ARIZONA DEPARTMENT OF TRANSPORTATION

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EFFECTS OF IN-STREAM MINING ON CHANNEL STABILITY

Volume III: Appendices

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16. Abstract

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.

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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	% Rtnd
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 "grand-father" 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.

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[1]Arizona 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 varys 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 <u>Consulting Engineers</u>

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 statewide 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: ________________

	YES	NO
A. GENERAL		
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? ________

	YES	NO
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 defendent? ______________

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 design, regulate, and/or maintain any in-stream (or floodplain) structures (e.g., bridges, utility crossings or alignments, flood control structures, etc.)? (Please circle 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 design/regulation/maintenance of these structures? ___ ___

   b. consider the effect of in-stream sand and gravel mining on the design/regulation/maintenance of these structures? ___ ___

2. If the answer to Question B.1.b. is yes, please answer the followinn 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 segements. 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). ______________________________

____

____

____

QUESTIONNAIRE (Revised 9/24/86)

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 floodplain[1] 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 floodplain[1] 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.

TABLE 1. FACILITY RESOURCE INFORMATION
(Revised 9/24/86)

Facility Number	Location (County and Nearest Town)	River Name	Opening Date (mo/yr)	Closing Date (mo/yr)	Material Reserves (cu yd)		Extraction Rate (cu yd/yr)
					Initial	Current	

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.

____

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____

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 defendent? ____________

   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.)? ____

	YES	NO
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. ________________

____

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____

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 defendent? ____________________

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. <u>Engineering Analysis of In-Stream Gravel Extraction From the Agua Fria River, Vicinity of Indian School Road and Camelback Road</u>
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. <u>Development of Qualitative Guidelines for Sand and Gravel Mining in Salt, Gila and Agua Fria Rivers</u>
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. <u>Preliminary Engineering Analysis of In-Stream Sand and Gravel Extraction From Three Sites on the Salt River</u>

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

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. <u>Erosion and Sedimentation Analysis of Columbia Pit and San Xavier Pit in the Santa Cruz River, Tucson, Arizona</u>

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. <u>Study of Gravel Mining Impacts, Verde River at Cottonwood, Arizona</u>

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

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 overbank 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. <u>Hydraulic and Scour Analysis of Salt River Bridge at Phoenix-Casa Grande Highway for Long-Term Protection Against Scour</u>

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. <u>Analysis and Design Study of the Agua Fria River</u>

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. <u>Sediment Transport Analysis of Rillito River and Tributaries for the Tucson Urban Study</u>

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. <u>Scour/Migration Analysis of the Rillito River at Pontatoc Road</u>

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. <u>Hydraulic and sedimentation Analysis of the 7th Street Bridge over the Salt River</u>

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. <u>Scour and Sedimentation Analysis of the Proposed Channelization of the Salt River for Protecting the Sky Harbor international Airport</u>

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. <u>River Response Analysis Associated With Rio Nuevo-Santa Cruz River Flood Control and Channelization Project</u>

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. <u>Canada del Oro Flood Control Project (Oro Valley), Arizona</u>

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. <u>Sediment Transport Report for the New River and Skunk Creek</u>

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. <u>Excavation Plan/Salt River Southbank Project</u>

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
<u>Maricopa County and Roosevelt Irrigation District v. Allied Concrete, et. al.</u>

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. <u>Agua Fria River Materials v. Allied Concrete</u>

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. <u>Kane, Talent v. Maricopa County, United Metro</u>

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 defendent 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. <u>Wooten v. Phoenix Sand & Rock</u>

The defendant paid monetary damages.

M. <u>Mulcher v. Phoenix Sand & Rock</u>

The defendant paid monetary damages.

N. <u>Maricopa County v. Phoenix Sand & Rock</u>

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/ft^3.

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)
GRAVEL BED CHANNELS								
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
SAND BED CHANNELS								
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.

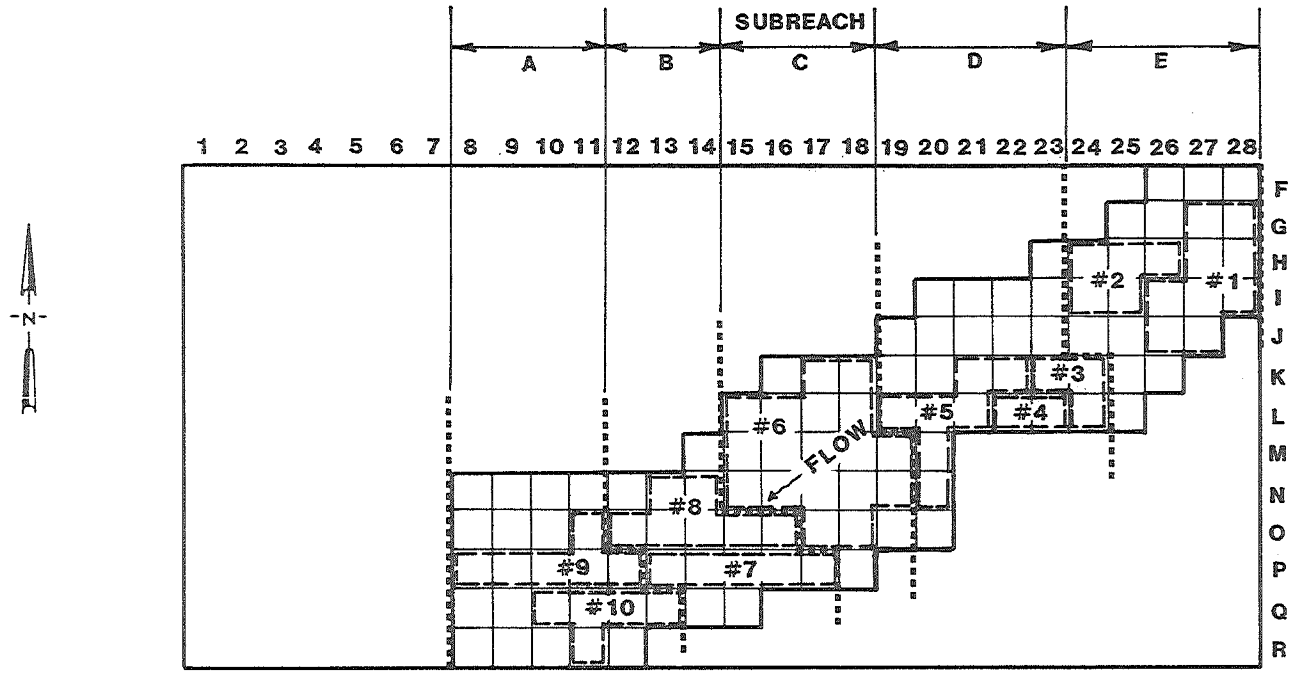

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FIGURE D.1

SALT RIVER

HAYDEN RD TO COUNTRY CLUB DR

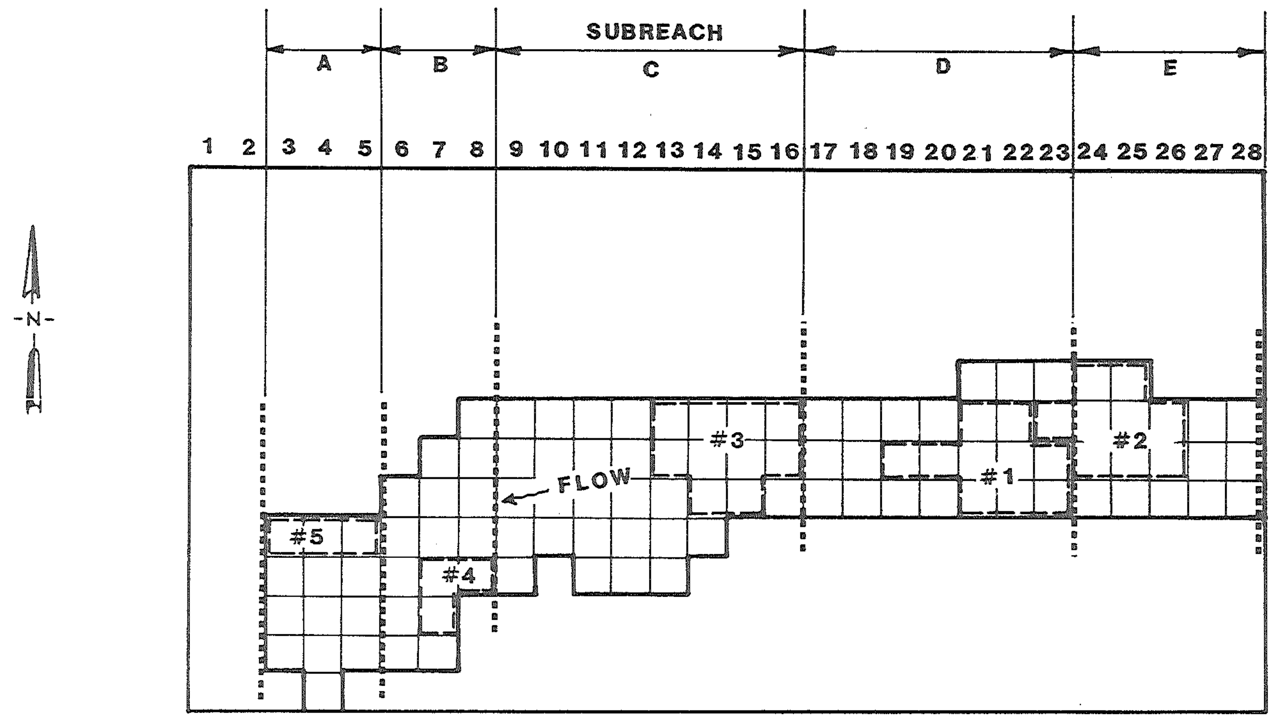

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FIGURE D.2

SALT RIVER

59TH — 19TH AVENUE

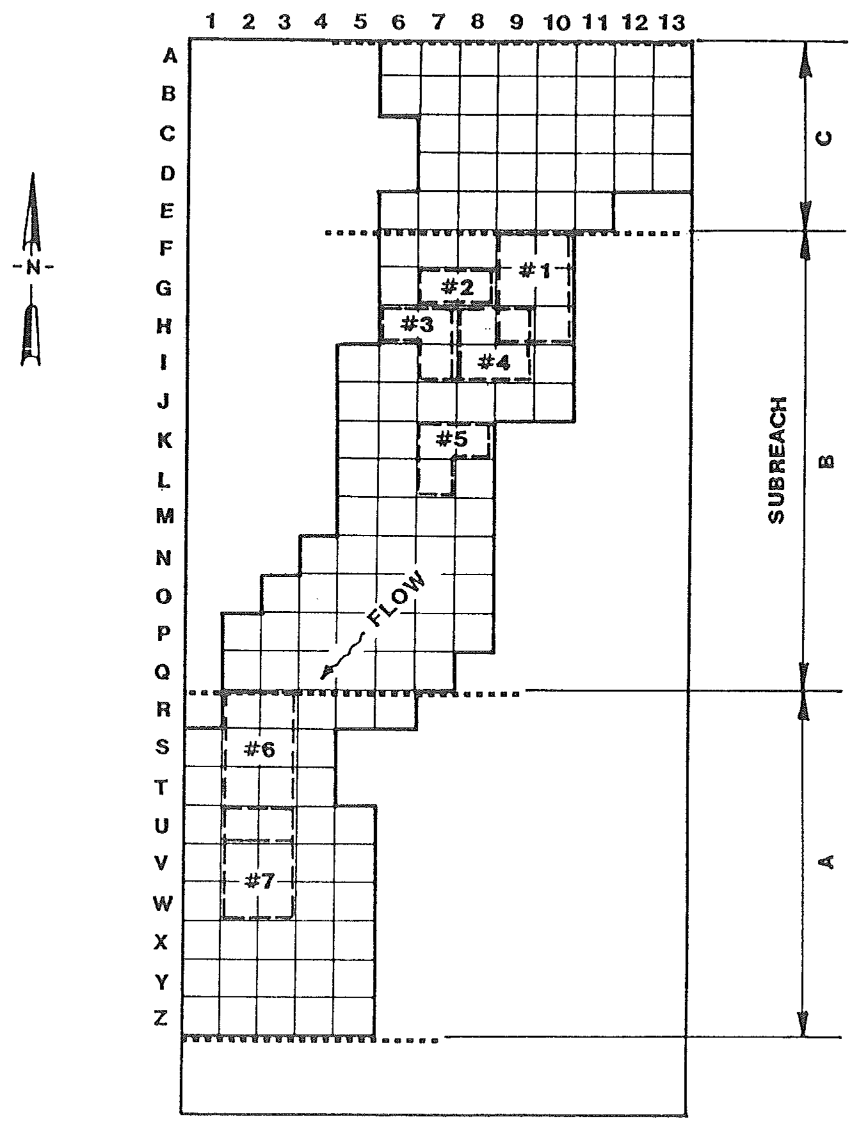

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FIGURE D.3

AGUA FRIA RIVER

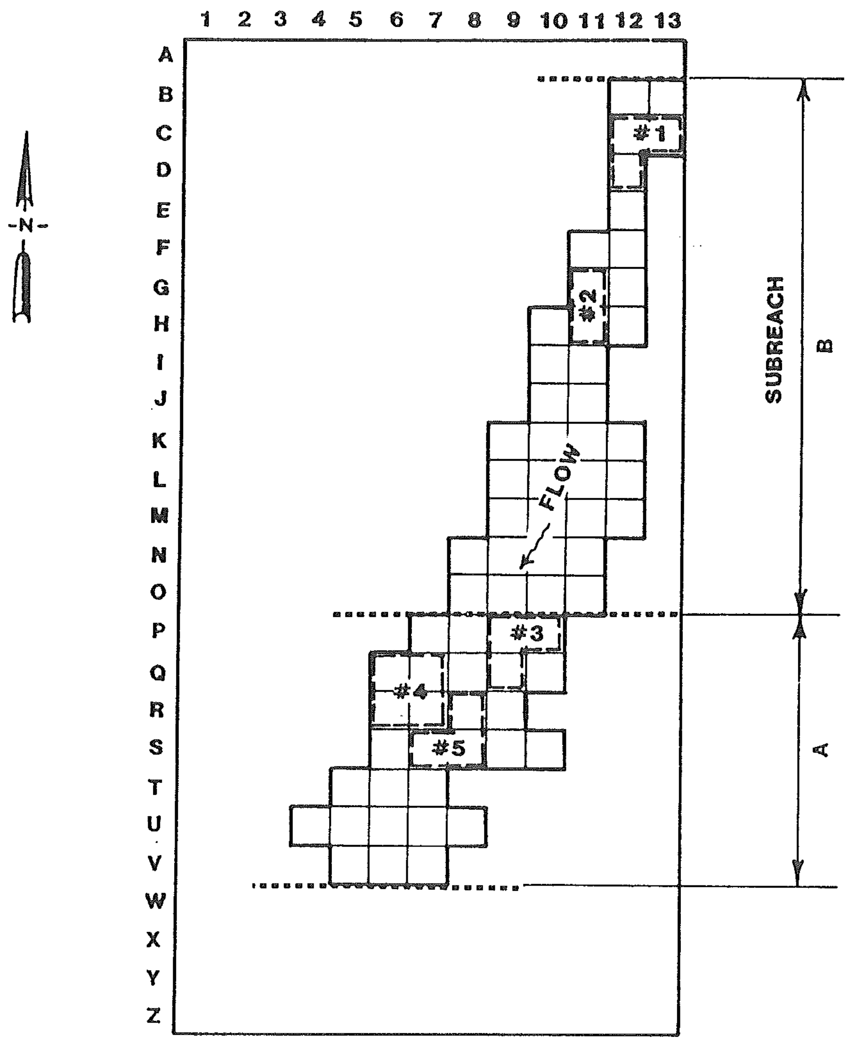

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FIGURE D.4

NEW RIVER

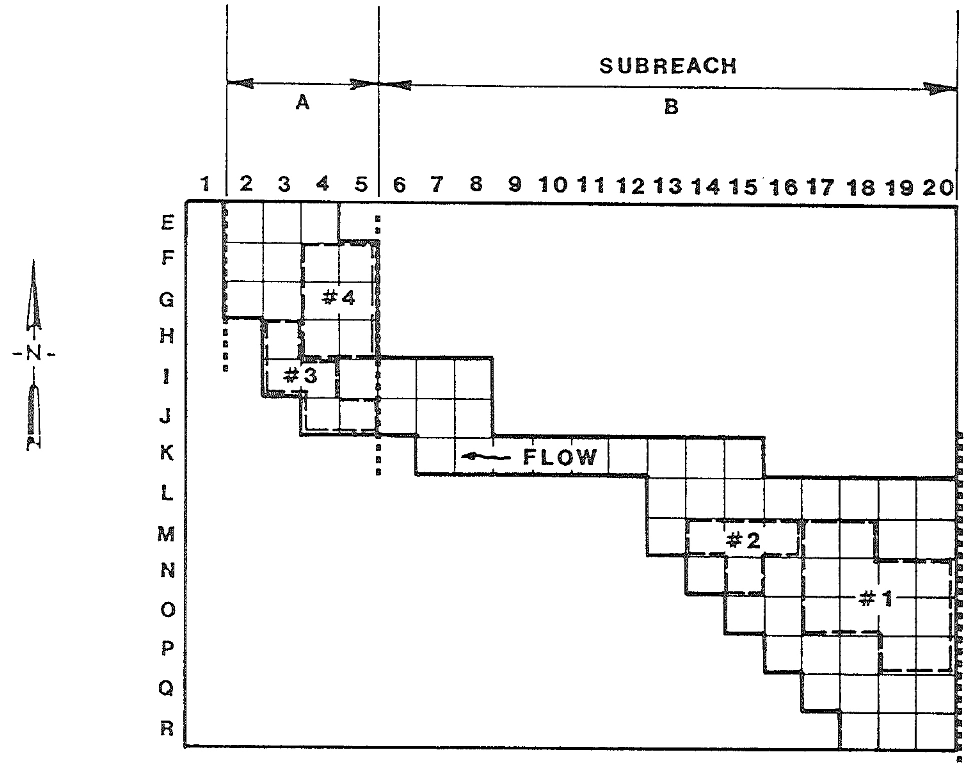

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FIGURE D.5

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.

$$\Delta Zave = \frac{V_p}{L \times W}$$

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,

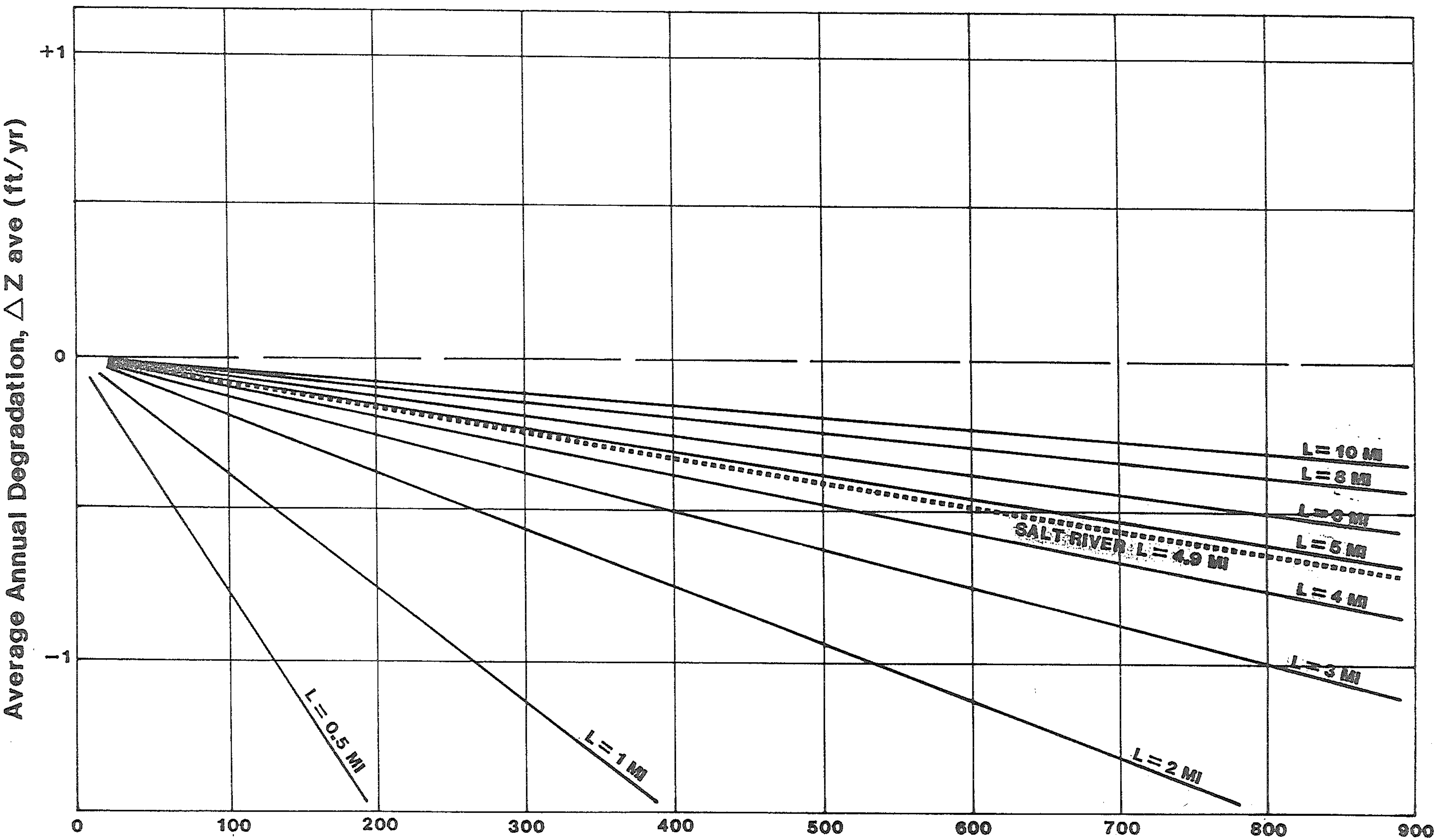
ΔV_{bed} = change in volume of the channel bed within the reach

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.



——— Based on geometric relationship $\Delta Z \text{ ave} = \dfrac{\forall p}{L \times W}$

.... Based on actual data

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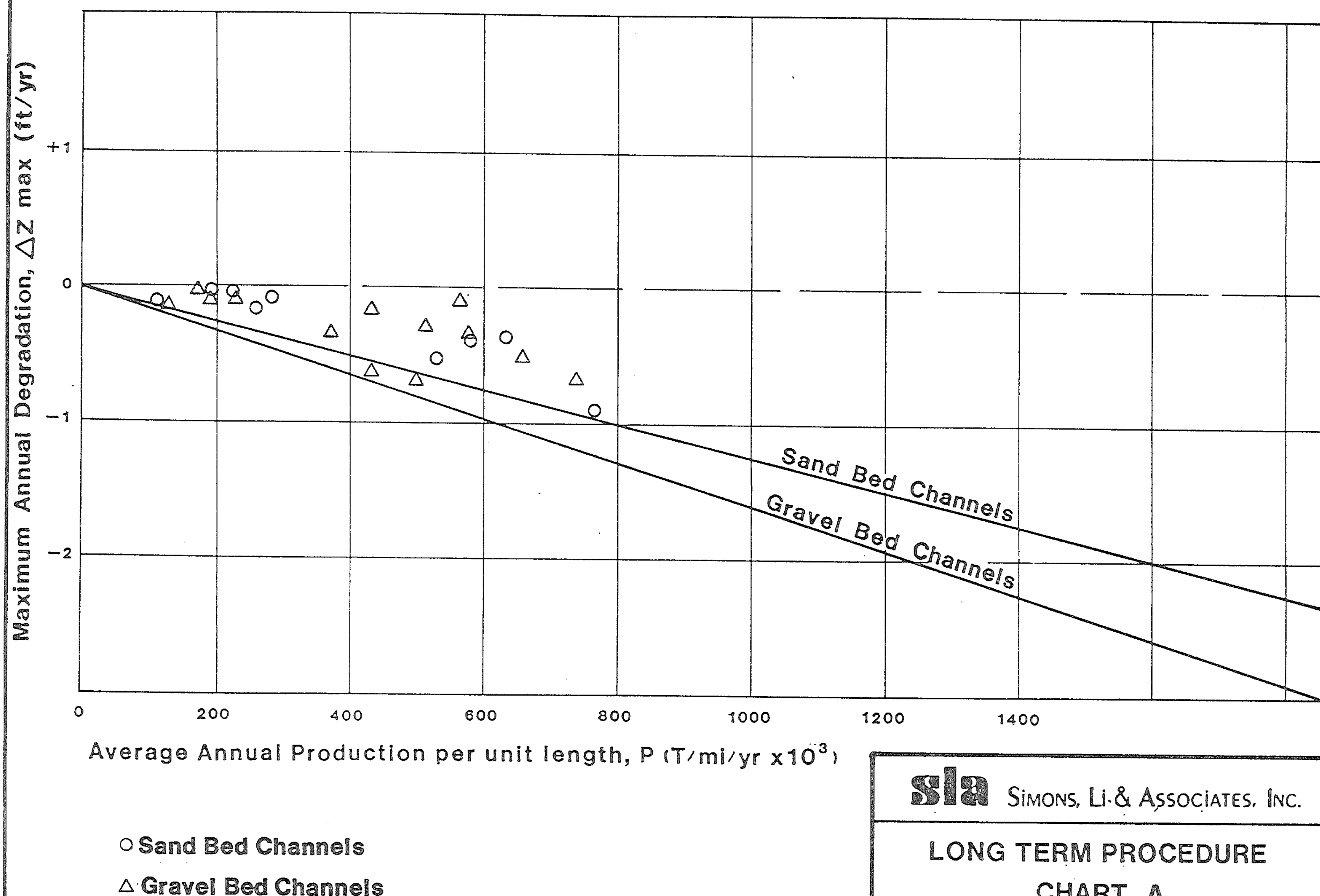
FIGURE D.6

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.



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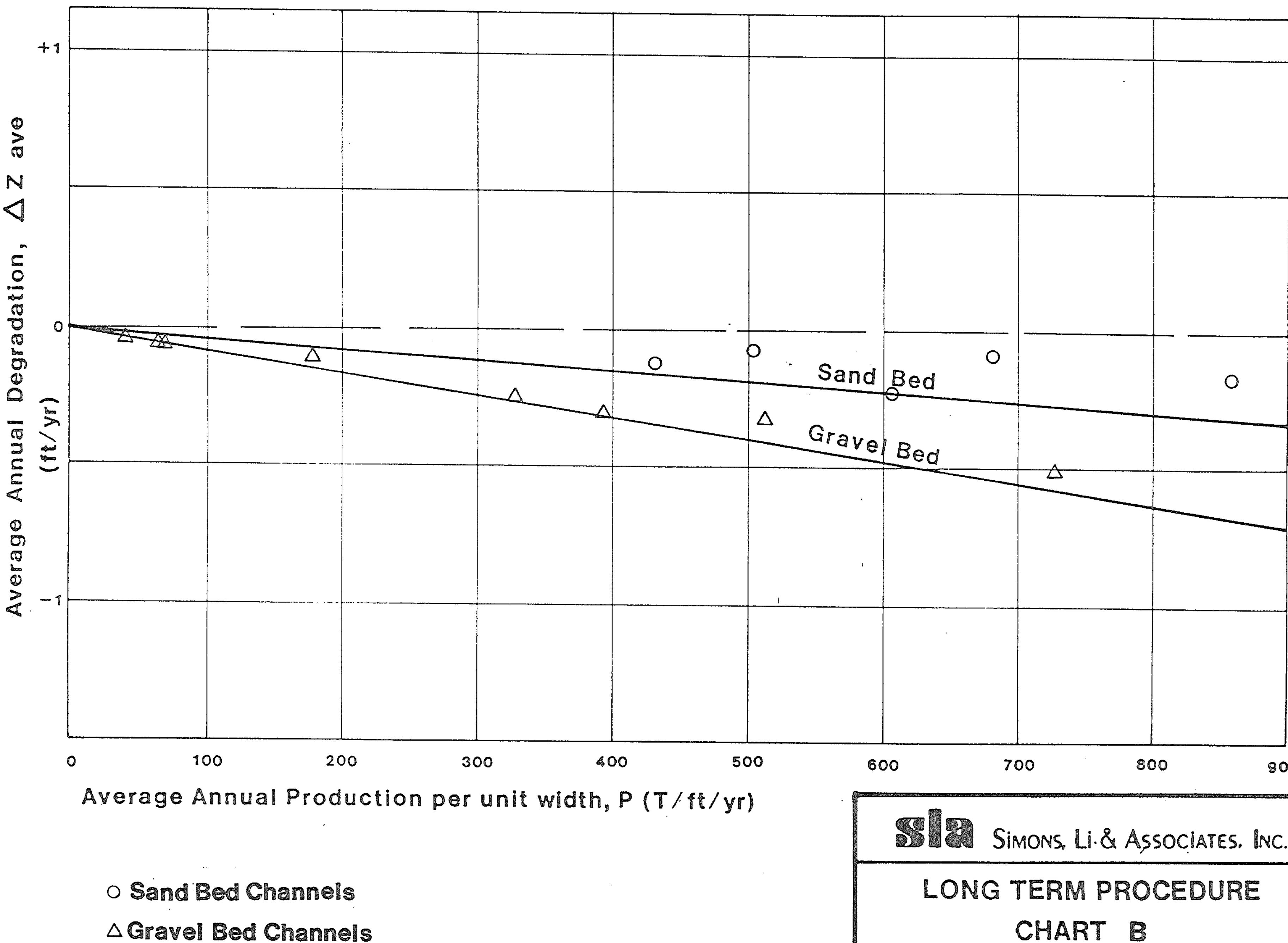
LONG TERM PROCEDURE
CHART A



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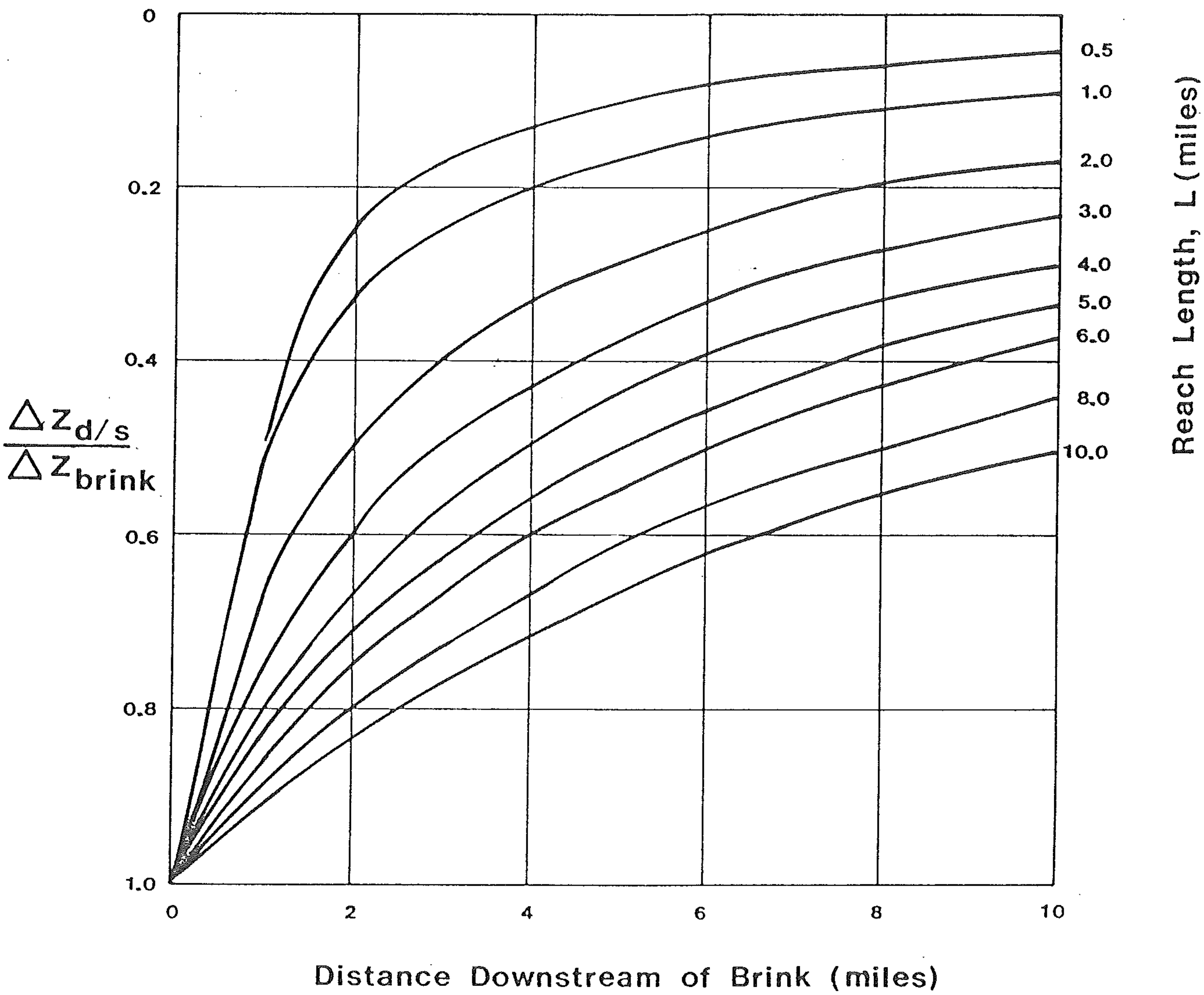
LONG TERM PROCEDURE
CHART B

DOWNSTREAM RECOVERY CURVE

GRAVEL BED CHANNELS



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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
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
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
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 HORIZ.	VERT.	'67 ELEV	'84 ELEV
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	.00
H	26	2.14	2.14	.00	.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	.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	.00
H	29	.00	.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	.00
H	31	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.98	6.28	6.94	.00
H	32	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	3.31	4.63	4.96	.00
I	20	.00	.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	.00
I	22	.00	.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	.00
I	24	2.63	2.63	.00	.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	.00
I	26	.00	.00	2.98	16.87	6.94	.00	11.57	.00	1.32	.00	.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	.00	3.31
I	28	.00	.00	.00	.00	9.59	.00	.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	.00
I	31	.00	.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	.00
J	19	.00	.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	.00
J	21	.00	.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	.00
J	23	3.12	1.64	.00	.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	.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	.00
J	26	.00	.00	4.96	2.64	4.30	.00	4.30	.00	2.64	.00	.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	.00
K	16	.00	.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	7.27
K	18	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	19.84	14.55	14.55
K	19	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	8.27	11.24	11.24
K	20	1.31	2.30	.00	.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	.00	6.94
K	22	1.64	1.97	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	7.27	10.58	18.18
K	23	6.57	5.91	.00	.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	.00
K	25	.00	.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	.00
L	15	.00	.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	13.55
L	17	.00	.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	.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	.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	.00	24.07	24.07	24.07
L	21	.00	3.24	.99	.00	.00	.00	.00	8.26	.00	.00	2.31	.00	.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	.00
L	23	3.12	3.78	.00	.00	.00	3.64	.00	.00	.00	.00	4.30	3.31	.00	.00	.00	.00
L	24	.00	.00	1.65	.00	.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	.00
M	14	.00	.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	5.62
M	16	.00	4.11	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	8.27	6.94	20.07	24.07

M	17	.00	4.44	.00	.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	.00	4.63	5.29	11.57	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	.00	7.93	9.59	9.59	3.97	22.56	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	.00	2.98	7.93	15.54	3.63	22.81	15.21	24.07
O	15	.00	.00	.00	1.65	.00	.00	.00	.00	.00	.00	.00	.00	.00	3.31	.00	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	.00	5.95	5.95	.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	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			10.35	1.64	5.26
H	25													5.91	9.53	8.21
H	26		11.01												7.39	7.06
H	27	5.81	10.89												1.15	4.11
H	28	10.64														
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 HORIZ.	VERT.	(Acres) '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													

