

ARIZONA DEPARTMENT OF TRANSPORTATION

REPORT NUMBER: FHWA/AZ 86/214

APPLICATION OF HEC-6 TO EPHEMERAL RIVERS OF ARIZONA

Prepared by:

D.W. Dust

M.T. Bowers

P.F. Ruff

Center for Advanced Research in Transportation

Arizona State University

Tempe, AZ 85287

January 1986

Prepared for:

Arizona Department of Transportation

206 South 17th Avenue

Phoenix, Arizona 85007

in cooperation with

U.S. Department of Transportation

Federal Highway Administration

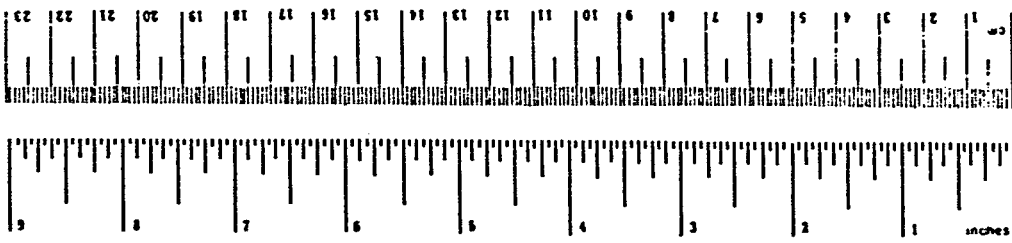
The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Arizona Department of Transportation or the Federal Highways Administration. This 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.	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Application of HEC-6 To Ephemeral Rivers of Arizona, United States		5. Report Date May 1985	6. Performing Organization Code
7. Author(s) Dust, D.W., Bowers, M.T., and Ruff, P.F.		8. Performing Organization Report No.	
9. Performing Organization Name and Address Center for Advanced Research in Transportation Arizona State University, ERC-476 Tempe, Arizona 85287		10. Work Unit No. (TRAIS)	11. Contract or Grant No.
12. Sponsoring Agency Name and Address Arizona Transportation Research Center Arizona Department of Transportation 205 S. 17th Ave. Phoenix, Arizona 85007		13. Type of Report and Period Covered	
15. Supplementary Notes		14. Sponsoring Agency Code	
16. Abstract The U.S. Army Corps of Engineers, computer program HEC-6 - "Scour and Deposition in Rivers and Reservoirs" was applied to three ephemeral rivers of Arizona - Agua Fria River, Salt River, and Rillito Creek. The input data development techniques and results from these three case studies were used to develop general input data development/calibration strategies. The theoretical and numerical bases of HEC-6 were reviewed and documented to clarify and further define the important aspects of the sediment routing portion of the program. The overall result of this study is a document designed to aid "users" in the application of HEC-6 to ephemeral rivers of Arizona.			
17. Key Words stream/river: sediment transport, scour, deposition, computer programs, models; bridge/hydraulic structure design; fluvial geomorphology, alluvial channels.		18. Distribution Statement	
19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price

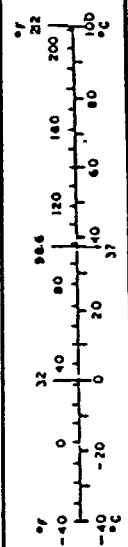
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures			Approximate Conversions from Metric Measures		
Symbol	When You Know	Multiply by	Symbol	When You Know	Multiply by
LENGTH					
in	inches	2.5	mm	millimeters	0.04
ft	feet	30	cm	centimeters	0.4
yd	yards	0.9	m	meters	3.3
mi	miles	1.6	km	kilometers	0.6
AREA					
in ²	square inches	6.5	cm ²	square centimeters	0.16
ft ²	square feet	0.09	m ²	square meters	1.2
yd ²	square yards	0.8	km ²	square kilometers	0.4
mi ²	square miles	2.6	ha	hectares (10,000 m ²)	2.6
MASS (weight)					
oz	ounces	28	g	grams	0.035
lb	pounds	0.45	kg	kilograms	2.2
	short tons (2000 lb)	0.9	t	tonnes (1000 kg)	1.1
VOLUME					
tsp	teaspoons	5	ml	milliliters	0.03
Tbsp	tablespoons	16	l	liters	2.1
fl oz	fluid ounces	30	qt	quarts	1.06
c	cups	0.24	gal	gallons	0.28
pt	pints	0.47	m ³	cubic meters	36
qt	quarts	0.95	m ³	cubic meters	1.3
gal	gallons	3.8			
ft ³	cubic feet	0.03			
yd ³	cubic yards	0.76			
TEMPERATURE (exact)					
°F	Fahrenheit temperature	5/9 (after subtracting 32)	°C	Celsius temperature	



