

Property of
Flood Control District of MC Library
Please Return to
2801 W. Durango
Phoenix, AZ 85009



ARIZONA DEPARTMENT OF TRANSPORTATION

REPORT NUMBER: FHWA-AZ89-250

EFFECTS OF IN-STREAM MINING ON CHANNEL STABILITY

Volume III - Appendices

Prepared by:

Dr. Ruh-Ming Li
George K. Cotton
Michael E. Zeller
Dr. Daryl B. Simons
Patricia O. Deschamps
Simons, Li and Associates, Inc.
4600 South Mill Avenue
Tempe, Arizona 85282

June 1989

Prepared for:

Arizona Department of Transportation
206 South 17th Avenue
Phoenix, Arizona 85007
in cooperation with
U.S. Department of Transportation
Federal Highway Administration

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Arizona Department of Transportation or the Federal Highways Administration. This report does not constitute a standard, specification, or regulation. Trade or manufacturer's names which may appear herein are cited only because they are considered essential to the objectives of the report. The U.S. Government and the State of Arizona do not endorse products or manufacturers.

Technical Report Documentation Page

1. Report No. FHWA-AZ89-250, III	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle EFFECTS OF IN-STREAM MINING ON CHANNEL STABILITY Appendices		5. Report Date June 1989	6. Performing Organization Code
		8. Performing Organization Report No.	
7. Author(s) Dr. Ruh-Ming Li, George K. Cotton, Michael E. Zeller, Daryl B. Simons, and Patricia Q. Deschamps		10. Work Unit No.	
9. Performing Organization Name and Address Simons, Li & Associates, Inc. 4600 South Mill Avenue, Suite 280 Tempe, Arizona 85282		11. Contact or Grant No. HPR-PL-1 (31) Item 250	
		13. Type of Report & Period Covered Appendices, Aug. 1986-June 1989	
12. Sponsoring Agency Name and Address ARIZONA DEPARTMENT OF TRANSPORTATION 206 S. 17TH AVENUE PHOENIX, ARIZONA 85007		14. Sponsoring Agency Code	
		15. Supplementary Notes <p style="text-align: center;">Prepared in cooperation with the U.S. Department of Transportation, Federal Highway Administration</p>	
16. Abstract <p>This report contains the Appendices to Volume II, Final Report, addressing the impacts of in-stream sand and gravel mining on channel stability in Arizona. The information contained in the Appendices provides further documentation in support of the major chapters of the final report. Topics addressed in the appendices include: summary of response to sand and gravel mining questionnaires, summary of gravel mining and sediment transport studies on major Arizona rivers, review of litigation related to in-stream mining, long-term procedure technical appendix, documentation of computer program for short-term Channel Response due to In-Stream Mining (CRISM), documentation of computer program HEC-2SR for single-event river response simulation, topographic dataset, bed-material gradation dataset, hydrologic dataset, and mining activity dataset.</p> <p>Executive Summary, Volume I Final Report, Volume II</p>			
17. Key Words Sand and gravel mining, channel stability, sediment transport, river mechanics.		18. Distribution Statement Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161	
19. Security Classification (of this report) Unclassified		20. Security Classification (of this page) Unclassified	21. No. of Pages 477
23. Registrant's Seal 		22. Price	

APPENDICES TABLE OF CONTENTS

	<u>Page</u>
LIST OF FIGURES	iv
LIST OF TABLES	vii
LIST OF CHARTS	viii
LIST OF GRAPHS	viii
LIST OF PLATES	ix
APPENDIX A - SUMMARY OF RESPONSES TO SAND AND GRAVEL MINING QUESTIONNAIRE	A-1
A.1 <u>Introduction</u>	A-1
A.2 <u>General</u>	A-1
A.2.1 <u>General Issues and Trends</u>	A-1
A.2.2 <u>Basis of Regulatory Program</u>	A-3
A.3 <u>Questionnaire Response Summary</u>	A-4
A.3.1 <u>Regulatory Agencies</u>	A-4
A.3.1.1 <u>Federal Agencies</u>	A-4
A.3.1.2 <u>State Agencies</u>	A-4
A.3.1.3 <u>County Agencies</u>	A-5
A.3.1.4 <u>Local Agencies</u>	A-6
A.3.2 <u>Sand and Gravel Operators</u>	A-6
A.3.3 <u>Consulting Engineers</u>	A-7
A.4 <u>Interview Summary</u>	A-8
A.4.1 <u>Interview Agenda</u>	A-8
A.4.2 <u>Interview Response</u>	A-8
A.5 <u>Damage Inventory</u>	A-11
A.6 <u>Recommended River Segments</u>	A-12
Regulatory Agency Questionnaire Form	A-14
Sand and Gravel Operator Questionnaire Form	A-18
Consulting Engineer Questionnaire Form	A-24
APPENDIX B - SUMMARY OF GRAVEL MINING AND SEDIMENT TRANSPORT STUDIES ON MAJOR ARIZONA RIVERS	B-1
B.1 <u>In-Stream Sand and Gravel Mining Studies</u>	B-1
B.2 <u>Hydraulic/Sediment Transport Studies</u>	B-8
APPENDIX C - REVIEW OF LITIGATION RELATED TO IN-STREAM MINING	C-1
APPENDIX D - LONG-TERM PROCEDURE TECHNICAL APPENDIX	D-1
D.1 <u>Database</u>	D-1
D.2 <u>Data Reduction</u>	D-1
D.3 <u>Data Analysis</u>	D-2
D.4 <u>Conclusions</u>	D-10
APPENDIX E - COMPUTER PROGRAM FOR CHANNEL RESPONSE DUE TO IN-STREAM MINING (CRISM)	E-1
E.1 <u>Introduction</u>	E-1
E.2 <u>Program Operation</u>	E-1
E.3 <u>Program Listings</u>	E-6
E.4 <u>Program Execution</u>	E-6
E.5 <u>Theory</u>	E-8
E.6 <u>Derivation of Sand-Bed Scour Equations</u>	E-13
E.7 <u>Derivation of Gravel-Bed Scour Equations</u>	E-13
References	E-33

APPENDICES TABLE OF CONTENTS
(continued)

	<u>Page</u>
APPENDIX F - COMPUTER PROGRAM HEC-2SR FOR SINGLE- EVENT RIVER RESPONSE SIMULATION, VERSION	
2.1	F-1
F.1 <u>Introduction</u>	F-1
F.2 <u>Program Operation</u>	F-2
F.3 <u>Program Flow Chart</u>	F-3
References	F-7
APPENDIX G - TOPOGRAPHIC DATASET	G-1
G.1 <u>Purpose/Objective</u>	G-1
G.2 <u>Sources of Data</u>	G-1
G.2.1 <u>Specific Location of Acquisition</u>	G-1
G.2.2 <u>People Involved in the Map Acquisition</u>	G-1
G.2.3 <u>Summary of Maps</u>	G-2
G.3 <u>Data Manipulation</u>	G-8
APPENDIX H - BED-MATERIAL GRADATION DATASET	H-1
H.1 <u>Purpose/Objective</u>	H-1
H.2 <u>Sources of Data</u>	H-1
H.3 <u>Data Manipulation</u>	H-3
H.3.1 <u>Discussion</u>	H-3
H.3.2 <u>Programs</u>	H-4
APPENDIX I - HYDROLOGIC DATASET	I-1
I.1 <u>Purpose/Objective</u>	I-1
I.2 <u>Soil Types</u>	I-1
I.3 <u>Geologic Formations</u>	I-6
I.4 <u>Sources of Data</u>	I-7
I.4.1 <u>Gage Station Data</u>	I-7
I.4.2 <u>Hydrograph Data</u>	I-7
I.4.3 <u>Flood Frequency Data</u>	I-8
References	I-60
APPENDIX J - MINING ACTIVITY DATASET	J-1
J.1 <u>Purpose/Objective</u>	J-1
J.2 <u>Sources of Data</u>	J-1
J.3 <u>Acquisition and Reduction of Data</u>	J-3
J.3.1 <u>Data Acquisition</u>	J-3
J.3.2 <u>Data Reduction</u>	J-3

APPENDICES TABLE OF CONTENTS
(continued)
LIST OF FIGURES

	<u>Page</u>
Study Reach Mining Cluster Maps	
Figure D.1 - Salt River-Hayden Road to Country Club Drive	D-4
Figure D.2 - Salt River-59th Avenue to 19th Avenue . . .	D-5
Figure D.3 - Agua Fria River	D-6
Figure D.4 - New River	D-7
Figure D.5 - Rillito Creek	D-8
Figure D.6 - Comparative Plot Actual vs. Geometric Curves	D-11
Figure E.1 - Printer Output File Format for Version 1.3 (CRISM)	E-4
Figure E.2 - Printer Output File Format for Version 1.2 (CRISM)	E-5
Figure E.3 - Flow Chart of the Main Program for CRISM . .	E-7
Figure E.4 - Hydraulics Flow Diagram	E-9
Figure E.5 - Schematic Diagram of Sediment Continuity . .	E-12
Figure E.6 - Normalized Downstream Scour Length Graph (q = 20 cfs/ft)	E-17
Figure E.7 - Normalized Downstream Scour Length Graph (q = 40 cfs/ft)	E-18
Figure E.8 - Normalized Downstream Scour Length Graph (q = 80 cfs/ft)	E-19
Figure E.9 - Normalized Downstream Scour Length Graph (q = 160 cfs/ft)	E-20
Figure E.10 - Normalized Downstream Scour Depth Graph (q = 20 cfs/ft)	E-21
Figure E.11 - Normalized Downstream Scour Depth Graph (q = 40 cfs/ft)	E-22
Figure E.12 - Normalized Downstream Scour Depth Graph (q = 80 cfs/ft)	E-23
Figure E.13 - Normalized Downstream Scour Depth Graph (q = 160 cfs/ft)	E-24
Figure E.14 - Normalized Upstream Scour Length Graph (q = 20 cfs/ft)	E-25
Figure E.15 - Normalized Upstream Scour Length Graph (q = 40 cfs/ft)	E-26
Figure E.16 - Normalized Upstream Scour Length Graph (q = 80 cfs/ft)	E-27
Figure E.17 - Normalized Upstream Scour Length Graph (q = 160 cfs/ft)	E-28
Figure E.18 - Normalized Upstream Scour Depth Graph (q = 20 cfs/ft)	E-29
Figure E.19 - Normalized Upstream Scour Depth Graph (q = 40 cfs/ft)	E-30
Figure E.20 - Normalized Upstream Scour Depth Graph (q = 80 cfs/ft)	E-31
Figure E.21 - Normalized Upstream Scour Depth Graph (q = 160 cfs/ft)	E-32
Figure F.1 - Flow Chart	F-4

APPENDICES TABLE OF CONTENTS
(continued)

	<u>Page</u>
Grid Location Vicinity Maps	
Figure G.1 - Salt River-Hayden Road to Country Club Drive	G-9
Figure G.2 - Salt River-59th Avenue to 19th Avenue	G-10
Figure G.3 - Verde River at Cottonwood	G-11
Figure G.4 - Verde River at I-17	G-12
Figure G.5 - Agua Fria River	G-13
Figure G.6 - New River	G-14
Figure G.7 - Santa Cruz River	G-15
Figure G.8 - Rillito Creek	G-16
Grid Data for Study Reaches	
Figure G.9 - Salt River-Hayden Road to Country Club Drive 1962 Average Contour Elevations	G-17
Figure G.10 - Salt River-Hayden Road to Country Club Drive 1986 Average Contour Elevations	G-18
Figure G.11 - Salt River-Hayden Road to Country Club Drive Net Change in Elevation	G-19
Figure G.12 - Salt River-59th Avenue to 19th Avenue 1962 Average Contour Elevations	G-20
Figure G.13 - Salt River-59th Avenue to 19th Avenue 1983 Average Contour Elevations	G-21
Figure G.14 - Salt River-59th Avenue to 19th Avenue Net Change in Elevation	G-22
Figure G.15 - Verde River at Cottonwood 1976 Average Contour Elevations	G-23
Figure G.16 - Verde River at Cottonwood 1982 Average Contour Elevations	G-24
Figure G.17 - Verde River at Cottonwood Net Change in Elevation	G-25
Figure G.18 - Verde River at I-17 1985 Average Contour Elevations	G-26
Figure G.19 - Agua Fria River-1972 Average Contour Elevations	G-27
Figure G.20 - Agua Fria River-1981 Average Contour Elevations	G-28
Figure G.21 - Agua Fria River-Net Change in Elevation	G-29
Figure G.22 - New River-1976 Average Contour Elevations	G-30
Figure G.23 - New River-1981 Average Contour Elevations	G-31
Figure G.24 - New River-Net Change in Elevation	G-32
Figure G.25 - Santa Cruz River-1984 Average Contour Elevations	G-33
Figure G.26 - Rillito Creek-1967 Average Contour Elevations	G-34
Figure G.27 - Rillito Creek-1984 Average Contour Elevations	G-35
Figure G.28 - Rillito Creek-Net Change in Elevation	G-36
Three-Dimensional Mesh Plots	
Figure G.29 - Three-Dimensional Mesh Program and Input Data	G-37
Figure G.30 - Salt River-Hayden Road to Country Club Drive	G-55
Figure G.31 - Salt River-59th Avenue to 19th Avenue	G-56

APPENDICES TABLE OF CONTENTS

(continued)

LIST OF FIGURES

Page

Figure G.32 - Verde River at Cottonwood	G-57
Figure G.33 - Agua Fria River	G-58
Figure G.34 - New River	G-59
Figure G.35 - Rillito Creek	G-60

Channel Thalweg Plots

Figure G.36 - Salt River-Hayden Road to Country Club Drive	G-61
Figure G.37 - Salt River-59th Avenue to 19th Avenue . . .	G-62
Figure G.38 - Verde River at Cottonwood	G-63
Figure G.39 - Verde River at I-17	G-64
Figure G.40 - Agua Fria River	G-65
Figure G.41 - New River	G-66
Figure G.42 - Santa Cruz River	G-67
Figure G.43 - Rillito Creek	G-68

Figure H.1 - ADOT Input Cards	H-2
---	-----

High, Low, Mean Plots

Figure H.2 - Salt River at Hayden Road	H-6
Figure H.3 - Salt River at 35th Avenue	H-7
Figure H.4 - Verde River at Cottonwood	H-8
Figure H.5 - Verde River at I-17	H-9
Figure H.6 - Agua Fria River	H-10
Figure H.7 - New River	H-11
Figure H.8 - Santa Cruz River	H-12
Figure H.9 - Rillito Creek	H-13

Gradation Coefficient vs. Probability Plots

Figure H.10 - Salt River at Hayden Road (D85/D50)	H-14
Figure H.11 - Salt River at Hayden Road (D50/D15)	H-15
Figure H.12 - Salt River at 35th Avenue (D85/D50)	H-16
Figure H.13 - Salt River at 35th Avenue (D50/D15)	H-17
Figure H.14 - Verde River at Cottonwood (D85/D50)	H-18
Figure H.15 - Verde River at Cottonwood (D50/D15)	H-19
Figure H.16 - Verde River at I-17 (D85/D50)	H-20
Figure H.17 - Verde River at I-17 (D50/D15)	H-21
Figure H.18 - Agua Fria River (D85/D50)	H-22
Figure H.19 - Agua Fria River (D50/D15)	H-23
Figure H.20 - New River (D85/D50)	H-24
Figure H.21 - New River (D50/D15)	H-25
Figure H.22 - Santa Cruz River (D85/D50)	H-26
Figure H.23 - Santa Cruz River (D50/D15)	H-27
Figure H.24 - Rillito Creek (D85/D50)	H-28
Figure H.25 - Rillito Creek (D50/D15)	H-29

Mean D50 vs. Gradation Coefficient Plots

Figure H.26 - Salt River at Hayden Road	H-30
Figure H.27 - Salt River at 35th Avenue	H-31
Figure H.28 - Verde River near Cottonwood	H-32

APPENDICES TABLE OF CONTENTS

LIST OF FIGURES	<u>Page</u>
Figure H.29 - Verde River at I-17	H-33
Figure H.30 - Agua Fria River	H-34
Figure H.31 - New River	H-35
Figure H.32 - Santa Cruz River	H-36
Figure H.33 - Rillito Creek	H-37

Figure I.1 - USGS Gaging Stations Vicinity Map	I-9
Figure I.2 - Analytical Frequency Analysis of Peak Flows, Santa Cruz River	I-50
Figure I.3 - Discharge Frequency Curves, Santa Cruz River	I-51
Figure I.4 - Analytical Frequency Analysis of Peak Flows, Rillito Creek	I-52
Figure I.5 - Discharge Frequency Curves, Rillito Creek .	I-53
Figure I.6 - Discharge Frequency Curves, Agua Fria River	I-54
Figure I.7 - Discharge Frequency Curves, New River at Bell Road	I-55
Figure I.8 - Discharge Frequency Curves, New River near Glendale	I-56
Figure I.9 - Discharge Frequency Curves, Verde River near Clarkdale	I-57
Figure I.10 - Discharge Frequency Curves, Verde River near Clarkdale	I-58
Figure I.11 - Discharge Frequency Curves, Verde River at Camp Verde	I-59

LIST OF TABLES

Topographic Database

Table D.1 - Salt River-Hayden Road to Country Club Drive	D-16
Table D.2 - Salt River-59th Avenue to 19th Avenue	D-20
Table D.3 - Verde River at Cottonwood	D-23
Table D.4 - Verde River near I-17	D-25
Table D.5 - Agua Fria River-Buckeye Road to Camelback Road	D-27
Table D.6 - New River-Agua Fria River Confluence to Peoria Avenue	D-30
Table D.7 - Santa Cruz River-Valencia Road to I-19	D-32
Table D.8 - Rillito Creek-I-10 to La Cholla Boulevard	D-33

Mining Activity Database

Table D.9 - Salt River-Hayden Road to Country Club Drive	D-36
Table D.10 - Salt River-59th Avenue to 19th Avenue	D-40
Table D.11 - Verde River at Cottonwood	D-43
Table D.12 - Verde River near I-17	D-45
Table D.13 - Agua Fria River-Buckeye Road to Camelback Road	D-46
Table D.14 - New River-Agua Fria River Confluence to Peoria Avenue	D-49
Table D.15 - Santa Cruz River-Valencia Road to I-19	D-51
Table D.16 - Rillito Creek-I-10 to La Cholla Boulevard	D-52

APPENDICES TABLE OF CONTENTS
(continued)

	<u>Page</u>
Table E.1 - Description of Input Data File, Version 1.3 Gravel-Bed Channel	E-2
Table E.2 - Description of Input Data File, Version 1.2 Sand-Bed Channel	E-3
Table E.3 - Coefficients for Envelope Curves	E-15
Table H.1 - Program Compilation Details	H-5

LIST OF CHARTS

Chart A - Long-Term Procedure - Maximum Annual Degradation.	D-13
Chart B - Long-Term Procedure - Average Annual Degradation.	D-14
Chart C - Long-Term Procedure - Downstream Recovery Curve .	D-15

LIST OF GRAPHS

Graph I.1 - Flood Hydrograph, Salt River at Jointhead Dam .	I-28
Graph I.2 - Average Discharges at Granite Reef Dam, Salt River	I-29
Graph I.3 - Average Discharges from Granite Reef Dam, Flows Less Than 7,000 cfs	I-30
Graph I.4 - Average Discharges at Granite Reef Dam, Flows Less Than 15,000 cfs	I-31
Graph I.5 - Average Discharges at Granite Reef Dam, Flows Less Than 40,000 cfs	I-32
Graph I.6 - Average Discharges from Granite Reef Dam, Flows Less Than 55,000 cfs	I-33
Graph I.7 - Average Discharges from Granite Reef Dam, Flows Less Than 110,000 cfs	I-34
Graph I.8 - Flood Hydrograph, New River at Bell Road near Peoria	I-35
Graph I.9 - Flood Hydrograph, Santa Cruz River, Flood of December 1965	I-36
Graph I.10 - Flood Hydrograph, Santa Cruz River, Flood of October 1977	I-37
Graph I.11 - Flood Hydrograph, Santa Cruz River, Flood of October 1983	I-38
Graph I.12 - Flood Hydrograph, Rillito Creek, Flood of December 1965	I-39
Graph I.13 - Flood Hydrograph, Rillito Creek, Flood of October 1983	I-40
Graph I.14 - Flood Hydrograph, Verde River near Clarkdale, Flood of December 1965	I-41
Graph I.15 - Flood Hydrograph, Verde River near Clarkdale, Flood of 1978	I-42
Graph I.16 - Flood Hydrograph, Verde River below Camp Verde, Flood of 1978	I-43
Graph I.17 - Flood Hydrograph, Santa Cruz River and Rillito Creek	I-44

APPENDICES TABLE OF CONTENTS
(continued)

	<u>Page</u>
Graph I.18 - Flood Hydrograph, Salt and Verde Rivers . . .	I-44
Graph I.19 - Flood Hydrograph, Santa Cruz River and Rillito Creek	I-45
Graph I.20 - Flood Hydrograph, Santa Cruz River	I-46
Graph I.21 - Flood Hydrograph, Agua Fria River	I-46

LIST OF PLATES

Plate J.1 - Salt River-Hayden Road to Country Club Drive.	J-4
Plate J.2 - Salt River-59th Avenue to 19th Avenue	J-4
Plate J.3 - Verde River at Cottonwood	J-5
Plate J.4 - Verde River at I-17	J-5
Plate J.5 - Agua Fria River	J-6
Plate J.6 - New River	J-6
Plate J.7 - Santa Cruz River	J-7
Plate J.8 - Rillito Creek	J-7

APPENDIX A. SUMMARY OF RESPONSES TO SAND AND GRAVEL MINING QUESTIONNAIRE

A.1 Introduction

In order to establish a comprehensive data base for this research project, questionnaires were developed to solicit relevant information from: 1) regulatory agencies; 2) sand and gravel operators; and 3) consulting engineers who have been involved in preparing technical studies for mining permit applications. This summary provides an overview of the input received from the questionnaire respondents.

A.2 General

Three different questionnaires were developed with questions oriented towards obtaining the type of data available from each of the three groups (i.e., regulatory agencies, sand and gravel operators, and consulting engineers). A total of 190 questionnaires were sent with the following results:

Respondent	No. of Questionnaires Transmitted	No. of Questionnaires Returned	% Rtn'd
1. Regulatory Agencies	32	31	97
2. Sand & Gravel Operators	152	12	8
3. Consulting Engineers	6	5	83

A.2.1 General Issues and Trends

A review of the respondents' comments identified the following general issues and trends related to in-stream sand and gravel mining:

- . Several respondents expressed concern regarding the feasibility of developing uniform guidelines at the State government level which would be justifiably applicable to all river systems within the State.
- . Some disagreement exists among respondents regarding which governing body should be responsible for regulating sand and gravel mining operations; however, a general consensus is that regulation should be left up to local jurisdictions backed by a State enabling law and physically based engineering standards.
- . At the present time, the primary vehicle for regulation of in-stream sand and gravel operations is through

local zoning and floodplain ordinances applied on a site specific basis. Requirements for issuance of a Floodplain Use Permit are tailored to the specific operation under consideration.

- . Enforcement is carried out first through contact with the operator and, if necessary, then through litigation in civil court. Several respondents have been or are currently involved in litigation both as defendants and/or plaintiffs. (A current court case examines the issue of whether the in-stream sand and gravel mining operation is exempt from zoning ordinance requirements.)
- . The primary benefit of in-stream sand and gravel mining was seen as providing an economical, convenient source of quality construction material upon which virtually all development of public and private infrastructure depends. Other benefits mentioned included: 1) increased channel capacity; 2) reduced potential for overbank flooding in some areas due to channel degradation; 3) partial runoff storage; 4) minor, local groundwater recharge; and 5) profits for companies that leads to the creation of jobs and an increased tax base.
- . It was noted that the issue of damaged transportation structures was not exclusively related to the impacts of sand and gravel mining. Also cited as a contributing factor to structure damage was a lack of proper planning on the part of engineers in predicting the magnitude of severe flood events and in designing structural foundations to withstand such flooding conditions. An in-depth study was called for to evaluate the cost effectiveness of designing new bridge foundations and/or refurbishing existing structures to handle 100-year flows versus the economic impacts of the loss of production of low-cost aggregates.
- . It was suggested that environmental concerns and long-term consequences be considered as they relate to the benefit of mining a particular site. A benefit/cost approach to regulating in-stream mining would weigh the type, quality and need for material versus the cost of mitigating mining impacts (e.g., grade control structures, site restoration, etc.)
- . A recommended technical approach would evaluate the long-term stability of the overall sediment system for a given river reach and then analyze the local effects resulting from in-stream mining within that system. The analysis should not always be based on the impacts of an individual pit, since such an approach might overlook the combined effect of adjacent operations on

the overall system.

A.2.2 Basis of Regulatory Program

The questionnaires solicited respondents' input regarding the objectives, procedures and criteria upon which a state-wide regulatory program should be based.

The main objective of the regulatory program was seen as preventing/mitigating negative impacts (due to mining operations) upon stream stability, water quality, adjacent property owners, and in-stream structures and improvements.

The procedures by which this objective would be pursued were also addressed. The majority of regulatory agency respondents supported regulation of gravel operators through local zoning and floodplain ordinances backed by State law and subject to State audit to ensure compliance. New operations, or expansion of existing operations onto new land, would be restricted so that existing or planned improvements were not at risk, while existing operations could be accommodated through some type of "grandfather" clause.

Although respondents provided information regarding criteria currently used to evaluate impacts of sand and gravel mining on channel stability, in-stream structures and bank protection, they provided very little information of specific technical procedures that were used to analyze the criteria. The following is a summary of respondents' comments regarding technical criteria that should be used in reviewing permits for in-stream mining:

1. Restrictions on distance from gravel pit to bridges, flood control structures, utilities and urban development.
2. Restriction on pit depth and side slopes.
3. Limitations on upstream headcutting, bank erosion, and downstream degradation.
4. Determination of "safe yield" through analysis of material extracted versus sediment supplied to mined reach.
5. Investigation of manner in which excavation will proceed (pit geometrics), excavation method to be used, and duration of mining activities.
6. Restrictions on stockpiling in the floodway.
7. Restrictions on diverting channels with diversion dikes at mining locations.
8. Requiring sediment routing analysis to consider different flow frequencies and durations.

9. Requiring grade control structures, as needed.
10. Requiring environmental rehabilitation and restoration for aesthetic purposes.

A.3 Questionnaire Response Summary

A.3.1 Regulatory Agencies

The regulatory agencies were asked to provide facts concerning the sand and gravel mining operations within their jurisdiction, regulatory guidelines/policies, enforcement programs and litigation information. If they were involved in the design, regulation or maintenance of in-stream structures, input regarding design methodologies and considerations was also requested.

A.3.1.1 Federal Agencies

The federal agencies responding to the questionnaire do not regulate the sand and gravel mining operations within their jurisdiction. The USDA Soil Conservation Service does consider erosion/sedimentation processes in the design of in-stream flood control structures and does account for the effects of sand and gravel mining upon the project design, as needed. Of concern to the U.S. Fish & Wildlife Service is the long-term impacts to fish and wildlife resources as a result of in-stream mining operations.

The U.S. Army Corps of Engineers (COE) Regulatory Branch administers a permit program under Section 404 of the Clean Water Act. Any person, firm or governmental agency planning work in "waters of the United States" must first obtain a permit from the COE. Activities related to sand and gravel mining which require permits are the disposal of fill or the discharge of dredged or fill materials in "waters of the United States" which cause the loss or substantial adverse modification of 10 acres or more. Under the provisions of Nationwide General Permit Number 26, for those discharges which adversely impact 1 to 10 acres, the COE District Engineer must be notified before work begins. This nationwide general permit eliminates the need for further permit processing by the COE for discharges which cause the substantial loss or adverse modification of less than 1 acre. In addition, sand and gravel operations outside the 20-year floodplain need not apply for individual permits.

A.3.1.2 State Agencies

The Arizona Department of Transportation (ADOT) does not directly regulate sand and gravel mining operations throughout the State. However, ADOT does control the use of materials on highway construction projects through their construction specifications. Section 106.03 of the 1985 ADOT Supplemental Specifications limits the use of material sources situated within the 100-year floodplain of a watercourse, and located within one mile upstream and two miles downstream of a highway structure or

roadway crossing. Within these boundaries, existing commercial sources may not be utilized as a source of borrow nor will any new source or existing non-commercial source be approved for any materials.

"The location of any new material source or existing non-commercial material source proposed for use on this project shall be reviewed by the appropriate agency having flood plain management jurisdiction for the area in which the proposed source is located. The contractor shall obtain a letter from the agency addressed to the Engineer certifying that the location of the proposed source conforms to the requirements of the Specifications."¹

In monitoring department-owned sources in the floodplain, ADOT requires the Materials Section to evaluate potential risk to public or private improvements located one mile up and downstream of the materials operation. A mining plan and an environmental assessment, which includes a hydraulic study, is required under certain conditions.

The Arizona Department of Health Services (ADHS) principal authority related to mining is to control the discharge of pollutants from point and non-point sources. The point source control program is implemented by National Pollutant Discharge Elimination System (NPDES) permits, issued under Section 402 of the Federal Clean Water Act. The non-point program consists of compliance evaluations in waters potentially impacted by diffused source discharges. If standards are exceeded, or protected water uses are impaired in these waters, then corrective actions are required. Water line crossings for proposed projects for water supply and wastewater systems receive detailed engineering reviews before approval to construct is granted. If buried lines cross watercourses, the impact of gravel mining and channel scouring are considered on a site-specific basis.

None of the respondents from State agencies had been involved in litigation related to sand and gravel mining operations.

A.3.1.3 County Agencies

Two-thirds of the county respondents have in-stream sand and gravel mining operations within their jurisdiction. It is interesting to note that two-thirds of county respondents do regulate mining operations; however, those regulating are not necessarily the same counties as those with mining activity occurring.

¹Arizona Department of Transportation, Standard Specifications for Road and Bridge Construction, 1985 Supplement, Sec. 106.03.

The counties regulate sand and gravel mining through floodplain and zoning boards. Floodplain Use Permits are required for new mines and major expansions of existing mining operations. Enforcement may require legal action; one-half of county respondents are involved in litigation related to sand and gravel mining as both defendant and/or plaintiff.

Cochise County has budgeted funds for this fiscal year to commence a mapping and study program designed to more effectively regulate sand and gravel mining operation within their jurisdiction.

A.3.1.4 Local Agencies

One-half of the local respondents have in-stream sand and gravel mining operations within their jurisdiction. One-half of the respondents also regulate in-stream mining in the form of Floodplain Use Permits with supplemental extraction data supplied by the operator. One of the local respondents had been involved in litigation related to sand and gravel operations.

At the local level, there is concern that mining operations tend to have a negative impact on adjacent property values. There is support for environmental rehabilitation through proper site restoration in these areas.

The City of Peoria has stipulated that the City will receive, as a license fee, a per ton royalty for material which is extracted for commercial use at off-site locations. This fee is placed in the flood control budget. The operator is responsible for submitting monthly reports indicating the amount of material removed.

A.3.2 Sand and Gravel Operators

The sand and gravel mining operators were asked to provide facts concerning their facilities resources for all operations they have conducted in the State during the past five years. Also requested were data regarding the total amount of rock products they produce and sell in Arizona, and estimates of future annual extraction rates for the next five years. In addition, information was solicited concerning regulatory compliance requirements, permit application submittals, and design practices, if applicable. Responses were received from individual operators.

The operators felt that there are some inconsistencies on the part of regulatory agencies with regard to requirements for issuance of permits for sand and gravel operations. The operators feel the agencies are uncertain as to what is really necessary to assure indemnity from litigation, and that engineering firms have over-emphasized to these agencies the need for sophisticated, costly studies to adequately assess mining impacts. This results in increased cost of aggregate materials to the end user. The most important economical factor in the total cost of gravel products is the transportation cost incurred

in hauling material from pit to end user, thus making a case for maintaining gravel pits in close proximity to development sites.

The turnaround time for regulatory agencies to process permit applications varies from two months to more than one year. The average total cost to the operator for completion of a permit application was estimated to be \$50,000. Major factors affecting the cost of submitting a permit application include:

1. Operation location relative to in-stream structures
2. Operation size
3. River characteristics
4. Varying requirements of different regulatory agencies.

The operators emphasize that a statewide program should consider the impact to the overall economy resulting from regulating or restricting the recovery of limited aggregate reserves which, in the major metropolitan areas, are centrally located to the market, therefore, providing low cost building materials for the State's growth. The operators are concerned about the economic impact on the sand and gravel industry as related to the cost of compliance with regulatory controls.

A.3.3 Consulting Engineers

The questionnaires sent to consulting engineers requested information concerning the criteria and procedures used in evaluating the effect of sand and gravel mining facilities on channel stability and the design of in-stream structural improvements. Input was solicited regarding the preparation of permit applications for sand and gravel mining operations.

Respondents identified the following as major hazards to in-stream structures caused by the presence of sand and gravel operations:

- . degradation/scour potential
- . headcut propagation
- . significant lateral channel migration impacts
- . concentration/diversion of flows at mining sites
- . perpetuation of mining activities

The criteria used to assess these hazards included:

- . sediment supply and balance
- . upstream and downstream channel conditions
- . pit geometrics/volume
- . set-back distances
- . proximity of structural improvements

The following procedures and methodologies are used to evaluate the effect of sand and gravel mining operations on channel stability and in-stream structural integrity:

- . computer programs: HEC-2, HEC-6, FLUVIAL-11, IALLUVIAL, QUASED, PIT, SETTLE
- . empirical sediment transport capacity equations
- . qualitative geomorphic assessments
- . hydrograph development techniques

In the preparation and submittal of permit applications for sand and gravel mining operations, it was estimated that approximately 70-80% of the applications were approved. The percentage approved increased with the operation's acceptance of modifications to the operating procedures or mining plan.

A.4 Interview Summary

As a follow-up to the questionnaire response, personal interviews were conducted with four regulatory agencies to solicit additional information relative to sand and gravel operations. The agencies interviewed include the Arizona Department of Transportation Structures Section, the Pima County Department of Transportation and Flood Control District, the Flood Control District of Maricopa County, and the City of Phoenix.

A.4.1 Interview Agenda

A brief synopsis of the general issues and trends identified from the questionnaire response (Section A.2.1) was presented to interviewees. Their input and feedback on these issues was then discussed. Additional information was requested on appropriate methodologies and technical procedures used in the analysis of the impact of sand and gravel operations on channel stability. The current status of regulation of mining operations at a federal, state, county, and local level was reviewed. The strong points and shortcomings of existing regulatory practices were evaluated. In addition, alternative approaches to regulation of sand and gravel operations were explored with attention to the appropriate means of administering and funding any recommended approach. The availability of technical data was discussed, especially in areas where damage has occurred in the past that was allegedly aggravated by the presence of sand and gravel operations. Data availability would impact the potential for use of these sites for case history studies. Finally, pertinent court cases, if any, within the area of jurisdiction of those interviewed were briefly reviewed.

A.4.2 Interview Response

A review of the questionnaire response indicated that very little information was received regarding specific technical procedures used in the analysis of in-stream pit impacts. Most respondents recognized that in-stream sand and gravel mining could impact channel stability, but few were able to provide details regarding appropriate methodologies for quantifying such impacts.

Those interviewed currently evaluate impacts on a case-by-case basis relying on various methodologies and engineering judgement. Two of those interviewed were cautious about relying solely on sediment routing model results and felt the regulations should allow for some simple, generalized guidelines and measures for use in analyzing sand and gravel mining impacts. The Flood Control District of Maricopa County (FCDMC) has relied on the use of design measures to mitigate impacts. Mitigation alternatives include: 1) low-flow side weirs or spillways which allow drowning of in-stream pits during periods of channel flow; 2) provisions for protection at the upstream side of a pit from headcutting by installing dumped or grouted riprap; and 3) conservative setbacks as an alternative to stabilization measures.

Those interviewed generally agreed there was a need to establish guidelines for proper use of analytical techniques and to implement a standardized approach so that consistency is maintained. Sand and gravel operators have been concerned that local board decisions have not been consistent nor based on adequate techniques. The need to develop criteria and guidelines addressing several specific areas was identified. These areas include:

- . appropriate flood events to use in sediment routing models
- . evaluation of annual sediment yield
- . determination of a profile line above which extraction is permitted
- . setback distances and development plans for overbank pits
- . guidelines for long-term sediment yield modeling
- . proper analysis techniques for determining the cumulative impacts of several adjacent pits on the overall system.

The interviewees support more comprehensive study on a river basin level to evaluate an overall river system rather than relying on site specific analyses which do not consider cumulative impacts. FCDMC is currently discussing the possibility of conducting several floodplain/environmental river system studies which might integrate well with river basin level studies of gravel mining impacts.

With regard to regulation, discussion centered on a workable regulatory approach to in-stream sand and gravel operations. A three-tier approach recommended by SLA was discussed with each of those interviewed and is summarized as follows:

1. Based on data to be collected by SLA during subsequent tasks of this research project, an effort will be made to develop regionalized envelope curves for major river basins within the State. Depending on the availability of data, these curves will be developed to provide guidelines relating pit depth to: 1) headcut length; 2) downstream degradation; 3) lateral migration distance; and 4) any other parameters that may be

deemed necessary. Although these envelope curves will be based on data specific to different river basins within the State, they will have to incorporate a degree of conservatism that will permit their application to any site within the region for which they were developed. The factor of safety that would have to be included under such a scheme may make the envelope curves very restrictive in terms of allowable excavation limits.

2. At the county/local level, general river basin studies would be recommended for basins within county/local jurisdiction in order to develop an "optimal red-line standard" defining both the lateral and vertical limits for sand and gravel mining. These guidelines, which would be less conservative and more site-specific than the envelope curves developed under Level 1, would define the extraction slopes, elevations, and width along the mining reach. These studies could be funded through a tax on sand and gravel extractions (levied on a per ton basis) or possibly, through State appropriations similar to those previously approved for flood control projects.
3. For those individuals who feel the envelope curves or "red-line" approach are too conservative, a third alternative would be available. This third level of this multi-tier approach would allow for a site specific engineering analysis to be performed at the sand and gravel operators' discretion and expense. This third level of analysis could be invoked in those cases where the sand and gravel operators feel the envelope curves and "optimal red-line standard" are unfairly restricting the volume of material that could potentially be excavated from a specific site. This third tier of analysis would provide a very detailed site-specific study of a pit. The objective of this study would be to provide technical documentation that would show the excavation limits established by the envelope curves or "optimal red-line standard" could be exceeded without causing damage to adjacent property.

With some reservations, those interviewed generally support the three-tier approach. At the present time, the regulatory approach at the county level is two-tiered using either conservative guidelines or detailed site specific studies. A middle ground, as represented by a "red-line standard", would help to reduce the number of site specific studies required.

The opinion of those interviewed was divided over the role of a State-level authority to monitor this program. It was recognized that a State-level authority would be needed to assist smaller counties (without the expertise in this field) by providing technical support and/or developing model ordinances.

However, one of those interviewed did not see a need for state-wide resource identification and there was some concern that a State-level regulation could serve to interfere with local decisions regarding mining operations. It was felt such interference would be to the detriment of the local community. To circumvent this issue, it was proposed that the regulatory control be maintained at the county level while allowing the incorporated cities and towns to assume the responsibility of regulation of mining activities. Similar to floodplain management responsibility under ARS Title 48, Section 3610, the cities or towns could opt to let the county flood control district assume the gravel mining regulatory function for them. Thus large cities with adequate technical staff could support this regulatory function themselves while the flood control districts could support small cities and towns.

Other issues of concern to those interviewed are summarized below:

- . FCDMC is concerned with the need to regulate in-stream gravel mining operations which are outside of official FEMA delineated floodplains. ARS Title 48 and the county floodplain ordinance do not cover these cases.
- . The Pima County Department of Transportation and Flood Control District (PCDOT & FCD) is concerned with adequate enforcement of operator compliance with permit stipulations. PCDOT & FCD recommends consideration be given to requiring assurance of compliance by the operators through bonds, etc.
- . "Grandfathering in" existing gravel mining operations can be problematic as to where to establish a cut-off point.
- . Consideration should be given to requiring rehabilitation and restoration of the site following the termination of a mining operation.
- . In general, current regulatory policy is not opposed to in-stream mining when there is a surplus in the sediment balance of the reach being mined. There is support for allowing the scalping of river bars and vegetation to restore channel conveyance. The use of sand and gravel mining as a channel clearing function is seen as beneficial, realizing there are possible long-term degradational impacts on the river being mined.

A.5 Damage Inventory

This section includes an inventory of damage to public or private property allegedly due to, or in part from, in-stream sand and gravel mining operations. This information was taken

from the questionnaires returned to SLA and is presented here for information purposes only. The respondents that provided this information do not indicate what proof, if any, has been developed to link the sand and gravel operations to the alleged damage. This information may be used as a source of data for case history studies that will be pursued in subsequent sections of this research project.

1. Gila River-damage to streets and adjacent lands in Goodyear, AZ
2. Salt River-I-10 bridge foundation (1979, 1980, 1981)
3. Agua Fria River-Indian School Road bridge failure (Feb., 1980)
4. Agua Fria River-Glendale Avenue crossing (Dec., 1978)
5. Agua Fria River-Rose Garden Lane crossing (Dec., 1978)
6. Agua Fria River-East overbank upstream of Northern Avenue crossing (Dec., 1978)
7. Verde River-I-17 bridge crossing
8. Verde River-Vicinity of Cottonwood, AZ, damage to downstream properties, destabilized banks, reduced riparian vegetation/biota
9. Verde River-upstream of Camp Verde, AZ
10. Santa Cruz River-Silverlake Road bridge pier exposure
11. Santa Cruz River-T13S, R12E, Sec. 1 and T12S, R12E, Sec. 35, capture of overbank pits resulting in increased channel width and lateral migration
12. Pantano Wash-increased lateral migration between Houghton Road and Rincon Creek (1983)
13. San Pedro River-impact upon fish and wildlife resources
14. Ehrenberg, AZ-some damming and ponding exacerbated damage due to flood of July 21, 1986
15. Cottonwood Wash-aggradation/degradation at SR77 bridge, Snowflake, AZ
16. Granite Creek-damage to U.S. Highway 89 bridge near Prescott, AZ
17. Kingman, AZ-exposure of utility line crossings in channel

A.6 Recommended River Segments

The following river segments were recommended for detailed study of in-stream sand and gravel mining operations:

1. Gila River-Gillespie Dam to Salt River confluence
2. Gila River-Salt River confluence to Coolidge Dam
3. Salt River-Gila River confluence to Granite Reef Dam
4. Agua Fria River-Salt River confluence to Waddell Dam
5. New River-Agua Fria River confluence to Maricopa-Yavapai County line
6. Hassayampa River-U.S. Highway 60-89 bridge to 1/2-mile upstream of bridge
7. Verde River-Salt River confluence to Paulden, AZ
8. Oak Creek-limits unspecified
9. Wet and Dry Beaver Creek-limits unspecified

10. Santa Cruz River-I-10 bridge (Martinez Hill) to Avra Valley Road
11. Rillito Creek-Santa Cruz River confluence to Craycroft Road
12. Pantano Wash-Tanque Verde Wash confluence to 5-6 miles upstream of Houghton Road
13. Santa Cruz River, Sonoita Creek, Potrero Creek, and Harshaw Creek-within Santa Cruz County (limits unspecified)
14. San Pedro River-Hereford to Winkelman, AZ
15. San Pedro River, Garden Canyon Wash, and Cayote Wash-immediately outside Sierra Vista city limits
16. Rye Creek-4 miles upstream to 4 miles downstream of SR87
17. Tyson Wash-5 miles upstream to 2 miles downstream of Quartzite, AZ
18. Ehrenberg, AZ-site of flooding of July 21, 1986 (limits unspecified)
19. Cottonwood Wash-between SR277 and SR77 bridges in Snowflake, AZ
20. Sols Wash-in vicinity of River Street, Wickenburg, AZ

QUESTIONNAIRE

Effects of In-Stream Mining on Channel Stability

Arizona Department of Transportation

Project Number HPR-PL-1-31(250)

Name of Agency: _____

Name of Respondent: _____

Area of Jurisdiction: _____

A. GENERAL

YES NO

1. Do you have in-stream sand and gravel mining operations within your jurisdiction? _____

2. Do you regulate in-stream sand and gravel mining operations? _____

3. If the answer to Question No. A.2 is yes, please answer the following questions.

a. What year did the regulatory program start? _____

b. How many permits have been issued....

- since the program started? _____

- in the last five years? _____

- in the last year? _____

c. How many gravel mining operations are currently active within your jurisdiction? _____

4. If you regulate in-stream sand and gravel mining, do you have written guidelines/policies? _____

If yes, please attach a copy of these guidelines/policies.

5. If you regulate in-stream sand and gravel mining, what kind of enforcement program do you have? _____

6. If you do not regulate in-stream sand and gravel mining, does any other agency have this responsibility in your jurisdiction? _____

If yes, please identify this agency and give the name of the person in charge. _____

7. If there is no regulation of in-stream sand and gravel mining in your jurisdiction, do you feel there should be regulation? _____

8. If a state-wide program were to be adopted to regulate in-stream sand and gravel mining, upon what criteria or factors should such a program be based? _____

9. Do you perceive that damage to public or private property has occurred due to, or in part from, in-stream sand and gravel mining operations? _____

If yes, please list cases and note when and where the damage took place. _____

10. What benefits to public or private property has accrued due to, or in part from, in-stream sand and gravel operations? _____

11. Has your agency been involved in litigation attributed

to any damage listed under Question A.9? _____

Was your agency the plaintiff or defendant? _____

Please state the status or outcome of the litigation and the name and date of the case. _____

B. DESIGN PRACTICE	YES	NO
--------------------	-----	----

1. Does your agency <u>design</u> , <u>regulate</u> , and/or <u>maintain</u> any in-stream (or floodplain) structures (e.g., bridges, utility crossings or alignments, flood control structures, etc.)? (Please <u>circle</u> which function(s) your agency performs.)	_____	_____
--	-------	-------

If yes, do you...

a. consider the effects of erosion/sedimentation (e.g., scour, lateral movement of the channel banks, sediment deposition, etc.) on the <u>design/regulation/maintenance</u> of these structures?	_____	_____
b. consider the effect of in-stream sand and gravel mining on the <u>design/regulation/maintenance</u> of these structures?	_____	_____

2. If the answer to Question B.1.b. is yes, please answer the following questions. Do you base structure design requirements on the following gravel pit characteristics:		
---	--	--

a. Pit depth?	_____	_____
b. Distance from gravel pit to structure?	_____	_____
c. Pit side-slopes?	_____	_____
d. Other? _____		

3. If the answer to any part of Question B.2. is yes, please state or include the design methods used. Please list and name the source of information from which these methods were developed (e.g., computer programs, design manuals, agency reports, research reports, collected data,		
---	--	--

in-house analysis, etc.) _____

C. INFORMATION

YES

NO

1. Do you know of any data or reports that would be helpful to this research project?

If yes, please provide a copy of the data or a citation for the reports. _____

2. Would you recommend any Arizona river segments in your area of jurisdiction be included in a detailed study of in-stream sand and gravel mining operations?

If yes, please list recommended river segments. Note segment location (approximate starting and ending points) and provide a brief description of river features and gravel mining effects that prompt you to recommend this river. _____

- D. ADDITIONAL COMMENTS. Please note below any additional comments which you feel are relevant to this study. (Please feel free to use attachments, if necessary). _____

Effects of In-Stream Mining on Channel Stability

Arizona Department of Transportation

Project Number HPR-PL-1-31(250)

Name of Company: _____

Name of Respondent: _____

A. RESOURCE INFORMATION

1. Please complete Table 1 (attached) for sand and gravel mining operations that you have conducted from pits located within a floodplain¹ in the State of Arizona during the past five years.
2. Considering product demand and resource areas available to your company, please complete Table 2 and estimate your company's future annual production from pits within a floodplain¹ for the next five years.

TABLE 2. ESTIMATED FUTURE ANNUAL PRODUCTION

Facility Number	Years From Present				
	1	2	3	4	5

¹ This refers to areas within the designated flood hazard boundary area as defined on a flood hazard boundary map issued by the Federal Emergency Management Agency.

B. REGULATORY COMPLIANCE

1. List the local, state and/or federal agencies to which your company has submitted permit applications for in-stream sand and gravel mining as related to floodplain locations in Arizona.

2. Please indicate (without reference to specific permit submittals) the average length of time (in months) required for the regulatory agency to process a permit application submitted by your company. (That is, the time from the date the permit was submitted to the date the permit was either granted or denied.) Also, indicate the minimum and maximum length of time that was required to process a permit application.

3. Based on your companies experience, please estimate the average total cost (survey, engineering, testing, etc.) required to complete a permit application. Also, estimate the maximum and minimum cost for submitting permit applications.

4. What are the major factors that lead to different costs for submitting permits? (circle applicable factors)
- a. Operation location to in-stream structures (e.g., bridges)
 - b. Operation size (pit volume, depth, etc.)
 - c. River characteristics
 - d. Varying requirements of different regulatory agencies
 - e. Public comment
 - d. Other factors (please list)

5. How many permit applications have you submitted? _____

a. How many were approved? _____

How many were denied? _____

b. To the best of your knowledge, state the reasons for permit denial. _____

6. Has your firm been involved in litigation attributed to effects of sand and gravel mining on in-stream or floodplain structures? YES ___ NO ___

Was your firm the plaintiff or the defendant? _____

Please state the status or outcome of the litigation, and the name and date of the case. _____

7. If a state-wide program were to be adopted to regulate in-stream sand and gravel mining, upon what criteria or factors should such a program be based? _____

8. Based on your experience, what benefits do in-stream gravel mining operations offer? _____

C. DESIGN PRACTICE YES NO

1. Does your company design/analyze in-stream sand and gravel mining facilities using your own engineering staff? _____ _____

If your own engineering staff is used, please answer the following questions.

a. What are the design criteria you use to assess effects of mining on channel stability (e.g., sediment supply, pit volume, pit shape, trap efficiency, location with respect to bridges or utilities, etc.)? _____

b. Do you use specific design procedures in the analysis of a sand and gravel pit operation to assess channel stability? _____ _____

If yes, please cite the source of these procedures (e.g., computer programs, design manuals, reports, articles, etc.). _____

c. Based on your experience, what factors or parameters related to channel stability are the most difficult

to evaluate in the analysis of sand and gravel
mining facilities? _____

D. GENERAL INFORMATION

YES

NO

1. Do you know of any data or reports that would be helpful to this research project?

If yes, please provide references to where this information could be obtained. _____

2. Would you recommend any Arizona river segments that should be included as a detailed study of in-stream sand and gravel mining operations?

If yes, please list recommended river segments. Note segment location (approximate starting and ending points) and provide a brief description of river features and gravel mining effects that prompt you to recommend this river segment. _____

- D. ADDITIONAL COMMENTS. Please note below any additional comments which you feel are relevant to this study. (Please feel free to use attachments, if necessary.) _____
- _____

QUESTIONNAIRE

Effects of In-Stream Mining on Channel Stability

Arizona Department of Transportation

Project Number HPR-PL-1-31(250)

Name of Firm: _____

Name of Respondent: _____

A. DESIGN PRACTICE YES NO

1. Has your firm designed and/or analyzed in-stream sand and gravel mining facilities? _____ _____

If yes, please answer the following questions.

a. What are the design criteria you use to assess effects of mining on channel stability (e.g., sediment supply, pit volume, pit shape, trap efficiency, location with respect to bridges or utilities, etc.)? _____

b. Do you use specific design procedures in the analysis of a sand and gravel pit operation to assess channel stability? _____ _____

If yes, please list and name the source of these procedures (e.g., computer programs, design manuals, reports, articles, etc.). _____

2. Do you consider the effect of in-stream sand and gravel mining during the design of in-stream structures (e.g., bridges, utility crossings or alignments, channel stabilization works, etc.)? _____ _____

If yes, please answer the following questions.

a. What are the design criteria you use to assess

potential effects of mining on the structure
(e.g., distance of the pit from the structure)? _____

- b. Do you use specific analysis procedures in the design of a structure to assess potential problems related to in-stream mining? _____

If yes, please list and name the source of these procedures (e.g., computer programs, design manuals, reports, articles, etc.). _____

- c. Based on your experience, what are the major hazards to in-stream structures caused by the presence of sand and gravel operations? Please note which of these hazards are the most difficult to accurately assess during design. _____

- d. Based on your experience, what are the major benefits from in-stream sand and gravel mining operations. _____

3. Has your firm been involved in litigation attributed to effects of sand and gravel mining on in-stream structures? _____

Was your firm representing the plaintiff or the defendant? _____

Please state the status or outcome of the litigation, and the name and date of the case. _____

B. REGULATORY COMPLIANCE YES NO

1. Has your firm prepared permit application information for in-stream sand and gravel mining operations? _____

If yes, please answer the following questions.

a. Please list the agency(s) to which the permit submittal(s) was(were) made and the approximate date of the submittal(s). _____

b. Based on your experience, please estimate the total cost (your fee, subcontracted services, testing, etc.) required to complete permit application preparation for the following size sand and gravel mining operations in Arizona.

100,000 cu yd or less _____

500,000 cu yd or less _____

1,000,000 cu yd or less _____

5,000,000 cu yd or less _____

Greater than 5,000,000 cu yd _____

c. Please indicate (without naming specific cases) the length of time (in months) from the date the permit was submitted to the date the permit was either granted or denied. _____

d. Please indicate (approximately) the percentage of permit applications approved and the percent denied. _____

e. Please list the reasons why permits were denied. _____

2. Has your firm provided permit application review services of in-stream sand and gravel mining operations to a local, state, or federal agency? _____

If yes, please answer the following questions.

a. Please list agencies for which you have provided review services and give the total number of reviews that your firm has conducted. _____

b. In what percent of the cases, as a part of the review process, did you conduct a separate analysis of the potential impacts on in-stream mining on channel stability in addition to the analysis submitted by the applicant? _____

c. What was the average length of time required to conduct your review? _____

What was the longest and shortest period of time required?

C. GENERAL INFORMATION

YES

NO

1. Do you know of any data or reports that would be helpful to this research project?

If yes, please provide references as to where this information could be obtained. _____

2. Would you recommend any Arizona river segments that should be included as a detailed study of in-stream sand and gravel mining operations?

If yes, please list recommended river segments. Note segment location (approximate starting and ending points) and provide a brief description of river features and gravel mining effects that prompt you to recommend this river segment. _____

- D. ADDITIONAL COMMENTS. Please note below any additional comments which you feel are relevant to this study. (Please feel free to use attachments, if necessary). _____

APPENDIX B. SUMMARY OF GRAVEL MINING AND SEDIMENT TRANSPORT STUDIES ON MAJOR ARIZONA RIVERS

Previous studies on Arizona river systems provide a valuable source of data for the river-basin classification work. Such studies are also useful in identifying and evaluating different engineering methodologies that have previously been used to conduct analyses of in-stream gravel mining operations.

In order to locate such studies, the questionnaires that were sent to regulatory agencies, consulting engineers, and gravel mining companies (see Appendix A) included a request for data or reports that the questionnaire recipients thought would be pertinent to this research project. Unfortunately, the response to this category of requested information was minimal. Accordingly, SLA had to rely heavily on previous sediment transport, hydraulic, and gravel mining studies prepared by SLA. This accounts for the large number of SLA reports referenced in this section.

Studies selected for inclusion in this chapter were based on their relation to major Arizona river systems that have a high potential for in-stream sand and gravel mining. The data that has been collected relative to previous studies is summarized according to two categories:

- . In-Stream Sand and Gravel Mining Studies
- . Hydraulic/Sediment Transport Studies

Each of the following studies is described by: 1) name; 2) location; 3) date; 4) consultant preparing study; 5) name of client; 6) synopsis of results; and 7) list of computer models used in the study.

B.1 In-Stream Sand & Gravel Mining Studies

1. Analysis of Effects of Sand & Gravel Mining Activities on the Stability of the Oracle Highway Bridge
Location : Rillito River, Tucson, Arizona
Date : January 1981
Consultant : Simons, Li & Associates, Inc.
Client : Pima County Department of Transportation & Flood Control District
Synopsis : Study identified and examined causes of past, present, and future degradation and/or aggradation at the Oracle Highway bridge and, in particular, examined the effects of gravel mining activities on the stability of the bridge.
Computer Models: HEC-2, PIT
2. Impact of Gravel Mining on the Proposed Salt River Channelization Project

Location : Salt River, Phoenix, Arizona
Date : November 1980
Consultant : Anderson-Nichols & Colorado State University
Client : U.S. Army Corps of Engineers, Sacramento District
Synopsis : A physical model was constructed to simulate the impact of in-stream gravel pits on the stability of a proposed channelization scheme for the Salt River from I-10 to Sky Harbor Airport. The model results were used to develop guidelines to implement proper control of these mining operations to avoid adverse impacts.
Computer Models: None.

3. Sand and Gravel Mining Guidelines

Location : Salt and Gila Rivers, Maricopa County
Date : July 1980
Consultant : Boyle Engineering Corporation
Client : U.S. Army Corps of Engineers, Los Angeles District
Synopsis : Develops guidelines for sand and gravel extraction from the Salt and Gila Rivers in order that such guidelines might be used to reduce flood damages associated with in-stream mining. The report discusses hydraulic and erosion processes associated with such operations and outlines mitigation measures to minimize adverse impacts on the river system.

4. An Evaluation of Effects of Excavations in the Vicinity of the I-10 Salt River Bridge on the Flow Regime and Local Scour at the Bridge

Location : Salt River, Phoenix, Arizona
Date : December 1980
Consultant : W.R. Bruesch, Arizona Department of Transportation
Client : Arizona Department of Transportation
Synopsis : Presents an extensive photo-documentary on the changes in river regime near the I-10 bridge. These photos illustrate changes in flow patterns resulting from man's activities in and adjacent to the river channel. A subjective evaluation of the effects of changes in the flow regime on local scour at the bridge is also presented.
Computer Models: None.

5. Hydraulic and Geomorphic Analysis and Mine Plan Study for the Blue Circle Arizona, Inc. Pantano Wash Lease Site

Location : Pantano Wash, Pima County, Arizona
Date : January 1986
Consultant : Simons, Li & Associates, Inc.
Client : Blue Circle Arizona, Inc.
Synopsis : This study was a hydraulic and geomorphic analysis to assess the feasibility of developing a 200-acre sand and gravel mining operation along Pantano Wash. The study resulted in a mining plan that included measures to mitigate adverse impacts to the river system.

Computer Models: HEC-2, QUASED

6. Engineering Analysis of In-Stream Gravel Extraction From the Agua Fria River, Vicinity of Indian School Road and Camelback Road

Location : Agua Fria River, Phoenix, Arizona
Date : September 1985
Consultant : Simons, Li & Associates, Inc.
Client : Flood Control District of Maricopa County
Synopsis : This study presents a detailed analysis of river system impacts that would be expected to accompany the proposed excavation of two large gravel pits on either side of the Indian School Road Bridge. The analysis addresses both short- and long-term impacts that would be expected upstream and downstream of the proposed pits. The report is based on a head-cut and trap efficiency analysis of the two pits as well as a sediment routing model which was used to predict a downstream degradation profile of the riverbed.

Computer Models: HEC-2, QUASED, SETTLE

7. Development of Qualitative Guidelines for Sand and Gravel Mining in Salt, Gila and Agua Fria Rivers

Location : Salt, Gila and Agua Fria Rivers, Maricopa County, Arizona
Date : June 1980
Consultant : Simons, Li & Associates, Inc.
Client : Boyle Engineering Corporation
Synopsis : This study focuses on the following objectives: (1) explain physical processes governing mechanics of the gravel pit during low, medium and high flows, considering both headcutting upstream and degradation downstream of the pit, along with the significance of the depth, size and volume of the pit; (2) provide a typical example of a simulation run of real-time response for an assumed storm hydrograph and a hypothetical gravel pit; (3) suggest a qualitative guide for sand and

gravel extraction in the Salt, Gila and Agua Fria Rivers; and (4) recommend a study plan for developing a quantitative guide for sand and gravel extraction in the Salt River as a function of sediment supply and transporting capacity of the river.

Computer Models: None.

8. Preliminary Engineering Analysis of In-Stream Sand and Gravel Extraction From Three Sites on the Salt River

Location : 67th Avenue, 48th Street, and Indian Bend Wash Confluence, Salt River, Maricopa County, Arizona
Date : November 1985
Consultant : Simons, Li & Associates, Inc.
Client : The Tanner Companies
Synopsis : An engineering investigation was made of three potential in-stream gravel pit locations on the Salt River in order to identify any utility conflicts and river mechanics problems that might restrict the excavation limits at each site. The report utilizes data from a physical-model study on the Salt River to: 1) establish recommended excavation limits (vertically and horizontally); and 2) to determine the maximum permissible yield from each pit.

Computer Models: None.

9. Sand and Gravel Mining Feasibility Study for The Tanner Companies - Los Reales/Pantano Wash Site

Location : Pantano Wash, Pima County, Arizona
Date : February 1986
Consultant : Simons, Li & Associates, Inc.
Client : The Tanner Companies
Synopsis : This report presents the results of a hydraulic and geomorphic analysis to assess the feasibility of realigning a one-mile section of Pantano Wash to allow for expansion of an existing gravel pit. Bank protection and erosion buffer zones were recommended as mitigation measures to prevent adverse river system impacts that might result from the proposed pit expansion.

Computer Models: HEC-2, QUASED

10. Erosion and Sedimentation Analysis of Columbia Pit and San Xavier Pit in the Santa Cruz River, Tucson, Arizona

Location : Santa Cruz River, Tucson, Arizona
Date : 1980
Consultant : Simons, Li & Associates, Inc.
Client : Cella, Barr, Evans and Associates

Synopsis : This report presents an analysis of the hydrologic, long-term geomorphic, hydraulic, and erosion and sedimentation processes for the river system. Aerial photographs and hydrologic records were used to determine gradual changes in the channel alignment and configuration that were occurring in the Santa Cruz River through the study areas. The response of both the river and the gravel pits during a 100-year flood was analyzed for a variety of possible gravel pit configurations and management schemes by using a water and sediment routing procedure developed by Simons and Li (1979). The long-term changes in the system and the changes resulting from a severe event (a 100-year flood) were used to make recommendations for engineering control measures for preventing any harmful interaction between the gravel pits and the Santa Cruz River.

Computer Models: HEC-2, PIT

11. Study of Gravel Mining Impacts, Verde River at Cottonwood, Arizona

Location : Verde River at Cottonwood, Arizona
Date : May 1985
Consultant : Simons, Li & Associates, Inc.
Client : Yavapai County Flood Control District
Synopsis : This study presents an engineering analysis of river system impacts associated with in-stream gravel mining on the Verde River at Cottonwood. The analysis was specifically structured to address head-cutting upstream of the gravel pit, bank erosion, shifting of the channel alignment, and downstream channel degradation. Extensive use was made of historical aerial and ground photographs, historical bed profiles and hydrologic data.

Computer Models: HEC-2, MPM

12. Engineering Analysis to Establish Excavation Limits for In-Stream Extraction of Sand and Gravel Between 51st Avenue and 59th Avenue on the Salt River

Location : Salt River, Maricopa County, Arizona
Date : January 1986
Consultant : Simons, Li & Associates, Inc.
Client : Arizona Crushing Company
Synopsis : This report presents the development of an excavation plan for extracting sand and gravel from a specific reach of the Salt River floodplain. Excavation limits, both

vertical and horizontal, were developed to reduce the potential for creating a river system response, which would have a high probability of causing damage to nearby utility lines and a major bridge structure.

Specifically, the study addressed potential damage that might result from pit-induced headcutting, downstream scour, and lateral erosion. Using physical model study data developed by the principals of SLA, excavation limits for pit depths of 20 feet, 40 feet, and 60 feet were established for the site. The excavation limits were offset a sufficient distance inside the property boundaries so as to minimize offsite erosion and scour damage. Approximate excavation volumes were then computed in order that a determination could be made of the feasibility for commercial sand and gravel extraction at the site.

Computer Models: None.

13. (Exact title unknown, information provided by the Pima County Department of Transportation and Flood Control District)
- | | | |
|------------|---|--|
| Location | : | Santa Cruz River, Pima County, Arizona |
| Date | : | 1975 |
| Consultant | : | Cella, Barr, Evans & Associates, Inc. |
| Client | : | Granite Construction Company |
| Synopsis | : | This study examined a proposal to modify the river channel near the approach to an existing bridge. The excavation was to be done by Granite Construction Company. |

Computer Models: HEC-2

14. (Exact title unknown, information provided by the Pima County Department of Transportation and Flood Control District)
- | | | |
|------------|---|--|
| Location | : | Santa Cruz River, Pima County, Arizona |
| Date | : | 1981 |
| Consultant | : | Dooley-Jones & Associates, Inc. |
| Client | : | San Xavier Rock and Materials |
| Synopsis | : | This study presented a mining plan for sand and gravel extraction from the over-bank of the river. Forms of bank protection were investigated. |

Computer Models: HEC-2

15. (Exact title unknown, information provided by the Pima County Department of Transportation and Flood Control District)

Location : Rillito River, Pima County, Arizona
Date : 1978
Consultant : Cella, Barr, Evans & Associates, Inc.
Client : Pueblo Pebbles
Synopsis : This report was prepared to determine safe setback limits for a sand and gravel mining operation in the overbank of the Rillito River.

Computer Models: HEC-2

16. (Exact title unknown, information provided by the Pima County Department of Transportation and Flood Control District)

Location : Rillito River, Pima County, Arizona
Date : 1984
Consultant : Cella, Barr, Evans & Associates, Inc.
Client : Pueblo Pebbles
Synopsis : The gravel mining limits recommended in the 1978 study were exceeded. This new study presents additional engineering analyses required to justify further excavation.

Computer Models: HEC-2

17. (Exact title unknown, information provided by the Pima County Department of Transportation and Flood Control District)

Location : Pima County, Arizona
Date : 1986
Consultant : CMG Drainage
Client : Blue Circle
Synopsis : This study presents the results of a seepage analysis, river cross-sections, and historical photos that were used to determine a safe setback limit for an overbank sand and gravel operation.

Computer Models: None.

18. (Toby Allen-Pantano Wash - exact title unknown, information provided by the Pima County Department of Transportation and Flood Control District)

Location : Pantano Wash, Pima County, Arizona
Date : 1986
Consultant : Dooley-Jones & Associates, Inc.
Client : Toby Allen
Synopsis : Analysis of in-stream sand and gravel extraction. Details are unknown.

Computer Models: HEC-2, HEC-6, FLUVIAL 2

B.2 Hydraulic/Sediment Transport Studies

1. Santa Cruz River Mechanics Study - Rillito Creek to Cortaro Road

Location : Santa Cruz River, Pima County, Arizona
Date : September 1985
Consultant : Simons, Li & Associates, Inc.
Client : Tucson Sand and Soil, Inc.
Synopsis : This study was a hydraulic and geomorphic analysis conducted to assess the impact of channelization and realignment of the Santa Cruz River between the Rillito River confluence and Cortaro Road. Also contained within the plan was a proposal to widen the Santa Cruz River at the confluence with the Canada del Oro Wash to a width of approximately 1250 feet for the purpose of inducing sediment deposition in order to provide a source of mineable sand and gravel material. The objectives of this plan were to advance the economical development of the property as a sand and gravel mining operation, and to prevent future floods from causing additional bank erosion and lateral migration of the channel which has historically resulted in significant damage to private and public properties within the project area.

Computer Models: HEC-2, QUASED

2. Hydraulic, Erosion and Sedimentation Analysis of Indian School Road Bridge Over the Agua Fria River

Location : Agua Fria River, Maricopa County, Arizona
Date : 1982
Consultant : Simons, Li & Associates, Inc.
Client : Flood Control District of Maricopa County
Synopsis : This study addresses the failure of the Indian School Road Bridge during the February 20, 1980 flood on the Agua Fria River and investigates stability measures to prevent a recurrence of the failure.

The three-level analysis applied to the ISRB failure included: (1) a qualitative geomorphic analysis; (2) a quantitative engineering geomorphic analysis; and (3) an application of a mathematical model to evaluate the potential local scour, general regional scour, and potential aggradation/degradation at the ISRB and the RID flume crossing. The results of the three-level analysis were used in a litigation suit involving nearby gravel mining com-

panies and were also used to develop mitigation measures to prevent future damage.
Computer Models: HEC-2, QUASED

3. Hydraulic and Scour Analysis of Salt River Bridge at Phoenix-Casa Grande Highway for Long-Term Protection Against Scour

Location : Salt River, Phoenix, Arizona
Date : 1980
Consultant : Simons, Li & Associates, Inc.
Client : Dames and Moore
Synopsis : Excessive scour caused settlement of the I-10 bridge piers during the February 1980 flood. This report analyzes the susceptibility of the pier foundations to scouring during future floods in order to evaluate alternative structural and/or nonstructural methods that could be used to protect the piers from such scouring. Structural alternatives that were analyzed include: (1) channelization using guidebanks; (2) a downstream grade control structure; and (3) control of side drainage flows. Nonstructural measures include: (1) control of gravel mining; and (2) operation of upstream reservoirs to regulate flow.

Computer Models: QUASED

4. Analysis and Design Study of the Agua Fria River

Location : Agua Fria River, Maricopa County, Arizona
Date : November 1983
Consultant : Simons, Li & Associates, Inc.
Client : Flood Control District of Maricopa County
Synopsis : A hydrologic, hydraulic, erosion and sedimentation study was completed for a nine-mile reach of the Agua Fria River from the confluence with the Gila River to the confluence with the New River. This investigation utilized a three-level approach which included: (1) a qualitative geomorphic analysis; (2) a quantitative engineering geomorphic analysis; and (3) a mathematical model simulation. The results of this analysis were used to design a channelization project for the Agua Fria River.

Computer Models: HEC-2, QUASED

5. Sediment Transport Analysis of Rillito River and Tributaries for the Tucson Urban Study

Location : Rillito River, Pantano Wash, Tanque Verde Creek, Sabino Creek, and Agua Caliente Wash, Tucson, Arizona

Date : February 1982
 Consultant : Simons, Li & Associates, Inc.
 Client : Pima County Department of Transportation and Flood Control District
 Synopsis : A sediment transport analysis was conducted for approximately 45 miles of various river systems in the Tucson area in order to determine the potential for aggradation and degradation associated with the 10-year and 100-year floods. This information was used to help manage the watersheds and river systems in order to minimize the potential for adverse impacts resulting from development activity.
 Computer Models: HEC-2, QUASED

6. Hydraulic and Geomorphic Analysis of the Proposed New Tanque Verde Road Bridge Over the Tanque Verde Creek

Location : Tanque Verde Creek, Tucson, Arizona
 Date : 1981
 Consultant : Simons, Li & Associates, Inc.
 Client : Pima County Department of Transportation and Flood Control District
 Synopsis : This report presents an engineering-geomorphic assessment (erosion/sedimentation) of the long-term bridge and river stability for a bridge that would pass a 100-year flood, versus a bridge that would pass a lesser flood. Hydraulic modeling investigated various bridge lengths and corresponding channel improvements. Environmental concerns for long-term river stability were also addressed.
 Computer Models: HEC-2, QUASED

7. Sediment and Debris Transport Analysis at Eight Bridge Locations, Tucson, Arizona

Location : Magee Road, Thornydale Road, Ina Road, Craycroft Road, Sabino Canyon Road, Swan Road, Tanque Verde Road, and La Canada Drive, Tucson, Arizona
 Date : 1981
 Consultant : Simons, Li & Associates, Inc.
 Client : Pima County Department of Transportation and Flood Control Division
 Synopsis : This debris and sediment transport analysis developed information to: (1) evaluate the stability of the bridge structures; (2) determine the lateral-migration tendencies of the channel; (3) estimate the extent of expected general downstream channel scour; (4) determine the potential local scour around bridge piers

and abutments; and (5) estimate the long-term effects of sediment degradation and aggradation on the water-surface profile. The potential problems associated with vegetative debris were also studied, particularly in relation to possible partial blockage of the channel and increased local scour at the bridge sites.

Computer Models: HEC-2, QUASED

8. Scour/Migration Analysis of the Rillito River at Pontatoc Road

Location : Rillito River, Tucson, Arizona
Date : 1984
Consultant : Simons, Li & Associates, Inc.
Client : Brown and Caldwell Consulting Engineers
Synopsis : This study presents the results of a hydraulic and geomorphic analysis that was performed to determine the river response to a 10-, 25-, 50-, and 100-year flood. The analysis considered responses during previous floods for comparison with the quantitative responses which were estimated using locally accepted procedures.

Computer Models: HEC-2, QUASED

9. Hydraulic and sedimentation Analysis of the 7th Street Bridge over the Salt River

Location : Salt River, Phoenix, Arizona
Date : April 1981
Consultant : Simons, Li & Associates, Inc.
Client : RGA Consulting Engineers
Synopsis : This report presents the results of a sediment transport and scour analysis that was used to determine hydraulic bridge design parameters as a function of existing river conditions and a proposed channelization scheme. A three-level approach was used which included: (1) a qualitative geomorphic analysis; (2) a quantitative engineering geomorphic analysis; and (3) a physical process model.

Computer Models: HEC-2, QUASED

10. Scour and Sedimentation Analysis of the Proposed Channelization of the Salt River for Protecting the Sky Harbor international Airport

Location : Salt River, Phoenix, Arizona
Date : 1980
Consultant : Simons, Li & Associates, Inc.
Client : Howard Needles Tammen and Bergendoff
Synopsis : Past floods caused significant damage to the Sky Harbor International Airport. The main runway was so severely damaged that

2400 feet of its length was unusable. As a result, a \$10 million channelization project to protect the airport from a 100-year flood was formulated. Simons, Li & Associates, Inc. performed an analysis of the scour and sedimentation processes associated with the selected channelization alternative. The study considered the 100-year design event.

The investigation was carried out utilizing three levels: (1) a qualitative geomorphic analysis; (2) a quantitative engineering geomorphic analysis; and (3) a physical process model. The results of the analysis were used to provide recommendations to modify the proposed channelization scheme to prevent failure due to scour and sedimentation problems.

Computer Models: HEC-2, QUASED

11. River Response Analysis Associated With Rio Nuevo-Santa Cruz River Flood Control and Channelization Project

Location : Santa Cruz River, Tucson, Arizona
Date : 1981
Consultant : Simons, Li & Associates, Inc.
Client : Cella, Barr, Evans & Associates
Synopsis : Using a HEC-2 model prepared by Cella, Barr, Evans & Associates, SLA performed a three-level analysis to assess erosion and sedimentation problems which included qualitative geomorphic, engineering geomorphic and physical process model analyses. This information was used to answer questions regarding short-term and long-term responses to different flood events. The study concluded with an analysis of several design alternatives for bank protection.

Computer Models: HEC-2, QUASED

12. Canada del Oro Flood Control Project (Oro Valley), Arizona

Location : Canada del Oro Wash, Oro Valley, Arizona
Date : 1981
Consultant : Simons, Li & Associates, Inc.
Client : Arizona Department of Water Resources
Synopsis : This reconnaissance-level report addressed the flooding problems along a two-mile reach of the Canada del Oro Wash in the vicinity of the town of Oro Valley in Pima County, Arizona. The study involved: (1) review of existing hydrologic, hydraulic, erosion, and sedimentation information; (2) determination of existing and potential flooding problems in the study reach;

(3) evaluation of potential erosion and sedimentation problems using a sediment routing model; (4) formulation of flood control alternative plans; and (5) evaluation of alternative plans considering operation and maintenance, environmental factors, and economics.

Computer Models: HEC-2, QUASED

13. Sediment Transport Report for the New River and Skunk Creek

Location : New River and Skunk Creek, Maricopa County, Arizona
Date : January 1985
Consultant : Simons, Li & Associates, Inc.
Client : U.S. Army Corps of Engineers, Los Angeles District
Synopsis : In order to evaluate the impact of rapid urbanization and commercial/industrial development within the New River/Skunk Creek watersheds, the Corps of Engineers retained Simons, Li & Associates, Inc. (SLA) to prepare a comprehensive hydraulic/sediment transport/flood control study for nine miles of the New River (upstream of the confluence with the Agua Fria River) and three miles of Skunk Creek (upstream of its confluence with New River).

The study involved three levels of analysis: (1) qualitative geomorphic; (2) quantitative geomorphic; and (3) sediment routing. Existing conditions were first investigated in order to determine specific problem areas within the river systems. A flood control solution, prescribed by the Corps of Engineers, was then evaluated using a sediment routing model developed by SLA.

Computer Models: HEC-2, QUASED

14. Excavation Plan/Salt River Southbank Project

Location : Salt River, Phoenix, Arizona
Date : January 1986
Consultant : Born, Barrett & Associates
Client : DENRO LTD. DEVELOPERS
Synopsis : The information provided on this project by the City of Phoenix consisted of plan/profile sheets and river cross-sections which depict a river excavation and levee plan extending from the I-10 bridge to about 36th Street. The analysis consists of HEC-2 runs showing "before" and "after" hydraulic conditions in the river.

Computer Models: HEC-2

15. Hydraulic Analysis for Salt River Between 19th Avenue and 35th Avenue

Location : Salt River, Phoenix, Arizona
Date : October 1986
Consultant : Water Resources Associates
Client : Harding Greene, Ltd.
Synopsis : This report presents a hydraulic analysis of a river channelization scheme that was investigated as part of a plan to install a conveyor bridge across the Salt River. A scour analysis was also performed to determine the scour depth for the piers supporting the conveyor bridge.

Computer Models: HEC-2

16. River Mechanics and Floodplain Analysis, Phase 1, East Papago Extension-SR217, Hohokam Expressway Extension-SR143

Location : Salt River, Phoenix/Tempe, Arizona
Date : June 1986
Consultant : Simons, Li & Associates, Inc.
Client : John Carollo Engineers
Synopsis : This is the first of a three-phase study which will determine design parameters for the East Papago/Hohokam Freeway alignments that encroach into the Salt River floodplain. The Phase 1 report presents a preliminary examination of river system impacts associated with these alignments and investigates mitigation measures (including major river channelization) that would protect the freeway system from flood damage. Increased scour effects around existing bridge piers are also examined. Subsequent phases of this study will provide a historical geomorphic analysis of the river and will include the development of a sediment routing model for this reach of the Salt River.

Computer Models: HEC-2, QUASED

APPENDIX C. REVIEW OF LITIGATION RELATED TO IN-STREAM MINING

A review of litigation related to in-stream sand and gravel mining was performed in order to determine the general magnitude of this type of litigation and to investigate the factors that lead to such litigation. The following is a partial listing of pertinent court cases. This information has been gathered by SLA staff through review of news articles and verbal discussions with people associated with the cases.

- A. Maricopa County Superior Court, Cause #C453677
Maricopa County and Roosevelt Irrigation District v. Allied Concrete, et. al.

Location: Agua Fria River downstream of Indian School Road Bridge, Phoenix, Arizona

Sand and gravel mining operations encroached into the river channel downstream of the Indian School Road Bridge and upstream of the Roosevelt Irrigation District (RID) canal flume. The in-stream gravel pits necessitated the construction of dikes to prevent inundation of these operations during periods of flow, thereby restricting the channel opening to approximately 500 feet. The Indian School Road Bridge failed during the flood of February 1980. The RID flume did not fail; however, significant degradation did occur at this location.

The County prevailed in an out-of-court settlement. The objective of the settlement was to return the river channel to a "natural state". The defendants agreed to 1) provide funds which would be used to channelize and stabilize the river at this location and 2) deed ownership of the river bottom over to the County.

- B. Agua Fria River Materials v. Allied Concrete

Location: Agua Fria River downstream of Indian School Road Bridge, Phoenix, Arizona

Sand and gravel mining operations encroached into the river channel downstream of the Indian School Road Bridge. Property owned by the plaintiff was located downstream of the sand and gravel operation owned by the defendant. The plaintiff's property was inundated during the February 1980 flood, allegedly as a result of the upstream mining operation.

The defendant settled out of court.

- C. Kane, Talent v. Maricopa County, United Metro

Location: Agua Fria River upstream of Glendale Avenue Bridge, Phoenix, Arizona

The Maricopa County Highway Department had constructed a bridge over the low-flow channel at Glendale Avenue. The approaches to the bridge consisted of fill which encroached into the floodplain. An in-stream sand and gravel mining operation was located upstream of the Glendale Avenue Bridge. The plaintiff owned a business located in the floodplain upstream of the approach roadway. The plaintiff's property was inundated during the flood of December 1978, allegedly due to the combined effect of flow diversions from the upstream sand and gravel operation and backwater caused by the roadway approaches and a restricted bridge opening.

The plaintiff prevailed in an out-of-court settlement.

D. City of Phoenix v. Union Rock & Materials

Location: Salt River at the Central Avenue Bridge, Phoenix, Arizona

A gravel pit was located at the northwest corner of the bridge and another mining operation was located upstream of the bridge on the south side of the river channel. The flood of December 31, 1965 damaged the bridge causing failure of a pier.

A negotiated settlement was reached restricting the limits of sand and gravel mining in the vicinity of the bridge.

E. Yavapai County v. Valley Concrete & Materials, Inc.

Location: Verde River in the vicinity of Cottonwood, AZ

During recent years, increased gravel mining activity by the defendant in the Verde River floodplain upstream of the roadway crossing to Dead Horse Ranch State Park caused the plaintiff concern over river system changes allegedly related to the extraction of sand and gravel. This concern focused primarily on increased bank erosion, the shifting of the low-flow channel alignment, downstream channel degradation, and environmental damage to the riverbanks.

Following the flood of October 1983, the plaintiff filed a suit and a criminal charge against the defendant for diverting the course of the river. The criminal charge was dropped before going to court when the parties reached an agreement to implement, on a specified schedule, a bank stabilization plan to mitigate the damage. When it was ascertained that the defendant was not proceeding on schedule with the agreed upon mitigation plan, the plaintiff revoked the defendant's operating permit and secured a Temporary Restraining Order (TRO) from the court. The TRO was later overturned when the court decided that it was not

convinced that the defendant's sand and gravel operation was the sole source of downstream property damage. The issue of damages is still to be heard.

F. Arizona State Land Department v. Valley Concrete & Materials, Inc.

Location: Verde River in the vicinity of Cottonwood, AZ

The plaintiff owns the Dead Horse Ranch State Park located downstream of the defendant's sand and gravel operation on the Verde River. During the flood of October 1983, environmental damage occurred at the park site. The plaintiff has filed a suit seeking monetary damages. The issue of ownership of the river bottom is also being tested. The plaintiff seeks sovereign ownership of the land located between the river's ordinary high water marks as part of a statewide effort to claim lands given to Arizona at the time of statehood under the Equal Footing Doctrine.

G. Pima County Superior Court Case No. 217116

Addison/Philips v. Churchman Trucking, Cienega Ltd., and Columbia Materials

Plaintiff prevailed.

H. Pima County Superior Court Case No. 178620

Bohman v. Estes

Plaintiff prevailed.

I. Pima County Superior Court Case No. 162577

Pima County v. John Cardi

The ruling stated that if an existing use creates a hazard to life or property, a permit is required.

J. Pima County Court Case No. 1855856

Charles Cindrich v. Pima County

The court ruled that the plaintiff must obtain a Floodplain Use Permit to mine sand and gravel within the Tanque Verde Wash.

K. Maricopa County v. Phoenix Sand & Rock

The defendant paid monetary damages and deeded over fifteen acres for channelization.

L. Wooten v. Phoenix Sand & Rock

The defendant paid monetary damages.

M. Mulcher v. Phoenix Sand & Rock

The defendant paid monetary damages.

N. Maricopa County v. Phoenix Sand & Rock

The case involves condemnation of sixty-six acres of land.
Outcome pending.

APPENDIX D - LONG-TERM PROCEDURE TECHNICAL APPENDIX

The objective of this technical appendix is to present the topographic and mining activity database used in developing the procedure to assess the long-term impacts of sand and gravel mining on changes in channel bed topography. In addition, specific information is provided regarding the groupings and subsequent analysis of the data which lead to the development of the envelope curves incorporated in the procedure.

D.1 Database

The available topographic data is presented for each of the eight selected study reaches in Tables D.1 through D.8 located at the end of this appendix. The mining activity database for each study reach is presented in Tables D.9 through D.16. For each cell unit within the 2-D matrix covering the length and width of the study reach, an alpha-numeric identifier has been assigned. The topographic database contains the mean elevation (MSL) of each cell unit for the two different years of topographic mapping defining the data window. The mining activity database consists of the surface area of mining (acres) measured for each year of available aerial photography. The data window for the mining activity database does not exactly coincide with the topographic database and, thus, some adjustments were made in the reduction of the data.

D.2 Data Reduction

The data analysis process began with the initial reduction of the raw data. For the topographic database, the change in the mean elevation for each cell unit was computed by subtracting the elevation derived for the most recent year of mapping from the elevation for the earliest year of mapping in the data window. For the mining activity database, the sum of the positive, annual incremental changes in mining area was calculated for each mined cell unit. The total active mining area was converted to an estimated mining production volume, in tons, by applying an interpreted mined depth and assuming the average unit weight of the material to be 100 lb/ft³.

Where the data window for the two databases did not coincide, adjustments were made to the estimated mining production volume. In most cases, the topographic mapping data window encompassed more years of record than the time period spanned by the aerial photographs comprising the mining activity database. A method was devised for approximating the volume of material removed from the study reaches for those years in the data gap not covered by available aerial photographs. The approximation of production for those years included in the mining activity data gap assumed that production increased linearly with time from zero excavation in the earliest year of the topographic mapping window, to the actual volume measured for the first available year of aerial photography. This

approximation was then added to the actual volume of production measured from the available aerial photography for the entire mining activity data window. The result was a total estimated production volume for a time period which coincided with the topographic mapping window for analysis purposes.

Table D.17 summarizes the range of certain data parameters determined from the reduction of the topographic and mining activity databases.

D.3 Data Analysis

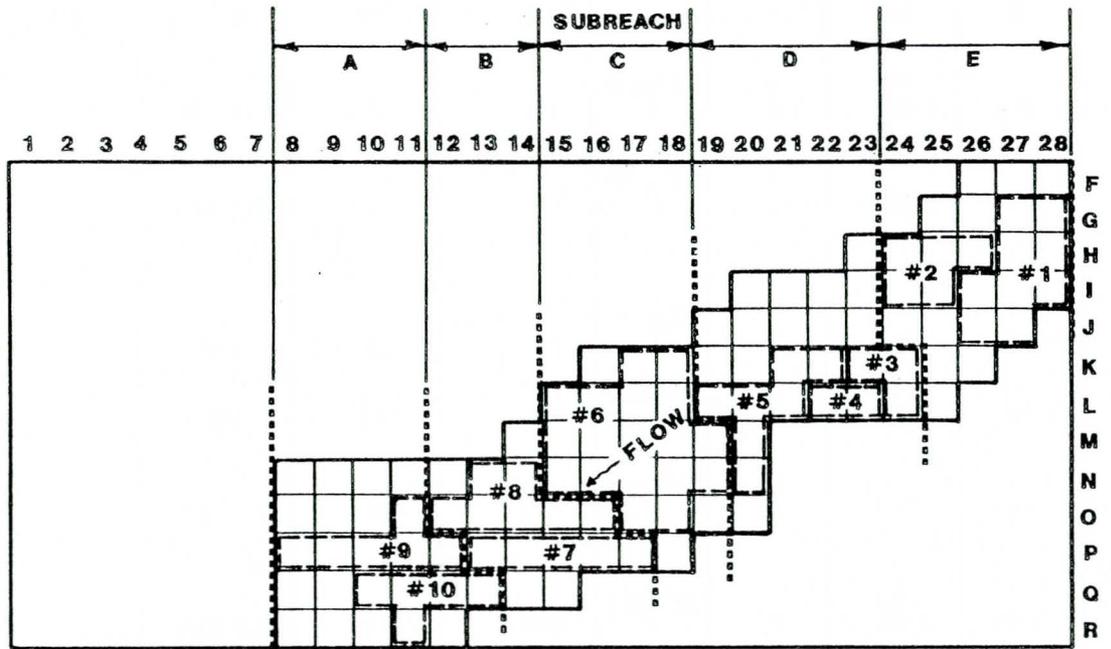
The data analysis process consisted of three steps directed towards evaluating the long-term impact of sand and gravel mining production upon changes in the bed topography within and directly downstream of an actively mined river reach. The analysis was based on the basic physical principle of sediment continuity. The first step of the analysis process evaluated the relationship between the maximum change in bed elevation versus mining production within the actively mined reach. The active mining cells were grouped into mining clusters which encompassed the entire mining operation at a particular location within the study reach. Refer to Figures D.1 through D.5 for schematic illustrations showing the individual mined cells grouped to form each particular mining cluster for the study reaches included in the analysis.

An average of the elevation changes for the actively mined cells comprising the cluster was calculated. The excavated volumes for all cells within the cluster were summed and divided by the cluster length to yield the total volume of production per unit length. The mining production per unit length was then plotted versus the average elevation change for each cluster in each study reach. These two variables, production and elevation change, were observed to be highly correlated for the mining clusters contained within each study reach. However, the data sample resulting from a limited database was considered too small to analyze using linear regression techniques with a high degree of confidence. Therefore, the analysis approach selected involved the development of envelope curves encompassing all the data.

The plots for each study reach were then grouped by bed material type (i.e. gravel or sand bed channels). The gravel bed channels consisted of the two study reaches of the Salt River; the sand bed channels consisted of the Agua Fria River and Rillito Creek study reaches. New River was dropped from this portion of the analysis because of problems encountered in accurately determining the total volume of material removed from the study reach as discussed in the main report. Curves were developed for both bed material types which enveloped all the data for the mining clusters within the study reaches, refer to Chart A. For a given production volume within an actively mined reach, this curve will yield the maximum predicted degradation

TABLE D.17								
LONG-TERM PROCEDURE SUMMARY OF DATA								
Study Reach	Actively Mined Reach Length L	Actively Mined Reach Width W	Estimated Average Exc. Depth d	Estimated Production within Actively Mined Reach P	Data Window n	Topo. Map C.I.	Topo. Map Scale	Aerial Photo Scale
	(mi)	(ft)	(ft)	(Tons x10 ⁶)	(yrs)	(ft)	(ft to the inch)	(ft to the inch)
<u>GRAVEL BED CHANNELS</u>								
1. Salt River Hayden Rd to Country Club Drive	4.9	2800-5200	10-30	58.5	24 (1962-86)	2	100 & 200	1200
2. Salt River 59th-19th Avenue	2.9	3070-4100	12-35	22.1	21 (1962-83)	2 & 4	200	1200
*3. Verde River-Cottonwood	0.4	300	20	0.4	5 (1982-87)	2 & 4	200 & 400	200 & 750
*4. Verde River-I-17	1.1	400	10	0.3	1 (1979)	4	400	1000
<u>SAND BED CHANNELS</u>								
5. Agua Fria River Buckeye Rd to Camelback Rd	1.4	1200-2400	6-35	9.8	9 (1972-81)	2 & 4	200	1200
6. New River Confluence to Peoria Avenue	1.0	400-650	15-20	1.6	5 (1976-81)	2 & 4	200 & 400	1200
*7. Santa Cruz River-Valencia Road to I-19	0.8	1500	20	2.6	11 (1974-85)	2	200	400
8. Rillito Creek I-10 to La Cholla Blvd.	0.8	360-450	6-10	1.4	17 (1967-84)	2	200 & 400	400 & 1200
* This data not used in developing envelope curves.								

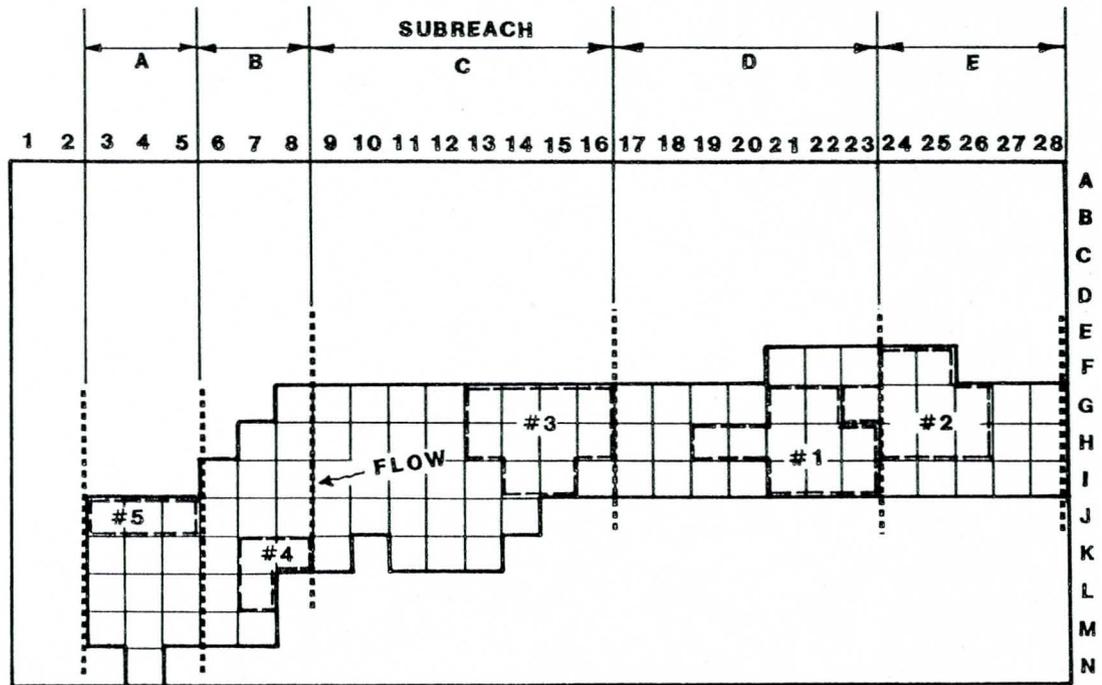
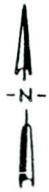
D-4



sla SIMONS, LI & ASSOCIATES, INC.

FIGURE D.1

SALT RIVER
HAYDEN RD TO COUNTRY CLUB DR

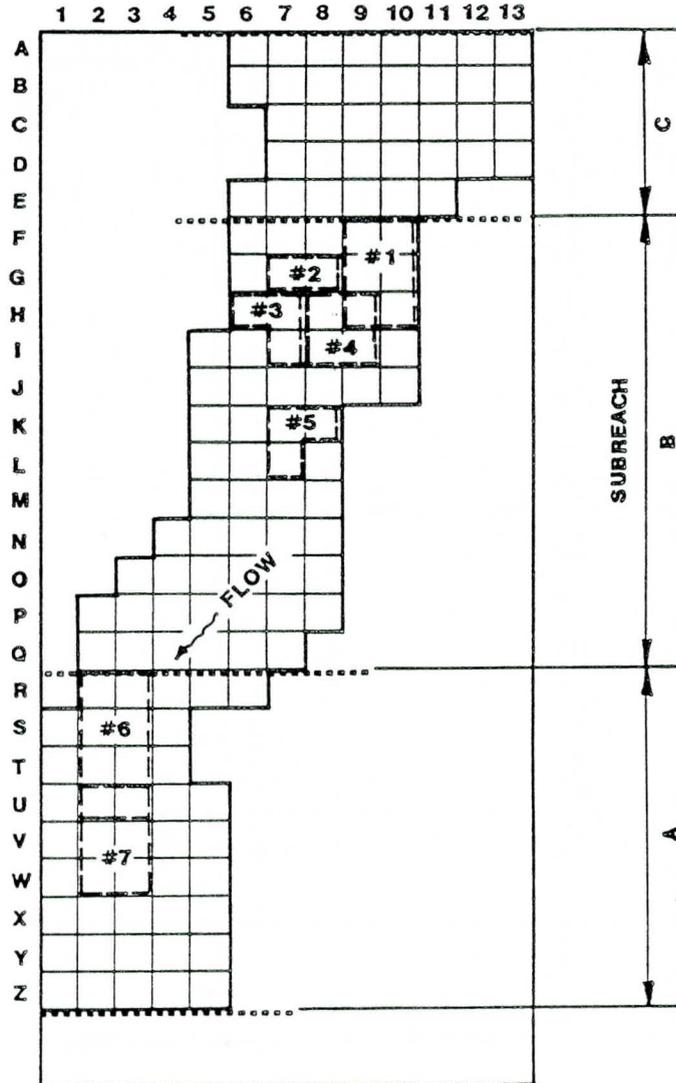
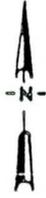


sla SIMONS, LI & ASSOCIATES, INC.

FIGURE D.2

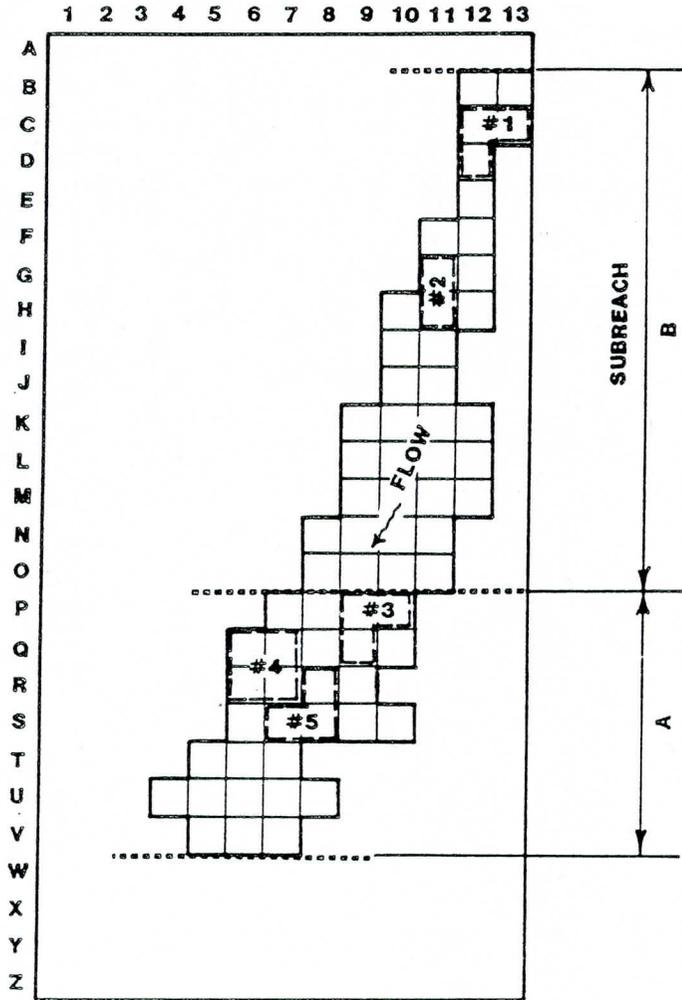
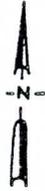
SALT RIVER

59TH - 19TH AVENUE



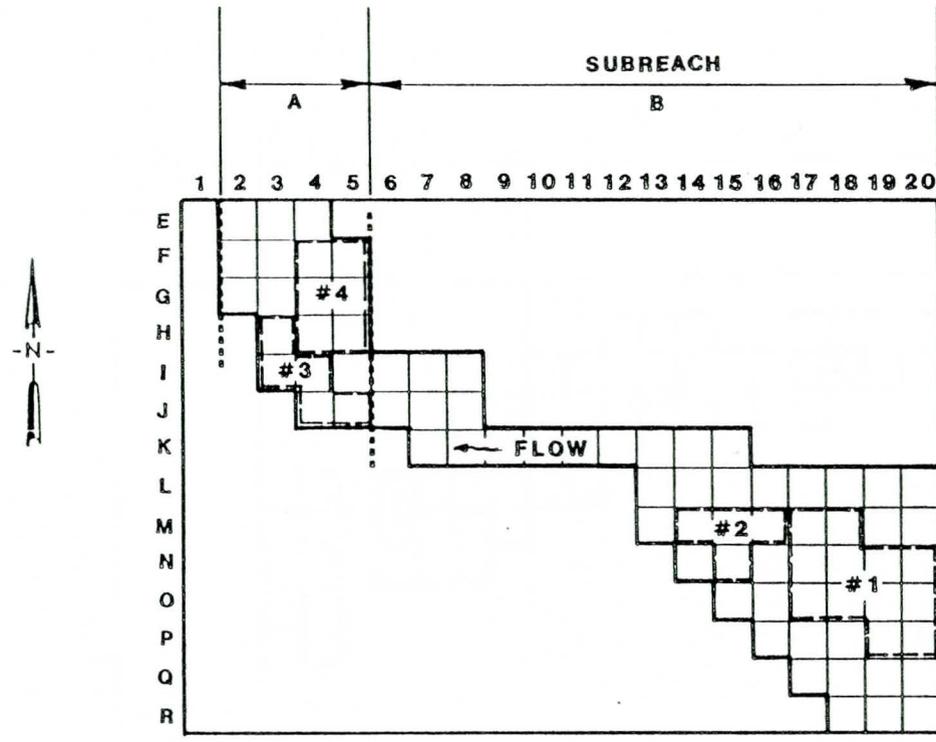
sla SIMONS, LI & ASSOCIATES, INC.

FIGURE D.3
AGUA FRIA RIVER



sla SIMONS, LI & ASSOCIATES, INC.

FIGURE D.4
NEW RIVER



sla SIMONS, LI & ASSOCIATES, INC.

FIGURE D.5
RILLITO CREEK

rate in terms of feet per year distributed laterally across the average width of the active mining cluster.

The second step of the analysis process sought to evaluate the relationship between the total volume of mining production versus the average change in the channel bed elevation on a subreach basis. The study reaches were divided into subreaches encompassing one or more mining clusters. Refer to Figures D.1 through D.5 for schematic illustrations showing the subreach limits for each study reach included in the analysis.

The sum of the total volume of mining production upstream of the downstream limit of each subreach was divided by the average width of the actively mined reach to yield a volume per unit width. The average change in elevation in all cells, both mined and non-mined, upstream of the downstream limit of each subreach was computed. It should be noted that certain mined and non-mined cells were excluded from the calculation of the average elevation change for each subreach according to the following criteria. Non-mined cells exhibiting a change in elevation of less than 0.1 feet during the time period covered by the topographic data window were excluded from the computation. Likewise, certain heavily mined cells were not included where the elevation change occurring during the data window time frame reflected man-induced, deep pit excavation inconsistent with the naturally occurring elevation changes observed in surrounding cells.

The mining production per unit width versus the average elevation change for each subreach was plotted. The plots for each study reach were grouped by bed material type (i.e. gravel or sand bed channels). The gravel bed channels consisted of the two study reaches of the Salt River; the Agua Fria River, Rillito Creek, and New River comprised the sand bed channel group. Curves were developed for both bed material types which enveloped the data for the subreaches within the study reaches. Refer to Chart B. For a given total upstream production volume of an actively mined reach, this curve yields the average predicted degradation rate, in terms of feet per year, at the downstream limit of the reach distributed laterally across the width and longitudinally along the length of the actively mined reach. This width is defined in geomorphic terms as the main low-flow channel width plus the width of the first overbank terraces on both sides of the channel.

It was noted that the curve for gravel bed channels closely approximated a geometric relationship where the volume of the change in the channel bed distributed over the actively mined reach approximately equals the volume of material removed by sand and gravel mining operations.

$$\Delta Z_{ave} = \frac{V_p}{L \times W}$$

Where,

ΔZ_{ave} = average elevation change within the reach;
 V_p = volume of production;
 L = reach length; and,
 W = reach width.

signifying,

$$V_p \cong \Delta V_{bed}$$

Where,

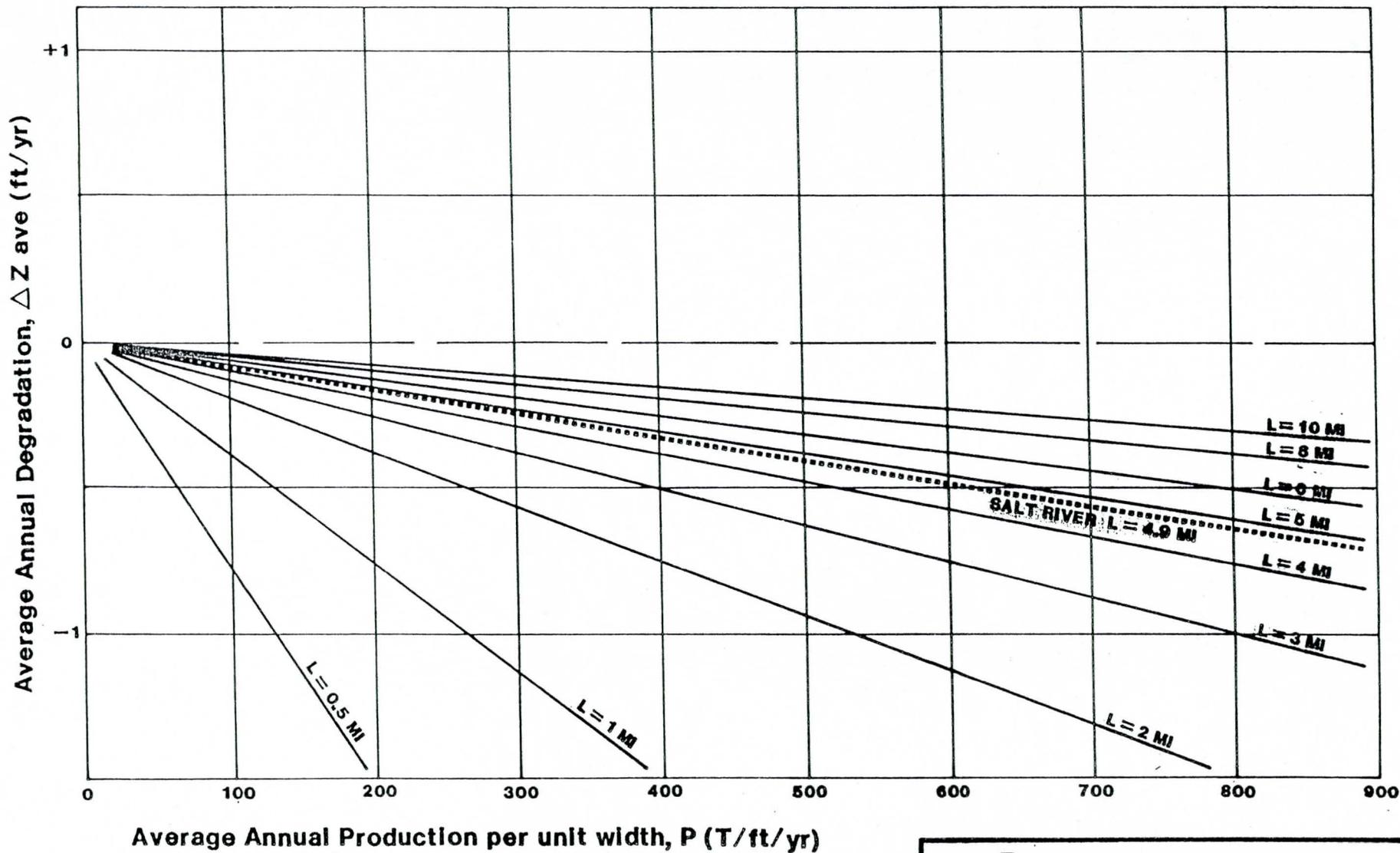
ΔV_{bed} = change in volume of the channel bed within the reach

The volume of material mined from gravel bed channels is equal to the volume of the degradation of the channel within that reach. This signifies that the sediment supply to the reach and transport out of the reach approach negligible values. Figure D.6 shows a set of curves for various reach lengths developed from the geometric relationship. Also plotted for comparative purposes, is the envelope curve developed from the actual measured data for the Salt River for the relationship between the average annual change in elevation and the average annual production per unit width. The relative position of the Salt River curve would verify the findings stated above.

This principle was applied in the third, and final, step of the data analysis process which evaluated the downstream degradation below the actively mined reach. For gravel bed channels, the predicted downstream recovery curve was quantified by holding the excavated volume and the average width constant while increasing the reach length, such that a set of values for the downstream elevation changes was determined. Refer to Chart C for a plot of the downstream recovery curves for gravel bed channels. For sand bed channels, the measured data indicated that the downstream recovery of the system below an actively mined reach occurred over shorter distances and did not follow any identifiable pattern. Several possible factors which influenced this finding were explored and are discussed in the main report.

D.4 Conclusions

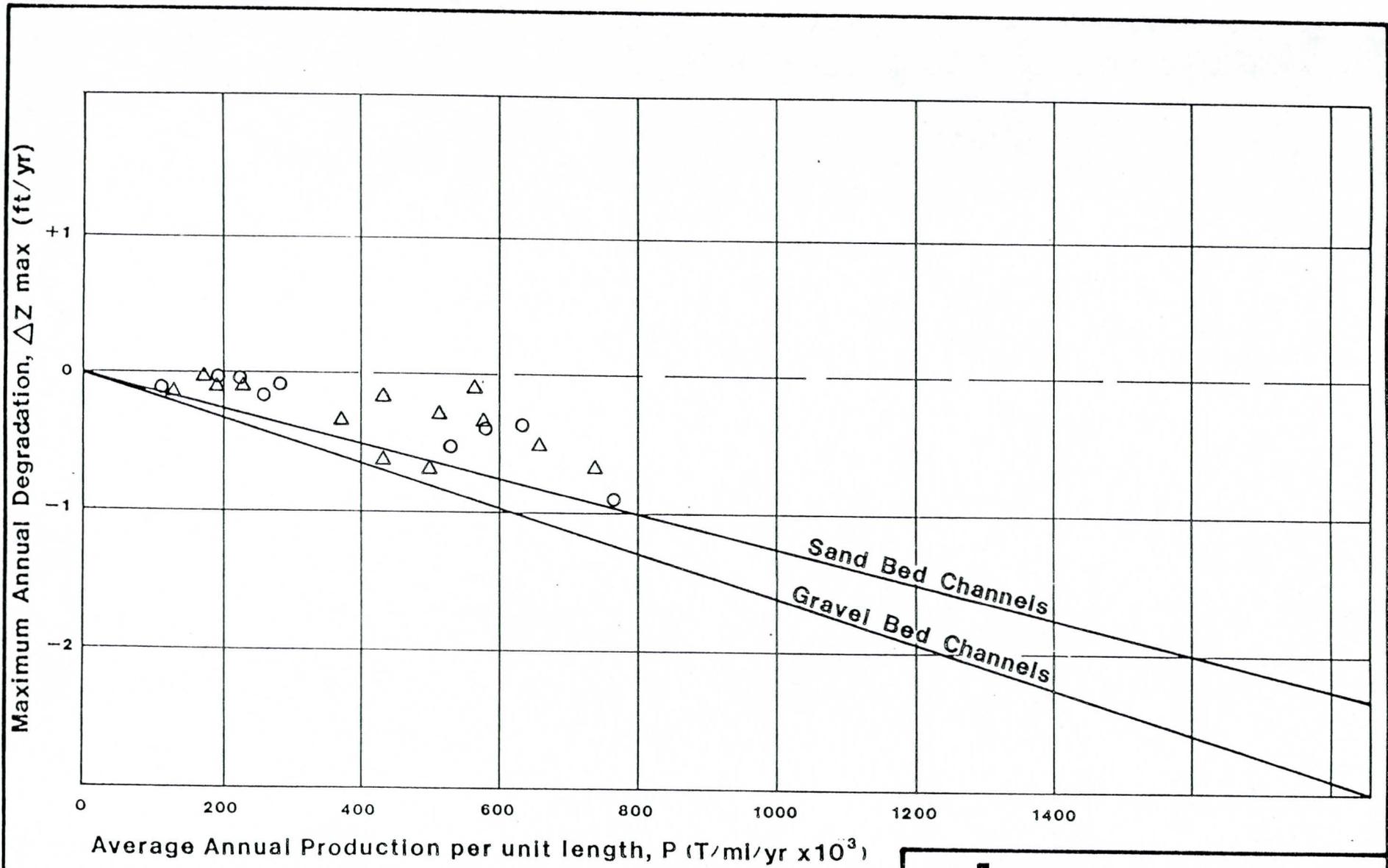
The process used to develop the long-term procedure was data intensive. Gaps occurred in the database which precluded the utilization of all the selected river study reaches in the analysis process. Thus, the resulting procedure is based on a small sample of study reaches. In addition, the data window varied from 1 to 24 years, averaging 11 years. The data window encompassed the years during which major hydrologic events caused substantial flooding to occur in the study reaches.



sla SIMONS, LI & ASSOCIATES, INC.

FIGURE D.6
COMPARATIVE PLOT
ACTUAL VS. GEOMETRIC CURVES

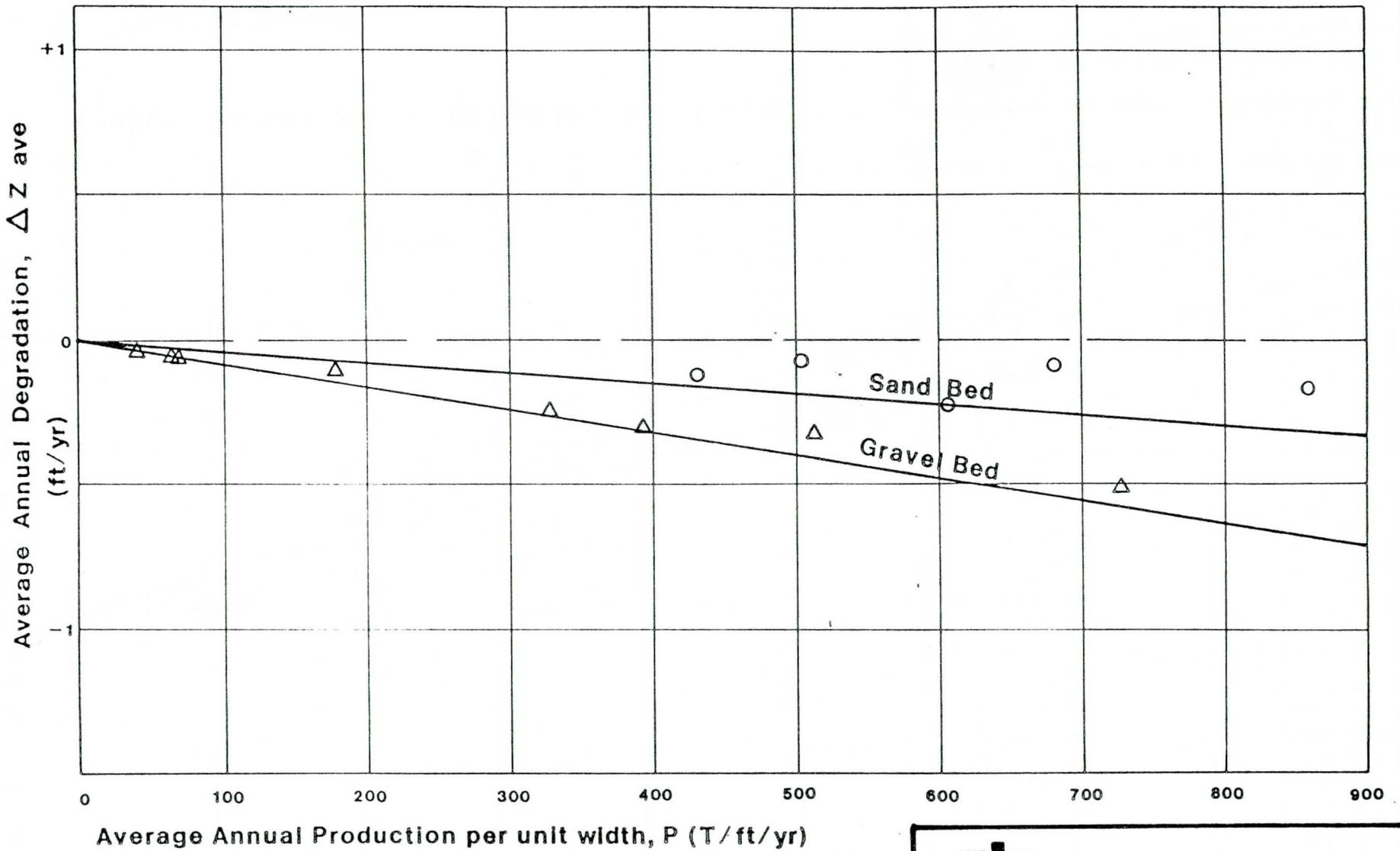
In consideration of the acknowledged limitations of the data base forming the foundation of the long-term procedure, it is strongly recommended that an on-going data-gathering effort be adopted to refine the procedure and improve its validity.



Average Annual Production per unit length, P (T/ml/yr x 10³)

- Sand Bed Channels
- △ Gravel Bed Channels

sla SIMONS, LI. & ASSOCIATES, INC.
LONG TERM PROCEDURE
CHART A



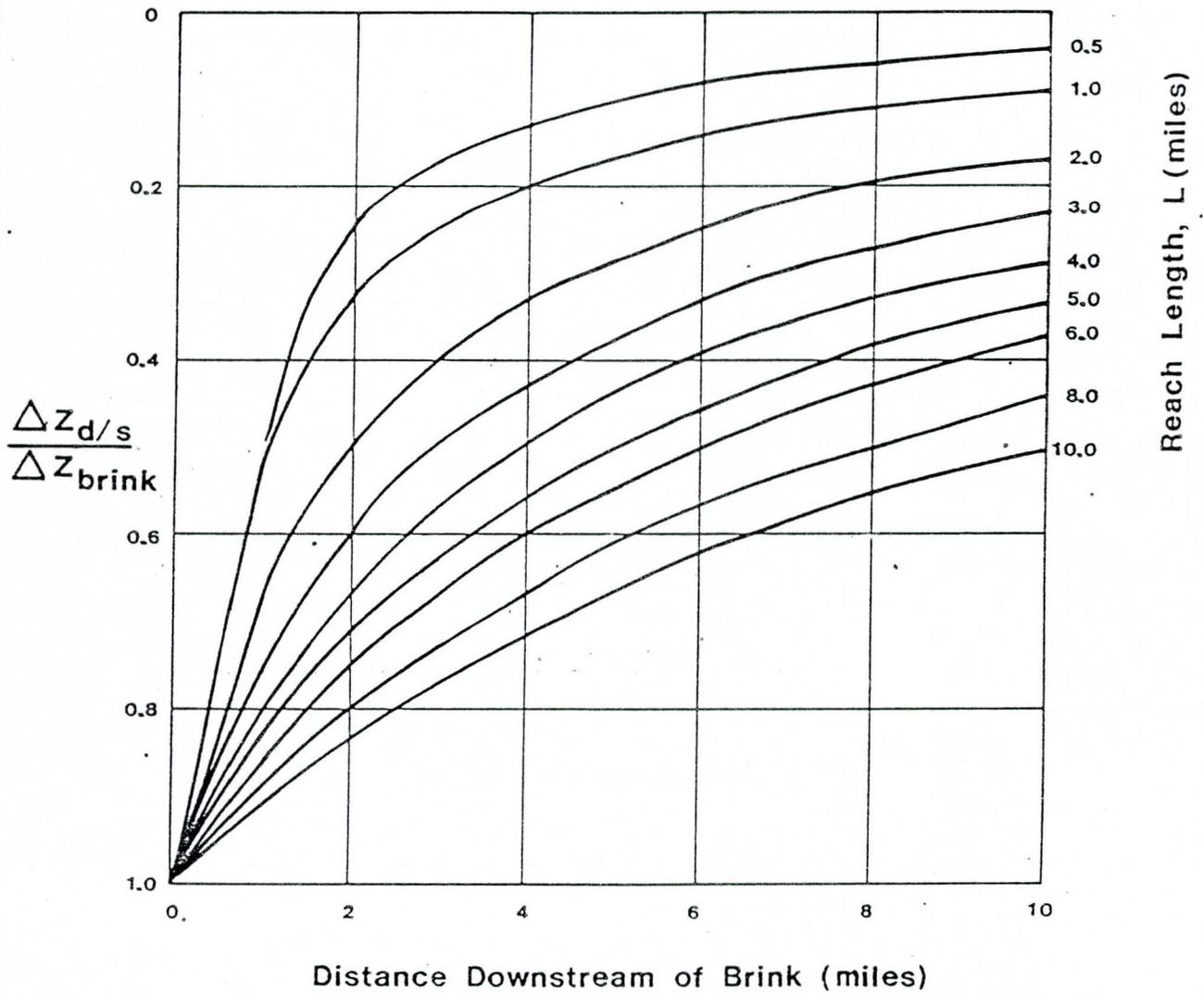
- Sand Bed Channels
- △ Gravel Bed Channels

sla SIMONS, LI. & ASSOCIATES, INC.

LONG TERM PROCEDURE
CHART B

DOWNSTREAM RECOVERY CURVE

GRAVEL BED CHANNELS



sla SIMONS, LI & ASSOCIATES, INC.

LONG TERM PROCEDURE
CHART C

TABLE D.1
SALT RIVER
Hayden Rd. to Country Club Dr.

Topographic Database

CELL NUMBER			
HORIZ.	VERT.	'62 ELEV	'86 ELEV
A	31		1252.50
A	32		1237.50
A	33		1205.30
B	30		1238.00
B	31		1236.80
B	32		1211.50
B	33		1197.50
C	29		1225.90
C	30		1226.40
C	31		1212.50
C	32		1205.40
C	33		1212.30
C	34		1223.20
D	28		
D	29		1219.40
D	30		1209.30
D	31		1204.30
D	32		1211.10
D	33		1215.10
D	34		1223.30
E	28		1206.00
E	29		1195.60
E	30		1191.10
E	31		1200.50
E	32		1215.70
E	33		1227.90
F	26	1214.40	1214.60
F	27	1212.10	1208.10
F	28	1209.80	1201.00
F	29		1197.50
F	30		1201.70
F	31		1202.60
F	32		1208.20
F	33		1216.30
G	25	1211.10	1210.50
G	26	1211.10	1211.80
G	27	1204.10	1200.50
G	28	1203.40	1199.00
G	29		1211.60
G	30		1217.40
G	31		1228.20
G	32		1211.80
G	33		1215.30
H	23	1206.30	1205.30
H	24	1205.80	1206.30

H	25	1206.20	1205.30
H	26	1207.30	1202.80
H	27	1202.50	1193.40
H	28	1204.80	1198.30
H	29		1215.00
H	30		1219.50
H	31		1221.20
H	32		1223.80
I	20	1196.50	1201.90
I	21	1209.90	1204.90
I	22	1201.80	1198.10
I	23	1201.30	1194.50
I	24	1203.40	1200.10
I	25	1204.80	1201.40
I	26	1204.40	1199.60
I	27	1205.30	1201.30
I	28	1211.90	1208.00
I	29		1216.70
I	31		1221.30
I	32		1223.00
J	19	1193.50	1196.00
J	20	1195.30	1195.50
J	21	1202.10	1186.00
J	22	1198.50	1176.90
J	23	1195.30	1184.60
J	24	1198.00	1196.80
J	25	1205.50	1201.40
J	26	1208.00	1207.80
J	27	1210.50	1211.90
K	16	1192.90	1192.10
K	17	1193.30	1193.50
K	18	1193.90	1186.40
K	19	1196.00	1192.70
K	20	1197.90	1196.00
K	21	1197.60	1175.80
K	22	1197.50	1159.50
K	23	1195.30	1178.30
K	24	1197.30	1201.30
K	25	1206.40	1204.20
K	26	1211.00	1214.30
L	15	1189.50	1183.00
L	16	1189.40	1176.70
L	17	1190.50	1186.20
L	18	1191.40	1182.00
L	19	1192.80	1183.80
L	20	1193.00	1188.00
L	21	1192.90	1177.00
L	22	1193.40	1163.70
L	23	1197.70	1177.60
L	24	1204.90	1210.80
L	25	1207.30	1209.80
M	14	1185.90	1184.70
M	15	1184.60	1175.40
M	16	1185.10	1168.40

M	17	1187.90	1171.90
M	18	1190.80	1176.70
M	19	1191.10	1176.50
M	20	1190.10	1175.30
M	21		1173.50
M	22		1176.00
M	23		1192.80
N	8	1175.10	1175.00
N	9	1175.80	1175.00
N	10	1177.90	1177.80
N	11	1178.80	1179.80
N	12	1179.40	1177.50
N	13	1180.10	1172.10
N	14	1180.70	1165.90
N	15	1181.10	1163.20
N	16	1183.60	1170.80
N	17	1186.90	1166.00
N	18	1188.90	1167.00
N	19	1189.00	1176.70
N	20	1189.50	1180.80
N	21		1179.70
N	22		1186.50
O	8	1170.40	1171.40
O	9	1169.60	1157.20
O	10	1172.00	1149.70
O	11	1176.10	1156.50
O	12	1175.30	1161.30
O	13	1176.40	1159.60
O	14	1179.30	1156.00
O	15	1181.60	1158.80
O	16	1186.10	1171.50
O	17	1187.30	1174.50
O	18	1188.50	1178.10
O	19	1191.60	1188.40
O	20	1199.90	1197.10
O	21		1193.40
O	22		1196.10
P	6		1156.00
P	7		1158.90
P	8	1164.90	1162.10
P	9	1166.80	1154.80
P	10	1172.40	1150.00
P	11	1177.00	1156.30
P	12	1177.10	1165.80
P	13	1178.80	1170.30
P	14	1179.30	1171.50
P	15	1183.30	1173.50
P	16	1190.00	1180.50
P	17	1190.00	1186.30
P	18	1188.30	1189.20
P	21		1198.10
P	22		1201.40
Q	4		1158.50
Q	5		1161.90

Q	6		1163.60
Q	7		1169.20
Q	8	1163.90	1161.30
Q	9	1166.80	1169.70
Q	10	1173.90	1176.90
Q	11	1177.90	1178.60
Q	12	1179.10	1181.00
Q	13	1180.90	1182.10
Q	14	1180.70	1183.10
Q	15	1183.80	1185.00
R	4		1164.40
R	5		1168.40
R	6		1170.40
R	7		1169.90
R	8	1169.40	1170.90
R	9	1170.20	1174.00
R	10	1172.80	1177.10
R	11	1175.70	1178.40
R	12	1177.50	1179.60

TABLE D.2
SALT RIVER
59th to 19th Avenue

Topographic Database

CELL NUMBER
HORIZ. VERT. '62 ELEV '83 ELEV

CELL NUMBER	HORIZ.	VERT.	'62 ELEV	'83 ELEV
D		19		
D		20		
D		21		
D		22		
D		23		
E		19		
E		20		
E		21		
E		22		
E		23		
F	21		1037.10	1035.50
F	22		1039.60	1038.50
F	23		1041.50	1044.80
F	24		1042.90	1046.30
F	25		1044.80	1045.30
F	26		1046.60	
G	8		1016.40	1017.30
G	9		1017.30	1019.30
G	10		1019.90	1020.30
G	11		1020.20	1021.40
G	12		1020.30	1021.90
G	13		1022.50	1017.30
G	14		1024.90	1013.50
G	15		1025.80	1017.80
G	16		1026.80	1023.70
G	17		1028.80	1030.80
G	18		1029.40	1032.30
G	19		1030.30	1031.60
G	20		1033.80	1034.00
G	21		1036.30	1031.10
G	22		1038.80	1031.10
G	23		1041.60	1037.80
G	24		1044.50	1033.00
G	25		1047.00	1027.00
G	26		1041.00	1036.00
G	27		1040.70	1050.00
G	28		1049.20	1062.50
G	29			
H	7		1015.00	1011.80
H	8		1015.50	1011.80
H	9		1016.20	1013.40
H	10		1017.30	1017.60
H	11		1017.00	1019.50
H	12		1016.40	1018.00
H	13		1017.40	1009.80

H	14	1019.20	1007.80
H	15	1021.20	1014.50
H	16	1023.50	1020.30
H	17	1026.60	1027.10
H	18	1027.30	1026.80
H	19	1028.30	1026.60
H	20	1029.80	1030.00
H	21	1032.00	1025.30
H	22	1028.30	1023.50
H	23	1030.00	1030.30
H	24	1038.20	1030.10
H	25	1041.00	1024.60
H	26	1038.70	1034.00
H	27	1032.70	1041.30
H	28	1038.90	1046.40
H	29		
I	4		
I	6	1007.70	1010.10
I	7	1007.50	1004.10
I	8	1009.60	1003.50
I	9	1012.10	1005.20
I	10	1014.00	1010.20
I	11	1015.40	1014.90
I	12	1016.90	1015.90
I	13	1018.30	1012.60
I	14	1019.50	1016.10
I	15	1022.50	1021.80
I	16	1025.10	1023.30
I	17	1027.40	1027.00
I	18	1029.60	1027.00
I	19	1031.20	1029.30
I	20	1031.50	1033.40
I	21	1033.90	1032.00
I	22	1030.50	1032.60
I	23	1032.90	1035.80
I	24	1040.90	1039.90
I	25	1042.50	1042.10
I	26	1046.50	1047.30
I	27	1046.10	1047.00
I	28	1046.40	1047.80
J	2		
J	3	1000.30	999.00
J	4	997.80	995.60
J	5	1003.00	997.10
J	6	1004.30	999.60
J	7	1004.10	1001.50
J	8	1008.00	1005.50
J	9	1012.60	1008.50
J	10	1015.00	1011.20
J	11	1013.50	1012.60
J	12	1018.80	1013.10
J	13	1021.50	1015.90
J	14	1024.20	1021.90
J	15	1026.40	1026.50

J	16	1029.60	
K	2		
K	3	994.90	997.40
K	4	997.20	998.00
K	5	1003.30	998.30
K	6	1006.50	1002.80
K	7	1009.60	1008.30
K	8	1011.60	1012.30
K	9	1014.30	1014.60
K	10	1017.20	1017.10
K	11	1019.40	1016.40
K	12	1020.60	1014.90
K	13	1023.10	1020.10
L	3	998.50	997.40
L	4	1002.30	1001.60
L	5	1005.60	1002.30
L	6	1007.30	1005.10
L	7	1011.20	1009.60
L	8		1012.80
L	9		1016.30
L	10		1018.70
L	11		1020.30
L	12		
M	3	999.50	997.80
M	4	1002.20	1002.80
M	5	1006.20	1007.30
M	6	1009.30	1010.10
M	7	1012.20	1011.70
M	8		1014.20
N	4	1003.50	1005.20
N	5		1008.00

TABLE D.3
 VERDE RIVER
 Cottonwood, Arizona

Topographic Database

CELL NUMBER
 HORIZ. VERT. '76 ELEV '82 ELEV

CELL NUMBER	HORIZ.	VERT.	'76 ELEV	'82 ELEV
A	1		3383.10	
B	1		3362.00	
C	1		3360.40	
C	2		3357.30	
D	1		3370.90	
D	2		3350.50	
D	3		3357.00	3356.60
E	2		3371.80	
E	3		3353.30	3350.10
E	4		3350.50	3349.30
E	5		3352.60	3353.40
F	3		3386.50	3384.00
F	4		3350.50	3349.30
F	5		3338.80	3340.30
F	6		3340.30	3341.00
F	7		3342.30	3341.30
F	8		3338.30	3336.80
F	9		3334.80	3335.50
F	10		3336.00	3332.80
F	11		3331.60	3325.80
F	12		3320.60	3320.50
F	13		3316.10	3318.00
F	14		3337.10	3347.30
G	5		3412.80	3414.50
G	6		3369.30	3369.80
G	7		3353.30	3353.40
G	8		3376.00	3375.60
G	9		3393.60	3393.30
G	10		3361.80	3360.10
G	11		3326.30	3323.10
G	12		3319.00	3320.10
G	13		3312.80	3315.10
G	14		3338.00	3341.50
H	10		3378.90	3375.90
H	11		3319.40	3319.60
H	12		3317.50	3319.00
H	13		3316.40	3322.30
H	14		3340.10	3345.00
I	10		3341.60	3338.00
I	11		3315.10	3316.00
I	12		3314.30	3314.30
I	13		3318.00	3320.80
I	14		3336.60	3340.80
J	10		3314.60	3313.80
J	11		3311.00	3311.10

J	12	3309.00	3309.00
J	13	3316.00	3314.30
J	14	3333.90	3332.90
K	9	3311.60	3312.50
K	10	3308.30	3307.80
K	11	3306.00	3306.80
K	12	3305.90	3308.10
K	13	3316.80	3317.00
L	9	3299.40	3302.10
L	10	3303.10	3303.90
L	11	3306.60	3306.80
L	12	3309.00	3310.10
L	13	3315.80	3315.60
M	9	3298.40	3300.10
M	10	3299.60	3300.40
M	11	3305.60	3305.90
N	8	3341.50	3340.80
N	9	3299.10	3299.80
N	10	3295.60	3297.00
N	11	3298.00	3300.50
N	12	3301.30	3303.00
N	13	3302.30	3303.50
O	9	3308.30	3310.60
O	10	3294.50	3296.90
O	11	3293.00	3297.00
O	12	3293.30	3297.30
O	13	3293.00	3296.30
P	9	3324.00	3325.60
P	10	3296.60	3297.40
P	11	3293.30	3292.60
P	12	3291.00	3292.60
P	13	3290.50	3291.50
P	19		
P	20		
Q	10	3310.30	3309.80
Q	11	3295.30	3297.40
Q	12	3291.50	3289.60
Q	13	3289.80	3285.50
R	11	3309.50	3314.30
R	12	3302.00	3302.00
R	13	3296.30	3292.50

TABLE D.4
VERDE RIVER
Near Interstate 17

Topographic Database

CELL NUMBER
HORIZ. VERT. '85 ELEV

A	1	3130.00
A	2	3122.50
A	3	3110.00
A	4	3121.50
B	1	3129.50
B	2	3120.00
B	3	3107.50
B	4	3114.50
C	1	3130.00
C	2	3116.80
C	3	3106.40
C	4	3108.50
C	5	3116.70
D	1	3132.30
D	2	3116.80
D	3	3105.30
D	4	3103.00
D	5	3106.80
E	2	3126.00
E	3	3106.80
E	4	3098.40
E	5	3101.40
E	6	3104.00
F	3	3121.00
F	4	3105.20
F	5	3094.50
F	6	3093.80
F	7	3094.40
F	8	3099.90
F	9	3111.70
F	11	3104.80
G	6	2480.50
G	7	3088.80
G	8	3085.50
G	9	3093.50
G	10	3103.00
G	11	3099.00
G	12	3092.80
H	7	3093.70
H	8	3088.00
H	9	3082.50
H	10	3083.50
H	11	3087.10
H	12	3087.40
I	9	3094.30

I	10	3089.30
I	11	3088.00
I	12	3088.50
J	11	3105.10
J	12	3102.80

TABLE D.5
 AGUA FRIA RIVER
 Buckeye Rd. to Camelback Rd.

