U.S. Army Corps
of Engineers
South Pacific Division
Los Angeles District

SANTA CRUZ RIVER WATERSHED MANAGEMENT STUDY

PIMA COUNTY, ARIZONA

Appendix E1
Hydrology Appendix

August 2001

SANTA CRUZ RIVER

WATERSHED MANAGEMENT STUDY:

MIXED POPULATION

DISCHARGE-FREQUENCY ANALYSIS

Pima County, Arizona

Continental Road to Cortaro Road

HYDROLOGY APPENDIX (E1)

Los Angeles District
U.S. Army Corps of Engineers
29 September 2000

HYDROLOGY APPENDIX (E1)

MIXED POPULATION

DISCHARGE-FREQUENCY ANALYSIS

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SANTA CRUZ RIVER

MIXED POPULATION DISCHARGE-FREQUENCY ANALYSIS

Los Angeles District, U.S. Army Corps of Engineers (COE)

29 September 2000

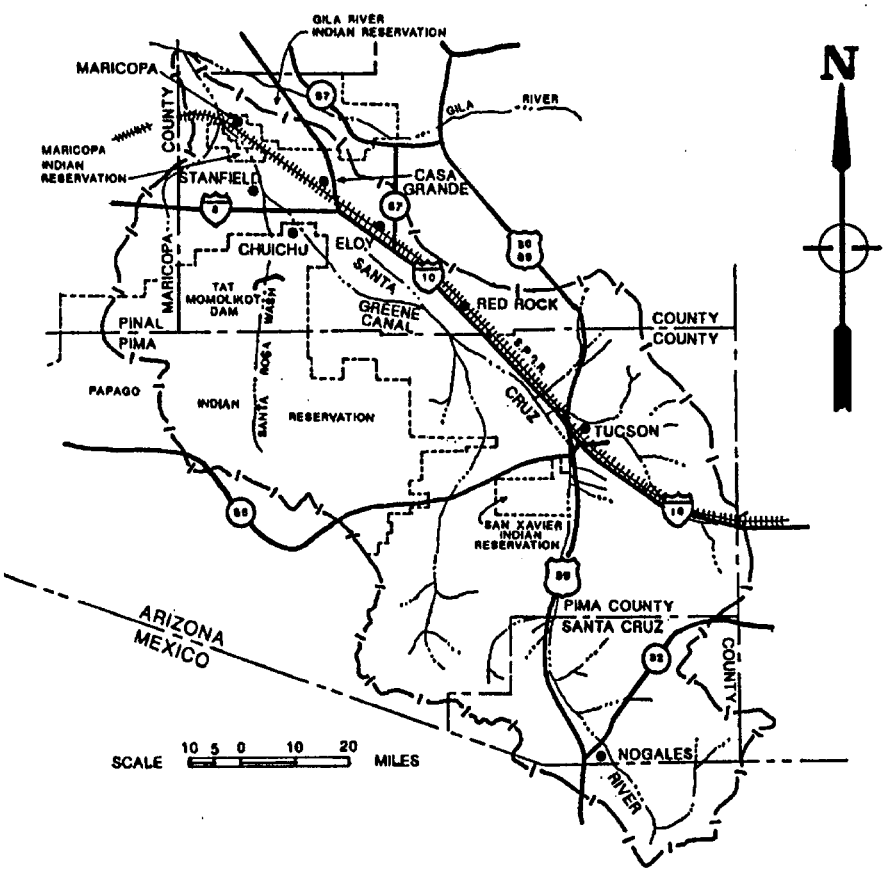
1 INTRODUCTION

When flood events are caused by different types of hydrologic phenomena, special treatment may be required in order to make adequate estimates of the potential for flooding. The COE began applying special treatment to flood events occurring along the Atlantic and Gulf coasts where hurricane events strongly influence the perceived flood threat. In such cases, discharge-frequency relationships have been developed using sets of annual maximum streamflow (samples) that originate from two or more separate causal factors, often referred to as a **mixed population** discharge-frequency analysis (hereafter referred to simply as **mixed population** analysis). The terminology used is a bit confusing, however, as a discharge-frequency curve derived directly form the annual peak data set is referred to as a mixed population frequency curve, while the discharge-frequency curve developed from separate causal factors, or samples (and the resulting separate discharge-frequency curves), is referred to as the combined population frequency curve. Within this report the term **mixed population** analysis will be used in the context of classifying the causal factors into differing storm and flood types, developing separate samples or populations, statistical analysis of each separate sample or population, and finally generating a combined population frequency curve.

In the Santa Cruz River basin, flood events are linked to at least three differing storm types, categorized within this report as *cyclonic*, *monsoonal*, and *frontal*. There is some interrelationship between the meteorological circumstances leading to these differing types of storms, but generally speaking they result from differing factors, occur at different times of the year, and have different precipitation and runoff characteristics, including magnitude (both intensity and depth) and duration. Statistical analysis of the systematic flood record based solely upon annual maxima results in discharge-frequency relationships for the Santa Cruz River which are inconsistent from station-to-station, and which do not fit the data well (the observed or systematic data exhibit a much more extreme likelihood of flooding than the resultant discharge-frequency curves), especially for the larger drainage areas (near Tucson, 2222 sq.mi., and Cortaro Road, 3503 sq.mi.). Consequently, a statistical analysis based upon a **mixed population** approach was considered to be a viable alternative to the annual maxima approach.

This report summarizes the **mixed population** discharge-frequency analysis conducted for each of these (above) storm and flood samples or populations. This study is one aspect of the Santa Cruz River Watershed Management Study (Feasibility phase) conducted by the COE in conjunction with

local sponsors. The purpose of this technical summary (Appendix E1) is to present some of the background, as well as a discussion of the technical aspects of the analysis which led to the final product. Finally, this technical summary includes the results of this study - discharge-frequency curves and a table of discharge-frequency values - for each of the Santa Cruz River gaging stations from Nogales to Cortaro. Raw data and data modified specifically for use in this study have been included in accompanying exhibits. Additional graphics to assist the reader are provided in figures and plates within this appendix. The Santa Cruz River basin is shown on the map below. Although the study area is limited to Pima County, AZ., the Nogales streamgage was used to supplement the study. Plate E1-1 contains a map of the Santa Cruz River basin extending downstream to Red Rock (located in Pinal County, and a State of Arizona map for general location and reference.



Santa Cruz River Basin

2 BACKGROUND

2.1 Historical Perspective.

2.1.1 Corps of Engineers (COE) Involvement. In the early-mid 1970's the COE proposed a peak 100-year (1% chance of being exceeded per annum) which was greater than most other agencies interpretations of the available streamflow data. This was due to a cross-correlation analysis performed by the COE with results for the adjacent watershed on the immediate east of the Santa Cruz River basin, the San Pedro River, which had experienced a maximum discharge (at the time of the study) approaching 100,000 cfs at several gages during an event which occurred on September 28, 1926. The drainage areas for the gages at which the event was recorded or estimated ranged from approximately 1200 sq. mi. to nearly 3600 sq. mi. (this compares well with the drainage area of the Santa Cruz River in Pima County which ranges from 1662 sq. mi. at Continental to 3503 sq. mi. at Cortaro). Because of the geographic proximity and the hydrometeorologic similarity, COE investigators felt that the chance of such a large event occurring in the Santa Cruz basin was just as likely. Subsequently, a meeting of Federal agencies and others took place at which participants agreed to a compromise 100-year peak discharge which was less than the peak flow rate endorsed by the COE.

2.1.1.1 *September 1926 Flood.* While that September 1926 peak discharge is still the largest event in history in the San Pedro River upstream of Aravaipa Creek, the October 1983 flood, which produced peaks of record in the Santa Cruz River within Pima County and Maricopa County, downstream of Aravaipa Creek was estimated by the United States Geological Survey (USGS) at 135,000 cfs. The October 1983 event also produced peak discharges of record in the Gila River both upstream and downstream of Coolidge Dam (Coolidge Dam stored the inflow from the event). For later reference, the October 1983 flood resulted from a dissipating tropical cyclone; it is likely that the earlier event in the San Pedro watershed (September 1926) also resulted from a dissipating tropical cyclone.

2.1.1.2 *October 1993 Flood.* Due to the widespread nature of the October 1983 flood event, and it's relative magnitude in numerous very large watersheds in the state of Arizona, the COE considered this event to be an "outlier", that is not representative of the expected magnitude of events within the period of record. The peak discharges associated with this event were considered to be representative of a 500-year event at Tucson (0.2% chance of exceedance per year) and even less likely at Cortaro. The extreme rarity of this event at Cortaro was moderated by the COE in a study conducted in the late 1980's for flood protection within Pinal County. The results were documented in the July 1990 hydrologic documentation to support that Feasibility Study. Based upon that study, the October 1983 event at Cortaro was considered to be less rare than at Tucson because of the possible contribution(s) from Rillito Creek, a significant tributary (drainage area of approximately 1000 sq. mi.). The return period at Cortaro was about 300-years (0.3% chance of exceedance per year.