Q	6													
Q	7													
R	1													
R	2			3.31	3.31									
R	3			.99										
R	4													
R	5													
R	6													
R	7													
S	1													
S	2	3.64	12.23	8.26	8.93	1.98								
S	3					2.31								.99
S	4													
T	1													
T	2	1.65	4.96	3.64	3.97		1.65	11.57				6.94	6.28	
T	3		.33			2.97	3.96	5.95		3.31		5.95	7.60	
T	4													
U	1													
U	2		1.32		.99			8.93		1.65	.33			
U	3		.99					5.95		3.64	1.65	2.98	12.90	
U	4													
U	5													
V	1													
V	2					2.98			2.98	1.32	.66			
V	3					1.65				2.64	7.60	7.60	1.32	
V	4													
V	5													
W	1													
W	2				1.65	1.98						1.32		
W	3				3.97	2.31						6.28	3.31	
W	4													
W	5													
X	1													
X	2													
X	3													
X	4													
X	5													
Y	1													
Y	2													
Y	3													
Y	4													
Y	5													
Z	1													
Z	2													
Z	3													
Z	4													
Z	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					2.31			1.65		1.65	2.98
R	8						9.26		6.94	9.59		10.58	12.56
R	9												2.98
S	6												
S	7	8.26				13.22	13.55	12.89	12.89	15.21	14.21	15.21	17.85
S	8						1.65	1.32	1.32	4.96		1.65	7.60
S	9												
S	10												
T	5												
T	6												
T	7										3.97		3.97
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. Variation 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.*
```

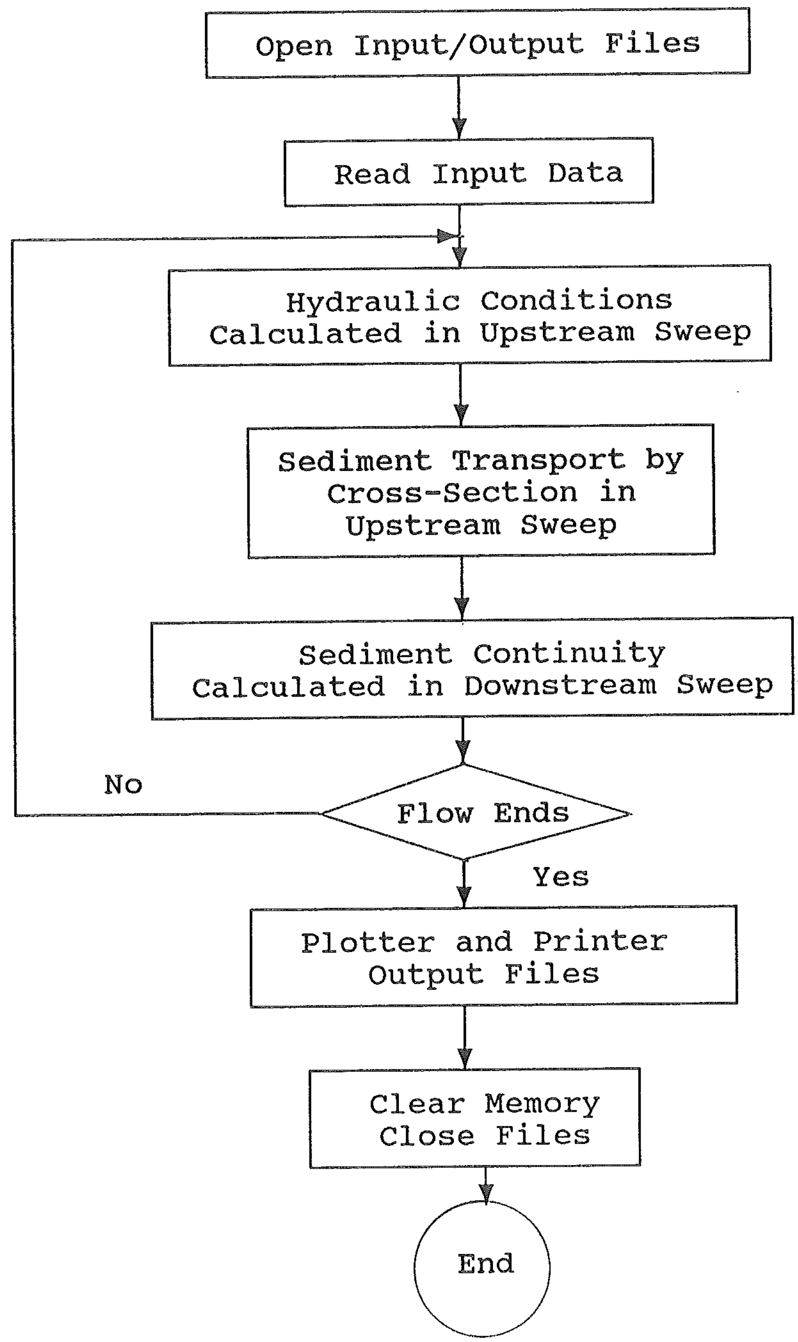


Figure E.3. Flow Chart of the Main Program for CRISM.

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,

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

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,

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

where g is the gravitational constant (32.2 ft/sec^2). Rouse (1936) found that for a free overfall, critical depth is about 1.4 times the brink depth, or yc = 1.4 yb. Therefore, normal depth calculations near the excavation brink were limited to yn = 0.71 yc.

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:

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

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:

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

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

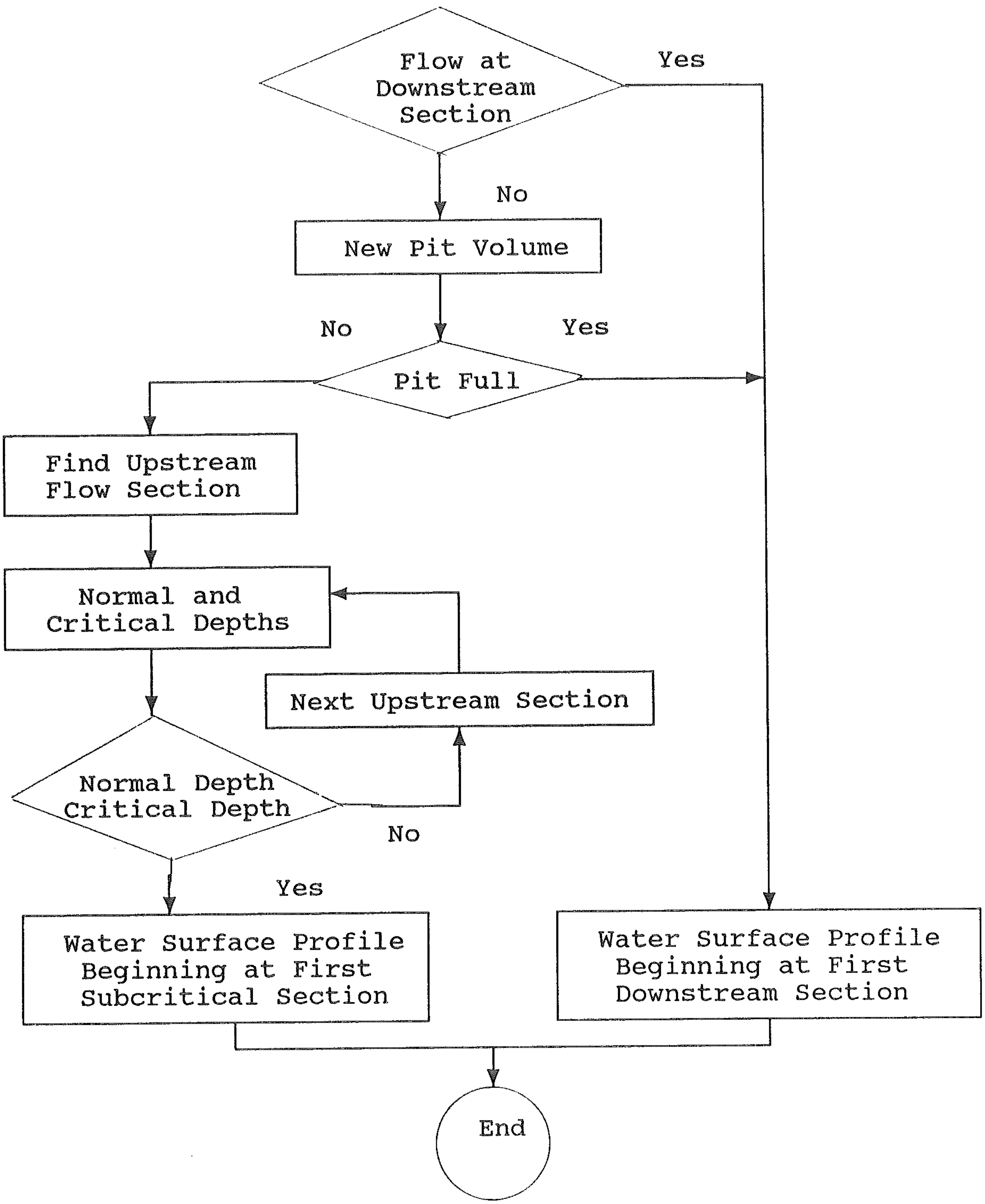


Figure E.4. Hydraulics Flow Diagram

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

Flow-energy equation:

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

Energy head-loss equation:

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

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:

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

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 ith size fraction, g_{ti}, is lb/sec/foot of channel width,

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

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/ft^3);
$\gamma' s$ = the submerged unit weight of sediment (103 lb/ft^3);
S_e = the slope of the energy gradeline;
C_s = a constant of 0.047; and,
d_{si} = the sediment size of the ith 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,

$$g_t = \Sigma g_{ti} p_i \qquad \text{(E.8)}$$

where p_i is the fraction of the gradation in the ith size interval.

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

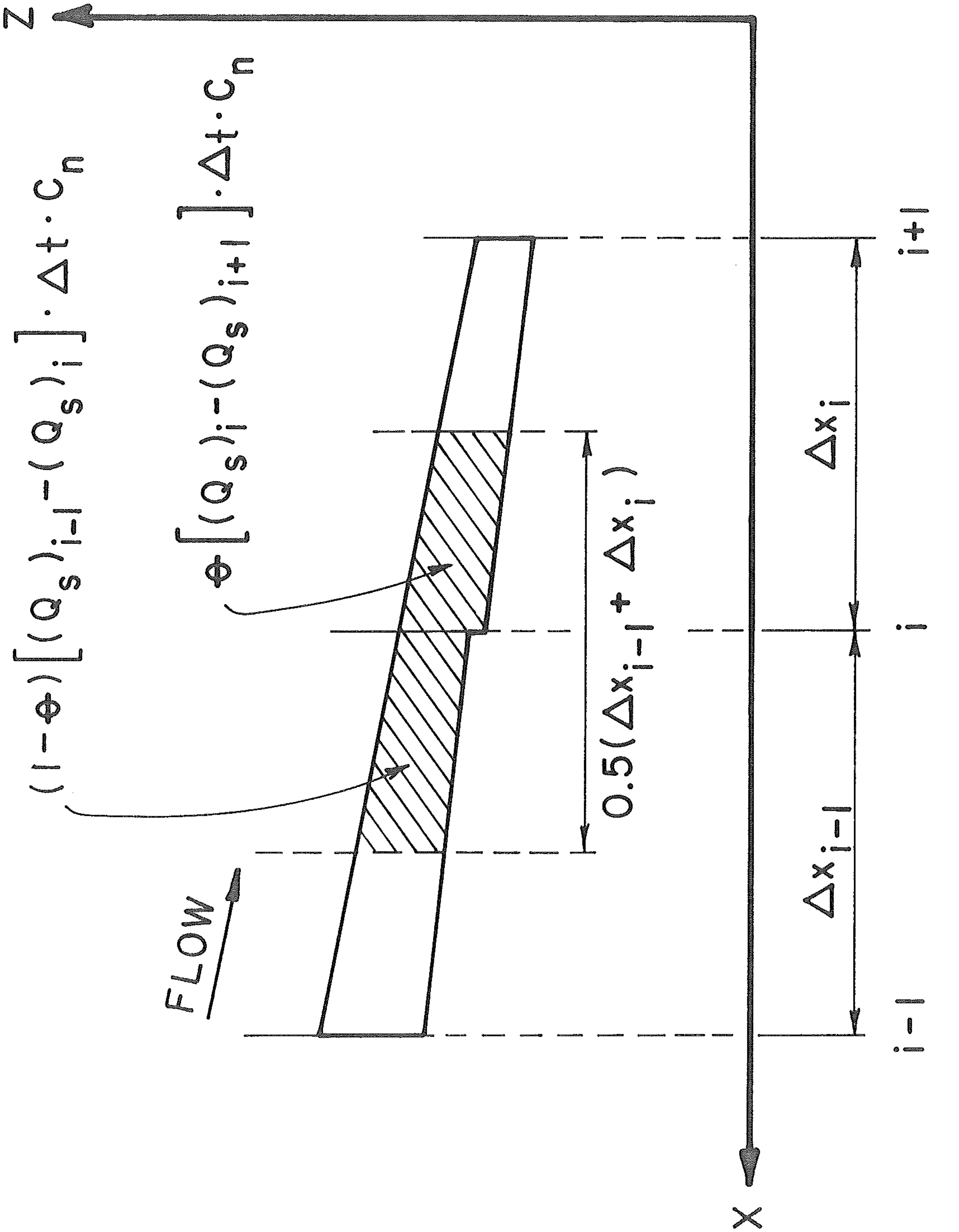
$$\frac{\delta q_s}{\delta x} + (1-\lambda)\frac{\delta z_b}{\delta t} = q_{sl} \qquad \text{(E.9)}$$

where
q_s = the sediment dishcarge (cfs/ft);
z_b = cross-section elevation (feet);
qse = 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):

$$\Delta z_i = (1-\Theta)[(G_t)_{i-1}-(G_t)_i] + \Theta[(G_t)_i-(G_t)_{i+1}] \cdot \frac{\Delta t}{0.5(\Delta x_{i-1}+\Delta x_i)} *(Cn/Wi) \qquad \text{(E.10)}$$

in which Θ = is a weighting factor with a value between 0 and 1, Gti = gti* Wi, and Cn 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 transfered 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:

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

$$\frac{y_{smax}}{y_p} = 0.50 \quad \text{for } \frac{y_{smax}}{y_p} >= 0.5$$

$$a_1 = 0.120\ W_*^{0.672}$$
$$b_1 = 0.286\ W_*^{-0.350}$$

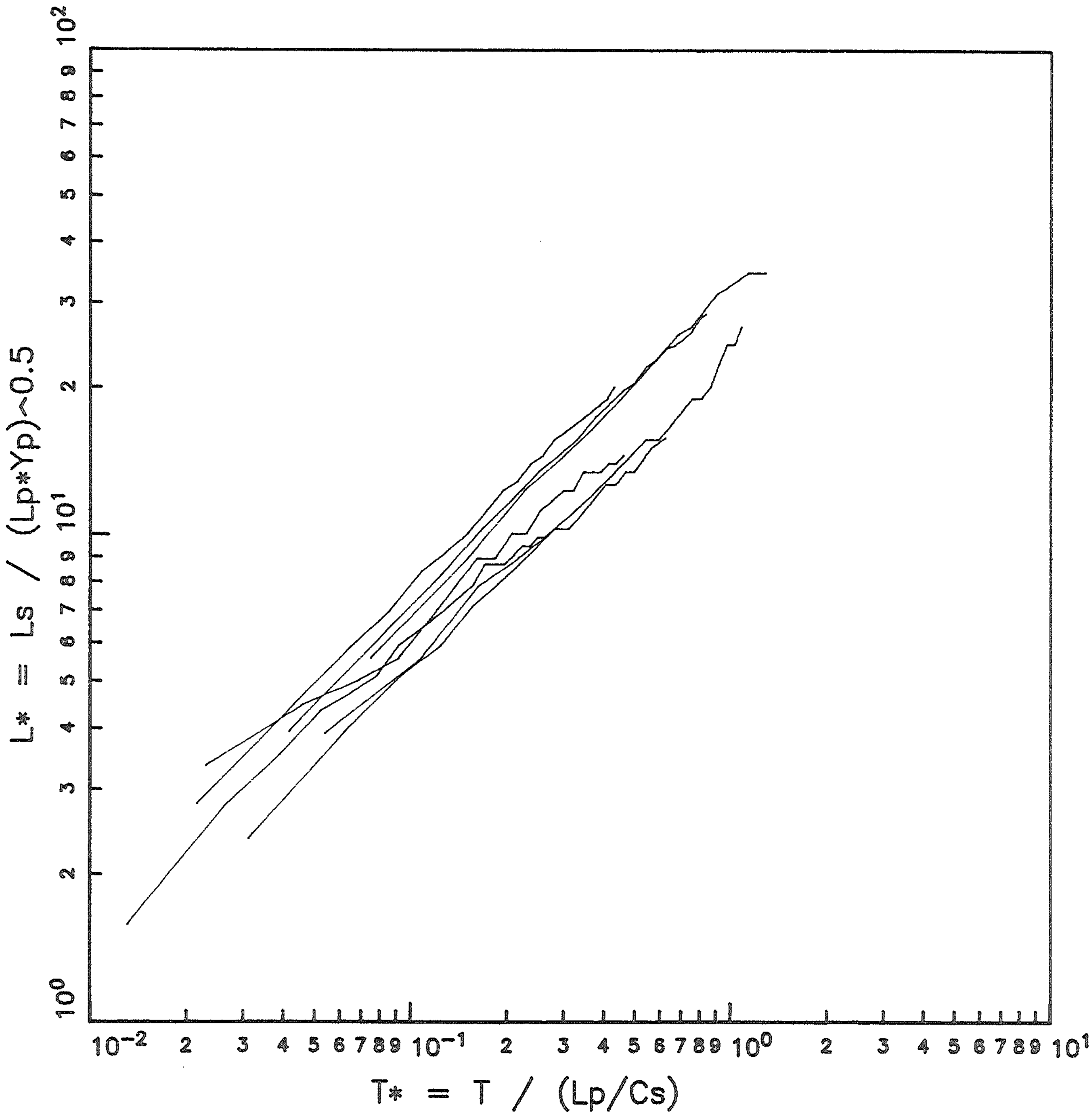


Figure E.6. Normalized Downstream Scour Length Graph (q = 20 cfs/ft)

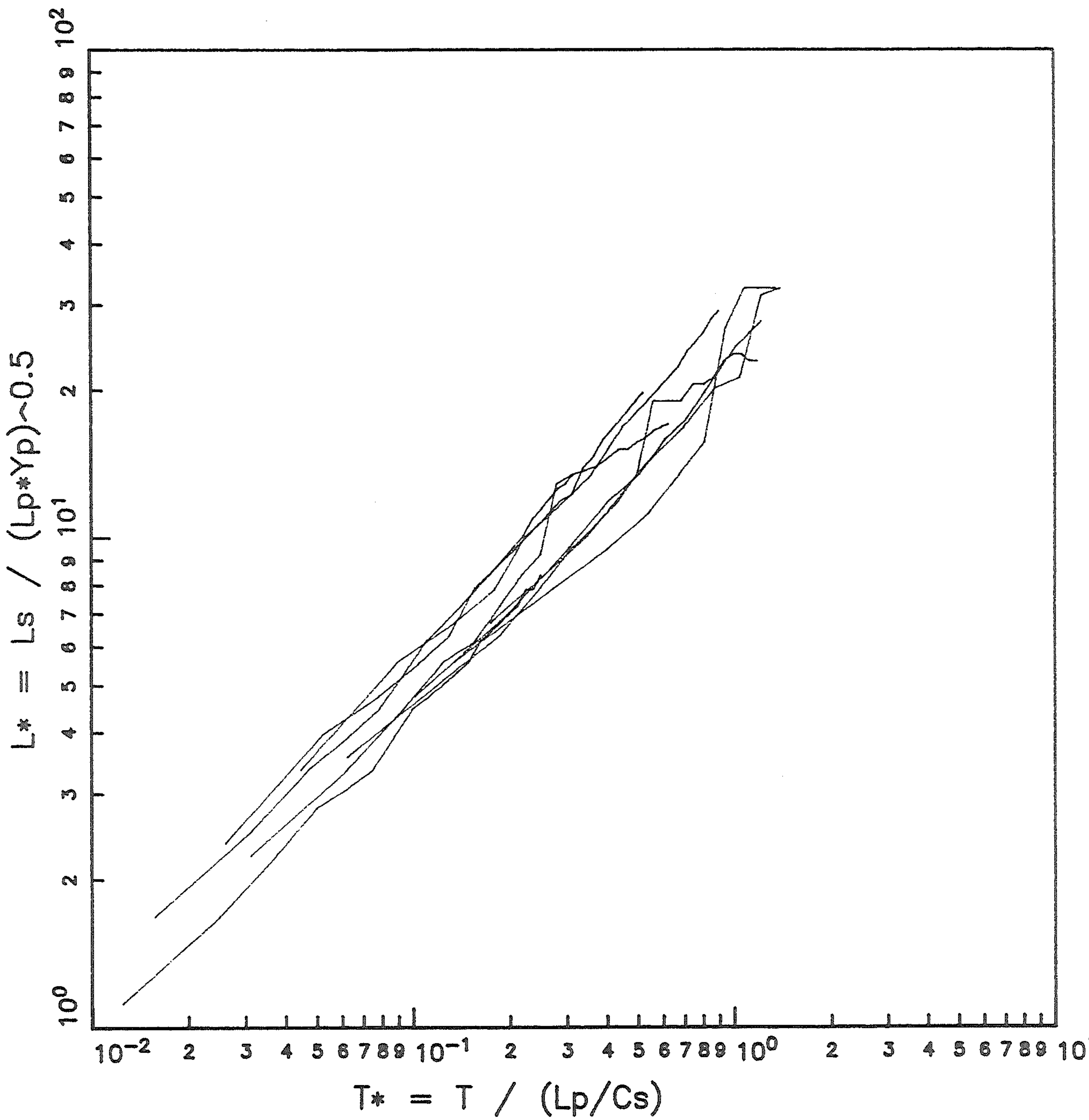


Figure E.7. Normalized Downstream Scour Length Graph (q = 40 cfs/ft)

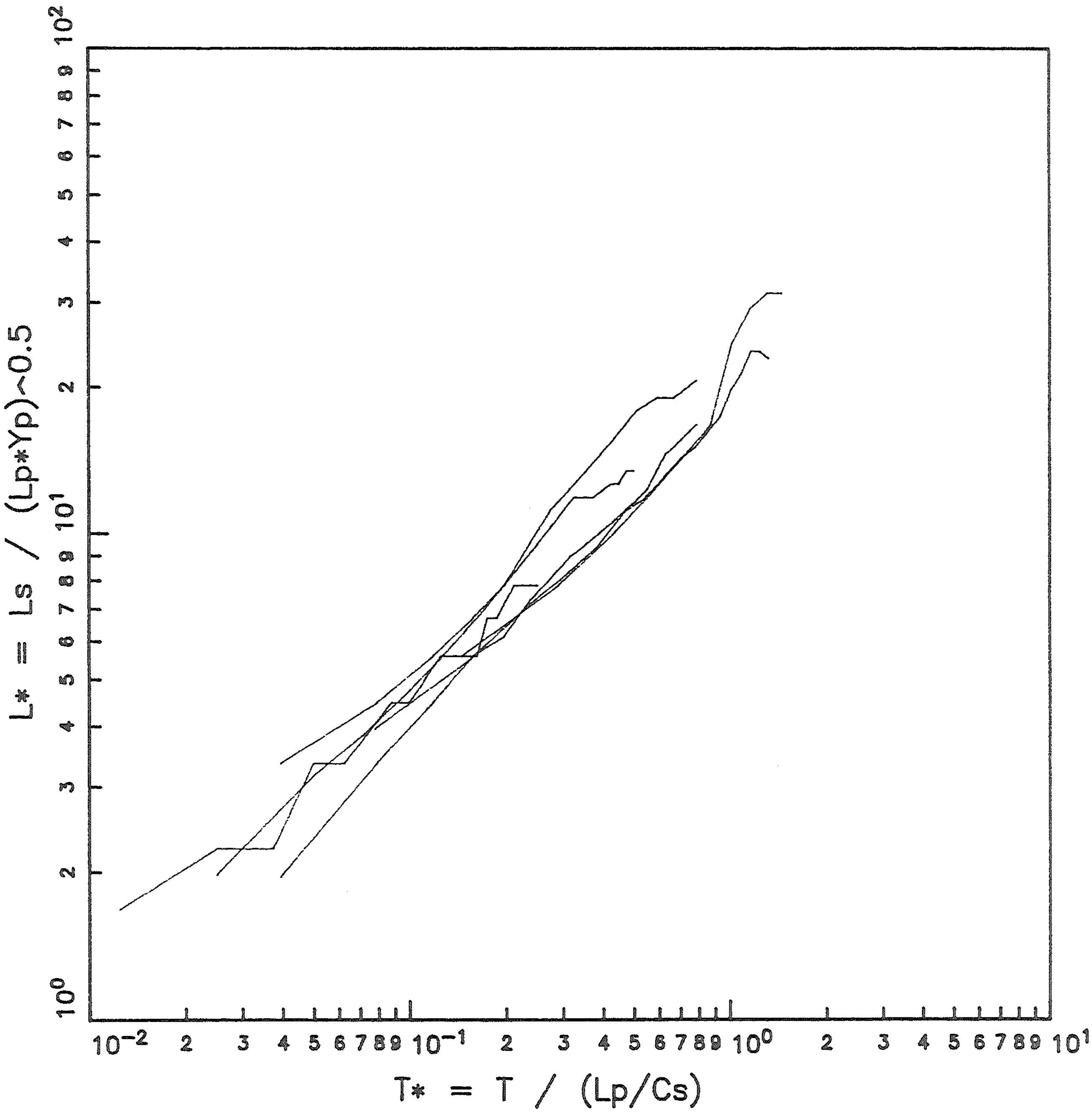


Figure E.8. Normalized Downstream Scour Length Graph (q = 80 cfs/ft)

q = 80 cfs/ft

q=160 cfs/ft

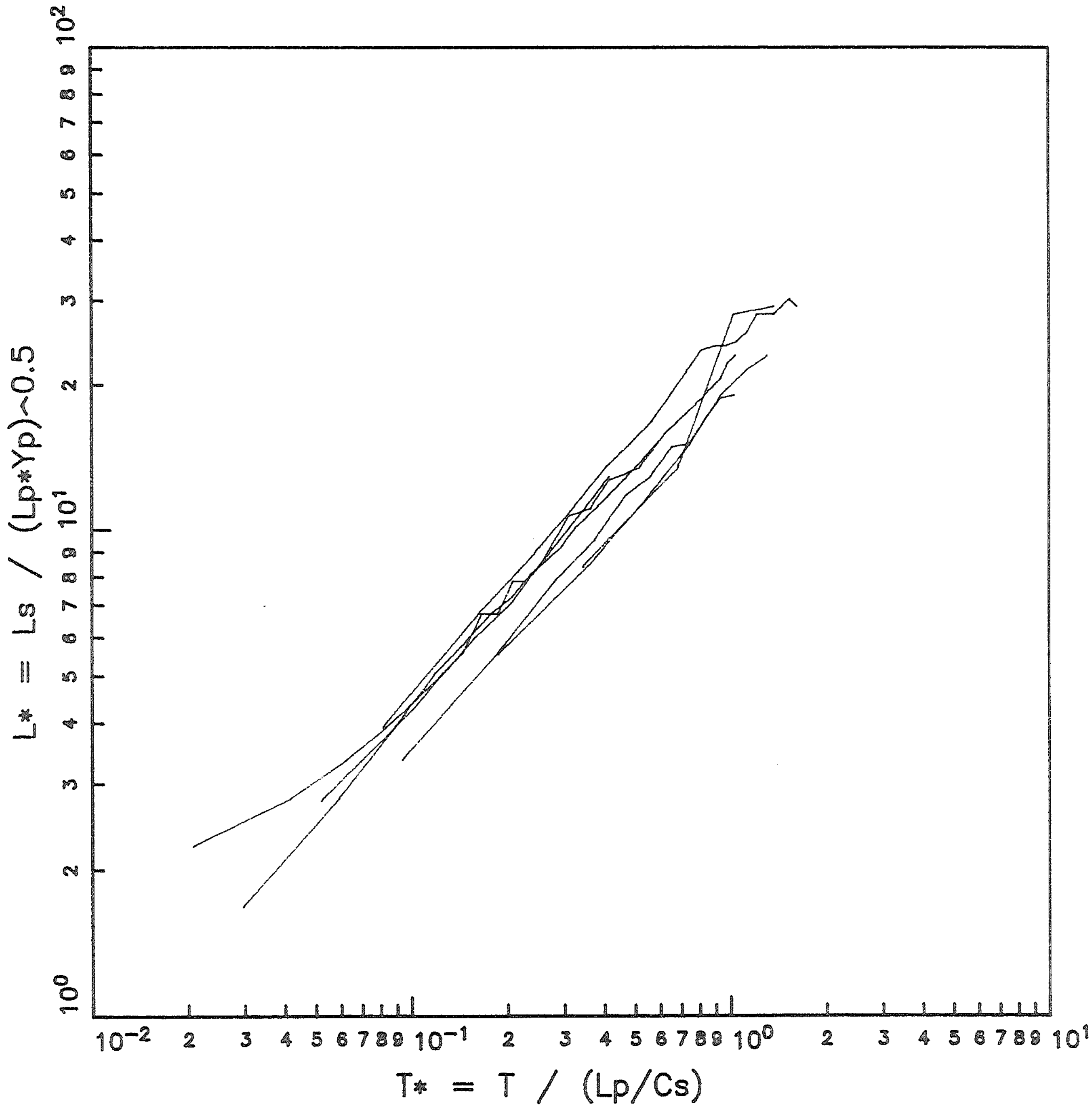


Figure E.9. Normalized Downstream Scour Length Graph (q = 160 cfs/ft)

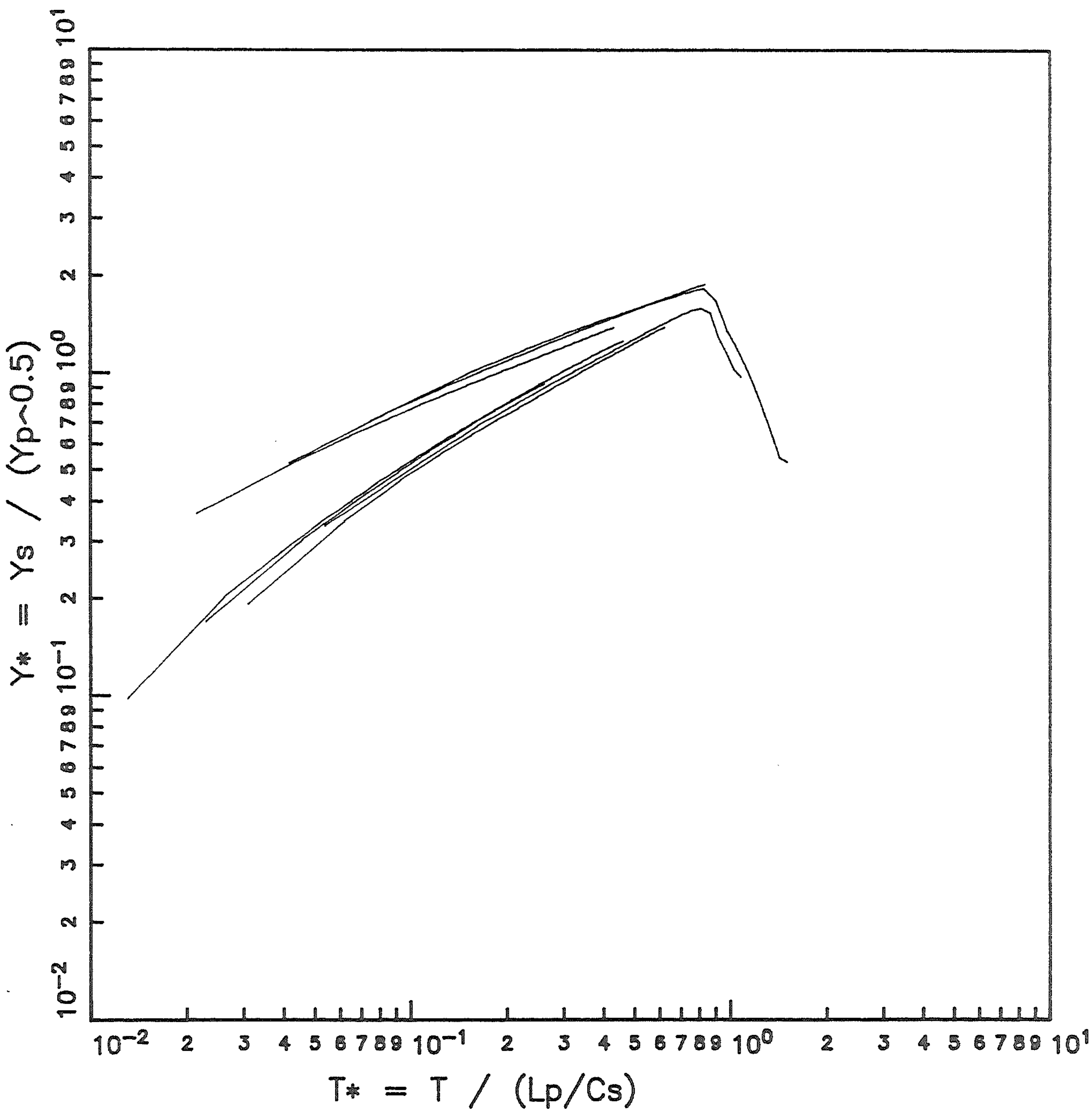


Figure E.10. Normalized Downstream Scour Depth Graph (q = 20 cfs/ft)

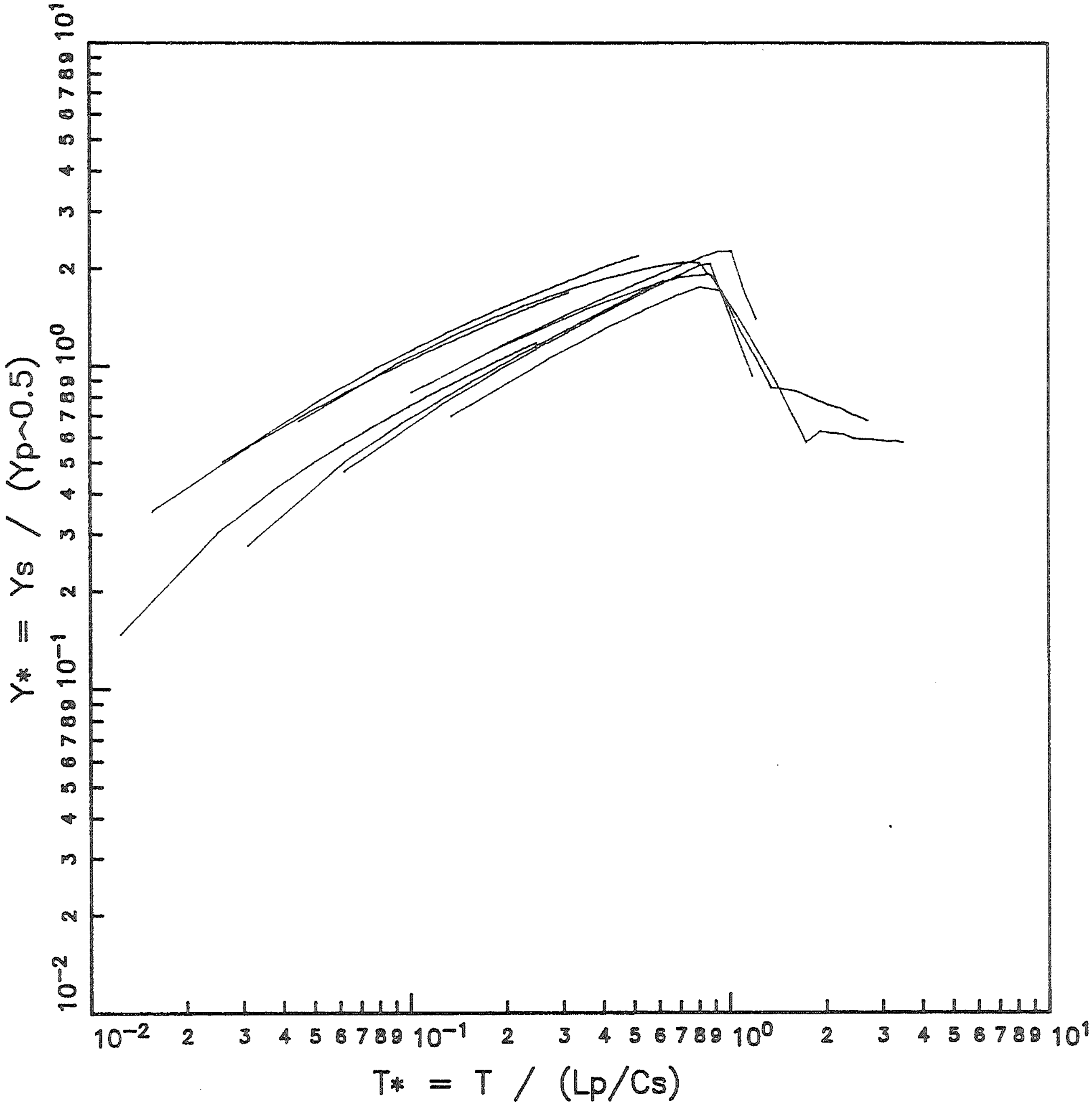


Figure E.11. Normalized Downstream Scour Depth Graph (q = 40 cfs/ft)

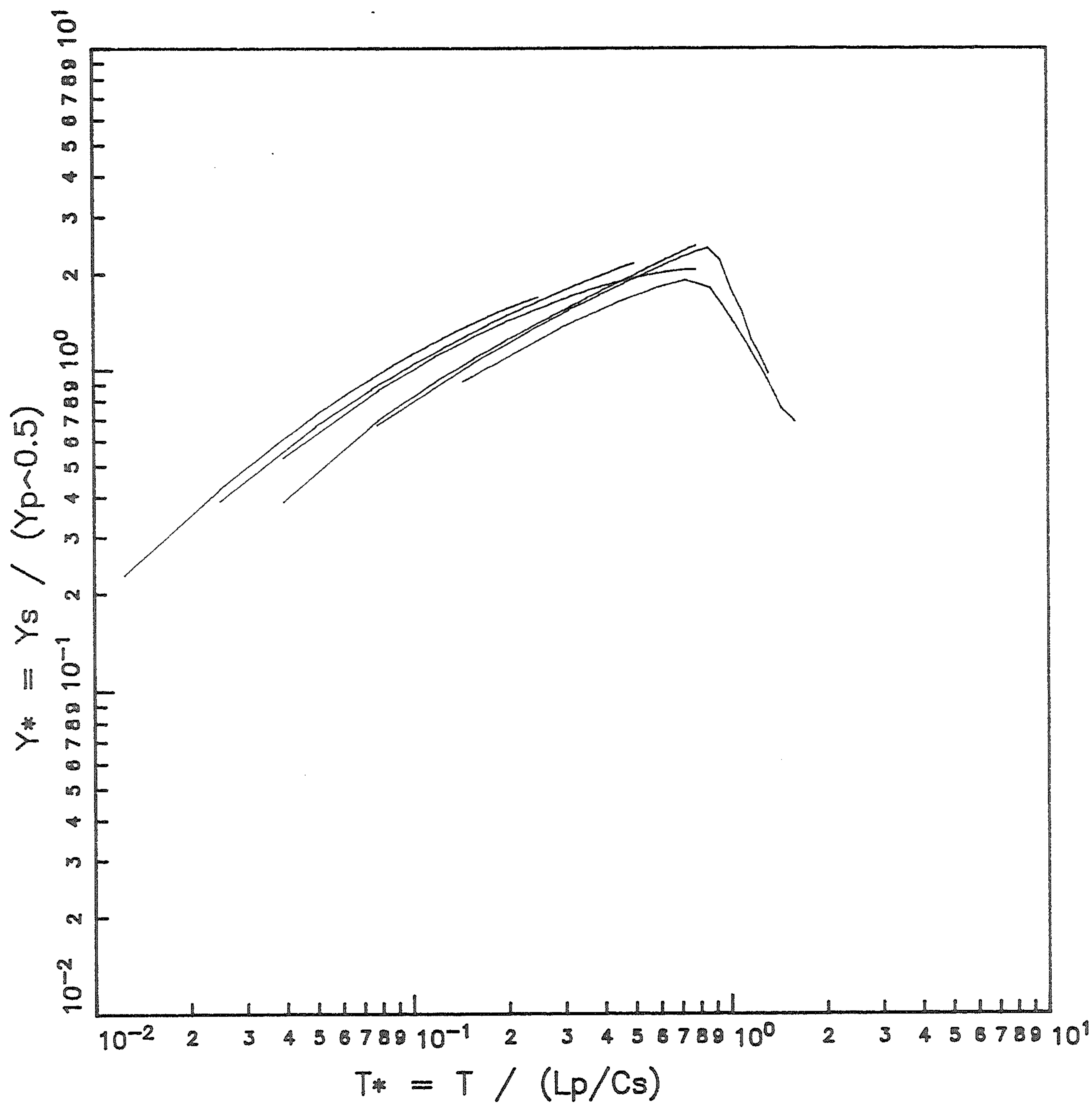


Figure E.12. Normalized Downstream Scour Depth Graph (q = 80 cfs/ft)

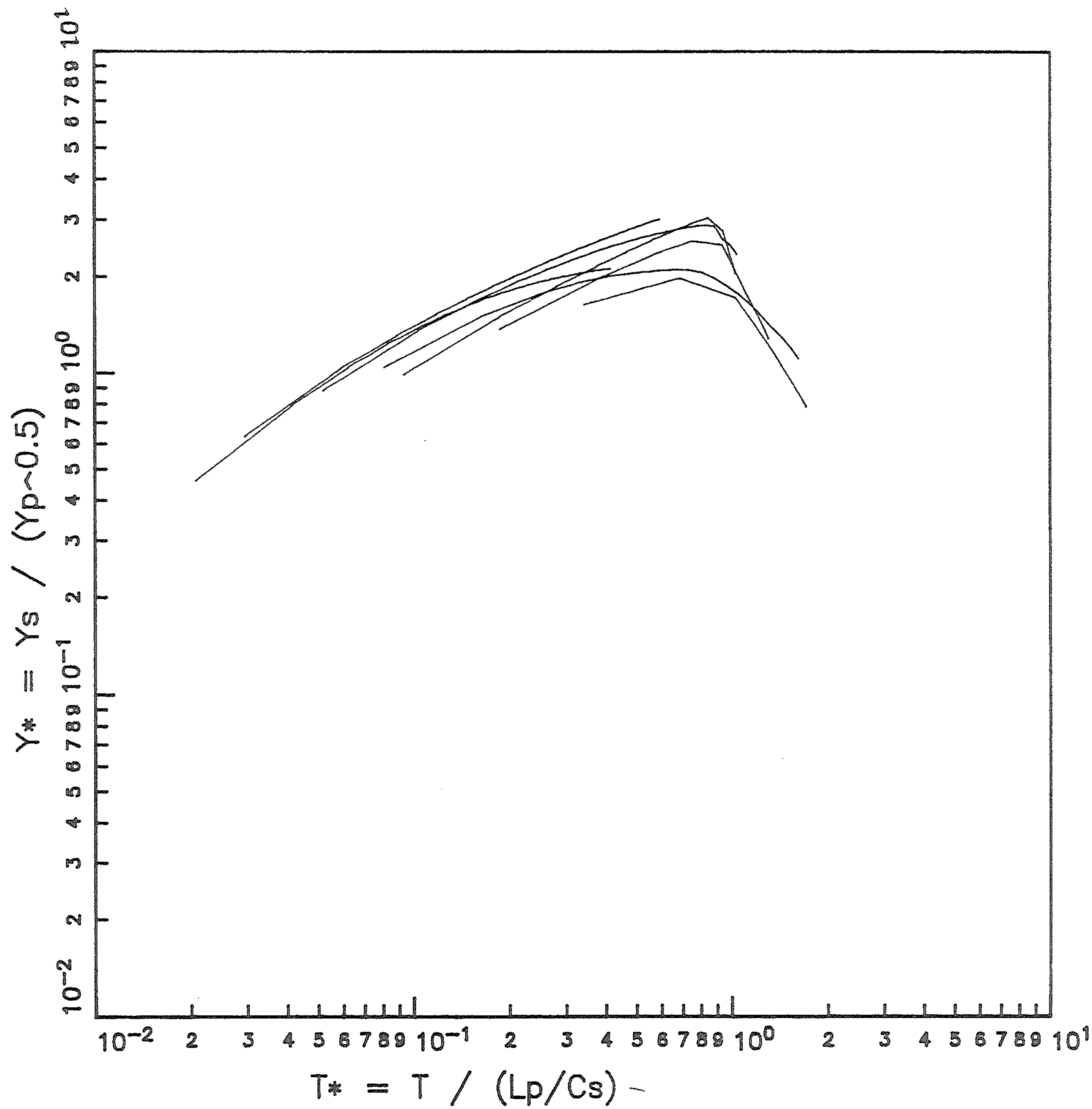


Figure E.13. Normalized Downstream Scour Depth Graph (q = 160 cfs/ft)

q = 20 cfs/ft

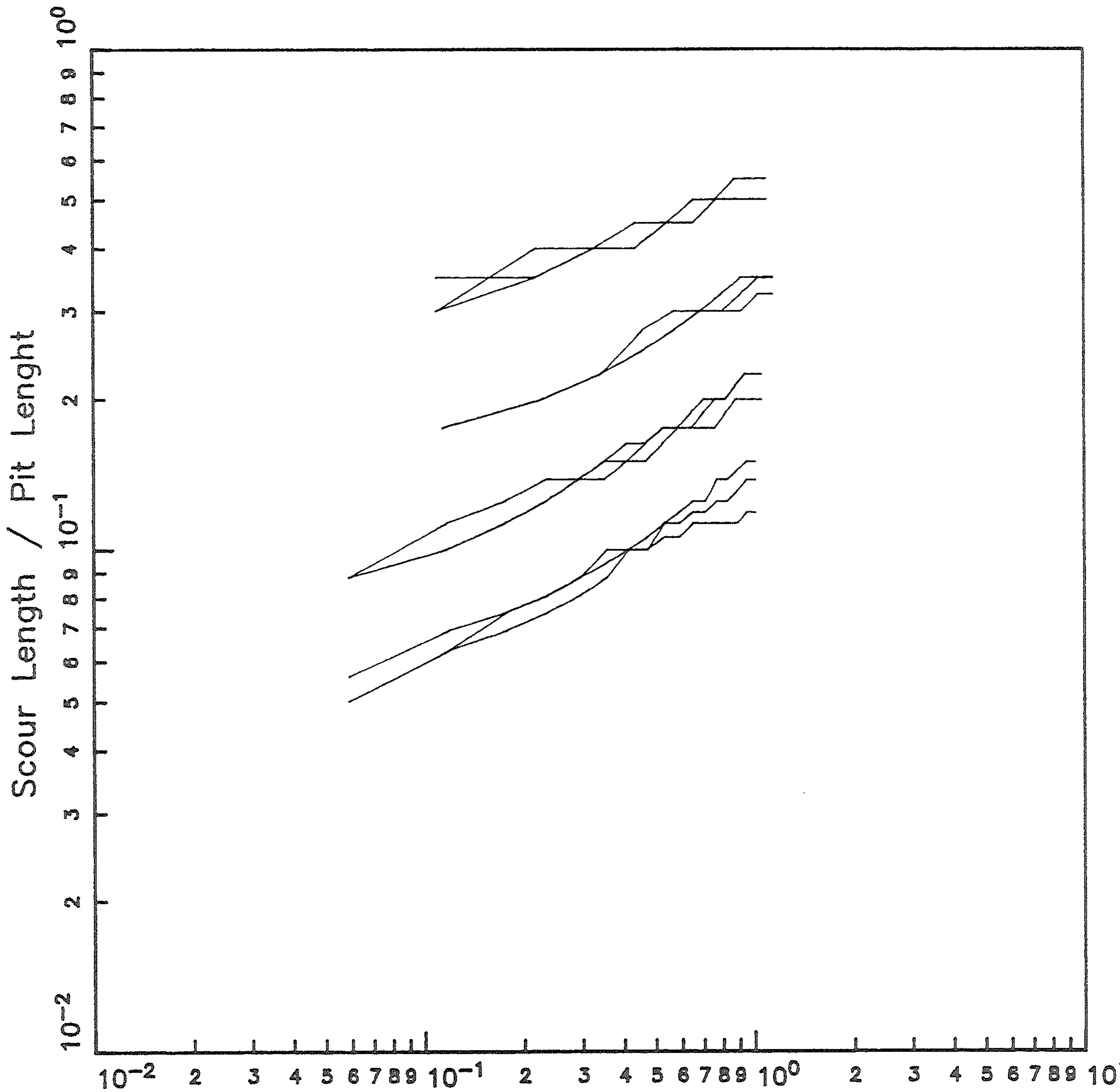


Figure E.14. Normalized Upstream Scour Length Graph (q = 20 cfs/ft)

q = 40 cfs/ft

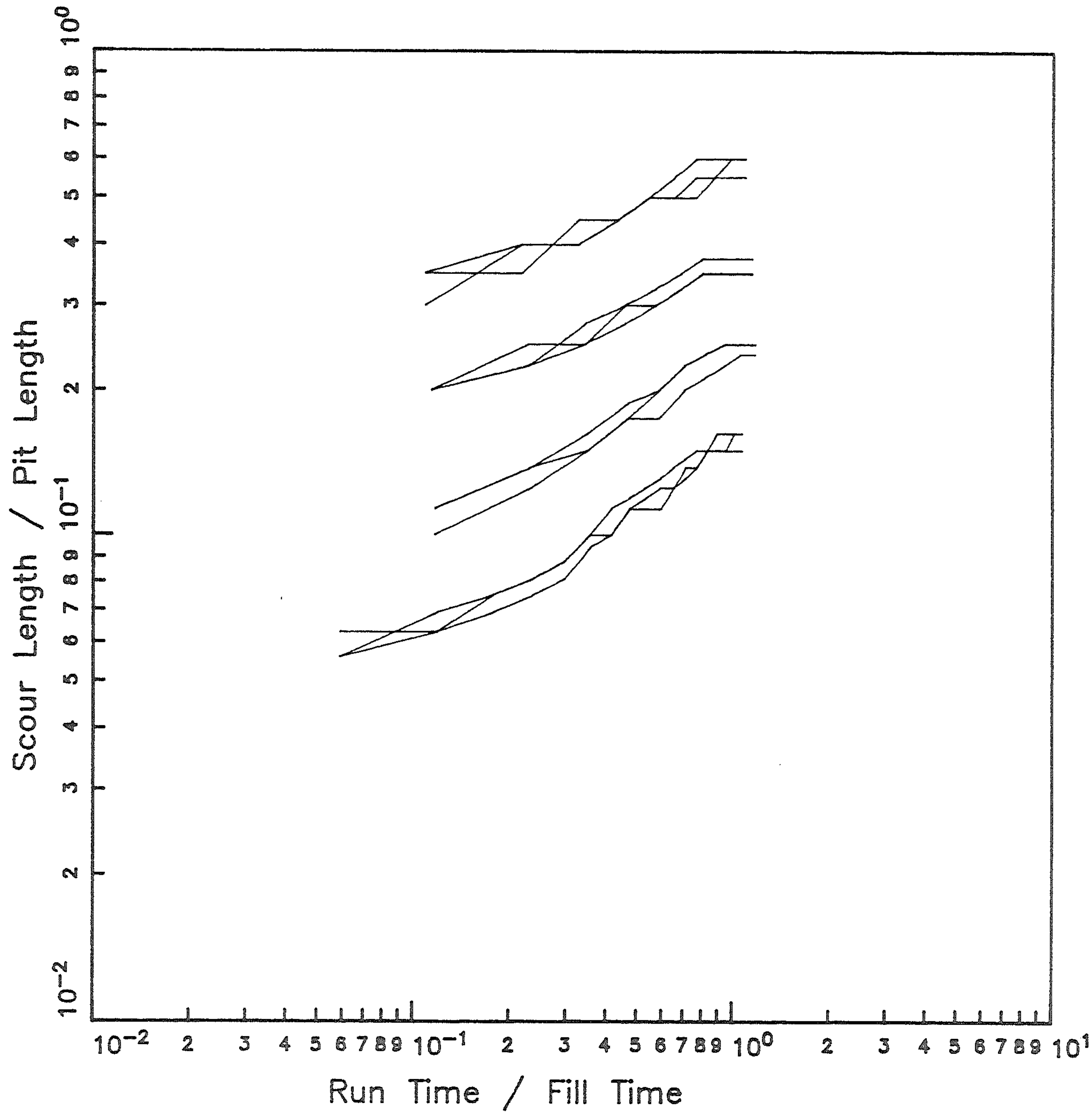


Figure E.15. Normalized Upstream Scour Length Graph (q = 40 cfs/ft)

q = 80 cfs/ft

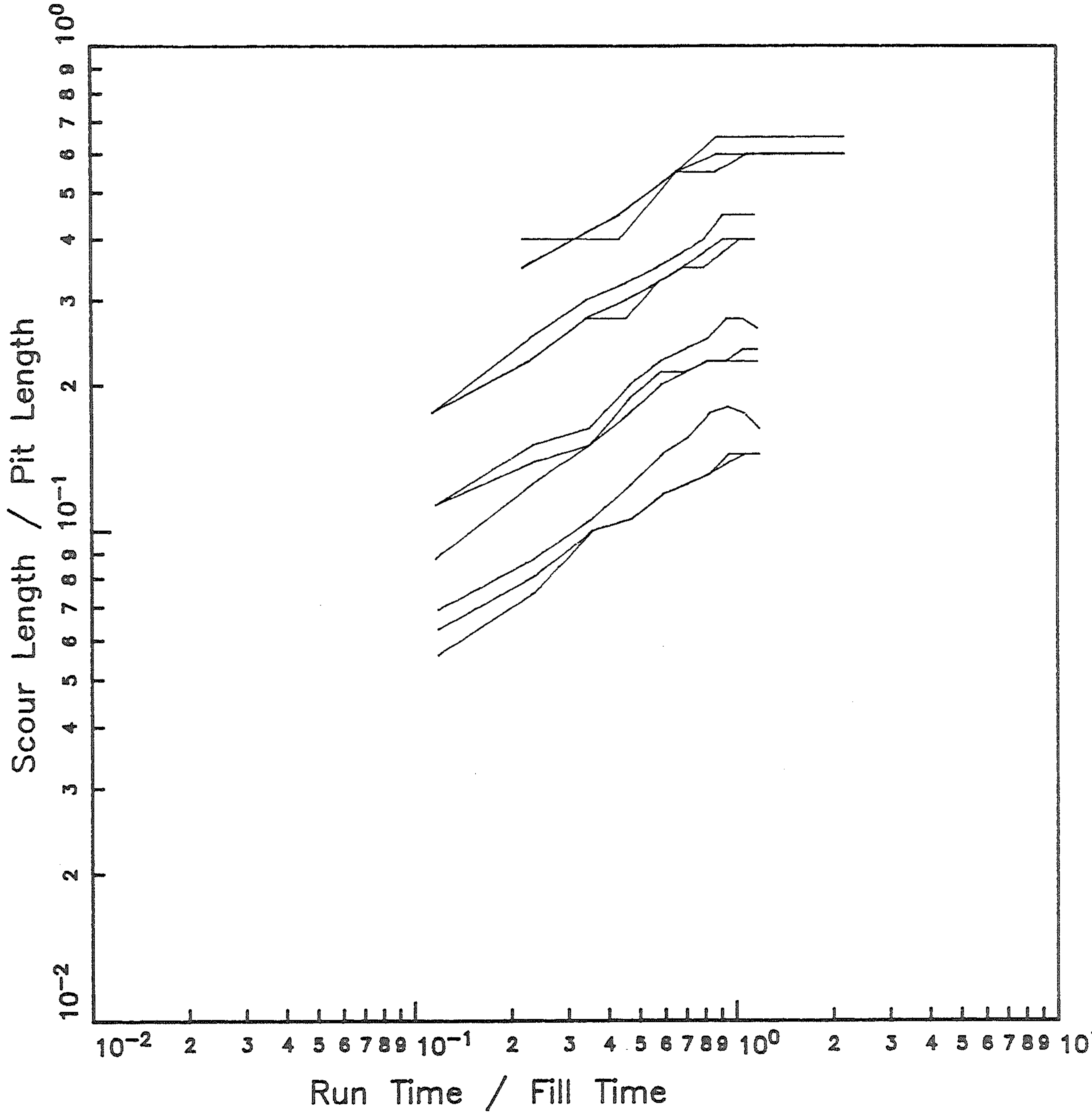


Figure E.16. Normalized Upstream Scour Length Graph (q = 80 cfs/ft)

q = 160 cfs/ft

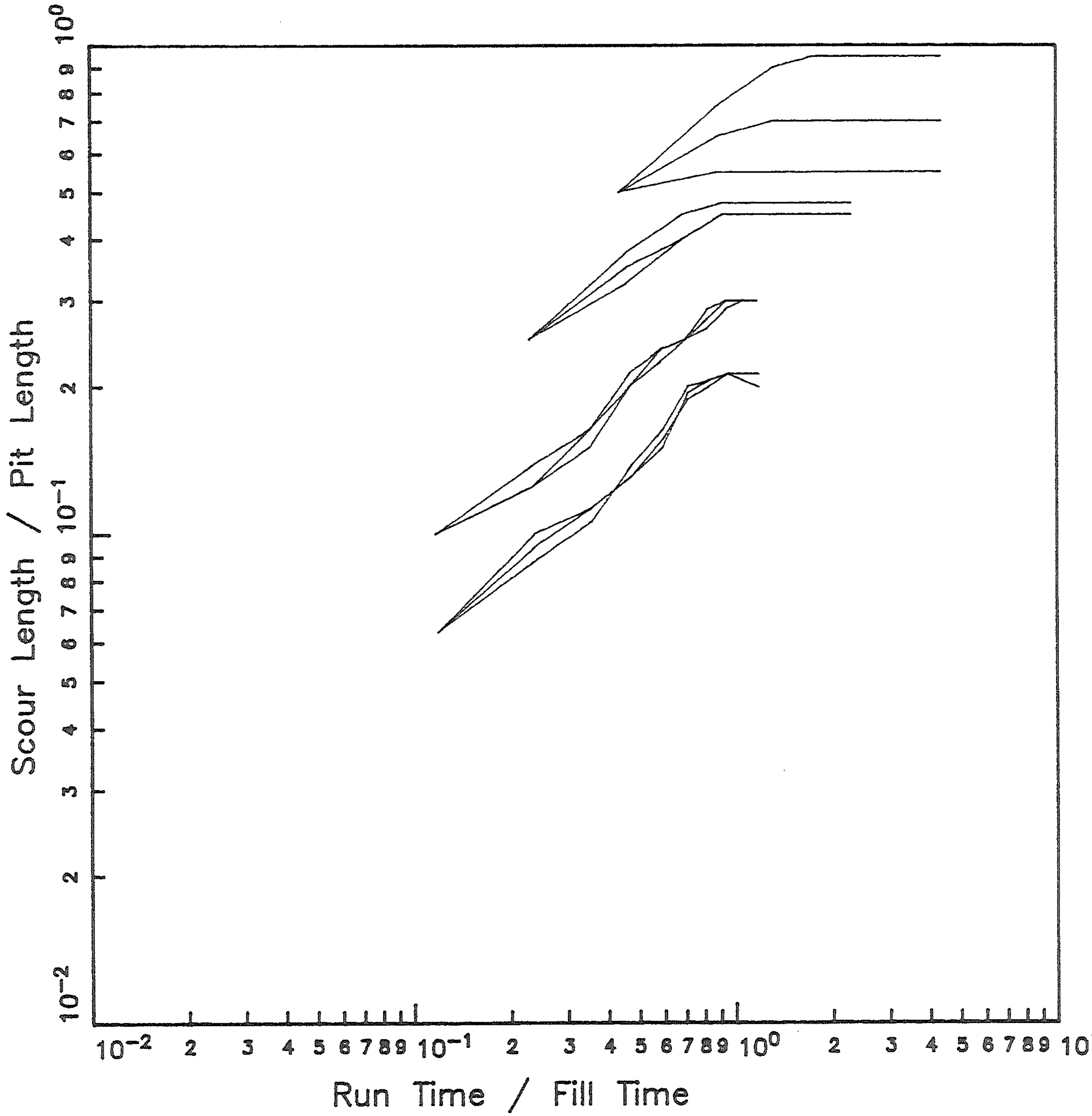


Figure E.17. Normalized Upstream Scour Length Graph (q = 160 cfs/ft)

q = 20 cfs/ft

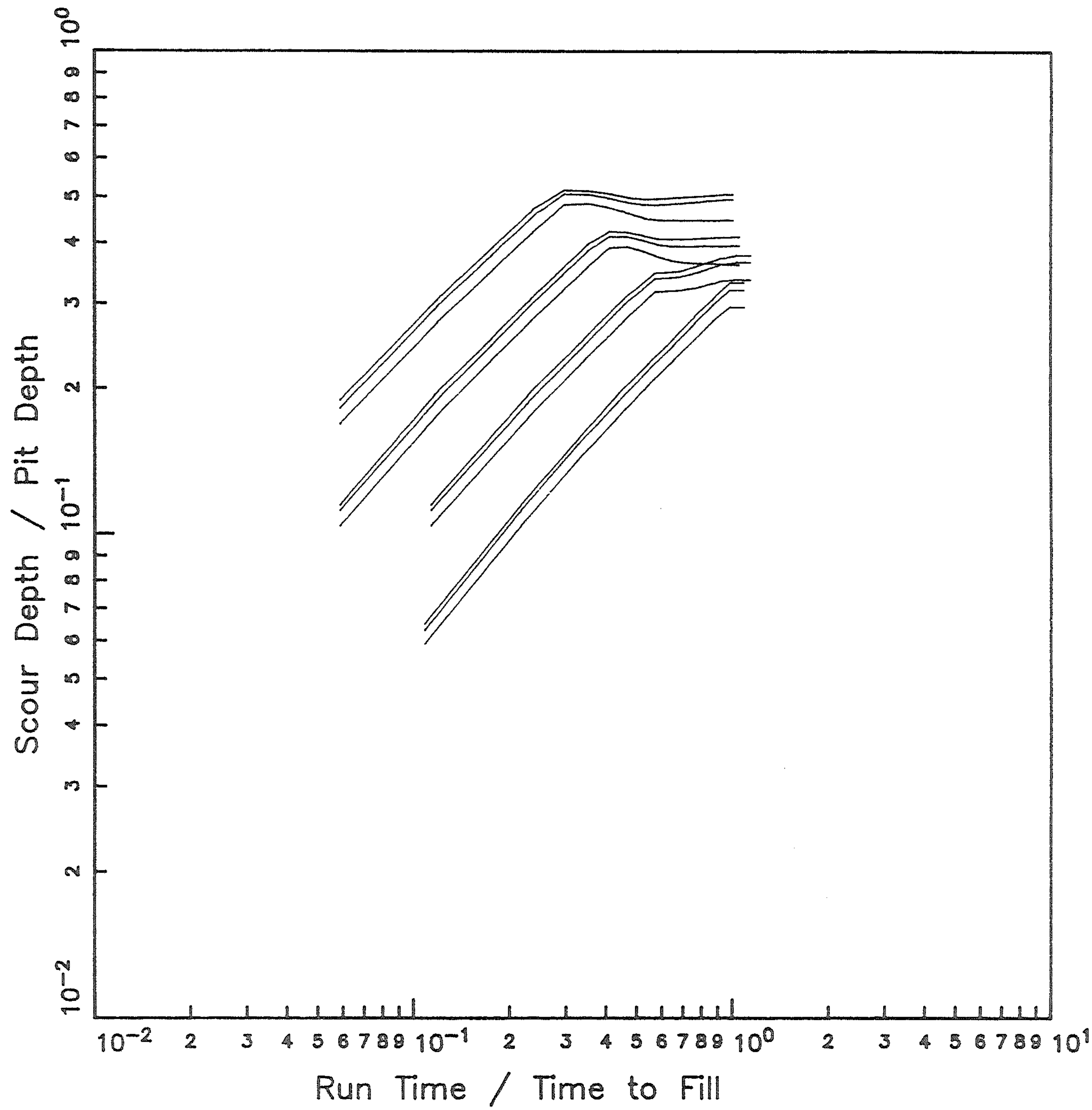


Figure E.18. Normalized Upstream Scour Depth Graph (q = 20 cfs/ft)

q = 40 cfs/ft

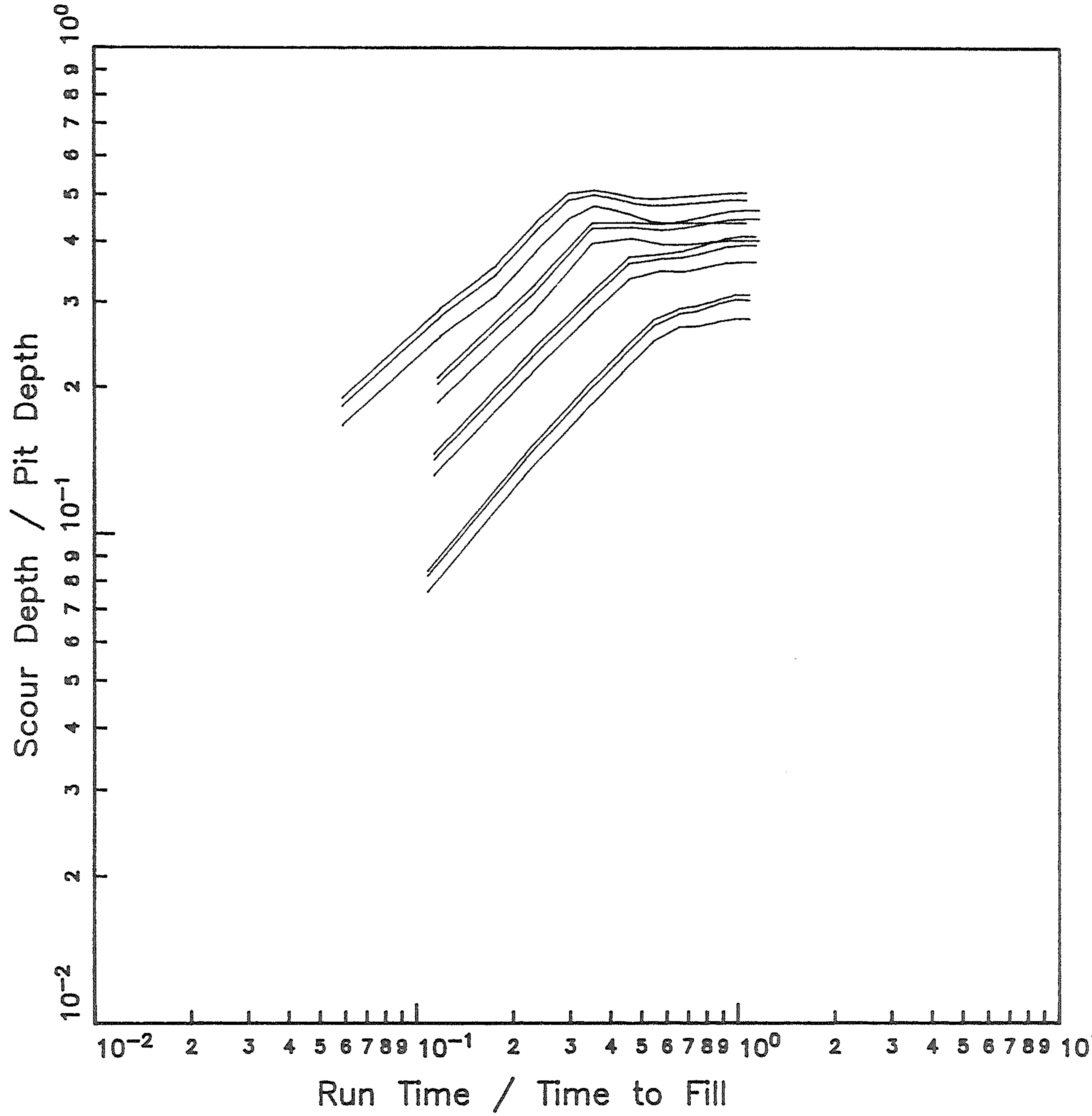


Figure E.19. Normalized Upstream Scour Depth Graph (q = 40 cfs/ft)

q = 80 cfs/ft

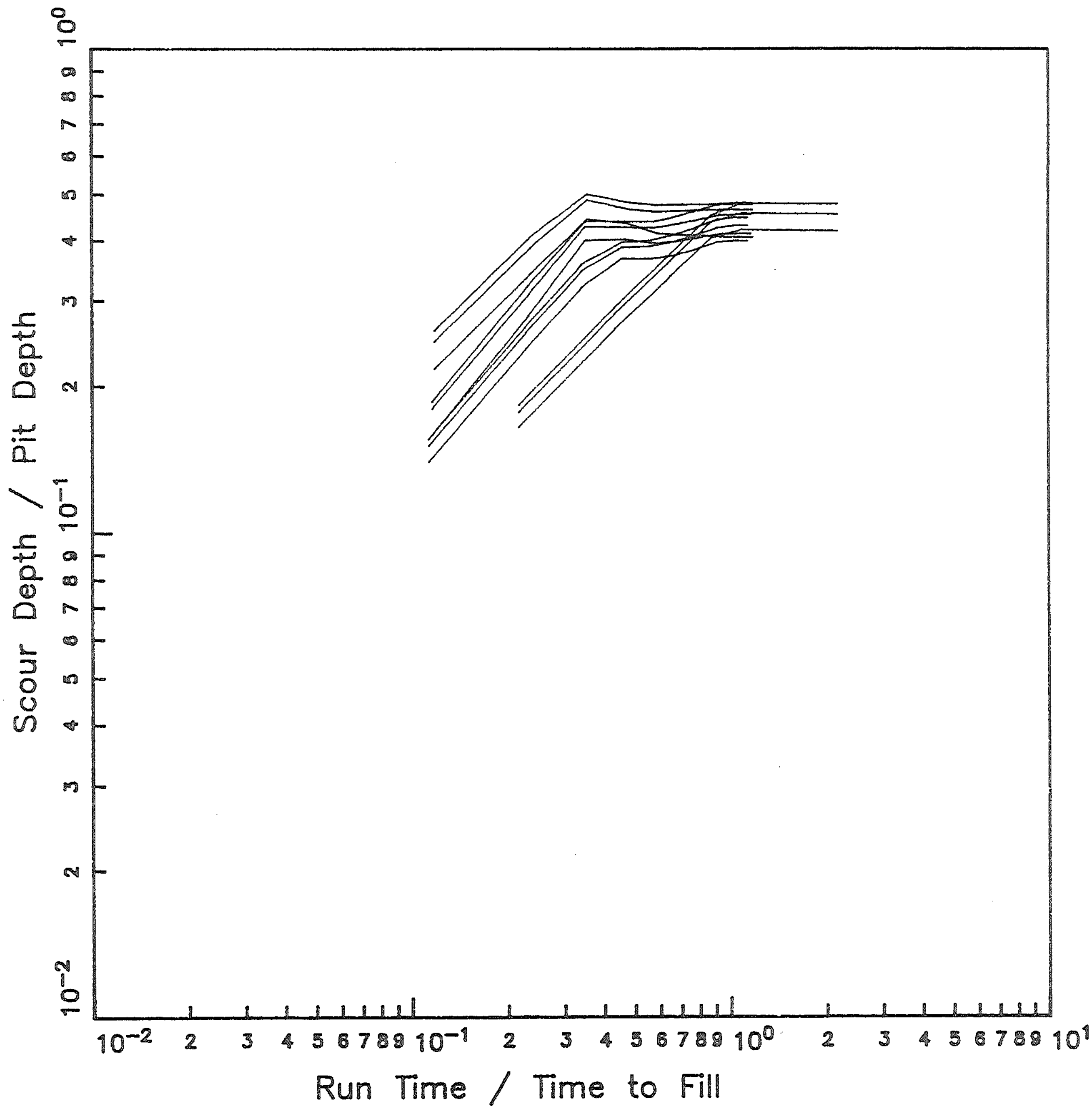


Figure E.20. Normalized Upstream Scour Depth Graph (q = 80 cfs/ft)

q = 160 cfs/ft

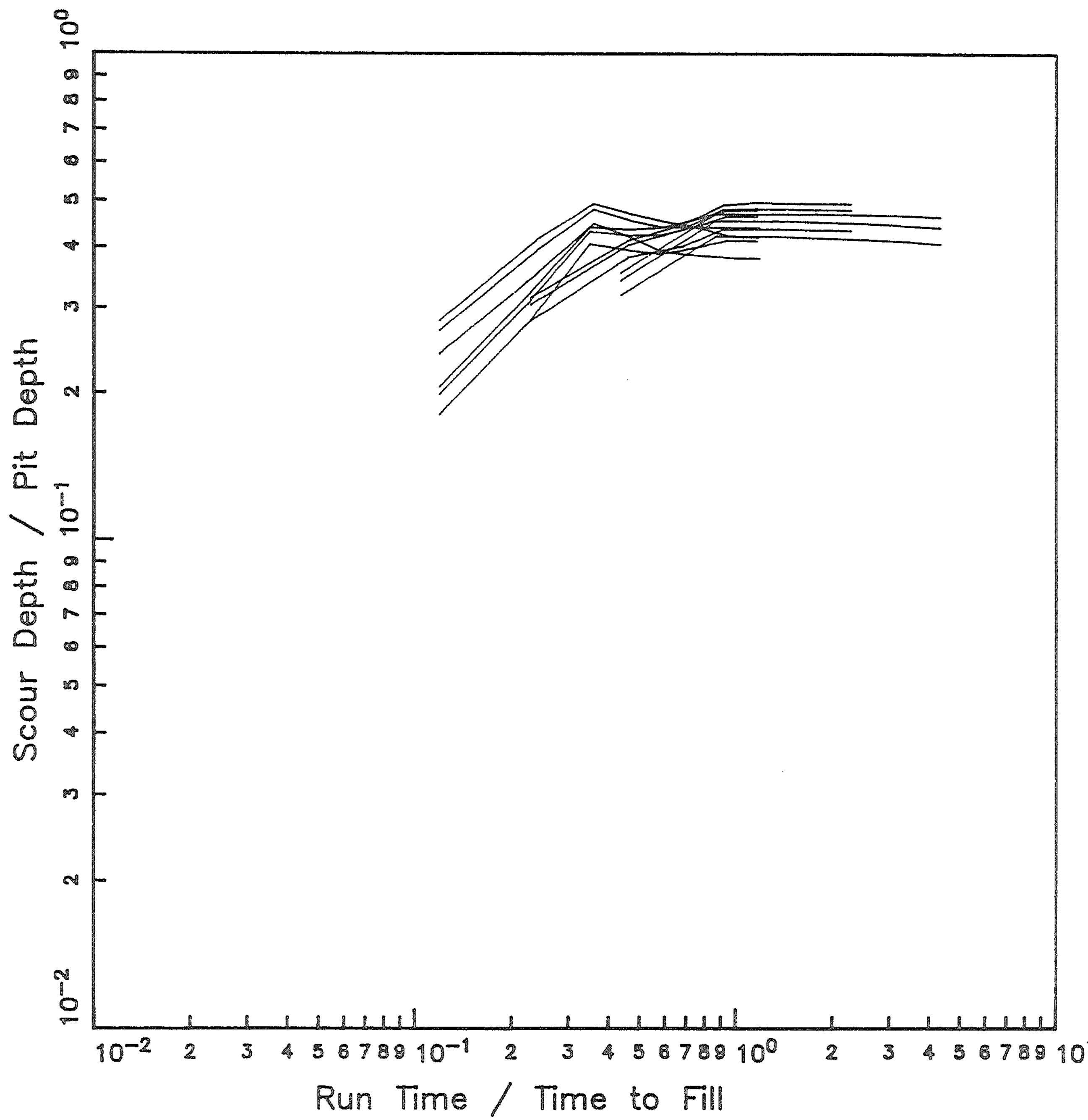


Figure E.21. Normalized Upstream Scour Depth Graph (q = 160 cfs/ft)

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```
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);
```

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

begin
  with recpack do
  begin
    ax := $2a shl 8;
  end;
  MsDos(recpack);                         { call function }
  with recpack 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
  recpack:          regpack;              {assign record}
  ah,al,ch,cl,dh:   byte;
  hour,min,sec:     string[2];

begin
  ah := $2c;                              {initialize correct registers}
  with recpack do
  begin
    ax := ah shl 8 + al;
  end;
  intr($21,recpack);                      {call interrupt}
  with recpack 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 & Asssociates
                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
```

```
      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^.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 & Asssociates 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 }
  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 + 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;
{-------------------------------------------------------------------------}
```

```
{
                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 & Asssociates 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.')
end;
{--------------------------------------------------------------------------}
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;
```

```
{-----------------------------------------------------------------------------}
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,            { Cummulative 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;
      dzt := dzt + dzf[m];
      dbt := dbt + dbf[m]
```

```
    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 tranport 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
  j, 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,nsize,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 }
```

```
      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');
```

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

begin
  with recpack do
  begin
    ax := $2a shl 8;
  end;
  MsDos(recpack);                        { call function }
  with recpack 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
  recpack:          regpack;              {assign record}
  ah,al,ch,cl,dh:   byte;
  hour,min,sec:     string[2];

begin
  ah := $2c;                              {initialize correct registers}
  with recpack do
  begin
    ax := ah shl 8 + al;
  end;
  intr($21,recpack);                      {call interrupt}
  with recpack 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;
{-----------------------------------------------------------------------------}
```

```
{
                Procedures for program CRISM11
                Include file name : MEM11.LIB
                Description       : Linked list procedures
                Programmers       : Robert J. Smolinsky, P.E.
                                    George K. Cotton, P.E.
                                    Simons, Li & Asssociates
                Last revision     : February 2, 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
```

```
      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^.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 CRISM
                File name: HYD.LIB
                Description : Hydraulic routines
                Include file for program CRISM.PAS

                Simons, Li & Asssociates 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;
{-------------------------------------------------------------------------}
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 & Asssociates 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);
      zbi[j] := HydRec.zb;
      new(Root);                      { Create empty dynamic record }
      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);   Write(Title1);
    Gotoxy(5,6);   Write(Title2);
    Gotoxy(5,8);   Write(' # of x-sections     = ',nsec:4);
    Gotoxy(5,9);   Write(' # of time steps     = ',ntime:4);
    Gotoxy(5,10);  Write(' Output interval     = ',tintprt:4);
    Gotoxy(5,11);  Write(' DS Pit X-Section    = ',DSPitSecNum:4);
    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:6:4);
    Gotoxy(33,11); Write(' Plot file output    = '); if PlotInd = 1 then write('Yes') else write('No');
    Gotoxy(5,12);  Write('-----------------------------------------------------------');
    Gotoxy(5,13);  Write(' Mean particle size (mm)  : ',D50*304.8:6:2);
    Gotoxy(5,14);  Write(' Gradation coefficient    : ',Grd:6:2);
    Gotoxy(5,19);  Write('-----------------------------------------------------------')
  end
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:7:2);
        Write(FV2,' ',    zb:8:3);
        Write(FV2,' ', depth+zb:8:2);
        Write(FV2,' ',    Ab*57.296:6:2);
        Write(FV2,' ',  segl:8:5);
        Write(FV2,' ',   vel:6:2);
        Write(FV2,' ',    nc:6:3);
        Write(FV2,' ',   tau:6:2);
        Write(FV2,' ',    Gt:6:3);
```

```
      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
        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;
{----------------------------------------------------------------------------}
```

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, as 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.

