters (1)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Dissolved Oxygen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Percent Saturation	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
pH, pH Units	7.9/7.6/7.2	7.2/7.1/7.2	7.6/7.4/7.2	11/3/1	11/3/1
Conductivity, umhos/cm @ 25°C	226/467/124	121/351/124	161/400/124	18/3/1	18/3/1
Temperature, °C	10.5/0.0/6.5	0.0/0.0/1.5	5.5/0.0/4.0	47/3/6	47/3/6
Free Carbon Dioxide	5.2/25/5.8	1.5/5.5/5.8	3.1/12.9/5.8	11/3/1	11/3/1
Alkalinity, as $CaCO_3$	75/161/47	42/112/47	55/136/47	11/3/1	11/3/1
Settleable Solids, ml/l	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Laboratory Parameters (1)					
Ammonia Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Organic Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Kjeldahl Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Nitrate Nitrogen	.09/.07/.05	0.0/0.0/.05	.03/.04/.05	11/3/1	11/3/1
Nitrite Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ortho-Phosphate	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Phosphorus	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

21-7-2

s3/u23

TABLE 2.6 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S GEOLOGICAL SURVEY
Station: NR. DENALI 1957 - 1982
Elevation: 2490 FT

Laboratory Parameters (1) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Alkalinity, as $CaCO_3$	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Chemical Oxygen Demand	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Chloride	11/30/4.2	1.5/19/4.2	4.7/23.3/4.2	11/3/1	11/3/1
Conductivity, umhos/cm @ 25°C	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
True Color, Color Units	10/5/30	0/0/30	5/5/30	14/3/1	14/3/1
Hardness, as $CaCO_3$	87/181/50	52/135/50	67/157/50	11/3/1	11/3/1
Sulfate	31/39/9.2	13/36/9.2	17/37/9.2	11/3/1	11/3/1
Total Dissolved Solids	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
TSS → Total Suspended Solids	5690/78/1190	85/5/102	1163/7/542	45/2/8	45/2/8
Turbidity, NTU	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Uranium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Radioactivity, Gross Alpha, pCi/l	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Organic Carbon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Inorganic Carbon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Organic Chemicals					
Endrin	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Lindane	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

S1-7-2

TABLE 2.6 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: NR. DENALI 1957 - 1982
Elevation: 2440 FT.

Laboratory Parameters (1) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Methoxychlor	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Toxaphene	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
2, 4-D	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
2, 4, 5-TP Silvex	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Elements (Dissolved)					
Ag, Silver	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Al, Aluminum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
As, Arsenic	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Au, Gold	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
B, Boron	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ba, Barium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Bi, Bismuth	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ca, Calcium	29/51/17	17/41/17	21/46/17	11/3/1	11/3/1
Cd, Cadmium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Co, Cobalt	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Cr, Chromium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Cu, Copper	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Fe, Iron	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Hg, Mercury	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

ble

s3/u25

TABLE 2.6 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: NR: DENALI 1957 - 1982
Elevation: 2440 FT.

Laboratory Parameters (1) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
K, Potassium	3.6/6.6/2.3	1.3/6.3/2.3	2.6/6.5/2.3	11/3/1	11/3/1
Mg, Magnesium	6.4/16/1.9	1.7/6.8/1.9	3.5/10.3/1.9	11/3/1	11/3/1
Mn, Manganese	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Mo, Molybdenum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Na, Sodium	10/23/3.6	2.1/15/3.6	4.3/18.7/3.6	11/3/1	11/3/1
Ni, Nickel	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Pb, Lead	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Pt, Platinum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sb, Antimony	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Se, Selenium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Si, Silicon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sn, Tin	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sr, Strontium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ti, Titanium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
W, Tungsten	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
V, Vanadium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Zn, Zinc	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Zr, Zirconium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

1. Table values are mg/l unless noted otherwise.

SI-7-2

TABLE 2.7

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: VEE CANYON 1962 - 1982
Elevation: 1900 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Field Parameters (1)					
Dissolved Oxygen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Percent Saturation	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
pH, pH Units	8.1/-/7.6	7.2/-/7.6	7.7/-/7.6	9/0/1	9/0/1
Conductivity, umhos/cm @ 25°C	187/250/136	91/250/114	146/250/125	20/1/2	20/1/2
Temperature, °C	13.0/0.1/7.0	1.0/-0.1/2.0	7.9/0.0/4.3	49/4/4	49/4/4
Free Carbon Dioxide	6.8/-/2.2	0.7/-/2.2	2.6/-/2.2	9/0/1	9/0/1
Alkalinity, as $CaCO_3$	59/-/44	39/-/44	52/-/44	9/0/1	9/0/1
Settleable Solids, ml/l	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Laboratory Parameters (1)					
Ammonia Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Organic Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Kjeldahl Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Nitrate Nitrogen	.88/-/.16	.00/-/.16	.20/-/.16	9/0/1	9/0/1
Nitrite Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ortho-Phosphate	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Phosphorus	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

91-7-2

Lin

s3/u19

TABLE 2.7 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: VEE CANYON 1962 - 1982
Elevation: 1900 FT.

Laboratory Parameters (1) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Alkalinity, as $CaCO_3$	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Chemical Oxygen Demand	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Chloride	9.2/-/7.4	2.1/-/7.4	5.3/-/7.4		9/0/1
Conductivity, umhos/cm @ 25°C	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
True Color, Color Units	40/-/30	5/-/30	10/-/30	8/0/1	8/0/1
Hardness, as $CaCO_3$	76/-/54	42/-/54	63/-/54	9/0/1	9/0/1
Sulfate	18/-/12	7.5/-/12	14/-/12	9/0/1	9/0/1
Total Dissolved Solids	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
TSS → Total Suspended Solids	2790/14/726	34/14/661	799/14/694	36/1/2	36/1/2
Turbidity, NTU	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Uranium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Radioactivity, Gross Alpha, pCi/l	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Organic Carbon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Inorganic Carbon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Organic Chemicals					
Endrin	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Lindane	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

11-7-2

s3/u20

TABLE 2.7 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: VEE CANYON 1962 - 1982
Elevation: 1900 FT.

Laboratory Parameters (1) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Methoxychlor	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Toxaphene	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
2, 4-D	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
2, 4, 5-TP Silvex	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Elements (Dissolved)					
Ag, Silver	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Al, Aluminum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
As, Arsenic	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Au, Gold	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
B, Boron	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ba, Barium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Bi, Bismuth	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ca, Calcium	27/-/17	14/-/17	21/-/17	9/0/1	9/0/1
Cd, Cadmium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Co, Cobalt	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Cr, Chromium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Cu, Copper	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Fe, Iron	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Hg, Mercury	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

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TABLE 2.7 - Continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: VEE CANYON 1962 - 1982
Elevation: 1900 FT.

Laboratory Parameters (1) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
K, Potassium	7.3/-/2.8	1.4/-/2.8	3.5/-/2.8	9/0/1	9/0/1
Mg, Magnesium	4.4/-/2.4	1.1/-/2.4	2.7/-/2.4	9/0/1	9/0/1
Mn, Manganese	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Mo, Molybdenum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Na, Sodium	6.3/-/4.8	2.1/-/4.8	3.8/-/4.8	9/0/1	9/0/1
Ni, Nickel	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Pb, Lead	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Pt, Platinum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sb, Antimony	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Se, Selenium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Si, Silicon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sn, Tin	-/-/-	-/-/-	/-/-	0/0/0	0/0/0
Sr, Strontium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ti, Titanium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
W, Tungsten	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
V, Vanadium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Zn, Zinc	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Zr, Zirconium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

1. Table values are mg/l unless noted otherwise.

61-7-2

TABLE 2.8

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: GOLD CREEK 1949 - 1982
Elevation: 676.5 FT.

Field Parameters (1)	Maximum (Summer/Winter/Break-Up)	Minimum (Summer/Winter/Break-Up)	Mean (Summer/Winter/Break-Up)	Number of Detectable Values	Total Number of Observations
Dissolved Oxygen	13.3/15.8/14.1	9.5/11.0/14.1	11.9/13.9/14.1	9/5/1	9/5/1
Percent Saturation	110/110/111	83/77/111	102/97/111	6/5/1	6/5/1
pH, pH Units	7.9/8.1/8.0	6.5/7.0/6.5	7.3/7.5/7.0	66/31/7	66/31/7
Conductivity, umhos/cm @ 25°C	227/300/147	90/164/70	147/250/97	66/32/7	66/32/7
Temperature, °C	14.0/0.5/6.0	0.4/0.0/1.0	9.2/0.1/3.1	39/12/8	39/12/8
Free Carbon Dioxide	20/16/24	1.1/1.2/2.9	5.8/6.2/10.8	57/26/6	57/26/6
Alkalinity, as $CaCO_3$	87/88/47	23/49/25	51/72/33	62/30/7	62/30/7
Settleable Solids, ml/l	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Laboratory Parameters (1)					
Ammonia Nitrogen	.33/.08/.13	.01/.03/.13	.16/.06/.13	7/5/1	7/6/1
Organic Nitrogen	.39/.44/.07	.10/.18/.07	.27/.29/.07	7/5/1	7/5/1
Kjeldahl Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Nitrate Nitrogen	.36/.32/.69	.02/.05/.05	.12/.16/.24	55/25/7	55/25/7
Nitrite Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Nitrogen	.60/.66/-	.25/.44/-	.50/.51/-	5/6/0	5/6/0
Ortho-Phosphate	.03/.03/.04	.00/.01/.04	.01/.02/.04	11/4/1	12/4/1
Total Phosphorus	.23/.05/.09	.02/.01/.09	.13/.03/.09	7/6/1	7/6/1

02-7-2

s3/u15

TABLE 2.8 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: GOLD CREEK 1949 - 1982
Elevation: 676.5 FT

1 2 3
Summer/Winter/Break-Up

Laboratory Parameters (1) (Continued)	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Alkalinity, as $CaCO_3$	45/85/27	35/82/27	40/83/27	5/3/1	5/3/1
Chemical Oxygen Demand	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Chloride	15/35/7.6	1.4/6.2/1.8	5.5/22/4.4	62/28/7	62/28/7
Conductivity, umhos/cm @ 25°C	142/289/115	114/266/84	128/279/100	5/6/2	5/6/2
True Color, Color Units	45/10/50	0/0/5	10/5/25	55/22/6	55/22/6
Hardness, as $CaCO_3$	107/120/56	35/60/30	64/98/39	62/28/7	62/28/7
Sulfate	31/38/11	1.0/12/5.0	16.1/21/7.6	61/28/6	62/28/7
Total Dissolved Solids	140/174/90	55/133/53	93/154/66	43/18/6	43/18/6
Total Suspended Solids	2620/76/1330	7/1/120	740/12/621	56/10/13	56/10/13
Turbidity, NTU	1807.70/29	42/.10/29	126/.40/29	5/2/1	5/2/1
Uranium	.33/-/-	.12/-/-	.25/-/-	3/0/0	3/0/0
Radioactivity, Gross Alpha, pCi/l	1.8/-/-	0.5/-/-	1.3/-/-	3/0/0	3/0/0
Total Organic Carbon	2.6/5.5/10.0	1.4/1.1/1.8	2.0/2.6/5.9	2/3/2	2/3/2
Total Inorganic Carbon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Organic Chemicals					
Endrin	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Lindane	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

2-39

12-7-21

s3/u16

TABLE 2.8 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: GOLD CREEK 1949 - 1982
Elevation: 676.5 FT.

Laboratory Parameters (1) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Methoxychlor	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Toxaphene	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
2, 4-D	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
2, 4, 5-TP Silvex	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Elements (Dissolved)					
Ag, Silver	.000/.001/-	.000/.001/-	.000/.001/-	2/1/0	3/1/0
Al, Aluminum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
As, Arsenic	.002/.002/-	.001/.002/-	.001/.002/-	3/1/0	3/1/0
Au, Gold	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
B, Boron	-/-/-	-/-/-	-/-/-	0/0/-	0/0/0
Ba, Barium	.031/.060/-	.000/.060/-	.010/.060/-	3/1/0	3/1/0
Bi, Bismuth	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ca, Calcium	37/39/18	11/24/9.9	20/30/13	62/28/7	62/28/7
Cd, Cadmium.	.001/-/-	.001/-/-	.001/-/-	2/0/0	3/1/0
Co, Cobalt	.000/.001/-	.000/.001/-	.000/.001/-	1/1/0	3/1//0
Cr, Chromium	.010/-/-	.000/-/-	.005/-/-	2/0/0	3/1/0
Cu, Copper	.005/.001/-	.003/.001/-	.004/.001/-	3/1/0	3/1/0
Fe, Iron	.14/.015/-	.04/.015/-	.10/.015/-	6/1/0	6/1/0
Hg, Mercury	.0002/-/-	.0000/-/-	.0001/-/-	2/0/0	3/1/0

2-7-22

s3/u17

TABLE 2.8 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: GOLD CREEK 1949 - 1982
Elevation: 676.5 FT.

Laboratory Parameters (1) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
K, Potassium	4.4/5.0/1.7	1.0/1.2/1.2	2.4/2.3/1.4	52/22/5	52/22/5
Mg, Magnesium	7.8/8.3/2.8	1.2/3.6/0.3	3.2/5.4/1.7	62/28/7	62/28/7
Mn, Manganese	.18/.003/-	.00/.003/-	.036/.003/-	7/1/0	7/1/0
Mo, Molybdenum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Na, Sodium	6.5/17/3.8	2.4/5.2/2.8	4.1/11.3/3.1	52/22/5	52/22/5
Ni, Nickel	.000/.001/-	.000/.001/-	.000/.001/-	2/1/0	3/1/0
Pb, Lead	.001/.003/-	.000/.003/-	.000/.003/-	3/1/0	3/1/0
Pt, Platinum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sb, Antimony	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Se, Selenium	.001/-/-	.000/-/-	.000/-/-	3/0/0	3/1/0
Si, Silicon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sn, Tin	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sr, Strontium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ti, Titanium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
W, Tungstem	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
V, Vanadium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Zn, Zinc	.014/-/-	.006/-/-	.010/-/-	3/0/0	3/1/0
Zr, Zirconium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

2-7-23

s3/u10

TABLE 2.9

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: SUNSHINE 1971 - 1982
Elevation: 270 FT.

Field Parameters (1)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Dissolved Oxygen	13.3/13.8/-	10.6/13.0/-	12.0/13.4/-	5/3/0	5/3/0
Percent Saturation	107/94/-	99/90/-	103/92/-	2/3/0	2/3/0
pH, pH Units	7.7/7.3/-	7.1/6.2/-	7.4/6.9/-	7/3/0	7/3/0
Conductivity, umhos/cm @ 25°C	170/242/-	61/225/-	115/232/-	9/3/0	9/3/0
Temperature, °C	12.0/0.0/9.2	3.8/0.0/9.2	8.6/0.0/9.2	9/3/1	9/3/1
Free Carbon Dioxide	3.9/-/-	2.1/-/-	3.1/-/-	3/0/0	3/0/0
Alkalinity, as $CaCO_3$	43/71/-	25/63/-	36/68/-	6/2/0	6/2/0
Settleable Solids, ml/l	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Laboratory Parameters (1)					
Ammonia Nitrogen	.37/.06/-	.08/.03/-	.19/.05/-	6/3/0	6/4/0
Organic Nitrogen	1.10/.42/-	.19/.18/-	.63/.29/-	6/3/0	6/3/0
Kjeldahl Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Nitrate Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Nitrite Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Nitrogen	2.30/.72/-	.71/.42/-	1.17/.61/-	5/4/0	5/4/0
Ortho-Phosphate	.04/.04/-	.00/.04/-	.02/.04/-	3/1/0	3/1/0
Total Phosphorus	.33/.01/-	.05/.01/-	.15/.01/-	6/2/0	6/4/0

42-4-2

s3/u11

TABLE 2.9 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: SUNSHINE 1971 - 1982
Elevation: 270 FT.

Laboratory Parameters (1) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Alkalinity, as $CaCO_3$	48/74/-	28/63/-	41/70/-	6/3/0	6/3/0
Chemical Oxygen Demand	-/-/-	-/-/-	---	0/0/0	0/0/0
Chloride	7.3/21/-	2.2/16/-	3.7/18/-	9/4/0	9/4/0
Conductivity, umhos/cm @ 25°C	129/233/-	82/222/-	115/229/-	6/3/0	6/3/0
True Color, Color Units	100/0/-	8/0/-	44/0/-	3/1/0	3/1/0
Hardness, as $CaCO_3$	72/96/-	33/87/-	50/91/-	9/4/0	9/4/0
Sulfate	13/18/-	3/16/-	10/17/-	9/4/0	9/4/0
Total Dissolved Solids	101/141/-	54/130/-	70/134/-	8/4/0	8/4/0
Total Suspended Solids	3510/2/508	288/1/508	1485/2/508	5/2/1	5/2/1
Turbidity, NTU	300/1.3/-	160/.20/-	233/.67/-	6/3/0	6/3/0
Uranium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Radioactivity, Gross Alpha, pCi/l	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Organic Carbon	3.2/0.8/-	2.9/0.4/-	3.0/0.6/-	2/2/0	2/2/0
Total Inorganic Carbon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Organic Chemicals					
Endrin	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Lindane	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

52-2-25

TABLE 2.9 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: SUNSHINE 1971 - 1982
Elevation: 270 FT.

Laboratory Parameters (1) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Methoxychlor	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Toxaphene	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
2, 4-D	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
2, 4, 5-TP Silvex	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Elements (Dissolved)					
Ag, Silver	.000/.000/-	.000/.000/-	.000/.000/-	2/1/0	3/1/0
Al, Aluminum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
As, Arsenic	.003/.001/-	.002/.001/-	.002/.001/-	3/1/0	3/1/0
Au, Gold	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
B, Boron	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ba, Barium	.070/.040/-	.000/.040/-	.032/.040/-	3/1/0	3/1/0
Bi, Bismuth	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ca, Calcium	23/31/-	11/28/-	16/29/-	9/4/0	9/4/0
Cd, Cadmium.	.000/-/-	.000/-/-	.000/-/-	1/0/0	3/1/0
Co, Cobalt	.000/-/-	.000/-/-	.000/-/-	1/0/0	3/1/0
Cr, Chromium	.020/.010/-	.000/.010/-	.010/.010/-	3/1/0	3/1/0
Cu, Copper	.005/.004/-	.003/.004/-	.004/.004/-	3/1/0	3/1/0
Fe, Iron	.250/.040/-	.060/.010/-	.180/.025/-	5/2/0	5/2/0
Hg, Mercury	.0001/.0001/-	.0000/.0001/-	.0001/.0001/-	2/1/0	3/1/0

s3/u13

TABLE 2.9 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: US. GEOLOGICAL SURVEY
Station: SUNSHINE 1971 - 1982
Elevation: 270 FT.

Laboratory Parameters (1) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
K, Potassium	2.8/2.1/-	1.1/1.8/-	1.5/1.9/-	9/4/0	9/4/0
Mg, Magnesium	3.5/4.5/-	1.4/4.1/-	2.3/4.3/-	9/4/0	9/4/0
Mn, Manganese	.020/.004/-	.000/.000/-	.009/.002/-	5/2/0	5/2/0
Mo, Molybdenum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Na, Sodium	4.4/11/-	1.9/10/-	2.8/11/-	9/4/0	9/4/0
Ni, Nickel	.002/.002/-	.000/.002/-	.001/.002/-	3/1/0	3/1/0
Pb, Lead	.001/.008/-	.000/.008/-	.000/.008/-	3/1/0	3/1/0
Pt, Platinum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sb, Antimony	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Se, Selenium	.000/.000/-	.000/.000/-	.000/.000/-	2/1/0	3/1/0
Si, Silicon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sn, Tin	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sr, Strontium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ti, Titanium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
W, Tungsten	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
V, Vanadium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Zn, Zinc	.020/.030/-	.006/.030/-	.012/.030/-	3/1/0	3/1/0
Zr, Zirconium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

12-7-2

s3/u6

TABLE 2.10

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: SUSITNA 1955 - 1982
Elevation: 40 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Field Parameters (1)					
Dissolved Oxygen	12.8/13.5/12.4	10.5/10.6/11.4	11.5/11.6/12.1	13/14/4	13/14/4
Percent Saturation	100/94/99	90/74/97	97/80/98	9/7/2	9/7/2
pH, pH Units	8.3/7.9/7.8	7.0/6.8/6.5	7.7/7.3/7.2	26/20/7	26/20/7
Conductivity, umhos/cm @ 25°C	160/225/116	90/182/85	122/205/93	27/22/7	27/22/7
Temperature, °C	12.5/0.5/7.0	2.0/0.0/3.4	8.4/0.04/5.3	25/22/7	25/22/7
Free Carbon Dioxide	8/17/19	0.6/1.8/1.1	2.5/7.8/6.5	15/15/5	15/15/5
Alkalinity, as $CaCO_3$	57/75/39	36/60/30	44/69/34	21/19/6	21/19/6
Settleable Solids, ml/l	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Laboratory Parameters (1)					
Ammonia Nitrogen	.19/.09/.21	.00/.00/.01	.04/.04/.08	12/10/3	12/10/3
Organic Nitrogen	1.5/.46/.70	.16/.00/.16	.60/.27/.43	12/9/2	12/9/2
Kjeldahl Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Nitrate Nitrogen	.00/.19/-	.00/.19/-	.00/.19/0	1/1/0	1/1/0
Nitrite Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Nitrogen	1.70/.99/1.20	.26/.24/.67	.72/.55/.92	22/17/4	22/17/4
Ortho-Phosphate	.02/-/.02	.02/-/.02	.02/-/.02	1/0/1	1/2/1
Total Phosphorus	1.10/.38/.29	.03/.00/.01	.40/.05/.14	23/20/7	23/20/7

82-2-28

Inc.

TABLE 2.10 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: SUSITNA 1955 - 1982
Elevation: 40 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Laboratory Parameters (1)					
(Continued)					
Alkalinity, as $CaCO_3$	49/76/34	46/63/27	47/71/30	3/4/2	3/4/2
Chemical Oxygen Demand	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Chloride	6.7/18/4.6	1.2/5.7/3.1	2.7/13/3.7	24/21/7	24/21/7
Conductivity, umhos/cm @ 25°C	133/222/104	114/208/94	122/217/99	4/4/2	4/4/2
True Color, Color Units	10/0/-	10/0/-	10/0/-	2/2/0	4/4/0
Hardness, as $CaCO_3$	66/96/48	44/73/36	54/85/39	25/21/7	25/21/7
Sulfate	20.7/20/10	1.0/15/3.7	13.2/17.3/6.7	25/21/7	25/21/7
Total Dissolved Solids	114/139/71	56/109/51	73/123/65	24/20/7	24/20/7
Total Suspended Solids	2367/12/683	158/2/257	745/5/461	21/19/5	21/19/5
Turbidity, NTU	790/3.0/160	21/1.0/25	233/1.5/69	18/13/5	18/13/5
Uranium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Radioactivity, Gross Alpha, pCi/l	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Organic Carbon	11.0/4.0/9.1	2.7/0.4/3.8	4.4/1.6/6.0	7/9/4	7/9/4
Total Inorganic Carbon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Organic Chemicals					
Endrin	-/-/-	-/-/-	-/-/-	0/0/0	7/10/4
Lindane	-/-/-	-/-/-	-/-/-	0/0/0	7/10/4

0 0 0 1 1 6 7

TABLE 2.10 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: SUSITNA 1955 - 1982
Elevation: 40 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Laboratory Parameters (1)					
(Continued)					
Methoxychlor	-/-/-	-/-/-	-/-/-	0/0/0	7/10/4
Toxaphene	-/-/-	-/-/-	-/-/-	0/0/0	7/9/4
2, 4-D	-/-/-	-/-/-	-/-/-	0/0/0	2/6/2
2, 4, 5-TP Silvex	-/-/-	-/-/-	-/-/-	0/0/0	2/6/2
Elements (Dissolved)					
Ag, Silver	.000/.000/-	.000/.000/-	.000/.000/-	4/2/0	8/6/3
Al, Aluminum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
As, Arsenic	.003/.003/.001	.001/.000/.001	.002/.001/.001	13/8/3	13/9/6
Au, Gold	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
B, Boron	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ba, Barium	.200/.040/.020	.027/.040/.020	.068/.040/.020	7/4/1	8/6/3
Bi, Bismuth	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ca, Calcium	22/31/15	14/23/11	17/27/13	25/21/7	25/21/7
Cd, Cadmium	.001/-/-	.001/-/-	.001/-/-	1/0/0	13/9/6
Co, Cobalt	.007/.002/.001	.001/.002.001	.003/.002/.001	5/1/1	13/9/6
Cr, Chromium	.030/.010/.005	.000/.000/.005	.010/.005/.005	5/2/1	13/9/5
Cu, Copper	.007/.004/.006	.003/.000/.004	.004/.002/.005	7/7/4	13/9/6
Fe, Iron	.460/.060/.190	.020/.060/.110	.096/.088/.152	12/9/6	13/9/6
Hg, Mercury	.0002/.0000/-	.0000/.0000/-	.0001/.0000/-	5/2/0	13/9/6

s3/u9

TABLE 2.10 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: SUSITNA 1955 - 1982
Elevation: 40 FT.

Laboratory Parameters (1) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
K, Potassium	1.8/2.5/1.4	1.0/1.4/0.8	1.4/1.7/1.0	25/21/7	25/21/7
Mg, Magnesium	3.7/4.9/2.6	2.0/3.7/1.6	2.5/4.3/1.9	25/21/7	25/21/7
Mn, Manganese	.020/.030/.011	.004/.017/.008	.006/.023/.010	7/8/2	13/9/6
Mo, Molybdenum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Na, Sodium	4.0/9.0/3.2	1.8/4.9/2.4	2.7/7.7/2.9	25/21/7	25/21/7
Ni, Nickel	.004/.003/.002	.000/.002/.002	.001/.002/.002	5/2/1	5/3/1
Pb, Lead	.009/.004/.011	.002/.000.003	.004/.002/.006	8/6/4	13/9/6
Pt, Platinum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sb, Antimony	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Se, Selenium	.001/.001/-	.000/.000/-	.0004/.0008/-	7/6/0	13/9/6
Si, Silicon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sn, Tin	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sr, Strontium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ti, Titanium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
W, Tungsten	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
V, Vanadium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Zn, Zinc	.020/.003/.020	.004/.003/.020	.008/.003/.020	5/1/2	13/9/6
Zr, Zirconium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

13-7-2

s16/r1

TABLE 2.11
TURBIDITY AND SUSPENDED SEDIMENT ANALYSIS OF THE SUSITNA, CHULITNA AND TALKEETNA RIVERS

Location	Date[1] Sampled	Date Analysed	Turbidity[2] (NTU)	Suspended[3] Sediment Concentration (mg./l.)	Discharge[4] (CFS)
Susitna at Sunshine Parks Highway Bridge (RM. 83.3)	6/3/82	6/11/82	164	847	71,000
	6/10/82	6/24/82	200	414	64,500
	6/17/82	6/24/82	136	322	50,800
	6/21/82	8/3/82	360	755	78,300
	6/28/82	8/18/82	1056	668	75,700
	7/6/82	8/3/82	352	507	46,600
	7/12/82	8/3/82	912	867	59,800
	7/19/82	8/18/82	552	576	60,800
	7/26/82	8/18/82	696	1180	96,800
	8/2/82	8/18/82	544	704	62,400
	8/9/82	8/26/82	720	746	54,000
	8/16/82	8/26/82	784	728	47,800
	8/23/82	9/14/82	552	496	38,600
	8/30/82	9/14/82	292	439	39,800
	9/17/82	10/12/82	784	1290	86,500
Susitna Below Talkeetna (RM 91)	5/26/82*	5/29/82	98		
	5/28/82*	6/2/82	256		43,600
	5/29/82*	6/2/82	140		42,900
	5/30/82*	6/2/82	65		38,400
	5/31/82*	6/2/82	130		39,200
	6/1/82*	6/2/82	130		47,000
Susitna at LRX-4 (RM 99)	5/26/82*	5/29/82	81		
Susitna near Chase (R.R. Mile 232, RM 103)	6/3/82	6/11/82	140	769	35,800
	6/8/82	6/24/82	130	547	44,400
	6/15/82	6/24/82	94	170	24,200
	6/22/82	8/3/82	74	426	37,000
	6/30/82	8/18/82	376	392	30,200
	7/8/82	8/18/82	132	156	20,700
	7/14/82	8/3/82	728	729	30,800
	7/21/82	8/18/82	316	232	24,900
	7/28/82	8/18/82	300	464	30,800
	8/4/82	8/18/82	352	377	22,700
	8/10/82	8/26/82	364	282	20,000
	8/18/82	8/26/82	304	275	17,700
	8/25/82	9/14/82	244	221	16,800
	8/31/82	9/14/82	188	252	19,300
	9/19/82	10/12/82	328	439	28,700

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TABLE 2.11 (continued)

Location	Date[1] Sampled	Date Analysed	Turbidity[2] (NTU)	Suspended[3] Sediment Concentration (mg./l.)	Discharge[4] (CFS)
Susitna at Vee Canyon (RM 223)	6/4/82	6/11/82	82		
	6/30/82	8/3/82	384		
	7/27/82	8/18/82	720		
	8/26/82	9/14/82	320		
Chulitna (Canyon) (RM 18)	6/4/82	6/11/82	272	424	11,500
	6/22/82	8/3/82	680	813	19,500
	6/29/82	8/18/82	1424	1600	29,000
	7/7/82	8/3/82	976	1030	20,700
	7/13/82	8/18/82	1136	1200	22,700
	7/20/82	8/18/82	1392	1250	23,100
	7/27/82	8/18/82	664	1010	31,900
	8/3/82	8/18/82	704	960	23,300
	8/11/82	8/26/82	592	753	21,300
	8/17/82	8/26/82	1296	1250	21,900
	8/24/82	9/14/82	632	843	18,200
	9/1/82	9/14/82	316	523	17,300
	9/18/82	10/12/82	1920	1550	29,200
Chulitna near Confluence (RM 1)	5/26/82*	5/29/82	194		
	5/28/82*	6/2/82	272		
	5/29/82*	6/2/82	308		
	5/30/82*	6/2/82	120		
	5/31/82*	6/2/82	360		
	6/1/82*	6/2/82	324		
Talkeetna at U.S.G.S. Cable (RM 6)	6/2/82	6/11/82	146	1340	17,900
	6/9/82	6/24/82	49	311	14,200
	6/17/82	6/24/82	28	216	11,400
	6/23/82	8/3/82	26	164	12,400
	6/29/82	8/18/82	41	321	10,700
	7/7/82	8/3/82	20	100	6,750
	7/13/82	8/3/82	132	226	8,880
	7/20/82	8/18/82	148	226	8,400
	7/28/82	8/18/82	272		14,200
	8/3/82	8/18/82	49	180	8,980
	8/10/82	8/26/82	53	212	6,980
	8/17/82	8/26/82	82	198	6,230
	8/24/82	9/14/82	68	263	5,920
	8/31/82	9/14/82	37	276	9,120
	9/20/82	10/12/82	34	301	14,800

2-7-33

TABLE 2.11 (Continued)

Location	Date[1] Sampled	Date Analysed	Turbidity[2] (NTU)	Suspended[3] Sediment Concentration (mg./l.)	Discharge[4] (CFS)
eetna at R.R.	5/26/82*	5/29/82	17		5,680
ge	5/28/82*	6/2/82	39		6,250
RM 0.5)	5/29/82*	6/2/82	21		5,860
	5/30/82*	6/2/82	20		5,660
	5/31/82*	6/2/82	44		7,400
	6/1/82*	6/2/82	55		9,560

e: 1. *Refers to samples collected by R&M Consultants, all other samples were collected by U.S.G.S.

2. R&M Consultants conducted all turbidity measurements.

3. Suspended sediment concentrations are preliminary, unpublished data provided by the U.S. Geological Survey.

4. Discharges for "Susitna at Sunshine" and "Susitna Below Talkeetna" are from the U.S. Geological Survey stream gage at the Parks Highway Bridge at Sunshine.

   Discharges for "Susitna at LRX-4" and "Susitna near Chase" are from the U.S.G.S. stream gage at the Alaska Railroad Bridge at Gold Creek.

   Discharges for "Chulitna" and "Chulitna near Confluence" are from the U.S.G.S stream gage at the Parks Highway Bridge at Chulitna.

   Discharges for "Talkeetna at U.S.G.S. Cable" and "Talkeetna at RR Bridge" are from the U.S.G.S. streamgage near Talkeetna.

2-7-34

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2-7-35

EXHIBIT E

2. Water Use and Quality

Comment 9 (p. E-2-29)

Provide data on suspended sediment concentrations in sloughs on a seasonal basis.

Response

Data regarding suspended sediment concentrations in sloughs are contained in the Alaska Department of Fish & Game Phase II Basic Data Report, Volume 4, Aquatic Habitat and Instream Flow Studies, 1982. The attached pages contain selected segments of Appendix Table 4-D-6 (see highlighted data).

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3 of 3

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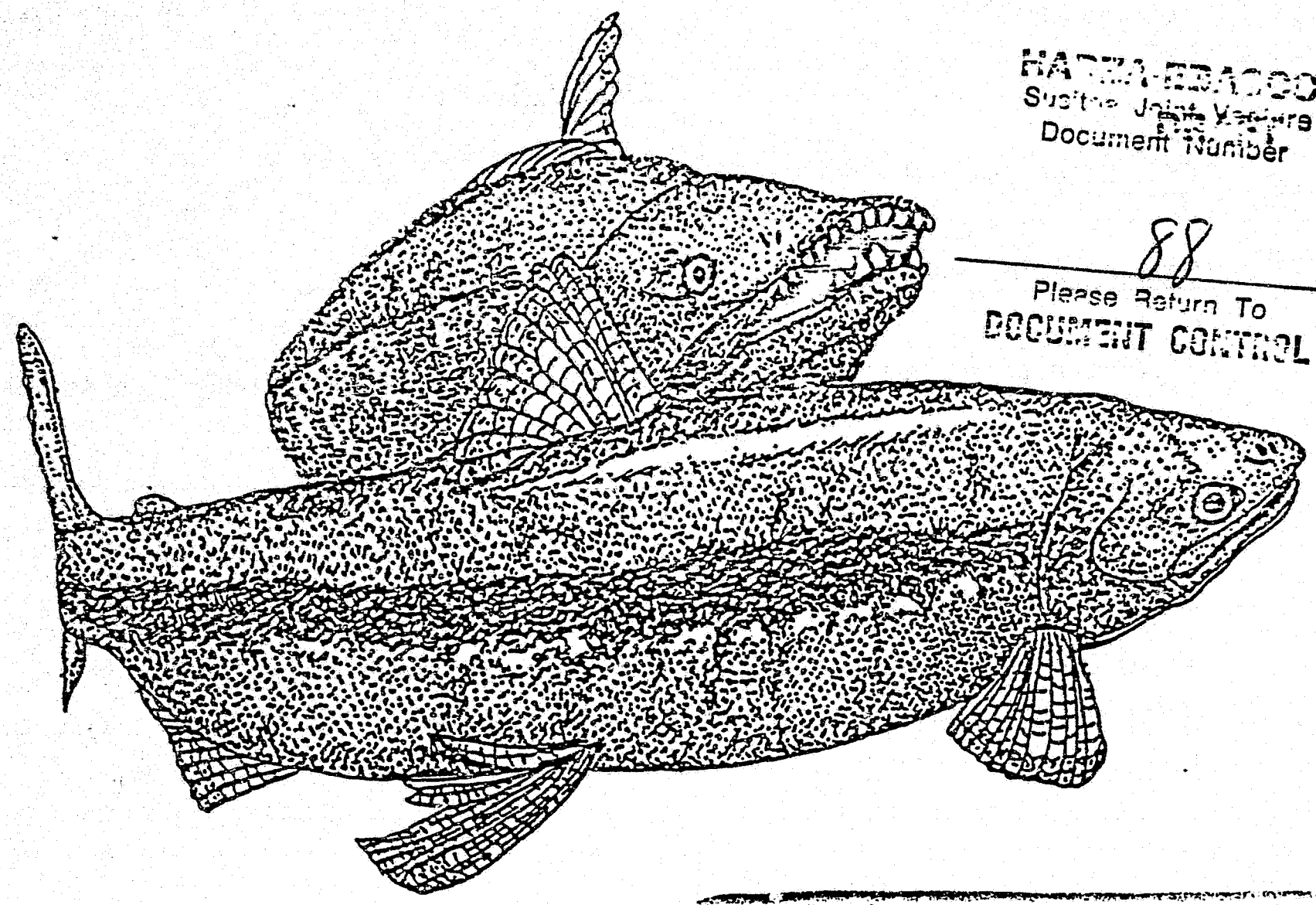

SUSITNA HYDRO AQUATIC STUDIES
PHASE II BASIC DATA REPORT

Volume 4: Aquatic Habitat and Instream Flow Studies, 1982.

Appendices D-J



-by-

ALASKA DEPARTMENT OF FISH AND GAME
Susitna Hydro Aquatic Studies
2207 Spenard Road
Anchorage, Alaska 99503
1983

2-9-2

Appendix Table 4-D-6. Summary of provisional water quality data for sloughs 8A, 9, 16B, 19, 21, and mainstem Susitna River at Gold Creek, collected by ADF&G and USGS in June, July, and September, 1981, and in January and February, 1982.

Parameter	Date[a]	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Physical and Field Parameters[b]							
*Water Temperature °C	June	15.5	14.2	14.0	5.5	10.7	12.4
	July	11.2	10.9	9.0	9.8	11.3	10.5
	September	3.5	5.6	4.8	1.8	2.4	0.4
	January	0.5	0.5	1.5	2.0	1.5	0.0
	March	0.5	0.5	2.0	1.0	1.5	0.0
Air Temperature °C	June	21.0	20.1	---	---	23.0	---
	July	16.0	14.0	15.5	---	---	---
	September	8.0	7.5	---	3.0	---	---
	January	---	---	---	---	---	---
	March	---	---	---	---	-11.0	---
Streamflow (discharge) cfs	June	6.4	2.9	0.7	0.2	3.2	1,780.0
	July	551.0	714.0	503.0	0.0	142.0	42,500.0
	September	2.8	1.5	0.3	<0.1	0.43	8,540.0
	January	---	---	---	---	---	---
	March	---	---	---	---	---	1,520.0
*Specific Conductance (field) umho^5/cm	June	140	145	71	146	226	---
	July	117	124	72	127	130	119
	September	135	113	64	150	205	172
	January	193	121	59	148	221	260
	March	142	143	59	129	196	266

[a]Sloughs and mainstem Susitna River were sampled on 2 or 3 consecutive days in each month (except January) as follows.

	8A	9	16B	19	21	Susitna River at Gold Creek
June	25	24	23	23	24	23
July	21	21	22	22	22	21
September	30	30	28	29	29	28
January	20	20	20	20	20	20
March	31	30	30	30	30	30

[b]Parameters marked with an * are averages of transect point measurements (see methods).

--- indicates data not available.

Appendix Table 4-D-6 (Continued).

Parameter	Date	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Physical and Field Parameters - Cont'd							
Alkalinity (lab) mg/l $CaCO_3$	June	47	33	24	52	63	45
	July	41	39	24	52	47	35
	September	42	36	26	62	61	44
	January	64	36	30	53	63	83
	March	46	42	27	50	64	82
Turbidity NTU	June	0.9	0.6	0.5	0.4	0.4	100.0
	July	130.0	130.0	43.0	2.5	150.0	170.0
	September	1.1	0.6	0.6	0.5	0.5	5.5
	January	0.4	0.5	0.5	0.3	0.5	0.7
	March	0.1	0.1	0.1	0.1	0.1	0.1
Sediments, suspended mg/l	June	1	2	1	1	5	327
	July	220	417	107	8	356	680
	September	1	1	1	2	4	44
	January	1	2	0	1	0	2
	March	7	3	6	1	6	8
Sediments, discharge suspended tons/day	June	0.02	0.02	0.0	0.0	0.04	1,570.0
	July	327.0	804.0	145.0	0.0	136.0	78,000.0
	September	0.01	0.0	0.0	0.0	0.0	1,020.0
	January	---	---	---	---	---	---
	March	---	---	---	---	---	33.0
Solids, residue at 180°C mg/l	June	88	100	51	94	137	79
	July	70	75	41	81	78	74
	September	82	69	42	95	119	101
	January	111	73	38	78	114	152
	March	92	93	42	80	124	160
Solids, sum of constituents mg/l	June	93	91	47	90	130	83
	July	61	68	43	89	68	65
	September	71	71	48	90	120	80
	January	120	76	---	92	130	165
	March	86	83	43	65	127	160

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EXHIBIT E

2. Water Use and Quality

Comment 10 (p. E-2-29, para. 4)

Clarify reference provided in Figure E.2.79 and explain procedure used to create this figure.

Response

Reference

The reference for Figure E.2.79 is R & M Consultants, Inc. 1982. Susitna Hydroelectric Project, Reservoir Sedimentation; prepared for Acres American Incorporated.

Suspended sediment rating curves shown on Figure E.2.79 (attached) are based on the results of periodic suspended sediment sampling on the Susitna River at Denali, Cantwell, and Gold Creek and the Maclaren River near Paxson. Table 1 give the period of record, number of samples collected and range of observed suspended sediment discharge with corresponding water (water- sediment mixture) discharge.

The suspended sediment rating curve at each station was approximated by a power relationship of the following form:

$$q_s = A(q)^B$$

in which:

q_s = suspended sediment transport in tons per day based on observed suspended sediment concentration and corresponding water discharge;

q = water (water-sediment mixture) discharge, cfs;

A = constant, an index of relative erodibility in the watershed;

B = slope of the sediment-discharge rating curve on logarithmic paper.

The above equation was fitted to the observed data at each site by the least square method. The resulting relationships are given in Table 2.

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TABLE 1

RANGE OVER WHICH SUSPENDED SEDIMENT DISCHARGE EQUATIONS ARE VALID AND PERIOD OF RECORD OF OBSERVATIONS

Station	Period of Record	Number of Samples	Observed Range of Sediment and Water Discharge			
			q_1,[1] cfs		q_s,[2] tons/day	
			Max	Min	Max	Min
Susitna River near Denali	Jun. 1958 - Aug. 1980	51	13,700[3]	963[4]	186,000[3]	221[4]
Maclaren River near Paxson	Jun. 1958 - Jul. 1975	32	16,000[6]	624[7]	5,320[8]	42[7]
Susitna River near Cantwell	Jul. 1962 - Aug. 1972	37	26,000[9]	5750[10]	196,000[9]	528[10]
Susitna River at Gold Creek		286	52,000[11]	1100[12]	218,000[13]	29[12]

1/ q = streamflow
2/ q_s = suspended Sediment Discharge

Date of observation
3/ August 11, 1977
4/ October 1, 1964
5/ August 30, 1974
6/ August 22, 1961
7/ September 30, 1966
8/ August 16, 1967
9/ July 8, 1963
10/ September 28, 1967
11/ Date not available
12/ May 1, 1952
13/ July 26, 1957

TABLE 2

SUSPENDED SEDIMENT DISCHARGE EQUATIONS
SUSITNA RIVER BASIN

Station	Equation	Number of Samples	Coefficient of Determination (r2)
Susitna River near Denali	$q_s = 1.43\ (10^{-4})\ q^{2.122}$	51	0.891
MacLaren River near Paxson	$q_s = 8.04\ (10^{-6})\ q^{2.523}$	32	0.931
Susitna River near Cantwell	$q_s = 6.33\ (10^{-8})\ q^{2.784}$	37	0.881
Susitna River at Gold Creek	$q_s = 2.39\ (10^{-6})\ q^{2.354}$	286	0.735

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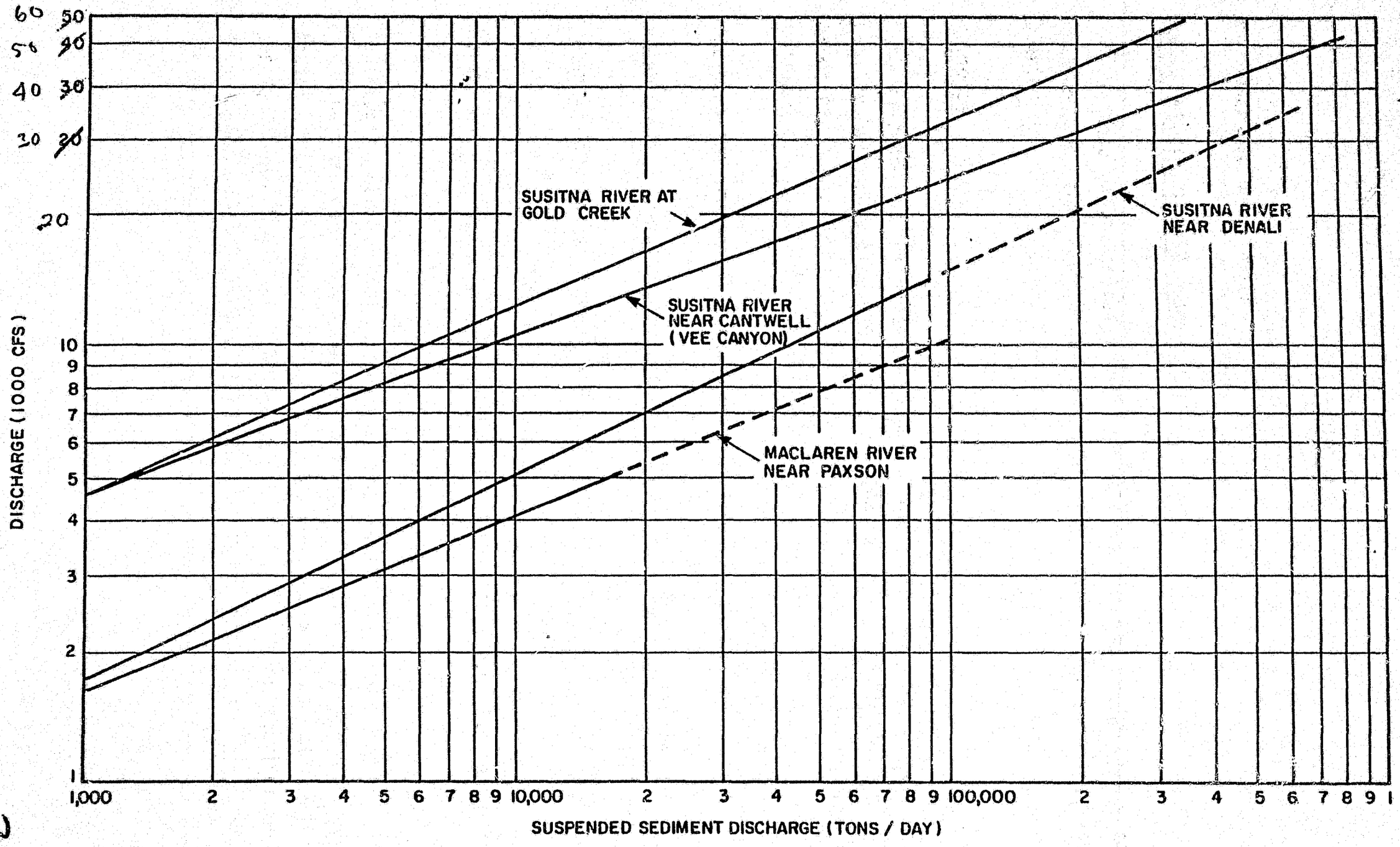
q = Streamflow, cfs
q_s = Suspended sediment discharge, tons/day



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SUSPENDED SEDIMENT RATING CURVES
MIDDLE AND UPPER SUSITNA RIVER BASINS

SOURCE: R & M 1982

FIGURE E.2.79

EXHIBIT E

2. Water Use and Quality

Comment 11 (p. E-2-32, para. 2)

Provide data on biologically available and total soluble phosphorus concentrations in the Susitna River water for each water quality sampling station.

Response

Data referred to in this paragraph (Figure E.2.87) are found in Water Quality Annual Reports 1980, 1981, and 1982 by R & M Consultants, Inc. prepared for Acres American, Inc. Pertinent excerpts from those reports are enclosed as pages 2-11-2 to 2-11-83 of this response.

The data are presented in the tables of those reports:

Water Quality Annual Report, 1980 - Tables 1, 6, 9, 10, 11, 12

Water Quality Annual Report, 1981 - Tables 4.1, 4.2, 4.3, 4.4; 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7

Water Quality Annual Report, 1982 - Tables 2.2, 2.3, 2.6, 2.7, 2.8, 2.9, 2.10

Additional measurements of soluble phosphorus are available for selected riverine sloughs and the Gold Creek River Station in the Susitna Hydro Aquatic Studies - Phase II Basic Data Report, Volume 4. Aquatic Habitat and Instream Flow Studies, 1982, Appendix 4.D.6. These sections are also enclosed as pages 2-11-84 to 2-11-100 of this response.

TABLE I

WATER QUALITY DATA - SUSITNA RIVER
NEAR CANTWELL (VEE CANYON SITE)

Field Parameters (1)	DATE SAMPLED Date 6/19/80	Date 8/8/80	Date 9/5/80	Date 9/17/80	Date 10/17/80	Date 1/13/81
Dissolved Oxygen	12.4	8.7	----	9.7	13.8	10.7
Percent Saturation	98	82	----	84	104	84
pH pH Units	7.8	7.9	7.8	7.6	7.6	7.2
Conductivity, umhos/cm @ 25°C	—	144	171	124	142	242
Temperature, °C	5.7	9.3	5.3	5.9	-0.1	0.1
Free Carbon Dioxide (2)	2.0	1.7	3.6	4.5	5.5	22.0
Alkalinity, as $CaCO_3$	47	54	81	63	88	187
Settleable Solids, ml/l	0.1	< 0.1	< 0.1	< 0.1	≪0.1	≪
Laboratory Parameters (1)(3)						
Ammonia Nitrogen	0.26	----	0.10	< 0.05	0.26	<0.05
Organic Nitrogen	< 0.1	----	0.22	0.62	0.28	0.85
Kjeldahl Nitrogen	0.26	----	0.32	0.62	0.54	0.85
Nitrate Nitrogen	0.19	0.15	0.15	0.09	<0.10	<0.1
Nitrite Nitrogen	< 0.01	----	< 0.01	< 0.01	<0.01	<0.01
Total Nitrogen	0.45	----	0.47	0.71	0.54	0.85
Ortho-Phosphate	< 0.01	0.03	0.05	< 0.05	<0.01	<0.01
Total Phosphate	0.05	0.03	0.09	0.10	<0.01	0.07
Alkalinity	-	-	-	-	66	106
Chemical Oxygen Demand	28	12.6	124	156	6	12
Chloride	3	9	11	8	18	18
Conductivity umhos/cm @ 25°C	150	-	-	-	190	196
True Color, Color Units	-	40	10	45	10	10
Hardness, as $CaCO_3$ (4)	51	76	69	55	90	-

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Laboratory Parameters (1)(3) (continued)

	6/19/80	8/8/80	9/5/80	9/17/80	10/17/80	1/13/81
Sulfate	4	9	9	7	13	16
Total Dissolved Solids	70	90	114	38	115	149
Total Suspended Solids	242	310	25	132	8.3	0.6
Turbidity, NTU	94	97	10	33	1.8	0.35
Uranium	----	<0.05	----	----	----	<0.05
Radioactivity, Gross Alpha, pCi/l	----	11.6±0.6	----	----	----	10.3±0.6
Total Organic Carbon	----	----	----	----	----	23
Total Inorganic Carbon	----	----	----	----	-21	106
Organic Chemicals						
Endrin	---	<0.0001	----	----	----	<0.0002
Lindane	----	<0.001	----	----	----	<0.004
Methoxychlor	----	<0.05	----	----	----	<0.1
Toxaphene	----	<0.001	----	----	----	<0.005
2, 4-D	----	<0.05	----	----	----	<0.1
2, 4, 5-TP Silvex	----	<0.005	----	----	----	<0.01
CAP Scan						
Ag, Silver	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Al, Aluminum	1.6	<0.1	0.28	2.2	0.18	<0.05
As, Arsenic	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1
Au, Gold	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
B, Boron	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ba, Barium	<0.1	0.11	<0.05	0.07	<0.05	<0.05
Bi, Bismuth	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ca, Calcium	13	16	22	18	28	36
Cd, Cadmium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Co, Cobalt	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cr, Chromium	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cu, Copper	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Fe, Iron	2.1	4.0	0.46	2.7	0.37	<0.05
Hg, Mercury	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1
K, Potassium	<1.0	2.3	2.1	5.0	<1.0	2
Mg, Magnesium	1.4	3.4	3.1	1.2	4.5	7.6
Mn, Manganese	<0.05	0.10	<0.05	0.07	<0.05	<0.05
Mo, Molybdenum	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

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Laboratory Parameters (1)(3) (continued)

	6/19/80	8/8/80	9/5/80	9/17/80	10/17/80	1/13/81
Na, Sodium	2.6	2.4	5.1	3.5	7.2	6.6
Ni, Nickel	< 0.05	< 0.05	< 0.05	< 0.05	<0.05	<0.05
Pb, Lead	< 0.05	< 0.05	< 0.05	< 0.05	<0.05	<0.05
Pt, Platinum	< 0.05	< 0.05	< 0.05	< 0.10	<0.05	<0.05
Sb, Antimony	< 0.1	< 0.1	< 0.05	< 0.1	<0.1	<0.1
Se, Selenium	< 0.05	< 0.1	< 0.1	< 0.1	<0.1	<0.1
Si, Silicon	4.8	5.3	3.6	6.9	4.1	5.0
Sn, Tin	< 0.1	< 0.1	< 0.1	< 0.1	<0.1	<0.1
Sr, Strontium	< 0.05	0.06	0.07	0.07	0.10	0.13
Ti, Titanium	0.13	0.24	< 0.05	0.17	<0.05	<0.05
W, Tungsten	< 1.0	< 1.0	< 1.0	----	<0.1	0.4
V, Vanadium	< 0.05	< 0.05	< 0.05	< 0.05	<0.05	<0.05
Zn, Zinc	< 0.05	< 0.05	< 0.05	< 0.05	<0.05	<0.05
Zr, Zirconium	< 0.05	< 0.05	< 0.05	< 0.05	<0.05	<0.05

(1) Table values are mg/l unless noted otherwise.

(2) All values for free CO_2 determined from nomograph on p. 297 of Standard Method, 14th edition.

(3) Samples for all parameters except chemical oxygen demand, dissolved and suspended solids, and turbidity were filtered.

(4) Hardness calculated by R&M personnel.

TABLE 6

WATER QUALITY DATA - SUSITNA RIVER
AT GOLD CREEK

Field Parameters (1)	DATE SAMPLED Date 08/08/80	Date 10/14/80	Date 1/14/81
Dissolved Oxygen	8.6	14.0	13.3
Percent Saturation	81	100	101
pH, pH Units	7.8	7.8	7.1
Conductivity, umhos/cm @ 25°C	169	167	249
Temperature, °C	11.7	0.0	0.3
Free Carbon Dioxide (2)	2.1	3.2	23.0
Alkalinity, as $CaCO_3$	55	74	144
Settleable Solids, ml/l	< 0.1	≪0.1	≪0.1
Laboratory Parameters (1)(3)			
Ammonia Nitrogen	----	0.32	<0.05
Organic Nitrogen	----	0.34	0.81
Kjeldahl Nitrogen	----	0.66	0.81
Nitrate Nitrogen	0.18	<0.10	0.18
Nitrite Nitrogen	----	<0.01	<0.01
Total Nitrogen	----	0.66	0.99
Ortho-Phosphate	< 0.02	<0.01	<0.01
Total Phosphate	< 0.02	<0.01	<0.01
Alkalinity, as $CaCO_3$	-	57	90
Chemical Oxygen Demand	13.8	8	16
Chloride	14	16	29
Conductivity, umhos/cm @ 25°C	-	165	----
True Color, Color Units	45	10	10
Hardness, as $CaCO_3$	62	74	121

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0 0 1 1 6 7

Field Parameters (1)(3) (continued)	Gold Creek (cont.) 08/08/80	10/14/80	1/14/81
Sulfate	12	10	16
Total Dissolved Solids	74	100	188
Total Suspended Solids	175	7.7	< 1
Turbidity, NTU	58	0.9	0.30
Uranium	<0.05	----	< 0.05
Radioactivity, Gross Alpha, pCi/l	2.6±0.4	----	
Total Organic Carbon	----	----	39
Total Inorganic Carbon	----	----	90
Organic Chemicals			
Endrin	<0.0001	----	<0.000
Lindane	<0.001	----	<0.00
Methoxychlor	<0.05	----	<0.1
Toxaphene	<0.001	----	<
2, 4-D	<0.05	----	<0.
2, 4, 5-TP Silvex	<0.005	----	<0.01
ICAP Scan			
Ag, Silver	<0.05	<0.05	<0.05
Al, Aluminum	0.7	0.18	<0.05
As, Arsenic	<0.1	<0.1	<0.1
Au, Gold	<0.05	<0.05	<0.05
B, Boron	<0.05	<0.05	<0.05
Ba, Barium	0.08	<0.05	<0.05
Bi, Bismuth	<0.05	<0.05	0.07
Ca, Calcium	15	23	32
Cd, Cadmium	<0.01	<0.01	<0.01
Co, Cobalt	<0.05	<0.05	<0.05
Cr, Chromium	<0.05	<0.05	<0.05
Cu, Copper	<0.05	<0.05	<0.05
Fe, Iron	2.3	0.35	<0.05
Hg, Mercury	<0.1	<0.1	<
K, Potassium	1.8	<1	2
Mg, Magnesium	2.7	3.7	10
Mn, Manganese	0.05	<0.05	<0.05

2-11-6

Field Parameters (1)(3) (continued)	Gold Creek (cont.) 08/08/80	10/14/80	1/14/81
Mo, Molybdenum	<0.05	<0.05	<0.05
Na, Sodium	3.3	8.5	13
Ni, Nickel	<0.05	<0.05	<0.05
Pb, Lead	<0.05	<0.05	<0.05
Pt, Platinum	<0.05	<0.05	<0.05
Sb, Antimony	<0.10	<0.1	<0.1
Se, Selenium	<0.1	<0.1	<0.1
Si, Silicon	4.6	4.2	5.0
Sn, Tin	<0.1	<0.1	<0.1
Sr, Strontium	<0.05	0.11	0.19
Ti, Titanium	0.14	<0.05	<0.05
W, Tungsten	<1.0	<0.1	<0.1
V, Vanadium	<0.05	<0.05	<0.05
Zn, Zinc	<0.05	<0.05	<0.05
Zr, Zirconium	<0.05	<0.05	<0.05

(1) Table values are mg/l unless noted otherwise.

(2) All values for free CO_2 determined from nomograph on p. 297 of Standard Method, 14th edition.

(3) Samples for all parameters except chemical oxygen demand, dissolved and suspended solids, and turbidity were filtered.

(4) Hardness calculated by R&M personnel.

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. Geological Survey

Station: Nr. Denali Elevation: 2440 Ft.

1957-1978

TABLE 9

Field Parameters (1)	MAXIMUM	MINIMUM	MEAN	NUMBER OBSERVATIONS
		Summer/Winter		
Dissolved Oxygen				
Percent Saturation				
pH, pH Units	7.8/7.6	7.1/7.1	7.5/7.4	15/4
Conductivity, umhos/cm @ 25°C.	205/467	121/194	157/349	18/4
Temperature, °C	10.5/-	0.5/-	5.5/-	50/-
Free Carbon Dioxide	5.8/25	1.5/4.5	3.2/10.8	11/4
Alkalinity, as $CaCO_3$	68/161	42/57	54/116	11/4
Settleable Solids, ml/l				
Laboratory Parameters (1)				
Ammonia Nitrogen				
Organic Nitrogen				
Kjeldahl Nitrogen				
Nitrate Nitrogen	.09/-	.00/-	.03/-	15/-
Nitrite Nitrogen				
Total Nitrogen				
Ortho-Phosphate				
Total Phosphate				
Chemical Oxygen Demand				
Chloride	12.0/30.0	2.0/3.8	4.8/19.0	11/4
True Color, Platinum-Cobalt Unit				
Hardness, as $CaCO_3$	87/181	50/84	64/139	11/4

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Laboratory Parameters (1) (continued)

	MAXIMUM	MINIMUM	MEAN	NUMBER OBSERVATIONS
		Summer/Winter		
Sulfate	23/39	9/31	15/36	11/4
Total Dissolved Solids	120/270	72/109	91/204	11/4
Total Suspended Solids	5690/-	85/-	1350/-	32/-
Turbidity, NTU				
Uranium				
Radioactivity, Gross Alpha, pCi/l				
Total Organic Carbon				
Total Inorganic Carbon				
Organic Chemicals				
Endrin				
Lindane				
Methoxychlor				
Toxaphene				
2, 4-D				
2, 4, 5-TP Silvex				
ICAP Scan				
Ag, Silver				
Al, Aluminum				
As, Arsenic				
Au, Gold				
B, Boron				
Ba, Barium				
Bi, Bismuth				
Ca, Calcium	29/51	17/23	21/40	11/4
Cd, Cadmium				
Co, Cobalt				
Cr, Chromium				
Cu, Copper				

Laboratory Parameters (1)

	MAXIMUM	MINIMUM	MEAN	NUMBER OBSERVATIONS
		Summer/Winter		
Fe, Iron	4.0/.06	0/0	1.0/.03	11/4
Hg, Mercury				
K, Potassium	3.0/6.6	1.3/3.6	2.5/5.8	11/4
Mg, Magnesium	3.8/16	1.7/6.2	3.1/9.3	11/4
Mn, Manganese	.06/.02	0/.01	.008/.01	10/3
Mo, Molybdenum				
Na, Sodium	10/23	2.1/3.8	4.3/15	11/4
Ni, Nickel				
Pb, Lead				
Pt, Platinum				
Sb, Antimony				
Se, Selenium				
Si, Silicon				
Sn, Tin				
Sr, Strontium				
Ti, Titanium				
W, Tungsten				
V, Vanadium				
Zn, Zinc				
Zr, Zirconium				

(1) Table values are mg/l unless noted otherwise.

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. Geological Survey

Station: Vee Canyon (Nr. Cantwell) 1962-1972 Elevation: 1900 Ft.

TABLE 10

		MAXIMUM	MINIMUM	MEAN	NUMBER OBSERVATIONS
Field Parameters (1)					
		Summer Values Only			
Dissolved Oxygen					
Percent Saturation					
pH, pH Units		8.1	7.2	7.7	10
Conductivity, umhos/cm @ 25°C		250	91	150	25
Temperature, °C		13.0	1.0	7.7	38
Free Carbon Dioxide		6.8	.7	2.6	10
Alkalinity, as $CaCO_3$		59	39	51	10
Settleable Solids, ml/l					
Laboratory Parameters (1)					
Ammonia Nitrogen					
Organic Nitrogen					
Kjeldahl Nitrogen					
Nitrate Nitrogen		0.88	0.0	.20	10
Nitrite Nitrogen					
Total Nitrogen					
Ortho-Phosphate					
Total Phosphate					
Chemical Oxygen Demand					
Chloride		9.2	2.1	5.5	10
True Color, Platinum	Unit	40	5	14	9
Hardness, as $CaCO_3$		76	42	62	10

susi4/i1

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Laboratory Parameters (1) (continued)

	MAXIMUM	MINIMUM	MEAN	NUMBER OBSERVATIONS
		Summer Values Only		
Sulfate	18	7.5	14	10
Total Dissolved Solids	110	66	90	10
Total Suspended Solids	2790	34	804	38
Turbidity, NTU				
Uranium				
Radioactivity, Gross Alpha, pCi/l				
Total Organic Carbon				
Total Inorganic Carbon				
Organic Chemicals				
Endrin				
Lindane				
Methoxychlor				
Toxaphene				
2, 4-D				
2, 4, 5-TP Silvex				
ICAP Scan				
Ag, Silver				
Al, Aluminum				
As, Arsenic				
Au, Gold				
B, Boron				
Ba, Barium				
Bi, Bismuth				
Ca, Calcium	27	14	21	10
Cd, Cadmium				
Co, Cobalt				
Cr, Chromium				
Cu, Copper				

0 0 1 1 6 7

Laboratory Parameters (1)

	MAXIMUM	MINIMUM	MEAN	NUMBER OBSERVATIONS
	Summer Values Only			
Fe, Iron	12.0	.05	2.9	10
Hg, Mercury				
K, Potassium	7.3	1.8	3.4	10
Mg, Magnesium	4.4	1.1	2.7	10
Mn, Manganese				
Mo, Molybdenum				
Na, Sodium				
Ni, Nickel	6.3	2.1	3.9	10
Pb, Lead				
Pt, Platinum				
Sb, Antimony				
Se, Selenium				
Si, Silicon				
Sn, Tin				
Sr, Strontium				
Ti, Titanium				
W, Tungsten				
V, Vanadium				
Zn, Zinc				
Zr, Zirconium				

(1) Table values are mg/l unless noted otherwise.

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. Geological Survey

Station: Gold Creek Elevation: 676.5 Ft.
1949-1978

TABLE 11

Field Parameters (1)	MAXIMUM	MINIMUM	MEAN	NUMBER OBSERVATIONS
		Summer/Winter/Break-up		
Dissolved Oxygen	12.6/-/-	11.1/-/-	12.0/-/-	3/-/-
Percent Saturation	106/-/-	96/-/-	102/-/-	3/-/-
pH, pH Units	8.0/8.1/8.0	6.6/7.0/6.5	7.4/7.4/7.1	31/20/8
Conductivity, umhos/cm @ 25°C	227/300/121	90/164/82	162/248/65	60/25/7
Temperature, °C	13.5/0.5/8.0	1.0/0.0/1.0	8.6/0.5/3.4	22/5/7
Free Carbon Dioxide	20/16/24	1.1/1.2/5.6	5.6/6.3/8.0	60/22/5
Alkalinity, as $CaCO_3$	87/88/80	30/49/29	52/70/48	64/23/3
Settleable Solids, ml/l				
Laboratory Parameters (1)				
Ammonia Nitrogen				
Organic Nitrogen				
Kjeldahl Nitrogen				
Nitrate Nitrogen	.36/.32/.29	.02/.05/.05	.13/.14/.17	58/22/3
Nitrite Nitrogen				
Total Nitrogen				
Ortho-Phosphate				
Total Phosphate				
Chemical Oxygen Demand				
Chloride	15/35/4.5	1.4/9/1.8	5.4/22/3.2	60/25/4
True Color, Platinum-Cobalt Unit	20/5/50	0/0/10	8/3.5/28	52/20/6
Hardness, as $CaCO_3$	107/114/113	35/60/32	61/97/60	58/24/3

Laboratory Parameters (1) (continued)

	MAXIMUM	MINIMUM	MEAN	NUMBER OBSERVATIONS
		Summer/Winter/Break-up		
Sulfate	28/38/27	4/13/5.5	17/21/16	63/22/2
Total Dissolved Solids	134/167/70	51/102/48	93/149/55	59/26/4
Total Suspended Solids	2630/76/1330	23/1/120	832/18/652	59/8/11
Turbidity, NTU				
Uranium				
Radioactivity, Gross Alpha, pCi/l	50/-/-	2.7/-/-	20/-/-	3/-/-
Total Organic Carbon				
Total Inorganic Carbon				
Organic Chemicals				
Endrin				
Lindane				
Methoxychlor				
Toxaphene				
2, 4-D				
2, 4, 5-TP Silvex				
ICAP Scan				
Ag, Silver				
Al, Aluminum				
As, Arsenic				
Au, Gold				
B, Boron				
Ba, Barium				
Bi, Bismuth				
Ca, Calcium	37/11/-	37/24/-	19/30/-	58/26/-
Cd, Cadmium				
Co, Cobalt				
Cr, Chromium				
Cu, Copper				

0 0 1 1 6 7

Laboratory Parameters (1)

	MAXIMUM	MINIMUM	MEAN	NUMBER OBSERVATIONS
		Summer/Winter/Break-up		
Fe, Iron	.46/.03	0/0/-	.16/.01	27/21/0
Hg, Mercury				
K, Potassium	4.4/5.0/1.7	1.0/1.2/1.3	2.4/2.3/1.6	49/18/3
Mg, Magnesium	6.3/8.3/7.4	1.4/3.6/.3	3.3/5.7/2.5	55/27/4
Mn, Manganese	.18/.0	0/0/-	.010/0/-	23/2/0
Mo, Molybdenum				
Na, Sodium	6.5/17.0/2.9	2.4/5.2/2.8	4.1/11.0/2.9	48/19/2
Ni, Nickel				
Pb, Lead				
Pt, Platinum				
Sb, Antimony				
Se, Selenium				
Si, Silicon				
Sn, Tin				
Sr, Strontium				
Ti, Titanium				
W, Tungsten				
V, Vanadium				
Zn, Zinc				
Zr, Zirconium				

(1) Table values are mg/l unless noted otherwise.

0011616

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. Geological Survey

Station: Sunshine Elevation: 270 ft.
1971-1977

TABLE 12

Field Parameters (1)	MAXIMUM	MINIMUM	MEAN	NUMBER OBSERVATIONS
			Summer/Winter	
Dissolved Oxygen	12.8	10.6	12.0	3
Percent Saturation	102	97	99	3
pH, pH Units	7.6	7.1	7.4	3
Conductivity, umhos/cm @ 25°C	170	100	132/242	6/1
Temperature, °C	12.0	4.0	8.0	6
Free Carbon Dioxide	3.9	2.1	3.2	3
Alkalinity, as $CaCO_3$	43	25	37/71	3/1
Settleable Solids, ml/l				
Laboratory Parameters (1)				
Ammonia Nitrogen			-/.05	
Organic Nitrogen			-/.18	
Kjeldahl Nitrogen				
Nitrate Nitrogen				
Nitrite Nitrogen				
Total Nitrogen			-/.42	
Ortho-Phosphate	.12	.00	.07	4
Total Phosphate				
Chemical Oxygen Demand				
Chloride	7.3	2.7	5.3/21	3/1
True Color, Platinum-Cobalt Unit				
Hardness, as $CaCO_3$	72	37	54/91	3/1

2-11-17

Laboratory Parameters (1) (continued)

	MAXIMUM	MINIMUM	MEAN	NUMBER OBSERVATIONS
			Summer/Winter	
Sulfate	12	5.7	9.6/17	3/1
Total Dissolved Solids	51	102	77/137	3/1
Total Suspended Solids	3510	288	1419	6
Turbidity, NTU				
Uranium				
Radioactivity, Gross Alpha, pCi/l				
Total Organic Carbon				
Total Inorganic Carbon				
Organic Chemicals				
Endrin				
Lindane				
Methoxychlor				
Toxaphene				
2, 4-D				
2, 4, 5-TP Silvex				
ICAP Scan				
Ag, Silver				
Al, Aluminum				
As, Arsenic				
Au, Gold				
B, Boron				
Ba, Barium				
Bi, Bismuth				
Ca, Calcium	23	12	17/29	3/1
Cd, Cadmium				
Co, Cobalt				
Cr, Chromium				
Cu, Copper				

0011676

Laboratory Parameters (1)

	MAXIMUM	MINIMUM	MEAN	NUMBER OBSERVATIONS
			Summer/Winter	
Fe, Iron	.18	.06	.12/.01	2/1
Hg, Mercury				
K, Potassium	2.8	1.1	1.7/2.1	3/1
Mg, Magnesium	3.5	1.6	2.7/4.5	3/1
Mn, Manganese	.02	0	.01/0	2/1
Mo, Molybdenum				
Na, Sodium	4.4	1.9	3.0/11	3/1
Ni, Nickel				
Pb, Lead				
Pt, Platinum				
Sb, Antimony				
Se, Selenium				
Si, Silicon				
Sn, Tin				
Sr, Strontium				
Ti, Titanium				
W, Tungsten				
V, Vanadium				
Zn, Zinc				
Zr, Zirconium				

(1) Table values are mg/l unless noted otherwise.

susi4/i6

2-11-19

TABLE 4.1

R&M CONSULTANTS, INC.

1981 WATER QUALITY DATA - SUSITNA RIVER

AT VEE CANYON

NOTE: Dash indicates data not available

	Date			
	1/13/81	5/20/81	6/18/81	6/30/81
Field Parameters (1)				
Dissolved Oxygen	10.7	10.4	----	11.6
Percent Saturation	84	83	----	99
pH, pH Units	7.2	6.6	7.8	7.7
Conductivity, umhos/cm @ 25°C	242	100	120	124
Temperature, °C	0.1	6.5	11.9	7.9
Free Carbon Dioxide (2)	20.0	----	3.2	2.2
Alkalinity, as $CaCO_3$	99	----	79	41
Settleable Solids, ml/l	≪0.1	≪0.1	≪0.1	<0.1
Discharge c.f.s.	1,800	9,810	11,600	13,700
Laboratory Parameters (1)(3)				
Ammonia Nitrogen	<0.05	0.13	0.12	<0.05
Organic Nitrogen	0.85	0.34	0.63	0.39
Kjeldahl Nitrogen	0.85	0.47	0.75	0.39
Nitrate Nitrogen	<0.1	<0.1	<0.10	<0.10
Nitrite Nitrogen	<0.01	<0.01	<0.01	<0.01
Total Nitrogen	0.85	0.47	0.75	0.39
Ortho-Phosphate	<0.01	<0.01	<0.01	0.49
Total Phosphorus	0.07	<0.05	<0.05	0.49
Alkalinity, as $CaCO_3$	----	----	----	----
Chemical Oxygen Demand	12	8	8	16

2-11-20

0011677

TABLE 4.1 - CONTINUED

	Date			
	1/13/81	5/20/81	6/18/81	6/30/81
Laboratory Parameters (1)(3) (Cont'd)				
Chloride	18	4.5	5.0	5.0
Conductivity, umhos/cm @ 25°C	----	----	----	----
True Color, Color Units	10	15	5	20
Hardness, as $CaCO_3$ (4)	121	40	49	59
Sulfate	16	4	8	7
Total Dissolved Solids	149	100	170	91
Total Suspended Solids	0.6	93	340	130
Turbidity, NTU	0.35	25	66	29
Uranium	<0.05	----	----	----
Radioactivity, Gross Alpha, pCi/l	10.3±0.6	----	----	----
Total Organic Carbon	23	40	11	23
Total Inorganic Carbon	106	46	46	59
Organic Chemicals				
Endrin	<0.0002	----	----	<0.0002
Lindane	<0.004	----	----	<0.004
Methoxychlor	<0.1	----	----	<0.1
Toxaphene	<0.005	----	----	<0.005
2, 4-D	<0.1	----	----	<0.1
2, 4, 5-TP Silvex	<0.01	----	----	<0.01
ICAP Scan				
Ag, Silver	<0.05	<0.05	<0.05	<0.05
Al, Aluminum	<0.05	<0.05	<0.05	<0.05
As, Arsenic	<0.10	<0.10	<0.10	<0.10
Au, Gold	<0.05	<0.05	<0.05	<0.05
B, Boron	<0.05	<0.05	<0.05	<0.05

TABLE 4.1 - CONTINUED

	Date			
	1/13/81	5/20/81	6/18/81	6/30/81
Laboratory Parameters (1)(3) (Cont'd)				
Ba, Barium	<0.05	<0.05	0.07	0.11
Bi, Bismuth	<0.05	<0.05	<0.05	0.19
Ca, Calcium	36	13	16	19
Cd, Cadmium	<0.01	<0.01	<0.01	<0.01
Co, Cobalt	<0.05	<0.05	<0.05	<0.05
Cr, Chromium	<0.05	<0.05	<0.05	<0.05
Cu, Copper	<0.05	<0.05	<0.05	<0.05
Fe, Iron	<0.05	0.08	0.05	0.07
Hg, Mercury	<0.10	<0.10	<0.10	<0.10
K, Potassium	2	1.6	2.0	2.1
Mg, Magnesium	7.6	1.7	2.0	2.8
Mn, Manganese	<0.05	<0.05	<0.05	<0.05
Mo, Molybdenum	<0.05	<0.05	<0.05	<0.05
Na, Sodium	6.6	2.0	3.3	4.6
Ni, Nickel	<0.05	<0.05	<0.05	<0.05
Pb, Lead	<0.05	<0.05	<0.05	<0.05
Pt, Platinum	<0.05	<0.05	<0.05	<0.05
Sb, Antimony	<0.10	<0.10	<0.10	<0.10
Se, Selenium	<0.10	<0.10	<0.10	<0.10
Si, Silicon	5.0	1.7	2.0	2.6
Sn, Tin	<0.10	<0.10	<0.10	<0.10
Sr, Strontium	0.13	<0.05	0.06	0.07
Ti, Titanium	<0.05	<0.05	<0.05	<0.05

0001167

TABLE 4.1 - CONTINUED

	Date			
	1/13/81	5/20/81	6/18/81	6/30/81
Laboratory Parameters (1)(3) (Cont'd)				
W, Tungsten	0.4	<1.0	<1.0	<1.0
V, Vanadium	<0.05	<0.05	<0.05	<0.05
Zn, Zinc	<0.05	<0.05	0.07	<0.05
Zr, Zirconium	<0.05	<0.05	<0.05	<0.05

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(1) Table values are mg/l unless noted otherwise.

(2) All values for free CO_2 determined from nomograph on p. 297 of Standard Method, 14th edition.

(3) Samples for all parameters except chemical oxygen demand, dissolved and suspended solids, and turbidity were filtered.

(4) Hardness calculated by R&M personnel.

2-11-23

TABLE 4.2

R&M CONSULTANTS, INC.

1981 WATER QUALITY DATA - SUSITNA RIVER

AT VEE CANYON

NOTE: Dash indicates data not available.

	Date Sampled				
	8/2/81	8/3/81	8/3/81	9/15/81	10/7/81
Field Parameters (1)					
Dissolved Oxygen	11.8	12.6	12.3	12.6	13.2
Percent Saturation	104	107	107	110	102
pH, pH Units	7.1	7.0	7.2	7.7	7.5
Conductivity, umhos/cm @ 25°C	108	106	103	162	130
Temperature, °C	8.3	7.5	9.1	5.9	0.0
Free Carbon Dioxide (2)	----	----	----	3.5	5.5
Alkalinity, as $CaCO_3$	----	----	----	62	57
Settleable Solids, ml/l	1.0	0.9	0.7	≪0.1	≪0.1
Discharge c.f.s.	26,375	29,420	28,700	7,790	<4,500
Laboratory Parameters (1)(3)					
Ammonia Nitrogen	0.27	0.09	0.11	<0.05	0.09
Organic Nitrogen	0.52	0.48	0.63	0.45	0.08
Kjeldahl Nitrogen	0.79	0.57	0.74	0.45	0.17
Nitrate Nitrogen	0.13	<0.10	<0.10	<0.10	<0.10
Nitrite Nitrogen	<0.01	<0.01	<0.01	<0.01	<0.01
Total Nitrogen	0.92	0.57	0.74	0.45	0.17
Ortho-Phosphate	<0.01	<0.01	<0.01	<0.01	0.02
Total Phosphorus	<0.05	0.08	<0.05	<0.05	<0.05
Alkalinity, as $CaCO_3$	44	46	40	60	----

2-11-24

TABLE 4.2 - CONTINUED

	Date Sampled				
	8/2/81	8/3/81	8/3/81	9/15/81	10/7/81
Laboratory Parameters (1)(3) (continued)					
Chemical Oxygen Demand	27	39	20	8	8
Chloride	<1.0	<1.0	<1.0	6	16
Conductivity, umhos/cm @ 25°C	----	----	----	----	----
True Color, Color Units	150	150	175	50	30
Hardness, as $CaCO_3$ (4)	51	51	51	72	78
Sulfate	4	2	2	8	11
Total Dissolved Solids	90	105	91	120	143
Total Suspended Solids	1150	870	745	40	14
Turbidity, NTU	108	120	112	8.7	2.5
Uranium	<0.05	<0.05	<0.05	<0.05	<0.05
Radioactivity, Gross Alpha, pCi/l	----	----	----	5.0±2.5	----
Total Organic Carbon	15	20	13	----	----
Total Inorganic Carbon	54	56	49	60	----
Organic Chemicals					
Endrin	----	----	----	<0.0002	----
Lindane	----	----	----	<0.004	----
Methoxychlor	----	----	----	<0.1	----
Toxaphene	----	----	----	<0.005	----
2, 4-D	----	----	----	<0.1	----
2, 4, 5-TP Silvex	----	----	----	<0.01	----
ICAP Scan					
Ag, Silver	<0.05	<0.05	<0.05	<0.05	<0.05
Al, Aluminum	<0.05	<0.05	<0.05	<0.05	<0.05
As, Arsenic	<0.10	<0.10	<0.10	<0.10	<0.10
Au, Gold	<0.05	<0.05	<0.05	<0.05	<0.05
B, Boron	<0.05	<0.05	<0.05	<0.05	<0.05

2-11-25

TABLE 4.2 - CONTINUED

Laboratory Parameters (1)(3) (continued)	Date Sampled 8/2/81	8/3/81	8/3/81	9/15/81	10/7/81
Ba, Barium	0.12	0.10	0.10	<0.05	<0.05
Bi, Bismuth	<0.05	<0.05	<0.05	<0.05	<0.05
Ca, Calcium	17	17	17	23	25
Cd, Cadmium	<0.01	<0.01	<0.01	<0.01	<0.01
Co, Cobalt	<0.05	<0.05	<0.05	<0.05	<0.05
Cr, Chromium	<0.05	<0.05	<0.05	<0.05	<0.05
Cu, Copper	<0.05	<0.05	<0.05	<0.05	<0.05
Fe, Iron	0.13	0.10	0.08	<0.05	<0.05
Hg, Mercury	<0.10	<0.10	<0.10	<0.10	<0.10
K, Potassium	1.9	1.9	1.7	2	9.0
Mg, Magnesium	2.1	2.0	2.1	3.4	3.8
Mn, Manganese	<0.05	<0.05	<0.05	<0.05	<0.05
Mo, Molybdenum	<0.05	<0.05	<0.05	<0.05	<0.05
Na, Sodium	2.7	2.5	2.6	5.1	6.3
Ni, Nickel	<0.05	<0.05	<0.05	<0.05	<0.05
Pb, Lead	<0.05	<0.05	<0.05	<0.05	<0.05
Pt, Platinum	<0.05	<0.05	<0.05	<0.05	<0.05
Sb, Antimony	<0.10	<0.10	<0.10	<0.10	<0.10
Se, Selenium	<0.10	<0.10	<0.10	<0.10	<0.10
Si, Silicon	2.2	2.2	2.4	3.2	3.7
Sn, Tin	<0.10	<0.10	<0.10	<0.10	<0.10
Sr, Strontium	0.06	<0.05	0.06	0.08	0.06
Ti, Titanium	<0.05	<0.05	<0.05	<0.05	<0.05

TABLE 4.2 - CONTINUED

	Date Sampled				
	8/2/81	8/3/81	8/3/81	9/15/81	10/7/81
Laboratory Parameters (1)(3) (continued)					
W, Tungsten	<1.0	<1.0	<1.0	<1.0	<1.0
V, Vanadium	<0.05	<0.05	<0.05	<0.05	<0.05
Zn, Zinc	<0.05	<0.05	<0.05	<0.05	<0.05
Zr, Zirconium	<0.05	<0.05	<0.05	<0.05	<0.05

(1) Table values are mg/l unless noted otherwise.

(2) All values for free CO_2 determined from nomograph on p. 297 of Standard Method, 14th edition.

(3) Samples for all parameters except chemical oxygen demand, dissolved and suspended solids, and turbidity were filtered.

(4) Hardness calculated by R&M personnel.

2-11-27

TABLE 4.3

R&M CONSULTANTS, INC.

1981 WATER QUALITY DATA - SUSITNA RIVER

AT GOLD CREEK

NOTE: Dash indicates data not available.

	Date			
	1/14/81	5/27/81 (A)	5/27/81 (B)	6/17/81
Field Parameters (1)				
Dissolved Oxygen	13.3	11.2	11.5	----
Percent Saturation	101	102	101	----
pH, pH Units	7.1	6.7	6.4	7.7
Conductivity, umhos/cm @ 25°C	249	105	106	126
Temperature, °C	0.3	10.5	10.3	12.8
Free Carbon Dioxide (2)	20.0	----	----	3.0
Alkalinity, as $CaCO_3$	74	----	----	64
Settleable Solids, ml/l	≪0.1	≪0.10	<0.10	≪0.10
Discharge c.f.s.	----	14,400	14,400	17,700
Laboratory Parameters (1)(3)				
Ammonia Nitrogen	<0.05	<0.05	0.08	0.09
Organic Nitrogen	0.81	0.34	0.27	0.39
Kjeldahl Nitrogen	0.81	0.34	0.35	0.48
Nitrate Nitrogen	0.18	<0.10	<0.10	<0.10
Nitrite Nitrogen	<0.01	<0.01	<0.01	<0.01
Total Nitrogen	0.99	0.34	0.35	0.48
Ortho-Phosphate	<0.01	<0.01	<0.01	<0.01
Total Phosphorus	<0.01	0.08	<0.05	<0.05
Alkalinity, as $CaCO_3$	----	----	----	----

TABLE 4.3 - CONTINUED

	Date			
	1/14/81	5/27/81 (A)	5/27/81 (B)	6/17/81
Laboratory Parameters (1)(3) (Cont'd)				
Chemical Oxygen Demand	16	8	12	12
Chloride	29	10	6	5
Conductivity, umhos/cm @ 25°C	----	----	----	----
True Color, Color Units	10	15	10	5
Hardness, as $CaCO_3$ (4)	121	43	43	52
Sulfate	16	6	5	5
Total Dissolved Solids	188	90	87	98
Total Suspended Solids	<1.0	56	49	120
Turbidity, NTU	0.30	15	19	31
Uranium	<0.05	----	----	----
Radioactivity, Gross Alpha, pCi/l	2.0±0.4	----	----	----
Total Organic Carbon	39	15	25	41
Total Inorganic Carbon	90	41	44	45
Organic Chemicals				
Endrin	<0.0002	----	----	----
Lindane	<0.004	----	----	----
Methoxychlor	<0.1	----	----	----
Toxaphene	<0.005	----	----	----
2, 4-D	<0.1	----	----	----
2, 4, 5-TP Silvex	<0.01	----	----	----
ICAP Scan				
Ag, Silver	<0.05	<0.05	<0.05	<0.05
Al, Aluminum	<0.05	<0.05	<0.05	----
As, Arsenic	<0.1	<0.10	<0.10	<0.10
Au, Gold	<0.05	<0.05	<0.05	<0.05
B, Boron	<0.05	<0.05	<0.05	<0.05

TABLE 4.3 - CONTINUED

	Date			
	1/14/81	5/27/81 (A)	5/27/81 (B)	6/17/81
Laboratory Parameters (1)(3) (Cont'd)				
Ba, Barium	0.05	0.07	0.05	0.06
Bi, Bismuth	0.07	<0.05	<0.05	<0.05
Ca, Calcium	32	14	14	15
Cd, Cadmium	<0.01	<0.01	<0.01	<0.01
Co, Cobalt	<0.05	<0.05	<0.05	<0.05
Cr, Chromium	<0.05	<0.05	<0.05	<0.05
Cu, Copper	<0.05	<0.05	<0.05	<0.05
Fe, Iron	<0.05	0.07	<0.05	2.0
Hg, Mercury	<0.1	<0.10	<0.10	<0.10
K, Potassium	2.0	1.9	1.8	2.0
Mg, Magnesium	10	2.0	2.0	2.6
Mn, Manganese	<0.05	<0.05	<0.05	<0.05
Mo, Molybdenum	<0.05	<0.05	<0.05	<0.05
Na, Sodium	13	4.1	3.9	3.8
Ni, Nickel	<0.05	<0.05	<0.05	<0.05
Pb, Lead	<0.05	<0.05	<0.05	<0.05
Pt, Platinum	<0.05	<0.05	<0.05	<0.05
Sb, Antimony	<0.10	<0.10	<0.10	<0.10
Se, Selenium	<0.10	<0.10	<0.10	<0.10
Si, Silicon	5.0	2.5	2.4	5.9
Sn, Tin	<0.10	<0.10	<0.10	<0.10
Sr, Strontium	0.19	0.07	0.06	0.06
Ti, Titanium	<0.05	<0.05	<0.05	0.11

TABLE 4.3 - CONTINUED

	Date			
	1/14/81	5/27/81 (A)	5/27/81 (B)	6/17/81
Laboratory Parameters (1)(3) (Cont'd)				
W, Tungsten	<1.0	<1.0	<1.0	<1.0
V, Vanadium	<0.05	<0.05	<0.05	<0.05
Zn, Zinc	<0.05	<0.05	<0.05	<0.05
Zr, Zirconium	<0.05	<0.05	<0.05	<0.05

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(1) Table values are mg/l unless noted otherwise.

(2) All values for free CO_2 determined from nomograph on p. 297 of Standard Method, 14th edition.

(3) Samples for all parameters except chemical oxygen demand, dissolved and suspended solids, and turbidity were filtered.

(4) Hardness calculated by R&M personnel.

(A) Grab sampling method.

(B) Depth - integrated sampling method.

2-11-31

TABLE 4.4

R&M CONSULTANTS, INC.

1981 WATER QUALITY DATA - SUSITNA RIVER

AT GOLD CREEK

TE: Dash indicates data not available.

	Date Sampled					
	6/30/81	7/1/81	8/2/81	8/3/81	9/14/81	10/8/81
d Parameters (1)						
Dissolved Oxygen	13.4	13.4	12.5	13.2	12.8	14.1
Percent Saturation	114	116	113	115	107	101
pH, pH Units	7.0	7.3	7.5	7.3	7.4	7.2 5
Conductivity, umhos/cm @ 25°C	98	109	75	91	144	162
Temperature, °C	7.3	8.6	9.3	9.2	6.8	0.8
Free Carbon Dioxide (2)	8.6	3.3	----	----	4.8	9.0
Alkalinity, as $CaCO_3$	33	25	----	----	45	46
Settleable Solids, ml/l	0.1	<0.1	<0.1	0.60	≪0.1	≪0.1
Discharge c.f.s.	24,550	21,700	51,100	46,000	12,600	6,300
boratory Parameters (1)(3)						
Ammonia Nitrogen	0.07	0.08	<0.05	<0.05	<0.05	0.52
Organic Nitrogen	0.48	0.39	0.63	0.67	0.74	0.47
Kjeldahl Nitrogen	0.55	0.47	0.63	0.67	0.74	0.99
Nitrate Nitrogen	0.22	0.17	0.32	0.18	<0.10	<0.10
Nitrite Nitrogen	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total Nitrogen	0.77	0.64	0.95	0.85	0.74	0.99
Ortho-Phosphate	<0.01	0.10	<0.01	<0.01	<0.01	0.02
Total Phosphorus	0.12	0.24	0.07	<0.05	<0.05	<0.05 .05
Alkalinity, as $CaCO_3$	----	----	28	36	----	----

TABLE 4.4 - CONTINUED

	Date Sampled					
	6/30/81	7/1/81	8/2/81	8/3/81	9/14/81	10/8/81
Laboratory Parameters (1)(3) (continued)						
Chemical Oxygen Demand	24	12	23	24	18	2
Chloride	4	5	<1	<1	8	14
Conductivity, umhos/cm @ 25°C	----	----	----	----	----	----
True Color, Color Units	30	20	90	110	50	40
Hardness, as $CaCO_3$ (4)	40	47	31	43	62	68
Sulfate	5.5	5.2	1.5	2.4	6.2	9.5
Total Dissolved Solids	68	79	63	96	99	118
Total Suspended Solids	140	68	490	1255	57	7.7
Turbidity, NTU	29	18	64	86	14	1.2
Uranium	----	----	<0.05	<0.05	<0.05	<0.05
Radioactivity, Gross Alpha, pCi/l	----	----	----	----	5.5±2.5	----
Total Organic Carbon	20	10	16	14	33	34
Total Inorganic Carbon	41	44	34	44	61	----
Organic Chemicals						
Endrin	----	<0.0002	----	----	<0.0002	----
Lindane	----	<0.004	----	----	<0.004	----
Methoxychlor	----	<0.1	----	----	<0.1	----
Toxaphene	----	<0.005	----	----	<0.005	----
2, 4-D	----	<0.1	----	----	<0.1	----
2, 4, 5-TP Silvex	----	<0.01	----	----	<0.01	----
ICAP Scan						
Ag, Silver	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Al, Aluminum	<0.05	<0.05	<0.05	0.08	<0.05	<0.05
As, Arsenic	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Au, Gold	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
B, Boron	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

TABLE 4.4 - CONTINUED

	Date Sampled					
	6/30/81	7/1/81	8/2/81	8/3/81	9/14/81	10/8/81
oratory Parameters (1)(3)						
tinued)						
Ba, Barium	0.09	0.10	0.09	0.11	0.11	<0.05
Bi, Bismuth	<0.05	<0.05	<0.05	0.19	<0.05	<0.05
Ca, Calcium	13	14	10	14	20	22
Cd, Cadmium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Co, Cobalt	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cr, Chromium	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cu, Copper	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Fe, Iron	0.07	0.07	0.10	0.07	<0.05	<0.05
Hg, Mercury	<0.01	<0.10	<0.10	<0.10	<0.10	<0.10
K, Potassium	1.4	1.5	1.3	1.9	2.0	2.4
Mg, Magnesium	1.8	2.8	1.4	1.9	2.9	3.2
Mn, Manganese	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Mo, Molybdenum	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Na, Sodium	3.8	4.3	2.8	3.4	6.2	7.4
Ni, Nickel	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Pb, Lead	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Pt, Platinum	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Sb, Antimony	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Se, Selenium	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Si, Silicon	2.6	2.8	2.6	2.7	3.4	3.9
Sn, Tin	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Sr, Strontium	0.06	<0.06	<0.05	0.06	0.09	0.10
Ti, Titanium	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

TABLE 4.4 - CONTINUED

	Date Sampled					
	6/30/81	7/1/81	8/2/81	8/3/81	9/14/81	10/8/81
Laboratory Parameters (1)(3) (continued)						
W, Tungsten	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
V, Vanadium	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Zn, Zinc	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Zr, Zirconium	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

(1) Table values are mg/l unless noted otherwise.

(2) All values for free CO_2 determined from nomograph on p. 297 of Standard Method, 14th edition.

(3) Samples for all parameters except chemical oxygen demand, dissolved and suspended solids, and turbidity were filtered.

(4) Hardness calculated by R&M personnel.

2-11-35

TABLE 5.1

WATER QUALITY DATA SUMMARY

SUSITNA RIVER

Agency: U.S. Geological Survey
Station: NR. DENALI - 1957-1981
Elevation: 2440 FT.

	Summer/Winter			
	Maximum	Minimum	Mean	Number Observations
Field Parameters (1)				
Dissolved Oxygen	-	-	-	-
Percent Saturation	-	-	-	-
pH, pH Units	7.8/7.6	7.1/7.1	7.5/7.4	15/4
Conductivity, umhos/cm @ 25°C	205/467	121/194	157/349	18/4
Temperature, °C	10.5/-	0.5/-	5.5/-	50/-
Free Carbon Dioxide	5.8/25	1.5/4.5	3.2/10/8	11/4
Alkalinity, as $CaCO_3$	68/161	42/57	54/116	11/4
Settleable Solids, ml/l	-	-	-	-
Laboratory Parameters (1)				
Ammonia Nitrogen	-	-	-	-
Organic Nitrogen	-	-	-	-
Kjeldahl Nitrogen	-	-	-	-
Nitrate Nitrogen	.09/-	.00/-	.05/-	15/-
Nitrite Nitrogen	-	-	-	-
Total Nitrogen	-	-	-	-
Ortho Phosphate	-	-	-	-
Total Phosphorus	-	-	-	-
Alkalinity, as $CaCO_3$	-	-	-	-
Chemical Oxygen Demand	-	-	-	-
Chloride	11.0/30.0	2.0/3.8	4.8/19.0	11/4

2-11-36

TABLE 5.1 CONTINUED

Laboratory Parameters (1) (continued)	Summer/Winter Maximum	Minimum	Mean	Num Obse vatic
Conductivity, umhos/cm @ 25°C	-	-	-	-
True Color, Color Units	-	-	-	-
Hardness, as $CaCO_3$	87/181	50/84	64/139	11/
Sulfate	23/39	9/31	15/36	11/
Total Dissolved Solids	120/270	72/109	91/204	11/
Total Suspended Solids	5690/-	5/-	1004/-	58/
Turbidity, NTU	350/-	20/-	176/-	8/-
Uranium	-	-	-	-
Radioactivity, Gross Alpha, pCi/l	-	-	-	-
Total Organic Carbon	-	-	-	-
Total Inorganic Carbon	-	-	-	-
Organic Chemicals				
Endrin	-	-	-	-
Lindane	-	-	-	-
Methoxychlor	-	-	-	-
Toxaphene	-	-	-	-
2, 4-D	-	-	-	-
2, 4, 5-TP Silvex	-	-	-	-
ICAP Scan				
Ag, Silver	-	-	-	-
Al, Aluminum	-	-	-	-
As, Arsenic	-	-	-	-
Au, Gold	-	-	-	-
B, Boron	-	-	-	-
Ba, Barium	-	-	-	-
Bi, Bismuth	-	-	-	-
Ca, Calcium	29/51	17/23	21/40	11/
Cd, Cadmium	-	-	-	-
Co, Cobalt	-	-	-	-
Cr, Chromium	-	-	-	-
Cu, Copper	-	-	-	-

2-11-37

TABLE 5.1 CONTINUED

Laboratory Parameters (1) (continued)	Summer/Winter Maximum	Minimum	Mean	Number Observations
Fe, Iron	4.0/.06	.03/0	1.0/.02	11/4
Hg, Mercury	-	-	-	-
K, Potassium	3.0/6.6	1.3/3.6	2.5/5.8	11/4
Mg, Magnesium	3.8/16	1.7/6.2	3.1/9.3	11/4
Mn, Manganese	.06/.02	0/0	.009/.01	10/3
Mo, Molybdenum	-	-	-	-
Na, Sodium	10/23	2.1/3.8	4.3/15	11/4
Ni, Nickel	-	-	-	-
Pb, Lead	-	-	-	-
Pt, Platinum	-	-	-	-
Sb, Antimony	-	-	-	-
Se, Selenium	-	-	-	-
Si, Silicon	-	-	-	-
Sn, Tin	-	-	-	-
Sr, Strontium	-	-	-	-
Ti, Titanium	-	-	-	-
W, Tungsten	-	-	-	-
V, Vanadium	-	-	-	-
Zn, Zinc	-	-	-	-
Zr, Zirconium	-	-	-	-

(1) Table values are mg/l unless noted otherwise.

2-11-38

TABLE 5.2
WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. Geological Survey
Station: VEE CANYON 1962 - 1981
Elevation: 1900 FT.

	Summer Values Only			
	Maximum	Minimum	Mean	Number of Observations
Field Parameters (1)				
Dissolved Oxygen	-	-	-	-
Percent Saturation	-	-	-	-
pH, pH Units	8.1	7.2	7.7	10
Conductivity, umhos/cm @ 25°C	168	91	150	25
Temperature, °C	13.0	1.0	7.7	38
Free Carbon Dioxide	6.8	.7	2.6	10
Alkalinity, as $CaCO_3$	59	39	51	10
Settleable Solids, ml/l	-	-	-	-
Laboratory Parameters (1)				
Ammonia Nitrogen	-	-	-	-
Organic Nitrogen	-	-	-	-
Kjeldahl Nitrogen	-	-	-	-
Nitrate Nitrogen	0.88	0.0	.20	10
Nitrite Nitrogen	-	-	-	-
Total Nitrogen	-	-	-	-
Ortho-Phosphate	-	-	-	-
~~Total Phosphorus~~				
Alkalinity, as $CaCO_3$	-	-	-	-
Chemical Oxygen Demand	-	-	-	-
Chloride	9.2	2.1	5.5	10

2-11-39

TABLE 5.2 CONTINUED

Laboratory Parameters (1) (continued)	Summer Values Only			
	Maximum	Minimum	Mean	Number Observations
Conductivity, umhos/cm @ 25°C	-	-	-	-
True Color, Color Units	40	5	14	9
Hardness, as $CaCO_3$	76	42	62	10
Sulfate	18	7.5	14	10
Total Dissolved Solids	110	66	90	10
Total Suspended Solids	2790	34	773	38
Turbidity, NTU	-	-	-	-
Uranium	-	-	-	-
Radioactivity, Gross Alpha, pCi/l	-	-	-	-
Total Organic Carbon	-	-	-	-
Total Inorganic Carbon	-	-	-	-
Organic Chemicals				
Endrin	-	-	-	-
Lindane	-	-	-	-
Methoxychlor	-	-	-	-
Toxaphene	-	-	-	-
2, 4-D	-	-	-	-
4, 5-TP Silvex	-	-	-	-
ICAP Scan				
Ag, Silver	-	-	-	-
Al, Aluminum	-	-	-	-
As, Arsenic	-	-	-	-
Au, Gold	-	-	-	-
B, Boron	-	-	-	-
Ba, Barium	-	-	-	-
Bi, Bismuth	-	-	-	-
Ca, Calcium	27	14	21	10
Cd, Cadmium	-	-	-	-
Co, Cobalt	-	-	-	-
Cr, Chromium	-	-	-	-
Cu, Copper	-	-	-	-

2-11-40

TABLE 5.2 CONTINUED

Laboratory Parameters (1) (continued)	Summer Values Only			
	Maximum	Minimum	Mean	Number of Observations
Fe, Iron	12.0	.05	2.9	10
Hg, Mercury	-	-	-	-
K, Potassium	7.3	1.4	3.4	10
Mg, Magnesium	4.4	1.1	2.7	10
Mn, Manganese	.23	0	.12	2
Mo, Molybdenum	-	-	-	-
Na, Sodium	6.3	2.1	3.9	10
Ni, Nickel	-	-	-	-
Pb, Lead	-	-	-	-
Pt, Platinum	-	-	-	-
Sb, Antimony	-	-	-	-
Se, Selenium	-	-	-	-
Si, Silicon	-	-	-	-
Sn, Tin	-	-	-	-
Sr, Strontium	-	-	-	-
Ti, Titanium	-	-	-	-
W, Tungsten	-	-	-	-
V, Vanadium	-	-	-	-
Zn, Zinc	-	-	-	-
Zr, Zirconium	-	-	-	-

(1) Table values are mg/l unless noted otherwise.

2-11-41

TABLE 5.3

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: R&M CONSULTANTS, INC.
Station: VEE CANYON 1980 - 1981
Elevation: 1900 FT.

NOTE: Not Detectable is abbreviated ND

	Summer/Winter/Break-Up			
	Maximum	Minimum	Mean	Number Observations
Field Parameters (1)				
Dissolved Oxygen	12.6/13.8/10.4	8.7/10.7/10.4	11.5/12.6/10.4	8/3/1
Percent Saturation	110/104/83	82/84/83	99/97/83	8/3/1
pH, pH Units	7.9/7.6/6.6	7.0/7.2/6.6	7.6/7.4/6.6	10/3/1
Conductivity, umhos/cm @ 25°C	171/242/100	103/130/100	129/171/100	9/3/1
Temperature, °C	11.9/0.1/6.5	5.3/-0.1/6.5	7.7/0.0/6.5	10/3/1
Free Carbon Dioxide (2)	4.5/20.0/-	1.7/5.5/-	3.0/10.3/-	7/3/0
Alkalinity, as $CaCO_3$	81/187/-	41/57/-	61/111/-	7/3/0
Settleable Solids, ml/l	1.0/ND/ND	ND/ND/ND	0.27/ND/ND	10/3/1
Laboratory Parameters (1)(3)				
Ammonia Nitrogen	0.27/0.26/0.13	ND/ND/0.13	0.11/0.12/0.13	9/3/1
Organic Nitrogen	0.63/0.85/0.34	ND/0.08/0.34	0.44/0.40/0.34	9/3/1
Kjeldahl Nitrogen	0.79/0.85/0.47	0.26/0.17/0.47	0.60/0.52/0.47	9/3/1
Nitrate Nitrogen	0.19/ND/ND	ND/ND/ND	0.07/ND/ND	10/3/1
Nitrite Nitrogen	ND	ND	ND	9/3/1
Total Nitrogen	0.92/0.85/0.47	0.39/0.17/0.47	0.61/0.52/0.47	9/3/1
Ortho-Phosphate	0.49/0.02/ND	ND/ND/ND	0.06/0.01/ND	10/3/1
Total Phosphorus	0.49/0.07/ND	ND/ND/ND	0.08/0.02/ND	10/3/1
Alkalinity, as $CaCO_3$	60/66/-	40/66/-	48/66/-	4/1/0
Chemical Oxygen Demand	39/12/8	8/6/8	20/9/8	8/3/1
Chloride	11/18/4.5	ND/16/4.5	4.7/17/4.5	10/3/1

2-11-42

TABLE 5.3 CONTINUED

Laboratory Parameters (1)(3) (continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Num Obse vati
Conductivity, umhos/cm @ 25°C	-	-	-	-
True Color, Color Units	175/30/15	5/10/15	72/70/15	9/3/
Hardness, as $CaCO_3$ (4)	76/121/37	51/78/37	58/96/37	10/3
Sulfate	9/16/4	2/11/4	6/13/4	10/3
Total Dissolved Solids	170/149/100	38/115/100	98/136/100	10/3
Total Suspended Solids	1150/14/93	25/0.6/93	398/7.6/93	10/3
Turbidity, NTU	120/2.5/25	8.7/0.35/25	68/1.6/25	10/3
Uranium	ND	ND	ND	5/2/
Radioactivity, Gross Alpha, pCi/l	-	-	11.6±0.6/10.3±0.6	1/1/
Total Organic Carbon	23/23/40	11/23/40	16/23/40	5/1/
Total Inorganic Carbon	60/106/46	46/21/46	54/64/46	6/2/
Organic Chemicals				
Endrin	ND	ND	ND	3/1/
Lindane	ND	ND	ND	3/1/
Methoxychlor	ND	ND	ND	3/1/
Toxaphene	ND	ND	ND	3/1/
2, 4-D	ND	ND	ND	3/1/
2, 4, 5-TP Silvex	ND	ND	ND	3/1/
ICAP Scan				
Ag, Silver	ND	ND	ND	10/3
Al, Aluminum	2.2/0.18/ND	ND/ND/ND	0.41/0.06/ND	10/3
As, Arsenic	ND	ND	ND	10/3
Au, Gold	ND	ND	ND	10/3
B, Boron	ND	ND	ND	10/3
Ba, Barium	0.12/ND/ND	ND/ND/ND	0.07/ND/ND	10/3
Bi, Bismuth	0.19/ND/ND	ND/ND/ND	0.02/ND/ND	10/3
Ca, Calcium	23/36/13	13/25/13	18/30/13	10/3
Cd, Cadmium	ND	ND	ND	10/3
Co, Cobalt	ND	ND	ND	10/3
Cr, Chromium	ND	ND	ND	10/3
Cu, Copper	ND	ND	ND	10/3

2-11-43

TABLE 5.3 CONTINUED

Laboratory Parameters (1)(3) (continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number Observations
Fe, Iron	4.0/0.37/0.08	ND/ND/0.08	0.97/0.12/.08	10/3/1
Hg, Mercury	ND	ND	ND	10/3/1
K, Potassium	5.0/9.0/1.6	ND/ND/1.6	2.1/3.7/1.6	10/3/1
Mg, Magnesium	3.4/7.6/1.7	ND/ND/1.7	1.5/3.8/1.7	10/3/1
Mn, Manganese	ND	ND	ND	10/3/1
Mo, Molybdenum	ND	ND	ND	10/3/1
Na, Sodium	5.1/7.2/2.0	2.4/6.3/2.0	3.4/6.7/2.0	10/3/1
Ni, Nickel	ND	ND	ND	10/3/1
Pb, Lead	ND	ND	ND	10/3/1
Pt, Platinum	ND	ND	ND	10/3/1
Sb, Antimony	ND	ND	ND	10/3/1
Se, Selenium	ND	ND	ND	10/3/1
Si, Silicon	6.9/5.0/1.7	2.0/3.7/1.7	3.5/4.3/1.7	10/3/1
Sn, Tin	ND	ND	ND	10/3/1
Sr, Strontium	0.08/0.13/ND	ND/0.06/ND	0.05/0.10/ND	10/3/1
Ti, Titanium	0.24/ND/ND	ND/ND/ND	0.05/ND/ND	10/3/1
W, Tungsten	ND/0.4/ND	ND/ND/ND	ND/0.13/ND	9/3/1
V, Vanadium	ND	ND	ND	10/3/1
Zn, Zinc	0.07/ND/ND	ND/ND/ND	0.01/ND/ND	10/3/1
Zr, Zirconium	ND	ND	ND	10/3/1

(1) Table values are mg/l unless noted otherwise.

(2) All values for free CO_2 determined from nomograph on p. 297 of Standard Method, 14th edition.

(3) Samples for all parameters except chemical oxygen demand, dissolved and suspended solids, and turbidity were filtered.

(4) Hardness calculated by R&M personnel.

2-11-44

TABLE 5.4

WATER QUALITY DATA SUMMARY

SUSITNA RIVER

Agency: U.S. Geological Survey
Station: GOLD CREEK 1949 - 1981
Elevation: 676.5 FT.

	Summer/Winter/Break-Up			
	Maximum	Minimum	Mean	Numl' Obse vatio
Field Parameters (1)				
Dissolved Oxygen	13.3/14.4/-	9.5/11.0/-	11.7/12.7/-	5/2/0
Percent Saturation	106/102/-	83/77/-	98/90/-	5/2/0
pH, pH Units	8.0/8.1/8.0	6.6/7.0/6.5	7.3/7.4/7.1	34/23/
Conductivity, umhos/cm @ 25°C	227/300/280	90/164/82	161/248/121	63/27/
Temperature, °C	14.0/0.5/8.0	1.0/0.0/1.0	8.6/0.5/3.4	22/5/
Free Carbon Dioxide	20/16/24	1.1/1.2/5.6	5.6/6.3/8.0	61/22/
Alkalinity, as $CaCO_3$	87/88/80	30/49/29	52/70/48	66/23/
Settleable Solids, ml/l	-	-	-	-
Laboratory Parameters (1)				
Ammonia Nitrogen	.33/.08/-	.01/.03/-	.13/.06/-	4/3/-
Organic Nitrogen	.39/.44/-	.10/.27/-	.27/.36/-	4/3/-
Kjeldahl Nitrogen	-	-	-	-
Nitrate Nitrogen	.36/.32/.29	.02/.05/.05	.13/.14/.17	60/22/
Nitrite Nitrogen	.03/.01/-	.02/0/-	.02/0/-	2/3/-
Total Nitrogen	.58/.66/-	.25/.51/-	.47/.57/-	4/3/-
Ortho-Phosphate	.03/.03/-	0/.01/-	.01/.02/-	9/2/1
Total Phosphorus	.04/.03/-	0/.03/-	.02/.03/-	5/2/1
Alkalinity, as $CaCO_3$	-	-	-	-
Chemical Oxygen Demand	-	-	-	-
Chloride	15/35/4.5	1.4/9/1.8	5.5/22/3.2	62/25/

2-11-45

TABLE 5.4 CONTINUED

Laboratory Parameters (1) (continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number Observations
Conductivity, umhos/cm @ 25°C	-	-	-	-
True Color, Color Units	20/5/50	0/0/10	8/3.5/28	52/20/6
Hardness, as $CaCO_3$	107/114/113	35/60/32	61/97/60	60/24/3
Sulfate	28/38/27	1/13/5.5	17/21/16	65/22/2
Total Dissolved Solids	134/167/70	51/102/48	93/149/55	61/26/4
Total Suspended Solids	2620/76/1330	7/1/120	805/18/652	63/8/11
Turbidity, NTU	-	-	-	-
Uranium	-	-	-	-
Radioactivity, Gross Alpha, pCi/l	50/-/-	2.7/-/-	20/-/-	3/1/1
Total Organic Carbon	-	-	5.5/5/1.8	1/1/1
Total Inorganic Carbon	-	-	-	-
Organic Chemicals				
Endrin	-	-	-	-
Lindane	-	-	-	-
Methoxychlor	-	-	-	-
Toxaphene	-	-	-	-
2, 4-D	-	-	-	-
2, 4, 5-TP Silvex	-	-	-	-
ICAP Scan				
Ag, Silver	0/-/-	0/-/-	0/-/-	2/-/-
Al, Aluminum	-	-	-	-
As, Arsenic	-	-	-	-
Au, Gold	-	-	-	-
B, Boron	-	-	-	-
Ba, Barium	0/-/-	0/-/-	0/-/-	2/-/-
Bi, Bismuth	-	-	-	-
Ca, Calcium	37/11/-	37/24/-	19/30/-	60/26/-
Cd, Cadmium	0/-/-	0/-/-	0/-/-	2/-/-
Co, Cobalt	0/-/-	0/-/-	0/-/-	2/-/-
Cr, Chromium	.01/-/-	0/-/-	.005/-/-	2/-/-
Cu, Copper	.005/-/-	.004/-/-	.004/-/-	2/-/-

2-11-46

TABLE 5.4 CONTINUED

Laboratory Parameters (1) (continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Observations
Fe, Iron	.46/.03/-	0/0/-	.16/.01/-	30/21/0
Hg, Mercury	.002/-/-	0/-/-	.001/-/-	2/-/-
K, Potassium	4.4/5.0/1.7	1.0/1.2/1.3	2.4/2.3/1.6	51/18/
Mg, Magnesium	6.3/8.3/7.4	1.4/3.6/.3	3.2/5.7/2.5	57/27/
Mn, Manganese	.18/.0/-	0/0/-	.010/0/-	26/2/0
Mo, Molybdenum	-	-	-	-
Na, Sodium	6.5/17.0/2.9	2.4/5.2/2.8	4.1/11.0/2.9	48/19/
Ni, Nickel	0/-/-	0/-/-	0/-/-	2/-/-
Pb, Lead	0/-/-	0/-/-	0/-/-	2/-/-
Pt, Platinum	-	-	-	-
Sb, Antimony	-	-	-	-
Se, Selenium	0/-/-	0/-/-	0/-/-	2/-/-
Si, Silicon	-	-	-	-
Sn, Tin	-	-	-	-
Sr, Strontium	-	-	-	-
Ti, Titanium	-	-	-	-
W, Tungsten	-	-	-	-
V, Vanadium	-	-	-	-
Zn, Zinc	.01/-/-	.006/-/-	.008/-/-	2/-/-
Zr, Zirconium	-	-	-	-

(1) Table values are mg/l unless noted otherwise.

2-11-47

TABLE 5.5
WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: R&M CONSULTANTS, INC.
Station: GOLD CREEK 1980 - 1981
Elevation: 676.5 FT.

NOTE: Not Detectable is abbreviated ND

	Summer/Winter/Break-Up			
	Maximum	Minimum	Mean	Number Observations
Field Parameters (1)				
Dissolved Oxygen	13.4/14.1/11.5	8.6/13.3/11.2	12.3/13.8/11.4	6/3/2
Percent Saturation	116/101/102	81/100/101	108/101/102	6/3/2
pH, pH Units	7.8/7.8/6.7	7.0/7.1/6.4	7.4/7.4/6.5	7/3/2
Conductivity, umhos/cm @ 25°C	169/249/106	75/162/105	116/193/106	7/3/2
Temperature, °C	12.8/0.8/10.5	6.8/0.0/10.3	9.4/0.4/10.4	7/3/2
Free Carbon Dioxide (2)	36/23/-	2.1/3.2/0	17/13/-	5/3/-
Alkalinity, as $CaCO_3$	64/144/-	25/46/-	44/88/-	5/3/-
Settleable Solids, ml/l	0.6/ND/ND	ND/ND/ND	0.1/ND/ND	7/3/2
Laboratory Parameters (1)(3)				
Ammonia Nitrogen	0.09/0.52/0.08	ND/ND/ND	.04/0.28/.04	6/3/2
Organic Nitrogen	0.74/0.81/0.34	0.39/0.34/0.27	0.55/0.54/0.31	6/3/2
Kjeldahl Nitrogen	0.74/0.99/ND	0.47/0.66/ND	0.59/0.82/0.34	6/3/2
Nitrate Nitrogen	0.32/0.18/ND	ND/ND/ND	0.15/.06/ND	7/3/2
Nitrite Nitrogen	ND/ND/ND	ND/ND/ND	ND/ND/ND	6/3/2
Total Nitrogen	0.95/0.99/0.35	0.48/0.66/0.34	0.74/0.88/0.35	6/3/2
Ortho-Phosphate	0.10/0.02/ND	ND/ND/ND	0.01/0.01/ND	7/3/2
Total Phosphorus	0.34/ND/0.08	ND/ND/ND	0.08/ND/0.04	7/3/2
Alkalinity, as $CaCO_3$	-	-	-	-
Chemical Oxygen Demand	24/16/11.9	12/2/7.9	18/9/10	7/3/2
Chloride	14/29/10	ND/14/6	5/20/8	7/3/2

2-11-48

TABLE 5.5 CONTINUED

Laboratory Parameters (1)(3) (continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Observations
Conductivity, umhos/cm @ 25°C	-	-	-	-
True Color, Color Units	110/40/15	5/10/10	50/20/13	7/3/7
Hardness, as $CaCO_3$ (4)	62/121/43	31/68/43	48/88/43	7/3/2
Sulfate	12/16/6	1.5/9.5/5	5.4/11.8/6	7/3/2
Total Dissolved Solids	99/188/90	63/100/87	82/135/89	7/3/2
Total Suspended Solids	1255/7.7/56	57/ND/49	329/5/53	7/3/2
Turbidity, NTU	86/1.2/19	14/0.3/15	43/0.8/17	7/3/2
Uranium	ND	ND	ND	4/2/0
Radioactivity, Gross Alpha, pCi/l	-/2.6/-	-/2.0/-	-/2.3/-	0/2/0
Total Organic Carbon	41/39/25	10/27/15	20/33/20	5/2/2
Total Inorganic Carbon	61/90/44	34/90/41	45/90/43	6/1/2
Organic Chemicals				
Endrin	ND	ND	ND	3/1/0
Lindane	ND	ND	ND	3/1/0
Methoxychlor	ND	ND	ND	3/1/0
Toxaphene	ND	ND	ND	3/1/0
2,. 4-D	ND	ND	ND	3/1/0
2, 4, 5-TP Silvex	ND	ND	ND	3/1/0
ICAP Scan				
Ag, Silver	ND	ND	ND	7/3/2
Al, Aluminum	0.70/0.18/ND	ND/ND/ND	0.13/0.06/ND	6/3/2
As, Arsenic	ND	ND	ND	7/3/2
Au, Gold	ND	ND	ND	7/3/2
B, Boron	ND	ND	ND	7/3/2
Ba, Barium	0.11/0.05/0.07	0.06/ND/0.05	0.09/0.02/0.06	7/3/2
Bi, Bismuth	0.19/0.07/ND	ND/ND/ND	0.03/0.02/ND	7/3/2
Ca, Calcium	20/32/14	10/22/14	14/26/14	7/3/2
Cd, Cadmium	ND	ND	ND	7/3/2
Co, Cobalt	ND	ND	ND	7/3/2
Cr, Chromium	ND	ND	ND	7/3/2
Cu, Copper	ND	ND	ND	7/3/2

2-11-49

TABLE 5.5 CONTINUED

Laboratory Parameters (1)(3) (continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number Observations
Fe, Iron	2.3/0.35/0.07	ND/ND/0.05	0.67/0.12/.06	7/3/2
Hg, Mercury	ND	ND	ND	7/3/2
K, Potassium	2.0/2.4/1.9	1.3/2.0/1.8	1.7/2.2/1.9	7/2/2
Mg, Magnesium	2.9/10.0/2.0	1.4/3.2/2.0	2.3/5.6/2.0	7/3/2
Mn, Manganese	ND	ND	ND	7/3/2
Mo, Molybdenum	ND	ND	ND	7/3/2
Na, Sodium	6.2/13.0/4.1	2.8/7.4/3.9	3.9/9.6/4.00	7/3/2
Ni, Nickel	ND	ND	ND	7/3/2
Pb, Lead	ND	ND	ND	7/3/2
Pt, Platinum	ND	ND	ND	7/3/2
Sb, Antimony	ND	ND	ND	7/3/2
Se, Selenium	ND	ND	ND	7/3/2
Si, Silicon	5.9/5.0/2.5	2.6/3.9/2.4	3.5/4.4/2.5	7/3/2
Sn, Tin	ND	ND	ND	7/3/2
Sr, Strontium	0.09/0.19/0.07	ND/0.10/.06	0.05/0.13/0.07	7/3/2
Ti, Titanium	0.14/ND/ND	ND/ND/ND	0.04/ND/ND	7/3/2
W, Tungsten	ND	ND	ND	7/3/2
V, Vanadium	ND	ND	ND	7/3/2
Zn, Zinc	ND	ND	ND	7/3/2
Zr, Zirconium	ND	ND	ND	7/3/2

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(1) Table values are mg/l unless noted otherwise.

(2) All values for free CO_2 determined from nomograph on p. 297 of Standard Method, 14th edition.

(3) Samples for all parameters except chemical oxygen demand, dissolved and suspended solids, and turbidity were filtered.

(4) Hardness calculated by R&M personnel.

2-11-50

TABLE 5.6

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. Geological Survey
Station: SUNSHINE - 1971-1977
Elevation: 270 FT.

	Summer/Winter			
	Maximum	Minimum	Mean	Number of Observations
Field Parameters (1)				
Dissolved Oxygen	12.8/13	10.6/13	11.8/13	3/1
Percent Saturation	-	-	-/90	0/1
pH, pH Units	7.6/7.2	7.1/7.2	7.4/7.2	3/1
Conductivity, umhos/cm @ 25°C	170/242	100/230	130/236	5/2
Temperature, °C	12/0	3.8/0	8.1/0	5/1
Free Carbon Dioxide	3.9/0	2.1/0	3.1/0	3/0
Alkalinity, as $CaCO_3$	43/71	25/63	37/67	3/2
Settleable Solids, ml/l	-	-	-	-
Laboratory Parameters (1)				
Ammonia Nitrogen	.28/.05	.09/.03	.18/.04	2/2
Organic Nitrogen	.77/.42	.24/.18	.5/.3	2/2
Kjeldahl Nitrogen	-	-	-	-
Nitrate Nitrogen	-	-	-	-
Nitrite Nitrogen	-	-	-	-
Total Nitrogen	2.3/.7	.7/.4	1/.25	2/2
Ortho-Phosphate	.12/.12	0/.12	.06/.12	3/1
Total Phosphorus	.14/.01	.07/.01	.07/.01	2/2
Alkalinity, as $CaCO_3$	-	-	-	-
Chemical Oxygen Demand	-	-	-	-
Chloride	7.3/21	2.2/17	4.2/19	5/2

2-11-51

TABLE 5.6 CONTINUED

	Summer/Winter			
	Maximum	Minimum	Mean	Number Observations
Laboratory Parameters (1) (continued)				
Conductivity, umhos/cm @ 25°C	100/0	8/0	44/0	3/1
True Color, Color Units	72/91	37/89	52/90	5/2
Hardness, as $CaCO_3$	13/18	3/17	9/17	5/2
Sulfate	-	-	-	-
Total Dissolved Solids	-	-	-	-
Total Suspended Solids	250/1.3	200/1.3	225/1.3	2/1
Turbidity, NTU	-	-	-	-
Uranium	-	-	-	-
Radioactivity, Gross Alpha, pCi/l	-	-	-	-
Total Organic Carbon	-	-	-	-
Total Inorganic Carbon				
Organic Chemicals				
Endrin	-	-	-	-
Lindane	-	-	-	-
Methoxychlor	-	-	-	-
Toxaphene	-	-	-	-
2, 4-D	-	-	-	-
2, 4, 5-TP Silvex	-	-	-	-
ICAP Scan				
Ag, Silver	0/0	0/0	0/0	2/1
Al, Aluminum	-	-	-	-
As, Arsenic	.003/.001	.002/.001	.002/.001	2/1
Au, Gold	-	-	-	-
B, Boron	-	-	-	-
Ba, Barium	.07/.04	0/.04	.04/.04	2/1
Bi, Bismuth	-	-	-	-
Ca, Calcium	23/29	12/29	17/29	5/2
Cd, Cadmium	0/0	0/0	0/0	2/1
Co, Cobalt	0/0	0/0	0/0	2/1
Cr, Chromium	.01/.01	0/.01	.005/.01	2/1
Cu, Copper	.004/.004	.002/.004-	.003/.004	2/1

2-11-52

TABLE 5.6 CONTINUED

	Summer/Winter			
	Maximum	Minimum	Mean	Number Observations
Laboratory Parameters (1) (continued)				
Fe, Iron	.18/.01	.06/.01	.12/.01	2/1
Hg, Mercury	.001/.001	0/.001	.001/.001	2/1
K, Potassium	2.8/2.1	1.1/.19	1.6/2.0	5/2
Mg, Magnesium	3.5/4.5	1.6/4.1	2.5/4.3	5/2
Mn, Manganese	.02/.004	0/0	.009/.002	4/2
Mo, Molybdenum	-	-	-	-
Na, Sodium	4.4/11	1.9/11	2.8/11	5/2
Ni, Nickel	0/.002	.001/.002	.001/.002	2/1
Pb, Lead	0/.008	0/.008	0/.008	2/1
Pt, Platinum	-	-	-	-
Sb, Antimony	-	-	-	-
Se, Selenium	0/0	0/0	0/0	2/1
Si, Silicon	-	-	-	-
Sn, Tin	-	-	-	-
Sr, Strontium	-	-	-	-
Ti, Titanium	-	-	-	-
W, Tungsten	-	-	-	-
V, Vanadium	-	-	-	-
Zn, Zinc	.02/.03	.006/.03	.01/.03	2/1
Zr, Zirconium	-	-	-	-

(1) Table values are mg/l unless noted otherwise.

2-11-53

TABLE 5.7

WATER QUALITY DATA SUMMARY

SUSITNA RIVER

Agency: U.S. Geological Survey
Station: SUSITNA - 1955-1981
Elevation: 40 FT.

	Summer/Winter/Break-Up			
	Maximum	Minimum	Mean	Number Observations
Field Parameters (1)				
Dissolved Oxygen	13/13.9/12.7	10.1/9.9/10.6	11.5/11.5/12.1	12/12/4
Percent Saturation	100/97/100	90/67/95	99/79/98	53/19/11
pH, pH Units	8.3/7.9/7.8	7/6.7/6.5	7.7/7.3/7.3	62/45/18
Conductivity, umhos/cm @ 25°C	168/225/120	90/179/85	120/205/94	21/20/6
Temperature, °C	12.5/0.5/8.0	3.6/0/4.5	8.8/0/6.3	109/52/33
Free Carbon Dioxide	-	-	-	-
Alkalinity, as $CaCO_3$	57/75/39	39/58/30	44/69/34	52/30/6
Settleable Solids, ml/l	-	-	-	-
Laboratory Parameters (1)				
Ammonia Nitrogen	.19/.09/.21	0.0/.01/.01	.04/.04/.08	15/7/3
Organic Nitrogen	1.5/.46/.70	.16/0.0/.16	.60/.27/.43	12/9/2
Kjeldahl Nitrogen	-	-	-	-
Nitrate Nitrogen	-/.19/-	-/.16/-	-/.18/-	0/2/0
Nitrite Nitrogen	-	-	-	-
Total Nitrogen	1.7/.99/1.2	.26/.24/.67	.72/.55/.87	22/17/5
Ortho-Phosphate	-/-/.03	-/-/.03	-/-/.03	0/0/1
Total Phosphorus	-	-	-	-
Alkalinity, as $CaCO_3$	-	-	-	-
Chemical Oxygen Demand	-	-	-	-
Chloride	6.7/18/4.6	1.2/5.7/3.1	2.8/12.9/3.6	23/21/6

2-11-54

TABLE 5.7 CONTINUED

Laboratory Parameters (1) (continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Observations
Conductivity, umhos/cm @ 25°C	-	-	-	-
True Color, Color Units	10/5/-	5/0/-	7.5/2.5/-	4/4/
Hardness, as $CaCO_3$	60/96/48	46/73/36	55/84/40	20/2
Sulfate	22/20/7.7	1/10/3.7	13/17/7	23/2
Total Dissolved Solids	82/139/65	57/105/52	75/123/55	24/2
Total Suspended Solids	2980/12/683	151/2/257	745/4.4/461	67/2
Turbidity, NTU	790/3/160	30/1/25	286/2/74	13/1
Uranium	-	-	-	-
Radioactivity, Gross Alpha, pCi/l	-	-	-	-
Total Organic Carbon	11/9.3/9.1	2.3/.4/3.8	4.2/2.4/6.0	8/10/
Total Inorganic Carbon	-	-	-	-
Organic Chemicals				
Endrin	-	-	-	-
Lindane	-	-	-	-
Methoxychlor	-	-	-	-
Toxaphene	-	-	-	-
2, 4-D	-	-	-	-
2, 4, 5-TP Silvex	-	-	-	-
ICAP Scan				
Ag, Silver	.003/0/-	0/0/-	.001/0/-	6/2/(
Al, Aluminum	-	-	-	-
As, Arsenic	.003/.003/.001	.001/0/.001	.017/.013/.001	10/8/
Au, Gold	-	-	-	-
B, Boron	-	-	-	-
Ba, Barium	2.0/1.0/1.0	.3/.4/.1	.8/.6/.1	7/5/2
Bi, Bismuth	-	-	-	-
Ca, Calcium	22/31/15	14/24/11	18/27/13	23/21
Cd, Cadmium	.002/.002/.002	.001/.001/.002	.015/.015/.002	8/4/2
Co, Cobalt	.007/.003/-	.002/.002/-	.003/.003/-	9/6/(
Cr, Chromium	.030/.020/.020	0/0/.005	.014/.008/.013	8/4/2
Cu, Copper	.007/.004/.020	.002/0/.002	.003/.002/.008	10/9/

2-11-55

TABLE 5.7 CONTINUED

Laboratory Parameters (1) (continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number Observations
Fe, Iron	.460/.160/.170	.010/.060/.110	.091/.091/.144	12/8/5
Hg, Mercury	.0005/.0005/.0005	0/0/.0001	.0003/.0002/.0003	12/8/5
K, Potassium	.0018/.0025/.0011	.001/.0014/.0008	.001/.002/.001	23/21/6
Mg, Magnesium	.003/.005/.003	.002/.004/.002	.003/.004/.002	25/20/5
Mn, Manganese	/020/.030/.070	.004/.010/.008	.009/.022/.010	16/8/5
Mo, Molybdenum	-	-	-	-
Na, Sodium	4.0/8.9/3.2	2.0/6.2/2.4	2.7/7.6/2.9	23/21/6
Ni, Nickel	.004/.003/-	0/.002/-	.001/.003/-	4/2/0
Pb, Lead	.009/.004/.011	.002/0/.002	.003/.002/.005	12/8/4
Pt, Platinum	-	-	-	-
Sb, Antimony	-	-	-	-
Se, Selenium	.001/.001/.001	0/0/.001	.0006/.0009/.001	11/8/5
Si, Silicon	-	-	-	-
Sn, Tin	-	-	-	-
Sr, Strontium	-	-	-	-
Ti, Titanium	-	-	-	-
W, Tungsten	-	-	-	-
V, Vanadium	-	-	-	-
Zn, Zinc	.020/.020/.020	.003/.003/.020	.012/.012/.020	0/7/4
Zr, Zirconium	-	-	-	-

(1) Table values are mg/l unless noted otherwise.

2-11-56

SUSITNA HYDROELECTRIC PROJECT

1982

WATER QUALITY

ANNUAL REPORT

LIBRARY COPY

DECEMBER 1982

PROPERTY OF:
Alaska Power Authority
334 W. 5th Ave.
Anchorage, Alaska 99501

PREPARED BY:

R&M CONSULTANTS, INC.

PREPARED FOR:

ALASKA POWER AUTHORITY

2-11-57

s17/h

TABLE 2.2
R&M CONSULTANTS, INC.
1982 WATER QUALITY DATA - SUSITNA RIVER AT VEE CANYON (RM 223.1)

NOTE: Dash indicates data not available.

	Date Sampled 2/4/82*
Field Parameters(1)	
Dissolved Oxygen	14.5
Percent Saturation	101
pH, pH Units	5.95
Conductivity, umhos/cm @ 25°C	3[illegible]3
Temperature, °C	0.[illegible]
Free Carbon Dioxide (2)	----
Alkalinity, as $CaCO_3$	----
Settleable Solids, ml/l	----
Discharge c.f.s.	----
Laboratory Parameters(1)(3)	
Ammonia Nitrogen	<0.01
Organic Nitrogen	----
Kjeldahl Nitrogen	< 1
Nitrate Nitrogen	0.30
Nitrite Nitrogen	0.01
Total Nitrogen	----
Ortho-Phosphate	0.02
Total Phosphorus	0.02
Alkalinity, as $CaCO_3$	----
Chemical Oxygen Demand	13
Chloride	18.0
Conductivity, umhos/cm @ 25°C	----
True Color, Color Units	5 @ pH 7.1 @ 12.8°C

2-11-58

s17/h

TABLE 2.2 (Continued)

NOTE: Dash indicates data not available.

	Date Sampled 2/4/82*
Laboratory Parameters(1)(3) (continued)	
Hardness, as $CaCO_3$(4)	122
Sulfate	18
Total Dissolved Solids	157
Total Suspended Solids	1.3
Turbidity, NTU	0.55
Uranium	----
Radioactivity, Gross Alpha, pCi/l	----
Total Organic Carbon	2
Total Inorganic Carbon	2
Ca, Calcium	40.59
Mg, Magnesium	5.0
K, Potassium	4.5
Na, Sodium	12.0
Fe, Iron	1.35
Si, Silicon	5.0

---

* Analysed by Northern Testing Laboratories, Inc., Fairbanks.

(1) Table values are mg/l unless noted otherwise.

(2) All values for free CO_2 determined from nomograph on p. 297 of Standard Method, 14th edition.

(3) Samples for all parameters except chemical oxygen demand, dissolved and suspended solids, and turbidity were filtered.

(4) Hardness calculated by R&M personnel.

2-11-59

s1 s17/h

TABLE 2.3
R&M CONSULTANTS, INC.
1982 WATER QUALITY DATA - SUSITNA RIVER AT GOLD CREEK (RM 136.7)

NOTE: Dash indicates data not available.

	Date Sampled					
	2/06/82*	7/10/82	7/16/82	7/23/82	8/05/82*	8/10/82*
Field Parameters(1)						
Dissolved Oxygen	----	11.7	11.8	11.6	10.8	11.4
Percent Saturation	----	110	108	105	104	103
pH, pH Units	----	----	----	----	----	----
Conductivity, umhos/ cm @ 25°C	230	183	157	117	149	124
Temperature, °C	0.0	12.0	10.5	10.5	12.4	9.6
Free Carbon Dioxide (2)	----	----	----	----	----	----
Alkalinity, as $CaCO_3$	----	----	----	----	----	----
Settleable Solids, ml/l	----	----	----	----	----	----
Discharge c.f.s.	----	21,700	24,200	23,600	16,300	15,400
Laboratory Parameters(1)(3)						
Ammonia Nitrogen	<0.01	0.15	0.21	0.08	----	0.03
Organic Nitrogen	----	0.50	0.51	0.56	----	----
Kjeldahl Nitrogen	<1.00	0.65	0.72	0.64	4.80	0.06
Nitrate Nitrogen	0.34	0.28	<0.10	0.57	0.86	0.29
Nitrite Nitrogen	<0.01	<0.01	<0.01	<0.01	----	<0.01
Total Nitrogen	1.34	0.93	0.82	1.21	5.66	0.35
Ortho-Phosphate	0.02	<0.01	<0.01	<0.01	----	0.01
Total Phosphorus	0.02	0.10	0.21	0.43	0.01	0.01
Alkalinity, as $CaCO_3$	----	----	----	----	----	43
Chemical Oxygen Demand	10.0	5.0	1.3	4.1	6.0	1.0
Chloride	26.0	----	----	----	4.2	12.0
Conductivity, umhos/cm @ 25°C	----	----	----	----	----	----
True Color, Color Units	----	----	----	----	----	----

2-11-60

TABLE 2.3 (Continued)

NOTE: Dash indicates data not available.

	Date Sampled					
	2/06/82*	7/10/82	7/16/82	7/23/82	8/05/82*	8/10/82*
Laboratory Parameters[1][3] (continued)						
Hardness, as $CaCO_3$[4]	104	----	----	----	97	48
Sulfate	17.0	6.1	<1.0	<1.0	14.7	14.8
Total Dissolved Solids	166	85	100	72	89	103
Total Suspended Solids	1	580	56	213	231	206
Turbidity, NTU	----	----	----	----	----	----
Uranium	----	----	----	----	----	----
Radioactivity, Gross Alpha, pCi/l	----	----	----	----	----	----
Total Organic Carbon	1.0	2.8	2.5	1.4	----	2.1
Total Inorganic Carbon	4	11	11	12	----	12
Ca, Calcium	34.4	----	----	----	33.5	16.2
Mg, Magnesium	4.4	----	----	----	3.1	1.7
K, Potassium	2.7	----	----	----	1.9	1.3
Na, Sodium	21.1	----	----	----	4.3	10.0

* Samples that were analysed by Northern Testing Laboratories, Fairbanks. Other laboratory analyses were performed by Chemical and Geological Laboratories of Anchorage, Alaska.

(1) Table values are mg/l unless noted otherwise.

(2) All values for free CO_2 determined from nomograph on p. 297 of Standard Methods, 14th edition.

(3) Samples for all parameters except chemical oxygen demand, dissolved and suspended solids, and turbidity were filtered.

(4) Hardness calculated by R&M personnel.

2-11-61

s1 s17/h

TABLE 2.3 (Continued)

NOTE: Dash indicates data not available.

	Date Sampled				
	8/10/82	8/26/82*	9/04/82*	9/15/82*	10/14/82*
Field Parameters(1)					
Dissolved Oxygen	----	10.5	11.6	11.1	----
Percent Saturation	----	95	100	----	----
pH, pH Units	----	6.83	----	----	----
Conductivity, umhos/cm @ 25°C	----	135	133	103	84
Temperature, °C	----	10.5	7.8	7.8	0.0
Free Carbon Dioxide (2)	----	----	----	----	----
Alkalinity, as $CaCO_3$	----	----	----	----	----
Settleable Solids, ml/l	----	----	----	----	----
Discharge c.f.s.	15,400	12,000	13,500	29,400	7,300
Laboratory Parameters (1)(3)					
Ammonia Nitrogen	0.07	0.18	0.02	0.02	----
Organic Nitrogen	<0.05	----	----	----	----
Kjeldahl Nitrogen	0.07	<0.1	15.00	<0.01	<0.10
Nitrate Nitrogen	<0.10	<0.10	0.14	<0.10	0.12
Nitrite Nitrogen	<0.01	<0.01	<0.01	<0.01	----
Total Nitrogen	----	----	----	----	----
Ortho-Phosphate	<0.01	<0.01	<0.01	<0.01	----
Total Phosphorus	<0.05	0.02	0.01	<0.01	0.01
Alkalinity, as $CaCO_3$	----	37	40	35	----
Chemical Oxygen Demand	1.3	<1.0	<1.0	7.5	6.0
Chloride	----	8.8	6.4	5.2	9.0
Conductivity, umhos/cm @ 25°C	----	37	37	----	----
True Color, Color Units	----	----	----	----	----

2-11-62

TABLE 2.3 (Continued)

NOTE: Dash indicates data not available.

	Date Sampled				
	8/10/82	8/26/82*	9/04/82*	9/15/82*	10/14/82*
Laboratory Parameters(1)					
Hardness, as $CaCO_3$(4)	----	37	37	----	67
Sulfate	6.0	11.5	11.5	3.2	15.8
Total Dissolved Solids	100	95	68	83	104
Total Suspended Solids	181	219	60	231	7
Turbidity, NTU	----	----	----	----	----
Uranium	----	----	----	----	----
Radioactivity, Gross Alpha, pCi/l	----	----	----	----	----
Total Organic Carbon	2.0	1.6	2.2	3.8	----
Total Inorganic Carbon	8.7	11	9.6	8.6	----
Ca, Calcium	----	12.9	12.4	16.1	21.0
Mg, Magnesium	----	1.2	1.4	2.4	3.4
K, Potassium	----	1.6	1.4	0.9	1.2
Na, Sodium	----	6.7	6.5	6.0	8.4

* Samples that were analysed by Northern Testing Laboratories, Inc., Fairbanks. Other laboratory analyses were performed by Chemical and Geological Laboratories of Alaska, Anchorage.

(1) Table values are mg/l unless noted otherwise.

(2) All values for free CO_2 determined from nomograph on p. 297 of Standard Methods, 14th edition.

(3) Samples for all parameters except chemical oxygen demand, dissolved and suspended solids, and turbidity were filtered.

(4) Hardness calculated by R&M personnel.

2-11-63

s3/u22

TABLE 2.6

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: NR. DENALI 1957 - 1982
Elevation: 2440 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Field Parameters (1)					
Dissolved Oxygen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Percent Saturation	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
pH, pH Units	7.9/7.6/7.2	7.2/7.1/7.2	7.6/7.4/7.2	11/3/1	11/3/1
Conductivity, umhos/cm @ 25°C	226/467/124	121/351/124	161/400/124	18/3/1	18/3/1
Temperature, °C	10.5/0.0/6.5	0.0/0.0/1.5	5.5/0.0/4.0	47/3/6	47/3/6
Free Carbon Dioxide	5.2/25/5.8	1.5/5.5/5.8	3.1/12.9/5.8	11/3/1	11/3/1
Alkalinity, as $CaCO_3$	75/161/47	42/112/47	55/136/47	11/3/1	11/3/1
Settleable Solids, ml/l	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Laboratory Parameters (1)					
Ammonia Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Organic Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Kjeldahl Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Nitrate Nitrogen	.09/.07/.05	0.0/0.0/.05	.03/.04/.05	11/3/1	11/3/1
Nitrite Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ortho-Phosphate	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Phosphorus	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

2-11-84

s3/u23

TABLE 2.6 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S GEOLOGICAL SURVEY
Station: NR. DENALI 1957 - 1982
Elevation: 2440 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Laboratory Parameters (1)					
(Continued)					
Alkalinity, as $CaCO_3$	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Chemical Oxygen Demand	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Chloride	11/30/4.2	1.5/19/4.2	4.7/23.3/4.2	11/3/1	11/3/1
Conductivity, umhos/cm @ 25°C	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
True Color, Color Units	10/5/30	0/0/30	5/5/30	14/3/1	14/3/1
Hardness, as $CaCO_3$	87/181/50	52/135/50	67/157/50	11/3/1	11/3/1
Sulfate	31/39/9.2	13/36/9.2	17/37/9.2	11/3/1	11/3/1
Total Dissolved Solids	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
TSS → Total Suspended Solids	5690/8/1190	85/5/102	1163/7/542	45/2/8	45/2/8
Turbidity, NTU	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Uranium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Radioactivity, Gross Alpha, pCi/l	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Organic Carbon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Inorganic Carbon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Organic Chemicals					
Endrin	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Lindane	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

S7-11-2

TABLE 2.6 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: NR. DENALI 1957 - 1982
Elevation: 2440 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Laboratory Parameters (1) (Continued)					
Methoxychlor	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Toxaphene	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
2, 4-D	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
2, 4, 5-TP Silvex	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Elements (Dissolved)					
Ag, Silver	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Al, Aluminum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
As, Arsenic	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Au, Gold	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
B, Boron	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ba, Barium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Bi, Bismuth	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ca, Calcium	29/51/17	17/41/17	21/46/17	11/3/1	11/3/1
Cd, Cadmium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Co, Cobalt	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Cr, Chromium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Cu, Copper	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Fe, Iron	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
(b) Mercury	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

s3/u25

TABLE 2.6 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: NR. DENALI 1957 - 1982
Elevation: 2440 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Laboratory Parameters (1)					
(Continued)					
K, Potassium	3.6/6.6/2.3	1.3/6.3/2.3	2.6/6.5/2.3	11/3/1	11/3/1
Mg, Magnesium	6.4/16/1.9	1.7/6.8/1.9	3.5/10.3/1.9	11/3/1	11/3/1
Mn, Manganese	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Mo, Molybdenum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Na, Sodium	10/23/3.6	2.1/15/3.6	4.3/18.7/3.6	11/3/1	11/3/1
Ni, Nickel	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Pb, Lead	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Pt, Platinum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sb, Antimony	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Se, Selenium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Si, Silicon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sn, Tin	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sr, Strontium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ti, Titanium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
W, Tungsten	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
V, Vanadium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Zn, Zinc	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Zr, Zirconium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

1. Table values are mg/l unless noted otherwise.

29-11-2

TABLE 2.7

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: VEE CANYON 1962 - 1982
Elevation: 1900 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Field Parameters (1)					
Dissolved Oxygen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Percent Saturation	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
pH, pH Units	8.1/-/7.6	7.2/-/7.6	7.7/-/7.6	9/0/1	9/0/1
Conductivity, umhos/cm @ 25°C	187/250/136	91/250/114	146/250/125	20/1/2	20/1/2
Temperature, °C	13.0/0.1/7.0	1.0/-0.1/2.0	7.9/0.0/4.3	49/4/4	49/4/4
Free Carbon Dioxide	6.8/-/2.2	0.7/-/2.2	2.6/-/2.2	9/0/1	9/0/1
Alkalinity, as $CaCO_3$	59/-/44	39/-/44	52/-/44	9/0/1	9/0/1
Settleable Solids, ml/l	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Laboratory Parameters (1)					
Ammonia Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Organic Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Kjeldahl Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Nitrate Nitrogen	.88/-/.16	.00/-/.16	.20/-/.16	9/0/1	9/0/1
Nitrite Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ortho-Phosphate	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Phosphorus	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

89-11-2

TABLE 2.7 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: VEE CANYON 1962 - 1982
Elevation: 1900 FT.

Laboratory Parameters (1) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Alkalinity, as $CaCO_3$	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Chemical Oxygen Demand	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Chloride	9.2/-/7.4	2.1/-/7.4	5.3/-/7.4		9/0/1
Conductivity, umhos/cm @ 25°C	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
True Color, Color Units	40/-/30	5/-/30	10/-/30	8/0/1	8/0/1
Hardness, as $CaCO_3$	76/-/54	42/-/54	63/-/54	9/0/1	9/0/1
Sulfate	18/-/12	7.5/-/12	14/-/12	9/0/1	9/0/1
Total Dissolved Solids	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
TSS → Total Suspended Solids	2790/14/726	34/14/661	799/14/694	36/1/2	36/1/2
Turbidity, NTU	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Uranium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Radioactivity, Gross Alpha, pCi/l	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Organic Carbon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Inorganic Carbon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Organic Chemicals					
Endrin	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Lindane	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

82-11-2

s3/u20
7

TABLE 2.7 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: VEE CANYON 1962 - 1982
Elevation: 1900 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Laboratory Parameters (1)					
(Continued)					
Methoxychlor	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Toxaphene	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
2, 4-D	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
2, 4, 5-TP Silvex	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Elements (Dissolved)					
Ag, Silver	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Al, Aluminum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
As, Arsenic	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Au, Gold	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
B, Boron	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ba, Barium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Bi, Bismuth	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ca, Calcium	27/-/17	14/-/17	21/-/17	9/0/1	9/0/1
Cd, Cadmium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Co, Cobalt	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Cr, Chromium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Cu, Copper	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Fe, Iron	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Hg, Mercury	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

2-11-70

s3/

TABLE 2.7 - Continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: VEE CANYON 1962 - 1982
Elevation: 1900 FT.

Laboratory Parameters (1) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
K, Potassium	7.3/-/2.8	1.4/-/2.8	3.5/-/2.8	9/0/1	9/0/1
Mg, Magnesium	4.4/-/2.4	1.1/-/2.4	2.7/-/2.4	9/0/1	9/0/1
Mn, Manganese	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Mo, Molybdenum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Na, Sodium	6.3/-/4.8	2.1/-/4.8	3.8/-/4.8	9/0/1	9/0/1
Ni, Nickel	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Pb, Lead	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Pt, Platinum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sb, Antimony	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Se, Selenium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Si, Silicon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sn, Tin	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sr, Strontium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ti, Titanium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
W, Tungsten	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
V, Vanadium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Zn, Zinc	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Zr, Zirconium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

1. Table values are mg/1 unless noted otherwise.

17-11-2

s3/u14

TABLE 2.8

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: GOLD CREEK 1949 - 1982
Elevation: 676.5 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Field Parameters (1)					
Dissolved Oxygen	13.3/15.8/14.1	9.5/11.0/14.1	11.9/13.9/14.1	9/5/1	9/5/1
Percent Saturation	110/110/111	83/77/111	102/97/111	6/5/1	6/5/1
pH, pH Units	7.9/8.1/8.0	6.5/7.0/6.5	7.3/7.5/7.0	66/31/7	66/31/7
Conductivity, umhos/cm @ 25°C	227/300/147	90/164/70	147/250/97	66/32/7	66/32/7
Temperature, °C	14.0/0.5/6.0	0.4/0.0/1.0	9.2/0.1/3.1	39/12/8	39/12/8
Free Carbon Dioxide	20/16/24	1.1/1.2/2.9	5.8/6.2/10.8	57/26/6	57/26/6
Alkalinity, as $CaCO_3$	87/88/47	23/49/25	51/72/33	62/30/7	62/30/7
Settleable Solids, ml/l	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Laboratory Parameters (1)					
Ammonia Nitrogen	.33/.08/.13	.01/.03/.13	.16/.06/.13	7/5/1	7/6/1
Organic Nitrogen	.39/.44/.07	.10/.18/.07	.27/.29/.07	7/5/1	7/5/1
Kjeldahl Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Nitrate Nitrogen	.36/.32/.69	.02/.05/.05	.12/.16/.24	55/25/7	55/25/7
Nitrite Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Nitrogen	.60/.66/-	.25/.44/-	.50/.51/-	5/6/0	5/6/0
Ortho-Phosphate	.03/.03/.04	.00/.01/.04	.01/.02/.04	11/4/1	12/4/1
Total Phosphorus	.23/.05/.09	.02/.01/.09	.13/.03/.09	7/6/1	7/6/1

27-11-2

s3/u15

TABLE 2.8 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: GOLD CREEK 1949 - 1982
Elevation: 676.5 FT.

1 2 3
Summer/Winter/Break-Up

Laboratory Parameters (1) (Continued)	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Alkalinity, as $CaCO_3$	45/85/27	35/82/27	40/83/27	5/3/1	5/3/1
Chemical Oxygen Demand	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Chloride	15/35/7.6	1.4/6.2/1.8	5.5/22/4.4	62/28/7	62/28/7
Conductivity, umhos/cm @ 25°C	142/289/115	114/266/84	128/279/100	5/6/2	5/6/2
True Color, Color Units	45/10/50	0/0/5	10/5/25	55/22/6	55/22/6
Hardness, as $CaCO_3$	107/120/56	35/60/30	64/98/39	62/28/7	62/28/7
Sulfate	31/38/11	1.0/12/5.0	16.1/21/7.6	61/28/6	62/28/7
Total Dissolved Solids	140/174/90	55/133/53	93/154/66	43/18/6	43/18/6
Total Suspended Solids	2620/76/1330	7/1/120	740/12/621	56/10/13	56/11/13
Turbidity, NTU	180/.70/29	42/.10/29	126/.40/29	5/2/1	5/2/1
Uranium	.33/-/-	.12/-/-	.25/-/-	3/0/0	3/0/0
Radioactivity, Gross Alpha, pCi/l	1.8/-/-	0.5/-/-	1.3/-/-	3/0/0	3/0/0
Total Organic Carbon	2.6/5.5/10.0	1.4/1.1/1.8	2.0/2.6/5.9	2/3/2	2/3/2
Total Inorganic Carbon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Organic Chemicals					
Endrin	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Lindane	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

34-11-2

TABLE 2.8 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: GOLD CREEK 1949 - 1982
Elevation: 676.5 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Laboratory Parameters (1)					
(Continued)					
Methoxychlor	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Toxaphene	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
2, 4-D	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
2, 4, 5-TP Silvex	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Elements (Dissolved)					
Ag, Silver	.000/.001/-	.000/.001/-	.000/.001/-	2/1/0	3/1/0
Al, Aluminum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
As, Arsenic	.002/.002/-	.001/.002/-	.001/.002/-	3/1/0	3/1/0
Au, Gold	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
B, Boron	-/-/-	-/-/-	-/-/-	0/0/-	0/0/0
Ba, Barium	.031/.060/-	.000/.060/-	.010/.060/-	3/1/0	3/1/0
Bi, Bismuth	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ca, Calcium	37/39/18	11/24/9.9	20/30/13	62/28/7	62/28/7
Cd, Cadmium.	.001/-/-	.001/-/-	.001/-/-	2/0/0	3/1/0
Co, Cobalt	.000/.001/-	.000/.001/-	.000/.001/-	1/1/0	3/1//0
Cr, Chromium	.010/-/-	.000/-/-	.005/-/-	2/0/0	3/1/0
Cu, Copper	.005/.001/-	.003/.001/-	.004/.001/-	3/1/0	3/1/0
Fe, Iron	.14/.015/-	.04/.015/-	.10/.015/-	6/1/0	6/1/0
Hg, Mercury	.0002/-/-	.0000/-/-	.0001/-/-	2/0/0	3/1/0

2-11-24

s3/(

TABLE 2.8 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: GOLD CREEK 1949 - 1982
Elevation: 676.5 FT.

Laboratory Parameters (1) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
K, Potassium	4.4/5.0/1.7	1.0/1.2/1.2	2.4/2.3/1.4	52/22/5	52/22/5
Mg, Magnesium	7.8/8.3/2.8	1.2/3.6/0.3	3.2/5.4/1.7	62/28/7	62/28/7
Mn, Manganese	.18/.003/-	.00/.003/-	.036/.003/-	7/1/0	7/1/0
Mo, Molybdenum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Na, Sodium	6.5/17/3.8	2.4/5.2/2.8	4.1/11.3/3.1	52/22/5	52/22/5
Ni, Nickel	.000/.001/-	.000/.001/-	.000/.001/-	2/1/0	3/1/0
Pb, Lead	.001/.003/-	.000/.003/-	.000/.003/-	3/1/0	3/1/0
Pt, Platinum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sb, Antimony	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Se, Selenium	.001/-/-	.000/-/-	.000/-/-	3/0/0	3/1/0
Si, Silicon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sn, Tin	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sr, Strontium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ti, Titanium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
W, Tungstem	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
V, Vanadium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Zn, Zinc	.014/-/-	.006/-/-	.010/-/-	3/0/0	3/1/0
Zr, Zirconium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

2-11-75

TABLE 2.9

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: SUNSHINE 1971 - 1982
Elevation: 270 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Field Parameters (1)					
Dissolved Oxygen	13.3/13.8/-	10.6/13.0/-	12.0/13.4/-	5/3/0	5/3/0
Percent Saturation	107/94/-	99/90/-	103/92/-	2/3/0	2/3/0
pH, pH Units	7.7/7.3/-	7.1/6.2/-	7.4/6.9/-	7/3/0	7/3/0
Conductivity, umhos/cm @ 25°C	170/242/-	61/225/-	115/232/-	9/3/0	9/3/0
Temperature, °C	12.0/0.0/9.2	3.8/0.0/9.2	8.6/0.0/9.2	9/3/1	9/3/1
Free Carbon Dioxide	3.9/-/-	2.1/-/-	3.1/-/-	3/0/0	3/0/0
Alkalinity, as $CaCO_3$	43/71/-	25/63/-	36/68/-	6/2/0	6/2/0
Settleable Solids, ml/l	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Laboratory Parameters (1)					
Ammonia Nitrogen	.37/.06/-	.08/.03/-	.19/.05/-	6/3/0	6/4/0
Organic Nitrogen	1.10/.42/-	.19/.18/-	.63/.29/-	6/3/0	6/3/0
Kjeldahl Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Nitrate Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Nitrite Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Nitrogen	2.30/.72/-	.71/.42/-	1.17/.61/-	5/4/0	5/4/0
Ortho-Phosphate	.04/.04/-	.00/.04/-	.02/.04/-	3/1/0	3/1/0
Total Phosphorus	.33/.01/-	.05/.01/-	.15/.01/-	6/2/0	6/4/0

84-11-2

s3/l

TABLE 2.9 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: SUNSHINE 1971 - 1982
Elevation: 270 FT.

Laboratory Parameters (1) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Alkalinity, as $CaCO_3$	48/74/-	28/63/-	41/70/-	6/3/0	6/3/0
Chemical Oxygen Demand	-/-/-	-/-/-	---	0/0/0	0/0/0
Chloride	7.3/21/-	2.2/16/-	3.7/18/-	9/4/0	9/4/0
Conductivity, umhos/cm @ 25°C	129/233/-	82/222/-	115/229/-	6/3/0	6/3/0
True Color, Color Units	100/0/-	8/0/-	44/0/-	3/1/0	3/1/0
Hardness, as $CaCO_3$	72/96/-	33/87/-	50/91/-	9/4/0	9/4/0
Sulfate	13/18/-	3/16/-	10/17/-	9/4/0	9/4/0
Total Dissolved Solids	101/141/-	54/130/-	70/134/-	8/4/0	8/4/0
Total Suspended Solids	3510/2/508	288/1/508	1485/2/508	5/2/1	5/2/1
Turbidity, NTU	300/1.3/-	160/.20/-	233/.67/-	6/3/0	6/3/0
Uranium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Radioactivity, Gross Alpha, pCi/l	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Organic Carbon	3.2/0.8/-	2.9/0.4/-	3.0/0.6/-	2/2/0	2/2/0
Total Inorganic Carbon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Organic Chemicals					
Endrin	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Lindane	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

s3/u12

TABLE 2.9 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: SUNSHINE 1971 - 1982
Elevation: 270 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Laboratory Parameters (1) (Continued)					
Methoxychlor	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Toxaphene	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
2, 4-D	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
2, 4, 5-TP Silvex	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Elements (Dissolved)					
Ag, Silver	.000/.000/-	.000/.000/-	.000/.000/-	2/1/0	3/1/0
Al, Aluminum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
As, Arsenic	.003/.001/-	.002/.001/-	.002/.001/-	3/1/0	3/1/0
Au, Gold	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
B, Boron	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ba, Barium	.070/.040/-	.000/.040/-	.032/.040/-	3/1/0	3/1/0
Bi, Bismuth	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ca, Calcium	23/31/-	11/28/-	16/29/-	9/4/0	9/4/0
Cd, Cadmium.	.000/-/-	.000/-/-	.000/-/-	1/0/0	3/1/0
Co, Cobalt	.000/-/-	.000/-/-	.000/-/-	1/0/0	3/1/0
Cr, Chromium	.020/.010/-	.000/.010/-	.010/.010/-	3/1/0	3/1/0
Cu, Copper	.005/.004/-	.003/.004/-	.004/.004/-	3/1/0	3/1/0
Fe, Iron	.250/.040/-	.060/.010/-	.180/.025/-	5/2/0	5/2/0
Hg, Mercury	.0001/.0001/-	.0000/.0001/-	.0001/.0001/-	2/1/0	3/1/0

87-11-2

TABLE 2.9 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: US. GEOLOGICAL SURVEY
Station: SUNSHINE 1971 - 1982
Elevation: 270 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Laboratory Parameters (1) (Continued)					
K, Potassium	2.8/2.1/-	1.1/1.8/-	1.5/1.9/-	9/4/0	9/4/0
Mg, Magnesium	3.5/4.5/-	1.4/4.1/-	2.3/4.3/-	9/4/0	9/4/0
Mn, Manganese	.020/.004/-	.000/.000/-	.009/.002/-	5/2/0	5/2/0
Mo, Molybdenum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Na, Sodium	4.4/11/-	1.9/10/-	2.8/11/-	9/4/0	9/4/0
Ni, Nickel	.002/.002/-	.000/.002/-	.001/.002/-	3/1/0	3/1/0
Pb, Lead	.001/.008/-	.000/.008/-	.000/.008/-	3/1/0	3/1/0
Pt, Platinum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sb, Antimony	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Se, Selenium	.000/.000/-	.000/.000/-	.000/.000/-	2/1/0	3/1/0
Si, Silicon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sn, Tin	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sr, Strontium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ti, Titanium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
W, Tungsten	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
V, Vanadium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Zn, Zinc	.020/.030/-	.006/.030/-	.012/.030/-	3/1/0	3/1/0
Zr, Zirconium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

2-11-82

s3/u6

TABLE 2.10

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: SUSITNA 1955 - 1982
Elevation: 40 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Field Parameters (1)					
Dissolved Oxygen	12.8/13.5/12.4	10.5/10.6/11.4	11.5/11.6/12.1	13/14/4	13/14/4
Percent Saturation	100/94/99	90/74/97	97/80/98	9/7/2	9/7/2
pH, pH Units	8.3/7.9/7.8	7.0/6.8/6.5	7.7/7.3/7.2	26/20/7	26/20/7
Conductivity, umhos/cm @ 25°C	160/225/116	90/182/85	122/205/93	27/22/7	27/22/7
Temperature, °C	12.5/0.5/7.0	2.0/0.0/3.4	8.4/0.04/5.8	25/22/7	25/22/7
Free Carbon Dioxide	8/17/19	0.6/1.8/1.1	2.5/7.8/6.5	15/15/5	15/15/5
Alkalinity, as $CaCO_3$	57/75/39	36/60/30	44/69/34	21/19/6	21/19/6
Settleable Solids, ml/l	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Laboratory Parameters (1)					
Ammonia Nitrogen	.19/.09/.21	.00/.00/.01	.04/.04/.08	12/10/3	12/10/3
Organic Nitrogen	1.5/.46/.70	.16/.00/.16	.60/.27/.43	12/9/2	12/9/2
Kjeldahl Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Nitrate Nitrogen	.00/.19/-	.00/.19/-	.00/.19/0	1/1/0	1/1/0
Nitrite Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Nitrogen	1.70/.99/1.20	.26/.24/.67	.72/.55/.92	22/17/4	22/17/4
Ortho-Phosphate	.02/-/.02	.02/-/.02	.02/-/.02	1/0/1	1/2/1
Total Phosphorus	1.10/.38/.29	.03/.00/.01	.40/.05/.14	23/20/7	23/20/7

28-11-2

s3/07

TABLE 2,10 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: SUSITNA 1955 - 1982
Elevation: 40 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Laboratory Parameters (1) (Continued)					
Alkalinity, as $CaCO_3$	49/76/34	46/63/27	47/71/30	3/4/2	3/4/2
Chemical Oxygen Demand	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Chloride	6.7/18/4.6	1.2/5.7/3.1	2.7/13/3.7	24/21/7	24/21/7
Conductivity, umhos/cm @ 25°C	133/222/104	114/208/94	122/217/99	4/4/2	4/4/2
True Color, Color Units	10/0/-	10/0/-	10/0/-	2/2/0	4/4/0
Hardness, as $CaCO_3$	66/96/48	44/73/36	54/85/39	25/21/7	25/21/7
Sulfate	20.7/20/10	1.0/15/3.7	13.2/17.3/6.7	25/21/7	25/21/7
Total Dissolved Solids	114/139/71	56/109/51	73/123/65	24/20/7	24/20/7
Total Suspended Solids	2367/12/683	158/2/257	705/5/461	21/19/5	21/19/5
Turbidity, NTU	790/3.0/160	21/1.0/25	233/1.5/69	18/13/5	18/13/5
Uranium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Radioactivity, Gross Alpha, pCi/l	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Organic Carbon	11.0/4.0/9.1	2.7/0.4/3.8	4.4/1.6/6.0	7/9/4	7/9/4
Total Inorganic Carbon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Organic Chemicals					
Endrin	-/-/-	-/-/-	-/-/-	0/0/0	7/10/4
Lindane	-/-/-	-/-/-	-/-/-	0/0/0	7/10/4

18-11-2

TABLE 2.10 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: SUSITNA 1955 - 1982
Elevation: 40 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Laboratory Parameters (1) (Continued)					
Methoxychlor	-/-/-	-/-/-	-/-/-	0/0/0	7/10/4
Toxaphene	-/-/-	-/-/-	-/-/-	0/0/0	7/9/4
2, 4-D	-/-/-	-/-/-	-/-/-	0/0/0	2/6/2
2, 4, 5-TP Silvex	-/-/-	-/-/-	-/-/-	0/0/0	2/6/2
Elements (Dissolved)					
Ag, Silver	.000/.000/-	.000/.000/-	.000/.000/-	4/2/0	8/6/3
Al, Aluminum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
As, Arsenic	.003/.003/.001	.001/.000/.001	.002/.001/.001	13/8/3	13/9/6
Au, Gold	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
B, Boron	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ba, Barium	.200/.040/.020	.027/.040/.020	.068/.040/.020	7/4/1	8/6/3
Bi, Bismuth	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ca, Calcium	22/31/15	14/23/11	17/27/13	25/21/7	25/21/7
Cd, Cadmium	.001/-/-	.001/-/-	.001/-/-	1/0/0	13/9/6
Co, Cobalt	.007/.002/.001	.001/.002.001	.003/.002/.001	5/1/1	13/9/6
Cr, Chromium	.030/.010/.005	.000/.000/.005	.010/.005/.005	5/2/1	13/9/5
Cu, Copper	.007/.004/.006	.003/.000/.004	.004/.002/.005	7/7/4	13/9/6
Fe, Iron	.460/.060/.190	.020/.060/.110	.096/.088/.152	12/9/6	13/9/6
Hg, Mercury	.0002/.0000/-	.0000/.0[illegible]/-	.0001/.0000/-	5/2/0	13/9/6

28-11-2

TABLE 2.10 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: SUSITNA 1955 - 1982
Elevation: 40 FT.

Laboratory Parameters (1) (Continued)	Maximum (Summer/Winter/Break-Up)	Minimum (Summer/Winter/Break-Up)	Mean (Summer/Winter/Break-Up)	Number of Detectable Values	Total Number of Observations
K, Potassium	1.8/2.5/1.4	1.0/1.4/0.8	1.4/1.7/1.0	25/21/7	25/21/7
Mg, Magnesium	3.7/4.9/2.6	2.0/3.7/1.6	2.5/4.3/1.9	25/21/7	25/21/7
Mn, Manganese	.020/.030/.011	.004/.017/.008	.008/.023/.010	7/8/2	13/9/6
Mo, Molybdenum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Na, Sodium	4.0/9.0/3.2	1.8/4.9/2.4	2.7/7.7/2.9	25/21/7	25/21/7
Ni, Nickel	.004/.003/.002	.000/.002/.002	.001/.002/.002	5/2/1	5/3/1
Pb, Lead	.009/.004/.011	.002/.000.003	.004/.002/.006	8/6/4	13/9/6
Pt, Platinum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sb, Antimony	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Se, Selenium	.001/.001/-	.000/.000/-	.0004/.0008/-	7/6/0	13/9/6
Si, Silicon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sn, Tin	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sr, Strontium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ti, Titanium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
W, Tungsten	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
V, Vanadium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Zn, Zinc	.020/.003/.020	.004/.003/.020	.008/.003/.020	5/1/2	13/9/6
Zr, Zirconium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

2-11-83

3 of 3

HATFIELD-EBASCO
Susitna Joint Venture
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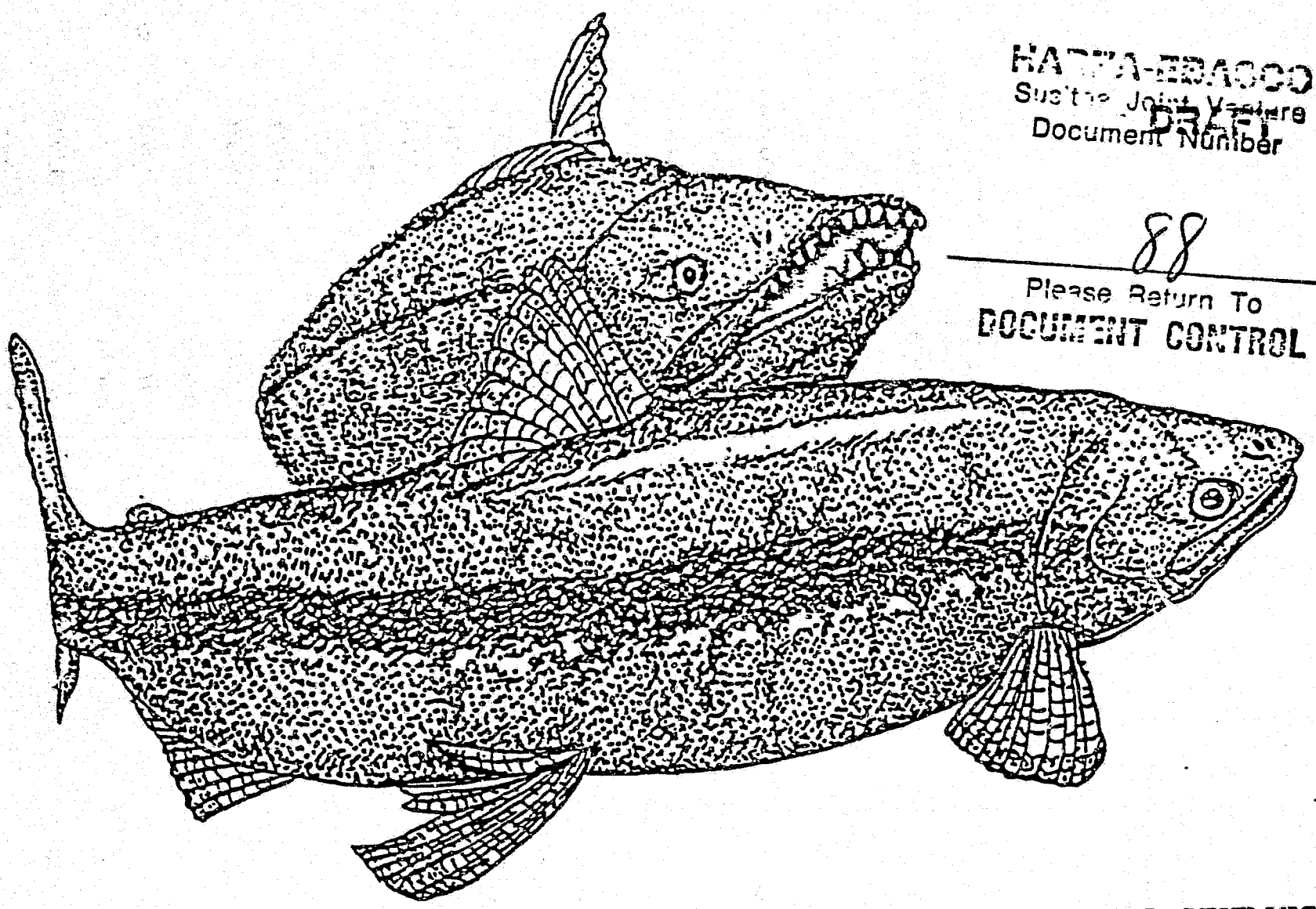

SUSITNA HYDRO AQUATIC STUDIES PHASE II BASIC DATA REPORT

Volume 4. Aquatic Habitat and Instream Flow Studies, 1982.

Appendices D - J

-by-

ALASKA DEPARTMENT OF FISH AND GAME
Susitna Hydro Aquatic Studies
2207 Spenard Road
Anchorage, Alaska 99503
1983

2-11-84

DRAFT
ADFG01/t06

Appendix Table 4-D-6. Summary of provisional water quality data for sloughs 8A, 9, 16B, 19, 21, and mainstem Susitna River at Gold Creek, collected by ADF&G and USGS in June, July, and September, 1981, and in January and February, 1982.

Parameter	Date[a]	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Physical and Field Parameters[b]							
*Water Temperature °C	June	15.5	14.2	14.0	5.5	10.7	12.4
	July	11.2	10.9	9.0	9.8	11.3	10.5
	September	3.5	5.6	4.8	1.8	2.4	0.4
	January	0.5	0.5	1.5	2.0	1.5	0.0
	March	0.5	0.5	2.0	1.0	1.5	0.0
Air Temperature °C	June	21.0	20.1	---	---	23.0	---
	July	16.0	14.0	15.5	---	---	---
	September	8.0	7.5	---	3.0	---	---
	January	---	---	---	---	---	---
	March	---	---	---	---	-11.0	---
Streamflow (discharge) cfs	June	6.4	2.9	0.7	0.2	3.2	1,780.0
	July	551.0	714.0	503.0	0.0	142.0	42,500.0
	September	2.8	1.5	0.3	<0.1	0.43	8,540.0
	January	---	---	---	---	---	---
	March	---	---	---	---	---	1,520.0
*Specific Conductance (field) umho^5/cm	June	140	145	71	146	226	---
	July	117	124	72	127	130	119
	September	135	113	64	150	205	172
	January	193	121	59	148	221	260
	March	142	143	59	129	196	266

[a]Sloughs and mainstem Susitna River were sampled on 2 or 3 consecutive days in each month (except January) as follows.

	8A	9	16B	19	21	Susitna River at Gold Creek
June	25	24	23	23	24	23
July	21	21	22	22	22	21
September	30	30	28	29	29	28
January	20	20	20	20	20	20
March	31	30	30	30	30	30

[b]Parameters marked with an * are averages of transect point measurements (see methods).

--- indicates data not available.

4-D-20

58-11-2

Appendix Table 4-D-6 (Continued).

Parameter	Date	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Physical and Field Parameters - Cont'd							
Specific Conductance (lab) umho/cm	June	153	158	70	146	226	141
	July	118	124	71	129	131	114
	September	132	113	64	130	205	170
	January	193	121	59	148	221	260
	March	142	143	59	129	196	266
*Dissolved Oxygen mg/l	June	10.8	10.6	10.8	9.4	10.7	10.8
	July	11.4	11.4	11.7	10.4	11.3	11.7
	September	12.1	11.3	11.5	9.5	10.3	---
	January	7.0	11.7	6.6	7.7	9.0	15.8
	March	10.2	10.9	7.3	9.6	9.8	14.2
*Dissolved Oxygen (%) saturation	June	108	103	107	76	98	104
	July	104	105	102	90	105	104
	September	94	93	88	98	76	---
	January	49	82	47	57	65	110
	March	72	77	59	70	72	99
*pH (field)	June	6.9	6.8	6.4	6.5	7.0	7.4
	July	---	---	---	---	---	7.7
	September	7.6	7.4	7.1	7.3	7.7	6.5
	January	6.5	6.6	6.0	6.0	6.7	7.5
	March	6.6	7.0	6.4	6.5	7.4	6.7
pH (lab)	June	7.4	7.5	7.2	7.2	7.6	7.5
	July	7.6	7.7	7.3	7.0	7.7	7.7
	September	7.4	6.7	6.6	7.2	7.0	7.2
	January	7.2	7.3	6.9	7.1	7.6	7.6
	March	7.2	7.1	7.1	7.2	7.3	7.5
Alkalinity (field) mg/l $CaCO_3$	June	---	39	24	50	62	---
	July	41	39	24	52	47	35
	September	43	34	26	62	62	---
	January	62	34	24	39	62	82
	March	43	39	23	46	61	78

28-11-2

Appendix Table 4-D-6 (Continued).

Parameter	Date	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Physical and Field Parameters - Cont'd							
Alkalinity (lab) mg/l $CaCO_3$	June	47	33	24	52	63	45
	July	41	39	24	52	47	35
	September	42	36	26	62	61	44
	January	64	36	30	53	63	83
	March	46	42	27	50	64	82
Turbidity NTU	June	0.9	0.6	0.5	0.4	0.4	100.0
	July	130.0	130.0	43.0	2.5	150.0	170.0
	September	1.1	0.6	0.6	0.5	0.5	5.5
	January	0.4	0.5	0.5	0.3	0.5	0.7
	March	0.1	0.1	0.1	0.1	0.1	0.1
Sediments, suspended mg/l	June	1	2	1	1	5	327
	July	220	417	107	8	356	680
	September	1	1	1	2	4	44
	January	1	2	0	1	0	2
	March	7	3	6	1	6	8
Sediments, discharge suspended tons/day	June	0.02	0.02	0.0	0.0	0.04	1,570.0
	July	327.0	804.0	145.0	0.0	136.0	78,000.0
	September	0.01	0.0	0.0	0.0	0.0	1,020.0
	January	---	---	---	---	---	---
	March	---	---	---	---	---	33.0
Solids, residue at 180°C mg/l	June	88	100	51	94	137	79
	July	70	75	41	81	78	74
	September	82	69	42	95	119	101
	January	111	73	38	78	114	152
	March	92	93	42	80	124	160
Solids, sum of constituents mg/l	June	93	91	47	90	130	83
	July	61	68	43	89	68	65
	September	71	71	48	94	120	80
	January	120	76	---	92	130	165
	March	86	83	43	85	127	160

4-D-73

8-11-2

Appendix Table 4-D-6 (Continued).

Parameter	Date	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Physical and Field Parameters - Cont'd							
Solids, dissolved tons/day	June	1.5	0.8	0.1	0.1	1.1	380.0
	July	104.0	145.0	55.7	0.0	29.9	8,490.0
	September	0.62	0.3	<0.1	<0.1	0.1	2,330.0
	January	---	---	---	---	---	---
	March	---	---	---	---	---	657.0
Solids, dissolved tons/acre-foot	June	0.12	0.14	0.07	0.13	0.19	0.11
	July	0.10	0.10	0.06	0.11	0.11	0.10
	September	0.11	0.09	0.06	0.13	0.16	0.14
	January	0.15	0.10	0.05	0.11	0.16	0.21
	March	0.13	0.13	0.06	0.11	0.17	0.22
Suspended sediment (%) less than 0.062 mm sieve diameter	June	---	---	---	---	---	70
	July	89	55	56	---	85	49
	September	---	---	---	---	---	81
	January	---	---	---	---	---	---
	March	---	---	---	---	---	---
Major Constituents							
Hardness mg/a $CaCO_3$	June	57	56	32	69	83	57
	July	48	50	30	61	54	51
	September	54	45	30	72	77	60
	January	79	47	34	67	87	120
	March	60	52	26	58	82	100
Hardness, non-carbonate mg/1 $CaCO_3$	June	10.0	17.0	8.0	19.0	21.0	12
	July	7.0	11.0	6.0	9.0	7.0	16
	September	11.0	11.0	4.0	10.0	15.0	16
	January	17.0	13.0	10.0	14.0	25.0	33
	March	15.0	13.0	3.0	12.0	21.0	19
Bicarbonate, incremental titration mg/1 $CaCO_3$	June	---	---	---	---	---	---
	July	---	---	---	---	---	---
	September	53	42	32	75	75	---
	January	---	---	---	---	---	---
	March	---	---	---	---	---	---

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Appendix Table 4-D-6 (Continued).

Parameter	Date	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Major Constituents - Cont'd							
Carbonate, incremental titration mg/l $CaCO_3$	June	---	---	---	---	---	---
	July	---	---	---	---	---	---
	September	0	0	0	0	0	---
	January	---	---	---	---	---	---
	March	---	---	---	---	---	---
Calcium, dissolved mg/l Ca	June	18	18	10	23	27	19
	July	16	17	10	20	18	16
	September	17	14	9	24	25	15
	January	26	15	11	22	29	39
	March	19	17	8	19	27	33
Magnesium, dissolved mg/l Mg	June	2.8	2.7	1.6	2.7	3.9	2.2
	July	1.9	1.9	1.3	2.6	2.1	1.7
	September	2.8	2.4	1.6	3.0	3.5	1.9
	January	3.4	2.3	1.6	3.0	3.5	4.6
	March	3.1	2.4	1.5	2.6	3.6	4.5
Sodium, dissolved mg/l Na	June	6.8	8.2	2.5	2.5	12.0	4.2
	July	3.0	3.0	1.8	1.8	3.4	3.4
	September	6.1	5.6	2.6	3.0	11.0	7.4
	January	11.0	5.7	2.9	4.3	12.0	15.0
	March	6.2	7.2	2.1	2.2	11.0	17.0
Sodium, (%)	June	20	24	14	7	23	14
	July	12	11	11	6	12	13
	September	19	21	15	8	23	21
	January	23	20	15	12	23	22
	March	18	23	14	7	22	26
Sodium, adsorption ratio	June	0.4	0.5	0.2	0.1	0.6	0.3
	July	0.2	0.2	0.1	0.1	0.2	0.2
	September	0.4	0.4	0.2	0.2	0.5	0.4
	January	0.5	0.4	0.2	0.2	0.6	0.6
	March	0.4	0.5	0.2	0.1	0.5	0.8

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Appendix Table 4-D-6 (Continued).

Parameter	Date	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Nutrients - Cont'd							
Nitrogen, total mg/l NO_3	June	8.5	8.4	4.1	10.0	4.2	2.4
	July	3.4	3.5	3.3	9.3	2.9	2.3
	September	7.4	7.3	2.9	9.0	4.9	2.7
	January	5.8	7.9	2.9	7.0	4.2	1.9
	March	5.7	6.4	3.3	7.6	4.3	1.9
Nitrogen, dissolved mg/l N	June	1.8	1.6	1.0	2.0	1.0	0.5
	July	---	0.7	---	2.2	0.7	0.6
	September	1.5	1.7	0.6	1.9	1.0	0.6
	January	1.3	1.6	0.6	1.2	0.9	0.4
	March	1.2	1.2	0.6	1.5	0.8	0.4
Nitrogen, total organic mg/l N	June	0.53	0.82	0.50	0.88	0.37	0.34
	July	0.40	0.54	0.31	0.45	0.44	0.10
	September	---	0.41	0.17	0.44	0.18	0.28
	January	---	---	0.18	0.50	---	0.18
	March	0.24	0.41	---	0.43	0.30	0.21
Nitrogen, dissolved organic mg/l N	June	0.45	0.51	0.55	0.62	0.49	0.34
	July	0.44	0.48	---	0.41	0.43	0.21
	September	0.36	0.44	0.10	0.49	0.19	0.34
	January	0.22	0.39	0.15	0.14	0.20	0.15
	March	0.20	0.16	---	0.22	---	0.19
Nitrogen, dissolved ammonia mg/l N	June	0.07	0.11	0.10	0.10	0.09	0.08
	July	0.10	0.13	0.13	0.32	0.14	0.24
	September	0.15	0.14	0.16	0.13	0.11	0.09
	January	0.15	0.08	0.09	0.08	0.08	0.09
	March	0.07	0.07	<0.06	0.08	<0.06	0.07
Nitrogen, dissolved ammonia mg/l NH_4	June	0.09	0.14	0.13	0.13	0.12	0.10
	July	0.13	0.17	0.17	0.41	0.18	0.31
	September	0.19	0.18	0.21	0.17	0.14	0.12
	January	0.19	0.10	0.12	0.10	0.10	0.12
	March	0.09	0.09	0.08	0.10	0.08	0.09

Appendix Table 4-D-6 (Continued).

Parameter	Date	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Major Constituents - Cont'd							
Potassium, dissolved mg/l K	June	1.5	1.4	0.9	1.0	2.1	2.0
	July	1.6	1.6	0.9	1.6	1.9	1.6
	September	1.1	0.9	0.9	1.1	2.1	1.5
	January	2.1	1.0	0.8	1.2	2.0	2.1
	March	1.3	1.1	0.8	1.1	2.1	2.2
Chloride, dissolved mg/l Cl	June	9.1	16.0	1.3	0.9	20.0	5.6
	July	2.9	2.9	0.9	0.6	3.7	12.0
	September	7.7	6.9	1.5	0.9	17.0	11.0
	January	14.0	9.6	1.1	3.5	20.0	24.0
	March	10.0	13.0	1.2	1.1	17.0	27.0
Sulfate, dissolved mg/l SO_4	June	11.0	9.0	4.7	13.0	14.0	17.0
	July	1.0	11.0	6.0	14.0	3.1	1.0
	September	6.0	5.0	5.0	9.0	10.0	< 5.0
	January	11.0	5.0	5.0	11.0	12.0	17.0
	March	8.0	6.0	0.0	13.0	13.0	13.0
Fluoride, dissolved mg/l F	June	0.0	0.1	0.1	0.1	0.1	0.0
	July	0.0	0.0	0.1	0.0	0.0	0.1
	September	0.1	0.1	0.1	0.1	0.1	0.1
	January	0.1	0.1	0.1	0.1	0.1	0.1
	March	0.1	0.1	0.1	0.1	0.1	0.1
Silica, dissolved mg/l SiO_2	June	9.7	11.0	10.0	10.0	11.0	5.5
	July	6.6	6.6	6.2	10.0	6.6	6.2
	September	0.0	10.0	10.0	10.0	11.0	6.1
	January	10.0	11.0	11.0	10.0	11.0	12.0
	March	11.0	11.0	11.0	10.0	12.0	13.0
Nutrients							
Nitrogen, total mg/l N	June	1.9	1.9	0.9	2.3	0.94	0.5
	July	0.8	0.8	0.8	2.1	0.2	0.5
	September	1.7	1.7	0.7	2.0	1.1	0.6
	January	1.3	1.6	0.7	1.6	1.0	0.4
	March	1.3	1.4	0.7	1.7	1.0	0.4

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Appendix Table 4-D-6 (Continued).