* 1 in = 2.54 centimeters. For other exact conversions and more detailed tables, see NBS Mon. Publ. 760, Units of Weights and Measures, Part 2, 50 Catalog No. C 1.11a, 1966.

METRIC CONVERSION FACTORS



PREFACE

The objective of this report is to present and discuss various aspects of the generalized computer program HEC-6, in order to aid in its application to rivers of Arizona. More specifically, this report includes discussion of the theoretical/numerical bases of HEC-6, input data development, supplemental programs, and case studies. The report is essentially a compilation of both available literature and insights gained from the application of HEC-6 to three rivers in Arizona.

ABSTRACT

The computer program HEC-6 - "Scour and Deposition in Rivers and Reservoirs" was applied to three ephemeral rivers of Arizona - Agua Fria River, Salt River, and Rillito Creek. The input data development techniques and results from these three case studies were used to develop general input data development/calibration strategies. The theoretical and numerical bases of HEC-6 were reviewed and documented to clarify and further define the important aspects of the sediment routing portion of the program. Hence, the overall result of this study was a document designed to aid "users" in the application of HEC-6 to ephemeral rivers of Arizona.

ACKNOWLEDGEMENTS

The authors wish to express their appreciation to the Arizona Transportation Research Center of the Arizona Department of Transportation for their funding and support of this research.

The supervisory committee for this project included Mr. Len Erie (Erie and Associates), Mr. Herb Skibitzke (Skibitske and Associates); Mr. Marvin Sheldon, Mr. Ray Jordan, and Mr. Mumtaz Sarsam (ADOT). The authors extend their appreciation to the members of the supervisory committee for their many contributions.

Special thanks are extended to Mr. William A. Thomas and Dr. Robert MacArthur, A.S. Army Corps of Engineers, for their diligence in responding to our many enquiries concerning HEC-6.

Appreciation is extended to the following agencies and private enterprises for supplying the data that formed the bases of our research into the application of HEC-6: Cella Barr and Associates (Tucson), U.S. Geological Survey (Tucson), Maricopa County Flood Control District, the floodplain office of the City of Phoenix, Salt River Project (Tempe), and Maricopa County Water Conservation District #1.

TABLE OF CONTENTS

<u>Item:</u>	<u>Page</u>
PREFACE	iii
ABSTRACT	iv
ACKNOWLEDGEMENTS	v
i) LIST OF FIGURES	ix
ii) LIST OF TABLES	xii
A) INTRODUCTION	1
B) THEORETICAL AND NUMERICAL BASES OF HEC-6	3
B.1) Introduction	3
B.2) Theoretical Basis	3
B.3) Numerical Scheme	4
B.3.1) Data Entry	5
B.3.2) Calculation of Hydraulic Parameters	5
B.3.3) Equilibrium Depth and Armor Layer Formation/Stability Computations	7
B.3.4) Movement of Sediment Material	9
B.3.5) Computational Stability	13
B.3.6) Gravel Mining Option	14
B.3.7) HEC-6+ : A Modified Version of HEC-6	14
C) INPUT DATA DEVELOPMENT STRATEGIES	16
C.1) Geometric Data	18
C.1.1) Geometric Cross Sections and Reach Lengths	18
C.1.2) Designation of Channel Boundaries, Movable Bed Boundaries, and the Elevation of the Movable Bed Bottom	19
C.1.3) Designation of Ineffective Flow Areas and Hydraulic Weighting Factors	21
C.1.4) Manning's n Values for Channel and Overbanks	23
C.2) Sediment Data	23
C.2.1) Initial Gradation of Bed Material	26
C.2.2) Inflowing Sediment Load at Upstream Boundary	26
C.2.3) Armoring Data	29
C.3) Hydrologic Data	30
C.3.1) Discretized Hydrograph	30
C.3.2) Water Temperature	33
C.3.3) Water Surface Elevation at Downstream Boundary	33
D) SUPPLEMENTAL PROGRAMS	35
D.1) Program MAXTREND	35
D.2) Program STAP	37