2.1.1.3 *January 1993 Flood.* Subsequent to the October 1983 event, peak discharges in the Santa Cruz River were not unusually large until January of 1993. During that month the largest winter flood ever recorded/estimated occurred in the Santa Cruz River basin, and followed the trend of the October 1983 event, in that discharges increased as the flood wave moved downstream within Pima County. Until this current study the COE has not been involved in any recent flood control projects or associated studies which would have supported re-evaluation of discharge-frequency relationships within Pima County. However, Pima County has requested that the COE perform such a reevaluation on several instances. The most recent request resulted in funding of the Santa Cruz Watershed Management Study, within which the re-evaluation was intended to play an integral role.

2.1.1.4 *Miscellaneous COE Studies.*

2.1.1.4.1 1977-1978 STUDY. During the period from 1977-1978, the COE conducted a flood control study of the Santa Cruz River and tributaries, spanning Pima and Pinal Counties. Within the framework of that study, one objective was to develop a rainfall-runoff model for the Santa Cruz River basin. At that time the COE still designed projects based upon a "design-flood" concept, rather than NED (National Economic Development criteria). The purpose of the rainfall-runoff model was to develop a Standard Project Flood (SPF)[1] which could be used to provide information about the source and magnitude of a large flood within the Santa Cruz River basin. Interestingly, the SPF[2] peak discharges determined were larger than the October 1983 flood event both upstream and downstream of Tucson (about 90,000 cfs at both Continental and Cortaro), but approximately equal at Tucson. The channel routing model, based upon mapping in use at that time, showed considerable attenuation downstream of Continental. This aspect of the Santa Cruz River streamflow characteristics was investigated within the current study framework using a "hydraulic screening" approach discussed later in this report. The SPF peak discharges were approximately twice the I 00-year peak at every location where gaged information existed between Continental and Laveen (the mouth of the Santa Cruz River).

Another interesting aspect of the 1977-1978 study is that analysis of streamflow record, with

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[1] The SPF is the flood which would result from a combination of the most severe meteorologic and hydrologic conditions considered reasonably characteristic of the drainage area.

[2] The storm considered to be most severe and reasonably characteristic of this watershed was the September 1939 Indio storm, a dissipating tropical cyclone, which had an areal extent sufficient to produce large peak discharges and volumes in a basin the size of the Santa Cruz River. This storm was transposed to the area based upon relative precipitation between the location of occurrence and the Santa Cruz River basin. The precipitation depths were similar to the October 1983 storm depths. Until October 1983, however, no such documented storm had occurred within the Santa Cruz River basin.

the intent of providing "smoothed" regionally-based results proved to be very difficult. Relationships that made sense based upon drainage area size/contributing watershed did not fit the observations. Hence, it was apparent that the record downstream (Tucson to Laveen) was inconsistent because no storm large enough to activate the entire watershed had occurred within the period-of-record. This conclusion was later supported - in October 1983 and again in January 1993.

During the 1977-1978 study of the Santa Cruz River basin, *which resulted in a negative project report,* the largest flood of record occurred in the Santa Cruz River in Pima County (October 1977). This flood event, however, was characteristic of preceding moderate-runoff events in the basin - the peak discharge at Continental (26,500 cfs/drainage area = 1662 sq.mi.) exceeded the peak discharge at both Tucson (23,700 cfs/2222 sq.mi.) and Cortaro (23, 000 cfs/3 5 03 sq. mi.). The occurrence of this event, however, did lend support to a greater 100-year discharge for the Santa Cruz River at Tucson and the event was incorporated into the study.

2.1.1.4.2 POST OCTOBER 1983 FLOOD. Following the October 1983 flood event, the COE re-opened the previous study to determine whether updating the discharge-frequency relationships to include that event might influence the economics sufficiently to support a project. The result of that cursory evaluation was also negative.

In December 1984, HJalmar (Win) HJalmarson, the surface water specialist with the USGS in Tucson, hosted a symposium on the Santa Cruz River. A COE representative attended this event, at which numerous experts from the academic and engineering community presented their interpretation of the recent results and most likely causes. The COE provided a brief paper which generally attempted to support our position: that recent occurrences of unusually large events occurred throughout the Gila River basin and were not indicative of channel changes or upstream development/disturbance (mean discharges for sampled periods was not changed, but peak discharges were much higher); and the concept of hydroclimatic variability is attractive, and presents an argument for a frequency analysis based upon a mixed population; however, there is no compelling reason to deduce that there has been a long-term shift in the seasonal distribution and magnitude of flood-producing storms.

In the late 1980's, Pinal County sponsored a study of the lower Santa Cruz River to determine if the flood damage resulting from the October 1983 flood was sufficient to support a flood-control project in the vicinity. This Feasibility study resulted in updated discharge-frequency relationships for the Santa Cruz River from Cortaro (previously discussed) to Laveen, and the enhancement of strearnflow-routing models (produced during the 1977-1978 study) to depict the flow patterns between the diversion at Greene's Canal and Laveen. A hydrology report was produced during this study, but because of stability problems resulting from surface subsidence due to groundwater depletion in the area, random fissures had formed, and designs to

address this issue proved too expensive. The study was closed out when it was determined that costs exceeded potential benefits.

2.1.1.4.3 CURRENT. Channel changes to the Santa Cruz River upstream as well as downstream of the city of Tucson have been documented. Loss of valley storage as well as increased channel capacity through processes such as headcutting and channel improvements have resulted in less upstream attenuation. The flood of October 1983 crystallized the fears of residents in Pima County concerning the increased flood risk due to these upstream changes. However, as Mr. Zeller reports, the combination of extreme antecedent moisture along with the rainfall of 28 September to 3 October 1983, which he estimated to be equivalent to a 100-year event, "... could have produced runoff exceeding a 100-year event." Moreover simple statistical examination of non-stationarity of recorded streamflow on the Santa Cruz River performed by the COE, as well as more sophisticated analyses performed by the USGS (Climatic Variability and Flood Frequency of the Santa Cruz River, Pima County, Arizona, United States Geological Survey Water-Supply Paper 2379) did not indicate that the channel changes have resulted in a greater flood risk to residents along the Santa Cruz River in Pima County.

Aware of the tremendous economic impacts of the October 1983 flood, the LAD evaluated flood control measures in the Lower Santa Cruz River during the early part of this decade. Although there has been no vehicle for performing a basin-wide study of potential peak surface water runoff, continuing interest in such a study has persisted. Consequently, the Los Angeles District (LAD) of the COE had been directed to perform such a study by Congress, and the Reconnaissance level evaluation was begun. To that end the LAD invited representatives from Maricopa County, Pinal County, Pima County, Santa Cruz County, Cochise County, Arizona Department of Water Resources, Arizona Department of Transportation, the United States Bureau of Reclamation, the USGS, the Natural Resources Conservation Service, and the Federal Emergency Management Agency (FEMA) to attend a meeting held on 29 August 1995, to form a task force to address the source of differences in evaluation of discharge frequency relationships for the Santa Cruz River. On 4 October 1995, the task force held its initial meeting at which plans to reevaluate streamflow in the Santa Cruz River were presented. A draft proposal by which such a study would be conducted was laid out by the LAD based upon that October meeting. Issues to be reconciled included:
adjustment of the systematic streamflow record for the Continental and Tucson streamflow gages to account for backwater influence and loss of overbank storage, respectively;
the use of a more stationary subset of the systematic record;
and, the use of confidence limits as well as probability in describing the regulatory discharges.

2.1.2 FEMA Involvement. In response to the October 1983 event, Pima County contracted for a flood evaluation study which generally supported the observed/estimated October 1983 peak flow rates as the 100-year event (1% chance of exceedance per year) and provided those results to FEMA for subsequent endorsement and use in floodplain regulation. The resulting difference between COE's discharge frequency estimates for the Santa Cruz River in Pima County and regulatory discharges approved and implemented by Pima County has served as an obstacle to any locally sponsored COE studies in this region.

2.1.3 Additional Information.

2.1.3.1 *October 1990 Meeting - ADWR.* Because of the existence of differing flow rates to reflect the flooding potential along the Santa Cruz River among various agencies, a meeting was convened on 23 October 1990 at the COE Phoenix office. Participants included representatives from the Arizona Department of Water Resources (ADWR), the United States Geological Survey (USGS), the Pima County Transportation Department (Flood Control District), the Pinal County Flood Control District, and the Flood Control District of Maricopa County, as well as from the COE. Although the purpose at that time was to discuss the different flow rates with their application to an ongoing COE study in Pinal County, the basic issues involved the differences between the COE discharge-frequency values and those being implemented in Pima County (FEMA discharges used for floodplain regulation)

As documented in a letter written by the ADWR summarizing the results of that meeting, "the basic consensus among the participants was that although there are differences in some agencies [sic] Santa Cruz River flow rates, the previous hydrologic analysis [sic] are for different purposes and there are significant uncertainties in all approaches. It was agreed that each agency will review the COE hydrologic study when requested, but will coordinate all review comments through ADWR in order to simplify the review process and prevent misunderstandings."