Parameter	Date	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Nutrients - Cont'd							
Nitrogen, total ammonia mg/l N	June	0.08	0.10	0.09	0.07	0.10	0.14
	July	0.15	0.18	0.15	0.26	0.13	0.33
	September	---	0.15	0.16	0.19	0.20	0.17
	January	<0.07	<0.07	0.12	0.09	<0.07	0.08
	March	0.12	0.08	<0.06	0.08	0.06	0.06
Nitrogen, ammonia + dissolved organics mg/l N	June	0.52	0.62	0.65	0.72	0.58	0.42
	July	0.54	0.61	---	0.73	0.57	0.45
	September	0.51	0.58	0.26	0.62	0.30	0.43
	January	0.37	0.47	0.24	0.22	0.28	0.24
	March	0.27	0.23	0.24	0.30	0.22	0.26
Nitrogen, ammonia + total suspended organics mg/l N	June	0.09	0.30	0.00	0.23	0.00	0.06
	July	0.01	0.11	---	0.00	0.00	0.00
	September	0.07	0.00	0.07	0.01	0.08	0.02
	January	0.05	0.21	0.06	0.37	0.03	0.02
	March	0.09	0.26	0.14	0.21	0.14	0.01
Nitrogen, ammonia + total organics mg/l N	June	0.61	0.92	0.59	0.95	0.47	0.48
	July	0.55	0.72	0.46	0.71	0.57	0.43
	September	0.58	0.56	0.33	0.63	0.38	0.45
	January	0.42	0.68	0.30	0.59	0.31	0.26
	March	0.36	0.49	0.38	0.51	0.36	0.27
Nitrogen, total nitrate and nitrite mg/l N	June	1.3	1.0	0.33	1.3	0.5	0.1
	July	0.2	0.1	0.3	1.4	0.1	0.1
	September	1.1	1.1	0.3	1.4	0.7	0.2
	January	0.9	1.1	0.4	1.0	0.6	0.2
	March	0.9	1.0	0.4	1.2	0.6	0.2
Nitrogen, dissolved nitrate and nitrite mg/l N	June	1.3	1.0	0.4	1.3	0.4	0.1
	July	---	0.1	0.3	1.5	0.1	0.1
	September	1.0	1.1	0.3	1.3	0.7	0.2
	January	0.9	1.1	0.4	1.0	0.6	0.2
	March	0.9	1.0	0.4	1.2	0.6	0.2

Appendix Table 4-D-6 (Continued).

Parameter	Date	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Nutrients -- Cont'd							
Phosphorus, total mg/l P	June	0.05	0.01	0.01	0.01	<0.01	0.12
	July	0.27	0.48	0.14	0.01	0.38	0.02
	September	<0.01	<0.01	<0.01	<0.01	<0.01	0.02
	January	<0.01	<0.01	<0.01	0.02	0.01	0.01
	March	0.01	0.01	0.01	0.01	0.01	0.01
Phosphorus, total mg/l PO_4	June	0.2	<0.1	<0.1	<0.1	<0.1	0.4
	July	0.8	1.5	0.4	<0.1	1.2	0.1
	September	---	---	---	---	---	0.1
	January	---	---	---	0.1	<0.1	0.1
	March	<0.1	<0.1	<0.1	<0.1	<0.1	---
Phosphorus, dissolved mg/l P	June	0.03	0.01	0.01	0.01	<0.01	0.02
	July	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	September	0.01	<0.01	<0.01	<0.01	<0.01	0.01
	January	<0.01	<0.01	<0.01	0.02	0.04	0.01
	March	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Carbon, dissolved organic mg/l C	June	1.9	2.1	1.4	1.3	2.0	2.8
	July	13.0	9.0	3.3	6.2	6.0	18.0
	September	1.5	1.7	1.9	2.2	1.1	---
	January	1.4	1.3	0.5	0.7	0.5	---
	March	1.4	0.7	0.7	1.4	1.[illegible]	1.6
Carbon, total suspended organics mg/l C	June	---	0.2	---	0.2	0.2	0.9
	July	0.2	0.5	0.0	0.0	0.3	---
	September	0.1	0.1	0.1	0.1	0.1	---
	January	0.0	0.0	0.0	0.0	0.0	---
	March	0.0	0.0	0.0	0.1	0.1	0.1
Trace Metals							
Arsenic, total ug/l As	June	1	1	1	2	2	6
	July	2	5	4	1	5	7
	September	2	1	1	2	2	---
	January	2	2	1	2	2	---
	March	1	1	2	1	2	2

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Appendix Table 4-D-6 (Continued).

Parameter	Date	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Trace Metals - Cont'd							
Arsenic, total suspended ug/l As	June	0	0	0	1	1	5
	July	0	3	2	0	3	5
	September	1	0	0	1	1	---
	January	1	1	0	1	1	---
	March	---	0	1	0	1	0
Arsenic, dissolved ug/l As	June	2	1	1	1	1	1
	July	2	2	2	1	2	2
	September	1	1	1	1	1	---
	January	1	1	1	1	1	---
	March	<1	1	1	1	1	2
Barium, total recoverable ug/l Ba	June	0	0	0	0	100	200
	July	200	200	100	100	300	300
	September	100	200	100	100	100	---
	January	100	100	<100	100	100	---
	March	<100	<100	<100	<100	<100	100
Barium, suspended recoverable ug/l Ba	June	0	0	0	0	100	200
	July	200	200	70	50	300	300
	September	100	200	100	100	0	---
	January	0	---	---	---	0	---
	March	---	---	---	---	---	40
Barium, dissolved ug/l Ba	June	90	0	0	0	0	0
	July	40	40	30	50	40	0
	September	0	0	0	0	100	---
	January	100	<100	<100	<100	100	---
	March	29	27	14	29	47	60
Cadmium, total recoverable ug/l Cd	June	0	0	2	0	1	0
	July	0	0	0	1	0	5
	September	0	0	0	0	1	---
	January	<1	<1	<1	<1	<1	---
	March	<1	<1	<1	<1	<1	<1

Appendix Table 4-D-6 (Continued).

Parameter	Date	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Trace Metals - Cont'd							
Cadmium, suspended recoverable ug/l Co	June	---	0	2	0	0	---
	July	---	---	---	---	---	4
	September	0	0	0	0	1	---
	January	---	---	---	---	---	---
	March	---	---	---	---	---	---
Cadmium, dissolved ug/l Cd	June	1	0	0	0	5	<1
	July	<1	<1	<1	<1	<1	1
	September	0	0	1	0	0	---
	January	<1	1	1	1	<1	---
	March	<3	<3	<3	<3	<3	<3
Chromium, total recoverable ug/l Cr	June	0	10	0	0	0	40
	July	30	30	20	20	40	30
	September	0	10	10	10	10	---
	January	10	<1	10	<10	<10	---
	March	10	<1	10	10	<10	10
Chromium, suspended recoverable ug/l Cr	June	0	10	0	0	0	
	July	20	20	10	10	30	40
	September	0	10	10	10	10	20
	January	---	---	---	---	---	---
	March	---	---	---	---	---	---
Chromium, dissolved ug/l Cr	June	10	0	--- 0	0	0	0
	July	10	10	10	10	10	10
	September	0	0	0	0	0	---
	January	<10	1	<10	<10	<10	---
	March	<10	<3	<10	<10	<10	<10
Cobalt, total recoverable ug/l Co	June	2	0	0	0	2	8
	July	5	6	2	0	7	11
	September	0	0	0	0	1	---
	January	2	1	1	1	<1	---
	March	1	1	2	2	1	1

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26-11-2

Appendix Table 4-D-6 (Continued).

Parameter	Date	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Trace Metals - Cont'd							
Cobalt, suspended recoverable ug/l Co	June	---	0	0	0	1	---
	July	---	---	---	---	---	11
	September	0	0	0	0	1	---
	January	0	0	0	---	---	---
	March	---	---	---	---	---	0
Cobalt, dissolved ug/l Co	June	<3	0	0	0	1	<3
	July	<3	<3	<3	<3	<3	0
	September	0	0	0	0	0	---
	January	2	2	1	<1	2	---
	March	<1	<1	<1	<1	<1	1
Copper, total recoverable ug/l Cu	June	3	2	4	2	2	31
	July	20	23	10	3	23	190
	September	6	4	5	4	4	---
	January	4	2	1	2	1	---
	March	2	1	2	8	6	2
Copper, suspended recoverable ug/l Cu	June	1	1	1	0	0	27
	July	12	20	4	0	0	190
	September	5	3	3	2	18	---
	January	3	0	0	0	3	---
	March	1	0	1	7	0	1
Copper, dissolved ug/l Cu	June	2	1	3	2	2	4
	July	8	3	6	7	5	5
	September	1	1	2	2	1	---
	January	1	2	2	2	1	---
	March	1	1	1	1	1	1
Iron, total recoverable ug/l Fe	June	20	40	50	40	60	15,000
	July	13,000	16,000	5,800	220	18,000	19,000
	September	20	90	280	260	100	---
	January	20	140	20	10	10	---
	March	10	30	40	30	10	40

4-D-81

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Appendix Table 4-D-6 (Continued).

Parameter	Date	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Trace Metals - Cont'd							
Iron, suspended recoverable ug/l Fe	June	10	0	0	0	40	15,000
	July	13,000	16,000	5,700	140	18,000	19,000
	September	10	60	260	250	90	---
	January	0	80	0	0	0	---
	March	0	20	30	20	0	30
Iron, dissolved ug/l Fe	June	10	60	50	60	20	90
	July	48	110	52	79	97	120
	September	10	30	20	10	10	---
	January	40	60	20	30	20	---
	March	12	14	9	15	11	15
Lead, total recoverable ug/l Pb	June	0	5	3	3	15	18
	July	3	3	3	3	2	47
	September	4	1	1	2	4	---
	January	2	1	<1	1	<1	---
	March	<1	1	5	6	9	3
Lead, suspended recoverable ug/l Pb	June	0	5	3	3	15	18
	July	0	1	3	2	0	47
	September	2	0	0	0	0	---
	January	1	0	---	0	---	---
	March	---	---	4	---	---	0
Lead, dissolved ug/l Pb	June	0	0	0	0	0	0
	July	3	2	0	1	5	0
	September	2	3	4	3	5	---
	January	1	2	1	1	1	---
	March	1	<1	1	<1	<1	3
Manganese, total recoverable ug/l Mn	June	10	10	10	0	0	250
	July	230	290	100	20	300	320
	September	0	0	10	10	0	---
	January	10	20	10	10	20	---
	March	10	10	<10	10	<10	10

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Appendix Table 4-D-6 (Continued).

Parameter	Date	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Cold Creek
Trace Metals - Cont'd							
Manganese, suspended recoverable ug/l Mn	June	0	10	10	0	0	250
	July	220	280	90	10	290	310
	September	0	0	10	0	0	---
	January	0	10	---	0	10	---
	March	6	5	---	6	---	7
Manganese, dissolved ug/l Mn	June	10.0	0.0	0.0	0.0	0	4
	July	8.0	10.0	7.0	9.0	8	10
	September	0.0	0.0	0.0	10.0	0	---
	January	10.0	<0.1	<10.0	<10.0	10	---
	March	4.0	<0.1	3.0	4.0	3	3
Mercury, total recoverable ug/l Hg	June	0.1	0.1	0.1	0.1	0.2	0.4
	July	0.1	0.1	0.1	0.0	0.2	0.3
	September	0.1	0.0	0.0	0.0	0.0	---
	January	<0.1	<0.1	<0.1	<0.1	0.1	---
	March	0.1	0.1	0.1	0.1	0.1	0.1
Mercury, suspended recoverable ug/l Hg	June	0.1	0.1	0.1	0.1	0.2	0.4
	July	0.0	0.1	0.1	0.0	0.2	0.1
	September	0.1	0.0	0.0	0.0	0.0	---
	January	---	---	---	---	---	---
	March	---	---	---	---	---	---
Mercury, dissolved ug/l Hg	June	0.0	0.0	0.0	0.0	0.0	0.0
	July	0.1	0.0	0.1	0.0	0.0	0.2
	September	0.0	0.0	0.0	0.0	0.0	---
	January	<0.1	<0.1	<0.1	<0.1	<0.1	---
	March	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nickel, total recoverable ug/l Ni	June	3	2	2	1	6	23
	July	14	18	6	2	18	22
	September	1	0	7	3	4	36
	January	1	2	<1	<1	<1	---
	March	1	<1	2	2	1	2

Appendix Table 4-D-6 (Continued).

Parameter	Date	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Trace Metals - Cont'd							
Nickel, suspended recoverable ug/l Ni	June	2	2	1	0	1	23
	July	12	18	6	0	17	29
	September	1	0	7	3	4	29
	January	---	1	---	---	---	---
	March	0	---	1	1	0	1
Nickel, dissolved ug/l Ni	June	1	0	1	1	5	0
	July	2	0	0	3	1	<1
	September	0	0	0	0	0	7
	January	<1	1	<1	<1	<1	---
	March	2	<1	1	1	1	1
Selenium, total ug/l Se	June	0	0	0	1	1	<1
	July	0	0	0	0	0	0
	September	0	0	0	0	0	1
	January	<1	<1	<1	1	1	---
	March	1	<1	<1	<1	<1	<1
Selenium, total suspended ug/l Se	June	0	0	0	0	1	0
	July	0	0	0	0	0	0
	September	0	0	0	0	0	0
	January	---	---	---	---	---	---
	March	---	---	---	---	---	---
Selenium, dissolved ug/l Se	June	0	0	0	1	0	0
	July	1	0	0	1	0	0
	September	0	0	0	1	1	---
	January	<1	<1	<1	<1	<1	---
	March	<1	<1	<1	1	1	<1
Silver, total recoverable ug/l Ag	June	0	0	1	0	0	0
	July	0	0	0	1	0	0
	September	0	0	0	0	0	---
	January	<1	<1	<1	<1	<1	---
	March	<1	<1	<1	<1	<1	<1

t8-D-4

66-11-2

Appendix Table 4-D-6 (Continued).

Parameter	Date	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Trace Metals - Cont'd							
Silver, suspended recoverable ug/l Ag	June	0	0	1	0	0	0
	July	0	0	0	1	0	0
	September	0	0	0	0	0	---
	January	---	---	---	---	---	---
	March	---	---	---	---	---	---
Silver, dissolved ug/l Ag	June	0	0	0	0	0	0
	July	0	0	0	0	0	0
	September	0	0	0	0	0	---
	January	<1	<1	<1	1	<1	---
	March	<1	<1	1	<1	<1	1
Zinc, total recoverable ug/l Zn	June	20	40	10	10	10	60
	July	80	60	20	10	60	120
	September	20	30	30	10	20	---
	January	20	10	20	10	10	---
	March	10	10	40	30	20	10
Zinc, suspended recoverable ug/l Zn	June	10	30	0	0	10	50
	July	80	30	10	0	40	110
	September	10	10	0	10	0	---
	January	10	0	10	0	0	---
	March	0	---	---	20	---	---
Zinc, dissolved ug/l Zn	June	7	10	10	10	0	6
	July	4	35	10	10	17	14
	September	10	20	30	0	20	5
	January	10	20	10	10	10	---
	March	<12	<12	<12	12	<12	<12

001-11-2

EXHIBIT E

2. Water Use and Quality

Comment 12 (p. E-2-32, para. 5)

Provide references for, o' data on, ammonium concentrations (means and ranges) in water at monitoring stations on the Susitna River.

Response

Data on ammonium concentrations in water at monitoring stations on the Susitna River is contained in the enclosed reports:

1) R & M Consultants, Inc. 1982. Water Quality Annual Report. (See attached tables: 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, and 2.10 on pp. 2-12-2 2-12-32).

2) Alaska Department of Fish and Game, 1982. Susitna Hydro Aquatic Studies - Phase II Basic Data Report, Volume 4. Aquatic Habitat and Instream Flow Studies. Appendix 4.D.6. (See p. 2-12-39).

0011677

SUSITNA HYDROELECTRIC PROJECT

1982

WATER QUALITY

ANNUAL REPORT

LIBRARY COPY

DECEMBER 1982

PROPERTY OF:
Alaska Power Authority
334 W. 5th Ave.
Anchorage, Alaska 99501

PREPARED BY:
R&M CONSULTANTS, INC.

PREPARED FOR:
ACRES

ALASKA POWER AUTHORITY

2-12-2

TABLE 2.4

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: R&M CONSULTANTS, INC.
Station: VEE CANYON 1980 - 1982
Elevation: 1900 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Field Parameters (1)					
Dissolved Oxygen	12.6/14.5/10.4	9.7/10.7/10.4	11.9/13.1/10.4	7/4/1	7/4/1
Percent Saturation	110/104/83	84/84/83	101/98/83	7/4/1	7/4/1
pH, pH Units	7.9/7.6/6.6	7.0/6.0/6.6	7.6/7.1/6.6	10/4/1	10/4/1
Conductivity, umhos/cm @ 25°C	171/333/100	103/130/100	129/212/100	9/4/1	9/4/1
Temperature, °C	11.9/0.1/6.5	5.3/-0.1/6.5	7.7/0.0/6.5	10/4/1	10/4/1
Free Carbon Dioxide (2)	4.5/20.0/-	1.7/5.5/-	3.0/10.3/-	7/3/0	7/3/0
Alkalinity, as $CaCO_3$	81/99/-	41/57/-	61/81/-	7/3/0	7/3/0
Settleable Solids, ml/l	1.0/-/-	0.1/-/-	0.7/-/-	4/0/0	10/3/1
Laboratory Parameters (1)(3)					
Ammonia Nitrogen	.27/.26/.13	.09/.09/.13	.16/.19/.13	6/2/1	9/4/1
Organic Nitrogen	.63/.85/.34	.22/.08/.34	.49/.40/.34	8/3/1	9/3/1
Kjeldahl Nitrogen	.79/.85/.47	.26/.17/.47	.60/.52/.47	9/4/1	9/4/1
Nitrate Nitrogen	.19/.30/-	.09/.30/-	.14/.30/-	5/1/0	10/4/1
Nitrite Nitrogen	-/.01/-	-/.01/-	-/.01/-	0/1/0	9/4/1
Total Nitrogen	.92/.85/.47	.39/.17/.47	.61/.52/.47	9/3/1	9/3/1
Ortho-Phosphate	.05/.02/-	.03/.02/-	.04/.02/-	2/2/0	9/4/1
Total Phosphorus	.49/.07/-	.03/.02/-	.14/.05/-	6/2/0	10/4/1

s3/u2

TABLE 2.4 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: R&M CONSULTANTS, INC.
Station: VEE CANYON 1980 - 1982
Elevation: 1900 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Laboratory Parameters (1) (3) (Continued)					
Alkalinity, as $CaCO_3$	60/66/-	40/66/-	48/66/-	4/1/0	4/1/0
Chemical Oxygen Demand	39/13/8	8/6/8	20/10/8	8/4/1	8/4/1
Chloride	11/18/4.5	3/16/4.5	6.7/17.5/4.5	7/4/1	10/4/1
Conductivity, umhos/cm @ 25°C	150/190/-	150/190/-	150/190/-	1/1/0	1/1/0
True Color, Color Units	175/30/15	5/5/15	70/15/15	9/4/1	9/4/1
Hardness, as $CaCO_3$ (4)	76/122/40	49/78/40	58/103/40	10/4/1	10/4/1
Sulfate	9/18/4	2/11/4	6/14/4	10/4/1	10/4/1
Total Dissolved Solids	170/157/100	38/115/100	98/141/100	10/4/1	10/4/1
TSS → Total Suspended Solids	1150/14/93	25/0.6/93	358/6.0/93	10/4/1	10/4/1
Turbidity, NTU	720/2.5/25	8.7/.35/25	156/1.3/25	14/4/1	14/4/1
Uranium	-/-/-	-/-/-	-/-/-	0/0/0	5/2/0
Radioactivity, Gross Alpha, pCi/l	-/-/-	-/-/-	11.6 ± 0.6/ 10.3 ± 0.6/-	1/1/0	1/1/0
Total Organic Carbon	-/2/-	-/2/-	-/2/-	0/1/0	0/1/0
Total Inorganic Carbon	-/2/-	-/2/-	-/2/-	0/1/0	0/1/0
Organic Chemicals					
Endrin	-/-/-	-/-/-	-/-/-	0/0/0	3/1/0
[illegible]ane	-/-/-	-/-/-	-/-/-	0/0/0	3/1/0

4-21-2

TABLE 2.4 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: R&M CONSULTANTS, INC.
Station: VEE CANYON 1980 - 1982
Elevation: 1900 FT.

Laboratory Parameters (1) (3) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Methoxychlor	-/-/-	-/-/-	-/-/-	0/0/0	3/1/0
Toxaphene	-/-/-	-/-/-	-/-/-	0/0/0	3/1/0
2, 4-D	-/-/-	-/-/-	-/-/-	0/0/0	3/1/0
2, 4, 5-TP Silvex	-/-/-	-/-/-	-/-/-	0/0/0	3/1/0
Elements (Dissolved)					
Ag, Silver	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1
Al, Aluminum	2.2/.18/-	1.6/.18/-	1.4/.18/-	3/1/0	10/3/1
As, Arsenic	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1
Au, Gold	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1
B, Boron	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1
Ba, Barium	.12/-/-	.07/-/-	.10/-/-	7/0/0	10/3/1
Bi, Bismuth	.19/-/-	.19/-/-	.19/-/-	1/0/0	10/3/1
Ca, Calcium	23/41/13	13/25/13	18/33/13	10/4/1	10/3/1
Cd, Cadmium	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1
Co, Cobalt	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1
Cr, Chromium	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1
Cu, Copper	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1
Fe, Iron	4.0/.37/.08	.05/.37/.08	1.1/.37/.08	9/1/1	10/3/1
Hg, Mercury	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1

s3/u4

TABLE 2.4 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: R&M CONSULTANTS, INC.
Station: VEE CANYON 1980 - 1982
Elevation: 1900 FT.

Laboratory Parameters (1) (3) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
K, Potassium	5.0/9.0/1.6	1.7/2.0/1.6	2.3/5.2/1.6	9/3/1	10/4/1
Mg, Magnesium	3.4/7.6/1.7	1.2/3.8/1.7	2.4/5.2/1.7	10/4/1	10/4/1
Mn, Manganese	.10/-/-	.07/-/-	.09/-/-	2/0/0	10/3/0
Mo, Molybdenum	-/-/-	-/-/-	-/-/-	0/0/0	10/3/0
Na, Sodium	5.1/12.0/2.0	2.4/6.3/2.0	3.4/8.0/2.0	10/4/1	10/4/1
Ni, Nickel	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1
Pb, Lead	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1
Pt, Platinum	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1
Sb, Antimony	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1
Se, Selenium	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1
Si, Silicon	6.9/5.0/1.7	2.0/3.7/1.7	3.5/4.5/1.7	10/4/1	10/4/1
Sn, Tin	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1
Sr, Strontium	.08/.13/-	.05/.06/-	.06/.10/-	9/3/0	10/3/1
Ti, Titanium	.24/-/-	.13/-/-	.18/-/-	3/0/0	10/3/1
W, Tungsten	-/.4/-	-/.4/-	-/.4/-	0/1/0	10/3/1
V, Vanadium	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1
Zn, Zinc	.07/-/-	.07/-/-	.07/-/-	1/0/0	10/3/1
Zr, Zirconium	-/-/-	-/-/-	-/-/-	0/0/0	10/3/1

9-21-2

(1) Table values are mg/l unless noted otherwise.

(2) All values for free CO_2 determined from nomograph on p. 297 of Standard Method, 14th edition.

(3) Samples for all parameters except chemical oxygen demand, dissolved and suspended solids, and turbidity were filtered.

(4) Hardness calculated by R&M personnel.

2-12-7

s3/u26

TABLE 2.5

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: R&M CONSULTANTS, INC.
Station: GOLD CREEK 1980 - 1982
Elevation: 676.5 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Field Parameters (1)					
Dissolved Oxygen	12.8/14.1/11.5	8.6/13.3/11.2	11.2/13.8/11.4	10/3/2	10/3/2
Percent Saturation	110/101/102	81/100/101	101/101/102	9/3/2	9/3/2
pH, pH Units	7.8/7.8/6.7	6.8/7.1/6.4	7.3/7.4/6.5	8/3/2	8/3/2
Conductivity, umhos/cm @ 25°C	183/249/106	75/84/105	128/179/106	15/5/2	15/5/2
Temperature, °C	12.8/0.8/10.5	6.8/0.0/10.3	9.8/0.2/10.4	15/5/2	15/5/2
Free Carbon Dioxide (2)	8.6/20/-	2.1/3.2/-	4.4/10.7/-	5/3/0	5/3/0
Alkalinity, as $CaCO_3$	64/74/-	25/46/-	44/65/-	5/3/0	5/3/0
Settleable Solids, ml/l	0.6/-/-	0.1/-/-	0.4/-/-	7/3/2	7/3/2
Laboratory Parameters (1)(3)					
Ammonia Nitrogen	.21/.52/.08	.02/.32/.08	.09/.42/.08	11/2/1	14/4/2
Organic Nitrogen	.74/.81/.34	.05/.34/.27	.49/.54/.31	10/3/2	10/3/2
Kjeldahl Nitrogen	4.8/.99/.35	.06/.66/.34	.87/.82/.35	11/3/2	14/5/2
Nitrate Nitrogen	.86/.34/-	.14/.12/-	.32/.21/-	10/3/0	16/5/2
Nitrite Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	14/4/2
Total Nitrogen	5.66/1.34/0.35	.35/.66/.34	1.22/1.00/.35	11/4/2	11/4/2
Ortho-Phosphate	.10/.02/-	.01/.02/-	.04/.02/-	3/1/0	16/3/2
Total Phosphorus	.43/.02/.08	.01/.01/.08	.12/.02/.08	10/2/1	16/5/2

8-21-2

s3/u21

TABLE 2.5 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: R&M CONSULTANTS, INC.
Station: GOLD CREEK 1980 - 1982
Elevation: 676.5 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Laboratory Parameters (1) (3) (Continued)					
Alkalinity, as $CaCO_3$	36/57/-	28/57/-	32/57/-	2/1/0	2/1/0
Chemical Oxygen Demand	24/16/12	1.3/2/8	10.9/8.4/10	14/5/2	16/5/2
Chloride	14/29/10	4/9/6	7.3/19/8	10/5/2	12/5/2
Conductivity, umhos/cm @ 25°C	37/165/-	37/165/-	37/165/-	2/1/0	2/1/0
True Color, Color Units	110/40/15	5/10/10	50/20/10	7/3/2	7/3/2
Hardness, as $CaCO_3$(4)	97/121/43	31/67/43	50/87/43	11/5/2	11/5/2
Sulfate	14.8/17/6	1.0/9.5/5	6.7/13.6/5.5	16/5/2	16/5/2
Total Dissolved Solids	103/188/90	63/100/87	86/135/89	16/5/2	16/5/2
Total Suspended Solids	1255/8/56	56/1/49	268/6/53	16/5/2	16/5/2
Turbidity, NTU	728/1.2/19	14/0.3/15	199/0.8/17	22/3/2	22/3/2
Uranium	-/-/-	-/-/-	-/-/-	0/0/0	4/2/0
Radioactivity, Gross Alpha, pCi/l	5.5/2.0/-	2.6/2.0/-	4.1/2.0/-	2/1/0	2/1/0
Total Organic Carbon	3.8/1.0/-	1.4/1.0/-	23/1.0/-	8/1/0	8/1/0
Total Inorganic Carbon	12/4/-	8.6/4/-	10.5/4/-	8/1/0	8/1/0
Organic Chemicals					
Endrin	-/-/-	-/-/-	-/-/-	0/0/0	3/1/0
Lindane	-/-/-	-/-/-	-/-/-	0/0/0	3/1/0

6-12-9

TABLE 2.5 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: R&M CONSULTANTS, INC.
Station: GOLD CREEK 1980 - 1982
Elevation: 676.5 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Laboratory Parameters (1) (3) (Continued)					
Methoxychlor	-/-/-	-/-/-	-/-/-	0/0/0	3/1/0
Toxaphene	-/-/-	-/-/-	-/-/-	0/0/0	3/1/0
2, 4-D	-/-/-	-/-/-	-/-/-	0/0/0	3/1/0
2, 4, 5-TP Silvex	-/-/-	-/-/-	-/-/-	0/0/0	3/1/0
Elements (Dissolved)					
Ag, Silver	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Al, Aluminum	.70/.18/-	.08/.18/-	.39/.18/-	2/1/0	6/3/2
As, Arsenic	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Au, Gold	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
B, Boron	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Ba, Barium	.11/.05/.07	.06/.05/.05	.09/.05/.06	7/1/2	7/3/2
Bi, Bismuth	.19/.07/-	.19/.07/-	.19/.07/-	1/1/0	7/3/2
Ca, Calcium	33.5/34.4/14	10/21/14	16.0/26.5/14	12/5/2	12/5/2
Cd, Cadmium	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Co, Cobalt	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Cr, Chromium	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Cu, Copper	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Fe, Iron	2.3/.35/.07	.07/.35/.07	.77/.35/.07	6/1/1	7/3/2
Hg, Mercury	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2

s3/u29

TABLE 2.5 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: R&M CONSULTANTS, INC.
Station: GOLD CREEK 1980 - 1982
Elevation: 676.5

Laboratory Parameters (1) (3) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
K, Potassium	2.0/2.7/1.9	0.9/1.2/1.8	1.6/2.1/1.9	12/4/2	12/4/2
Mg, Magnesium	3.1/10.0/2.0	1.2/3.2/2.0	2.2/4.9/2.0	12/5/2	12/5/2
Mn, Manganese	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Mo, Molybdenum	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Na, Sodium	10.2/21.1/4.1	2.8/7.4/3.9	5.1/11.7/4.0	12/5/2	12/5/2
Ni, Nickel	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Pb, Lead	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Pt, Platinum	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Sb, Antimony	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Se, Selenium	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Si, Silicon	5.9/5.0/2.5	2.6/3.9/2.4	3.5/4.4/2.5	7/3/2	7/3/2
Sn, Tin	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Sr, Strontium	.09/.19/.07	.06/.10/.06	.07/.13/.07	4/3/2	7/3/2
Ti, Titanium	.14/-/-	.11/-/-	.13/-/-	2/0/0	7/3/2
W, Tungsten	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
V, Vanadium	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Zn, Zinc	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2
Zr, Zirconium	-/-/-	-/-/-	-/-/-	0/0/0	7/3/2

11-21-2

(1) Table values are mg/l unless noted otherwise.

(2) All values for free CO2 determined from nomograph on p. 297 of Standard Method, 14th edition.

(3) Samples for all parameters except chemical oxygen demand, dissolved and suspended solids, and turbidity were filtered.

(4) Hardness calculated by R&M personnel.

2-12-12

TABLE 2.6

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: NR. DENALI 1957 - 1982
Elevation: 2440 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Field Parameters (1)					
Dissolved Oxygen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Percent Saturation	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
pH, pH Units	7.9/7.6/7.2	7.2/7.1/7.2	7.6/7.4/7.2	11/3/1	11/3/1
Conductivity, umhos/cm @ 25°C	226/467/124	121/351/124	161/400/124	18/3/1	18/3/1
Temperature, °C	10.5/0.0/6.5	0.0/0.0/1.5	5.5/0.0/4.0	47/3/6	47/3/6
Free Carbon Dioxide	5.2/25/5.8	1.5/5.5/5.8	3.1/12.9/5.8	11/3/1	11/3/1
Alkalinity, as $CaCO_3$	75/161/47	42/112/47	55/136/47	11/3/1	11/3/1
Settleable Solids, ml/l	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Laboratory Parameters (1)					
Ammonia Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Organic Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Kjeldahl Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Nitrate Nitrogen	.09/.07/.05	0.0/0.0/.05	.03/.04/.05	11/3/1	11/3/1
Nitrite Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ortho-Phosphate	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Phosphorus	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

s3/u23

TABLE 2.6 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S GEOLOGICAL SURVEY
Station: NR. DENALI 1957 - 1982
Elevation: 2440 FT.

Laboratory Parameters (1) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Alkalinity, as $CaCO_3$	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Chemical Oxygen Demand	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Chloride	11/30/4.2	1.5/19/4.2	4.7/23.3/4.2	11/3/1	11/3/1
Conductivity, umhos/cm @ 25°C	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
True Color, Color Units	10/5/30	0/0/30	5/5/30	14/3/1	14/3/1
Hardness, as $CaCO_3$	87/181/50	52/135/50	67/157/50	11/3/1	11/3/1
Sulfate	31/39/9.2	13/36/9.2	17/37/9.2	11/3/1	11/3/1
Total Dissolved Solids	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Suspended Solids (TSS →)	5690/8/1190	85/5/102	1163/7/542	45/2/8	45/2/8
Turbidity, NTU	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Uranium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Radioactivity, Gross Alpha, pCi/l	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Organic Carbon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Inorganic Carbon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Organic Chemicals					
Endrin	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Lindane	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

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s3/u24

TABLE 2.6 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: NR. DENALI 1957 - 1982
Elevation: 2440 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Laboratory Parameters (1)					
(Continued)					
Methoxychlor	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Toxaphene	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
2, 4-D	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
2, 4, 5-TP Silvex	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Elements (Dissolved)					
Ag, Silver	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Al, Aluminum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
As, Arsenic	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Au, Gold	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
B, Boron	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ba, Barium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Bi, Bismuth	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ca, Calcium	29/51/17	17/41/17	21/46/17	11/3/1	11/3/1
Cd, Cadmium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Co, Cobalt	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Cr, Chromium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Cu, Copper	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Fe, Iron	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Hg, Mercury	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

TABLE 2.6 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: NR. DENALI 1957 - 1982
Elevation: 2440 FT.

Laboratory Parameters (1) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
K, Potassium	3.6/6.6/2.3	1.3/6.3/2.3	2.6/6.5/2.3	11/3/1	11/3/1
Mg, Magnesium	6.4/16/1.9	1.7/6.8/1.9	3.5/10.3/1.9	11/3/1	11/3/1
Mn, Manganese	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Mo, Molybdenum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Na, Sodium	10/23/3.6	2.1/15/3.6	4.3/18.7/3.6	11/3/1	11/3/1
Ni, Nickel	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Pb, Lead	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Pt, Platinum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sb, Antimony	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Se, Selenium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Si, Silicon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sn, Tin	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sr, Strontium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ti, Titanium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
W, Tungsten	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
V, Vanadium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Zn, Zinc	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Zr, Zirconium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

1. Table values are mg/l unless noted otherwise.

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TABLE 2.7

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: VEE CANYON 1962 - 1982
Elevation: 1900 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Field Parameters (1)					
Dissolved Oxygen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Percent Saturation	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
pH, pH Units	8.1/-/7.6	7.2/-/7.6	7.7/-/7.6	9/0/1	9/0/1
Conductivity, umhos/cm @ 25°C	187/250/136	91/250/114	146/250/125	20/1/2	20/1/2
Temperature, °C	13.0/0.1/7.0	1.0/-0.1/2.0	7.9/0.0/4.3	49/4/4	49/4/4
Free Carbon Dioxide	6.8/-/2.2	0.7/-/2.2	2.6/-/2.2	9/0/1	9/0/1
Alkalinity, as $CaCO_3$	59/-/44	39/-/44	52/-/44	9/0/1	9/0/1
Settleable Solids, ml/l	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Laboratory Parameters (1)					
Ammonia Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Organic Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Kjeldahl Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Nitrate Nitrogen	.88/-/.16	.00/-/.16	.20/-/.16	9/0/1	9/0/1
Nitrite Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ortho-Phosphate	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Phosphorus	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

TABLE 2.7 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: VEE CANYON 1962 - 1982
Elevation: 1900 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Laboratory Parameters (1) (Continued)					
Alkalinity, as $CaCO_3$	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Chemical Oxygen Demand	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Chloride	9.2/-/7.4	2.1/-/7.4	5.3/-/7.4		9/0/1
Conductivity, umhos/cm @ 25°C	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
True Color, Color Units	40/-/30	5/-/30	10/-/30	8/0/1	8/0/1
Hardness, as $CaCO_3$	76/-/54	42/-/54	63/-/54	9/0/1	9/0/1
Sulfate	18/-/12	7.5/-/12	14/-/12	9/0/1	9/0/1
Total Dissolved Solids	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Suspended Solids (TSS)	2790/14/726	34/14/661	799/14/694	36/1/2	36/1/2
Turbidity, NTU	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Uranium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Radioactivity, Gross Alpha, pCi/l	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Organic Carbon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Inorganic Carbon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Organic Chemicals					
Endrin	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Lindane	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

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TABLE 2.7 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: VEE CANYON 1962 - 1982
Elevation: 1900 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Laboratory Parameters (1) (Continued)					
Methoxychlor	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Toxaphene	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
2, 4-D	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
2, 4, 5-TP Silvex	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Elements (Dissolved)					
Ag, Silver	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Al, Aluminum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
As, Arsenic	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Au, Gold	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
B, Boron	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ba, Barium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Bi, Bismuth	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ca, Calcium	27/-/17	14/-/17	21/-/17	9/0/1	9/0/1
Cd, Cadmium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Co, Cobalt	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Cr, Chromium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Cu, Copper	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Fe, Iron	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Hg, Mercury	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

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s3/u21

TABLE 2.7 - Continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: VEE CANYON 1962 - 1982
Elevation: 1900 FT.

Laboratory Parameters (1) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
K, Potassium	7.3/-/2.8	1.4/-/2.8	3.5/-/2.8	9/0/1	9/0/1
Mg, Magnesium	4.4/-/2.4	1.1/-/2.4	2.7/-/2.4	9/0/1	9/0/1
Mn, Manganese	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Mo, Molybdenum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Na, Sodium	6.3/-/4.8	2.1/-/4.8	3.8/-/4.8	9/0/1	9/0/1
Ni, Nickel	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Pb, Lead	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Pt, Platinum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sb, Antimony	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Se, Selenium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Si, Silicon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sn, Tin	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sr, Strontium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ti, Titanium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
W, Tungsten	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
V, Vanadium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Zn, Zinc	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Zr, Zirconium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

1. Table values are mg/l unless noted otherwise.

s3/u1

TABLE 2.6

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: GOLD CREEK 1949 - 1982
Elevation: 676.5 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Field Parameters (1)					
Dissolved Oxygen	13.3/15.8/14.1	9.5/11.0/14.1	11.9/13.9/14.1	9/5/1	9/5/1
Percent Saturation	110/110/111	83/77/111	102/97/111	6/5/1	6/5/1
pH, pH Units	7.9/8.1/8.0	6.5/7.0/6.5	7.3/7.5/7.0	66/31/7	66/31/7
Conductivity, umhos/cm @ 25°C	227/300/147	90/164/70	147/250/97	66/32/7	66/32/7
Temperature, °C	14.0/0.5/6.0	0.4/0.0/1.0	9.2/0.1/3.1	39/12/8	39/12/8
Free Carbon Dioxide	20/16/24	1.1/1.2/2.9	5.8/6.2/10.8	57/26/6	57/26/6
Alkalinity, as $CaCO_3$	87/88/47	23/49/25	51/72/33	62/30/7	62/30/7
Settleable Solids, ml/l	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Laboratory Parameters (1)					
Ammonia Nitrogen	.33/.08/.13	.01/.03/.13	.16/.06/.13	7/5/1	7/6/1
Organic Nitrogen	.39/.44/.07	.10/.18/.07	.27/.29/.07	7/5/1	7/5/1
Kjeldahl Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Nitrate Nitrogen	.36/.32/.69	.02/.05/.05	.12/.16/.24	55/25/7	55/25/7
Nitrite Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Nitrogen	.60/.66/-	.25/.44/-	.50/.51/-	5/6/0	5/6/0
Ortho-Phosphate	.03/.03/.04	.00/.01/.04	.01/.02/.04	11/4/1	12/4/1
Total Phosphorus	.23/.05/.09	.02/.01/.09	.13/.03/.09	7/6/1	7/6/1

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TABLE 2.8 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: GOLD CREEK 1949 - 1982
Elevation: 676.5 FT.

Summer/Winter/Break-Up (1 2 3)

Laboratory Parameters (1) (Continued)	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Alkalinity, as $CaCO_3$	45/85/27	35/82/27	40/83/27	5/3/1	5/3/1
Chemical Oxygen Demand	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Chloride	15/35/7.6	1.4/6.2/1.8	5.5/22/4.4	62/28/7	62/28/7
Conductivity, umhos/cm @ 25°C	142/289/115	114/266/84	128/279/100	5/6/2	5/6/2
True Color, Color Units	45/10/50	0/0/5	10/5/25	55/22/6	55/22/6
Hardness, as $CaCO_3$	107/120/56	35/60/30	64/98/39	62/28/7	62/28/7
Sulfate	31/38/11	1.0/12/5.0	16.1/21/7.6	61/28/6	62/28/7
Total Dissolved Solids	140/174/90	55/133/53	93/154/66	43/18/6	43/18/6
Total Suspended Solids	2620/76/1330	7/1/120	740/12/621	56/10/13	56/11/13
Turbidity, NTU	180/.70/29	42/.10/29	126/.40/29	5/2/1	5/2/1
Uranium	.33/-/-	.12/-/-	.25/-/-	3/0/0	3/0/0
Radioactivity, Gross Alpha, pCi/l	1.8/-/-	0.5/-/-	1.3/-/-	3/0/0	3/0/0
Total Organic Carbon	2.6/5.5/10.0	1.4/1.1/1.8	2.0/2.6/5.9	2/3/2	2/3/2
Total Inorganic Carbon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Organic Chemicals					
Endrin	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Lindane	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

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s3/a1

TABLE 2.8 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: GOLD CREEK 1949 - 1982
Elevation: 676.5 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Laboratory Parameters (1)					
(Continued)					
Methoxychlor	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Toxaphene	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
2, 4-D	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
2, 4, 5-TP Silvex	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Elements (Dissolved)					
Ag, Silver	.000/.001/-	.000/.001/-	.000/.001/-	2/1/0	3/1/0
Al, Aluminum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
As, Arsenic	.002/.002/-	.001/.002/-	.001/.002/-	3/1/0	3/1/0
Au, Gold	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
B, Boron	-/-/-	-/-/-	-/-/-	0/0/-	0/0/0
Ba, Barium	.031/.060/-	.000/.060/-	.010/.060/-	3/1/0	3/1/0
Bi, Bismuth	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ca, Calcium	37/39/18	11/24/9.9	20/30/13	62/28/7	62/28/7
Cd, Cadmium.	.001/-/-	.001/-/-	.001/-/-	2/0/0	3/1/0
Co, Cobalt	.000/.001/-	.000/.001/-	.000/.001/-	1/1/0	3/1//0
Cr, Chromium	.010/-/-	.000/-/-	.005/-/-	2/0/0	3/1/0
Cu, Copper	.005/.001/-	.003/.001/-	.004/.001/-	3/1/0	3/1/0
Fe, Iron	.14/.015/-	.04/.015/-	.10/.015/-	6/1/0	6/1/0
Hg, Mercury	.0002/-/-	.0000/-/-	.0001/-/-	2/0/0	3/1/0

TABLE 2.8 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: GOLD CREEK 1949 - 1982
Elevation: 676.5 FT.

Laboratory Parameters (1) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
K, Potassium	4.4/5.0/1.7	1.0/1.2/1.2	2.4/2.3/1.4	52/22/5	52/22/5
Mg, Magnesium	7.8/8.3/2.8	1.2/3.6/0.3	3.2/5.4/1.7	62/28/7	62/28/7
Mn, Manganese	.18/.003/-	.00/.003/-	.036/.003/-	7/1/0	7/1/0
Mo, Molybdenum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Na, Sodium	6.5/17/3.8	2.4/5.2/2.8	4.1/11.3/3.1	52/22/5	52/22/5
Ni, Nickel	.000/.001/-	.000/.001/-	.000/.001/-	2/1/0	3/1/0
Pb, Lead	.001/.003/-	.000/.003/-	.000/.003/-	3/1/0	3/1/0
Pt, Platinum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sb, Antimony	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Se, Selenium	.001/-/-	.000/-/-	.000/-/-	3/0/0	3/1/0
Si, Silicon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sn, Tin	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sr, Strontium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ti, Titanium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
W, Tungsten	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
V, Vanadium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Zn, Zinc	.014/-/-	.006/-/-	.010/-/-	3/0/0	3/1/0
Zr, Zirconium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

s3/u10

TABLE 2.9

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: SUNSHINE 1971 - 1982
Elevation: 270 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Field Parameters (1)					
Dissolved Oxygen	13.3/13.8/-	10.6/13.0/-	12.0/13.4/-	5/3/0	5/3/0
Percent Saturation	107/94/-	99/90/-	103/92/-	2/3/0	2/3/0
pH, pH Units	7.7/7.3/-	7.1/6.2/-	7.4/6.9/-	7/3/0	7/3/0
Conductivity, umhos/cm @ 25°C	170/242/-	61/225/-	115/232/-	9/3/0	9/3/0
Temperature, °C	12.0/0.0/9.2	3.8/0.0/9.2	8.6/0.0/9.2	9/3/1	9/3/1
Free Carbon Dioxide	3.9/-/-	2.1/-/-	3.1/-/-	3/0/0	3/0/0
Alkalinity, as $CaCO_3$	43/71/-	25/63/-	36/68/-	6/2/0	6/2/0
Settleable Solids, ml/l	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Laboratory Parameters (1)					
Ammonia Nitrogen	.37/.06/-	.08/.03/-	.19/.05/-	6/3/0	6/4/0
Organic Nitrogen	1.10/.42/-	.19/.18/-	.63/.29/-	6/3/0	6/3/0
Kjeldahl Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Nitrate Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Nitrite Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Nitrogen	2.30/.72/-	.71/.42/-	1.17/.61/-	5/4/0	5/4/0
Ortho-Phosphate	.04/.04/-	.00/.04/-	.02/.04/-	3/1/0	3/1/0
Total Phosphorus	.33/.01/-	.05/.01/-	.15/.01/-	6/2/0	6/4/0

S2-21-2

s3/u11

TABLE 2.9 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: SUNSHINE 1971 - 1982
Elevation: 270 FT.

Laboratory Parameters (1) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Alkalinity, as $CaCO_3$	48/74/-	28/63/-	41/70/-	6/3/0	6/3/0
Chemical Oxygen Demand	-/-/-	-/-/-	---	0/0/0	0/0/0
Chloride	7.3/21/-	2.2/16/-	3.7/18/-	9/4/0	9/4/0
Conductivity, umhos/cm @ 25°C	129/233/-	82/222/-	115/229/-	6/3/0	6/3/0
True Color, Color Units	100/0/-	8/0/-	44/0/-	3/1/0	3/1/0
Hardness, as $CaCO_3$	72/96/-	33/87/-	50/91/-	9/4/0	9/4/0
Sulfate	13/18/-	3/16/-	10/17/-	9/4/0	9/4/0
Total Dissolved Solids	101/141/-	54/130/-	70/134/-	8/4/0	8/4/0
Total Suspended Solids	3510/2/508	288/1/508	1485/2/508	5/2/1	5/2/1
Turbidity, NTU	300/1.3/-	160/.20/-	233/.67/-	6/3/0	6/3/0
Uranium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Radioactivity, Cross Alpha, pCi/l	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Organic Carbon	3.2/0.8/-	2.9/0.4/-	3.0/0.6/-	2/2/0	2/2/0
Total Inorganic Carbon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Organic Chemicals					
Endrin	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Lindane	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

22-21-2

s3/u12

TABLE 2.9 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: SUNSHINE 1971 - 1982
Elevation: 270 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Laboratory Parameters (1)					
(Continued)					
Methoxychlor	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Toxaphene	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
2, 4-D	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
2, 4, 5-TP Silvex	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Elements (Dissolved)					
Ag, Silver	.000/.000/-	.000/.000/-	.000/.000/-	2/1/0	3/1/0
Al, Aluminum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
As, Arsenic	.003/.001/-	.002/.001/-	.002/.001/-	3/1/0	3/1/0
Au, Gold	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
B, Boron	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ba, Barium	.070/.040/-	.000/.040/-	.032/.040/-	3/1/0	3/1/0
Bi, Bismuth	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ca, Calcium	23/31/-	11/28/-	16/29/-	9/4/0	9/4/0
Cd, Cadmium.	.000/-/-	.000/-/-	.000/-/-	1/0/0	3/1/0
Co, Cobalt	.000/-/-	.000/-/-	.000/-/-	1/0/0	3/1/0
Cr, Chromium	.020/.010/-	.000/.010/-	.010/.010/-	3/1/0	3/1/0
Cu, Copper	.005/.004/-	.003/.004/-	.004/.004/-	3/1/0	3/1/0
Fe, Iron	.250/.040/-	.060/.010/-	.180/.025/-	5/2/0	5/2/0
Hg, Mercury	.0001/.0001/-	.0000/.0001/-	.0001/.0001/-	2/1/0	3/1/0

TABLE 2.9 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: US. GEOLOGICAL SURVEY
Station: SUNSHINE 1971 - 1982
Elevation: 270 FT.

Laboratory Parameters (1) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
K, Potassium	2.8/2.1/-	1.1/1.8/-	1.5/1.9/-	9/4/0	9/4/0
Mg, Magnesium	3.5/4.5/-	1.4/4.1/-	2.3/4.3/-	9/4/0	9/4/0
Mn, Manganese	.020/.004/-	.000/.000/-	.009/.002/-	5/2/0	5/2/0
Mo, Molybdenum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Na, Sodium	4.4/11/-	1.9/10/-	2.8/11/-	9/4/0	9/4/0
Ni, Nickel	.002/.002/-	.000/.002/-	.001/.002/-	3/1/0	3/1/0
Pb, Lead	.001/.008/-	.000/.008/-	.000/.008/-	3/1/0	3/1/0
Pt, Platinum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sb, Antimony	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Se, Selenium	.000/.000/-	.000/.000/-	.000/.000/-	2/1/0	3/1/0
Si, Silicon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sn, Tin	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sr, Strontium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ti, Titanium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
W, Tungsten	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
V, Vanadium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Zn, Zinc	.020/.030/-	.006/.030/-	.012/.030/-	3/1/0	3/1/0
Zr, Zirconium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

82-21-2

0 0 1 1 6

TABLE 2.10

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: SUSITNA 1955 - 1982
Elevation: 40 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Field Parameters (1)					
Dissolved Oxygen	12.8/13.5/12.4	10.5/10.6/11.4	11.5/11.6/12.1	13/14/4	13/14/4
Percent Saturation	100/94/99	90/74/97	97/80/98	9/7/2	9/7/2
pH, pH Units	8.3/7.9/7.8	7.0/6.8/6.5	7.7/7.3/7.2	26/20/7	26/20/7
Conductivity, umhos/cm @ 25°C	160/225/116	90/182/85	122/205/93	27/22/7	27/22/7
Temperature, °C	12.5/0.5/7.0	2.0/0.0/3.4	8.4/0.04/5.8	25/22/7	25/22/7
Free Carbon Dioxide	8/17/19	0.6/1.8/1.1	2.5/7.8/6.5	15/15/5	15/15/5
Alkalinity, as $CaCO_3$	57/75/39	36/60/30	44/69/34	21/19/6	21/19/6
Settleable Solids, ml/l	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Laboratory Parameters (1)					
Ammonia Nitrogen	.19/.09/.21	.00/.00/.01	.04/.04/.08	12/10/3	12/10/3
Organic Nitrogen	1.5/.46/.70	.16/.00/.16	.60/.27/.43	12/9/2	12/9/2
Kjeldahl Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Nitrate Nitrogen	.00/.19/-	.00/.19/-	.00/.19/0	1/1/0	1/1/0
Nitrite Nitrogen	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Nitrogen	1.70/.99/1.20	.26/.24/.67	.72/.55/.92	22/17/4	22/17/4
Ortho-Phosphate	.02/-/.02	.02/-/.02	.02/-/.02	1/0/1	1/2/1
Total Phosphorus	1.10/.38/.29	.03/.00/.01	.40/.05/.14	23/20/7	23/20/7

82-21-2

TABLE 2.10 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: SUSITNA 1955 - 1962
Elevation: 40 FT.

Laboratory Parameters (1) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Alkalinity, as $CaCO_3$	49/76/34	46/63/27	47/71/30	3/4/2	3/4/2
Chemical Oxygen Demand	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Chloride	6.7/18/4.6	1.2/5.7/3.1	2.7/13/3.7	24/21/7	24/21/7
Conductivity, umhos/cm @ 25°C	133/222/104	114/208/94	122/217/99	4/4/2	4/4/2
True Color, Color Units	10/0/-	10/0/-	10/0/-	2/2/0	4/4/0
Hardness, as $CaCO_3$	66/96/48	44/73/36	54/85/39	25/21/7	25/21/7
Sulfate	20.7/20/10	1.0/15/3.7	13.2/17.3/6.7	25/21/7	25/21/7
Total Dissolved Solids	114/139/71	56/109/51	73/123/65	24/20/7	24/20/7
Total Suspended Solids	2367/12/683	158/2/257	745/5/461	21/19/5	21/19/5
Turbidity, NTU	790/3.0/160	21/1.0/25	233/1.5/69	18/13/5	18/13/5
Uranium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Radioactivity, Gross Alpha, pCi/l	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Total Organic Carbon	11.0/4.0/9.1	2.7/0.4/3.8	4.4/1.6/6.0	7/9/4	7/9/4
Total Inorganic Carbon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Organic Chemicals					
Endrin	-/-/-	-/-/-	-/-/-	0/0/0	7/10/4
Lindane	-/-/-	-/-/-	-/-/-	0/0/0	7/10/4

ug/l

s3/ub

TABLE 2.10 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: SUSITNA 1955 - 1982
Elevation: 40 FT.

	Summer/Winter/Break-Up				
	Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
Laboratory Parameters (1)					
(Continued)					
Methoxychlor	-/-/-	-/-/-	-/-/-	0/0/0	7/10/4
Toxaphene	-/-/-	-/-/-	-/-/-	0/0/0	7/9/4
2, 4-D	-/-/-	-/-/-	-/-/-	0/0/0	2/6/2
2, 4, 5-TP Silvex	-/-/-	-/-/-	-/-/-	0/0/0	2/6/2
Elements (Dissolved)					
Ag, Silver	.000/.000/-	.000/.000/-	.000/.000/-	4/2/0	8/6/3
Al, Aluminum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
As, Arsenic	.003/.003/.001	.001/.000/.001	.002/.001/.001	13/8/3	13/9/6
Au, Gold	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
B, Boron	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ba, Barium	.200/.040/.020	.027/.040/.020	.068/.040/.020	7/4/1	8/6/3
Bi, Bismuth	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ca, Calcium	22/31/15	14/23/11	17/27/13	25/21/7	25/21/7
Cd, Cadmium	.001/-/-	.001/-/-	.001/-/-	1/0/0	13/9/6
Co, Cobalt	.007/.002/.001	.001/.002.001	.003/.002/.001	5/1/1	13/9/6
Cr, Chromium	.030/.010/.005	.000/.000/.005	.010/.005/.005	5/2/1	13/9/5
Cu, Copper	.007/.004/.006	.003/.000/.004	.004/.002/.005	7/7/4	13/9/6
Fe, Iron	.460/.060/.190	.020/.060/.110	.096/.088/.152	12/9/6	13/9/6
Hg, Mercury	.0002/.0000/-	.0000/.0000/-	.0001/.0000/-	5/2/0	13/9/6

13-21-2

TABLE 2.10 - continued

WATER QUALITY DATA SUMMARY
SUSITNA RIVER

Agency: U.S. GEOLOGICAL SURVEY
Station: SUSITNA 1955 - 1982
Elevation: 40 FT.

Laboratory Parameters (1) (Continued)	Summer/Winter/Break-Up Maximum	Minimum	Mean	Number of Detectable Values	Total Number of Observations
K, Potassium	1.8/2.5/1.4	1.0/1.4/0.8	1.4/1.7/1.0	25/21/7	25/21/7
Mg, Magnesium	3.7/4.9/2.6	2.0/3.7/1.6	2.5/4.3/1.9	25/21/7	25/21/7
Mn, Manganese	.020/.030/.011	.004/.017/.008	.008/.023/.010	7/8/2	13/9/6
Mo, Molybdenum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Na, Sodium	4.0/9.0/3.2	1.8/4.9/2.4	2.7/7.7/2.9	25/21/7	25/21/7
Ni, Nickel	.004/.003/.002	.000/.002/.002	.001/.002/.002	5/2/1	5/3/1
Pb, Lead	.009/.004/.011	.002/.000.003	.004/.002/.006	8/6/4	13/9/6
Pt, Platinum	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sb, Antimony	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Se, Selenium	.001/.001/-	.000/.000/-	.0004/.0008/-	7/6/0	13/9/6
Si, Silicon	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sn, Tin	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Sr, Strontium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Ti, Titanium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
W, Tungsten	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
V, Vanadium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0
Zn, Zinc	.020/.003/.020	.004/.003/.020	.008/.003/.020	5/1/2	13/9/6
Zr, Zirconium	-/-/-	-/-/-	-/-/-	0/0/0	0/0/0

0 0 1 1 6

3 of 3

HARZA-EBASCO
Susitna Joint Venture
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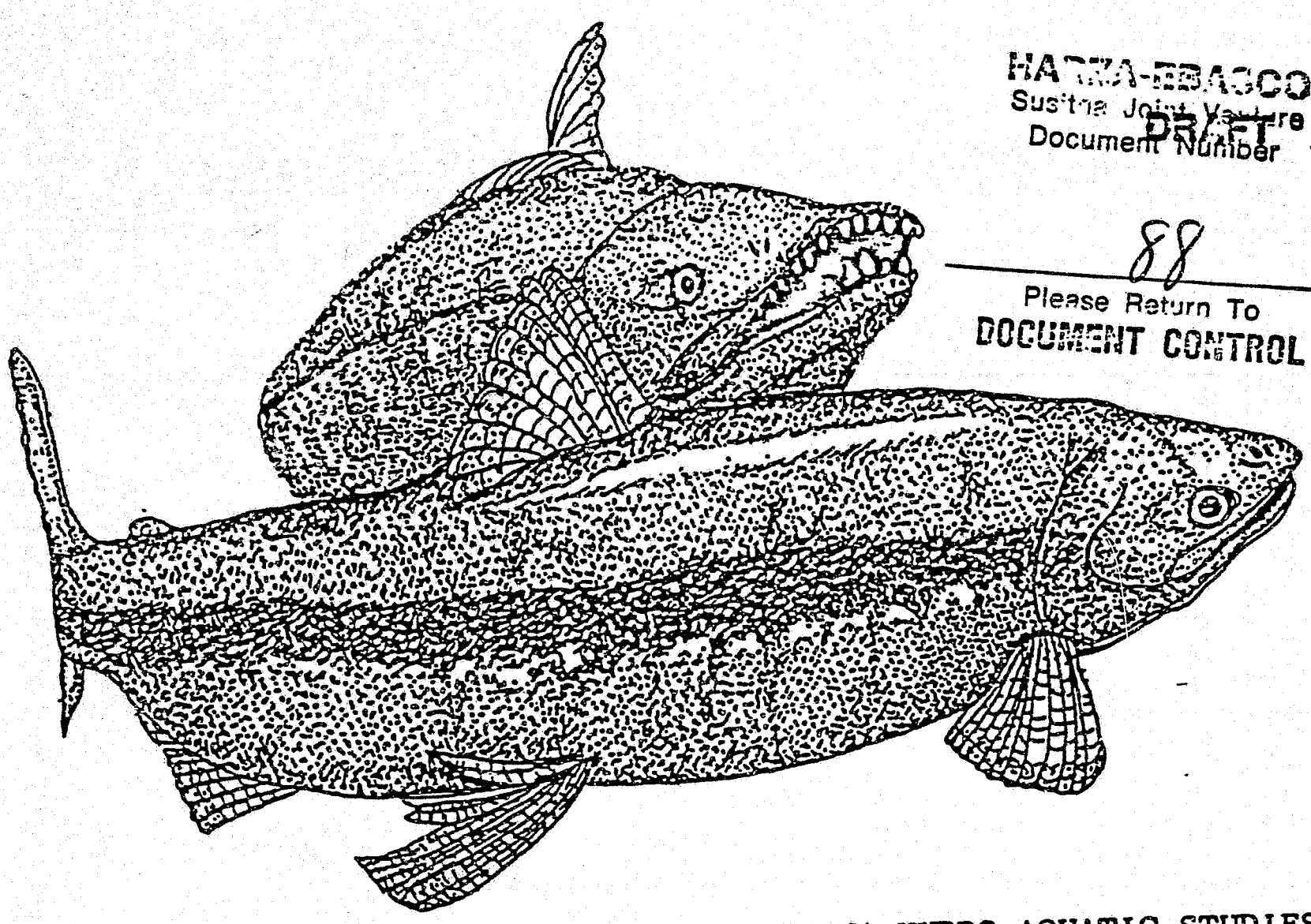

SUSITNA HYDRO AQUATIC STUDIES
PHASE II BASIC DATA REPORT

Volume 4. Aquatic Habitat and Instream Flow Studies, 1982.

Appendices D - J

-by-

ALASKA DEPARTMENT OF FISH AND GAME
Susitna Hydro Aquatic Studies
2207 Spenard Road
Anchorage, Alaska 99503
1983

2-12-33

Appendix Table 4-D-6. Summary of provisional water quality data for sloughs 8A, 9, 16B, 19, 21, and mainstem Susitna River at Gold Creek, collected by ADF&G and USGS in June, July, and September, 1981, and in January and February, 1982.

Parameter	Date[a]	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Physical and Field Parameters[b]							
*Water Temperature °C	June	15.5	14.2	14.0	5.5	10.7	12.4
	July	11.2	10.9	9.0	9.8	11.3	10.5
	September	3.5	5.6	4.8	1.8	2.4	0.4
	January	0.5	0.5	1.5	2.0	1.5	0.0
	March	0.5	0.5	2.0	1.0	1.5	0.0
Air Temperature °C	June	21.0	20.1	---	---	23.0	---
	July	16.0	14.0	15.5	---	---	---
	September	8.0	7.5	---	3.0	---	---
	January	---	---	---	---	---	--
	March	---	---	---	---	-11.0	---
Streamflow (discharge) cfs	June	6.4	2.9	0.7	0.2	3.2	1,780.0
	July	551.0	714.0	503.0	0.0	142.0	42,500.0
	September	2.8	1.5	0.3	<0.1	0.43	8,540.0
	January	---	---	---	---	---	---
	March	---	---	---	---	---	1,520.0
*Specific Conductance (field) umho^3/cm	June	140	145	71	146	226	---
	July	117	124	72	127	130	119
	September	135	113	64	150	205	172
	January	193	121	59	148	221	260
	March	142	143	59	129	196	266

[a]Sloughs and mainstem Susitna River were sampled on 2 or 3 consecutive days in each month (except January) as follows.

	8A	9	16B	19	21	Susitna River at Gold Creek
June	25	24	23	23	24	23
July	21	21	22	22	22	21
September	30	30	28	29	29	28
January	20	20	20	20	20	20
March	31	30	30	30	30	30

[b]Parameters marked with an * are averages of transect point measurements (see methods).

--- indicates data not available.

Appendix Table 4-D-6 (Continued).

Parameter	Date	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Physical and Field Parameters - Cont'd							
Specific Conductance (lab) umho^5/cm	June	153	158	70	146	226	141
	July	118	124	71	129	131	114
	September	132	113	64	130	205	170
	January	193	121	59	148	221	260
	March	142	143	59	129	196	266
*Dissolved Oxygen mg/1	June	10.8	10.6	10.8	9.4	10.7	10.8
	July	11.4	11.4	11.7	10.4	11.3	11.7
	September	12.1	11.3	11.5	9.5	10.3	---
	January	7.0	11.7	6.6	7.7	9.0	15.8
	March	10.2	10.9	7.3	9.6	9.8	14.2
*Dissolved Oxygen (%) saturation	June	108	103	107	76	90	104
	July	104	105	102	90	105	104
	September	94	93	88	98	76	---
	January	49	82	47	57	65	110
	March	72	77	59	70	72	99
*pH (field)	June	6.9	6.8	6.4	6.5	7.0	7.4
	July	---	---	---	---	---	7.7
	September	7.6	7.4	7.1	7.3	7.7	6.5
	January	6.5	6.6	6.0	6.0	6.7	7.5
	March	6.6	7.0	6.4	6.5	7.4	6.7
pH (lab)	June	7.4	7.5	7.2	7.2	7.6	7.5
	July	7.6	7.7	7.3	7.0	7.7	7.7
	September	7.4	6.7	6.6	7.2	7.0	7.2
	January	7.2	7.3	6.9	7.1	7.6	7.6
	March	7.2	7.1	7.1	7.2	7.3	7.5
Alkalinity (field) mg/1 $CaCO_3$	June	---	39	24	50	62	---
	July	41	39	24	52	47	35
	September	43	34	26	62	62	---
	January	62	34	24	39	62	82
	March	43	39	23	46	61	78

4-D-71

33-2-2

Appendix Table 4-D-6 (Continued).

Parameter	Date	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Physical and Field Parameters - Cont'd							
Alkalinity (lab) mg/l $CaCO_3$	June	47	33	24	52	63	45
	July	41	39	24	52	47	35
	September	42	36	26	62	61	44
	January	64	36	30	53	63	83
	March	46	42	27	50	64	82
Turbidity NTU	June	0.9	0.6	0.5	0.4	0.4	100.0
	July	130.0	130.0	43.0	2.5	150.0	170.0
	September	1.1	0.6	0.6	0.5	0.5	5.5
	January	0.4	0.5	0.5	0.3	0.5	0.7
	March	0.1	0.1	0.1	0.1	0.1	0.1
Sediments, suspended mg/l	June	1	2	1	1	5	327
	July	220	417	107	8	356	680
	September	1	1	1	2	4	44
	January	1	2	0	1	0	2
	March	7	3	6	1	6	8
Sediments, discharge suspended tons/day	June	0.02	0.02	0.0	0.0	0.04	1,570.0
	July	327.0	804.0	145.0	0.0	136.0	78,000.0
	September	0.01	0.0	0.0	0.0	0.0	1,020.0
	January	---	---	---	---	---	---
	March	---	---	---	---	---	33.0
Solids, residue at 180°C mg/l	June	88	100	51	94	137	79
	July	70	75	41	81	78	74
	September	82	69	42	95	119	101
	January	111	73	38	78	114	152
	March	92	93	42	80	124	160
Solids, sum of constituents mg/l	June	93	91	47	90	130	83
	July	61	68	43	89	68	65
	September	71	71	48	94	120	80
	January	120	76	---	92	130	165
	March	86	83	43	65	127	160

Appendix Table 4-D-6 (Continued).

Parameter	Date	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Physical and Field Parameters - Cont'd							
Solids, dissolved. tons/day	June	1.5	0.8	0.1	0.1	1.1	380.0
	July	104.0	145.0	55.7	0.0	29.9	8,490.0
	September	0.62	0.3	<0.1	<0.1	0.1	2,330.0
	January	---	---	---	---	---	---
	March	---	---	---	---	---	657.0
Solids, dissolved tons/acre-foot	June	0.12	0.14	0.07	0.13	0.19	0.11
	July	0.10	0.10	0.06	0.11	0.11	0.10
	September	0.11	0.09	0.06	0.13	0.16	0.14
	January	0.15	0.10	0.05	0.11	0.16	0.21
	March	0.13	0.13	0.06	0.11	0.17	0.22
Suspended sediment (%) less than 0.062 mm sieve diameter	June	---	---	---	---	---	70
	July	89	55	56	---	85	49
	September	---	---	---	---	---	81
	January	---	---	---	---	---	---
	March	---	---	---	---	---	---
Major Constituents							
Hardness mg/a $CaCO_3$	June	57	56	32	69	83	57
	July	48	50	30	61	54	51
	September	54	45	30	72	77	60
	January	79	47	34	67	87	120
	March	60	52	26	58	82	100
Hardness, non-carbonate mg/l $CaCO_3$	June	10.0	17.0	8.0	19.0	21.0	12
	July	7.0	11.0	6.0	9.0	7.0	16
	September	11.0	11.0	4.0	10.0	15.0	16
	January	17.0	13.0	10.0	14.0	25.0	33
	March	15.0	13.0	3.0	12.0	21.0	19
Bicarbonate, incremental titration mg/l $CaCO_3$	June	---	---	---	---	---	---
	July	---	---	---	---	---	---
	September	53	42	32	75	75	---
	January	---	---	---	---	---	---
	March	---	---	---	---	---	---

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Appendix Table 4-D-6 (Continued).

Parameter	Date	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Major Constituents - Cont'd							
Carbonate, incremental titration mg/l $CaCO_3$	June	---	---	---	---	---	---
	July	---	---	---	---	---	---
	September	0	0	0	0	0	---
	January	---	---	---	---	---	---
	March	---	---	---	---	---	---
Calcium, dissolved mg/l Ca	June	18	18	10	23	27	19
	July	16	17	10	20	18	16
	September	17	14	9	24	25	15
	January	26	15	11	22	29	39
	March	19	17	8	19	27	33
Magnesium, dissolved mg/l Mg	June	2.8	2.7	1.6	3.7	3.9	2.2
	July	1.9	1.9	1.3	2.6	2.1	1.7
	September	2.8	2.4	1.6	3.0	3.5	1.9
	January	3.4	2.3	1.6	3.0	3.5	4.6
	March	3.1	2.4	1.5	2.6	3.6	4.5
Sodium, dissolved mg/l Na	June	6.8	8.2	2.5	2.5	12.0	4.2
	July	3.0	3.0	1.8	1.8	3.4	3.4
	September	6.1	5.6	2.6	3.0	11.0	7.4
	January	11.0	5.7	2.9	4.3	12.0	15.0
	March	6.2	7.2	2.1	2.2	11.0	17.0
Sodium, (%)	June	20	24	14	7	23	14
	July	12	11	11	6	12	13
	September	19	21	15	8	23	21
	January	23	20	15	12	23	22
	March	18	23	14	7	22	26
Sodium, adsorption ratio	June	0.4	0.5	0.2	0.1	0.6	0.3
	July	0.2	0.2	0.1	0.1	0.2	0.2
	September	0.4	0.4	0.2	0.2	0.5	0.4
	January	0.5	0.4	0.2	0.2	0.6	0.6
	March	0.4	0.5	0.2	0.1	0.5	0.8

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2-12-38

Appendix Table 4-D-6 (Continued).

Parameter	Date	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Nutrients - Cont'd							
Nitrogen, total mg/l NO_3	June	8.5	8.4	4.1	10.0	4.2	2.4
	July	3.4	3.5	3.3	9.3	2.9	2.3
	September	7.4	7.3	2.9	9.0	4.9	2.7
	January	5.8	7.9	2.9	7.0	4.2	1.9
	March	5.7	6.4	3.3	7.6	4.3	1.9
Nitrogen, dissolved mg/l N	June	1.8	1.6	1.0	2.0	1.0	0.5
	July	---	0.7	---	2.2	0.7	0.6
	September	1.5	1.7	0.6	1.9	1.0	0.6
	January	1.3	1.6	0.6	1.2	0.9	0.4
	March	1.2	1.2	0.6	1.5	0.8	0.4
Nitrogen, total organic mg/l N	June	0.53	0.82	0.50	0.88	0.37	0.34
	July	0.40	0.54	0.31	0.45	0.44	0.10
	September	---	0.41	0.17	0.44	0.18	0.28
	January	---	---	0.18	0.50	---	0.18
	March	0.24	0.41	---	0.43	0.30	0.21
Nitrogen, dissolved organic mg/l N	June	0.45	0.51	0.55	0.62	0.49	0.34
	July	0.44	0.48	---	0.41	0.43	0.21
	September	0.36	0.44	0.10	0.49	0.19	0.34
	January	0.22	0.39	0.15	0.14	0.20	0.15
	March	0.20	0.16	---	0.22	---	0.19
[illegible]	June	0.07	0.11	0.10	0.10	0.09	0.08
	July	0.10	0.13	0.13	0.32	0.14	0.24
	September	0.15	0.14	0.16	0.13	0.11	0.09
	January	0.15	0.08	0.09	0.08	0.08	0.09
	March	0.07	0.07	<0.06	0.08	<0.06	0.07
[illegible]	June	0.09	0.14	0.13	0.13	0.12	0.10
	July	0.13	0.17	0.17	0.41	0.18	0.31
	September	0.19	0.18	0.21	0.17	0.14	0.12
	January	0.19	0.10	0.12	0.10	0.10	0.12
	March	0.09	0.09	0.08	0.10	0.08	0.09

Appendix Table 4-D-6 (Continued).

Parameter	Date	Slough 8A	Slough 9	Slough 168	Slough 19	Slough 21	Susitna River at Gold Creek
Major Constituents - Cont'd							
Potassium, dissolved mg/l K	June	1.5	1.4	0.9	1.0	2.1	2.0
	July	1.6	1.6	0.9	1.6	1.9	1.6
	September	1.1	0.9	0.9	1.1	2.1	1.5
	January	2.1	1.0	0.8	1.2	2.0	2.1
	March	1.3	1.1	0.8	1.1	2.1	2.2
Chloride, dissolved mg/l Cl	June	9.1	16.0	1.3	0.9	20.0	5.6
	July	2.9	2.9	0.9	0.6	3.7	12.0
	September	7.7	6.9	1.5	0.9	17.0	11.0
	January	14.0	9.6	1.1	3.5	20.0	24.0
	March	10.0	13.0	1.2	1.1	17.0	27.0
Sulfate, dissolved mg/l SO_4	June	11.0	9.0	4.7	13.0	14.0	17.0
	July	1.0	11.0	6.0	13.0	3.1	1.0
	September	6.0	5.0	5.0	9.0	10.0	15.0
	January	11.0	5.0	5.0	11.0	12.0	17.0
	March	8.0	6.0	0.0	13.0	13.0	13.0
Fluoride, dissolved mg/l F	June	0.0	0.1	0.1	0.1	0.1	0.0
	July	0.0	0.0	0.1	0.0	0.0	0.1
	September	0.1	0.1	0.1	0.1	0.1	0.1
	January	0.1	0.1	0.1	0.1	0.1	0.1
	March	0.1	0.1	0.1	0.1	0.1	0.1
Silica, dissolved mg/l SiO_2	June	9.7	11.0	10.0	10.0	11.0	5.5
	July	6.6	6.6	6.2	10.0	5.6	6.2
	September	0.0	10.0	10.0	10.0	11.0	6.1
	January	10.0	11.0	11.0	10.0	11.0	12.0
	March	11.0	11.0	11.0	10.0	12.0	13.0
Nutrients							
Nitrogen, total mg/l N	June	1.9	1.9	0.9	2.3	0.94	0.5
	July	0.8	0.8	0.8	2.1	0.2	0.5
	September	1.7	1.7	0.7	2.0	1.1	0.6
	January	1.3	1.8	0.7	1.6	1.0	0.4
	March	1.3	1.4	0.7	1.7	1.0	0.4

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Appendix Table 4-D-6 (Continued).

Parameter	Date	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Nutrients - Cont'd							
Nitrogen, total ammonia mg/l N	June	0.08	0.10	0.09	0.07	0.10	0.14
	July	0.15	0.18	0.15	0.26	0.13	0.33
	September	---	0.15	0.16	0.19	0.20	0.17
	January	<0.07	<0.07	0.12	0.09	<0.07	0.08
	March	0.12	0.08	<0.06	0.08	0.06	0.06
Nitrogen, ammonia + dissolved organics mg/l N	June	0.52	0.62	0.65	0.72	0.58	0.42
	July	0.54	0.61	---	0.73	0.57	0.45
	September	0.51	0.58	0.26	0.62	0.30	0.43
	January	0.37	0.47	0.24	0.22	0.28	0.24
	March	0.27	0.23	0.24	0.30	0.22	0.26
Nitrogen, ammonia + total suspended organics mg/l N	June	0.09	0.30	0.00	0.23	0.00	0.06
	July	0.01	0.11	---	0.00	0.00	0.00
	September	0.07	0.00	0.07	0.01	0.08	0.02
	January	0.05	0.21	0.06	0.37	0.03	0.02
	March	0.09	0.26	0.14	0.21	0.14	0.01
Nitrogen, ammonia + total organics mg/l N	June	0.61	0.92	0.59	0.95	0.47	0.48
	July	0.55	0.72	0.46	0.71	0.57	0.43
	September	0.58	0.56	0.33	0.63	0.38	0.45
	January	0.42	0.68	0.30	0.59	0.31	0.26
	March	0.36	0.49	0.38	0.51	0.36	0.27
Nitrogen, total nitrate and nitrate mg/l N	June	1.3	1.0	0.33	1.3	0.5	0.1
	July	0.2	0.1	0.3	1.4	0.1	0.1
	September	1.1	1.1	0.3	1.4	0.7	0.2
	January	0.9	1.1	0.4	1.0	0.6	0.2
	March	0.9	1.0	0.4	1.2	0.6	0.2
Nitrogen, dissolved nitrate and nitrite mg/l N	June	1.3	1.0	0.4	1.3	0.4	0.1
	July	---	0.1	0.3	1.5	0.1	0.1
	September	1.0	1.1	0.3	1.3	0.7	0.2
	January	0.9	1.1	0.4	1.0	0.6	0.2
	March	0.9	1.0	0.4	1.2	0.6	0.2

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4-2-2-4

Appendix Table 4-D-6 (Continued).

Parameter	Date	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Nutrients, - Cont'd							
Phosphorus, total mg/1 P	June	0.05	0.01	0.01	0.01	<0.01	0.12
	July	0.27	0.48	0.14	0.01	0.38	0.02
	September	<0.01	<0.01	<0.01	<0.01	<0.01	0.02
	January	<0.01	<0.01	<0.01	0.02	0.01	0.01
	March	0.01	0.01	0.01	0.01	0.01	0.01
Phosphorus, total mg/1 PO_4	June	0.2	<0.1	<0.1	<0.1	<0.1	0.4
	July	0.8	1.5	0.4	<0.1	1.2	0.1
	September	---	---	---	---	---	0.1
	January	---	---	---	0.1	<0.1	0.1
	March	<0.1	<0.1	<0.1	<0.1	<0.1	---
Phosphorus, dissolved mg/1 P	June	0.03	0.01	0.01	0.01	<0.01	0.02
	July	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	September	0.01	<0.01	<0.01	<0.01	<0.01	0.01
	January	<0.01	<0.01	<0.01	0.02	0.04	0.01
	March	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Carbon, dissolved organic mg/1 C	June	1.9	2.1	1.4	1.3	2.0	2.8
	July	13.0	9.0	3.3	6.2	6.0	18.0
	September	1.5	1.7	1.9	2.2	1.1	---
	January	1.4	1.3	0.5	0.7	0.5	---
	March	1.4	0.7	0.7	1.4	1.1	1.6
Carbon, total suspended organics mg/1 C	June	---	0.2	---	0.2	0.2	0.9
	July	0.2	0.5	0.0	0.0	0.3	---
	September	0.1	0.1	0.1	0.1	0.1	---
	January	0.0	0.0	0.0	0.0	0.0	---
	March	0.0	0.0	0.0	0.1	0.1	0.1
Trace Metals							
Arsenic, total ug/1 As	June	1	1	1	2	2	6
	July	2	5	4	1	5	7
	September	2	1	1	2	2	---
	January	2	2	1	2	2	---
	March	1	1	2	1	2	2

87-0-78

24-21-2

Appendix Table 4-D-6 (Continued).

Parameter	Date	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Trace Metals - Cont'd							
Arsenic, total suspended ug/l As	June	0	0	0	1	1	5
	July	0	3	2	0	3	5
	September	1	0	0	1	1	---
	January	1	1	0	1	1	---
	March	---	0	1	0	1	0
Arsenic, dissolved ug/l As	June	2	1	1	1	1	1
	July	2	2	2	1	2	2
	September	1	1	1	1	1	---
	January	1	1	1	1	1	---
	March	<1	1	1	1	1	2
Barium, total recoverable ug/l Ba	June	0	0	0	0	100	200
	July	200	200	100	100	300	300
	September	100	200	100	100	100	---
	January	100	100	<100	100	100	---
	March	<100	<100	<100	<100	<100	100
Barium, suspended recoverable ug/l Ba	June	0	0	0	0	100	200
	July	200	200	70	50	300	300
	September	100	200	100	100	0	---
	January	0	---	---	---	0	---
	March	---	---	---	---	---	40
Barium, dissolved ug/l Ba	June	90	0	0	0	0	0
	July	40	40	30	50	40	0
	September	0	0	0	0	100	---
	January	100	<100	<100	<100	100	---
	March	29	27	14	29	47	60
Cadmium, total recoverable ug/l Cd	June	0	0	2	0	1	0
	July	0	0	0	1	0	5
	September	0	0	0	0	1	---
	January	<1	<1	<1	<1	<1	---
	March	<1	<1	<1	<1	<1	<1

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E4-21-2

Appendix Table 4-D-6 (Continued).

Parameter	Date	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Trace Metals - Cont'd							
Cadmium, suspended recoverable ug/l Co	June	---	0	2	0	0	---
	July	---	---	---	---	---	4
	September	0	0	0	0	1	---
	January	---	---	---	---	---	---
	March	---	---	---	---	---	---
Cadmium, dissolved ug/l Cd	June	1	0	0	0	5	<1
	July	<1	<1	<1	<1	<1	1
	September	0	0	1	0	0	---
	January	<1	1	1	1	<1	---
	March	<3	<3	<3	<3	<3	<3
Chromium, total recoverable ug/l Cr	June	0	10	0	0	0	40
	July	30	30	20	20	40	30
	September	0	10	10	10	10	---
	January	10	<1	10	<10	<10	---
	March	10	<1	10	10	<10	10
Chromium, suspended recoverable ug/l Cr	June	0	10	0	0	0	
	July	20	20	10	10	30	40
	September	0	10	10	10	10	20
	January	---	---	---	---	---	---
	March	---	---	---	---	---	---
Chromium, dissolved ug/l Cr	June	10	0	0	0	0	0
	July	10	10	10	10	10	10
	September	0	0	0	0	0	---
	January	<10	1	<10	<10	<10	---
	March	<10	<3	<10	<10	<10	<10
Cobalt, total recoverable ug/l Co	June	2	0	0	0	2	8
	July	5	6	2	0	7	11
	September	0	0	0	0	1	---
	January	2	1	1	1	<1	---
	March	1	1	2	2	1	1

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44-21-2

Appendix Table 4-D-6 (Continued).

Parameter	Date	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Trace Metals - Cont'd							
Cobalt, suspended recoverable ug/1 Co	June	---	0	0	0	1	---
	July	---	---	---	---	---	11
	September	0	0	0	0	1	---
	January	0	0	0	---	---	---
	March	---	---	---	---	---	0
Cobalt, dissolved ug/1 Co	June	<3	0	0	0	1	<3
	July	<3	<3	<3	<3	<3	0
	September	0	0	0	0	0	---
	January	2	2	1	<1	2	---
	March	<1	<1	<1	<1	<1	1
Copper, total recoverable ug/1 Cu	June	3	2	4	2	2	31
	July	20	23	10	3	23	190
	September	6	4	5	4	4	---
	January	4	2	1	2	1	---
	March	2	1	2	8	6	2
Copper, suspended recoverable ug/1 Cu	June	1	1	1	0	0	27
	July	12	20	4	0	0	190
	September	5	3	3	2	18	---
	January	3	0	0	0	3	---
	March	1	0	1	7	0	1
Copper, dissolved ug/1 Cu	June	2	1	3	2	2	4
	July	8	3	6	7	5	5
	September	1	1	2	2	1	---
	January	1	2	2	2	1	---
	March	1	1	1	1	1	1
Iron, total recoverable ug/1 Fe	June	20	40	50	40	60	15,000
	July	13,000	16,000	5,800	220	18,000	19,000
	September	20	90	280	260	100	---
	January	20	140	20	10	10	---
	March	10	30	40	30	10	40

Appendix Table 4-D-6 (Continued).

Parameter	Date	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Cold Creek
Trace Metals - Cont'd							
Iron, suspended recoverable ug/l Fe	June	10	0	0	0	40	15,000
	July	13,000	16,000	5,700	140	18,000	19,000
	September	10	60	260	250	90	---
	January	0	80	0	0	0	---
	March	0	20	30	20	0	30
Iron, dissolved ug/l Fe	June	10	60	50	60	20	90
	July	48	110	52	79	97	120
	September	10	30	20	10	10	---
	January	40	60	20	30	20	---
	March	12	14	9	15	11	15
Lead, total recoverable ug/l Pb	June	0	5	3	3	15	18
	July	3	3	3	3	2	47
	September	4	1	1	2	4	---
	January	2	1	<1	1	<1	---
	March	<1	1	5	6	9	3
Lead, suspended recoverable ug/l Pb	June	0	5	3	3	15	18
	July	0	1	3	2	0	47
	September	2	0	0	0	0	---
	January	1	0	---	0	---	---
	March	---	---	4	---	---	0
Lead, dissolved ug/l Pb	June	0	0	0	0	0	0
	July	3	2	0	1	5	0
	September	2	3	4	3	5	---
	January	1	2	1	1	1	---
	March	1	<1	1	<1	<1	3
Manganese, total recoverable ug/l Mn	June	10	10	10	0	0	250
	July	230	290	100	20	300	320
	September	0	0	10	10	0	---
	January	10	20	10	10	20	---
	March	10	10	<10	10	<10	10

4-D-82

24-21-2

Appendix Table 4-D-6 (Continued).

Parameter	Date	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Trace Metals - Cont'd							
Manganese, suspended recoverable ug/l Mn	June	0	10	10	0	0	250
	July	220	280	90	10	290	310
	September	0	0	10	0	0	---
	January	0	10	---	0	10	---
	March	6	5	---	6	---	7
Manganese, dissolved ug/l Mn	June	10.0	0.0	0.0	0.0	0	4
	July	8.0	10.0	7.0	9.0	8	10
	September	0.0	0.0	0.0	10.0	0	---
	January	10.0	<0.1	<10.0	<10.0	10	---
	March	4.0	<0.1	3.0	4.0	3	3
Mercury, total recoverable ug/l Hg	June	0.1	0.1	0.1	0.1	0.2	0.4
	July	0.1	0.1	0.1	0.0	0.2	0.3
	September	0.1	0.0	0.0	0.0	0.0	---
	January	<0.1	<0.1	<0.1	<0.1	0.1	---
	March	0.1	0.1	0.1	0.1	0.1	0.1
Mercury, suspended recoverable ug/l Hg	June	0.1	0.1	0.1	0.1	0.2	0.4
	July	0.0	0.1	0.1	0.0	0.2	0.1
	September	0.1	0.0	0.0	0.0	0.0	---
	January	---	---	---	---	---	---
	March	---	---	---	---	---	---
Mercury, dissolved ug/l Hg	June	0.0	0.0	0.0	0.0	0.0	0.0
	July	0.1	0.0	0.1	0.0	0.0	0.2
	September	0.0	0.0	0.0	0.0	0.0	---
	January	<0.1	<0.1	<0.1	<0.1	<0.1	---
	March	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nickel, total recoverable ug/l Ni	June	3	2	2	1	6	23
	July	14	18	6	2	18	22
	September	1	0	7	3	4	36
	January	1	2	<1	<1	<1	---
	March	1	<1	2	2	1	2

Appendix Table 4-D-6 (Continued).

Parameter	Date	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Trace Metals - Cont'd							
Nickel, suspended recoverable ug/l Ni	June	2	2	1	0	1	23
	July	12	18	6	0	17	29
	September	1	0	7	3	4	29
	January	---	1	---	---	---	---
	March	0	---	1	1	0	1
Nickel, dissolved ug/l Ni	June	1	0	1	1	5	0
	July	2	0	0	3	1	<1
	September	0	0	0	0	0	7
	January	<1	1	<1	<1	<1	---
	March	2	<1	1	1	1	1
Selenium, total ug/l Se	June	0	0	0	1	1	<1
	July	0	0	0	0	0	0
	September	0	0	0	0	0	1
	January	<1	<1	<1	1	1	---
	March	1	<1	<1	<1	<1	<1
Selenium, total suspended ug/l Se	June	0	0	0	0	1	0
	July	0	0	0	0	0	0
	September	0	0	0	0	0	0
	January	---	---	---	---	---	---
	March	---	---	---	---	---	---
Selenium, dissolved ug/l Se	June	0	0	0	1	0	0
	July	1	0	0	1	0	0
	September	0	0	0	1	1	---
	January	<1	<1	<1	<1	<1	---
	March	<1	<1	<1	1	1	<1
Silver, total recoverable ug/l Ag	June	0	0	1	0	0	0
	July	0	0	0	1	0	0
	September	0	0	0	0	0	---
	January	<1	<1	<1	<1	<1	---
	March	<1	<1	<1	<1	<1	<1

4-D-84

84-21-2

Appendix Table 4-D-6 (Continued).

Parameter	Date	Slough 8A	Slough 9	Slough 16B	Slough 19	Slough 21	Susitna River at Gold Creek
Trace Metals - Cont'd							
Silver, suspended recoverable ug/l Ag	June	0	0	1	0	0	0
	July	0	0	0	1	0	0
	September	0	0	0	0	0	---
	January	---	---	---	---	---	---
	March	---	---	---	---	---	---
Silver, dissolved ug/l Ag	June	0	0	0	0	0	0
	July	0	0	0	0	0	0
	September	0	0	0	0	0	---
	January	<1	<1	<1	1	<1	---
	March	<1	<1	1	<1	<1	1
Zinc, total recoverable ug/l Zn	June	20	40	10	10	10	60
	July	80	60	20	10	60	120
	September	20	30	30	10	20	---
	January	20	10	20	10	10	---
	March	10	10	40	30	20	10
Zinc, suspended recoverable ug/l Zn	June	10	30	0	0	10	50
	July	80	30	10	0	40	110
	September	10	10	0	10	0	---
	January	10	0	10	0	0	---
	March	0	---	---	20	---	---
Zinc, dissolved ug/l Zn	June	7	10	10	10	0	6
	July	4	35	10	10	17	14
	September	10	20	30	0	20	5
	January	10	20	10	10	10	---
	March	<12	<12	<12	12	<12	<12

4-D-85

64-21-2

2. Water Use and Quality

Comment 13 (p. E-2-40, para. 3)

Provide water levels as a function of observation time for each well. Provide data associated with core drillings and piezometer installations. Provide bathymetry from sampled sloughs.

Response

Water level data for sloughs 8A and 9 are presented as a function of observation time in Tables 1 and 2. The average daily discharge at Gold Creek for the date of each observation is also presented. The location of the observation well is illustrated in pp. 2-13-62 to 2-13-63

Wellhole logs for the shallow wells identified in Tables 1 and 2 are illustrated in pp. 2-13-6 to 2-13-19. Four deeper wells were drilled in Slough 9 during November 1982. Information associated with the core drillings of these wells is presented in pp. 2-13-20 to 2-13-23. Generally the well logs indicate well-graded sandy gravel overlain by 0 to 10 feet of silt and sand. The gravel contains well rounded cobbles and boulders 1/2 to 6 inches in diameter and does not contain silt.

Details of the piezometer installation for the deeper wells are illustrated in p. 2-13-24.

Bathymetry in the form of cross sections and thalweg profiles for sloughs 8A and 9 are presented in pp. 2-13-25 to 2-13-61. Locations of cross sections are presented in pp. 2-13-62 to 2-13-63.

TABLE 1

GROUNDWATER ELEVATIONS AT SLOUGH 8A
(In feet above mean sea level)

Date	Well No. 8-1	8-3	8-4	8-5	8-6	8-7	8-8	8-9	USGS Provisional Discharge at Gold Creek (cfs)
1982									
April 26	579.47	575.42	574.39	574.76	d	572.79	568.24	568.42	2,300
May 15					576.31				15,000
May 27	581.16	577.87	573.94	574.91	573.22	573.43	569.91	568.62	23,000
June 24	581.42	577.54	575.06	574.99	573.11	573.32	569.36	568.56	26,000
June 29	581.26	576.38	575.00	574.94	572.98	573.23	569.03	568.55	29,000
July 18	580.99	575.69	574.89	574.83	572.80	573.13	568.61	568.40	25,400
August 3									19,800
August 5									17,400
August 6									16,800
August 9	580.41	576.18	574.87	574.77	572.97	573.12	569.09	568.43	17,000
August 27									12,900
September 3		577.41	575.10	574.97	573.17	573.32	569.66	568.52	14,600
September 5									13,600
September 10		575.54	574.64	574.56	572.90	572.96	569.12	568.31	14,400
September 20	581.41	578.45	575.32	575.30	573.44	573.58	570.33	568.91	24,000
October 5	d	576.57	574.90	574.77	573.03	573.15	569.64	568.37	9,800
October 13	d	574.74	574.06	d	572.78	572.78		568.16	8,040

s = silted
d = dry

Source - R&M Consultants, Inc. Susitna Hydroelectric Project Slough Hydrology Interim Report. Prepared for Acres American Incorporated.

TABLE 1 (Cont'd)

GROUNDWATER ELEVATIONS AT SLOUGH 8A
(In feet above mean sealevel)

Date	Well No. 8-10	8-11	8-12	S.G. 8-1A	8-1A	8-2A	8-3A	8-4A	USGS Provisional Discharge at Gold Creek (cfs)
1982									
April 26	566.15	565.64	566.33						2,300
May 15									15,000
May 27	565.30	565.49	s						23,000
June 24	565.15	565.79	s						26,000
June 29	565.34		s						29,000
July 18	565.54	565.51	564.38	572.63	572.32	572.23			25,400
August 3				572.19	572.33	572.35			19,800
August 5				571.85	571.86	571.83			17,400
August 6				571.79	571.75	571.73	571.87		16,800
August 9	565.56	565.83	564.29	571.81	d	571.61	571.81		17,000
August 27					d	d	571.05	571.26	12,900
September 3	565.76	566.28	d	571.24	d	571.41	571.87	572.32	14,600
September 5				570.99	d		571.74	572.28	13,600
September 10	565.75			571.16	d	d	571.36	572.24	14,400
September 20	566.00	566.70	564.44	573.24	573.33	573.25	573.42	573.72	24,000
October 5	565.70	566.12	d	570.39	d	d	571.22	573.09	9,800
October 13			d		d	d	570.48	572.58	8,040

s = silted
d = dry

2-13-3

TABLE 2

GROUNDWATER ELEVATIONS AT SLOUGH 9
(In feet above mean sealevel)

Date	Well No. 9-1	9-1A	9-3	9-4	9-5	9-6	9-7	9-9	USGS Provisional Discharge at Gold Creek (cfs)
1982									
April 26			603.06	603.62	603.33	d	d	603.01	2,300
May 11	607.71		605.42	604.46	604.51	604.15	602.68		10,500
May 15									15,000
May 27	607.58		606.62	604.47	604.76	604.34	602.45		23,000
June 23	608.50		606.66	604.77	604.40	604.91	603.02		27,000
July 1	607.94		606.22	604.67	604.11	604.48	602.78	604.08	25,000
July 20	607.32		605.67	604.03	603.81	604.08	602.30		22,900
August 25	605.99		604.69	d	603.34	d	601.05	602.56	13,400
September 6	606.16	605.50	605.70	604.16	603.61	d	601.32	604.37	12,200
September 9	606.08	605.27	605.49	d	603.60	d	601.14	604.22	13,400
September 20	608.01	607.07	607.65	605.23	604.74	604.62	602.78	605.07	24,000
October 7	605.88	605.21	605.29	603.97	603.52	d	d	603.26	8,640
October 15	605.81	604.85	604.91	d	603.39	d	d	602.91	7,110

s = silted
d = dry

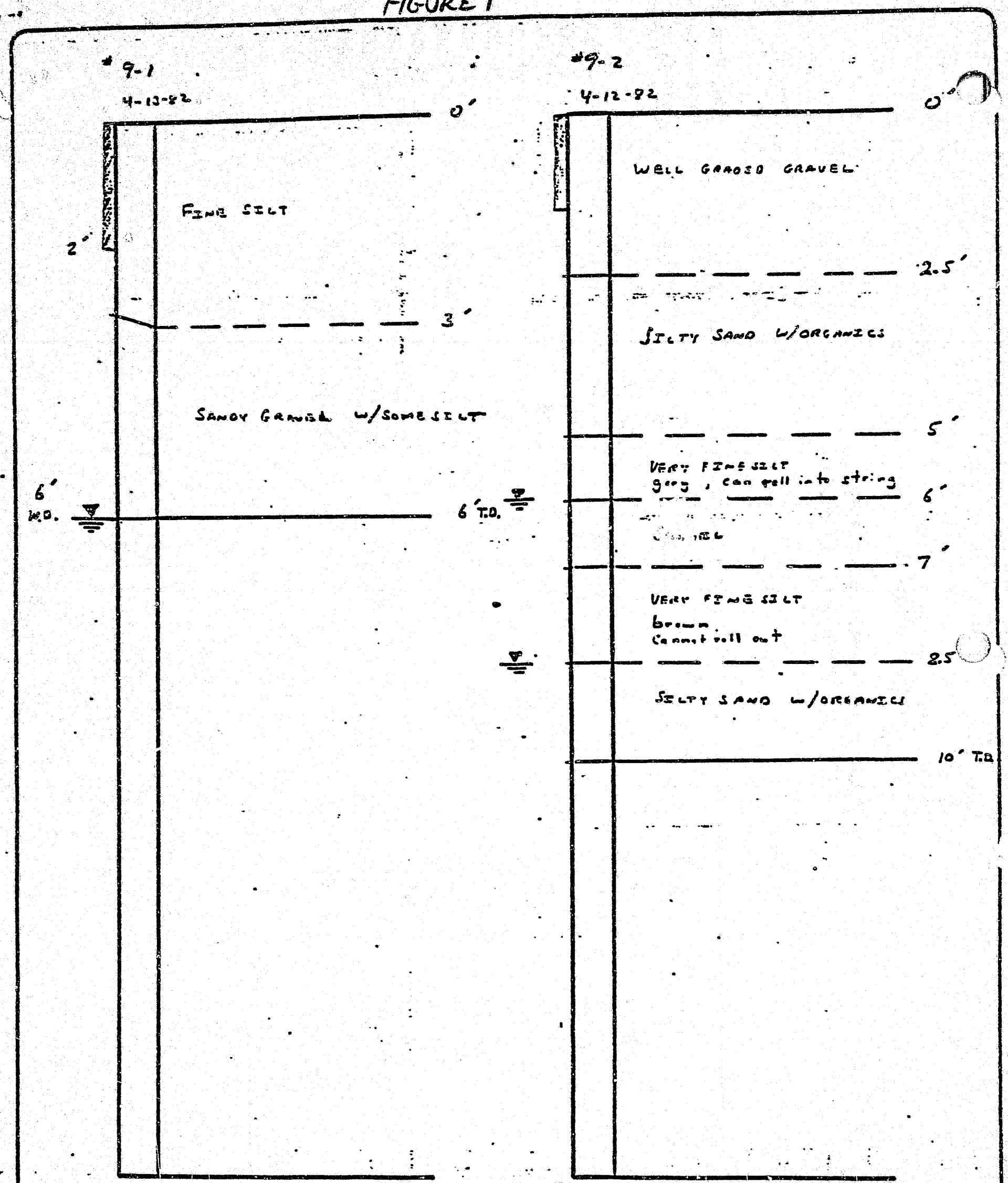
TABLE 2 (Cont'd)

GROUNDWATER ELEVATIONS AT SLOUGH 9
(In feet above mean sealevel)

Date	Well No. 9-10	9-11	9-12	9-13	9-14	9-15	USGS Provisional Discharge at Gold Creek (cfs)
1982							
April 26	600.32	600.06	598.53	d	594.14	d	2,300
May 11	601.20	601.21		694.09	594.57	593.90	10,500
May 15	604.00						15,000
May 27	s	601.16	599.94	s	s	s	23,000
June 23	s	601.69	600.64	s	s	s	27,000
July 1	s	601.38	600.40	s	s	s	25,000
July 20	600.99	601.07	99.55	s	s	s	22,900
August 25	600.34	600.28	d	d	593.66	592.74	13,400
September 6	600.50	600.46					12,200
September 9	600.43	600.35	d	d	593.74	592.83	13,400
September 20	601.37	601.49	d	594.29	594.77		24,000
October 7	d	d	d	d	593.76	d	8,640
October 15	d	d	d	d	593.66	d	7,110

s = silted
d = dry

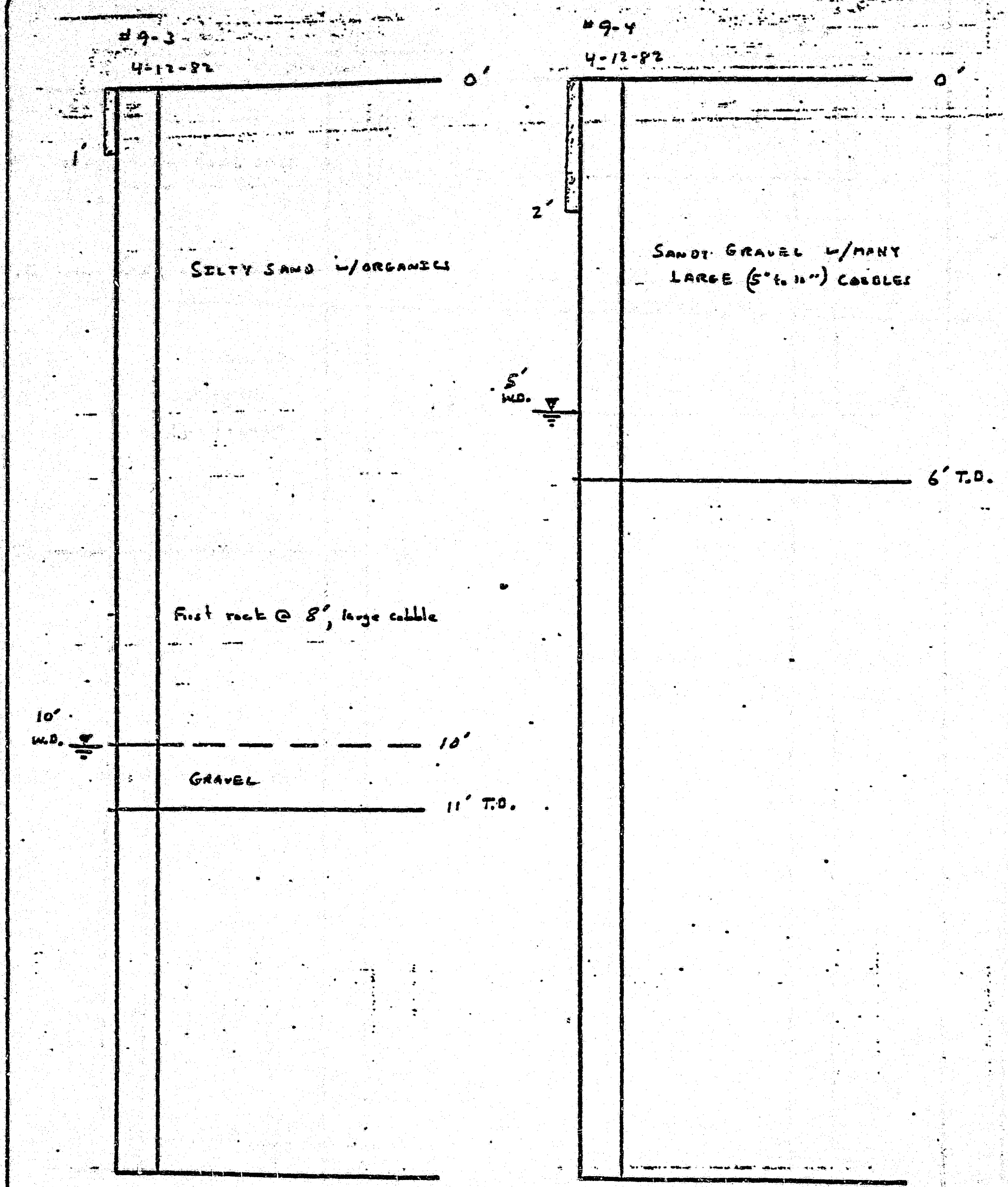
FIGURE 1



2-13-6

DWN. RB	R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS	WELL HOLE LOGS	FB.
CKD.		SUSITNA GROUND WATER STUDY	GRID
DATE 4-82			PROJ.NO. 052314
SCALE 1" = 2'			DWG NO.

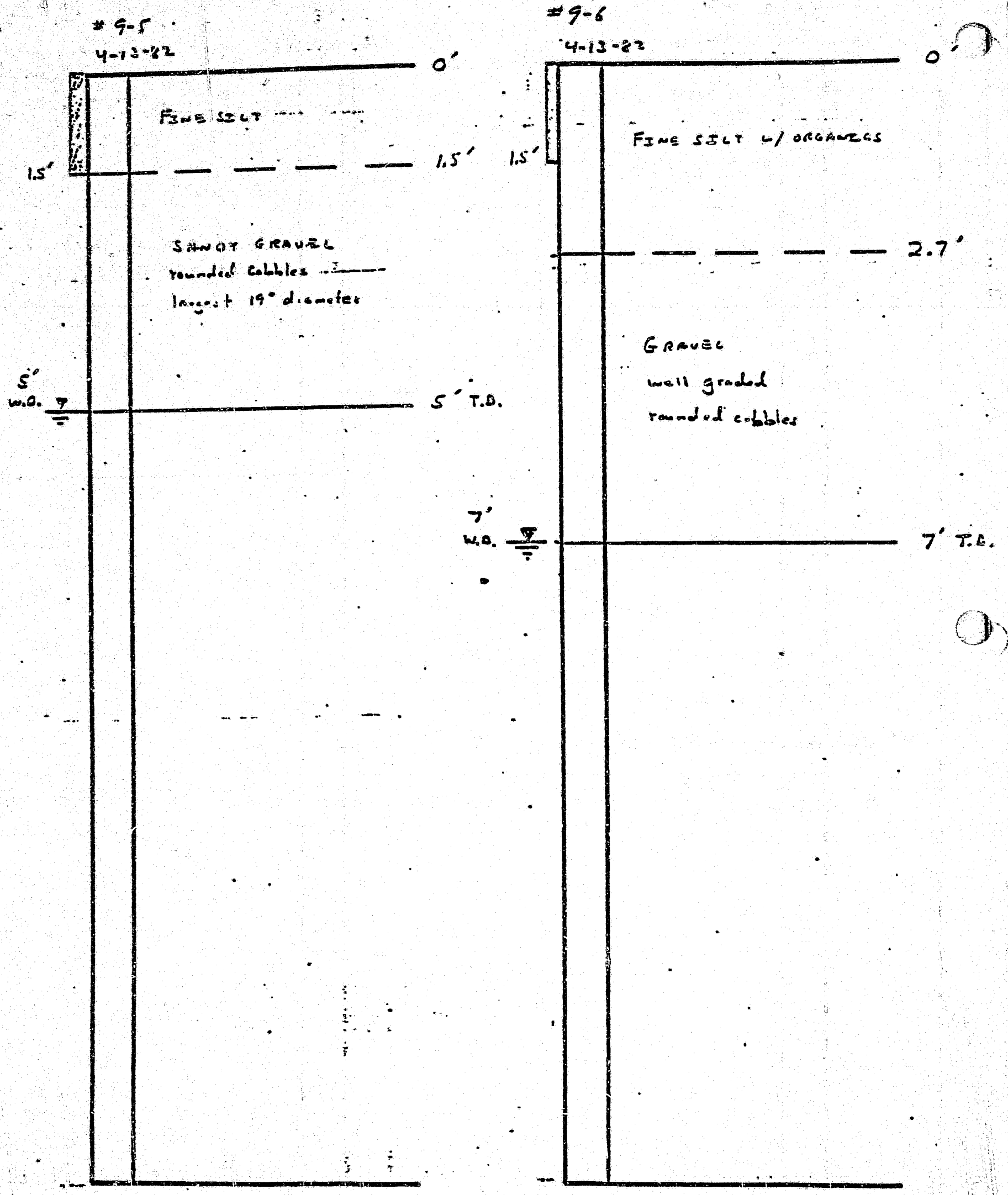
FIGURE 2



2-13-7

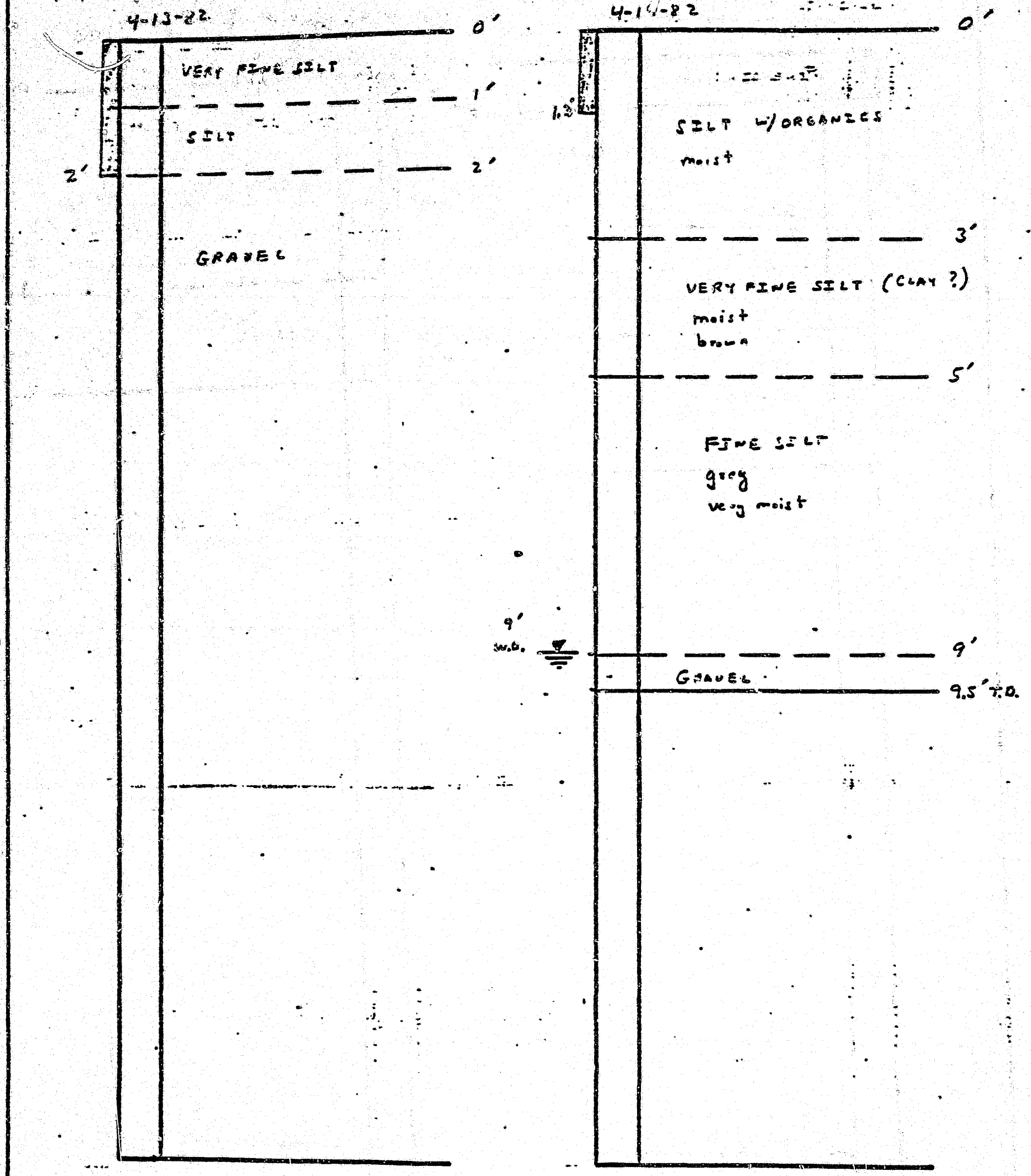
DWN. RB	R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS	WELL HOLE LOGS SWISHA GROUND WATER STUDY	FB.
CKD.			GRID
DATE 4-82			PROJ. NO. 05-2319

FIGURE 3



DWN RB.	R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS	WELL - HOLE LOGS	FB.
CKD			GRID
DATE 4-82		SUSITNA GROUND WATER STUDY	PROJ NO 052314
SCALE			DWG NO.

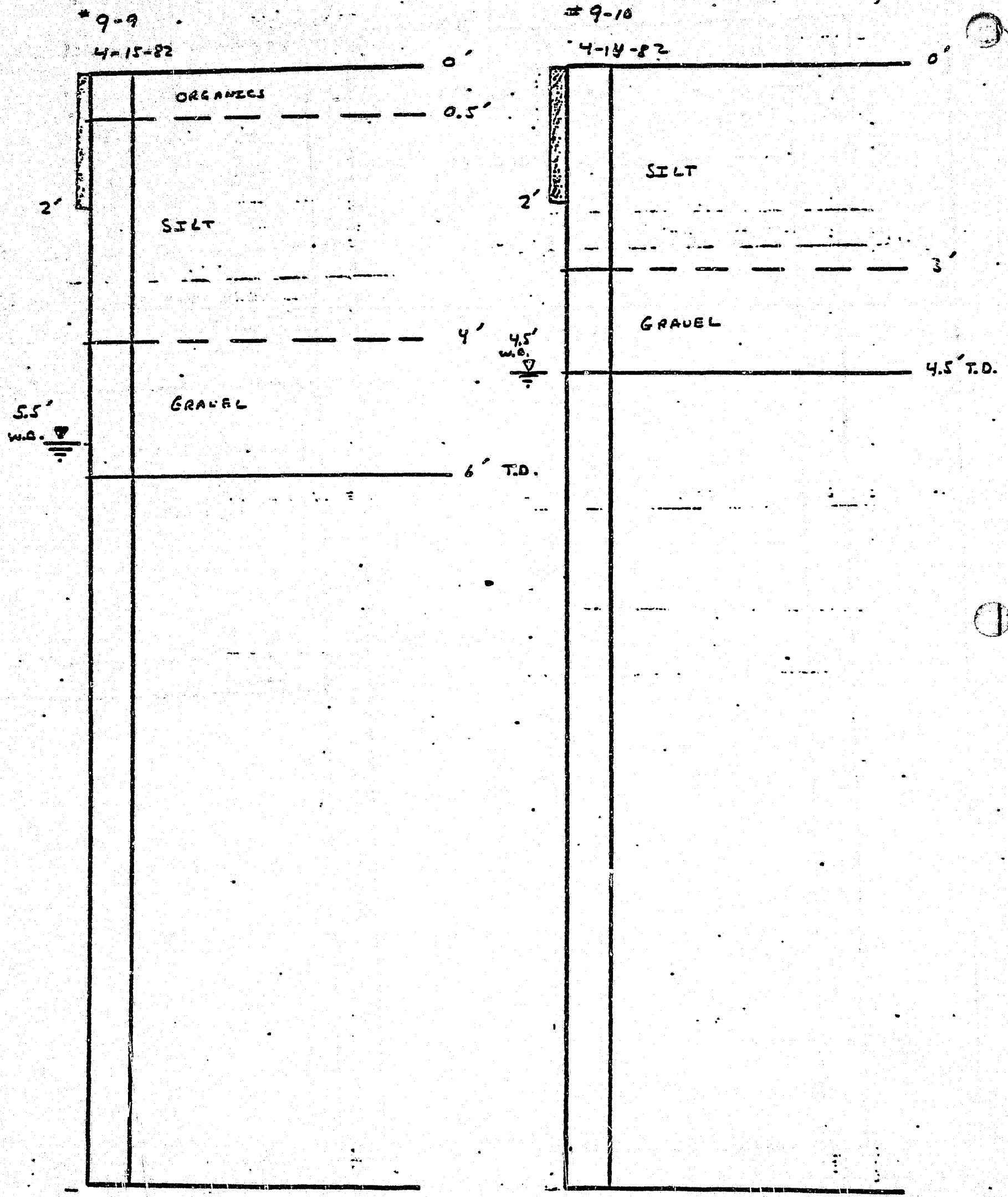
FIGURE 4



2-13-9

DWN. RG	R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS	WELL HOLE LOGS	FB.
CKD.		SUSITNA GROUND WATER STUDY	GRID
DATE 4-82			PROJ.NO. 052304
SCALE			DWG.NO.

FIGURE 5



2-13-10

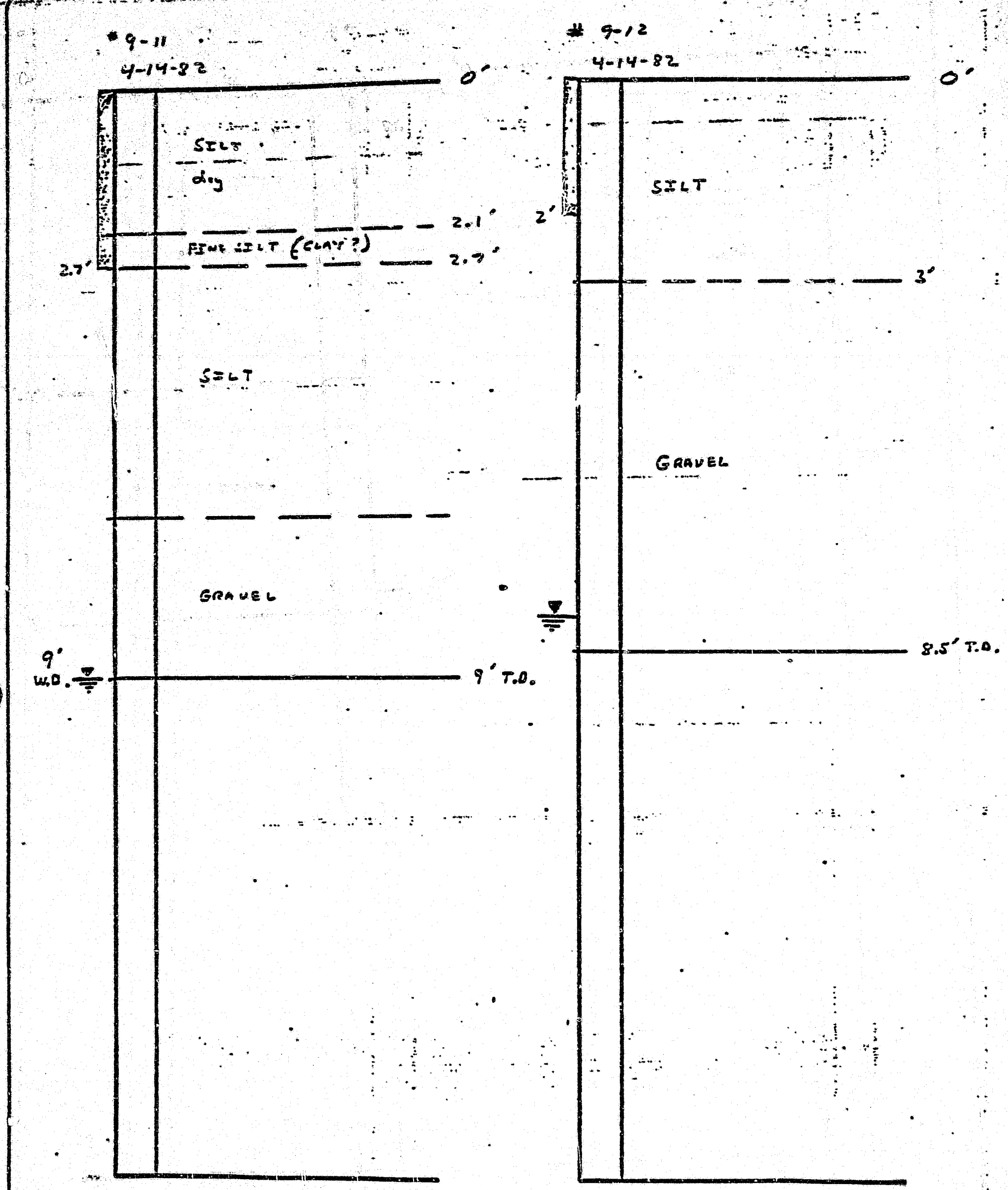
DWN	RG
CKD	
DATE	4-22
SCALE	1" =

R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

WELL HOLE LOGS
SUSITNA BASIN WATER STUDY

EE	
GEOL	
PROJ NO	05214
DWG NO	

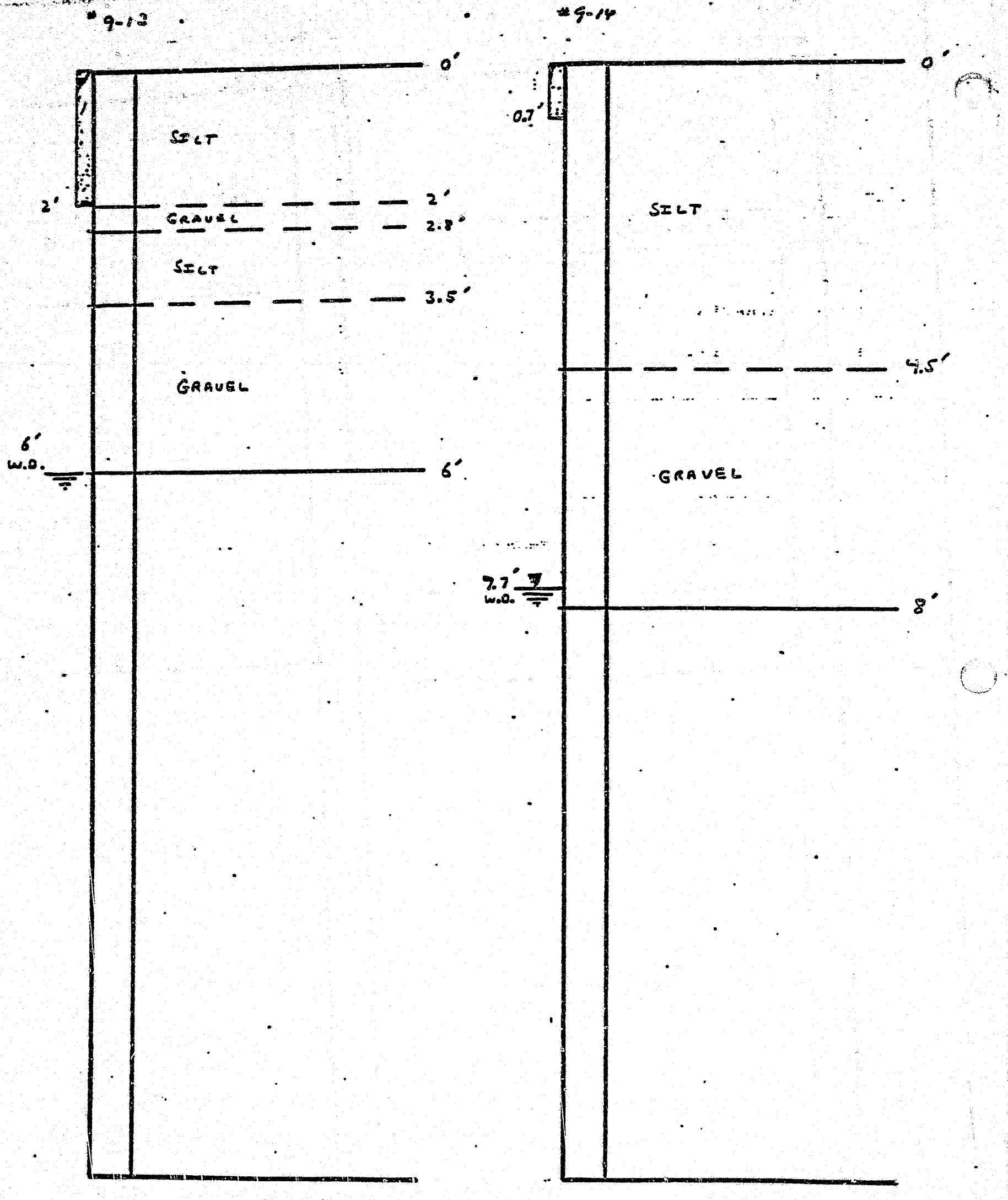
FIGURE 6



2-13-11

DWN. RB	R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS	WELL HOLE LOGS	FB.
CKD.		SWIFTNA GROUND WATER STUDY	GRID
DATE 4-82			PROJ. NO. 07214
SCALE 1" =			DWG NO.

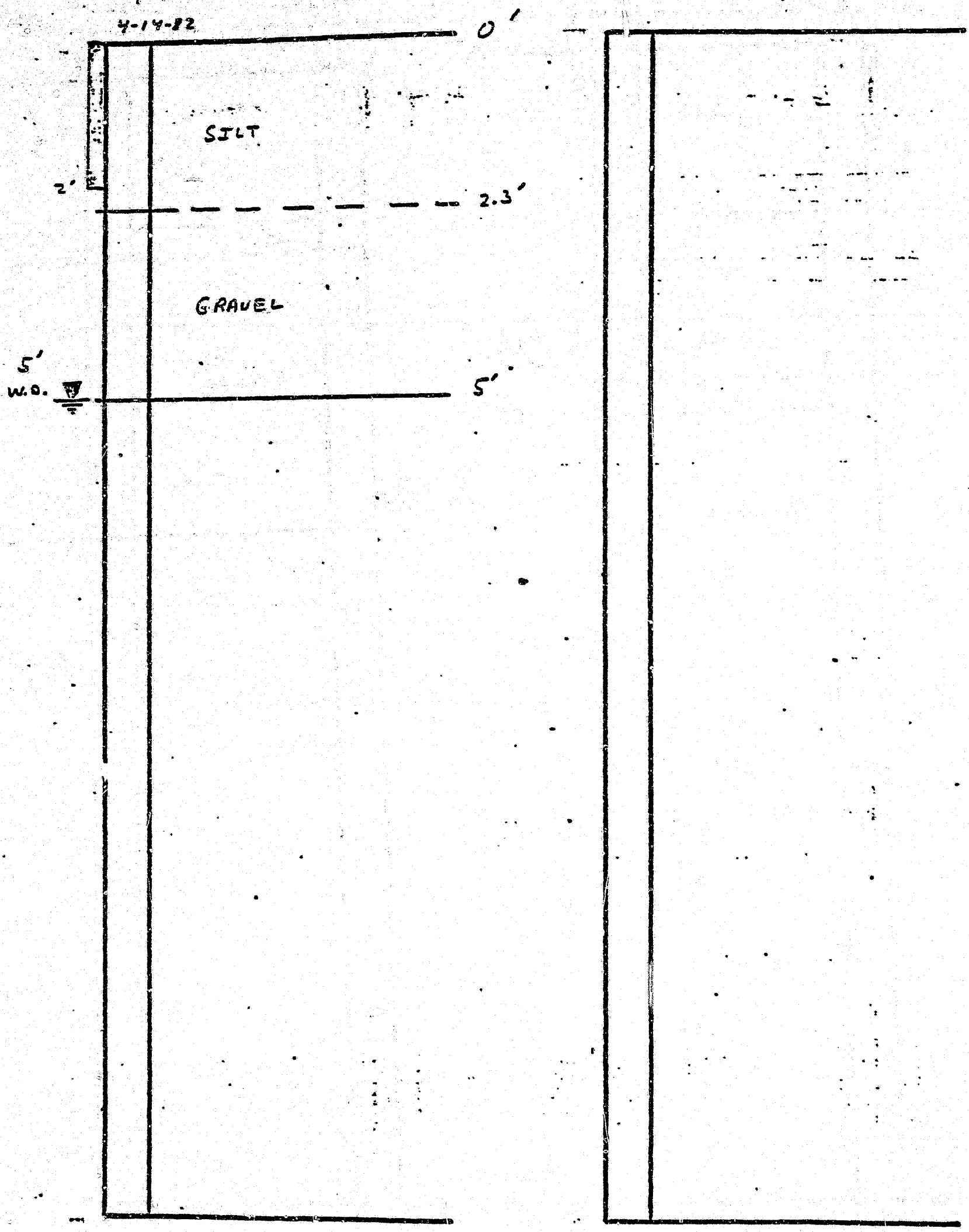
FIGURE 7



2-13-12

DWN. R.B.	R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS	WELL HOLE LOGS SUSITNA GROUND WATER PROJECT	EB.
CKD.			GRID
DATE 4-82			PROJ.NO. 0823.14
SCALE 1" = 7'			DWG.NO.

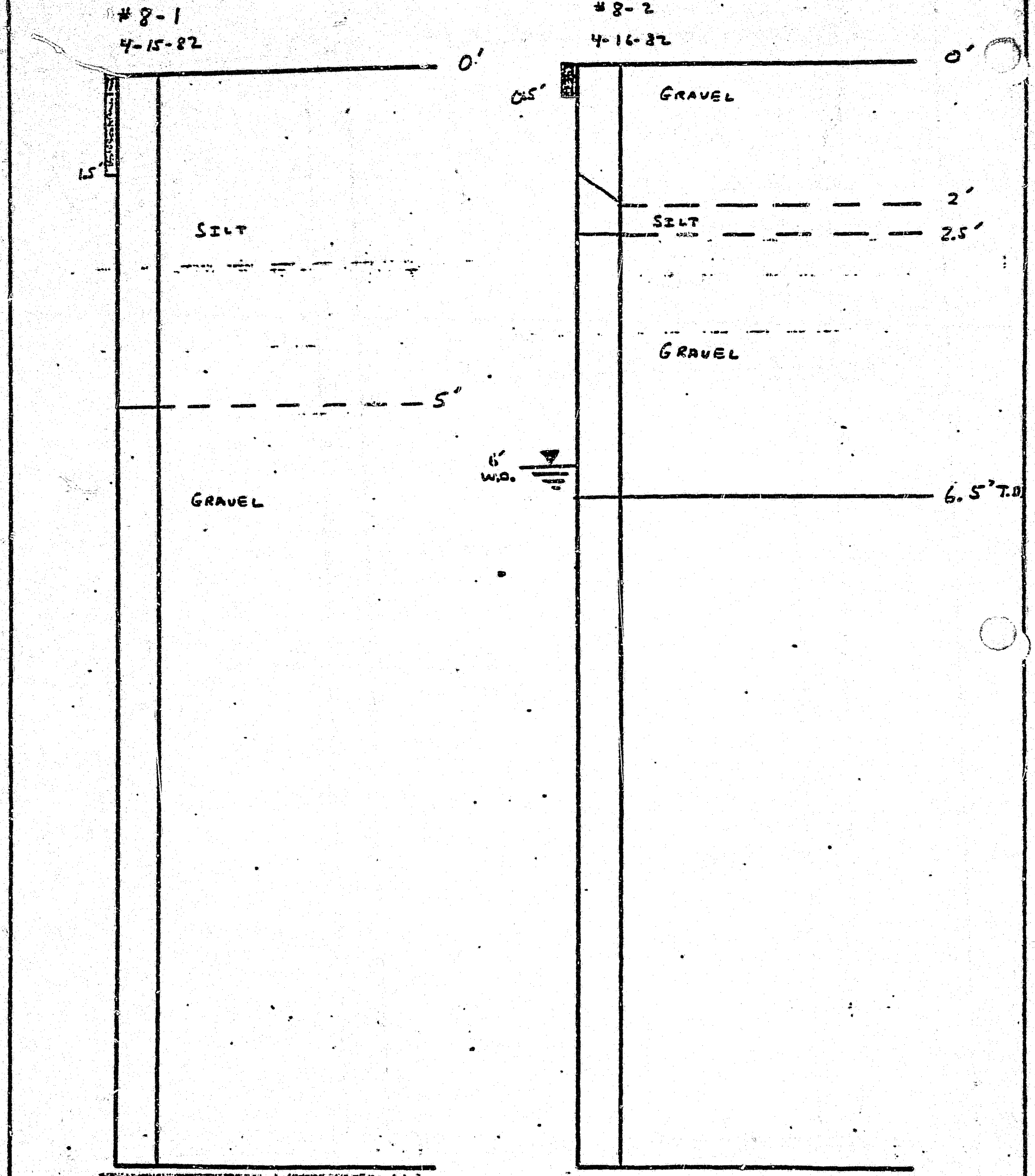
FIGURE 8



2-13-13

DWN. RB	R&M CONSULTANTS, INC.	WELL HOLE LOGS	FIL.
CKD.	ENGINEERS GEOLOGISTS PLANNERS SURVEYORS	SUSITNA GROUND WATER STUDY	GRID
DATE 4-82			PROJ NO. 05234
SCALE 1" = 2'			DWG NO.

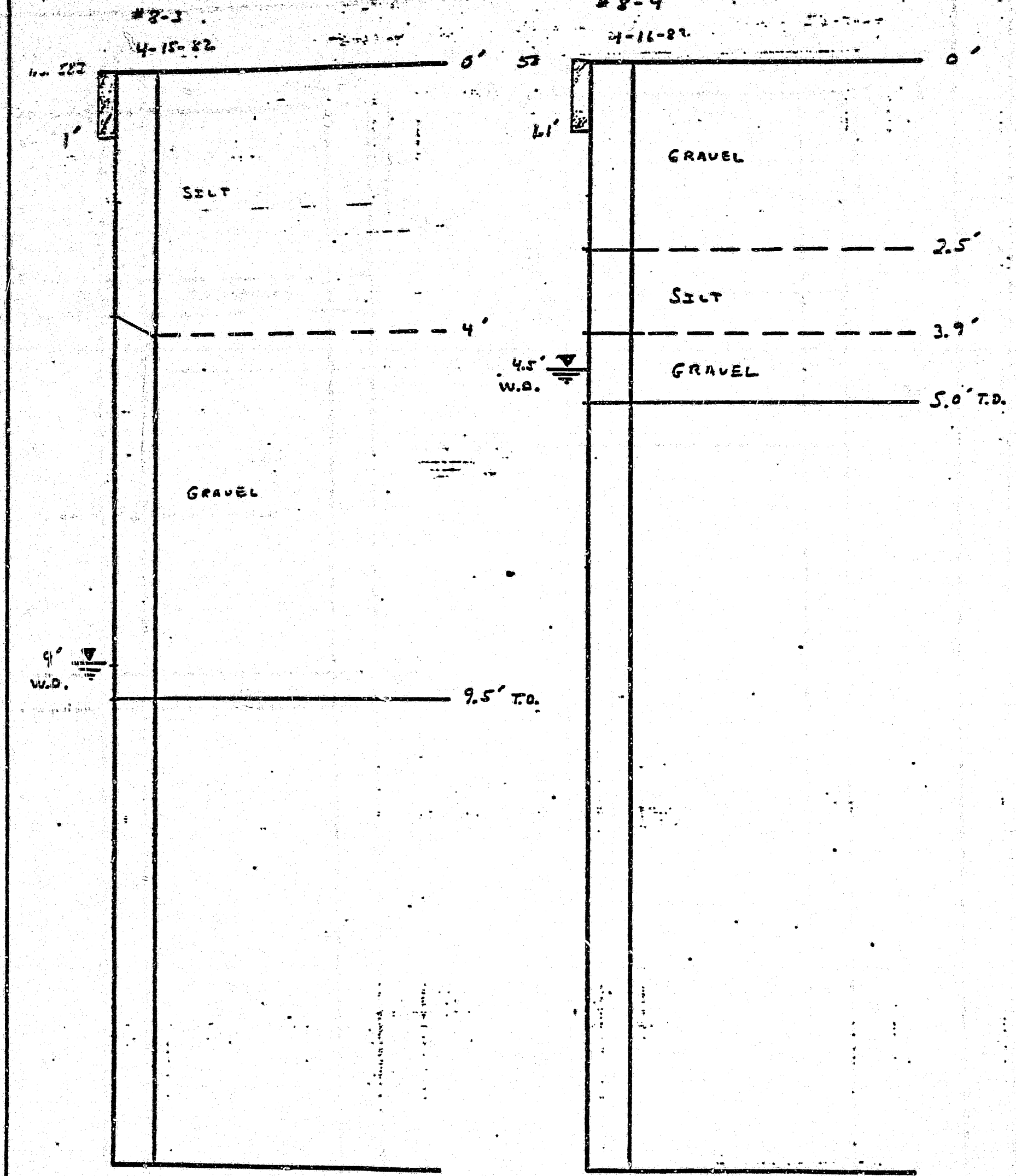
FIGURE 9



2-13-14

DWN. R.B.	R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS	WELL HOLE LOGS	EB.
CKD.		SUISUN GROUND WATER STUDY	GRID
DATE. 4/22			PROJ.NO 052314.
SCALE 1"=2'			DWG.NO

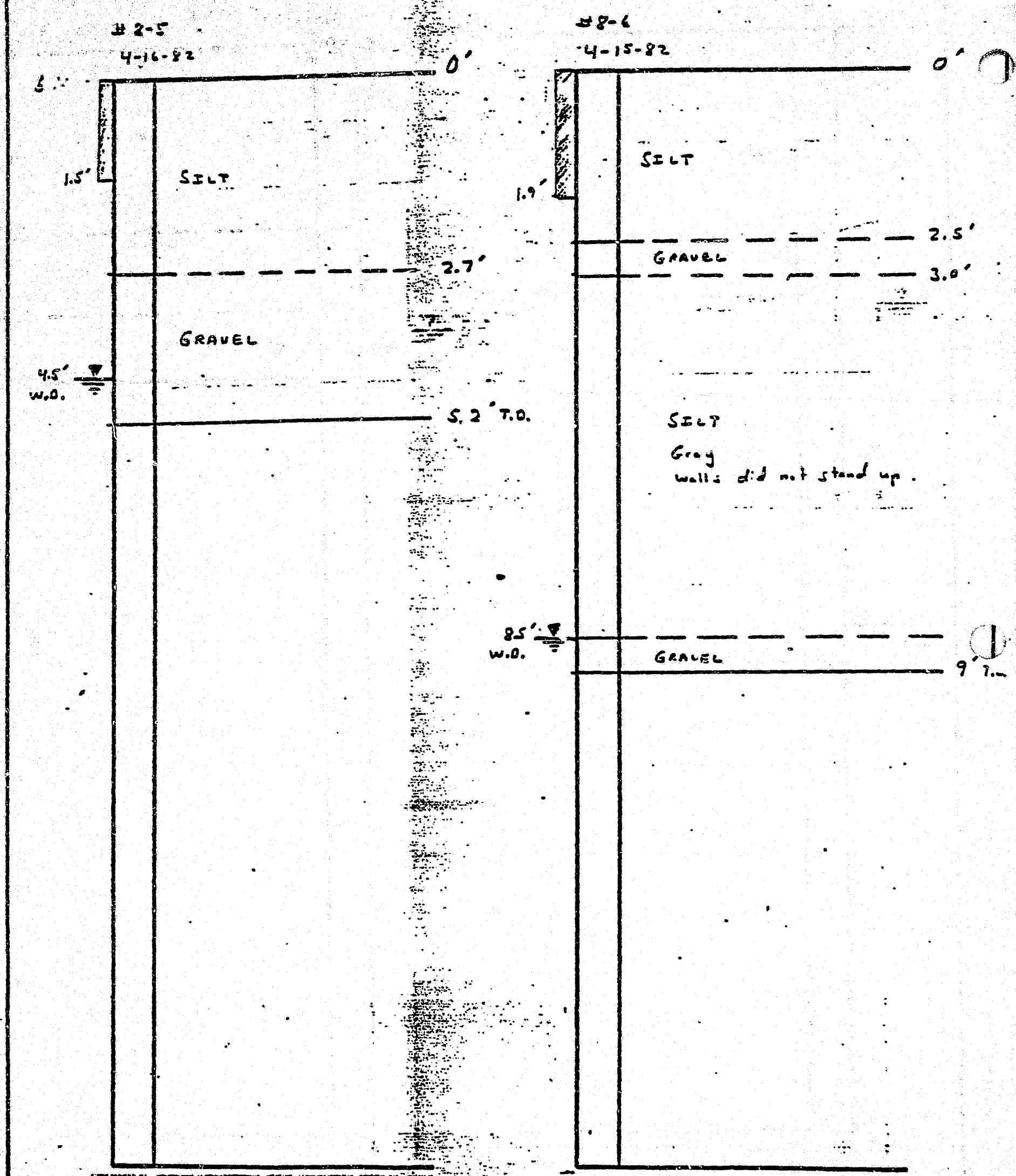
FIGURE 10



2-13-15

DWN. R.B.	R&M CONSULTANTS, INC.	WELL HOLE LOGS	FB
CKD	ENGINEERS GEOLOGISTS PLANNERS SURVEYORS	SUSITNA GROUND WATER STUDY	GRID
DATE 4/82			PROJ NO. 052314
SCALE 1" = 7'			DWG NO

FIGURE 11



2-13-160

DWN. RS	
CKD.	
DATE. 4/82	
SCALE 1" = 2'	

R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

WELL HOLE LOGS

SUSITNA GROUND WATER STUDY

EB.	
GRID.	
PROJ.NO. 0572.14	
DWG.NO.	

0 0 1 1 6

FIGURE 12

#8-7
4-16-82

0'
0.7'
SILT
2.5'
GRAVEL
3.5' W.D.
4.5' T.D.

#8-8
4-16-82

0'
SILT
1.5'
1.5'
GRAVEL
3.7' W.D.
4.5' T.D.

2-13-17

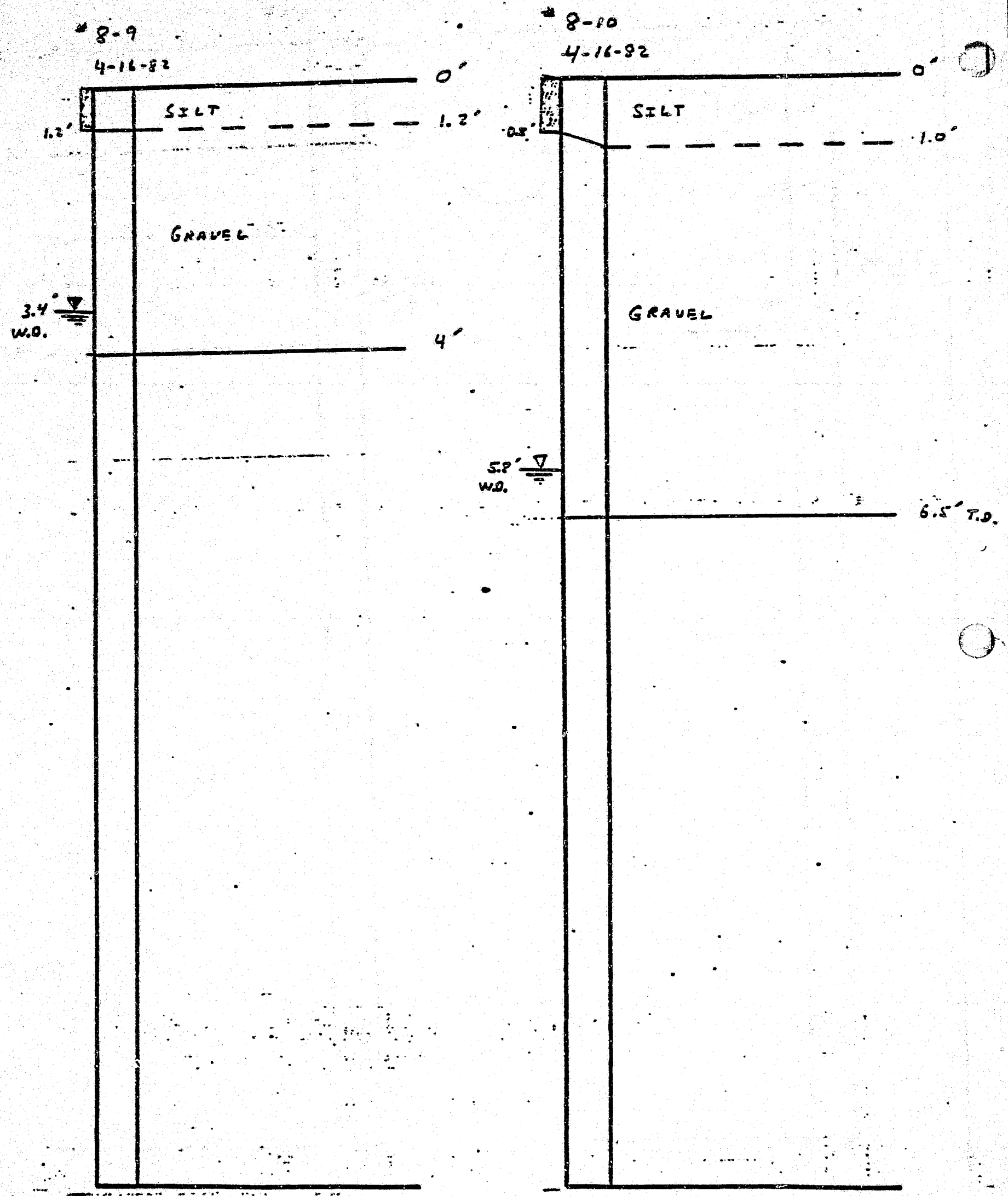
DWN. RG
CKD.
DATE 4-23
SCALE 1" = 1'

R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

WELL HOLE LOGS
SUBSTATION GROUNDING WASTE STUDY

FB.
GRID
PROJ.NO. 0232.14
DWG.NO.

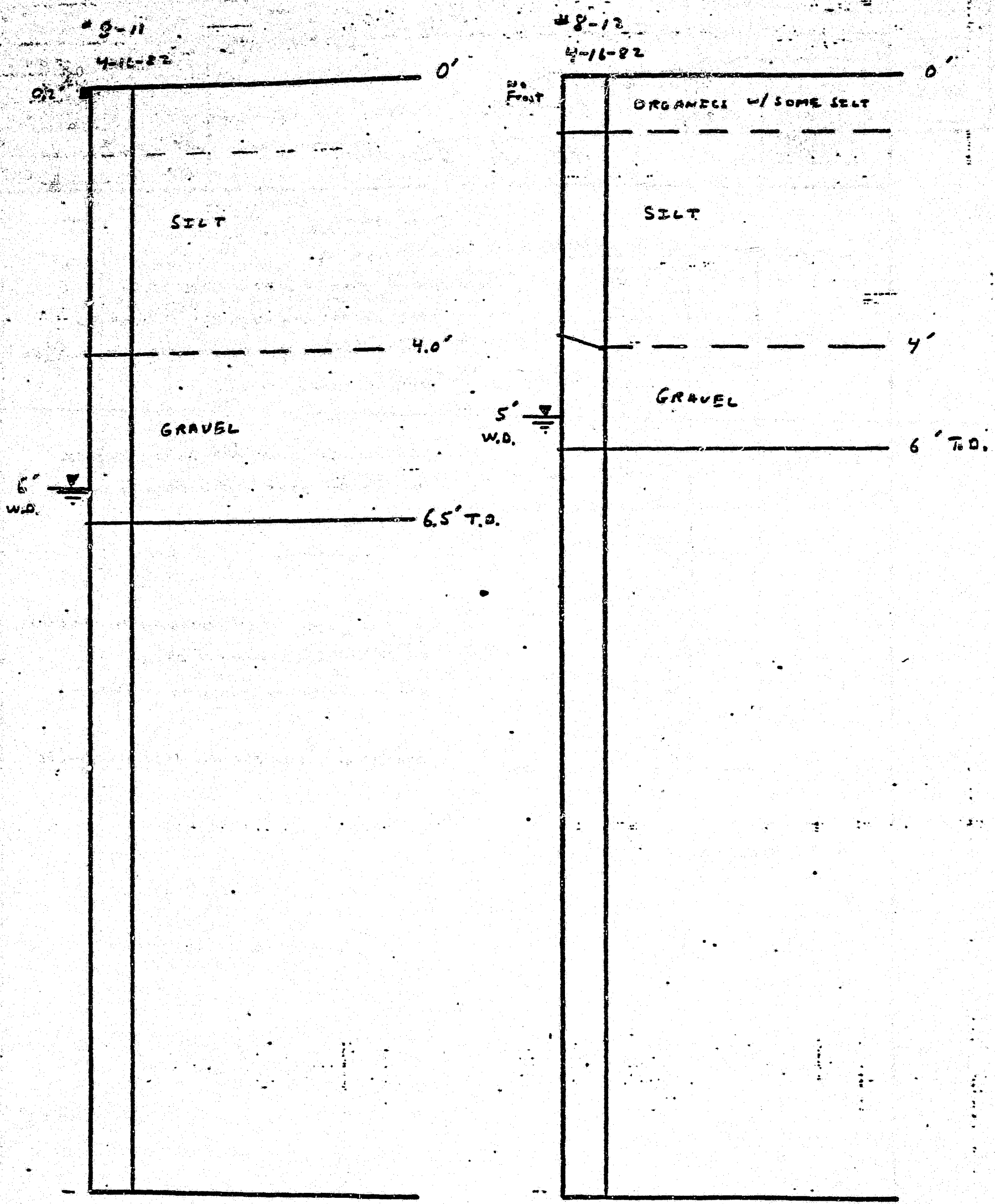
FIGURE 13



2-13-18

DWN. R.E.	R&M CONSULTANTS, INC.	WELL HOLE LOGS	FB.
CKD.	ENGINEERING GEOLOGISTS PLANNERS SURVEYORS	SUSITNA GROUND WATER STUDY	GRID
DATE 4-82			PROJ NO. 052.314
SCALE 1"=2'			DWG. NO.

FIGURE 14



2-13-19

DWN. RB	R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS	WELL HOLE LOGS SUSITNA GROUND WATER STUDY	FB.
CKD.			GRID
DATE 4-82			PROJ NO. 052314
SCALE 1"=1'			DWG NO.

FIGURE 15

ACRES

Calculations

SUBJECT: SLOUGH 9

AH-1 GEOLOGY

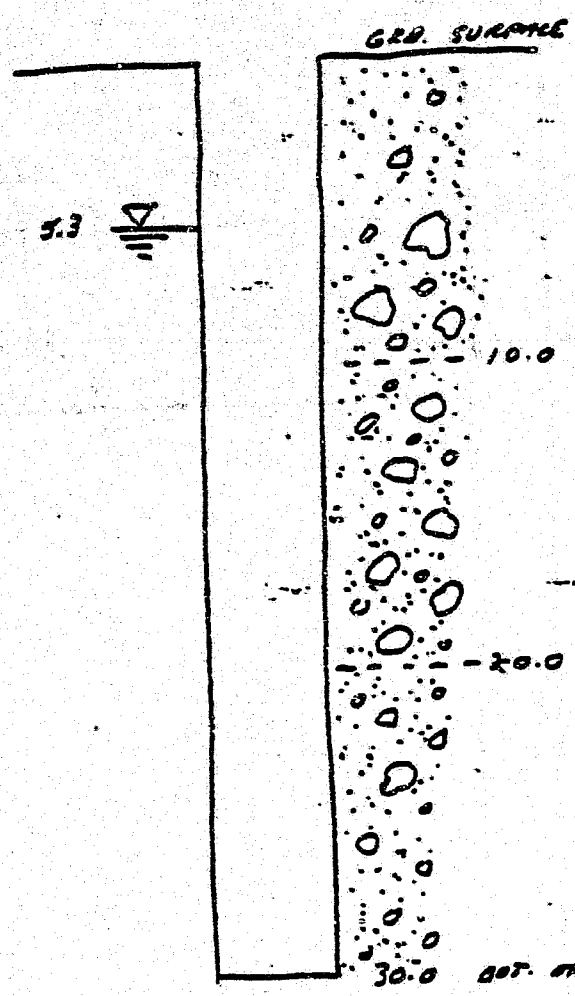
JOB NUMBER 25701.77

FILE NUMBER

SHEET 3 OF 5

BY CAH DATE 1/6/20

APP DATE



MED BROWN, FINE TO MED GRAINED SAND WITH SOME GRAVEL AND COBBLES, DAMP TO MOIST, PREDOMINANTLY WELL ROUNDED, UP TO 4" DIAM. EASY TO MODERATE DRILLING.

SAND AND GRAVEL WITH NUMEROUS COBBLES. PREDOMINANTLY HARD, BUT SOMEWHAT DRILLING SOME FLOWING SAND

SAND AND GRAVEL WITH OCCASIONAL COBBLES EASIER DRILLING. DOWN TO 25. FT. GRAINED SAND IS VERY FINE & TENDS FLOWS EASILY

COBBLES AND BOULDERS AT 30 FT - REFUSAL

AH-1 A&B (9-18)

2-13-20

FORM NO. 162 REV. 1

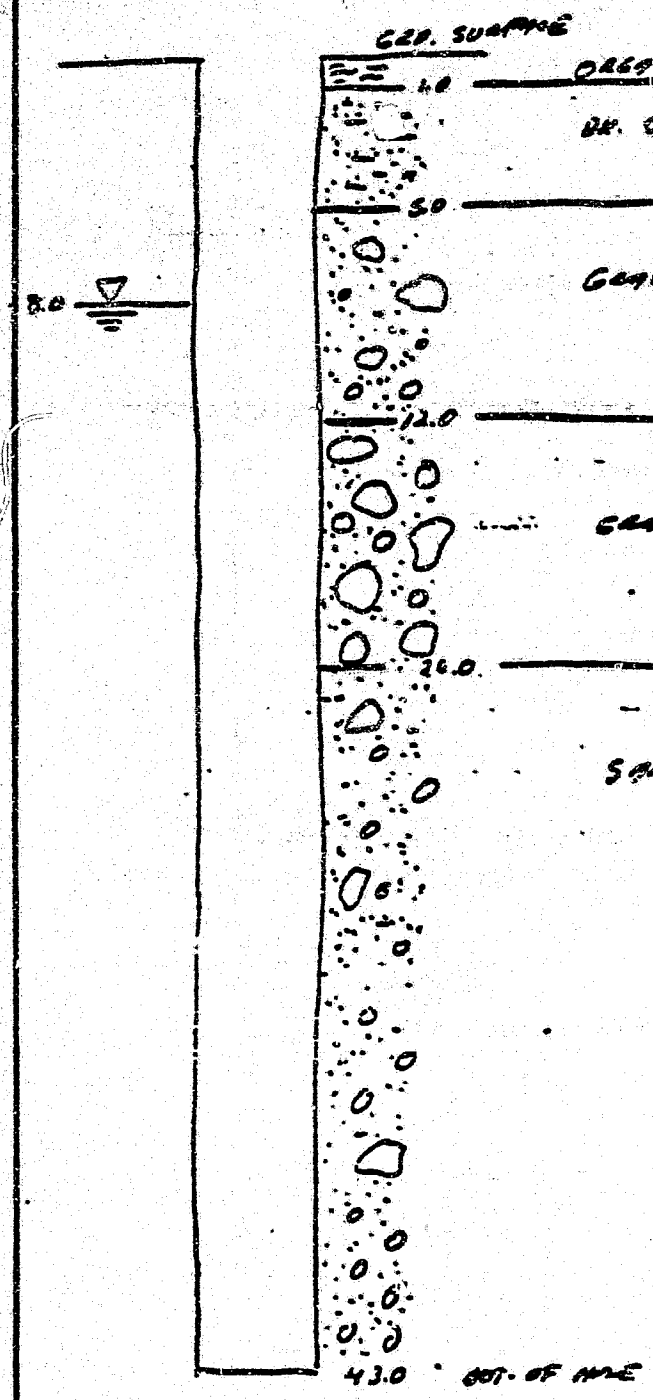
FIGURE 16

ACRES

Calculations

SUBJECT: SLOUGH 9 - GEOLOGY - AUGER HOLES -

JOB NUMBER P5701.77
FILE NUMBER
SHEET 2 OF 5
BY R HENSCHEL DATE 1/2/83
APP DATE



ORGANIC MAT

DK. BROWN, VERY FINE GRAINED SAND, TO SILTY SAND, LOOSE, MOIST EASY DRILLING

GRAVEL AND COBBLES WITH SAND MATRIX, ALLUVIAL WELL ROUNDED PARTICLES, ½ - 6" DIAMETER HARD DRILLING

GRAVEL, COBBLES AND BOULDERS WITH SAND MATRIX LARGER PARTICLES THAN LAYER ABOVE VERY HARD DRILLING, WELL PACKED

SAND AND GRAVEL WITH OCCASIONAL COBBLES EASY DRILLING, LOOSE TO MED DENSE

20.0 - 22' - BROWN-GRAY COLOR

22 - 23' - BROWN.

23 - - GRAY

AH-4 (9-3A)

SCALE ¼" = 2ft

FORM NO. 162 REV. 1

2-13-21

FIGURE 17

Calculations

SUBJECT: SLOUGH 9

AH-3 GEOLOGY

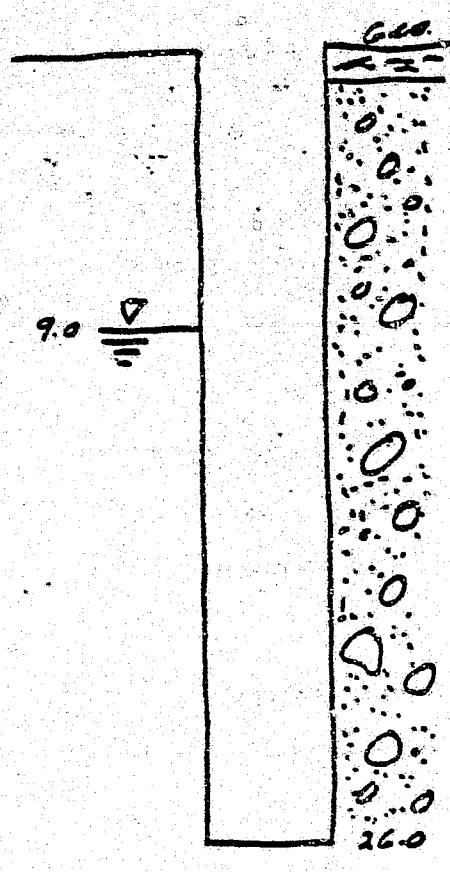
JOB NUMBER P5701.77

FILE NUMBER

SHEET 5 OF 5

BY RAH DATE 1/2/8

APP DATE



ORGANIC MAT

NO LOG DURING DRILLING

SAND, GRAVEL AND COBBLES, MODERATELY HARD DRILLING.

HIT BOULDERS AT 26.0 ft. - REFUSAL

AH-3 (9-4A)

2-13-22

FORM NO. 152 REV. 1

FIGURE 18

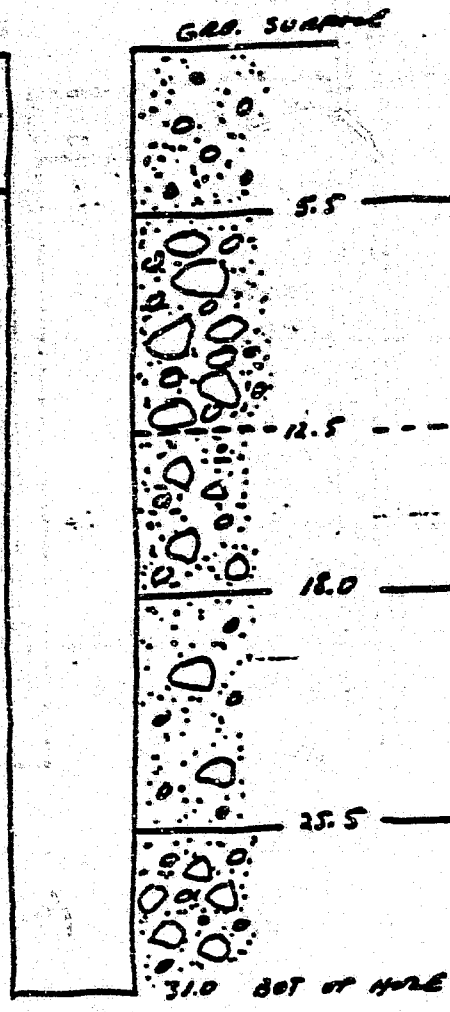
ACRES

Calculations

SUBJECT: SLOUGH 9

AH-2 GEOLOGY

JOB NUMBER 135701.37
FILE NUMBER
SHEET 4 OF 5
BY RAH DATE 1/2/23
APP DATE



BROWN, FINE TO COARSE GRAINED SAND AND GRAVEL, WET, EASY DRILLING, LOOSE GRADES INTO GRAVEL AND COBBLES

COBBLES AND SMALL BOULDERS WITH GRAVEL AND SAND MATRIX, MODERATELY HARD DRILLING

SAND, GRAVEL AND COBBLES, DENSE, SLIGHTLY EASIER DRILLING, STEADY

SAND AND GRAVEL WITH OCCASIONAL COBBLES EASY DRILLING

COBBLES AND GRAVEL WITH SAND MATRIX. VERY OCCASIONAL BOULDERS. MOD. HARD TO FAIRLY EASY DRILLING

AH-2 A:B (9-5A)

2-13-23

FORM NO. 162 REV. 1

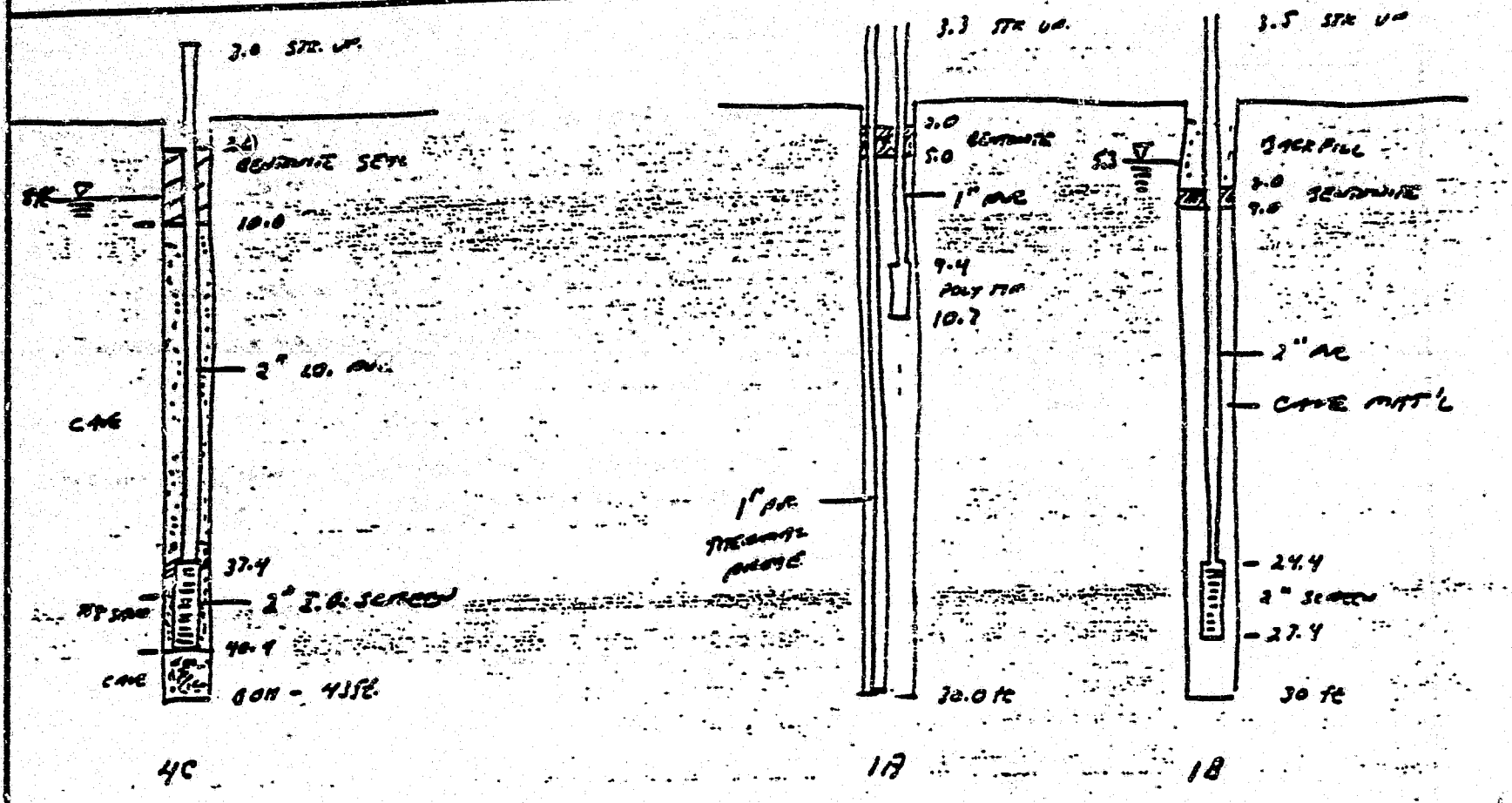
FIGURE 19

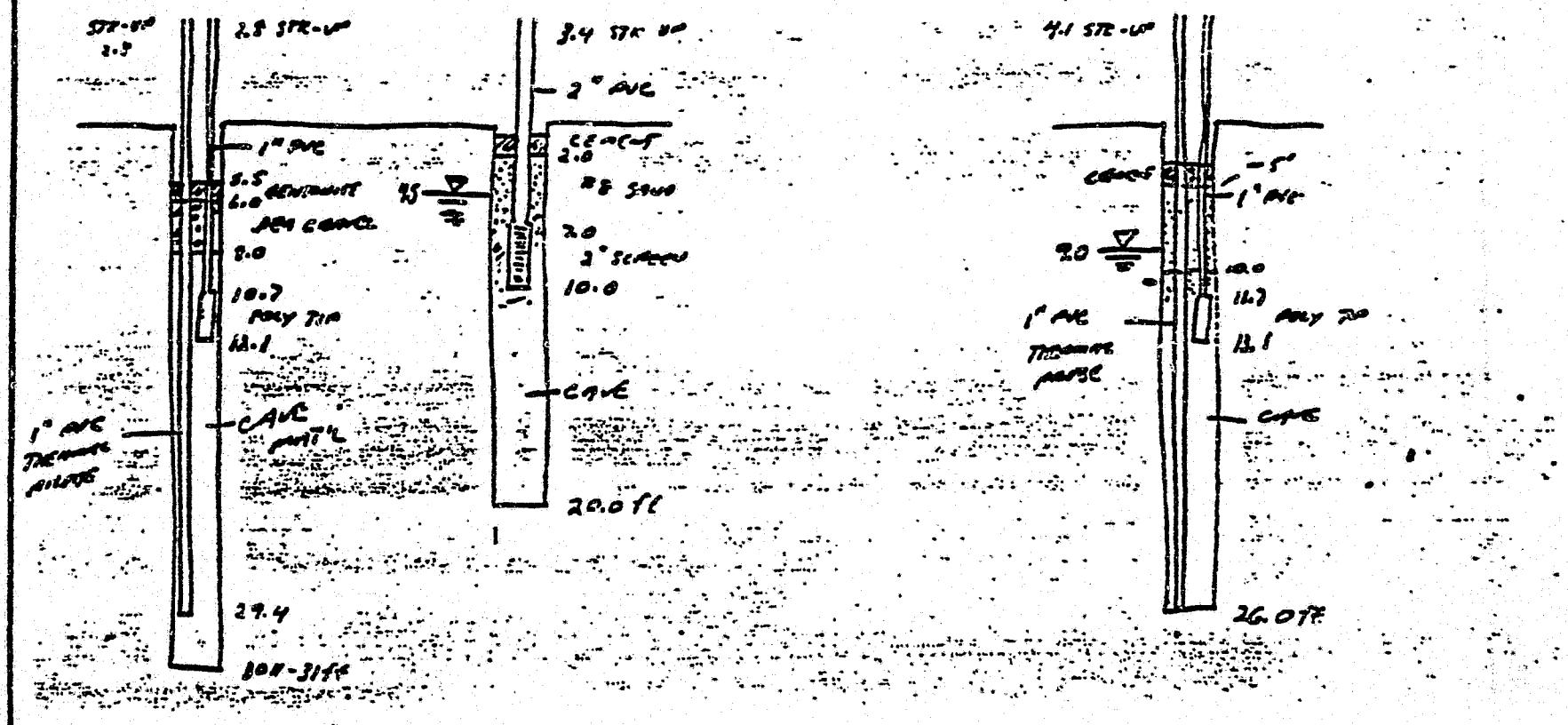
ACRES

Calculations

SUBJECT: DETAILS OF PIEZOMETER INSTALLATIONS
SLOUGH AND 9

JOB NUMBER PS 701. 77
FILE NUMBER
SHEET 1 OF 5
BY R. HENSCHEL DATE 12/31
APP DATE





AH-2 (9-5A)

AH-3 (9-4A)

NOTE - THERMAL PROBES - PVC CUT AT ANGLE

FORM NO. 162 REV. 1

2-13

SLOUGH 8A

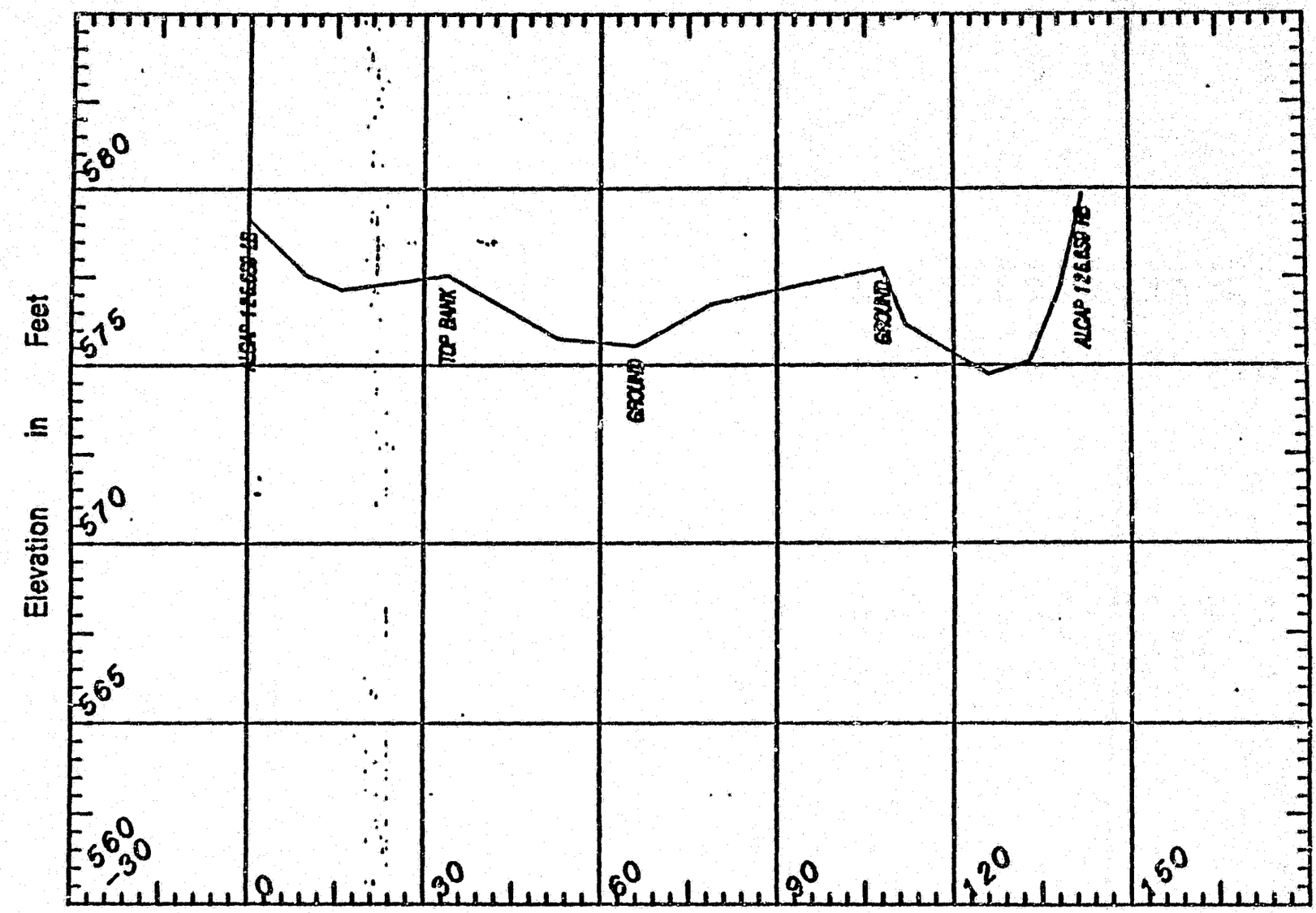
SUSITNA HYDROGRAPHIC SURVEYS
cross section SLOUGH 8 126.6S9

Date of Survey: AUGUST 4, 1982

POINT	'X'	'Y'	DESCRIPTION
Cross section data:			
1	0.000	579.150	ALCAP 126.6S9 LB
2	10.000	577.530	
3	16.000	577.130	
4	34.000	577.530	TOP BANK
5	53.000	575.730	
6	66.000	575.530	GROUND
7	79.000	576.730	
8	93.000	577.230	
9	108.000	577.730	GROUND
10	112.000	576.130	
11	119.000	575.430	
12	126.000	574.730	
13	133.000	575.130	
14	138.000	577.130	
15	142.000	579.840	ALCAP 126.6S9 RB
MIN	0.000	574.730	
MAX	142.000	579.840	

2-13-25

SUSITNA HYDROGRAPHIC SURVEYS



PREPARED BY:

R&M CONSULTANTS, INC.

cross section SLOUGH 8 126.6S9
Date of Survey: AUGUST 4, 1982

PREPARED FOR:

ACRES

B-80

2-13-26

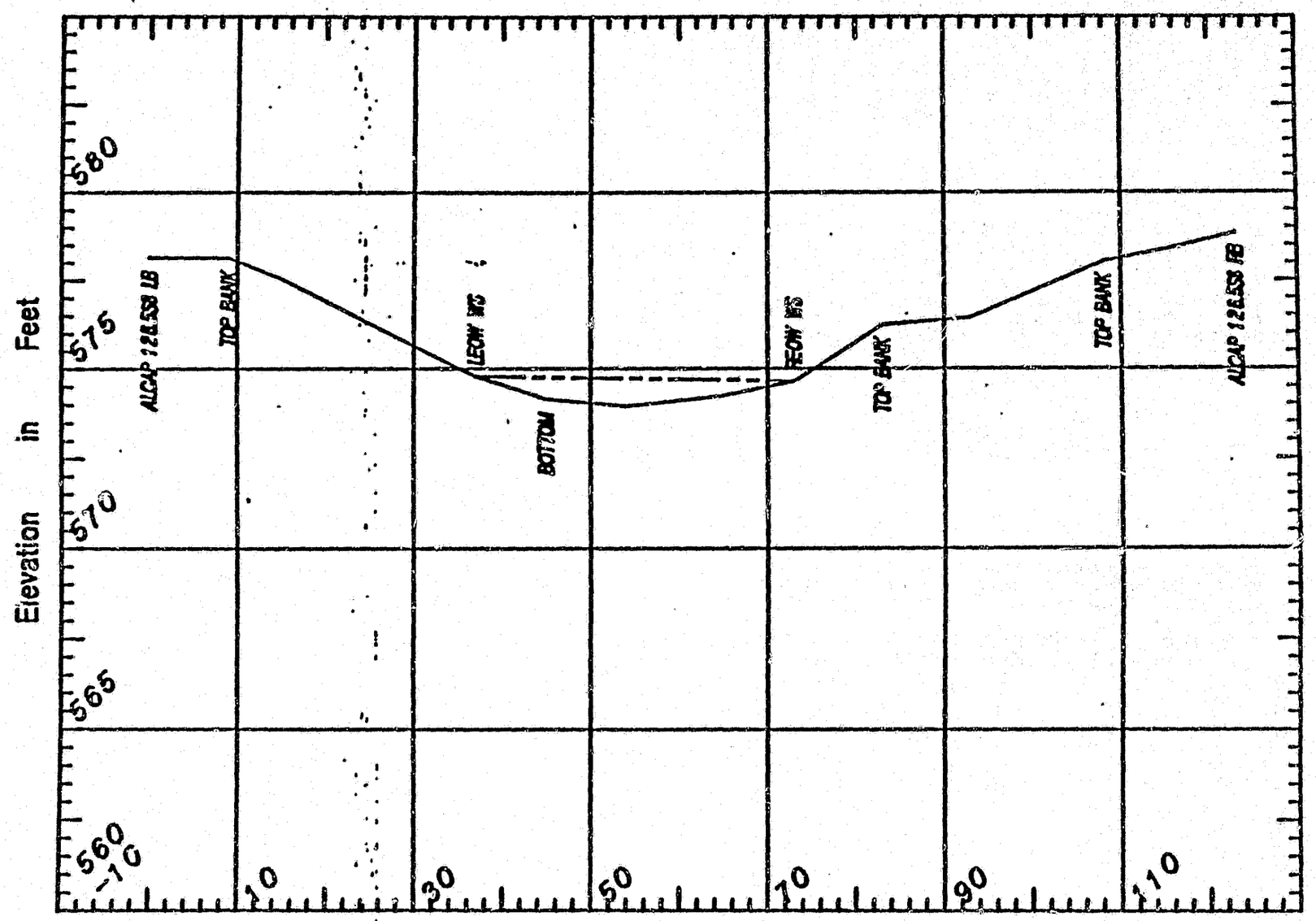
SUSITNA HYDROGRAPHIC SURVEYS
cross section SLOUGH 8 126.5SB

Date of Survey: AUGUST 4, 1982

POINT	'X'	'Y'	DESCRIPTION
Cross section data:			
1	0.000	578.140	ALCAP 126.5SB LB
2	9.000	578.130	TOP BANK
3	15.000	577.530	
4	37.000	574.770	
5	45.000	574.130	BOTTOM
6	54.000	573.930	
7	65.000	574.230	
8	73.000	574.630	
9	83.000	576.230	TOP BANK
10	93.000	576.430	
11	108.000	578.030	TOP BANK
12	116.000	578.430	
13	123.000	578.850	ALCAP 126.5SB RB
Water surface data:			
1	37.000	574.770	LEOW WS
2	73.000	574.630	REOW WS
MIN	0.000	573.930	
MAX	123.000	578.850	

2-13-27

SUSITNA HYDROGRAPHIC SURVEYS



B-82

2-13-28

PREPARED BY:

R&M CONSULTANTS, INC.

cross section SLOUGH 8 126.5S8

Date of Survey: AUGUST 4, 1982

PREPARED FOR:

ACRES

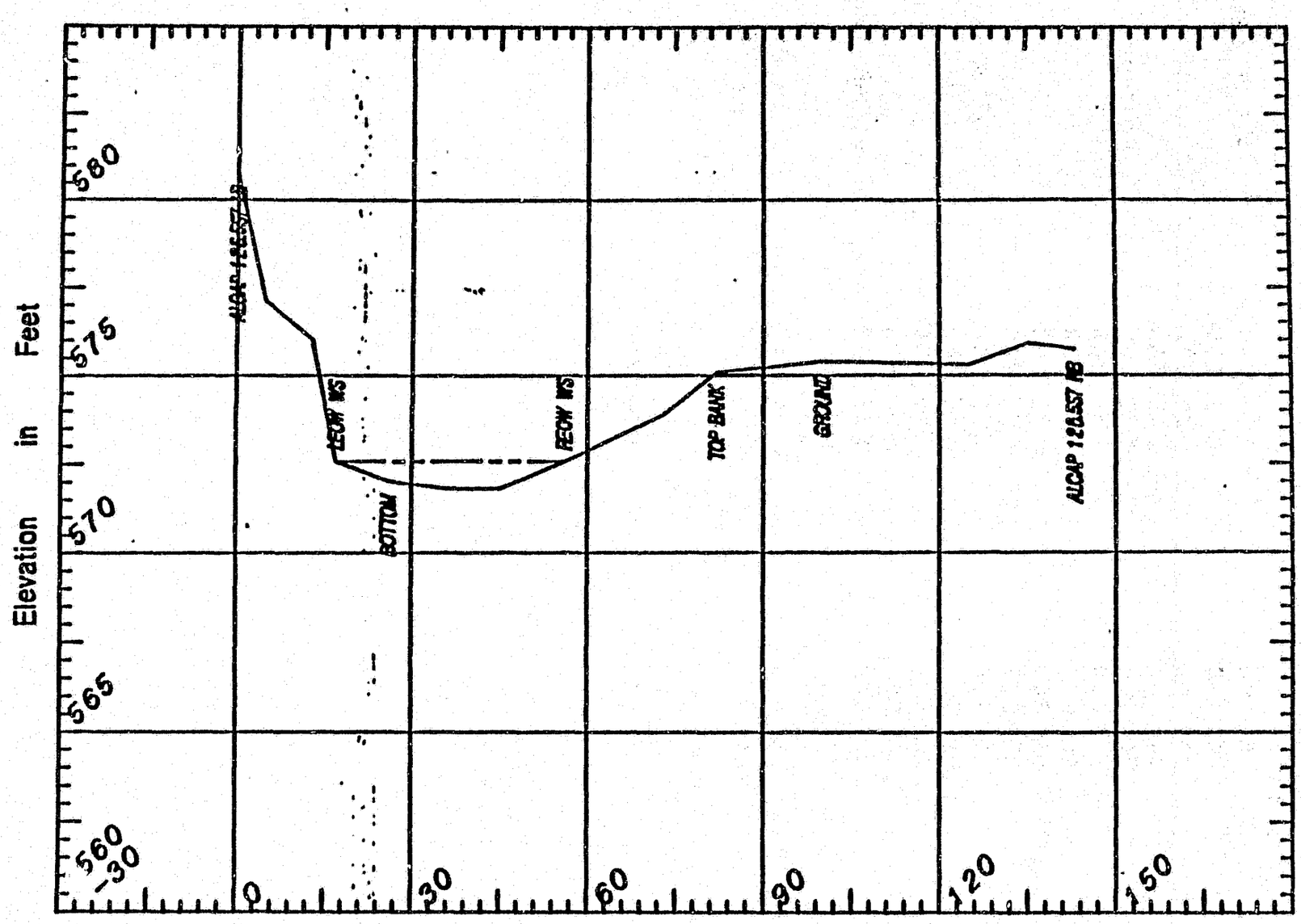
SUSITNA HYDROGRAPHIC SURVEYS
cross section SLOUGH 8 126.5S7

Date of Survey: AUGUST 4, 1982

POINT	'X'	'Y'	DESCRIPTION
Cross section data:			
1	0.000	580.790	ALCAP 126.5S7 LB
2	5.000	577.100	
3	13.000	576.000	
4	17.000	572.560	
5	26.000	572.000	BOTTOM
6	36.000	571.800	
7	45.000	571.800	
8	56.000	572.560	
9	73.000	573.900	
10	82.000	575.100	TOP BANK
11	100.000	575.400	GROUND
12	125.000	575.300	
13	135.000	575.900	
14	143.000	575.730	ALCAP 126.5S7 RB
Water surface data:			
1	17.000	572.560	LEOW WS
2	56.000	572.560	REOW WS
MIN	0.000	571.800	
MAX	143.000	580.790	

2-13-29

SUSITNA HYDROGRAPHIC SURVEYS



PREPARED BY:

R&M CONSULTANTS, INC.

cross section SLOUGH 8 126.5S7
Date of Survey: AUGUST 4, 1982

PREPARED FOR:

ACRES

B-84

2-13-30

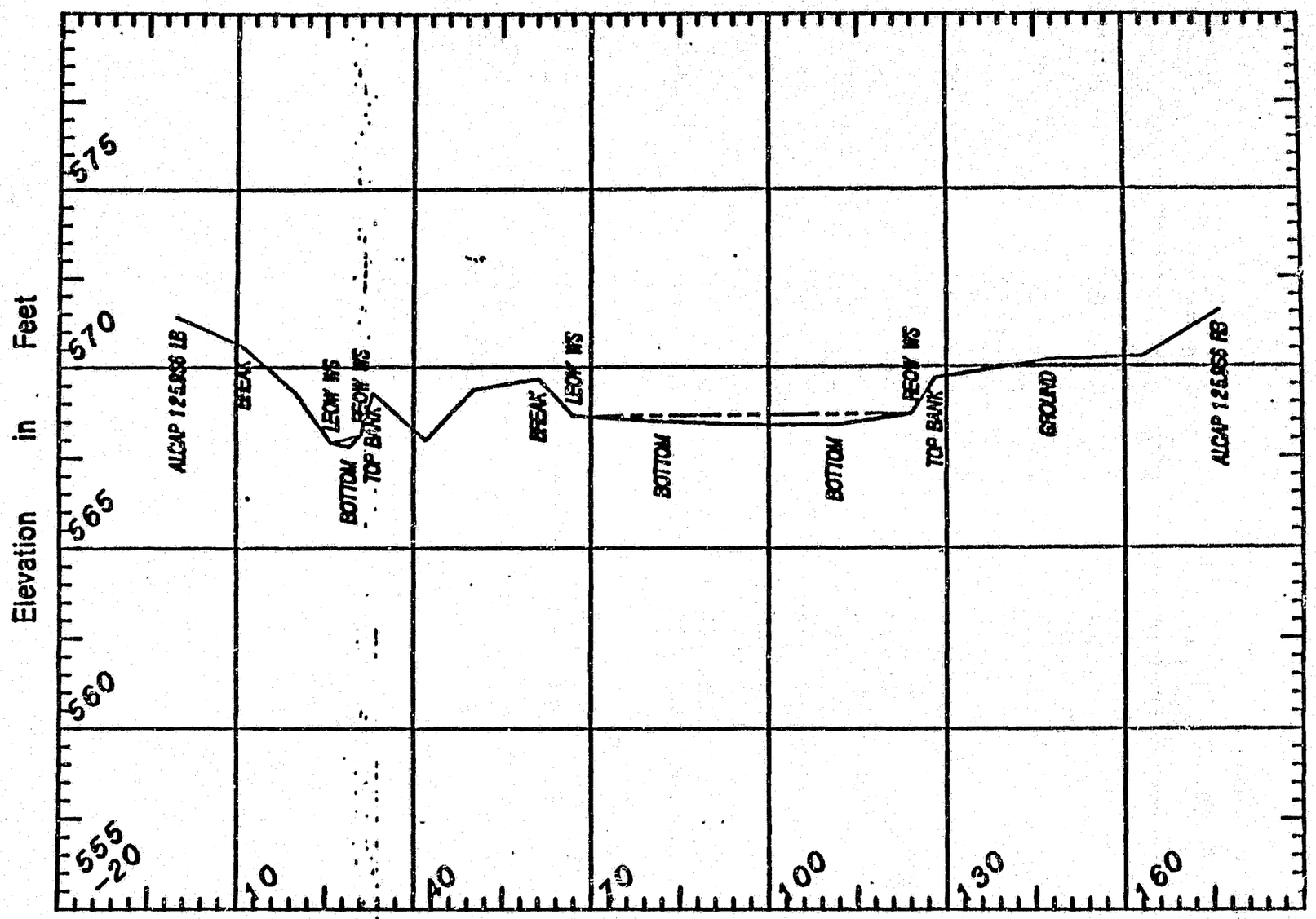
SUSITNA HYDROGRAPHIC SURVEYS
cross section SLOUGH 8 125.9S6

Date of Survey: AUGUST 4, 1982

POINT	'X'	'Y'	DESCRIPTION
Cross section data:			
1	0.000	571.400	ALCAP 125.9S6 LB
2	11.000	570.580	BREAK
3	20.000	569.280	
4	26.000	567.900	
5	29.000	567.780	BOTTOM
6	31.000	568.140	
7	33.000	569.280	TOP BANK
8	42.000	567.980	
9	50.000	569.380	
10	61.000	569.680	BREAK
11	67.000	568.640	
12	82.000	568.480	BOTTOM
13	98.000	568.380	
14	111.000	568.380	BOTTOM
15	124.000	568.700	
16	128.000	569.680	TOP BANK
17	147.000	570.180	GROUND
18	163.000	570.280	
19	176.000	571.560	ALCAP 125.9S6 RB
Water surface data:			
1	26.000	567.900	LEOW WS
2	31.000	568.140	REOW WS
			SPLIT
4	67.000	568.640	LEOW WS
5	124.000	568.700	REOW WS
MIN	0.000	567.780	
MAX	176.000	571.560	