Topographic Database

CELL NUMBER
 HORIZ. VERT. '72 ELEV '81 ELEV

CELL NUMBER	HORIZ.	VERT.	'72 ELEV	'81 ELEV
A	6		1024.80	1020.10
A	7		1023.50	1019.90
A	8		1022.50	1024.70
A	9		1021.80	1018.30
A	10		1020.90	1017.90
A	11		1021.10	1019.20
A	12		1022.30	1020.10
A	13		1023.10	1020.20
B	6		1023.30	1018.20
B	7		1020.60	1018.60
B	8		1020.10	1023.20
B	9		1019.80	1016.30
B	10		1018.10	1015.50
B	11		1018.10	1017.30
B	12		1019.40	1018.00
B	13		1020.20	1018.90
C	6			
C	7		1018.60	1018.40
C	8		1016.90	1014.20
C	9		1016.10	1013.60
C	10		1016.10	1013.80
C	11		1017.70	1015.40
C	12		1018.30	1016.70
C	13		1018.60	1018.40
D	7		1015.10	1017.80
D	8		1014.30	1009.90
D	9		1014.10	1008.90
D	10		1014.60	1011.40
D	11		1016.40	1013.90
D	12		1016.80	1015.30
D	13		1017.50	1017.80
E	6		1015.30	1013.80
E	7		1011.30	1008.70
E	8		1011.20	1006.30
E	9		1012.10	1005.40
E	10		1013.40	1009.10
E	11		1014.90	1012.10
F	6		1009.80	1009.60
F	7		1007.70	1008.00
F	8		1005.20	1005.30
F	9		1005.60	1003.90
F	10		1009.40	1007.60
G	6		1004.30	1004.20
G	7		1004.80	993.00
G	8		1001.80	991.50

G	9	1002.00	999.80
G	10	1005.90	1001.60
H	6	1002.10	1002.10
H	7	1001.60	988.50
H	8	1001.30	983.30
H	9	1002.00	993.50
H	10	1003.00	1000.50
I	5	1001.70	999.70
I	6	1001.50	1000.10
I	7	998.80	997.70
I	8	999.10	995.40
I	9	1001.20	998.70
I	10	1002.10	1004.60
J	5	999.50	997.70
J	6	999.90	998.20
J	7	997.80	995.60
J	8	997.30	996.30
J	9	1000.20	1001.90
J	10	1003.40	1005.70
K	5	996.00	995.00
K	6	997.10	995.60
K	7	995.10	994.20
K	8	994.80	995.60
L	5	992.60	992.10
L	6	994.30	993.60
L	7	992.70	992.90
L	8	994.60	995.40
M	5	990.10	989.30
M	6	991.30	991.50
M	7	992.80	992.50
M	8	997.00	996.10
N	4	986.80	986.20
N	5	987.40	987.20
N	6	989.30	989.00
N	7	992.40	992.50
N	8	996.60	997.20
O	3	983.10	983.00
O	4	984.00	984.00
O	5	984.90	984.90
O	6	986.50	985.20
O	7	990.00	989.10
O	8	995.50	995.70
P	2	984.60	984.30
P	3	978.90	979.10
P	4	981.20	981.00
P	5	982.90	980.70
P	6	983.80	980.60
P	7	986.40	985.20
P	8	992.50	991.30
Q	1	988.20	
Q	2	980.40	981.60
Q	3	976.80	979.90
Q	4	980.00	979.30
Q	5	981.30	979.90

Q	6	980.70	980.10
Q	7	983.80	984.30
R	1	985.30	
R	2	979.70	978.60
R	3	976.60	975.40
R	4	977.30	977.80
R	5	978.60	979.70
R	6	977.70	979.30
R	7		982.90
S	1	977.10	975.60
S	2	974.10	972.40
S	3	974.10	974.80
S	4	974.30	971.50
T	1	971.40	968.50
T	2	971.40	972.30
T	3	982.10	983.60
T	4	979.30	981.00
U	1	975.30	976.10
U	2	969.80	968.70
U	3	968.50	967.30
U	4	969.50	969.30
U	5	969.40	969.90
V	1	972.10	972.80
V	2	966.30	965.70
V	3	966.00	966.00
V	4	967.40	967.50
V	5	968.10	967.20
W	1	970.80	971.00
W	2	965.60	963.30
W	3	965.00	964.00
W	4	965.20	966.00
W	5	966.10	964.50
X	1	968.60	968.10
X	2	963.80	961.20
X	3	963.30	960.90
X	4	963.70	963.30
X	5	964.50	963.80
Y	1	962.80	964.20
Y	2	961.30	961.10
Y	3	961.10	959.30
Y	4	961.80	960.30
Y	5	963.40	963.30
Z	1	959.80	960.70
Z	2	957.40	958.80
Z	3	958.90	958.50
Z	4	960.30	959.10
Z	5	963.50	963.10

TABLE D.6
 NEW RIVER
 Agua Fria River Confluence to Peoria Ave.

Topographic Database

CELL NUMBER		HORIZ.	VERT.	'76 ELEV	'81 ELEV
B	12			1109.00	1110.20
B	13			1108.00	1108.50
C	12			1104.30	1103.90
C	13			1104.00	1103.80
D	12			1106.30	1104.60
E	12			1102.00	1101.70
F	11			1099.00	1098.40
F	12			1097.00	1096.80
G	11			1091.00	1093.60
G	12			1094.00	1092.50
H	10			1087.00	1091.10
H	11			1084.30	1088.00
H	12			1091.50	1090.90
I	10			1083.40	1085.30
I	11			1080.90	1082.80
J	10			1079.00	1080.90
J	11			1077.00	1078.70
K	9			1087.40	1086.00
K	10			1077.20	1078.40
K	11			1075.30	1076.30
K	12			1083.40	1080.30
L	9			1084.00	1082.70
L	10			1076.30	1077.50
L	11			1075.00	1076.30
L	12			1080.50	1078.20
M	9			1075.00	1077.10
M	10			1071.90	1073.30
M	11			1074.30	1073.70
M	12			1078.00	1076.30
N	8			1073.80	1074.70
N	9			1067.10	1070.20
N	10			1069.00	1073.80
N	11			1072.90	1070.20
O	7			1077.50	
O	8			1069.60	1065.20
O	9			1064.50	1062.70
O	10			1067.30	1065.30
O	11			1070.30	1068.20
P	7			1070.40	1067.50
P	8			1064.00	1057.60
P	9			1063.40	1057.80
P	10			1066.10	1063.40
Q	6			1067.90	
Q	7			1060.10	1064.20
Q	8			1056.40	1052.50

Q	9	1059.50	1054.40
Q	10	1063.70	1060.90
R	6	1058.40	1060.30
R	7	1053.80	1052.80
R	8	1053.80	1046.50
R	9	1055.60	1053.70
S	6	1053.30	1051.40
S	7	1050.80	1047.50
S	8	1052.50	1046.00
S	9	1053.90	1052.80
S	10	1055.70	1054.40
T	5	1045.60	1046.80
T	6	1045.00	1046.20
T	7	1047.00	1046.10
U	4	1042.30	1040.30
U	5	1040.00	1043.40
U	6	1041.00	1043.60
U	7	1044.50	1043.80
U	8	1048.30	1045.70
V	4	1038.30	
V	5	1039.10	1035.80
V	6	1040.40	1041.70
V	7	1042.50	1041.10
V	8	1046.70	
W	5	1036.60	
W	6	1038.20	
W	7	1042.30	
X	6	1037.60	
X	7	1042.10	

TABLE D.7
SANTA CRUZ RIVER
Valencia Rd. to I-19

Topographic Database

CELL NUMBER		
HORIZ.	VERT.	'84 ELEV
E	1	2472.00
E	2	2468.00
E	3	2464.50
E	4	2471.80
F	1	2471.50
F	2	2469.50
F	3	2462.20
F	4	2458.40
F	5	2478.30
G	1	2476.10
G	2	2468.80
G	3	2457.30
G	4	2461.40
G	5	2485.80
H	1	2480.50
H	2	2468.50
H	3	2453.80
H	4	2471.50

TABLE D.8
 RILLITO CREEK
 I-10 to La Cholla Blvd.

Topographic Database

CELL NUMBER		'67 ELEV	'84 ELEV
HORIZ.	VERT.		
E	2	2221.30	2220.10
E	3	2223.30	2222.50
E	4	2227.00	2226.30
F	2	2216.70	2219.00
F	3	2219.10	2221.80
F	4	2223.60	2221.30
F	5	2226.10	2221.80
G	2	2219.50	2212.60
G	3	2220.10	2221.50
G	4	2221.90	2211.80
G	5	2223.00	2218.10
G	6	2224.00	
G	7	2226.00	
G	8	2229.00	
H	2	2219.50	
H	3	2220.90	2218.00
H	4	2222.40	2213.50
H	5	2223.80	2216.10
H	6	2224.60	
H	7	2226.50	
H	8	2228.80	
I	3	2221.70	2219.00
I	4	2223.60	2221.10
I	5	2225.60	2222.50
I	6	2227.80	2224.10
I	7	2228.50	2227.90
I	8	2228.50	2227.70
J	3	2222.00	
J	4	2226.40	2225.30
J	5	2229.80	2224.10
J	6	2230.90	2227.50
J	7	2231.60	2229.30
J	8	2231.50	2227.40
K	7	2235.50	2231.60
K	8	2235.60	2230.60
K	9	2236.30	2232.60
K	10	2240.50	2232.40
K	11	2239.60	2234.80
K	12	2238.80	2237.30
K	13	2240.00	2239.50
K	14	2242.20	2240.50
K	15	2244.00	2241.60
K	16	2248.20	
K	17	2250.30	
K	18	2253.00	

K	19	2254.30	
L	11	2242.80	
L	12	2242.80	
L	13	2238.80	2238.30
L	14	2240.80	2238.60
L	15	2245.50	2242.50
L	16	2247.80	2243.70
L	17	2250.50	2248.30
L	18	2252.90	2256.60
L	19	2252.40	2252.60
L	20	2256.50	2253.70
M	13	2239.30	2239.60
M	14	2240.80	2239.10
M	15	2243.80	2242.60
M	16	2244.80	2242.20
M	17	2247.80	2244.60
M	18	2251.50	2246.80
M	19	2253.80	2250.80
M	20	2257.00	2255.60
M	21	2259.00	
M	22	2261.10	
N	14	2246.40	2246.50
N	15	2245.50	2245.20
N	16	2245.60	2244.20
N	17	2247.60	2245.50
N	18	2249.80	2247.30
N	19	2251.80	2247.00
N	20	2255.00	2251.00
N	21	2259.50	
N	22	2262.00	
O	15	2250.00	2246.60
O	16	2249.50	2249.10
O	17	2250.80	2251.10
O	18	2253.00	2254.00
O	19	2253.30	2250.30
O	20	2253.80	2251.10
O	21	2257.60	
O	22	2258.80	
O	23	2263.00	
O	24	2265.10	
P	16	2250.90	2250.90
P	17	2252.30	2254.00
P	18	2249.80	2252.60
P	19	2248.90	2252.40
P	20	2255.30	2257.00
P	21	2255.00	
P	22	2255.00	
P	23	2260.90	
P	24	2264.10	
Q	17	2253.30	2255.90
Q	18	2254.00	2254.90
Q	19	2250.60	2255.00
Q	20	2247.00	2258.50
Q	21	2256.90	

Q	22	2258.90	
Q	23	2261.30	
Q	24	2264.10	
Q	25	2268.40	
R	18	2257.10	2257.50
R	19	2255.80	2258.40
R	20	2257.90	2260.80
R	21	2262.20	
R	22	2264.30	
R	23	2264.80	
R	24	2264.40	
R	25	2263.80	
S	23	2266.00	
S	24	2266.00	
S	25		
S	26		
T	23	2267.30	
T	24	2268.10	

TABLE D.9
SALT RIVER
Hayden Rd. to Country Club Dr.

Mining Activity Database

CELL NUMBER		Area of Active Mining (Acres)															
HORIZ.	VERT.	1969	1972	1973	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
A	31	.00	.00	5.29	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
A	32	.00	.00	7.60	.00	7.27	.00	.00	.00	.00	6.28	.00	.00	.00	.00	.00	.00
A	33	.00	.00	.00	.00	.00	.00	.00	.00	.00	5.95	.00	.00	.00	.00	1.65	.00
B	30	6.24	8.21	5.95	.00	15.21	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
B	31	6.41	12.48	11.90	2.31	20.17	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
B	32	.00	2.30	4.96	3.97	13.23	.00	.00	.00	.00	4.30	.00	.00	.00	.00	6.61	.00
B	33	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	13.55	.00
C	29	4.93	1.23	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	13.55	.00
C	30	18.89	12.16	7.60	19.51	19.51	19.51	19.51	.00	7.60	.00	.00	.00	.00	.00	.00	.00
C	31	6.41	3.29	7.60	16.20	16.20	18.51	18.51	.00	.00	.00	.00	.00	.00	.00	.00	.00
C	32	.00	.00	.00	12.56	13.89	11.57	11.57	.00	.00	8.27	.00	.00	.00	.00	.00	.00
C	33	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
C	34	.00	.00	3.64	.00	.00	13.89	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
D	28	.00	.00	.00	.00	.00	.00	.00	.00	4.63	.00	.00	.00	.00	.00	.00	.00
D	29	4.60	2.79	3.31	13.22	13.22	13.22	13.22	.00	18.18	.00	.00	.00	.00	.00	.00	.00
D	30	18.89	14.62	14.87	4.30	4.30	4.30	4.30	.00	4.30	.00	.00	.00	.00	.00	.00	.00
D	31	4.11	3.61	4.30	.00	.00	.00	.00	5.29	3.97	.00	.00	.00	.00	.00	.00	.00
D	32	.00	6.41	1.65	.00	.00	.00	8.60	4.63	.00	.00	.00	.00	.00	.00	.00	.00
D	33	.00	.00	2.64	2.31	.00	.00	.00	4.63	.00	.00	5.95	.00	.00	1.65	.00	.00
D	34	.00	.00	.00	.00	.00	6.28	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
E	28	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
E	29	1.97	3.12	3.31	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
E	30	1.64	9.86	13.55	.00	.00	12.89	3.30	.00	4.30	.00	.00	.00	.00	.00	.00	.00
E	31	.00	6.90	4.96	3.97	2.98	13.56	8.27	10.25	9.59	.00	5.29	.00	.00	.00	.00	.00
E	32	1.31	5.91	2.97	11.57	7.60	6.28	8.92	10.25	2.98	.00	3.64	.00	.00	.00	.00	.00
E	33	.00	.00	3.30	7.61	.00	.00	3.31	2.98	.00	.00	.00	.00	3.97	.00	.00	.00
F	26	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
F	27	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
F	28	1.31	1.31	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
F	29	.00	.00	.00	.00	.00	.00	.00	.00	.00	4.63	1.98	.00	9.59	.00	.00	.00
F	30	.00	.00	.00	.00	.00	.00	1.65	.00	19.84	13.22	6.94	.00	5.29	.00	.00	.00
F	31	.00	.00	.00	.00	7.93	12.23	13.22	16.53	4.63	4.96	12.89	.00	3.97	.00	.00	.00
F	32	.00	.00	.00	10.58	13.89	7.27	7.27	10.25	.00	.00	10.91	.00	8.93	.00	.00	.00
F	33	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
G	25	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
G	26	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
G	27	1.64	1.15	1.65	.00	1.65	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
G	28	4.76	2.63	5.95	.00	6.94	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
G	29	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
G	30	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
G	31	4.11	15.93	.00	7.27	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
G	32	4.60	11.33	7.60	6.94	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	5.20	1.98
G	33	.00	.00	1.36	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	2.31
H	23	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
H	24	.00	3.12	.00	.00	3.30	.00	.00	.00	.00	.00	1.32	.00	.00	.00	.00	.00

H	25	3.29	6.57	.00	.00	4.63	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
H	26	2.14	2.14	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
H	27	3.29	5.09	13.55	3.64	11.57	3.31	.00	.00	.00	.00	.00	.00	1.65	.00	.00
H	28	.00	7.06	12.56	.00	13.55	2.98	.00	.00	1.98	.00	.00	.00	.00	.00	.00
H	29	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
H	30	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
H	31	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.98	6.28	6.94
H	32	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	3.31	4.63	4.96
I	20	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
I	21	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
I	22	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
I	23	1.15	1.31	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
I	24	2.63	2.63	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
I	25	.00	4.11	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
I	26	.00	.00	2.98	16.87	6.94	.00	11.57	.00	1.32	.00	.00	.00	.00	.00	.00
I	27	2.96	7.39	16.53	2.98	22.48	.00	12.56	.00	.00	.00	.00	.00	.00	.00	3.31
I	28	.00	.00	.00	.00	9.59	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
I	29	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
I	31	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
I	32	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
J	19	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
J	20	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
J	21	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
J	22	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
J	23	3.12	1.64	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
J	24	1.64	1.64	.00	.00	.00	.00	.00	.00	5.29	.00	.00	.00	.00	.00	.00
J	25	1.81	1.81	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
J	26	.00	.00	4.96	2.64	4.30	.00	4.30	.00	2.64	.00	.00	.00	.00	.00	.00
J	27	.00	.00	1.65	.00	4.63	.00	2.98	.00	.00	.00	.00	.00	.00	.00	.00
K	16	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
K	17	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	8.93	7.27
K	18	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	19.84	14.55
K	19	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	8.27	11.24
K	20	1.31	2.30	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	9.26	.00
K	21	.82	1.15	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	5.29	6.94
K	22	1.64	1.97	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	7.27	10.58
K	23	6.57	5.91	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	3.64
K	24	.00	9.36	9.59	11.57	7.60	7.60	8.27	.00	6.29	.00	.00	.00	.00	.00	.00
K	25	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
K	26	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
L	15	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	4.63
L	16	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	5.95	7.27
L	17	.00	.00	.00	.00	.00	.00	.00	.00	1.32	4.96	.00	1.32	16.53	24.07	24.07
L	18	.00	.00	.00	.00	.00	.00	.00	.00	13.22	2.98	.00	.00	24.07	24.07	24.07
L	19	.00	.00	.00	.00	.00	.00	.00	6.92	7.93	3.64	7.60	.00	24.07	24.07	24.07
L	20	.00	1.64	.00	5.29	.00	12.56	6.94	6.28	.00	.00	12.89	.00	24.07	24.07	24.07
L	21	.00	3.24	.99	.00	.00	.00	.00	8.26	.00	.00	2.31	.00	13.89	.00	17.19
L	22	4.27	4.76	.00	.00	.00	5.95	.00	4.63	.00	.00	3.64	2.64	.00	5.29	1.65
L	23	3.12	3.78	.00	.00	.00	3.64	.00	.00	.00	.00	4.30	3.31	.00	.00	.00
L	24	.00	.00	1.65	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
L	25	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
M	14	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
M	15	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	2.64	.00	4.63
M	16	.00	4.11	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	8.27	6.94	20.07

M	17	.00	4.44	.00	.00	.00	.00	.00	.00	.00	1.32	14.22	3.97	24.07	24.07	24.07	
M	18	.00	4.93	.00	.00	.00	.00	.00	.00	3.97	.00	1.65	3.64	.00	12.23	24.07	24.07
M	19	.00	8.71	.00	.00	.00	.00	.00	2.98	4.96	.00	.00	.00	.00	9.26	22.81	24.07
M	20	.00	5.75	7.27	.00	6.61	.00	5.95	1.65	.00	12.56	6.94	.00	.00	11.24	.00	16.53
M	21	.00	3.12	2.98	.00	.00	.00	.00	4.63	.00	.00	1.65	.00	.00	1.65	.00	.00
M	22	.00	.00	.00	.00	.00	1.98	.00	.00	.00	.00	.00	.00	.00	3.63	.00	.00
M	23	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	3.31	1.65	.00	.00	6.28	.00
N	8	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
N	9	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
N	10	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
N	11	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
N	12	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
N	13	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	4.63	.00	.00
N	14	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.99	4.63	.00	3.31	.00	7.27
N	15	.00	3.12	.00	.00	.00	.00	.00	.00	.00	.00	.00	4.63	5.29	11.57	18.51	18.51
N	16	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	3.97	14.55	13.89	18.18
N	17	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	15.87	13.89	19.84	24.07
N	18	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.65	24.07	24.07	24.07
N	19	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	3.64	6.28	4.96	13.89
N	20	.00	.00	3.64	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
N	21	.00	.00	.00	.00	.00	.00	2.64	.00	.00	.00	.00	.00	1.98	18.18	.00	.00
N	22	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.99	6.94	.00	.00
O	8	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
O	9	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
O	10	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
O	11	.00	.00	2.64	.00	.00	.00	.00	.00	.00	.00	.99	.00	.00	3.64	3.97	3.97
O	12	.00	.00	.11	5.95	5.95	.00	.00	.00	7.93	9.59	9.59	3.97	22.56	14.22	14.22	14.22
O	13	.00	.00	.00	.00	2.64	.00	4.63	.00	.00	14.88	19.84	13.55	.00	23.14	20.17	20.17
O	14	.00	.00	.00	.00	.00	.00	.00	.00	2.98	7.93	15.54	3.63	22.81	15.21	24.07	24.07
O	15	.00	.00	.00	1.65	.00	.00	.00	.00	.00	.00	.00	.00	3.31	.00	16.86	16.86
O	16	.00	.00	.00	4.63	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.98
O	17	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	11.24	10.25	10.25
O	18	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	4.63	7.27	6.94	6.94
O	19	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
O	20	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
O	21	.00	.00	.00	.00	.00	.00	4.96	5.95	.00	.00	.00	16.86	.00	21.82	.00	.00
O	22	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
P	6	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
P	7	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
P	8	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
P	9	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	14.55	9.26	19.26
P	10	.00	.00	.00	.00	.00	.00	.00	5.95	5.95	.00	.00	.00	4.96	20.50	16.20	16.20
P	11	.00	.00	19.51	2.97	.00	4.63	.00	3.97	14.88	1.65	10.91	.00	.00	24.07	16.53	16.53
P	12	.00	8.21	1.65	.00	.00	.00	2.31	4.96	6.28	.00	20.17	.00	.00	24.07	24.07	24.07
P	13	.00	.00	.00	.00	.00	1.65	4.30	8.60	12.23	7.27	2.98	4.63	.00	5.95	.00	24.07
P	14	.00	.00	.00	.00	.00	.00	2.98	6.94	13.89	12.56	.00	14.55	.00	2.98	.00	24.07
P	15	.00	.00	.00	6.28	.00	.00	2.98	4.30	6.94	7.60	.00	9.26	.00	.00	.00	.00
P	16	.00	.00	.00	.00	.00	.00	3.97	.00	.00	.00	.00	.00	.00	.00	.00	.00
P	17	.00	.00	.00	.00	.00	.00	7.27	.00	.00	.00	.00	.00	.00	.00	.00	.00
P	18	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
P	21	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	4.63	.00	.00
P	22	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Q	4	.00	.00	.00	.00	.00	.00	4.63	.00	.00	.00	.00	.00	.00	.00	.00	.00
Q	5	.00	.00	.00	.00	.00	.99	4.63	.00	1.98	.00	.00	.00	.00	.00	.00	.00

Q	6	.00	.00	.00	.00	.00	5.62	4.96	.00	2.64	.00	.00	.00	.00	.00	.00	.00
Q	7	.00	.00	.00	.00	.00	.00	.00	.00	.00	2.98	.00	.00	1.32	.00	.00	.00
Q	8	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Q	9	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Q	10	.00	.00	.00	.00	.00	7.27	7.27	.00	11.57	11.57	4.96	.00	.00	4.96	.00	.00
Q	11	.00	.00	5.95	.00	.00	12.56	12.56	.00	13.22	13.22	18.18	.00	.00	18.18	.00	.00
Q	12	.00	3.29	3.31	.00	.00	.00	.00	.00	.00	.00	16.53	.00	.00	15.21	.00	.00
Q	13	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	2.64	.00	.00	.00	.00	.00
Q	14	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Q	15	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
R	4	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
R	5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
R	6	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
R	7	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
R	8	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
R	9	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
R	10	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
R	11	.00	.00	1.65	.00	.00	11.24	11.24	.00	10.58	10.58	9.26	.00	.00	9.26	.00	.00
R	12	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

TABLE D.10
SALT RIVER
59th to 19th Avenue

Mining Activity Database

CELL NUMBER		Area of Active Mining (Acres)														
HORIZ.	VERT.	1972	1973	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
D	19							2.97	2.97	2.97	2.97	2.97	8.54	8.54	8.54	8.54
D	20							3.71	3.71	3.71	3.71	3.71	11.99	11.99	11.99	11.99
D	21				10.39	10.39	10.39	11.13	11.13	11.13	11.13	11.13	12.65	12.65	12.65	12.65
D	22				13.61	13.61	13.61	13.61	13.61	13.61	13.61	13.61	13.61	13.61	13.61	13.61
D	23				9.03	9.03	9.03	9.03	9.03	9.03	9.03	9.03	9.03	9.03	9.03	9.03
E	19							3.09	9.90	9.90	9.90	9.90	9.90	9.90	9.90	9.90
E	20					6.19	11.38	16.08	16.08	16.08	16.08	16.08	16.08	16.08	16.08	16.08
E	21			11.26	13.61	16.58	16.58	17.20	17.20	17.20	17.20	17.20	17.20	17.20	17.20	17.20
E	22		7.55	14.97	17.32	17.32	17.32	17.32	17.32	17.32	17.32	17.32	17.32	17.32	17.32	17.32
E	23		8.78	9.40	10.64	10.64	10.64	10.64	10.64	10.64	10.64	10.64	10.64	10.64	10.64	10.64
F	21															
F	22															
F	23														2.30	3.12
F	24				4.58	4.58	4.58	1.86	13.49	13.49	13.49	13.49	13.14	13.14	13.14	14.46
F	25									3.71	3.71	3.71	7.43	7.23	7.23	9.86
F	26												6.08	4.76	4.76	4.76
G	8															
G	9															
G	10															
G	11															
G	12															
G	13		1.11	1.11	1.48	1.48	1.73	3.71	2.85	1.73	1.73	1.73	2.79	2.79	2.79	2.79
G	14		7.42	13.49	14.48	14.97	15.71	15.71	14.60	4.58	4.58	4.58	5.26	5.26	5.26	12.98
G	15					3.84	7.18	7.67	3.34	3.71	3.71	3.71	8.05	8.05	8.05	20.86
G	16									3.84	3.84	3.84	3.84	2.30	14.29	18.73
G	17														2.79	3.29
G	18				.74	.74	.74	1.11								
G	19												13.14	13.47	14.95	14.95
G	20												12.98	12.32	13.96	16.43
G	21	9.90	9.90	12.37	4.58	4.58	4.58	6.93				3.29			2.46	2.46
G	22	6.93	6.93	10.51	12.37	12.37	12.37	14.10				10.51				
G	23	.99	1.73		3.71	3.71	3.71					6.08		7.56	9.86	9.86
G	24										2.85	6.90	12.98	15.44	15.44	20.21
G	25	4.70	4.70	4.70	4.70	4.70	4.70	2.60		13.49	19.42	17.58	19.55	18.07	18.07	19.71
G	26	9.90	13.49	6.80				4.70			10.89	8.05	8.21	8.21	8.21	9.36
G	27	15.22	3.71					5.57								
G	28	3.71														
G	29	13.98	18.93		3.96	3.96	7.18									
H	7															
H	8															
H	9															
H	10															
H	11															
H	12							5.57	5.57	5.57	5.57	5.57	6.65	8.62	8.62	8.62
H	13							3.34	4.70	3.71	3.71	3.71	6.41	6.41	6.41	6.41

H	14		1.73	1.73	1.73	3.59	3.96	12.74	4.70	4.70	4.70	11.83	11.83	11.83	11.83
H	15							7.42	7.92	7.92	7.92	4.60	13.30	13.30	13.30
H	16											.99	12.32	12.32	12.32
H	17														
H	18						4.33	4.62							
H	19	4.93	4.93	2.85	2.85	3.22	3.22	1.48							
H	20	4.90	6.19	9.03	7.05	7.05	7.05								
H	21	12.00	12.00	22.02	21.03	21.03	21.03								
H	22	20.78	20.78	21.16	15.84	15.84	15.84	8.91	4.33						
H	23	3.84	3.84	1.86	1.86	9.65	10.27	7.55	2.85	2.47	9.77				
H	24										3.96				
H	25											10.35	1.64	5.26	
H	26		11.01									5.91	9.53	8.21	
H	27	5.81	10.89										7.39	7.06	
H	28	10.64											1.15	4.11	
H	29	9.90	16.95												
I	4														
I	6							.99	3.22						
I	7							.99	7.30						
I	8														
I	9	1.11	1.11	1.11	1.11	1.11	1.11								
I	10														
I	11														
I	12														
I	13														
I	14								2.60						
I	15											2.79	2.79	2.79	2.79
I	16														
I	17														
I	18														
I	19	1.36	1.36	1.24	1.24	1.73	1.73	3.22							
I	20	1.86	1.86	1.86	1.86	1.86	1.86								
I	21			8.04	8.54	8.54	8.54								
I	22					1.98	1.98		1.61	4.95					
I	23			5.07	5.07	4.83	4.83								
I	24												1.48	2.30	
I	25												3.29	1.97	
I	26														
I	27													4.27	
I	28													.99	
J	2				2.10	3.71	3.71								
J	3		1.36	1.11	1.61	1.61	1.61			2.47	3.12				11.99
J	4									11.75	9.86		2.30	19.71	
J	5										2.96		1.15	8.21	
J	6							.74	4.45						
J	7							1.36							
J	8							4.70							
J	9	1.36	1.36	2.47	2.47	2.47	2.47								
J	10														
J	11														
J	12														
J	13														
J	14														
J	15														

J	16														
K	2	5.57	10.76	9.65	11.01	11.88	11.88								
K	3		2.85	3.71	3.71	3.71	3.71						3.78		
K	4														
K	5														
K	6												1.48		
K	7							1.24	4.83	9.53	9.53	6.57	10.84	10.84	
K	8								6.19	8.05	8.05		2.63	2.63	
K	9														
K	10														
K	11													1.31	
K	12												1.64	8.21	7.39
K	13														
L	3														
L	4														
L	5														
L	6														
L	7										2.96		3.78	3.78	
L	8												1.15	1.15	
L	9														
L	10														
L	11														
L	12														
M	3														
M	4														
M	5														
M	6														
M	7														
M	8														
N	4														
N	5														

TABLE D-11
 VERDE RIVER
 Cottonwood, Arizona

Mining Activity Database

CELL NUMBER		(Acres)	
HORIZ.	VERT.	'82 AREA	'87 AREA
A	1		
B	1		
C	1		
C	2		
D	1		
D	2		
D	3		
E	2		
E	3		
E	4		
E	5		
F	3		
F	4		
F	5		
F	6		
F	7		
F	8		
F	9		
F	10		
F	11		
F	12		
F	13		
F	14		
G	5		
G	6		
G	7		
G	8		
G	9		
G	10		
G	11		
G	12		
G	13		
G	14		
H	10		
H	11		
H	12		
H	13		
H	14		
I	10		
I	11		
I	12		
I	13		
I	14		
J	10		
J	11		

J	12	
J	13	
J	14	
K	9	
K	10	
K	11	
K	12	
K	13	
L	9	
L	10	
L	11	
L	12	
L	13	
M	9	
M	10	2.86
M	11	
N	8	
N	9	
N	10	1.10
N	11	.13
N	12	
N	13	
O	9	
O	10	
O	11	1.62
O	12	1.04
O	13	
P	9	
P	10	
P	11	.13
P	12	2.14
P	13	
P	19	
P	20	
Q	10	
Q	11	
Q	12	
Q	13	
R	11	
R	12	
R	13	

TABLE D.12
VERDE RIVER
Near Interstate 17

Mining Activity Database

CELL NUMBER		(Acres)
HORIZ.	VERT.	'79 AREA
G	7	3.93
G	8	.35
G	9	4.16
G	10	1.27
H	9	1.15
H	10	1.96

TABLE D.13
 AGUA FRIA RIVER
 Buckeye Rd. to Camelback Rd.

Mining Activity Database

CELL NUMBER		Area of Active Mining (Acres)												
HORIZ.	VERT.	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
A	6													6.28
A	7										3.31	8.60		12.23
A	8	3.31				4.29	4.29							
A	9													
A	10													
A	11													
A	12													
A	13													
B	6													1.65
B	7								5.62		5.62	3.64		4.30
B	8					.99	3.64				1.65			
B	9													
B	10													
B	11													
B	12													
B	13													
C	6													
C	7								1.98		2.98			
C	8													
C	9													
C	10													
C	11													
C	12													
C	13													
D	7													
D	8													
D	9													
D	10													
D	11													
D	12													
D	13													
E	6													
E	7													
E	8													
E	9													
E	10													
E	11													
F	6												2.31	.99
F	7												.33	.99
F	8	2.64												
F	9		1.65	2.64										
F	10						1.65							
G	6								1.65					
G	7	4.30	2.98	5.95	11.57	2.98	3.63				3.31		.99	4.30
G	8	3.63	3.97	7.27	4.63	.66	5.95				1.98			

G	9			2.98	2.31	3.31	2.31		.99		2.64	3.97		
G	10						3.30		1.32		1.32			
H	6							3.97	6.28	8.26	10.91	8.26	4.63	4.30
H	7					3.64	6.28	10.58		9.25		11.24		.99
H	8	1.98	3.31			6.28								
H	9	5.61	8.51			2.64	8.60		9.26		7.93			
H	10	.66	.99				1.65	6.28	1.65					
I	5													
I	6										7.93	8.60		7.27
I	7						3.64	3.31		3.97		8.27		3.64
I	8					2.98			4.63	4.63				
I	9					1.65	3.31		7.93	4.62	.99			
I	10													
J	5													
J	6													
J	7													
J	8										1.65	6.94	8.26	8.26
J	9									3.64	2.64	.13	13.55	15.87
J	10													
K	5													
K	6													
K	7	2.64	4.63			6.28	4.63	4.63						1.65
K	8	1.65	1.32			1.65								1.32
L	5													
L	6													
L	7	1.65	3.31			3.31		3.63						
L	8													
M	5													
M	6													
M	7													
M	8													
N	4													
N	5													
N	6													
N	7													
N	8													
O	3													
O	4													
O	5													
O	6								1.65	5.95				
O	7								1.32	1.65				
O	8													
P	2													
P	3													
P	4													
P	5													
P	6													
P	7													
P	8													
Q	1													
Q	2													
Q	3													
Q	4													
Q	5													

TABLE D.14
 NEW RIVER
 Agua Fria River Confluence to Peoria Ave.

Mining Activity Database

CELL NUMBER		Area of Active Mining (Acres)											
HORIZ.	VERT.	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
B	12												
B	13												
C	12	1.98		2.64		.99							
C	13			1.65		1.65							
D	12	1.65		1.32								1.65	
E	12												
F	11												
F	12												
G	11	4.96		2.98									
G	12												
H	10												
H	11	2.64		2.64									
H	12												
I	10												
I	11												
J	10												
J	11												
K	9												
K	10												
K	11												
K	12												
L	9												
L	10												
L	11												
L	12												
M	9											1.32	1.32
M	10						1.98	3.97	2.64		1.32	7.93	10.25
M	11												
M	12												
N	8												
N	9											5.95	11.90
N	10							1.65	3.97	1.65		5.29	
N	11												
O	7												
O	8												
O	9												1.65
O	10												
O	11												
P	7												
P	8								1.65		2.31		
P	9	5.62			2.31	2.31	6.28						
P	10	1.65					2.98						
Q	6		1.32										
Q	7		7.61										
Q	8							.66		2.64			

Q	9	2.64											
Q	10												
R	6	1.65											
R	7	1.98											
R	8												
R	9												
S	6												
S	7	8.26											
S	8												
S	9												
S	10												
T	5												
T	6												
T	7												
U	4												
U	5												
U	6												
U	7												
U	8												
V	4												
V	5												
V	6												
V	7												
V	8												
W	5												
W	6												
W	7												
X	6												
X	7												

TABLE D.15
 SANTA CRUZ RIVER
 Valencia Rd. to I-19

Mining Activity Database

CELL NUMBER		Area of Active Mining (Acres)			
HORIZ.	VERT.	1974	1980	1984	1985
F	4	4.56	4.77	4.77	
F	5	.57	1.00	1.00	
G	1				.15
G	3			.67	1.27
G	4	7.22	3.84	6.08	
G	5	.24		.28	
H	1			2.03	9.02
H	2				7.37
H	3		.09	6.93	14.69
H	4	.39	14.45	1.57	.46
H	5	.11			
I	1			.50	.72
I	2				2.09
I	3			.81	3.44
I	4		.17	3.86	4.36
J	3	1.57			
L	3			1.64	
M	2	2.38		.17	
M	3	.95			
N	2	1.66		.65	
N	3	.02			

TABLE D-16
 RILLITO CREEK
 I-10 to La Cholla Blvd.

Mining Activity Database

CELL NUMBER		Area of Active Mining (Acres)				
HORIZ.	VERT.	1974	1980	1983	1984	1985
E	2					
E	3					
E	4					
F	2					
F	3					
F	4		1.14	.99	.55	
F	5		1.54	1.03	3.23	.70
G	2					
G	3					
G	4		3.31	4.04	3.23	5.18
G	5		2.64	5.51	1.76	5.50
G	6					
G	7					
G	8					
H	2				1.40	.44
H	3		.84		.55	3.90
H	4		.70	.88	.84	.66
H	5		.44	2.50	.74	1.21
H	6					
H	7					
H	8					
I	3		2.39		.40	3.20
I	4		.81		1.73	5.47
I	5				.51	
I	6					
I	7					
I	8					
J	3		.15			.51
J	4		1.24			2.87
J	5		1.80			1.62
J	6					
J	7					
J	8					
K	7					
K	8					
K	9					
K	10					
K	11					
K	12					
K	13					
K	14					
K	15					
K	16					
K	17					
K	18					

K	19					
L	11					
L	12					
L	13					
L	14					
L	15					
L	16					
L	17					
L	18					
L	19					
L	20					
M	13					
M	14			3.05	.77	
M	15	.44		2.28	4.74	
M	16	1.58		.15		
M	17			.70		
M	18	.66		.55		
M	19	.40	.40			
M	20					
M	21					
M	22					
N	14					
N	15			.84		
N	16	.55				
N	17	1.00			.84	
N	18	3.97	3.93	2.87	.40	1.29
N	19	.18	.70		.55	
N	20	1.06			.59	
N	21					
N	22					
O	15					
O	16					
O	17	.59	1.54	.98	1.10	
O	18	.88	5.80	.33	1.87	1.58
O	19	.95	3.42	1.54	2.42	2.42
O	20	1.69	.66	.38	.99	.66
O	21	1.91				
O	22	1.69				
O	23					
O	24					
P	16					
P	17					
P	18					
P	19			.51	.59	.59
P	20			.59	.44	.44
P	21	.07				
P	22	1.95				
P	23	.77				
P	24	.15				
Q	17					
Q	18					
Q	19					
Q	20					
Q	21					

Q	22		.73	
Q	23	2.10	.59	
Q	24	.70		
Q	25			
R	18			
R	19			
R	20			
R	21			
R	22			
R	23	.18		
R	24			
R	25			
S	23			
S	24			
S	25	.26		1.87
S	26	.18		.44
T	23			
T	24			

APPENDIX E - COMPUTER PROGRAM FOR CHANNEL RESPONSE DUE TO IN-STREAM MINING (CRISM)

E.1 Introduction

The computer program CRISM was developed for the purpose of synthesizing the longitudinal response of a channel to the presence of a single in-stream excavation. The model is intended as a research tool and not as a general river mechanics simulation modeling. Analysis of the synthesized longitudinal scour datasets was combined with a model of lateral scour to provide a complete procedure for scour at an in-stream excavation. This appendix documents the operation and computer language code for the CRISM model. Two versions of the model were prepared: Version 1.3 is for gravel-bed channels and includes channel-bed armoring procedures; and Version 1.2 which is for sand-bed channels and does not account for channel-armoring.

Version 1.0 of the model, was used to test the sensitivity of the sand-bed and gravel-bed gradations to armoring. The sand-bed gradation showed no change or armoring formation during aggradation/degradation, while the gravel-bed gradation varied significantly during aggradation/degradation periods. Also, it was found by this analysis that sediment transport rates for the sand-bed gradation required the computation of both the contact bed-load and the suspended bed-load transport. However, since the armoring potential of the sand-bed gradation was negligible, the transport rate could be based on a more general relation without the computation of the transport rates by individual size fractions. A regressed form of the Meyer-Peter Muller (MPM) bed-load equation with computation of the suspended-load using the Einstein procedure developed by Zeller and Fullerton (1983) was chosen.

For the gravel-bed gradation, it was found that the suspended bed-load was quite small relative to the contact bed-load. In this case, the MPM equation was used without computation of the suspended load. Because armoring was important, the sediment transport was calculated by size fraction.

E.2 Program Operation

The CRISM program requires a relatively simple input file and produces several output files. The program is designed for execution in batch mode so that several different input files can be run consecutively. Information on program status is displayed on the screen permitting the user to monitor the program execution. The required input data for Version 1.3 and 1.2 are given in Tables E.1 and E.2, respectively. The printer output file format for the two versions of the model are slightly different, and are shown in Figures E.1 and E.2, respectively. The program also produces an output file formatted for use with a

TABLE E.1

Description of Input Data File, Version 1.3
Gravel-Bed Channel

Operational Data: (One record)		
Number of cross sections		:integer
Number of sediment sizes		:integer
Number of discharge intervals		:integer
Time increment, minutes		:real
Initial downstream channel slope		:real
Finite difference weighting factor		:real
Output print interval		:integer
Plot file toggle (1=on, 0=off)		:integer
Section number of downstream pit brink		:integer
Gradation Data: (Three records)		
Record 1		
Interval sizes, mm		:array of real
Record 2		
Size fractions for parent layer		:array of real
Record 3		
Size fractions for active layer		:array of real
Flow Data: (One record for each discharge interval)		
Number of discharges in the interval		:integer
Interval discharge, cfs/ft		:real
Cross Section Data: (One record for each cross-section)		
Section number		:integer
Reach length, feet		:real
Bed elevation, feet		:real

TABLE E.2

Description of Input Data File, Version 1.2
Sand-Bed Channel

Operational Data: (One record)		
Number of cross sections		:integer
Number of discharge intervals		:integer
Time increment, minutes		:real
Initial downstream channel slope		:real
Finite difference weighting factor		:real
Output print interval		:integer
Plot file toggle (1=on, 0=off)		:integer
Section number of downstream pit brink		:integer
Gradation Data: (One record)		
Mean bed material diameter, mm		:real
Gradation coefficient		:real
Flow Data: (One record for each discharge interval)		
(One record for each interval)		
Number of discharges in the interval		:integer
Interval discharge, cfs/ft		:real
Cross Section Data: (One record for each cross-section)		
Section number		:integer
Reach length, feet		:real
Bed elevation, feet		:real

FIGURE E.1

Channel Response due to In-Stream Mining
 ----- Program CRISM (Ver 1.3) -----
 Gravel-Bed Channels, with Armoring
 and Channel Width Variation

Simons, Li & Associates Inc.
 March 1988

Run Date : 3/26/1988
 Run Time : 12:48:19

Run Number: 30
 Q = 160 cfs; Pit Depth = 5 ft; Slope = 0.004 ft/ft

of x-sections = 80
 # of time steps = 480
 # of sediment sizes = 10
 Downstream bed slope = 0.0040
 FD Weighting Factor = 0.400
 Shields parameter = 0.054
 Time step interval = 1.0 minutes

Particle Size (mm) :
 0.125 0.500 2.000 5.660 11.300 22.600 45.300 90.500 181.000 362.000
 Parent Layer Fractions (%) :
 3.000 5.000 8.000 5.000 7.000 7.000 9.000 8.000 37.000 11.000

TIME STEP # 24 Q = 160.00 cfs

Sec #	Reach Length (ft)	Width (ft)	Bed Elev (ft)	WS Elev (ft)	Flow Depth (ft)	Energy Slope (ft/ft)	Vel (ft/s)	nc	ng	Taug (lb/sf)	Gt (lb/s)	dz (ft)	da (ft)	D50 (mm)
1	0.0	1.0	985.600	998.09	12.49	0.00400	12.81	0.040	0.040	3.22	21.9	0.00000	0.7299	120.95
2	800.0	1.0	988.800	1001.29	12.49	0.00401	12.81	0.040	0.040	3.23	22.0	-0.00006	0.7299	121.00
3	400.0	1.0	990.395	1002.89	12.50	0.00401	12.80	0.040	0.040	3.22	21.8	-0.00042	0.7299	121.67
4	400.0	1.0	991.982	1004.51	12.53	0.00400	12.77	0.040	0.040	3.23	21.5	-0.00095	0.7299	123.41
5	200.0	1.0	992.777	1005.38	12.60	0.00393	12.70	0.040	0.040	3.19	20.9	-0.00071	0.7299	123.98
6	200.0	1.0	993.589	1006.22	12.63	0.00388	12.67	0.040	0.040	3.15	20.9	0.00013	0.7299	122.19
7	200.0	1.0	994.403	1007.04	12.63	0.00384	12.66	0.039	0.039	3.13	21.0	0.00101	0.7299	120.35
8	200.0	1.0	995.231	1007.83	12.60	0.00383	12.70	0.039	0.039	3.11	21.5	0.00230	0.7299	116.77
9	100.0	1.0	995.646	1008.17	12.52	0.00389	12.78	0.039	0.039	3.13	22.1	0.00253	0.7299	115.04
10	100.0	1.0	996.040	1008.52	12.48	0.00394	12.82	0.039	0.039	3.17	22.4	0.00225	0.7299	115.74
11	100.0	1.0	996.442	1008.87	12.43	0.00400	12.88	0.039	0.039	3.20	22.8	0.00237	0.7299	115.46
12	100.0	1.0	996.842	1009.22	12.38	0.00405	12.93	0.039	0.039	3.23	23.2	0.00222	0.7299	115.62
13	100.0	1.0	997.241	1009.57	12.33	0.00411	12.98	0.039	0.039	3.26	23.6	0.00204	0.7299	115.76
14	100.0	1.0	997.638	1009.92	12.29	0.00417	13.02	0.039	0.039	3.30	23.9	0.00171	0.7299	116.13
15	100.0	1.0	998.035	1010.28	12.25	0.00422	13.06	0.039	0.039	3.33	24.2	0.00124	1.1877	117.05
16	100.0	1.0	998.425	1010.65	12.22	0.00427	13.09	0.039	0.039	3.36	24.3	-0.00269	1.1877	118.37

FIGURE E.2

Channel Response due to In-Stream Mining
Sand-bed Conditions / No Armoring
----- Program CRISM (Ver 1.2) -----

Simons, Li & Associates Inc.
February 1988

Run Date : 2/15/1987
Run Time : 18:26:54

Sand Channel - 1600' x 5' pit
(So = 0.002, q = 160 cfs, duration = 0.167 days)

of x-sections = 81
of time steps = 480
Downstream bed slope = 0.0020
FD Weighting Factor = 0.000
Time step interval = 0.5 minutes

TIME STEP # 24, q = 160.00 cfs/ft

Sec #	Reach Length (ft)	Bed Elev (ft)	WS Elev (ft)	Bed Angle (deg)	Energy Slope (ft/ft)	Vel (ft/s)	nc	Tau (lb/sf)	Gt (lb/s)	dz (ft)
1	0.00	992.600	1007.20	0.00	0.00199	10.96	0.036	1.87	76.631	0.00000
2	800.00	994.201	1008.82	0.11	0.00198	10.95	0.036	1.86	76.374	0.00003
3	400.00	995.000	1009.61	0.11	0.00198	10.95	0.036	1.87	76.427	-0.00003
4	400.00	995.796	1010.41	0.11	0.00198	10.95	0.036	1.87	76.380	-0.00019
5	200.00	996.195	1010.82	0.11	0.00198	10.94	0.036	1.86	76.192	-0.00011
6	200.00	996.599	1011.23	0.12	0.00198	10.94	0.036	1.86	76.120	0.00033
7	200.00	997.013	1011.63	0.12	0.00198	10.95	0.036	1.86	76.342	0.00144
8	200.00	997.451	1012.03	0.13	0.00200	10.98	0.036	1.88	77.303	0.00311
9	100.00	997.671	1012.18	0.13	0.00203	11.03	0.036	1.89	78.858	0.00333
10	100.00	997.868	1012.33	0.11	0.00205	11.06	0.036	1.90	79.967	0.00195
11	100.00	998.046	1012.48	0.10	0.00206	11.08	0.036	1.91	80.616	0.00029
12	100.00	998.202	1012.63	0.09	0.00206	11.09	0.036	1.91	80.713	-0.00550
13	100.00	998.392	1012.90	0.10	0.00203	11.03	0.036	1.89	78.879	0.00294
14	100.00	998.582	1013.05	0.11	0.00204	11.06	0.036	1.90	79.858	-0.00143
15	100.00	998.810	1013.30	0.13	0.00204	11.05	0.036	1.90	79.381	0.00134
16	100.00	998.983	1013.45	0.10	0.00204	11.06	0.036	1.90	79.828	-0.00188
17	100.00	999.207	1013.70	0.13	0.00203	11.04	0.036	1.90	79.201	0.00125
18	100.00	999.381	1013.86	0.10	0.00204	11.05	0.036	1.90	79.617	-0.00177
19	100.00	999.606	1014.11	0.13	0.00203	11.03	0.036	1.89	79.028	0.00081
20	100.00	999.778	1014.27	0.10	0.00203	11.04	0.036	1.90	79.298	-0.00005
21	100.00	1000.021	1014.51	0.14	0.00203	11.04	0.036	1.90	79.279	0.00185
22	100.00	1000.197	1014.66	0.10	0.00204	11.06	0.036	1.90	79.897	-0.00426
23	100.00	1000.402	1014.93	0.11	0.00202	11.02	0.036	1.89	78.477	0.00385
24	100.00	1000.606	1015.08	0.12	0.00204	11.06	0.036	1.90	79.759	0.00214
25	100.00	1000.783	1015.22	0.10	0.00205	11.08	0.036	1.91	80.474	-0.00343
26	100.00	1000.992	1015.48	0.12	0.00203	11.04	0.036	1.90	79.329	0.00215

plotting program. A flow chart of the main program for CRISM is given in Figure E.3.

E.3 Program Listings

A complete listing of CRISM, Versions 1.3 and 1.2 is given at the end of this Appendix.

E.4 Program Execution

The program runs under the MS-DOS operating system (Version 2.0 or higher). Typically, the program is executed using a batch file that automatically assigns the correct file names to the input and output files used by the program. A listing of this batch file is given below. Variations on the batch file were used to execute programs consecutively.

CRISM BATCH EXECUTION

```
copy %1.dat crm.dat
crism12
copy crm.dat %1.dat
copy crm.out %1.out
copy crm.plt %1.plt
del crm.*
```

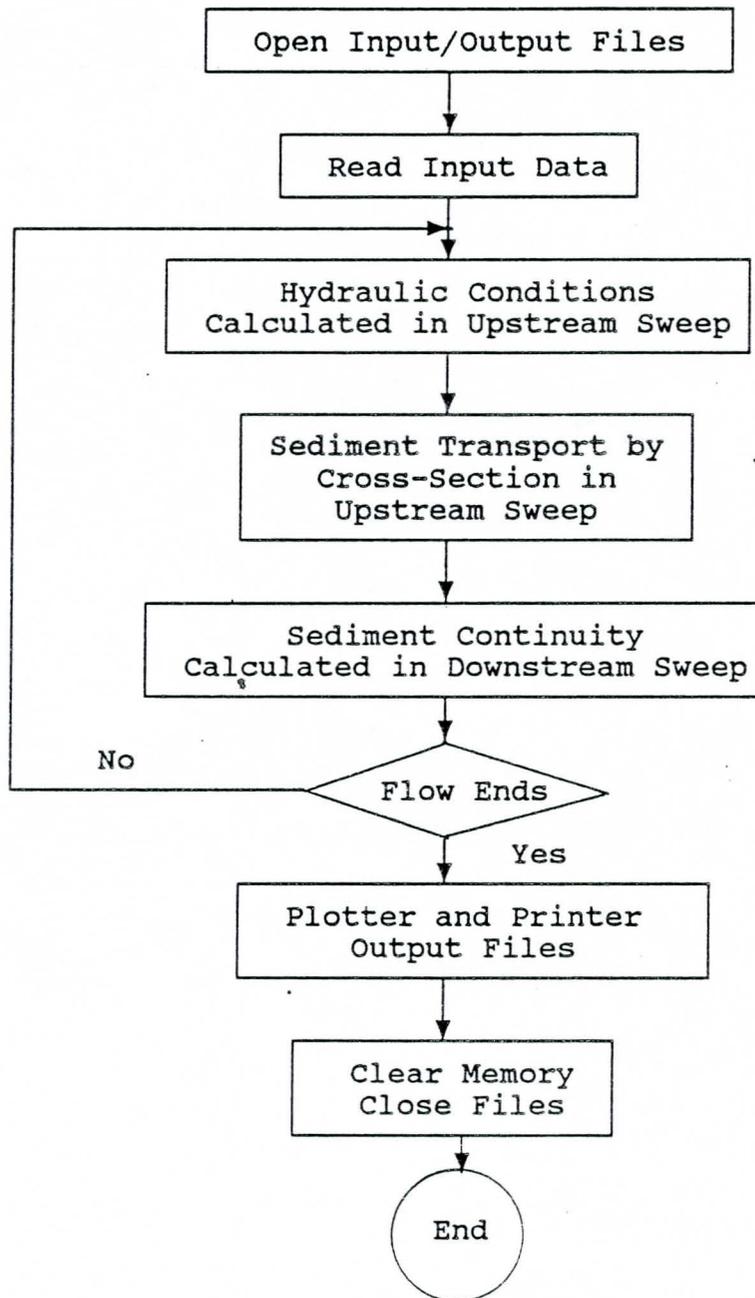


Figure E.3. Flow Chart of the Main Program for CRISM.

E.5 Theory

The hydraulic computations are calculated using a standard step backwater procedure supplemented with several routines that account for the filling of the excavation and the rapidly varied flow conditions near the excavation brink. Figure E.4 shows a flow chart of the hydraulics computation conducted by the CRISM model. Since the model is setup to be a numerical flume, the flow computations can be simplified to those for a wide rectangular channel. For this condition, the equation for normal depth is,

$$y_n = \left(\frac{q n}{1.486 S^{1/2}} \right)^{3/5} \quad (E.1)$$

where y_n = the normal depth (ft);
 q = the unit discharge (cfs/ft);
 n = the Manning roughness coefficient; and,
 S = the channel bed slope.

and the equation for critical depth is,

$$y_c = \left(\frac{q^2}{g} \right)^{1/3}$$

where g is the gravitational constant (32.2 ft/sec²). Rouse (1936) found that for a free overfall, critical depth is about 1.4 times the brink depth, or $y_c = 1.4 y_b$. Therefore, normal depth calculations near the excavation brink were limited to $y_n = 0.71 y_c$.

The channel roughness was based on alluvial resistance equations developed by Blodgett (1986). For large relative roughness conditions ($y/D_{50} < 54$) the roughness coefficient is given by the following equation:

$$n = C * D_{50}^{1/6} \quad (E.2)$$

where

$$C = \frac{(y/D_{50})^{1/6}}{[8.58 + 20.0 * \log(y/D_{50})]}$$

D_{50} is the mean of the bed-material gradation.

For small relative roughness conditions ($y/D_{50} > 54$), the roughness coefficient is simply:

$$n = 0.0231 * y^{1/6} \quad (E.3)$$

The water surface profile is calculated from the first section in the reach that is determined to have a subcritical flow regime. When the pit is full, profile calculations begin at

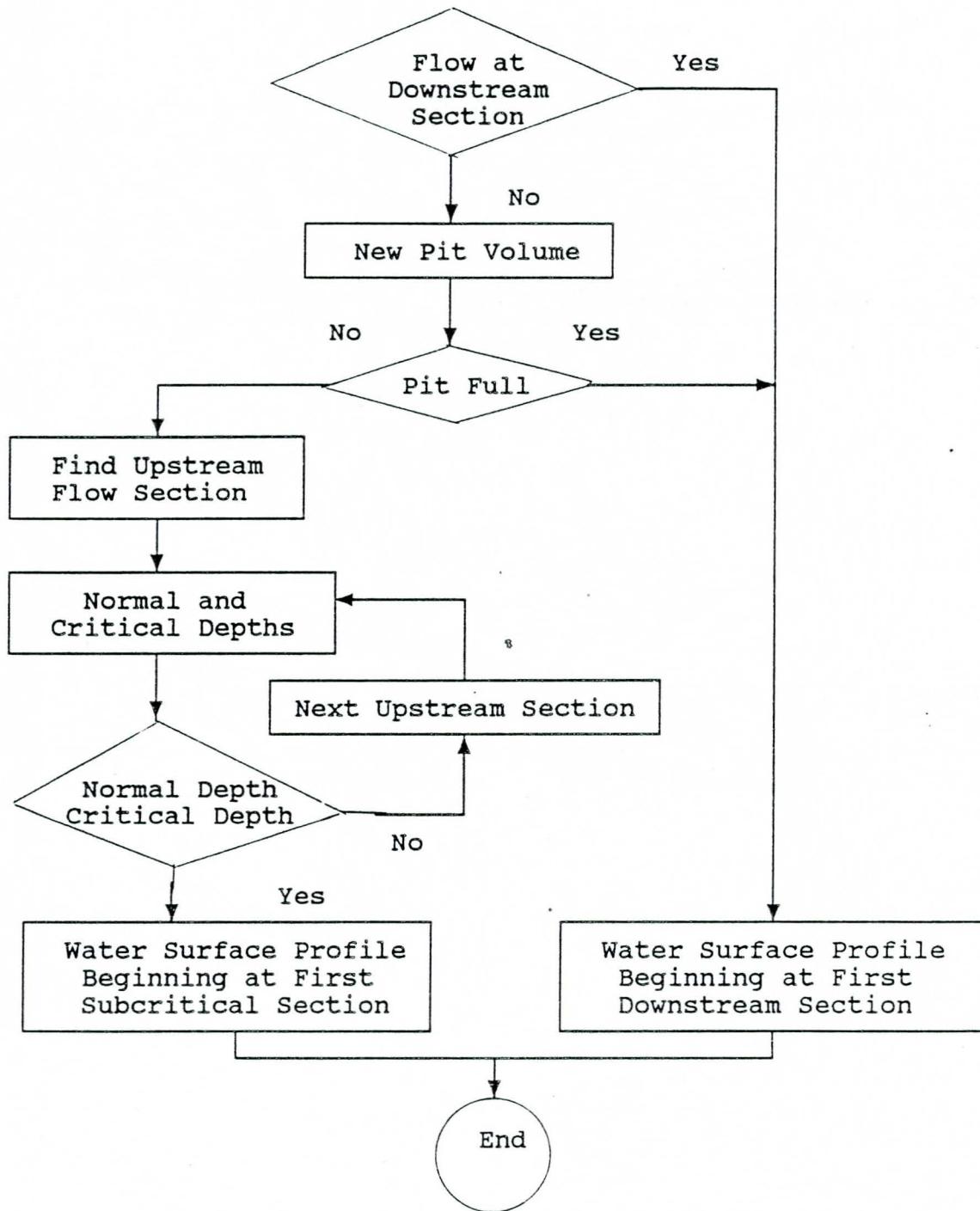


Figure E.4. Hydraulics Flow Diagram

the first downstream section using normal depth as the boundary condition. The basic equations employed are:

Flow-energy equation:

$$y_2 + \frac{\alpha_2 V_2^2}{2g} = y_1 + \frac{\alpha_1 V_1^2}{2g} + h_e \quad (E.4)$$

Energy head-loss equation:

$$h_e = L\bar{S}_f + C \left[\frac{\alpha_2 V_2^2}{2g} - \frac{\alpha_1 V_1^2}{2g} \right] \quad (E.5)$$

where

- y_1, y_2 = water-surface elevations at ends of reach;
- V_1, V_2 = mean velocities at ends of reach;
- α_1, α_2 = velocity-head correction factors for flow at ends of reach;
- h_e = energy head loss;
- L = discharge-weighted reach length;
- \bar{S}_f = representative friction slope for reach; and,
- C = expansion or contraction loss coefficient.

The sediment transport rates for sand-bed and gravel-bed conditions are computed using the Zeller-Fullerton and the Meyer-Peter, Muller equations, respectively. The Zeller-Fullerton equation (1983) is derived from the combined solution of the Meyer-Peter, Muller and Einstein equations for sand-bed gradations. The equation is a multiple regression of total transport rate (lb/sec/ft) based on five independent variables:

$$g_t = 1.058 n^{1.77} V^{4.32} y^{-0.30} D_{50}^{-0.61} G^{0.45} \quad (E.6)$$

where n = the Manning roughness coefficient;

V = the flow velocity (ft/sec);

y = the flow depth (ft);

D_{50} = the mean bed-material size (mm); and,

G = the gradation coefficient, where

$$G = 1/2 [D_{84}/D_{50} + D_{50}/D_{16}]$$

The Meyer-Peter, Muller bed-load transport equation was used to calculate the sediment transport by size fraction for gravel-bed conditions. The unit of sediment transport for the i th size fraction, g_{ti} , is lb/sec/foot of channel width,

$$g_{ti} = 9.23 (K * \tau_o - \tau_c)^{1.5} \quad (E.7)$$

where

$$K = n_g/n_c$$

$$\tau_o = \gamma Y S_e$$

$\tau_c = \gamma' s C_s d_{si}$
 n_g = the grain roughness from equation E.2;
 n_c = the total channel roughness;
 γ = the unit weight of water (62.4 lb/ft³);
 $\gamma' s$ = the submerged unit weight of sediment (103 lb/ft³);
 S_e = the slope of the energy gradeline;
 C_s = a constant of 0.047; and,
 d_{si} = the sediment size of the i th size interval (feet).

The total sediment transport per foot of width for gravel-bed conditions is the sum of the transport for each size fraction,

$$g_t = \sum g_{ti} p_i \quad (E.8)$$

where p_i is the fraction of the gradation in the i th size interval.

The volumetric change in the channel-bed profile at a section is computed based on the sediment continuity equation which states:

$$\frac{\delta q}{\delta x} + (1-\lambda) \frac{\delta z}{\delta t} = q_{sl} \quad (E.9)$$

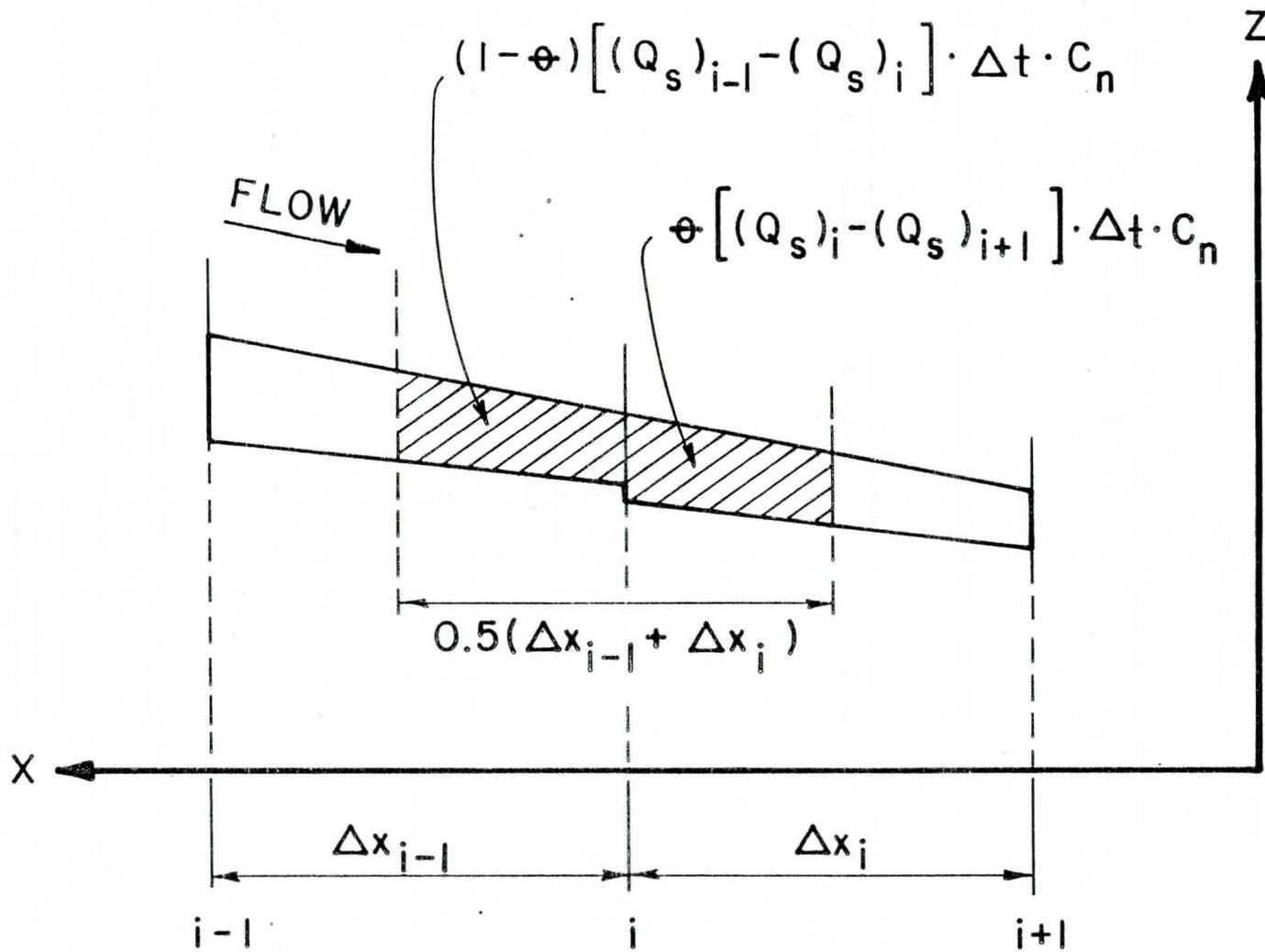
where

q_s = the sediment discharge (cfs/ft);
 z_b = cross-section elevation (feet);
 q_{se} = the lateral sediment inflow (cfs/ft); and,
 λ = porosity of the bed sediment.

A general finite difference formulation of the sediment continuity equation was used to calculate the aggradation/degradation at section i , Δz_i , as follows (Figure E.5):

$$\Delta z_i = \frac{(1-\theta)[(G_t)_{i-1} - (G_t)_i] + \theta[(G_t)_i - (G_t)_{i+1}]}{0.5(\Delta x_{i-1} + \Delta x_i)} * (C_n/W_i) \quad (E.10)$$

in which θ = is a weighting factor with a value between 0 and 1, $G_{ti} = g_{ti} * W_i$, and C_n is a conversion factor from unbulked mass transport in lb/sec to bulked transport in cfs. By varying the weighting factor, various schemes for longitudinal sediment distribution are reproduced. For $\theta = 0.5$, equation E.10 is equivalent to the central difference scheme used in the HEC-6 model (1976). When $\theta = 0.25$ (triangular shape with sharp edge facing upstream), the longitudinal sediment distribution is equivalent to the one used by Simons, Li and Brown (1979). When $\theta = 0.0$, the longitudinal sediment distribution is equivalent to the upstream (backward) difference scheme used by Perdreau and



Schematic Diagram of Sediment Continuity

Cunge (1971) and Chang and Hill (1976). Finally, when $\theta = 1.0$, the longitudinal sediment distribution is a downstream (forward) difference scheme that cannot be used for simulating the degradation process because the degradation at the upstream end does not propagate downstream with this scheme.

The process of bed armoring is an important mechanism through which degrading gravel-bed channels achieve a new equilibrium condition. A numerical model for predicting bed armoring was used in the CRISM model. The model is based on the findings of earlier experimental studies (Gessler, 1967; Harrison, 1950; and Little and Meyer, 1972) and was verified in the calibration of the model.

A two-layer model, consisting of a surface layer and a parent layer, is used to simulate the armoring process. The thickness of the surface layer is assumed equal to the mean of non-moving sizes in the gradation. Sediment particles finer than a critical size are removed from the surface layer. The amount and size distribution of the eroded material depends on the size distribution in the surface layer and the transport capacity of the flow. The surface layer contains sediment of all size fractions of the parent bed material, but the fraction of coarser particles in the surface layer increases as the armoring develops.

The surface layer distribution is modified in the following manner. The scoured volumes for each size fraction are picked from the surface layer, if available; otherwise a deficit volume is determined. Finally, a volume equal to the total deficit volume is transferred from the parent bed layer to the surface layer to maintain the volume of the surface layer and mixed with the remaining material of the surface layer. A new surface layer thickness is then computed at the end of the time step.

E.6 Derivation of Sand-Bed Scour Equations

Datasets were synthesized using the CRISM program and varying each of the input parameters over a determined range. Two modes of scouring were evaluated: upstream headcutting and downstream scour. To synthesize a dataset for upstream headcutting, model parameters were varied in the following manner:

Channel slope	= 0.001, 0.002, 0.004
Inflow unit discharge	= 20, 40, 80, 160 cfs/ft
Pit depth	= 10 feet
Pit length	= 1000 ft
Pit width/channel width ratio	= 1, 2, 4, 8

This resulted in 48 computer runs. To synthesize the dataset for downstream scour, model parameters were varied in the following manner.

Channel slope = 0.001, 0.002, 0.004
Inflow unit discharge = 20, 40, 80, 160 cfs/ft
Pit depth = 5, 10, 20 feet
Pit length = 1600 feet

This resulted in 36 computer runs, for a total number of runs of 84 for the sand-bed condition.

From these runs for each time interval, the maximum scour depth and scour length at 5 percent of maximum scour depth was determined. It was found that the scour dimensions for the two scour modes could be normalized in time by dividing the cumulative time by a characteristic time. For headcutting, the characteristic time was found to be the fill time for the excavation (i.e., the volume of the excavation divided by the inflow rate). For downstream scour, the characteristic time was equal to the travel time of the sediment wave through the excavation (i.e., the length of the excavation divided by the sediment wave celerity). It was found that the scour depths and lengths could be normalized by dividing by characteristic length dimensions. For headcutting, the scour depth was divided by the pit depth and the scour length was divided by the pit length. For downstream scour, the scour depth was divided by the square root of the pit depth and the scour length by the product of pit length and depth. Figures E.6 through E.21 show plots of the normalized scour dimension and time.

A step wise development of envelope relationships was conducted using the normalized datasets. Envelope curves were visually identified for the family of runs made. The slope and intercept of the linear portion of each curve was determined. The maximum value for each curve was also determined. These coefficients are summarized in Table E.3.

TABLE E.3

Coefficients for Envelope Curves

Location	q	W*	Intercept b	Slope m	Maximum Scour
Headcut Depth	20	1	1.21	0.656	0.501
		2	0.815	0.690	0.408
		4	0.535	0.708	0.378
		8	0.340	0.747	0.333
	40	1	1.043	0.603	0.501
		2	0.878	0.669	0.464
		4	0.626	0.671	0.408
		8	0.389	0.692	0.308
	80	1	0.929	0.597	0.479
		2	0.995	0.782	0.447
		4	0.795	0.751	0.480
		8	0.492	0.649	0.477
	160	1	0.834	0.508	0.470
		2	0.911	0.693	0.496
		4	0.419	0.196	0.478
		8	0.497	0.409	0.490
Headcut Length	20	1	.567	.217	.567
		2	.361	.333	.361
		4	.230	.340	.230
		8	.153	.355	.153
	40	1	.646	.277	.646
		2	.384	.103	.384
		4	.256	.382	.256
		8	.171	.394	.171
	80	1	.682	.350	.682
		2	.469	.454	.469
		4	.283	.428	.283
		8	.186	.465	.186
	160	1	.812	.584	.812
		2	.551	.536	.551
		4	.311	.528	.311
		8	.223	.595	.223
Downstream Scour Depth	20	NA	2.03	.435	1.88
	40	NA	2.41	.438	2.24
	80	NA	2.71	.435	2.51
	160	NA	3.41	.435	3.16
Downstream Scour Length	20	NA	34.7	0.628	34.7
	40	NA	32.4	0.634	32.4
	80	NA	31.3	0.627	31.3
	160	NA	30.2	0.635	30.2

where W_* is the relative width ratio, N_p/W_c (pit width/inflow channel width) $\log(L_{S*} \text{ or } Y_{S*}) = b + m \log(T_*)$
 L_{S*} , Y_{S*} and T_{S*} are dimensionless scour length, scour depth and time, respectively.

The coefficients of the envelope curves were plotted with respect to the independent variables of unit discharge and relative width (the ratio of pit width to inflow channel width), and equations developed. The following equations summarize the coefficient equations:

Headcut Depth

$$b_1 = 1.24 W_*^{-2.46} q^{-0.451}$$

$$m_1 = 0.648$$

Headcut Length

$$b_2 = 0.219 q^{0.262} W_*^{-0.624}$$

$$m_2 = 0.216 q^{0.155}$$

Downstream Scour Depth

$$b_3 = 0.960 q^{0.25}$$

$$m_3 = 0.435$$

Downstream Scour Length

$$b_4 = 41.8 q^{-0.0625}$$

$$m_4 = 0.631$$

The time of maximum downstream scour depth was found to equal $T_* = 0.84$. This indicates that as the sediment wave approaches the downstream pit brink, that scour stops. The time of maximum headcutting depth was found to be less than or equal to $T_* = 1.0$. This indicates that once the pit fills with water that headcutting ends. The headcutting depth can be limited by deposition below the headcut; therefore, a separate equation was developed to calculate the maximum headcut depth. It was found that headcut scour depth never exceeded half the pit depth. The following equation was developed for maximum headcut depth:

$$\frac{Y_{smax}}{Y_p} = a_1 q^{b_1} \quad \text{for } \frac{Y_{smax}}{Y_p} < 0.5$$

$$\frac{Y_{smax}}{Y_p} = 0.50 \quad \text{for } \frac{Y_{smax}}{Y_p} \geq 0.5$$

$$a_1 = 0.120 W_*^{0.672}$$

$$b_1 = 0.286 W_*^{-0.350}$$

E-17

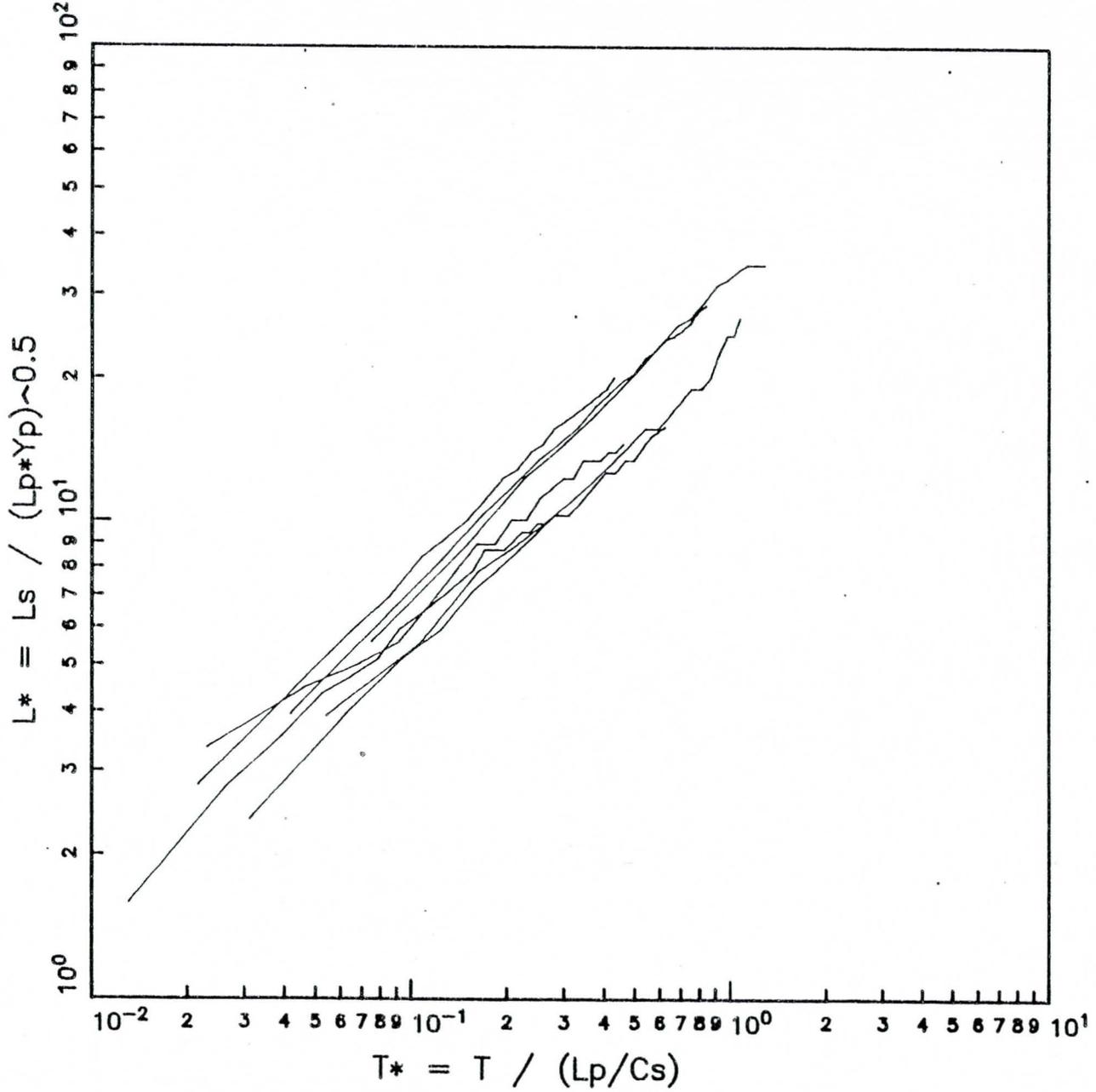


Figure E.6. Normalized Downstream Scour Length Graph ($q = 20$ cfs/ft)

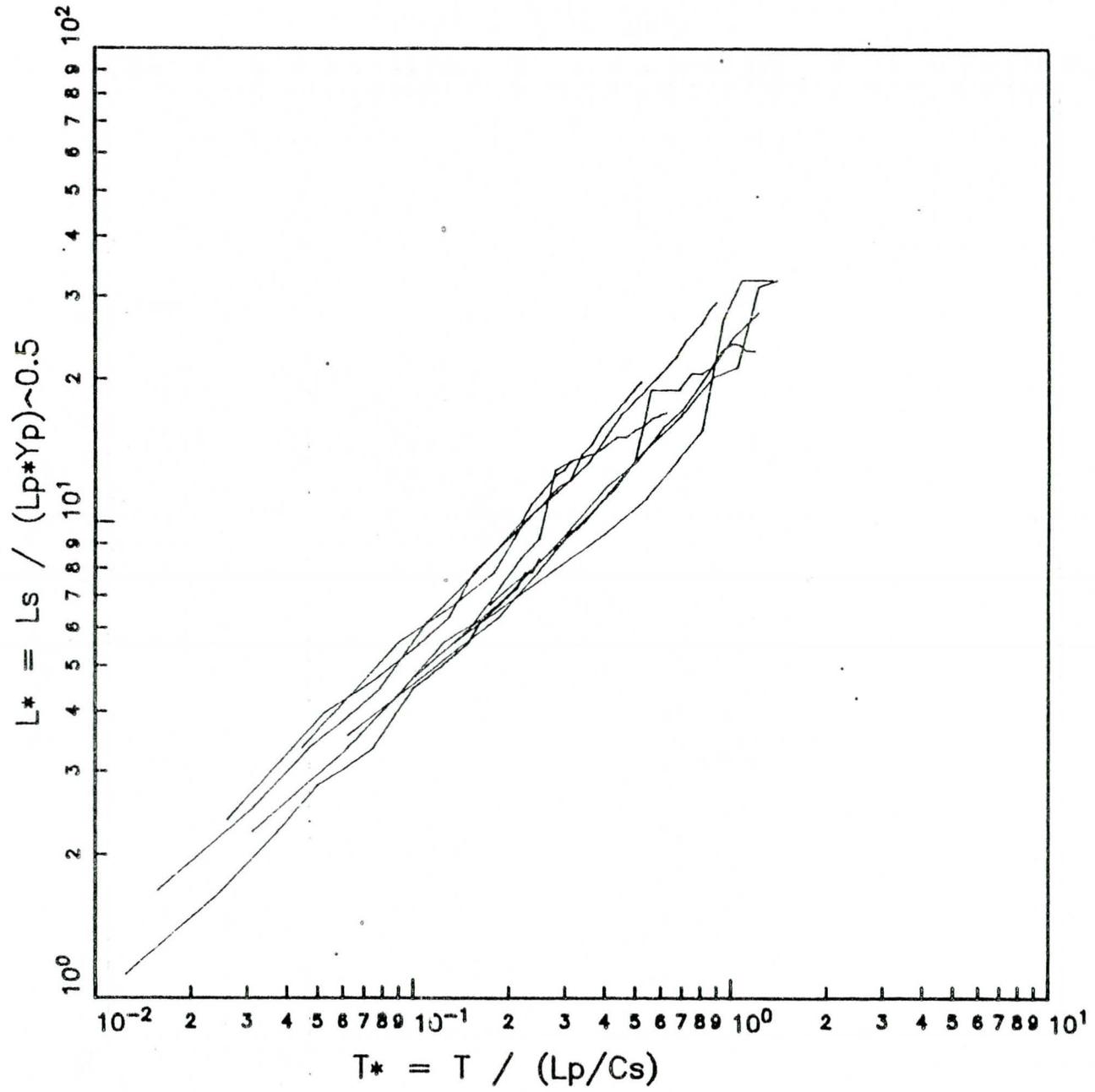


Figure E.7. Normalized Downstream Scour Length Graph ($q = 40$ cfs/ft)

$q = 80 \text{ cfs/ft}$

E-19

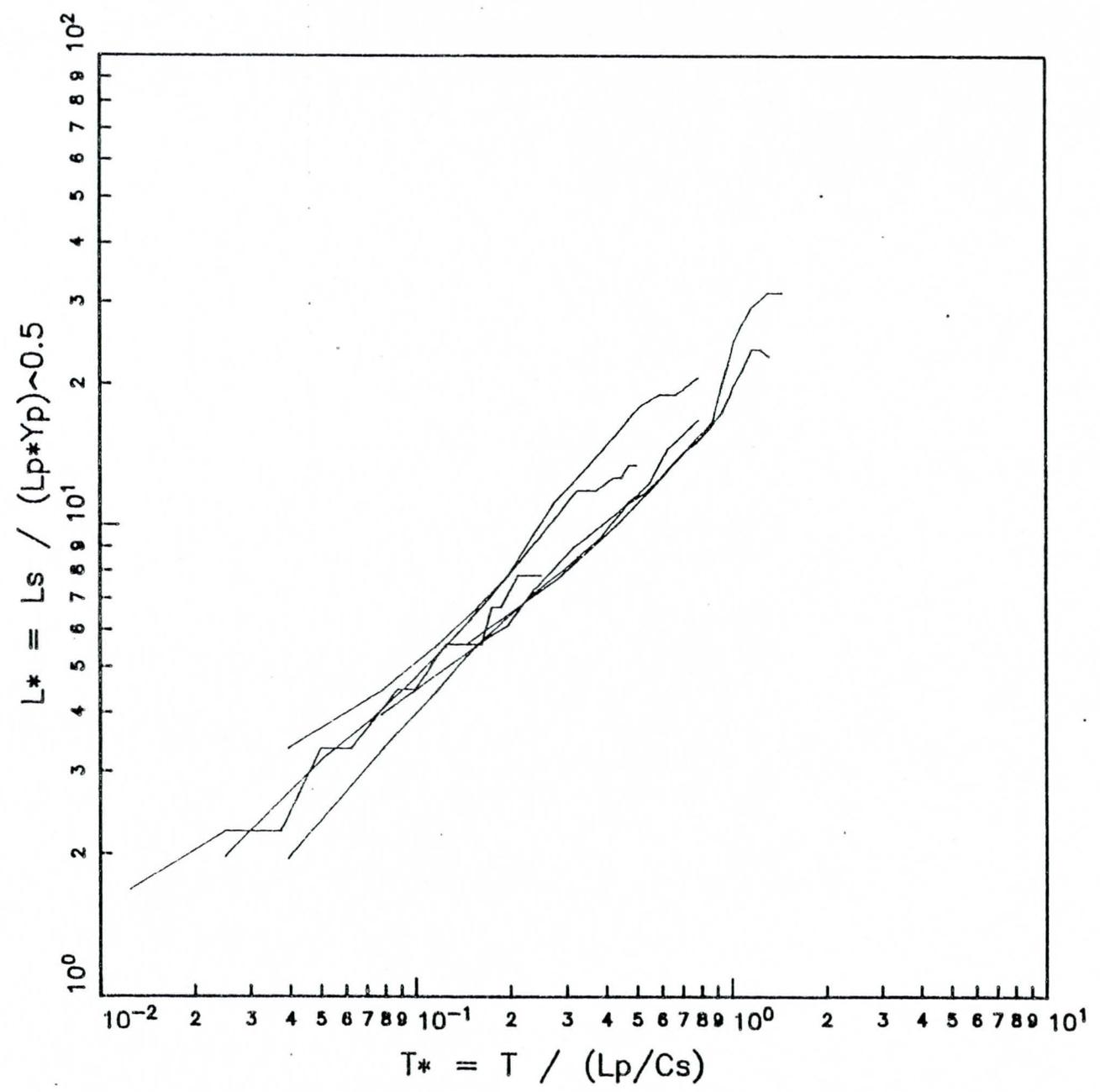


Figure E.8. Normalized Downstream Scour Length Graph ($q = 80 \text{ cfs/ft}$)

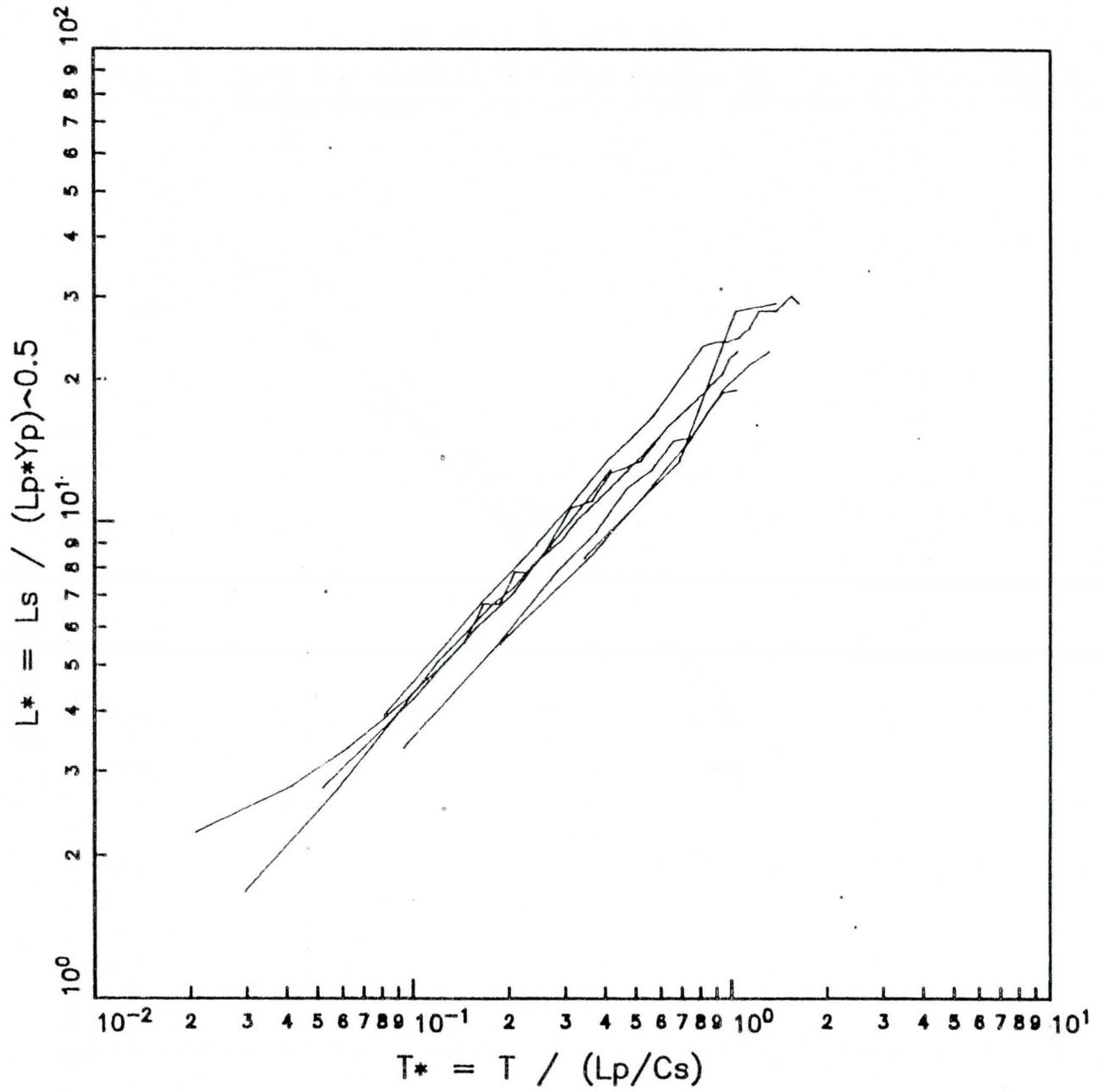


Figure E.9. Normalized Downstream Scour Length Graph ($q = 160$ cfs/ft)

E-21

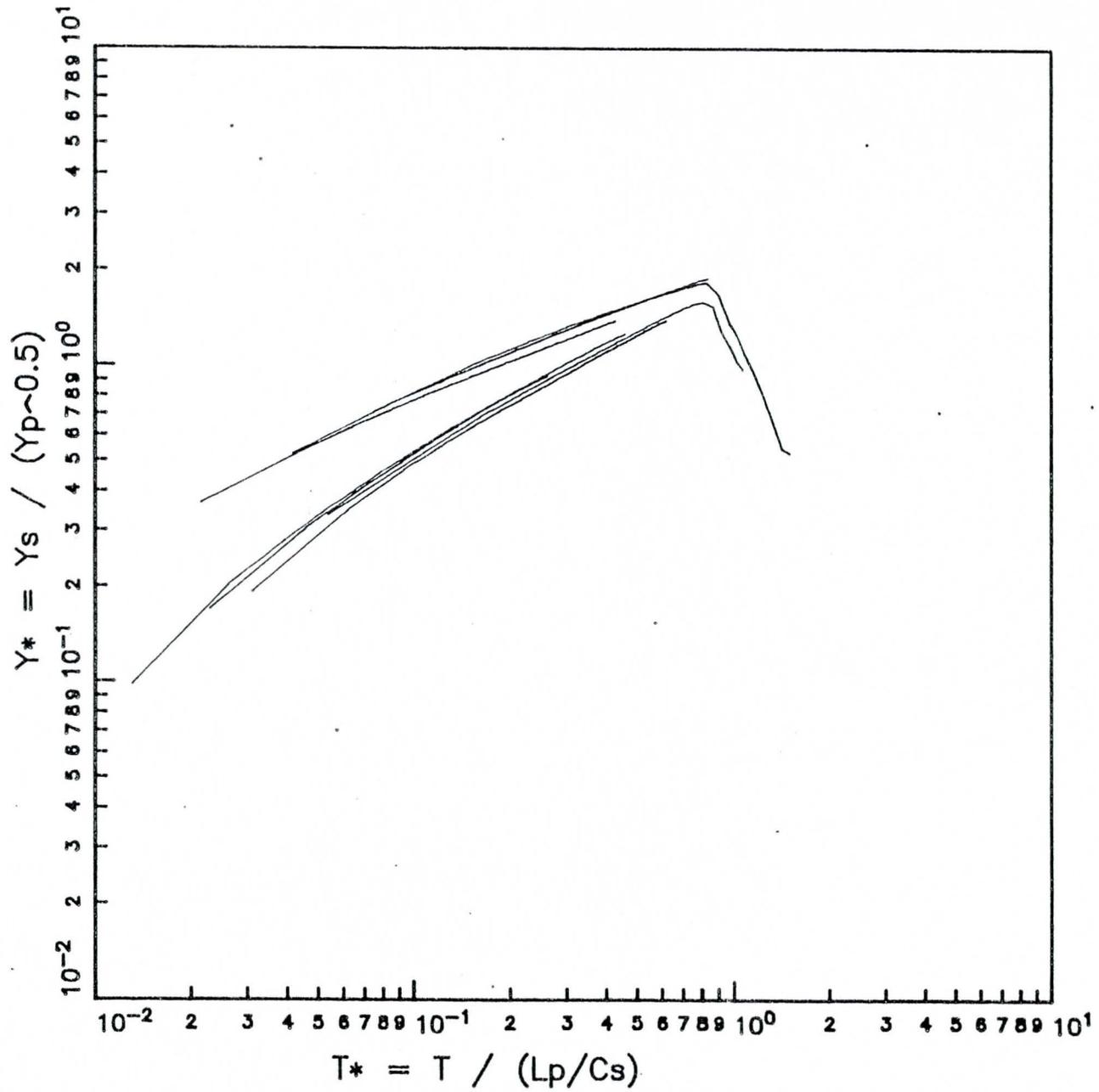
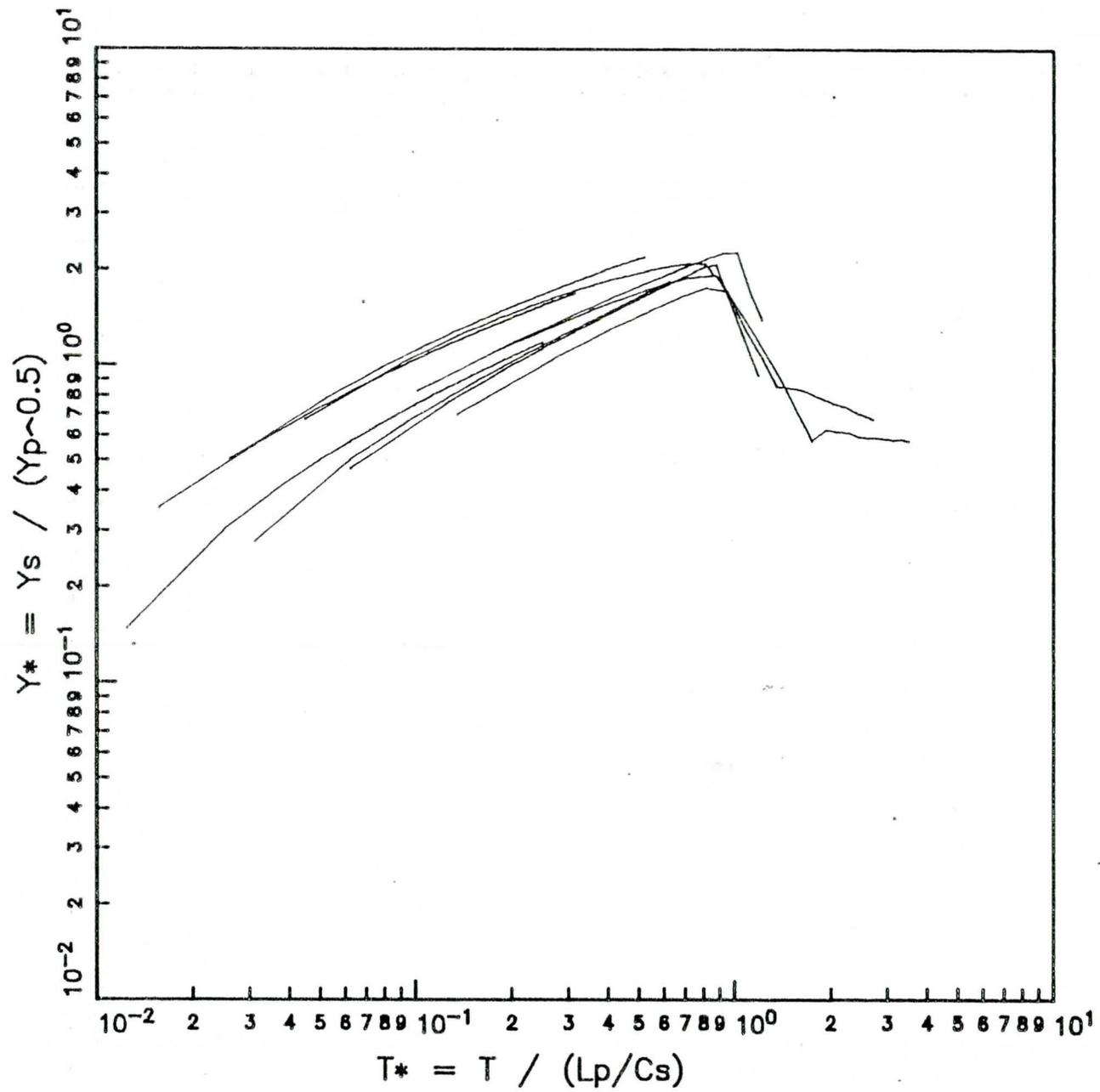


Figure E.10. Normalized Downstream Scour Depth Graph (q = 20 cfs/ft)

Figure E.11. Normalized Downstream Scour Depth Graph ($q = 40$ cfs/ft)

$q = 80$ cfs/ft

E-23

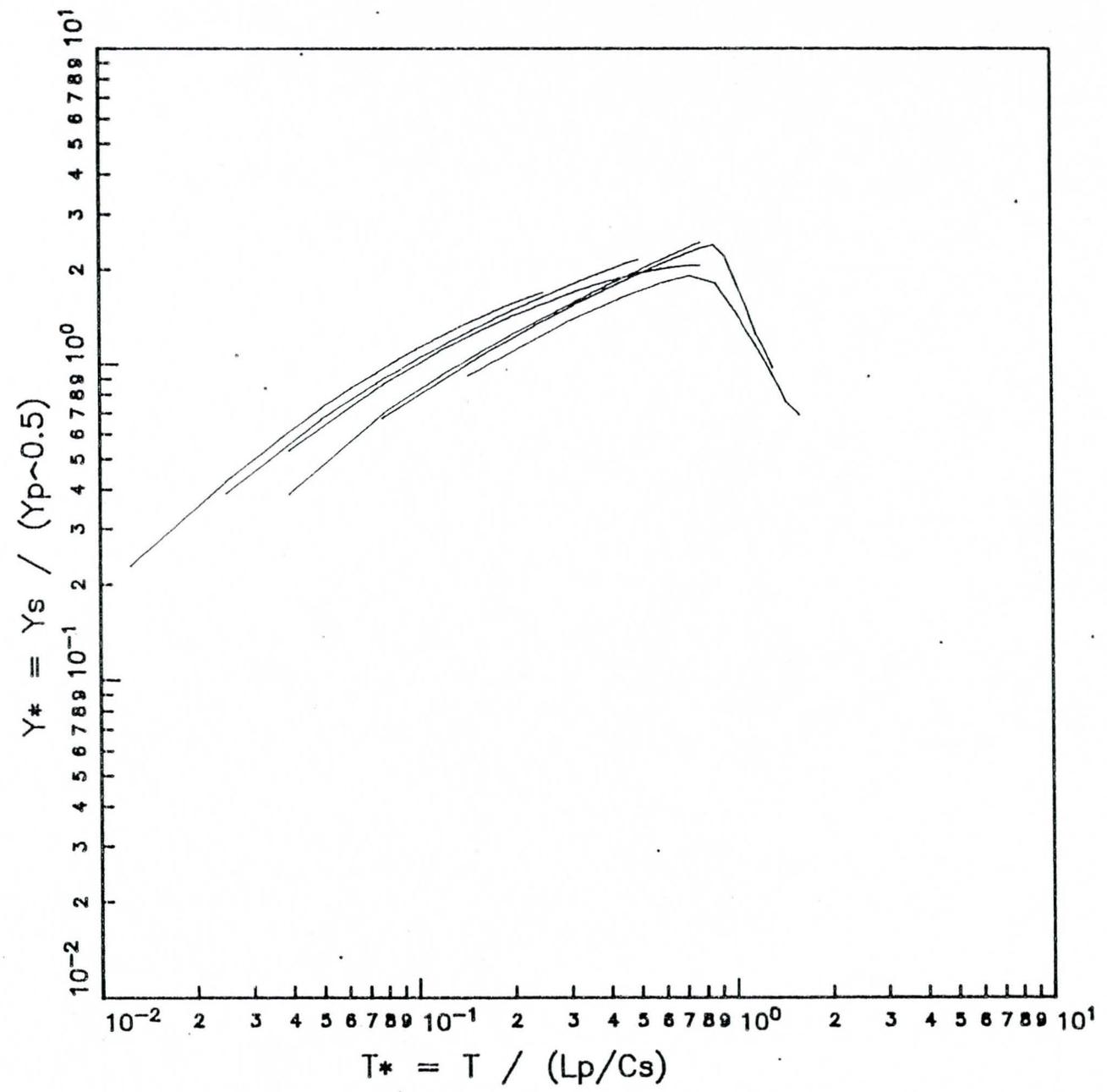


Figure E.12. Normalized Downstream Scour Depth Graph ($q = 80$ cfs/ft)

9-10-73

E-24

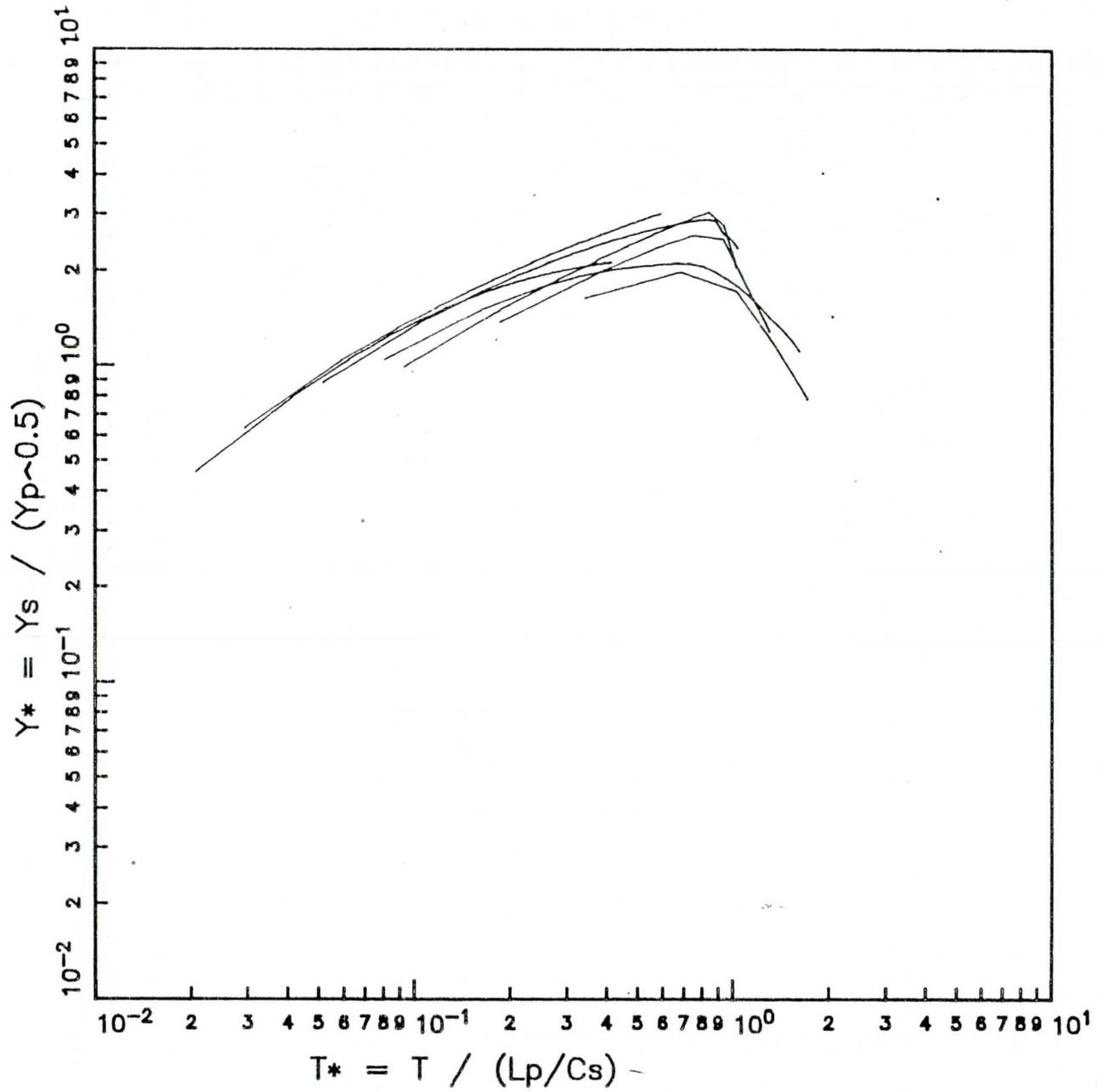


Figure E.13. Normalized Downstream Scour Depth Graph ($q = 160$ cfs/ft)

$q = 20 \text{ cfs/ft}$

E-25

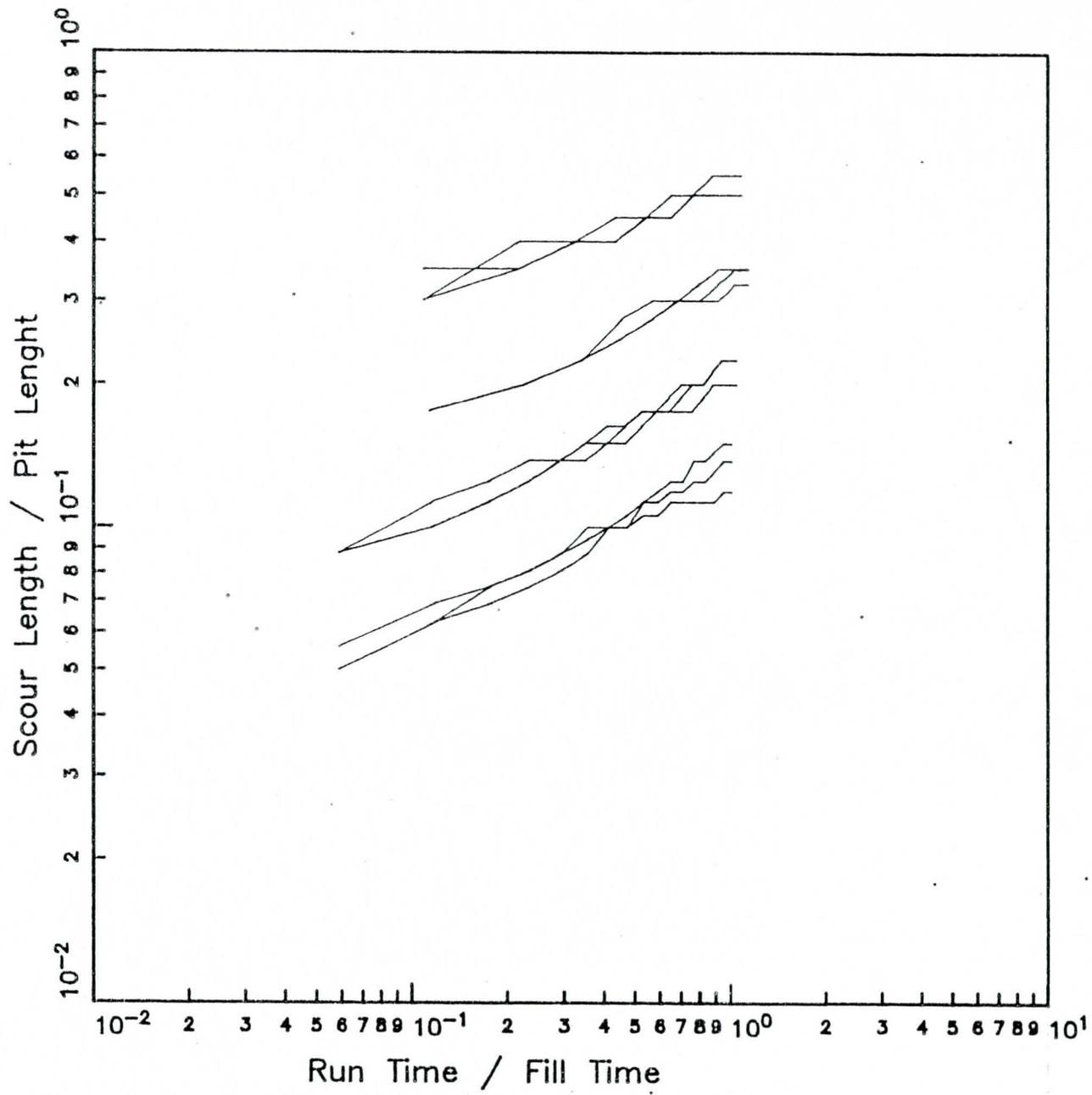


Figure E.14. Normalized Upstream Scour Length Graph ($q = 20 \text{ cfs/ft}$)

q = 40

E-26

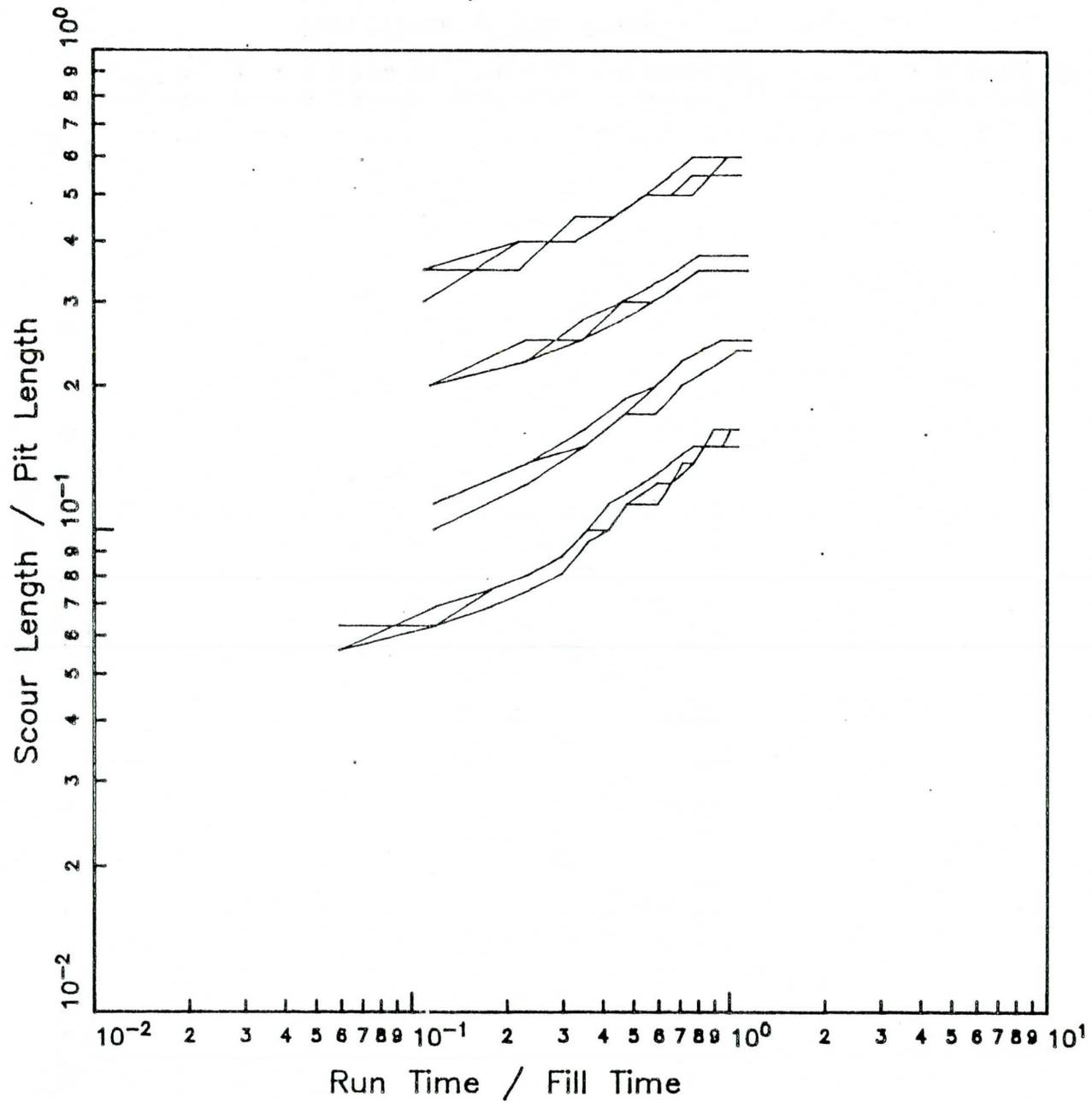


Figure E.15. Normalized Upstream Scour Length Graph (q = 40 cfs/ft)

$q = 80 \text{ cfs/ft}$

E-27

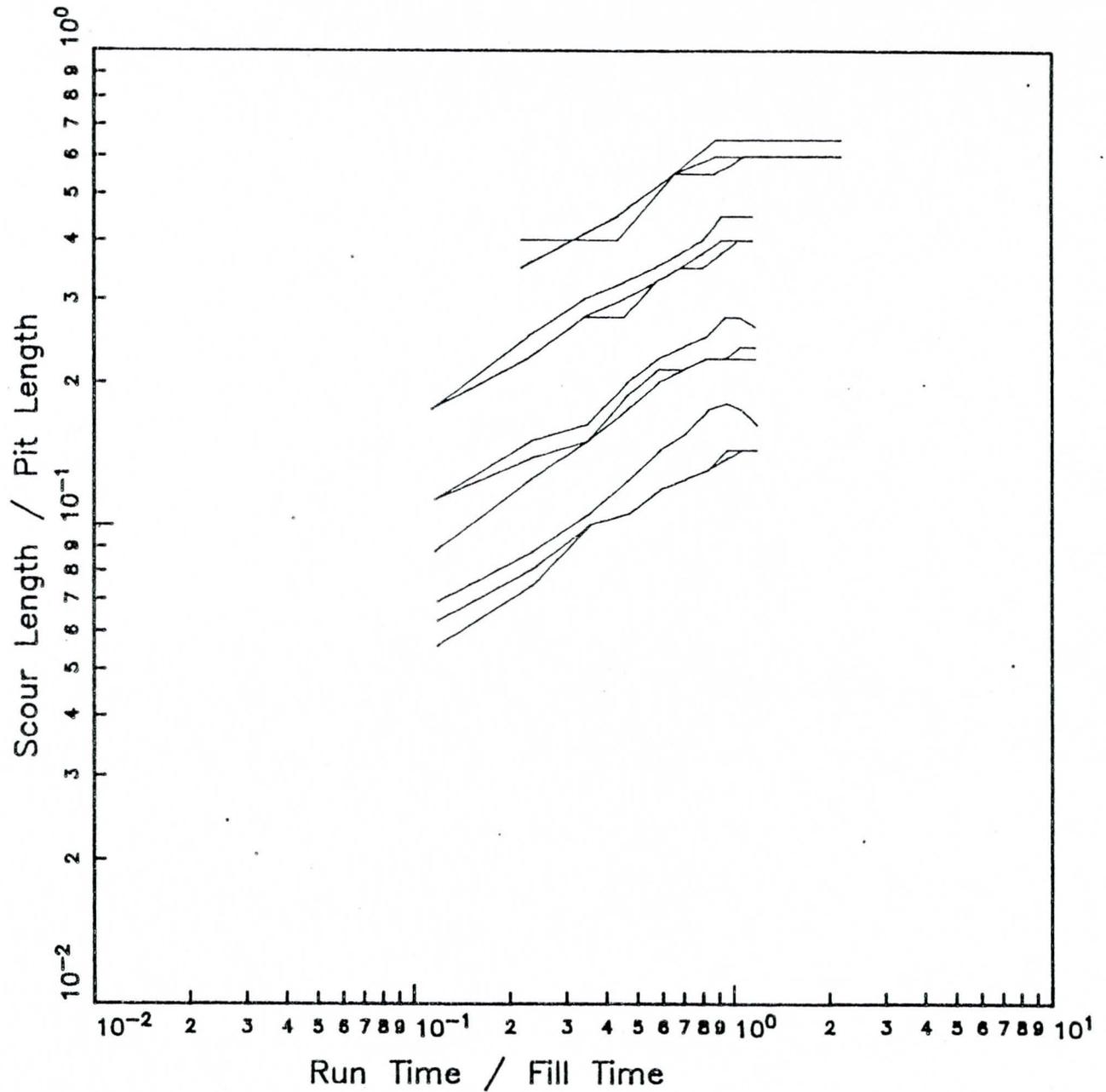


Figure E.16. Normalized Upstream Scour Length Graph ($q = 80 \text{ cfs/ft}$)

$q = 160$ $\frac{\text{ft}^3}{\text{ft} \cdot \text{s}}$

E-28

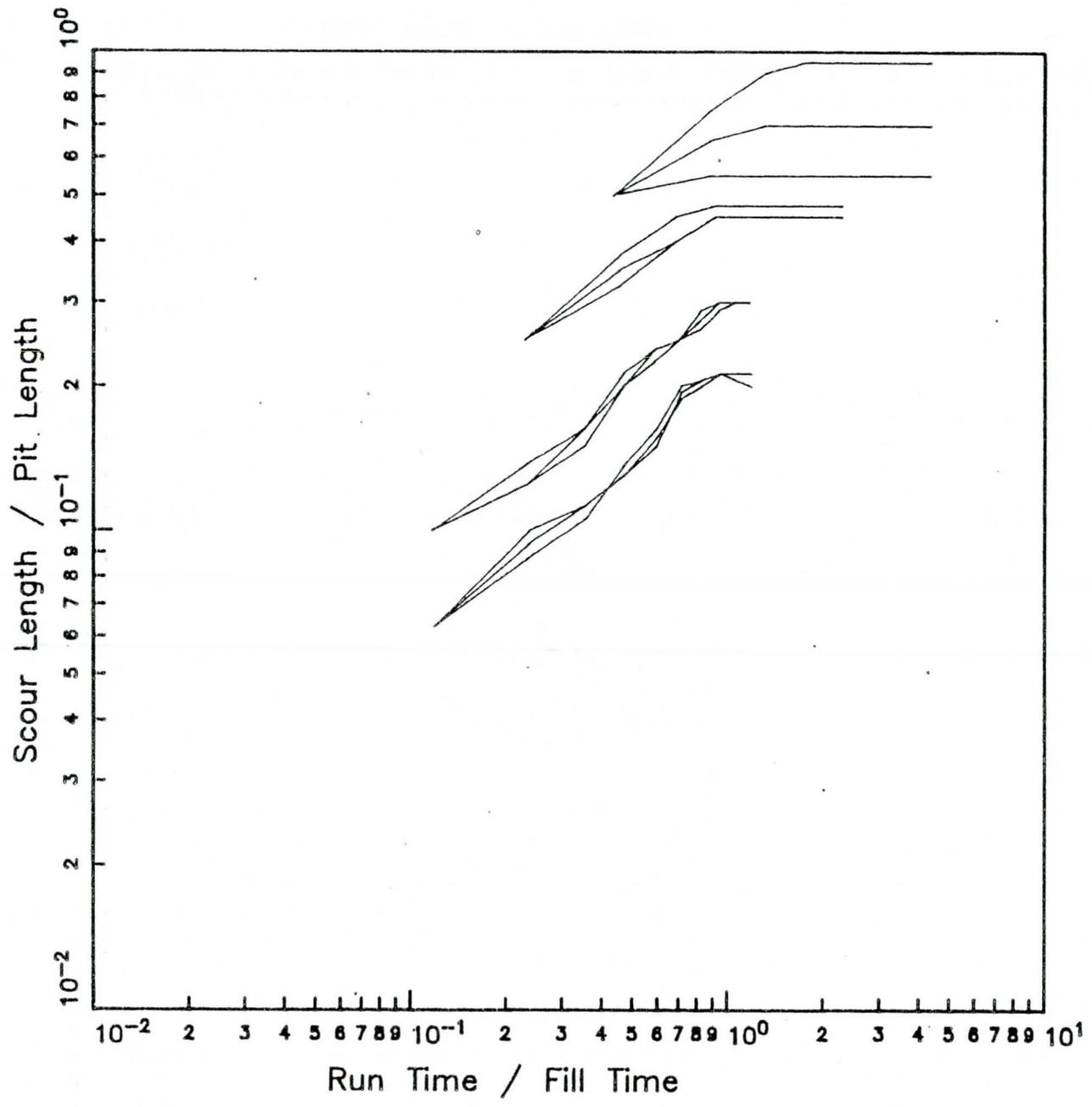


Figure E.17. Normalized Upstream Scour Length Graph ($q = 160$ cfs/ft)

$q = 20 \text{ cfs/ft}$

E-29

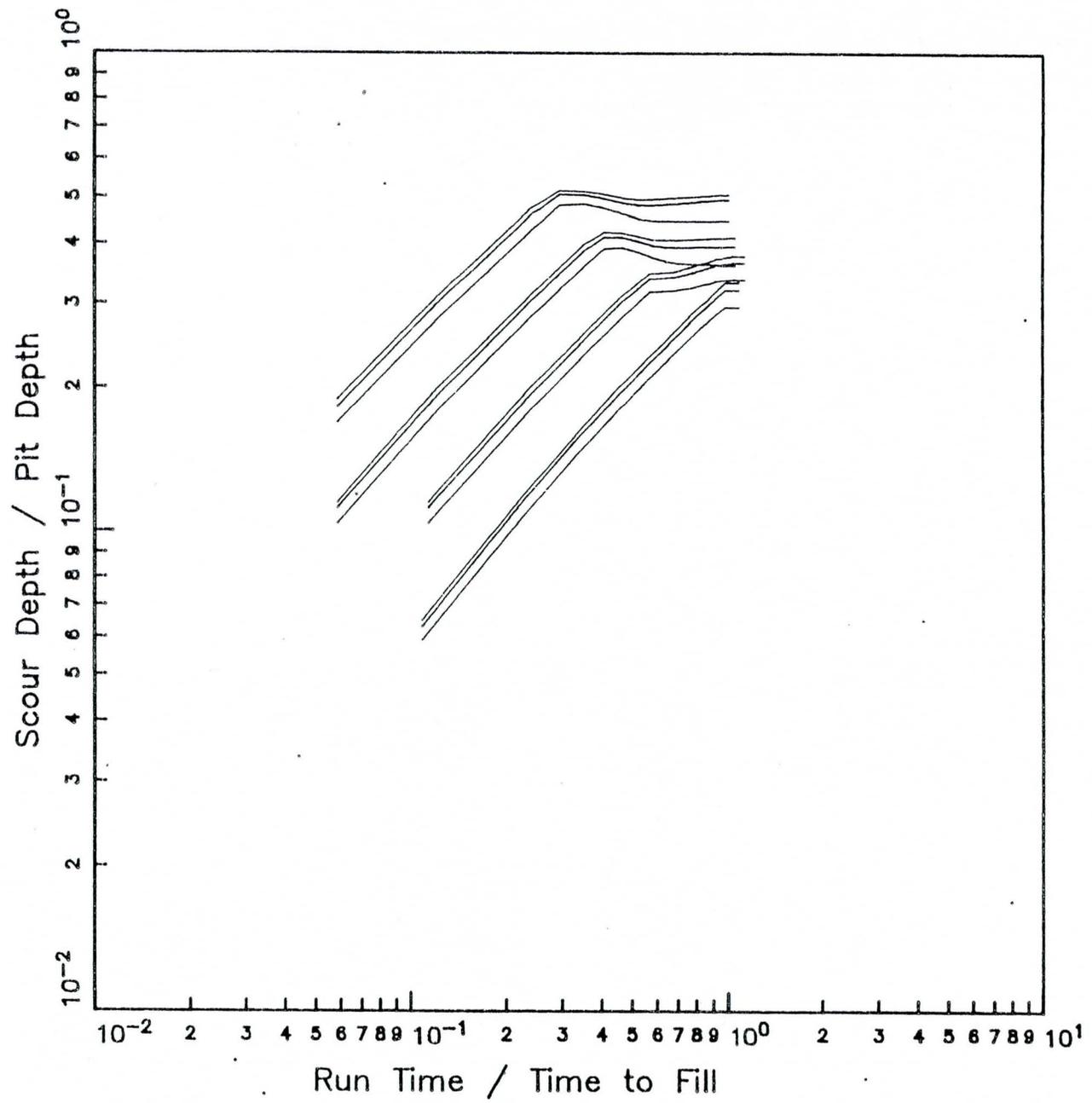


Figure E.18. Normalized Upstream Scour Depth Graph ($q = 20 \text{ cfs/ft}$)

E-30

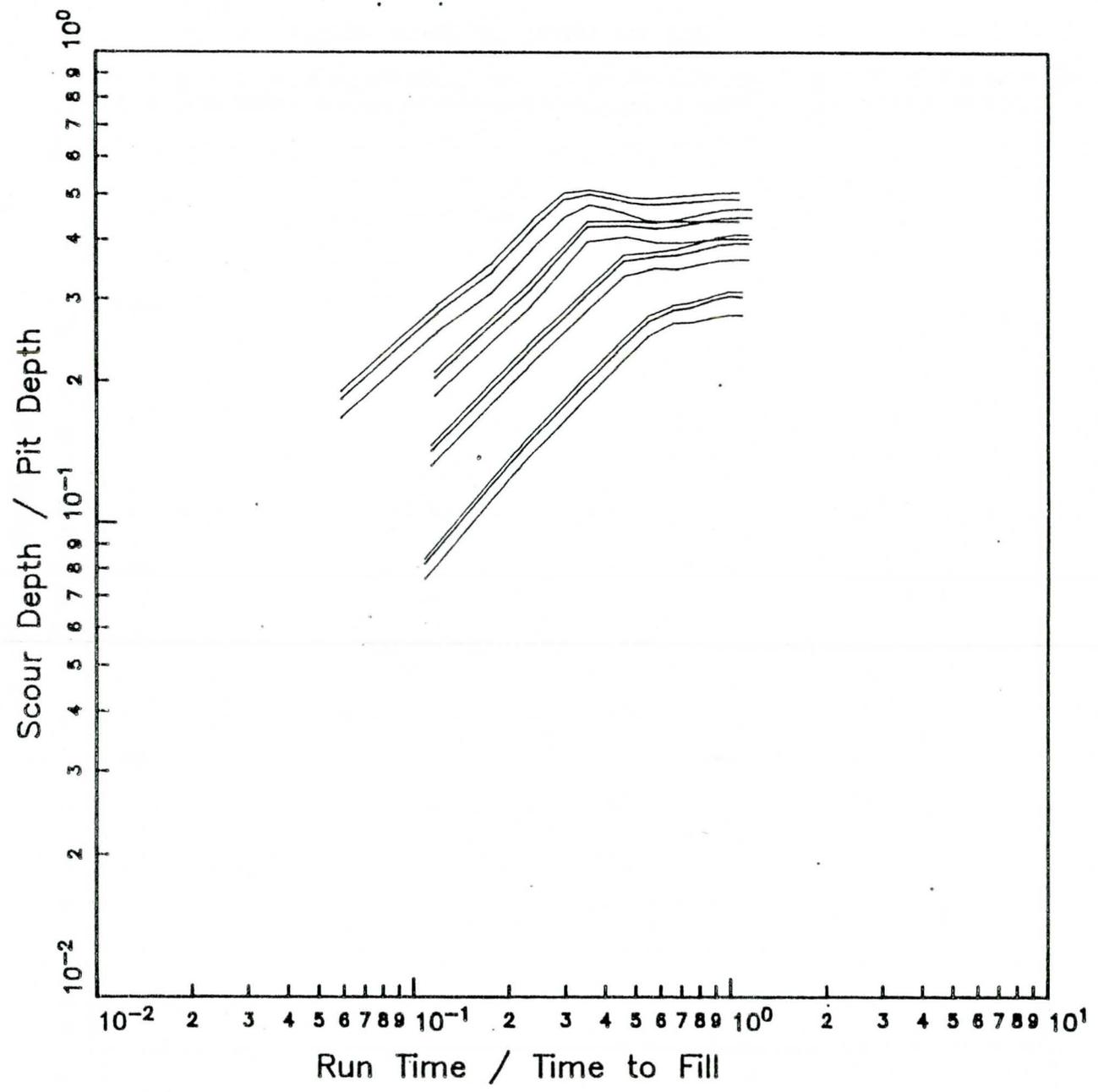


Figure E.19. Normalized Upstream Scour Depth Graph (q = 40 cfs/ft)

$q = 80 \text{ cfs/ft}$

E-31

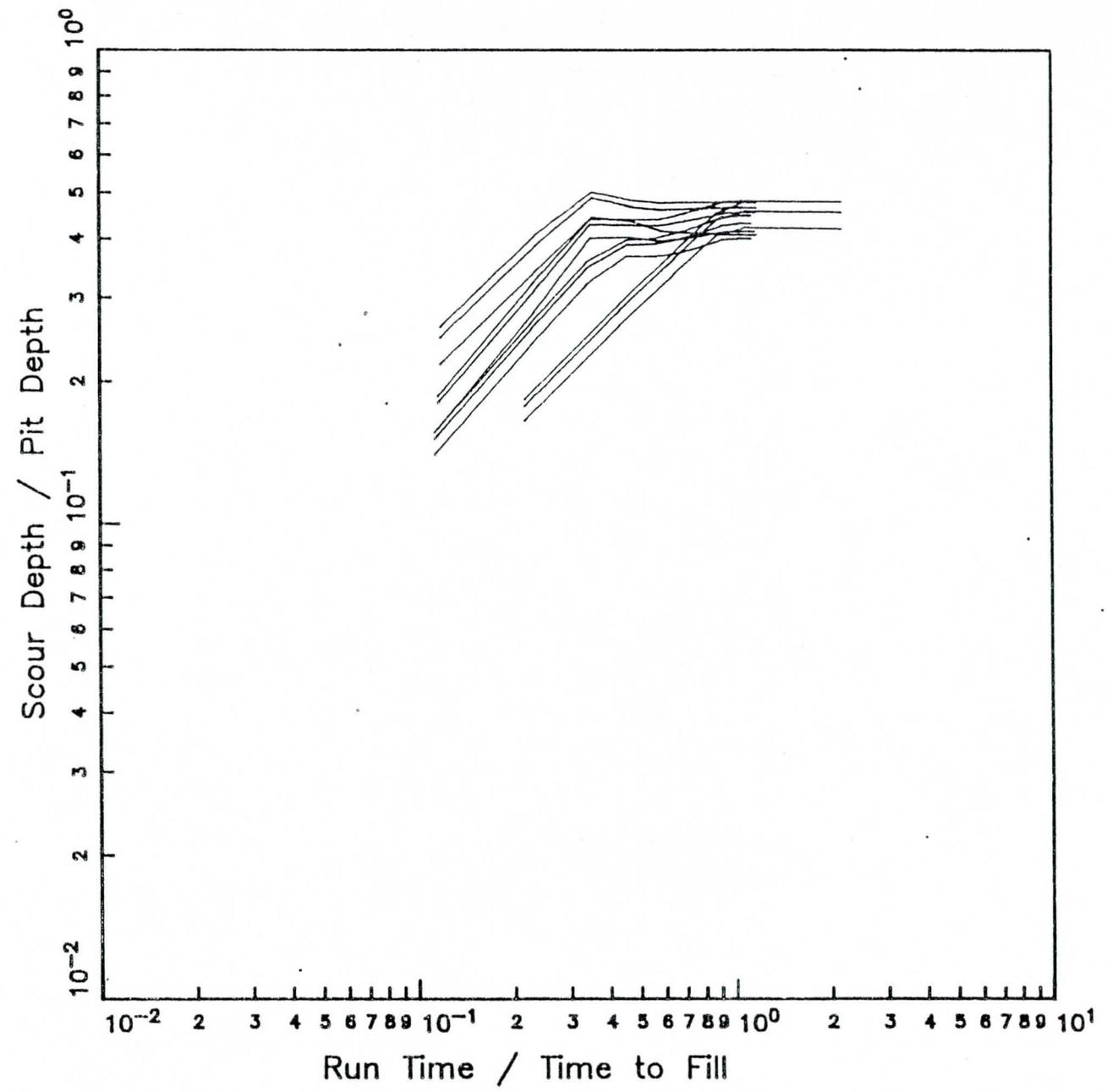


Figure E.20. Normalized Upstream Scour Depth Graph ($q = 80 \text{ cfs/ft}$)

E-32

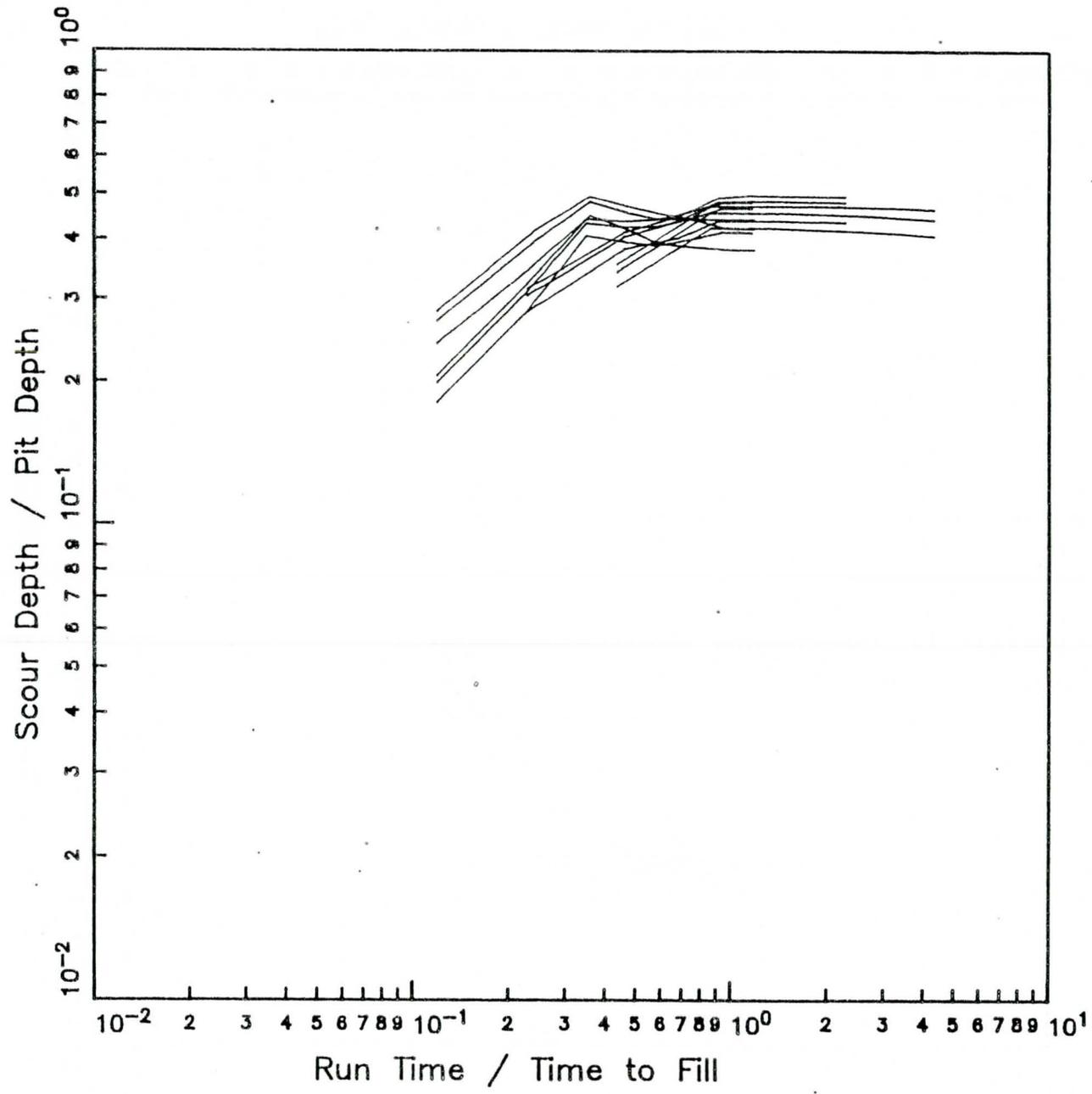


Figure E.21. Normalized Upstream Scour Depth Graph (q = 160 cfs/ft)

REFERENCES TO APPENDIX E

- Blodgett, J.C., 1986, "Rock Riprap Design for Protection of Stream Channels Near Highway Structures, Volume 1 - Hydraulic Characteristics of Open Channels," U.S. Geological Survey, Water-Resources Investigations Report 86-4127.
- Chang, H.H., and J.C. Hill, 1976, "Computer Modeling of Erodible Flood Channels and Deltas," Journal of the Hydraulics Division, ASCE, Vol. 102, No. HY10, Proc. Paper 12485, pp. 1461-1478.
- Gessler, J., 1967, "The Beginning of Bedload Movement of Mixtures Investigated as Natural Armoring in Channels," W.M. Keck Laboratory of Hydraulics and Water Resources Translation T-5, California Institute of Technology, Pasadena, California.
- Harrison, A.S., 1950, "Report on Special Investigation of Bed Sediment Segregation in a Degrading Bed," University of California Institute of Engineering Research Series No. 33, Issue No. 1.
- Little, W.C. and P.G. Mayer, 1972, "The Role of Sediment Gradation on Channel Armoring," Publication No. ERC-0672, School of Civil Engineering in Cooperation with Environmental Research Center, Georgia Institute of Technology, Atlanta, Georgia.
- Perdreau, N., and J.A. Cunge, 1971, "Sedimentation dans les Estuaries et les Embouchures Bouchon Marin et Bouchon Fluvial," IAHR, Paris, France.
- Rouse, H., 1936, "Discharge Characteristics of a Free Overfall," Civil Engineering, Vol. 6, No. 7, pp. 257-260.
- Simons, D.B., R.M. Li, and G.O. Brown, 1979, "Sedimentation Study of the Yazoo River Basin," Colorado State University, Fort Collins, Colorado.
- U.S. Army Corps of Engineers, 1976, "HEC-6, Scour and Deposition in Rivers and Reservoirs," User's Manual, Hydrologic Engineering Center, Davis, California.
- Zeller, M.E. and W.T. Fullerton, 1983, "A Theoretically-Derived Sediment Transport Equation for Sand-Bed Channels in Arid Regions," Proceedings of the D.B. Simons Symposium on Erosion and Sedimentation, R.M. Li and P.F. Lagasse, editors, Colorado State University, Fort Collins, Colorado.