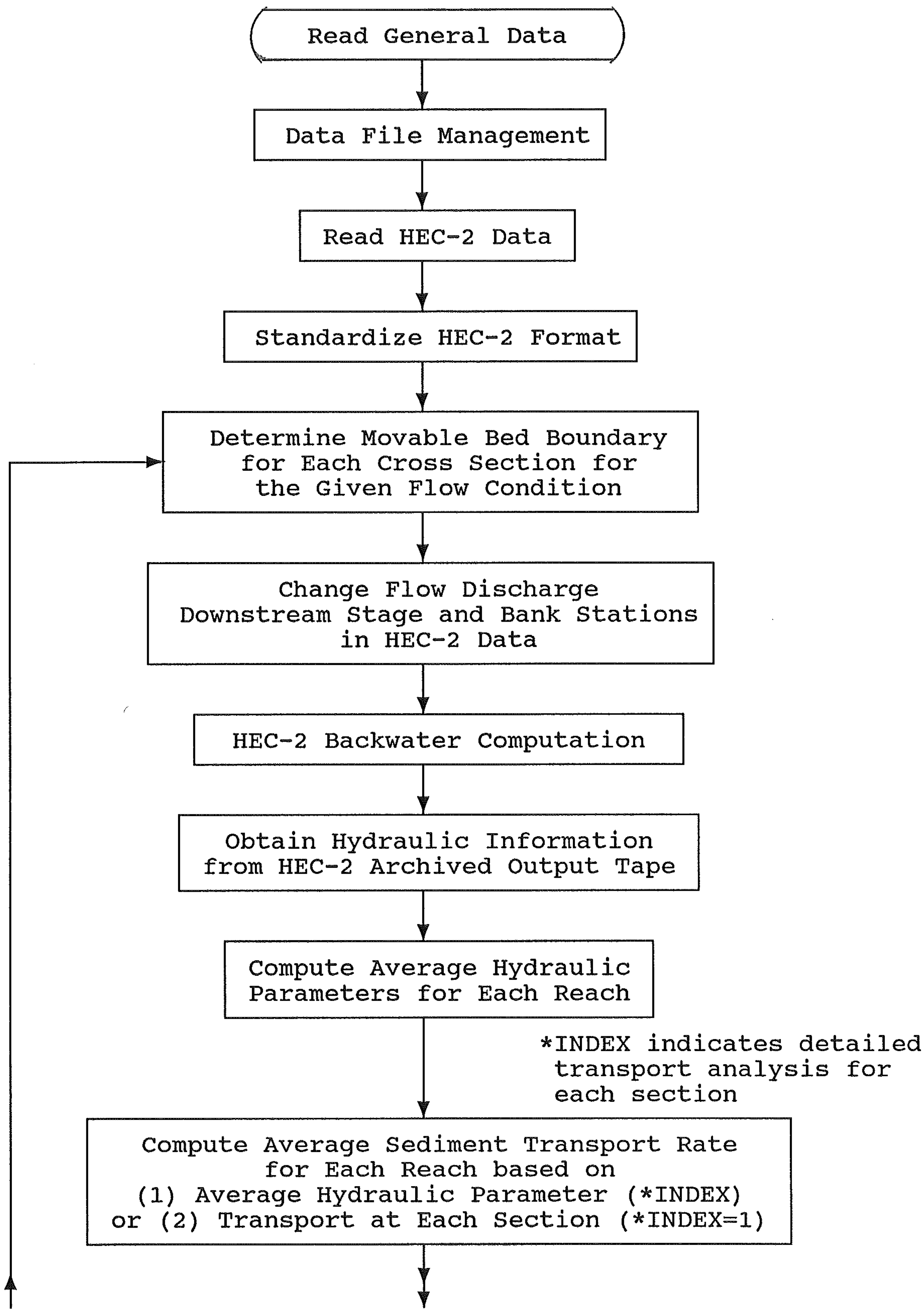
F.2 Program Operation

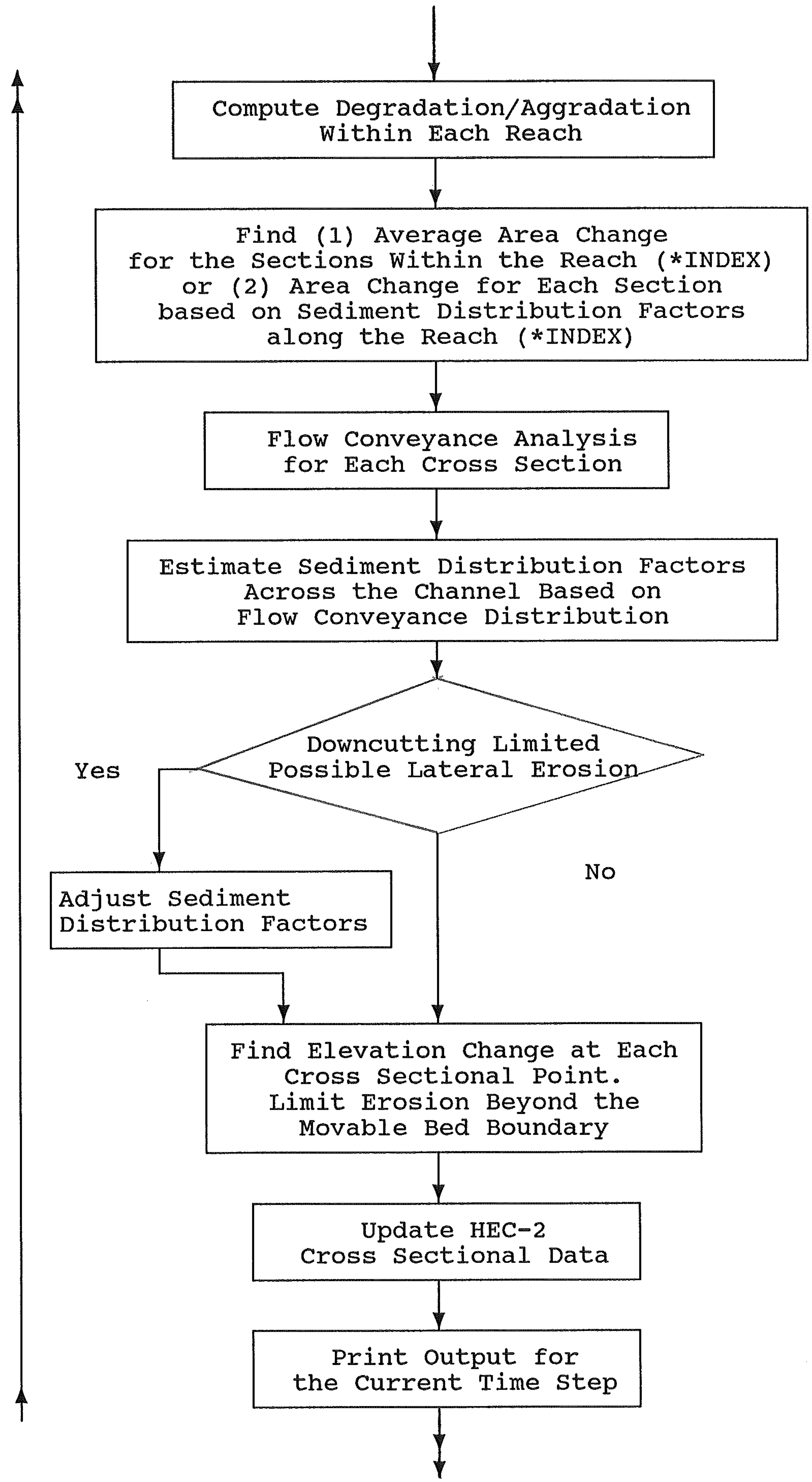
Model HEC-2SR contains the HEC-2 program and nine other computer programs, all coded in Fortran IV. These ten programs perform the modular functions for hydraulic, sediment transport, and degradation or aggradation computations as illustrated in Figure F.1. A command file was prepared to execute these 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.


Read General Data
Data File Management
Read HEC-2 Data
Standardize HEC-2 Format
Determine Movable Bed Boundary for Each Cross Section for the Given Flow Condition
Change Flow Discharge Downstream Stage and Bank Stations in HEC-2 Data
HEC-2 Backwater Computation
Obtain Hydraulic Information from HEC-2 Archived Output Tape
Compute Average Hydraulic Parameters for Each Reach
*INDEX indicates detailed transport analysis for each section
Compute Average Sediment Transport Rate for Each Reach based on (1) Average Hydraulic Parameter (*INDEX) or (2) Transport at Each Section (*INDEX=1)


Compute Degradation/Aggradation Within Each Reach
Find (1) Average Area Change for the Sections Within the Reach (*INDEX) or (2) Area Change for Each Section based on Sediment Distribution Factors along the Reach (*INDEX)
Flow Conveyance Analysis for Each Cross Section
Estimate Sediment Distribution Factors Across the Channel Based on Flow Conveyance Distribution
Downcutting Limited Possible Lateral Erosion
Yes
No
Adjust Sediment Distribution Factors
Find Elevation Change at Each Cross Sectional Point. Limit Erosion Beyond the Movable Bed Boundary
Update HEC-2 Cross Sectional Data
Print Output for the Current Time Step

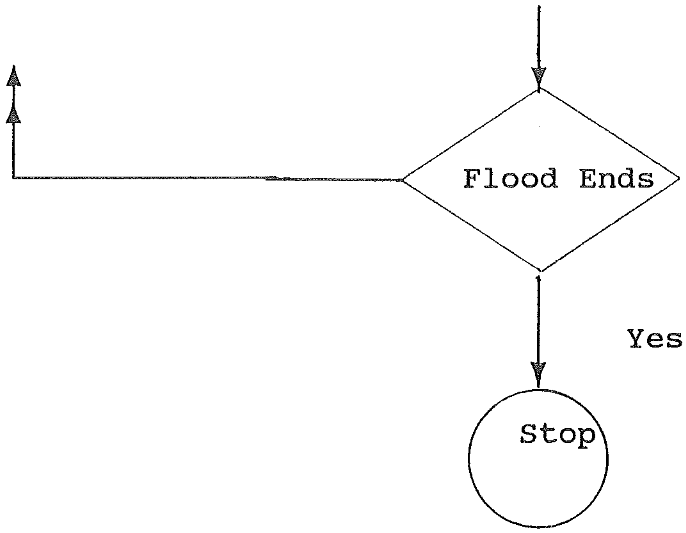


Figure F.1. Flow Chart

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 of 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:

	format
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 (HECXS) 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

WGTFACT: 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 tract 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.

INPUT FILE	PROGRAM	OUTPUT FILE
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	WGTFACT
HECSTD, RCHDAT QDAT, AREAFAC, WGTFACT	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 rchtemp.qua rchdat.qua
DEL QDAT.QUA > NUL
rename qtemp.qua qdat.qua
weicavc > nul
chdcavc > 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='MOVBDY.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,*)'      *******     IBM 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 60 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     MOVABILE 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(6E12.5)
      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
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C !!!!CHANGE!!!! "WRTJ1(IA)" TO "WRTJ1"
C
      SUBROUTINE WRTJ1
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
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
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C !!!!CHANGE!!!! "WRTX1(JP,JS,IA)" TO "WRTX1(JP,JS)"
C
      SUBROUTINE WRTX1(JP,JS)
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
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!!!! "8F8.0" 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
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C !!!!CHANGE!!!! "WRTGR(JP,JS,IA)" TO "WRTGR(JP,JS)"
C
      SUBROUTINE WRTGR(JP,JS)
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
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
```

```
      JS = JS + 1
      WRITE(2,502) (ZF(L),XF(L),L=1,NP)
C
C !!!!CHANGE!!!! "F8.0,4(F8.2,F8.0)" TO "9F8.2"
  502 FORMAT('GR',F6.2,9F8.2)
      RETURN
      END
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
      SUBROUTINE WRTQT(JP,JQ)
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
      COMMON/BLKA/  QE,STG,RLM(150),RRM(150),NP,NRUN
      JP = 1
C
C     TRIBUTARY CONTRIBUTES 2% DISCHARGE - SANTA PAULA CREEK
C
      IF ( JQ .EQ. 2 ) QE = QE *.98
      WRITE (2,500) QE
  500 FORMAT ('QT     1',F8.0)
      JQ = JQ + 1
      RETURN
      END
```

```
      PROGRAM INFCAVC
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
      CHARACTER LINE*4
C
      OPEN(16,FILE='HEC96.QUA',STATUS='OLD')
      OPEN(18,FILE='HYDINF.QUA',STATUS='NEW')
      OPEN(6,FILE='WSINF.QUA',STATUS='NEW')
C
   10 READ(16,100) LINE
C
C !!!!CHANGE!!!! "FORMAT(A132)" TO "FORMAT(A4)"
C
  100 FORMAT(A4)
C
C !!!!CHANGE!!!! "LINE(1:4)" TO "LINE"
C
      IF(LINE.NE.'4444') GOTO 10
   20 READ(16,100) LINE
C
C !!!!CHANGE!!!! "LINE(1:4)" TO "LINE"
C
      IF (LINE.EQ.'5555') STOP
C
C !!!!CHANGE!!!! ADD "BACKSPACE(16)"
C
      BACKSPACE(16)
C
C !!!!CHANGE!!!! READ "SEGL", THE SLOPE OF THE ENERGY GRADE LINE
C
      READ(16,102) CWSEL,SEG,TOPWID,SEGL
      READ(16,104) QLOB,QCH,QROB
      READ(16,106) STCHL,STCHR,XLBEL,RBEL
      READ(16,108) VCH
      READ(16,110) SECNO,XLCH
      READ(16,112) ELMIN,Q
      READ(16,113) SSTA,ENDST,VLOB,VROB
C
C !!!!CHANGE!!!! "2E16.8" TO "3E16.8"
C
  102 FORMAT(E16.8,16X,3E16.8)
  104 FORMAT(64X,3(2X,E14.8))
  106 FORMAT(64X,4(2X,E14.8))
  108 FORMAT(18X,E14.8)
  110 FORMAT(80X,2(2X,E14.8))
  112 FORMAT(16X,2(2X,E14.8))
  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 = EDITTED 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 ELMIN(150),TOPCH(150),QCH(150)  ,VCH(150)  ,XLCH(150) ,
     $          BNKWL(150),VLOB(150) ,QLOB(150) ,BNKWR(150),VROB(150) ,
     $          QROB(150) ,DHM(150)  ,DHL(150)  ,DHR(150)  ,VWM(150)  ,
     $          VWL(150)  ,VWR(150)  ,DWM(150)  ,DWL(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 RDX(50),ZBL(50,10),DZ(50),TQT(30),DTT(30),GSSM(50)
C
C !!!!CHANGE!!!! ADD "DIMENSION SEGL(150) AND EGLAVE(150)"
C
      DIMENSION VCHT(150),DHM(150),TOPCH(150),SEGL(150)
      DIMENSION VLOBT(150),DHL(150),BNKWL(150),EGLAVE(150)
      DIMENSION VROBT(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 !!!!CHANGE!!!! 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 !!!!CHANGE!!!! "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
      DO 15 IR=1,NREACH
C
C !!!!CHANGE!!!! READ "EGLAVE(IR)"
C
      READ(8) VCH(IR),DCH(IR),WCH(IR),VLOB(IR),DLOB(IR),WLOB(IR),
     &        VROB(IR),DROB(IR),WROB(IR),EGLAVE(IR)
   15    CONTINUE
      IS = 1
C
C !!!!CHANGE!!!! READ "SEGL(IS)"
C
   25 READ(10,190,END=200) VCHT(IS),DHM(IS),TOPCH(IS),
     +                 VLOBT(IS),DHL(IS),BNKWL(IS),
     +                 VROBT(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
      DO 30 J = 1,IS
      AFAC(J) = 1.
      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
      CALL SEDTR(EGLAVE(IR),DCH(IR),WCH(IR),NSIZ,GBCM)
C
C     LEFT BANK
C
C !!!!CHANGE!!!! REPLACE "VLOB(IR)" WITH "EGLAVE(IR)"
C
```

```
      CALL SEDTR(EGLAVE(IR),DLOB(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),BNKWL(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
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
      SUBROUTINE SEDIN(NRUN,NQ,NSIZ,QS)
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
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
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C !!!!CHANGE!!!! THIS SUBROUTINE IS ENTIRELY DIFFERENT FROM LAN-YIN'S
C
      SUBROUTINE SEDTR(S,D,W,NSIZ,QS)
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
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='WGTFACT.QUA',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 ELSED
C
      IF(KFLAG.NE.1) GO TO 55
         DO 53 I=1,ND
           IF(Z(NSEC,I).LT.ELSED) Z(NSEC,I)=ELSED
   53      CONTINUE
C
C     SET THE MANNING ROUGHNESS VALUE FOR EACH SEGMENT OF THE
C     CROSS SECTION

   55 IF (JFLAG .NE. 1) GO TO 70
      DO 80 I=1,ND

      IF(X(NSEC,I) .LE. STCHL(NSEC)) F(NSEC,I)=XNL
      IF(X(NSEC,I) .GT. STCHL(NSEC) .AND. X(NSEC,I) .LE. STCHR(NSEC))
     +  F(NSEC,I)=XNCH
      IF(X(NSEC,I) .GT. STCHR(NSEC)) F(NSEC,I)=XNR
   80 CONTINUE
      GO TO 10
   70 DO 90 I=1,ND
        IF(X(NSEC,I) .GT. STN(1)) GO TO 100
          F(NSEC,I)=VALN(1)
            GO TO 90
  100 DO 110 J=2,NUM
        IF(X(NSEC,I) .GT. STN(J-1) .AND. X(NSEC,I) .LE. STN(J))
     +    F(NSEC,I)=VALN(J)
  110 CONTINUE
   90 CONTINUE
      GO TO 10
C
C      READ X3 CARD
C
C !!!!CHANGE!!!! THE SAME BACKSPACE AND READ STATEMENT CHANGES AS ABOVE
C
  120 BACKSPACE(5)
      READ(5,360) IEARA(NSEC),ELSED,ENCFP,STENCL(NSEC),ELENCL(NSEC),
     &            STENCR(NSEC),ELENCR(NSEC)
  360 FORMAT(2X,I6,9F8.2)
      IF(ELSED.NE.0.0) KFLAG=1
      GO TO 10
  789 RETURN
      END

      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
      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)
```

```
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
      IF(IEARA(K).NE.10) GO TO 200
C
C      FIND STATION CORRESPONDING TO LEFT AND RIGHT OVERBANK.
C
         DO 210 I=1,N
            IF(X(K,I).EQ.STCHL(K)) ILOB=I
            IF(X(K,I).EQ.STCHR(K)) IROB=I
  210       CONTINUE
         IF(WS.LE.Z(K,ILOB)) N1=ILOB+1
         IF(WS.LE.Z(K,IROB)) N2=IROB
C
C      CHECK LEFT ENCROACHMENT IS SPECIFIED.
C
  200 IF(STENCL(K).EQ.0.) GO TO 230
C
C      FIND STATION CORRESPONDING TO STENCL.
C
         DO 240 I=1,N
            IF(X(K,I).EQ.STENCL(K)) ISTNL=I
  240       CONTINUE
         IF(ELENCL(K).EQ.0.0.OR.WS.LT.ELENCL(K)) N1=ISTNL+1
C
C      CHECK IF RIGHT ENCROACHMENT IS SPECIFIED.
C
  230 IF(STENCR(K).EQ.0.) GO TO 220
C
C      FIND STATION CORRESPONDING TO STENCR.
CC
         DO 260 I=1,N
            IF(X(K,I).EQ.STENCR(K)) ISTNR=I
  260       CONTINUE
      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
         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                               GM 0520
        IF (Z(K,I - 1).GE.WS) GO TO 110                           GM 0530
C                                                                 GM 0540
C     CALCULATE AREA OF FLOW, WETTED PERIMETER, AND DEPTH.        GM 0550
C                                                                 GM 0560
        DA = WS - 0.5 * (Z(K,I - 1) + Z(K,I))                     GM 0570
        A = XB * DA                                               GM 0580
        ZB = ABS(Z(K,I) - Z(K,I - 1))                             GM 0590
        P = SQRT(XB * XB + ZB * ZB)                               GM 0600
        GO TO 160                                                 GM 0610
  110   ZB = WS - Z(K,I)                                          GM 0620
        XB = XB * ZB/(Z(K,I - 1) - Z(K,I))                        GM 0630
        GO TO 150                                                 GM 0640
  120   IF (Z(K,I - 1).GE.WS) GO TO 170                           GM 0650
        ZB = WS - Z(K,I - 1)                                      GM 0670
        XB = XB * ZB/(Z(K,I) - Z(K,I - 1))                        GM 0680
  150   A = 0.5 * XB * ZB                                         GM 0860
        P = SQRT(XB * XB + ZB * ZB)                               GM 0870
        DA = 0.5 * ZB                                             GM 0880
  160   R = A/P                                                   GM 0890
        C = 1.486 * A * R *  * (2./3.)/FM                         GM 0900
C                                                                 GM 0910
C     SUM FLOWS BETWEEN CROSS SECTION POINTS.                     GM 0920
C                                                                 GM 0930
        TA = TA + A
        TK = TK + C                                               GM 0950
        AREA(I-1) = A
        WD(I - 1) = C                                             GM 1000
  170 CONTINUE                                                    GM 1020
      WRITE(*,*) TA
      WRITE(*,*) TK
      DO 190 I = 1,NP                                             GM 1060
        WD(I) = WD(I)/TK                                          GM 1070
  190 CONTINUE                                                    GM 1080
C                                                                 GM 1090
      RETURN                                                      GM 1100
      END                                                         GM 1110
      SUBROUTINE OUT1(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)
```

```
      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        TAPE51 = ELMIN
C        TAPE 9 = WGTFACT
C
      COMMON/BLKA/ NP,IR,IQ,NQ,BL,BR,JS,NSEC
      COMMON/BLKB/ CWSEL(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='HSTDTMP.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)
  516 FORMAT(64X,2I8)
C
      END
      SUBROUTINE WRTX1(JP)
C
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/ CWSEL(150),TOPCH(150),ASC(150),VAL(10),QM(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
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/ CWSEL(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 136
      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),VROB(50),DROB(50),WROB(50)
      DIMENSION G(50),DV(50),XL(50),AQS(2),BQS(2),CQS(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)
     &        ,VROB(JR),DROB(JR),WROB(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),VLOB(IR),DLOB(IR),
   &             WLOB(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'/,
   *       '    SECNO   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) SECNO,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,CWSEL

       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,CWSEL,VCHXS,TWCH,VLOBXS,
  &               TWL,VROBXS,TWR,STCHL,STCHR
620   FORMAT(I2,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
   SW¼ Section 12 T1N R4E
   NW¼ Section 13 T1N R4E
   SW¼ Section 13 T1N R4E
   SE¼ Section 12 T1N R4E
   NE¼ Section 13 T1N R4E
   SE¼ Section 13 T1N R4E
   NW¼ Section 7 T1N R5E
   SW¼ Section 7 T1N R5E

NW¼ Section 18 T1N R5E
SE¼ Section 6 T1N R5E
NE¼ Section 7 T1N R5E
SE¼ Section 7 T1N R5E
NE¼ Section 18 T1N R5E
NW¼ Section 8 T1N R5E
SW¼ Section 8 T1N R5E
SE¼ Section 5 T1N R5E
NE¼ Section 8 T1N R5E
NW¼ Section 4 T1N R5E
SW¼ Section 4 T1N R5E
NW¼ Section 9 T1N R5E
SE¼ Section 33 T2N R5E
NE¼ Section 4 T1N R5E
SE¼ Section 4 T1N R5E
NE¼ 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
NE¼ Section 24 T1N R2E
SE¼ Section 24 T1N R2E
NW¼ Section 24 T1N R2E
SW¼ Section 24 T1N R2E
NE¼ Section 23 T1N R2E
SE¼ Section 23 T1N R2E
NW¼ Section 23 T1N R2E
SW¼ Section 23 T1N R2E
NW¼ Section 26 T1N R2E
NE¼ Section 26 T1N R2E
NE¼ Section 22 T1N R2E
SE¼ Section 22 T1N R2E
NE¼ Section 27 T1N R2E
NW¼ Section 22 T1N R2E
SW¼ Section 22 T1N R2E
NW¼ Section 27 T1N R2E
NE¼ Section 21 T1N R2E
SE¼ Section 21 T1N R2E
NE¼ Section 28 T1N R2E
SW¼ Section 21 T1N R2E
NW¼ Section 28 T1N R2E
SE¼ Section 20 T1N R2E
NE¼ Section 29 T1N R2E
SE¼ Section 29 T1N R2E
NW¼ Section 29 T1N R2E
SW¼ 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

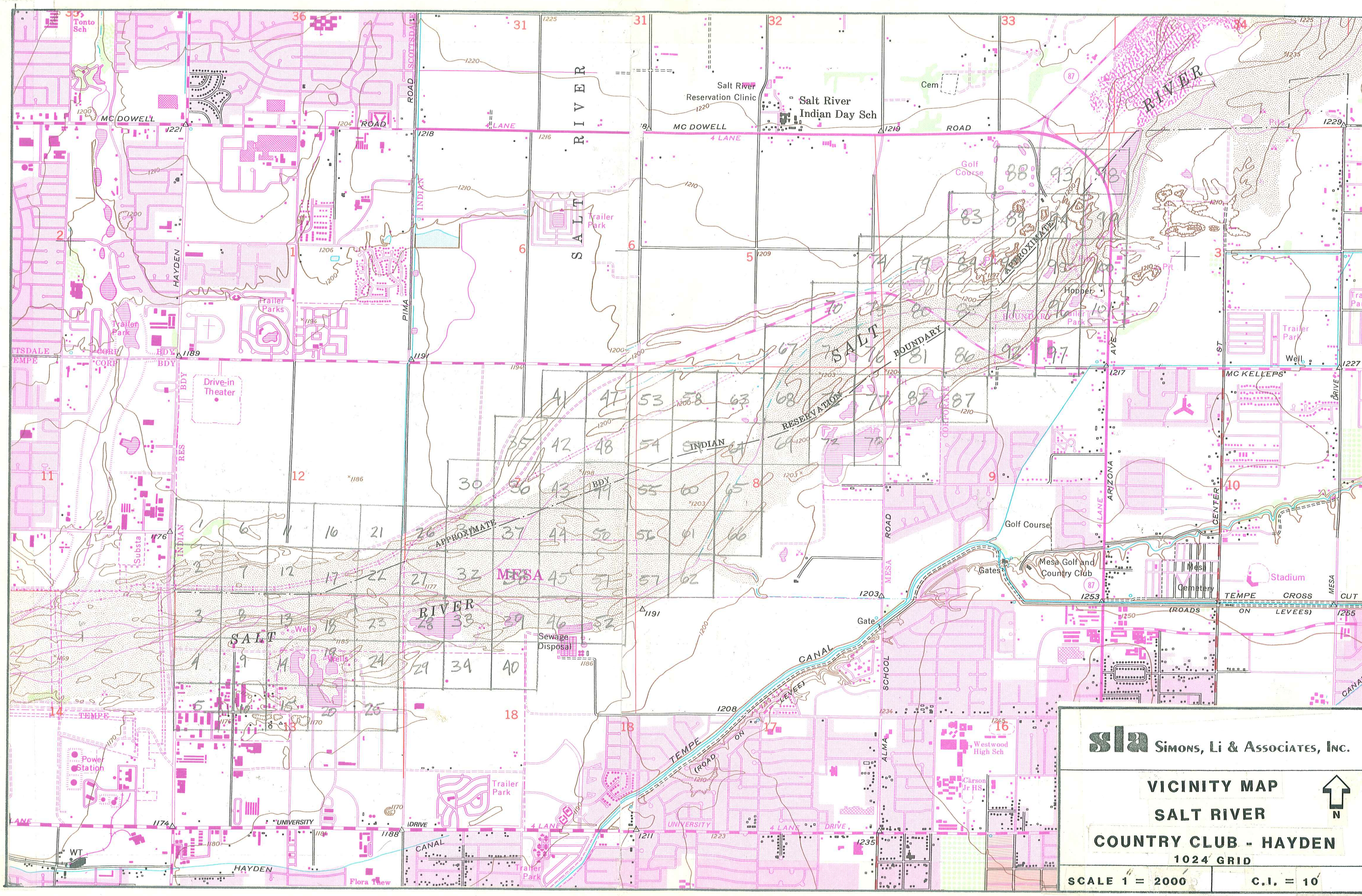
G.3 Data Manipulation

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 reachs. 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.



sla SIMONS, LI & ASSOCIATES, INC.

VICINITY MAP

SALT RIVER

COUNTRY CLUB - HAYDEN

1024 GRID

N

SCALE 1 = 2000 | C.I. = 10

FIGURE G.1

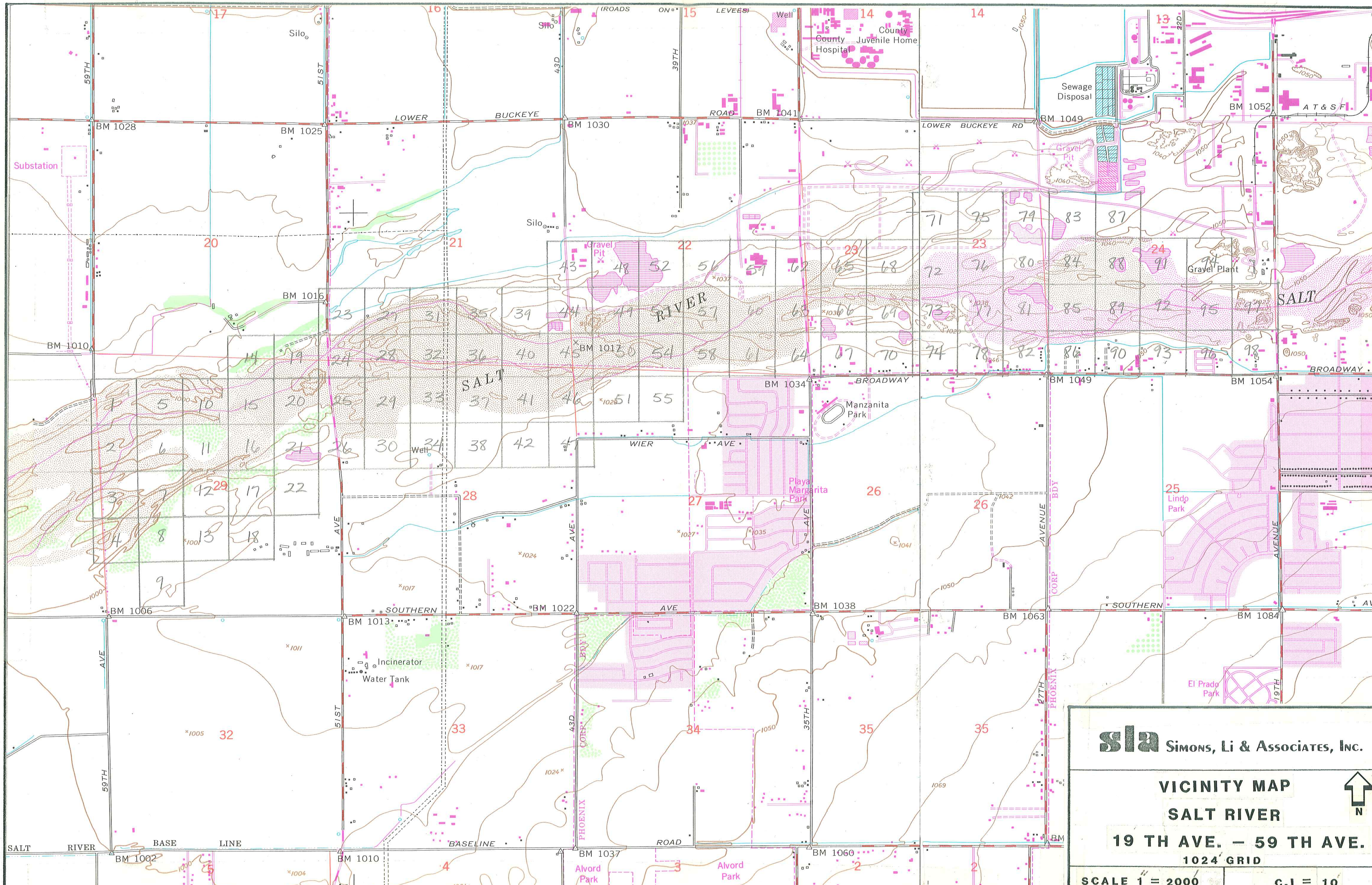

sla Simons, Li & Associates, Inc.
VICINITY MAP
SALT RIVER
19 TH AVE. – 59 TH AVE.
1024 GRID
SCALE 1" = 2000'
C.I = 10'
N
SALT RIVER
LOWER BUCKEYE ROAD
LOWER BUCKEYE RD
BROADWAY
WIER AVE
SOUTHERN AVE
BASELINE ROAD
SALT RIVER BASE LINE
59TH AVE
51ST AVE
43D AVE
39TH
35TH AVE
27TH AVENUE
19TH AVENUE
PHOENIX CORP BDY
County Hospital
County Juvenile Home
Sewage Disposal
Gravel Pit
Gravel Plant
Substation
Silo
Well
Manzanita Park
Playa Margarita Park
Lindo Park
El Prado Park
Alvord Park
Incinerator
Water Tank
A T & S F
BM 1028
BM 1025
BM 1030
BM 1041
BM 1049
BM 1052
BM 1016
BM 1010
BM 1017
BM 1034
BM 1054
BM 1006
BM 1013
BM 1022
BM 1038
BM 1063
BM 1084
BM 1002
BM 1037
BM 1060

FIGURE G.2

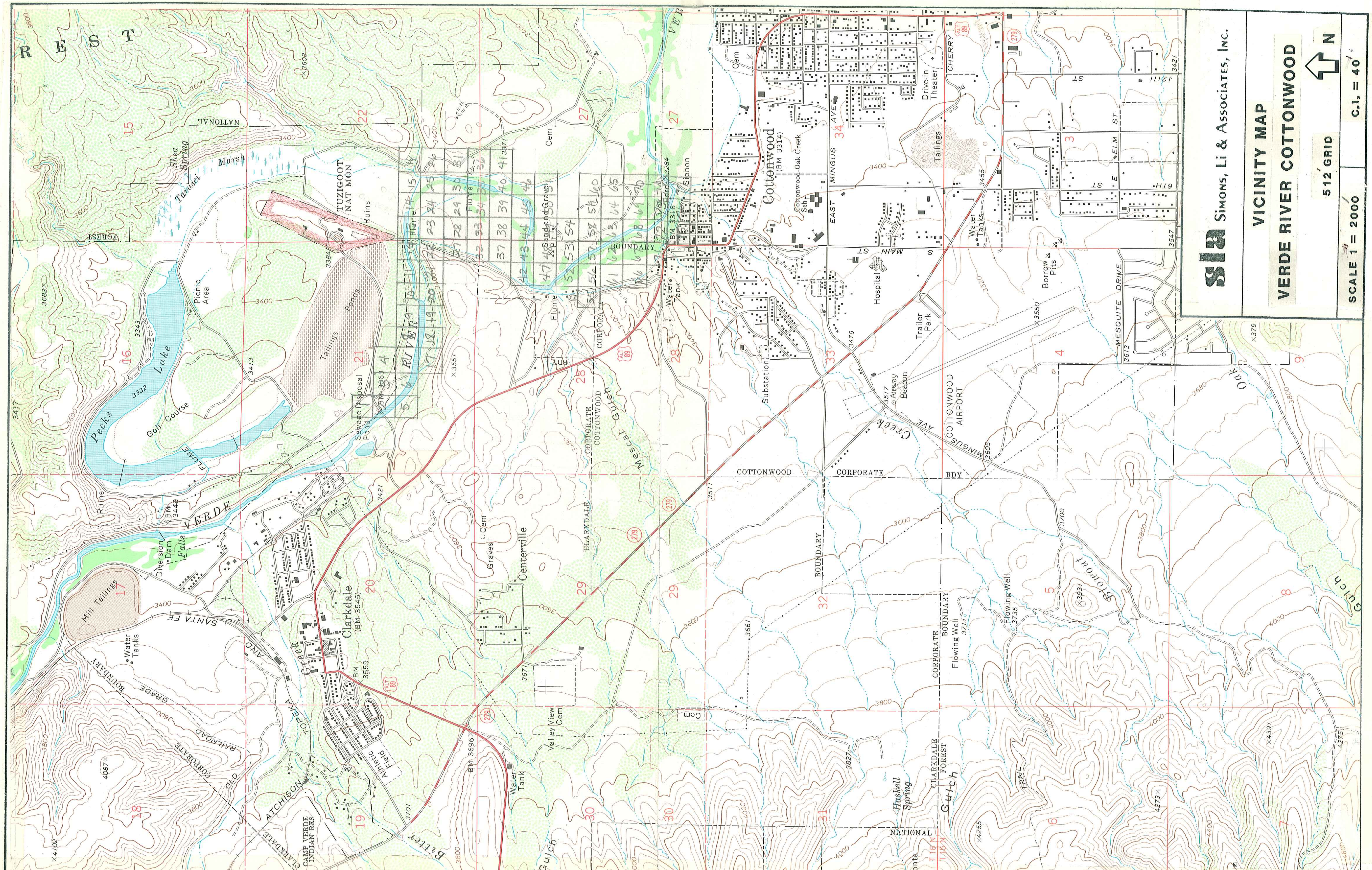
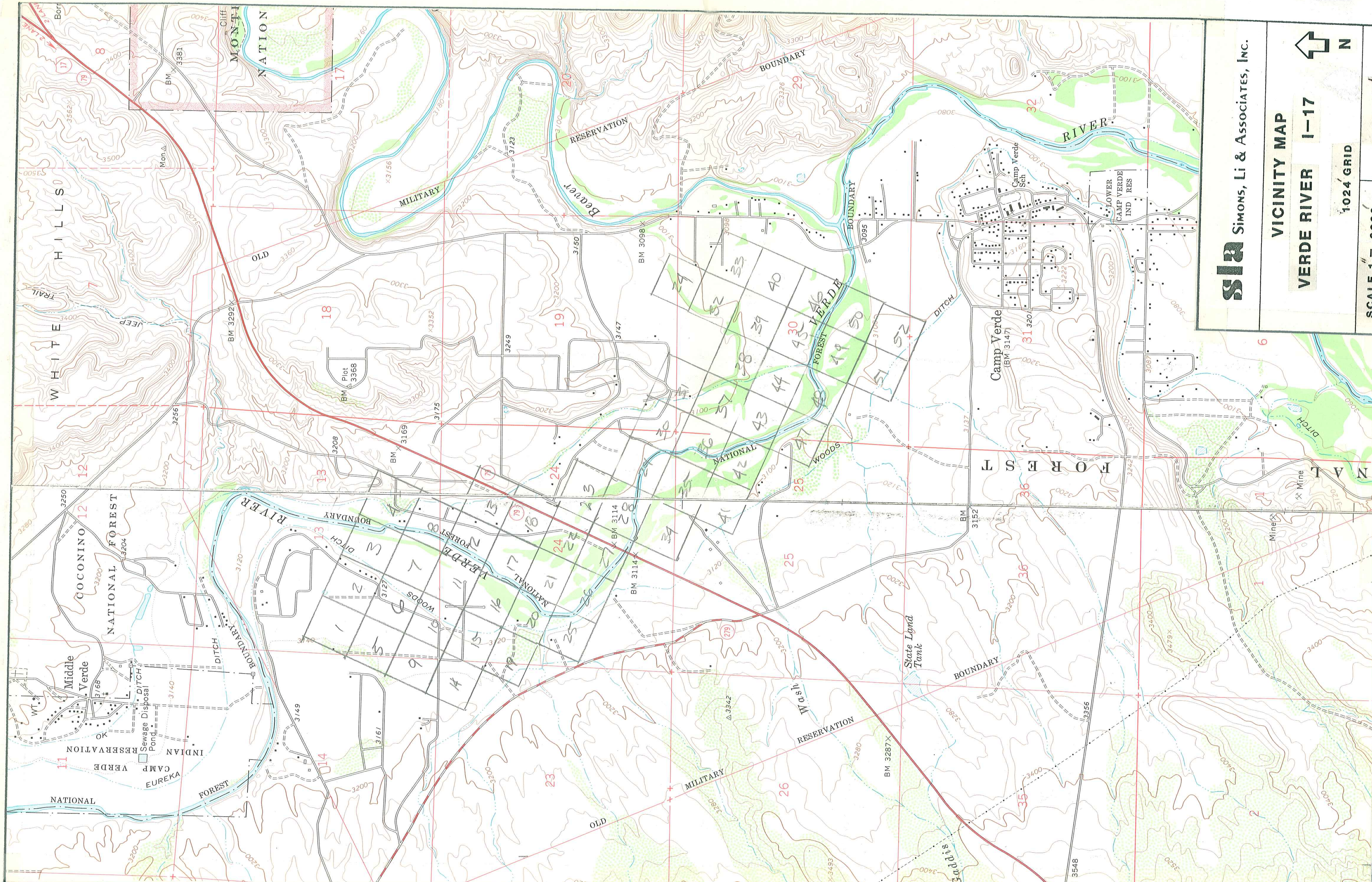
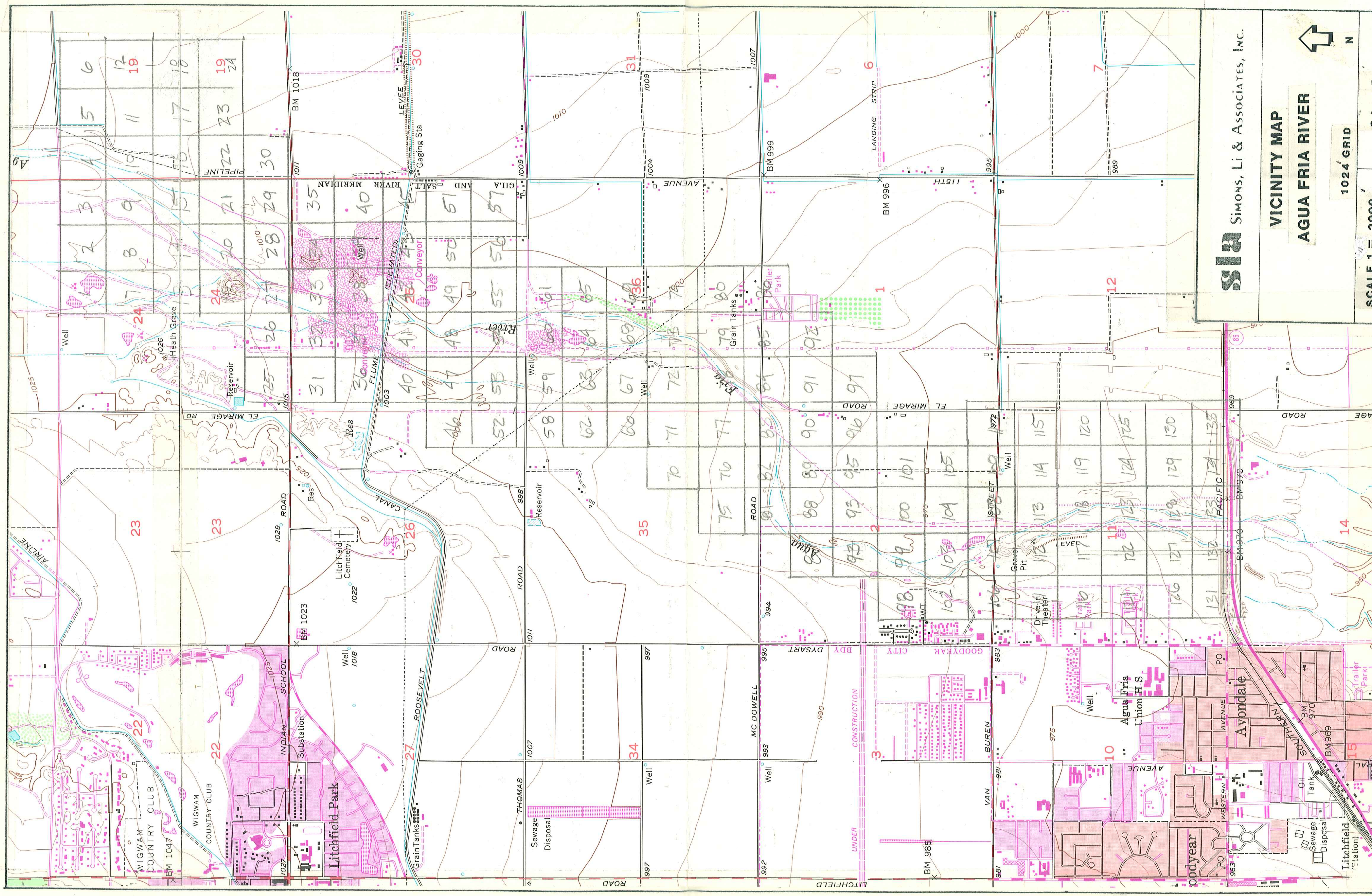

SIA Simons, Li & Associates, Inc.
VICINITY MAP
VERDE RIVER COTTONWOOD
N
512' GRID
SCALE 1 = 2000
C.I. = 40'
Cottonwood
Clarkdale
Centerville
TUZIGOOT NAT MON
Peck's Lake
Tavasci Marsh
VERDE RIVER
Mill Tailings
Tailings Ponds
COTTONWOOD AIRPORT
Hospital
Trailer Park
Mescal Gulch
Bitter Gulch
Haskell Spring
ATCHISON TOPEKA AND SANTA FE
CAMP VERDE INDIAN RES

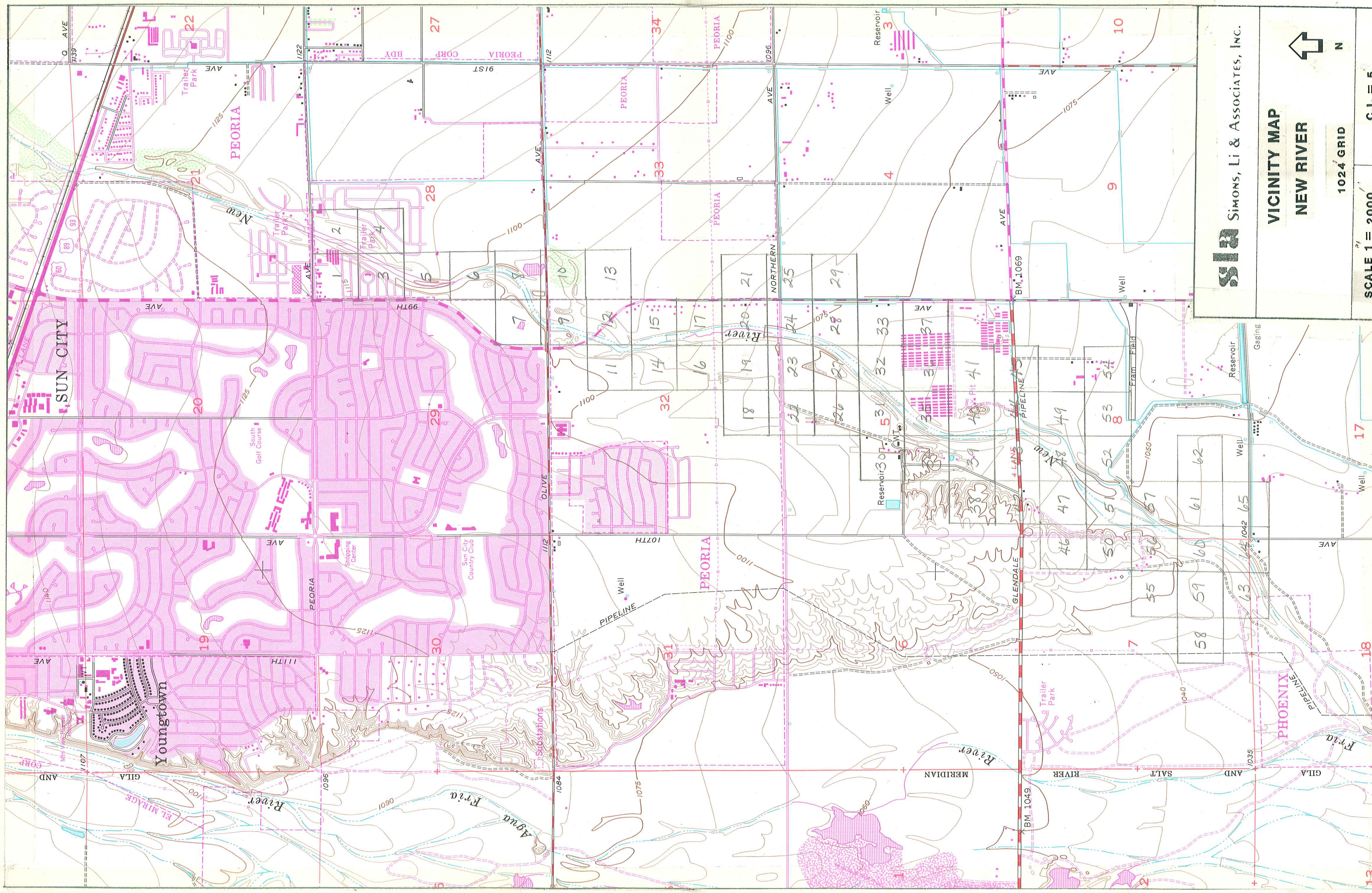
FIGURE G.3

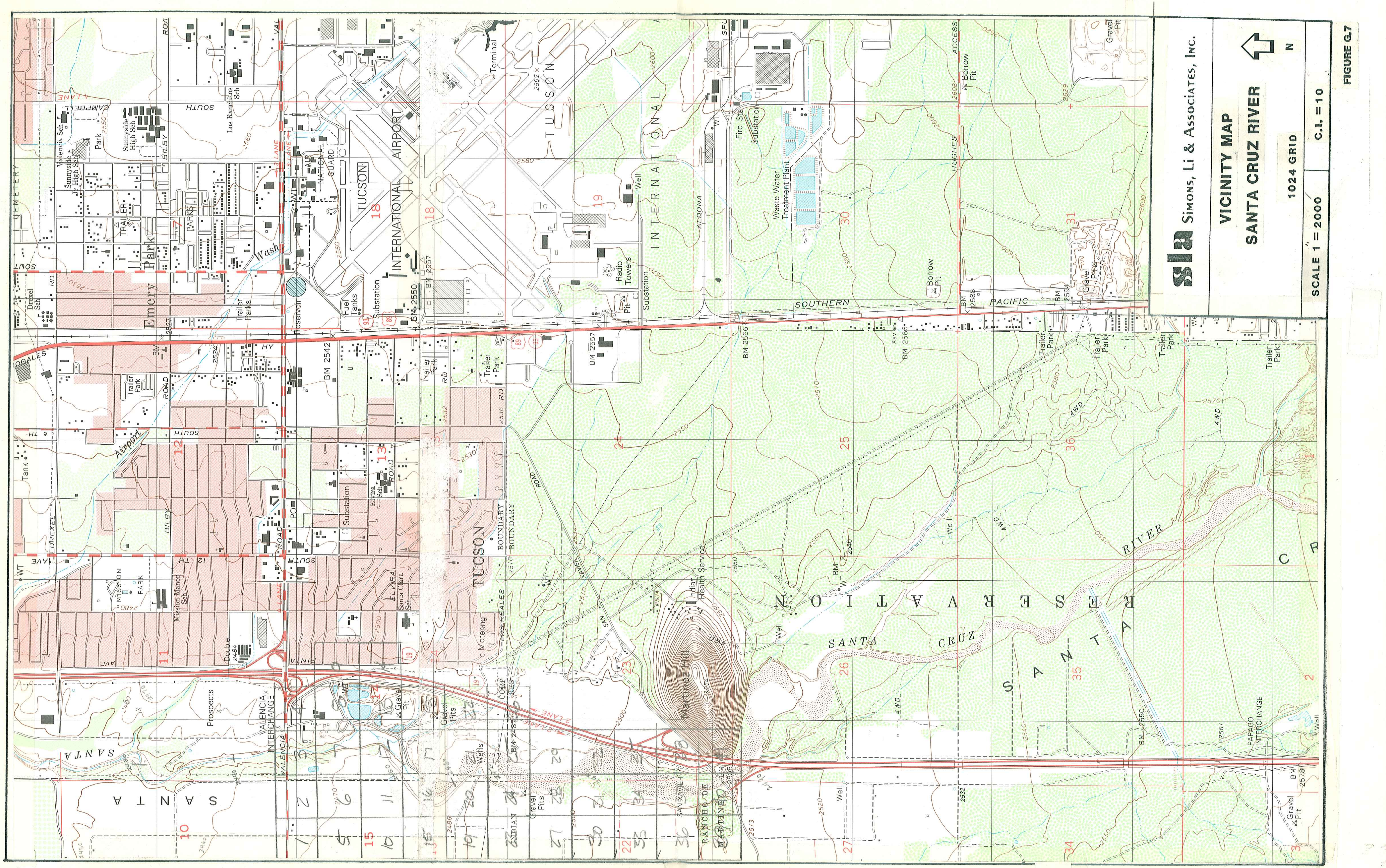

Simons, Li & Associates, Inc.
VICINITY MAP
VERDE RIVER I–17
1024' GRID
SCALE 1" = 2000'
C.I. = 40'
FIGURE G.4
Camp Verde
Middle Verde
VERDE RIVER
COCONINO NATIONAL FOREST
WHITE HILLS
OLD MILITARY RESERVATION BOUNDARY
CAMP VERDE INDIAN RESERVATION
LOWER CAMP VERDE IND RES
Camp Verde Sch
Beaver
State Land Tank
Wash
Gaddis
Sewage Disposal Pond
DITCH
EUREKA
TRAIL
JEEP



Simons, Li & Associates, Inc.
VICINITY MAP
AGUA FRIA RIVER
1024 GRID
SCALE 1" = 2000'
C.I. = 5
N

FIGURE G.5


Simons, Li & Associates, Inc.
VICINITY MAP
NEW RIVER
1024 GRID
N
SCALE 1" = 2000'
C.I. = 5
FIGURE G.6
SUN CITY
PEORIA
Youngtown
PHOENIX
New River
Agua Fria River
Gila and Salt River Meridian
Pipeline
South Golf Course
Sun City Country Club
Shopping Center
Trailer Park
Reservoir
Well
Substations


Simons, Li & Associates, Inc.
VICINITY MAP
SANTA CRUZ RIVER
1024 GRID
SCALE 1" = 2000
C.I. = 10
N
FIGURE G.7
TUCSON INTERNATIONAL AIRPORT
SANTA CRUZ RIVER
SAN XAVIER INDIAN RESERVATION
Martinez Hill
SOUTHERN PACIFIC
VALENCIA INTERCHANGE
PAPAGO INTERCHANGE
Waste Water Treatment Plant
Emery Park
TUCSON

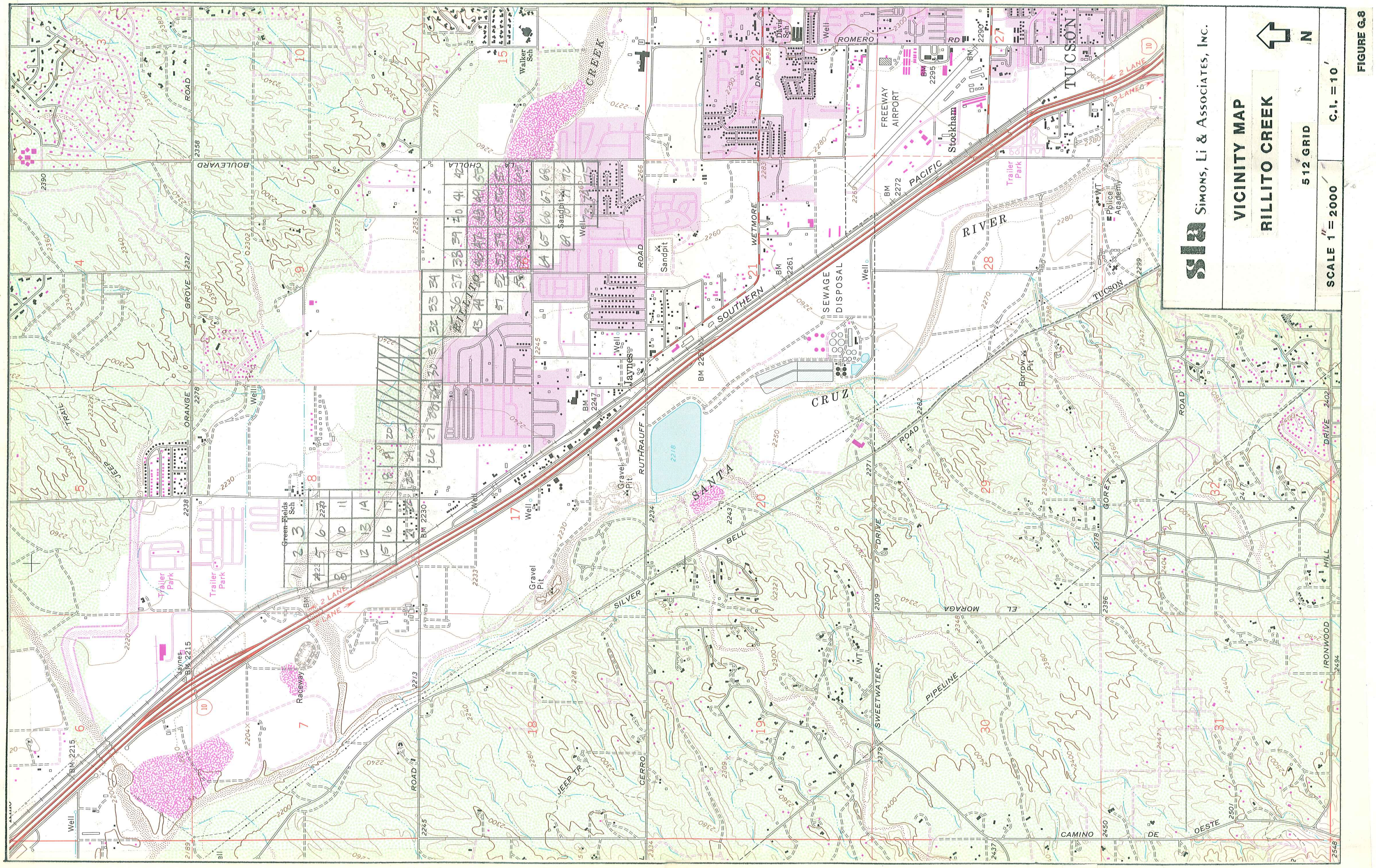


FIGURE G.8
Simons, Li & Associates, Inc.
VICINITY MAP
RILLITO CREEK
512 GRID
SCALE 1" = 2000'
C.I. = 10'
N
TUCSON
ROMERO RD
WETMORE
FREEWAY AIRPORT
Stockham
SOUTHERN PACIFIC
SEWAGE DISPOSAL
SANTA CRUZ RIVER
RILLITO CREEK
RUTHRAUFF ROAD
ORANGE GROVE ROAD
BOULEVARD
CHOLLA
JEEP TRAIL
Trailer Park
Raceway
Gravel Pit
Sandpit
Borrow Pit
Police Academy
Green Fields Sch
Walker Sch
SILVER BELL
SWEETWATER DRIVE
EL MORAGA
PIPELINE
CERRO
CAMINO DE OESTE
IRONWOOD HILL DRIVE
GORE ROAD
TUCSON
2 LANE

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 D_{50}, 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, ¼ section, and nearest highway station.