2.1.3.2 *Mike Zeller Paper.* A paper prepared by Michael E. Zeller of Simons, Li & Associates (now TTISG, Tetra Tech International Southwest Group) for Pima County suggested that the October 1983 flood be considered as the present conditions 100-year flood. Based upon rainfall-frequency information presented in his paper he states that the October 1983 storm "...could have produced runoff exceeding a 100-year event both in terms of volume and peak rate of discharge." In addition he states that the "...present-day hydrologic conditions within the Santa Cruz river basin...are definitely nonstationary, especially with regard to the hydraulic efficiency of the main conveyance systems within the watershed, and are continually changing in a manner that tends to lead to further increases in peak-discharge rates of future flow events."

3 HYDROLOGIC TASK FORCE

3.1 Phase 1: Reconnaissance Study - Plan Development.

3.1.1 Initial Task Force Formation. At the request of Pima County, congress authorized the COE to conduct the current Watershed Management Study, within the framework of which the COE is revisiting the discharge-frequency evaluation of the Santa Cruz River in Pima County, Arizona. The Reconnaissance phase of this study began in 1995 with an initial meeting held in Tucson on 29 August 1995. Participants were invited from a list prepared for the COE by a contractor for the public involvement phase of the study. The attendees included representatives from the Arizona Department of Water Resources (ADWR), Pinal County, Natural Resources Conservation Service (NRCS), United States Geological Survey (USGS), the Flood Control District of Maricopa County (FCDMC), the Pima County Department of Transportation and Flood Control District (Pima County FCD), the Arizona Department of Transportation (ADOT), and the COE. Numerous others were invited but did not attend. The purpose of this meeting as stated was

"...to develop a technical approach by which the agencies involved in floodplain regulation might reach agreement on discharge frequency relationships for the *mainstem* Santa Cruz River. Emphasis should be on this restricted generalized topic, and not on peripheral flooding problems or specific associated problems within the Santa Cruz River basin. To restate: this meeting is not being held to air out or resolve problems associated with flooding, but only to attempt to develop a PLAN by which agreement on discharge frequency relationships for the *mainstem* Santa Cruz River might be derived during subsequent studies, dependent upon the Los Angeles District, United States Army Engineer District (LAD), being funded."

Participants introduced themselves and discussed their involvement with Santa Cruz River hydrology. From the group present a "task force" was formed to develop a plan of study to meet the stated objective. Additional meetings were held during 1995 and the spring of 1996, culminating in the PLAN.

3.1.2 The PLAN. As proposed, the PLAN incorporated the following processes:

- hydraulic evaluation of the Santa Cruz River channel capacity for sub-periods of history, and an estimation of future channel changes;
- modification of the *recorded and historic* annual maximum peak discharges to reflect

changes in channel conveyance where appropriate, using an "index flood"[3] procedure;

- separation of adjusted annual maximum series into **mixed populations** - for simplicity, June through October, and November through March.

  [Note: this was later modified at the request of Pima County FCD to include a 3rd population - dissipating tropical cyclones, which typically occur in late September into October. The **mixed population** analysis thus included 3 seasons: *cyclonic* (typically late September to October), *monsoon* (typically June to September), and *frontal* (herein restricted to winter events, typically November through March/April) The accompanying diagram (refer to Plate E1-2) presents the initial PLAN process, and was not revised to reflect this additional season.]

- discharge frequency analysis of the **mixed populations** (using Bulletin 17B guidelines, assuming Log-Pearson Type III distribution) and combination of these results into an annual discharge frequency relationship;
- estimation of confidence levels for the combined discharge frequency curves (as explained later in this report, this task was later eliminated after conferring with the local sponsor - Pima County FCD).

3.2 Phase 2: Feasibility Study - Plan Implementation.

3.2.1 Continuation of Task Force. Although the Feasibility Study itself had begun earlier, the 1st meeting of the Task Force (now being facilitated by Simons, Li and Associates, SLA, a subsidiary of Tetra Tech International Southwest Group, TTISG, under contract with the COE) was not held until 22 January 1998[4]. Due to conflicting priorities, the COE was unable

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[3] Index flood here refers to an arbitrary range of synthetic floods, based upon observed record, which will be used to estimate relationships between upstream and downstream peak discharges. The "index"/"reference" floods have a range of magnitudes from small/frequent to large/rare in terms of peak and volume, and are based upon observed flows in the Santa Cruz River. Since no lateral inflow will be introduced into the flood routing, attenuation of the flood peaks reflects *only* the effects of channel geometry. Hence the relative attenuation for each reach and historic period could be used to adjust the data base. For example, if the attenuation for some historic channel condition in a designated reach were greater than the attenuation for that reach under existing conditions, the historic peak discharges would be adjusted upward (increased) based upon the ratio of the existing condition attenuation to the historic condition attenuation in each reach, dependent upon the magnitude of the flood peaks. The observed flood peak magnitude would be compared to the range of values considered in the *Index Floods* and adjusted accordingly. This would be done for present conditions and future conditions (if necessary). All *Index Floods* used in the "hydraulic screening" analysis are provided in Exhibit E1-10, and data used to develop these synthetic flood hydrographs, including the "pattern flood" (October 1983) are included in Exhibit E1-11.
Note: a pattern flood hydrograph is necessary in order to distribute duration flows in a reasonable manner.

[4] Prior to this a PSP (project study plan, including scope/time/costs) had been developed and tasks allotted between local sponsor(s) and the COE. However, this funding document was later determined to be inadequate and was modified in the latter part (November - December) of 1998.

to commit sufficient resources to the study at that time. Hence, the Task Force did not reconvene until 21 April, 1999. During the intervening period between the PLAN development (Reconnaissance Study) and the implementation of the PLAN (Feasibility Study), some aspects of the **mixed population** analysis were not wholly endorsed by the local sponsor among others. Regardless, this meeting marked the initiation of the engineering evaluation.

3.2.2 Follow-up meeting, 27 July, 1999. At this meeting COE personnel presented the results of the hydraulic screening to determine if man-made disturbances to the channel conveyance had resulted in decreased attenuation, hence greater downstream peak discharges within Pima County. (Please refer to Table E1-1 for summary tables comparing the results of the *Index Flood* routing. Also, Figure E1-1 graphically depicts the *Index Flood* routing results.) The period chosen was approximately 1976-1977 to the present. While it would have been desirable to reproduce or mimic the channel conditions during earlier periods (e.g. back to 1940), adequate data to accomplish this was scarce. Additional data to describe the channel and overbank geometry had been sought from others sources such as the USGS and Pima County FCD, but quantitative information was not easily accessible, nor was such information offered. Since the period chosen preceded the first of the 3 recent, basin-wide flood events[5], it is likely that the channel condition prior to October 1977 was similar in most locations to the channel configuration at that time. In order to reflect ***only*** the effects of channel geometry on peak discharges, the upstream hydrographs were routed downstream without any tributary inflow or channel percolation.

3.2.3 Results of Hydraulic Screening. (Refer to Table E1-1 and Figure E1-1) showed[6]:

"...that, in general, attenuation of peak flows for the 1976-1977 channel condition was greater than for the present channel configuration. However, for some smaller floods, this condition is actually reversed. In any case, it does not appear that the changes are sufficient to merit further investigation of the period prior to 1976-1977, for which only sparse geometric and flood data is available from which to reliably reconstruct historic channel conditions. Furthermore, were such information available, it is unlikely that the results would have a

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[5] The 3 large, regional floods are the October 1977 and 1983 floods (source: dissipating tropical cyclones, i.e. *cyclonic*), and the January 1993 flood (source: *frontal*)

[6] Conclusion/quote excerpted from Documentation entitled **SANTA CRUZ RIVER-WATERSHED STUDY - EVALUATION OF IMPACTS OF CHANNEL CHANGES ON PEAK DISCHARGE,** prepared for the Hydrologic Task Force by the COE, and provided at the July 27, 1999 meeting to participants (Exhibit E1-8a). A more thorough discussion of the hydraulic model is included in Exhibit E1-8.

significant impact[7] on the subsequent evaluation of discharge-frequency relationships for the Santa Cruz River...Based upon this initial evaluation of the available hydraulic data for the Santa Cruz River in Pima County, AZ., it is our recommendation that discharge-frequency relationships be developed considering the streamflow data since 1940 to be homogeneous in character, at least based upon channel geometry. Hence, recorded streamflow data would be used *without* adjustment in order to pursue development of seasonal discharge-frequency relationships and the resulting annual discharge-frequency relationships."

3.2.4 Study Limitations. In addition, the COE informed the participants that time/funding to develop a parallel **mixed population** analysis for the recent flood history was *not* within our current capabilities. Regardless of whether this additional aspect was investigated or not, the analysis of the 1940 - present period would not be hindered. (This issue was later brought to the attention of managers at Pima County FCD and the COE for resolution.) A "final" task force meeting was scheduled to follow completion of the **mixed population** discharge-frequency analysis, anticipated to be in mid-November.