Program CRISM13;

{

Channel Response to In-Stream Mining
 Simons, Li & Associates Inc.
 Version Number: 1.3 - Gravel-Bed, with armoring
 Programmers : George K. Cotton P.E.
 Robert J. Smolinsky P.E.
 Last Revised : March 8, 1988

}

const

Ccoef = 0.1; { contraction coef for hydraulic calc's }
 Ecoef = 0.3; { expansion coef. for hydraulic calc's }
 grav = 32.2; { gravitational constant }
 maxsize = 10; { maximum number of sediment sizes }
 maxsec = 100; { maximum number of cross sections }
 maxtime = 500; { maximum number of time intervals }
 spc : Char = #32; { space, for formatting }

type ..

Str = String[20];
 Strg = String[10];
 DateStr = String[10];
 TimeString = String[8];
 SizeArray = array[1..maxsize] of real;
 ReachArray = array[1..maxsec] of real;
 TimeArray = array[1..maxtime] of real;
 HydType = record
 SecNum: integer; { x-section number }
 length, { reach length }
 width, { channel width }
 depth, { channel depth }
 zb, { channel invert elevation }
 segl, { slope of the energy grade line }
 Ab, { angle of the channel bed }
 vel, { channel mean velocity }
 tau, { mean channel shear stress }
 taug, { applied grain shear stress }
 nc, { channel roughness coefficient }
 ng : real; { grain roughness coefficient }
 flow: boolean; { true if x-sec has flow }
 zone: integer; { flow zone indicator }
 end;
 SedType = record
 ppl : SizeArray; { parent layer gradation }
 pal : SizeArray; { active layer gradation }
 ptc : SizeArray; { transport capacity distribution }
 D50, { mean sediment size in active layer }
 dz, { change in bed elevation }
 da, { active layer thickness }
 Gt : real { transport from reach }
 end;
 XSecPtr = ^XSecType;

```

XSecType = record
    HydRec : HydType;
    SedRec : SedType;
    TSNum : integer;
    NextXS,
    PrevXS,
    NextTS : XSecPtr;
end;
BedMatType = record
    ds : SizeArray; { mean particle size }
    Fvb : SizeArray; { fall velocity of particles }
end;
IOType = record
    FV1,           { Input file variable }
    FV2 : text;    { Output file variable }
    FVcach : file of XSecType; { Disk cach file }
    FnIn,         { Input file name }
    FnOut : String[14]; { Output file name }
end;
OpType = record
    Title1,           { Run title }
    Title2 : String[65]; { Run title }
    RunDate : DateStr; { Date model was run }
    RunTime : TimeString; { Time model was run }
    DSPitSecNum,     { Section number of the pit brink }
    PlotInd,         { if 1, plot file is output }
    nsec,           { Number of cross-sections in reach }
    nsize,          { Number of sediment sizes }
    tintprt,        { time step print interval }
    ntime : integer; { Number of time intervals }
    Cs,             { Shields parameter }
    theta;          { Finite difference weighting factor }
    Sinit,          { Initial D/S channel slope }
    TimeStep: real  { length of time step (min.) }
end;

var
    FillVolume, { cumulative vol. of water in pit up to current time step }
    PitWSEL,    { water surface elevation in pit during ponding conditions }
    TSMemReq,   { memory, in bytes, required for each time step }
    NormalDepth,
    CritDepth : real;
    j,m,n      : integer; { indices for space, sed size and time, respectively }
    Q          : TimeArray; { total discharge array - hydrograph }
    zbi       : ReachArray; { initial bed elevations }
    XSecData  : XSecType;
    HydRec    : HydType;
    BedMatRec : BedMatType;
    SedRec    : SedType;
    IORec     : IOType;
    OpRec     : OpType;
    FirstTS,  { pointer to first time step }
    USXS,     { pointer to upstream section of current time step }
    DSXS,     { pointer to downstream section of current time step }

```

```

DSPitLimit,      ( points' at x-sec defined as the d/s limit of pit )
Root,
Current  : XSecPtr;
OK,
Cached   : Boolean; ( flag to indicate if output has been cached to disk )

{----- add these include files in this order -----}
{$I UTIL13.LIB }
{$I MEM13.LIB  }
{$I HYD13.LIB  }
{$I SED13.LIB  }
{$I INOUT13.LIB }
{-----}

Begin ( Main Program )
  BatchOpen(IORec);
  ReadData(OpRec, BedMatRec, zbi, Q, DSXS, USXS, FirstTS, DSPitLimit);

  Cached   := false;
  FillVolume := 0;
  TSMemReq  := OpRec.nsec * SizeOf(XSecData);

  for n := 1 to OpRec.ntime do
  begin
    gotoxy(50,22); Write('Executing time step :',n:3);
    gotoxy(50,23); Write('Memory Left = ',MemoryLeft:6:0,' bytes');

    { hydraulics established in u/s sweep }
    FillVolume := FillVolume + (Q[n]*OpRec.timeStep*60.0);
    Hydraulics(DSXS, FillVolume, Q[n]);

    { transport calculated in u/s sweep }
    Current := DSXS; { reset root pointer to d/s most x-sec }
    for j := 1 to OpRec.nsec do
    begin
      if Current^.HydRec.flow then
        Transp(OpRec, Current^)
      else
        ZeroTransp(Current^);
      Current := Current^.NextXS;
    end;

    { sediment continuity calculated in d/s sweep }
    Current := USXS^.PrevXS;
    for j := 2 to (OpRec.nsec-1) do
    begin
      SedCon(OpRec, Current^);
      Current := Current^.PrevXS;
    end;

    { Create a new reach list }
    If (n mod OpRec.tintprt) = 0 then
    begin
      if (MemoryLeft < TSMemReq) then DiskCach(OpRec.NSec, Cached, FirstTS);
    end;
  end;

```

```
      BuildReachList(OpRec.nsec,n,DSXS,USXS,DSPitLimit)
    end;

end;

{ Output Files }
PrinterOutput;
if OpRec.PlotInd = 1 then PlotterOutput;

ClearMem(FirstTS);
If cached then
begin
  close(IOrec.FVcach);
  erase(IOrec.FVcach);
end;
close(IOrec.FV1);
close(IOrec.FV2);
End.
```

```

Function Power(X,Y : Real):real;
{
  Description : Returns the value of X raised to the Y power.
}
begin
  if X <= 0 then power := 0 else power := exp(Y*ln(X))
end;
-----}
Function Date: DateStr;

```

```

{-----Returns the system date--the type "DateStr" MUST be specified
in the calling program as:

```

```

      type
        DateStr = string[10];
    }

```

```

type
  regpack = record
    ax,bx,cx,dx,bp,si,ds,es,flags: integer;
  end;

var
  rcpack:    regpack;          {record for MsDos call}
  month,day: string[2];
  year:     string[4];
  dx,cx:    integer;

```

```

begin
  with rcpack do
  begin
    ax := $2a shl 8;
  end;
  MsDos(rcpack);          { call function }
  with rcpack do
  begin
    str(cx,year);          {convert to string}
    str(dx mod 256,day);   { " }
    str(dx shr 8,month);   { " }
  end;
  date := month+'/' + day+'/' + year;
end;
-----}
Function time: TimeString;

```

```

{----Returns the system time----the TYPE "TimeString" MUST be specified
in the calling program as:

```

```

      type
        TimeString = string[8]
    }

```

```

type
  regpack = record
    ax,bx,cx,dx,bp,di,si,ds,es,flags: integer;

```

```

        end;

var
    reccount:      reccount;          {assign record}
    ah,al,ch,cl,dh: byte;
    hour,min,sec:  string[2];

begin
    ah := $2c;                          {initialize correct registers}
    with reccount do
    begin
        ax := ah shl 8 + al;
    end;
    intr($21,reccount);                  {call interrupt}
    with reccount do
    begin
        str(cx shr 8,hour);              {convert to string}
        str(cx mod 256,min);             { " }
        str(dx shr 8,sec);               { " }
    end;
    time := hour+'!'+min+'!'+sec;
end;
{-----}
Procedure FRAME(UpperLX,UpperLY,LowerRX,LowerRY : Integer);

Var
    i : Integer;

Begin
    GoToXY(UpperLX,UpperLY);Write(chr(218));
    for i:=UpperLX+1 to LowerRX-1 do Write (chr(196));
    Write(chr(191));
    for i:=UpperLY+1 to LowerRY-1 do
    begin
        GoToXY(UpperLX,i);Write(chr(179));
        GoToXY(LowerRX,i);Write(chr(179));
    end;
    GoToXY(UpperLX,LowerRY);
    Write(chr(192));
    for i:=UpperLX+1 to LowerRX-1 do Write(chr(196));
    Write(chr(217));
End; { FRAME }
{-----}
Procedure FRAME2(UpperLX,UpperLY,LowerRX,LowerRY : Integer);

Var
    i : Integer;

Begin
    GoToXY(UpperLX,UpperLY);Write(chr(201));
    for i:=UpperLX+1 to LowerRX-1 do Write (chr(205));
    Write(chr(187));
    for i:=UpperLY+1 to LowerRY-1 do
    begin

```

```
GoToXY(UpperLX,i);Write(chr(186));
GoToXY(LowerRX,i);Write(chr(186));
end;
GoToXY(UpperLX,LowerRY);
Write(chr(200));
for i:=UpperLX+1 to LowerRX-1 do Write(chr(205));
Write(chr(188));
End; { FRAME2 }
{-----}
```

```

(
    Procedures for program CRISM13
    Include file name : MEM13.LIB
    Description       : Linked list procedures
    Programmers      : Robert J. Smolinsky, P.E.
                    : George K. Cotton, P.E.
                    : Simons; Li & Associates
    Last revision    : March 3, 1988
)
{-----}
Function MemoryLeft : real;
(
    Description: Returns size (in bytes) of largest block of free memory in heap.
)
Var R : real;
begin
    R := MaxAvail;
    if R < 0 then R := R + 65536.;
    R := R * 16;
    MemoryLeft := R;
end;
{-----}
Procedure DiskCach(   NSec   : integer;
                    var Cached : boolean;
                    var FirstTS : XSecPtr);
(RJS
    Description: Writes linked list to disk if heap/stack collision is imminent.
)
var
    j : integer;
    Current, Holder : XSecPtr;
begin
    gotoXY(50,22); write('Disk caching required.');
```

If not Cached then (this is first call to DiskCach)

```

begin
    Cached := true;
    Assign(IOrec.FVCach,'CACH.$$$');
    Rewrite(IOrec.FVCach)
end;
Current := FirstTS; ( point to first time step since last cach )

while FirstTS^.NextTS <> nil do
begin
    FirstTS := FirstTS^.NextTS;
    for j := 1 to NSec do
begin
    Write(IOrec.FVCach,Current^);
    if j <> NSec then
begin
        Holder := Current;
        Current := Current^.NextXS;
        dispose(Holder);
    end
end
end
```

```

    else
      dispose(Current);
    end;
    Current := FirstTS
  end;
  FirstTS := Current;
  { all but the last time step have been cached to disk }
end;
{-----}
Procedure BuildReachList(  NSec, NTime : integer;
                          var DSXS,
                              USXS,
                              DSPitLimit : XSecPtr);
{GKC
  Description : Builds a linked list of cross-section data for a new
                time interval.
}
var
  Root, Holder, Current : XSecPtr;
  j : integer;

begin
  Root := nil;
  Holder := Root;
  Current := DSXS;
  for j := 1 to NSec do
    begin
      new(Root);
      Root^.TSNum := Current^;
      Root^.TSNum := NTime;
      Root^.PrevXS := Holder;
      Root^.NextXS := nil;
      Holder^.NextXS := Root;
      Root^.NextTS := nil;
      Current^.NextTS := Root;
      Holder := Root;
      Current := Current^.NextXS;
      if j = 1 then DSXS := Root;
      if j = NSec then USXS := Root;
      if (Current^.HydRec.SecNum = OpRec.DSPitSecNum) then DSPitLimit := Root
    end
  end;
{-----}
Procedure ClearMem(var FirstTS : XSecPtr);
{
  Description : Clears linked lists from memory.
}
var
  Root, Holder, TSHolder : XSecPtr;

begin
  if FirstTS <> nil then
    repeat
      TSHolder := FirstTS^.NextTS;

```

```
Root := FirstTS;
repeat
  Holder := Root^.NextXS;
  Dispose(Root);
  Root := Holder;
until Root = nil;
FirstTS := TSHolder;
until FirstTS = nil
end;
{-----}
```

```

{
    Procedures for program CRISM13
    File name: HYD13.LIB
    Description : Hydraulic routines
    Include file for program CRISM13.PAS

    Simons, Li & Associates Inc.
    Programmers: George K. Cotton P.E.
                Robert J. Smolinsky P.E.

    Last revision: March 7, 1988
}

Procedure Depths(    Sav,                { bed slope }
                   D50,                { mean gradation size }
                   unitdis : real;     { unit discharge }
    var NormalDepth,
        CritDepth   : real);

{
GKC/RJS
Description: Returns normal and critical depth at current x-sec.
Reference   : Blodgett resistance equations used, see USGS WRI xxxx
              Sand-bed resistance coefficient = 0.0231.
}
Const
    RRMax = 54.4; { Maximum relative depth for gravel resistance eq. }

Var
    C,          { Resistance coefficient }
    dn : real;  { estimated normal depth }

Begin

    { Critical depth calculation }
    CritDepth := power(unitdis*unitdis/grav,1/3);

    { Normal depth calculation }
    If Sav <= 0 then
        NormalDepth := 9999
    else
        begin
            NormalDepth := power(0.0156*unitdis/sqrt(Sav),2/3);
            gotoxy(5,10);
            if NormalDepth/D50 < RRmax then
                repeat
                    dn := NormalDepth;
                    if (dn/D50 < RRmax) then
                        begin
                            if dn/D50 < 1.5 then
                                C := 12.1
                            else
                                C := 8.58 + 20.0*ln(dn/D50)/ln(10);
                            NormalDepth := power(unitdis/(1.486*C*sqrt(Sav)),2/3)

```

```

        end
      else
        NormalDepth := power(0.0156*unitdis/sqrt(Sav),2/3);
      until abs(dn-NormalDepth) < 0.01
    end
  End;
}-----}
Procedure BedSlope(  zbup,      { downstream bed elevation }
                   zbc,      { current bed elevation   }
                   xrc : real; { current reach length   }
                   var Ab,    { bed slope angle         }
                   So  : real);

{GKC
Description: Returns the angle of the channel bed and the bed slope.
}
Var
  Sdn : real; { average bed gradient downstream of current section }

Begin
  if xrc <= 0 then
    Sdn := 0
  else
    Sdn := (zbup - zbc)/xrc;
    Ab := ArcTan(Sdn);
    So := sin(Ab)
  End;
}-----}
Procedure HydParm(  WSEL,      { Water surface elevation }
                   D50,      { Mean sediment size     }
                   unitdis : Real; { Unit discharge       }
                   var HydRec : HydType); { Hydraulic data record }

{RJS
Description : Calculates hydraulic parameters for a given WSEL.
}
const
  RRMax = 54.4; { Maximum relative depth for gravel resistance eq. }

var
  Aws : real; { angle of the water surface }

Begin
  with HydRec do
    begin
      depth := (WSEL - zb);
      if depth > 0 then
        begin
          if (depth/D50 < RRMax) then
            if depth/D50 < 1.5 then
              nc := power(depth,1/6)/12.1
            else
              nc := power(depth,1/6)/(8.58+20.0*ln(depth/D50)/ln(10))
            else
              nc := 0.0231*power(depth,1/6);

```

```

    segl := Sqr(unitdis * nc / (1.486 * POWER(depth,5/3)));
    tau  := 64.4 * depth * segl;
    vel  := unitdis / depth;
    flow := true
  end
end
End;
{-----}
Procedure Balance (      Q,                (total discharge)
                     D50,                (mean gradation size)
                     CritDepth2 : Real;  (critical depth at current x-sec)
                     HydRec1   : HydType; (previous x-section)
                     var HydRec2 : HydType; (current x-section )
{RJS
  Description: Establishes energy balance between x-sections.
}
Label
  FINIS, SUBID, SUBDD, AGAIN, AGAIN2 ;
Var
  FLAG, F : INTEGER;
  WSEL1,      ( WSEL at previous x-sec )
  WSEL2,      ( WSEL approximation at current x-sec )
  CWSEL2,     ( calculated WSEL at current x-sec )
  WSCORR,     ( correction applied to WSEL for new approximation )
  CrWSEL2,    ( critical WSEL @ current x-sec )
  AvSt,      ( average friction slope for reach )
  CEloss,    ( contraction/expansion loss )
  Vh1,       ( velocity head @ prev. x-sec )
  Vh2,       ( velocity head @ current x-sec )
  Vhdif : Real; ( difference in velocity heads )
  COUNT : Byte; ( counter for # of iterations in energy balance )

{-----}

Function EnergyLoss: Real;

Var
  Eqn : Integer;

Begin
  Vhdif := (Vh2 - Vh1); { compute shock losses }
  If Vhdif > 0 then
    CEloss := Ecoef*Vhdif
  else
    CEloss := -Ccoef*Vhdif;

  { select proper friction averaging eqn. }
  If HydRec2.segl >= HydRec1.segl then
    AvSf := (HydRec2.segl + HydRec1.segl)/2
  else
    AvSf := 2 * (HydRec2.segl * HydRec1.segl)/(HydRec2.segl + HydRec1.segl);

```

```

    EnergyLoss := CEloss + Avsf * HydRec2.length
End;

{-----}

BEGIN
  WSEL1 := HydRec1.Depth + HydRec1.zb;
  CrWSEL2 := CritDepth2 + HydRec2.zb;
  COUNT := 0;
  WSEL2 := CrWSEL2; { first approximation of WSEL }
  HYDPARM (WSEL2, D50, Q/HydRec2.width, HydRec2);
  Vh1 := HydRec1.Vel * HydRec1.Vel / (2*grav);
  Vh2 := HydRec2.Vel * HydRec2.Vel / (2*grav);
  { subcritical energy balance }
  COUNT := COUNT + 1;
  CWSEL2 := WSEL1 + Vh1 + EnergyLoss - Vh2;
  IF ABS(CWSEL2 - WSEL2) < 0.05 then goto FINIS;
  IF CWSEL2 > WSEL2 then
    WSCORR := (CWSEL2 - WSEL2)/2
  else
    {assume critical depth}
  begin
    WSEL2 := CrWSEL2;
    HydParm(WSEL2,D50,Q/HydRec2.width,HydRec2);
    goto FINIS;
  end;
  { increase depth, subcritical profile }
  F:=1; FLAG:=0;
AGAIN:
  WSEL2 := WSEL2 + F * WSCORR;
  HYDPARM(WSEL2,D50,Q/HydRec2.width,HydRec2);
  Vh2 := HydRec2.Vel * HydRec2.Vel / 64.4;
  CWSEL2 := WSEL1 + Vh1 + EnergyLoss - Vh2;
  IF ABS(CWSEL2 - WSEL2) < 0.05 then goto FINIS;
  COUNT := COUNT + 1; IF COUNT > 20 then goto FINIS;
  IF (CWSEL2 > WSEL2) and (FLAG = 0) then goto AGAIN;
  FLAG:=1;
  IF CWSEL2 < WSEL2 then F := -1 else F := 1;
  WSCORR:=WSCORR/2; goto AGAIN;
FINIS : { WSEL2 computed to within 0.05' if Count <= 20}
  If Count > 20 then { could not balance energy equation, assume critical depth }
  begin
    WSEL2 := CrWSEL2;
    HYDPARM(WSEL2,D50,Q/HydRec2.width,HydRec2);
  end
End;

{-----}
Procedure BackWater(Q      : Real;
                   DSPt : XSecPtr); {pointer to first d/s x-sec with flow }

{RJS
Description: Calculates backwater profile upstream beginning at root pointer.
}

Var

```

```

Sav      : real;   { Average channel slope in a reach }
Current  : XSecPtr; { Pointer index }

Begin
  Current := DSpt;

  { downstream boundary condition }
  if Current^.PrevXS <> nil then { starting wsel occurs internally }
  begin
    BedSlope(Current^.NextXS^.HydRec.zb,Current^.HydRec.zb,Current^.HydRec.length,Current^.HydRec.Ab,Sav);
    Depths(Sav,Current^.SedRec.D50,Q/Current^.Hydrec.width,NormalDepth,CritDepth);
    Current^.HydRec.zone := 5;
    HydParm(Current^.HydRec.zb + CritDepth,Current^.SedRec.D50,Q/Current^.Hydrec.width,Current^.HydRec)
  end
  else
    { starting wsel at downstream limit of reach }
  begin
    Depths(OpRec.Sinit,Current^.SedRec.D50,Q/Current^.Hydrec.width,NormalDepth,CritDepth);
    Current^.HydRec.zone := 6;
    HydParm(Current^.HydRec.zb + NormalDepth,Current^.SedRec.D50,Q/Current^.Hydrec.width,Current^.HydRec)
  end;

  repeat
    { water surface profile calculated }
    Current := Current^.NextXS;
    Current^.HydRec.zone := 7;
    BedSlope(Current^.NextXS^.HydRec.zb,Current^.HydRec.zb,Current^.HydRec.length,Current^.HydRec.Ab,Sav);
    Depths(Sav,Current^.SedRec.D50,Q/Current^.Hydrec.width,NormalDepth,CritDepth);
    Balance(Q,Current^.SedRec.D50,CritDepth,Current^.PrevXS^.HydRec,Current^.HydRec);
  until Current^.NextXS = Nil

End;
{-----}
Procedure CalcPitWSEL (   Volume : real;   { total volume of water in pit }
                        var FillChk : boolean; { indicates if pit is full }
                        var PitWSEL : real);

{ RJS
Description: Calculates pit WSEL for a given volume of water.
}
{-----}
Procedure CalcPitVolume(   PitWSEL : real;
                          var CVolume : real); { calculated pit volume }

var
  Current : XSecPtr;

begin
  CVolume := 0;           { initialize }
  Current := DSPitLimit;  { start @ d/s pit limit }

  { search for ground points which bracket the pit WSEL }
  While (PitWSEL < Current^.HydRec.zb) and (PitWSEL < Current^.NextXS^.HydRec.zb)
  do Current := Current^.NextXS;

  { calculate the first vertical wedge of storage }
  CVolume := 0.5*(PitWSEL - Current^.NextXS^.HydRec.zb)*
            (Current^.NextXS^.HydRec.length *

```

```

(PitWSEL - Current^.NextXS^.HydRec.zb)/
(Current^.HydRec.zb - Current^.NextXS^.HydRec.zb))*
(Current^.NextXS^.HydRec.width+Current^.HydRec.width)/2;
Current := Current^.NextXS; { move u/s one ground point }

{ calculate intermediate storage wedges }
While (PitWSEL > Current^.NextXS^.HydRec.zb) do
begin
  CVolume := CVolume + (PitWSEL -
    0.5 * (Current^.HydRec.zb + Current^.NextXS^.HydRec.zb))*
    Current^.NextXS^.HydRec.length *
    (Current^.NextXS^.HydRec.width+Current^.HydRec.width)/2;
  Current := Current^.NextXS
end;

{ calculate last vertical wedge of storage }
CVolume := CVolume + 0.5*(PitWSEL - Current^.HydRec.zb) *
(PitWSEL - Current^.HydRec.zb)/
(Current^.NextXS^.HydRec.zb - Current^.HydRec.zb) *
Current^.NextXS^.HydRec.length *
(Current^.NextXS^.HydRec.width+Current^.HydRec.width)/2;
end;
{-----}

Var
  MinPitBedElev, { lowest ground elevation u/s of dsPitElev }
  CVolume : real; { calculated volume in pit for a given Pit WSEL }

Begin
  { find MinPitBedElev }
  MinPitBedElev := DSPitLimit^.HydRec.zb; { initially set to DSPitLimit invert }
  Current := DSPitLimit^.NextXS;
  Repeat
    If Current^.HydRec.zb < MinPitBedElev then MinPitBedElev := Current^.HydRec.zb;
    Current := Current^.NextXS;
  Until Current = nil;
  PitWSEL := DSPitLimit^.HydRec.zb - 0.001; { first approximation - assume pit is full }
  CalcPitVolume(PitWSEL,CVolume);
  If CVolume > Volume then { Pit WSEL is NOT full }
  begin
    FillChk := false;
    repeat { until Pit WSEL is found to within 1 foot }
      PitWSEL := PitWSEL - 1;
      If PitWSEL < MinPitBedElev then PitWSEL := MinPitBedElev + 0.01;
      CalcPitVolume(PitWSEL,CVolume);
    until CVolume < Volume;
    repeat { until Pit WSEL is found to within 0.1 foot }
      PitWSEL := PitWSEL + 0.1;
      CalcPitVolume(PitWSEL,CVolume);
    until CVolume > Volume;
  end
  else
    FillChk := true
End;

```

```

-----
Procedure Hydraulics (FirstXS : XSecPtr; { pointer to d/s most x-sec }
                    WaterVol,   { water volume in pit, cu.ft. }
                    Q           : Real); { total discharge }
{ RJS
  Description: Main procedure for establishing hydraulic parameters
              throughout the reach.
}
Var
  zav,           { Average bed elevation }
  Sav           : real;   { Average bed slope }
  PitFull       : boolean; { Indicates when pit is full }

Begin
  If FirstXS^.HydRec.flow then
    BackWater (Q, FirstXS)   { calc. water surface profile }
  else
    begin                  { no flow d/s of pit }
      CalcPitWSEL (WaterVol,PitFull,PitWSEL); {returns new PitWSEL}
      If PitFull then
        begin              { flow now exists d/s of pit }
          Current := FirstXS;
          repeat          { set flow flags to true}
            Current^.HydRec.flow := true;
            Current^.HydRec.zone := 8;
            Current := Current^.NextXS;
          until (Current^.HydRec.flow = true) or (Current = nil);
          BackWater (Q,FirstXS);   { calc water surface profile }
        end
      else                  { pit is still not filled }
        begin              { find next u/s point where flow = true }
          Current := FirstXS;

          while Current^.HydRec.SecNum <> OpRec.DSPitSecNum do
            begin
              Current^.HydRec.zone := 1;
              Current := Current^.NextXS;
            end;

          while Current^.HydRec.zb > PitWSEL do
            begin
              Current^.HydRec.zone := 2;
              Current := Current^.NextXS;
            end;

          if (Current^.HydRec.zb > Current^.NextXS^.HydRec.zb) then
            begin
              zav := 0.5*(Current^.HydRec.zb + Current^.NextXS^.HydRec.zb);
              Current^.HydRec.zb := zav;
              Current^.NextXS^.HydRec.zb := zav
            end;

          while (Current^.HydRec.zb < PitWSEL) do

```

```

begin
  Current^.HydRec.segl := 0;
  BedSlope(Current^.NextXS^.HydRec.zb,Current^.HydRec.zb,Current^.HydRec.length,Current^.HydRec.Ab,Sav);
  Current^.HydRec.depth := PitWSEL - Current^.HydRec.zb;
  Current^.HydRec.vel := 0;
  Current^.HydRec.tau := 0;
  Current^.HydRec.taug := 0;
  Current^.HydRec.nc := 0;
  Current^.HydRec.ng := 0;
  Current^.HydRec.flow := false;
  Current^.HydRec.zone := 3;
  Current := Current^.NextXS;
  if (Current^.HydRec.zb > Current^.NextXS^.HydRec.zb) then
    begin
      zav := 0.5*(Current^.HydRec.zb + Current^.NextXS^.HydRec.zb);
      Current^.HydRec.zb := zav;
      Current^.NextXS^.HydRec.zb := zav
    end
  end;

  if (Current^.HydRec.zb > Current^.NextXS^.HydRec.zb) then
    begin
      zav := 0.5*(Current^.HydRec.zb + Current^.NextXS^.HydRec.zb);
      Current^.HydRec.zb := zav;
      Current^.NextXS^.HydRec.zb := zav
    end;

  BedSlope(Current^.NextXS^.HydRec.zb,Current^.HydRec.zb,Current^.HydRec.length,Current^.HydRec.Ab,Sav);
  Depths(Sav,Current^.SedRec.D50,Q/Current^.HydRec.width,NormalDepth,CritDepth);

  while (NormalDepth <= CritDepth) and (Current^.NextXS <> nil) do
    begin
      Current^.HydRec.zone := 4;
      HydParm(Current^.HydRec.zb + CritDepth,Current^.SedRec.D50,Q/Current^.HydRec.width,Current^.HydRec);
      Current := Current^.NextXS;
      if (Current^.HydRec.zb > Current^.NextXS^.HydRec.zb) then
        begin
          zav := 0.5*(Current^.HydRec.zb + Current^.NextXS^.HydRec.zb);
          Current^.HydRec.zb := zav;
          Current^.NextXS^.HydRec.zb := zav
        end;
      BedSlope(Current^.NextXS^.HydRec.zb,Current^.HydRec.zb,Current^.HydRec.length,Current^.HydRec.Ab,Sav);
      Depths(Sav,Current^.SedRec.D50,Q/Current^.HydRec.width,NormalDepth,CritDepth)
    end;

  if Current^.NextXS <> nil then
    BackWater(Q,Current)
  else
    begin
      BedSlope(Current^.HydRec.zb,Current^.PrevXS^.HydRec.zb,Current^.HydRec.length,Current^.HydRec.Ab,Sav);
      Depths(Sav,Current^.SedRec.D50,Q/Current^.HydRec.width,NormalDepth,CritDepth);
      HydParm(Current^.HydRec.zb + NormalDepth,Current^.SedRec.D50,Q/Current^.HydRec.width,Current^.HydRec)
    end
  end
end

```

end
End;

{-----}

```

{
    Include file for program CRISM1.PAS

    File name   : SED13.LIB
    Description  : Sediment routing routines using a
                  simplified routine for the suspended
                  load.
    Programmer  : George K. Cotton, P.E.
                  Senior Engineer
                  Simons, Li & Associates Inc.
    Last revised : March 6, 1988
}

Function ActiveThickness(ps,
                        ds : SizeArray;
                        Taug : real): real;
{
    Description : Determines the active bed layer thickness. The procedure uses
                  the mean of the non-moving sediment sizes to characterize the
                  active bed layer thickness. A logarithmic distribution is assumed.
}
var
    m : integer;
    Tauc,
    dsum,
    psum : real;

begin
    psum := 0.;
    dsum := 0.;
    for m := 1 to OpRec.nsize do
        begin
            Tauc := 102.96*OpRec.Cs*ds[m];
            if Taug < Tauc then
                begin
                    psum := psum + ps[m];
                    dsum := dsum + ps[m]*ds[m]
                end
            end;
        if psum > 0 then
            ActiveThickness := dsum/psum
        else
            ActiveThickness := ds[OpRec.nsize]
        end;
    }
    -----}
Function MeanSize(ps,ds : SizeArray):real;
{
    Description : Determines the mean bed material size assuming a logarithmic
                  distribution.
    Programmer  : George K. Cotton, P.E.
}
var
    m : integer;
    psum,

```

```

dsum,
dml : real;

begin
  psum := 0;
  dsum := 0;
  for m := 1 to OpRec.nsize do
    begin
      psum := psum + ps[m];
      dsum := dsum + ps[m]*ds[m]
    end;
  if psum > 0 then MeanSize := dsum/psum else
    WriteLn(' At Section Number :',Root^.HydRec.SecNum:3,' Bed material fractions are zero.')
```

-----}

```

Procedure Transp( OpRec      : OpType;
                  var XSecRec : XSecType);
{
  Description : Determines the total bedload transport capacity by sediment
                size fractions using the Meyer-Peter Muller bedload equation.
                Unit for sediment transport is lbs/sec/ft.
  Programmer  : George K. Cotton, P.E.
}
var
  m      : integer;           { index for particle sizes }
  tauc   : real;             { incipient shear stress, lb/sf }
  Gtf    : array[1..maxsize] of real; { Sediment transport by size fractions, lbs/sec/ft }

begin
  with XSecRec do
    begin
      with HydRec, BedMatRec, SedRec do
        begin
          ng := power(depth,1/6)/(8.58+20.0*ln(depth/D50)/ln(10));
          if ng > nc then ng := nc;
          Taug := (ng/nc) * Tau;
          da := ActiveThickness(pal,ds,Taug);
          Gt := 0.0;
          for m := 1 to OpRec.nsize do
            begin
              tauc := 102.96*OpRec.Cs*ds[m];
              if taug > tauc then
                Gtf[m] := 9.23*power((taug-tauc),1.5)*pal[m]*width
              else
                Gtf[m] := 0;
              Gt := Gt + Gtf[m]
            end;
          if Gt > 0 then
            for m := 1 to OpRec.nsize do ptc[m] := Gtf[m]/Gt
          else
            for m := 1 to OpRec.nsize do ptc[m] := 0.0
          end
        end
      end
    end
  end;
end;
```

```

{-----}
Procedure ZeroTransp(var XSecRec : XSecType);
{
  Description : Sets the transport capacity to zero if no flow.
  Programmer  : George K. Cotton, P.E.
}
begin
  with XSecRec.SedRec do
    begin
      Gt := 0;
      for m := 1 to OpRec.nsize do ptc[m] := 0;
      da := ActiveThickness(pal, BedMatRec.ds, 0)
    end
  end;
{-----}
Procedure ActiveGradation( dzf : SizeArray; { Change in bed elev. by size fraction }
                          var XSecRec : XSecType);
{
  Description : Determines the gradation in the bed layer after scour or deposition.
  Programmer  : George K. Cotton, P.E.
}
var
  m : integer;
  deficit, % { Cumulative excess scour }
  rd,      { Deficit ratio }
  dbt,     { Total remaining bed thickness }
  dzt : real; { Total bed change thickness }
  daf,     { Active layer thickness by fraction }
  dbf : SizeArray; { Remaining bed thickness by fraction }

begin
{
(**) gotoxy(5,5); write('Bed elevation change by fraction, dzf'); clreol;
(**) gotoxy(5,6); for m := 1 to OpRec.nsize do write(dzf[m]:6:3); clreol;
}
  with XSecRec.SedRec do
    begin
      dbt := 0;
      dzt := 0;
      deficit := 0;
      for m := 1 to OpRec.nsize do
        begin
          dzf[m] := -dzf[m]; { sign is reversed : scour +, deposition - }
          daf[m] := da*pal[m];
          if dzf[m] < daf[m] then
            dbf[m] := daf[m] - dzf[m]
          else
            begin
              deficit := deficit + (dzf[m] - daf[m]);
              dbf[m] := 0;
              dzf[m] := daf[m]
            end
          end;
          dzt := dzt + dzf[m];
          dbt := dbt + dbf[m]
        end
      end
    end
  end
end

```

```

end;
{
(**) gotoxy(5,9); write('Adjusted bed elevation change, dzf');clreol;
(**) gotoxy(5,10); for m := 1 to OpRec.nsize do write(-dzf[m]:6:3); clreol;
(**) gotoxy(5,11); write('Remaining bed layer by fraction, dbf'); clreol;
(**) gotoxy(5,12); for m := 1 to OpRec.nsize do write(dbf[m]:6:3); clreol;
(**) gotoxy(5,7); write('Active layer thickness by fraction, daf'); clreol;
(**) gotoxy(5,8); for m := 1 to OpRec.nsize do write(daf[m]:6:3); clreol;
(**) gotoxy(5,13); clreol;
(**) gotoxy(5,14); write('New total scour :',dzt:6:3,' and total bed remaining:',dbt:6:3); clreol;
(**) gotoxy(5,15); clreol;
}
rd := 1 - deficit/da;
if dbt > 0 then
  if dzt >= 0 then
    for m := 1 to OpRec.nsize do
      pal[m] := (dbf[m] + ppl[m]*deficit)/(dbt + deficit)
    else
      for m := 1 to OpRec.nsize do
        pal[m] := (pal[m]*da - dzf[m])/dbt
      else
        pal := ppl;
    {
(**) gotoxy(5,16); write('Active layer gradation, pal');clreol;
(**) gotoxy(5,17); for m := 1 to OpRec.nsize do write(pal[m]*100:6:2); clreol;
    }
  end
end;
{-----}
Procedure SedCon( OpRec : OpType;
var XSecRec : XSecType);
{
Description : Determines the bed elevation after scour or deposition at a
section. An explicit finite difference procedure is used.
Programmer : George K. Cotton, P.E.
}
const
Cv = 0.01; { Conversion factor: lbs/sec to bulked cfs with porosity = 0.4 }
var
dzf : SizeArray; { bed change by size fraction }
TWat, { topwidth at current section }
RLup, { u/s reach length }
RLdn, { d/s reach length }
Gtup, { transport into section }
Gtat, { transport at current section }
Gtdn : real; { transport out of section }
ptcup, { upstream transport by size fraction }
ptcat, { current section transport by size fraction }
ptcdn : SizeArray; { downstream transport by size fraction }
m : integer;
begin

```

```

Gtup := XSecRec.NextXS^.SedRec.Gt;
Gtat := XSecRec.SedRec.Gt;
Gtdn := XSecRec.PrevXS^.SedRec.Gt;
ptcup := XSecRec.NextXS^.SedRec.ptc;
ptcat := XSecRec.SedRec.ptc;
ptcdn := XSecRec.PrevXS^.SedRec.ptc;
RLup := XSecRec.NextXS^.HydRec.length;
RLdn := XSecRec.HydRec.length;
TWat := XSecRec.HydRec.width;

XSecRec.SedRec.dz := 0;
for m := 1 to OpRec.nsize do
begin
  dzf[m] := ((1-OpRec.theta)*(Gtup*ptcup[m] - Gtat*ptcat[m]) +
             OpRec.theta*(Gtat*ptcat[m] - Gtdn*ptcdn[m])) *
            (OpRec.timestep*60.0)/(0.5*(RLup + RLdn)) * (Cv/TWat);
  XSecRec.SedRec.dz := XSecRec.SedRec.dz + dzf[m]
end;
{
(**) gotoxy(5,22); write(' Section Number: ',XSecRec.HydRec.SecNum:3);
}
ActiveGradation(dzf,XSecRec);
XSecRec.SedRec.D50 := MeanSize(XSecRec.SedRec.pal, BedMatRec.ds);
XSecRec.HydRec.zb := XSecRec.HydRec.zb + XSecRec.SedRec.dz
end;
{-----}

```

```

{
    Procedures for program CRISM13
    Include file name : InOut13.lib
    Description       : Input/Output routines.
    Programmer       : George K. Cotton, P.E.
                    : Simons, Li & Associates, Inc.
    Last Revised     : March 3, 1988
}
-----}
Procedure BatchOpen(Var IORec : IOType);
Begin
    ClrScr;
    Frame(1,21,80,24); Frame2(1,1,80,24);
    GoToXY(33,3); Write(' -- CRISM --');
    Frame2(32,2,46,4);

    Assign(IORec.FV1,'CRM.DAT');
    {$I-} Reset(IORec.FV1); {$I+}
    OK := (IOresult = 0);
    If not OK then
    begin
        GotoXY(3,22); Write('Input file CRM.DAT not found - program halted. ');
        Halt
    end;

    Assign(IORec.FV2,'CRM.OUT');
    Rewrite(IORec.FV2)

End;
-----}
Procedure ReadData(var OpRec      : OpType;
                  var BedMatRec   : BedMatType;
                  var zbi         : ReachArray;
                  var Q           : TimeArray;
                  var DSXS,USXS,
                      FirstTS,
                      DSPitLimit : XSecPtr);

{
    Description : Reads the user supplied hydraulic and bed material data sets.
                  and builds the first linked list for a reach.
}
var
    i, m, n,
    nchg, nint,
    NumQChg,
    NumQInt : integer;
    qInt    : real;
    XSecData : XSecType;
    Holder,
    Root    : XSecPtr;

    Procedure Initialize(var XSecData : XSecType);
    begin

```

```

With XSecData, HydRec, SedRec do
begin
  TSNum := 1;  flow := false; depth := 0;
  segl  := 0;  Ab   := 0;    vel  := 0;
  tau   := 0;  taug := 0;    nc   := 0;
  ng    := 0;  dz   := 0;    da   := 0;
  Gt    := 0;  zone := 0;
end
end;
{-----}

begin
with IORec, XSecData do
begin
  with OpRec do
  begin
    readln(FV1,Title1);
    readln(FV1,Title2);
    RunTime := Time;
    RunDate := Date;
    readln(FV1,nsec,nsiz,NumQChg,timestep,Cs,sinit,theta,tintprt,PlotInd,DSPitSecNum);
  end;

  with BedMatRec, SedRec do
  begin
    for m := 1 to OpRec.nsize do read(FV1,ds[m]); readln(FV1);
    for m := 1 to OpRec.nsize do read(FV1,ppl[m]); readln(FV1);
    for m := 1 to OpRec.nsize do read(FV1,pal[m]); readln(FV1);
    for m := 1 to OpRec.nsize do ds[m] := ds[m]/304.8;
    D50 := MeanSize(pal,ds);
  end;

  { Read data into unit discharge array }
  n := 1;
  for nchg := 1 to NumQChg do
  begin
    ReadLn(FV1,NumQInt,qInt);
    for nint := 1 to NumQInt do
    begin
      Q[n] := qInt;
      n := n + 1
    end
  end;
  OpRec.ntime := n - 1;

  { Build the cross-section linked list for the first time step }
  Root := nil;
  Holder := Root;
  for j := 1 to OpRec.nsec do
  begin
    Initialize(XSecData);
    ReadLn(FV1, HydRec.SecNum,HydRec.length,HydRec.zb, HydRec.width);
    zbi[j] := HydRec.zb;
    new(Root);           { Create empty dynamic record }
  end;
end;
end;
end;

```

```

Root^      := XSecData;   { Copy data into dynamic record }
Root^.PrevXS := Holder;   { Assign pointers to dynamic record }
Root^.NextXS := nil;
Holder^.NextXS := Root;
Root^.NextTS := nil;
Holder      := Root;
if j = 1 then
begin
  DSXS := Root;
  FirstTS := Root;
end;
if j = OpRec.nsec then USXS := Root;
if HydRec.SecNum = OpRec.DSPitSecNum then DSPitLimit := Root
end
end;

{ Echo input data to screen }
With OpRec do
begin
  Gotoxy(5,5); WriteLn(Title1);
  Gotoxy(5,6); WriteLn(Title2);
  Gotoxy(5,8); Write(' # of x-sections      = ',nsec:4);
  Gotoxy(5,9); Write(' # of time steps      = ',ntime:4);
  Gotoxy(5,10); Write(' # of sediment sizes = ',nsize:4);
  Gotoxy(5,11); Write(' Output interval      = ',tintprt:4);
  Gotoxy(5,12); Write(' Plotter Output      = '); if plotind = 1 then write('on') else write('off');
  Gotoxy(33,8); Write(' Time step interval = ',timestep:6:1,' minutes');
  Gotoxy(33,9); Write(' Downstream bed slope= ',sinit:6:4);
  Gotoxy(33,10); Write(' FD weighting factor = ',theta:6:3);
  Gotoxy(33,11); Write(' Shields parameter   = ',Cs:6:3);
end;
Gotoxy(5,13); WriteLn('-----');
With BedMatRec do
begin
  Gotoxy(5,14); WriteLn(' Particle Size (mm) : ');
  Gotoxy(5,15);
  for m := 1 to OpRec.nsize do
    Write(' ',ds[m]*304.8:6:3);
  Gotoxy(5,16); WriteLn(' Surface Layer Fractions (%) : ');
  Gotoxy(5,17);
  for m := 1 to OpRec.nsize do
    Write(' ',XSecData.SedRec.pal[m]*100:6:3);
  Gotoxy(5,18); WriteLn(' Parent Layer Fractions (%) : ');
  Gotoxy(5,19);
  for m := 1 to OpRec.nsize do
    Write(' ',XSecData.SedRec.ppl[m]*100:6:3);
end;
Gotoxy(5,20); WriteLn('-----');
end;
{-----}

Procedure PrinterOutput;
{RJS/GKC
Description: Dump X-Section record to output device file.

```

```

)
var
  i,m,n : integer;
  Current, Holder : XSecPtr;

Procedure DumpXSecData(XSecRec:XSecType);
begin
  with IOrec, XSecRec do
  begin
    with Hydrec do
    begin
      Write(FV2,' ',SecNum:3);
      Write(FV2,' ',length:7:1);
      Write(FV2,' ', width:7:1);
      Write(FV2,' ',   zb:8:3);
      Write(FV2,' ', depth+zb:8:2);
      Write(FV2,' ', depth:6:2);
      (* Write(FV2,' ',   Ab*57.296:6:2); *)
      Write(FV2,' ',   segl:8:5);
      Write(FV2,' ',   vel:6:2);
      Write(FV2,' ',   nc:6:3);
      Write(FV2,' ',   ng:6:3);
      Write(FV2,' ',   taug:6:2);
    end;
    with SedRec do
    begin
      Write(FV2,' ',   Gt:8:1);
      Write(FV2,' ',   dz:9:5);
      Write(FV2,' ',   da:7:4);
      Write(FV2,' ',D50*304.8:7:2);
      (* for m := 1 to OpRec.nsize do Write(FV2,' ',pal[m]*100:6:3) *)
    end;
    if HydRec.flow then Write(FV2,' f') else Write(FV2,' n');
    Write(FV2,HydRec.zone:3);
    WriteLn(FV2)
  end
end;
{-----}

Procedure TSHeader(ts : integer; { time step number      }
                  Qt : real); { discharge for time period }
begin
  GoToXY(4,23); Write('Writing time step # ',ts:3);
  with IOrec do
  begin
    WriteLn(FV2);
    WriteLn(FV2);
    WriteLn(FV2,
      'TIME STEP # ',ts,'   Q = ',Qt:8:2,' cfs!');
    WriteLn(FV2);
    WriteLn(FV2,
' | Sec  Reach  Width  Bed    WS    Flow Energy  Vel  nc  ng  Taug  Gt  dz  da  D50');
    WriteLn(FV2,
' | #   Length                Elev  Elev  Depth  Slope!');
  end
end;

```

```

    WriteLn(FV2,
    ' (ft) (ft) (ft) (ft) (ft) (ft/ft) (ft/s) (lb/sf) (lb/s) (ft) (ft) (mm)');
    WriteLn(FV2,
    '-----');
end
end;
(-----)

Begin
with IORec do
begin
WriteLn(FV2,' Channel Response due to In-Stream Mining!);
WriteLn(FV2,' ----- Program CRISM (Ver 1.3) -----!);
WriteLn(FV2,' Gravel-Bed Channels, with Armoring!);
WriteLn(FV2,' and Channel Width Variation!);
WriteLn(FV2);
WriteLn(FV2,' Simons, Li & Associates Inc.);
WriteLn(FV2,' March 1988!);
WriteLn(FV2);WriteLn(FV2);
With OpRec do
begin
WriteLn(FV2,'Run Date : ',RunDate);
WriteLn(FV2,'Run Time : ',RunTime);
WriteLn(FV2);
WriteLn(FV2,Title1);
WriteLn(FV2,Title2);
WriteLn(FV2);
WriteLn(FV2,' # of x-sections = ',nsec:4);
WriteLn(FV2,' # of time steps = ',ntime:4);
WriteLn(FV2,' # of sediment sizes = ',nsize:4);
WriteLn(FV2,' Downstream bed slope = ',sinit:6:4);
WriteLn(FV2,' FD Weighting Factor = ',theta:6:3);
WriteLn(FV2,' Shields parameter = ',Cs:6:3);
WriteLn(FV2,' Time step interval = ',timestep:6:1,' minutes')
end;
WriteLn(FV2,'-----');
WriteLn(FV2);
WriteLn(FV2);
With BedMatRec do
begin
WriteLn(FV2,' Particle Size (mm) : ');
for m := 1 to OpRec.nsize do
Write(FV2,' ',ds[m]*304.8:6:3);
WriteLn(FV2);
WriteLn(FV2,' Parent Layer Fractions (%) : ');
for m := 1 to OpRec.nsize do
Write(FV2,' ',FirstTS^.SedRec.ppl[m]*100:6:3);
WriteLn(FV2)
end;
WriteLn(FV2,'-----');

n := 1;
If Cached then
begin

```

```

Reset(IORec.FVcach);
While Not EOF(IORec.FVCach) do
begin
  TSHeader(n*OpRec.tintprt,Q[n*OpRec.tintprt]);
  for i := 1 to OpRec.nsec do
  begin
    read(IORec.FVcach,XSecData);
    DumpXSecData(XSecData)
  end;
  n := n + 1;
end
end;

Current := FirstTS;
Holder := Current;
repeat
  Holder := Current;
  TSHeader(n*OpRec.tintprt,Q[n*OpRec.tintprt]);
  for i := 1 to OpRec.nsec do
  begin
    DumpXSecData(Current^);
    Current := Current^.NextXS
  end;
  Current := Holder^.NextTS;
  n := n + 1
until Current^.NextTS = nil;

end
End;
{-----}

Procedure PlotterOutput;

Var
  j, m, n : integer;
  SumLength : real;
  PlotFile : text;
  Current, Holder : XSecPtr;

Procedure DumpRecord(var SumLength : real; XSecData : XSecType);
begin
  SumLength := SumLength + XSecData.Hydrec.Length;
  Write(PlotFile,SumLength:10:1);
  Write(PlotFile,XSecData.HydRec.zb:10:2);
  Write(Plotfile,XSecData.Hydrec.zb+XSecData.Hydrec.Depth:10:2);
  Write(PlotFile,XSecData.HydRec.zb-zbi[j]:10:2);
  WriteLn(PlotFile)
end;

Begin
  Assign(PlotFile,'CRM.PLT');
  ReWrite(PlotFile);

  n := 1;

```

```
If Cached then
begin
  Reset(IORec.FVcach);
  While Not EOF(IORec.FVcach) do
  begin
    SumLength := 0;
    GoToXY(4,23); Write('Writing time step # ',n*OpRec.tintprt:3);
    for j := 1 to OpRec.nsec do
    begin
      read(IORec.FVcach,XSecData);
      DumpRecord(SumLength,XSecData)
    end;
    n := n + 1
  end
end;

Current := FirstTS;
repeat
  Holder := Current;
  SumLength := 0;
  GoToXY(4,23); Write('Writing time step # ',n*OpRec.tintprt:3);
  for j := 1 to OpRec.nsec do
  begin
    DumpRecord(SumLength,Current^);
    Current := Current^.NextXS
  end;
  Current := Holder^.NextTS;
  n := n + 1;
until Current^.NextTS = nil;

Close(PlotFile)
end;
{-----}
```

```
Program CRISM12;
```

```
{
```

```
Channel Response to In-Stream Mining
Simons, Li & Associates Inc.
Version Number: 1.2 - Sand-Bed, non-armoring
Programmers : George K. Cotton P.E.
              Robert J. Smolinsky P.E.
Last Revised : February 1, 1988
```

```
}
```

```
const
```

```
Ccoef = 0.1; { contraction coef for hydraulic calc's }
Cs     = 0.047; { Shield's parameter }
Ecoef = 0.3; { expansion coef. for hydraulic calc's }
maxsec = 100; { maximum number of cross sections }
maxtime = 1000; { maximum number of time intervals }
spc : Char = #32; { space, for formatting }
```

```
type
```

```
Str = String[20];
Strg = String[10];
DateStr = String[10];
TimeString = String[8];
ReachArray = array[1..maxsec] of real;
TimeArray = array[1..maxtime] of real;
HydType = record
    SecNum: integer; { x-section number }
    length, { reach length }
    width, { channel width }
    depth, { channel depth }
    zb, { channel invert elevation }
    segl, { slope of the energy grade line }
    Ab, { angle of the channel bed }
    vel, { channel mean velocity }
    tau, { mean channel shear stress }
    nc, { channel roughness coefficient }
    dz, { change in bed elevation }
    Gt : real; { transport from reach }
    flow: boolean { true if x-sec has flow }
end;
```

```
XSecPtr = ^XSecType;
```

```
XSecType = record
    HydRec : HydType;
    TSNUM : integer;
    NextXS,
    PrevXS,
    NextTS : XSecPtr;
end;
```

```
IOType = record
    FV1, { Input file variable }
    FV2 : text; { Output file variable }
    FVcach : file of XSecType; { Disk cach file }
    FnIn, { Input file name }
```

```

        FnOut : String[14];      { Output file name      }
    end;
OpType = record
    Title1,           { Run title                }
    Title2 : String[65]; { Run title                }
    RunDate : DateStr; { Date model was run      }
    RunTime : TimeString; { Time model was run     }
    DSPitSecNum,     { Section number of the pit brink }
    PlotInd,         { if 1, plot file is output }
    nsec,            { Number of cross-sections in reach }
    tintprt,        { time step print interval }
    ntime : integer; { Number of time intervals }
    D50,            { mean sediment size }
    Grd,            { gradation coefficient }
    theta,          { Finite difference weighting factor }
    Sinit,          { Initial D/S channel slope }
    TimeStep: real   { length of time step (min.) }
end;

var
    FillVolume, { cumulative vol. of water in pit up to current time step }
    PitWSEL,    { water surface elevation in pit during ponding conditions }
    TSMemReq,   { memory, in bytes, required for each time step }
    NormalDepth,
    CritDepth : real;
    j,n : integer; { indices for space and time, respectively }
    q : TimeArray; { unit discharge array - hydrograph }
    zbi : ReachArray; { initial bed elevations }
    XSecData : XsecType;
    HydRec : HydType;
    IORec : IOType;
    OpRec : OpType;
    Root,
    FirstTS, { pointer to first time step }
    USXS, { pointer to upstream section of current time step }
    DSXS, { pointer to downstream section of current time step }
    DSPitLimit, { points at x-sec defined as the d/s limit of pit }
    Current : XSecPtr;
    OK,
    Cached, { flag to indicate if output has been cached to disk }
    PitFull : Boolean; { flag to indicate if pit has been filled }

{----- add these include files in this order -----}
{$I UTIL11.LIB }
{$I MEM11.LIB }
{$I HYD12.LIB }
{$I SED12.LIB }
{$I INOUT12.LIB }
{-----}

Begin { Main Program }
    BatchOpen(IORec);
    ReadData(OpRec,zbi,q,DSXS,USXS,FirstTS,DSPitLimit);

```

```

Cached      := false;
FillVolume := 0;
TSMemReq    := OpRec.nsec * SizeOf(XSecData);

for n := 1 to OpRec.ntime do
begin
  gotoxy(50,22); Write('Executing time step :',n:3);
  gotoxy(50,23); Write('Memory Left = ',MemoryLeft:6:0,' bytes');

  { hydraulics established in u/s sweep }
  Hydraulics(DSXS, OpRec.timeStep, q[n]);

  { transport calculated in u/s sweep }
  Current := DSXS; { reset root pointer to d/s most x-sec }
  for j := 1 to OpRec.nsec do
  begin
    if Current^.HydRec.flow then
      Transp(OpRec, Current^)
    else
      Current^.HydRec.Gt := 0;
    if Current^.NextXS <> nil then
      Current := Current^.NextXS { move u/s to next XSec }
  end;

  { sediment continuity calculated in d/s sweep }
  Current := USXS^.PrevXS;
  for j := 2 to (OpRec.nsec-1) do
  begin
    SedCon(OpRec,Current^);
    Current := Current^.PrevXS
  end;

  { Create a new reach list }
  If (n mod OpRec.tintprt) = 0 then
  begin
    if (MemoryLeft < TSMemReq) then DiskCach(OpRec.NSec,Cached,FirstTS);
    BuildReachList(OpRec.nsec,n,DSXS,USXS,DSPitLimit)
  end

end;

{ Output Files }
PrinterOutput;
if OpRec.PlotInd = 1 then PlotterOutput;

ClearMem(FirstTS);
If cached then
begin
  close(IOrec.FVcach);
  erase(IOrec.FVcach);
end;
close(IOrec.FV1);
close(IOrec.FV2);
End.

```

```

Function Power(X,Y : Real):real;
{
  Description: Returns the value of X raised to the Y power.
}
begin
  if X <= 0 then power := 0 else power := exp(Y*ln(X))
end;
{-----}
Function Log(X: real):real;
begin
  log := ln(X)/ln(10);
end;
{-----}
function Date: DateStr;
{
  Description: Returns the system date--the type "DateStr" MUST be specified
              in the calling program as:

              type
                DateStr = string[10];          }

type
  regpack = record
    ax,bx,cx,dx,bp,si,ds,es,flags: integer;
  end;

var
  regpack:    regpack;          {record for MsDos call}
  month,day:  string[2];
  year:       string[4];
  dx,cx:      integer;

begin
  with regpack do
  begin
    ax := $2a shl 8;
  end;
  MsDos(regpack);              { call function }
  with regpack do
  begin
    str(cx,year);              {convert to string}
    str(dx mod 256,day);        { " }
    str(dx shr 8,month);        { " }
  end;
  date := month+'/'+day+'/' +year;
end;
{-----}

function time: TimeString;
{
  Description: Returns the system time----the TYPE "TimeString" MUST be
              specified in the calling program as: type
              TimeString = string[8]
}

```

```

)
type
  regpack = record
    ax,bx,cx,dx,bp,di,si,ds,es,flags: integer;
  end;

var
  regpack:      regpack;      {assign record}
  ah,al,ch,cl,dh: byte;
  hour,min,sec: string[2];

begin
  ah := $2c;                  {initialize correct registers}
  with regpack do
  begin
    ax := ah shl 8 + al;
  end;
  intr($21,regpack);         {call interrupt}
  with regpack do
  begin
    str(cx shr 8,hour);       {convert to string}
    str(cx mod 256,min);      { " }
    str(dx shr 8,sec);       { " }
  end;
  time := hour+':'+min+':'+sec;
end;
{-----}

Procedure FRAME(UpperLX,UpperLY,LowerRX,LowerRY : Integer);

Var
  i : Integer;

Begin
  GoToXY(UpperLX,UpperLY);Write(chr(218));
  for i:=UpperLX+1 to LowerRX-1 do Write (chr(196));
  Write(chr(191));
  for i:=UpperLY+1 to LowerRY-1 do
  begin
    GoToXY(UpperLX,i);Write(chr(179));
    GoToXY(LowerRX,i);Write(chr(179));
  end;
  GoToXY(UpperLX,LowerRY);
  Write(chr(192));
  for i:=UpperLX+1 to LowerRX-1 do Write(chr(196));
  Write(chr(217));
End; { FRAME }
{-----}

Procedure FRAME2(UpperLX,UpperLY,LowerRX,LowerRY : Integer);

Var
  i : Integer;

```

```
Begin
  GoToXY(UpperLX,UpperLY);Write(chr(201));
  for i:=UpperLX+1 to LowerRX-1 do Write (chr(205));
  Write(chr(187));
  for i:=UpperLY+1 to LowerRY-1 do
  begin
    GoToXY(UpperLX,i);Write(chr(186));
    GoToXY(LowerRX,i);Write(chr(186));
  end;
  GoToXY(UpperLX,LowerRY);
  Write(chr(200));
  for i:=UpperLX+1 to LowerRX-1 do Write(chr(205));
  Write(chr(188));
End; { FRAME2 }
{-----}

Procedure NormalScreen;
Begin TextColor(LightGray); TextBackGround(Black) end;
{-----}

Procedure BrightScreen;
Begin TextColor(White); TextBackGround(Black) end;
{-----}

Procedure ErrorScreen;
Begin TextColor(Black); TextBackGround(LightGray) end;
{-----}
```



```

        else
            dispose(Current);
        end;
        Current := FirstTS
    end;
    FirstTS := Current;
    ( all but the last time step have been cached to disk )
end;
{-----}
Procedure BuildReachList(   NSec, NTime : integer;
                           var DSXS,
                               USXS,
                               DSPitLimit : XSecPtr);
{GKC
  Description : Builds a linked list of cross-section data for a new
                time interval.
}
var
    Root, Holder, Current : XSecPtr;
    j : integer;

begin
    Root := nil;
    Holder := Root;
    Current := DSXS;
    for j := 1 to NSec do
        begin
            new(Root);
            Root^. := Current^;
            Root^.TNum := NTime;
            Root^.PrevXS := Holder;
            Root^.NextXS := nil;
            Holder^.NextXS := Root;
            Root^.NextTS := nil;
            Current^.NextTS := Root;
            Holder := Root;
            Current := Current^.NextXS;
            if j = 1 then DSXS := Root;
            if j = NSec then USXS := Root;
            if (Current^.HydRec.SecNum = OpRec.DSPitSecNum) then DSPitLimit := Root
        end
    end;
end;
{-----}
Procedure ClearMem(var FirstTS : XSecPtr);
{
  Description : Clears linked lists from memory.
}
var
    Root, Holder, TSHolder : XSecPtr;

begin
    if FirstTS <> nil then
        repeat
            TSHolder := FirstTS^.NextTS;

```

```
Root := FirstTS;
repeat
  Holder := Root^.NextXS;
  Dispose(Root);
  Root := Holder;
until Root = nil;
FirstTS := TSHolder;
until FirstTS = nil
end;
{-----}
```

```

(
    Procedures for program CRISM
    File name: HYD.LIB
    Description : Hydraulic routines
    Include file for program CRISM.PAS

    Simons, Li & Associates Inc.
    Programmers: George K. Cotton P.E.
                Robert J. Smolinsky P.E.

    Last revision: February 8, 1988
)

Procedure Depths( Sav,          { bed slope }
                 D50,          { mean gradation size }
                 q : real;     { unit discharge }
                 var NormalDepth,
                     CritDepth : real);

(
GKC/RJS
    Description: Returns normal and critical depth at current x-sec.
)
Var
    C,          { Resistance coefficient }
    dn : real; { estimated normal depth }

Begin

    { Critical depth calculation }
    CritDepth := power(q*q/32.2,1/3);

    { Normal depth calculation }
    If Sav <= 0 then
        NormalDepth := 9999
    else
        begin
            NormalDepth := power(0.0156*q/sqrt(Sav),2/3); { Blodgett coefficient = 0.0231 }
            if D50 > 0 then
                begin
                    if NormalDepth/D50 < 185 then
                        repeat
                            dn := NormalDepth;
                            if D50 >= 0 then
                                if dn/D50 < 185 then
                                    begin
                                        C := 8.58 + 20.0*ln(dn/D50)/ln(10);
                                        NormalDepth := Power(q/(1.486*C*sqrt(Sav)),2/3)
                                    end
                                else
                                    NormalDepth := power(0.0156*q/sqrt(Sav),2/3) { Blodgett coefficient = 0.0231 }
                            until abs(dn-NormalDepth) < 0.01
                        end
                    end
                end
            end
        end
    end
end

```

```

End;
{-----}
Procedure BedSlope(  zbdn,      { downstream bed elevation }
                   zbc,      { current bed elevation   }
                   xrc : real; { current reach length   }
                   var Ab,    { bed slope angle         }
                   So  : real);

{GKC
  Description: Returns the angle of the channel bed and the bed slope.
}
Var
  Sdn : real; { average bed gradient downstream of current section }

Begin
  if xrc <= 0 then
    Sdn := 0
  else
    Sdn := (zbc - zbdn)/xrc;
  Ab := ArcTan(Sdn);
  So := sin(Ab)
End;
{-----}
Procedure HydParm(  WSEL,      { Water surface elevation }
                   D50,      { Mean sediment size     }
                   q : Real;  { Unit discharge        }
                   var HydRec : HydType); { Hydraulic data record }

{RJS
  Description : Calculates hydraulic parameters for a given WSEL.
}
var
  Aws : real; { angle of the water surface }

Begin
  with HydRec do
  begin
    depth := (WSEL - zb);
    if depth > 0 then
    begin
      if (depth/D50 < 185) and (depth/D50 > 1.5) then
        nc := power(depth,1/6)/(8.58+20.0*ln(depth/D50)/ln(10))
      else if depth/D50 < 1.5 then
        nc := 0.159
      else
        nc := 0.0231*power(depth,1/6);
      segl := Sqr(q * nc / (1.486 * POWER(depth,5/3)));
      Aws := ArcTan(segl);
      depth := depth*cos(Aws);
      tau := 64.4 * depth * sin(Aws);
      vel := q / depth;
      flow := true
    end
  end
End;

```

```

-----}
Procedure Balance ( q,           {unit discharge}
                  D50,         {mean gradation size}
                  CritDepth2 : Real; {critical depth at current x-sec}
                  HydRec1   : HydType; {previous x-section}
                  var HydRec2 : HydType; {current x-section }
{RJS
  Description: Establishes energy balance between x-sections.
}

```

Label

```
FINIS, SUBID, SUBDD, AGAIN, AGAIN2 ;
```

Var

```

FLAG, F : INTEGER;
WSEL1,   { WSEL at previous x-sec }
WSEL2,   { WSEL approximation at current x-sec }
CWSEL2,  { calculated WSEL at current x-sec }
WSCORR,  { correction applied to WSEL for new approximation }
CrWSEL2, { critical WSEL @ current x-sec }
AvSf,    { average friction slope for reach }
CELoss,  { contraction/expansion loss }
Vh1,     { velocity head @ prev. x-sec }
Vh2,     { velocity head @ current x-sec }
Vhdif : Real; { difference in velocity heads }
COUNT : Byte; { counter for # of iterations in energy balance }

```

```
-----}
```

```
Function EnergyLoss : Real;
```

Var

```
Eqn : Integer;
```

Begin

```

Vhdif := (Vh2 - Vh1); { compute shock losses }
If Vhdif > 0 then
  CELoss := Ecoef*Vhdif
else
  CELoss := Ccoef*Vhdif;

{ select proper friction averaging eqn. }
If HydRec2.segl >= HydRec1.segl then
  AvSf := (HydRec2.segl + HydRec1.segl)/2
else
  AvSf := 2 * (HydRec2.segl * HydRec1.segl)/(HydRec2.segl + HydRec2.segl);

EnergyLoss := CELoss + Avsf * HydRec2.length
End;

```

```
-----}
```

BEGIN

```

WSEL1 := HydRec1.Depth + HydRec1.zb;
CrWSEL2 := CritDepth2 + HydRec2.zb;
COUNT := 0;
WSEL2 := CrWSEL2; { first approximation of WSEL }
HYDPARM (WSEL2, D50, q, HydRec2);
Vh1 := HydRec1.Vel * HydRec1.Vel / 64.4;
Vh2 := HydRec2.Vel * HydRec2.Vel / 64.4;
{ subcritical energy balance }
COUNT := COUNT + 1;
CWSEL2 := WSEL1 + Vh1 + EnergyLoss - Vh2;
IF ABS(CWSEL2 - WSEL2) < 0.05 then goto FINIS;
IF CWSEL2 > WSEL2 then
  WSCORR := (CWSEL2 - WSEL2)/2
else
  {assume critical depth}
begin
  WSEL2 := CrWSEL2;
  HydParm(WSEL2, D50, q, HydRec2);
  goto FINIS;
end;
{ increase depth, subcritical profile }
F:=1; FLAG:=0;
AGAIN:
WSEL2 := WSEL2 + F * WSCORR;
HYDPARM(WSEL2, D50, q, HydRec2);
Vh2 := HydRec2.Vel * HydRec2.Vel / 64.4;
CWSEL2 := WSEL1 + Vh1 + EnergyLoss - Vh2;
IF ABS(CWSEL2 - WSEL2) < 0.05 then goto FINIS;
COUNT := COUNT + 1; IF COUNT > 20 then goto FINIS;
IF (CWSEL2 > WSEL2) and (FLAG = 0) then goto AGAIN;
FLAG:=1;
IF CWSEL2 < WSEL2 then F := -1 else F := 1;
WSCORR:=WSCORR/2; goto AGAIN;
FINIS : { WSEL2 computed to within 0.05' if Count <= 20}
If Count > 20 then { could not balance energy equation, assume critical depth }
begin
  WSEL2 := CrWSEL2;
  HydParm(WSEL2, D50, q, HydRec2)
end
End;
{-----}
Procedure BackWater(      q : Real;
                        var DSPT : XSecPtr); { pointer to first d/s x-sec with flow }
{RJS
Description: Calculates backwater profile upstream beginning at root pointer.
}
Var
BeginningXSEC : boolean; { flags the first x-sec -- normal depth used as
                          beginning WSEL }
Sav : real;      { Average channel slope in a reach }
Current : XSecPtr;

Begin
  Current := DSPT;

```

```

BeginningXSEC := true;
Repeat
  If BeginningXSEC then {calc crit. depth for use as beginning WSEL }
  begin
    if Current^.PrevXS <> nil then
    begin
      BedSlope( Current^.PrevXS^.HydRec.zb, Current^.HydRec.zb, Current^.HydRec.length, Current^.HydRec.Ab, Sav);
      Depths(Sav, OpRec.D50, q, NormalDepth, CritDepth);
      HydParm(Current^.HydRec.zb + CritDepth, OpRec.D50, q, Current^.HydRec)
    end
    else
    begin
      Depths(OpRec.Sinit, OpRec.D50, q, NormalDepth, CritDepth);
      HydParm(Current^.HydRec.zb + NormalDepth, OpRec.D50, q, Current^.HydRec)
    end;
    BeginningXSEC := false
  end;
  Current := Current^.NextXS;
  BedSlope( Current^.PrevXS^.HydRec.zb, Current^.HydRec.zb, Current^.HydRec.length, Current^.HydRec.Ab, Sav);
  Depths(Sav, OpRec.D50, q, NormalDepth, CritDepth);
  if NormalDepth < CritDepth then
  begin
    if NormalDepth < 0.71*CritDepth then NormalDepth := 0.71*CritDepth;
    if (Current^.PrevXS^.HydRec.zb+Current^.PrevXS^.HydRec.depth < Current^.HydRec.zb+NormalDepth) then
      HydParm(Current^.HydRec.zb + NormalDepth, OpRec.D50, q, Current^.HydRec)
    else
      Balance(q, OpRec.D50, CritDepth, Current^.PrevXS^.HydRec, Current^.HydRec);
    end
  else
    Balance(q, OpRec.D50, CritDepth, Current^.PrevXS^.HydRec, Current^.HydRec);
  Until Current^.NextXS = Nil;
End;
{-----}
Procedure CalcPitWSEL (Volume : Real; { total volume of water in pit }
  Var PitWSEL : Real);
{ RJS
Description: Calculates pit WSEL for a given volume of water.
}
{-----}
Procedure CalcPitVolume(PitWSEL : Real;
  var CVolume : Real); { calculated pit volume }

begin
  CVolume := 0; { initialize }
  Root := DSPitLimit; { start @ d/s pit limit }

  { search for ground points which bracket the pit WSEL }
  While (PitWSEL < Root^.HydRec.zb) and (PitWSEL < Root^.NextXS^.HydRec.zb)
  do Root := Root^.NextXS;

  { calculate the first vertical wedge of storage }
  CVolume := 0.5*(PitWSEL - Root^.NextXS^.HydRec.zb)*
    (Root^.NextXS^.HydRec.length *
    (PitWSEL - Root^.NextXS^.HydRec.zb)/

```

```

        (Root^.HydRec.zb - Root^.NextXS^.HydRec.zb));
Root := Root^.NextXS; { move u/s one ground point }

{ calculate intermediate storage wedges }
While (PitWSEL > Root^.NextXS^.HydRec.zb) do
begin
    CVolume := CVolume + (PitWSEL -
        0.5 * (Root^.HydRec.zb + Root^.NextXS^.HydRec.zb))*
        Root^.NextXS^.HydRec.length;
    Root := Root^.NextXS
end;

{ calculate last vertical wedge of storage }
CVolume := CVolume + 0.5*(PitWSEL - Root^.HydRec.zb) *
    (PitWSEL - Root^.HydRec.zb)/
    (Root^.NextXS^.HydRec.zb - Root^.HydRec.zb) *
    Root^.NextXS^.HydRec.length;

end;
{-----}

Var
    MinPitBedElev, { lowest ground elevation u/s of dsPitElev }
    CVolume : real; { calculated volume in pit for a given Pit WSEL }

Begin
    { find MinPitBedElev }
    MinPitBedElev := DSPitLimit^.HydRec.zb; { initially set to DSPitLimit invert }
    Root := DSPitLimit^.NextXS;
    Repeat
        If Root^.HydRec.zb < MinPitBedElev then MinPitBedElev := Root^.HydRec.zb;
        Root := Root^.NextXS;
    Until Root = nil;

    PitWSEL := DSPitLimit^.HydRec.zb - 0.001; { first approximation - assume pit is full }
    CalcPitVolume(PitWSEL,CVolume);
    If CVolume > Volume then { Pit WSEL is NOT full }
    begin
        PitFull := false;
        repeat { until Pit WSEL is found to within 1 foot }
            PitWSEL := PitWSEL - 1;
            If PitWSEL < MinPitBedElev then
            begin
                PitWSEL := MinPitBedElev;
                CVolume := 0;
            end
            else
                CalcPitVolume(PitWSEL,CVolume);
        until CVolume < Volume;
        repeat { until Pit WSEL is found to within 0.1 foot }
            PitWSEL := PitWSEL + 0.1;
            CalcPitVolume(PitWSEL,CVolume);
        until CVolume > Volume;
    end
    else

```

```

PitFull := true
End;

```

```

{-----}
Procedure Hydraulics ( FirstXS : XSecPtr; { pointer to d/s most x-sec }
                    delT,      { time step (minutes) }
                    q          : Real); { unit discharge }
{ RJS
Description: Main procedure for establishing hydraulic parameters
            throughout the reach.
}
Var
Sav : real; { Average bed slope }
Current : XSecPtr;

Begin
If FirstXS^.HydRec.flow then
  BackWater(q, FirstXS) { calc. water surface profile }
else
begin { no flow d/s of pit }
  FillVolume := FillVolume + (q * delT * 60.0); {volume in cu. ft.}
  CalcPitWSEL ( FillVolume, PitWSEL ); {returns new PitWSEL}
  If PitFull then
  begin { flow now exists d/s of pit }
    Current := FirstXS;
    repeat { set flow flags to true}
      Current^.HydRec.flow := true;
      Current := Current^.NextXS;
    until (Current^.HydRec.flow = true) or (Current = nil);
    BackWater(q, FirstXS); { calc water surface profile }
  end
else { pit is still not filled }
begin { find next u/s point where flow = true }
  Current := FirstXS;
  repeat
    Current := Current^.NextXS;
  until Current^.HydRec.SecNum = OpRec.DSPitSecNum;
  While Current^.HydRec.zb > PitWSEL do Current := Current^.NextXS;
  repeat
    Current := Current^.NextXS;
  until Current^.HydRec.zb > PitWSEL; { find first point of flow u/s of pit }
  repeat
    BedSlope(Current^.PrevXS^.HydRec.zb, Current^.HydRec.zb, Current^.HydRec.length, Current^.HydRec.Ab, Sav);
    Depths(Sav, OpRec.D50, q, NormalDepth, CritDepth);
    if NormalDepth < 0.71*CritDepth then NormalDepth := 0.71*CritDepth;
    HydParm(Current^.HydRec.zb + NormalDepth, OpRec.D50, q, Current^.HydRec);
    Current := Current^.NextXS
  until (NormalDepth >= CritDepth) or (Current^.NextXS = nil);
  if Current^.NextXS <> nil then
    BackWater(q, Current); { subcritical flow, do backwater}
  end
end
End;
{-----}

```

```

{
    Include file for program CRISM12.PAS

    File name   : SED12.LIB
    Description  : Sediment routing routines for
                  sand-bed conditions. No armoring
                  routines are included.
    Programmer  : George K. Cotton, P.E.
                  Senior Engineer
                  Simons, Li & Associates Inc.
    Last revised : February 8, 1988
}

Procedure Transp( OpRec   : OpType;
                 var XSecRec : XSecType);
{
    Description : Determines the total bedload transport capacity by sediment
                  size fractions. The Zeller-Fullerton regression equation is
                  used. Unit for sediment transport is lbs/sec/ft.
    Programmer  : George K. Cotton, P.E.
}
begin
    with XSecRec.HydRec, OpRec do
        Gt := 1.058*power(nc, 1.77)*
            power(vel, 4.32)*
            power(depth, -0.30)*
            power(D50*304.8, -0.61)*
            power(Grd, 0.45)
end;
{-----}
Procedure SedCon( OpRec : OpType;
                 var XSecRec : XSecType);
{
    Description : Determines the bed elevation after scour or deposition at a
                  section. An explicit finite difference procedure is used.
    Programmer  : George K. Cotton, P.E.
}
const
    Cv = 0.01; { Conversion factor: lbs/sec to bulked cfs with porosity = 0.4 }

var
    TWat,      { topwidth at current section }
    RLup,      { u/s reach length }
    RLdn,      { d/s reach length }
    Gtup,      { transport into section }
    Gtat,      { transport at current section }
    Gtdn : real; { transport out of section }

begin
    Gtup := XSecRec.NextXS^.HydRec.Gt;
    Gtat := XSecRec.HydRec.Gt;
    Gtdn := XSecRec.PrevXS^.HydRec.Gt;
    RLup := XSecRec.NextXS^.HydRec.length;

```

```
RLdn := XSecRec.HydRec.length;  
TWat := XSecRec.HydRec.width;  
  
with OpRec do  
XSecRec.HydRec.dz := ((1-theta)*(Gtup - Gtat) + theta*(Gtat - Gtdn)) *  
                    (timestep*60.0)/(0.5*(RLup + RLdn)) * (Cv/TWat);  
XSecRec.HydRec.zb := XSecRec.HydRec.zb + XSecRec.HydRec.dz  
  
end;  
{-----}
```

```

(
    Procedures for program CRISM11
    Include file name : InOut11.lib
    Description       : Input/Output routines.
    Programmer        : George K. Cotton, P.E.
                     : Simons, Li & Associates, Inc.
    Last Revised      : February 2, 1988
)
{-----}
Procedure BatchOpen(Var IORec : IOType);
Begin
    ClrScr;
    Frame(1,21,80,24); Frame2(1,1,80,24);
    GoToXY(33,3); Write(' -- CRISM --');
    Frame2(32,2,46,4);

    Assign(IORec.FV1,'CRM.DAT');
    {$I-} Reset(IORec.FV1); {$I+}
    OK := (IOresult = 0);
    If not OK then
    begin
        GotoXY(3,22); Write('Input file CRM.DAT not found - program halted. ');
        Halt
    end;

    Assign(IORec.FV2,'CRM.OUT');
    Rewrite(IORec.FV2)

End;
{-----}
Procedure ReadData(var OpRec      : OpType;
                  var zbi        : ReachArray;
                  var q          : TimeArray;
                  var DSXS,USXS,
                      FirstTS,
                      DSPitLimit : XSecPtr);
(
    Description : Reads the user supplied hydraulic and bed material data sets.
                 and builds the first linked list for a reach.
)
var
    j, m, n,
    nchg, nint,
    NumQChg,
    NumQInt : integer;
    qint    : real;
    XSecData : XSecType;
    Holder,
    Root    : XSecPtr;

    Procedure Initialize(var XSecData : XSecType);
    begin
        With XSecData.HydRec do

```

```

begin
  width := 1.0; flow := false; depth := 0;
  segl := 0; Ab := 0; vel := 0;
  tau := 0; nc := 0;
  dz := 0; Gt := 0
end;
XSecData.TSNum := 1
end;
{-----}

begin
with IORec, XSecData do
begin
with OpRec do
begin
  readln(FV1,Title1);
  readln(FV1,Title2);
  RunTime := Time;
  RunDate := Date;
  readln(FV1,nsec,NumQChg,timestep,sinit,theta,tintprt,PlotInd,DSPitSecNum);
  readln(FV1,D50,Grd);
  D50 := D50/304.8;
end;

{ Read data into unit discharge array }
n := 1;
for nchg := 1 to NumQChg do
begin
  ReadLn(FV1,NumQInt,qInt);
  for nint := 1 to NumQInt do
begin
  q[n] := qInt;
  n := n + 1
end
end;
OpRec.ntime := n - 1;

{ Build the cross-section linked list for the first time step }
Root := nil;
Holder := Root;
for j := 1 to OpRec.nsec do
begin
  Initialize(XSecData);
  ReadLn(FV1, HydRec.SecNum,HydRec.length,HydRec.zb);
  zb[j] := HydRec.zb;
  new(Root); { Create empty dynamic record }
  Root^.PrevXS := XSecData; { Copy data into dynamic record }
  Root^.NextXS := Holder; { Assign pointers to dynamic record }
  Root^.NextXS := nil;
  Holder^.NextXS := Root;
  Root^.NextTS := nil;
  Holder := Root;
  if j = 1 then

```



```

        Write(FV2,' ', dz:8:5);
    end;
    WriteLn(FV2)
end
end;
{-----}

Procedure TSHeader(ts : integer; ( time step number      )
                  qt : real); ( discharge for time period )
begin
    GoToXY(4,23); Write('Writing time step # ',ts:3);
    with IORec do
    begin
        WriteLn(FV2);
        WriteLn(FV2);
        WriteLn(FV2, 'TIME STEP # ',ts,' q = ',qt:8:2,' cfs/ft');
        WriteLn(FV2);
        WriteLn(FV2,' Sec   Reach   Bed   WS   Bed   Energy   Vel   nc   Tau   Gt   dz');
        WriteLn(FV2,' #   Length Elev   Elev Angle   Slope');
        WriteLn(FV2,'      (ft)   (ft)   (ft) (deg) (ft/ft) (ft/s)   (lb/sf) (lb/s) (ft)');
        WriteLn(FV2,'-----');
    end
end;
{-----}

Begin
with IORec do
begin
    WriteLn(FV2,'          Channel Response due to In-Stream Mining!');
    WriteLn(FV2,'          Sand-bed Conditions / No Armoring  ');
    WriteLn(FV2,'          ----- Program CRISM (Ver 1.2) -----');
    WriteLn(FV2);
    WriteLn(FV2,'          Simons, Li & Associates Inc. ');
    WriteLn(FV2,'          February 1988');
    WriteLn(FV2);WriteLn(FV2);
    With OpRec do
    begin
        WriteLn(FV2,'Run Date : ',RunDate);
        WriteLn(FV2,'Run Time : ',RunTime);
        WriteLn(FV2);
        WriteLn(FV2,Title1);
        WriteLn(FV2,Title2);
        WriteLn(FV2);
        WriteLn(FV2,' # of x-sections   = ',nsec:4);
        WriteLn(FV2,' # of time steps   = ',ntime:4);
        WriteLn(FV2,' Downstream bed slope = ',sinit:6:4);
        WriteLn(FV2,' FD Weighting Factor = ',theta:6:3);
        WriteLn(FV2,' Time step interval = ',timestep:6:1,' minutes')
    end;
    WriteLn(FV2,'-----');

    n := 1;
    If Cached then

```

```

begin
  Reset(IORec.FVcach);
  While Not EOF(IORec.FVCach) do
    begin
      TSHdr(n*OpRec.tintprt,q[n*OpRec.tintprt]);
      for i := 1 to OpRec.nsec do
        begin
          read(IORec.FVcach,XSecData);
          DumpXSecData(XSecData)
        end;
        n := n + 1;
      end
    end;

  Current := FirstTS;
  Holder := Current;
  repeat
    Holder := Current;
    TSHdr(n*OpRec.tintprt,q[n*OpRec.tintprt]);
    for i := 1 to OpRec.nsec do
      begin
        DumpXSecData(Current^);
        Current := Current^.NextXS
      end;
      Current := Holder^.NextTS;
      n := n + 1
    until Current^.NextTS = nil;

  end
End;
(-----)

Procedure PlotterOutput;

Var
  j, m, n : integer;
  SumLength : real;
  PlotFile : text;
  Current, Holder : XSecPtr;

Procedure DumpRecord(var SumLength : real; XSecData : XSecType);
begin
  SumLength := SumLength + XSecData.Hydrec.Length;
  Write(PlotFile,SumLength:10:1);
  Write(PlotFile,XSecData.HydRec.zb:10:2);
  Write(Plotfile,XSecData.Hydrec.zb+XSecData.Hydrec.Depth:10:2);
  Write(PlotFile,XSecData.HydRec.zb-zbi[j]:10:2);
  WriteLn(PlotFile)
end;

Begin
  Assign(PlotFile,'CRM.PLT');
  Rewrite(PlotFile);

```

```
n := 1;
If Cached then
begin
  Reset(IORec.FVcach);
  While Not EOF(IORec.FVcach) do
  begin
    SumLength := 0;
    GoToXY(4,23); Write('Writing time step # ',n*OpRec.tintprt:3);
    for j := 1 to OpRec.nsec do
    begin
      read(IORec.FVcach,XSecData);
      DumpRecord(SumLength,XSecData)
    end;
    n := n + 1
  end
end;

Current := FirstTS;
repeat
  Holder := Current;
  SumLength := 0;
  GoToXY(4,23); Write('Writing time step # ',n*OpRec.tintprt:3);
  for j := 1 to OpRec.nsec do
  begin
    DumpRecord(SumLength,Current^);
    Current := Current^.NextXS
  end;
  Current := Holder^.NextTS;
  n := n + 1;
until Current^.NextTS = nil;

Close(PlotFile)
end;
{-----}
```

APPENDIX F - COMPUTER PROGRAM HEC-2SR FOR SINGLE-EVENT RIVER RESPONSE SIMULATION, VERSION 2.1

F.1 Introduction

The computer program HEC-2SR was developed for the purpose of simulating the longitudinal and lateral response of a river reach to a single flood event. The model when combined with the short-term erosion procedure for sand and gravel excavations provides a general simulation of river reaches that have in-stream sand and gravel mining. The model is a modified version of a series of programs that have been under development since 1978, under the direction of Dr. Ruh-Ming Li. Model HEC-2SR has been modified for a number of specific application. This version of the model consolidates a number of these specific developments into a more general application. The current version number of the model is 2.0.

The first version of Model HEC-2SR was developed in 1978 by Dr. Ruh-Ming Li for evaluation of river response to the proposed flood control alternatives along Boulder Creek, Colorado (Simons, Li & Associates, 1980a). The HEC-2 model was adopted for hydraulic computation due to the project requirements. It was found to be a significant advantage to adopt Model HEC-2 in HEC-2SR, since the computed water-surface profiles are comparable to the FIA flood mapping method. Using the HEC-2 output, hydraulic variables were determined and sediment transport capacities were computed for each sediment size. Sediment routing by size fractions was utilized to estimate river degradation and aggradation through each reach. Simulation of sediment coarsening and river bed armoring was considered. This initial version of Model HEC-2SR was developed to achieve the study purpose while adhering to the project budget constraint.

In 1980, modifications were made to the program to refine the calculation of the armoring process for analysis of the Salt River in Phoenix, Arizona, to evaluate various channel alternatives and scour protection needs for bridge crossings (Simons, Li & Associates, Inc., 1980b, 1980c). The model predicted that the Arizona Department of Transportation interim channel improvement condition for the Maricopa Highway Bridge (I-10) under 100-year flood conditions would have a total scour potential of 19.3 feet. In February 1980, the Salt River experienced a flood with a return period of nearly 100 years. The post-flood channel geometry confirmed the model's prediction. The measured total scour depth during the flood was estimated to be 18.6 feet, very close to the predicted value. The model also predicted the river bed backfill during the recession limb.

Later in 1980, HEC-2SR was intensively applied in Pima County, Arizona, on the Canada del Oro, Rillito River, Santa Cruz River, Pentano Wash, and Tanque Verde River. One of the modifications made at this time was the computation of wash load using the Universal Soil Loss Equation (Smith and Wischmeier,

1957; Wischmeier, 1973; and Williams and Berndt, 1972), to correct the computed bed material discharge for wash load concentration using Colby's empirical relationships (Colby, 1964). Also, several HEC-2 input data options, such as to repeat cross-section data and to modify cross-section data by channelization, were incorporated into model HEC-2SR.

In 1981, as part of the study of the river systems in parts of Pima County, a special version of the model was developed to compute a mix of subcritical and supercritical flows. This special version of HEC-2SR (Simons, Li & Associates, Inc., 1981b) calculates the water-surface profile resulting from both subcritical and supercritical flow. A subroutine will determine the actual flow regime based on the calculated information. Since then, there have been numerous applications of the different versions of HEC-2SR (also named QUASED) to streams and rivers in Arizona, Colorado, and California (Simons, Li & Associates, Inc., 1981a). In 1983, a large flood occurred in Tucson, Arizona. The general river responses compared closely with what was predicted by the model. In addition, the soil cement bank protection project along the Rio Nuevo, which was designed based on the application of HEC-2SR, performed excellently, and fully verified the applicability of the methodology.

In 1983, HEC-2SR was applied to evaluate the river response to various levels of hydropower operation for the Cowlitz Falls hydroelectric project, Washington. This application required modification of the model to include settling of various sizes of sediment in the reservoir. There have also been many other changes, such as taking into account a weir and/or geologic control in the river.

In 1983, HEC-2SR was applied to develop sand and gravel mining regulations and a river management plan for Ventura County, California. The model was modified to define effective erosion areas (movable bed) in a braided river, and to account for lateral erosion of the low-flow channel due to limitation of channel downcutting.

F.2 Program Operation

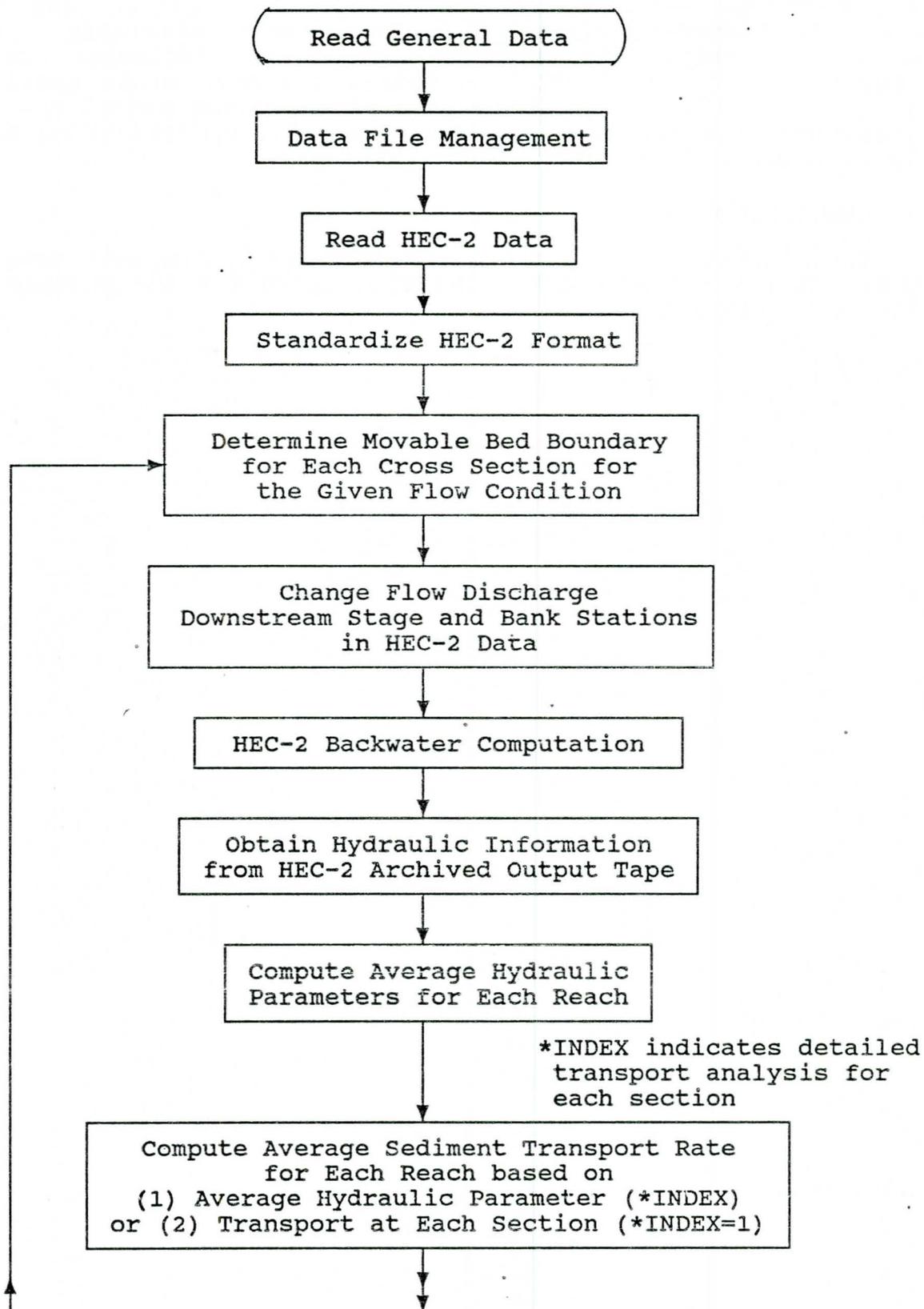
Model HEC-2SR contains the HEC-2 program and nine other computer programs, all coded in Fortran IV. These ten programs perform the modular functions for hydraulic, sediment transport, and degradation or aggradation computations as illustrated in Figure F.1. A command file was prepared to execute these programs and to link the input and output paths data from each program. The programs (other than HEC-2), the command file, and the input and output descriptions follow at the end of this appendix.

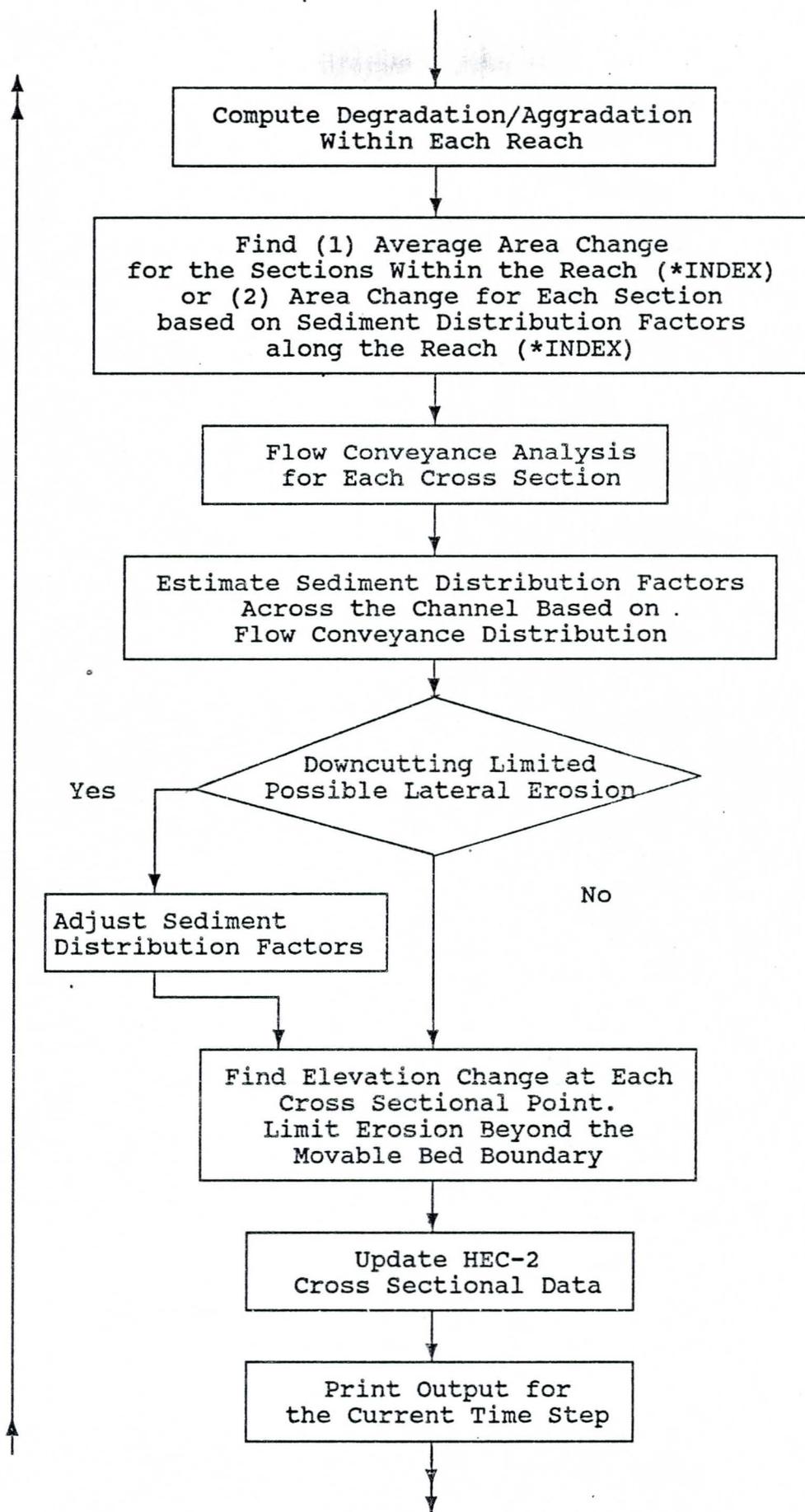
The input data include the HEC-2 data and the general data file, which contains reach information, flow hydrographs,

sediment inflow hydrographs, bed material size distributions, stage-discharge relationship for downstream control, and the movable bed boundary versus flow discharge relationship. For each routing step, Model HEC-2SR provides the following output information: (1) hydraulic parameters for each cross section; (2) sediment inflow and outflow data and average degradation or aggradation area for each subreach; and, (3) updated HEC-2 data file (including the updated channel geometry).

F.3 Program Flow Chart

This section gives a schematic overview of the main program algorithms via a flow chart. The flow chart for the program is given in Figure F.1.





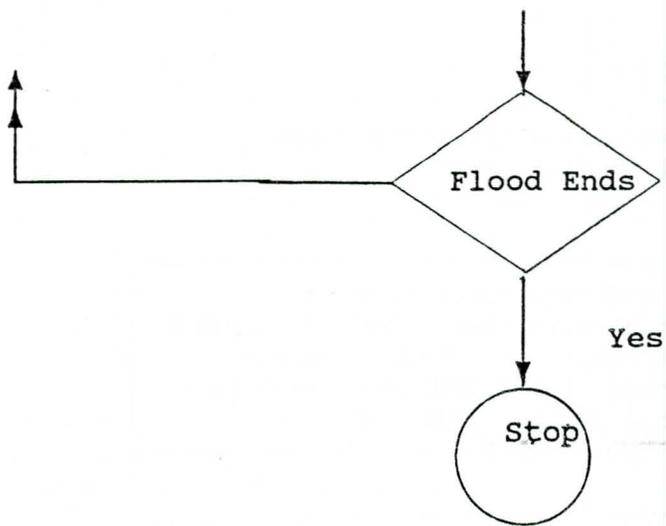


Figure F.1. Flow Chart

REFERENCES TO APPENDIX F

- Colby, B.R., 1964, "Practical Computations of Bed-Material Discharge," Journal of the Hydraulics Division, American Society of Civil Engineers, Vol. 90, No. HY2.
- Simons, Li & Associates, Inc., 1980a, "Erosion, Sedimentation and Debris Analysis of Boulder Creek (24th Street Bridge to 30th Street Bridge), Boulder, Colorado," prepared for URS Company, Denver, Colorado.
- Simons, Li & Associates, Inc., 1980b, "Hydraulic and Scour Analysis of the Salt River Bridge at Phoenix-Casa Grande Highway for Long-Term Protection Against Scour," prepared for Dames and Moore, Phoenix, Arizona.
- Simons, Li & Associates, Inc., 1980c, "Scour and Sedimentation Analysis of the Proposed Channelization of the Salt River for Protecting the Sky Harbor International Airport in Phoenix, Arizona," prepared for Howard Needles Tammen and Bergendoff, Kansas City, Missouri.
- Simons, Li & Associates, Inc., 1981a, "QUASED User Manual (Version 3), Quasi-Dynamic Sediment Routing Model."
- Simons, Li & Associates, Inc., 1981b, "Sediment and Debris Transport Analysis at Eight Bridge Locations, Tucson, Arizona," prepared for Pima County Department of Transportation and Flood Control District, Arizona.
- Smith, D.D., and W.H. Wischmeier, 1957, "Factors Affecting Sheet and Rill Erosion," Transactions, American Geophysical Union, Vol. 38, pp. 889-896.
- Williams, J.R. and H.D. Berndt, 1972, "Sediment Yield Computed with Universal Equation," Journal of the Hydraulics Division, American Society of Civil Engineers, Vol. 98, No. HY12, Proceedings Paper 9426, December, pp. 2087-2097.
- Wischiemer, W.H., 1973, "Upslope Erosion Analysis," in Environmental Impact on Rivers, H.W. Shen (ed.), Colorado State University, Fort Collins, Colorado.

F.4. Input Requirements

Two data files are required as input to this model. The first file, HEC2DAT, contains the standard input for HEC-2. The second file, GENDAT, contains general river information.

F.4.1 HEC-2 File

This file includes the standard information needed to run HEC-2 with the following specifications:

1. The initial and subsequent starting downstream water surface elevations are computed and updated automatically for each time step. The stage discharge relationship should be included in the file GENDAT.
2. A QT card should be used to define discharge values; the initial and subsequent discharges are updated automatically for each time step by using discharge data included in the file GENDAT.
3. Either NH or NC cards can be used, but no NV cards.

F.4.2 General Data File (GENDAT)

This file contains information on the reach division, downstream stage-discharge relationship, storm hydrograph, particle size distribution, sediment inflow hydrographs, and the data for determining the movable bed boundary. The input data are described as follows:

	<u>format</u>
Card A (one card)	
Number of time steps (max of 30), NQ	I8
Number of study reaches (max of 50), NREACH	I8
Number of particle sizes (max of 10), NSIZ	I8
Soil Porosity, PORO	F8.2
Threshold stable bank height (ft), ZC	F8.2
Card B (repeat for each study reach)	
Number of Cross sections in each reach, NSEC(I)	I8
Distance to beginning of reach section (ft), RBEG(I)	F8.0
Distance to ending reach section (ft), REND(I)	F8.0
Index of sediment distribution, INDEX	I8
0 - uniform distribution	
1 - distribution according to the transport capacity	
2 - armoring reach, no degradation allowed	
Card C (one card)	
Constant A of stage-discharge relationship, AST	E12.5
Constant B of stage-discharge relationship, BST	E12.5
Constant C of stage-discharge relationship, CST	E12.5

Card D (one card per ten time steps)		
Time increment for each time step (hr), TDT(I)		10F8.1
Card E (one card per ten discharges)		
Hydrograph discharge for each time step (cfs), TQ(I)		10F8.0
Card F (repeat for each study reach)		
Thickness of active soil layer (ft), SUMB(I)		F8.1
Percent Size fraction for each particle size, PB1(I,J), j = NSIZ		10F8.4
Card G (one card per ten sediment inflow, repeat for each particle size)		
Sediment inflow from upstream reach for each time step (cfs), QS1(I,J), I = 1,NQ		10F8.2
Card H (one card)		
Discharge table for defining the movable bed boundary, QQ(I), I = 1,5		5F8.0
Card I (one card for each cross section, including following data in one card)		
Cross section identification number		F8.1
Left bank station of movable bed boundary for QQ(1)		F8.1
Right bank station of movable bed boundary for QQ(1)		F8.1
Width of movable bed for QQ(1)		F8.1
Repeat left station, right station and width of movable bed for other discharge levels		

Cards A, B, C, D, E, H, and I are used to define the river system and the hydrographs. The primary task is to identify the river study reaches. These study reaches are portions of the river system where sediment transport characteristics are similar. The cross sections within a reach should be geometrically similar in width and depth. Sediment particle size distributions should be similar within a reach. Study reaches can contain as few as two cross sections, and there is no upper limit on the number of cross sections per study reach. Location of the beginning and ending sections of the river must be given so that the study reach length can be determined.

The discharge hydrograph is divided by time increments and can vary, giving the user flexibility in describing the hydrograph.

F.5 Output Description

The model output contains the following information for each time step:

1. The first portion of the output data include the flow discharge, time increment and sediment inflow data.

2. The second portion shows the average hydraulic parameters, sediment transport capacity and cross-sectional area change for each reach.
3. The third portion indicates the water surface elevation at the beginning of the time step for each cross section, the minimum bed elevation at the beginning and ending of the time step, and the left and right bank stations of the movable bed boundary under the given flow condition.

In addition, Model HEC-2SR provides a HEC-2 file (HECX5) containing updated channel geometry, hydrologic and hydraulic data at the end of each time step.

F.6 Program Execution

The modular format of the sediment routing model is illustrated in Table F.1. This table shows all the model components (one program for each component), the execution sequence, and the input/output file for each component. Descriptions of the data files are given as follows:

STEPS: Time step counter file

GENDAT: General river reach information

QDAT: Flow discharges, particle size distribution and sediment inflow

RCHDAT: Information on reaches, includes number of cross sections, beginning and ending distance and cross-sectional area change

MOVBDV: Movable bed boundary information

HEC2DAT: HEC-2 input data

HECSTD: Standardized HEC-2 input data

HEC96: Output file TAPE96 from HEC-2 computation

HYDINF: Hydraulic parameters for each cross section

WSINF: Water surface elevation information

HYDAT: Average hydraulic parameters for each reach

HYIND: Hydraulic parameters for each cross section

SEDDAT: Average sediment transport information for each reach

AREAFAC: Area change correction factor for each cross section

WGTFAC: Conveyance weighting factors for each cross section

- ELIMIN: Minimum river bed elevation at the end of each time step for each cross section
- SBOUT: Summary output containing hydraulics and sediment transport data for each time step
- HECXs: Accumulated HEC-2 input file for each time step and the final cross-sectional geometry

If the modeling execution is performed successfully, only the major output file HECXS and SBOUT will be saved; however, if the model aborts all the intermediate output files will be available for debugging purposes.

The program series is executed via the MS-DOS operating system. A batch file controls the model execution by linking the twelve program modules following the execution sequence indicated in Table F.1. The file STEPS keeps track of the actual number of sediment routing time steps to be executed.

In addition to the HEC-2 program, there are nine programs involved in the sediment routing model, with listings on the following pages.

<u>INPUT FILE</u>	<u>PROGRAM</u>	<u>OUTPUT FILE</u>
USER PROMPTED	INITTMP	STEPS, DUMMY
GENDAT	FLMCAVC	QDAT, RCHDAT, MOVBDY, SBOUT
HEC2DAT	STDCAVC	HECSTD
HECSTD, QDAT RCHDAT, MOVBDY	HCHCAVC	HECSTD
HECSTD	HEC2	HEC96
HEC96	INFCAVC	HYDINF, WSINF
RCHDAT, HYDINF	RCHCAVC	HYDAT, HYIND
RCHDAT, QDAT HYDAT, HYIND	SROCAVC	SEDDAT, RCHDAT, QDAT, AREAFAC
HECSTD, WSINF	WEICAVC	WGTFAC
HECSTD, RCHDAT QDAT, AREAFAC, WGTFAC	CHDCAVC	HECSID, QDAT, ELMIN
RCHDAT, QDAT, HYDAT, SEDDAT, HYDINF, ELMIN, WSINF	OUTCAVC	SBOUT
STEPS	LOOPTMP	DUMMY

Table F.1 Program execution sequence and input/output files
for Model HEC-2SR

```
ECHO OFF
CLS
INITTMP
COPY GENDAT GENDAT.DAT > NUL
FLMCAVC > NUL
COPY HEC2DAT HEC2DAT.DAT > NUL
stdCavc > NUL
copy HECSTD.QUA HECXS.QUA > NUL
:loop1
hchcavc > NUL
DEL HECSTD.QUA
rename hchtmp.qua hecstd.qua
copy hecxs.qua + hecstd.qua > NUL
COPY HECSTD.QUA X1.DAT > NUL
HEC2 X1.DAT X1.OUT; > NUL
DEL X1.*
COPY TAPE96 HEC96.QUA > NUL
DEL TAPE*
infcavc > nul
rchCavc > nul
srocavc > nul
DEL RCHDAT.QUA > NUL
rename rchtmp.qua rchdat.qua
DEL QDAT.QUA > NUL
rename qtemp.qua qdat.qua
weicavc > nul
chlcavc > nul
DEL HECSTD.QUA > NUL
rename hstdtmp.qua hecstd.qua
DEL QDAT.QUA > NUL
rename qdattmp.qua qdat.qua
outcavc > nul
copy sbout.qua + sbtemp.qua > nul
del hec96.qua > NUL
loopTMP
if exist dummy goto loop1
del qdat.qua > nul
del rchdat.qua > nul
del sbtemp.qua > nul
del hecstd.qua > nul
del areafac.qua > nul
del wsinf.qua > nul
del hydinf.qua > nul
del elmin.qua > nul
del hydat.qua > nul
del hyind.qua > nul
del movbdy.qua > nul
del seddat.qua > nul
del wgtfact.qua > nul
echo on
```

Program Inittmp;

{ Program to initialize data files prior to running HEC-2SR

last revision : April 18, 1988 (JRM)

File Name: INITTMP.PAS

}

Type

Str = String[50];

TimeString = string[8]; { 5/27/87 }

Var

TimeStepInterval,

NumSteps : Integer; { number of time steps for the routing }

File1, { STEPS.DAT }

File4 : Text; { DUMMY }

Begin

ClrScr;

WriteLn(' ***** HEC-2SR SEDIMENT ROUTING MODEL *****');

WriteLn(' ***** IBM PC Version, April 1988 *****');

WriteLn(' ***** Simons, Li & Assoc., Inc. *****');

WriteLn;

Write(' Enter number of time steps for this run - ');

ReadLn(NumSteps);

Write(' Enter time step interval for output - ');

ReadLn(TimeStepInterval);

Assign(File1, 'STEPS.DAT');

ReWrite(File1);

WriteLn(File1, NumSteps);

WriteLn(File1, NumSteps);

WriteLn(File1, TimeStepInterval);

Close(File1);

Assign(File4, 'DUMMY');

ReWrite(File4); Close(File4);

WriteLn;

WriteLn(NumSteps:4, ' Time steps left to process');

End.

```

PROGRAM FLMCAVC
C
DIMENSION TDT(60),TQ(60)
DIMENSION NSEC(50),RBEG(50),REND(50)
DIMENSION QS1(60,10),QS2(60,10),QQ(5),RLW(5,150),RRW(5,150)
DIMENSION PB(50,10),INDEX(50),SUMB(50)
C
OPEN(5,FILE='GENDAT',STATUS='OLD')
OPEN(4,FILE='QDAT.QUA',STATUS='NEW')
OPEN(2,FILE='RCHDAT.QUA',STATUS='NEW')
OPEN(10,FILE='MOVBOY.QUA',STATUS='NEW',FORM='UNFORMATTED')
OPEN(30,FILE='SBOUT.QUA',STATUS='NEW')
C
C   READ IN AND WRITE OUT THE DATA WHICH SHOULD BE IN TAPE2.
C
C   !!!!!CHANGE!!!!!! READ IN "ZC"
C
READ(5,505) NQ,NREACH,NSIZ,PORO,ZC
IF(PORO.LT.0.3) PORO=0.3
IST = 0
DO 110 I=1,NREACH
READ(5,520) NSEC(I),RBEG(I),REND(I),INDEX(I)
IST = IST + NSEC(I)
110 CONTINUE
READ(5,532) AST,BST,CST
C
NRUN=1
SI=0.
C
C   !!!!!CHANGE!!!!!! WRITE "ZC"
C
WRITE(2,540) NREACH,PORO,ZC
WRITE(2,620) (NSEC(IR),RBEG(IR),REND(IR),INDEX(IR),IR=1,NREACH)
WRITE(2,532) AST,BST,CST
C
READ(5,530) (TDT(IQ),IQ=1,NQ)
READ(5,530) (TQ(IQ),IQ=1,NQ)
DO 120 IR=1,NREACH
READ(5,545) SUMB(IR),(PB(IR,J),J=1,NSIZ)
DO 121 J = 1,NSIZ
PB(IR,J) = PB(IR,J) / 100.
121 CONTINUE
120 CONTINUE
DO 125 J = 1,NSIZ
READ(5,550) (QS1(IQ,J),IQ=1,NQ)
READ(5,550) (QS2(IQ,J),IQ=1,NQ)
125 CONTINUE
WRITE(4,510) NRUN,NQ,NSIZ
WRITE(4,535) (TQ(IQ),TDT(IQ),IQ=1,NQ)
DO 130 IR = 1,NREACH
WRITE(4,545) SUMB(IR),(PB(IR,J),J=1,NSIZ)
130 CONTINUE
WRITE(4,535) ((QS1(IQ,J),QS2(IQ,J),J=1,NSIZ),IQ=1,NQ)
C

```

```

      READ(5,550) (QQ(K),K=1,5)
      DO 220 IS=1,IST
      READ(5,560) (RLW(K,IS),RRW(K,IS),K=1,5)
220 CONTINUE
      WRITE(10) (QQ(K),K=1,5)
      WRITE(10) IST
      DO 230 IS = 1,IST
      WRITE(10) (RLW(K,IS),K=1,5),(RRW(K,IS),K=1,5)
230 CONTINUE
C
C This segment creates the banner for the HEC-2SR output file.
C
      WRITE(30,*)
      WRITE(30,*)
      WRITE(30,*)' ***** HEC-2SR SEDIMENT ROUTING MODEL *****'
      WRITE(30,*)' ***** IEM PC Version April 1988 *****'
      WRITE(30,*)' ***** Simons, Li & Assoc., Inc. *****'
      WRITE(30,*)
      WRITE(30,*)
      CLOSE (30)
C
C !!!!CHANGE!!!! "F8.0" TO "2F8.0"
C
505 FORMAT(3I8,2F8.0)
510 FORMAT(10I8)
520 FORMAT(I8,2F8.0,I8)
530 FORMAT(10F8.0)
532 FORMAT(6E12.5)
535 FORMAT(8F10.2)
C
C !!!!CHANGE!!!! "F10.2" TO "2F10.2"
C
540 FORMAT(I10,2F10.2)
545 FORMAT(11F8.4)
550 FORMAT(10F8.0)
560 FORMAT(5(8X,2F8.1))
620 FORMAT(I10,2F10.1,I10)
      END

```

```

PROGRAM STDCAVC
C
C THIS PROGRAM CONVERTS THE CHANNEL GEOMETRY INPUT FROM HEC-2 (X1 AND GR
C CARDS) TO A STANDARD FORM. ONLY IN THIS FORM WILL HEC-2 INPUT BE
C COMPATIBLE WITH THE SEDIMENT ROUTING ROUTINE.
C
COMMON/WBLK/ VAL(10),ND,BL,BR,ELDIF
COMMON/WBLKCH/ IA
COMMON/WCIBLK/ IST
C
CHARACTER IA*2,IB*6,IVAL*80
C
OPEN(1,FILE='HEC2DAT',STATUS='OLD')
OPEN(2,FILE='HECSTD.QUA',STATUS='NEW')
C
C SKIP HEADER CARDS
C
10 READ(1,500) IA,IB,IVAL
WRITE(2,500) IA,IB,IVAL
500 FORMAT(A2,A6,A70)
IF(IA.NE.'T3') GOTO 10
C
C SEARCH FOR X1 AND GR CARDS AND WRITE IN STANDARD FORM
C
20 IST=0
READ(1,502,END=789) IA,(VAL(L),L=1,10)
IF(IA.EQ.'X1') THEN
CALL WRTX1
IF (IST.EQ.1) GO TO 20
ELSE IF (IA.EQ.'GR') THEN
CALL WRTGR(0)
ELSE
BACKSPACE 1
READ(1,504) IVAL
WRITE(2,504) IVAL
ENDIF
GO TO 20
C
C !!!!CHANGE!!!! "F6.0" TO "F6.2" AND "9F8.0" TO "9F8.2"
C
502 FORMAT(A2,F6.2,9F8.2)
504 FORMAT(A80)
C
789 STOP
END
SUBROUTINE WRTX1
C
C THIS SUBROUTINE WRITES THE X1 CARD IN STANDARD FORM
C
COMMON/WCIBLK/ IST
COMMON/WBLK/ VAL(10),ND,BL,BR,ELDIF
COMMON/WBLKCH/ IA
C
CHARACTER IVAL*78

```

```

      CHARACTER IA*2,IB*2
C
C INITIALIZE VARIABLES
C
      ZERO=0.
      IV2=INT(VAL(2))
      ELDIF=VAL(9)
      IGR=0
C
C CHECK IF GR CARDS ARE REPEATED
C
      IF(IV2.NE.0) GOTO 30
      IGR=1
C
C IF REPEATED WRITE PREVIOUS X1 INFORMATION
C
      WRITE(2,502) IA,VAL(1),ND,BL,BR,(VAL(L),L=5,7),ZERO,ZERO,ZERO
      GOTO 20
C
C TEST FOR CI (CHANNEL IMPROVEMENT) CARDS
C
      30 READ(1,507) IB
      BACKSPACE 1
      IF(IB.NE.'CI') GOTO 110
      CALL WRTCI
      RETURN
C
C IF NOT REPEATED AND CI CARDS ARENOT USED, WRITE CURRENT X1 INFORMATION
C
      110 WRITE(2,502) IA,VAL(1),IV2,(VAL(L),L=3,7),ZERO,ZERO,ZERO
      ND=IV2
      BL=VAL(3)
      BR=VAL(4)
      20 CONTINUE
C
C CHECK FOR X2 AND X3 CARDS, WRITE IF FOUND
C
      READ(1,500) IA,IVAL
      IF(IA.NE.'X2'.AND.IA.NE.'X3') GOTO 10
      WRITE(2,500) IA,IVAL
      GOTO 20
      10 CONTINUE
C
C RESET TAPE 1, WRITE GR CARDS IF SECTION IS REPEATED, AND RESET IA
C
      BACKSPACE 1
      IF(IGR.EQ.1) CALL WRTGR(1)
      IA='X1'
      RETURN
      500 FORMAT(A2,A78)
C
C !!!!CHANGE!!!! "F6.1" TO "F6.2" AND "5F8.0,3F8.2" TO "8F8.2"
C
      502 FORMAT(A2,F6.2,I8,8F8.2)

```

```

507 FORMAT(A2)
END
SUBROUTINE WRTGR(IGR)
C
C THIS SUBROUTINE WRITES THE GR CARDS IN STANDARD FORM
C
COMMON/WBLK/ VAL(10),ND,BL,BR,ELDIF
COMMON/WBLKC/ IA
C
DIMENSION Z(100),X(100)
CHARACTER IA*2
C
C IF SECTION IS REPEATED (IGR=1) WRITE PREVIOUS GR CARDS FOR THIS SECTION
C
IF(IGR.EQ.1) GOTO 10
BACKSPACE 1
READ(1,504) (Z(L),X(L),L=1,ND)
C
C !!!!CHANGE!!!! "F6.0" TO "F6.2" AND "9F8.0" TO "9F8.2"
C
504 FORMAT(2X,F6.2,9F8.2)
C
C CORRECT FOR ELEVATION CHANGE IF ANY
C
10 IF(ELDIF.LT.0.01) GOTO 30
DO 50 L=1,ND
Z(L)=Z(L)+ELDIF
60 CONTINUE
C
30 WRITE(2,506) (Z(L),X(L),L=1,ND)
C
C !!!!CHANGE!!!! "F8.0,4(F8.2,F8.0)" TO "9F8.2"
C
506 FORMAT('GR',F6.2,9F8.2)
RETURN
END
SUBROUTINE WRTCI
C
C THIS SUBROUTINE WRITES CI (CHANNEL IMPROVEMENT) CARDS INTO A GR FORMAT
C
C
COMMON/WCIBLK/IST
DIMENSION Z(100),X(100),ELV(6),STA(6),Y(10),XR(100),ZR(100)
CHARACTER IC*2
C
C INITIALIZE VARIABLES
C
ZERO=0.
NP=0
J=0
C
C BACKSPACE TAPE1 RECORD TO X1 CARD
C
BACKSPACE 1

```

```

C
C READ X1 CARD, CI CARD, AND 1ST CARD AFTER CI( AN X3 OR GR CARD )
C
  READ(1,300) VAL,ND,STCHL,STCHR,BL,BR,RCH
  READ(1,301) CLSTA,ELCHI,CHN,XLSS,RSS,CHBW,XLBH,RBH
  READ(1,302) IC,(Y(L),L=1,10)
300 FORMAT(2X,F6.0,I8,5F8.0)
301 FORMAT(2X,F6.0,7F8.0)
302 FORMAT(A2,F6.0,9F8.0)
C
C TEST TO SEE IF FIRST CARD AFTER CI IS AN X3 OR GR
C
  IF(IC.NE.'X3') GOTO 15
  IEA=INT(Y(1))
  NP=1
  GOTO 35
15 CONTINUE
  NP=6
  DO 25 K=1,5
  J=J+1
  Z(K)=Y(J)
  J=J+1
  X(K)=Y(J)
25 CONTINUE
35 READ(1,303) (Z(L),X(L),L=NP,ND)
303 FORMAT(2X,F6.0,9F8.0)
C
C TRAPEZOIDAL CHANNEL GENERATION ROUTINE
C
  STA(1)=0.
  STA(6)=0.
  STA(2)=CLSTA-.5*CHBW-XLBH*XLSS
  ELV(2)=ELCHI+XLBH
  STA(3)=CLSTA-.5*CHBW
  ELV(3)=ELCHI
  STA(4)=CLSTA+.5*CHBW
  ELV(4)=ELCHI
  STA(5)=CLSTA+.5*CHBW+RBH*RSS
  ELV(5)=ELCHI+RBH
C
C REDEFINE TOP OF BANK STATIONS
C
  STCHL=STA(2)
  STCHR=STA(5)
  WRITE(20,200) (ELV(I),STA(I),I=1,6)
200 FORMAT(' 200 ',6(F10.2,F10.0))
C
C DETERMINE ELEVATION AND STATION AT (1) AND (6) - THE TY-IN POINTS
C
  NTS=2
  ADJSTA=STCHL-1.
  DLTAP=1.
  DO 20 I=1,6,5
  DO 10 N=1,ND

```

```

      IF(X(N).GT.ADJSTA) GOTO 45
10  CONTINUE
45  STA(I)=STA(NTS)-DLTAP
      IF(Z(N).EQ.Z(N-1)) GOTO 30
      RATE=-((Z(N)-Z(N-1))/(X(N)-X(N-1)))
      ELV(I)=RATE*(X(N)-STA(I))+Z(N)
      GOTO 40
30  ELV(I)=Z(N)
40  ADJSTA=STCHR-1.
      DLTAP=-1.
      NTS=5
20  CONTINUE
      WRITE(20,205) (ELV(I),STA(I),I=1,6)
205  FORMAT(' 205 ',6(F10.2,F10.0))
C
C  POINT COMPARISON ROUTINE - DEFINE NEW GROUND LINE DATA SET
C
      M=0
      MP=0
      IST=0
      DO 50 LN=1,ND
      IF(X(LN).LT.STA(1)) GOTO 60
      IF(X(LN).LE.STA(6)) GOTO 70
      IF(X(LN).GT.STA(6)) GOTO 60
60  M=M+1
      XR(M)=X(LN)
      ZR(M)=Z(LN)
      WRITE(20,210) M,ZR(M),XR(M)
210  FORMAT(' 210 ',I10,F10.2,F10.0)
      GOTO 50
70  M=M+1
      MP=MP+1
      XR(M)=STA(MP)
      ZR(M)=ELV(MP)
      WRITE(20,215) M,MP,ZR(M),XR(M)
215  FORMAT(' 215 ',2I5,F10.2,F10.0)
      GOTO 50
50  CONTINUE
      ND=M
C
C  WRITE REVISED X1 AND GR CARDS ONTO TAPE2
C
      WRITE(2,400) VAL,ND,STCHL,STCHR,BL,BR,RCH,ZERO,ZERO,ZERO
      IF(NP.EQ.1) WRITE(2,401) IC,IEA,(Y(L),L=2,10)
      WRITE(2,402) (ZR(M),XR(M),M=1,ND)
400  FORMAT('X1',F6.1,I8,5F8.0,3F8.2)
401  FORMAT(A2,I6,9F8.2)
402  FORMAT(('GR',F6.2,F8.0,4(F8.2,F8.0)))
      IST=1
      RETURN
      END

```

```

PROGRAM HCHCAVC
C
C THIS PROGRAM DEFINES BANK STATIONS BASED ON THE RESULTS FROM
C MOVABLE BED BOUNDARY ANALYSIS AND SET UP DISCHARGE AND STAGE
C
COMMON/BLKA/ QE,STG,RLM(150),RRM(150),NP,NRUN
COMMON/BLKB/ XL,XR
DIMENSION QQ(5),RLW(5,150),RRW(5,150),IVAL(8)
DIMENSION AQS(2),BQS(2),CQS(2)
CHARACTER IA*80
OPEN(1,FILE='HECSTD.QUA',STATUS='OLD')
OPEN(4,FILE='QDAT.QUA',STATUS='OLD')
OPEN(5,FILE='RCHDAT.QUA',STATUS='OLD')
OPEN(10,FILE='MOVBDY.QUA',STATUS='OLD',FORM='UNFORMATTED')
OPEN(2,FILE='HCHTMP.QUA',STATUS='NEW')
READ(4,410) NRUN,NQ
READ(4,430) (QE,DT,ID=1,NRUN)
410 FORMAT(2I8)
430 FORMAT(8F10.1)
READ(10) (QQ(K),K=1,5)
READ(10) NSEC
DO 230 IS=1,NSEC
READ(10) (RLW(K,IS),K=1,5),(RRW(K,IS),K=1,5)
230 CONTINUE
C
C LINEAR INTERPOLATION USING LN(Q)-RLW AND LN(Q)-RRW RELATIONS
C
IF (QE .LE. QQ(1)) GO TO 240
IF (QE .GE. QQ(5)) GO TO 270
DO 200 KK=2,5
IF (QE .LE. QQ(KK)) GO TO 210
200 CONTINUE
210 K2=KK
K1=KK-1
DO 215 IS=1,NSEC
A = ALOG(QE/QQ(K1)) / ALOG(QQ(K2)/QQ(K1))
B = RLW(K2,IS) - RLW(K1,IS)
C = RRW(K2,IS) - RRW(K1,IS)
C
C !!!!CHANGE!!!! "AINT(RLW(K1,IS))" TO "RLW(K1,IS)" AND SAME FOR RRW
C
RLM(IS) = RLW(K1,IS) + B*A
RRM(IS) = RRW(K1,IS) + C*A
215 CONTINUE
GO TO 350
240 DO 260 IS=1,NSEC
C
C !!!!CHANGE!!!! SAME AS ABOVE FOR RLW AND RRW, EXCEPT USING "1"
C INSTEAD OF "K1"
C
RLM(IS) = RLW(1,IS)
RRM(IS) = RRW(1,IS)
260 CONTINUE
GO TO 350

```

```

270 DO 280 IS=1,NSEC
C
C !!!!CHANGE!!!! SAME AS ABOVE FOR RLW AND RRW, EXCEPT USING "5"
C           INSTEAD OF "K1"
C
      RLM(IS) = RLW(5,IS)
      RRM(IS) = RRW(5,IS)
280 CONTINUE
350 CONTINUE
C
C FIND DOWNSTREAM STAGE USING STAGE-DISCHARGE RATING CURVE
C
      READ(5,300) NREACH
      READ(5,310) (NS,RB,RE,INDEX,IR=1,NREACH)
      READ(5,320) AST,BST,CST
300 FORMAT(I10)
310 FORMAT(I10,2F10.1,I10)
320 FORMAT(5E12.5)
      STG = AST * QE ** BST + CST
C
C READ HEC-2 AND CHANGE DISCHARGE-STAGE AND BANK STATION DATA
C
370 READ(1,512) IA
      WRITE(2,512) IA
      IF ( IA(1:2) .NE. 'T3' ) GO TO 370
C
C !!!!CHANGE!!!! "WRTJ1(IA)" TO "WRTJ1"
C
      CALL WRTJ1
      JS = 1
      JQ = 1
375 READ(1,512,END=789) IA
      JP = 0
      IF ( IA(1:2) .EQ. 'QT' ) CALL WRTQT(JP,JQ)
C
C !!!!CHANGE!!!! "CALLWRTX1(JP,JS,IA)" TO "THEN"
C
      IF ( IA(1:2) .EQ. 'X1' ) THEN
C
C !!!!CHANGE!!!! ADD THE NEXT 5 LINES
C
      BACKSPACE(1)
      CALL WRTX1(JP,JS)
      ELSE
      CONTINUE
      ENDIF
C
C !!!!CHANGE!!!! "CALL WRTGR(JP,JS,IA)" TO "THEN"
C
      IF ( IA(1:2) .EQ. 'GR' ) THEN
C
C !!!!CHANGE!!!! ADD THE NEXT 5 LINES
C
      BACKSPACE(1)

```

```

CALL WRTGR(JP,JS)
ELSE
CONTINUE
ENDIF
IF ( JP .EQ. 1 ) GO TO 375
WRITE (2,512) IA
GO TO 375
390 CONTINUE
512 FORMAT(A80)
789 STOP
END

```

C
CC

C
C !!!!CHANGE!!!! "WRTJ1(IA)" TO "WRTJ1"

C
SUBROUTINE WRTJ1
C
CC

```

C  

COMMON/BLKA/ QE,STG,RLM(150),RRM(150),NP,NRUN
CHARACTER IA*80
READ(1,500) IA
IF ( IA(1:2) .NE. 'J1' ) STOP
500 FORMAT(A80)
IV1 = 0
IV2 = 2
IV3 = 0
IV4 = 0
V5 = 0.
V6 = 0.
V7 = 0.
V8 = 0.
V9 = STG
V10 = 0.
WRITE(2,510) IV1,IV2,IV3,IV4,V5,V6,V7,V8,V9,V10
510 FORMAT('J1',I6,3I8,6F8.1)
RETURN
END

```

C
CC

C
C !!!!CHANGE!!!! "WRTX1(JP,JS,IA)" TO "WRTX1(JP,JS)"

C
SUBROUTINE WRTX1(JP,JS)
C
CC

```

C  

COMMON/BLKA/ QE,STG,RLM(150),RRM(150),NP,NRUN
COMMON/BLKB/ XL,XR
DIMENSION VAL(10)
CHARACTER IA*80
CHARACTER IVAL*8
JP = 1

```

```

C
C !!!!CHANGE!!!! "READ(IA,500)" TO "READ(1,500)"
C
  READ(1,500) IVAL,NP,(VAL(L),L=3,10)
  XL = VAL(3)
  XR = VAL(4)
  VAL(3) = RLM(JS)
  VAL(4) = RRM(JS)
  IF ( NRUN .GT. 1 ) THEN
    NP2 = NP
  ELSE
    NP2 = NP + 2
  ENDIF
  WRITE (2,504) IVAL,NP2,(VAL(L),L=3,10)
C
C !!!!CHANGE!!!! "9F8.0" TO "8F8.2"
C
  500 FORMAT(A8,I8,8F8.2)
C
C !!!!CHANGE!!!! "5F8.0,3F8.2" TO "8F8.2"
C
  504 FORMAT(A8,I8,8F8.2)
  RETURN
  END
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C !!!!CHANGE!!!! "WRTGR(JP,JS,IA)" TO "WRTGR(JP,JS)"
C
  SUBROUTINE WRTGR(JP,JS)
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
  COMMON/BLKA/ QE,STG,RLM(150),RRM(150),NP,NRUN
  COMMON/BLKB/ XL,XR
  DIMENSION ZT(100),XT(100),Z(100),X(100),ZF(100),XF(100),XB(2)
  CHARACTER IA*80
  JP = 1
  XB(1) = RLM(JS)
  XB(2) = RRM(JS)
  IF ( NP .LE. 5 ) THEN
    READ(1,500) (ZT(L),XT(L),L=1,NP)
  ELSE
C
C !!!!CHANGE!!!! "READ(IA,500)" TO "READ(1,500)"
C
    READ(1,500) (ZT(L),XT(L),L=1,5)
    READ(1,500) (ZT(L),XT(L),L=6,NP)
  ENDIF
C
C !!!!CHANGE!!!! "F6.0" TO "F6.2" AND "9F8.0" TO "9F8.2"
C
  500 FORMAT(2X,F6.2,9F8.2)
  XT(NP+1) = 0.