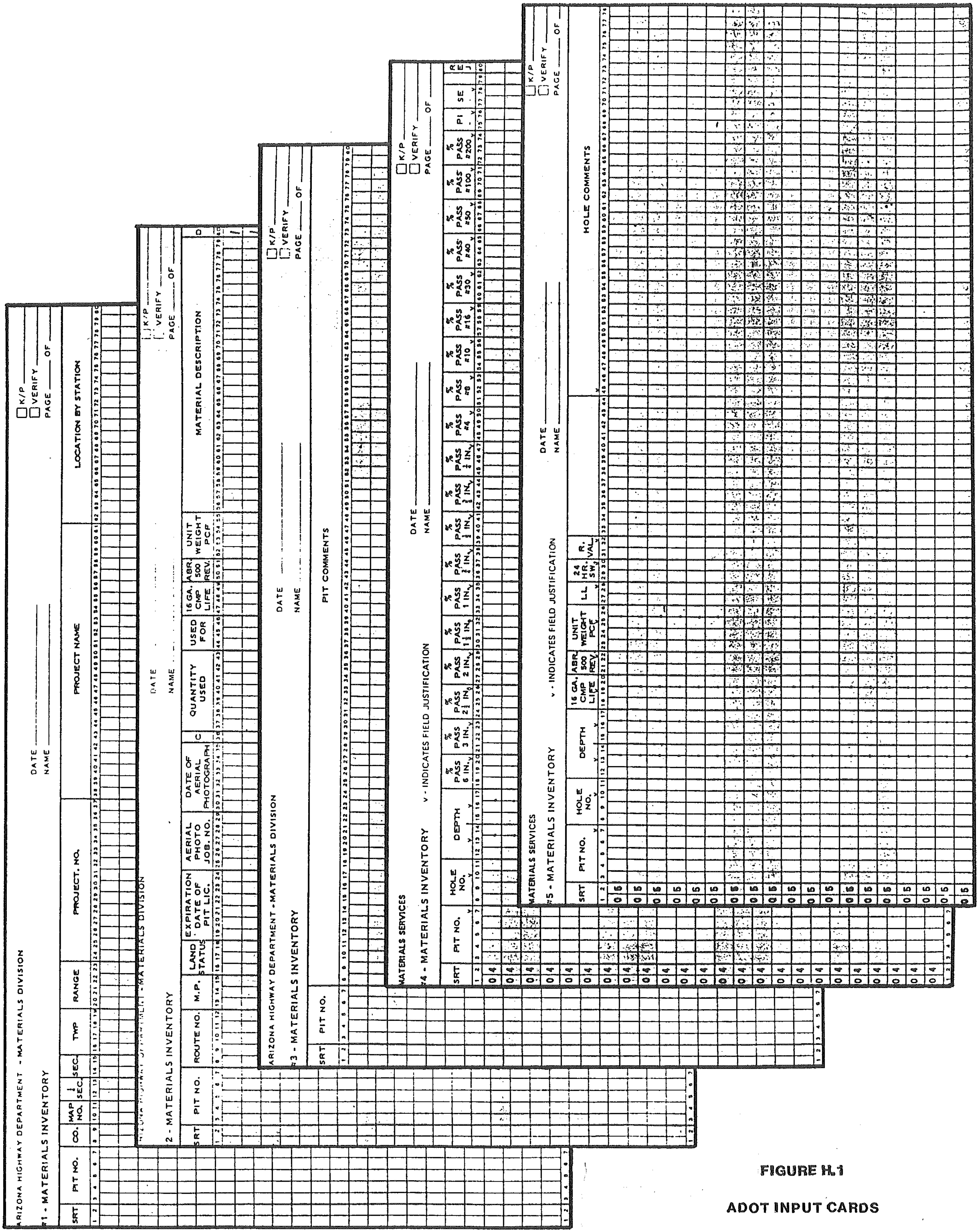


FIGURE H.1

ADOT INPUT CARDS

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 ocurrences 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

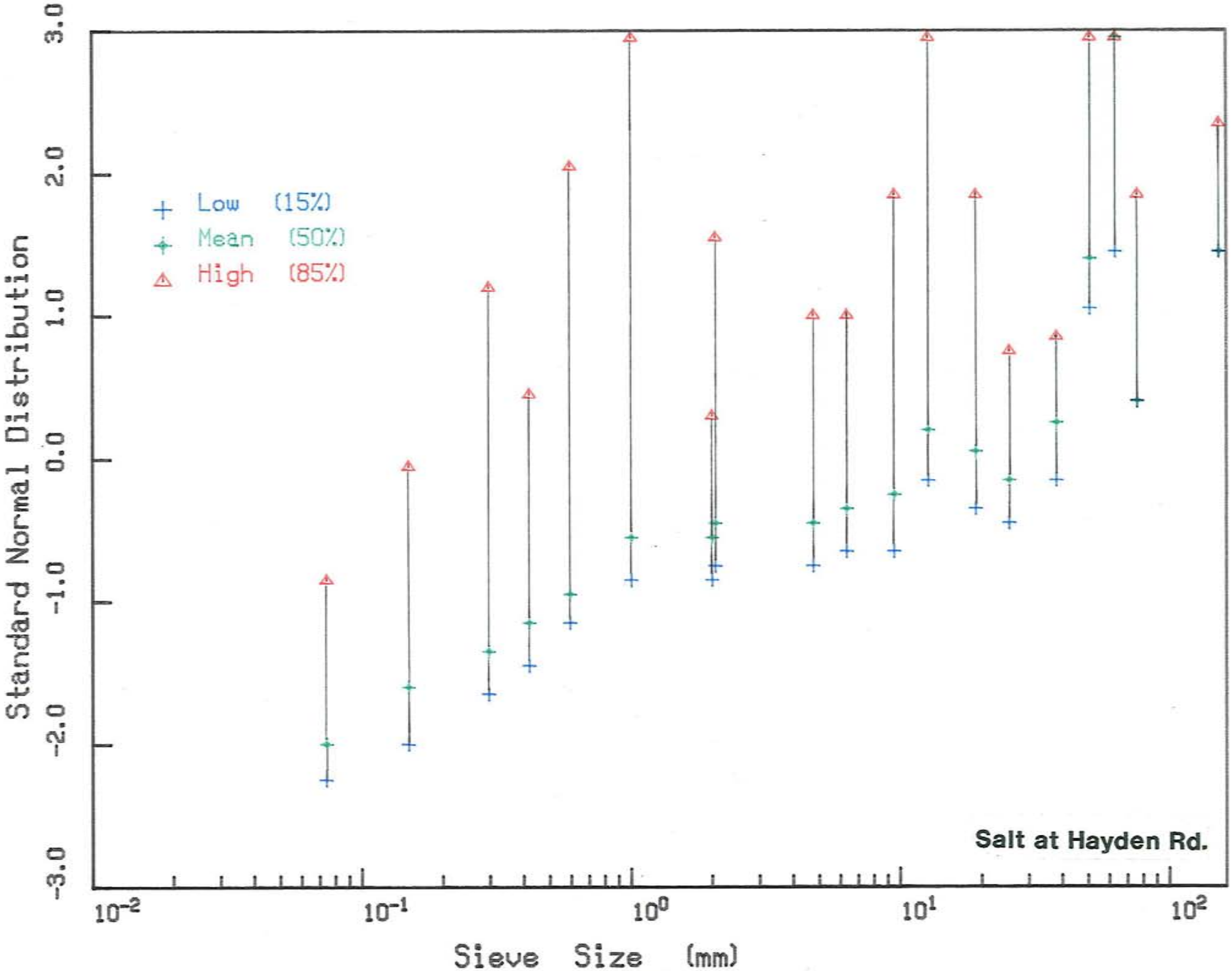
with -999 flags for plotting purposes. This data was used to plot Figures H.26 to H.33.

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

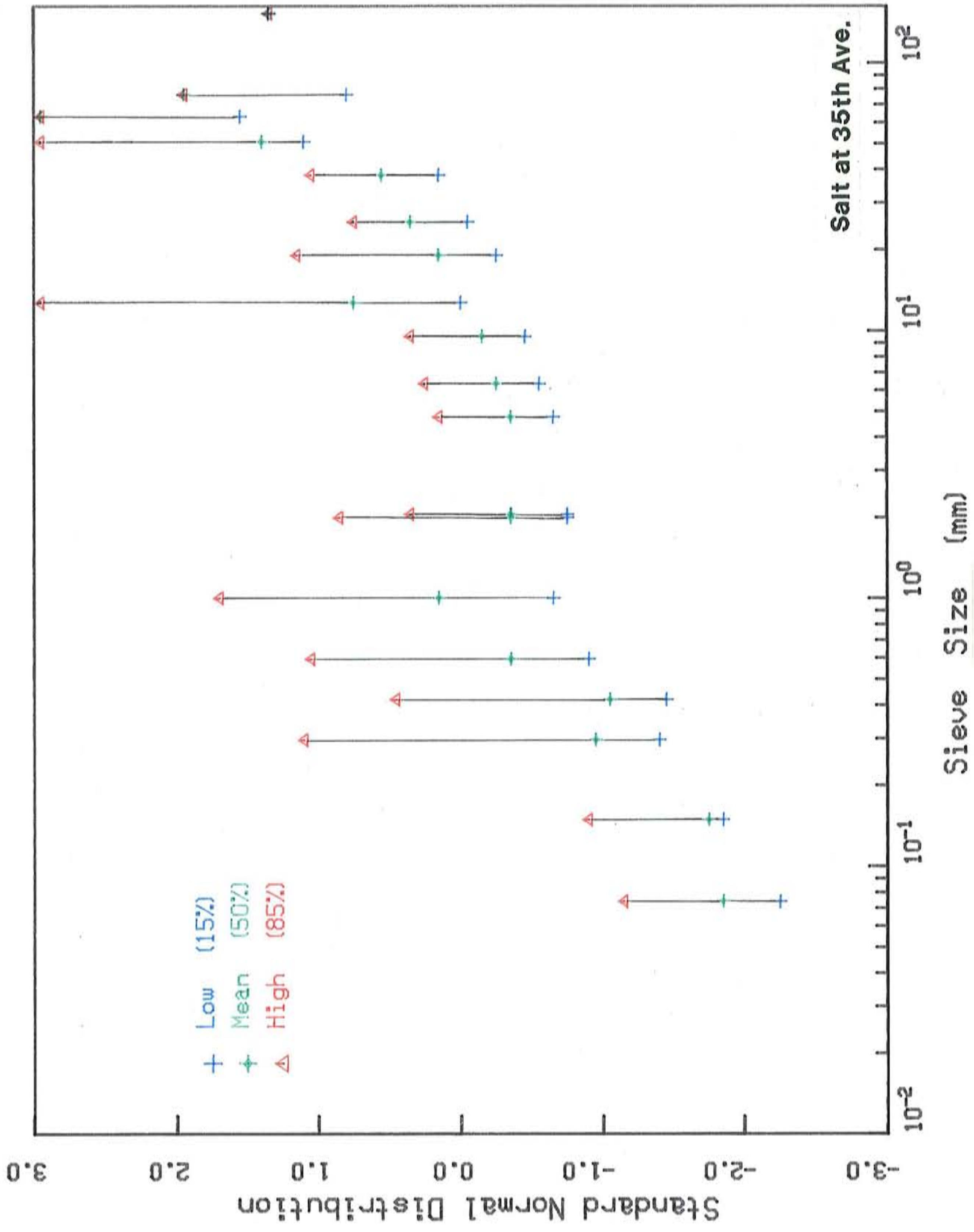
Program Compilation Details

PROGRAM	LANGUAGE	COMPILER	COMMENTS
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



3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
Standard Normal Distribution
Low (15%)
Mean (50%)
High (85%)
Salt at Hayden Rd.
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
Sieve Size (mm)

FIGURE H.2



Salt at 35th Ave.
Low (15%)
Mean (50%)
High (85%)
Standard Normal Distribution
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
Sieve Size (mm)
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}

FIGURE H.3

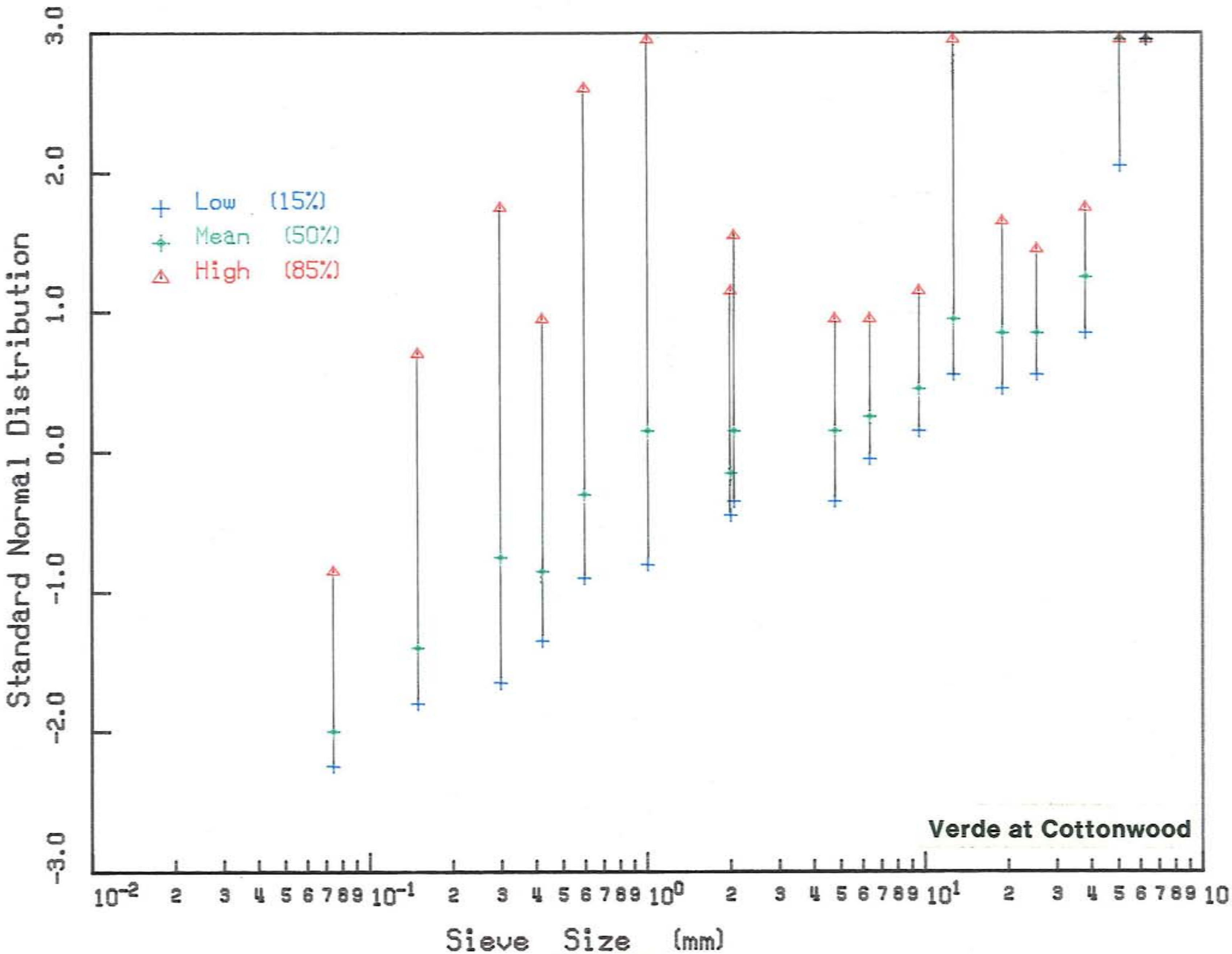

Standard Normal Distribution
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
Low (15%)
Mean (50%)
High (85%)
Verde at Cottonwood
10^{-2} 2 3 4 5 6 7 8 9 10^{-1} 2 3 4 5 6 7 8 9 10^{0} 2 3 4 5 6 7 8 9 10^{1} 2 3 4 5 6 7 8 9 10
Sieve Size (mm)

FIGURE H.4

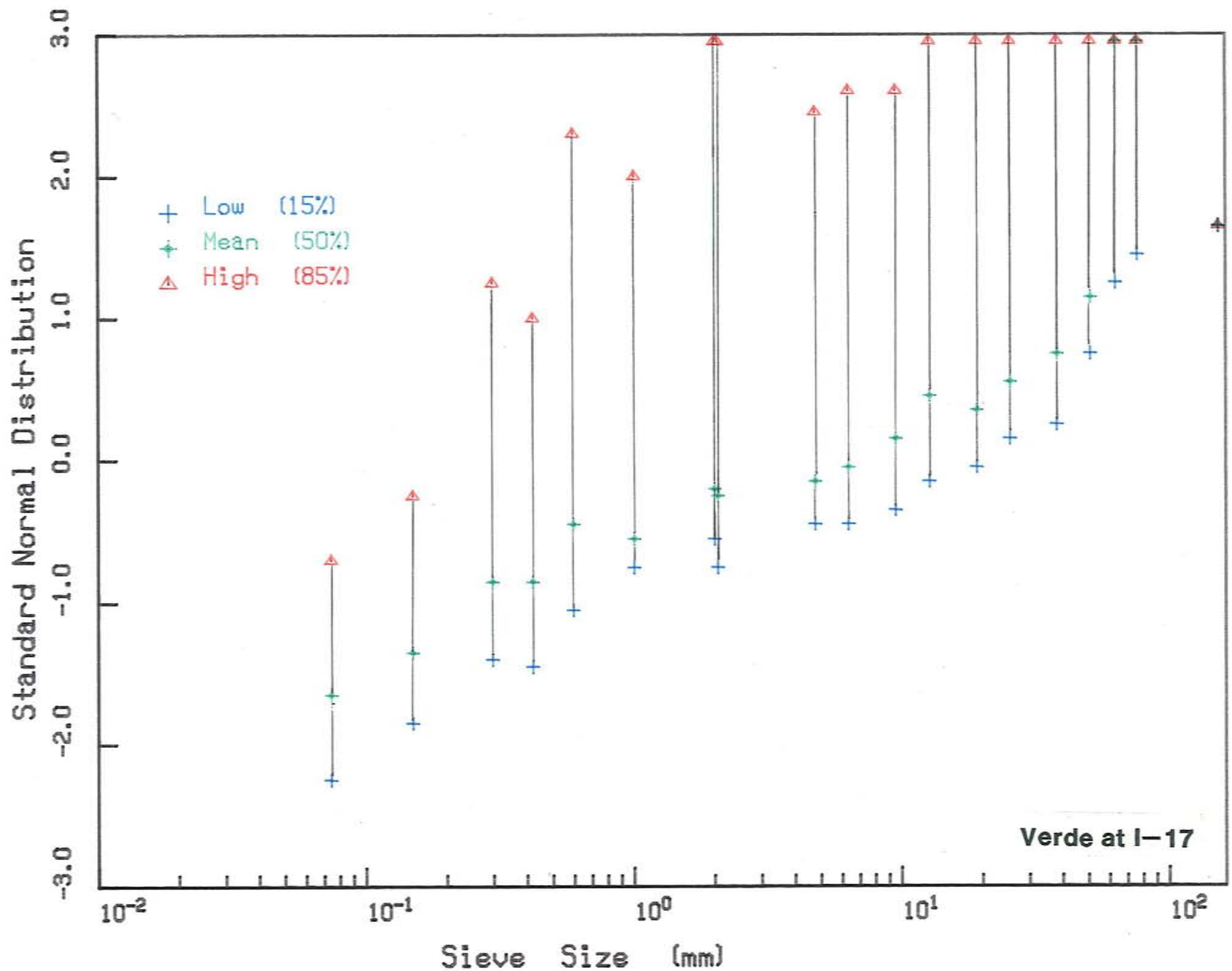

Standard Normal Distribution
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
Low (15%)
Mean (50%)
High (85%)
Verde at I—17
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
Sieve Size (mm)

FIGURE H.5

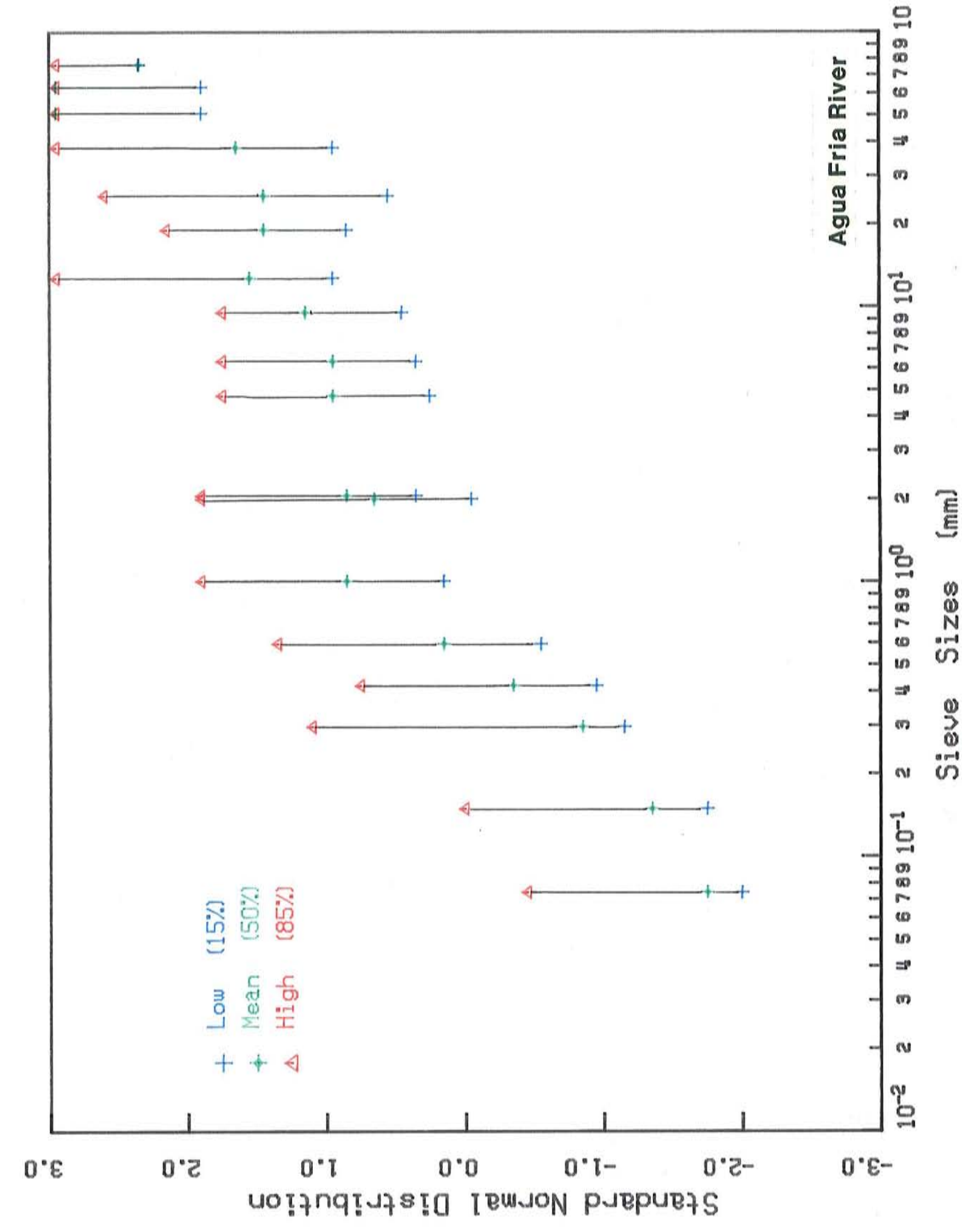
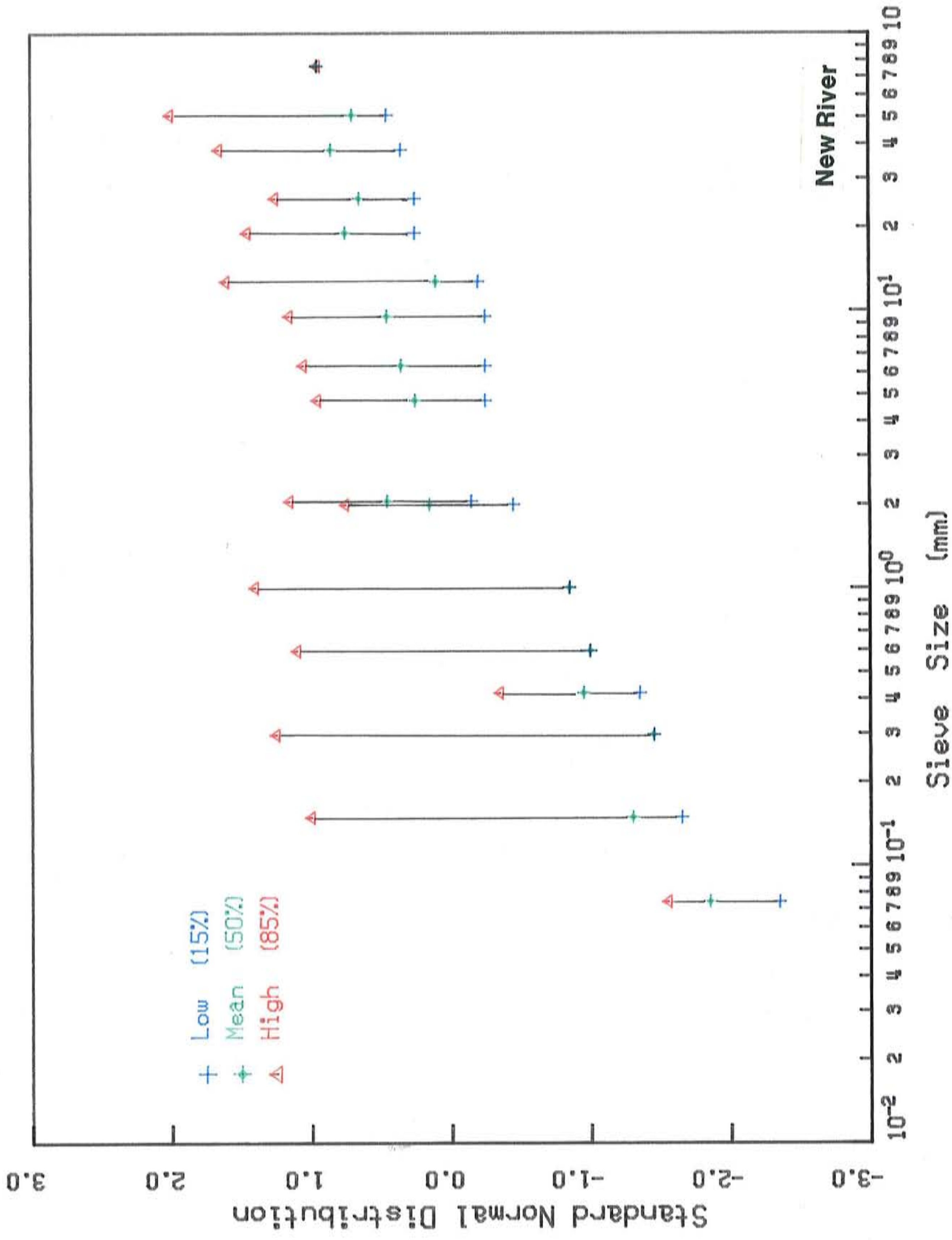

Agua Fria River
Low (15%)
Mean (50%)
High (85%)
Standard Normal Distribution
Sieve Sizes (mm)
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
10^-2 2 3 4 5 6 7 8 9 10^-1 2 3 4 5 6 7 8 9 10^0 2 3 4 5 6 7 8 9 10^1 2 3 4 5 6 7 8 9 10

FIGURE H.6



New River
Low (15%)
Mean (50%)
High (85%)
Standard Normal Distribution
Sieve Size (mm)

FIGURE H.7

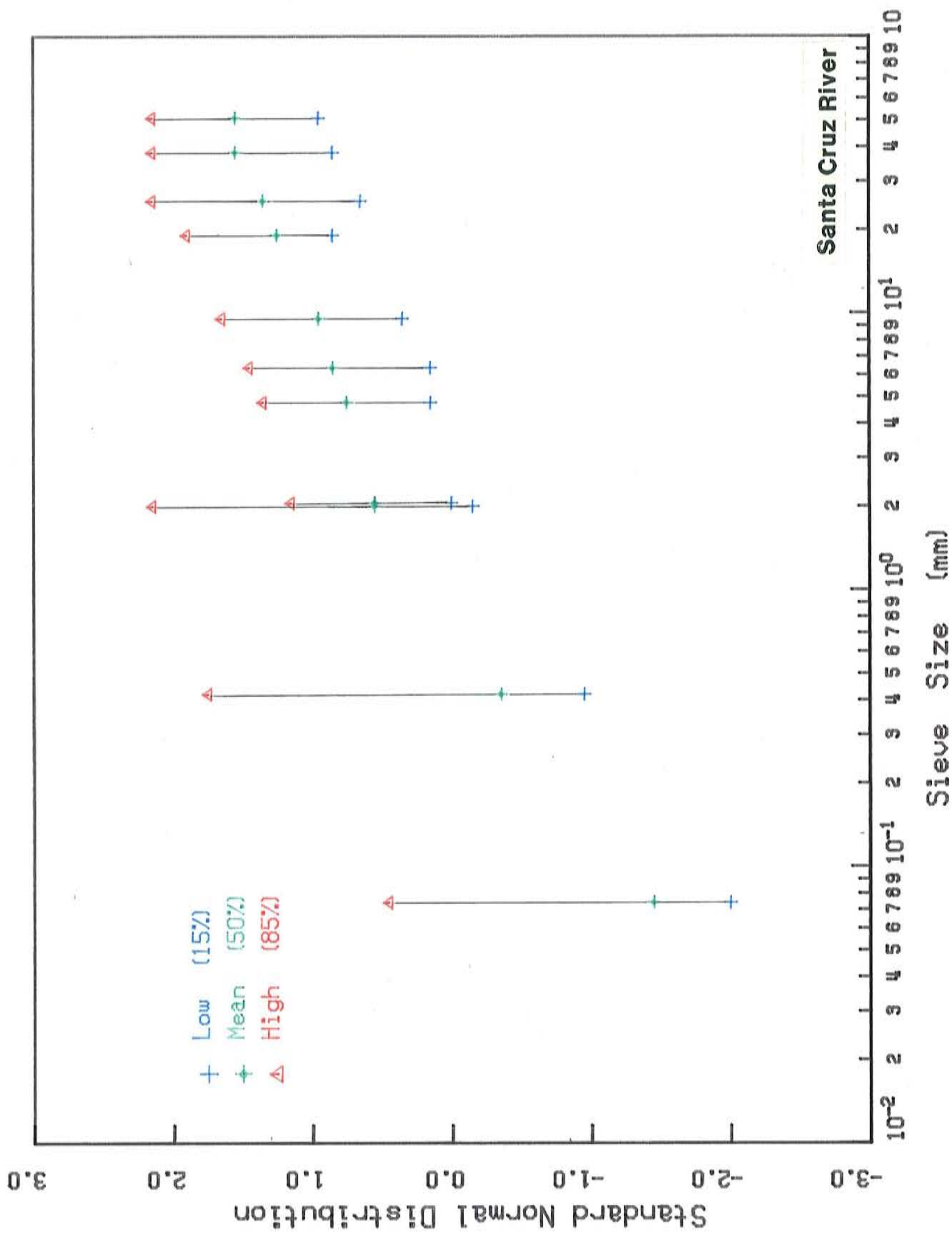
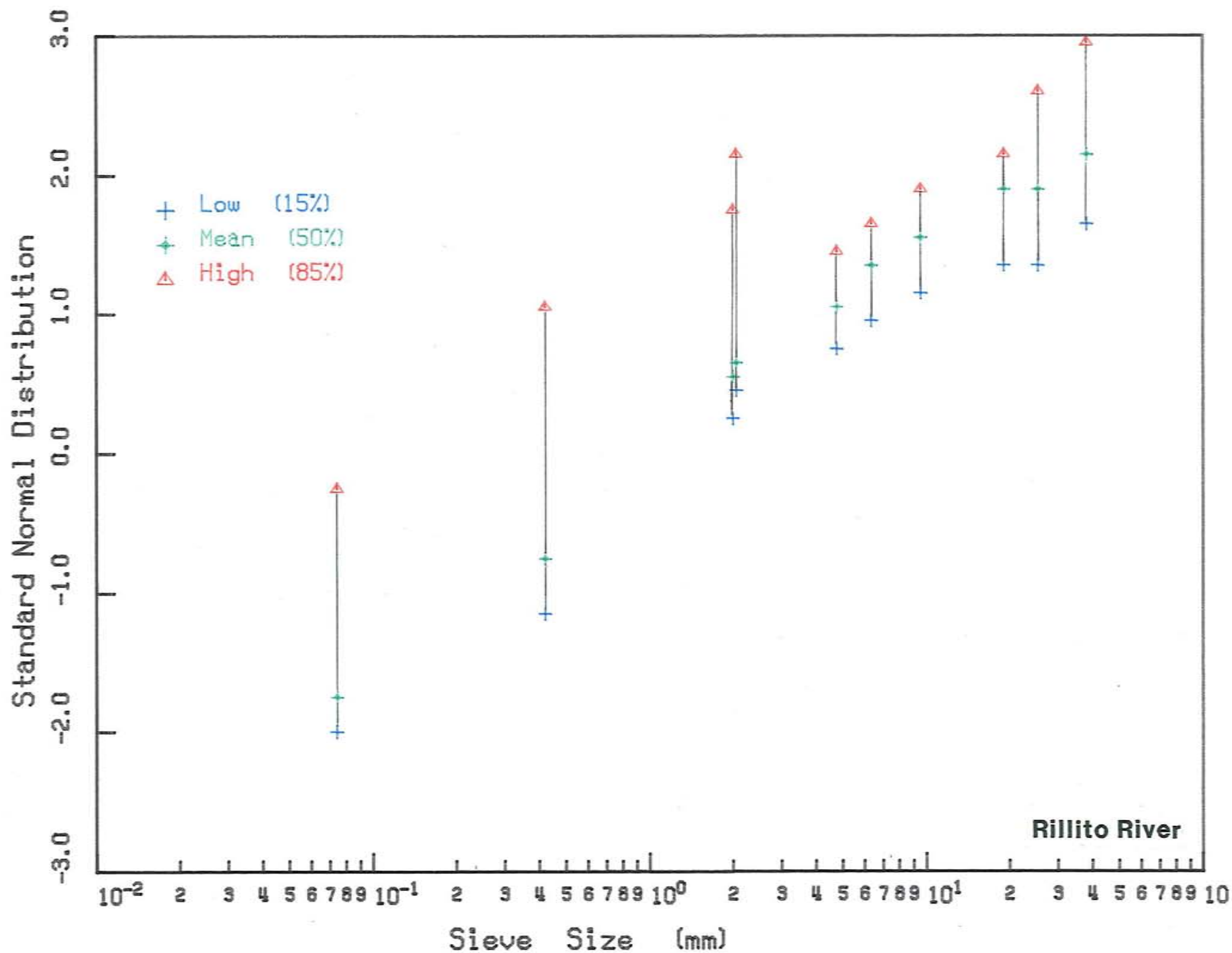

Santa Cruz River
Low (15%)
Mean (50%)
High (85%)
Standard Normal Distribution
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
Sieve Size (mm)
10^{-2}
10^{-1}
10^{0}
10^{1}
10

FIGURE H.8



Standard Normal Distribution
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
Low (15%)
Mean (50%)
High (85%)
Rillito River
10^{-2} 2 3 4 5 6 7 8 9 10^{-1} 2 3 4 5 6 7 8 9 10^{0} 2 3 4 5 6 7 8 9 10^{1} 2 3 4 5 6 7 8 9 10
Sieve Size (mm)

FIGURE H.9

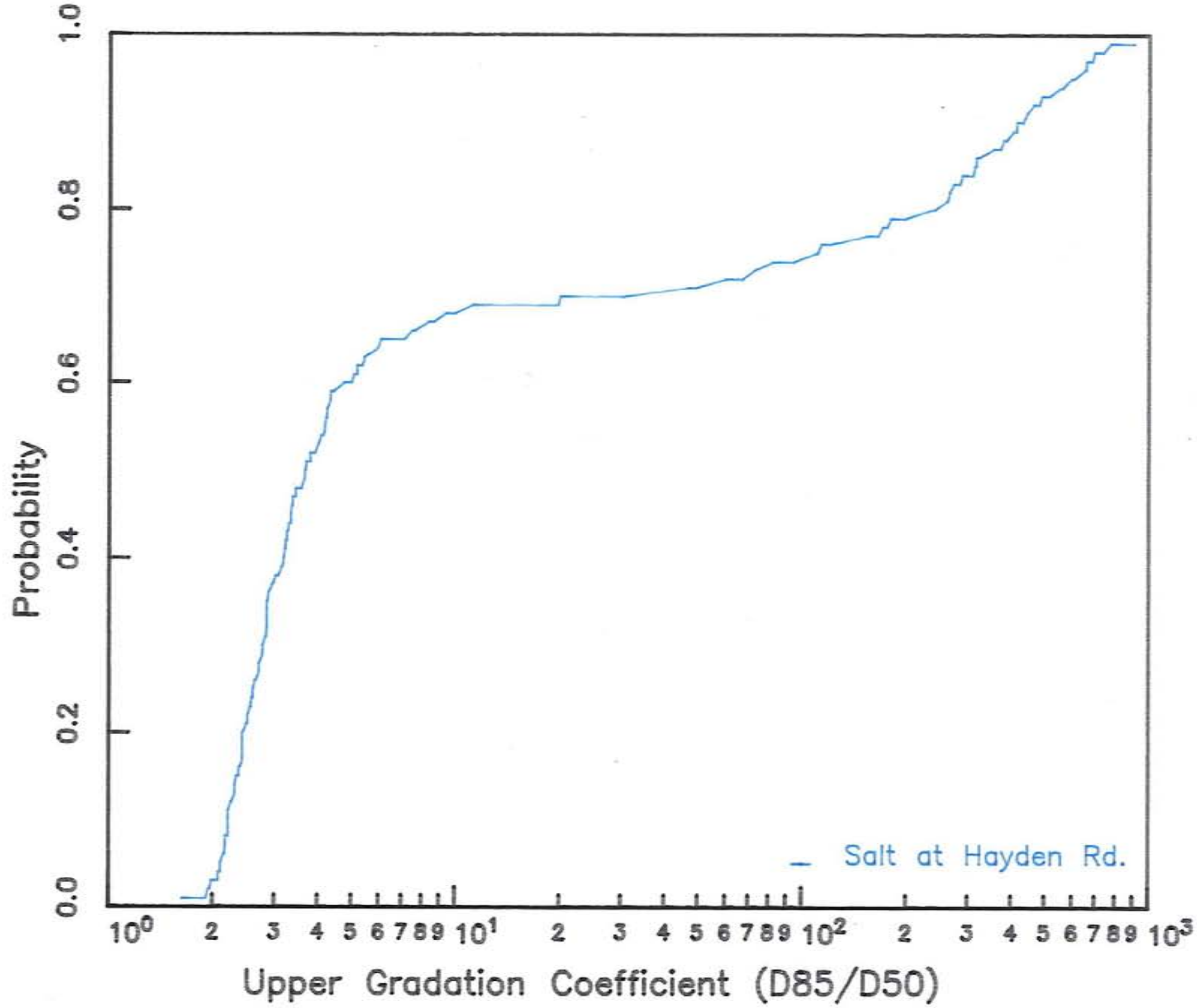

1.0
0.8
0.6
0.4
0.2
0.0
Probability
10^0 2 3 4 5 6 7 8 9 10^1 2 3 4 5 6 7 8 9 10^2 2 3 4 5 6 7 8 9 10^3
Upper Gradation Coefficient (D85/D50)
Salt at Hayden Rd.

FIGURE H.10

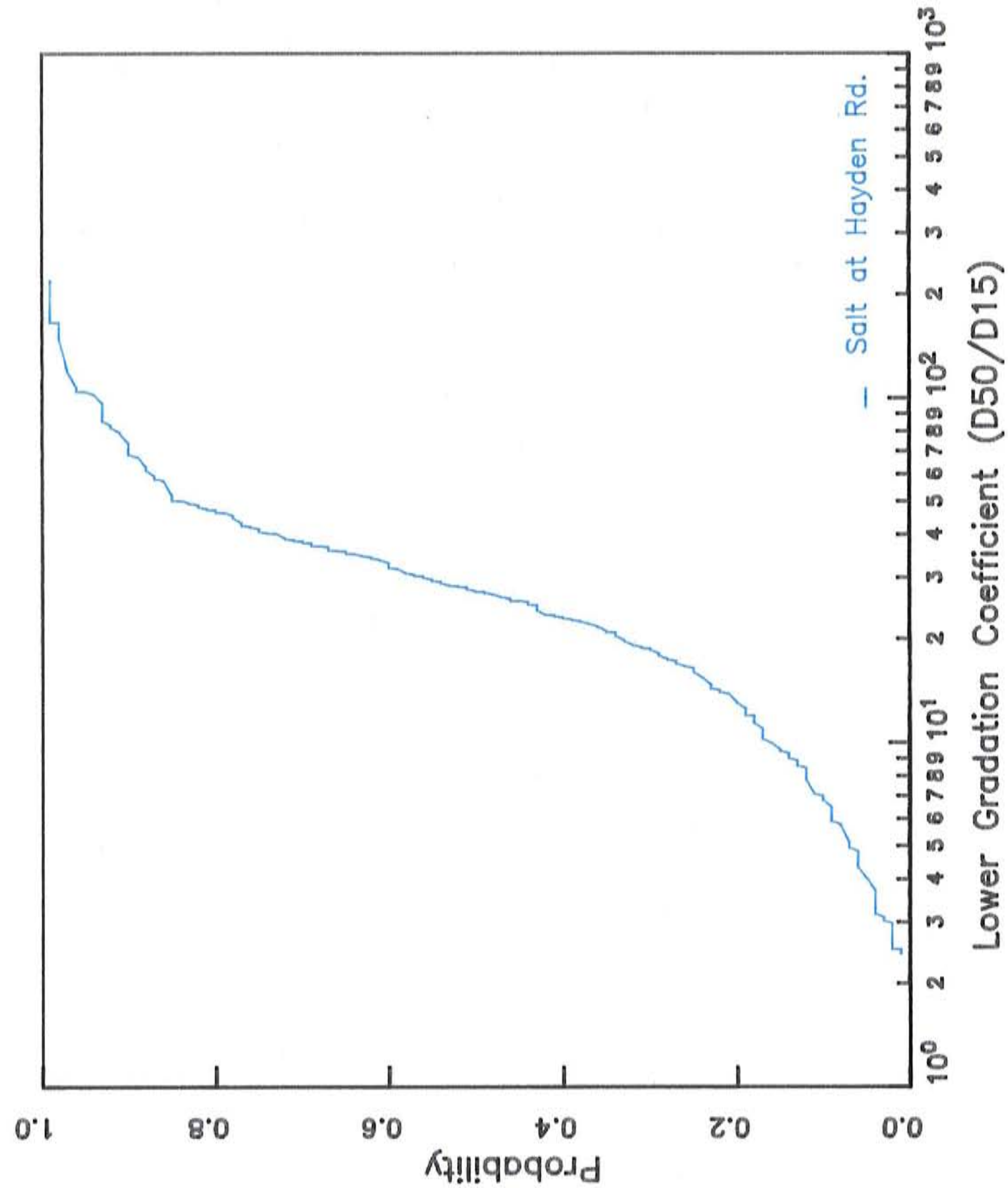

Salt at Hayden Rd.
Lower Gradation Coefficient (D50/D15)
Probability
0.0
0.2
0.4
0.6
0.8
1.0
10^0
10^1
10^2
10^3

FIGURE H.11

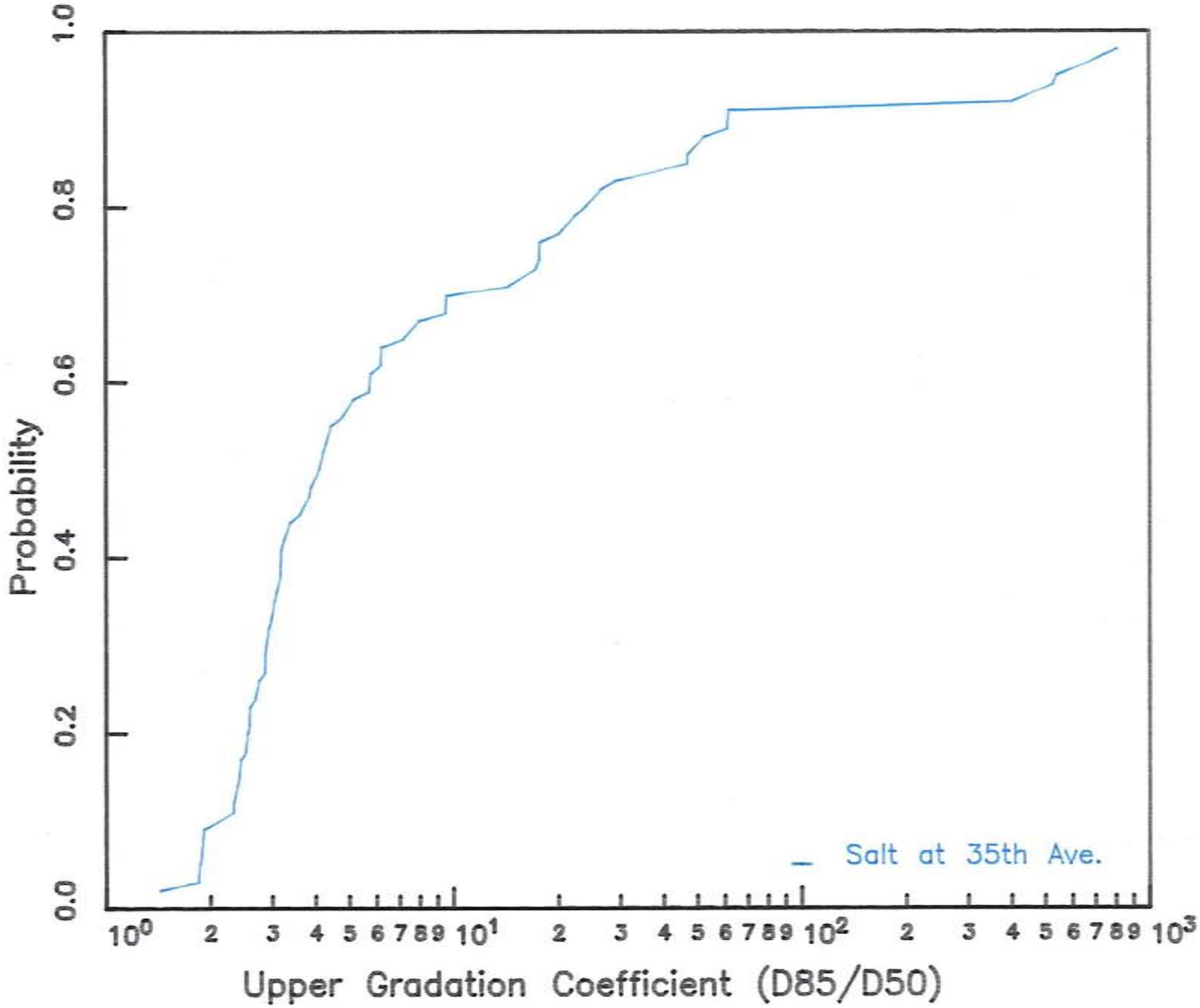

Probability
0.0
0.2
0.4
0.6
0.8
1.0
10^0 2 3 4 5 6 7 8 9 10^1 2 3 4 5 6 7 8 9 10^2 2 3 4 5 6 7 8 9 10^3
Upper Gradation Coefficient (D85/D50)
Salt at 35th Ave.

FIGURE H.12

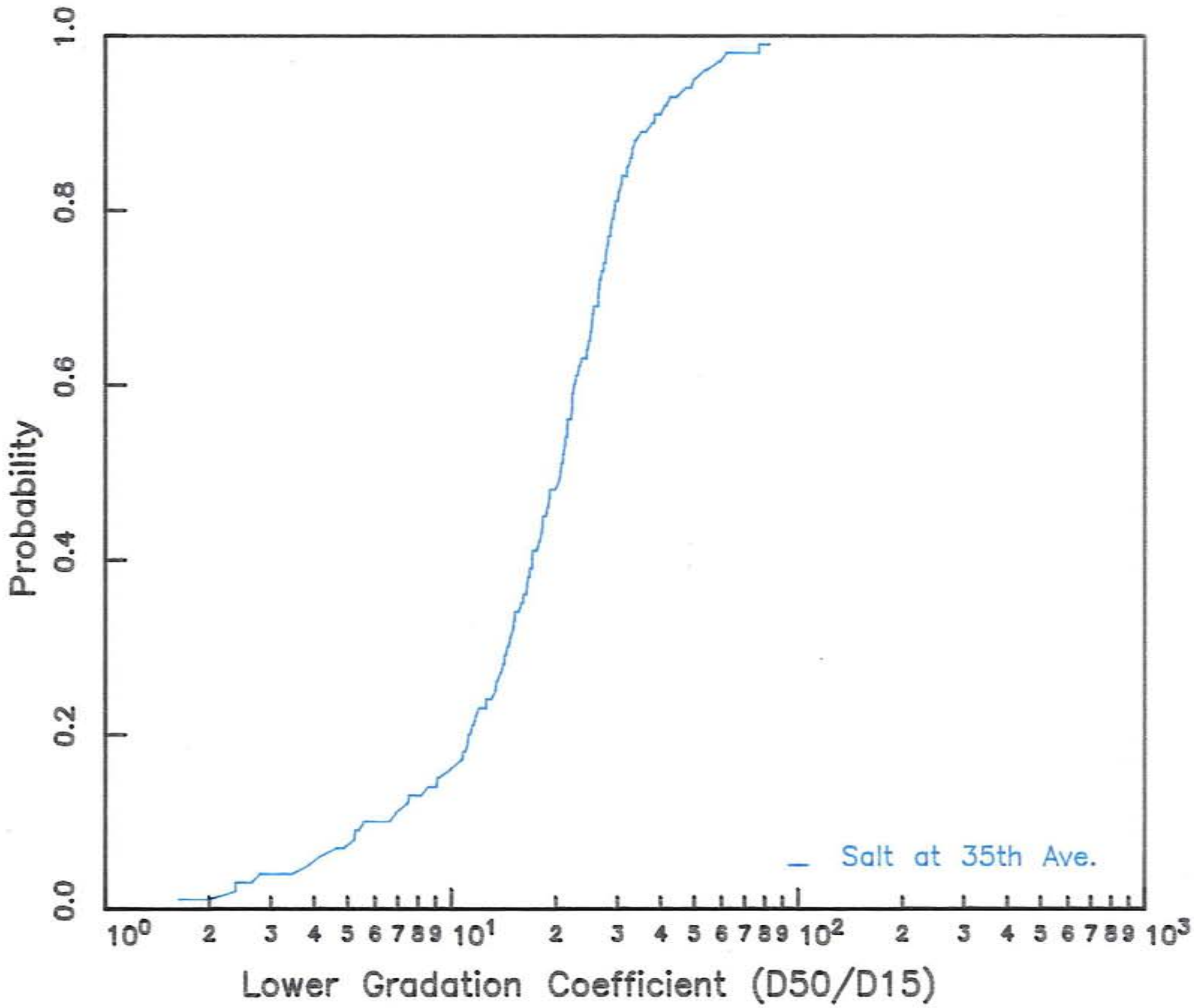

Probability
0.0
0.2
0.4
0.6
0.8
1.0
10⁰ 2 3 4 5 6 7 8 9 10¹ 2 3 4 5 6 7 8 9 10² 2 3 4 5 6 7 8 9 10³
Lower Gradation Coefficient (D50/D15)
Salt at 35th Ave.