3.2.5 Initial **mixed population** Findings. In November, 1999, the COE met with Pima County FCD representatives to present our initial findings. The results presented were a set of combined "annual" discharge-frequency relationships, based upon a **mixed population** analysis of Santa Cruz River streamflow from the Nogales, Az. gage to the Cortaro gage, which *supported* the regulatory discharges currently in place. These preliminary 100-year (1% chance of exceedance in any year) discharges were approximately equal to the regulatory discharges (slightly lower for the downstream locations). Based upon this outcome the COE recommended two further steps:

- shelving of the issue of determining results based solely upon the recent flood history, which involves the concept of "climate change";
- elimination of the need to "qualify" the annual median-frequency discharge-frequency relationships to reflect varying degrees of risk - i.e. confidence limits would not be developed.

3.2.6 Final Task Force Meeting, December, 1999. (A set of notes from that meeting, prepared by Doug Lantz, TTISG, are included in Exhibit E1-9.) Prior to the meeting Task Force members were presented with a technical summary, including a table of results via FAX; in addition each participant was furnished a hardcopy of that summary report along with pertinent tables and graphics under separate cover. At the December meeting the COE presented their "draft" results (100-year discharge-frequency values for the Santa Cruz River

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[7] This conclusion was reached for several reasons. First, the differences in the degree of attenuation resulting from the existing condition channel geometry compared to the selected historic period channel geometry were typically < 5%, which is well within the data "noise". More importantly, there were no significant flood events within the period from 1940 to 1976 which would have been increased sufficiently, after adjustments for the existing channel geometry, to alter the final **mixed population** results.

from Nogales to Cortaro), along with an informal discussion of the study methodology, including assumptions made and potential shortcomings. Participants were asked to provide review comments on the report, either by FAX or electronically, to Mr. Doug Lantz of TTISG or Mr. Nick Adelmeyer of the COE. In addition, Mr. Adelmeyer, the COE investigator performing the statistical analysis, also indicated that the "draft" results would be refined in a subsequent iteration to address his concerns about discharges for frequencies beyond the 100-year event (1% chance of exceedance in any given year). That refinement is included in this report, as well as additional modifications to address comments received.

4 DRAINAGE AREA DESCRIPTION

The Santa Cruz River is a tributary to the Gila River, which in turn is a tributary to the Colorado River. The Gila River Basin comprises 58,200 mi^2 in New Mexico, Arizona, and Mexico. The Santa Cruz River Basin consists of approximately 8200 mi^2 in southern Arizona and 400 mi^2 in Mexico. A map delineating the Santa Cruz River drainage basin from its headwaters downstream into Pinal County, and its location within the State of Arizona is provided in Plate E1-1.

The Santa Cruz River rises in the Patagonia and Huachuca Mountains in southern Arizona near the town of Lochiel, flows south across the international boundary and makes a 35 mile long loop westward through Sonora, Mexico and then turns northward and reenters the United States about 6 miles east of Nogales. The channel continues north to Tucson, then turns northwestward and flows 42 miles to Greene Canal. From here, most of the flow is diverted to Greene Canal and continues through several distributary channels about 75 miles towards Laveen at the confluence with the Gila River (about 10 miles upstream of the Salt River confluence and about 80 miles upstream of Painted Rock Dam on the Gila River).

The Santa Cruz River basin is characterized by a wide valley broken by several broad, low hills and mountains. The basin area has a maximum length of approximately 175 miles and is about 80 miles wide at its widest point. Stream gradients in the basin range from about 29 feet per mile near Lochiel to 18.5 feet per mile at Tucson to 8 feet per mile at the Gila River confluence.

The Santa Cruz River and principle tributaries are mostly ephemeral, being dry for long periods of time. Flows in the river are a result of direct or upstream precipitation or irrigation tailwater in the basin. For a short distance downstream of Tucson, the river conveys a perennial flow of sewage effluent from a sewage treatment plant.

Analysis of the basin indicates the confluence with Los Robles Wash marks a change in the character of the runoff; just upstream the Los Robles Wash system (Altar Wash, Brawley Wash, drainage area = 1390 mi^2) enters the Santa Cruz River and is the last major source of uncontrolled runoff from mountainous terrain.

From the headwaters to the confluence with Los Robles Wash, the Santa Cruz River is a "gaining" river, meaning discharge generally increases with drainage area. Downstream from the confluence to the mouth (at the confluence with the Gila River), the flood plain flattens and broadens out in the area known as the "Santa Cruz Flats" and becomes a "losing" river. In this reach flood flows are dramatically attenuated such that discharge decreases with an increase in drainage area. Flows originating in the upper reaches of the Santa Cruz River rarely reach the Gila River; when they do reach the Gila River, they are usually augmented by tributary flows originating in the lower part of the basin. The streambed materials are extremely permeable especially from Cortaro to Laveen, resulting in high rates of infiltration.

Total rainfall and the areal distribution of rainfall are affected by relative elevations of the various parts of the drainage area. Elevations in the basin range from 9432 feet NGVD at Mount Wrightson in the Santa Rita Mountains to about 1000 feet NGVD at the Gila River confluence. The crest-stage gage at Congress Street in Tucson was located at datum 2317.82 feet, National Geodetic Vertical Datum of 1929 (it has since been moved about 300 feet downstream).

Valleys occupy almost 70% of the area and the primary land use in the basin is irrigation agriculture, both on Indian as well as private land. Agriculture is limited by the available water supplies. Irrigation water is supplied principally from groundwater sources, which are recharged by precipitation over the area. The growing season in the basin is fairly long and a wide variety of crops are produced. Much of the flood plain contains soil suitable for growing such crops as cotton (the principle agriculture crop), grains, and pecans where irrigation water is available.

Vegetation in the Santa Cruz River basin is sparse and consists of typical desert cover of creosote bush, sagebrush, paloverde, desert shrubs, and cacti in the lower elevations, assorted grasses in the upper valleys, and fir, pine, juniper, chaparral, and pinon forests in the higher mountains. Along the stream channels thicker and denser vegetation made up of mesquite forests, cottonwood and willow trees and various reeds and grasses can be found.

Soils in the Santa Cruz River watershed are extremely varied. The mountains consist of weathered native rock, while the valley floors contain unconsolidated gravels, sands, silts, and the clays derived from these rocks. The soils of the mountain area are shallow and stony with occasional rock outcrops. Desert and semi-desert soils occur in the hills and valleys. The valley surface soils generally range from fine silty clays to clay and are fairly deep. The stony or gravelly alluvial fans, formed by coarse material shed from the mountains, are underlain by subsoil material that is highly calcareous and more or less firmly cemented.

5 PRECIPITATION AND RUNOFF

5.1 General. The climate in the Santa Cruz River Basin is typically desert in character with short, mild winters and long, hot summers. High diurnal temperature variations are characteristic of the region. Temperature extremes range from about 12° Fahrenheit in the winter to 122° Fahrenheit in the summer. The prevailing winds are from the east and are usually light, although severe windstorms occur at rare intervals.

Mean annual precipitation ranges from 11 inches in the valleys to over 37 inches at elevations greater than 8000 feet NGVD. Studies conducted in the Tucson vicinity show an extremely low percentage (about 1%) of the rainfall appears as runoff, generally evaporating or returning to groundwater.

Precipitation occurs in two distinct seasons of the year; summer (late June, July, August, September, and into October; and winter - December, January, February, and March.

5.2 Monsoon Season. Summer rains in the form of thunderstorms originating in moist air that flows into Arizona from the Gulf of Mexico generally occur in middle to late afternoon and are usually of local extent. Approximately 80% of the thunderstorms over the basin occur in the summer months. Floods associated with summer thunderstorms can be extremely flashy (up to 3 hours) and are of short duration.

5.3 Cyclonic Season. Some general summer storms do occur during the period July through September. They are associated with an influx of tropical maritime air originating over the Gulf of Mexico or the south Pacific Ocean and entering the area from a southeast or a southwest direction. Usually the influx of tropical air is caused by the circulation about a high-pressure area centered in the southeastern United States, but occasionally is caused by remnants of a tropical hurricane. There is often relatively heavy precipitation for periods of up to 24 hours and showers may continue intermittently for as long as 3 days. Flooding commonly covers a wide area with durations of about 24 hours.

5.4 Frontal Season. Winter precipitation is normally associated with the passage of cyclonic storm centers originating in the Pacific Ocean, which commonly are a result of interaction between polar Pacific and tropical Pacific air masses. Some snow falls at the higher elevations, but the effect on flood flows is negligible. Individual storms usually are of several days' duration and wide areal extent, with slow and steady intensity. Winter floods from these storms are of longer duration with lower flood crests.