2-1331

SUSITNA HYDROGRAPHIC SURVEYS



B-86

PREPARED BY:

R&M CONSULTANTS, INC.

cross section SLOUGH 8 125.9S6

Date of Survey: AUGUST 4, 1982

PREPARED FOR:

ACRES

2-13-32

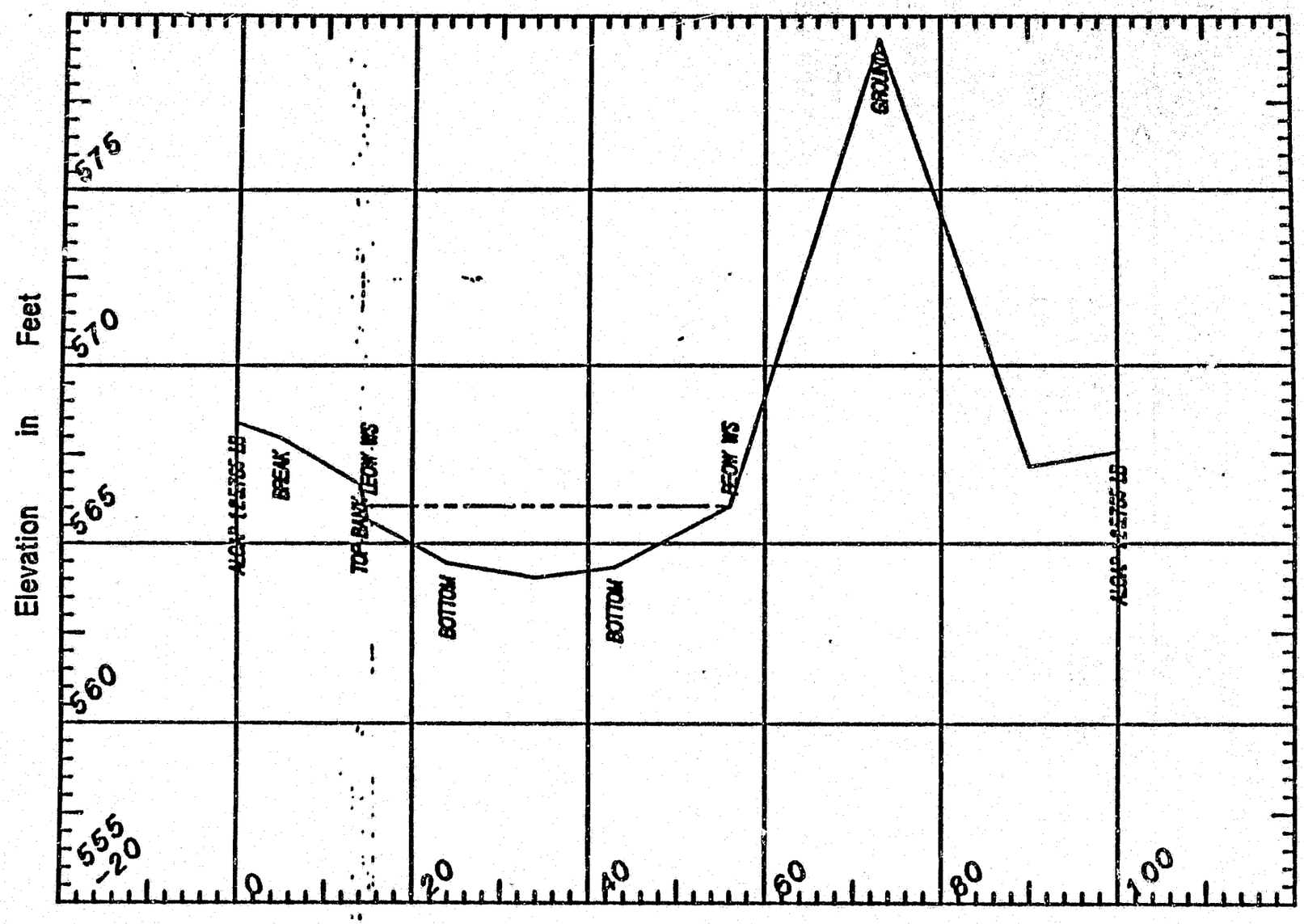
SUSITNA HYDROGRAPHIC SURVEYS
cross section SLOUGH 8 125.7S5

Date of Survey: AUGUST 4, 1982

POINT	'X'	'Y'	DESCRIPTION
Cross section data:			
1	0.000	568.370	ALCAP 125.7S5 LB
2	5.000	567.950	BREAK
3	14.000	566.650	TOP BANK
4	15.000	565.640	
5	24.000	564.450	BOTTOM
6	34.000	564.050	
7	43.000	564.350	BOTTOM
8	56.000	566.040	
9	73.000	579.350	GROUND
10	90.000	567.150	
11	100.000	567.560	ALCAP 125.7S5 LB
Water surface data:			
1	15.000	566.040	LEOW WS
2	56.000	566.040	REOW WS
MIN	0.000	564.050	
MAX	100.000	579.350	

2-13-33

SUSITNA HYDROGRAPHIC SURVEYS



PREPARED BY:

R&M CONSULTANTS, INC.

cross section SLOUGH 8 125.7S5

Date of Survey: AUGUST 4, 1982

PREPARED FOR:

ACRES

B-88

2-13-34

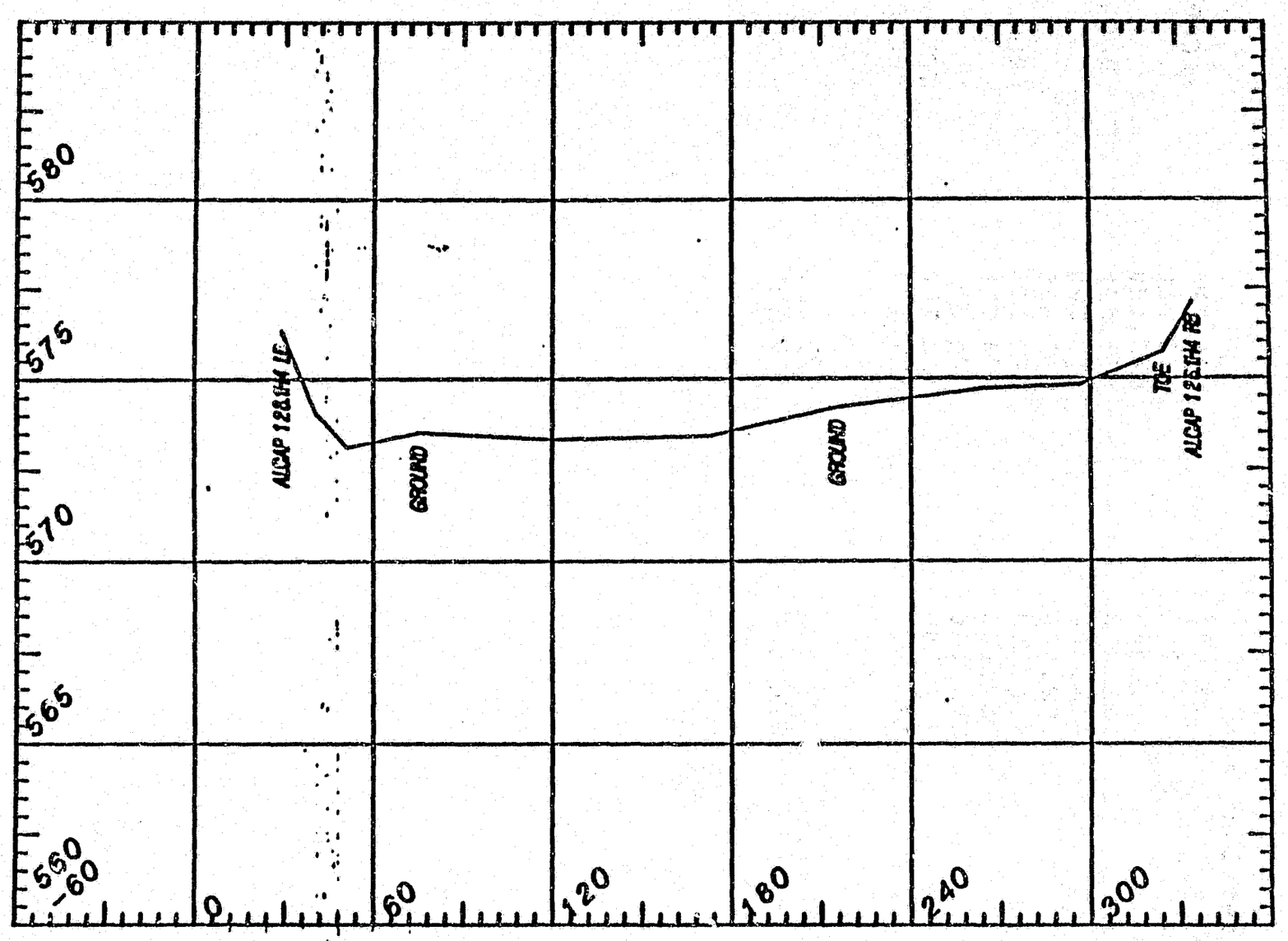
SUSITNA HYDROGRAPHIC SURVEYS
cross section SLOUGH 8 126.1H4

Date of Survey: AUGUST 4, 1982

POINT	'X'	'Y'	DESCRIPTION
Cross section data:			
1	29.000	576.320	ALCAP 126.1H4 LB
2	41.000	574.020	
3	51.000	573.120	
4	75.000	573.520	GROUND
5	119.000	573.320	
6	172.000	573.420	
7	215.000	574.220	GROUND
8	264.000	574.720	
9	296.000	574.820	
10	324.000	575.720	TOE
11	334.000	577.120	ALCAP 126.1H4 RB
MIN	29.000	573.120	
MAX	334.000	577.120	

2-13-35

SUSITNA HYDROGRAPHIC SURVEYS



B-90

PREPARED BY:

R&M CONSULTANTS, INC.

cross section SLOUGH 8 126.1H4
Date of Survey: AUGUST 4, 1982

PREPARED FOR:

ACRES

2-13-36

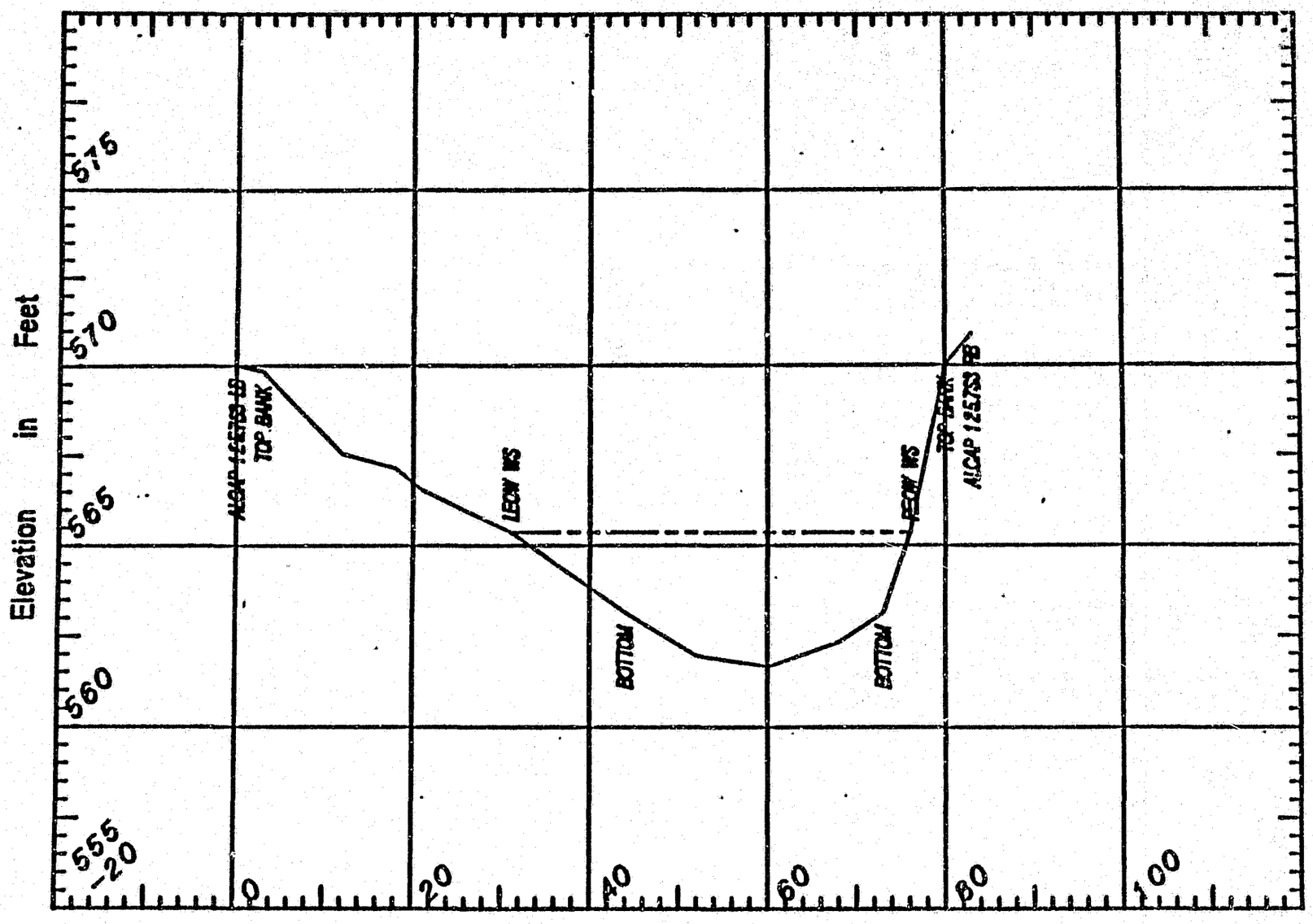
SUSITNA HYDROGRAPHIC SURVEYS
cross section SLOUGH 8 125.7S3

Date of Survey: AUGUST 4, 1982

POINT	'X'	'Y'	DESCRIPTION
Cross section data:			
1	0.000	570.000	ALCAP 125.7S3 LB
2	3.000	569.830	TOP BANK
3	12.000	567.530	
4	18.000	567.130	
5	21.000	566.530	
6	31.000	565.360	
7	44.000	563.130	BOTTOM
8	52.000	561.930	
9	60.000	561.630	
10	68.000	562.330	
11	73.000	563.130	BOTTOM
12	76.000	565.350	
13	80.000	570.030	TOP BANK
14	83.000	570.900	ALCAP 125.7S3 RB
Water surface data:			
1	31.000	565.360	LEOW WS
2	76.000	565.350	REOW WS
MIN	0.000	561.630	
MAX	83.000	570.900	

2-13-37

SUSITNA HYDROGRAPHIC SURVEYS



B-92

PREPARED BY:

R&M CONSULTANTS, INC.

cross section SLOUGH 8 125.7S3

Date of Survey: AUGUST 4, 1982

PREPARED FOR:

ACRES

2-13-38

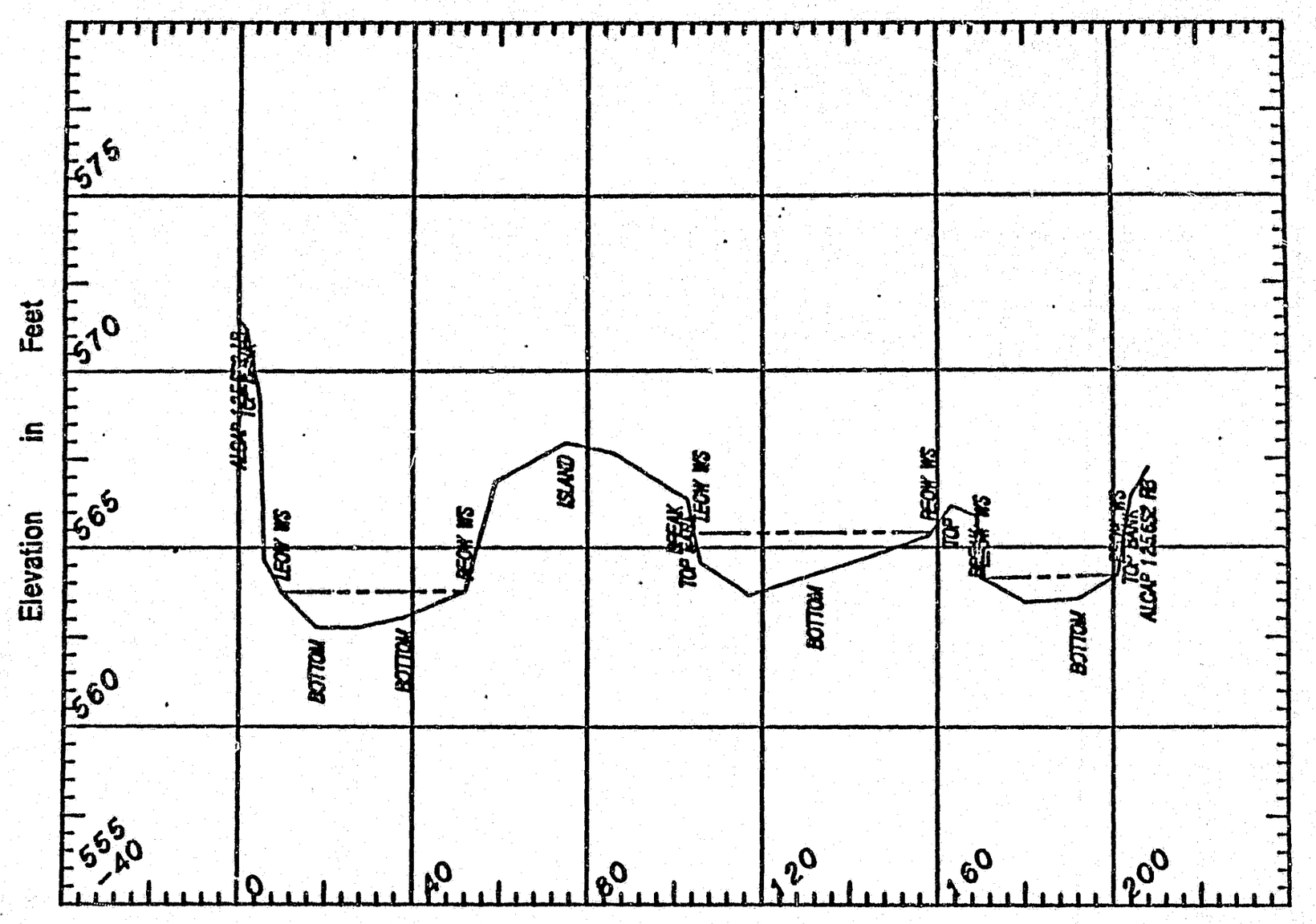
SUSITNA HYDROGRAPHIC SURVEYS
cross section SLOUGH 8 125.6S2

Date of Survey: AUGUST 4, 1982

POINT	'X'	'Y'	DESCRIPTION
Cross section data:			
1	0.000	571.470	ALCAP 125.6S2 LB
2	2.000	571.160	TOP BANK
3	5.000	569.260	
4	6.000	564.660	
5	10.000	563.750	
6	18.000	562.760	BOTTOM
7	27.000	562.760	
8	38.000	563.060	BOTTOM
9	52.000	563.780	
10	59.000	566.860	
11	75.000	567.960	ISLAND
12	86.000	567.660	
13	100.000	566.560	BREAK
14	103.000	566.360	TOP BANK
15	106.000	564.560	
16	117.000	563.660	
17	132.000	564.260	BOTTOM
18	145.000	564.760	
19	158.000	565.330	
20	163.000	566.160	TOP
21	169.000	565.860	BREAK
22	170.000	564.130	
23	180.000	563.460	
24	192.000	563.560	BOTTOM
25	201.000	564.220	
26	204.000	566.440	TOP BANK
27	208.000	567.250	ALCAP 125.6S2 RB
Water surface data:			
1	10.000	563.750	LEOW WS
2	52.000	563.780	REOW WS
			SPLIT
4	106.000	565.410	LEOW WS
5	158.000	565.430	REOW WS
			SPLIT
7	170.000	564.130	LEOW WS
8	201.000	564.220	REOW WS
MIN	0.000	562.760	
MAX	208.000	571.470	

2-13-39

SUSITNA HYDROGRAPHIC SURVEYS



PREPARED BY:

PREPARED FOR:

cross section SLOUGH 8 125.6S2
Date of Survey: AUGUST 4, 1982

B-94 - 2-13-40

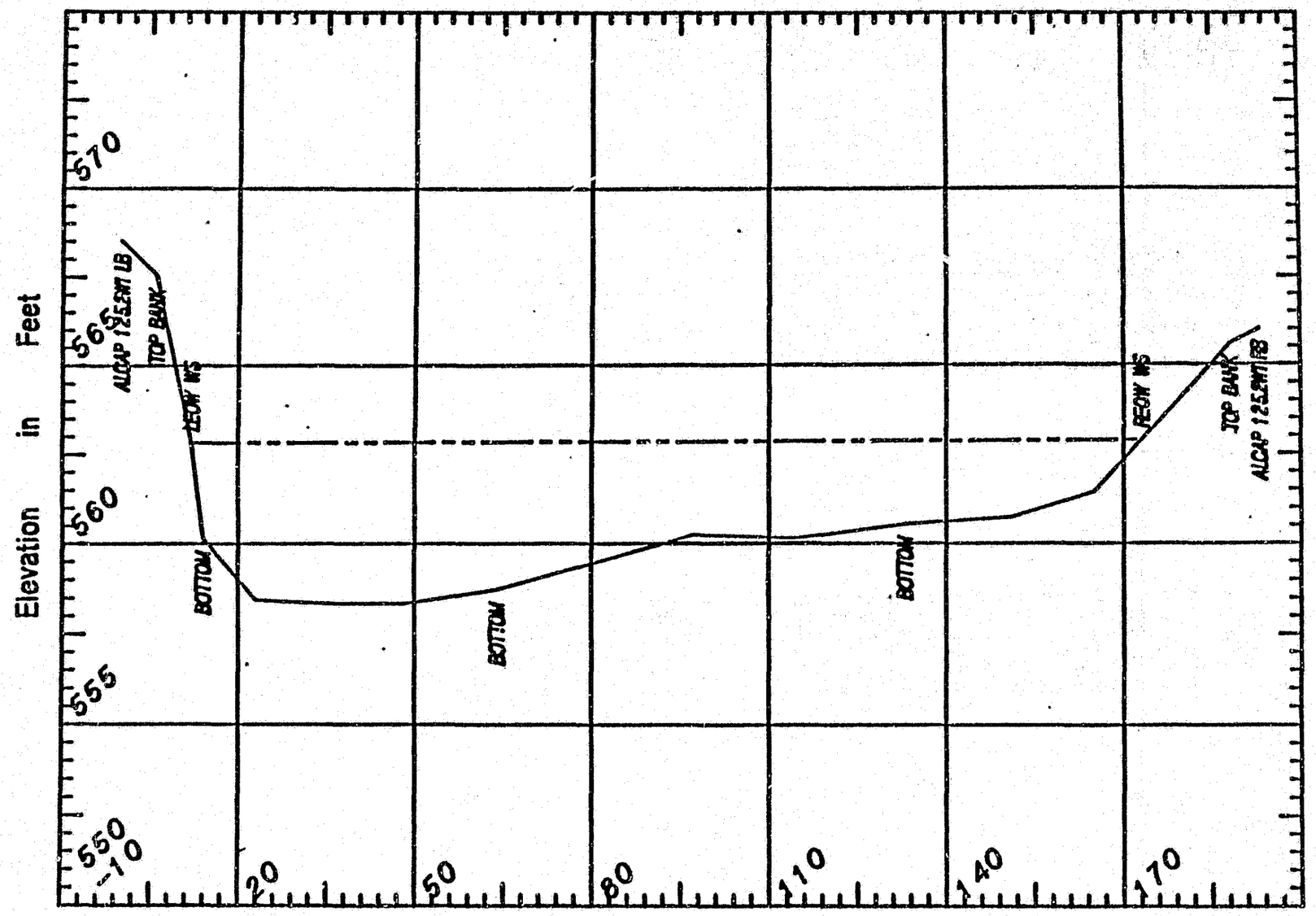
SUSITNA HYDROGRAPHIC SURVEYS
cross section SLOUGH 8 125.2W1

Date of Survey: AUGUST 4, 1982

POINT	'X'	'Y'	DESCRIPTION
Cross section data:			
1	0.000	568.510	ALCAP 125.2W1 LB
2	6.000	567.540	TOP BANK
3	12.000	562.810	
4	14.000	560.140	BOTTOM
5	23.000	558.440	
6	35.000	558.340	
7	48.000	558.340	
8	64.000	558.740	BOTTOM
9	80.000	559.440	
10	97.000	560.240	
11	114.000	560.140	
12	133.000	560.540	BOTTOM
13	151.000	560.740	
14	165.000	561.440	
15	173.000	562.880	
16	188.000	560.590	TOP BANK
17	193.000	566.010	ALCAP 125.2W1 RB
Water surface data:			
1	12.000	562.810	LEOW WS
2	173.000	562.880	REOW WS
MIN	0.000	558.340	
MAX	193.000	568.510	

2-13-41

SUSITNA HYDROGRAPHIC SURVEYS



PREPARED BY:

R&M CONSTANTS, INC.

cross section SLOUGH 8 125.2W1

Date of Survey: AUGUST 4, 1982

PREPARED FOR:

ACRES

B-96

2-13-42

SUSITNA HYDROGRAPHIC SURVEYS
cross section LANE CR SLOUGH 114.1H1

Date of Survey: AUGUST 16, 1982

POINT	'X'	'Y'	DESCRIPTION
Cross section data:			
1	0.000	481.810	ALCAP 114.1H1 LB
2	10.000	473.620	TOP BANK
3	14.000	473.220	
4	17.000	472.920	
5	22.000	473.920	BREAK
6	33.000	474.420	
7	53.000	474.520	
8	75.000	474.820	
9	89.000	475.120	GROUND
10	118.000	475.420	
11	136.000	475.420	
12	160.000	475.820	GROUND
13	180.000	476.120	
14	189.000	475.720	
15	205.000	475.720	BREAK
16	215.000	475.120	TOE
17	222.000	476.230	REBAR 114.1H1 RB
MIN	0.000	472.920	
MAX	222.000	481.810	

2-13-43

SLOUGH 9

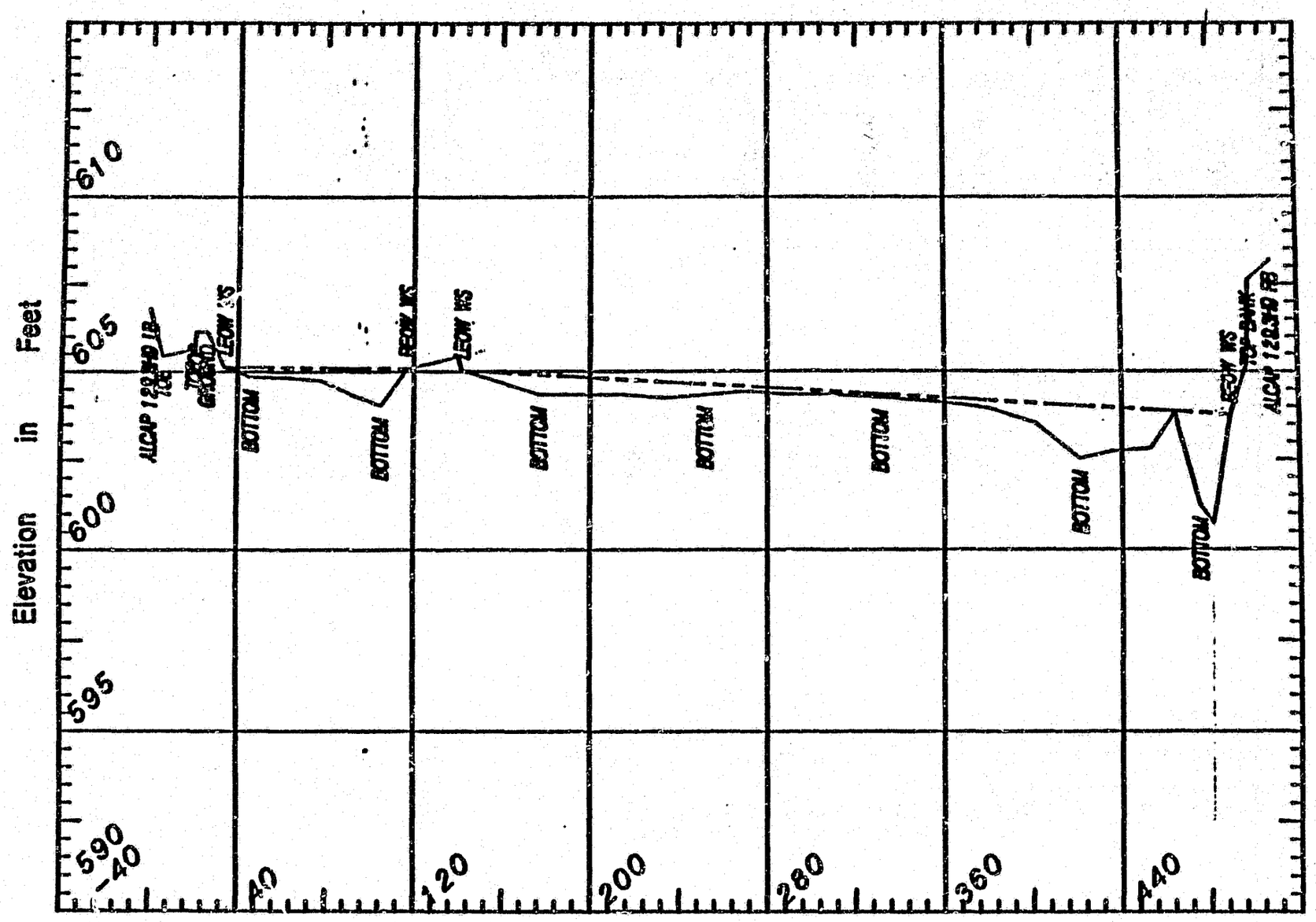
SUSITNA HYDROGRAPHIC SURVEYS
cross section SLOUGH 9 129.3H9

Date of Survey: AUGUST 1, 1982

POINT	'X'	'Y'	DESCRIPTION
Cross section data:			
1	0.000	606.770	ALCAP 129.3H9 LB
2	6.000	605.430	TOE
3	20.000	605.630	TOE
4	21.000	606.130	TOP
5	26.000	606.130	GROUND
6	34.000	605.130	
7	46.000	604.830	BOTTOM
8	61.000	604.830	
9	78.000	604.730	
10	92.000	604.330	
11	105.000	604.030	BOTTOM
12	117.000	605.090	
13	140.000	605.430	
14	142.000	605.020	
15	177.000	604.330	BOTTOM
16	197.000	604.330	
17	215.000	604.330	
18	232.000	604.230	
19	252.000	604.330	BOTTOM
20	271.000	604.430	
21	288.000	604.330	
22	308.000	604.330	
23	331.000	604.230	BOTTOM
24	354.000	604.130	
25	380.000	603.930	
26	401.000	603.530	
27	421.000	602.530	BOTTOM
28	435.000	602.730	
29	453.000	602.830	
30	464.000	603.830	
31	475.000	601.230	BOTTOM
32	481.000	600.730	
33	489.000	603.760	
34	497.000	605.230	
35	498.000	607.630	TOP BANK
36	508.000	608.180	ALCAP 129.3H9 RB
Water surface data:			
1	34.000	605.130	LEOW WS
2	117.000	605.090	REOW WS
			SPLIT
4	142.000	605.020	LEOW WS
5	489.000	603.760	REOW WS
MIN	0.000	600.730	
MAX	508.000	608.180	

2-13-44

SUSITNA HYDROGRAPHIC SURVEYS



2-13-45

PREPARED BY:

R&M CONSULTANTS, INC.

cross section SLOUGH 9 129.3H9
Date of Survey: AUGUST 1, 1982

PREPARED FOR:

ACRES

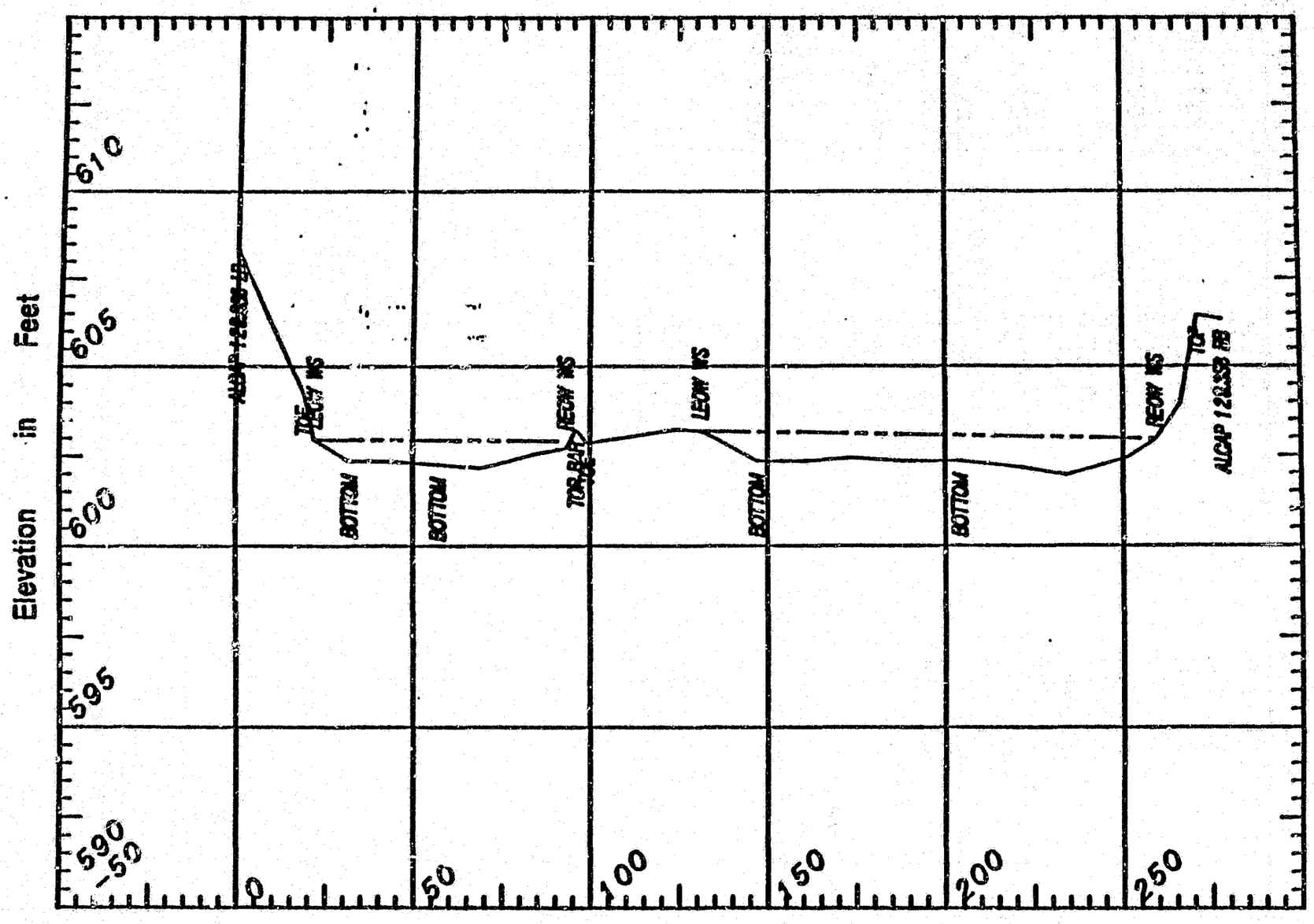
SUSITNA HYDROGRAPHIC SURVEYS
cross section SLOUGH 9 129.358

Date of Survey: AUGUST 1, 1982

POINT	'X'	'Y'	DESCRIPTION
Cross section data:			
1	0.000	608.280	ALCAP 129.358 LB
2	8.000	606.540	
3	19.000	604.240	TOE
4	22.000	602.940	
5	32.000	602.340	BOTTOM
6	43.000	602.340	
7	57.000	602.240	BOTTOM
8	69.000	602.140	
9	84.000	602.540	
10	93.000	602.710	
11	96.000	603.240	TOP BAR
12	99.000	602.840	TOE
13	124.000	603.240	
14	131.000	603.190	
15	147.000	602.340	BOTTOM
16	160.000	602.340	
17	173.000	602.440	
18	188.000	602.340	
19	204.000	602.340	BOTTOM
20	222.000	602.140	
21	234.000	601.940	
22	251.000	602.440	
23	259.000	602.950	
24	266.000	603.940	
25	271.000	606.440	TOP
26	278.000	606.330	ALCAP 129.358 RB
Water surface data:			
1	22.000	602.940	LEOW WS
2	93.000	602.900	REOW WS
			SPLIT
4	131.000	603.190	LEOW WS
5	259.000	602.950	REOW WS
MIN	0.000	601.940	
MAX	278.000	608.280	

2-13-46

SUSITNA HYDROGRAPHIC SURVEYS



2-13-47

PREPARED BY:

R&M CONSULTANTS, INC.

cross section SLOUGH 9 129.3S8
Date of Survey: AUGUST 1, 1982

PREPARED FOR:

ACRES

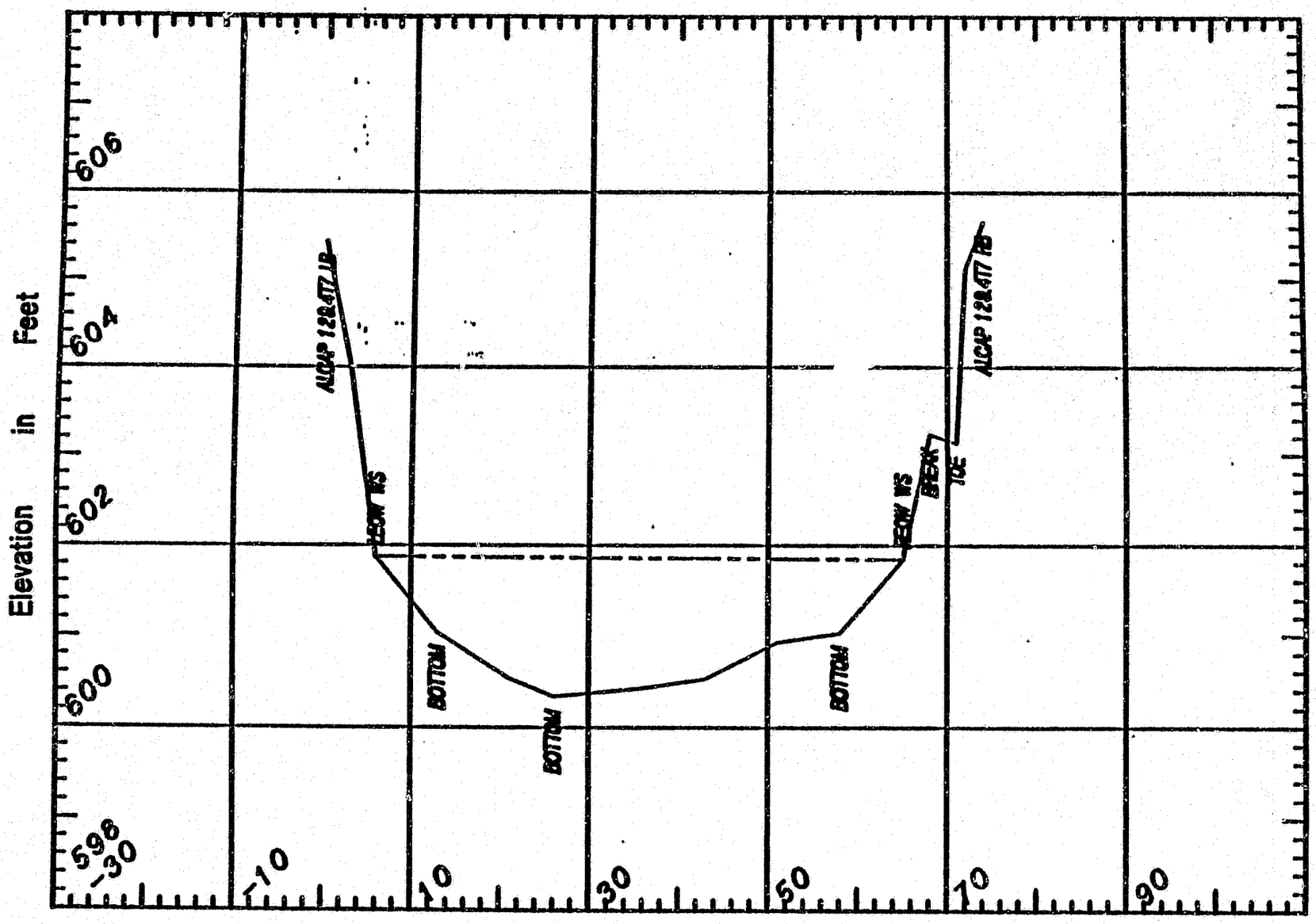
SUSITNA HYDROGRAPHIC SURVEYS
cross section SLOUGH 9 129.4T7

Date of Survey: AUGUST 1, 1982

POINT	'X'	'Y'	DESCRIPTION
Cross section data:			
1	0.000	605.430	ALCAP 129.4T7 LB
2	3.000	604.000	
3	6.000	601.870	
4	13.000	601.030	BOTTOM
5	21.000	600.530	
6	26.000	600.330	BOTTOM
7	36.000	600.430	
8	43.000	600.530	
9	51.000	600.930	
10	58.000	601.030	BOTTOM
11	65.000	601.840	
12	68.000	603.230	BREAK
13	71.000	603.130	TOE
14	72.000	605.130	
15	74.000	605.660	ALCAP 129.4T7 RB
Water surface data:			
1	6.000	601.870	LEOW WS
2	65.000	601.840	REOW WS
MIN	0.000	600.330	
MAX	74.000	605.660	

2-13-48

SUSITNA HYDROGRAPHIC SURVEYS



2-13-49

PREPARED BY:

R&M CONSULTANTS, INC.

cross section SLOUGH 9 129.4T7
Date of Survey: AUGUST 1, 1982

PREPARED FOR:

ACRES

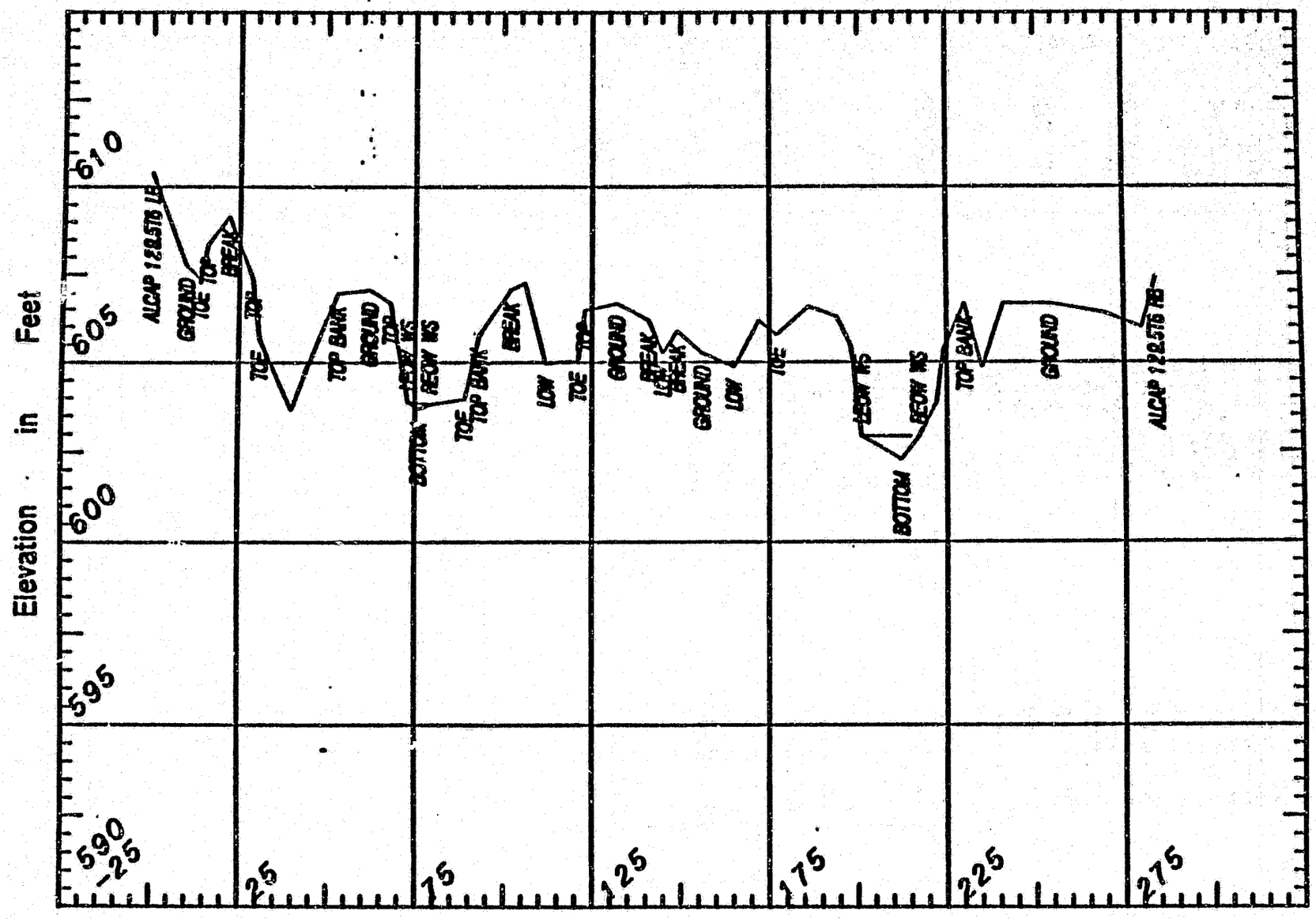
SUSITNA HYDROGRAPHIC SURVEYS
cross section SLOUGH 9 129.5T6

Date of Survey: AUGUST 1, 1982

POINT	'X'	'Y'	DESCRIPTION
Cross section data:			
1	0.000	610.390	ALCAP 129.5T6 LB
2	10.000	607.760	GROUND
3	14.000	607.360	TOE
4	16.000	608.360	TOP
5	22.000	609.160	BREAK
6	29.000	607.360	TOP
7	31.000	605.660	TOE
8	40.000	603.660	
9	44.000	604.760	
10	53.000	606.960	TOP BANK
11	62.000	607.060	GROUND
12	68.000	606.660	TOP
13	73.000	603.870	
14	76.000	603.660	BOTTOM
15	79.000	603.800	
16	89.000	603.960	TOE
17	93.000	605.760	TOP BANK
18	102.000	607.060	BREAK
19	106.000	607.260	
20	112.000	604.960	LOW
21	121.000	605.060	TOE
22	123.000	606.460	TOP
23	132.000	606.660	GROUND
24	141.000	606.160	BREAK
25	145.000	605.260	LOW
26	149.000	605.860	BREAK
27	156.000	605.260	GROUND
28	165.000	604.860	LOW
29	172.000	606.160	
30	177.000	605.760	TOE
31	186.000	606.560	
32	194.000	606.260	
33	198.000	605.460	
34	201.000	602.920	
35	212.000	602.260	BOTTOM
36	217.000	602.910	
37	222.000	603.860	
38	224.000	605.360	
39	230.000	606.660	TOP BANK
40	235.000	604.860	
41	241.000	606.660	
42	254.000	606.660	GROUND
43	270.000	606.360	
44	280.000	605.960	
45	284.000	607.410	ALCAP 129.5T6 RB
Water surface data:			
1	73.000	603.870	LEOW WS
2	79.000	603.800	REOW WS
			SPLIT
4	201.000	602.920	LEOW WS
5	217.000	602.910	REOW WS

2-13-50

SUSITNA HYDROGRAPHIC SURVEYS



2-13-51

PREPARED BY:

R&M CONSULTANTS, INC.

cross section SLOUGH 9 1 2 9.5T6

Date of Survey: AUGUST 1, 1 9 8 2

PREPARED FOR:

ACRES

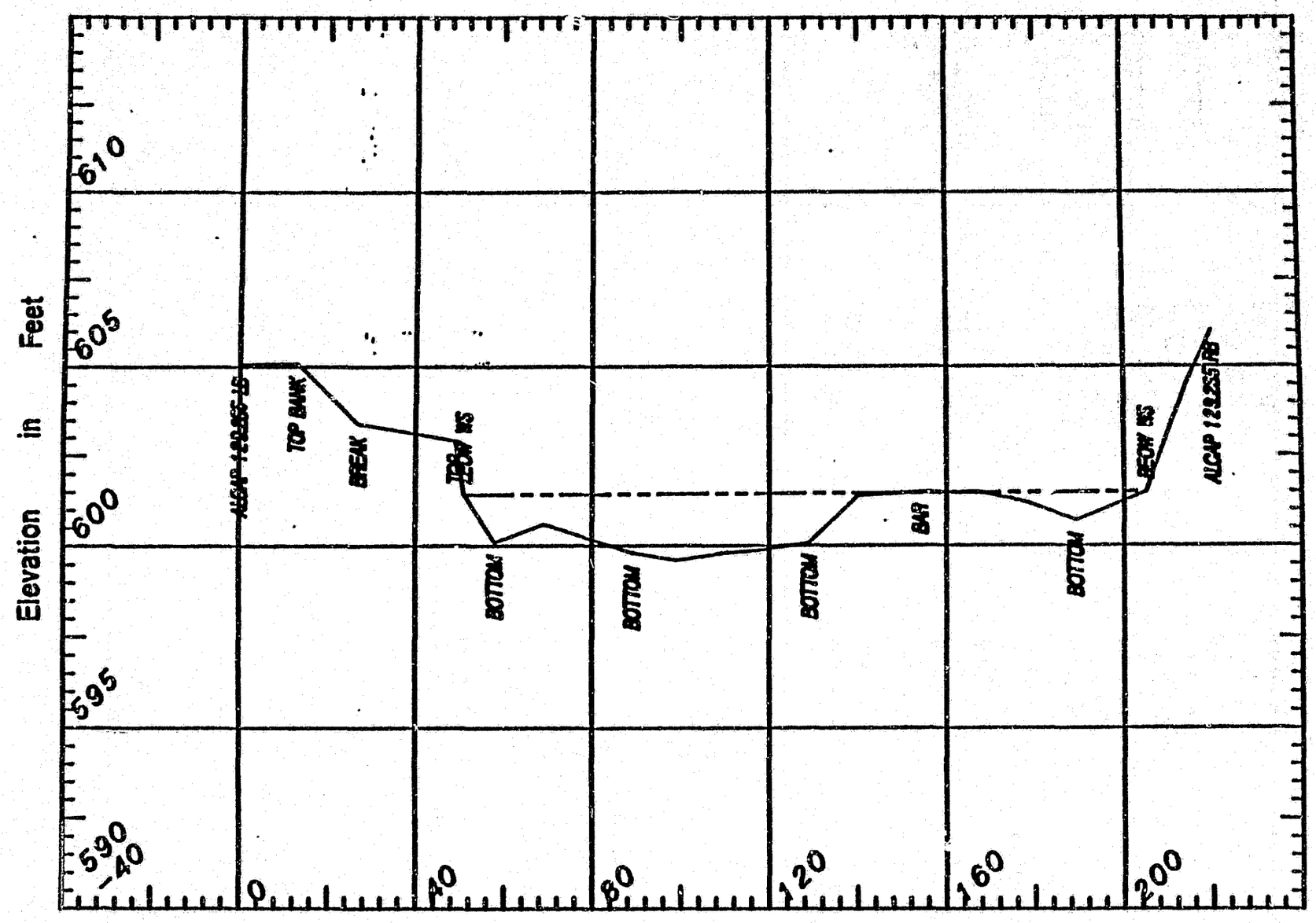
SUSITNA HYDROGRAPHIC SURVEYS
cross section SLOUGH 9 129.2S5

Date of Survey: AUGUST 1, 1982

POINT	'X'	'Y'	DESCRIPTION
Cross section data:			
1	0.000	605.080	ALCAP 129.2S5 LB
2	13.000	605.090	TOP BANK
3	27.000	603.390	BREAK
4	49.000	602.890	TOP
5	51.000	601.410	
6	58.000	600.090	BOTTOM
7	69.000	600.590	
8	79.000	600.190	
9	89.000	599.790	BOTTOM
10	99.000	599.590	
11	109.000	599.790	
12	119.000	599.890	
13	129.000	600.090	BOTTOM
14	140.000	601.390	
15	154.000	601.490	BAR
16	167.000	601.490	
17	178.000	601.190	
18	189.000	600.690	BOTTOM
19	205.000	601.490	
20	214.000	604.490	
21	220.000	606.010	ALCAP 129.2S5 RB
Water surface data:			
1	51.000	601.410	LEOW WS
2	205.000	601.490	REOW WS
MIN	0.000	599.590	
MAX	220.000	606.010	

2-13-52

SUSITNA HYDROGRAPHIC SURVEYS



2-13-53

PREPARED BY:

R&M CONSULTANTS, INC.

cross section SLOUGH 9 129.2S5
Date of Survey: AUGUST 1, 1982

PREPARED FOR:

ACRES

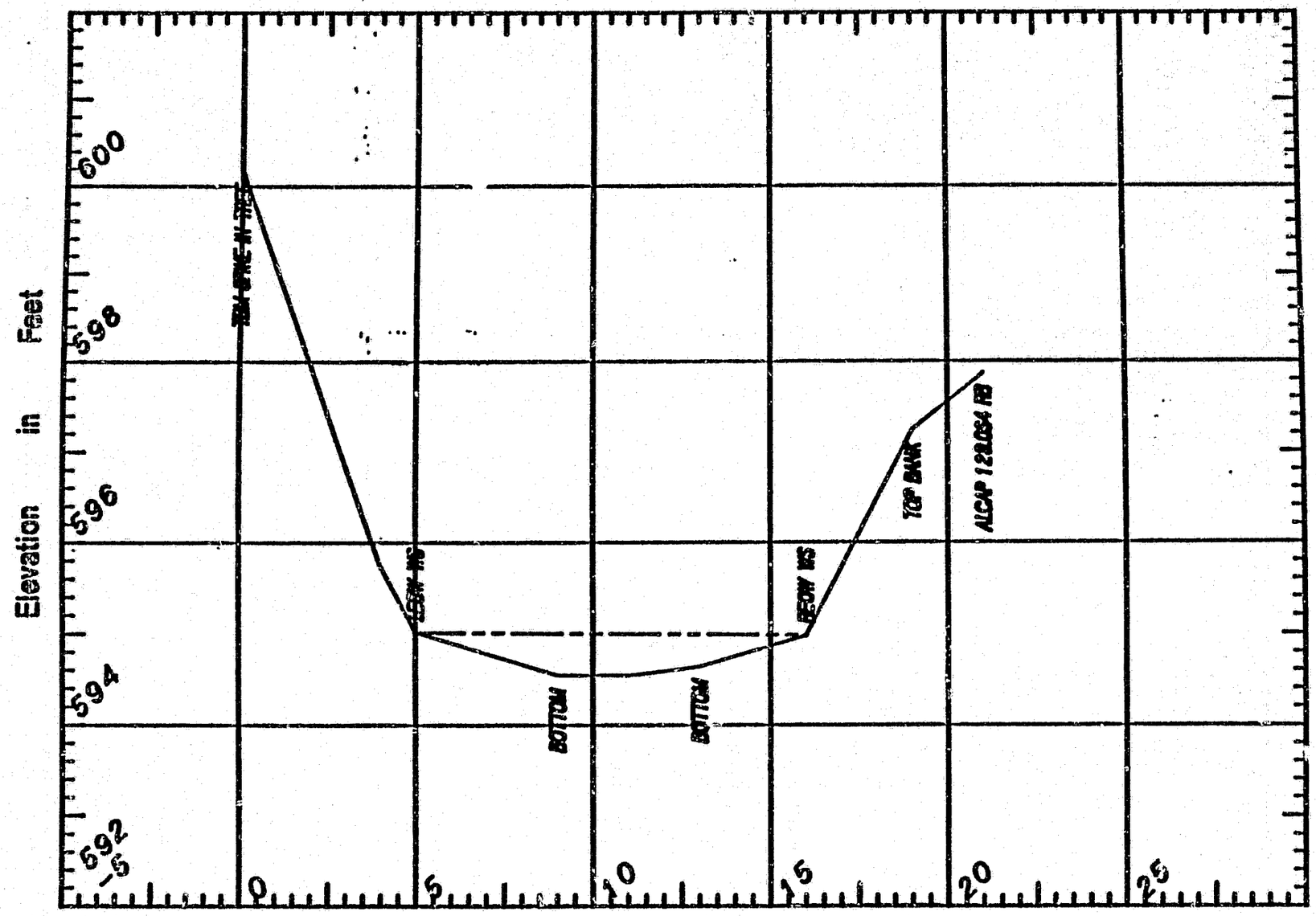
SUSITNA HYDROGRAPHIC SURVEYS
cross section SLOUGH 9 129.0S4

Date of Survey: AUGUST 1,1982

POINT	'X'	'Y'	DESCRIPTION
Cross section data:			
1	0.000	600.180	TBM SPIKE IN TREE
2	4.000	595.740	
3	5.000	595.010	
4	9.000	594.540	BOTTOM
5	11.000	594.540	
6	13.000	594.640	BOTTOM
7	16.000	594.980	
8	19.000	597.240	TOP BANK
9	21.000	597.870	ALCAP 129.0S4 RB
Water surface data:			
1	5.000	595.010	LEOW WS
2	16.000	594.980	REOW WS
MIN	0.000	594.540	
MAX	21.000	600.180	

2-13-54

SUSITNA HYDROGRAPHIC SURVEYS



B-71

2-13-55

PREPARED BY:

R&M CONSULTANTS, INC.

cross section SLOUGH 9 1 2 9.0S4
Date of Survey: AUGUST 1,1 9 8 2

PREPARED FOR:

ACRES

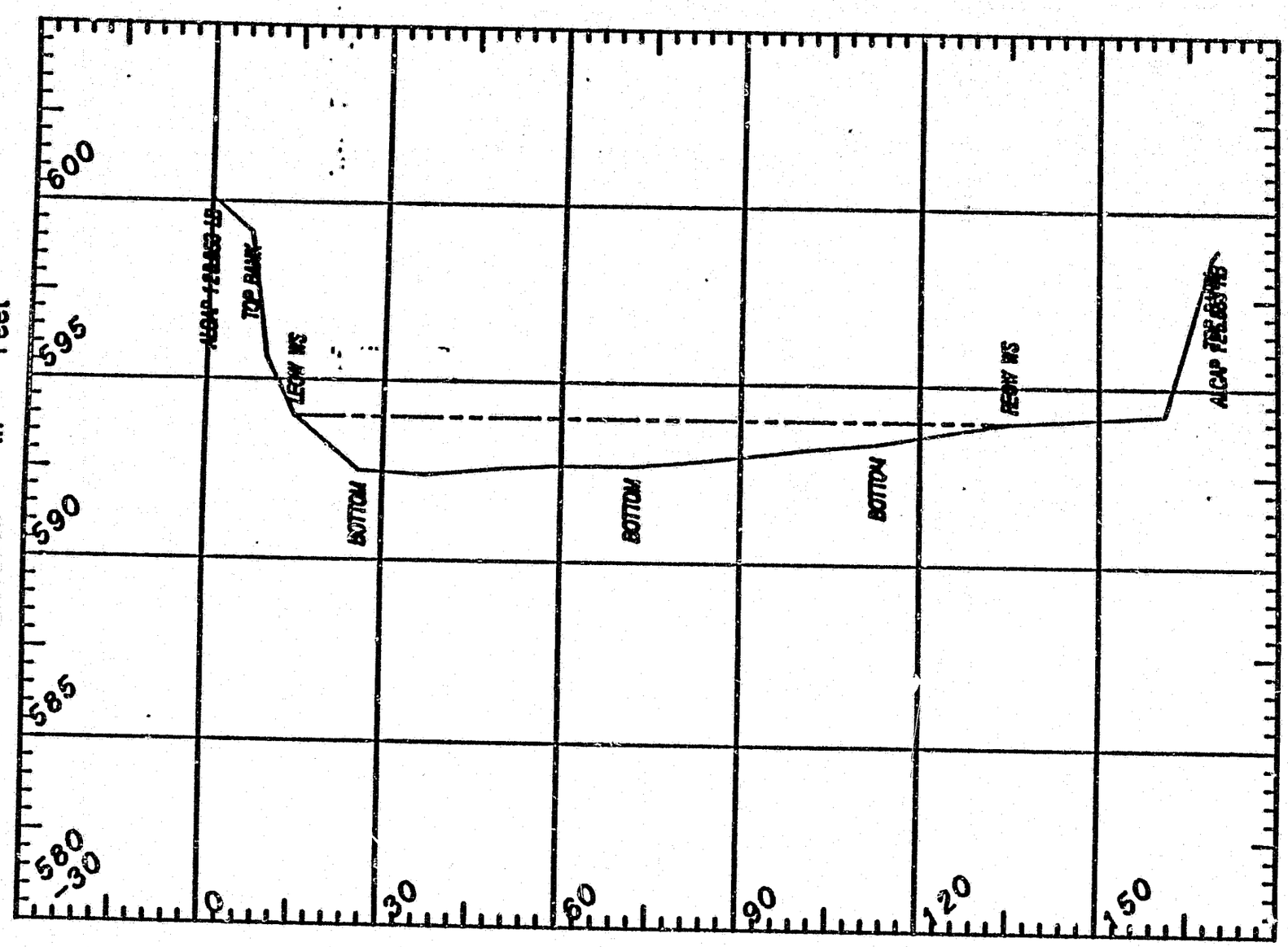
SUSITNA HYDROGRAPHIC SURVEYS
cross section SLOUGH 9 128.8S3

Date of Survey: AUGUST 1, 1982

POINT	'X'	'Y'	DESCRIPTION
Cross section data:			
1	0.000	600.100	ALCAP 128.8S3 LB
2	7.000	599.130	TOP BANK
3	10.000	595.630	
4	15.000	593.960	
5	26.000	592.460	BOTTOM
6	37.000	592.360	
7	49.000	592.560	
8	59.000	592.660	
9	72.000	592.660	BOTTOM
10	85.000	592.860	
11	100.000	593.160	
12	113.000	593.360	BOTTOM
13	135.000	593.960	
14	161.000	594.230	
15	169.000	598.730	TOP BANK
16	170.000	598.940	ALCAP 128.8S3 RB
Water surface data:			
1	15.000	593.960	LEOW WS
2	135.000	593.960	REOW WS
MIN	0.000	592.360	
MAX	170.000	600.100	

2-13-56

SUSITNA HYDROGRAPHIC SURVEYS



2-13-57

PREPARED BY:

R&M CONSULTANTS, INC.

cross section SLOUGH 9 128.8S3
Date of Survey: AUGUST 1, 1982

PREPARED FOR:

ACRES

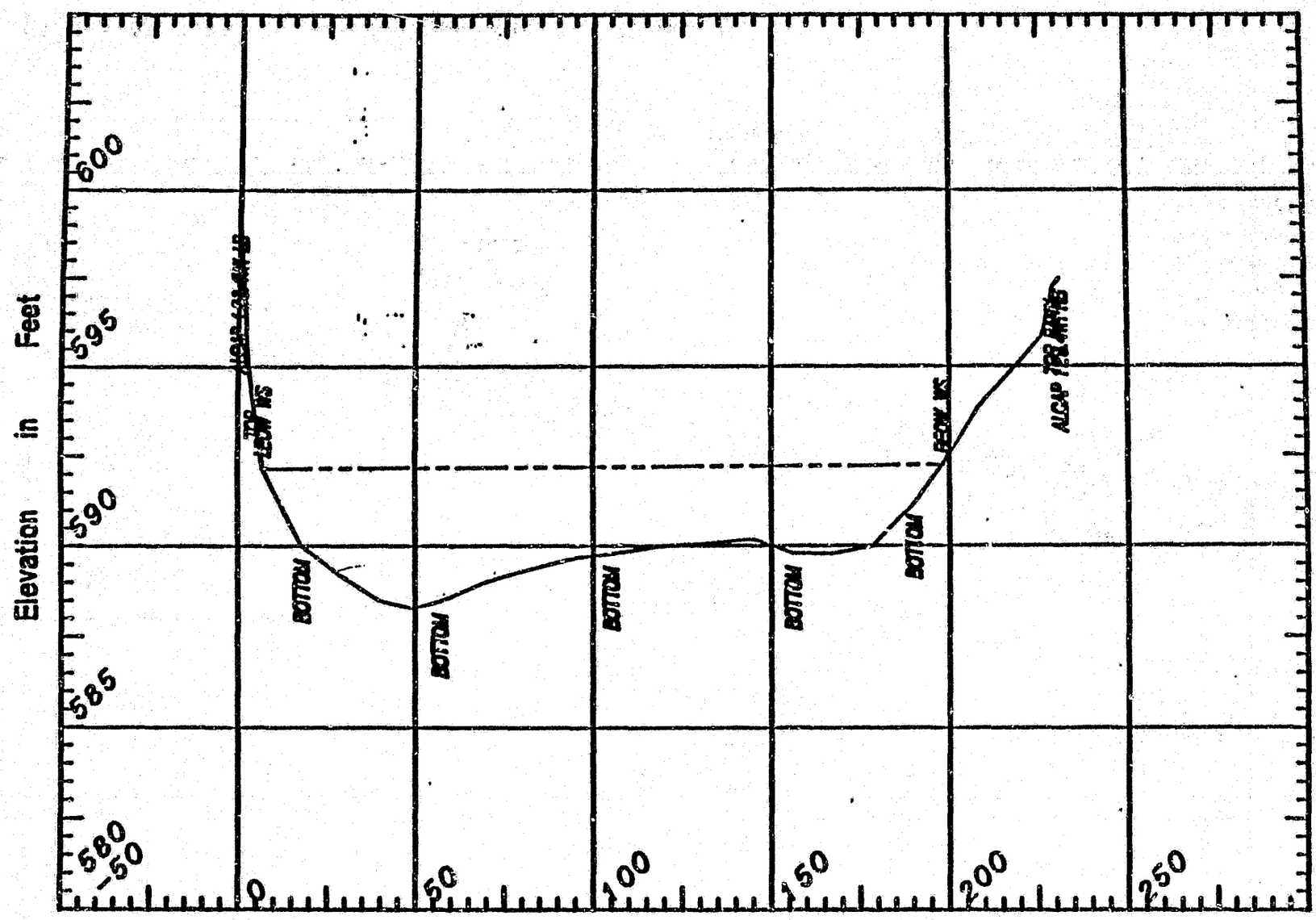
SUSITNA HYDROGRAPHIC SURVEYS
cross section SLOUGH 9 128.4W1

Date of Survey: AUGUST 2, 1982

POINT	'X'	'Y'	DESCRIPTION
Cross section data:			
1	0.000	599.080	ALCAP 128.4W1 LB
2	3.000	594.830	
3	4.000	594.130	TOP
4	7.000	592.130	
5	18.000	589.980	BOTTOM
6	29.000	589.180	
7	40.000	588.480	
8	49.000	588.280	
9	57.000	588.480	BOTTOM
10	69.000	588.980	
11	79.000	589.280	
12	95.000	589.680	
13	105.000	589.780	BOTTOM
14	118.000	589.980	
15	132.000	590.080	
16	145.000	590.180	
17	156.000	589.780	BOTTOM
18	167.000	589.780	
19	178.000	589.980	
20	190.000	591.180	BOTTOM
21	198.000	592.240	
22	208.000	593.830	
23	226.000	595.830	
24	229.000	597.230	TOP BANK
25	231.000	597.480	ALCAP 128.4W1 RB
Water surface data:			
1	7.000	592.130	LEOW WS
2	198.000	592.240	REOW WS
MIN	0.000	588.280	
MAX	231.000	599.080	

2-13-58

SUSITNA HYDROGRAPHIC SURVEYS



E-75

2-13-59

PREPARED BY:

R&M CONSULTANTS, INC.

cross section SLOUGH 9 128.4W1
Date of Survey: AUGUST 2, 1982

PREPARED FOR:

ACRES

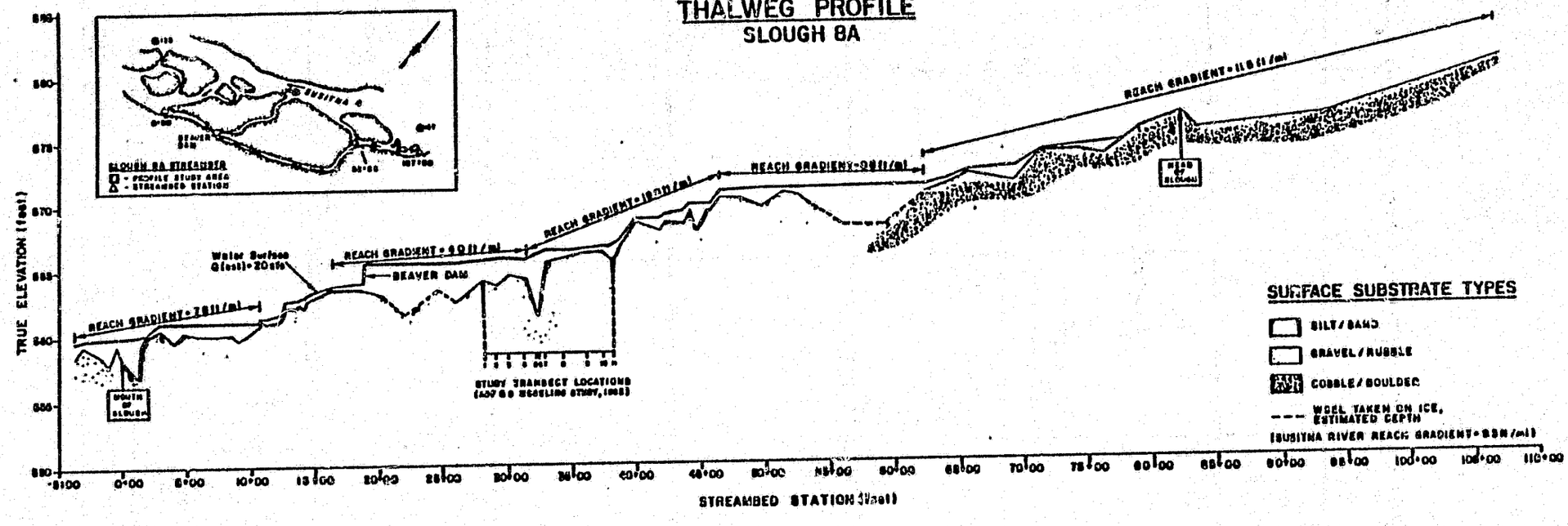
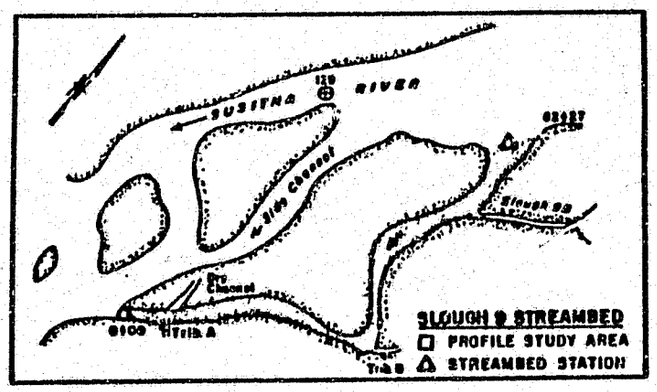


Figure 4I-3-36. Streambed profile for Slough 8A.



THALWEG PROFILE
SLOUGH 9

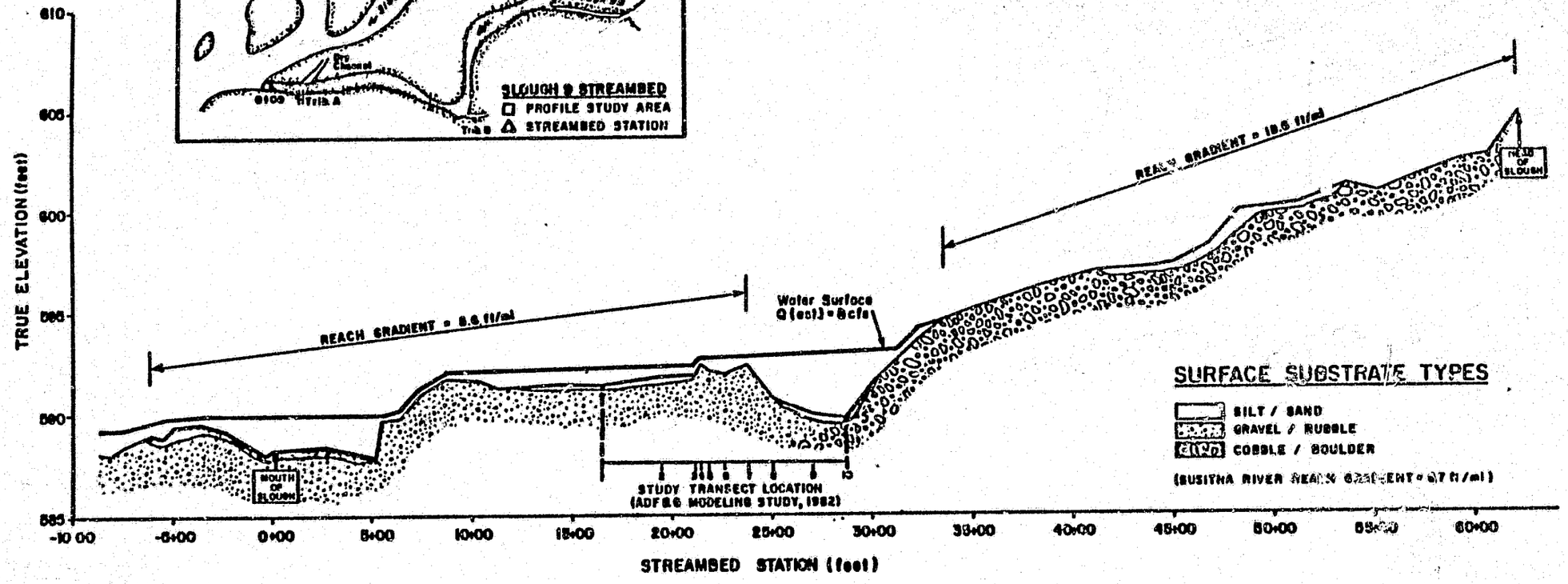
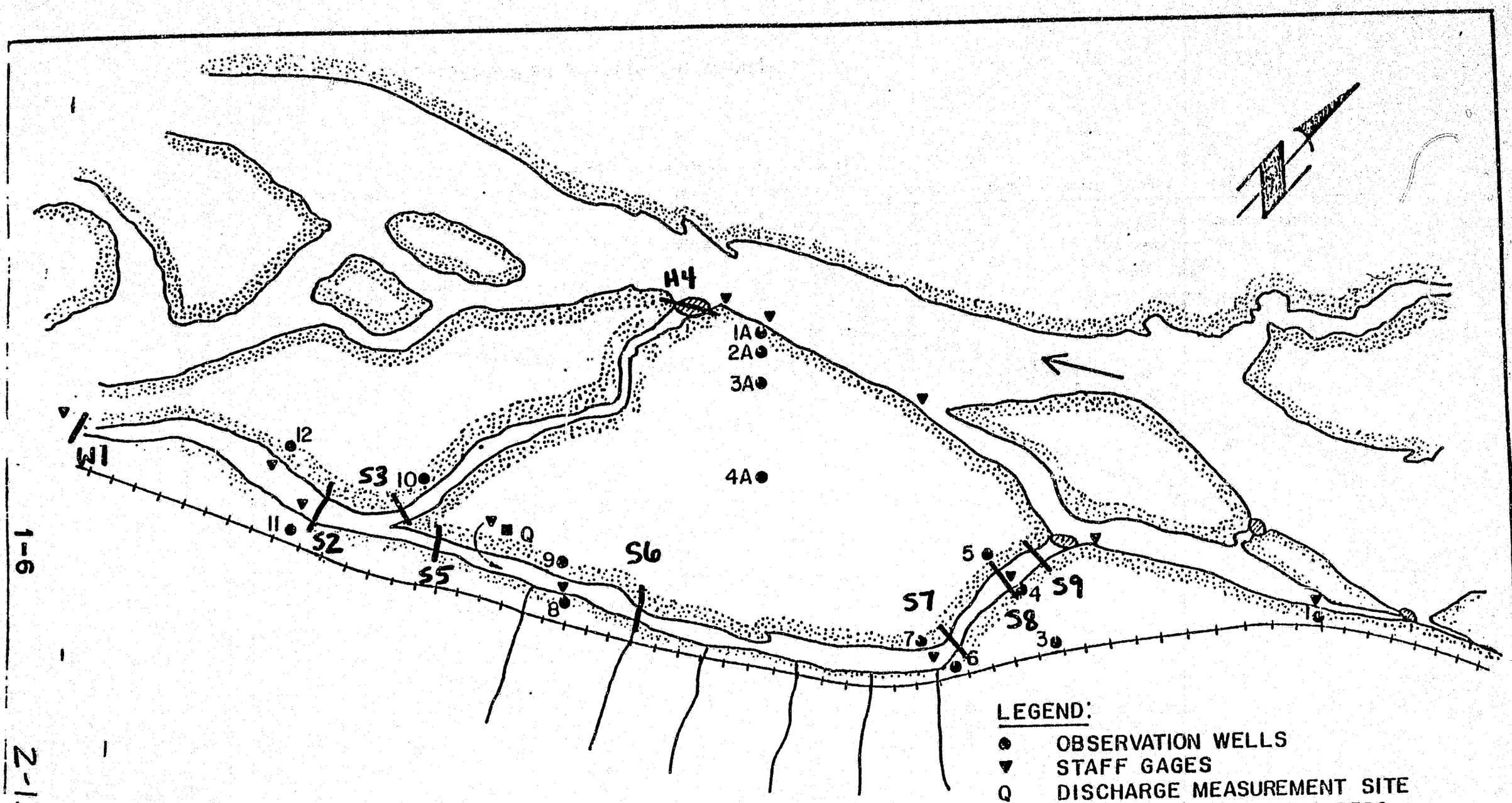


Figure 4I-3-37. Streambed profile for Slough 9.

2-13-81



1-6

2-13-62

PREPARED BY:

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FIG. 1.3 SLOUGH 8 A

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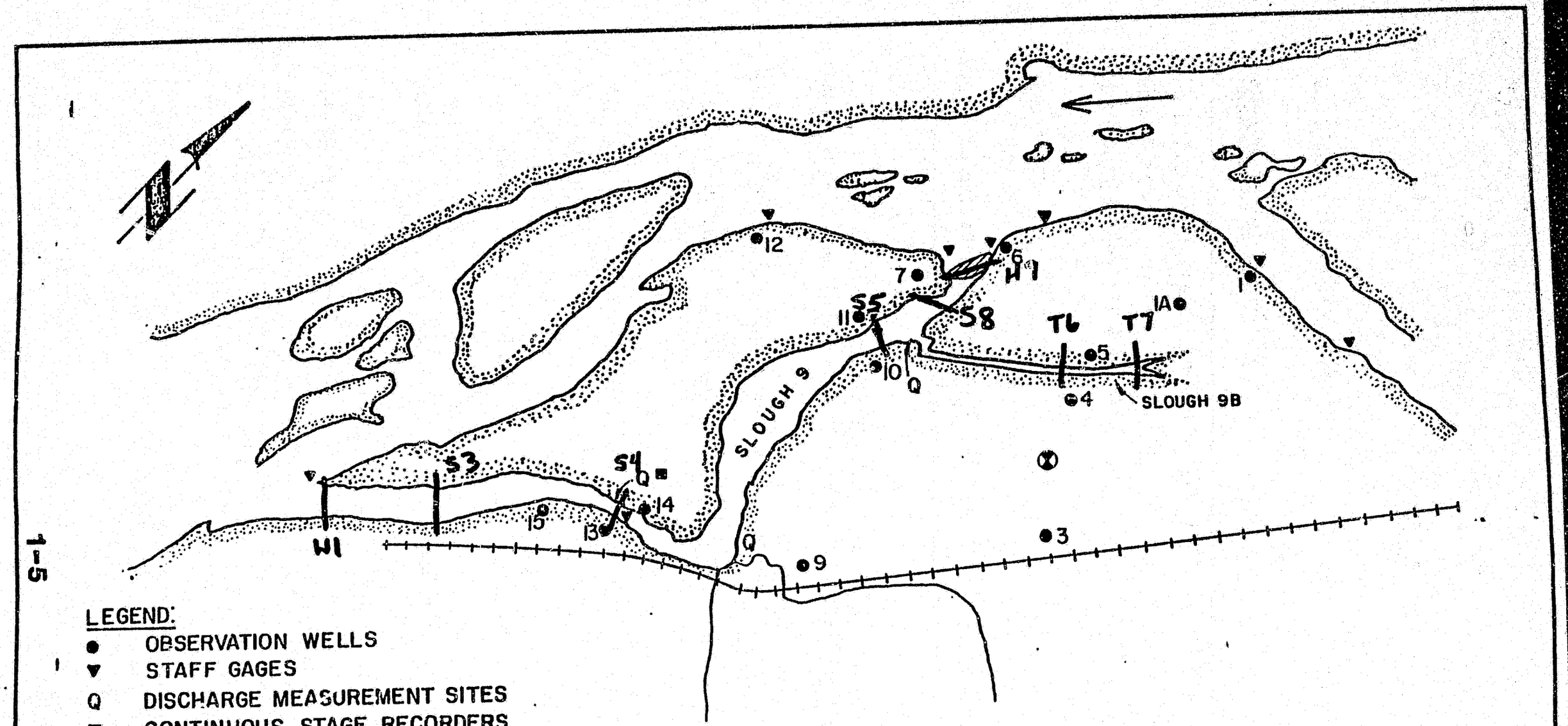
ACHRS



LEGEND:

- ● OBSERVATION WELLS
- ▼ STAFF GAGES
- Q DISCHARGE MEASUREMENT SITES
- ■ CONTINUOUS STAGE RECORDERS
- ⊘ CONTROLLING BERMS
- ⊗ CLIMATE STATION
- ~ STREAMBED
- — CROSS-SECTIONS

1-5

2-13-63

PREPARED BY:

R&M CONSULTANTS, INC.

PREPARED FOR:

ACWPS

FIG. 1.2 SLOUGHS 9 & 9B

EXHIBIT E

2. Water Use and Quality

Comment 15 (p. E-2-41)

Describe or reference the technique that has been developed for measuring upwelling in sloughs. Provide the date and mainstem flow at the time groundwater flow was estimated.

Response

The technique for measuring upwelling water flows is contained in the attached references in pp. 2-15-2 to 2-15-14.

Lee, D. R. 1977. A Device for Measuring Seepage Flux in Lakes and Estuaries. Limnology and Oceanography, Volume 22, p. 140.

Lee, D. R. and J. A. Cherry 1978. A Field Exercise on Groundwater Flow Using Seepage Meters and Mini-piezometers. Journal of Geological Education, Volume 27, p. 6.

The date and mainstem flow of the Slough 9 groundwater flow measurements are as follows:

Date	Slough 9 Groundwater Flow (cfs)	Slough 9 Total Discharge (cfs)	Mainstem Flow at Gold Creek (cfs)
08/25/82	1.00	1.64	13,400
09/09/82	0.74	2.06	13,400

A device for measuring seepage flux in lakes and estuaries[1]

Abstract—Seepage flux can be measured and samples of groundwater flowing into lakes and estuaries collected by enclosing an area of bottom with a cylinder vented to a plastic bag. The method has the advantage of not requiring measurements of permeability of bottom sediments. Seepage velocities from −0.1–2.58 $\mu m\ s^{-1}$ were measured in Minnesota and Wisconsin lakes and in Nova Scotia and North Carolina estuaries.

Where seepage inflow was rapid (0.4–0.8 $\mu m\ s^{-1}$), water collected with the seepage meter was chemically similar to water from wells on the same flow path, and the distribution and chemistry of the seepage concurred with a theoretical flow net. The rate and direction of seepage flux were correlated with water surface elevation during a tidal cycle.

This paper describes a simple, inexpensive instrument that has been used successfully to make direct measurements of seepage flux in lakes and estuaries (Table 1). The technique has the advantage of *not* requiring measurements of the permeability of sediments. The method yields a sample of water suitable for chemical analysis, and the equipment involved is relatively inexpensive.

Evaluation and management of lakes and estuaries often require specific information on water and chemical budgets. All of the inflow-outflow components must be measured or estimated, and almost invariably the greatest uncertainty involves the groundwater component. Rarely are direct measurements attempted, presumably because the investigators believe that this would require excessive investments of time and equipment. There is a severe lack of methodology for site-specific study of nutrient input to lakes via groundwater (Uttormark et al. 1974), and ground-

[1] Work was sponsored in part by a grant from the Pelican River Watershed, Detroit Lakes, Minnesota, to J. K. Neel, Department of Biology, University of North Dakota, Grand Forks.

Table 1. Seepage measurements using seepage meter at various locations.

Location	Seepage velocity ($\mu m\ s^{-1}$)	No. measurements	Bottom type	Water depth (m)	Comments
Lake Sallie, MN (46°46'N, 95°54'W)	0.01–2.58	494	sand, gravel	0.2–2.0	measurements made around entire periphery of the lake, 1970–72
Lake Huvil, MN (47°33'N, 95°08'W)	1.0	3	gravel	1.0	south shore, 8 Aug 1975
Lake Mendota, WI (43°07'N, 88°25'W)	0.32–0.46	2	sand	0.7	Mendota Park on north shore, 10 Aug 1975
Minas Basin, NS (44°55'N, 64°08')	0.5–1.4	6	sand, silt	1.5–2.0	measurements made during falling tide on upper third of beach, 25 Jun 1975
Bogue Sound, NC (34°42'N, 76°45'W)	0.32	1	sand	0.9	measurements made during falling tide about 0.1 m below MLW, 16 May 1975
Duke Marine Lab, NC (34°42'N, 76°49'W)	−0.1–0.8	44	sand,	0.1–1.5	measurements made during falling and rising tide 0.1 m below MLW; 9 May 1974, 15–16 May 1975

2-15-2

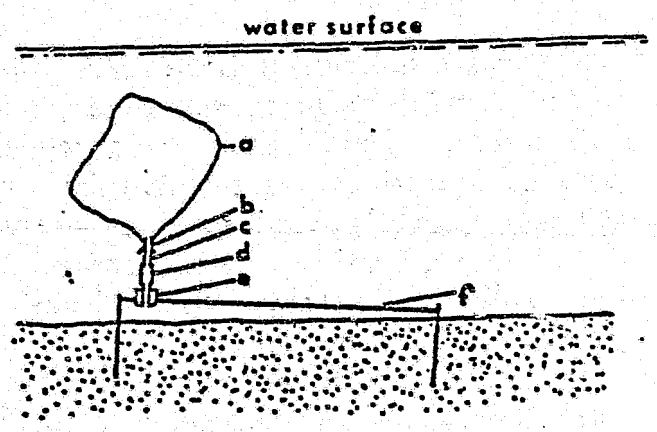


Fig. 1. Full-section view of seepage cylinder showing proper placement in sediment. a—4-liter, 0.017-mm-membrane, plast. Baggies Alligator bag (open end heat-sealed); b—rubber-band wrap; c—0.64-cm-ID, 6 cm long, polyethylene tube; d—0.79-cm-ID, 4.5 cm long, amber-latex tube; e—No. 5½ one-hole rubber stopper with polyethylene tube; f—15- × 57-cm-diameter epoxy-coated cylinder (end-section of a steel drum).

water flow systems around lakes (Born et al. 1974) and estuaries are poorly documented.

The usual approach for obtaining estimates of groundwater-surface water interaction is to install observation wells on land near the shore or in the water basin. The wells are then used to obtain measurements of the distribution of the hydraulic head and estimates of permeability. This is generally unsatisfactory because it is seldom feasible to estimate permeability by less than an order of magnitude and because surface-groundwater interaction is often controlled at or very near the sediment–water interface.

I thank J. K. Neel for guidance in the initial phases of this work. J. K. Neel, Q. L. Gehle, J. A. Cherry, and L. S. Clayton provided comments. Work space and equipment were provided by the staff of the Lake Sallie Fisheries Station, Minnesota Department of Conservation, and by the Department of Geology, Virginia Polytechnic Institute and State University. Part of this work appeared in my M.S. thesis (University of North Dakota).

Groundwater seeping into standing surface waters can be collected by covering an area of lakebed with a bottomless cylinder vented to a deflated plastic bag (Fig. 1). The cylinder is turned slowly (≃1 cm s^{-1}), open-end down, into the sediment until its top is about 2 cm above the sediment surface. The vent hole is elevated slightly so that any gas from the sediment may freely escape. The cylinder is marked and left for several days to allow benthic organisms to escape (although preliminary measurements can be started immediately). Then a stopper with tube is inserted into the cylinder hole.

To collect a sample, a deflated plastic bag is connected to the tube and left for a specified time or until it contains 0.5–3 liters. Where surface water seeps *into* the sediment, the plastic bag is filled with a known amount of water before it is connected to the tube. Macroscopic seepage velocity is determined as

$$v = \frac{1.075\ V}{t},$$

where V is liters of water entering (+ value) or leaving (− value) the bag, t is hours of elapsed time, and v is seepage velocity (+ is upward, − is downward) expressed as micrometers per second. The factor 1.075 converts units of volume, time, and area covered by the cylinder (0.255 m^2) to equivalent units of velocity ($\mu m\ s^{-1}$) or seepage flux ($ml\ m^{-2}\ s^{-1}$). The macroscopic seepage velocity should not be confused with the average interstitial velocity, which is equal to 100 times the seepage velocity divided by the percent porosity of the sediment.

Most problems in measuring seepage are due to improper placement of the cylinder. If the cylinder is not positioned with its hole near the highest point, gas from the sediment accumulates and reduces seepage. Measurements are also reduced if the cylinder lid presses against the lakebed. If the cylinder is pushed too rapidly into the sediment, blowouts can cause erratic results. In areas where sediment accumulates, the vent hole should be extended with a short length of pipe. Plugging from algal growth may necessitate periodic examination and cleaning of the vent tube. About 5 ml of water unavoidably enter the plastic bag during

2-15-3

connection. A lightweight, steel fence-picket, notched to hook the lower edge of the cylinder, helps in removal of the cylinder. It is easier to find the cylinders if the tops are painted white. Material for constructing each seepage meter costs $4 to $9 (in 1976) if two cylinders are cut from one 55-gallon (208 liter) drum.

The method will probably find its greatest application where surface waters lie in high to moderately permeable material. Without modifications, it is not designed for use in the turbulent water of the surf zone or in rapidly flowing rivers. In fine, low permeability sediments, groundwater velocity may be too low to measure with this technique, or flow may be restricted to distinct springs or leaks.

The principle of the method described here was first used to measure water losses from irrigation canals (Israelsen and Reeve 1944). Other methods (Bower and Rice 1968; Warnick 1951; Zuber 1970) have also been suggested to measure flow into or away from surface waters, but all involve substantial cost and none is appropriate for sample collection.

Laboratory-scale tests were designed to see if the seepage meter gave an accurate measure of groundwater flow over the velocity range encountered in the field. A rectangular test tank 1.3 m deep and 1.26 × 2.66 m in area held a bed of sand (0.5–0.125-mm-diameter granules, 4% silt and clay) 0.76 m deep. A permeable plate supported the sand 10 cm above the bottom of the tank. Upward or downward seepage through the sandbed was controlled with a variable-head tank connected to the water beneath the permeable plate. An overflow pipe kept 0.40 m of water over the sandbed. The seepage flux through the sand was controlled by the difference in the piezometric head measured by two tubes, one open to the water beneath the permeable plate and one open to the water above the sand. Measurements of seepage flux were made at several hydraulic gradients ranging from −0.071 to 0.097.

Reproducibility of velocity measurements was evaluated at Lake Sallie, Minnesota. Two seepage meters were placed 0.15 m apart. Simultaneous measurements were made during 3 consecutive days and at longer intervals over 2 months. The water surface elevations were recorded for Lake Sallie and nearby Muskrat Lake, 50 m away and 1.6 m higher.

A site near the Duke Marine Lab (Beaufort, North Carolina) was selected for additional tests because there was a recording tide gauge operated by the National Oceanic and Atmospheric Administration. About 20 m southwest of the tide gauge, three seepage meters were placed 0.65 m apart on a line perpendicular to shore in water about 0.4 m deep at mean low tide. The sediment was composed of sand and pieces of shells. Seepage flux was measured during 53–79-min intervals over a complete tidal cycle. When the tide was above mean sea level, measurements were started with 1 liter of water in the bag to permit detection of seepage into the sediment.

For evaluation of the seepage meter as a groundwater collection device, a site was selected in an area of fairly uniform groundwater discharge at Lake Sallie. Wells were installed to intercept water before it reached the lake, and seepage meters were placed in the lake adjacent to these wells to collect entering seepage (Fig. 2). Wells, driven 1.72 to 2.11 m into the water table, were sampled 8 times during 108 days. Only small amounts of water (0.6 liter) and soil (20 to 30 g) were removed at each sampling.

Water samples were either frozen and analyzed several weeks later or stored at 0° to 5°C and analyzed within 48 h. Ammonia, nitrite, and nitrate nitrogen, and soluble orthophosphate were determined according to *Standard methods* (Am. Public Health Assoc. 1965, 1971). Specific conductivity was measured at 20°C with a conductivity bridge. Chloride was determined with a specific-ion electrode. Samples were analyzed for total phosphate by a persulfate procedure (Dominick 1971). Filtration through medium-grade filter

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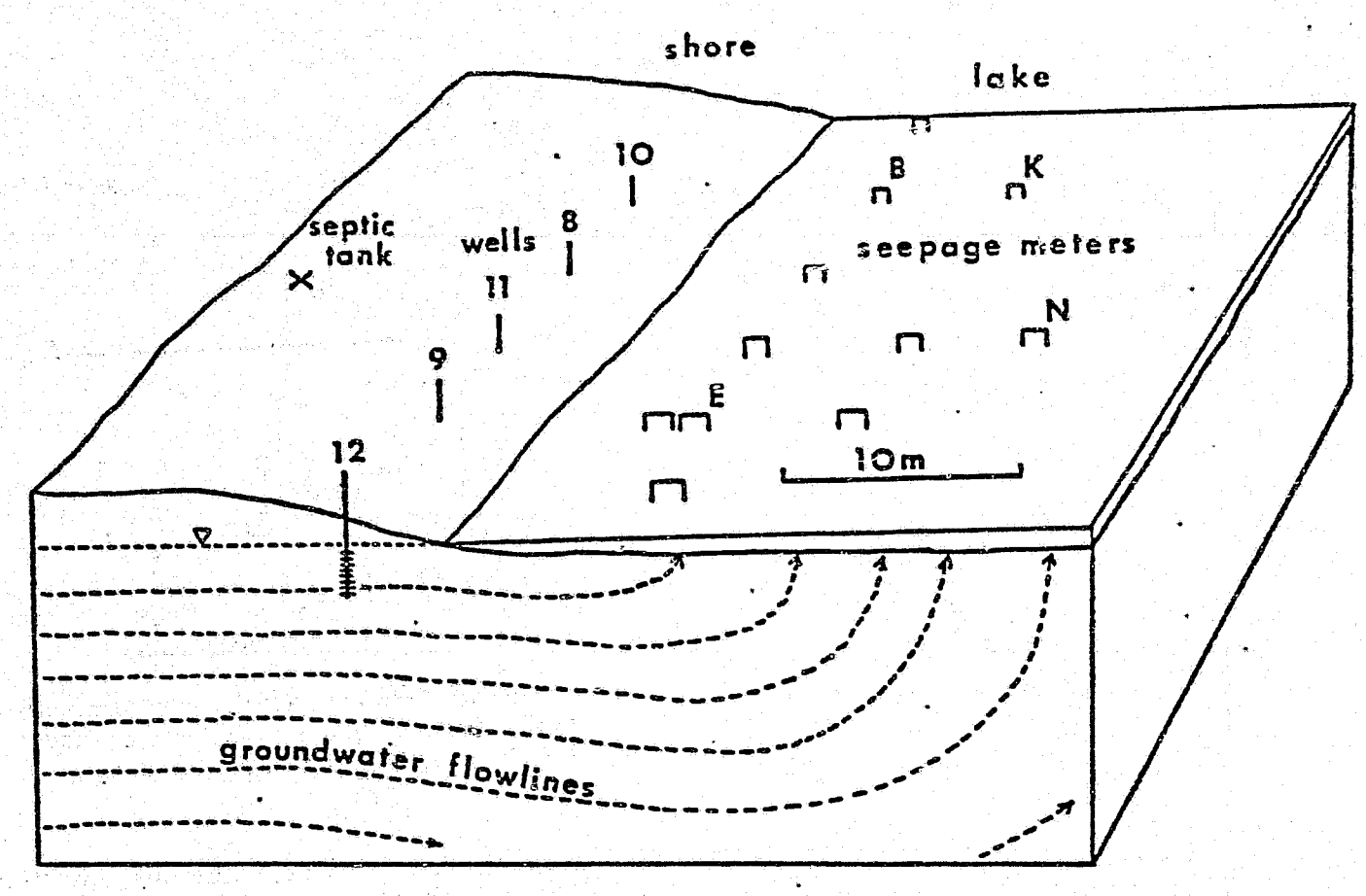

Fig. 2. Position of wells and seepage meters where seepage-meter technique was evaluated for collection of groundwater for chemical analysis. Flow lines show seepage distribution pattern.

paper (Sargent 501 or equivalent) preceded analyses for orthophosphate, nitrite, and nitrate.

Regression coefficients for the relation of velocity and hydraulic gradient in the experimental tank ranged from 0.998 to 0.994. Results for a representative seepage meter are shown in Fig. 3. Slopes for the regression lines for seepage at different locations in the test tank differed slightly (16 to 22 for upward seepage and 9.1 to 20 for downward seepage) probably due to heterogeneity in the test tank. However for any particular location in the tank, the slopes of the regression lines were significantly higher (at $p = 0.05$) for upward than for downward seepage. A 2–3-mm layer of fine clay particles accumulated at the surface of the sediment, and these particles may have controlled permeability by impeding downward seepage more than upward seepage.

Results of the experiments on simultaneous measurement of seepage velocity showed that velocity for the two seepage meters always differed by about 0.1 $\mu m\ s^{-1}$ and ranged from 0.596–0.854 $\mu m\ s^{-1}$ over the 2-month period (Fig. 4). Variation in seepage velocity over time was not significantly correlated with changes in the relative elevation of nearby Muskrat Lake and Lake Sallie (Fig. 4). Changes in atmospheric pressure may have caused variations in velocity by changing the permeability of the sediment (Christiansen 1944; Peck 1960). Small variations in velocity were reproduced with closely placed seepage meters.

Measurements of velocity and water surface elevation during a tidal cycle at Beaufort, North Carolina, are presented in Fig. 5. Seepage velocity, measured with three seepage meters, was significantly correlated with water surface elevation ($R = 0.853$, $n = 32$). Seepage *into* the sediment (groundwater recharge) was detected in only 2 of 32 measurements. The close agreement of the three seepage meters over the tidal cycle showed that the technique gave reproducible results..

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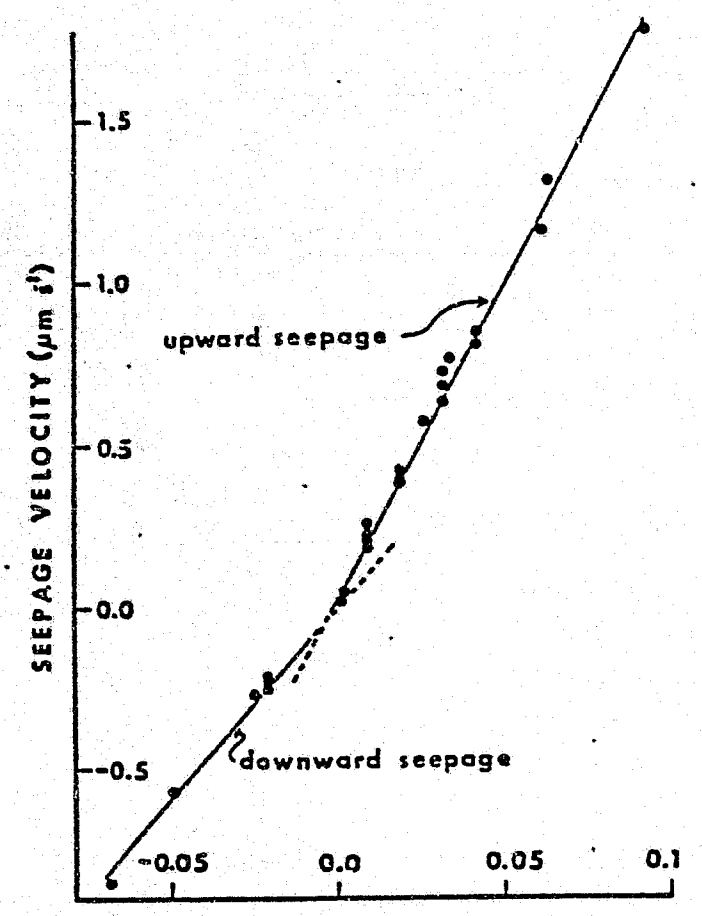

Fig. 3. Relation of hydraulic gradient and velocity measured with seepage meter in experimental tank. For upward seepage: velocity = (19.07 ± 0.32) gradient + (0.0220 ± 0.0012), R = 0.996, n = 29. For downward seepage: velocity = −(11.68 ± 0.94) gradient − (0.0028 ± 0.0110), R = 0.984, n = 7.

Along an 800-m segment of Lake Sallie shoreline, seepage measurements were made 5–160 m from shore. Near the midpoint of this section of shoreline, a site was selected for evaluation of the seepage meter as a groundwater collection device. At this site there was about 10 m of clean sand and gravel below the water table; the sand and gravel was underlain by a thick, relatively impermeable, clay layer (USGS well records. M.S. McBride personal communication).

A flow net (Fig. 6) was drawn assuming isotropic-homogeneous conditions, relatively low permeability of the underlying clay compared to the sand and gravel, and predominantly horizontal flow in the sand and gravel around the lake. The flow net showed that seepage velocity decreased exponentially with distance from shore and

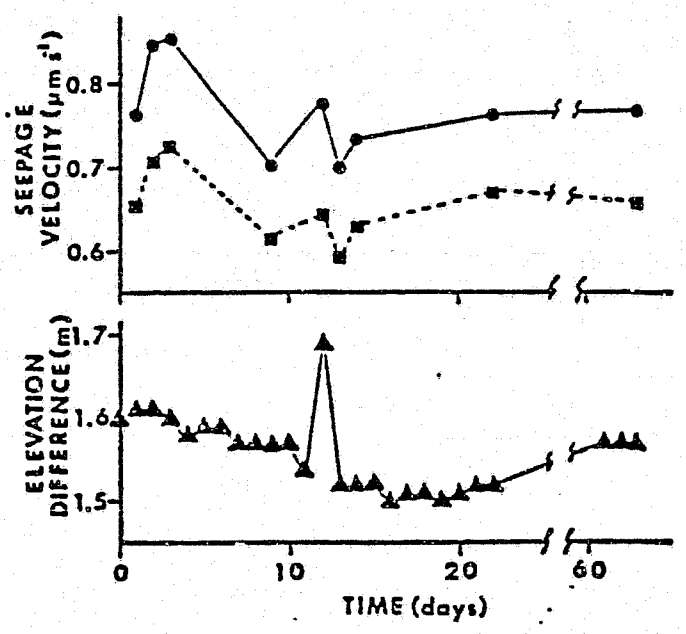

Fig. 4. Seepage velocity measurements from two seepage meters set 0.15 m apart, and relative elevations of lakes Sallie and Muskrat.

that shallow groundwater was discharged nearshore, deeper groundwater farther from shore.

Seepage measurements along the shoreline showed that nearshore discharge was rapid (0.3–0.8 μm s^{-1}) and that velocity did decline approximately exponentially

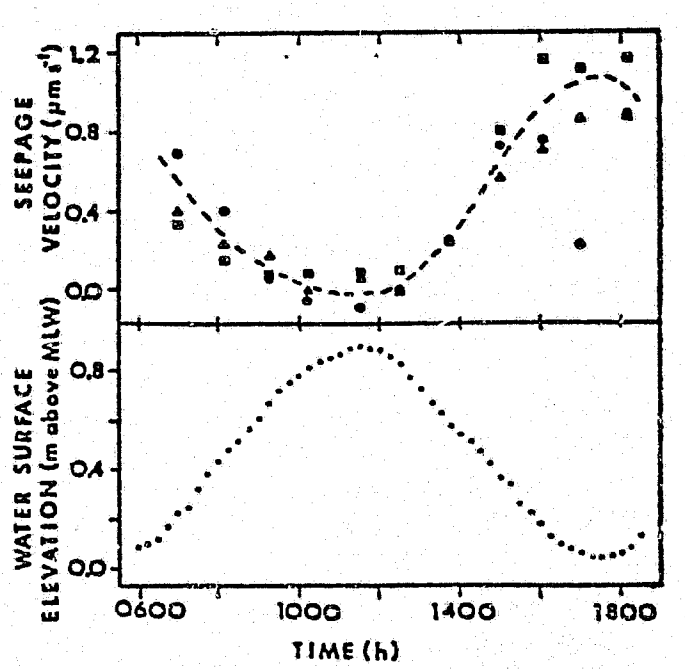

Fig. 5. Seepage velocity and water surface elevation during tidal cycle at Beaufort, North Carolina, 16 May 1975. Symbols (▲, ●, ■) denote different seepage meters. Water surface elevation data was obtained from NOAA tide gauge located at study site.

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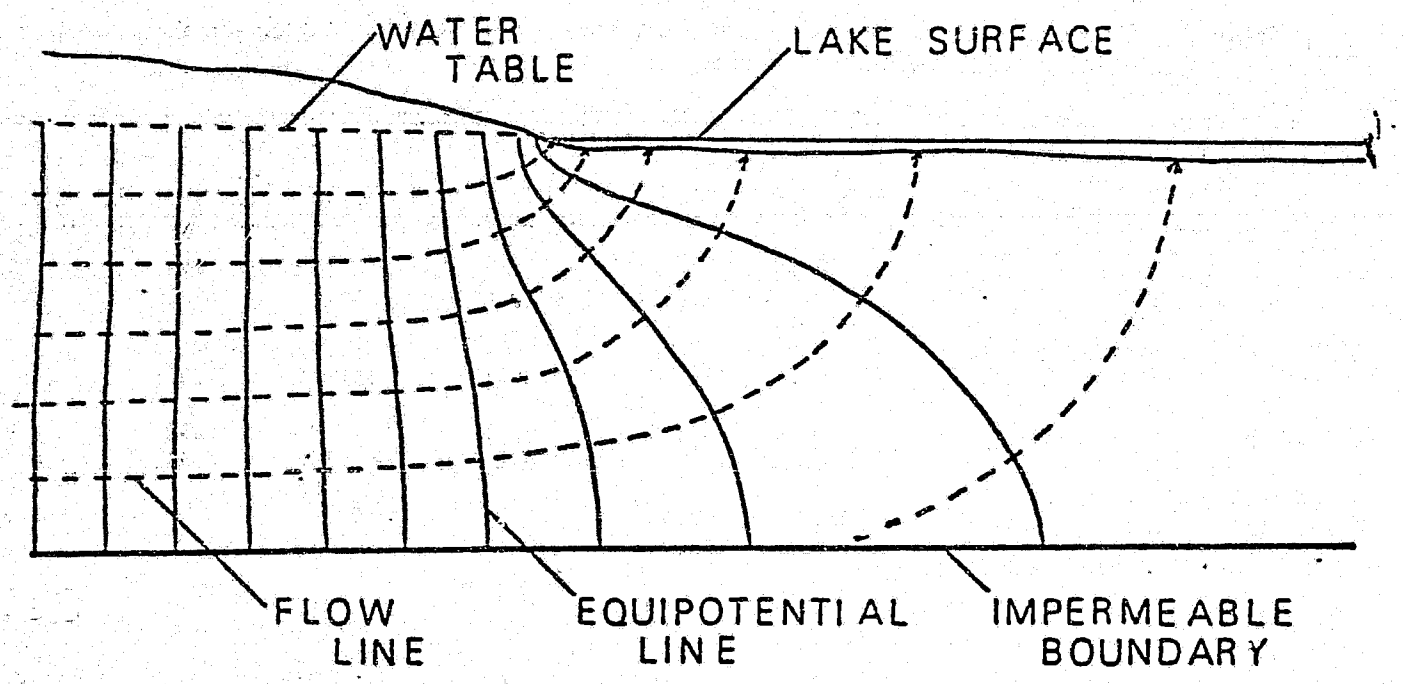

Fig. 6. Theoretical flow net showing distribution of groundwater discharge into Lake Sallie.

with distance from shore (Fig. 7). Substantial seepage influx occurred 60–80 m from shore, whereas the flow net showed high rates of flow to only about 15 m from shore. Seepage distribution would be skewed lakeward in this way if the horizontal to vertical permeability ratio were about 1½:1S (Cedergren 1968), a common feature of glacial outwash terrain (Weeks 1969). McBride and Pfannkuch (1975) have also discussed the distribution of groundwater flow into lakes.

Seepage influx at the site adjacent to the wells ranged from 0.4–0.8 μm s^{-1}. Water collected from the seepage meters initially contained high and varying concentrations of orthophosphate (0.21–1.15 mg liter^{-1}) which eventually stabilized in the range 0.02–0.30 mg liter^{-1}, the average concentration being 0.15 (Fig. 8). Ammonia concentrations in the water collected from the seepage meters were also high initially, but there was a steady decline over a 2-month period. Ammonia levels dropped below 0.25 mg liter^{-1} after 900 liters of groundwater passed through the seepage meters. An exception, seepage meter E, consistently yielded water containing over

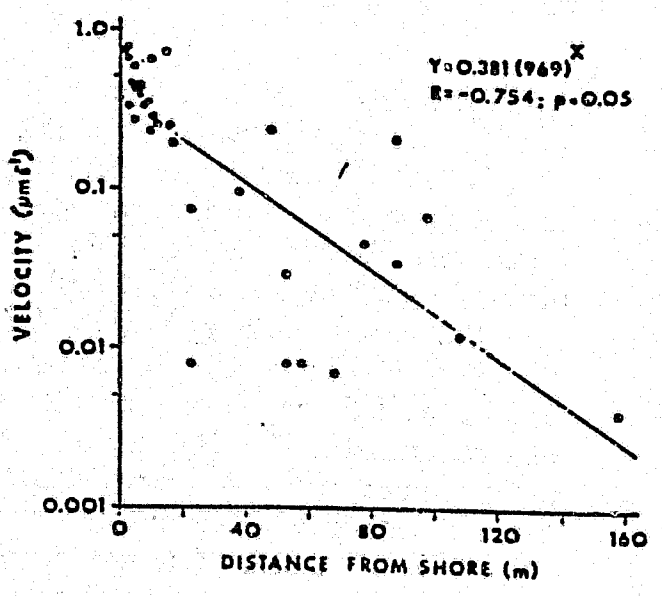

Fig. 7. Relation of seepage velocity and distance from shore along an 800-m shoreline segment at Lake Sallie.

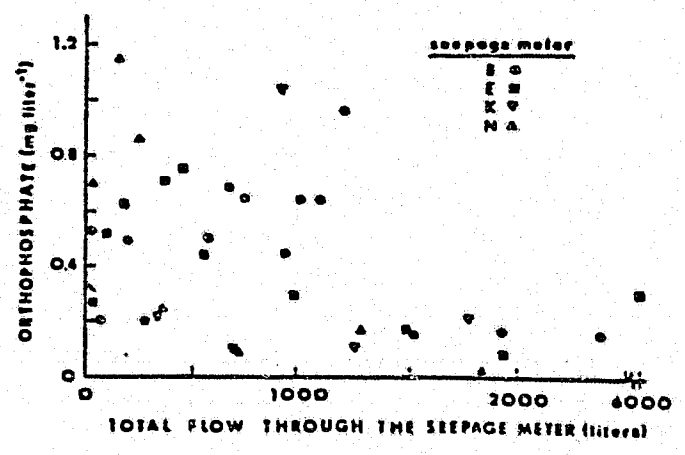

Fig. 8. Phosphate concentration and total groundwater discharged through four seepage meters over 4-month period.

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Table 2. Chemical features of well water, lake water, and velocity and chemical features of seepage at a Lake Sallie experimental site, 1971.

Well no.		Ortho-PO_4	Total PO_4	NH_3-N	NO_3-N	Sp. cond. (μmhos cm^{-1})	Chloride
8	Summary of	0.30 (±0.17)	4.49 (±1.64)	1.35 (±1.03)	12.4 (±6.4)	614 (±101)	30.1 (±39.2)
9	eight samples	0.45 (±0.25)	2.96 (±1.40)	0.46 (±0.29)	24.3 (±11.1)	782 (±208)	56.6 (±50.3)
10	collected	0.25 (±0.12)	4.05 (±2.65)	0.68 (±0.24)	11.0 (±1.6)	493 (±41)	8.73 (±1.86)
11	semimonthly	0.40 (±0.13)	2.84 (±1.91)	3.42 (±0.64)	31.8 (±5.1)	1160 (±103)	65.0 (±17.6)
12	Aug–Nov	0.15 (±0.10)	2.79 (±1.86)	0.36 (±0.19)	8.78 (±1.8)	423 (±42)	9.56 (±2.3)
Lake	23 Oct	0.20	0.40	0.02	0.026	363	21.1
	27 Nov	0.07	0.14	0.03	0.004	384	26.0
	30 Dec	0.09	0.28	0.16	3.92	-	-

Seepage meter		Liters through meter*	Velocity ($\mu m\ s^{-1}$)						
B	23 Oct	1,510	0.623	0.15	0.54	0.13	10.0	460	-
B	27 Nov	1,930	0.276	0.16	0.20	0.08	12.3	459	4.95
B	30 Dec	2,380	0.543	0.14	0.32	0.00	8.8	-	-
E	27 Nov	1,460	0.764	0.17	0.22	2.09	13.2	490	10.3
E	30 Dec	1,940	0.487	0.08	0.32	3.4	14	-	-
E	26 May	4,050+	1.03	0.30	0.30	2.48	16.0	-	-
K	27 Nov	1,240	0.492	0.11	0.20	0.17	0.003	530	6.37
K	30 Dec	1,780	0.743	0.21	0.32	0.20	0.003	-	-
N	27 Nov	1,270	0.747	0.17	0.28	0.11	0.002	480	5.5
N	30 Dec	1,830	0.650	0.02	0.28	0.16	0.004	-	-

* This column shows the volume of water which flowed through the seepage meter before the sample was collected. The average flow during the preceding months was used to calculate this number.

\+ This number, for a sample collected in 1972, was calculated using the autumn flow rate.

2.0 mg $liter^{-1}$ NH_3-N even after 4,000 liters of groundwater and 9 months had passed. However, the phosphate concentration in seepage meter E was not higher than that of the other meters at this site (Table 2). Wells 9 and 11 (Fig. 2), located lakeward of a septic tank, had the highest specific conductivity and the highest concentration of orthophosphate, nitrate nitrogen, and chloride (Table 2). Average orthophosphate concentration of water from the other wells (8, 10, and 12) was in the same range as the orthophosphate concentration of water from the seepage meters.

Some evidence indicated that a high nitrate zone capped the water table. The seepage inflow 7 m from shore (B and E, Fig. 2) contained from 8.8–16 mg $liter^{-1}$ NO_3-N, but in groundwater discharged 12 m and 17 m from shore, nitrate concentrations were <0.005 mg $liter^{-1}$ N. Average nitrate concentrations in the shallow wells near the lakeshore ranged from 8.78–31.8 mg $liter^{-1}$ N (Table 2). Monthly samples from a well 57 m from the edge of the lake contained 1.57–0.34 mg $liter^{-1}$ NO_3-N at the surface of the water table, but when the well was driven 0.5 m deeper, nitrate levels fell to <0.012. It is not uncommon to find high nitrate concentrations in shallow groundwater near the water table (Behnke 1975).

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Lake water contained less phosphate, less inorganic nitrogen, lower conductivity, and higher chloride than the seepage water (Table 2). Seepage water contained about the same amount of orthophosphate and about the same conductivity as the well water not affected by the septic tank.

The inexpensive seepage meter was used on moderately permeable sediment of lakes and estuaries to measure seepage velocities ranging from −0.1–2.58 $\mu m\ s^{-1}$. Where seepage is upward, the seepage meter yields a sample of water which can be used for chemical analysis.

For the velocity range encountered in the field, a linear relation was observed between measured seepage velocity and an experimentally controlled hydraulic gradient. Changes in the rate and direction of seepage flux during a tidal cycle were correlated with changes in the water surface elevation of an estuary. Closely placed seepage meters gave reproducible results.

Velocity and chemistry of seepage inflow to Lake Sallie thus concurred with results predicted by the theoretical flow net: shallow groundwater discharged nearshore contained high concentrations of nitrate, whereas deeper groundwater, discharged farther from shore, contained very little nitrate; nearshore seepage was rapid and declined with distance from shore. Where groundwater discharge was relatively rapid (0.4–0.8 $\mu m\ s^{-1}$), water collected with the seepage meter became chemically consistent after about 4 months and was chemically similar to water from wells located along the same flow path.

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2-15-9

A Field Exercise on Groundwater Flow Using Seepage Meters and Mini-piezometers*

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Abstract

Basic principles of physical hydrogeology and the nature of the hydrologic interactions between groundwater and surface water can be convincingly demonstrated in the field using two inexpensive and easily-constructed devices known as the miniature piezometer and the seepage meter. These instruments have been successfully used during a hydrogeology field course at the University of Waterloo and have been adopted as a routine teaching aid. Seepage meters and miniature piezometers are inserted in the sediment of shallow areas in lakes, estuaries, or streams. In a matter of a few hours, the devices can be installed, monitored, and removed. Information on the direction and rate of groundwater flow can be obtained. Hydraulic conductivity can be measured using several types of tests. Samples of the groundwater can be collected and, with field measurements of parameters such as specific conductance, dissolved oxygen, pH, and chloride, comparisons between groundwater and surface water quality can be made. Student investigations can include the identification of groundwater inflow or outflow areas in lakes, streams, or estuaries, measurement of the spatial and temporal viarations in seepage flux through bottom sediments, and identification of zones of subsurface pollutant migration into surface waters. A day of equipment preparation and a preliminary site visit are prerequisites to the student field activities. Materials for a seepage meter and a miniature piezometer can be acquired for less than 25 dollars.

Key Words: education, hydrogeology, groundwater, limnology, hydrology, water quality, contaminant, seepage, field exercise, lake, stream, estuary.

Introduction

This paper describes the use of two simple inexpensive devices that enable students to measure the flow of groundwater and to demonstrate for themselves some of the basic principles of hydrogeology. A half-day field trip to a shallow body of surface water, preferably with a sandy bottom, makes it possible for students to acquire data that can serve as an impressive indication of the dynamic nature of groundwater flow in a natural setting. The methods are rapid and direct and provide information that cannot otherwise be obtained even if expensive drilling equipment is available. The exercise involves the use of seepage meters to measure groundwater flow rates and the use of manually-installed miniature piezometers to measure hydraulic head (groundwater potential) and hydraulic conductivity. These methods have been used during field experiments in a groundwater hydrology course at the University of Waterloo and as a means of investigating groundwater-flow conditions in lake- and streambeds. The devices are also being used in current research projects, including thesis studies by undergraduate and graduate students.

The basic elements of groundwater flow are related through the Darcy equation,

$$Q = A \frac{dh}{dl} K.$$

*This work was sponsored in part by a research agreement with Environment Canada.

Q is the flux of groundwater (volume/unit time), A is the area through which flow occurs, dh/dl is the hydraulic gradient (the change in hydraulic head over a distance along the line of flow (unitless)) and K is the hydraulic conductivity of the material (usually expressed as cm/s). Hydraulic head is a measure of the energy per unit weight of the groundwater. Textbooks on hydrogeology such as Todd (1959), Davis and De Weist (1966) and Domenico (1972) present more detailed discussions of the Darcy equation and its significance in groundwater studies.

Figure 1 shows schematic illustrations of groundwater flow near lakes, in lake bottoms, and in stream bottoms. The flow systems are represented by isopotential lines (contour lines of hydraulic head) and arrows showing the direction of groundwater flow. In lake bottoms and streambeds groundwater flow is upward, downward, or horizontal but is rarely non-existent. The direction and rate of flow is dependant on the physiography, texture and stratigraphy of the subsurface materials. Locally, the flow in streambeds and lake bottoms can vary dramatically, thus providing a variety of observational conditions within a single study area.

The two devices described below provide information on the flow net and on the flux and velocity of water moving along the flow lines at and near the interface. The seepage meter and the minipiezometer also provide a means of sampling the water that is either leaving or entering the groundwater zone beneath the lake or stream. This can often serve to demonstrate the influence The

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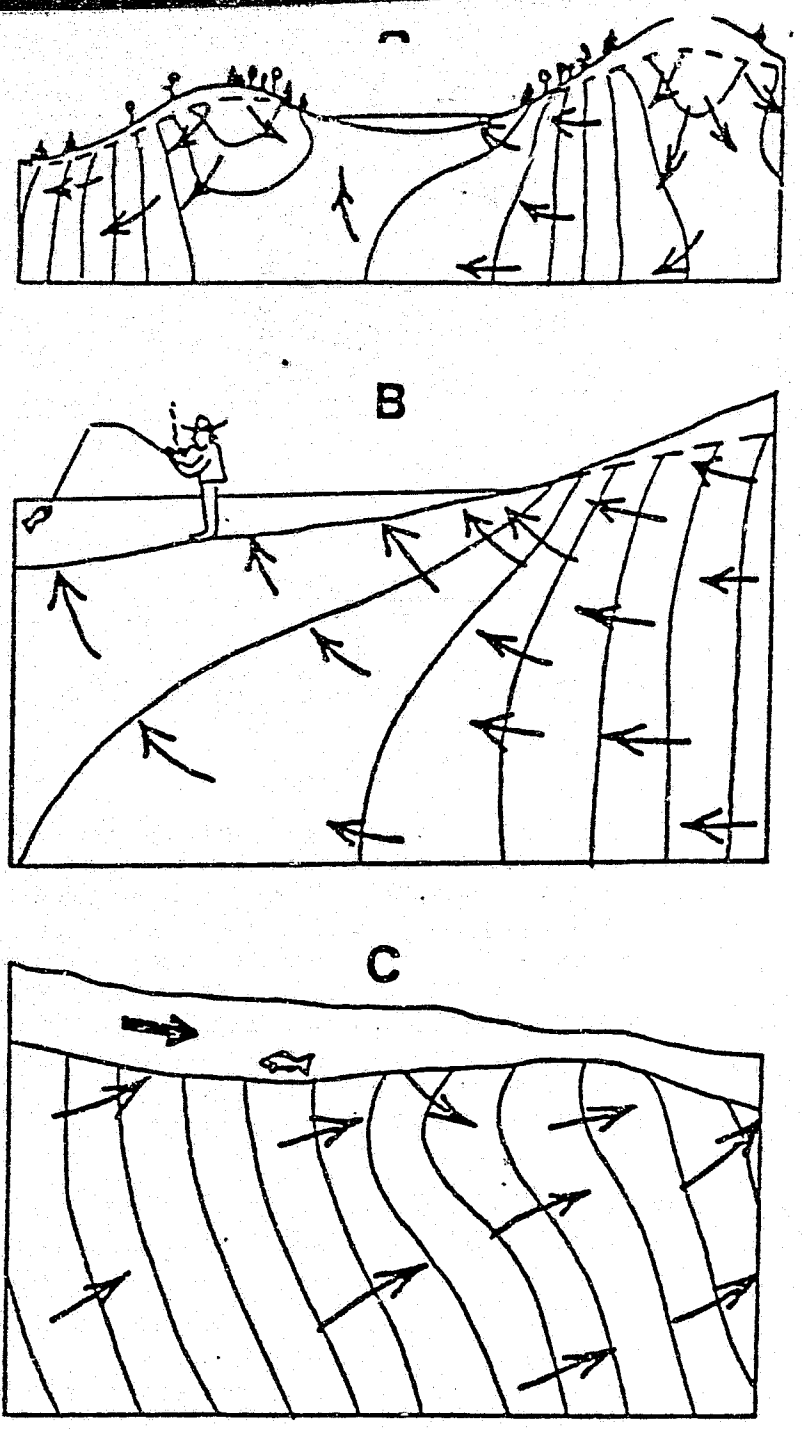

Fig. 1. — Idealized sections showing groundwater flow near bodies of surface water. A, topographic highs are recharge zones and the topographic lows (often occupied by lakes or streams) are discharge zones; B, pattern of groundwater discharge into a lake or estuary; C, longitudinal section of a streambed indicating flow into the sediment where the stream bed is concave. (A modified from Winter, 1976; B modified from Lee, 1977; C modified from Vaux, 1968)

of groundwater on surface-water quality. In some cases it is possible to demonstrate that pollutants are fed to lakes or streams by groundwater seepage.

Miniature Piezometers

Piezometers are used to measure the hydraulic head in geologic materials that are saturated under positive pressure. They consist of pipes with slotted tips or well points on the end. Piezometers are normally installed in boreholes drilled by power auger, wash-boring, rotary drill or cable-tool equipment. Piezometers installed at depths between several meters and many tens of meters below ground surface have been used routinely by hydrogeologists and soil engineers for several decades. The miniature piezometer (mini-piezometer) is a similar device but is smaller in size and is installed manually.

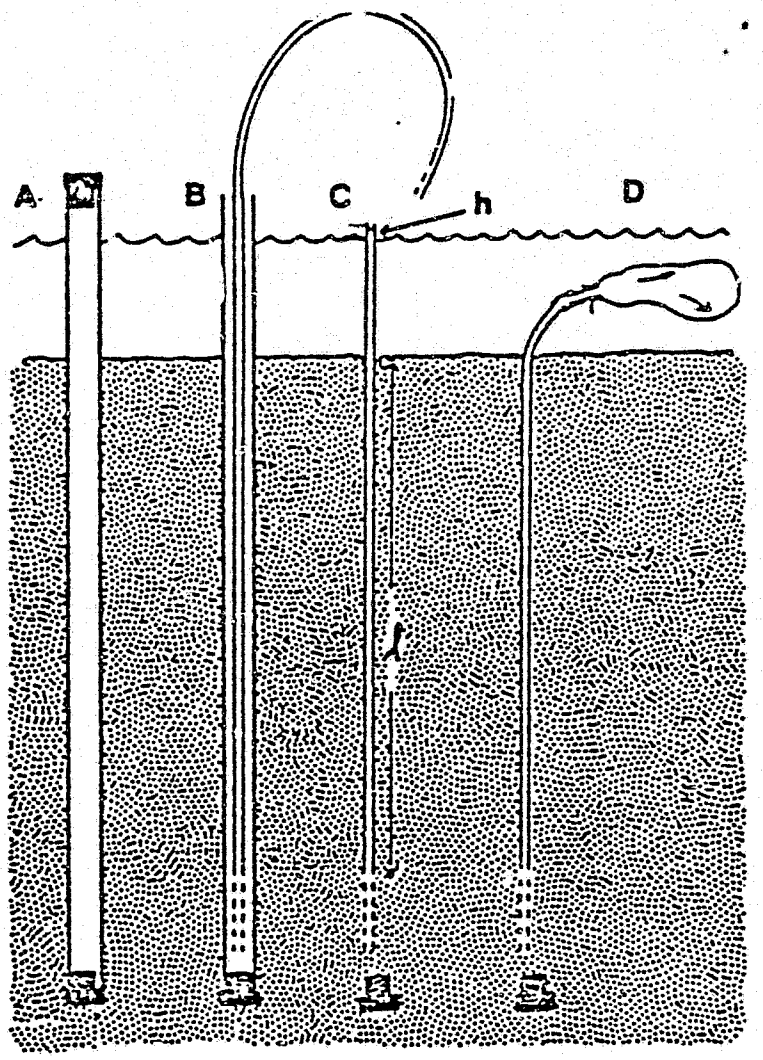

Fig. 2. — General features and method of installation of a mini-piezometer. A, casing driven into the sediment; B, plastic tube with screened tip inserted in the casing; C, plastic tube is a piezometer and indicates differential head (h) with respect to the surface water; D, plastic bag attached to the piezometer collects sediment-porewater. (See text for details)

Figure 2 shows the general features and method of installation of the mini-piezometer. The piezometer consists of a 0.31 cm ID translucent polyethylene tube (approximately $0.12/m) with a perforated tip wrapped with 0.2 mm nylon mesh netting or fiberglass cloth. The netting protects the tip from influx of sediment. The piezometer is installed using a 1.7 cm ID steel pipe that is driven into the bed by hammer or vibrator. The casing pipe is loosely fitted with 1.4 cm (5/8 inch) lag bolts at each end. When the steel pipe is driven to the desired depth the plastic tube is inserted and held in place as the pipe is pulled out. The bottom lag bolt remains in the sediment near the piezometer tip. Raised above the water level, the translucent tube shows the head differential with respect to the surface water.

Small differences in hydraulic head relative to the surface water are measured using a manometer that overcomes the difficulties of observing head differences that are slightly above or below the level of the surface water. The principle of the apparatus is indicated in figure 3A which shows how the difference in head between the piezometer and the surface water may be elevated and measured accurately. The equipment needed to measure this differential head in mini-piezometers is shown in figure 3B. The meter stick is attached to a rod and installed vertically next to the piezometer. The apparatus is prepared for use by blowing water out of the tygon tube using a rubber suction bulb. The bulb is squeezed and released slowly allowing water to rise to a static level. The

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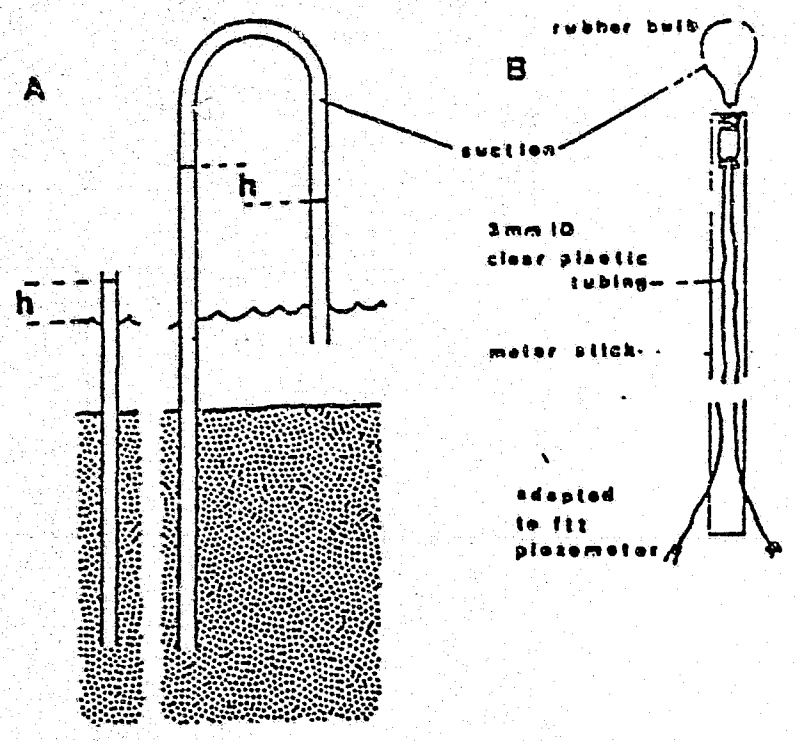

Fig. 3. — The manometer used to measure differential heads in minipiezometers. A, principle of operation; B, the field apparatus.

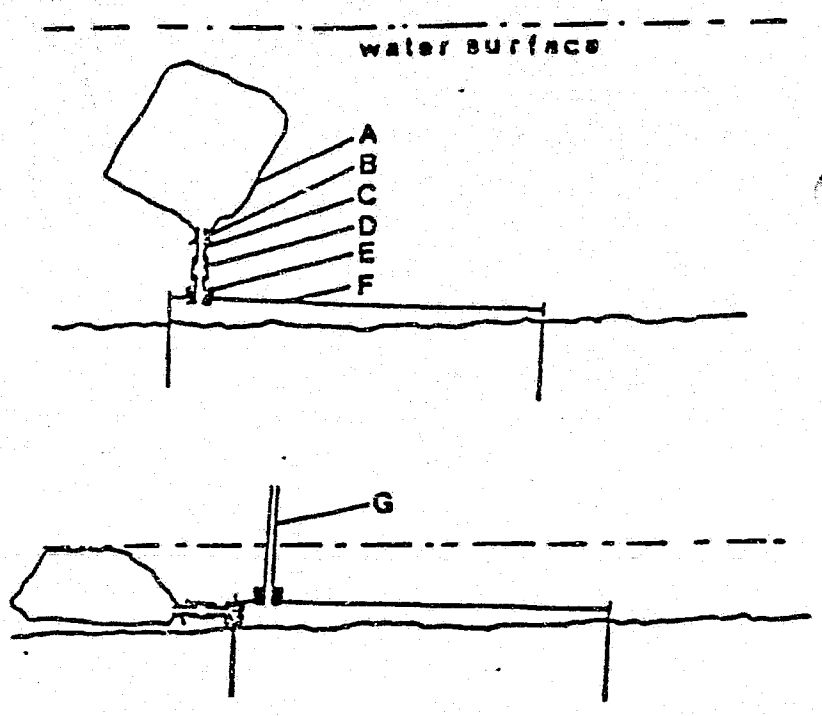

Fig. 4 — Full section view of seepage meter showing proper placement in the sediment. A, 4 liter, 0.017 mm membrane plastic Baggies Alligator bag (open end was heat sealed); B, rubber-band wrap; C, 0.64 cm inside diameter, 6 cm long, polyethylene tube; D, 0.79 cm inside diameter, 4.5 cm long, amber-latex tube; F, 15 cm x 57 cm diameter epoxy-coated cylinder (end-section of a steel drum); G, 0.64 cm inside diameter, polyethylene tube long enough to reach above the surface water. E, No. 5½ one-hole rubber stopper with polyethylene tube.

levels in the two tubes are compared to be sure no bubbles of air are causing different heads in the two tubes. One end of the tube is then attached to the piezometer tube and the other is left in the overlying water. When the water levels in the two tubes reach static levels, the differential head, Δh, is read on the meter stick. The vertical hydraulic gradient is $\Delta h/\Delta \ell$, where $\Delta \ell$ is the depth of the piezometer screen below the sediment-water interface.

To measure the hydraulic conductivity of the sediment adjacent to the piezometer tip, two types of tests can be conducted, a falling head test and a constant head test. For the falling head test the piezometer tube is extended vertically above the surface-water level and then filled with water to a condition of overflow. The overflow condition is discontinued at a time that is recorded as t initial. The rate at which the water level in the tube declines is then recorded. This can be facilitated by taking stop-watch readings of times at which the water level passes marked intervals on the tube. If the hydraulic conductivity is very high, the rate of water-level fall will be very rapid. Increased accuracy can be obtained if the fall distance is lengthened by extending the tube a couple meters above the surface-water level or by feeding water to the piezometer from a larger diameter reservoir with marked intervals. A constant head test can be performed by placing a known volume of water in a plastic bag attached to the submerged tube. The hydraulic head in the submerged bag is the level of the stream or lake level. The change in volume of water in the bag over a recorded time interval is measured. Example results and calculation procedures are summarized in Table 1. The derivations of the equations used in this analysis were first presented by Hvorslev (1951) and have been summarized by Lambe and Whitman (1969). The constant head and falling head formulas are based on significantly different assumptions. Comparison of hydraulic conductivities determined by these two methods can be an interesting endeavor.

Where the hydraulic gradient is downward, groundwater from the piezometer can be collected using a suction bulb or hand-operated vacuum pump connected to a bottle. Where the gradient is upward samples can be obtained by simply letting water discharge from the piezometer tube. Where the gradient is weak or the material poorly conductive, the screened area of the piezometer tip must be increased and suction must be applied to obtain water samples.

Seepage Meters

Seepage flux between the groundwater and the overlying surface water can be measured directly by covering an area of sediment with an open-bottomed container and then measuring the time and change of water volume in a bag connected to the container (Lee 1977). Two of these devices, known as seepage meters (Fig. 4), can be made by cutting 15-cm-long, end-sections from a 0.208 m^3 (55 gallon) metal drum. Seepage meters can detect flux as low as 0.001 cm^3/m^2 s (about 0.1 mm/day) if the bag is left connected for a day or longer. In water over 20 cm deep, a single tube through the top of the seepage meter serves both as a vent for any gas released from the sediment and as a connection for the measuring bag. In shallow water an additional outlet tube on the side of the seepage meter permits the bag to be submerged as it must be to maintain the same piezometric head in the seepage meter and in the surface water.

In use, the seepage meter is pushed slowly into the sediment and tilted slightly so that the vent will function properly (Fig. 4). Unless the sediment surface is soft or irregular, it is often unnecessary to push the seepage meter more than 8 cm into the sediment to obtain an adequate seal. The stopper with tube is then twisted into cylinder hole. Where flow is upward, it is unnecessary to

2-15-12

Table 1. Sample field data and calculations.

Piezometer observations

Piezometer number: P1 Depth of screen below sediment: 1 m

Time	Δh, mm	Gradient Δh/ℓ	Elapsed time, min	Volume change, cm³
1630	35	.035	—	—
1650	33	.033	—	—
1739	36	.036	—	—
1705-1723	—	—	18	+12

Hydraulic conductivity calculation: Assuming a case G screen (Hvorslev 1951), Constant head test

$$K_h = \frac{q \ln [(mL/D)+(1+(mL/D)^2)^{.5}]}{2\pi L H_c}$$

where

D = diameter, intake, sample (cm)
L = length, intake, sample (cm) ← ?
H_c = constant piezometric head (cm)
q = flow of water (cm³/s)
t = time (s)
m = transformation ratio, $(K_h/K_v)^{.5}$ assumed to equal 1*
ln = 2.3 $\log_{10}$.

Therefore K_h =

$$\frac{(12\ cm^3/1080\ s)\ LN\ [(10\ cm/.31\ cm) + (1+(10\ cm/.31\ cm)^2)^{.5}]}{2\pi (10\ cm)(3.5\ cm)}$$

$= 2.1 \times 10^{-4}$ cm/s

Seepage meter observations

Seepage meter number: SM 1
Depth of water: 0.2m
Sediment type: sand and organic matter

Time	Volume change, cm³	Elapsed time, min	Seepage flux, μm/s	Hydraulic conductivity, cm/s
1630-1648	+126	18	+.450	1.3×10^{-3}
1650-1736	+355	46	+.498	1.5×10^{-3}
1739-1752	+ 94	13	+.465	1.2×10^{-3}

Seepage flux calculation:

$$Q, \mu m/s = \frac{(\text{volume change, cm}^3)\ 0.0643}{(\text{elapsed time, min})}$$

$$= \frac{(126)\ 0.0643}{18} = 0.450\ \mu m/s$$

Hydraulic conductivity calculation:
From the Darcy equation K = v/S, where
v = Darcy velocity
S = hydraulic gradient, Δh/Δℓ
K = hydraulic conductivity

Therefore $K = \frac{0.450\ \mu m/s}{0.035} = 1.3 \times 10^{-3}$ cm/s

* The effect of this assumption is small (e.g. if m = 10, $K_h = 2.7 \times 10^{-4}$ cm/s; if m = 1000, $K_h = 3.9 \times 10^{-4}$ cm/s.

add a known volume of water to the measuring bag before connecting it to the seepage meter.

The Darcy velocity, v, (volume per unit area per unit time) is calculated from the relation 0.0643V ÷ t = v, where V is the volume of water (cm³) entering or leaving the bag, and t is the elapsed time (min). The Darcy velocity is expressed as micrometers per second (1 μm/s = 8.64 cm/day). The factor 0.0643 converts units of time, volume, and area covered by a seepage meter (0.255 m²) to equivalent units of velocity (μm/s) or seepage flux (cm³/m² s). The average linear interstitial velocity is equal to the Darcy velocity divided by the porosity of the sediment. For most sandy sediments, porosities are in the range of 0.3 to 0.4 (expressed as a fraction).

Student Activities

Students from the University of Waterloo used these techniques to investigate the migration of tritium-contaminated groundwater to a small lake and stream in an experimental watershed at the Chalk River Nuclear Laboratories in eastern Ontario. To minimize the number of pieces of equipment required, this exercise was combined with stream-flow metering so the students could rotate from one activity to the other. Each student installed a piezometer and a seepage meter and measured piezometric head during seepage-measurement intervals ranging from 10 to 45 minutes. Because of the difficulty of removing deeper casings by hand, most students elected to emplace their piezometer 0.6 to 1 m into the sediment. Each student conducted a constant head test to determine the hydraulic conductivity of material near the piezometer screen, and then removed the seepage meter so that subsequent students could install the equipment themselves.

The study sites met the following selection criteria:
Wave height less than 0.3 m;
Current speed less than 0.2 m/s;
Firm sand with very little gravel and cobble; and
Water depth 0.1 to 0.6 m.

Preliminary measurements were made to be sure the students could install the equipment and find seepage rates high enough to complete the exercise in 2 to 3 hours. Because seepage rates are generally highest near the shore, as illustrated in figure 1B, and because shoreline areas were accessible by wading, students worked within 10 m of the shoreline.

Data collected by one student and some sample calculations are shown in Table 1. Piezometric head and seepage rate generally decreased with distance from the lakeshore but seepage rates were quite variable in the streambed. Current effects probably accounted for the variability of replicate seepage measurements in the stream. Streambed heterogeneity probably caused variability between points. No zones of downward seepage were found in either the lake or the stream.

Direct measurements of seepage flux, made by the students, showed that groundwater flowed into the lake along the northern shore. A pore-water constituent (in this case tritiated water) indicated that this seepage water is contaminated by tritium, contained in waste waters pumped into disposal pits located about 800 m north of the lakeshore. The use of seepage meters and mini-piezometers thus enabled the students within a very short time to draw conclusions with regard to the occurrence and source of contaminants entering the lake. Analysis of water from mini-piezometers in the nearby streambed

2-15-13

showed no tritium contamination despite the presence of considerable tritium in the stream itself.

The dynamic nature of the groundwater regime was demonstrated in a visibly impressive manner by filling of the measuring bag attached to the seepage meter. All but 2 of 14 piezometers functioned properly as indicated by raising and lowering the piezometer tube and watching the water level fall or rise to a static level and by the constant-head response tests. Failure to obtain responsive piezometers was due to lifting of the piezometer tube while pulling the casing out of the sediment and consequent loss of the nylon-mesh screen.

We anticipate that a similar approach could be used by others to teach general principles of hydrogeology. This exercise could be included as a part of an introductory course in hydrogeology. It could also be used in hydrology, limnology, geomorphology or sedimentology courses. It could serve as a springboard for student projects designed to determine the importance of the groundwater component to the water budget of a lake or pond, to identify contaminant migration from groundwater to surface waters, to study the effects of seepage flux on sediment chemistry, or to study the role of groundwater in fluvial erosion and deposition. Because these topics have only recently begun to receive research attention, this work offers an opportunity and a freshness which is attractive to students.

Planning the Field Exercise

Sandy shores of gravel-quarry ponds, lakes, reservoirs, and estuaries are ideal sites for these exercises, but the importance of making preliminary measurements to identify suitable sites cannot be overemphasized. Seepage rates must be high enough so that volume changes of at least 50 cm^3 can occur in the measuring bag in 1-2 hours. The sediment should not contain rocks which will bend piezometer drive-casings. Strong wave action and currents interfere with accurate measurements of seepage, although piezometers would probably not be affected adversely. Mud bottoms may not have sufficient flow to permit flux measurement in 1-2 hours.

In estuaries, where tidal fluctuations induce seepage flux through sediment, it may be helpful to consult tide tables before planning a field exercise. At low tide, the highest rates of upward seepage and the strongest upward gradients occur (Lee 1977), and it is easier to install seepage meters at this time. Estimates of net seepage flux will require measurement through an entire tidal cycle.

In streams where surface-water velocity is low and especially in sandy areas, these methods can be used successfully. In other stream environments, however, it may be difficult to find suitable demonstration sites. Downward seepage in streams may be induced where permeability or depth of gravel increases in the direction of streamflow or where the longitudinal bed profile is concave (Vaux 1968). These factors, heterogeneity and current, make data from streambeds more difficult to interpret than comparable data from quieter waters.

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Winter, T.C., 1976, Numerical simulation analysis of the interaction of lakes and ground water: *United States Geological Survey Professional Paper* 1001.

2-15-14

00116

EXHIBIT E

2. Water Use and Quality

Comment 16 (p. E-2-42, para. 4)

Provide the following information for tributaries at their confluence with the Susitna River: bathymetry, morphology, and stage discharge relationships.

Response

No stage-discharge relationships are available for the tributaries which will be inundated by the Watana and Devil Canyon reservoirs. Discharge data were measured on selected tributaries within the proposed impoundment study area in 1982. These data are contained in Table I. Mean annual discharge for each of the streams flowing into the reservoirs can be estimated using the following equation development by Freethey, G. W. and D.R. Scully. 1980.

$$Qa = 0.0119\ A^{0.99}\ E^{0.22}\ p^{0.93}$$

where Qa = mean annual discharge (cfs)
A = drainage area (square miles)
E = mean basin elevation (feet above mean sea level)
P = mean annual precipitation (inches)

Information on the bathymetry and morphology of Fog Creek, Tsusena Creek, Deadman Creek, Watana Creek, Kosina Creek, Jay Creek, Goose Creek and the Oshetna River at the confluence with the Susitna River is contained in Figures 1 through 8. A legend is provided for reference.

At Cheechako Creek (River Mile 152.4) large boulders are present at the mouth. Depths are uniform and relatively shallow at 3 to 4 feet.

At the confluence of Devil Creek with the Susitna River, the substrate consists of large boulders, cobble and rubble. The depth appears to drop off quickly but this has not been confirmed by measurement. There is a large clear pool at the mouth which is estimated to be 6 to 7 feet deep and which drops off toward the main river.

References

Freethey, G.W. and D.R. Scully. 1980. Water Resources of the Cook Inlet Basin, Alaska. USGS Hydrological Investigations Atlas HA-620.

TABLE 1

Discharge data on selected tributaries within the proposed impoundment study area, 1982

Tributary[a]	Date (1982)	Discharge (cfs)
Fog Creek	8/15	269
	9/12	307
Tsusena Creek	8/16	330
	9/12	363
Deadman Creek	8/21	228
Watana Creek	8/15	229
	9/19	557
Jay Creek	8/12	61
	9/19	154
Goose Creek	8/19	79
	9/10	150

[a]All discharges were taken near the mouth of the respective stream with the exception of Deadman Creek where it was taken approximately three miles upstream from the mouth.

LEGEND FOR FIGURES

- silt
- sand
- gravel - 1/4" - 3"
- rubble 3-5"
- cobble 5-10"
- boulder greater than 10"
- rock outcrop
- cliff
- cut bank
- undercut bank
- log
- debris pile
- beaver dam
- flow direction
- eddy
- mixing zone
- spawning redd
- spawning area
- grass
- trees
- shrubs
- aquatic vegetation
- overhanging vegetation
- SU HYDRO site marker
- Hydrolab sample site
- USGS sample site
- staff gage site
- thermograph (intragravel)
- thermograph (surface)
- site boundary

2-16-4

Substrate at the confluence area (10-20' into the right) is similar to that present at the mouth of Fog Creek. Some larger boulders are found out in the mixing zone. Depths at the mouth of Fog Cr. are between 2-4 feet. Visual observations indicate that the bottom slopes off gently from the mouth of Fog Creek out into the Susitna. Depths increase 1-3 below the mouth. At times there is a pool 2-4' deep near the mouth.

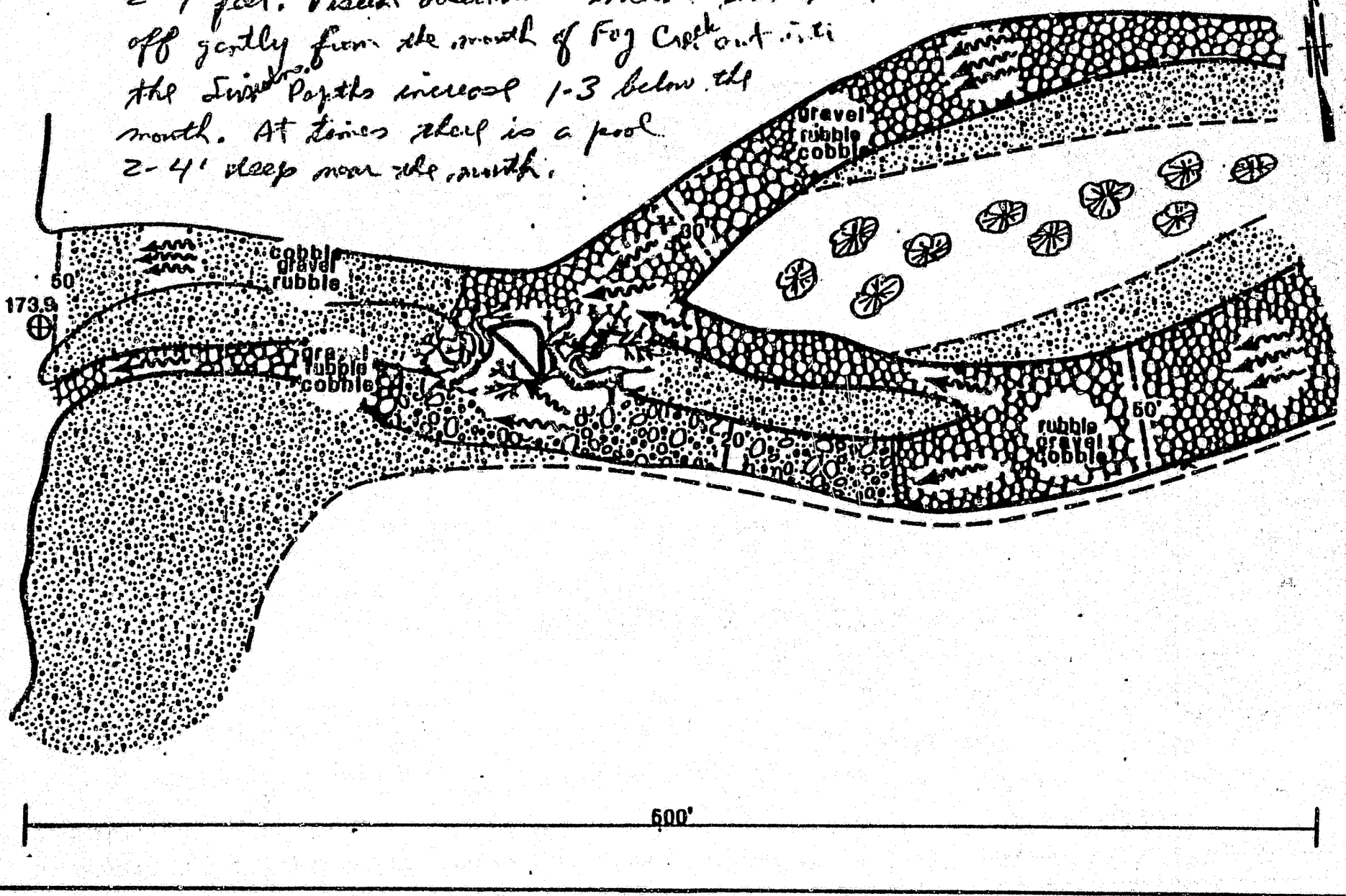


FIGURE 1

Planimetric map of Fog Creek - Site 01 (R.M. 173.9, G.C. 31N04E16DBB).

Substrates found at the mouth of Tsusena [redacted] extend into the Susitna. Substrates generally become a little coarser farther out into the swifter water of the main Susitna. Depths at the mouth of Tsusena are between 1-2 feet and gradually increase to 3-5' out into the mixing zone.

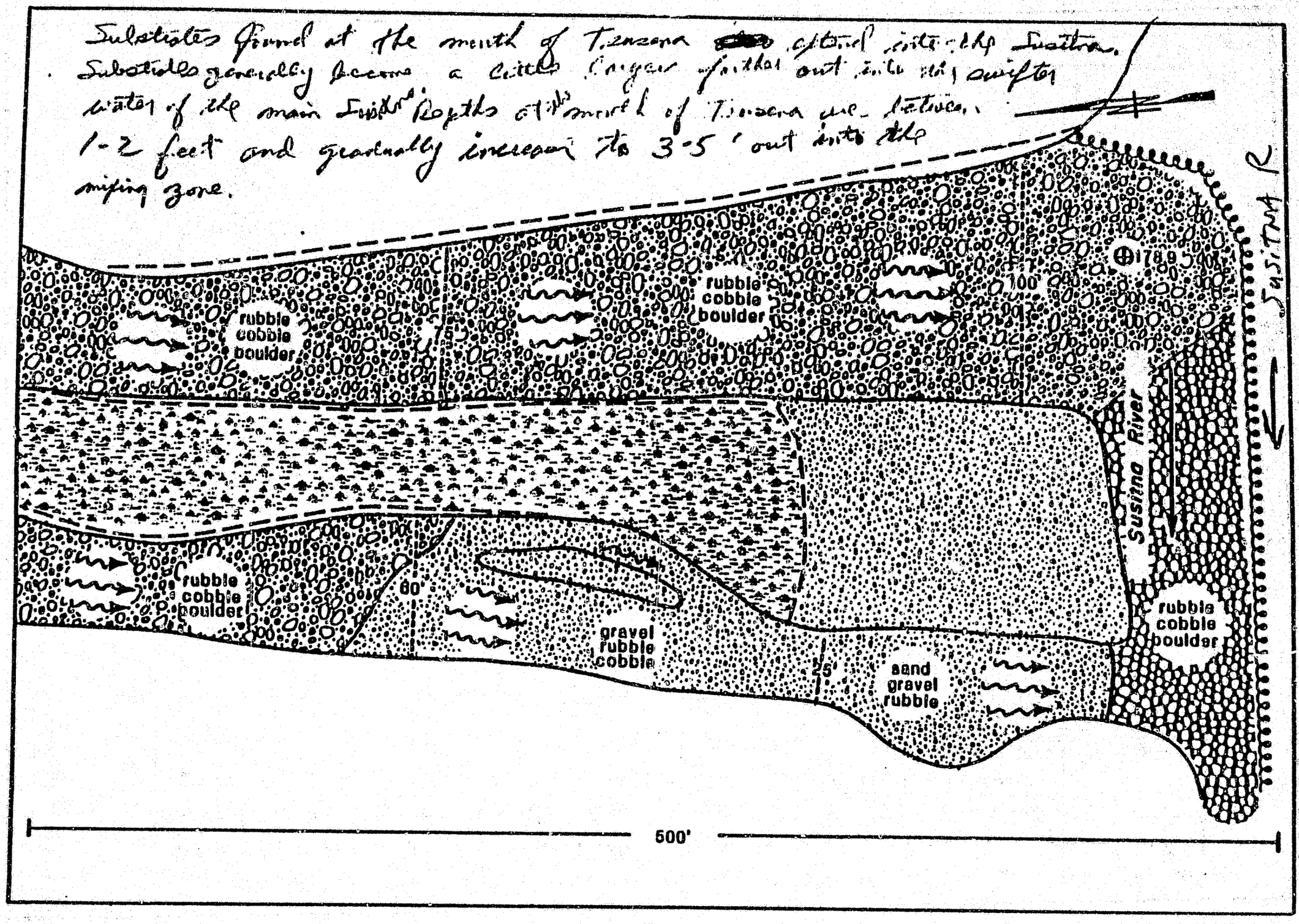


FIGURE 2

Planimetric map of Tsusena Creek - Site 01 (R.M. 178.9, G.C. 32N04E36ADB).

2-16-6

Substrates at the confluence are similar to those found in the lower reach of Deadman Cr. Many large boulders represent in the confluence zone. Depths in the confluence area are generally between 2-4' and are fairly uniform in the immediate area of the mouth.

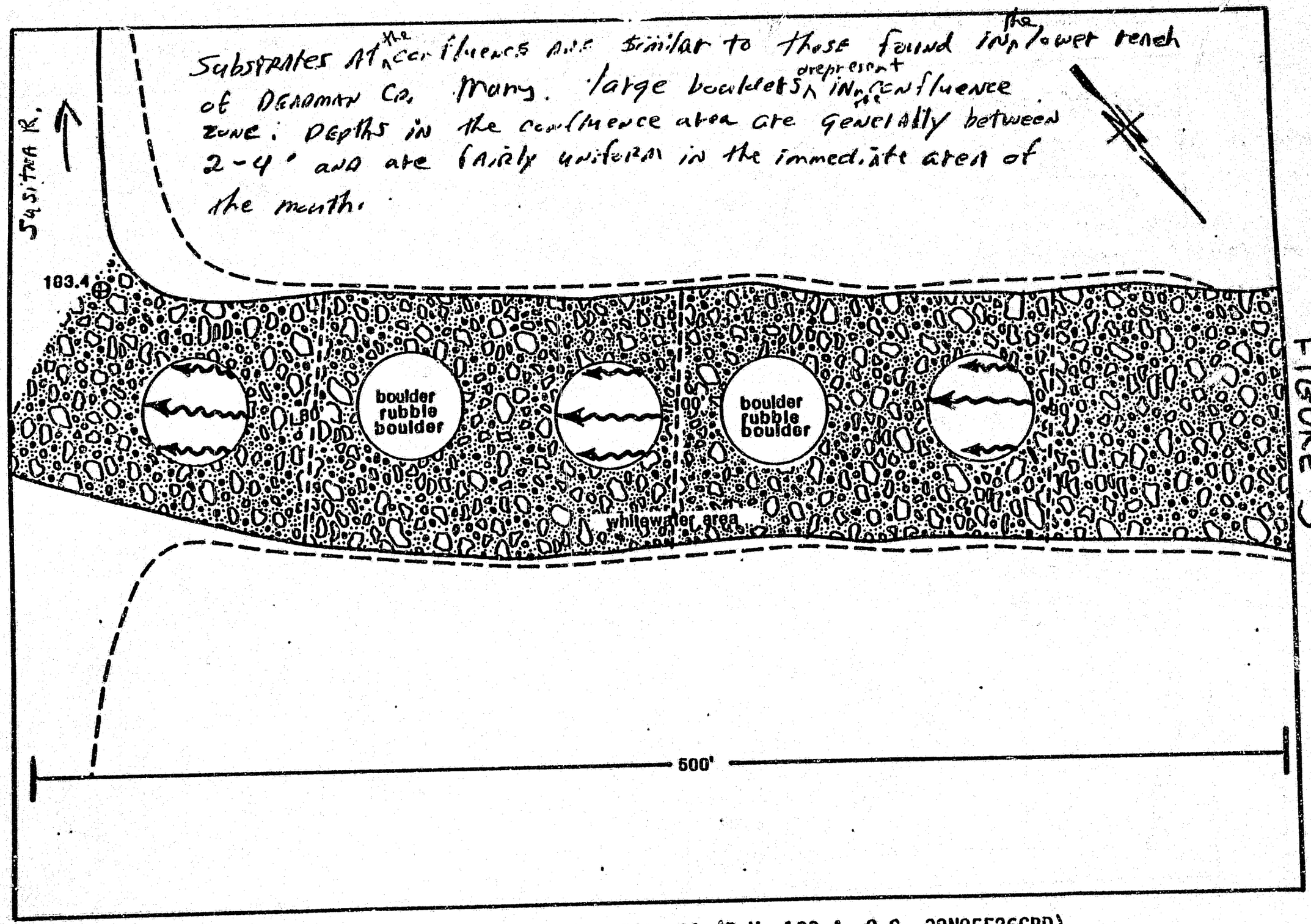


FIGURE 3

Planimetric map of Deadman Creek - Site 01 (R.M. 183.4, G.C. 32N05E26CBD).

2-16-7

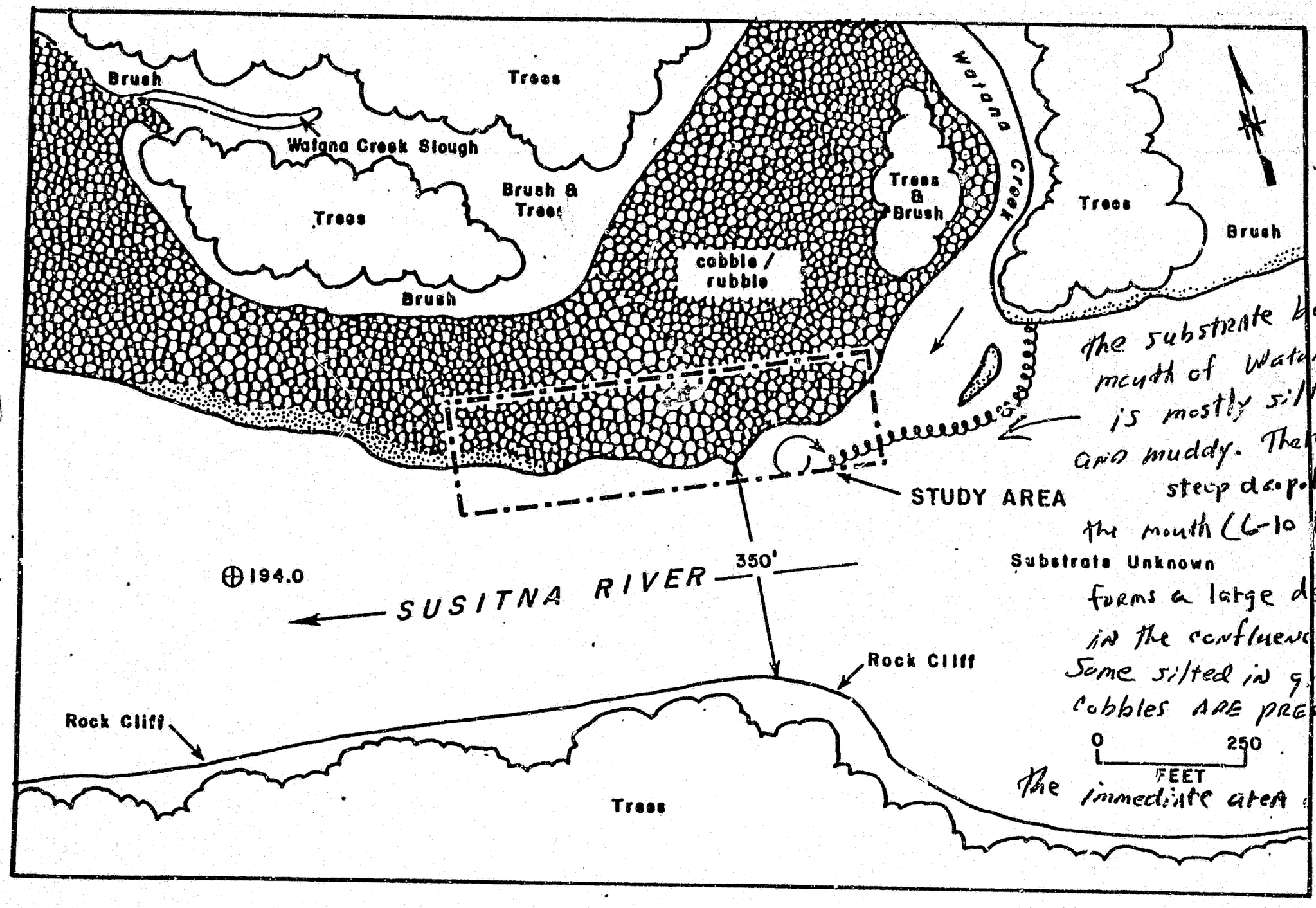


FIGURE 4

the substrate below the mouth of Watana CREEK is mostly silted in and muddy. There is a steep dropoff below the mouth (6-10 feet) which forms a large deep pool in the confluence AREA. Some silted in gravel and cobbles ARE PRESENT IN the immediate area of the mouth

Mainstem Susitna River habitat evaluation site at Watana Creek, RM 194.1, GC S32N06E25CCA.

2-16-8

Substrates in the confluence AREA are similar to those found in the lower reaches of Kosina. AREA within dashed line and below mixing zone is a very gradual sloping shelf. Depths are usually between 3-5 feet extending 40-60 feet from shore.

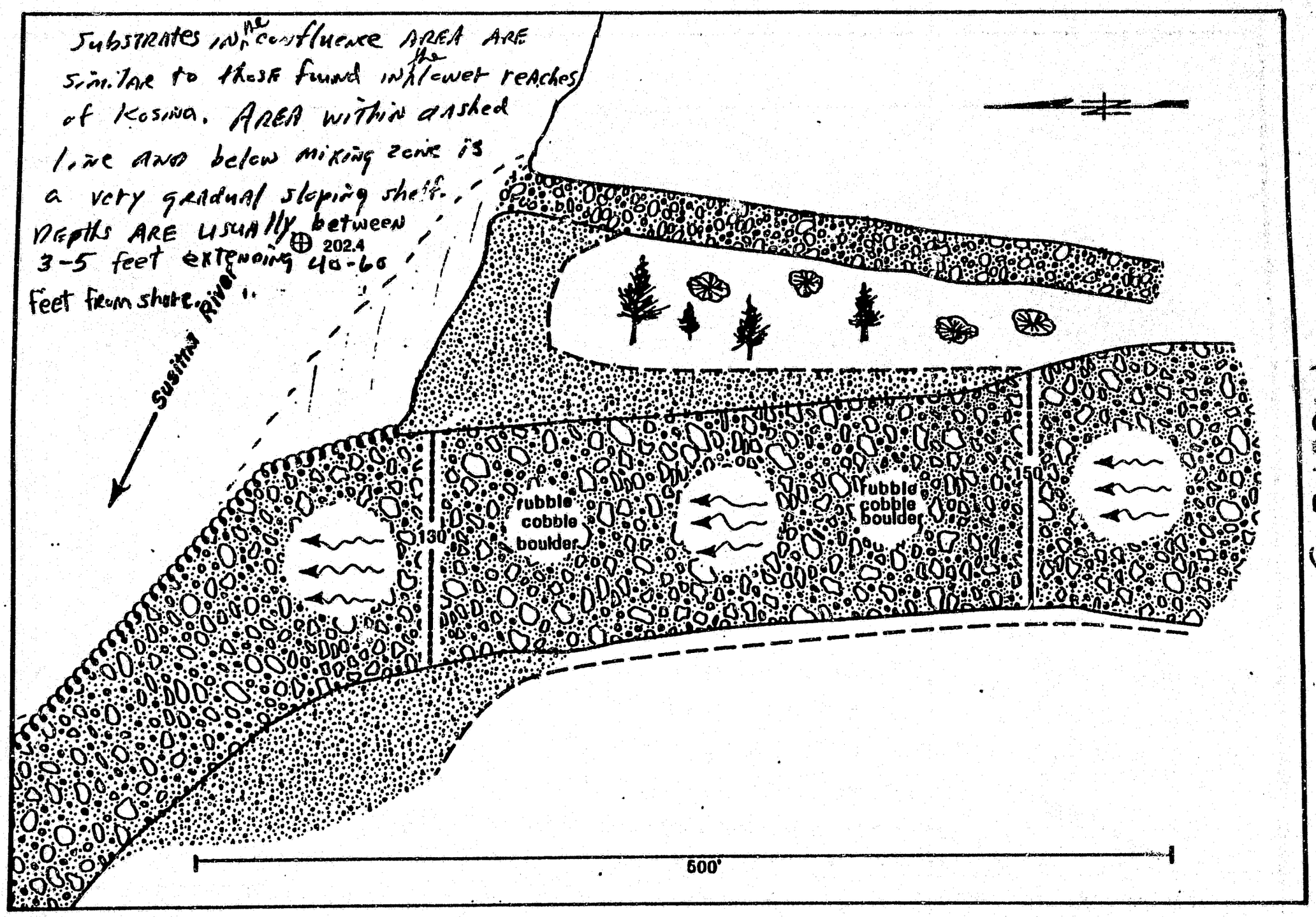
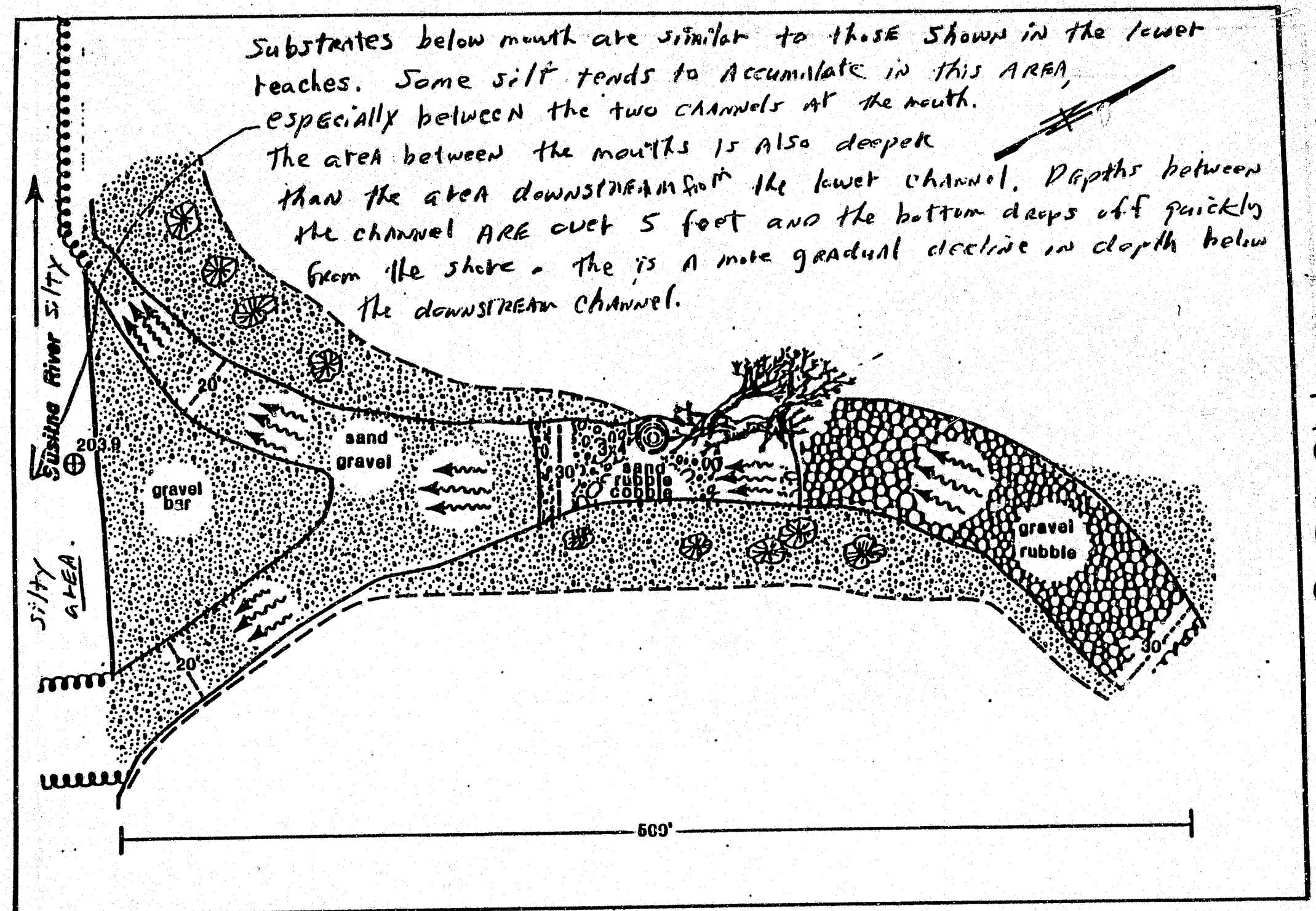


FIGURE 5

Planimetric map of Kosina Creek - Site 01 (R.M. 202.4, G.C. 31N08E15BAB).

2-16-9.

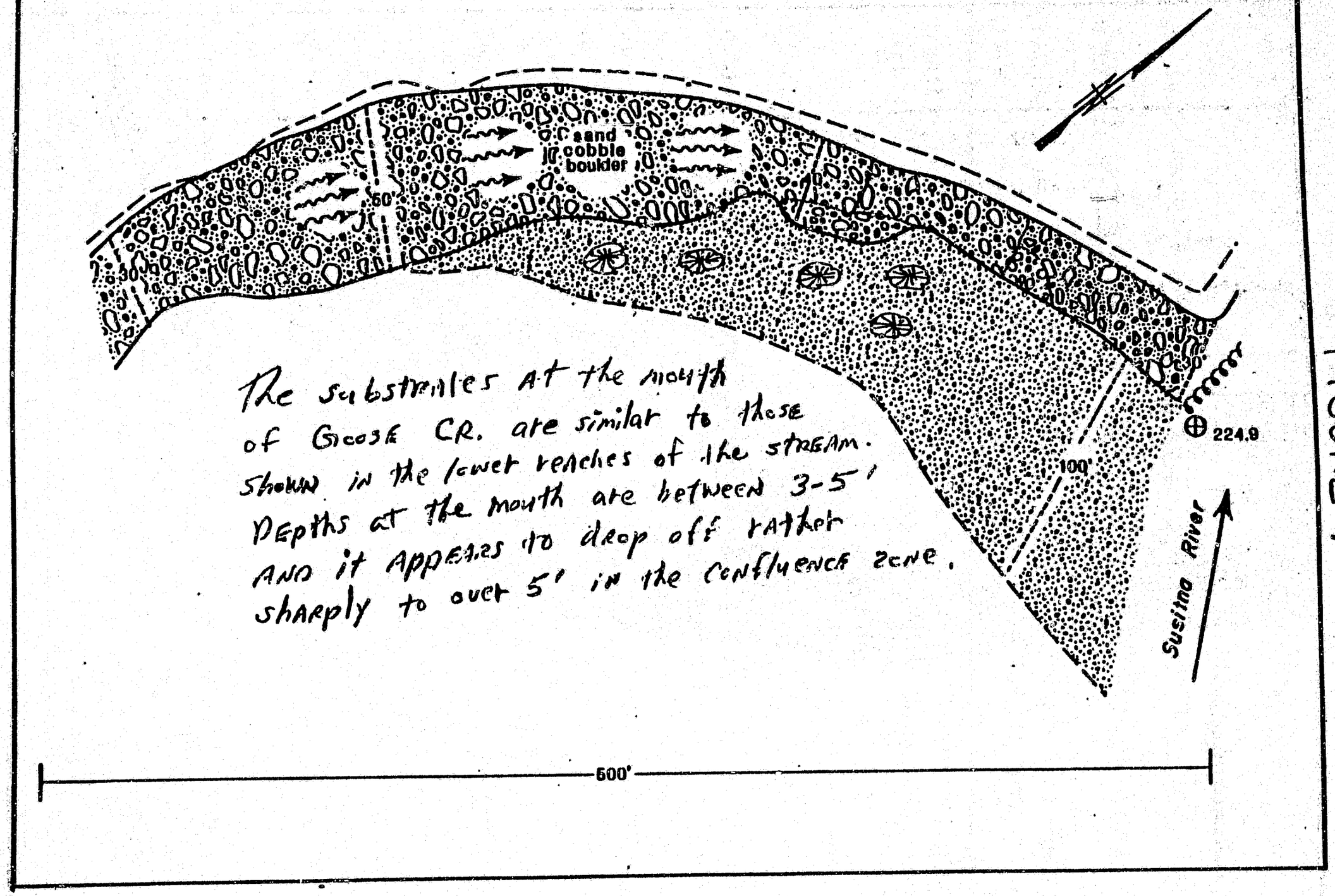
Substrates below mouth are similar to those shown in the lower reaches. Some silt tends to accumulate in this area, especially between the two channels at the mouth. The area between the mouths is also deeper than the area downstream from the lower channel. Depths between the channel are over 5 feet and the bottom drops off quickly from the shore. There is a more gradual decline in depth below the downstream channel.



Planimetric map of Jay Creek - Site 01 (R.M. 203.9, G.C. 31N08E13BCC).

FIGURE 6

2-16-10



The substrates at the mouth of Goose CR. are similar to those shown in the lower reaches of the stream. Depths at the mouth are between 3-5' AND it APPEARS to drop off rather sharply to over 5' in the confluence zone.

FIGURE 7

Planimetric map of Goose Creek (Upper) - Site 01 (R.M. 224.9, G.C. 30N11E32DBC).

2-16-11

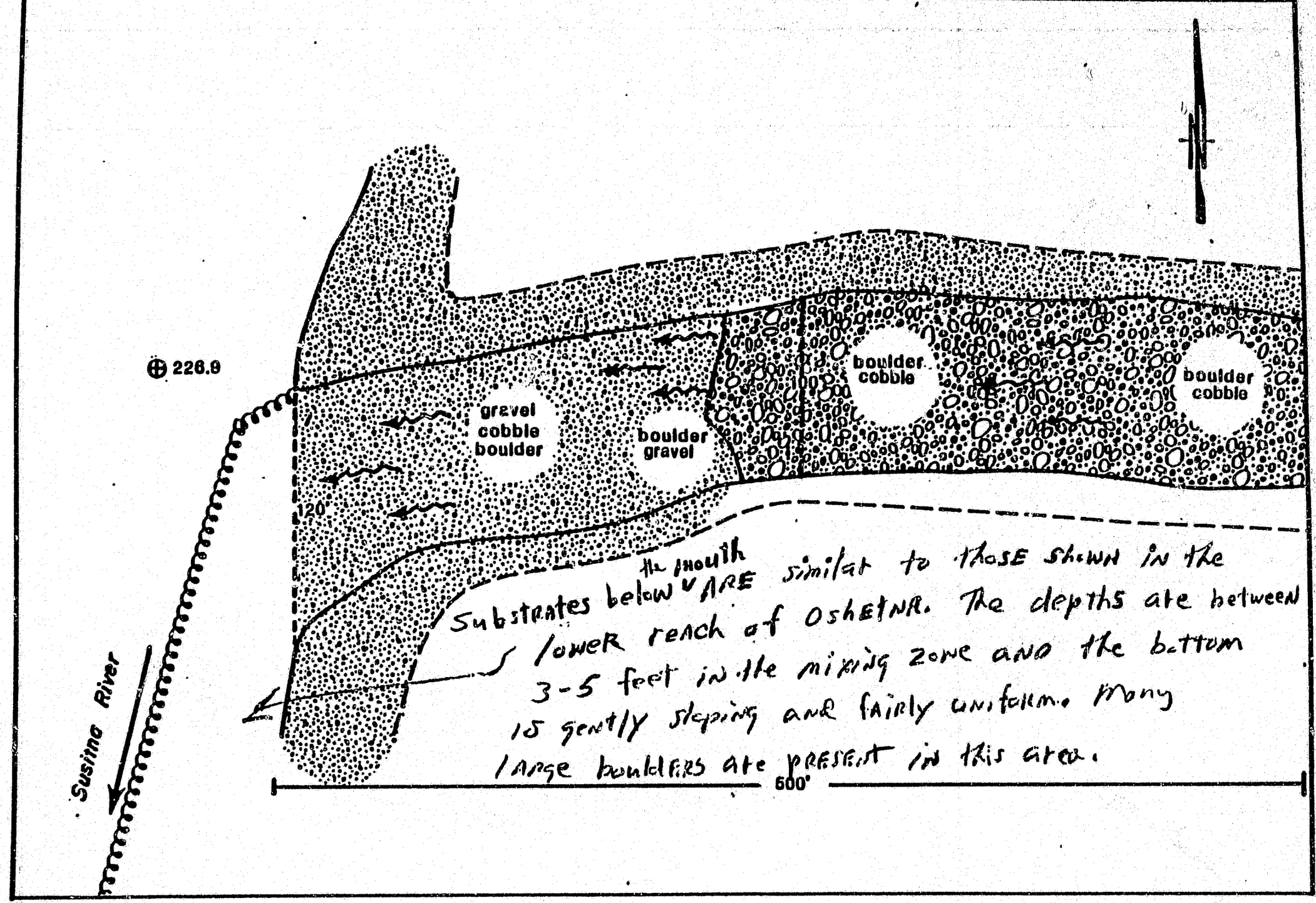


FIGURE 8

Planimetric map of Oshetna River - Site 01 (R.M. 226.9, G.C. 30N11E34CCD).

2-16-12

EXHIBIT E

2. Water Use and Quality

Comment 17 (p. E-2-46, para. 2)

Provide the basis for extrapolating HEC-2 water surface profiles outside the range of calibration flows (9,700 to 52,000 cfs at Gold Creek) listed in the R&M "Hydraulic and Ice Studies" report. Provide references to any additional calibration data sets for the HEC-2 model. Provide methodology and supporting data used to derive the estimated HEC-2 accuracy of ±1 foot.

Response

EXTRAPIOGLATION OF HEC-2 WATER SURFACE PROFILES

The HEC-2 analysis presented in the R&M "Hydraulic and Ice Studies" report was carried out for Gold Greek flows ranging from 9,700 cfs to 52,000 cfs. For Cross-section LRX-32 at River Mile 129.67 (Figure E.2.10), where a potential navigation restriction was identified, the HEC-2 analysis was used to estimate the water surface elevation for a Gold Creek flow of 6,000 cfs, the minimum summer flow proposed. Since LRX-32 was similar in cross- sectional shape at flows of 9,700 and 6,000 cfs, the rate curve for LRX-32 was extrapolated to provide the water surface elevation for a flow of 6,000 cfs. Pursuant to this, an HEC-2 verification run at a Gold Creek discharge of 3,000 cfs demonstrated that the water surface elevation for a flow of 6,000 cfs was as valid extrapolation. (See Reference to Additional HEC-2 Calibration Data Sets - below).

Figure 1 depicts the HEC-2 computed depth for Cross-section LRX-32 at a flow of 3,000 cfs. The rating curve computed for the flows from 9,700 cfs to 52,000 cfs has been extended to include added data points. Interpolation

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between 3,000 cfs and 9,700 cfs, at a discharge of 6,000 cfs, indicates a depth (2.45 feet) which is consistent with the estimated depth in Figure E.2.10 of Exhibit E in the License Application.

REFERENCE TO ADDITIONAL HEC-2 CALIBRATION DATA SETS

An HEC-2 verification run at a Gold Creek flow of 3,000 cfs was performed in 1981. The results, including a comparison of computed and observed water levels for various cross-sections, are presented in Appendix A, attached. All computed elevations are within ±1.0 feet of the observed elevations.

Methodology to Derive Estimated HEC-2 Accuracy

Manning's n values used in the calibration of the HEC-2 analysis are presented in Table 1 (attached) for four discharge conditions. A flow of 9,700 cfs was used as the base flow for Manning's n values. For flows other than 9,700 cfs, an adjustment for n values was made as follows:

$$n_{3,000} = (1.20)\ n_{9,700}$$
$$n_{13,000} = (0.95)\ n_{9,700}$$
$$n_{17,000} = (0.90)\ n_{9,700}$$
$$n_{23,400} = (0.90)\ n_{9,700}$$
$$n_{34,500} = (0.81)\ n_{9,700}$$
$$n_{52,000} = (0.81)\ n_{9,700}$$

A discussion of the rational used to adjust the Manning roughness coefficient is contained in R&M Consultants Inc. 1982. Susitna Hydroelectric Project Hydraulic and Ice Studies.

A comparison of the computed water surface elevations using the respective Manning's n values and observed water surface elevations for mainstem stations where stage data was available is presented in Table 2.

Based on the table of observed and calculated water surface elevations, all computed values except one were within ±1 foot of the observed values. The one value that differed by more than one foot differed by +1.2 foot and was at LRX-28 at a flow of 9,700 cfs. Considering the possibility of a small error in any stage observation, it was estimated that the accuracy is ±1 foot.

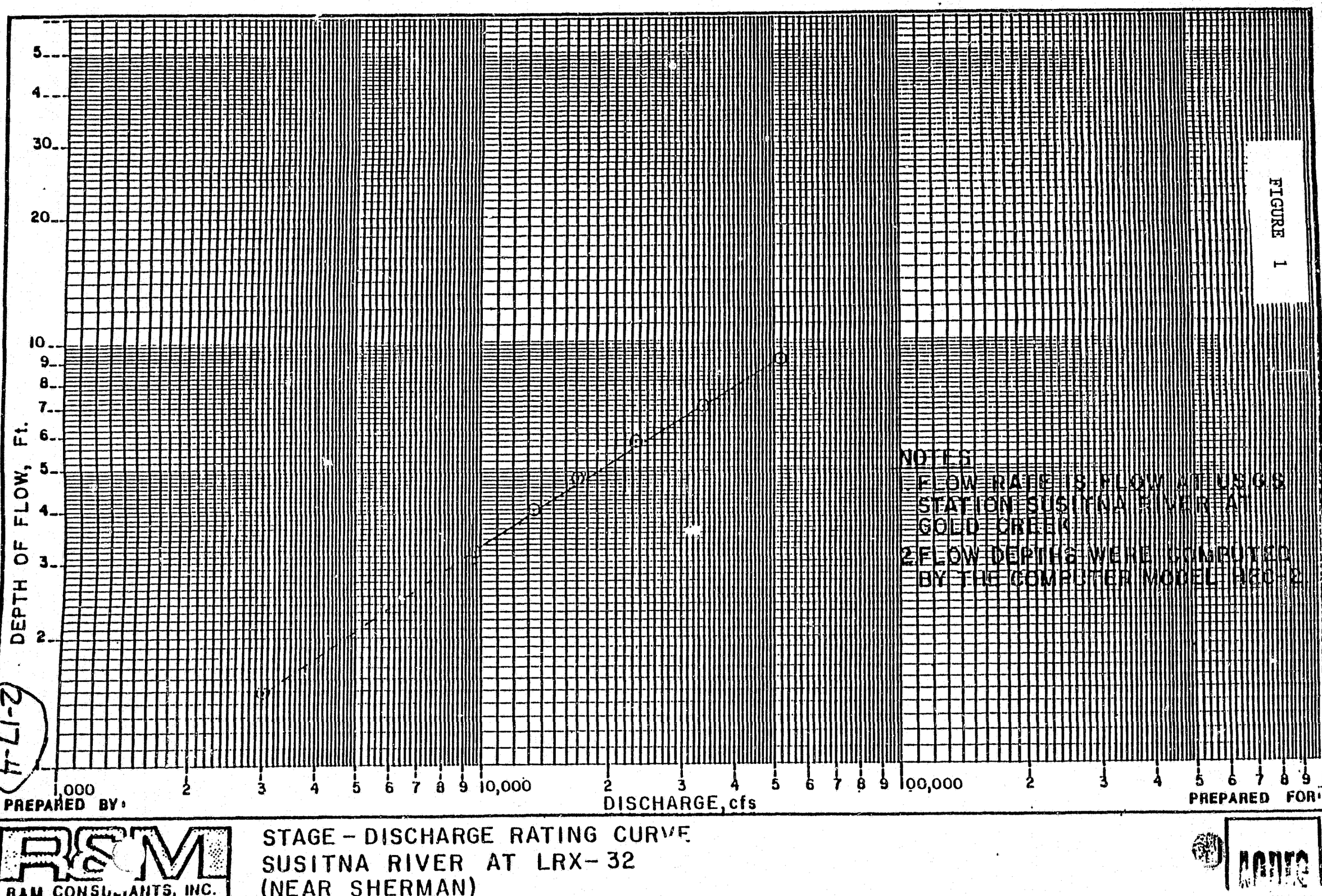

FIGURE 1

H-LI-2

R&M CONSULTANTS, INC.