```

```

IF ( NRUN .GT. 1 ) THEN
  K = 0
  IDL = 0
  DO 100 I = 1, NP
    IF ( XT(I) .NE. XL ) GO TO 95
    IDL = IDL + 1
    IF ( IDL .GT. 1 ) GO TO 95
    GO TO 100
95  IF ( XT(I).EQ.XR .AND. XT(I+1).NE.XR ) GO TO 100
    K = K + 1
    X(K) = XT(I)
    Z(K) = ZT(I)
100 CONTINUE
    NP = K
  ELSE
    DO 105 I = 1, NP
      X(I) = XT(I)
      Z(I) = ZT(I)
105 CONTINUE
  ENDIF
  IK = 1
  M = 0
  IF ( X(1) .LT. XB(1) ) GO TO 111
  XF(1) = XB(1)
  IF ( XF(1) .EQ. X(1) ) XF(1) = XB(1) - 1.
  ZF(1) = Z(1)
  IK = 2
  M = 1
111 DO 116 L = 1, NP
  IF ( IK .GT. 2 ) GO TO 114
  IF ( X(L) .LT. XB(IK) ) GO TO 114
113 M = M + 1
  XF(M) = XB(IK)
  IF ( XF(M) .EQ. X(L) ) THEN
    XF(M) = X(L) - 1.
    ZF(M) = Z(L)
    IK = IK + 1
  ELSE
    ZF(M) = Z(L) + (X(L)-XF(M))/(X(L)-X(L-1))*(Z(L-1)-Z(L))
    IK = IK + 1
  ENDIF
  IF ( IK .EQ. 3 ) GO TO 114
  IF ( X(L) .LT. XB(IK) ) GO TO 114
  GO TO 113
114 M = M + 1
  ZF(M) = Z(L)
  XF(M) = X(L)
116 CONTINUE
  IF ( IK .GT. 2 ) GO TO 170
  M = M + 1
  ZF(M) = Z(NP)
  XF(M) = XB(2)
  IF ( XF(M) .EQ. X(NP) ) XF(M) = XB(2) + 1.
170 NP = M

```



```

PROGRAM INFCV.C
C
C HYDRAULIC CONDITIONS ARE OBTAINED FROM HEC2 OUTPUT IN THE ARCHIVED FORMAT.
C TAPE16 = SUBCRITICAL ARCHIVED INFORMATION
C
C STEP ONE: CREATE NEW TAPES FROM THE ARCHIVED HEC2 INFORMATION
C TAPE18 = SUBCRITICAL VARIABLES
C
C !!!!CHANGE!!!! "LINE*132" TO "LINE*4"
C
C CHARACTER LINE*4
C
C OPEN(16,FILE='HEC96.QUA',STATUS='OLD')
C OPEN(18,FILE='HYDINF.QUA',STATUS='NEW')
C OPEN(6,FILE='WSINF.QUA',STATUS='NEW')
C
C 10 READ(16,100) LINE
C
C !!!!CHANGE!!!! "FORMAT(A132)" TO "FORMAT(A4)"
C
C 100 FORMAT(A4)
C
C !!!!CHANGE!!!! "LINE(1:4)" TO "LINE"
C
C IF(LINE.NE.'4444') GOTO 10
C 20 READ(16,100) LINE
C
C !!!!CHANGE!!!! "LINE(1:4)" TO "LINE"
C
C IF (LINE.EQ.'5555') STOP
C
C !!!!CHANGE!!!! ADD "BACKSPACE(16)"
C
C BACKSPACE(16)
C
C !!!!CHANGE!!!! READ "SEGL", THE SLOPE OF THE ENERGY GRADE LINE
C
C READ(16,102) CWSEL,SEG, TOPWID,SEGL
C READ(16,104) QLOB,QCH,QROB
C READ(16,106) STCHL,STCHR,XLBEL,RBEL
C READ(16,108) VCH
C READ(16,110) SECNO,XLCH
C READ(16,112) ELMIN,Q
C READ(16,113) SSTA,ENDST,VLOB,VROB
C
C !!!!CHANGE!!!! "2E16.8" TO "3E16.8"
C
C 102 FORMAT(E16.8,16X,3E16.8)
C 104 FORMAT(64X,3(2X,E14.8))
C 106 FORMAT(64X,4(2X,E14.8))
C 108 FORMAT(18X,E14.8)
C 110 FORMAT(80X,2(2X,E14.8))
C 112 FORMAT(16X,2(2X,E14.8))
C 113 FORMAT(64X,4(2X,E14.8),5(/))

```

```

C
C CONVERT SLOPE OF THE ENERGY GRADE LINE FROM HEC-2'S 10K*S FORMAT INTO
C THE ACTUAL VALUE
C
  SEGL=SEGL/10000.
C
C CALCULATE VELOCITY, HYDR. DEPTH AND TOPWIDTH IN THE MAIN CHANNEL,
C AND LEFT AND RIGHT OVERBANK
C
  TWL=0.
  TWCH=0.
  TWR=0.
  BNKWID=STCHR-STCHL
  TOPCH=AMIN1(BNKWID, TOPWID)
  BNKWL=STCHL-SSTA
  IF(BNKWL.LT.0.1) BNKWL=0.
  BNKWR=ENDST-STCHR
  IF(BNKWR.LT.0.1) BNKWR=0.
  TWCH=TOPCH
  TWL=BNKWL
  TWR=BNKWR
  DCH=QCH/VCH/TWCH
  IF ( VLOB .GT. 0. .AND. TWL .GT. 0. ) THEN
    DLOB=QLOB/VLOB/TWL
  ELSE
    DLOB=0.
  ENDIF
  IF ( VROB .GT. 0. .AND. TWR .GT. 0. ) THEN
    DROB=QROB/VROB/TWR
  ELSE
    DROB=0.
  ENDIF
C
C !!!!CHANGE!!!! WRITE "SEGL"
C
  WRITE(18,120) SECNO,XLCH,QCH,QLOB,QROB,ELMIN,SEGL
  WRITE(18,130) VCH,TWCH,VLOB,TWL,VROB,TWR,STCHL,STCHR
C
C !!!!CHANGE!!!! "FORMAT(6F10.2)" TO "FORMAT(6F10.2,F9.6)"
C
  120 FORMAT(6F10.2,F9.6)
  130 FORMAT(10F8.2)
  WRITE(6,140) SECNO,CWSEL
  140 FORMAT(2F8.2)
  GO TO 20
  END

```

```

PROGRAM RCHCAVC
C
C THIS PROGRAM CALCULATES THE AVERAGE HYDRAULIC CONDITIONS IN A REACH
C TAPE 2 = REACH INFORMATION DATA FILE
C TAPE 8 = REACH HYDRAULIC INFORMATION OUTPUT
C TAPE18 = EDITED HEC-2 INFORMATION FILE
C
C !!!!CHANGE!!!! ADD "DIMENSION SEGL(150) , EGLAVE(150)"; SEGL IS THE
C SLOPE OF THE ENERGY GRADE LINE AND EGLAVE IS THE
C EFFECTIVE ENERGY GRADE LINE SLOPE FOR EACH REACH
C
DIMENSION ELMTN(150),TOPCH(150),QCH(150) ,VCH(150) ,XLCH(150) ,
$   BNKWL(150),VLOB(150) ,QLOB(150) ,BNKWR(150),VROB(150) ,
$   QROB(150) ,DWM(150) ,DHL(150) ,DHR(150) ,VWM(150) ,
$   VWL(150) ,VWR(150) ,DWM(150) ,DML(150) ,DWR(150) ,
$   TWM(150) ,TWL(150) ,TWR(150) ,DME(150) ,DLE(150) ,
$   DRE(150) ,TME(150) ,TLE(150) ,TRE(150) ,VME(150) ,
$   VLE(150) ,VRE(150) ,SE (150) ,XR (150) ,
$   NTR(150) ,SEG(150),SWE(150),SECNO(150),SEGL(150) ,
$   EGLAVE(150)
C
OPEN(2,FILE='RCHDAT.QUA',STATUS='OLD')
OPEN(18,FILE='HYDINF.QUA',STATUS='OLD')
OPEN(8,FILE='HYDAT.QUA',STATUS='NEW',FORM='UNFORMATTED')
OPEN(10,FILE='HYIND.QUA',STATUS='NEW')
C
C READ REACH DATA FROM TAPE 2
C
READ(2,500) NREACH
500 FORMAT(8I10)
C
C READ IN HYDRAULIC PARAMETERS FROM TAPE 18 (IS=SECTION INDEX, NSR=NUMBER
C OF SECTION REACHES
C
IS=1
C
C !!!!CHANGE!!!! READ "SEGL(IS)"
C
10 READ(18,502,END=20) SECNO(IS),XLCH(IS),QCH(IS),QLOB(IS),QROB(IS),
&   SEGL(IS)
READ(18,504) VCH(IS),TOPCH(IS),VLOB(IS),BNKWL(IS),
&   VROB(IS),BNKWR(IS),STCHL,STCHR
C
C !!!!CHANGE!!!! "FORMAT(5F10.2)" TO "FORMAT (5F10.2,10X,F9.6)
C
502 FORMAT(5F10.2,10X,F9.6)
504 FORMAT(10F8.2)
C
C !!!!CHANGE!!!! DELETE FORMAT STATEMENTS NUMBERED 604 AND 606 SINCE
C THEY ARE NOT USED
C
C NOTE: TOPCH,BNKWL,BNKWR ARE THE EFFECTIVE TOPWIDTHS CORRESPONDING
C TO TWCH, TWL AND TWR IN PROGRAM SUBINF.
C

```

```

C
C CALCULATE DEPTH IN OVERBANKS AND MAIN CHANNEL
C
  DHM(IS)=0.
  DHL(IS)=0.
  DHR(IS)=0.
  IF(VCH(IS).LE.0..OR.TOPCH(IS).LE.0.) GOTO 12
  DHM(IS)=(QCH(IS)/(VCH(IS)*TOPCH(IS)))
  12 IF(VLOB(IS).LE.0..OR.BNKWL(IS).LE.0.) GOTO 14
  DHL(IS)=(QLOB(IS)/(VLOB(IS)*BNKWL(IS)))
  14 IF(VROB(IS).LE.0..OR.BNKWR(IS).LE.0.) GOTO 16
  DHR(IS)=(QROB(IS)/(VROB(IS)*BNKWR(IS)))
C
C SEDIMENT DISTRIBUTION WEIGHTING FACTORS
C
C
C !!!!CHANGE!!!! WRITE "SEGL(IS)"
C
  16 WRITE(10,610) SECNO(IS),VCH(IS),DHM(IS),TOPCH(IS),
    +          VLOB(IS),DHL(IS),BNKWL(IS),
    +          VROB(IS),DHR(IS),BNKWR(IS),STCHL,STCHR,
    +          SEGL(IS)
C
C !!!!CHANGE!!!! ADD "F9.6" TO THE END OF THE FORMAT STATEMENT
C
  610 FORMAT(F10.1,3(2F10.2,F10.0),2F10.0,F9.6)
    IS=IS+1
    GOTO 10
  20 NSR=IS-2
C
C CALCULATE DISTANCE WEIGHTED PARAMETERS FOR EACH SECTION REACH
C
C
C INITIALIZE INDEXES FOR BEGINNING AND ENDING OF REACH
C
  NBR=1
  NER=0
C
C CALCULATE EFFECTIVE VELOCITY, DEPTH, TOPWIDTH, EGL SLOPE
C FOR EACH REACH
C
  DO 40 IR=1,NREACH
C
C !!!!CHANGE!!!! ADD THE INITIALIZATION OF THE EFFECTIVE ENERGY GRADE
C LINE SLOPE
C
  EGLAVE(IR)=0.
  XR(IR)=0.
  DME(IR)=0.
  DLE(IR)=0.
  DRE(IR)=0.
  TME(IR)=0.
  TLE(IR)=0.
  TRE(IR)=0.

```

```

VME(IR)=0.
VLE(IR)=0.
VRE(IR)=0.
READ(2,500) NSEC
NER=NER+NSEC
IFF=0
C
DO 50 JS=NBR,NER
52 VME(IR)=VME(IR)+VCH(JS)
VLE(IR)=VLE(IR)+VLOB(JS)
VRE(IR)=VRE(IR)+VROB(JS)
DME(IR)=DME(IR)+DHM(JS)
DLE(IR)=DLE(IR)+DHL(JS)
DRE(IR)=DRE(IR)+DHR(JS)
TME(IR)=TME(IR)+TOPCH(JS)
TLE(IR)=TLE(IR)+BNKWL(JS)
TRE(IR)=TRE(IR)+BNKWR(JS)
C
C !!!!CHANGE!!!! ADD THE EFFECTIVE ENERGY GRADE LINE SLOPE CUMULATIVE
C VALUE CALCULATION FOR EACH REACH
C
EGLAVE(IR)=EGLAVE(IR)+SEGL(JS)
50 CONTINUE
FS=FLOAT(NSEC)-IFF
C
C !!!!CHANGE!!!! CALCULATE THE EFFECTIVE ENERGY GRADE LINE SLOPE
C
EGLAVE(IR)=EGLAVE(IR)/FS
VME(IR)=VME(IR)/FS
VLE(IR)=VLE(IR)/FS
VRE(IR)=VRE(IR)/FS
DME(IR)=DME(IR)/FS
DLE(IR)=DLE(IR)/FS
DRE(IR)=DRE(IR)/FS
TME(IR)=TME(IR)/FS
TLE(IR)=TLE(IR)/FS
TRE(IR)=TRE(IR)/FS
C
C !!!!CHANGE!!!! WRITE "SEGL(IR)" AND "EGLAVE(IR)"
C
NBR=NER+1
WRITE(8) VME(IR),DME(IR),TME(IR),
+ VLE(IR),DLE(IR),TLE(IR),
+ VRE(IR),DRE(IR),TRE(IR),SEGL(IR),EGLAVE(IR)
C $ VLE(IR),DLE(IR),TLE(IR),
C $ VRE(IR),DRE(IR),TRE(IR)
C
C !!!!CHANGE!!!! DELETE FORMAT STATEMENT NUMBER 602 SINCE IT IS NOT USED
C
40 CONTINUE
C
STOP
END

```

```

PROGRAM SROCAVC
C
C   THIS PROGRAM COMPUTES THE SEDIMENT TRANSPORT FOR EACH REACH
C
COMMON/BLKA/ QS1(300),QS2(300),NT
DIMENSION NSEC(50),RBEG(50),REND(50),VCH(50),DCH(50),WCH(50)
DIMENSION VLOB(50),DLOB(50),WLOB(50),VROB(50),DROB(50),WROB(50)
DIMENSION G(50),DV(50),AREA(50),AQS(2),BQS(2),CQS(2),INDEX(50)
DIMENSION PB(50,10),GB(10),GBC(10),GBCM(10),GBCL(10),GBCR(10)
DIMENSION ROX(50),ZBL(50,10),DZ(50),TQT(30),DTT(30),GSSM(50)
C
C !!!CHANG!!!! ADD "DIMENSION SEGL(150) AND EGLAVE(150)"
C
DIMENSION VCHT(150),DHM(150),TOPCH(150),SEGL(150)
DIMENSION VLCBT(150),CHL(150),BNKWL(150),EGLAVE(150)
DIMENSION VRCBT(150),DHR(150),BNKWR(150)
DIMENSION GSSMI(150),GSSMJ(150),AFAC(150),SUMB(50),ZBF(50)
C
OPEN(1,FILE='RCHDAT.QUA',STATUS='OLD')
OPEN(2,FILE='QDAT.QUA',STATUS='OLD')
OPEN(8,FILE='HYDAT.QUA',STATUS='OLD',FORM='UNFORMATTED')
OPEN(10,FILE='HYIND.QUA',STATUS='OLD')
OPEN(7,FILE='SEDDAT.QUA',STATUS='NEW',FORM='UNFORMATTED')
OPEN(6,FILE='RCHTEMP.QUA',STATUS='NEW')
OPEN(5,FILE='AREAFAC.QUA',STATUS='NEW')
OPEN(3,FILE='QTEMP.QUA',STATUS='NEW')
C
C   READ REACH DATA
C
C !!!CHANG!!!! READ "ZC"
C
READ(1,100) NREACH,PORO,ZC
READ(1,110) (NSEC(IR),RBEG(IR),REND(IR),INDEX(IR),IR=1,NREACH)
READ(1,120) AST,BST,CST
C
C !!!CHANG!!!! "F10.2" TO "2F10.2"
C
100 FORMAT(I10,2F10.2)
110 FORMAT(I10,2F10.1,I10)
120 FORMAT(6E12.5)
C
C   READ DISCHARGE HYDROGRAPH
C
READ(2,130) NRUN,NQ,NSIZ
130 FORMAT(3I8)
READ(2,140) (TQT(ID),DTT(ID),ID=1,NQ)
140 FORMAT(8F10.2)
TQ = TQT(NRUN)
DT = DTT(NRUN)
DO 142 IR = 1,NREACH
READ(2,145) SUMB(IR),(PB(IR,J),J=1,NSIZ)
142 CONTINUE
145 FORMAT(11F8.4)
C

```

```

C   READ HYDRAULIC DATA FOR EACH REACH
C
C   DO 15 IR=1,NREACH
C
C   !!!!CHANGE!!!! READ "EGLAVE(IR)"
C
C       READ(8) VCH(IR),DCH(IR),WCH(IR),VLOB(IR),DLOB(IR),WLOB(IR),
C       &       VROB(IR),DROB(IR),WROB(IR),EGLAVE(IR)
15   CONTINUE
      IS = 1
C
C   !!!!CHANGE!!!! READ "SEGL(IS)"
C
C       25 READ(10,190,END=200) VCHT(IS),DHM(IS),TOPCH(IS),
C       +       VLOBT(IS),DHL(IS),BNKHL(IS),
C       +       VRCBT(IS),DHR(IS),BNKWR(IS),SEGL(IS)
C
C   !!!!CHANGE!!!! ADD "F9.6" TO THE END OF THE FORMAT STATEMENT
C
190  FORMAT(10X,3(2F10.2,F10.0),F9.6)
      IS = IS + 1
      GO TO 25
C
C   SEDIMENT INFLOW
C
200  IS = IS - 1
      CALL SEDIN(NRUN,NQ,NSIZ,GB)
      GSUP = 0.
      DO 10 J = 1,NSIZ
      GSUP = GSUP + GB(J)
10   CONTINUE
C
C   ROUTING FROM UPSTREAM REACH TO DOWNSTREAM REACH
C
C       DO 30 J = 1,IS
C       AFAC(J) = 1.
C       GSSMI(J) = 0.
30   CONTINUE
      JBS = IS + 1
      DO 35 JJ = 1,NREACH
      IR = NREACH - JJ + 1
      JES = JBS - 1
      JBS = JES - NSEC(IR) + 1
C
C   MAIN CHANNEL
C
C   !!!!CHANGE!!!! REPLACE "VCH(IR)" WITH "EGLAVE(IR)"
C
C       CALL SEDTR(EGLAVE(IR),DCH(IR),WCH(IR),NSIZ,GSCM)
C
C   LEFT BANK
C
C   !!!!CHANGE!!!! REPLACE "VLOB(IR)" WITH "EGLAVE(IR)"
C

```

```

      CALL SEDTR(EGLAVE(IR),DLCS(IR),WLOB(IR),NSIZ,GBCL)
C
C   RIGHT BANK
C
C   !!!!CHANGE!!!! REPLACE "VROB(IR)" WITH "EGLAVE(IR)"
C
      CALL SEDTR(EGLAVE(IR),DROB(IR),WROB(IR),NSIZ,GBCR)
C
      GSSM(IR) = 0.
      DO 20 J = 1,NSIZ
      GBC(J) = (GBCM(J)+GBCL(J)+GBCR(J)) * PB(IR,J)
      GSSM(IR) = GSSM(IR) + GBC(J)
20 CONTINUE
C
C   IF NECESSARY, COMPUTE AREA CHANGE CORRECTION FACTOR FOR
C   INDIVIDUAL CROSS SECTION
C
      IF ( INDEX(IR) .EQ. 0 ) GO TO 65
      SGSSMJ = 0.
      DO 210 IK = JBS,JES
C
C   !!!!CHANGE!!!! REPLACE "VCHT(IK)" WITH "SEGL(IK)"
C
      CALL SEDTR( SEGL(IK),DHM(IK),TOPCH(IK),NSIZ,GBCM )
C
C   !!!!CHANGE!!!! REPLACE "VLOBT(IK)" WITH "SEGL(IK)"
C
      CALL SEDTR( SEGL(IK),DHL(IK),BNKHL(IK),NSIZ,GBCL )
C
C   !!!!CHANGE!!!! REPLACE "VROBT(IK)" WITH "SEGL(IK)"
C
      CALL SEDTR( SEGL(IK),DHR(IK),BNKWR(IK),NSIZ,GBCR )
      DO 205 IJK = 1,NSIZ
      GBCI = ( GBCM(IJK)+GBCL(IJK)+GBCR(IJK) ) * PB(IR,IJK)
      GSSMI(IK) = GSSMI(IK) + GBCI
205 CONTINUE
210 CONTINUE
      DO 215 IK = JBS,JES
      IF ( GSSMI(IK-1) .NE. 0. ) THEN
      GSSMJ(IK) = (GSSMI(IK-1)+GSSMI(IK+1))*0.25 + GSSMI(IK)*0.5
      ELSE
      GSSMJ(IK) = GSSMI(IK+1)*0.5 + GSSMI(IK)*0.5
      ENDIF
      SGSSMJ = GSSMJ(IK) + SGSSMJ
215 CONTINUE
      AVGSS = SGSSMJ / NSEC(IR)
      GSSM(IR) = AVGSS
      PG = ABS( (GSUP-AVGSS) / AVGSS )
      IF ( PG .LT. .05 ) GO TO 65
      DO 220 IK = JBS,JES
      AFAC(IK) = (GSUP-GSSMJ(IK)) / (GSUP-AVGSS)
220 CONTINUE
C
C   DETERMINE THE ADDITIONAL LOOSE SOIL LAYER

```

```

C
65 W = WCH(IR) + WLOB(IR) + WROB(IR)
   RDX(IR) = ABS( REND(IR) - RBEG(IR) )
   CONVS = DT*3600./RDX(IR)/W
   PBT = 0.
   DO 70 J = 1,NSIZ
     PBT = PBT + PB(IR,J)
     ZBL(IR,J) = SUMB(IR) * PB(IR,J)
70 CONTINUE
   ZBF(IR) = (1-PBT) * SUMB(IR)
C
C   DETERMINE ACTUAL TRANSPORT RATE BY COMPARING AVAILABILITY AND
C   TRANSPORT CAPACITY.  UPDATE THE VALUE OF LOOSE SOIL LAYER FOR
C   NEXT TIME STEP
C
   DO 80 J = 1,NSIZ
     ZBL(IR,J) = ZBL(IR,J) + (GB(J)-GBC(J))*CONVS
C   ZBL(IR,J) = (ZBL(IR,J) / CONVS + GB(J) /
C   &      (GBC(J)*PBT/PB(IR,J) / SUMB(IR) + 1./CONVS)
C   GBC(J) = ZBL(IR,J) * GBC(J) / SUMB(IR)
80 CONTINUE
C
C   CHANGE IN AREA FOR EACH CROSS SECTION IN REACH IR
C
   IF ( INDEX(IR) .EQ. 2 .AND. GSUP .LT. GSSM(IR) ) GSSM(IR) = GSUP
   DZ(IR) = (GSUP-GSSM(IR))*CONVS/(1.-PORO)
   AREA(IR) = DZ(IR) * W
   DV(IR) = AREA(IR) * RDX(IR)
   SUMB(IR) = 0.
   DO 85 J = 1,NSIZ
     SUMB(IR) = SUMB(IR) + ZBL(IR,J)
85 CONTINUE
   SUMB(IR) = SUMB(IR) + ZBF(IR)
   DO 90 J = 1,NSIZ
     PB(IR,J) = ZBL(IR,J) / SUMB(IR)
     GB(J) = GBC(J)
90 CONTINUE
   GSUP = GSSM(IR)
35 CONTINUE
C
C   WRITE RESULTS
C
   WRITE(3,130) NRUN,NQ,NSIZ
   WRITE(3,140) (TQT(ID),DTT(ID),ID=1,NQ)
   DO 40 IR = 1,NREACH
     WRITE(3,145) SUMB(IR),(PB(IR,J),J=1,NSIZ)
40 CONTINUE
   WRITE(3,140) (QS1(J),QS2(J),J=1,NT)
   WRITE(5,500) (AFAC(I),I=1,IS)
500 FORMAT(F12.4)
C
C   !!!!CHANGE!!!! WRITE "ZC"
C
   WRITE(6,100) NREACH,PORO,ZC

```

```

WRITE(6,150)(NSEC(IR),RBEG(IR),REND(IR),INDEX(IR),AREA(IR),
+           IR=1,NREACH)
WRITE(7) (GSSM(I),DV(I),I=1,NREACH)
. 150 FORMAT(I10,2F10.1,I10,F10.2)
WRITE(6,120) AST,BST,CST
END

C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
SUBROUTINE SEDIN(NRUN,NQ,NSIZ,QS)
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
COMMON/BLKA/ QS1(300),QS2(300),NT
DIMENSION QS(10)
NT = NSIZ * NQ
READ(2,140) (QS1(J),QS2(J),J=1,NT)
140 FORMAT(8F10.1)
NB = (NRUN-1) * NSIZ
DO 10 J = 1,NSIZ
K = NB + J
QS(J) = QS1(K) + QS2(K)
10 CONTINUE
RETURN
END

C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C !!!!CHANGE!!!! THIS SUBROUTINE IS ENTIRELY DIFFERENT FROM LAN-YIN'S
C
SUBROUTINE SEDTR(S,D,W,NSIZ,QS)
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
DIMENSION QS(10),DS(10)
DATA DS(1),DS(2),DS(3),DS(4),DS(5)/.125,.5,2.,5.66,11.31/
DATA DS(6),DS(7),DS(8),DS(9),DS(10)/22.6,45.2,90.5,181.,362./
DO 10 J = 1,NSIZ
TEST=62.4*D*S-0.0159*DS(J)
IF(TEST.LT.0.0) GO TO 11
QS(J) = (0.090*(62.4*D*S-0.0159*DS(J))**1.5)*W
GO TO 10
11 QS(J) = 0.0
10 CONTINUE
RETURN
END

```

```

PROGRAM WEICAVC
C
C THIS PROGRAM READS A HEC-2 INPUT FILE AND COMPUTES THE CONVEYANCE
C WEIGHTING FACTORS FOR SELECTED CROSS SECTIONS.
C
COMMON /DATA/ SECNO(150), X(150,100), Z(150,100), F(150,100),
& IZMIN(150), NUMST(150),STCHL(150),STCHR(150),
& STENCL(150),STENCR(150),ELENCL(150),ELENCR(150),
& WD(100),AREA(100),IEARA(150)
DIMENSION SECID(150),WS(150)
C
OPEN(5,FILE='HECSTD.QUA',STATUS='OLD')
OPEN(1,FILE='WSINF.QUA',STATUS='OLD')
OPEN(7,FILE='WGTFAC.TQA',STATUS='NEW',FORM='UNFORMATTED')
C
DO 15 I=1,150
  SECNO(I)=0.
C
C !!!!CHANGE!!!! SET IZMIN(I), NUMST(I), AND IEARA(I) EQUAL TO "0"
C NOT "0."
C
  IZMIN(I)=0
  NUMST(I)=0
  STCHL(I)=0.
  STCHR(I)=0.
  STENCL(I)=0.
  STENCR(I)=0.
  ELENCL(I)=0.
  ELENCR(I)=0.
  IEARA(I)=0
  SECID(I)=0.
  WS(I)=0.
  DO 16 J=1,100
    X(I,J)=0.
    Z(I,J)=0.
    F(I,J)=0.
    AREA(J)=0.
    WD(J)=0.
16 CONTINUE
15 CONTINUE
C
C READ THE HEC-2 INPUT FILE.
C
CALL READHEC(NSEC)
C
C INPUT CROSS SECTIONS AND WATER SURFACE ELEVATIONS TO ANALYSED.
C
READ(1,100)(SECNO(IS),WS(IS),IS=1,NSEC)
100 FORMAT(2F8.2)
C
C COMPUT THE CONVEYANCE WEIGHTING FACTORS BETWEEN CROSS SECTION POINTS.
C
NMSEC=1
DO 10 I=1,NSEC

```

```

      CALL GEOM(I,WS(NMSEC),TA)
      CALL OUT1(I,WS(NMSEC),TA)
      NMSEC = NMSEC + 1
10  CONTINUE
      STOP
      END
      SUBROUTINE READHEC(NSEC)

      COMMON /DATA/ SECNO(150), X(150,100), Z(150,100), F(150,100),
&          IZMIN(150), NUMST(150), STCHL(150), STCHR(150),
&          STENCL(150), STENCR(150), ELENCL(150), ELENCR(150),
&          WD(100), AREA(100), IEARA(150)
      DIMENSION VALN(50), STN(50)
      CHARACTER LINE*80

C
C   THIS SUBROUTINE READS THE HEC-2 INPUT FILE AND ESTABLISHES THE
C   MANNINGS N VALUE FOR EACH CROSS SECTION POINT.
C
      NSEC=0
10  IFLAG = 1
      READ(5,300,END=789) LINE
300  FORMAT(A80)
      IF(LINE(1:2).EQ.'NC') IFLAG = 2
      IF(LINE(1:2).EQ.'NH') IFLAG = 3
      IF(LINE(1:2).EQ.'X1') IFLAG = 4
      IF(LINE(1:2).EQ.'X3') IFLAG = 6
      IF(LINE(1:2).EQ.'GR') IFLAG = 5
      GO TO (10,20,30,40,50,120) IFLAG

C
C   READ NC CARD
C
C   !!!!CHANGE!!!! ADD "BACKSPACE(5)"
C
20  BACKSPACE(5)

C
C   !!!!CHANGE!!!! "READ(LINE,310)" TO "READ(5,310)"
C
      READ(5,310) XNL,XNR,XNCH
310  FORMAT(2X,F6.4,2F8.4)
      JFLAG=1
      GO TO 10

C
C   READ NH CARD
C
C   !!!!CHANGE!!!! THE SAME TWO CHANGES AS ABOVE
C
30  BACKSPACE(5)
      READ(5,320) NUM
320  FORMAT(2X,I6)

C
C   !!!!CHANGE!!!! SEE READ STATEMENT CHANGE ABOVE
C
      READ(5,330) DUMMY,(VALN(I),STN(I),I=1,NUM)

```

```

330  FORMAT(2X,F6.4,9F8.4)
      JFLAG=2
      GO TO 10
C
C  READ X1 CARD
C
40   NSEC=NSEC+1
      KFLAG=0
C
C  !!!!CHANGE!!!! THE SAME TWO CHANGES AS ABOVE AND REPLACE "XNUMST"
C      WITH "NUMST(NSEC)" IN THE READ STATEMENT
C
      BACKSPACE(5)
      READ(5,340) SECNO(NSEC),NUMST(NSEC),STCHL(NSEC),STCHR(NSEC)
C
C  !!!!CHANGE!!!! "F8.0" TO "I8"
C
340  FORMAT(2X,F6.2,I8,2F8.2)
C
C  !!!!CHANGE!!!! DELETE "NUMST(NSEC)=INT(XNUMST)"
C
C  IF PREVIOUS GR CARDS ARE TO BE REPEATED, SET X,Z VALUES FOR CURRENT
C  CROSS SECTION.
C
      IF(NUMST(NSEC).NE.0) GO TO 10
      NUMST(NSEC)=NUMST(NSEC-1)
      ND=NUMST(NSEC)
      DO 60 I=1,ND
          X(NSEC,I)=X(NSEC-1,I)
          Z(NSEC,I)=Z(NSEC-1,I)
60   CONTINUE
      GO TO 10
C
C  READ GR CARDS
C
50   ND = NUMST(NSEC)
C
C  !!!!CHANGE!!!! ADD "BACKSPACE(5)"
C
      BACKSPACE(5)
      IF (ND.LE.5) THEN
C
C  !!!!CHANGE!!!! "READ(LINE,350)" TO "READ(5,350)"
C
          READ(5,350) (Z(NSEC,I),X(NSEC,I),I=1,ND)
          ELSE
C
C  !!!!CHANGE!!!! SAME AS ABOVE
C
          READ(5,350) (Z(NSEC,I),X(NSEC,I),I=1,5)
          READ(5,350) (Z(NSEC,I),X(NSEC,I),I=6,ND)
          ENDIF
350  FORMAT(2X,F6.2,9F8.2)

```

```

C
C   IF SEDIMENT OPTION IS USED, SET ELEVATIONS EQUAL TO ELSESED
C
C   IF(KFLAG.NE.1) GO TO 55
C       DO 53 I=1,ND
C           IF(Z(NSEC,I).LT.ELSESED) Z(NSEC,I)=ELSESED
53   CONTINUE
C
C   SET THE MANNING ROUGHNESS VALUE FOR EACH SEGMENT OF THE
C   CROSS SECTION
C
55 IF (JFLAG .NE. 1) GO TO 70
C       DO 80 I=1,ND
C
C           IF(X(NSEC,I) .LE. STCHL(NSEC)) F(NSEC,I)=XNL
C           IF(X(NSEC,I) .GT. STCHL(NSEC) .AND. X(NSEC,I) .LE. STCHR(NSEC))
C           + F(NSEC,I)=XNCH
C           IF(X(NSEC,I) .GT. STCHR(NSEC)) F(NSEC,I)=XNR
80   CONTINUE
C       GO TO 10
70   DO 90 I=1,ND
C       IF(X(NSEC,I) .GT. STN(1)) GO TO 100
C       F(NSEC,I)=VALN(1)
C       GO TO 90
100  DO 110 J=2,NUM
C       IF(X(NSEC,I) .GT. STN(J-1) .AND. X(NSEC,I) .LE. STN(J))
C       + F(NSEC,I)=VALN(J)
110  CONTINUE
90   CONTINUE
C       GO TO 10
C
C   READ X3 CARD
C
C   !!!!CHANGE!!!! THE SAME BACKSPACE AND READ STATEMENT CHANGES AS ABOVE
C
120  BACKSPACE(5)
C       READ(5,360) IEARA(NSEC),ELSESED,ENCFP,STENCL(NSEC),ELENCL(NSEC),
C       &          STENCR(NSEC),ELENCR(NSEC)
360  FORMAT(2X,I6,9F8.2)
C       IF(ELSESED.NE.0.0) KFLAG=1
C       GO TO 10
789  RETURN
C       END
C
C   SUBROUTINE GEOM (K,WS,TA)
C
C   THIS SUBROUTINE CALCULATES THE CONVEYANCE WEIGHTING FACTORS
C   A CROSS SECTION, GIVEN THE CHANNEL GEOMETRY AND THE
C   WATER SURFACE ELEVATION.
C
C   COMMON /DATA/ SECNO(150), X(150,100), Z(150,100), F(150,100),
C   &          IZMIN(150), NUMST(150),STCHL(150),STCHR(150),
C   &          STENCL(150),STENCR(150),ELENCL(150),ELENCR(150),
C   &          WD(100),AREA(100),IEARA(150)

```

```

GM 0010
GM 0020
GM 0030
GM 0040
GM 0050
GM 0060

```

```

C           GM 0300
N = NUMST(K)           GM 0310
NP = N - 1            GM 0320
IFLAG = 0             GM 0330
TA = 0.              GM 0340
TK = 0.              GM 0350
DO 100 I = 1,N
  WD(I) = 0.         GM 0410
100 CONTINUE         GM 0420
  N1=2
  N2=N

C
C   CHECK IF EFFECTIVE FLOW AREA OPTION IS USED.
C
C   IF(IEARA(K).NE.10) GO TO 200

C
C   FIND STATION CORRESPONDING TO LEFT AND RIGHT OVERBANK.
C
C
C   DO 210 I=1,N
C     IF(X(K,I).EQ.STCHL(K)) ILOB=I
C     IF(X(K,I).EQ.STCHR(K)) IROB=I
210  CONTINUE
C     IF(WS.LE.Z(K,ILOB)) N1=ILOB+1
C     IF(WS.LE.Z(K,IROB)) N2=IROB

C
C   CHECK LEFT ENCROACHMENT IS SPECIFIED.
C
C   200 IF(STENCL(K).EQ.0.) GO TO 230

C
C   FIND STATION CORRESPONDING TO STENCL.
C
C
C   DO 240 I=1,N
C     IF(X(K,I).EQ.STENCL(K)) ISTNL=I
240  CONTINUE
C     IF(ELENCL(K).EQ.0.0.OR.WS.LT.ELENCL(K)) N1=ISTNL+1

C
C   CHECK IF RIGHT ENCROACHMENT IS SPECIFIED.
C
C   230 IF(STENCR(K).EQ.0.) GO TO 220

C
C   FIND STATION CORRESPONDING TO STENCR.
C
C
C   DO 260 I=1,N
C     IF(X(K,I).EQ.STENCR(K)) ISTNR=I
260  CONTINUE
C     IF(ELENCR(K).EQ.0.0.OR.WS.LT.ELENCR(K)) N2=ISTNR

C           GM 0430
C   ITERATE OVER EACH CROSS SECTION POINT           GM 0440
C           GM 0450
220 DO 170 I = N1,N2           GM 0460
C           GM 0470
C   CALCULATE DISTANCE AND MANNINGS N BETWEEN CROSS SECTION POINTS. GM 0480
C           GM 0490
C     XB = (X(K,I) - X(K,I - 1)) + 1.0E - 6       GM 0500

```

```

      FM = F(K,I)
      IF (Z(K,I).GE.WS) GO TO 120
      IF (Z(K,I - 1).GE.WS) GO TO 110
C
C   CALCULATE AREA OF FLOW, WETTED PERIMETER, AND DEPTH.
C
      DA = WS - 0.5 * (Z(K,I - 1) + Z(K,I))
      A = XB * DA
      ZB = ABS(Z(K,I) - Z(K,I - 1))
      P = SQRT(XB * XB + ZB * ZB)
      GO TO 160
110  ZB = WS - Z(K,I)
      XB = XB * ZB / (Z(K,I - 1) - Z(K,I))
      GO TO 150
120  IF (Z(K,I - 1).GE.WS) GO TO 170
      ZB = WS - Z(K,I - 1)
      XB = XB * ZB / (Z(K,I) - Z(K,I - 1))
150  A = 0.5 * XB * ZB
      P = SQRT(XB * XB + ZB * ZB)
      DA = 0.5 * ZB
160  R = A/P
      C = 1.486 * A * R * * (2./3.)/FM
C
C   SUM FLOWS BETWEEN CROSS SECTION POINTS.
C
      TA = TA + A
      TK = TK + C
      AREA(I-1) = A
      WD(I - 1) = C
170 CONTINUE
      WRITE(*,*) TA
      WRITE(*,*) TK
      DO 190 I = 1, NP
          WD(I) = WD(I)/TK
190 CONTINUE
C
      RETURN
      END
      SUBROUTINE CUT1(I,WS,TA)
C
C   THIS SUBROUTINE PRINTS THE RESULTS OF THE CALCULATIONS.
C
      COMMON /DATA/ SECNO(150), X(150,100), Z(150,100), F(150,100),
&             IZMIN(150), NUMST(150),STCHL(150),STCHR(150),
&             STENCL(150),STENCR(150),ELENCL(150),ELENCR(150),
&             WD(100),AREA(100),IEARA(150)
      ND=NUMST(I)
C
C   !!!!CHANGE!!!! "J=1,ND" TO "J=1,ND-1" SINCE THERE ARE ONLY ND-1
C   SEGMENTS BETWEEN ND POINTS
C
      WRITE(7) ND,(WD(J),J=1,ND-1)

```

GM 0520
GM 0530
GM 0540
GM 0550
GM 0560
GM 0570
GM 0580
GM 0590
GM 0600
GM 0610
GM 0620
GM 0630
GM 0640
GM 0650
GM 0670
GM 0680
GM 0860
GM 0870
GM 0880
GM 0890
GM 0900
GM 0910
GM 0920
GM 0930
GM 0950
GM 1000
GM 1020
GM 1060
GM 1070
GM 1080
GM 1090
GM 1100
GM 1110

HEC-2SR

PROGRAM WEICAVC.FOR

RETURN
END

```

PROGRAM CHDCAVC
C
C THIS PROGRAM UPDATES THE DATA FILES REACH AND THE HEC-2 DATA FILES
C TAPE 1 = HECSTD      UPDATE ON TAPE 11
C TAPE 3 = RCHDAT
C TAPE 5 = QDAT        UPDATE ON TAPE 21
C TAPES1 = ELMIN
C TAPE 9 = WGTFACT
C
COMMON/BLKA/ NP,IR,IQ,NQ,BL,BR,JS,NSEC
COMMON/BLKB/ CWSL(150),TOPCH(150),ASC(150),VAL(10),QM(30)
COMMON/BLKC/ AREA(150),BNKWL(150),BNKWR(150),WD(150,100)
DIMENSION NS(50),DT(30),QT(30),SUMB(50),AT(150),INDEX(50)
DIMENSION QS1(300),QS2(300),AFAC(150),PB(50,10)
CHARACTER LINE*80
C
OPEN(1,FILE='HECSTD.QUA',STATUS='OLD')
OPEN(3,FILE='RCHDAT.QUA',STATUS='OLD')
OPEN(5,FILE='QDAT.QUA',STATUS='OLD')
OPEN(7,FILE='AREAFAC.QUA',STATUS='OLD')
OPEN(9,FILE='WGTFACT.QUA',STATUS='OLD',FORM='UNFORMATTED')
OPEN(11,FILE='HSTD TMP.QUA',STATUS='NEW')
OPEN(21,FILE='QDATTMP.QUA',STATUS='NEW')
OPEN(51,FILE='ELMIN.QUA',STATUS='NEW')
C
C READ REACH DATA FILE
C
C !!!!CHANGE!!!! READ "ZC"
C
READ(3,300) NREACH,ZC
READ(3,302) (NS(JR),RB,RE,INDEX(JR),ASC(JR),JR=1,NREACH)
22 FORMAT(5F10.2)
C
C !!!!CHANGE!!!! "FORMAT(I10)" TO "FORMAT(I10,10X,F10.2)"
C
300 FORMAT(I10,10X,F10.2)
302 FORMAT(I10,2F10.1,I10,F10.2)
C
C CROSS SECTIONAL AREA CHANGE AT EACH SECTION
C
20 CONTINUE
JES=0
DO 110 JR=1,NREACH
JBS=JES+1
JES=JES+NS(JR)
DO 115 JN=JBS,JES
READ(7,520) AFAC(JN)
520 FORMAT(F12.4)
AT(JN)= ASC(JR) * AFAC(JN)
AREA(JN) = AT(JN)
115 CONTINUE
110 CONTINUE
NSEC=JES
IE = JES - 2

```

```

DO 125 I = 3,IE
AREA(I) = ( AT(I-2)+AT(I-1)+AT(I+1)+AT(I+2) ) * 0.15 +
+         AT(I) * 0.4
WRITE(*,*) AREA(I)
125 CONTINUE
JES = 0
DO 140 JR = 1 , NREACH
JBS = JES + 1
JES = JES + NS(JR)
IF ( INDEX(JR) .NE. 2 ) GO TO 140
DO 135 JN = JBS , JES
IF ( AREA(JN) .LT. 0. ) AREA(JN) = 0.
135 CONTINUE
140 CONTINUE
C
C   READ AND UPDATE HYDROGRAPH FILE
C
READ(5,600) NRUN,NQ,NSIZ
NT = NSIZ * NQ
READ(5,610)(QM(I),DT(I),I=1,NQ)
DO 120 I=1,NREACH
READ(5,620) SUMB(I),(PB(I,J),J=1,NSIZ)
120 CONTINUE
READ(5,610) (QS1(I),QS2(I),I=1,NT)
600 FORMAT(3I8)
610 FORMAT(8F10.2)
620 FORMAT(11F8.4)
NRUN=NRUN+1
WRITE(21,600) NRUN,NQ,NSIZ
WRITE(21,610)(QM(I),DT(I),I=1,NQ)
DO 130 I=1,NREACH
WRITE(21,620) SUMB(I),(PB(I,J),J=1,NSIZ)
130 CONTINUE
WRITE(21,610) (QS1(I),QS2(I),I=1,NT)
C
C   READ SEDIMENT DISTRIBUTION FACTORS
C
DO 30 IS=1,NSEC
READ(9)ND,(WD(IS,J),J=1,ND-1)
30 CONTINUE
C
C   CHANGE HEC-2 DATA FILES
C
70 READ(1,512) LINE
WRITE(11,512) LINE
IF(LINE(1:2).NE.'T3') GOTO 70
C
JS=1
80 READ(1,512,END=90) LINE
JP=0
IF(LINE(1:2).EQ.'X1') THEN
BACKSPACE(1)
CALL WRTX1(JP)
ELSE

```

```

CONTINUE
ENDIF
IF(LINE(1:2).EQ.'GR') THEN
BACKSPACE(1)
CALL WRTGR(JP)
ELSE
CONTINUE
ENDIF
IF(JP.EQ.1) GOTO 80
WRITE(11,512) LINE
GOTO 80
C
90 CONTINUE
C
STOP
C
500 FORMAT(10I8)
502 FORMAT(I8,3F8.1)
506 FORMAT(10F8.1)
510 FORMAT(8X,F8.0)
511 FORMAT(16X,F8.0,16X,2F8.0)
512 FORMAT(A80)
515 FORMAT(64X,2I8)
C
END
SUBROUTINE WRTX1(JP)
C THIS SUBROUTINE WRITES NEW X1 CARDS AND COMPUTES THE SEDIMENT
C DISTRIBUTION WIDTH
C
COMMON/BLKA/ NP,IR,IQ,NQ,BL,BR,JS,NSEC
COMMON/BLKB/ CHSEL(150),TOPCH(150),ASC(150),VAL(10),CM(30)
COMMON/BLKC/ AREA(150),BNKWL(150),BNKWR(150),WD(150,100)
C
CHARACTER LINE*80
CHARACTER IVAL*8
C
JP=1
C
READ(1,500) IVAL,NP,(VAL(L),L=3,9)
BL = VAL(3)
BR = VAL(4)
WRITE(11,504) IVAL,NP,(VAL(L),L=3,9)
RETURN
C
500 FORMAT(A8,I8,7F8.2)
504 FORMAT(A8,I8,5F8.2,2F8.2)
C
END
SUBROUTINE WRTGR(JP)
C THIS SUBROUTINE UPDATES THE GR CARDS IN THE HEC-2 DATA FILE.
C
COMMON/BLKA/ NP,IR,IQ,NQ,BL,BR,JS,NSEC

```

```

COMMON/BLKB/ CWSL(150),TOPCH(150),ASC(150),VAL(10),QM(30)
COMMON/BLKC/ AREA(150),BNKWL(150),BNKWR(150),WD(150,100)
C
DIMENSION Z(100),X(100),F(100),FT(100),WID(100)
CHARACTER LINE*80
C
JP=1
C
IF (NP.LE.5) THEN
  READ(1,500) (Z(L),X(L),L=1,NP)
ELSE
  READ(1,500) (Z(L),X(L),L=1,5)
  READ(1,500) (Z(L),X(L),L=6,NP)
ENDIF
C
C   DISTRIBUTE AREA CHANGE BASED ON WEIGHTING FACTORS
C
NPM1=NP-1
C
C   FIND WEIGHTING FACTOR (*2) FOR DISTRIBUTE AREA(JS) NEAR EACH POINT
C
WID(1) = X(2) - X(1)
WID(NP) = X(NP) - X(NPM1)
DO 95 I = 2, NPM1
  WID(I) = X(I+1) - X(I-1)
95 CONTINUE
DO 98 I = 1, NP
  IF ( WID(I) .GT. 0. ) GO TO 98
  WID(I) = 0.5
98 CONTINUE
FT(1) = WD(JS,1) / WID(1)
FT(NP) = WD(JS,NPM1) / WID(NP)
DO 100 I = 2, NPM1
  FT(I) = (WD(JS,I-1) + WD(JS,I)) / WID(I)
100 CONTINUE
DO 106 I = 1, NP
  WIF = WID(I) / 2.
  RR = WIF
  RL = WIF
  IF ( I .EQ. 1 ) GO TO 102
  IF ( I .EQ. NP ) GO TO 104
  IF ( WIF .GT. WID(I-1) ) RL = WID(I-1)
  IF ( WIF .GT. WID(I+1) ) RR = WID(I+1)
  F(I) = (FT(I-1)*RL + FT(I)*WID(I) + FT(I+1)*RR) * WID(I)
  +      / (RL + WID(I) + RR)
  GO TO 106
102 IF ( WIF .GT. WID(I+1) ) RR = WID(I+1)
  F(I) = (FT(I)*WID(I) + FT(I+1)*RR) * WID(I) / (WID(I) + RR)
  GO TO 106
104 IF ( WIF .GT. WID(I-1) ) RL = WID(I-1)
  F(I) = (FT(I)*WID(I) + FT(I-1)*RL) * WID(I) / (WID(I) + RL)
106 CONTINUE
C
C   CHECKING FOR ARMORING AND MIGRATION POTENTIAL WHEN DEGRATION OCCURS

```

```

C
C !!!!CHANGE!!!! DELETE "ZC = 10"
C
  IF ( ABS(AREA(JS)) .LT. 10. ) GO TO 230
  IF ( AREA(JS) .GE. 0. ) GO TO 220
  IDI = 0
  DO 122 I = 2 , NPM1
  IF ( X(I) .LE. BL .OR. X(I) .GE. BR ) GO TO 110
  ZDL = Z(I-1) - Z(I)
  ZDR = Z(I+1) - Z(I)
  IF ( ZDL .LT. ZC ) GO TO 160
C
C-1 ELEVATION DROP MORE THAN ZC
C
  IF ( IDI .EQ. 1 ) GO TO 135
  IF ( ZDR .LE. 0 ) GO TO 134
C
C-1.1 NORMAL CASE
C
  F(I-1) = F(I-1) + F(I)/2.
  F(I+1) = F(I+1) + F(I)/2.
  F(I) = 0.
  GO TO 155
C
C-1.2 NEXT POINT Z(I+1) LOWER THAN Z(I), NO DISTRIBUTION FOR Z(I+1)
C
  134 F(I-1) = F(I-1) + F(I)
  F(I) = 0.
  GO TO 155
C
C-1.3 PREVIOUS POINT Z(I-1) HAS BEEN LIMITED, NO DISTRIBUTION FOR Z(I-1)
C
  136 IF ( ZDR .LT. 0. ) GO TO 138
  F(I+1) = F(I+1) + F(I)
  F(I) = 0.
  GO TO 155
  138 F(I) = 0.
  155 IDI = 1
  160 CONTINUE
  IF ( ZDR .LT. ZC ) GO TO 110
C
C-2 ELEVATION RISE MORE THAN ZC
C
  IF ( IDI .EQ. 1 ) GO TO 144
  IF ( ZDL .LT. 0. ) GO TO 144
C
C-2.1 NORMAL CASE
C
  F(I-1) = F(I-1) + F(I)/2.
  F(I+1) = F(I+1) + F(I)/2.
  F(I) = 0.
  GO TO 165
C
C-2.2 PREVIOUS POINT Z(I-1) LOWER THAN Z(I) OR HAS BEEN LIMITED

```

```

C
144 F(I+1) = F(I+1) + F(I)
    F(I) = 0.
165 IDI = 1
C
C   CHECK IF PREVIOUS POINTS ARE LOWER THAN CURRENT POINTT
C
    KB = I
148 IF ( ( Z(KB-1)-Z(KB)) .GT. 0. .OR. KB .LE. 2 ) GO TO 122
    F(I+1) = F(I+1) + F(KB-1)
    F(KB-1) = 0.
    KB = KB - 1
    GO TO 148
C
C   ZDR .LT. 10 .AND. ZDL .LT. 10, CHECK IF PREVIOUS POINT HAS BEEN LIMITED
C
110 IF ( IDI .EQ. 1 ) GO TO 112
    GO TO 122
112 IF ( ZDL .LT. 0. ) GO TO 114
    IF ( ZDR .LE. 0. ) F(I+1) = F(I+1) + F(I)
    F(I) = 0.
    IDI = 1
    GO TO 122
114 IDI = 0
122 CONTINUE
220 DO 200 I= 1 , NP
    IF ( AREA(JS) .GE. 0. ) GO TO 210
    IF ( X(I) .LE. BL .OR. X(I) .GE. BR ) GO TO 200
210   DZ=0.0
    IF(WID(I).LE.0.0) GO TO 200
    DZ=F(I)*AREA(JS)/WID(I)
    WRITE(*,*) 'F',F(I),'AREA',AREA(JS),'WID',WID(I),'DZ',DZ
    IF ( DZ .GT. 5.0 ) DZ = 5.0
    Z(I)=Z(I)+DZ
200   CONTINUE
230 WRITE(11,502) (Z(L),X(L),L=1,NP)
    ZMIN=1.0E+06
    DO 20 L=1,NP
    ZMIN=AMIN1(ZMIN,Z(L))
20   CONTINUE
    WRITE(51,120) ZMIN
120   FORMAT(F8.2)
    JS=JS+1
    RETURN
C
500   FORMAT(2X,F6.2,9F8.2)
502   FORMAT(('GR',F6.2,F8.2,4(F8.2,F8.2)))
C
    END

```

```

PROGRAM OUTCAVC
C
C THIS PROGRAM PRINTS THE OUTPUT FROM THE SEDIMENT ROUTING ROUTINE
C
DIMENSION NS(50),RB(50),RE(50),AREA(50),VCH(50),DCH(50),WCH(50)
DIMENSION VLOB(50),DLOB(50),WLOB(50),VRCB(50),DRCB(50),WRCB(50)
DIMENSION G(50),DV(50),XL(50),ACS(2),BCS(2),CCS(2),SUMB(50)
DIMENSION TQT(60),DTT(60),PB(50,10),QS1(600),QS2(600)
C
OPEN(1,FILE='RCHDAT.QUA',STATUS='OLD')
OPEN(3,FILE='QDAT.QUA',STATUS='OLD')
OPEN(4,FILE='HYDAT.QUA',STATUS='OLD',FORM='UNFORMATTED')
OPEN(5,FILE='SEDDAT.QUA',STATUS='OLD',FORM='UNFORMATTED')
OPEN(7,FILE='HYDINF.QUA',STATUS='OLD')
OPEN(8,FILE='ELMIN.QUA',STATUS='OLD')
OPEN(9,FILE='WSINF.QUA',STATUS='OLD')
OPEN(6,FILE='SBTEMP.QUA',STATUS='NEW')
C
NSEC=0
READ(1,100) NREACH
READ(1,110)(NS(JR),RB(JR),RE(JR),AREA(JR),JR=1,NREACH)
READ(1,115) AST,BST,CST
100 FORMAT(I10)
110 FORMAT(I10,2F10.1,10X,F10.2)
115 FORMAT(6E12.5)

READ(3,300) NRUN,NQ,NSIZ
NT = NSIZ * NQ
NRUN=NRUN-1
READ(3,310) (TQT(I),DTT(I),I=1,NQ)
300 FORMAT(3I8)
310 FORMAT(8F10.1)
TQ = TQT(NRUN)
DT = DTT(NRUN)
DO 15 I = 1,NREACH
READ(3,320) SUMB(I),(PB(I,J),J=1,NSIZ)
15 CONTINUE
320 FORMAT(11F8.4)
READ(3,310) (QS1(I),QS2(I),I=1,NT)
NB = (NRUN-1)* NSIZ + 1
NE = NRUN * NSIZ
QS1T = 0.
QS2T = 0.
DO 35 J = NB,NE
QS1T = QS1T + QS1(J)
QS2T = QS2T + QS2(J)
35 CONTINUE
DO 20 IR=1,NREACH
NSEC=NSEC+NS(IR)
XL(IR)=RE(IR)-RB(IR)
20 CONTINUE
DO 25 JR=1,NREACH
READ(4)VCH(JR),DCH(JR),WCH(JR),VLOB(JR),DLOB(JR),WLOB(JR)
& ,VRCB(JR),DRCB(JR),WRCB(JR)

```

```

999 FORMAT(9F8.2)
25 CONTINUE
  READ(5) (G(I),DV(I),I=1,NREACH)
777 FORMAT(2F15.4)
  WRITE(6,*)
  WRITE(6,*) '*****'
  WRITE(6,*) '  ** HEC-2SR SEDIMENT ROUTING OUTPUT **'
  WRITE(6,*) '*****'
  WRITE(6,*)
  WRITE(6,599) NRUN
599 FORMAT(19X,'TIME STEP NO. = ',I3)
  WRITE(6,603) AST,BST,CST
  WRITE(6,605) TQ,DT,QS1T,QS2T
  WRITE(6,600)
  WRITE(6,610) (IR,VCH(IR),DCH(IR),WCH(IR),VLCB(IR),DLDB(IR),
&              WLCB(IR),VROB(IR),DROB(IR),WROB(IR),XL(IR),G(IR),
&              AREA(IR),IR=1,NREACH)
600 FORMAT('AVERAGE HYDRAULICS PER REACH',
+         ' - REACH NUMBER INCREASES FROM D/S TO U/S',/,
*         ' REACH  MAIN  CHANNEL      LEFT BANK  ',
*         '   RIGHT BANK      REACH SEDIMENT  AREA  '/T8,
*         'VELOCITY DEPTH WIDTH VELOCITY DEPTH WIDTH VELOCITY',
*         ' DEPTH WIDTH LENGTH TRANSPORT  CHANGE')
603 FORMAT(///,'COEFFICIENTS A, B, C FOR STAGE-Q RELATION : ',
+         7X,3E12.5)
605 FORMAT(///'TOTAL DISCHARGE (CFS) = ',F10.0,
+         19X,'TIME INCREMENT (HS) = ',F10.2,/,
+         'SED. INFLOW (CFS) U/S OF SESPE = ',F10.2,10X,
+         'SED. INFLOW (CFS) FROM SESPE = ',F10.2,///)
610 FORMAT((I6,3(2F8.2,F8.0),3F10.2))
  WRITE(6,609)
609 FORMAT(3(/))
  WRITE(6,625)
625 FORMAT('HYDRAULICS PER CROSS SECTION'/,
*         '   SEENO MAIN CHNL',T30,'THALWEG',T47,'WATER  MAIN',
&T62,'CHANNEL',T79,'LEFT BANK',T98,'RIGHT BANK'/
&T13,'DISCHARGE INITIAL FINAL SURFACE VELOCITY WIDTH',
&T73,'VELOCITY WIDTH VELOCITY WIDTH  STCHL  STCHR')
  NXS = 0
  NR = 1
  DO 30 IS=1,NSEC
    READ(7,700) SEENO,QCH,ELMIN
    READ(7,710) VCHXS,TWCH,VLOBXS,TWL,VROBXS,TWR,STCHL,STCHR
700  FORMAT(F10.2,10X,F10.2,20X,F10.2)
710  FORMAT(10F8.2)

    READ(8,710) ELMINN

    READ(9,710) DUM,CNSEL

    NXS = NXS + 1
    IF ( NXS .LE. NS(NR) ) GO TO 615
    NR = NR + 1
    NXS = 1

```

```
615 WRITE(6,620) NR,SECNO,QCH,ELMIN,ELMINN,CHSEL,VCHXS,TWCH,VLOBXS,  
& TWL,VROBXS,TWR,STCHL,STCHR  
620 FORMAT(12,F8.1,F10.0,3F10.2,3(F10.2,F10.0),2F10.0)  
30 CONTINUE  
STOP  
END
```

```
Program LOOPTMP;
  { Looping routine for HEC-2SR
    with output counter }
Var
  counter,TimeStepInterval,
  NumSteps : Integer;
  File1,    { STEPS.DAT }
  File2 : Text; { DUMMY }
Begin
  Assign(File1,'STEPS.DAT');
  ReSet(File1);
  ReadLn(File1,NumSteps,counter,TimeStepInterval);
  NumSteps := NumSteps -1;
  If NumSteps <= 0 then { delete DUMMY }
  begin
    Assign(File2,'DUMMY');
    Erase(File2);
  end
  else
  begin
    Rewrite(File1);
    WriteLn(File1,NumSteps);
    WriteLn(File1,counter);
    WriteLn(File1,TimeStepInterval);
    WriteLn(NumSteps:4,' Time steps left to process');
    Close(File1);
  end;
End.
```

APPENDIX G. TOPOGRAPHIC DATASET

G.1 Purpose/Objective

The objective in gathering topographic maps was to obtain a direct measurement of changes in the channel shape and size over time. To assess this change, topographic mapping was acquired for the earliest period of large scale mapping and the most recent period of mapping. In most cases, this mapping was conducted in conjunction with floodplain information studies and data from the initiation of that program in the early 1970s. The small scale U.S. Geological Survey maps were also included in this dataset, but generally their accuracy is not sufficient for the purposes of this study.

Presentation of the dataset is made in several ways, with the intent of being able to assess the effect of mining activity both in the channel and on the floodplain. Profile plots were drawn to show the change in thalweg elevations over time. To show the various changes in the floodplain as a whole, each reach was digitized on a two-dimensional grid. This allows the net volume of degradation to be computed and can allow for a correlation between excavation location and channel degradation.

G.2 Sources of Data

G.2.1 Specific Location of Acquisition

The rivers were separated into two separate categories: sand-bed and cobble-bed. The specific reaches of sand-bed rivers studied are as follows:

1. Agua Fria River - Camelback Road to Buckeye Road
2. New River - Peoria Avenue to the confluence with the Agua Fria River
3. Santa Cruz River - I-19 bridge to 3 miles downstream
4. Rillito River - I-10 to 3 miles upstream.

The list of the cobble-bed river reaches is as follows:

1. Salt River
 - a. Country Club Drive to Hayden Road
 - b. 19th Avenue to 59th Avenue
2. Verde River
 - a. 1.5 miles upstream to 1.5 miles downstream of the I-17 bridge
 - b. 2-mile reach near the Dead Horse Ranch crossing at Cottonwood

G.2.2 People Involved in the Map Acquisition

We would like to thank the following people for their efforts to provide us with contour maps of interest: Doug Placentia and Davar Khalili of the Maricopa County Flood Control District; Paul Wisheropp, formerly the County Hydrologist for

Yavapai County; Chad Hale of the U.S. Forest Service in Flagstaff; Gaby Stelmach of the Yavapai County Flood Control District; Wayne Rich, Lynn Jacobs, and Irene Booth of the Photogrammetry and Mapping Department at the Arizona Department of Transportation; Don Gross of the Corps of Engineers; and Francine Romero of Cooper Aerial Survey in Tucson.

G.2.3 Summary of Maps

The following maps were used for the analysis of the Agua Fria River:

1. New River, Agua Fria
Scale: 1"=200'
Contour Interval: 4'
Date flown: February 2, 1972
Flown and compiled by: Aerial Mapping Company, Inc.
Manuscript Numbers: 2, 11, 15, 16, 17, 18, 19, 21, 23, 24, 25, 26, 27, 28, 29, 31, 33.
2. U.S.G.S. Quadrangle Map
Tolleson - 1957
Scale: 1"=2000'
Contour Interval: 5'
3. U.S.G.S. Quadrangle Map
El Mirage - 1957
Scale: 1"=2000'
Contour Interval: 5'
4. Agua Fria River
Scale: 1"=200'
Contour Interval: 2'
August, November 1981
Sheets 3A East, 3A West, 3B East, 3B West, 4, 5, 6 East, 6 West, 7 East, 7 West.

The following maps were used for the analysis of the New River:

1. 100-Year Floodplain Delineation
New River, Skunk Creek, Scatter Wash and Tributaries
Flood Control District of Maricopa County
Scale: 1"=400'
Contour Interval: 4'
Drawing Number: FD-NR2-75
January 5, 1976
Sheets 2, 3, 4
2. U.S.G.S. Quadrangle Map
Tolleson - 1957
Scale: 1"=2000'
Contour Interval: 5'

3. New River Area Arizona
Scale: 1"=200'
Contour Interval: 2'
Date flown: November 20, 1981
Flown by: Aerial Mapping Company, Inc.
Compiled by: U.S. Corps of Engineers
File Number: AR-2415
Sheets 1, 2, 3

The following maps were used for the analysis of the Santa Cruz River:

1. Pima County
Scale: 1"=200'
Contour Interval: 2'
July 31, 1984
Flown by Cooper Aerial Survey Co.
Section 14 T155 R13E - Sheet 23
Section 15 T155 R13E - Sheet 22
Section 22 T155 R13E - Sheet 22
Section 23 T155 R13E - Sheet 23
2. Nogales - Tucson Highway Interstate 19 (U.S. 89)
San Xavier Mission Interchange
Pima County
Station 3000+00 to 3025+00
Scale: 1"=50'
Contour Interval: 1'
A.F.E. 8945, Proj. No. I-19-1(2)42, Contract No. 100
November 1960
Arizona Highway Department
Roll 1 of 1
3. Nogales - Tucson Highway (I-19)
Santa Cruz River
October 13, 1983
Pima County
Scale: 1"=100'
Contour Interval: 2'
Roll 1 of 1
4. U.S.G.S. Quadrangle Map
Tucson - 1957
Scale: 1"=2000'
Contour Interval: 10'
5. U.S.G.S. Quadrangle Map
Tucson - 1983
Scale: 1"=2000'
Contour Interval: 10'

6. U.S.G.S. Quadrangle Map
Tucson SW - 1983
Scale: 1"=2000'
Contour Interval: 10'

The following maps were used for the analysis of the Rillito Creek:

1. Estes - El Camino Del Terra Rezoning
Scale: 1"=400'
Contour Interval: 2'
1967
Job 885
2. Pima County
Scale: 1"=200'
Contour Interval: 2'
June 29, 1984
Flown by: Cooper Aerial Survey Co.
Section 8 T133 R13E - Sheet 20
Section 16 T13S R13E - Sheet 21
3. U.S.G.S. Quadrangle Map
Tucson North - 1957
Scale; 1"=2000'
Contour Interval: 10'
4. U.S.G.S. Quadrangle Map
Tucson North - 1968
Scale: 1"=2000'
Contour Interval: 10'
5. U.S.G.S. Quadrangle Map
Jaynes - 1968
Scale: 1"=2000'
Contour Interval: 10'

The following maps were used for the analysis of the Salt River from Country Club Drive to Hayden Road:

1. Salt River Channel
Country Club Drive in Mesa to 59th Avenue
Flood Control District of Maricopa County
Scale: 1"=100'
Contour Interval: 2'
July, August 1962
SW $\frac{1}{4}$ Section 12 T1N R4E
NW $\frac{1}{4}$ Section 13 T1N R4E
SW $\frac{1}{4}$ Section 13 T1N R4E
SE $\frac{1}{4}$ Section 12 T1N R4E
NE $\frac{1}{4}$ Section 13 T1N R4E
SE $\frac{1}{4}$ Section 13 T1N R4E
NW $\frac{1}{4}$ Section 7 T1N R5E
SW $\frac{1}{4}$ Section 7 T1N R5E

NW $\frac{1}{4}$ Section 18 T1N R5E
SE $\frac{1}{4}$ Section 6 T1N R5E
NE $\frac{1}{4}$ Section .7 T1N R5E
SE $\frac{1}{4}$ Section 7 T1N R5E
NE $\frac{1}{4}$ Section 18 T1N R5E
NW $\frac{1}{4}$ Section 8 T1N R5E
SW $\frac{1}{4}$ Section 8 T1N R5E
SE $\frac{1}{4}$ Section 5 T1N R5E
NE $\frac{1}{4}$ Section 8 T1N R5E
NW $\frac{1}{4}$ Section 4 T1N R5E
SW $\frac{1}{4}$ Section 4 T1N R5E
NW $\frac{1}{4}$ Section 9 T1N R5E
SE $\frac{1}{4}$ Section 33 T2N R5E
NE $\frac{1}{4}$ Section 4 T1N R5E
SE $\frac{1}{4}$ Section 4 T1N R5E
NE $\frac{1}{4}$ Section 9 T1N R5E

2. Arizona Department of Transportation
Location Study
East Papago and Hohokam Freeways
ADOT Projects Nos. AZM-600-5-304 and BPM-600-3-308
Scale: 1"=200'
Contour Interval: 2'
Flown by: Kenney Aerial Mapping Inc.
1986
Sheets 14, 14A, 15
3. Salt River Floodplain Analysis, Outer Loop and Red
Mountain Parkway
Job Number: 860315-1
Scale: 1"=200'
Contour Interval: 2'
Flown by: Kennery Aerial Mapping, Inc.
1986
Sheets 7, 18, 5, 8, 17, 4, 9, 34, 3, 10
4. U.S.G.S. Quadrangle Map
Tempe - 1952
Scale: 1"=2000'
Contour Interval: 10'
5. U.S.G.S. Quadrangle Map
Mesa - 1952
Scale: 1"=2000'
Contour Interval: 10'

The following maps were used for the analysis of the Salt River from 19th Avenue to 59th Avenue:

1. Salt River Channel
Country Club Drive in Mesa to 59th Avenue
Flood Control District of Maricopa County
Scale: 1"=200'
Contour Interval: 2'

July, August 1962

NE $\frac{1}{4}$ Section 24 T1N R2E
SE $\frac{1}{4}$ Section 24 T1N R2E
NW $\frac{1}{4}$ Section 24 T1N R2E
SW $\frac{1}{4}$ Section 24 T1N R2E
NE $\frac{1}{4}$ Section 23 T1N R2E
SE $\frac{1}{4}$ Section 23 T1N R2E
NW $\frac{1}{4}$ Section 23 T1N R2E
SW $\frac{1}{4}$ Section 23 T1N R2E
NW $\frac{1}{4}$ Section 26 T1N R2E
NE $\frac{1}{4}$ Section 26 T1N R2E
NE $\frac{1}{4}$ Section 22 T1N R2E
SE $\frac{1}{4}$ Section 22 T1N R2E
NE $\frac{1}{4}$ Section 27 T1N R2E
NW $\frac{1}{4}$ Section 22 T1N R2E
SW $\frac{1}{4}$ Section 22 T1N R2E
NW $\frac{1}{4}$ Section 27 T1N R2E
NE $\frac{1}{4}$ Section 21 T1N R2E
SE $\frac{1}{4}$ Section 21 T1N R2E
NE $\frac{1}{4}$ Section 28 T1N R2E
SW $\frac{1}{4}$ Section 21 T1N R2E
NW $\frac{1}{4}$ Section 28 T1N R2E
SE $\frac{1}{4}$ Section 20 T1N R2E
NE $\frac{1}{4}$ Section 29 T1N R2E
SE $\frac{1}{4}$ Section 29 T1N R2E
NW $\frac{1}{4}$ Section 29 T1N R2E
SW $\frac{1}{4}$ Section 29 T1N R2E

2. Salt River
City of Phoenix
Scale: 1"=200'
Contour Interval: 4'
Date flown: February 23, 1983
Flown by: Cooper Aerial Survey Company
Sheets 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
3. U.S.G.S. Quadrangle Map
Phoenix - 1952
Scale: 1"=2000'
Contour Interval: 10'
4. U.S.G.S. Quadrangle Map
Fowler - 1952
Scale: 1"=2000'
Contour Interval: 10'

The following maps were used for the analysis of the Verde River near I-17:

1. U.S. Forest Service
Coconino and Prescott National Forests
Middle Verde Quadrangle - 1977
Scale: 1"=2000'
Contour Interval: 40'

2. U.S. Forest Service
Coconino and Prescott National Forests
Camp Verde Quadrangle - 1977
Scale: 1"=2000'
Contour Interval: 20'
3. U.S.G.S. Quadrangle Map
Middle Verde - 1969
Scale: 1"=2000'
Contour Interval: 20'
4. U.S.G.S. Quadrangle Map
Camp Verde - 1969
Scale: 1"=2000'
Contour Interval: 20'
5. National Flood Insurance Program Floodway
Flood Boundary and Floodway Map
Yavapai County, Arizona
Effective date: August 19, 1985
Scale: 1"=400'
Contour Interval: 4'
Panels 7, 8

The following maps were used for the analysis of the Verde River near Cottonwood:

1. Yavapai County, Arizona
Unincorporated
Verde River
Scale: 1"=400'
Contour Interval: 4'
H.D.R. Inc. of Arizona
June 1982
Sheets 19, 20, 21
2. U.S.G.S. Quadrangle Map
Cottonwood - 1973
Scale: 1"=2000'
Contour Interval: 40'
3. U.S.G.S. Quadrangle Map
Clarkdale - 1973
Scale: 1"=2000'
Contour Interval: 20'
4. U.S. Forest Service
Coconino and Prescott National Forests
Clarkdale S.E. Quadrangle - 1977
Scale: 1"=2000'
Contour Interval: 40'

5. Flood Plain Information
Verde River and Tributaries
Vicinity of Clarkdale and Cottonwood
Yavapai County, Arizona
Corps of Engineers
Los Angeles District
August 1976
Scale: 1"=400'
Contour Interval: 5'
Plates 4, 5, 6, 7

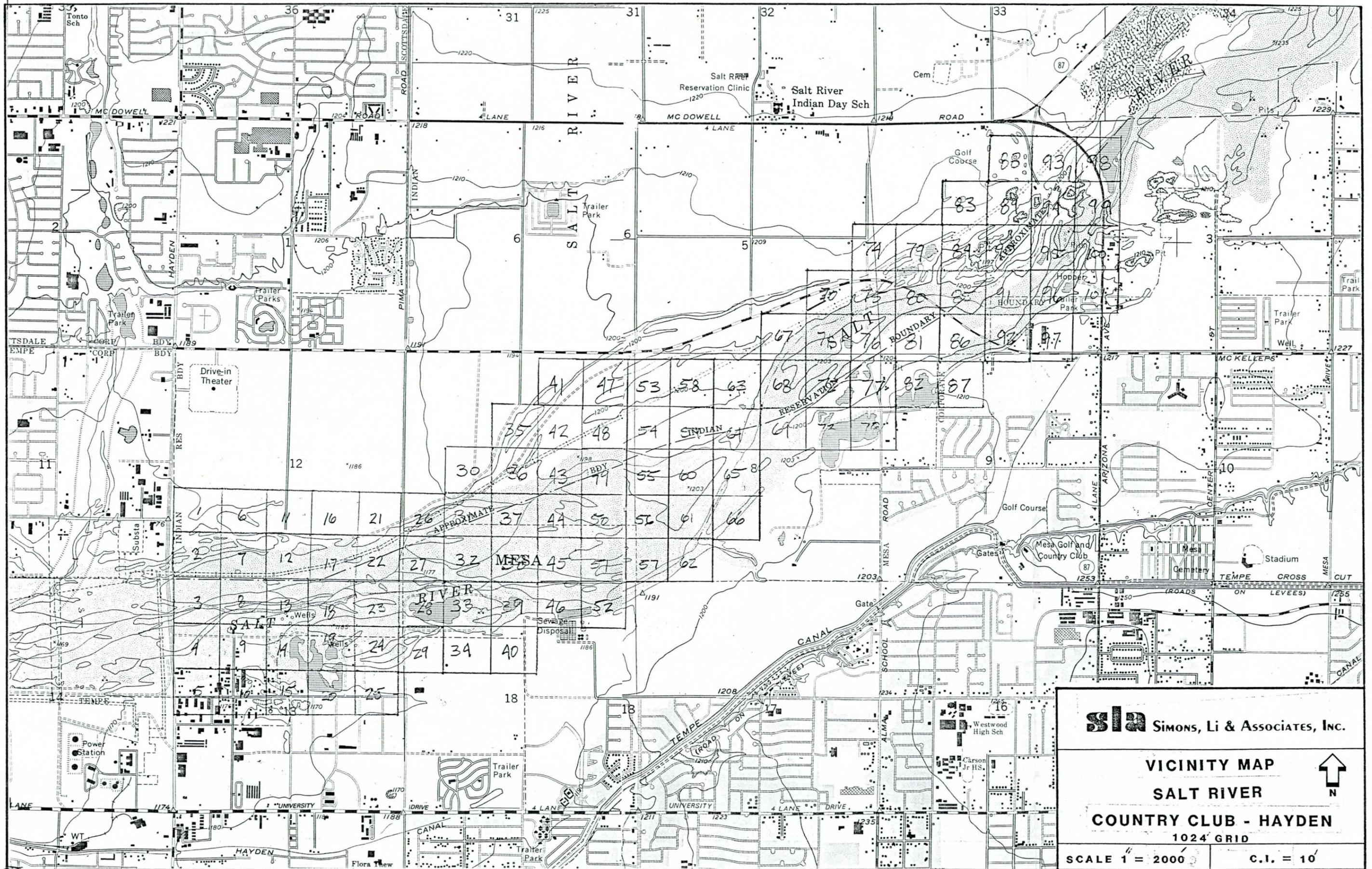
G.3 Data Manipulation

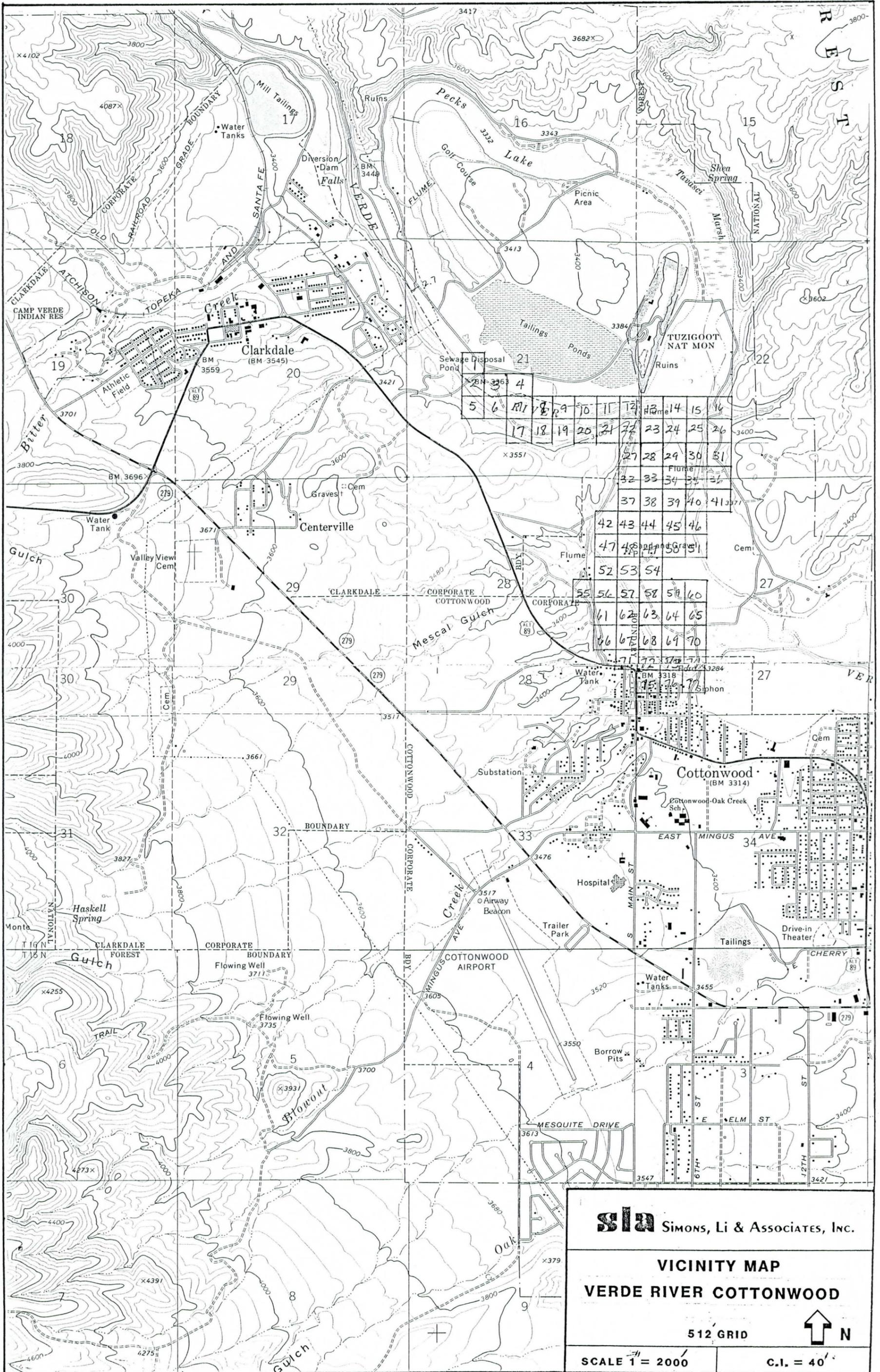
For purposes of comparing the elevation at points of similar location, but at different periods in time, a series of grid overlays with squares either 512 or 1024 feet on a side, depending on the width of the river channel, were developed for each of the different map scale sizes. For the maps of comparable reaches, a common starting point was used so that the overlays would cover similar points. Within each grid square, the elevations at all four of the corners were noted and an average elevation was determined. The difference in elevation between common grid squares was then computed, taking into account any discrepancies in elevation between the maps at common non-fluctuating points like roadway intersections. Only one set of contour maps were available for determining average elevations for both the Santa Cruz River and the Verde River near I-17, so no comparisons could be made for these two reaches. A series of vicinity maps showing grid locations for each reach can be found in Figures G.1 to G.8. Figures G.9 to G.28 show the grid data gathered for this analysis.

Using these elevation differences, a three-dimensional mesh was developed. The location of the grid squares was noted in the x- and y-directions and the change in elevation was shown in the z-direction. The source code example EXA47 in the PLOT88 Software Library Reference Manual, developed by PLOTWORKS, Inc., was modified for each reach comparison to take into account the various array sizes based on the number of grid points being compared. A copy of this program and the associated input sequence for each reach can be found in the Figure G.29. Each program was compiled using Microsoft Fortran Compiler, version 3.3. The object code was linked to Plot88 graphics libraries using the Microsoft 8086 Object Linker, Version 3.04. The libraries were linked as follows:

```
FORTRAN + PLOT88 + FONT + MATH/SEGMENTS:256
```

The plotted output for each study reach can be found in Figures G.30 to G.35. The thalweg of each river was also plotted from each of the maps. These plots can be found in Figures G.36 to G.43.





G-11

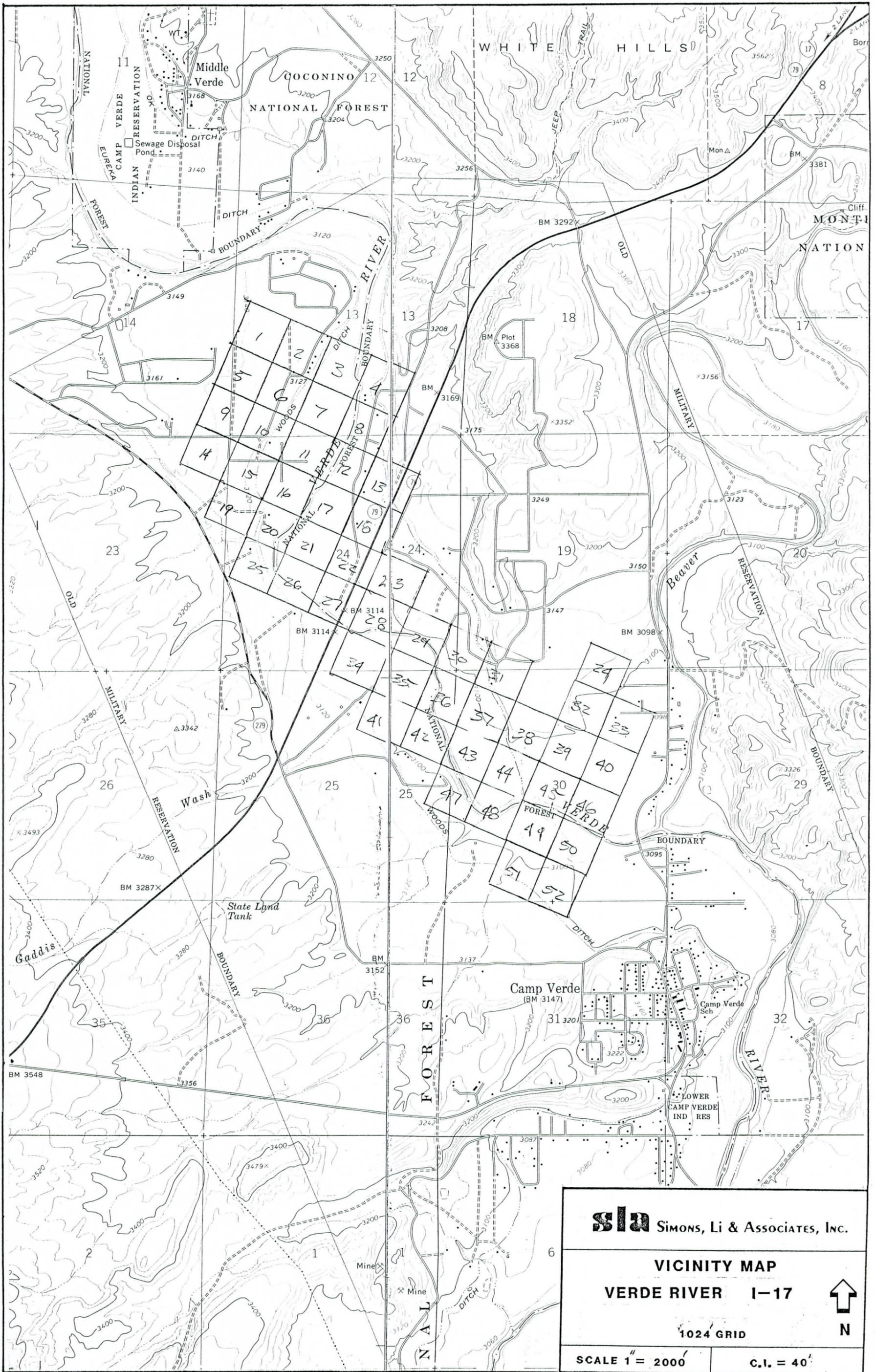
sla SIMONS, LI & ASSOCIATES, INC.

VICINITY MAP
VERDE RIVER COTTONWOOD

512 GRID  N

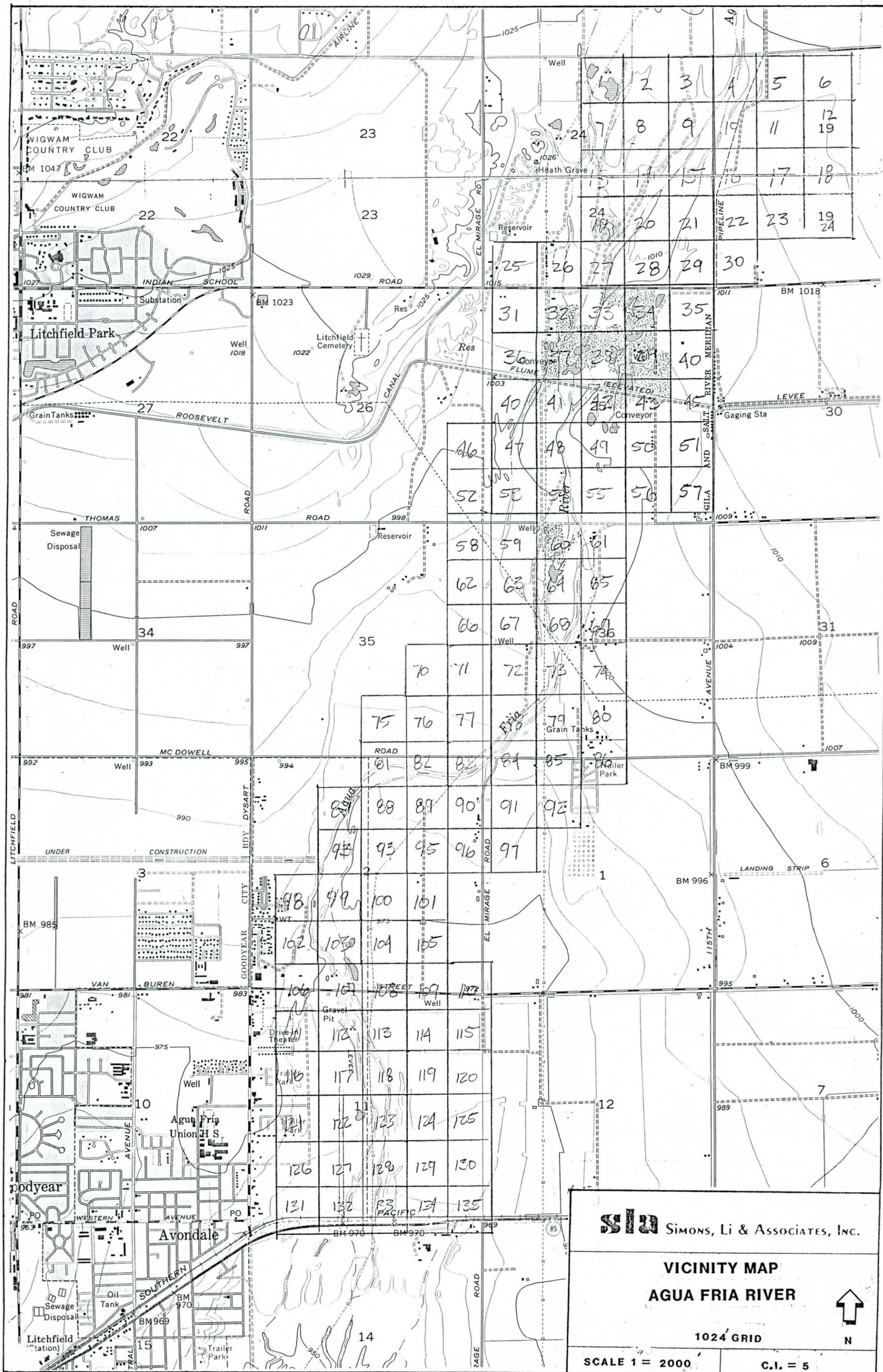
SCALE 1" = 2000' C.I. = 40'

FIGURE G.3



G-12

FIGURE G.4



SLA SIMONS, LI & ASSOCIATES, INC.

VICINITY MAP
AGUA FRIA RIVER

1024 GRID

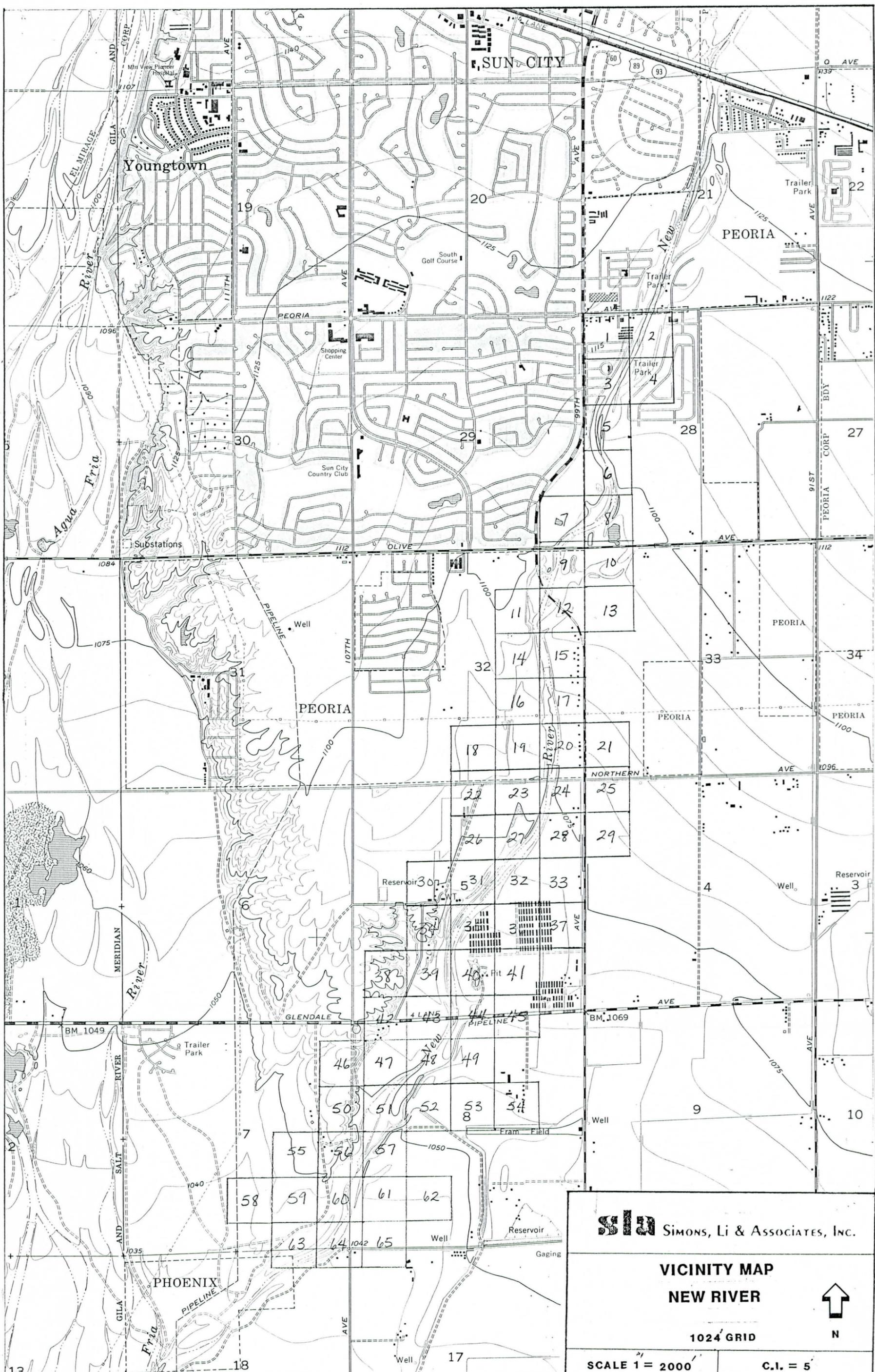
SCALE 1 = 2000 C.I. = 5

↑
N

FIGURE G.5

G-13

G-14



SLA SIMONS, LI & ASSOCIATES, INC.

VICINITY MAP
NEW RIVER

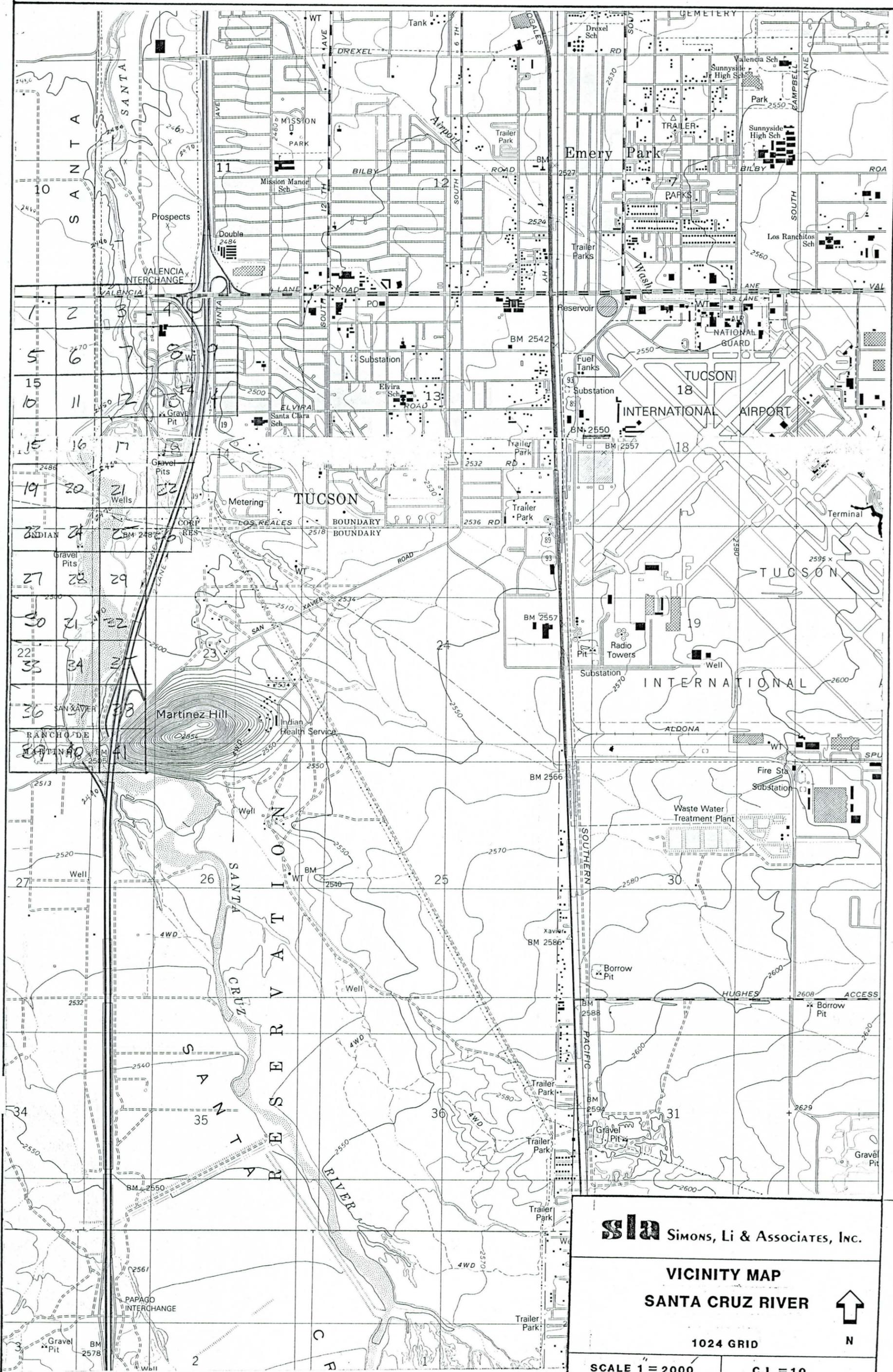
1024' GRID

SCALE 1" = 2000'

C.I. = 5

N

FIGURE G.6



sla SIMONS, LI & ASSOCIATES, INC.

**VICINITY MAP
SANTA CRUZ RIVER**



1024 GRID

SCALE 1" = 2000

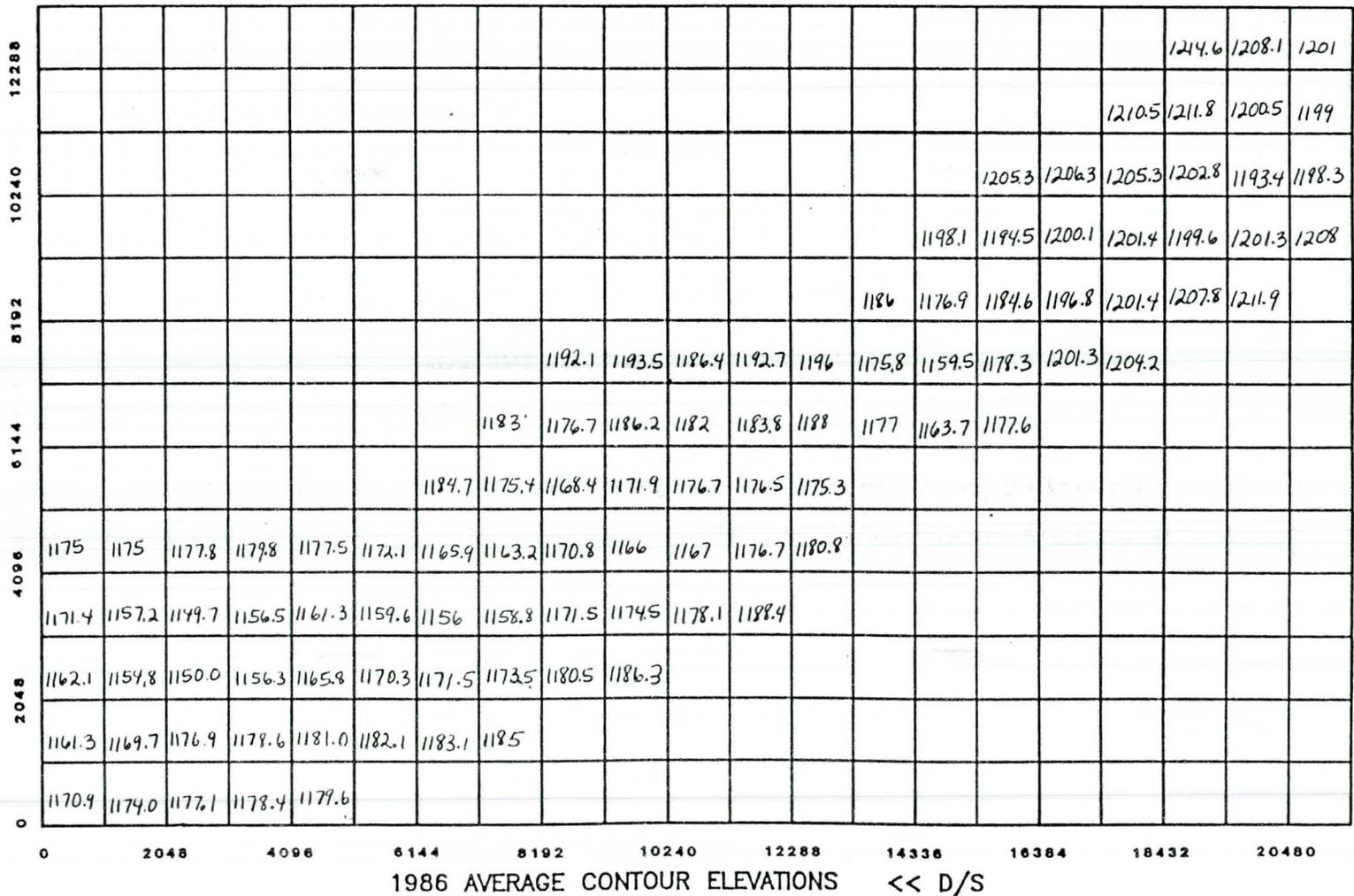
C.I. = 10

FIGURE G.7

_ SALT RIVER
HAYDEN RD TO COUNTRY CLUB DR

G-18

NORTH >>



1986 AVERAGE CONTOUR ELEVATIONS << D/S

FIGURE G.10

— SALT RIVER
19TH AVE TO 59TH AVE

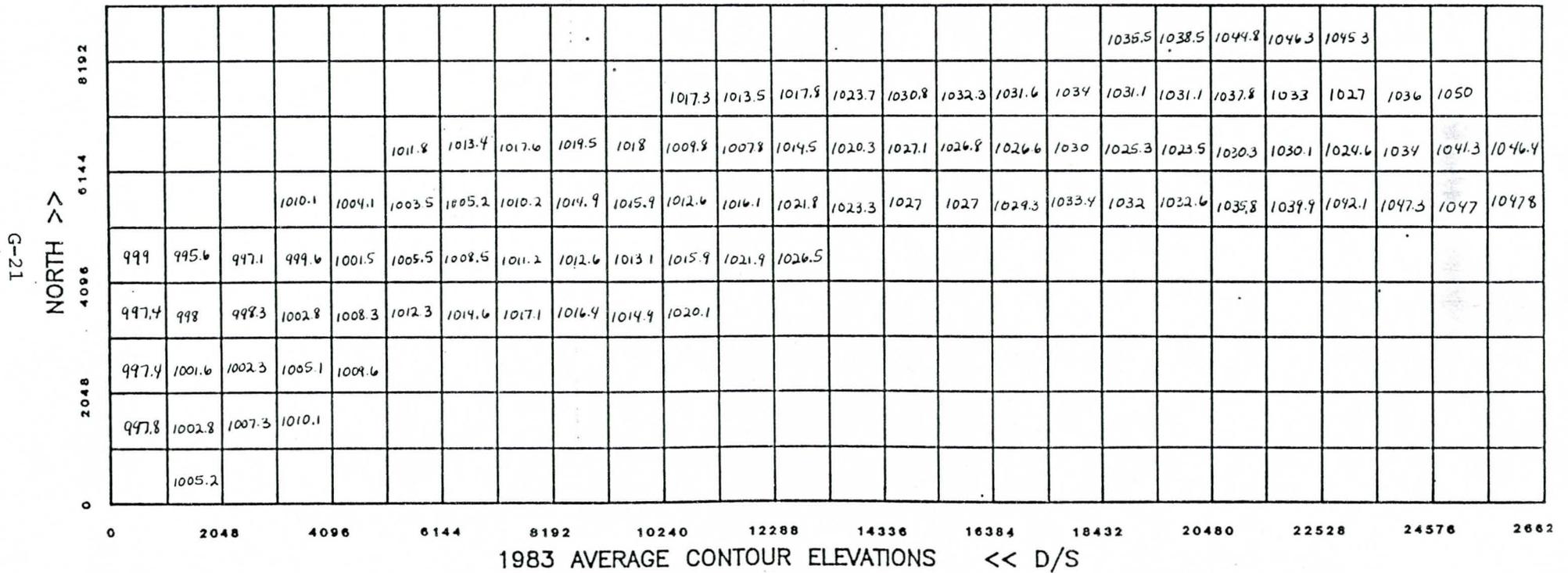
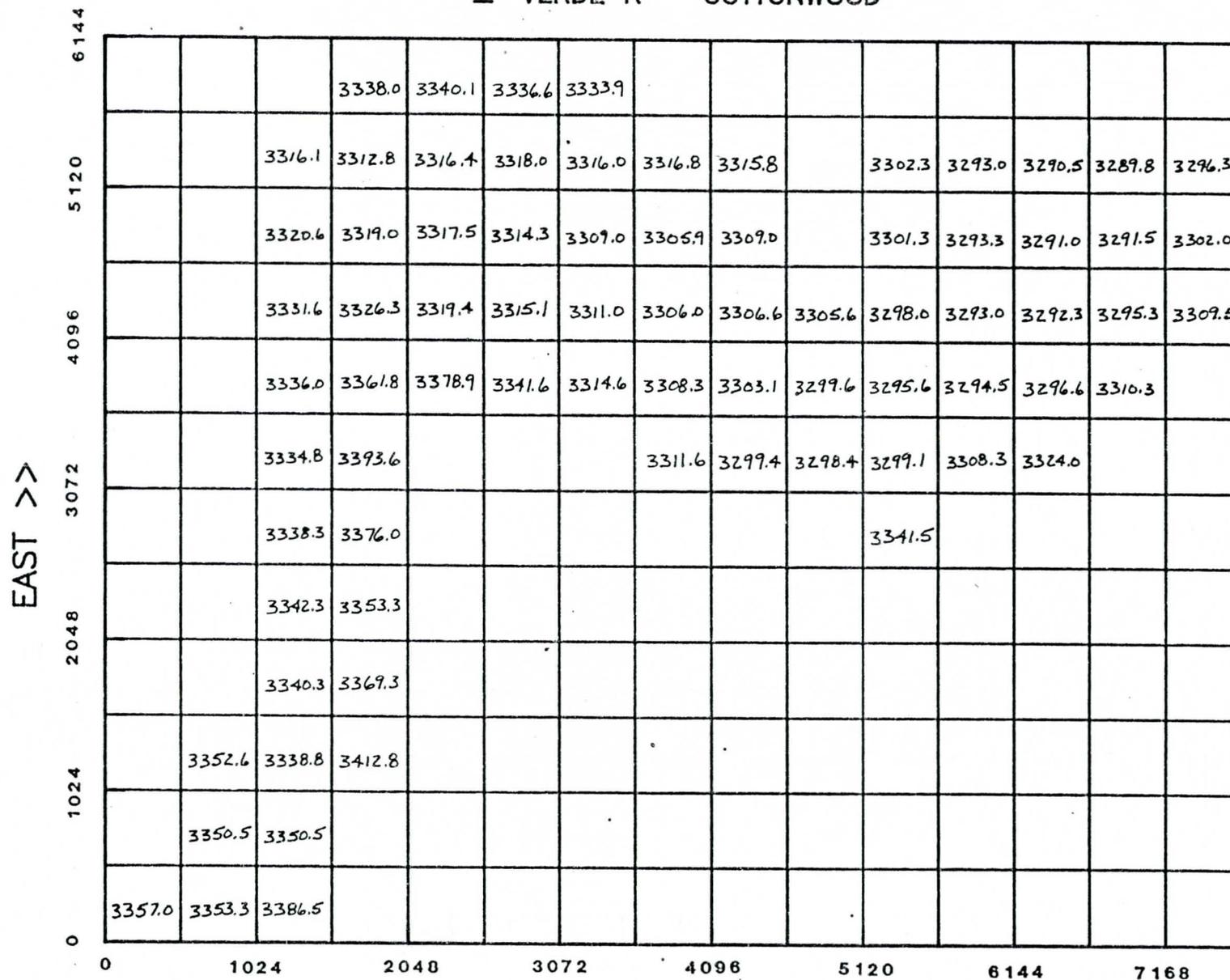


FIGURE G.13

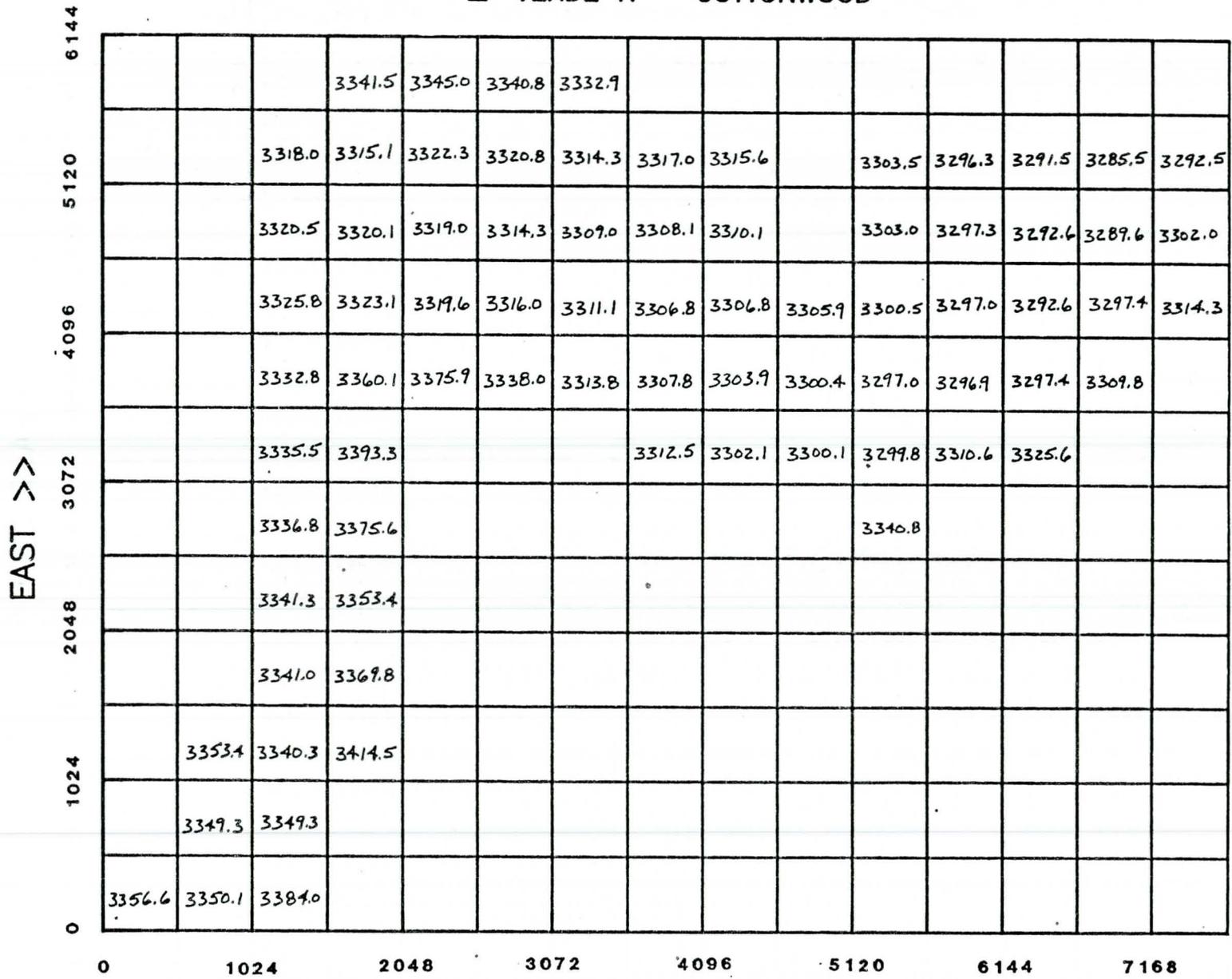
- VERDE R - COTTONWOOD



1976 AVERAGE CONTOUR ELEVATIONS D/S >>

FIGURE G.15

- VERDE R - COTTONWOOD



G-24

1982 AVERAGE CONTOUR ELEVATIONS D/S >>

FIGURE G.16

— VERDE R — COTTONWOOD

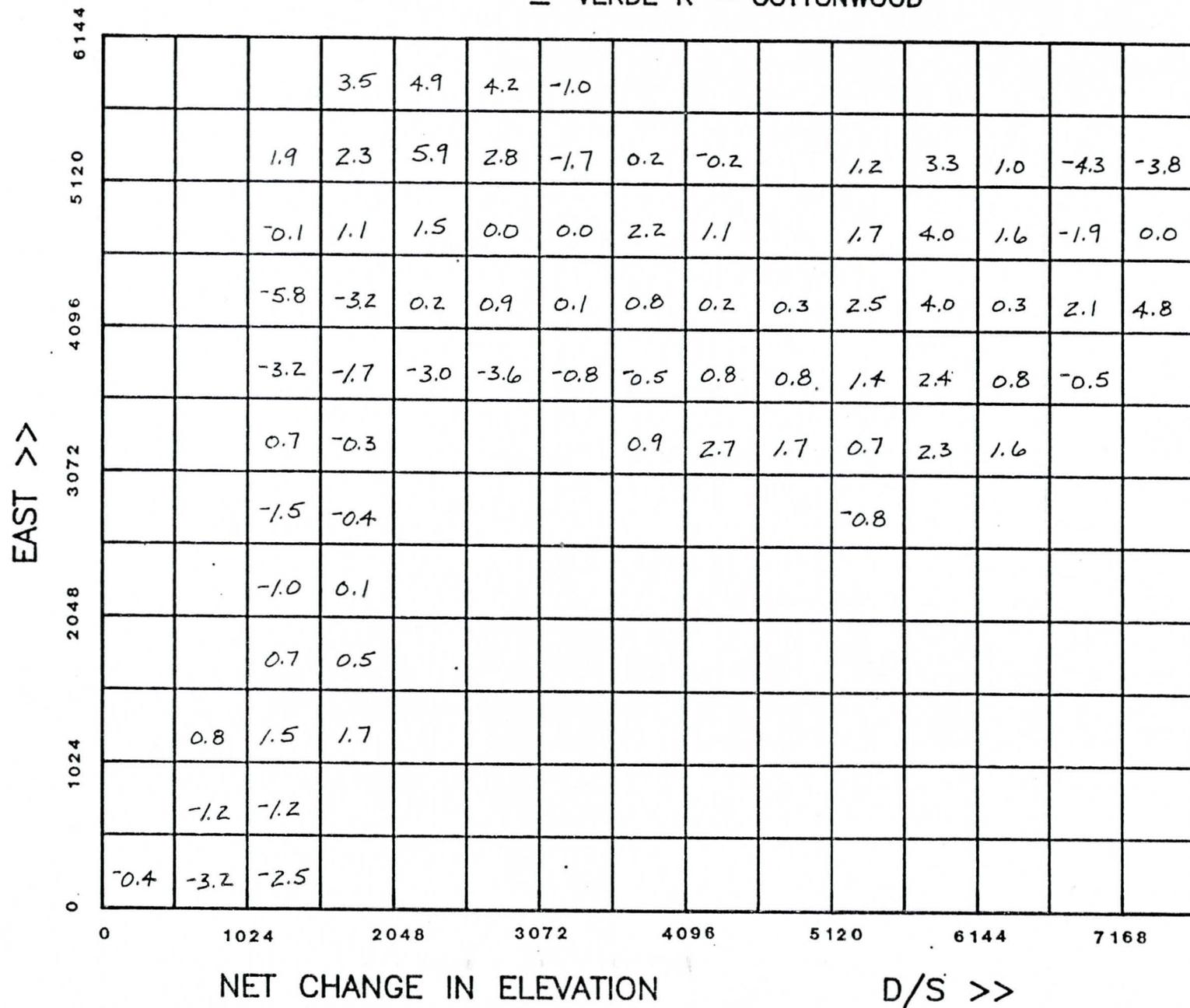
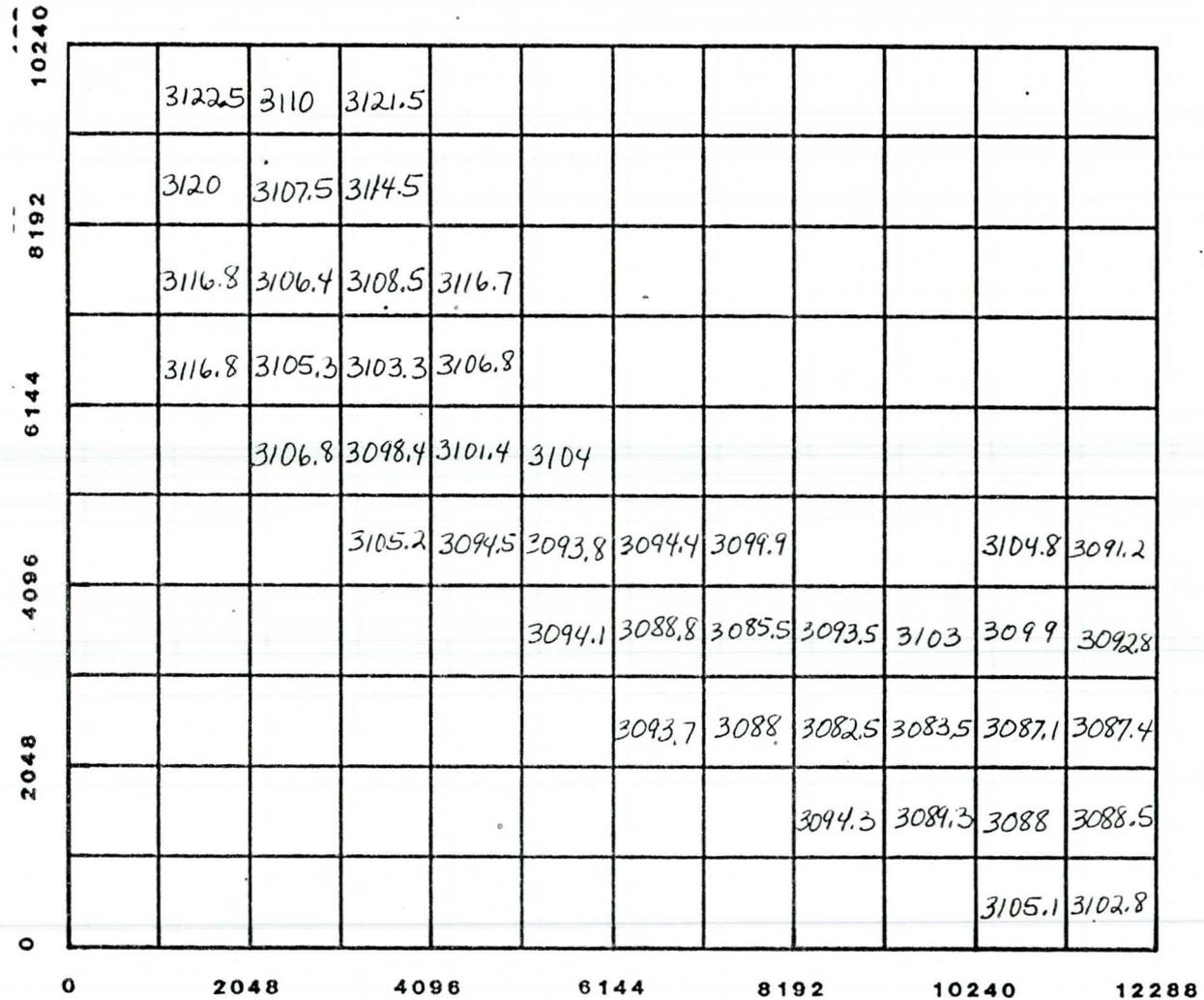