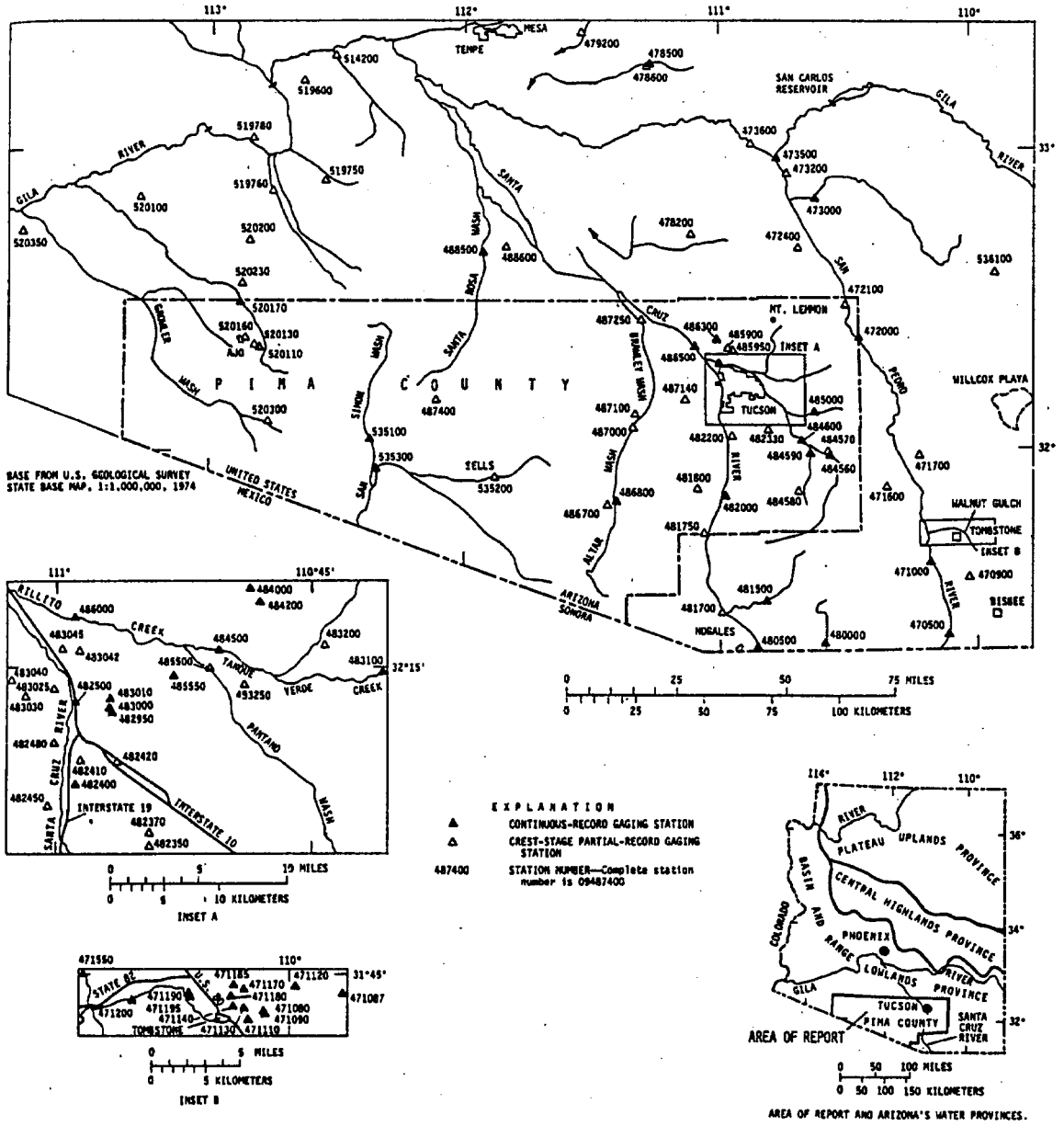
5.5 Recorded Data. Currently the USGS operates streamflow recording gages on the Santa Cruz River at the locations listed in the following table:

USGS Streamgage Information for Santa Cruz River

USGS Streamgage Number	Location	Drainage Area (mi^2)	Period of Record	
			Systematic	Historic
09480000	Santa Cruz River nr. Lochiel	82.2	1949-present	1926-present
09480500	Santa Cruz River near Nogales	533	1930-present	1892-present
09482000	Santa Cruz River at Continental	1662	1940-present	1892-present
09482500	Santa Cruz River at Tucson	2222	1915-1981, 1984-present	1892-present
09486500	Santa Cruz River at Cortaro	3503	1940-1984, 1990-present	1914-present
09489000	Santa Cruz River near Laveen	8581[a]	1940-present	1940-present

[a] 1780 mi^2 is controlled by Tat Momolikot Dam

[**Note:** Locations of pertinent stream gages are included on the accompanying maps on the following page.]



Locations of stream gages

6 HISTORIC STORMS AND FLOODS

Available streamflow records, most commonly collected by the USGS, indicate significant floods occurred in the Santa Cruz Basin in 1887, 1926, 1945, 1961, 1962, 1964, 1965, 1967, 1977, 1983, 1991, 1993, and 1995. The largest flood of record for most of the basin occurred in October of 1983. Following is a historical account of some of the flooding and precipitation in the Santa Cruz River basin during the October 1983 event.

6.1 October 1983. Tropical storm Octave off the coast of Baja California, was the main cause of large floods (in numerous cases the period-of-record peak flow) on the San Francisco, Gila, San Pedro, Santa Cruz Rivers, and other smaller streams. The long period of rainfall from September 27 to October 3 was the result of the interaction of a high-altitude low-pressure trough and a persistent supply of moist tropical air that was vastly increased on September 30 by the arrival of moisture associated with tropical storm Octave.

As much as 11 inches of precipitation fell during the 7-day storm period. Rainfall during the storm period contributed to the highest annual precipitation and the highest September-October seasonal precipitation at many of the precipitation stations in the area. The highest recorded precipitation in the Santa Cruz Basin was measured at an elevation of 7,000 feet in the Santa Catalina Mountains, just north of Tucson.

Before the storm period began, rainfall had been above normal in most parts of the area, soil conditions being mostly saturated. Flood flows in the Santa Cruz River Basin originated mostly between Nogales and Cortaro, with large volumes of water breaking out of the channel and spreading out over a broad area, especially downstream from Red Rock (refer to Plate 1 for location of Red Rock).

The flood on the Santa Cruz River was the largest on record from Continental to the junction with the Gila River. At Interstate 8, the inundation area was more than 8 miles wide. Large channel changes took place on many streams. Total damages were estimated to be $226.5 million.

The following peaks were recorded or estimated on the Santa Cruz River: 3880 ft^3/s near Lochiel, 16,200 ft^3/s near Nogales, 45,000 ft^3/s at Continental, 52,700 ft^3/s at Tucson, 65,000 ft^3/s at Cortaro, and 33,000 ft^3/s near Laveen.

Other peak discharges in the Santa Cruz River basin included 29,700 ft^3/s on Rillito Creek, 12,500 ft^3/s on Los Robles Wash, 19,100 ft^3/s on Brawley Wash, 6600 ft^3/s on Canada Del Oro, and 1890 ft^3/s on Santa Rosa Wash, (**note**: this is outflow from Tat Momolikot Dam).

7 MIXED POPULATION ANALYSIS

7.1 **Censored Data Acquisition - SLA.** At the beginning of the Feasibility Study several tasks were undertaken either as "in-kind services" (e.g. the continuous hydraulic model of the Santa Cruz River developed by Pima County FCD, later modified by the COE for use in screening for effects of channel modifications), or contracted directly (for a description of the hydraulic modeling effort, please refer to Exhibit E1-8, Exhibit E1-8a). The Tucson office of SLA/TTISG was contracted to develop subsets of "annual maxima" for each of the 3 seasons identified in the PLAN.

7.1.1 Flood Separation by Storm Type. The flood "seasons" were categorized according to the following storm "types" described in the USGS WSP 2379 (see Reference 10.12) and summarized by SLA:

- *Cyclonic* (Dissipating tropical cyclones) - storms that typically occur in later summer and early fall caused by intrusion into Arizona of the remnants of tropical cyclones which originally formed over the Pacific Ocean. This intrusion is atypical and results from recurvature of the normal storm path to the northeast as a result of atmospheric conditions. These type of tropical cyclones dissipate over land and result in intense precipitation over large areas. Although more tropical cyclones form in the months of July and August than in the late summer-early fall period, conditions conducive to recurvature (e.g. cutoff lows) are at a maximum in October. Hence these dissipating tropical cyclones occur over Arizona more frequently during those latter periods of time when recurvature is a more frequent pattern.
- *Monsoonal* (Thunderstorms) - storms which typically occur in summer, when subtropical high-pressure cells shift rapidly northward and induce advection of moist tropical air into Arizona. These surges have been likened to monsoonal circulation elsewhere, and result in isolated or complex groups of thunderstorms characterized by high intensity, short duration, and limited areal extent.
- *Winter* (Frontal and cutoff low-pressure systems) - storms originating from large-scale, low-pressure frontal systems emanating from the Pacific Ocean. This type of storm occurs in this area when a low-pressure trough develops over the Western United States, displacing the storm track to the south. In addition, when high pressure forms over the Pacific, low-pressure systems can stagnate and become cut off. These cutoff lows can intensify off the coast of California before moving inland and can produce substantial precipitation. These cutoff lows can also form in the fall and steer dissipating tropical cyclones inland (see above discussion).