STAGE – DISCHARGE RATING CURVE
SUSITNA RIVER AT LRX-32
(NEAR SHERMAN)

ACRES

APPENDIX A

R&M CONSULTANTS, INC. 5024 CORDOVA • BOX 6087 • ANCHORAGE, ALASKA 99502 • PH 907-279-0483 • TLX 090-25280

ENGINEERS
GEOLOGISTS
PLANNERS
SURVEYORS

September 11, 1981 R&M No. 052306

Project Manager
Susitna Hydroelectric Project
Acres American Incorporated
Liberty Bank Building
Main @ Court
Buffalo, New York 14202

Attention: Mr. George Cotroneo

Re: Run of HEC-2 on Lower River at 3,000 cfs, Subtask 3.06

Dear George:

As we discussed on the phone this week, I am sending you the results of an HEC-2 run on the Devil Canyon - Talkeetna reach of the Susitna with a river flow of 3,000 cfs. The computed water surface elevations (W.S.E.'s) agree within 1.0 feet at all cross-sections where observations are available. The low flow did present some problems in the computations, however.

Initially, the channel n values were all increased by 10% from the values used with Q = 9,700 cfs. For comparison, another run was made with a 20% increase in n value. Both runs produced critical flow at a number of cross-sections, but better agreement between computed and observed W.S.E.'s was obtained with the higher n's. This rapid increase in n value at the very low flows is to be expected as the depth of flow more closely approaches the size of the bed material in the channel.

The table below gives the observed and computed W.S.E.'s and the differences between them for the crest gage cross-sections. The observations were made on November 11, 1980, when the flow at Gold Creek was approximately 3,000 cfs. This was a full month after frazil ice first appeared in the river, so it is possible there are ice effects at some of these locations.

Comparison of Water Surface Elevations at 3,000 cfs. (ft, msl)

LRX	Computed	Observed	Difference
3	340.2 ft.	340.2 ft.	0.0 ft.
4	346.4 ft.	-	-
9	374.3 ft.	375.1 ft.	-0.8 ft.
24	519.1 ft.	519.1 ft.	0.0 ft.
28	552.2 ft.	-	-
35	615.0 ft.	614.7 ft.	+0.3 ft.
45	681.1 ft.	681.4 ft.	-0.3 ft.
62	831.2 ft.	831.9 ft.	-0.7 ft.

Some additional attached sheets give specific comments pertaining to cross-sections where problems were noted in the HEC-2 output.

If you have any questions or comments, feel free to give me a call.

Very truly yours,

R&M CONSULTANTS, INC.

Jeffrey H. Coffin, P.E.
Senior Engineer

JHC/jcr

2-17-6

****
HEC2 RELEASE DATED NOV 76 UPDATED APRI 1980
ERROR CORR - 01,02,03,04
MODIFICATION - 50,51,52,53,54
****

NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF E[illegible] LIST

LOWER SUSITNA RIVER--

SUMMARY PRINTOUT

SECNO	G	CWSEL	VCH	DEPTH	K*CHSL	K*XNCH	AREA	TOPWID	SSTA	ENDST
3.000	3000.00	340.20	1.38	7.60	0.00	48.00	2169.04	444.29	4036.71	4481.00
4.000	3000.00	346.36	6.11	2.36	2.16	48.00	490.74	438.25	3173.02	5771.27
5.000	3000.00	357.37	1.52	4.77	1.85	48.00	1978.63	816.20	6049.64	7253.62
6.000	3000.00	360.62	1.87	3.52	1.41	48.00	1603.72	827.32	6684.61	7676.30
7.000	3000.00	364.41	1.99	5.01	.79	48.00	1506.74	573.36	1128.18	2337.89
8.000	3000.00	369.99	1.98	5.89	1.02	60.00	1517.30	458.77	3136.90	3595.67
9.000	3000.00	374.26	1.69	7.66	.51	66.00	1771.62	339.62	3248.55	2588.17
10.000	3000.00	388.91	4.89	2.71	2.60	66.00	613.58	522.90	1221.30	2919.81
11.000	3000.00	407.67	1.25	6.67	1.45	66.00	2395.76	671.32	2073.68	2745.00
12.000	3000.00	418.46	2.55	4.06	1.47	66.00	1177.14	480.58	1136.64	1617.22
13.000	3000.00	434.30	1.81	7.80	1.18	66.00	1654.03	349.28	1079.51	2737.63
14.000	3000.00	440.96	4.92	3.76	3.79	66.00	609.24	453.79	1108.63	2534.68
15.000	3000.00	450.50	1.39	4.40	1.79	54.00	2158.29	723.37	1068.09	2261.29
16.000	3000.00	453.38	2.47	3.68	1.33	48.00	1213.18	606.92	1073.70	2873.83
17.000	3000.00	457.57	2.37	4.17	2.03	48.00	1263.92	581.04	1102.07	2191.23
18.000	3000.00	458.92	1.45	6.02	-.29	48.00	2063.43	548.15	1092.49	1640.65
19.000	3000.00	483.30	6.10	1.60	1.60	48.00	491.44	433.00	1682.88	2115.88

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SECNO	Q	CWSEL	VCH	DEPTH	K*CHSL	K*XNCH	AREA	TOPWID	SSTA	ENDST
20.000	3000.00	492.38	1.99	9.08	.39	48.00	1505.32	387.58	1330.87	3652.34
21.000	3000.00	506.56	3.58	5.66	1.72	48.00	838.67	353.21	1648.83	2002.04
22.000	3000.00	508.79	3.41	5.39	2.78	36.00	880.73	297.11	1351.91	1649.02
23.000	3000.00	518.07	2.80	2.57	2.46	36.00	1073.19	623.21	1375.84	2587.72
24.000	3000.00	519.13	1.78	11.53	-3.66	36.00	1686.41	301.19	1280.65	1561.84
24.500	3000.00	523.20	6.83	2.20	4.19	36.00	439.23	308.19	3842.98	4151.17
25.000	3000.00	529.72	2.74	3.52	2.78	36.00	1095.58	568.30	1663.36	4207.96
26.000	3000.00	535.98	2.28	3.88	1.18	42.00	1313.96	526.01	2538.70	3064.71
27.000	3000.00	540.25	2.64	6.45	.44	42.00	1137.73	310.64	2448.39	2759.03
28.000	3000.00	552.24	4.80	4.24	2.44	42.00	625.25	304.97	1772.52	2702.20
29.000	3000.00	569.02	2.62	5.72	1.71	42.00	1487.91	531.64	3522.65	4054.28
30.000	3000.00	583.08	4.47	4.68	2.06	45.60	670.95	385.98	1192.04	2527.28
31.000	3000.00	592.25	1.95	5.45	1.37	45.60	1540.86	386.56	3474.76	3861.32
32.000	3000.00	603.44	6.37	1.49	2.84	45.60	471.25	378.03	4282.18	4660.21
33.000	3000.00	610.79	1.99	4.29	1.91	43.32	1503.93	600.55	2886.69	4027.65
34.000	3000.00	613.96	2.81	5.06	1.13	43.32	1067.41	516.73	1907.99	2424.72
35.000	3000.00	615.00	1.63	9.50	-1.88	43.32	1836.96	315.94	1431.70	1747.63
36.000	3000.00	616.40	7.11	2.40	5.09	43.32	421.99	270.38	1505.70	2058.54
37.000	3000.00	625.08	2.09	6.28	1.47	43.32	1434.02	475.63	1061.67	1537.29
38.000	3000.00	637.04	4.46	2.34	2.75	43.32	672.46	491.99	1319.40	2625.49
39.000	3000.00	644.50	2.06	3.50	2.78	43.32	1455.82	742.50	1854.27	2887.61
40.000	3000.00	653.10	2.47	3.10	1.80	45.60	1216.62	561.41	1098.52	1659.93
41.000	3000.00	658.55	3.10	3.25	2.26	45.60	908.22	392.24	2615.25	3007.48
42.000	3000.00	667.68	2.27	3.78	2.55	45.60	1320.52	840.35	1816.18	2996.00
43.000	3000.00	668.58	1.62	10.98	-3.32	48.00	1852.19	238.74	2963.50	3202.24
43.500	3000.00	669.13	4.97	4.63	4.93	48.00	603.53	185.34	3186.43	3371.77

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SECNO	Q	CWSEL	VCH	DEPTH	K*CHSL	K*XNCH	AREA	TOPWID	SSTA	ENDST
44.000	3000.00	678.79	3.49	4.19	4.59	48.00	859.01	327.35	3065.58	3392.93
45.000	3000.00	681.08	2.30	7.58	-.75	48.00	1304.40	306.67	1229.92	1536.58
46.000	3000.00	684.21	6.85	2.81	5.27	54.00	437.72	261.33	1761.67	2023.00
47.000	3000.00	688.11	2.52	6.21	.49	48.00	1189.32	308.64	2203.20	2511.84
48.000	3000.00	690.40	3.20	5.10	2.57	48.00	937.36	385.35	1734.12	2119.47
49.000	3000.00	699.13	2.65	4.93	2.06	48.00	1131.16	318.30	1283.40	1601.70
50.000	3000.00	700.53	1.84	7.03	-.52	54.00	1633.60	431.63	1031.83	1463.46
51.000	3000.00	705.11	5.38	3.21	3.93	60.00	557.69	412.76	1034.88	1624.60
52.000	3000.00	713.55	1.96	6.35	1.82	60.00	1533.55	372.56	1049.90	2048.00
53.000	3000.00	720.48	2.99	3.28	2.63	60.00	1002.66	448.38	1926.06	2374.44
54.000	3000.00	731.42	2.24	5.12	2.53	66.00	1337.04	406.10	1694.79	2100.89
55.000	3000.00	741.14	2.65	5.94	2.55	66.00	1133.40	453.07	1662.26	2259.26
56.000	3000.00	749.90	2.18	5.50	2.76	66.00	1374.22	400.62	1859.28	2259.90
57.000	3000.00	751.79	1.99	6.29	.95	60.00	1504.19	489.56	1127.67	1740.41
58.000	3000.00	761.71	3.03	4.81	2.57	60.00	989.67	362.93	1443.23	1806.16
59.000	3000.00	782.86	2.41	7.06	2.16	60.00	1243.71	334.60	1199.82	1534.43
60.000	3000.00	815.93	2.98	7.43	2.27	66.00	1007.55	294.59	1204.91	1499.50
61.000	3000.00	828.62	2.58	9.12	1.78	66.00	1163.28	210.92	1003.16	1214.08
62.000	3000.00	831.21	3.47	8.91	2.50	66.00	864.28	269.35	1005.22	1274.58
63.000	3000.00	834.34	2.55	7.14	4.41	66.00	1178.14	259.15	1006.90	1266.05
64.000	3000.00	836.15	2.60	10.75	-1.73	66.00	1153.03	251.56	1005.69	1257.25
65.000	3000.00	839.11	7.07	3.01	19.11	66.00	424.28	276.86	1014.98	1629.76
66.000	3000.00	842.26	2.60	5.06	3.79	66.00	1153.26	393.01	1001.64	1643.55
67.000	3000.00	845.64	2.09	5.04	2.10	66.00	1433.50	373.46	1007.29	1380.74
68.000	3000.00	847.18	1.66	17.28	-5.35	66.00	1809.71	284.21	1038.74	1322.95

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SUMMARY OF ERRORS

CAUTION SECNO= 4.000 PROFILE= 1 CRITICAL DEPTH ASSUMED
CAUTION SECNO= 4.000 PROFILE= 1 PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO= 4.000 PROFILE= 1 20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO= 19.000 PROFILE= 1 CRITICAL DEPTH ASSUMED
CAUTION SECNO= 19.000 PROFILE= 1 MINIMUM SPECIFIC ENERGY

CAUTION SECNO= 24.500 PROFILE= 1 CRITICAL DEPTH ASSUMED
CAUTION SECNO= 24.500 PROFILE= 1 PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO= 24.500 PROFILE= 1 20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO= 32.000 PROFILE= 1 CRITICAL DEPTH ASSUMED
CAUTION SECNO= 32.000 PROFILE= 1 PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO= 32.000 PROFILE= 1 20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO= 36.000 PROFILE= 1 CRITICAL DEPTH ASSUMED
CAUTION SECNO= 36.000 PROFILE= 1 PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO= 36.000 PROFILE= 1 20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO= 44.000 PROFILE= 1 20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO= 65.000 PROFILE= 1 CRITICAL DEPTH ASSUMED
CAUTION SECNO= 65.000 PROFILE= 1 PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO= 65.000 PROFILE= 1 20 TRIALS ATTEMPTED TO BALANCE WSEL

01-17-2

Comments on 3,000-cfs HEC-2 Run

LRX	Comments
4	Critical flow @ both n values. Critical depth does <u>not</u> seem reasonable, based on channel slope (not especially steep) or geometry. Likely explanation is that assumed W.S.E. @ 3 is not correct. Trial W.S.E. @ 3 <u>is</u> an observed elevation, but no observation at 4 to ~~rise~~ *use* for check. Tried various starting W.S.E.'s @ 3, from 0.5 feet lower to 1.8 feet higher -- all produced critical depth at 4. That appears to be what happens. <u>True</u> W.S.E @ 4 may be a little higher than that shown.
19	Critical flow @ both n values. Depth is quite shallow, and average depth is fairly close to maximum depth (1.1', compared to 1.6'). However, critical depth does <u>not</u> seem reasonable - perhaps it is "caused" in the model by the great distance from 18 to 19 (18,000 feet), making the transition not too well-defined. The true W.S.E. @ 19 is probably 0.5 to 1.0 feet higher than the computed one given.
24.5	Critical flow @ both n values. Fairly steep bottom slope to deep hole @ 24. Critical depth seems reasonable, based on field observations of a "riffle" in the bend u/s of Curry at low flows.
32	Critical flow @ both n values. Flow is fairly wide and quite shallow (average depth is 1.25' and maximum depth is 1.5'). Reach length from 31 to

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32 is rather long, so transition is probably not too well-defined. Critical depth does not really seem reasonable - true level is perhaps 0.5 - 1.0 feet higher than computed.

36 Critical flow at both n values. River goes from shallow depth @ 36 to deep hole @ 35. Bottom slope is fairly steep, and existence of critical depth at low flow appears reasonable.

44 Computation of W.S.E. took 23 trials. Resulting answer looks reasonable compared to other flow levels.

46 Citical flow with 10% increase in n, but not with 20% increase (W.S.E. = 0.1' higher). Avoidance of critical seems more reasonable. There is quite an expansion in flow area from 46 to 45, due to relatively great depth @ 45. Thus, depth <u>close</u> to critical is probably justified.

51 Flow is not as close to critical depth when n is increased by 20% as when increased by only 10%. Thus, the former (20% increase) seems more reasonable.

65 Critical flow with both n values. Bed is high at river bend, causing steep bed gradient to 64. High bed also causes low flow area. Critical depth at low flow seems reasonable.

TABLE 1

MANNING's n VALUES USED FOR CALIBRATION OF SUSITNA RIVER HEC-2 MODEL

X-Section	Q=9700 cfs	Q-17,000 cfs	Q=34,500 cfs	Q=52,000 cfs
3	.040	.036	.0324	.0324
4	.040	.036	.0324	.0324
5	.040	.036	.0324	.0324
6	.040	.036	.0324	.0324
7	.040	.036	.0324	.0324
8	.050	.045	.0405	.0405
9	.055	.0495	.0446	.0446
10	.055	.0495	.0446	.0446
11	.055	.0495	.0446	.0446
12	.055	.0495	.0446	.0446
13	.055	.0495	.0446	.0446
14	.055	.0495	.0446	.0446
15	.045	.0405	.0365	.0365
16	.040	.036	.0324	.0324
17	.040	.036	.0324	.0324
18	.040	.036	.0324	.0324
19	.040	.036	.0324	.0324
20	.040	.036	.0324	.0324
21	.040	.036	.0324	.0324
22	.030	.027	.0243	.0243
23	.030	.027	.0243	.0243
24	.030	.027	.0243	.0243
25	.030	.027	.0243	.0243
26	.035	.0315	.0284	.0284
27	.035	.0315	.0284	.0284
28	.035	.0315	.0284	.0284
29	.035	.0315	.0284	.0284

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MANNING's n VALUES USED FOR CALIBRATION OF SUSITNA RIVER HEC-2 MODEL
(continued)

X-Section	Q=9700 cfs	Q-17,000 cfs	Q=34,500 cfs	Q=52,000 cfs
30	.038	.0342	.0308	.0308
31	.038	.0342	.0308	.0308
32	.038	.0342	.0308	.0308
33	.0361	.0325	.0292	.0292
34	.0361	.0325	.0292	.0292
35	.0361	.0325	.0292	.0292
36	.0361	.0325	.0292	.0292
37	.0361	.0325	.0292	.0292
38	.0361	.0325	.0292	.0292
39	.0361	.0325	.0292	.0292
40	.038	.0342	.0308	.0308
41	.038	.0342	.0308	.0308
42	.038	.0342	.0308	.0308
43	.040	.036	.0324	.0324
44	.040	.036	.0324	.0324
45	.040	.036	.0324	.0324
46	.045	.0405	.0365	.0365
47	.040	.036	.0405	.0405
48	.040	.036	.0405	.0405
49	.040	.036	.0405	.0405
50	.045	.0405	.0365	.0365
51	.050	.045	.0405	.0405
52	.050	.045	.0405	.0405
53	.050	.045	.0405	.0405
54	.055	.0495	.0446	.0446
55	.055	.0495	.0446	.0446

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MANNING's n VALUES USED FOR CALIBRATION OF SUSITNA RIVER HEC-2 MODEL (continued)

X-Section	Q=9700 cfs	Q-17,000 cfs	Q=34,500 cfs	Q=52,000 cfs
56	.055	.0495	.0446	.0446
57	.050	.045	.0405	.0405
58	.050	.045	.0405	.0405
59	.050	.045	.0405	.0405
60	.055	.0495	.0446	.0446
61	.055	.0495	.0446	.0446
62	.055	.0495	.0446	.0446
63	.055	.0495	.0446	.0446
64	.055	.0495	.0446	.0446
65	.055	.0495	.0446	.0446
66	.055	.0495	.0446	.0446
67	.055	.0495	.0446	.0446
68	.055	.0495	.0446	.0446

NOTES:

1. Discharges stated are for Susitna River at Gold Creek.

2. Tabulated numbers are main-channel n values. The highest calibration flow used (52,000 cfs) is approximately bank-full, which avoided precise definition of overbank n values. A general value of n = .080 was assigned to all the overbanks to cover the occasional flooded areas above the bank levels. For higher flows (i.e. 100-year flood and PMF), in the 1983 analyses, overbank n values were assigned as described in Table 4.10 in "Hydraulic and Ice Studies" (R&M Consultants, March 1982).

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TABLE 2

OBSERVED AND CALCULATED WATER SURFACE ELEVATION (1)

DISCHARGE (cfs):	9,700	13,400	17,000	23,400	34,500	52,000
LRX4 Observed	348.1	349.5	350.5	352.0	352.9	354.6
Computed	348.6	350.0	350.8	352.2	353.1	355.1
(Com-Obs)Difference	+0.5	+0.5	+0.3	+0.2	+0.2	+0.5
LRX9 Observed	378.4	379.0	379.8	381.6	383.1	385.4*
Computed	378.1	379.4	380.3	381.8	383.4	386.2
(Com-Obs)Difference	-0.3	+0.4	+0.5	+0.2	+0.3	+0.8
LRX24 Observed	521.3	522.0	522.9	523.8*	525.4	527.5
Computed	521.7	522.6	523.2	524.3	525.4	527.2
(Com-Obs)Difference	+0.4	+0.6	+0.3	+0.5	0	-0.3
LRX28 Observed	553.8	555.3	556.0	557.0	558.2	559.8
Computed	555.0	555.7	556.2	557.0	558.1	560.1
(Com-Obs)Difference	+1.2	+0.4	+0.2	0	-0.1	+0.3
LRX35 Observed	617.3	617.9	619.0	620.0	621.3	623.3
Computed	617.7	618.7	619.4	620.3	621.6	623.3
(Com-Obs)Difference	+0.4	+0.8	+0.4	+0.3	+0.3	0

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TABLE 2 continued

OBSERVED AND CALCULATED WATER SURFACE ELEVATION (1)

DISCHARGE (cfs):	9,700	13,400	17,000	23,400	34,500	52,000
LRX45 Observed	684.1	685.2	685.9	687.0	688.4	690.0
Computed	684.0	685.1	685.8	687.0	688.1	689.9
(Com-Obs)Difference	-0.1	-0.1	-0.1	0	-0.3	-0.1
LRX62 Observed	835.4	835.9	837.5	838.3*	840.7*	843.9*
Computed	835.1	836.4	837.5	838.0	840.8	844.2
(Com-Obs)Difference	-0.3	+0.5	0	-0.3	+0.1	+0.3
LRX68 Observed	851.4*	852.2*	852.9	854.1	856.0*	859.0*
Computed	850.6	851.8	852.8	854.0	855.8	858.7
(Com-Obs)Difference	-0.8	-0.4	-0.1	-0.1	-0.2	-0.3

(1) Adapted from "Hydraulic and Ice Studies" - Table 4.18

*OBS water surface elevation determined from rating curves.

0419A

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EXHIBIT E

2. Water Use and Quality

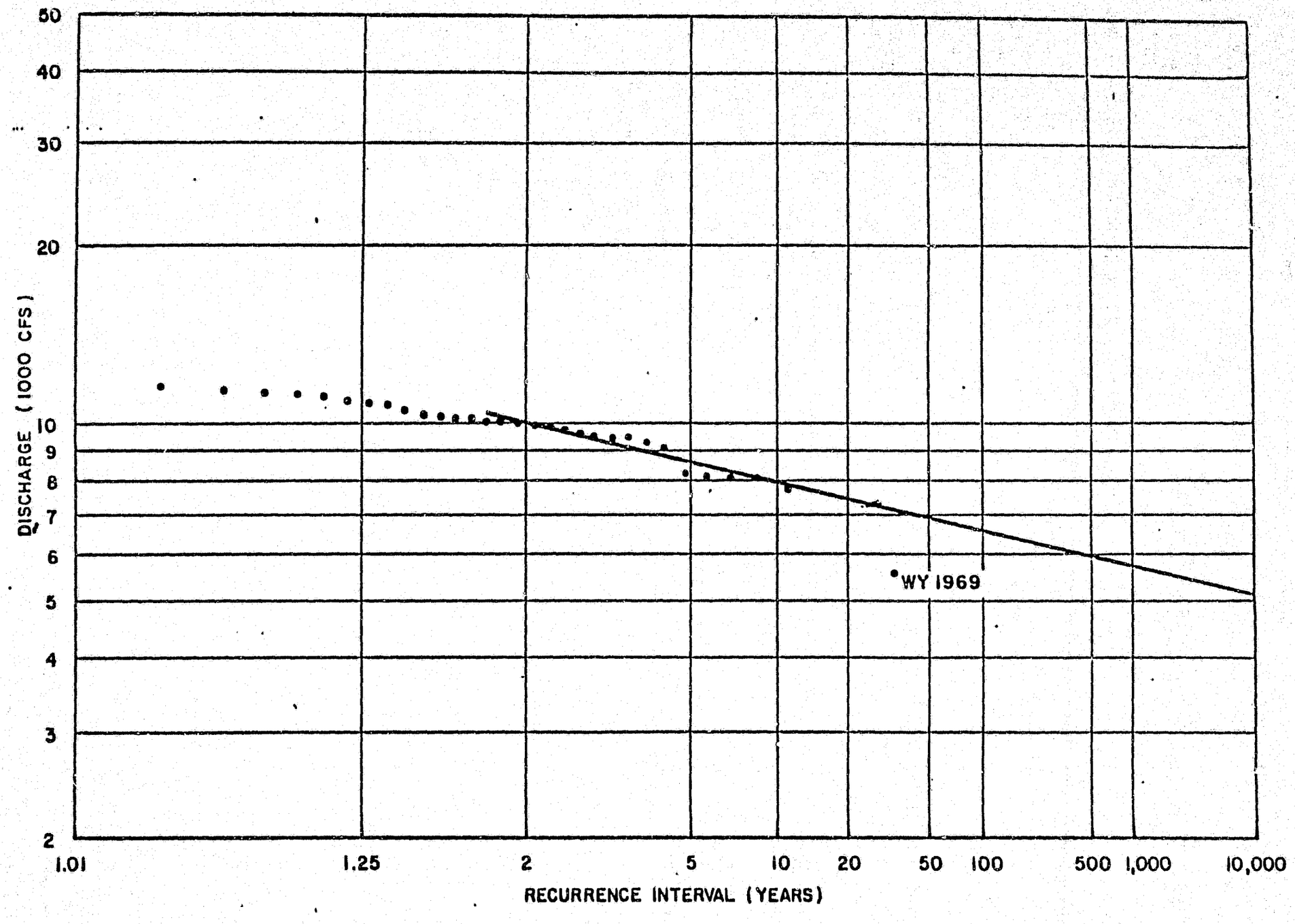
Comment 18 (p. E-2-57, Fig. E.2.23)

Provide a complete description of the curve-fitting technique used to generate this frequency analysis.

Response

The curve presented on Figure E.2.23 was fitted by visual judgement. A Log Normal and a Log-Pearson Type III distribution fitted to the data are shown in Figure 18.1. Based on these two curves, the 1969 low flow of 5596 cfs at Gold Creek has a recurrence interval of about 2500 years for the Log Normal curve and 125 years for the Log Pearson Type III curve fit, rather than the 1000 years stated on page E-2-57 of Exhibit E in the License Application.

The adjusted 1969 flow of 7200 cfs at Gold Creek used in the analysis in the License Application has a recurrence interval of about 30 years and 20 years based on the Log Normal and the Log-Pearson Type III analysis, respectively.

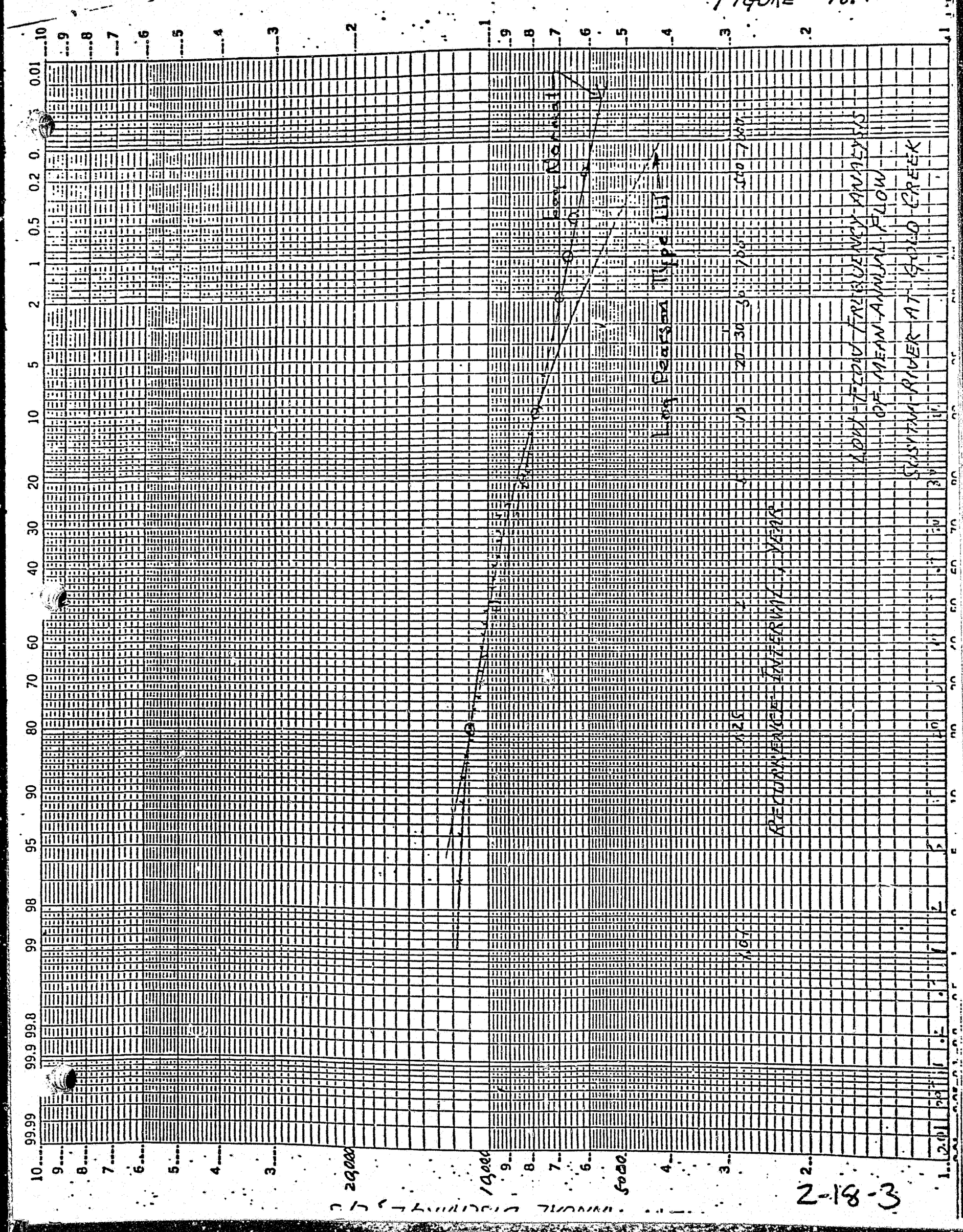


LOW-FLOW FREQUENCY ANALYSIS
OF MEAN ANNUAL FLOW
AT GOLD CREEK

FIGURE E.2.23

2-18-2

FIGURE 18.1



FREQUENCY ANALYSIS OF MEAN ANNUAL FLOW
SOUTH RIVER AT SOLO CREEK

2. Water Use and Quality

Comment 19 (p. E-2-58, Table E-2-34)

Provide a table of proposed minimum flows which resolves the apparent contradiction between this table (Table E-2-34) and Exhibit B (Table B.54), especially for the months of lowest post-project flows (October-May).

Response

Table E-2-34 is the correct table. This table replaces Table B.54 in Exhibit B.

In Table E-2-34 the Gold Creek flows for the October-April period have been increased to 5,000 cfs. Monthly flows in the Susitna River during this period with Case C operation will normally average 8,000 to 11,000 cfs at the Gold Creek gaging station. A minimum flow of 5,000 cfs is the maximum flow that could be guaranteed in the event of a reoccurence of a drought as severe as that which occurred in Water Year 1969.

If this severe a drought were to occur, with Case C operation, approximately 4,000 cfs could be taken out of storage over the winter on a continuous basis. This coupled with a natural flow of 1,000 cfs, would provide a total flow of 5,000 cfs.

TABLE E.2.34: MONTHLY FLOW REQUIREMENTS AT GOLD CREEK

	Case (cfs)						
MONTH	A	A1	A2	C	C1	C2	D
OCT	5000	5000	5000	5000	5000	5000	5000
NOV	5000	5000	5000	5000	5000	5000	5000
DEC	5000	5000	5000	5000	5000	5000	5000
JAN	5000	5000	5000	5000	5000	5000	5000
FEB	5000	5000	5000	5000	5000	5000	5000
MAR	5000	5000	5000	5000	5000	5000	5000
APR	5000	5000	5000	5000	5000	5000	5000
MAY	4000	5000	5000	6000	6000	6000	6000
JUN	4000	5000	5000	6000	6000	6000	6000
JUL[1]	4000	5100	5320	6480	6530	6920	7260
AUG	6000	8000	10000	12000	14000	16000	19000
SEP[1]	5000	6500	7670	9300	10450	11620	13170

Notes:

Derivation of transitional flows.

[1]

DATE		CASE (cfs)						
JUL	SEP	A	A1	A2	C	C1	C2	D
25	21	4000	5000	5000	6000	6000	6000	6000
26	20	4000	5000	5000	6000	7000	7000	7500
19	19	4000	5000	5000	7000	8000	8500	9000
18	18	4000	5000	6000	8000	9000	10000	10500
17	17	4000	5000	7000	9000	10000	11500	12000
16	16	4000	6000	8000	10000	11000	13000	14000
15	15	5000	7000	9000	11000	12500	14500	16000

2. Water Use and Quality

Comment 21 (p. E-2-67, para. 3)

Provide estimates of the magnitude of increase in suspended sediments in Watana, Devil Canyon, and the Susitna River associated with vegetation removal in the impoundment zones.

Response

Quantitative estimates of the magnitude of increases in suspended sediments in the proposed reservoir sites associated with vegetation removal are difficult if not infeasible to produce at present. The best estimates available indicate that a very small amount of increased suspended sediments would result from the removal of only the above ground biomass of trees larger than 4 inches in diameter. No plans are envisioned for removal of tree root systems, brush or smaller vegetation which falls within the impoundment zone.

The increased suspended sediments associated with tree removal are expected to be negligible when compared to the annual suspended sediment discharge for the Susitna River at Gold Creek (e.g., 8.5×10^6 metric tons per year). Increased suspended sediment discharge due to tree removal is expected to be within the range of natural variation for Susitna River suspended sediment discharges.

Exact plans for the removal of trees from the impoundment zone have not been defined. Factors to be considered in estimating increases in suspended sediments must consider the harvesting methedology which likely will not be firmly delineated until approximately 1988.

EXHIBIT E

2. Water Use and Quality

Comment 22 (p. E-2-67, para. 3; p. E-2-143)

Provide quantitative estimates of increases in suspended sediment concentrations in winter and in summer and the downstream extent of such increases during construction of Watana and Devil Canyon Dams.

Response

A preliminary estimate has been computed of the suspended sediments added to the river from gravel mining sites during construction of Watana and Devil Canyon Dams. It is estimated that 52,000 metric tons[1/] of suspendable particles (i.e., those less than 10 microns mean diameter) will be liberated to the river during the May to September working season in each of the six years during which gravel mining is scheduled to occur.

The estimated amount is less than 1 percent of the 1952 suspended sediment discharge of the Susitna River at Gold Creek during May to September, and represents a 4 percent increase (page E-2-69, para. 2) in suspended sediment load over the summer 1982 loading. Sufficient data does not exist to calculate meaningful suspended sediment discharge statistics for summer, winter or annual periods.

Details described in E-2-69, para. 2, 3, and 4 and E-2-70, para. 1, 2, and 3 explain how additions of suspended sediment will be minimized in winter and during the primary processing of stockpiled borrow material. Disposal of primary processing wash waters containing suspended particles is also discussed.

1/ The figure 52,000 metric tons per annual work season was derived from:

50 million m^3 x 0.01 (1% estimated loss of mined material back to river from Dragline Operations) = 5.0 x $10^5 m^3$ lost to river.

- 5.0 x $10^5 m^3$ lost to river x 0.35 (Maximum Estimate of Potentially Suspendable Sediments per Unit) = 1.75 x $10^5 m^3$ Potentially Suspendable Sediments

- 1.75 x $10^5 m^3$ SS x 3900 lbs. per m^3 = 6.9 x 10^8 lbs. Potentially Suspendable Sediments

- 3.4 x 10^5 ton Potentially Suspendable Sediments

or

- 3.1 x 10^5 metric tons Potentially Suspended Sediments during six years of gravel mining.

- Conservative Overestimate of approximately 52,000 metric tons of Potentially Suspenable Sediments per summer work season.

2. Water Use and Quality

Comment 23 (p. E-2-67, para. 4)

Provide environmental criteria used for selection and elimination of borrow sites.

Response

Generic criteria used for selection and elimination of borrow sites included:

1) Quantity and quality of available borrow materials;

2) Processing required (washing of fines);

3) Hauling distance, stockpiling site availability, site preparation and rehabilitation requirements;

4) Location with respect to riparian vegetation, wetlands or important wildlife habitat;

5) Absence of archoeological sites.

Specific criteria and gravel harvesting methods will follow resource agency guidelines as outlined in Supplemental Attachment No. 2-23:

References

U. S. Fish and Wildlife Service. 1980. Gravel Removal Guidelines Manual for Arctic and Subarctic Floodplains, FWS/OBS-80/09.169 pp.

EXHIBIT E

2. Water Use and Quality

Comment 24 (p. E-2-69, para. 3)

Provide data on the quantity and particle size distribution of materials lost through entrainment and erosion from borrow sites at other construction sites in Alaska (e.g., Lake Eklutna Hydro Project).

Response

Data are presently not available to specifically answer this request. No studies relating to this question are known to exist for Alaska. However, a publication related to this topic is contained in Supplemental Attachment No. 2-24 (SA2-24).

References

U. S. Fish and Wildlife Service. 1980. FWS/OBS-80/08. Gravel Removal Studies in Arctic and Subarctic Floodplains in Alaska, 403 pp.

EXHIBIT E

2. Water Use and Quality

Comment 25 (p. E-2-70, para. 1)

Provide description of methods for preventing entrainment of backfill materials in river water and erosion of such materials into the river.

Response

Generalized descriptions of methods for preventing entrainment and erosion of backfill materials into the river are discussed on pp. E-2-67 through E-2-70 of the License Application.

More specific guidelines for mining gravel in subarctic floodplains are contained in Supplemental Attachment No. 2-23 (SA2-23): U. S. Fish and Wildlife Service. 1980. FWS/OBS-80/09. Gravel Removal Guidelines Manual for Arctic and Subarctic Floodplains, 169 pp.

2. Water Use and Quality

Comment 26 (p. E-2-75, para. 4)

Provide coefficient values used in regression analysis and how they were determined.

Response

A regional analysis of low-flow conditions in streams of the Cook Inlet Basin was performed by the U.S. Geological Survey in 1980 (Freethey and Scully, 1980, to provide a series of equations for use by Water Resources Planners to estimate flow characteristics for streams in the basin which do not have long term flow records. This information is contained in Supplemental Attachment 2-26 which also describes the derivation of the equations mentioned on p. E-2-75. The equations are presented as footnotes to Table E.2.32 attached as pp. 2-26-3. Values of the coefficients were determined by regression of flow data against basin characteristics from 25 gaging stations in the Cook Inlet Basin. Values for the coefficients for (30) day minimum flows with recurrence intervals of 2,10, and 20 years are:

Coefficient	Recurrence Interval 2 yrs.	10 yrs.	20 yrs.
a	.132	.0839	.0656
b	.98	.98	.99
c	.20	.16	.15
d[1/]	.31	.38	.43

1/ This coefficient "d" should not be confused with the subscript "d" shown in the term Md,rt in the USGS regression equation. The subscript "d" in the term Md,rt denotes number of days and is not a coefficient. The footnote No. 1 for Table E.2.32 therefore should be revised as follows:

1/ Minimum flows estimated from the following USGS regression equation (Freethey and Scully 1980).

$$MD,rt = aA^{b} (LP + 1)^{c} (J + 10)^{d}$$

where:
- M = minimum flow (cfs)
- D = number of days
- rt = recurrence interval (yrs)
- A = drainage area (mi^2)
- LP = area of lakes and ponds (percent)
- J = mean minimum January air temperature (°F)
- a, b, c, d = coefficients

TABLE E.2.32: ESTIMATED LOW AND HIGH FLOWS AT ACCESS ROUTE STREAM CROSSINGS

Drainage Basin	Road Mile Location	Area (mi^2)	30-Day Minimum Flow (cfs)[1] Recurrence Interval (yrs)			Peak Flows (cfs)[2] Recurrence Interval (yrs)			
			2	10	20	2	10	25	50
Denali Highway to Watana Camp Segment									
Lily Creek	3	3.7	0.8	0.6	0.5	25	54	78	96
Seattle Creek	6	11.1	2.4	1.8	1.5	74	147	205	248
Seattle Creek Tributary	8	1.5	0.3	0.2	0.2	10	24	35	44
Seattle Creek Tributary	9	2.7	0.8	0.5	0.4	13	29	42	51
Brushkana Creek	12	22.0	5.5	3.8	3.4	115	217	299	354
Brushkana Creek Site	14	21.0	4.9	3.5	3.1	121	228	315	374
Upper Deadman Creek	20	12.1	3.0	2.1	1.9	64	127	177	211
Deadman Creek Tributary	28	54.5	13.2	9.3	8.2	276	488	661	767
Watana to Devil Canyon Segment									
Tsusena Creek	2.5	126.6	26	19	17	780	1309	1744	2000
Devil Creek	22	31.0	6.7	4.8	4.2	199	369	506	597
Devil Canyon to Gold Creek Railroad Segment									
Gold Creek	0.2[3]	25.0	5.4	3.9	3.4	162	304	418	497

NOTES:

1 Minimum flows estimated from the following USGS regression equation (Freethey and Scully 1980).

$$M_{d,rt} = aA^{b} (LP + 1)^{c} (J + 10)^{d}$$

where: M = minimum flow (cfs)
d = number of days
rt = recurrence interval (yrs)
A = drainage area (mi^2)
LP = area of lakes and ponds (percent)
J = mean minimum January air temperature (°F)
a,b,c = coefficients

2 Peak flows estimated from the following USGS regression equation (Freethey and Scully 1980).

$$Q_{t} = aA^{b} (LP + 1)^{c} P^{d}$$

where: Q = annual peak discharge (cfs)
t = recurrence interval (yrs)
A = drainage area (mi^2)
LP = areas of lakes and ponds (percent)
P = mean annual precipitation (in)
a,b,c,d = coefficients

3 Railroad mile location.

EXHIBIT E

2. Water Use and Quality

Comment 27 (p. E-2-77, para. 1)

Provide details of regression analysis used for Deadman Creek including derivation of coefficients and input data.

Response

The regression equation used to determine the 1:20-year, 30-day low flow for Deadman Creek is the same regression equation presented in Table E.2.32 attached as page 2-27-2. Also note the correction in footnote No. 1 on the attached sheet. Values of the coefficients are:

a = 0.0656
b = 0.99
c = 0.15
d = 0.43

The derivation of the coefficients is discussed in the Freethey and Scully (1980) Supplemental Attachment 2-26.

The input data are:

Drainage area A = 172 square miles.
Area of lakes and ponds = 1.6 percent.
Mean minimum January air temperature = -4°F.

TABLE [illegible] SUMMER LOW AND HIGH FLOW ACCESS ROUTE STREAM CROSSINGS

Drainage Basin	Road Mile Location	A Area (mi^2)	30-Day Minimum Flow (cfs)[1] Recurrence interval (yrs)			Peak Flows (cfs)[2] Recurrence Interval (yrs)			
			2	10	20	2	10	25	50
Denali Highway to Watana Camp Segment									
Lily Creek	3	3.7	0.8	0.6	0.5	25	54	78	96
Seattle Creek	6	11.1	2.4	1.8	1.5	74	147	205	248
Seattle Creek Tributary	8	1.5	0.3	0.2	0.2	10	24	35	44
Seattle Creek Tributary	9	2.7	0.8	0.5	0.4	13	29	42	51
Brushkana Creek	12	22.0	5.5	3.8	3.4	115	217	299	354
Brushkana Creek Site	14	21.0	4.9	3.5	3.1	121	228	315	374
Upper Deadman Creek	20.	12.1	3.0	2.1	1.9	64	127	177	211
Deadman Creek Tributary	28	54.5	13.2	9.3	8.2	276	488	661	767
Watana to Devil Canyon Segment									
Tsusena Creek	2.5	126.6	26	19	17	780	1309	1744	2000
Devil Creek	22	31.0	6.7	4.8	4.2	199	369	506	597
Devil Canyon to Gold Creek Railroad Segment									
Gold Creek	0.2[3]	25.0	5.4	3.9	3.4	162	304	418	497

NOTES:

1 Minimum flows estimated from the following USGS regression equation (Freethey and Scully 1980).

$$M_{D,rt} = aA^{b} (LP + 1)^{c} (J + 10)^{d}$$

where: M = minimum flow (cfs)
D = number of days
rt = recurrence interval (yrs)
A = drainage area (mi^2)
LP = area of lakes and ponds (percent)
J = mean minimum January air temperature (°F)
a,b,c,d = coefficients

} ORIGINAL USGS REGRESSION EQUATION

2 Peak flows estimated from the following USGS regression equation (Freethey and Scully 1980).

$$Q_{t} = aA^{b} (LP + 1)^{c} P^{d}$$

where: Q = annual peak discharge (cfs)
t = recurrence interval (yrs)
A = drainage area (mi^2)
LP = areas of lakes and ponds (percent)
P = mean annual precipitation (in)
a,b,c,d = coefficients

3 Railroad mile location.

2-27-2

EXHIBIT E

2. Water Use and Quality

Comment 31 (p. E-2-91, para. 2; p, E-2-170)

Provide quantitative estimates of increases in suspended sediments resulting from skin slides, biomodal flow type slides, and shallow rotational slide in the Watana and Devil Canyon impoundment zone. Document locations where each type of slide is likey to occur in each of the impoundment zones.

Response

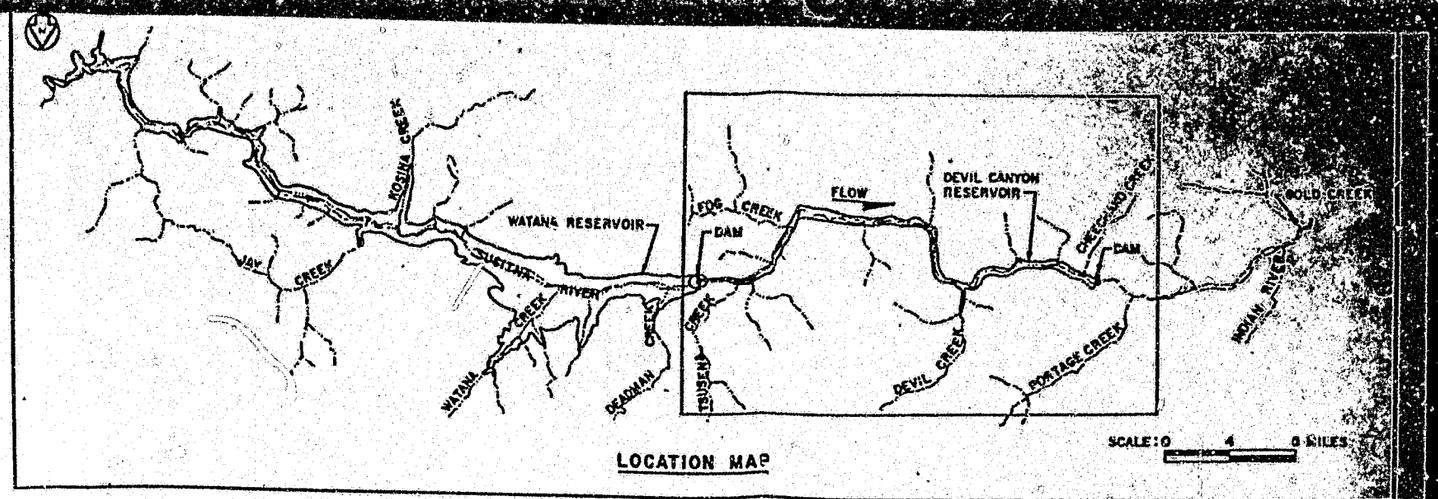
A "worst case" scenario involving slumping of all the known potential shallow slides of skin types, bimodal flow types, shallow rotational types and assorted frozen, partially frozen, and non-frozen block slides (i.e. the latter were assumed to be up to 20 meters deep) was calculated to potentially yield a maximum of $2.0 \times 10^8 m^3$ of unconsolidated materials to the river/resevoir. The assumption was made that particles of 10 microns or less mean diameter (i.e. those which constitute silt, clay and colloidal particles taking longer than 30 minutes to settle one vertical foot) constitute "suspendable sediments." A conservative estimate was used that assumed 35 percent (by dry weight) of the unconsolidated soil materials was 10 microns or less mean diameter. Thus, potential slides of both shallow and block types were estimated to potentially contribute approximately 1.3×10^8 metric tons of suspendable sediments to the river/ reservoir.

Most of the slides should occur after impoundment of the Watana and Devil Canyon reservoirs. Therefore, the two reservoirs could be expected to trap at least 75 percent (see reference in Exhibit E in the License Application, p. E-2-138, para. 3, and E-2-170, para. 3 and 4) of any

particles added to them. Approximately 33 million metric tons of suspended particulates (at a maximum) may pass through the dams to the downstream environment as a result of potential slides of unconsolidated soil materials. The actual amount will likely be much less than the maximum amount.

Any downstream movement of suspended sediments due to soils erosion and slope instability will take place over an extended period of time (probably during the first five years of reservoir operation), and should therefore constitute only a portion of the annual suspended sediment discharge of the Susitna River at Gold Creek.

Further details of the locations of unstable soil slopes within the reservoirs are presented in the attached maps (E-6-21 through E-6-45).

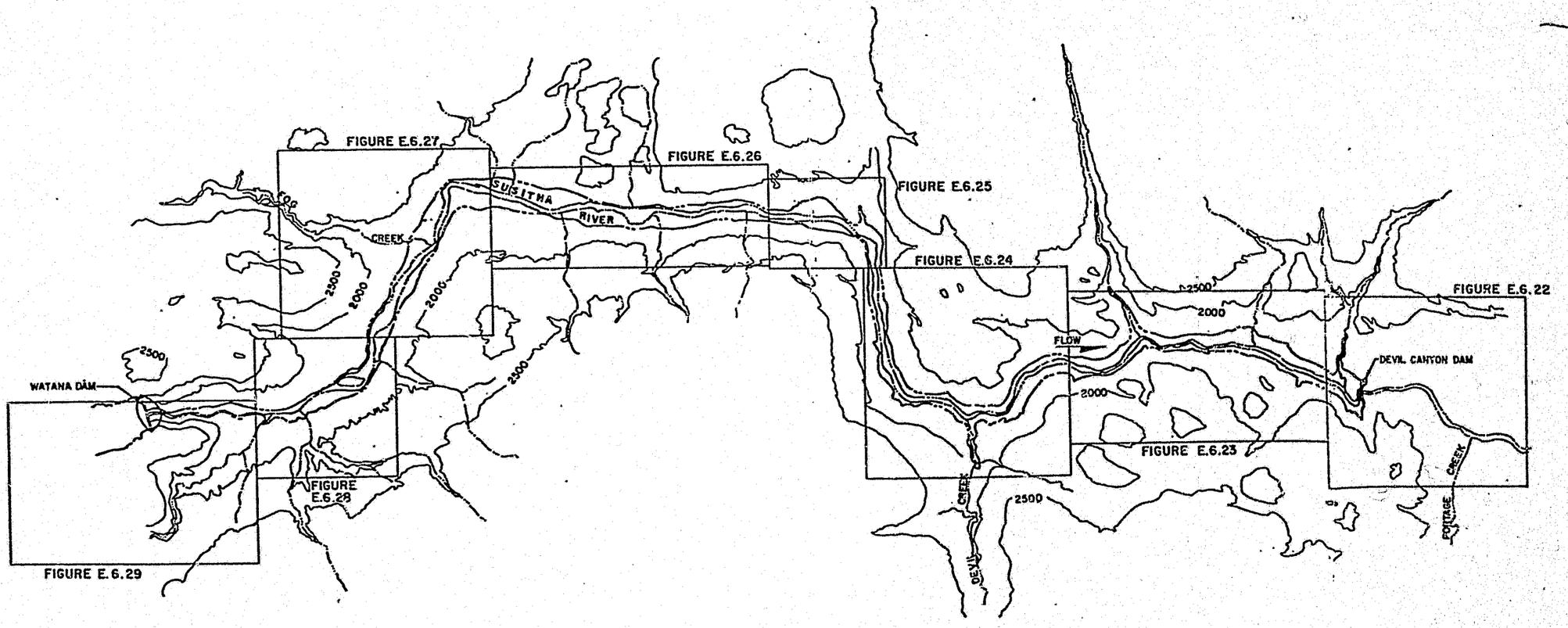


LOCATION MAP

LEGEND

NORMAL MAXIMUM OPERATING LEVEL EL. 1455

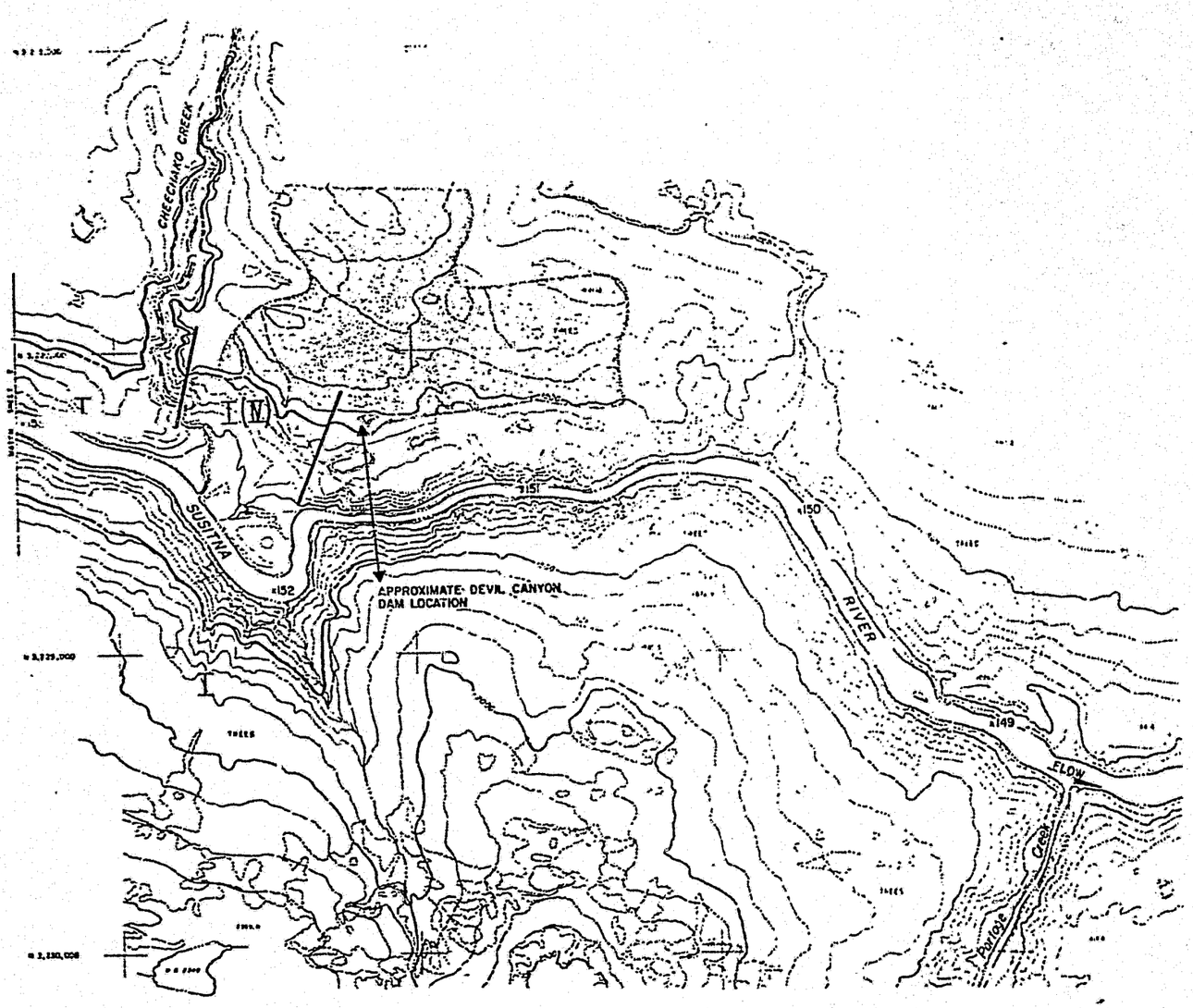
2000 CONTOUR IN FEET ABOVE MSL



DEVIL CANYON RESERVOIR
INDEX MAP

FIGURE E.6.21

2-31-83


CHEECHAKO CREEK
SUSITNA
APPROXIMATE DEVIL CANYON DAM LOCATION
RIVER
FLOW
Portage Creek
TREES
TREES
TREES



LEGEND

AREAS OF CURRENT SLOPE INSTABILITY

TYPES OF SLOPE INSTABILITY:

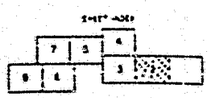
I	BEACHING
II	FLOWS
III	SLIDING (UNFROZEN)
IV	SLIDING (PERMAFROST)
/I/	DENOTES AREA EXTENT AND TYPE OF INSTABILITY
I(IV)	PRIMARY BEACHING INSTABILITY WITH SOME POTENTIAL SLIDING
I=II	BEACHING AND FLOWS POSSIBLE IN DEFINED AREA
	NORMAL MAXIMUM OPERATING LEVEL
•	RIVER MILES

AREA OF POTENTIAL PERMAFROST

NOTES

1. REFER TO FIGURES E.6.19 AND E.6.20 FOR DETAILED DESCRIPTION OF TYPE OF SLOPE INSTABILITY MODELS
2. NO DELINEATION OF PERMAFROST AREA ABOVE ELEVATION 2300 FEET
3. AREAS OF POTENTIAL PERMAFROST BASED PRINCIPALLY ON AIR PHOTO INTERPRETATION AND WILL REQUIRE FUTURE VERIFICATION

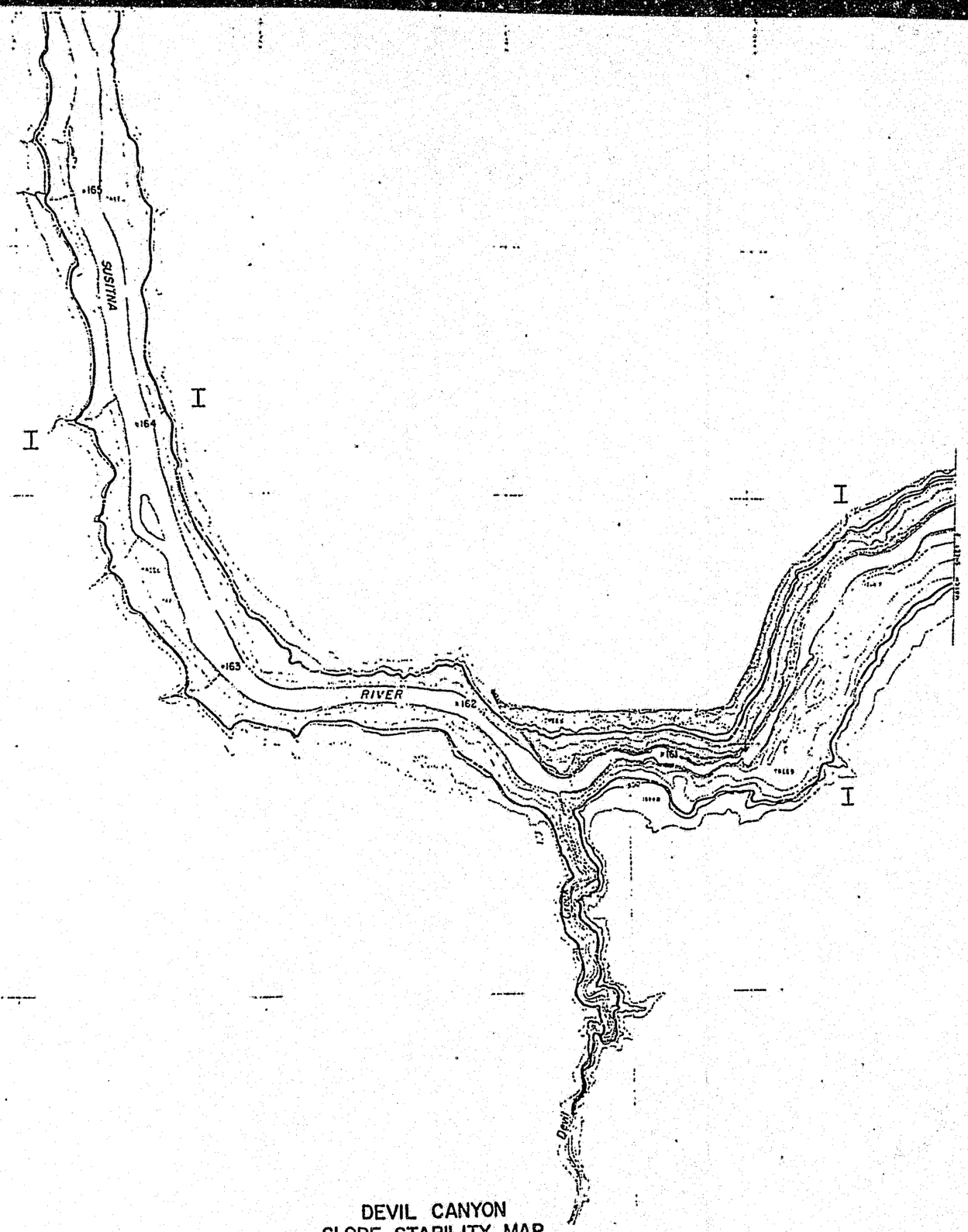
SCALE 0 1000 2000 FEET



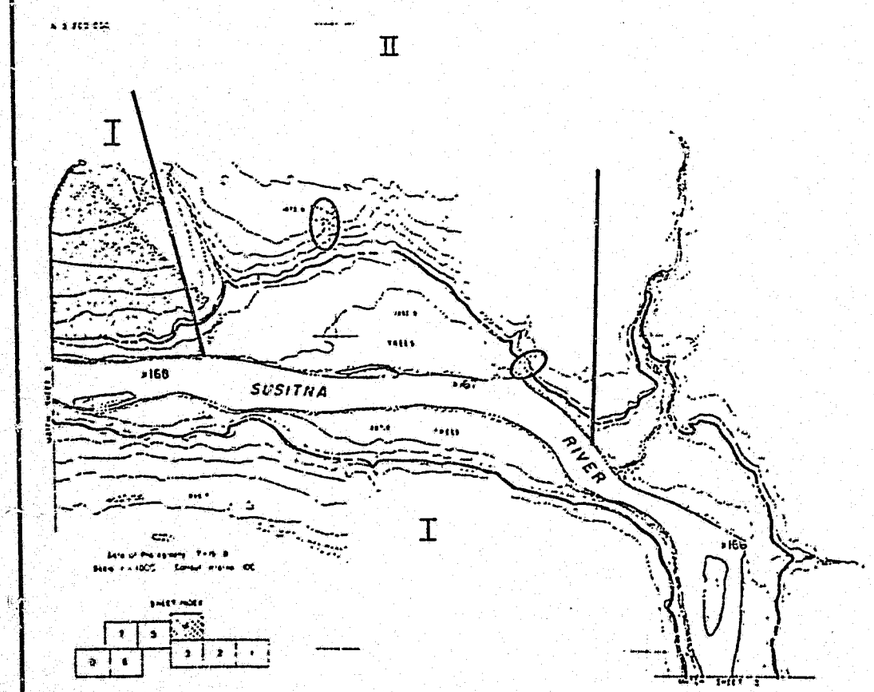
DEVIL CANYON
SLOPE STABILITY MAP

FIGURE E.6.23

2-31-5


SUSITNA
RIVER
Devil Creek
I
I
I

0 0 4 1 6 7



LEGEND

AREAS OF CURRENT SLOPE INSTABILITY

TYPES OF SLOPE INSTABILITY:

- I BEACHING
- II FLOWS
- III SLIDING (UNFROZEN)
- IV SLIDING (PERMAFROST)
- I/IV DEFINED AREA EXTENT AND TYPE OF INSTABILITY
- I(IV) PRIMARY BEACHING INSTABILITY WITH SOME POTENTIAL SLIDING
- I-II BEACHING AND FLOWS POSSIBLE IN DEFINED AREA

NORMAL MAXIMUM OPERATING LEVEL
RIVER MILES

AREA OF POTENTIAL PERMAFROST

NOTES

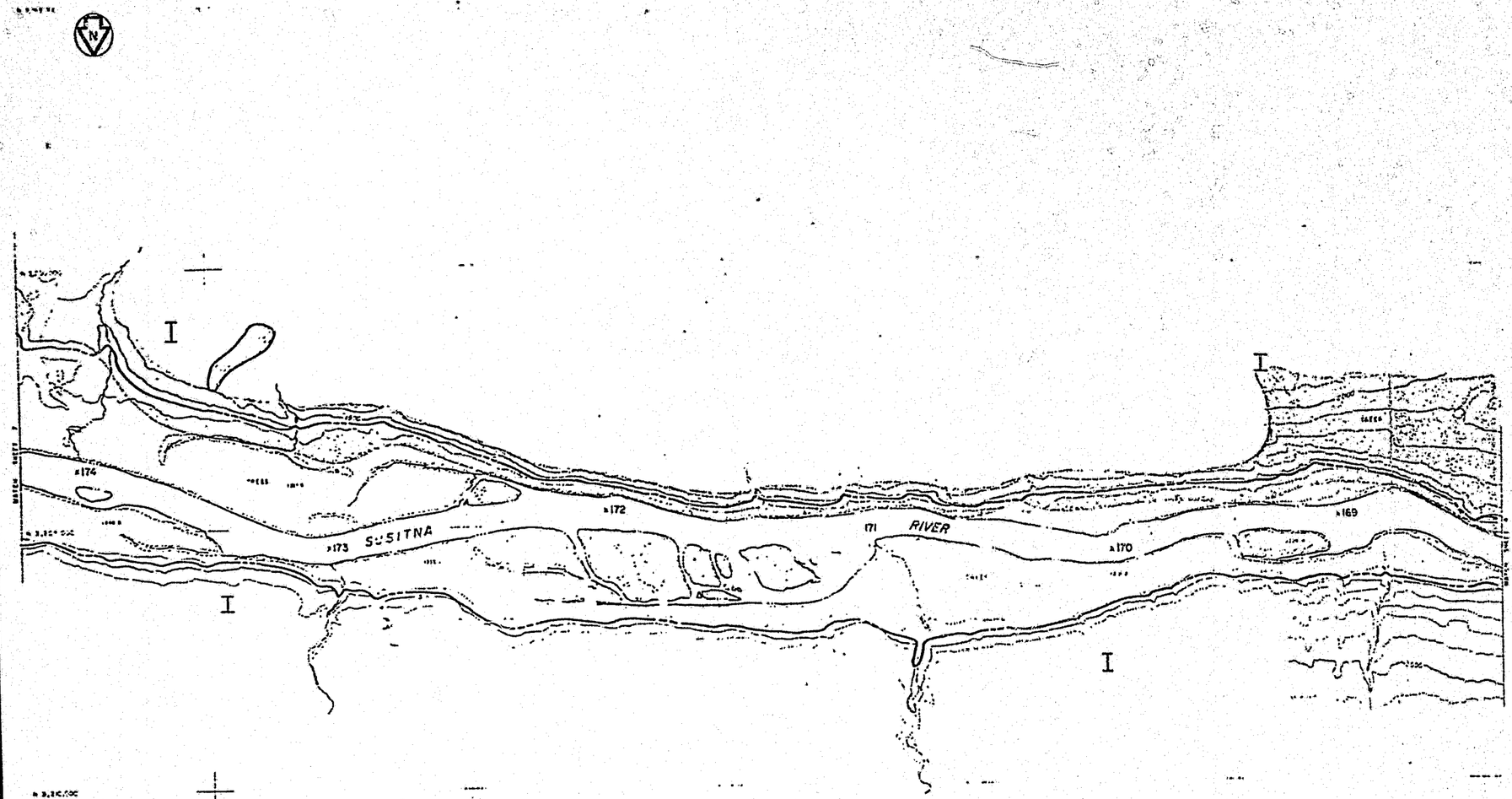
1. REFER TO FIGURES E.6.19 AND E.6.20 FOR DETAILED DESCRIPTION OF TYPE OF SLOPE INSTABILITY MODELS
2. NO DELINEATION OF PERMAFROST AREA ABOVE ELEVATION 2300 FEET
3. AREAS OF POTENTIAL PERMAFROST BASED PRINCIPALLY ON AIR PHOTO INTERPRETATION AND WILL REQUIRE FUTURE VERIFICATION

SCALE 0 1000 2000 FEET

DEVIL CANYON
SLOPE STABILITY MAP

FIGURE E.6.25

2-31-7



LEGEND

AREAS OF CURRENT SLOPE INSTABILITY

TYPES OF SLOPE INSTABILITY:

- I BEACHING
- II FLOWS
- III SLIDING (UNFROZEN)
- IV SLIDING (PERMAFROST)
- /I/ DENOTES AREA EXTENT AND TYPE OF INSTABILITY
- I (III) PRIMARY BEACHING INSTABILITY WITH SOME POTENTIAL SLIDING
- I-II BEACHING AND FLOWS POSSIBLE IN DEFINED AREA
- ——— NORMAL MAXIMUM OPERATING LEVEL.
- RIVER MILES

AREA OF POTENTIAL PERMAFROST

NOTES

1. REFER TO FIGURES E.6.19 AND E.6.20 FOR DETAILED DESCRIPTION OF TYPE OF SLOPE INSTABILITY MODELS
2. NO DELINEATION OF PERMAFROST AREA ABOVE ELEVATION 2300 FEET
3. AREAS OF POTENTIAL PERMAFROST BASED PRIMARILY ON AIR PHOTO INTERPRETATION AND WILL REQUIRE FUTURE VERIFICATION

SCALE 0 1000 2000 FEET

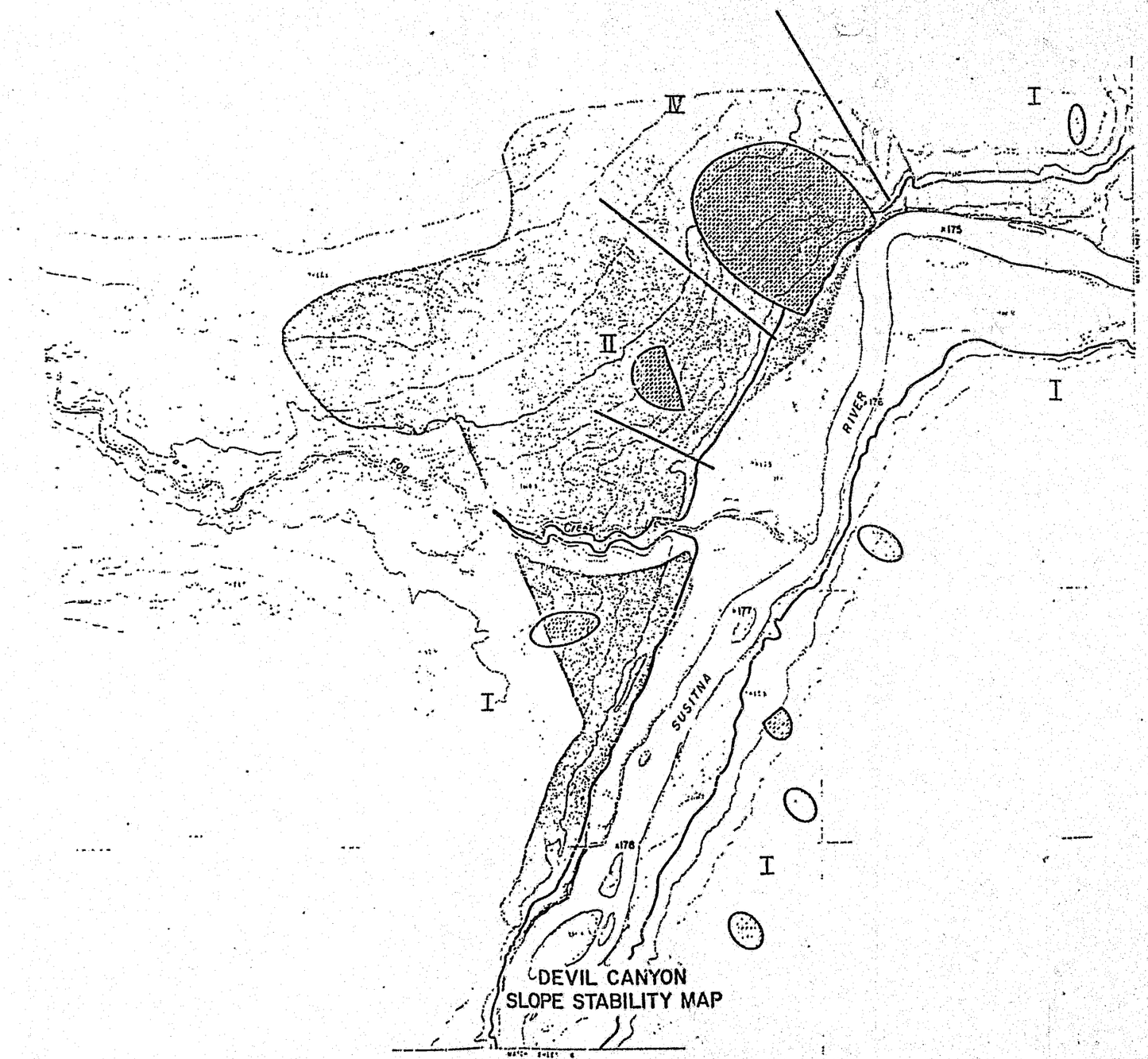
SHEET INDEX

7		4		
8	6	3	2	1

DEVIL CANYON SLOPE STABILITY MAP

FIGURE E.6.26

2-31-82



DEVIL CANYON
SLOPE STABILITY MAP

LEGEND

AREAS OF CURRENT SLOPE INSTABILITY

TYPES OF SLOPE INSTABILITY

- I BEACHING
- II FLOWS
- III SLIDING (UNFROZEN)
- IV SLIDING (PERMAFROST)
- /I/ DENOTES AREA EXTENT AND TYPE OF INSTABILITY
- I(IV) PRIMARY BEACHING INSTABILITY WITH SOME POTENTIAL SLIDING
- I-II BEACHING AND FLOWS POSSIBLE IN DEFINED AREA
- NORMAL MAXIMUM OPERATING LEVEL
- RIVER MILES

AREA OF POTENTIAL PERMAFROST

NOTES

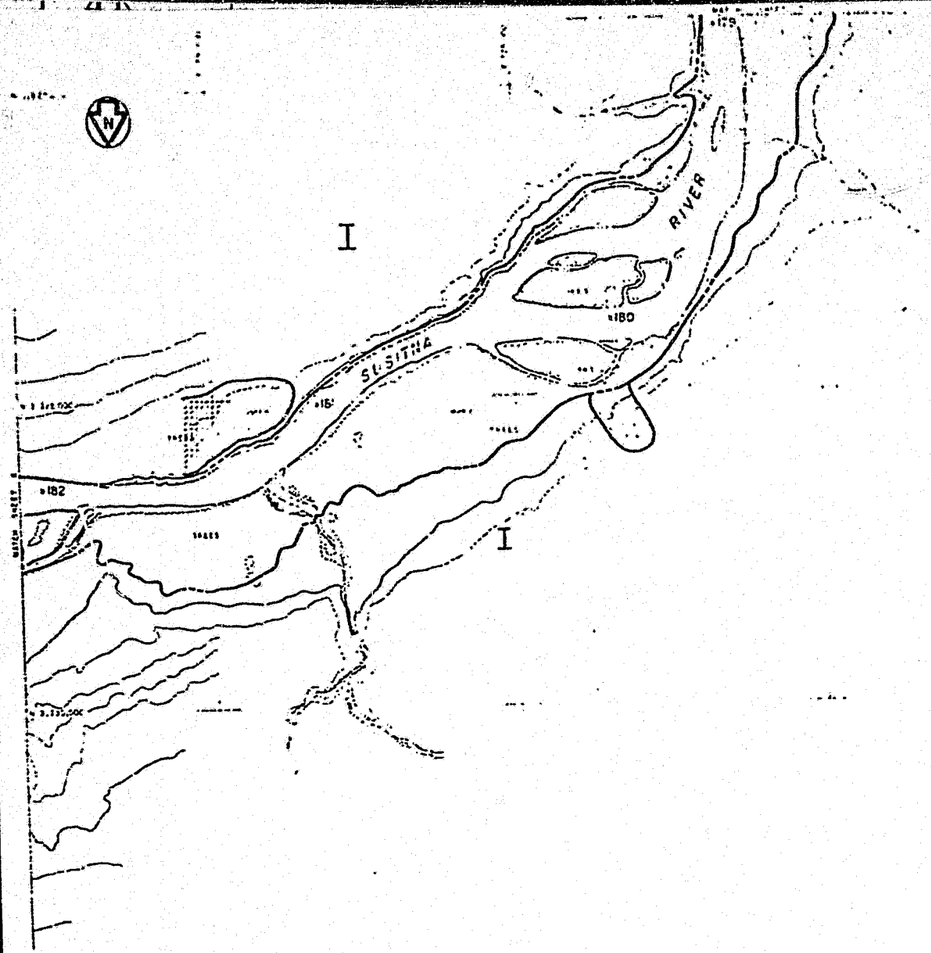
1. REFER TO FIGURES E.6.19 AND E.6.20 FOR DETAILED DESCRIPTION OF TYPE OF SLOPE INSTABILITY MODELS
2. NO DELINEATION OF PERMAFROST AREA ABOVE ELEVATION 2300 FEET
3. AREAS OF POTENTIAL PERMAFROST BASED PRINCIPALLY ON AIR PHOTO INTERPRETATION AND WILL REQUIRE FUTURE VERIFICATION

SCALE 0 1000 2000 FEET

FIGURE E.6.27

2-31-9

0 0 1 1 6 7



LEGEND

AREAS OF CURRENT SLOPE INSTABILITY

TYPES OF SLOPE INSTABILITY:

I	BEACHING
II	FLOWS
III	SLIDING (UNFROZEN)
IV	SLIDING (PERMAFROST)
/I/	DENOTES AREA EXTENT AND TYPE OF INSTABILITY
I(IV)	PRIMARY BEACHING INSTABILITY WITH SOME POTENTIAL SLIDING
I-II	BEACHING AND FLOWS POSSIBLE IN DEFINED AREA
——	NORMAL MAXIMUM OPERATING LEVEL
	RIVER MILES

NOTES

1. REFER TO FIGURES E.6.19 AND E.6.20 FOR DETAILED DESCRIPTION OF TYPE OF SLOPE INSTABILITY MODELS
2. NO DELINEATION OF PERMAFROST AREA ABOVE ELEVATION 2300 FEET
3. AREAS OF POTENTIAL PERMAFROST BASED PRINCIPALLY ON AIR PHOTO INTERPRETATION AND WILL REQUIRE FUTURE VERIFICATION

SCALE 0 1000 2000 FEET

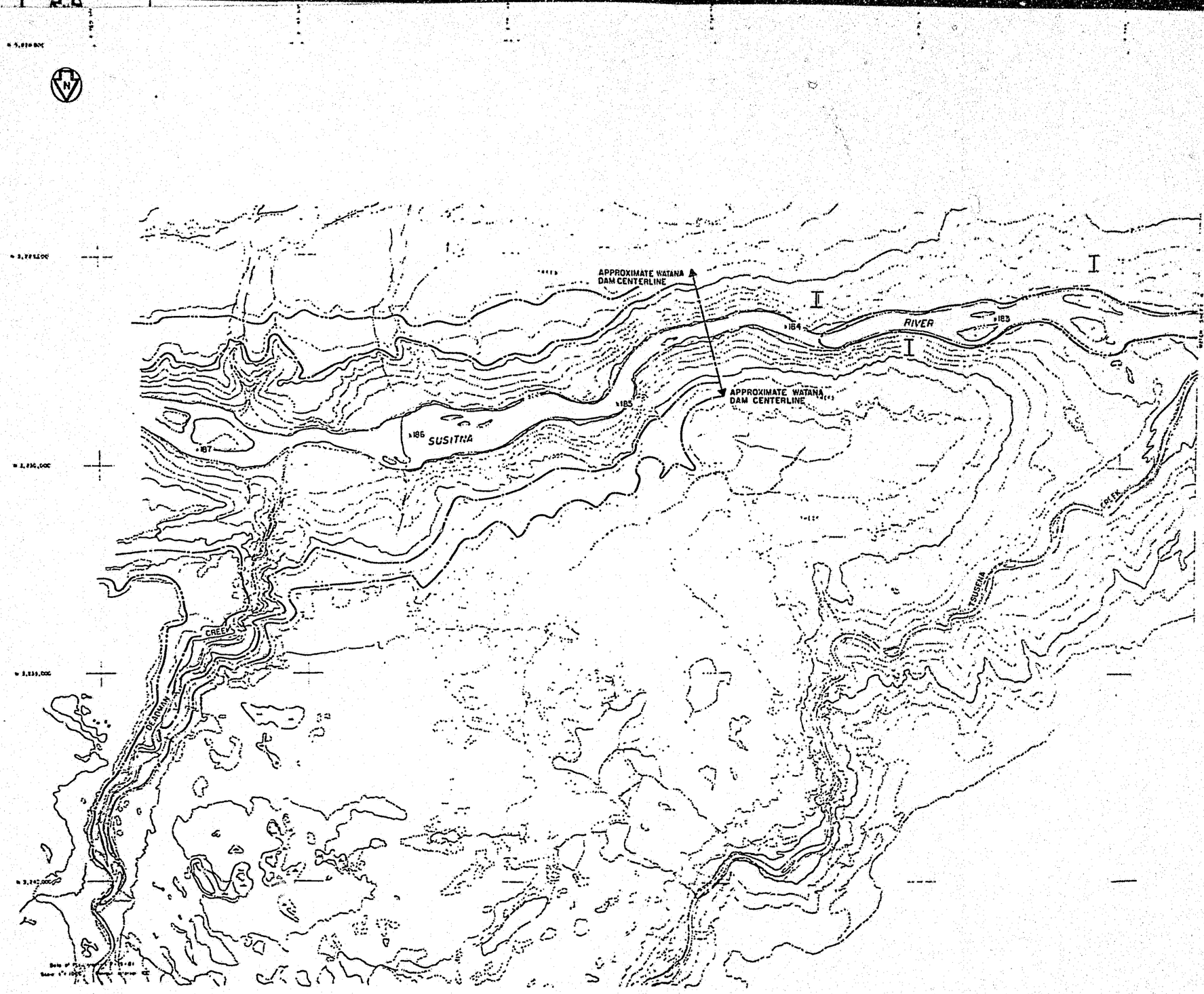
SHEET INDEX

8	7	5	4	3	2	1

DEVIL CANYON
SLOPE STABILITY MAP

FIGURE E.6.28

2-31-10



LEGEND

AREAS OF CURRENT SLOPE INSTABILITY

TYPES OF SLOPE INSTABILITY:

I	BEACHING
II	FLOWS
III	SLIDING (UNFROZEN)
IV	SLIDING (PERMAFROST)
/I/	DENOTES AREA EXTENT AND TYPE OF INSTABILITY
I(III)	PRIMARY BEACHING INSTABILITY WITH SOME POTENTIAL SLIDING
I-II	BEACHING AND FLOWS POSSIBLE IN DEFINED AREA
———	NORMAL MAXIMUM OPERATING LEVEL
- - - -	NORMAL MINIMUM OPERATING LEVEL
x	RIVER MILES

NOTES

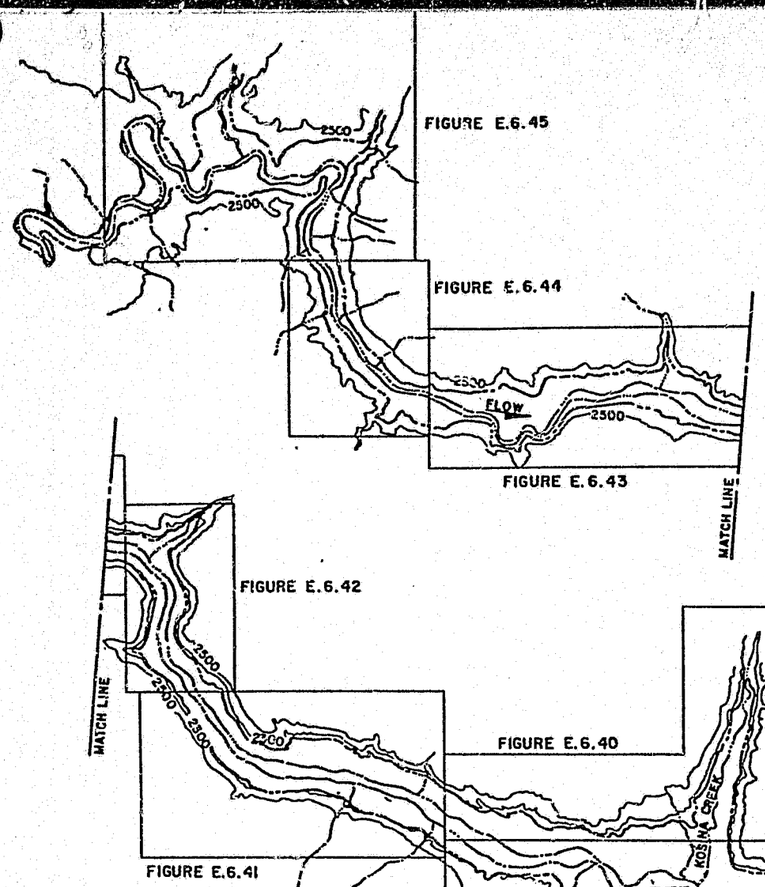
1. REFER TO FIGURES E.6.19 AND E.6.20 FOR DETAILED DESCRIPTION OF TYPE OF SLOPE INSTABILITY MODELS
2. NO DELINEATION OF PERMAFROST AREA ABOVE ELEVATION 2300 FEET
3. AREAS OF POTENTIAL PERMAFROST BASED PRINCIPALLY ON AIR PHOTO INTERPRETATION AND WILL REQUIRE FUTURE VERIFICATION

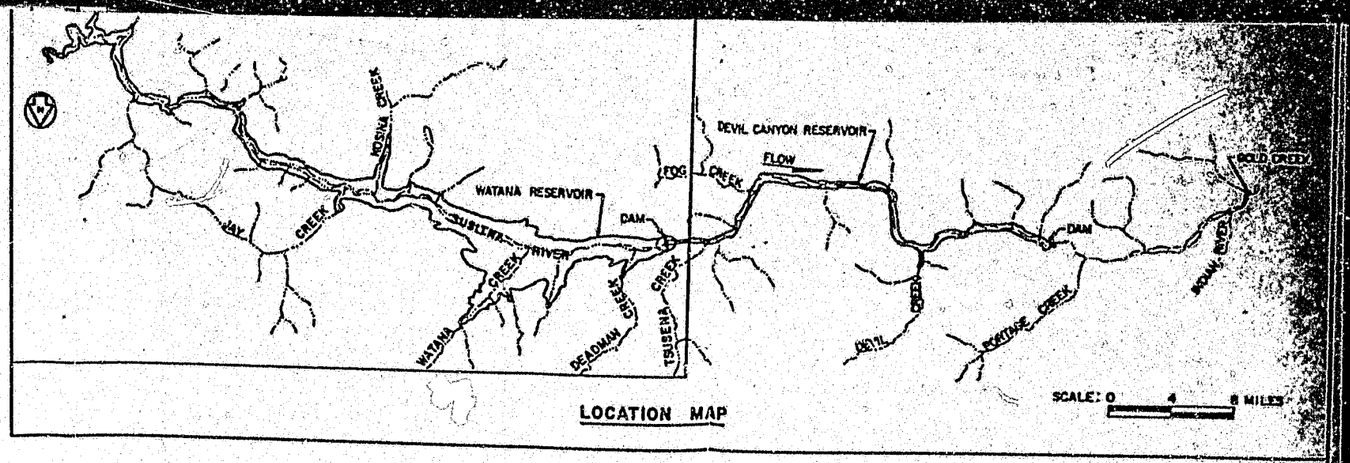
SCALE 0 1000 2000 FEET

DEVIL CANYON
SLOPE STABILITY MAP

FIGURE E.6.29

2-31-11

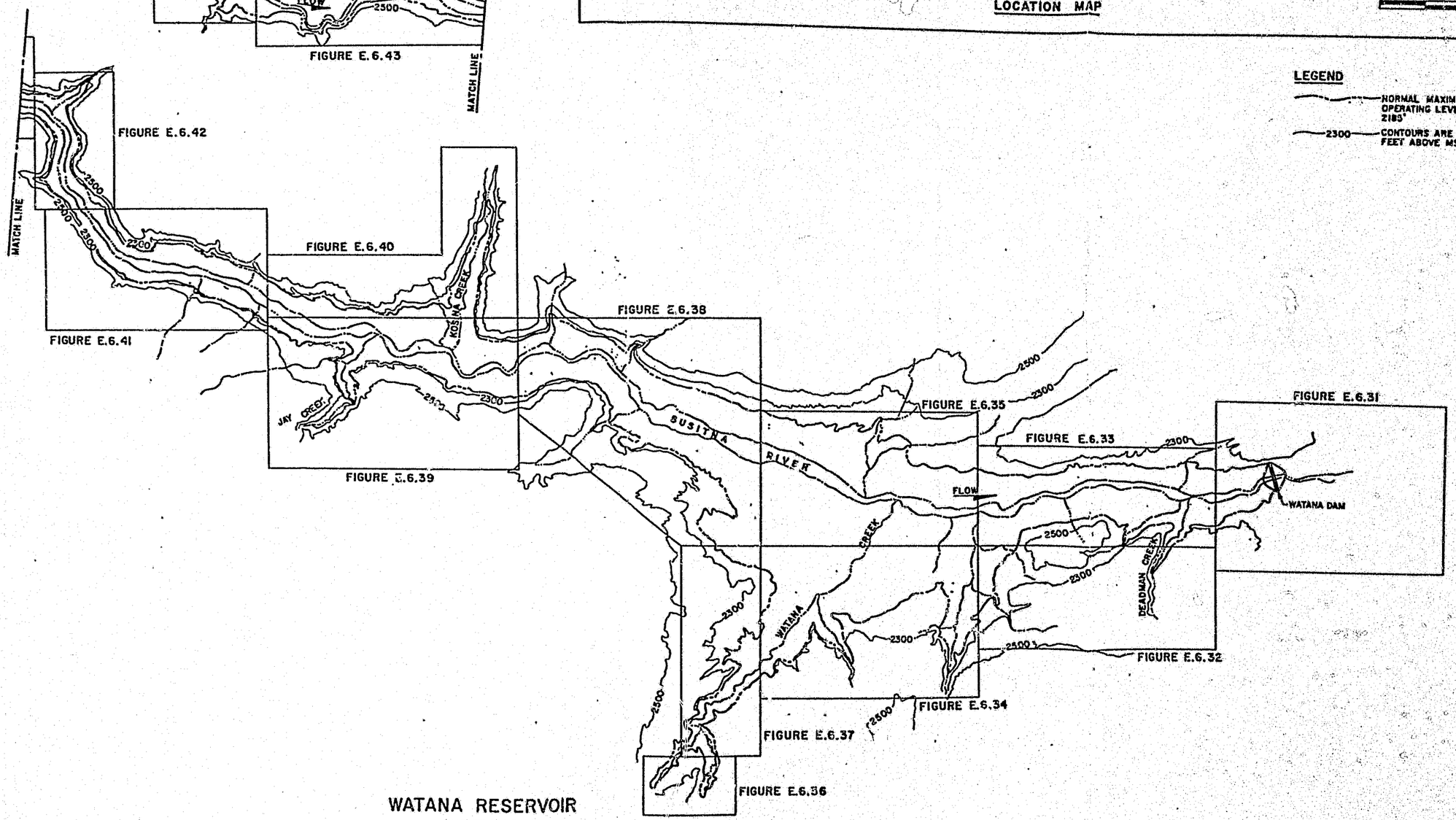




LEGEND

NORMAL MAXIMUM OPERATING LEVEL 2185'

2300 CONTOURS ARE IN FEET ABOVE MSL

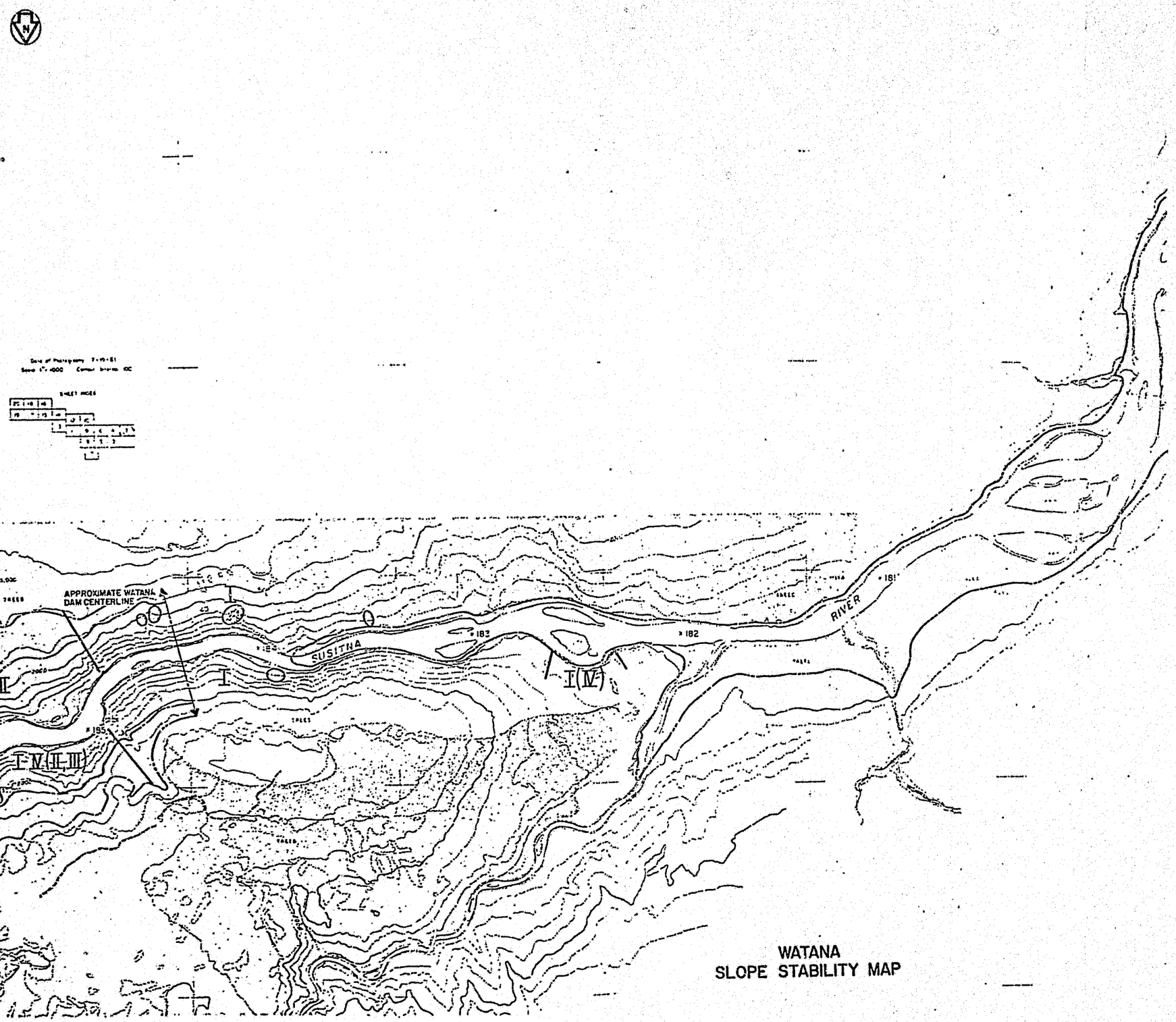


WATANA RESERVOIR
INDEX MAP

FIGURE E.6.30

2-31-12

0 0 1 1 8 7



LEGEND

AREAS OF CURRENT SLOPE INSTABILITY

TYPES OF SLOPE INSTABILITY

I	BEACHING
II	FLOWS
III	SLIDING (UNFROZEN)
IV	SLIDING (PERMAFROST)
/I/	DENOTES AREA EXTENT AND TYPE OF INSTABILITY
I(III)	PRIMARY BEACHING INSTABILITY WITH SOME POTENTIAL SLIDING
I-II	BEACHING AND FLOWS POSSIBLE IN DEFINED AREA
———	NORMAL MAXIMUM OPERATING LEVEL
– – – –	NORMAL MINIMUM OPERATING LEVEL
	RIVER MILES

AREA OF POTENTIAL PERMAFROST

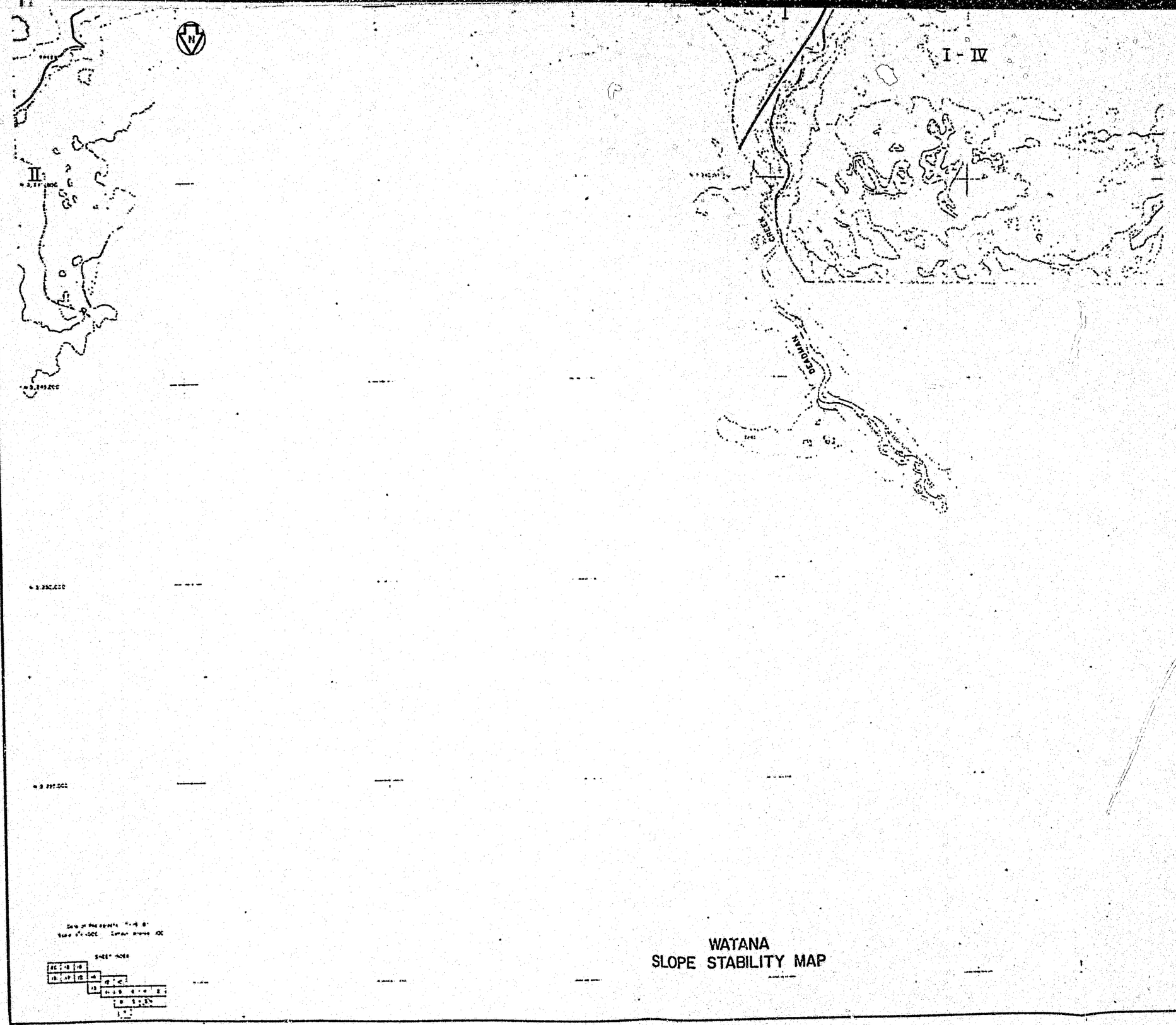
NOTES

1. REFER TO FIGURES E.6.19 AND E.6.20 FOR DETAILED DESCRIPTION OF TYPE OF SLOPE INSTABILITY MODELS
2. NO DELINEATION OF PERMAFROST AREA ABOVE ELEVATION 2300 FEET
3. AREAS OF POTENTIAL PERMAFROST BASED PRINCIPALLY ON AIR PHOTO INTERPRETATION AND WILL REQUIRE FUTURE VERIFICATION.

WATANA
SLOPE STABILITY MAP

FIGURE E.6.21

2-31-12



WATANA
SLOPE STABILITY MAP

FIGURE E.6.32

2-31-14

AREAS OF CURRENT SLOPE INSTABILITY

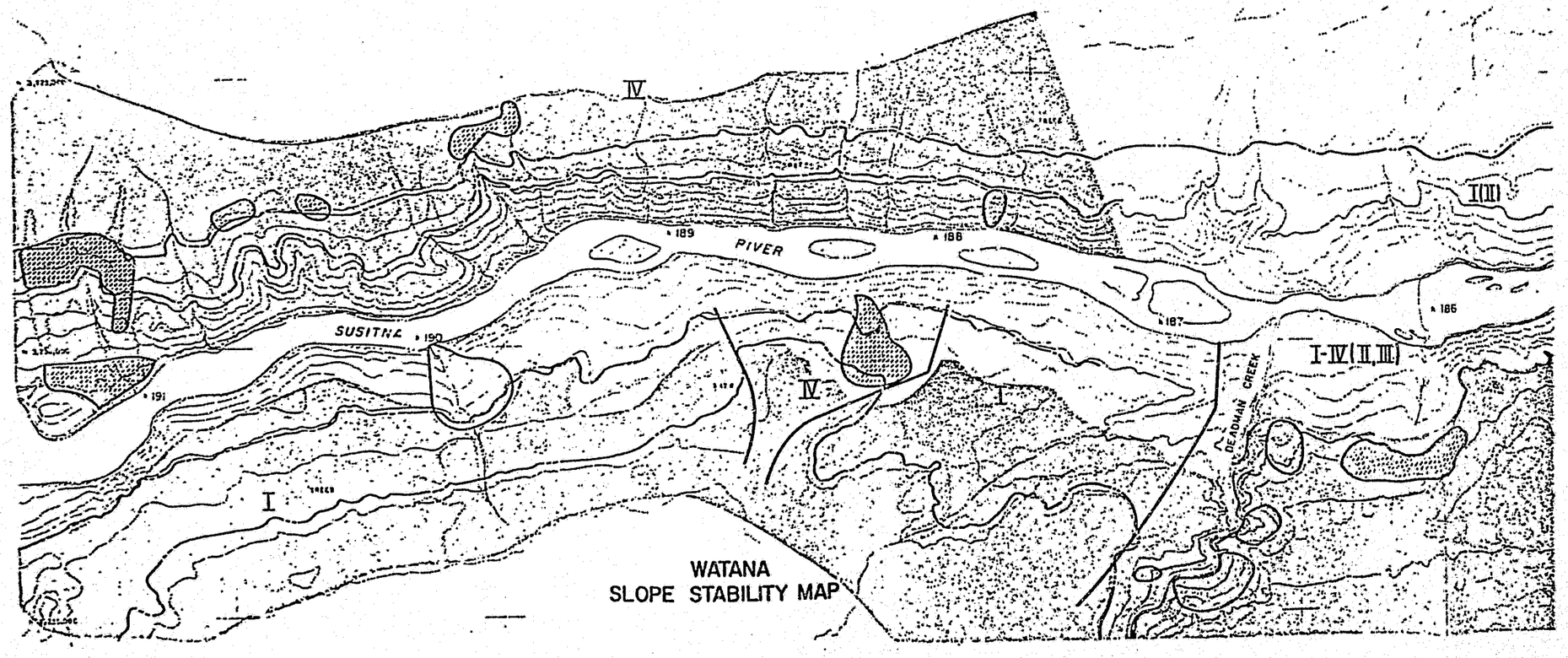
TYPES OF SLOPE INSTABILITY:

I	BEACHING
II	FLOWS
III	SLIDING (UNFROZEN)
IV	SLIDING (PERMAFROST)
/I/	DENOTES AREA EXTENT AND TYPE OF INSTABILITY
I(III)	PRIMARY BEACHING INSTABILITY WITH SOME POTENTIAL SLIDING
I-II	BEACHING AND FLOWS POSSIBLE IN DEFINED AREA
———	NORMAL MAXIMUM OPERATING LEVEL
———	NORMAL MINIMUM OPERATING LEVEL
	RIVER MILES

AREA OF POTENTIAL PERMAFROST

NOTES

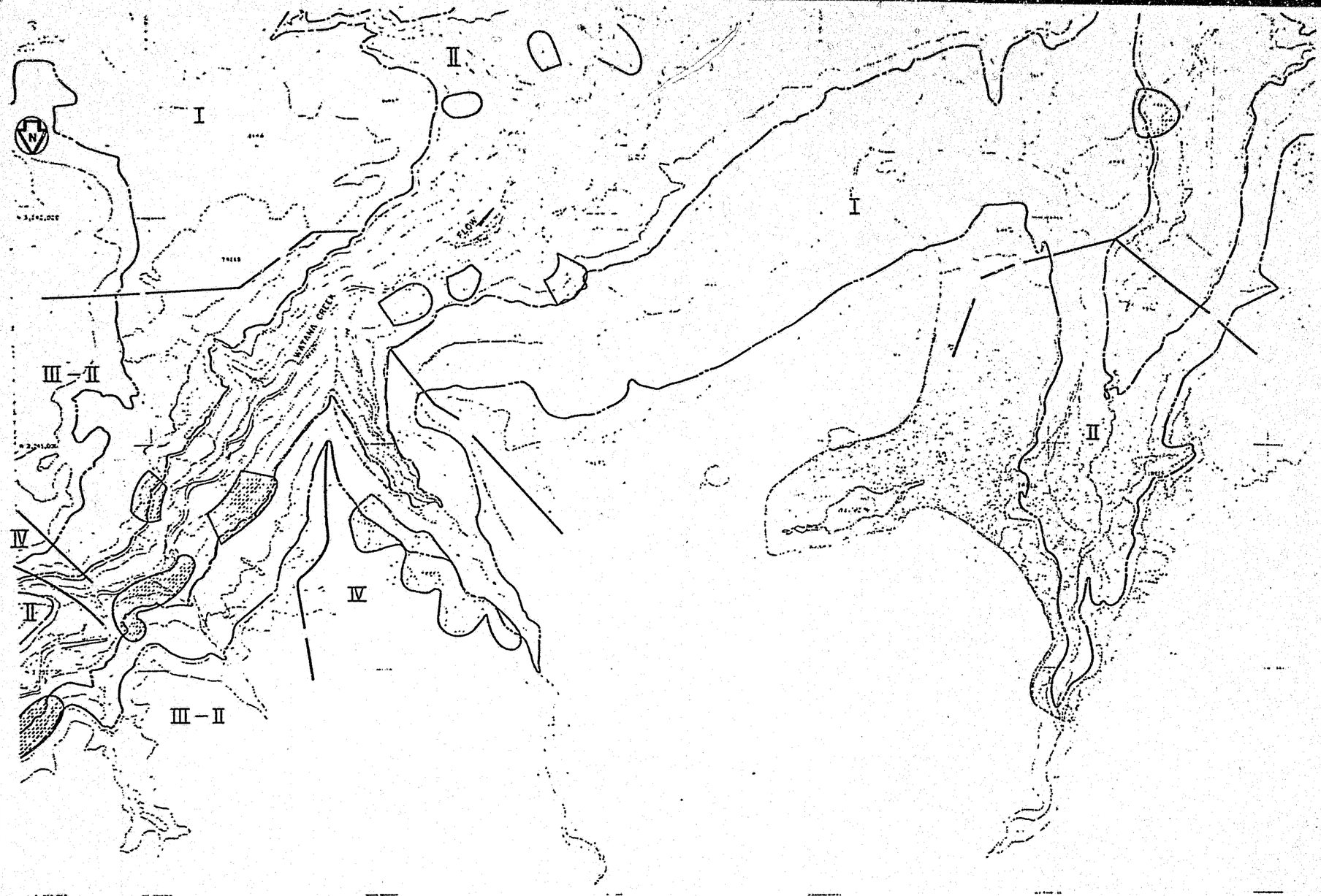
1. REFER TO FIGURES E.6.19 AND E.6.20 FOR DETAILED DESCRIPTION OF TYPE OF SLOPE INSTABILITY MODELS
2. NO DELINEATION OF PERMAFROST AREA ABOVE ELEVATION 2300 FEET
3. AREAS OF POTENTIAL PERMAFROST BASED PRINCIPALLY ON AIR PHOTO INTERPRETATION AND WILL REQUIRE FUTURE VERIFICATION



WATANA
SLOPE STABILITY MAP

FIGURE E.S.33

2-31-15



LEGEND

AREAS OF CURRENT SLOPE INSTABILITY

TYPES OF SLOPE INSTABILITY

I	BEACHING
II	FLOWS
III	SLIDING (UNFROZEN)
IV	SLIDING (PERMAFROST)
/I/	DENOTES AREA EXTENT AND TYPE OF INSTABILITY
I(III)	PRIMARY BEACHING INSTABILITY WITH SOME POTENTIAL SLIDING
I-II	BEACHING AND FLOWS POSSIBLE IN DEFINED AREA
———	NORMAL MAXIMUM OPERATING LEVEL
- - - -	NORMAL MINIMUM OPERATING LEVEL
	RIVER MILES

AREA OF POTENTIAL PERMAFROST

NOTES

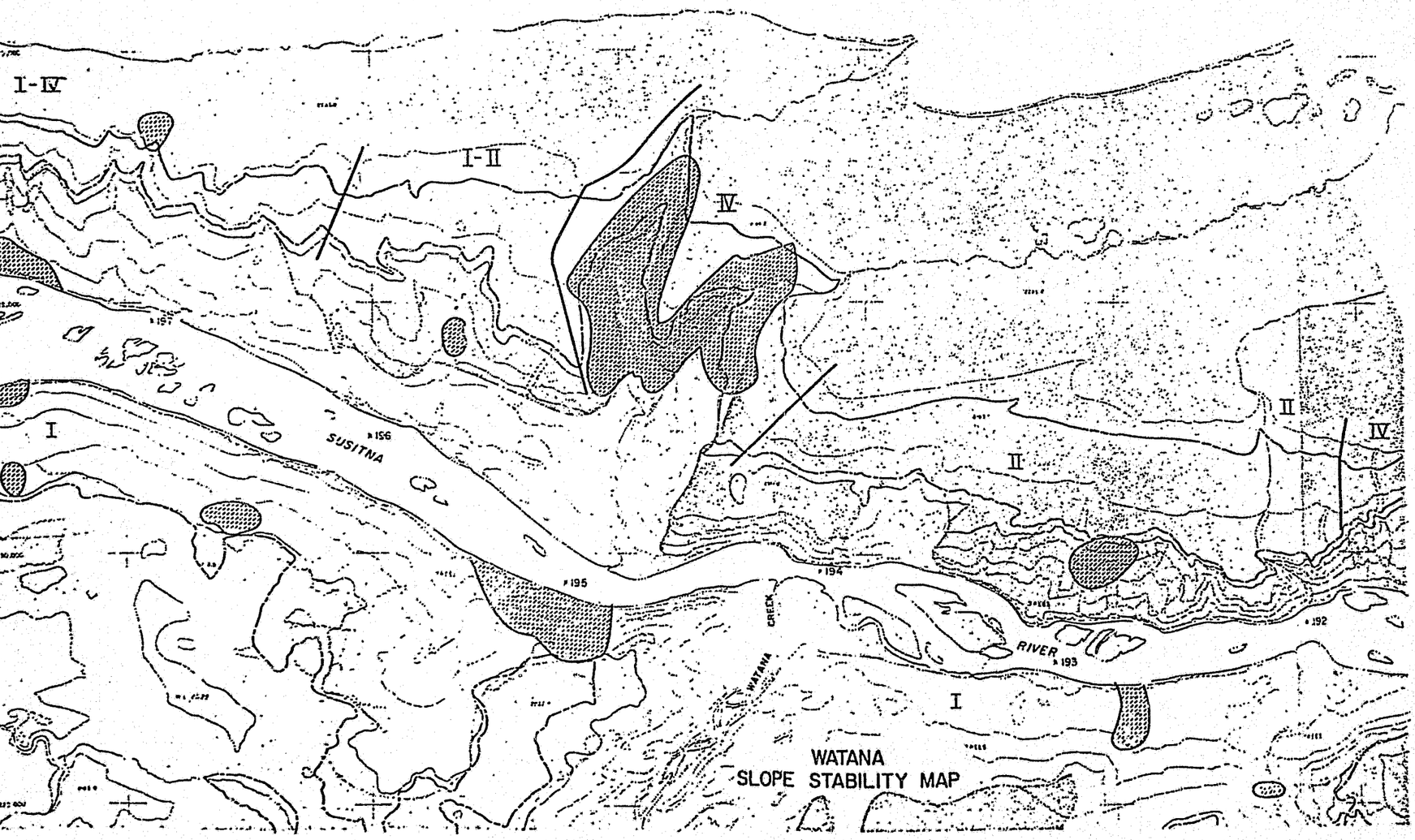
1. REFER TO FIGURES E.6.19 AND E.6.20 FOR DETAILED DESCRIPTION OF TYPE OF SLOPE INSTABILITY MODELS
2. NO DELINEATION OF PERMAFROST AREA ABOVE ELEVATION 2300 FEET
3. AREAS OF POTENTIAL PERMAFROST BASED PRINCIPALLY ON AIR PHOTO INTERPRETATION AND WILL REQUIRE FUTURE VERIFICATION

SCALE 0 1000 2000 FEET

WATANA
SLOPE STABILITY MAP

FIGURE E.6.

2-31-16



LEGEND

AREAS OF CURRENT SLOPE INSTABILITY

TYPES OF SLOPE INSTABILITY:

I	BEACHING
II	FLOWS
III	SLIDING (UNFROZEN)
IV	SLIDING (PERMAFROST)
/I/	DENOTES AREA EXTENT AND TYPE OF INSTABILITY
I(III)	PRIMARY BEACHING INSTABILITY WITH SOME POTENTIAL SLIDING
I-II	BEACHING AND FLOWS POSSIBLE IN DEFINED AREA
———	NORMAL MAXIMUM OPERATING LEVEL
- - - -	NORMAL MINIMUM OPERATING LEVEL
x	RIVER MILES

AREA OF POTENTIAL PERMAFROST

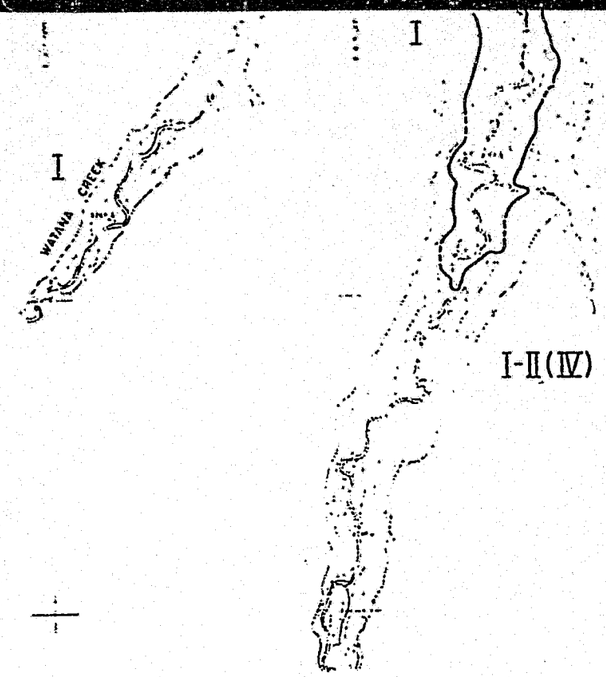
NOTES

1. REFER TO FIGURES E.6.19 AND E.6.20 FOR DETAILED DESCRIPTION OF TYPE OF SLOPE INSTABILITY MODELS
2. NO DELINEATION OF PERMAFROST AREA ABOVE ELEVATION 2300 FEET
3. AREAS OF POTENTIAL PERMAFROST BASED PRINCIPALLY ON AIR PHOTO INTERPRETATION AND WILL REQUIRE FUTURE VERIFICATION

SCALE 0 1000 2000 FEET

FIGURE E.6.35

2-31-17



LEGEND

AREAS OF CURRENT SLOPE INSTABILITY

TYPES OF SLOPE INSTABILITY[1]

I	BEACHING
II	FLOWS
III	SLIDING (UNFROZEN)
IV	SLIDING (PERMAFROST)
/I/	DENOTES AREA EXTENT AND TYPE OF INSTABILITY
I(IV)	PRIMARY BEACHING INSTABILITY WITH SOME POTENTIAL SLIDING
I-II	BEACHING AND FLOWS POSSIBLE IN DEFINED AREA
———	NORMAL MAXIMUM OPERATING LEVEL
- - - -	NORMAL MINIMUM OPERATING LEVEL
	RIVER MILES

NOTES

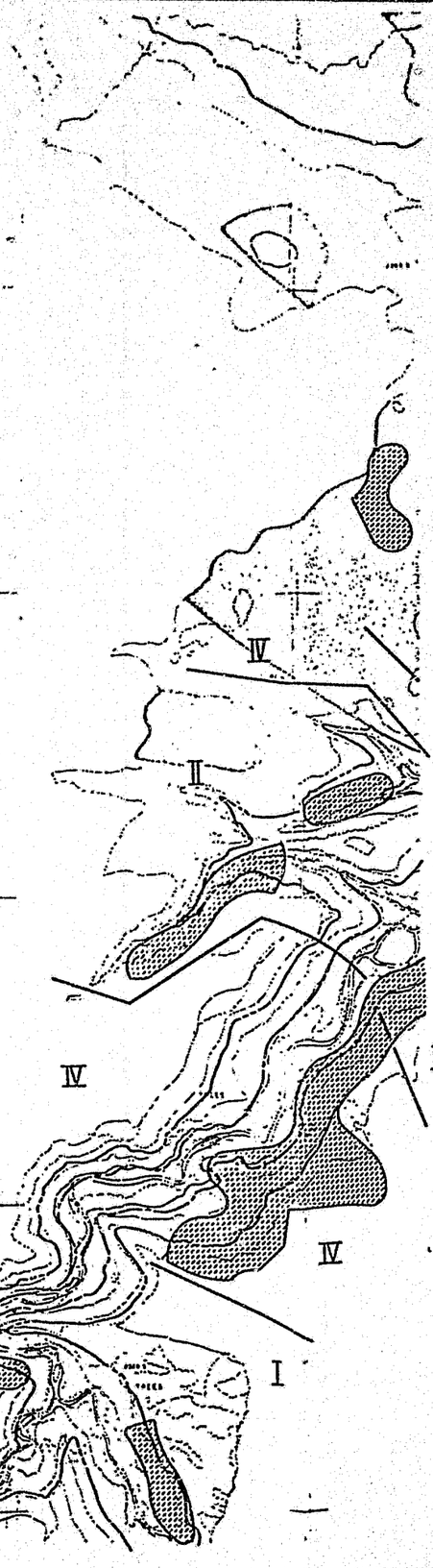
1. REFER TO FIGURES E.6.19 AND E.6.20 FOR DETAILED DESCRIPTION OF TYPE OF SLOPE INSTABILITY MODELS
2. NO DELINEATION OF PERMAFROST AREA ABOVE ELEVATION 2300 FEET
3. AREAS OF POTENTIAL PERMAFROST BASED PRINCIPALLY ON AIR PHOTO INTERPRETATION AND WILL REQUIRE FUTURE VERIFICATION

SCALE 0 1000 2000 FEET

WATANA
SLOPE STABILITY MAP

FIGURE E.6.36

2-31-18



LEGEND

AREAS OF CURRENT SLOPE INSTABILITY

TYPES OF SLOPE INSTABILITY:

I	BEACHING
II	FLOWS
III	SLIDING (UNFROZEN)
IV	SLIDING (PERMAFROST)
/I/	DENOTES AREA EXTENT AND TYPE OF INSTABILITY
I(III)	PRIMARY BEACHING INSTABILITY WITH SOME POTENTIAL SLIDING
I-II	BEACHING AND FLOWS POSSIBLE IN DEFINED AREA
———	NORMAL MAXIMUM OPERATING LEVEL
——·——	NORMAL MINIMUM OPERATING LEVEL
	RIVER MILES

AREA OF POTENTIAL PERMAFROST

NOTES

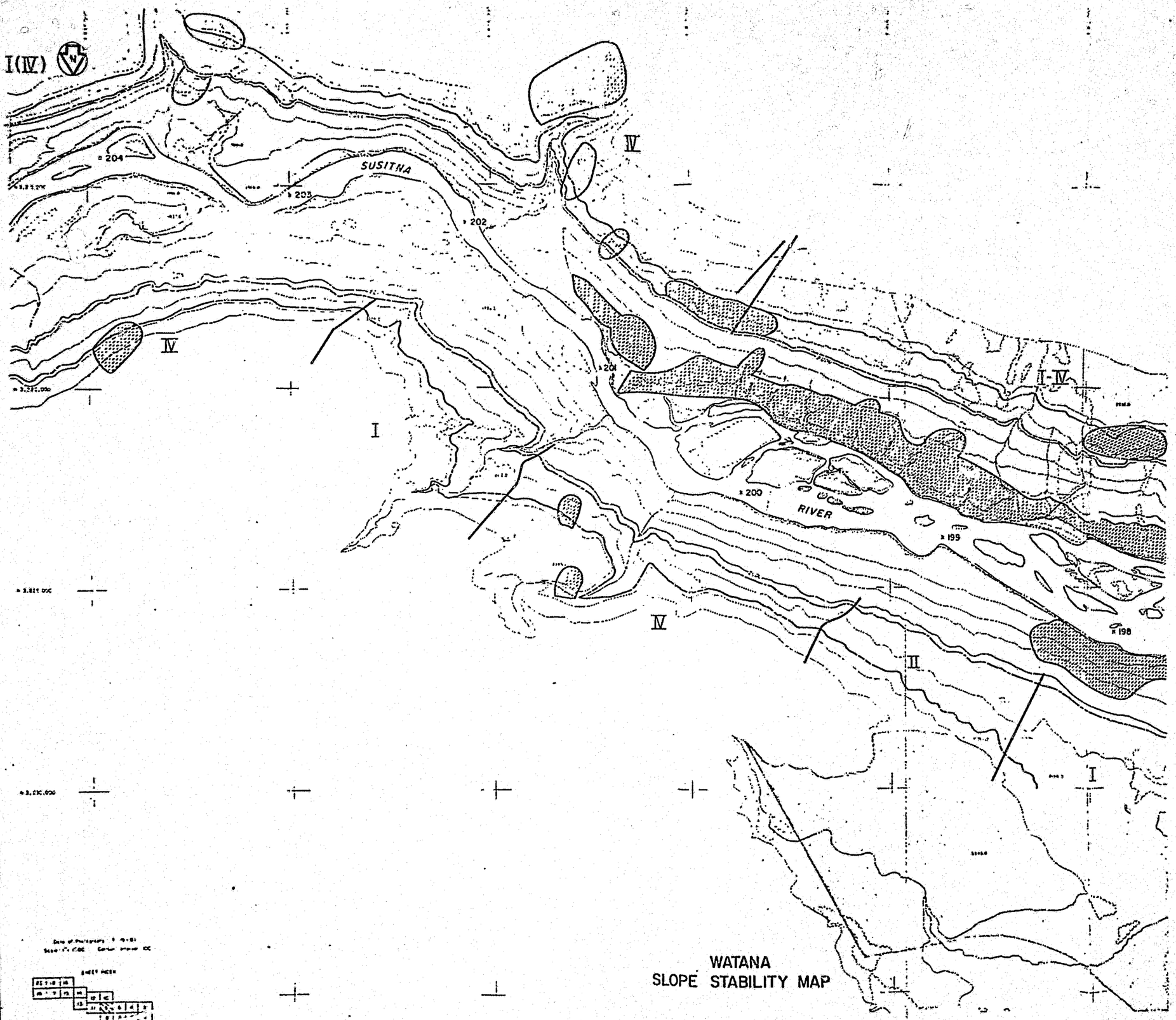
1. REFER TO FIGURES E.6.19 AND E.6.20 FOR DETAILED DESCRIPTION OF TYPE OF SLOPE INSTABILITY MODELS
2. NO DELINEATION OF PERMAFROST AREA ABOVE ELEVATION 2500 FEET
3. AREAS OF POTENTIAL PERMAFROST BASED PRINCIPALLY ON AIR PHOTO INTERPRETATION AND WILL REQUIRE FUTURE VERIFICATION.

SCALE 0 1000 2000 FEET

WATANA
SLOPE STABILITY MAP

FIGURE E.6.37

2-31-19



LEGEND

AREAS OF CURRENT SLOPE INSTABILITY

TYPES OF SLOPE INSTABILITY[1]

I	BEACHING
II	FLOWS
III	SLIDING (UNFROZEN)
IV	SLIDING (PERMAFROST)
/I/	DENOTES AREA EXTENT AND TYPE OF INSTABILITY
I(III)	PRIMARY BEACHING INSTABILITY WITH SOME POTENTIAL SLIDING
I-II	BEACHING AND FLOWS POSSIBLE IN DEFINED AREA
———	NORMAL MAXIMUM OPERATING LEVEL
- - - -	NORMAL MINIMUM OPERATING LEVEL
x	RIVER MILES

AREA OF POTENTIAL PERMAFROST

NOTES

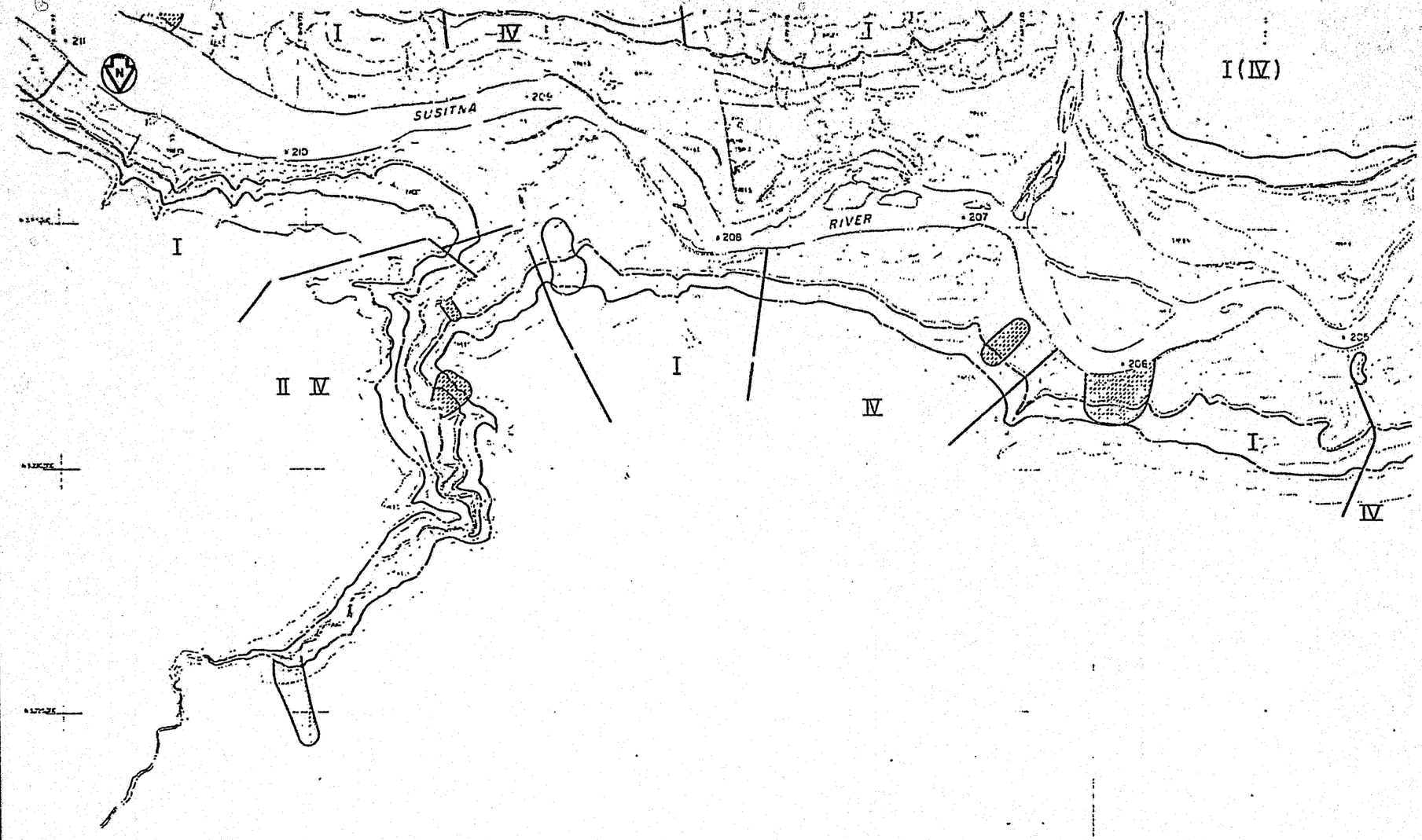
1. REFER TO FIGURES E.6.19 AND E.6.20 FOR DETAILED DESCRIPTION OF TYPE OF SLOPE INSTABILITY MODELS
2. NO DELINEATION OF PERMAFROST AREA ABOVE ELEVATION 2300 FEET
3. AREAS OF POTENTIAL PERMAFROST BASED PRINCIPALLY ON AIR PHOTO INTERPRETATION AND WILL REQUIRE FUTURE VERIFICATION

SCALE 0 1000 2000 FEET

WATANA
SLOPE STABILITY MAP

FIGURE E.6.38

2-31-20



LEGEND

AREAS OF CURRENT SLOPE INSTABILITY

TYPES OF SLOPE INSTABILITY:

I	BEACHING
II	FLOWS
III	SLIDING (UNFROZEN)
IV	SLIDING (PERMAFROST)
/X/	DENOTES AREA EXTENT AND TYPE OF INSTABILITY
I(IV)	PRIMARY BEACHING INSTABILITY WITH SOME POTENTIAL SLIDING
I-II	BEACHING AND FLOWS POSSIBLE IN DEFINED AREA
———	NORMAL MAXIMUM OPERATING LEVEL
- - - -	NORMAL MINIMUM OPERATING LEVEL
•	RIVER MILES

AREA OF POTENTIAL PERMAFROST

NOTES

1. REFER TO FIGURES E.6.19 AND E.6.20 FOR DETAILED DESCRIPTION OF TYPE OF SLOPE INSTABILITY MODELS
2. NO DELINEATION OF PERMAFROST AREA ABOVE ELEVATION 2300 FEET
3. AREAS OF POTENTIAL PERMAFROST BASED PRINCIPALLY ON AIR PHOTO INTERPRETATION AND WILL REQUIRE FUTURE VERIFICATION

SCALE 0 1000 2000 FEET

WATANA
SLOPE STABILITY MAP

FIGURE E.6.39

2-31-21

LEGEND

AREAS OF CURRENT SLOPE INSTABILITY

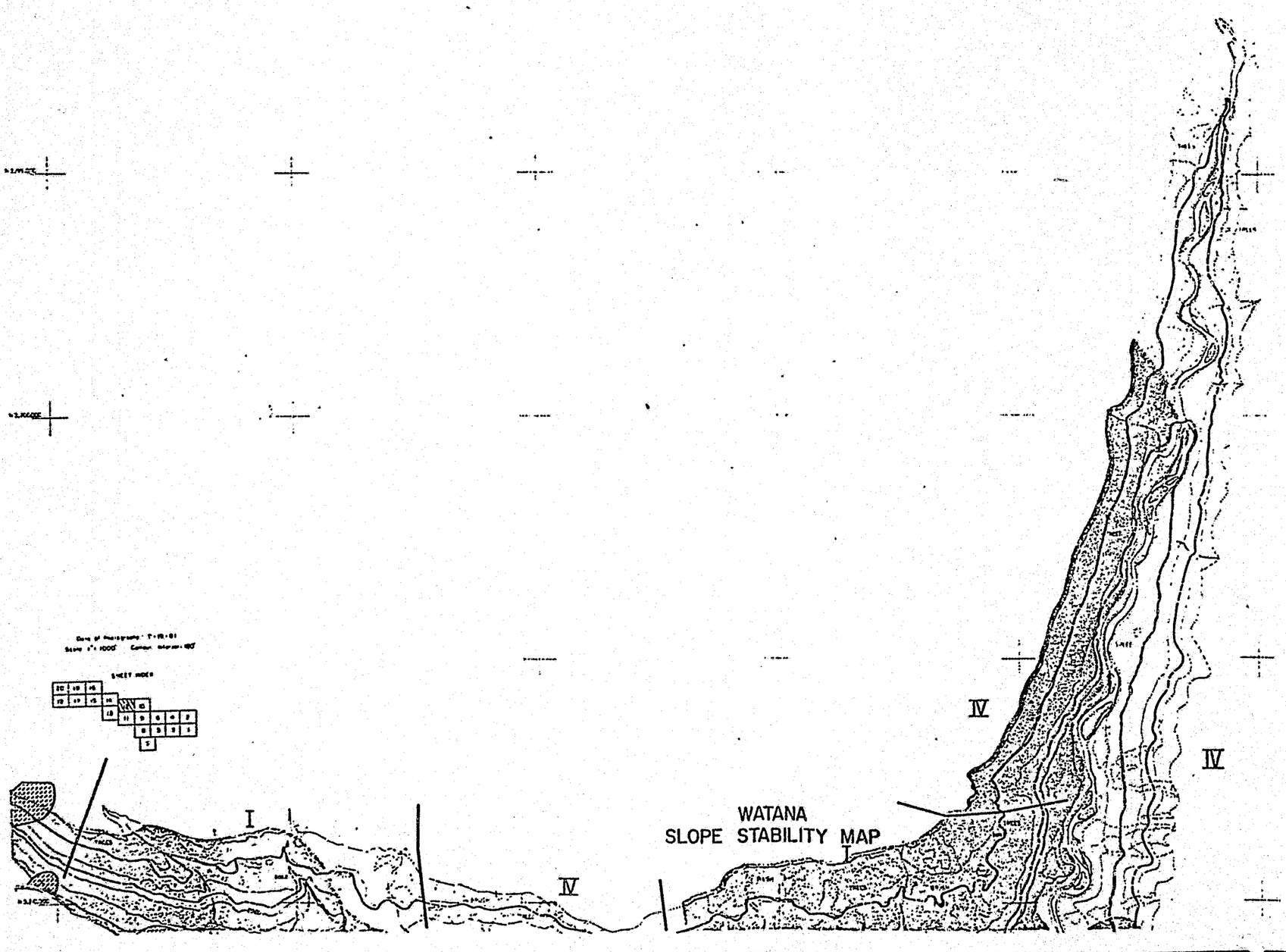
TYPES OF SLOPE INSTABILITY:

I	BEACHING
II	FLOWS
III	SLIDING (UNFROZEN)
IV	SLIDING (PERMAFROST)
/I/	DENOTES AREA EXTENT AND TYPE OF INSTABILITY
I(II)	PRIMARY BEACHING INSTABILITY WITH SOME POTENTIAL SLIDING
I-II	BEACHING AND FLOWS POSSIBLE IN DEFINED AREA
———	NORMAL MAXIMUM OPERATING LEVEL
- - - -	NORMAL MINIMUM OPERATING LEVEL
	RIVER MILES

AREA OF POTENTIAL PERMAFROST

NOTES

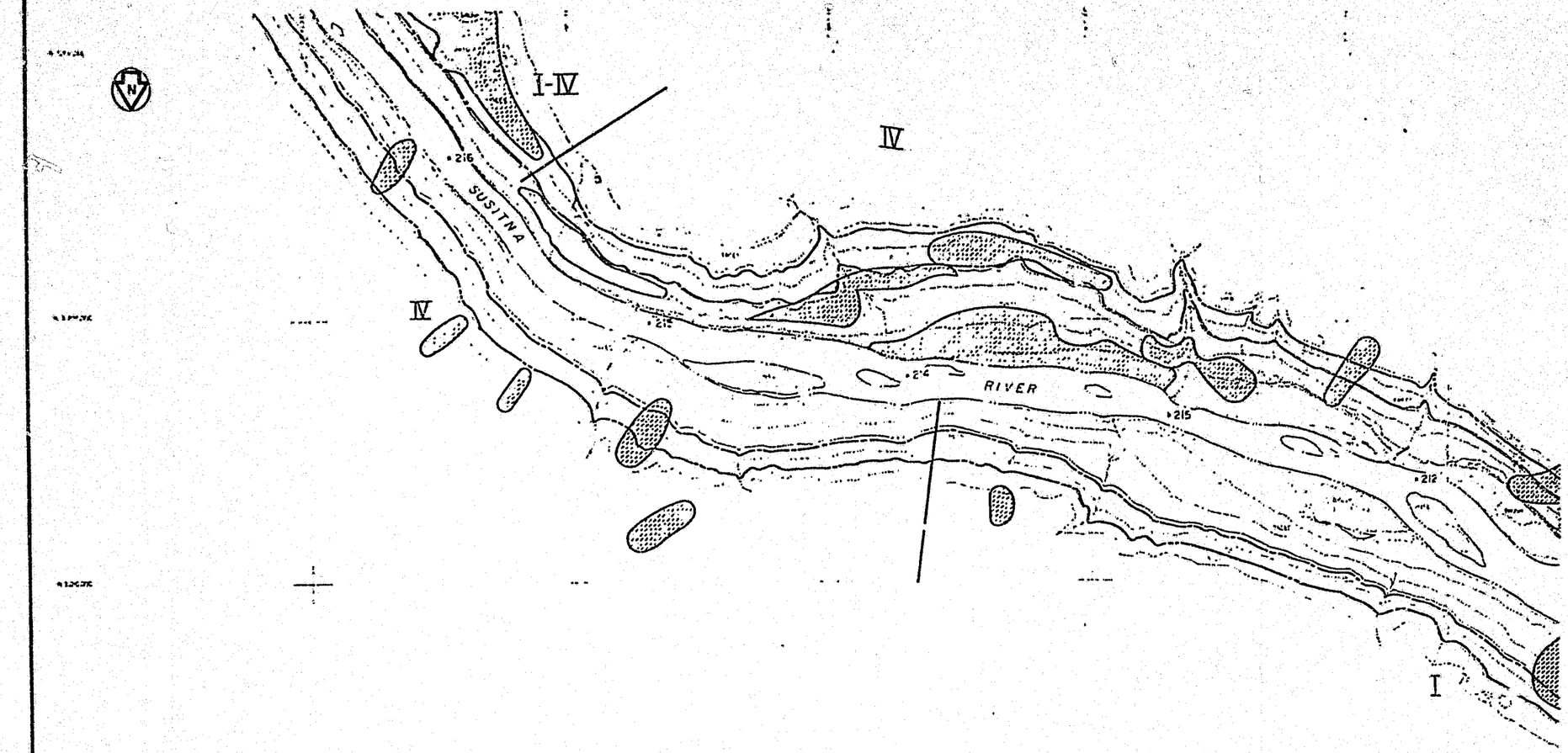
1. REFER TO FIGURES E.6.19 AND E.6.20 FOR DETAILED DESCRIPTION OF TYPE OF SLOPE INSTABILITY MODELS
2. NO DELINEATION OF PERMAFROST AREA ABOVE ELEVATION 2300 FEET
3. AREAS OF POTENTIAL PERMAFROST BASED PRINCIPALLY ON AIR PHOTO INTERPRETATION AND WILL REQUIRE FUTURE VERIFICATION



WATANA
SLOPE STABILITY MAP

SCALE 0 1000 2000 FEET

FIGURE E.6.40



LEGEND

AREAS OF CURRENT SLOPE INSTABILITY

TYPES OF SLOPE INSTABILITY:

I	BEACHING
II	FLOWS
III	SLIDING (UNFROZEN)
IV	SLIDING (PERMAFROST)
/X/	DENOTES AREA EXTENT AND TYPE OF INSTABILITY
I(III)	PRIMARY BEACHING INSTABILITY WITH SOME POTENTIAL SLIDING
I-II	BEACHING AND FLOWS POSSIBLE IN DEFINED AREA
———	NORMAL MAXIMUM OPERATING LEVEL
- - - -	NORMAL MINIMUM OPERATING LEVEL
X	RIVER MILES

AREA OF POTENTIAL PERMAFROST

NOTES

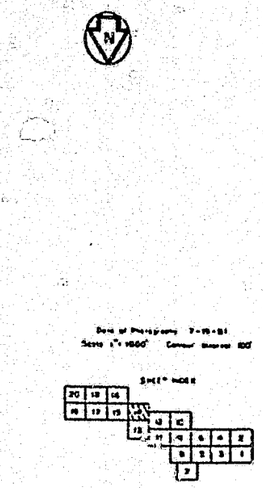
1. REFER TO FIGURES E.6.19 AND E.6.20 FOR DETAILED DESCRIPTION OF TYPE OF SLOPE INSTABILITY MODELS
2. NO DELINEATION OF PERMAFROST AREA ABOVE ELEVATION 2300 FEET
3. AREAS OF POTENTIAL PERMAFROST BASED PRINCIPALLY ON AIR PHOTO INTERPRETATION AND WILL REQUIRE FUTURE VERIFICATION

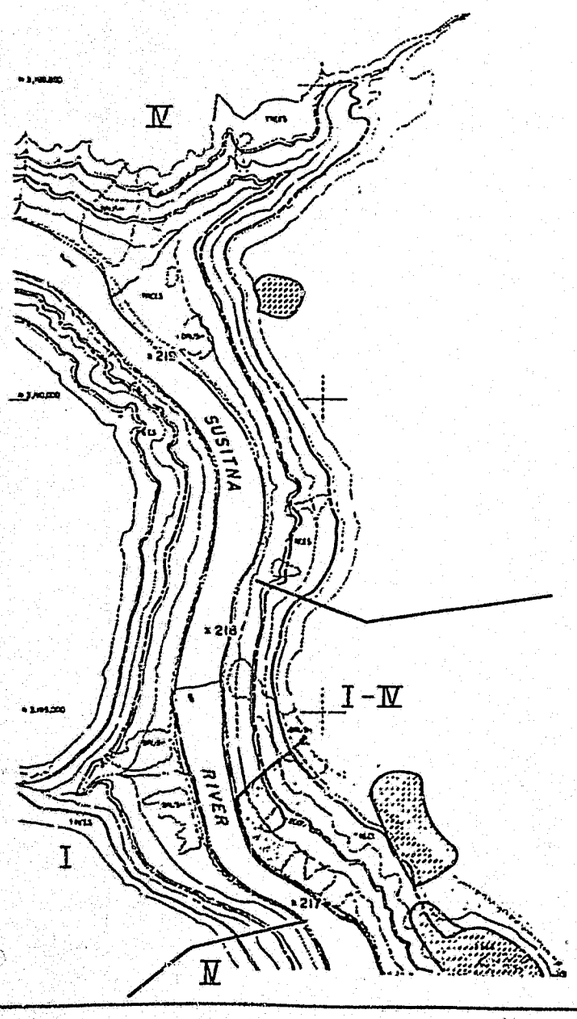
SCALE 0 1000 2000 FEET

WATANA
SLOPE STABILITY MAP

FIGURE E.6.41

2-31-23





LEGEND

AREA OF CURRENT SLOPE INSTABILITY

TYPES OF SLOPE INSTABILITY:

I	BEACHING
II	FLOWS
III	SLIDING (UNFROZEN)
IV	SLIDING (PERMAFROST)
/I/	DENOTES AREA EXTENT AND TYPE OF INSTABILITY
I(III)	PRIMARY BEACHING INSTABILITY WITH SOME POTENTIAL SLIDING
I-II	BEACHING AND FLOWS POSSIBLE IN DEFINED AREA
———	NORMAL MAXIMUM OPERATING LEVEL
- - - -	NORMAL MINIMUM OPERATING LEVEL
x	RIVER MILES

AREA OF POTENTIAL PERMAFROST

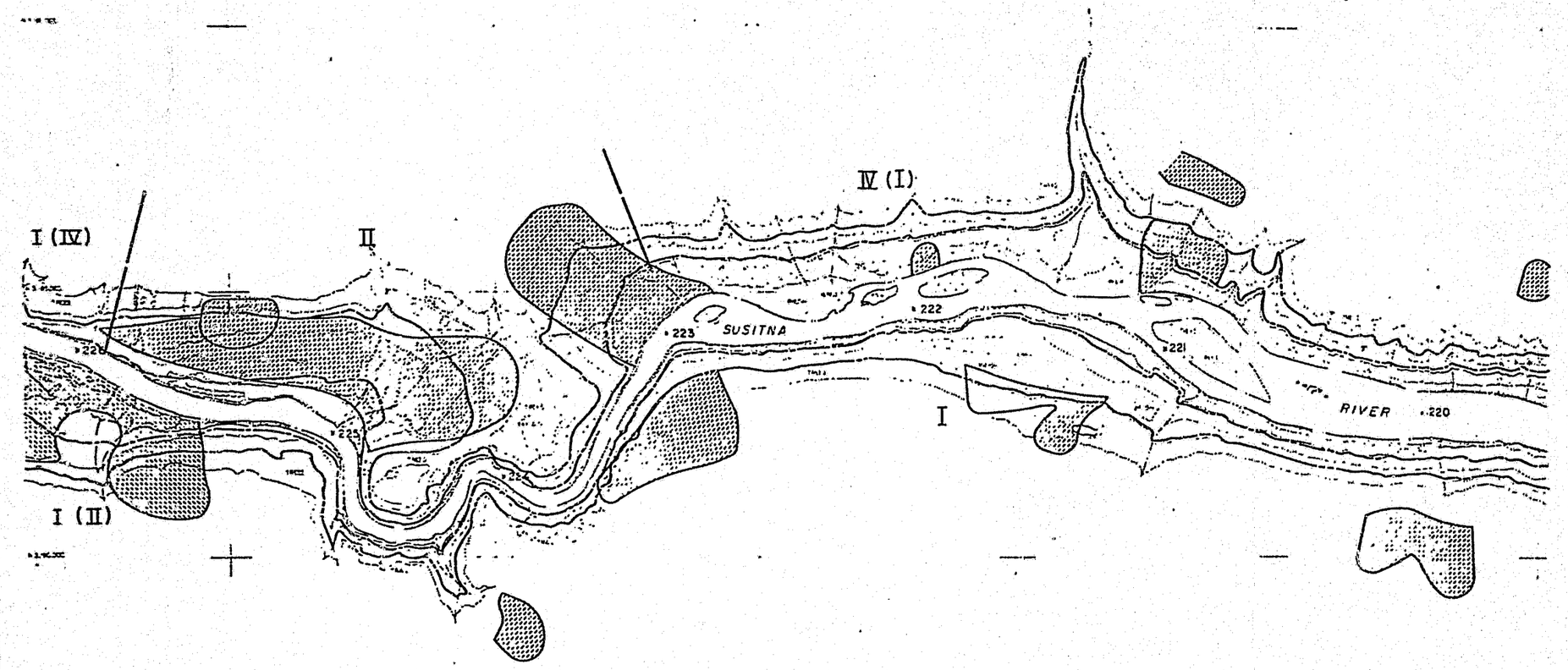
NOTES

1. REFER TO FIGURES E.6.19 AND E.6.20 FOR DETAILED DESCRIPTION OF TYPE OF SLOPE INSTABILITY MODELS
2. NO DELINEATION OF PERMAFROST AREA ABOVE ELEVATION 2300 FEET
3. AREAS OF POTENTIAL PERMAFROST BASED PRINCIPALLY ON AIR PHOTO INTERPRETATION AND WILL REQUIRE FUTURE VERIFICATION

SCALE 0 1000 2000 FEET

WATANA
SLOPE STABILITY MAP

FIGURE E.6.42
2-31-24



LEGEND

AREAS OF CURRENT SLOPE INSTABILITY

TYPES OF SLOPE INSTABILITY:

I	BEACHING
II	FLOWS
III	SLIDING (UNFROZEN)
IV	SLIDING (PERMAFROST)
/I/	DENOTES AREA EXTENT AND TYPE OF INSTABILITY
I(IV)	PRIMARY BEACHING INSTABILITY WITH SOME POTENTIAL SLIDING
I-II	BEACHING AND FLOWS POSSIBLE IN DEFINED AREA
———	NORMAL MAXIMUM OPERATING LEVEL
- - - -	NORMAL MINIMUM OPERATING LEVEL
,	RIVER MILES

NOTES

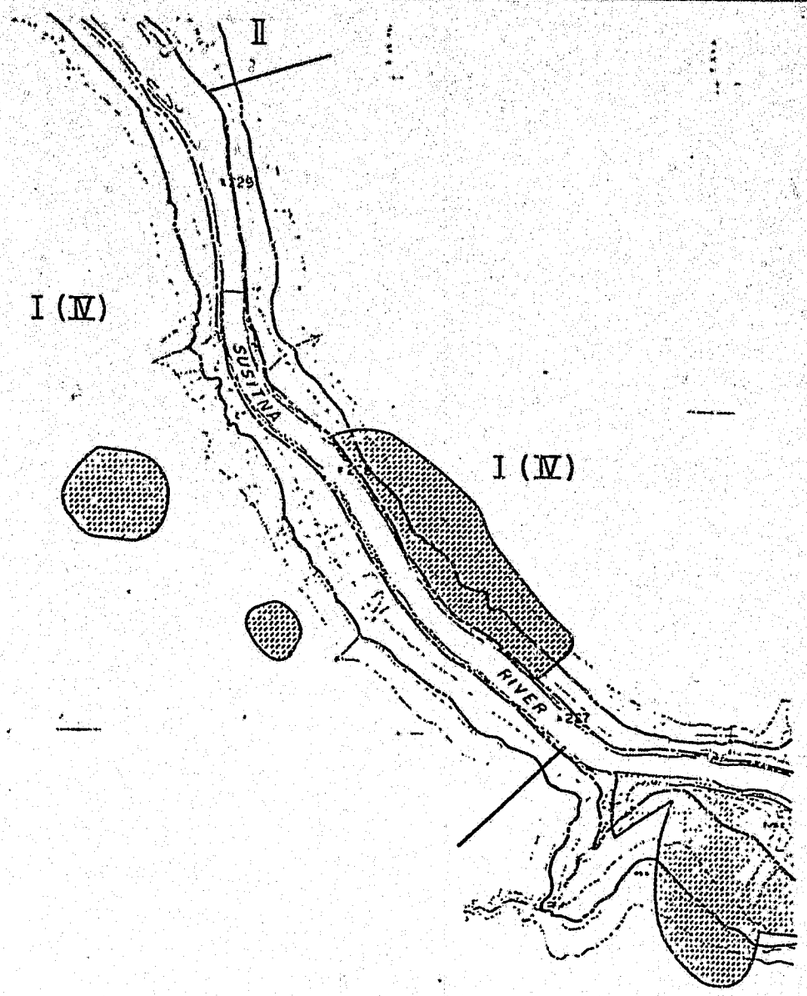
1. REFER TO FIGURES E.6.19 AND E.6.20 FOR DETAILED DESCRIPTION OF TYPE OF SLOPE INSTABILITY MODELS
2. NO DELINEATION OF PERMAFROST AREA ABOVE ELEVATION 2300 FEET
3. AREAS OF POTENTIAL PERMAFROST BASED PRINCIPALLY ON AIR PHOTO INTERPRETATION AND WILL REQUIRE FUTURE VERIFICATION

SCALE 0 1000 2000 FEET

WATANA
SLOPE STABILITY MAP

FIGURE E.6.43

2-31-25



LEGEND

AREAS OF CURRENT SLOPE INSTABILITY

TYPES OF SLOPE INSTABILITY:

I	BEACHING
II	FLOWS
III	SLIDING (UNFROZEN)
IV	SLIDING (PERMAFROST)
/I/	DENOTES AREA EXTENT AND TYPE OF INSTABILITY
I(III)	PRIMARY BEACHING INSTABILITY WITH SOME POTENTIAL SLIDING
I-II	BEACHING AND FLOWS POSSIBLE IN DEFINED AREA
———	NORMAL MAXIMUM OPERATING LEVEL
- - - -	NORMAL MINIMUM OPERATING LEVEL
X	RIVER MILES

NOTES

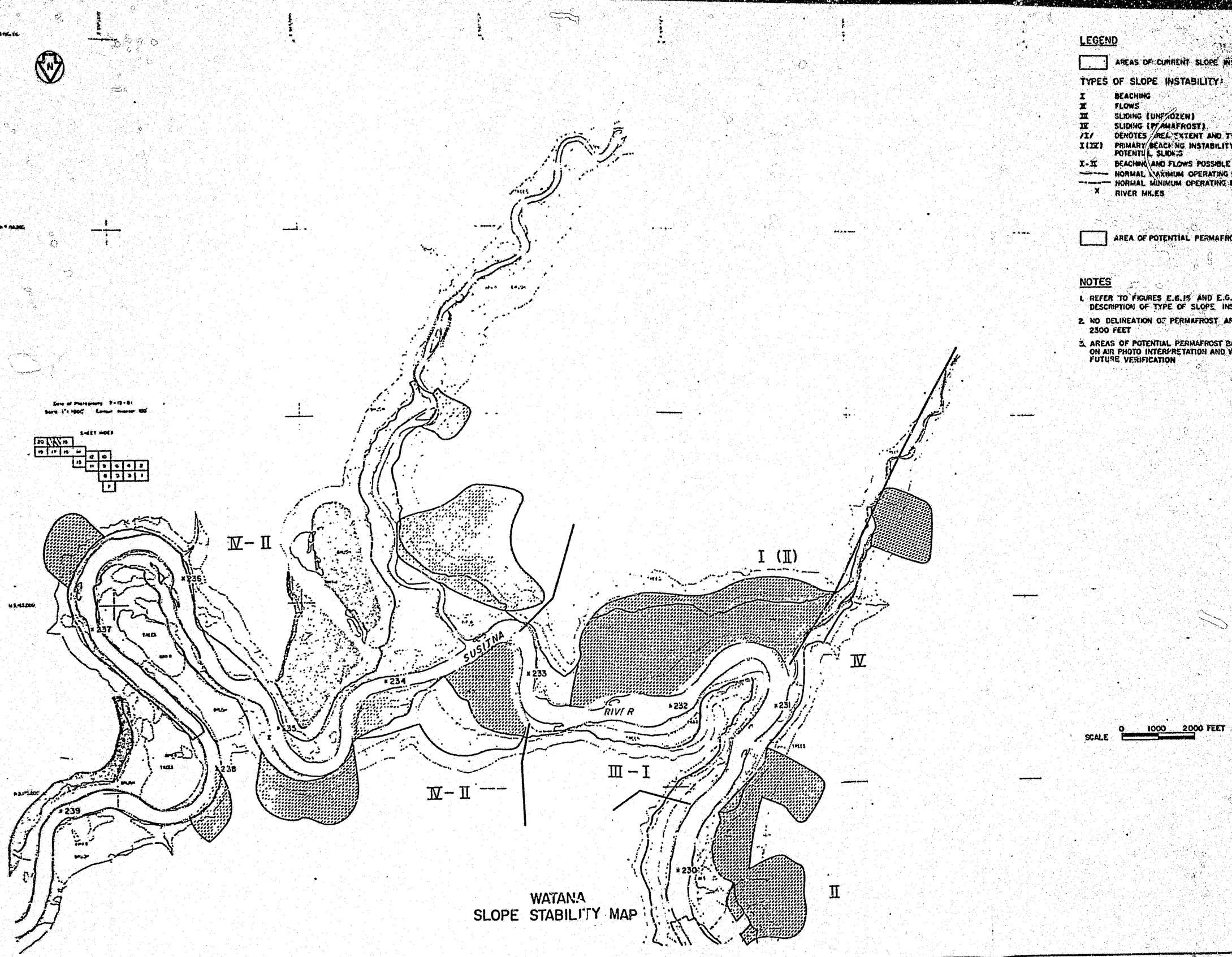
1. REFER TO FIGURES E.6.19 AND E.6.20 FOR DETAILED DESCRIPTION OF TYPE OF SLOPE INSTABILITY MODELS
2. NO DELINEATION OF PERMAFROST AREA ABOVE ELEVATION 2300 FEET
3. AREAS OF POTENTIAL PERMAFROST BASED PRINCIPALLY ON AIR PHOTO INTERPRETATION AND WILL REQUIRE FUTURE VERIFICATION

SCALE 0 1000 2000 FEET

WATANA
SLOPE STABILITY MAP

FIGURE E.6.44

2-31-2



WATANA
SLOPE STABILITY MAP

FIGURE E.6.45

2-81-27

EXHIBIT E

2. Water Use and Quality

Comment 32 (p. E-2-92, para. 1)

Provide anaylsis of the effects of filling and operation of Watana on suspended sediment concentrations and suspended particle sizes passing downstream through Watana Reservoir.

Response

Analysis of the effects of filling and operations of Watana on suspended sediments (concentrations and particle sizes) passing downstream are provided in the attached reports.

SUSITNA RESERVOIR SEDIMENTATION AND WATER CLARITY STUDY

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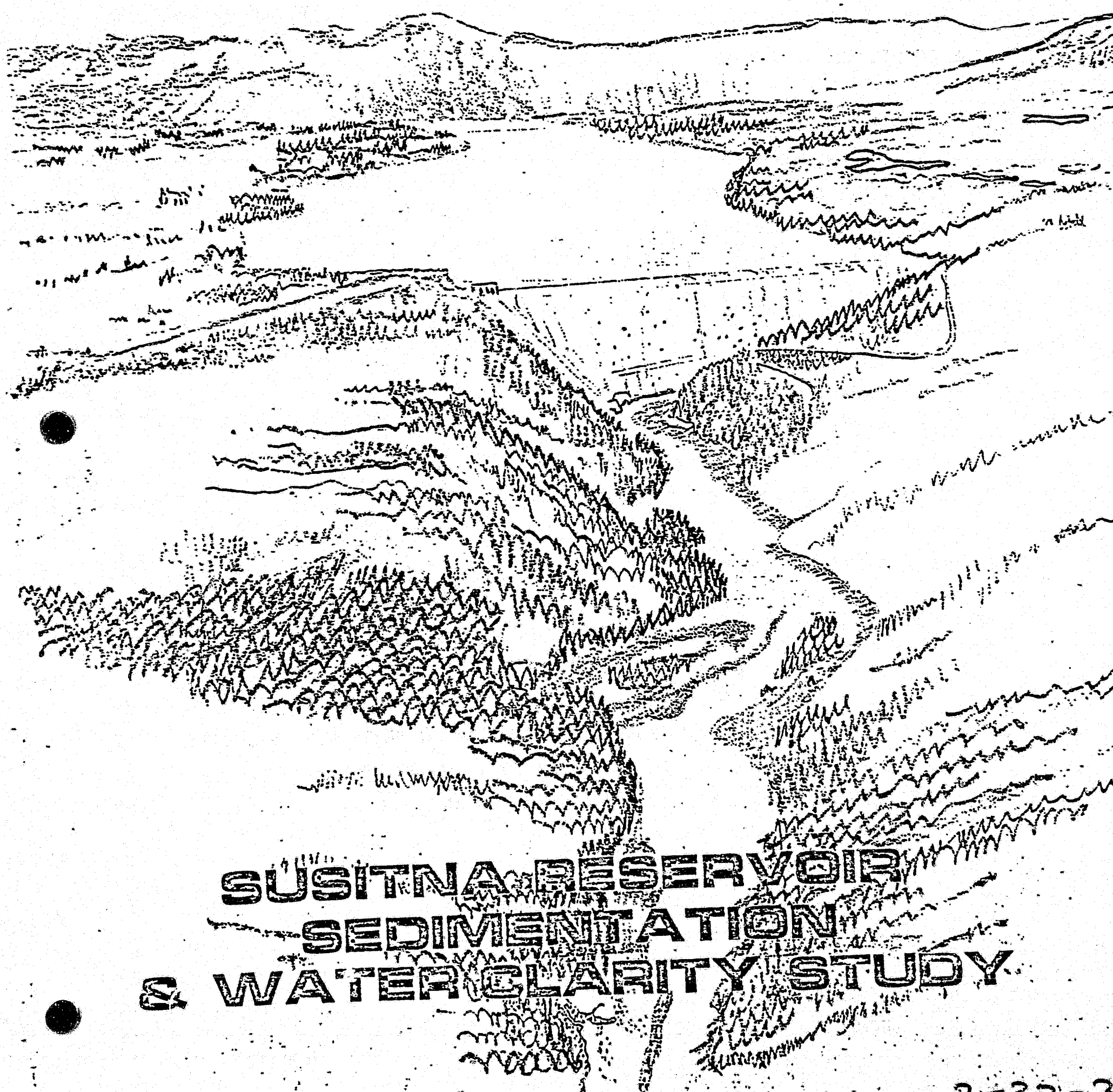
November, 1982

2-32-2



SUSITNA RESERVOIR SEDIMENTATION & WATER CLARITY STUDY

2-32-3

Peratrovich, Nottingham & Drage, Inc.
Engineering Consultants

SUSITNA RESERVOIR SEDIMENTATION & WATER CLARITY STUDY

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1. PURPOSE AND SCOPE

1.1 Background

This report summarizes the results of the Phase 2 investigations aimed at determining turbidity levels in the proposed Watana reservoir. The Phase 1 studies were completed by R&M Consultants, Inc., (January 1982). These earlier studies developed trap efficiencies for the Watana and Devil Canyon reservoirs. Total sediment accummulation for each of the reservoirs was also estimated. An indication of what downstream river turbidity levels were likely to be was also provided. These studies included a brief description of the delta formation in the reservoir, the likely behavior of glacial flour within the reservoir, and a general discussion on the temperature regime.

The Phase 2 studies which are described here were initiated in order to analyze in more detail additional data obtained on other lake systems throughout the world and to attempt to predict, on a more quantitative basis, likely turbidity levels in the Watana reservoir.

A plan view of the proposed Watana reservoir and the sediment and climatic data stations on the Susitna River used in Phase 2 studies are shown on Figure 1.1.

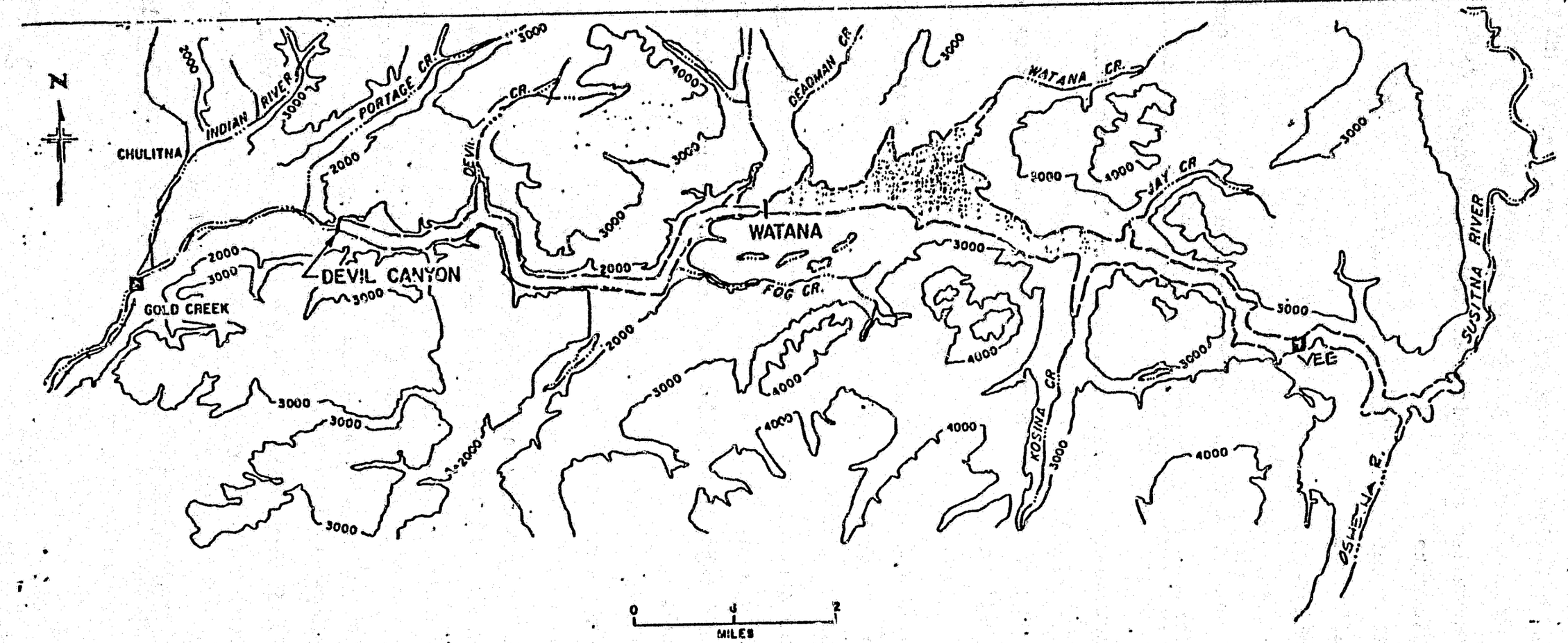
1.2 Study Objectives

The objective of the study is to estimate the range of sediment concentrations and turbidity levels in the Watana reservoir for the various months of the year. It should be stressed that the objective is not to provide a detailed quantitative estimate, but rather to perform an exploratory type investigation to determine order of magnitude estimates.

1.3 Scope of Work

The scope of work was outlined in a letter to Acres American, Inc., (Acres) dated April 19, 1982. A brief summary of the proposed program follows.

2-32-8



SAMPLING STATIONS	PARAMETER
GOLD CREEK	STREAMFLOW SEDIMENT DISCHARGE WATER TEMPERATURE
WATANA	STREAMFLOW CLIMATE WATER TEMPERATURE
VEE	STREAMFLOW SEDIMENT DISCHARGE

2-32-9

Petratovich & Nottingham, Inc.
Engineering Consultants

FIGURE 1.1

(a) Obtain and review all additional data including:
- o climatic data
- o reservoir data
- o sediment data
- o literature survey

(b) Verify the sediment concentration versus turbidity relationship.

(c) Conduct quiescent settling analyses for the reservoir.

(d) Quantify the wind and thermal mixing characteristics of the reservoir.

(e) Estimate ranges of sediment and turbidity values for the reservoir for each month of the year.

Limited input to these studies was derived from the thermal lake modeling conducted by Acres American, Inc. (1982), on the Watana reservoir, and baseline turbidity and sediment concentration data from Eklutna Lake collected by R&M (1982).

1.4 Study Approach

Under quiescent conditions, sediment with particle size greater than about 2 um that flows into the Watana reservoir would practically all settle out. However, the reservoir water is continually subjected to internal mixing induced by meterologic conditions such as wind and temperature, as well as turbulence induced by inflowing and outflowing water. Because of this mixing, many of the smaller particles would not settle, but would remain in suspension and contribute to increased turbidity levels in the reservoir. In addition, turbulence in the water also reintrains sediment that has settled out on the bottom of the shallow portions of the reservoir perimeter, again contributing to increased turbidity levels.

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The basic approach to the study involved a semi-quantitive evaluation of the process described above, and consisted of several distinct tasks. These include:

(a) Literature and Data Review

Literature and data relating to other glacial lakes under similar conditions have been reviewed. Any useful information which could be extrapolated to Watana has been abstracted and summarized. This information is then used to support some of the conclusions drawn from the simplified sediment analyses.

(b) Description of the Lake Sedimentation Process

A detailed description of the likely sedimentation process has been developed. It is based on current knowledge of the Watana reservoir and documented descriptions of other similar lakes and reservoirs. This description aided in the determination of sediment types and turbulent mixing analyses.

(c) Description of the Watana Reservoir

All relevant data for the Watana reservoir has been assembled and summarized. These data include a description of the monthly inflows and sediment concentrations, sediment grain size distributions, reservoir storage volumes and releases, and monthly wind and temperature data.

(d) Analysis of Sediment Behavior

The amount of sediment that would settle out under quiescent conditions has been calculated for various sediment inputs, reservoir elevations, and withdrawal rates. Following this, quantitative assessments have been made of wind and temperature induced mixing currents in the reservoir. Use has

been made of the thermal modeling conducted by Acres (1982). Approximate turbidity-sediment concentration relationships, previously developed by R&M (January 1982), have been updated using additional Susitna River data, and also used in the analysis.

(e) Prediction of Reservoir Turbidity

Based on the assumption that reservoir mixing velocities of the same order of magnitude as the particle settling velocities would disrupt the settling process, typical ranges of sediment concentrations in the Watana Reservoir, near the outlet, have been estimated. These sediment concentrations are converted to turbidity using the appropriate turbidity sediment concentration relationships.

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2. SUMMARY

2.1 Past Studies

The Phase 1 studies conducted by R&M (January 1982) on the Watana reservoir indicated the following:

Typical sediment gradations of Susitna River water in the Watana reservoir area are 15 to 20 percent finer by weight than 2 microns, 25 to 35 percent finer than 10 microns, and 95 to 100 percent finer than 500 microns (0.5 mm). The sediment trap efficiency of the Watana reservoir was estimated to be between 70 and 95 percent with particles less than 2 microns possibly passing through the reservoir. Under worse case sedimentation conditions of 100 percent trap efficiency, an estimated 472,500 acre.ft. of sediment would be deposited in the reservoir over a 100-year period.

Turbidity in the downstream river would decrease significantly during the summer months due to the large amount of sediment trapped by the reservoir. It is likely that the turbidity of water released in the winter months when a stable ice cover exists would be near natural conditions, as suspended sediment in the near-surface water would settle out once the reservoir ice cover reduces surface disturbance and essentially quiescent conditions occur.

2.2 Summary and Conclusions

Due to the complexity of glacial flour sediment behavior in large water bodies, the general shortage of quantitative data, and little direct experience with large glacial feed reservoirs, the conclusions drawn at this time should be considered qualitative. However, the following conclusions are considered defensible and provide order of magnitude quantitative values that should allow project personnel to reevaluate the effects of reservoir water clarity on other physical and biological aspects of the Susitna project.

1. There will be some level of turbidity in the reservoir at all times.

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2. It is likely that sediment particles less than 3 to 4 microns will remain in suspension. This constitutes up to 20% of the summer sediment input. Maximum turbidity levels at the outlet are on the order of 50 NTU's, which corresponds to a sediment concentration of 200 to 400 mg/l. Minimum turbidity levels will be in the order of 10 NTU's. This corresponds to a sediment concentration of 30 to 70 mg/l.

3. Order of magnitude turbidity levels at the reservoir outlet during each month appear to be primarily dependent on the travel time it takes sediment slugs, delivered to the reservoir during previous summers, to reach the reservoir outlet. Longitudinal mixing, primarily induced by wind turbulence, will tend to mask the near surface sediment slugs. Quantification of longitudinal mixing has not been directly addressed within the scope of this task.

4. Wind mixing is significant in retaining sediment less than about 12 microns in suspension for the upper 50-foot water layer.

5. Reintrainment of sediment from the shallow depths along the reservoir periphery during severe storms will result in short-term high turbidity levels. This will be particularly evident during the summer refilling process when water levels will rise, resubmerging sediment deposited along the shoreline during the winter.

6. In spite of some limitations, the data gathered from outside sources supports the conclusion that Watana reservoir turbidity levels will be in the range of 10-50 NTU's.

7. Preliminary results from the Eklutna Lake study show summer turbidity levels in the near surface layers to be in the range of 20-40 NTU's. This generally agrees with the range of turbidity values predicted for the Watana reservoir.

2-32-14

2.3 Recommendations

Should more reliable and accurate estimates of turbidity levels be required, futher work is warranted to firm up predictions of sediment concentration and turbidity in the Watana reservoir. Some of the major weaknesses in the current data base and analytical approach include the lack of knowledge of the electrochemical behavior of the sediment, the role of phytoplankton and its effect on turbidity, and the simplistic nature of the analysis of the sedimentation process. To overcome these deficiencies, the following study program is recommended:

(a) Conduct more detailed laboratory settling tests on river sediment samples.

(b) Develop more reliable relationships between turbidities and sediment concentration incorporating the effects of phytoplankton growths should this be regarded important, and incorporating results from USGS summer field program to measure sediment discharge.

(c) Apply a two-dimensional model to analyze the longitudinal distribution of sediments deposition in the reservoir. The model should incorporate the values of mixing velocities derived from the Acres (1982) thermal modeling using a diffusion type analogy. It is important to incorporate a relatively long sequence (several years) of representative inflow and sediment concentration data in these studies. This will facilitate a more accurate determination of turbidity ranges likely to occur in the reservoir.

3. REVIEW OF AVAILABLE LITERATURE

Under Phase I of the current reservoir sedimentation study, investigations have been ongoing to retrieve any unpublished data or reports from those references included in the Reservoir Sedimentation Report (January, 1982) and to search out any additional information from sources worldwide.

Appendix B includes a bibliography of all additional reports of data obtained from the literature search. It has been separated into two parts; the first containing references from New Zealand Lake studies, the second listing additional general references on reservoir sedimentation or the behavior of fine particles in a water body. Efforts have been made not to duplicate those publications referenced in the earlier reservoir sedimentation study (R&M, January, 1982).

Compilation of information from these sources has been an on-going process. Contacts in New Zealand have provided the most relevant information for Susitna. Table 3.1 summarizes the available basin and reservoir/lake characteristics for major study sites.

Lakes Tekapo, Pukaki and Ohau lie in adjacent mountain valleys at slightly different altitudes. Each basin is a long, narrow glacial trough exposed to strong winds, primarily from the northwest, blowing down the valleys. Thermal stratification is weakly developed and deep, and all lakes have a low chemical content of the water (specific conductance at 25°C of 5.0-7.0 umhos/cm).

In general, the lakes are clearest in autumn as precipitation in the upper basins falls as snow and inflow to the lakes is reduced. Turbidity increases in the late spring as the snow melt period begins and flow increases. Inflow to the lakes then carries a heavy silt load. The mean SECCHI disc readings for one year were: Lake Ohau - 9.36m (30.7 ft.), Lake Tekapo - 4.99m (16.37 ft.), and Lake Pukaki - 0.57m (1.87 ft.). The maximum readings were 21.74m (71.31 ft.), 7.0m (23.0 ft.), and 1.0m (3.28 ft.) respectively.

The literature reports that the differences in turbidity indicated by the SECCHI disc readings are related to silt content, rather than to algal production affecting light penetration.

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The variations in extinction depth appear to be due in part to the percent of each drainage basin covered by glaciers.

However, at this time, limitations on the data preclude making direct comparisons between the behavior of fine sediments in the proposed Watana reservoir and existing New Zealand lakes. Additional supporting data on climatic characteristics, ice regime, incoming sediment size distribution, and seasonal turbidity or extinction depth for each lake are needed to complete the analysis.

TABLE 3.1
COMPARISON OF BASIN CHARACTERISTICS

BASIN CHARACTERISTICS	WATANA	EKLUTNA	PUKAKI	NEW ZEALAND TEKAPO	OHAU
Drainage Area (mi^2)	5,180	119	545	565	463
Glacier Area (mi^2)	290	6.2	73	16.6	8.0
% of Drainage Area	5.9	5.2	13.4	2.9	1.7
Annual Inflow (ac.ft.)	5,750,263	234,300	1,557,442	989,990	917,548
RESERVOIR/LAKE CHARACTERISTICS					
Length (miles)	48	7	14	15.5	10.5
Maximum Depth (feet)	680	200	230	395	423
Mean Depth (feet)	360	-	154	226	243
Maximum Width (miles)	5	0.7	-	-	-
Mean Width (miles)	1.5	0.6	5.0	3.7	3.2
Surface Area (acres)	37,800	3,420	24,460	21,500	13,340
Elevation of Water Surface (feet)	2,185	871	1,624	2,322	1,696
Capacity, Total (ac. ft.)	9,500,000	414,000	3,780,400	4,866,180	3,260,340
Average	8,330,000	-	-	-	-
Live	4,210,000	213,271	-	-	-
Average	3,040,000	-	-	-	-
Maximum Drawdown (feet)	140	60	-	-	-
Live Storage/Total Storage	0.44	0.52	-	-	-
Total Storage/Surface Area	251	121	155	226	244
Length/Average Depth	704	-	480	362	228
Drawdown/Depth	0.21	0.30	-	-	-
Length/Average Width	32	11.7	2.8	4.2	3.3
Mean Water Residence Time	635	646	418	847	612

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4. SEDIMENTATION PROCESS

4.1 General

Sediment inflow to the Watana reservoir is derived mainly from the glaciers - located in the upper portions of the drainage basin. The sediment size generally varies from less than 2 microns (0.002 mm) to 1 mm. As the river flows into the reservoir, the coarse fraction of sediment will settle out in the upper reaches and form a delta deposit. The finer particles will continue to flow into the reservoir where some will settle. Some of the fine particles will not settle, others will be reintrained and ultimately will be discharged from the reservoir through the powerhouse or over the spillway.

Under quiescent conditions, as the water flows through the reservoir, shear stress will be generated around the sides and along the bottom and density strata boundaries. These will generate some turbulence within the reservoir which will keep some of the smaller particles in suspension.

Under actual conditions, a large reservoir such as Watana does not experience these quiescent conditions. Continuous mixing processes are generated by climatic influences on the lake's surface and by inflowig and outflowing currents. These processes create a substantial amount of additional turbulence within the reservoir which would tend to keep the smaller fraction of the sediment in suspension.

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The following sections describe the above-mentioned processes in more detail. Much of the information has been obtained from the work done by Imberger and Patterson (1981).

2-32-19

4.2 Sediment Settling Characteristics

4.2.1 Settling Velocities for Spherical Particles

The behavior and rate of a particle settling in a fluid is not only dependent on the fluid flow, but also on the characteristics of the sediment particles. Fluid flow governs whether the sediment particle will be entrained, transported, or eventually deposited. In time and space, the eventual deposition of very fine particles is also dependent on the physical characteristics of the sediment. Size of the sediment particle is the most important property. However, the specific weight and shape of the particle along with the electrochemical characteristics of the fluid medium and concentration of sediment in the fluid, directly affect the sediment fall velocity.

The classical relationship that defines the physics of a sphere falling within a quiescent fluid medium is Stokes Law.

$$w = \frac{gd^2}{18}\left(\frac{\delta_s - \delta}{\mu}\right)$$

w = settling velocity
g = acc. of gravity
d = particle diameter
μ = kinematic viscosity
δ_s = sp. wt. of sediment
δ = sp. wt. of liquid

The above equation assumes the drag coefficient on the particles is constant and is therefore only valid for particle Reynolds numbers of less than 0.1.

Table 4.1 lists the settling velocities calculated for particle sizes ranging from 0.5 micron to 1 mm. Values for the .1 mm to 1 mm range (100 to 1000 microns) were obtained from curves for spherical particles given by W.N. Graf (1971). All the above values have been

2-32-20

TABLE 4.1

PARTICLE SETTLING RATES

Particle Diameter		Settling Velocity of Spherical Particles (S.G = 2.5, T = 40°F)	Particle Reynolds No. (R) of Spherical Particles	Assumed Settling Velocity of Glacial Particles
mm	microns	fps		fps
1		3.1×10^{-1}	61	2.7×10^{-1}
0.5		1.5×10^{-1}	14	1.3×10^{-1}
0.2		4.9×10^{-2}	2	4.3×10^{-2}
0.1	100	1.6×10^{-2}	0.3	1.4×10^{-2}
	50	4.4×10^{-3}	<.1	3.8×10^{-3}
	20	6.9×10^{-4}	"	6.0×10^{-4}
	10	1.7×10^{-4}	"	1.5×10^{-4}
	5	4.3×10^{-5}	"	3.7×10^{-5}
	2	6.9×10^{-6}	"	6.0×10^{-6}
	1	1.7×10^{-6}	"	1.5×10^{-6}
	.5	4.3×10^{-7}	"	3.7×10^{-7}

Note: (1) Values for R > .1 based on curves in Reference (7) by W.H. Graf (1971).

(2) Values for R < .1 based on Stokes equation

(3) Settling velocities of glacial sediment particles are based on 1/1.15 x velocity of spherical particles.

12-32-21

calculated for a temperature of 40°F and assumed particle specific gravity of 2.5.(1)

Figure 4.1 shows the depth of settling with time in the upper active layer for 2, 5, and 10 micron size particles using the settling velocities listed in Table 4.1.

The above analytic technique is for an ideal situation that would reveal the maximum settling velocities that could be expected. As previously discussed, even under quiescent conditions, the rate of settlement would be less due to the influence of other physical properties on the particle fall velocity.

4.2.2 Effect of Particle Shape on Settling Velocity

Sediment grains are rarely spherical in shape and vary from a rod-shaped particle to a disc-shaped particle. Glacial sediments tend towards a platy-type shape, but the shape is dependent on the parent mineral and process of decomposition.

Preliminary results from shape analysis of Susitna River sediments show that finer sediments tend towards a platy-type shape due to the relatively high percentage of mica and feldspar.

A study conducted by McNown, et al, (1951), determined the settling velocities for various machine-shaped particles and related the resistance factor 'K' to the shape factor 'SF', as shown on Figure 4.2. These tests were run for Reynolds numbers less than 0.1, which are representative of particles less than sand size. The curves represent theoretical results for ellipsoids (McNown & Malaika, 1950). The numbers beside each data point give the shape factor (b/c), and the shapes used are indicated in the Figure.