FIGURE H.13

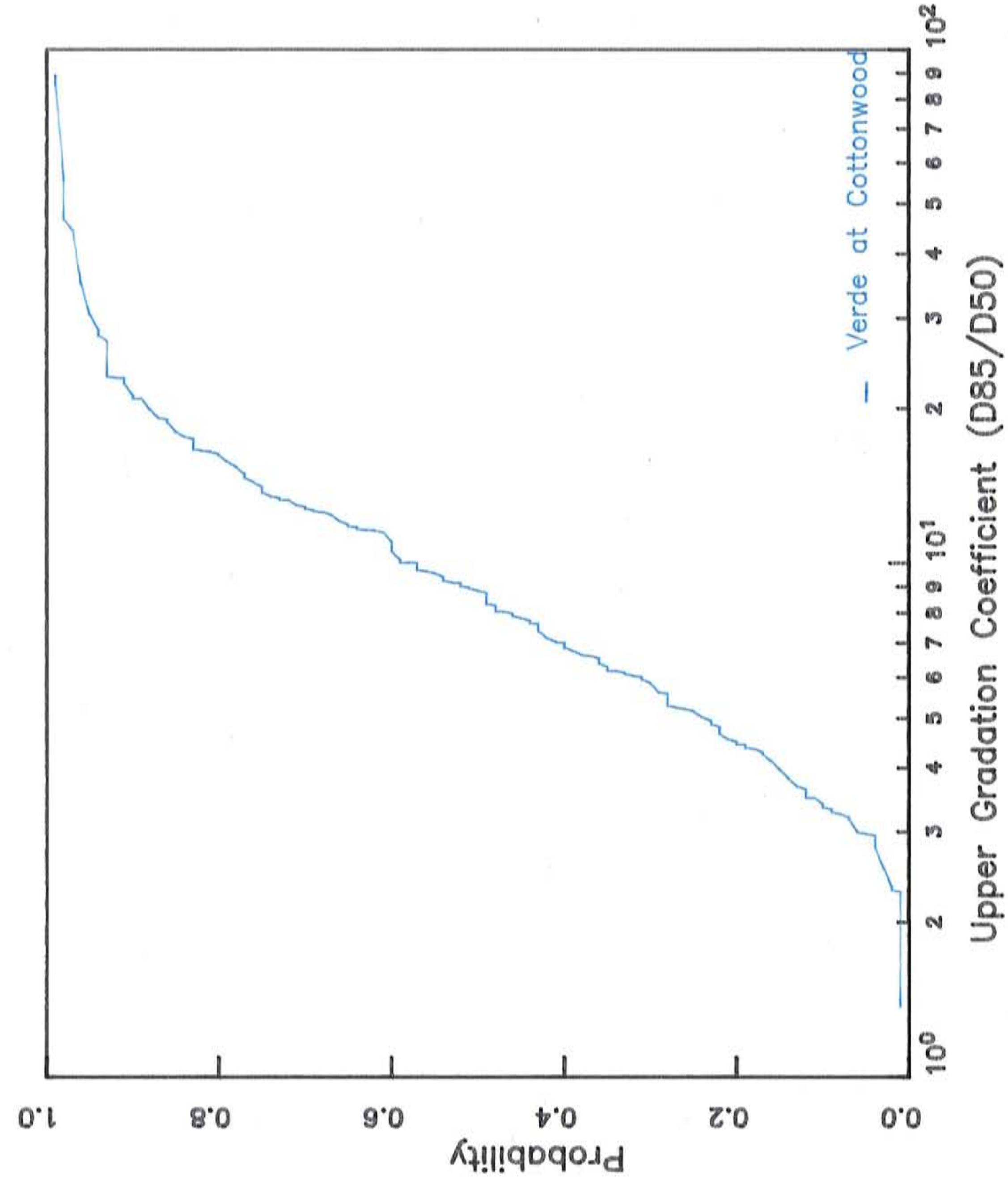

Probability
0.0
0.2
0.4
0.6
0.8
1.0
Upper Gradation Coefficient (D85/D50)
— Verde at Cottonwood

FIGURE H.14

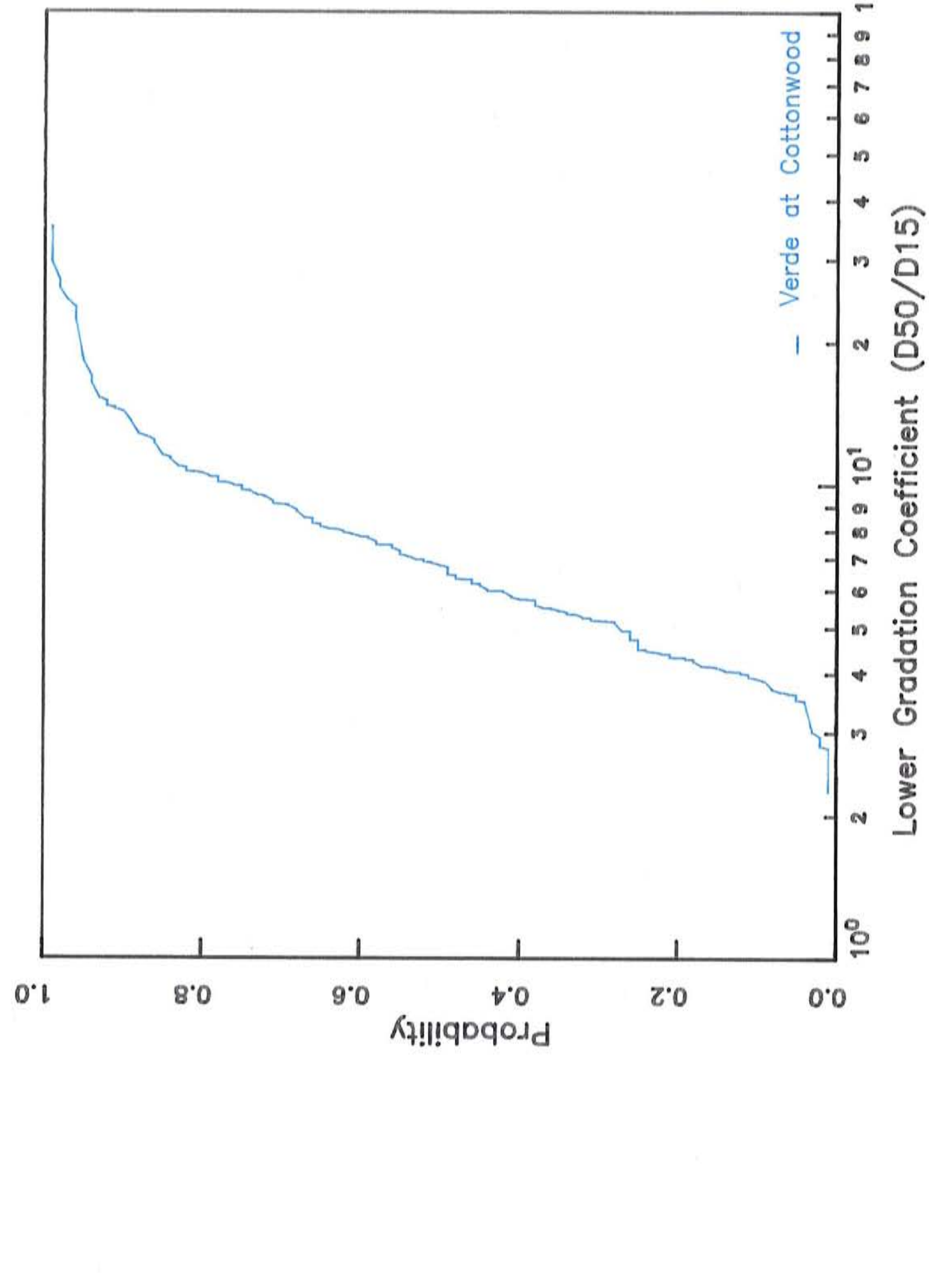

Probability
0.0
0.2
0.4
0.6
0.8
1.0
10^0
2
3
4
5
6
7
8
9
10^1
2
3
4
5
6
7
8
9
10^2
Lower Gradation Coefficient (D50/D15)
Verde at Cottonwood

FIGURE H.15

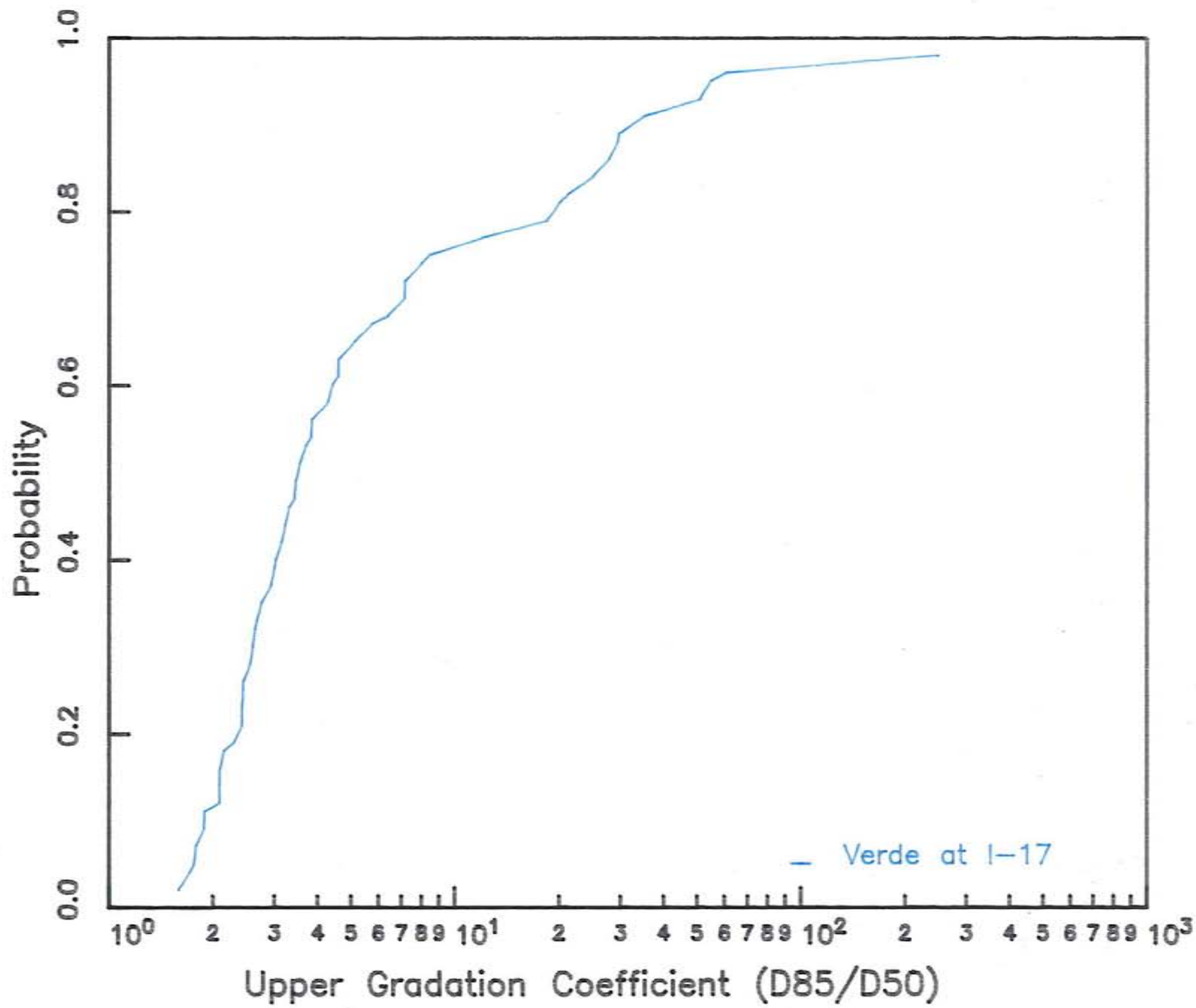

1.0
0.8
0.6
0.4
0.2
0.0
Probability
10^0 2 3 4 5 6 7 8 9 10^1 2 3 4 5 6 7 8 9 10^2 2 3 4 5 6 7 8 9 10^3
Upper Gradation Coefficient (D85/D50)
Verde at I-17

FIGURE H.16

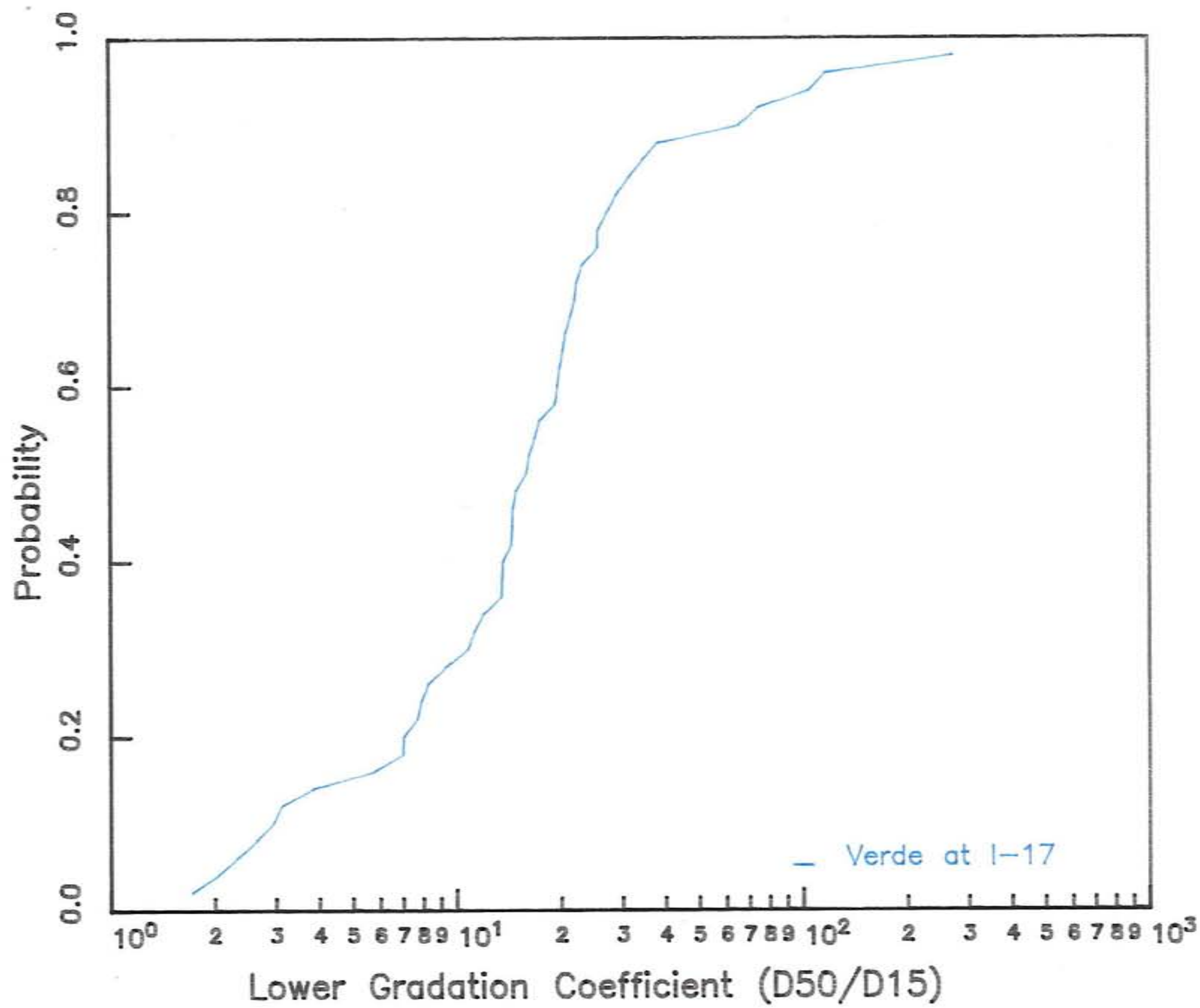

Probability
0.0
0.2
0.4
0.6
0.8
1.0
10^0 2 3 4 5 6 7 8 9 10^1 2 3 4 5 6 7 8 9 10^2 2 3 4 5 6 7 8 9 10^3
Lower Gradation Coefficient (D50/D15)
Verde at I-17

FIGURE H.17

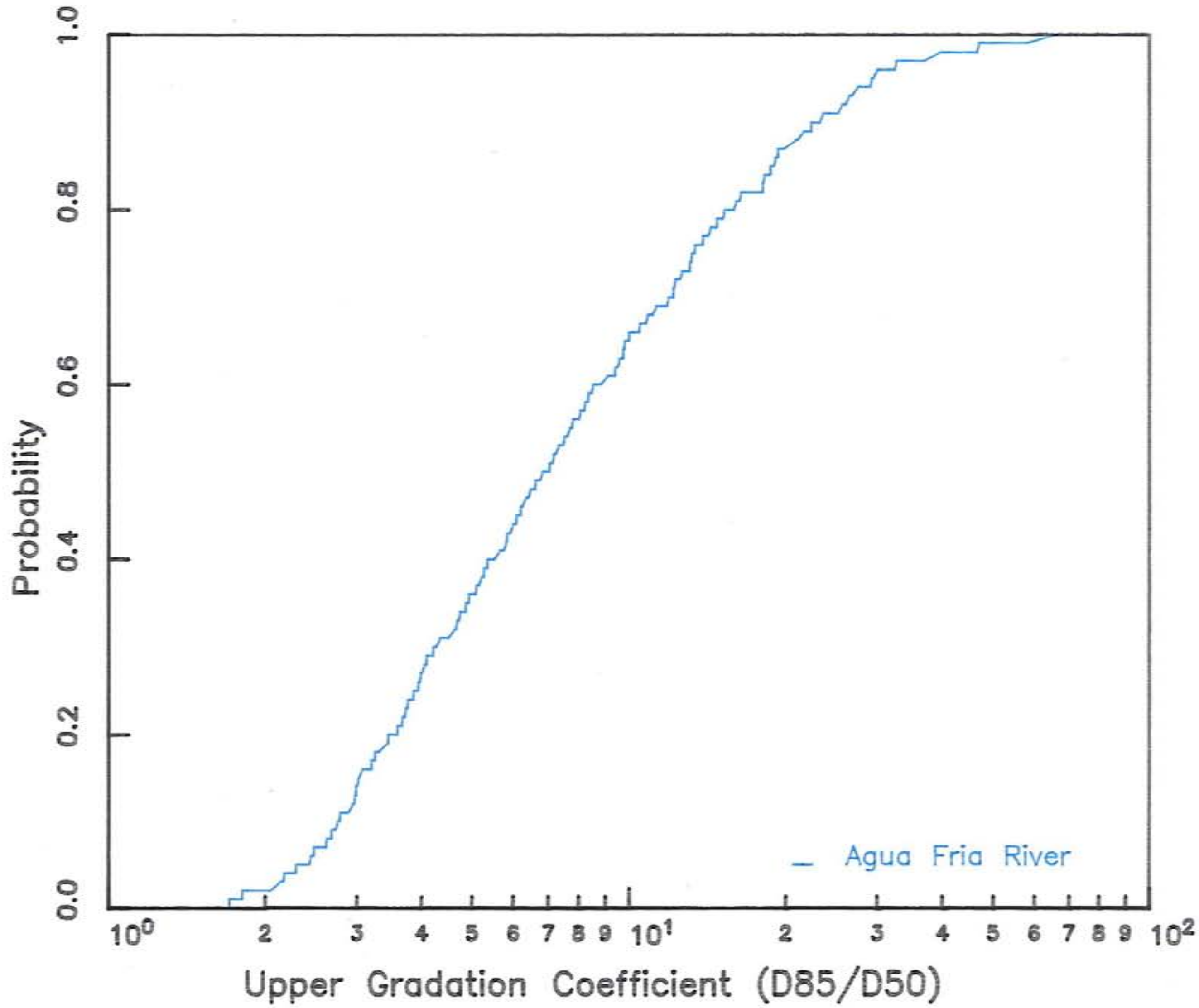
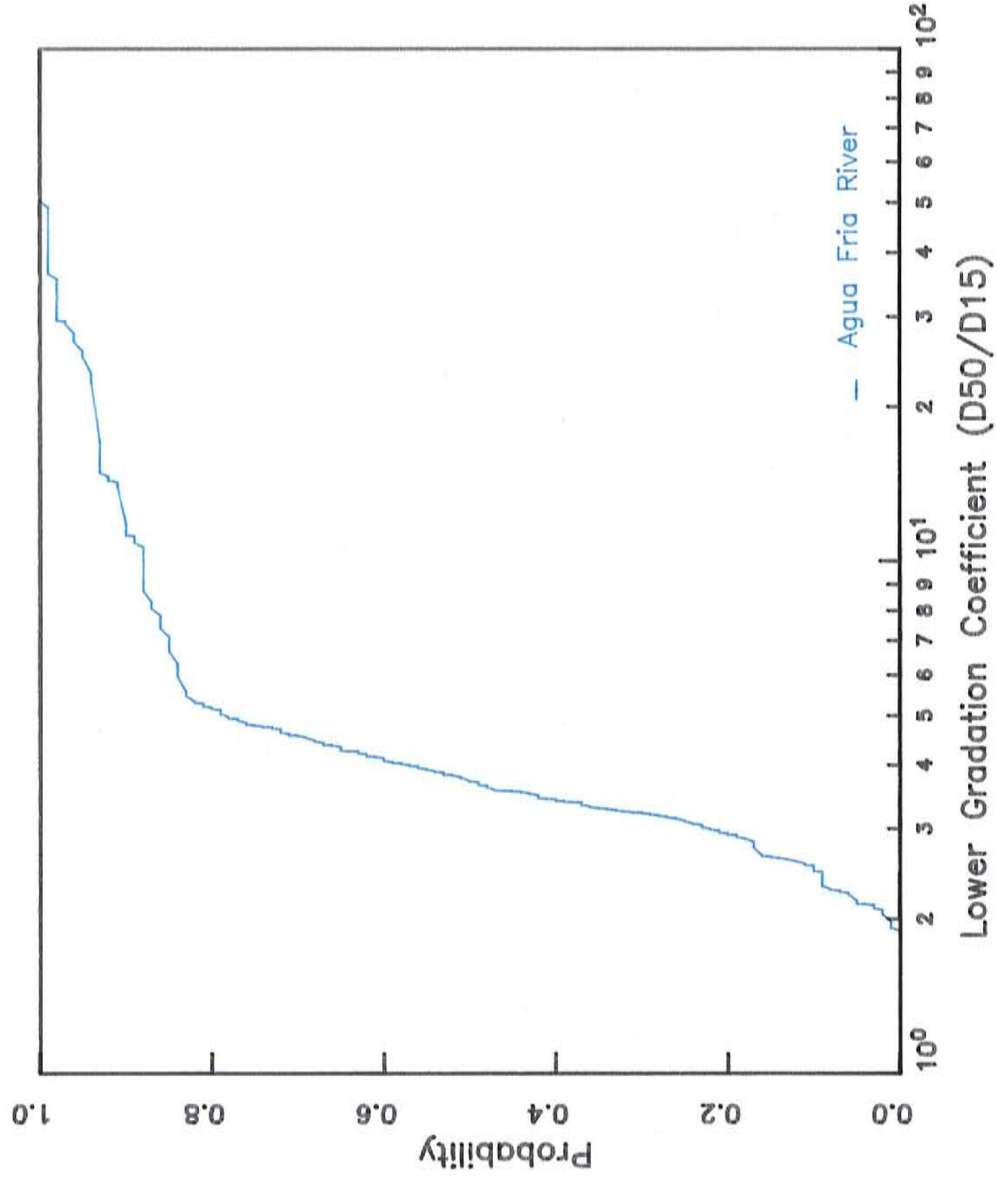
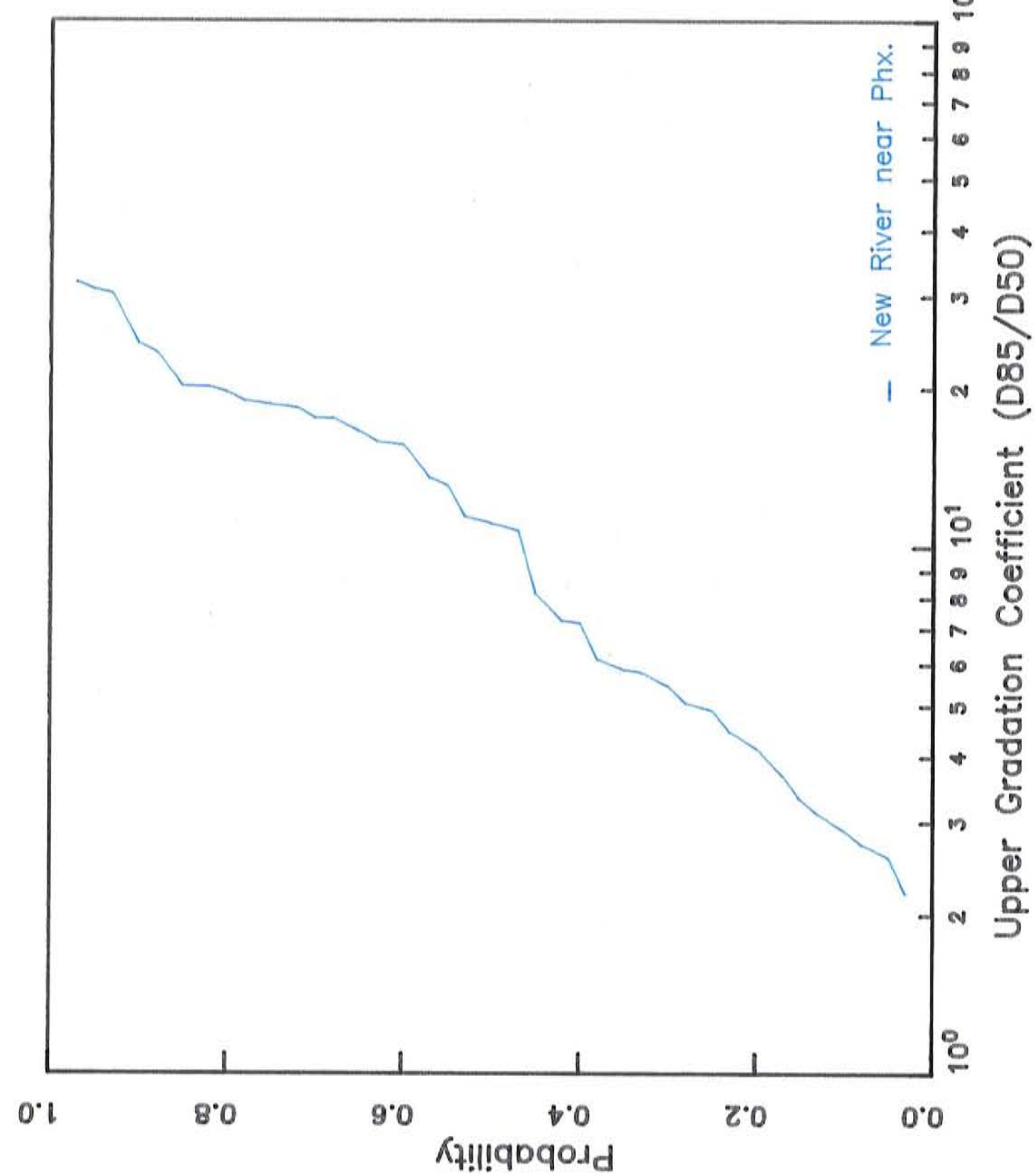

Probability
1.0
0.8
0.6
0.4
0.2
0.0
10^0
2
3
4
5
6
7
8
9
10^1
2
3
4
5
6
7
8
9
10^2
Upper Gradation Coefficient (D85/D50)
Agua Fria River

FIGURE H.18



Probability
0.0
0.2
0.4
0.6
0.8
1.0
Lower Gradation Coefficient (D50/D15)
Agua Fria River

FIGURE H.19



Probability
0.0
0.2
0.4
0.6
0.8
1.0
10⁰
2
3
4
5
6
7
8
9
10¹
10²
Upper Gradation Coefficient (D85/D50)
New River near Phx.

FIGURE H.20

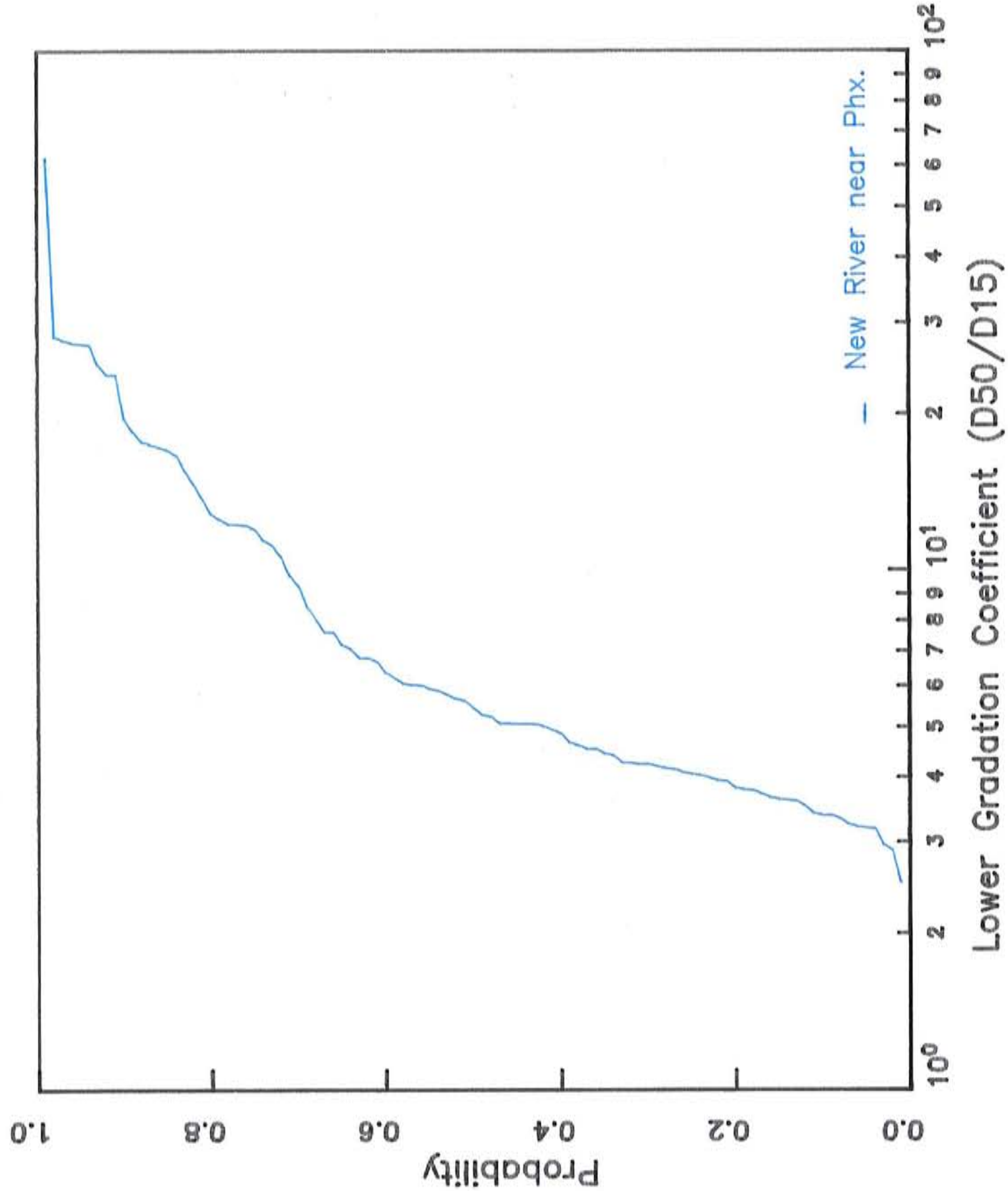
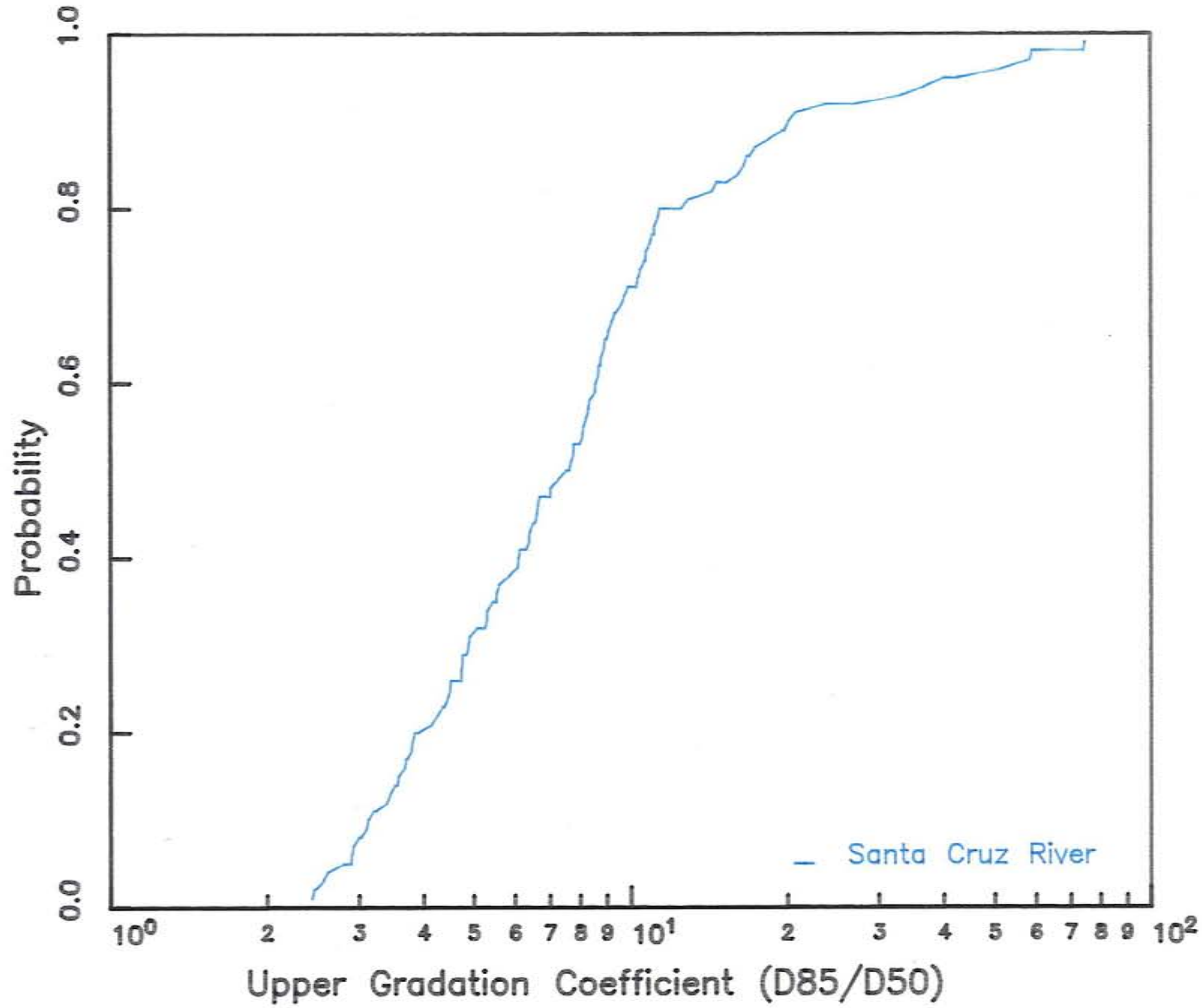
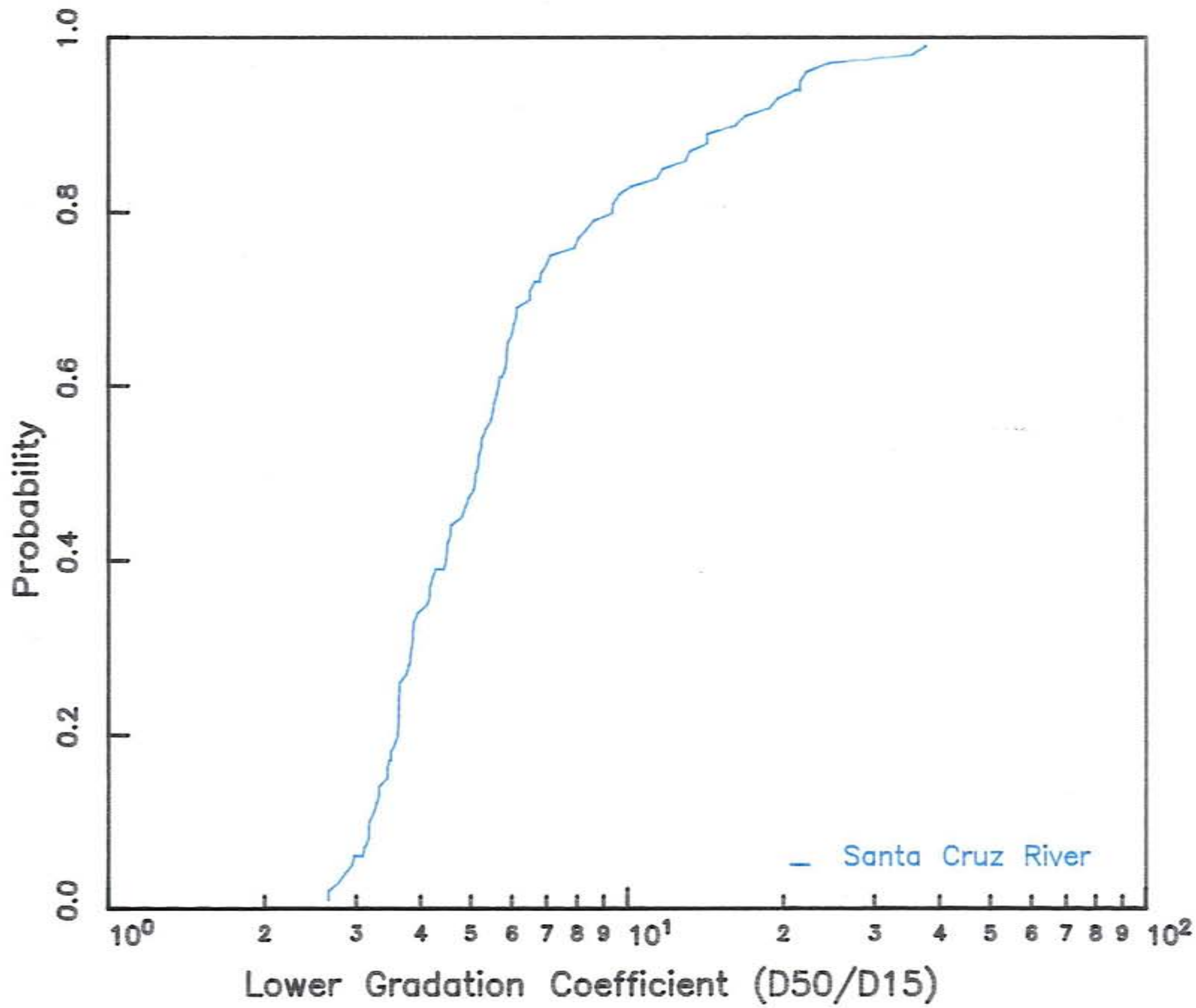

Probability
0.0
0.2
0.4
0.6
0.8
1.0
10^0 2 3 4 5 6 7 8 9 10^1 2 3 4 5 6 7 8 9 10^2
Lower Gradation Coefficient (D50/D15)
— New River near Phx.

FIGURE H.21



Probability
0.0
0.2
0.4
0.6
0.8
1.0
10⁰
2
3
4
5
6
7
8
9
10¹
2
3
4
5
6
7
8
9
10²
Upper Gradation Coefficient (D85/D50)
— Santa Cruz River

FIGURE H.22



Probability
0.0
0.2
0.4
0.6
0.8
1.0
10^0
2
3
4
5
6
7
8
9
10^1
2
3
4
5
6
7
8
9
10^2
Lower Gradation Coefficient (D50/D15)
Santa Cruz River

FIGURE H.23

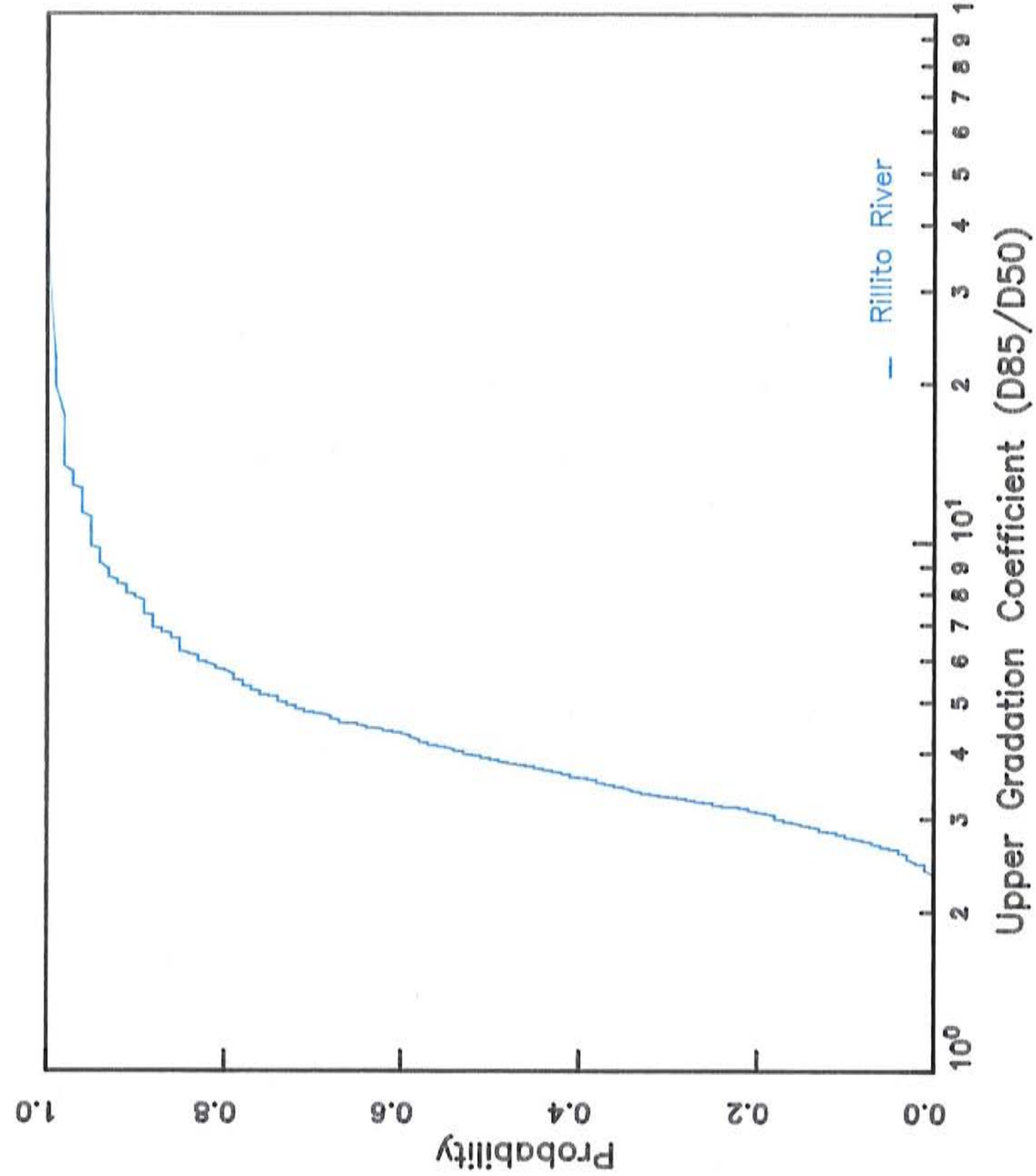
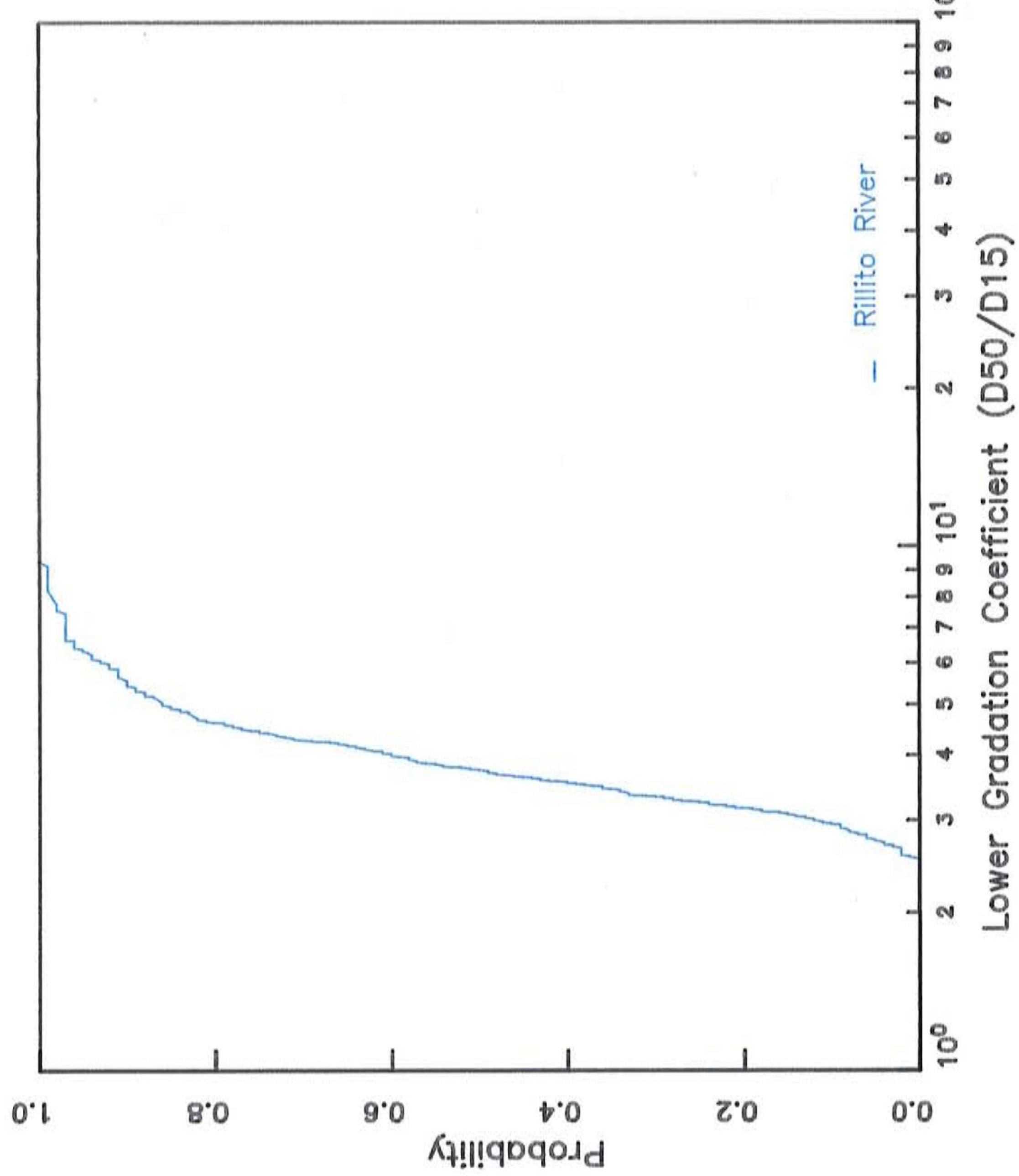

Probability
0.0
0.2
0.4
0.6
0.8
1.0
Upper Gradation Coefficient (D85/D50)
Rillito River

FIGURE H.24



Probability
0.0
0.2
0.4
0.6
0.8
1.0
Lower Gradation Coefficient (D50/D15)
10⁰
10¹
10²
Rillito River

FIGURE H.25

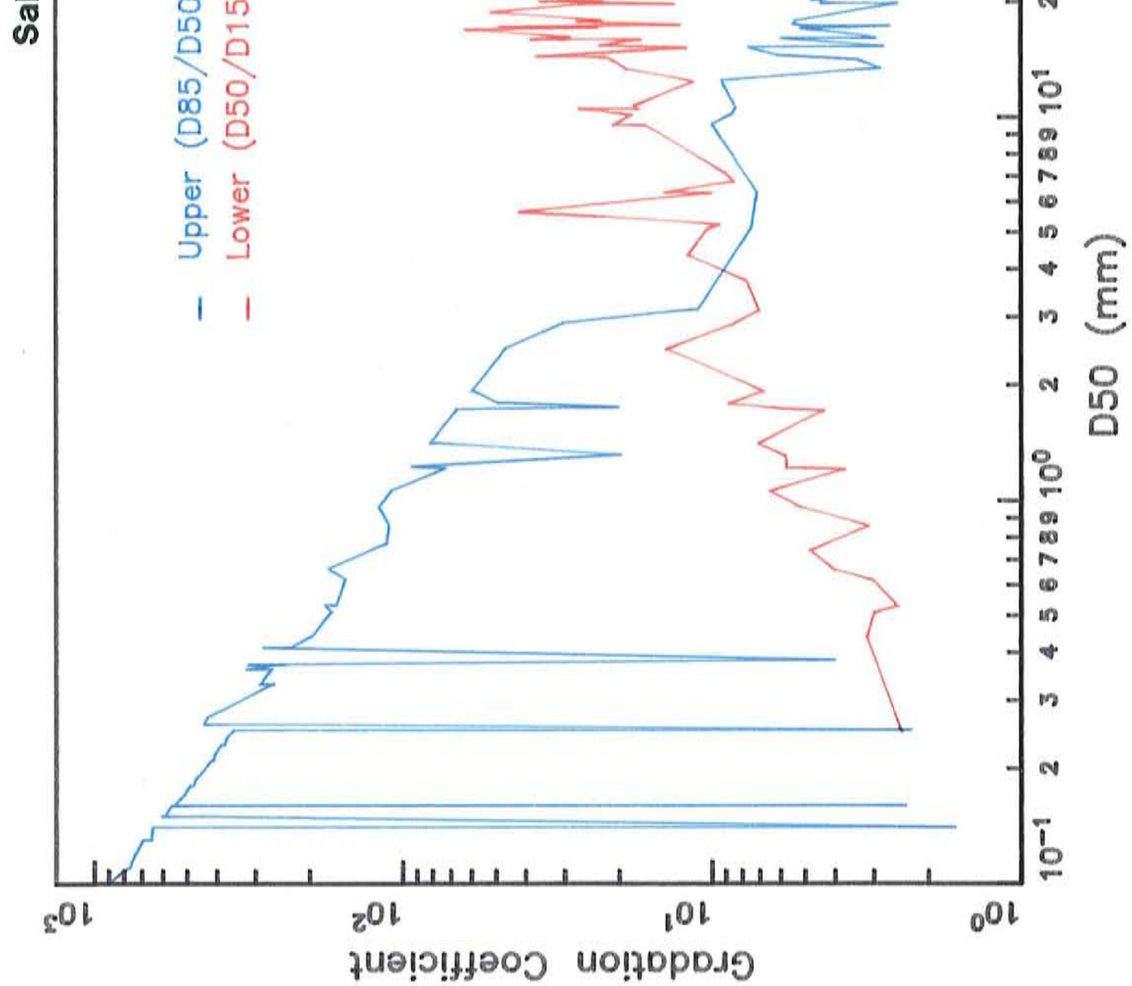
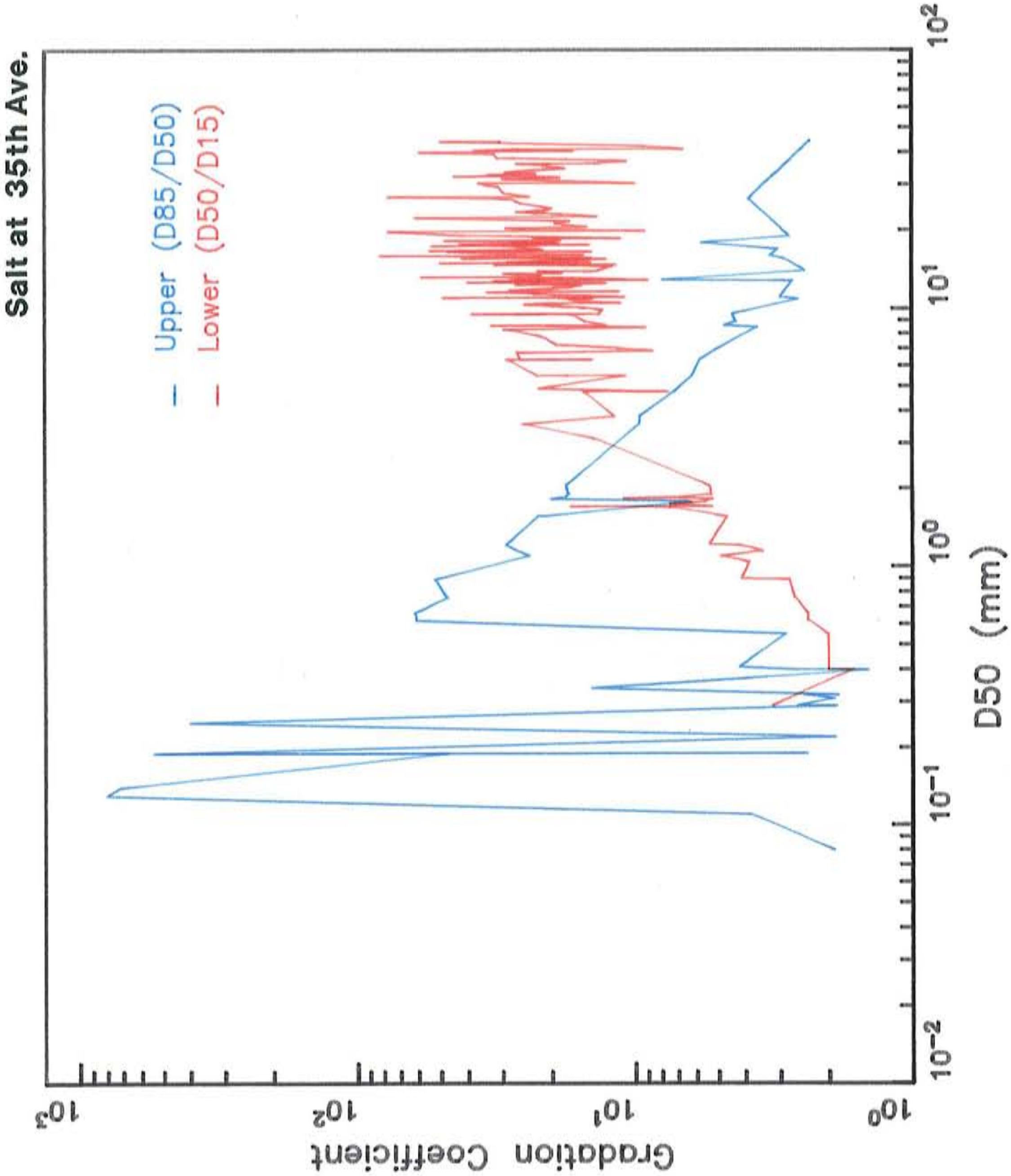
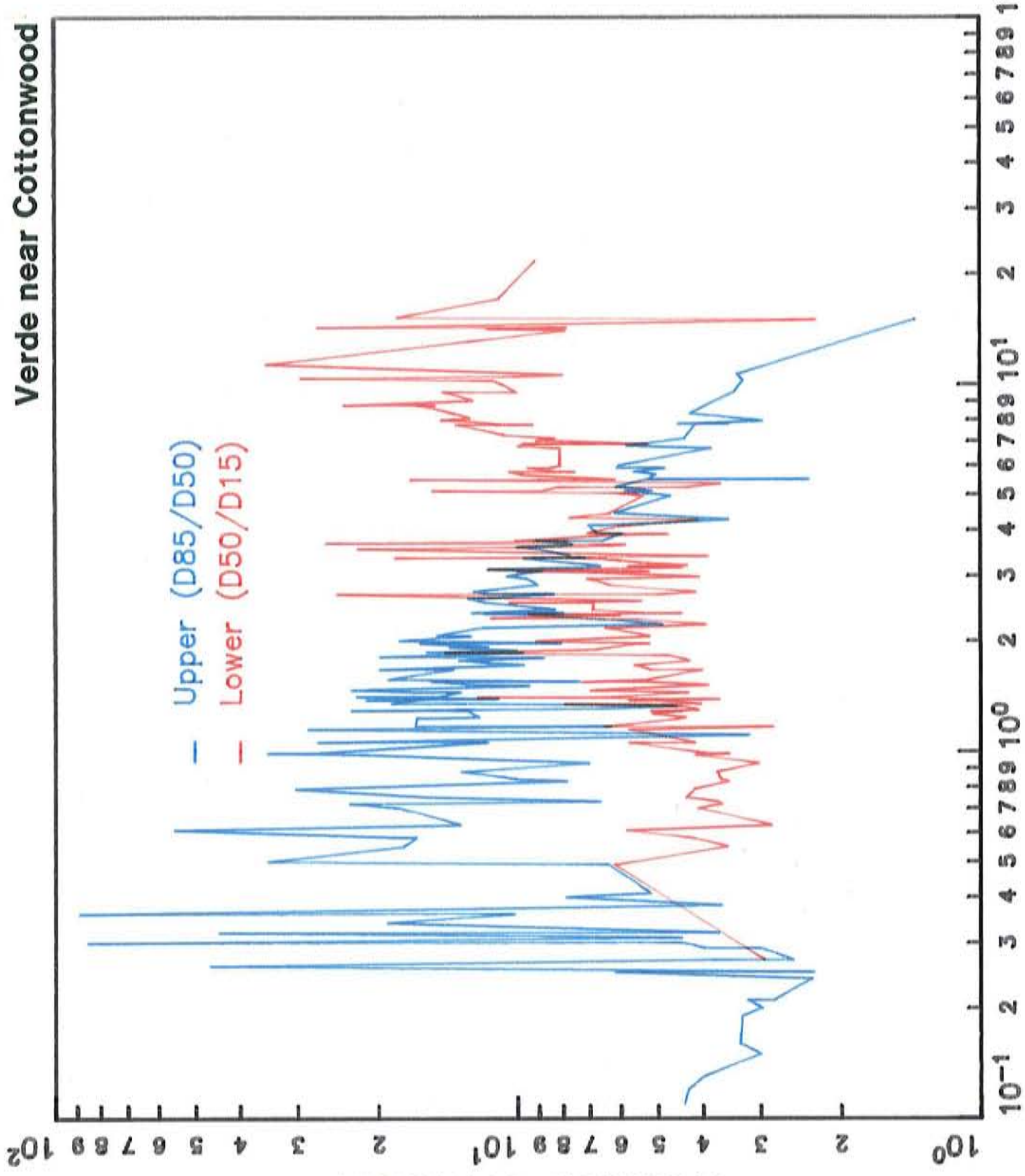

Salt at Hayden Rd.
Upper (D85/D50)
Lower (D50/D15)
Gradation Coefficient
D50 (mm)