E) CASE STUDIES FOR THREE EPHEMERAL RIVERS	41
E.1) Case Study #1: Agua Fria River - 1964 to 1983	41
E.1.1) Study Reach Description	41
E.1.2) Input Data Sources and Development	46
E.1.2.1) Geometric Cross Sections and Reach Lengths	51
E.1.2.2) Designation of Channel Boundaries, Movable Bed Boundaries, and the Elevation of the Movable Bed Bottom	51
E.1.2.3) Designation of Ineffective Flow Areas and Hydraulic Weighting Factors	52
E.1.2.4) Manning's n Values for Channel and Overbanks	53
E.1.2.5) Initial Gradation of Bed Material	53
E.1.2.6) Inflowing Sediment Load at Upstream Boundary	54
E.1.2.7) Armoring Data	56
E.1.2.8) Discretized Hydrograph	56
E.1.2.9) Water Temperature	61
E.1.2.10) Rating Curve	61
E.1.3) Results and Discussion	61
E.2) Case Study #2: Salt River - 1977 to 1983	69
E.2.1) Study Reach Description	69
E.2.2) Input Data Sources and Development	78
E.2.2.1) Geometric Cross Sections and Reach Lengths	78
E.2.2.2) Designation of Channel Boundaries, Movable Bed Boundaries, and the Elevation of the Movable Bed Bottom	79
E.2.2.3) Designation of Ineffective Flow Areas and Hydraulic Weighting Factors	79
E.2.2.4) Manning's n Values for Channel and Overbanks	80
E.2.2.5) Initial Gradation of Bed Material	80
E.2.2.6) Inflowing Sediment Load at Upstream Boundary	81
E.2.2.7) Armoring Data	84
E.2.2.8) Discretized Hydrograph	84
E.2.2.9) Water Temperature	87
E.2.2.10) Rating Curve	88
E.2.3) Results and Discussion	88
E.3) Case Study #3: Rillito Creek - October 1983	89
E.3.1) Study Reach Description	89
E.3.2) Input Data Sources and Development	97
E.3.2.1) Geometric Cross Sections and Reach Lengths	101
E.3.2.2) Designation of Channel Boundaries, Movable Bed Boundaries, and the Elevation of the Movable Bed Bottom	101
E.3.2.3) Designation of Ineffective Flow Areas and Hydraulic Weighting Factors	102

E.3.2.4) Manning's n Values for Channel and Overbanks	102
E.3.2.5) Initial Gradation of Bed Material	102
E.3.2.6) Inflowing Sediment Load at Upstream Boundary	102
E.3.2.7) Armoring Data	104
E.3.2.8) Discretized Hydrograph	104
E.3.2.9) Water Temperature	107
E.3.2.10) Rating Curve	107
E.3.3) Results and Discussion	108
E.4) Limits in the Applicability of HEC-6 to Ephemeral Rivers of Arizona - Conclusions from Three Case Studies	111
F) EXAMINATION OF GRAVEL MINING AND HEADCUTTING CAPABILITIES OF COMPUTER PROGRAM HEC-6	114
F.1) Contents of HEC Special Memo 80-1	114
F.2) HEC-6 Simulation of Headcutting and Gravel Pit Sedimentation	116
G) CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH	121
G.1) Revised Sediment Sorting and Armoring Algorithm	121
G.2) Alternate Stability Criterion	121
H) REFERENCES	125
APPENDIX A: SUPPLEMENTAL PROGRAMS FOR HEC-6 STUDIES	128