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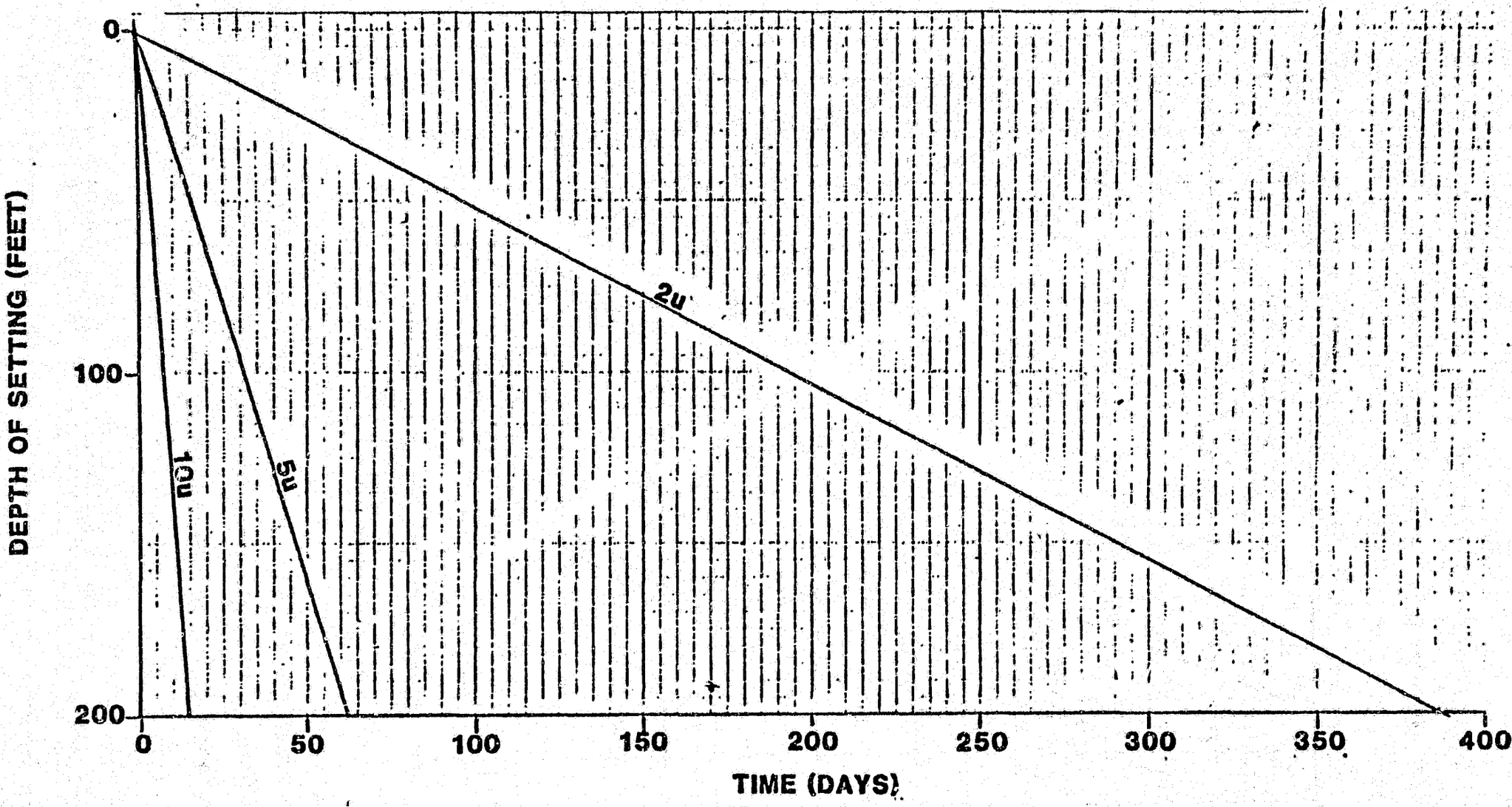
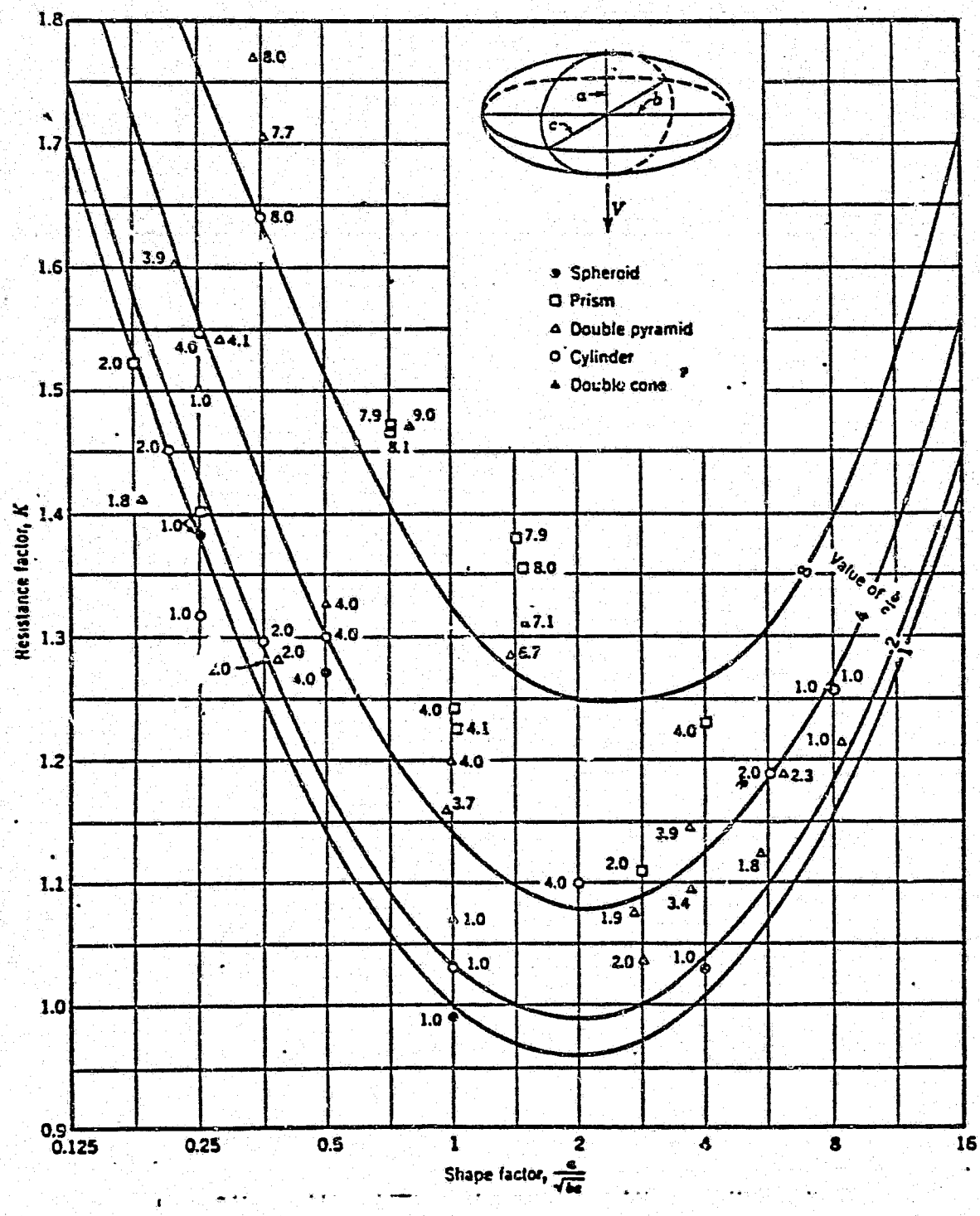
[1]Recent petrographic lab data indicates that Susitna River Sediment may have a higher mean specific gravity.



DEPTH OF PARTICLE SETTLING OVER TIME UNDER QUIESCENT CONDITIONS

FIGURE 4.1

2-22-23



COMPARISON OF THEORETICAL VALUES OF K FOR ELLIPSOIDS AND OBSERVED VALUES FOR ELLIPSOIDS AND SEVERAL OTHER SHAPES FOR REYNOLDS NUMBERS LESS THAN 0.1 (McNOWN,et al., 1951)

VANONI, V.A. (1975) SEDIMENTATION ENGINEERING

PERATROVICH, NOTTINGHAM & DRAGE, INC.
ENGINEERING CONSULTANTS

FIGURE 4.2

2-32-24

There is little difference between the theoretical values for perfect ellipsoids and the observed values for ellipsoids and other shaped particles. The values of 'K' based on the two ratios, $a/\sqrt{bc}$ and b/c are within 10 percent of the theoretical value for ellipsoids, thus indicating that the axis ratios represent the principal hydrodynamic features of the particle shape. These curves can then be used to estimate settling velocities of nonuniform shaped particles occurring in nature. The value for 'K' is equal to the ratio of the fall velocity of a sphere with the same volume and weight as the particle to the fall velocity of the particle. For example, comparing a 20-micron sphere with an ellipsoid particle that has the same specific gravity, volume, and a shape factor of b/c = 4 would produce a resistance factor of 1.15 for the ellipsoid. This means that an ellipsoid with the ratio of dimensions presented above would have a fall velocity of 15 percent less than an equivalent spheroid.

In the particle size range being investigated here, there are few particles that approach a spherical shape. As yet, no information is available on the actual particle shapes. For purposes of this study, therefore, it has been assumed that a resistance factor of 1.15 applies. Table 4.1 lists the corresponding settling velocities for these assumed glacial sediment particles.

4.2.3 Effect of Sediment Concentration on Settlement Velocity

The previous discussion addressed a single particle settling in a clear infinite fluid. Influence of other particles falling within the water column could retard or accelerate the settling rate of a single particle. If the particle was one of an isolated group of similar particles, the settling rate of the particle group and hence, the single particle would tend to increase. This situation approaches that of flocculation. However, in the natural system that is continuously being supplied by sediment, it is likely that a variable spectra of sediment sizes would be found in the water column. When this occurs, the interference between neighboring particles will tend to reduce their fall velocity, which is often referred to as hindered settling.

2-32-25

McNown and Lin (1952) studied theoretically and experimentally this phenomena, generating a relationship between the ratio of clear water settling velocity (W_o) and the particle velocity in a fluid with a given sediment concentration (W_c). The curves shown in Figure 4.2 are for an approximate theory based on the Oseen modification of Stoke's theory for the motion of a sphere in a viscous liquid at a low velocity. The curves apply for Reynolds numbers less than 2, which is representative of most of the particle size range being considered for this project. In referencing Figure 4.3, the influence of sediment concentration on the fall velocity can be significant when the sediment concentration is around 0.1 percent or 1000 mg/l. Susitna River suspended sediment concentrations measured at Gold Creek generally fall between 500 mg/l and 2000 mg/l when the discharge is greater than 20,000 cfs. Concentrations within the reservoir, however, are expected to be significantly lower.

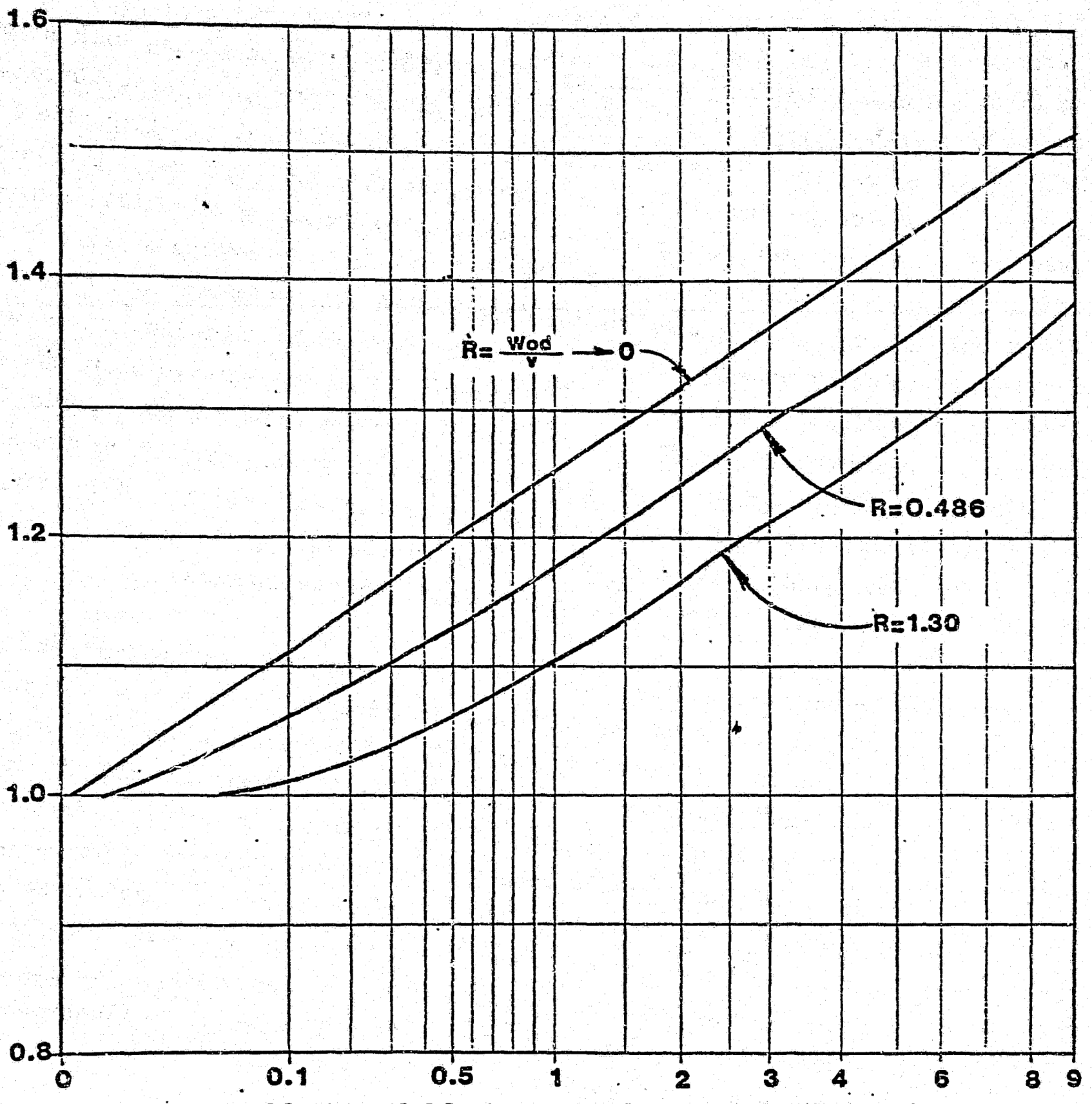
As an example, if the inflow to the reservoir has a sediment concentration of 1000 ppm, it would be expected that the settling rate would be retarded by about 10 percent. The solid lines on Figure 4.3 are representative for different particle Reynolds number. For particle sizes of 50 microns or less, the Reynolds number is less than 0.1, therefore, the upper curve should be used for the Susitna Project.

As the sediment concentrations within the lake generally will be significantly lower than 1000 mg/l, the impact on settling velocities will therefore be much less than 10 percent. For purposes of these studies, therefore, the effect of sediment concentration on settling velocity has been neglected.

4.2.4 Effects of Flocculation on Settling Rates

If the mineralogy of the particles and the water chemistry are compatible, electrochemical forces will tend to hold particles together once they come in contact. Contact of particles and the potential subsequent formation of an agglomeration, or floc, can be

2-32-26



EFFECT OF CONCENTRATION ON FALL VELOCITY OF UNIFORM QUARTZ SPHERES (McNOWN AND LIN, 1952)

VANONI, V.A. (1975). SEDIMENTATION ENGINEERING

PERATROVICH, NOTTINGHAM & DRAGE, INC.
ENGINEERING CONSULTANTS

FIG. 4.3

2-32-27

induced by internal mixing of the fluid or by particles with higher fall velocities overtaking and capturing slower particles. Once two or more particles combine, the floc will settle at a higher rate than any of the individual particles of the floc falling alone. Low levels of turbulent mixing will tend to aid the formation of the floc; higher levels will break the floc apart. There is therefore a limit to the floc size depending on the level of turbulence within the system and electromagnetic forces. When the relatively turbulent river water initially enters the relatively quiescent reservoir water, the sediment particles will be dispersed in the water column. During this initial period, the greatest opportunity for heavier particles to encounter and adhere a smaller particle will occur. With time, the particles will tend to stratify in similar particle sized bands and therefore decrease the number of particle encounters.

To date, no studies have been done on the flocculating characteristics of the sediment in the Susitna River. However, metal shadowed micrographs of sediment samples from the Susitna River near Chase sho a significant amount of agglomeration. Petrographic analysis revealed that these were composed of denser materials (pyrite, iron oxides, illenite) agglomerated onto lighter minerals (quartz, feldspar). More thorough investigation of the processes of agglomeration and flocculation would be needed to assess the impact of these processes on sediment behavior, particularly settling rates. For purposes of these studies, the effect of flocculation or agglomeration have therefore been neglected.

4.3 Quiescent Settling in the Reservoir Basin

The approach used for estimating quiescent settling involved application of a reservoir sedimentation computer model. The model, DEPOSITS, has been developed by A. Ward (1979) for the design of sedimentation ponds. It describes the sediment transport and deposition process in a reservoir as a function of the basin geometry, inflow hydrograph, the inflow sediment graph, the sediment characteristics, the outlet structure the hydraulic behavior of flow within the basin. The model determines

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basin trap efficiency, loss in storage due to sediment accummulation and effluent suspended sediment concentrations. The model has been verified with data from several different ponds and reservoirs located throughout the nation, but not with a basin that has significant glacial flow and sediment contribution.

In the model, flow within the basin is idealized by plug flow concepts. Plug flow assumes no mixing between plugs and routes the flow on a first in, first out basis with each plug representing an equal time increment. Settling of the sediment particles is described by Stoke's Law of Settling. The reservoir bed is considered a perfect absorber of sediment and resuspension or saltation of the particles is disregarded. The model accounts for the variation in sediment concentration with depth by subdividing each plug into four layers. Selective withdrawal, at the basin outlet, from these layers is provided for in the model.

The basic inputs to the model include:

1) Inflow hydrography
2) Viscosity of the flow
3) Stage-area curve for the basin
4) Stage-discharge curve for the basin
5) Stage-discharge distribution curve
6) Degree of dead storage or short-circulating
7) Sediment inflow graph or load
8) Particle size distribution and specific gravity of the suspended sediment

For purposes of these studies, the model has been modified to accept specified discharge values rather than a stage discharge curve.

Because it ignores dispersive mixing within the reservoir, the model will tend to underestimate the minimum discharge concentrations and overestimate the maximum outflow concentrations. This must be taken into account when interpreting the results of the model runs.

A second approach has been used to check on the results of the model runs. It is described by H.T. Rouse (1948) and is based on work done by Camp (1943). This approach is briefly outlined below.

The Watana reservoir is a relatively long (48 miles) and narrow (1 1/2 miles basin). For purposes of sediment deposition calculations, it can therefore by treated as a channel. Water flows into the upstream end, passes through the channel-shaped basin, and flows out at the downstream end. Storage changes take place which result in differences in the inflow and outflow rates. As the sediment particles pass through the reservoir, they gradually settle out. The velocity of flow through the basin generates shear stress along the boundaries, and hence, turbulence within the reservoir. This turbulence tends to reduce the rate of settling, particularly of the small particles.

Camp (1943) evaluated the turbulent transport function for two-dimensional flow. He assumed the water velocity is the same at every point in the channel and that the mixing coefficient is also the same at all points. The functional relationship he developed is as follows:

$$\frac{(qs)e}{(qs)i} = \frac{w}{t/p}, \frac{wL}{Vy}$$

in which

(qs)e = quantity of sediment of given particle size in effluent

(qs)i = quantity of sediment of given particle size in influent

w = fall velocity of the given particle size

t/p = shear velocity $\frac{Vn \quad g}{1.49y^{1/6}}$

y = basin depth

n = Manning's roughness coefficient

L = basin length

V = mean velocity of flow in basin

2-32-30

This function has been evaluated analytically and verified experimentally. It is shown on Figure 4.4.

4.4 Reservoir Mixing Process

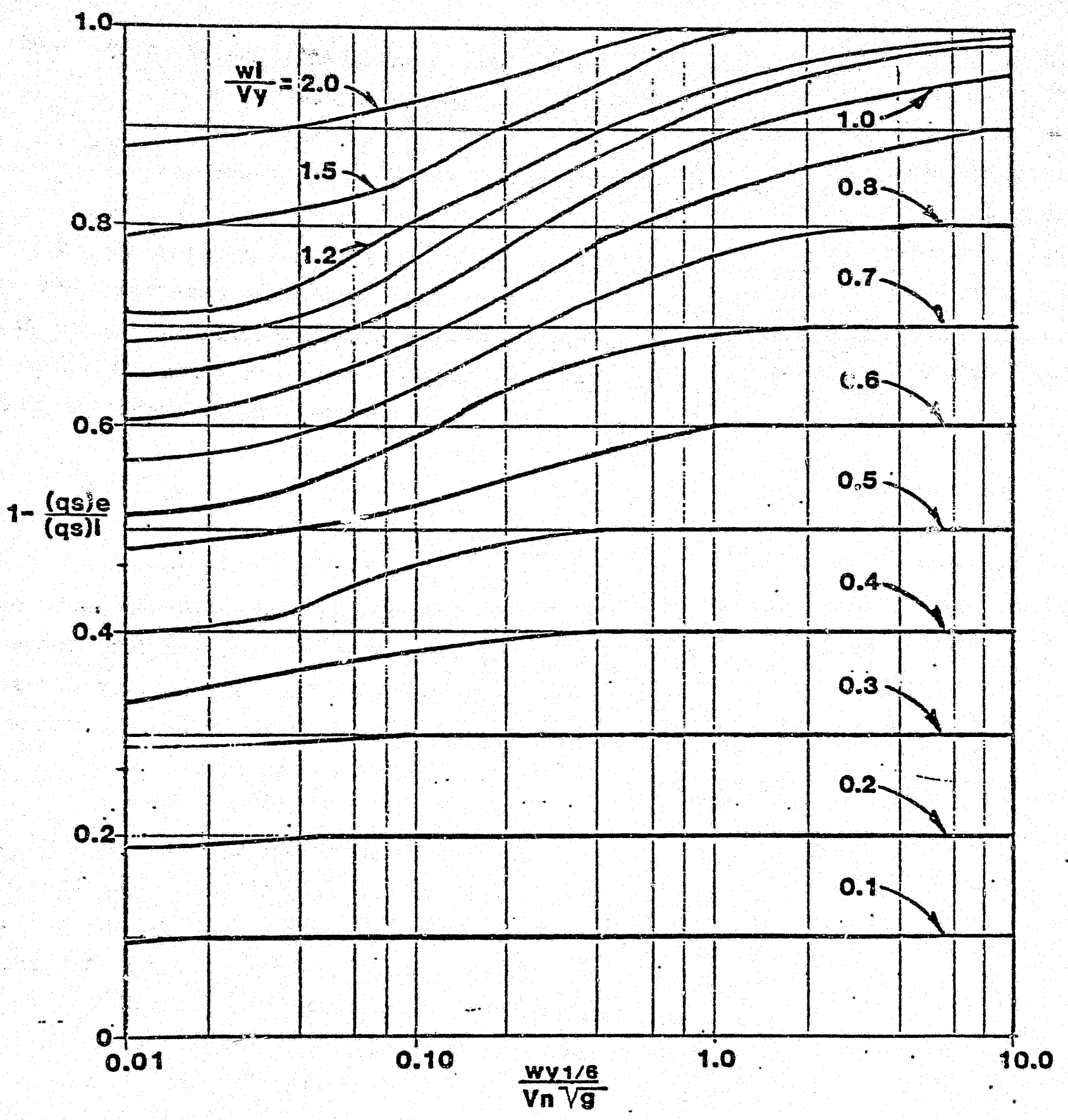
As outlined by Imberger and Patterson in Fisher et al (1979), the major mixing processes occurring in the Watana reservoir are meterologic conditions and the inflowing and outflowing water. These processes al tend to generate turbulent eddies within the reservoir which continuall stir the sediment in the water. The basic processes are discusse below.

4.4.1 The Annual Cycle

The annual thermal regime of the reservoir is currently being studie by Acres (1982). Based on preliminary results from these studies, a well as earlier thermal modeling also conducted by Acres (1982), t reservoir's thermal regime appears to be relatively stable as compar to more moderate climate reservoirs and lakes.

During the winter months (November through April), most of the wat in the reservoir would be at 4°C (40°F). In the upper layer temperatures would drop to 0°C (32°F). During the spring and sum warming period (May through July), surface temperatures wo gradually increase to approximately 9 to 10°C (48-50°F). reservoir would be reasonably well stratified with a thermocl located up to 50 meters (165 feet) below the surface. Wa temperatures below depths of approximately 100 meters (328 feet) wo remain at 4°C. During the cooling periods (August through Octobe the surface water would cool down. Overturning would take place the upper 100 meters as the surface temperatures reach 4°C. Dur this period, the upstream 10-mile reach of the reservoir which depths less than 100 meters would probably be subjected to comp overturning.

2-32-31



SEDIMENT-REMOVAL FUNCTION FOR SETTLING BASINS

ROUSE, H. (ed.), 1950, ENGINEERING HYDRAULICS

PERATROVICH, NOTTINGHAM & DRAGE, INC.
ENGINEERING CONSULTANTS

FIG 4.4

2-32-32

will tend to flow into the near surface layers of the reservoir which are the same temperature. During the spring warming period, from May to June, the river water would warm at a quicker rate than the reservoir surface, and, therefore, continue to flow into the upper layers of the reservoir. During the July to September period, river water would start to cool more rapidly than the reservoir water. Flow into the reservoir would gradually tend to enter at lower layers; and towards September, the flow would be entering the reservoir in the vicinity of the thermocline. As the lake water cools, the river inflow would gradually move back to the surface layers.

Based on the above discussion, it is evident that the sediment entering the reservoir will flow in near the surface most of the year. The exception is during the late summer and fall months when it would tend to flow into deeper layers near the thermocline. During this period, the overturning that occurs in the upper layers of the reservoir would provide some mixing of the sediment particles in these layers and somewhat reduce the amount of sediment that settles out.

R&M (1982) is currently conducting studies on Eklutna Lake, located approximately 100 air miles to the south of Watana, in support of ongoing model efforts. These studies indicate that Eklutna Lake is subject to complete overturning during the fall period. In addition, sufficient mixing forces over the length of the lake surface result in little variation in surface turbidity levels, regardless of the distance from inflowing streams. Maximum turbidity is not always recorded at the surface. Turbidity plumes below the surface have been traced in the lake.

The observed behavior at Eklutna Lake and predicted behavior of the Watana reservoir still need to be confirmed. The two are not necessarily consistent in all respects. Data for a full annual cycle at Eklutna Lake will be needed to strengthen assumptions and conclusions about the similarity in behavior of the two systems.

4.4.2 Particle Mixing in the Epilimnion

The major mixing forces active in the upper layers of the reservoir, Fisher et al, 1979, include:

- o penetrative convection
- o wind induced mixing
- o mixing induced by inflowing or outflowing water

These are discussed in more detail below.

(a) Penetrative Convection

The epilimnion would be subjected to diurnal temperature fluctuations due to daytime heating and nighttime cooling. The depth of penetration of the short wave radiation depends on the water clarity, but in the absence of wind there is always an identifiable temperature rise and stratification layers during the sunlight hours. As night falls and radiative heat losses begin to dominate the thermal exchange at the surface, the surface layer cools and convective motions mix the upper layers. Often these convective motions proceed until they reach the mature thermocline where they begin to erode the stable temperature structure.

(b) Mixing Due to Weak Winds

A wind blowing over a lake exerts a stress on the water surface that causes waves to form, break, and transfer momentum to the water. The wave motion, especially when waves are breaking, produces turbulence in the upper layer. This turbulence then interacts with the mean shear in the upper few meters to produce further turbulent kinetic energy. Often this interaction produces a secondary motion as well as a mean windward drift. Such secondary motions are called Langmuir cells and they are distinguishable to an observer by the

2-32-34

characteristic slick pattern associated with the regions of convergence. The net turbulent kinetic energy produced in these upper few meters is then exported to the lower parts of the epilimnion during turbulent diffusion or by the advective motion associated with the Langmuir circulation.

In addition to this stirring of the surface water layers, the wind will also cause the water to accelerate so that after a short time the whole epilimnion will have a mean motion with a velocity. The shear associated with this mean motion may then further contribute to the production of turbulent mixing.

(c) Reservoir Behavior Under Severe Wind Conditions

So far, the discussion of wind mixing in the epilimnion has not taken into account the motion of the water in the reservoir. The wind stress will initiate motion and move the water in the epilimnion in the direction of the wind. If the water surface is to remain nearly horizontal, as it does, then the water in the hypolimnion must counter this flow and move in the reverse direction. A shear will develop across the thermocline which will increase with time until the thermocline has tilted sufficiently to set up a hydrostatic pressure gradient which just balances the surface stress. At this stage the motion changes from a whole basin circulation to two closed gyres, one each in the epilimnion and the hypolimnion, and the shear at the interface will decrease to a very small value. All the work done by the wind is then either dissipated internally or used to deepen the epilimnion. The set up time is proportional to the seiching period of the thermocline which may be as much as two or three days, giving the wind stress ample opportunity to develop an appreciable shear across the thermocline.

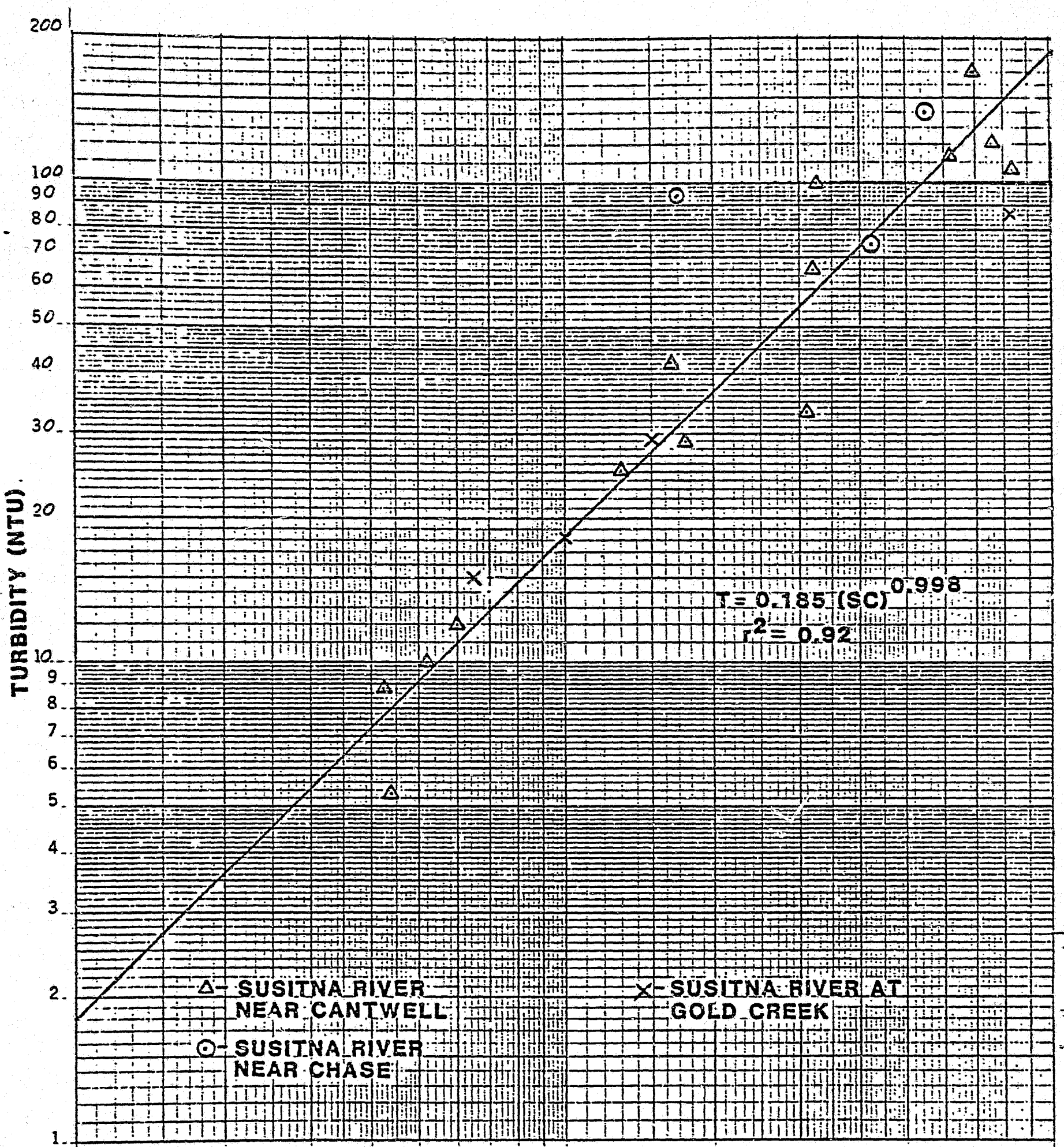
4.4.3 Vertical Mixing in the Hypolimnion

Observations in large lakes using measured distribution of natural or artificial traces indicate that vertical diffusive mixing in the hypolimnion ranges from molecular diffusion to values up to 10^{-4} to 10^{-5} in m^2/sec (10^{-6} to 10^{-7} $ft.^2$/sec.) (Fisher et al 1979, and Hamblin, 1982). In addition to this, sometimes relatively rigorous mixing occurs. The only apparent explanation for this is that although overall there is not sufficient kinetic energy to cause mixing, there are portions of the lake at any particular time where the energy density has been increased by some type of concentrating mechanisms, allowing a local breakdown in the mixing of the structure. The mixing is thus patchy and intermittent and quickly collapses under the action of buoyancy. Upon collapse, the mixed patches elongate and interleave with themselves and their surroundings, leading to steplike vertical density structures.

4.4.4 Outflow and Inflow Dynamics

Local mixing is generated in the zone where the inflow and outflow occurs. Depending on the magnitude of the discharge, the outflow may draw water from several layers within the reservoir. The velocity field induced by the withdrawal will generate additional turbulent mixing. However, for a reservoir as large and as long as Watana, this mixing influence is expected to be limited to a small local area near the power intakes.

A river entering a reservoir nearly always will be at a different temperature, and thus density, than the surface water in the reservoir. Upon entering the reservoir, it will thus push the stagnant lake water ahead of itself only until buoyancy forces, due to the density differences, have become sufficient to arrest the inflow. At that point, the inflowing water will either flow over the surface of the lake if it is warmer, or plunge and flow submerged if it is colder. There are three distinct mixing regimes associated with the inflow.



TURBIDITY vs SUSPENDED SEDIMENT CONCENTRATION

FIGURE 4.5

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First, there is mixing associated with the plunge line. Second, in the case of the underflowing situation, the bottom roughness often leads to mixing, called entrainment, at the interface between the reservoir water and the inflow. Third, whenever the density of the inflowing water equals that opposite in the reservoir, then the inflowing water will leave the bottom and intrude horizontally into the reservoir. These intrusions may also occur along the surface if the density of the inflowing water is less than that of the surface water.

4.5 Reintrainment of Sediment

Along the shoresline of the reservoir, the convective and wind mixing effects will reach the bottom sediment. Some of these sediments will be resuspended and reintrained in the water. The maximum particle size and, hence, the amount of sediment that will be reintrained will depend on the strength of the mixing currents. During high wind periods, this reintrainment can contribute substantially to turbidity in the reservoir along the shore.

4.6 Turbidity Versus Sediment Concentration

Biological activity in the lake is dependent on light penetration, which in turn, is a function of the concentration of suspended matter. A relationship is therefore required to convert predicted lake sediment concentrations to turbidity.

R&M (1982) developed a regression equation relating to turbidity in NTU's to sediment concentration in mg/l. The data was derived from measurements at the Gold Creek and Vee stations. Subsequent to these studies, additional data have become available at the Susitna River station near Chase. A new regression equation has been developed combining all the available data and is shown in Figure 4.5.

Much of the subsequent analysis in this report is based on this turbidity-sediment concentration relationship because of limitations on

other available data. It is important to incorporate all additional data from the USGS 1982 field sampling program as it becomes available. Weekly measurement of turbidity and sediment concentration in the Susitna River near Chase will provide data to verify the relationship presented here. These results can then be modified to account for the variation in behavior in lakes and rivers.

5. WATANA RESERVOIR SYSTEM

5.1 Climate

Wind-induced mixing is one of the principal mixing processes occurring in the Watana reservoir. Winds blowing over the reservoir surface produce turbulence in the upper layers and can initiate water motion in the direction of the wind.

To carry out detailed wind analysis, data from three weather stations in the Susitna Basin were reviewed. Data on wind magnitude and direction from the Watana weather station were selected for use in analysis. This station most nearly represents conditions at the reservoir and also has the most complete record.

5.2 Hydrology

Case C intermediate flow and power conditions, presented in Volume 4, Appendix A, of the Susitna Feasibility Report, has been used to provide baseline hydrology information for determining monthly reservoir operating conditions.

5.3 Sediment Regime

Data from several sources has been compiled to define the sediment regime in the Susitna River near the proposed dam site. Historical data from the USGS on sediment concentration and particle size distribution has been summarized on a monthly basis for input into the DEPOSITS model using data collected at the Gold Creek Station. Figures 5.1 and 5.2 present average monthly sediment concentration with maximum and minimum values, and average monthly particle size distribution. The crosses on both figures indicate values used in the DEPOSITS model.

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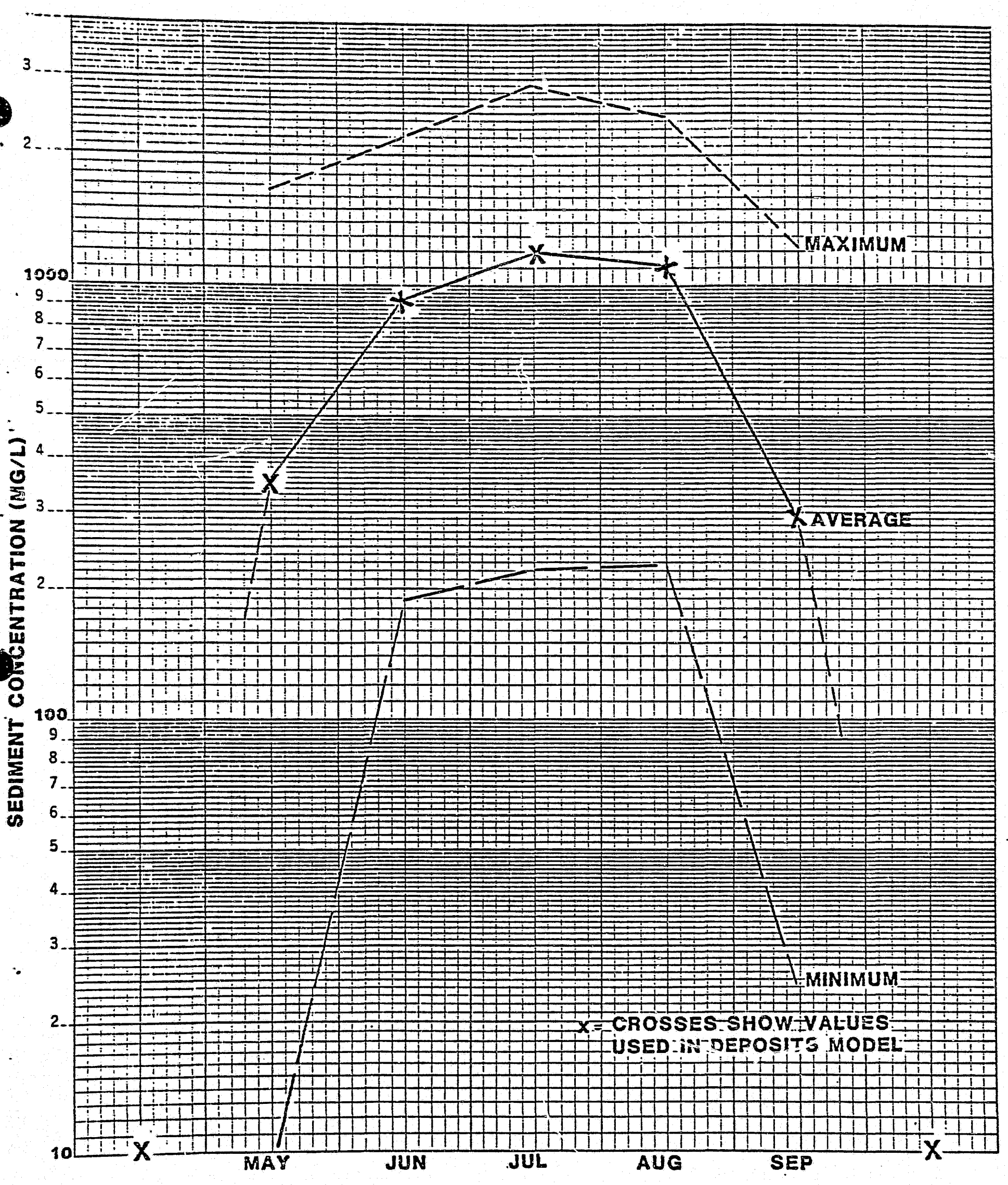

SUSITNA RIVER AT GOLD CREEK SEDIMENT CONCENTRATION-SUMMER VALUES ONLY (1952-1981)*

* DOES NOT INCLUDE 1981 USGS DATA-

FIGURE 5.1

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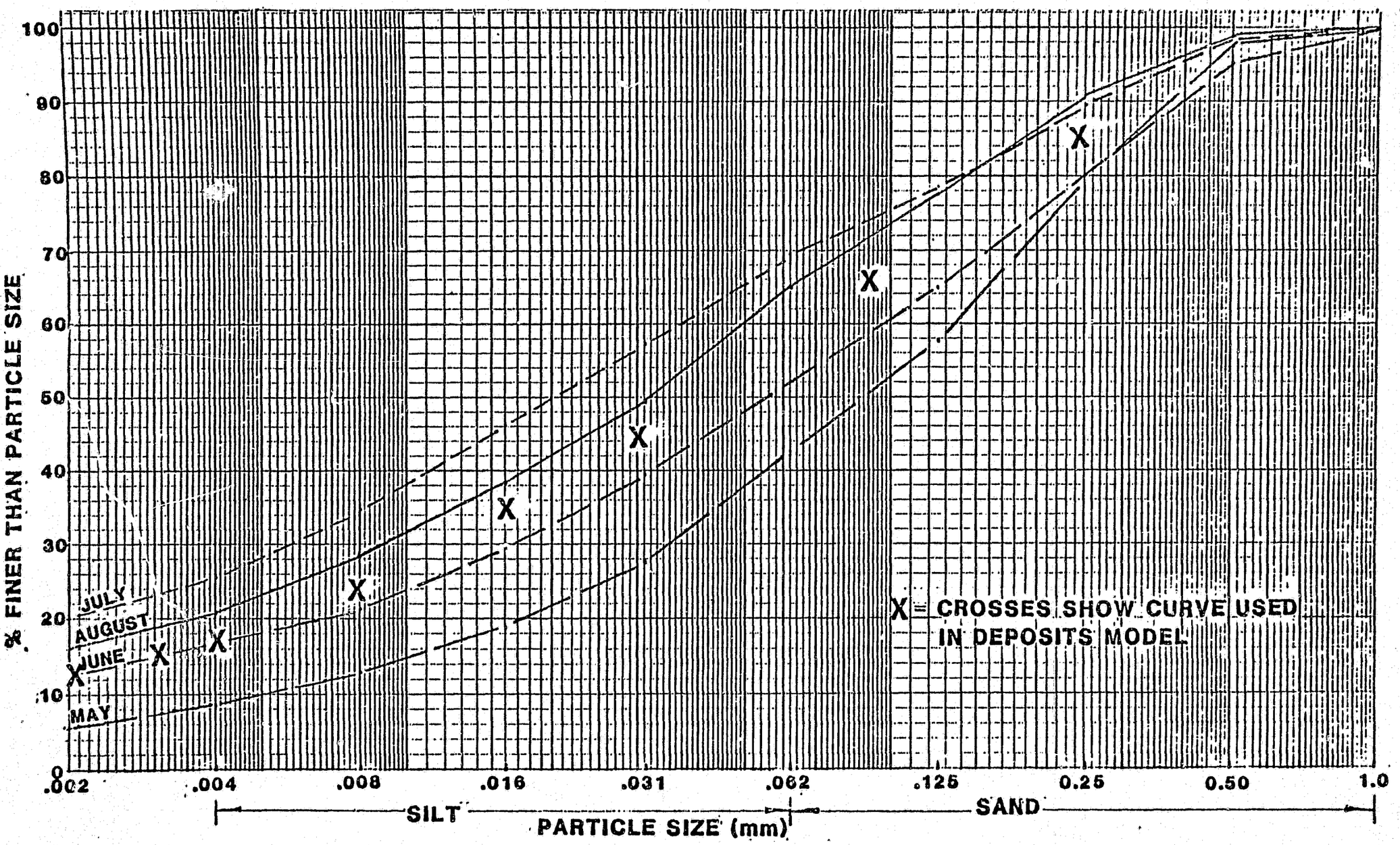

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SUSITNA RIVER AT GOLD CREEK
AVERAGE MONTHLY PARTICLE SIZE DISTRIBUTION

FIGURE 5.2

During the summer of 1982, an extensive sediment sampling program was carried out by the R&M Consultants, Inc., and the USGS, to improve understanding of the existing sediment regime. Samples collected on a weekly basis through the summer months included turbidity, sediment concentration, and bedload. Analysis of the turbidity samples is complete, however, sediment concentration and bedload sample analyses have not been completed at this time. When these results become available, they should be incorporated into the statistical analysis of turbidity versus sediment concentration to add strength to the correlation.

For this report, existing turbidity versus concentration values for the Susitna River at Cantwell (Vee), at Gold Creek, and near Chase have all been combined to revise the regression line presented in the earlier report. Figure 4.4 shows the new regression line used to convert predicted sediment concentration in the reservoir to turbidity.

5.4 Reservoir

Information on daily inflow to reservoir and projected powerhouse flows used in determining monthly water retention time, flow-through velocities, and live storage for the reservoir have been taken from the Susitna Feasibility Report, Volume 4, Appendix A. Table 5.1 shows the resulting monthly values of the above mentioned parameters used in this report for modelling and analysis.

2-32-43

TABLE 5.1
WATANA RESERVOIR CHARACTERISTICS

MONTH	INFLOW(cfs) AVG.	MAX.	MIN.	POWERHOUSE FLOW (cfs)	AVERAGE FLOW (cfs)	WATER SURFACE AT END OF MONTH (ft.) AVG.	MAX.	MIN.	STORAGE (ac.ft.) LIVE	TOTAL	VELOCITY (fps) LIVE	TOTAL	RETENTION TIME (yrs) LIVE	TOTAL	RESERVOIR LENGTH AT END OF MONTH
OCTOBER	4513.1	6458.0	2403.1	7370.5	5941.8	2177	2185.6	2122.5	3.98×10^6	9.27×10^6	.009	.004	.93	2.15	49.3 miles
NOVEMBER	2052.4	3525.0	1020.9	8723.6	5388.0	2166	2173.2	2112.6	3.67×10^6	8.97×10^6	.009	.004	.94	2.30	48.4
DECEMBER	1404.8	2258.5	709.3	11135.4	6270.1	2150	2155.9	2097.3	3.22×10^6	8.51×10^6	.011	.004	.71	1.87	47.2
JANUARY	1157.3	1779.9	619.2	9535.0	5346.1	2133	2138.2	2081.2	2.75×10^6	8.04×10^6	.011	.004	0.71	2.08	46.9 miles
FEBRUARY	978.9	1560.4	602.1	9150.3	5064.6	2119	2122.0	2068.5	2.35×10^6	7.64×10^6	.012	.004	0.64	2.08	46.6 miles
MARCH	898.3	1560.4	569.1	6865.4	3881.9	2107	2110.0	2054.5	2.01×10^6	7.30×10^6	.011	.003	0.71	2.60	46.4
APRIL	1112.6	1965.0	609.2	6176.9	3664.7	2097	2100.0	2045.3	1.73×10^6	7.02×10^6	.012	.003	0.65	2.64	46.2
MAY	10397.6	15973.1	2857.2	5767.5	8082.5	2106	2119.1	2045.2	1.99×10^6	7.28×10^6	0.023	0.006	0.34	1.24	46.4 miles
JUNE	22912.9	42841.9	13233.4	6099.7	14506.3	2139	2164.7	2075.9	2.91×10^6	8.21×10^6	0.028	0.010	0.28	0.78	47.0 miles
JULY	20778.0	28767.4	14843.5	5483.7	13130.9	2166	2190.0	2109.0	3.67×10^6	8.97×10^6	0.021	0.009	0.39	0.94	48.4 miles
AUGUST	18431.4	31435.0	7771.9	9329.3	13880.3	2181	2190.0	2130.3	4.10×10^6	9.39×10^6	0.020	0.009	0.41	0.93	49.7 miles
SEPTEMBER	10670.4	17205.5	4260.0	10158.7	10414.5	2182	2190.0	2126.8	4.13×10^6	9.41×10^6	0.015	0.007	0.55	1.25	49.8 miles
AVERAGE	7942 (cfs)	42841.9 (cfs)	569.1 (cfs)	7983 (cfs)	7741.5 (cfs)	2150 (ft.)	2190 (ft.)	2045.2 (ft.)	3.04×10^6 (ac.ft.)	8.33×10^6 (ac.ft.)	0.015 (fps)	0.006 (fps)	0.60 (yrs.)	1.74 (yrs.)	47.7 miles

44-25-2

6. ANALYSIS OF SEDIMENT BEHAVIOR

6.1 Quiescent Settling

a. DEPOSITS Model

In order to allow for an initital start-up period, the model was run for a period of four average years. The resultant steady state discharge sediment concentrations are summarized in Table 6.1. The discharge values range from approximately 0 to 60 mg/l for the upper portion of a dead storage area of 900,000 acre-ft., and range from 0 to 100 mg/l for the upper portion of a dead storage area of 5,290,000 acre-ft.

An additional run was done assuming all the volume below elevation 2,050 feet to be dead storage. In this run, the discharge was assumed to occur uniformly over the full depth of the active storage zone, i.e. above 2,050 feet. The results are similar to those using a dead storage value of 5,290,000 acre-feet. As mentioned in Section 4.3, the program neglects dispersive mixing. The range of values stated using all the different dead storage areas is therefore probably over estimated.

The amount of dead storage selected represents a range from a minimum value of approximately 10 percent of the total storage to maximum level equal to the annual average difference between total and live storage as reported in Table 5.1.

The trap efficiency predicted by these model runs ranges from 94 to 96 percent, depending on the dead storage area. The inflow and predicted outflow sediment gradation curves are shown in Figure 6.1. It can be seen that only particles with diameters of 2 microns or less travel through the reservoir under quiescent conditions.

As the model does not take into account horizontal mixing, and because it is difficult to predict the actual amount of dead storage, it is not possible to estimate the time variation of sediment concentrations at the discharge point.

2-32-45

TABLE 6.1
RESULTS OF "DEPOSITS" MODEL RUNS
SEDIMENT CONCENTRATION (mg/1)

SIMULATION CASE	DEAD STORAGE VOLUME ACRE FT.	INFLOW PEAK	INFLOW SUMMER AVERAGE	OUTFLOW MAXIMUM	OUTFLOW AVERAGE	OUTFLOW MINIMUM	TRAP EFFICIENCY (%)
Quiescent	900,000	1197	773	61	30	0	96
	5,290,000	1197	773	95	56	2	94
	Volume below 2050*	1197	773	94	54	5	94
Minimum	900,000	1197	773	211	84	2	93
Mixing	5,290,000	1197	773	213	121	2	87
	Volume below 2050*	1197	773	224	134	12	86
Maximum	900,000	1197	773	316	124	3	90
Mixing	5,290,000	1197	773	316	179	2	81
	Volume below 2050*	1197	773	345	206	18	78

Note: * Assume uniform withdrawal over depths at discharge end of reservoir. All other runs assume withdrawal is limited to upper 25% of depth at discharge end of reservoir.

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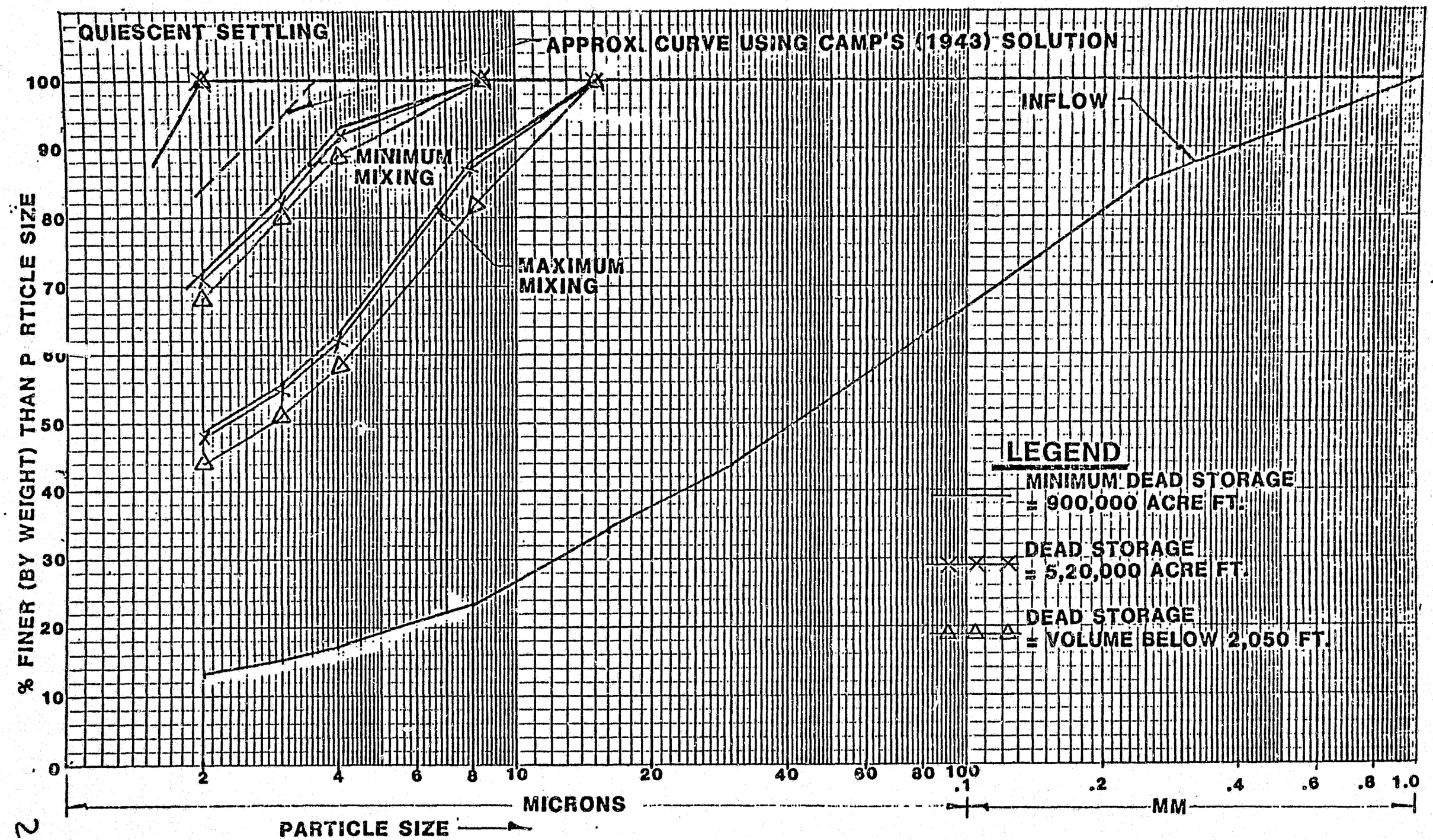


PARTICLE SIZE DISTRUBUTIONS PREDICTED BY DEPOSITS MODEL

FIGURE 6.1

2-23-4

b. Camp Curves

The relationship shown in Figure 4.4 was also used to calculate the amount of sediment that would settle out in the Watana reservoir. The monthly sediment size gradation curves shown in Figures 5.2 and the corresponding settling velocities contained in Table 4.1 were used. The integration of the total amount of sediment which settles out was carried out using particle sizes of 0.5, 0.1 mm, 50, 10, 5, and 1 micron. Monthly reservoir velocities were calculated by the following equation:

$$V = \frac{QL}{Vol}$$

Where:

V = average longitudinal velocity through the reservoir (ft./s)

Q = average monthly outflow ($ft.^3/s$)

K = length of reservoir (ft.)

Vol = average monthly reservoir volume ($ft.^3$)

Reservoir volumes were obtained from Table 5.1, and an average reservoir length of 48 miles was used. Reservoir depths were calculated by subtracting the average monthly reservoir stage from the minimum active zone elevation of 1,950 feet, which is approximately 50 feet below the power intake elevation.

The results of these analyses for the summer months are summarized in Table 6.2. They demonstrate that a large proportion of the sediment would settle out and that only particles of diameter of less than 3 to 4 microns would leave the reservoir.

These results agree reasonably well with the DEPOSITS computer model results. The following sections describe how these results should be modified to give a more realistic indication of sediment concentration by incorporating the turbulent mixing in the reservoir.

TABLE 6.2

RESULTS OF QUIESCENT SETTLING ANALYSES
FOR THE WATANA RESERVOIR

Month	Percentage of Sediment Inflow Running Through the Reservoir - %	Approximate Maximum Size of Sediment Particle Running Through The Reservoir (microns)
May	4	3
June	10	4
July	21	3
August	16	4
September	17	3

2-32-49

6.2 Induced Mixing

Two approaches were adopted in quantitatively evaluating the mixing induced by wind, thermal input, and the inflow and outflow. The first approach involved evaluating the effect of wind wave action only. For each month of the year, the total period in which wave heights exceed critical values was evaluated. The critical wave heights were those which induce an orbital current of 2×10^{-4} ft./s at depths of 25 and 50 feet respectively.

The second approach involved using the results of the Acres (1982) thermal modeling of Watana Reservoir. The program was modified to print out the shear velocities associated with wind and thermal mixing in the epilimnion and with mixing induced by inflow and outflow in the hypolimnion. The two approaches are discussed in more detail below.

6.2.1 Wind-Induced Mixing

The main objective of this analysis was to determine the impact of oscillating wind-induced currents on small suspended particles. A particle settling velocity of 2×10^{-4} ft./s was arbitrarily selected for this study. It corresponds to a particle size of approximately 12 microns (see Table 4.1).

Equations for calculating oscillating wave velocities at depth for a given wave height and period have been developed by the U.S. Army Coastal Engineering Research Center (1977). These equations were orbital velocities of 2×10^{-4} ft./s at depths of 25 and 50 feet respectively. Effective wind fetches were calculated for the reservoir for each 22 1/2 degree directional component. Using this information in conjunction with the equations developed by the U.S. Army Coastal Engineering Research Center (1981) for determining fetch limited wave height and periods, and the critical wave heights calculated previously, the corresponding critical wave speeds were calculated. These winds speeds were calculated for each directional component for each month during 1981, and for critical velocities

2-32-50

occurring at 25- and 50-foot depths respectively. Using these wind speeds and the results of the monthly wind speed direction duration analyses, the percentage of time the critical wind speed is exceeding in each month was calculated. For these analyses a water depth of 600 feet was used.

The results of the analyses for the open water period are summarized in Tables 6.3 and 6.4. The percentage durations reflect the integrated duration of winds from all directions during that month. As can be seen, significant mixing to a depth of 25 feet occurs between 35 and 55 percent of the time during the summer months except during the month of August, when the prevailing winds were from the north. A significant reduction in mixing occurs at the 50-foot level.

The wave orbital velocities above the indicated depths increase over the value of 2×10^{-4} as one gets closer to the water surface. This means that in the shallower layers, particles with settling velocities much larger than 12 microns will be held in suspension by the wave action.

The results of those analyses indicate that under certain conditions, particles as large as 12 microns could pass through the reservoir. It is important to remember that these analyses are based on 1981 recorded data and do not necessarily reflect average monthly conditions.

6.2.2 Wind and Thermal Mixing

The dynamic reservoir simulation model, DYRESM, is a one-dimensional (vertical) numerical model for the prediction of temperature and salinity in lakes and reservoirs. It is a comprehensive model, and attempts to model all the mixing mechanisms within the reservoir.

The model is provided with 6 hourly averaged input data, including air and inflowing water temperature, long and short wave radiation, and

2-32-51

TABLE 6.3

DURATION OF WAVE MIXING TO 25-FOOT DEPTHS

Month	% of Month During Which Wind Waves Generate Orbital Velocity Exceeding 2×10^{-4} ft/s
May	40
June	41
July	35
August	8
September	30
October	35
November	55

TABLE 6.4

DURATION OF WAVE MIXING TO 50-FOOT DEPTHS

Month	% of Month During Which Wind Waves Generate Orbital Velocity Exceeding 2×10^{-4} ft/s
May	4
June	2
July	1
August	0
September	1
October	0
November	12

2-32-52

evaporation. Withdrawal rates and changes in reservoir storage are also specified. The model then simulates the vertical mixing due to the meterologic forcing functions and turbulence introduced by the inflowing and outflowing water. It is vertically layered and calculates the temperature and salinity for each layer at the end of each computational period. A detailed description of the model is given by Imberger and Patterson (1981). Acres (1982) applied the model to the Watana Reservoir for the May to October 1981 period. The temperature profiles predicted by the model are shown in Figure 6.2. Modifications have been made to the model in order to calculate and print out the shear velocities induced by the mixing process. In the epilimnion, the root mean square shear velocity of the velocities, induced by convective penetration and by wind shear, and the associated depth of mixing are calculated. This shear velocity is assumed to be constant with depth over the calculated depth of mixing.

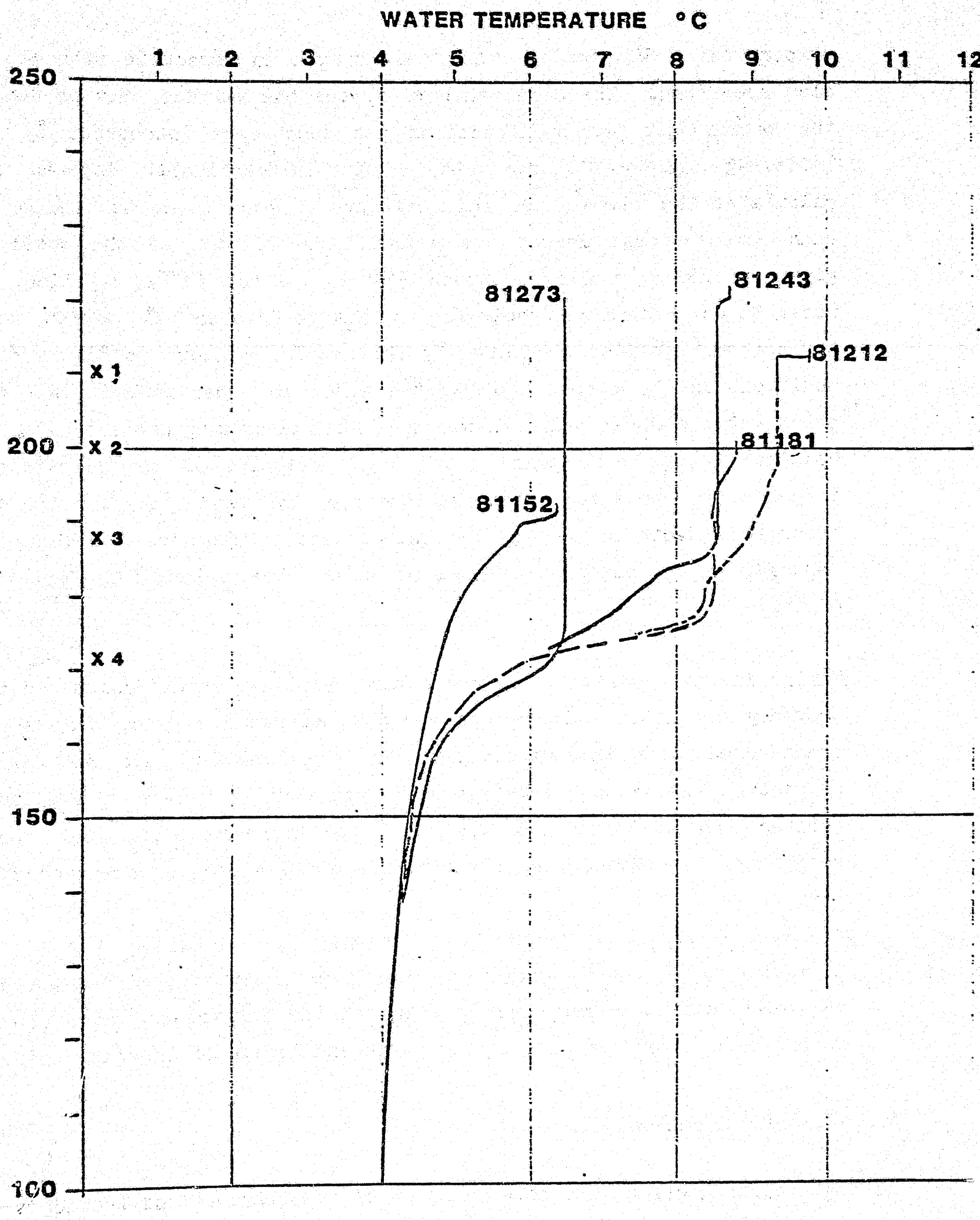
Mixing in the hypolimnion is controlled by molecular diffusion and the buoyancy frequency between the various reservoir layers, wind shear transferred from the epilimnion, and the inflowing and outflowing currents. The latter terms generally are several orders of magnitude greater than molecular diffusion. The program prints out these velocities for each of the reservoir layers for each calculation time period.

When interpreting the results, it should be remembered that the model is one-dimensional, and that all the mixing parameters are averaged within each layer over the entire width and length of the reservoir.

6.3 Sediment Reintrainment

As outlined in Section 4.5, reintrainment of particles around the edges of the reservoir will occur, particularly during windy periods. Figure 6.3 illustrates the relationship between the mixing depth and the percentage of the reservoir area in which water depths are less than the mixing depth. This curve gives some indication of how much of the lake surface would be subject to reintrainment. The 25-foot mixing depth calculated in

2-32-53



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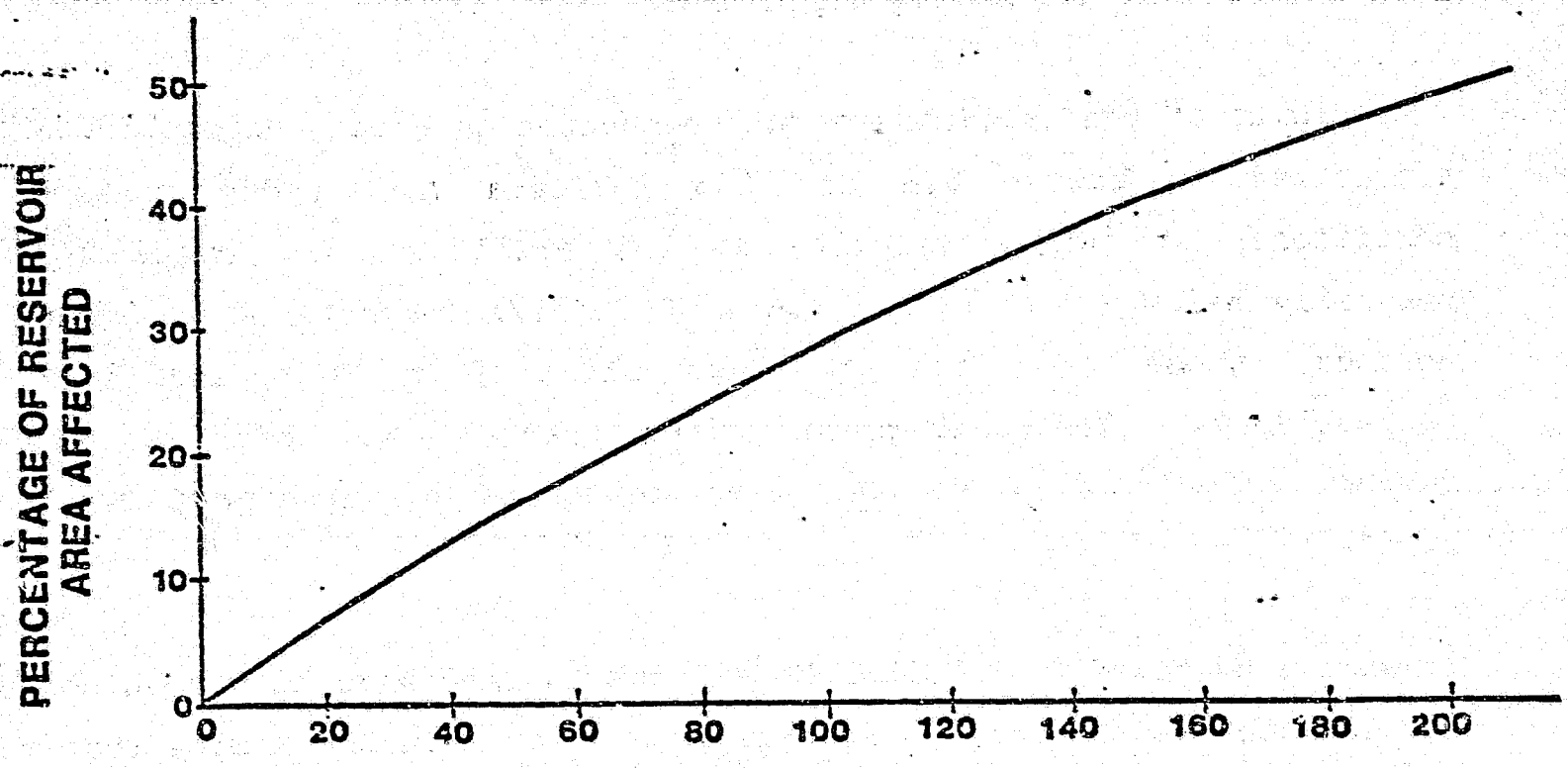
SUSITNA HEP
RESERVOIR TEMPERATURE MODEL
WATANA
FROM ACRES AMERICAN, INC.

2-32-54

FIGURE 6.2

NOTE: CURVE VALID FOR RESERVOIR WATER LEVELS BETWEEN 2050 AND 2200 FEET



RELATIONSHIP BETWEEN MIXING DEPTH AND PERCENTAGE OF RESERVOIR AREA AFFECTED BY MIXING

PERATROVICH, NOTTINGHAM & DRAGE, INC.
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FIGURE 6.3

2-32-55

Section 6.2 indicates that approximately 8 percent of the reservoir surface area would be subjected to reintrainment of particles of sizes 12 microns and less, between 35 and 55 percent of the time during the summer months (to be confirmed by reference to thermal model output).

Based on the above, it can be concluded that reintrainment would occur, but that it would not present a major problem except during severe storm events when the wave mixing depth exceeds 25 feet.

The results of the preliminary runs conducted on Watana using DYRESM model summarized in Tables 6.5 and 6.6 indicate that under maximum wind conditions, the shear velocity in the epilimnion and hypolimnion are generally below 3×10^{-3} and 1.5×10^{-4} ft./s respectively. During calm periods, these can drop to just above 3×10^{-4} and 3×10^{-5} respectively. The epilimnion values bracket the order of magnitude numbers calculated using the wave equations as described in Section 6.2.1.

It should be noted that DYRESM Model runs to date have only been conducted for the open water period. No data is available on the mixing that occurs during the ice cover months. It is, however, not expected to be very dissimilar to the values quoted above for the hypolimnion during calm periods.

The DEPOSITS Model was updated to allow for the reduction in the calculated settling velocities due to shear velocities. The effective settling velocity was assumed equal to the quiescent settling velocity minus the shear velocity. The upper quarter depth of the water plugs in the model were subjected to the epilimnion shear velocity an the lower three quarters to the hypolimnion velocity. As before, the inflow was assumed to be well mixed over the full reservoir depth and all discharge was taken from the top one-quarter depth.

The results of these model runs are shown on Table 6.1. They indicate that discharge sediment concentrations could range from below 50 mg/l during quiescent conditions to over 300 mg/l during windy periods.

TABLE 6.5

ROOT MEAN SQUARE SHEAR VELOCITY OF VELOCITIES
INDUCED BY CONVECTIVE PENETRATION
AND WIND SHEAR

Month	Average (fps)	Maximum	Minimum
June	1.6×10^{-3}	2.6×10^{-3}	4.1×10^{-4}
July	1.4×10^{-3}	3.0×10^{-3}	5.0×10^{-4}
August	1.9×10^{-3}	3.7×10^{-3}	3.3×10^{-3}

TABLE 6.6

HYPOLIMNION MIXING SCALE

Month	Average (fps)	Maximum	Minimum
June	1.0×10^{-4}	2.3×10^{-4}	5.8×10^{-5}
July	6.3×10^{-5}	1.1×10^{-4}	5.3×10^{-5}
August	1.1×10^{-4}	2.0×10^{-4}	5.3×10^{-5}

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As mentioned earlier, considerable care must be taken when interpreting these results, as longitudinal dispersion in the reservoir is not taken into account. Also, these values are only representative of conditions near the dam. Higher concentrations could occur towards the upstream reaches.

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7. PROJECTED RESERVOIR TURBIDITY

All the anaytical work described above is based on limited data and very idealistic models. In determining reservoir mixing velocities, the reservoir has been treated as a one-dimensional body of water. This is a severe limitation when one considers that the body of water is 48 miles long and averages 1 1/2 miles wide.

In this section, an attempt is made to project expected reservoir turbidities under post-project conditions. Because of the analytical limitations outlined above, these projections must be regarded as tentative order of magnitude estimates only. The values reported apply to conditions averaged over the reservoir, and no attempt is made to distinguish between conditions at the upstream and downstream ends respectively.

The first step in evaluating reservoir turbidity involves projecting likely sediment concentrations in the lake by adjusting the values predicted by the quiescent settling calculations for wind- and thermal-induced mixing. The second step involves converting these concentrations to turbidity using the curves presented in Section 4.6.

7.1 Projected Sediment Concentrations

It is assumed that sediment particles within the reservoir will tend to remain in suspension provided the mixing velocities are equal to or greater than the particle settling velocities. This approach tends to overestimate the sediment concentration in the reservoir, as some settling will still occur even when the mixing velocity equals the particle settling velocity.

7.2 Projected Turbidity Levels

Using the suspended sediment concentration versus turbidity relationships given in Figure 4.4, the projected lake turbidities would be in the range of 10-50 NTU's.

2-32-59

List of References for Sections 1, 2, 4, 6 and 7

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(2) Acres American, Inc. - New Report - Results of Temperature Modeling.

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(20) Ward, Al, Maan, T., Tapp, J., "The DEPOSITS Sedimentation Pond Design Manual," Institute for Mixing and Mineral Research, Kentucky Center for Energy Research Laboratory, University of Kentucky, Lexington, Kentucky, 1979.

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APPENDIX A

BIBLIOGRAPHY OF ADDITIONAL INFORMATION SOURCES

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PART I

NEW ZEALAND LAKE STUDIES

Brodie, J.W., and J. Irwin, 1970, "Morphology and Sedimentation in Wakatipu, New Zealand," New Zealand Journal of Marine and Freshwater Research, 4 (4): 479-96.

Study of the morphology of the lake floor has shown a system of current channels developed by movement of underflows related to flood discharges of inflowing rivers, or turbidity currents generated by slumping of previously deposited slope sediments. For Lake Wakatipu, the surface waters are reported to be clear at all times due the continuous sinking of turbid inflowing water.

Irwin, J., 1968, "Observations of Temperatures in Some Rotorua District Lakes," New Zealand Journal of Marine and Freshwater Research, 2(4): 591-605.

Irwin, J, 1971, "Exploratory Limnological Studies of Lake Manapouri, South Island, New Zealand," New Zealand Journal of Marine and Freshwater Research, 5(1): 164-77.

Lake Manapouri develops thermal stratification by mid-summer and continues into late fall. Near isothermal conditions exist in late winter. Water temperatures below 200m is between 7.8° and 8.0°C throughout the year. Surface temperature varies between 16.25°C in summer (January-March) and 8.0°C in winter (August - September). Tritium values suggest mixing has taken place to at least 400m.

Irwin, J, 1972, "Sediments of Lake Pukaki, South Island, New Zealand," New Zealand Journal of Marine and Freshwater Research, 6(4): 482-91.

Through most of the lake, excluding the delta slope, 80-90% of bottom sediments are less than 8 microns. At great depths there is little variation in spring and summer core samples.

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No information is given in the report on incoming suspended sediment size distribution or climatic conditions for the lake. However, the lake is reported to be turbid throughout the year with average depth of disc disappearances of 0.5 meters.

Irwin, J., 1974, "Water Clarity Records From Twenty-Two New Zealand Lakes," New Zealand Journal of Marine and Freshwater Research, 8(1): 223-7.

Four lake types were studied:

1) associated with glacial activity
2) associated with volcanic activity
3) formed by wind
4) formed by landslide

Water clarity values are greatest in lakes of glacial origin, as these are generally the largest and deepest. However, values are affected by glacial silt. Smaller and shallower lakes formed by wind and volcanic activity have lower water clarity values.

Irwin, J., 1978, "Bottom Sediments of Lake Tekapo Compared With Adjacent Lakes Pukaki and Ohau, South Island, New Zealand," New Zealand Journal of Marine and Freshwater Research, 12(3): 245-250.

After travelling 1.3 km into the lake, 25 % of bottom sediments are less than 4 microns in size. However, water clarity values are low for this deep, glacially fed lake. Average depth of disappearance of the secchi disc was 4.9m in May 1971 and 1.6m in April 1974.

Irwin, J., 1978, "Seasonal Water Temperatures of Lakes Rotoiti and Rotoroa: South Island, New Zealand," New Zealand Oceanographic Institute Records, 4(2): 9-15.

Irwin, J., and R.A. Heath, 1972, "Winter Temperature Structure in Lake Atiamuri and Ohakuri, New Zealand," New Zealand Journal of Marine and Freshwater Research, 6(4): 492-496.

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Irwin, J., and V. Hilary Jolly, 1970, "Seasonal and Areal Temperature Variation in Lake Wakatipu (Note)," New Zealand Journal of Marine and Freshwater Research, 4(2): 210-6

Irwin, J., and R.A. Pickrill, in press, "Water Temperature and Turbidity in Glacial-Fed Lake Tekapo," New Zealand Journal of Marine and Freshwater Research

Surveys of lake temperature and turbidity suggest a seasonal cycle of lake-river interactions. Waters are clearest in early spring. Inflowing water either interflows or underflows down-slope to the deepest basin. Coriolis force deflects inflowing water to the east. Lake water stratifies as summer progresses. Significant diurnal fluctuations result from water travelling through wide braided delta channel. Turbid water, at 5 times the lake concentration, enters the lake as interflow. Winter is associated with near isothermal lake water at 8°C but the lake remains turbid. Cold inflowing water (2-3°C) underflows to deepest basin.

Jolly, V.H., 1975, "Thermal conditions," New Zealand Lakes, V.H. Jolly and J.M.A. Brown, eds., Auckland University Press/Oxford University Press, p. 90-105.

Important thermal regime characteristics for the New Zealand lakes investigated show:

1) The coldest temperatures occur from the end of June to mid-August and full circulation for stratified lakes when holomictic would be at least three months.

2) Warmest temperatures are found from mid-December to mid-March, but usually in January or February.

3) Thermoclines, particularily in large deep lakes, form late in the warming period because of strong winds and develop very deep epilimnia.

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4) Many relatively deep lakes do not permanently stratify, because of the turbulent waves created by winds blowing over long fetches.

5) The annual temperature range is not as great as that observed in most lakes in similar latitudes due to mild oceanic climate.

Jowett, I.G., and D.M. Hicks, 1981, "Surface Suspended and Bedload Sediment - Clutha River System," Journal of Hydrology, 20(2): 121-130.

Pickrill, R.A., 1980, "Beach and Nearshore Morphology and Sedimentation in Fiordland, New Zealand: A Comparison Between Fiords and Glacial Lakes," New Zealand Journal of Geology and Geophysics, 23: 469-480.

Pickrill, R.A., and J. Irwin, in press, "Sedimentation in Deep Glacier-Fed Lake, Lake Tekapo, New Zealand," Sedimentology

Major controlling processes of sedimentation in Lake Tekapo:

1) Single dominant inflow at head of lake has resulted in delta progradation.

2) Underflows appear to be predominant inflow mechanism during spring freshets and floods.

3) Small changes in bed morphology can produce large changes in sedimentation rates over short distances. Morphology controls the direction and distance travelled by underflows.

4) Across lake variaton in sedimentation rates are controlled by Coriolis force deflecting inflowing water.

5) Seasonal cycle of sed. input controls temporal variations in sedimentation rate and texture.

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6) Lake level fluctuations redistribute coarse sediment downslope.

7) Rotational slumping redeposits delta sediments down lake.

Pickrill, R.A., J. Irwin, and B.S. Shakespeare, 1981, "Circulation and Sedimentation in a Tidal-Influenced Fjord Lake: Lake McKerrow, New Zealand," Estuarine, Coastal and Shelf Science, 12: 23-37.

Stout, V.M., 1978, "Effects of Different Silt Loads and of Hydro-Electric Developments on Four Large Lakes," Verh International Verein Limnol, 20: 1182-1185.

Brief review of key basin and lake characteristics for Lakes Tekapo, Pukaki, Ohau, and Benmore including physical features, mean and maximum SECCHI disc readings, and kinds of phytoplankton present.

Stout, V.M., 1981, "Some Year to Year Fluctuations in a Natural and in an Artificial Lake, South Island, New Zealand," Verh International Verein Limnol, 21: 699-702.

Both chlorophyll a content and zooplankton populations have retained similar seasonal patterns. However, turbidity of the water in both lakes during spring and summer months has shown significant changes from year to year due to climatic variations.

Thompson, S.M., 1978, "Clutha Power Development - Siltation of Hydro-Electric Lakes, August, 1976," Environmental Impact Report on Design and Construction Proposals, New Zealand Ministry of Works and Development.

Report describes siltation problems in the Clutha River, processes causing the problems and possible remedies.

Appendix 2 describes the method used to determine the grain size distribution in the total load of the river from the distribution of sediment grain sizes on the lake bed.

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PART II

GENERAL INFORMATION

Baxter, R.M., and P. Glaude, 1980, "Environmental Effects of Dams and Impoundments in Canada: Experience and Prospects," Can. Bull. Fish Aquat. Sci., 205: 34 p.

Brylinsky, M., and K.H. Mann, 1973, "An Analysis of Factors Governing Productivity in Lakes and Reservoirs," Limnology and Oceanography, 18(1): 1-14.

Data collected from 43 lakes and 12 reservoirs from the tropics to the arctic showed that variables related to solar energy input have a greater influence on production than those related to nutrient concentration. Morphological factors have little influence on productivity per unit area.

Csanady, G.T., 1978, "Water Circulation and Dispersal Mechanisms," Abraham Lerman, ed., Lakes: Chemistry, Geology and Physics, Springer-Verlag Press, New York, Pages 21-64

Conceptual model developed to describe lake hydrodynamics including special cases for long and narrow basins with discussions on such things as effect of bottom friction and coriolis force, coastal jets, and spontaneous thermocline movements near shore.

Elder, Rex A., and Walter O. Wunderlich, 1972, "Inflow Density Currents in TVA Reservoirs," Paper 7, International Symposium on Stratified Flows, Novosibirsk.

Irwin, J., 1975, "Morphology and Classification," V.H. Jolly and J.M.A. Brown, eds., " New Zealand Lakes, Auckland University Press/Oxford University Press, Pages 25-56.

Kellerhals, R., M. Church, and L.B. Davies, 1979, "Morphological Effects of Interbasin River Diversions," Can. Jour. Civ. Eng., 6: 18-31.

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Kellerhals, R., and D. Gill, 1973, "Observed and Potential Downstream Effects of Large Storage Projects in Northern Canada," Proceedings of 11th International Congress on Large Dams, Madrid, 1973, Pages 731-753.

Kinnunen, Kari A.I., 1981, "Problems Connected with Modeling Artificial Lakes in Finland," Unpublished Report, National Board of Waters, Finland.

Kinnunen, Kari A.I., B. Nyholm, and J.S. Niemi, 1981, "Ecological Model of a Subarctic Lake," Verh. Internat. Verein. Limnol., 21: 102-108.

- Variation of EPAECO model calibrated for temperature with ice cover and effect of wind mixing on Finland Lake Paijanne.
- Max. surface temp. in early August (~18°C).
- Thermocline at 10-20m below surface-average max. depth at 30m in mid-September.
- Becomes isothermal by early-mid November. Stays isothermal until mid-May.
- Effect of wind especially important in early summer when stratif. perice starts. Without wind consideration simulated temperature stratification is too steep.

Kinnunen, Kari A.I., J.S. Niemi, T. Frisk, T. Kyla-Harakka, 1981, "Water Quality Modeling at the National Board of Waters, Finland," Unpublished Report, National Board of Waters, Helsinki, Finland.

- Evolution of the FINNECO model from the EPAECO model.
- New model includes: mixing effect of wind
  precipitation of phosphorous
  new temp. correction
  ice formation routine
  denitrification process

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- Investigation of some river water quality models.

Kjeldsen, O., 1981, "Sediment Transport Studies in Norwegian Glacial Streams, 1980," Report 4-81, Norwegian Water Resources and Electricity Board, Oslo, Norway.

Kjeldson, O., and G. Østrem, 1977, "Sediment Transport Studies in Norwegian Glacial Streams, 1975," Report 3-77, Norwegian Water Resources and Electricity Board, Oslo, Norway.

Kuenen, Ph.H., 1968, "Settling Convection and Grain-Size Analysis," Journal of Sed. Petrology, 38: 817-831.

Lambert, A., and K.J. Hsu, 1979, "Non-Annual Cycles of Varve-Like Sedimentation in Walenese, Switzerland," Sedimentology, 26: 453-461.

- multiple layers deposited in lake bed represent continuous-fed turbidity currents generated by hyperpycnal inflow during river-flood stages.

- Currents with bottom velocities up to 50 cm/sec. were detected during summertime even when the lake is thermally stratified.

Lambert, A., and S.M. Luthi, 1977, "Lake Circulation Induced by Density Currents: An Experimental Approach," Sedimentology, 24: 735-741.

Saltwater was continuously fed into a tank of freshwater to model turbidity underflows caused by flood-stage discharge.

In most cases the height of lake water dragged along by the underflow is about equal to the underflow thickness. Maximum return velocity occurs in the lower (denser) parts of a lake basin.

2-32-70

Lee, Dong-Yong, W. Lick, and S.W. Kang, 1981, "The Entrainment and Deposition of Fine-Grained Sediments in Lake Erie," J. of Great Lakes Research, 7(3) 224-233.

- Provides quantitative data on the entrainment rates. Variations depend on shear stress, water content and type of sediment (size and mineralogy). Vertical variation in thin surficial layer active in deposition - entrainment produce different entrainment rates.

- effect of benthic organism not considered.

- Main cause of entrainment is oscillating wave action.

- Report does not include settling, flocculation, and mechanical degradation in calculations of sediment transport in a lake.

Lerman, A., Devendra Lal, and Michael F. Dacey, 1974, "Stoke's Settling and Chemical Reactivity of Suspended Particles in Natural Waters," R. Gibbs, ed., Suspended Solids in Water, Plenum Press, New York, Pages 17-44.

Organization for Economic Cooperation and Development, 1979, Joint Activity on Multi-Purpose Hydraulic Projects: The Planning of the Vuotos Reservoir, National Board of Waters, Finland.

Østrem, G., T. Ziegler, S.R. Ekmkan, H.C. Olsen, J. Andersson, and B. Lunden, 1971, Studies of Sediment Transport at Norwegian Glacier Streams, Stockholm University, Department of Physical Geography, Report 12, 133 pp.

Ragotzkie, R.A., 1974, "Vertical Motions Along the North Shore of Lake Superior," Proceedings from the 17th Conference on Great Lakes Research, Pages 456-461.

Slow net upward motion has been documented in Lake Superior. Vertical motion extending from as deep as 190 meters to near surface levels with vertical velocities up to 30 meters per day have been observed during the period of thermal stratification.

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Ritchie, J.C., Frank Schiebe, and J. Roger McHenry, 1976, "Estimating Suspended Sediment Loads from Measurements of Reflected Solar Radiation," H.L. Gotterman, ed., Proceedings of the 1st Symposium on Interaction between Sediments and Freshwater, Amsterdam, 1976.

Data from temperate region lake has shown that a quantitative relationship exists between surface suspended sediments and reflected solar radiation. Most significant in the wave lengths between 700-800 mm. Concentration of surface suspended sediment can be used to estimate total suspended sediment concentration in a vertical water column.

Scott, Kevin, M., 1982, "Erosion and Sedimentation in the Kenai River, Alaska," Geological Survey Prof. Paper 1235, 34 pp.

o Sediment concentration generally lower primarily due to storage in lakes.

o Give sediment concentration for Kenai River at Soldotna and Kenai River at Cooper Landing.
- No turbidity measurements reported.
- No turbidity-sediment concentration correlation presented.

Shuter, N., K. Stortz, G. Oman, M. Sydor, 1978, "Turbidity Dispersion in Lake Superior Through Use of Landsat Data," Journal of Great Lakes Research, 4(3-4): 359-360.

Sly, P.G., 1978, "Sedimentary Processes in Lakes," Abraham Lerman, ed., Lakes: Chemistry, Geology and Physics, Springer-Verlag Press, New York, Pages 65-89.

o Review and discussion of various factors influencing sedimentary processes in lakes including, but not limited to, lake morphology, characteristics of inflowing sediment, and climatic settling.

2-32-72

Stortz, K., R. Clapper, and M. Sydor, 1976, "Turbidity Sources in Lake Superior," Journal of Great Lakes Research, 2(2): 393-401.

- Strong correlation found between average turbidity and average suspended load of red clay in turbidity plumes.

- Major source of turbidity due to shoreline erosion by wind driven waves during ice free season.

- Most of scattered light observed arises from fines less than 3μ (=25% of bank material).

- For maximum sediment concentration observed in plume = 20 mg/l
  $T_{(NTU)}$ 18.5 based on correlation
  $$S = 1.3 \times T - 4.0$$

- Sediment resuspension in winter with partial ice cover
  $= 10^6$ metric tons

- During severe storms: range = 5×10^5 metric tons of eroded material/storm.

  Suggest 50% of lake turbidity comes from these storms.

Sturm, M., 1979, "Origin and Composition of Elastic Varves," Ch. Schluchter, ed., Moraines and Varves-Origin, Genesis and Classification, A.A. Balkema, Rotterdam, Pages 281-285.

Sturm, M., _____, "Depositional and Erosional Sedimentary Features in a Turbidity Current Controlled Basin (Lake Brienz)," IXth International Congress on Sedimentology, 5(2): 385-390.

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Sundborg, Ake, 1980, "Symposium Theme No. IV: Reservoir Sedimentation," Proceedings of the International Symposium on River Sedimentation, Beijing, China, March 24-29, 1980, Pages 1325-1333.

Sundborg, Ake, 1981, "Environmental Problems of Reservoir Development with Special Regard to Conditions in Sweden," Proceedings of the International Symposium of Reservoir Ecology and Management, Quebec, June 1981, Pages 63-72.

Thomas, R.L., 1968, A Note on the Relationship of Grain Size, Clay Content, Quartz and Organic Carbon in Some Lake Erie and Lake Ontario Sediments

Wunderlich, Walter O., _____, "The Dynamics of Density-Stratified Reservoirs, Gordon E. Hall, ed., Reservoir Fisheries and Limnology, Special Publication No. 8, Pages 219-231.

Data from Tennessee Valley Authority field investigations are used to illustrate dynamic reservoir processes and their influence on water quality. Water movement into, within, and out of, the reservoir in the presence of density stratification are described.

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TASK 3 - HYDROLOGY
RESERVOIR SEDIMENTATION

JANUARY 1982

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ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

TASK 3 - HYDROLOGY

RESERVOIR SEDIMENTATION

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1 - PURPOSE AND SCOPE OF STUDY

The purpose of this report is to present the results of analyses of sedimentation within the proposed Watana and Devil Canyon Reservoirs. Analyses of the sedimentation were complicated due to the large percentage of very fine suspended sediment contributed by glaciers in the Susitna River headwaters, possibly making results from the usual analytical techniques to be in error.

The approach to analyzing the reservoir trap efficiency was to first analyze the trap efficiency of the reservoirs based on the capacity-inflow ratio. A literature search was then conducted to determine the trap efficiency of natural glacial lakes and to gather information on their sedimentation processes. Settling column studies of suspended sediment samples from the Susitna River were then conducted to gather empirical data. The information from these three information sources was then assimilated to project the reservoir sedimentation processes.

The annual sediment load entering the reservoirs was estimated using the flow duration sediment rating curve method for the nearest gaging stations and an estimated sediment yield for the area draining directly into the reservoirs. The unit weight and volume of the deposited sediments were estimated using standard techniques.

Modelling of sediment deposition within the reservoirs was considered but was not deemed appropriate or necessary at this time. The settling properties of the very fine "glacial flour" are such that it remains in suspension for long periods of time, affecting the reliability of the model. In addition, the estimated volume of sediment deposited in Watana Reservoir is less than 5% of the total volume of the reservoir. A large proportion of the sediment will be deposited in the dead storage portions of the reservoir due to the slow settling characteristics of the very fine suspended sediments.

Turbidity could not be assessed on a quantitative basis. However, pre-project conditions were assessed, and a qualitative analysis conducted of probable turbidity patterns in the reservoirs and downstream river.

2-32-80

2 - SUMMARY OF RESERVOIR SEDIMENTATION

Trap efficiency estimates based on detention - storage time indicate that 95-100 percent of sediment entering Watana Reservoir would settle, even shortly after filling of the reservoir starts. However, data from Kamloops Lake, British Columbia, a 3 million acre-ft. glacial lake confined in a narrow valley, indicates that up to one-third of the incoming sediment passes through it. Median grain size at the lower end of Kamloops Lake is about 2 microns. For the Susitna River near Cantwell, about 15 percent of the suspended sediment is finer than 2 microns. Preliminary estimates indicate that between 70-95 percent of incoming sediment would be trapped in the reservoir, with particles smaller than 2 microns possibly passing through the reservoir. As Watana Reservoir is longer, deeper, and has a longer retention time than Kamloops Lake, it is possible that even smaller particle sizes may settle in the reservoir. Under the worst case sedimentation condition of 100% trap efficiency, an estimated 472,500 ac-ft. of sediment would be deposited in Watana Reservoir in 100 years.

Devil Canyon Reservoir would have a slightly lower trap efficiency than Watana due to its smaller volume. However, most sediment will be deposited in Watana, the upstream reservoir. Assuming that both reservoirs have a 70% trap efficiency, an estimated 109,000 ac. ft. of sediment would be deposited in Devil Canyon Reservoir in 100 years.

Three interdependent but distinct sedimentation processes occur in glacial lakes. These processes consist of: (a) delta progradation into the lake; (b) sediment density surges down the steep upper slope, depositing material on the lake floor which had previously been on the delta slope; and (c) river plume dispersion, which spreads the fine-grained material throughout the lake. The sediment-laden streamflow will initially spread through the lake either as surface flow, interflow, or underflow, depending on the relative densities of the lake water and the stream water.

Turbidity downstream of the reservoir will decrease sharply during the summer months due to the sediment trapping characteristics of the reservoirs. It is likely that the turbidity of water released in the winter months will be near natural conditions, as suspended sediment in near-surface waters should rapidly settle once the reservoir ice cover forms and essentially quiescent conditions occur.

2-32-81

3 - TRAP EFFICIENCY

Only a portion of the sediment brought into a reservoir is normally trapped and retained, with the balance being transported through and carried out of the reservoir by outflow water. The ability of a reservoir to trap sediment is known as its trap efficiency, and is expressed as the percent of sediment yield (incoming sediment) which is retained in the reservoir.

3.1 - Factors Influencing Trap Efficiency

The trap efficiency of a reservoir depends on the sediment characteristics and the rate of flow through the reservoir. As streamflow enters a reservoir, the cross-sectional area is increased, resulting in a decrease in velocity with a consequent decrease in sediment-transport capacity. The coarse-grained particles are dropped immediately near the head of the back water, with the finer grains remaining in suspension until they are deposited farther into the reservoir or carried out of the reservoir in the outflow water. The percent of total sediment trapped in the reservoir depends on the fall velocity of particles and the rate at which the particles are transported through the reservoir.

The fall velocity of particles in water depends on a number of variables, including the size and shape of the particle, its chemical composition and the viscosity of the water. Electrochemical processes play an important role in determining the fall velocity of fine particles less than 10 microns in diameter, such as clays or glacial flour. In some areas, clays and colloids may aggregate into clusters which have settling properties similar to larger particles, and conversely, highly dispersed particles may stay in suspension for long periods of time and transported out of the reservoir.

Although no mineralogic analyses of suspended sediment from the Susitna River are available, there are mineralogic analyses of suspended sediment from a number of surrounding glacial rivers. Clay minerals (montmorillonite) were absent from all samples except from the Knik - Matanuska Rivers, where less than 2 percent clay minerals were detected (Everts, 1979; Tice, et. al, 1972).

The rate of flow of water through a reservoir determines the detention - storage time. The ratio of reservoir detention - storage time is influenced by the inflow volume with respect to reservoir storage capacity and the outflow rate. Watana Reservoir has a storage volume of 9,650,000 acre-feet, and Devil Canyon Reservoir a volume of 1,092,000 acre-feet. Average annual inflow at Watana and Devil Canyon Reservoirs is 5,880,000 acre-feet and 6,630,000 acre-feet, respectively. Watana Reservoir will release approximately the average annual inflow each year, so that the average annual inflow to Devil Canyon should not differ

significantly from pre-project conditions. The ratio of capacity to inflow for the two reservoirs is 1.64 for Watana and 0.16 for Devil Canyon.

The size and location of reservoir outlets also influences the trap efficiency, with bottom outlets more effective in removing the higher sediment concentrations near the bottom. Either multi-level outlets or single outlets at a depth of about 200 feet will be used. Neither type of outlet is near the reservoir bottom. Consequently, the effects of the location of the reservoir outlets will not be further considered in this study.

3.2 - Trap Efficiency Estimates

Although several factors influence trap efficiency, the detention - storage time appears to be the controlling factor in many reservoirs. Brune (1953) developed the generalized trap efficiency envelope curves shown in Figure 3.1, which relate trap efficiency to the storage capacity - inflow ratio. Using the Brune curve, the following range of trap efficiencies were estimated.

Reservoir	Capacity/Inflow	Maximum	Minimum	Median
Watana	1.64	100	95	97
Devil Canyon	0.16	96	84	92

The Brune curve was developed on detention storage time. However, the variation due to differing reservoir shape, operation, and sediment characteristics has not been determined (Gottschalk, 1964). Using the Brune curve, it would appear that about 97 percent of the sediment entering Watana Reservoir would be trapped. Devil Canyon Reservoir would trap about 92 percent of the sediment passing Watana Reservoir and any suspended sediment picked up in the intervening river reach. Consequently, it would appear that very little of the suspended sediment load entering Watana Reservoir would eventually leave Devil Canyon Reservoir. However, some concern has been expressed that the very fine glacial flour would remain in suspension and pass through the reservoir system. This may not be detrimental in the summer, but if it remained in suspension throughout the winter months, winter releases would be turbid instead of clear, as is the natural condition. Consequently, a literature review of sedimentation (Att. B) in glacial lakes was conducted to estimate the trap efficiency of glacial lakes. Settling column studies of water samples from the Susitna River were also conducted to determine the sediment deposition rate under quiescent conditions (Att. A).

Estimates of sediment trap efficiency at two lakes immediately below glaciers were on the order of 70-75% (Ziegler, 1973; ostrem, 1975). Of more relevance is the estimate of trap efficiency for Kamloops Lake by Pharo and Carmack (1979). Kamloops Lake is somewhat similar in morphometry to Devil Canyon Reservoir. It is 15 miles long by 1.6 miles wide, and has a volume of about 3 million acre-feet. Mean annual flow of the Thompson River entering the lake is about 25,000 cfs. This results in a capacity - inflow ratio of about 0.16, very similar to that of Devil Canyon. Observations of turbidity at the lake inlet and outlet (Figure 3.2) led Pharo and Carmack to estimate that nearly one-third of the incoming sediment is carried through the lake and not deposited, resulting in a trap efficiency of about 67%.

Use of the Brune curve on Kamloops Lake results in trap efficiencies ranging from 84 to 96 percent. This would see to indicate that the sedimentation processes occurring in this deep glacial lake result in a lower sedimentation rate than in those reservoirs analyzed by Brune.

For estimating the volume of sediment deposited in the reservoirs, trap efficiency estimates were in the range of 70-100 percent. A trap efficiency of 70 percent is considered the minimum efficiency, and allows an estimate for the maximum amount of sediment passing through Watana Reservoir and entering Devil Canyon Reservoir. The trap efficiency of 100 percent allows an estimate of the maximum amount of sediment deposited in Watana Resevoir. All bedload is assumed to be deposited.

3.3 - Trap Efficiency during Reservoir Filling

The trap efficiency of a reservoir is sometimes reduced during its filling period due to the reduced storage capacity. An analysis was conducted to estimate the effects at Watana Reservoir. It was assumed that reservoir filling would begin in May. The increase in reservoir storage was estimated using average monthly flows for the Susitna River at Watana.

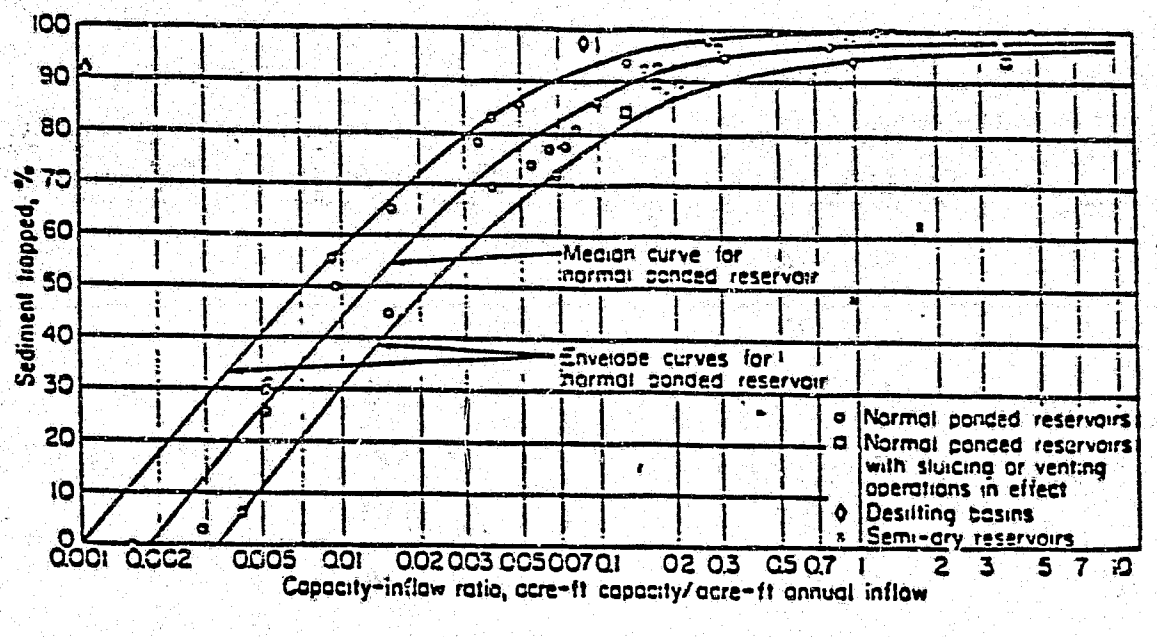
The Brune curve was used to estimate the trap efficiencies during the filling period. The results are tabulated in Table 3.1. The high flow in May and June fills the reservoir to such a level that trap efficiency rapidly reaches the 95% level. The reservoir would be about 30 miles long within 2 months after filling commences. Consequently, it would appear that sediment deposition during the filling period would be similar to that during full pool.

2-32-84

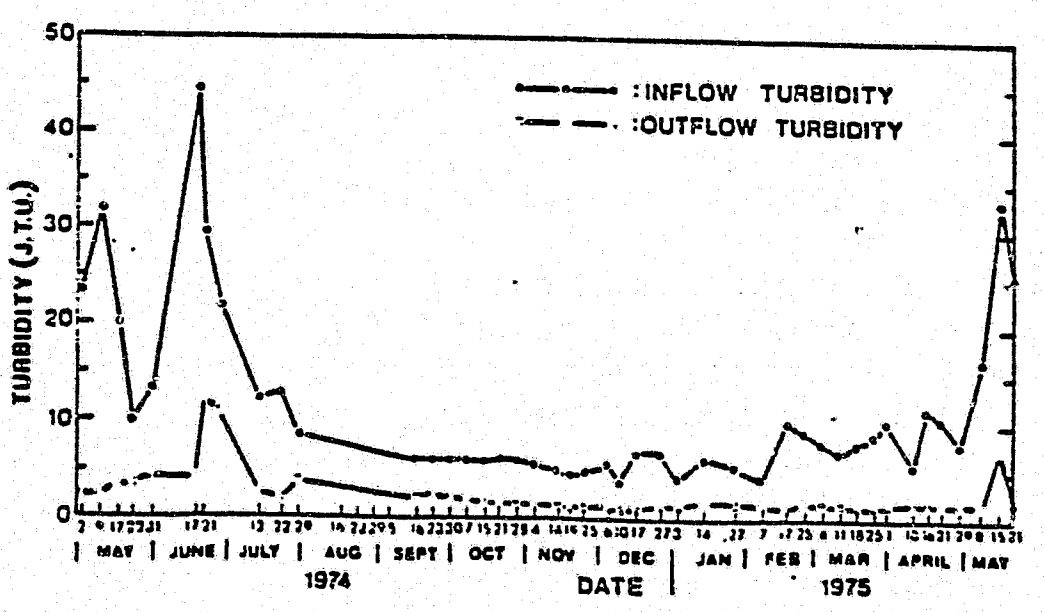
TABLE 3.1

ESTIMATED TRAP EFFICIENCIES DURING RESERVOIR FILLING

End of Month (1st Year)	Flow at Watana (cfs)	Required Flow at Gold Creek	Trap Efficiency (Brune Curve)
May	10,406	6,000	83
June	22,293	7,000	94
1-15 July	20,344	7,000	95
16-31 July	20,344	12,000	95
August	18,012	12,000	96
1-15 September	10,614	12,000	96
16-30 September	10,614	7,000	96



(Brune, 1953)



(Pharo and Carmach, 1979)

2-32-86

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3.1 - TRAP EFFICIENCY CURVES
3.2 - INFLOW & OUTFLOW TURBIDITY LEVELS
KAMLOOPS LAKE, B.C.

FIGURES 3.1, 3.2

4 - RESERVOIR SEDIMENTATION

4.1 - Sediment Load

Suspended sediment - discharge relationships were established for gaging sites on the Susitna River. The rating curves for stations near the proposed reservoirs are illustrated on Figure 4.1. Using the flow-duration - sediment-rating curve method, the average annual suspended sediment load was estimated for the following four stations.

Gaging Station	Average Annual Suspended Sediment Load (tons/year)
Susitna River at Denali	2,965,000
MacLaren River near Paxson	543,000
Susitna River near Cantwell	6,898,000
Susitna River at Gold Creek	7,731,000

The suspended sediment load entering Watana Reservoir from the Susitna River is assumed to be that at the gaging site for the Susitna River near Cantwell, or 6,898,000 tons/year. No bedload data is available for this site. However, the channel is well-armored, and little bedload movement appears possible. Bedload at Susitna River at Gold Creek is estimated to be 1.6 percent of suspended sediment load at 37,200 cfs. Bedload movement in the Tanana River, a braided glacial river north of the Susitna River, is about 1 percent of the suspended sediment load at Fairbanks (Emmett, et.al, 1978). Consequently, bedload entering Watana Reservoir was conservatively estimated as 3 percent of suspended sediment load, or 207,000 tons/year.

The sediment contributed by the tributaries directly to the reservoirs was estimated from the unit sediment runoff per square mile between the gaging sites near Cantwell and at Gold Creek. The difference in annual suspended sediment loads at the two sites was divided by the difference in drainage areas, resulting in a unit sediment load of 412.4 tons/mi.^{2}. Bedload is again assumed to be 3 percent of suspended sediment load. The resulting tributary sediment load is 429,000 tons/year of suspended sediment and 13,000 tons/year of bedload at Watana Reservoir and 260,000 tons/year suspended sediment and 8,000 tons/year bedload at Devil Canyon. The total annual sediment load entering Watana Reservoir is estimated as 7,547,000 tons/year. The estimated trap efficiency of 70 percent for suspended sediment results in an estimated 5,349,000 tons of sediment being deposited per year, with the full 7,547,000 tons/year deposited at 100% trap efficiency.

2-32-87

The total annual sediment load entering Devil Canyon Reservoir consists of the sediment bypassing Watana at 70% trap efficiency, 2,198,000 tons/year, plus the tributary sediment load of 268,000 tons/year, for a total of 2,466,000 tons/year. Using trap efficiencies of 70-100 percent for suspended sediment results in 1,729,000 - 2,198,000 tons/year being trapped in Devil Canyon Reservoir.

4.2 - Unit Weight of Deposited Sediment

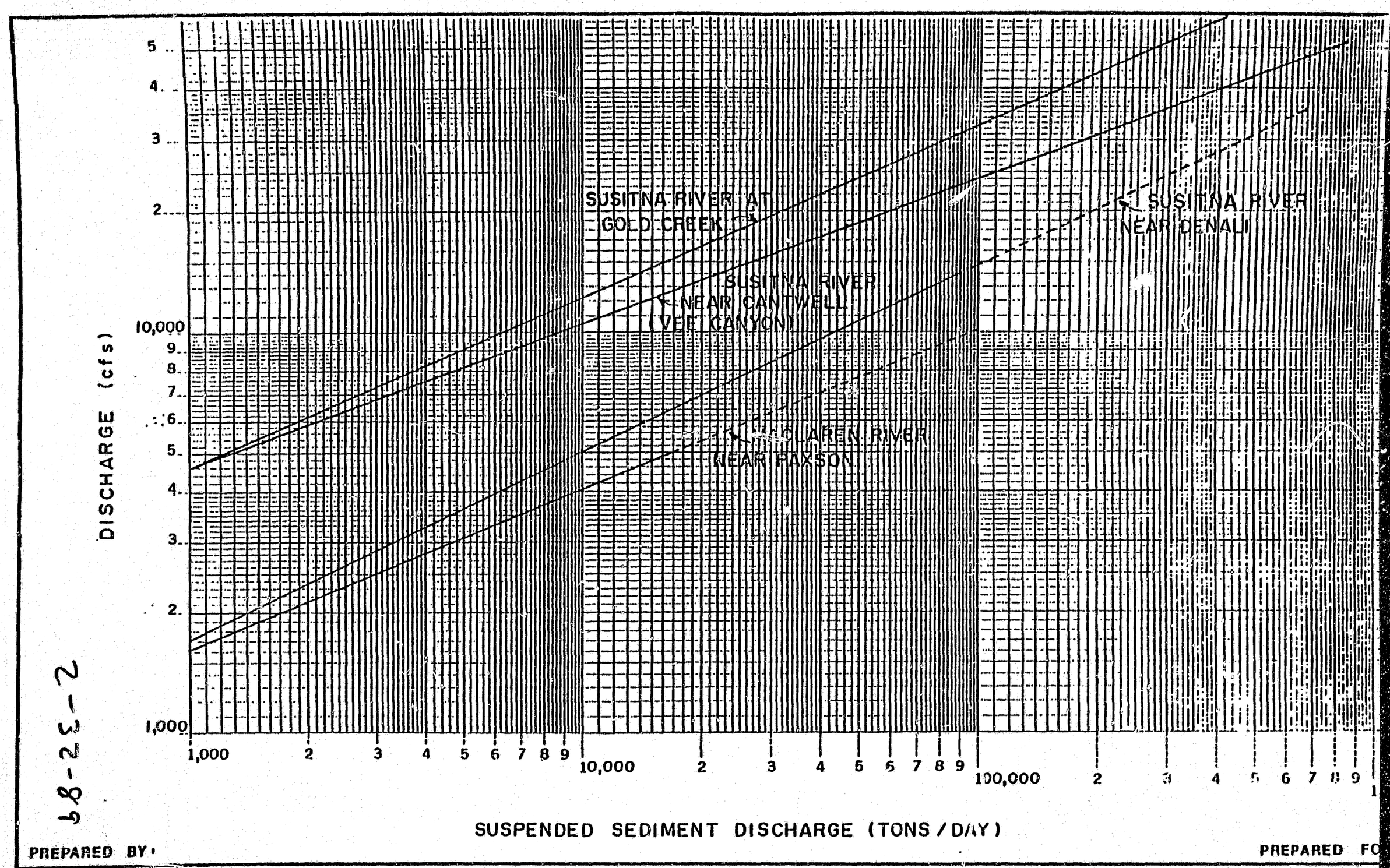
Estimates of the volume of sediment deposited in the reservoirs require the unit weight of the deposited sediment. Published values of the unit weight of deposited sediment vary from 18 to 125 lb/ft.^{3}, depending on the sediment size, depth of deposit, degree of submergence or exposure of the deposit, and length of time the material has been deposited. The initial density for each of seven sediment sizes was estimated using the Trask method. The 50-year and 100-year unit weights were estimated using the Lane and Koelzer method (1958) as modified by Miller (1963). The sediment size analysis developed by the Corps of Engineers (1975) for the Susitna River at Cantwell (Figure 4.2) was utilized to estimate the percentage of each size range of suspended sediment entering Watana Reservoir. The resulting average unit weights for suspended sediment after 50 years and 100 years were estimated at 71.6 and 72.3 lb/ft.^{3}, respectively, assuming the sediment was always submerged or nearly submerged. The unit weight for bedload was assumed to be 97 lb/ft^3.

4.3 - Volume of Sediment Deposits

Using the sediment loads and unit weight previously developed, the following sedimentation volumes were estimated.

	50-Year	100-Year
Watana		
100% trap eff.	240,000 ac-ft.	472,500 ac-ft.
70% trap eff.	170,000 ac-ft.	334,000 ac-ft.
Devil Canyon w/Watana at 70% Trap Efficiency		
100% trap eff.	79,000 ac-ft.	155,000 ac-ft.
70% trap eff.	55,000 ac-ft.	109,000 ac ft.
Devil Canyon w/Watana at 100% Trap Efficiency		
100% trap eff.	8,600 ac-ft.	16,800 ac-ft.
70% trap eff.	6,100 ac-ft.	6,000 ac-ft.

2-32-88



68-23-2

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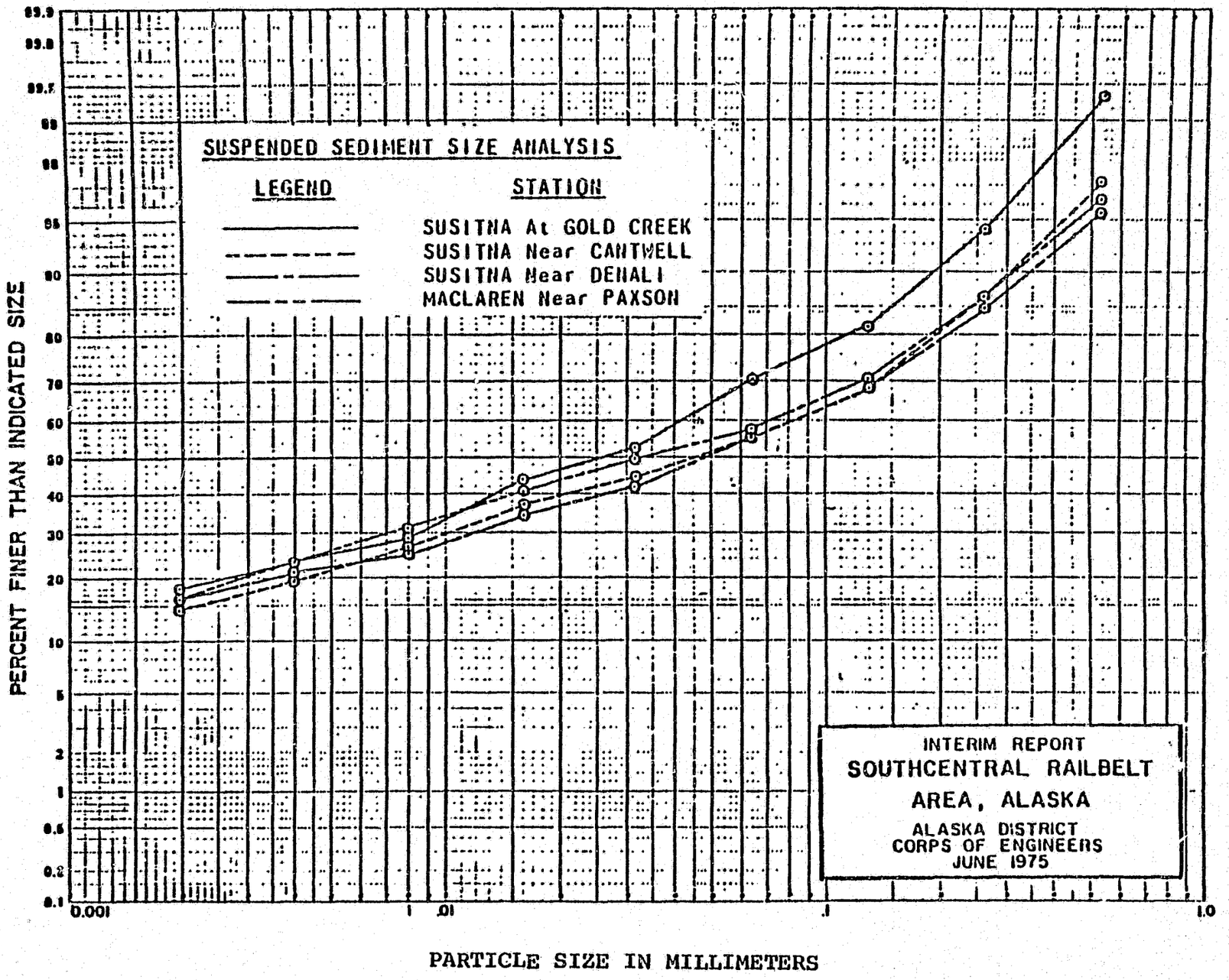
SUSPENDED SEDIMENT RATING CURVES
UPPER SUSITNA RIVER BASIN

FIGURE 4.1



06-23-2

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ACRES

SUSPENDED SEDIMENT SIZE ANALYSIS

SUSITNA RIVE

FIGURE 4.

5 - SEDIMENTATION PROCESSES AND SEDIMENT DISTRIBUTION

Sediment distribution within a lake or reservoir is dependent on several factors, including sediment characteristics, inflow-outflow relations, reservoir shape, and reservoir operation. When a stream enters a reservoir, its velocity drops sharply due to the large increase in cross-sectional area, with a subsequent decrease in the stream's sediment-transport capacity. As the velocity decreases, the coarser particles are deposited initially, forming a delta at the river's mouth. Much of the fine-grained suspended sediment is carried past the delta to be deposited in the deeper parts of the lake.

5.1 - Delta Deposits

As a stream enters a standing water body the channel form and process are altered in the backwater conditions. Bed aggradation and reduced flow velocities extend upstream some distance from the lake. Although most of the fine-grained suspended sediment passes through the backwater zone, much of the bed load is deposited, thus lowering the bed slope and raising the water surface and stream bed elevations. As the delta builds, the front forms a sharp slope break over which the remaining bedload is dumped. As sedimentation continues, the river channel changes to accomodate the changed profile so that sediment continues to be carried to the delta front before being deposited. Examples from Lake Mead on the Colorado River (Lara and Sanders, 1970) and glacial Lake Lillooet, British Columbia (Church and Gilbert, 1975) illustrate the resulting morphology (Figure 5.1). A second process, noted by Pharo and Carmacks (1979) in Kamloops Lake, British Columbia, is that of episodic density surges which redeposit material initially dumped on the delta slope. Sediment density surges differ from the third process, that of river plume dispersion (as overflow, interflow, or underflow), in that density surges are episodic and relatively short-lived compared to the relatively continnous nature of river plume dispersion; sediment density surges involve the redeposition of material already deposited on the delta slope, rather than the uninterrupted extension of river-borne sediment into the lake; and sediment concentrations within sediment density surges dominate the fluid density and drive the downslope flow.

There will be considerable variation in the summer water levels at Watana Reservoir, resulting in a complex delta formation at the head of the reservoir, with the bed elevation trying to re-establish equilibrium.

2-32-91

5.2 - Glacial Lake-Floor Sedimentation

It has been noted by several authors (Embleton and King, 1975; Bryan, 1974) that glacial lake-floor deposits beyond the area of delta growth are predominantly fine, becoming increasingly so as the central or deepest parts of the lake are approached. The very fine material is the glacial rock flour which discolors the water of glacial streams and lakes, and which often requires long periods and quiet water conditions to settle (E.M. Kindle, 1930).

Deep lakes offer the best opportunities for the trapping and deposition of the finest material. In shallow glacial lakes, the existence of more powerful currents prevents the settling of fine material, and often cause it to be washed towards and through the lake outlet, resulting in its loss from the lake.

Glacial lake floor deposits are often laminated, caused by sudden changes of grain size from finest mud to slightly coarser silt between successive thin layers, and often accompanied by a color change between layers. These laminated deposits are known as rhythmites, with an individual pair of one fine and one slightly coarser layer known as a couplet. The thin dark layer of a couplet consists of very fine and partly colloidal material, representing a period of slow deposition under very quiet water conditions, such as when a lake was frozen over in winter with little or no meltwater entering. The light-colored coarser layer indicates a more rapid period of sediment deposition under more disturbed conditions, such as when meltwater is entering the lake and lake currents are spreading silt over the whole lake floor. Some couplets form on an annual basis, and are known as varves. De Geer (1912) indicated that the fine lamina of a couplet was the result of deposition in winter when the lake was frozen and meltwater limited. The abrupt break at the top of the fine lamina represents the spring thaw when new coarser silt enters the lake. Confirmation of this theory has come from pollen studies of rhythmites, and from studies of modern glacial lake-floor deposits, such as that made by W.A. Johnston (1922) on Lake Louise, Alberta. Nonannual rhythmites may also form from sudden fluctuations in discharge, such as from the bursting of an ice-dammed lake upstream, unseasonal warm or cold spells, or periodic storms.

The deposition of the coarser laminae is attributed to turbid underflows and interflows of denser sediment-laden water from glacial meltwater streams. The phenomena of underflow and interflow have been noted in numerous studies of sedimentation in glacial lakes (Emerson, 1898; Kuenen, 1951; Mathews, 1956; Gilbert, 1973; Bryan, 1974 a, b; Theakstone, 1976; Ziegler, 1973; Østream, 1975; Gustavson, 1975; Pharo and Carmack, 1979). The frequency, duration, and intensity of the underflows and interflows have been attributed to stream temperature and sediment load, temperature and suspended sediment distribution in the lake, and lake bathymetry, especially near the stream mouth.

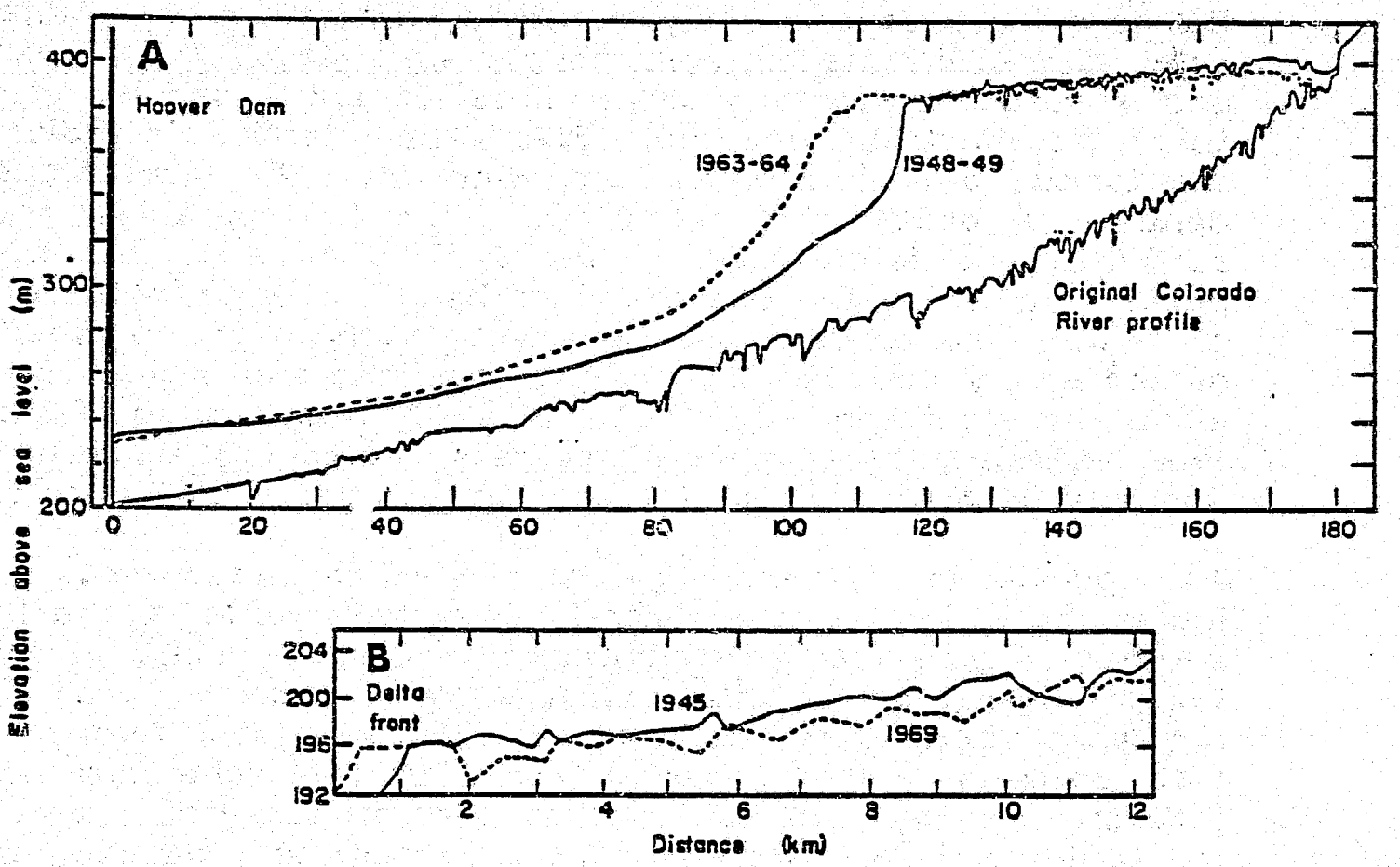
The uninterrupted downlake transport of the silt and clay - sized material was noted as being due to the interflow process in Kamloops Lake (Pharo and Carmack, 1979). During summer the lake surface waters warm more rapidly than those of the incoming river. The river water first moves to the plunge line, where it sinks and flows down along the slope of the delta as a turbulent gravity current. The plume entrains lake water as it sinks, causing convergence at the lake surface and resulting in a color change at the plunge line. When the plume reaches a depth where its density is approximately equal to that of the lake water, the river plume with its large suspended load leaves the bottom slope and spreads horizontally along lines of equal density (temperature), as illustrated in Figure 5.2. The interflow is indicated by the tongue of turbid water extending from the face of the river delta at a depth of about 20 m. The flow parallels isothermal surfaces, and is modified by the Coriolis force so that the river plume is directed towards the right hand shoreline in the direction of flow. The preferential movement to the right-hand side was evidenced by both higher turbidity readings and coarser sediments along the right-hand shore of the lake. A schematic of the three interdependent but distinct processes controlling sediment transport and deposition within Kamloops Lake is shown in Figure 5.3.

As previously noted, glacial lake-floor sediments become increasingly fine as the central or deepest parts of the lake are reached. Grain size distribution in Kamloops Lake varied from 0.5 mm near the lake inlet to 0.002 mm (2 microns) near the lake outlet. Accumulation rates decreased with distance from the delta, with rates of 8.00 cm/year adjacent to the delta decreasing to 0.35 cm/year near the lake outlet. Not all sediment was deposited in Kamloops Lake. Measurement of inflow and outflow turbidity levels indicated that nearly one third of the incoming sediment was not deposited, with the percentage varying with time. As illustrated in Figure 3.2, turbidity at the lake outlet increased following periods of very high turbidity levels at the inlet.

5.3 - Glacial Lake Temperatures

Deep glacial lakes commonly show temperature stratification (Mathews, 1956; Gilbert, 1973; Pharo and Carmack, 1979, Gustavson, 1975), although stratification is often relatively weak. Bradley Lake, Alaska, (Figure 5.4) demonstrated a weak thermocline in late July, 1980, but was virtually isothermal by late September, and demonstrated a reverse thermocline during winter months (Corps of Engineers, unpublished data). Temperature data for Kluane Lake (Bryan, 1974b) are also illustrated in Figure 5.4. Selected thermal profiles from Malaspina Lake, Alaska, are illustrated in Figure 5.5 (Gustavson, 1975), as are bathythermograms showin the destruction and reforming of the thermocline in Lillooet Lake (Gilbert, 1973) during periods of strong underflow. Garibaldi Lake, British Columbia, also demonstrates a thermocline in the summer months, as seen on Figure 5.6 (Mathews, 1956).

2-32-93



Profiles of (A) Colorado River at Lake Mead (after Lara and Sanders, 1970, p. 155) and (B) Lillooet River at Lillooet Lake, showing that the greatest accumulation on an established delta occurs at the delta front and on the foreset beds. Lake Mead data reproduced by courtesy of the *United States Bureau of Reclamation.*

(Church and Gilbert, 1975)

2-32-94

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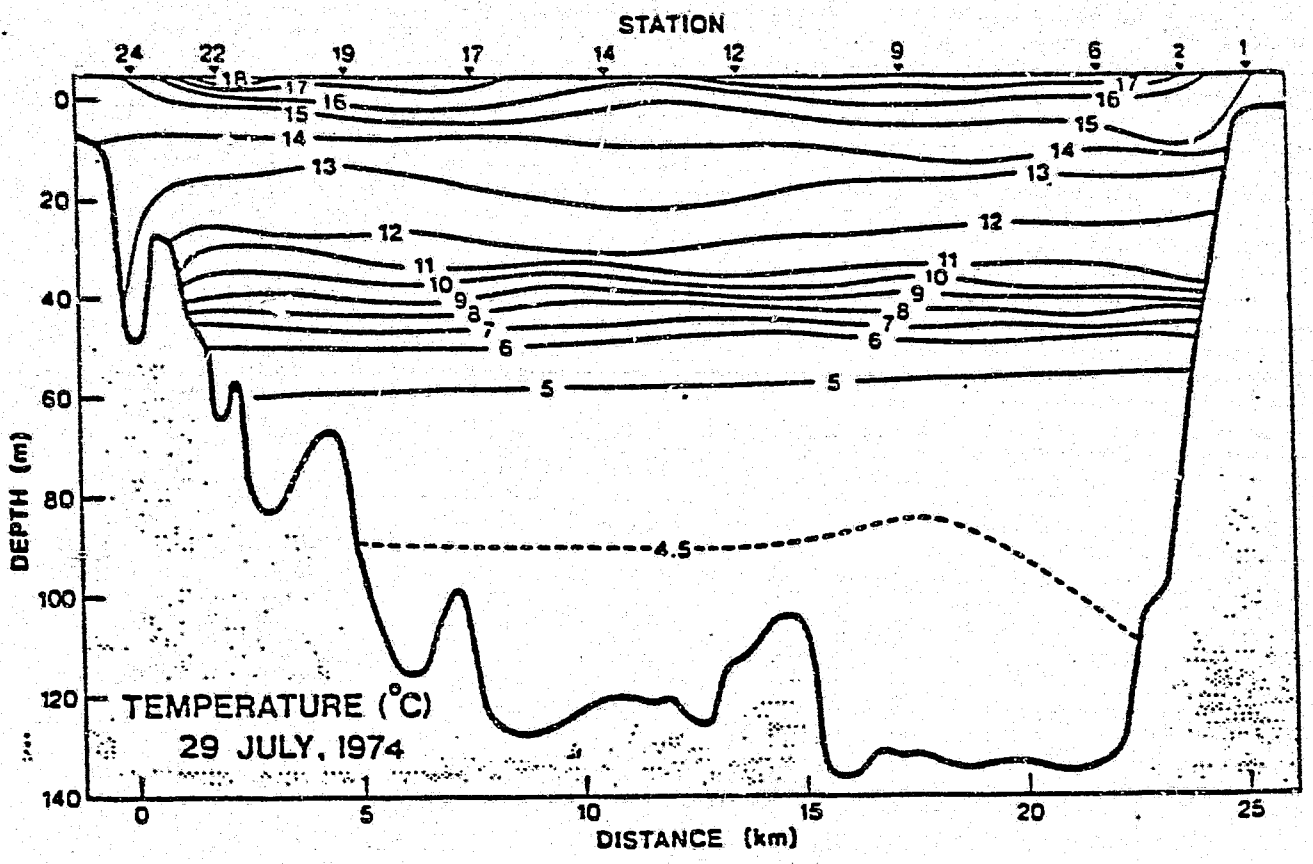
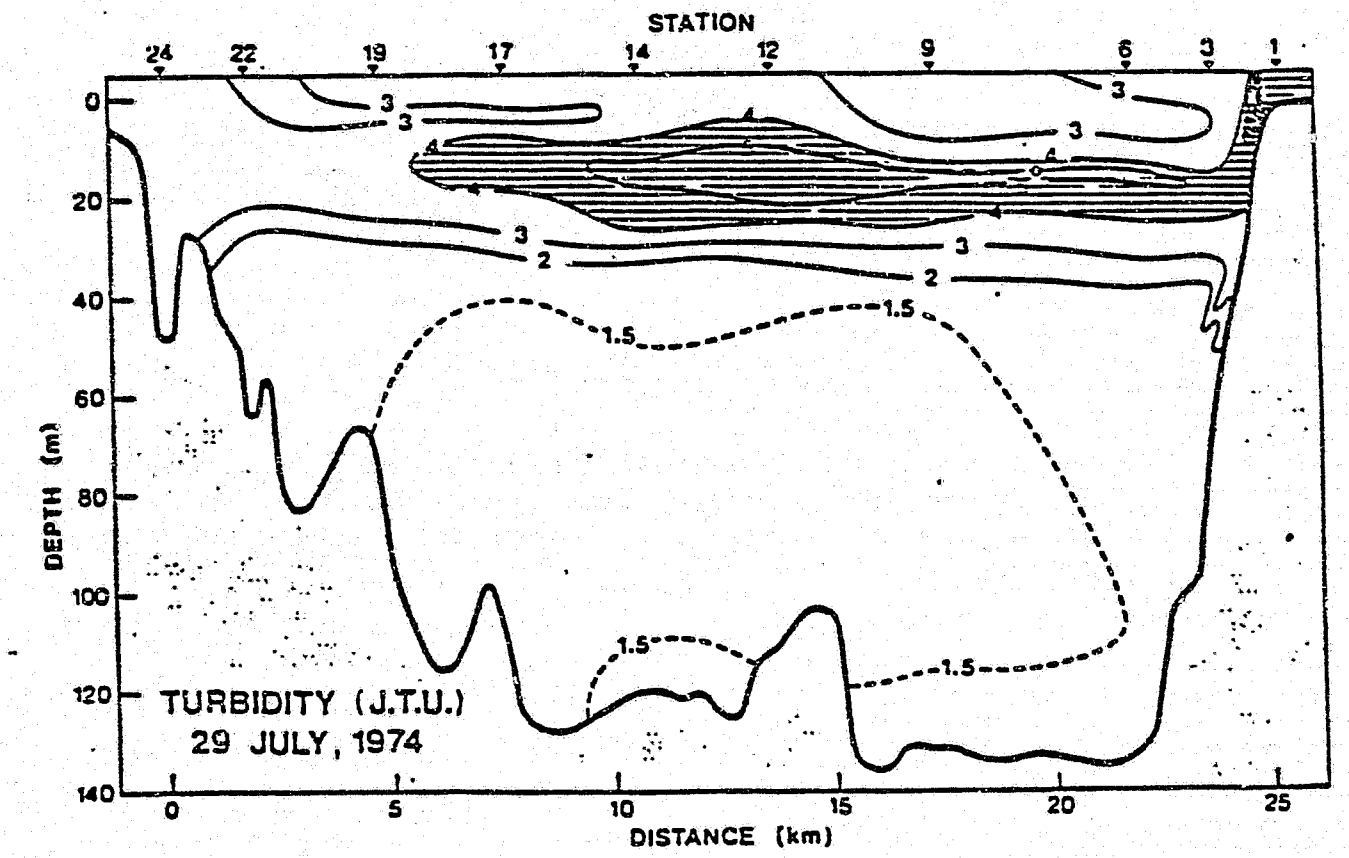
DELTA FORMATION
LAKE MEAD AND LILLOOET LAKE

FIGURE 5.1





(Plan and Carmachs, 1979)

2-32-95

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TEMPERATURE & TURBIDITY ISOLINES
KAMLOOPS LAKE

FIGURE 5.2

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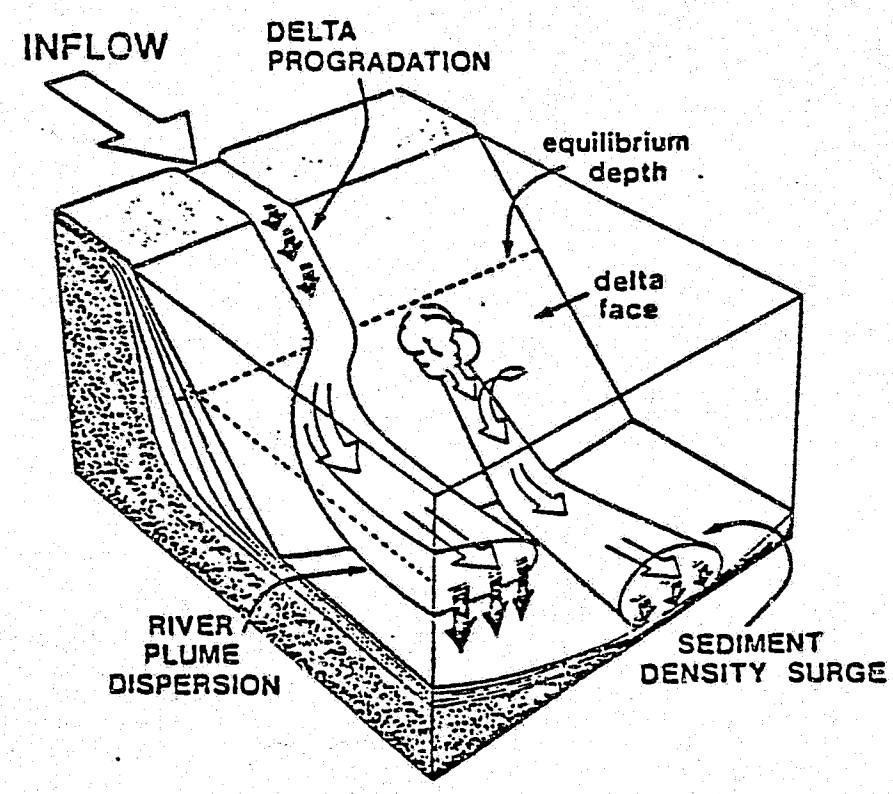

NOTE:
BLACK ARROWS DENOTE SEDIMENTATION: ↓
LIGHT ARROWS DENOTE FLUID MOTION : ⇒

Schematic illustration of sediment transport and deposition mechanisms associated with a river entering a lake assumed to be temperature stratified. The equilibrium depth is that at which the inflowing river water has the same density as the lake water, and at which the river water flows down the lake.

(Pharo and Carmachs, 1979)

2-32-96

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SCHEMATIC OF SEDIMENTATION PROCESSES
KAMLOORS LAKE

FIGURE 5.3

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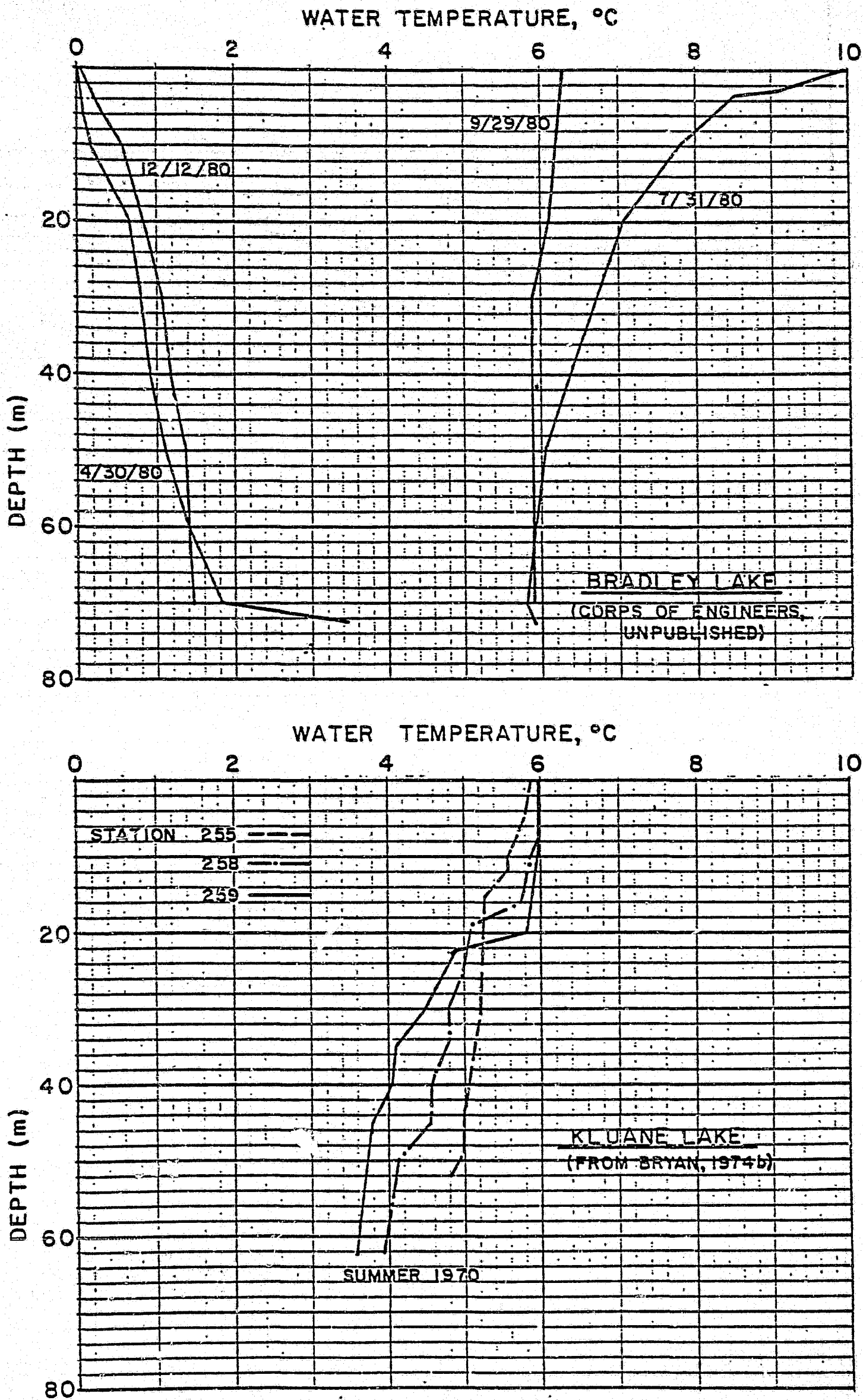

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2-32-97

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WATER TEMPERATURE PROFILES
BRADLEY LAKE, ALASKA AND
KLUANE LAKE, YUKON TERRITORY

FIGURE 5.4

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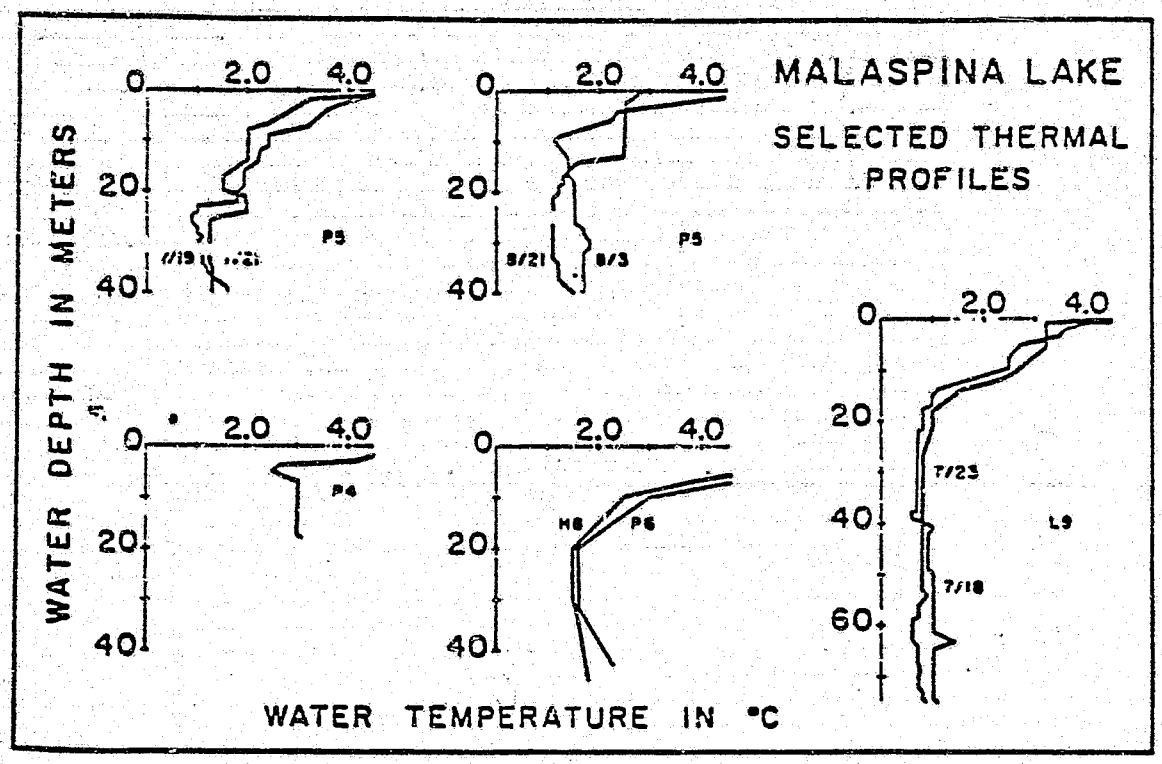
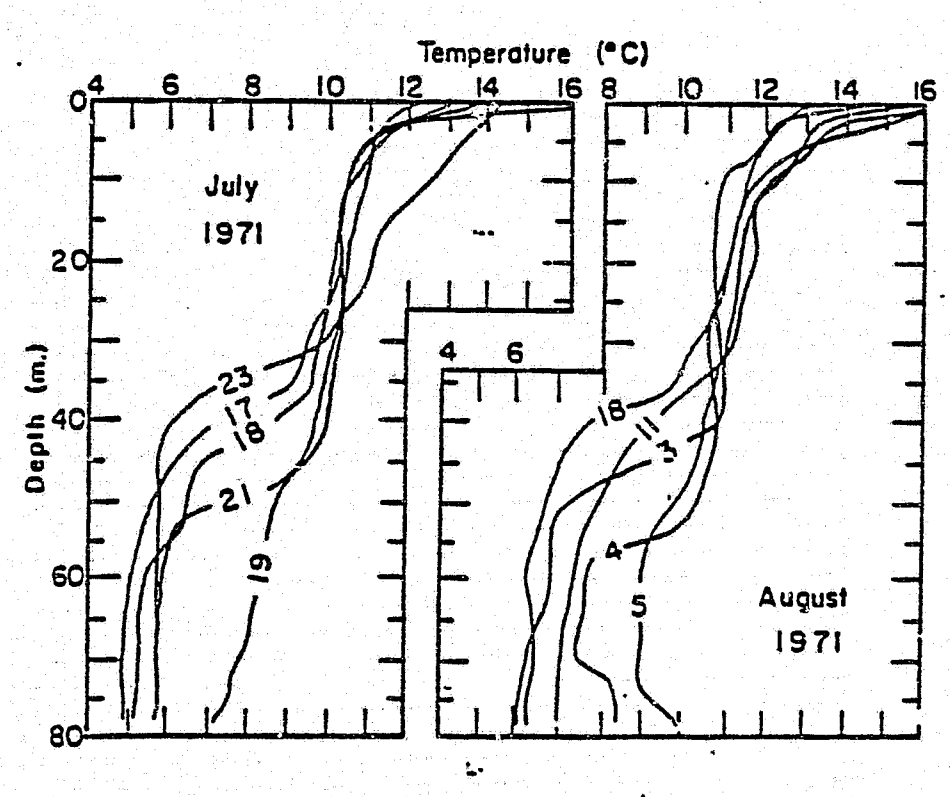


Water temperature throughout Malaspina Lake decreases with depth. Alphanumeric symbols (P5) identify instrument station (fig. 3) where thermal profile was recorded. Two profiles at same site are identified by date (7/21) on which they were recorded. Profiles measured in 1970

(Gustavson, 1975)



Bathythermograms showing the destruction and reforming of the thermal structure of Lillooet Lake associated with two periods of strong interflow and underflow. Numbers refer to dates of the observations in July and August 1971.

(Gilbert, 1973)

2-32-98

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TEMPERATURE PROFILES, MALASPINA LAKE, ALASKA, & DURING STRONG UNDERFLOW, LILLOOET LAKE, B.C.

FIGURE 5.5

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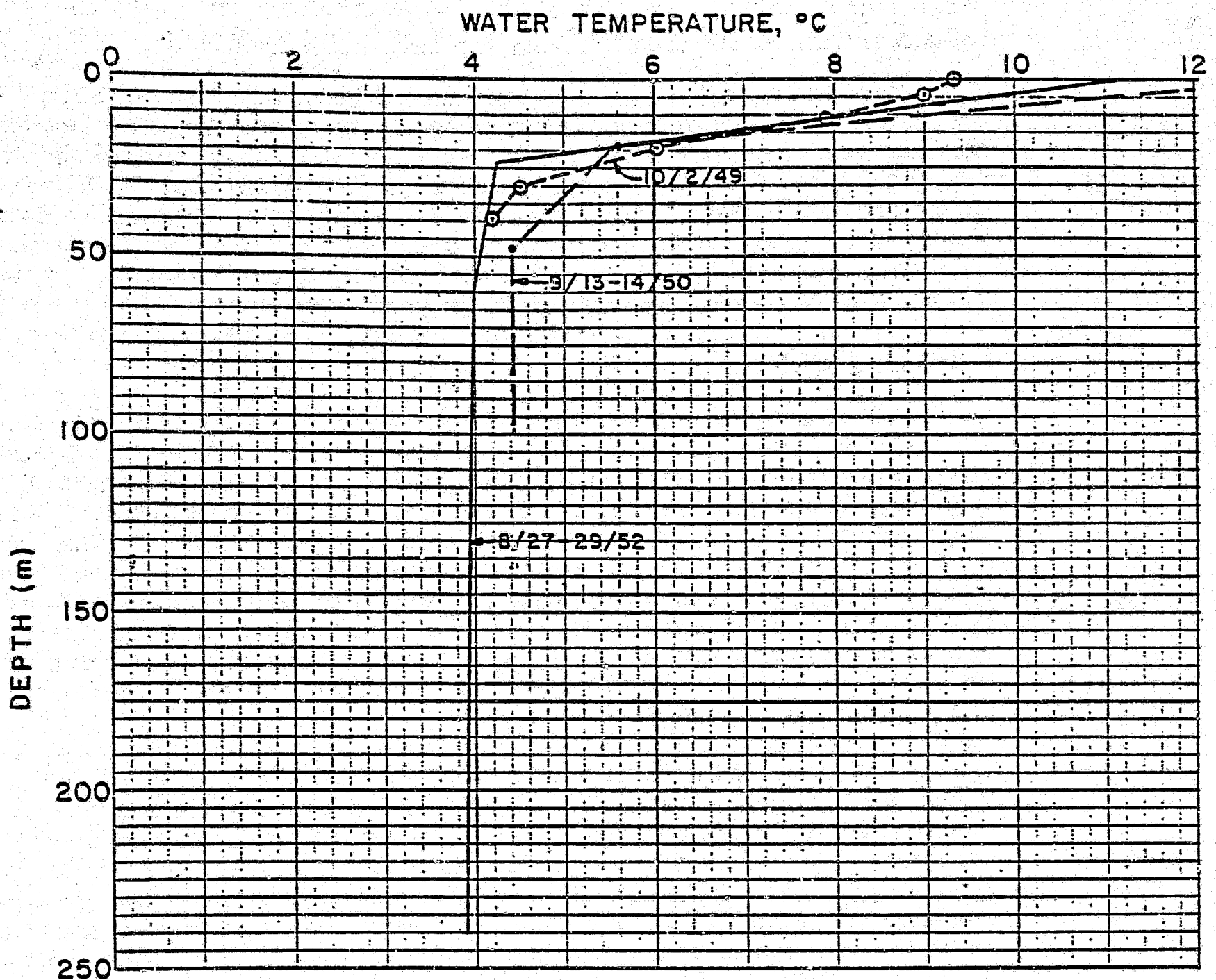

2-32-99

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Prepared for:

AGRA

WATER TEMPERATURE PROFILES
GARIBALDI LAKE, BRITISH COLUMBIA

FIGURE 5.6

6 - RESERVOIR AND DOWNSTREAM TURBIDITY

The reservoirs will have a significant impact on the turbidity of the Susitna River between Devil Canyon and the Susitna-Chulitna confluence, with the river being considerably less turbid in the summer and possibly more turbid in the winter. A rigid quantitative analysis is not possible with the available data. However, a qualitative analysis discussing the interrelated factors will shed some light on the probable post-project turbidity in the reservoir and downstream of Devil Canyon.

6.1 - Pre-Project Turbidity

Turbidity data for the Susitna River were reviewed for the Gold Creek and Vee Canyon sites. The U.S. Geological Survey gathered turbidity data during 1974, 1975 and 1976, with turbidity visually measured in Jackson Turbidity Units (JTU). R&M Consultants measured turbidity using photoelectric detectors during 1980 and 1981 at both the Gold Creek and Vee Canyon sites, with the data presented in nephelometric turbidity units (NTU). The units are approximately equivalent, but due to the subjective nature of visual observations, nephelometric means are generally considered more accurate, especially in the lower ranges of turbidity (less than 40 NTU's).

The nephelometric turbidity data was logorithmically plotted against vertically integrated samples of suspended sediment concentration for the Gold Creek and Vee Canyon sites. The plots, regression equations and correlation coefficients for both sites are shown on Figure 6.1. Best fits for the data were obtained by the general equation $T = a[ss]^b$, where T is turbidity, ss is suspended sediment concentration in mg/l, and a and b are coefficients. Sediment concentration and turbidity have a very high correlation. Available USGS data were also analyzed to obtain relationships for discharge and suspended sediment concentration for the above two gaging sites. The following relationships were derived for turbidity, suspended sediment concentration, and discharge.

Susitna River near Cantwell

$$T = 0.3568(ss)^{.8607} \quad n = 9, \; r^2 = 0.98$$
$$ss = 0.0000553\, Q^{1.70}, \; n = 37, \; r^2 = 0.703$$

Susitna River at Gold Creek

$$T = 0.2496(ss)^{.9551} \quad n = 6, \; r^2 = 0.95$$
$$ss = 0.000673\, Q^{1.381}, \; n = 332, \; r^2 = 0.585$$

The poor correlation coefficients between suspended sediment concentration and discharge are to be expected on glacial rivers, where glaciers contribute irregular amounts of sediment.

2-32-100

Even though the determine coefficients are rather poor, the regression equations are still useful in determining the seasonal variation in turbidity. The turbidity-suspended sediment concentration equations and the suspended sediment concentration - discharge euqations were used together with the mean daily flow summary hydrographs for the two sites to estimate the monthly pattern of turbidity. The summary hydrographs used are found in the Corps of Engineers Interim Feasibility Report (1975). The resulting estimated average annual turbidity patterns are shown on Figure 6.2. The actual turbidity patterns show much greater variation in a single year due to the larger variations in suspended sediment concentration.

6.2 - Factors Effecting Turbidity

Reservoir sedimentation processes described in Section 5.2 are the main processes affecting reservoir turbidity. The sediment-laden river will enter the reservoir as either overflow, interflow, or underflow, depending on its density relative to that of the reservoir waters. Once it reaches its equilibrium density level, the inflowing river plume spreads horizontally along lines of equal density. The flow parallels isothermal surfaces, and is modified by the Coriolis force so that the river plume is directed towards the right hand shoreline in the direction of flow.

The turbidity at the reservoir outlet is also dependent on the residence time of inflowing waters in the reservoirs. Watana Reservoir has mean annual bulk residence time (volume/mean annual streamflow) of 600 days, with Devil Canyon having a mean annual bulk residence time of 60 days. However, the bulk residence time varies with flow, with the bulk residence time decreasing to about 110 days for the mean annual flood entering Watana. The residence times for summer flows are affected by the relative reservoir level. As the reservoirs will be filling during the early high flow periods, the residence time would be somewhat increased above 110 days for the breakup flood.

The long residence times indicate that an ice cover would form before much of the late summer flow passes through the reservoirs. Settling column studies (Attachment A) indicated that suspended sediment rapidly settled out under quiescent conditions, with turbidity also rapidly decreasing (Figure 6.3). Once an ice cover forms, essentially quiescent conditions will exist in the reservoirs, with wind action no longer disturbing the surface, and inflow dropping to minimal levels. Consequently, relatively rapid sedimentation should commence once an ice cover forms, with surface waters rapidly clearing beneath the ice. The turbidity of inflowing waters is also quite low during this period, thus contributing little additional sediment.

6.3 - Post-Project Turbidity

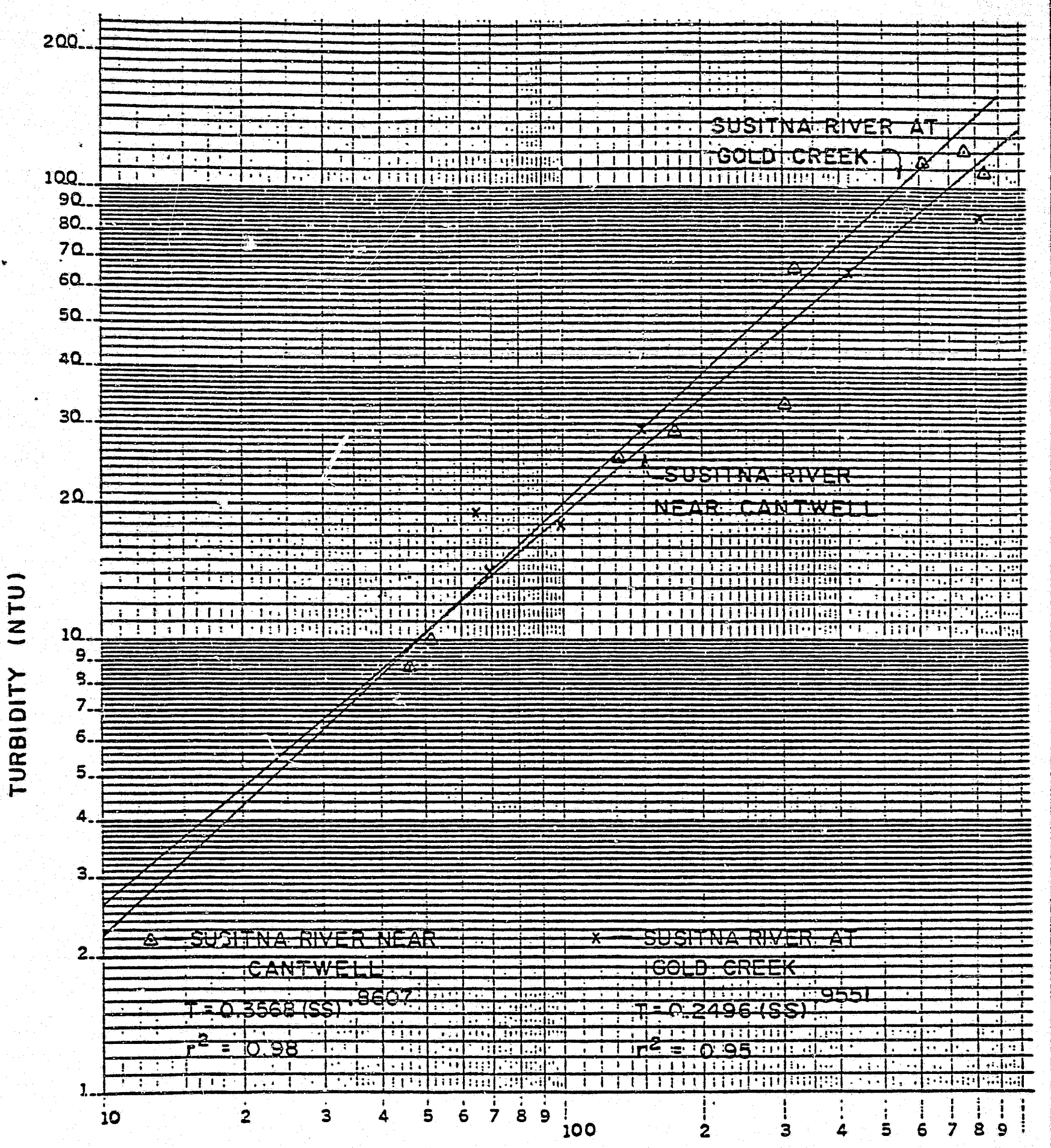
A discussion of the timing of certain events occurring within the reservoirs and Upper Susitna River will serve to help describe the changes in the turbidity pattern. Breakup normally occurs in late April or early May on the Susitna River. Suspended sediment concentrations and turbidity sharply increase in May, and remain high into September, as the glaciers are contributing significant amounts of sediment during their melt period. However, the ice cover on the reservoirs will remain longer than ice now remains on the river, as the lake ice will not be flushed out of the system by breakup but will instead melt in place. Consequently, relatively quiescent conditions will occur through most of the lake until the ice cover has significantly decreased, which will probably not occur until late May or early June. Even though turbid water will enter the reservoir in early May, an increase in turbidity in outlet waters should not occur until early to mid-June.

During the summer months, turbidity will increase as suspended sediment concentrations increase at the reservoir inlet. Pulses of sediment may pass through the reservoir when very large sediment concentrations enter the reservoir, such as during a large flood, but they will be sharply dampered. The pattern will probably be similar to that shown at Kanloops Lake on Figure 3.2, except that the decrease should be even larger in the Susitna River system due to relatively larger size of the reservoirs (longer residence time).

Downstream turbidity can not be accurately quantitied, but tentative estimates indicate that is possible that it will not exceed maximum values of 35-45 NTU during peak flows, and will normally be in the 10-20 NTU range during summer months, based on cursory estimates from flow suspended sediment concentrations, trap efficiency, and reservoir outflow. Reservoir turbidity will decrease in the downstream direction as the larger sediment sizes settle out.

In September and October, inflowing turbidity levels to the reservoir are significantly less than summer values, as the glaciers contribute less meltwater and sediment. Ice cover on the reservoirs will normally start to form about the third week in October. Once the ice cover forms, essentially quiescent conditions occur, and turbidity in the upper levels of the reservoir should rapidly decrease.

2-32-102



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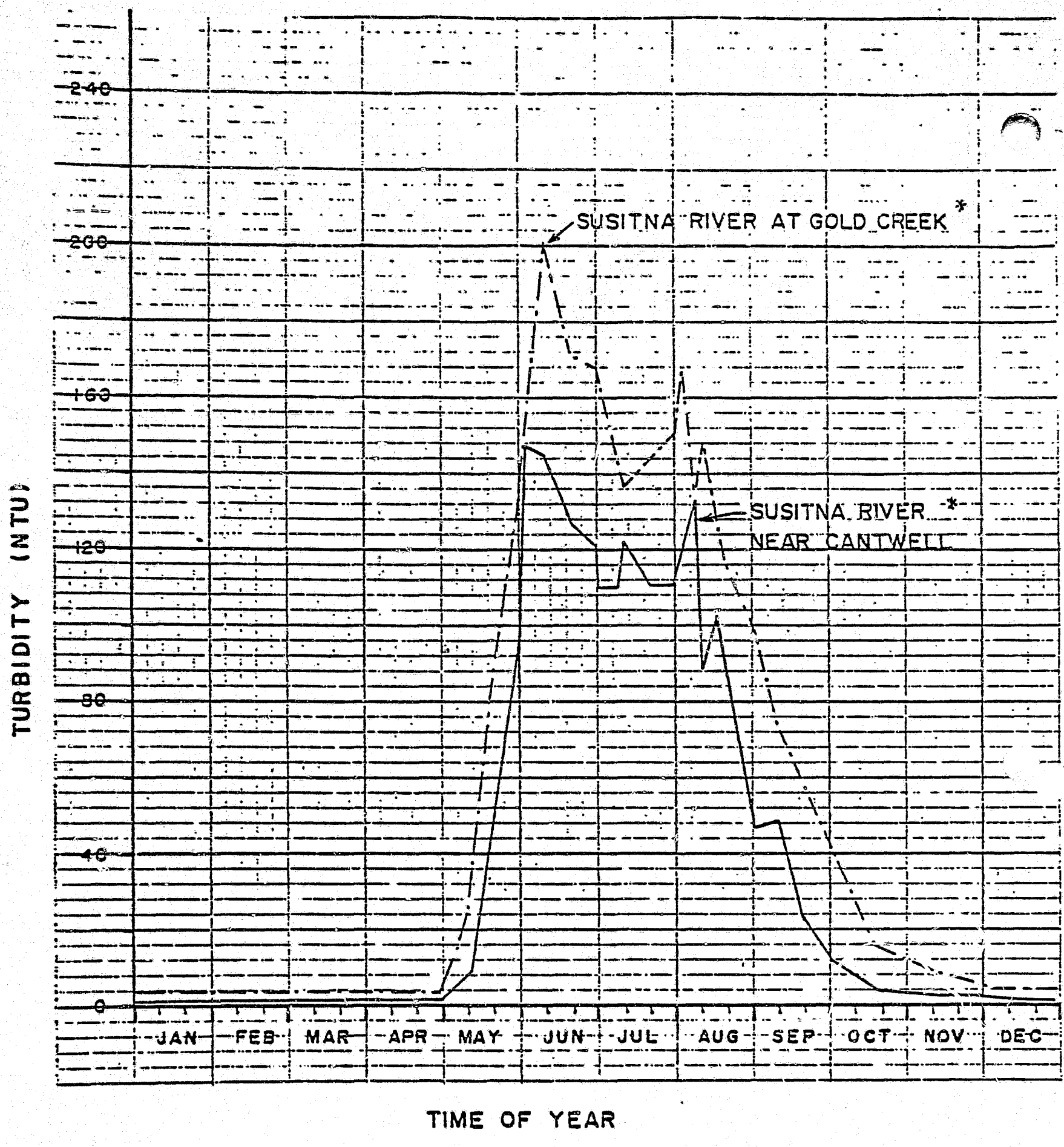
2-32-103

PREPARED FOR:

TURBIDITY VS.
SUSPENDED SEDIMENT
CONCENTRATION

FIGURE 6.1



* Curves are estimates based on the mean daily flow summary hydrographs and from regression equations relating discharge, suspended sediment concentration, and turbidity. Turbidity in a single year displays greater daily variation.

2-32-104

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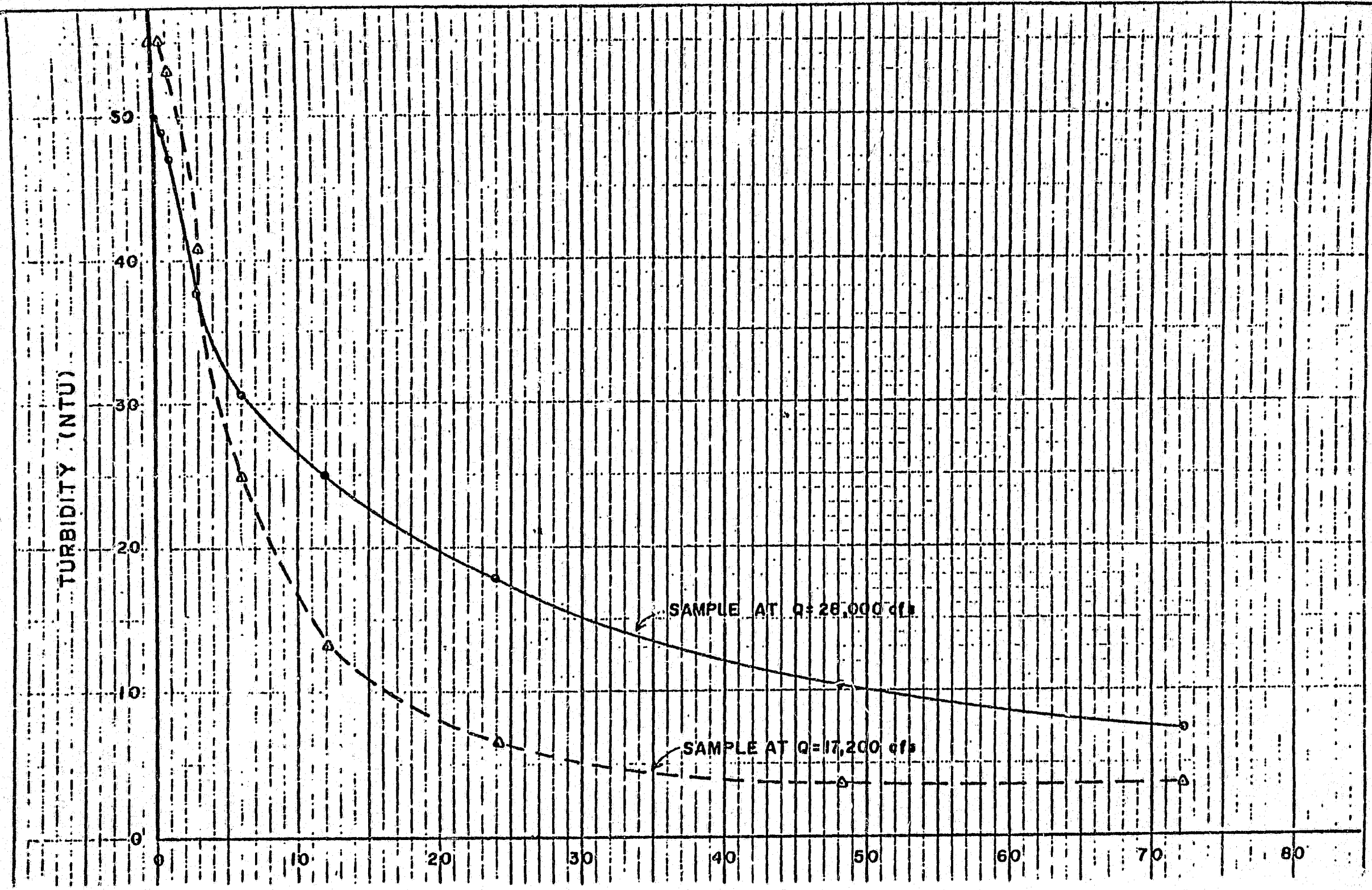
AVERAGE ANNUAL TURBIDITY PATTERN
SUSITNA RIVER

FIGURE 6.2



2-32-105

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TURBIDITY VS TIME
SUSITNA RIVER
SETTLING COLUMN STUDY

FIGURE 6.3

PREPARED FOR:

ACRES

7 - PROJECTED RESERVOIR SEDIMENTATION

Trap efficiency estimates using the Brune curve indicate 90-100 percent of the incoming sediment will be trapped in the reservoirs, even shortly after reservoir filling, but sedimentation studies at glacial lakes indicate that fine glacial sediment may pass through the lake. Delta formation at the head of the reservoir will be constantly adjusting to the changing water level. Sediment passes through the channels on the delta to be deposited over the lip of the delta. Depending on the relative densities of the lake water and the river, the sediment-laden water will either enter the lake as overflow, interflow, or underflow (turbidity current). It is probable that the turbid summer flows of the Susitna River will initially dive below the surface, seeking an equilibrium density layer. The settling process will then commence somewhere below the surface.

Estimates of the total amount of deposition of fine flacial sediment in the reservoirs are somewhat uncertain. Glacial lakes immediately below glaciers have trap efficiencies of 70-75%. Kamloops Lake, B.C., retains about 66% of the incoming sediment. Sediment concentration at the outlet of Kamloops Lake increased during periods of high sediment inflow, which would correspond to high stream flows. Kamloops Lake is a natural lake, so retention time of high flows decreases to about 20 days during the spring freshet. However, Watana Reservoir has significant active storage capacity. During the May - July period the reservoir will normally be filling, so that outflow will be much less than inflow. The increased residence time due to refilling of the reservoir would tend to allow more of the sediment to settle. Once the reservoir is full, there may be periods of increased turbidity downstream following periods of very high streamflow, similar to that evidenced at Kamloops Lake on Figure 3.2. The median grain size at the lower end of Kamloops Lake was 0.002 mm, and appeared to be uniformly distributed across the lower end of the lake. The suspended sediment size analysis for stations on the upper Susitna River (Corps of Engineers, 1975), shown on Figure 4.2, indicates that about 15 percent of the suspended sediment entering Watana Reservoir (Susitna River near Cantwell gaging station) is smaller than 2 microns (.002 mm). The trap efficiency of Watana Reservoir is estimated be between 70 - 97 percent, with only the material finer than 2 microns possibly passing through the reservoir.

The minimum assumed trap efficiency for Devil Canyon Reservoir is 70 percent, based on data from other lakes. However, it is possible that the trap efficiency may be much lower, as only fine material with very slow settling rates would pass through Watana Reservoir.

2-32-106

Based on the results of the settling column studies, (Att. A) much of the suspended sediment still in suspension when an ice cover forms would settle, as quiescent conditions would soon be prevalent.

8 - REFERENCES

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2-32-108

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2-32-110

ATTACHMENT A

SETTLING COLUMN STUDIES

SETTLING COLUMN STUDIES

Settling column studies were conducted to obtain data on the settling rates of suspended sediment and on time based turbidity levels of Susitna River water after it enters standing water.

Procedure

Two 55 gallon water samples were obtained from the Susitna River near Watana damsite. These samples were taken in an area of turbulent flow using a pump whose inlet depth was varied to allow depth integrated sampling. The samples were retrieved at the following flow rates and water temperatures.

Sample #1	July 29, 1981 at 3:00 p.m.	28,000 c.f.s.	50°F
Sample #2	Sept. 3, 1981 at 5:00 p.m.	17,200 c.f.s.	46°F

The samples were placed in the settling columns, thoroughly mixed and initial (time zero) samples taken from ports which were located at 0.5, 2.5, 4.5, 6.5 and 8.5 feet from the bottom of the column. The depth of water in the columns varied during testing as water was removed for testing. In column 1 the average depth of water was 9.2 feet and in column 2 the average depth was 8.9 feet.

Samples were taken at 0, 0.5, 1, 3, 6, 12, 24, 48 and 72 hour intervals and analyzed for turbidity (N.T.U.) and total suspended solids (T.S.S. in mg./liter). Air and water temperatures at these times were also recorded.

Results

Results of the settling column studies are illustrated for suspended solids in Figures A.1 and A.2. In 72 hours, total suspended sediment concentration decreased by 93% in the 28,000 cfs sample and by 98% in the 17,200 cfs sample. Little density stratification was noted in the 28,000 cfs sample during the settling period, but was more noticeable in the 1-6 hour period for the 17,200 cfs sample.

Turbidity levels showed a similar decrease. The composite average for each time period is shown on Figure 6.3. There was little variation in turbidity with depth. As would be expected from the suspended sediment results, turbidity decreased significantly, with reductions of 85 percent for the 28,000 cfs sample and 94 percent for the 17,200 cfs sample.

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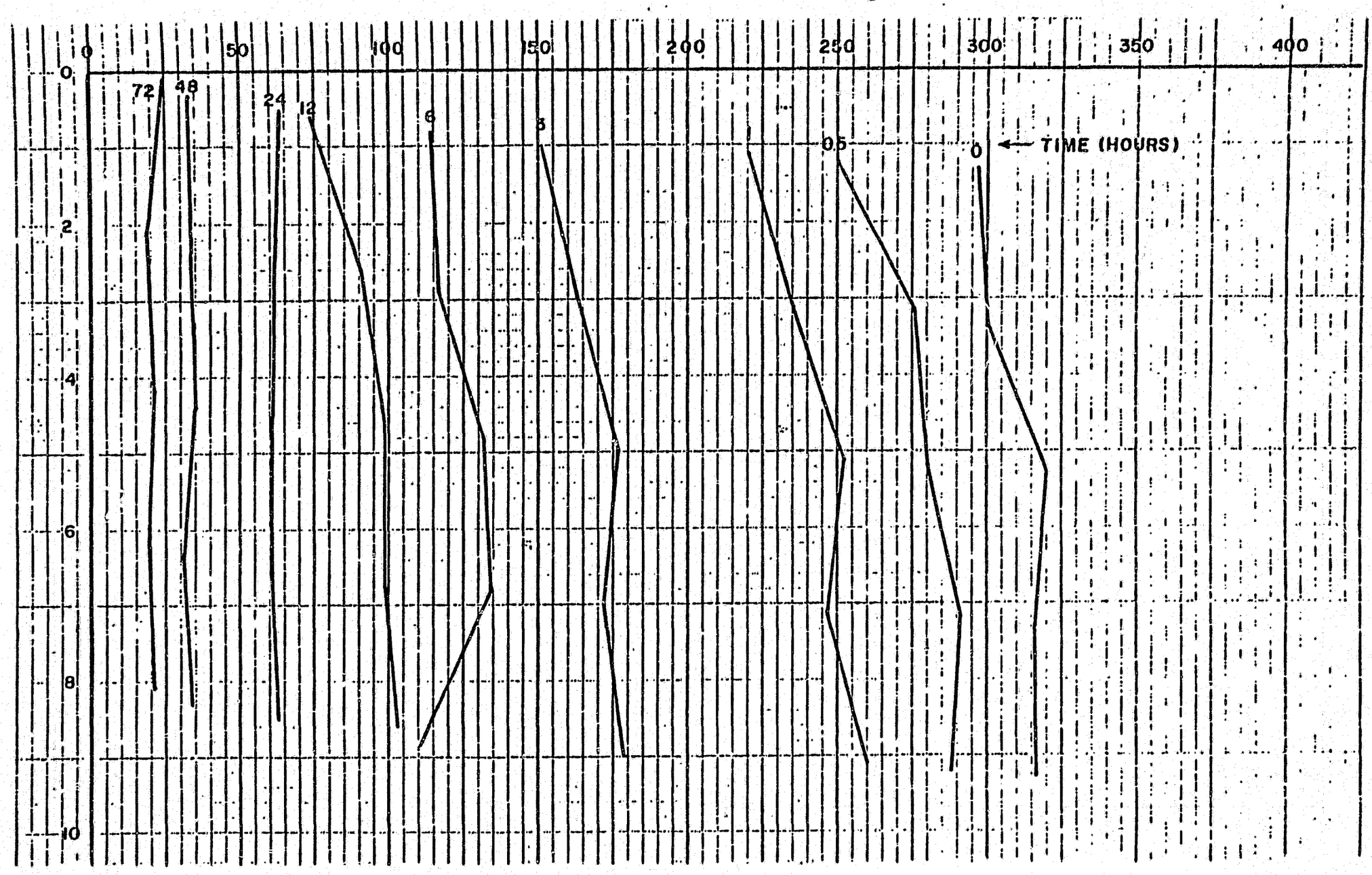

A-2

11-32-113

SAMPLE COLLECTED ON 29 JULY 1981, 1 MILE ABOVE WATANA DAM SITE
WATER TEMPERATURE (7/29/81) = 50° F

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PREPARED FOR

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SUSPENDED SEDIMENT CONCENTRATION VS TIME & DEPTH

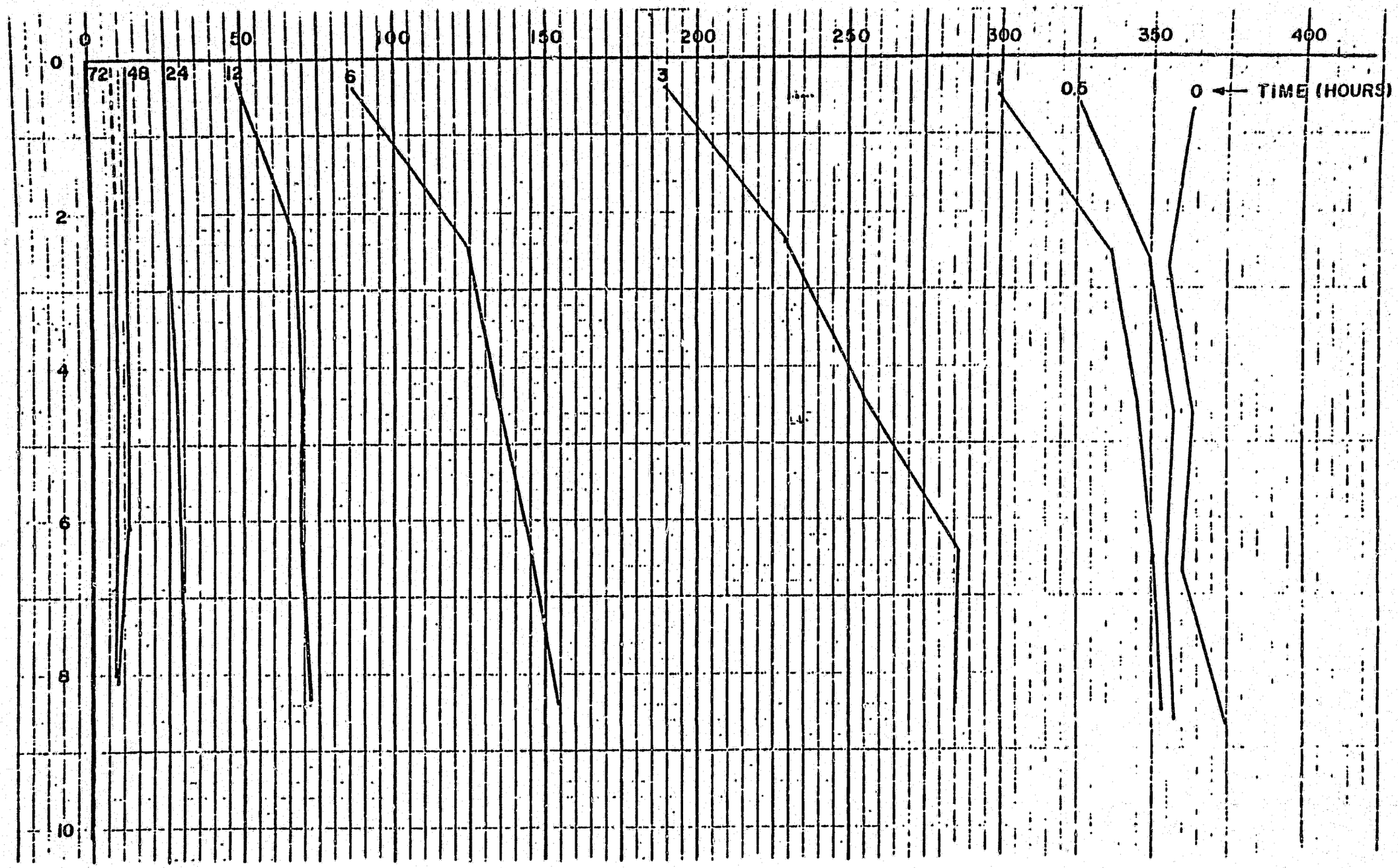
SETTLING COLUMN STUDY

28,000 CFS SAMPLE

FIGURE A-1

ACRES

SUSPENDED SEDIMENT CONCENTRATION (mg/l)



SAMPLE COLLECTED ON 3 SEPT. 1981, 1 MILE ABOVE WATANA DAM SITE
WATER TEMPERATURE (9/3/81) = 46°F

PREPARED BY:

R&M CONSULTANTS, INC.

PREPARED FOR:

ACRES

SUSPENDED SEDIMENT CONCENTRATION VS TIME & DEPTH
SETTLING COLUMN STUDY
17,200 CFS SAMPLE

FIGURE A-2

A-3

h11-23-2

ATTACHMENT B

ANNOTATED BIBLIOGRAPHY OF SEDIMENTATION PROCESSES IN GLACIAL LAKES AND RIVERS

INTRODUCTION

A literature search was conducted to obtain information on glacial lake trap efficiency of suspended sediments, with emphasis on materials smaller than 50 microns. Relevant information will provide a basis for predicting the fate of suspended sediments entering the reservoirs of the proposed Susitna Hydroelectric Project.

The bibliography contains annotations for 36 references with relevant information and a listing of 31 additional references with no specific information. There is information on depositional processes when proglacial rivers enter standing water bodies (Church and Gilbert 1975; Carmack, Gray, Pharo, and Daley 1979; Embleton and King 1975; Gilbert 1973, 1975; Gilbert and Shaw 1981; Hamlin and Carmack 1978; Pharo and Carmack 1979; Smith 1978; Sturm and Matter 1978), with details on particle size distribution for two ancient lake environments (Ashley 1975; Shaw 1975). However, research reveals that reconstructing modern depositional environments from analyses of ancient environments may be misleading, as distance from source and shore and depth of lake are not as significant as density, wind-induced currents, and stratification (Bryan 1974a, b). Furthermore, misinterpretation of depositional events can lead to overestimation of the time involved in deposition (Shaw, Gilbert, and Archer 1978). A method is presented for determining sedimentation rates by radioactive fallout (Ashley 1979). One study on a modern lake shows that suspended sediment concentrations affect density stratification (Gustavson 1975b). Two studies (Ostrem 1975; Theakstone 1976) address lake trap efficiency and distance of deposition from the source.

The literature search included a review of University of Alaska theses and publications of the University of Alaska's Institute of Water Resources and Geophysical Institute, the U.S. Geological Survey, and the U.S. Army Corps of Engineers' Cold Regions Research and Engineering Laboratory (CRREL). A computer search was conducted on the CRREL Bibliography and on Selected Water Resources Abstracts.

2-32-116

PART I - RELEVANT INFORMATION

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Discussion of suspended sediment data collected during one year (1962) for hydrologic-morphologic study of the Colville River delta. Three aspects of suspended load considered were: quantity transported in water; size of particles in suspension; and total quantity transported in a given period of time. As unit volume increases, median grain size and total load carried increases. Grain size analyses for samples representative of selected locations, depths, and times are presented. The amount and size of suspended material increased with depth at one location.

2. Ashley, G.M. 1975. Rhythmic sedimentation in glacial Lake Hitchcock, Massachusetts-Connecticut. Pages 304-320 in A.V. Jopling and B.C. McDonald, eds. Glaciofluvial and glaciolacustrine sedimentation. Society of Economic Paleontologists and Mineralogists, Tulsa, OK. Special Publication 23.

Discussion of seasonal silt and clay deposition (varves) in an ancient environment. Suspended sediment concentration affects water density far more than temperature in glacial lakes. The settling velocity of a 60 silt grain in 4°C water undisturbed by currents is 0.05 cm/second. Therefore, such a grain would settle 50 m in 1.15 days. However, silt was found in all winter clay layers, and could indicate that lake currents were present, preventing settling, or sediment was introduced year-round. Mean grain size of silt layers depends on location in the lake whereas grain size distribution of clay layers is uniform. Grain size analyses are presented, but there is no specific information on the distance traveled across the lake prior to deposition.

3. Ashley, G.M. 1979. Sedimentology of a tidal lake, Pitt Lake, British Columbia, Canada. Pages 327-345 in Ch. Schluchter, ed. Moraines and Varves. Proceedings of an INQUA Symposium of Genesis and Lithology of Quaternary Deposits, Zurich, September 10-20, 1978. A.A. Balkema, Rotterdam.

Sedimentation rates were determined by ^{137}Cs dating techniques. Grain size analyses were determined for 190 samples and mean grain size distribution was mapped. Annual sediment accumulation equalled 150± 20 x 10^3 tons, of which 50% was coarser than 50.

4. Ashley, G.M., and L.E. Moritz. 1979. Determination of lacustrine sedimentation rates by radioactive fallout (^{137}Cs), Pitt Lake, British Columbia. Canadian Journal of Earth Sciences. 16(4):965-970.

Discussion of techniques for determining modern lacustrine sedimentation rates.

5. Borland, W.M. 1961. Sediment transport of glacier-fed streams in Alaska. Journal of Geophysical Research. 66(10):3347-3350.

Developed empirical formula for sediment yield rates for glacial drainage basins based on glacier area, total drainage area, and length of watercourse. No differentiation by particle size. Used five years of U.S. Geological Survey suspended sediment data from Denali and Gold Creek stations to test formula.

6. Bryan, M.L. 1974a. Sedimentation in Kluane Lake. Pages 151-154 in V.C. Bushnell and M.G. Marcus, eds. Ice Field Ranges Research Project Scientific Results, Vol 4. American Geographical Society, New York, NY, and Arctic Institute of North America, Montreal, Canada.