FIGURE H.26



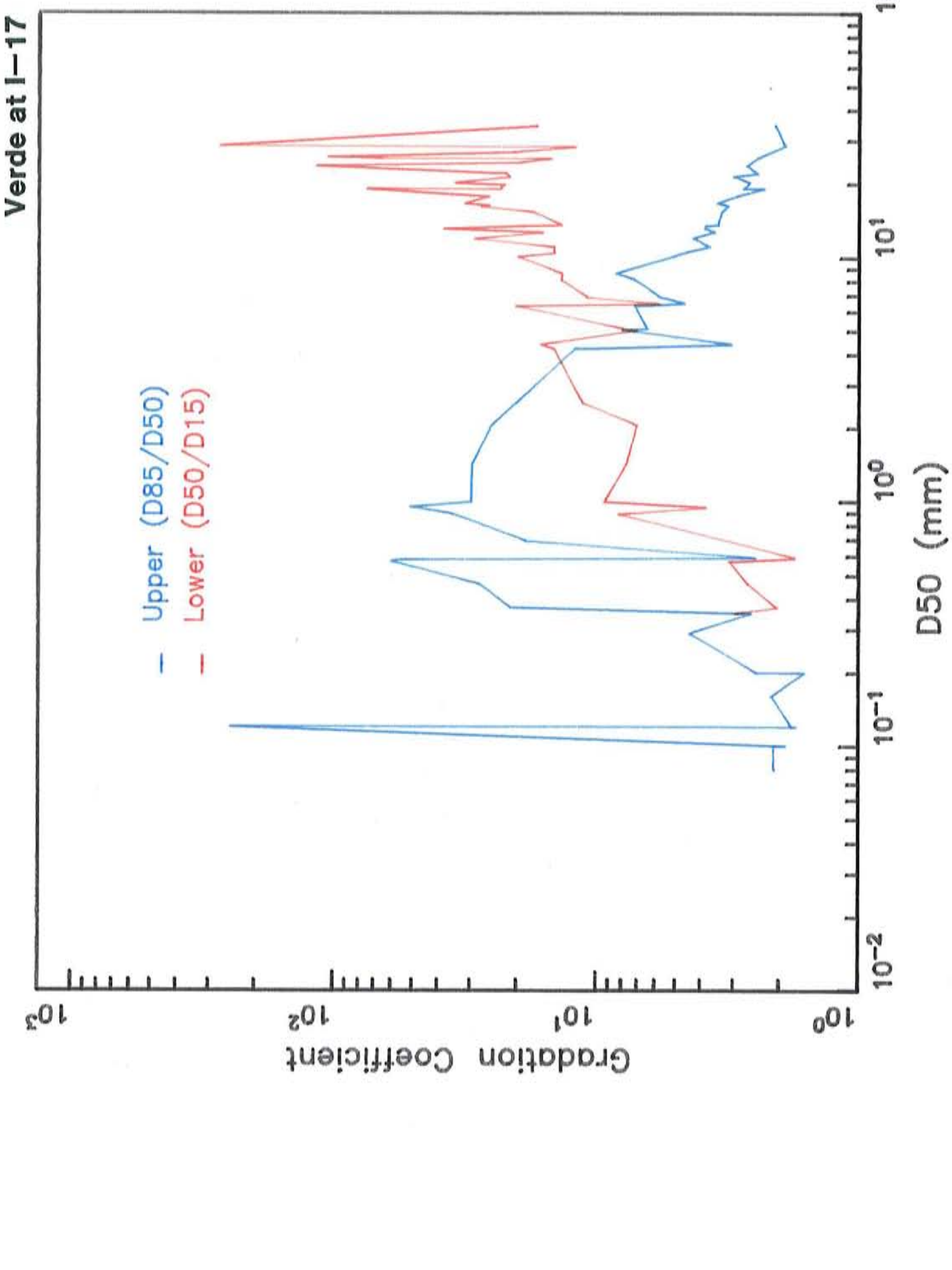
Salt at 35th Ave.
Upper (D85/D50)
Lower (D50/D15)
Gradation Coefficient
D50 (mm)

FIGURE H.27



Verde near Cottonwood
Upper (D85/D50)
Lower (D50/D15)
Gradation Coefficient
D50 (mm)

FIGURE H.28



Verde at I—17
Upper (D85/D50)
Lower (D50/D15)
Gradation Coefficient
D50 (mm)
10^0
10^1
10^2
10^3
10^{-2}
10^{-1}
10^0
10^1
10^2

FIGURE H.29

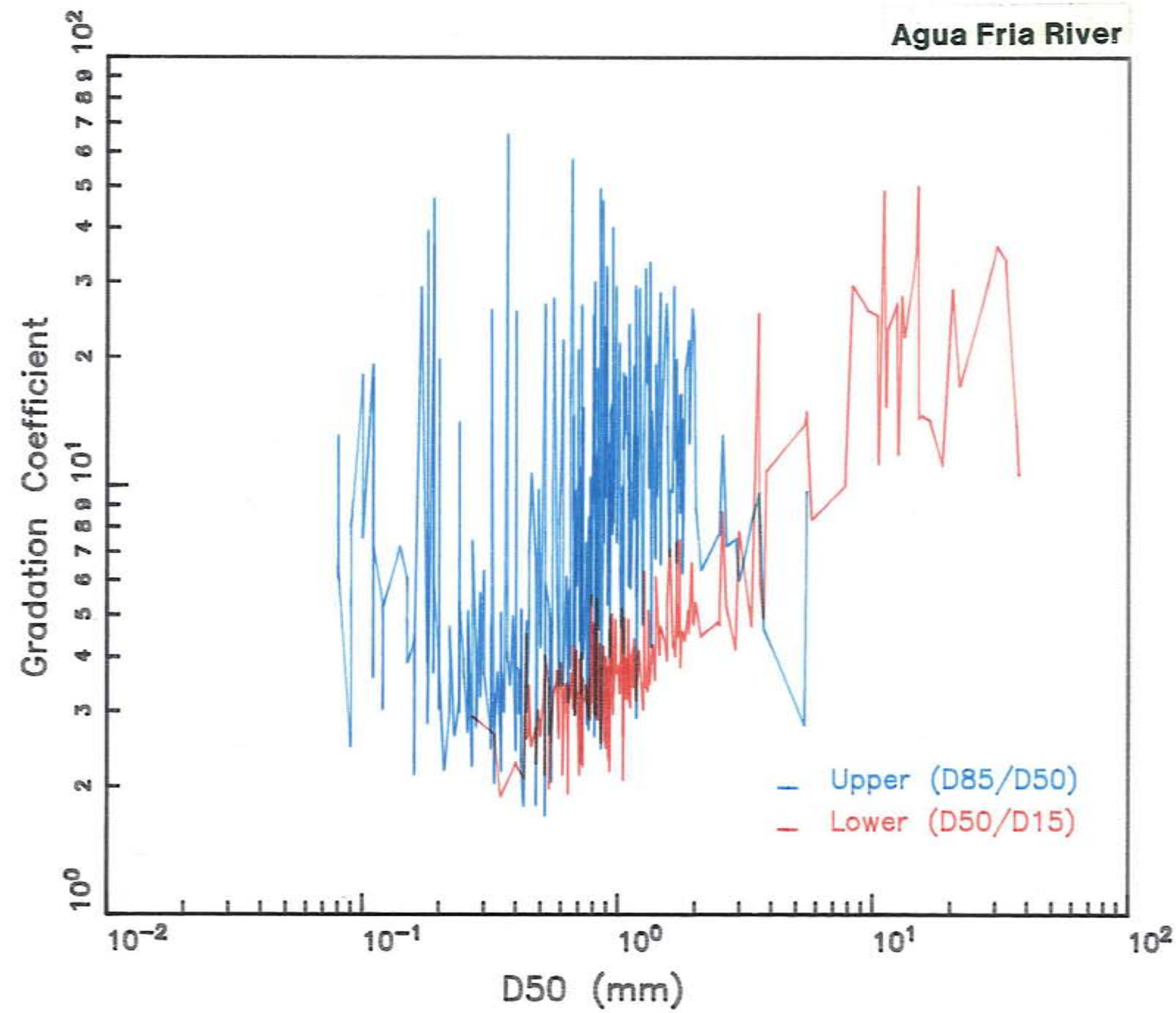

Agua Fria River
Gradation Coefficient
10^0
2
3
4
5
6
7
8
9
10^1
10^2
10^-2
10^-1
10^0
10^1
10^2
D50 (mm)
Upper (D85/D50)
Lower (D50/D15)

FIGURE H.30

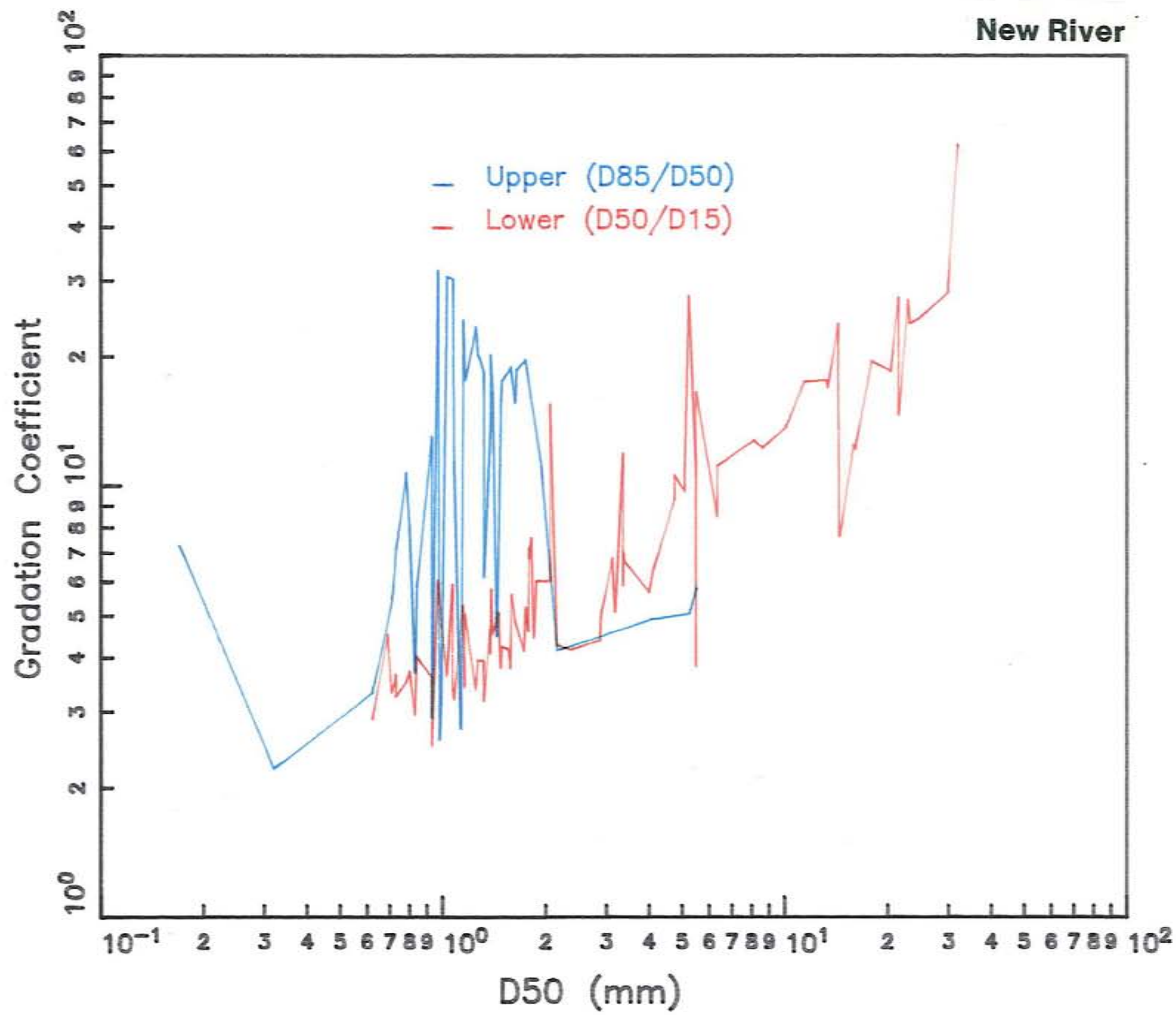

New River
Upper (D85/D50)
Lower (D50/D15)
Gradation Coefficient
D50 (mm)
10^{-1} 2 3 4 5 6 7 8 9 10^0 2 3 4 5 6 7 8 9 10^1 2 3 4 5 6 7 8 9 10^2
10^0 2 3 4 5 6 7 8 9 10^1 2 3 4 5 6 7 8 9 10^2

FIGURE H.31

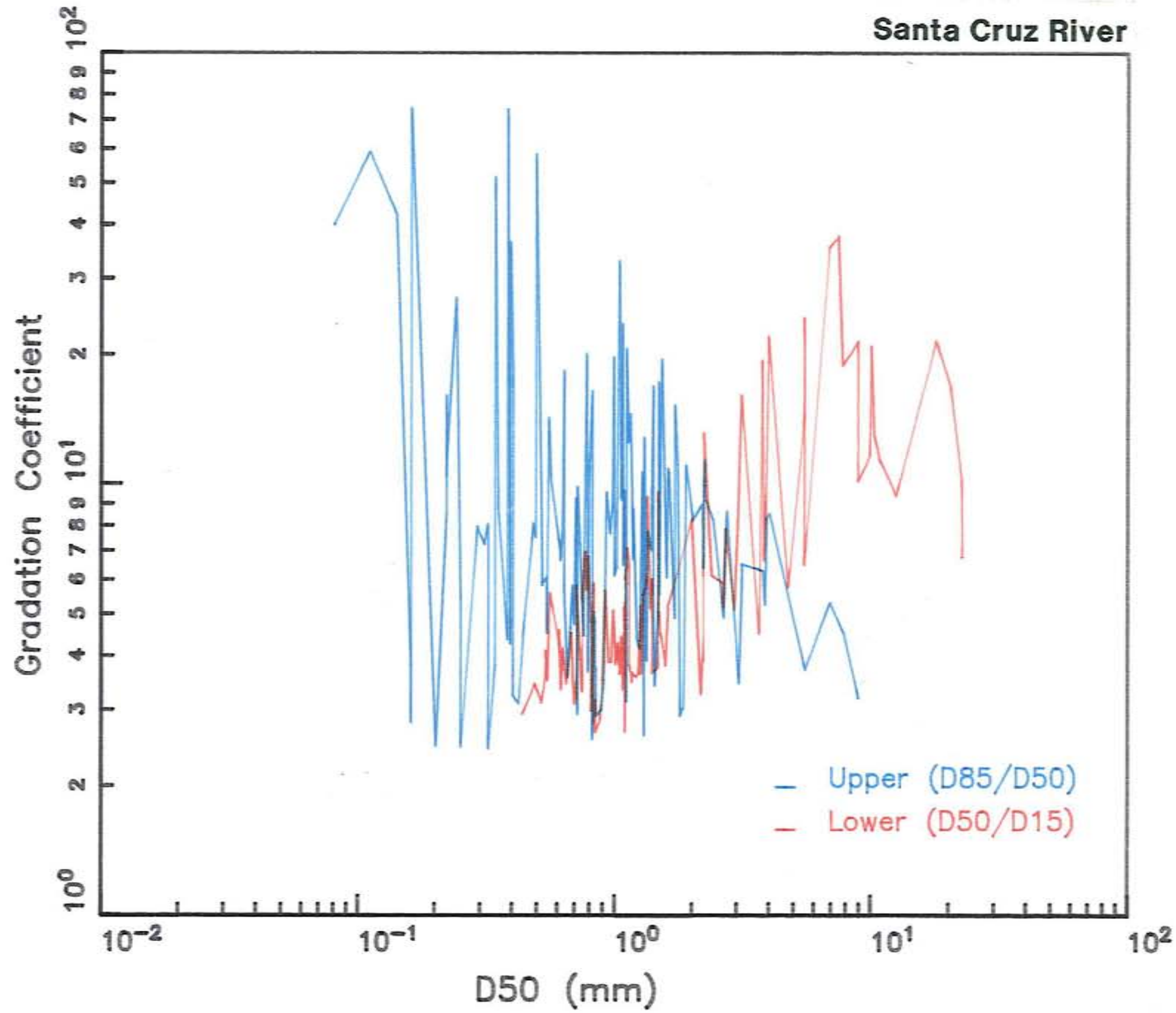

Santa Cruz River
Gradation Coefficient
D50 (mm)
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
2
3
4
5
6
7
8
9
Upper (D85/D50)
Lower (D50/D15)

FIGURE H.32

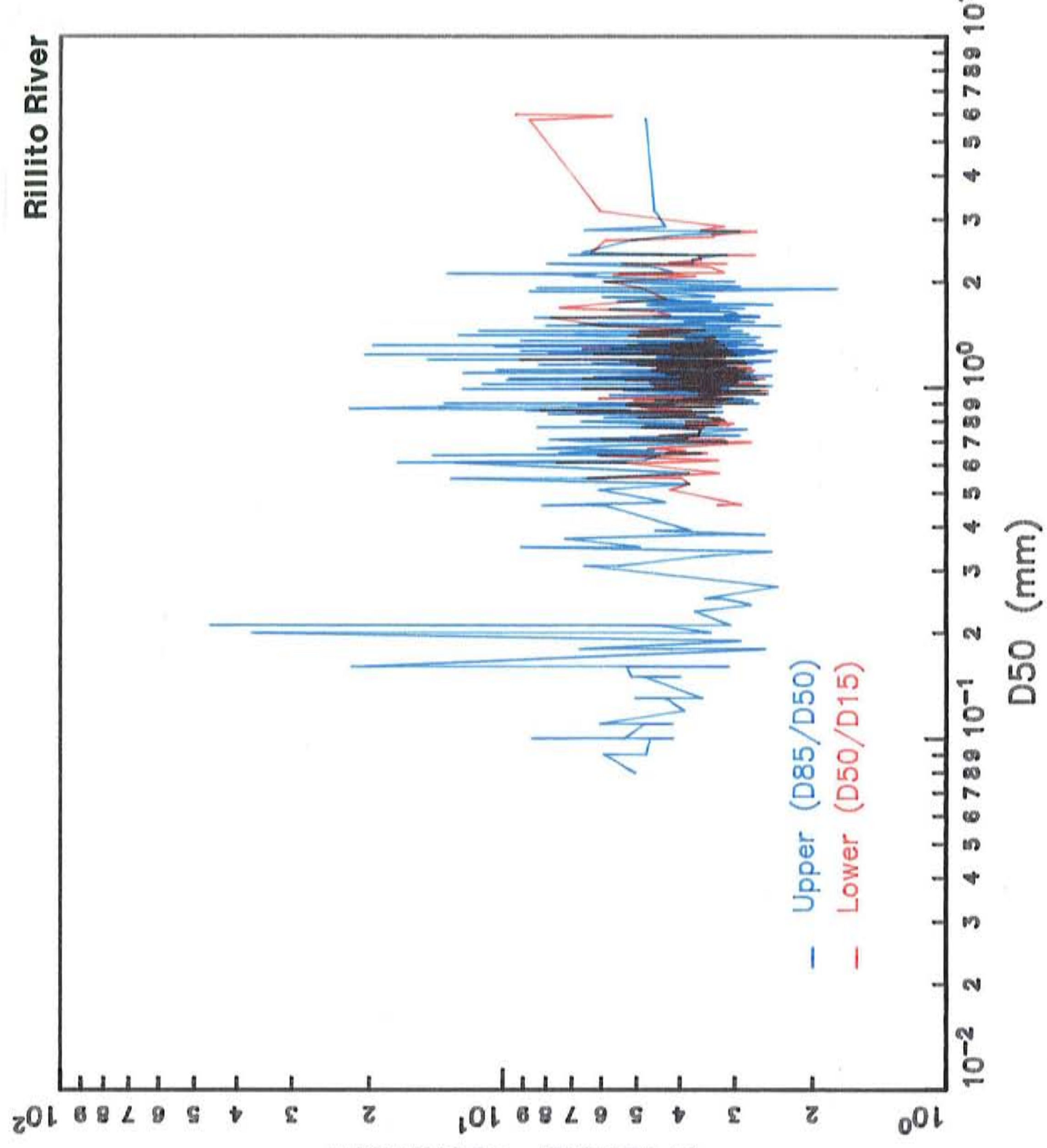

Rillito River
Gradation Coefficient
D50 (mm)
Upper (D85/D50)
Lower (D50/D15)

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
```



```
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 analized:'
      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 occurances 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 occurances 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 occurances 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 analize 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 MULTIPLOT

      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
```

```
        ELSE
           TRIAL=0
           TRIAL=Y(I)/100
           IF (TRIAL.GE.0.5) THEN
              NCOUNT=0
              DO 10 J=1,31
                 IF(TRIAL.GE.(PZ(J)+0.5)) NCOUNT=NCOUNT+1
   10         CONTINUE
           ELSE
              NCOUNT=0
              DO 20 J=1,31
                 IF(TRIAL.LT.(0.5-PZ(J))) NCOUNT=NCOUNT+1
   20         CONTINUE
           ENDIF

C          Interpolate to actual value

           TEMP=0
           PFLG=0
           PINT=0
           IF (TRIAL.GE.0.5) THEN
               PINT=TRIAL-0.5
               PFLG=1.0
           ELSE
               PINT=0.5-PZ(NCOUNT)
               PFLG=-1.0
           ENDIF

           IF (TRIAL.GE.0.5) THEN
              TEMP=0.1*(PINT-PZ(NCOUNT))/(PZ(NCOUNT+1)-PZ(NCOUNT))
              Z(I)=(PFLG*(NCOUNT-1)*0.1)+TEMP
           ELSE
              TEMP=0.1*(((PINT-TRIAL))/(PINT-(0.5-PZ(NCOUNT+1))))
              Z(I)=(PFLG*(NCOUNT-1)*0.1)+(PFLG*TEMP)
           ENDIF
        ENDIF
  100 CONTINUE

      RETURN
      END

****************************************

      SUBROUTINE PRINTSUB

****************************************

      CHARACTER*30 OUTFILE

      COMMON /BLOCK2/ AIVAL(65,6),NOIVALS,SIEVE(20),ICOL

C  Output routine to disk or printer.

      WRITE (*,*) ' '
      WRITE (*,*) 'If you would like the output directed'
      WRITE (*,*) 'to a disk file type (Y=YES):'
      READ (*,'(A1)') DISK
      IF (DISK.EQ.'Y') THEN
```

```
      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 MULTIPLOT

***************************************

      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='Cumumative 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 (*,*) '       analized 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 analizing 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),pa
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 analize 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 analizing 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),pa
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,l=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 l
    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 l

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(*,*) ' '
```

```
      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(*,*) ILINES
      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,IVALS,1,LINTYP,INTEQ(I),LOGTYP)
      ELSE
      CALL  LINE(X,Y,IVALS,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, ILINES
      isymbl = inteq(i)
      if(isymbl.eq.99) then
         isymbl = 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,isymbl,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)
```

```
      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        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        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   1B 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 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 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	18B	00120	93	61	57	48	45	43	43	41	21	NP85
04	74	19B	70140	93	61	49	39	34	31	30	27	15	183
04	74	20B	00 40	93	61	49	39	34	32	31	29	20	7NP26
04	74	20B	40130	93	61	40	29	24	22	21	18	8	1NP48
04	74	21B	10150	93	61	51	44	40	39	38	37	20	2NP71
04	74	22B	00130	93	61						61	51	8NP54
04	74	23B	00 90	93	61	61	59	58	57	57	48	30	7NP48
04	74	23B	90150	93	61	45	35	30	27	26	23	7	1NP71
04	74	24B	00160	93	61	45	34	28	26	24	23	7	1NP67
04	74	25B	00 90	93	61	49	38	33	31	30	28	16	2NP57
04	74	25B	90130	93	61	38	26	21	18	17	14	4	1NP35
04	74	26B	00150	93	61	49	37	31	27	26	21	4	NP83
04	74	27B	00110	93	61	60	60	59	59	59	59	54	10NP49
04	74	28B	90150	93	61	48	36	29	27	26	24	11	2NP42
04	74	29B	00 90	93	61	51	41	35	33	32	29	11	1NP74
04	74	29B	90130	93	61	46	38	32	29	27	24	7	2NP42
04	74	30B	00 90	93	61	43	37	33	31	30	28	12	1NP78
04	74	30B	90130	93	61	41	31	26	24	23	19	3	1NP48
04	74	31B	00130	93	61	48	39	34	32	31	28	11	1NP75
04	74	32B	00160	93	61	38	32	27	26	25	23	8	1NP84
04	74	33B	00160	93	61	37	29	26	24	23	21	7	1NP89
04	74	34B	00120	93	61	47	33	27	24	23	20	7	1NP76
04	74	35B	00130	93	61	49	34	26	23	21	18	8	1NP69
04	74	36B	00150	93	61	52	41	32	29	26	21	5	1NP72
04	74	37B	00150	93	61	51	42	37	35	34	32	13	1NP80
04	74	38B	40140	93	61	46	38	32	31	29	26	4	1NP92
04	74	39B	40140	93	61	46	36	30	27	25	22	7	1NP74
04	74	40B	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	1B	00120			01							
05	74	2B	00110			02				CRUSHED			
05	74	4B	00 50			01							
05	74	4B	50 66			05							
05	74	6B	30110			01							
05	74	8B	00 30			01							
05	74	8B	30 90			01							
05	74	10B	00 80			01							
05	74	10B	80200			01							
05	74	14B	00 90			01							
05	74	14B	90130			01							
05	74	16B	50170		181440	01							
05	74	20B	00 40			01							
05	74	20B	40130			01							
05	74	25B	00 90			01							
05	74	25B	90130			01							

```
05   74 30B 00 90            01
05   74 30B 90130            01
05   74 36B 00150            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  00140              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  00140    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  2481011NW2315 S13 EFI-29 (5)     TUCSON-NOGALES          2MI LT STA 3136
02  248    89 591  NODATA            6NO DATA            NO DATA IN FILE         2
03  248NO TEST DATA IN FILE: ALSO LOCATED IN NW1/2 SEC 23 SW1/4 SEC 14 SE1/4 15
04  248  0  00 00
01  2501012NW 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  00110                 100              93    85         52       13NP
04  250  2  00105                  96              85    81         47       16NP
04  250  3  00120                  91              73    67         44       16NP
04  250  4  00 80                  99              89    82         65       25NP
04  250  5  00 50                  98              89    73         16        4NP
04  250  6  00 55                  84              67    60         26        4NP
04  250  7  00 95                  97              88    80         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         0NP
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         0NP
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   1001001001001001001001001001001001001001001001100 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   100100100100100100100100100100100100100 99 93 44 33NP47
04  256  9  20120   100100 97 95 93 92 90 88 86 84 81 79 71 50 39 28 12  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
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04 2792  0   00 00
04 2793  0   00 00
04 6967  1   00110       100 91 81 68 61     47 41 34     28 21       8       3  2NP76
04 6967  2   00105       100 84 75 64 57     44 39 37     31 27      18       9  5NP30
04 6967  3   00105       100 87 78 70 66     56 50 47     39 33      21       7  3NP53
04 6967  4   10 65       100 83 71 60 54     41 35 32     23 18       7       2  1NP59
04 6967  5   15 90       100 79 71 62 55     45 40 37 28     24       8       3  1NP56
04 6967  6   00100       100 73 67 56 50     38 33 30 24     19       8       3  2NP71
04 6967  7   15110       100 75 68 57 49     38 34 32 24     18       7       3  2NP76
04 6967  8   00110       100 84 80 71 67     57 53 51 44     41      21       9  5NP78
04 6967  9   00120       100 66 61 52 48     38 34 31 22     16       6       2  1NP49
04 6967 10   00 65       100 76 69 58 51     41 36 34 27     23       9       3  2NP63
04 6967 11   00100       100 73 64 54 49     39 34 32 26     24      12       5  3NP83
04 6967  1A 00 15                                     100            96        40NP   R
04 6967  1A 15 95 95 86        52      38      30 27 25 16             2         0NP
04 6967  2A 10 90              60      43      32 28 26 19             3         1NP
04 6967  3A 10 95              59      38      26 23 21 15             4         1NP
04 6967  4A 10 85              58      44      37 34 33 30            20         9NP   R
04 6967  4A 10 85              59      45      36 32 30 23             6         1NP
04 6967  4A 85100              55      45      35 31 28 22             6         3 4   R
04 8239  1   00 40                        98 80 69 57 51 40 38 32 24 20 17 10  6  71
04 8276  1   00 40    100100100100100 99 97 95 92 89 87 86 83 75 64 51 27 17NP
04 8276  2   00 50     92 89 75 67 56 52 46 42 37 34 30 29 24 17 14 11  6  3NP74
04 8276  3   00 45    100100100 97 89 87 84 82 79 76 72 70 65 55 48 33 12  8NP
04 8276  4   00 35    100 92 84 77 73 67 62 59 56 53 49 47 41 29 23 19 12  8NP48
04 8276  5   00 50    100100100100100100100100100100100100100100 99 76 46NP
04 8276  6   00 35     92 92 92 79 74 70 65 62 59 56 53 52 48 39 31 24 13  8NP
04 8276  7   00 40    100100 96 91 78 74 68 65 61 58 55 54 50 43 38 33 20 12NP
04 8276  8   00 70     95 93 90 86 82 80 77 74 71 67 62 60 53 40 34 30 20 12NP52
04 8276  9   00 20    100100100100100100100100100100100100100100 99 62 41NP25
04 8276  9   20 45     92 92 82 71 56 53 45 40 35 32 28 27 23 15 12 10  6  4NP57
04 8276 10   00 20    100 96 83 75 64 59 51 46 41 37 33 32 26 19 16 14 11  9 3
04 8276 11   00 45    100100 96 95 90 88 84 81 77 74 72 71 62 45 39 35 26 20NP37
04 8276 12   00 40    100100 95 90 81 80 76 73 69 66 65 65 64 62 62 60 54 43 2
04 8276 13   00 50    100 93 88 85 81 79 76 74 72 70 67 66 62 51 42 32 11  6NP
04 8276 14   00 40     90 86 63 58 50 47 42 40 37 35 33 32 29 22 17 13  8  5NP
04 8276 15   00 30    100 90 81 67 43 35 30 28 27 26 26 26 25 23 22 21 18 14 1
04 8276 15   30 70     91 87 79 73 69 65 57 52 47 44 39 37 30 16  9  5  2  1NP80
04 8276 16   00 60    100 93 83 74 66 61 54 49 44 41 36 34 29 20 12  7  3  2NP
04 8276 17   00 50    100100100100100100 99 99 99 98 97 96 87 69 56 44 20  9NP
04 8276 18   00 70     95 87 84 80 76 73 67 64 60 56 50 48 40 26 20 16 10  7NP
04 8276 19   00 20    100100100100100100100100100100100 99 95 90 83 27 19NP
04 8276 19   20 70    100 97 94 90 79 75 70 68 49 36 24 21 15 10  8  7  5  4 152
04 8276 20   00 50    100100 94 87 80 78 75 74 73 71 69 68 65 51 37 23  4  2NP
04 8276 21   00 80    100 92 90 77 59 50 43 41 38 36 33 32 29 24 21 18 10  7NP
04 8276 22   00 60    100 97 94 88 76 69 61 58 53 49 41 38 29 14  7  4  2  1NP
04 8276 23   00 90    100 79 72 66 53 48 42 39 34 31 24 22 16  7  5  4  2  1NP
04 8276 24   00 70     95 84 69 61 51 47 43 41 39 36 34 33 30 26 24 22 12  9NP
04 8276 24   70 80    100 90 90 83 70 63 57 54 49 44 35 32 23 15 13 12  9  7 241
04 8276 25   00 70    100 91 86 74 64 59 52 49 44 40 33 31 24 12  9  7  4  2NP
04 8276 26   00 50    100 94 85 79 71 69 65 64 62 60 57 56 51 41 33 22  5  3NP
04 8276 27   00 40    100100100100100 99 98 98 97 94 90 88 79 51 26 11  2  1NP
04 8276 28   00 70     96 88 84 74 66 52 47 45 41 38 33 31 25 16 11  7  3  2NP
04 8276 29   00 50    100100100 96 92 89 86 85 83 81 78 77 73 67 57 37 10  5NP
04 8276 30   00 50    100100100100100100100100100100100100100100 99 98 59 34NP
04 8276 31   00 50    100100100100100100100100100100100 99 96 91 78 47 40NP
04 8276 32   00 60    100 95 91 82 76 72 64 60 54 49 39 35 25 12  8  6  3  2NP
04 8276 33   00 80    100 96 88 71 59 55 49 46 42 38 29 26 16  6  3  2  1  1NP
04 8276 34   00 80     86 77 77 73 65 60 54 51 47 43 34 31 23 15 11  7  3  2NP
```

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.	96.	-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
4.760	-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: VERDEIM.GUL)

.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-textures oils 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

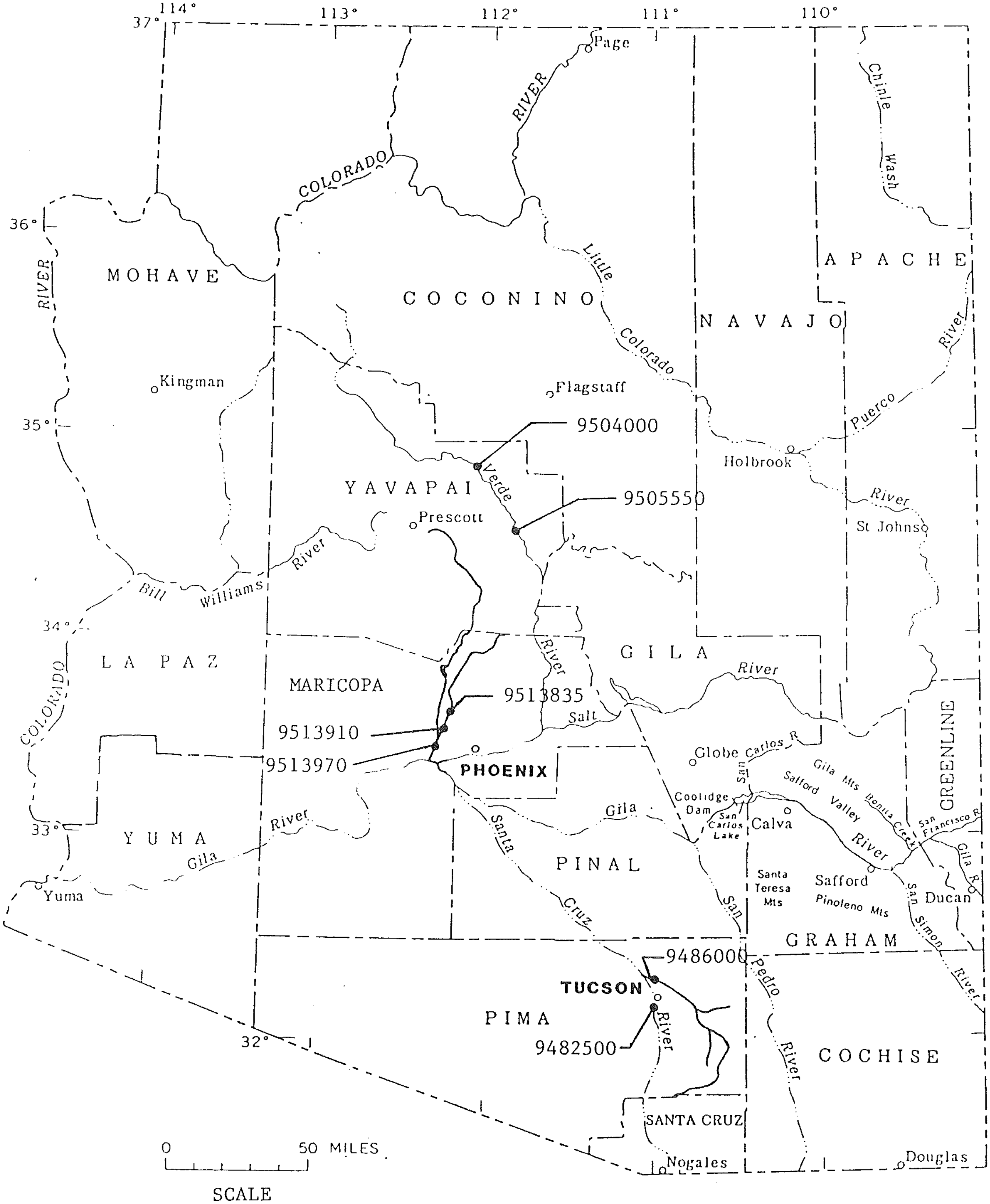
A majority of the hydrograph data was obtained from the U.S. Geological Survey's Water-Supply Papers. These papers are referenced at the end of this appendix. Most, if not all, of the data gathered for the Salt River was supplied by the Salt River Project, Tempe, Arizona. In some instances, hydrograph 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 Crops 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 I.1

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 upstream. 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 dischargees, 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 acerage 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:

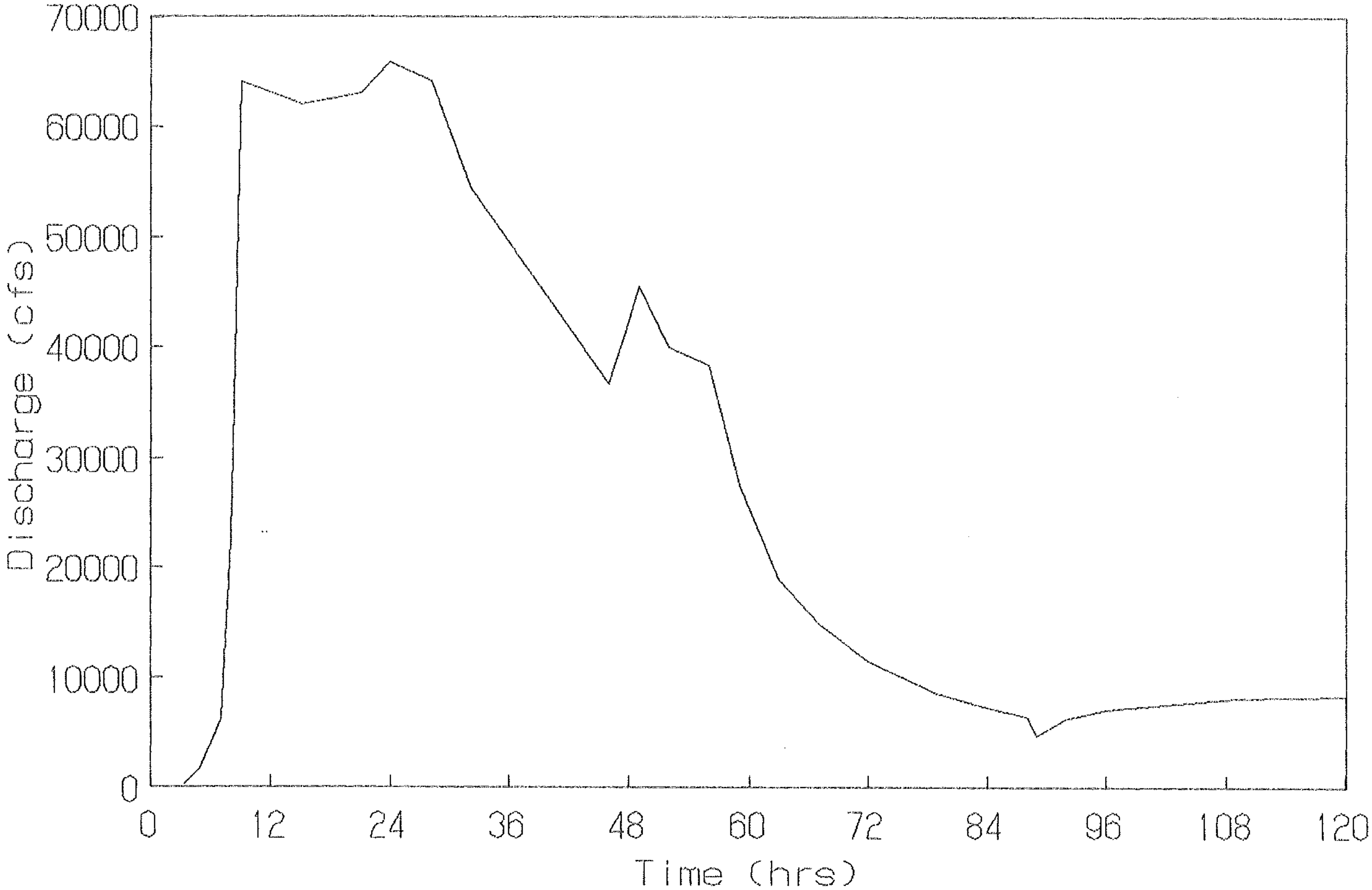
* Indicates a multiple peak hydrograph.

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

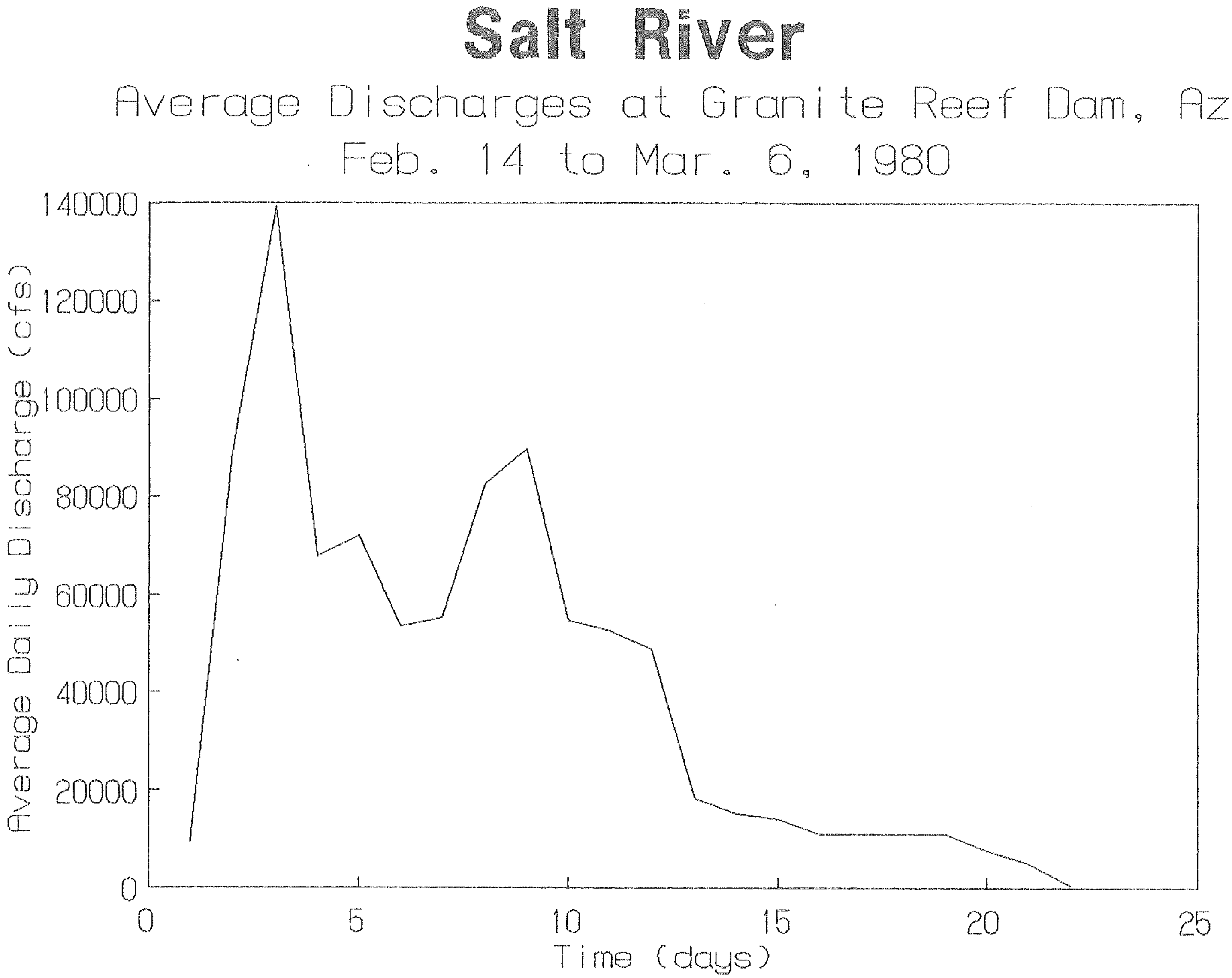
Salt River at Jointhead Dam, Az

Dec. 30, 1965 to Jan. 4, 1966



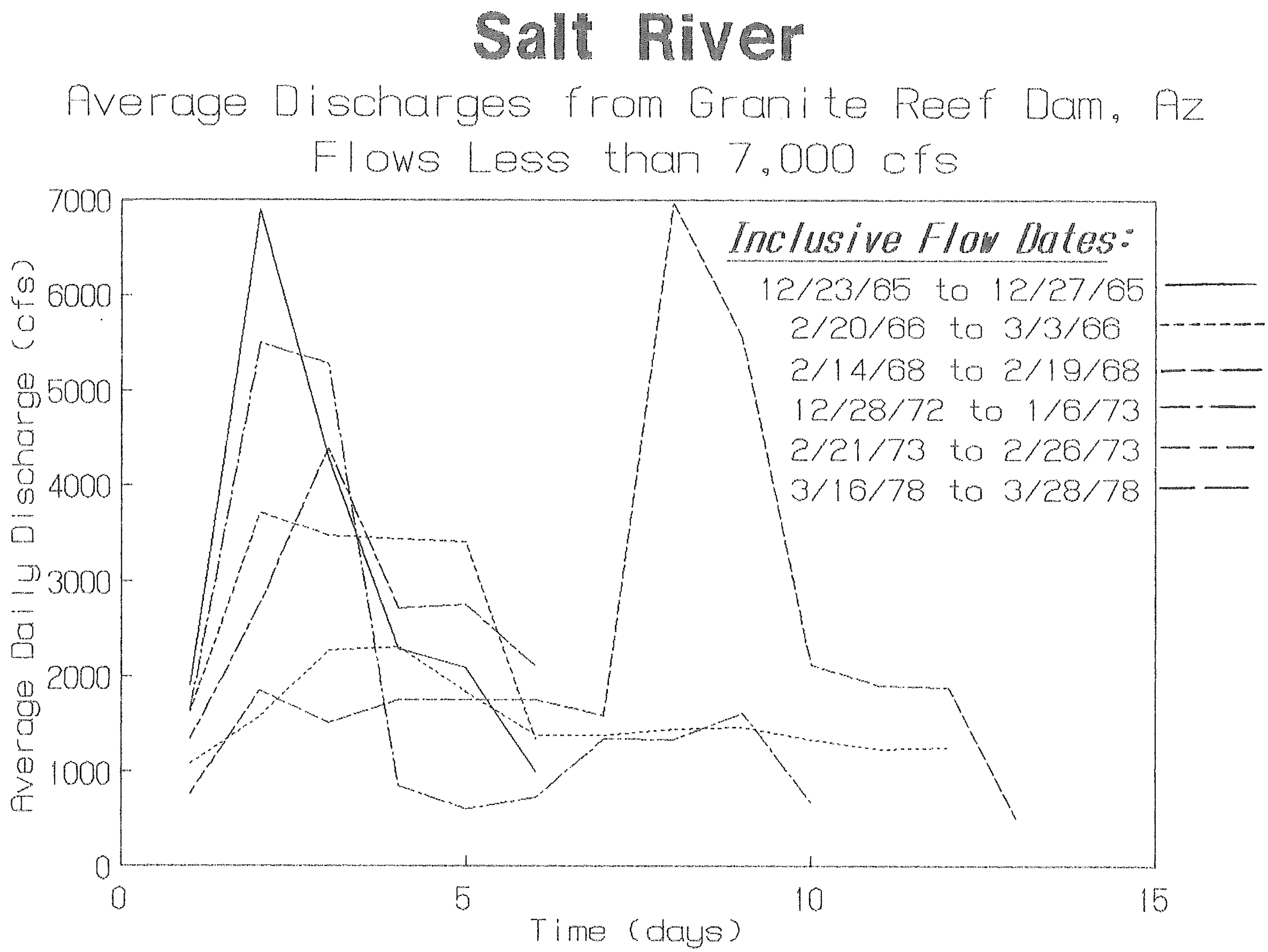
(U.S.G.S. WSP No. 1850-C)

GRAPH I.1



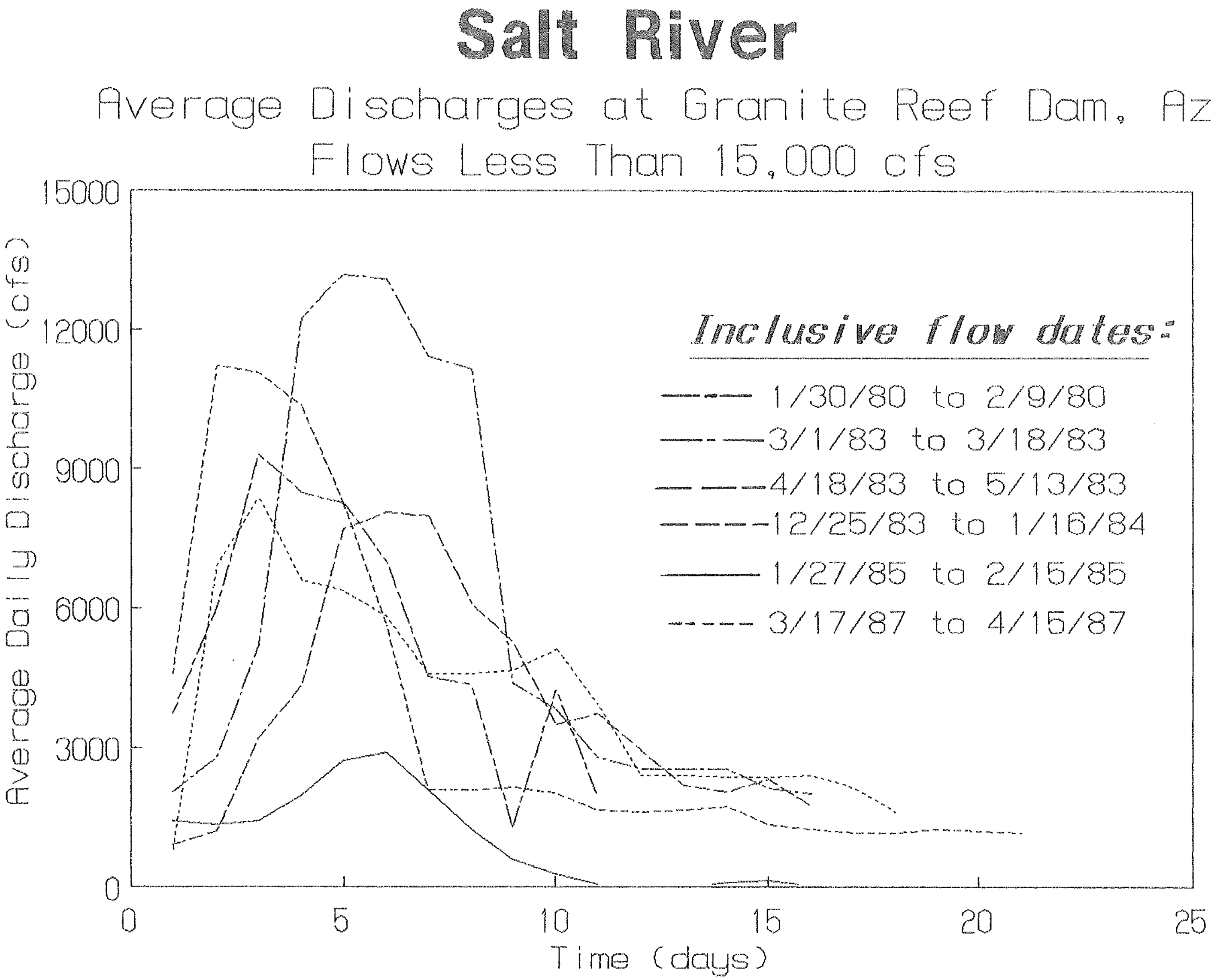
(SRP Data Base, Hydrology Group)

GRAPH I.2



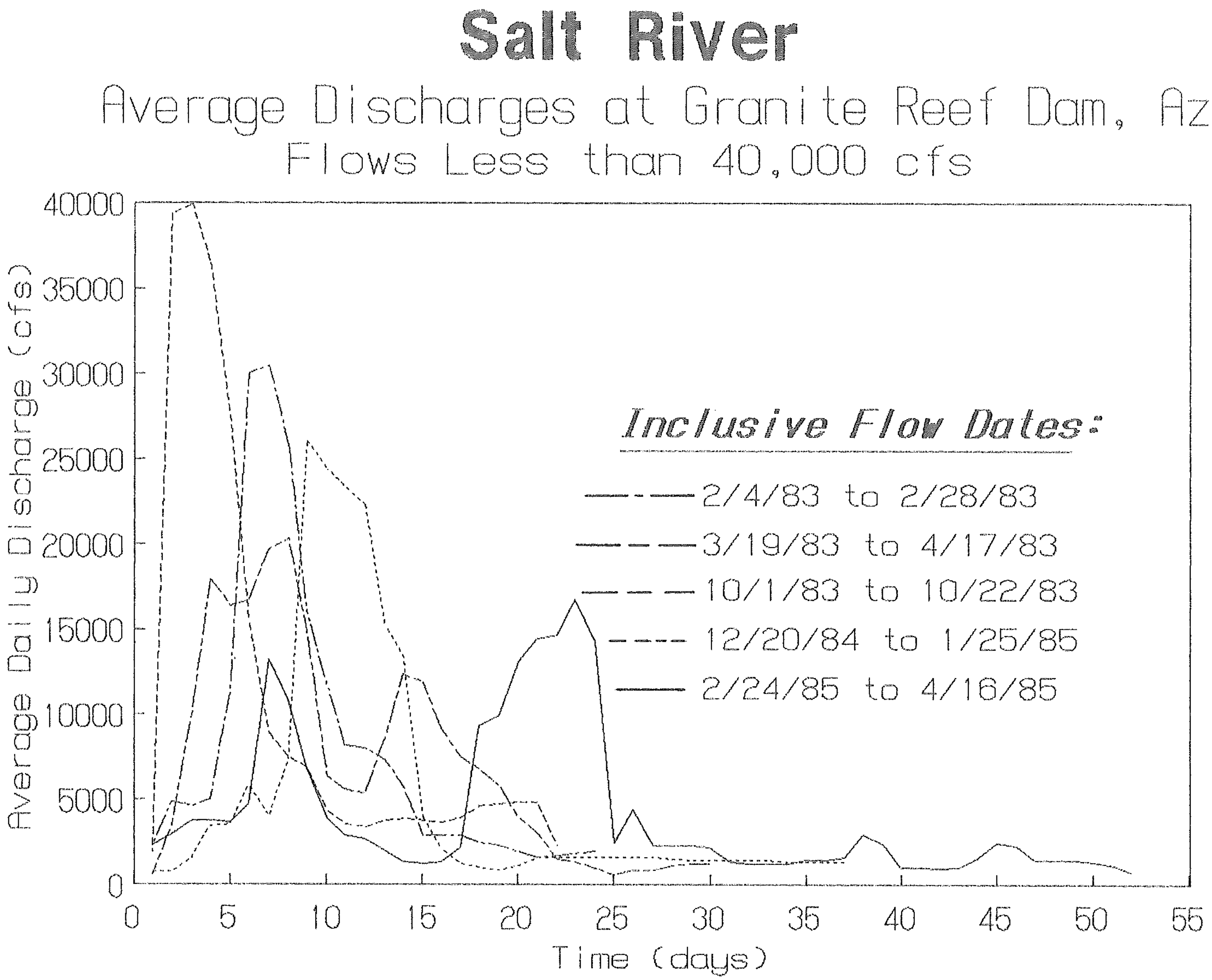
(SRP Data Base, Hydrology Group)

GRAPH I.3



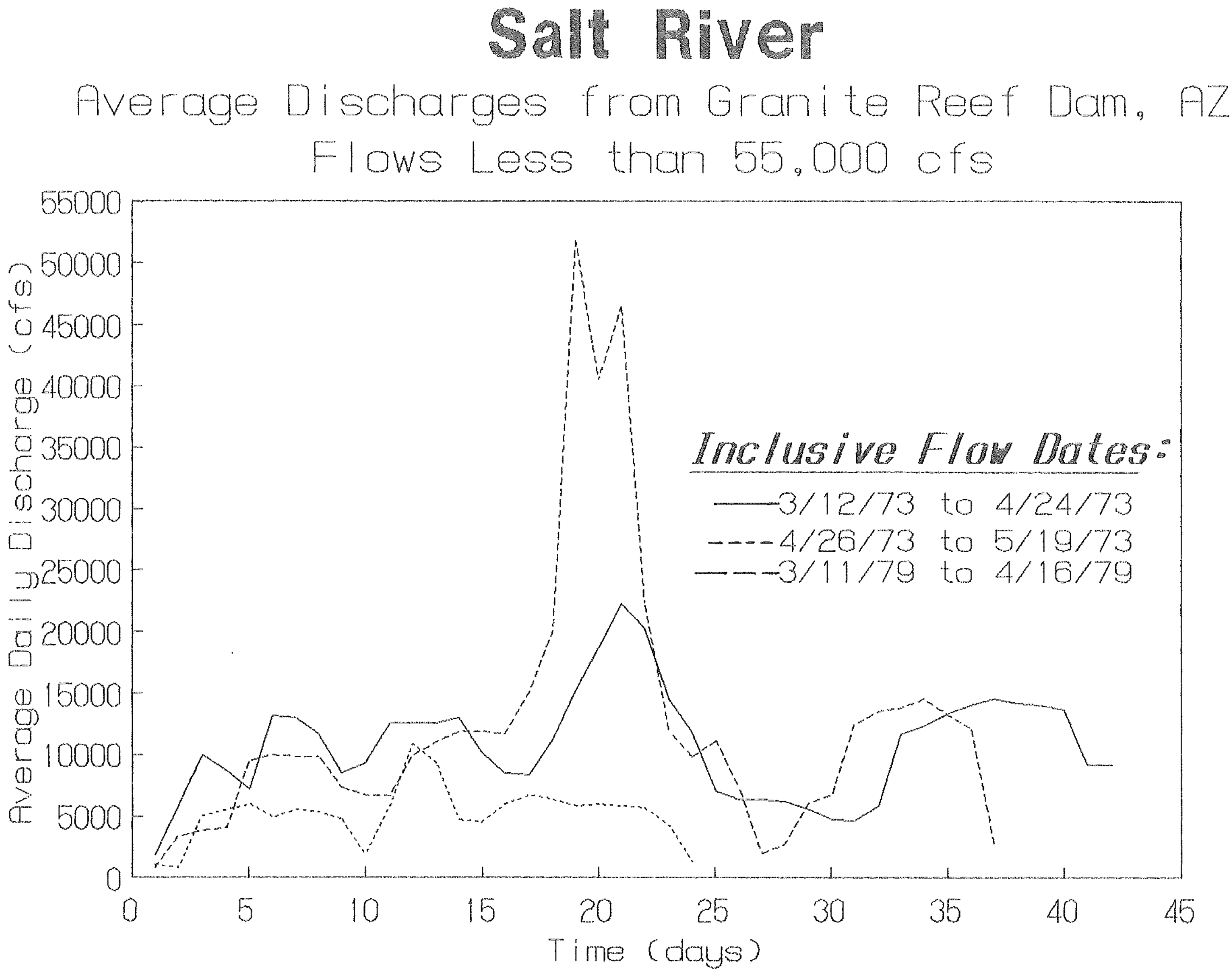
(SRP Data Base, Hydrology Group)