FIGURE G.17

— VERDE R. NEAR I-17

G-26



1985 AVERAGE CONTOUR ELEVATIONS D/S >>

FIGURE G.18

NEW RIVER

G-30

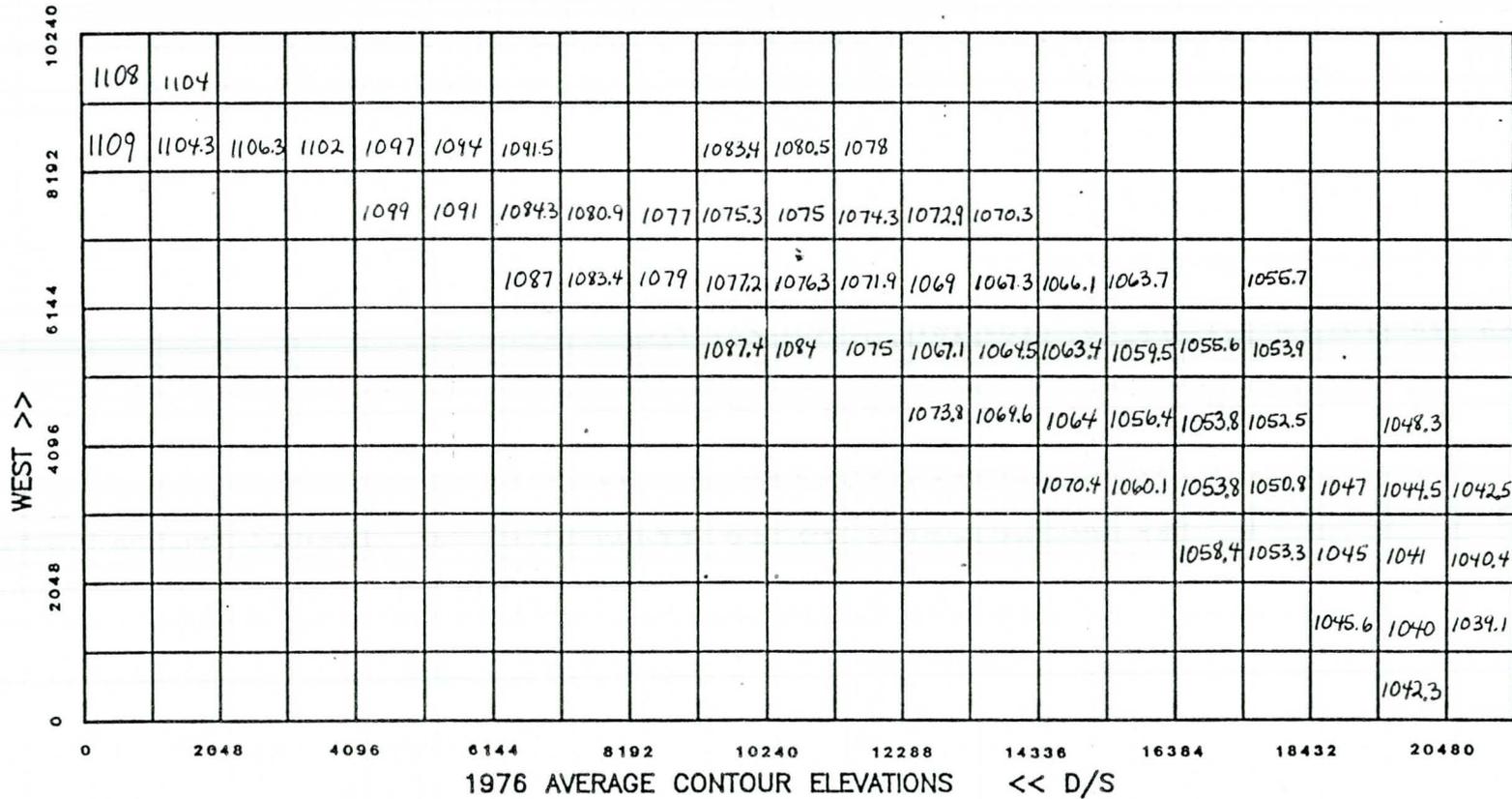


FIGURE Q.22

- NEW RIVER

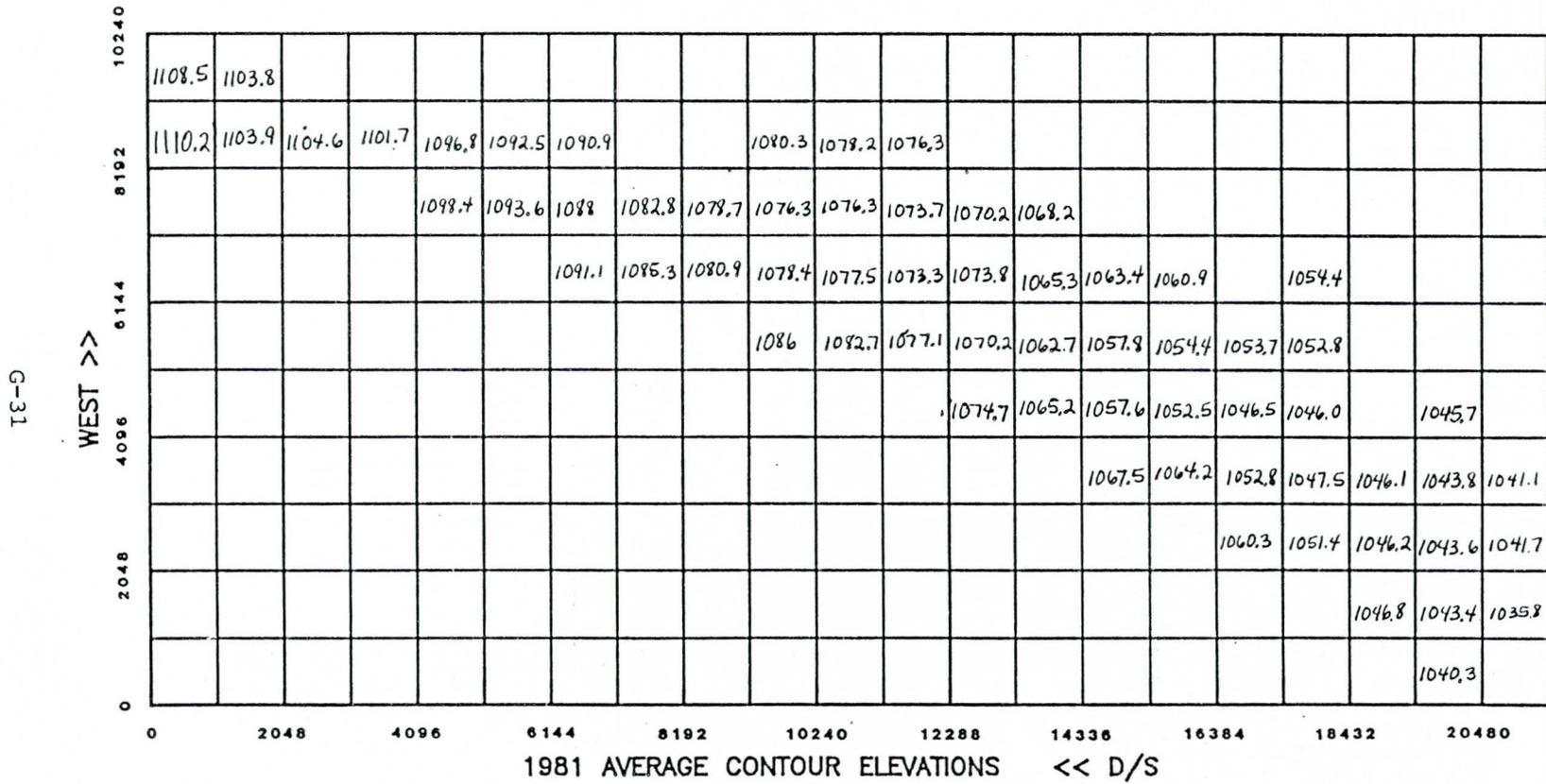


FIGURE Q.23

NEW RIVER

G-32

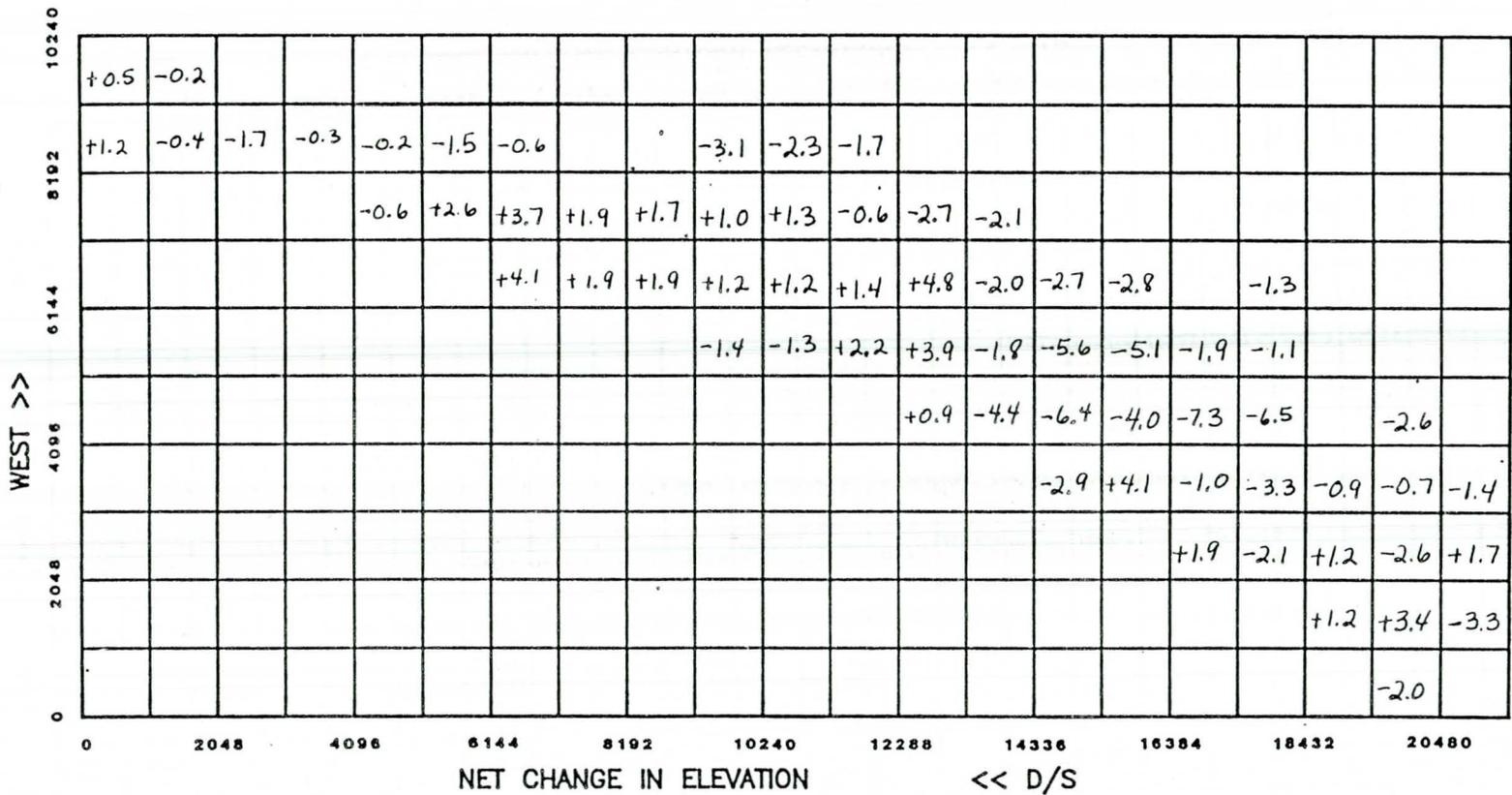


FIGURE G.24

G-33

— SANTA CRUZ RIVER

4096	2512	2506.3	2501.2	2498.4	2492.9	2488.5	2485.1	2480.5	2476.1	2471.5	2472
2048	2504.1	2497.1	2490.1	2486.8	2482.5	2480.6	2475.7	2468.5	2468.8	2469.5	2468
0	2523.1	2520.9	2491.5	2487	2483.2	2477.5	2462.9	2453.8	2457.3	2462.2	2464.5
						2487.2	2475.8	2471.5	2461.4	2458.4	2471.8
									2485.8	2478.3	

0 2048 4096 6144 8192 10240
1984 AVERAGE CONTOUR ELEVATIONS D/S >>

FIGURE G.25

- RILLITO CREEK

G-34

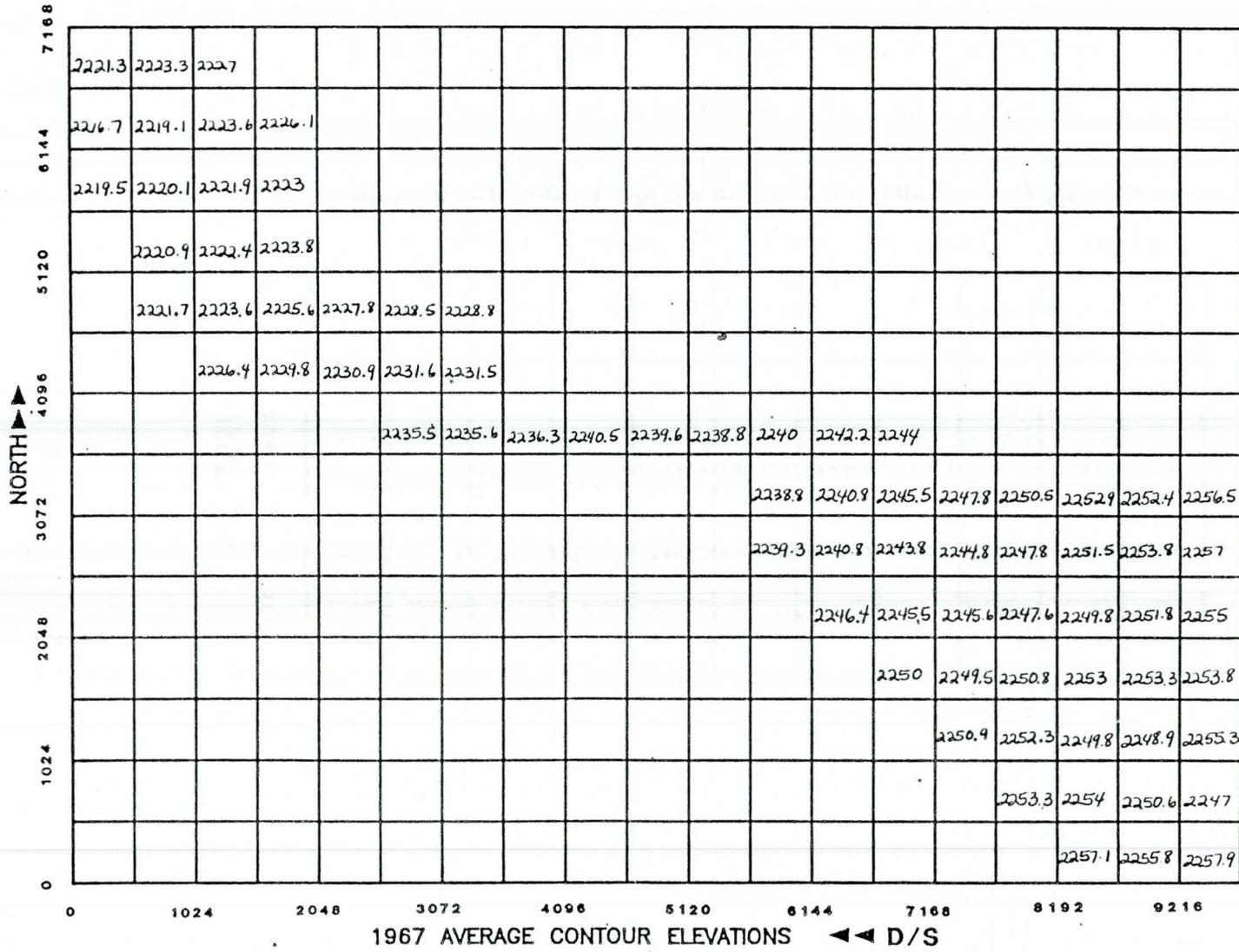


FIGURE G.26

— RILLITO CREEK

G-35

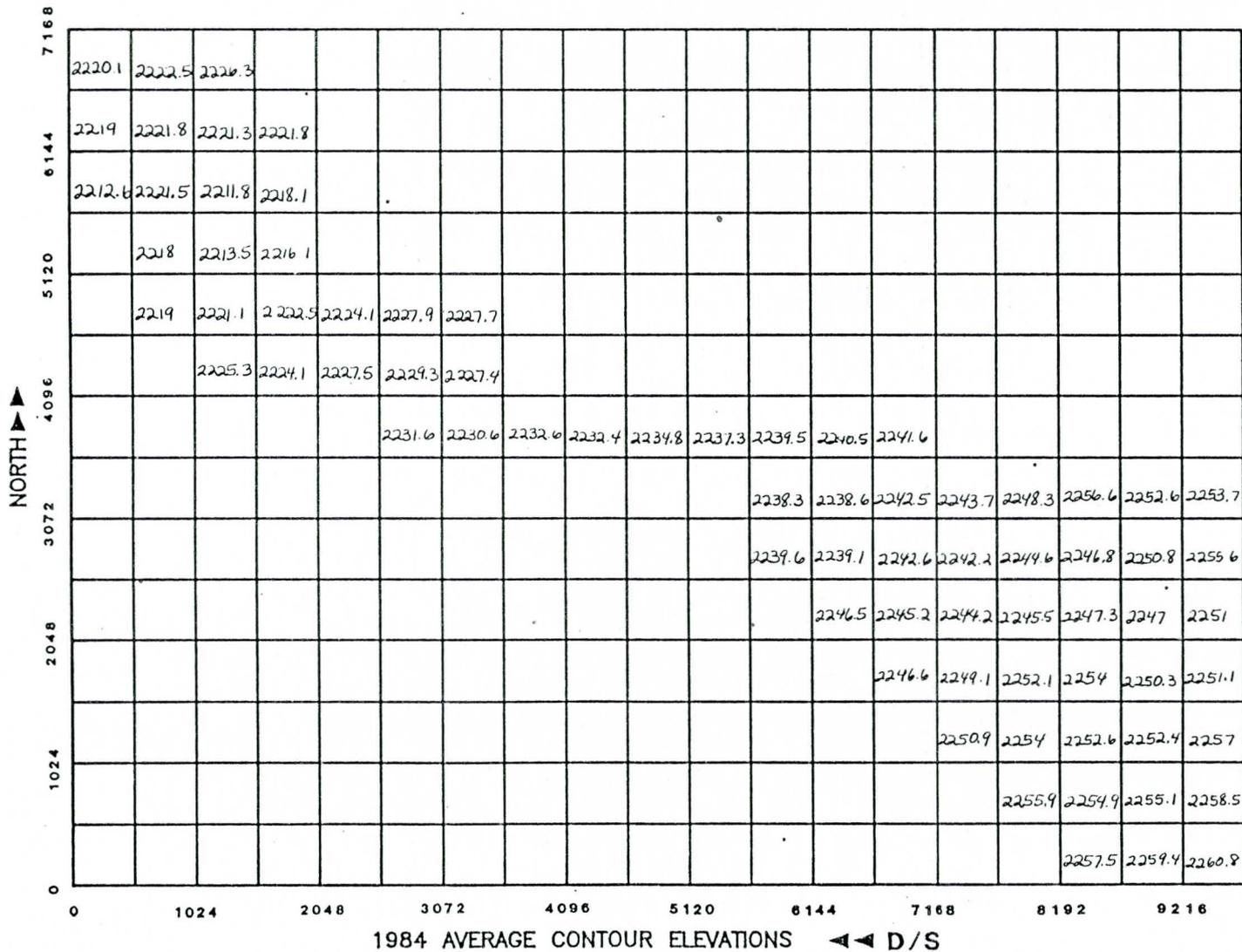


FIGURE G.27

— RILLITO CREEK

G-36

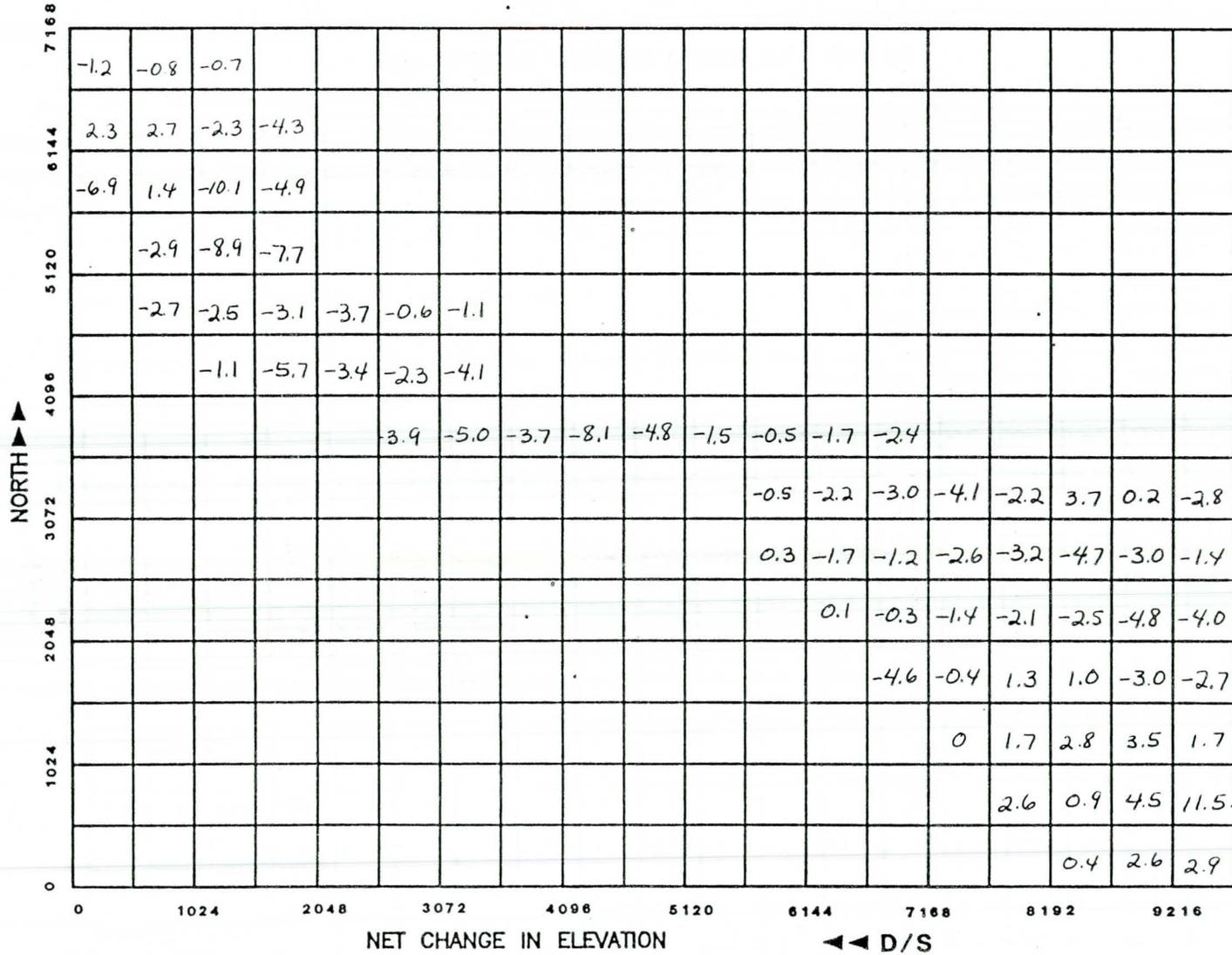


FIGURE G.28

```

      C
      PROGRAM EXA47
      C
      C... INPUT FILE NAME CHARACTER STRING
      CHARACTER*80 NAME
      C
      C... ARRAY WHICH CONTAINS GRIDDED DATA
      REAL Z(21,13)
      C
      C... X,Y AND Z ARRAYS
      REAL DIL(202),DIS(202),ZP(200)
      C
      C... WORK ARRAYS
      REAL ZPIJ(200)
      INTEGER KNXT(200)
      C
      C... MASK ARRAY FOR MESH.
      INTEGER MASK(8600)
      C
      C... VERTEX ARRAY
      REAL VERTEX(16)
      C
      COMMON XLOWW,YLOWW,DXX,DYY
      C
      C... DEFINE LOWER LEFT CORNER OF OUTPUT IN INCHES
      DATA XLOL,YLOL/2.0,2.0/
      C
      C... INPUT DATA WORLD COORDINATES
      DATA XLOW/0.0/, YLOW/0.0/, XHIGH/20992./, YHIGH/12800./
      C
      C... CALCULATE PROJECTION
      DATA IPROJ/0/
      C
      C... Size of z array.
      DATA NNX,NNY/21,13/
      C
      C-----
      C
      C... ENTER IOPRT, MODEL AND FACT.
      WRITE(*,*) 'Enter IOPORT, MODEL and FACT > '
      READ(*,*) IOPORT, MODEL, FACT
      C
      C... DEFINE PHYSICAL SIZE OF PLOT
      WRITE(*,*) 'Enter length, in inches, of X & Y axes> '
      READ(*,*) XLENG,YLENG
      C
      C... ENTER CAY
      WRITE(*,*) 'Enter CAY>'
      READ(*,*) CAY
      C
      C... ENTER NUMBER OF SMOOTHINGS
      WRITE(*,*) 'Enter number of smoothings> '
      READ(*,*) NSM
      C
      C... ENTER NUMBER OF DIVISIONS
      WRITE(*,*) 'Enter number of divisions> '

```

FIGURE G.29

THREE-DIMENSIONAL MESH PROGRAM AND INPUT DATA

```

      READ(*,*) NDIV
C
C... ENTER ROTATION AROUND THE DRAWING
      WRITE(*,314)
314  FORMAT(' Enter PHI (around z axis)>')
      READ(*,*) PHI
C
C... ENTER VIEW ABOVE THE X-Y PLANE.
      WRITE(*,315)
315  FORMAT(' Enter THETA (about x-y plane)>')
      READ(*,*)THETA
C
C... ENTER DIRECTION OF MESH LINES.
      WRITE(*,*) 'Enter mesh direction [1=X, 2=Y, 3=X+Y]> '
      READ(*,*)IDIR
C
C... ENTER EDGING.
      WRITE(*,*) 'Enter edging [0=none, 1=X, 2=Y, 3=X+Y]> '
      READ(*,*)IEDGE
C
C... FRAMING
      WRITE(*,*) 'Enter framing [0=NO, 1=YES]> '
      READ(*,*)IFRAME
C
C... ZLOW
      WRITE(*,*) 'Enter framing zlow [real, world]> '
      READ(*,*)ZLOW
C
C... ICUT (CUT OFF UNDERSIDE OF DRAWING)
      WRITE(*,*) 'Enter underside cutoff[ 0=none, 1=X; 2=Y,3=X+Y]> '
      READ(*,*)ICUT
C
C... TRIM LINES?
      WRITE(*,*) 'Enter trim [0=none, 1=Xs, 2=Ys]> '
      READ(*,*)ITRIM
C
C... READ INPUT DATA (CONTROL POINT) FILE NAME
      WRITE(*,*) 'Enter input file name> '
      READ(*,401) NAME
C
-----
C
C ***** BEGIN PROCESSING *****
C
C... COMPUTE UPPER END OF X AXIS
      XUPR = XLENG + XL0L
C
C... COMPUTE UPPER END OF Y AXIS
      YUPR = YLENG + YL0L
C
C... INITIALIZE PLOT88
      CALL PLOTS(0,IOPORT,MODEL)
C
C... Select the complx font.
      CALL COMPLX
C

```

```

C... SET UP FACTOR SIZE.
      CALL FACTOR( FACT )
C
C... OPEN INPUT FILE
      OPEN(9,FILE=NAME)
C
C... READ INPUT RANDOM DATA
      DO 1 NDP = 1,200
        READ(9,*,END=2) L,DIL(NDP),DIS(NDP),ZP(NDP)
        1 CONTINUE
        2 CONTINUE
        NDP = NDP -1
C
C----- GRIDDING -----
C... ZERO ARRAY Z
      DO 200 I=1,NNX
        DO 200 J=1,NNY
          Z(I,J)=0.0
        200 CONTINUE
C
C... GRID SIZE PARAMETERS
      NX=21
      NY=13
      DX=(XHIGH-XLOW)/FLOAT(NX-1)
      DY=(YHIGH-YLOW)/FLOAT(NY-1)
C
C... GRID THE RANDOM POINTS.
      CALL ZGRID(Z,NNX,NNY,NX,NY,XLOW,YLOW,XHIGH,YHIGH,DIL,DIS,ZP,
        1 NDP,CAY,10,ZPIJ,KNXT)
C
C... Put mesh in color number two.
      CALL COLOR( 2, 0 )
C
C----- DRAW THE MESH SURFACE -----
C
      CALL MESH(Z, NNX,NNY, NX, NY, PHI, THETA, XLOW, YLOW,
        1 XUPR, YUPR, NDIV, IEDGE, IDIR, IPROJ, IFRAME, ZLOW,
        2 ICUT, ITRIM, MASK, VERTEX)
C
C*** THE 3D TO 2D TRANSFORM THAT HAS BEEN DEFINED BY
C ZMESH. SAVE THE OFFSET AND SCALE VALUES.
C
      XLOWH= XLOW
      YLOWH= YLOW
      DXX= DX
      DYY= DY
C
C... DRAW THE SURFACE AND END OUTPUT
      CALL PLOT(0.0,0.0,999)
C
C... FORMATS
      297 FORMAT(1X)
      401 FORMAT(A)
C
C... END OF PROGRAM
      CLOSE(9)

```

CLOSE(7)
STOP
END

INPUT DATA SEQUENCE

for program EXA47

3-D mesh plots:

Enter IOPORT, MODEL, and FACT> 9600 30 0.8
Enter length, in inches, of X & Y axes> 8.5 6.5
Enter CAY > 5.
Enter number of smoothings> 1
Enter number of divisions> 2
Enter PHI (around z-axis)> 0 to 360
Enter THETA (around x-y plane)> 0 to 90
Enter mesh direction [1=X, 2=Y, 3=X+Y]> 3
Enter edging [0=none, 1=X, 2=Y, 3=X+Y]> 0
Enter framing [0=NO, 1=YES]> 1
Enter framing zlow [real, world]> 1.0E35
Enter underside cutoff [0=none, 1=X, 2=Y, 3=X+Y]> 0
Enter trim [0=none, 1=Xs, 2=Ys]> 0
Enter input file name> see attached input files

SALT1959.DAT

input file for the Salt River
19th Ave. to 59th Ave.:

1 512. 4608. -1.3
2 512. 3584. 2.5
3 512. 2560. -1.1
4 512. 1536. -1.7
5 1536. 4608. -2.2
6 1536. 3584. 0.8
7 1536. 2560. -0.7
8 1536. 1536. 0.6
9 1536. 512. 1.7
10 2560. 4608. -5.9
11 2560. 3584. -5.0
12 2560. 2560. -3.3
13 2560. 1536. 1.1
14 3584. 5632. 2.4
15 3584. 4608. -4.7
16 3584. 3584. -3.7
17 3584. 2560. -2.2
18 3584. 1536. 0.8
19 4608. 5632. -3.4
20 4608. 4608. -2.6
21 4608. 3584. -1.3
22 4608. 2560. -1.6
23 5632. 6656. -3.7
24 5632. 5632. -6.1
25 5632. 4608. -2.5
26 5632. 3584. 0.7
27 6656. 6656. -2.8
28 6656. 5632. -6.9
29 6656. 4608. -4.1
30 6656. 3584. 0.3
31 7680. 6656. 0.3
32 7680. 5632. -3.8
33 7680. 4608. -3.8
34 7680. 3584. -0.1
35 8704. 6656. 2.5
36 8704. 5632. -0.5
37 8704. 4608. -0.9
38 8704. 3584. -3.0
39 9728. 6656. 1.6
40 9728. 5632. -1.0
41 9728. 4608. -5.7
42 9728. 3584. -3.7
43 10752. 7680. -5.2
44 10752. 6656. -7.6
45 10752. 5632. -5.7
46 10752. 4608. -5.6
47 10752. 3584. -3.0
48 11776. 7680. -9.4
49 11776. 6656. -11.4
50 11776. 5632. -3.4
51 11776. 4608. -2.3
52 12800. 7680. -8.0

note: the array size for the EXA47 program
is 26,9

53	12800.	6656.	-6.7
54	12800.	5632.	-0.7
55	12800.	4608.	0.1
56	13824.	7680.	-3.1
57	13824.	6656.	-3.2
58	13824.	5632.	-1.8
59	14848.	7680.	2.0
60	14848.	6656.	0.5
61	14848.	5632.	-0.4
62	15872.	7680.	2.9
63	15872.	6656.	-0.5
64	15872.	5632.	-2.6
65	16896.	7680.	1.3
66	16896.	6656.	-1.7
67	16896.	5632.	-1.9
68	17920.	7680.	0.2
69	17920.	6656.	0.2
70	17920.	5632.	1.9
71	18944.	8704.	-1.6
72	18944.	7680.	-5.2
73	18944.	6656.	-6.7
74	18944.	5632.	-1.9
75	19968.	8704.	-1.1
76	19968.	7680.	-7.7
77	19968.	6656.	-4.8
78	19968.	5632.	2.1
79	20992.	8704.	3.3
80	20992.	7680.	-3.8
81	20992.	6656.	0.3
82	20992.	5632.	2.9
83	22016.	8704.	3.4
84	22016.	7680.	-10.5
85	22016.	6656.	-8.1
86	22016.	5632.	-1.0
87	23040.	8704.	0.5
88	23040.	7680.	-20.0
89	23040.	6656.	-16.4
90	23040.	5632.	-0.4
91	24064.	7680.	-5.0
92	24064.	6656.	-4.7
93	24064.	5632.	0.8
94	25088.	7680.	9.3
95	25088.	6656.	8.6
96	25088.	5632.	0.9
97	26112.	6656.	7.5
98	26112.	5632.	1.4

53	10752.	7680.	-7.5
54	10752.	6656.	-9.4
55	10752.	5632.	-14.1
56	10752.	4608.	-21.9
57	10752.	3584.	-10.4
58	11776.	7680.	-3.3
59	11776.	6656.	-9.0
60	11776.	5632.	-14.6
61	11776.	4608.	-12.3
62	11776.	3584.	-3.2
63	12800.	7680.	-1.9
64	12800.	6656.	-5.0
65	12800.	5632.	-14.8
66	12800.	4608.	-8.7
67	13824.	8704.	-16.1
68	13824.	7680.	-21.8
69	13824.	6656.	-15.9
70	14848.	9728.	-3.7
71	14848.	8704.	-21.6
72	14848.	7680.	-48.0
73	14848.	6656.	-29.7
74	15872.	10752.	-1.0
75	15872.	9728.	-6.8
76	15872.	8704.	-10.7
77	15872.	7680.	-17.0
78	15872.	6656.	-20.1
79	16896.	10752.	0.5
80	16896.	9728.	-3.3
81	16896.	8704.	-1.2
82	16896.	7680.	4.0
83	17920.	11776.	-0.6
84	17920.	10752.	-0.9
85	17920.	9728.	-3.4
86	17920.	8704.	-4.1
87	17920.	7680.	-2.2
88	18944.	12800.	0.2
89	18944.	11776.	0.7
90	18944.	10752.	-4.5
91	18944.	9728.	-4.8
92	18944.	8704.	-0.2
93	19968.	12800.	-4.0
94	19968.	11776.	-3.6
95	19968.	10752.	-9.1
96	19968.	9728.	-4.0
97	19968.	8704.	1.4
98	20992.	12800.	-8.8
99	20992.	11776.	-4.4
100	20992.	10752.	-6.5
101	20992.	9728.	-3.9

SALHTCC.DAT

input file for the Salt River
Hayden Rd. to Country Club Dr.:

1	512.	4608.	-0.1
2	512.	3584.	1.0
3	512.	2560.	-2.8
4	512.	1536.	-2.6
5	512.	512.	1.5
6	1536.	4608.	-0.8
7	1536.	3584.	-12.4
8	1536.	2560.	-12.0
9	1536.	1536.	2.9
10	1536.	512.	3.8
11	2560.	4608.	-0.1
12	2560.	3584.	-22.3
13	2560.	2560.	-22.4
14	2560.	1536.	3.0
15	2560.	512.	4.3
16	3584.	4608.	1.0
17	3584.	3584.	-19.6
18	3584.	2560.	-20.7
19	3584.	1536.	0.7
20	3584.	512.	2.7
21	4608.	4608.	-1.9
22	4608.	3584.	-12.0
23	4608.	2560.	-11.3
24	4608.	1536.	1.9
25	4608.	512.	2.1
26	5632.	4608.	-8.0
27	5632.	3584.	-16.8
28	5632.	2560.	-8.5
29	5632.	1536.	1.2
30	6656.	5632.	-1.2
31	6656.	4608.	-14.8
32	6656.	3584.	-23.3
33	6656.	2560.	-7.8
34	6656.	1536.	1.2
35	7680.	6656.	-6.5
36	7680.	5632.	-9.2
37	7680.	4608.	-17.9
38	7680.	3584.	-22.8
39	7680.	2560.	-9.8
40	7680.	1536.	1.2
41	8704.	7680.	-0.8
42	8704.	6656.	-12.7
43	8704.	5632.	-16.7
44	8704.	4608.	-12.8
45	8704.	3584.	-14.6
46	8704.	2560.	-9.5
47	9728.	7680.	0.2
48	9728.	6656.	-4.3
49	9728.	5632.	-16.0
50	9728.	4608.	-20.9
51	9728.	3584.	-12.8
52	9728.	2560.	-3.7

note: the array size for the EXA47 program
is 21,13

AGUAFRIA.DAT

input file for the Agua Fria River:

1 512. 7680. 2.2
2 512. 8704. -3.5
3 512. 9728. -3.0
4 512. 10752. -1.9
5 512. 11776. -2.2
6 512. 12800. -2.9
7 1536. 7680. 3.1
8 1536. 8704. -3.5
9 1536. 9728. -2.6
10 1536. 10752. -0.8
11 1536. 11776. -1.4
12 1536. 12800. -1.3
13 2560. 7680. -2.7
14 2560. 8704. -2.5
15 2560. 9728. -2.3
16 2560. 10752. -2.3
17 2560. 11776. -1.6
18 2560. 12800. -0.2
19 3584. 7680. -4.4
20 3584. 8704. -5.2
21 3584. 9728. -3.2
22 3584. 10752. -2.5
23 3584. 11776. -1.5
24 3584. 12800. 0.3
25 4608. 5632. -1.5
26 4608. 6656. -2.6
27 4608. 7680. -4.9
28 4608. 8704. -6.7
29 4608. 9728. -4.3
30 4608. 10752. -2.8
31 5632. 5632. -0.2
32 5632. 6656. 0.3
33 5632. 7680. 0.1
34 5632. 8704. -1.7
35 5632. 9728. -1.8
36 6656. 5632. -0.1
37 6656. 6656. -11.8
38 6656. 7680. -10.3
39 6656. 8704. -2.2
40 6656. 9728. -4.3
41 7680. 5632. 0.0
42 7680. 6656. -13.1
43 7680. 7680. -18.0
44 7680. 8704. -8.5
45 7680. 9728. -2.5
46 8704. 4608. -2.0
47 8704. 5632. -1.4
48 8704. 6656. -1.1
49 8704. 7680. -3.7
50 8704. 8704. -2.5
51 8704. 9728. 2.5
52 9728. 4608. -1.8
53 9728. 5632. -1.7

note: the array size for the EXA47 program
is 26,13

54	9728.	6656.	-2.2
55	9728.	7680.	-1.0
56	9728.	8704.	1.7
57	9728.	9728.	2.3
58	10752.	4608.	-1.0
59	10752.	5632.	-1.5
60	10752.	6656.	-0.9
61	10752.	7680.	0.8
62	11776.	4608.	-0.5
63	11776.	5632.	-0.7
64	11776.	6656.	0.2
65	11776.	7680.	0.8
66	12800.	4608.	-0.8
67	12800.	5632.	0.2
68	12800.	6656.	-0.3
69	12800.	7680.	-0.9
70	13824.	3584.	-0.6
71	13824.	4608.	-0.2
72	13824.	5632.	-0.3
73	13824.	6656.	0.1
74	13824.	7680.	0.6
75	14848.	2560.	-0.1
76	14848.	3584.	0.0
77	14848.	4608.	0.0
78	14848.	5632.	-1.3
79	14848.	6656.	-0.9
80	14848.	7680.	0.2
81	15872.	2560.	0.2
82	15872.	3584.	-0.2
83	15872.	4608.	-2.2
84	15872.	5632.	-3.2
85	15872.	6656.	-1.2
86	15872.	7680.	-1.2
87	16896.	1536.	1.2
88	16896.	2560.	3.1
89	16896.	3584.	-0.7
90	16896.	4608.	-1.4
91	16896.	5632.	-0.6
92	16896.	6656.	0.5
93	17920.	1536.	-1.1
94	17920.	2560.	-1.2
95	17920.	3584.	0.5
96	17920.	4608.	1.1
97	17920.	5632.	1.6
98	18944.	512.	-1.5
99	18944.	1536.	-1.7
100	18944.	2560.	0.7
101	18944.	3584.	-2.8
102	19968.	512.	-2.9
103	19968.	1536.	0.9
104	19968.	2560.	1.5
105	19968.	3584.	-1.7
106	20992.	512.	0.8
107	20992.	1536.	-1.1
108	20992.	2560.	-1.2
109	20992.	3584.	-0.2

110	20992.	4608.	5.5
111	22016.	512.	0.7
112	22016.	1536.	-0.6
113	22016.	2560.	0.0
114	22016.	3584.	0.1
115	22016.	4608.	-0.9
116	23040.	512.	0.2
117	23040.	1536.	-2.3
118	23040.	2560.	-1.0
119	23040.	3584.	0.8
120	23040.	4608.	-1.6
121	24064.	512.	-0.5
122	24064.	1536.	-2.6
123	24064.	2560.	-2.4
124	24064.	3584.	-0.4
125	24064.	4608.	-0.7
126	25088.	512.	1.4
127	25088.	1536.	-0.2
128	25088.	2560.	-1.8
129	25088.	3584.	-1.5
130	25088.	4608.	-0.1
131	26112.	512.	0.9
132	26112.	1536.	1.4
133	26112.	2560.	-0.4
134	26112.	3584.	-1.2
135	26112.	4608.	-0.4

NEWRIVER.DAT

input file for the New River:

1	512.	8704.	1.2
2	512.	9728.	0.5
3	1536.	8704.	-0.4
4	1536.	9728.	-0.2
5	2560.	8704.	-1.7
6	3584.	8704.	-0.3
7	4608.	7680.	-0.6
8	4608.	8704.	-0.2
9	5632.	7680.	2.6
10	5632.	8704.	-1.5
11	6656.	6656.	4.1
12	6656.	7680.	3.7
13	6656.	8704.	-0.6
14	7680.	6656.	1.9
15	7680.	7680.	1.9
16	8704.	6656.	1.9
17	8704.	7680.	1.7
18	9728.	5632.	-1.4
19	9728.	6656.	1.2
20	9728.	7680.	1.
21	9728.	8704.	-3.1
22	10752.	5632.	-1.3
23	10752.	6656.	1.2
24	10752.	7680.	1.3
25	10752.	8704.	-2.3
26	11776.	5632.	2.2
27	11776.	6656.	1.4
28	11776.	7680.	-0.6
29	11776.	8704.	-1.7
30	12800.	4608.	-0.9
31	12800.	5632.	3.9
32	12800.	6656.	4.8
33	12800.	7680.	-2.7
34	13824.	4608.	-4.4
35	13824.	5632.	-1.8
36	13824.	6656.	-2.0
37	13824.	7680.	-2.1
38	14848.	3584.	-2.9
39	14848.	4608.	-6.4
40	14848.	5632.	-5.6
41	14848.	6656.	-2.7
42	15872.	3584.	4.1
43	15872.	4608.	-4.0
44	15872.	5632.	-5.1
45	15872.	6656.	-2.8
46	16896.	2560.	1.9
47	16896.	3584.	-1.0
48	16896.	4608.	-7.3
49	16896.	5632.	-1.9
50	17920.	2560.	-2.1
51	17920.	3584.	-3.3
52	17920.	4608.	-6.5
53	17920.	5632.	-1.1

note: the array size for the EXA47 program
is 21,10

54 17920. 6656. -1.3
55 18944. 1536. 1.2
56 18944. 2560. 1.2
57 18944. 3584. -0.9
58 19968. 512. -2.0
59 19968. 1536. 3.4
60 19968. 2560. -2.6
61 19968. 3584. -0.7
62 19968. 4608. -2.6
63 20992. 1636. -3.3
64 20992. 2560. 1.7
65 20992. 3584. -1.4

VERDEHR.DAT

input file for the Verde River

near Cottonwood:

1	256.	256.	-.4
2	768.	256.	-3.2
3	768.	768.	-1.2
4	768.	1280.	.8
5	1280.	256.	-2.5
6	1280.	768.	-1.2
7	1280.	1280.	1.5
8	1280.	1792.	.7
9	1280.	2304.	-1.0
10	1280.	2816.	-1.5
11	1280.	3328.	.7
12	1280.	3840.	-3.2
13	1280.	4352.	-5.8
14	1280.	4864.	-.1
15	1280.	5376.	1.9
16	1792.	1280.	1.7
17	1792.	1792.	.5
18	1792.	2304.	.1
19	1792.	2816.	-.4
20	1792.	3328.	-.3
21	1792.	3840.	-1.7
22	1792.	4352.	-3.2
23	1792.	4864.	1.1
24	1792.	5376.	2.3
25	1792.	5888.	3.5
26	2304.	3840.	-3.0
27	2304.	4352.	.2
28	2304.	4864.	1.5
29	2304.	5376.	5.9
30	2304.	5888.	4.9
31	2816.	3840.	-3.6
32	2816.	4352.	.9
33	2816.	4864.	.0
34	2816.	5376.	2.8
35	2816.	5888.	4.2
36	3328.	3840.	-.8
37	3328.	4352.	.1
38	3328.	4864.	.0
39	3328.	5376.	-1.7
40	3328.	5888.	-1.0
41	3840.	3328.	.9
42	3840.	3840.	-.5
43	3840.	4352.	.8
44	3840.	4864.	2.2
45	3840.	5376.	.2
46	4352.	3328.	2.7
47	4352.	3840.	.8
48	4352.	4352.	.2
49	4352.	4864.	1.1
50	4352.	5376.	-.2
51	4864.	3328.	1.7
52	4864.	3840.	.8
53	4864.	4352.	.3

note: the array size for the EXA47
program is 15,12

54	5376.	2816.	-.8
55	5376.	3328.	.7
56	5376.	3840.	1.4
57	5376.	4352.	2.5
58	5376.	4864.	1.7
59	5376.	5376.	1.2
60	5888.	3328.	2.3
61	5888.	3840.	2.4
62	5888.	4352.	4.0
63	5888.	4864.	4.0
64	5888.	5376.	3.3
65	6400.	3328.	1.6
66	6400.	3840.	.8
67	6400.	4352.	.3
68	6400.	4864.	1.6
69	6400.	5376.	1.0
70	6912.	3840.	-.5
71	6912.	4352.	2.1
72	6912.	4864.	-1.9
73	6912.	5376.	-4.3
74	7424.	4352.	4.8
75	7424.	4864.	.0
76	7424.	5376.	-3.8

RILLITO.DAT

input file for Rillito Creek:

1	256.	7424.	-1.2	note: the array size for the EXA47 program is 19,14
2	768.	7424.	-0.8	
3	1280.	7424.	-0.7	
4	256.	6912.	2.3	
5	768.	6912.	2.7	
6	1280.	6912.	-2.3	
7	1792.	6912.	-4.3	
8	256.	6400.	-6.9	
9	768.	6400.	1.4	
10	1280.	6400.	-10.1	
11	1792.	6400.	-4.9	
12	768.	5376.	-2.9	
13	1280.	5376.	-8.9	
14	1792.	5376.	-7.7	
15	768.	4864.	-2.7	
16	1280.	4864.	-2.5	
17	1792.	4864.	-3.1	
18	2304.	4864.	-3.7	
19	2816.	4864.	-0.6	
20	3328.	4864.	-1.1	
21	1280.	4352.	-1.1	
22	1792.	4352.	-5.7	
23	2304.	4352.	-3.4	
24	2816.	4352.	-2.3	
25	3328.	4352.	-4.1	
26	2816.	3480.	-3.9	
27	3328.	2480.	-5.0	
28	3840.	2480.	-3.7	
29	4352.	3480.	-8.1	
30	4864.	3480.	-4.8	
31	5376.	3480.	-1.5	
32	5888.	3480.	-0.5	
33	6400.	3480.	-1.7	
34	6912.	3480.	-2.4	
35	5888.	3328.	-0.5	
36	6400.	3328.	-2.2	
37	6912.	3328.	-3.0	
38	7424.	3328.	-4.1	
39	7936.	3328.	-2.2	
40	8448.	3328.	3.7	
41	8960.	3328.	0.2	
42	9472.	3328.	-2.8	
43	5888.	2816.	0.3	
44	6400.	2816.	-1.7	
45	6912.	2816.	-1.2	
46	7424.	2816.	-2.6	
47	7936.	2816.	-3.2	
48	8448.	2816.	-4.7	
49	8960.	2816.	-3.0	
50	9472.	2816.	-1.4	
51	6400.	2304.	0.1	
52	6912.	2304.	-0.3	
53	7424.	2304.	-1.4	

54	7936.	2304.	-2.1
55	8448.	2304.	-2.5
56	8960.	2304.	-4.8
57	9472.	2304.	-4.0
58	6912.	1792.	-4.6
59	7424.	1792.	-0.4
60	7936.	1792.	1.3
61	8448.	1792.	1.0
62	8960.	1792.	-3.0
63	9472.	1792.	-2.7
64	7424.	1280.	0.0
65	7936.	1280.	1.7
66	8448.	1280.	2.8
67	8960.	1280.	3.5
68	9472.	1280.	1.7
69	7936.	768.	2.6
70	8448.	768.	0.9
71	8960.	768.	4.5
72	9472.	768.	11.5
73	8448.	256.	0.4
74	8960.	256.	2.6
75	9472.	256.	2.9

SALT RIVER
HAYDEN RD TO COUNTRY CLUB DR
CHANGE IN ELEVATION : 1962 TO 1986

G-55

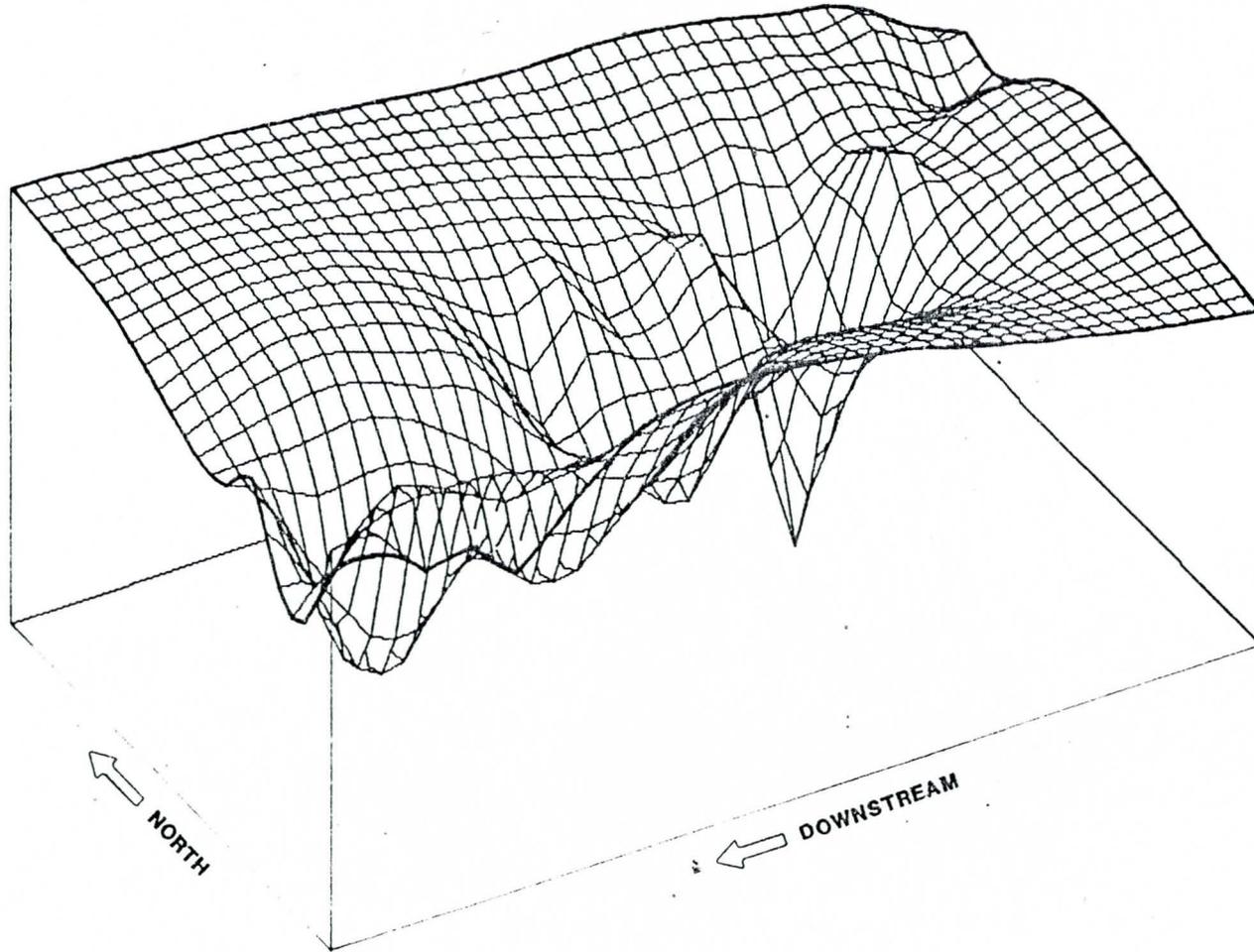


FIGURE G.30

SALT RIVER

19TH AVE TO 59TH AVE

CHANGE IN ELEVATION: 1962 TO 1983

G-56

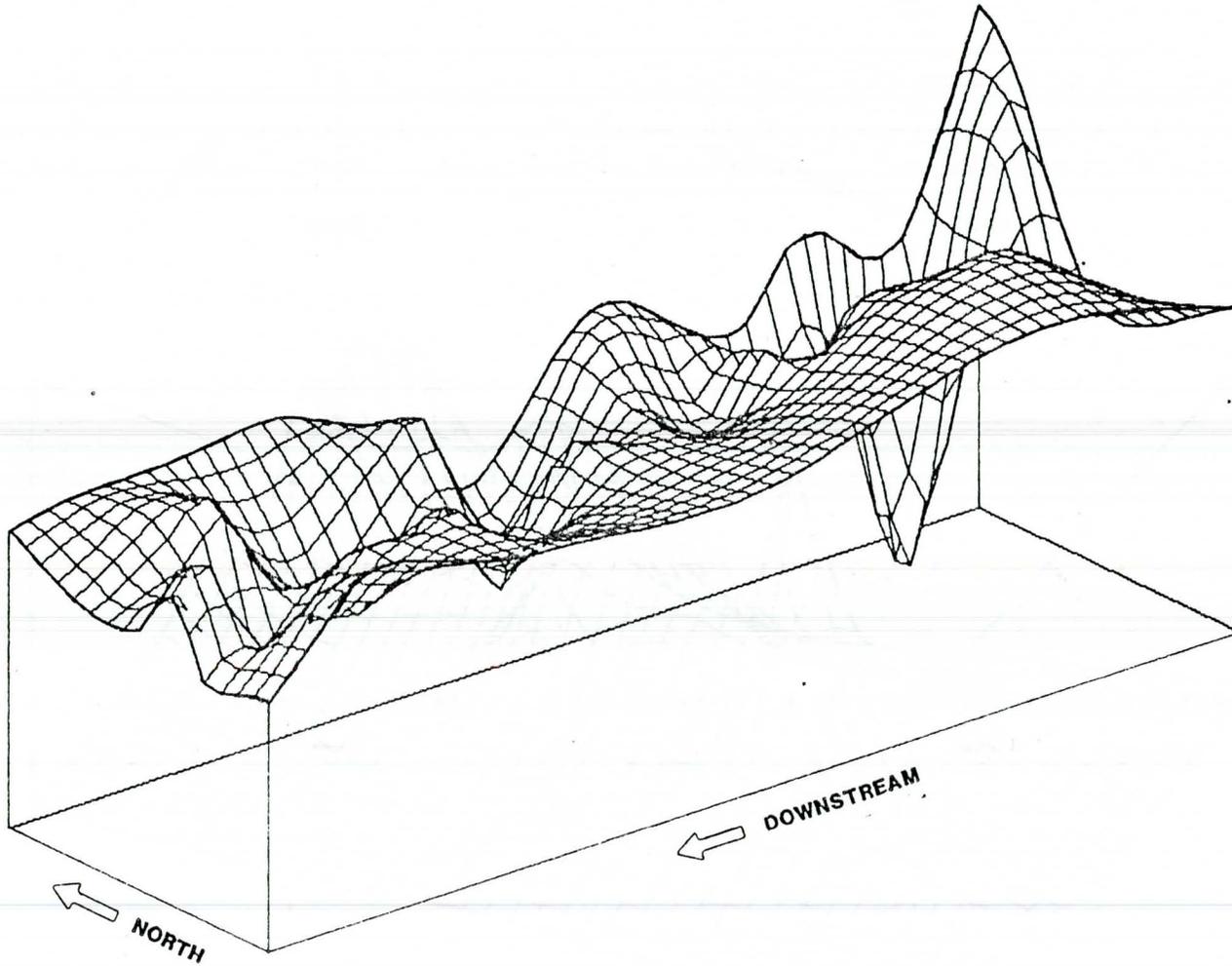
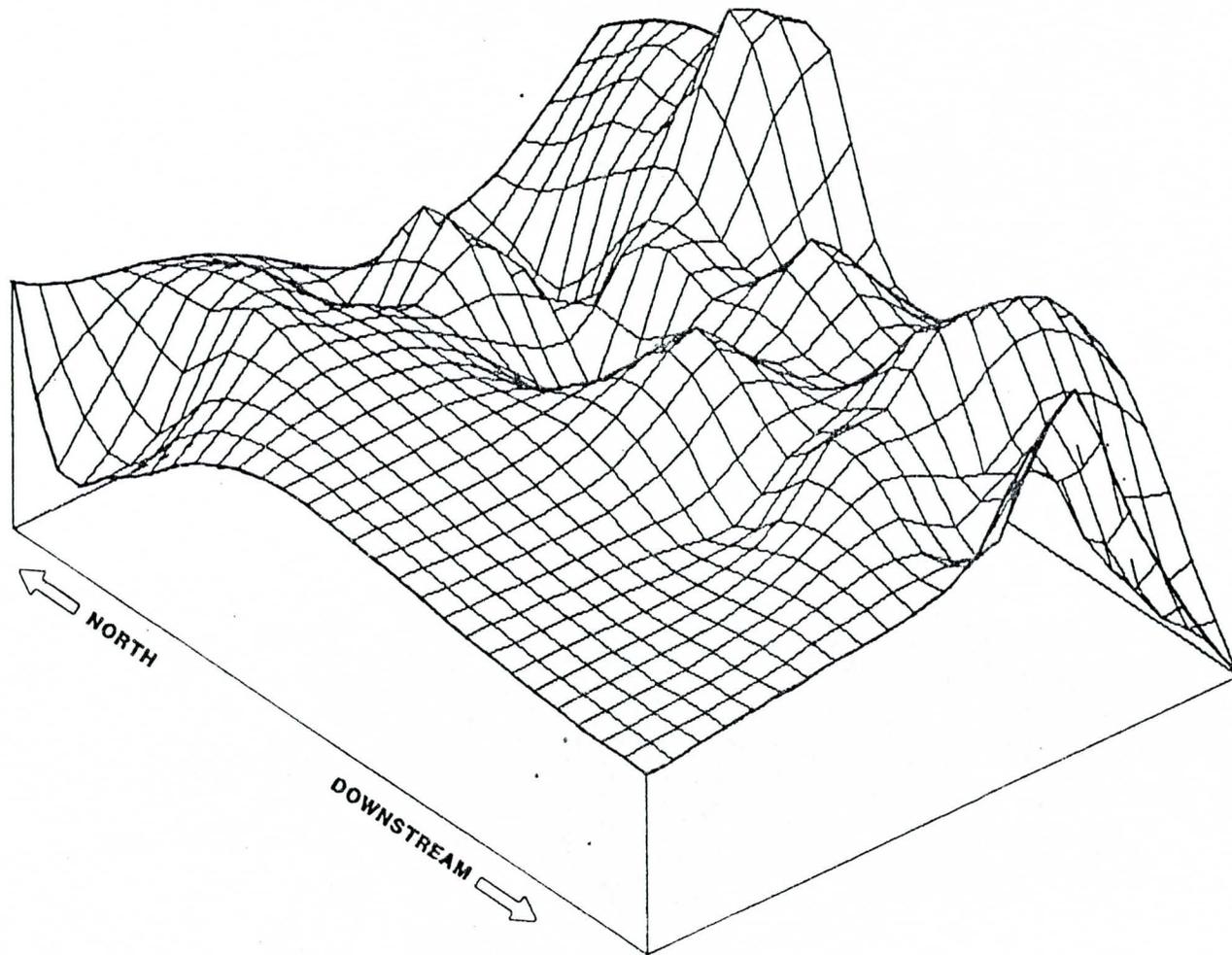


FIGURE G.31

**VERDE RIVER
NEAR COTTONWOOD**

CHANGE IN ELEVATION: 1976 TO 1982



G-57

FIGURE G.32

AGUA FRIA RIVER

CHANGE IN ELEVATION: 1972 TO 1981

G-58

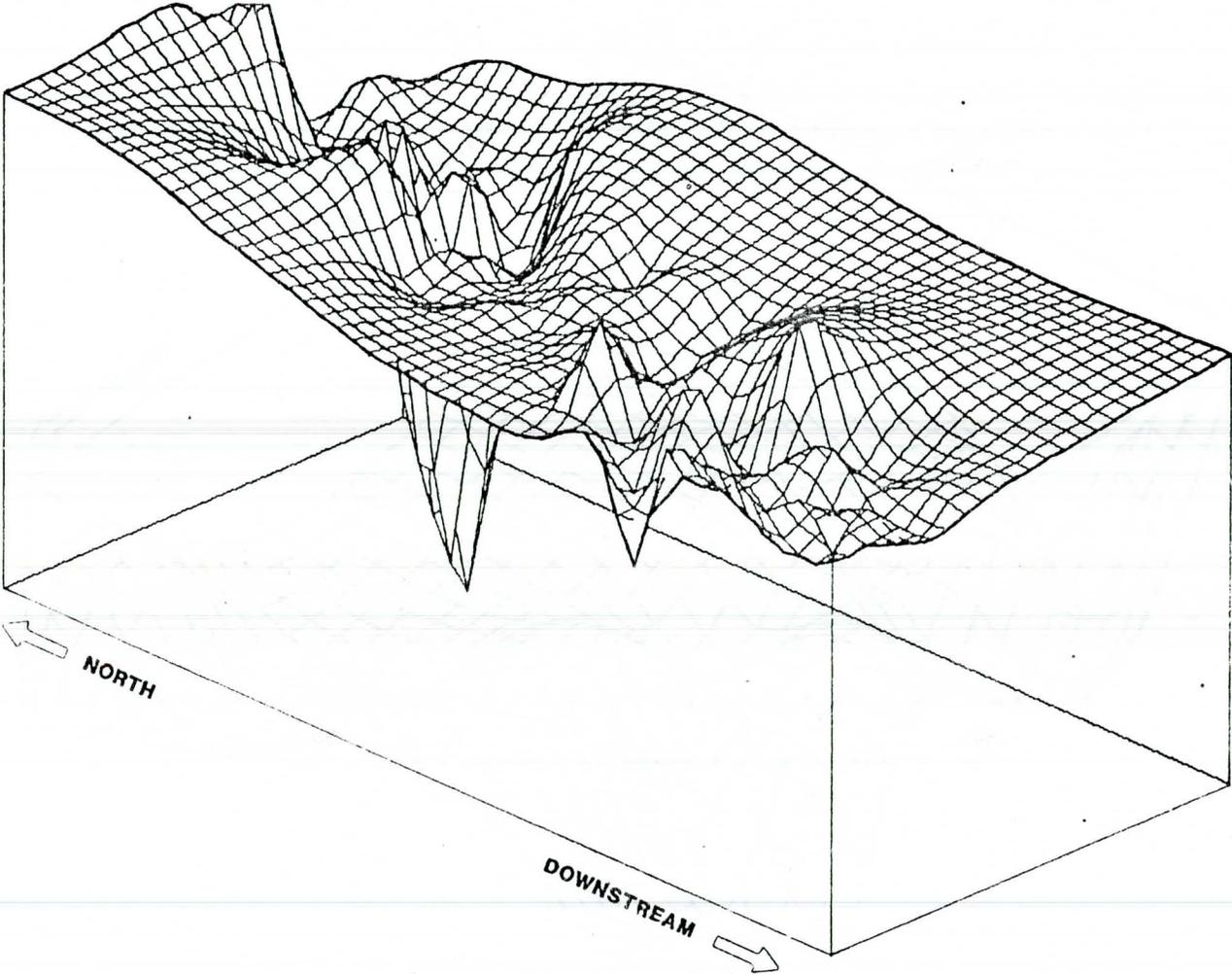
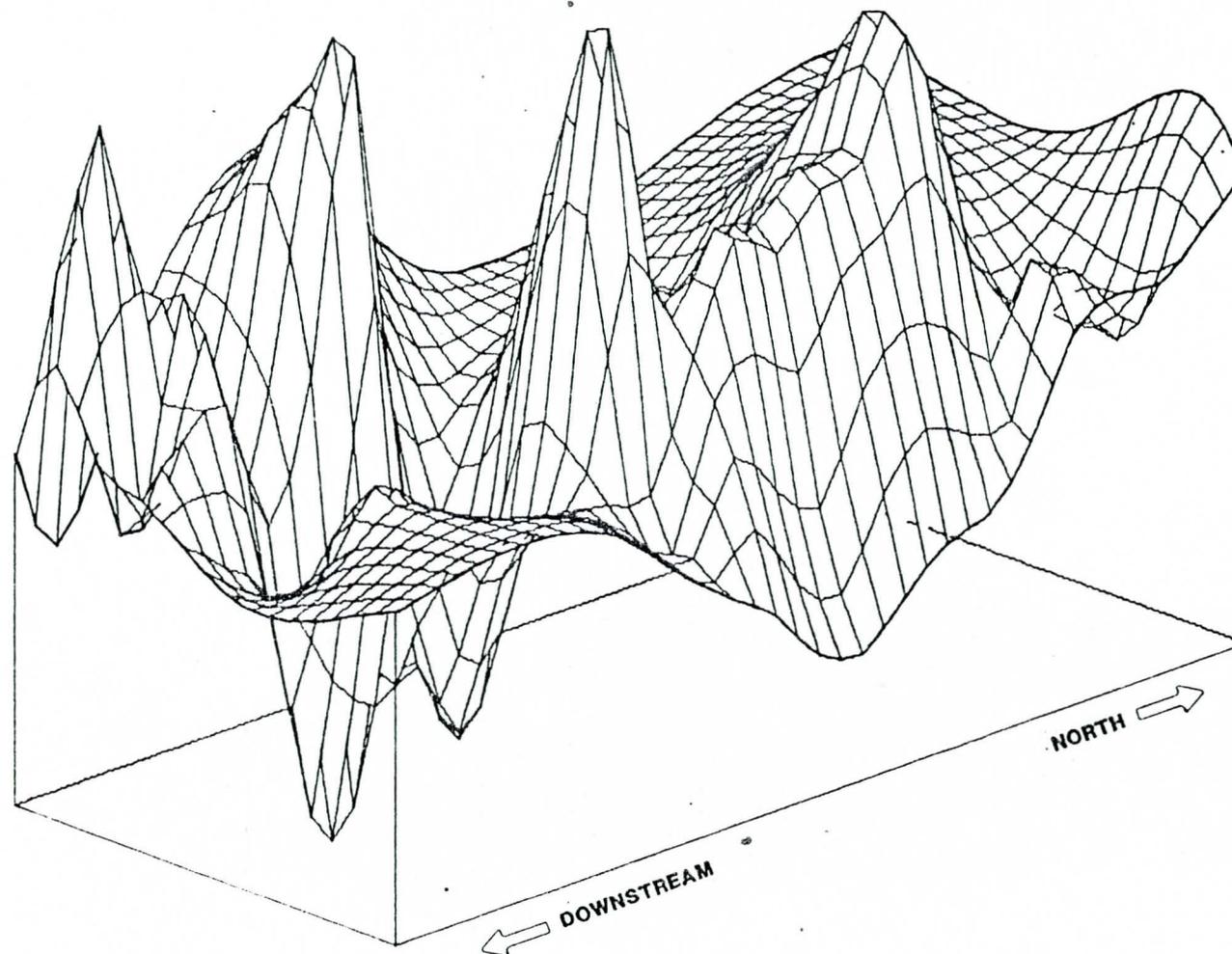


FIGURE G.33

NEW RIVER

CHANGE IN ELEVATION: 1976 TO 1981



G-59

FIGURE G.34

RILLITO CREEK

CHANGE IN ELEVATION: 1967 TO 1984

G-60

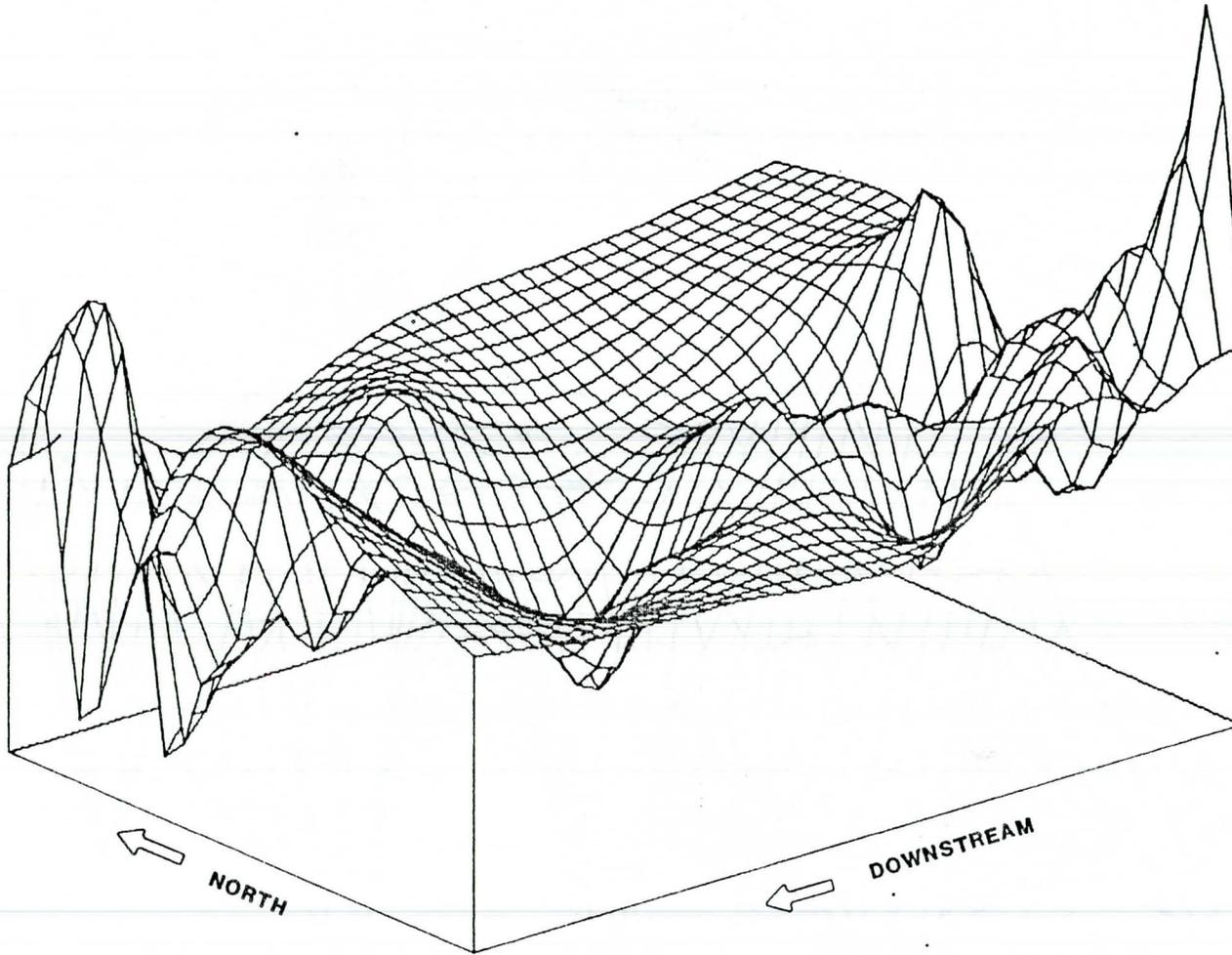


FIGURE G.35

I9-G

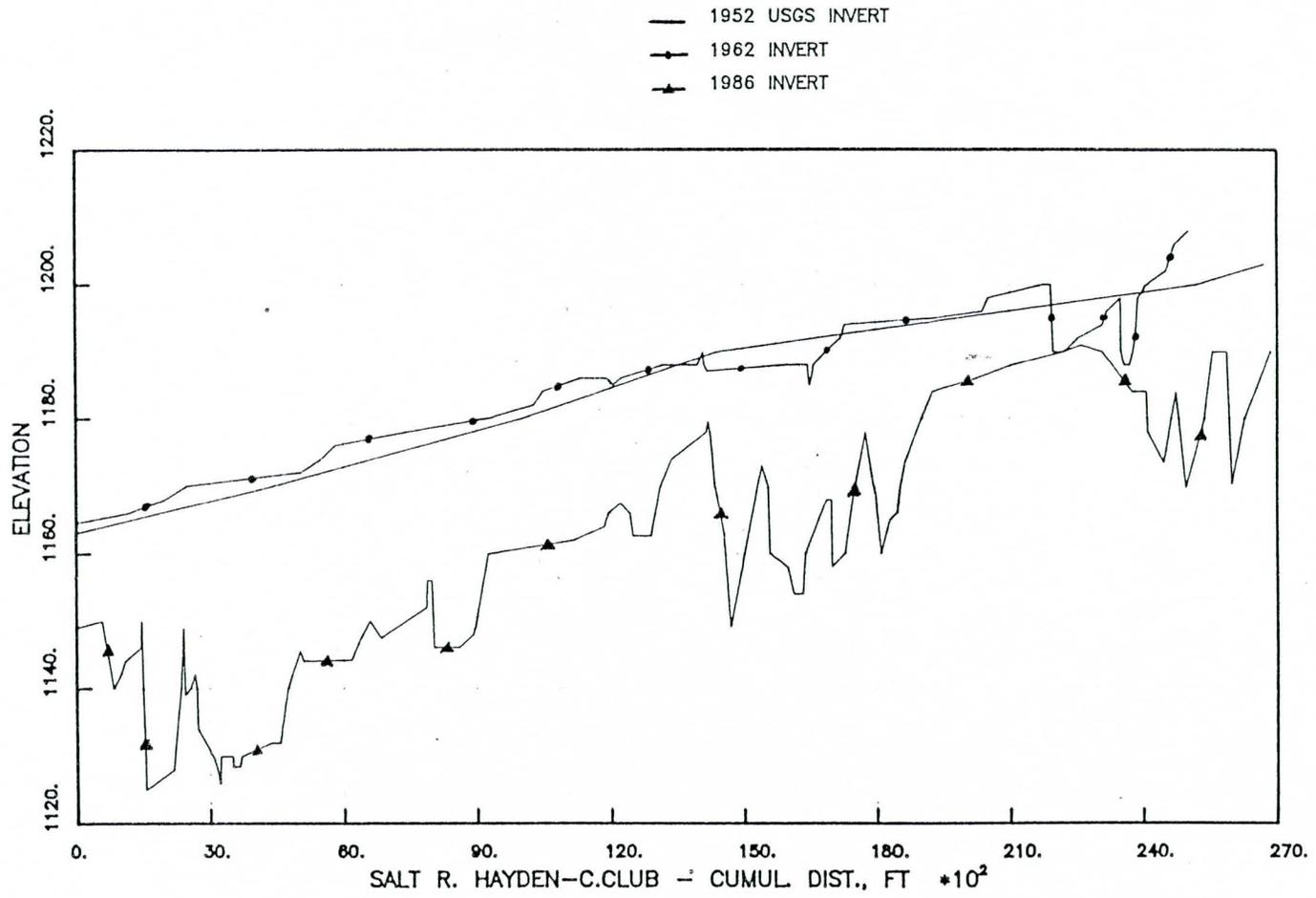


FIGURE G.36

G-62

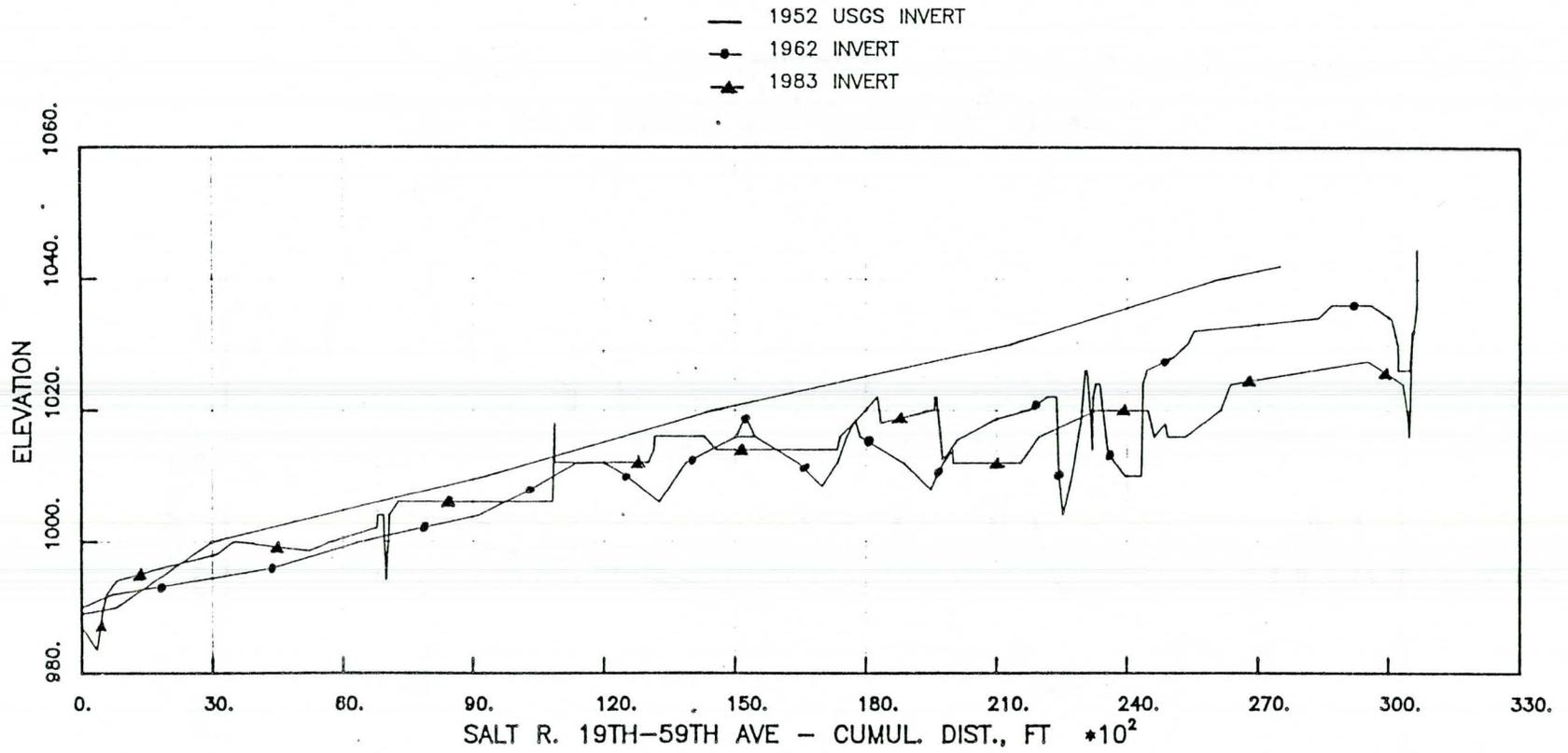


FIGURE G.37

69-5

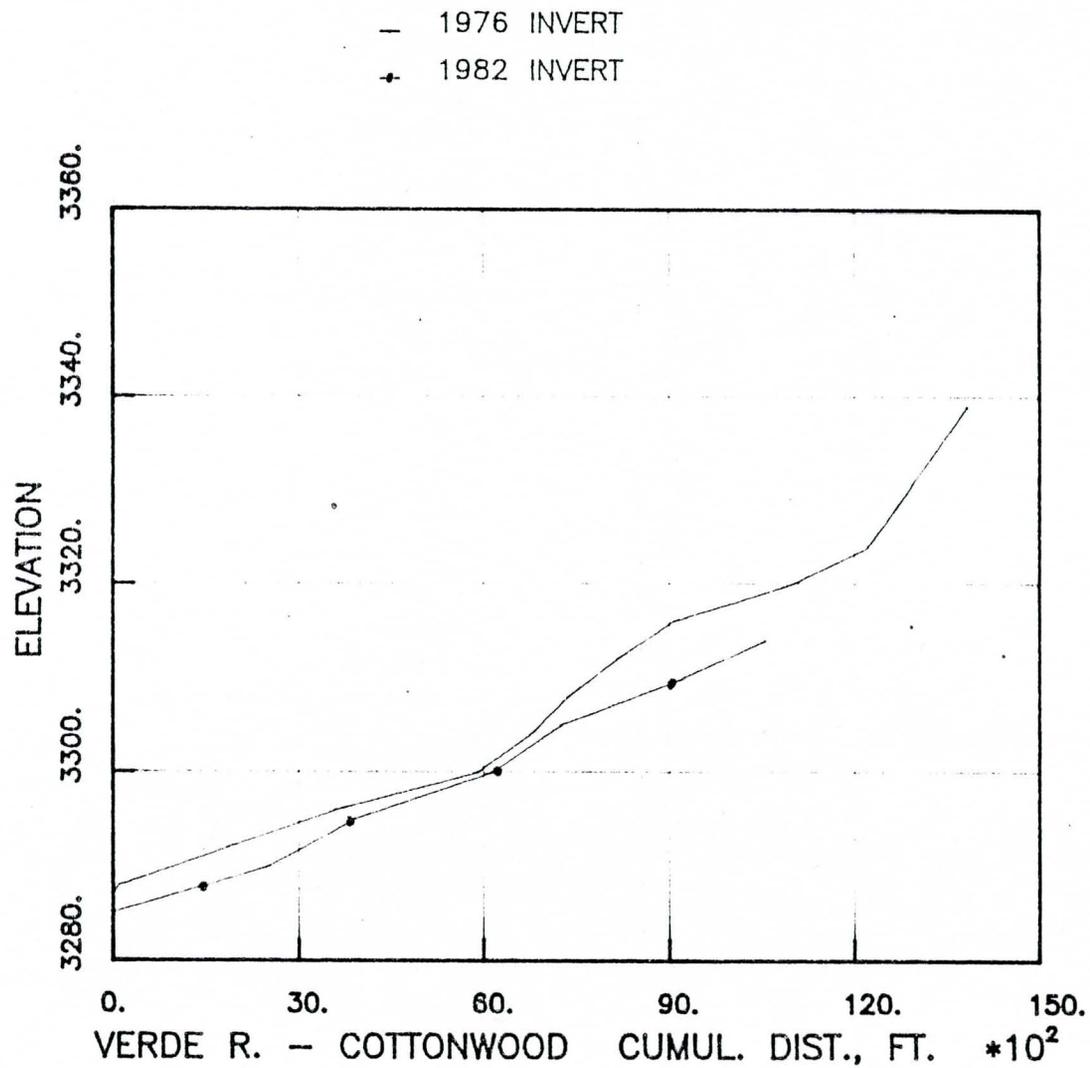


FIGURE G.38

G-64

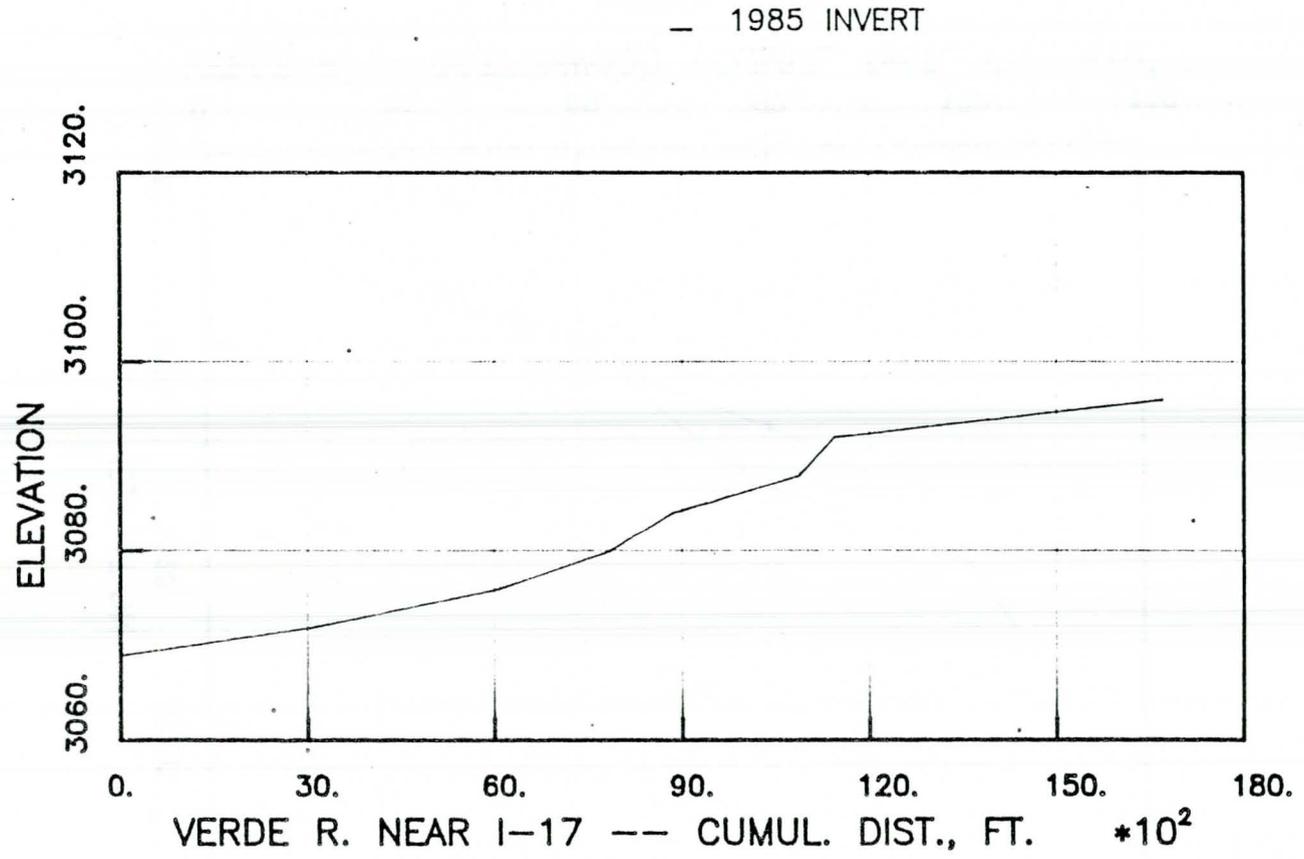


FIGURE G.39

S9-G

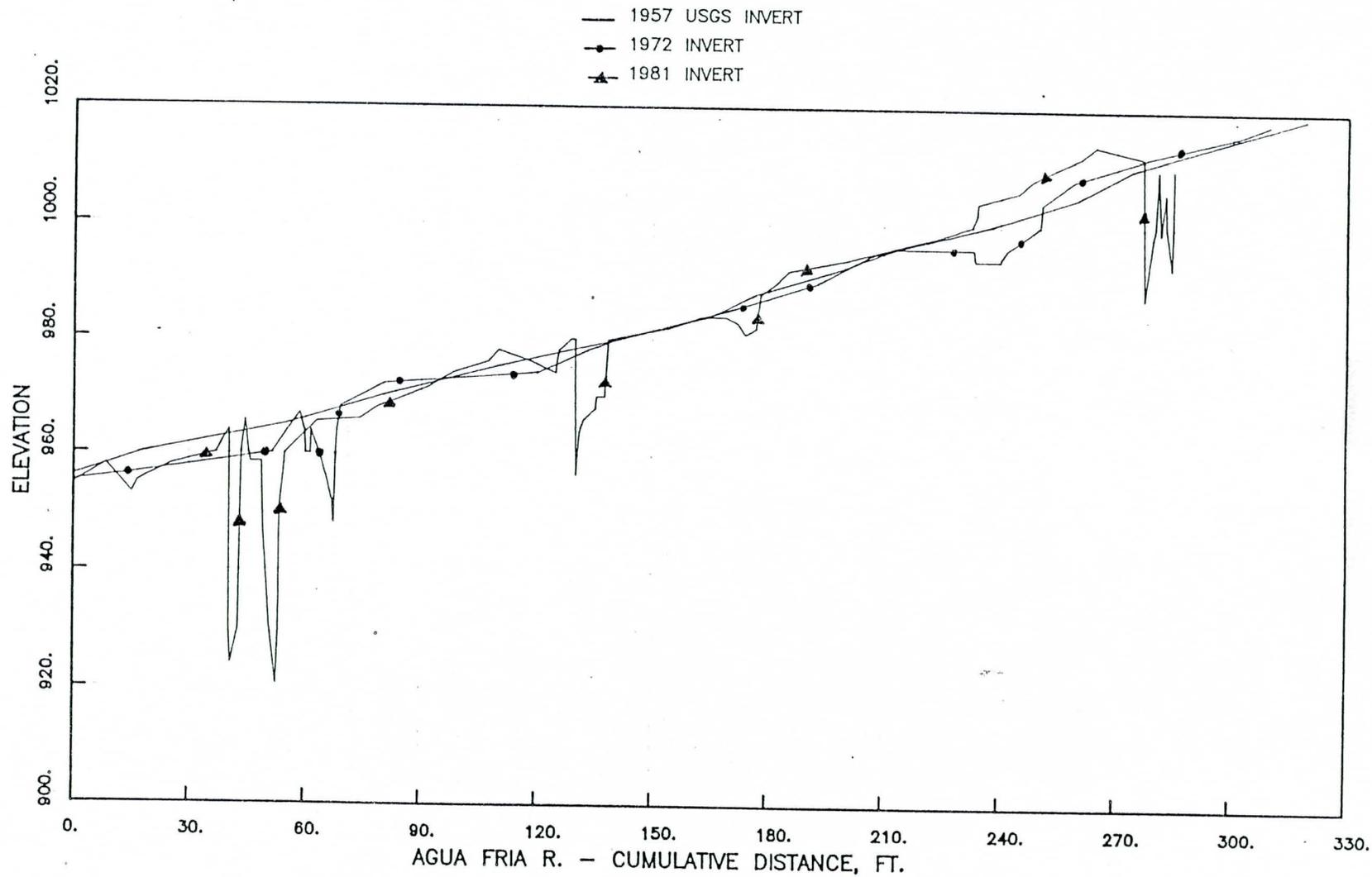


FIGURE G.40

99-G

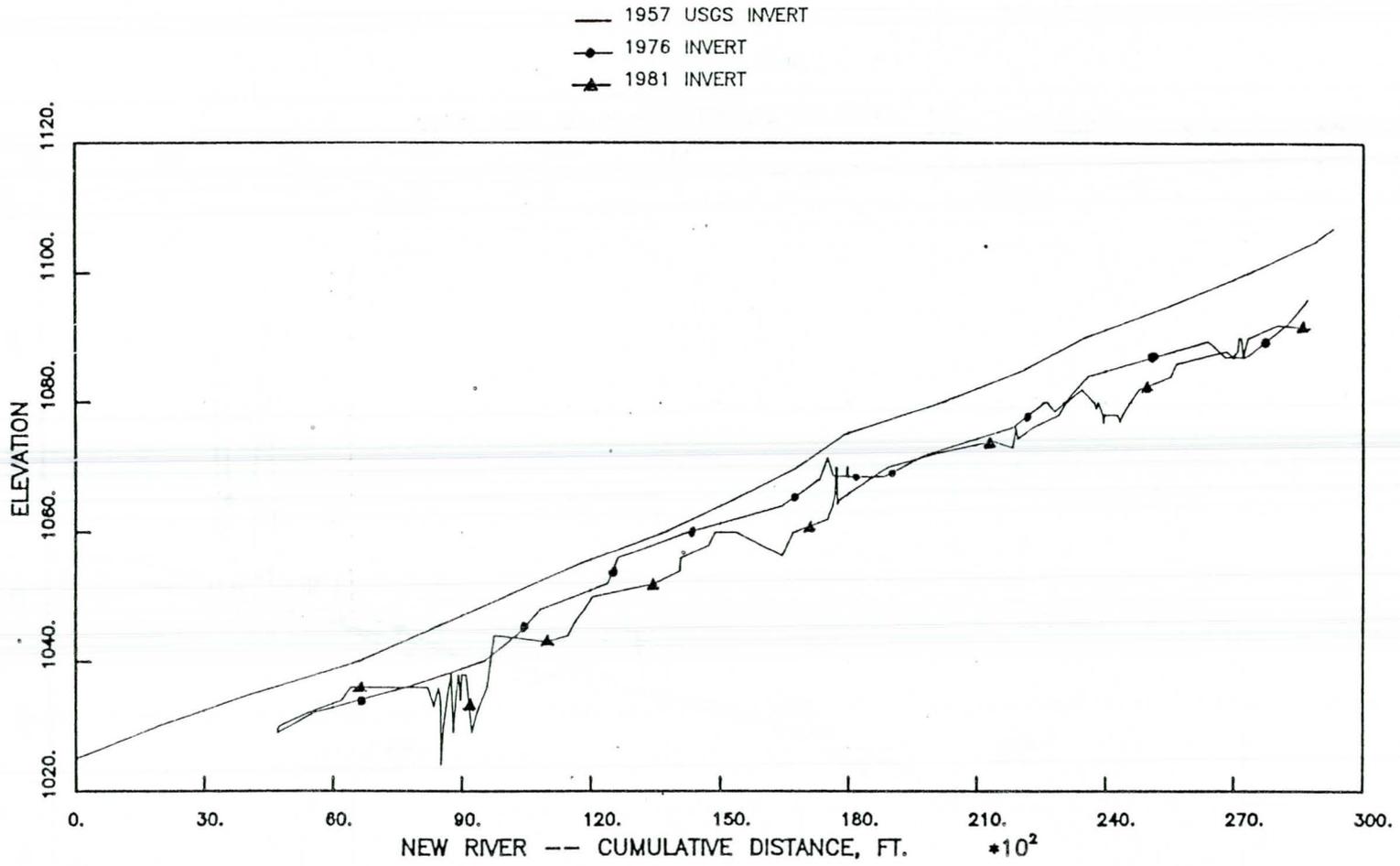


FIGURE G.41

G-67

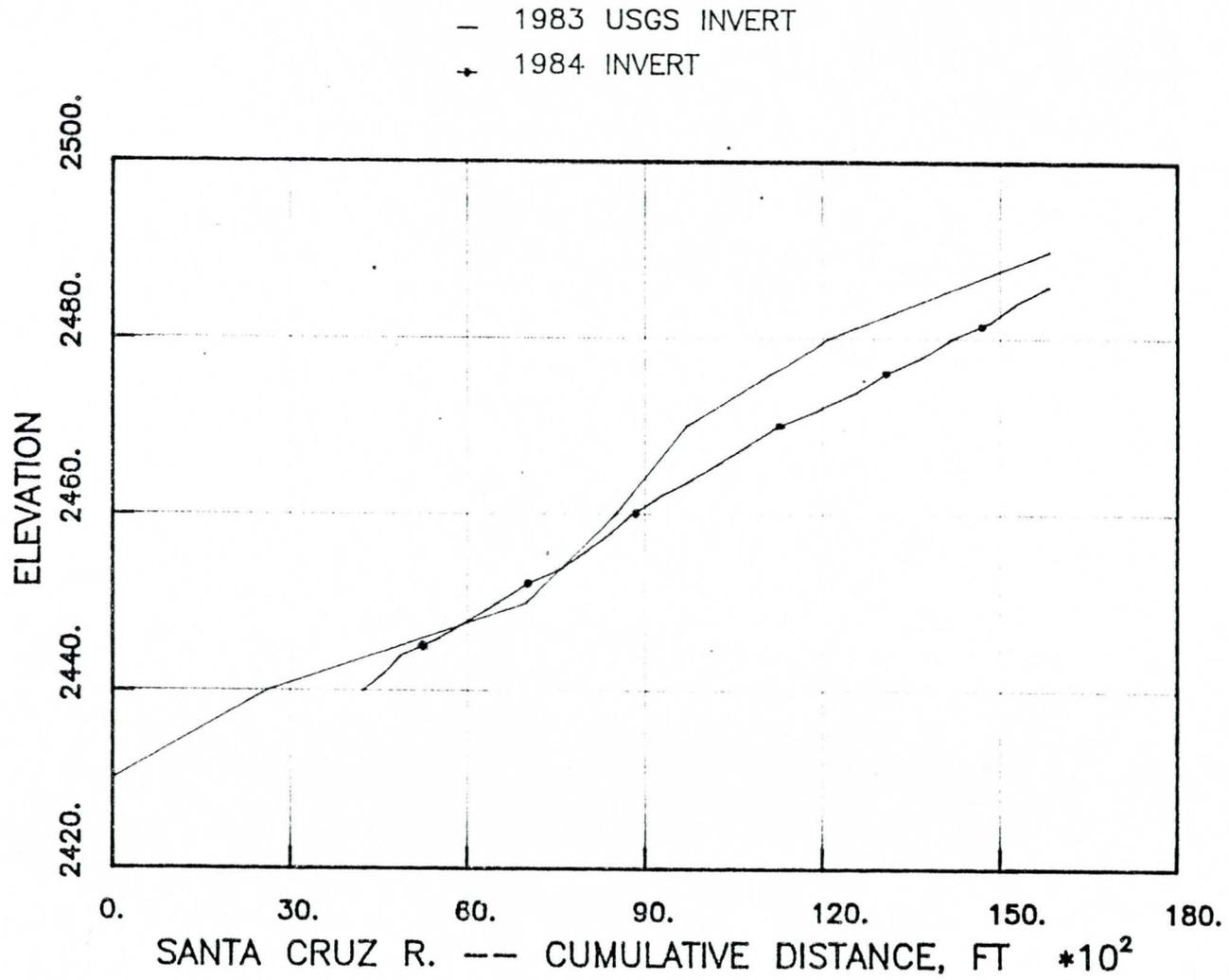


FIGURE G.42

89-G

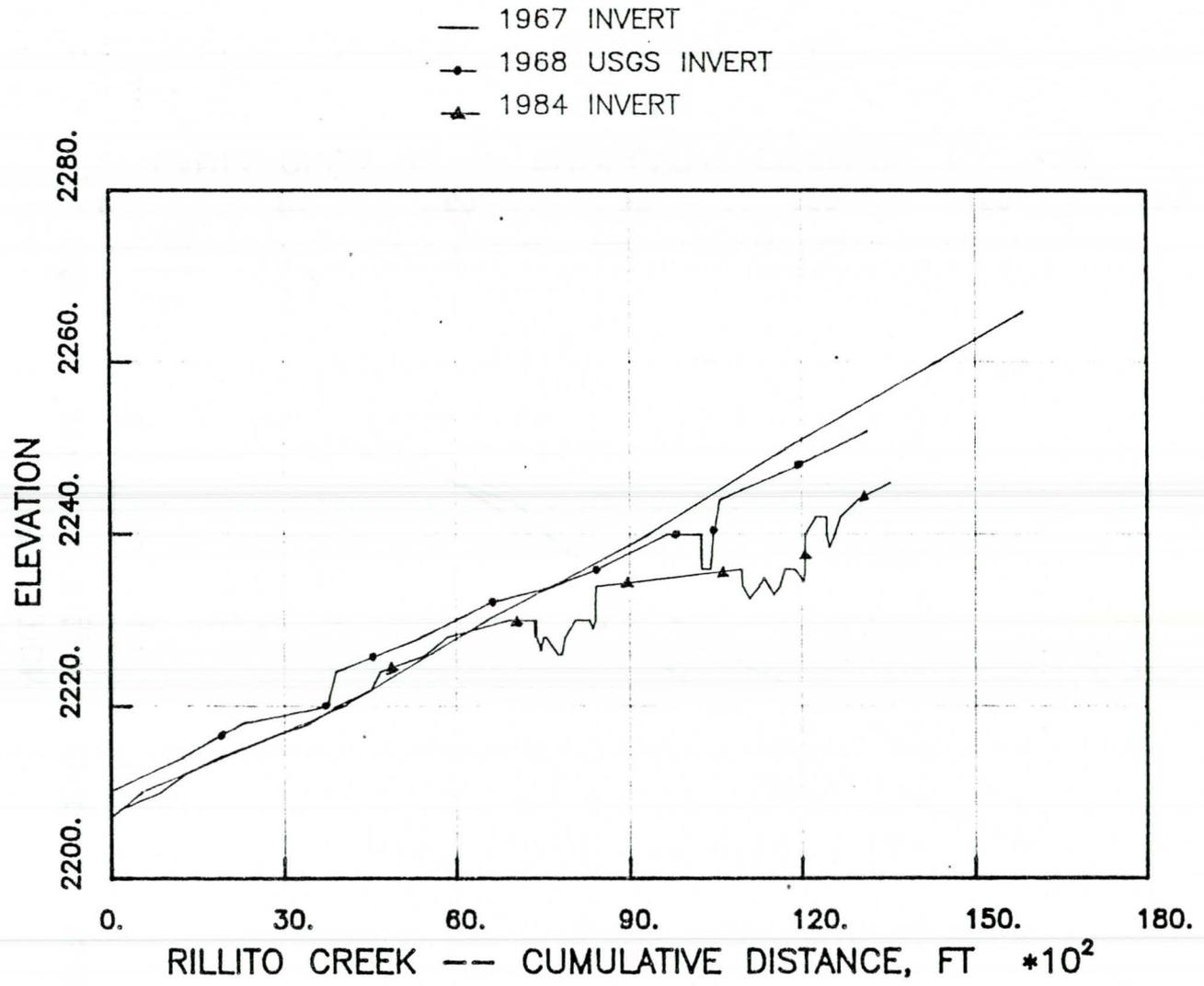


FIGURE G.43

APPENDIX H. BED MATERIAL GRADATION DATASET

H.1 Purpose/Objective

Sediment transport analysis is dependent on many physical parameters, not the least of which includes an accurate description of the river's bed and bank material. One of the key elements in the modeling of localized sediment transport is an accurate determination of the characteristic particle size. Upon acquiring bed material gradation data from the Arizona Department of Transportation's Materials Section, the bed material samples associated with this study's river reaches were statistically analyzed. This statistical analysis permits a probabilistic assessment to be developed for the median particle size, the D₅₀, and gradation coefficient. The analyzed bed material data can then be used to define limits, within reasonable probability, for various input parameters required by a localized sediment transport model.

H.2 Sources of Data

1. Arizona Department of Transportation, Materials Section; "Materials Inventory Database", Geotechnical Group, started in the early 1960s.

2. Arizona Department of Transportation, Materials Section, "Materials Pit Inventory Files", Geotechnical Group.

Thanks must be extended to the following people for their assistance in the acquisition of the raw data:

Ottozawa Chatupron, P.E., AZ Transportation Research Center
Albert R. Gastelum, ADOT Materials Pavement Analyst
Ronald W. Krohn, ADOT Materials Geotechnical Section
John E. Lawson, P.E., ADOT Geotechnical Services Engineer
Donald Mercer, P.E., ADOT Materials Investigation Engineer

To acquire the raw data for the specific river reaches, pit numbers in the area of interest were located using ADOT's Materials Inventory Maps. With the location of the specific pit numbers of interest, a list was developed to sort out the pertinent data from the Materials Inventory Database. With the help of ADOT personnel, this information was downloaded in card format to a file accessible by a personal computer to be statistically manipulated at a later date.

Each material pit could contain up to a maximum number of five different card types (see Figure H.1):

Card #1 - Contained pit number and location by township and range, county, map number, $\frac{1}{4}$ section, and nearest highway station.

1 - MATERIALS INVENTORY

DATE _____
NAME _____

K/P _____
 VERIFY _____
PAGE _____ OF _____

SRT	PIT NO.	CO.	MAP NO.	SEC.	TWP.	RANGE	PROJECT, NO.	PROJECT NAME	LOCATION BY STATION
1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80

2 - MATERIALS INVENTORY

DATE _____
NAME _____

K/P _____
 VERIFY _____
PAGE _____ OF _____

SRT	PIT NO.	ROUTE NO.	M.P.	LAND STATUS	EXPIRATION DATE OF PIT LIC.	AERIAL PHOTO JOB NO.	DATE OF AERIAL PHOTOGRAPH	C	QUANTITY USED	USED FOR	16 GA. CMP LIFE	ABR. 500 REV.	UNIT WEIGHT PCF	MATERIAL DESCRIPTION
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
76	77	78	79	80	81	82	83	84	85	86	87	88	89	90

3 - MATERIALS INVENTORY

DATE _____
NAME _____

K/P _____
 VERIFY _____
PAGE _____ OF _____

SRT	PIT NO.	PIT COMMENTS
1	2	3
4	5	6
7	8	9
10	11	12
13	14	15
16	17	18
19	20	21
22	23	24
25	26	27
28	29	30
31	32	33
34	35	36
37	38	39
40	41	42
43	44	45
46	47	48
49	50	51
52	53	54
55	56	57
58	59	60
61	62	63
64	65	66
67	68	69
70	71	72
73	74	75
76	77	78
79	80	81
82	83	84
85	86	87
88	89	90
91	92	93
94	95	96
97	98	99
100	101	102

MATERIALS SERVICES

4 - MATERIALS INVENTORY v - INDICATES FIELD JUSTIFICATION

DATE _____
NAME _____

K/P _____
 VERIFY _____
PAGE _____ OF _____

SRT	PIT NO.	HOLE NO.	DEPTH	% PASS 6 IN.	% PASS 3 IN.	% PASS 2 1/2 IN.	% PASS 2 IN.	% PASS 1 1/2 IN.	% PASS 1 IN.	% PASS 3/4 IN.	% PASS 1/2 IN.	% PASS 1/4 IN.	% PASS #4	% PASS #8	% PASS #10	% PASS #16	% PASS #20	% PASS #40	% PASS #50	% PASS #100	% PASS #200	PI	SE	R	J
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	
51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	
76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	

MATERIALS SERVICES

5 - MATERIALS INVENTORY v - INDICATES FIELD JUSTIFICATION

DATE _____
NAME _____

K/P _____
 VERIFY _____
PAGE _____ OF _____

SRT	PIT NO.	HOLE NO.	DEPTH	16 GA. CMP LIFE	ABR. 500 REV.	UNIT WEIGHT PCF	LL	24 HR. SW.	R. VAL.	HOLE COMMENTS
1	2	3	4	5	6	7	8	9	10	11
12	13	14	15	16	17	18	19	20	21	22
23	24	25	26	27	28	29	30	31	32	33
34	35	36	37	38	39	40	41	42	43	44
45	46	47	48	49	50	51	52	53	54	55
56	57	58	59	60	61	62	63	64	65	66
67	68	69	70	71	72	73	74	75	76	77
78	79	80	81	82	83	84	85	86	87	88
89	90	91	92	93	94	95	96	97	98	99
100	101	102	103	104	105	106	107	108	109	110
111	112	113	114	115	116	117	118	119	120	121
122	123	124	125	126	127	128	129	130	131	132
133	134	135	136	137	138	139	140	141	142	143
144	145	146	147	148	149	150	151	152	153	154
155	156	157	158	159	160	161	162	163	164	165
166	167	168	169	170	171	172	173	174	175	176
177	178	179	180	181	182	183	184	185	186	187
188	189	190	191	192	193	194	195	196	197	198
199	200	201	202	203	204	205	206	207	208	209
210	211	212	213	214	215	216	217	218	219	220
221	222	223	224	225	226	227	228	229	230	231
232	233	234	235	236	237	238	239	240	241	242
243	244	245	246	247	248	249	250	251	252	253
254	255	256	257	258	259	260	261	262	263	264
265	266	267	268	269	270	271	272	273	274	275
276	277	278	279	280	281	282	283	284	285	286
287	288	289	290	291	292	293	294	295	296	297
298	299	300	301	302	303	304	305	306	307	308
309	310	311	312	313	314	315	316	317	318	319
320	321	322	323	324	325	326	327	328	329	330
331	332	333	334	335	336	337	338	339	340	341
342	343	344	345	346	347	348	349	350	351	352
353	354	355	356	357	358	359	360	361	362	363
364	365	366	367	368	369	370	371	372	373	374
375	376	377	378	379	380	381	382	383	384	385
386	387	388	389	390	391	392	393	394	395	396
397	398	399	400	401	402	403	404	405	406	407
408	409	410	411	412	413	414	415	416	417	418
419	420	421	422	423	424	425	426	427	428	429
430	431	432	433	434	435	436	437	438	439	440
441	442	443	444	445	446	447	448	449	450	451
452	453	454	455	456	457	458	459	460	461	462
463	464	465	466	467	468	469	470	471	472	473
474	475	476	477	478	479	480	481	482	483	484
485	486	487	488	489	490	491	492	493	494	495
496	497	498	499	500	501	502	503	504	505	506
507	508	509	510	511	512	513	514	515	516	517
518	519	520	521	522	523	524	525	526	527	528
529	530	531	532	533	534	535	536	537	538	539
540	541	542	543	544	545	546	547	548	549	550
551	552	553	554	555	556	557	558	559	560	561
562	563	564	565	566	567	568	569	570	571	572
573	574	575	576	577	578	579	580	581	582	583
584	585	586	587	588	589	590	591	592	593	594
595	596	597	598	599	600	601	602	603	604	605
606	607	608	609	610	611	612	613	614	615	616
617	618	619	620	621	622	623	624	625	626	627
628	629	630	631	632	633	634	635	636	637	638
639	640	641	642	643	644	645	646	647	648	649
650	651	652	653	654	655	656	657	658	659	660
661	662	663	664	665	666	667	668	669	670	671
672	673	674	675	676	677	678	679	680	681	682
683	684	685	686	687	688	689	690	691	692	693
694	695	696	697	698	699	700	701	702	703	704
705	706	707	708	709	710	711	712	713	714	715
716	717	718	719	720	721	722	723	724	725	726
727	728	729	730	731	732	733	734	735	736	737
738	739	740	741	742	743	744	745	746	747	748
749	750	751	752	753	754	755	756	757	758	759
760	761	762	763	764	765	766	767	768	769	770
771	772	773	774	775	776	777	778	779	780	781
782	783	784	785	786	787	788	789	790	791	792
793	794	795	796	797	798	799	800	801	802	803
804	805	806	807	808	809	810	811	812	813	814
815	816	817	818	819	820	821	822	823	824	825
826	827	828	829	830	831	832	833	834	835	836
837	838	839	840	841	842	843	844	845	846	847
848	849	850	851	852	853	854	855	856	857	858
859	860	861	862	863	864	865	866	867	868	869
870	871	872	873	874	875	876	877	878	879	880</

Card #2 - Contained pit number, route and milepost location, aerial photograph date, quantity of material removed from pit, unit weight and description of the material.

Card #3 - Contained the pit number and any comments.

Card #4 - Contained pit number, hole number, depth of sample, gradation data of percent passing from the 6 inch to the #200 screen, plasticity index, and sand equivalent data.

Card #5 - Contained pit number, hole number, depth of sample, unit weight, liquid limit, 24-hour swell, R value, and comments on the hole.

NOTE: Card type data refers to data in 80 column format and reserving the first two columns for the card number, the data type indicator.

H.3 Data Manipulation

H.3.1 Discussion

The raw card type data was separated into #4 cards only, which contained the various river gradation samples. Concurrent with this process, the data was flagged to distinguish non-measured values from zero (zero from blank) and the data separated with blanks to permit easy access by subsequent programs.

Using an interpolation and look-up routine written in Fortran, the percent passing each sieve size was converted to a normal variate in the standard normal distribution. The in-house developed program subdivided the normalized values into intervals with a maximum number of 10 subdivisions per interval. The number of occurrences per interval were summed and a percentage determined for each.

Using this data, the D_{15} , D_{50} , D_{85} values were tabulated for plotting. For each sieve size, the mean variate and plus and minus one standard deviation were determined. This data is displayed as a high, low, mean graph relative to sieve size and the standard normal distribution.

The next two data manipulations, written in-house using a basic programming language, TRUE BASIC, produced upper and lower gradation coefficient graphs (D_{85}/D_{50} and D_{50}/D_{15} respectively). One graph shows the cumulative probability for the upper and lower gradation coefficients in each reach. The other graph shows the correlation between upper and lower gradation coefficients and the mean particle size, D_{50} . Tables were also developed to display: the D_{85} , D_{50} , D_{15} , upper and lower gradation coefficients. Each sample, where possible, was portrayed in this tabular format.

H.3.2 Programs

The programs developed to analyze the bed material gradation data are briefly summarized below. Complete program listings for these programs follow, as well as a sample input data set listing.

EDIT1.FOR

Uses raw ADOT data as input and sorts out the number 4 cards which contain individual sample gradation data.

EDIT2.FOR

Uses the output data from EDIT1.FOR as input. The data was checked for zeros and filled with -99 as a flag. This prevents the blanks from being interpreted as zeros in calculations. The output data set used as input for most of the following programs consisted of: record 1, sieve size in millimeters; record 2 through the end of the file was the respective percent passing data, entirely column dependent.

FREQ.FOR

Uses the output data from EDIT2.FOR as input. The percent passing data is transformed into standard normal distribution values. This transformed data is then put through a frequency analysis with respect to intervals determined by the user. A percentage is calculated for each interval relative to the number of occurrences per interval. Another column displays a running sum of the percentage per interval. Each sieve size with data is analyzed in this way. From this output, another dataset was compiled. From the frequency analysis of each sieve, a dataset was compiled displaying: sieve size, the standard normal values of 15, 50, 85 percentile for plotting purposes. This data was used in the high, low, mean plot. (See Figure H.2 to H.9.) This program also had the capabilities of producing a cumulative histogram.

GRAD.TRU

This program uses a modified version of EDIT2.FOR's output as input, the difference being the data is comma separated which enables this language to read the input files. Again, the percent passing data is transformed into a standardized value. This data is then used to calculate the upper and lower gradation coefficients. Each coefficient is then individually ranked in ascending order. This data is used for the plots of Figures H.10 to H.25. Another output option includes a table which displays the D_{85} , D_{50} , D_{15} and the upper and lower gradation coefficient. This output can be used to review calculations for individual samples.

GRAD1.TRU

This program uses the same front end as the GRAD.TRU program. Again, the standardized percent passing calculation is performed. This time the D_{50} is sorted in ascending order with its respective upper or lower gradation coefficient. This data is printed to a file and the fields are brought to equal lengths

with -999 flags for plotting purposes. This data was used to plot Figures H.26 to H.33.

XYPLOT1.FOR

This fortran plotting program was used on all the figures displayed in this appendix. This program has capabilities of plotting x-y graphs on either normal or logarithmic scales.