Study of bathymetry, thermal structure, and sediment distribution in Kluane Lake, 1968. A weak thermocline developed in July and August, which was occasionally destroyed by storm-induced mixing. The lake is ice-covered for eight months, and receives sediment from the Slims River for four months. Statistical parameters of grain size analyses are presented. Sedimentation is affected by density, by wind-induced lake currents, and by stratification as well as by bathymetry, distance from shore and input, point and sediment composition. Highly turbid, cold glacial waters may be sufficiently dense to flow across the lake bottom regardless of thermal stratification. When the Slims River warms, it flows over the lake.

7. Bryan, M.L. 1974b. Sublacustrine morphology and deposition, Kluane Lake, Yukon Territory. Pages 171-187 in V.C. Bushnell and M.B. Marcus, eds. Icefield Ranges Research Project Scientific Results, Vol 4. American Geographical Society, New York, NY, and Arctic Institute of North American, Montreal, Canada.

Discussion of processes affecting sedimentation in lakes from glacial streams. Bathymetric mapping of Kluane Lake in 1968 and 1970 revealed growth of the Slims River delta. Cartographic and statistical analyses of bottom sediments are presented. Finest sediments farthest from the Slims River

were not in the deepest portion of the lake. Distance from source, depth of lake, and distance from shore are not significant in controlling deposition. Reconstructing depositional environments based on sediment size analysis may be misleading.

8. Carmack, E.C., C.B.J. Gray, C.H. Pharo, and R.J. Daley. 1979. Importance of lakeriver interaction on the physical limnology of the Kamloops Lake/Thompson River system Limnology and Oceangraphy. 24(4):634-644.

Discussion of physical effects of large river entering a deep, intermontane lake. No information of particle size analysis.

9. Church, M., and R. Gilbert. 1975. Proglacial fluvial and lacustrine environments. Pages 22-100 in A.V. Jopling and B.C. McDonald, eds. Glaciofluvial and glaciolacustrine sedimentation. Society of Economic Paleontologists and Mineralogists. Tulsa, OK. Special Publication 23.

Discussion of deposition when proglacial rivers enter standing water bodies. Significant events are: aggradation on the bed due to deposition of bed load extends upstream from the lake, along with reduced flow velocities; development of a high angle delta, with transport of sediment to the delta lip; movement of coarse material over the lip and down into the lake in turbidity flows (bottom flow); movement of river water down the delta front to lake water of equal density (interflow); movement of river water onto the surface of the lake if density is less than the lake (surface flow); deposition of fine-grained material and formation of varves, of which the silt (summer) portion is deposited by turbidity currents, and the clay (winter) portion by the turbidity current after stagnation, and then by slow, continuous settling from suspension. Turbidity underflow is not a continuous event in the melt season. Varve formation cannot be directly correlated to mean annual discharge, because a single large flood can create a turbidity flow. Turbidity flows resulting in more rapid deposition depend on discharge, river and lake water temperature, thermal structure of the lake, quantity of sediment suspended in the lake from previous events, and river and lake dissolved sediment concentrations. No specific information on particle size is presented.

10. Embleton, C., and C.A.M. King. 1975. Glacial geomorphology. John Wiley and Sons, New York, NY. pp. 532-558.

Review of general principles affecting sediment deposition in lacustrine environments with examples. Lake floor deposits become increasingly fine toward center or deepest parts of

lakes, requiring quiet water and long settling periods. Turbidity currents formed by cold, silt-laden stream water are important in distributing sediment across the lake floor. Rhythmites (laminated deposits) develop in cold freshwater lakes receiving intermittent streamflow, and in some cases form on an annual basis (varves). They can also form from sudden fluctuations in discharge (bursting of an ice-dammed lake upstream), unseasonal warm or cold spells, or periodic storms.

11. Everts, C.H. 1976. Sediment discharge by glacier-fed rivers in Alaska. Pages 907-923 in Rivers '76. Vol. 2. Symposium on Inland Waterways for Navigation, Flood Control and Water Diversions. 3rd Annual Symposium, Colorado State University, Fort Collins, CO. Waterways, Harbors and Coastal Engineering Div., American Society of Civil Engineers, New York, NY.

    Investigation of glacial sediments discharged into the coastal zone (Knik, Matanuska). Size distribution, composition, and settling characteristics of glacial sediment are important characteristics in determining where the sediment will be transported and deposited when it reaches the marine environment. Based on particle size distribution analyses, it appears that fine-grained particles pass completely through the river system. Ice margin lakes fringing glaciers are depositories for coarse sediments. Clay minerals were absent, which is significant because clay particles form aggregates with other fine-grained particles and settle more rapidly. This absence may be common in other glacial areas because of negligible chemical weathering in the source areas.

12. Fahnestock, R.K. 1963. Morphology and hydrology of a glacial stream: White River, Mount Rainier, Washington. U.S. Geological Survey. Professional Paper 422A. 70 pp.

    Investigation of formation of a valley train by a proglacial stream. Particle size analyses of deposited material showed silts and clays were washed out of stream deposits. Analysis of suspended load indicated that silt and clay stay in suspension and are carried out of the study area into Puget Sound.

13. Fahnestock, R.K. 1969. Morphology of the Slims River. Pages 161-172 in V.C. Bushnell and R.H. Ragle, eds. Ice Field Ranges Research Project Scientific Results, Vol. 1. American Geographical Society, New York, NY, and Arctic Institute of North America, Montreal, Canada.

    Investigation of the Slims River, a proglacial stream flowing 14 miles from Kaslawulsh Glacier to Kluane Lake. The river is modifying a valley train deposited when the glacier was up

against a terminal moraine. It is regrading, ie, adjusting to a decrease in load at the source by cutting in the upper reaches and depositing in the lower reaches. The Slims River is also affected by downstream changes in the base level, which is controlled by the extension of the delta into Kluane Lake and the variation in lake level. As the volume growth rate of the delta is not known, the sediment transport rate cannot be estimated. Suspended sediment is predominantly silt and clay. No data on particle size distribution.

14. Gaddis, B. 1974. Suspended-sediment transport relationships for four Alaskan glacier streams. M.S. Thesis. University of Alaska, Fairbanks, AK. 102 pp.

    Investigation of suspended sediment transport relationships in glacial streams at Gulkana, Maclaren, Eklutna, and Wolverine glaciers. Data on mean particle size is presented for four glacial streams for one season at sites near the terminus. Sediment availability depends on amount of sediment, distance travelled downstream, and mechanical nature of sediment entrainment (no specific information on entrainment).

15. Gilbert, R. 1973. Processes of underflow and sediment transport in a British Columbia mountain lake. Pages 493-507 in Fluvial Processes and Sedimentation. Proceedings of the 9th Hydrology Sympasuim, University of Alberta, Edmanton. Canada, May 8-9. Subcommittee on Hydrology, Associate Committee on Geodesy and Geophysics, National Research Council of Canada.

    Description of processes involved in formation of varved sediment deposits in proglacial lakes, primarily underflow and interflow. Underflow increases with increase of water and suspended sediment inflow. Cores obtained to determine thickness and comparision of varves. No information on particle size distribution.

16. Gilbert, R. 1975. Sedimentation in Lillooet Lake, British Columbia. Canadian Journal of Earth Sciences. 12(10):1697-1711.

    Lillooet Lake receives sediment from a 3,580 sq km drainage basin, of which 7% is glacier-covered. Interflow and underflow distribute sediment through the lake in summer when the lake is stratified. Factors affecting distribution are: density characteristics of the lake and inflowing water, as determined by temperature and suspended sediment concentrations; currents induced by wind and inflow; thermal structure of the lake water, which determines the nature of circulation patterns and allows interflow along the thermocline; diurnal and seasonal fluctuations in inflowing waters and sediment;

and the large annual volume of inflow (4.5 times greater than the lake volume on the average). Interflow carries sediment at the base of the epilimnion to the distal end of the lake in one to two days. No specific information on particle size.

17. Gilbert, R., and J. Shaw. 1981. Sedimentation in proglacial Sunwapta Lake, Alberta. Canadian Journal of Earth Sciences. 18(1):81-93.

Examination of hydrologic and limnologic conditions of Sunwapta Lake, a small, proglacial lake in the Canadian Rockies. Sediment input was measured and sedimentation rates were calculated. Sediments of small, shallow lakes with large and highly variable inflows are expected to demonstrate lateral and vertical variability, whereas those in large proglacial lakes are more predictable due to modification by large, stable water masses.

18. Gustavson, T.C. 1975a. Bathymetry and sediment distribution in proglacial Malaspina Lake, Alaska. Journal of Sedimentary Petrology. 45:450-461.

See next abstract

See next abstract

19. Gustavson, T.C. 1975b. Sedimentation and physical limnology in proglacial Malaspina Lake, southeastern Alaska. Pages 249-263 in A.V. Jopling and B.C. McDonald, eds. Glaciofluvial and glaciolacustrine sedimentation. Society of Economic Paleontologists and Mineralogists, Tulsa, OK. Special Publication 23.

Underflow, interflow, and overflow water entered Malaspina Lake, and the type of flow is dependent on the relative suspended sediment content of the lake water and the inflowing melt water. The 18-km long lake is density stratified (increasing suspended sediment concentration with depth) but not thermally stratified. No specific information on particle size or trap efficiency is presented.

20. Guymon, G.L. 1974. Regional sediment yield analysis of Alaska streams. Journal of the Hydraulics Div. of the American Society of Civil Engineers. 100(HY1):41-51.

Analyzed Borland's (1961) formula. Considered particle size, but used an average particle size in the formula. However, concluded that particle size affects application of the formula.

21. Hamblin, P.F., and E.C. Carmack. 1978. River-induced currents in a fjord lake. Journal of Geophysical Research. 83(C2):885-889.

Discussion of dynamics of strong flowing river entering a long, narrow lake (Kamloops Lake, B.C.). River-induced currents influence circulation patterns in a fjord lake. No specific information on sedimentation rates or particle size analysis.

22. Hobbie, J.E. 1973. Arctic limnology: a review. Pages 127-168 in M.E. Britton, ed. Alaskan arctic tundra. Arctic Institute of North America. Technical Paper 25.

    Review of properties of lake in northern tundra regions. Thermal cycle of deep arctic lakes is highly variable, and stratification is uncommon, occurring only in warm, calm weather after lake waters rise to 4°C. Deep lakes maintain circulation even when ice covered. Deeper lakes are relatively turbid as a result of glacial flour from streams draining active glaciers. Lake Peters is fed by glacial streams and drains via a 1-km long, 15-m deep channel into Lake Schrader in the Brooks Range. Both are 50-60 m deep. Lake Peters acts as a settling basin. When dense glacial water enters Lake Peters in June, it sinks to the bottom, and the lake fills upward with turbid water.

23. Mathews, W.H. 1956. Physical limnology and sedimentation in a glacial lake. Bulletin of the Geological Society of America. 67:537-552.

    Garibaldi Lake, British Columbia, receives sediment from two glacial streams with relatively low sediment content. Particle size and composition of bottom deposit analyses revealed slow transport to site of deposition and slow rate of deposition for clays. No information on amount of sediment passing through system.

24. Ostrem, G. 1975. Sediment transport in glacial meltwater streams. Pages 101-122 in A.V. Jopling and B.C. McDonald, eds. Glaciofluvial and glaciolacustrine sedimentation. Society of Economic Paleontologists and Mineralogists, Tulsa, OK. Special Publication 23.

    Recognized problems of utilizing glacial waters for hydroelectric projects, specifically in reservoirs and turbines. Grain size analyses of cores of varved sediments showed that summer layers consisted of coarser material than winter layers (based on 20 micron grain size variation). X-ray diffraction analyses showed that summer deposits contained more quartz (rapid sedimentation), and winter deposits, more mica (slower sedimentation). For one 1,800-m long proglacial lake over 29 years, about 70 percent of the total suspended sediment input was deposited.

Discussion of dynamics of strong flowing river entering a long, narrow lake (Kamloops Lake, B.C.). River-induced currents influence circulation patterns in a fjord lake. No specific information on sedimentation rates or particle size analysis.

22. Hobbie, J.E. 1973. Arctic limnology: a review. Pages 127-168 in M.E. Britton, ed. Alaskan arctic tundra. Arctic Institute of North America. Technical Paper 25.

Review of properties of lake in northern tundra regions. Thermal cycle of deep arctic lakes is highly variable, and stratification is uncommon, occurring only in warm, calm weather after lake waters rise to 4°C. Deep lakes maintain circulation even when ice covered. Deeper lakes are relatively turbid as a result of glacial flour from streams draining active glaciers. Lake Peters is fed by glacial streams and drains via a 1-km long, 15-m deep channel into Lake Schrader in the Brooks Range. Both are 50-60 m deep. Lake Peters acts as a settling basin. When dense glacial water enters Lake Peters in June, it sinks to the bottom, and the lake fills upward with turbid water.

23. Mathews, W.H. 1956. Physical limnology and sedimentation in a glacial lake. Bulletin of the Geological Society of America. 67:537-552.

Garibaldi Lake, British Columbia, receives sediment from two glacial streams with relatively low sediment content. Particle size and composition of bottom deposit analyses revealed slow transport to site of deposition and slow rate of deposition for clays. No information on amount of sediment passing through system.

24. Ostrem, G. 1975. Sediment transport in glacial meltwater streams. Pages 101-122 in A.V. Jopling and B.C. McDonald, eds. Glaciofluvial and glaciolacustrine sedimentation. Society of Economic Paleontologists and Mineralogists, Tulsa, OK. Special Publication 23.

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25. Ostrem, G., T. Ziegler, and S.R. Ekman. 1970. A study of sediment transport in Norwegian glacial rivers, 1969. Institute of Water Resources, Dept. of Hydrology, Oslo, Norway. Report 6/70. Report for Norwegian Water Resources and Electricity Board. Translated from Norwegian by H. Carstens. 1973. Institute of Water Resources, University of Alaska, Fairbanks, AK. Report 35. 1 vol.

Investigations were conducted on water discharge and sediment volume measurements in glacial rivers above and at the outlet of glacial lakes to calculate the sedimentation of fine material on the bottom of the lakes. Volume of material available for transport is probably largest at the beginning of the season. No data on particle size.

26. Pharo, C.H., and E.D. Carmack. 1979. Sedimentation processes in a short residence-time intermontane lake, Kamloops Lake, British Columbia. Sedimentology. 26:523-541.

Sediment transport and deposition in the lake is controlled by three interdependent processes: delta progradation at the lake-river confluence; sediment density surges originating along the delta face, which result in turbidite sequences lakeward from the base of the delta; and dispersal by the interflowing river plume, which, due to Coriolis effects, results in a higher sedimentation rate and greater fraction of coarser material along the right-hand of the lake in the direction of flow. Suspended sediment concentrations are high above the thermocline where higher turbulence, maintained by wind mixing and river inter interflow, reduces settling velocities. Particles settle rapidly once they enter the hypolimnion.

27. Ritchie, J.C., J.R. McHenry, and A.C. Gill. 1973. Dating recent reservoir sediments. Limnology and Oceanography. 18:254-283.

Discussion of radioactive ^{137}Cs dating. Method could be used to date sediment in reserviors that have not been surveyed.

28. Shaw, J. 1975. Sedimentary successions in Pleistocene ice-marginal lakes. Pages 281-302 in A.V. Jopling and B.C. McDonald, eds. Glaciofluvial and glaciolacustrine sedimentation. Society of Economic Paleontologists and Mineralogists, Tulsa, OK. Special Publication 23.

Discussion of sedimentation in proximal portion of a glacial lake based on interpretation on the ancient environment. Mean grain size values were determined for sections of each facies from o to 80. No information on transport of fine materials.

29. Shaw, J. 1977. Sedimentation in an alpine lake during deglaciation, Okanagan Valley, British Columbia, Canada. Geografiska Annaler. 59(A):221-240.

Ancient lake sediments were examined to develop a model of alpine lake sedimentation based on changing depositional processes with time and distance from the ice margin.

30. Shaw, J., R. Gilbert, and J.J.J. Archer. 1978. Proglacial lacustrine sedimentation during winter. Arctic and Alpine Research. 10(4):689-699.

Discussion of deposition of coarse-grained sediments during winter in Lillooet Lake. Misinterpretation can lead to overestimation of time seqences of deposition.

31. Slatt, R.M. 1970. Sedimentological and geochemical aspects of sediment and water from ten Alaskan valley glaciers. Ph.D. Thesis. University of Alaska, Fairbanks, AK. 125 pp. Studied five groups of glaciers with different bedrock lithologies; Worthington and Matanuska; Castner and Fels; Gulkana and College; Rendu and Reed; and Carroll and Norris. Particle size analyses and mineralogy of superglacial and suspended stream sediments are presented. The environment of transport has a much greater effect on grain size than the nature of the starting material.

32. Slatt, R.M. 1971. Texture of ice-cored deposits from ten Alaskan valley glaciers. Journal of Sedimentary Petrology. 41(3):828-834.

Revised and condensed portions of Ph.D. thesis (see above).

33. Smith, N.D. 1978. Sedimentation processes and patterns in a glacier-fed lake with low sediment input. Canadian Journal of Earth Sciences. 15(5):714-756. Snow melt and glacial melt waters carrying relatively low suspended sediment concentrations enter Hector Lake in the eastern Rocky Mountains, Alberta. When stratified, water and fine sediments enter the lake as interflow and overflow. Grain size analyses were conducted on 42 cores. Deposition varies left to right as well as distally due to katabatic winds generating downlake currents in the epilimnion that are deflected southward (rightward) by the Coriolis force.

34. Sturm, M., and A. Matter. 1978. Turbidites and varves in Lake Brienz (Switzerland): deposition of clastic detritus by density currents. Pages 147-168 in A. Matter and M.E. Tucker, eds. Modern and ancient lake sediments. International Association of Sedimentologists. Special Publication 2.

Discussion of sediment transport and deposition by overflow, interflow, and underflow in a long, narrow, deep basin with rivers entering at each end. Fine-grained sediments supplied by overflows and interflows settle continuously during summer thermal stratification. Most of the fine-grained particles remain in suspension at the thermocline because the vertical density gradient is more dependent on temperature than on an increase in density due to suspended particles. During fall turnover, the remaining sediment trapped at the thermocline settles.

35. Theakstone, W.H. 1976. Glacial lake sedimentation, Austerdalsisen, Norway. Sedimentology. 23(5):671-688.

A lake completely filled with glacial sediments, over which braided stream deposits formed. A new proglacial lake then formed. Discussion of bedding and composition of ancient lake sediments. Initially, deposition was very slow in deep (80 m) water. In another lake 300 m from a glacier, about 75 percent of the sediment transported in suspension is retained in the basin, but the amount retained in one day is highly variable. The daily summer values exceeded the minimum by 200 times (data not presented).

36. Tice, A.R., L.W. Gatto, and D.M. Anderson. 1972. The mineralogy of suspended sediment in some Alaskan glacial streams and lakes. Cold Regions Research and Engineering Laboratory Corps of Engineers, U.S. Army, Hanover, NH. Research Report 305. 10 pp.

Investigation of the role of chemical weathering of bedrock in cold regions determined that no chemical changes occurred in fine suspended material. Suspended sediment samples were obtained for X-ray diffraction analyses from galcial outwash streams and lakes in seven areas (Chackachamna, Palmer-Matanuska, Moose Pass-Portage, Valdez, Juneau, Mt. McKinley National Park, and Black Rapids).

0 0 1 1 6

PART II- NO SPECIFIC INFORMATION

1. Agterberg. F.P., and I. Banerjee. 1969. Stochastic model for the deposition of varves in glacial Lake Barlow-Ojibway, Ontario, Canada. Canadian Journal of Earth Sciences. 6:625-652

2. Banerjee, I., and B.C. McDonald. 1975. Nature of esker sedimentation. Pages 132-154 in A.V. Jopling and B.C. McDonald, eds. Glaciofluvial and glaciolacustrine sedimentation. Society of Economic Paleontologists and Mineralogists, Tulsa, OK. Special Publication 23.

3. Boothroyd, J.C. and G.M Ashley. 1975. Processes, bar morphology, and sedimentary structures on braided outwash fans, northeastern Gulf of Alaska. Pages 193-222 in A.V. Jopling and B.C. McDonald, eds. Glaciofluvial and glaciolacustrine sedimentation. Society of Economic Paleontologists and Mineralogists, Tulsa, OK. Special Publication 23.

4. Bradley, W.H. 1965. Vertical density currents. Science. 150(3702):1423-1428.

5. Clague, J.J. 1975. Sedimentology and paleohydrology of late Wisconsinan outwash, Rocky Mountain trench, southeastern British Columbia. Pages 223-237 in A.V. Jopling and B.C. McDonald, eds. Glaciofluvial and glaciolacustrine sedimentation. Society of Economic Paleontologists and Mineralogists, Tulsa, OK. Special Publication 23.

6. Everts, C.H. and H.E. Moore. 1976. Shoaling rates and related data from Knik Arm near Anchorage, Alaska. Coastal Engineering Research Center, Corps of Engineers, U.S. Army, Fort Belvoir, VA. Technical Paper 76-1. 84 pp.

7. Gilbert, R. 1971. Observations on ice-dammed Summit Lake, British Columbia, Canada. Journal of Glaciology. 10(60):351-356.

8. Gustavason, T.C., G.M. Ashley, and J.C. Boothroyd. 1975. Depositional sequences in glaciolacustrine deltas. Pages 264-280 in A.V. Jopling and B.C. McDonald, eds. Glaciofluvial and glaciolacustrine sedimentation. Society of Economic Paleontologists and Mineralogists, Tulsa, OK. Special Publication 23.

9. Guymon, G.L. 1974. Sediment relations of selected Alaskan glacier-fed streams. Institute of Water Resources, University of Alaska, Fairbanks, AK. Report 51. 17 pp.

10. Hobbie, J.E., ed. 1980. Limnology of tundra ponds: Barrow, Alaska. Dowden, Hutchinson and Ross, Inc., Stroudsburg, PA. US/IBP Synthesis Series 13. 514 pp.

11. Howarth, P.J., and R.J. Price. 1969. The proglacial lakes of Breidamerdurjokull and Fjallsjokull, Iceland. Geographical Journal. 135:573-581.

12. Jopling, A.V. 1975. Early studies on stratified drift. Pages 4-21 in A.V. Jopling and B.C. McDonald, eds. Glaciofluvial and glaciolacustrine sedimentation. Society of Economic Paleontologists and Mineralogists, Tulsa, OK. Special Publication 23.

13. Kindle, E.M. 1930. Sedimentation in a glacial lake. Journal of Geology. 38(1):81-87.

14. Lawson, D.E. 1977. Sedimentation in the terminus region of the Matanuska Glacier, Alaska. Ph.D. Thesis. University of Illinois, Urbana-Champaign, IL. 287 pp.

15. Long, W.E. 1972. Glacial processes and their relationship to streamflow; Flute Glacier, Alaska. Institute of Water Resources, University of Alaska, Fairbanks, AK. Report 18. 1 vol.

16. Ludlam, S.D. 1967. Sedimentation in Cayuga Lake, New York. Limnology and Oceanography. 12(4):618-632.

17. McDonald, B.C., and W.W. Shilts. 1975. Interpretation of faults in glaciofluvial sediments. Pages 123-131 in A.V. Jopling and B.C. McDonald, eds. Glaciofluvial and glaciolacustrine sedimentation. Society of Economic Paleontologists and Mineralogists, Tulsa, OK. Special Publication 23.

18. Moores, E.A. 1962. Configuration of the surface velocity profile of Gulkana Glacier, central Alaska Range, Alaska. M.S. Thesis. University of Alaska, Fairbanks, AK. 47pp.

19. Moravek, J.R. 1973. Some further observations on the behavior of an ice-dammed self-draining lake, Glacier Bay, Alaska, USA. Journal of Glaciology. 12(66):505-507.

20. Reger, R.D. 1964. Recent glacial history of Gulkana and College Glaciers, central Alaska Range, Alaska. M.S. Thesis. University of Alaska, Fairbanks, AK. 75 pp.

21. Rust, B.R. 1975. Fabric and structure in glaciofluvial gravels. Pages 238-248 in A.V. Jopling and B.C. McDonald, eds. Glaciofluvial and glaciolacustrine sedimentation. Society of Economic Paleontologists and Mineralogists, Tulsa, OK. Special Publication 23.

2-32-129

22. Rust, B.R., and R. Romanelli. 1975. Late quaternary subaqueous outwash deposits near Ottawa, Canada. Pages 177-192 in A.V. Jopling and B.C. McDonald, eds. Glaciofluvial and glaciolacustrine sedimentation. Society of Economic Paleontologists and Mineralogists, Tulsa, OK. Special Publication 23.

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25. Sellmann, P.V. 1962. Flow and ablation of Gulkana Glacier, central Alaska Range, Alaska. M.S. Thesis University of Alaska, Fairbanks, AK. 36 pp.

26. Shira, D.L. 1978. Hydroelectric powerplant siting in glacial areas of Alaska. Pages 59-76 in Applied Techniques for Cold Environments, Vol. 1. Proceedings of the Cold Regions Specialty Conference, Anchorage, AK, May 17-19. American Society of Civil Engineers, New York, NY.

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28. Stone, K.H. 1963. Alaskan ice-dammed lakes. Association of American Geographers: Annals. 52:332-349.

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31. Yould, E.P., and T. Osterkamp. 1978. Cold regions considerations relative to development of the Susitna hydroelectric project. Pages 887-895 in Applied Techniques for

Cold Environments, Vol 2. Proceedings of the Cold Regions Specialty Conference, Anchorage, AK, May 17-19. American Society of Civil Engineers, New York, NY.

2. Water Use and Quality

Comment 33 (p. E-2-96, para. 2)

Provide quantitative estimates of nutrient adsorption on suspended sediments (e.g., glacial flour) that will be transported into Watana Reservoirs. Provide data on levels of exchangeable phosphorus in soils in the Watana and Devil Canyon impoundment zones.

Response

Quantitative estimates of nutrient adsorption on suspended sediments (e.g., glacial flour) that will be transported into Watana Reservoir are not available at the present time. Data on levels of exchangeable phosphorus in soils in the Watana and Devil Canyon impoundment zones do not presently exist.

Additionally, to our knowledge at the present time, approved and standardized methods do not exist for quantitatively estimating exchangeable phosphorus in soil samples. In fact, the definition of the term "exchangeable phosphorus" is not standardized in state-of-the-art limnological literature.

The present level of knowledge about the Susitna River drainage basin and the limnology of the two proposed reservoirs indicates that the project reservoirs will maintain a low productivity (oligotrophic) trophic status due to phosphorus limitation (Peratrovich, Nottingham and Drage, Inc. and Hutchison, 1982; Peterson and Nichols, 1982; Rast and Lee, 1978; Stuart, 1983; Vollenweider and Kerekes, 1980).

Data about nutrients attached to turbidity particles which are potentially exchangeable with juxtapositioned microbial biomass are difficult, time consuming, and expensive to acquire. We hope that the FERC staff will agree with our position and withdraw or temper this request.

References

Peratrovich, Nottingham and Drage, Inc. and Ian P.G. Hutchinson, 1982. Susitna Reservoir Sedimentation and Water Clarity Study. Prepared for Acres American Inc., Anchorage, Alaska, 35 pp.

Peterson, L.A. and G. Nichols, 1982. Water Quality Effects Resulting from Impoundment of the Susitna River. Prepared with R & M Consultants, Inc. for Acres American Inc., Buffalo, New York, 18 pp.

Rast, W. and G.F. Lee, 1978. Summary analysis of the North American (U.S. portion) OECD entrophication project: nutrient loading - lake response relationships and trophic state indices. EPA-600/3-78-008. 455 pp.

Stuart, T.J., 1983. The effects of freshet turbidity on selected aspects of the biogeochemistry and the trophic status of Flathead Lake, Montana, U.S.A., Ph.D. dissertation, North Texas State University, Denton, Texas, 229 pp.

Vollenweider, R.A. and J. Kerekes, 1980. The loading concept as a basis for controlling eutrophication philosophy and preliminary results of the OECD Programme on eutrophication. Prog. Wat. Tech., Vol. 12, Norway, pp. 5-18. IAWPR/Pergamon Press Ltd.

EXHIBIT E

2. Water Use and Quality

Comment 35 (p. E-2-100, para. 4)

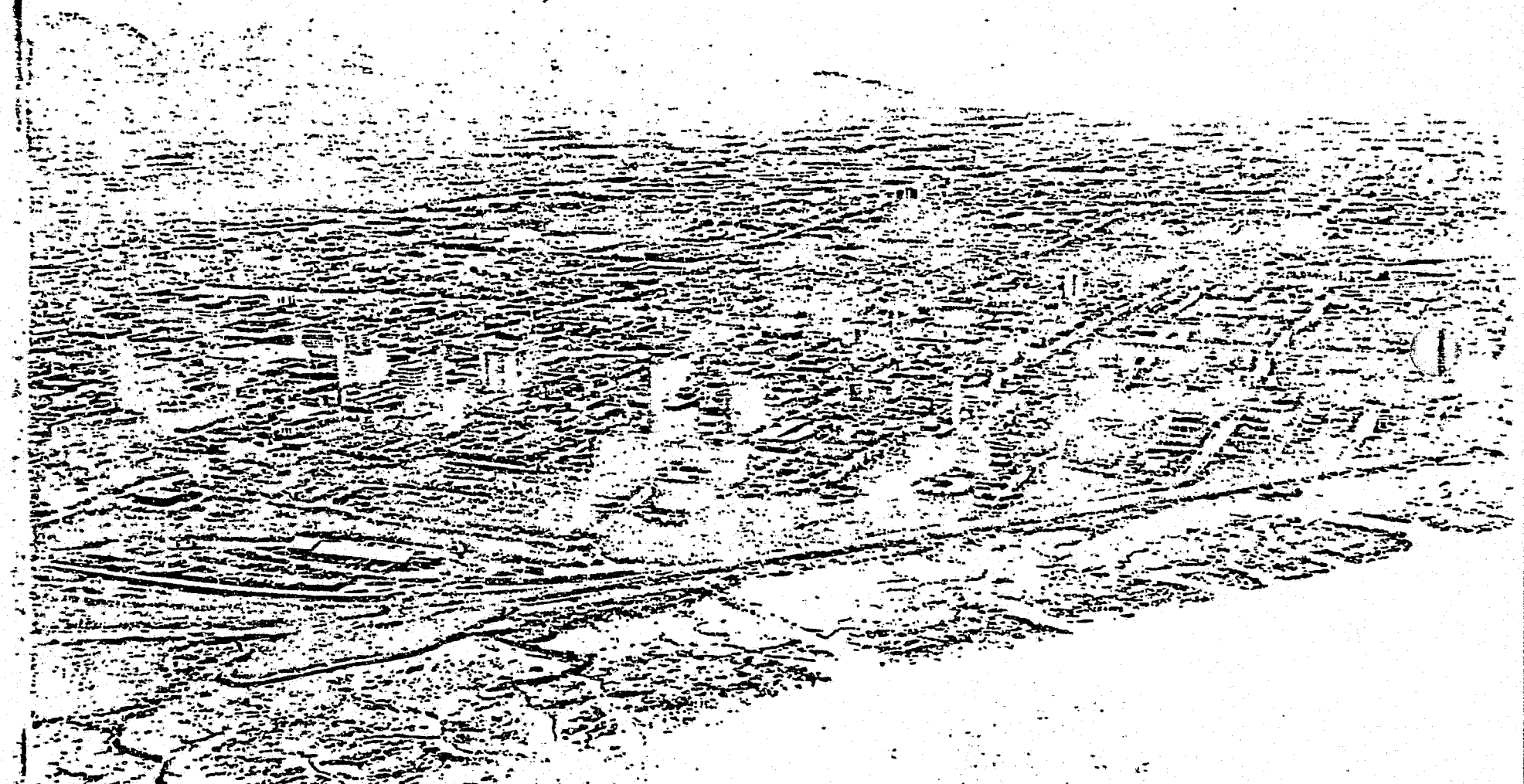
Provide real and simulated salinity data which show the accuracy of the Corps of Engineers salinity model for predicting salinity in Cook Inlet at different locations (e.g., Node 27) under different flow conditions. Also, provide parameter values used in these simulations and document the source of the values used.

Response

Real and simulated salinity data for Node 27 near the Susitna River mouth are provided in pp. 2-35-2 to 2-35-35.

Also provided is a user's guide (pp. 2-35-36 to 2-35-171) for the computer modeling effort conducted by the Corps of Engineers on the estuary hydrodynamics and water quality of Cook Inlet. The user's guide documents parameter values and their source for use in the Cook Inlet water quality modeling effort. An example problem data set and simulation results are presented on pp. 2-35-92 to 2-35-131.

Volume 3
WATER QUALITY, KNIK ARM - UPPER COOK INLET



METROPOLITAN ANCHORAGE URBAN STUDY

The Alaska District, Corps of Engineers and The Municipality of Anchorage

1979

2-35-7

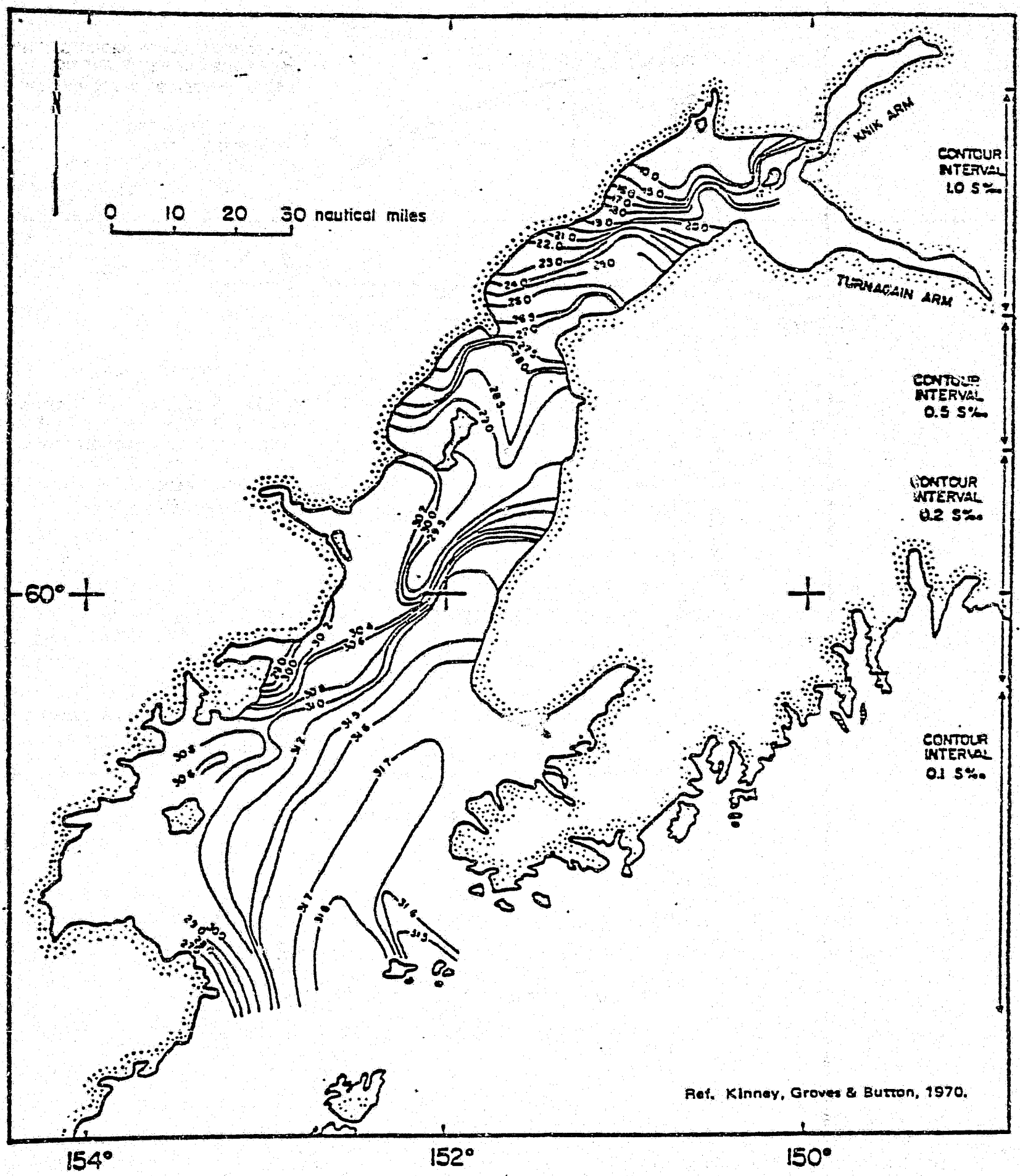


FIGURE 2.5 Surface Salinity Distribution in Cook Inlet

2-35-3

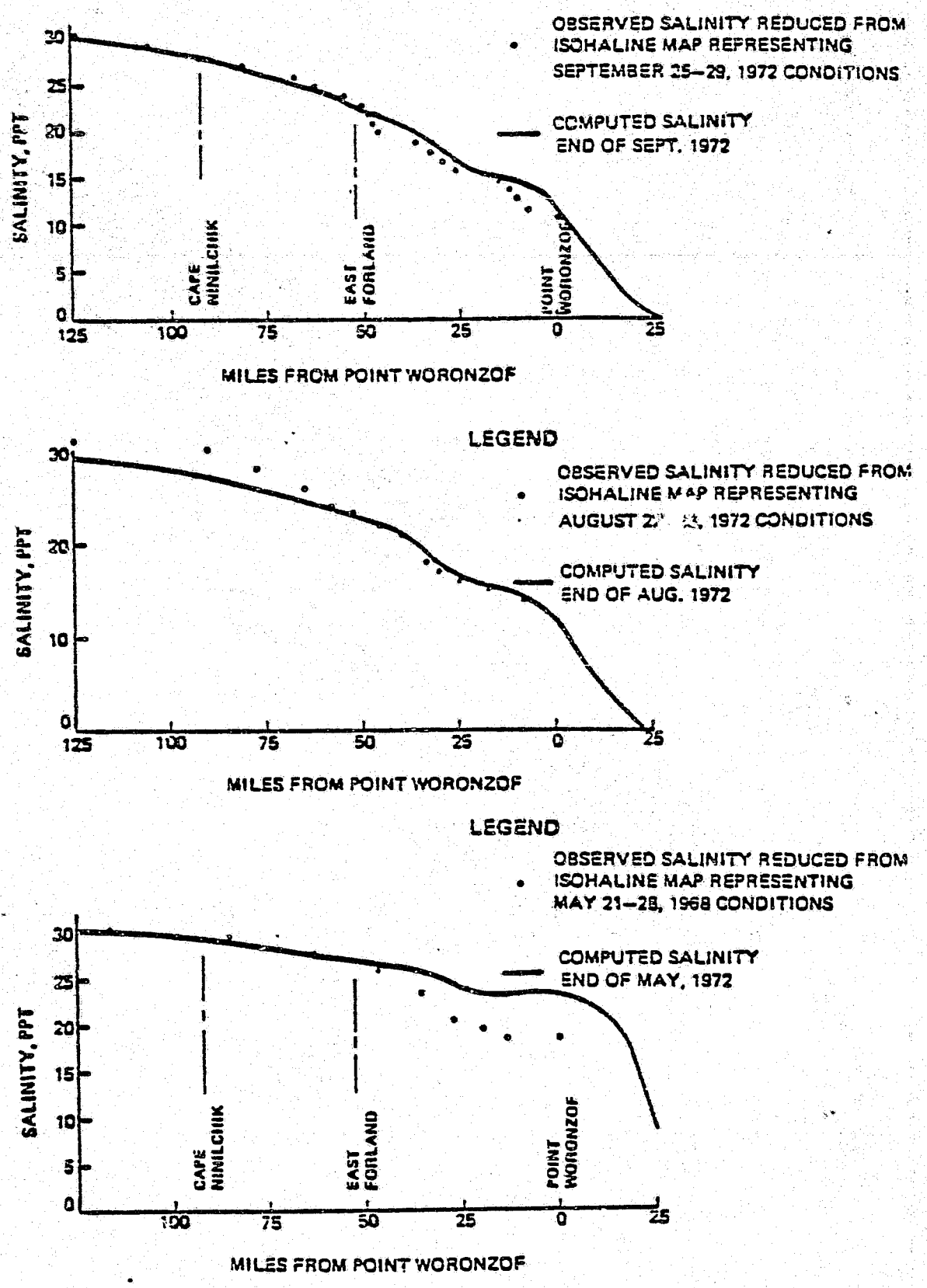


FIGURE 7.4 Computed and Observed Salinity between Anchor Point and Knik Arm

2-35-4

RESOURCE MANAGEMENT ASSOCIATES
Research • Development • Applications

11 October 1982

HARZA-EBASCO
Susitna Joint Venture
Document Number

525

Please Return To
DOCUMENT CONTROL

Mr. Wayne M. Dyok
Acres American Inc.
Suite 305
1577 C Street
Anchorage, Alaska 99501

Dear Mr. Dyok:

As authorized by your letter to Dr. Robert Carlson, dated September 23a 1982, I have performed a numerical modeling study to determine the effects of altered Susitna River flows on the salinity of Cook Inlet. The following describes the results of this study.

Background

The construction and operation of the proposed Susitna River Hydroelectric Project will alter the amount of freshwater which enters Cook Inlet from the Big Susitna River. With this project, inflows during the high runoff summer months will be reduced and increased during the low runoff winter months. To assess the effects of this change in freshwater inflow on the salinity distribution within Cook Inlet, a numerical model previously applied to Cook Inlet during a Corps of Engineers sponsored study was used (1,2).

Model Application

The numerical model used in this application represents the estuary as a series on nodes (discrete volume elements) and interconnecting channels. In the aggregate this node-channel representation provides a 2-dimensional (i.e., 2-dimensional in the horizontal plane and uniform vertically) description of the estuary including flow rates and velocities and water quality parameter concentrations over time and space.

The model representation of Cook Inlet shown in Figure 1 was developed in the beforementioned study. This model representation is adequate for this study, therefore no modification or further calibration was performed. To provide a more detailed description of the model concepts and its application to Cook Inlet, excerpts from the report to the Corps of Engineers (1) have been included as Exhibit A.

Typical hydraulic conditions were used for the study. Monthly average inflows from the various streams tributary to Cook Inlet were provided by Dr. Robert Carlson. These tributary flows, including the

pre and post Susitna Hydroelectric Project flows along with the model inflow locations are shown in Table 1.

Study Results

To assess the effects of the proposed project on the salinity of Cook Inlet, the following hydrodynamic and dynamic water quality simulations were performed.

[redacted]

Cases 3 and 4 had very similar Susitna River flow and therefore the effects on Cook Inlet salinity were quite similar.

[redacted] (i.e., Node 27). [redacted] The pre and post project salinities distribution at six locations within the inlet are shown in Figures 2 through 7. The end of month salinities at selected nodal locations are presented in Exhibit B.

I hope that this brief summary of our modeling approach and results meets the requirements of your project. It has been a pleasure providing this service to Acres American and I hope we are able to assist you in future studies.

Sincerely,

Donald J. Smith

DJS/ch
cc: Dr. Robert Carlson
Enclosures

2-35-1

REFERENCES

1. Tetra Tech Inc., "Water Quality Study, Knik Arm and Upper Cook Inlet, Alaska," report to the Corps of Engineers, September, 1977.

2. Smith, D. J., "User's Guide for the Estuary Hydrodynamic and Water Quality Models," Tetra Tech report to the Corps of Engineers, September, 1977.

Z-3577

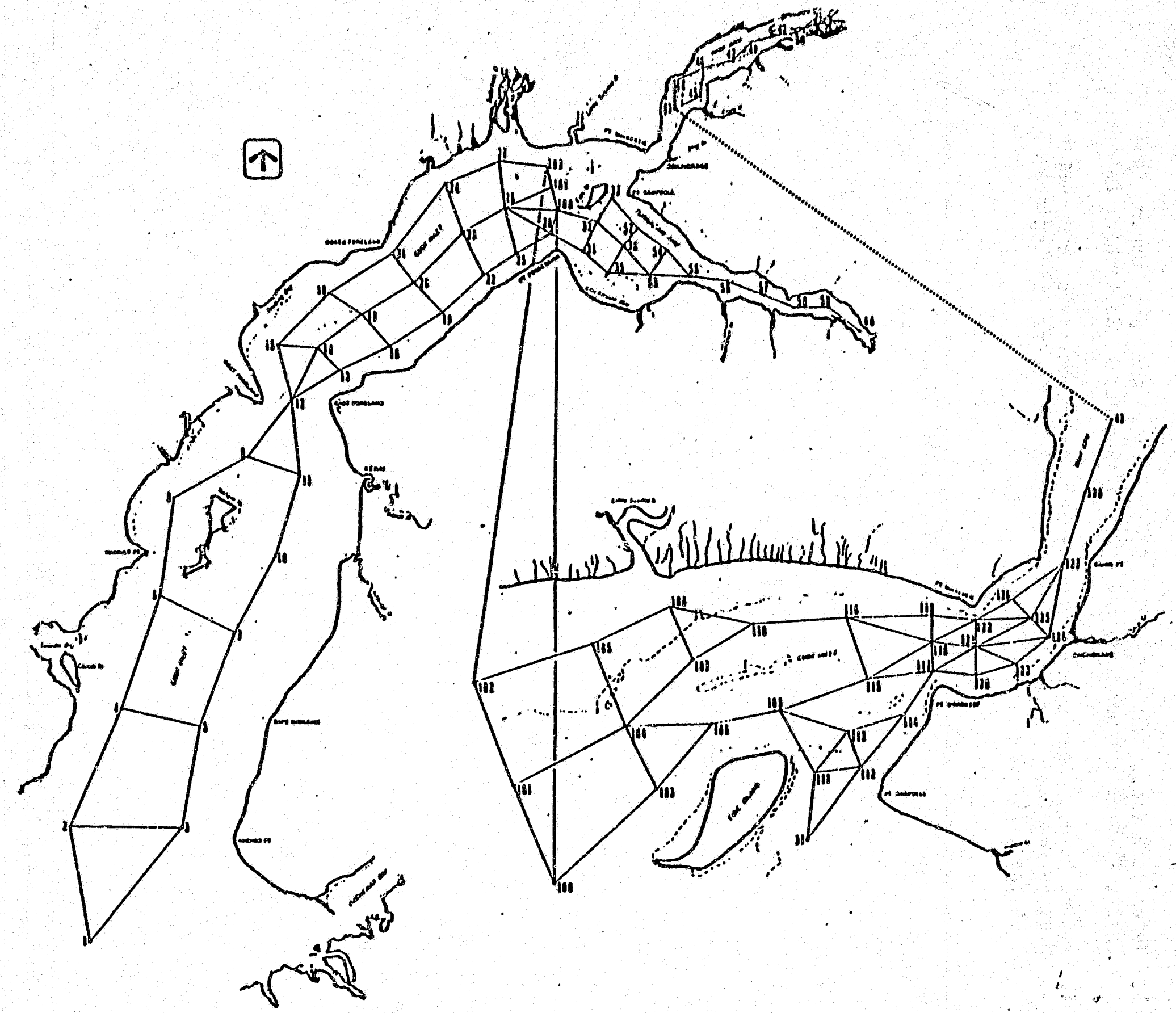


FIGURE 1

NODE-CHANNEL NETWORK REPRESENTATION OF COOK INLET

TABLE 1

TYPICAL RIVER INFLOWS (cfs) TO COOK INLET

RIVER LOCATION	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
NODE 27 .. CASE 1 +	30035	12658	8215	7906	7037	6320	6979	60463	123698	131932	110841	65963
NODE 27 .. CASE 3 ++	32392	19191	17033	16108	14705	13500	13319	57611	107381	117024	102348	62629
NODE 27 .. CASE 4 ++	32184	19772	17820	16973	15922	14415	13640	59930	105702	116333	101733	63254
NODE 11	6262	2768	1787	1616	1030	1200	1218	2852	7246	11955	13895	12010
NODE 10	4441	2266	1267	794	631	571	573	737	1519	4293	7434	7079
NODE 7	394	309	185	160	173	205	518	723	401	280	286	387
NODE 8	4590	2243	1521	1140	939	828	820	1938	10669	22353	22461	11279
NODE 24	9329	4459	3073	2317	1909	1682	1667	3939	12682	45428	45647	22922
NODE 50	7695	3457	2068	1646	1399	1225	1707	7483	28070	47454	38654	20983
NODE 125	761	288	193	143	119	121	155	561	2363	4048	3815	2060
NODE 55	1083	400	209	91	45	45	100	1028	3485	2721	2120	1556
NODE 116	3700	2082	1511	1130	904	869	880	3427	7354	6319	4200	2856

+ .. PRE PROJECT SUSITNA RIVER FLOWS

++ .. POST PROJECT SUSITNA RIVER FLOWS

2-35-9

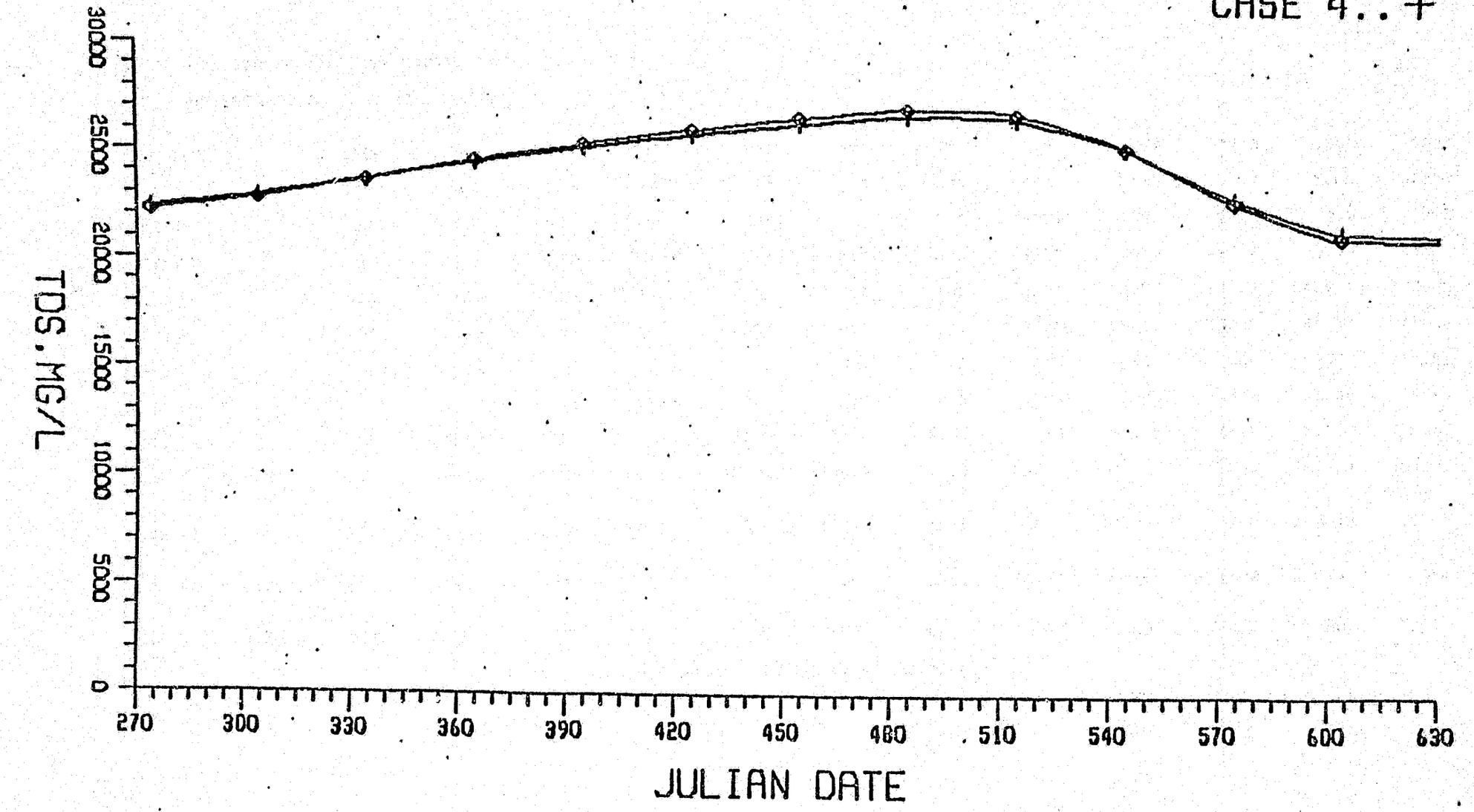


FIGURE 2

TEMPORAL VARIATION IN SALINITY WITHIN COOK INLET NEAR
EAST FORLAND UNDER PRE AND POST
SUSITNA HYDROELECTRIC PROJECT CONDITIONS

2-35-10

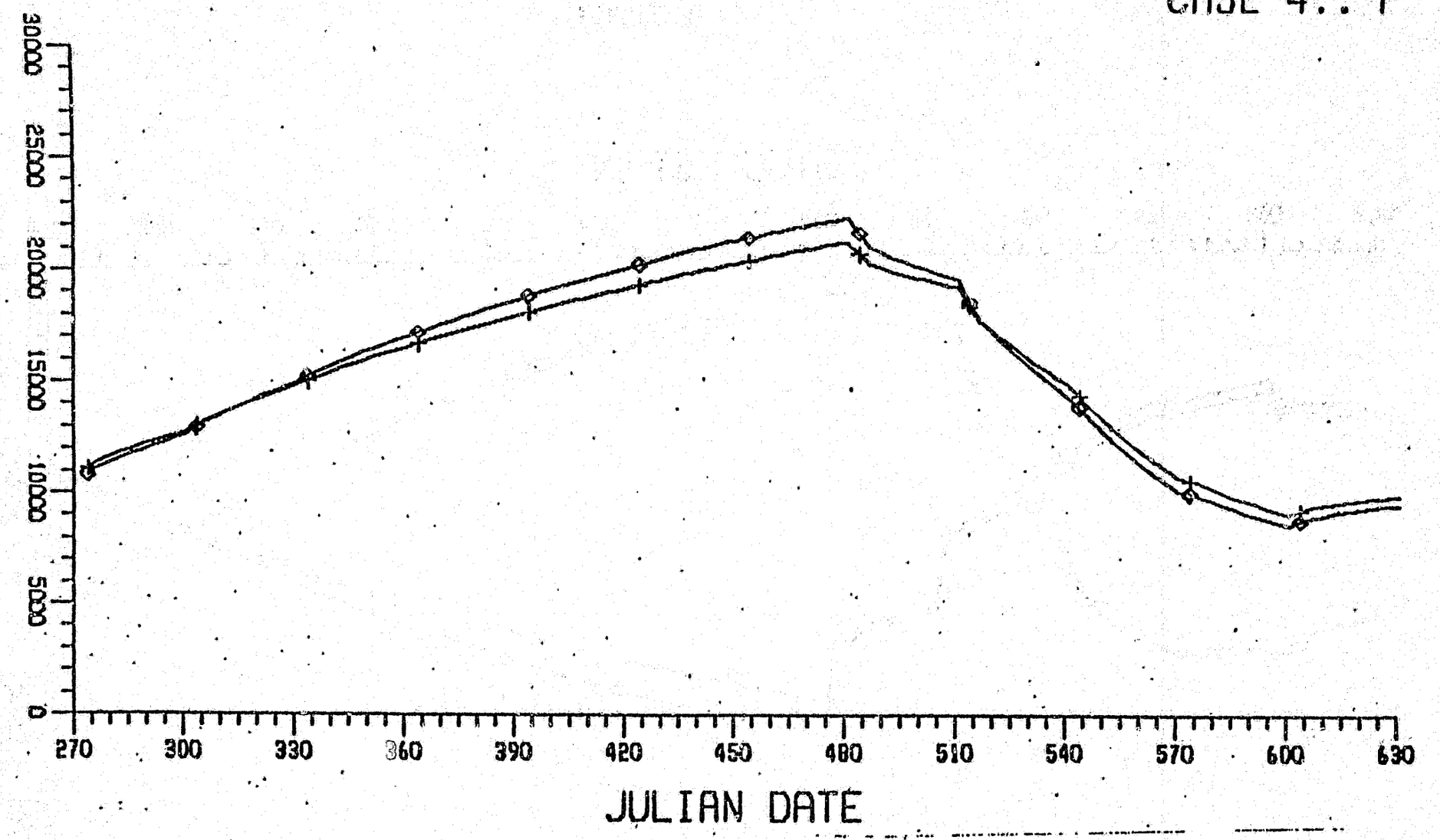


FIGURE 3

TEMPORAL VARIATION IN SALINITY WITHIN CENTRAL COOK INLET SOUTH OF THE SUSITNA RIVER UNDER PRE AND POST SUSITNA HYDROELECTRIC PROJECT CONDITIONS

2.35-1

NODE NO. P7

CASE 1..◇
CASE 4..+

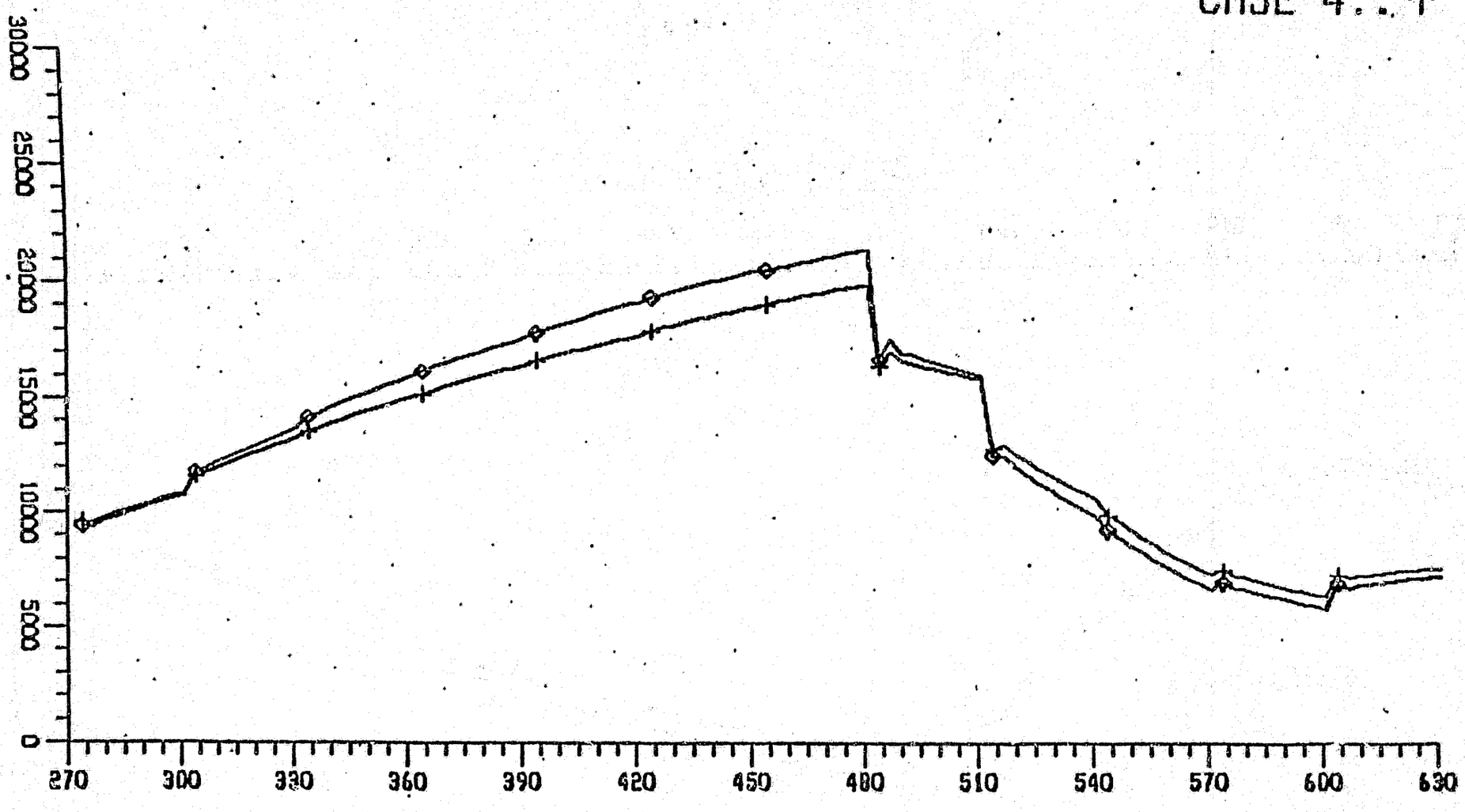


FIGURE 4

TEMPORAL VARIATION IN SALINITY WITHIN COOK INLET NEAR
THE SUSITNA RIVER UNDER PRE AND POST
SUSITNA HYDROELECTRIC PROJECT CONDITIONS

2-24-1

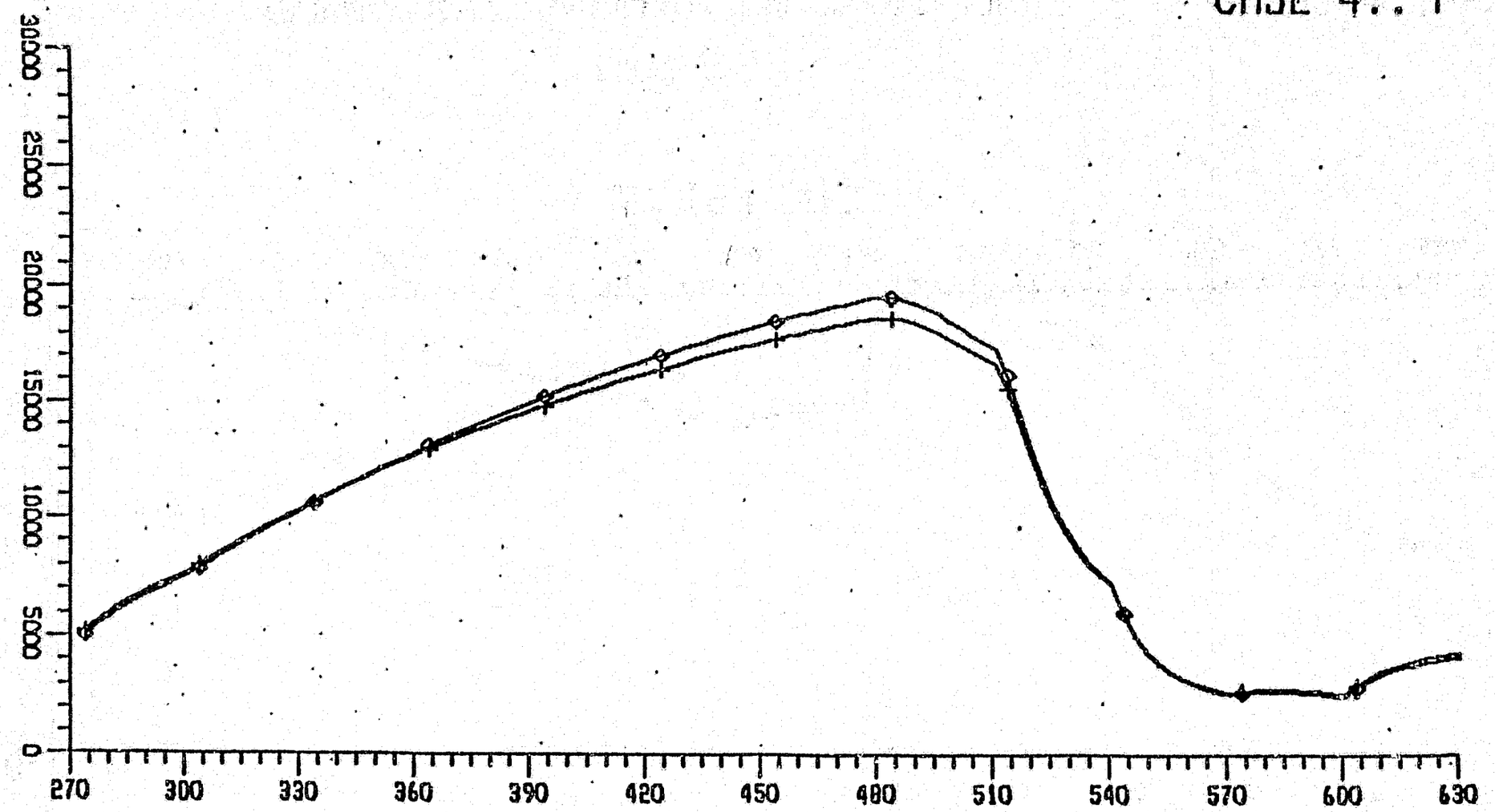


FIGURE 5

TEMPORAL VARIATION IN SALINITY WITHIN KNIK ARM NEAR
ANCHORAGE UNDER PRE AND POST
SUSITNA HYDROELECTRIC PROJECT CONDITIONS

2-34+53

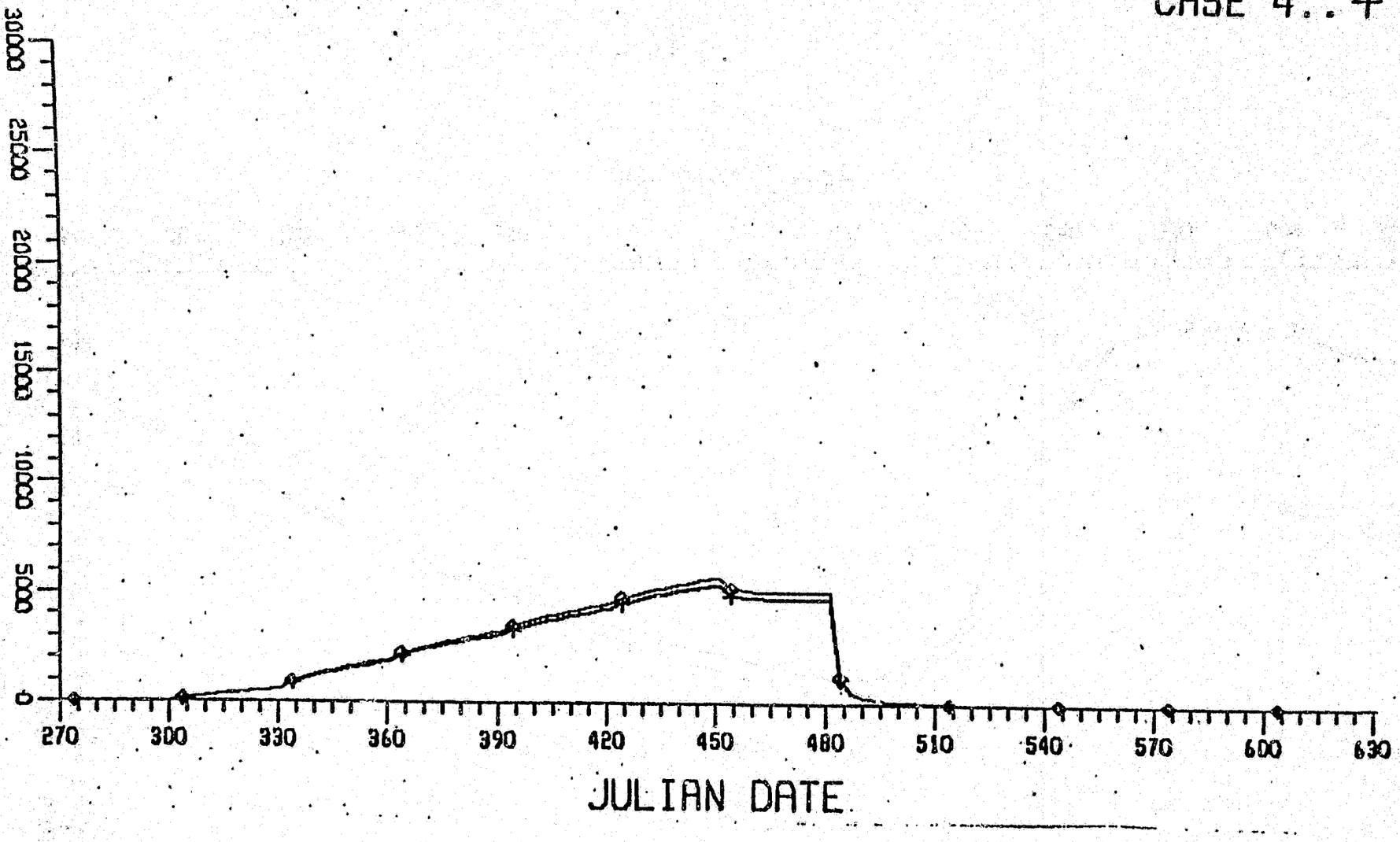


FIGURE 6

TEMPORAL VARIATION IN SALINITY NEAR THE UPPER END OF KNIK ARM UNDER PRE AND POST SUSITNA HYDROELECTRIC PROJECT CONDITIONS

2.25-15

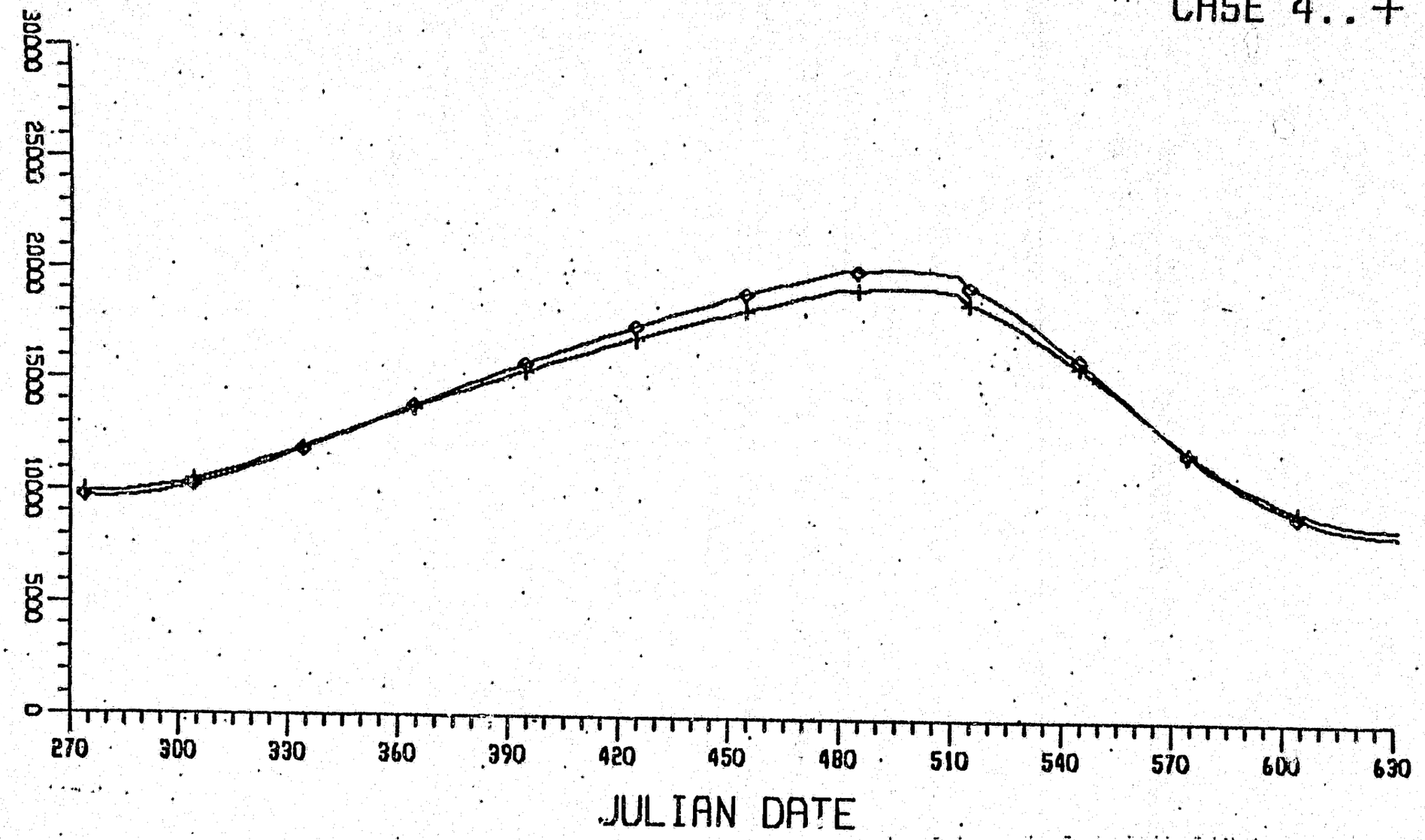


FIGURE 7

TEMPORAL VARIATION IN SALINITY WITHIN TURNAGAIN ARM
UNDER PRE AND POST SUSITNA
HYDROELECTRIC PROJECT CONDITIONS

EXHIBIT A

2-35-11

7.2 Estuary Model Application to Water Quality in Knik Arm and Upper Cook Inlet

7.2.1 Model Description

The numerical model used in this study was originally developed for the California State Water Resources Control Board (Evenson and Smith, 1974) and later modified for 208 planning studies on Long Island, New York (Johanson, et al., 1977). Further model modifications were made during this project and instruction on the model use can be found in the user's guide (Smith, 1977) prepared under this contract.

The model represents the estuarine system as a variable grid network of "nodes" and "channels." Nodes are discrete volume units of waterbody, characterized by surface area, depth, side slope and volume. The nodes are interconnected by channels, each having associated length, width, cross-sectional area, hydraulic radius, side scope and friction factor. Water is constrained to flow from one node to another through these

2-35-17

defined channels, advecting and diffusing water quality constituents between nodes.

The following are underlying assumptions of the estuary model:

- The estuarine system is well mixed vertically.
- The law of conservation of mass is obeyed for water quality constituents.
- Chemical reaction rates may be estimated using first order kinetics characterized by reaction-specific rate coefficients.

The overall estuary model is composed of two separate components: a hydrodynamic model (HYDRO) and a tidally averaged dynamic/steady-state quality-model (AQUAL). These numerical models are used in sequence so that the results of the hydrodynamic model become input to the quality models. The advantage of dividing the overall model into modular units is that the individual models can be calibrated separately. Considerable savings of computer time is realized by storing results of the hydrodynamic model on disk files to be used repeatedly in the calibration of the quality model and during water quality evaluations.

HYDRO calculates the hydrodynamics of the estuary using tidal time-stage data at the estuary boundary, hydrologic conditions, and estuary geometry data such as depth, surface area, tidal flat slope and bottom roughness. HYDRO prepares a permanent file which portrays the two-dimensional hydrodynamic characteristics of the estuary, including tidally averaged values of flow, velocity, volume, depth, surface area and parameters indicative of the dispersive characteristics of tidal mixing.

2-35-14

AQUAL is a tidally averaged quality model which can be operated in either a steady-state or dynamic (time dependent) mode to simulate advective- iffusive transport as well as physical, chemical, and biological reactions of the parameters being modeled. Net advective flows and dispersion coefficients to simulate the effects of tidal mixing provide the physical mass transport. The results are representative of the two-dimensional distribution of daily average quality conditions in the estuary.

The dynamic mode is used when the estuary quality does not approach steady-state within the period of time the boundary conditions remain constant. If significant changes in tributary inflow occur before steady-state is approached, the dynamic operation gives more representative results. In the dynamic mode, the model uses multiples of the tidal cycles as the basic time step and yields average daily results.

The AQUAL code provides the option to include up to four user-specified constituents in addition to the following parameters which may be selected for simulation.

1. Salinity
2. Total Nitrogen
3. Total Phosphorus
4. Total Coliform Bacteria
5. Fecal Coliform Bacteria
6. Carbonaceous BOD
7. Nitrogenous BOD
8. Dissolved Oxygen
9. Temperature

2-35-19

A more detailed description of the model and its use can be found in the model documentation.

7.2.2 Model Adaptation and Calibration

A node-channel network scheme has been designed to represent the entire Cook Inlet study area. This network, shown in Figure 7.1, extends from Anchor Point on the south to the upper reaches of Knik Arm and Turnagain Arm. This network scheme employs a coarse representation in the southern portion of Cook Inlet where the impact of development in the Anchorage area is small. In Upper Cook Inlet and Knik Arm, where impact of waste discharge from the Anchorage area is greatest, a more detailed representation has been utilized. The node and channel data were generated from National Oceanic and Atmospheric Administration (NOAA) navigation charts numbers 16664, G&GS 8854, and 16660. The node and channel data are presented in Appendix III.

Calibration of a tidal hydrodynamic model entails a series of simulations during which boundary conditions are held constant and the frictional resistance is adjusted. When the tidal stage, current velocity, and the high and low water time lag are adequately represented throughout the estuary, the hydrodynamic model can be considered calibrated.

For model calibration, average 1972 tributary inflow rates were used. An average tide was selected from the daily predictions at Seldovia and adjusted to Port Graham, the NOAA tide station nearest the southerly boundary of the study area. This tide has approximately the same diurnal tide range as that reported in the 1973 NOAA Tide Tables. The results of the comparison are summarized in Table 7.3. Good agreement between the calculated values and tide table predictions of tidal stage and phase was observed at most locations.

2-35-20

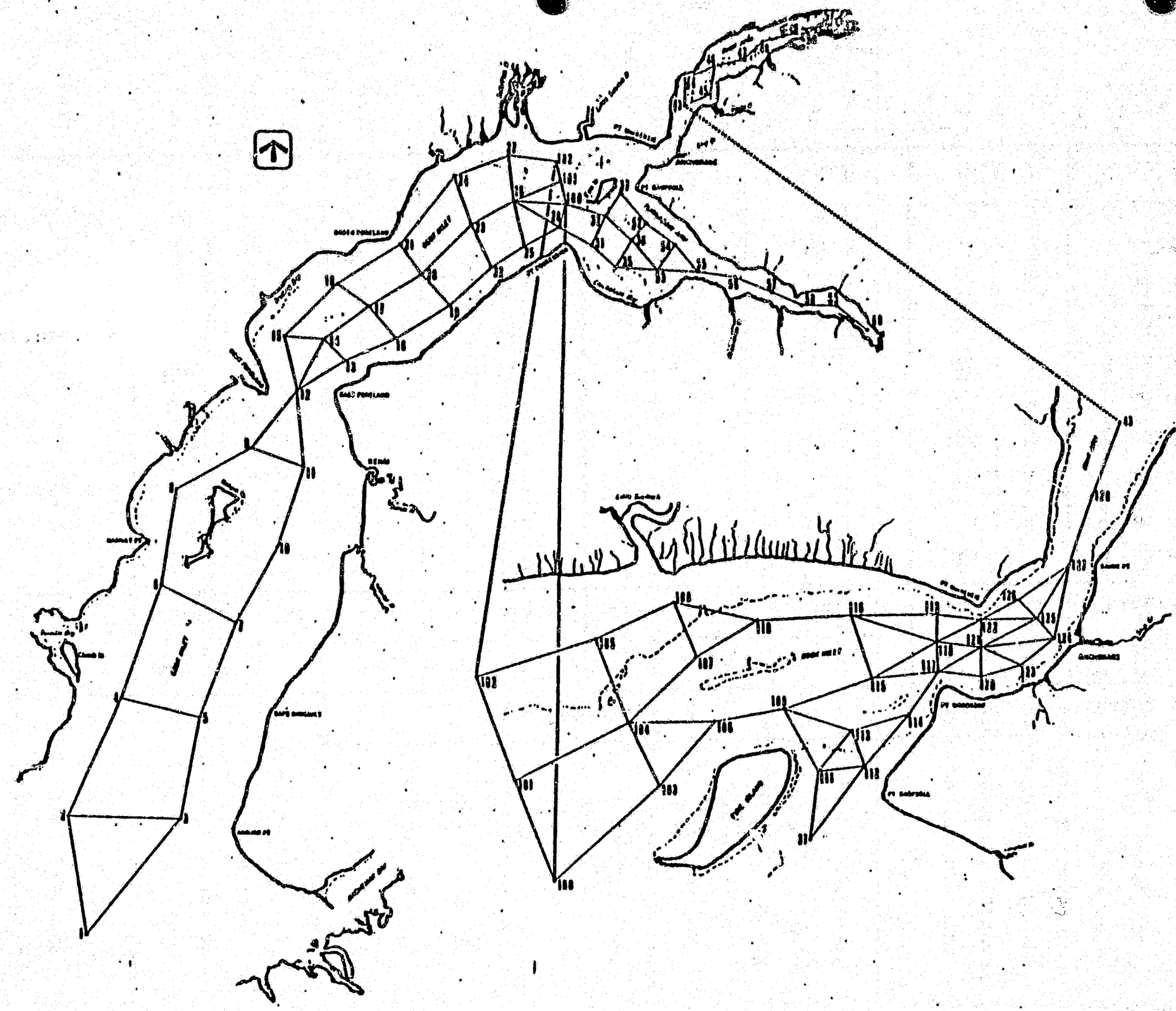


FIGURE 7.1 Node-Channel Network Scheme of Cook Inlet Study Area

2-35.21

Table 7.3

CALCULATED AND PREDICTED HIGH AND LOW WATER
TIME LAG AND DIURNAL TIDE RANGE

Location	Network Node Number	Time Lag(hrs)				Diurnal Tidal Range(ft)	
		High Water		Low Water			
		Predicted	Calculated	Predicted	Calculated	Predicted	Calculated
Port Graham	1	0	0	0	0	16.5	16.6
Cape Ninilchik	5	.7	.8	.8	1.1	19.1	18.1
Kenai River Entrance	11	1.9	2.0	2.2	2.7	20.7	19.2
Nikiski	12	2.4	2.7	2.7	3.3	20.7	20.0
East Foreland	12	2.6	2.7	2.9	3.3	21.0	20.0
Fire Island	100	4.5	4.1	4.8	4.9	27.5	28.9
Sunrise, Turnagain Arm	58	5.4	5.6	6.7	6.6	33.3	30.4
Anchorage	124	4.9	4.4	5.5	5.5	29.0	31.8
North Foreland	21	3.8	3.3	4.0	4.1	21.0	24.3
Drift River Terminal	8	1.7	1.7	2.0	2.1	18.1	19.5
Tuxedni Channel	4	.7	.8	.8	1.1	16.6	18.3

Comparisons between computed current velocities and those based on NOAA tidal current predictions were made. Figure 7.2 shows the calculated and predicted tidal stage and tidal current near Anchorage off Pt. Woronzof. The tidal current predictions were obtained by applying corrections to the daily predictions at the Wrangell Narrows. Both the computed tidal stage and current velocity compare well with predicted values.

Surface current velocity data (Britch, 1976) measured off Pt. Woronzof were compared with current velocities calculated for a similar period. Figure 7.3 shows the results of the current velocity comparison along with the corresponding tidal stage. The tidal stage comparison was used only to obtain the proper current phase. The model calculated current velocities slightly lower than those observed. However, it would be expected that vertical integrated currents would be less than those measured at the surface due to lower velocities near the bottom.

Based on the good agreement between calculated and reported tidal stage, tidal phase lag and current velocity, the hydrodynamic model can be considered calibrated.

Calibration of the water quality model is accomplished by first setting boundary conditions to observed values and then adjusting dispersion coefficients so that the measured concentrations of a conservative water quality parameter are matched adequately. Salinity is particularly suited to this procedure, since the concentrations in the tributary inflows are near zero with the sole source of salinity being the tidal boundary.

Changes in salinity take place rather slowly in such a large estuary; consequently, a dynamic water quality simulation is required for dispersion coefficient calibration. A steady-state approach would result in unrealistically high dispersion coefficients for high flow conditions, and low dispersion coefficients for low flow conditions.

2-35-22

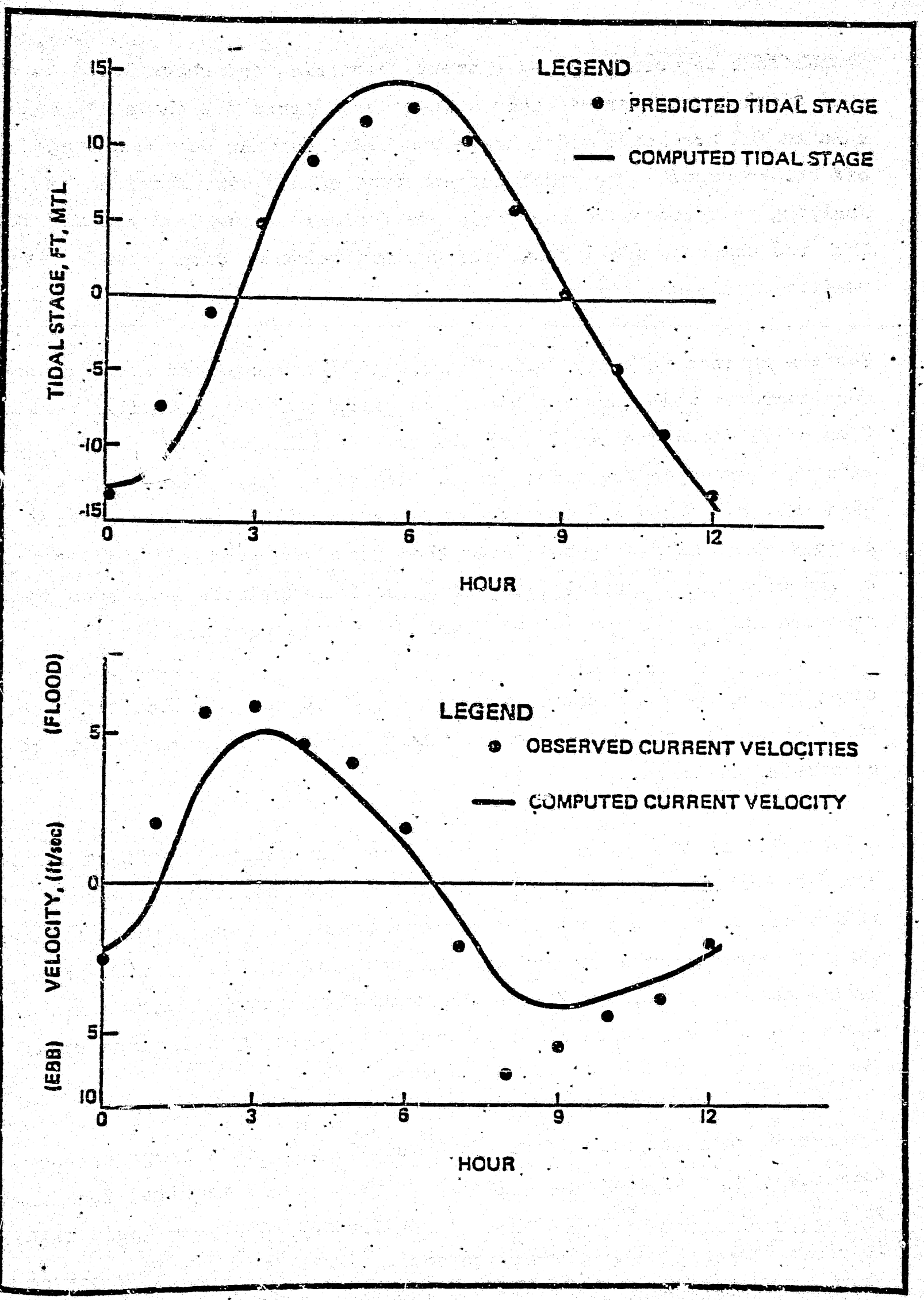


FIGURE 7.2 Computed and Predicted Tidal Stage and Tidal Current off Pt. Woronzof

2-35-24

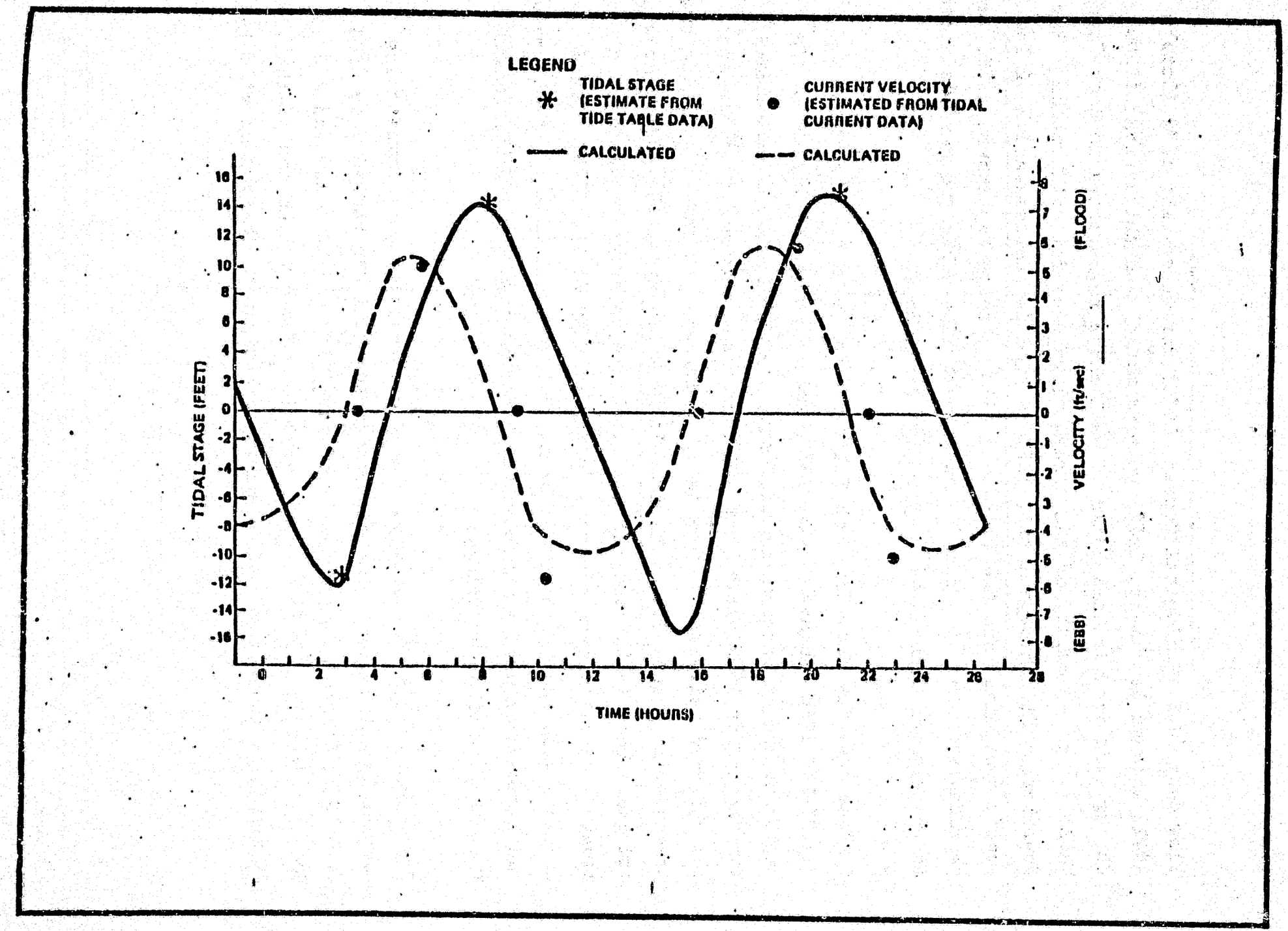


FIGURE 7.3 Current Velocity Compared with Tidal Stage

2-35-25

Flow data (U.S. Geological Survey, 1973) for water year 1972 (October, 1971, through September, 1972) were examined, and the average flows during four periods calculated for all major tributaries to Cook Inlet. Table 7.4 is a summary of the stream flows used for calibration. The November, 1971 through April, 1972, period is representative of low runoff conditions and the mid-June, 1972 through September, 1972, is representative of high runoff conditions. The other two periods serve as transitions between the major flow conditions.

Surface salinity data for Cook Inlet is available for the periods May 21-28, 1968, August 22-23, 1972, and September 25-29, 1972. To calibrate the dispersion coefficients, the model was run dynamically for the entire 1972 water year. A comparison between the calculated and observed salinity between Anchor Point and the end of Knik Arm are presented in Figure 7.4. The calculated salinity at the end of August and September, 1972, compares well with the observed salinities at those times. The salinities observed during the May 21-28, 1968, period were compared with the computed end of May, 1972, salinities. The observed and computed salinities for the end of May agree reasonably well, considering the dissimilar hydrology.

The above comparison indicates that the dispersion coefficients are adequately calibrated. The dispersion coefficients ranged from 2000 to 6000 sq ft/sec along the axis of the inlet and Knik Arm and 200 to 600 sq ft/sec perpendicular to that axis. These values are of the same magnitude as those reported by other investigators (Murphy et al., 1972).

2-35-26

Table 7.4

FLOW RATES OF MAJOR TRIBUTARIES TO COOK INLET

Stream	Average Flow Rate (cfs)			
	Oct 1971	Nov 1971-April 1972	May 1972-Mid-June 1972	Mid-June 1972-Sept 1972
Knik and Matanuska Rivers	7,170	1,420	7,590	31,200
Peters & Cottonwood Creeks	120	30	120	280
Eagle River	191	51	210	1,445
Ship Creek	126	25	114	270
Little Susitna River	200	60	250	1,800
Susitna River	18,600	5,800	58,300	77,500
Kenai River	4,800	1,310	2,590	11,600

31,207 4,676 79,774 124,095

2-35-27

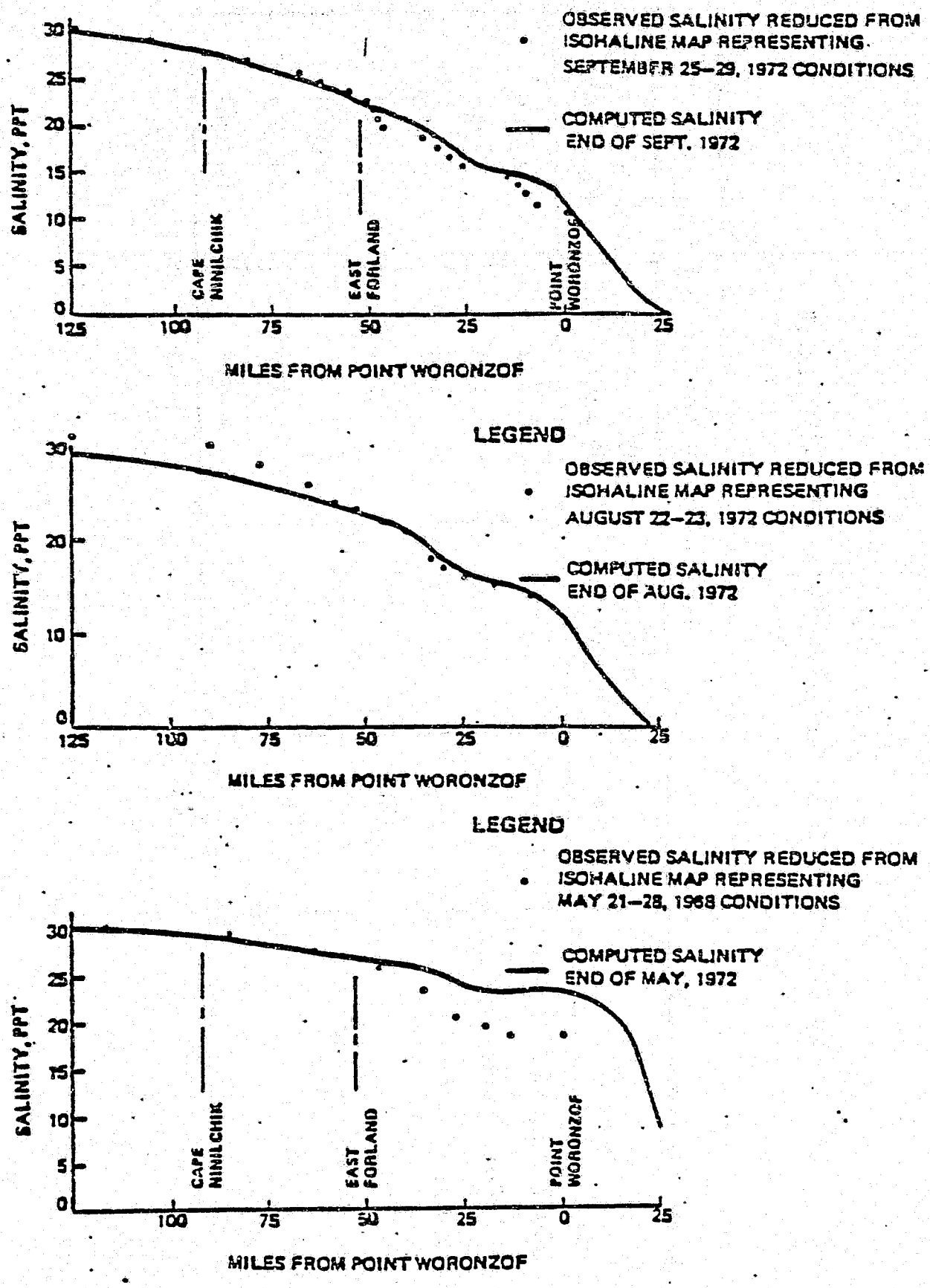


FIGURE 7.4 Computed and Observed Salinity between Anchor Point and Knik Arm

233278

EXHIBIT B

TABLE B-1

COMPUTED SALINITY CONCENTRATION (MG/L) AT SELECTED LOCATIONS WITHIN COOK INLET

NODE #	OCTOBER / APRIL		NOVEMBER / MAY		DECEMBER / JUNE		JANUARY / JULY		FEBRUARY / AUGUST		MARCH / SEPTEMBER	
	CASE#1	CASE#3	CASE#1	CASE#3	CASE#1	CASE#3	CASE#1	CASE#3	CASE#1	CASE#3	CASE#1	CASE#3
1	29276	29278	29624	29589	29826	29763	29971	29900	30100	30023	30209	30127
	30281	30200	29851	29831	29031	29104	28298	28383	28135	28211	28585	28642
2	28033	28062	28377	28371	28693	28652	28971	28906	29219	29137	29437	29339
	29609	29503	29411	29339	28804	28802	27997	28041	27399	27477	27362	27448
3	27369	27409	27785	27784	28172	28130	28514	28443	28819	28724	29086	28971
	29299	29172	29128	29031	28483	28460	27491	27539	26673	26775	26577	26685
4	26976	27027	27315	27335	27727	27705	28116	28058	28468	28379	28777	28665
	29035	28906	29028	28910	28581	28516	27696	27705	26746	26826	26321	26430
5	25804	25876	26294	26319	26834	26806	27335	27261	27783	27669	28175	28030
	28500	28332	28508	28350	27907	27823	26625	26664	25348	25477	24918	25065
6	26706	26762	27050	27075	27486	27468	27903	27847	28281	28191	28612	28498
	28892	28757	28927	28799	28471	28392	27505	27507	26484	26563	26028	26146
7	24663	24751	25247	25286	25906	25882	26521	26437	27068	26934	27545	27372
	27943	27741	28025	27824	27328	27217	25721	25777	24154	24314	23628	23804
8	26182	26244	26610	26641	27104	27088	27572	27512	27990	27894	28357	282[illegible]
	28665	28519	28702	28559	27960	27872	26557	26564	25464	25531	25284	254[illegible]
9	25018	25097	25586	25619	26208	26178	26785	26700	27300	27169	27750	27583
	28128	27934	28158	27971	27351	27161	25523	25578	24164	24305	23931	24090
10	23555	23658	24284	24328	25068	25037	25788	25684	26424	26262	26979	26770
	27444	27201	27525	27284	26587	26473	24570	24663	22780	22979	22305	22510
11	22948	23058	23778	23817	24630	24584	25402	25277	26085	25897	26680	26442
	27179	26904	27193	26929	25983	25888	23668	23804	21847	22077	21532	21754
12	22673	22783	23555	23584	24442	24377	25239	25093	25942	25730	26553	26291
	27066	26767	26995	26723	25568	25504	23056	23234	21281	21538	21154	21389
13	20786	20922	21915	21939	23019	22919	23995	23792	24849	24565	25[illegible]91	25245
	26212	25822	26062	25717	24288	24226	21290	21523	19138	19472	18[illegible]92	19284
14	19717	19857	21049	21050	22279	22136	23347	23088	24276	23930	25[illegible]12	24668
	25791	25290	25324	24989	22944	22974	19448	19790	17439	17819	17666	17979
15	21082	21211	22183	22204	23253	23153	24199	23999	25026	24749	25746	25408
	26347	25966	26151	25823	24308	24275	21300	21556	19333	19654	19310	19589
16	19023	19177	20403	20413	21711	21565	22848	22579	23838	23472	24696	24257
	25411	24921	25029	24632	22717	22705	19218	19535	16951	17340	16954	17285
17	18667	18815	20149	20141	21501	21328	22663	22363	23673	23275	24548	24075
	25271	24749	24673	24280	21881	21959	18037	18439	16000	16419	16402	16740
18	19740	19879	21063	21066	22291	22150	23356	23101	24285	23941	25090	24679
	25759	25301	25348	24982	22953	22985	19394	19744	17377	17764	17649	17963
19	15500	15668	17407	17365	19114	18846	20558	20122	21807	21244	22890	22229
	23773	23051	22345	22085	18810	18976	14438	14910	12325	12787	12867	13244
20	16238	16402	18043	18009	19668	19421	21046	20639	22239	21711	23273	22653
	24119	23440	23023	22581	19368	19549	15033	15316	13015	13478	13652	14025
21	17107	17268	18787	18767	20314	20099	21617	21252	22745	22267	23783	23158
	24526	23905	23651	23224	20431	20546	16283	16712	14198	14634	14669	150[illegible]
22	13861	14027	16021	15943	17911	17568	19489	18959	20856	20184	22039	21259
	22994	22149	21209	20738	16830	17076	12275	12777	10295	10760	11008	11394
23	14143	14294	16350	16244	18215	17839	19754	19198	21090	20398	22245	21449
	23167	22313	21090	20658	16446	16774	11904	12443	10163	10634	11147	11531

TABLE B-1
(continued)

COMPUTED SALINITY CONCENTRATION (MG/L) AT SELECTED LOCATIONS WITHIN COOK INLET

NODE #	OCTOBER APRIL		NOVEMBER MAY		DECEMBER JUNE		JANUARY JULY		FEBRUARY AUGUST		MARCH SEPTEMBER	
	CASE#1	CASE#3	CASE#1	CASE#3	CASE#1	CASE#3	CASE#1	CASE#3	CASE#1	CASE#3	CASE#1	CASE#3
24	14506	14644	16763	16642	18594	18203	20088	19523	21382	20686	22499	21703
	23378	22530	21134	20735	16379	16707	11337	11845	9845	10282	11302	11667
25	12819	13000	15003	14948	16990	16666	18672	18146	20131	19450	21394	20593
	22419	21544	20785	20261	16384	16551	11749	12200	9598	10045	10073	10458
26	12572	12717	14942	14795	16966	16507	18630	17969	20083	19268	21341	20409
	22337	21343	19607	19181	14389	14819	10168	10748	8578	9058	9534	9925
[illegible]												
28	11803	11991	14011	13969	16079	15765	17855	17326	19399	18702	20737	19909
	21824	20914	20160	19608	15504	15639	10842	11252	8755	9171	9144	9516
31	10976	11181	13116	12729	15236	14995	17103	16638	18729	18085	20138	19352
	21294	20412	20078	19459	15447	15432	10565	10869	8368	8730	8515	8866
32	10927	11127	13178	13177	15331	15069	17199	16714	18818	18156	20215	19413
	21349	20456	19875	19277	14711	14742	9723	10042	7852	8212	8302	8650
35	10514	10731	12433	12497	14512	14347	16425	16033	18113	17531	19385	18851
	20814	19971	20153	19474	16149	15976	11406	11605	8787	9103	8402	8735
36	10495	10710	12530	12580	14650	14464	16567	16153	18246	17645	19704	18954
	20912	20056	20051	19387	15611	15482	10688	10913	8337	8659	8228	8562
37	10489	10684	12927	12923	15160	14896	17066	16578	18705	18040	20107	19304
	21225	20333	19427	18841	13146	13191	7886	8170	6642	6963	7612	7939
43	7466	7641	10275	10341	12830	12697	15000	14651	16844	16309	18421	17734
	19504	18791	17328	16714	7231	7182	2535	2616	2489	2609	4103	4290
44	4117	3270	9045	9126	11714	11625	13979	13684	15902	15422	17552	16916
	18696	17950	15769	15186	4760	4721	1237	1276	1332	1398	2786	2918
45	5593	5734	8532	8612	11225	11149	13522	13247	15476	15018	17154	16539
	18300	17573	15050	14489	4114	4081	1012	1044	1099	1153	2408	2524
46	4076	4182	7100	7177	9883	9836	12245	12018	14260	13857	16000	15442
	17035	16367	12282	11815	1958	1943	329	340	405	426	1262	1325
47	2155	2208	4856	4899	7499	7457	9796	9615	11796	11464	13552	13080
	14338	13766	7477	7202	432	430	44	45	64	67	339	358
48	854	872	2961	2965	5297	5236	7373	7209	9235	8948	10906	10498
	11285	10800	3282	3174	51	51	3	3	5	5	51	54
49	213	217	1485	1468	3352	3275	5067	4933	6706	6456	8205	7855
	8098	7702	924	899	3	3	0	0	0	0	4	4
50	19	19	554	529	1878	1789	3188	3035	4479	4250	5722	5412
	5098	4780	85	83	0	0	0	0	0	0	0	0
52	10338	10548	12550	12586	14735	14527	16666	16230	18341	17722	19787	19021
	20966	20100	19776	19133	14497	14421	9320	9558	7474	7788	7830	8157
53	10231	10450	12000	12092	14036	13916	15969	15623	17692	17153	19203	18506
	20475	19660	20088	19379	16361	16096	11805	11930	9014	9291	8333	8648
54	10165	10387	11900	12000	13932	13824	15873	15538	17606	17076	19127	18437
	20411	19601	20123	19403	16523	16235	11966	12076	9090	9362	8322	8635
55	10069	10281	11637	11751	13579	13504	15505	15209	17253	16761	18799	18143
	20109	19326	19902	19178	16426	16082	12328	12375	9413	9644	8411	8701
56	10241	10429	11288	11422	12963	12948	14796	14578	16544	16130	18134	17549
	19521	18796	19848	19109	17437	16972	13779	13695	10574	10723	8989	9236

2-35-31

TABLE B-1
(continued)

COMPUTED SALINITY CONCENTRATION (MG/L) AT SELECTED LOCATIONS WITHIN COOK INLET

NODE #	OCTOBER / APRIL		NOVEMBER / MAY		DECEMBER / JUNE		JANUARY / JULY		FEBRUARY / AUGUST		MARCH / SEPTEMBER	
	CASE#1	CASE#3	CASE#1	CASE#3	CASE#1	CASE#3	CASE#1	CASE#3	CASE#1	CASE#3	CASE#1	CASE#3
57	10692	10834	11132	11269	12441	12472	14104	13960	15812	15478	17428	16918
	18880	18220	19609	18884	18157	17605	15095	14882	11848	11897	9794	9982
58	11275	11362	11143	11269	12067	12128	13531	13445	15171	14906	16792	16391
	18293	17694	19291	18593	18575	17971	16113	15792	12999	12950	10633	10757
59	12039	12057	11267	11372	11731	11816	12941	12914	14483	14293	16098	15732
	17643	17112	18874	18216	18875	18232	17103	16672	14250	14091	11626	11674
60	13014	12947	11574	11643	11512	11608	12404	12428	13804	13686	15388	15099
	16965	16506	18360	17756	18951	18294	17917	17391	15488	15213	12740	12700
100	11751	11936	13991	13941	16072	15744	17850	17306	19395	18683	20733	19890
	21817	20893	20036	19492	15248	15413	10599	11026	8592	9013	9050	9424
101	12212	12376	14537	14430	16592	16186	18307	17691	19800	19023	21092	20192
	22124	21155	19787	19311	14789	15110	10395	10913	8596	9055	9318	9705
102	11854	12029	14177	14097	16267	15894	18025	17438	19551	18799	20869	19990
	21928	20974	19780	19272	14754	14996	10207	10673	8389	8825	9036	9415
103	11672	11859	13921	13875	16014	15690	17802	17260	19354	18643	20696	19855
	21784	20860	20024	19475	15200	15354	10500	10919	8508	8925	8971	9344
104	11792	11973	14081	14017	16171	15821	17941	17375	19478	18745	20806	19944
	21877	20937	19922	19394	15003	15203	10365	10808	8457	8884	9021	9398
105	11489	11675	13805	13758	15928	15601	17733	17187	19295	18579	20640	19792
	21725	20797	19831	19285	14728	14881	9982	10389	8165	8572	8752	9121
106	11572	11759	13853	13807	15962	15638	17759	17216	19317	18605	20662	19819
	21750	20825	19948	19399	14964	15114	10194	10603	8299	8708	8837	9207
107	11276	11467	13617	13582	15765	15453	17594	17061	19174	18469	20530	19693
	21625	20704	19771	19213	14541	14660	9710	10089	7961	8354	8564	8926
108	10999	11193	13366	13344	15542	15249	17401	16885	19003	18313	20374	19549
	21479	20569	19638	19068	14176	14263	9288	9637	7652	8026	8305	8660
109	11348	11538	13662	13626	15797	15486	17617	17086	19192	18490	20549	19714
	21644	20726	19855	19297	14617	14740	9721	10101	7961	8352	8587	8948
110	10959	11153	13342	13321	15523	15231	17385	16871	18989	18301	20360	19537
	21465	20555	19591	19022	14051	14135	9172	9515	7578	7948	8259	8611
111	10498	10691	12946	12939	15179	14912	17083	16593	18720	18053	20119	19315
	21234	20341	19392	18810	13042	13093	7787	8072	6589	6908	7598	7923
115	11120	11311	13472	13445	15634	15335	17477	16957	19069	18376	20437	19610
	21537	20625	19724	19159	14196	14297	9212	9564	7605	7977	8330	8682
116	10825	11015	13244	13222	15440	15149	17312	16801	18924	18239	20296	19477
	21396	20491	19396	18834	13609	13694	8766	9096	7317	7674	8103	8447
117	10484	10676	12948	12939	15183	14914	17087	16595	18722	18055	20121	19316
	21232	20339	19344	18766	12912	12965	7674	7955	6517	6834	7563	7886
125	9384	9774	12168	12185	14503	14276	16488	16040	18187	17559	19637	18867
	20767	19902	18842	18243	11151	11161	5777	5983	5082	5329	6452	6733
127	8891	9077	11551	11587	13961	13767	16009	15595	17757	17160	19250	18507
	20396	19554	18432	17823	9862	9843	4542	4698	4128	4328	5651	5900
128	8233	8415	10968	11019	13447	13282	15553	15168	17345	16777	18678	18160
	20034	19214	17966	17352	8630	8593	3521	3639	3310	3470	4914	5133

2-25-22

TABLE B-2

COMPUTED SALINITY CONCENTRATION (MG/L) AT SELECTED LOCATIONS WITHIN COOK INLET

NODE #	OCTOBER APRIL		NOVEMBER MAY		DECEMBER JUNE		JANUARY JULY		FEBRUARY AUGUST		MARCH SEPTEMBER	
	CASE#1	CASE#4	CASE#1	CASE#4	CASE#1	CASE#4	CASE#1	CASE#4	CASE#1	CASE#4	CASE#1	CASE#4
1	29276	29282	29624	29586	29826	29759	29971	29894	30100	30012	30209	30117
	30281	30194	29851	29839	29031	29114	28298	28389	28135	28217	28565	28640
2	28033	28068	28377	28372	28693	28651	28971	28902	29219	29127	29437	29328
	29609	29493	29411	29338	28804	28806	27997	28046	27399	27486	27362	27451
3	27369	27416	27785	27786	28172	28128	28514	28437	28819	28713	29086	28958
	29299	29160	29128	29029	28483	28463	27491	27546	26673	26785	26577	26689
4	26976	27035	27315	27339	27727	27705	28116	28054	28468	28371	28777	28654
	29035	28893	29028	28904	28581	28516	27696	27711	26746	26836	26321	26437
5	25806	25886	26294	26324	26834	26807	27335	27256	27783	27658	28175	28015
	28500	28315	28508	28339	27907	27823	26625	26673	25348	25491	24918	25074
6	26706	26770	27050	27080	27486	27469	27903	27843	28281	28183	28612	28486
	28892	28744	28927	28791	28471	28391	27505	27512	26484	26573	26028	26149
7	24663	24763	25247	25293	25906	25803	26521	26432	27068	26922	27545	27354
	27943	27721	28025	27809	27328	27217	25721	25789	24154	24331	23628	23816
8	26182	26253	26610	26646	27104	27089	27572	27509	27990	27886	28357	28220
	28663	28504	28702	28549	27960	27871	26557	26570	25464	25562	25284	25415
9	25018	25108	25586	25624	26208	26179	26785	26695	27300	27157	27750	27566
	28128	27915	28158	27958	27231	27163	25523	25589	24164	24320	23931	24101
10	23555	23671	24284	24336	25068	25037	25788	25678	26424	26247	26979	26748
	27444	27176	27525	27266	26587	26475	24570	24680	22780	23000	22305	22523
11	22948	23072	23778	23824	24630	24584	25402	25269	26085	25880	26680	26416
	27179	26876	27193	26912	25983	25894	23668	23824	21847	22100	21532	21767
12	22673	22797	23555	23590	24442	24375	25239	25082	25942	25710	26553	26262
	27066	26736	26995	26708	25568	25515	23056	23257	21281	21562	21154	21402
13	20786	20938	21915	21945	23019	22916	23995	23778	24649	24536	25591	25206
	26212	25781	26062	25699	24288	24243	21290	21553	19138	19503	18992	19300
14	19717	19874	21049	21055	22279	22129	23347	23069	24276	23893	25082	24621
	25751	25244	25324	24946	22944	23002	19448	19826	17439	17854	17666	17993
15	21082	21227	22183	22210	23253	23150	24199	23985	25026	24721	25746	25370
	26347	25927	26151	25807	24308	24293	21300	21585	19333	19685	19310	19603
16	19023	19194	20403	20418	21711	21559	22848	22559	23839	23434	24696	24207
	25411	24871	25029	24616	22717	22730	19218	19571	16951	17378	16956	17302
17	18667	18832	20149	20144	21501	21319	22663	22340	23673	23232	24548	24021
	25271	24697	24673	24270	21881	21994	18037	18479	16000	16457	16402	16753
18	19740	19896	21063	21071	22291	22143	23356	23082	24285	23905	25090	24632
	25759	25255	25348	24970	22953	23013	19394	19781	17377	17799	17649	17979
19	15500	15687	17407	17366	19114	18831	20558	20086	21807	21181	22890	22152
	23773	22981	22545	22086	18810	19026	14438	14955	12325	12828	12867	13258
20	16238	16421	18043	18011	19668	19407	21046	20606	22239	21653	23273	22581
	24119	23874	23023	22580	19368	19599	15033	15561	13015	13519	13652	14038
21	17107	17287	18787	18770	20314	20088	21617	21224	22745	22215	23723	23093
	24526	23844	23651	23218	20431	20588	16283	16754	14198	14673	14669	15040
22	13861	14048	16021	15940	17911	17548	19489	18915	20856	20107	22039	21168
	22194	22070	21209	20751	16830	17135	12275	12823	10295	10801	11008	11406
23	14143	14315	16350	16239	18215	17818	19754	19151	21090	20317	22245	21356
	23167	22234	21090	20681	16446	16840	11904	12490	10163	10675	11147	11540

2-35-33

TABLE B-2
(continued)

NODE #	OCTOBER APRIL		NOVEMBER MAY		DECEMBER JUNE		JANUARY JULY		FEBRUARY AUGUST		MARCH SEPTEMBER	
	CASE#1	CASE#4	CASE#1	CASE#4	CASE#1	CASE#4	CASE#1	CASE#4	CASE#1	CASE#4	CASE#1	CASE#4
24	14506	14665	16763	16636	18594	18180	20088	19475	21382	20604	22499	21611
	23378	22454	21134	20761	16379	16770	11337	11887	9845	10319	11302	11674
25	12819	13021	15003	14948	16990	16648	18672	18104	20131	19374	21394	20501
	22419	21461	20785	20266	16384	16604	11749	12246	9598	10085	10073	10472
26	12572	12740	14942	14787	16966	16480	18630	17912	20083	19171	21341	20301
	22337	21255	19607	19220	14389	14896	10168	10796	8578	9100	9534	9931
[illegible]	[illegible]											
28	11803	12012	14011	13970	16079	15747	17855	17283	19399	18625	20737	19814
	21824	20827	20160	19509	15504	15688	10842	11294	8755	9209	9144	9530
31	10976	11202	13116	13135	15236	14982	17103	16602	18729	18017	20138	19262
	21294	20325	20078	19440	15447	15465	10565	10906	8368	8765	8515	8884
32	10927	11147	13178	13181	15331	15055	17199	16676	18818	18085	20215	19322
	21349	20369	19875	19263	14711	14780	9723	10078	7852	8245	8302	8666
35	10514	10752	12433	12507	14512	14340	16425	16004	18113	17474	19585	1877[illegible]
	20814	19884	20153	19437	16149	15994	11406	11637	8787	9136	8402	875[illegible]
36	10495	10730	12330	12589	14650	14455	16567	16123	18246	17585	19704	18870
	20912	19969	20051	19355	15611	15505	10688	10946	8337	8692	8228	8583
37	10489	10703	12927	12927	15160	14881	17066	16540	18705	17969	20107	19212
	21225	20245	19427	18829	13146	13227	7886	8202	6642	6992	7612	7953
43	7466	7655	10273	10350	12830	12691	15000	14626	16844	16257	18421	17658
	19584	18708	17328	16675	7231	7194	2535	2626	2489	2620	4103	4300
44	6117	6281	9045	9135	11714	11621	13979	13664	15902	15378	17552	16847
	18696	17871	15769	15143	4760	4729	1237	1281	1332	1404	2786	2925
45	5593	5745	8532	8621	11225	11146	13522	13229	15476	14977	17154	16473
	18300	17496	15050	14447	4114	4088	1012	1048	1099	1158	2408	2530
46	4076	4190	7100	7185	9883	9835	12245	12004	14260	13823	16000	15383
	17035	16295	12282	11780	1958	1947	329	341	405	426	1262	1329
47	2155	2213	4856	4903	7499	7456	9796	9603	11796	11436	13552	13031
	14338	13705	7477	7189	432	431	44	46	64	68	339	358
48	854	874	2961	2966	5297	5232	7373	7197	9235	8922	10906	10456
	11285	10751	3282	3177	51	51	3	3	5	5	51	54
49	213	217	1465	1466	3352	3270	5087	4921	6706	6431	8205	7819
	8098	7665	924	902	3	3	0	0	0	0	4	4
50	19	19	554	527	1878	1783	3188	3021	4479	4223	5722	5379
	5098	4753	85	84	0	0	0	0	0	0	0	0
52	10338	10368	12550	12594	14735	14517	16666	16198	18341	17658	19787	18934
	20966	20012	19776	19106	14497	14447	9320	9590	7474	7818	7830	8176
53	10231	10471	12000	12105	14036	13913	15969	15600	17692	17102	19203	18429
	20475	19574	20088	19332	16361	16103	11805	11958	9014	9322	8333	8671
54	10165	10408	11900	12013	13932	13821	15873	15516	17606	17027	19127	18362
	20411	19516	20123	19353	16525	16240	11966	12104	9090	9392	8322	8639
55	10069	10302	11637	11766	13579	13504	15505	15191	17253	16717	18799	18072
	20109	19243	19902	19123	16426	16080	12328	12398	9413	9671	8411	8729
56	10241	10452	11288	11440	12963	12954	14796	14567	16544	16096	18134	17488
	19521	18719	19848	19045	17437	16954	13779	13709	10574	10746	8989	9260

7-35-34

TABLE B-2
(continued)

COMPUTED SALINITY CONCENTRATION (MG/L) AT SELECTED LOCATIONS WITHIN COOK INLET

NODE #	OCTOBER APRIL		NOVEMBER MAY		DECEMBER JUNE		JANUARY JULY		FEBRUARY AUGUST		MARCH SEPTEMBER	
	CASE#1	CASE#4	CASE#1	CASE#4	CASE#1	CASE#4	CASE#1	CASE#4	CASE#1	CASE#4	CASE#1	CASE#4
57	10692	10859	11132	11290	12441	12487	14104	13955	15812	15453	17428	16868
	18880	18151	19609	18816	18157	17573	13095	14884	11848	11914	9794	10003
58	11275	11388	11143	11291	12067	12141	13531	13446	15171	14889	16792	16310
	18293	17632	19291	18525	18575	17929	16113	15782	12999	12950	10633	10776
59	12039	12083	11267	11395	11731	11833	12941	12920	14483	14283	16098	15701
	17643	17059	18874	18150	18875	18179	17103	16649	14250	14093	11626	11689
60	13014	12972	11574	11667	11512	11628	12404	12438	13804	13683	15388	15077
	16965	16462	18360	17694	18951	18235	17917	17355	15488	15205	12740	12709
100	11751	11957	13991	13941	16072	15725	17850	17262	19395	18604	20733	19793
	21817	20805	20036	19497	15248	15485	10599	11068	8592	9051	9050	9438
101	12212	12398	14537	14425	16592	16162	18307	17639	19800	18933	21092	20087
	22124	21067	19787	19336	14789	15177	10395	10960	8596	9096	9318	9715
102	11854	12050	14177	14094	16267	15873	18025	17389	19551	18713	20869	19889
	21928	20885	19780	19288	14754	15055	10207	10717	8389	8864	9036	9427
103	11672	11880	13921	13876	16014	15671	17802	17216	19354	18564	20696	19757
	21784	20772	20024	19478	15200	15405	10500	10961	8508	8963	8971	9358
104	11792	11994	14081	14016	16171	15801	17941	17329	19478	18662	20806	19849
	21877	20849	19922	19404	15003	15258	10365	10851	8457	8923	9021	9410
105	11489	11696	13805	13758	15928	15582	17733	17142	19295	18499	20640	19695
	21725	20708	19831	19289	14728	14931	9982	10430	8165	8609	8752	9134
106	11572	11780	13853	13808	15962	15619	17759	17172	19317	18525	20662	19722
	21750	20736	19948	19402	14964	15164	10194	10644	8299	8746	8837	9221
107	11276	11487	13617	13583	15765	15436	17594	17018	19174	18391	20530	19596
	21625	20615	19771	19212	14541	14706	9710	10128	7961	8390	8564	8941
108	10999	11212	13366	13346	15542	15232	17401	16844	19003	18238	20374	19454
	21479	20480	19638	19062	14176	14305	9288	9675	7652	8060	8305	8675
109	11348	11558	13662	13627	15797	15468	17617	17044	19192	18412	20549	19618
	21644	20638	19855	19296	14617	14787	9721	10141	7961	8387	8587	8962
110	10999	11172	13342	13323	15523	15219	17385	16830	18989	18226	20360	19443
	21465	20467	19591	19016	14051	14177	9172	9552	7578	7981	8259	8626
111	10498	10710	12946	12943	15179	14897	17083	16554	18720	17982	20119	19223
	21234	20253	19392	18799	13042	13129	7787	8103	6589	6938	7598	7938
115	11120	11331	13472	13446	15634	15318	17477	16916	19069	18300	20437	19515
	21537	20536	19724	19156	14196	14341	9212	9601	7605	8010	8330	8697
116	10825	11034	13244	13225	15440	15133	17312	16760	18924	18164	20296	19383
	21396	20403	19396	18828	13609	13735	8766	9131	7317	7707	8103	8462
117	10484	10695	12948	12943	15183	14899	17087	16556	18722	17983	20121	19224
	21232	20251	19344	18755	12912	13001	7674	7985	6517	6863	7563	7901
125	9584	9791	12168	12191	14503	14264	16488	16005	18187	17493	19637	18780
	20767	19816	18842	18224	11151	11188	5777	6006	5082	5352	6452	6747
127	8891	9093	11551	11594	13961	13757	16009	15562	17757	17099	19230	18424
	20396	19469	18432	17795	9862	9864	4542	4716	4128	4347	5691	5913

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1-4-K

USER'S GUIDE FOR THE ESTUARY HYDRODYNAMIC AND WATER QUALITY MODELS

Prepared for the

Department of the Army
Alaska District
Corps of Engineers
Anchorage, Alaska

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I. INTRODUCTION

BACKGROUND

The Federal Water Pollution Control Act Amendments (PL 92-500) of 1972 establishes specific requirements directed to the control of point sources of pollution. The Department of the Army, Alaska District, Corps of Engineers was given the responsibility to determine the effects of various levels of treatment and levels of wastewater effluent discharges, as defined in PL 92-500, on the water quality of Upper Cook Inlet including Knik Arm.

Tetra Tech, Inc. was contracted to prepare the Knik Arm and Upper Cook Inlet water quality report. Included in the study was the selection and use of appropriate mathematical models to aid in the evaluation of the effects of wastewater effluent discharges. The models selected and documented herein are:

- A two-dimensional horizontal, complete mixed vertical, dynamic hydrodynamic model interfaced with

- A two-dimensional horizontal, complete mixed vertical tidally averaged dynamic/steady-state water quality model.

This manual provides basic instructions for the set-up and use of the general estuary hydrodynamics and quality models. An example problem data set and simulation results are presented in Appendix A through D. The example utilizes the node-channel representation (see Figure I-1) used for the water quality evaluation portion of this project. A listing of the computer program codes for the hydrodynamic and water quality models are presented in Appendix E and F.

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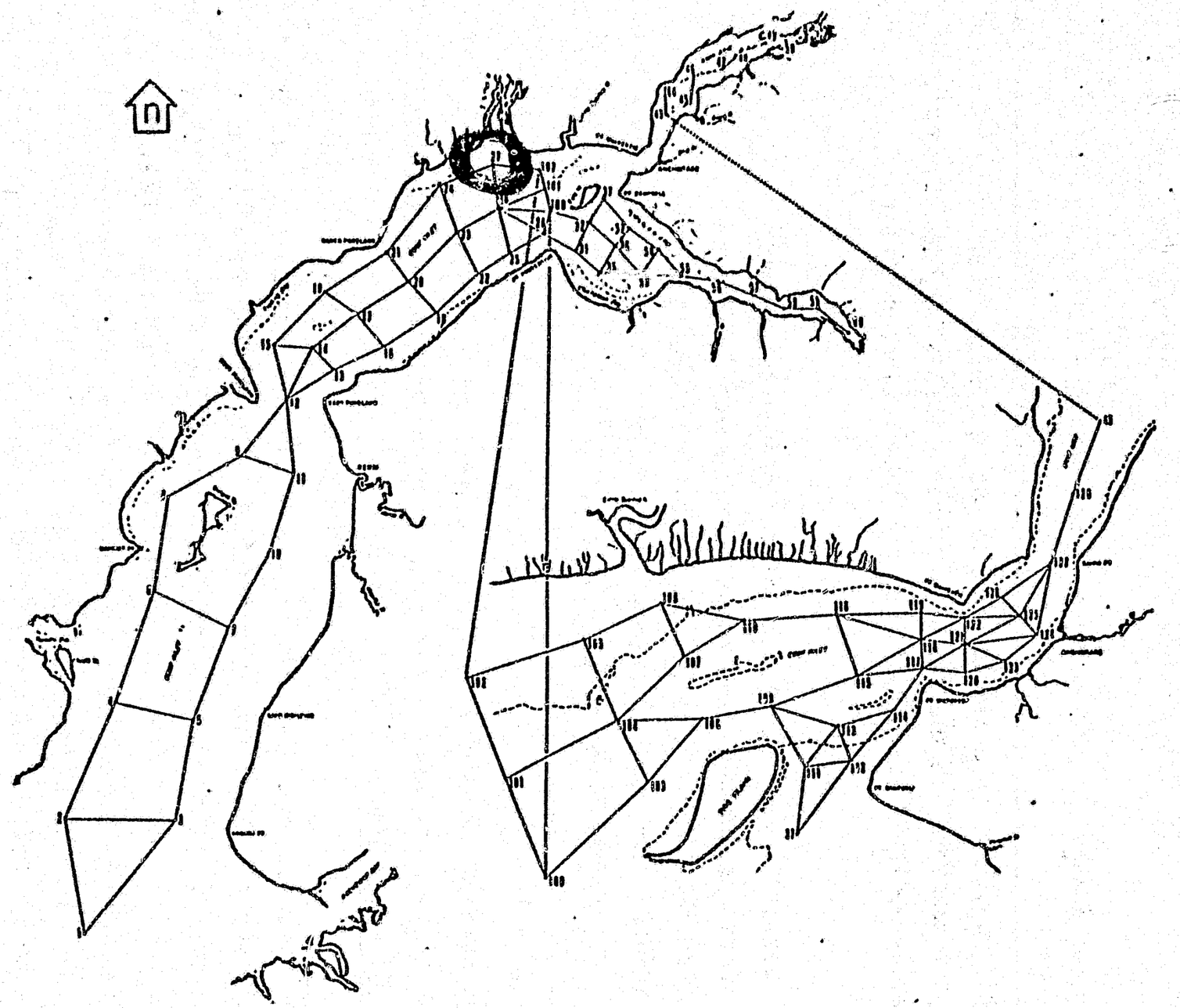

FIGURE I-1 NODE AND CHANNEL LAYOUT FOR UPPER COOK INLET INCLUDING KNIK AND TURNAGAIN ARMS

Detailed descriptions of the theoretical background and mathematical formulations essential in the estuary model development are presented in the Documentation Report*.

PURPOSE AND SCOPE

This manual is intended to provide the user with information which is fundamental in the set up and use of the estuary hydrodynamic and quality models. It includes general instructions regarding:

- Geometric representations of the prototype system;
- Data requirements and input format specifications;
- Program subroutines and computational sequence;
- General modeling procedure; and
- Interpretation of model results.

MODEL DESCRIPTION

Conceptual Formulation

The numerical model represents the estuarine system as a variable grid network of "nodes" and "channels". Nodes are discrete volume units of waterbody, characterized by surface area, depth, side slope and volume. The nodes are interconnected by channels, each having associated length, width, cross sectional area, hydraulic radius, side slope and friction factor. Water is constrained to flow from one node to another through these defined channels, advecting and diffusing water quality constituents between nodes.

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*Johanson, P.J., D.J. Smith, F.M. Haydock, and M.W. Lorenzen, "Documentation Report for the Estuary Water Quality Models." A Report to Nassau-Suffolk Regional Planning Board, Long Island, New York, May, 1977.

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The following are underlying assumptions of the estuary model.

- The estuarine system is well mixed vertically.
- The law of conservation of mass is obeyed for water quality constituents.
- Chemical reaction rates may be estimated using first order kinetics characterized by reaction-specific rate coefficients.

Program Operational Sequence

The overall two-dimensional estuary model is composed of two separate components, a hydrodynamic model (HYDRO) and a tidally averaged quality model (AQUAL).

The numerical models are used in sequence so that the results of the hydrodynamic model become input for the water quality model. The chief advantage of dividing the overall model into segments is that HYDRO can be calibrated separately and then used repeatedly in the calibration and application of AQUAL.

HYDRO calculates the hydrodynamics of the estuary using detailed information about geometric configurations, hydrologic conditions and predicted tidal time-stage relationships. The equations of motion and continuity are applied to determine the physical transport mechanisms of water flows and velocities in channels, and volume changes in nodes. The resulting data are averaged over the complete tidal cycle and written on disk files to be used as input to AQUAL.

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AQUAL combines formulations for biological and chemical reactions with advective and diffusive properties in a mass balance equation to calculate tidally averaged water quality at any location and time. Required inputs include system geometry and tidally averaged hydrodynamics from HYDRO, boundary conditions, dispersion coefficients, point and non-point source quality, reaction rate coefficients, and meteorological conditions. The dispersion coefficients are used to estimate net dispersion in the prototype since tidally induced advection is not directly modeled. AQUAL may be operated in either a steady-state or dynamic mode. The final results in the steady-state mode are representative of daily average conditions which would prevail if all inputs remained constant over time. The dynamic mode is useful for simulating long-term changes in water quality which result when system conditions or waste inputs change significantly over time. In this mode the model uses tidal cycles as the basic time step and yields average daily results. Figure I-2 summarizes the program operational sequence for the tidally averaged quality model.

The quality model can be used to simulate any combination of the following thirteen parameters and have the capability to include up to four additional user specified constituents. Optional constituents may include any dissolved or particulate constituent with first order decay, settling and transfer between constituents through decay.

1. Salinity
2. Total Nitrogen
3. Total Phosphorus
4. Total Coliform Bacteria
5. Fecal Coliform Bacteria
6. Carbonaceous BOD
7. Nitrogenous BOD
8. Dissolved Oxygen
9. Temperature

10.-13. Optional Constituents

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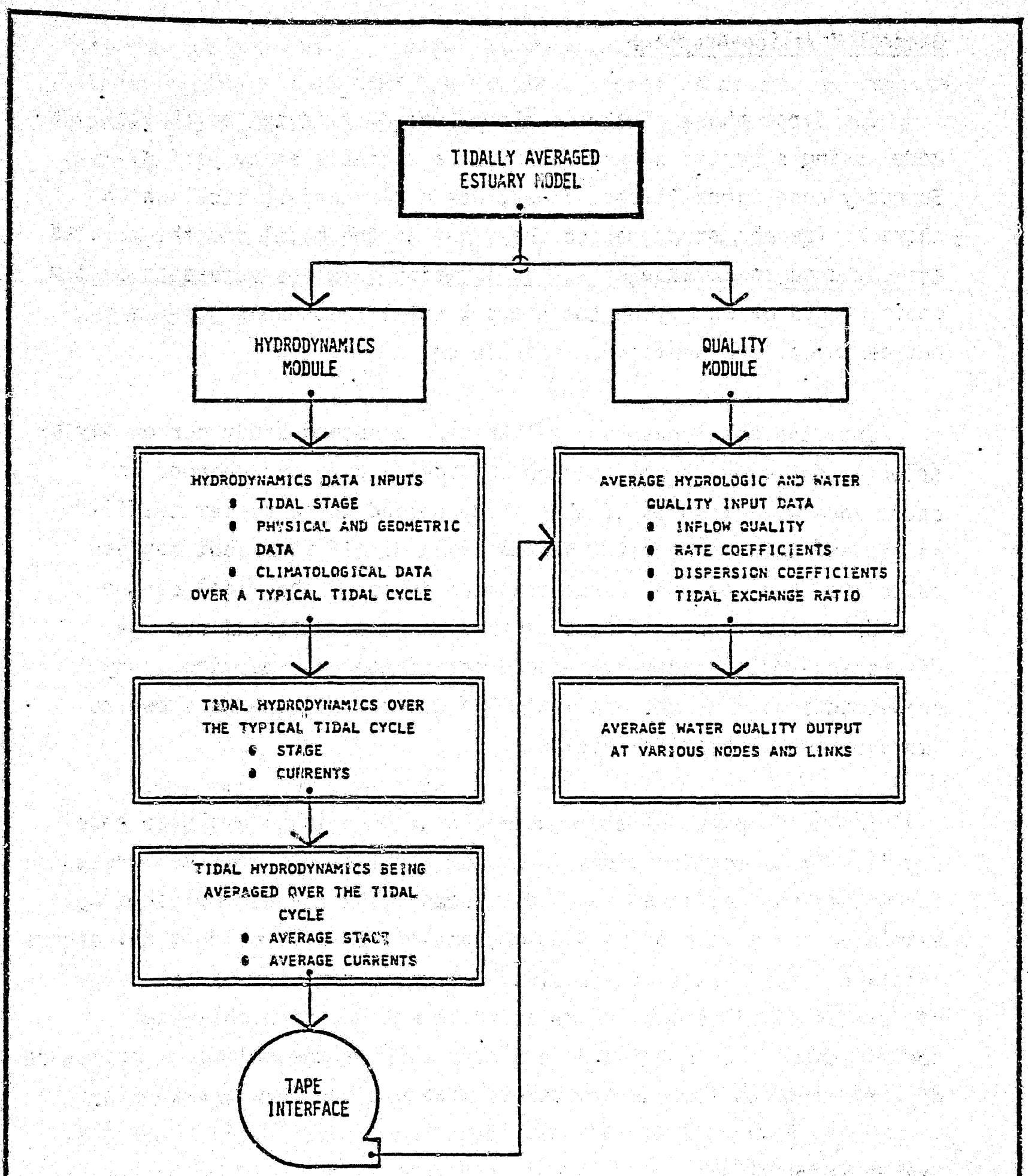

FIGURE I-2 TIDALLY AVERAGED ESTUARY MODEL FLOW CHART

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General Modeling Approach

The first phase of the modeling procedure is to "calibrate" the model using synoptic survey data from a suitable study period. Boundary conditions (tides, flows, waste discharges, etc.) which characterize the study period are input to the model and the results are compared to *in situ* data. Calibration involves adjusting system coefficients or modifying the network until reasonable agreement between model and prototype is achieved.

Once the model has been calibrated, a second study period may be selected for model "verification". Model inputs are changed in accordance with results of this study period while system coefficients and network geometry are maintained. If agreement between calculated and observed concentrations is good, the model can be considered verified. If agreement is poor, the reasons for the discrepancy must be determined and satisfactorily resolved. Any adjustments made to the model at this point must also be shown to improve the calibration results.

The third phase of the modeling procedure is to evaluate model sensitivity to modifications in system coefficients, and unit response to changes in individual loading sources. This is accomplished by examining the effect of varying one parameter while holding all others constant. The sensitivity analysis allows estimation of the range of results possible and the relative importance of each system coefficient. The unit response analysis shows the relative importance of various waste sources and boundary conditions on water quality.

System Layout

The nonuniform grid system used in the numerical models enables the user to specify greater detail in areas where the impact of pollutants is the greatest. Efficient utilization of computer

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resources weighs heavily on judicious preparation of the node and channel system. Among the most important considerations are computational time step increment, system geometry and location of waste sources.

The computational (hydrodynamic) time step increment is governed by the stability criteria of the channel according to the following relationship:

$$\Delta t < \frac{L}{\sqrt{gR}} \qquad (1)$$

where:

Δt = maximum hydrodynamic time step
L = channel length
g = gravitational constant
R = hydraulic radius (approximately equal to the average channel depth)

Since the same time step is used for the entire system, a single short deep channel can necessitate the use of a much smaller time step than would otherwise be required. Channel lengths should be selected to minimize this constraint as much as possible without interfering with natural system geometry.

In order to obtain the greatest possible correspondence between model and prototype hydrodynamics it is important to attempt to align model channels with natural channels as much as possible. In addition, areas with widely varying characteristics (e.g. depth, roughness) should not be combined in one node. Smaller nodes and shorter channels are warranted in regions which are known to have water quality problems or where major gradients in water quality parameters exist.

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II. HYDRODYNAMIC MODULE

INPUT REQUIREMENTS

The following inputs are required for the computation of estuary hydrodynamics:

- Physical and geometric characteristics of the node-channel representation of the estuary;
- Tidal time-stage relationships at seaward boundaries;
- Meteorological and climatological data, including evaporation, wind speed and direction, and precipitation;
- Point inflows and outflows;
- Non-point inflows; and
- Control specifications for computational options and output formats.

Table II-1 outlines the card groups and format specifications required to set up the hydrodynamic model card deck. These card descriptions together with the illustrative example data presented in Appendix A and the simulation results presented in Appendix B should enable the user to set up, run, and interpret the results of the estuary hydrodynamics model.

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Table II-1

HYDRO

Estuary Hydrodynamic Model
Data Requirements

Card Number	Card Column	Format	Variable	Description
Card Group 1 - Title Cards				
				These headings will be printed on each page of the input data summary.
1a	1-80	20A4	TITLE	Main heading
1b.	1-80	20A4	TITL	Subheading
Card Group 2 - Input/Output Control Card				
				Two or three tidal cycles are normally required to reach steady-state hydrodynamics. Results of the final tidal cycle for each hydrologic condition are averaged and stored through NSTEAD for later use as input to AQUAL. Examples of the plotting options are presented in Appendix B.
				A renumbering routine is included in the HYDRO code which arranges the channel-node system to minimize storage and computational requirements. Internal renumbering should begin with a node located at some extreme of the network such as a tidal boundary or lengthwise end of the system.
2a	1-5	11I5	NSESON	Sets of hydrologic conditions (48 maximum)
	6-10		NHPRT	Number of nodes specified for printout (1-30 allowed)
	11-15		NQPRT	Number of channels specified for printout (1-30 allowed)
	16-20		NTSL	Number of nodes specified for plots of mean tidal range and time of high water (max. 48)

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Table II-1 - Cont.

Card Number	Card Column	Format	Variable	Description
Card Group 2 - Input/Output Control Card - Cont.				
2a	21-25		NSTAGE	Number of pages of tidal stage plots (3 plots per page)
	26-30		NTFLOW	Number of pages of channel velocity and flow plots (3 plots per page)
	31-35		NDYNAM	Not used
	36-40		NSTEAD	HYDRO/AQUAL interface unit number
	41-45		NN	Node number to begin internal renumbering
2b	1-5	16I5	MDAY(1)	
	6-10		MDAY(2)	Number of tidal cycles for each hydrologic condition
	.		.	
	.		.	
	.		.	
			MDAY(NSESON)	
Card Group 3				
	1-5	16I5	JPRT(1)	
	6-10		JPRT(2)	Nodes specified for stage printout (NHPRT nodes required)
	.		.	
	.		.	
	.		.	
			JPRT(NHPRT)	

Repeat card type 3 as necessary to conform to limits set on card 2.

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Table II-1 - Cont.

Card Number	Card Column	Format	Variable	Description
Card Group 4				
4	1-5	16I5	CPRT(1)	Channels specified for velocity and flow printout (NQPRT channels required)
	6-10		CPRT(2)	
	.		.	
	.		.	
	.		.	
			CPRT(NQPRT)	

Repeat card type 4 as necessary to conform to limits set on card 2.

Card Group 5				
5	1-5	3I5	NJPLOT(NSTAGE,1)	Node specified for stage plots
	6-10		NJPLOT(NSTAGE,2)	
	11-15		NJPLOT(NSTAGE,3)	

Nodes specified here must have been included in JPRT array (card 3). NSTAGE (card 2) cards are required.

Omit card 5 if NSTAGE = 0.

Card Group 6				
6	1-5	3I5	NCPLOT(NTFLOW,1)	Channel specified for velocity plots
	6-10		NCPLOT(NTFLOW,2)	
	11-15		NCPLOT(NTFLOW,3)	

Channels specified here must have been included in CPRT array (card 4). NTFLOW (card 2) cards are required.

Omit card 6 if NTFLOW = 0.

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Table II-1 - Cont.

Card Number	Card Column	Format	Variable	Description
Card Group 7				
7	1-5	16I5	JTR(1)	
	6-10		JTR(2)	Nodes specified for profile plot of mean tidal range and time of high water (NTSL nodes required)
	.		.	
	.		.	
	.		.	
			JTR(NTSL)	

Repeat card 7 as required to conform to the limits set on card 2.

Omit card 7 if NTSL = 0.

Card Group 8

Hydrodynamic time step increment which is based on channel stability criteria can be determined by using Equation 1 or by previewing invariant channel data output generated by the model in a preliminary run using a large hydrodynamic time step.

8	1-10	4F10.0	DELT	Hydrodynamic time step increment, sec.
	11-20		DELTQ	Printed output interval, sec.
	21-30		PERIOD	Length of tidal cycle, hours
	31-40		DMIN	Anticipated maximum diurnal range in stage within the estuary (ft)

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Table II-1 - Cont.

Card Number	Card Column	Format	Variable	Description
Card Group 9 - Node Geometry				
				Node numbers greater than 200 are not allowed. Average nodal depth at mean sea level can be estimated from nautical charts keeping in mind that the charts show mean low water. Nodes with sizeable tide flat areas require an estimate of change in surface area per foot of change in depth. The X-Y coordinate location of nodes relative to some origin is measured in arbitrary units.
9	1-5	I5	J	Node number
	6-15	2F10.0	AREA	Water surface area at mean sea level, sq. ft.
	16-25		SLOPE	Change in surface area with increase in water surface elevation, sq. ft/ft.
	26-30	3F5.0	DEP	Water depth at mean sea level, ft.
	31-35		X1	X-coordinate, any unit
	36-40		Y1	Y-coordinate, any unit
	41-45	8I5	NTEMP(1)	
	46-50		NTEMP(2)	
	.		.	Channels entering node
	.		.	
	.		.	
	76-80		NTEMP(8)	
				Repeat card 9 for each node in the system terminating with a blank card. A maximum of 200 cards (including the blank card) is allowed.

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Table II-1 - Cont.

Card Number	Card Column	Format	Variable	Description

Card Group 10 - Channel Geometry

Channel numbers greater than 300 are not allowed. Channel length, average width, and the change in width per foot of change in depth in tide flat areas (side slope) can be estimated from nautical charts. The hydraulic radius is essentially equal to the channel depth except in tide flat areas where it is approximately equal to the average cross-sectional area at mean sea level divided by the surface width at mean sea level. Channel roughness, as represented by Mannings coefficient, is a function of channel configuration, bottom roughness and obstructions. Coefficients range from .02 for smooth straight channels to 0.08 for rough, irregular, obstructed channels.

10	1-5	I5	N	Channel number
	6-15	4F10.0	ALEN	Channel length, ft.
	16-25		WIDTH	Channel width at mean sea level, ft.
	26-35		RAD	Hydraulic radius at mean sea level, ft.
	36-45		COEF	Mannings roughness coefficient
	46-50	2I5	NTEMP (1)	Nodes at each end of channel
	51-55		NTEMP (2)	
	56-65	F10.0	SLOPE	Change in width with increase in water surface elevation, ft/ft.

Repeat card 10 for each channel in the system terminating with a blank card. A maximum of 300 cards (including the blank card) is allowed.

Card Group 11

This subheading replaces the title read from card 1b and will be printed with the following set of hydrologic conditions.

11	1-80	20A4	TITL	Subheading

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Card Number	Card Column	Format	Variable	Description
Card Group 12 - Hydrologic Input Control Switch				
				Set NTEMP( ) = 1 to skip the following inputs; new data will be read if NTEMP( ) = 0. Hydrological conditions are assumed zero until otherwise specified. Inputs are retained until replaced with new values.
12	1-5	6I5	NTEMP(1)	Read new tide data
	6-10		NTEMP(2)	Read new evaporation data
	11-15		NTEMP(3)	Read new wind velocity and direction
	16-20		NTEMP(4)	Read new point inflows and outflows
	21-25		NTEMP(5)	Read new groundwater inflow data
	26-30		NTEMP(6)	Read new storm water inflow data
Card Group 13 - Tidally Influenced Nodes				
13	1-5	I5	NJEX	Number of nodes with specified stage relationships
				Omit card 13 if NTEMP(1) (card 12) = 1.
Card Group 14 - Tide Data				
14a	1-5	4F5.0	JEX(NJEX)	Node number with specified stage relationships
	6-10		NI	Number of points defining stage relationship (must equal 6 or 25)
	11-15		MAXIT	Maximum number of iterations for tide fit (50)
	16-20		NCHTID	Print control, tidal curve fit results will be printed if equal to 1

Table II-1 - Cont.

Card Number	Card Column	Format	Variable	Description
Card Group 14 - Tide Data - Cont.				
14b	1-5	16F5.0	TT(1)	
	6-10		YY(1)	
	11-15		TT(2)	Time (TT=hrs) and stage (YY=ft) defining tide wave (NI pairs of data are required)
	16-20		YY(2)	
	.		.	
	.		.	
	.		.	
			TT(NI)	
			YY(NI)	

Repeat card 14b as required to define NI time-stage relationships. NJEX sets of card group 14 are required to define tides at all boundary nodes.

Omit card group 14 if NTEMP(1) (card 12) = 1.

Card Group 15 - Evaporation				
15	1-5	2I5	J1	First node of an evaporation zone
	6-10		J2	Last node of an evaporation zone
	11-20	F10.0	EVAPA	Evaporation rate, inches/ month

Repeat card 15 as necessary terminating with a blank card. A maximum of 20 evaporation zones are allowed which overrides the blank card requirement.

Omit card gr_ _ 15 if NTEMP(2) (card 12) = _

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Table II-1 - Cont.

Card Number	Card Column	Format	Variable	Description
Card Group 16 - Wind Velocity and Direction				
16a	1-5	2I5	J1	First channel of a wind zone
	6-10		J2	Last channel of a wind zone
16b	1-5	16F5.0	WIND(,1)	Wind speed (mph) and direction blowing from (degrees clockwise from Y-axis) at hour one
	6-10		WDIR(,1)	
	.		.	
	.		.	
	.		.	
			WIND(,25)	One set of values for each hour
	6-10 (Fourth Card)		WDIR(,25)	

Four 16b cards required for each wind zone. Repeat card group 16 as necessary terminating with a blank card. No blank card is required if 5 wind zones (the maximum allowed) are defined.

Omit card group 16 if NTEMP(3) (card 12) = 1.

Card Group 17 - Point Inflows/Outflows				
17	1-5	I5	N	Node number
	6-15	2F10.0	QQIN	Inflow to node, cfs
	16-25		QQOU	Outflow from node, cfs

Repeat as necessary terminating with a blank card. A maximum of NJ cards are allowed where NJ = number of nodes in the network.

Omit card group 17 if NTEMP(4) (card 12) = 1.

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Table II-1 - Cont.

Card Number	Card Column	Format	Variable	Description
Card Group 18 - Groundwater Inflows				
18	1-5	2I5	J1	First node for which groundwater inflow rate applies
	6-10		J2	Last node for which groundwater inflow rate applies
	11-15	F5.0	GROUND	Groundwater inflow rate, cfs

Repeat as necessary terminating with a blank card. A maximum of 199 groundwater inflows are allowed.

Omit card group 18 if NTEMP(5) (card 12) = 1.

Card Group 19 - Storm Water Inflows				
19a	1-5	I5	N	Node number
	6-10	12F5.0	TN(1)	
	11-15		TN(2)	Average hourly storm inflows (cfs) for first 12 hours of tidal cycle
	.		.	
	.		.	
	66-70		TN(12)	
19b	1-5	13F5.0	TN(13)	
	6-10		TN(14)	Average hourly storm inflows (cfs) for last 13 hours of tidal cycle
	.		.	
	.		.	
	.		.	
	61-65		TN(25)	

Repeat card group 19 as necessary terminating with a blank card. A maximum of 39 pairs are allowed.

Omit card group 19 if NTEMP(6) = 1.

Repeat card groups 11-19 for each hydrologic condition. There must be NSESON sets as specified on card 2.

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PROGRAM ROUTINES

Figure II-1 summarizes the general structure of the hydrodynamic model. Complete descriptions of model structure and solution techniques are included in the documentation report and will not be duplicated herein. The following brief synopsis is intended to serve only as a guide to aid in the interpretation of model outputs.

The main program HYDRO coordinates the hydrodynamic calculations, first reading title and control information for printing and plotting, and then calling GEOMET. This subroutine reads channel and junction configurations, including interconnectivity of nodes and channels, and computes invariant node and channel data before returning control to HYDRO.

HYDRO then calls NUMBER which renumbers the nodes internally so as to produce a more efficient matrix configuration for tidally averaged quality computations. The original numbering system is retained for output purposes. Control returns to HYDRO which prints the invariant geometric data and stores duplicates on disk files for later use in the quality model AQUAL.

The model then cycles through the following steps as often as required to compute steady-state hydrodynamics for each hydrologic condition. HYDRO calls TIDCF to fit the tide specifications with a polynomial which describes the time-stage relationship at a seaward boundary. Comparisons of observed and computed values are computed and printed. TIDCF is called repeatedly until the time-stage relationships are defined for each seaward boundary. Control is returned to HYDRO which then reads the remaining hydrodynamic inputs. At this point the major daily time step and quality time step loops are initiated and subroutine DYNFLO is called.

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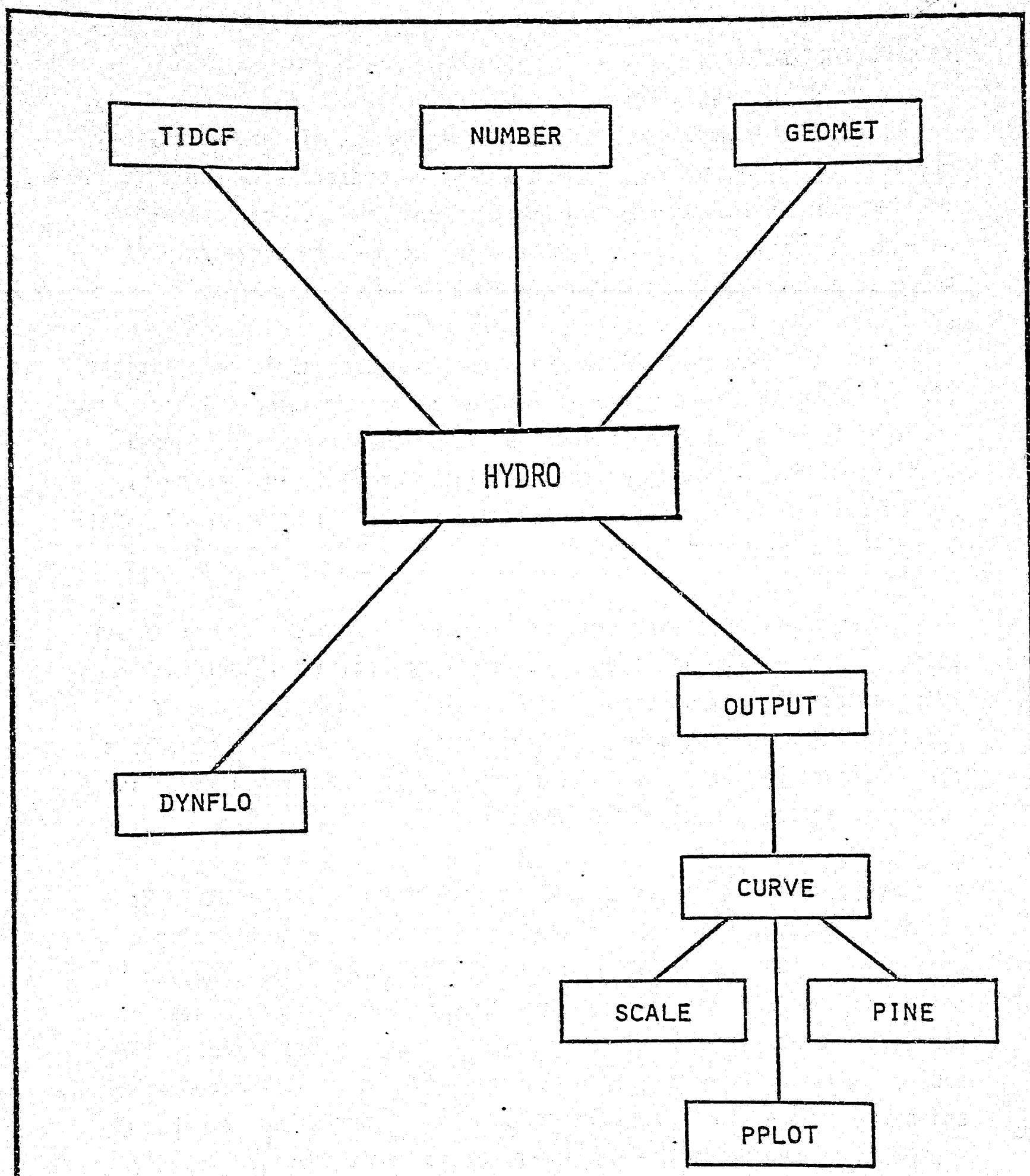

FIGURE II-1 ESTUARY HYDRODYNAMIC MODEL SUBROUTINES

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DYNFLO solves the equations of motion and continuity to determine fundamental hydrodynamic properties including velocities, discharges, water volumes, depths, surface areas and channel cross sectional areas. DYNFLO is called repeatedly to compute hydrodynamic properties for each simulation day of the hydrologic period.

Control then returns to HYDRO which averages the results of the final day of simulation over a complete tidal cycle and stored for later use in AQUAL. Finally, the subroutine OUTPUT is called which prints the results and controls the sequencing of the remaining subroutines which produce the user specified plots.

INTERPRETATION OF RESULTS

If errors occur in the node and channel inputs, one or more of the following messages will be printed:

- JUNCTION NUMBER _____ IS LARGER THAN PROGRAM DIMENSIONS.
  Junction numbers must not be greater than 200.

- CHANNEL NUMBER _____ IS LARGER THAN PROGRAM DIMENSIONS.
  Channel numbers must not be greater than 300.

- CHANNEL CARD COMPATIBILITY CHECK, CHANNEL _____ AND JUNCTION _____.
  Channel-junction interconnectivity is erroneous.

- JUNCTION CARD COMPATIBILITY CHECK, JUNCTION _____ AND CHANNEL _____.
  Junction-channel interconnectivity is erroneous.

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Assuming a HYDRO/AQUAL interface unit number was assigned, the first printed output (see Appendix Table B-1) shows the node renumbering scheme which is used internally in the steady-state/dynamic tidally averaged quality model. The maximum diagonal matrix width and the half band widths are also shown. The dimension limits in AQUAL will be exceeded if either of the half band widths are greater than ten (10). In this case the following error message is printed:

> THE HALF BAND WIDTH OF _____ FOR EQUATION
> NUMBER _____, NODE _____, EXCEEDS THE DIMENSION
> LIMITS IN PROGRAM AQUAL. PROGRAM EXECUTION
> WILL TERMINATE LATER.

If this message is printed, one of the following modifications is required.

- Select a different node which is located at some extremity of the network to begin renumbering (i.e., a tidal boundary or lengthwise end of the system).

- Restructure the grid system eliminating excess nodes which extend laterally from the lengthwise axis of the system.

- Increase the DIMENSION limits in program AQUAL.

When any of these errors occur, the model run will continue until invariant junction and channel data have been printed at which time the simulation will terminate.

The next output (see Appendix Table B-2) summarizes the computational and output control options specified on Card Groups 1-8.

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Invariant node and channel data follows the control summaries. An example of this output is presented in Appendix Table B-3 and B-4. In addition to printing input data, some computed data are included.

The column labeled "MAX TIME, SEC" on the channel data printout is useful for checking the maximum allowable computational time step. The hydrodynamic time step increment specified in columns 1-5 of Card 8 must not exceed the smallest value appearing in this column. The user may wish to modify the network layout slightly by lengthening channels or decrease the depth (along with an appropriate increase in width) which will increase the allowable time step.

The column labeled MIN ELEV, FT on the channel data printout is the water surface elevation at which the channel width becomes negative. The column labeled MIN ELEV, FT on the node data printout is the water surface elevation at which either the nodal volume or surface area will become negative.

The model checks to see if the anticipated low water level is exceeded by either of these minimum elevations. If potential problems exist, they will be noted by the following warnings incorporated in the list of junction and channel data.

- NOTE -- * INDICATES NEGATIVE WIDTH IS POSSIBLE WITH ANTICIPATED TIDAL STAGE.

- NOTE -- * INDICATES THAT DEPTH OF CHANNEL ENTERING JUNCTION IS LARGER THAN JUNCTION DEPTH.

  The latter message is to aid the user in modifying channel geometry data in the event that a negative node volume or surface area is encountered later in the hydrodynamic simulation.

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- ** INDICATES NEGATIVE VOLUME OR SURFACE AREA IS POSSIBLE WITH ANTICIPATED TIDAL STAGE.

It should be stressed that these are only warnings and may not cause further problems since the actual nodal stage often does not reach the anticipated low water level. If any of these anticipated problems materialize later in the simulation, error messages will be printed and the model run terminated at that time.

The remaining outputs will be repeated for each set of hydrodynamic conditions. Appendix Table B-5 shows an example of the output which is generated when the TIDCF subroutine successfully fits a polynomial with the input time-stage tide data*. The model will iterate until reasonable agreement is achieved between observed and computed values. The model computes and prints the individual and total differences between derived and observed time-stage relationships. These results should be checked for individual differences exceeding 5% of the maximum tide range which suggest possible errors in tide data inputs. One or more of the following variables may be the cause:

- Erroneous time-stage pairs defining the tide wave.
- Insufficient iterations for the tide fit. (50 is usually enough).
- Irregular spacing of tidal extremes.

The next page of output (see Appendix Table B-6) summarizes the evaporation, wind, inflows, and withdrawal data entered for the given hydrodynamic condition.

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*The user may suppress this output (see Card 14a).

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Model outputs to this point may be previewed most cost-effectively by setting the hydrodynamic time step increment to well in excess of a reasonable time step increment. The run will not go to completion, however, the output which is generated can be reviewed for input errors. The correct time step can be selected based on derived channel data output.

Selecting too large a time step will result in an unstable solution, terminates the runstream and cause the following error message to be printed:

HYDRODYNAMIC SOLUTION WAS UNSTABLE AT HOUR _____
IN CHANNEL _____, FLOW = _____ CFS, DEPTH = _____ FEET,
VELOCITY = _____ FT/SEC

As noted earlier, termination of the runstream will occur if negative nodal surface areas or volumes are encountered causing the following error messages to be printed:

- NEGATIVE SURFACE AREA ENCOUNTERED AT HOUR _____
  AT NODE _____, HEAD = _____ FEET, AREA = _____ SQ FT.

- NEGATIVE VOLUME ENCOUNTERED AT HOUR _____ AT NODE _____,
  HEAD = _____ FEET, VOLUME = _____ CU FT.

If this occurs one or both of the following adjustments in junction/channel configurations are required:

- Increase depth of node.

- Decrease area slope (change in surface area with respect to depth) in the junction. This adjustment may not be applicable when tide flats are being modeled.

2-35-65

- Decrease depth in channels which drain the junction. The channels which are sufficiently deep to cause the difficulty will have to be noted in the invariant channel data printout.

Once all errors are corrected the computations will go to completion. Appendix Tables B-7, B-8, B-9, and Appendix Figures B-1 through B-4 show examples of the model outputs. The following is a check list for testing the hydrodynamic model results before proceeding to the quality codes:

- Check for steady-state hydrodynamics by comparing heads at hour 25 with those at hour 50 for a given node. A similar check of flows and velocities for a given channel should also be made. Differences of more than 1% indicate that the model should be run for a longer period of time.

- Predicted time-stage relationships should be reasonable within the system.

- Check channel flows in tide flat areas to see whether times of no (or very little) flow are actually predicted.

- The values of average head should be approximately the same everywhere except where there is a large net flow or in tide flat areas where average heads will be greater since the flow out of these areas is stopped when a minimum depth is reached.

- The average velocity should be near zero except where there are net inflows or rapid changes in velocity such as in a narrow channel draining a large area.

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- Water balance at each junction should be zero except at tidal exchange nodes where it is equal to the net gain or loss at the boundaries.

- A flow diagram showing direction and magnitude of the average flows is useful in detecting circular flow patterns. While minor eddies are acceptable, unexplainable major circular flows should be corrected by adjusting the roughness coefficients in the channels.

Modifications in roughness coefficients or node-channel configurations may be required in orde" to produce acceptable model-prototype conformance. Once the above requirements are met to the satisfaction of the user, the model is considered calibrated and water quality computations can proceed.

2-35-67

III. TIDALLY AVERAGED QUALITY MODULE

INPUT REQUIREMENTS

The following inputs are required for the computation of tidally averaged water quality:

- Steady-state hydrodynamics as computed by HYDRO;
- Tidal exchange ratio and water quality at seaward boundaries;
- [redacted]
- [redacted]
- Dispersion coefficients;
- Reaction rate coefficients (benthic oxygen demand, coliform decay, photosynthesis oxygenation, etc.);
- Meteorological data, including cloud cover, dry and wet bulb air temperature, wind speed, and atmospheric pressure; and
- Control specifications for computational options and output formats.

Table III-1 outlines the card groups and format specifications required to set up the card deck for the AQUAL quality model. These card descriptions together with the illustrative example data presented in Appendix C and the formulation results presented in Appendix D should enable the user to set up, run, and interpret the results of the tidally averaged water quality model.

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Table III-1

AQUAL

Data Requirements
Tidal Average Estuary Quality Model

Card Number	Card Column	Format	Variable	Description
Card Group 1 - Title Cards				
				These headings will be printed on each page of the input data summary.
1a	1-80	20A4	TITLE	Main heading
1b	1-80	20A4	TITL	Subheading
Card Group 2 - Input/Output Control Card				
2	1-5	10I5	NHYD	Sets of boundary conditions
	6-10		IDAY	First Julian day of simulation
	11-15		IDELT	Computational time step increment, hours
	16-20		IALT	Print format option switch, (IALT = 0 for standard, IALT = 1 for alternate)
	21-25		IPCYC	Printout interval, days
	26-30		NJP	Number of junctions for time history plots (6 max.)
	31-35		NPP	Number of concentration profile plots (2 max.)
	36-40		IEE	Number of iterations for computing dispersion coefficients. (Default value = 10, five is usually sufficient)

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Table III-1 - Cont.

Card Number	Card Column	Format	Variable	Description
Card Group 2 - Input/Output Control Card - Cont.				
2	41-45		NFILE	HYDRO/AQUAL interface unit number
	46-50		INQUAL	Not used
Card Group 3 - Steady-State/Dynamic Mode Switch				
	The code allows the user to select either steady-state or dynamic solutions for each set of boundary conditions. Set IDYN ( ) = 1 for steady-state solution, IDYN ( ) = 0 for steady-state.			
3	1-5	16I5	NOPERH(1)	Number of days for first boundary condition
	6-10		IDYN(1)	Solution type selector
	.		.	
	.		.	
	.		.	
			NQPERH(NHYD)	NHYD pairs required
			IDYN(NHYD)	
	Repeat as necessary to conform to limits set on card 2.			
Card Group 4 - Parameter Selection				
	Set ISKIP( ) = 0 to simulate any of the following 13 constituents. If ISKIP( ) = 1 the constituent will be omitted.			
4	1-5	13I5	ISKIP(1)	[redacted]
	6-10		ISKIP(2)	Total nitrogen, mg/l as N
	11-15		ISKIP(3)	Total phosphorus, mg/l as P
	16-20		ISKIP(4)	Total coliforms, MPN/100 ml
	21-25		ISKIP(5)	Fecal coliforms, MPN/100 ml

2-35-7C

Table III-1 - Cont.

Card Number	Card Column	Format	Variable	Description
Card Group 4 - Parameter Selection - Cont.				
4	26-30		ISKIP(6)	Ultimate carbonaceous BOD, mg/l
	31-35		ISKIP(7)	Nitrogenous BOD, mg/l
	36-40		ISKIP(8)	Dissolved oxygen, mg/l
	41-45		ISKIP(9)	Temperature, °C
	46-50		ISKIP(10)	Optional constituent #1
	51-55		ISKIP(11)	Optional constituent #2
	56-60		ISKIP(12)	Optional constituent #3
	61-65		ISKIP(13)	Optional constituent #4
Card Group 5 - Optional Constituent Name				
The names will be printed on the first page of output for optional constituent identification.				
5	1-16	16A4	CNAME(1)	Optional constituent #1
			CNAME(4)	
	17-32		CNAME(5)	Optional constituent #2
			CNAME(8)	
	33-48		CNAME(9)	Optional constituent #3
			CNAME(12)	
	49-64		CNAME(13)	Optional constituent #4
			CNAME(16)	

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Card Number	Card Column	Format	Variable	Description
Card Group 6 - Time History Plot Control				
	One to four constituents may be selected for time history plots. Constituents are numbered from 1 to 13 in the order shown on card 4.			
6	1-5	10I5	IPLOT(1)	
	6-10		IPLOT(2)	Constituents for time history plots (constituent number)
	11-15		IPLOT(3)	
	16-20		IPLOT(4)	
	21-25		JPLOT(1)	
	26-30		JPLOT(2)	Junctions for time history plots (NJP junctions required)
	.		.	
	.		.	
	.		.	
			JPLOT(NJP)	
	Omit card 6 if NJP (card 2) = 0.			
Card Group 7 - Profile Plot Control				
	One to four constituents may be specified for concentration profiles. Constituents are numbered from 1 to 13 in the order shown on card 4.			
7a	1-5	7I5	NCONP(1)	
	6-10		NCONP(2)	Constituents for concentration profiles (constituent number)
	11-15		NCONP(3)	
	16-20		NCONP(4)	
	21-25		IPDAY(1)	
	26-30		IPDAY(2)	Julian day of profile plot
	31-35		IPDAY(3)	

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Card Number	Card Column	Format	Variable	Description
Card Group 7 - Profile Plot Control - Cont.				
7b	1-5	16I5	NODEP(1,NPP)	
	6-10		NODEP(2,NPP)	
	.		.	Junction for concentration profile (21 required)
	.		.	
	.		.	
	21-25 (Second Card)		NODEP(21,NPP)	

NPP (card 2) sets of card group 7b are required.

Omit card group 7 if NPP = 0.

Card Group 8 - Initial Conditions

A negative oxygen concentration signifies the fraction of saturation.

8	1-5	2I5	J1	First junction for which data applies
	6-10		J2	Last junction for which data applies
	11-15	13F5.0	ALL(1)	[redacted]
	16-20		ALL(2)	Total nitrogen, mg/l as N
	21-25		ALL(3)	Total phosphorus, mg/l as P
	26-30		ALL(4)	Total coliforms, MPN/100 ml
	31-35		ALL(5)	Fecal coliforms, MPN/100 ml
	36-40		ALL(6)	Ultimate carbonaceous BOD, mg/l
	41-45		ALL(7)	Nitrogenous BOD, mg/l

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Table III-1 - Cont.

Card Number	Card Column	Format	Variable	Description
Card Group 8 - Initial Conditions - Cont.				
8	46-50		ALL(8)	Dissolved oxygen, mg/l
	51-55		ALL(9)	Temperature, °C
	56-60		ALL(10)	Optional constituent #1
	61-65		ALL(11)	Optional constituent #2
	66-70		ALL(12)	Optional constituent #3
	71-75		ALL(13)	Optional constituent #4

Repeat as necessary terminating with a blank card. NJ initial condition cards are allowed, where NJ - number of junctions in the network.

Card Group 9 - Dispersion Parameters

Dispersion coefficients provide a means for simulating estuarine mixing. Generally these coefficients are adjusted as required for calibration based on a conservative constituent and then do not change thereafter.

The tidally induced dispersion parameter (C1) includes the effect of flow induced and tidal mixing. Open embayments and estuaries which are strongly influenced by tidal effects will generally require a larger C1 than more protected regions. The values for this coefficient generally range from 5 to 25.

[redacted]

9	1-5	2I5	J1	First channel for which data applies
	6-10		J2	Last channel for which data applies
	11-15	2F5.0	C1	Dispersion parameter

7-35-7

Table III-1 - Cont.

Card Number	Card Column	Format	Variable	Description
Card Group 9 - Dispersion Coefficient - Cont.				
9	16-20	[redacted]	[redacted]	

Repeat card 9 as required to define all dispersion zones terminating with a blank card. NC cards are allowed, where NC = number of channels in the network.

Card Group 10 - Tidal Boundary Nodes				
10	1-5	11I5	NBOUND	Number of tidal boundary nodes (10 max)
	6-10		JBOUND(1)	Tidal boundary node numbers
	.		.	
	.		.	
	.		.	
			JBOUND(NBOUND)	

Card Group 11 - Title Card

This subheading replaces the title read from card 1b. It will be printed with the output for the following set of boundary conditions.

11	1-80	20A4	TITL	Subheading

Card Group 12 - Read/Write Control Switches

Set NTEMP( ) = 0 to read new data; skip if NTEMP( ) = 1. Hydrodynamic conditions are normally read in order from the HYDRO/AQUAL interface tape; however the file may be repositioned if the user wishes a computation sequence different from that of the hydrodynamic simulation. Positive values of NTEMP(10) will advance the file and negative values will rewind it a specified number of records.

2-35-75

Table III-1 - Cont.

Card Number	Card Column	Format	Variable	Description
Card Group 12 - Read/Write Control Switches - Cont.				
12	1-5	10I5	NTEMP(1)	Read new hydrodynamic conditions
	6-10		NTEMP(2)	Read new tidal exchange ratios and quality
	11-15		NTEMP(3)	Read new inflow quality
	16-20		NTEMP(4)	Print aggregated inflow quality if NTEMP(4) = 0.
	21-25		NTEMP(5)	Read new non-point source quality
	26-30		NTEMP(6)	Read new return water quality increments
	31-35		NTEMP(7)	Read new system coefficients
	36-40		NTEMP(8)	Read new meteorological data
	41-45		NTEMP(9)	Print weather data if NTEMP(9) = 0
	46-50		NTEMP(10)	Position of HYDRO/AQUAL hydrodynamic file
Card Group 13 - Tidal Exchange Ratios and Quality				
				The tidal exchange ratio refers to the fraction of ebbing estuary water which is lost from the system at the boundary node and does not return. Values can range from 0.-1.
13a	1-5	5X		Card identification

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Table III-1 - Cont.

Card Number	Card Column	Format	Variable	Description
Card Group 13 - Tidal Exchange Ratios and Quality - Cont.				
13a	6-10	10F5.0	XR(1) . . . XR(NBOUND)	Tidal exchange ratio at each tidal input node

If salinity is not modeled as constituent 1 then it must be entered as CEX(1,14) for dispersion coefficient calculations. A negative value for dissolved oxygen signifies a fraction of saturation.

13b	1-5	5X		Card identification
	6-10	14F5.0	CEX(1,1)	[redacted]
	11-15		CEX(1,2)	Total nitrogen, mg/l as N
	16-20		CEX(1,3)	Total phosphorus, mg/l as P
	21-25		CEX(1,4)	Total coliforms, MPN/100 ml
	26-30		CEX(1,5)	Fecal coliforms, MPN/100 ml
	31-35		CEX(1,6)	Ultimate carbonaceous BOD, mg/l
	36-40		CEX(1,7)	Nitrogenous BOD, mg/l
	41-45		CEX(1,8)	Dissolved oxygen, mg/l
	46-50		CEX(1,9)	Temperature, °C
	51-55		CEX(1,10)	Optional constituent #1
	56-60		CEX(1,11)	Optional constituent #2
	61-65		CEX(1,12)	Optional constituent #3
	66-70		CEX(1,13)	Optional constituent #4

Table III-1 - Cont.

Card Number	Card Column	Format	Variable	Description
Card Group 13 - Tidal Exchange Ratios and Quality - Cont.				
13b	71-75		CEX(1,14)	[redacted]

Repeat as necessary to define conditions at all boundary nodes. NBOUND cards are required.

Omit card group 13 if NTEMP(2) = 1 (card 12).

Card Group 14 - Inflow Quality

The model will aggregate the water quality into a given node when multiple point source inflows occur. A negative concentration signifies a mass emission rate in pounds per day or equivalent except for oxygen where it signifies a fraction of saturation. No more than 500 inflows are allowed which can be distributed into a maximum of 100 junctions.

14	1-5	I5	JJ	Junction number
	6-10	14F5.0	QQ	Inflow, cfs
	11-15		ALL(1)	[redacted]
	16-20		ALL(2)	Total nitrogen, mg/l as N
	21-25		ALL(3)	Total phosphorus, mg/l as P
	26-30		ALL(4)	Total coliforms, MPN/100 ml
	31-35		ALL(5)	Fecal coliforms, MPN/100 ml
	36-40		ALL(6)	Ultimate carbonaceous BOD, mg/l
	41-45		ALL(7)	Nitrogenous BOD, mg/l
	46-50		ALL(8)	Dissolved oxygen, mg/l
	51-55		ALL(9)	Temperature, °C
	56-60		ALL(10)	Optional constituent #1

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Card Number	Card Column	Format	Variable	Description
Card Group 14 - Inflow Quality - Cont.				
14	61-65		ALL(11)	Optional constituent =2
	66-70		ALL(12)	Optional constituent =3
	71-75		All(13)	Optional constituent =4
	76-80		ALL(14)	[redacted]

Repeat as necessary terminating with a blank card. The blank card is not allowed when 500 inflows are specified.

Omit card 14 if NTEMP(3) = 1 (card 12).

Card Group 15 - Non-Point Source

These constituent concentrations represent aggregated quality of all non-point sources entering a given node or successive group of nodes at the flow rate specified in HYDRO. A negative dissolved oxygen concentration signifies a fraction of saturation.

15	1-5	16I5	J1	First junction for which quality applies
	6-10		J2	Last junction for which quality applies
	11-15		ALL(1)	[redacted]
	16-20		ALL(2)	Total nitrogen, mg/l as N
	21-25		ALL(3)	Total phosphorus, mg/l as P
	26-30		ALL(4)	Total coliforms, MPN/100 ml
	31-35		ALL(5)	Fecal coliforms, MPN/100 ml
	36-40		ALL(6)	Ultimate carbonaceous BOD, mg/l

Table III-1 - Cont.

Card Number	Card Column	Format	Variable	Description
Card Group 15 - Non-Point Source				
15	41-45		ALL(7)	Nitrogenous BOD, mg/l
	46-50		ALL(8)	Dissolved oxygen, mg/l
	51-55		ALL(9)	Temperature, °C
	56-60		ALL(10)	Discharge influence #1
	61-65		ALL(11)	Discharge influence #2
	66-70		ALL(12).	Discharge influence #3
	71-75		ALL(13)	Discharge influence #4
	76-80		ALL(14)	[redacted]

Repeat as necessary terminating with a blank card. A maximum of 29 non-point water types are allowed.

Omit card 15 if NTEMP(5) = 1 (card 12).

Card Group 16 - Return Water

Return water to any node may originate from as many as five other nodes. The model aggregates the initial concentration given the fraction from each node. Incremental changes specified on card 16b are then added to determine the return water concentration.

16a	1-5	I5	J1	Discharge junction
	6-10	I5	NTEMP(1)	
	11-16	F5.0	ALL(1)	Junctions from which discharge is withdrawn (NTEMP) and fraction of withdrawal which is discharged to junction J1(ALL)
	.		.	
	.		.	
	.		.	
	46-50		NTEMP(5)	
	51-55	F5.0	ALL(5)	

7-2<-8r

Table III-1 - Cont.

Card Number	Card Column	Format	Variable	Description
Card Group 16 - Return Water - Cont.				
16b	1-5	14F5.0	ALL(1)	[redacted]
	6-10		ALL(2)	Incremental total nitrogen
	11-15		ALL(3)	Incremental total phosphorus
	16-20		ALL(4)	Incremental total coliforms
	21-25		ALL(5)	Incremental fecal coliforms
	26-30		ALL(6)	Incremental carbonaceous BOD
	31-35		ALL(7)	Incremental nitrogenous BOD
	36-40		ALL(8)	Incremental dissolved oxygen
	41-45		ALL(9)	Incremental temperature, °C
	46-50		ALL(10)	Incremental optional constituent #1
	51-55		ALL(11)	Incremental optional constituent #2
	56-60		ALL(12)	Incremental optional constituent #3
	61-65		ALL(13)	Incremental optional constituent #4

Repeat card group 16 as necessary terminating with a blank card. The blank card is not required if 20 sets of card group 16 are entered. Omit card group 16 if NTEMP(6) (card 11) = 1.

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Table III-1 - Cont.

Card Number	Card Column	Format	Variable	Description

Card Group 17 - Quality Coefficients

The following coefficients representing first order decay kinetics vary as a function of temperature, oxygen concentration, salinity, light intensity, wind speed and many other physical and chemical influences. Optional constituent may include any dissolved or particulate constituent with first order decay, settling and transfer between constituents (i.e., ammonia decay to nitrate). Rate coefficients of constituents which may be of interest have been included. Typical values (at 20°C) are as follows:

Chemical, Physical and Biological Coefficient	*Range of Values*
Stoichiometric equivalence between optional constituent decay	*.0-1.0*
Rate coefficient temperature adjustment constant	*1.02-1.08*
Carbonaceous BOD decay rate, day^{-1}	*.1-.3*
Nitrogenous BOD decay rate, day^{-1}	*.05-.15*
Coliform die-off rate, day^{-1}	*.5-8.0*
Total nitrogen benthic sink rate, $mg/m^2/day$	*0-500*
Total phosphorus benthic sink rate, $mg/m^2/day$	*0-200*
Algal photosynthetic oxygen production, $mg/m^2/day$	*0-15,000*
Algae oxygen consumption due to respiration, $mg/m^2/day$	*0-7,500*
Benthic oxygen demand rate, $mg/m^2/day$	*0-5,000*
Reaeration rate, $days^{-1}$	*.1-10.*
Ammonia decay, day^{-1}	*.05-.2*

7-35-82

Card Number	Card Column	Format	Variable	Description

Card Group 17 - Quality Coefficients - Cont.

Chemical, Physical and Biological Coefficient	*Range of Values*
Nitrite decay, day^{-1}	*.2-1.*
Volatile suspended solids decay, day^{-1}	*.002-.05*
Suspended solids settling, meters/day	*0-2*

17a	1-5	5F5.0	TYPEEQ(1)	Fraction of an optional constituent produced with the decay at one unit of the preceding optional constituent (stoichiometric equivalence).
	6-10		TYPEEQ(2)	
	11-15		TYPEEQ(3)	
	16-20		QTEN(1)	Rate coefficient temperature adjustment constant for carbonaceous BOD decay (default = 1.05)
	21-25		QTEN(2)	Rate coefficient temperature adjustment constant for the remaining rate coefficients (default = 1.03)
17b	1-5	2I5	J1	Junction limits for which coefficients apply
	6-10		J2	
	11-15	4F5.0	ALL(2)	Carbonaceous BOD decay rate, day^{-1}
	16-20		ALL(3)	Nitrogenous BOD decay rate, day^{-1}
	21-25		ALL(4)	Total coliform die-off rate, day^{-1}
	26-30		ALL(5)	Fecal coliform die-off rate, day^{-1}

Table III-1 - Cont.

Card Number	Card Column	Format	Variable	Description
Card Group 17 - Quality Coefficients - Cont.				
17c	1-5	15F5.0	ALL(6)	Total nitrogen benthic sink rate, $mg/m^2/day$
	6-10		ALL(7)	Total phosphorus benthic sink rate, $mg/m^2/day$
	11-15		ALL(8)	Algal photosynthetic oxygen production, $mg/m^2/day$
	16-20		ALL(9)	Algae oxygen consumption due to respiration, $mg/m^2/day$
	21-25		ALL(10)	Benthic oxygen demand rate, $mg/m^2/day$
	26-30		ALL(11)	Minimum reaeration rate, day^{-1}
	31-35		ALL(12)	Maximum reaeration rate, day^{-1}
	36-40		ALL(13)	
	41-45		ALL(14)	Optional constituents #1 through #4 decay, day^{-1}
	46-50		ALL(15)	
	51-55		ALL(16)	
	56-60		ALL(17)	
	61-65		ALL(18)	Optional constituents #1 through #4 settling rate, meters/day
	66-70		ALL(19)	
	71-75		ALL(20)	

One card 17a is required. Repeat sets of cards 17b and 17c as required terminating with a blank card. No blank card is required if NJ sets of card 17b and 17c are entered.

Omit card group 17 if NTEMP(7) = 1 (card 12).

2-35-84

Table III-1 - Cont.

Card Number	Card Column	Format	Variable	Description
Card Group 18 - Meteorological Conditions				
18a	1-5	I5	NWZONE	Number of weather zones (5 max.)
	6-10	5F5.0	DAY	Julian date
	11-15		EPS	East west longitude switch (-1 for U.S.A.)
	16-20		AA	Evaporation coefficient a
	21-25		BB	Evaporation coefficient b (Default = 1.5×10^{-9})
	26-30		DEW	Wet bulb/dew point switch, dew = 1 for wet bulb temperature
Hourly meteorological conditions for each weather zone are computed by interpolation of the information supplied on card 18c.				
18b	1-5	2I5	JWZONE(1)	Junction limits of weather zone
	6-10		JWZONE(2)	
	11-15	3F5.0	XLAT	Latitude, degrees
	16-20		XLON	Longitude, degrees
	21-25		TURB	Atmospheric turbidity (2 for clear up to 5 for smog)
18c	1-5	I5	J2	Hour of observation
	6-10	5F5.0	CLOUD	Cloud cover, fraction
	11-15		DBT	Dry bulb temperature, °C

2-35-85

Table III-1 - Cont.

Card Number	Card Column	Format	Variable	Description
Card Group 18 - Meteorological Conditions - Cont.				
18c	16-20		WBT	Wet bulb or dew point temperature
	21-25		WIND	Wind speed, meters/sec
	26-30		APR	Atmospheric pressure, mb

A set of between 2 and 25 cards (type 18c) are required for each weather zone. Each set must begin with values for hour 1 and ending with values for hour 25. Repeat sets of cards 18b and 18c as required to define all weather zones (NWZONE sets).

Repeat card groups 11-18 as necessary to define all boundary conditions. There must be NHYD sets as specified on card 2.

2-35-86

PROGRAM ROUTINES

Figure III-1 summarizes the general structure of the tidally averaged quality model. The following brief description is intended to serve only as a guide to aid in the interpretation of model outputs. The reader is again referred to the documentation report for a more thorough treatment of model development, theoretical considerations, and solution techniques.