GRAPH I.4



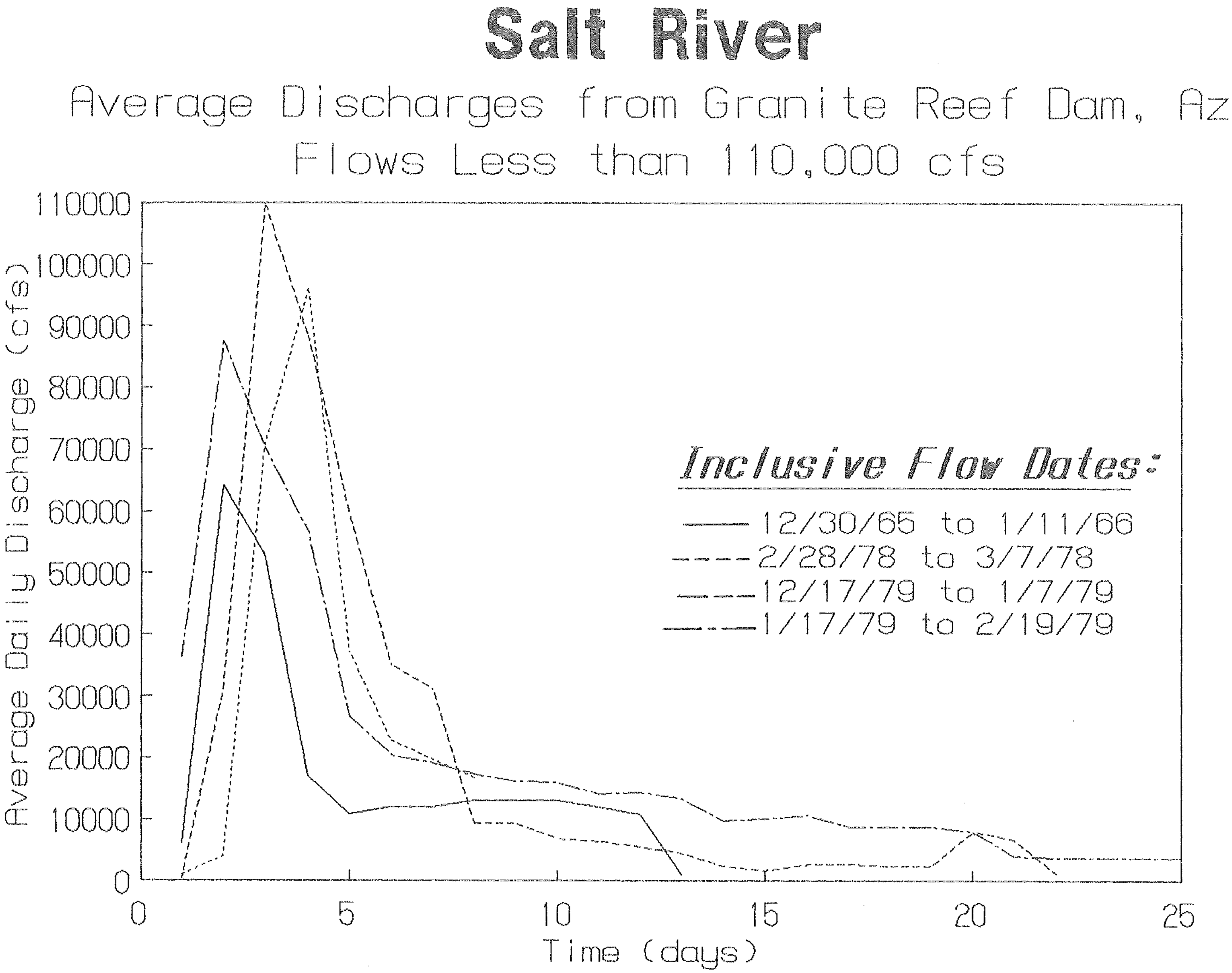
(SRP Data Base, Hydrology Group)

GRAPH I.5



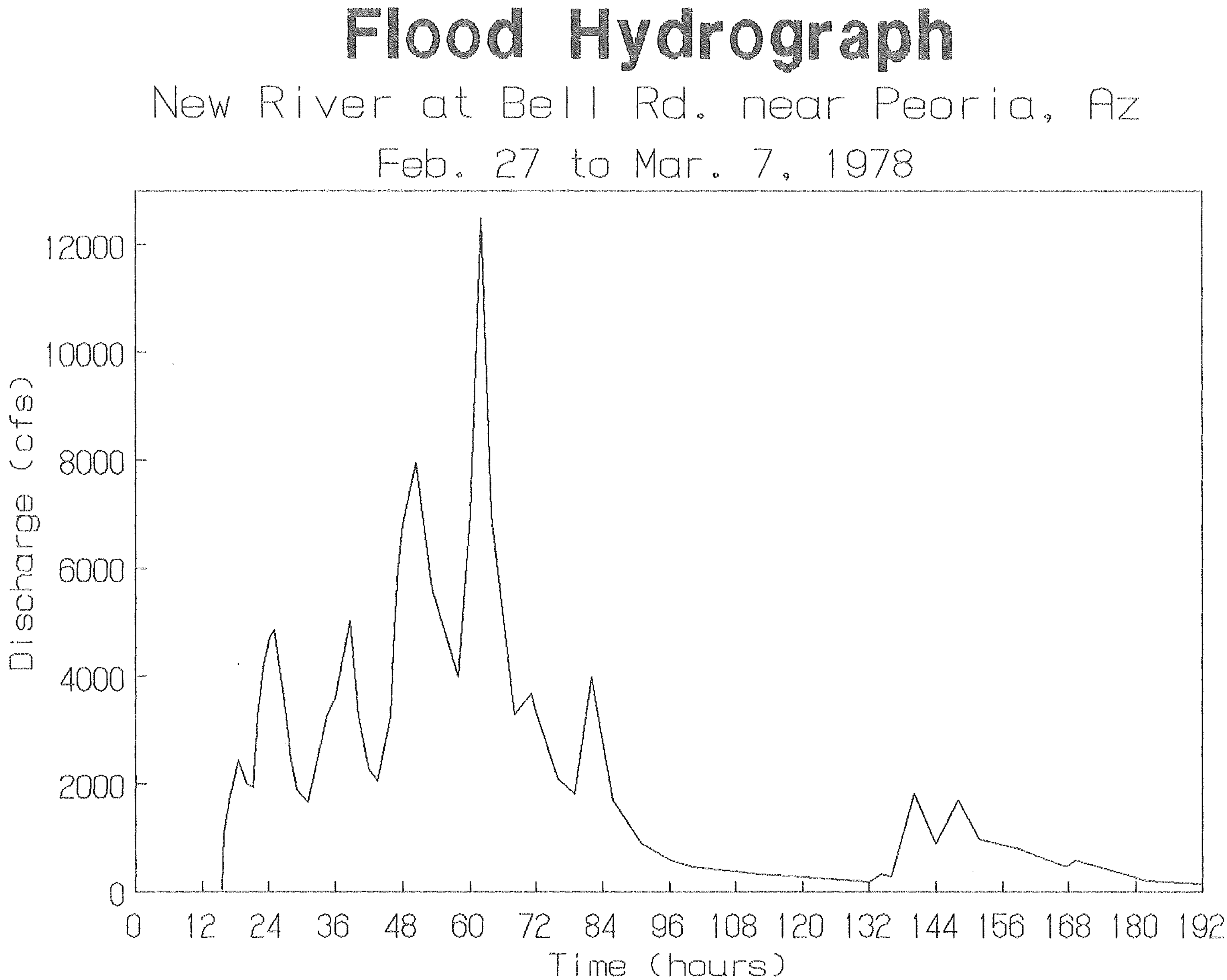
(SRP Data Base, Hydrology Group)

GRAPH I.6



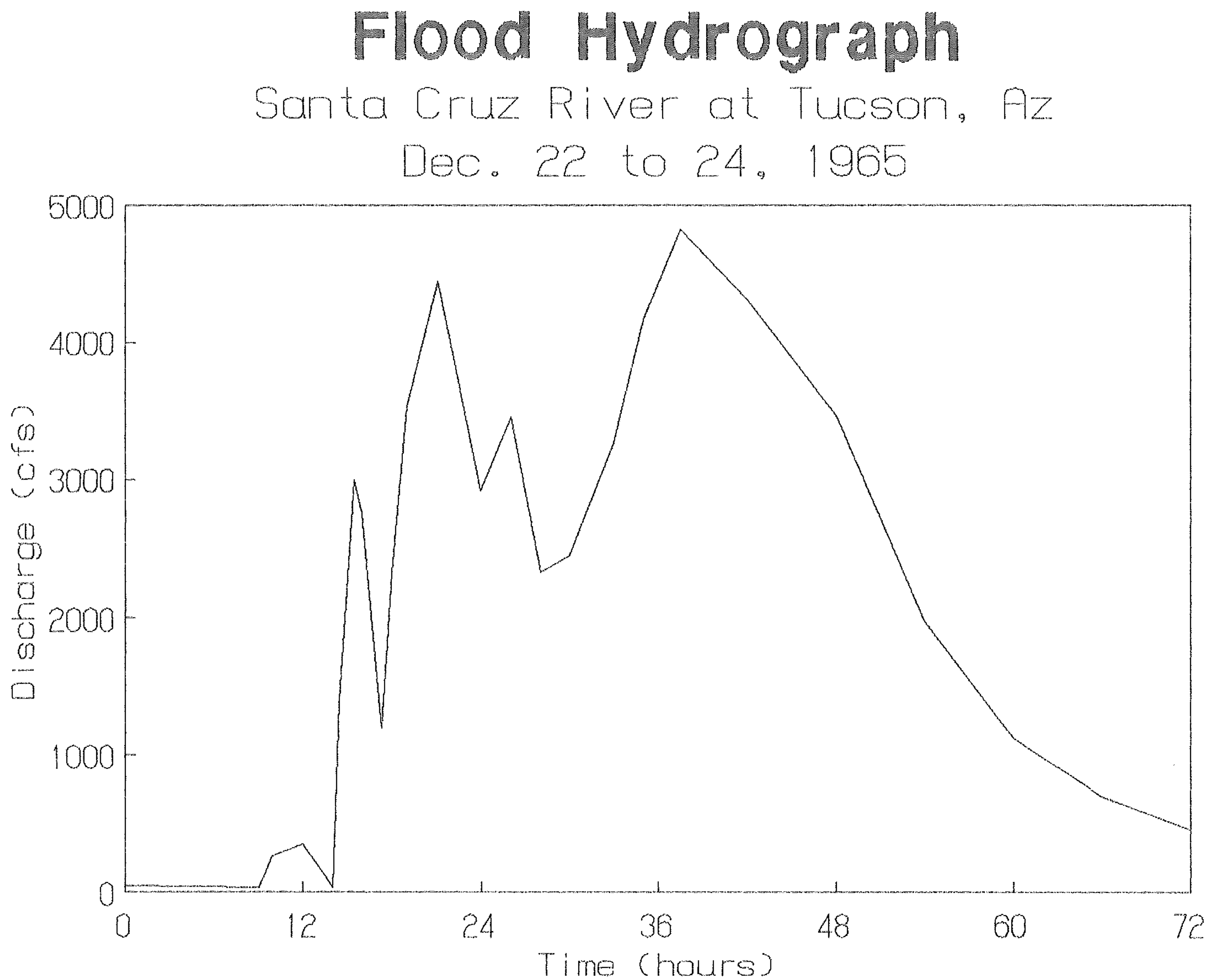
(SRP Data Base, Hydrology Group)

GRAPH I.7



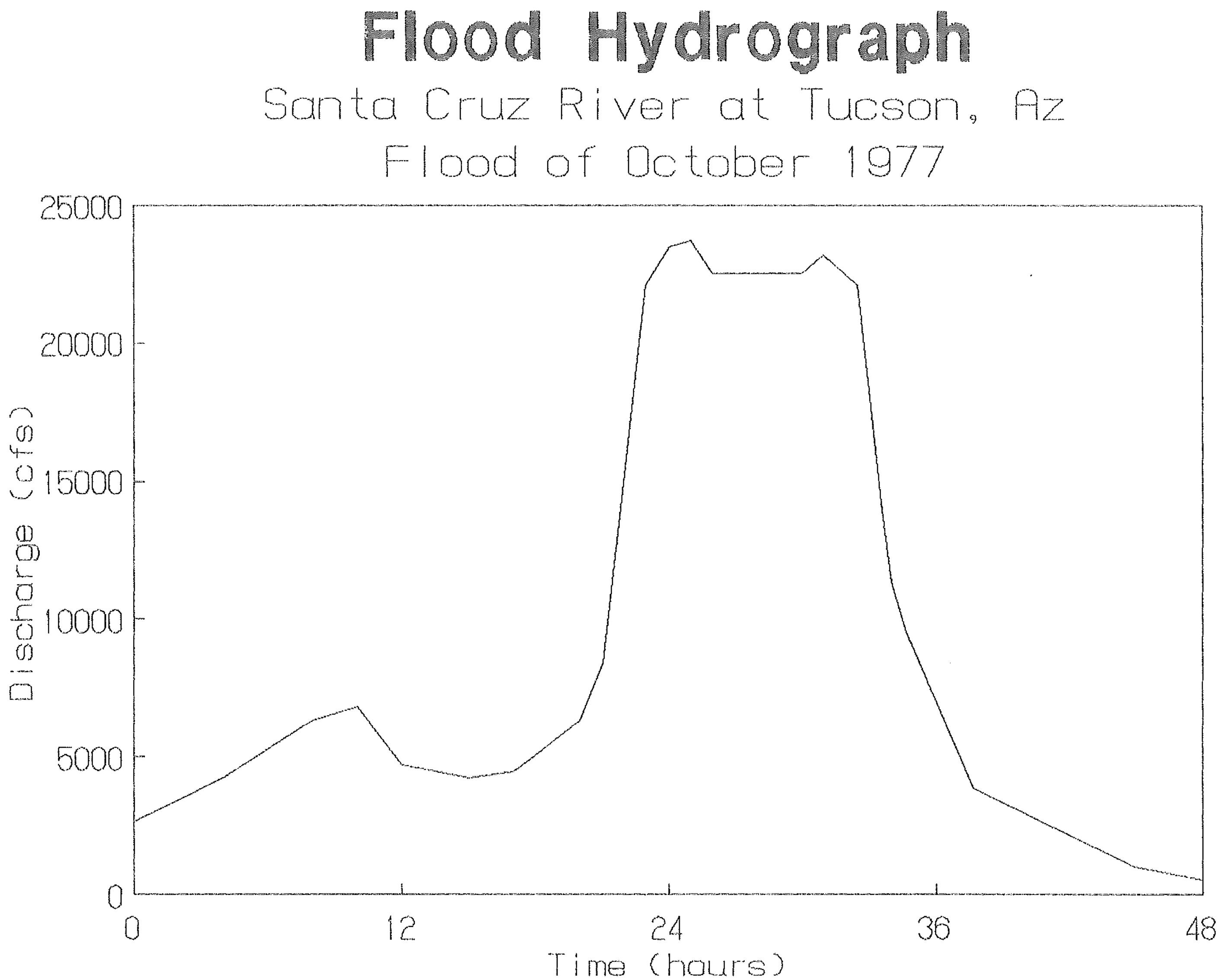
(U.S.G.S., OFR 82-687)

GRAPH I.8



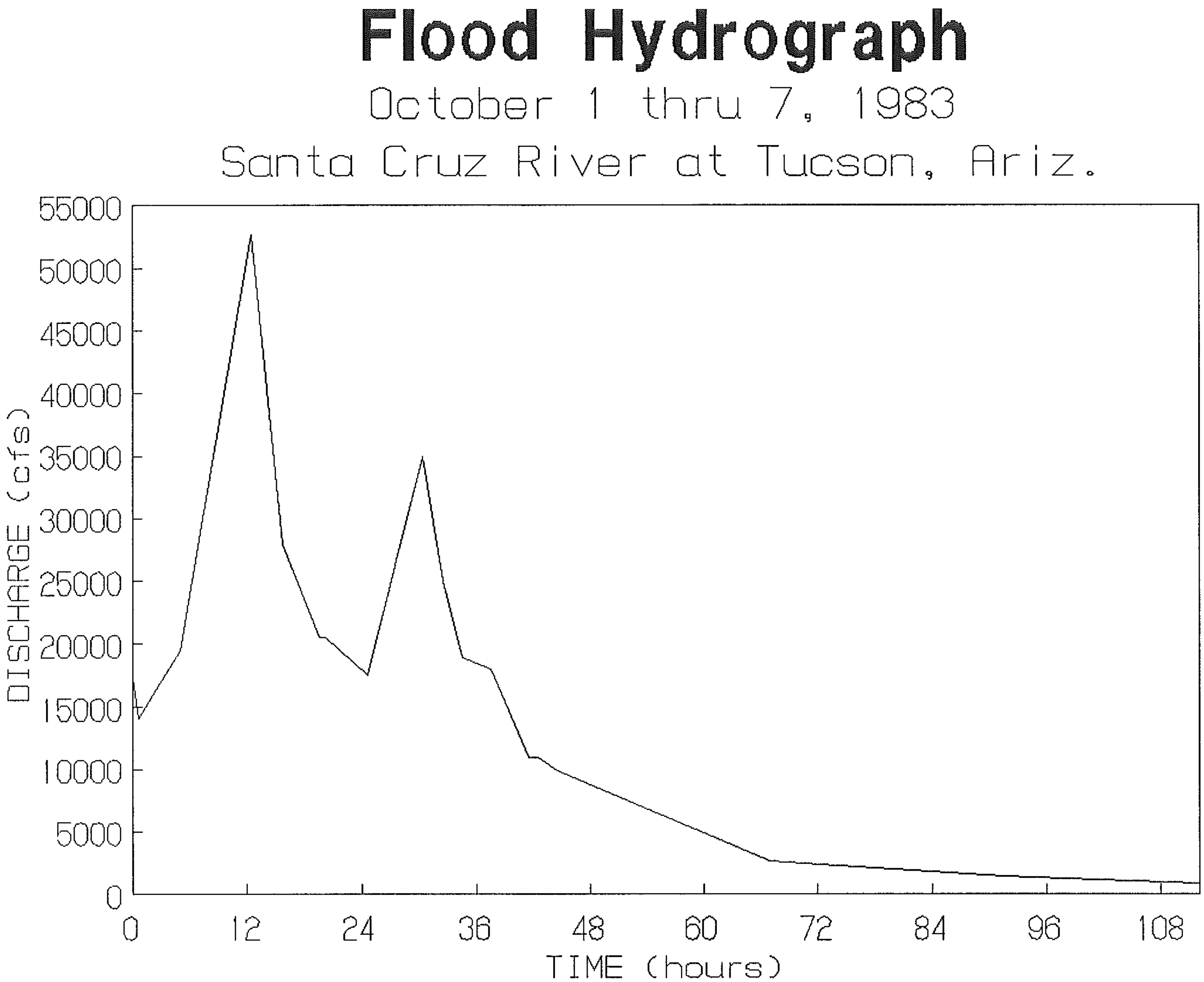
(U.S.G.S., WSP No. 1850-C)

GRAPH I.9



(U.S.G.S., WSP No. 2223)

GRAPH I.10

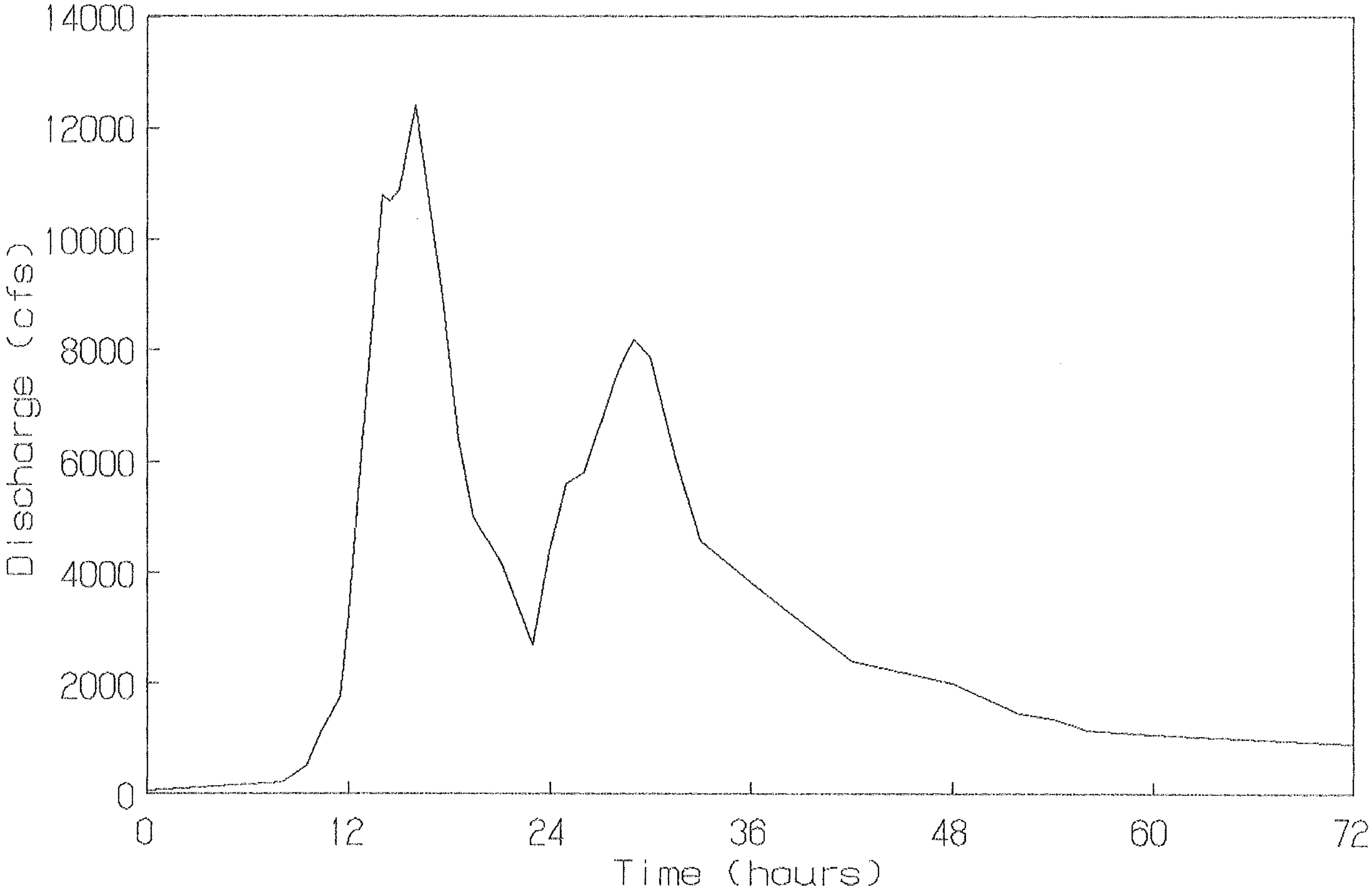

Flood Hydrograph
October 1 thru 7, 1983
Santa Cruz River at Tucson, Ariz.
DISCHARGE (cfs)
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
0
12
24
36
48
60
72
84
96
108
TIME (hours)

GRAPH I.11

Flood Hydrograph

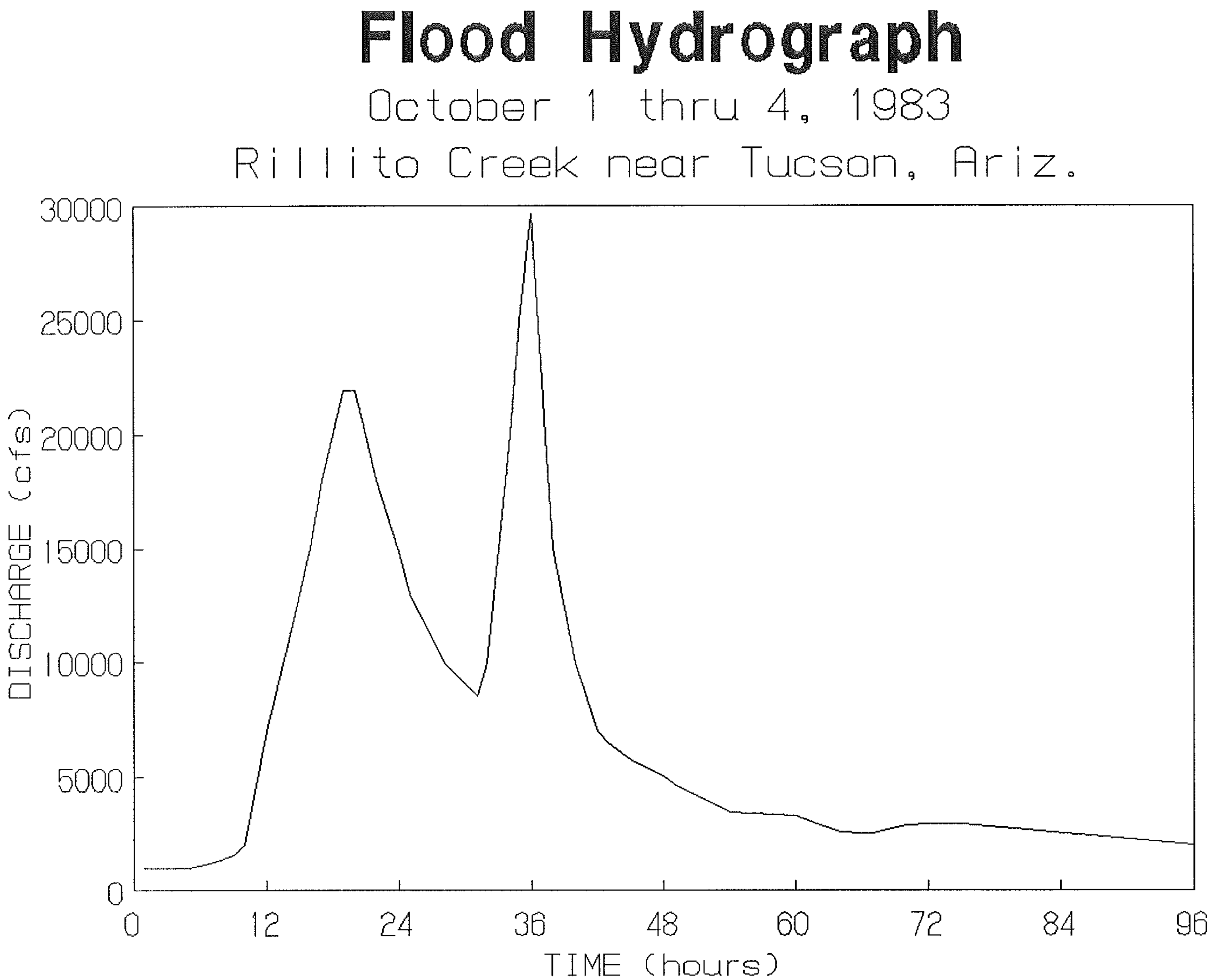
Rillito Creek near Tucson, Az

Dec. 21 to 24, 1965



(U.S.G.S., WSP No. 1850-C)

GRAPH I.12

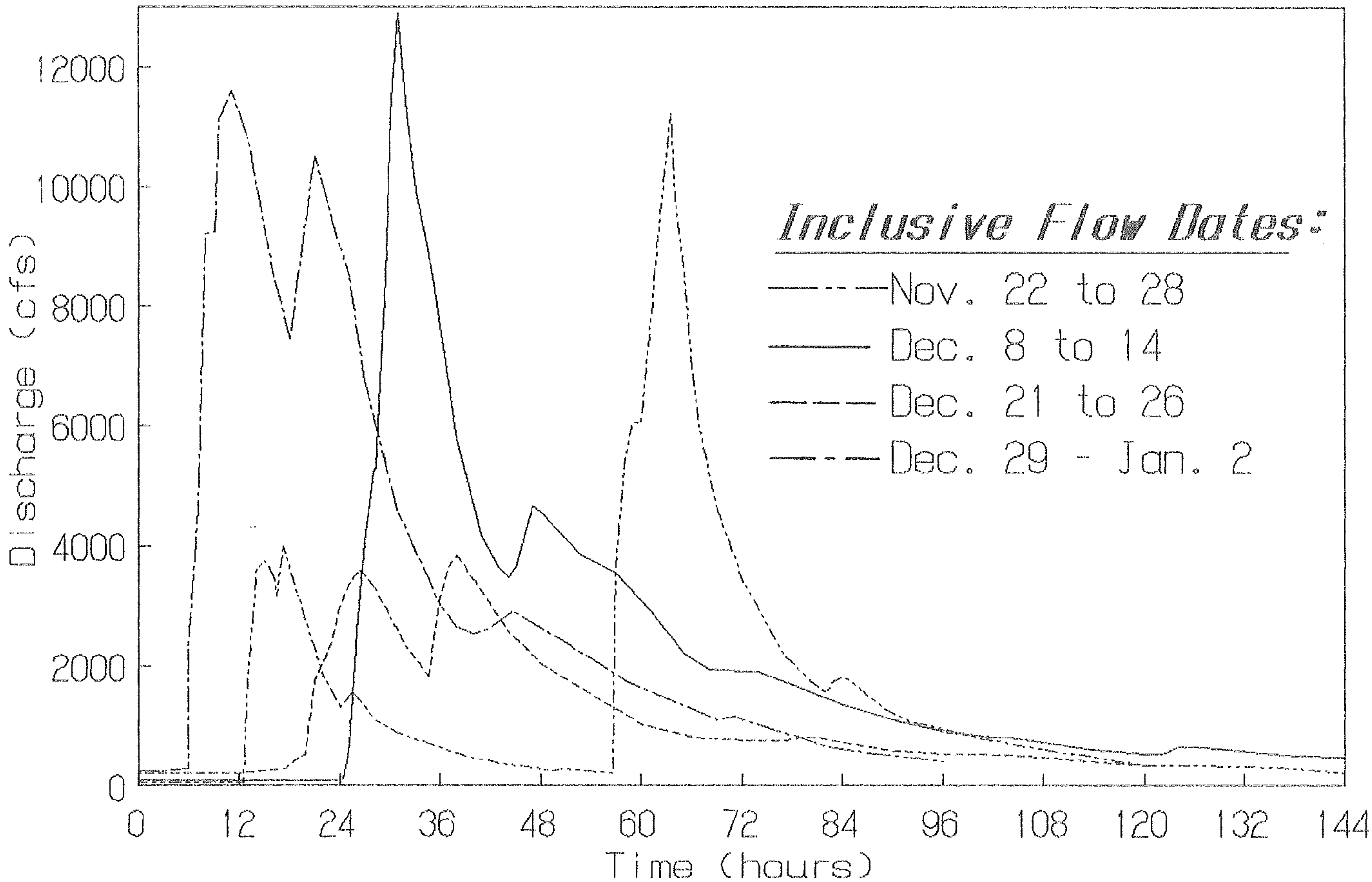

Flood Hydrograph
October 1 thru 4, 1983
Rillito Creek near Tucson, Ariz.
30000
25000
20000
15000
10000
5000
0
DISCHARGE (cfs)
0
12
24
36
48
60
72
84
96
TIME (hours)

GRAPH I.13

Flood Hydrographs

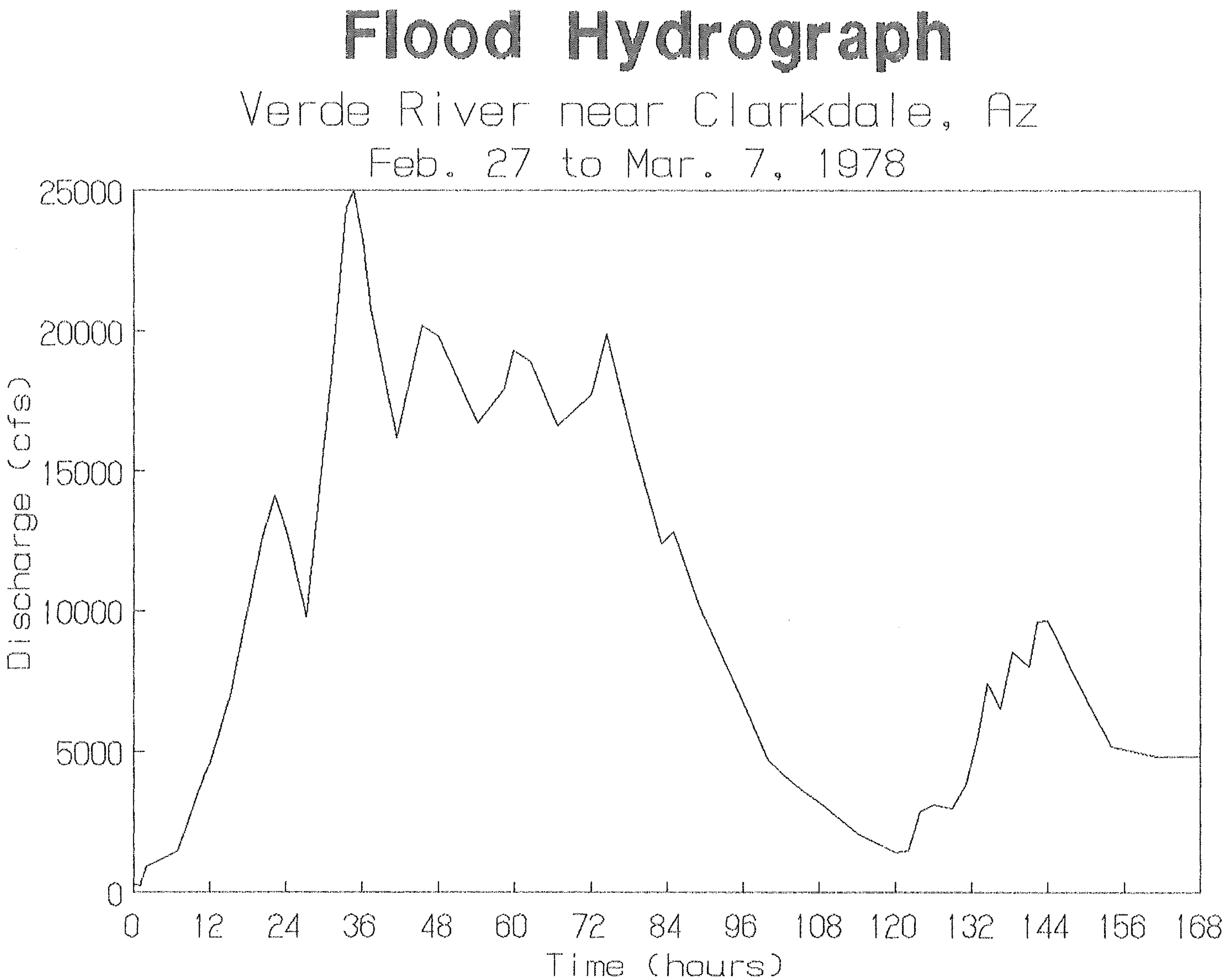
Verde River near Clarkdale, Az

Floods of 1965



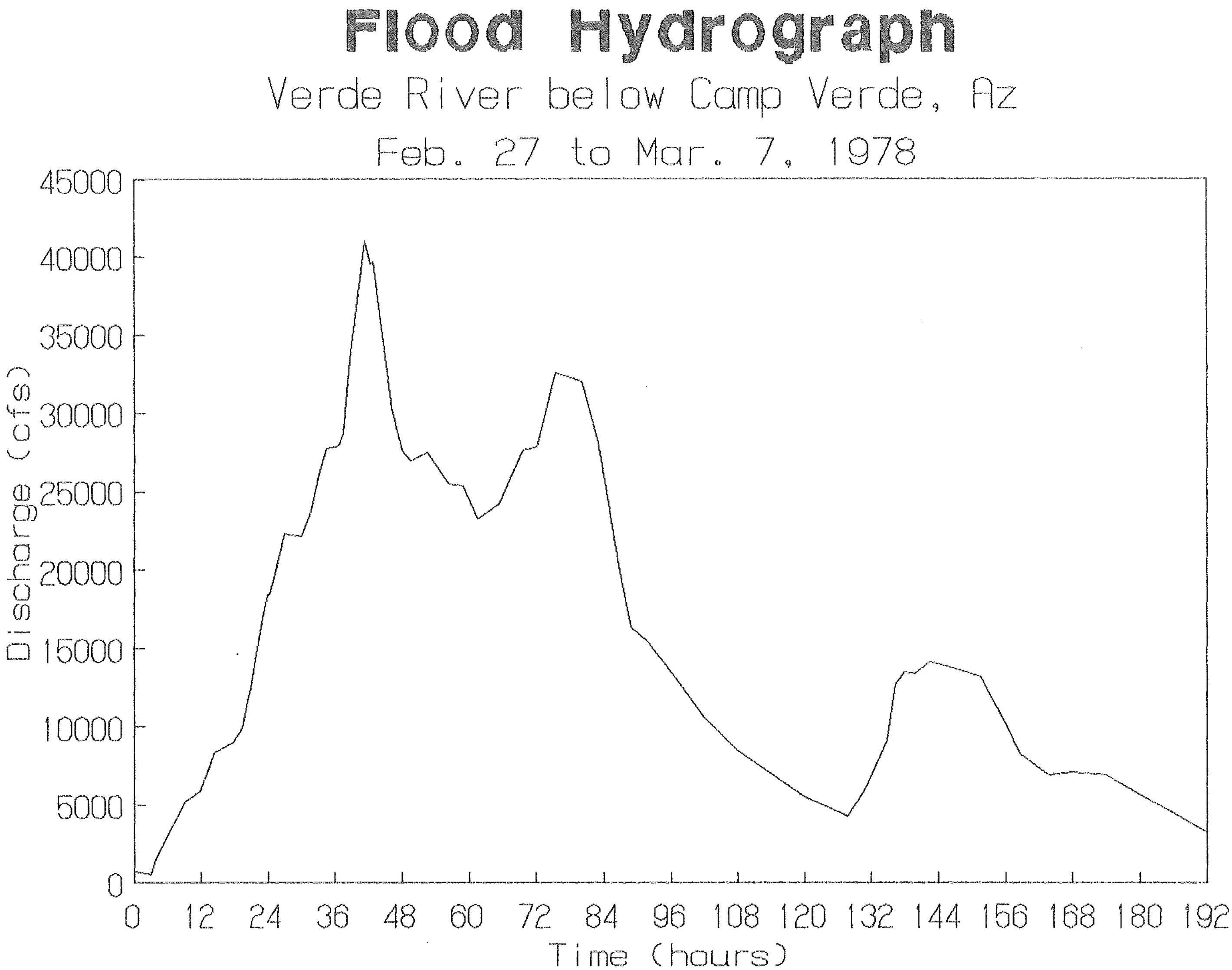
(U.S.G.S., WSP No. 1850-C)

GRAPH I.14



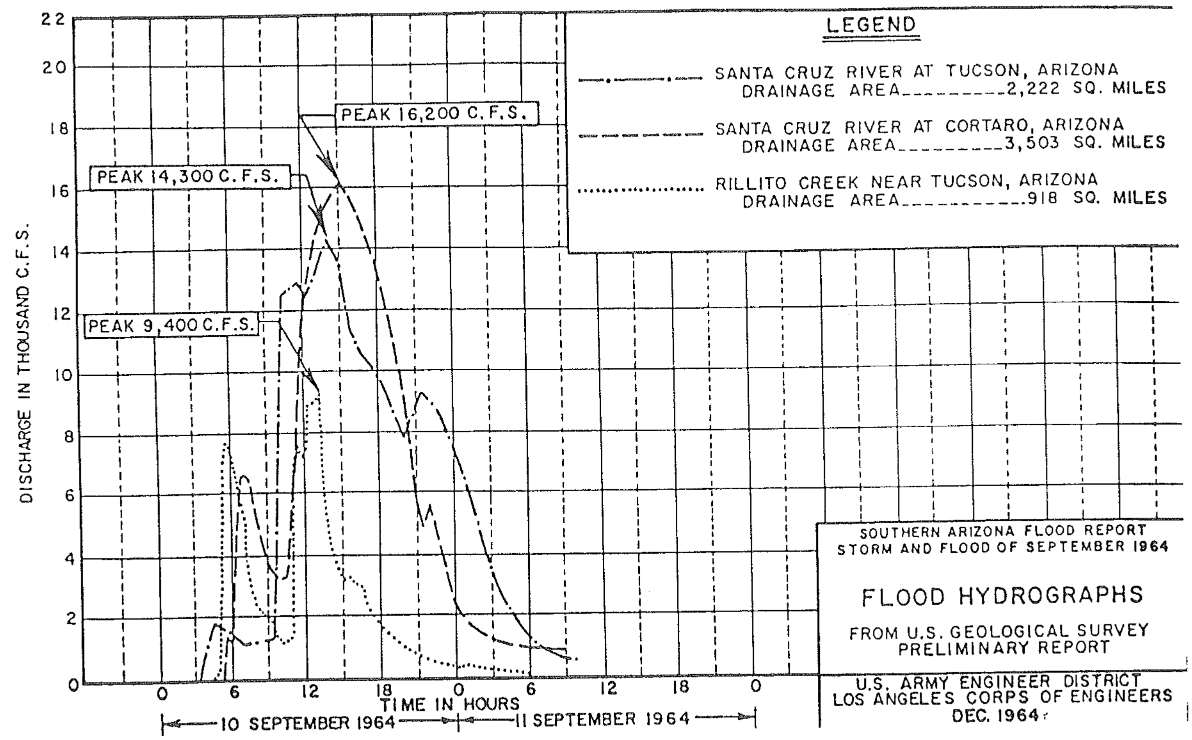
(U.S.G.S., WSP No. 2223)

GRAPH I.15



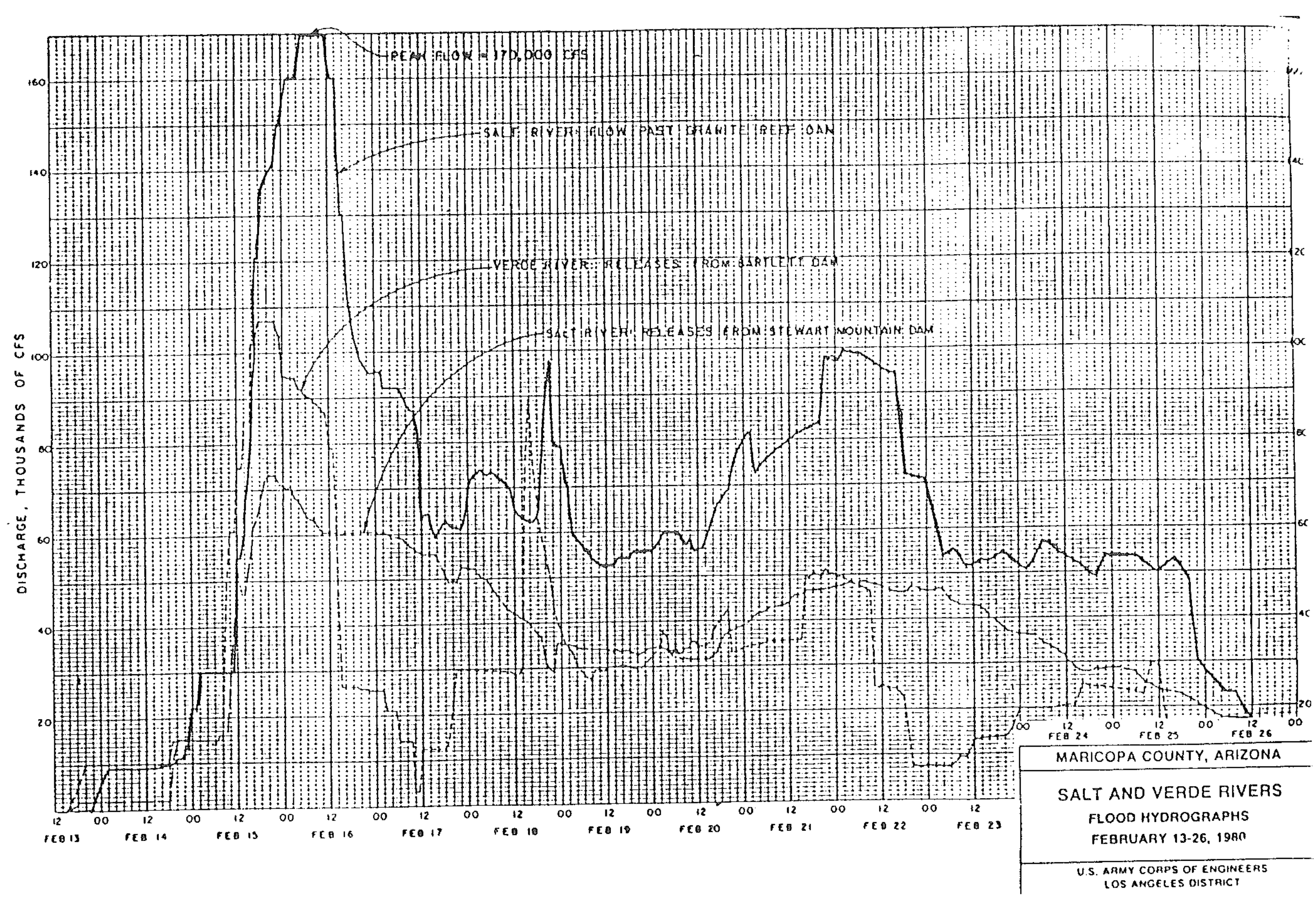
(U.S.G.S., WSP No. 2223)

GRAPH I.16



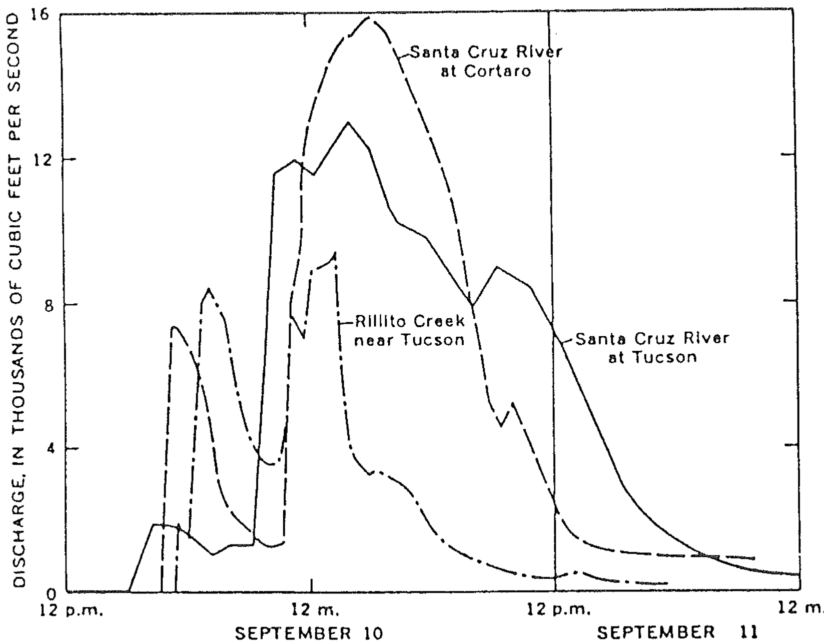
(COE, 1965)

GRAPH I.17



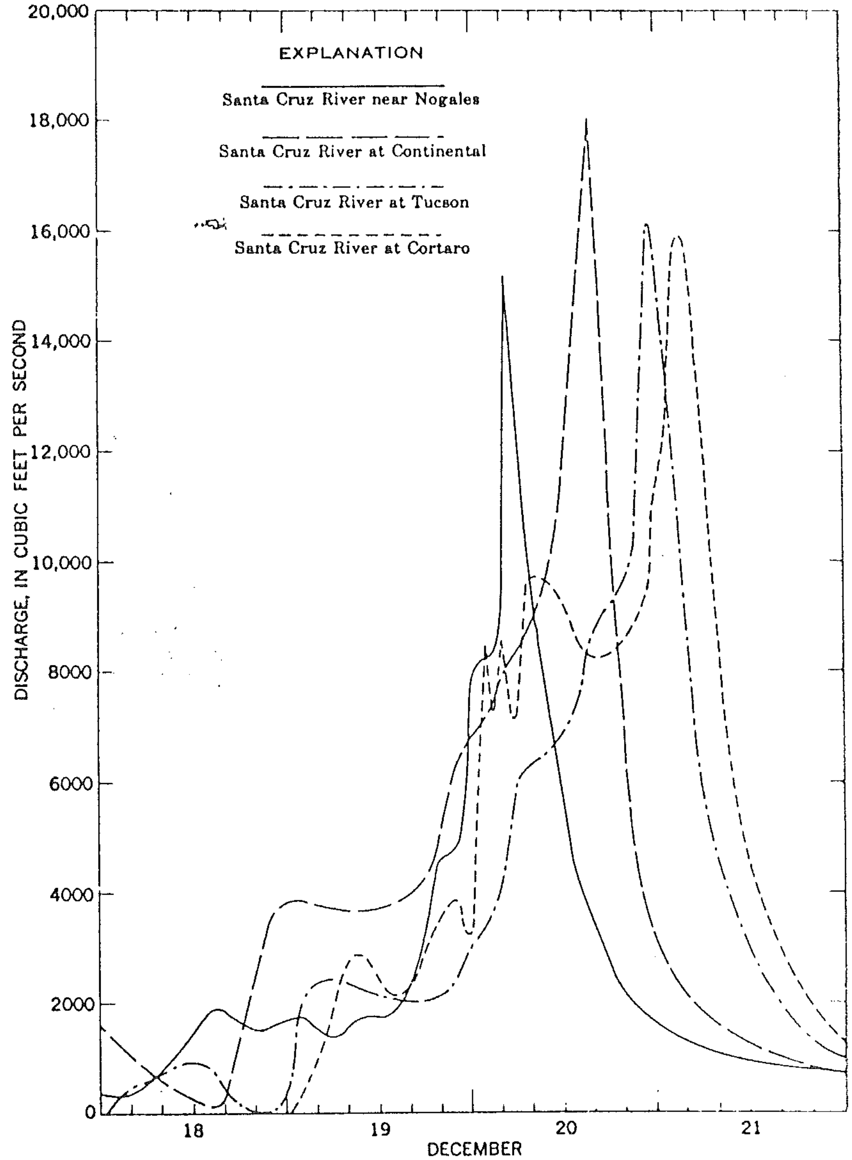
(COE, 1980)

GRAPH I.18



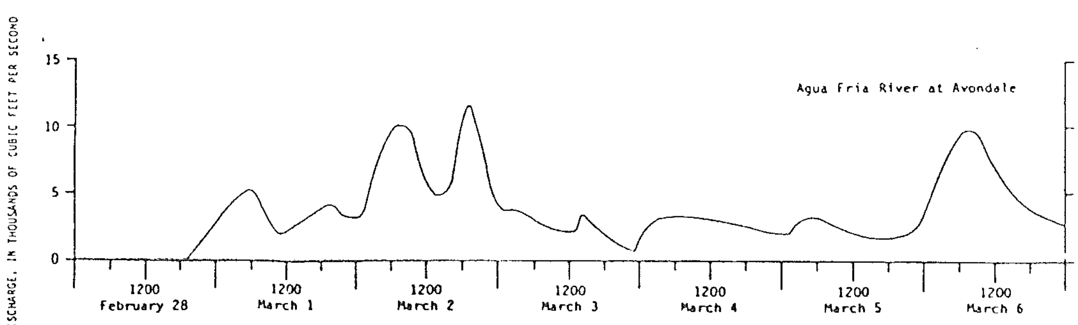
(U.S.G.S., WSP No. 1850-C, 1965)

GRAPH I.19



(U.S.G.S., WSP No. 1880-C, 1965)

GRAPH I.20



(U.S.G.S., WSP No. 2223, 1977)

GRAPH I.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
6/24/86	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 contitions 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 Infromation 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 Infromation 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		
Water Year	Peak Discharge (cfs)	Rank	Water Year	Peak Discharge (cfs)	Median Plotting Positions
1906	9634	1	1978	23700	.0099
1907	8145	2	1908	16607	.0241
1908	16607	3	1961	16600	.0384
1909	4277	4	1968	16100	.0526
1910	3075	5	1915	15000	.0668
1913	808	6	1964	13000	.0810
1914	776	7	1926	11400	.0952
1915	15000	8	1940	11300	.1094
1916	5000	9	1955	10900	.1236
1917	7500	10	1945	10800	.1378
1918	4900	11	1929	10400	.1520
1919	1950	12	1935	10300	.1662
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	6360	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 Peak Discharge vs Frequency Estimate

Exceedence Probability	Computed Discharge (cfs)	Expected Probability Discharge (cfs)	Confidence Limits .05 Limit	Confidence Limits .95 Limit
.002	30900	32800	43100	23800
.005	26300	27600	35900	20600
.010	23000	23900	30700	18300
.020	19700	20300	25800	15900
.040	16500	16900	21100	13500
.100	12400	12600	15300	10400
.200	9350	9420	11200	8000
.500	5230	5230	6050	4540
.800	2780	2750	3240	2320
.900	1950	1920	2330	1570
.950	1440	1400	1770	1120
.990	792	741	1030	565

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

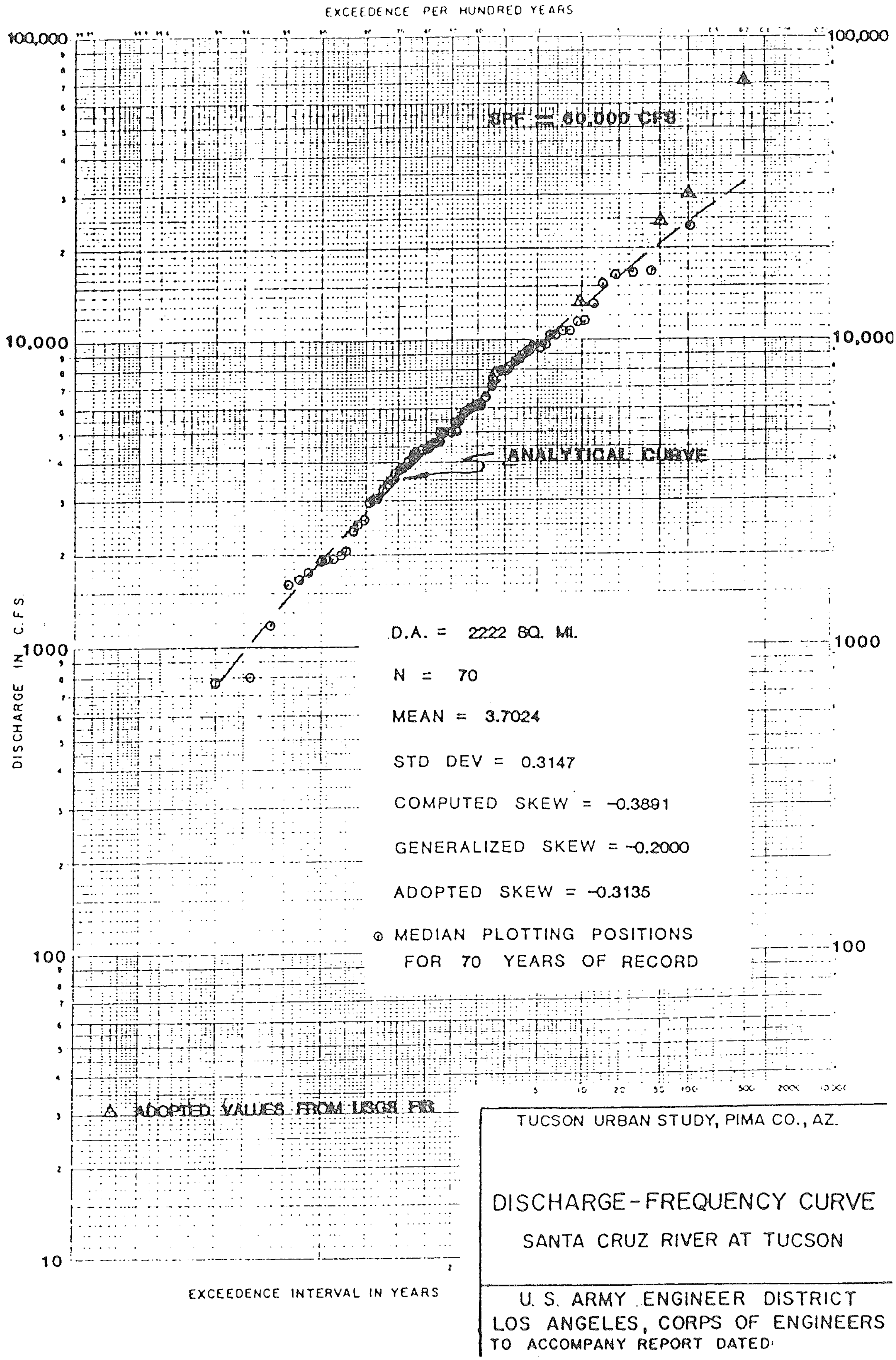

EXCEEDENCE PER HUNDRED YEARS
100,000
10,000
1000
100
10
DISCHARGE IN C.F.S.
SPF = 60,000 CFS
ANALYTICAL CURVE
D.A. = 2222 SQ. MI.
N = 70
MEAN = 3.7024
STD DEV = 0.3147
COMPUTED SKEW = -0.3891
GENERALIZED SKEW = -0.2000
ADOPTED SKEW = -0.3135
MEDIAN PLOTTING POSITIONS FOR 70 YEARS OF RECORD
ADOPTED VALUES FROM USGS FIS
EXCEEDENCE INTERVAL IN YEARS
TUCSON URBAN STUDY, PIMA CO., AZ.
DISCHARGE-FREQUENCY CURVE
SANTA CRUZ RIVER AT TUCSON
U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:

FIGURE I.3

ANALYTICAL FREQUENCY ANALYSIS OF PEAK FLOWS

RILLITO CREEK NEAR TUCSON, AZ

USGS GAGE NO. 09486000, DA = 918 SQ. MI.