TABLE H.1

Program Compilation Details

<u>PROGRAM</u>	<u>LANGUAGE</u>	<u>COMPILER</u>	<u>COMMENTS</u>
EDIT1.FOR	FORTRAN	MS-FORTRAN77 V3.31 MS-8086 OBJECT LINKER VERSION 3.04	LIBRARIES: /FORTRAN
EDIT2.FOR	FORTRAN	MS-FORTRAN77 V3.31 MS-8086 OBJECT LINKER VERSION 3.04	LIBRARIES: /FORTRAN
FREQ.FOR	FORTRAN	MS-FORTRAN77 V3.31 MS-8086 OBJECT LINKER VERSION 3.04	LIBRARIES: /FORTRAN/ PLOT88/FONT/MATH/ SEGMENTS: 256
GRAD.TRU	BASIC	TRUE BASIC VERSION 2.0	NO LIBRARIES NEEDED
GRAD1.TRU	BASIC	TRUE BASIC VERSION 2.0	NO LIBRARIES NEEDED
XYPLOT1.FOR	FORTRAN	MS-FORTRAN77 V3.31 MS-8086 OBJECT LINKER VERSION 3.04	LIBRARIES: /FORTRAN/ PLOT88/FONT/MATH/ SEGMENTS: 256

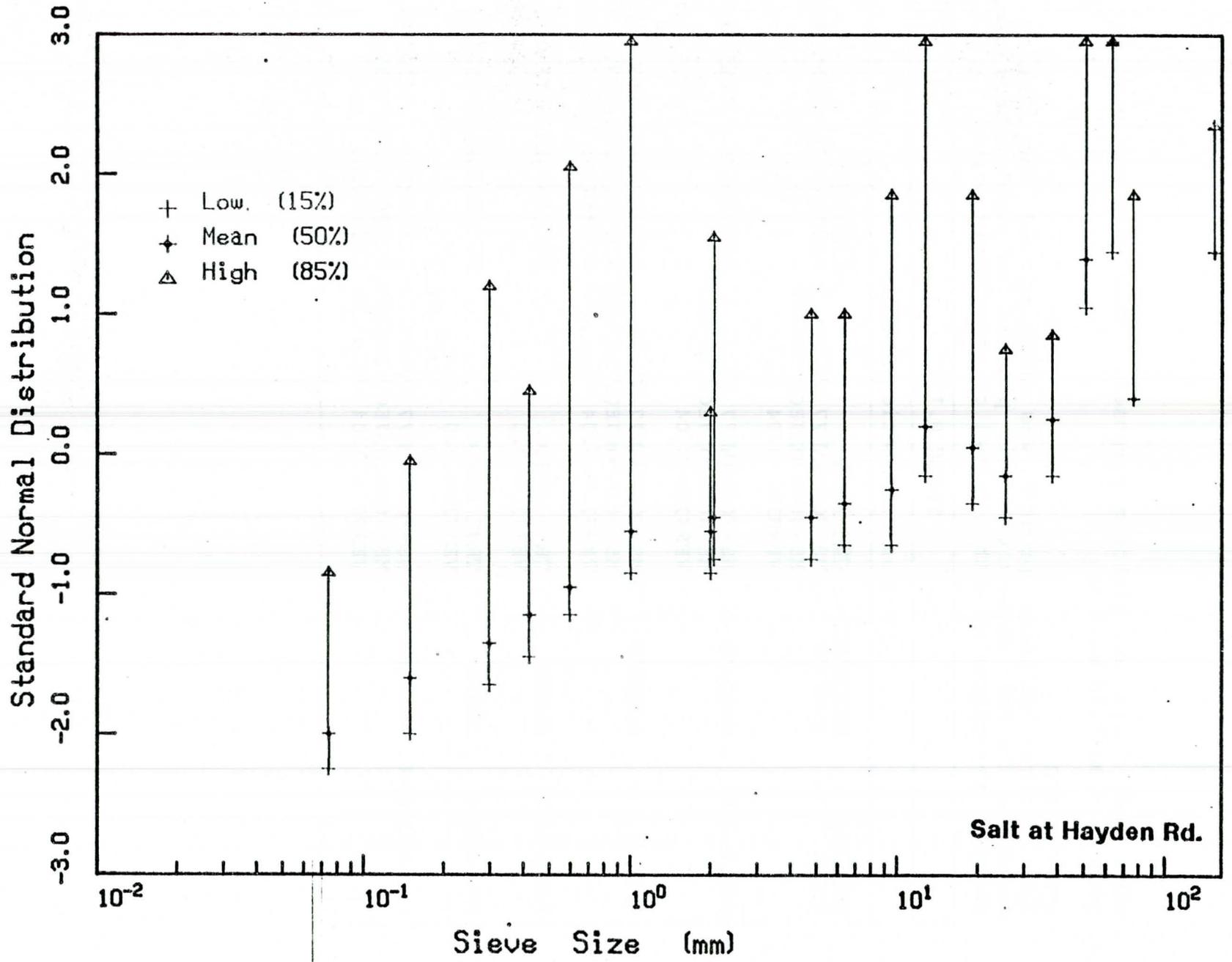


FIGURE H.2

H-7

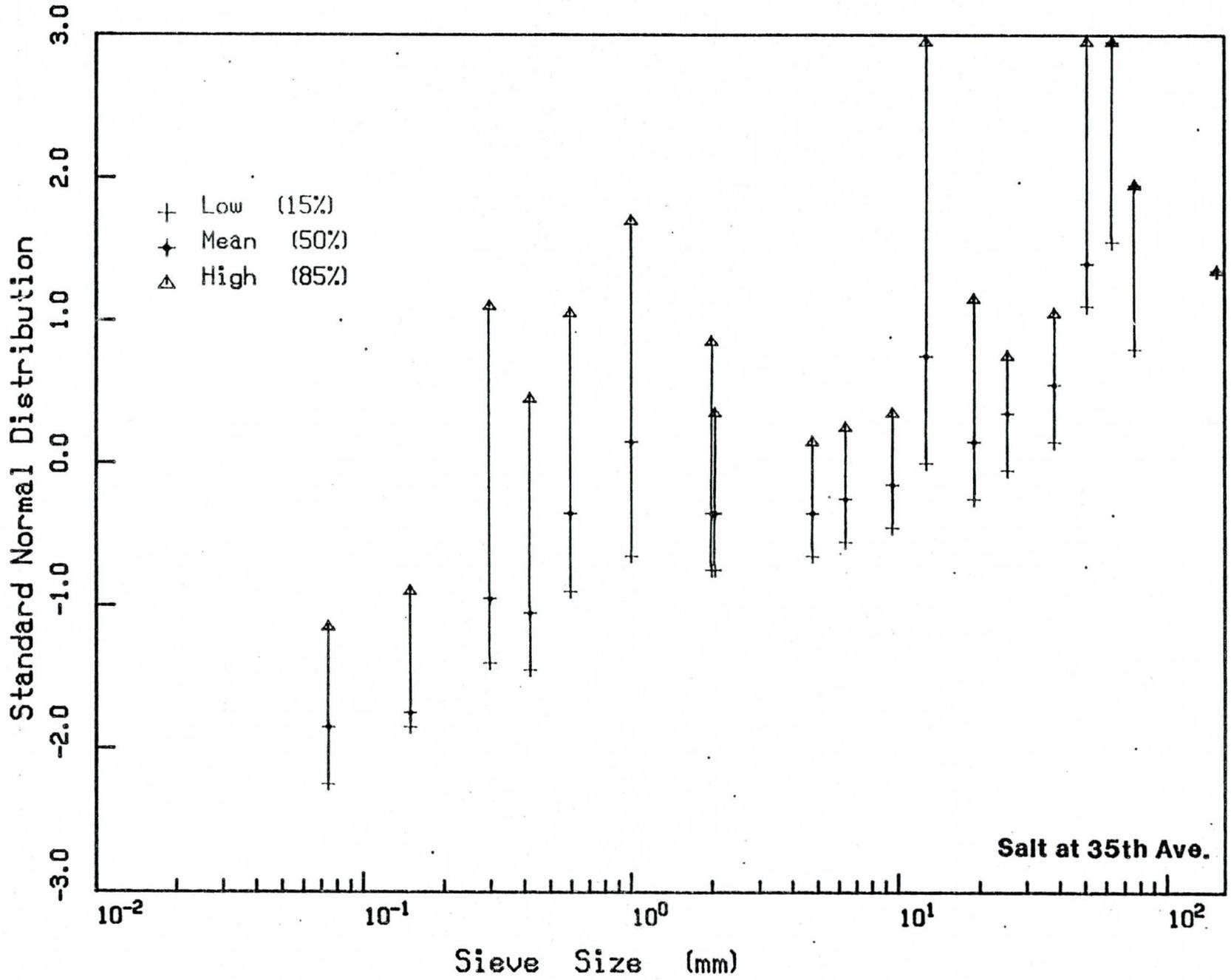


FIGURE H.3

8-H

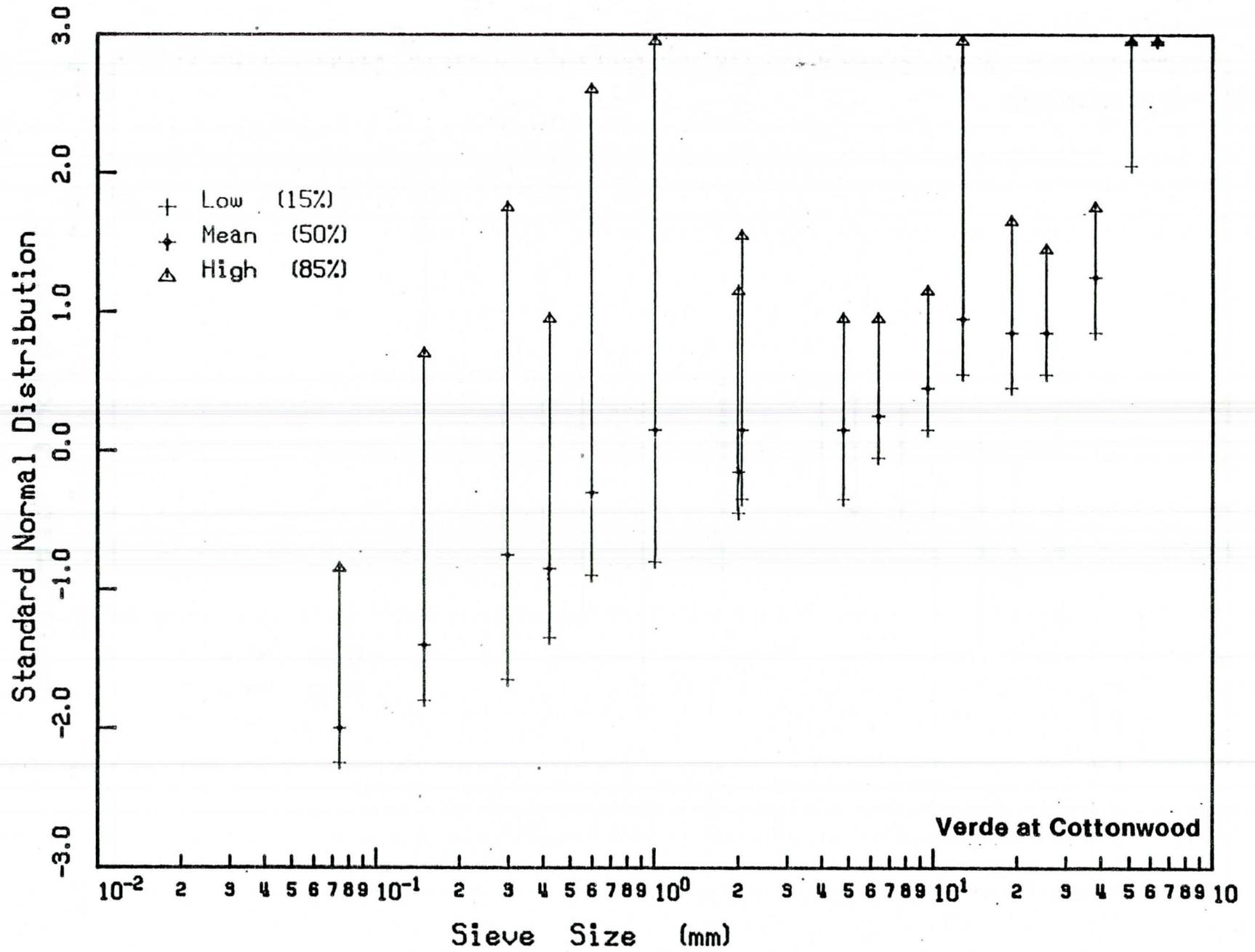


FIGURE M.4

6-H

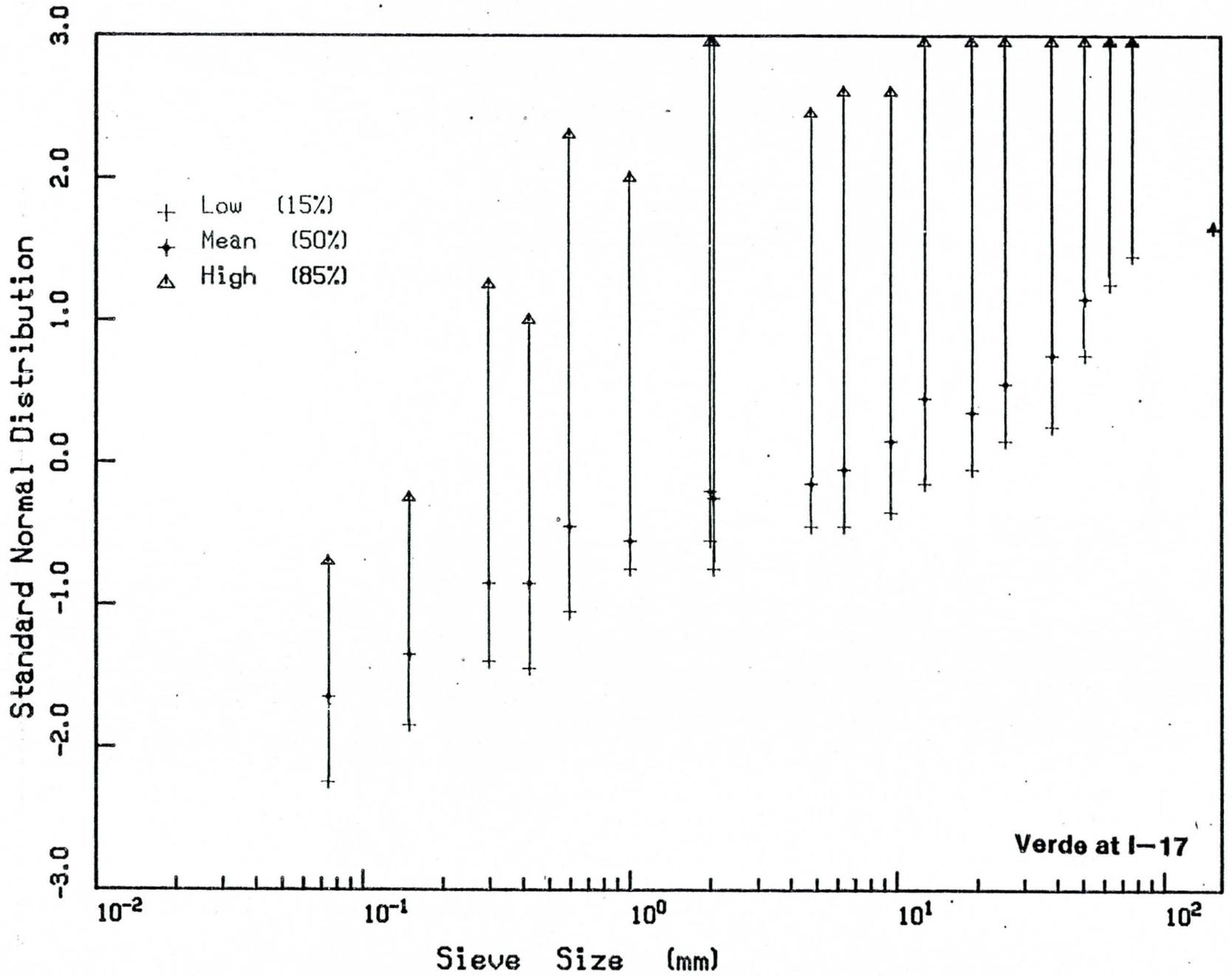
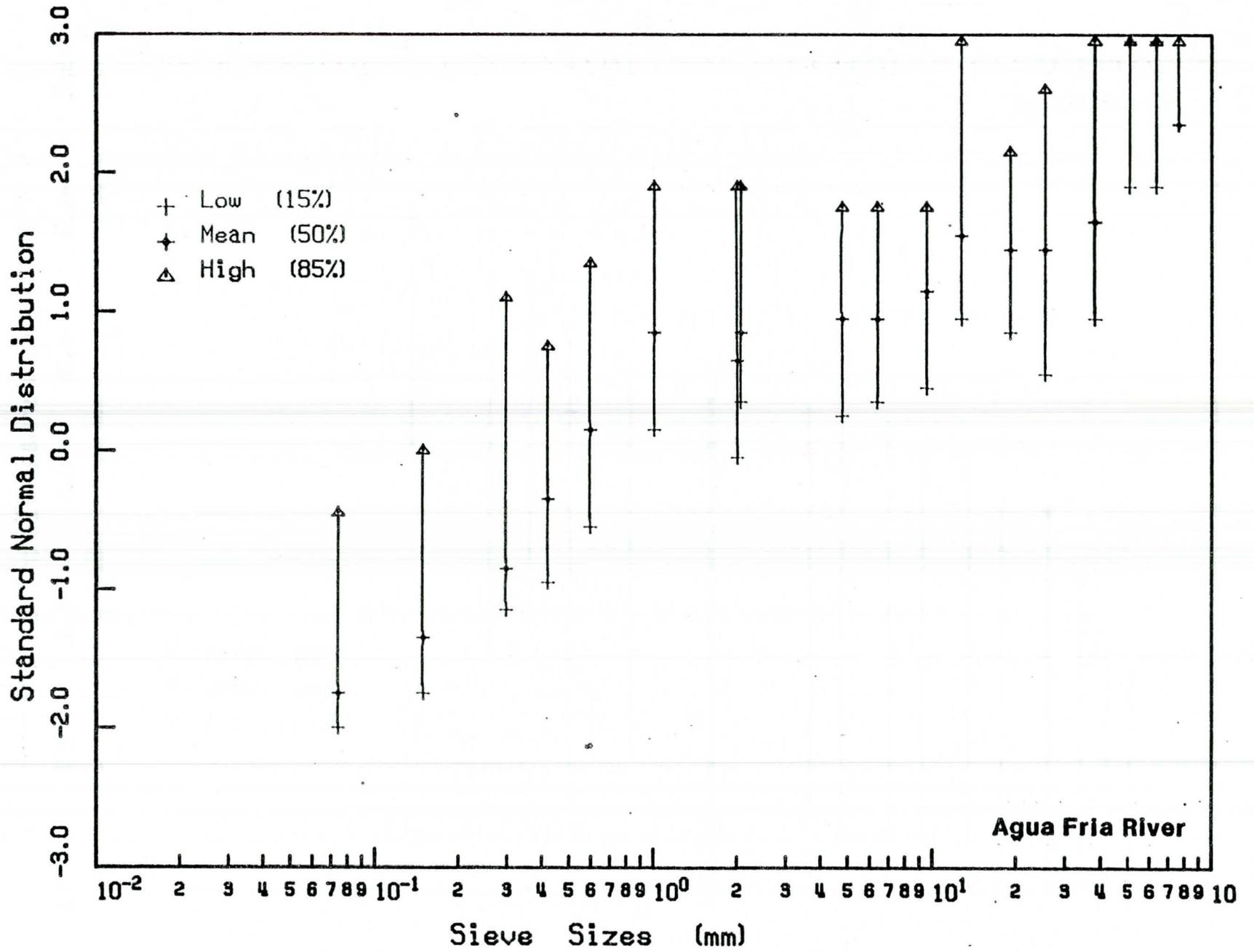


FIGURE H.5

H-10



TI-H

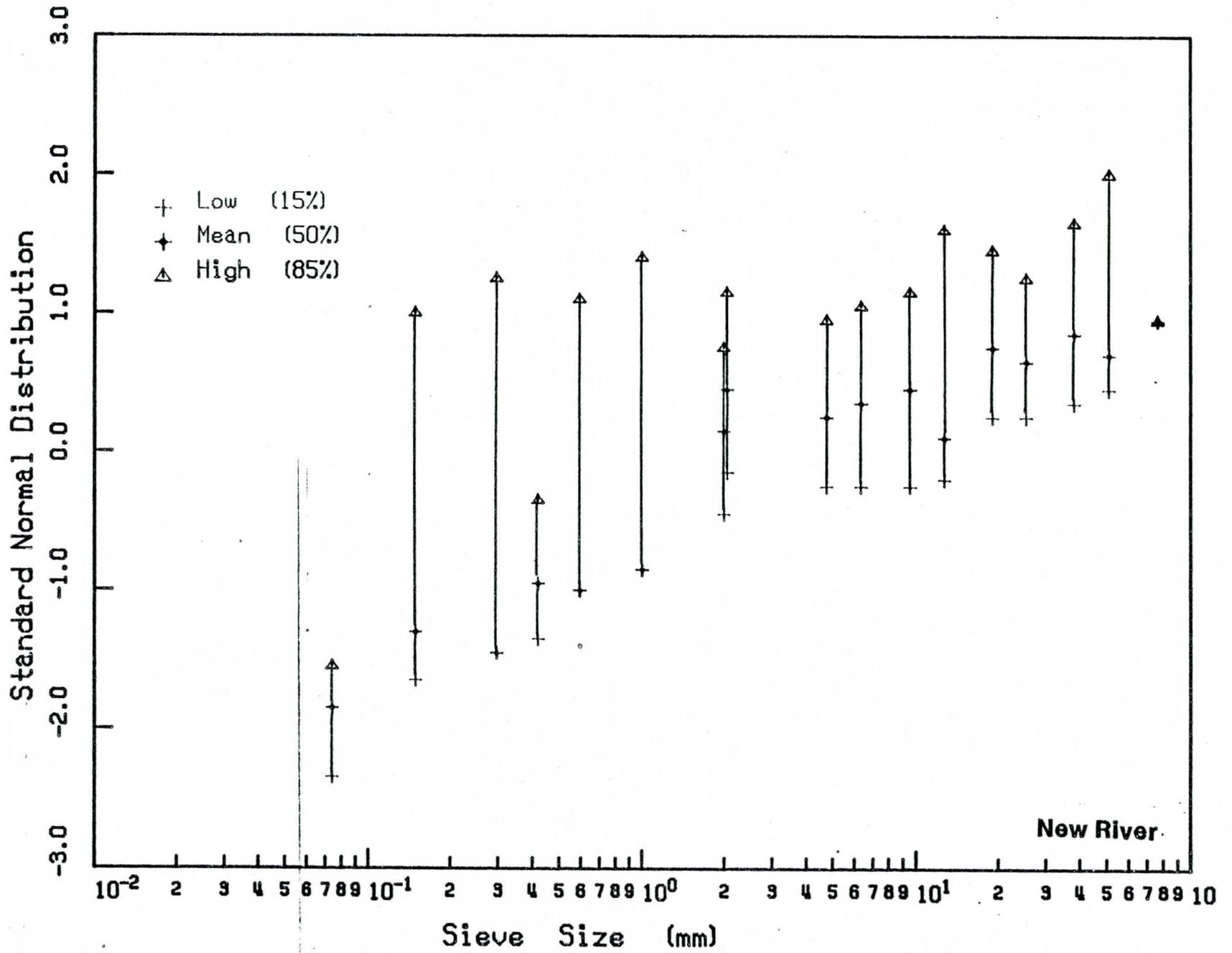


FIGURE M.7

H-12

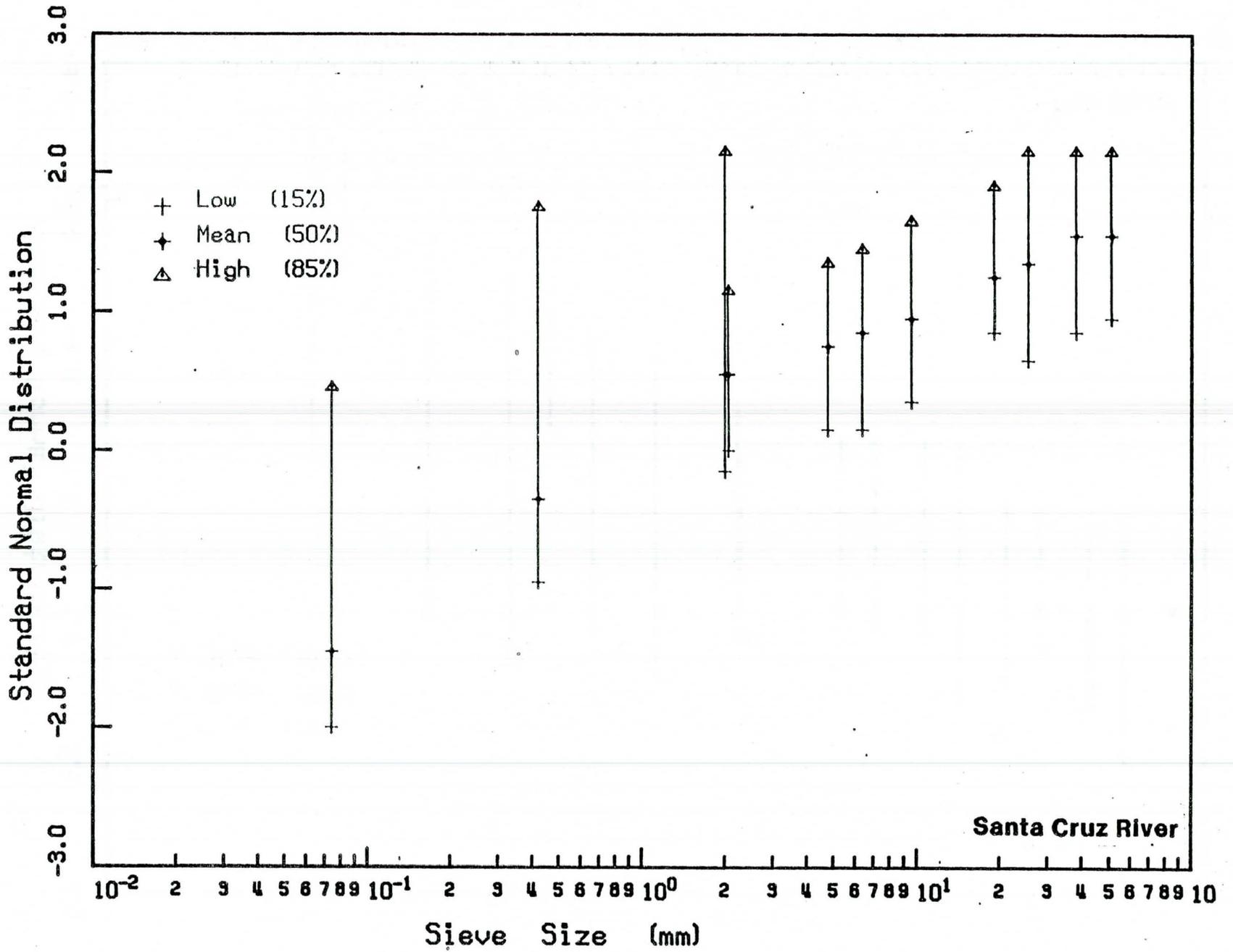


FIGURE H.8

H-13

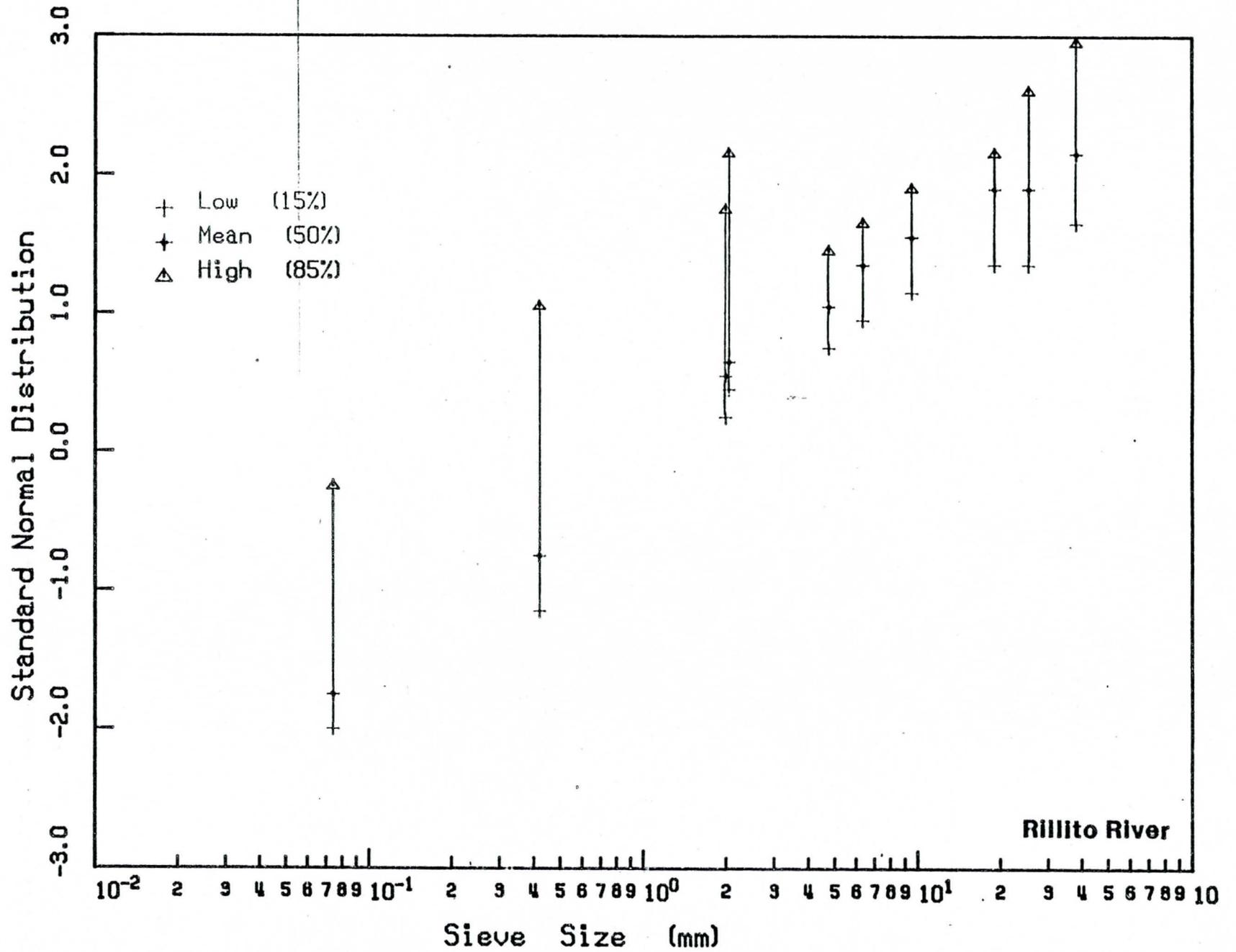


FIGURE H.9

H-14

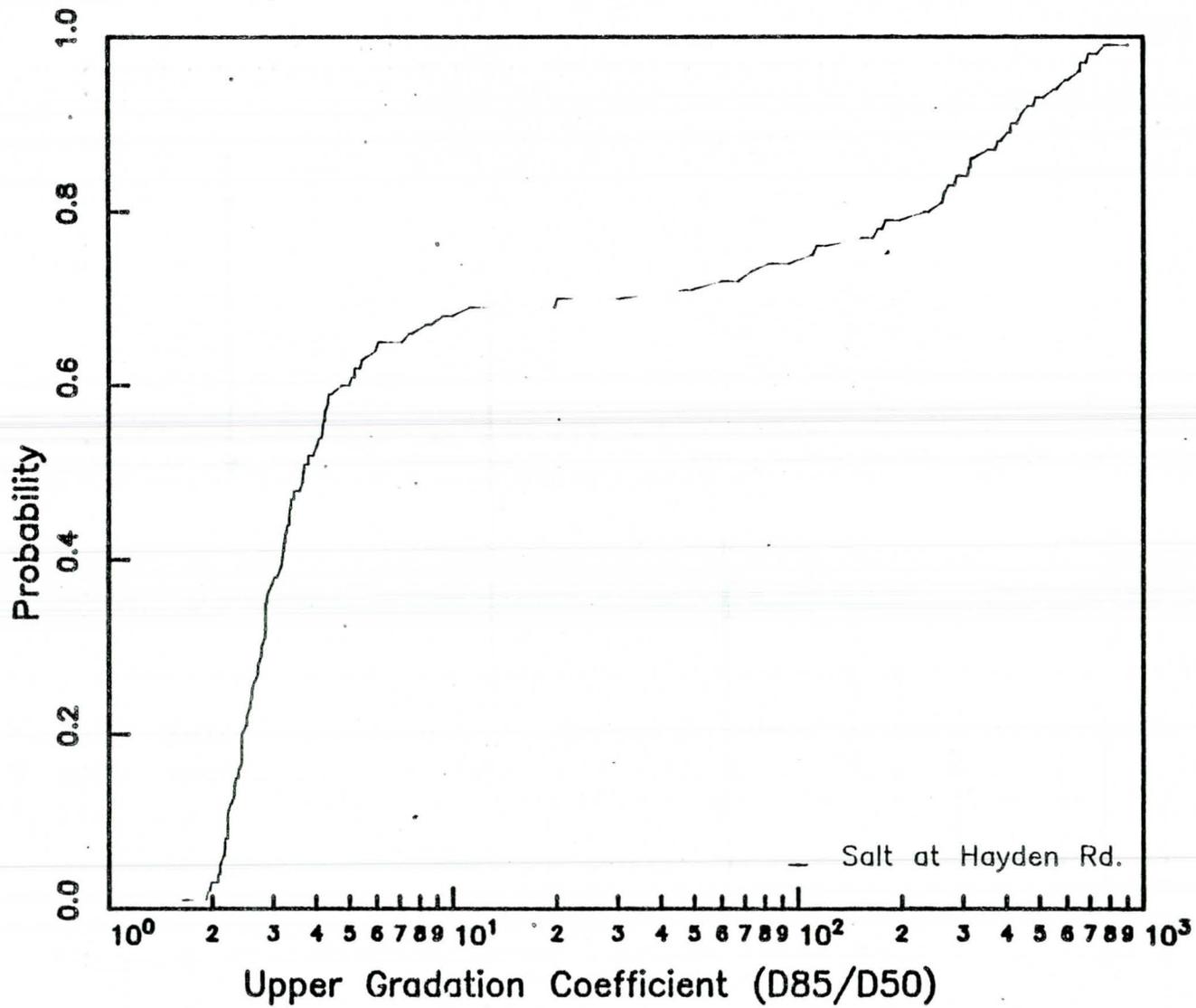


FIGURE H.10

SI-H

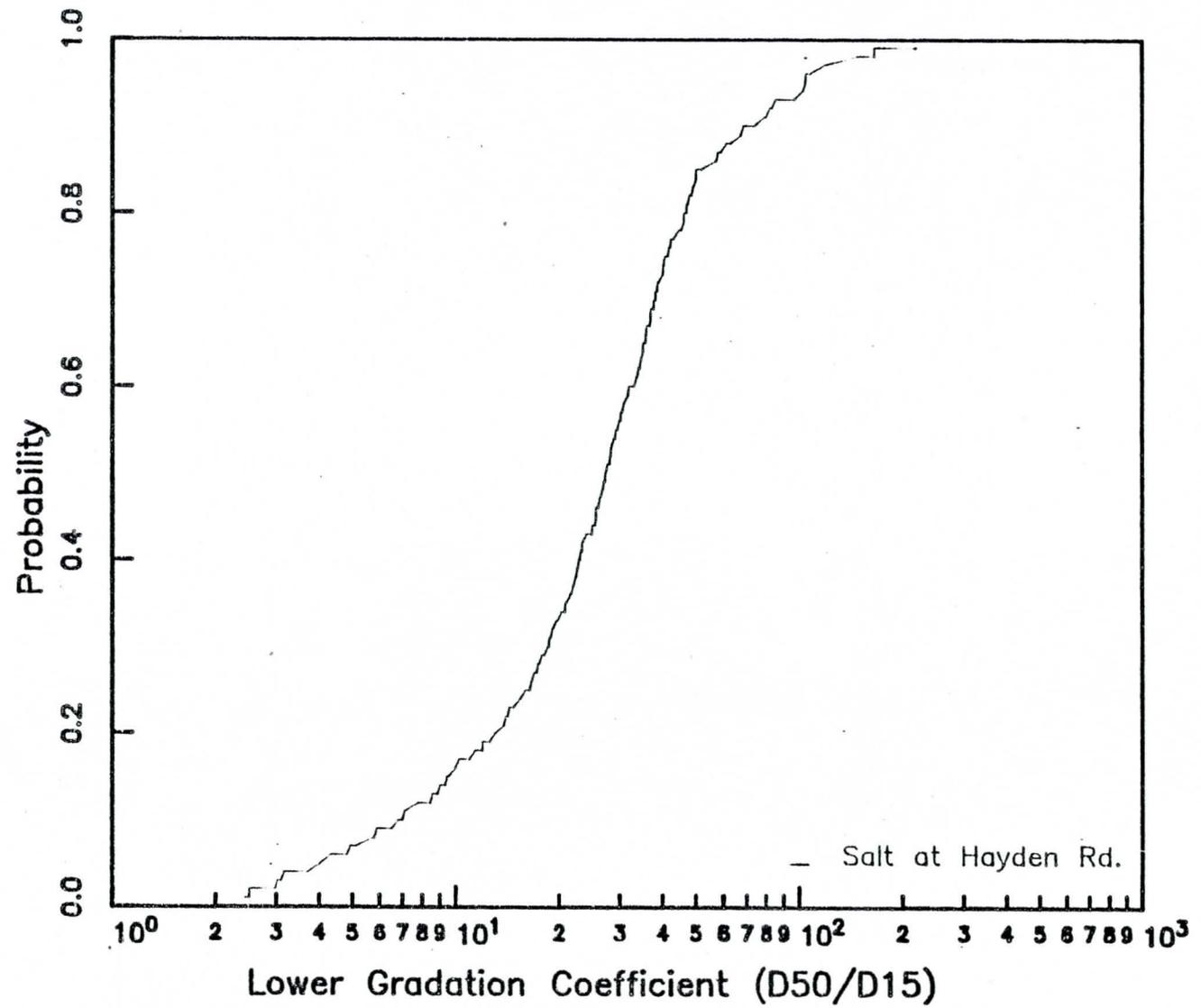


FIGURE HL11

91-H

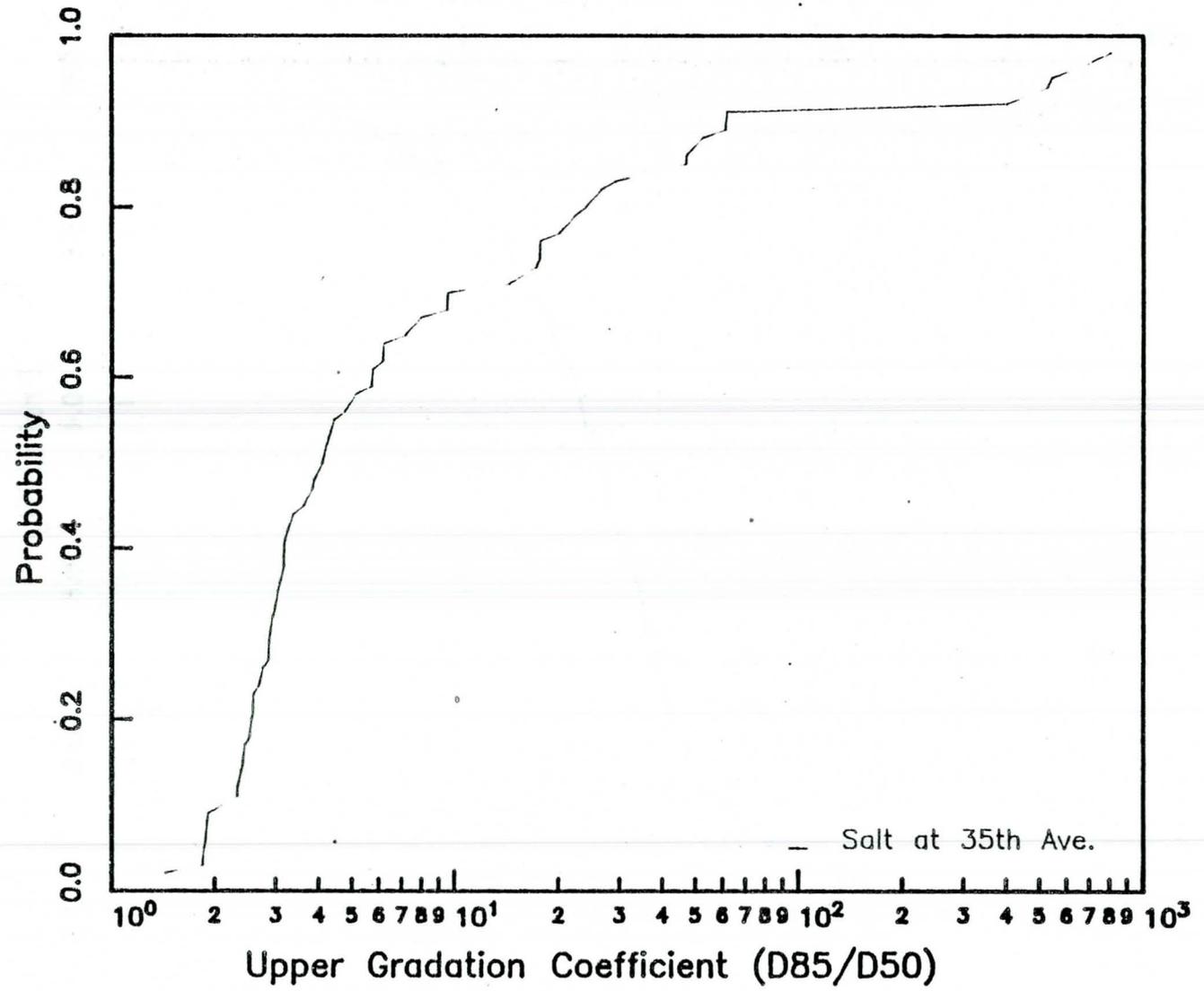


FIGURE H.12

LT-H

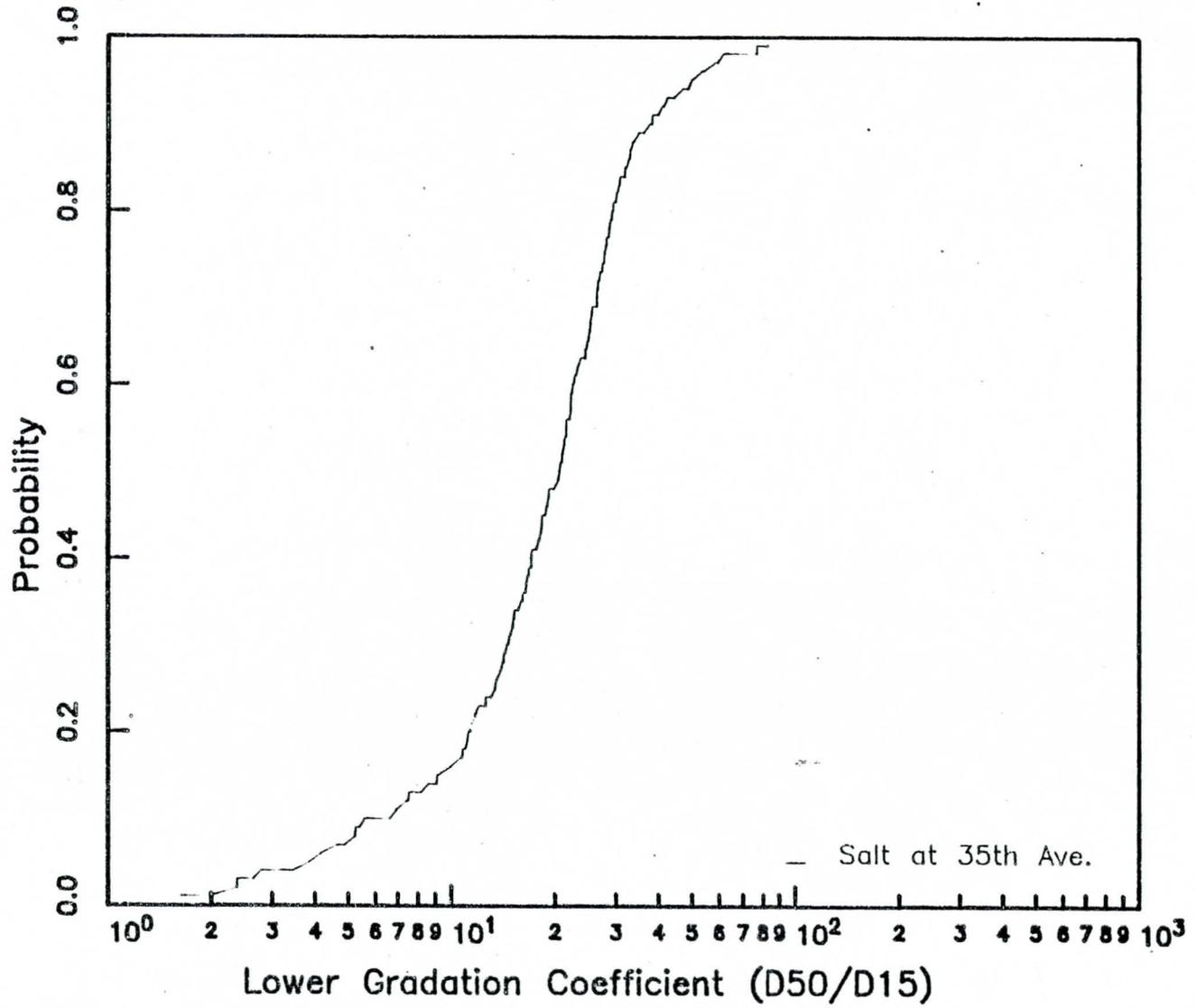


FIGURE H.13

H-18

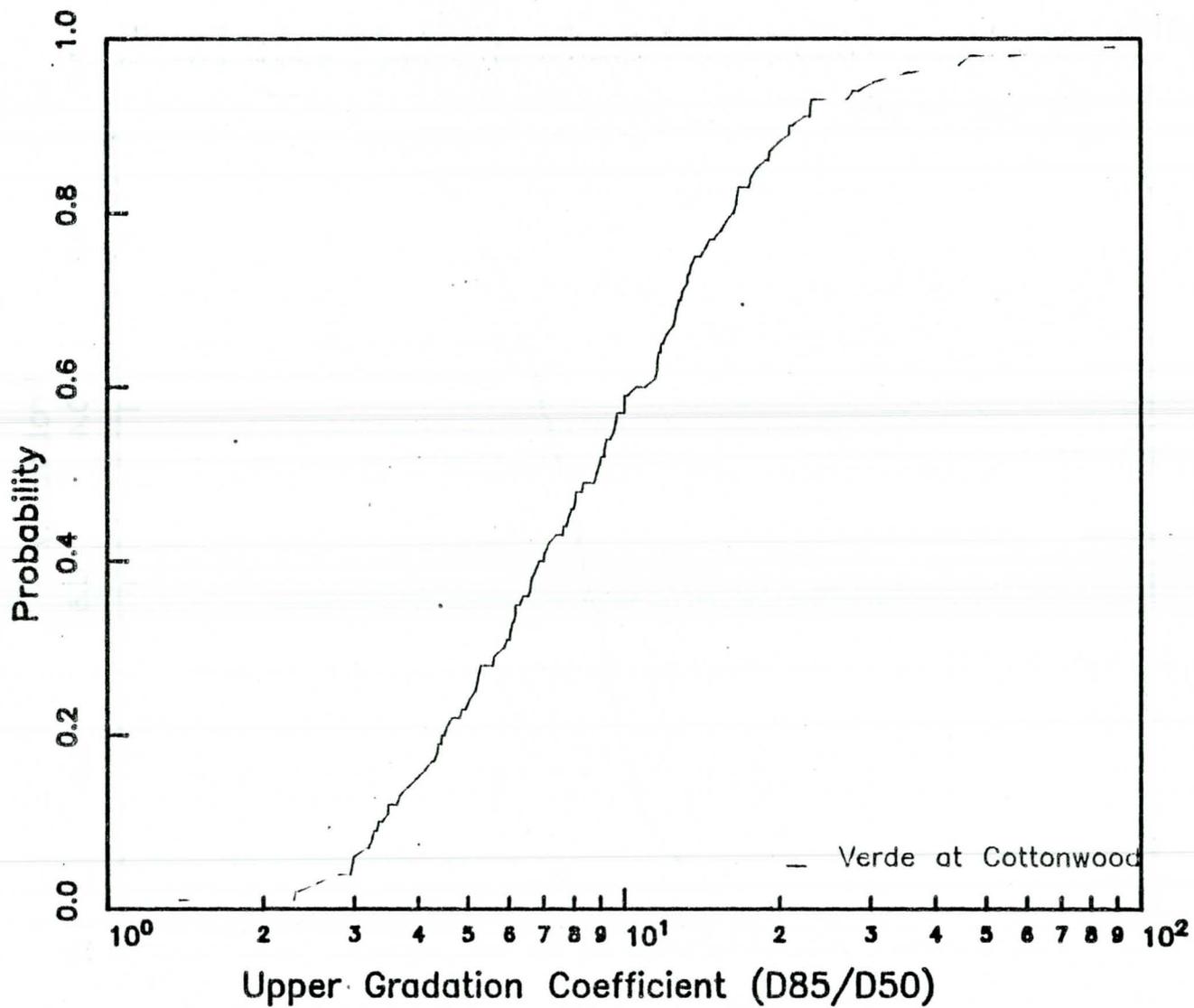


FIGURE H.14

67-H

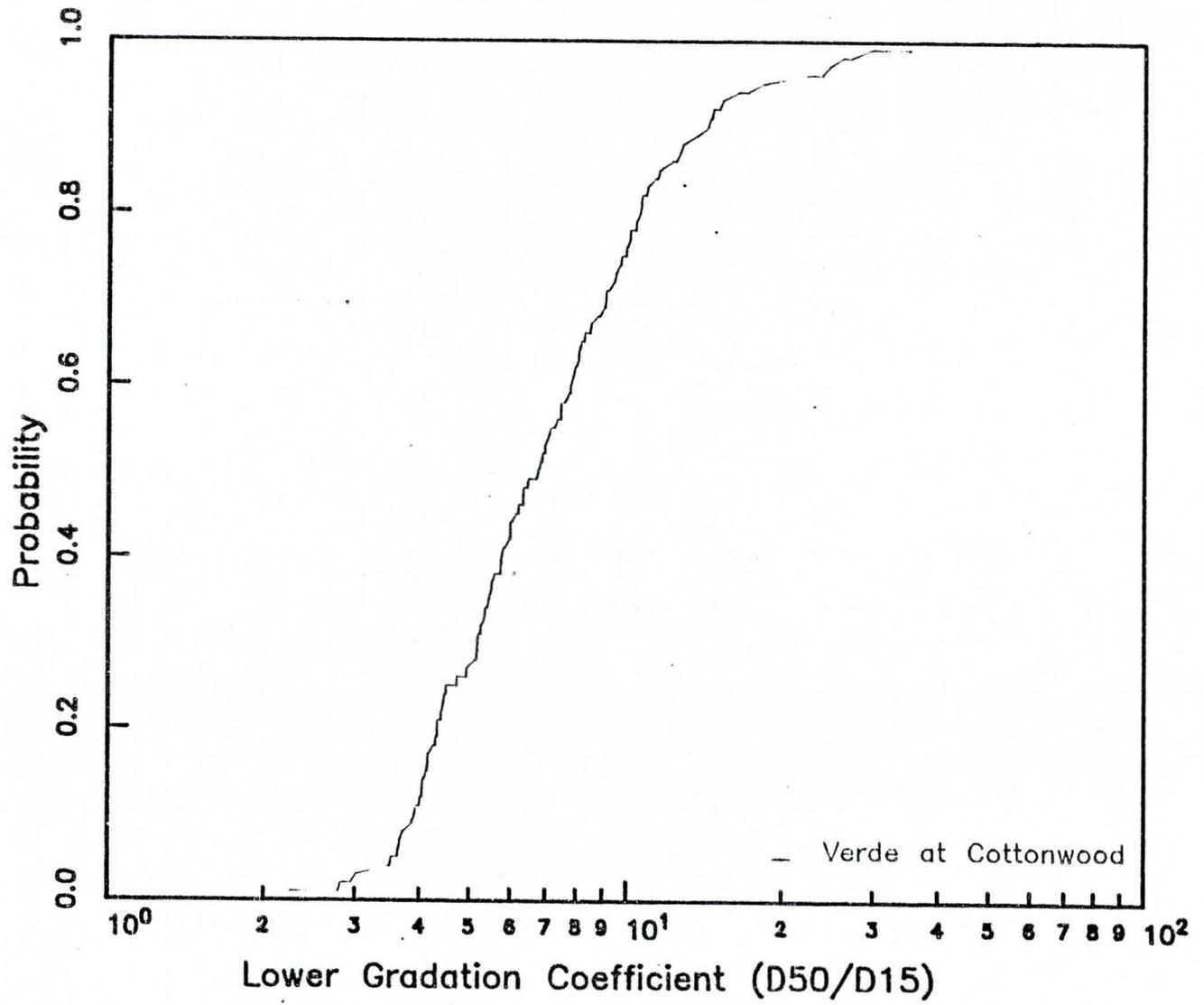


FIGURE H.15

H-20

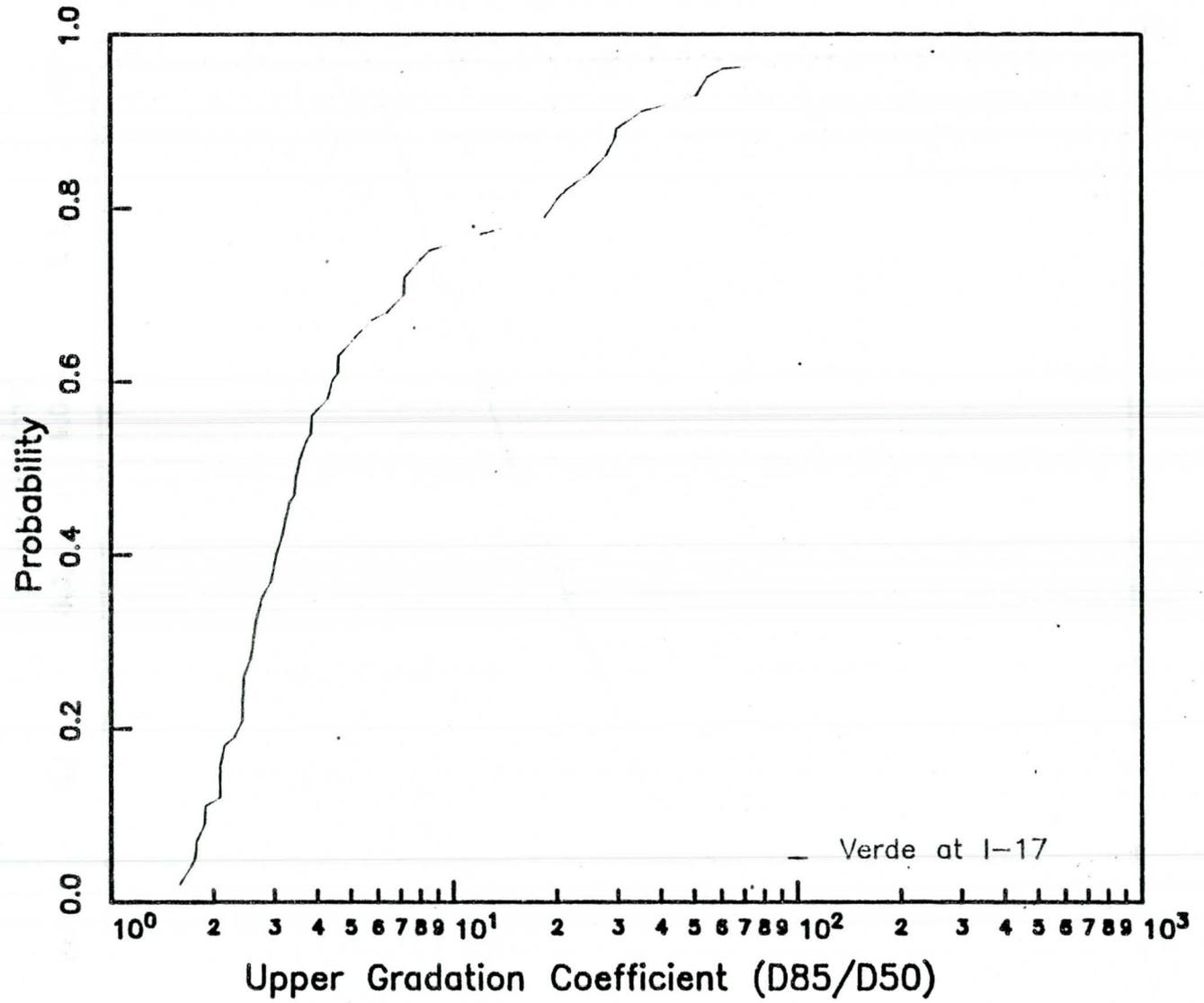


FIGURE H.16

H-21

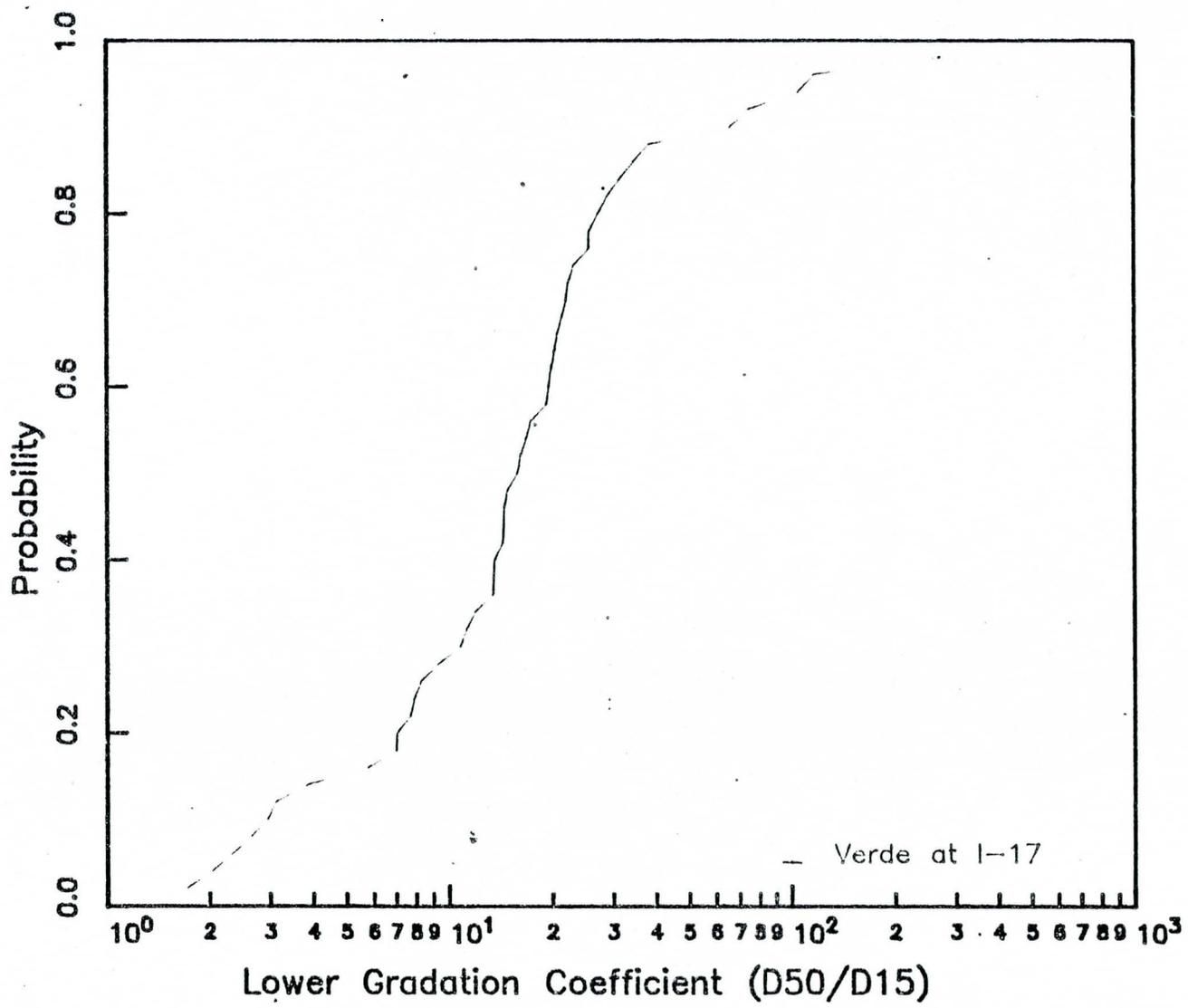


FIGURE H.17

H-22

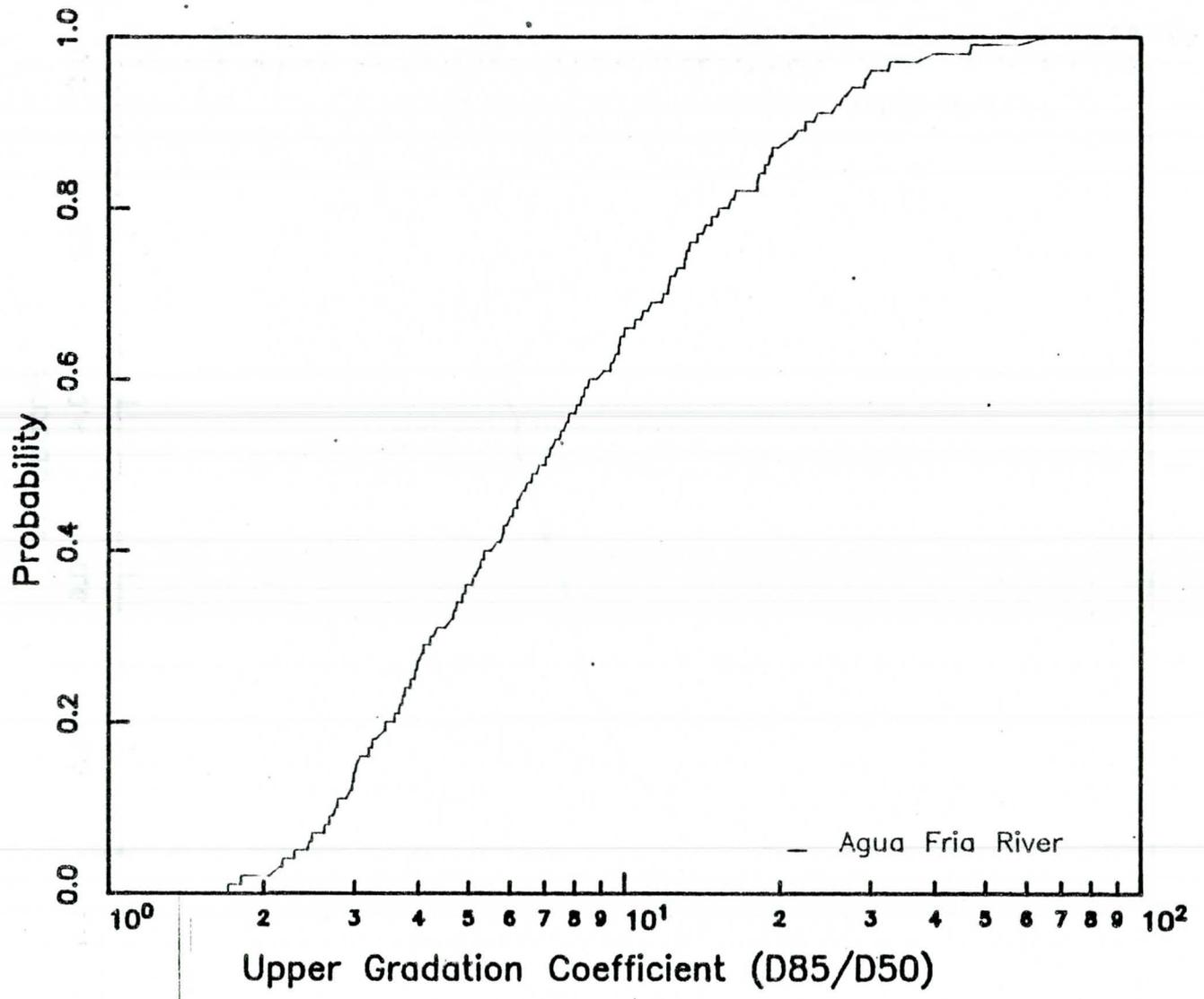


FIGURE H.18

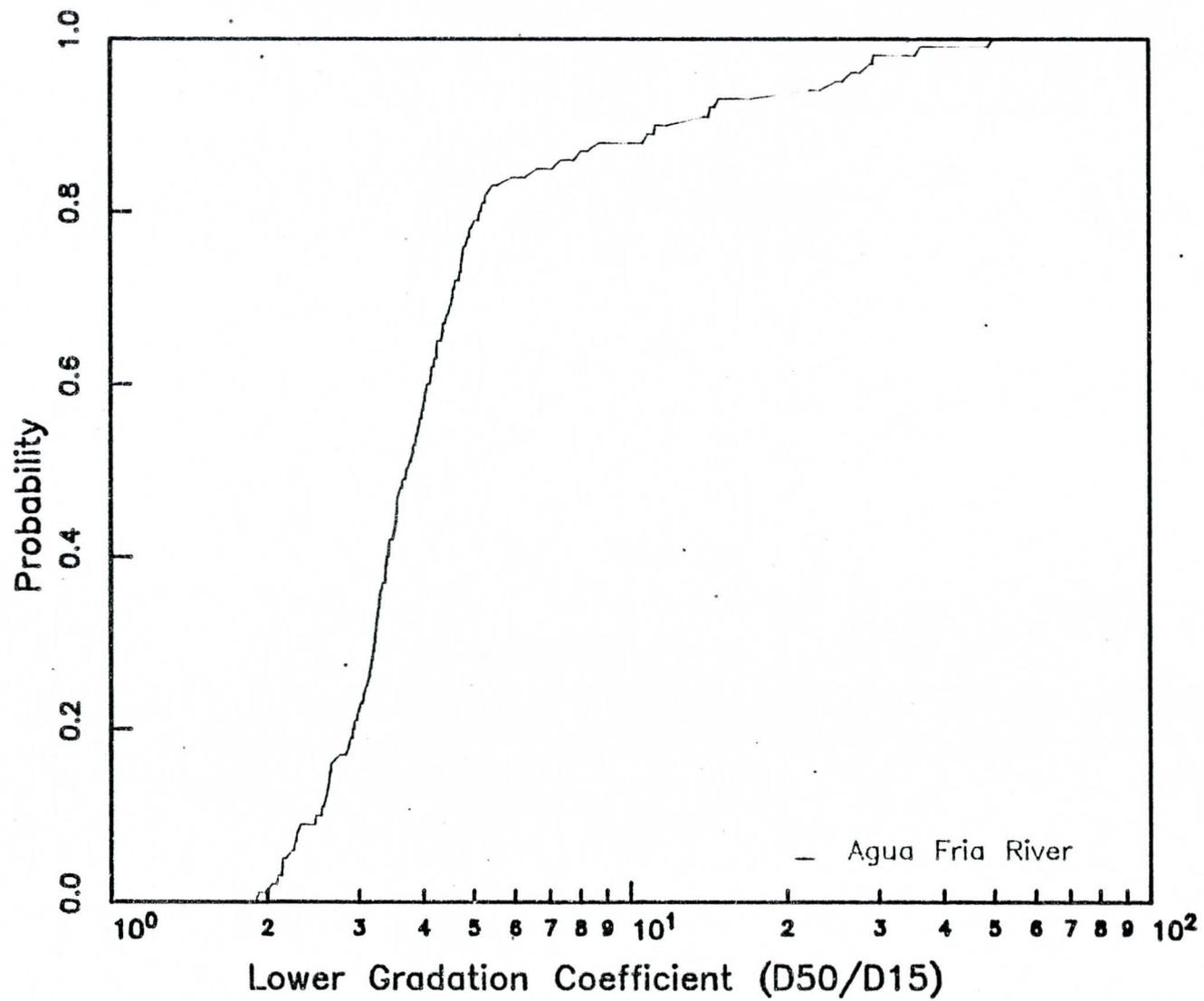


FIGURE H.19

H-24

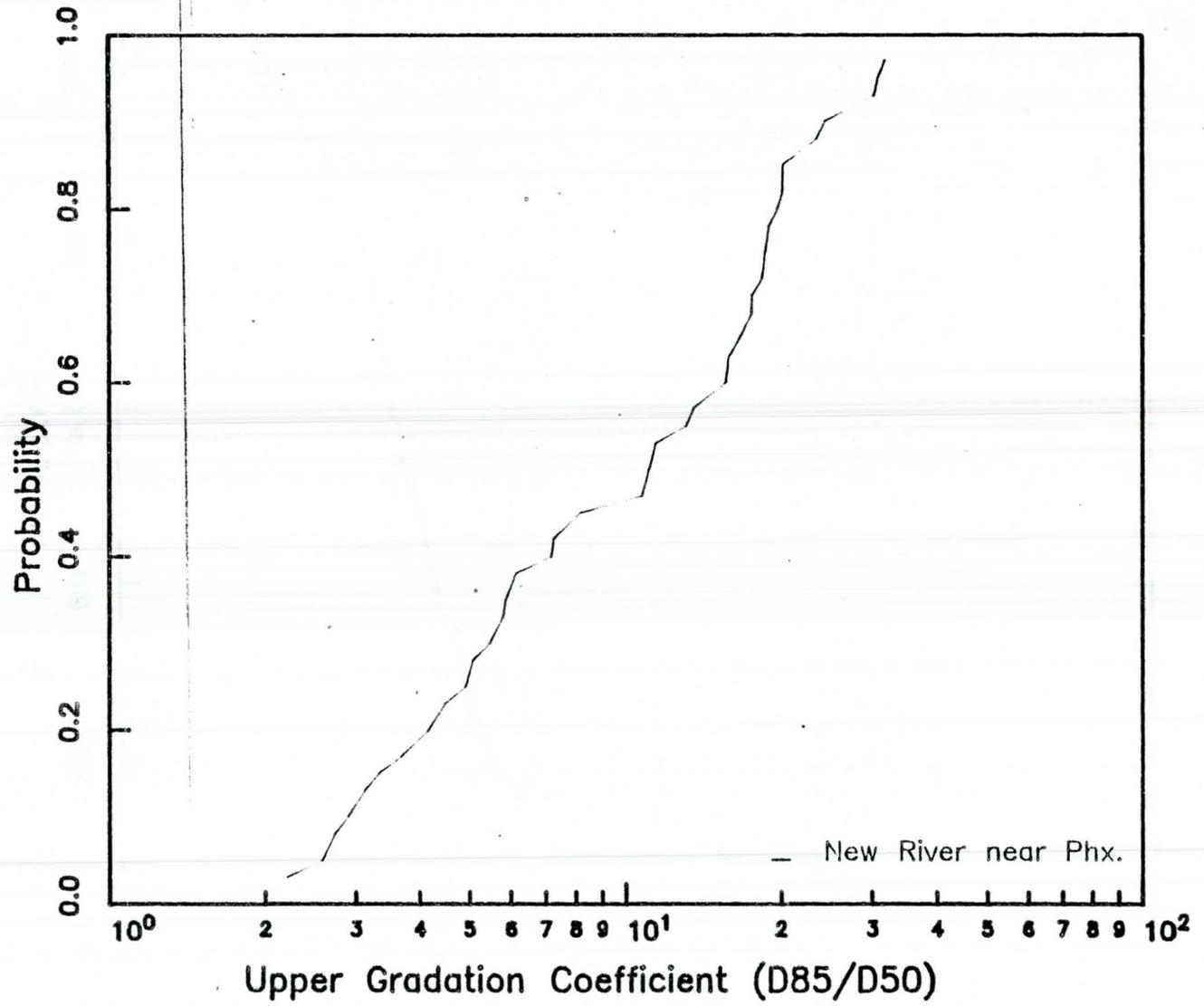


FIGURE H.20

H-25

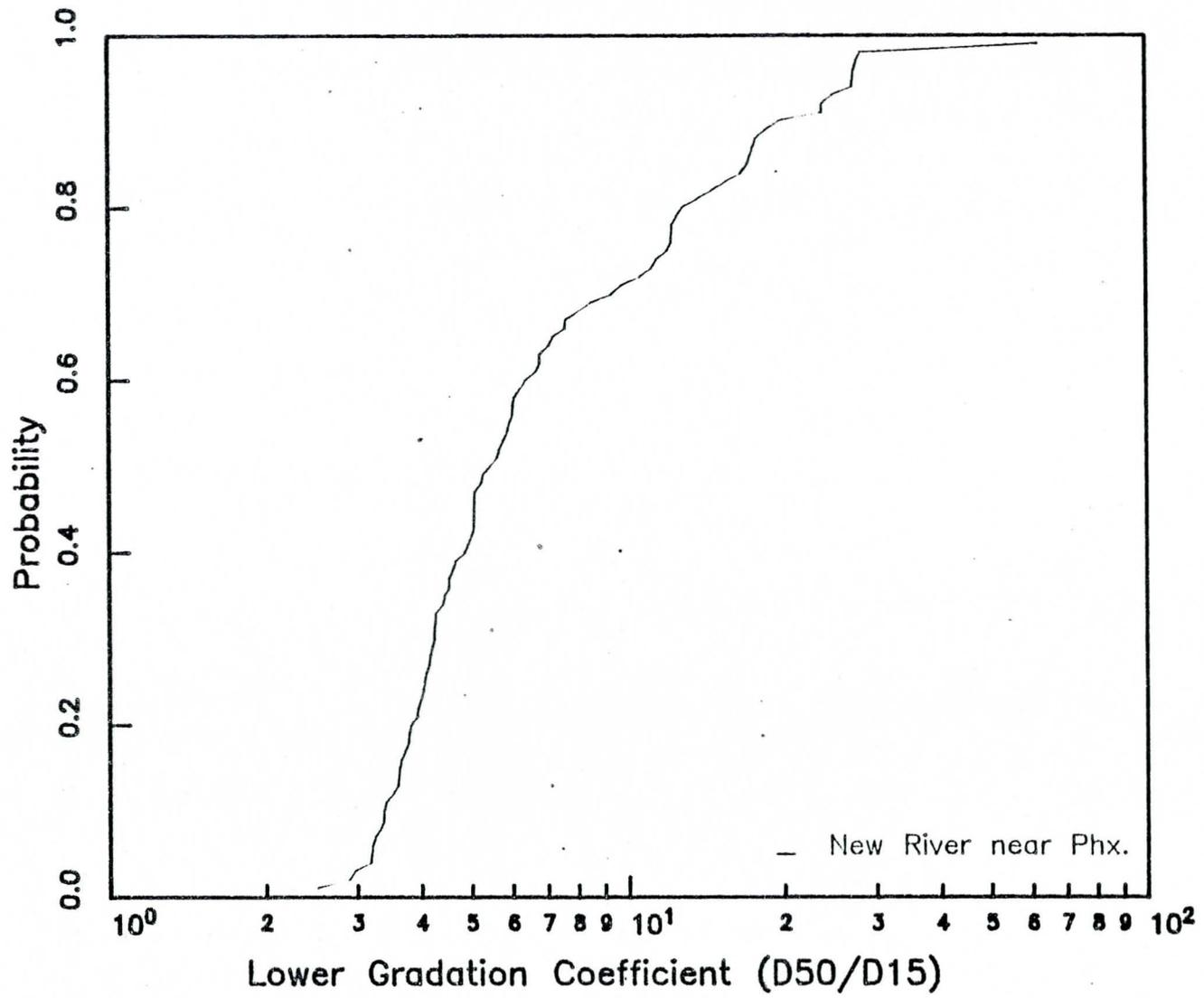


FIGURE H.21

H-26

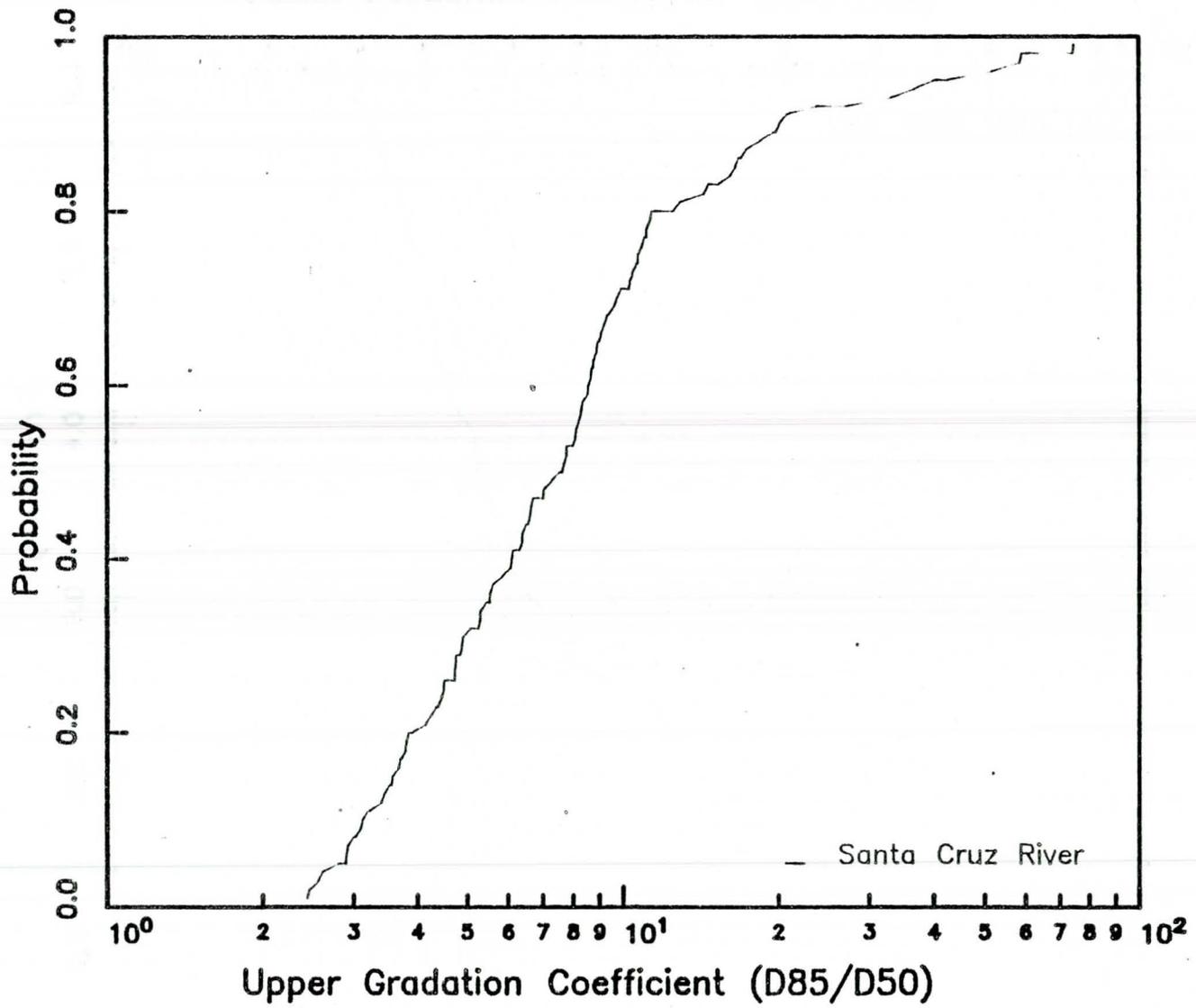


FIGURE H.22

H-27

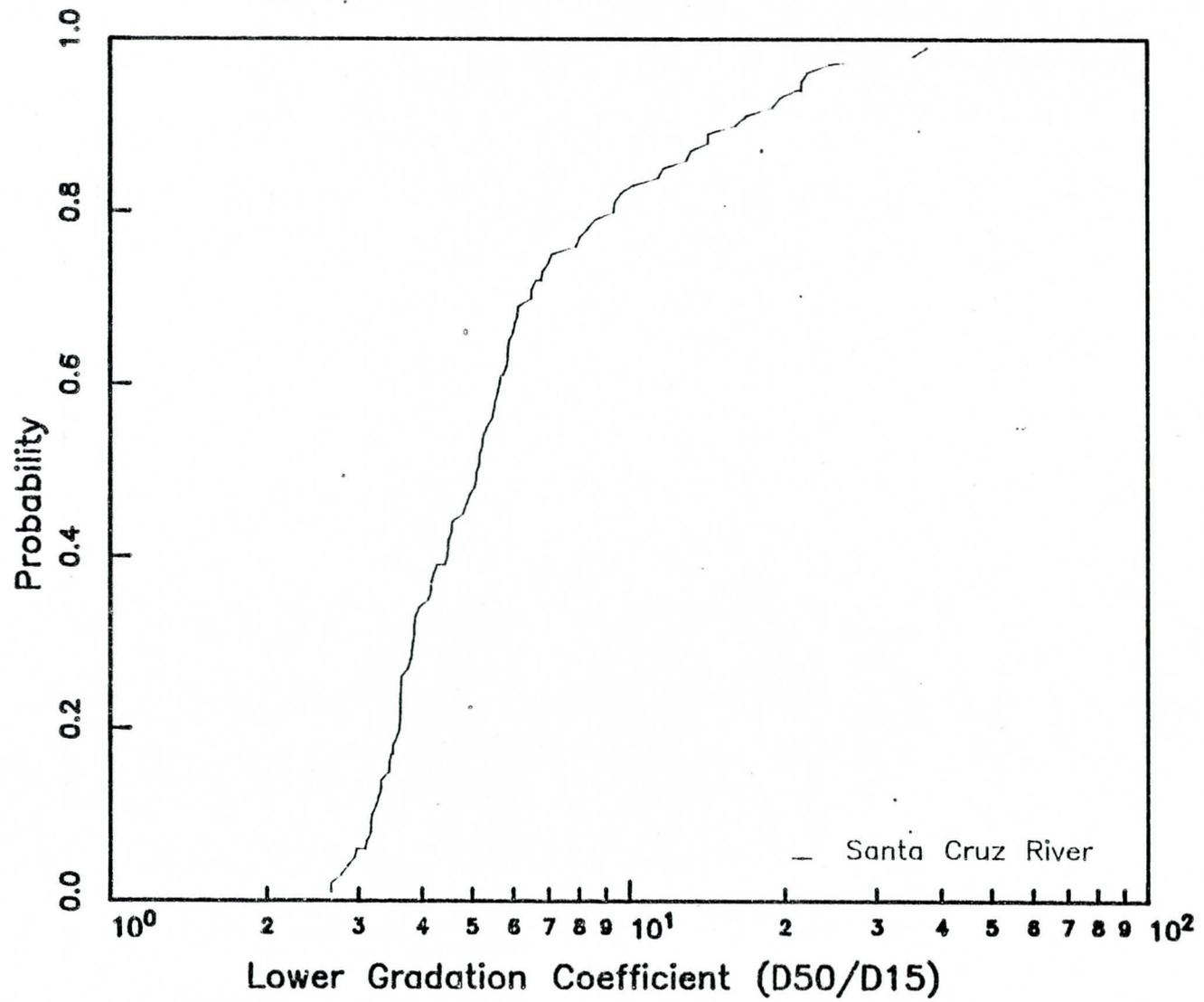


FIGURE H.23

H-28

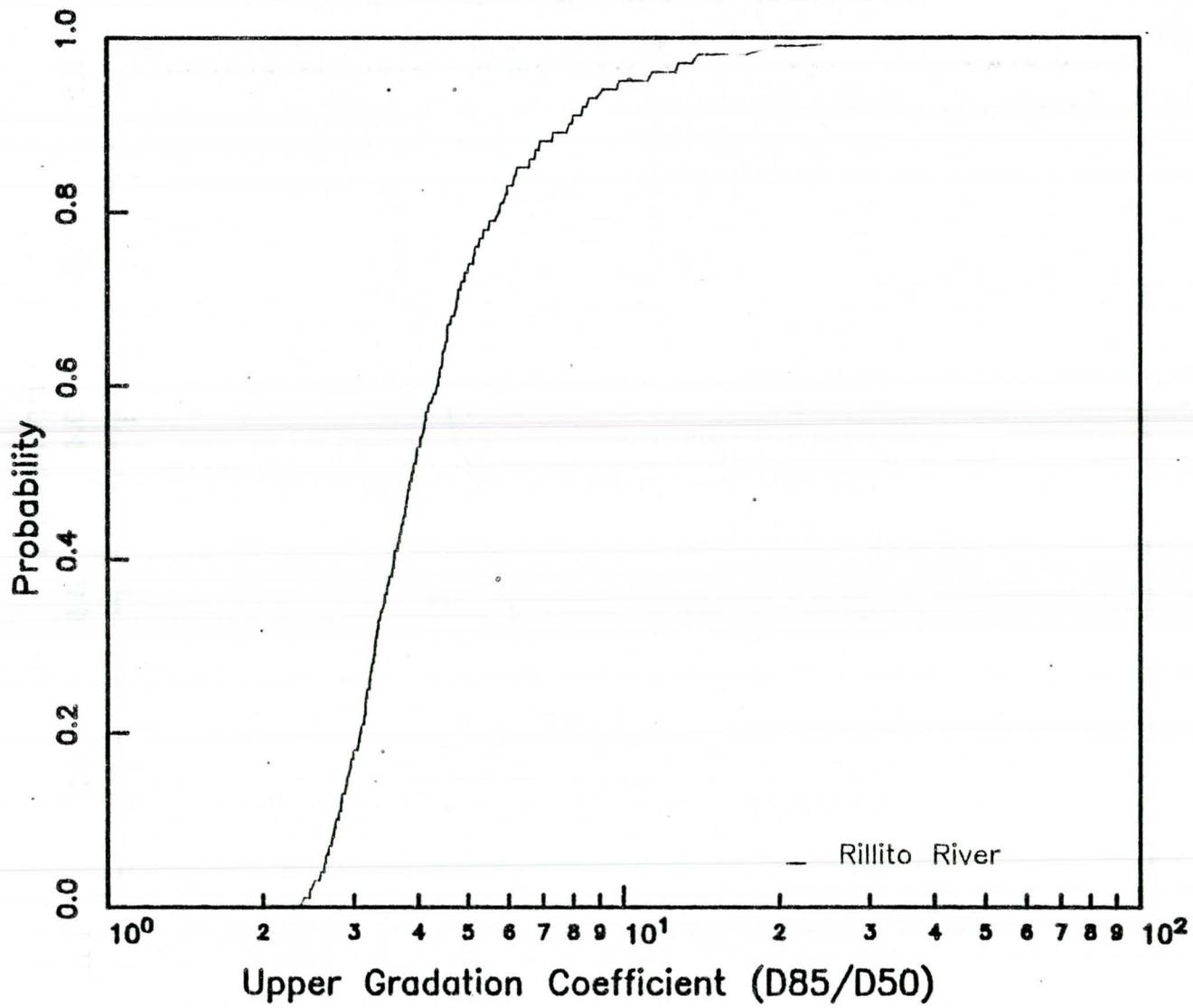


FIGURE H.24

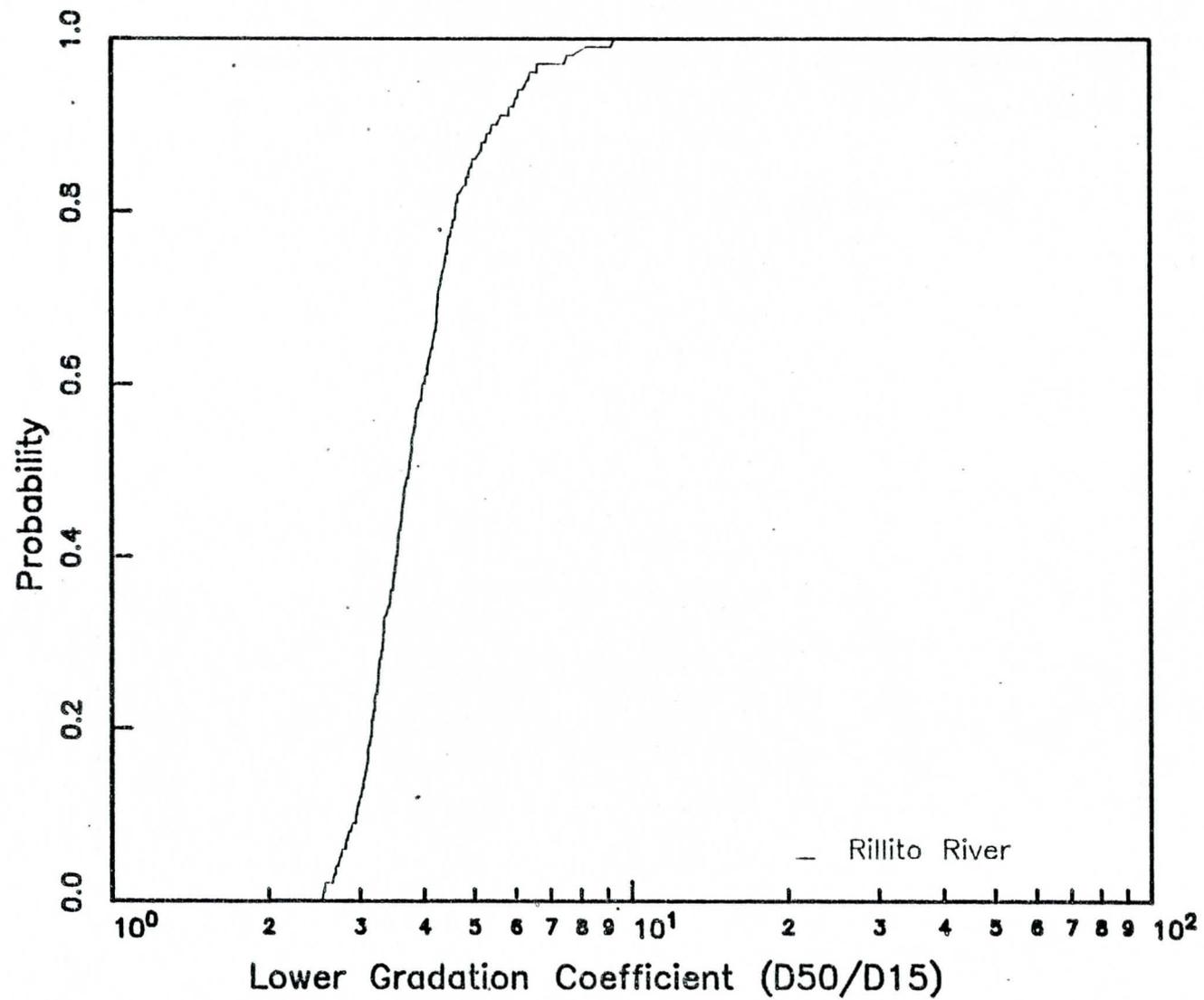


FIGURE H.25

H-30

Salt at Hayden Rd.

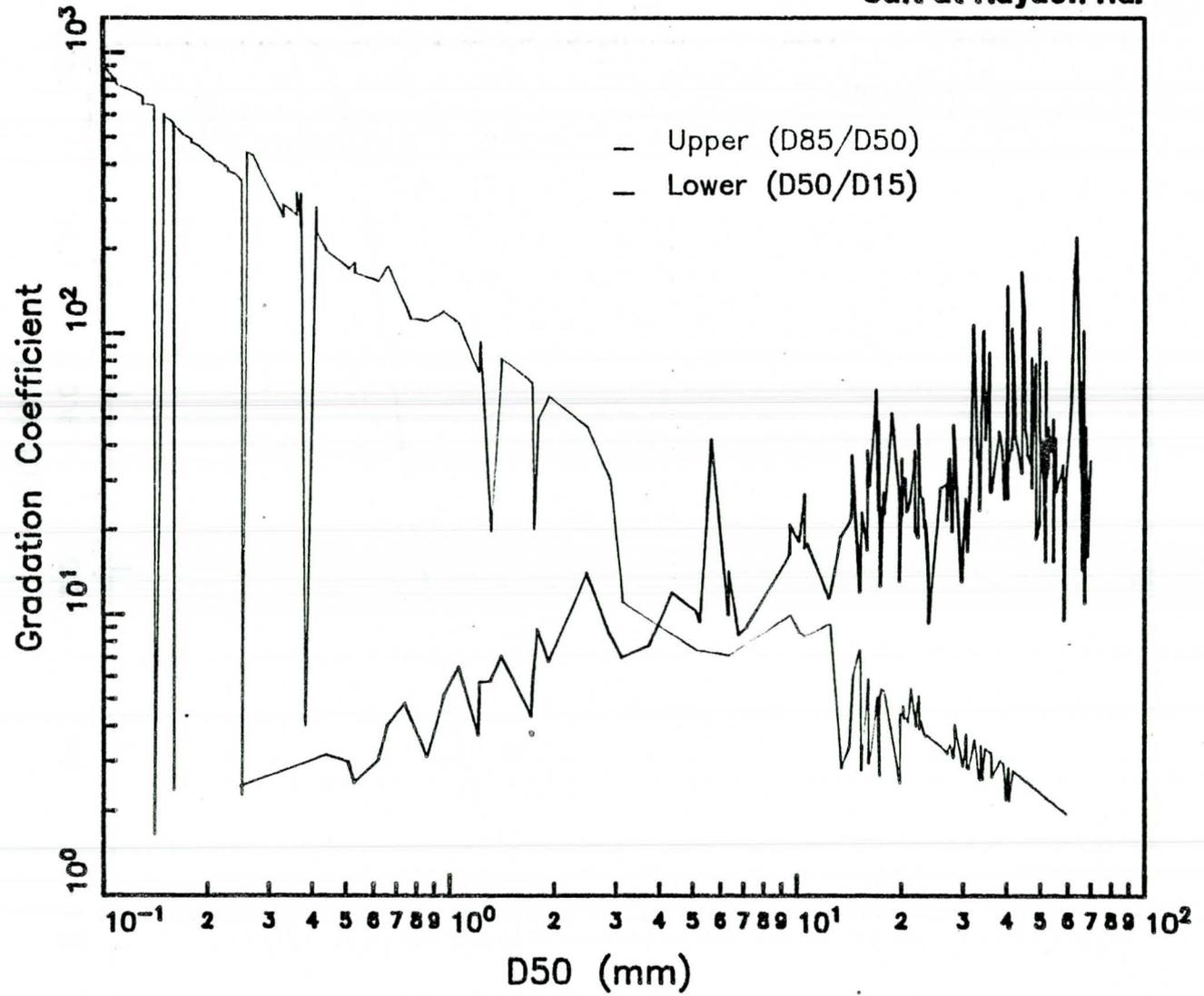


FIGURE H.26

Salt at 35th Ave.

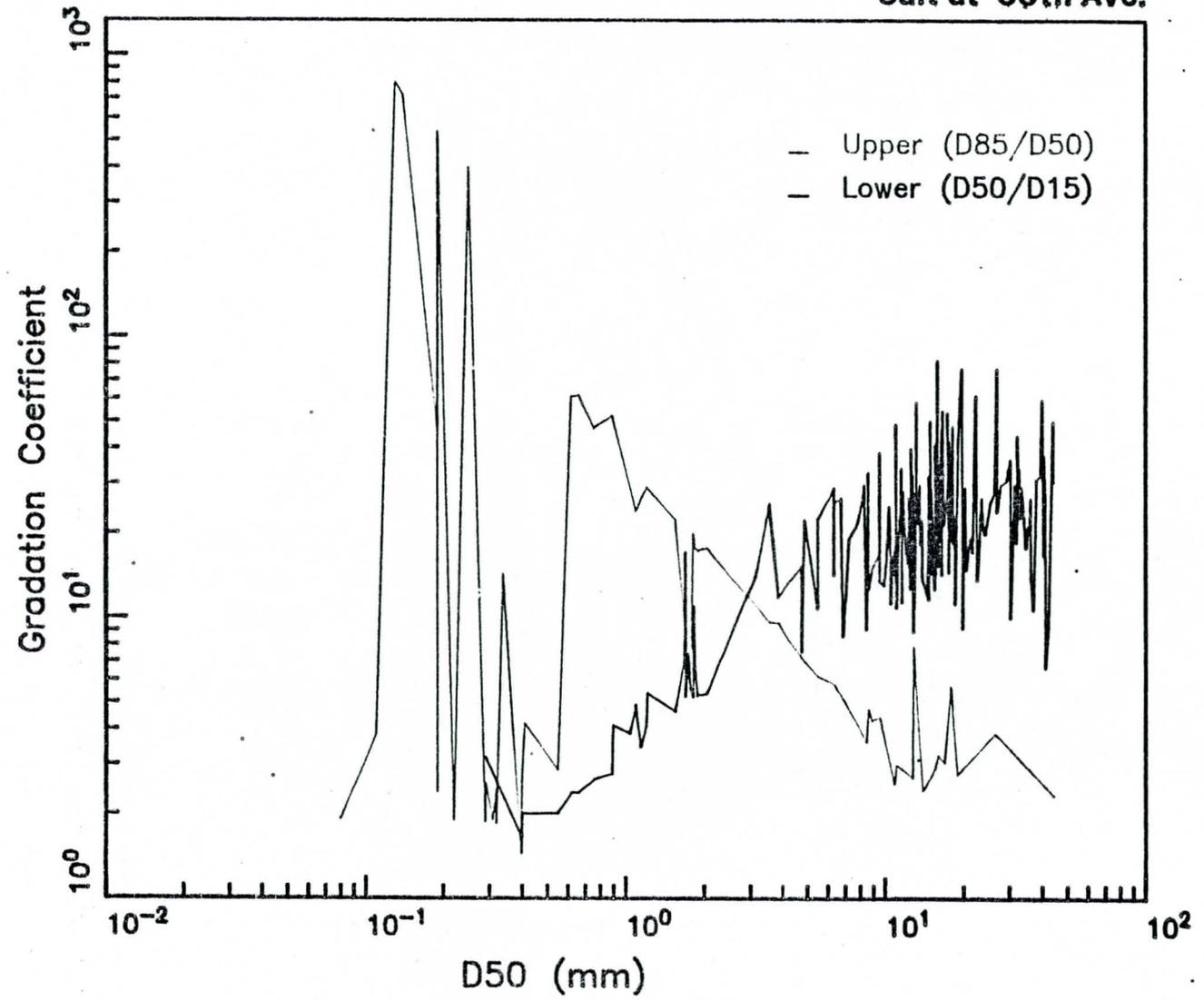


FIGURE H.27

H-32

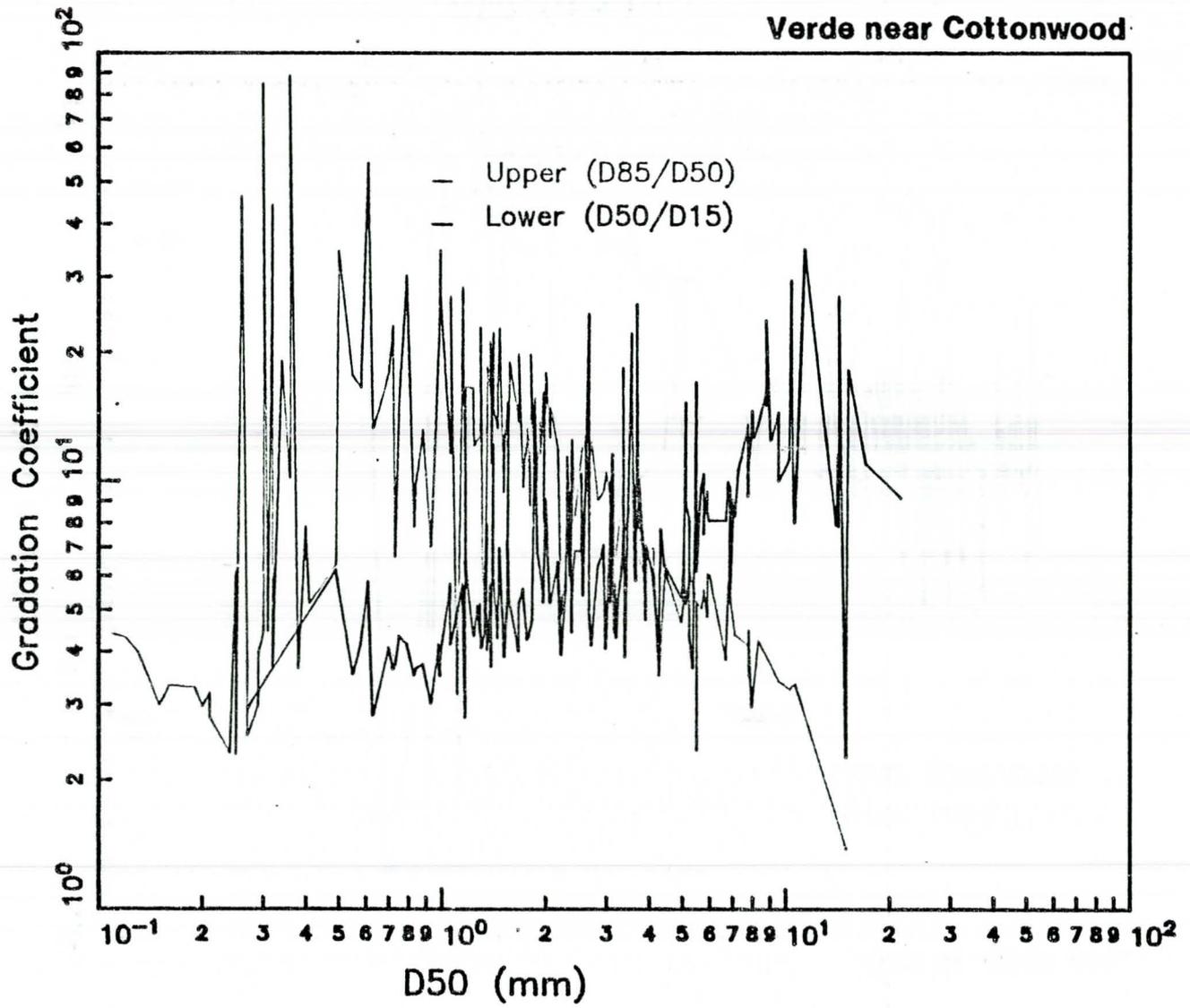


FIGURE HL28

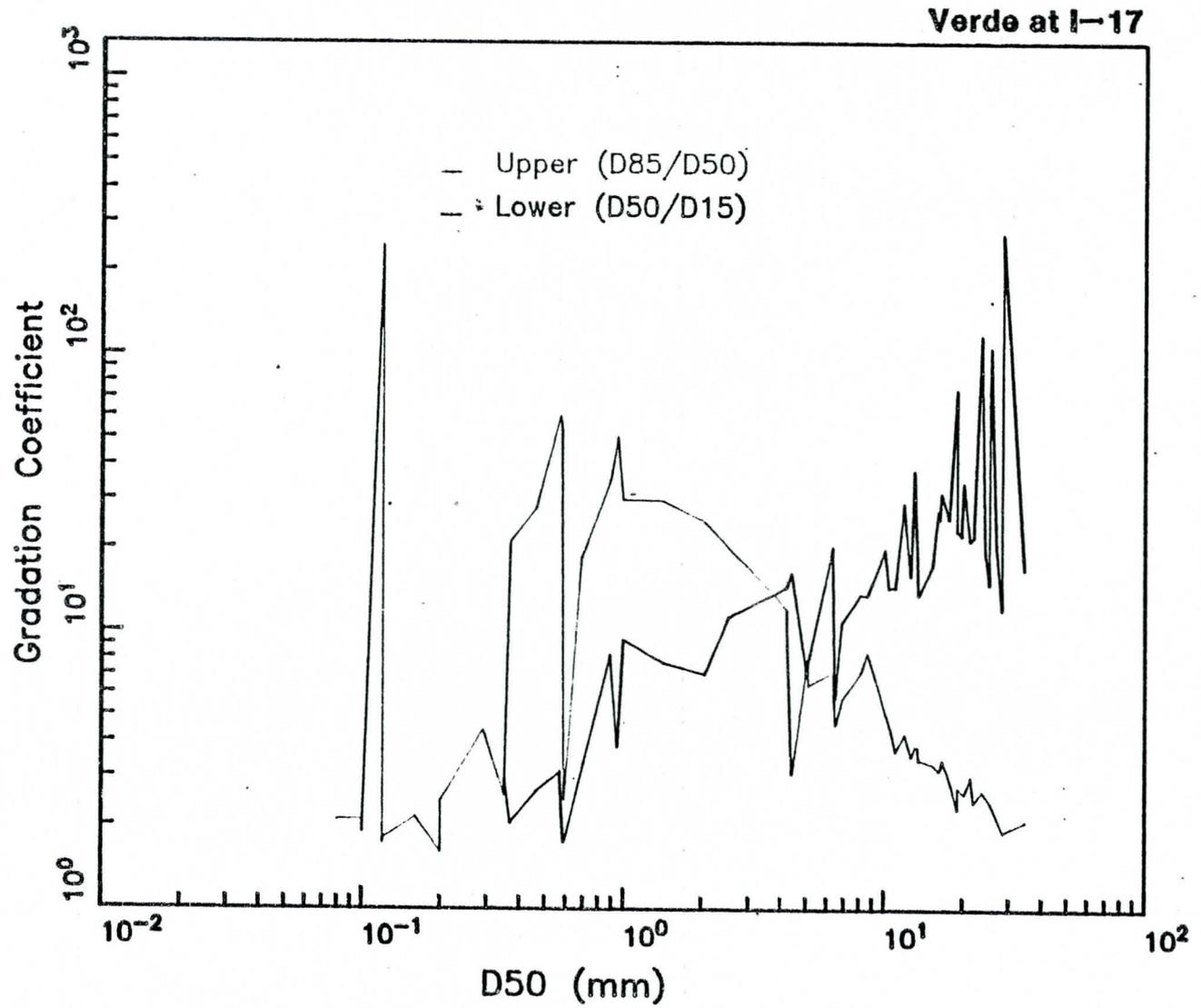


FIGURE H.29

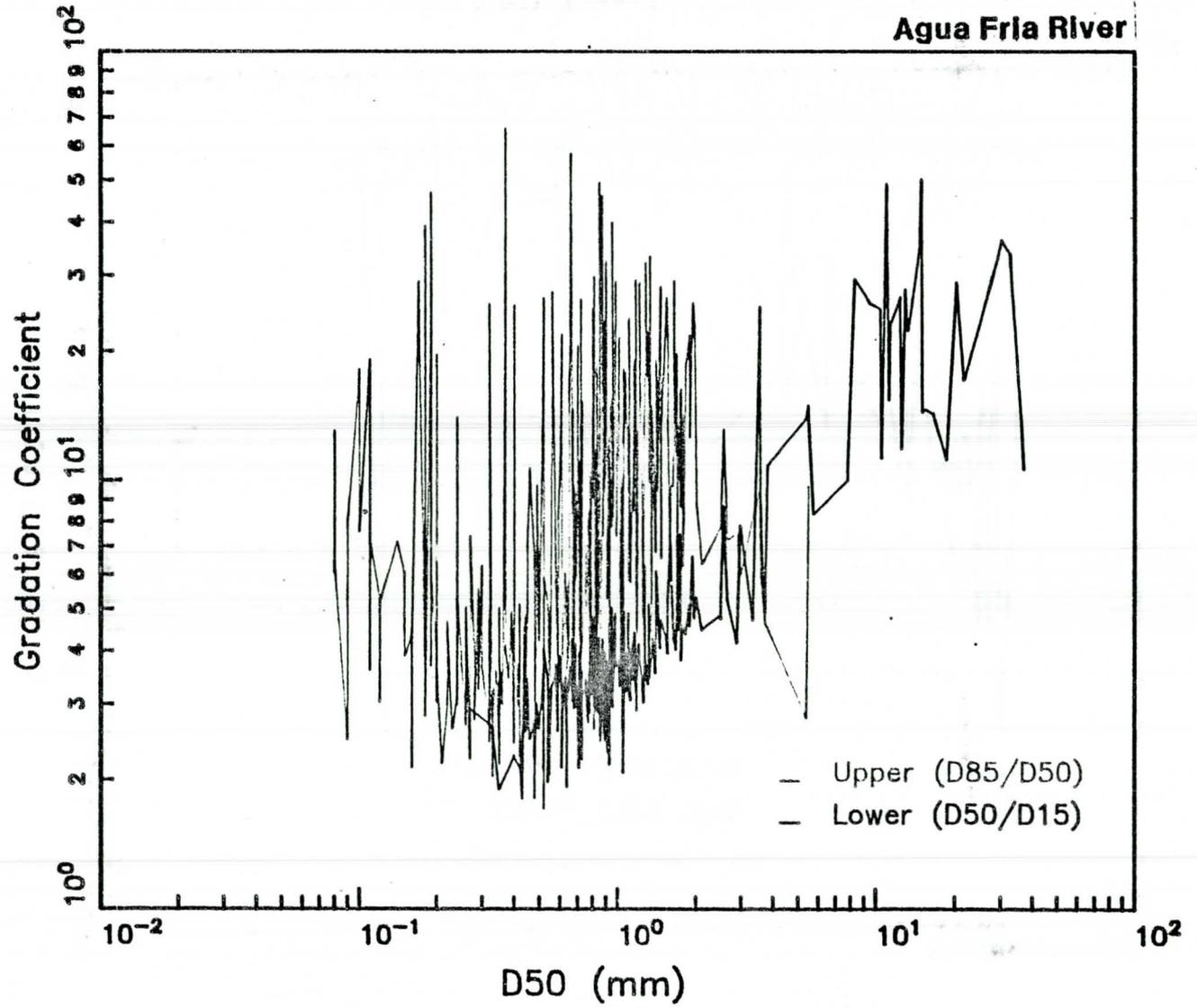


FIGURE H.30

H-35

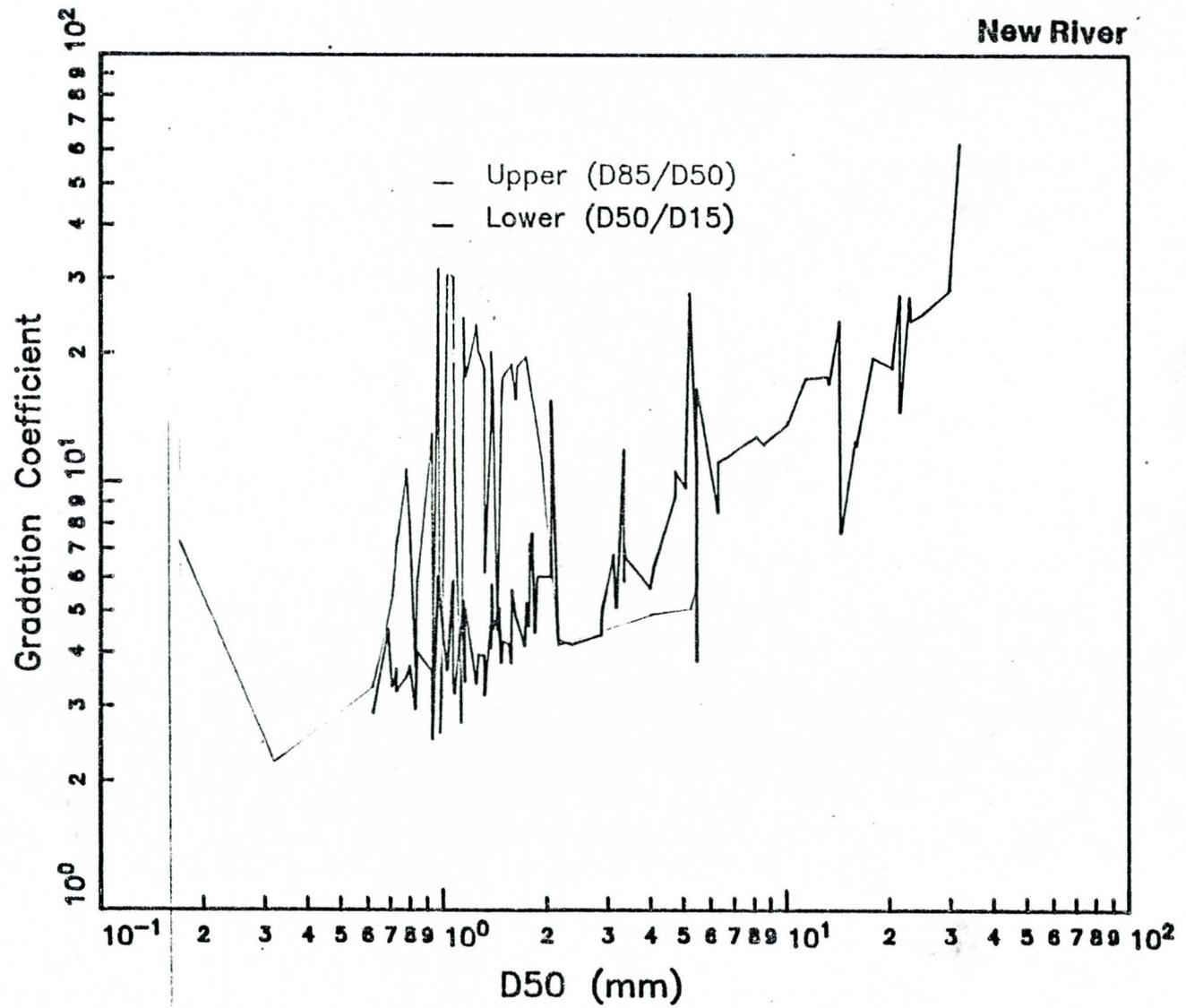


FIGURE H.31

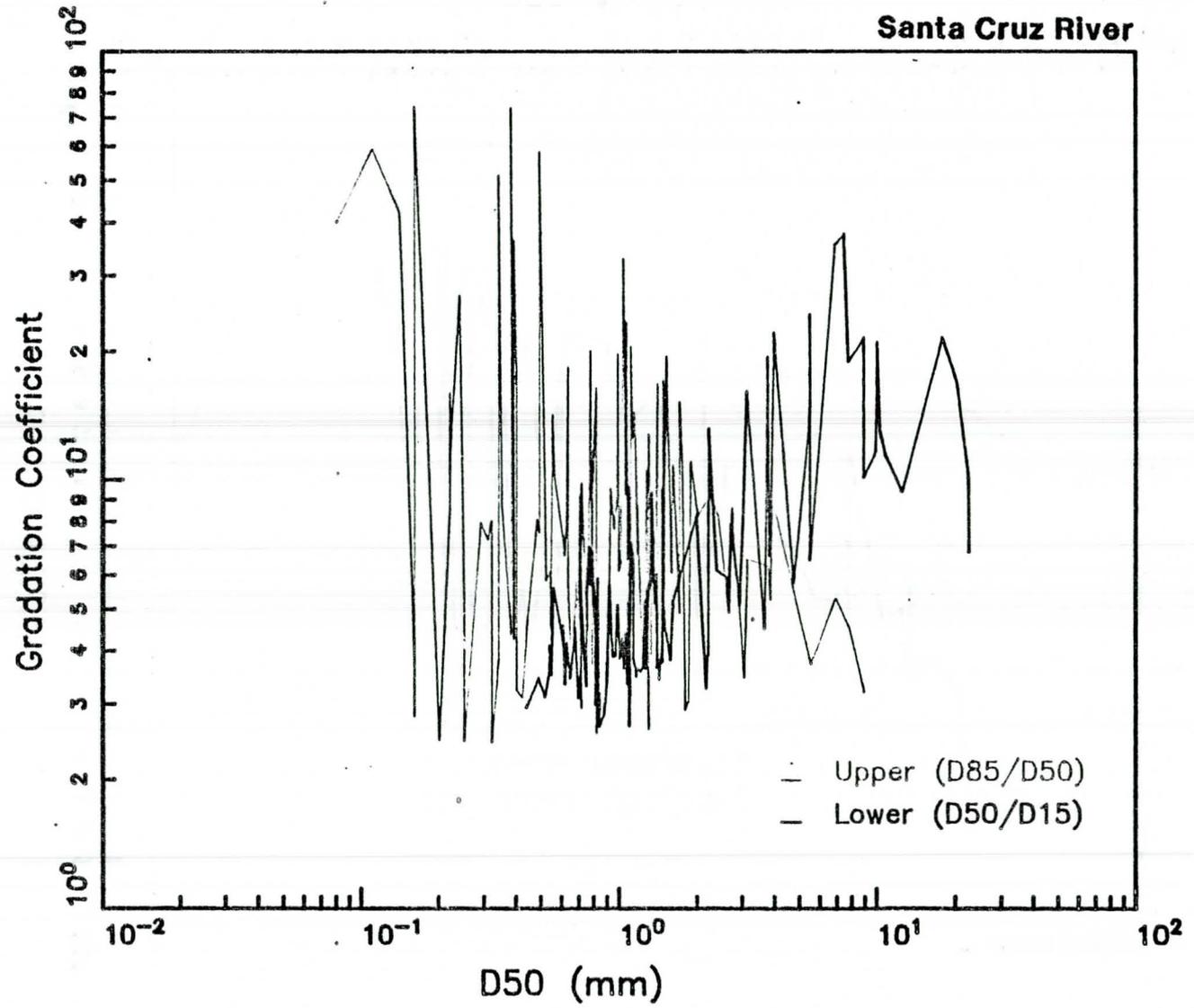


FIGURE H.32

H-37

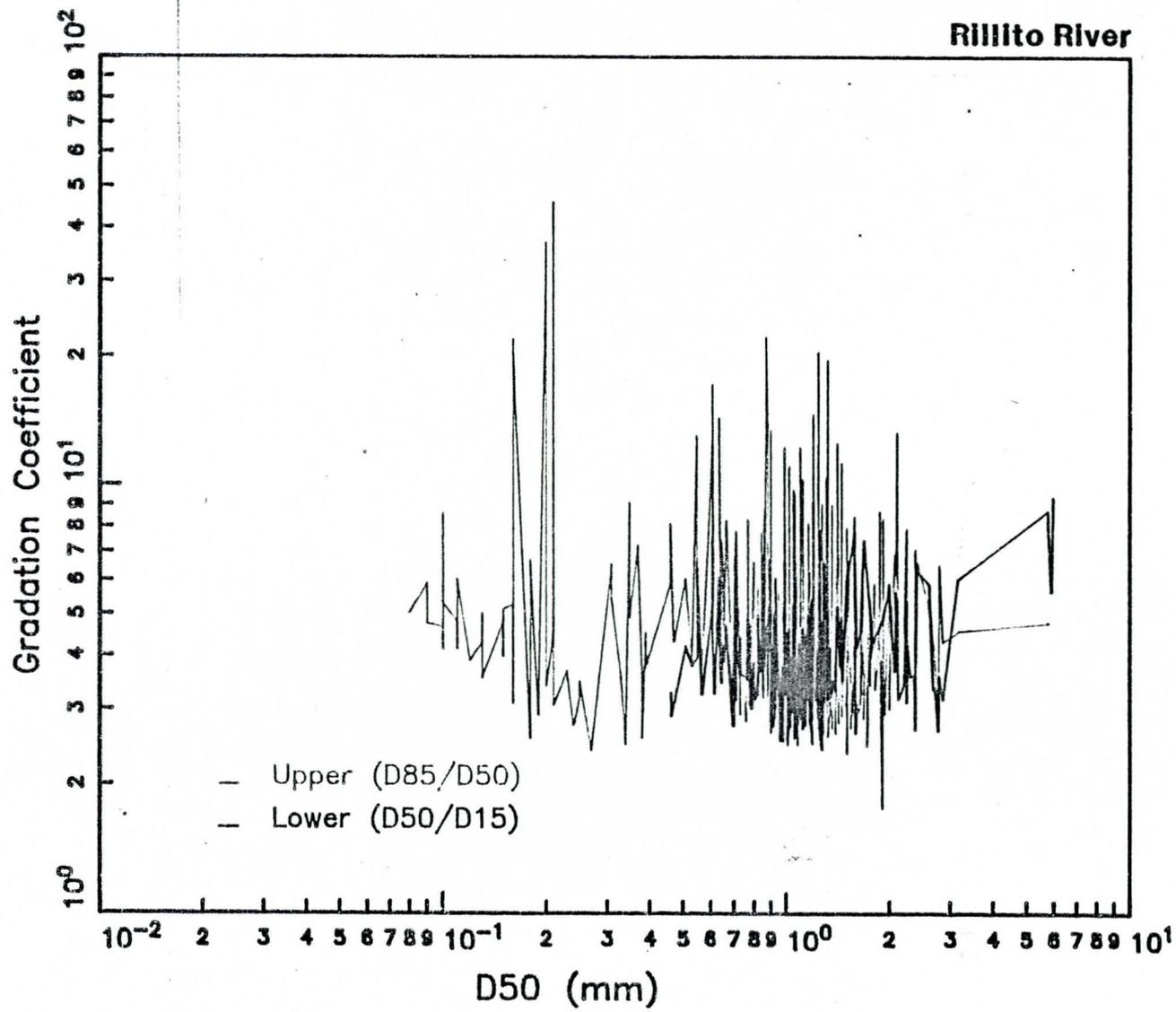


FIGURE H.33

APPENDIX H
PROGRAM LISTINGS

CHARACTER*30 INPUT, OUTPUT
CHARACTER*80 DATA

DIMENSION FLAG(4000)

WRITE (*,*) ' '
WRITE (*,*) 'INPUT THE NAME OF THE DATA FILE:'
READ (*,'(A30)') INPUT

WRITE (*,*) ' '
WRITE (*,*) 'INPUT THE NAME OF THE OUTPUT FILE:'
READ (*,'(A30)') OUTPUT

OPEN (1,FILE=INPUT, STATUS='OLD')
OPEN (2,FILE=OUTPUT, STATUS='NEW')

ICOUNT=0

10 READ(1,20,END=40) CARDNUM,DATA

20 FORMAT (F2.0,A78)

IF (CARDNUM.EQ.4.)THEN

WRITE (2,30) CARDNUM,DATA

WRITE (*,30) CARDNUM,DATA

30 FORMAT (F2.0,A78)

ENDIF

GOTO 10

40 STOP
END

```
DIMENSION P(20)

CHARACTER*30 INPUT, OUTPUT
CHARACTER HA,PI,SE,REJ

WRITE (*,*) ' '
WRITE (*,*) 'INPUT THE NAME OF THE DATA FILE:'
READ (*,'(A30)') INPUT

WRITE (*,*) ' '
WRITE (*,*) 'INPUT THE NAME OF THE OUTPUT FILE:'
READ (*,'(A30)') OUTPUT

OPEN (1,FILE=INPUT, STATUS='OLD')
OPEN (2,FILE=OUTPUT, STATUS='NEW')

ICOUNT=0
10 READ(1,20,END=50) ICD,IPITNO,HOLE,HA,D1,D2,(P(I),I=1,19)
20 FORMAT (I2,I5,F3.0,A1,2F3.1,19F3.0,)
DO 30, J=1, 19
    IF(P(J).EQ.0.) P(J)=-99.
30 CONTINUE

DO 35, I=1, 19.
    IF (P(I).EQ.0) P(I)=-99
35 CONTINUE

WRITE (2,40) (P(I),I=1,19)
40 FORMAT (19(F6.0,1X))

GOTO 10

50 STOP
END
```

PROGRAM FREQ

CHARACTER*30 INFILE

DIMENSION PASS(1000), PERC(20), CUM(65)

COMMON /BLOCK1/ Y(1000),Z(1000),NPSIZ

COMMON /BLOCK2/ AIVAL(65,6),NOIVALS,SIEVE(20),ICOL

COMMON /BLOCK3/ PASSX(125,20),PASSY(125,20),NOSIZ,IFLAG,LP(20)

```

WRITE (*,*) ' '
WRITE (*,*) '          PROGRAM DESCRIPTION'
WRITE (*,*) ' '
WRITE (*,*) 'This program calculates the standard normal'
WRITE (*,*) 'distribution values for the given data.'
WRITE (*,*) 'Due to practical limitations, all intervals'
WRITE (*,*) 'are forced to fall within the range of -3'
WRITE (*,*) 'and +3 standard deviations of the mean.'
WRITE (*,*) 'This limits the probability to within the'
WRITE (*,*) '99.9 percentile. Gradations with percentages'
WRITE (*,*) 'outside this range will be assigned the'
WRITE (*,*) 'standard normal distribution value of -3 or'
WRITE (*,*) '+3 respectively. Also, the user will be allowed'
WRITE (*,*) 'to plot a cumulative histogram of the data at the'
WRITE (*,*) 'end of the program.'
WRITE (*,*) ' '
WRITE (*,*) ' '
WRITE (*,*) '          PROGRAM LIMITATIONS'
WRITE (*,*) ' 1) Maximum No. of data records = 1000'
WRITE (*,*) ' 2) Maximum No. of sieve sizes = 20'
WRITE (*,*) ' 3) Maximum No. of interval subdivisions = 10'
WRITE (*,*) ' 4) Maximum No. of lines on the plot = 20'
WRITE (*,*) ' '

```

C Author: Jeffrey R. Minch
C Simons, Li and Associates, Inc.

C Date last revised: 6/19/87

```

10 WRITE (*,*) ' '
WRITE (*,*) 'Please input the number of interval subdivisions'
WRITE (*,*) 'you would like to use for this frequency analysis:'
READ (*,*) NODIV
IF(NODIV.GT.10) THEN
  CALL ERROR1
  GOTO 10
ENDIF

```

C Calculate the size of one increment and the number of intervals.

```

AINCRE=1.0/NODIV
NOIVALS=6*NODIV

```

```

* WRITE (*,*) 'NOIVALS VARIABLE'
* WRITE (*,*) NOIVALS
* PAUSE

```

H-41

C DATA INPUT FROM FILE

```
WRITE (*,*) ' '  
WRITE (*,*) 'Enter the name of the input file:'  
READ (*,'(A30)') INFILE  
OPEN (4,FILE=INFILE, STATUS='OLD')
```

```
20 WRITE (*,*) ' '  
WRITE (*,*) 'Input the number of sample sizes'  
WRITE (*,*) 'in the data file:'  
READ (*,*) NSSIZ  
IF (NSSIZ.GT.20) THEN  
CALL ERROR4  
GOTO 20  
ENDIF
```

C Reinitialize the output array.

```
IFLAG=0  
NOSIZ=0  
30 NOSIZ=NOSIZ+1
```

C Initialize the frequency data array to zero.

```
DO 50, I=1, NOIVALS  
DO 40, J=1, 5  
AIVAL(I,J)=0.  
40 CONTINUE  
50 CONTINUE
```

C Initialize the sieve array to zero.

```
DO 55, J=1,NSSIZ  
SIEVE(J)=0.  
55 CONTINUE
```

```
SIZPLT=0.
```

```
WRITE (*,*) ' '  
WRITE (*,*) 'Input which sieve size you would like analyzed:'  
READ (*,*) SIZPLT
```

```
READ (4,*)(SIEVE(J),J=1,NSSIZ)
```

```
* WRITE (*,*) 'SIEVE ARRAY'  
* WRITE (*,*)(SIEVE(J),J=1,NSSIZ)  
* PAUSE
```

C Search for the matching sieve size in the data file.

```
ICT=1  
ICOL=0  
DO 60, J=1, NSSIZ  
IF (SIZPLT.EQ.SIEVE(J)) THEN  
ICOL=ICT  
ELSE  
ICT=ICT+1  
ENDIF  
60 CONTINUE
```

```
IF (ICOL.EQ.0) THEN
```

```
CALL ERROR2  
REWIND 4  
GOTO 30  
ENDIF
```

```
* WRITE (*,*) 'ICOL VARIABLE'  
* WRITE (*,*) ICOL  
* PAUSE
```

C Setting up of the output array with interval data.

```
SUM=AINCRE  
DO 70, I=1, NOIVALS  
  IF (I.EQ.1) THEN  
    AIVAL(1,1)=-3.001  
    AIVAL(1,2)=-3.0+AINCRE  
  ELSEIF (I.EQ.NOIVALS) THEN  
    AIVAL(I,2)=3.001  
    AIVAL(I,1)=3.0-AINCRE  
  ELSE  
    SUM=SUM+AINCRE  
    AIVAL(I,1)=AIVAL(I-1,2)  
    AIVAL(I,2)=-3.0+SUM  
  ENDIF  
70 CONTINUE
```

```
* WRITE (*,*) 'AIVAL ARRAY'  
* DO 80, I=1, NOIVALS  
*   WRITE (*, '(5F6.1)')(AIVAL(I,J),J=1,5)  
* 80 CONTINUE  
* PAUSE
```

C Read data from the input file.

```
I=0  
DO 90, I=1, 1001  
  IF (I.GT.1000) THEN  
    CALL ERROR3  
  ELSE  
    READ (4,*,END=100)(PERC(J),J=1,NSSIZ)  
    PASS(I)=PERC(ICOL)  
  ENDIF  
90 CONTINUE
```

100 NUMREC=I-1

```
* WRITE (*,*) 'NUMREC VARIABLE'  
* WRITE (*,*) NUMREC  
* PAUSE  
* WRITE (*,*) 'PASS ARRAY'  
* WRITE (*,*)(PASS(I),I=1,NUMREC)  
* PAUSE
```

C Reinitialize the "Y" array.

```
DO 110, I=1, NSSIZ  
  Y(I)=0.  
110 CONTINUE
```

C Pack the "Y" array with usable values.

```

NPSIZ=0
DO 120, I=1, NUMREC
  IF (PASS(I).NE.-99.0) THEN
    NPSIZ=NPSIZ+1
    Y(NPSIZ)=PASS(I)
  ENDIF
120 CONTINUE

```

```

* WRITE (*,*) 'NPSIZ VARIABLE'
* WRITE (*,*) NPSIZ
* PAUSE
* WRITE (*,*) 'Y ARRAY'
* WRITE (*,*)(Y(I),I=1,NPSIZ)
* PAUSE

```

```
CALL LOGNORM
```

```

* WRITE (*,*) 'Z ARRAY'
* WRITE (*,*)(Z(I),I=1,NPSIZ)
* PAUSE

```

C Count the number of occurrences for each interval.

```

DO 140, I=1, NPSIZ
  DO 130, J=1, NOIVALS
    IF (Z(I).GT.AIVAL(J,1).AND.Z(I).LE.AIVAL(J,2)) THEN
      AIVAL(J,3)=AIVAL(J,3)+1.
    ENDIF
130 CONTINUE
140 CONTINUE

```

C Totals the number of occurrences for all the intervals.

```

ICNT=0
DO 150, I=1, NOIVALS
  ICNT=ICNT+AIVAL(I,3)
150 CONTINUE
IF (ICNT.EQ.0) THEN
  CALL ERROR2
  GOTO 700
ENDIF

```

C Calculates the percentage of occurrences for each interval
C and the average interval value.

```

DO 160, I=1, NOIVALS
  AIVAL(I,4)=(AIVAL(I,3)/ICNT)*100.
  AIVAL(I,5)=(AIVAL(I,1)+AIVAL(I,2))/2
160 CONTINUE

```

```

DO 165, I=1, NOIVALS
  CUM(I)=CUM(I-1)+AIVAL(I,4)
165 CONTINUE

```

```

DO 170, I=1, NOIVALS
  AIVAL(I,6)=CUM(I)
170 CONTINUE

```

C Option to print calculated data to disk or printer.

```
WRITE (*,*) ' '
WRITE (*,*) 'If you would like to print the output data to'
WRITE (*,*) 'to a disk or printer, type (Y=YES):'
READ (*, '(A1)') PLT
IF (PLT.EQ.'Y') CALL PRINTSUB
```

C Option to plot a cumulative histogram.

```
WRITE (*,*) ' '
WRITE (*,*) 'If you would like a cumulative histogram'
WRITE (*,*) 'plotted type (Y=YES):'
READ (*, '(A1)') PLOT
IF (PLOT.EQ.'Y') CALL FREQPLOT
```

C Option to analyze other sieve sizes.

```
700 WRITE (*,*) ' '
WRITE (*,*) 'If you would like to analyze another'
WRITE (*,*) 'sieve size type (Y=YES):'
READ (*, '(A1)') ANOTHER
IF (ANOTHER.EQ.'Y') THEN
  REWIND 4
  GOTO 30
ENDIF
```

```
IF (IFLAG.EQ.1) CALL MULTILOT
```

```
STOP
END
```

```
SUBROUTINE LOGNORM
```

C This subroutine calculates the standard normal value for
C each element in the "Y" array.

```
DIMENSION PZ(31)
```

```
COMMON /BLOCK1/ Y(1000),Z(1000),NPSIZ
```

```
DATA PZ /0.0,0.0398,0.0793,0.1179,0.1554,0.1915,0.2258,0.2580,  
10.2881,0.3159,0.3413,0.3643,0.3849,0.4032,0.4192,0.4332,0.4452,  
20.4554,0.4641,0.4713,0.4772,0.4821,0.4861,0.4893,0.4918,0.4938,  
30.4953,0.4965,0.4974,0.4981,0.4987/
```

C Search for the Z value

```
DO 100 I=1,NPSIZ
```

```
IF (Y(I).EQ.0) THEN
  Z(I)=-3.0
ELSEIF (Y(I).EQ.100) THEN
  Z(I)=3.0
```



```
WRITE(*,*) ' '  
WRITE(*,*) 'Enter the name of the output file:'  
READ(*,'(A30)') OUTFILE
```

```
OPEN (1,FILE=OUTFILE,STATUS='NEW')
```

```
WRITE (1,400) SIEVE(ICOL)  
400 FORMAT (/ ,23X,'FREQUENCY ANALYSIS',//,20X,'SIEVE SIZE:',  
+F7.3,'(mm)')  
WRITE (1,410)  
410 FORMAT (/ ,10X,'LOWER UPPER NUMBER OF PERCENTAGE AVERAGE OF',  
+/,10X,'BOUND BOUND OCCURANCES OF TOTAL INTREVAL')  
WRITE (1,420)  
420 FORMAT (10X,'-----')  
DO 440, I=1, NOIVALS  
WRITE (1,430)(AIVAL(I,J),J=1,6)  
430 FORMAT (8X,2F7.2,2X,F7.2,6X,F7.2,5X,F7.2,3X,F7.2)  
440 CONTINUE  
WRITE (1,450)  
450 FORMAT (10X,'-----')  
ENDIF
```

```
WRITE(*,*) ' '  
WRITE(*,*) 'If you would like a printed output of the'  
WRITE(*,*) 'analized data type (Y=YES):'  
READ(*,'(A1)') PRINT  
IF (PRINT.EQ.'Y') THEN
```

```
OPEN (2,FILE='LPT1',STATUS='NEW')
```

```
WRITE (2,510) SIEVE(ICOL)  
510 FORMAT (1H,///,33X,'FREQUENCY ANALYSIS',//,20X,'SIEVE SIZE:',  
+F7.3,'(mm)')  
WRITE (2,520)  
520 FORMAT (/ ,20X,'LOWER UPPER NUMBER OF PERCENTAGE AVERAGE OF',  
+/,20X,'BOUND BOUND OCCURANCES OF TOTAL INTREVAL')  
WRITE (2,530)  
530 FORMAT (20X,'-----')  
DO 550, I=1, NOIVALS  
WRITE (2,540)(AIVAL(I,J),J=1,5)  
540 FORMAT (18X,2F7.2,2X,F7.2,6X,F7.2,5X,F7.2)  
550 CONTINUE  
WRITE (2,560)  
560 FORMAT (20X,'-----')  
ENDIF
```

```
RETURN  
END
```

```
SUBROUTINE FREQPLOT
```

```
DIMENSION XP(1000),YP(1000),CUM(65)  
  
COMMON /BLOCK2/ AIVAL(65,6),NOIVALS,SIEVE(20),ICOL  
COMMON /BLOCK3/ PASSX(125,20),PASSY(125,20),NOSIZ,IFLAG,LP(20)
```

```
IFLAG=1
```

```
C Initialize the cumulative array.
```

```
DO 5, I=1, NOIVALS
  CUM(I)=0.
5 CONTINUE
```

```
C Use the output array to develop the plot arrays.
```

```
DO 10, I=1, NOIVALS
  CUM(I)=CUM(I-1)+AIVAL(I,4)
10 CONTINUE
```

```
* WRITE (*,*) 'CUM ARRAY'
* WRITE (*,*)(CUM(I),I=1,NOIVALS)
* PAUSE
```

```
L=0
DO 30, I=1, NOIVALS
  DO 20, J=1, 2
    L=L+1
    IF (AIVAL(I,J).LT.-3.0) THEN
      XP(L)=-3.0
      YP(L)=CUM(I)
    ELSEIF (AIVAL(I,J).GT.3.0) THEN
      XP(L)=3.0
      YP(L)=CUM(I)
    ELSE
      XP(L)=AIVAL(I,J)
      YP(L)=CUM(I)
    ENDIF
  20 CONTINUE
30 CONTINUE
```

```
LP(NOSIZ)=L
```

```
* WRITE (*,*) 'XP ARRAY'
* WRITE (*,*)(XP(I),I=1,L)
* PAUSE
* WRITE (*,*) 'YP ARRAY'
* WRITE (*,*)(YP(I),I=1,L)
* PAUSE
```

```
C Transfer plotable values to the multiple plot arrays.
```

```
DO 40, I=1, L
  PASSX(I,NOSIZ)=XP(I)
  PASSY(I,NOSIZ)=YP(I)
40 CONTINUE
```

```
* WRITE (*,*) 'NOSIZ VARIABLE'
* WRITE (*,*) NOSIZ
* PAUSE
* WRITE (*,*) 'PASSX ARRAY'
* WRITE (*,*)(PASSX(I,NOSIZ),I=1,L)
* PAUSE
* WRITE (*,*) 'PASSY ARRAY'
```

```
* WRITE (*,*)(PASSY(I,NOSIZ),I=1,L)
* PAUSE

RETURN
END
```

SUBROUTINE MULTILOT

```
CHARACTER*26 YNAME
CHARACTER*28 XNAME
CHARACTER*45 TITLE
```

```
DIMENSION XP(130),YP(130),IPEN(20)
```

```
COMMON /BLOCK3/ PASSX(125,20),PASSY(125,20),NOSIZ,IFLAG,LP(20)
```

C Initialize the plot device to HP-7475A.

```
CALL PLOTS (0,9600,30)
```

C Set paper and plot window sizes.

```
XLENGTH=6.0
YLENGTH=5.0
```

```
XPAPER=11.0
YPAPER=8.5
```

C Determine corners of the window and draw a box about the window.

```
XMIN=(XPAPER-XLENGTH)/2.+0.5
XMAX=XMIN+XLENGTH
YMIN=(YPAPER-YLENGTH)/2.
YMAX=YMIN+YLENGTH
```

```
CALL PLOT(XMIN,YMIN,3)
CALL PLOT(XMAX,YMIN,2)
CALL PLOT(XMAX,YMAX,2)
CALL PLOT(XMIN,YMAX,2)
CALL PLOT(XMIN,YMIN,2)
```

C Redefine the origin of the plot so that (0,0) is at (XMIN,YMIN) inches.

```
CALL PLOT(XMIN,YMIN,-3)
```

C Place labels, tic marks, and numbering.

```
YNAME='Cumulative Percent Passing'
XNAME='Standard Normal Distribution'
```

C Initialize the Simplex symbol set.

```
CALL SIMPLX
```

C Characterize axis annotation with respect to paper and plot size.

```

IEXP=INT(XPAPER-XLENGTH)
FACT=0.95**IEXP
ANNHGT=0.10*FACT
TIHGT =0.125*FACT
EXPHGT=0.10*FACT
TICLNG=0.075*FACT
NDECA=1
DELTAY=20.

```

C Draw the axis for the plot.

```

CALL STAXIS (ANNHGT,TIHGT,EXPHGT,TICLNG,NDECA)

CALL AXIS (0.,0.,XNAME,-28,-XLENGTH,0.,-3.,1.)

CALL AXIS (0.,0.,YNAME,26,-YLENGTH,90.,0.,DELTAY)

```

C Set the pen color for each line.

```

IPEN(1)=2
DO 10, I=2, NOSIZ
  IF (IPEN(I-1).EQ.5) THEN
    IPEN(I)=2
  ELSE
    IPEN(I)=IPEN(I-1)+1
  ENDIF
10 CONTINUE

```

```

* WRITE (*,*) ' '
* WRITE (*,*) 'IPEN ARRAY'
* WRITE (*,*)(IPEN(I),I=1,NOSIZ)
* PAUSE

```

C Initialize the line characteristics.

```

CALL STLINE (1,0.05*FACT,0)

```

C Load each line into the plot arrays.

```

DO 30, J=1, NOSIZ

  DO 20, I=1, LP(NOSIZ)
    XP(I)=PASSX(I,J)
    YP(I)=PASSY(I,J)
  20 CONTINUE

  XP(LP(NOSIZ)+1)=-3.0
  XP(LP(NOSIZ)+2)=1.0
  YP(LP(NOSIZ)+1)=0.
  YP(LP(NOSIZ)+2)=DELTAY

```

```

* WRITE (*,*) 'NOSIZ VARIABLE'
* WRITE (*,*) NOSIZ
* PAUSE
* WRITE (*,*) 'XP ARRAY'
* WRITE (*,*)(XP(I),I=1,LP(NOSIZ))
* PAUSE
* WRITE (*,*) 'YP ARRAY'

```

```
* WRITE (*,*)(YP(I),I=1,LP(NOSIZ))  
* PAUSE
```

```
CALL COLOR(IPEN(J),IERR)
```

```
CALL LINE (XP,YP,LP(NOSIZ),1,0,3)
```

```
30 CONTINUE
```

```
WRITE (*,*) ' '  
WRITE (*,*) 'Enter the title of the plot (45 char. max.):'  
WRITE (*,*) '<----->'  
READ (*,'(A45)') TITLE
```

```
CALL COLOR (0,IERR)  
CALL SYMBOL(1.0,5.5,0.125,TITLE,0.,45)
```

C Terminate plot.

```
CALL PLOT (0.,0.,999)
```

```
RETURN  
END
```

SUBROUTINE ERROR1

```
WRITE (*,*) ' '  
WRITE (*,*) 'ERROR: The maximum number of interval'  
WRITE (*,*) ' subdivisions is 10.'  
RETURN  
END
```

SUBROUTINE ERROR2

```
WRITE (*,*) ' '  
WRITE (*,*) 'ERROR: The sieve size you requested to be '  
WRITE (*,*) ' analyzed does not exist or contains'  
WRITE (*,*) ' no data!'  
RETURN  
END
```

SUBROUTINE ERROR3

```
WRITE (*,*) ' '  
WRITE (*,*) 'ERROR: The maximum number of records'  
WRITE (*,*) ' in the data file is 1000.'  
RETURN
```

END

SUBROUTINE ERROR4

```
WRITE (*,*) ' '  
WRITE (*,*) 'ERROR: The maximum number of sieve'  
WRITE (*,*) '      sizes allowed is 20.'  
RETURN  
END
```

!
! This program was developed to assist in analyzing data from the ADOT
! data base. This program statistically manipulates the data to
! permit its user to estimate an accurate average gradation coeff-
! icient for a specific data set.
!
! Author: Jeffrey R. Minch
! Simons, Li & Associates, Inc.
!
! Date last revised: 6/24/87

! DIM pas(600,20), sv(20), pz(31), t(600,20), coeff(600,5), gradco(600), sieve(19), sample(19)

! Program data aquisition thru user input file.

! PRINT"
! INPUT prompt "What is the name of the input file ? ":infile\$
! PRINT"

OPEN #1: name infile\$, access input, organization text

INPUT #1: sv(1),sv(2),sv(3),sv(4),sv(5),sv(6),sv(7),sv(8),sv(9),sv(10),sv(11),sv(12),sv(13),sv(14),sv(15),sv(16),sv(17),sv(18),sv(19)

LET i=0

DO while more #1

LET i=i+1

INPUT #1: pas(i,1),pas(i,2),pas(i,3),pas(i,4),pas(i,5),pas(i,6),pas(i,7),pas(i,8),pas(i,9),pas(i,10),pas(i,11),pas(i,12),pas(i,13),pas(i,14),pas(i,15),pas(i,16),pas(i,17),pas(i,18),pas(i,19)
LOOP

LET numrec=i

!
! Calculation of standard normal values for the percent passing.
!