The main program AQUAL calls INPUT to read system geometry, hydrodynamics, input/output controls, boundary conditions, dispersion and system coefficients and inflow quality. INPUT calls METDAT to read meteorological conditions, compute derived conditions, and write results. Control then returns to AQUAL which directs SETUP, FORM and SOLVIT to compute salinity for dispersion coefficient computations. AQUAL then computes oxygen saturation based on salinity and temperature. SETUP is then called to set up the final coefficient matrix which is used in SOLVIT to compute the concentration of the water quality constituents in all nodes. The constituent concentrations are determined in the following order:

- Inert dissolved solids
- Temperature
- Optional coefficients (user specified)
- Total nitrogen
- Total phosphorus
- Total coliform
- Fecal coliform
- Carbonaceous BOD
- Nitrogenous BOD
- Dissolved oxygen

2-35-87

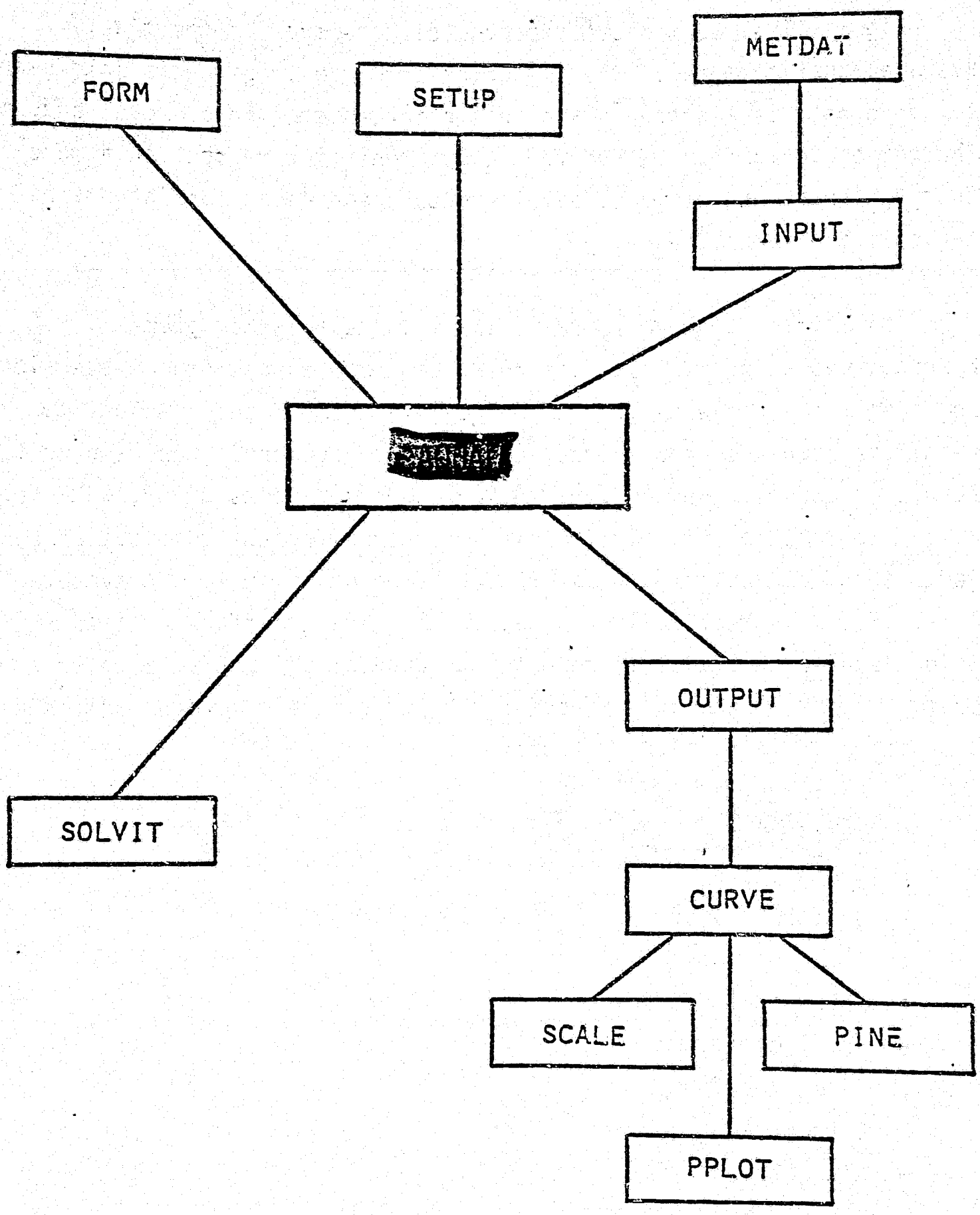

FIGURE III-1 TIDALLY AVERAGED QUALITY MODEL. SUBROUTINES

2-35-88

AQUAL then calls OUTPUT which controls the remaining subroutines in printing and plotting the results. The process repeats for each set of boundary conditions.

INTERPRETATION OF RESULTS

Provided input formats are correct and program dimensions have not been exceeded the model will print out invariant data including computational control specifications, initial conditions, and dispersion parameters as shown in Appendix Table D-1 and D-2. The model will check the junction limits assigned to the initial conditions and print the following message if errors are found:

* ERROR * THE FOLLOWING NODE LIMITS ARE IN ERROR:

The remaining outputs will be repeated for each set of boundary conditions. Appendix Table D-3 shows an example of the output which summarizes exchange conditions, observed and aggregated† inflow quality, non-point inflow quality, return water quality, system coefficients, derived flow and wind induced reaeration coefficients, and coefficients used by nodes. If dimension limits have been exceeded the runstream will terminate and one of the following messages will be printed:

- WARNING ** THE MAXIMUM OF 100 INFLOW LOCATIONS HAS BEEN EXCEEDED.**
- * ERROR * A MAXIMUM OF 29 GROUNDWATER TYPES ARE ALLOWED.
- * ERROR * RETURN WATER IS ALLOWED AT 20 NODES MAXIMUM.

---

†The user may suppress this aggregated inflow quality printout.

2-35-84

Appendix Table D-4 shows an example of the printout of observed and derived meteorological data*. [redacted] Since calculation of dispersion coefficients is an iterative process, the last two values of the coefficients are [redacted]inted for comparison. If there is a significant difference between the values, dispersion parameter C4 may need to be reduced or the number of iterations for computing dispersion coefficients increased. [redacted]

[redacted] Appendix Table D-7 shows the alternate output format. Examples of the plotting options are shown in Appendix Figures D-1 and D-2.

Calibration of the tidally averaged quality model is accomplished in two phases. The first is to simulate a conservative substance such as salinity to establish the mixing characteristics of the estuary.

The dispersion coefficients can not generally be specified *a priori*. The procedure is to start with values which have proven effective before and proceed, on a trial and error basis, to adjust the coefficients until model results compare reasonably well with field data. The model is then considered calibrated for advective and dispersive transport. The second phase of the model calibration is to adjust reaction rate coefficients (benthic oxygen demand, photosynthesis oxygenation, coliform decay, etc.) until *in situ* data are reasonably reproduced.

---

*The user may suppress this output.

2-35-90

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APPENDIX

APPENDIX A.

2-35-92

Table A-1

Hydrodynamic Model Input Card Specification

Card Group \ Col.	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80
1a	UPPER COOK INLET, KNIK ARM AND TURNAGAIN ARM															
1b	SAMPLE PROBLEM															
2a	1	6	6	28	1	1	0	12	1							
2b	3															
3	1	12	26	49	56	117										
4	18	72	83	127	140	157										
5	1	117	49													
6	72	127	140													
7	1	3	5	7	10	11	12	14	17	20	23	26	101	104	106	109
	115	118	121	125	127	128	43	46	47	48	49	50				
8	100	3600	25	40												
9	01	999,+7		30,+6	150	610	470	01	02							
	02	850,+7		00,+6	130	600	527	01	03	04						
	03	850,+7		00,+6	140	654	525	02	03	05						
	04	900,+7		20,+6	150	624	564	04	06	07						
	05	690,+7		00,+6	130	665	574	05	06	08						
	06	500,+7		18,+6	100	645	636	07	09	10						
	07	760,+7		00,+6	100	682	619	08	09	12						
	08	370,+7		30,+6	080	652	661	10	11							
	09	420,+7		21,+6	050	668	701	11	14	15						
	10	690,+7		12,+6	080	702	655	12	13							
	11	460,+7		02,+6	100	714	693	13	14	16						
	12	240,+7		00,+6	130	711	729	15	16	17	18	19				
	13	120,+7		01,+6	070	735	744	17	21	22						
	14	897,+7		00,+6	100	724	752	18	20	21	23					
	16	140,+7		02,+6	053	759	756	22	25	27						
	15	200,+7		25,+6	110	704	756	19	20	24						
	17	135,+7		00,+6	085	746	770	23	25	26	28					
	18	197,+7		18,+6	70	730	781	24	26	29						
	19	140,+7		07,+6	047	786	770	27	30	32						
	20	161,+7		00,+6	095	772	785	28	30	31	33					
	21	168,+7		01,+6	085	762	799	29	31	34						
	22	116,+7		04,+6	055	808	788	32	35	37						
	23	176,+7		00,+6	080	796	809	33	35	36	38					
	24	165,+7		25,+6	060	768	832	34	36	39						
	25	088,+7		01,+6	070	822	799	37	40	42						
	26	120,+7		00,+6	060	817	820	38	40	41	101	102	100			
	27	095,+7		40,+6	022	815	841	39	41	44						
	28	067,+7		00,+6	065	839	808	42	47	100	103					
	31	070,+7		03,+6	050	854	799	47	51	53						
	32	067,+7		3,+6	43	861	814	48	51	54	55					
	35	092,+7		20,+6	020	864	788	53	75	77						
	36	058,+7		00,+6	036	874	802	54	75	76	78					
	37	25,+7		15,+6	9	869	824	55	56	120	127					
	43	039,+7		03,+6	035	901	865	65	66	67						
	44	023,+7		03,+6	025	901	878	66	69							
	45	025,+7		03,+6	025	913	870	67	68							
	46	051,+7		15,+6	015	915	864	68	69	70						
	47	026,+7		18,+6	012	929	887	70	71							
	48	013,+7		22,+6	006	938	896	71	72							
	49	005,+7		45,+6	2	950	899	72	73							
	50	002,+7		10,+6	1	959	901	73								
	52	036,+7		28,+6	8	882	810	56	76	79						
	53	102,+7		10,+6	030	887	788	77	78	80	89					

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Table A-1 - (Cont.)

Hydrodynamic Model Input Card Specification

9

58	049,+7	23,+6	010	895	800	79	81	89				
55	059,+7	30,+6	020	906	787	80	81	82				
56	062,+7	30,+6	020	925	784	82	83					
57	38,+7	20,+6	15	903	777	83	84					
58	25,+7	10,+6	12	937	771	84	85					
59	32,+7	15,+6	12	974	771	85	86					
60	18,+7	10,+6	10	989	759	86						
100	580,+6	0,+6	80	843	820	101	103	104	48	106		
101	516,+6	0,+6	75	839	829	102	104	105	107			
102	340,+6	15,+6	10	835	839	44	105	108				
103	229,+6	1,+6	60	853	829	106	109	111				
104	231,+6	0,+6	50	850	835	107	109	110	112	113		
105	156,+6	10,+6	10	847	843	108	110	114				
106	149,+6	0,+6	80	860	836	111	112	115				
107	108,+6	0,+6	30	857	842	113	116	117				
108	90,+6	6,+6	6	855	847	114	116	118				
109	160,+6	0,+6	70	867	837	115	119	120	121			
110	178,+6	5,+6	30	863	845	117	118	122				
111	84,+6	0,+6	15	870	830	126	119	123	125			
112	46,+6	2,5+6	15	873	831	127	125	124	128			
113	54,+6	0,+6	45	874	835	129	123	124	129			
114	52,+6	1,+6	30	879	836	128	129	131				
115	124,+6	0,+6	55	875	840	121	130	132	133			
116	149,+6	4,+6	40	873	846	122	130	134	135			
117	81,+6	0,+6	45	881	840	131	132	136	138	139		
118	56,+6	0,+6	60	881	843	133	134	136	137	140	141	
119	60,+6	1,+6	35	881	846	135	137	142				
120	30,+6	0,+6	30	886	840	138	143	145				
121	40,+6	0,+6	90	886	843	139	140	143	144	146	147	148
122	32,+6	,+6	50	886	846	141	142	144	149	150		
123	33,+6	1,+6	30	890	841	145	146	151				
124	44,+6	0,+6	55	894	844	147	151	152	154			
125	33,+6	0,+6	70	891	846	148	149	152	153	155		
126	37,+6	1,+6	40	889	848	150	153	156				
127	96,+6	0,+6	95	895	851	154	155	156	157			
128	136,+6	1,+6	50	897	858	157	65					

10

01	090000	80000	130	.022	01	02		0000
02	80000	80000	130	.022	01	03		0000
03	089000	080000	200	.022	02	03		0000
04	100000	070000	120	.022	02	04		0000
05	080000	088000	130	.022	03	05		0000
06	064000	085000	120	.022	04	05		0000
07	092000	070000	130	.022	04	06		0100
08	077000	092000	105	.022	05	07		0000
09	056000	070000	050	.022	06	07		0000
10	075000	040000	085	.025	06	08		0300
11	066000	040000	070	.025	08	09		0300
12	067000	110000	090	.022	07	10		0000
13	065000	095000	090	.022	10	11		0000
14	037000	055000	050	.022	09	11		0000
15	058000	040000	060	.022	09	12		0300
16	060000	055000	100	.022	11	12		0000
17	044000	023000	070	.025	12	13		0000
18	045000	023000	100	.022	13	14		0000
19	043000	030000	130	.022	12	15		0000
20	031000	038000	040	.022	14	15		0000

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Table A-1 - (Cont.)

Hydrodynamic Model Input Card Specification

10

21	025000	042000	080	.022	13	14	0000
22	044000	025000	080	.025	13	16	0000
23	044000	022000	140	.022	14	17	0000
24	058000	036000	130	.025	15	18	0500
25	033000	046000	070	.022	16	17	0000
26	031000	053000	040	.025	17	18	0000
27	050000	033000	050	.025	16	19	0100
28	044000	031000	100	.022	17	20	0000
29	058000	038000	100	.022	18	21	0050
30	033000	050000	070	.022	19	20	0000
31	028000	055000	100	.022	20	21	0000
32	044000	027000	040	.025	19	22	0200
33	055000	033000	090	.022	20	23	0000
34	068000	030000	070	.025	21	24	0100
35	037000	045000	060	.022	22	23	0000
36	039000	052000	100	.022	23	24	0000
37	032000	030000	060	.025	22	25	0050
38	038000	037000	085	.022	23	26	0000
39	046000	025000	030	.025	24	27	0700
40	035000	030000	080	.022	25	26	0000
41	035000	034000	070	.022	26	27	0000
42	031000	022000	065	.022	25	28	0000
44	38000	18000	7	.025	27	102	1200
47	029000	019000	040	.022	25	31	0000
48	32000	16000	50	.022	32	100	0
51	025000	028000	045	.022	31	32	0000
53	026000	026000	040	.025	31	35	0500
54	027000	022000	080	.022	32	36	0000
55	022000	022000	010	.025	32	37	0000
56	030000	022000	006	.025	37	52	1000
65	12500	13000	50	.020	43	128	30
66	020000	015000	025	.025	43	44	0100
67	022000	014000	020	.025	43	45	0100
68	023000	012000	20	.025	45	46	0100
69	025000	012000	20	.025	44	46	0100
70	023000	016000	8	.025	46	47	0800
71	021000	008000	3	.025	47	48	1000
72	020000	004000	1	.025	48	49	1000
73	018000	002000	0.5	.025	49	50	1000
75	024000	022000	030	.025	35	36	0000
76	018000	030000	010	.025	36	52	0000
77	033000	030000	030	.025	35	53	0400
78	031000	019000	035	.025	36	53	0000
79	025000	015000	68	.025	52	54	1000
80	032000	015000	040	.025	53	55	0100
81	028000	025000	010	.025	54	55	0500
82	031000	015000	35	.025	55	56	0200
83	030000	012000	25	.022	56	57	300
84	026000	010000	20	.022	57	58	400
85	027000	010000	15	.022	58	59	500
86	031000	6000	15	.022	59	60	350
89	24000	25000	15	.025	53	54	0
100	40000	12000	75	.020	26	28	0
101	41000	12000	75	.020	26	100	0
102	41000	18000	75	.020	26	101	0
103	18003	19000	60	.020	28	100	0
104	17300	27000	40	.020	100	101	0

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Table A-1 (Cont.)

Hydrodynamic Model Input Card Specification

	105	17600	30000	13	.020	101	102	0
	106	23000	14000	60	.020	100	103	0
	107	20500	15000	60	.020	101	104	0
	108	21000	10000	7	.025	102	105	700
	109	11300	15000	60	.020	103	104	0
	110	14000	17000	14	.025	104	105	0
	111	13800	9000	85	.020	103	106	0
	112	14100	7000	75	.020	104	106	0
	113	15200	8000	25	.022	104	107	0
	114	14000	7000	7	.025	105	108	500
	115	11500	12000	75	.020	106	109	30
	116	9400	11000	14	.025	107	108	0
	117	11400	8500	30	.022	107	110	0
	118	13800	6000	8	.025	108	110	300
	119	11300	5500	15	.025	109	111	0
	120	11500	4800	65	.020	109	113	0
	121	15200	8700	50	.020	109	115	0
	122	15200	12700	35	.022	110	116	150
	123	8500	5500	15	.022	111	113	0
	124	6000	5800	15	.025	112	113	0
	125	7700	7000	10	.025	111	112	0
	126	11000	7000	15	.025	37	111	0
	127	15000	4000	5	.025	37	112	250
	128	11000	3700	15	.025	112	114	70
10	129	9700	4200	40	.022	113	114	0
	130	10300	1500	35	.020	115	116	0
	131	8200	3800	35	.020	114	117	25
	132	10800	4500	55	.020	115	117	0
	133	12000	4800	60	.020	115	118	0
	134	14500	4000	40	.020	116	118	0
	135	14200	6500	35	.022	116	119	50
	136	8000	10000	60	.020	117	118	0
	137	8000	10000	60	.020	118	119	0
	138	7000	4000	30	.022	117	120	0
	139	8000	3000	75	.020	117	121	0
	140	7300	4000	75	.020	118	121	0
	141	8200	3000	85	.020	118	122	0
	142	7300	3800	35	.022	119	122	60
	143	10000	8000	60	.020	120	121	0
	144	10000	8000	60	.020	121	122	0
	145	6800	4300	30	.022	120	123	20
	146	7000	3300	40	.022	121	123	0
	147	12000	2300	75	.020	121	124	0
	148	10100	2700	80	.020	121	125	0
	149	9000	2500	75	.020	122	125	0
	150	6800	3500	40	.022	122	126	40
	151	6600	4800	35	.022	123	124	20
	152	8000	10000	60	.020	124	125	0
	153	8000	10000	60	.020	125	126	0
	154	12000	3500	80	.020	124	127	0
	155	10100	3500	80	.020	125	127	0
	156	9900	3000	50	.020	126	127	20
	157	11800	8000	75	.020	127	128	30

11 WATER YEAR 1972 AVERAGE TRIBUTARY INFLOWS

12 0 0 0 0 0 0 0

13 1

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Table A-1 - (Cont.)

Hydrodynamic Model Input Card Specification

14a	1	6	30	1												
14b	-2.9	-6.5	3.4	7.4	9.6	-9.	16.	7.6	22.1	-6.5	28.4	7.4				
15	1	130	3.													
16a	1	160														
16b	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0														
17	11	8600.														
	27	33000.														
	45	470.														
	48	120.														
	50	10880.														
	60	1000.														
	108	600.														
	117	75.														
	124	110.														
18	1	130	0													
19																

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APPENDIX B

2-35-98

Table B-1

Node Renumbering Scheme

CROSS REFERENCE - - INTERNAL NODE NUMBER V3, EXTERNAL NODE NUMBER (USED IN QUALITY PROGRAM AQUAL)

1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	10	10	9
11	11	12	12	13	13	14	14	15	15	16	16	17	17	18	18	19	19	20	20
21	21	22	22	23	23	24	24	25	25	26	26	27	27	28	28	29	100	30	101
31	102	32	31	33	32	34	103	35	104	36	105	37	35	38	36	39	37	40	106
41	107	42	108	43	53	44	52	45	111	46	112	47	109	48	110	49	55	50	54
51	113	52	114	53	115	54	116	55	56	56	117	57	118	58	119	59	57	60	120
61	121	62	122	63	58	64	123	65	124	66	125	67	126	68	59	69	127	70	60
71	128	72	43	73	44	74	45	75	46	76	47	77	48	78	49	79	50		

THE WIDEST TOTAL BAND WIDTH IS 14 , THE HIGH SIDE MAXIMUM WIDTH IS 7 , AND THE LOW SIDE MAXIMUM WIDTH IS 7

2-35-99

Table B-2

Computational and Output Control Options

UPPER COOK INLET, KNIK ARM AND TURNAGAIN ARM
SAMPLE PROBLEM

NUMBER OF HYDRAULIC CONDITIONS	1
NUMBER OF TIDAL CYCLES PER CONDITION	3
NUMBER OF HYDRAULIC TIME STEPS PER CYCLE	900
NUMBER OF QUALITY TIME STEPS PER CYCLE	25
NUMBER OF TIDAL STAGE PLOTS	1
NUMBER OF TIDAL VELOCITY PLOTS	1
DYNAMIC HYDRAULIC OUTPUT UNIT	0
STEADY STATE HYDRAULICS OUTPUT UNIT	12
TIDAL PERIOD, HOURS	25.

RESULTS PRINTED AT THE FOLLOWING 6 JUNCTIONS

1 12 26 49 56 117

AND FOR THE FOLLOWING 6 CHANNELS

18 72 83 127 140 157

FOLLOWING PLOTS ARE MADE

TIDAL STAGE FOR JUNCTIONS	1	117	49
TIDAL FLOW FOR CHANNELS	72	127	140

Table B-3

Invariant Channel Data

UPPER COOK INLET, KNIK ARM AND TURNAGAIN ARM
SAMPLE PROBLEM

INVARIANT CHANNEL DATA

CHANNEL	LENGTH, FT	WIDTH, FT	HYD RAD, FT	MIN ELEV, FT	MANNINGS N	END JUNCTIONS		SIDE SLOPE	MAX TIME, SEC
1	90000.	80000.	130.0	130.0	.022	1	2	0.	1295.
2	90000.	80000.	130.0	130.0	.022	1	3	0.	1295.
3	89000.	80000.	200.0	200.0	.0*	2	3	0.	1057.
4	100000.	70000.	120.0	120.0	.022	2	4	0.	1489.
5	80000.	80000.	130.0	130.0	.022	3	5	0.	1151.
6	64000.	85000.	120.0	120.0	.022	4	5	0.	953.
7	92000.	70000.	130.0	145.1	.022	4	6	0.	1324.
8	77000.	92000.	105.0	105.0	.022	5	7	0.	1214.
9	66000.	70000.	50.0	50.0	.022	6	7	0.	1390.
10	75000.	40000.	65.0	133.3	.025	6	8	300.	1290.
11	68000.	40000.	70.0	133.3	.025	8	9	300.	1263.
12	67000.	110000.	90.0	90.0	.022	7	10	0.	1126.
13	65000.	95000.	90.0	90.0	.022	10	11	0.	1092.
14	37000.	55000.	50.0	50.0	.022	9	11	0.	779.
15	58000.	40000.	60.0	91.2	.022	9	12	300.	1183.
16	60000.	55000.	100.0	100.0	.022	11	12	0.	965.
17	44000.	23000.	70.0	70.0	.025	12	13	0.	817.
18	45000.	23000.	100.0	100.0	.022	12	14	0.	724.
19	43000.	30000.	130.0	130.0	.022	12	15	0.	619.
20	31000.	38000.	40.0	40.0	.022	14	15	0.	705.
21	25000.	42000.	80.0	80.0	.022	13	14	0.	441.
22	44000.	25000.	80.0	80.0	.025	13	16	0.	775.
23	44000.	22000.	140.0	140.0	.022	14	17	0.	813.
24	58000.	36000.	130.0	72.0	.025	15	18	500.	835.
25	33000.	46000.	70.0	70.0	.022	16	17	0.	613.
26	31000.	53000.	40.0	40.0	.025	17	18	0.	705.
27	50000.	33000.	50.0	54.6	.023	16	19	100.	1053.
28	48000.	31000.	100.0	100.0	.022	17	20	0.	772.
29	58000.	20000.	100.0	111.1	.022	18	21	50.	933.
30	33000.	50000.	70.0	70.0	.022	19	20	0.	613.
31	20000.	55000.	100.0	100.0	.022	20	21	0.	450.
32	44000.	27000.	40.0	48.9	.025	19	22	200.	1001.
33	55000.	33000.	90.0	90.0	.022	20	23	0.	924.
34	60000.	30000.	70.0	81.0	.025	21	24	100.	1263.
35	37000.	45000.	60.0	60.0	.022	22	23	0.	729.
36	39000.	52000.	100.0	100.0	.022	23	24	0.	627.
37	32000.	30000.	60.0	63.4	.025	22	25	50.	630.
38	30000.	37000.	85.0	85.0	.022	23	26	0.	654.
39	46000.	25000.	30.0	35.7	.025	24	27	700.	1100.
40	35000.	30000.	80.0	80.0	.022	25	26	0.	617.
41	35000.	38000.	70.0	70.0	.022	26	27	0.	650.
42	31000.	22000.	65.0	65.0	.022	25	28	0.	593.
44	39000.	18000.	7.0	11.2	.025	27	102	1200.	1289.
47	27000.	19000.	40.0	40.0	.022	28	31	0.	660.
48	32000.	16000.	50.0	50.0	.022	32	100	0.	674.

NOTE - - * INDICATES NEGATIVE WIDTH IS POSSIBLE WITH ANTICIPATED TIDAL STAGE

Table B-3 - (Cont.)

Invariant Channel Data

UPPER COOK INLET, KNIK ARM AND TURNAGAIN ARM
SAMPLE PROBLEM

INVARIANT CHANNEL DATA

CHANNEL	LENGTH, FT	WIDTH, FT	HYD RAD, FT	MIN ELEV, FT	MANNINGS N	END JUNCTIONS		SIDE SLOPE	MAX TIME, SEC
51	25000.	28000.	45.0	45.0	.022	31	32	0.	546.
53	26000.	28000.	40.0	56.0	.025	31	35	500.	592.
54	27000.	22000.	40.0	40.0	.022	32	36	0.	614.
55	22000.	22000.	10.0	10.0	.025	32	37	0.	706.
56	30000.	22000.	6.0	7.2	.025	37	52	1000.	1037.
65	12500.	13000.	50.0	53.3	.020	43	128	30.	263.
66	20000.	15000.	25.0	27.6	.025	43	44	100.	525.
67	22000.	14000.	20.0	21.7	.025	43	45	100.	611.
68	23000.	12000.	20.0	22.1	.025	45	46	100.	641.
69	25000.	12000.	20.0	22.1	.025	44	46	100.	697.
70	23000.	16000.	8.0	11.1	.025	46	47	800.	766.
71	21000.	8000.	3.0	4.1	.025	47	48	1000.	772.
72	20000.	4000.	1.0	1.2	.025	48	49	1000.	769.
73	18000.	2000.	.5	.6	.025	49	50	1000.	701.
75	24000.	22000.	30.0	30.0	.025	35	36	0.	598.
76	18000.	30000.	10.0	10.0	.025	36	52	0.	579.
77	33000.	30000.	30.0	41.5	.025	35	53	400.	822.
78	31000.	19000.	35.0	35.0	.025	36	53	0.	737.
79*	28000.	15000.	68.0	15.0	.025	52	54	1000.	526.
80	32000.	15000.	40.0	47.6	.025	53	55	100.	728.
81	28000.	25000.	10.0	11.3	.025	54	55	500.	901.
82	31000.	15000.	35.0	55.7	.025	55	56	200.	737.
83	30000.	12000.	25.0	40.0	.022	56	57	300.	788.
84	26000.	10000.	20.0	25.0	.022	57	58	400.	724.
85	27000.	10000.	15.0	20.0	.022	58	59	500.	804.
86*	31000.	6000.	15.0	17.1	.022	59	60	350.	923.
89	24000.	25000.	15.0	15.0	.025	53	54	0.	715.
100	40000.	12000.	75.0	75.0	.020	26	28	0.	723.
101	41000.	12000.	75.0	75.0	.020	26	100	0.	741.
102	41000.	18000.	75.0	75.0	.020	26	101	0.	741.
103	18000.	19000.	60.0	60.0	.020	28	100	0.	355.
104	17300.	27000.	40.0	40.0	.020	100	101	0.	394.
105	17600.	30000.	13.0	13.0	.020	101	102	0.	540.
106	23000.	14000.	60.0	60.0	.020	100	103	0.	453.
107	20500.	15000.	60.0	60.0	.020	101	104	0.	404.
108	21000.	10000.	7.0	12.3	.025	102	105	700.	712.
109	11300.	15000.	60.0	60.0	.020	103	104	0.	223.
110	14000.	17000.	14.0	14.0	.025	104	105	0.	423.
111	13800.	9000.	85.0	85.0	.020	103	106	0.	237.
112	14100.	7000.	75.0	75.0	.020	104	106	0.	255.
113	15200.	8000.	25.0	25.0	.022	104	107	0.	399.
114	14000.	7000.	7.0	14.0	.025	105	108	500.	475.
115	11500.	12000.	75.0	63.8	.020	106	109	30.	208.
116	9400.	11000.	14.0	14.0	.025	107	108	0.	284.
117	11400.	8500.	30.0	30.0	.022	107	110	0.	284.

NOTE - * INDICATES NEGATIVE WIDTH IS POSSIBLE WITH ANTICIPATED TIDAL STAGE

Table B-3 - (Cont.)

Invariant Channel Data

UPPER COOK INLET, KNIK ARM AND TURNAGAIN ARM
SAMPLE PROBLEM

INVARIANT CHANNEL DATA

CHANNEL	LENGTH, FT	WIDTH, FT	HYD RAD, FT	MIN ELEV, FT	MANNINGS N	END JUNCTIONS		SIDE SLOPE	MAX TIME, SEC
118	13900.	6000.	8.0	11.1	.025	108	110	300.	460.
119	11300.	5500.	15.0	15.0	.025	109	111	0.	337.
120	11500.	4800.	65.0	65.0	.020	109	113	0.	220.
121	15200.	8700.	50.0	50.0	.020	109	115	0.	320.
122	15200.	12700.	35.0	49.5	.022	110	116	150.	361.
123	8500.	5500.	15.0	15.0	.022	111	113	0.	253.
124	6000.	5800.	15.0	15.0	.025	112	113	0.	179.
125	7700.	7000.	10.0	10.0	.025	111	112	0.	248.
126	11000.	7000.	15.0	15.0	.025	37	111	0.	328.
127	15000.	4000.	5.0	6.3	.025	37	112	250.	529.
128	11000.	3700.	15.0	18.1	.025	112	114	70.	328.
129	9700.	4200.	40.0	40.0	.022	113	114	0.	221.
130	10300.	11500.	35.0	35.0	.020	115	116	0.	245.
131	8200.	3800.	35.0	40.4	.020	114	117	25.	195.
132	10900.	4500.	55.0	55.0	.020	115	117	0.	220.
133	12000.	4800.	60.0	60.0	.020	115	118	0.	236.
134	14500.	4000.	40.0	40.0	.020	116	118	0.	330.
135	14200.	6500.	35.0	41.7	.022	116	119	50.	337.
136	8000.	10000.	60.0	60.0	.020	117	118	0.	158.
137	8000.	10000.	60.0	60.0	.020	118	119	0.	158.
138	7900.	4000.	30.0	30.0	.022	117	120	0.	174.
139	8000.	3000.	75.0	75.0	.020	117	121	0.	145.
140	7300.	4000.	75.0	75.0	.020	118	121	0.	132.
141	8200.	3000.	85.0	85.0	.020	118	122	0.	141.
142	7300.	3800.	35.0	63.3	.022	119	122	60.	173.
143	10000.	4000.	60.0	60.0	.020	120	121	0.	197.
144	10000.	8000.	60.0	60.0	.020	121	122	0.	197.
145	6800.	4300.	30.0	32.5	.022	120	123	20.	169.
146	7000.	3300.	40.0	40.0	.022	121	123	0.	159.
147	12000.	2300.	75.0	75.0	.020	121	124	0.	217.
148	10100.	2700.	80.0	80.0	.020	121	125	0.	178.
149	9000.	2500.	75.0	75.0	.020	122	125	0.	163.
150	6800.	3800.	40.0	57.3	.022	122	126	40.	155.
151	6000.	4800.	35.0	38.1	.022	123	124	20.	162.
152	8000.	10000.	60.0	60.0	.020	124	125	0.	158.
153	8000.	10000.	60.0	60.0	.020	125	126	0.	158.
154	12000.	3500.	80.0	89.0	.020	124	127	0.	211.
155	10100.	3500.	80.0	80.0	.020	125	127	0.	178.
156	9900.	3000.	50.0	63.4	.020	126	127	20.	209.
157	11800.	8000.	75.0	90.3	.020	127	128	30.	213.

NOTE - - * INDICATES NEGATIVE WIDTH IS POSSIBLE WITH ANTICIPATED TIDAL STAGE

2-35-103

Table B-4

Invariant Node Data

UPPER COOK INLET, KNIK ARM AND TURNAGAIN ARM
SAMPLE PROBLEM

INVARIANT JUNCTION DATA

JUNCTION	AREA, MSF	SLOPE, MSF/FT	DEPTH, FT	MIN ELEV, FT	X-CORD	Y-CORD	CHANNELS ENTERING JUNCTION							
1	9940.	0	150.0	150.0	610.0	470.0	1	2	0	0	0	0	0	0
2	8500.	0	130.0	130.0	600.0	527.0	1	3*	4	0	0	0	0	0
3	8500.	0	140.0	140.0	654.0	525.0	2	3*	5	0	0	0	0	0
4	9000.	20.0	150.0	190.2	624.0	584.0	4	6	7	0	0	0	0	0
5	6900.	0	130.0	130.0	665.0	574.0	5	6	8	0	0	0	0	0
6	5000.	18.0	100.0	130.8	645.0	636.0	7*	9	10*	0	0	0	0	0
7	7600.	0	100.0	100.0	682.0	619.0	8*	9	12	0	0	0	0	0
8	3700.	30.0	80.0	123.3	652.0	681.0	10*	11*	0	0	0	0	0	0
9	4200.	21.0	50.0	58.6	668.0	701.0	11*	14	15*	0	0	0	0	0
10	6900.	12.0	89.0	86.6	702.0	655.0	12*	13*	0	0	0	0	0	0
11	4600.	2.0	100.0	102.3	714.0	693.0	13	14	16	0	0	0	0	0
12	2400.	0	130.0	130.0	711.0	729.0	15	16	17	18	19	0	0	0
13	1200.	1.0	70.0	72.2	735.0	744.0	17	21*	22*	0	0	0	0	0
14	970.	0	100.0	100.0	724.0	754.0	18	20	21	23*	0	0	0	0
15	2000.	25.0	110.0	80.0	704.0	756.0	19*	20	24	0	0	0	0	0
16	1400.	2.0	53.0	55.2	759.0	756.0	22*	25*	27	0	0	0	0	0
17	1350.	0	85.0	85.0	746.0	770.0	23*	25	26	28*	0	0	0	0
18	1970.	10.0	70.0	109.4	730.0	781.0	24	26	29*	0	0	0	0	0
19	1400.	7.0	47.0	54.4	786.0	770.0	27*	30*	32	0	0	0	0	0
20	1610.	0	95.0	95.0	772.0	765.0	28*	30	31*	33	0	0	0	0
21	1680.	1.0	85.0	87.3	762.0	799.0	29*	31*	34	0	0	0	0	0
22	1160.	4.0	55.0	61.6	806.0	788.0	32	35	37*	0	0	0	0	0
23	1760.	0	80.0	80.0	796.0	809.0	33*	35	36*	38*	0	0	0	0
24	1650.	25.0	60.0	66.0	788.0	832.0	34*	36*	39	0	0	0	0	0
25	880.	1.0	70.0	73.1	822.0	799.0	37	40*	42	0	0	0	0	0
26	1200.	0	80.0	80.0	817.0	820.0	38*	40	41	101	102	100	0	0
27	950.	40.0	22.0	23.7	815.0	841.0	39*	41*	44	0	0	0	0	0
28	670.	0	65.0	65.0	839.0	808.0	42	47	100*	103	0	0	0	0
31	700.	3.0	50.0	57.0	854.0	799.0	47	51	53	0	0	0	0	0
32	670.	3.0	43.0	48.3	861.0	814.0	40*	51	54	55	0	0	0	0
35	920.	20.0	20.0	29.4	864.0	788.0	53*	75*	77*	0	0	0	0	0
36	580.	0	36.0	36.0	874.0	802.0	54*	75	76	78	0	0	0	0
37**	250.	15.0	9.0	16.7	869.0	824.0	55	56	126	127	0	0	0	0
43	390.	4.0	35.0	45.8	901.0	865.0	65*	66	67	0	0	0	0	0
44	230.	3.0	25.0	31.5	901.0	878.0	66	69	0	0	0	0	0	0
45	250.	3.0	25.0	30.7	913.0	870.0	67	68	0	0	0	0	0	0
46	510.	15.0	15.0	22.4	915.0	884.0	68	69	70	0	0	0	0	0
47**	260.	18.0	12.0	14.4	929.0	887.0	70	71	0	0	0	0	0	0
48**	130.	22.0	6.0	5.9	938.0	896.0	71	72	0	0	0	0	0	0
49**	50.	45.0	2.0	1.1	950.0	899.0	72*	73	0	0	0	0	0	0
50	20.	10.0	1.0	2.0	959.0	901.0	73	0	0	0	0	0	0	0
52**	360.	28.0	8.0	12.9	882.0	810.0	56	76	79*	0	0	0	0	0
53	1020.	10.0	30.0	36.6	887.0	788.0	77*	78	80*	89	0	0	0	0
54	490.	23.0	10.0	16.1	895.0	800.0	79	81	89	0	0	0	0	0
55**	590.	30.0	20.0	19.7	906.0	787.0	80*	81	82*	0	0	0	0	0

NOTE - - * INDICATES THAT DEPTH OF CHANNEL ENTERING JUNCTION IS LARGER THAN JUNCTION DEPTH
** INDICATES NEGATIVE VOLUME OR AREA IS POSSIBLE WI[illegible] ANTICIPATED TIDAL STAGE

Table B-4 - (Cont.)

Invariant Node Data

UPPER COOK INLET, KNIK ARM AND TURNAGAIN ARM
SAMPLE PROBLEM

INVARIANT JUNCTION DATA

JUNCTION	AREA, MSF	SLOPE, MSF/FT	DEPTH, FT	MIN ELEV, FT	X-CORD	Y-CORD	CHANNELS ENTERING JUNCTION							
56	620.	30.0	20.0	20.7	925.0	784.0	82*	83*	0	0	0	0	0	0
57**	380.	20.0	15.0	19.0	943.0	777.0	83*	84*	0	0	0	0	0	0
58	230.	10.0	12.0	20.1	957.0	771.0	84*	85	0	0	0	0	0	0
59	320.	15.0	12.0	21.3	974.0	771.0	85	86	0	0	0	0	0	0
69**	180.	10.0	10.0	10.0	989.0	759.0	86	0	0	0	0	0	0	0
100	580.	.0	80.0	80.0	843.0	820.0	101	103	104	48	106	0	0	0
101	516.	.0	75.0	75.0	839.0	829.0	102	104	105	107	0	0	0	0
102	340.	15.0	10.0	14.9	835.0	839.0	44	105	108	0	0	0	0	0
103	229.	.0	60.0	71.1	853.0	829.0	106	109	111*	0	0	0	0	0
104	231.	.0	50.0	50.0	850.0	835.0	107*	109*	110	112*	113	0	0	0
105**	156.	10.0	10.0	15.6	847.0	843.0	108	110	114	0	0	0	0	0
106	149.	.0	80.0	80.0	860.0	836.0	111*	112	115*	0	0	0	0	0
107	108.	.0	30.0	30.0	857.0	842.0	113	116	117	0	0	0	0	0
108**	90.	6.0	8.0	15.0	855.0	847.0	114	116	118	0	0	0	0	0
109	100.	.0	70.0	70.0	867.0	837.0	115*	119	120	121	0	0	0	0
110	178.	5.0	30.0	35.6	863.0	845.0	117	118	122*	0	0	0	0	0
111	84.	.0	15.0	15.0	870.0	830.0	126	119	123	125	0	0	0	0
112**	46.	2.5	15.0	18.4	873.0	831.0	127	125	124	128	0	0	0	0
113	54.	.0	45.0	45.0	874.0	835.0	120*	123	124	129	0	0	0	0
114	52.	1.0	30.0	52.0	879.0	836.0	128	129	131	0	0	0	0	0
115	124.	.0	55.0	55.0	875.0	840.0	121	130	132	133*	0	0	0	0
116	149.	4.0	40.0	37.2	873.0	846.0	122*	130	134*	135*	0	0	0	0
117	41.	.0	45.0	45.0	881.0	840.0	131	132*	136*	138	139*	0	0	0
118	56.	.0	60.0	60.0	881.0	843.0	133	134	136	137	140*	141*	0	0
119	60.	1.0	55.0	60.0	881.0	846.0	135	137	142*	0	0	0	0	0
120	30.	.0	30.0	30.0	886.0	840.0	138	143*	145*	0	0	0	0	0
121	40.	.0	90.0	90.0	886.0	843.0	139	140	143	144	146	147	148	0
122	32.	.0	50.0	50.0	886.0	846.0	141*	142*	144*	149*	150*	0	0	0
123	35.	1.0	30.0	33.0	890.0	841.0	145	146*	151*	0	0	0	0	0
124	44.	.0	55.0	55.0	894.0	844.0	147*	151	152*	154*	0	0	0	0
125	33.	.0	70.0	70.0	891.0	846.0	148*	149*	152	153	155*	0	0	0
126	37.	1.0	40.0	37.0	889.0	848.0	150*	153*	156*	0	0	0	0	0
127	96.	.0	95.0	95.0	895.0	851.0	154	155	156	157	0	0	0	0
128	136.	1.0	50.0	66.1	897.0	818.0	157*	65	0	0	0	0	0	0

NOTE - - * INDICATES THAT DEPTH OF CHANNEL ENTERING JUNCTION IS LARGER THAN JUNCTION DEPTH
** INDICATES NEGATIVE VOLUME OR AREA IS POSSIBLE WITH ANTICIPATED TIDAL STAGE

ESTUARY STATISTICS (AT MSL)

TOTAL VOLUME, CU FT	.1117+14
TOTAL SURFACE AREA, SQ FT	.1122+12
MEAN DEPTH, FT	.9954+02

2-35-105

Table B-5

Tidal Time-Stage Data

UPPER COOK INLET, KNIK ARM AND TURNAGAIN ARM
WATER YEAR 1972 AVERAGE TRIBUTARY INFLOWS

TIDAL COEFFICIENTS FOR JUNCTION 1

-.1307 -.0067 7.5438 -.1313 .7978 -1.0495 -.0606

TIME	OBSERVED	COMPUTED	DIFF
-2.9000	-6.5000	-6.4705	.0295
3.4000	7.4000	7.3798	-.0202
9.6000	-9.0000	-9.0190	-.0190
16.0000	7.6000	7.5996	-.0004
22.1000	-6.5000	-6.4705	.0295
28.4000	7.4000	7.3798	-.0202
-1.3250	-4.4637	-4.5220	-.0584
.2500	.4500	.4346	-.0154
1.8250	5.3636	5.4382	.0745
8.9500	4.9974	4.9040	-.0934
6.5000	-.8000	-.7725	.0275
8.0500	-6.5974	-6.5193	.0781
11.2000	-6.5681	-6.6396	-.0715
12.8000	-.7000	-.6810	.0190
14.4000	5.1681	5.2223	.0542
17.5250	5.5343	5.4829	-.0514
19.0500	.5500	.5239	-.0261
20.5750	-4.4344	-4.3719	.0625
23.6750	-4.4637	-4.5221	-.0584
25.2500	.4500	.4345	-.0155
26.8250	5.3636	5.4381	.0745
TOTAL			.8993

SUMMARY BY HOUR

1	3.02 2	5.85 3	7.30 4	6.93 5	4.76 6	1.24 7	-2.80 8	-6.37 9	-8.59 10	-8.89
11	-7.19 12	-3.91 13	.14 14	3.97 15	6.65 16	7.60 17	6.65 18	4.12 19	.70 20	-2.73
21	-5.32 22	-6.45 23	-5.85 24	-3.67 25	-.48 26	3.02				

201-55-2

Table B-6

Summary of Boundary Conditions

UPPER COOK INLET, KNIK ARM AND TURNAGAIN ARM
WATER YEAR 1972 AVERAGE TRIBUTARY INFLOWS

JUNCTION TO JUNCTION		EVAPORATION RATE, INCHES/MONTH
1	130	3.00

HOURLY WIND VELOCITY (MPH) AND DIRECTION (DEGREES CLOCKWISE FROM NORTH)
CHANNEL TO CHANNEL

1	160	1	.0	0.	2	.0	0.	3	.0	0.	4	.0	0.	5	.0	0.
		6	.0	0.	7	.0	0.	8	.0	0.	9	.0	0.	10	.0	0.
		11	.0	0.	12	.0	0.	13	.0	0.	14	.0	0.	15	.0	0.
		16	.0	0.	17	.0	0.	18	.0	0.	19	.0	0.	20	.0	0.
		21	.0	0.	22	.0	0.	23	.0	0.	24	.0	0.	25	.0	0.

INFLOW AND OUTFLOW DATA

JUNCTION	INFLOW, CFS	WITHDRAWL, CFS
11	4600.00	.00
27	33000.00	.00
45	470.00	.00
48	120.00	.00
50	10800.00	.00
60	1000.00	.00
108	600.00	.00
117	75.00	.00
124	110.00	.00

JUNCTION TO JUNCTION		GROUND WATER INFLOW, CFS
1	130	.00

JUNCTION — STORM WATER INFLOW, HOUR AND FLOW, CFS

2-35-07

Table B-7

Computed Time-Stage at Selected Nodes

UPPER COOK INLET, KNIK ARM AND TURNAGAIN ARM
WATER YEAR 1972 AVERAGE TRIBUTARY INFLOWS

HOUR	JUNCTION 1 HEAD(FEET)	JUNCTION 12 HEAD(FEET)	JUNCTION 26 HEAD(FEET)	JUNCTION 49 HEAD(FEET)	JUNCTION 56 HEAD(FEET)	JUNCTION 117 HEAD(FEET)
1.00	3.02	-7.28	-10.12	10.78	-2.82	-9.40
2.00	5.85	-3.23	-11.20	9.86	-7.14	-12.87
3.00	7.30	1.33	-6.79	9.06	-11.12	-11.99
4.00	6.93	5.31	-.14	8.35	-11.01	-4.61
5.00	4.76	8.07	5.83	7.71	-2.52	3.81
6.00	1.24	8.98	10.35	7.15	5.16	10.41
7.00	-2.80	7.74	12.68	7.27	11.25	14.13
8.00	-6.37	4.40	11.96	9.46	15.05	14.79
9.00	-8.59	.79	8.45	12.16	15.01	12.20
10.00	-8.89	-2.65	3.51	13.64	11.09	7.09
11.00	-7.19	-6.14	-1.69	12.86	7.12	1.11
12.00	-3.91	-9.12	-6.62	11.74	2.46	-4.52
13.00	.14	-10.33	-10.86	10.72	-2.22	-9.38
14.00	3.97	-7.61	-13.63	9.81	-6.72	-13.36
15.00	6.65	-1.91	-12.17	9.02	-11.19	-15.63
16.00	7.60	2.86	-4.39	8.31	-14.76	-10.74
17.00	6.65	6.93	2.42	7.68	-7.16	-.99
18.00	4.12	9.23	8.48	7.12	.21	7.01
19.00	.70	9.54	12.32	6.63	8.13	12.93
20.00	-2.73	7.58	13.65	7.88	13.84	15.56
21.00	-5.32	4.17	11.65	10.80	16.48	15.15
22.00	-6.45	.81	7.76	13.50	14.58	11.49
23.00	-5.85	-2.35	2.76	14.22	10.63	5.95
24.00	-3.67	-5.44	-2.19	13.09	6.42	.12
25.00	-.44	-7.53	-6.66	11.92	1.70	-5.06
26.00	3.02	-7.26	-10.09	10.87	-2.85	-9.38
27.00	5.85	-3.22	-11.18	9.94	-7.16	-12.44
28.00	7.30	1.34	-6.78	9.13	-11.13	-11.96
29.00	6.93	5.31	-.14	8.41	-10.98	-4.60
30.00	4.76	8.07	5.83	7.77	-2.52	3.81
31.00	1.24	8.98	10.35	7.20	5.16	10.42
32.00	-2.80	7.73	12.68	7.31	11.25	14.13
33.00	-6.37	4.40	11.95	9.50	15.05	14.79
34.00	-8.59	.79	8.45	12.19	15.00	12.19
35.00	-8.89	-2.66	3.50	13.66	11.09	7.09
36.00	-7.19	-6.14	-1.69	12.87	7.11	1.11
37.00	-3.91	-9.12	-6.62	11.75	2.46	-4.52
38.00	.14	-10.33	-10.87	10.73	-2.22	-9.38
39.00	3.97	-7.61	-13.63	9.82	-6.73	-13.37
40.00	6.66	-1.91	-12.17	9.02	-11.19	-15.63
41.00	7.60	2.87	-4.38	8.31	-14.76	-10.74
42.00	6.65	6.93	2.42	7.68	-7.16	-.99
43.00	4.12	9.23	8.49	7.12	.21	7.01
44.00	.70	9.54	12.32	6.63	8.13	12.93
45.00	-2.73	7.58	13.65	7.89	13.84	15.56
46.00	-5.32	4.17	11.65	10.80	16.48	15.15
47.00	-6.45	.81	7.76	13.50	14.58	11.49
48.00	-5.85	-2.35	2.76	14.22	10.63	5.95
49.00	-3.67	-5.44	-2.19	13.09	6.42	.12
50.00	-.44	-7.53	-6.66	11.92	1.70	-5.08

Table B-8

Computed Flow and Velocity in Selected Channels

UPPER COOK INLET, KNIK ARM AND TURNAGAIN ARM
WATER YEAR 1972 AVERAGE TRIBUTARY INFLOWS

HOUR	CHANNEL 18 FLOW (CFS)	CHANNEL 18 VEL. (FPS)	CHANNEL 72 FLOW (CFS)	CHANNEL 72 VEL. (FPS)	CHANNEL 83 FLOW (CFS)	CHANNEL 83 VEL. (FPS)	CHANNEL 127 FLOW (CFS)	CHANNEL 127 VEL. (FPS)	CHANNEL 140 FLOW (CFS)	CHANNEL 140 VEL. (FPS)	CHANNEL 157 FLOW (CFS)	CHANNEL 157 VEL. (FPS)
1.00	-5516137.	-2.58	-191106.	-2.12	-1416006.	-5.00	0.	.00	-741366.	-2.82	-1845617.	-3.49
2.00	4032225.	1.87	-157056.	-2.01	-1131625.	-4.80	0.	.00	-508879.	-2.03	-1236665.	-2.46
3.00	13065712.	5.67	-130323.	-1.91	-881862.	-4.49	0.	.00	-67976.	-.25	-245198.	-.47
4.00	16710525.	6.94	-109507.	-1.83	-699315.	-2.71	-672.	-.09	967181.	3.47	2653444.	4.85
5.00	16129833.	6.49	-92521.	-1.74	1043164.	4.02	-69893.	-1.87	1628563.	5.18	4605526.	7.38
6.00	11782740.	4.67	-79968.	-1.69	1924263.	5.55	-178443.	-2.52	1517019.	4.43	4151891.	6.05
7.00	4283398.	1.69	156219.	2.10	2509075.	5.76	-212347.	-2.16	1123602.	3.14	2975000.	4.12
8.00	-5566803.	-2.33	427380.	3.50	2522007.	5.00	-91991.	-.87	479272.	1.32	913813.	1.23
9.00	-13021632.	-5.58	498215.	3.24	1339124.	2.55	63170.	.75	-393000.	-1.14	-1754202.	-2.50
10.00	-15589311.	-6.96	75090.	.49	-1362350.	-2.95	71553.	1.37	-1163165.	-3.54	-3706707.	-5.57
11.00	-15123041.	-6.96	-254550.	-2.04	-2102561.	-5.11	38906.	1.58	-1276370.	-4.18	-3610244.	-5.87
12.00	-12677975.	-6.04	-224709.	-2.14	-1806388.	-5.19	5753.	.99	-1058064.	-3.74	-2780918.	-4.90
13.00	-8622689.	-4.18	-188387.	-2.10	-1469392.	-5.06	0.	.00	-816265.	-3.10	-2032426.	-3.84
14.00	-804126.	-.38	-155304.	-2.00	-1183491.	-4.91	0.	.00	-605990.	-2.45	-1452206.	-2.92
15.00	11024306.	4.97	-128979.	-1.90	-938852.	-4.75	0.	.00	-349983.	-1.46	-845584.	-1.77
16.00	17216028.	7.34	-108448.	-1.83	-697645.	-4.26	0.	.00	504433.	2.01	1132499.	2.31
17.00	18438397.	7.52	-92100.	-1.76	416818.	2.11	-29117.	-2.04	1477122.	5.02	3896596.	6.70
18.00	15810787.	6.28	-78192.	-1.68	1391206.	4.84	-124044.	-2.43	1786918.	5.45	4949007.	7.56
19.00	9650968.	3.79	-54528.	-1.03	2357999.	6.10	-229931.	-2.59	1489251.	4.23	4027935.	5.69
20.00	1127001.	.43	295429.	3.12	2804474.	5.88	-197888.	-1.78	968407.	2.66	2454119.	3.33
21.00	-8669117.	-3.61	574295.	3.93	2424605.	4.55	-29663.	-.26	232280.	.63	82531.	.09
22.00	-14245907.	-6.11	477885.	2.84	501749.	.93	78115.	.98	-704050.	-2.05	-2669594.	-3.81
23.00	-15517683.	-6.86	-212701.	-1.45	-1930697.	-4.21	70338.	1.51	-1271635.	-3.92	-3902565.	-5.95
24.00	-13987978.	-6.40	-273139.	-2.14	-2098106.	-5.22	33209.	1.57	-1223747.	-4.06	-3398930.	-5.61
25.00	-10785537.	-5.06	-235749.	-2.20	-1737853.	-5.14	3667.	.83	-977504.	-3.48	-2546554.	-4.52
26.00	-5509153.	-2.57	-194788.	-2.13	-1409249.	-4.98	0.	.00	-742127.	-2.82	-1847510.	-3.50
27.00	4015633.	1.86	-159903.	-2.02	-1126490.	-4.78	0.	.00	-509165.	-2.03	-1238604.	-2.46
28.00	13045594.	5.66	-132556.	-1.92	-877829.	-4.48	0.	.00	-69580.	-.25	-249578.	-.48
29.00	16694896.	6.93	-111277.	-1.84	-493980.	-2.67	-693.	-.50	963481.	3.46	2644625.	4.83
30.00	16813445.	6.49	-93926.	-1.75	1043023.	4.02	-69855.	-1.87	1626394.	5.17	4600830.	7.37
31.00	11776429.	4.67	-81106.	-1.70	1924904.	5.55	-178499.	-2.52	1514354.	4.43	4144637.	6.08
32.00	4278481.	1.69	157078.	2.10	2508692.	5.76	-212250.	-2.16	1122138.	3.14	2970821.	4.11
33.00	-5571151.	-2.33	427859.	3.53	2521966.	5.00	-91870.	-.87	478154.	1.32	911110.	1.23
34.00	-13022721.	-5.58	497258.	3.23	1338242.	2.55	63262.	.75	-393946.	-1.15	-1755921.	-2.50
35.00	-15588236.	-6.96	72540.	.46	-1363059.	-2.95	71535.	1.37	-1163359.	-3.54	-3706470.	-5.57
36.00	-15121409.	-6.96	-255114.	-2.04	-2102309.	-5.11	38879.	1.58	-1276354.	-4.18	-3610118.	-5.87
37.00	-12676234.	-6.04	-225154.	-2.14	-1806106.	-5.19	5743.	.99	-1058093.	-3.74	-2781042.	-4.90
38.00	-8621019.	-4.18	-188721.	-2.10	-1469151.	-5.06	0.	.00	-816228.	-3.10	-2032656.	-3.84
39.00	-804941.	-.38	-155582.	-2.00	-1183298.	-4.91	0.	.00	-606042.	-2.45	-1452484.	-2.92
40.00	11026126.	4.97	-129182.	-1.91	-938695.	-4.75	0.	.00	-349963.	-1.46	-845857.	-1.77
41.00	17216832.	7.34	-108609.	-1.83	-697483.	-4.26	0.	.00	504540.	2.01	1132692.	2.31
42.00	18438511.	7.52	-92229.	-1.76	417400.	2.11	-29133.	-2.04	1477091.	5.02	3896532.	6.70
43.00	15810437.	6.28	-78294.	-1.68	1391336.	4.84	-124065.	-2.43	1786834.	5.45	4948606.	7.56
44.00	9650115.	3.79	-54579.	-1.03	2358132.	6.10	-229961.	-2.59	1489093.	4.23	4027442.	5.68
45.00	1125756.	.43	295789.	3.12	2804571.	5.88	-197873.	-1.78	968229.	2.66	2453568.	3.33
46.00	-8670219.	-3.61	574350.	3.93	2424557.	4.55	-29632.	-.26	232162.	.63	82169.	.09
47.00	-14245951.	-6.11	477750.	2.84	501650.	.93	78124.	.98	-704154.	-2.05	-2669950.	-3.81
48.00	-15517299.	-6.86	-213019.	-1.45	-1930851.	-4.21	70338.	1.51	-1271670.	-3.92	-3902656.	-5.95
49.00	-13987909.	-6.40	-273201.	-2.14	-2098113.	-5.22	33207.	1.57	-1223750.	-4.06	-3398905.	-5.61
50.00	-10785350.	-5.06	-235797.	-2.20	-1737643.	-5.14	3666.	.83	-977556.	-3.48	-2546568.	-4.52

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Table B-9

Summary of Miscellaneous Computed Hydrodynamic Data

UPPER COOK INLET, KNIK ARM AND TURNAGAIN ARM
WATER YEAR 1972 AVERAGE TRIBUTARY INFLOWS

AVERAGE HEADS FOR A TIDAL CYCLE

	1	2	3	4	5	6	7	8	9	10
1 TO 10	-.131	-.066	-.065	.001	-.002	.034	.115	.187	.403	.252
11 TO 20	.391	.567	.672	.670	.624	.708	.708	.662	.792	.789
21 TO 30	.784	.966	.935	.926	1.030	1.027	1.024	1.104	.000	.000
31 TO 40	1.467	1.458	.000	.000	1.585	1.593	1.757	.000	.000	.000
41 TO 50	.000	.000	1.480	1.765	2.162	2.433	6.864	9.545	10.051	10.077
51 TO 60	.000	2.327	1.844	2.338	2.196	2.495	3.063	3.537	3.778	3.725
61 TO 70	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
71 TO 80	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
81 TO 90	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
91 TO 100	.000	.000	.000	.000	.000	.000	.000	.000	.000	1.134
101 TO 110	1.111	1.449	1.170	1.167	1.324	1.186	1.263	1.413	1.204	1.302
111 TO 120	1.740	1.228	1.212	1.274	1.311	1.327	1.348	1.353	1.352	1.363
121 TO 130	1.364	1.366	1.374	1.386	1.385	1.386	1.408	1.434	.000	.000

AVERAGE VELOCITIES FOR A TIDAL CYCLE

	1	2	3	4	5	6	7	8	9	10
1 TO 10	-.144	-.109	-.038	-.095	-.149	-.027	-.043	-.226	-.084	-.213
11 TO 20	-.246	-.220	-.224	-.064	-.166	-.307	-.139	-.215	-.166	-.013
21 TO 30	-.049	.016	-.087	-.175	.030	.122	-.045	-.116	-.281	.079
31 TO 40	.101	-.239	-.203	-.128	.009	.006	-.103	-.207	-.125	.055
41 TO 50	-.021	-.185	.000	-.249	.000	.000	-.561	.473	.000	.000
51 TO 60	.076	.000	-.347	-.155	-.302	-.069	.000	.000	.000	.000
61 TO 70	.000	.000	.000	.000	.230	-.379	-.545	-.365	-.533	-1.455
71 TO 80	-1.192	-.573	-.185	.000	-.146	-.180	-.350	-.258	-.007	-.520
81 TO 90	-.103	-.434	-.660	-.645	-.434	-.094	.000	.000	-.185	.000
91 TO 100	.000	.000	.000	.000	.000	.000	.000	.000	.000	-.136
101 TO 110	-.223	-.110	-.023	.132	-.056	.056	-.163	-.178	.091	-.022
111 TO 120	.027	.029	-.301	-.238	.031	.003	-.177	-.188	-.410	.293
121 TO 130	-.243	-.147	-.005	-.249	-.287	-.354	-.300	-.322	-.160	.145
131 TO 140	-.377	-.245	-.298	.038	-.035	-.033	-.028	-.162	-.127	-.032
141 TO 150	-.139	-.100	-.042	-.013	-.034	.011	-.099	-.171	-.117	-.252
151 TO 160	-.022	.042	.033	-.121	-.206	-.136	-.182	.000	.000	.000

AVERAGE FLOWS FOR A TIDAL CYCLE

	1	2	3	4	5	6	7	8	9	10
1 TO 10	-251400.	210478.	-459389.	207164.	-249737.	-221684.	427980.	-472089.	422605.	4894.
11 TO 20	4538.	-50213.	-50869.	-291221.	295362.	-337926.	8235.	-41611.	-9413.	-315422.
21 TO 30	-193865.	202008.	79837.	-325024.	130294.	26365.	71580.	183640.	-298844.	273652.
31 TO 40	393498.	-202198.	63646.	94499.	-270363.	-176063.	66058.	-30816.	-81719.	106391.
41 TO 50	-58386.	-38415.	0.	-107199.	0.	0.	-150875.	3157.	0.	0.
51 TO 60	-10601.	0.	-140339.	125404.	-139228.	14549.	0.	0.	0.	0.
61 TO 70	0.	0.	0.	0.	11187.	-2781.	-8443.	-7997.	-2803.	-10855.
71 TO 80	-10896.	-10812.	-10867.	0.	-90085.	-9331.	-50343.	44597.	5165.	-68902.
81 TO 90	68170.	-799.	-870.	-914.	-942.	-978.	0.	0.	63060.	0.
91 TO 100	0.	0.	0.	0.	0.	0.	0.	0.	0.	54700.
101 TO 110	-24452.	103602.	167098.	-39017.	52671.	184767.	11867.	-54564.	47464.	15617.
111 TO 120	137281.	94958.	-51265.	-30965.	232225.	10676.	-61951.	-27701.	-6533.	156813.
121 TO 130	81930.	-89669.	-74635.	-54226.	-53737.	-121832.	-31972.	-31480.	27947.	131940.

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Summary of Missellaneous Computed Hydrodynamic Data

131 TO 140	-3547.	-18781.	-35241.	30859.	11397.	11770.	-32221.	-33287.	3261.	39723.
141 TO 150	-119.	-20830.	-26045.	-7325.	-7245.	10279.	13205.	777.	14860.	-63137.
151 TO 160	3031.	8190.	33097.	12151.	-13273.	-10043.	-11174.	0.	0.	0.

WATER BALANCE AT EACH JUNCTION (CFS)

	1	2	3	4	5	6	7	8	9	10
1 TO 10	39974.	19.	20.	14.	13.	7.	8.	4.	-1.	1.
11 TO 20	-1.	-3.	-2.	-2.	-3.	-3.	-2.	-3.	-3.	-5.
21 TO 30	-0.	-3.	-0.	-3.	-2.	-3.	0.	-2.	0.	0.
31 TO 40	-2.	-2.	0.	0.	-2.	-2.	5.	0.	0.	0.
41 TO 50	0.	0.	-1.	-0.	0.	3.	4.	4.	7.	2.
51 TO 60	0.	12.	-3.	4.	5.	4.	3.	1.	1.	1.
61 TO 70	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
71 TO 80	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
81 TO 90	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
91 TO 100	0.	0.	0.	0.	0.	0.	0.	0.	0.	-2.
101 TO 110	-1.	2.	-1.	-1.	2.	-0.	-0.	2.	-0.	0.
111 TO 120	-0.	1.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
121 TO 130	-0.	-0.	0.	-0.	-0.	0.	-0.	-0.	0.	0.

AVERAGE NODAL VOLUME (CU FT)

	1	2	3	4	5	6	7	8	9	10
1 TO 10	.1497+13	.1104+13	.1189+13	.1350+13	.8970+12	.5005+12	.7609+12	.2973+12	.2121+12	.5540+12
11 TO 20	.4618+12	.3130+12	.8083+11	.9765+11	.2218+12	.7525+11	.1157+12	.1397+12	.6713+11	.1542+12
21 TO 30	.1441+12	.6507+11	.1424+12	.1014+12	.6255+11	.9723+11	.2346+11	.4429+11	.0000	.0000
31 TO 40	.3616+11	.2992+11	.0000	.0000	.2081+11	.2180+11	.3362+10	.0000	.0000	.0000
41 TO 50	.0000	.0000	.1447+11	.6339+10	.6962+10	.9752+10	.5649+10	.3121+10	.2994+10	.7360+09
51 TO 60	.0000	.4031+10	.3296+11	.7056+10	.1455+11	.1541+11	.7806+10	.4338+10	.5716+10	.2944+10
61 TO 70	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
71 TO 80	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
81 TO 90	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
91 TO 100	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.4706+11
101 TO 110	.3927+11	.4514+10	.1405+11	.1182+11	.2225+10	.1210+11	.3376+10	.1139+10	.1139+11	.5831+10
111 TO 120	.1496+10	.8764+09	.2495+10	.1679+10	.6983+10	.6309+10	.1900+10	.3436+10	.2235+10	.9409+09
121 TO 130	.3655+10	.1648+10	.1091+10	.2481+10	.2356+10	.1587+10	.9255+10	.7055+10	.0000	.0000

POSITIVE AND NEGATIVE FLOWS FOR EACH CHANNEL

1	14694752.	14996151.	2	16288461.	16077982.	3	2219259.	2678648.	4	11185579.	10978015.
5	16975227.	17224962.	6	894570.	1116250.	7	9561386.	9133405.	8	15659051.	16131139.
9	2840515.	2821911.	10	5958323.	5953429.	11	5010987.	5006449.	12	16905114.	16955329.
13	15517668.	15568558.	14	933132.	1224353.	15	4976468.	4683107.	16	13397142.	13735068.
17	3233275.	3225040.	18	5573923.	5615534.	19	8920408.	8933820.	20	927364.	1242786.
21	282405.	476290.	22	3202413.	3000405.	23	5967253.	5887416.	24	7058861.	7383680.
25	206587.	116293.	26	1056082.	1029717.	27	2457099.	2385515.	28	6633549.	6849910.
29	3306874.	5605718.	30	377529.	103877.	31	1525529.	1132031.	32	1850182.	2052379.
33	6982561.	6918736.	34	3523119.	3428621.	35	1560990.	1831361.	36	1868507.	2044569.
37	2855205.	2787147.	38	6366523.	6397439.	39	801606.	883325.	40	226594.	120203.
41	175905.	234331.	42	2483053.	2522048.	43	0.	0.	44	60522.	167720.
45	0.	0.	46	0.	0.	47	2047458.	2198338.	48	2213933.	2210777.
49	0.	0.	50	0.	0.	51	237065.	250266.	52	0.	0.
53	1733967.	1874305.	54	1658781.	1535377.	55	79314.	218559.	56	172232.	157603.
57	0.	0.	58	0.	0.	59	0.	0.	60	0.	0.
61	0.	0.	62	0.	0.	63	0.	0.	64	0.	0.
65	1190072.	1182038.	66	590487.	503268.	67	423975.	432417.	68	260781.	260778.
69	349142.	350949.	70	292584.	303439.	71	163598.	174093.	72	100502.	111358.

III-53-2

Table B-9 - (Cont.)

Summary of Miscellaneous Computed Hydrodynamic Data

73	17841.	20708.	74	0.	0.	75	33689.	123774.	76	368225.	377556.
77	1150133.	1200476.	78	972499.	927902.	79	305546.	300381.	80	1196218.	1265120.
81	318197.	250027.	82	1141910.	1142709.	83	764702.	765571.	84	528055.	528969.
85	369325.	369264.	86	140776.	141754.	87	0.	0.	88	0.	0.
89	324529.	261469.	90	0.	0.	91	0.	0.	92	0.	0.
93	0.	0.	94	0.	0.	95	0.	0.	96	0.	0.
97	0.	0.	98	0.	0.	99	0.	0.	100	1485991.	1431292.
101	1802330.	1826781.	102	2599198.	2495596.	103	1552659.	1385561.	104	480106.	519152.
105	195958.	143288.	106	1341039.	1156272.	107	1630658.	1618791.	108	35274.	89618.
109	154002.	106934.	110	122797.	107180.	111	1304939.	1167658.	112	899654.	804896.
113	391190.	442455.	114	98400.	87365.	115	2118526.	1886301.	116	37722.	27046.
117	286948.	348899.	118	23724.	31425.	119	104113.	110646.	120	633992.	477179.
121	1294254.	1212325.	122	192635.	282304.	123	66442.	141077.	124	71973.	126199.
125	8749.	62527.	126	114656.	236486.	127	14487.	46459.	128	17066.	46554.
129	338196.	310249.	130	344919.	212979.	131	309007.	312554.	132	409453.	424233.
133	478475.	513716.	134	182024.	151164.	135	210834.	207437.	136	208865.	197035.
137	39970.	63191.	138	124385.	157672.	139	373729.	370468.	140	464395.	444672.
141	388608.	398777.	142	148654.	169483.	143	8215.	34260.	144	57797.	69122.
145	103143.	110388.	146	123064.	112765.	147	275035.	261830.	148	377465.	376668.
149	348665.	333805.	150	225727.	268864.	151	262964.	199933.	152	76705.	72515.
153	73609.	40512.	154	504741.	492590.	155	577317.	590589.	156	258824.	266868.
157	1273502.	1284680.									

MINIMUM HEAD, MAXIMUM HEAD AND TIDAL RANGE

1	-9.02	7.60	16.62	2	-9.24	8.08	17.32	3	-9.27	8.14	17.41	4	-9.68	8.59	18.27
5	-9.57	8.54	18.11	6	-10.13	9.07	19.20	7	-9.65	8.90	18.54	8	-10.14	9.40	19.54
9	-10.14	9.49	19.62	10	-9.69	9.03	18.72	11	-9.96	9.27	19.23	12	-10.35	9.67	20.02
13	-11.08	10.47	21.55	14	-11.04	10.44	21.48	15	-10.98	10.38	21.36	16	-11.77	11.16	22.94
17	-11.75	11.17	22.92	18	-11.67	11.06	22.73	19	-12.55	11.96	24.50	20	-12.50	11.94	24.43
21	-12.44	11.90	24.34	22	-13.50	13.08	26.58	23	-13.35	12.97	26.31	24	-13.25	12.87	26.12
25	-13.93	13.65	27.58	26	-13.88	13.67	27.55	27	-13.84	13.66	27.50	28	-14.30	14.28	28.58
29	.00	.00	.00	30	.00	.00	.00	31	-14.28	15.22	29.51	32	-14.30	15.27	29.57
33	.00	.00	.00	34	.00	.00	.00	35	-14.62	15.70	30.32	36	-14.67	15.76	30.43
37	-11.62	15.57	27.19	38	.00	.00	.00	39	.00	.00	.00	40	.00	.00	.00
41	.00	.00	.00	42	.00	.00	.00	43	-16.49	16.86	33.35	44	-16.03	17.08	33.12
45	-13.86	17.13	30.99	46	-13.62	17.34	30.96	47	-.76	17.22	17.97	48	4.69	16.24	11.55
49	6.60	14.35	7.74	50	6.72	14.57	7.85	51	.00	.00	.00	52	-11.17	15.99	27.16
53	-14.77	16.09	30.86	54	-13.13	16.26	27.39	55	-14.79	16.39	31.18	56	-14.85	16.52	31.37
57	-13.95	16.42	30.37	58	-13.04	16.69	29.73	59	-11.46	17.75	29.21	60	-12.68	18.68	31.36
61	.00	.00	.00	62	.00	.00	.00	63	.00	.00	.00	64	.00	.00	.00
65	.00	.00	.00	66	.00	.00	.00	67	.00	.00	.00	68	.00	.00	.00
69	.00	.00	.00	70	.00	.00	.00	71	.00	.00	.00	72	.00	.00	.00
73	.00	.00	.00	74	.00	.00	.00	75	.00	.00	.00	76	.00	.00	.00
77	.00	.00	.00	78	.00	.00	.00	79	.00	.00	.00	80	.00	.00	.00
81	.00	.00	.00	82	.00	.00	.00	83	.00	.00	.00	84	.00	.00	.00
85	.00	.00	.00	86	.00	.00	.00	87	.00	.00	.00	88	.00	.00	.00
89	.00	.00	.00	90	.00	.00	.00	91	.00	.00	.00	92	.00	.00	.00
93	.00	.00	.00	94	.00	.00	.00	95	.00	.00	.00	96	.00	.00	.00
97	.00	.00	.00	98	.00	.00	.00	99	.00	.00	.00	100	-14.48	14.50	28.98
101	-14.48	14.43	28.91	102	-11.09	14.51	25.60	103	-14.80	14.83	29.64	104	-14.78	14.83	29.61
105	-12.78	14.91	27.68	106	-14.98	15.05	30.03	107	-15.31	15.18	30.49	108	-12.89	15.18	28.07
109	-15.17	15.29	30.46	110	-15.52	15.40	30.92	111	-11.82	15.52	27.34	112	-15.58	15.55	31.14
113	-15.32	15.50	30.81	114	-15.46	15.62	31.08	115	-15.45	15.57	31.02	116	-15.50	15.58	31.14
117	-15.64	15.76	31.40	118	-15.68	15.77	31.45	119	-15.69	15.77	31.46	120	-15.78	15.87	31.65
121	-15.78	15.88	31.66	122	-15.79	15.90	31.69	123	-15.85	15.95	31.80	124	-15.94	16.06	31.99
125	-15.93	16.05	31.98	126	-15.93	16.06	31.98	127	-16.11	16.29	32.40	128	-16.31	16.60	32.91

Table B-9 - (Cont.)

Summary of Miscellaneous Computed Hydrodynamic Data

TIME OF MINIMUM AND MAXIMUM HEAD, HOUR

1	9.68	16.00	2	10.19	16.39	3	10.19	16.44	4	10.75	16.81
5	10.75	16.81	6	11.03	17.11	7	11.33	17.25	8	11.75	17.67
9	12.42	18.90	10	11.92	17.64	11	12.39	18.00	12	12.92	18.69
13	13.28	18.94	14	13.28	18.94	15	13.17	18.92	16	13.47	19.14
17	13.47	19.14	18	13.39	19.17	19	13.75	19.42	20	13.75	19.36
21	13.72	19.31	22	14.17	19.75	23	14.11	19.81	24	14.11	19.86
25	14.33	19.89	26	14.33	19.89	27	14.31	19.86	28	14.47	20.03
29	.00	.00	30	.00	.00	31	15.06	20.36	32	15.03	20.36
33	.00	.00	34	.00	.00	35	15.28	20.47	36	15.31	20.50
37	16.00	20.44	38	.00	.00	39	.00	.00	40	.00	.00
41	.00	.00	42	.00	.00	43	15.31	20.53	44	15.69	20.56
45	16.08	20.58	46	16.33	20.61	47	17.67	20.92	48	16.44	21.39
49	19.14	22.75	50	19.33	22.78	51	.00	.00	52	16.39	20.56
53	15.64	20.56	54	16.42	20.58	55	15.89	20.75	56	16.11	21.14
57	16.47	21.56	58	16.86	22.08	59	17.44	22.39	60	17.81	22.50
61	.00	.00	62	.00	.00	63	.00	.00	64	.00	.00
65	.00	.00	66	.00	.00	67	.00	.00	68	.00	.00
69	.00	.00	70	.00	.00	71	.00	.00	72	.00	.00
73	.00	.00	74	.00	.00	75	.00	.00	76	.00	.00
77	.00	.00	78	.00	.00	79	.00	.00	80	.00	.00
81	.00	.00	82	.00	.00	83	.00	.00	84	.00	.00
85	.00	.00	86	.00	.00	87	.00	.00	88	.00	.00
89	.00	.00	90	.00	.00	91	.00	.00	92	.00	.00
93	.00	.00	94	.00	.00	95	.00	.00	96	.00	.00
97	.00	.00	98	.00	.00	99	.00	.00	100	14.56	20.11
101	14.53	20.14	102	2.67	20.19	103	14.64	20.19	104	14.60	20.19
105	15.42	20.19	106	14.69	20.22	107	14.92	20.33	108	15.75	20.36
109	14.75	20.28	110	15.00	20.39	111	15.72	20.33	112	15.14	20.36
113	14.81	20.33	114	14.92	20.36	115	15.00	20.39	116	15.03	20.42
117	15.06	20.42	118	15.08	20.42	119	15.08	20.42	120	15.11	20.42
121	15.11	20.42	122	15.11	20.42	123	15.11	20.42	124	15.14	20.44
125	15.14	20.44	126	15.14	20.44	127	15.19	20.44	128	15.25	20.50

TOTAL EVAPORATION RATE, CFS	.1080+05
AVERAGE SURFACE AREA, SQ FT	.1131+12
AVERAGE VOLUME, CU FT	.1124+10
AVERAGE DEPTH, FT	.9938+02

2-35-113

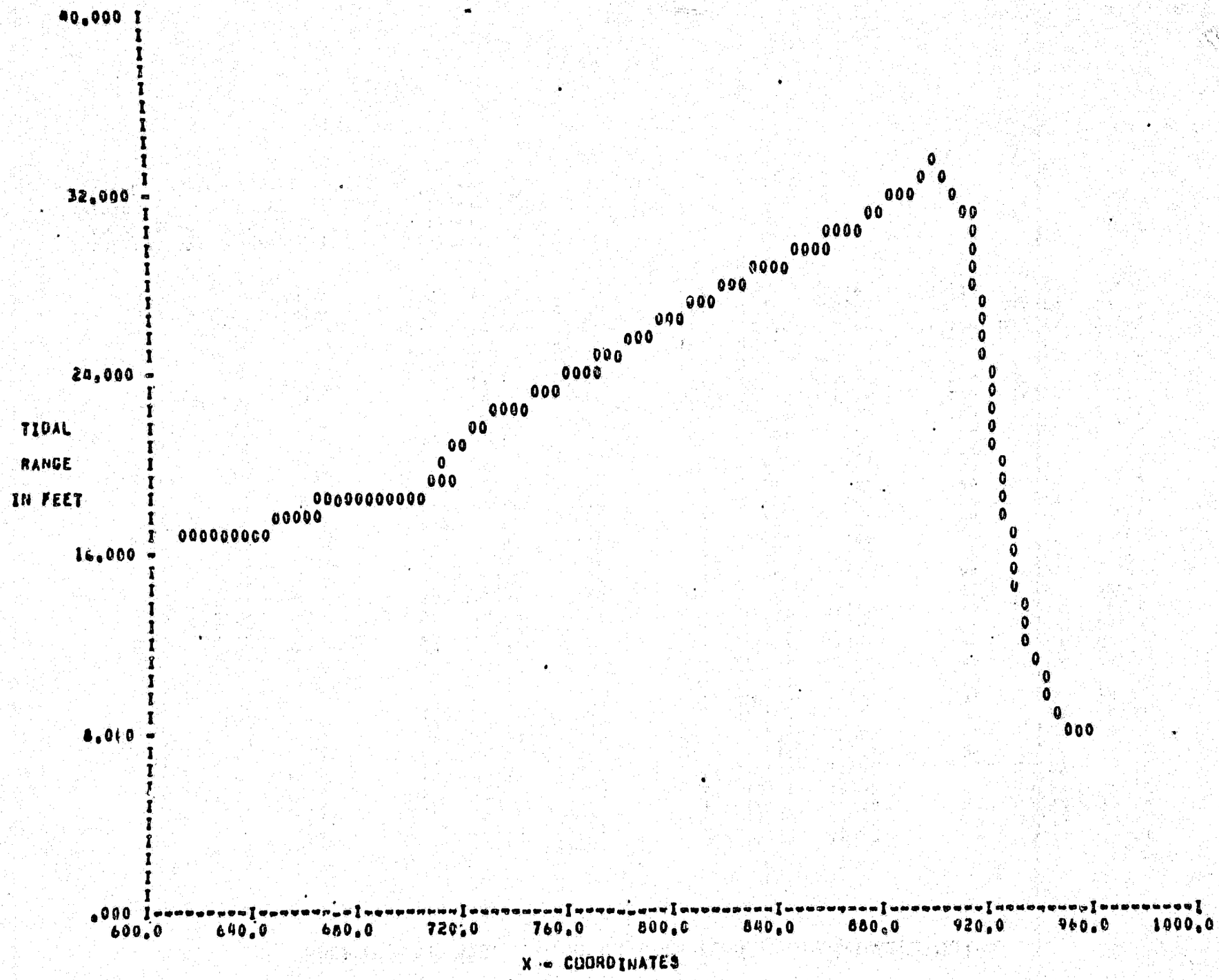

FIGURE B-1 TIDAL RANGE VERSUS X-COORDINATE

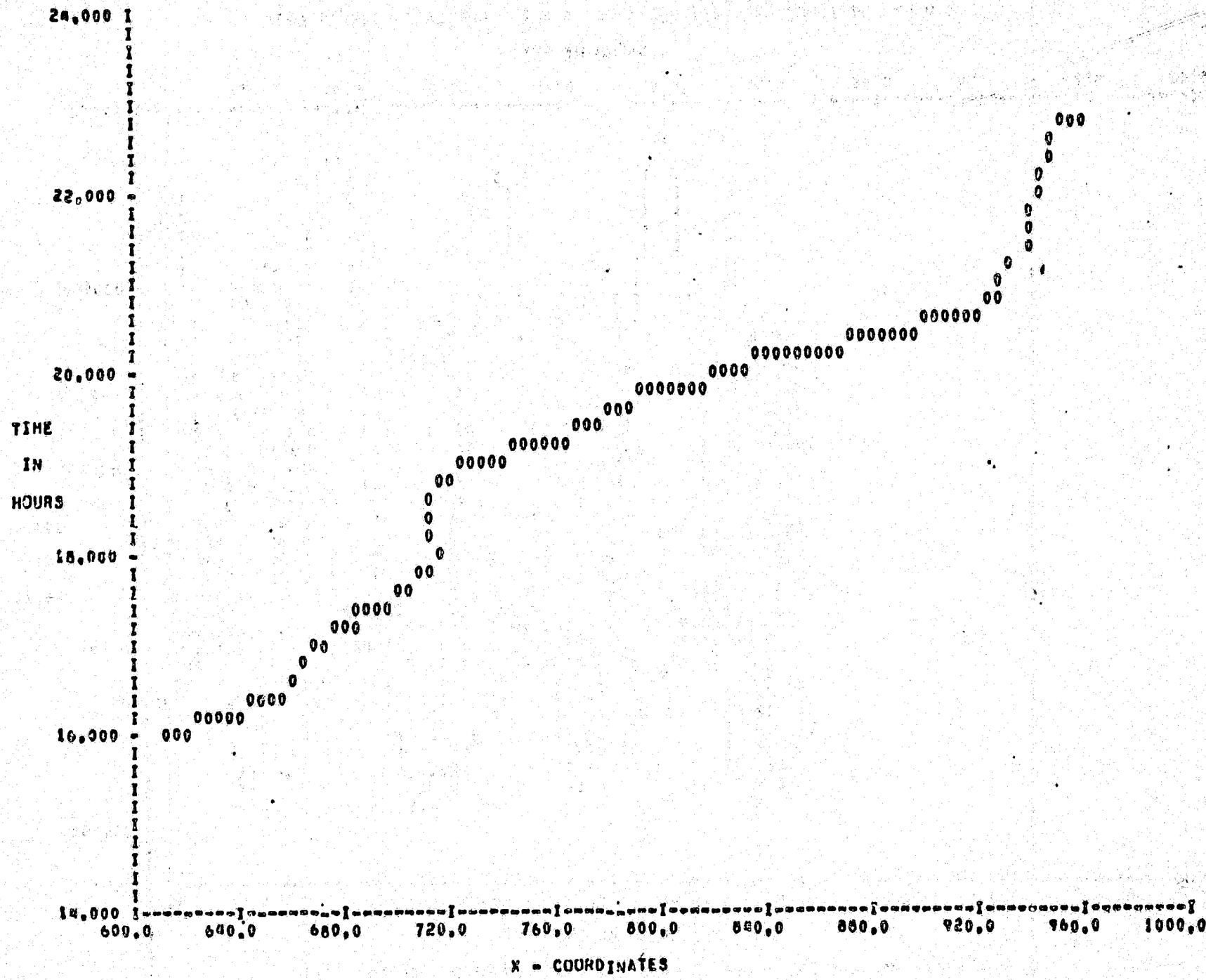

FIGURE B-2 TIME OF HIGH WATER VERSUS X-COORDINATE

511-55-2

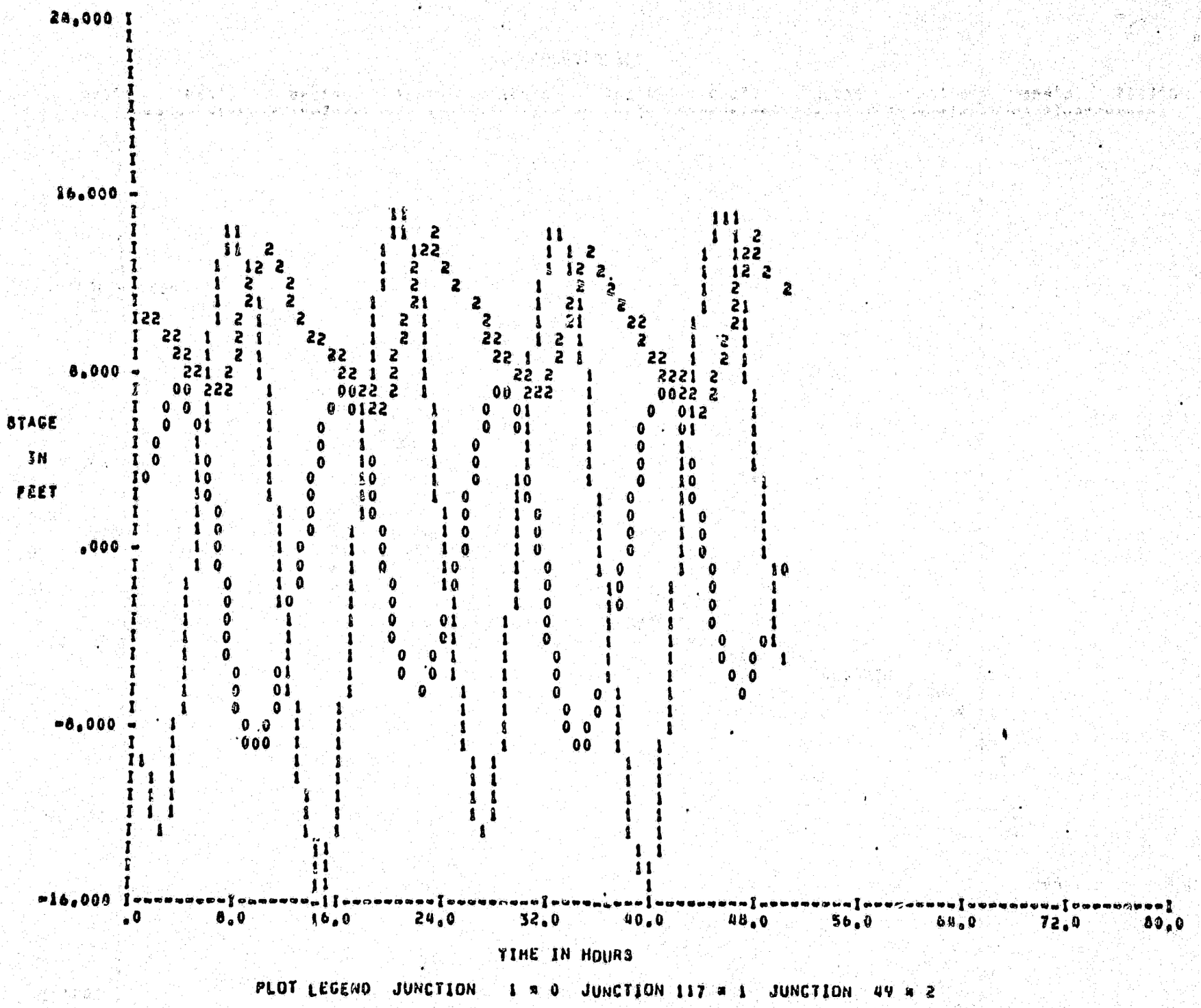

FIGURE B-3 STAGE VERSUS TIME AT SELECTED NODES

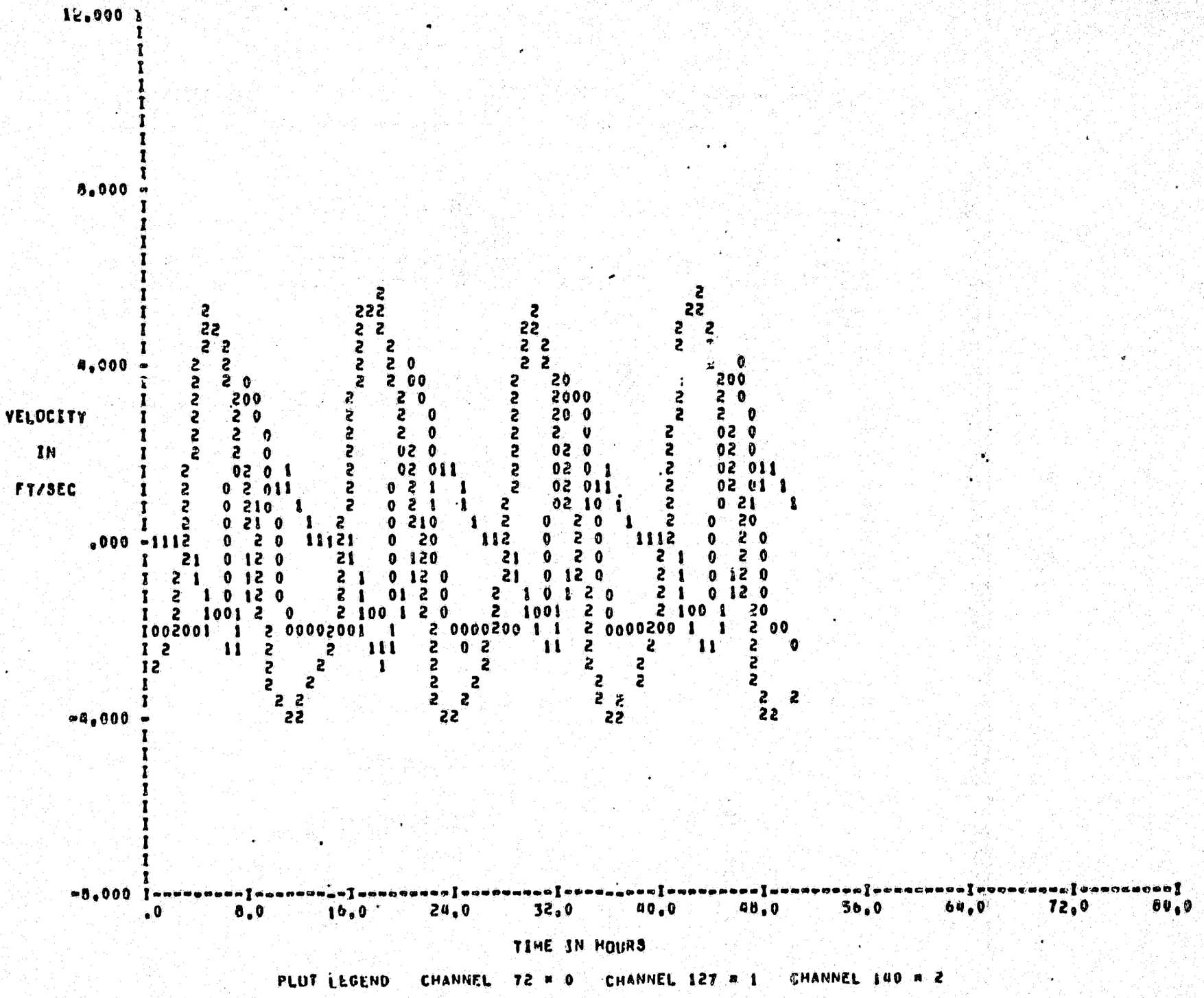

FIGURE B-4 CHANNEL VELOCITY VERSUS TIME IN SELECTED CHANNEL

APPENDIX C

Table C-1

Tidally Averaged Quality Model Input Card Specifications

```
1a      UPPER COOK INLET, KNIK ARM AND TURNAGAIN ARM
1b      SAMPLE PROBLEM
2          1  135   24    0    1    0    1    3   12
3          1    1
4          [redacted]    0    0    0    1    0    0    0    0    0    0    1    1
5       NH3-N, MG/L PRIMNO3-N, MG/L PRIM
7a         1    0    0    0  135
7b         5    7   10   11   12   14   17   20   23   26  101  107  115  117  121  127
           44   46   48   49   50                                10
8          1  130
9          1   16   10 3000
           17  160    5 [redacted]
10         1    1
11      AVERAGE RUNOFF CONDITIONS - STEADY STATE
12         0    0    0    0    1    1    0    0    0    0
13a        1   .1                                      -1   10
13b        1 [redacted]
14         11 4600        .25  .01    0         0    0   -1   10
           [redacted]        .25  .01    0         0    0   -1   10
           45  470        .25  .01    0         0    0   -1   10
           48  120        .25  .01    0         0    0   -1   10
           5010880        .25  .01    0         0    0   -1   10
           60 1000        .25  .01    0         0    0   -1   10
          108  600        .25  .01    0         0    0   -1   10
          124  110        .25  .01    0         0    0   -1   10
          117  155         30    335000       120   90    2   15   20   .5
           45 15.5         25    510000        30   75    6   15   17   .5
17a        1    0    0 1.08 1.04
17b        1  130   .2   .1    1    0
17c        0    0    0    0    0    0   10   .1
17
18a        1  135   -1    0    0    0
18b        1  130   61  150    2
18c        1  .75    8    2    3 1000
           25  .75    8    2    3 1000
```

2-35-119

APPENDIX D

Table D-1

Computation and Output Control Options

[redacted]

SIMULATION BEGINS ON DAY	135	
TIME STEPS OF	24	HOUR(S)
PRINTOUT EVERY	1	TIME STEP(S)
HYDRAULIC INTERFACE UNIT	12	
QUALITY INTERFACE UNIT	0	
NUMBER OF BOUNDARY CONDITIONS	1	
1 TIME STEPS FOR CONDITION	1	STEADY STATE

THE FOLLOWING CONSTITUENTS ARE BEING MODELED

[redacted]
TOTAL N
TOTAL P
TOTAL COLIF
CARBON BOD
NITRO BOD
OXYGEN
TEMPERATURE
OPP CONST 1 NH3-N, MG/L PRIM
OPP CONST 2 NO3-N, MG/L PRIM

2-35-12

Table D-2

Initial Conditions and Dispersion Parameters

UPPER COOK INLET, KNIK ARM AND TURNAGAIN ARM
SAMPLE PROBLEM

INITIAL QUALITY CONDITIONS

JUN	TO JUN	TOT N MG/L	TOT P MG/L	T COL NO/100ML	F COL NO/100ML.	C BOD MG/L	N BOD MG/L	D O MG/L	TEMP C	CONST 1 UNITS	CONST 2 UNITS	CONST 3 UNITS	CONST UNIT.
1	130	.00	.00	.00	.00	.00	.00	.00	10.0	.00	.00	.00	.00

DISPERSION COEFFICIENTS

CHAN	TO CHAN	C1	C4
1	16	10.	3000.
17	160	5.	1500.

221-33-2

Table D-3

Summary of Boundary Conditions and System Coefficients

UPPER COOK INLET, KNIK ARM AND TURNAGAIN ARM
AVERAGE RUNOFF CONDITIONS - STEADY STATE

EXCHANGE CONDITIONS DURING HYDRULOGIC CYCLE 1

JUN	EXCH RATIO	EBB MCFS	FLOOD MCFS	[illegible] MG/L	TOT N MG/L	TOT P MG/L	T COL N/100ML	F COL N/100ML	C BOD MG/L	N BOD MG/L	OXY MG/L	TEMP C	CON 1 UNITS	CON 2 UNITS	CON 3 UNITS	CON 4 UNITS
1	.10	31.028	30.983	[illegible]	.00	.00	.00	.00	.00	.00	9.3	10.0	.00	.00	.00	.00

INFLOW CONDITIONS DURING HYDRAULIC CYCLE 1

JUN	INFLOW CFS	TDS MG/L	TOT N MG/L	TOT P MG/L	T COL NO/100ML	F COL NO/100ML	C BOD MG/L	N BOD MG/L	OXY MG/L	TEMP C	CONST 1 UNITS	CONST 2 UNITS	CONST 3 UNITS	CONST 4 UNITS
11	4600.00	0.	.25	.01	.00	.00	.00	.00	11.3	10.0	.00	.00	.00	.00
[illegible]	33000.00	[illegible]	.25	.01	.00	.00	.00	.00	11.3	10.0	.00	.00	.00	.00
45	470.00	0.	.25	.01	.00	.00	.00	.00	11.3	10.0	.00	.00	.00	.00
48	120.00	0.	.25	.01	.00	.00	.00	.00	11.3	10.0	.00	.00	.00	.00
50	10880.00	0.	.25	.01	.00	.00	.00	.00	11.3	10.0	.00	.00	.00	.00
60	1000.00	0.	.25	.01	.00	.00	.00	.00	11.3	10.0	.00	.00	.00	.00
108	600.00	0.	.25	.01	.00	.00	.00	.00	11.3	10.0	.00	.00	.00	.00
124	110.00	0.	.25	.01	.00	.00	.00	.00	11.3	10.0	.00	.00	.00	.00
117	155.00	0.	30.00	3.00	.35+05	.00	120.00	90.00	2.0	15.0	20.00	.50	.00	.00
45	15.50	0.	25.00	5.00	.10+05	.00	30.00	75.00	6.0	15.0	17.00	.50	.00	.00
AGGREGATED QUALITY														
11	4600.00	0.	.25	.01	.00	.00	.00	.00	11.3	10.0	.00	.00	.00	.00
27	33000.00	0.	.25	.01	.00	.00	.00	.00	11.3	10.0	.00	.00	.00	.00
45	470.00	0.	1.07	.17	.33+03	.00	.99	2.47	11.3	10.5	.56	.02	.00	.00
48	120.00	0.	.25	.01	.00	.00	.00	.00	11.3	10.0	.00	.00	.00	.00
50	10880.00	0.	.25	.01	.00	.00	.00	.00	11.3	10.0	.00	.00	.00	.00
60	1000.00	0.	.25	.01	.00	.00	.00	.00	11.3	10.0	.00	.00	.00	.00
108	600.00	0.	.25	.01	.00	.00	.00	.00	11.3	10.0	.00	.00	.00	.00
117	75.00	0.	62.00	6.20	.72+05	.00	248.00	186.00	4.1	31.0	41.33	1.03	.00	.00
124	110.00	0.	.25	.01	.00	.00	.00	.00	11.3	10.0	.00	.00	.00	.00

SYSTEM COEFFICIENTS

JUN TO JUN		BOD DECAY CARB 1/DAY	BOD DECAY NITR 1/DAY	COLIF DECAY TOTAL FECAL 1/DAY		BENTHIC SINK RATES N MF/M2/DAY	BENTHIC SINK RATES P MF/M2/DAY	BENTHIC SINK RATES O MF/M2/DAY	ALGAL OXYGEN PHOTO MG/M2/DAY	ALGAL OXYGEN RESP MG/M2/DAY	REAERATION MIN 1/DAY	REAERATION MAX 1/DAY	OPP CONST DECAY 1 1/DAY	OPP CONST DECAY 2 1/DAY	OPP CONST DECAY 3 1/DAY	OPP CONST DECAY 4 1/DAY	OPP CONST SETTLING 1 M/DAY	OPP CONST SETTLING 2 M/DAY	OPP CONST SETTLING 3 M/DAY	OPP CONST SETTLING 4 M/DAY
1	130	.20	.10	1.00	.00	0.	0.	0.	0.	0.	.0	10.0	.10	.00	.00	.00	.00	.00	.00	.00

STOICHIOMETRIC EQUIVALENCE BETWEEN OPTIONAL CONSTITUENTS

CONST NO 1 DECAY TO CONST NO 2. 1.00
CONST NO 2 DECAY TO CONST NO 3. .00
CONST NO 3 DECAY TO CONST NO 4. .00

RATE COEFFICIENT TEMPERATURE ADJUSTMENT CONSTANT FOR

BOD 1.080

2-35-123

Table D-3 - (Cont.)

Summary of Boundary Conditions and System Coefficients

ALL OTHERS 1.040

FLOW AND WIND INDUCED REAERATION COEFFICIENT AND COEFF. USED BY NODES, 1/DAY

1	.015	.037	.037	2	.010	.042	.042	3	.010	.039	.039	4	.012	.036	.036	5	.014	.042	.042
6	.022	.054	.054	7	.028	.055	.055	8	.035	.065	.065	9	.044	.105	.105	10	.028	.067	.067
11	.029	.054	.054	12	.032	.042	.042	13	.027	.077	.077	14	.023	.054	.054	15	.021	.045	.045
16	.031	.101	.101	17	.022	.064	.064	18	.023	.072	.072	19	.042	.110	.110	20	.020	.057	.057
21	.024	.064	.064	22	.050	.096	.096	23	.025	.068	.068	24	.031	.081	.081	25	.026	.077	.077
26	.024	.068	.068	27	.062	.169	.169	28	.054	.083	.083	29	.000	.000	.000	30	.000	.000	.000
31	.070	.105	.105	32	.079	.121	.121	33	.000	.000	.000	34	.000	.000	.000	35	.087	.233	.233
36	.110	.146	.146	37	.458	.360	.458	38	.000	.000	.000	39	.000	.000	.000	40	.000	.000	.000
41	.000	.000	.000	42	.000	.000	.000	43	.141	.143	.143	44	.177	.194	.194	45	.196	.196	.196
46	.285	.292	.292	47	.526	.449	.526	48	.549	.966	.966	49	.430	1.899	1.899	50	.300	1.747	1.747
51	.000	.000	.000	52	.145	.436	.436	53	.120	.169	.169	54	.113	.400	.400	55	.150	.245	.245
56	.140	.265	.265	57	.206	.368	.368	58	.273	.440	.440	59	.283	.476	.476	60	.244	.566	.566
61	.000	.000	.000	62	.000	.000	.000	63	.000	.000	.000	64	.000	.000	.000	65	.000	.000	.000
66	.000	.000	.000	67	.000	.000	.000	68	.000	.000	.000	69	.000	.000	.000	70	.000	.000	.000
71	.000	.000	.000	72	.000	.000	.000	73	.000	.000	.000	74	.000	.000	.000	75	.000	.000	.000
76	.000	.000	.000	77	.000	.000	.000	78	.000	.000	.000	79	.000	.000	.000	80	.000	.000	.000
81	.000	.000	.000	82	.000	.000	.000	83	.000	.000	.000	84	.000	.000	.000	85	.000	.000	.000
86	.000	.000	.000	87	.000	.000	.000	88	.000	.000	.000	89	.000	.000	.000	90	.000	.000	.000
91	.000	.000	.000	92	.000	.000	.000	93	.000	.000	.000	94	.000	.000	.000	95	.000	.000	.000
96	.000	.000	.000	97	.000	.000	.000	98	.000	.000	.000	99	.000	.000	.000	100	.051	.067	.067
101	.057	.072	.072	102	.383	.332	.383	103	.034	.087	.087	104	.063	.107	.107	105	.354	.271	.354
106	.035	.067	.067	107	.153	.175	.175	108	.343	.327	.343	109	.067	.077	.077	110	.097	.149	.149
111	.303	.327	.327	112	.349	.219	.349	113	.107	.118	.118	114	.124	.156	.156	115	.069	.097	.097
116	.066	.115	.115	117	.049	.118	.118	118	.031	.089	.089	119	.043	.138	.138	120	.032	.175	.175
121	.023	.060	.060	122	.034	.107	.107	123	.081	.147	.147	124	.031	.097	.097	125	.022	.077	.077
126	.033	.115	.115	127	.040	.057	.057	128	.054	.103	.103								

Table D-4

Meteorological Conditions

UPPER COOK INLET, KNIK ARM AND TURNAGAIN ARM
AVERAGE RUNOFF CONDITIONS - STEADY STATE

TABLE OF METEOROLOGIC DATA FOR WEATHER ZONE 1, JUNCTION 1 TO 130

LATITUDE = 61.0
LONGITUDE = 150.0

HOUR	WIND SPEED (M/SEC)	CLOUD COVER FRACTION	DRY BULB TEMPERATURE (C)	**** TEMPERATURE (C)	ATMOSPHERIC PRESSURE (MB)	SHORT WAVE SOLAR (KCAL/M2/SEC)	LONG WAVE SOLAR (KCAL/M2/SEC)	VAPOR PRESSURE (MB)
1	3.5	.75	7.0	1.0	1000.	.0000	.0609	7.
2	3.5	.75	7.0	1.0	1000.	.0000	.0609	7.
3	3.5	.75	7.0	1.0	1000.	.0000	.0609	7.
4	3.5	.75	7.0	1.0	1000	.0000	.0609	7.
5	3.5	.75	7.0	1.0	1000.	.0007	.0609	7.
6	3.5	.75	7.0	1.0	1000.	.0100	.0609	7.
7	3.5	.75	7.0	1.0	1000.	.0263	.0609	7.
8	3.5	.75	7.0	1.0	1000.	.0455	.0609	7.
9	3.5	.75	7.0	1.0	1000.	.0648	.0609	7.
10	3.5	.75	7.0	1.0	1000.	.0820	.0609	7.
11	3.5	.75	7.0	1.0	1000.	.0956	.0609	7.
12	3.5	.75	7.0	1.0	1000.	.1043	.0609	7.
13	3.5	.75	7.0	1.0	1000.	.1072	.0609	7.
14	3.5	.75	7.0	1.0	1000.	.1043	.0609	7.
15	3.5	.75	7.0	1.0	1000.	.0956	.0609	7.
16	3.5	.75	7.0	1.0	1000.	.0820	.0609	7.
17	3.5	.75	7.0	1.0	1000.	.0648	.0609	7.
18	3.5	.75	7.0	1.0	1000.	.0455	.0609	7.
19	3.5	.75	7.0	1.0	1000.	.0263	.0609	7.
20	3.5	.75	7.0	1.0	1000.	.0100	.0609	7.
21	3.5	.75	7.0	1.0	1000.	.0007	.0609	7.
22	3.5	.75	7.0	1.0	1000.	.0000	.0609	7.
23	3.5	.75	7.0	1.0	1000.	.0000	.0609	7.
24	3.5	.75	7.0	1.0	1000.	.0000	.0609	7.

**** DEW POINT

Table D-5

Dispersion Coefficients and Steady-State Salinity

CHANNEL DISPERSION COEFFICIENTS, 80 FT/SEC (LAST TWO ITERATIONS)

1	8180.	8184.	2	8934.	8939.	3	1338.	1340.	4	7015.	7018.	5	8589.	8595.	
6	548.	554.	7	5900.	5901.	8	7721.	7727.	9	1830.	1839.	10	6752.	6762.	
11	5752.	5767.	12	6955.	6965.	13	7378.	7388.	14	945.	951.	15	5508.	5000.	
16	11002.	11010.	17	3223.	3229.	18	5444.	5455.	19	6576.	6585.	20	702.	703.	
21	215.	219.	22	2826.	2830.	23	5928.	5933.	24	4029.	4036.	25	104.	109.	
26	509.	514.	27	1802.	1810.	28	4767.	4776.	29	4390.	4395.	30	127.	133.	
31	549.	550.	32	1822.	1832.	33	4827.	4839.	34	2726.	2738.	35	894.	894.	
36	862.	867.	37	2249.	2255.	38	3980.	3999.	39	991.	1027.	40	154.	159.	
41	286.	326.	42	2705.	2712.	43	0.	0.	44	277.	345.	45	0.	0.	
46	0.	0.	47	2851.	2857.	48	3429.	3434.	49	0.	0.	50	0.	0.	
51	245.	248.	52	0.	0.	53	1636.	1638.	54	1857.	1857.	55	231.	236.	
56	223.	225.	57	0.	0.	58	0.	0.	59	0.	0.	60	0.	0.	
	0.	0.	62	0.	0.	63	0.	0.	64	0.	0.	65	2415.	2449.	
	1165.	1206.	67	1192.	1240.	68	811.	857.	69	1121.	1172.	70	812.	879.	
71	526.	584.	72	316.	336.	73	87.	90.	74	0.	0.	75	89.	89.	
76	422.	424.	77	1063.	1064.	78	1348.	1349.	79	467.	468.	80	2091.	2093.	
81	322.	324.	82	1923.	1928.	83	1697.	1707.	84	1452.	1467.	85	1121.	1142.	
86	803.	836.	87	0.	0.	88	0.	0.	89	436.	436.	90	0.	0.	
91	0.	0.	92	0.	0.	93	0.	0.	94	0.	0.	95	0.	0.	
96	0.	0.	97	0.	0.	98	0.	0.	99	0.	0.	100	2831.	2832.	
101	3532.	3534.	102	3305.	3308.	103	1871.	1873.	104	408.	408.	105	300.	313.	
106	2163.	2166.	107	2635.	2642.	108	191.	201.	109	247.	254.	110	315.	335.	
111	3211.	3217.	112	2878.	2878.	113	1564.	1565.	114	314.	326.	115	3956.	3962.	
116	183.	198.	117	1022.	1029.	118	172.	176.	119	654.	660.	120	2774.	2777.	
121	3721.	3741.	122	470.	472.	123	683.	686.	124	577.	589.	125	184.	190.	
126	767.	767.	127	202.	204.	128	292.	305.	129	2131.	2154.	130	669.	695.	
131	2379.	2418.	132	2383.	2409.	133	2631.	2661.	134	1137.	1157.	135	932.	955.	
136	531.	539.	137	125.	128.	138	1053.	1078.	139	3030.	3055.	140	2808.	2826.	
141	3123.	3152.	142	1192.	1220.	143	69.	71.	144	227.	238.	145	741.	761.	
146	984.	1005.	147	2850.	2875.	148	3381.	3409.	149	3302.	3321.	150	1782.	1813.	
151	1199.	1225.	152	191.	192.	153	152.	156.	154	3027.	3049.	155	4025.	4052.	
156	2272.	2296.	157	3477.	3903.										

[redacted]

1	30.60		2	30.16		3	29.89		4	29.74		5	29.23		
6	29.38		7	28.63		8	28.41		9	27.08		10	27.71		
11	26.77		12	26.16		13	25.55		14	25.12		15	25.02		
16	24.93		17	24.48		18	24.02		19	22.78		20	23.29		
21	23.45		22	21.58		23	21.62		24	21.04		25	21.03		
26	20.58		[redacted]			28	20.40		29	.01		30	.01		
31	19.99		32	19.20		33	.01		34	.01		35	19.86		
36	19.84		37	19.58		38	.01		39	.01		40	.01		
41	.01		42	.01		43	13.99		44	11.43		45	10.47		
46	7.36		47	3.20		48	.75		49	.19		50	.00		
51	.01		52	19.72		53	19.73		54	19.74		55	19.61		
56	19.18		57	18.36		58	17.24		59	15.55		60	12.02		
61	.00		62	.00		63	.00		64	.00		65	.01		
66	.01		67	.01		68	.01		69	.01		70	.01		
71	.00		72	.00		73	.00		74	.00		75	.01		
76	.01		77	.01		78	.01		79	.01		80	.01		
81	.01		82	.01		83	.01		84	.01		85	.01		
86	.01		87	.00		88	.00		89	.01		90	.00		
91	.00		92	.00		93	.00		94	.00		95	.00		
96	.00		97	.00		98	.00		99	.00		100	20.30		
101	20.34		102	19.72		103	20.16		104	19.94		105	19.12		
106	19.96		107	19.05		108	18.67		109	19.77		110	18.84		
111	19.59		112	18.46		113	19.67		114	19.06		115	16.94		
116	18.79		117	16.14		118	17.95		119	17.87		120	17.04		
121	17.60		122	17.20		123	17.27		124	16.78		125	16.81		
126	16.70		127	16.05		128	15.20								

Table D-6

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UPPER COOK INLET, KNIK ARM AND TURNAGAIN ARM
AVERAGE RUNOFF CONDITIONS - STEADY STATE

JUN	[redacted]	TOT N MG/L	TOT P MG/L	T COL NO/100ML	F COL NO/100ML	C BOD MG/L	N BOD MG/L	OXY MG/L	O SAT MG/L	TEMP C	CONST 1 UNITS	CONST 2 UNITS	CONST 3 UNITS	CONST 4 UNITS
1	30596.	.01	.00	.70-10	.00	.00	.00	9.3	9.3	10.0	.00	.00	.00	.00
2	30159.	.01	.00	.11-09	.00	.00	.00	9.3	9.3	10.0	.00	.00	.00	.00
3	29889.	.02	.00	.11-08	.00	.00	.00	9.3	9.3	10.1	.00	.00	.00	.00
4	29736.	.02	.00	.63-09	.00	.00	.00	9.3	9.3	10.1	.00	.00	.00	.00
5	29235.	.02	.00	.96-08	.00	.00	.00	9.4	9.4	10.1	.00	.00	.00	.00
6	29342.	.02	.00	.88-08	.00	.00	.00	9.4	9.3	10.1	.00	.00	.00	.00
7	28933.	.03	.00	.62-07	.00	.00	.00	9.4	9.4	10.1	.00	.01	.00	.00
8	28405.	.04	.00	.10-06	.00	.00	.00	9.4	9.4	10.1	.00	.01	.00	.00
9	27886.	.05	.00	.17-05	.00	.00	.00	9.5	9.5	10.1	.00	.01	.00	.00
10	27713.	.04	.00	.49-06	.00	.00	.00	9.5	9.4	10.1	.00	.01	.00	.00
11	26771.	.05	.00	.31-05	.00	.00	.00	9.5	9.5	10.1	.00	.01	.00	.00
12	26158.	.06	.00	.13-04	.00	.00	.00	9.6	9.5	10.1	.00	.01	.00	.00
13	25356.	.07	.00	.23-04	.00	.00	.00	9.6	9.6	10.1	.00	.01	.00	.00
14	25121.	.08	.00	.65-04	.00	.00	.00	9.6	9.6	10.1	.00	.01	.00	.00
15	25024.	.08	.00	.08-04	.00	.00	.00	9.6	9.6	10.1	.00	.02	.00	.00
16	24953.	.08	.00	.79-04	.00	.00	.00	9.6	9.6	10.1	.00	.02	.00	.00
17	24483.	.08	.01	.22-03	.00	.00	.00	9.7	9.7	10.1	.00	.02	.00	.00
18	24091.	.09	.01	.30-03	.00	.00	.00	9.7	9.7	10.1	.00	.02	.00	.00
19	22740.	.11	.01	.12-02	.00	.00	.00	9.8	9.8	10.1	.00	.02	.00	.00
20	23292.	.10	.01	.12-02	.00	.00	.00	9.7	9.7	10.1	.00	.02	.00	.00
21	23252.	.10	.01	.11-02	.00	.00	.00	9.7	9.7	10.1	.00	.02	.00	.00
22	21542.	.12	.01	.43-02	.00	.00	.00	9.8	9.8	10.1	.00	.02	.00	.00
23	21671.	.12	.01	.89-02	.00	.00	.00	9.8	9.8	10.1	.00	.02	.00	.00
24	21008.	.12	.01	.19-01	.00	.00	.01	9.9	9.9	10.1	.00	.02	.00	.00
25	21032.	.13	.01	.11-01	.00	.00	.01	9.9	9.9	10.1	.00	.03	.00	.00
26	20500.	.13	.01	.37-01	.00	.01	.01	9.9	9.9	10.1	.00	.03	.00	.00
[redacted]		.17	.01	.21+00	.00	.02	.02	10.2	10.2	10.1	.00	.02	.00	.00
28	20398.	.18	.01	.51-01	.00	.01	.01	9.9	9.9	10.1	.00	.03	.00	.00
31	19993.	.15	.01	.10+00	.00	.01	.02	9.9	9.9	10.1	.00	.03	.00	.00
32	19860.	.16	.01	.31+01	.00	.03	.03	9.9	10.0	10.1	.01	.03	.00	.00
35	19857.	.16	.01	.16+00	.00	.02	.02	9.9	10.0	10.1	.00	.04	.00	.00
36	19838.	.16	.01	.53+00	.00	.02	.02	9.9	10.0	10.1	.01	.03	.00	.00
37	19570.	.16	.01	.36+01	.00	.05	.04	10.0	10.0	10.1	.01	.03	.00	.00
43	14015.	.22	.01	.14+01	.00	.05	.06	10.3	10.3	10.1	.01	.04	.00	.00
48	11477.	.23	.01	.39+00	.00	.03	.04	10.5	10.5	10.1	.01	.04	.00	.00
45	10536.	.24	.02	.20+01	.00	.04	.06	10.5	10.6	10.1	.01	.03	.00	.00
46	7456.	.24	.01	.21+00	.00	.02	.03	10.8	10.8	10.1	.01	.03	.00	.00
47	3319.	.25	.01	.26-01	.00	.01	.01	11.0	11.0	10.1	.00	.01	.00	.00
48	812.	.25	.01	.23-02	.00	.00	.00	11.2	11.2	10.1	.00	.00	.00	.00
49	181.	.25	.01	.95-04	.00	.00	.00	11.3	11.2	10.1	.00	.00	.00	.00
50	3.	.25	.01	.20-05	.00	.00	.00	11.3	11.3	10.0	.00	.00	.00	.00
52	19719.	.16	.01	.84+00	.00	.03	.03	10.0	10.0	10.1	.01	.04	.00	.00
53	19733.	.16	.01	.11+00	.00	.01	.02	10.0	10.0	10.1	.00	.04	.00	.00
54	19736.	.16	.01	.10+00	.00	.02	.02	10.0	10.0	10.1	.00	.04	.00	.00
55	19608.	.16	.01	.66-01	.00	.01	.01	10.0	10.0	10.1	.00	.04	.00	.00
56	19175.	.16	.01	.13-01	.00	.01	.01	10.0	10.0	10.1	.00	.04	.00	.00
57	18365.	.17	.01	.28-02	.00	.00	.01	10.1	10.1	10.1	.00	.04	.00	.00
58	17247.	.18	.01	.68-03	.00	.00	.00	10.1	10.1	10.1	.00	.03	.00	.00
59	15569.	.18	.01	.10-03	.00	.00	.00	10.2	10.2	10.1	.00	.03	.00	.00
60	12088.	.20	.01	.12-04	.00	.00	.00	10.5	10.5	10.1	.00	.02	.00	.00

421-55-2

Table D-6 - (Cont.)

Standard Printout Format for Computed Water Quality

UPPER COOK INLET, KNIK ARM AND TURNAGAIN ARM
AVERAGE RUNOFF CONDITIONS - STEADY STATE

TETRA TECH, INC.
LAFAYETTE, CALIF.

QUALITY RESULTS, DAY 136

JUN	TDS MG/L	TOT N MG/L	TOT P MG/L	T COL NO/100ML	F COL NO/100ML	C BOD MG/L	N BOD MG/L	OXY MG/L	O SAT MG/L	TEMP C	CONST 1 UNITS	CONST 2 UNITS	CONST 3 UNITS	CONST 4 UNITS
100	20303.	.14	.01	16+00	.00	.01	.01	9.9	9.9	10.1	.00	.03	.00	.00
101	20337.	.14	.01	17+00	.00	.01	.01	9.9	9.9	10.1	.00	.03	.00	.00
102	19717.	.15	.01	71+00	.00	.03	.03	10.0	10.0	10.1	.01	.03	.00	.00
103	20154.	.15	.01	40+00	.00	.02	.02	9.9	9.9	10.1	.00	.03	.00	.00
104	19937.	.15	.01	81+00	.00	.02	.02	9.9	9.9	10.1	.01	.03	.00	.00
105	19125.	.17	.01	18+01	.00	.05	.04	10.0	10.0	10.1	.01	.04	.00	.00
106	19958.	.15	.01	11+01	.00	.02	.02	9.9	9.9	10.1	.01	.03	.00	.00
107	19051.	.19	.01	29+01	.00	.06	.05	10.0	10.0	10.1	.01	.04	.00	.00
108	18672.	.18	.01	31+01	.00	.06	.06	10.0	10.0	10.1	.01	.04	.00	.00
109	19773.	.16	.01	22+01	.00	.03	.03	9.9	10.0	10.1	.01	.03	.00	.00
110	18839.	.18	.01	44+01	.00	.07	.06	10.0	10.0	10.1	.01	.04	.00	.00
111	19509.	.16	.01	41+01	.00	.05	.04	9.9	10.0	10.1	.01	.03	.00	.00
112	19462.	.17	.01	61+01	.00	.06	.05	10.0	10.0	10.1	.01	.03	.00	.00
113	19065.	.16	.01	35+01	.00	.04	.04	9.9	10.0	10.1	.01	.03	.00	.00
114	19063.	.18	.01	13+02	.00	.09	.08	10.0	10.0	10.1	.02	.04	.00	.00
115	18902.	.18	.01	87+01	.00	.08	.07	10.0	10.0	10.1	.02	.04	.00	.00
116	18789.	.18	.01	87+01	.00	.08	.07	10.0	10.0	10.1	.02	.04	.00	.00
117	18106.	.21	.02	30+02	.00	.17	.14	10.0	10.1	10.1	.03	.04	.00	.00
118	17957.	.20	.01	11+02	.00	.10	.09	10.0	10.1	10.1	.02	.04	.00	.00
119	17876.	.20	.01	65+01	.00	.08	.08	10.0	10.1	10.1	.02	.04	.00	.00
120	17650.	.21	.01	15+02	.00	.12	.11	10.0	10.1	10.1	.02	.04	.00	.00
121	17606.	.20	.01	13+02	.00	.11	.10	10.0	10.1	10.1	.02	.04	.00	.00
122	17292.	.20	.01	80+01	.00	.09	.08	10.1	10.1	10.1	.02	.04	.00	.00
123	17281.	.21	.01	10+02	.00	.10	.09	10.1	10.1	10.1	.02	.04	.00	.00
124	16704.	.21	.01	74+01	.00	.09	.08	10.1	10.1	10.1	.02	.04	.00	.00
125	16820.	.21	.01	77+01	.00	.09	.08	10.1	10.1	10.1	.02	.04	.00	.00
126	16707.	.21	.01	59+01	.00	.08	.08	10.1	10.2	10.1	.02	.04	.00	.00
127	16057.	.21	.01	43+01	.00	.07	.07	10.1	10.2	10.1	.02	.04	.00	.00
128	15216.	.22	.01	27+01	.00	.06	.07	10.2	10.3	10.1	.01	.04	.00	.00

Table D-7

Alternative Printout Format for Computed Water Quality
(This printout was not generated by the sample problem)

1 YEAR DYNAMIC SIMULATION OF SALINITY AND STP INFLUENCE

UPPER COOK INLET, KNIK ARM AND TURNAGAIN ARM
JUNE - SEPT RUNOFF CONDITIONS - DYNAMIC

1	30558.	2	30108.	3	29731.	4	29662.	5	28925.	6	29203.	7	28116.	8	27871.	9	25948.	10	20800.
11	25404.	12	24503.	13	23368.	14	22960.	15	22800.	16	22741.	17	21937.	18	21239.	19	19101.	20	19937.
21	19986.	22	17130.	23	17052.	24	16370.	25	16357.	26	15317.	[illegible]		28	15416.	29	0.	30	0.
31	14960.	32	14399.	33	0.	34	0.	35	14763.	36	14095.	37	13713.	38	0.	39	0.	40	0.
41	0.	42	0.	43	5591.	44	3297.	45	2750.	46	1190.	47	214.	48	10.	49	1.	50	0.
51	0.	52	10372.	53	14711.	54	14684.	55	14603.	56	14214.	57	13005.	58	11227.	59	8772.	60	8700.
61	0.	62	0.	63	0.	64	0.	65	0.	66	0.	67	0.	68	0.	69	0.	70	0.
71	0.	72	0.	73	0.	74	0.	75	0.	76	0.	77	0.	78	0.	79	0.	80	0.
81	0.	82	0.	83	0.	84	0.	85	0.	86	0.	87	0.	88	0.	89	0.	90	0.
91	0.	92	0.	93	0.	94	0.	95	0.	96	0.	97	0.	98	0.	99	0.	100	15167.
101	15011.	102	13953.	103	14859.	104	14340.	105	12869.	106	14445.	107	12743.	108	12030.	109	14086.	110	12354.
111	13731.	112	13477.	113	13873.	114	12711.	115	12493.	116	12242.	117	11163.	118	10930.	119	10677.	120	10342.
121	10255.	122	9778.	123	9755.	124	9008.	125	9037.	126	8877.	127	7948.	128	6879.				

OPP CONST 1 , UNITS FOR DAY 360

1	.04	2	.08	3	.10	4	.12	5	.16	6	.15	7	.20	8	.22	9	.31	10	.27
11	.33	12	.38	13	.43	14	.45	15	.45	16	.46	17	.49	18	.51	19	.60	20	.56
21	.55	22	.66	23	.63	24	.58	25	.76	26	.71	27	.57	28	.85	29	.00	30	.00
31	.97	32	1.02	33	.00	34	.00	35	1.01	36	1.02	37	1.11	38	.00	39	.00	40	.00
41	.00	42	.00	43	.20	44	.42	45	.35	46	.15	47	.03	48	.00	49	.00	50	.00
51	.00	52	1.06	53	1.02	54	1.03	55	1.01	56	.96	57	.86	58	.93	59	.56	60	.30
61	.00	62	.00	63	.00	64	.00	65	.00	66	.00	67	.00	68	.00	69	.00	70	.00
71	.00	72	.00	73	.00	74	.00	75	.00	76	.00	77	.00	78	.00	79	.00	80	.00
81	.00	82	.00	83	.00	84	.00	85	.00	86	.00	87	.00	88	.00	89	.00	90	.00
91	.00	92	.00	93	.00	94	.00	95	.00	96	.00	97	.00	98	.00	99	.00	100	.66
101	.81	102	.98	103	.91	104	.95	105	1.09	106	.96	107	1.18	108	1.17	109	1.02	110	1.30
111	1.10	112	1.16	113	1.07	114	1.33	115	1.25	116	1.25	117	1.69	118	1.32	119	1.24	120	1.42
121	1.34	122	1.21	123	1.29	124	1.17	125	1.15	126	1.12	127	1.02	128	.88				

621-33-2

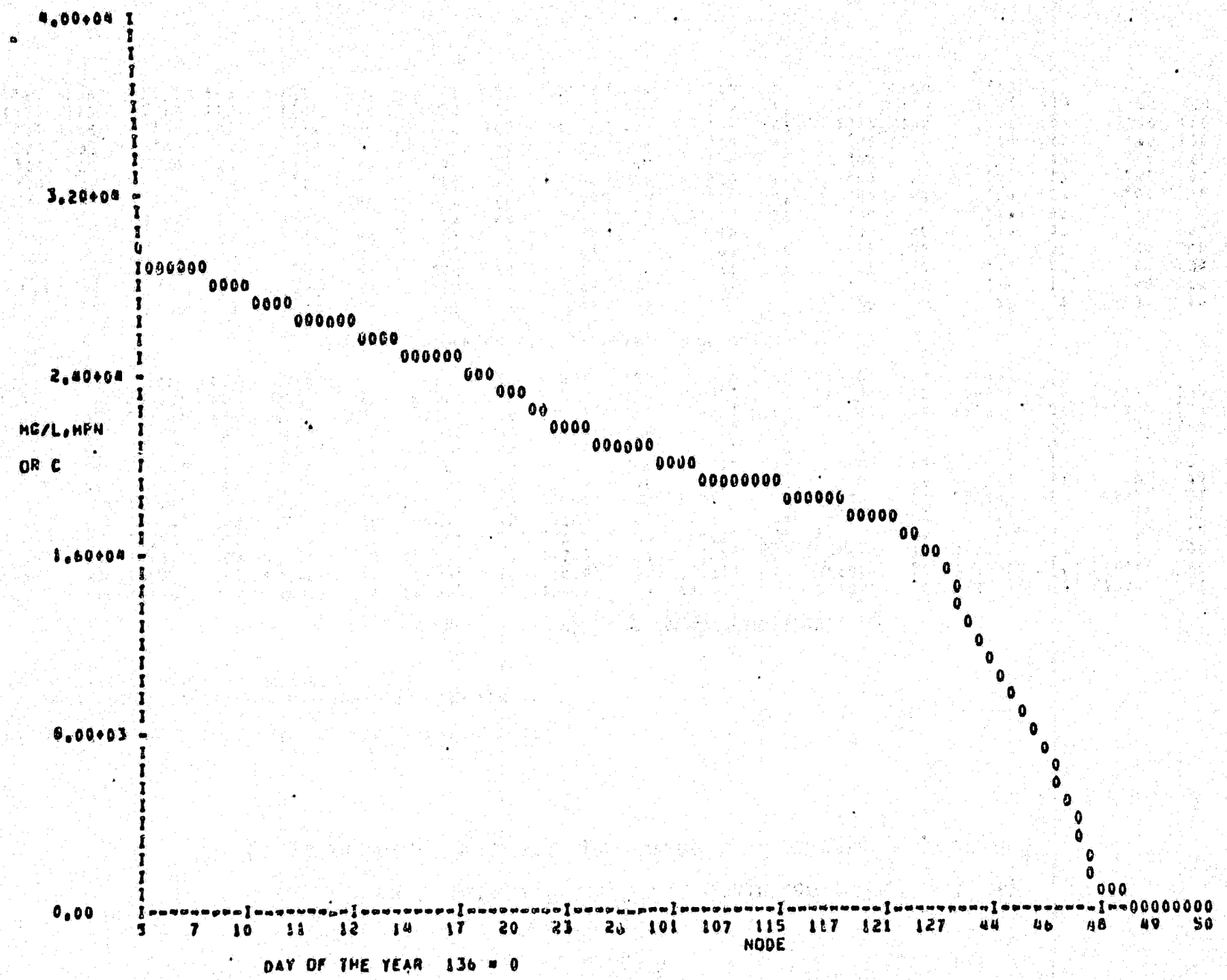

FIGURE D-1 COMPUTED CONCENTRATION VERSUS NODE LOCATION

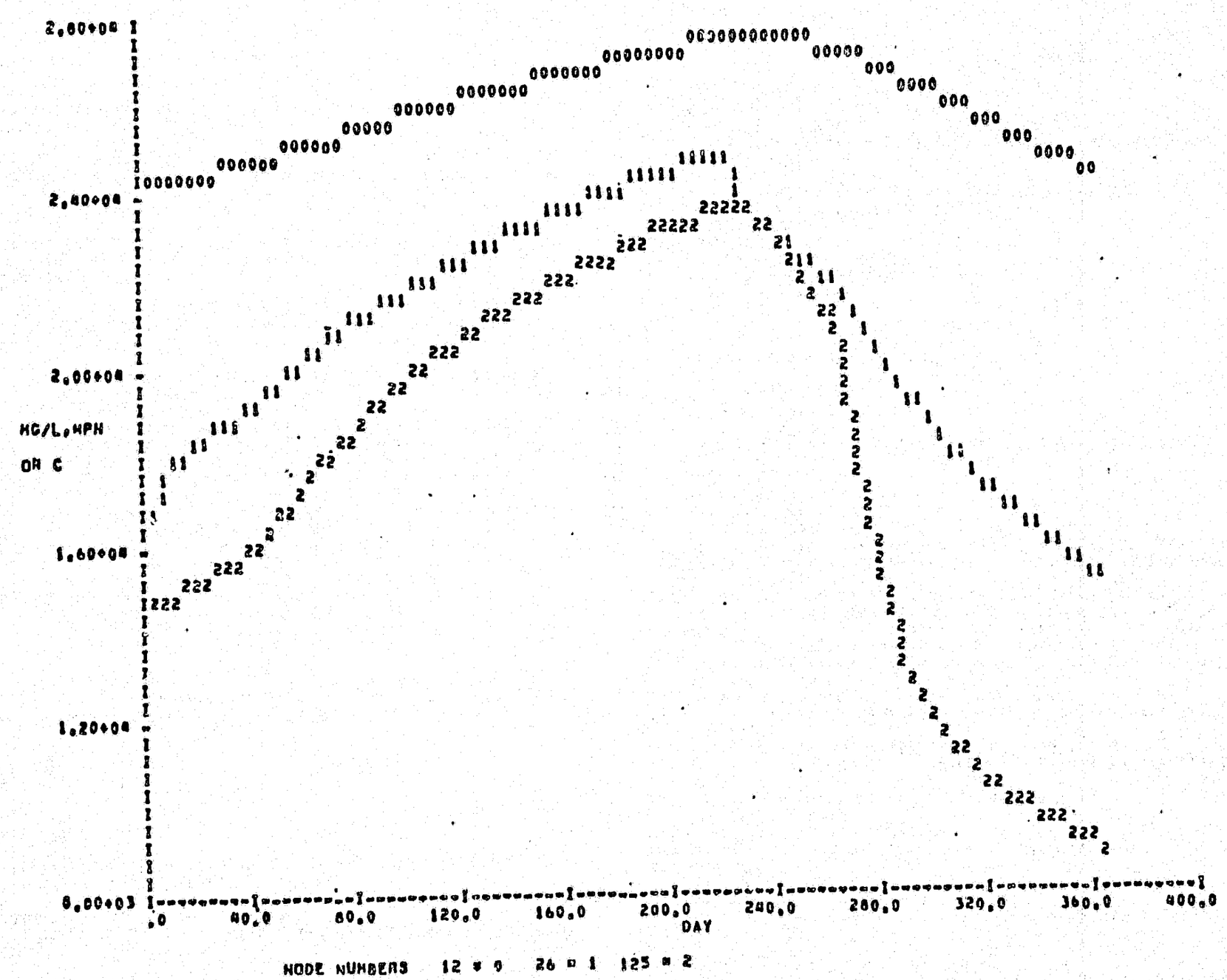

FIGURE D-2 COMPUTED CONCENTRATION VERSUS TIME AT SELECTED NODES
(THIS PRINTOUT WAS NOT GENERATED BY THE SAMPLE PROBLEM)

APPENDIX E

```
C....:
C     HYDRO IS A MATHEMATICAL MODEL DEVELOPED TO SIMULATE
C     THE HYDRODYNAMICS OF AN ESTUARY.
C
C     DEVELOPMENT OF THE MODEL WAS DONE UNDER THE SPONSORSHIP
C     OF THE CALIFORNIA DEPARTMENT OF WATER RESOURCES, CALIFORNIA
C     STATE WATER RESOURCES CONTROL BOARD AND THE NASSAU-SUFFOLK
C     REGIONAL PLANNING BOARD, NEW YORK.
C
C     ADDITIONAL MODIFICATIONS WERE MADE UNDER CONTRACT NO.
C     DACW85-78-C-0044, DEPARTMENT OF THE ARMY, ALASKA DISTRICT,
C     ANCHORAGE, ALASKA.
C
C     QUESTIONS REGARDING THE COMPUTER CODE OR THE MODEL APPLICATION
C     SHOULD BE DIRECTED TO DONALD J. SMITH, TETRA TECH, INC.,
C     3700 MT. DIABLO BLVD., LAFAYETTE, CALIF., 94549 (415-283-3771)
C....:
C....:
      COMMON /TID/ NJEX,JEX(50),AX(7,10),MM,TT(50),YY(50),PERIOD,JGM(200)
     1,     RANGE(200,2),ILAG(200,2)
      COMMON/GEOM/ JUN(200),NCHAN(200,6),NJUNC(300,2),NQIN(200)
     1,     QSIN(41,26),QGIN(200),QQU(200),QIN(200),A(300),ACK(300)
     2,     AB(300),EVAP(200),AK(300),AS(200),ASX(200),AT(300),B(300)
     3,     CHA(360),DEPTH(200),H(200),LEN(300),R(300),V(300),X(200)
     4,     VOL(200),Y(200),Q(300),ACAVE(300),ASAVE(200),ASB(200)
     5,     RAVE(300),DEPAVE(200),DEPTHB(200),QWIND(300),HAVE(200)
     6,     WN(200),WTT(200),QAVE(300),QR(300),QP(300),PAVE(300),RQH(200)
     7,     RS(300),PSQ(300),SELDA(200),VARS(300),VAVE(300),QN(300)
     8,     VOLAVE(200),VOLB(200),VB(300),VSQ(300),VT(300),VB(300)
      COMMON/MISC/ NJ,NC,DELT,DELTQ,NMSTEP,NOSTEP,T,T2,DELT2,IDAY
     1,          DMIN,ID,NMPERQ,ITS,QTEMP(8),QLAB(10),QFLOOD(10)
      COMMON/IO/ NPRT,KPRT,NOPRT,NMPRT,IPOL(10),JPRT(30),CPRT(30)
     1,     PRTH(50,30),PRTV(50,10),PRTQ(50,30),MOUH(50),NJPLOT(5,3)
     2,     NCPLOT(5,3),TITLE(20),TITL(20),LTIME,JTR(88),NTSL
      DIMENSION WAIND(5,2),WIND(5,25),WDIR(5,25),DVDT(200),IN(25)
      DIMENSION MDAY(48)
      DIMENSION STAR(9)
C     DIMENSION EVAPO(25),WAIND(25),EVAPQ(20,25),NEVAP(20,2),SUMEV(200)
      DIMENSION EVAPQ(20,25),NEVAP(20,2),SUMEV(200)
      INTEGER CPRT
      REAL LFM
      EQUIVALENCE(WN(1),DVDT(1))
      DATA STAPO/1H /, STAR1/1H*/

C
C**** TITLE INFORMATION
      READ (5,100) TITLE,TITL
  100 FORMAT (20A4)
  110 FORMAT (1H1,20A4,10X,'TETRA TECH INC.'//1X,20A4,10X,'LAFAYETTE, CA
     1LIFORNIA',//,1H ,20X,'TIDAL HYDRODYNAMICS PROGRAM'/)
C
C**** GENERAL CONTROL FOR SIMULATION AND PRINT
      READ (5,120) NSEASON,NMPRT,NOPRT,NTSL,NSTAGE,NTFLOW,NDYNAM,NSTEAD,N
     1N
      NDYNAM=0
      READ (5,120) (MDAY(I),I=1,NSEASON)
      N20=NDYNAM
      N30=NSTEAD
  120 FORMAT (16I5)
```



```
      READ (5,120) (JPRT(I),I=1,NMPRT)
      READ (5,120) (CPRT(I),I=1,NOPRT)
      IF (NSTAGE.GT.0) READ (5,130) ((NJPLOT(I,N),N=1,3),I=1,NSTAGE)
      IF (NTFLOW.GT.0) READ (5,130) ((NCPLOT(I,N),N=1,3),I=1,NTFLOW)
  130 FORMAT (3I5)
      JTR(2)=0
      IF (NTSL.GT.0) READ (5,120) (JTR(I),I=1,NTSL)
      READ (5,140) DELT,DELTQ,PERIOD,DMIN
      DMIN=DMIN/2.
  140 FORMAT (16F5.0)
      NOSTEP=3600.*PERIOD/DELTQ+0.1
      NMSTEP=3600.*PERIOD/DELT+0.1
      NMPERQ=NMSTEP/NOSTEP
      NPRT=NMPERQ
C
C
C**** READ AND PROCESS SYSTEM GEOMETRY DATA
      NEXIT=0
      CALL GEOMET (NEXIT)
      IF (NEXIT.GT.0) GO TO 150
C
C**** CALL RENUMBERING ROUTINE IF STEADY STATE QUALITY TAPE IS SPECIFIED
      IF (NSTEAD.GT.0) CALL NUMBER (NN)
  150 CONTINUE
      IF (NN.EQ.999) NEXIT=1
      WRITE (6,110) TITLE,TITL
      WRITE (6,160) NSEASON,(MDAY(I),I=1,NSEASON)
      WRITE (6,170) NMSTEP,NOSTEP,NSTAGE,NTFLOW,N20,N30,PERIOD
  160 FORMAT ('0NUMBER OF HYDRAULIC CONDITIONS',T50,I5/,'0NUMBER OF TIDA
     1L CYCLES PER CONDITION',T50,16I5/,(T50,16I5))
  170 FORMAT (,'0NUMBER OF HYDRAULIC TIME STEPS PER CYCLE',T50,I5/,'0NUM
     1BER OF QUALITY TIME STEPS PER CYCLE',T50,I5/,'0NUMBER OF TIDAL STA
     2GE PLOTS          ',T50,I5/,'0NUMBER OF TIDAL VELOCITY PLOTS
     3   ',T50,I5/,'0DYNAMIC HYDRAULIC OUTPUT UNIT          ',T50,I5/,'0S
     4TEADY STATE HYDRAULICS OUTPUT UNIT  ',T50,I5/,'0TIDAL PERIOD, HOU
     5RS',T50,F5.0/)
      WRITE (6,180) NMPRT (JPRT(I),I=1,NMPRT)
  180 FORMAT (' RESULTS PRINTED AT THE FOLLOWING',I3,' JUNCTIONS'//,(10X
     1,16I6))
      WRITE (6,190) NOPRT,(CPRT(I),I=1,NOPRT)
  190 FORMAT (//15X,'AND FOR THE FOLLOWING'I3,' CHANNELS'//(10X,16I6))
      WRITE (6,200)
  200 FORMAT ('0FOLLOWING PLOTS ARE MADE'//)
      DO 220 I=1,NSTAGE
      WRITE (6,210) (NJPLOT(I,N),N=1,3)
  210 FORMAT (15X,' TIDAL STAGE FOR JUNCTION'I3,3I5)
  220 CONTINUE
      DO 240 I=1,NTFLOW
      WRITE (6,230) (NCPLOT(I,N),N=1,3)
  230 FORMAT (15X,' TIDAL FLOW FOR CHANNELS  ',3I5)
  240 CONTINUE
C
C**** WRITE INVARIENT GEOMETRY DATA
  250 FORMAT (50X,'INVARIANT CHANNEL DATA'//,' CHANNEL     LENGTH, FT
     1  WIDTH, FT   HYD RAD, FT  MIN ELEV, FT   MANNINGS N   END JUNCTIO
     2NS   SIDE SLOPE   MAX TIME, SEC'/)
      II=0
```

```
      DO 300 J=1,NC
      IF (NJUNC(J,1).EQ.0) GO TO 300
      IF (MOD(II,45).NE.0) GO TO 260
      WRITE (6,110) TITLE,TITL
      WRITE (6,250)
  260 II=II+1
      STAR(1)=STAR0
      TC=R(J)
      IF (ACW(J).LE.0.0) GO TO 290
      TU=0.0
      DO 270 I=1,10000
      TU=TU+0.1
      TA=D(J)*R(J)-TU*(B(J)+(B(J)-TU*ACW(J)))/2.0
      IF (TA.LE.0.0) GO TO 280
  270 CONTINUE
  280 TC=D(J)/ACW(J)
      TC=AMIN1(TC,TU)
      IF (ABS(TU-TC).GT.0.01.AND.TC.LT.DMIN) STAR(1)=STAR1
  290 CONTINUE
      AS(J)=TC
      WRITE (6,310) J,STAR(1),LEN(J),B(J),R(J),TC,CMN(J),(NJUNC(J,K),K=1
     1,2),ACW(J),VT(J)
      IF (MOD(II,45).EQ.0) WRITE (6,320)
  300 CONTINUE
  310 FORMAT (I7,A1,F13.0,F10.0,F14.1,F14.1,F12.3,I9,I6,F13.0,F14.0)
      IF (MOD(II,45).NE.0) WRITE (6,320)
  320 FORMAT ('0NOTE - - * INDICATES NEGATIVE WIDTH IS POSSIBLE WITH ANT
     1ICIPATED TIDAL STAGE')
  330 FORMAT (50X,'INVARIANT JUNCTION DATA'///' JUNCTION   AREA, M3F   3L
     1OPE, M3F/FT   DEPTH, FT    MIN ELEV, FT     X-CORD      Y-CORD
     2     CHANNELS ENTERING JUNCTION'/)
      II=0
      TD=0.
      TE=0.
      DO 390 J=1,NJ
      IF (NCHAN(J,1).EQ.0) GO TO 390
      IF (MJO(II,45).NE.0) GO TO 340
      WRITE (6,110) TITLE,TITL
      WRITE (6,330)
  340 II=II+1
      TD=TD+VOL(J)
      TE=TE+AJ(J)
      TC=DEPTH(J)
      STAR(9)=STAR0
      IF (ASK(J).LE.0.0) GO TO 370
      SH=0.0
      DO 350 I=1,10000
      TU=TU+0.1
      TA=VOL(J)-TU*(AS(J)+(AS(J)-TU*ASK(J)))/2.0
      IF (TA.LE.0.0) GO TO 360
  350 CONTINUE
  360 TC=AS(J)/ASK(J)
      TC=AMIN1(TC,TU)
      IF (ABS(TU-TC).GT.0.01.AND.TC.LT.DMIN) STAR(9)=STAR1
  370 CONTINUE
      DO 380 K=1,8
      NN=NCHAN(J,K)
```



```
      STAR(K)=STAR0
      IF (TC.LT.HS(NN)) STAR(K)=STAR1
  380 CONTINUE
      WRITE (6,400) J,STAR(9),STAR(9),AB(J),ASK(J),DEPTH(J),TC,X(J),Y(J)
     1,(NCHAN(J,K),STAR(K),K=1,8)
      IF (MOD(II,45).EQ.0) WRITE (6,410)
  390 CONTINUE
  400 FORMAT (I7,2A1,-6PF10.0,F13.1,0PF15.1,F14.1,F13.1,F11.1,I7,A1,7(I8
     1,A1))
      IF (MOD(II,45).NE.0) WRITE (6,410)
  410 FORMAT ('0NOTE - - * INDICATES THAT DEPTH OF CHANNEL ENTERING JUNC
     1TION IS LARGER THAN JUNCTION DEPTH'/,9X,'** INDICATES NEGATIVE VOL
     2UME OR AREA IS POSSIBLE WITH ANTICIPATED TIDAL STAGE')
      TA=TD/TE
      WRITE (6,420) TD,TE,TA
  420 FORMAT (///20H ESTUARY STATISTICS (AT MSL)//5X,26H TOTAL VOLUME, C
     1U FT          ,E13.4,//5X,26H TOTAL SURFACE AREA, SQ FT,E13.4,//5X,26H M
     2EAN DEPTH, FT              ,E13.4)
C
      IF (N20.LE.0) GO TO 430
      REWIND N20
      WRITE (N20) NJ,NC,((NCHAN(J,I),I=1,8),J=1,NJ),((NJUNC(N,I),I=1,2),
     1LEN(N),N=1,NC)
  430 CONTINUE
C
      IF (N30.LE.0) GO TO 440
      REWIND N30
      WRITE (N30) NJ,NC,IIO
      WRITE (N30) (JUN(J),(NCHAN(J,I),I=1,8),J=1,NJ),(NJUNC(N,I),NJUNC(N
     1,2),LEN(N),N=1,NC)
  440 CONTINUE
C
C.... HYDRAULIC CONDITIONS LOOP
      DO 1170 IS=1,NSESON
      READ (5,100) TITL
      READ (5,120) NTEMP
      WRITE (6,110) TITLE,TITL
      IF (NTEMP(1).EQ.1) GO TO 460
C
C.... INPUT TIDAL CONDITIONS
      READ (5,120) NJEX
      W=2.*3.14159/PERIOD
      DO 450 N=1,NJEX
      READ (5,120) JEX(N),NI,MAXII,NCNTID
      READ (5,100) (TT(I),YY(I),I=1,NI)
      CALL INDEF (NI,MAXII,NCNTID,N)
  450 CONTINUE
      WRITE (6,110) TITLE,TITL
  460 IF (NTEMP(2).EQ.1) GO TO 530
C
C.... EVAPORATION
      P=1./(12.*30.5*86400.)
      WRITE (6,470)
  470 FORMAT('0JUNCTION TO JUNCTION    EVAPORATION RATE, INCHES/MONTH'/)
C 470 FORMAT ('0HOURLY EVAPORATION AND RAINFALL RATE'/,' JUNCTION TO JUN
C     1CTION    /   EVAPORATION, INCHES/MONTH    /   RAINFALL, INCHES/HOUR')
      DO 480 J=1,NJ
```

```
  480 EVAP(J)=0
      DO 510 I=1,21
      READ (5,700) J1,J2,EVAPA
      IF (J1.LE.0) GO TO 520
C     READ (5,550) (EVAPO(J),RAINO(J),J=1,23)
      WRITE(6,490) J1,J2,EVAPA
  490 FORMAT(19,I12,F20.2)
C     WRITE (6,490) J1,J2,EVAPO,RAINO
C 490 FORMAT (19,I12,/(5X,2F5.1))
      NEV=1
      NEVAP(1,1)=J1
      NEVAP(1,2)=J2
      TAEVAPA=F
      DO 500 J=1,25
  500 EVAPH(I,J)=TA
C 500 EVAPH(I,J)=EVAPO(J)*F-RAINO(J)/43200.
  510 CONTINUE
  520 CONTINUE
  530 IF (NTEMP(3).EQ.1) GO TO 600
C
C.... WIND VELOCITY AND DIRECTION
      WRITE (6,540)
  540 FORMAT ('0HOURLY WIND VELOCITY (MPH) AND DIRECTION (DEGREES CLOCKW
     1ISE FROM NORTH)'/,' CHANNEL TO CHANNEL'/)
      DO 570 I=1,NJ
      READ (5,130) J1,J2
      IF (J1.EQ.0) GO TO 580
      NWIND(I,1)=J1
      NWIND(I,2)=J2
      READ (5,550) (WIND(I,J),WDIR(I,J),J=1,25)
  550 FORMAT (16F5.0)
      IZUN=1
      WRITE (6,560) J1,J2,(J,WIND(I,J),WDIR(I,J),J=1,25)
  560 FORMAT (10,111,5(I9,F6.1,F6.0)/,(19X,5(I9,F6.1,F6.0)))
  570 CONTINUE
  580 CONTINUE
      IF (NTEMP(2)+NTEMP(5)+NTEMP(6).LT.3) WRITE (6,590)
  590 FORMAT (//,' INFLOW AND OUTFLOW DATA')
  600 IF (NTEMP(4).EQ.1) GO TO 670
C
C.... INFLOW AND OUTFLOW
      DO 610 J=1,NJ
      QIN(J)=0.0
      QOU(J)=0.0
  610 CONTINUE
      WRITE (6,620)
  620 FORMAT ('0JUNCTION     INFLOW, CFS     WITHDRAWL, CFS'/)
      DO 650 J=1,NJ
      READ (5,630) N,QQIN,QQOU
  630 FORMAT (I5,2F10.0)
      IF (N.LE.0) GO TO 660
      WRITE (6,640) N,QQIN,QQOU
  640 FORMAT (I9,F14.2,F16.2)
      QIN(N)=QQIN
      QOU(N)=QQOU
  650 CONTINUE
  660 CONTINUE
```



```
  670 IF (NTEMP(5).EQ.1) GO TO 740
C
C.... GROUND WATER INFLOW
      DO 680 J=1,NJ
  680 QGIN(J)=0
      WRITE (6,690)
  690 FORMAT ('0JUNCTION TO JUNCTION     GROUND WATER INFLOW, CFS')
      DO 720 I=1,NJ
      READ (5,700) J1,J2,GROUND
  700 FORMAT (2I5,F5.0)
      IF (J1.LE.0) GO TO 730
      WRITE (6,710) J1,J2,GROUND
  710 FORMAT (I9,I12,F19.2)
      DO 720 JJ=J1,J2
  720 QGIN(JJ)=GROUND
  730 CONTINUE
  740 IF (NTEMP(6).EQ.1) GO TO 840
C
C.... STORM WATER INFLOW
      DO 750 J=1,24
  750 QSIN(N1,J)=0.
      DO 760 J=1,NJ
  760 NQIN(J)=0
      WRITE (6,770)
  770 FORMAT ('0JUNCTION',T27,'STORM WATER INFLOW, HOUR AND FLOW, CFS')
      DO 820 J=1,40
      READ (5,780) N,(TN(I),I=1,12)
  780 FORMAT (I5,12F5.0)
      IF (N.EQ.0) GO TO 830
      READ (5,790) (TN(I),I=13,25)
  790 FORMAT (13F5.0)
      TA=0
      DO 800 I=1,25
      QSIN(J,I)=TN(I)
  800 TA=TA+TN(I)
      QSIN(J,26)=TA/25.
      WRITE (6,810) N,(I,QSIN(J,I),I=1,26)
  810 FORMAT (I9,/(13(I4,F6.1)))
      NQIN(N)=J
  820 CONTINUE
  830 CONTINUE
  840 CONTINUE
      IF (NEVIT.LE.0) GO TO 860
      WRITE (6,850)
  850 FORMAT (///,10(1OH   STOP   ),///,30X,' PROGRAM TERMINATION DUE TO
     1PREVIOUS ERROR',//,10(1OH   SORRY  ))
      STOP
  860 CONTINUE
C
      T=0.0
      DELT2=DEL1/2.0
      W=6.2832/(3600.*PERIOD)
      LTIME=0
      DO 870 I=1,50
      DO 870 J=1,30
      PHIN(I,J)=0.0
      PHIU(I,J)=0.0
```

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```
870 PRTY(I,J)=0.0
    DO 880 J=1,NJ
    SUMEV(J)=0.
    JGW(J)=0
    ASAVE(J)=0.0
    RUN(J)=0.0
    DVDI(J)=0.0
    VOLAVE(J)=0.0
    DEPAVE(J)=0.0
    HAVE(J)=0.
    RANGE(J,1)=-1000
    RANGE(J,2)=1000
    DO 880 I=1,2
880 TLAG(J,I)=0.0
    DO 890 N=1,NC
    VS(N)=0.0
    RS(N)=0.0
    VABS(N)=0.
    ACAVE(N)=0.0
    RSD(N)=0.0
    VSD(N)=0.0
    RAVE(N)=0.0
    QAVE(N)=0.
    BAVE(N)=0
    QP(N)=0
    QN(N)=0
890 VAVE(N)=0.
    DO 900 N=1,NJEX
    J=JEX(N)
    JGW(J)=N
    QFLOOD(N)=0.0
    QEBB(N)=0.0
900 CONTINUE
C
C.... DAILY TIME STEP LOOP
    IDAY=MDAY(IS)
    DO 1060 II=1,IDAY
    IQ=II
C
C.... QUALITY TIME STEP LOOP
    DO 1050 IQ=1,NQSTEP
    IIQ=IQ
    IF (ID.LT.IDAY) GO TO 940
    KPRI=NPRI
    DO 910 J=1,NJ
    DEPTHB(J)=0.
    VOLB(J)=0.
    ASB(J)=0.0
910 CONTINUE
    DO 920 I=1,NEV
    J1=NEVAP(I,1)
    J2=NEVAP(I,2)
    DO 920 J=J1,J2
920 SUMEV(J)=SUMEV(J)+EVAPR(I,IQ)*AS(J)
    DO 930 N=1,NC
    QB(N)=0.
    AB(N)=0.
```



```
930 VB(N)=0.0
C
C.... WIND FORCE
940 DO 950 N=1,NC
950 FWIND(N)=0.0
    DO 970 I=1,IZON
    IF (WIND(I,IQ).LE.0.0) GO TO 970
    J1=NWIND(I,1)
    J2=NWIND(I,2)
    DO 960 N=J1,J2
    IF (NJUNC(N,1).EQ.0) GO TO 960
    NL=NJUNC(N,1)
    NH=NJUNC(N,2)
    XD=X(NH)-X(NL)
    YD=Y(NH)-Y(NL)
    IF (ABS(XD)+ABS(YD).LE.0.0) GO TO 960
    FWIND(N)=-WIND(I,IQ)**2*COS(WDIR(I,IQ)/57.-ATAN2(XD,YD))*1.5E-6
960 CONTINUE
970 CONTINUE
C
C     EVAPORATION
    DO 980 I=1,NEV
    J1=NEVAP(I,1)
    J2=NEVAP(I,2)
    DO 980 J=J1,J2
980 EVAP(J)=EVAPR(I,IQ)
C
    CALL DYNFLO
    IF (ID.LT.IDAY) GO TO 1050
    F=FLOAT(NHPERQ)
    DO 990 J=1,NJ
    DEPAVE(J)=DEPAVE(J)+DEPTHB(J)
    DEPTHB(J)=DEPTHB(J)/F
    VOLB(J)=VOLB(J)/F
    ASB(J)=ASB(J)/F
990 CONTINUE
    DO 1000 N=1,NC
    QB(N)=QB(N)/F
    ACAVE(N)=ACAVE(N)+AB(N)
    AB(N)=AB(N)/F
1000 VB(N)=VB(N)/F
    DO 1030 J=1,NJ
    IF (NCHAN(J,1).EQ.0) GO TO 1030
    TA=0.0
    DO 1010 K=1,8
    IF (NCHAN(J,K).EQ.0) GO TO 1020
    N=NCHAN(J,K)
1010 TA=TA+ABS(Q(N))
1020 SFLOW(J)=0.5*TA*DELTQ/VOL(J)
1030 CONTINUE
C
    IF (N20.LE.0) GO TO 1050
    DO 1040 I=1,NJ
    K=NQIN(I)
1040 Q(I)=QSIN(K,IQ)
    WRITE (N20) IQ,(DEPTHB(J),VOL(J),ASB(J),QIN(J),Q(J),QGIN(J),QOU(J)
   1,J=1,NJ),(QB(N),AB(N),VB(N),N=1,NC)
```

```
 1050 CONTINUE
 1060 CONTINUE
C
      F=FLOAT(NHSTEP)
      DO 1070 J=1,NJ
      IF (NCHAN(J,1).EQ.0) GO TO 1070
      VOLAVE(J)=VOLAVE(J)/F
      HAVE(J)=HAVE(J)/F
      ASAVE(J)=AS(J)*ASK(J)*HAVE(J)
      DEPAVE(J)=DEPAVE(J)/F
 1070 CONTINUE
      DO 1080 N=1,NC
      IF (NJUNC(N,1).EQ.0) GO TO 1080
      VS(N)=VS0(N)-VAVE(N)**2/F
      RS(N)=RS0(N)-RAVE(N)**2/F
      VS(N)=SQRT(VS(N)/(F-1.0))
      RS(N)=SQRT(RS(N)/(F-1.0))
      RAVE(N)=RAVE(N)/F
      QAVE(N)=QAVE(N)/F
      VABS(N)=VABS(N)/F
      VAVE(N)=VAVE(N)/F
      HAVE(N)=HAVE(N)/F
      ACAVE(N)=ACAVE(N)/F
 1080 CONTINUE
      DO 1090 N=1,NJEX
      QFLUID(N)=QFLUID(N)/F
 1090 QLOU(N)=QLOU(N)/F
      IF (N2O+N3O.LE.0) GO TO 1160
C
C     CALCULATE HEATNATION COEFFICIENTS
      DO 1120 J=1,NJ
      SUMVH=0.0
      SUMAC=0.0
      DO 1100 K=1,8
      N=CHAN(J,K)
      IF (N.LE.0) GO TO 1110
      J1=NJUNC(N,1)
      J2=NJUNC(N,2)
      AREAC=HAVE(N)*ELEN(N)
      HCHAN=B(N)-(H(J1)+H(J2))/2.+(HAVE(J1)+HAVE(J2))/2.
      SUMAC=SUMAC+AREAC*HCHAN
      VCHAN=(VABS(N)/HCHAN)**0.5
      SUMVH=SUMVH+VCHAN*AREAC
 1100 CONTINUE
 1110 CONTINUE
      HIN(J)=SUMVH*12.95/SUMAC
 1120 CONTINUE
      IF (N3O.LE.0) GO TO 1160
      DO 1130 I=1,NJ
      K=NOIN(I)
      Q(I)=QIN(I)*QSIN(K,26)
 1130 VT(I)=QLIN(I)
      EVAP(1)=0.
      DO 1150 J=1,NJ
      IF (NCHAN(J,1).EQ.0) GO TO 1150
      K=NOIN(J)
      SUMEV(J)=SUMEV(J)/FLOAT(NOSTEP)
```



```
      EVAP(1)=EVAP(1)+SUMEV(J)
      DVDT(J)=QIN(J)+QGIN(J)+QSIN(K,26)-QOU(J)-SUMEV(J)
      DO 1140 K=1,8
      IF (NCHAN(J,K).EQ.0) GO TO 1150
      N=NCHAN(J,K)
      F=1.0
      IF (NJUNC(N,1).EQ.J) F=-1.0
 1140 DVDT(J)=DVDT(J)+F*QAVE(N)
 1150 CONTINUE
      WRITE (N3O) NERR,QFLOUD,(DVDT(J),DEPAVE(J),ASAVE(J),VOLAVE(J),Q(J)
     1,VT(J),QOU(J),RAIN(J),J=1,NJ),(ACAVE(N),QAVE(N),HS(N),HAVE(N),VS(N)
     2,VABS(N),N=1,NC)
 1160 CONTINUE
      IF (N2O.GT.0) WRITE (N2O) (ROR(J),DEPAVE(J),J=1,NJ)
C
      CALL OUTPUT (LTIME,NSTAGE,NIFLOW)
 1170 CONTINUE
      IF (N2O.GT.0) END FILE N2O
      IF (N3O.GT.0) END FILE N3O
      STOP
C
      END
```

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C U R V E

```
      SUBROUTINE CURVE (X,Y,NPT,NCV,NPLOT)
C
C     DIMENSION X(NPT,NCV),Y(NPT,NCV)  WHERE
C     NPT=NUMBER OF INPUT POINTS ON EACH CURVE
C     NCV=NUMBER OF CURVES ON EACH GRAPH.
C     NPLOT=PRINTED KEY.
C     IF 'NPLOT' = -1, NO PAGE EJECT OR TITLE IS PRINTED.
C     *CURVE. DOES NOT HAVE VARIABLE DIMENTIONS.  CHANGE NEXT CARD
      DIMENSION X(103,1), Y(103,1), NPT(1), DUMX(4), DUMY(4)
      COMMON /LAB/ XLAB(11),YLAB(6),TITLE(12),HORIZ(13),VERT(6),IUNITO
C
C                                        SET UP X AND Y SCALES
C
      XMAX=-1.0E30
      XMIN=1.0E30
      YMAX=-1.0E30
      YMIN=1.0E30
      DO 100 K=1,NCV
      N=NPT(K)
      DO 100 J=1,N
      IF (X(J,K).GT.XMAX) XMAX=X(J,K)
      IF (X(J,K).LT.XMIN) XMIN=X(J,K)
      IF (Y(J,K).GT.YMAX) YMAX=Y(J,K)
      IF (Y(J,K).LT.YMIN) YMIN=Y(J,K)
  100 CONTINUE
      DUMX(1)=XMIN
      DUMX(2)=XMAX
      CALL SCALE (DUMX,10.0,2,1)
      DUMY(1)=YMIN
      DUMY(2)=YMAX
      CALL SCALE (DUMY,5.0,2,1)
      DO 105 K=1,NCV
      N=NPT(K)
      X(N+1,K)=DUMX(3)
      X(N+2,K)=DUMX(4)
      Y(N+1,K)=DUMY(3)
      Y(N+2,K)=DUMY(4)
  105 CONTINUE
C
C                                        FORM X LABELS AND FACTORS
C
      XMIN=DUMX(3)
      DELTX=DUMX(4)
      XLAB(1)=XMIN
      DO 110 I=1,10
  110 XLAB(I+1)=XLAB(I)+DELTX
      XSCAL=100./(XLAB(11)-XMIN)
C
C                                        FORM Y LABELS AND FACTORS
C
      YMIN=DUMY(3)
      DELTY=DUMY(4)
      YLAB(6)=YMIN
      DO 115 I=1,5
  115 YLAB(6-I)=YLAB(7-I)+DELTY
      YSCAL=50./(YLAB(1)-YMIN)
C
```

C U R V E

```
C
C                                        INITIALIZE PLOT OUTLINE
      NCD=100
      CALL PPLOT (0,0,NCD,NPLOT)
      K=1
C
C                                        DRAW IN EACH CURVE
C
      DO 130 L=1,NCV
      IF (NPT(L).EQ.0) GO TO 125
C
C                                        JOINING XO YO AND XT YT
C
      XO=XSCAL*(X(1,L)-XMIN)
      YO=YSCAL*(Y(1,L)-YMIN)
      NPOINT=NPT(L)
      DO 120 N=2,NPOINT
      XT=XSCAL*(X(N,L)-XMIN)
      YT=YSCAL*(Y(N,L)-YMIN)
      CALL PINE (XO,YO,XT,YT,K,NPLOT)
      XO=XT
      YO=YT
  120 CONTINUE
  125 K=K+1
  130 CONTINUE
C
C                                        OUTPUT FINAL PLOT
C
      NC=99
      CALL PPLOT (0,0,NC,NPLOT)
      RETURN
      END
```

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```
      SUBROUTINE DYNFLO
      COMMON /TIO/ NJEX,JEX(10),AXLT,10),N,TT(50),YY(50),PERIOD,JGN(200)
     ,,     RANGE(200,2),TLAB(200,2)
      COMMON/GROW/ JUN(200),NCHAN(200,8),NJUNC(300,2),NOIN(200)
     ,,     OSIN(40,20),OGIN(200),OUU(200),UIN(200),A(300),ACK(300)
     ,,     AB(300),EVAP(200),AK(300),AS(200),ASK(200),AT(300),B(300)
     ,,     CHN(300),DEPTH(200),H(200),LEN(300),R(300),V(300),X(200)
     ,,     VOL(200),Y(200),Q(300),ACAVE(300),ASAVE(200),ASH(200)
     ,,     RAVE(300),QERAVE(200),DEPTHB(200),FWIND(300),HAVE(200)
     ,,     HN(200),HT(200),QAVE(300),QB(300),QP(300),QAVE(300),QUR(200)
     ,,     PS(300),RSQ(300),SFLOW(200),VARY(300),VAVE(300),QN(300)
     ,,     VOLAVE(200),VOLB(200),VS(300),VSQ(300),VT(300),VB(300)
      COMMON/TIME/ NJ,NC,DELT,DELTB,NMSTEP,NOSTEP,T,T2,DELT2,IDAY
     ,,          DMIN,IQ,NHPERQ,ITU,NTEMP(8),QERR(10),QPLOND(10)
      COMMON/IO/ NPRT,KPRT,NQPRT,NHPRT,ICOL(10),JPRT(30),CPRT(30)
     ,,     PRTH(50,30),PRTV(50,30),PRTQ(50,30),HOUR(50),NJPLOT(5,3)
     ,,     NCPLOT(5,3),TITLE(20),TITL(20),LTIME,JTH(48),NTSL
C
      INTEGER CPRT
      REAL LEN
      DATA ISTOP /0/
      DATA TIME/0.0/
      DT=DELT/3600.
      TH=T/3600.
C
      DO 270 IH=1,NHPERQ
      T2=T+DELT2
      T=T+DELT
C
C**** VELOCITIES AT T+DELT/2
C**** FLOWS AT T+DELT/2
C
      DO 105 N=1,NC
      IF (NJUNC(N,1).LE.0) GO TO 105
C
C******* CHECK FOR DRY (R.LT.0.5 FT) CHANNEL
      RNT=A(N)/B(N)
      IF (RNT.GT.0.5) GO TO 100
      VT(N)=0.0
      Q(N)=0.0
      GO TO 105
100   CONTINUE
      NL=NJUNC(N,1)
      NH=NJUNC(N,2)
      DELV2=V(N)*(1.-AT(N)/A(N))*DELT2*((V(N)**2/RNT)-32.1739)*(H(NH)-H(
     1NL))/LEN(N)
      V2=V(N)+DELV2
      TEMP=DELT2*AK(N)/RNT**1.3333333
      DELV1=0.5*((1./TEMP+2.*ABS(V2))-SQRT((1./TEMP+2.*ABS(V2))**2-8.*V2
     1**2))
      DELV1=-SIGN(DELV1,V2)
      VT(N)=V(N)+DELV1+DELV2+DELT2*FWIND(N)/RNT
      Q(N)=VT(N)*A(N)
105   CONTINUE
C
C**** HEADS AT T+DELT/2
      DO 135 J=1,NJ
      IF (NCHAN(J,1).LE.0) GO TO 135
      IF (JGN(J).EQ.0) GO TO 115
      N=JGN(J)
      TA=A*T2
      HT(J)=AX(1,N)
      DO 110 I=2,4
      TB=I-1
110   HT(J)=HT(J)+AX(I,N)*SIN(TA*TB)+AX(I+3,N)*COS(TA*TB)
      GO TO 135
115   CONTINUE
      L=NOIN(J)
      SUMQ=QOU(J)-QIN(J)-QGIN(J)-QSIN(L,IQ)+EVAP(J)*AS(J)
      DO 125 K=1,8
      IF (NCHAN(J,K).LE.0) GO TO 130
      N=NCHAN(J,K)
      IF (J.NE.NJUNC(N,1)) GO TO 120
      SUMQ=SUMQ+Q(N)
      GO TO 125
120   SUMQ=SUMQ-Q(N)
125   CONTINUE
130   HT(J)=H(J)-DELT2*SUMQ/AS(J)
135   CONTINUE
C
C**** CHANNEL AREAS AT T+DELT/2
C**** VELOCITIES AT T+DELT
C**** FLOWS AT T+DELT/2
C
      DO 165 N=1,NC
      IF (NJUNC(N,1).LE.0) GO TO 165
      NL=NJUNC(N,1)
      NH=NJUNC(N,2)
      DELH=0.5*(HT(NH)-H(NH)+HT(NL)-H(NL))
      TA=H(N)+ACK(N)*DELH
      AT(N)=A(N)+0.5*(B(N)+TA)*DELH
      RNT=AT(N)/TA
C
C******* CHECK FOR DRY (R.LT.0.5 FT) CHANNEL
      IF (RNT.GT.0.50) GO TO 140
      V(N)=0.0
      Q(N)=0.
      GO TO 165
140   CONTINUE
      DELV2=2.*VT(N)*(1.-A(N)/AT(N))+DELT*((VT(N)**2/RNT)-32.1739)*(HT(N
     1H)-HT(NL))/LEN(N)
      V2=V(N)+DELV2
      TEMP=DELT*AK(N)/RNT**1.3333333
      DELV1=0.5*((1./TEMP+2.*ABS(V2))-SQRT((1./TEMP+2.*ABS(V2))**2-8.*V2
     1**2))
      DELV1=-SIGN(DELV1,V2)
      V(N)=V(N)+DELV1+DELV2+DELT*FWIND(N)/RNT
      Q(N)=0.5*(Q(N)+V(N)*AT(N))
165   CONTINUE
C
C**** HEADS AT T+DELT (TEMPORARILY STORED IN HN)
      DO 175 J=1,NJ
      IF (NCHAN(J,1).LE.0) GO TO 175
      IF (JGN(J).EQ.0) GO TO 155
```

```
      [illegible]GM(J)
      [illegible]
      [illegible]=AX(1,N)
      [illegible] 150 I=2,4
      [illegible]=I-1
1[illegible]  HN(J)=HN(J)+AX([illegible],N)*SIN(TA*TB)+AX(I+3,N)*COS(TA*TB)
      GO TO 175
155   CONTINUE
      ASAJ=AS(J)+ASK(J)*(HT(J)-H(J))
      L=NJIN(J)
      SUMQ=QOU(J)-QIN(J)-QGIN(J)-QSIN(L,TIQ)+EVAP(J)*AS(J)
      DO 165 K=1,8
      IF (NCHAN(J,K).LE.0) GO TO 170
      N=NCHAN(J,K)
      IF (J.NE.NJUNC(N,1)) GO TO 160
      SUMQ=SUMQ+Q(N)
      GO TO 165
160   SUMQ=SUMQ-Q(N)
165   CONTINUE
170   HN(J)=H(J)-DELT*SUMQ/ASAJ
175   CONTINUE
C
C**** HYDRAULIC RADIUS AT T+DELT
C**** CHANNEL AREAS AT T+DELT
C
      DO 180 N=1,NC
      IF (NJUNC(N,1).LE.0) GO TO 180
      NL=NJUNC(N,1)
      NH=NJUNC(N,2)
      DELH=0.5*(HN(NH)-H(NH)+HN(NL)-H(NL))
      R(N)=R(N)+DELH
      TA=B(N)+ACK(N)*DELH
      A(N)=A(N)+0.5*(B(N)+TA)*DELH
      B(N)=TA
180   CONTINUE
C**** COMPUTE NEW SURFACE AREAS, VOLUME, DEPTH
C**** SHIFT HEADS AT T+1 TO H ARRAY
C
      IF(ID.EQ.IDAY) TIME=TIME+DT
      DO 200 J=1,NJ
      IF (NCHAN(J,1).EQ.0) GO TO 200
      DELH=HN(J)-H(J)
      DEPTH(J)=DEPTH(J)+DELH
      ASAJ=AS(J)+ASK(J)*DELH
      VOL(J)=VOL(J)+0.5*(ASAJ+AS(J))*DELH
      AS(J)=ASAJ
      IF(VOL(J).GT.0.0) GO TO 181
      ISTOP=ISTOP+1
      WRITE(6,182) TH,J,H(J),VOL(J)
182   FORMAT('GNEGATIVE VOLUME ENCOUNTERED AT HOUR',F7.2,' AT NODE'
     *,      I4,', HEAD =',F7.1,' FEET, VOLUME =',E9.2,' CU FT')
181   CONTINUE
      IF(AS(J).GT.0.0) GO TO 195
      WRITE(6,190) TH,J,H(J),AS(J)
190   FORMAT('GNEGATIVE SURFACE AREA ENCOUNTERED AT HOUR',F7.2
     *,  ' AT NODE',I4,', HEAD =',F7.1,' FEET, AREA =',E9.2,' SQ FT')
      ISTOP=ISTOP+1
```



```
      IF(ISTOP.GT.50) GO TO 202
195   CONTINUE
      H(J)=HN(J)
      IF(ID.NE.IDAY) GO TO 200
      IF(H(J).LT.RANGE(J,1)) GO TO 202
      RANGE(J,1)=H(J)
      TLAG(J,1)=TIME
      GO TO 200
202   IF(H(J).GT.RANGE(J,2)) GO TO 200
      RANGE(J,2)=H(J)
      TLAG(J,2)=TIME
200   CONTINUE
C
C                    CHECK FOR ABNORMAL VELOCITIES
C
      DO 210 N=1,NC
      IF(NJUNC(N,1).LE.0) GO TO 210
      IF (ABS(V(N)).LE.20.0) GO TO 210
      ISTOP=ISTOP+1
      WRITE (6,205) TH,N,Q(N),R(N),V(N)
205   FORMAT('0HYDRODYNAMIC SOLUTION HAS UNSTABLE AT HOUR',F7.2
     *,  ' IN CHANNEL',I4,', FLOW =',E9.2,' CFS, DEPTH =',F7.1
     *,  ' FEET, VELOCITY =',F7.0,' FT SEC')
      IF(ISTOP.GT.50) GO TO 202
210   CONTINUE
C
      IF ((ID.EQ.IDAY-1).AND.(IH.EQ.NHPERD)) GO TO 255
      IF (ID.LT.IDAY) GO TO 270
C
C                    SUM FOR LATER AVERAGING
C
      DO 215 J=1,NJ
      DEPTHB(J)=DEPTHB(J)+DEPTH(J)
      VOLB(J)=VOLB(J)+VOL(J)
      ASB(J)=ASB(J)+AS(J)
      VOLAVE(J)=VOLAVE(J)+VOL(J)
      HAVE(J)=HAVE(J)+H(J)
215   CONTINUE
      DO 230 N=1,NC
C
C      SUM FLOWS IN EACH CHANNEL
C
      IF ((Q(N)).GT.0.0) GO TO 220
      QN(N)=QN(N)-Q(N)
      GO TO 225
220   QP(N)=QP(N)+Q(N)
225   CONTINUE
C
      QAVE(N)=QAVE(N)+Q(N)
      VAVE(N)=VAVE(N)+V(N)
      RSQ(N)=RSQ(N)+R(N)**2
      VSQ(N)=VSQ(N)+V(N)**2
      RAVE(N)=RAVE(N)+R(N)
      QB(N)=QB(N)+Q(N)
      AB(N)=AB(N)+A(N)
      RAVE(N)=RAVE(N)+R(N)
      VABS(N)=VABS(N)+ABS(V(N))
```

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```
230   VB(N)=VB(N)+V(N)
C
C     SUM TIDAL EBB AND FLOUD
C
      DO 250 J=1,NJEX
      I=JEX(J)
      DO 240 K=1,6
      N=NCHAN(I,K)
      IF (N.EQ.0) GO TO 245
      F=1.
      IF (NJUNC(N,2).EQ.I) F=-1.
      IF (Q*D(N).LE.0.) GO TO 235
      QFLOOD(J)=QFLOOD(J)+ABS(Q(N))
      GO TO 240
235   QEBB(J)=QEBB(J)+ABS(Q(N))
240   CONTINUE
245   CONTINUE
250   CONTINUE
C
C                STORE OUPUT DATA FOR SUBSEQUENT PRINTOUT
C
      IF (TIME.NE.KPRT) GO TO 270
      KPRT=KPRT+NPRT
255   LTIME=LTIME+1
C
C**** STORE HEADS TO BE PRINTED
      DO 260 I=1,NHPRT
      MJPRT=JPRT(I)
      PRTH(LTIME,I)=H(MJPRT)
260   CONTINUE
C
C**** STORE FLOWS AND VELOCITIES TO BE PRINTED
      DO 265 I=1,NQPRT
      MQPRT=QPRT(I)
      PRTQ(LTIME,I)=Q(MQPRT)
      PRTV(LTIME,I)=V(MQPRT)
265   CONTINUE
270   CONTINUE
      IF(ISTOP.EQ.0) RETURN
  282 WRITE(6,283)
  283 FORMAT('0CHANNEL DEPTH AND VELOCITY'/)
      WRITE(6,284) (I,H(I),V(I),I=1,NC)
  284 FORMAT(5(I6,2F10.1))
      WRITE(6,285)
  285 FORMAT('0NODAL DEPTH'/)
      WRITE(6,286) (I,H(I),I=1,NJ)
  286 FORMAT(10(I6,F7.1))
      STOP
      END
```

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```
      SUBROUTINE GEOMET(NEXIT)
      COMMON/GEOM/ JUN(200),NCHAN(200,8),NJUNC(300,2),NQIN(200)
     **      QBIN(*1,26),QGIN(200),QDU(200),QIN(200),A(300),ACK(300)
     **      AB(300),EVAP(200),AK(300),AS(200),ASK(200),AT(300),B(300)
     **      CHN(300),DEPTH(200),H(200),LEN(300),R(300),V(300),X(200)
     **      VOL(200),Y(200),Q(300),ACAVE(300),ASAVE(200),ASB(200)
     **      BAVE(300),DEPAVE(200),DEPTHB(200),FWIND(300),HAVE(200)
     **      HN(200),HI(200),QAVE(300),QB(300),QP(300),RAVE(300),RUR(200)
     **      RS(300),RSQ(300),SFLOW(200),VABS(300),VAVE(300),UN(300)
     **      VOLAVE(200),VOLB(200),VS(300),VSQ(300),VT(300),VB(300)
      COMMON/MISC/ NJ,NC,DELT,DELTQ,NHSTEP,NOSTEP,T,T2,DELT2,IDAY
     **          DMIN,ID,NMPERQ,IIQ,NTEMP(8),QEBB(10),QFLOOD(10)
      REAL LEN
      DIMENSION BIG(1)
      EQUIVALENCE (JUN(1),BIG(1))
C
      MCHAN=300
      MJUN=200
      N=32*MJUN+29*MCHAN+*1*26
      DO 10 J=1,N
   10 BIG(J)=0.0
C
C**** JUNCTION DATA
C
      NJ=0
      DO 100 I=1,MJUN
      H(I)=0.
      DO 100 J=1,8
      NCHAN(I,J)=0
100   CONTINUE
      DO 120 I=1,MJUN
      READ (5,105) J,AREA,SLOPE,DEP,X1,Y1,(NTEMP(K),K=1,8)
 105  FORMAT (I5,2F10.0,3F5.0,8I5)
      IF (J.LE.0) GO TO 125
      IF (J.LE.MJUN) GO TO 115
      WRITE (6,110) J
 110  FORMAT ('0 *** ERROR ***   JUNCTION NUMBER',I6,' IS LARGER THAN PR
     1OGRAM DIMENSIONS')
      STOP
 115  CONTINUE
      IF (J.GT.NJ) NJ=J
      AS(J)=AREA
      ASK(J)=SLOPE
      DEPTH(J)=DEP
      X(J)=X1
      Y(J)=Y1
      DO 120 K=1,8
      NCHAN(J,K)=NTEMP(K)
 120  CONTINUE
 125  CONTINUE
C
C**** CHANNEL DATA
C
      NC=0
      DO 130 I=1,MCHAN
      DO 130 J=1,2
      NJUNC(I,J)=0
```



```
 130  CONTINUE
      DO 150 I=1,MCHAN
      READ(5,135) N,ALEN,WIDTH,RAD,COEF,(NTEMP(K),K=1,2),SLOPE
 135  FORMAT(I5,4F10.0,2I5,F10.0)
      IF (N.LE.0) GO TO 155
      IF (N.LE.MCHAN) GO TO 145
      WRITE (6,140) N
 140  FORMAT ('0 *** ERROR ***  CHANNEL NUMBER',I6,' IS LARGER THAN PROG
     1RAM DIMENSIONS')
      STOP
 145  CONTINUE
      IF (N.GT.NC) NC=N
      CHN(N)=COEF
      LEN(N)=ALEN
      B(N)=WIDTH
      R(N)=RAD
      AK(N)=COEF
      V(N)=0.0
      ACK(N)=SLOPE
      NJUNC(N,1)=MIN0(NTEMP(1),NTEMP(2))
 150  NJUNC(N,2)=MAX0(NTEMP(1),NTEMP(2))
 155  CONTINUE
C
C**** COMPATIBILITY CHECK
C
      DO 170 N=1,NC
      DO 170 I=1,2
      IF (NJUNC(N,I).LE.0) GO TO 170
      J=NJUNC(N,I)
      DO 160 K=1,8
      IF (N.EQ.NCHAN(J,K)) GO TO 170
 160  CONTINUE
      NEXIT=NEXIT+1
      WRITE (6,165) N,J
 165  FORMAT ('0CHANNEL CARD COMPATIBILITY CHECK, CHANNEL ',I3,' AND JUN
     1CTION ',I3)
 170  CONTINUE
      DO 190 J=1,NJ
      DO 185 K=1,8
      IF (NCHAN(J,K).LE.0) GO TO 190
      N=NCHAN(J,K)
      DO 175 I=1,2
      IF (J.EQ.NJUNC(N,I)) GO TO 185
 175  CONTINUE
      NEXIT=NEXIT+1
      WRITE (6,180) J,N
 180  FORMAT ('0JUNCTION CARD COMPATIBILITY CHECK, JUNCTION ',I3,' AND C
     1HANNEL ',I3)
 185  CONTINUE
 190  CONTINUE
C
C**** DERIVED CHANNEL DATA.
C
      DO 195 N=1,NC
      IF (NJUNC(N,1).LE.0) GO TO 195
      AK(N)=32.1739*AK(N)**2/2.208196
      A(N)=B(N)*R(N)
```

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```
      AT(N)=A(N)
193   CONTINUE
C
C**** DERIVED JUNCTION DATA
C
      DO 205 J=1,NJ
      IF (NCHAN(J,1).EQ.0) GO TO 205
      VOL(J)=AS(J)*DEPTH(J)
      IF (DEPTH(J).GT.0.) GO TO 205
      VOL(J)=0.
      IF (AS(J).LE.0.0) GO TO 205
      AREA=0.
      VOLUME=0.
      DO 200 K=1,8
      N=NCHAN(J,K)
      IF (N.LE.0) GO TO 200
      AREA=AREA+B(N)*LEN(N)
      VOLUME=VOLUME+B(N)*LEN(N)*R(N)
200   CONTINUE
      DEPTH(J)=VOLUME/AREA
      VOL(J)=DEPTH(J)*AS(J)
205   CONTINUE
      G=SQRT(32.2)
      IP=0
      DO 225 N=1,NC
      IF (NJUNC(N,1).EQ.0) GO TO 225
      DG=SQRT(R(N)*DM(N))*G
      TT=LEN(N)/DG
      VT(N)=TT
225   CONTINUE
      IF(NEXIT.GT.0) WRITE(6,227)
  227 FORMAT('0PROUGHAM EXECUTION WILL TERMINATE LATER DUE TO CHANNEL-N
     *ODE INCOMPATIBILITY')
      RETURN
C
      END
```

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```
      SUBROUTINE NUMBER(NN)
      COMMON/GEOM/ JUN(200),NCHAN(200,8),NJUNC(300,2),SPACE(11156)
     *,     IBOOK(200,8),JHOLD(100,2),JIN(200),NSTART(10),FILL(600)
      COMMON/MISC/ NJ,NC,DELT,DELTO,NHSTEP,NOSTEP,T,T2,DELT2,IDAY
     *,          DMIN,ID,NHPERO,IIO,NTEMP(8),QERR(10),QFLOW(10)
      ISTOP=0
      ISUMH=0
      ISUML=0
      NSTAR=NN
      JUN(1)=NSTAR
      I=1
      DO 130 L=1,8
      N=NCHAN(NSTAR,L)
      IF (N.LE.0) GO TO 135
      JOPP=NJUNC(N,1)
      IF (NSTAR.EQ.JOPP) GO TO 105
      GO TO 110
  105 JOPP=NJUNC(N,2)
  110 JHOLD(I,1)=JOPP
      I=I+1
      DO 120 KK=1,8
      NN=NCHAN(JOPP,KK)
      IF (NN.LE.0) GO TO 125
      JJOPP=IABS(NJUNC(NN,1))
      IF (JJOPP.EQ.JOPP) GO TO 115
      NJUNC(NN,2)=-IABS(NJUNC(NN,2))
      GO TO 120
  115 NJUNC(NN,1)=-IABS(NJUNC(NN,1))
  120 CONTINUE
  125 CONTINUE
      NJUNC(N,1)=-IABS(NJUNC(N,1))
      NJUNC(N,2)=-IABS(NJUNC(N,2))
  130 CONTINUE
  135 CONTINUE
      K=1
C
C        MAIN LOOP
C
      DO 190 MAIN=1,NJ
      K=1
      DO 175 I=1,200
      J=JHOLD(I,1)
      IF (J.LE.0) GO TO 180
      K=K+1
      JUN(K)=J
      DO 170 L=1,8
      N=NCHAN(J,L)
      IF (N.LE.0) GO TO 170
      JOPP=IABS(NJUNC(N,1))
      IF (J.EQ.JOPP) GO TO 140
      JOPP=NJUNC(N,1)
      IF (JOPP.LE.0) GO TO 165
      GO TO 145
  140 JOPP=NJUNC(N,2)
      IF (JOPP.LE.0) GO TO 165
  145 JHOLD(M,2)=JOPP
      M=M+1
```



```
      DO 155 KK=1,8
      NN=NCHAN(JOPP,KK)
      IF (NN.LE.0) GO TO 160
      JJOPP=IABS(NJUNC(NN,1))
      IF (JJOPP.EQ.JOPP) GO TO 150
      NJUNC(NN,2)=-IABS(NJUNC(NN,2))
      GO TO 155
  150 NJUNC(NN,1)=-IABS(NJUNC(NN,1))
  155 CONTINUE
  160 CONTINUE
  165 CONTINUE
      NJUNC(N,1)=-IABS(NJUNC(N,1))
      NJUNC(N,2)=-IABS(NJUNC(N,2))
  170 CONTINUE
  175 CONTINUE
  180 CONTINUE
      DO 185 I=1,200
      JHOLD(I,1)=JHOLD(I,2)
  185 JHOLD(I,2)=0
      IF (JHOLD(1,1).EQ.0) GO TO 195
C
C        END OF MAIN LOOP
C
  190 CONTINUE
  195 CONTINUE
      NP=K
      WRITE(6,204)
  204 FORMAT('1CROSS REFERENCE. * = INTERNAL NODE NUMBER VS. EXTERNAL NODE
     *E NUMBER (USED IN QUALITY PROGRAM AQUAL)'/)
      DO 200 N=1,NC
      DO 200 KK=1,2
  200 NJUNC(N,KK)=IABS(NJUNC(N,KK))
      WRITE (6,205) (J,JUN(J),J=1,NP)
  205 FORMAT(10(I7,I5))
      DO 210 K=1,NP
      J=JUN(K)
  210 JIN(J)=K
      DO 2[illegible] K=1,NP
      J=JU[illegible]
      DO 2[illegible],8
      N=NC[illegible]N(J,M)
      IF (N.LE.0) GO TO 225
      JOPP=NJUNC(N,1)
      IF (J.NE.JOPP) GO TO 215
      JOPP=NJUNC(N,2)
  215 CONTINUE
      IBOOK(K,M)=JIN(JOPP)
  220 CONTINUE
  225 CONTINUE
  230 CONTINUE
      DO 250 J=1,NP
      IMIN=J
      IMAX=J
      DO 240 K=1,8
      IF (IBOOK(J,K).LE.0) GO TO 240
      IMIN=MINO(IBOOK(J,K),IMIN)
      IMAX=MAXO(IBOOK(J,K),IMAX)
```