That information was provided to the COE in September, 1997[8]. As discussed in the SLA

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[8] *Santa Cruz Watershed Hydrology - Research of Historic Flood record and Separation by Storm Type*, Simons, Li and Associates, September 11, 1997 (prepared by John Wallace).

report;

"...separation of flood events by storm type was accomplished using a number of different references and criteria. The primary references...were USGS WSP 2379 and a study entitled 'Hydroclimatology of Flow Events in the Gila River Basin, Central and Southern Arizona', Katherine Kristin Hirshboeck PhD dissertation, University of Arizona, 1985".

These two references (provided the basis for most of the storm classifications for Santa Cruz River stations. Supplemental classifications were made by associating the date of occurrence of events at other stations with the date of occurrence for which classifications had previously been made (USGS WSP 2379 and Hirshboeck's dissertation). Finally, the COE investigator added another station - the Santa Cruz River at Nogales - linking the storm category for events at this additional location to the classifications already made and the date of occurrence. In addition, some modifications to the classifications provided by SLA were made consistent with the investigator's knowledge of storm type and time of occurrence. For example, summer *frontal* storms were included within the category of *cyclonic* events, due to their meteorological similarity (i.e. strong influence of cutoff lows, similarity in duration and areal expanse) and hydrologic dissimilarity (e.g., differences in antecedent conditions, soil moisture, evapotranspiration rates, etc.) ; in addition, several floods were re-classified as *cyclonic* rather than *monsoonal* because of previous knowledge of the actual storm type from storm/flood investigations and reports; finally classification for uncertain events was made by the COE investigator based upon date of occurrence only, if no other information was available.

Since the USGS publishes only those peak discharges which exceed an arbitrary base[9], the collected data was thus "censored".

7.2 Estimated Data.

7.2.1 January 1993 Flood. The peak discharge for the large flood of January 1993 was not published for the Santa Cruz River at Cortaro. Since the published peak flow rates for the upstream Santa Cruz River and Rillito Creek stations were quite significant, an accurate estimate of this event for the Cortaro location was considered to be mandatory for a valid evaluation of the flooding potential. At the upstream Santa Cruz River stations - Tucson and Continental - this event was the largest *winter* flood of record, and similar in magnitude to the greatest recorded flood in the history of the Santa Cruz River, which occurred in October

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[9] The "base" varies for each station and reflects the magnitude of peak flows experienced. For the Santa Cruz River stations investigated in this study, the base flows are:
Nogales - 2000 cfs; Continental - 2000 cfs; Tucson - 1700 cfs; Cortaro - 2700 cfs. *Note: during years in which NO peak flow exceeded the base, the maximum discharge for that year was determined and published in the Water Supply Paper.*

of 1983. To estimate the peak discharge at Cortaro Road, hydrographs for the period January 17-20, 1993, were developed from the published data for the following locations: the Santa Cruz River at Tucson, Rillito Creek at La Cholla Boulevard[10], Canada del Oro; in addition local intervening runoff between Tucson and Cortaro was estimated based upon the ratio of the local intervening drainage area to the drainage contributing to the flow in the Santa Cruz River at Tucson (approximately 5.1%). A hydrologic routing model developed during previous Santa Cruz River studies by the COE was utilized to route and combine these component hydrographs in order to estimate the peak discharge at Cortaro - 40,000 cfs. This value was then added to the data base and used in the **mixed population** analysis.

7.2.2 Flows below the Base. The COE undertook an investigation of peak flows below the "base" in order to determine if the these flows, rather than only the censored discharges, could be reliably developed. The purpose of this investigation was to provide the full range of discharges for statistical analysis, since projection of the probability of rare flows is a function of low flows as well as high flows. In addition, statistical treatment of the seasonal sets of "censored" data, especially for *cyclonic* and *frontal* subsets, would involve many years of "zero" flow or "missing" record[11]. While conditional probability adjustments can be made, the COE investigator believed that actual events should be included whenever possible. This belief was founded on the concept that the full spectrum of peak discharges more accurately reflects the actual hydrometeorological conditions; moreover, this would permit statistical analysis using familiar tools with linked data storage capabilities. Basically the issue was whether it is preferable to use statistically acceptable adjustments to censored, peak-seasonal flows to account for the missing data or to make a reasonable attempt to determine the peak-seasonal flows below the base.

7.2.2.1 *Analytical Steps*. Estimates of peak discharges below the base were made in the following sequence of steps[12]:

- Collect annual daily flow data for all stations (Hydrosphere CDROM, © 1999: Reference 10.2);
- Tabulate all daily flows associated with censored peaks;
- Inspect the data to determine if/when runoff events occurred which were not documented since they were < base flow;

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[10] It should be noted here that the flood peak for this location (Rillito Creek) actually occurred on January 8, 1993, and was approximately twice the magnitude of this latter event. However, the peak discharge in the Santa Cruz River at Tucson was much smaller during the January 8 event.

[11] For the *cyclonic* and *frontal* subsets, the censored discharges, i.e. discharges greater than the base, were less than half of the total sampled years from 1940 - 1997.

[12] Note: although not initially included within the PLAN umbrella, the COE investigator included streamflow for the Nogales gage in order to more consistently interpret the results for the downstream locations, especially the Continental gage.

- Segregate any events characterized by daily flow results into appropriate seasons;
- Perform correlation analysis using the censored peaks and associated daily flows and the daily flows for which peak flows were not available (i.e., the peaks did not exceed the base). In addition to correlation between peak flows and daily flows, correlation was expanded to include peak flows and daily flows at the other Santa Cruz River stations for each season. Correlation was performed initially using the Regional Frequency Computation program[13] with input = "Raw Data" (Results are provided in Tables E1-2 through E1-4);
- Compare the "estimated" peak discharges to the "base". The peak flows have the following bounds: $Q_{1.day} \leq Q_{estimated} \leq Q_{base}$. If necessary, "estimated" peak flows based upon correlation analyses were "adjusted"[14] based upon these constraints. In addition, because smaller peaks are more sensitive to baseflow, daily flows were adjusted prior to correlation analysis to ensure that only the runoff event was portrayed. (The "Modified" results are included in Tables E1-5 through E1-7, based upon results of Regional Frequency Computation simulation.)
- Incorporate the estimated (and modified as required) peak discharges in the annual maxima data sets for each season.

7.2.3 Missing Record. Published streamflow record for the period from 1940 to 1997 was utilized within this study and augmented as discussed above. In addition, missing records were estimated using the same steps presented above whenever record for other mainstem Santa Cruz River was available. These estimated discharges were used directly (their accessibility was not a function of their magnitude, but of the operation/existence of the gage itself) without any external "adjustment", and based solely on correlation with existing information. Estimates of missing record were made to provide more consistency between stations for the seasonal analysis. This data might have merely been treated as broken record without altering the results greatly, but whenever information was available, reasonable estimates were made. (Exhibit E1-1 through Exhibit E1-3 provide a tabulation of all seasonal data for each streamgage in the Santa Cruz River from Nogales to Cortaro for the period from 1940 to 1996, including all estimate. Estimates of missing record are likewise included in Exhibit E1-4 through Exhibit E1-6, attached HEC-FFA input data files. Finally, a graphical display of annual seasonal maxima for each of the 4 streamgages is provided in Figures E1-2 through E1-4, a-d, inclusive; and for comparison, a 3-D depiction of annual seasonal maxima is also included in Figure E1-5, a-c, inclusive. Interrelationship "trends" for varying size/seasonal flood events are evidenced in this latter graphic.)

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[13] HEC software which has capability to estimate missing events based on cross-correlation between station-duration discharges and inter-station-duration discharges (Reference 10.7)

[14] In some instances the regressed peak flow associated with the recorded daily flow exceeded the "base". Since the associated peak flows in these instances were not "reported" by the USGS, it is virtually a certainty that the maximum flow rate was < the "base". Hence, the regressed flow rate was scaled down such that it was < the "base". This was accomplished using a "relative" adjustment, so that higher associated daily flow rates resulted in higher peaks, keeping the boundaries as upper and lower limits.