FOR i=1 to 31

READ pz(i)

NEXT i

DATA 0.0,0.0389,0.0793,0.1179,0.1554,0.1915,0.2258,0.2580
DATA 0.2881,0.3159,0.3413,0.3643,0.3849,0.4032,0.4192,0.4332,0.4452
DATA 0.4554,0.4641,0.4713,0.4772,0.4821,0.4861,0.4893,0.4918,0.4938
DATA 0.4953,0.4965,0.4974,0.4981,0.4987

LET i,j=0

FOR i=1 to numrec

FOR j=1 to 19

IF pas(i,j)=0 then

LET t(i,j)=-3.0

ELSEIF pas(i,j)=100 then

LET t(i,j)=3.0

ELSEIF pas(i,j)=-99 then

LET t(i,j)=pas(i,j)

ELSE

LET trial=0

LET trial= pas(i,j)/100

IF trial>=0.5 then

LET ncount=0

FOR k=1 to 31

IF trial>=(pz(k)+0.5) then LET ncount=ncount+1

NEXT k

```

ELSE
  LET ncount=0
  FOR k=1 to 31
    IF trial<(0.5-pz(k)) then LET ncount=ncount+1
  NEXT k
END IF
LET temp,pflg,pint=0
IF trial>=0.5 then
  LET pint=trial-0.5
  LET pflg=1.0
ELSE
  LET pint=0.5-pz(ncount)
  LET pflg=-1.0
END IF
IF trial>=0.5 then
  LET temp=0.1*(pint-pz(ncount))/(pz(ncount+1)-pz(ncount))
  LET t(i,j)=(pflg*(ncount-1)*0.1)+temp
ELSE
  LET temp=0.1*((pint-trial)/(pint-(0.5-pz(ncount+1))))
  LET t(i,j)=(pflg*(ncount-1)*0.1)+(pflg*temp)
END IF
END IF
NEXT j
NEXT i
!
! Assignment of values to be interpolated.
!
LET t85=1
LET t50=0
LET t15=-1
LET i,j,m=0
!
! Loop through the converted data and pack arrays with usable data.
!
FOR i=1 to numrec
  LET k=0
  FOR j=1 to 19
    IF t(i,j)<>-99 then
      LET k=k+1
      LET sample(k)=t(i,j)
      LET sieve(k)=sv(j)
    END IF
  NEXT j
  !
  ! Decision structure to interpolate values.
  !
  IF k>>0 then
    LET j=0
    FOR j=1 to k-1
      LET ub=sample(j)
      LET lb=sample(j+1)
      IF ub>=t85 and t85>lb then
        LET flg=1
        CALL interp
      ELSEIF ub>=t50 and t50>lb then
        LET flg=2
        CALL interp
      ELSEIF ub>=t15 and t15>lb then
        LET flg=3

```

```
        CALL interp
      END IF
    NEXT j
  END IF
NEXT i
!
! Decision structure to calculate the gradation coefficients.
!
LET i=0
FOR i=1 to numrec
  IF coeff(i,1)=0 and coeff(i,2)=0 and coeff(i,3)=0 then
    LET coeff(i,4)=9999
    LET coeff(i,5)=0
  ELSE IF coeff(i,2)=0 and coeff(i,3)=0 then
    LET coeff(i,4)=9999
    LET coeff(i,5)=0
  ELSE IF coeff(i,2)=0 and coeff(i,3)<>0 then
    LET coeff(i,4)=9999
    LET coeff(i,5)=coeff(i,2)/coeff(i,3)
  ELSE IF coeff(i,2)<>0 and coeff(i,3)=0 then
    LET coeff(i,4)=coeff(i,1)/coeff(i,2)
    LET coeff(i,5)=0
  ELSE
    LET coeff(i,4)=coeff(i,1)/coeff(i,2)
    LET coeff(i,5)=coeff(i,2)/coeff(i,3)
  END IF
NEXT i

DO
! Initialization of the gradation coefficient array.

LET i=0
FOR i=1 to numrec
  LET gradco(i)=0
NEXT i

PRINT ""
PRINT "If you would like an assending sort on a"
INPUT prompt " gradation coefficient, type (Y=YES) ? ":ans1$
IF ans1$="y" or ans1$="Y" then
  PRINT ""
  PRINT "Assending sort on: Upper Coefficient (Type 1) or"
  INPUT prompt " Lower Coefficient (Type 2) ? ":ans1

  SELECT CASE ans1
  CASE 1
    LET i,m=0
    FOR i=1 to numrec
      IF coeff(i,4)<>9999 and coeff(i,4)<>0 then
        LET m=m+1
        LET gradco(m)=coeff(i,4)
      END IF
    NEXT i
  CASE 2
    LET i,m=0
    FOR i=1 to numrec
      IF coeff(i,5)<>9999 and coeff(i,5)<>0 then
        LET m=m+1
```

```

        LET gradco(m)=coeff(i,5)
    END IF
NEXT i
CASE ELSE
    PRINT ""
    PRINT "FATAL ERROR"
    PRINT ""
    STOP
END SELECT

PRINT ""
INPUT prompt "If you would like a rank file output to disk type (Y=YES) ?":ans2$
IF ans2$="Y" or ans2$="y" then
    PRINT ""
    INPUT prompt "Input the name of the output file ?":outfile$
    OPEN #3: name outfile$, create new, access output, organization text
    !
    !     Selection with interchange sort technique.
    !
    LET n=m-1
    LET i,j=0
    FOR i=1 to n
        LET iplus1=i+1
        FOR j=iplus1 to m
            IF gradco(i)>gradco(j) then
                LET temp=gradco(i)
                LET gradco(i)=gradco(j)
                LET gradco(j)=temp
            END IF
        NEXT j
    NEXT i
END IF

FOR i=1 to m
    PRINT #3, using " ###.## ####.##":i/(m+1),gradco(i)
NEXT i
END IF
CLOSE #3

PRINT ""
INPUT prompt "If you would like to analyze the other coefficient, type (Y=YES) ? ":ans3$
PRINT ""

LOOP until ans3$<>"y" and ans3$<>"Y"

CALL printout

SUB interp
!
! This subroutine linearly interpolates between two values
! with a conversion of the sieve size variable to a
! logarithmic value. The percent passing was previously
! converted to a standard normal value.
!
SELECT CASE flg
CASE 1
    LET d=1
CASE 2
    LET d=0

```

CASE 3

LET d=-1

END SELECT

LET tmp1=ub-d

LET tmp2=ub-lb

LET factor=tmp1/tmp2

LET tmp3=(log10(sieve(j))-log10(sieve(j+1)))*factor

LET coeff(i,flg)=10^(log10(sieve(j))-tmp3)

END SUB

SUB printout

!

! This subroutine prints to the printer the one to one correspondence
 ! of the interpolated percent passing values and their respective
 ! upper and lower gradation coefficients.
 !

INPUT prompt "If you would like a print out of the data for this file type (Y=YES)":ans3\$

IF ans3\$="Y" or ans3\$="y" then

OPEN #2: printer

PRINT #2: ""

PRINT #2: ""

PRINT #2: tab (10); "Data File: ";infile\$

PRINT #2: ""

PRINT #2: ""

PRINT #2: " D85 D50 D15 Upper Lower"

PRINT #2: "-----"

LET i=0

FOR i=1 to numrec

PRINT #2, using " ###.## ###.## ###.## ####.### #####.###":coeff(i,1),coeff(i,2),coeff(i,3),coeff(i,4),coeff(i,5)

NEXT i

PRINT #2: "-----"

END IF

END SUB

END

```
!
! This program was developed to assist in analyzing data from the ADOT
! data base. This program statistically manipulates the data to
! permit its user to estimate an accurate average gradation coeff-
! icient for a specific data set. Specifically, the output to disk
! lists the D50 versus the gradation coefficients for plotting purposes.
!
```

```
! Author: Jeffrey R. Minch
!         Simons, Li & Associates, Inc.
!
```

```
! Date last revised: 6/24/87
!
```

```
DIM pas(600,20), sv(20), pz(31), t(600,20), coeff(600,5), gradco(600), sieve(19), sample(19), delta (600), out(600,4)
```

```
! Program data aquisition thru user input file.
!
```

```
PRINT**
```

```
INPUT prompt "What is the name of the input file ? ":infile$
```

```
PRINT**
```

```
OPEN #1: name infile$, access input, organization text
```

```
INPUT #1: sv(1),sv(2),sv(3),sv(4),sv(5),sv(6),sv(7),sv(8),sv(9),sv(10),sv(11),sv(12),sv(13),sv(14),sv(15),sv(16),sv(17),sv(18),sv(19)
```

```
LET i=0
```

```
DO while more #1
```

```
  LET i=i+1
```

```
  INPUT #1: pas(i,1),pas(i,2),pas(i,3),pas(i,4),pas(i,5),pas(i,6),pas(i,7),pas(i,8),pas(i,9),pas(i,10),pas(i,11),pas(i,12),pas(i,13),pas
```

```
LOOP
```

```
LET numrec=i
```

```
!
```

```
! Calculation of standard normal values for the percent passing.
!
```

```
FOR i=1 to 31
```

```
  READ pz(i)
```

```
NEXT i
```

```
DATA 0.0,0.0389,0.0793,0.1179,0.1554,0.1915,0.2258,0.2580
```

```
DATA 0.2881,0.3159,0.3413,0.3643,0.3849,0.4032,0.4192,0.4332,0.4452
```

```
DATA 0.4554,0.4641,0.4713,0.4772,0.4821,0.4861,0.4893,0.4918,0.4938
```

```
DATA 0.4953,0.4965,0.4974,0.4981,0.4987
```

```
LET i,j=0
```

```
FOR i=1 to numrec
```

```
  FOR j=1 to 19
```

```
    IF pas(i,j)=0 then
```

```
      LET t(i,j)=-3.0
```

```
    ELSEIF pas(i,j)=100 then
```

```
      LET t(i,j)=3.0
```

```
    ELSEIF pas(i,j)=-99 then
```

```
      LET t(i,j)=pas(i,j)
```

```
    ELSE
```

```
      LET trial=0
```

```
      LET trial= pas(i,j)/100
```

```
      IF trial>=0.5 then
```

```
        LET ncount=0
```

```
        FOR k=1 to 31
```

```

        IF trial>=(pz(k)+0.5) then LET ncount=ncount+1
    NEXT k
ELSE
    LET ncount=0
    FOR k=1 to 31
        IF trial<(0.5-pz(k)) then LET ncount=ncount+1
    NEXT k
END IF
LET temp,pflg,pint=0
IF trial>=0.5 then
    LET pint=trial-0.5
    LET pflg=1.0
ELSE
    LET pint=0.5-pz(ncount)
    LET pflg=-1.0
END IF
IF trial>=0.5 then
    LET temp=0.1*(pint-pz(ncount))/(pz(ncount+1)-pz(ncount))
    LET t(i,j)=(pflg*(ncount-1)*0.1)+temp
ELSE
    LET temp=0.1*((pint-trial)/(pint-(0.5-pz(ncount+1))))
    LET t(i,j)=(pflg*(ncount-1)*0.1)+(pflg*temp)
END IF
END IF
NEXT j
NEXT i
!
!   Assignment of values to be interpolated.
!
LET t85=1
LET t50=0
LET t15=-1
LET i,j,m=0
!
!   Loop through the converted data and pack arrays with usable data.
!
FOR i=1 to numrec
    LET k=0
    FOR j=1 to 19
        IF t(i,j)<>-99 then
            LET k=k+1
            LET sample(k)=t(i,j)
            LET sieve(k)=sv(j)
        END IF
    NEXT j
    !
    !   Decision structure to interpolate values.
    !
    IF k<>0 then
        LET j=0
        FOR j=1 to k-1
            LET ub=sample(j)
            LET lb=sample(j+1)
            IF ub>=t85 and t85>lb then
                LET flg=1
                CALL interp
            ELSEIF ub>=t50 and t50>lb then
                LET flg=2
                CALL interp
            
```

```
ELSEIF ub>=t15 and t15>lb then
  LET flg=3
  CALL interp
END IF
NEXT j
END IF
NEXT i
```

! Decision structure to calculate the gradation coefficients.

```
LET i=0
FOR i=1 to numrec
  IF coeff(i,1)=0 and coeff(i,2)=0 and coeff(i,3)=0 then
    LET coeff(i,4)=9999
    LET coeff(i,5)=0
  ELSE IF coeff(i,2)=0 and coeff(i,3)=0 then
    LET coeff(i,4)=9999
    LET coeff(i,5)=0
  ELSE IF coeff(i,2)=0 and coeff(i,3)<>0 then
    LET coeff(i,4)=9999
    LET coeff(i,5)=coeff(i,2)/coeff(i,3)
  ELSE IF coeff(i,2)<>0 and coeff(i,3)=0 then
    LET coeff(i,4)=coeff(i,1)/coeff(i,2)
    LET coeff(i,5)=0
  ELSE
    LET coeff(i,4)=coeff(i,1)/coeff(i,2)
    LET coeff(i,5)=coeff(i,2)/coeff(i,3)
  END IF
NEXT i
```

```
LET flg1,1=0
FOR l=1 to 2
  LET flg1=flg1+1
```

! Initialization of the gradation coefficient array.

```
LET i=0
FOR i=1 to numrec
  LET gradco(i)=0
NEXT i
```

! Initialization and transfer of D50 data to output/sort array.

```
LET i=0
FOR i=1 to numrec
  LET delta(i)=0
NEXT i
```

```
SELECT CASE 1
CASE 1
  LET i,m=0
  FOR i=1 to numrec
    IF coeff(i,4)<>9999 and coeff(i,4)<>0 then
      LET m=m+1
      LET gradco(m)=coeff(i,4)
      LET delta(m)=coeff(i,2)
    END IF
  NEXT i
CASE 2
```

```

    LET i,m=0
    FOR i=1 to numrec
        IF coeff(i,5)<>9999 and coeff(i,5)<>0 then
            LET m=m+1
            LET gradco(m)=coeff(i,5)
            LET delta(m)=coeff(i,2)
        END IF
    NEXT i
CASE ELSE
    PRINT ""
    PRINT "FATAL ERROR"
    PRINT ""
    STOP
END SELECT

!
!     Selection with interchange sort technique.
!
LET n=m-1
LET i,j=0
FOR i=1 to n
    LET iplus1=i+1
    FOR j=iplus1 to m
        IF delta(i)>delta(j) then
            LET temp=gradco(i)
            LET gradco(i)=gradco(j)
            LET gradco(j)=temp
            LET temp1=delta(i)
            LET delta(i)=delta(j)
            LET delta(j)=temp1
        END IF
    NEXT j
NEXT i

IF flg1=1 then
    LET k=m
    LET i=0
    FOR i=1 to m
        LET out(i,1)=delta(i)
        LET out(i,2)=gradco(i)
    NEXT i
ELSE
    LET i=0
    FOR i=1 to m
        LET out(i,3)=delta(i)
        LET out(i,4)=gradco(i)
    NEXT i
END IF

NEXT 1

PRINT ""
INPUT prompt "Input the name of the output file ?":outfile$
OPEN #3: name outfile$, create new, access output, organization text

LET maxval=max(k,m)

IF k>m then
    LET i=0

```

```
FOR i=1 to k-m
  LET m=m+1
  LET out(m,3)=-999
  LET out(m,4)=-999
NEXT i
ELSE IF k<m then
  LET i=0
  FOR i=1 to m-k
    LET k=k+1
    LET out(k,1)=-999
    LET out(k,2)=-999
  NEXT i
END IF

LET i=0
FOR i=1 to maxval
  PRINT #3, using "####.##  ####.##  ####.##  ####.##":out(i,1),out(i,2),out(i,3),out(i,4)
NEXT i

CLOSE #3

SUB interp
!
! This subroutine linearly interpolates between two values
! with a conversion of the sieve size variable to a
! logarithmic value. The percent passing was previously
! converted to a standard normal value.
!
SELECT CASE flg
CASE 1
  LET d=1
CASE 2
  LET d=0
CASE 3
  LET d=-1
END SELECT
LET tmp1=ub-d
LET tmp2=ub-lb
LET factor=tmp1/tmp2
LET tmp3=(log10(sieve(j))-log10(sieve(j+1)))*factor
LET coeff(i,flg)=10^(log10(sieve(j))-tmp3)
END SUB

END
```

```
program xyplot
```

```
character*30 infile
character*40 xname
character*30 yname
character*20 legend
COMMON x(600), y(600), column(10,600)
integer inteq(10), ipen(10)
```

```
C
C THIS PROGRAM HAS BEEN CONVERTED SO THAT THE NUMBER OF DATA POINTS
C WOULD NOT BE LIMITED TO 200. TO CHANGE FOR DATA FILES > 600:
C 1) change COMMON x,y,column arrays to desired dimension.
C 2) change IROW, ICOL as necessary.
C
```

```
IROW=600
ICOL=10
```

```
do 10 i=1,ICOL
    inteq(i) = 99
10 continue
```

```
C INITIALIZE PLOT DEVICE TO HP-7475A
```

```
call plots(0,9600,30)
WRITE(*,*) ' '
WRITE(*,*) ' '
WRITE(*,*) ' Program XYPLOT is a general plotting routine'
WRITE(*,*) ' which utilizes the PLOT88 library to produce'
WRITE(*,*) ' 1 or more X-Y lines on a single plot using the'
WRITE(*,*) ' HP-7475A pen plotter. Both 8.5 x 11 and 11" x 17"'
WRITE(*,*) ' paper sizes are supported.'
WRITE(*,*) ' '
WRITE(*,*) ' '
WRITE(*,*) ' This program was written by Paul Clopper '
WRITE(*,*) ' of Simons, Li & Associates, Inc., '
WRITE(*,*) ' Fort Collins, Colorado, February 1987.'

WRITE(*,*) ' '
WRITE(*,*) ' '
WRITE(*,*) ' 1 = IBM FONT'
WRITE(*,*) ' 2 = SIMPLEX FONT'
WRITE(*,*) ' 3 = DUPLEX FONT (HEAVY VERSION OF SIMPLEX)'
WRITE(*,*) ' 4 = COMPLEX FONT (LIKE A TYPEWRITER)'
WRITE(*,*) ' 5 = TRIPLEX FONT (HEAVY VERSION OF COMPLEX)'
WRITE(*,*) ' 6 = SCRIPT FONT'
WRITE(*,*) ' 7 = GREEK FONT'
WRITE(*,*) ' ENTER THE FONT TYPE YOU DESIRE (#2 RECOMMENDED):'
READ(*,*) IFONT
WRITE(*,*) ' '
WRITE(*,*) ' '
WRITE(*,*) ' THIS PROGRAM WILL READ UP TO 10 COLUMNS'
WRITE(*,*) ' OF FREE-FORMATTED DATA.'
WRITE(*,*) ' HOWEVER, IF YOUR COLUMNS ARE OF UNEQUAL LENGTH,'
WRITE(*,*) ' YOU NEED TO FILL THE SHORTER COLUMNS WITH A -999 FLAG'
WRITE(*,*) ' SO THAT ALL THE COLUMNS ARE EQUAL IN LENGTH.'
WRITE(*,*) ' THIS ALLOWS THE DATA TO BE SORTED PROPERLY.'
WRITE(*,*) ' IF YOU HAVE NOT DONE THIS, HIT ^ (BREAK) TO ABORT NOW'
WRITE(*,*) ' SO THAT YOU CAN FIX YOUR FILE, YOU SILLY PERSON.'
WRITE(*,*) ' '
WRITE(*,*) ' '
H-63
```

```

WRITE(*,*) 'LOAD PAPER INTO THE PLOTTER AT THIS TIME.'
WRITE(*,*) 'CHECK THAT THE B/A3 LIGHT IS ON'
WRITE(*,*) 'WHEN USING 11x17 PAPER.'
WRITE(*,*) ' '
WRITE(*,*) 'ENTER THE TOTAL NUMBER OF COLUMNS IN YOUR DATA FILE:'
READ(*,*) ICOL
WRITE(*,*) 'ENTER THE NUMBER OF LINES YOU WISH TO PLOT:'
READ(*,*) I LINES
WRITE(*,*) ' ENTER 1 IF THIS IS AN 11 x 17 PLOT:'
READ(*,*) ISIZE

```

C DRAW AN XLENGTH BY YLENGTH BOX

```

WRITE(*,*) 'ENTER LENGTH OF X AXIS IN EVEN INCHES (14 MAX):'
READ(*,*) XLENGTH
WRITE(*,*) 'ENTER LENGTH OF Y AXIS IN EVEN INCHES (8 MAX):'
READ(*,*) YLENGTH

```

```

xpaper = 11.
ypaper = 8.5
if(isize.eq.1) then
    xpaper = 17.
    ypaper = 11.
endif
XMIN = (XPAPER-XLENGTH)/2. + 0.5
XMAX = XMIN + XLENGTH
YMIN = (YPAPER-YLENGTH)/2.
YMAX = YMIN + YLENGTH

```

```

CALL PLOT(XMIN,YMIN,3)
CALL PLOT(XMAX,YMIN,2)
CALL PLOT(XMAX,YMAX,2)
CALL PLOT(XMIN,YMAX,2)
CALL PLOT(XMIN,YMIN,2)

```

C REDEFINE ORIGIN OF PLOT SO THAT (0,0) IS AT (XMIN,YMIN) INCHES

```

CALL PLOT(XMIN,YMIN,-3)

```

C PLACE AXIS LABELS, TIC MARKS, AND NUMBERING

```

WRITE(*,*) 'ENTER X-AXIS LABEL (40 CHAR. MAX):'
WRITE(*,*) ' <----->'
READ(*,1) xname
1 FORMAT(A40)
WRITE(*,*) 'ENTER Y-AXIS LABEL (30 CHAR. MAX):'
WRITE(*,*) ' <----->'
READ(*,2) yname
2 FORMAT(A30)
WRITE(*,*) 'ENTER 1 FOR LOGARITHMIC X-AXIS, 0 OTHERWISE:'
READ(*,*) ILOGX
WRITE(*,*) 'ENTER 1 FOR LOGARITHMIC Y-AXIS, 0 OTHERWISE:'
READ(*,*) ILOGY

```

```

if(ILOGX.eq.1.and.ILOGY.eq.1) LOGTYP = 0
if(ILOGX.eq.1.and.ILOGY.eq.0) LOGTYP = -1
if(ILOGX.eq.0.and.ILOGY.eq.1) LOGTYP = 1

```

```
WRITE(*,*) 'ENTER XMIN (min. x-axis value):'  
READ(*,*) FIRSTX  
IF(ILOGX.EQ.1) THEN  
WRITE(*,*) 'ENTER NLOGSX (no. inches per log cycle):'  
READ(*,*) DELX  
DELX = 1./DELX  
ELSE  
WRITE(*,*) '# OF PLACES TO RIGHT OF DECIMAL FOR X-VALUES? :'  
READ(*,*) NDECAX  
WRITE(*,*) 'ENTER XINCREM (units/inch):'  
READ(*,*) DELX  
ENDIF  
WRITE(*,*) 'ENTER YMIN (min y-axis value):'  
READ(*,*) FIRSTY  
IF(ILOGY.EQ.1) THEN  
WRITE(*,*) 'ENTER NLOGSY (no. inches per log cycle):'  
READ(*,*) DELY  
DELY = 1./DELY  
ELSE  
WRITE(*,*) '# OF PLACES TO RIGHT OF DECIMAL FOR Y-VALUES? :'  
READ(*,*) NDECAY  
WRITE(*,*) 'ENTER YINCREM (units/inch):'  
READ(*,*) DELY  
ENDIF  
  
WRITE(*,*) ' '  
WRITE(*,*) 'SETTING UP AXIS CALLS. ONE MOMENT PLEASE.'  
  
IEXP = INT(XPAPER-XLENGTH)  
FACT = 0.95**IEXP  
ANNHGT = 0.13*FACT  
TIHGT = 0.17*FACT  
EXPHGT = 0.10*FACT  
TICLNG = 0.15*FACT  
  
IF(IFONT.EQ.1)CALL IBMPLX  
IF(IFONT.EQ.2)CALL SIMPLX  
IF(IFONT.EQ.3)CALL DUPLX  
IF(IFONT.EQ.4)CALL COMPLX  
IF(IFONT.EQ.5)CALL TRIPLX  
IF(IFONT.EQ.6)CALL SCRPLX  
IF(IFONT.EQ.7)CALL GRKPLX  
  
CALL STAXIS(ANNHGT, TIHGT, EXPHGT, TICLNG, NDECAX)  
  
IF(ILOGX.EQ.1) THEN  
CALL LGAXS(0., 0., XNAME, -40, -XLENGTH, 0., FIRSTX, DELX)  
ELSE  
CALL AXIS(0., 0., XNAME, -40, -XLENGTH, 0., FIRSTX, DELX)  
ENDIF  
  
CALL STAXIS(ANNHGT, TIHGT, EXPHGT, TICLNG, NDECAY)  
  
IF(ILOGY.EQ.1) THEN  
CALL LGAXS(0., 0., YNAME, 30, -YLENGTH, 90., FIRSTY, DELY)  
ELSE  
CALL AXIS(0., 0., YNAME, 30, -YLENGTH, 90., FIRSTY, DELY)  
ENDIF
```

```

WRITE(*,*) 'ENTER INPUT FILE NAME:'
READ(*,5) INFILE
open(4,file=INFILE,status='old')
5  FORMAT(A30)

```

C READ ALL DATA IN THE INPUT FILE IN COLUMN FORMAT

```

ivaltot = 0
DO 100 I=1,IROW
    read(4,*,end=101)(column(j,i),j=1,icol)
    ivaltot = ivaltot + 1
100 continue
101 continue

```

```

DO 200 I=1,ILINES
    WRITE(*,*) 'LINE NUMBER ',I
    WRITE(*,*) 'ENTER COL. # WHICH CONTAINS X-VALUES:'
    READ(*,*)IX
    WRITE(*,*) 'ENTER COL. # WHICH CONTAINS Y-VALUES:'
    READ(*,*)JY

```

C PLACE COLUMN VALUES INTO X AND Y ARRAYS FOR PLOTTING

```

ivals = 0
DO 150 K=1,IVALTOT
    ivals = ivals + 1
    if(column(ix,k).eq.-999.or.column(jy,k).eq.-999) then
        ivals = ivals - 1
        go to 130
    else
        x(ivals) = column(ix,k)
        y(ivals) = column(jy,k)
    endif

```

```

130 continue
150 continue

```

```

x(ivals+1) = firstx
x(ivals+2) = delx
y(ivals+1) = firsty
y(ivals+2) = dely

```

```
CALL STLINE(1,0.1*fact,0.)
```

```

WRITE(*,*) 'ENTER PEN COLOR (1-6) FOR LINE NO. ',I
READ(*,*) IPEN(I)
IPEN(I) = IPEN(I) - 1
WRITE(*,*) 'ENTER 1, 0, OR -1 TO DETERMINE LINE TYPE'
WRITE(*,*) 'WHERE:  1 = POINTS WITH CONNECTING LINES'
WRITE(*,*) '          0 = LINE ONLY (NO POINTS)'
WRITE(*,*) '          -1 = POINTS ONLY (NO LINES)'
READ(*,*) LINTYP
IF(LINTYP.NE.0) THEN
    WRITE(*,*) 'ENTER SYMBOL NUMBER (0-15):'
    READ(*,*) INTEQ(I)
ENDIF
IF(LINTYP.NE.-1) THEN
    WRITE(*,*) 'ENTER -1 FOR DASHED LINE, 1 OTHERWISE:'
    READ(*,*) ILNTYP
    CALL STLINE(ILNTYP,0.1*fact,0.)
ENDIF

```

```
CALL COLOR(IPEN(I),IERR)

IF(ILOGX.EQ.1.OR.ILOGY.EQ.1) THEN
CALL LGLIN(X,Y,IVAL,1,LINTYP,INTEQ(I),LOGTYP)
ELSE
CALL LINE(X,Y,IVAL,1,LINTYP,INTEQ(I))
ENDIF
```

```
200 CONTINUE
```

```
C PUT IN THE LEGEND
```

```
WRITE(*,*) 'ENTER X AND Y VALUES WHICH DEFINE THE'
WRITE(*,*) 'LOCATION OF THE UPPER LEFT CORNER OF'
WRITE(*,*) 'THE LEGEND BOX (in inches from origin):'
READ(*,*) xlegnd, ylegnd
```

```
height = 0.1389*fact
nc = -1
ang = 0.
```

```
DO 300 I = 1, I LINES
isymb1 = inteq(i)
if(isymb1.eq.99) then
isymb1 = 13
ang = 90.
endif
```

```
ylegnd = ylegnd - 0.25
WRITE(*,*) 'ENTER SUBTITLE (20 char. max) FOR LINE',I
WRITE(*,*) '<----->'
READ(*,3) LEGEND
3 FORMAT(A20)
```

```
CALL COLOR(IPEN(I),IERR)
CALL SYMBOL(xlegnd,ylegnd,height,isymb1,ang,nc)
CALL SYMBOL(xlegnd+0.25,ylegnd,height,LEGEND,0.,20)
300 CONTINUE
```

```
WRITE(*,*) 'ENTER 1 IF YOU WOULD LIKE A GRID OVERLAY:'
READ(*,*) IGRID
IF(IGRID.EQ.1) THEN
WRITE(*,*) 'ENTER PEN NUMBER (1-6) FOR GRID OVERLAY:'
READ(*,*) IPGRID
IPGRID = IPGRID - 1
CALL COLOR(IPGRID,IERR)
CALL STAXIS(0.,0.,0.,YLENGTH,0)
IF(ILOGX.EQ.1) THEN
CALL LGAXS(0.,0.,XNAME,0,XLENGTH,0.,FIRSTX,DELX)
CALL LGAXS(0.,YLENGTH,XNAME,0,-XLENGTH,0.,FIRSTX,DELX)
ELSE
CALL AXIS(0.,0.,XNAME,0,XLENGTH,0.,FIRSTX,DELX)
ENDIF
CALL STAXIS(0.,0.,0.,XLENGTH,0)
IF(ILOGY.EQ.1) THEN
CALL LGAXS(0.,0.,YNAME,0,-YLENGTH,90.,FIRSTY,DELY)
CALL LGAXS(XLENGTH,0.,YNAME,0,YLENGTH,90.,FIRSTY,DELY)
```

File: XYPLOT1 .FOR Wed 07/01/87 10:53:53

```
ELSE  
  CALL AXIS(0.,0.,YNAME,0,-YLENGTH,90.,FIRSTY,DELY)  
ENDIF  
  
ENDIF
```

```
C TERMINATE PLOT  
  call plot(0.,0.,999)  
  stop  
  end
```

APPENDIX H
INPUT DATA SETS

01	74	7	7NW	3	1	N	5	EF-022-3-425	MESA-PAYSON	500	FT	RT	STA	294	
02	74	871773	051567	65M0401666	41701654	CLAY/SILT/SAND/GRAVEL									1
04	74	00	10	93	61	43	35	24	22	20	15	3	1NP76		
04	74	1	00	30	93	61	60	59	58	58	41	3NP			
04	74	1	30100	93	61	41		27	26	22	9	1NP			
04	74	2	00	30	93	61				61	59	1NP			
04	74	2	30	86	93	61	47	36	35	33	25	1NP			
04	74	3	00	80	93	61	45	34	32	29	16	1NP			
04	74	4	00	20	93	61				61	57	2NP			
04	74	4	20	80	93	61	38	31	29	29	18	1NP			
04	74	5	00	80	93	61	43	28	26	22	10	1NP			
04	74	6	00	70	93	61	42	31	29	26	12	1NP			
04	74	7	00	86	93	61	45	34	32	31	14	1NP			
04	74	8	00	90	93	61	41	31	29	28	17	1NP			
04	74	9	00	20	93	61				61	57	2NP			
04	74	9	20	80	93	61	41	31	30	26	7	NP			
04	74	10	00	80	93	61				61	61	21NP			
04	74	11	00	56	93	61				61	60	25NP			
04	74	12A	00170	93	61	44	38	32	31	30	27	13	3NP		
04	74	13A	00150	93	61	45	38	27	25	24	21	6	1NP		
04	74	14A	00150	93	61	45	41	34	33	32	31	13	2NP		
04	74	15A	00150	93	61	39	35	27	25	24	20	6	1NP		
04	74	17A	00150	93	61	45	39	30	27	26	22	7	1NP		
04	74	18A	00170	93	61	41	38	32	31	31	29	12	1NP		
04	74	19A	00	46	93	61	60	60	59	59	59	37	6NP		
04	74	19A	46150	93	61	41	37	27	24	23	20	5	1NP		
04	74	20A	00110	93	61	31	27	20	18	18	16	6	1NP		
04	74	21A	00	40	93	61		61	60	60	46	4NP			
04	74	21A	40120	93	61	42	38	29	27	26	22	7	1NP		
04	74	18	00120	93	61	56	52	41	40	38	31	8	1NP78		
04	74	2B	00110	93	61	61		46	37	32	23	8	2NP		
04	74	3B	00100	93	61	43	40	34	32	32	29	15	NP87		
04	74	3B100210	93	61	40	35		27	26	24	21	9	1NP57		
04	74	4B	00	50	93	61	47	44	40	40	39	39	30	1NP78	
04	74	4B	50	66	93	61				61	59	5512	1		
04	74	4B	66110	93	61	33	29	24	23	22	19	2	NP94		
04	74	5B	00100	93	61	50	45	35	34	32	28	9	1NP85		
04	74	5B100200	93	61	44	35		21	20	18	15	3	1NP55		
04	74	6B	30110	93	61	45	40	32	31	31	27	10	1NP92		
04	74	7B	00	46	93	61				61	54	8NP59			
04	74	7B	46100	93	61	38	29	21	20	19	17	10	1NP67		
04	74	8B	00	30	93	61	59	59	57	57	54	17	1NP87		
04	74	8B	30	90	93	61	41	34	21	19	18	13	3	1NP67	
04	74	9B	00	80	93	61	49	44	37	35	35	33	21	1NP83	
04	74	10B	20150	93	61	45	38	28	26	24	18	5	1NP81		
04	74	10B	80200	93	61	55	46	31	29	27	21	6	1NP83		
04	74	11B	20150	93	61	48	38	32	30	29	26	8	1NP75		
04	74	12B	00	70	93	61	61	58	56	56	54	37	3NP81		
04	74	12B	70140	93	61	41	32	27	25	24	21	10	1NP61		
04	74	13B	20160	93	61	51	43	37	34	32	29	9	1NP82		
04	74	14B	00	90	93	61		60	59	59	58	34	1NP82		
04	74	14B	90130	93	61	43	34	29	27	26	24	9	1NP89		
04	74	15B	00	70	93	61	59	56	54	53	52	51	27	1NP82	
04	74	15B	70140	93	61	51	39	32	29	27	23	6	NP87		
04	74	16B	50170	93	61	41	29	23	20	19	17	6	1		
04	74	16B	50170	93	61	61	57	36	30	27	22	9	1NP75		
04	74	16B	50170	93	61	32	23	17	16	15	13	4	NP77		
04	74	17B	20150	93	61	37	27	22	20	19	16	7	1NP76		

04	74	188	00120	93	61	57	48	45	43	43	41	21	NP85	
04	74	198	70140	93	61	49	39	34	31	30	27	15	183	
04	74	208	00	40	93	61	49	39	34	32	31	29	7NP26	
04	74	208	40130	93	61	40	29	24	22	21	18	8	1NP48	
04	74	218	10150	93	61	51	44	40	39	38	37	20	2NP71	
04	74	228	00130	93	61						61	51	8NP54	
04	74	238	00	90	93	61	61	59	58	57	57	48	30	7NP48
04	74	238	90150	93	61	45	35	30	27	26	23	7	1NP71	
04	74	248	00160	93	61	45	34	28	26	24	23	7	1NP67	
04	74	258	00	90	93	61	49	38	33	31	30	28	16	2NP57
04	74	258	90130	93	61	38	26	21	18	17	14	4	1NP35	
04	74	268	00150	93	61	49	37	31	27	26	21	4	NP83	
04	74	278	00110	93	61	60	60	59	59	59	59	54	10NP49	
04	74	288	90150	93	61	48	36	29	27	26	24	11	2NP42	
04	74	298	00	90	93	61	51	41	35	33	32	29	11	1NP74
04	74	298	90130	93	61	46	38	32	29	27	24	7	2NP42	
04	74	308	00	90	93	61	43	37	33	31	30	28	12	1NP78
04	74	308	90130	93	61	41	31	26	24	23	19	3	1NP48	
04	74	318	00130	93	61	48	39	34	32	31	28	11	1NP75	
04	74	328	00160	93	61	38	32	27	26	25	23	8	1NP84	
04	74	338	00160	93	61	37	29	26	24	23	21	7	1NP89	
04	74	348	00120	93	61	47	33	27	24	23	20	7	1NP76	
04	74	358	00130	93	61	49	34	26	23	21	18	8	1NP69	
04	74	368	00150	93	61	52	41	32	29	26	21	5	1NP72	
04	74	378	00150	93	61	51	42	37	35	34	32	13	1NP80	
04	74	388	40140	93	61	46	38	32	31	29	26	4	1NP92	
04	74	398	40140	93	61	46	36	30	27	25	22	7	1NP74	
04	74	408	20130	93	61	56	42	35	33	31	29	13	2NP66	

05	74	1	00	30		01								
05	74	1	30100			01								
05	74	2	00	30		01								
05	74	2	30	86		02								
05	74	3	00	80		02								
05	74	4	00	20		01								
05	74	4	20	80		01								
05	74	5	00	80		01								
05	74	6	00	70		01								
05	74	7	00	86		01								
05	74	8	00	90		02								
05	74	9	00	20		01								
05	74	9	20	80		01								
05	74	10	00	80		04								
05	74	11	00	56		03								
05	74	18	00120			01								
05	74	28	00110			02								
05	74	48	00	50		01								
05	74	48	50	66		05								
05	74	68	30110			01								
05	74	88	00	30		01								
05	74	88	30	90		01								
05	74	108	00	80		01								
05	74	108	80200			01								
05	74	148	00	90		01								
05	74	148	90130			01								
05	74	168	50170	181440		01								
05	74	208	00	40		01								
05	74	208	40130			01								
05	74	258	00	90		01								
05	74	258	90130			01								

CRUSHED

05	74	308	00	90					01
05	74	308	90	130					01
05	74	368	00	150					01
01	198	7	7NW	3 1	N 5 ES-23	MESA RD-GILBERT RD	500 FT RT STA 294		
02	198	871773	NODATA			6 NODATA	SAND/GRAVEL/ROCK		1
04	198	1	00	140		65	44 41 34	12	1NP
04	198	2	00	76		52	33 30 24	8	2NP
04	198	3	00	70		67	51 49 46	24	5NP
04	198	1A	00	40				100	43NP
05	198	1	00	140	18				02
05	198	2	00	76					03
05	198	3	00	70					02
05	198	1A	00	40					04
01	200	7	7NW13	1 N 4 ES-23(5)		BASELINE ROAD	4 MI N STA 112		
02	200	601751	NODATA			6 NODATA	SILT/SAND/GRAVEL		1
04	200	1	00	66		79	55 51 41	19	1NP
04	200	2	00	66		99	96 94 87	30	1NP
04	200	3	00	60		52	40 39 38	19	0NP
04	200	4	00	70		58	36 33 28	12	1NP
04	200	5	00	60		74	52 49 43	12	0NP
04	200	6	00	70		67	40 37 33	12	1NP
04	200	7	00	60		96	90 89 88	55	1NP
04	200	8	00	66				100	53NP
04	200	9	00	50			100	97	41NP
04	200	10	00	60		76	63 61 58	33	3NP
05	200	1	00	66					01
05	200	2	00	66					01
05	200	3	00	60					01
05	200	4	00	70					01
05	200	5	00	60					01
05	200	6	00	70					01
05	200	7	00	60					01
05	200	8	00	66					03
05	200	9	00	50					03
05	200	10	00	60					01
01	248	1011NW2315	S13	EFI-29 (5)		TUCSON-NOGALES	2MI LT STA 3136		
02	248	89 591	NODATA			6NO DATA	NO DATA IN FILE		2
03	248	NO	TEST DATA IN FILE: ALSO LOCATED IN NW1/2 SEC 23 SW1/4 SEC 14 SE1/4 15						
04	248	0	00	00					
01	250	1012NW 215	S13	EFI-29 (5)		TUCSON-NOGALES	2MI + LT STA 3299		
02	250	89 620	NODATA			1NO DATA	CLAY/SAND/GRAVEL		2
04	250	1	00	110		100	93 85 52	52	13NP
04	250	2	00	105		96	85 81 47	47	16NP
04	250	3	00	120		91	73 67 44	44	16NP
04	250	4	00	80		99	89 82 65	65	25NP
04	250	5	00	50		98	89 73 16	16	4NP
04	250	6	00	55		84	67 60 26	26	4NP
04	250	7	00	95		97	88 80 45	45	4NP
01	254	7	7NW19	1 N 3 ES-35		NORTH SEVENTH AVENUE	1700 FT S CITY DUMP		
02	254	I-101461	NODATA			6 NODATA	SILT/SAND/GRAVEL		1
04	254	1	00	20			100	99	11NP
04	254	1	20	86		74	48 45 37	11	1NP
04	254	2	00	80		70	53 50 44	20	4NP
04	254	4	00	90		58	41 39 36	20	10NP
04	254	5	00	80		71	49 47 41	22	6NP
04	254	6	00	66		67	47 45 38	18	3NP
04	254	7	00	26		100	99 99 99	93	29NP
04	254	7	26	90		63	40 38 35	19	3NP
05	254	1	00	20					01

05 254 1 20 86 01
 05 254 2 00 80 02
 05 254 4 00 90 03
 05 254 5 00 80 02
 05 254 6 00 66 01
 05 254 7 00 26 03
 05 254 7 26 90 02

01 255 7 7NW13 1 N 4 ES-126 MCCLINTOCK DRIVE 2 MI N N END ITEM34

02 255	601751	NODATA	6	NODATA	SILT/SAND/GRAVEL/ROCK	1
04 255	1 00110		49	32 29	25	9 2NP
04 255	2 00100		57	40 38	34	11 ONP
04 255	3 00110		54	38 36	31	9 1NP
04 255	4 00100		49	37 35	31	10 2NP
04 255	5 00 80		46	35 34	31	10 1NP
04 255	6 00120		55	40 36	29	7 ONP
04 255	7 00 20		100	98 98	98	86 36NP
04 255	7 20120		53	39 37	35	18 3NP
04 255	8 00 60		79	71 70	68	56 25NP
04 255	9 00 60		81	77 76	76	68 22NP
05 255	1 00110	01				
05 255	2 00100	01				
05 255	3 00110	01				
05 255	4 00100	01				
05 255	5 00 80	02				
05 255	6 00120	02				
05 255	7 00 20	04				
05 255	7 20120	02				
05 255	8 00 60	04				
05 255	9 00 60	02				

01 256 7 6SE11 1 N 1 WS-36 WEST VAN BUREN STREET 3000' LT STA 857

02 256	801803	NODATA	609M0624756	NODATA	NO DATA	1
04 256	7 00 20		100100100100100100100100100100100100100100100100100100	96	83NP22	
04 256	7 20120		100 99 97 94 89 86 83 81 78 76 71 69 61 45 35 24	8	4NP78	
04 256	8 00 80		100 95 95 93 89 88 86 84 82 80 76 75 65 41 26 14	4	2NP64	
04 256	8 80120		100100 92 88 82 77 72 68 63 60 54 52 41 21 14 10	6	5NP65	
04 256	9 00 20		100100100100100100100100100100100100100100100100100100	99 93 44	33NP47	
04 256	9 20120		100100 97 95 93 92 90 88 86 84 81 79 71 50 39 28 12	6	6NP50	
04 256	10 00 80		100100100100 98 97 96 95 93 92 89 88 79 55 36 19	5	3NP47	
04 256	10 80120	100				

152.4	76.20	63.20	50.80	38.10	25.40	19.05	12.70	9.525	6.350	4.760	2.057	2.000	1.003	0.595	0.420	0.297	0.149	0.074
-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.
-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.
-99.	-99.	100.	91.	81.	68.	61.	-99.	47.	41.	34.	-99.	28.	21.	-99.	8.	-99.	3.	2.
-99.	-99.	100.	84.	75.	64.	57.	-99.	44.	39.	37.	-99.	31.	27.	-99.	18.	-99.	9.	5.
-99.	-99.	100.	87.	78.	70.	66.	-99.	56.	50.	47.	-99.	39.	33.	-99.	21.	-99.	7.	3.
-99.	-99.	100.	83.	71.	60.	54.	-99.	41.	35.	32.	-99.	23.	18.	-99.	7.	-99.	2.	1.
-99.	-99.	100.	79.	71.	62.	55.	-99.	45.	40.	37.	28.	-99.	24.	-99.	8.	-99.	3.	1.
-99.	-99.	100.	73.	67.	56.	50.	-99.	38.	33.	30.	24.	-99.	19.	-99.	8.	-99.	3.	2.
-99.	-99.	100.	75.	68.	57.	49.	-99.	38.	34.	32.	24.	-99.	18.	-99.	7.	-99.	3.	2.
-99.	-99.	100.	84.	80.	71.	67.	-99.	57.	53.	51.	44.	-99.	41.	-99.	21.	-99.	9.	5.
-99.	-99.	100.	66.	61.	52.	48.	-99.	38.	34.	31.	22.	-99.	16.	-99.	6.	-99.	2.	1.
-99.	-99.	100.	76.	69.	58.	51.	-99.	41.	36.	34.	27.	-99.	23.	-99.	9.	-99.	3.	2.
-99.	-99.	100.	73.	64.	54.	49.	-99.	39.	34.	32.	26.	-99.	24.	-99.	12.	-99.	5.	3.
-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.	100.	-99.	-99.	-99.	95.	-99.	-99.	40.
95.	86.	-99.	-99.	52.	-99.	38.	-99.	30.	27.	25.	16.	-99.	-99.	-99.	2.	-99.	-99.	-99.
-99.	-99.	-99.	-99.	60.	-99.	43.	-99.	32.	28.	26.	19.	-99.	-99.	-99.	3.	-99.	-99.	1.
-99.	-99.	-99.	-99.	59.	-99.	38.	-99.	26.	23.	21.	15.	-99.	-99.	-99.	4.	-99.	-99.	1.
-99.	-99.	-99.	-99.	58.	-99.	44.	-99.	37.	34.	33.	30.	-99.	-99.	-99.	20.	-99.	-99.	9.
-99.	-99.	-99.	-99.	59.	-99.	45.	-99.	36.	32.	30.	23.	-99.	-99.	-99.	6.	-99.	-99.	1.
-99.	-99.	-99.	-99.	55.	-99.	45.	-99.	35.	31.	28.	22.	-99.	-99.	-99.	6.	-99.	-99.	3.
-99.	-99.	-99.	-99.	-99.	-99.	98.	80.	69.	57.	51.	40.	38.	32.	24.	20.	17.	10.	6.
-99.	100.	100.	100.	100.	100.	99.	97.	95.	92.	89.	87.	86.	83.	75.	64.	51.	27.	17.
-99.	92.	89.	75.	67.	56.	52.	46.	42.	37.	34.	30.	29.	24.	17.	14.	11.	6.	3.
-99.	100.	100.	100.	97.	89.	87.	84.	82.	79.	76.	72.	70.	65.	55.	48.	33.	12.	8.
-99.	100.	92.	84.	77.	73.	67.	62.	59.	56.	53.	49.	47.	41.	29.	23.	19.	12.	8.
-99.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	99.	76.	46.
-99.	92.	92.	92.	79.	74.	70.	65.	62.	59.	56.	53.	52.	48.	39.	31.	24.	13.	8.
-99.	100.	100.	96.	91.	78.	74.	68.	65.	61.	58.	55.	54.	50.	43.	38.	33.	20.	12.
-99.	95.	93.	90.	86.	82.	80.	77.	74.	71.	67.	62.	60.	53.	40.	34.	30.	20.	12.
-99.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	99.	62.	41.
-99.	92.	92.	82.	71.	56.	53.	45.	40.	35.	32.	28.	27.	23.	15.	12.	10.	6.	4.
-99.	100.	96.	83.	75.	64.	59.	51.	46.	41.	37.	33.	32.	26.	19.	16.	14.	11.	9.
-99.	100.	100.	96.	95.	90.	88.	84.	81.	77.	74.	72.	71.	62.	45.	39.	35.	26.	20.
-99.	100.	100.	95.	90.	81.	80.	76.	73.	69.	66.	65.	65.	64.	62.	62.	60.	54.	43.
-99.	100.	93.	88.	85.	81.	79.	76.	74.	72.	70.	67.	66.	62.	51.	42.	32.	11.	6.
-99.	90.	86.	63.	58.	50.	47.	42.	40.	37.	35.	33.	32.	29.	22.	17.	13.	8.	5.
-99.	100.	90.	81.	67.	43.	35.	30.	28.	27.	26.	26.	26.	25.	23.	22.	21.	18.	14.
-99.	91.	87.	79.	73.	69.	65.	57.	52.	47.	44.	39.	37.	30.	16.	9.	5.	2.	1.
-99.	100.	93.	83.	74.	66.	61.	54.	49.	44.	41.	36.	34.	29.	20.	12.	7.	3.	2.
-99.	100.	100.	100.	100.	100.	100.	99.	99.	99.	98.	97.	96.	87.	69.	56.	44.	20.	9.
-99.	95.	87.	84.	80.	76.	73.	67.	64.	60.	56.	50.	48.	40.	26.	20.	16.	10.	7.
-99.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	99.	95.	90.	83.	27.	19.
-99.	100.	97.	94.	90.	79.	75.	70.	68.	49.	36.	24.	21.	15.	10.	8.	7.	5.	4.
-99.	100.	100.	94.	87.	80.	78.	75.	74.	73.	71.	69.	68.	65.	51.	37.	23.	4.	2.
-99.	100.	92.	90.	77.	59.	50.	43.	41.	38.	36.	33.	32.	29.	24.	21.	18.	10.	7.
-99.	100.	97.	94.	88.	76.	69.	61.	58.	53.	49.	41.	38.	29.	14.	7.	4.	2.	1.
-99.	100.	79.	72.	66.	53.	48.	42.	39.	34.	31.	24.	22.	16.	7.	5.	4.	2.	1.
-99.	95.	84.	69.	61.	51.	47.	43.	41.	39.	36.	34.	33.	30.	26.	24.	22.	12.	9.
-99.	100.	90.	90.	83.	70.	63.	57.	54.	49.	44.	35.	32.	23.	15.	13.	12.	9.	7.
-99.	100.	91.	86.	74.	64.	59.	52.	49.	44.	40.	33.	31.	24.	12.	9.	7.	4.	2.
-99.	100.	94.	85.	79.	71.	69.	65.	64.	62.	60.	57.	56.	51.	41.	33.	22.	5.	3.
-99.	100.	100.	100.	100.	100.	99.	98.	98.	97.	94.	90.	88.	79.	51.	26.	11.	2.	1.
-99.	96.	88.	84.	74.	66.	52.	47.	45.	41.	38.	33.	31.	25.	16.	11.	7.	3.	2.
-99.	100.	100.	100.	96.	92.	89.	86.	85.	83.	81.	78.	77.	73.	67.	57.	37.	10.	5.
-99.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	99.	98.	59.	34.
-99.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	99.	96.	91.	78.	47.	40.
-99.	100.	95.	91.	82.	76.	72.	64.	60.	54.	49.	39.	35.	25.	12.	8.	6.	3.	2.
-99.	100.	96.	88.	71.	59.	55.	49.	46.	42.	38.	29.	26.	16.	6.	3.	2.	1.	1.

FREQUENCY ANALYSIS

SIEVE SIZE: .420(mm)

LOWER BOUND	UPPER BOUND	NUMBER OF OCCURANCES	PERCENTAGE OF TOTAL	AVERAGE OF INTREVAL	
-3.00	-2.90	.00	.00	-2.95	.00
-2.90	-2.80	.00	.00	-2.85	.00
-2.80	-2.70	.00	.00	-2.75	.00
-2.70	-2.60	.00	.00	-2.65	.00
-2.60	-2.50	.00	.00	-2.55	.00
-2.50	-2.40	.00	.00	-2.45	.00
-2.40	-2.30	.00	.00	-2.35	.00
-2.30	-2.20	.00	.00	-2.25	.00
-2.20	-2.10	.00	.00	-2.15	.00
-2.10	-2.00	3.00	1.24	-2.05	1.24
-2.00	-1.90	.00	.00	-1.95	1.24
-1.90	-1.80	8.00	3.31	-1.85	4.55
-1.80	-1.70	6.00	2.48	-1.75	7.02
-1.70	-1.60	7.00	2.89	-1.65	9.92
-1.60	-1.50	12.00	4.96	-1.55	14.88
-1.50	-1.40	41.00	16.94	-1.45	31.82
-1.40	-1.30	16.00	6.61	-1.35	38.43
-1.30	-1.20	16.00	6.61	-1.25	45.04
-1.20	-1.10	22.00	9.09	-1.15	54.13
-1.10	-1.00	9.00	3.72	-1.05	57.85
-1.00	-.90	11.00	4.55	-.95	62.40
-.90	-.80	8.00	3.31	-.85	65.70
-.80	-.70	3.00	1.24	-.75	66.94
-.70	-.60	4.00	1.65	-.65	68.60
-.60	-.50	5.00	2.07	-.55	70.66
-.50	-.40	3.00	1.24	-.45	71.90
-.40	-.30	2.00	.83	-.35	72.73
-.30	-.20	3.00	1.24	-.25	73.97
-.20	-.10	3.00	1.24	-.15	75.21
-.10	.00	3.00	1.24	-.05	76.45
.00	.10	3.00	1.24	.05	77.69
.10	.20	7.00	2.89	.15	80.58
.20	.30	8.00	3.31	.25	83.88
.30	.40	2.00	.83	.35	84.71
.40	.50	2.00	.83	.45	85.54
.50	.60	3.00	1.24	.55	86.78
.60	.70	8.00	3.31	.65	90.08
.70	.80	8.00	3.31	.75	93.39
.80	.90	8.00	3.31	.85	96.69
.90	1.00	.00	.00	.95	96.69
1.00	1.10	1.00	.41	1.05	97.11
1.10	1.20	1.00	.41	1.15	97.52
1.20	1.30	.00	.00	1.25	97.52
1.30	1.40	.00	.00	1.35	97.52
1.40	1.50	.00	.00	1.45	97.52
1.50	1.60	1.00	.41	1.55	97.93
1.60	1.70	.00	.00	1.65	97.93
1.70	1.80	.00	.00	1.75	97.93
1.80	1.90	1.00	.41	1.85	98.35
1.90	2.00	.00	.00	1.95	98.35
2.00	2.10	2.00	.83	2.05	99.17

2.10	2.20	.00	.00	2.15	99.17
2.20	2.30	.00	.00	2.25	99.17
2.30	2.40	.00	.00	2.35	99.17
2.40	2.50	.00	.00	2.45	99.17
2.50	2.60	.00	.00	2.55	99.17
2.60	2.70	.00	.00	2.65	99.17
2.70	2.80	.00	.00	2.75	99.17
2.80	2.90	.00	.00	2.85	99.17
2.90	3.00	2.00	.83	2.95	100.00

VERDE RIVER NEAR I-17

SIEVE SIZE (mm)	STANDARD NORMAL DISTRIBUTION		
	LOW (15%)	MEAN (50%)	HIGH (85%)
152.400	1.65	1.65	1.65
76.200	1.45	2.95	2.95
63.200	1.25	2.95	2.95
50.800	0.75	1.15	2.95
38.100	0.25	0.75	2.95
25.400	0.15	0.55	2.95
19.050	-0.05	0.35	2.95
12.700	-0.15	0.45	2.95
9.525	-0.35	0.15	2.60
6.350	-0.45	-0.05	2.60
4.760	-0.45	-0.15	2.45
2.057	-0.75	-0.25	2.95
2.000	-0.55	-0.20	2.95
1.003	-0.75	-0.55	2.00
0.595	-1.05	-0.45	2.30
0.420	-1.45	-0.85	1.00
0.297	-1.40	-0.85	1.25
0.149	-1.85	-1.35	-0.25
0.074	-2.25	-1.65	-0.70

VERDE RIVER NEAR COTTONWOOD, AZ.

SIEVE SIZE (mm)	STANDARD NORMAL DISTRIBUTION		
	LOW (15%)	MEAN (50%)	HIGH (85%)
63.200	2.95	2.95	2.95
50.800	2.05	2.95	2.95
38.100	0.85	1.25	1.75
25.400	0.55	0.85	1.45
19.050	0.45	0.85	1.65
12.700	0.55	0.95	2.95
9.525	0.15	0.45	1.15
6.350	-0.05	0.25	0.95
4.760	-0.35	0.15	0.95
2.057	-0.35	0.15	1.55
2.000	-0.45	-0.15	1.15
1.003	-0.80	0.15	2.95
0.595	-0.90	-0.30	2.60
0.420	-1.35	-0.85	0.95
0.297	-1.65	-0.75	1.75
0.149	-1.80	-1.40	0.70
0.074	-2.25	-2.00	-0.85

SALT RIVER AT HAYDEN RD.

SIEVE SIZE (mm)	STANDARD NORMAL DISTRIBUTION		
	LOW (15%)	MEAN (50%)	HIGH (85%)
152.400	1.45	1.45	2.35
76.200	0.40	0.40	1.85
63.200	1.45	2.95	2.95
50.800	1.05	1.40	2.95
38.100	-0.15	0.25	0.85
25.400	-0.45	-0.15	0.75
19.050	-0.35	0.05	1.85
12.700	-0.15	0.20	2.95
9.525	-0.65	-0.25	1.85
6.350	-0.65	-0.35	1.00
4.760	-0.75	-0.45	1.00
2.057	-0.75	-0.45	1.55
2.000	-0.85	-0.55	0.30
1.003	-0.85	-0.55	2.95
0.595	-1.15	-0.95	2.05
0.420	-1.45	-1.15	0.45
0.297	-1.65	-1.35	1.20
0.149	-2.00	-1.60	-0.05
0.074	-2.25	-2.00	-0.85

SALT RIVER NEAR 35th AVENUE

SIEVE SIZE (mm)	STANDARD NORMAL DISTRIBUTION		
	LOW (15%)	MEAN (50%)	HIGH (85%)
152.400	1.35	1.35	1.35
76.200	0.80	1.95	1.95
63.200	1.55	2.95	2.95
50.800	1.10	1.40	2.95
38.100	0.15	0.55	1.05
25.400	-0.05	0.35	0.75
19.050	-0.25	0.15	1.15
12.700	0.00	0.75	2.95
9.525	-0.45	-0.15	0.35
6.350	-0.55	-0.25	0.25
4.750	-0.65	-0.35	0.15
2.057	-0.75	-0.35	0.35
2.000	-0.75	-0.35	0.85
1.003	-0.65	0.15	1.70
0.595	-0.90	-0.35	1.05
0.420	-1.45	-1.05	0.45
0.297	-1.40	-0.95	1.10
0.149	-1.85	-1.75	-0.90
0.074	-2.25	-1.85	-1.15

SANTA CRUZ RIVER NEAR TUCSON, AZ

SIEVE SIZE (mm)	STANDARD NORMAL DISTRIBUTION		
	LOW (15%)	MEAN (50%)	HIGH (85%)
50.800	0.95	1.55	2.15
38.100	0.85	1.55	2.15
25.400	0.65	1.35	2.15
19.050	0.85	1.25	1.90
9.525	0.35	0.95	1.65
6.350	0.15	0.85	1.45
4.760	0.15	0.75	1.35
2.057	0.00	0.55	1.15
2.000	-0.15	0.55	2.15
0.420	-0.95	-0.35	1.75
0.074	-2.00	-1.45	0.45

RILLITO RIVER AT TUCSON, AZ.

SIEVE SIZE (mm)	STANDARD NORMAL DISTRIBUTION		
	LOW (15%)	MEAN (50%)	HIGH (85%)
38.100	1.65	2.15	2.95
25.400	1.35	1.90	2.60
19.050	1.35	1.90	2.15
9.525	1.15	1.55	1.90
6.350	0.95	1.35	1.65
4.760	0.75	1.05	1.45
2.057	0.45	0.65	2.15
2.000	0.25	0.55	1.75
0.420	-1.15	-0.75	1.05
0.074	-2.00	-1.75	-0.25

NEWRIVER NEAR PHOENIX, AZ

SIEVE SIZE (mm)	STANDARD NORMAL DISTRIBUTION		
	LOW (15%)	MEAN (50%)	HIGH (85%)
76.200	0.95	0.95	0.95
50.800	0.45	0.70	2.00
38.100	0.35	0.85	1.65
25.400	0.25	0.65	1.25
19.050	0.25	0.75	1.45
12.700	-0.20	0.10	1.60
9.525	-0.25	0.45	1.15
6.350	-0.25	0.35	1.05
4.760	-0.25	0.25	0.95
2.057	-0.15	0.45	1.15
2.000	-0.45	0.15	0.75
1.003	-0.85	-0.85	1.40
0.595	-1.00	-1.00	1.10
0.420	-1.35	-0.95	-0.35
0.297	-1.45	-1.45	1.25
0.149	-1.65	-1.30	1.00
0.074	-2.35	-1.85	-1.55

AGUA FRIA RIVER NEAR PHOENIX, AZ

SIEVE SIZE (mm)	STANDARD NORMAL DISTRIBUTION		
	LOW (15%)	MEAN (50%)	HIGH (85%)
76.200	2.35	2.35	2.95
63.200	1.90	2.95	2.95
50.800	1.90	2.95	2.95
38.100	0.95	1.65	2.95
25.400	0.55	1.45	2.60
19.050	0.85	1.45	2.15
12.700	0.95	1.55	2.95
9.525	0.45	1.15	1.75
6.350	0.35	0.95	1.75
4.760	0.25	0.95	1.75
2.057	0.35	0.85	1.90
2.000	-0.05	0.65	1.90
1.003	0.15	0.85	1.90
0.595	-0.55	0.15	1.35
0.420	-0.95	-0.35	0.75
0.297	-1.15	-0.85	1.10
0.149	-1.75	-1.35	0.00
0.074	-2.00	-1.75	-0.45

UPPER GRADATION COEFFICIENT (FILE: NEWRIVER, GUP)

.03	2.21
.05	2.58
.08	2.73
.10	2.90
.13	3.12
.15	3.33
.17	3.69
.20	4.16
.23	4.48
.25	4.91
.28	5.08
.30	5.46
.33	5.80
.35	5.86
.38	6.14
.40	7.18
.42	7.26
.45	8.15
.47	10.74
.50	11.09
.53	11.43
.55	13.09
.57	13.55
.60	15.65
.63	15.88
.65	16.60
.68	17.59
.70	17.60
.72	18.41
.75	18.68
.78	18.96
.80	19.70
.82	20.17
.85	20.24
.88	23.47
.90	24.39
.93	30.28
.95	30.84
.97	31.85

LOWER GRADATION COEFFICIENT (FILE: VERDEI17.GLO)

.02	1.73
.04	2.04
.06	2.33
.08	2.64
.10	2.95
.12	3.12
.14	3.83
.16	5.78
.18	7.01
.20	7.05
.22	7.71
.24	7.93
.26	8.29
.28	9.36
.30	10.83
.32	11.32
.34	12.01
.36	13.54
.38	13.62
.40	13.68
.42	14.48
.44	14.59
.46	14.61
.48	14.92
.50	15.98
.52	16.30
.54	16.89
.56	17.44
.58	19.35
.60	19.70
.62	19.98
.64	20.38
.66	20.75
.68	21.43
.70	22.11
.72	22.44
.74	23.20
.76	25.72
.78	25.78
.80	27.43
.82	29.14
.84	31.63
.86	34.66
.88	38.31
.90	66.14
.92	75.11
.94	105.51
.96	117.35
.98	273.18

Data File: VERDEI17.DAT

D85	D50	D15	Upper	Lower
.00	.00	.00	9999.000	.000
.00	.00	.00	9999.000	.000
41.08	11.07	.76	3.712	14.608
50.83	13.12	.34	3.873	38.312
45.80	6.35	.31	7.213	20.381
51.04	15.36	.88	3.324	17.439
51.79	13.47	.70	3.844	19.352
52.63	19.05	.82	2.763	23.204
52.37	19.76	.88	2.651	22.436
50.83	4.22	.29	12.054	14.589
53.38	22.00	1.00	2.427	22.106
52.24	17.76	.69	2.942	25.778
52.63	20.18	.58	2.608	34.656
.22	.00	.00	9999.000	.000
72.14	34.48	2.04	2.092	16.891
.00	25.33	1.70	.000	14.920
.00	28.34	2.36	.000	12.008
.00	25.66	.24	.000	105.507
.00	24.43	1.24	.000	19.699
.00	26.94	1.30	.000	20.748
13.38	4.41	.27	3.038	16.296
1.28	.29	.00	4.432	.000
57.76	16.64	.53	3.471	31.633
12.90	.46	.18	27.789	2.641
50.94	2.54	.22	20.078	11.315
.17	.08	.00	2.087	.000
41.80	1.42	.18	29.516	7.711
29.85	1.00	.11	29.765	9.363
31.21	.89	.11	35.141	8.290
.19	.10	.00	1.892	.000
52.74	16.35	.64	3.225	25.716
51.42	11.99	.41	4.289	29.138
12.85	.69	.00	18.514	.000
28.69	.12	.00	248.971	.000
34.60	.57	.18	60.481	3.122
61.72	25.40	.38	2.430	66.141
54.24	28.53	.10	1.901	273.181
57.94	8.10	.59	7.154	13.682
51.76	10.09	.50	5.130	19.984
.90	.35	.12	2.555	2.954
51.23	2.06	.29	24.905	7.011
.31	.20	.00	1.596	.000
29.95	6.49	1.12	4.617	5.775
31.77	.58	.25	54.746	2.333
43.73	19.05	.25	2.296	75.112
32.72	5.12	.64	6.397	7.933
64.25	21.37	1.00	3.006	21.428
63.29	23.64	.20	2.678	117.345
39.62	6.89	.64	5.753	10.832
48.15	10.48	.72	4.593	14.484
48.46	.95	.25	50.946	3.831
1.44	.59	.34	2.451	1.727
51.11	16.20	.59	3.156	27.432

7.91	.37	.18	21.232	2.036
.20	.12	.00	1.716	.000
.34	.16	.00	2.150	.000
40.32	5.04	.71	7.995	7.053
46.83	13.59	1.00	3.445	13.618
72.88	8.61	.64	8.468	13.537
45.26	12.70	.79	3.564	15.978
.22	.12	.00	1.785	.000
.21	.10	.00	2.096	.000
.22	.12	.00	1.769	.000
.48	.20	.00	2.448	.000

UPPER AND LOWER GRADATION COEFFICIENT

(FILE: VERDEI7.GWL)

.08	2.09	.35	2.95
.10	2.10	.37	2.04
.10	1.89	.46	2.64
.12	248.97	.57	3.12
.12	1.72	.58	2.33
.12	1.77	.59	1.73
.12	1.79	.89	8.29
.16	2.15	.95	3.83
.20	1.60	1.00	9.36
.20	2.45	1.42	7.71
.29	4.43	2.06	7.01
.35	2.56	2.54	11.32
.37	21.23	4.22	14.59
.46	27.79	4.41	16.30
.57	60.48	5.04	7.05
.58	54.75	5.12	7.93
.59	2.45	6.35	20.38
.69	18.51	6.49	5.78
.89	35.14	6.89	10.83
.95	50.95	8.10	13.68
1.00	29.76	8.61	13.54
1.42	29.52	10.09	19.98
2.06	24.90	10.48	14.48
2.54	20.08	11.07	14.61
4.22	12.05	11.99	29.14
4.41	3.04	12.70	15.98
5.04	8.00	13.12	38.31
5.12	6.40	13.47	19.35
6.35	7.21	13.59	13.62
6.49	4.62	15.36	17.44
6.89	5.75	16.20	27.43
8.10	7.15	16.35	25.72
8.61	8.47	16.64	31.63
10.09	5.13	17.76	25.78
10.48	4.59	19.05	75.11
11.07	3.71	19.05	23.20
11.99	4.29	19.76	22.44
12.70	3.56	20.18	34.66
13.12	3.87	21.37	21.43
13.47	3.84	22.00	22.11
13.59	3.44	23.64	117.35
15.36	3.32	24.43	19.70
16.20	3.16	25.33	14.92
16.35	3.23	25.40	66.14
16.64	3.47	25.66	105.51
17.76	2.94	26.94	20.75
19.05	2.30	28.34	12.01
19.05	2.76	28.53	273.18
19.76	2.65	34.48	16.89
20.18	2.61	-999.00	-999.00
21.37	3.01	-999.00	-999.00
22.00	2.43	-999.00	-999.00
23.64	2.68	-999.00	-999.00
25.40	2.43	-999.00	-999.00
28.53	1.90	-999.00	-999.00
34.48	2.09	-999.00	-999.00

APPENDIX I. HYDROLOGIC DATASET

I.1 Purpose/Objective

Hydrologic data is necessary for a localized sediment transport model. This dataset is one of many needed for this purpose. From this collection of data, characteristic hydrographs will be developed and supplied to the model providing volumes and peak flows characteristic of the storms in that region.

I.2 Soil Types

Most of the data was collected from the U.S. Department of Agriculture, Soil Conservation Service, via the general soil maps they publish. These maps varied in scale from 1:250,000 to 1:633,600 and are intended to be used for general planning purposes only. Therefore, only general trends will be described for each watershed at the eight sites being studied.

A special thanks should be extended to the Phoenix office of the Soil Conservation Service for their complete cooperation and assistance of our data acquisition. A sincere thanks should be given to Dave L. Richmond for his help.

Salt River at Hayden Road

It should be noted that soil types of the Salt River basin are only being considered below Bartlett and Stewart Mountain Dams. This is because the soils in the drainage area above these reservoirs have little affect on the sediment transport characteristics of the Salt River through our study reach.

The following soil types are dominant in this reach:

1. Soils from old alluvium:
Gravelly to very gravelly limy soils on old alluvial fans and valley plains.

Gravelly to very gravelly clay and clay loam soils on old alluvial fans at the base of mountains.
2. Soils of mountains and low hills:
Rock outcrops with shallow and very shallow soils on mountains and low hills.

Other soil types that occur with relative frequency:

1. Soils from recent alluvium:
Loam soils on valley plains and floodplains.
Sandy loam soils on alluvial fans and valley plains.

Salt River at Phoenix, Arizona

The following soil types are dominant in this reach:

1. Soils from recent alluvium:
Loam soils on the valley plains and floodplains.
2. Soils from old alluvium:
Gravelly to very gravelly limy soils on old alluvial fans and valley plains.

Gravelly to very gravelly clay and clay loam soils on old alluvial fans at the base of mountains.
3. Soils of mountains and low hills:
Rock outcrops with shallow to very shallow soils on mountains and low hills.

Other soil types that occur with relative frequency:

1. Soils from recent alluvium:
Sandy loam soils on alluvial fans and valley plains.
Sandy soils in stream channels.
2. Soils from old alluvium:
Limy, sandy loam and loam soils on old alluvial fans and valley plains.

Agua Fria River

It should be noted that soil types of the Agua Fria River basin are only being considered below Waddell Dam (Lake Pleasant) because only soils below this point are considered to affect the sediment transport characteristics of this study reach.

The following soils are dominant in this reach:

1. Soils from recent alluvium:
Loam soils on valley plains and flood plains.
2. Soils from old alluvium:
Loam and clay loam soils on old valley plains and alluvial fans.
3. Soils of mountains and low hills:
Rock outcrops with shallow to very shallow soils on mountains and low hills.

Other soil types that occur with relative frequency:

1. Soils from recent alluvium:
Sandy loam soils on alluvial fans and valley plains.

2. Soils from old alluvium:
Gravelly to very gravelly limy soils on old alluvial fans and valley plains.

Limy, sandy loam and loam soils on old alluvial fans and valley plains.

Gravelly to very gravelly clay and clay loam soils on old alluvial fans at the base of mountains.

3. Soils of mountains and low hills:
Rock outcrops with shallow and very shallow soils on mountains and low hills.

New River

The dominant soil in this basin is a shallow to very shallow rock outcrop common to mountains and low hills.

Other soil types of relative frequency include:

1. Soils from old alluvium:
Gravelly to very gravelly limy soils on old alluvial fans and valley plains.

Limy, clay loam, sandy loam soils of old alluvial fans and valley plains.

Gravelly to very gravelly clay and clay loam soils on old alluvial fans at the base of mountains.

Clay to loam soils on old alluvial fans at the base of mountains.

Santa Cruz River

It should be noted that this is not a basin wide description of the soils in the Santa Cruz River basin. The generalizations that are about to be made are relative to the sediment transport characteristics of the study reach.

The dominant soil types in this reach include:

Deep, coarse to fine-loamy, arid soils on the uplands.

Rock outcrops with very shallow and shallow, semi-arid soils of the mountains and foothills.

Deep, fine-textured and gravelly, moderately fine and moderately coarse-textured soils on dissected valley slopes.

Other soil types of relative frequency:

Deep, moderately coarse to fine-textured soils of the arid zone.

Deep, fine-textured and gravelly moderately coarse-textured soils of the semi-arid rolling plains.

Deep, gravelly, moderately fine, fine and very fine-textured soils on the dissected valley slopes in the subhumid zone.

Deep, coarse loamy, calcareous, arid soil on the alluvial fans and valley slopes.

Rillito River

The following soil types are dominant in the Rillito Basin:

Deep, fine-textured and gravelly, moderately coarse-textured soils of the semi-arid rolling plains.

Deep, fine-textured and gravelly, moderately fine and moderately coarse-textured soils on dissected valley slopes in the semi-arid zone.

Rock outcrop with very shallow and shallow, loamy semi-arid soils of the mountains and foothills.

Other soil types of relative frequency include:

Shallow, rocky soils of the subhumid mountains.

Deep, arid, gravelly, calcareous soils on uplands and deeply dissected uplands.

Verde River at Cottonwood, Arizona

The following soils are dominant in this reach:

Cobbly or stony clayey soils on basalt bedrock.

Shallow, gravelly, stony and rocky, medium-textured soils on limestone and sandstone bedrock.

Deep, loamy soils and gravelly or cobbly loam soils with cemented lime layers at moderate to shallow depths.

Other soil types that occur with relative frequency:

Deep, moderately fine and fine-textured soils.

Gravelly or cobbly, moderately coarse and medium-textured soils on weathered granite or fractured schist bedrock.

Fine and medium-textured gravelly or cobbly loam soils with cemented lime layers at shallow depths.

Verde River at I-17

The Verde River basin above this point includes the soil types above Cottonwood, Arizona. Therefore, this description of soil types in the basin will be exclusive of the area above Cottonwood.

The dominant soil types of this region include:

Moderately coarse and fine-textured soils with cemented lime layers at moderate to shallow depths.

Shallow, gravelly, stony and rocky, medium-textures soils on limestone and sandstone bedrock.

Shallow, gravelly, medium-textured, calcareous soils on limestone bedrock and related formations.

Another soil type of relatively frequent occurrence is the rock outcrops and pockets of very shallow and shallow soils on sandstone and shale formations.

I.3 Geologic Formations

The geologic formations of the basins under study were reviewed under a larger scale, 1:2,500,000. Because of this large scale, each basin was studied in totality instead of being site specific like the soil type data. Due to this basin-wide investigation, the data is quite generalized.

Salt River

The Salt River, due to its large physical size, was broken into three sub-areas: the upper Salt region, the upper Verde region, and the lower Salt region. The physical divisions are assigned to the two lowest major reservoirs on the system, Stewart Mountain and Bartlett Dams.

Upper Salt Region:

The dominant types of geologic formations of this region include: pliocene volcanic rocks, sedimentary rocks, and the lower part of the Leonardian series. Other prominent formations include: pliocene continental deposits with miocene and quaternary deposits in places, granitic rocks, metasedimentary rocks, and upper paleozoic formations.

Upper Verde Region:

The prominent formation in this region consists of pliocene volcanic rocks. Other relatively substantial deposits include: the quaternary stratified sequence, upper paleozoic deposits, the lower part of the Leonardian series, quarternary volcanic rocks, and pliocene continental with

miocene and quaternary deposits in places.

Lower Salt Region:

This region is much different with respect to the previous two regions. The dominant formation of this region is the quaternary stratified sequence with a few locations of granitic rocks about 1700 to 1800 million years old.

Agua Fria River

This basin is also controlled by a reservoir, Lake Pleasant and Waddell Dam. Due to the map scale used to review the geologic formations, the Agua Fria River basin was investigated as a whole unit.

The dominant geologic formations in this basin include: metasedimentary rocks, pliocene volcanic rocks, and the quaternary stratified sequence. Other formations of common occurrence include: the lower tertiary volcanic rocks, some of which include cretaceous deposits, granitic rocks about 1700 to 1800 million years old.

New River

The New River basin is a major tributary of the Agua Fria River, therefore, it contains many of the same geologic formations. The dominant formations are: metasedimentary rocks, pliocene volcanic rocks, and the quaternary stratified sequence. Some formations of granitic rocks are also present.

Santa Cruz River

The Santa Cruz basin is unique in that two-thirds of the basin is the quaternary stratified sequence. Other formations that exist in this very large basin include: miocene volcanic rocks, latest cretaceous granitic rocks, and lower tertiary volcanic rocks which may contain some cretaceous deposits.

Rillito River

The Rillito basin is a major tributary of the Santa Cruz River, but the geologic formations in this area are much different in comparison. The dominant formations include: pliocene continental deposits which may contain deposits of miocene and quaternary in places, orthogeniss and parageniss deposits, and the quaternary stratified sequence. Another deposit of common occurrence includes the latest cretaceous granitic rocks.

Verde River

The two sites on the Verde River are in such close proximity to each other, the geological formations are for the most part

the same. The dominant formation of this region consists of pliocene volcanic rock. Other deposits of some significance include: the quaternary stratified sequence, upper paleozoic deposits, the lower part of the Leonardian series, and quaternary volcanic rocks.

I.4 Sources of Data

Several people were helpful in the acquisition of this data. The following key personnel should be recognized:

Robin Anderson, Salt River Project, Administrative Assistant
David E. Creighton, Jr., P.E., Department of Water Resources, State of Arizona, Flood Control Planning Engineer

Donald J. Gross, U.S. Army Corps of Engineers, Phoenix Subdistrict, Civil Engineer

Fran Jelinek, U.S. Department of the Interior, Geological Survey, Data Technician

Darrel Jordan, Salt River Project, Hydrology Department, Supervisor

Edmund G. Nassar, U.S. Department of the Interior, Geological Survey, Subdistrict Chief.

I.4.1 Gage Station Data

The process involved to acquire gage station data can most easily be described as a historical data search. The end of this appendix contains a list of references that were located, for the most part, in Arizona State University's Hayden Library. The most recent Salt River hydrologic data was courtesy of the Salt River Project in Tempe, Arizona. However, until 1986, the Salt River Project only kept track of average daily spills over Granite Reef Dam. On major storm events, hourly records were kept but access is very difficult because the records have been archived. In places where gaps developed in this dataset, the U.S. Geological Survey was contacted to assist in the identification of data sources where the missing data may be located.

Through the research of the above references, a table was compiled showing the years of record, days of flow, yearly volume of flow, maximum flow during that water year, and date of the peak flow.

I.4.2 Hydrograph Data

A majority of the hydrograph data was obtained from the U.S. Geological Survey's Water-Supply Papers. These papers are referenced at the end of this appendix. Most, if not all, of the data gathered for the Salt River was supplied by the Salt River Project, Tempe, Arizona. In some instances, hydrograph data was available in the U.S. Army Corps of Engineer's Flood Damage Reports and Flood Plain Information Studies.

This data was then graphed to display the hydrographs. From these hydrographs, several characteristics were determined: the date of peak flow, time to peak flow (hours), duration of flow (hours), maximum flow (cfs), volume of flow (ac-ft). These parameters were determined by either graphical measurements (planimeter) or were calculated directly from recorded values.

I.4.3 Flood Frequency Data

Most of the flood frequency data was obtained from FEMA flood insurance studies that were available from the Department of Water Resources, State of Arizona. Other sources of data included: U.S. Army Corps of Engineer's Flood Plain Information Studies and hydrology reports for FEMA Flood Insurance Studies. Also, consultants and other state agencies reports were referenced for data.

Once all the data was located, important parameters were compiled into a table showing the different analytical values of flood flows for each study location. From this collection of values, it becomes possible to see trends in the values.



U.S.G.S. GAGING STATIONS VICINITY MAP

FIGURE L1

BASIN DESCRIPTION

The Santa Cruz River Basin consists of 8,200 square miles in southern Arizona and 400 square miles in Mexico. The drainage area is about 170 miles long and 50 miles wide. After entering the United States at a point 6 miles east of Nogales, Arizona, the river flows northward about 74 miles to Tucson and then turns northwestward about 42 miles to the confluence with Greene Canal. Overbank flows continue along the old river bed. Beginning at this confluence, Greene Canal, together with Greene Wash, the Santa Cruz River and Santa Cruz Wash form a system of channelized streams about 75 miles long carrying Santa Cruz flows to the Gila River. Because the Santa Cruz has a very broad flood plain, the river can reduce flood peaks rather quickly.

GILA RIVER BASIN

09482500 Santa Cruz River at Tucson, Az.

WATER YEAR	DURATION (DAYS)	VOLUME (ac-ft)	MAX Q (cfs)	DATE OF PEAK
15		80,920	15,000	12/23/14
16		37,310	5,000	1/20/16
17		28,380	7,500	9/8/17
18		4,940	4,900	8/17/18
19		24,480	4,700	8/2/19
20		7,920	1,950	8/9/20
21		32,100	4,000	8/1/21
22		10,850	2,000	6/20/22
23		15,710	1,900	8/17/23
24		3,700	2,050	11/17/23
25		6,940	3,400	9/18/25
26		20,180	11,400	9/28/26
27		3,140	1,950	9/7/27
28		2,920	1,600	8/1/28
29		24,300	10,400	9/24/29
30		8,080	1,770	8/7/27
31		37,290	9,200	8/10/31
32		14,730	4,200	7/30/32
33		7,300	6,100	8/21/33
34		7,570	6,000	8/23/34
35		20,440	10,300	9/1/35
36		8,760	5,400	7/26/36
37		8,260	3,280	7/10/37
38	40	7,620	9,000	8/5/38
39		24,430	8,000	8/3/39
40		13,490	11,300	8/14/40
41		4,990	2,490	8/14/41
42		3,060	1,670	8/9/42
43		11,070	4,510	8/2/43
44		9,750	6,530	8/16/44
45		20,730	10,800	8/10/45
46		14,870	4,260	8/4/46
47		6,520	2,960	10/1/46
48		8,660	3,860	8/16/48
49		10,500	3,800	8/8/49
50		28,890	9,490	7/30/50
51		7,230	5,020	8/2/51
52		6,050	3,820	8/16/52
53	35	9,710	5,900	6/15/53
54	76	35,970	9,570	6/24/54
55		50,180	10,900	8/3/55
56		1,290	2,610	7/29/56
57		2,220	3,050	8/31/57
58		17,730	6,350	7/29/58
59	49	6,870	4,420	8/20/59
60	62	13,030	6,140	8/10/60

61	41	16,290	16,600	8/23/61
62	30	8,240	4,980	9/26/62
63	53	16,210	4,670	8/26/63
64	54	38,130	13,000	9/10/64
65	34	936	1,190	7/16/65
66	76	43,150	5,500	8/19/66
67	35	5,880	5,860	6/17/67
68	71	38,210	16,100	12/20/67
69	26	5,200	8,710	8/6/69
70	66	8,680	8,530	7/20/70
71	41	11,750	8,000	8/17/71
72	46	5,220	3,470	7/15/72
73	47	13,220	4,710	10/19/72
74	94	7,790	7,930	7/8/74
75	50	5,800	2,480	6/12/75
76	49	10,340	7,100	9/25/76
77	39	5,320	2,660	8/15/77
78	80	56,790	23,700	10/10/77
79	87	77,730	13,500	12/19/79
80	62	5,710	2,760	8/13/80
81	56	9,480	2,700	6/27/81

=====

LOCATION: NE 1/4 NE 1/4 SECTION 14, T.14 S. & R.13 E., Pima County, on the down stream side of center pier of Congress Street Bridge in Tucson, Az.

DRAINAGE AREA: 2222 sq miles, of which 395 sq miles is in Mexico. This area is adjusted for 15.2 sq miles of Tucson Arroyo drainage area contributing to this station effective July 1956.

REMARKS: Records fair except those below 20 cfs, which are poor. Irrigation above station of about 26,000 acres, including about 2,300 acres in Mexico, mostly from pumping ground water. Ground water is also pumped above this station for municipal supply and mining. Since October 1969 all flow past station includes waste water when known.

AVERAGE DISCHARGE: 76 years of record, 16,450 acre-ft/yr; median of yearly mean discharges, 10,100 ac-ft/yr

EXTREMES OF RECORD: Maximum discharge, 45,000 cfs, Oct. 1, 1983 on the basis of slope-area measurement of the peak flow.

GILA RIVER BASIN

09486000 Rillito Creek near Tucson, AZ

WATER YEAR	DURATION (days)	VOLUME (ac-ft)	MAX Q (cfs)	DATE OF PEAK
09		28,000		
10		4,610		
11		11,290		
12		11,760		
13		1,650		
14		8,800		
15		120,000	17,000	12/23/14
16		52,280	7,620	1/19/16
17		9,770	10,000	8/11/17
18		9,400	5,300	3/1/18
19		37,210	9,250	2/27/19
20		26,020	7,800	2/21/20
21		42,500	16,000	7/31/21
22		3,030	3,250	8/9/22
23		6,670	4,000	8/26/23
24		5,760	1,980	12/26/23
25		4,720	3,500	9/17/25
26		1,940	1,750	9/27/26
27		4,580	2,200	9/12/27
28		1,280	4,500	8/1/28
29		26,820	24,000	9/23/29
30		10,590	4,600	8/8/30
31		12,050	7,200	8/10/31
32		14,830	7,200	7/29/32
33		1,650	4,400	9/10/33
34		2,100	3,000	7/17/34
35		18,270	13,400	8/31/35
36		3,600	4,500	8/17/36
37		4,450	2,980	8/17/37
38	20	2,500	3,000	3/4/38
39		6,880	9,710	8/3/39
40		8,360	13,200	8/13/40
41		29,740	9,900	12/31/40
42		2,170	1,600	9/14/42
43		2,600	3,850	8/15/43
44		3,190	4,100	8/9/44
45		3,890	7,000	8/10/45
46		3,040	4,160	8/31/46
47		4,120	7,660	8/15/47
48		959	779	9/26/48
49		2,920	1,640	9/15/49
50		7,260	9,490	7/30/50
51		4,140	9,500	7/25/51
52		6,150	1,630	11/11/51
53	16	1,740	5,470	7/16/53

54	37	13,040	7,680	7/24/54
55		12,300	8,070	7/21/55
56		315	2,050	7/29/56
57		4,210	4,500	1/9/57
58		11,260	8,930	8/12/58
59	29	5,260	7,710	8/17/59
60	44	13,490	3,610	1/12/60
61	17	2710	4,140	7/22/61
62	41	4350	2,690	9/26/62
63	26	5,730	7,640	8/26/63
64	29	9,500	9,420	9/10/64
65	38	1,030	754	9/12/65
66	81	53,260	12,400	12/22/65
67	9	1,890	3,100	8/19/67
68	38	16,280	7,740	2/12/68
69	10	707	2,200	8/5/69
70	35	7,370	7,000	9/6/70
71	21	11,150	9,290	8/20/71
72	31	2,420	1,820	8/12/72
73	63	28,180	5,160	10/20/72
74	8	846	1,440	8/2/74
75	8	555	2,270	7/16/75

=====

LOCATION: SW 1/4 SE 1/4 SECTION 14, T.13 S. & R.13 E., on the right bank 600 ft downstream from Pima Canyon, 1800 ft downstream from the bridge on U.S. Highway 89.

DRAINAGE AREA: 918 sq miles. At former site (station 09485850), 892 sq miles.

REMARKS: Records poor. Several small diversions above the station for irrigation and for municipal and domestic water supply, mostly by pumping ground water.

AVERAGE DISCHARGE: 67 years of record. 16.1 cfs, 11,660 ac-ft/yr median of yearly mean discharges, 7.9 cfs, 5,700 ac-ft/yr.

EXTREMES OF RECORD: Maximum discharge, 24,000 cfs, Sept. 23, 1929 on the basis of velocity-area studies.

BASIN DESCRIPTION

LOCATION:

The Salt River Basin is situated in south central Arizona. It is a tributary of the Gila River Basin which in total encompasses a drainage area of 58,200 square miles. Large diversions above these reaches are used for irrigation, municipal and industrial use. Flow is regulated by 4 dams on the Salt River (capacity, 1,755,000 acre-ft) and 2 dams on the Verde River (capacity, 317,700 acre-ft).

CLIMATE:

Most of the drainage area has an arid, subtropical climate, characterized by hot summers, mild winters and infrequent rainfall. Summer thunderstorms, of high intensity but short duration, normally account for most of the annual rainfall but are responsible for less than half of the annual runoff. In the higher elevation portions of the drainage, the climate is somewhat cooler, with greater precipitation, and with considerable snow during the winter months.

TOPOGRAPHY:

A majority of the settlements in the basin are located in Maricopa County. The Phoenix metropolitan area situated in the Salt River Valley and is effectively surrounded by the Phoenix Mountains to the north, the McDowell Mountains to the northeast, the Usury Mountains to the east, the South Mountains to the south and the Sierra Estrella to the southwest. Only to the west and the southeast do the rolling desert plains typical of the metropolitan area continue uninterrupted. The highest elevation in the county is Four Peaks (7,468 ft) in the McDowell Mountains, which drain into the Salt River. The Salt River flows into the Gila River southeast of Central Phoenix (elevation 925 ft). The Gila River exits Maricopa County at an elevation of 430 ft.

VEGETATION:

Natural vegetation in the drainage area is sparse. Cactus, creosote bush, sagebrush and paloverde are the dominant desert plants. Natural vegetation within the floodplain is mostly composed of tamarisk, mesquite, saltbrush, cattail, desert upland and desert wash plant communities. Irrigation has resulted in the transformation of the desert plain in productive farmland and urban communities.

RIVERS AND STREAMS:

The principal rivers in Maricopa County are the Gila and its major tributary, the Salt. The Hassayampa River and the Agua Fria River join the Gila River below its confluence with the Salt. New River and Skunk Creek are, in turn, tributaries to the Agua Fria. The Verde River is the major tributary of the Salt.

Four streams, Triby Wash, Cave Creek, Indian Bend Wash, and Queen Creek, also carry significant flows during periods of high runoff. Additional inflow to these watercourses is contributed by numerous washes, creeks, and urban runoff.

CANALS:

In addition to the natural watercourses, the metropolitan Phoenix area is crisscrossed by canals which deliver irrigation water from the Salt River to the agricultural areas west and southeast of the central city.

SPILLS TO THE SALT RIVER AT GRANITE REEF DAM
PLUS RELEASES FROM DRAINS ABOVE HAYDEN ROAD
THROUGH MARCH 1987

WATER YEAR	DURATION (days)	VOLUME (ac-ft)	MAX Q (cfs)	DATE OF PEAK
62	-----	NO FLOW	-----	
63	10	942	235	8/17/63
64	7	7,005	2,575	8/1/64
65	4	19,982	3,590	4/20/65
66	44	380,371	64,000	12/31/65
67	6	970	414	7/17/67
68	42	117,215	3,703	2/15/68
69	1	178	91	3/10/69
70	-----	NO FLOW	-----	
71	1	79	40	8/15/71
72	-----	NO FLOW	-----	
73	142	1,316,444	22,273	4/1/73
74	6	982	268	8/3/74
75	2	397	124	7/13/75
76	7	1,582	468	2/9/76
77	1	516	260	10/23/76
78	8	325,429	95,800	3/3/78
79	163	2,787,536	110,000	12/19/78
80	68	2,056,693	139,132	2/16/80
81	-----	NO FLOW	-----	
82	8	79,411	9,017	3/14/82
83	118	1,305,856	30,441	2/10/83
84	45	619,838	39,976	10/03/83
85	123	994,749	26,010	12/28/84
86	25	76,792	2,124	12/14/85
87	9	* 33,185	2,898	3/22/87

* Indicates valid up to last known flow of 4/15/87.

DRAINS INCLUDE:

- 1) HENNESEY
- 2) EVERGREEN
- 3) TEMPE

SPILLS TO THE SALT RIVER AT GRANITE REEF DAM
PLUS RELEASES FROM DRAIN ABOVE 59TH AVENUE
THROUGH MARCH 1987

WATER YEAR	DURATION (days)	VOLUME (ac-ft)	MAX Q (cfs)	DATE OF PEAK
62	-----	NO FLOW	-----	
63	10	942	235	8/17/63
64	7	7,005	2,575	8/1/64
65	4	19,982	3,590	4/20/65
66	44	380,371	64,000	12/31/65
67	6	970	414	7/17/67
68	42	117,215	3,703	2/15/68
69	1	178	91	3/10/69
70	-----	NO FLOW	-----	
71	1	79	40	8/15/71
72	-----	NO FLOW	-----	
73	142	1,316,444	22,273	4/1/73
74	6	982	268	8/3/74
75	2	397	124	7/13/75
76	7	1,582	468	2/9/76
77	1	516	260	10/23/76
78	8	325,429	95,800	3/3/78
79	163	2,787,536	110,000	12/19/78
80	68	2,056,693	139,132	2/16/80
81	-----	NO FLOW	-----	
82	8	79,495	9,022	3/14/82
83	118	1,311,572	30,441	2/10/83
84	48	642,127	40,318	10/03/83
85	125	1,023,434	26,365	12/28/84
86	25	78,051	2,134	12/17/85
87	9	* 33,185	2,898	3/22/87

* Indicates valid up to last known flow of 4/15/87.

DRAINS INCLUDE:

- 1) HENNESEY
- 2) EVERGREEN
- 3) TEMPE
- 4) PUEBLO GRANDE

GILA RIVER BASIN

09513970 Agua Fria River at Avondale, AZ

WATER YEAR	DURATION (days)	VOLUME (ac-ft)	MAX Q (cfs)	DATE OF PEAK
60			4700	12/23/66
61	-----	NO FLOW	-----	
62	-----	NO FLOW	-----	
63			63	8/63-9/63
64			3,000	8/1/64
65			460	4/4/65
66			800	12/23/66
67	-----	NO FLOW	-----	
68	7	14,570	20,000	12/20/68
69		180		
70	3	7,890	20,600	9/6/70
71	2	1,470	8,200	8/21/71
72	4	958	5,180	7/17/72
73			5,000	10/7/72
74	-----	NO DATA	-----	
75	-----	NO DATA	-----	
76	-----	NO FLOW	-----	
77	-----	NO FLOW	-----	
78	28	56,390	13,100	3/2/78
79	25	72,370	29,300	12/19/79
80	23	168,800	44,200	2/20/80
81	-----	NO FLOW	-----	
82	-----	NO FLOW	-----	

LOCATION: NW 1/4 OF SECTION 14, T.1 N. & R.1 W.,
Buckeye Road, half a mile east of Avondale.

DRAINAGE AREA: 2013 sq miles total
~~-1459~~ sq miles above Lake Pleasant
 554 sq miles subtotal
 + 247 sq miles above McMicken Dam
 801 sq miles possible direct
 drainage area

REMARKS: Flow partly regulated by Lake Pleasant, 35 miles up-
 stream. Records at times may include waste water
 from the Arizona Canal of the Salt River Project.
 Excess flood water released from McMicken Dam on Trilby
 Wash may enter Agua Fria River basin but the amount
 is usually negligible.

AVERAGE DISCHARGE: 14 years of record, 31.7 cfs, 22,970 ac-ft/yr
median of yearly mean discharges, 0.7 cfs,
510 ac-ft/yr.

EXTREMES OF RECORD: Maximum discharge, 44,200 cfs on Feb. 20,
1980 from water stage recorder. No flow for
most of the time each year.

GILA RIVER BASIN

09513835 New River at Bell Road, near Peoria, AZ

WATER YEAR	DURATION (days)	VOLUME (ac-ft)	MAX Q (cfs)	DATE OF PEAK
63			1,550	8/17/63
64	-----NO RECORD-----			
65			1,020	4/5/65
66			4,060	12/22/65
67			100	6/18/67
68	8	14,110	14,600	12/19/67
69	-----NO FLOW-----			
70	3	5,910	11,900	9/5/70
71	5	785	4,800	8/21/71
72	2	169	1,520	7/17/72
73	56	12,850	2,590	10/7/72
74	-----NO FLOW-----			
75	2	288	257	11/3/74
76	9	2,240	2,280	2/9/76
77	-----NO FLOW-----			
78	30	35,250	12,500	3/2/78
79	43	17,800	8,410	12/19/79
80	37	32,920	12,100	2/20/80
81	2	1	21	9/5/81
82	26	2,830	876	3/15/82
83	44	20,020	4,240	12/1/82
84	-----NO FLOW-----			

LOCATION: NE 1/4 NE 1/4 SECTION3, T.3 N. & R.1 E., on the downstream side of the bridge at Bell Road, 1.6 miles upstream from Skunk Creek, and 9 miles upstream from the mouth.

DRAINAGE AREA: 187 sq miles.

REMARKS: Records poor as per U.S.G.S. streamflow records.

EXTREMES OF RECORD: Maximum discharge, 14,600 cfs, Dec. 19, 1967, on the basis of slope-area measurements of the peak flood.

AVERAGE DISCHARGE: 17 years record, 11.8 cfs, 8,550 ac-ft/yr; median of yearly mean discharges, 3.1 cfs, 2,200 ac-ft/yr.

GILA RIVER BASIN

09513910 New River near Glendale, Az

WATER YEAR	DURATION (days)	VOLUME (ac-ft)	MAX Q (cfs)	DATE OF PEAK
61	-----	NO FLOW	-----	
62	-----	NO FLOW	-----	
63			690	8/30/63
64			7,000	8/1/64
65	38	5,010	1,100	1/8/65
66	34	18,510	4,840	12/23/65
67	-----	NO FLOW	-----	
68	14	16,950	19,800	12/19/68
69	-----	NO FLOW	-----	
70	5	9,130	19,200	9/5/70

LOCATION: NE 1/4 NW 1/4 SECTION 8, T.2 N. & R.1 E., Maricopa County, on the downstream side of the bridge at Glendale Avenue, 2 miles upstream from the mouth.

DRAINAGE AREA: 323 sq miles.

REMARKS: Records poor. During periods of local storm runoff records may include waste water from the Arizona Canal of the Salt River Project.

AVERAGE DISCHARGE: 6 years record, 11.4 cfs (8260 ac-ft/yr).

EXTREMES OF RECORD: Maximum discharge, 19,800 cfs, Dec. 19, 1967, on the basis of slope-area measurements of peak flow.

GILA RIVER BASIN

09504000 Verde River near Clarkdale, AZ

WATER YEAR	DURATION (days)	VOLUME (ac-ft)	MAX Q (cfs)	DATE OF PEAK
65	154	*27600	7,040	4/17/65
66	365	162,900	12,900	12/10/65
67	365	113,300	22,500	12/6/66
68	366	84,620	1,630	1/28/68
69	365	113,600	14,800	1/25/69
70	365	65,850	717	9/6/70
71	365	63,760	3,930	7/31/71
72	366	69,620	7,540	12/26/71
73	365	306,300	14,000	10/19/72
74	365	60,960	3,960	9/26/74
75	365	69,400	1,560	3/20/75
76	366	108,600	18,000	2/9/76
77	-----	NO DATA	-----	-----
78	365	246,100	25,000	3/1/78
79	365	244,500	19,900	12/18/78
80	366	324,900	30,100	2/15/80
81	365	62,200	1,150	9/23/81
82	365	144,500	15,720	3/12/82
83	365	213,200	14,400	9/24/83
84	365	85,690	4,930	10/1/83

* This record is incomplete showing only volumes from April thru September in 1965.

LOCATION: NW 1/4 SE 1/4 SECTION 17, T.17 N. & R.3 E., Yavapai County, on left bank 1.7 miles downstream from Sycamore Creek and 5.6 miles north of Clarkdale, AZ.

DRAINAGE AREA: 3,520 sq miles, approximately (includes 373 sq miles in Aubrey Valley Playa, a closed basin).

REMARKS: Records good. Water quality records kept at this station from March of 1976.

AVERAGE DISCHARGE: 22 years of record, 207 cfs, 150,000 ac-ft/yr; median of yearly mean discharges, 170 cfs, 123,000 ac-ft/yr.

EXTREMES OF RECORD: Maximum discharge, 50,600 cfs on Feb. 21, 1920, on the basis of float-area measurement at 35,000 cfs; minimum daily, 55 cfs on Aug. 31, Sept. 1, 1920.

GILA RIVER BASIN

09506000 Verde River near Camp Verde, AZ

WATER YEAR	MAX Q (cfs)	DATE OF PEAK
34	5,500	7/17/34
35	11,500	4/9/35
36	6,820	2/24/36
37	41,700	2/7/37
38	97,000	3/3/38
39	16,100	9/13/39
40	7,560	8/4/40
41	30,000	3/14/41
42	6,080	10/13/41
43	11,600	3/5/43
44	5,160	3/5/43
45	8,380	4/16/45

LOCATION: In section 1, T.12 N. & R.5 E. (unsurveyed), 750 ft upstream from Chasm Creek, 800 ft downstream from Camp Verde damsite, and 9 miles southeast of Camp Verde.

DRAINAGE AREA: 5,024 sq miles (includes 373 sq miles in Aubrey Valley playa, a closed basin).

REMARKS: Peak discharges unaffected by irrigation diversions. Base for partial-duration series, 4,000 cfs.

EXTREMES OF RECORD: Maximum discharge, 97,000 cfs on Mar. 3, 1938

GILA RIVER BASIN

09505000 Verde River at Camp Verde, AZ

LOCATION: SE 1/4 SECTION 30, T.14 N. & R.5 E., Yavapai County, at highway bridge 600 ft upstream from Beaver Creek and 1 mile north of Camp Verde.

DRAINAGE AREA: 4,234 sq miles (revised), including 373 sq miles in Aubrey Valley Playa, a closed basin.

PERIOD OF RECORD: December 1912, January 1913 to March 1920.
Gage discontinued.

AVERAGE DISCHARGE: 6 years of record, 435 cfs, 315,200 ac-ft/yr.

EXTREMES: (1913-20) Maximum discharge not determined, probably exceeded 60,000 cfs on Feb. 21, 1920. Minimum observed flow, 31 cfs on June 28, 29, 1914.

REMARKS: About 10,000 acres above station are irrigated by surface water and ground water; Irrigated acreage was less during period of these records (1976).

GILA RIVER BASIN

09505550 Verde River below Camp Verde, Az

WATER YEAR	DURATION (days)	VOLUME (ac-ft)	MAX Q (cfs)	DATE OF PEAK
72	336	*101,290	15,800	12/26/71
74	365	71,450	2,200	7/8/74
75	365	129,000	3,280	4/15/75
76	366	196,400	30,100	2/9/76
77	365	62,140	3,490	8/23/77

* Indicates that data was not available for October and parts of November. Volume does not include full water year.

LOCATION: SW 1/4 NW 1/4 OF SECTION 5, T.13 N. & R.5 E., Yavapai County on downstream side of bridge on county highway, 0.5 miles southeast of Camp Verde, 2.2 miles downstream from Beaver Creek.

DRAINAGE AREA: 4,670 sq miles, approximately (includes 373 sq miles in Aubrey Valley playa, a closed basin).

REMARKS: Records good. About 10,000 acres above station are irrigated by surface water and ground water.

AVERAGE DISCHARGE: 5 Years record, 332 cfs, 240,500 ac-ft/yr.

EXTREMES OF RECORD: Maximum discharge, 50,000 cfs on 2/15/80. Minimum daily, 13 cfs July 6, 7, 1976.

EXTREMES OUTSIDE: A peak discharge of 97,000 cfs was recorded at former gaging station at site 8.5 miles downstream on March 3, 1938, and is the highest near this site since at least 1924 (1977 report).

HYDROGRAPH DATA

RIVER LOCATION	DATE OF PEAK	TIME TO PEAK (HOURS)	FLOW DURATION (HOURS)	PEAK FLOW (CFS)	VOLUME (AC-FT)
Agua Fria @ Avondale, Az	3/2/78	47	150	11,430	49,390 *
New River @ Bell Rd.	3/2/78	62	192	12,500	30,460 *
Rillito near Tucson, Az	10/2/83	35	95	29,700	52,725 *
Rillito near Tucson, Az	12/22/65	8	36	12,400	17,930 *
Rillito near Tucson, Az	9/10/64	8	19	9,360	6,300 *
Rillito near Tucson, Az	9/10/64	9	26	9,400	5,240 *
Salt @ Jointhead Dam, Az	12/31/65	24	120	66,000	261,470 *
Salt River @ Granite Reef	2/16/80	58	302	170,000	619,610 *
Salt River @ Phoenix, Az	3/22/87	144	384	2,898	33,185
Salt River @ Phoenix, Az	1/29/85	72	432	8,353	154,481 *
Salt River @ Phoenix, Az	3/18/85	144	1,248	16,731	420,105 *
Salt River @ Phoenix, Az	12/28/84	216	888	26,010	372,946
Salt River @ Phoenix, Az	2/10/83	168	600	30,441	434,015
Salt River @ Phoenix, Az	3/5/83	120	384	13,195	190,421
Salt River @ Phoenix, Az	3/26/83	144	720	20,372	428,757 *
Salt River @ Phoenix, Az	4/23/83	144	384	8,055	125,845
Salt River @ Phoenix, Az	10/3/83	72	528	39,976	467,219
Salt River @ Phoenix, Az	12/26/83	48	504	11,200	152,544
Salt River @ Phoenix, Az	2/1/80	72	216	9,300	117,538
Salt River @ Phoenix, Az	2/16/80	72	528	139,132	1,826,839 *
Salt River @ Phoenix, Az	1/18/79	48	816	87,546	1,003,843 *
Salt River @ Phoenix, Az	3/29/79	456	888	51,803	921,558 *
Salt River @ Phoenix, Az	12/19/79	72	528	110,000	846,853 *
Salt River @ Phoenix, Az	3/3/78	96	192	95,809	531,001
Salt River @ Phoenix, Az	3/23/78	192	312	6,963	59,321 *
Salt River @ Phoenix, Az	2/23/73	72	144	4,380	31,887 *
Salt River @ Phoenix, Az	4/1/73	504	1056	22,321	926,078 *
Salt River @ Phoenix, Az	5/7/73	288	576	10,929	246,402 *
Salt River @ Phoenix, Az	12/29/72	48	240	5,493	38,819 *
Salt River @ Phoenix, Az	2/15/68	48	144	3,703	33,735
Salt River @ Phoenix, Az	2/23/66	96	288	2,308	36,865 *
Salt River @ Phoenix, Az	12/23/65	48	144	6,900	36,675
Salt River @ Phoenix, Az	12/31/65	48	312	64,000	472,271 *
Santa Cruz @ Tucson, Az	10/2/83	13	137	52,700	101,630 *
Santa Cruz @ Tucson, Az	10/10/77	25	48	23,700	33,000 *
Santa Cruz @ Tucson, Az	12/20/67	48	96	16,100	14,350 *
Santa Cruz @ Tucson, Az	12/23/65	24	59	4,830	12,200 *
Santa Cruz @ Tucson, Az	9/10/64	11	33	13,000	14,930 *
Santa Cruz @ Tucson, Az	9/10/64	11	31	14,300	14,900 *
Verde below Camp Verde	3/1/78	41	192	41,000	228,340 *
Verde near Clarkdale, Az	11/25/65	7	144	11,200	18,200 *
Verde near Clarkdale, Az	12/10/65	7	144	12,900	23,070 *
Verde near Clarkdale, Az	12/23/65	18	120	3,810	11,620 *
Verde near Clarkdale, Az	12/30/65	5	96	11,600	26,300 *
Verde near Clarkdale, Az	3/1/78	35	168	25,000	134,590 *

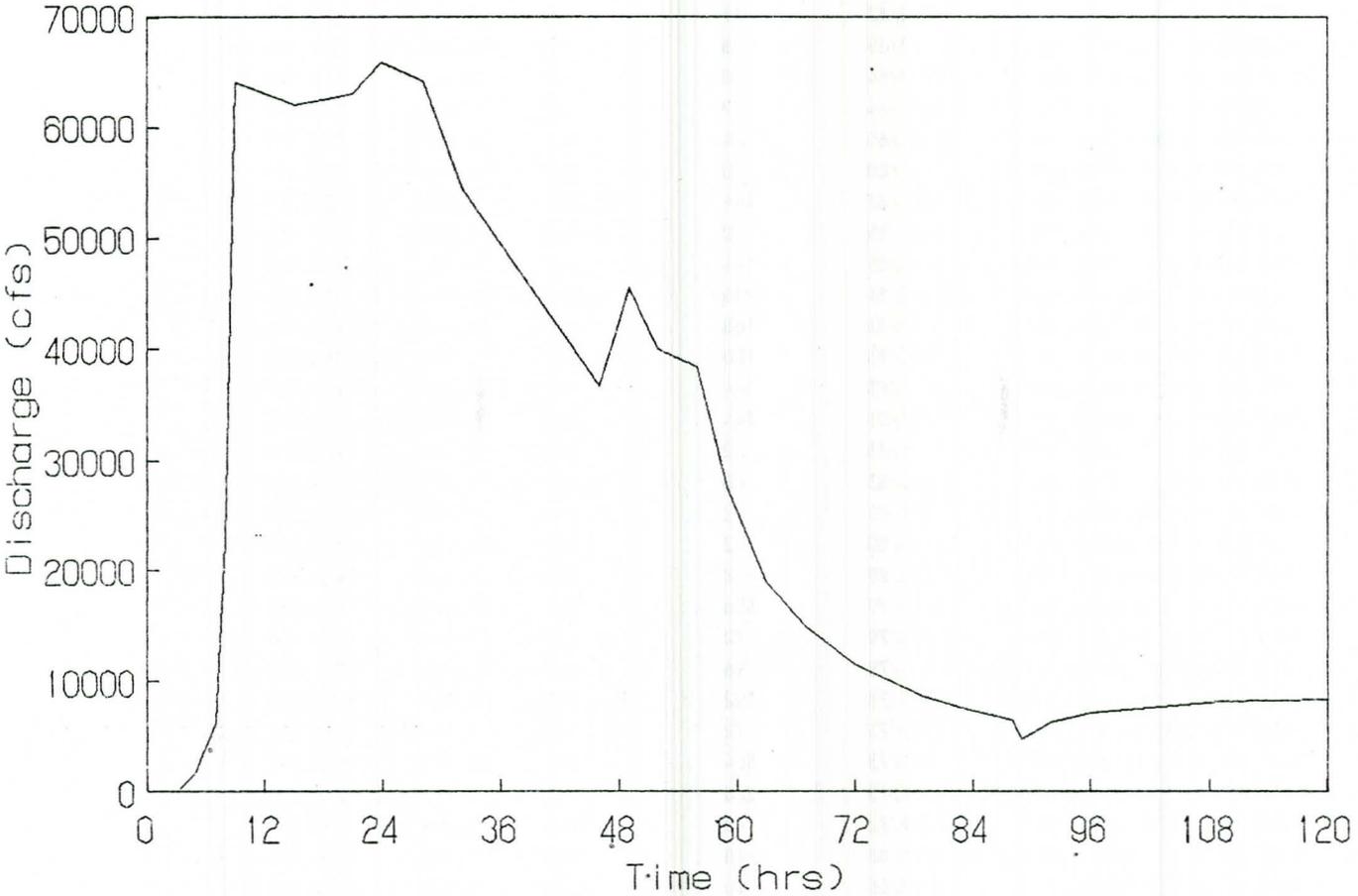
NOTES:

* Indicates a multiple peak hydrograph.

Reference to the Salt River at Phoenix, Az indicates the data was compiled from The Salt River Project's average spill data over Granite Reef Diversion Dam with applicable irrigation cannal drains added in. This does not include flow into the Salt River at Phoenix, like Indian Bend Wash, South Mountain Tributary etc..

Flood Hydrograph

Salt River at Jointhead Dam, Az
Dec. 30, 1965 to Jan. 4, 1966

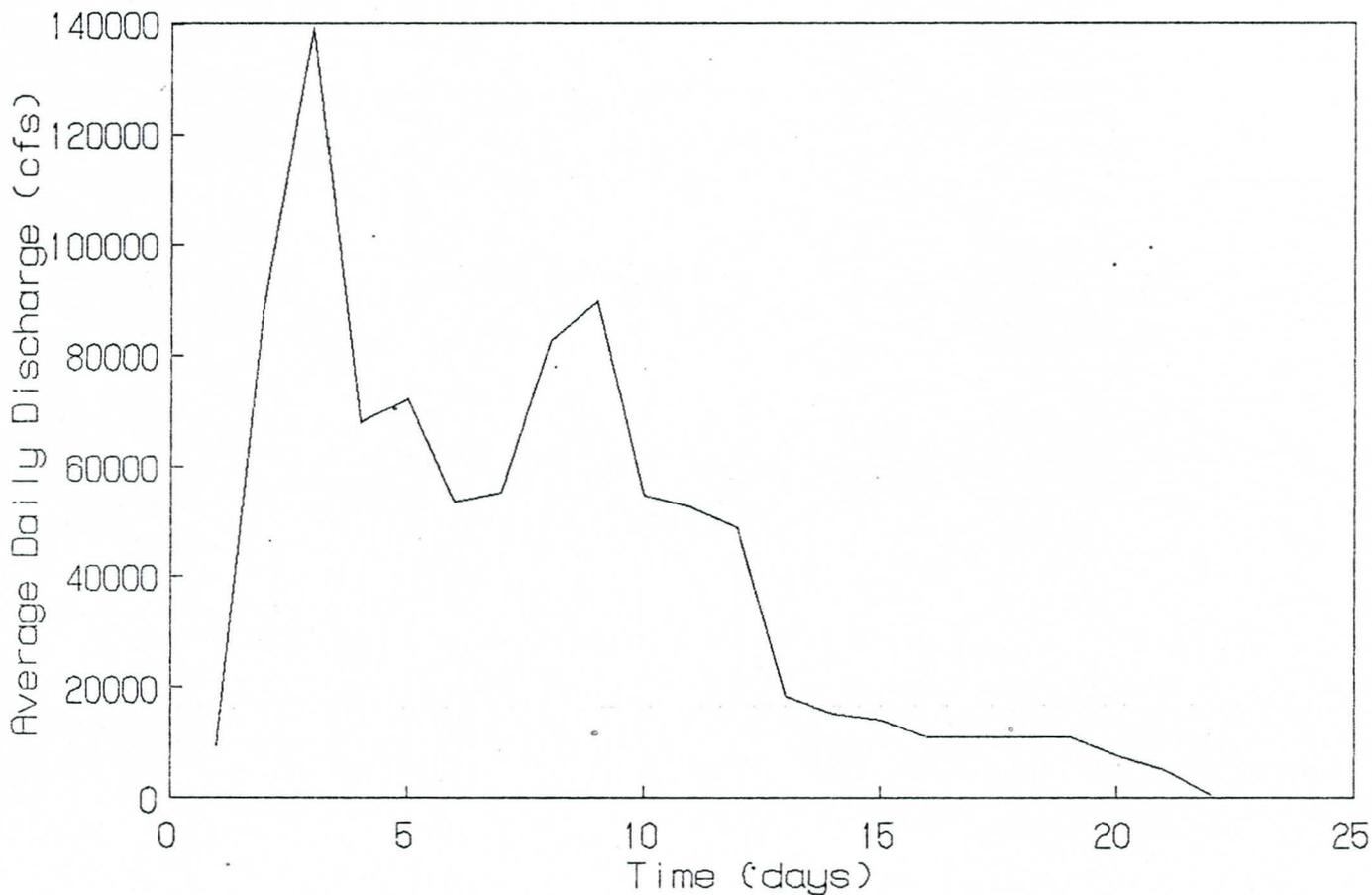


(U.S.G.S. WSP No. 1850-C)

GRAPH 1

Salt River

Average Discharges at Granite Reef Dam, Az
Feb. 14 to Mar. 6, 1980

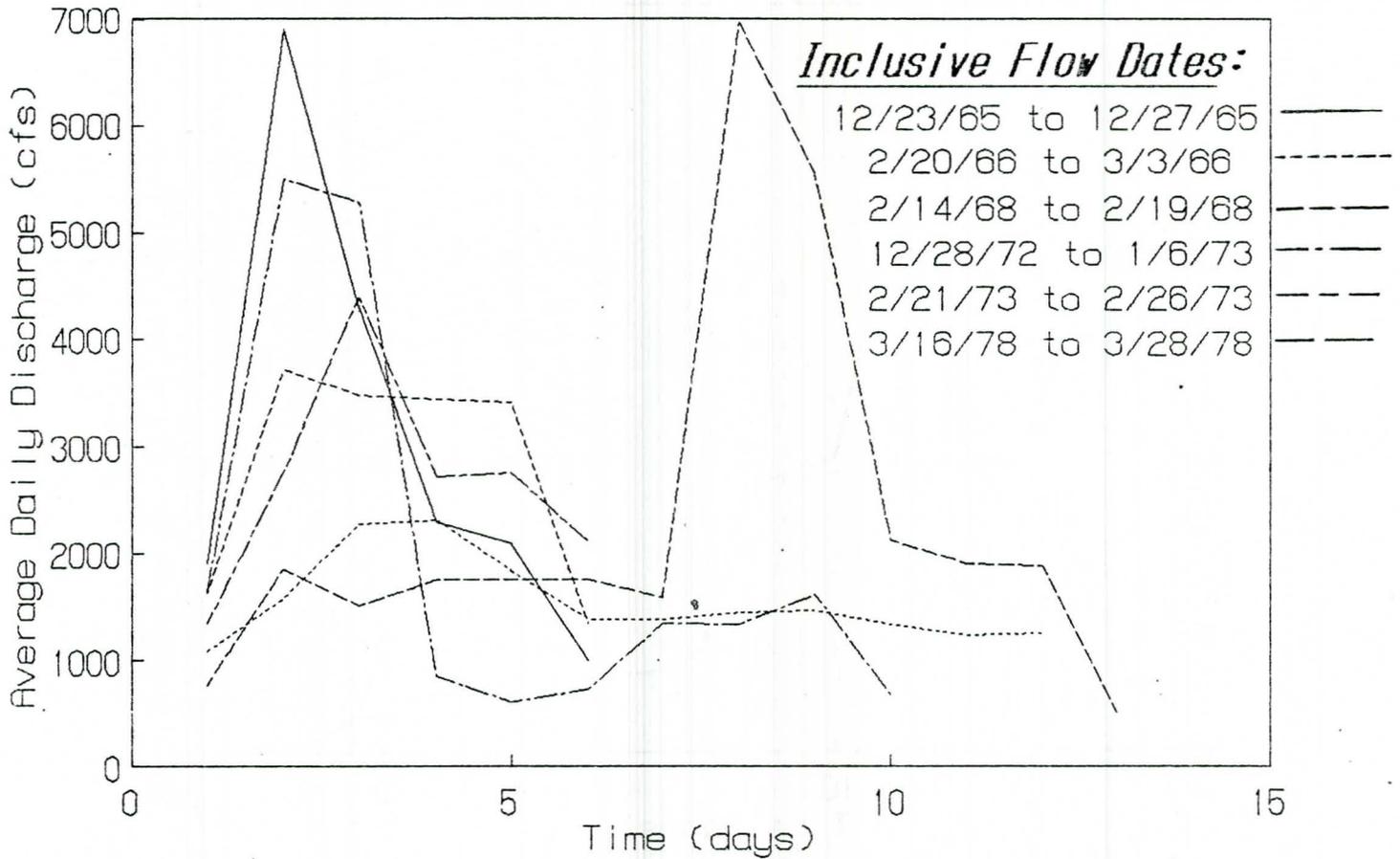


(SRP Data Base, Hydrology Group)

GRAPH L2

Salt River

Average Discharges from Granite Reef Dam, Az
Flows Less than 7,000 cfs

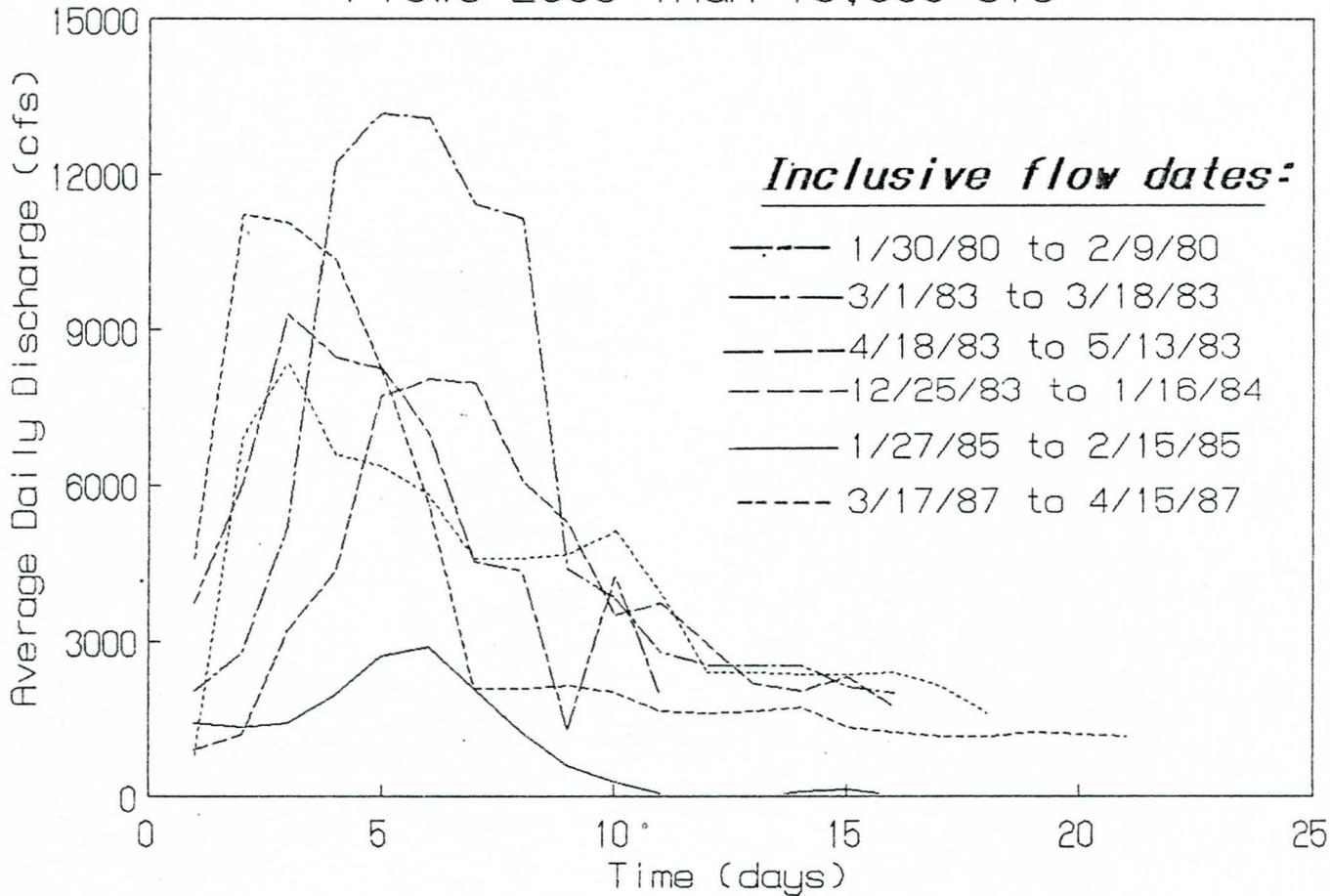


(SRP Data Base, Hydrology Group)

GRAPH L3

Salt River

Average Discharges at Granite Reef Dam, Az
Flows Less Than 15,000 cfs

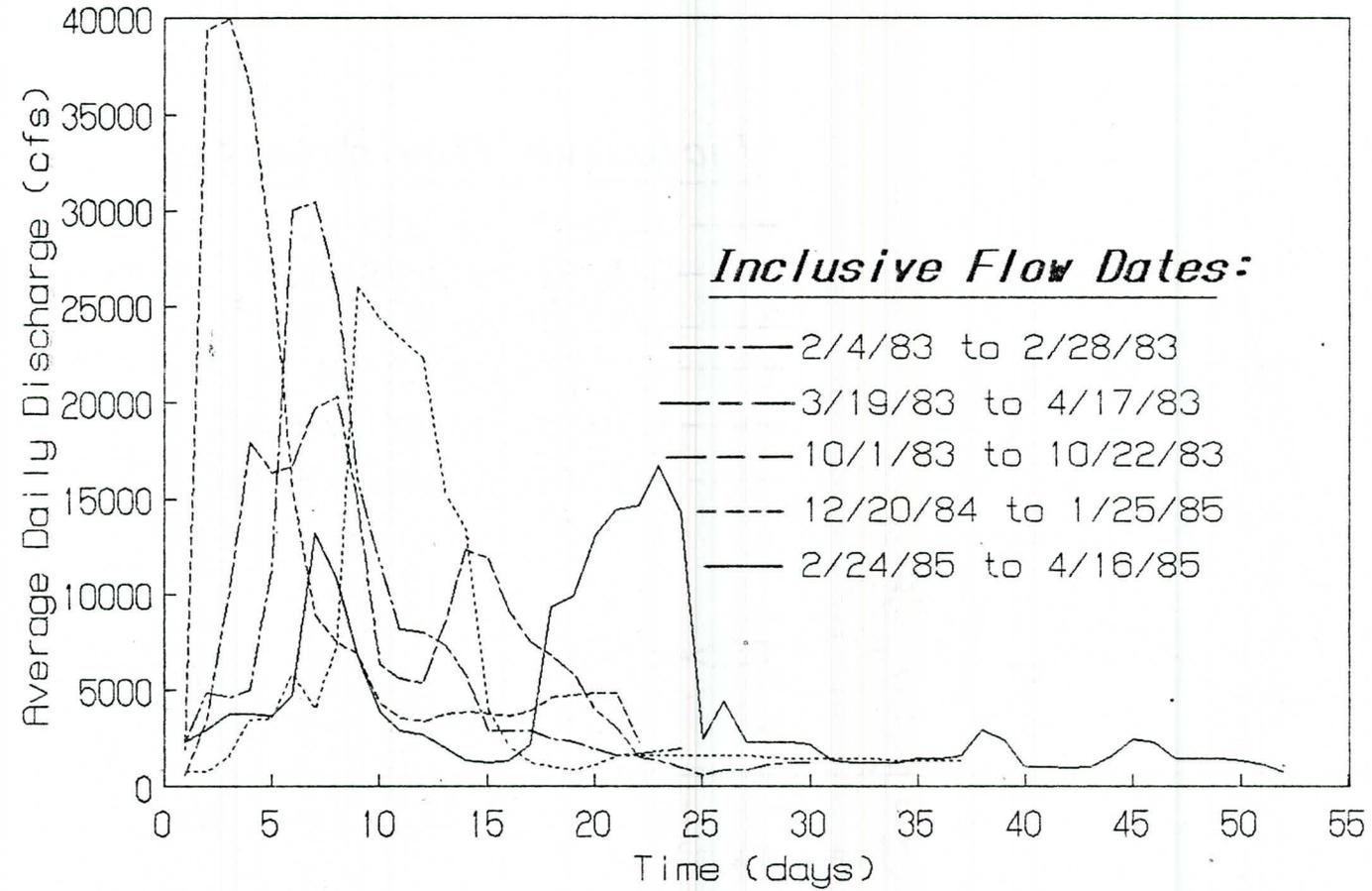


(SRP Data Base, Hydrology Group)

GRAPH L4

Salt River

Average Discharges at Granite Reef Dam, Az
Flows Less than 40,000 cfs

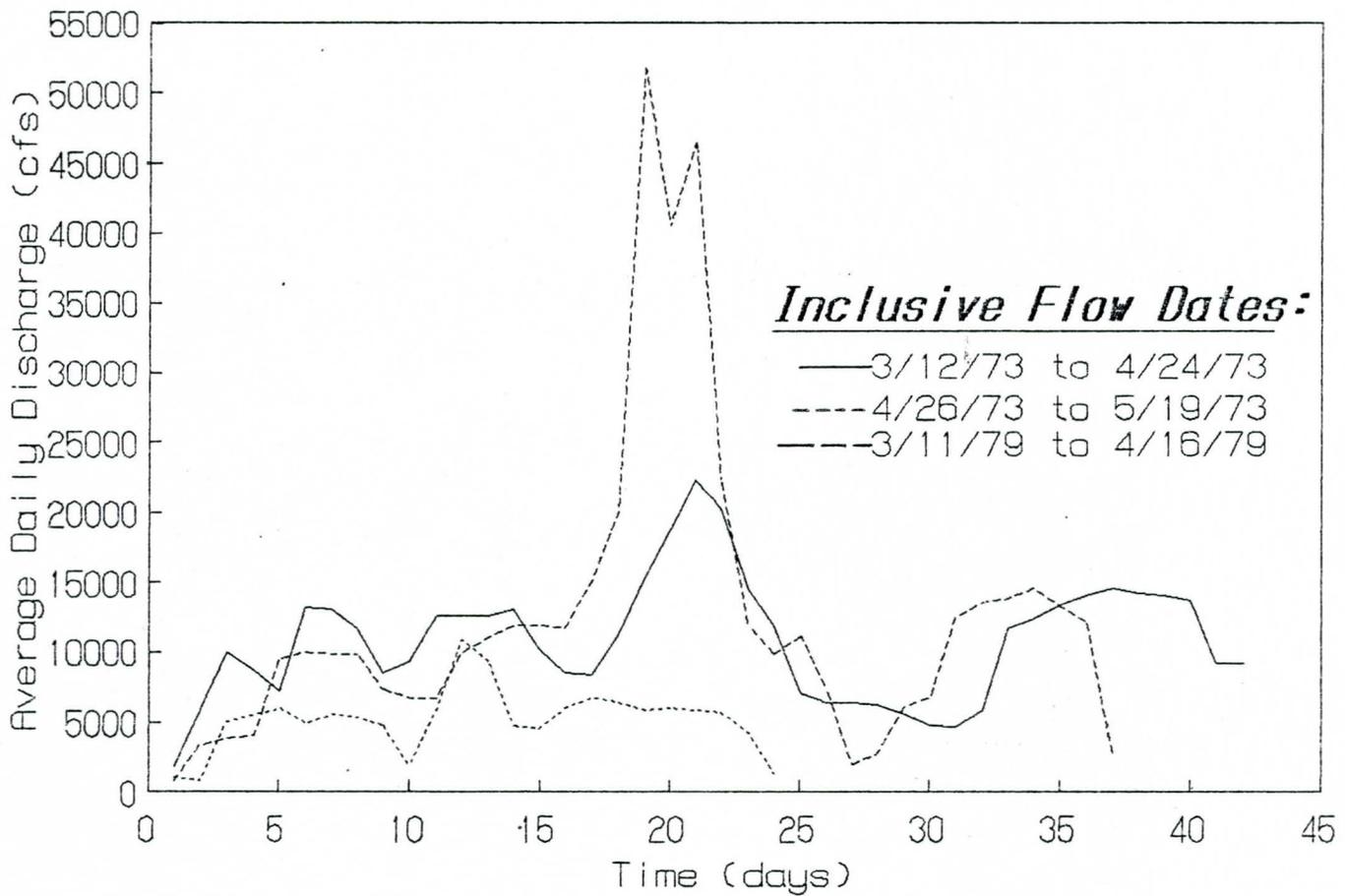


(SRP Data Base, Hydrology Group)

GRAPH L5

Salt River

Average Discharges from Granite Reef Dam, AZ
Flows Less than 55,000 cfs

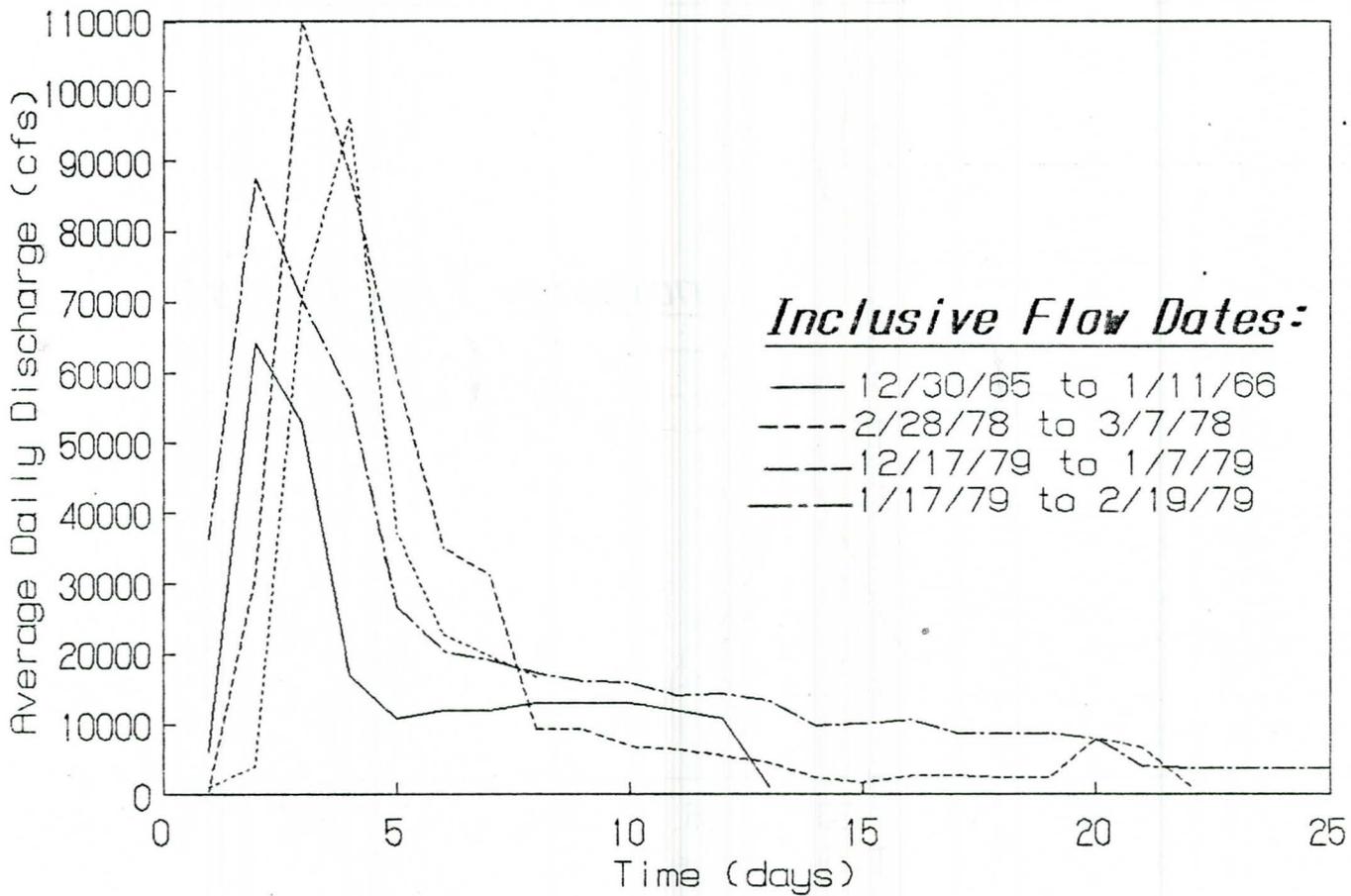


(SRP Data Base, Hydrology Group)