Analyzed Data		Ordered Data			
Water Year	Peak Discharge (cfs)	Rank	Water Year	Peak Discharge (cfs)	Median Plotting Positions
1915	17000.	1	1929	24000.	.0109
1916	7620.	2	1915	17000.	.0264
1917	10000.	3	1921	16000.	.0419
1918	5300.	4	1935	13400.	.0575
1919	9250.	5	1940	13200.	.0730
1920	7800.	6	1966	12400.	.0885
1921	16000.	7	1917	10000.	.1040
1922	3250.	8	1941	9900.	.1196
1923	4000.	9	1939	9710.	.1351
1924	1980.	10	1951	9500.	.1506
1925	3500.	11	1950	9490.	.1661
1926	1750.	12	1964	9420.	.1817
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	2690.	.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 Peak Discharge vs Frequency Estimate

Exceedance Probability	Computed Discharge (cfs)	Expected Probability Discharge (cfs)	Confidence .05 Limit (cfs)	Limits .95 Limit (cfs)
.002	32600.	35100.	47200.	24500.
.005	27500.	29100.	38800.	21100.
.010	23800.	24900.	32900.	18500.
.020	20200.	20900.	27200.	16000.
.040	16700.	17200.	22000.	13500.
.100	12400.	12600.	15600.	10200.
.200	9170.	9250.	11200.	7720.
.500	4980.	4980.	5830.	4250.
.800	2560.	2530.	3030.	2100.
.900	1770.	1730.	2150.	1390.
.950	1290.	1250.	1610.	973.
.990	692.	642.	923.	477.

FINAL STATISTICS BASED ON 64 YEARS

MEAN LOGARITHM	3.6805
STANDARD DEVIATION	.3306
COMUPTED SKEW	-.3877
GENERALIZED SKEW	-.2000
ADOPTED SKEW	-.2976

(COE, TUCSON URBAN STUDY)

FIGURE I.4

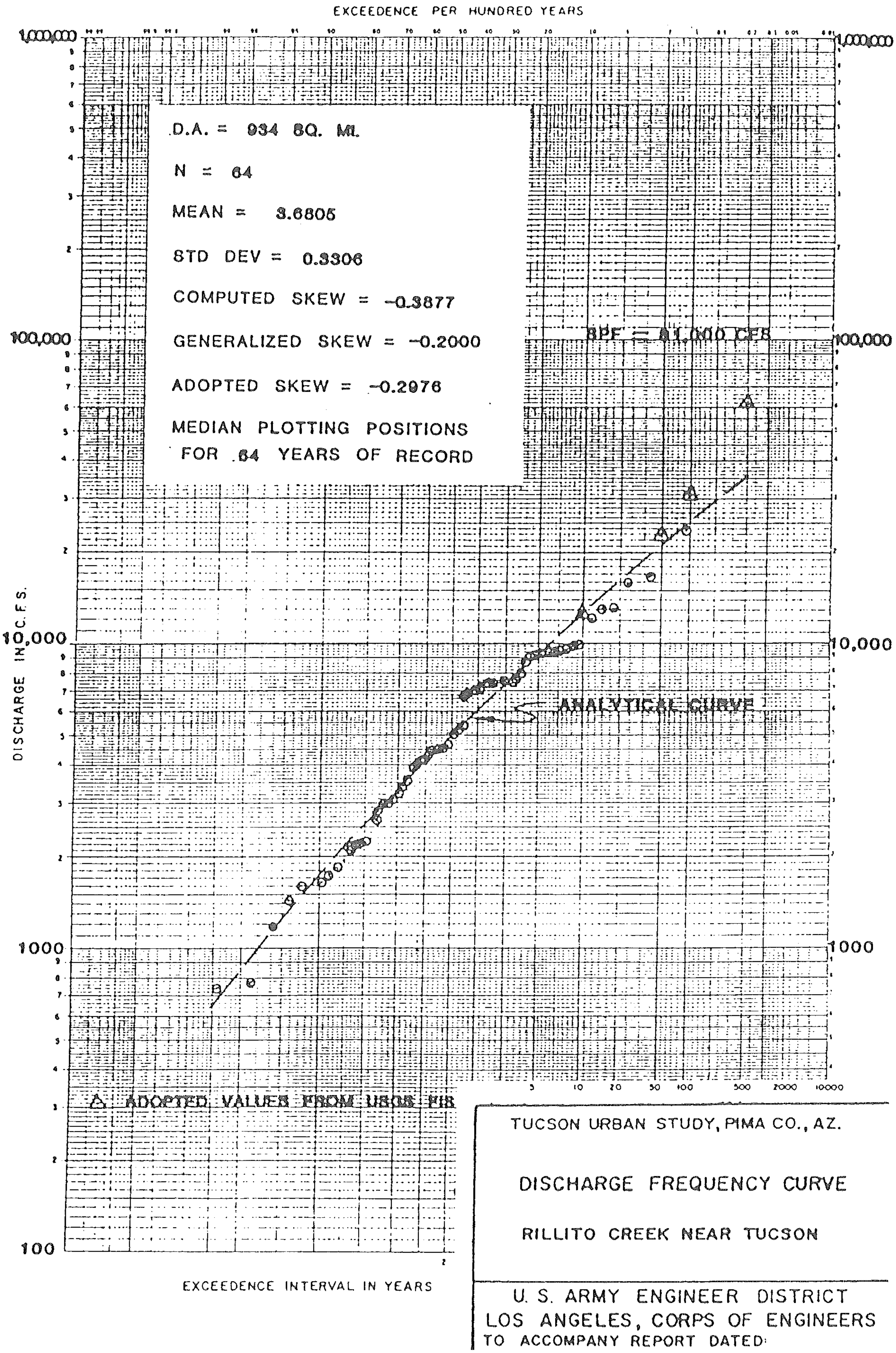

EXCEEDENCE PER HUNDRED YEARS
D.A. = 934 SQ. MI.
N = 64
MEAN = 3.6805
STD DEV = 0.3306
COMPUTED SKEW = -0.3877
GENERALIZED SKEW = -0.2000
ADOPTED SKEW = -0.2976
MEDIAN PLOTTING POSITIONS
FOR 64 YEARS OF RECORD
ANALYTICAL CURVE
DISCHARGE IN C.F.S.
1,000,000
100,000
10,000
1000
100
EXCEEDENCE INTERVAL IN YEARS
TUCSON URBAN STUDY, PIMA CO., AZ.
DISCHARGE FREQUENCY CURVE
RILLITO CREEK NEAR TUCSON
U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:

FIGURE I.5

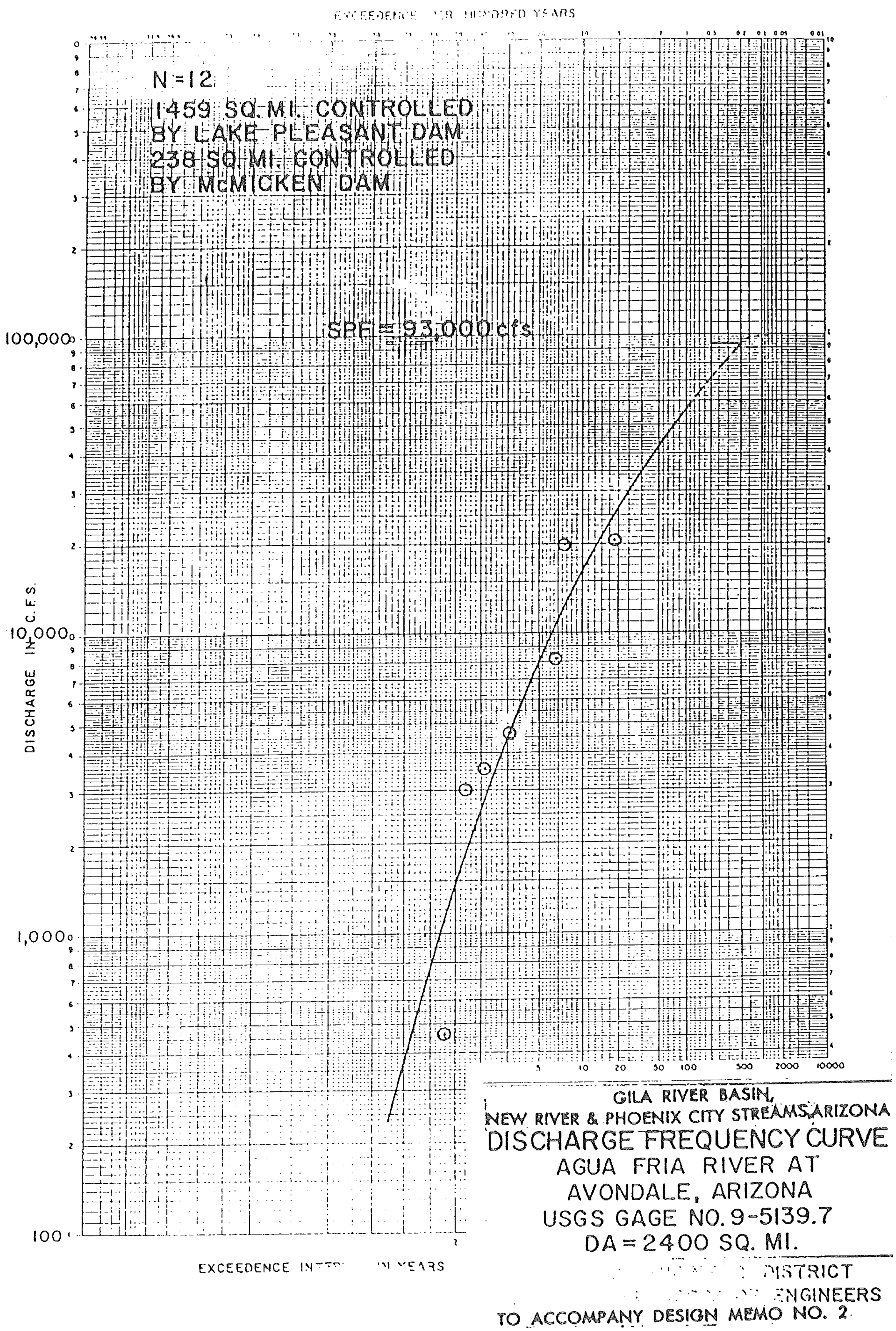

N = 12
1459 SQ. MI. CONTROLLED
BY LAKE PLEASANT DAM
238 SQ. MI. CONTROLLED
BY McMICKEN DAM
SPF = 93,000 cfs
100,000
10,000
1,000
100
DISCHARGE IN C.F.S.
5
10
20
50
100
500
2000
10000
GILA RIVER BASIN,
NEW RIVER & PHOENIX CITY STREAMS, ARIZONA
DISCHARGE FREQUENCY CURVE
AGUA FRIA RIVER AT
AVONDALE, ARIZONA
USGS GAGE NO. 9-5139.7
DA = 2400 SQ. MI.
DISTRICT
ENGINEERS
TO ACCOMPANY DESIGN MEMO NO. 2

FIGURE I.6

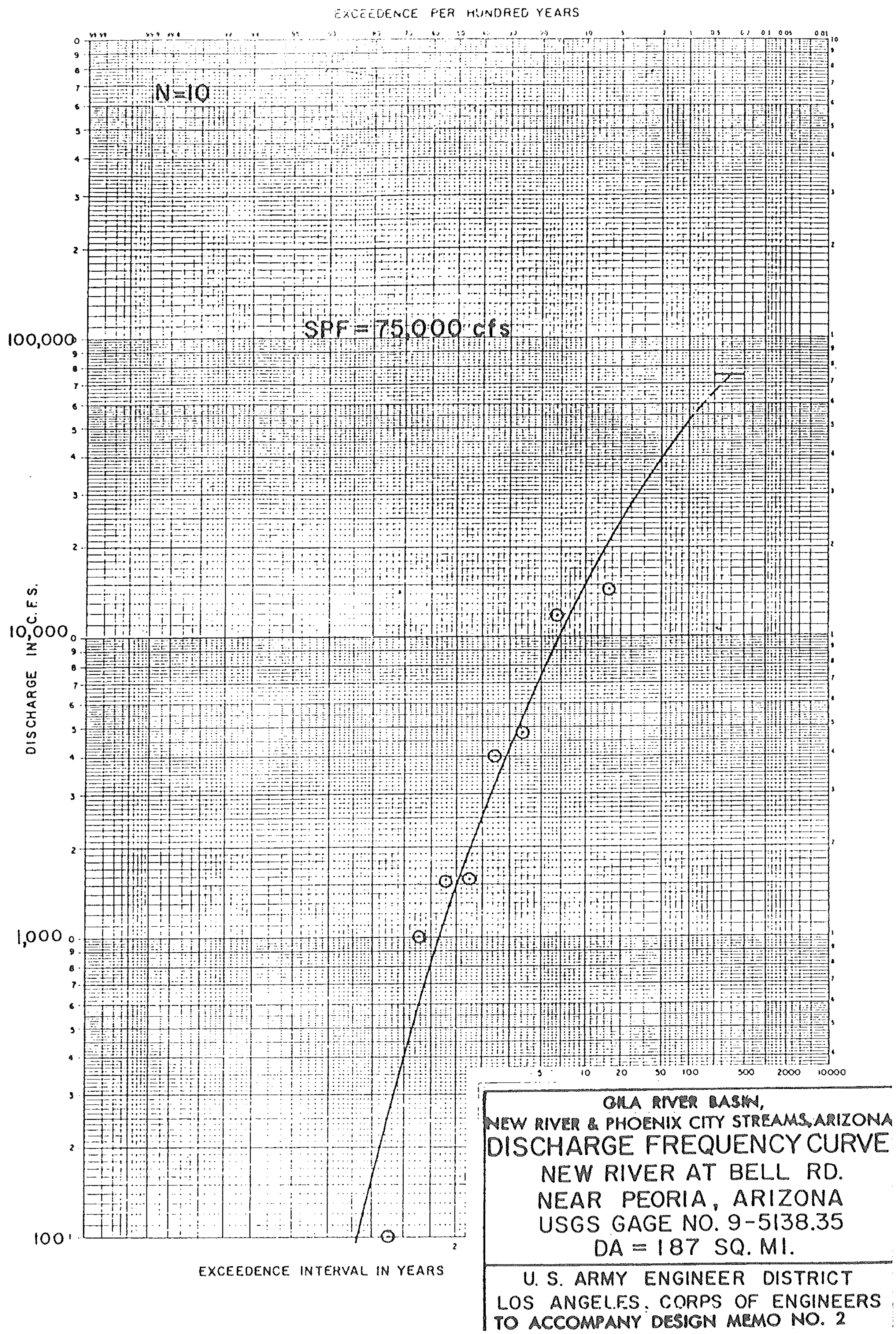
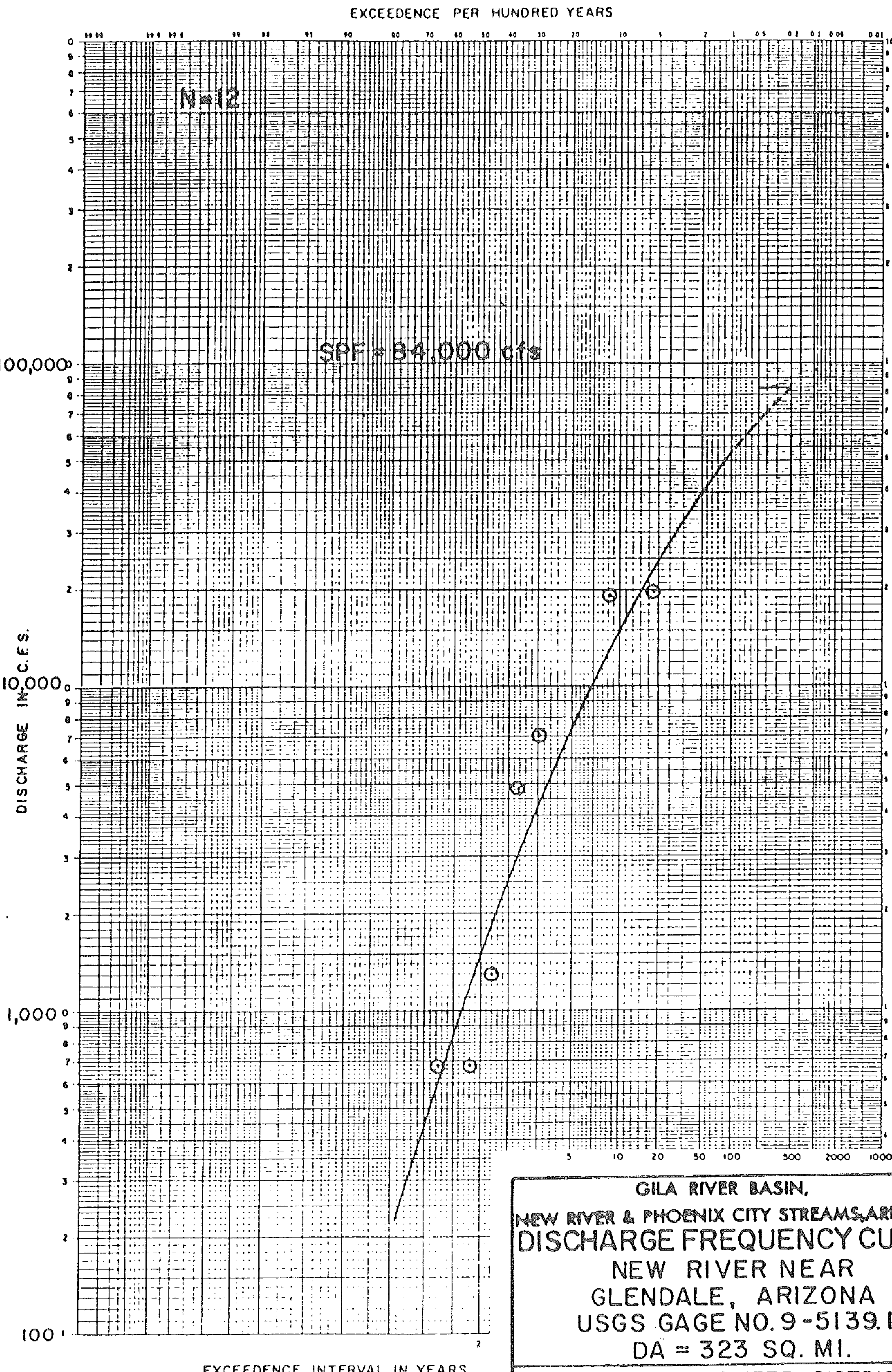

EXCEEDENCE PER HUNDRED YEARS
N=10
SPF = 75,000 cfs
100,000
10,000
1,000
100
DISCHARGE IN C.F.S.
EXCEEDENCE INTERVAL IN YEARS
GILA RIVER BASIN,
NEW RIVER & PHOENIX CITY STREAMS, ARIZONA
DISCHARGE FREQUENCY CURVE
NEW RIVER AT BELL RD.
NEAR PEORIA, ARIZONA
USGS GAGE NO. 9-5138.35
DA = 187 SQ. MI.
U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY DESIGN MEMO NO. 2

FIGURE I.7



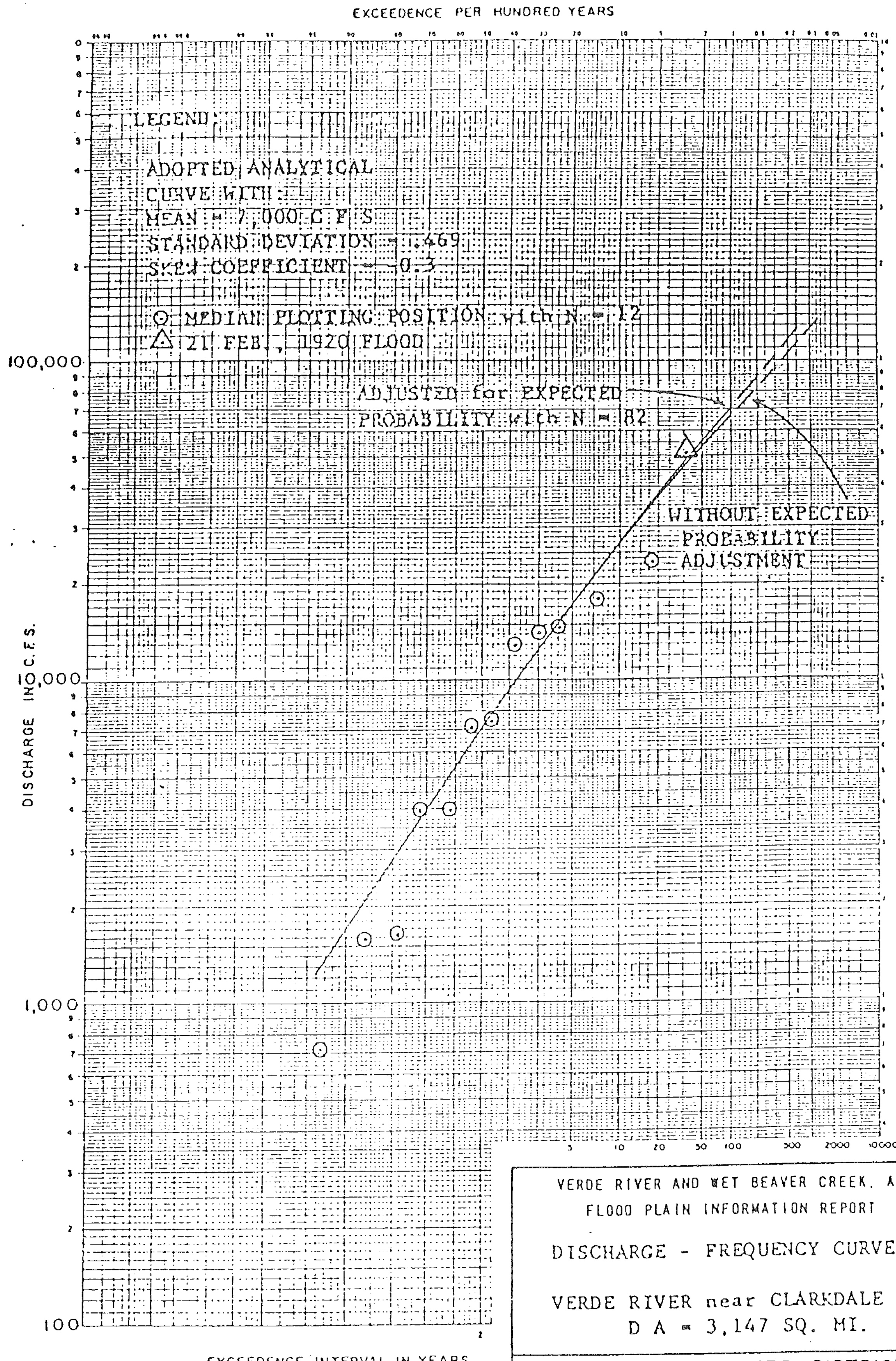
GILA RIVER BASIN,
NEW RIVER & PHOENIX CITY STREAMS, ARIZONA

DISCHARGE FREQUENCY CURVE

NEW RIVER NEAR
GLENDALE, ARIZONA
USGS GAGE NO. 9-5139.1
DA = 323 SQ. MI.

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY DESIGN MEMO NO. 2

FIGURE I.8



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 I.9

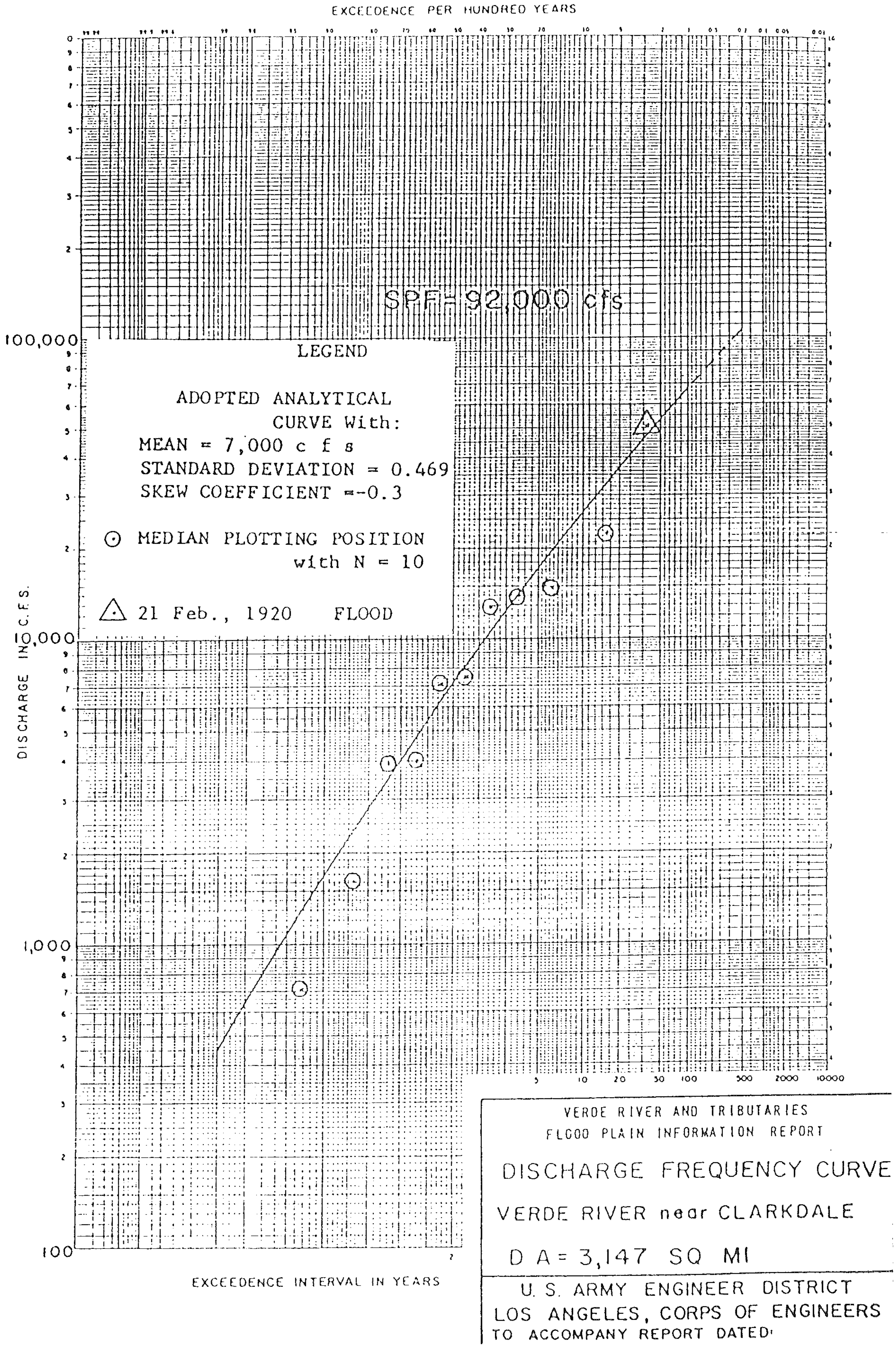
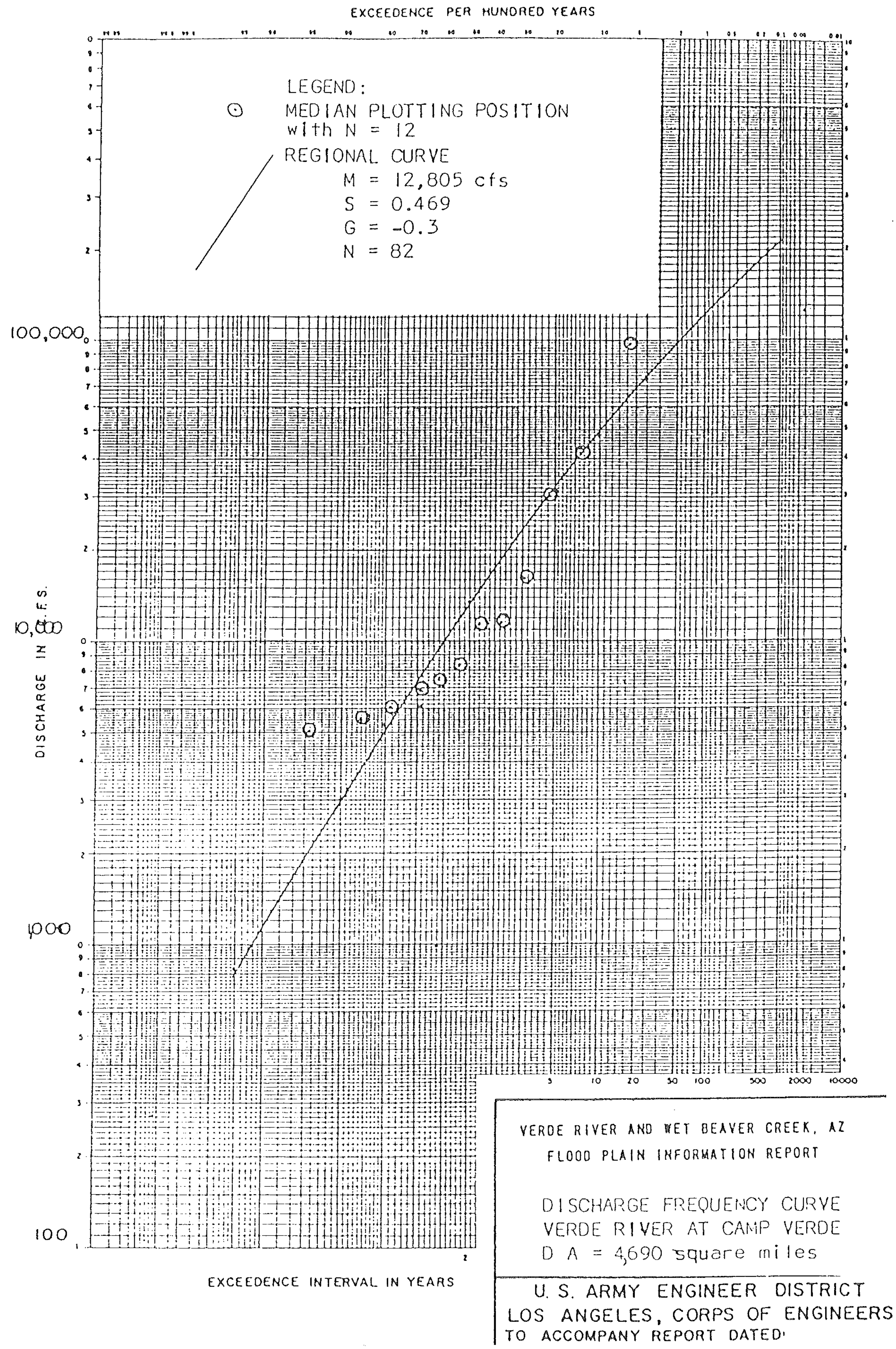

EXCEEDENCE PER HUNDRED YEARS
SPF = 92,000 cfs
100,000
10,000
1,000
100
DISCHARGE IN C.F.S.
LEGEND
ADOPTED ANALYTICAL CURVE With:
MEAN = 7,000 c f s
STANDARD DEVIATION = 0.469
SKEW COEFFICIENT =-0.3
MEDIAN PLOTTING POSITION with N = 10
21 Feb., 1920 FLOOD
EXCEEDENCE INTERVAL IN YEARS
VERDE RIVER AND TRIBUTARIES
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 I.10



EXCEEDENCE PER HUNDRED YEARS
LEGEND:
MEDIAN PLOTTING POSITION
with N = 12
REGIONAL CURVE
M = 12,805 cfs
S = 0.469
G = -0.3
N = 82
100,000
10,000
1000
100
DISCHARGE IN C.F.S.
EXCEEDENCE INTERVAL IN YEARS
VERDE RIVER AND WET BEAVER CREEK, AZ
FLOOD PLAIN INFORMATION REPORT
DISCHARGE FREQUENCY CURVE
VERDE RIVER AT CAMP VERDE
D A = 4,690 square miles
U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED

FIGURE I.11

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FLOOD INSURANCE STUDIES

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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

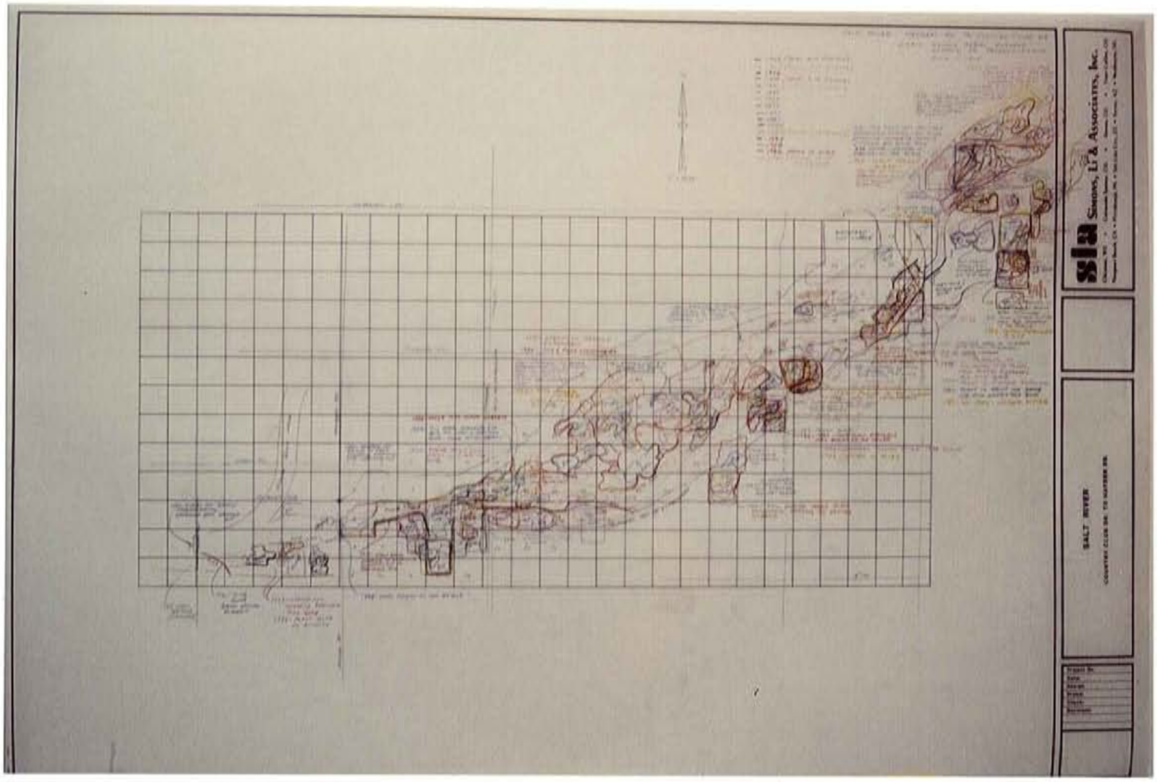
J.3.1 Data Acquisition

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.

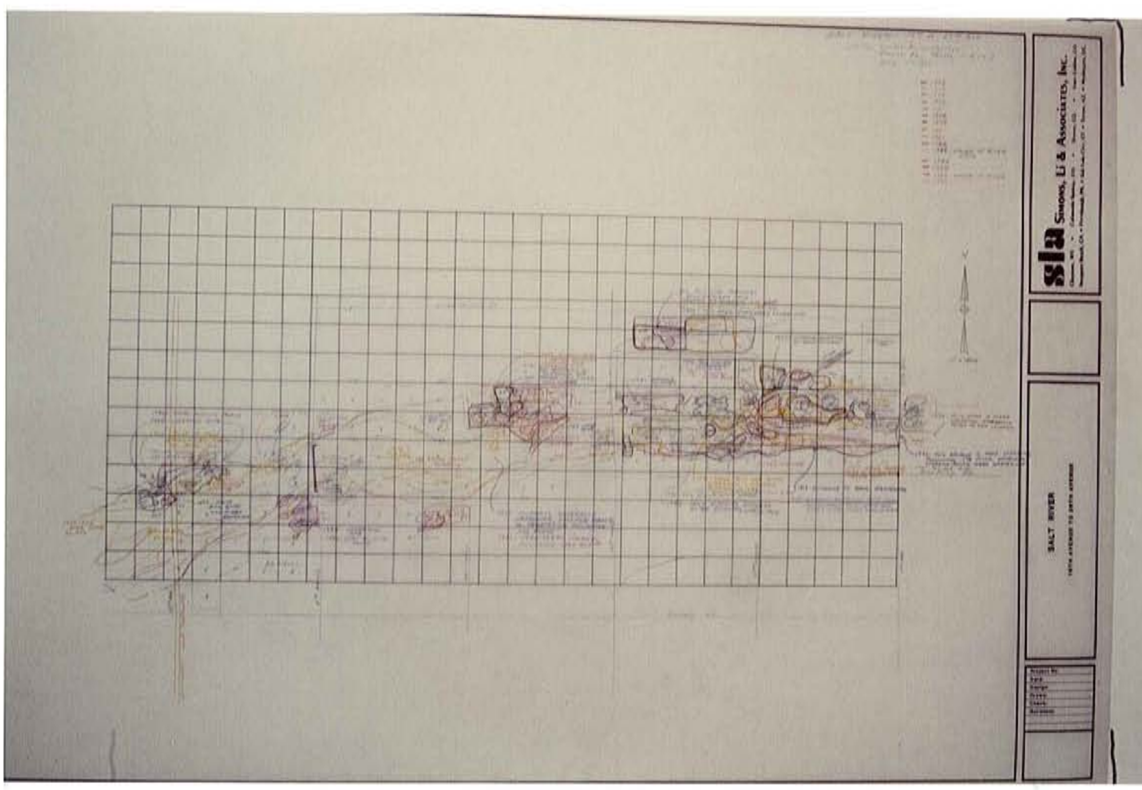
J.3.2 Data Reduction

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.

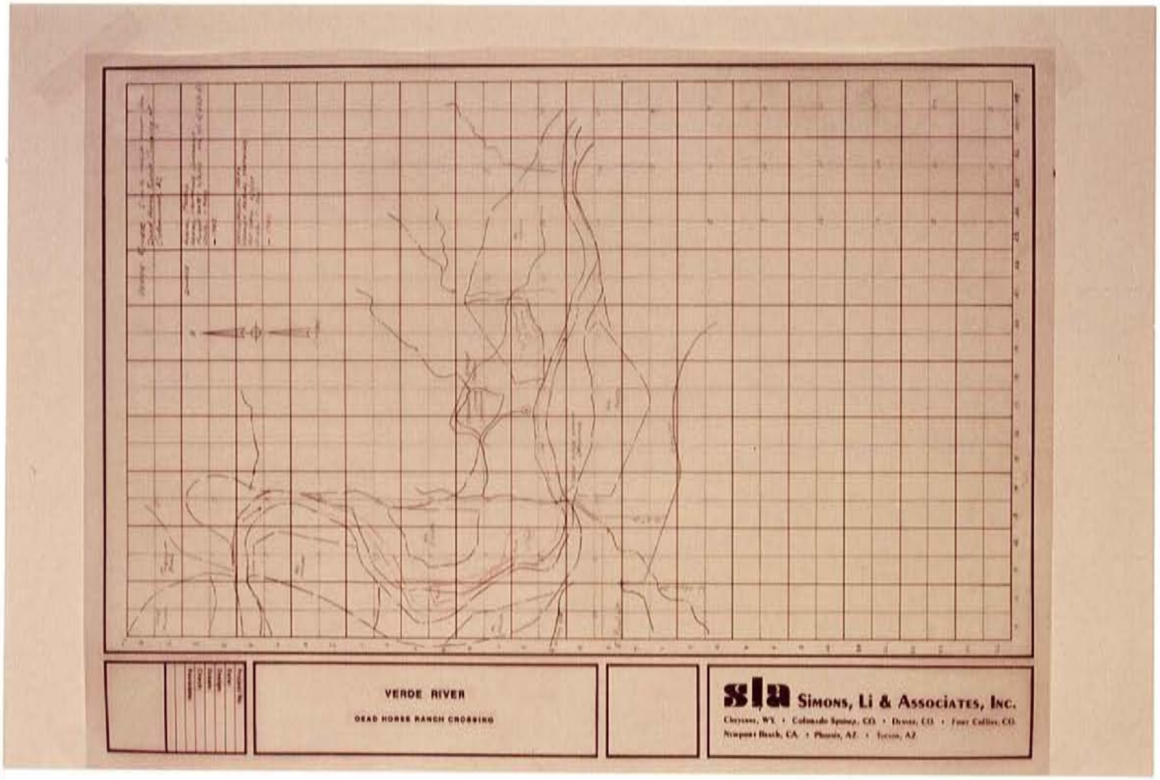
This information was converted to a digital database by compiling a spreadsheet which itemizes the area mined for each grid square for each photo year. With input from the gravel mining operators, these aerial extraction data was converted to volumetric estimates so that an annual extraction volume could 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

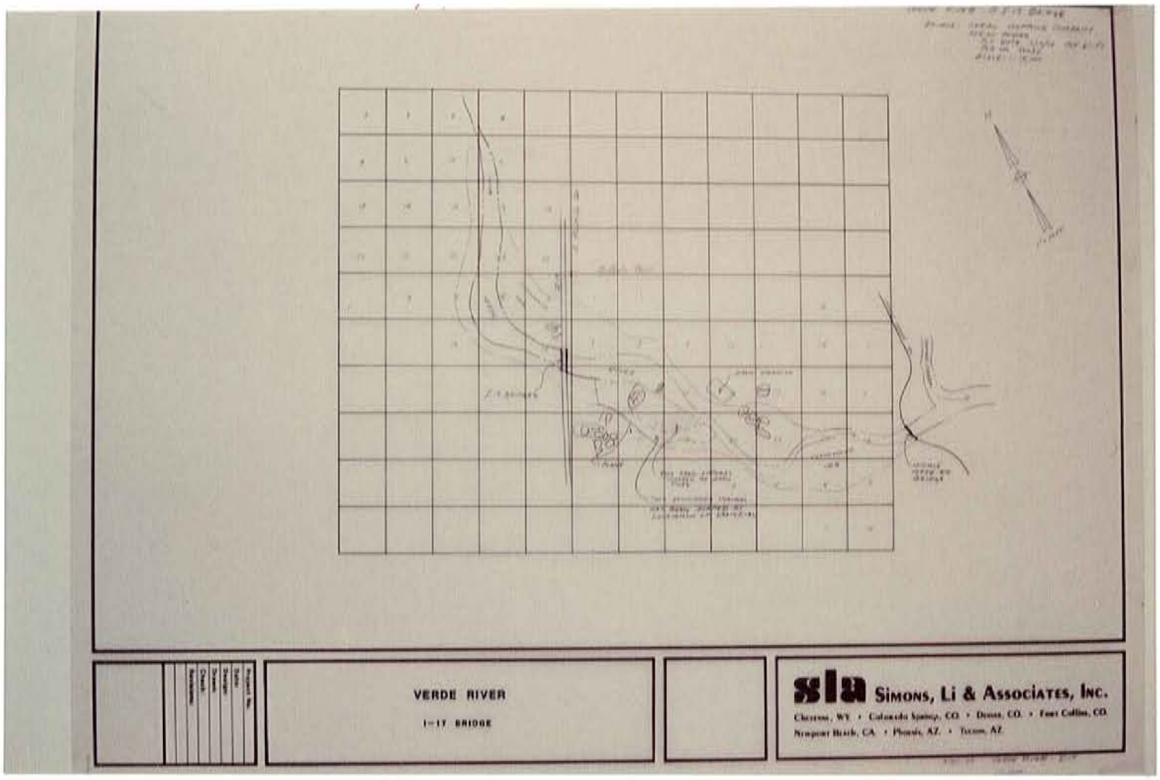


SALT RIVER--59TH AVENUE TO 19TH AVENUE
PLATE J.2



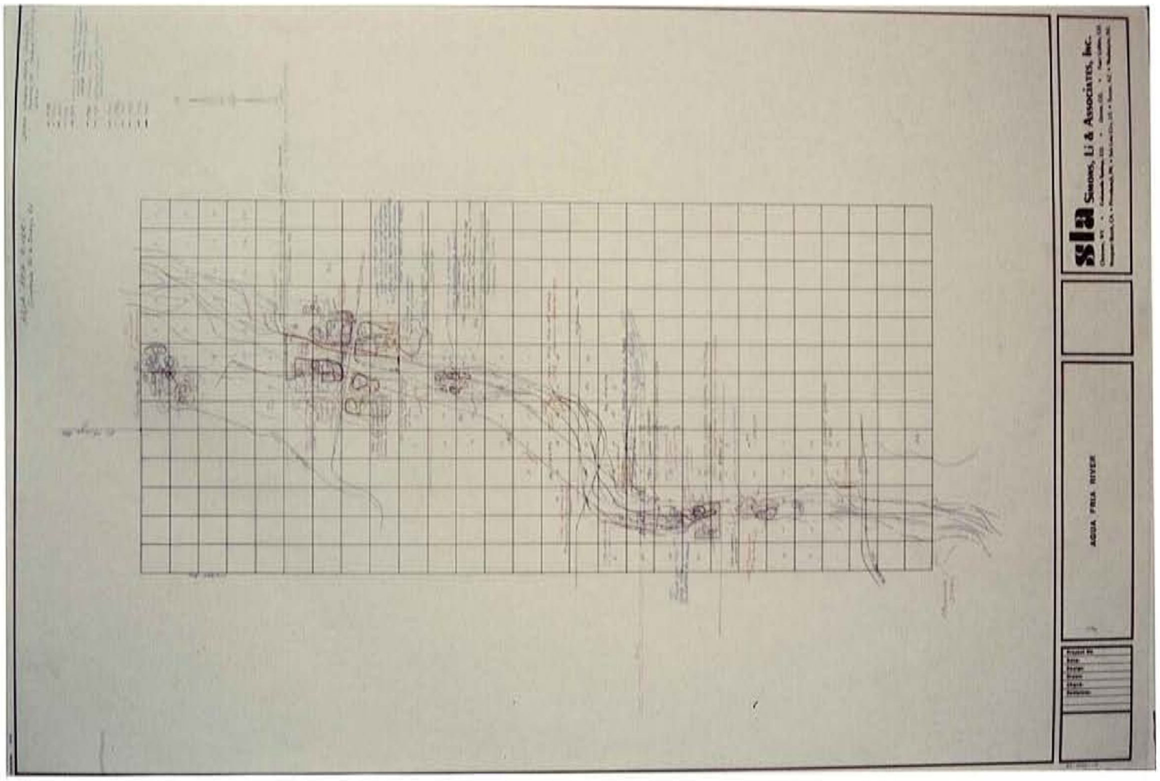
VERDE RIVER AT COTTONWOOD

PLATE J.3

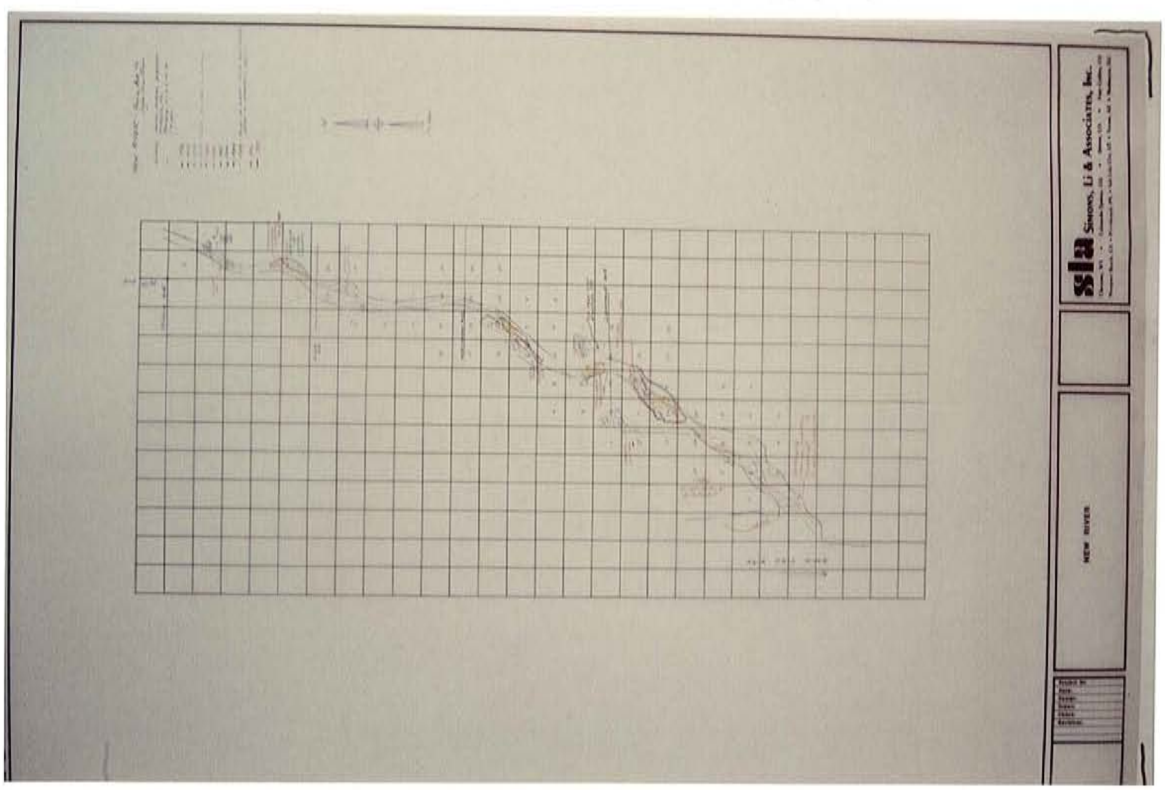


VERDE RIVER AT I-17

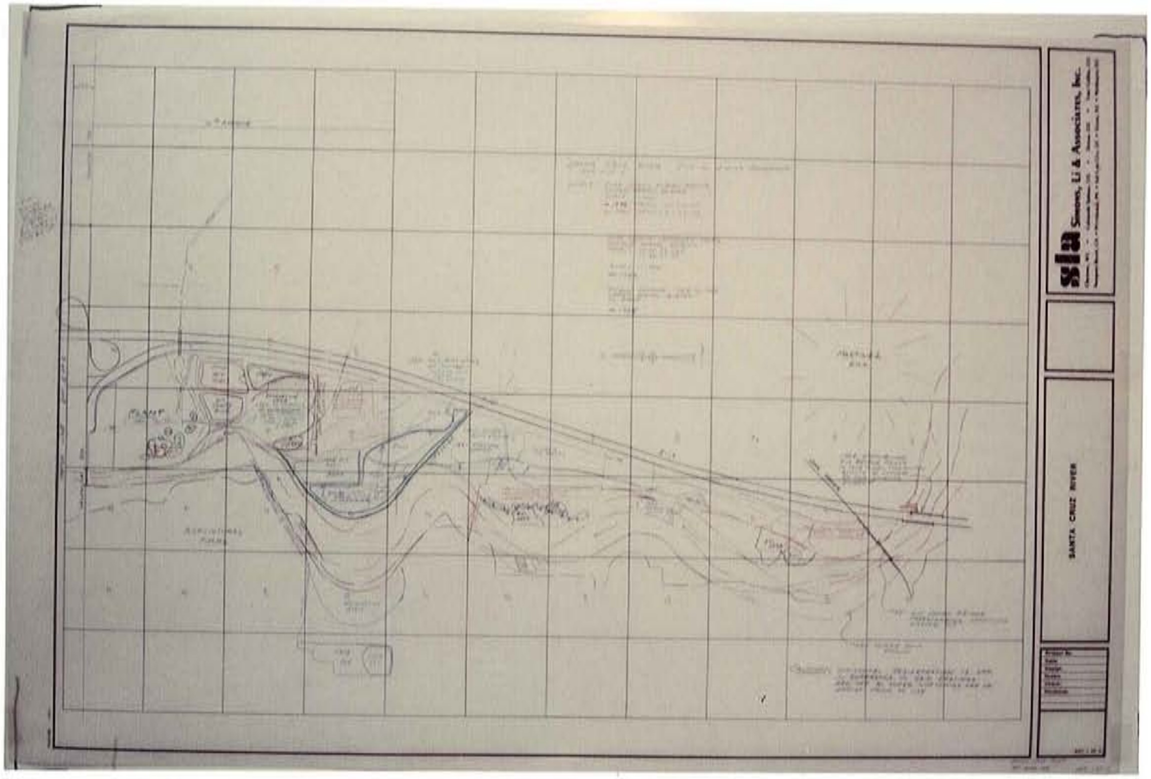
PLATE J.4



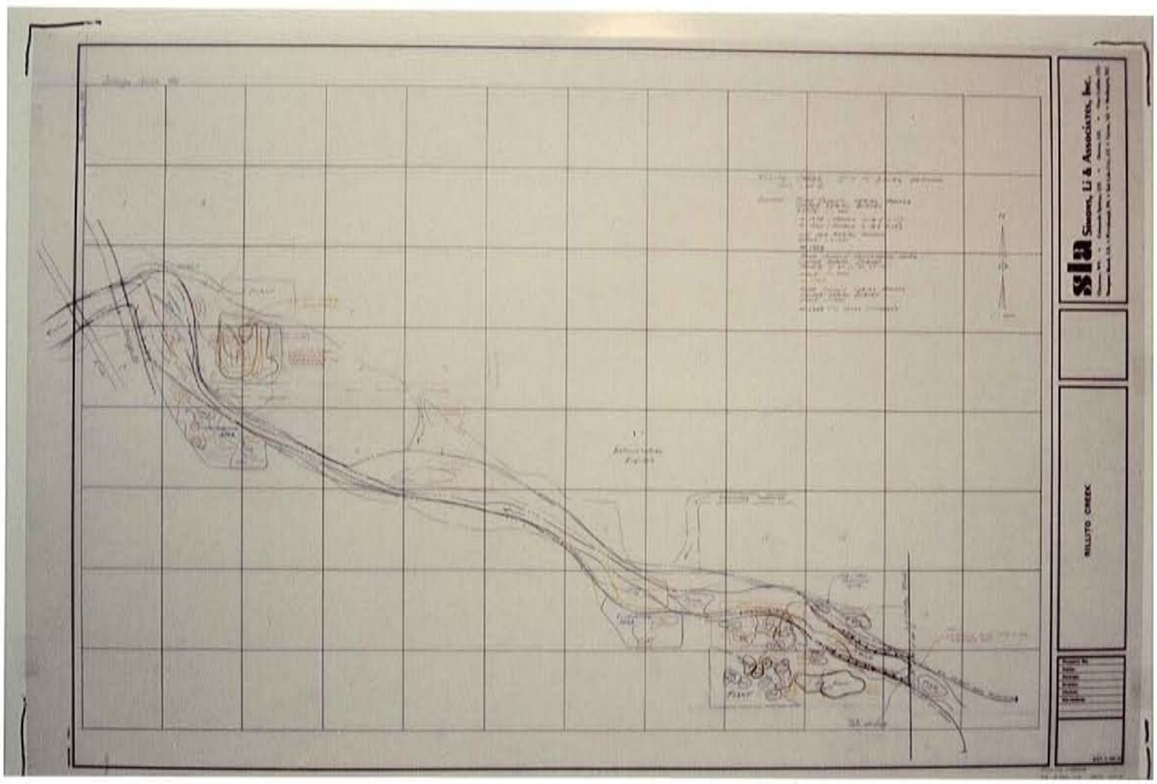
AGUA FRIA RIVER
PLATE J.5



NEW RIVER
PLATE J.6



SANTA CRUZ RIVER
PLATE J.7



RILLITO CREEK
PLATE J.8