7.2.4 Mixed population Discharge-Frequency Analysis.

7.2.4.1 Log-Pearson Type III Distribution. Frequency histograms were developed for a range of class intervals for each location and season to evaluate the applicability of log-Pearson Type III Distribution to the data sets. In addition, seasonal data was plotted on log-probability paper to observe distribution tendencies. In some cases extremely low flows tended to bias the results and were considered to be "low outliers"[15]. The data, especially for the *monsoon* and *frontal* seasons appears to be negatively skewed; hence, skews reflecting this tendency, and generalized from station-to-station, were adopted. Even when treating the October 1983 event within the framework of **mixed population**, it appears to be a high outlier within the Tucson and Cortaro data sets. The *cyclonic* data appear positively skewed at those two locations, and a slightly positive "adopted" skew (0.1 and 0.2, respectively) was used. In every case the adopted skews were based upon a general evaluation of all the stations and the trend from station-to-station. (Please see Tables E1-8 and E1-9, which contain the annual[16] as well as the seasonal/**mixed population** computed and adopted statistics.) No single distribution is correct for annual seasonal peaks. Observation of the data, however, convinced the investigator that an interpretation based upon a log-normal (in this case log-Pearson Type III) distribution was acceptable. In some locations, e.g. coastal Southern California, recorded annual maxima are the result of a single storm/flood type - general *winter* or *frontal* events. Log-Pearson Type III distributions are used for analysis of streams in this area with confidence and yield reasonable results. In certain low-lying, small, desert-drainage areas in Arizona, California, and Nevada, annual maxima are dominated by a different single storm/flood type - local thunderstorms resulting from *monsoon* flow; again log-Pearson Type III distributions are used for analysis of these streams with confidence and are capable of providing a good fit to observed data. In larger low-lying, desert areas, annual maxima are characterized by multiple storm/flood types, although typically limited to *monsoon* and *cyclonic* flow. Hence, there is no definitive reason why the log-Pearson Type III distribution could not be utilized in the framework of this analysis. Based upon observations of the distributions, the characteristics of the plotted data, and the aforementioned reasoning, log-Pearson Type III distributions were utilized within the framework of the HEC-FFA (Flood Frequency Analysis) computer program.

[Note: there is some serial correlation between peak *monsoon* flows and peak *cyclonic* flows, which are often "nested". In most cases, the selected seasonal maximum is not dependent upon a previous seasonal maximum, but may be linked to conditions conducive to runoff due to antecedent moisture from a separate seasonal sample. In general, *frontal* events are independent of the other seasons.]

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[15] E.g. at Continental, for the *cyclonic* season flows <50 cfs, and for the *frontal* season flows < 8 cfs , were treated as "low outliers". This is consistent with our information about the gage, which has experienced problems with low flows during the systematic record.

[16] Here, annual refers to the set of data developed from the annual maximum series, with no separation due to meteorological dissimilarity.

7.2.4.2 Plotting Positions. Median plotting positions were used to display each seasonal data set. Use of median plotting positions implies that there is a 50% chance that each observed event is greater or less than the actual analytical discharge-frequency curve intercept. Selection of plotting positions does NOT affect the statistical analysis of the data, but only the appearance of the way that the computed curve fits the data. Median (often referred to as Beard) plotting positions (P) can be approximated by the following formula:

$$P = \frac{m - 0.3}{N + 0.4}, \text{ where}$$

m = integer rank, 1 = highest, and
N = number of events in the sample.

7.2.4.3 Historic Adjustments. The floods of October 1983 and January 1993 are the largest floods in the Santa Cruz River basin since, at least, the great flood of February 1891. Hence, both the *cyclonic* and *frontal* subsets utilized a historic period of 106 years in developing seasonal statistics[17]. It was not possible to categorize the *monsoon* season events in the historic context, since the peak flows within the systematic period are not of such a magnitude to have likely exceeded others within the historic period. In addition, *monsoon* peaks are the most consistent/persistent of all the seasonal flows, so it is very likely the subset available is representative of the entire historic period.

7.2.4.4 MSE Adjustments. Bulletin 17b recommends use of a regionally developed skew and provides a skew map to be used in the absence of a basin/area-wide analysis. A mean squared error[18] (MSE) of 0.302 corresponds to that map. For this **mixed population** analysis, the computed MSE for each season was determined and then "fixed" into the input data stream. In each season analyzed the computed MSE was very consistent from station-to-station, and use of this computed value rather than the suggested "regionally"-mapped value provided a much better fit to the observed data (refer to Tables E1-8 and E1-9, MSE).

7.2.4.5 Regional Skew Adjustments. Initial analyses were made to determine the range of computed skews. Based upon statistical "trends", consistency between stations, and observed data, adjustments were made to force the adopted skew to vary "smoothly" between stations for each season sampled (refer again to Tables E1-8 and E1-9, computed vs. adopted skew).

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[17] For Nogales, the December 1967 flood is the greatest *frontal* recorded event, and certainly the greatest *frontal* event since at least January 1916. The relative magnitude of this event for the period between February 1891 and January 1916 is not know. The investigator treated it using the same 106-year historic period, because results based upon the longer period were more consistent with the downstream station statistical trends and curve fit. The difference between an 86- and 106-year historic period is not too significant for this location/season - refer to Table E1-9 for a comparison of *winter* statistics.

[18] MSE is a measure of the "goodness" of fit of the computed statistics. The lower the number, the better the data fits the computed curve.

7.3 **Annual Combined Curves**. The final *seasonal* discharge-frequency curves are included in this package (please refer to Figures E1-6 through E1-8, a-d, inclusive, HP Plots) for each of the 4 gaged locations. Spreadsheets for each location were then developed to integrate the seasonal results into combined annual discharge-frequency results, and are also included (the computational spreadsheets are provided in Exhibit E1-7). The input to the spreadsheet was a series of discharges to cover a wide range of likely frequencies for each seasonal sample/population, paired with the accompanying probability of exceedance for each station and season[19]. Intermediate calculations are also included in Exhibit E1-7. The general equation for combining multiple frequency curves from *independent series* is:

$$P_c = 1 - (1-P_1)(1-P_2)...(1-P_n), \text{ where}$$

P_c is the exceedance probability of the combined annual frequency curve for a selected discharge;
$P_1, P_2, ..., P_n$ are the exceedance probabilities associated with the selected discharge from each of the separate samples or populations - 1,2, through n;
and n is the number of frequency curves (seasonal samples or populations) that are combined.

For the Santa Cruz River, based upon three separate "seasons" this equation becomes:

$$P_c = P_1 + P_2 + P_3 - P_1 P_2 - P_1 P_3 - P_2 P_3 + P_1P_2P_3, \text{ or}$$

$$P_c = P(C) + P(M) + P(F) - P(C)P(M) - P(C)P(F) - P(M)P(F) + P(C)P(M)P(F),$$

where the 3 "seasons" are represented as
C = *cyclonic*, M = *monsoon*, and F = *frontal*. Refer to spreadsheet (Exhibit E1-7) for calculations.

At each location the *monsoon* season dominates the annual curve until approximately the 20-year event (5% chance per year of exceedance). What is notably different in this analysis and the analysis performed by USGS researchers and published in 1992 as Water Supply Paper 2379[20] is the influence of the *frontal* events on the final curve. This is attributable to the inclusion of the January 1993 flood event, by far the largest winter event in history, and the inclusion of "non-censored" data which results in a discharge-frequency curve characterized by a very steep slope (high standard deviation). For the Pima County locations investigated, the *cyclonic* season overtakes the *monsoon* season for events greater than the 20-year, but the

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[19] The probability of exceedance was determined from the seasonal sample discharge-frequency curves shown in Figures E1-6 through E1-8, a-d, inclusively.

[20] Reference 10.12.

frontal season is as important or more so. Combined annual discharge-frequency curves are provided for each location and compared to the seasonal curves in Figure E1-9, a-d, inclusive. In addition, the combined annual discharge-frequency curves for each station (Nogales through Cortaro) are compared in Figure E1-10; Annual seasonal maxima and resulting seasonal discharge-frequency curves are compared for each station in Figure E1-11, a-c, inclusive. Finally, a complete table of discharge-frequency values for each station is included in Table E1-10.

7.4 **Climatic Variability versus Climate Change.** The concept of climatic variability is endorsed by the COE. Most drainage basins in the Los Angeles District are strongly affected by these episodic variations, including the ENSO (El Nino southern oscillation), which result in greater or less than normal precipitation during (sometimes) predictable seasons of the year. However, the persistence of climatic variability (periods of above or below normal precipitation and runoff) is less clearly established. In this time of concern over global warming, tropical deforestation, ozone depletion in the troposphere, and ensuing global climatic disturbances, there is reason for concern. However, it seems unlikely that the Santa Cruz River basin alone is experiencing such an understood/predictable transition. Recent runoff events in the State of Arizona have been significant, but not out of character with historic events. The adoption of the most recent data set, e.g. 1970 or so to the present is certainly tempting from the position of flood regulation (which actually ties-in to the previous COE design-flood concept, based upon an SPF, the largest flood reasonably characteristic of a drainage basin). However, that approach is dependent upon the concept of climate change, perhaps even an *abrupt* change. More than likely, if such changes exist they are transitional, and may fluctuate or vary rather than be cumulative. At the present time, the COE considers the life-span of projects to be unaffected by long-term climate change.

8 RESULTS

In general, the 100-year peak discharges developed by the COE in this study support the Pima County's regulatory discharges which have been adopted by FEMA. The combined probability discharge-frequency results indicate slightly lower 100-year peaks at Tucson and Cortaro.