GRAPH 6

Salt River

Average Discharges from Granite Reef Dam, Az
Flows Less than 110,000 cfs



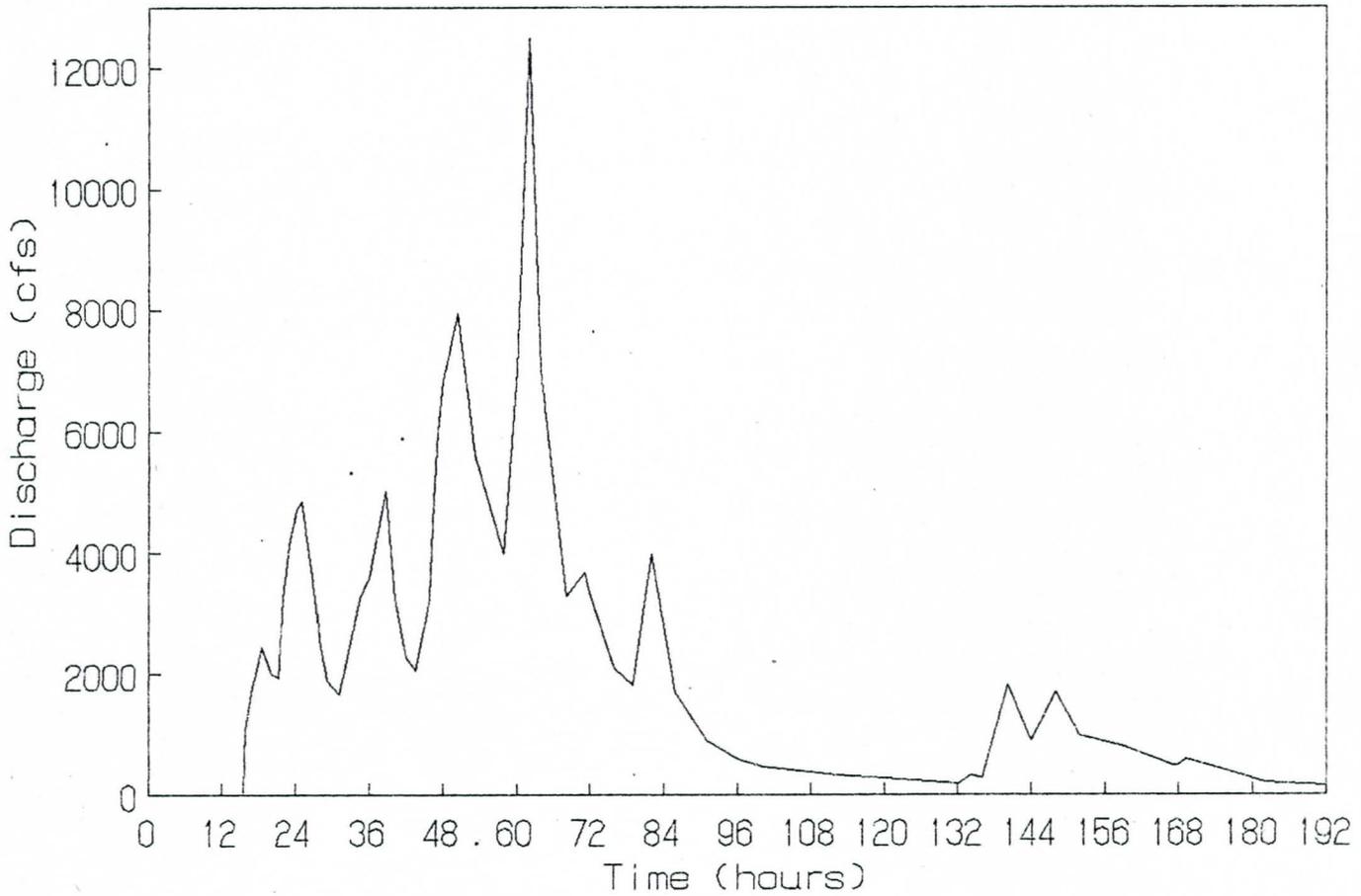
(SRP Data Base, Hydrology Group)

GRAPH L7

Flood Hydrograph

New River at Bell Rd. near Peoria, Az

Feb. 27 to Mar. 7, 1978



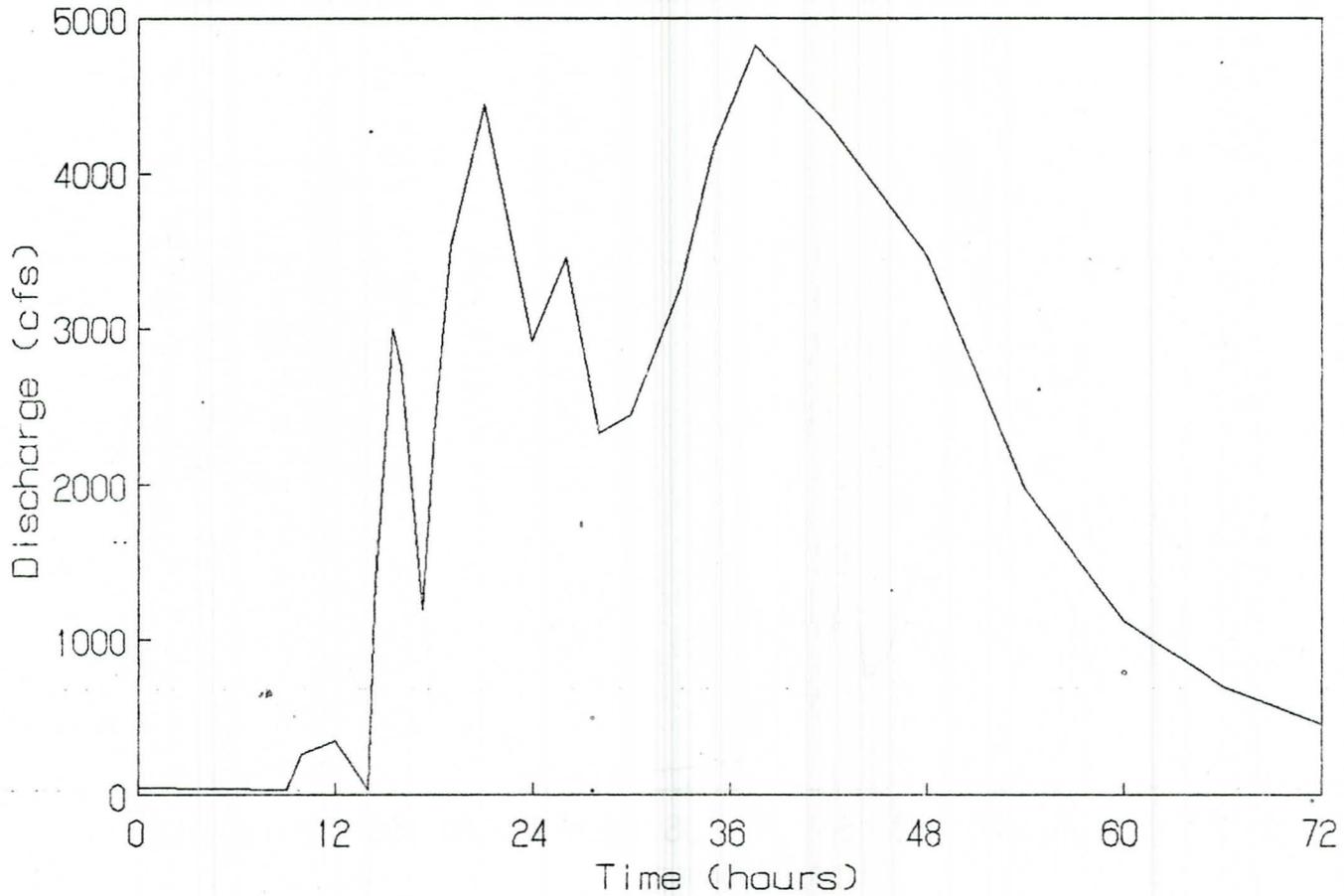
(U.S.G.S., OFR 82-687)

GRAPH L8

Flood Hydrograph

Santa Cruz River at Tucson, Az

Dec. 22 to 24, 1965

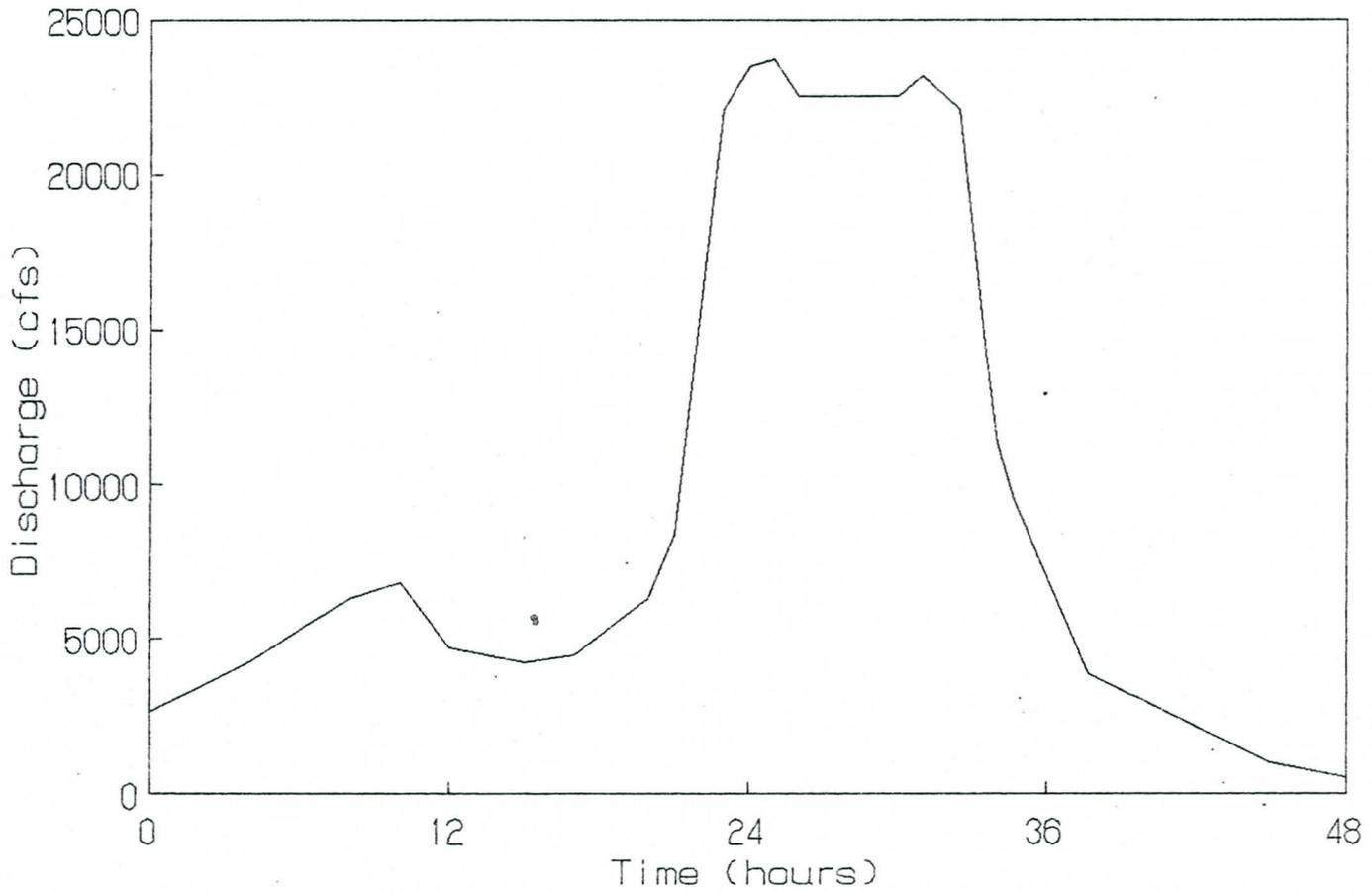


(U.S.G.S., WSP No. 1850-C)

GRAPH L9

Flood Hydrograph

Santa Cruz River at Tucson, Az
Flood of October 1977



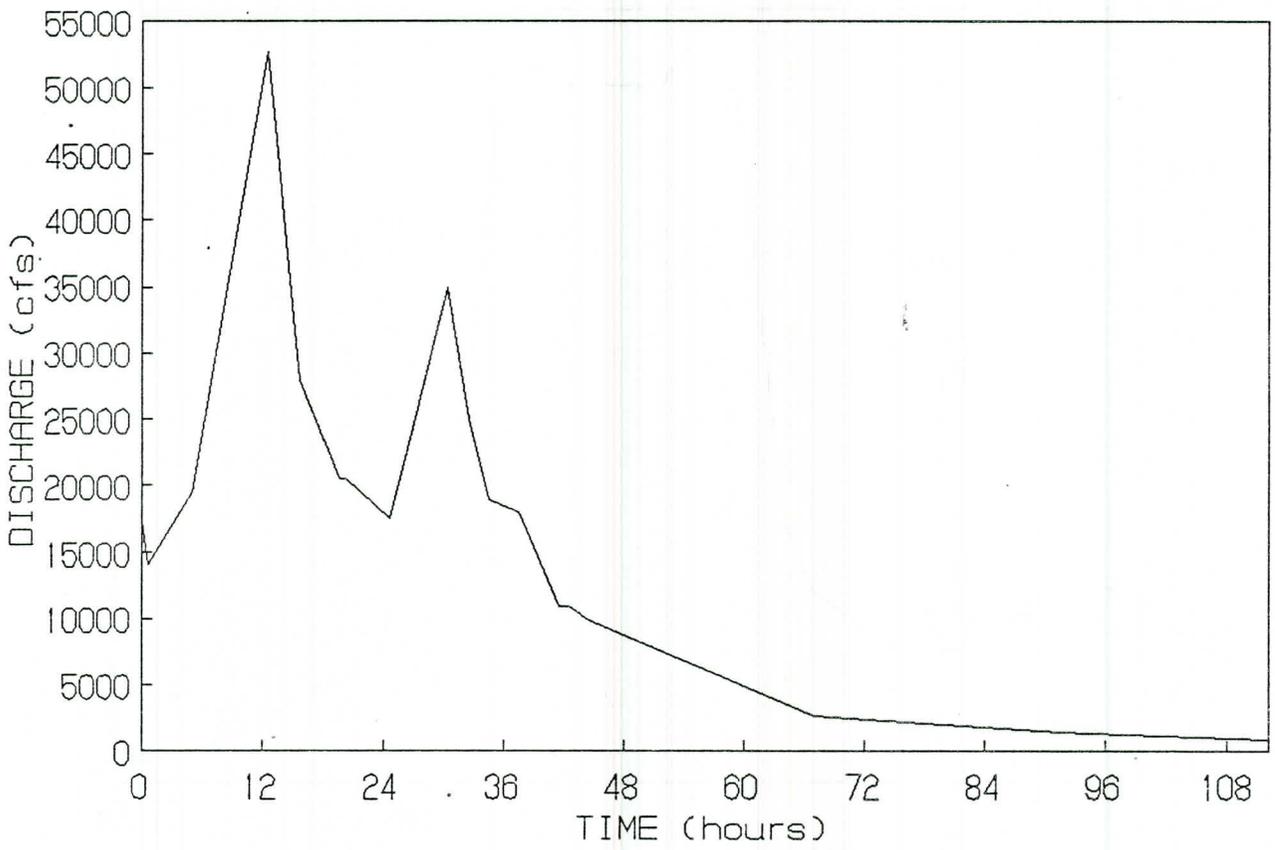
(U.S.G.S., WSP No. 2223)

GRAPH L.10

Flood Hydrograph

October 1 thru 7, 1983

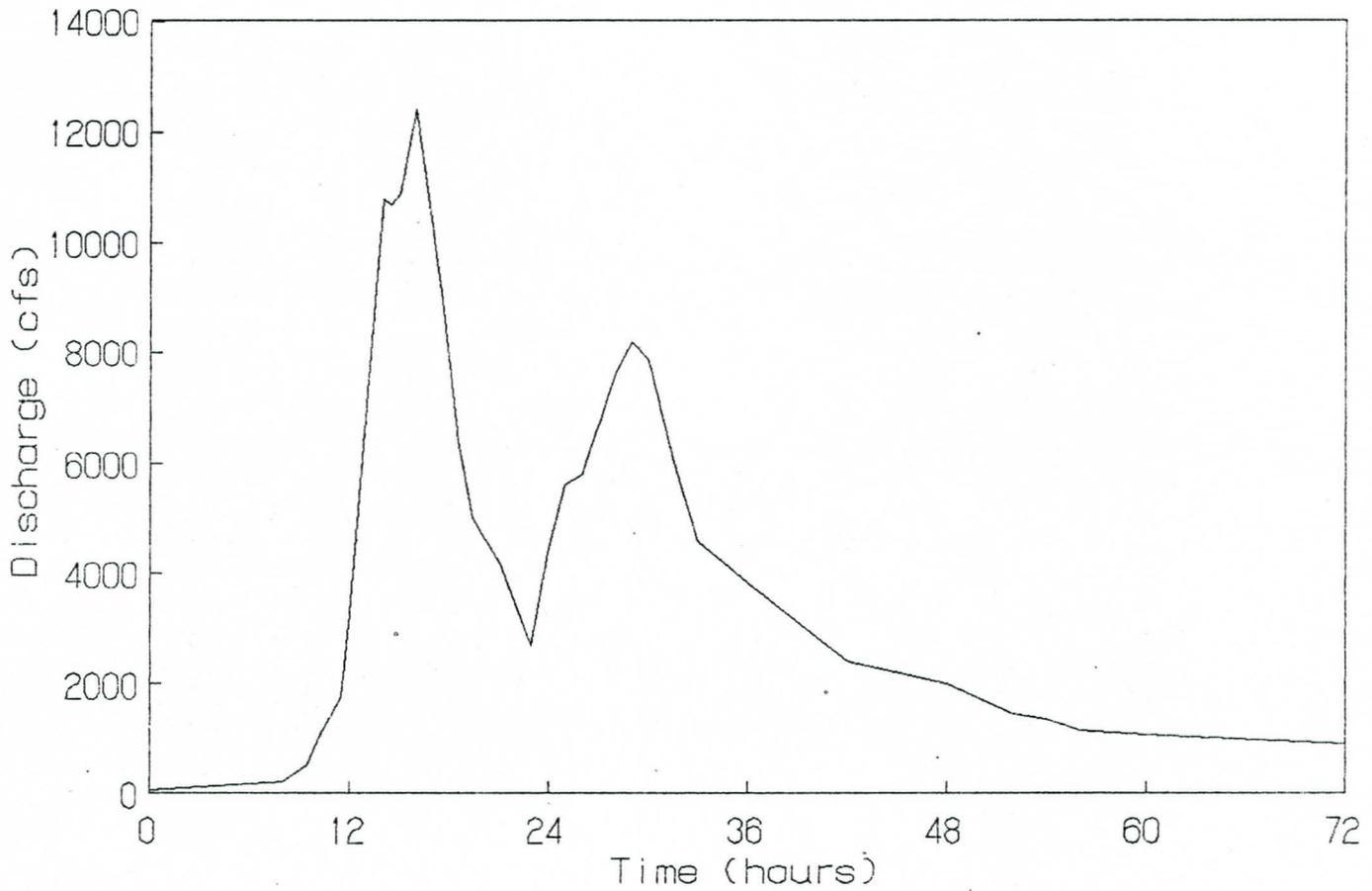
Santa Cruz River at Tucson, Ariz.



GRAPH L11

Flood Hydrograph

Rillito Creek near Tucson, Az
Dec. 21 to 24, 1965



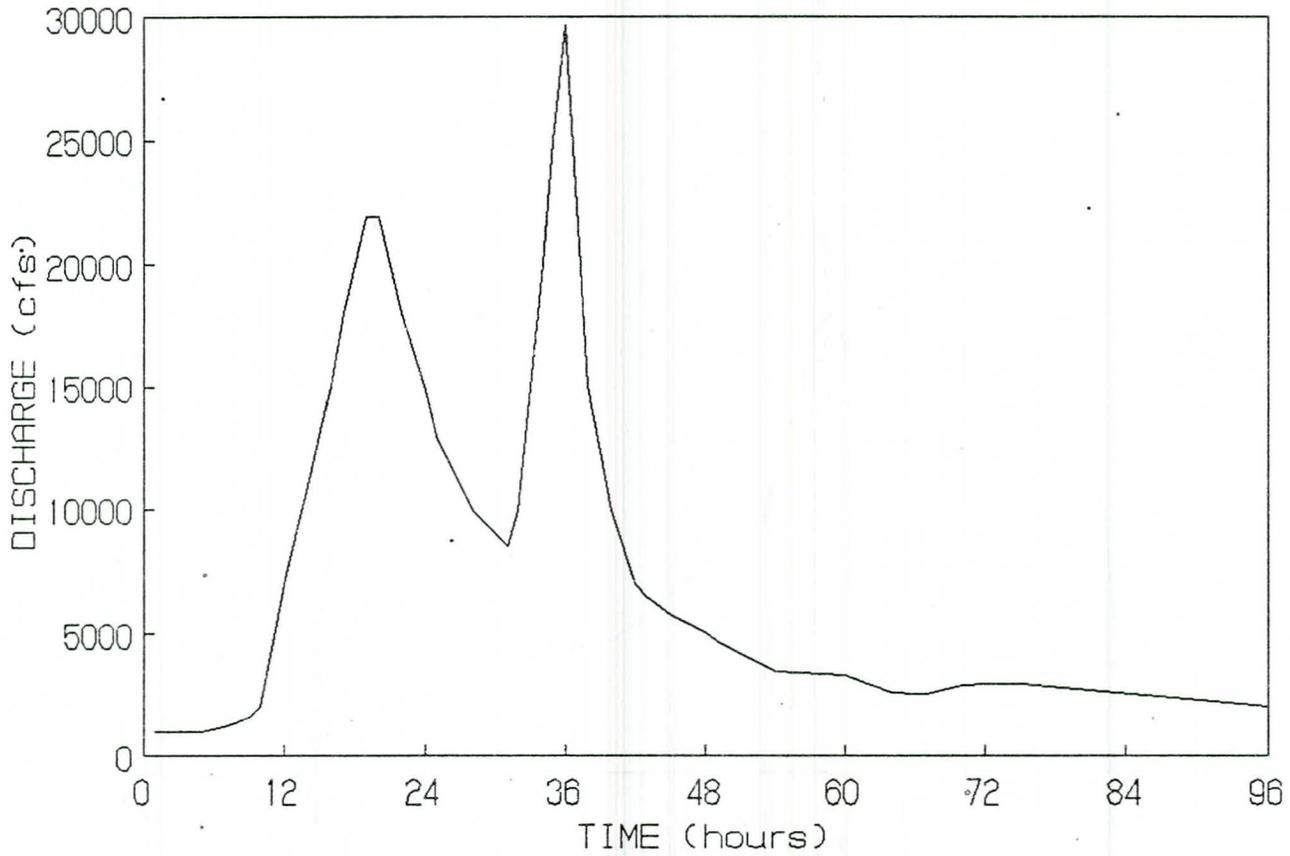
(U.S.G.S., WSP No. 1850-C)

GRAPH L12

Flood Hydrograph

October 1 thru 4, 1983

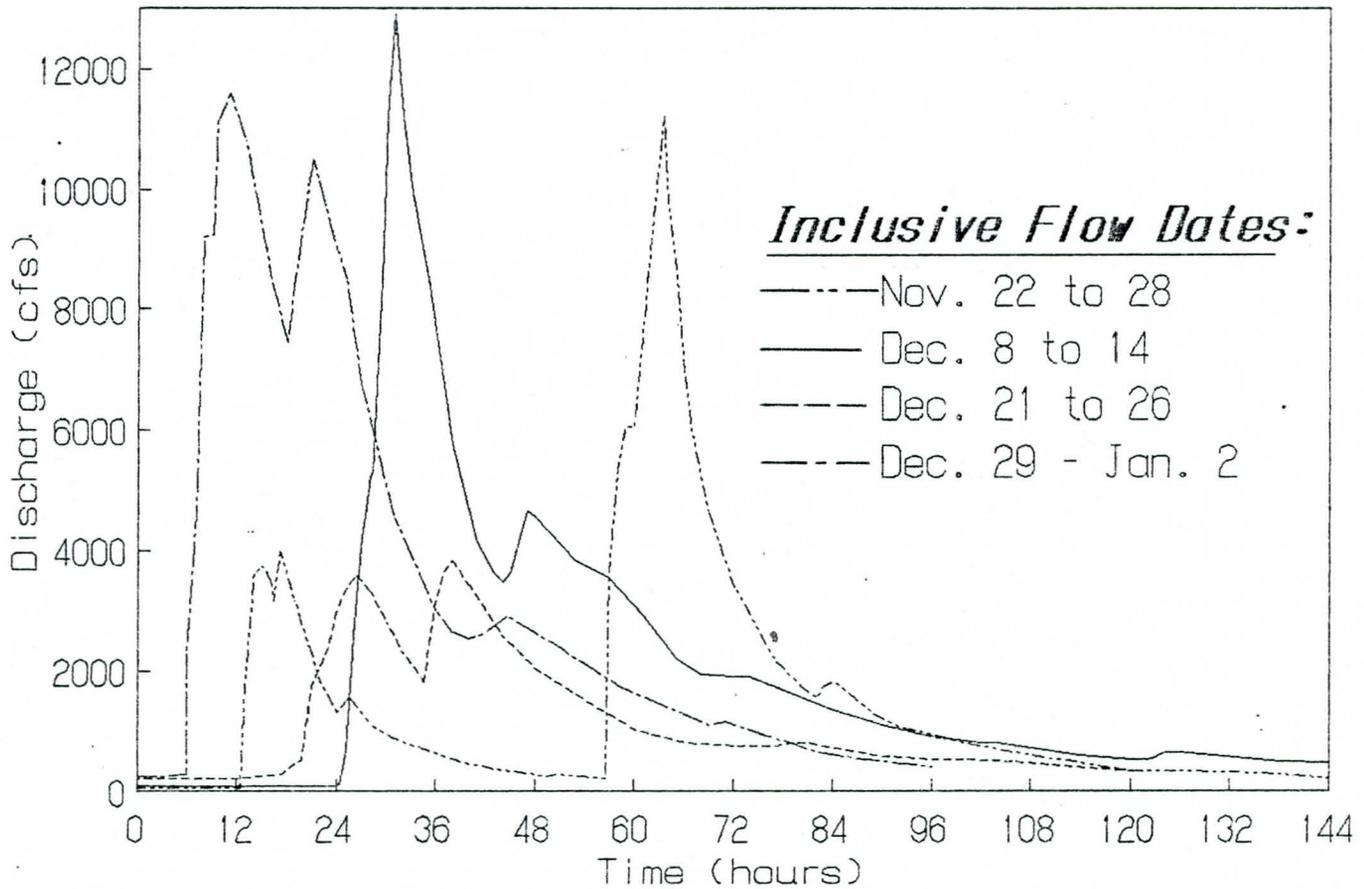
Rillito Creek near Tucson, Ariz.



GRAPH L.13

Flood Hydrographs

Verde River near Clarkdale, Az
Floods of 1965



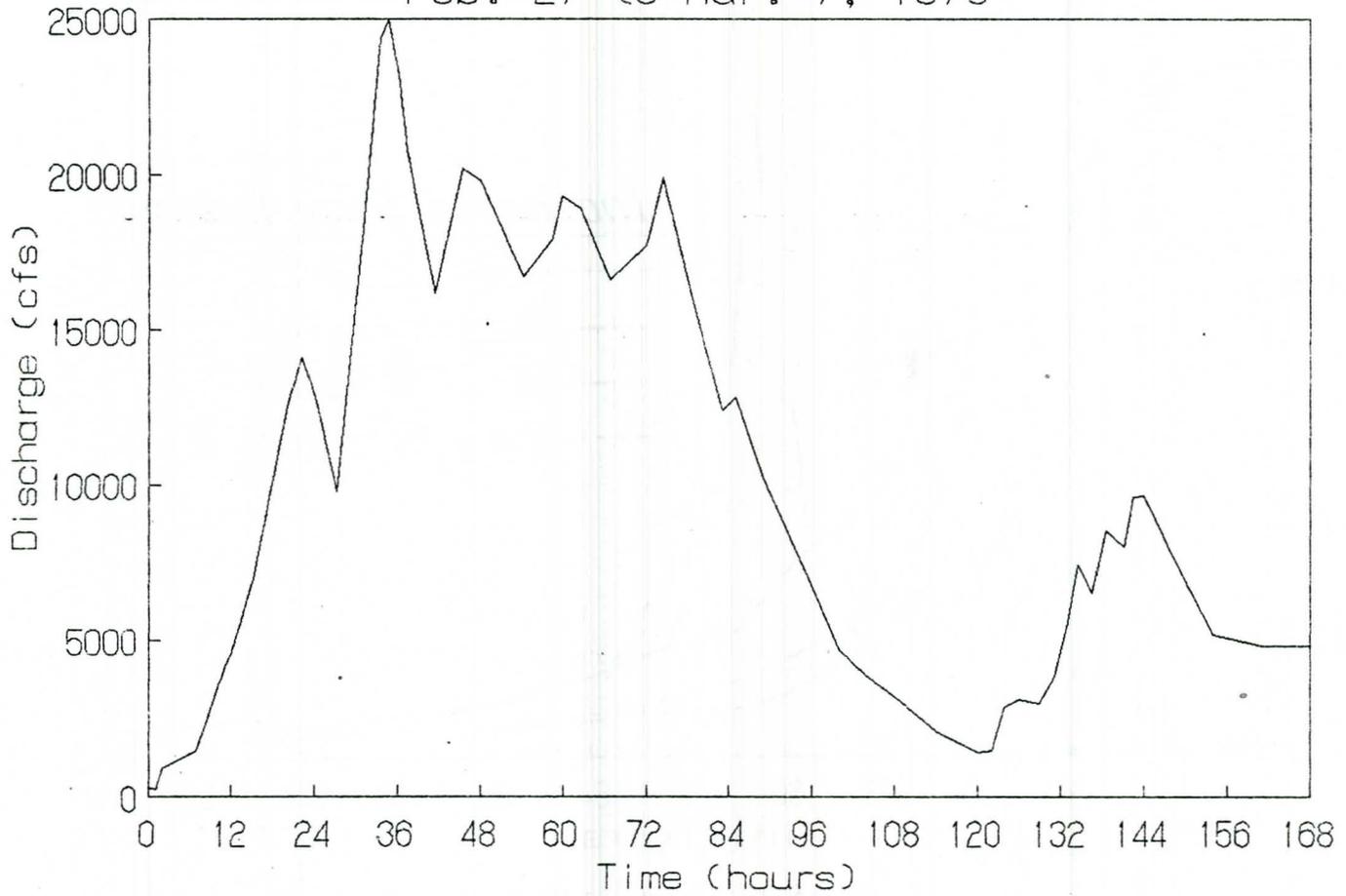
(U.S.G.S., WSP No. .1850-C)

GRAPH L 14

Flood Hydrograph

Verde River near Clarkdale, Az

Feb. 27 to Mar. 7, 1978



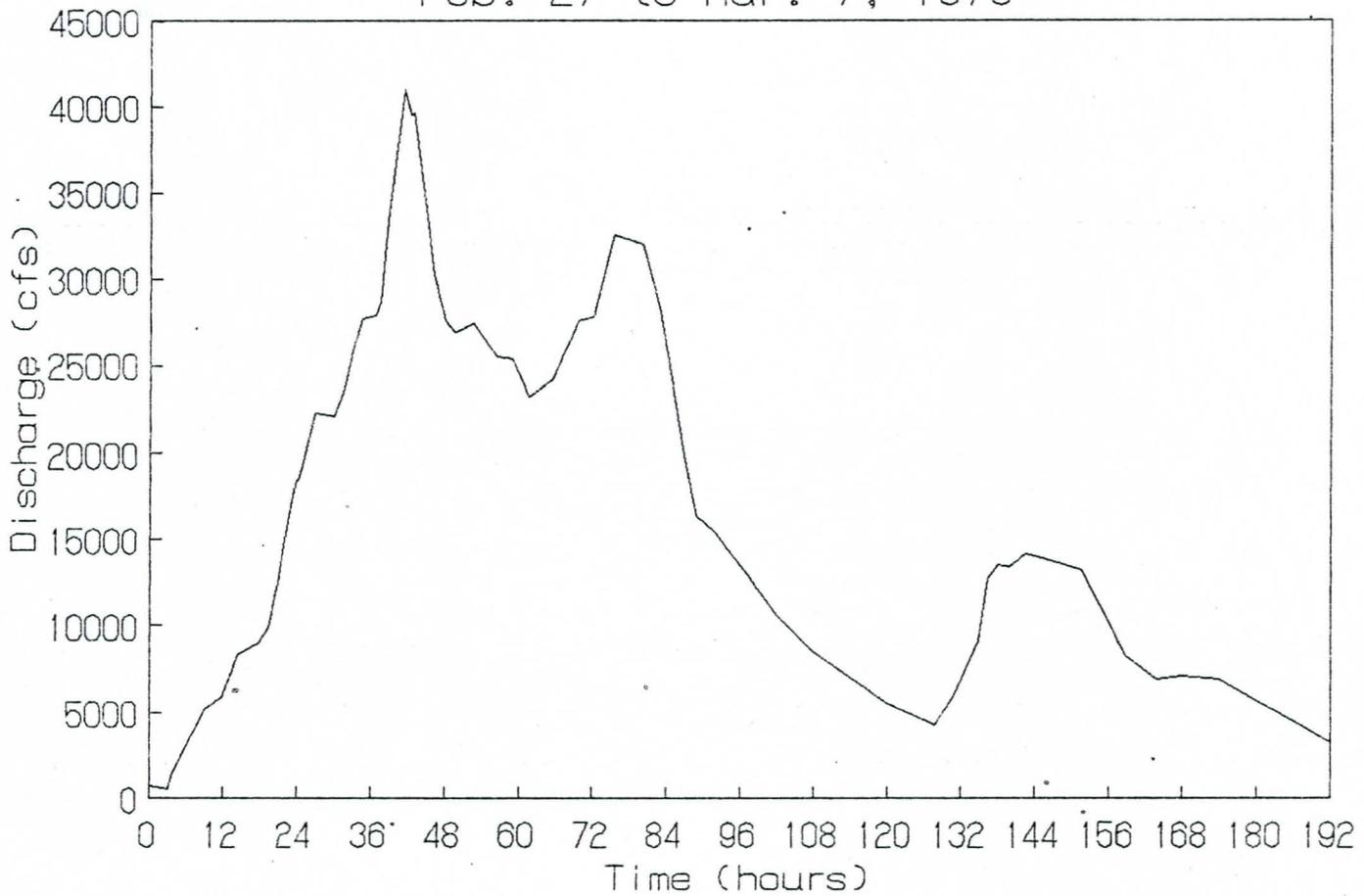
(U.S.G.S., WSP No. 2223)

GRAPH L15

Flood Hydrograph

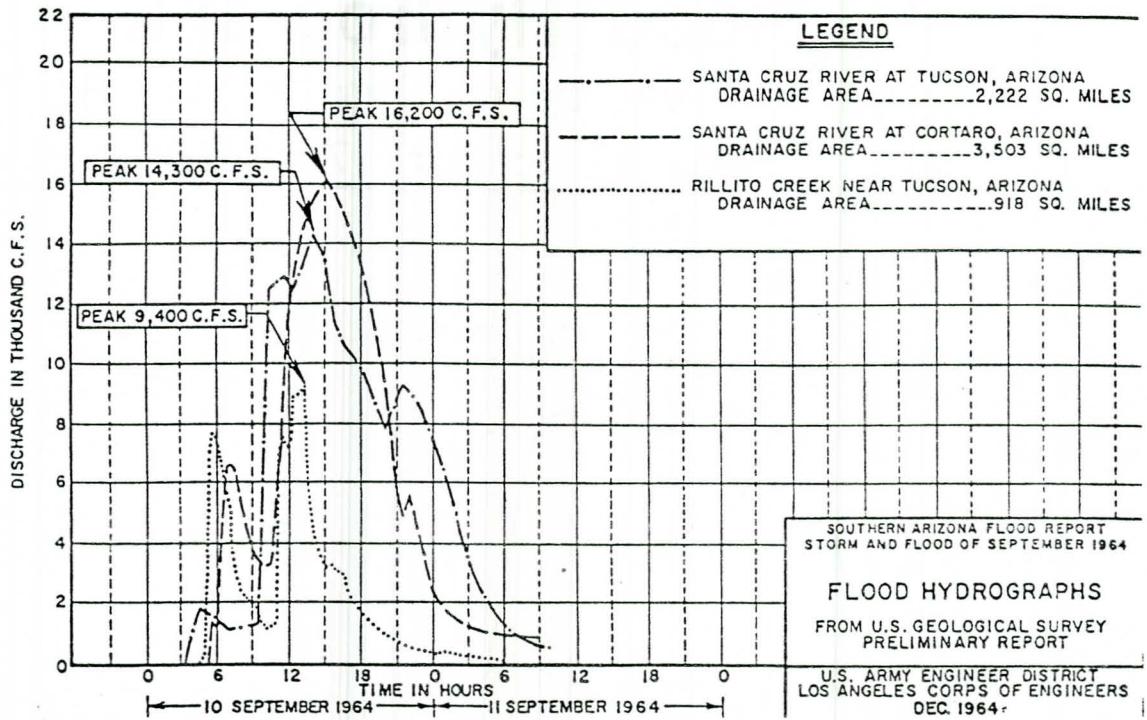
Verde River below Camp Verde, Az

Feb. 27 to Mar. 7, 1978

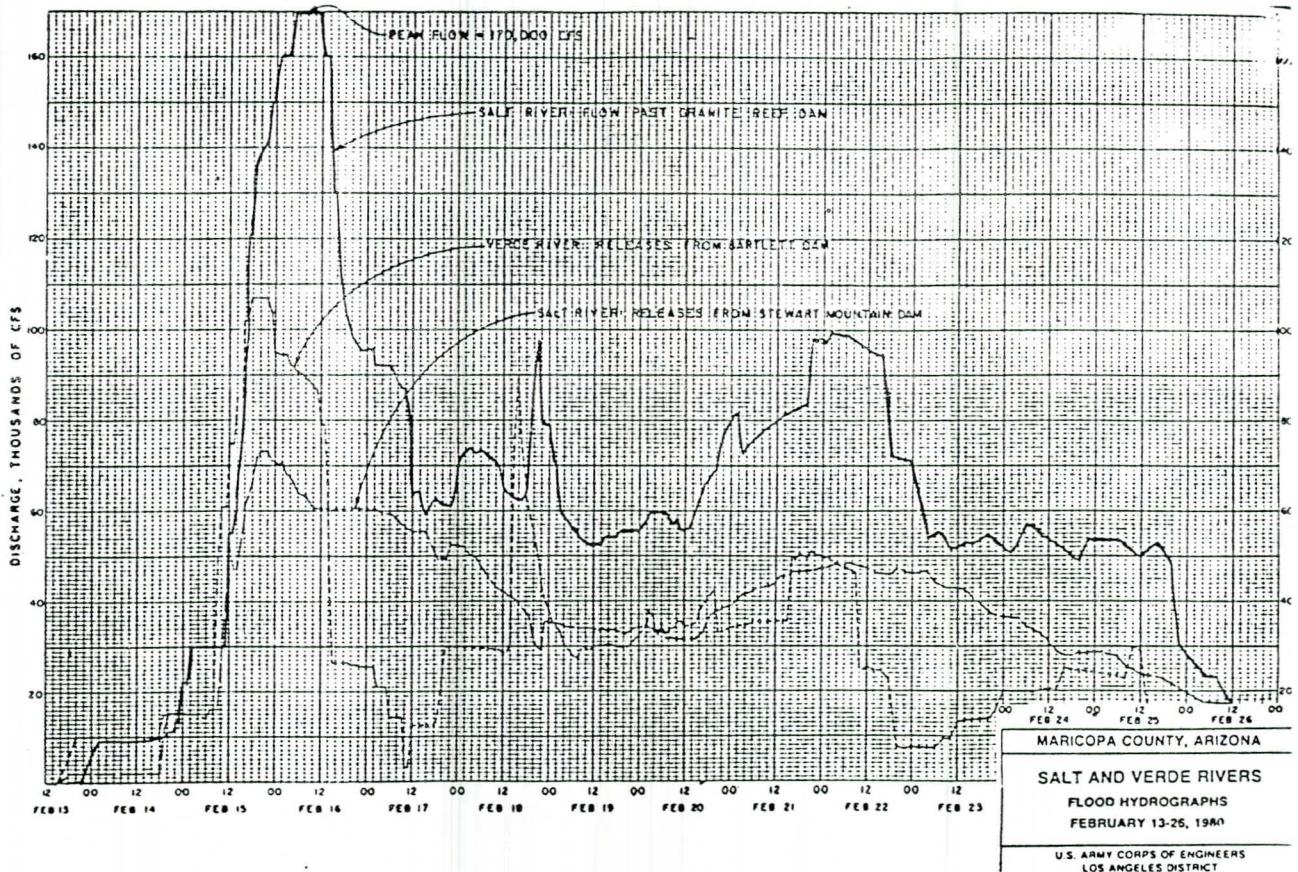


(U.S.G.S., WSP No. 2223)

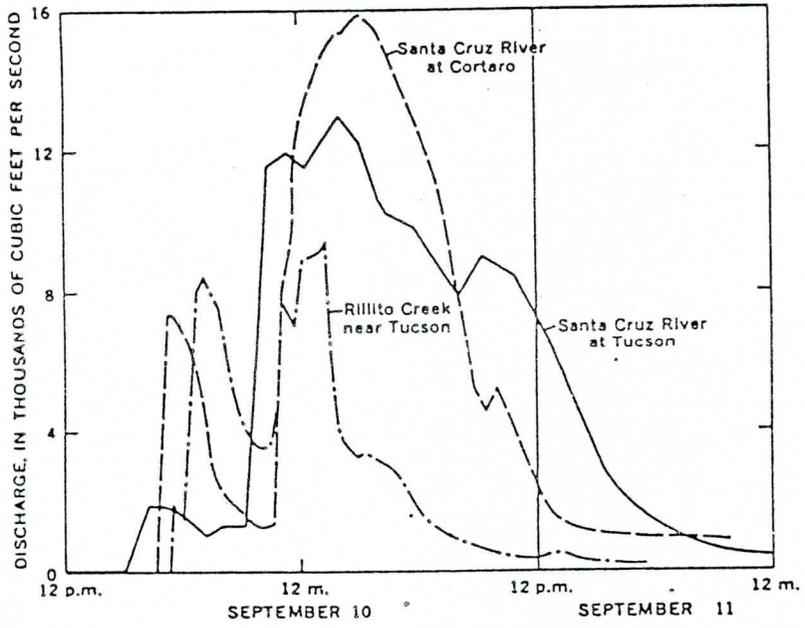
GRAPH I.16



(COE, 1965)
GRAPH I.17

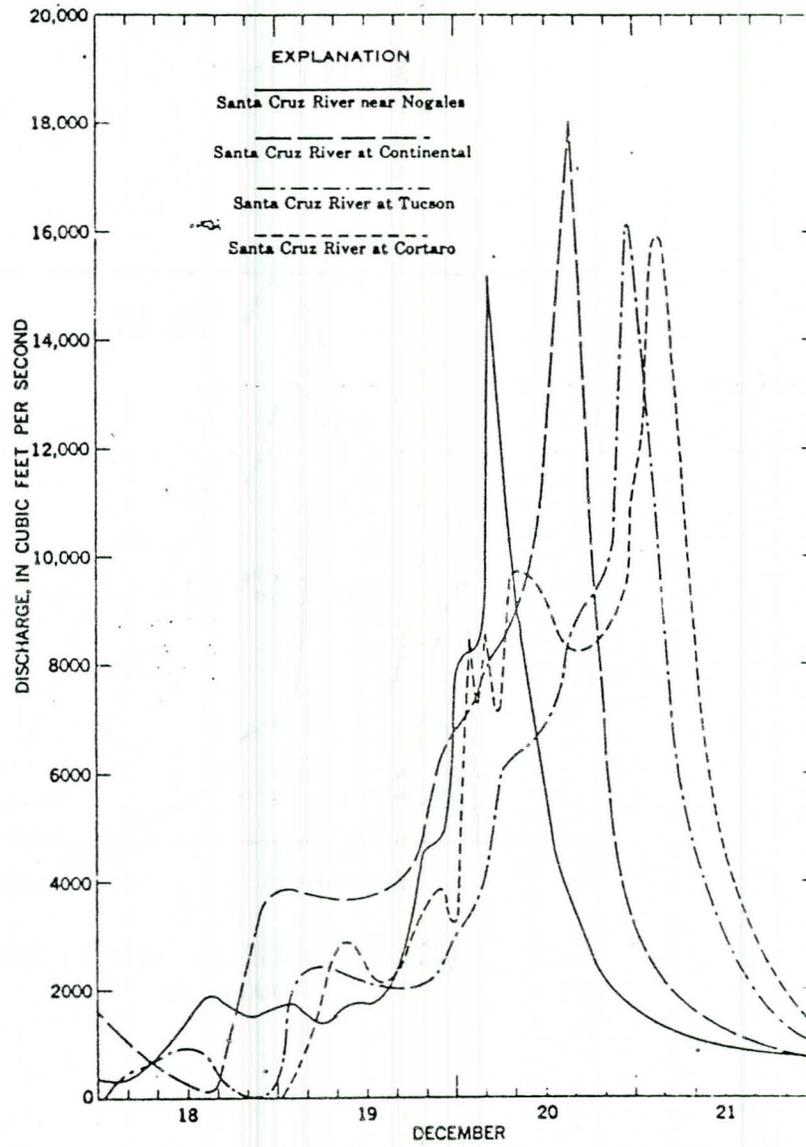


(COE, 1980)
GRAPH I.18



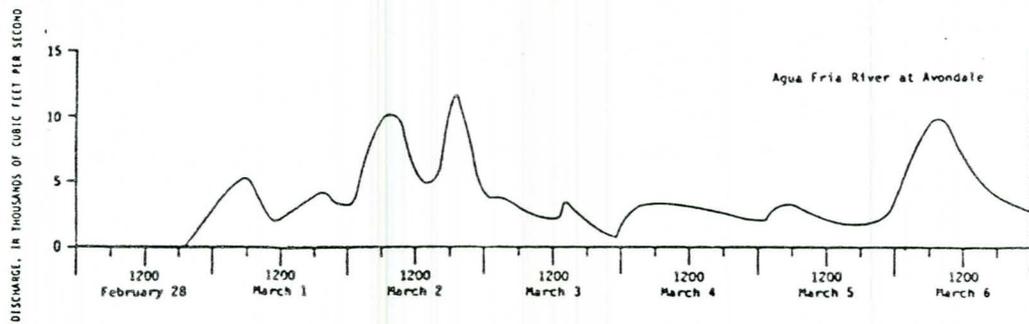
(U.S.G.S., WSP No. 1850-C, 1965)

GRAPH L.19



(U.S.G.S., WSP No. 1880-C, 1965)

GRAPH L.20



(U.S.G.S., WSP No. 2223, 1977)

GRAPH L.21

FLOOD FREQUENCY DATA

DATE OF STUDY	STATION NAME	DRAINAGE AREA (sq miles)	Q2	Q5	Q10	Q25	Q50	Q100	Q500	SOURCE REFERENCES
10/73	Agua Fria River @ Avondale, Az	718	1,500	8,000	16,000	30,000	42,000	56,000		2
1982	Agua Fria River @ Avondale, Az	718				47,000	68,000	90,000		1
* 1982	Agua Fria River @ Avondale, Az	2,241				47,000	67,000	90,000	179,000	1
1982	Agua Fria River @ Bell Rd.					60,000	87,000	115,000		1
* 1982	Agua Fria River @ Bell Rd.	1,870				60,000	87,000	115,000	182,000	1
09/78	Agua Fria River @ El Mirage, Az	178	602	2,760	6,100	13,100	21,400	32,300	74,900	4
09/81	Agua Fria River @ Glendale, Az	Dam Controlled				16,000	40,000	54,000	78,000	5
08/82	Agua Fria River @ U.S. 80	Dam Controlled				30,000	42,000	56,000	93,000	6
1982	Agua Fria River below New River					50,000	69,000	95,000		1
* 1982	Agua Fria River below New River	2,088				50,000	69,000	95,000	184,000	1
01/79	New River @ Bell Rd.	187	1,470	5,110	9,650	18,800	28,800	42,100		15
10/73	New River @ Bell Rd.	187	1,500	7,400	15,000	28,000	39,000	53,000		2
09/81	New River @ Skunk Cr Confluence	314.6			17,000		44,000	58,000	86,000	5
10/73	New River below Skunk Creek	123.6	1,700	84,000	17,000	31,000	44,000	58,000		2
1982	New River below Skunk Creek	123.6						41,000		1
09/78	New River near Glendale, Az	323	2,420	8,600	16,500	32,400	49,600	72,300	153,000	4
10/73	New River near Glendale, Az	325	1,500	7,400	15,000	28,000	39,000	53,000		2
03/16/82	Rillito Creek @ 1st St.	892			12,500		24,000	32,000	64,000	7
12/15/82	Rillito Creek @ 1st St.	892			12,500		24,000	32,000	64,000	8
01/79	Rillito Creek near Tucson, Az	892	4,980	9,130	12,300	16,700	20,200	23,800		15
09/78	Rillito Creek near Tucson, Az	892	4,940	9,070	12,200	16,700	20,300	24,000	33,500	4
5/82	Salt River @ 67th Ave.			38,000	90,000		150,000	190,000	315,000	16
11/79	Salt River @ City of Mesa	13,000			50,000		137,000	194,000	375,000	13
1979	Salt River @ I-10				47,000	87,000	130,000	173,000		22
7/80	Salt River @ I-10				47,000	87,000	130,000	176,000		23
7/80	Salt River @ I-10				92,000	140,000	160,000	200,000		23
02/80	Salt River @ Mill Ave. Bridge	13,300			47,000		130,000	178,500	368,000	12
06/01/84	Salt River @ Mill Ave. Bridge	13,260			47,000		130,000	178,500	368,000	14
5/82	Salt River @ Tempe Bridge			40,000	93,000		160,000	215,000	330,000	16
03/16/82	Santa Cruz @ Congress St.	2,222			11,500		23,000	30,000	72,000	7
12/15/82	Santa Cruz @ Rillito Confluence	2,282			11,500		23,000	30,000	72,000	8
01/79	Santa Cruz @ Tucson, Az	2,222	5,160	8,700	11,300	14,800	17,500	20,300		15
09/78	Santa Cruz @ Tucson, Az	2,222	5,240	9,050	12,000	16,100	19,400	22,600	31,300	4
03/16/81	Verde River @ Clarkdale	3,272			22,362		52,015	69,699	124,971	9
06/01/82	Verde River @ Clarkdale	3,272			22,362		52,015	69,699	124,971	10
2/18/77	Verde River @ I-17	3,892			34,000		70,000	90,000	142,000	19
2/18/77	Verde River @ I-17	3,892			38,000		77,000	96,000	154,000	20
5/24/86	Verde River @ I-17	4,220						106,200		21
08/19/85	Verde River @ U.S. 89 Alt.	3,275			27,000		54,000	68,000	106,000	11
08/76	Verde River above Clarkdale, Az	3,218			27,000		54,000	68,000	106,000	17,18
08/76	Verde River below Cottonwood, Az	3,272			27,000		54,000	68,000	106,000	17,18
01/79	Verde River near Clarkdale, Az	3,150	5,140	13,600	22,700	3,900	55,400	75,900		15
09/78	Verde River near Clarkdale, Az	3,150	4,600	11,400	18,100	30,100	41,500	56,500	103,000	4

NOTE:

* Flood frequency projections for future conditions with the project recommended by the Army Corps of Engineers.

SOURCE REFERENCES

- (1) U.S. Army Corps of Engineers, Los Angeles District, Gila River Basin, Phoenix, Arizona and Vicinity (Including New River), Hydrology, Part 2, Design Memorandum No. 2, 1982.
- (2) U.S. Army Corps of Engineers, Los Angeles District, Gila River Basin, New River and Phoenix City Streams, Arizona, Design Memorandum No. 2, Hydrology, Part 1, October 1973.
- (3) U.S. Army Corps of Engineers, Los Angeles District, Tucson Urban Study Working Papers, Draft, Hydrology Appendix, April 1982.
- (4) Arizona Department of Transportation, ADOT-R5-15-(121), Methods for Estimating the Magnitude and Frequency of Floods in Arizona, by R. H. Roeske, September 1978.

FLOOD INSURANCE STUDIES:

- (5) City of Glendale, Arizona, Maricopa County, September 1981.
- (6) City of Avondale, Arizona, Maricopa County, August 1982.
- (7) City of Tucson, Arizona, Pima County, March 16, 1982.
- (8) Pima County, Arizona, Unincorporated Areas, December 15, 1982.
- (9) Town of Cottonwood, Arizona, Yavapai County, March 16, 1981.
- (10) Town of Clarkdale, Arizona, Yavapai County, June 1, 1982.
- (11) Yavapai County, Arizona, Unincorporated Areas, August 19, 1985.
- (12) City of Tempe, Arizona, Maricopa County, February 1980.
- (13) City of Mesa, Arizona, Maricopa County, November 1979.
- (14) City of Phoenix, Arizona, Maricopa County, June 1, 1984.

- (15) U.S. Department of the Interior, Geological Survey, Statistical Summaries of Arizona Streamflow Data, by T.W. Anderson & Natalie White, Water Resources Investigations 79-5, January 1979.
- (16) U.S. Army Corps of Engineers, Los Angeles District, Gila River and Tributaries, Central Arizona Water Control Study, Hydrology, May 1982.
- (17) U.S. Army Corps of Engineers, Los Angeles District, Flood Plain Information, Verde River and Tributaries, Vicinity of Clarkdale and Cottonwood, Yavapai County, Arizona, August 1976.

- (18) U.S. Army Corps of Engineers, Los Angeles District,
Hydrology for Flood Plain Information Studies, Verde River
and Tributaries, Yavapai and Coconino Counties, Arizona, May
11, 1976.
- (19) U.S. Army Corps of Engineers, Los Angeles District,
Hydrology for Flood Plain Information Studies, Verde River
and Wet Beaver Creek, Yavapai County, Arizona, February
1980.
- (20) U.S. Army Corps of Engineers, Los Angeles District,
Hydrology for Flood Plain Information Studies, Verde River
and Wet Beaver Creek, Yavapai County, Arizona, (Revisions
for the '77 floods).
- (21) Arizona Department of Transportation, Structures Section,
Drainage, Scour Calculations for I-17 Bridge Over the Verde
River, Project No. IR-17-2(97)PE, June 24, 1986.
- (22) Howard, Needles, Tammen, Bergendoff, Johannessen and Girand,
Preliminary Engineering Study - 19th Avenue Bridge Over Salt
River, Phoenix, Arizona, 1979.
- (23) Dames and Moore, Report, Phases C and D, Final Design,
Permanent Protection Against Scour, Salt River Bridge -
Interstate 10, For Arizona Department of Transportation,
Contract No. 79-9, July 1980.

ANALYTICAL FREQUENCY ANALYSIS OF PEAK FLOWS

SANTA CRUZ RIVER AT TUCSON, AZ

USGS GAGE NO. 09482500, DA = 2222 SQ. MI.

Analyzed Data

Ordered Data

Final Peak Discharge vs Frequency Estimate

Water Year	Peak Discharge (cfs)	Rank	Water Year	Peak Discharge (cfs)	Median Plotting Positions	Exceedence Probability	Computed Discharge (cfs)	Expected Probability Discharge (cfs)	Confidence Limits	
									.05 Limit	.95 Limit
1906	9634	1	1978	23700	.0099	.002	30900	32800	43100	23800
1907	8145	2	1908	16607	.0241	.005	26300	27600	35900	20600
1908	16607	3	1961	16600	.0384	.010	23000	23900	30700	18300
1909	4277	4	1968	16100	.0526	.020	19700	20300	25800	15900
1910	3075	5	1915	15000	.0668	.040	16500	16900	21100	13500
1913	808	6	1964	13000	.0810	.100	12400	12600	15300	10400
1914	776	7	1926	11400	.0952	.200	9350	9420	11200	8000
1915	15000	8	1940	11300	.1094	.500	5230	5230	6050	4540
1916	5000	9	1955	10900	.1236	.800	2780	2750	3240	2320
1917	7500	10	1945	10800	.1378	.900	1950	1920	2330	1570
1918	4900	11	1929	10400	.1520	.950	1440	1400	1770	1120
1919	1950	12	1935	10300	.1662	.990	792	741	1030	565
1920	1950	13	1906	9634	.1804					
1921	4000	14	1954	9570	.1946					
1922	2000	15	1950	9490	.2088					
1923	1900	16	1931	9200	.2230					
1924	2050	17	1938	9000	.2372					
1925	3400	18	1969	8710	.2514					
1926	11400	19	1970	8530	.2656					
1927	1950	20	1907	8145	.2798					
1928	1600	21	1939	8000	.2940					
1929	10400	22	1971	8000	.3082					
1930	1770	23	1974	7930	.3224					
1931	9200	24	1917	7500	.3366					
1932	4200	25	1976	7100	.3509					
1933	6100	26	1944	6530	.3651					
1934	6000	27	1958	6360	.3793					
1935	10300	28	1969	6140	.3935					
1936	5400	29	1933	6100	.4077					
1937	3260	30	1934	6000	.4219					
1938	9000	31	1953	5900	.4361					
1939	8000	32	1967	5860	.4503					
1940	11300	33	1966	5500	.4645					
1941	2490	34	1936	5400	.4787					
1942	1670	35	1951	5020	.4929					
1943	4510	36	1916	5000	.5071					
1944	6530	37	1962	4980	.5213					
1945	10800	38	1918	4900	.5355					
1946	4260	39	1973	4710	.5497					
1947	2960	40	1919	4700	.5639					
1948	3860	41	1963	4670	.5781					
1949	3800	42	1943	4510	.5923					
1950	9490	43	1959	4420	.6065					
1951	5020	44	1909	4277	.6207					
1952	3820	45	1946	4260	.6349					
1953	5900	46	1932	4200	.6491					
1954	9570	47	1921	4000	.6634					
1955	10900	48	1948	3860	.6776					
1956	2610	49	1952	3820	.6918					
1957	3050	50	1949	3800	.7060					
1958	6350	51	1972	3470	.7202					
1959	4420	52	1925	3400	.7344					
1960	6140	53	1937	3260	.7486					
1961	16600	54	1910	3075	.7628					
1962	4980	55	1957	3050	.7770					
1963	4670	56	1947	2960	.7912					
1964	13000	57	1956	2610	.8054					
1965	1190	58	1941	2490	.8196					
1966	5500	59	1975	2480	.8338					
1967	5860	60	1924	2050	.8480					
1968	16100	61	1922	2000	.8622					
1969	8710	62	1927	1950	.8764					
1970	8530	63	1920	1050	.8906					
1971	8000	64	1923	1900	.9048					
1972	3470	65	1930	1770	.9190					
1973	4710	66	1942	1670	.9332					
1974	7930	67	1928	1600	.9474					
1975	2480	68	1965	1190	.9616					
1976	7100	69	1913	808	.9759					
1978	23700	70	1914	776	.9901					

FINAL STATISTICS BASED ON 70 YEARS

MEAN LOGARITHM	3.7024
STANDARD DEVIATION	.3147
COMPUTED SKEW	-.3891
GENERALIZED SKEW	-.2000
ADOPTED SKEW	-.3135

(COE, TUCSON URBAN STUDY)

FIGURE L2

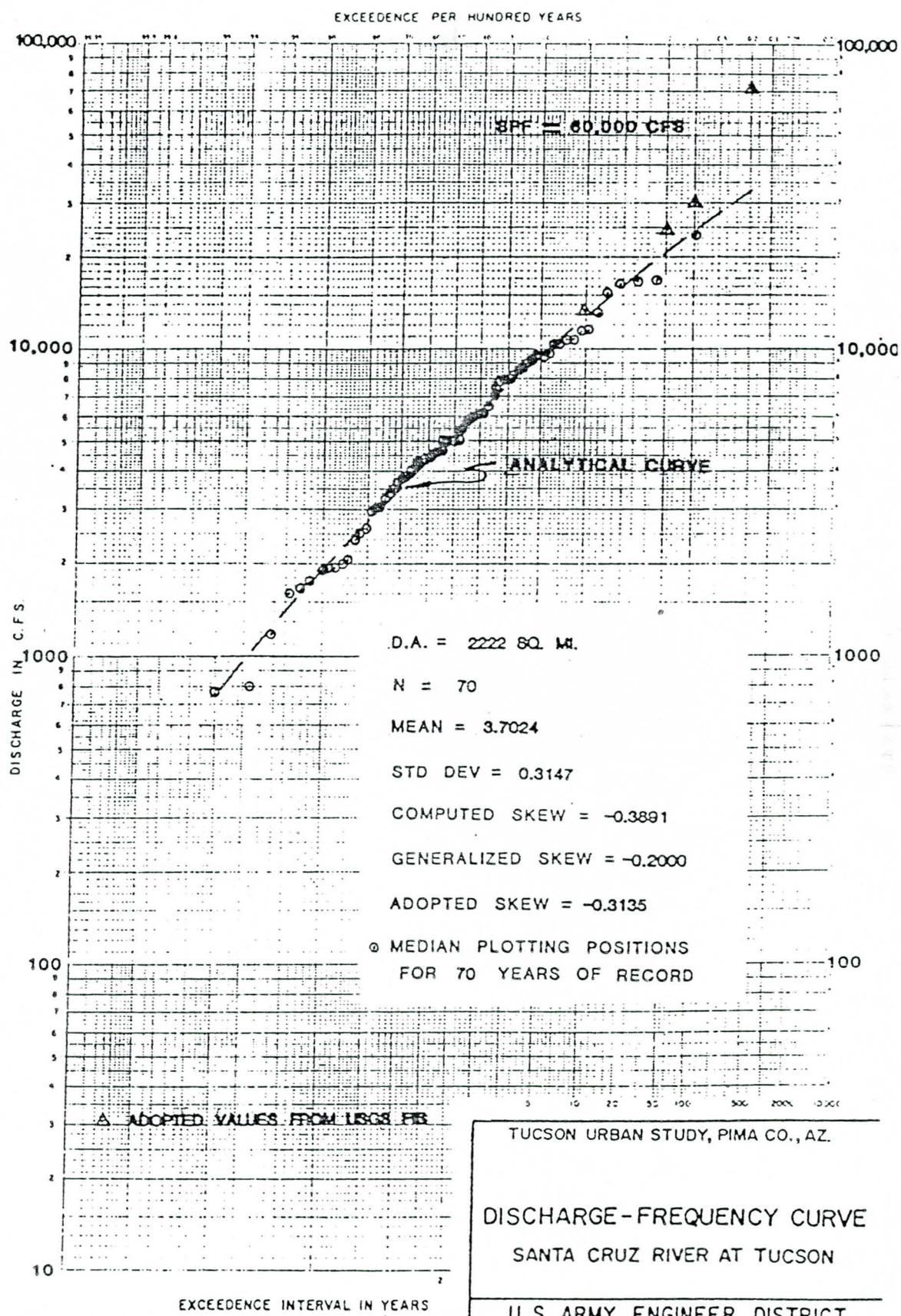


FIGURE L3

ANALYTICAL FREQUENCY ANALYSIS OF PEAK FLOWS

RILLITO CREEK NEAR TUCSON, AZ

USGS GAGE NO. 09486000, DA = 918 SQ. MI.

Analyzed Data			Ordered Data			Final Peak Discharge vs Frequency Estimate				
Water Year	Peak Discharge (cfs)	Rank	Water Year	Peak Discharge (cfs)	Median Plotting Positions	Exceedance Probability	Computed Discharge (cfs)	Expected Probability Discharge (cfs)	Confidence .05 Limit (cfs)	Limits .95 Limit (cfs)
1915	17000.	1	1929	24000.	.0109	.002	32600.	35100.	47200.	24500.
1916	7620.	2	1915	17000.	.0264	.005	27500.	29100.	38800.	21100.
1917	10000.	3	1921	16000.	.0419	.010	23800.	24900.	32900.	18500.
1918	5300.	4	1935	13400.	.0575	.020	20200.	20900.	27200.	16000.
1919	9250.	5	1940	13200.	.0730	.040	16700.	17200.	22000.	13500.
1920	7800.	6	1966	12400.	.0885	.100	12400.	12600.	15600.	10200.
1921	16000.	7	1917	10000.	.1040	.200	9170.	9250.	11200.	7720.
1922	3250.	8	1941	9900.	.1196	.500	4980.	4980.	5830.	4250.
1923	4000.	9	1939	9710.	.1351	.800	2560.	2530.	3030.	2100.
1924	1980.	10	1951	9500.	.1506	.900	1770.	1730.	2150.	1390.
1925	3500.	11	1950	9490.	.1661	.950	1290.	1250.	1610.	973.
1926	1750.	12	1964	9420.	.1817	.990	692.	642.	923.	477.
1927	2200.	13	1976	9400.	.1972					
1928	4500.	14	1971	9290.	.2127					
1929	24000.	15	1919	9250.	.2283					
1930	4600.	16	1958	8930.	.2438					
1931	7200.	17	1955	8070.	.2593					
1932	7200.	18	1920	7800.	.2748					
1933	4400.	19	1968	7740.	.2904					
1934	3000.	20	1959	7710.	.3059					
1935	13400.	21	1954	7680.	.3214					
1936	4500.	22	1947	7660.	.3370					
1937	2980.	23	1963	7640.	.3525					
1938	3000.	24	1916	7620.	.3680					
1939	9710.	25	1978	7500.	.3835					
1940	13200.	26	1931	7200.	.3991					
1941	9900.	27	1932	7200.	.4146					
1942	1600.	28	1945	7000.	.4301					
1943	3850.	29	1970	7000.	.4457					
1944	4100.	30	1953	5470.	.4612					
1945	7000.	31	1918	5300.	.4767					
1946	4160.	32	1973	5160.	.4922					
1947	7660.	33	1930	4600.	.5078					
1948	779.	34	1957	4500.	.5233					
1949	1640.	35	1936	4500.	.5388					
1950	9490.	36	1928	4500.	.5543					
1951	9500.	37	1933	4400.	.5699					
1952	1630.	38	1946	4160.	.5854					
1953	5470.	39	1961	4140.	.6009					
1954	7680.	40	1944	4100.	.6165					
1955	8070.	41	1923	4000.	.6320					
1956	2050.	42	1943	3850.	.6475					
1957	4500.	43	1960	3610.	.6630					
1958	8930.	44	1925	3500.	.6786					
1959	7710.	45	1922	3250.	.6941					
1960	3610.	46	1967	3100.	.7096					
1961	4140.	47	1934	3000.	.7252					
1962	2690.	48	1938	3000.	.7407					
1963	7640.	49	1937	2980.	.7562					
1964	9420.	50	1962	2590.	.7717					
1965	754.	51	1975	2270.	.7873					
1966	12400.	52	1969	2220.	.8028					
1967	3100.	53	1927	2200.	.8183					
1968	7740.	54	1956	2050.	.8339					
1969	2220.	55	1924	1980.	.8494					
1970	7000.	56	1972	1820.	.8649					
1971	9290.	57	1926	1750.	.8804					
1972	1820.	58	1949	1640.	.8960					
1973	5160.	59	1952	1630.	.9115					
1974	1440.	60	1942	1600.	.9270					
1975	2270.	61	1974	1440.	.9425					
1976	9400.	62	1977	1200.	.9581					
1977	1200.	63	1948	779.	.9736					
1978	7500.	64	1965	754.	.9891					

FINAL STATISTICS BASED ON 64 YEARS

MEAN LOGARITHM	3.6805
STANDARD DEVIATION	.3306
COMPUTED SKEW	-.3877
GENERALIZED SKEW	-.2000
ADOPTED SKEW	-.2976

(COE, TUCSON URBAN STUDY)

FIGURE L4

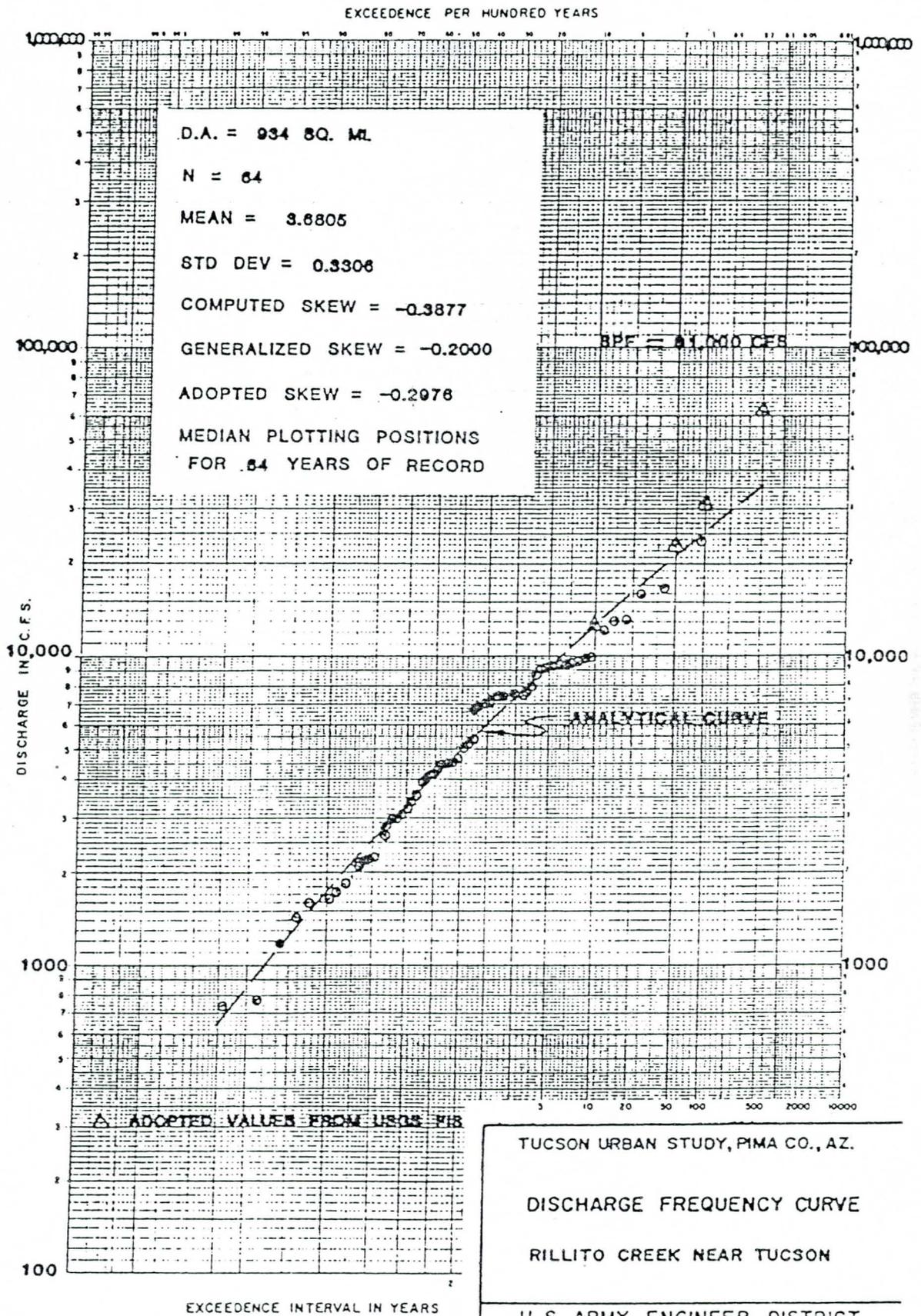
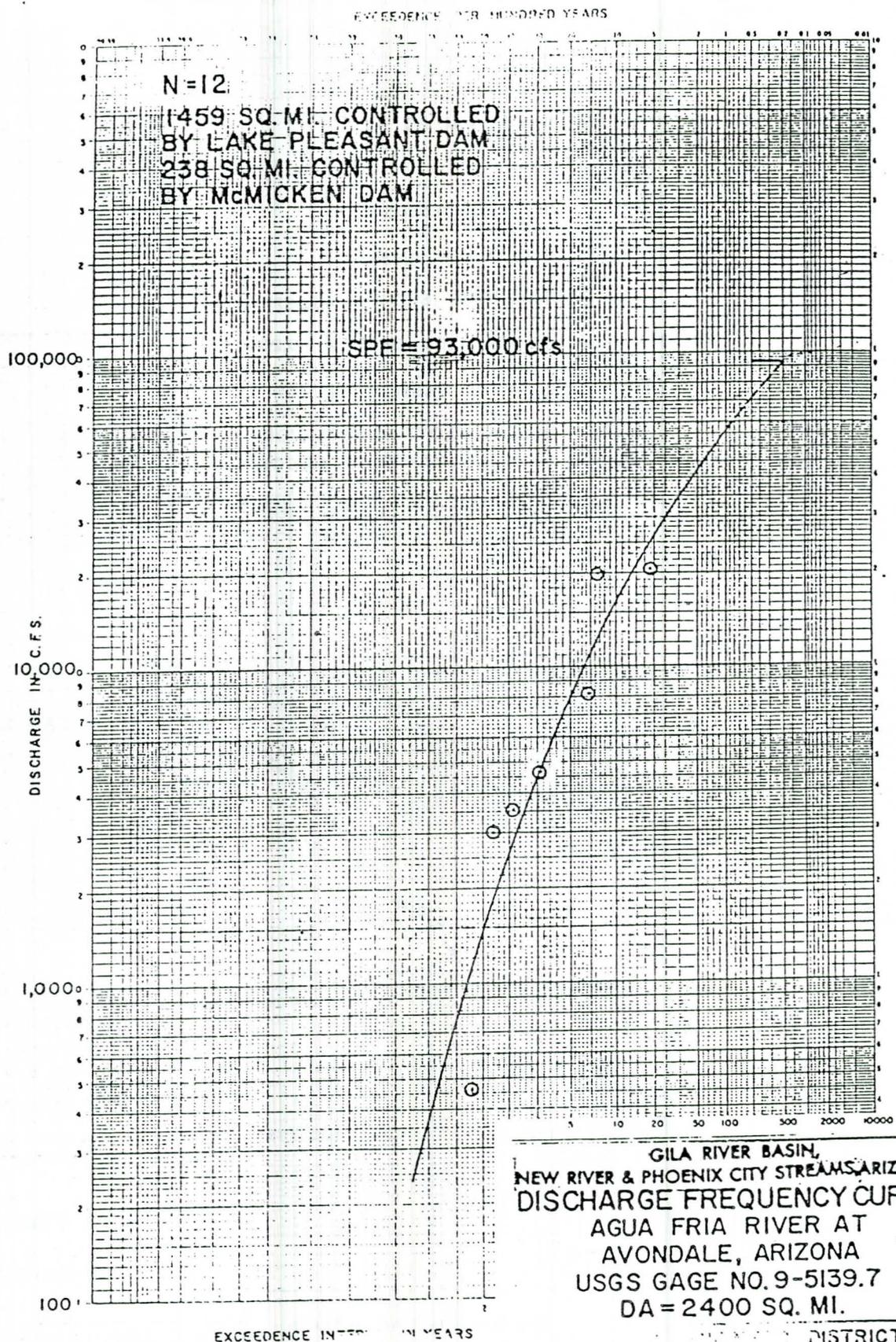


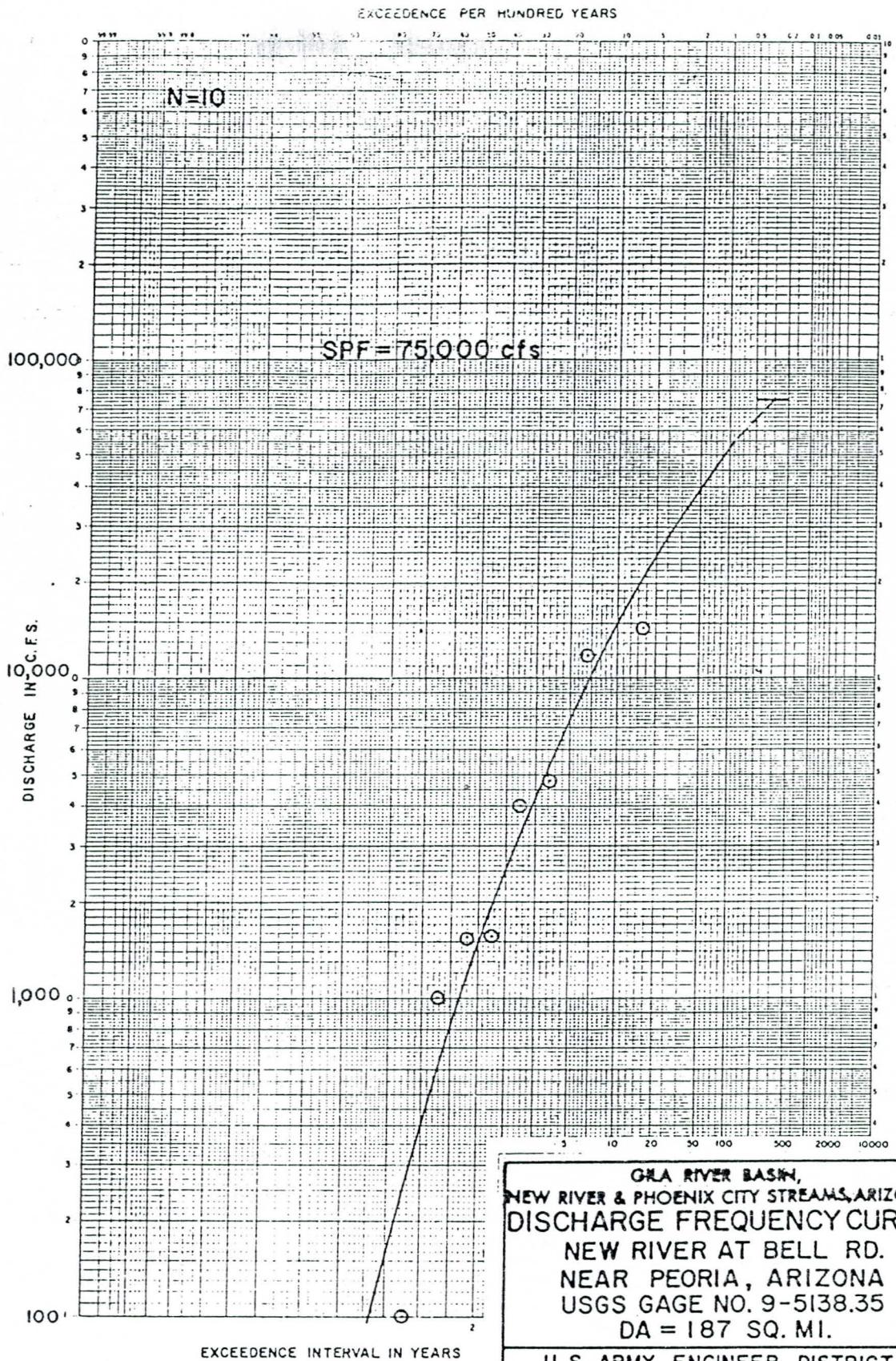
FIGURE L5



GILA RIVER BASIN,
 NEW RIVER & PHOENIX CITY STREAMS, ARIZONA
 DISCHARGE FREQUENCY CURVE
 AGUA FRIA RIVER AT
 AVONDALE, ARIZONA
 USGS GAGE NO. 9-5139.7
 DA = 2400 SQ. MI.

DISTRICT
 ENGINEERS
 TO ACCOMPANY DESIGN MEMO NO. 2.

FIGURE L6



**GILA RIVER BASIN,
 NEW RIVER & PHOENIX CITY STREAMS, ARIZONA
 DISCHARGE FREQUENCY CURVE
 NEW RIVER AT BELL RD.
 NEAR PEORIA, ARIZONA
 USGS GAGE NO. 9-5138.35
 DA = 187 SQ. MI.**

U. S. ARMY ENGINEER DISTRICT
 LOS ANGELES, CORPS OF ENGINEERS
 TO ACCOMPANY DESIGN MEMO NO. 2

FIGURE L7

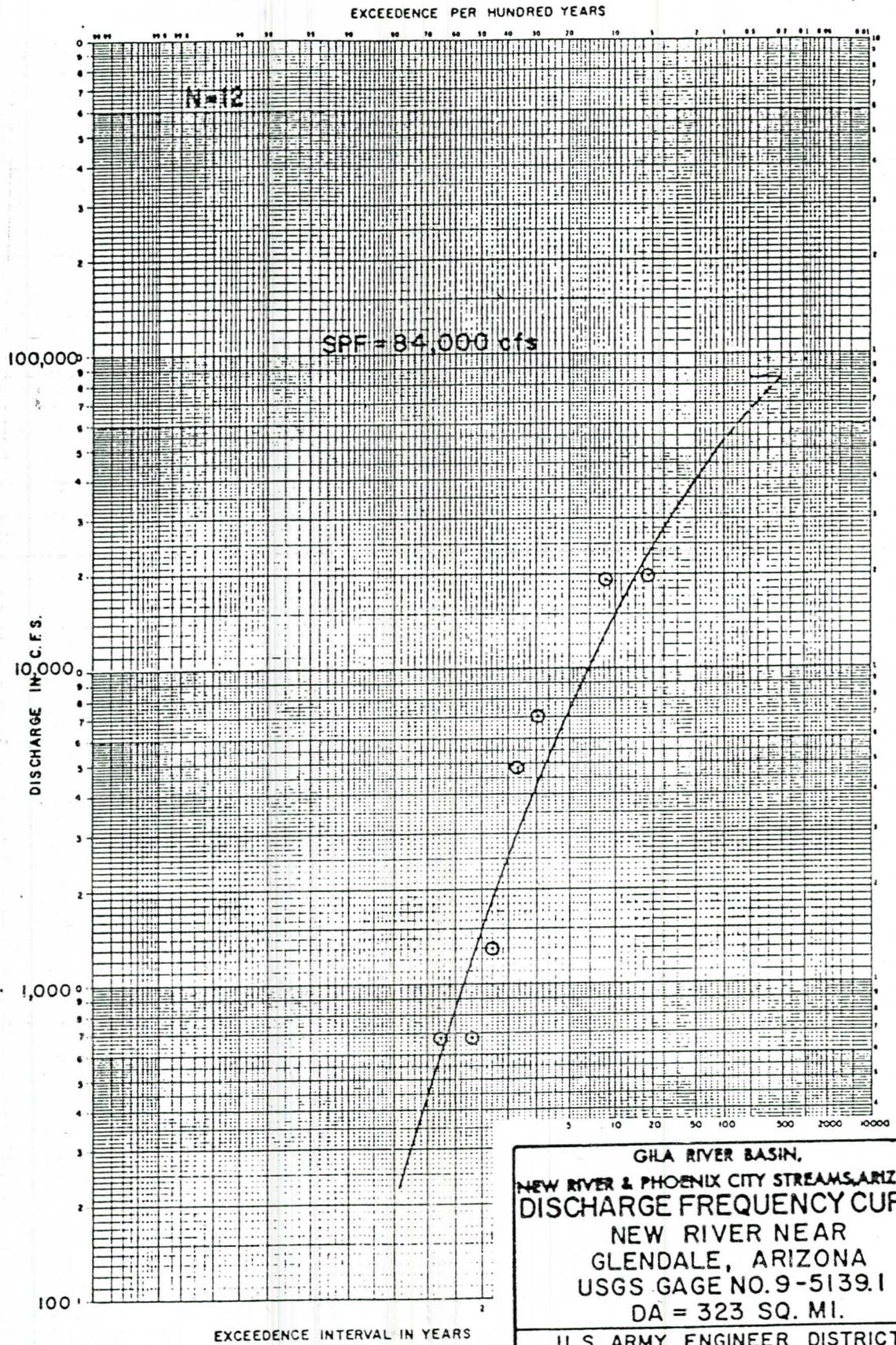
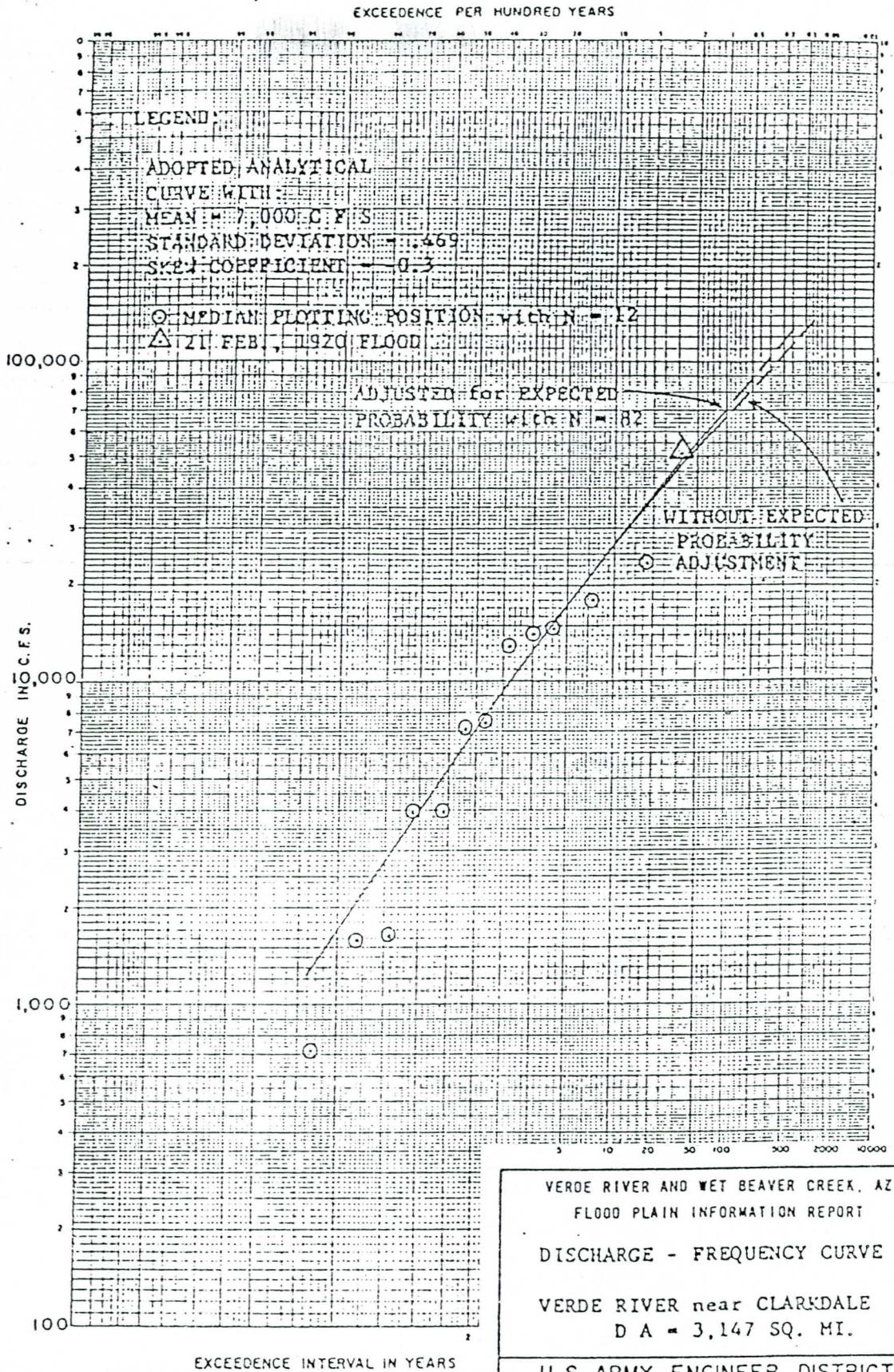


FIGURE L8



VERDE RIVER AND WET BEAVER CREEK, AZ
 FLOOD PLAIN INFORMATION REPORT

DISCHARGE - FREQUENCY CURVE

VERDE RIVER near CLARKDALE
 D A = 3,147 SQ. MI.

U. S. ARMY ENGINEER DISTRICT
 LOS ANGELES, CORPS OF ENGINEERS
 TO ACCOMPANY REPORT DATED:

FIGURE L9

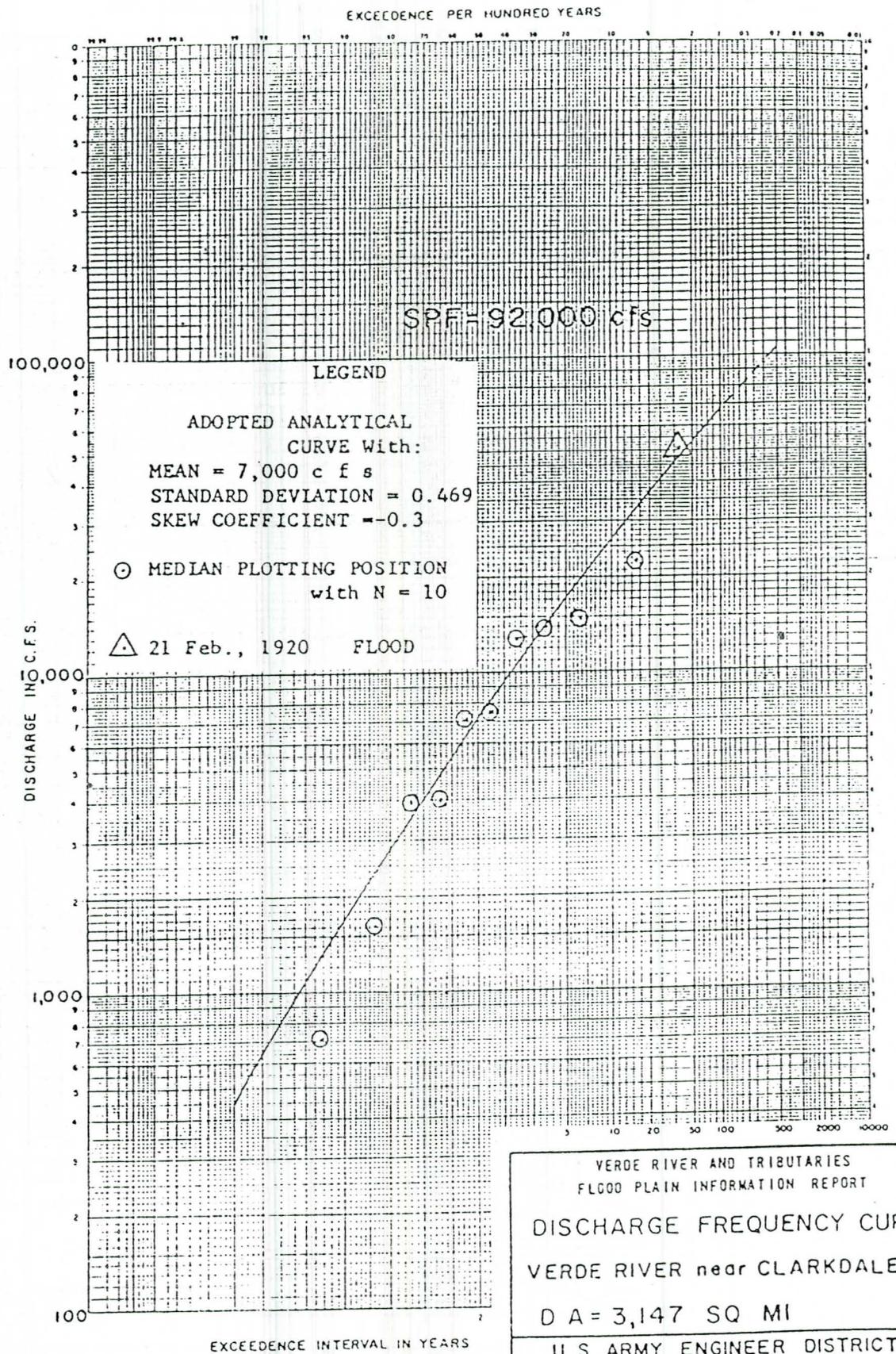
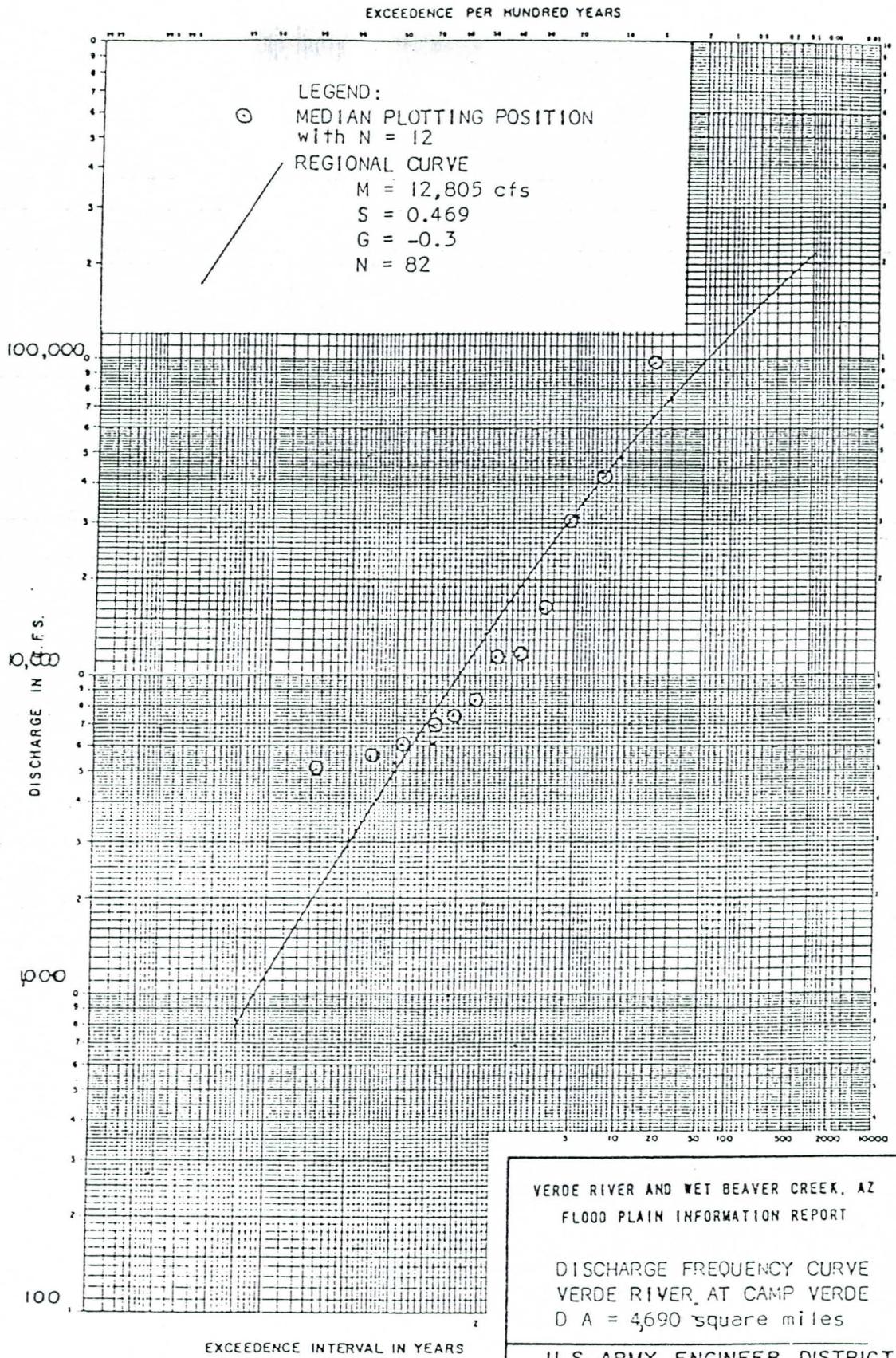


FIGURE L10



VERDE RIVER AND WET BEAVER CREEK, AZ
 FLOOD PLAIN INFORMATION REPORT

DISCHARGE FREQUENCY CURVE
 VERDE RIVER, AT CAMP VERDE
 D A = 4690 square miles

U. S. ARMY ENGINEER DISTRICT
 LOS ANGELES, CORPS OF ENGINEERS
 TO ACCOMPANY REPORT DATED

FIGURE L11

REFERENCES TO APPENDIX I

- Army Corps of Engineers, Los Angeles District, Flood Damage Report on Flood of December 1965 - January 1966, Salt and Gila Rivers, Granite Reef Dam to Gillespie Dam, Arizona, April 1966.
- Army Corps of Engineers, Los Angeles District, Flood Damage Report on Storm and Floods on Santa Cruz, Gila and San Pedro Rivers, Arizona, 6-10 October 1977, September 1978.
- Army Corps of Engineers, Los Angeles District, Flood Damage Report, 28 February - 6 March 1978 on the Storm and Floods in Maricopa County, Arizona, February 1979.
- Army Corps of Engineers, Los Angeles District, Flood Damage Report, Phoenix Metropolitan Area, December 1978 Flood, November 1969.
- Army Corps of Engineers, Los Angeles District, Flood Damage Survey, Phoenix, Arizona, February 1980, April 1981.
- Army Corps of Engineers, Los Angeles District, Flood Plain Information, Verde River and Tributaries, Vicinity of Clarkdale and Cottonwood, Yavapai County, Arizona, August 1976.
- Army Corps of Engineers, Los Angeles District, Gila River and Tributaries, Central Arizona Water Control Study, Hydrology, May 1982.
- Army Corps of Engineers, Los Angeles District, Gila River Basin, New River and Phoenix City Streams, Arizona, Design Memorandum No. 2, Hydrology Part 1, October 1973.
- Army Corps of Engineers, Los Angeles District, Gila River Basin, Phoenix, Arizona and Vicinity (including New River), Hydrology Part 2, Design Memorandum No. 2, 1982.
- Army Corps of Engineers, Los Angeles District, Hydrology for Flood Plain Information Studies, Verde River and Tributaries, Yavapai and Coconino Counties, Arizona, May 11, 1976.
- Army Corps of Engineers, Los Angeles District, Hydrology for Flood Plain Information Studies, Verde River and Wet Beaver Creek, Yavapai County, Arizona, February 1980.
- Army Corps of Engineers, Los Angeles District, Hydrology for Flood Plain Information Studies, Verde River and Wet Beaver Creek, Yavapai County, Arizona, (Revisions for the 1977 floods.)

- Army Corps of Engineers, Los Angeles District, Phoenix Flood Damage Survey, February 1980.
- Army Corps of Engineers, Los Angeles District, Survey Report and Environmental Assessment, Rillito River and Associated Streams, Tucson, Arizona, May 1986, Revised February 13, 1987.
- Army Corps of Engineers, Los Angeles District, Tucson Urban Study Working Papers, Hydrology Appendix, April 1982.
- Army Corps of Engineers, Los Angeles District, Tucson Urban Study, Final Report, April 1985.
- Department of Agriculture, Soil Conservation Service, General Soil Map, Pinal County, Arizona, 1:500,000, March 1971.
- Department of Agriculture, Soil Conservation Service, General Soil Map, Santa Cruz County, Arizona, 1:250,000, July 1971.
- Department of Agriculture, Soil Conservation Service, General Soil Map, Cochise County, Arizona, 1:500,000, October 1971.
- Department of Agriculture, Soil Conservation Service, General Soil Map, Yavapai County, Arizona, 1:500,000, Revised April 1, 1972.
- Department of Agriculture, Soil Conservation Service, General Soil Map, Coconino County, Arizona, 1:633,600, Revised May 1972.
- Department of Agriculture, Soil Conservation Service, General Soil Map, Gila County, Arizona, 1:500,000, July 1973.
- Department of Agriculture, Soil Conservation Service, General Soil Map, Maricopa County, Arizona, 1:500,000, November 1973.
- Department of Agriculture, Soil Conservation Service, General Soil Map, Pima County, Arizona, 1:500,000, February 1974.
- Department of Commerce, National Oceanic and Atmospheric Administration, Report on the Arizona Floods of December 16-20, 1978, Western Regional Headquarters, National Weather Service, Salt Lake City, Utah, May 18, 1979.
- Department of the Interior, Geological Survey, Compilation of Records of Surface Waters of the United States through September 1950, Geological Survey Water-Supply Paper 1313, Part 9, Colorado River Basin.
- Department of the Interior, Geological Survey, Floods of October 1977 in Southern Arizona and March 1978 to Central Arizona, Geological Survey Water-Supply Paper 2223.

Department of the Interior, Geological Survey, Floods of October 1977 in Southern Arizona and March 1978 in Central Arizona, Open-file Report 82-687.

Department of the Interior, Geological Survey, Floods of November 1965 to January 1966 in the Gila River Basin, Arizona and New Mexico, and Adjacent Basins in Arizona, by B.N. Aldridge, Geological Survey Water-Supply paper 1850-c, (Washington, D.C.: Government Printing Office, 1970).

Department of the Interior, Geological Survey, Geologic Map of the United States, (Exclusive of Alaska and Hawaii), by Philip B. King, Helen M. Beikman and Gertrude J. Edmonston, 1:2,500,000, 1974.

Department of the Interior, Geological Survey, Magnitude and Frequency of Floods in the United States, Part 9. Somers, Geological Survey Water-Supply Paper 1683, (Washington, D.C.: Government Printing Office, 1966).

Department of the Interior, Geological Survey, Statistical Summaries of Arizona Streamflow Data, by T.W. Anderson & Natalie White, Water Resources Investigations 79-5, January 1979.

Department of the Interior, Geological Survey, Streamflow in the Upper Santa Cruz River Basin, Santa Cruz and Pima Counties, Arizona, by Alberto Condes De La Torre, Water Resources of the Tucson Basin, Geological Survey Water-Supply Paper 1939-A, (Washington, D.C.: Government Printing Office, 1970).

Department of the Interior, Geological Survey, Surface Water Records of Arizona, 1962, 1963, and 1964,

Department of the Interior, Geological Survey, Surface Water Supply of the United States, Geological Survey Water-Supply Paper 1926, Part 9, Colorado River Basin, Vol. 3, 1961-1965. Also Paper 1713, Part 9, Colorado River Basin, 1960; Paper 1633, Part 9, Colorado River Basin, 1959; Paper 1283, Part 9, Colorado River Basin, 1953; Paper 859, Part 9, Colorado River Basin, 1938; Paper 1733, Part 9, Colorado River Basin, October 1950-September 1960; Paper 1343, Part 9, Colorado River Basin, 1954.

Department of the Interior, Geological Survey, Water Resources Data for Arizona, Part 1, Surface Water Records, 1965, 1966, 1967, 1968, 1969, 1970, 1971, 1972, 1973, and 1974.

Department of the Interior, Geological Survey, Water Resources Data for Arizona, Water Year 1975, U.S. Geological Survey Water-Data Report AZ-75-1. Also for the years of 1976, 1977, 1978, 1979, 1980, and 1981.

Department of the Interior, Geological Survey, Water Resources Data for Arizona, Water Year 1982, by Natalie D. White, and W.B. Garrett, U.S. Geological Survey Water-Data Report AZ-82-1. Also for the year 1983.

AZ Department of Transportation, ADOT-R5-15-(121), Methods for Estimating the Magnitude and Frequency of Floods in Arizona, by R.H. Roeske, September 1978.

AZ Department of Transportation, Structures Section, Drainage, Scour Calculations for I-17 Bridge Over the Verde River, Project No. IR-17-2(97)PE, June 24, 1986.

Dames and Moore, Report, Phases C and D, Final Design, Permanent Protection Against Scour, Salt River Bridge - Interstate 10, for Arizona Department of Transportation, Contract No. 79-9, July 1980.

Howard, Needles, Tammen, Bergendoff, Johannessen and Girand, Preliminary Engineering Study - 19th Avenue Bridge Over Salt River, Phoenix, Arizona, 1979.

FLOOD INSURANCE STUDIES

City of Glendale, Arizona, Maricopa County, September 1981.
City of Avondale, Arizona, Maricopa County, August 1982.
City of Tucson, Arizona Pima County, March 16, 1982.
Pima County, Arizona, Unincorporated Areas, December 15, 1982.
Town of Cottonwood, Arizona, Yavapai County, March 16, 1981.
Town of Clarkdale, Arizona, Yavapai County, June 1, 1982.
Yavapai County, Arizona Unincorporated Ares, August 19, 1985.
City of Tempe, Arizona, Maricopa County, February 1980.
City of Mesa, Arizona, Maricopa County, November 1979.
City of Phoenix, Arizona, Maricopa County, June 1, 1984.

APPENDIX J. MINING ACTIVITY DATA SET

J.1 Purpose/Objective

As part of the process of formulating a detailed geomorphic database for the study reaches, information was compiled regarding the aerial extent of sand and gravel mining operations in these areas. This data was derived from aerial photographs for the period of time during which the mining activity occurred. The locations of the pit boundaries, operational activities, and changes in the river channel with time were delineated for each given set of photo coverage.

The objective of this data gathering effort was to approximate the volume of material excavated by sand and gravel mining in the various study reaches. Net extraction was estimated from the data set in conjunction with information from operators familiar with these mining activities. The correlation between extraction volume and changes in topographic conditions was then analyzed.

J.2 Sources of Data

The following is a summary of the sources used in compiling the mining activity data set for each study reach:

- A. Agua Fria River - Camelback Road to Buckeye Road
Phoenix, Arizona Aerial Photos
Landis Aerial Surveys
Panels M-12 and N-12
Scale: 1"=1200'
Copyright dates: 1975-1987, inclusive
- B. New River - Peoria Avenue to the Confluence with the Agua Fria River
Phoenix, Arizona Aerial Photos
Landis Aerial Surveys
Panels L-13 and M-13
Scale: 1"=1200'
Copyright dates: 1975-1987, inclusive
- C. Santa Cruz River - I-19 bridge to 3 miles downstream
 1. Pima County Aerial Photos
Cooper Aerial Survey
Scale: 1"=400'
Flight dates: Nov. 8, 1974 Panels 12-11 and 12-12
Apr. 11, 1980 Panels 8-11 and 8-12
 2. Pima County Orthophoto Maps
Cooper Aerial Survey
Scale: 1"=200'
Flight date: July 31, 1984 Panels 22-27, 23-27, 22-28,
23-28, 22-29, & 23-29

3. Tucson, Arizona Aerial Photo
Cooper Aerial Survey
Scale: unknown
Flight date: February 16, 1985
- D. Rillito Creek - I-10 to 3 miles upstream
1. Pima County Aerial Photos
Cooper Aerial Survey
Scale: 1"-400'
Flight dates: Nov. 8, 1974 Panels 10-18 and 11-17
Apr. 11, 1980 Panels 6-18 and 7-17
1985 No Panel Numbers Indicated
 2. Aerial Photos
October 1983 Flood
Scale: 1"=1200'
 3. Pima County Orthophoto Maps
Cooper Aerial Survey.
Scale: 1"=200'
Flight dates: May-Sept. 1985 Panels 21-39, 21-40 &
20-41
- E. Salt River
1. Country Club Drive to Hayden Road
Phoenix, Arizona Aerial Photos
Landis Aerial Surveys
Panels N-18 and N-19
Scale: 1"=1200'
Copyright dates: 1969, 1972, 1973, and 1975-1987,
inclusive
 2. 19th Avenue to 59th Avenue
Phoenix, Arizona Aerial Photos
Landis Aerial Surveys
Panels 0-14 and 0-15
Scale: 1"=1200'
Copyright dates: 1972, 1973, and 1975-1987, inclusive
- F. Verde River
1. 1.5 miles upstream to 1.5 miles downstream of the I-17
bridge
Aerial Photos
Aerial Mapping Company
Flight date: July 19, 1979 Flt. 3(1-7)
Scale: 1"=100'
 2. 2-mile reach near the Dead Horse Ranch Crossing at
Cottonwood
 - a. Aerial Photos
Aerial Mapping Company
Flight date: June 3, 1982 Flt. 3(3-5), 4(2-5)
Scale: 1"=750'

- b. Orthophoto Maps
Kenney Aerial Mapping Inc.
Flight date: February 9, 1987
Scale: 1"=200'

J.3 Acquisition and Reduction of Data

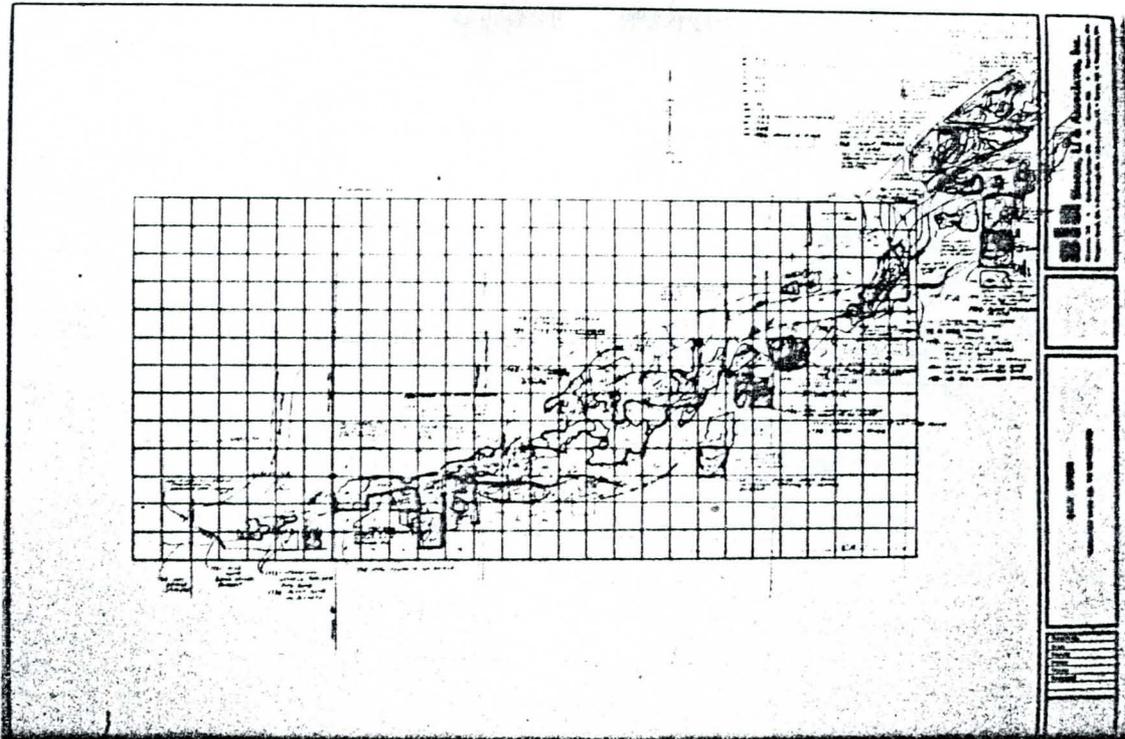
J.3.1 Data Acquisition

The photos used for the study reaches in the Phoenix area (i.e., Salt River, Agua Fria River and New River) were acquired through the Arizona State University Noble Science Library Map Collection. The data used for the Tucson area reaches (i.e., Santa Cruz River and Rillito Creek) were obtained from the Pima County Flood Control District. The photos used for the Verde River study reaches were acquired from HDR Infrastructure and Donohue & Associates, Inc.

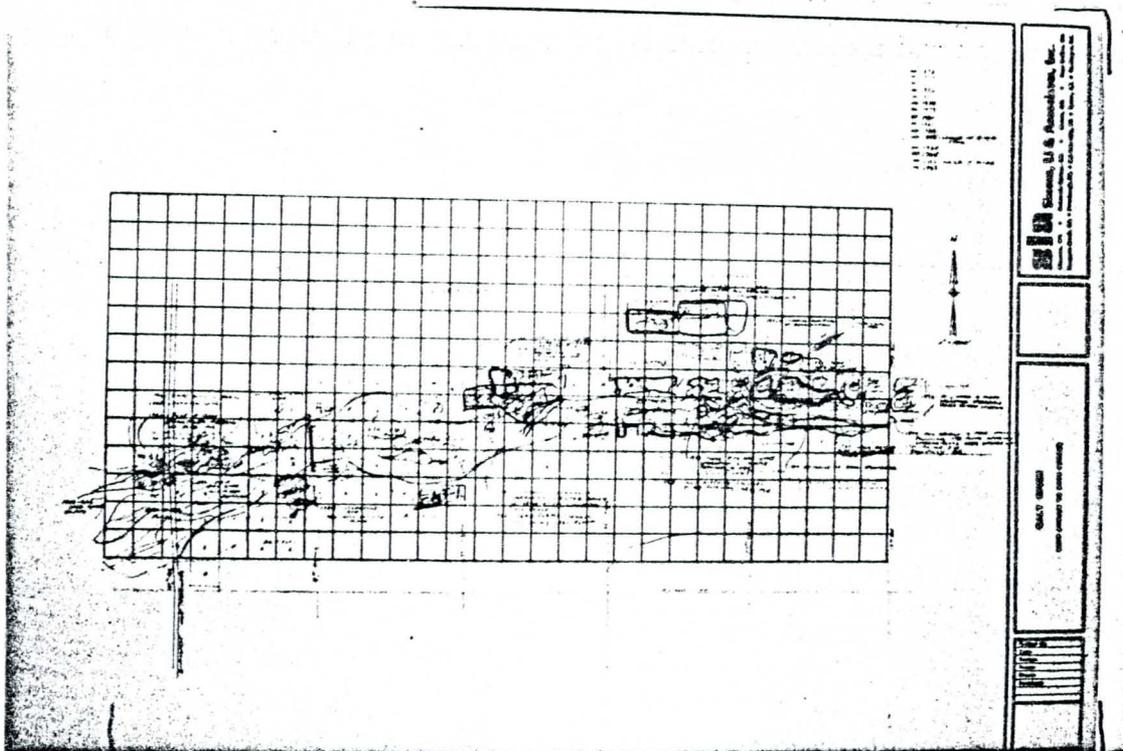
J.3.2 Data Reduction

The procedure used to reduce the available mining activity data began with the preparation of grid overlays with squares 1024 feet on a side at a scale matching the appropriate photo scale. The orientation of the grid over the photo was the same as that used in developing the topographic data set. See Appendix G. Pit boundaries, operational activities, river channel location, and channel improvements were traced from the photo using a different pencil color for each photo year. Where photos of different scales were used for the same reach, scale adjustments were made. The resultant product is a mylar overlay showing the progress of mining activity and channel changes with time. These overlays are included as Plates J.1 to J.8 of this Appendix.

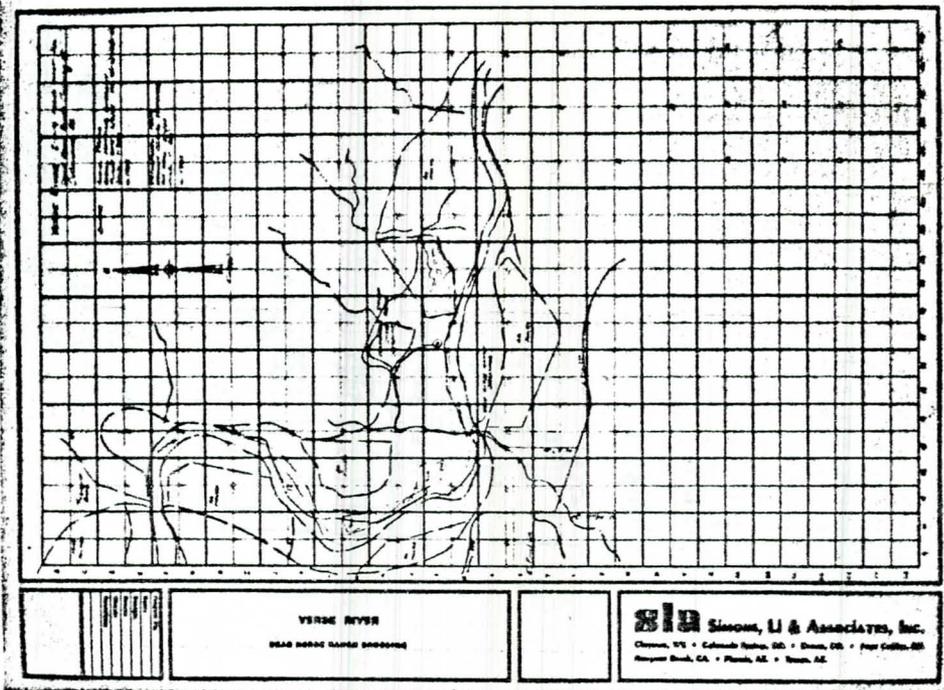
This information was converted to a digital database by compiling a spreadsheet which itemizes the area mined for each grid square for each photo year. With input from the gravel mining operators, these aerial extraction data was converted to volumetric estimates so that an annual extraction volume could be determined. The correlation between the extracted volume of material versus the change in channel topography was then analyzed. Refer to Appendix D for more detailed information.



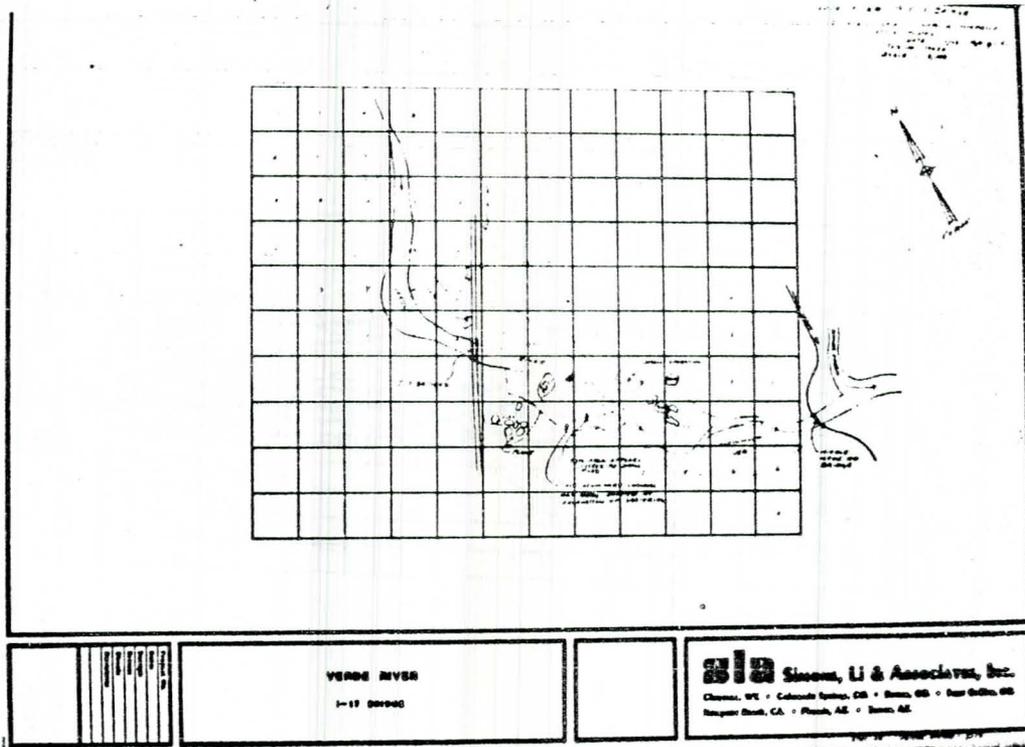
SALT RIVER--HAYDEN ROAD TO COUNTRY CLUB DRIVE
 PLATE J.1



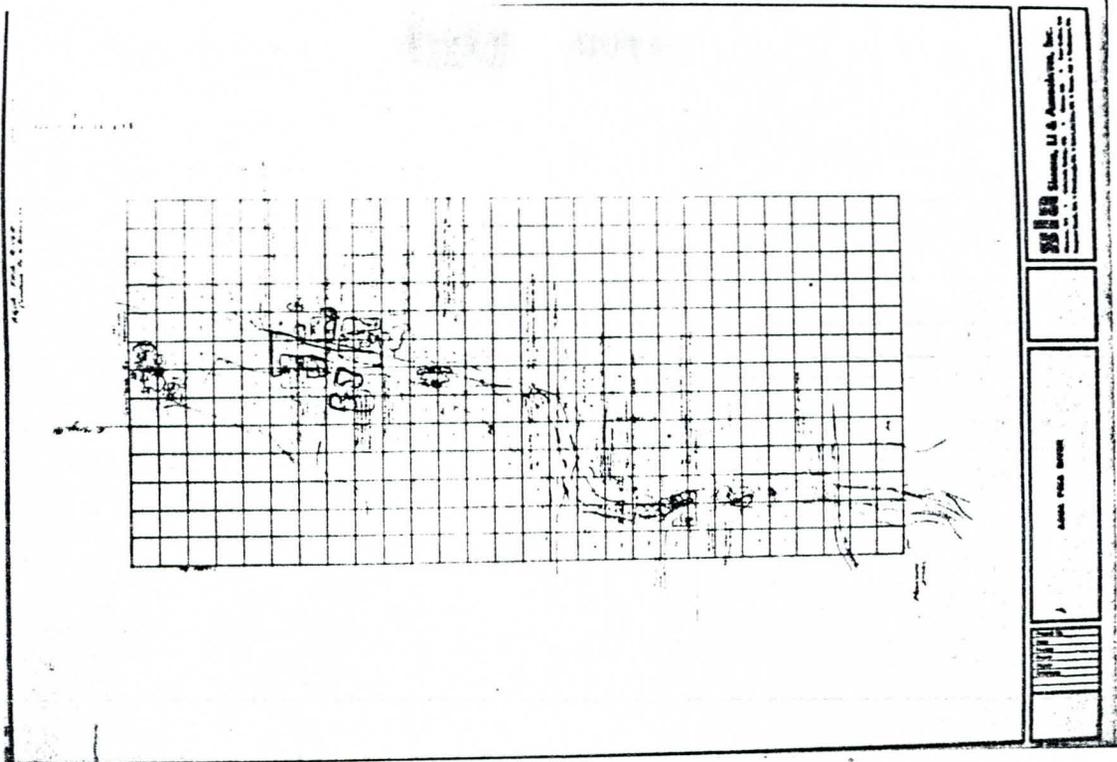
SALT RIVER--59TH AVENUE TO 19TH AVENUE
 PLATE J.2



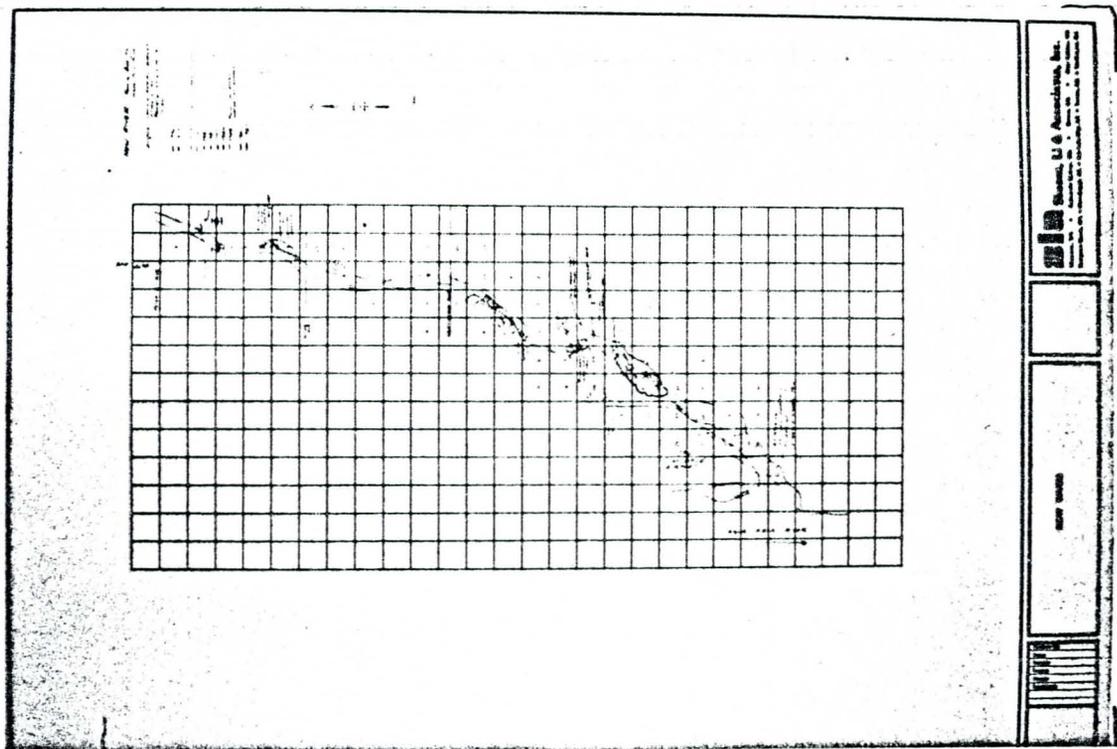
VERDE RIVER AT COTTONWOOD
 PLATE J.3



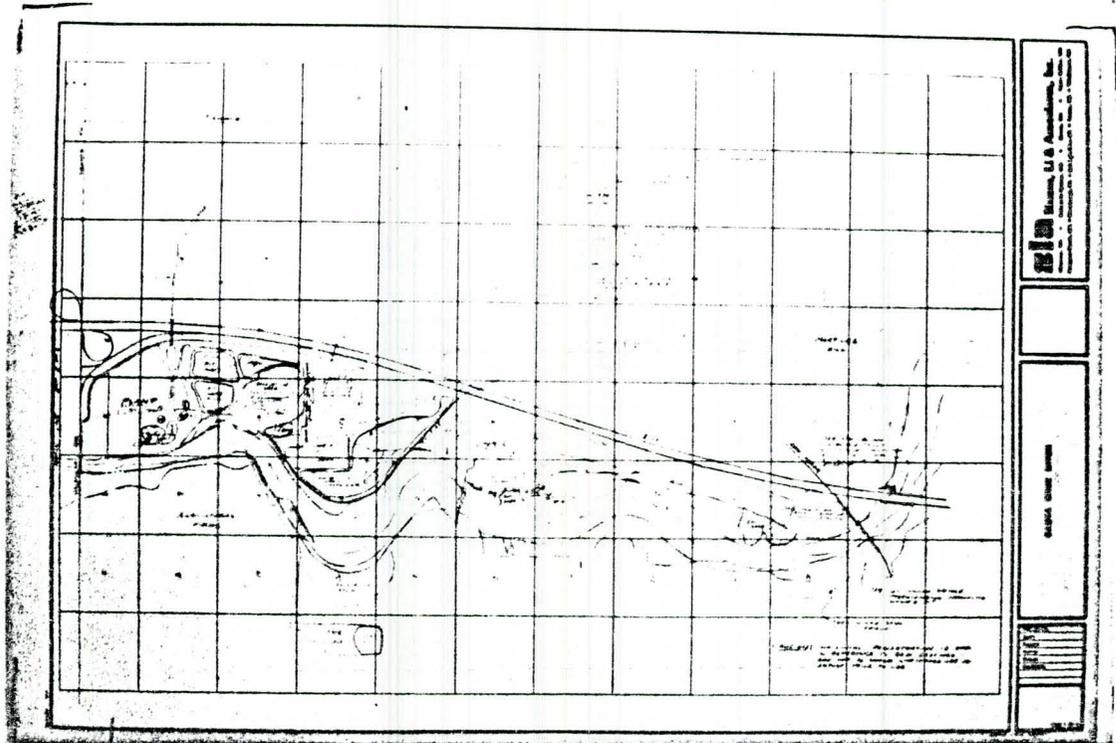
VERDE RIVER AT I-17
 PLATE J.4



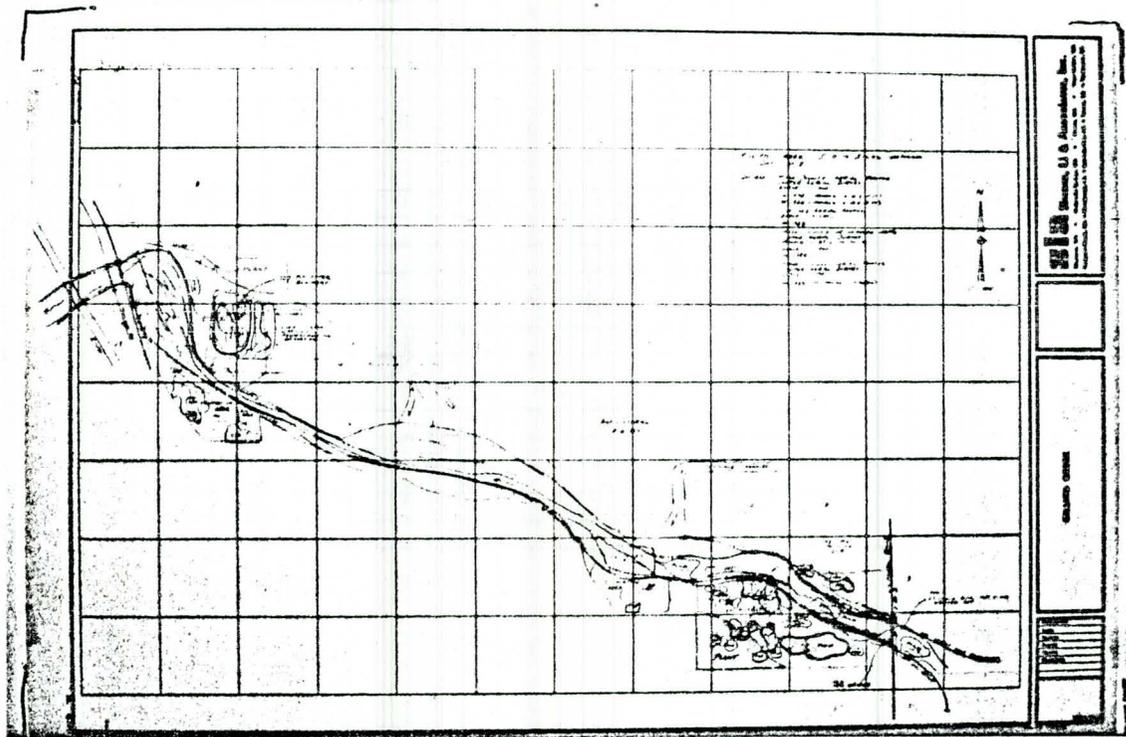
AGUA FRIA RIVER
PLATE J.5



NEW RIVER
PLATE J.6



**SANTA CRUZ RIVER
PLATE J.7**



**RILLITO CREEK
PLATE J.8**