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```
240   CONTINUE
      IDIF=IMAX-IMIN
      IDIF1=IMAX-J
      IDIF2=J-IMIN
      IF (ISUMH.LT.IDIF1) ISUMH=IDIF1
      IF (ISUML.LT.IDIF2) ISUML=IDIF2
      K=MAXO(IDIF1,IDIF2)
      IF(K.LE.10) GO TO 250
      NN=999
      WRITE(6,245) K,J,JUN(J)
  245 FORMAT('0THE HALF BAND WIDTH OF',I6,' FOR EQUATION NUMBER',I6
     *,  ', NODE',I4,' EXCEEDS THE DIMENSION LIMITS IN PROGRAM AQUAL'
     *,/'       PROGRAM EXECUTION WILL TERMINATE LATER')
  250 CONTINUE
      ISUMY=ISUMH+ISUML
      WRITE (6,255) ISUMT,ISUMH,ISUML
  255 FORMAT('0THE WIDEST TOTAL BAND WIDTH IS',I5,' , THE HIGH SIDE MAXIM
     *UM WIDTH IS',I5,' , AND THE LOW SIDE MAXIMUM WIDTH IS',I5,///)
C
  260 CONTINUE
      IIO=MAXO(ISUMH,ISUML)
      RETURN
      END
```

```
      SUBROUTINE OUTPUT (NPOINT,NSTAGE,NTFLOW)
      COMMON /TID/ NJEX,JEX(10),AA(7,10),M,TT(50),YY(50),PERIOD,JGM(200)
     *,     RANGE(200,2),TLAG(200,2)
      COMMON/GEOM/ JUN(200),NCHAN(200,8),NJUNC(300,2),NOIN(200)
     *,     QSIN(41,25),QGIN(200),QOU(200),QIN(200),A(300),ACK(300)
     *,     AB(300),EVAP(200),AK(300),AS(200),ASK(200),AT(300),B(300)
     *,     CHN(300),DEPTH(200),H(200),LEN(300),P(300),V(300),X(200)
     *,     VOL(200),Y(200),Q(300),ACAVE(300),ASAVE(200),ASO(200)
     *,     PAVE(300),DEPAVE(200),DEPTHO(200),FRICD(300),HAVE(200)
     *,     HN(200),HI(200),QAVE(300),QO(300),QP(300),WAVE(300),HOUR(200)
     *,     RO(300),RSO(300),SFLOW(200),VARS(300),VAVE(300),QN(300)
     *,     VOLAVE(200),VOLN(200),SPACE(579),XC(10,3),YC(10,3),NPT(3)
      COMMON/MISC/ DJ,NC,DELT,DELTO,NOSTEP,NOSTEP,T,T2,DELT2,IDAY
     *,     QMIN,ID,NMPLPT,ITO,NTEMP(8),QERR(10),QFLOOD(10)
      COMMON/IO/ NPRT,NPRT,NOPRT,NOPRT,ICOL(10),JPRT(30),CPRT(30)
     *,     PRTH(50,30),PRTV(50,30),PRTQ(50,30),NOUR(50),NJPLOT(5,3)
     *,     NCPLOT(5,3)          ,TITL(40),LTIME,JIN(48) ,NTSL
      COMMON /LABL/ XLAB(11),YLAB(6),TITLE(12),HDRIZ(13),VERT(6),IUNITO
      INTEGER CPRT
      REAL LEN
      DIMENSION VERT1(6,2),VERT2(6,2),HDRIZ1(13,2)
      DATA HDRIZ1/6*4H     ,4HTIME,4H IN ,4HHOUR,4HS     ,3*4H
     *,          6*4H     ,4HX = ,4HCOOR,4HDINA,4HTES   ,3*4H     /
      DATA      VERT1/4HVELO,4HCITY,4H   I,4HN   ,4H FT/,4HSEC
     *,               4H STA,4HGE  ,4H   I,4HN   ,4H  EL,4HEV  /
      DATA      VERT2/4H ELO,4HCITY,4H IN,4H FE,4HET  /
     *,          4H  EL,4HEVA ,4HTION,4H IN ,4HFEET /
C
      DO 105 I=1,NMPRT,6
      WRITE(6,10) TITL
   10 FORMAT   (1H1,20A4,10X,'TETRA TECH INC.',/1X,20A4,10X,'LAFAYETTE,
     1CALIFORNIA',//,1H 90X,'TIDAL HYDRODYNAMICS PROGRAM')
      WRITE (6,100) JPRT(I),JPRT(I+1),JPRT(I+2),JPRT(I+3),JPRT(I+4),JPRT
     1(I+5)
  100 FORMAT ('0'23X,'JUNCTION'I5,'     JUNCTION'I5,'     JUNCTION'I5,'
     1    JUNCTION'I5,'     JUNCTION'I5,'     JUNCTION'I5,'/'
     2   HOUR       HEAD(FEET)        HEAD(FEET)        HEAD(FEET)
     3  HEAD(FEET)        HEAD(FEET)        HEAD(FEET)'/')
      T=0.0
      DO 105 L=1,LTIME
      T=T+DELT*FLOAT(NPRT)
      HOUR(L)=T/3600.
  105 WRITE (6,110) HOUR(L),PRTH(L,I),PRTH(L,I+1),PRTH(L,I+2),PRTH(L,I+3
     1),PRTH(L,I+4),PRTH(L,I+5)
  110 FORMAT (11X,F6.2,F14.2,5F18.2)
C
C**** PRINT FLOWS AND VELOCITIES
      DO 120 I=1,NOPRT,6
      WRITE(6,10) TITL
      WRITE (6,115) CPRT(I),CPRT(I+1),CPRT(I+2),CPRT(I+3),CPRT(I+4),CPRT
     1(I+5)
  115 FORMAT ('0'23X,'CHANNEL'I5,'     CHANNEL'I5,'     CHANNEL'I5,'
     1 CHANNEL'I5,'     CHANNEL'I5,'     CHANNEL'I5,'/'                 HOU
     2R       FLOW  VEL.       FLOW  VEL.       FLOW  VEL.       FLOW  VE
     3L.       FLOW  VEL.       FLOW  VEL.'/25X,'(CFS) (FPS)      (CFS)
     4(FPS)      (CFS) (FPS)      (CFS) (FPS)      (CFS) (FPS)      (CFS
     5) (FPS)')
```



```
      DO 120 L=1,LTIME
  120 WRITE (6,125) HOUR(L),PRTQ(L,I),PRTV(L,I),PRTQ(L,I+1),PRTV(L,I+1),
     1PRTQ(L,I+2),PRTV(L,I+2),PRTQ(L,I+3),PRTV(L,I+3),PRTQ(L,I+4),PRTV(L
     2,I+4),PRTQ(L,I+5),PRTV(L,I+5)
  125 FORMAT (11X,F8.2,F10.0,F7.2,F10.0,F7.2,F10.0,F7.2,F10.0,F7.2,F10.0
     1,F7.2,F10.0,F7.2)
C
      WRITE(6,10) TITL
      DO 130 I=1,10
  130 ICOL(I)=I
      WRITE (6,135) (ICOL(I),I=1,10)
  135 FORMAT ('0AVERAGE HEADS FOR A  TIDAL CYCLE'//11X,I9,9I11)
      DO 145 I=1,NJ,10
      L=I+9
      WRITE (6,140) I,L,(HAVE(J),J=I,L)
  140 FORMAT (I4,' TO ',I3,10F11.3)
  145 CONTINUE
C
      WRITE (6,150) (ICOL(I),I=1,10)
  150 FORMAT ('0AVERAGE VELOCITIES FOR A  TIDAL CYCLE'//11X,I9,9I11)
      DO 160 I=1,NC,10
      L=I+9
      WRITE (6,155) I,L,(VAVE(J),J=I,L)
  155 FORMAT (I4,' TO ',I3,10F11.3)
  160 CONTINUE
C
      WRITE (6,165) (ICOL(I),I=1,10)
  165 FORMAT ('0AVERAGE FLOWS FOR A  TIDAL CYCLE'//11X,I9,9I11)
      DO 175 I=1,NC,10
      L=I+9
      WRITE (6,170) I,L,(QAVE(J),J=I,L)
  170 FORMAT (I4,' TO ',I3,10F11.0)
  175 CONTINUE
C
      WRITE (6,190) (ICOL(I),I=1,10)
  190 FORMAT ('0WATER BALANCE AT EACH JUNCTION (CFS)'//11X,I9,9I11)
      DO 200 I=1,NJ,10
      L=I+9
      WRITE (6,195) I,L,(HN(J),J=I,L)
  195 FORMAT (I4,'  TO  ',I3,10F11.0)
  200 CONTINUE
C
      WRITE (6,205) (ICOL(I),I=1,10)
  205 FORMAT ('0AVERAGE NODAL VOLUME (CU FT)',//11X,I9,9I11)
      DO 215 I=1,NJ,10
      L=I+9
      WRITE (6,210) I,L,(VOLAVE(J),J=I,L)
  210 FORMAT (I4,'  TO  ',I4,10E11.4)
  215 CONTINUE
C
C
      TA=DELT/(3600.*PERIOD)
      DO 220 N=1,NC
      QP(N)=QP(N)*TA
  220 QN(N)=QN(N)*TA
      WRITE (6,225) ((NA,QP(NA),QN(NA)),NA=1,NC)
  225 FORMAT ('0POSITIVE AND NEGATIVE FLOWS FOR EACH CHANNEL',//,(4(I10
```

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```
     1,2F11.6)))
C
      DO 295 I=1,NJ
      IF(NCHAN(I,1),GT,0) GO TO 295                                    *NEW
      RANGE(I,1)=0.                                                    *NEW
      RANGE(I,2)=0.                                                    *NEW
  295 SPACE(I)=RANGE(I,1)-RANGE(I,2)
      WRITE(6,290) (I,RANGE(I,2),RANGE(I,1),SPACE(I),I=1,NJ)
  290 FORMAT('0MINIMUM HEAD, MAXIMUM HEAD AND TIDAL RANGE'
     ..      /(0(I10,3F7.2)))
      WRITE(6,337) (I,TLAG(I,2),TLAG(I,1),I=1,NJ)
  337 FORMAT('0TIME OF MINIMUM AND MAXIMUM HEAD, HOUR',/(8(I10,2F8.2)))
C
C.... TOTAL EVAPORATION RATE
      TA=0.
      ATOTAL=0.
      DO 310 J=1,NJ
      TA=TA+VOLAVE(J)
  310 ATOTAL=ATOTAL+ASAVE(J)
      TO=TA/ATOTAL                                                     *NEW
      WRITE(6,312) EVAP(1),ATOTAL,TA,TO                                *NEW
  312 FORMAT(///29H TOTAL EVAPORATION RATE, CFS  ,E12.4                *NEW
     ..       /29H AVERAGE SURFACE AREA, SQ FT  ,E12.4                 *NEW
     ..       /29H AVERAGE VOLUME, CU FT        ,E12.4                 *NEW
     ..       /29H AVERAGE DEPTH, FT            ,E12.4  )              *NEW
C                                                                      44=5
C.... TIDAL RANGE PLOT
      IF(JTR(2),EQ,0) GO TO 410
      DO 412 I=1,6
  412 VERT(I)=VERT2(I,1)
      DO 420 I=1,13
  420 HORIZ(I)=HORIZ1(I,2)
      DO 414 M=1,NTSL
      J=JIN(M)
      YC(M,1)=SPACE(J)
      XC(M,1)=X(J)
  414 NPT(1)=M
      I=1
      CALL CURVE(XC,YC,NPT,1,1)
      DO 432 I=1,6
  432 VERT(I)=VERT2(I,2)
      DO 430 M=1,NTSL
      J=JIN(M)
  430 YC(M,1)=TLAG(J,1)
      I=1
      CALL CURVE(XC,YC,NPT,1,1)
  410 CONTINUE
C
      NCV=1
      DO 230 I=1,NCV
      NPT(I)=NPOINT
      DO 230 J=1,NPOINT
      XC(J,I)=HOUR(J)
  230 YC(J,I)=0.0
C
C.... TIDAL STAGE PLOT
      DO 422 I=1,13
```



```
  422 HORIZ(I)=HORIZ1(I,1)
      DO 256 I=1,6
  256 VERT(I)=VERT1(I,2)
      DO 255 K=1,NSTAGE
      DO 245 N=1,3
      DO 235 L=1,30
      IF (NJPLOT(K,N),EQ,JPRT(L)) GO TO 240
  235 CONTINUE
  240 DO 245 M=1,NPOINT
      YC(M,N)=PRTH(M,L)
  245 CONTINUE
      CALL CURVE (XC,YC,NPT,NCV,K)
      WRITE (6,250) (NJPLOT(K,N),N=1,3)
  250 FORMAT (1H0,30X,21HPLOT LEGEND  JUNCTION,I3,4H = 0,10H  JUNCTION,I
     .3,4H = 1,10H  JUNCTION,I3,4H = 2)
  255 CONTINUE
C
C.... TIDAL FLOW PLOT
      DO 281 I=1,6
  281 VERT(I)=VERT1(I,1)
      DO 280 K=1,NFLOW
      DO 270 N=1,3
      DO 260 L=1,30
      IF (NCPLOT(K,N),EQ,CPRT(L)) GO TO 265
  260 CONTINUE
  265 DO 270 M=1,NPOINT
      YC(M,N)=PRTV(M,L)
  270 CONTINUE
      CALL CURVE (XC,YC,NPT,NCV,K)
      WRITE (6,275) (NCPLOT(K,N),N=1,3)
  275 FORMAT (1H0,30X,21HPLOT LEGEND   CHANNEL,I3,4H = 0,10H   CHANNEL,I
     .3,4H = 1,10H   CHANNEL,I3,4H = 2)
  280 CONTINUE
      RETURN
      END
```

E-35-147

```
      SUBROUTINE PINE (X1,Y1,X2,Y2,NSYM,NCT)
      COMMON/GEOM/ SPACE(10315),A(51,101),FILL(709)
      DIMENSION SYM(3)
      DATA   SYM /1H0,1H1,1H2/
      AXA=X1
      AXB=X2
      AYA=Y1
      AYB=Y2
      N=1
      IF (ABS(AXB-AXA).LT.ABS(AYB-AYA)) GO TO 115
C
C     SET PARAMETERS FOR X DIRECTION
C
      IF (AXB.GT.AXA) GO TO 100
      AXA=X2
      AXB=X1
      AYA=Y2
      AYB=Y1
  100 CONTINUE
      IXA=AXA+.5
      IXB=AXB+.5
      IYA=AYA+.5
      IYB=AYB+.5
  105 CONTINUE
      IF (IXA.LT.0.OR.IXA.GT.100) GO TO 110
      IF (IYA.LT.0.OR.IYA.GT.50) GO TO 110
      A(51-IYA,IXA+1)=SYM(NSYM)
  110 CONTINUE
      IXA=IXA+1
      YA=(N*(AYB-AYA))/(AXB-AXA)
      IYA=AYA+YA+0.5
      N=N+1
      IF (IXA.LE.IXB) GO TO 105
      GO TO 140
C
C     SET PARAMETERS FOR Y DIRECTION
C
  115 CONTINUE
      IF (AYB.GT.AYA) GO TO 120
      AYB=Y1
      AYA=Y2
      AXB=X1
      AXA=X2
  120 CONTINUE
      IXA=AXA+.5
      IXB=AXB+.5
      IYA=AYA+.5
      IYB=AYB+.5
  125 CONTINUE
      IF (IXA.LT.0.OR.IXA.GT.100) GO TO 130
      IF (IYA.LT.0.OR.IYA.GT.50) GO TO 130
      A(51-IYA,IXA+1)=SYM(NSYM)
  130 CONTINUE
      IYA=IYA+1
      YA=(N*(AYB-AYA))/(AYB-AYA)
      IXA=XA+AXA+0.5
      N=N+1
      IF (IYA-IYB) 125,135,140
  135 IXA=IXB
      GO TO 125
  140 RETURN
      END
```

PINE

```
      SUBROUTINE PPLOT (IX,IY,K,NCT)
      COMMON/GEOM/ SPACE(10315),A(101,101),FILL(700)
      DIMENSION SYM(9)
      COMMON /LAB/ XLAB(11),YLAB(6),TITLE(12),HORIZ(13),VERT(6),IUNITO
      DATA SYM/7*1H ,1H1,1H=/
      IF(K.GT.99) GO TO 170
      I=0
      WRITE(6,200)
  200 FORMAT(1H1)
      DO 135 II=1,6
      I=I+1
      WRITE(6,150) YLAB(II),(A(I,J),J=1,101)
      IF (II.EQ.6) GO TO 140
      DO 130 JJ=1,9
      I=I+1
      IF (I.NE.25) GO TO 115
      WRITE(6,165) VERT(5),VERT(6),(A(I,J),J=1,101)
      GO TO 130
  115 IF (I.NE.20) GO TO 120
      WRITE(6,165) VERT(1),VERT(2),(A(I,J),J=1,101)
      GO TO 130
  120 IF (I.NE.26) GO TO 125
      WRITE(6,165) VERT(3),VERT(4),(A(I,J),J=1,101)
      GO TO 130
  125 WRITE(6,145) (A(I,J),J=1,101)
  130 CONTINUE
  135 CONTINUE
  140 CONTINUE
      WRITE(6,155) XLAB
      WRITE(6,160) HORIZ
  145 FORMAT (18X,101A1)
  150 FORMAT (F17.3,1X,101A1)
  155 FORMAT (F20.1,10F10.1)
  160 FORMAT (/30X,13A4)
  165 FORMAT(5X, 2A4,5X,101A1)
  170 DO 180 I=1,50
      DO 175 J=1,101
  175 A(I,J)=SYM(7)
      A(1,1)=SYM(8)
  180 CONTINUE
      DO 195 J=1,101
  185 A(51,J)=SYM(9)
      DO 190 I=1,101,10
  190 A(I,1)=SYM(8)
      DO 195 I=11,91,10
      A(I,1)=SYM(9)
  195 CONTINUE
      RETURN
      END
```

64-35-2

```
      SUBROUTINE SCALE (ARRAY,AXLEN,NPTS,INC)
      DIMENSION ARRAY(NPTS), INT(5)
      DATA INT  /2,4,5,8,10/
      INCT=IABS(INC)
C
C                                        SCAN FOR MAX AND MIN
C
      AMAX=ARRAY(1)
      AMIN=ARRAY(1)
      DO 100 N=1,NPTS,INCT
      IF (AMAX.LT.ARRAY(N)) AMAX=ARRAY(N)
      IF (AMIN.GT.ARRAY(N)) AMIN=ARRAY(N)
  100 CONTINUE
      IF (AMAX-AMIN) 120,105,120
C
C
  105 IF (AMIN) 115,150,110
  110 AMIN=0.0
      AMAX=2.0*AMAX
      GO TO 120
  115 AMAX=0.0
      AMIN=2.0*AMIN
  120 CONTINUE
C
C                                        COMPUTE UNITS/INCH
C
      RATE=(AMAX-AMIN)/AXLEN
C
C                                              SCALE INTERVAL TO
C                                              LESS THAN 10
      A=ALOG10(RATE)
      N=A
      IF (A.LT.0) N=A-0.9999
      RATE=RATE/(10.**N)
      L=RATE+1.00
C
C                                        FIND NEXT HIGHER INTERVAL
C
  125 DO 130 I=1,5
      IF (L-INT(I)) 135,135,130
  130 CONTINUE
C
C                                        I IS NEXT HIGHER INTERVAL
C                                        RANGE IS SCALED BACK TO FULL SET
C
  135 L=INT(I)
      RANGE=FLOAT(L)*10.**N
      IF (INC.LT.0) GO TO 165
C
C                                        SET UP POSITIVE STEPS
C
      K=AMIN/RANGE
      IF (AMIN.LT.0.) K=K-1
C
C                                        CHECK FOR MAX VALUE IN RANGE
C
      IF (AMAX.GT.(K+AXLEN)*RANGE) GO TO 140
```



```
      I=NPTS*INCT+1
      ARRAY(I)=K*RANGE
      I=I+INCT
      ARRAY(I)=RANGE
      RETURN
C
C                                        IF OUTSIDE RANGE, RESET L AND M
C
  140 L=L+1
      IF (L.LT.11) GO TO 125
      L=2
      N=N+1
      GO TO 125
C
C                                        SET UP NEGATIVE STEPS
C
  165 K=AMAX/RANGE
      IF (AMAX.GT.0.) K=K+1
      IF (AMIN.LT.(K*AXLEN)*RANGE) GO TO 140
      I=INCT*NPTS+1
      ARRAY(I)=K*RANGE
      I=I+INCT
      ARRAY(I)=-RANGE
      RETURN
  150 WRITE (6,155)
  155 FORMAT (//10X,'RANGE AND SCALE ARE ZERO ON PLOT ATTEMPT')
      RETURN
      END
```

051-55-2

```
      SUBROUTINE TIDCF (NI,MAXIT,NCHTID,NN)
      COMMON /TID/ NJEX,JEX(10),AX(7,10),N,TT(50),YY(50),PERIOD,JGH(200)
     *,     RANGE(200,2),FLAG(200,2)
      DIMENSION AA(10), XX(10), SXX(10,10), SXY(10),HN(26)
      DATA DELTA,NTT,NO /0.005,7,6/
C
      IF (NI.NE.6) GO TO 105
      DO 100 I=1,5
      J=I+1
      NI=NI+1
      TT(NI)=(3.*TT(I)+TT(J))/4.
      YY(NI)=0.8535*YY(I)+0.1465*YY(J)
      NI=NI+1
      TT(NI)=(TT(I)+TT(J))/2.
      YY(NI)=(YY(I)+YY(J))/2.
      NI=NI+1
      TT(NI)=(TT(I)+3.*TT(J))/4.
      YY(NI)=0.1465*YY(I)+0.8535*YY(J)
  100 CONTINUE
  105 CONTINUE
      DO 115 J=1,NTT
      DO 110 K=1,NTT
  110 SXX(K,J)=0.
      AA(J)=0.
  115 SXY(J)=0.
      NJ2=NTT/2+1
      DO 135 I=1,NI
      DO 125 J=1,NTT
      FJ1=FLOAT(J-1)
      FJ3=FLOAT(J-NJ2)
      IF (J.NE.NJ2) GO TO 120
      XX(J)=COS(FJ3*HO*TT(I))
      GO TO 125
  120 XX(J)=SIN(FJ1*HO*TT(I))
      IF (J.EQ.1) XX(J)=1.
  125 SXY(J)=SXY(J)+XX(J)*YY(I)
      DO 130 J=1,NTT
      DO 130 K=1,NTT
  130 SXX(K,J)=SXX(K,J)+XX(K)*XX(J)
  135 CONTINUE
      IT=0
  140 IT=IT+1
      DELMAX=0.
      DO 150 K=1,NTT
      SUM=0.
      DO 145 J=1,NTT
      IF (J.EQ.K) GO TO 145
      SUM=SUM+AA(J)*SXX(K,J)
  145 CONTINUE
      SUM=(SUM+SXY(K))/SXX(K,K)
      DEL=ABS(SUM-AA(K))
      IF (DEL.GT.DELMAX) DELMAX=DEL
  150 AA(K)=SUM
      IF (IT.GE.MAXIT) GO TO 155
      IF (DELMAX.GT.DELTA) GO TO 140
  155 CONTINUE
C
```



```
      DO 170 J=1,7
  170 AX(J,NN)=AA(J)
      IF (NCHTID.NE.1) GO TO 210
      WRITE (6,175) JEX(NN),(AX(I,NN),I=1,7)
  175 FORMAT ('0 TIDAL COEFFICIENTS FOR JUNCTION',I8,/7F13.4)
      WRITE (NO,180)
  180 FORMAT(8H0       TIME    OBSERVED    COMPUTED      DIFF)
      RES=0.
      DO 195 I=1,NI
      SUM=0.
      DO 190 J=2,NTT
      FJ1=FLOAT(J-1)
      FJ3=FLOAT(J-NJ2)
      IF (J.LE.NJ2) GO TO 185
      SUM=SUM+AA(J)*COS(FJ3*HO*TT(I))
      GO TO 190
  185 SUM=SUM+AA(J)*SIN(FJ1*HO*TT(I))
  190 CONTINUE
      SUM=SUM+AA(1)
      DIFF=SUM-YY(I)
      RES=RES+ABS(DIFF)
  195 WRITE (NO,200) TT(I),YY(I),SUM,DIFF
  200 FORMAT (4F12.4)
      WRITE (NO,205) RES
  205 FORMAT (6H0TOTAL,30X,F12.4)
      DO 702 J=1,26
      TA=FLOAT(J)*H
      HN(J)=AA(1,NN)
      DO 702 I=2,4
      TB=I-1
  702 HN(J)=HN(J)+AX(I,NN)*SIN(TA*TB)+AX(I+3,NN)*COS(TA*TB)
      WRITE(6,69)
   69 FORMAT(/,20X,'SUMMARY BY HOUR')
      WRITE(6,707) (I, HN(I),I=1,26)
  707 FORMAT(10(I3,F8.2))
  210 CONTINUE
C
      RETURN
      END
```

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APPENDIX F

```
C....
C       AQUAL IS A MATHEMATICAL MODEL DEVELOPED TO SIMULATE
C       THE WATER QUALITY OF AN ESTUARY.
C
C       DEVELOPMENT OF THE MODEL WAS DONE UNDER THE SPONSORSHIP OF
C       THE CALIFORNIA STATE WATER RESOURCES CONTROL BOARD AND THE
C       NASSAU-SUFFOLK REGIONAL PLANNING BOARD, NEW YORK.
C
C       ADDITIONAL MODIFICATIONS WERE MADE UNDER CONTRACT NO.
C       DACW85-76-C-0004, DEPARTMENT OF THE ARMY, ALASKA DISTRICT,
C       ANCHORAGE, ALASKA.
C
C       QUESTIONS REGARDING THE COMPUTER CODE OR THE MODEL APPLICATION
C       SHOULD BE DIRECTED TO DONALD J. SMITH, TETRA TECH, INC.,
C ...   3700 MT. DIABLO BLVD., LAFAYETTE, CALIF., 94549 (415-283-3771)
C....
      COMMON IF(200,3),CTUC(200)
      COMMON/BIG/ NCHAN(200,6),NJUNC(300,2),JUN(200),XLEN(300)
     1,     ALPH(200),ALPHI(200),AA(200),BB(200),BETA(200)
     2,     ASAVE(200,21),A(200,21),ALPHA(200,21),AC(300),AS(200)
     3,     DIF(300),D(300),VS(300) ,CON(200),ZZ(300)  ,VOL(200),Z(300)
     4,     CCI(300),CCH(300),DEP(200),RAVE(300),HS(300),VABS(300)
      COMMON/QUALS JUNIN(200),JUNOUT(200),JUNA(200),QIN(200),QOUIN(200)
     1,     TOSIN(150),TOTNIN(150),TOIPIN(150),COLTIN(150),COLFIN(150)
     2,     BODCIN(150),BODNIN(150),OXYIN(150),TEMPIN(150)
     3,     TYPEIN(150,4),SALTIN(150)
     4,     TOS(200),TOTN(200),TOIP(200),COLT(200),COLF(200),BODC(200)
     5,     BODN(200),OXY(200),TEMP(200),TYPE(200,4),TYPEOK(200,4)
     6,     DALG(200),OSED(200),ONOM(200),BODCOK(200),NODNOK(200)
     7,     COLTOK(200),COLFOK(200),OSAT(200),DENN(200),DENP(200)
      COMMON/ADD/TYPELO(4),TYSFIL(200,4),OTEN(2)
      COMMON/HACK/ INTAKE(20,5),FACTOR(20,5)
      COMMON/MISC/NJ,NC,NP,NDYN,NHYD,NLIM,DELT,IPAGE,NHYD,IDAY,IDELT
     1,     NJP,IEE,IPLOT,ISKIP(16),ALL(20),IDYN(52),TITLE(20),TITL(20)
     2,     NCPERM(52),IPCYC,LDAY,NCYCH,INQUAL
      COMMON/EXC/ NBOUND,JBOUND(10),DEPB(10),QFLOOD(10),XH(10),TOSEX(10)
     1,     TOTNEX(10),TOIPEX(10),COLTEX(10),COLFEX(10),BODCEX(10)
     2,     NODNEX(10),OXYEX(10),TEMPEX(10),TYPEEX(10,4),SALTEX(10)
      COMMON/PLOT/ IPLOT(4),CP(101,6,4),DAY(101),NPOINT,JPLOT(6)
     1,     IPP,KPP,IPDAY(3),NODEP(21,2),PROFA(21,3,4),NCONP(4)
     2,     PROFB(21,3,4)
      COMMON/WET/NWZONE,IWZONE(6,2),FONE(200),FTWO(200)
     1,     EV(200),QWS(24,6),WINDA(200)
      DIMENSION EESAVE(1),EE(1),TEMP(1),SALT(1),CON(200,1)
      EQUIVALENCE (EESAVE(1),VABS(1)),(EE(1),VS(1))
     1,     (TEMP(1),RAVE(1)),(SALT(1),RS(1)),(CON(1,1),TOS(1))
C

      SATOXY(X,Y)=14.5532-0.38217*X+5.4258E-3*X*X-0.555*Y*(1.665E-4-5.866E-6*X+9.796E-8*X*X)
      CALL INPUT (0)
      IPERD=24/IDELT
      IF (IPERD.LT.1) IPERD=1
      IDEL=IDELT/24
      IF (IDEL.LT.1) IDEL=1
C
      DO 760 NCYCI=1,NHYD
      NCYCH=NCYCI
```



```
C
      CALL INPUT (1)
C
C....
C.... DISPERSION COEFF
      IF (IEF.LT.0) GO TO 190
      NDYN=1
      DO 180 N=1,NC
      IF (NJUNC(N,1).LE.0) GO TO 180
      Z(N)=CCI(N)*(VABS(N)+VS(N))*(RAVE(N)+R9(N))
      EE(N)=Z(N)
      DIF(N)=EE(N)*AC(N)/XLEN(N)
  180 CONTINUE
      DO 110 J=1,NP
      K=JUN(J)
      SALT(K)=IDS(K)
      AA(J)=0.0
  110 BB(J)=0.0
      DO 170 NN=1,IEE
      CALL SETUP
      CALL FORM (SALT,SALTIN,SALTOK)
      CALL SOLVIT (SALT)
      DO 120 N=1,NC
      J1=NJUNC(N,1)
      IF (J1.EQ.0) GO TO 120
      J2=NJUNC(N,2)
      J1=JUN(J1)
      J2=JUN(J2)
      SX=ABS(SALT(J1)-SALT(J2))
      ZZ(N)=Z(N)*CCH(N)*SX/XLEN(N)
      EESAVE(N)=EE(N)
      EE(N)=(EE(N)+ZZ(N))*0.5
      DIF(N)=EE(N)*AC(N)/XLEN(N)
  120 CONTINUE
      IF (NN.NE.IEE) GO TO 170
      WRITE (6,130) NN
  130 FORMAT (1H1,10X,' CHANNEL DISPERSION COEFFICIENTS, SQ FT/SEC (LAST
     1 TWO ITERATIONS)')
      WRITE (6,140) (N,EESAVE(N),ZZ(N),N=1,NC)
  140 FORMAT (5(110,2F8.0))
      WRITE (6,150)
  150 FORMAT (//,10X,'STEADY STATE SALINITY, PPT')
      WRITE (6,160) (J,SALT(J),J=1,NJ)
  160 FORMAT (5(I13,=3PF8.2))
  170 CONTINUE
C.... ESTIMATE CHLORICITY
      DO 180 JJ=1,NP
      J=JUN(JJ)
      I=TEMP(J)-19.5
      IF(JJ,1)=OTEN(2)**I
      IF(JJ,2)=OTEN(1)**I
  180 OSAT(J)=SATOXY(TEMP(J),SALT(J))
  190 CONTINUE
      NDYN=IDYN(NCYCH)
C
C.... SET UP FINAL ALPHA MATRIX
C
      CALL SETUP
```

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```
C
C.... QUALITY LOOP, CONSTANT HYDRAULICS
C
      NOH=NOPERH(NCYCH)
      DO 750 NCYCO=1,NOH
      KPLOT=KPLOT+1
      LDAY=LDAY+IDEL
C
      DO 670 NCYCD=1,IPERD
C
C.... TDS
      IF (ISKIP(1),EQ,1) GO TO 210
      DO 200 J=1,NP
      AA(J)=0.0
      BB(J)=0.0
  200 CONTINUE
      CALL FORM (TDS,TDSIN,TDSEX)
      CALL SOLVIT (TDS)
  210 CONTINUE
C
C.... TEMPERATURE
      IF (ISKIP(9),EQ,1) GO TO 290
      IF (NDYN,EQ,1) GO TO 230
      CALL METDAT (1,TEMP)
      DO 220 J=1,NP
      JJ=JUN(J)
      AA(J)=0.003281*AS(JJ)*FTWO(JJ)*ALPH1(J)
      BB(J)=0.003281*AS(JJ)*(FONE(JJ)+FTWO(JJ)*TEMP(JJ)*ALPH(J))
  220 CONTINUE
      CALL FORM (TEMP,TEMPIN,TEMPEX)
      CALL SOLVIT (TEMP)
      GO TO 270
  230 CONTINUE
      LL=6/IPERD
      IF (LL.LT.2) LL=2
      DO 260 L=1,LL
      CALL METDAT (1,TEMP)
      DO 240 J=1,NP
      JJ=JUN(J)
      AA(J)=0.003281*AS(JJ)*FTWO(JJ)
      BB(J)=0.003281*AS(JJ)*FONE(JJ)
  240 CONTINUE
      CALL FORM (TEMP,TEMPIN,TEMPEX)
      CALL SOLVIT (TEMP1)
      IF (L.EQ.LL) GO TO 260
      DO 250 J=1,NJ
  250 TEMP(J)=(TEMP(J)+2.0*TEMP1(J))/3.0
  260 CONTINUE
  270 CONTINUE
      DO 280 JJ=1,NP
      J=JUN(JJ)
      T=TEMP(J)-19.5
      TF(JJ,1)=1.02**T
      TF(JJ,1)=BETA(2)**T
      TF(JJ,2)=BETA(1)**T
      CTOC(JJ)=0.0
  280 OSAT(J)=CSTOXY(TEMP(J),TDS(J))
  290 CONTINUE
C
C.... OPTIONAL CONSTITUENTS
      DO 370 I=1,4
      IF (ISKIP(I+9),EQ,1) GO TO 370
      IF (NDYN,EQ,1) GO TO 310
      DO 300 J=1,NP
      JJ=JUN(J)
      AA(J)=(TYPEDK(JJ,I)+TYSETL(JJ,I))*VOL(JJ)*ALPH1(J)*TF(J,1)
  300 BB(J)=(TYPEDK(JJ,I)+TYSETL(JJ,I))*VOL(JJ)*ALPH(J)*TYPE(JJ,I)*TF(J
     1,1)+CTOC(J)
      GO TO 330
  310 DO 320 J=1,NP
      JJ=JUN(J)
      AA(J)=(TYPEDK(JJ,I)+TYSETL(JJ,I))*VOL(JJ)*TF(J,1)
  320 BB(J)=CTOC(J)
  330 CONTINUE
      CALL FORM (TYPE(1,I),TYPEIN(1,I),TYPEEX(1,I))
      CALL SOLVIT (TYPE(1,I))
      IF (TYPEEQ(I),LE,0,0) GO TO 350
      DO 340 J=1,NP
      JJ=JUN(J)
  340 CTOC(J)=TYPEDK(JJ,I)*TF(J,1)*TYPE(JJ,I)*TYPEEQ(I)*VOL(JJ)
      GO TO 370
  350 IF (I,EQ,4) GO TO 370
      DO 360 J=1,NP
  360 CTOC(J)=0.
  370 CONTINUE
C
C.... TOTAL NITROGEN
      IF (ISKIP(2),EQ,1) GO TO 390
      DO 380 J=1,NP
      JJ=JUN(J)
      AA(J)=0.
  380 BB(J)=-VOL(JJ)*BETN(JJ)
      CALL FORM (TOTN,TOTNIN,TOTNEX)
      CALL SOLVIT (TOTN)
  390 CONTINUE
C
C.... TOTAL PHOSPHORUS
      IF (ISKIP(3),EQ,1) GO TO 410
      DO 400 J=1,NP
      JJ=JUN(J)
      AA(J)=0.
  400 BB(J)=-VOL(JJ)*BETP(JJ)
      CALL FORM (TOTP,TOTPIN,TOTPEX)
      CALL SOLVIT (TOTP)
  410 CONTINUE
C
C.... TOTAL COLIFORM BACTERIA
      IF (ISKIP(4),EQ,1) GO TO 460
      IF (NDYN,EQ,1) GO TO 430
      DO 420 J=1,NP
      JJ=JUN(J)
      AA(J)=COLTDK(JJ)*VOL(JJ)*ALPH1(J)*TF(J,1)
      BB(J)=-COLTDK(JJ)*VOL(JJ)*ALPH(J)*COLT(JJ)*TF(J,1)
  420 CONTINUE
```

AQUAL

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```
      GO TO 450
  430 CONTINUE
      DO 440 J=1,NP
      JJ=JUN(J)
      AA(J)=COLTDK(JJ)*VOL(JJ)*TF(J,1)
  440 BB(J)=0.0
  450 CONTINUE
      CALL FORM (COLT,COLTIN,COLTEX)
      CALL SOLVIT (COLT)
  460 CONTINUE
C
C.... FECAL COLIFORM BACTERIA
      IF (ISKIP(5).EQ.1) GO TO 510
      IF (NDYN.EQ.1) GO TO 480
      DO 470 J=1,NP
      JJ=JUN(J)
      AA(J)=COLFDK(JJ)*VOL(JJ)*ALPHI(J)*TF(J,1)
      BB(J)=-COLFDK(JJ)*VOL(JJ)*ALPH(J)*COLF(JJ)*TF(J,1)
  470 CONTINUE
      GO TO 500
  480 CONTINUE
      DO 490 J=1,NP
      JJ=JUN(J)
      AA(J)=COLFDK(JJ)*VOL(JJ)*TF(J,1)
  490 BB(J)=0.0
  500 CONTINUE
      CALL FORM (COLF,COLFIN,COLFEX)
      CALL SOLVIT (COLF)
  510 CONTINUE
C
C.... CARBONACEOUS BOD
      IF (ISKIP(6).EQ.1) GO TO 560
      IF (NDYN.EQ.1) GO TO 530
      DO 520 J=1,NP
      JJ=JUN(J)
      AA(J)=BODCDK(JJ)*VOL(JJ)*ALPHI(J)*TF(J,2)
      BB(J)=-BODCDK(JJ)*VOL(JJ)*ALPH(J)*BODC(JJ)*TF(J,2)
  520 CONTINUE
      GO TO 550
  530 CONTINUE
      DO 540 J=1,NP
      JJ=JUN(J)
      AA(J)=BODCDK(JJ)*VOL(JJ)*TF(J,2)
  540 BB(J)=0.0
  550 CONTINUE
      CALL FORM (BODC,BODCIN,BODCEX)
      CALL SOLVIT (BODC)
  560 CONTINUE
C
C.... NITROGENOUS BOD
      IF (ISKIP(7).EQ.1) GO TO 610
      IF (NDYN.EQ.1) GO TO 580
      DO 570 J=1,NP
      JJ=JUN(J)
      AA(J)=BODNDK(JJ)*VOL(JJ)*ALPHI(J)*TF(J,1)
      BB(J)=-BODNDK(JJ)*VOL(JJ)*ALPH(J)*BODN(JJ)*TF(J,1)
  570 CONTINUE
```



```
      GO TO 600
  580 CONTINUE
      DO 590 J=1,NP
      JJ=JUN(J)
      AA(J)=BODNDK(JJ)*VOL(JJ)*TF(J,1)
  590 BB(J)=0.0
  600 CONTINUE
      CALL FORM (BODN,BODNIN,BODNEX)
      CALL SOLVIT (BODN)
  610 CONTINUE
C
C.... DISSOLVED OXYGEN
      IF (ISKIP(8).EQ.1) GO TO 660
      IF (NDYN.EQ.1) GO TO 630
      DO 620 J=1,NP
      JJ=JUN(J)
      AA(J)=VOL(JJ)*ORDK(JJ)*ALPHI(J)
      BB(J)=VOL(JJ)*(-BODC(JJ)*BODCDK(JJ)*TF(J,2)*(-BODN(JJ)*BODNDK(JJ)*
     1DOEN(J,J)*DALG(JJ))*TF(J,1)*ORDR(JJ)*(DSAT(JJ)-ALPH(J)*OXY(JJ)))
  620 CONTINUE
      GO TO 650
  630 CONTINUE
      DO 640 J=1,NP
      JJ=JUN(J)
      AA(J)=VOL(JJ)*ORDR(JJ)
      BB(J)=VOL(JJ)*(-BODC(JJ)*BODCDK(JJ)*TF(J,2)*(-BODN(JJ)*BODNDK(JJ)*
     1DOEN(J,J)*DALG(JJ))*TF(J,1)*ORDR(JJ)*DSAT(JJ))
  640 CONTINUE
  650 CONTINUE
      CALL FORM (OXY,OXYIN,OXYEX)
      CALL SOLVIT (OXY)
  660 CONTINUE
  670 CONTINUE
C
      IF (MOD(KPLOT,IPCYC).EQ.0) CALL OUTPUT (LDAY)
      IF (NDYN.EQ.0.AND.IPDAY(IPP).NE.LDAY) GO TO 720
      IPDAY(IPP)=LDAY
C
C.... STORE PROFILE PLOT DATA
      IF (IPP.LT.4) GO TO 720
      DO 710 II=1,4
      IF (NCONP(II).EQ.0) GO TO 710
      I=NLOCP(II)
      DO 700 K=1,NPP
      DO 690 LL=1,2
      L=PROFLP(LL,K)
      IF (L.EQ.0) GO TO 710
      IF (K.EQ.2) GO TO 680
      PROFA(LL,IPP,II)=CON(L,I)
      GO TO 690
  680 PROFB(LL,IPP,II)=CON(L,I)
  690 CONTINUE
  700 CONTINUE
  710 CONTINUE
      IPP=IPP+1
  720 CONTINUE
C
```

```
C.... STORE TIME HISTORY PLOT DATA
      IF (KPLOT.GT.100) GO TO 750
      DAY(KPLOT)=LDAY
      DO 740 K=1,9
      IF (IPLOT(K).EQ.0) GO TO 740
      I=IPLOT(K)
      DO 730 II=1,NJP
      J=JPLOT(II)
      CP(KPLOT,II,K)=CON(J,I)
  730 CONTINUE
  740 CONTINUE
  750 CONTINUE
      IF (INQUAL.GT.0) WRITE (INQUAL) ((CON(J,K),K=1,13),J=1,NJ)
  760 CONTINUE
      IPP=IPP-1
      IF (NPP.GT.0.AND.IPP.GT.0) CALL OUTPUT (-3)
      NPOINT=KPLOT
      IF (NPOINT.GT.100) NPOINT=100
      IF (NJP.GT.0) CALL OUTPUT (0)
C
      END
```

```
      SUBROUTINE CURVE(X,Y,NPT,NCV,NPLOT)
C
C  CURVE FINDS THE MAX AND MIN X AND Y VALUES, AS WELL AS X AND Y LABELS
C  IT CALLS SCALE,PPLOT, AND PINE
C
C     DIMENSION X(NPT,NCV),Y(NPT,NCV)  WHERE
C     NPT=NUMBER OF INPUT POINTS ON EACH CURVE
C     NCV=NUMBER OF CURVES ON EACH GRAPH.
C     NPLOT=PRINTER KEY.
C
      DIMENSION X(103,1),Y(103,1),NPT(1)
     *         ,DUMX(4),DUMY(4)
      COMMON/LAB/XLAB(11),YLAB(6),TITLE(12),HORIZ(13),VERT(6),IUNIT
      COMMON/XAXE/NXPTS
C
C                                        SET UP X AND Y SCALES
C
      XMAX = -1.0E30
      XMIN = 1.0E30
      YMAX = -1.0E30
      YMIN = 1.0E30
      DO 150 K = 1, NCV
      N = NPT(K)
      DO 150 J = 1, N
      IF( X(J,K) .GT. XMAX ) XMAX = X(J,K)
      IF( X(J,K) .LT. XMIN ) XMIN = X(J,K)
      IF( Y(J,K) .GT. YMAX ) YMAX = Y(J,K)
      IF( Y(J,K) .LT. YMIN ) YMIN = Y(J,K)
  150 CONTINUE
      IF(NXPTS.EQ.21) XMIN=1.0
      IF(NXPTS.EQ.21) XMAX=21.0
      DUMX(1) = XMIN
      DUMX(2) = XMAX
      CALL SCALE(DUMX,10.0,2,1)
      DUMY(1) = YMIN
      DUMY(2) = YMAX
      CALL SCALE(DUMY,5.0,2,1)
      DO 160 K = 1, NCV
      N = NPT(K)
      X(N+1,K) = DUMX(3)
      X(N+2,K) = DUMX(4)
      Y(N+1,K) = DUMY(3)
      Y(N+2,K) = DUMY(4)
  160 CONTINUE
C
C                                        FORM X LABELS AND FACTORS
C
      XMIN= DUMX(3)
      DELTX= DUMX(4)
      XLAB(1)=XMIN
      DO 260 I=1,10
  260 XLAB(I+1)=XLAB(I)+DELTX
C  XSCAL IS THE NUMBER OF SPACES PER UNIT ALONG THE X-AXIS (5 FOR PROFILES)
      XSCAL=100./(XLAB(11)-XMIN)
      IF(NXPTS.EQ.21) XSCAL=5.0
C
C                                        FORM Y LABELS AND FACTORS
```



```
C
      YMIN= DUMY(3)
      DELTY= DUMY(4)
      YLAB(6)=YMIN
      DO 270 I=1,5
  270 YLAB(6-I)=YLAB(7-I)+DELTY
      YSCAL=50./(YLAB(1)-YMIN)
C
C                                        INITIALIZE PLOT OUTLINE
C
      CALL PPLOT(0,0,100,NPLOT)
      K = 1
C
C                                        DRAW IN EACH CURVE
C
      DO 450 L=1,NCV
       IF(NPT(L).EQ.0) GO TO 440
C
C                                        JOINING XO YO AND XT YT
C
C  FOR PROFILES THE ORIGIN IS THE FIRST DATA POINT
      IF(NXPTS.EQ.21) XMIN=1.0
      XO=XSCAL*(X(1,L)-XMIN)
      YO=YSCAL*(Y(1,L)-YMIN)
      NPOINT = NPT(L)
      DO 400 N = 2,NPOINT
      XT = XSCAL*(X(N,L) - XMIN)
      YT = YSCAL*(Y(N,L) - YMIN)
      CALL PINE(XO,YO,XT,YT,K,NPLOT)
      XO = XT
      YO = YT
  400 CONTINUE
  440 K = K + 1
  450 CONTINUE
C
C                                        OUTPUT FINAL PLOT
C
      CALL PPLOT(0,0,99,NPLOT)
      RETURN
      END
```

2-35-157

```
      SUBROUTINE FORM(CON,CIN,CEX)
      COMMON/MISC/NJ,NC,NP,NDYN,NBND,MLIM,DELT,IPASE,NHYD,IDAY,IDELT
     **     NJP,IEE,KPLOT,ISKIP(16),ALL(20),IDYN(52),TITLE(20),TITL(20)
     **     NUPERM(52),IPCYC,LDAY,NCYCH,INQUAL
      COMMON/BACK/ INTAKE(20,5),FACTOR(20,5)
      COMMON/EXC/ NBOUND,JBOUND(10),QERR(10),QFLOOD(10),XR(10),FILL(180)
      COMMON/BIG/ NCHAN(200,8),NJUNC(200,2),JUN(200),XLEN(300)
     **     ALPH(200),ALPHI(200),AA(200),BB(200),BETA(200)
     **     ASAVE(200,21),A(200,21),ALPHA(200,21),AC(300),AS(200)
     **     QIP(300),U(300),VS(300) ,QOUT(200),ZZ(300)  ,VOL(200),Z(300)
     **     CC1(300),CC4(300),QEP(200),RAVE(300),RS(300),VAUS(300)
      COMMON/QUAL/ JUNIN(200),JUNGIN(200),JUNA(200),QIN(200),QGIN(200)
     **     SPACE(7500)
      DIMENSION CON(1),CIN(1),CEX(1)

C
C.... FORM FINAL COEFFICIENT MATRIX AND CONSTANT VECTOR
      M=NBND+1
      DO 92 J=1,NP
      BETA(J)=0.0
      DO 92 K=1,MLIM
   92 ALPHA(J,K)=ASAVE(J,K)
      IF(NDYN.EQ.1) GO TO 150
      II=M
      DO 100 J=1,NP
      II=II+1
      KK=J-NBND
      LL=J+NBND
      IF(KK.LE.0) KK=1
      IF(II.LT.0) II=0
      IF(LL.GT.NP) LL=NP
      I=II
      DO 110 K=KK,LL
      I=I+1
      JJ=JUN(K)
  110 BETA(J)=BETA(J)+CON(JJ)*A(J,I)
      BETA(J)=BETA(J)+BB(J)
      ALPHA(J,M)=ALPHA(J,M)+AA(J)
  100 CONTINUE
      GO TO 120
  150 CONTINUE
      DO 160 J=1,NP
      ALPHA(J,M)=ALPHA(J,M)+AA(J)
      BETA(J)=BETA(J)+BB(J)
  160 CONTINUE
  120 CONTINUE
C
C.... INFLOWS
      DO 200 J=1,NP
      JJ=JUN(J)
      J1=JUNIN(JJ)
      J2=JUNGIN(JJ)
      BETA(J)=BETA(J)+CIN(J1)*QIN(JJ)+CIN(J2)*QGIN(JJ)
      IF(JUNA(JJ).EQ.0) GO TO 200
      KK=JUNA(JJ)
      DO 220 I=1,5
      M=INTAKE(KK,I)
      IF(M.EQ.0) GO TO 220
```



```
      BETA(J)=BETA(J)+(CON(K)+CIN(100+KK))*QOU(K)*FACTOR(KK,I)
  220 CONTINUE
  200 CONTINUE
C
C.... BOUNDARY EXCHANGE
      IF(NDYN.EQ.1) GO TO 400
      DO 400 L=1,NBOUND
      J=JBOUND(L)
      JJ=JUN(J)
      TA=QFLOOD(L)*(1.0-XR(L))-QERR(L)
      ALPHA(J,M)=ALPHA(J,M)-TA*ALPHI(J)
      BETA(J)=BETA(J)+TA*ALPH(J)*CON(JJ)+CEX(L)*QFLOOD(L)*XR(L)
  400 CONTINUE
      GO TO 418
  408 CONTINUE
      DO 420 L=1,NBOUND
      KEQ=JBOUND(L)
C     CONE=XR(L)*(QERR(L)+QFLOOD(L))/(2.-XR(L))
C     CTWO=2.0*CEX(L)*(QFLOOD(L)-(1.0-XR(L))*QERR(L))/(2.-XR(L))
C     ALPHA(KEQ,M)=ALPHA(KEQ,M)+CONE
C     BETA(KEQ)=BETA(KEQ)+CTWO
      J=JBOUND(L)
      TA=QFLOOD(L)*(1.0-XR(L))-QERR(L)
      ALPHA(J,M)=ALPHA(J,M)-TA
      BETA(J)=BETA(J)+CEX(L)*QFLOOD(L)*XR(L)
  420 CONTINUE
  418 CONTINUE
      RETURN
      END
```

2-35-15

```
      SUBROUTINE INPUT (KK)
      COMMON HOUR(200)
      COMMON/BIG/ NCHAN(200,8),NJUNC(300,2),JUN(800),XLEN(300)
     1,     ALPH(200),ALPHI(200),AA(200),BB(200),BETA(200)
     2,     ASAVE(200,21),A(200,21),ALPHA(200,21),AC(300),AS(200)
     3,     QIF(300),Q(300),YS(300) ,HOU(200),ZZ(300)   ,VOL(200),Z(300)
     4,     CC(300),CC4(300),DEP(200),RAVE(300),RS(300),VABS(300)
      COMMON/QUAL/ JUNIN(200),JUNGIN(200),JUNA(200),QIN(200),UGIN(200)
     1,     TDSIN(150),TQININ(150),TOTPIN(150),COLTIN(150),COLFIN(150)
     2,      BODCIN(150),UOUNIN(150),OXYIN(150),TEMPIN(150)
     3,     TYPEIN(150,4),SALTIN(150)
     4,     TDS(200),TOIN(200),TOIP(200),COLT(200),COLF(200),BODC(200)
     5,     BOON(200),OXY(200),TEMP(200),TYPE(200,4),TYPEOR(200,4)
     6,     BALG(200),OUEN(200),ORGN(200),BODCOR(200),NUONOR(200)
     7,     COLTOR(200),COLFOR(200),OSAT(200),BENN(200),BENP(200)
      COMMON/ARO/ITYPEO(8),ITYSET(200,4),UTEM(2)
      COMMON/BACK/ INTAPE(20,5),FACTOR(20,5)
      COMMON/MISC/NJ,NC,NP,NDYN,NOUND,NLIM,DELT,IPAGE,NHYD,IDAY,IDELT
     1,     NJP,IEE,NPLOT,ISKIP(16),ALL(20),IDYN(52),IFILE(20),TITL(20)
     2,     NOPENH(52),IPCYC,LDAY,NCYCH,INQUAL
      COMMON/EXC/ NROUND,JNOUND(10),ULAB(10),QFLOOD(10),XH(10),TDSEX(10)
     1,     TOTNEX(10),TOIPEX(10),COLTEX(10),COLFEX(10),BODCEX(10)
     2,     BOONEX(10),OXYEX(10),TEMPEX(10),TYPEEX(10,4),SALTEX(10)
      COMMON/PLOT/ IPLOT(4),CP(101,6,4),NAY(101),NPOINT,JPLOT(6)
     1,      IPP,NPP,IPDAY(3),NODEP(21,2),PROFA(21,3,4),NCOMP(8)
     2,     PROFB(21,3,4)
      COMMON/METZN/ZONE,IMZONE(6,2),FONE(200),FIMO(200)
     1,     XY(200),ONS(24,6),HINDA(200)
      DIMENSION CON(200,1),CIN(150,1),CEX(10,1)
      DIMENSION QVOI(200),AGAM(200)
      EQUIVALENCE (CON(1,1),TDS(1))
     1,     (CEX(1,1),TDSEX(1)),(CIN(1,1),TDSIN(1))
      DIMENSION NAME(3,13),NTEMP(10),CNAME(4,4)
      DATA NAME/4HTDS ,24HH     ,4HTOTA,4HL N ,4H    ,4HTOTA,4HL P
     1,     4H    ,4HTOTA,4HL CO,4HLIF ,4HFECA,4HL CO,4HLIF ,4HCARB
     2,     4HON B,4HOD  ,4HNITR,4HO UD,4HD   ,4HOXYG,4HEN  ,4H
     3,     4HTEMP,4HERAT,4HURE ,4HUPP ,4HCONS,4HT 1 ,4HUPP ,4HCONS
     4,     4HT 2 ,4HUPP ,4HCONS,4HT 3 ,4HUPP ,4HCONS,4HT 4  /
      DATA NJMAX/200/
      SATOXY(X,Y)=14.5532-0.38217*X+5.4258E-3*X*X-0.555*Y+(1.665E-4-5.86
     1E-6*X+9.796E-8*X*X)
      RATE(X)=X/86400.
C
      IF (KK.EQ.1) GO TO 520
      QIF(1)=1.0
      QIF(2)=1.0
      DO 100 J=1,300
  100 NJUNC(J,1)=0
      DO 110 J=1,200
  110 NCHAN(J,1)=0
      DO 120 I=1,8
      NCOMP(I)=0
  120 IPLOT(I)=0
      DO 130 I=1,3
  130 IPDAY(I)=0
      DO 140 I=1,6
  140 JPLOT(I)=0
```



```
      DO 160 I=1,21
      DO 150 J=1,3
      DO 150 K=1,4
      PROFA(I,J,K)=0.0
  150 PROFB(I,J,K)=0.0
      NODEP(1,1)=0
  160 NODEP(1,2)=0
      READ (5,170) TITLE,TITL
  170 FORMAT (20A4)
      READ (5,180) NHYD,IDAY,IDELT,IALT,IPCYC,NJP,NPP,IEE,NFILE,INQUAL
      INQUAL=0
  180 FORMAT (16I5)
      REWIND NFILE
      READ (NFILE) NJ,NC,NAND
      READ (NFILE) (JUN(J),(NCHAN(J,I),I=1,8),J=1,NJ),(NJUNC(N,I),NJUNC(
     1N,2),XLEN(N),N=1,NC)
      NLIM=2.*NOUND+1
      IPP=1
      NP=0
      NPLOT=0
      DO 190 J=1,NJ
  190 WINDA(J)=0.
      DO 200 I=1,14
  200 CIN(150,I)=0.
      DO 210 J=1,NJ
      JUNA(J)=0
      JUNIN(J)=150
      JUNGIN(J)=150
      IF (JUN(J).LE.0) GO TO 210
      NP=NP+1
  210 CONTINUE
C
      DO 220 J=1,NP
      DO 220 N=1,NC
      IF (JUN(J).EQ.NJUNC(N,1)) NJUNC(N,1)=J
      IF (JUN(J).EQ.NJUNC(N,2)) NJUNC(N,2)=J
  220 CONTINUE
      DO 230 N=1,NC
      NJUNC(N,1)=IABS(NJUNC(N,1))
      NJUNC(N,2)=IABS(NJUNC(N,2))
  230 CONTINUE
C
      IF (IEE.EQ.0) IEE=10
      IF (NJP.GT.6) NJP=6
      IF (NPP.GT.2) NPP=2
      IF (INQUAL.GT.0) REWIND INQUAL
      NEXPP=IPCYC
      LDAY=IDAY
      DELT=DBLE(IDELT)*3600.
      READ (5,190) (NOPENH(I),IDYN(I),I=1,NHYD)
      NDYN=IDYN(1)
      READ (5,190) (ISKIP(I),I=1,16)
      READ (5,200) CNAME
  240 FORMAT (16A4)
      ISKIP(16)=IALT
      IF (NJP.EQ.0) GO TO 250
      READ (5,190) (IPLOT(K),K=1,4),(JPLOT(K),K=1,6)
```

```
250 CONTINUE
    IF (NPP.EQ.0) GO TO 270
    READ (5,180) (NCONP(K),K=1,4),(IPDAY(I),I=1,3)
    DO 260 I=1,NPP
260 READ (5,180) (NODEP(J,I),J=1,21)
270 CONTINUE
    WRITE (6,280) TITLE,TITL
280 FORMAT (1H1,10X,20A4,'     TETRA TECH, INC.'//,11X,20A4,'     LAFAY
   1ETTE, CALIF.'/)
    WRITE (6,290) IDAY,IDELT,IPCYC,NFILE,INQUAL,NHYD
290 FORMAT (///,20X,'SIMULATION BEGINS ON DAY              ',I4,//,20X,'
   1TIME STEPS OF                  ',I4,' HOUR(S)',//,20X,'PRINTO
   2UT EVERY                  ',I4,' TIME STEP(S)',//,20X,'HYDRAUL
   3IC INTERFACE UNIT',I57,I4,//,20X,'QUALITY INTERFACE UNIT',I57,I4,/
   4/,20X,'NUMBER OF BOUNDARY CONDITIONS       ',I4/)
    DO 330 I=1,NHYD
    IF (IDELT.GT.24) NOPERH(I)=NOPERH(I)*24/IDELT
    IF (NOPERH(I).LE.0) NOPERH(I)=1
    IF (IDYN(I).EQ.0) GO TO 310
    WRITE (6,300) NOPERH(I),I
300 FORMAT (23X,I3,'  TIME STEPS FOR CONDITION   ',I5,'   STEADY STATE
   1')
    GO TO 330
310 WRITE (6,320) NOPERH(I),I
320 FORMAT (23X,I3,'  TIME STEPS FOR CONDITION   ',I5,'   DYNAMIC')
330 CONTINUE
    WRITE (6,340)
340 FORMAT (///,20X,'THE FOLLOWING CONSTITUENTS ARE BEING MODELED'/)
    DO 350 K=1,9
    IF (ISKIP(K).EQ.0) WRITE (6,360) (NAME(J,K),J=1,3)
350 CONTINUE
360 FORMAT (25X,3A4)
    I=0
    DO 370 K=1,3
    I=I+1
    IF (ISKIP(K).EQ.0) WRITE (6,380) (NAME(J,K),J=1,3),(CNAME(J,I),J=1
   1,4)
370 CONTINUE
380 FORMAT (25X,3A4,2X,4A4)
C
C.... INITIAL QUALITY CONDITIONS
    WRITE (6,280) TITLE,TITL
    WRITE (6,390)
390 FORMAT (//,30X,'INITIAL QUALITY CONDITIONS'/,' JUN TO JUN      TDS
   1     TOT N     TOT P     T COL     F COL     C BOD     N BOD     D O
   2  TEMP  CONST 1  CONST 2  CONST 3  CONST 4'/,11X,3(5X,'MG/L'),2('
   3MG/100ML'),3(5X,'MG/L'),7X,'C ',8('    UNITS')/)
    DO 400 JJ=1,NJ
    READ (5,400) J1,J2,(ALL(I),I=1,13)
400 FORMAT (2I5,10F5.0)
    IF (J1.EQ.0) GO TO 450
    IF (J1.GT.J2.OR.J2.GT.NJMAX) WRITE (6,410)
410 FORMAT ('0** ERROR ** THE FOLLOWING NODE LIMITS ARE IN ERROR')
    IF (ALL(8).LT.0.0) ALL(8)=-ALL(8)*SATOXY(ALL(9),ALL(1))
    WRITE (6,420) J1,J2,(ALL(J),J=1,13)
420 FORMAT (I4,I7,F9.0,2F9.2,2F9.2,3F9.2,F9.1,4F9.2)
    DO 430 J=J1,J2
```



```
    DO 430 I=1,13
    CON(J,I)=ALL(I)
430 CONTINUE
440 CONTINUE
450 CONTINUE
C
C.... DISPERSION COEFFICIENTS
    WRITE (6,460)
460 FORMAT (///,10X,'DISPERSION COEFFICIENTS'//,9X,'CHAN TO CHAN
   1    C1          C4')
470 FORMAT (I9,I8,2F12.6)
    DO 480 N=1,NE
    READ (5,400) J1,J2,C1,C4
    IF (J1.EQ.0) GO TO 490
    WRITE (6,470) J1,J2,C1,C4
    DO 480 J=J1,J2
    CC1(J)=C1
480 CC4(J)=C4
490 CONTINUE
C
C.... SEAWARD BOUNDARY
    READ (5,180) NBOUND,(JBOUND(J),J=1,10)
    DO 510 L=1,NBOUND
    DO 500 K=1,NP
    IF (JBOUND(L).NE.JUN(K)) GO TO 500
    JBOUND(L)=K
    GO TO 510
500 CONTINUE
510 CONTINUE
    RETURN
C
C
520 CONTINUE
    NDYN=IDYN(NCYCH)
    IPCYC=KEEPP
    IF (NDYN.EQ.1) IPCYC=1
    READ (5,170) TITL
    READ (5,180) (NTEMP(I),I=1,10)
    I=0
    DO 530 J=2,9
530 I=I+NTEMP(J)
    IF (I.LT.8) WRITE (6,280) TITLE,TITL
    IEE=-IABS(IEE)
    IF (NTEMP(1).EQ.1) GO TO 590
C
C.... HYDRODYNAMICS
    IF (NTEMP(10)) 540,550,560
540 I=-NTEMP(10)
    DO 550 K=1,I
550 BACKSPACE NFILE
    GO TO 590
560 I=NTEMP(10)
    DO 570 K=1,I
570 READ (NFILE)
580 CONTINUE
    READ (NFILE) NEBR,QFLOOD,(DVOI(J),DLP(J),AJ(J),VOL(J),QIN(J),QOUT
   1(J),QBOU(J),HBOU(J),J=1,NJ),(AC(N),QC(N),RO(N),RAVE(N),VO(N),VABS(N),
```

```
      2N=1,NC)
       TEER=IFE
  590 CONTINUE
C
C.... TIDAL CONDITIONS
       IF (NTEMP(2).EQ.1) GO TO 650
       READ (5,610) (XR(J),J=1,NBOUND)
       IPAGE=IPAGE+1
       WRITE (6,600) NCYCH
  600 FORMAT (///,30X,'EXCHANGE CONDITIONS DURING HYDROLOGIC CYCLE',I4,/'
      1 JUN  EXCH     EBD     FLOUD     TDS    TOT N    TOT P    T COL    F CO
      2L    C BOD    N BOD    OXY     TEMP    CON 1    CON 2    CON 3    CON 4'
      3/,5X,'RATIO     MCFS     MCFS ',3(4X,'MG/L'),2(' N/100ML'),3('    MG
      4/L'),5X,'C',7X,8('   UNITS')//)
       DO 630 K=1,NBOUND
       READ (5,610) (CEX(K,I),I=1,14)
  610 FORMAT (5X,14F5.0)
       J=JBOUND(K)
       J=JUN(J)
       IF (SALTEX(K).LE.0.0) SALTEX(K)=TDSEX(K)
       IF (OXYEX(K).LT.0.0) OXYEX(K)=-OXYEX(K)*SATOXY(TEMPEX(K),TDSEX(K))
       WRITE (6,620) J,XR(K),QEBB(K),QFLOUD(K),(CEX(K,I),I=1,13)
  620 FORMAT (I4,F5.2,F6.2F9.3,2PF8.0,F8.2,F7.2,2E9.2,F7.2,F8.2,2F8.1,4F
      10.2)
  630 CONTINUE
  640 FORMAT (///,30X,'INFLOW CONDITIONS DURING HYDRAULIC CYCLE',I4,/' J
      1UN   INFLOW      TDS    TOT N    TOT P    T COL    F COL    C BOD
      2   N BOD      OXY     TEMP  CONST 1  CONST 2  CONST 3  CONST 4'/9X
      3,'CFS ',3(5X,'MG/L'),2(' NO/100ML'),3(5X,'MG/L'),7X,'C ',8('    UN
      4ITS')/)
C
C.... INFLOW WATER QUALITY
  650 IF (NTEMP(3).EQ.1) GO TO 810
       WRITE (6,640) NCYCH
       DO 660 J=1,NJ
  660 JUNIN(J)=150
       DO 670 J=1,100
       DO 670 K=1,14
  670 CIN(J,K)=0.0
       L=1
       DO 730 LL=1,500
       READ (5,670) JJ,QQ,(ALL(K),K=1,14)
  680 FORMAT ('0* ERROR * RETURN WATER IS ALLOWED AT 20 NODES MAXIMUM')
  690 FORMAT (I5,15F5.0)
       IF (JJ.EQ.0) GO TO 740
       IF (ALL(14).LE.0.0) ALL(14)=ALL(1)
       IF (ALL(8).LT.0.0) ALL(8)=-ALL(8)*SATOXY(ALL(9),ALL(1))
       WRITE (6,800) JJ,QQ,(ALL(K),K=1,13)
       IF (LL.EQ.1) JUNIN(JJ)=1
       DO 700 K=1,L
       J=K
       IF (JUNIN(JJ).EQ.K) GO TO 710
  700 CONTINUE
       L=L+1
       J=L
       JUNIN(JJ)=J
  710 CONTINUE
```



```
       TAR=43.000,*35,31E/(1.66HE+8*00)
       DO 720 K=1,14
       F=1.
       IF (ALL(K).LT.0.0) F=TA
  720 CIN(J,K)=CIN(J,K)+ALL(K)*QQ*F
  730 CONTINUE
  740 CONTINUE
       IF (J.GT.100) WRITE (6,750)
  750 FORMAT ('0WARNING * * THE MAXIMUM OF 100 INFLOW LOCATIONS HAS BEEN
      1 EXCEEDED * *')
       IF (NTEMP(4).EQ.1) GO TO 810
       WRITE (6,760)
  760 FORMAT (/,10X,'AGGREGATED QUALITY')
       DO 790 J=1,NJ
       JJ=JUNIN(J)
       IF (JJ.EQ.150) GO TO 780
       IF (QIN(J).LE.0) QIN(J)=1.0
       DO 770 K=1,14
  770 CIN(JJ,K)=CIN(JJ,K)/QIN(J)
       IF (SALTIN(JJ).LE.0.) SALTIN(JJ)=TDSIN(JJ)
  780 IF (QIN(J).LE.0.0) GO TO 790
       WRITE (6,800) J,QIN(J),(CIN(JJ,K),K=1,13)
  790 CONTINUE
  800 FORMAT (I4,F9.2,F9.0,2F9.2,2E9.2,2F9.2,2F9.1,4F9.2)
C
C.... GROUND WATER INFLOW
  810 IF (NTEMP(5).EQ.1) GO TO 900
       WRITE (6,820)
  820 FORMAT (/,10X,'GROUND WATER INFLOW QUALITY',//'   JUN TO JUN')
       DO 890 J=1,NJ
  830 JUNGIN(J)=150
       DO 880 JJ=1,30
       READ (5,800) J1,J2,(ALL(I),I=1,14)
       IF (J1.EQ.0) GO TO 890
       IF (ALL(14).LE.0.0) ALL(14)=ALL(1)
       IF (ALL(8).LT.0.0) ALL(8)=-ALL(8)*SATOXY(ALL(9),ALL(1))
       WRITE (6,840) J1,J2,(ALL(I),I=1,13)
  840 FORMAT (I6,I7,F9.0,2F9.2,2F9.2,2F9.2,2F9.1,4F9.2)
       IF (JJ.EQ.30) WRITE (6,850)
  850 FORMAT ('0* ERROR * A MAXIMUM OF 29 GROUND WATER TYPES ARE ALLOWED
      1')
       DO 860 I=1,14
  860 CIN(120+JJ,I)=ALL(I)
       DO 870 I=J1,J2
  870 JUNGIN(I)=JJ+120
  880 CONTINUE
  890 CONTINUE
C
C.... RETURN WATER
  900 IF (NTEMP(6).EQ.1) GO TO 1010
       WRITE (6,910)
  910 FORMAT (///,10X,'RETURN WATER',//,' WITHDRAWAL JUNCTION AND FRACTION
      1 RETURNED',//' DISCHARGE JUNCTION AND CONCENTRATION INCREMENT',/)
       DO 920 J=1,NJ
  920 JUNA(J)=0
       DO 930 J=1,20
       DO 930 K=1,5
```

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```
      INTAKE(J,K)=0
  930 FACTOR(J,K)=0.0
      DO 990 J=1,21
      READ (5,940) JI,(NTEMP(I),ALL(I),I=1,5)
  940 FORMAT (I5,5(I5,F5.0))
      IF (JI.LE.0) GO TO 1000
      IF (J.EQ.21) WRITE (6,660)
      JUNK(JI)=J
      DO 950 I=1,5
      INTAKE(J,I)=NTEMP(I)
  950 FACTOR(J,I)=ALL(I)
      READ (5,960) (ALL(I),I=1,10)
      IF (ALL(14).LE.0.0) ALL(14)=ALL(1)
  960 FORMAT (16F5.0)
      DO 970 I=1,14
  970 CIN(100*J,I)=ALL(I)
      WRITE (6,980) (INTAKE(J,I),FACTOR(J,I),I=1,5),JI,(ALL(I),I=1,13)
  980 FORMAT (5(I5,F5.2),/I4,F10.9,2F9.2,2E9.2,2F9.2,2F9.1,4F9.2)
  990 CONTINUE
 1000 CONTINUE
      IPAGE=IPAGE+1
C
C.... SYSTEM COEFFICIENTS
 1010 IF (NTEMP(7).EQ.1) GO TO 1110
      WRITE (6,1020)
 1020 FORMAT (///,30X,'SYSTEM COEFFICIENTS',//' SUN TO SUN   BOD DECAY
     1COLIF DECAY   BENTHIC SINK RATES   ALGAL OXYGEN   REAERATION      O
     2PP CONST DECAY     OPP CONST SETTLING',/13X,'CARB  NITR    TOTAL FEC
     3AL       N       P       O    PHOTO   RESP   MIN     MAX       2
     4)    4       1       2       3     6',//16X,'1/DAY          1/DAY                MF
     5/M2/DAY          MG/M2/DAY        1/DAY                1/DAY
     6       M/DAY'/)
      READ (5,960) (TYPEEQ(I),I=1,3),(QTEN(I),I=1,2)
      IF (QTEN(1).LE.0.0) QTEN(1)=1.05
      IF (QTEN(2).LE.0.0) QTEN(2)=1.03
      TYPEEQ(4)=0.0
      DO 1080 JJ=1,NJ
      READ (5,400) J1,J2,(ALL(I),I=2,9)
      IF (J1.LE.0) GO TO 1090
      READ (5,1030) (ALL(I),I=6,20)
 1030 FORMAT (16F5.0)
      IF (J1.GT.J2.OR.J2.GT.NJMAX) WRITE (6,410)
      WRITE (6,1040) J1,J2,(ALL(I),I=2,7),ALL(10),ALL(8),ALL(9),(ALL(I),
     1I=11,20)
 1040 FORMAT (I4,I7,2F6.2,F8.2,F6.2,3F7.0,F8.0,F7.0,F6.1,F7.1,F6.2,3F5.2
     1,F7.2,3F5.2)
      TA=1.
      TB=1.
      ALL(2)=RATE(TA*ALL(2))
      ALL(3)=RATE(TA*ALL(3))
      ALL(4)=RATE(TA*ALL(4))
      ALL(5)=RATE(TA*ALL(5))
      DO 1050 I=13,16
 1050 ALL(I)=RATE(TA*ALL(I))
      DO 1070 J=J1,J2
      IF (NCHAN(J,1).EQ.0) GO TO 1060
      BODDK(J)=ALL(2)
```



```
      NODNDK(J)=ALL(3)
      COLTDK(J)=ALL(4)
      COLFDK(J)=ALL(5)
      DO 1060 I=1,4
      K=12+I
 1060 TYPEDK(J,I)=ALL(K)
      TC=0.00328*AS(J)/VOL(J)/86400.
      REAN(J)=TA*TC*ALL(6)
      REAP(J)=TA*TC*ALL(7)
      DALG(J)=TA*TC*(ALL(8)-ALL(9))
      DBEN(J)=TA*TC*ALL(10)
      TC=TC*1000.
      DO 1070 I=1,4
      K=16+I
 1070 TYPEIL(J,I)=ALL(K)*TC
      AA(J)=ALL(11)
      BB(J)=ALL(12)
 1080 CONTINUE
 1090 CONTINUE
      WRITE (6,1100) (TYPEEQ(I),I=1,3),(QTEN(I),I=1,2)
 1100 FORMAT ('0STOICHIOMETRIC EQUIVALENCE BETWEEN OPTIONAL CONSTITUENTS
     1',//' CONST NO 1 DECAY TO CONST NO 2.',F8.2,//' CONST NO 2 DECAY TO
     2 CONST NO 3.',F8.2,//' CONST NO 3 DECAY TO CONST NO 4.',F8.2,///' RA
     3TE COEFFICIENT TEMPERATURE ADJUSTMENT CONSTANT FOR',//' BOD
     4',F10.3,//' ALL OTHERS',F10.3)
 1110 CONTINUE
C
C.... METEOROLOGICAL CONDITIONS
      IF (NTEMP(8).NE.1) CALL METDAT (-1,TEMP)
      IF (NTEMP(7).EQ.1.AND.NTEMP(8).EQ.1) GO TO 1170
      IF (NTEMP(7).NE.1) GO TO 1130
      DO 1120 J=1,NJ
      WA(J)=0.0
 1120 WS(J)=10000.
 1130 CONTINUE
      DO 1140 J=1,NJ
      BOR=(J)=0.
      OROR(J)=0.
      IF (NCHAN(J,1).EQ.0) GO TO 1140
      OOR=(J)=6.48+0.097*WINDA(J)**2
      BORR(J)=BOR=(J)*AS(J)*3.28/VOL(J)
      BROR(J)=AMAX1(BOR=(J),BORR(J))
      BROR(J)=AMAX1(BROR(J),AA(J))
      BROR(J)=AMIN1(BROR(J),BB(J))
 1140 CONTINUE
      WRITE (6,1150) (J,BOOR(J),BOR=(J),OROR(J),J=1,NJ)
 1150 FORMAT ('0 WIND AND WIND INDUCED REAERATION COEFFICIENT AND COEFF.
     1 USED BY NODES, 1/DAY',//(5(I8,3F6.3)))
      TA=1.
      DO 1160 J=1,NJ
      IF (NCHAN(J,1).EQ.0) GO TO 1160
      OROR(J)=RATE(TA*OROR(J))
 1160 CONTINUE
      IF (NTEMP(8).NE.1) CALL METDAT (0,TEMP)
 1170 CONTINUE
      RETURN
      END
```

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```
      SUBROUTINE METDAT (JSKIP,TW)
C*****
C     THIS ROUTINE USES ARC SIN AND ARC COS LIBRARY FUNCTIONS.
C     THESE FUNCTIONS ARE SPELLED ASIN AND ACOS IN THIS CODE.
C*****
      COMMON/MISC/NJ,NO,NP,NDYN,NHRD,MLIM,DELT,IPAGE,NRYD,IDAY,IDELT
     1,     NJP,IEE,MPLOT,ISKIP(10),ALL(20),IDYN(52),TITLE(20),TITL(20)
     2,     NOPERM(52),IPCYC,LDAY,NCYCH,INQUAL
      COMMON/AI/XLAT(6),XLON(6),TURB(6),CLOUD(25,6),DBT(25,6),WBT(25,6)
     1,     APR(25,6),WIND(25,6),UNA(25,6),EA(25,6)
      COMMON/MET/NUMZONE,JMZONE(6,2),FUNC(200),FIND(200)
     1,     FV(200),DUM2(6),WINDA(200)
      DIMENSION ALPH(8), BETA(8), A(4), B(4) ,TW(200)
C
      DATA ALPH/6.05,5.10,2.65,-2.08,-9.99,-22.29,-40.63,-66.90/
      DATA BETA/0.522,0.710,0.950,1.265,1.659,2.151,2.761,3.511/
      DATA A/1.18,2.20,0.95,0.35/
      DATA B/-0.77,-0.97,-0.75,-0.45/
      DATA PI/3.14159/, HUM/0.3333333/, DTOR/0.01745/
C
      RO(X)=1000.-(((X-3.98)**2*(X+283.))/(503.57*(X+67.26)))
C
      IF (JSKIP) 100,210,290
  100 CONTINUE
      READ (5,110) NMZONE,DAY,EPS,AA,BB,DEW
  110 FORMAT (I5,10F5.0)
      IF (BB.LE.0.0) BB=1.5E-9
      DO 200 L=1,NMZONE
C
C READ NUMBERS OF JUNCTIONS DELIMITING THE WEATHER ZONE, THE LATITUDE
C AND LONGITUDE, AND ATMOSPHERIC TURBIDITY (2 FOR CLEAR, UP TO 5 FOR SMO
      READ (5,120) (JMZONE(L,J),J=1,2),XLAT(L),XLON(L),TURB(L)
  120 FORMAT (2I5,10F5.0)
C
      J1=1
      DO 140 J=1,25
C
C READ CLOUD COVER FRACTION(PCT), DRY BULB(C),WET BULB(C),ATMOSPHERIC PR
C (MB), AND WIND SPEED(M/SEC)
C
      READ (5,110) J2,(ALL(I),I=1,5)
      CLOUD(J2,L)=ALL(1)
      DBT(J2,L)=ALL(2)
      WBT(J2,L)=ALL(3)
      APR(J2,L)=ALL(4)
      WIND(J2,L)=ALL(5)
      IF (J2.EQ.1) GO TO 140
      NN=J2-J1-1
      IF (NN.LE.0) GO TO 140
      DO 130 N=1,NN
      JJ=J1+N
      TA=FLOAT(N)/FLOAT(NN+1)
      TB=1.0-TA
      CLOUD(JJ,L)=CLOUD(J2,L)*TA+CLOUD(J1,L)*TB
      DBT(JJ,L)=DBT(J2,L)*TA+DBT(J1,L)*TB
      WBT(JJ,L)=WBT(J2,L)*TA+WBT(J1,L)*TB
      APR(JJ,L)=APR(J2,L)*TA+APR(J1,L)*TB
```



```
  130 WIND(JJ,L)=WIND(J2,L)*TA+WIND(J1,L)*TB
      IF (J2.EQ.25) GO TO 150
  140 J1=J2
  150 CONTINUE
C
      SHERD=15.*IFIX(XLON(L)/15.0)
      DELTS=EPS*(SHERD-XLON(L))/15.0
C....                          COMPUTE DECLINATION,SUNUP, SUNSET, AND
C                              CONSTANTS USED IN RADIATION COMPUTATION
C
      DECL=0.4092*COS(0.01721*(172.0-DAY))
      TA=TAN(XLAT(L)*DTOR)*TAN(DECL)
C*****
      HSR=12.0*ACOS(-TA)/PI
C*****
      SUNUP=12.0-HSR+DELTS
      SUNSET=12.0+HSR+DELTS
      T1=SIN(DECL)*SIN(XLAT(L)*DTOR)
      T2=COS(DECL)*COS(XLAT(L)*DTOR)
C
C....                          RADIATION AT GIVEN INTERVALS THROUGHOUT A D
C
C....                          COMPUTE LONGWAVE ATMOSPHER, RADIATION
C
      DO 180 NN=1,24
      TA=1.21E-16*(1.0+0.17*CLOUD(NN,L)**2)
      UNA(NN,L)=TA*(DBT(NN,L)+273.0)**6
C
C....                          SHORTWAVE SOLAR RADIATION
C
      GNS(NN,L)=0.0
      TIME=NN-1
      IF (TIME.LE.SUNUP.OR.TIME.GE.SUNSET) GO TO 170
      CLD=CLOUD(NN,L)
      HA=PI*(TIME-12.0-DELTS)/12.0
      SINA=T1+T2*COS(HA)
      RAD=WIND*SINA
      A1=0.128-0.054*ALOG10(1.0/ABS(SINA))
      TA=TURB(L)*A1/SINA
      RAD=RAD/EXP(TA)
      RAD=RAD*(1.0-.65*CLD**2)
      NC=2.0*(CLD+1.0)
      IF (CLD.GT.0.05.AND.CLD.LT.0.95) GO TO 160
      NC=1
      IF (CLD.GT.0.95) NC=4
C*****
  160 ALBEDO=A(NC)*(57.3*ASIN(SINA))**B(NC)
C*****
      GNS(NN,L)=RAD*(1.-ALBEDO)
      IF (GNS(NN,L).LT.0.) GNS(NN,L)=0.
  170 CONTINUE
  180 CONTINUE
C
      TA=0.
      DO 190 JJ=1,24
      EA(JJ,L)=2.1718E-8*EXP(-4157.0/(WBT(JJ,L)+239.09))
      IF (DEW.GT.0.01) EA(JJ,L)=EA(JJ,L)-APR(JJ,L)*(DBT(JJ,L)-WBT(JJ,L))
```

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```
     1*(6.6E-4+7.59E-7*WBT(JJ,L))
      TA=TA+WIND(JJ,L)
  190 CONTINUE
      TA=TA/24.
      J1=JWZONE(L,1)
      J2=JWZONE(L,2)
      DO 200 J=J1,J2
  200 WINDA(J)=TA
      RETURN
  210 CONTINUE
      DO 280 L=1,NWZONE
      IPAGE=IPAGE+1
      WRITE (6,220) TITLE,TITL
  220 FORMAT (1H1,10X,20A4,'      TETRA TECH, INC.'/,11X,20A4,'      LAFAY
     1ETTE, CALIF.'/)
      WRITE (6,230) L,(JWZONE(L,J),J=1,2),XLAT(L),XLON(L)
  230 FORMAT (///,20X,44HTABLE OF METEOROLOGIC DATA FOR WEATHER ZONE ,I2
     1,10H, JUNCTION,I4,3H TO,I4/,T99,12HLATITUDE =  ,F5.1/,T99,12HLONGI
     2TUDE = ,F5.1//,120H       HOUR            WIND      CLOUD     DRY BULB
     3       ****       ATMOSPHERIC  SHORT WAVE       LONG WAVE        VAPOR
     4       /120H                        SPEED      COVER  TEMPERATURE  TEMPE
     5RATURE      PRESSURE       SOLAR                SOLAR        PRESSURE
     6/120H                      (M/SEC)   FRACTION     (C)            (C)
     7       (MB)    (KCAL/M2/SEC)    (KCAL/M2/SEC)      (MB)         /)
      DO 240 I=1,24
      WRITE (6,270) I,WIND(I,L),CLOUD(I,L),DBT(I,L),WBT(I,L),APR(I,L),QN
     1S(I,L),QNA(I,L),EA(I,L)
  240 CONTINUE
      IF (DEW.LE..01) WRITE (6,250)
  250 FORMAT ('0**** DEW POINT')
      IF (DEW.GT..01) WRITE (6,260)
  260 FORMAT ('0**** WET BULB')
  270 FORMAT (I10,F13.1,F10.2,F10.1,F13.1,F16.0,F12.4,F16.4,F12.0)
  280 CONTINUE
      RETURN
C                                  COMPUTE HEAT TRANSFER PARAMETERS...
  290 CONTINUE
      DO 310 L=1,NWZONE
      J1=JWZONE(L,1)
      J2=JWZONE(L,2)
      DO 310 J=J1,J2
      EV(J)=0.0
      FONE(J)=0.0
      FTWO(J)=0.0
      IF (TW(J).LE.0.0) GO TO 310
      DO 300 I=1,24
      PF=6.1E-4*APR(I,L)
      NN=TW(J)/5.0+1.0
      IF (NN.GT.8) NN=8
      IF (NN.LT.1) NN=1
C
C**   LONGWAVE BACK RADIATION
      ROL=RO(TW(J))*(597.0-0.57*TW(J))*(AA+BB*WIND(I,L))
      F=0.00693*ROL*(ALPH(NN)-EA(I,L)-PF*DBT(I,L))
      FONE(J)=QNS(I,L)+QNA(I,L)-F*FONE(J)
      FTWO(J)=ROL*(BETA(NN)+PF)+0.001471*FTWO(J)
      FS=ALPH(NN)+BETA(NN)*TW(J)
```



```
      EV(J)=(WIND(I,L)*CB+AA)*(ES-EA(I,L))+EV(J)
  300 CONTINUE
  310 CONTINUE
      DO 320 J=1,NJ
      FONE(J)=FONE(J)/24.
      FTWO(J)=FTWO(J)/24.
      IF (EV(J).LT.0.0) EV(J)=0.0
  320 EV(J)=EV(J)/24.
      RETURN
C
      END
```

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```
      SUBROUTINE OUTPUT (JSKIP)
C
      COMMON/LAB/XLAB(11),YLAB(6),TITLE(12),HORIZ(13),VERT(6),IUNITO
      COMMON/PLOT/ IPLOT(8),CP(101,6,4),DAY(101),NPOINT,JPLOT(6)
     1,     IPP,NPP,IPDAY(3),NODEP(21,2),PROFA(21,3,4),NCONP(4)
     2,     PROFB(21,3,4)
      COMMON/MISC/NJ,NC,NP,NDYN,NBNO,MLIM,DELT,IPAGE,NHYD,IDAY,IDELT
     1,     NJP,ILF,KPLOT,ISKIP(16),ALL(20),IDYN(52),TITL1(20),TITL(20)
     2,     NGPLPH(52),IPCYC,LDAY,NCYCH,INQUAL
      COMMON/DIG/NCHAN(200,8),FILL(18800)
      COMMON/QUAL/ JUNIN(200),JUNGIN(200),JUNA(200),DIN(200),UGIN(200)
     1,     TDSIN(150),TOTNIN(150),TOTPIN(150),COLTIN(150),COLFIN(150)
     2,     BODCIN(150),BODNIN(150),OXYIN(150),TEMPIN(150)
     3,     TYPEIN(150,4),SALTIN(150)
     4,     TDS(200),TOTN(200),TOTP(200),COLT(200),COLF(200),BODC(200)
     5,     BODN(200),OXY(200),TEMP(200),TYPE(200,4),TYPEDX(200,4)
     6,     SALG(200),QUEN(200),QBOD(200),BODCDX(200),BODNDX(200)
     7,     COLTDX(200),COLFDX(200),QSAT(200),QENN(200),QEMP(200)
      COMMON/XAXF/XAPIS
      DIMENSION X(103,3),Y(103,3),NPT(3),CON(200,1)
      DOUBLE PRECISION UNITS
      DIMENSION UNITS(13)
      DIMENSION TITLE(12,2),HORIZ(13,2),VERT(6)
      EQUIVALENCE (CON(1,1),TDS(1))
      REAL NAME(3,13)
      DATA NAME/4HTJ3 ,2*4H    ,4HTOTA,4HL N ,4H    ,4HTOTA,4HL P
     1,     4H    ,4HTOTA,4HL CO,4HLIF ,4HFECA,4HL CO,4HLIF ,4HCARB
     2,     4HON B,4H,D  ,4HNITR,4HO BO,4HD   ,4HOXYG,4HEN  ,4H
     3,     4HTEMP,4HERAT,4HURE ,4HOPP ,4HCONS,4HT 1 ,4HOPP ,4HCONS
     4,     4HT 2 ,4HOPP ,4HCONS,4HT 3 ,4HOPP ,4HCONS,4HT 4  /
      DATA UNITS
     1 /3*8HMG/L   ,2*8HNO/100ML,3*8HMG/L   ,8HDEG C  ,4*8HUNITS  /
      DATA TITLE1/2*4H    ,4HTIME,4H HIS,4HTORY,4*4H    ,4HCONC
     1,     4HENTR,4HATION,4HH PR,4HOFIL,4HE   ,3*4H    /
     2,     HORIZ/7*4H    ,4H DAY,12*4H    ,4HNODE,5*4H    /
     3,     VERT1/4HMG/L,4H,MPN,4HOR C,3*4H    /
C
      IF (JSKIP) 470,360,100
  100 CONTINUE
  110 FORMAT (1H1,10X,20A4,'     TETRA TECH, INC.'//,11X,20A4,'     LAFAY
     1ETTE, CALIF.'//)
  120 FORMAT (50X,'QUALITY RESULTS, DAY',I4,//'   JUN      TDS    TOT N
     1  TOT P    T COL    F COL    C BOD    N BOD      OXY    O SAT
     2TEMP  CONST 1  CONST 2  CONST 3  CONST 4'//,6X,3(5X,'MG/L'),2('NO/
     3100ML'),4(5X,'MG/L'),7X,'C ',4(4X,'UNITS')/)
      IF (ISKIP(16)-1) 130,170,260
  130 II=0
      DO 160 J=1,NJ
      IF (NCHAN(J,1).EQ.0) GO TO 160
      IF (MOD(II,50).NE.0) GO TO 140
      WRITE (6,110) TITL1,TITL
      WRITE (6,120) JSKIP
  140 II=II+1
      WRITE (6,150) J,(CON(J,I),I=1,8),QSAT(J),(CON(J,I),I=9,13)
  150 FORMAT (I6,F9.0,2F9.2,2E9.2,2F9.2,3F9.1,4F9.2)
  160 CONTINUE
      RETURN
```



```
C
C.... ALTERNATIVE PRINTOUT
  170 CONTINUE
      WRITE (6,110) TITL1,TITL
      DO 250 I=1,13
      IF (ISKIP(I).EQ.1) GO TO 250
      WRITE (6,180) (NAME(J,I),J=1,3),UNITS(I),JSKIP
  180 FORMAT (/,50X,3A4,', ',A8,' FOR DAY ',I3/)
      GO TO (190,210,210,230,230,210,210,210,210,210,210,210), I
  190 WRITE (6,200) (J,CON(J,I),J=1,NJ)
  200 FORMAT (10(I5,F8.0))
      GO TO 250
  210 WRITE (6,220) (J,CON(J,I),J=1,NJ)
  220 FORMAT (10(I5,F8.2))
      GO TO 250
  230 WRITE (6,240) (J,CON(J,I),J=1,NJ)
  240 FORMAT (10(I5,E8.2))
  250 CONTINUE
      RETURN
C
  260 CONTINUE
      IC=0
      DO 350 I=1,13
      IF (ISKIP(I).EQ.1) GO TO 350
      IC=IC+1
      IF (MOD(IC,2).EQ.1) WRITE (6,270)
  270 FORMAT (1H1)
      WRITE (6,280) (NAME(J,I),J=1,3),UNITS(I),JSKIP
  280 FORMAT (90X,3A4,', ',A8,' FOR DAY ',I3)
      GO TO (290,310,310,330,330,310,310,310,310,310,310,310,310), I
  290 WRITE (6,300) (J,CON(J,I),J=1,NJ)
  300 FORMAT (5(I7,F9.0))
      GO TO 350
  310 WRITE (6,320) (J,CON(J,I),J=1,NJ)
  320 FORMAT (5(I7,F9.3))
      GO TO 350
  330 WRITE (6,340) (J,CON(J,I),J=1,NJ)
  340 FORMAT (5(I7,E9.2))
  350 CONTINUE
      RETURN
  360 CONTINUE
C
C.... TIME HISTORY PLOTS
C
      DO 370 J=1,3
      DO 370 I=1,103
      X(I,J)=0.0
  370 Y(I,J)=0.0
      II=NPOINT/100+1
      NT=0
      DO 390 I=1,13
  380 HORIZ(I)=HORIZ1(I,1)
      DO 390 I=1,6
  390 TITLE(I)=TITLE(I,1)
      DO 400 I=1,6
  400 VERT(I)=VERT1(I)
      DO 460 I=1,4
```

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```
      IF (IPLOT(I).EQ.0) GO TO 460
      IP=IPLOT(I)
      TITLE(10)=NAME(1,IP)
      TITLE(11)=NAME(2,IP)
      TITLE(12)=NAME(3,IP)
      J=0
      DO 410 JJ=1,NPOINT,II
      J=J+1
      DO 410 K=1,3
      X(J,K)=DAY(JJ)
  410 CONTINUE
C
      NN=(NJP-1)/3+1
      LL=1
      DO 450 MM=1,NN
      NT=NT+1
      L=LL+2
      IF (NJP.GT.L) L=NJP
      K=0
      DO 430 MM=LL,L
      K=K+1
      J=0
      DO 420 KK=1,NPOINT,II
      J=J+1
      Y(J,K)=CP(KK,MM,I)
  420 CONTINUE
      NPT(K)=J
  430 CONTINUE
C  SET NXPTS TO 0 SO X-AXIS INCREMENTS WILL BE PRINTED IN PPLOT
      NXPTS=0
      CALL CURVE (X,Y,NPT,K,NT)
      WRITE (6,440) (JPLOT(LI),LI=LL,L)
  440 FORMAT (1H0,30X,'NODE NUMBERS',I5,4H = 0,I5,4H = 1,I5,4H = 2)
      LL=L+1
  450 CONTINUE
  460 CONTINUE
      RETURN
C
C.... CONCENTRATION PROFILES
C
  470 CONTINUE
      NN=0
      DO 480 I=1,21
      DO 480 J=1,IPP
  480 X(I,J)=I
      DO 490 I=1,13
  490 HORIZ(I)=HORIZ1(I,2)
      DO 500 I=1,9
  500 TITLE(I)=TITLE1(I,2)
      DO 510 I=1,6
  510 VERT(I)=VERT1(I)
      DO 590 II=1,4
      IF (NCURF(II).EQ.0) GO TO 590
      I=NCURF(II)
      TITLE(10)=NAME(1,I)
      TITLE(11)=NAME(2,I)
      TITLE(12)=NAME(3,I)
```



```
      DO 560 I=1,NPP
      NN=NN+1
      DO 550 J=1,IPP
      NPT(J)=21
      IF (I.EQ.2) GO TO 530
      DO 520 K=1,21
  520 Y(K,J)=PROFA(K,J,II)
      GO TO 550
  530 DO 540 K=1,21
  540 Y(K,J)=PPROFB(K,J,II)
  550 CONTINUE
C  SET NXPTS TO 21 SO PRINTING OF X-AXIS INCREMENTS IN PPLOT WILL BE SUP
      NXPTS=21
      CALL CURVE (X,Y,NPT,IPP,NN)
      WRITE (6,560) (NODEP(J,I),J=1,21)
  560 FORMAT (1I5,21I5,/,75X,'NODE')
      WRITE (6,570) (IPDAY(J),J=1,IPP)
  570 FORMAT (30X,'DAY OF THE YEAR',I5,4H = 0,I5,4H = 1,I5,4H = 2)
  580 CONTINUE
  590 CONTINUE
      RETURN
C
      END
```

221-55-2

```
      SUBROUTINE PINE(X1,Y1,X2,Y2,NSYM,NCT)
      COMMON/BIG/ SPACE(15249),A(51,101)
      DIMENSION SYM(3)
      DATA SYM/1H0,1H1,1H2/
      AXA=X1
      AXB=X2
      AYA=Y1
      AYB=Y2
      N=1
      IF(ABS(AXB-AXA).LT.ABS(AYB-AYA)) GO TO 290
C
C     SET PARAMETERS FOR X DIRECTION
C
      IF(AXB.GT.AXA) GO TO 245
      AXA=X2
      AXB=X1
      AYA=Y2
      AYB=Y1
  245 CONTINUE
      IXA=AXA+.5
      IXB=AXB+.5
      IYA=AYA+.5
      IYB=AYB+.5
  250 CONTINUE
      IF(IXA.LT.0.OR.IXA.GT.100) GO TO 260
      IF(IYA.LT.0.OR.IYA.GT.50) GO TO 260
      A(51-IYA,IXA+1)=SYM(NSYM)
  260 CONTINUE
      IXA=IXA+1
      YA=(N*(AYB-AYA))/(AXB-AXA)
      IYA=AYA+YA+0.5
      N=N+1
      IF(IXA.LE.IXB) GO TO 250
      GO TO 800
C
C     SET PARAMETERS FOR Y DIRECTION
C
  290 CONTINUE
      IF(AYB.GT.AYA)   GO TO 295
      AYB=Y1
      AYA=Y2
      AXB=X1
      AXA=X2
  295 CONTINUE
      IXA=AXA+.5
      IXB=AXB+.5
      IYA=AYA+.5
      IYB=AYB+.5
  300 CONTINUE
      IF(IXA.LT.0.OR.IXA.GT.100) GO TO 310
      IF(IYA.LT.0.OR.IYA.GT.50) GO TO 310
      A(51-IYA,IXA+1)=SYM(NSYM)
  310 CONTINUE
      IYA=IYA+1
      YA=(N*(AXB-AXA))/(AYB-AYA)
      IXA=XA+XA+0.5
      N=N+1
```



```
      IF(IYA-IYB) 300,320,400
  320 IXA = IXB
      GO TO 300
  400 RETURN
      END
```

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```
      SUBROUTINE PPLOT(IX,IY,K,NCT)
      DIMENSION SYM(9)
      COMMON/BIG/ SPACE(15289),A(51,101)
      COMMON/XAXE/NXPTS
      COMMON/LAB/XLAB(11),YLAB(6),TITLE(12),HORIZ(13),VERT(6),IUNITO
      DATA SYM/7*1H ,1HI,1H-/
C
      IF(K.EQ.100) GO TO 230
      IUNITO=6
      I=0
      IF (NCT .EQ. -1) GO TO 700
      WRITE(IUNITO,103) (TITLE(IN),IN=1,6),(TITLE(IN),IN=10,12),NCT
700   CONTINUE
C  THE FOLLOWING SECTION (THROUGH CARD 225) PRINTS ALL BUT THE X AXIS AND LABELS
      DO 225 II=1,6
      I=I+1
      WRITE (IUNITO,101) YLAB(II),(A(I,J),J=1,101)
      IF(II.EQ.6) GO TO 226
      DO 224 JJ=1,9
      I=I+1
      IF(I.NE.24) GO TO 221
      WRITE(IUNITO,106) VERT(5),VERT(6),(A(I,J),J=1,101)
      GO TO 224
  221 IF(I.NE.24) GO TO 222
C  PRINT Y-AXIS UNITS
      WRITE(IUNITO,106) VERT(1),VERT(2),(A(I,J),J=1,101)
      GO TO 224
  222 IF(I.NE.26) GO TO 223
      WRITE(IUNITO,106) VERT(3),VERT(4),(A(I,J),J=1,101)
      GO TO 224
  223 WRITE(IUNITO,100) (A(I,J),J=1,101)
  224 CONTINUE
  225 CONTINUE
C
  226 CONTINUE
C  NXPTS IS A FLAG FOR CONCENTRATION PROFILE PLOTS, SET TO 21 IN OUTPUT
C  IF NXPTS IS 21, DO NOT PRINT X-AXIS INCREMENTS OR UNITS
      IF(NXPTS.EQ.21) GO TO 229
C  PRINT THE X-AXIS UNITS FOR TIME HISTORY PLOTS
      WRITE(IUNITO,102) XLAB
      WRITE (IUNITO,105) HORIZ
  100 FORMAT(10X,101A1)
  101 FORMAT(1PE12.2,1X,101A1)
  102 FORMAT(F20.1,10F10.1)
  103 FORMAT(1H1,42X,9A4,'PLOT NO.',I3,/)
  105 FORMAT(40X,13A4)
  106 FORMAT(7X,2A4,3X,101A1)
  229 CONTINUE
      RETURN
C  THIS SECTION PREPARES PLOT OUTLINE
  230 DO 250 I=1,50
      DO 240 J=1,101
  240 A(I,J)=SYM(7)
      A(I,1)=SYM(8)
  250 CONTINUE
      DO 260 J=1,101
  260 A(51,J)=SYM(9)
      DO 270 I=1,101,10
  270 A(51,I)=SYM(8)
      DO 290 I=11,41,10
      A(I,1)=SYM(9)
  290 CONTINUE
      RETURN
      END
```

PPLOT

87-53-2

S C A L E

```
      SUBROUTINE SCALE (ARRAY,AXLEN,NPTS,INC)
      COMMON/XAXE/NXPTS
      DIMENSION ARRAY(1),INT(5)
      DATA INT /2,4,5,6,10/
      INCY=IABS(INC)
C
C                                     SCAN FOR MAX AND MIN
C
      AMAX=ARRAY(1)
      AMIN=ARRAY(1)
      DO 250 N=1,NPTS,INCY
      IF(AMAX.LT.ARRAY(N)) AMAX=ARRAY(N)
      IF(AMIN.GT.ARRAY(N)) AMIN=ARRAY(N)
  250 CONTINUE
      IF( AMAX - AMIN ) 275,255,275
C
C                                     RESET MAX AND MIN FOR ZERO RANGE
C
  255 IF( AMIN ) 265, 260, 260
  260 AMIN = 0.0
      AMAX = 2.0 * AMAX
      GO TO 275
  265 AMAX = 0.0
      AMIN = 2.0 * AMIN
  275 CONTINUE
C
C                                     COMPUTE UNITS/INCH
C
      RATE=(AMAX-AMIN)/AXLEN
C
C                                           SCALE INTERVAL TO
C                                           LESS THAN 10
      A=ALOG10(RATE)
      N=A
      IF(A.LT.0) N=A-0.9999
      RATE=RATE/(10.**N)
      L=RATE+1.00
C
C                                     FIND NEXT HIGHER INTERVAL
C
  280 DO 300 I=1,5
      IF(L-INT(I)) 320,320,300
  300 CONTINUE
C
C                                     L IS NEXT HIGHER INTERVAL
C                                     RANGE IS SCALED BACK TO FULL SET
C
  320 L=INT(I)
      RANGE=FLOAT(L)*10.**N
      IF(INC.LT.0) GO TO 350
C
C                                     SET UP POSITIVE STEPS
C
      K=AMIN/RANGE
      IF(AMIN.LT.0.) K=K-1
C
C                                     CHECK FOR MAX VALUE IN RANGE
```

S C A L E

```
C
      IF(AMAX.GT.(K+AXLEN)*RANGE) GO TO 330
      I=NPTS*INCY+1
      ARRAY(I)=K*RANGE
      I=I+INCY
      ARRAY(I)=RANGE
      RETURN
C
C                                     IF OUTSIDE RANGE RESET L AND N
C
  330 L=L+1
      IF(L.LT.11) GO TO 280
      L=2
      N=N+1
  340 GO TO 280
C
C                                     SET UP NEGATIVE STEPS
C
  350 K=AMAX/RANGE
      IF(AMAX.GT.0.) K=K+1
      IF(AMIN.LT.(K+AXLEN)*RANGE) GO TO 330
      I=INCY*NPTS+1
      ARRAY(I)=K*RANGE
      I=I+INCY
      ARRAY(I)=-RANGE
      RETURN
  400 WRITE(6,100)
  100 FORMAT( // 10X, 'RANGE AND SCALE ARE ZERO ON PLOT ATTEMPT' )
      RETURN
      END
```

321-53-2

```
      SUBROUTINE SETUP
      COMMON/QUAL/ ISPACE(600),QIN(200),FILL(7700)
      COMMON/MISC/NJ,NC,NP,NDYN,NUMD,MLIM,DELT,IPACE,NHYD,IDAY,IDELT
     ,,     NJP,IEE,KPLOT,ISKIP(10),ALL(20),IDYN(52),TITLE(20),TITL(20)
     ,,     NOPERH(52),IPSYS,LDAY,NCYCH,INDUAL
      COMMON/NIG/ NCHAN(200,8),NJUNC(300,2),JUN(200),XLEN(300)
     ,,     ALPH(200),ALPH1(200),AA(200),BB(200),DELTA(200)
     ,,     ASAVE(200,21),A(200,21),ALPHA(200,21),AC(300),AS(200)
     ,,     DIF(300),Q(300),VS(300) ,QOU(200),ZZ(300)  ,VOL(200),Z(300)
     ,,     CC1(300),CC4(300),DEP(200),HAVE(300),RS(300),VARS(300)
C
C.... INITIALIZE COEFFICIENT MATRIX TO ZERO
      NONBND=1
      DO 160 J=1,NP
      DO 160 K=1,MLIM
  160 ASAVE(J,K)=0.0
C
      DO 1000 J=1,NP
      JJ=JUN(J)
      IF(NDYN.EQ.1) GO TO 166
      ALPH(J)=0.5
C
C.... COMPENSATE FOR HIGH TRIBUTARY INFLOWS
      TA=VOL(JJ)/DELT-QIN(JJ)
      IF(TA.LT.0.0) ALPH(J)=VOL(JJ)/(2.0*DELT*QIN(JJ))
      ALPH1(J)=1.0-ALPH(J)
  166 CONTINUE
      ASAVE(J,M)=QOU(JJ)
C
C.... ADD ADVECTION AND DIFFUSION TO COEFFICIENT MATRIX
      DO 250 K=1,8
      NDIR=0
      N=NCHAN(JJ,K)
      IF(N.EQ.0) GO TO 250
      IF(J.EQ.NJUNC(N,1)) GO TO 200
      JUPP=NJUNC(N,1)
      IF (Q(N).LE.0.0) NDIR=1
      GO TO 220
  200 CONTINUE
      JUPP=NJUNC(N,2)
      IF (Q(N).GT.0.0) NDIR=1
  220 CONTINUE
      JDIF=J-JUPP
      MMM=JDIF
      IF(NDIR.EQ.1) GO TO 230
      ASAVE(J,M)=ASAVE(J,M)+DIF(N)
      ASAVE(J,MM)=ASAVE(J,MM)-ABS(Q(N))-DIF(N)
      GO TO 250
  230 ASAVE(J,M)=ASAVE(J,M)+ABS(Q(N))+DIF(N)
      ASAVE(J,MM)=ASAVE(J,MM)-DIF(N)
  250 CONTINUE
C
C.... ADD VOLUME EFFECTS AND APPLY ALPH AND ALPH1 FACTORS FOR DYNAMIC
      IF(NDYN.EQ.1) GO TO 1000
      DO 260 I=1,MLIM
      A(J,I)=ASAVE(J,I)*ALPH(J)
  260 ASAVE(J,I)=ASAVE(J,I)*ALPH1(J)
```



```
      A(J,M)=A(J,M)+VOL(JJ)/DELT
      ASAVE(J,M)=ASAVE(J,M)+VOL(JJ)/DELT
 1000 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE SOLVIT(CON)
      COMMON/MISC/NJ,NC,NEQ,NOYN,NBND,MLIM,DELT,IPAGE,NHYD,IDAY,IDELT
     ,,     NJP,IEE,KPLOT,ISKIP(16),ALL(20),IDYN(52),TITLE(20),TITL(20)
     ,,     NOPERH(52),IPCYC,LDAY,NCYCH,INOVAL
      COMMON/BIG/ NCHAN(200,8),NJUNC(300,2),JUN(200),XLEN(300)
     ,,     ALPH(200),ALPH1(200),AA(200),BB(200),BETA(200)
     ,,     ASAVE(200,21),A(200,21),ALPHA(200,21),AC(300),AB(200)
     ,,     DIF(300),D(300),VS(300) ,QOU(200),ZZ(300)  ,VOL(200),Z(300)
     ,,     CC1(300),CC2(300),DEP(200),RAVE(300),HS(300),VARS(300)
      DIMENSION CON(1)
C
C**** FORWARD ELIMINATION
      JMIN = NBND + 1
      JMAX = JMIN + NBND
      NEQ=NEQ-1
      DO 260 I=1,NEQ
C
C**   NORMALIZE COEFFICIENTS
      TA=ALPHA(I,JMIN)
      DO 200 J=JMIN,JMAX
      ALPHA(I,J)=ALPHA(I,J)/TA
  200 CONTINUE
      BETA(I)=BETA(I)/TA
C
C**   SET-UP BOUNDS FOR ELIMINATION
      KMIN = I + 1
      KMAX = I + NBND
      IF (KMAX.GT.NEQ) KMAX=NEQ
      JK=NBND+1
      DO 250 K=KMIN,KMAX
      JK=JK-1
      IF(ALPHA(K,JK)) 210,250,210
  210 CONTINUE
C
C**   ELIMINATE VARIABLE I FROM EQUATION K
      J=NBND+1
      JJMIN=JK+1
      JJMAX = JK + NBND
      DO 240 JJ=JJMIN,JJMAX
      J=J+1
      ALPHA(K,JJ)=ALPHA(K,JJ)-ALPHA(I,J)*ALPHA(K,JK)
  240 CONTINUE
      BETA(K)=BETA(K)-BETA(I)*ALPHA(K,JK)
  250 CONTINUE
  260 CONTINUE
C
C***% BACK SUBSTITUTION
      NN=0
      BETA(NEQ)=BETA(NEQ)/ALPHA(NEQ,JMIN)
      DO 400 II=2,NEQ
      I= NEQ + 1 - II
      NN=NN+1
      IF(NN.GT.NBND) NN=NBND
      K=I
      J=NBND+1
      DO 400 JJ=1,NN
      J=J+1
      K=K+1
      BETA(I)=BETA(I)-ALPHA(I,J)*BETA(K)
  400 CONTINUE
  480 CONTINUE
C
C.... ASSIGN CONCENTRATIONS BY EXTERNAL NODE NUMBERS
      DO 510 J=1,NEQ
      JJ=JUN(J)
      CON(JJ)=BETA(J)
  510 CONTINUE
      RETURN
      END
```

SOLVIT

2-35-171

EXHIBIT E

2. Water Use and Quality

Comment 36 (p. E-2-112, para. 2)

Estimate the probability and magnitude of supersaturated water passing through Watana and Devil Canyon reservoirs. Include specific estimates for water entering Watana reservoir, the likelihood of supersaturated conditions persisting through the reservoirs to the intake structures, any differences between saturation values of water entering outlet facilities and the turbine intakes, potential for air entrainment at both outlet facilities and the turbine intakes, and a description of the processes affecting supersaturation at the turbine outlet facilities.

Response

At present, no information is available on the level of gas saturation levels in waters entering the upstream end of the proposed Watana Reservoir. Therefore, no definitive statement about the probability and magnitude of such an occurrence can be made. It is assumed, however, that no supersaturation problem will exist in Watana Reservoir because of 1) the low potential for any sources of saturation above the proposed Watana Reservoir due to the low gradient of the river and lack of major turbulent areas, 2) the long residence time of water passing through the reservoir, 3) wind- induced mixing, and; 4) contributions of additional water from tributaries.

Intake facilities at both dams will be designed to prevent entrainment of air because such entrainment can lower the efficiency of the turbine and cause structural problems. The outlet facilities will have a subsurface discharge that will not entrain air and therefore will not increase saturation.

Cone valves will be provided in both dams to pass any discharges up to the 1 in 50 year flood. These structures are specifically designed to prevent supersaturation. Any discharges above the 1 in 50 flood will be passed over the spillway at each dam. These spillways will be designed to avoid or minimize any supersaturation problems. The final design of the spillways will follow the testing of a physical model before final design of the project is completed.

Water leaving Devil Canyon could be supersaturated even if no supersaturation were added by either dam. This is because supersaturation naturally occurs due to turbulent mixing at the rapids in Devil Canyon below the Devil Canyon damsite. This naturally occurring supersaturation would be generally lessened under the operation of either dam. The reason for this is that, under natural conditions, there is a positive correlation between increases in flows and increases in supersaturation values (see attached Figure 4I-3-45 from ADF&G 1983). This is probably related to the increase in turbulence and entrainment of air associated with increased flows. Under operation, the incidence of these higher flows will be diminished as would the corresponding supersaturation levels.

References

Alaska Dept. of Fish and Game. 1983. Susitna hydro aquatic studies phase II basic data report. Vol. 4. Aquatic Habitat and instream flow studies, 1982.

153

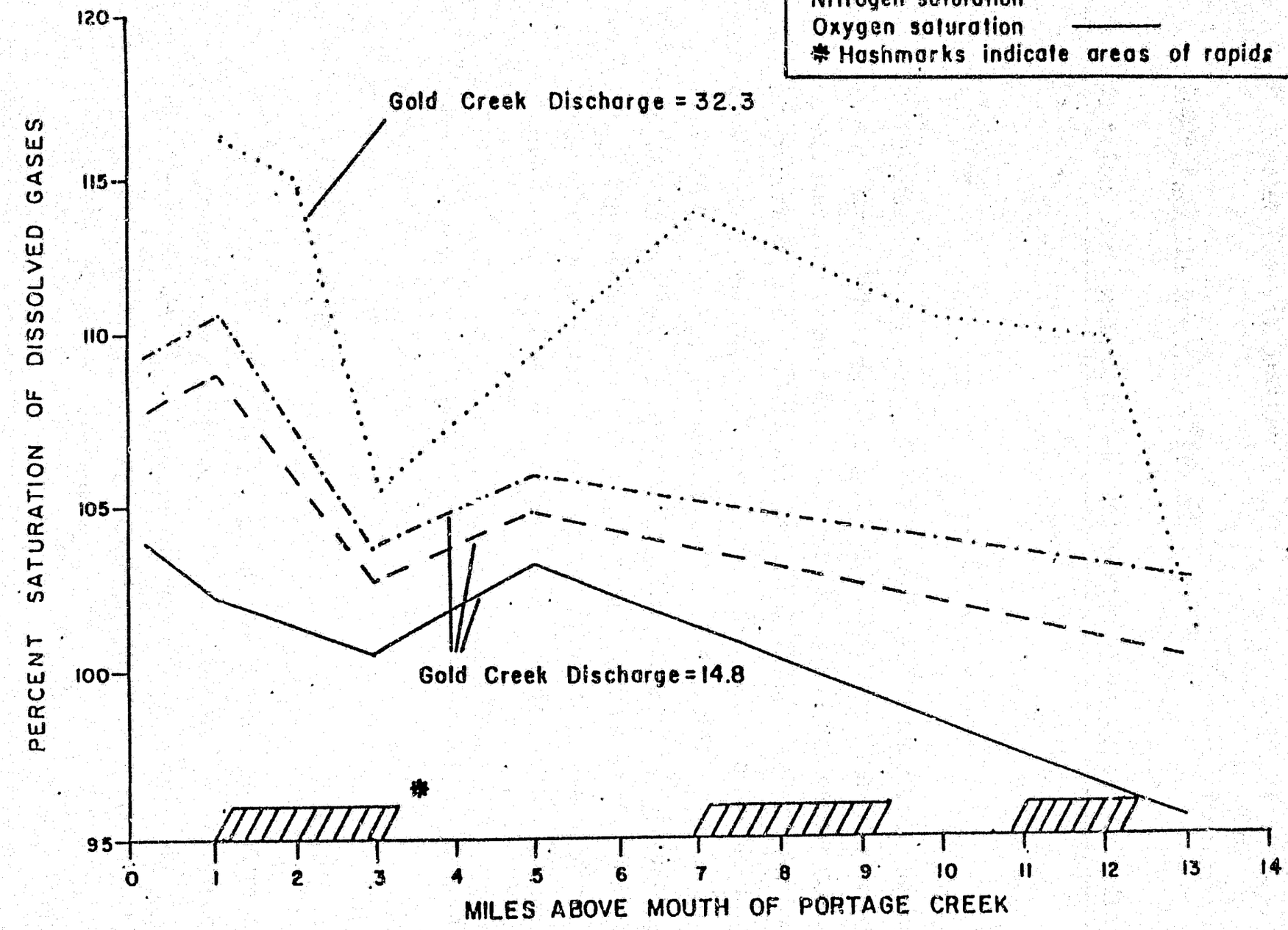

Figure 4I-3-45. Concentration of dissolved gases in the Devil Canyon rapids complex.

2-36-3

2. Water Use and Quality

Comment 38 (p. E-2-117, para. 2)

Describe the uncertainties associated with data collected during this period.

Response

Differences in the measured and simulated temperatures in the Eklutna Lake study (Acres American 1983, R&M 1982) may have resulted from uncertainties associated with the data collection and lake temperature measurements. Breakdowns of the instruments at the Eklutna Lake station resulted in data gaps in July and August. The missing data which occurred in periods of July 5-14, 16-21, 24-31, and August 1-11, 13-27, 1982, had to be estimated from the nearby stations (Figure 1) located at Palmer (Matanuska Valley Agricultural Experiment Station), Anchorage International Airport, and Chugach State Park Eagle River Visitor Center (Paradise Haven Lodge). Estimation of these missing data are the major sources of the data uncertainties.

The uncertainties associated with the estimation of the missing data are described below:

1. Air Temperature:

   The missing air temperatures at the Eklutna Lake station were estimated from the nearby stations, Chugach State Park Eagle River Visitor Center (11.4 miles southwest of lake, 630 ft. above mean sea level) and Eklutna River Hydro Power Station (10.8 miles north-norhtwest of lake, 38 ft. above mean sea level).

2. Wind Speed and Direction:

The missing wind speed and direction at Eklutna Lake were estimated from the station at Palmer.

3. Vapor Pressure:

The vapor pressures were converted from the relative humidity data. This was done by utilizing an empirical function of temperature to compute saturation vapor pressure at the average daily air temperature, which in turn was multiplied by average daily relative humidity. The missing relative humidity data for the periods were estimated from wind direction at the Eklutna Lake station.

4. Solar Radiation:

The missing data at the Eklutna Lake station for these periods were estimated from the Palmer and the Anchorage stations.

5. Cloud Cover and Long-Wave Radiation:

Due to various problems with power and connections to the instruments at the Eklutna Lake station, the cloud cover data obtained from the Anchorage station were used to estimate the long wave radiations.

6. Precipitation:

During the aforementioned periods, the precipitation at the Eklutna Lake station were estimated from the Chugach State Park Eagle River Visitor Center Station. From October through December the rain gauge experienced icing problems, therefore, the data from the Eagle River Visitor Center station were used.

7. Measured Temperature Profiles:

Error in measuring temperature profiles could occur from instrument's calibration being disturbed during relocation or operator error in reading the analog readout or instability in the temperature digital readout. In some cases during active convection, the instability in temperature would occur longer duration.

References

Acres American Incorporated, "Susitna Hydroelectric Project, Feasibility Study - Supplement, Chapter 8: Reservoir and River Temperature Studies," prepared for Alaska Power Authority, 1983.

R&M Consultants Incorporated, "Susitna Hydroelectric Project, Glacial Lake Studies," prepared for Acres and Alaska Power Authority, 1982.

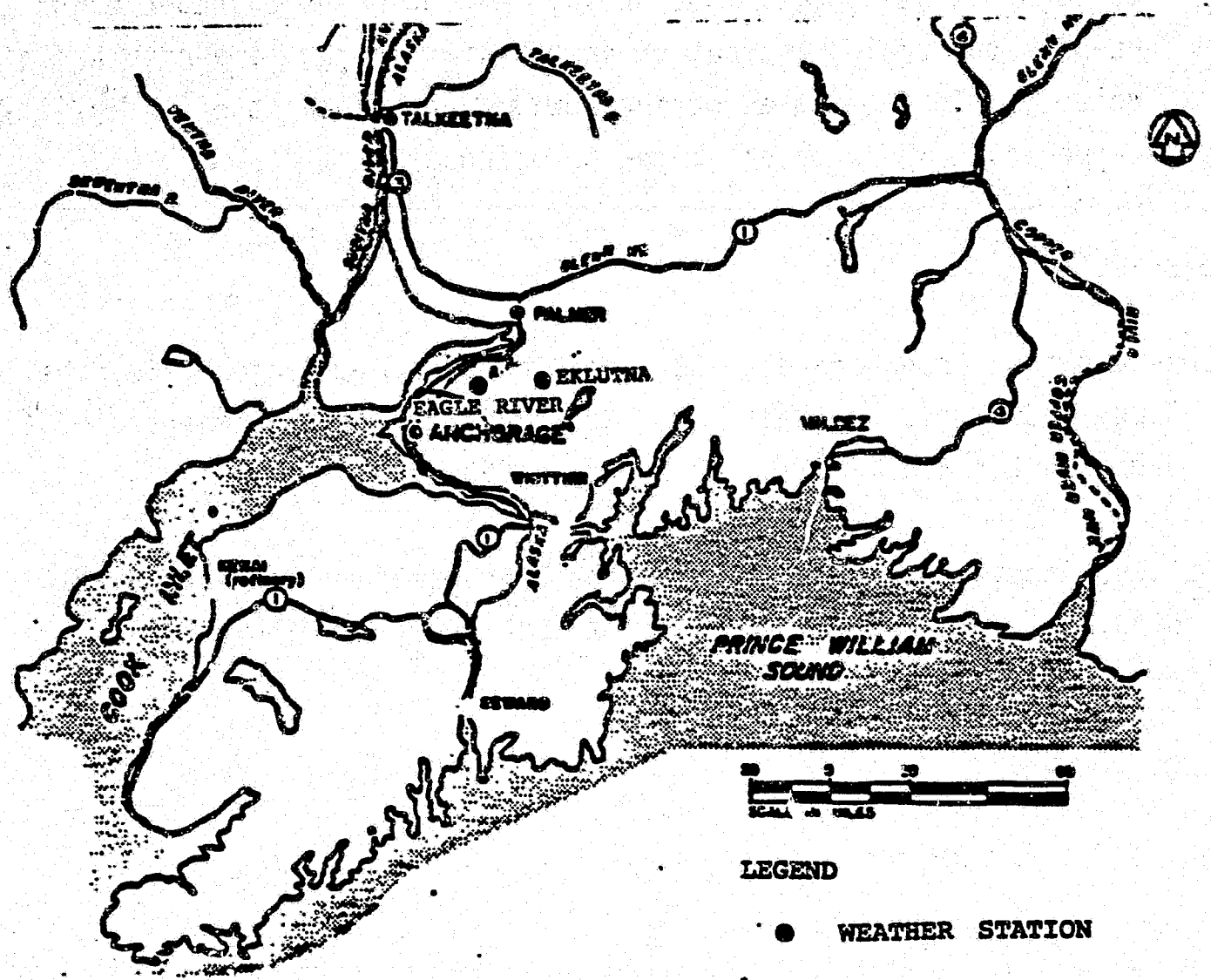

Figure 1 Approximate Location of Weather Station

2. Water Use and Quality

Comment 44 (p. E-2-132, para. 2)

Provide list of all discharges where cone valves will be used and a list of discharges where cone valves will not be used for Watana and for Devil Canyon.

Response

The use of the fixed cone valves depends on four parameters: reservoir inflow, reservoir water level, energy demand, and downstream flow requirements, if those flow requirements are greater than the flow necessary to satisfy the energy demand. Thus, there is not a one-to-one correspondence between the Watana or Devil Canyon discharge and the operation of the cone valves. For a given discharge, both use and non-use of the cone valves is possible. For example, the cone valves are used when the reservoir is full (i.e. at elevation 2,185 feet) and inflow is greater than the powerhouse flow. However, with the same inflow, if the reservoir elevation is less than the normal maximum operating level of 2,185 feet, the cone valves will likely not be operated. Flow above the powerhouse requirements will be used to fill the resevoir. There may however, be times when the reservoir is not full when the fixed cone valves will have to be operated to augment the powerhouse flows to provide the required downstream flow.

Tables 1 through 4 (attached) provide a list of Watana and Devil Canyon discharges where cone valves will and will not be used for four different energy demands. The tables are based on weekly energy simulations for a 32-year period. The discharges presented are mean weekly discharges. The number of weeks with or without cone valve operation represent the total number of weeks out of the 1664 weeks in the simulation that the valves do or do not operate for the given discharge interval. The number of weeks provides a relative indication of frequency of use.

As is evident from the enclosed tables, for weekly average discharges up to 16,000 cfs for Watana and up to 14,000 cfs for Devil Canyon, there are times when cone valves will and will not be operating. At higher discharges the cone valves will always operate.

It was necessary to present this information as a set of four tables because there will be a different operating scenario for each energy demand and the operation of the cone valves will be different for each demand.

TABLE 1
OPERATION OF WATANA CONE VALVES
TOTAL ENERGY DEMAND 4,922,000 MWH

WATANA DISCHARGE (cfs)	NO. OF WEEKS OF CONE VALVE OPERATION[1]	CORRESPONDING COMBINATIONS OF POWERHOUSE & CONE VALVE DISCHARGE AT FLOWS 13,000 cfs		NO. OF WEEKS WITHOUT CONE VALVE OPERATION[1]
		POWERHOUSE (cfs)	CONE VALVE (cfs)	
0- 3,800	0			0
3,800- 8,000	0			)
8,000- 9,000	3			)
9,000-10,000	40			) 1,386
10,000-11,000	35			)
11,000-12,000	2			)
12,000-13,000	6			102
13,000-14,000	3	1) 9,066	4,388	36
		2) 9,781	3,672	
		3) 8,901	4,907	
14,000-15,000	4	1) 8,887	6,009	37
		2) 9,090	4,926	
		3) 9,245	5,182	
		4) 9,076	5,597	
15,000-16,000	2	1) 8,713	6,652	
		2) 9,066	6,058	
16,000-17,000	1	1) 8,887	7,546	
17,000-18,000	1	1) 8,887	8,447	
18,000-19,000	2	1) 9,245	9,615	
		2) 9,424	8,955	
19,000-20,000	1	1) 9,066	10,755	
20,000-24,000	1	1) 8,887	12,111	
24,000-28,000	1	1) 9,066	15,380	
28,000-32,000	1	1) 8,710	21,526	
TOTAL	103[2]			1561

(1) The number of weeks is based on a total of 1664 weeks in the 32 year simulation period.

(2) The fixed cone valves will operate 6.2 percent of the time.

TABLE 2

OPERATION OF WATANA CONE VALVES

TOTAL ENERGY DEMAND 5,469,000 MWH

WATANA DISCHARGE (cfs)	NO. OF WEEKS OF CONE VALVE OPERATION (1)	CORRESPONDING COMBINATIONS OF POWERHOUSE & CONE VALVE DISCHARGE AT FLOWS 13,000 cfs		NO. OF WEEKS WITHOUT CONE VALVE OPERATION (1)
		POWERHOUSE (cfs	CONE VALVE (cfs)	
0- 3,800	0			0
3,800-10,000	0			
10,000-11,000	9			1454
11,000-12,000	2			
12,000-13,000	7			118
13,000-14,000	2	1) 9,879	3,210	32
		2) 10,869	2,586	
14,000-15,000	1	1) 10,273	4,155	26
15,000-16,000	1	1) 10,073	5,050	5
16,000-17,000				
17,000-18,000	1	1) 9,875	7,460	
18,000-19,000	2	1) 10,273	8,588	
		2) 10,471	7,908	
19,000-20,000	1	1) 10,073	9,748	
20,000-24,000	1	1) 9,875	11,123	
24,000-28,000	2	1) 10,074	14,373	
		2) 9,685	17,943	
TOTAL	29(2)			1635

(1) The number of weeks is based on a total of 1664 weeks in the 32 year simulation period.

(2) The fixed cone valves will operate 1.7 percent of the time.

TABLE 3
OPERATION OF DEVIL CANYON CONE VALVES
TOTAL ENERGY DEMAND 5,853,000 MWH(1)

DEVIL CANYON			WATANA		
DEVIL CANYON DISCHARGE (cfs)	NO. OF WEEKS OF CONE VALVE OPERATION(2)	NO. OF WEEKS WITHOUT CONE VALVE OPERATION	WATANA DISCHARGE (cfs)	NO. OF WEEKS WITH CONE VALVE OPERATION(7)	NO. OF WEEKS WITHOUT CONE VALVE OPERATION
0- 4,500	0	0	0- 2,000	0	0
4,500-12,000	0	1,496	2,000- 8,000	93	
12,000-13,000	1	11	8,000- 9,000	15	1331
13,000-14,000	5	6	9,000-10,000	22	
14,000-15,000	13		10,000-11,000	18	1
15,000-16,000	11		11,000-12,000	16	
16,000-17,000	10		12,000-13,000	21	
17,000-18,000	12		13,000-14,000	7	
18,000-19,000	14		14,000-15,000	14	
19,000-20,000	17		15,000-16,000	15	
20,000-24,000	34		16,000-17,000	19	
24,000-28,000	15		17,000-18,000	18	
28,000-32,000	9		18,000-19,000	17	
32,000-36,000	6(3)		19,000-20,000	12	
36,000-40,000	3(4)		20,000-24,000	24	
40,000-44,000	1(5)		24,000-28,000	9	
			28,000-32,000	8	
			32,000-36,000	3	
			36,000-40,000	1	
TOTAL	151(6)	1513		332	1332

(1) The number of weeks is based on a total of 1664 weeks in the 32 year simulation period.
(2) With few exceptions, when the Devil Canyon cone valves are operating, the Devil Canyon powerhouse discharge varies between 12,000 cfs and 13,000 cfs.
(3) During 5 of the 6 weeks of operation, the powerhouse flow is approximately 4000 cfs
(4) In each of the 3 weeks of operation, the Devil Canyon powerhouse flow is as follows: 0, 0, and 2400 cfs.
(5) Capacity of the Devil Canyon cone valves is exceeded and spillway is opened to pass 5344 cfs. Powerhouse flow is 0 cfs.
(6) The Devil Canyon and Watana fixed cone valves will operate 9.1 and 20.0 percent of the time, respectively.
(7) Maximum Watana cone valve discharge is 24,000 cfs. Above Watana discharges of 24,000 cfs, flow in excess of 24,000 cfs will be used to generate power up to the energy demand. This supercedes the priority use of the Devil Canyon powerhouse.

TABLE 4
OPERATION OF DEVIL CANYON CONE VALVES
TOTAL ENERGY DEMAND 7,791,000 MWH

DEVIL CANYON			WATANA		
DEVIL CANYON DISCHARGE (cfs)	NO. OF WEEKS OF CONE VALVE OPERATION[1][2]	NO. OF WEEKS WITHOUT CONE VALVE OPERATION	WATANA DISCHARGE (cfs)	NO. OF WEEKS WITH CONE VALVE OPERATION[1]	NO. OF WEEKS WITHOUT CONE VALVE OPERATION[1]
0- 4,200		0	0- 8,000	19	
4,200-12,000		1,524	8,000- 9,000	16	
12,000-13,000	0	99	9,000-10,000	26	1428
13,000-14,000	1	3	10,000-11,000	23	
14,000-15,000	6	0	11,000-12,000	12	
15,000-16,000	3		12,000-13,000	14	73
16,000-17,000	5		13,000-14,000	4	0
17,000-18,000	1		14,000-15,000	6	9
18,000-19,000	5		15,000-16,000	8	
19,000-20,000	3		16,000-17,000	5	
20,000-24,000	8		17,000-18,000	3	
24,000-28,000	3[3]		18,000-19,000	4	
28,000-32,000	2[4]		19,000-20,000	4	
32,000-36,000	1		20,000-24,000	5	
36,000-40,000	0		24,000-28,000	3	
40,000-44,000	0		28,000-32,000	2	
TOTAL	38[5]	1626		154[6]	1510

(1) The number of weeks is based on a total of 1664 weeks in the 32 year simulation period.

(2) The Devil Canyon powerhouse generallyoperates at 13,763 cfs whenever the conevalves are operating. Exceptions are noted below.

(3) Devil Canyon powerhouse flow is 11,401 cfs during one of the two weeks of conevalve operation at this Devil Canyon flow range.

(4) Devil Canyon powerhouse flow is 8,069 cfs.

(5) The Devil Canyon cone valves will operate 2.3 percent of the time.

(6) The Watana cone valves will operate 9.3 percent of the time.

EXHIBIT E

2. Water Use and Quality

Comment 45 (p. E-2-133, para. 3)

Provide data for each fraction of nitrogen and phosphorus used in the calculation of the N:P ratio in Susitna River water.

Response

The mass ratio for N:P of 28:1 listed in the FERC License Application on page E-2-133 was derived from data on concentrations of inorganic nitrogen fractions and inorganic soluble ortho-phosphorus found June 1980 and 1981 in Susitna River water samples (see attached excerpts from R & M 1981 Water Quality Report, Tables 3.1 and 4.1).

SUSITNA HYDROELECTRIC PROJECT

WATER QUALITY
ANNUAL REPORT
1981

PROPERTY OF:
Alaska Power Authority
334 W. 5th Ave.
Anchorage, Alaska 99501

DECEMBER 1981

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PREPARED BY:

R&M CONSULTANTS, INC.

PREPARED FOR:

ALASKA POWER AUTHORITY

2.109

2-45-2

TABLE 3.1

R&M CONSULTANTS, INC.

1980 WATER QUALITY DATA - SUSITNA RIVER

AT VEE CANYON

NOTE: Dash indicates data not available.

	Date Sampled				
	6/19/80	8/8/80	9/5/80	9/17/80	10/17/80
Field Parameters (1)					
Dissolved Oxygen	12.4	----	----	9.7	13.8
Percent Saturation	98	----	----	84	104
pH, pH Units	7.8	7.9	7.8	7.6	7.6
Conductivity, umhos/cm @ 25°C	----	144	171	124	142
Temperature, °C	5.7	9.3	5.3	5.9	-0.1
Free Carbon Dioxide (2)	2.0	1.7	3.6	4.5	5.5
Alkalinity, as $CaCO_3$	47	54	81	63	88
Settleable Solids, ml/l	0.1	<0.1	<0.1	<0.1	<0.1
Discharge c.f.s.	24,800	17,300	5,040	14,200	<5,000
Laboratory Parameters (1)(3)					
Ammonia Nitrogen	0.26	----	0.10	<0.05	0.26
Organic Nitrogen	<0.1	----	0.22	0.62	0.28
Kjeldahl Nitrogen	0.26	----	0.32	0.62	0.54
Nitrate Nitrogen	0.19	0.15	0.15	0.09	<0.10
Nitrite Nitrogen	<0.01	----	<0.01	<0.01	<0.01
Total Nitrogen	0.45	----	0.47	0.71	0.54
Ortho-Phosphate	<0.01	0.03	0.05	<0.05	<0.01
Total Phosphorus	0.05	0.03	0.09	0.10	<0.01
Alkalinity, as $CaCO_3$	----	----	----	----	66
Chemical Oxygen Demand	28	13	----	----	6

TABLE 3.1 - CONTINUED

	Date Sampled				
	6/19/80	8/8/80	9/5/80	9/17/80	10/17/80
Laboratory Parameters (1)(3) (continued)					
Chloride	3	9	11	8	18
Conductivity, umhos/cm @ 25°C	150	----	----	----	190
True Color, Color Units	----	40	10	45	10
Hardness, as $CaCO_3$ (4)	51	76	69	55	90
Sulfate	4	9	9	7	13
Total Dissolved Solids	70	90	114	38	115
Total Suspended Solids	242	310	25	132	8.3
Turbidity, NTU	94	97	10	33	1.8
Uranium	----	<0.05	----	----	----
Radioactivity, Gross Alpha, pCi/l	----	11.6±0.6	----	----	----
Total Organic Carbon	----	----	----	----	----
Total Inorganic Carbon	----	----	----	----	21
Organic Chemicals					
Endrin	----	<0.0001	----	----	----
Lindane	----	<0.001	----	----	----
Methoxychlor	----	<0.05	----	----	----
Toxaphene	----	<0.001	----	----	----
2, 4-D	----	<0.05	----	----	----
2, 4, 5-TP Silvex	----	<0.005	----	----	----
ICAP Scan					
Ag, Silver	<0.05	<0.05	<0.05	<0.05	<0.05
Al, Aluminum	1.6	<0.1	0.28	2.2	0.18
As, Arsenic	<0.05	<0.1	<0.1	<0.1	<0.1
Au, Gold	<0.05	<0.05	<0.05	<0.05	<0.05
B, Boron	<0.05	<0.05	<0.05	<0.05	<0.05

TABLE 3.1 - CONTINUED

	Date Sampled				
	6/19/80	8/8/80	9/5/80	9/17/80	10/17/80
Laboratory Parameters (1)(3) (continued)					
Ba, Barium	<0.1	0.11	<0.05	0.07	<0.05
Bi, Bismuth	<0.05	<0.05	<0.05	<0.05	<0.05
Ca, Calcium	13	16	22	18	28
Cd, Cadmium	<0.01	<0.01	<0.01	<0.01	<0.01
Co, Cobalt	<0.05	<0.05	<0.05	<0.05	<0.05
Cr, Chromium	<0.05	<0.05	<0.05	<0.05	<0.05
Cu, Copper	<0.05	<0.05	<0.05	<0.05	<0.05
Fe, Iron	2.1	4.0	0.46	2.7	0.37
Hg, Mercury	<0.05	<0.1	<0.1	<0.1	<0.1
K, Potassium	<1.0	2.3	2.1	5.0	<1.0
Mg, Magnesium	1.4	3.4	3.1	1.2	4.5
Mn, Manganese	<0.05	0.10	<0.05	0.07	<0.05
Mo, Molybdenum	<0.05	<0.05	<0.05	<0.05	<0.05
Na, Sodium	2.6	2.4	5.1	3.5	7.2
Ni, Nickel	<0.05	<0.05	<0.05	<0.05	<0.05
Pb, Lead	<0.05	<0.05	<0.05	<0.05	<0.05
Pt, Platinum	<0.05	<0.05	<0.05	<0.05	<0.05
Sb, Antimony	<0.1	<0.1	<0.05	<0.1	<0.1
Se, Selenium	<0.05	<0.1	<0.1	<0.1	<0.1
Si, Silicon	4.8	5.3	3.6	6.9	4.1
Sn, Tin	<0.1	<0.1	<0.1	<0.1	<0.1
Sr, Strontium	0.05	0.06	0.07	0.07	0.10
Ti, Titanium	0.13	0.24	<0.05	0.17	<0.05

2-45-5

TABLE 3.1 - CONTINUED

	Date Sampled				
	6/19/80	8/8/80	9/5/80	9/17/80	10/17/80
Laboratory Parameters (1)(3) (continued)					
W, Tungsten	<1.0	<1.0	<1.0	----	<1.0
V, Vanadium	<0.05	<0.05	<0.05	<0.05	<0.05
Zn, Zinc	<0.05	<0.05	<0.05	<0.05	<0.05
Zr, Zirconium	<0.05	<0.05	<0.05	<0.05	<0.05

(1) Table values are mg/l unless noted otherwise.

(2) All values for free CO_2 determined from nomograph on p. 297 of Standard Method, 14th edition.

(3) Samples for all parameters except chemical oxygen demand, dissolved and suspended solids, and turbidity were filtered.

(4) Hardness calculated by R&M personnel.

2-45-6

TABLE 4.1
R&M CONSULTANTS, INC.
1981 WATER QUALITY DATA - SUSITNA RIVER AT VEE CANYON

NOTE: Dash indicates data not available

	Date			
	1/13/81	5/20/81	6/18/81	6/30/81
Field Parameters (1)				
Dissolved Oxygen	10.7	10.4	----	11.6
Percent Saturation	84	83	----	99
pH, pH Units	7.2	6.6	7.8	7.7
Conductivity, umhos/cm @ 25°C	242	100	120	124
Temperature, °C	0.1	6.5	11.9	7.9
Free Carbon Dioxide (2)	20.0	----	3.2	2.2
Alkalinity, as $CaCO_3$	99	----	79	41
Settleable Solids, ml/l	≪0.1	≪0.1	≪0.1	<0.1
Discharge c.f.s.	1,800	9,810	11,600	13,700
Laboratory Parameters (1)(3)				
Ammonia Nitrogen	<0.05	0.13	0.12	<0.05
Organic Nitrogen	0.85	0.34	0.63	0.39
Kjeldahl Nitrogen	0.85	0.47	0.75	0.39
Nitrate Nitrogen	<0.1	<0.1	<0.10	<0.10
Nitrite Nitrogen	<0.01	<0.01	<0.01	<0.01
Total Nitrogen	0.85	0.47	0.75	0.39
Ortho-Phosphate	<0.01	<0.01	<0.01	0.49
Total Phosphorus	0.07	<0.05	<0.05	0.49
Alkalinity, as $CaCO_3$	----	----	----	----
Chemical Oxygen Demand	12	8	8	16

TABLE 4.1 - CONTINUED

	Date			
	1/13/81	5/20/81	6/18/81	6/30/81
Laboratory Parameters (1)(3) (Cont'd)				
Chloride	18	4.5	5.0	5.0
Conductivity, umhos/cm @ 25°C	----	----	----	----
True Color, Color Units	10	15	5	20
Hardness, as $CaCO_3$ (4)	121	40	49	59
Sulfate	16	4	8	7
Total Dissolved Solids	149	100	170	91
Total Suspended Solids	0.6	93	340	130
Turbidity, NTU	0.35	25	66	29
Uranium	<0.05	----	----	----
Radioactivity, Gross Alpha, pCi/l	10.3±0.6	----	----	----
Total Organic Carbon	23	40	11	23
Total Inorganic Carbon	106	46	46	59
Organic Chemicals				
Endrin	<0.0002	----	----	<0.0002
Lindane	<0.004	----	----	<0.004
Methoxychlor	<0.1	----	----	<0.1
Toxaphene	<0.005	----	----	<0.005
2, 4-D	<0.1	----	----	<0.1
2, 4, 5-TP Silvex	<0.01	----	----	<0.01
ICAP Scan				
Ag, Silver	<0.05	<0.05	<0.05	<0.05
Al, Aluminum	<0.05	<0.05	<0.05	<0.05
As, Arsenic	<0.10	<0.10	<0.10	<0.10
Au, Gold	<0.05	<0.05	<0.05	<0.05
B, Boron	<0.05	<0.05	<0.05	<0.05

TABLE 4.1 - CONTINUED

	Date			
	1/13/81	5/20/81	6/18/81	6/30/81
Laboratory Parameters (1)(3) (Cont'd)				
Ba, Barium	<0.05	<0.05	0.07	0.11
Bi, Bismuth	<0.05	<0.05	<0.05	0.19
Ca, Calcium	36	13	16	19
Cd, Cadmium	<0.01	<0.01	<0.01	<0.01
Co, Cobalt	<0.05	<0.05	<0.05	<0.05
Cr, Chromium	<0.05	<0.05	<0.05	<0.05
Cu, Copper	<0.05	<0.05	<0.05	<0.05
Fe, Iron	<0.05	0.08	0.05	0.07
Hg, Mercury	<0.10	<0.10	<0.10	<0.10
K, Potassium	2	1.6	2.0	2.1
Mg, Magnesium	7.6	1.7	2.0	2.8
Mn, Manganese	<0.05	<0.05	<0.05	<0.05
Mo, Molybdenum	<0.05	<0.05	<0.05	<0.05
Na, Sodium	6.6	2.0	3.3	4.6
Ni, Nickel	<0.05	<0.05	<0.05	<0.05
Pb, Lead	<0.05	<0.05	<0.05	<0.05
Pt, Platinum	<0.05	<0.05	<0.05	<0.05
Sb, Antimony	<0.10	<0.10	<0.10	<0.10
Se, Selenium	<0.10	<0.10	<0.10	<0.10
Si, Silicon	5.0	1.7	2.0	2.6
Sn, Tin	<0.10	<0.10	<0.10	<0.10
Sr, Strontium	0.13	<0.05	0.06	0.07
Ti, Titanium	<0.05	<0.05	<0.05	<0.05

TABLE 4.1 - CONTINUED

	Date			
	1/13/81	5/20/81	6/18/81	6/30/81
Laboratory Parameters (1)(3) (Cont'd)				
W, Tungsten	0.4	<1.0	<1.0	<1.0
V, Vanadium	<0.05	<0.05	<0.05	<0.05
Zn, Zinc	<0.05	<0.05	0.07	<0.05
Zr, Zirconium	<0.05	<0.05	<0.05	<0.05

(1) Table values are mg/l unless noted otherwise.

(2) All values for free CO_2 determined from nomograph on p. 297 of Standard Method, 14th edition.

(3) Samples for all parameters except chemical oxygen demand, dissolved and suspended solids, and turbidity were filtered.

(4) Hardness calculated by R&M personnel.

EXHIBIT E

2. Water Use and Quality

Comment 46 (p. E-2-136, para. 4)

Provide data on water quality, including nutrients, dissolved oxygen, and trace metal concentrations in Alaskan reservoirs of similar depths and in similar climatological regimes during and after filling.

Response

To our knowledge there are no Alaskan reservoirs of similar depths and similar climatological regimes from which to derive the data requested.

2. Water Use and Quality

Comment 47 (p. E-2-165, para. 4)

Provide a list of differences and similarities among Lake Eklutna, Watana, and Devil Canyon, including physiographic characteristics (e.g., depth, area, aspect, shoreline development) known to affect responses of reservoirs to meteorological changes and thermal characteristics.

Response

Table 1 provides a list of differences and similarities among Lake Eklutna, Watana, and Devil Canyon. Watana will have a much larger drainage area and a substantially greater inflow than Eklutna. However, the most notable difference between Lake Eklutna and Watana will be the size difference. Watana will be longer, deeper, wider, and have a much greater surface area and storage capacity. The shoreline length and shoreline development will also be greater. Maximum drawdown at Watana will be two times the drawdown at Eklutna. The length to width ratio at Watana will be approximately four times that at Eklutna. Eklutna is approximately 5 miles from the glacier, whereas Watana reservoir will be approximately 35 miles from its glacial source. This has a significant impact on the inflow water temperature during summer.

The similarities between the two reservoirs are also noteworthy. The percent of the drainage areas covered by glaciers are 5.9 and 5.2 percent for Watana and Eklutna respectively. Both reservoirs are glacially fed and have high a sediment input. Suspended sediment size distributions for both reservoirs indicate that a large fraction of the inflowing suspended sediment is finer than 2 microns. The ratios of live storage to total storage and the mean residence times will also be similar.

A comparison of Eklutna and Devil Canyon reservoir yields similar findings. Devil Canyon will be four times longer. It will also be much deeper and have more than twice the surface area and storage capacity. Discharge and distance downstream from the glaciers are greater significantly for Devil Canyon. Mean residence time for Devil Canyon will be much less than for Eklutna.

The percent of the drainage basins occupied by glaciers is virtually the same for both Eklutna and Devil Canyon. Although sediment input will be reduced because of the presence of Watana reservoir, Devil Canyon is expected to be turbid because of the fine suspended sediment particles passing through Watana. Maximum drawdown at both Eklutna and Devil Canyon will be similar.

TABLE 1

COMPARISON OF BASIN CHARACTERISTICS

BASIN CHARACTERISTICS	EKLUTNA	WATANA	DEVIL CANYON
Drainage Area (mi^2)	119	5,180	5,810
Glacier Areas (mi^2)	6.2	290	290
% of Drainage Area	5.2	5.9	5.0
Glacially Fed	Yes	Yes	Yes
Annual Inflow (ac. ft.)	234,300	5,750,000	6,610,000
RESERVOIR/LAKE CHARACTERISTICS			
Length (miles)	7	46.3	28.4
Maximum Depth (feet)	200	735	565
Mean Depth (feet)	121	250	140
Maximum Breadth (miles)	1.0	5	1.5
Mean Breadth (miles)	0.76	1.28	0.4
Surface Area (acres)	3,420	37,800	7,800
Capacity, Total (ac. ft.)	414,000	9,470,000	1,090,000
Live	213,271	3,920,000	351,000
Shoreline Length (miles)	16	183	76
Shoreline Development	1.95	6.7	6.1
Normal Maximum Elevation of Water Surface (feet)	868	2,185	1,455
Maximum Drawdown (feet)	60	120	50
Live Storage/Total Storage	0.52	0.41	0.32
Total Storage/Surface Area (feet)	121	250	140
Length/Average Depth	305	978	1,071
Drawdown/Average Depth	0.50	0.48	0.36
Length/Average Width	9.2	36	71
Mean Water Residence Time (days)	646	603	60
Water Quality	Turbid	Turbid	Turbid

0016

EXHIBIT E

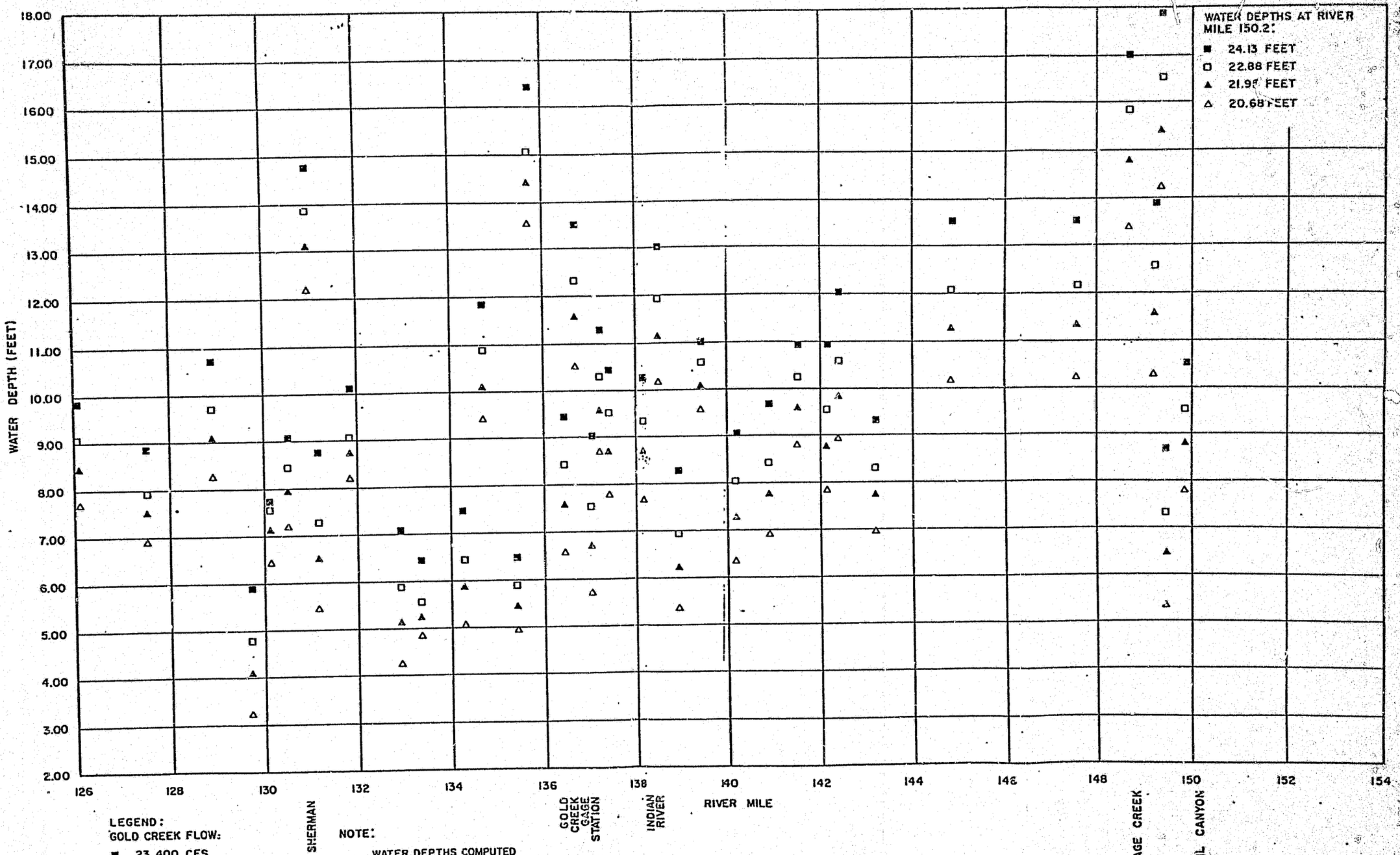
2. Water Use and Quality

Comment 49 (Fig. E.2.63 and E.2.64)

Provide clarification of the term "water depth" used in these figures (i.e., maximum depth, mean depth, or hydraulic radius).

Response

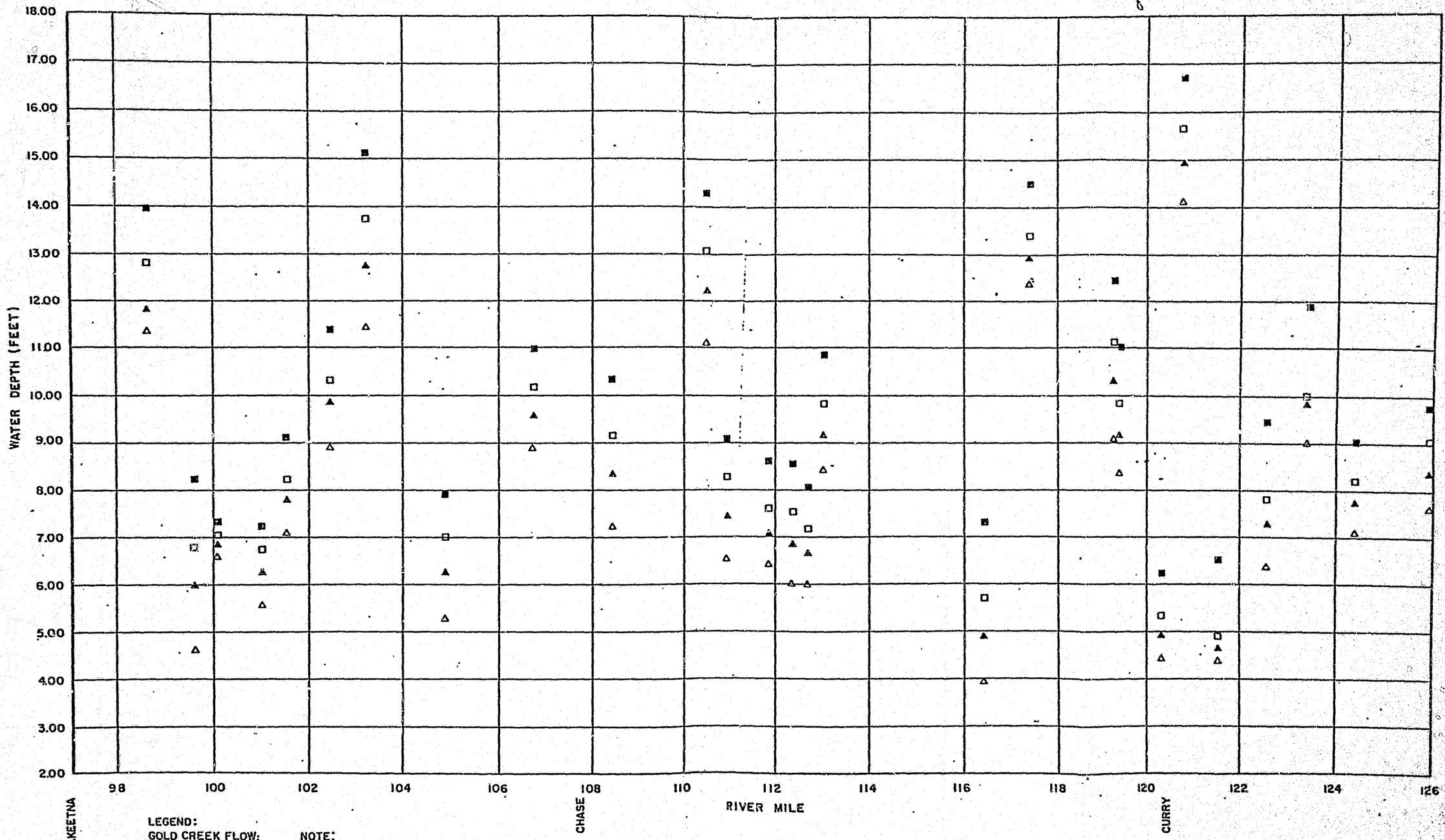
The term "water depth" used in these figures (attached in pp. 2-49-2 to 2-49-3) refers to maximum water depth in the cross-sections. That is, the distance from the water surface to the thalweg.



MAINSTEM WATER DEPTHS
DEVIL CANYON TO RM 126

2-49-2

FIGURE E.2.65



LEGEND:
GOLD CREEK FLOW:

- ■ 23,400 CFS
- □ 17,000 CFS
- ▲ 13,400 CFS
- △ 9,700 CFS

NOTE:

WATER DEPTHS COMPUTED BY U.S. ARMY CORPS OF ENGINEERS HEC-II COMPUTER PROGRAM.

MAINSTEM WATER DEPTHS RM 126 TO TALKEETNA

2-49-3

FIGURE E.2.6

2. Water Use and Quality

Comment 50 (Figure E.2.65)

Provide a description of the modeling procedures used to generate the water surface elevations in this figure. Provide the appropriate reference to Trihey's work (Trihey 1982 is ambiguous) and other ADF&G or R&M reports containing data used in this analysis.

Response

As stated in the response to Comment 4, (Exhibit E, Chapter 2) the water surface elevations (shown as solid lines in Figure E.2.65 p. 2-50-3) for mainstem flows of 12,500 cfs and 22,500 cfs are based on water surface measurements taken on August 2, 1982 and August 24, 1982. The water surface elevations at ADF&G gages #129.2 WIA and WIB (station -4 + 50) for the intermediate mainstem flows of 16,000 cfs and 10,000 cfs (shown as dashed lines in Figure E.2.65) were obtained from the water surface elevation - mainstem discharge relationship shown on Figure E.2.66 in the Exhibit, which was based on observed data. The water surface elevation was assumed to be the same at ADF&G gage #129.2 WI as it was at the upstream riffle, since pools existed at flows of 12,500 and 22,500 cfs. Also, since Slough 9 is not overtopped at mainstem discharges up to 18,000 cfs, outflow from the slough is quite small and it has no appreciable effect on the water surface profile downstream of the riffle at passage reach B. Slough flow was set at 3 cfs to represent a plausible worst case entrance condition during the inmigration period for spawning chum salmon. The depth of flow through the riffle at passage reach B for a flow of 3 cfs was estimated from water depths recorded by ADF&G while surveying the bed profile of Slough 9 on August 24, 1982. Slough flow was measured as 3.4 cfs on August 25, 1982.

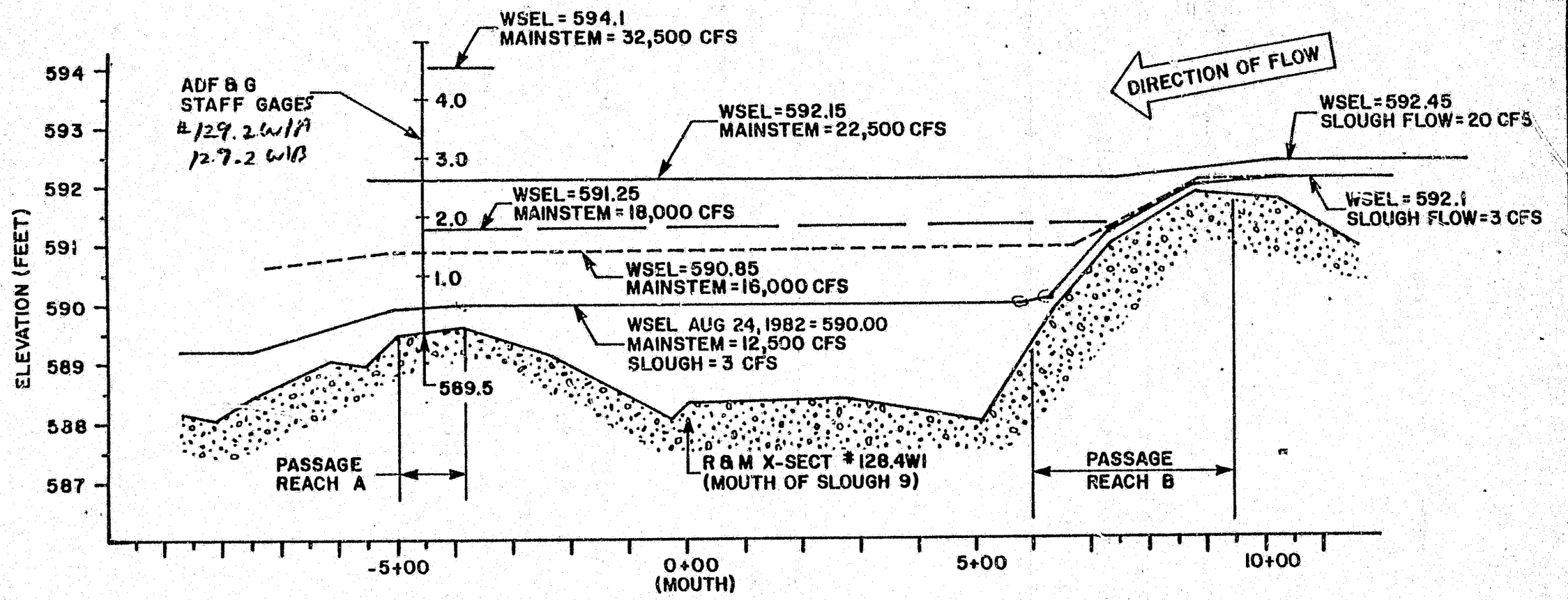
The reference to Trihey's work is given below:

Trihey, E. Woody. 1982. Preliminary Assessment of Access by Spawning Salmon to Side Slough Habitat Above Talkeetna. Prepared for Acres American Inc. Buffalo, New York. 26 pp.

Additional information is contained in the following references:

Alaska Department of Fish and Game (ADF&G), 1983. Susitna Hydro-Aquatic Studies Phase II Basic Data Report Volume 4. Aquatic Habitat and Instream Flow Studies, 1982.

R&M Consultants Inc. 1982. Susitna Hydroelectric Project 1982 Hydrographic Surveys Report, Prepared for Acres American Inc.



NOTES:

1. MOUTH OF SLOUGH AT STATION 0+00.
2. SELECT MAINSTEM DISCHARGES MEASURED AT GOLD CREEK.

2-50-3

BACKWATER PROFILES AT THE MOUTH OF SLOUGH 9

SOURCE: TRIVEX 1982

FIGURE E.2.65

2. Water Use and Quality

Comment 51 (Table E.2.2, Table E.2.4)

Provide tables of monthly average flow data at Gold Creek, Chulitna River, Talkeetna River, and Susitna Station for water years 1950 through 1981. Provide corresponding monthly average temperature data at these four stations for every month during water years 1950 through 1981 for which this is possible.

Response

Tables 1 through 4 of this response provide monthly average flow data at Gold Creek, Chulitna River, Talkeetna River, and Susitna Station for water years 1950 through 1981. The flow data is supplemented with filled in data obtained from a correlation analysis where flow records do not exist. The periods of estimated or filled-in data are noted in each table.

Available monthly average temperature data for water years 1950 through 1981 are presented in Tables 5 and 6 for Gold Creek and Susitna Station, respectively. For the Chulitna River, there are no continuous records from which monthly average temperature can be computed. For the Talkeetna River, the only monthly average temperature data available is for water year 1954 and is as follows: May 7.2°C, June 11.1°C, July 11.7°C, August 10.6°C, and September 7.2°C.

TABLE 1

GOLD CREEK MONTHLY FLOW (CFS)

USGS GAGE 15292000

WATER YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1950	6335.	2583.	1439.	1027.	788.	726.	870.	11510.	19600.	22600.	19880.	8301.
1951	3848.	1300.	1100.	960.	820.	740.	1617.	14090.	20790.	22570.	19670.	21240.
1952	5571.	2744.	1900.	1600.	1000.	880.	920.	5419.	32370.	26390.	20920.	14480.
1953	8202.	3497.	1700.	1100.	820.	820.	1615.	19270.	27320.	20200.	20610.	15270.
1954	5604.	2100.	1500.	1300.	1000.	780.	1235.	17280.	25250.	20360.	26100.	12920.
1955	5370.	2760.	2045.	1794.	1400.	1100.	1200.	9319.	29860.	27560.	25750.	14290.
1956	4951.	1900.	1300.	980.	970.	940.	950.	17660.	33340.	31090.	24530.	18330.
1957	5806.	3050.	2142.	1700.	1500.	1200.	1200.	13750.	30160.	23310.	20540.	19800.
1958	8212.	3954.	3264.	1965.	1307.	1148.	1533.	12900.	25700.	22880.	22540.	7550.
1959	4811.	2150.	1513.	1448.	1307.	980.	1250.	15990.	23320.	25000.	31180.	16920.
1960	6558.	2850.	2200.	1845.	1452.	1197.	1300.	15780.	15530.	22980.	23590.	20510.
1961	7794.	3000.	2694.	2452.	1754.	1810.	2650.	17360.	29450.	24570.	22100.	13370.
1962	5916.	2700.	2100.	1900.	1500.	1400.	1700.	12590.	43270.	25850.	23550.	15890.
1963	6723.	2800.	2000.	1600.	1500.	1000.	830.	19030.	26000.	34400.	23670.	12320.
1964	6449.	2250.	1494.	1048.	966.	713.	745.	4307.	50580.	22950.	16440.	9571.
1965	6291.	2799.	1211.	960.	860.	900.	1360.	12990.	25720.	27840.	21120.	19350.
1966	7205.	2098.	1631.	1400.	1300.	1300.	1775.	9645.	32950.	19860.	21830.	11750.
1967	4163.	1600.	1500.	1500.	1400.	1200.	1167.	15480.	29510.	26800.	32620.	16870.
1968	4900.	2353.	2055.	1981.	1900.	1200.	1210.	16180.	31550.	26420.	17170.	8816.
1969	~~4242.~~ 2822	~~1630.~~ 7630	~~1110.~~ 892	~~1000.~~ 724	~~732.~~ 722	~~800.~~ 816	~~1022.~~ 1510	~~11045.~~ 11045	~~20503.~~ 15503	~~11000.~~ 16103	~~11511.~~ 9519	~~7745.~~ 5913
1970	3124.	1215.	866.	824.	768.	776.	1080.	11380.	18630.	22660.	19980.	9121.
1971	5288.	3407.	2290.	1442.	1036.	950.	1082.	3745.	32930.	23950.	31910.	14440.
1972	5847.	3093.	2510.	2239.	2028.	1823.	1710.	21890.	34430.	22770.	19290.	12400.
1973	4826.	2253.	1465.	1200.	1200.	1000.	1027.	8235.	27800.	18250.	20290.	9074.
1974	3733.	1523.	1034.	874.	777.	724.	992.	16180.	17870.	18800.	16220.	12250.
1975	3739.	1700.	1603.	1516.	1471.	1400.	1593.	15350.	32310.	27720.	18090.	16310.
1976	7739.	1993.	1081.	974.	950.	900.	1373.	12620.	24380.	18940.	19800.	6881.
1977	3874.	2650.	2403.	1829.	1618.	1500.	1680.	12680.	37970.	22870.	19240.	12640.
1978	7571.	3525.	2589.	2029.	1668.	1605.	1702.	11950.	19050.	21020.	16390.	8607.
1979	4907.	2535.	1681.	1397.	1286.	1200.	1450.	13870.	24690.	28880.	20460.	10770.
1980	7311.	4192.	2416.	1748.	1466.	1400.	1670.	12060.	29080.	32660.	20960.	13280.
1981(1)	7725.	~~3986.~~ 3569	~~1773.~~ 1915	~~1754.~~ 2013	~~1236.~~ 1975	~~1114.~~ 1585	~~1368.~~ 2040	~~13317.~~ 16550	~~18143.~~ 19300	~~32000.~~ 33946	~~38538.~~ 37870	~~13171.~~ 13790

1/ USGS HAS REVISED THE GOLD CREEK MONTHLY FLOW DATA FOR 1981

TABLE 2

CHULITNA RIVER MONTHLY FLOW (CFS) 1/

USGS GAGE 15292400

WATER YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1950	9314.	3274.	2143.	1588.	1172.	1030.	1143.	19880.	27252.	33669.	25265.	6424.
1951	3268.	1236.	894.	980.	912.	845.	1282.	6109.	19760.	24161.	20964.	14193.
1952	6526.	2407.	1774.	1385.	1166.	1075.	1409.	11664.	28489.	26547.	19653.	11001.
1953	6142.	2047.	1496.	1597.	1141.	956.	1264.	9575.	19571.	22840.	17478.	10757.
1954	4389.	1680.	1287.	1221.	1043.	834.	1054.	16618.	22528.	25827.	27064.	11888.
1955	4668.	2304.	1437.	1148.	994.	861.	1047.	7928.	26568.	34256.	31862.	12604.
1956	6087.	2005.	1476.	1323.	1296.	1104.	1030.	20025.	33241.	31196.	23329.	23260.
1957	6516.	3014.	1741.	1673.	1298.	1238.	1306.	8447.	24914.	28656.	26519.	14017.
1958	5718.	2752.	1419.	1306.	1044.	948.	1220.	10460.	23170.	25010.	20760.	8000.
1959	4197.	1883.	1262.	1097.	1049.	738.	890.	7413.	23660.	25650.	22100.	9957.
1960	4723.	2283.	1700.	1448.	1103.	933.	1000.	13890.	17390.	23650.	19320.	12420.
1961	5135.	1950.	1745.	1452.	1100.	1079.	1600.	10100.	20490.	27420.	24580.	16030.
1962	5777.	2400.	1500.	1300.	1000.	930.	1170.	7743.	20620.	27220.	21980.	13470.
1963	3506.	1500.	1552.	1600.	1300.	846.	700.	11060.	17750.	28950.	18390.	11330.
1964	8062.	2300.	1000.	1007.	820.	770.	1133.	2355.	40330.	24430.	20250.	9235.
1965	5642.	2900.	2100.	1600.	1400.	1300.	1400.	7452.	20070.	23230.	22550.	22260.
1966	6071.	1620.	1350.	1200.	1100.	1100.	1300.	3771.	21740.	23750.	27720.	12200.
1967	4682.	1680.	1500.	1458.	1257.	1045.	972.	12400.	25520.	35570.	33670.	12510.
1968	3403.	1660.	1397.	1235.	1200.	1148.	1347.	10940.	29000.	30140.	20710.	7375.
1969	2898.	1480.	1139.	974.	900.	824.	1333.	6001.	18560.	20820.	11300.	6704.
1970	4570.	1887.	1316.	1200.	1154.	1100.	1437.	7643.	19670.	26100.	24660.	11330.
1971	3826.	2210.	1403.	1113.	950.	934.	982.	4468.	22180.	27280.	23810.	11080.
1972	5439.	2157.	1432.	1174.	1041.	939.	873.	9765.	17900.	25770.	20970.	12120.
1973	6461.	2176.	1508.	1160.	1031.	889.	1106.	4096.	20005.	22769.	18676.	7112.
1974	4478.	1891.	1397.	1330.	958.	904.	1218.	15330.	20941.	26814.	24749.	12557.
1975	4841.	1783.	1371.	1287.	1056.	1069.	1345.	6928.	25244.	33977.	22307.	12170.
1976	5525.	1528.	1091.	1120.	1077.	873.	1168.	10430.	22642.	25396.	24287.	10336.
1977	6209.	2537.	2097.	1498.	989.	962.	1447.	8160	33629.	25802.	20186.	12388.
1978	5429.	2113.	1644.	1458.	1123.	987.	1052.	4702.	15587.	24633.	15323.	10357.
1979	4900.	2184.	1651.	1406.5	1117.	936.	1276.	11396.	19616.	27740.	22897.	11234.5
1960	6420	3180	1740	1520	1371	1304	1767	9142	22490	34950	20780	8240
1961	5711	3213	2016	1623	1414	1171	1440	9972	22420	29860	33170	11960

(1) Discharge data for Water years 1950 through 1957 ~~and~~ for October, November, December and January of water year 1958, for water years 1973 through 1979 ~~and for October through April of~~ ~~year~~ estimated from correlation analysis. Discharge data for October through April of water year 1980 estimated from Gold Creek and Talkeetna discharge records and the long term average ratio of Gold Creek and Talkeetna discharges to the Susitna River discharge.

2-5-2

TABLE 3

TALKEETNA RIVER MONTHLY FLOW (CFS) 1/

USGS GAGE 15292700

WATER YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1956	3096.	1573.	1026.	616.	468.	396.	384.	4318.	8918.	11736.	10605.	5214.
1957	2319.	770.	515.	536.	407.	379.	607.	3156.	7543.	10122.	9355.	8460.
1958	2385.	1090.	780.	583.	469.	413.	489.	2638.	11369.	9476.	8770.	7048.
1959	3188.	1556.	931.	635.	470.	453.	653.	4946.	9868.	9499.	8029.	5616.
1960	2024.	1134.	693.	649.	472.	386.	429.	3564.	9556.	10045.	18033.	6926.
1961	2426.	926.	632.	594.	522.	414.	450.	2530.	10207.	12341.	14206.	6302.
1962	2294.	1033.	789.	630.	628.	502.	497.	6415.	14813.	11726.	12932.	8179.
1963	3017.	1786.	1034.	707.	606.	502.	524.	4355.	12779.	10848.	11373.	9327.
1964	3662.	1687.	1014.	822.	609.	515.	705.	4463.	16030.	13654.	12200.	4514.
1965	2424.	829.	615.	579.	527.	436.	569.	4174.	7490.	10509.	13065.	7053.
1966	2948.	933.	803.	623.	479.	412.	496.	3826.	5318.	9181.	12319.	7648.
1967	3264.	1485.	1239.	1001.	806.	621.	742.	4107.	15161.	12516.	14030.	7879.
1968	3095.	1556.	1034.	816.	736.	569.	648.	3260.	16992.	9665.	9270.	5663.
1969	3576.	1378.	1107.	777.	700.	537.	456.	4328.	9949.	13023.	10087.	3778.
1970	2040.	916.	693.	529.	440.	384.	371.	1694.	17080.	9820.	8396.	3815.
1971	3115.	1568.	1100.	720.	620.	540.	580.	3474.	11090.	12180.	11150.	10610.
1972	4438.	1460.	876.	711.	526.	395.	422.	2410.	12970.	10100.	10730.	5370.
1973	2208.	897.	750.	637.	546.	471.	427.	4112.	9286.	12600.	14160.	6971.
1974	2029.	1253.	987.	851.	777.	743.	983.	8840.	14100.	11230.	7546.	4120.
1975	1637.	827.	556.	459.	401.	380.	519.	3069.	5207.	7060.	3787.	2070.
1976	1450.	765.	587.	504.	458.	440.	545.	3950.	7979.	10320.	8752.	5993.
1977	2817.	1647.	1103.	679.	459.	402.	503.	2145.	19040.	11760.	16770.	5990.
1978	2632.	1310.	845.	727.	628.	481.	519.	3516.	12700.	12030.	9576.	8709.
1979	3630.	1373.	889.	748.	654.	574.	577.	3860.	12210.	7676.	9927.	3861.
1980	1807.	960.	745.	645.	559.	482.	535.	5678.	8030.	7755.	7704.	4763.
1981	1967.	1002.	774.	694.	586.	508.	522.	4084.	13180.	12070.	8487.	7960.
1982	2884.	773.	558.	524.	480.	470.	613.	3439.	10580.	9026.	8088.	3205.
1983	1857.	1105.	1069.	700.	549.	506.	548.	4244.	18280.	9344.	8005.	5826.
1984	3268.	1121.	860.	746.	576.	485.	534.	2950.	7429.	10790.	7001.	3567.
1985	1660.	1138.	932.	762.	652.	577.	710.	7790.	12010.	14440.	8274.	4039.
1986	3379	1718	868	808	741	700	1038	4823	11380	13800	7224	5402
1987	2600	1144	717	652	535	545	671	4529	6589	15410	14680	4384

(1) Discharge data for water years 1950 to 1964 estimated from correlation analysis. Continuous streamflow records are available from June 1964.

4-15-2

TABLE
SUSITNA STATION MONTHLY FLOW (CFS) 1/
USGS GAGE 15294350

WATER YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1950	26869.	11367.	6197.	6072.	5256.	5377.	5657.	66294.	101616.	124890.	106432.	39331.
1951	18026.	6933.	5981.	7074.	7295.	6382.	7354.	59273.	82255.	123164.	100947.	73471.
1952	31053.	16364.	6989.	8274.	7036.	5853.	5985.	45294.	132547.	137322.	116186.	82076.
1953	44952.	16289.	9746.	8069.	6775.	6350.	7993.	88840.	130561.	125949.	97610.	44168.
1954	20169.	11829.	5272.	7202.	4993.	4980.	6306.	58516.	108881.	116732.	128587.	66275.
1955	23896.	9168.	6183.	7255.	5845.	5316.	6412.	58164.	169045.	148877.	120120.	53504.
1956	19923.	10522.	7295.	6179.	6831.	6324.	7182.	82486.	161346.	168815.	131620.	104218.
1957	41822.	21548.	14146.	10600.	8356.	7353.	7705.	63204.	176219.	140318.	124813.	87825.
1958	52636.	19887.	10635.	7553.	6387.	6679.	8099.	70321.	112897.	122280.	99609.	53053.
1959	30543.	9528.	4763.	7795.	6564.	5666.	6468.	56601.	110602.	146217.	138334.	67904.
1960	25754.	10165.	7005.	6716.	6310.	5651.	5830.	50062.	84134.	129403.	113972.	81565.
1961	33782.	12914.	13769.	12669.	10034.	9193.	9803.	85457.	151715.	138969.	116697.	62504.
1962	29029.	13043.	8977.	9050.	6183.	5951.	6635.	54554.	163049.	143441.	121221.	74806.
1963	27716.	10755.	8865.	8671.	7854.	6058.	5565.	53903.	85648.	146420.	106707.	70782.
1964	37846.	11702.	5626.	6351.	5762.	4910.	5531.	35536.	153126.	124806.	92280.	46110.
1965	28747.	10458.	6127.	6952.	6196.	6170.	7120.	49485.	110075.	138407.	111846.	89944.
1966	36553.	12313.	9159.	8031.	7489.	7091.	8048.	52311.	125183.	117607.	118729.	63887.
1967	26396.	12963.	8322.	8029.	7726.	6683.	7281.	58107.	134881.	136306.	137318.	89527.
1968	37725.	15873.	15081.	11604.	11532.	8772.	8763.	94143.	137867.	130514.	86875.	42385.
1969	~~45540~~	~~15606~~	~~9279~~	~~5052~~	~~2723~~	~~2192~~	~~6452~~	~~44951~~	~~133426~~	~~142121~~	~~93358~~	~~32605~~
1970	22683.	6799.	5016.	6074.	5581.	5732.	5769.	53036.	94612.	132985.	117728.	80585.
1971	32817.	16607.	8633.	6509.	6254.	5883.	5788.	29809.	122258.	139183.	133310.	69021.
1972	32763.	14922.	8791.	9380.	8458.	6646.	6895.	74062.	176024.	142787.	107597.	60220.
1973	26782.	14853.	8147.	7609.	7477.	6313.	7608.	64534.	122797.	123362.	107261.	45227.
1974	20976.	10113.	6081.	7402.	6747.	6294.	6963.	61458.	67838.	102184.	80252.	56124.
1975	19520.	10400.	9419.	8597.	7804.	7048.	6867.	47540.	128800.	135700.	91360.	77740.
1976	31550.	9933.	6000.	6529.	5614.	5368.	7253.	70460.	107000.	115200.	99650.	48910.
1977	30140.	18270.	13100.	10100.	8911.	6774.	6233.	56180.	165900.	143900.	125500.	83810.
1978	38230.	12630.	7529.	6974.	6771.	6590.	7033.	48670.	90930.	117600.	102100.	55500.
1979	36810.	15000.	9306.	8823.	7946.	7032.	8683.	81260.	119900.	142500.	128200.	74340.
1980	58640.	31590.	14690.	10120.	9017.	8906.	12030.	66580.	142900.	181400.	126400.	~~47800.~~
1981	34970.	16200.	8516.	7774.	7589.	6177.	10350.	83580.	108700.	152800.	159600.	67170.

2-51-5

(1) Discharge data for water years 1950 & 1974 estimated from correlation analysis. Continous records are available from October 1974.

(2) ~~Form~~ 1983 Revision by USGS
streamflow

TABLE 5

GOLD CREEK MONTHLY AVERAGE WATER TEMPERATURES[1] (°C)
FOR WATER YEARS FOR WHICH DATA IS AVAILABLE

WATER YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1974										9.5[2]	8[2]	
1975		3.8[4]										6.5[2]
1976							2.5[3]	6.5	10.5[4]	11.0[5]	9.7[6]	
1977							5.3[7]	5.7	8.8[8]			
1978								9.5[9]	10.9[10]	11.5[11]	8.2[12]	
1979		1.9[13]	0.2	0.2			6.5[14]	7.9	11.6[15]	10.1	7.2	
1980		2.9	1.5				5.1[16]	6.0	9.3	7.6	4.8	
1981 →												

(2) MEAN OF MONTHLY MAXIMUM AND MINIMUM

(1) GOLD CREEK DATA MAY BE INFLUENCED BY INFLOW FROM GOLD CREEK

(3) MAY 11-31 (4) JUL 1-5, 7-17, 22-24 (5) AUG 5, 8-9, 19 (6) SEP 4-12 (7) MAY 29-31
(8) JUL 1-6 (9) JUN 15-30 (10) JUL 1-9 (11) AUG 14-31 (12) SEP 1-24 (13) DEC 1-15 (14) MAY 22-31 (15) JUL 1-9 (16) MAY 1-

NOTE: NO DATA AVAILABLE FOR WATER YEARS 1950-1973

TABLE 6

SUSITNA STATION 2 MONTHLY AVERAGE WATER TEMPERATURES (°C)

FOR WATER YEARS FOR WHICH DATA ARE AVAILABLE

WATER YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1974										10.8		
1975									10.3[1]	[illegible][1]	11[1]	7.8[1]
1976	2.3	0.5	0					0.5[2]	2.9	11.9	12.1	10.0	7.2
1977	4.8[3]								6.8[4]	10.5	12.5	11.5	7.5
1978									7.5[5]	11.0	12.0	12.0	9.0[6]
1979									9.5[7]	10.5	12.5	11.5	8.0
1980	3.7[8]	0.4[9]							7.4[10]	10.0	11.5	10.5	7.0
1981	2.6[11]												

(1) Values are mean of monthly maximum and (2) Apr 12-30 (3) Oct 1-6
(4) May 20-31 (5) May 1-2, 16, 24-31 (6) Sep 1-25 (7) May 15-31 (8) Oct 1-23, 31
(9) Nov 1-2, 9-24 (10) May 19-31 (11) Oct 1-23