1) LIST OF FIGURES

<u>No.</u>	<u>Title</u>	<u>Page</u>
B1	Functional Flow Chart for Computer Program HEC-6	6
B2	Explicit Computation Net and Reach Increment Illustration	12
C1	Representative Data Illustration	17
C2	A Typical River Cross Section Illustrating the HEC-6 Required Channel Divisions and the Influence of the Movable Bed Boundaries on the Calculated Channel Geometry	20
C3	Hydrograph Analysis for the Flood of December 18-22, 1978 on the Agua Fria River	31
D1	Functional Flow Chart for HEC-6 Analysis Program MAXTREND	36
D2	Functional Flow Chart for HEC-6 Analysis Program STAP	38
E1	Metropolitan Phoenix Map	42
E2	Metropolitan Tucson Map	43
E3	Study Area Map of the Agua Fria River with Surveyed Cross Section Locations	44
E4	The Agua Fria River Looking Upstream Toward Hatfield Road	45
E5	Armored Surface of the Agua Fria River Near Jonax Road	47
E6	Close-Up of the West Bank of the Agua Fria River, Near Rose Garden Lane	48
E7	The West Bank of the Agua Fria River Near Rose Garden Lane, Looking Downstream	49
E8	The Agua Fria River Near Rose Garden Lane, Flow Direction is from Right to Left	50
E9	Grain Size Distribution Curves for the Three Groups of Sediment Found in the Agua Fria River Channel	55
E10	Flow Histogram for the Agua Fria River Indicating Major Flood Events	59

E11	Salt River Study Area Map with Surveyed Cross Section Locations	71
E12	The Salt River West of 43rd Avenue; Flow Direction is From Right to Left	73
E13	Close-Up of a Test Pit in the Salt River, Near Cross Section 9.20	74
E14	Close-Up of a Test Pit in the Salt River, Near Cross Section 9.20	75
E15	Armored Bed Surface of the Salt River Near Cross Section 9.20, Flow Direction is From Right to Left	76
E16	The Salt River at 35th Avenue, Flow Direction is From Right to Left	77
E17	Grain Size Distribution Curves for the Salt River as Used in HEC-6 Computer Analyses	82
E18	Grain Size Distribution Curves of Composite Bed-Material Samples for the Salt River as Determined by Various Consulting Firms	83
E19	Flow Histogram for the Salt River Indicating Major Flood Events	86
E20	Rillito Creek Study Area Map With Study Reach Cross Sections	94
E21	Rillito Creek Near North Oracle Road - Looking Upstream	95
E22	Rillito Creek Near North Oracle Road - Looking Downstream	96
E23	Bed Surface of Rillito Creek Near Flowing Wells Road	98
E24	Rillito Creek Near North Oracle Road - Looking North	99
E25	Rillito Creek Between North Oracle Road and Flowing Wells Road - Looking Downstream	100
E26	Grain Size Distribution Curves for Rillito Creek Bed Material Samples	103
E27	Discretized Hydrograph for the October 1983 Flood Event on Rillito Creek	106
F1	Chronological Series of Longitudinal Profiles for a Synthetic Gravel Pit	118

F2	Chronological Series of Calculated Water Surface Elevations and Cross Section Profiles	119
G1	Flow Diagram for the Revised Sediment Sorting and Armoring Algorithm Proposed by DMA (1984)	122

ii) LIST OF TABLES

<u>No.</u>	<u>Title</u>	<u>Page</u>
C1	Values of the Manning Roughness Coefficient n for Various Channel Types and Descriptions	24
C2	Grain Size Classification of Sediment Material	27
E1	Inflowing Sediment Load for the Agua Fria River Using Group 1 Bed Material	57
E2	Inflowing Sediment Load for the Agua Fria River Using Group 2 Bed Material	58
E3	Model Evaluation Analysis for the Agua Fria River for the Study Period 1964 to 1983	63
E4	Model Evaluation Analysis for the Agua Fria River for the Study Period 1964 to 1979	65
E5	Model Evaluation Analysis for the Agua Fria River for the Study Period 1979 to 1983	67
E6	Actual Volume Change Comparisons for the Agua Fria River	70
E7	Inflowing Sediment Load for the Salt River Using Fine Bed Gradation	85
E8	Model Evaluation Analysis for the Salt River for the Study Period 1977 - 1983 Using Sediment Data Set No. 1	90
E9	Model Evaluation Analysis for the Salt River for the Study Period 1977 - 1983 Using Sediment Data Set No. 2	92
E10	Inflowing Sediment Load for Rillito Creek	105
E11	Model Evaluation for the HEC-6 Simulation of the October 1983 Flow Event on Rillito Creek	109
E12	Summary of the Results from Applying HEC-6 to Three Ephemeral Rivers of Arizona	113