Comparison Table: Floods of Record, COE/PIMA County 100-Year Discharges:

LOCATION	D.A. (mi^2)	WATER Year, POR PEAK[a]	DISCHARGE (Ft^3/s) POR PEAK[a]	OCT 83 PEAK[b]	COE 100-Year[c]	PIMA 100-Year
Santa Cruz River near Nogales	533	1974	31,000	17,100	32,000	NA
Santa Cruz River at Continental	1662	1993	32,400	45,000	45,000	45,000
Santa Cruz River at Tucson	2222	1993	37,400	52,700	55,000	60,000
Santa Cruz River at Cortaro	3503	1978 1993	23,000 40,000[d]	65,000	66,000	70,000

[a] Period-of-Record peak discharges excluding event of 10-2-83.
[b] Water Year 1984, annual maximum peak on 10-2-83 or 10-3-83 in Santa Cruz River.
[c] Mixed population analysis results - 1999 to 2000 COE study.
[d] Estimated peak discharge, COE, Mixed Population Analysis - 1999.

The results presented herein are based upon a *regional* **mixed population** approach in order to provide *consistent* discharge-frequency values, which are in agreement with observed streamflow data, and based upon reasonable application of statistical analysis. Tables of correlation coefficients, seasonal statistics, annual **mixed population** computations, and graphical depictions of the results are provided as referenced within this report.

9 CONCLUSIONS

It is interesting to note that the **mixed population** analysis presented herein has resulted in 100-year peak discharges for the Santa Cruz River stations from Nogales to Cortaro which are approximately equivalent to the greatest recorded discharge in the period of record (1891 to present), which is slightly in excess of 100-years (106 years). Analysis of annual maximum series *without* seasonal consideration results in recurrence interval estimates for the greatest recorded discharge which are >200-years upstream, and >500-years downstream. (For comparison purposes, Table E1-10 includes a complementary table presenting "expected" probability values based upon statistical analysis of annual maximum series using Bulletin 17b Guidelines.)

Some other comparisons:

- 50-year event - in general, the 50-year **mixed population** peak discharge is approximately equal to the 2nd largest recorded event in the period-of-record; by comparison, the "expected" probability for this event interpreted from the annual maximum series ranges from approximately 1% (100-year) at Continental and Cortaro to about 0.65% (150-year) at Tucson;
- Events ≤20-year are nearly equivalent;
- An SPF was computed by the COE investigator for the Santa Cruz River for a study conducted during the period 1977-1978. This synthetic, design-flood event was based on an observed storm event - an extremely large, dissipating tropical cyclone which occurred in September, 1939. This storm contained several large embedded cells, the most notable of which produced upwards of 7 inches of precipitation during a 72-hour period over an areal expanse of approximately 5,000 sq.mi. in the vicinity of Kingman-Truxton-Wikieup, Arizona. The synthetic peak discharges associated with this transposed event (assuming that the soils were relatively saturated due to antecedent rainfall) were similar in magnitude to the 200-year peak flow rates developed from the **mixed population** analysis documented in this report. In fact, the SPF peak discharges are (or would be[21]) slightly greater. It is "typical" in Arizona, especially for large drainage basins, that the SPF has an approximate return interval between 200- and 500-years; i.e. 0.5% chance per year ≤ Pr(Q ≥ SPF) ≤ 0.2% chance per year. Hence, the discharges associated with the more rare events, such as the 200-year are not obviously out-of-line. A comparison of SPF to 200-year discharges follows.

[21] Recall that the SPF model developed during the 1977-1978 period contained channel/floodplain data based upon older mapping, which resulted in significant attenuation between Continental and Tucson (please refer back to Section 21.1.4.1, 1977-1978 STUDY). Were the "existing conditions" routing model developed in this study used, the peak SPF discharges at Tucson and Cortaro would be increased significantly.

Comparison: SPF to 200-year Discharges:

Location	Drainage Area (sq.mi.)	SPF[a]	200-Year
		Discharges in ft^3/s	
SANTA CRUZ RIVER: MIXED POPULATION DISCHARGE-FREQUENCY ANALYSIS			
Continental	1662	84,600	72,000
Tucson	2222	57,400[b]	75,000
Cortaro	3503	89,000[b]	95,000

[a] Based upon the India September 1939 storm, Kingman-Truxton-Wikieup centering, transposed to the Santa Cruz River.

[b] The SPF discharge for this location is reduced due to upstream attenuation based upon outdated mapping. The existing conditions routing model would produce significantly less attenuation, but has not been applied to the SPF.

It is quite unlikely that 2 recorded events in the recent history of observations of peak discharge in the Santa Cruz River basin within Pima County would have equaled or exceeded the 100-year discharge (refer to the preceding discussion of the 50-year event). In addition, these 2 recently recorded flood events (October 1983 and January 1993) stem from considerably disparate meteorological causes:

- the first, a dissipating tropical cyclone, and
- the second, a general winter storm associated with a frontal pattern set up during the December to January period, which affected most of Arizona.

Because the flood-causing agents (i.e. storm type) vary considerably within the basin, and result in markedly different seasonal samples/populations, it is preferable to classify runoff events according to the storm type. Hence, the **mixed population** analysis provides a window to focus more closely on the runoff potential associated with each type of storm/flood event. As such, the **mixed population** analysis may provide more information about the runoff potential from rare events.

Finally, it is typical of smaller, high- and low-desert basins to have a high standard deviation associated with statistical analysis of observed flows, due to the sporadic nature of the events which drive the flood history (i.e., thunderstorm-type floods). For these types of drainage areas, the ratio of the estimated 100-year peak discharge to the estimated 500-year peak discharge, can be relatively small (≤ 0.4), especially if the discharges are reported based upon "expected" probability.

For larger, upland drainage areas, which are affected by both local and general type storms (such as the Santa Cruz River basin), it is more typical for the same ratio to be higher (≥ 0.5), and increasing with increasing drainage basin size (≥ 0.6). For the Santa Cruz River basin the ratio of the 100-year peak discharge to the 500-year peak discharge for the Pima County gages is between 0.45 and 0.40 (increasing with increasing drainage area size, which is consistent with general tendencies for other basins). However, these ratios are smaller than are usually associated with basins this large in areal extent. In order to develop more confidence in the magnitude of the remote flood events, especially the 500-year flood, the following course of action is recommended by the COE investigator:

- Develop *cyclonic* and *frontal/winter* estimates of the SPF for the Santa Cruz River in Pima County based upon the September 1939 storm (former), and an event such as the January 1993, January 1916 storm (latter);
- Use these estimated discharges to modify the associated seasonal discharge-frequency relationships for rare probabilities (between 0.5% and 0.2% annual recurrence events, i.e. the 200-year to 500-year flood events).

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10.12 United States Geological Survey, Water-Supply Paper 2379, "Climatic Variability and Flood Frequency of the Santa Cruz River, Pima County, Arizona" by Robert H. Webb and Julio L.

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10.14 U. S. Geological Survey, Water-Data Report AZ-93-1, "Water Resources Data, Arizona, Water Year 1993", by C.F. Smith, P.D. Rigas, L.K. Ham, N.R.Duet, and D.W. Anning

10.15 Oral/written Communication with David Goldman, The Hydrologic Engineering Center, 1998-1999

10.16 Oral/written Communication with Doug Lantz (TTISG), Joaquin Solis (City of Tucson), Chris Smith and John Parker (USGS, Tucson), Zbig Osmolski, Fazle Karim et al (Pima County FCD), and other Task Force Members

TABLES

TABLE E1-1. Santa Cruz River Flood Routing Comparison:
1998 Channel vs. 1976 Channel
N-year (Index) Floods
Continental Road to Pinal County Line

SANTA CRUZ RIVER Location	HEC-RAS Station	"500-YR" INDEX FLOOD			
		1998 Channel[1]		1976 Channel[2]	
		Peak Flow (cfs)	Time of Peak (hrs.)	Peak Flow (cfs)	Time of Peak (hrs.)
Continental Rd.	1*	63088	26.75	63088	26.75
Near Nogales Hwy	814**	62383	42.58	62223	42.75
Near Sahuarita Rd.	794***	61296	44.75	60893	45.08
Near San Xavier Rd.	41.05	60895	48.00	60501	48.25
Near Valencia Rd.	38.82	60799	48.33	60429	48.42
Congress St.	32.61	60439	49.08	59936	49.17
Camino Del Cerro	25.8	60156	49.92	58856	51.00
Near Ina Rd.	21.64	59899	50.83	57860	52.75
Cortaro Rd.	20.2	59877	51.00	57061	53.08
Near Avra Valley Rd.	15.81	59797	51.83	56940	54.25
Near Sanders Rd.	9.47	59491	54.33	56525	56.83
Trico Marana Rd.	6.24	58333	56.67	54818	5942
Trico Rd.	4.24	57954	58.08	54142	60.92
Pinal County Line	0.01	56933	61.00	53515	64.00

NOTES:
* 58.85 miles u/s of Pinal County Line
** 54.23 miles u/s of Pinal County Line
*** 51.85 miles u/s of Pinal County Line

[1] Source - C:\Projects\SANTCRUZ\1998h&h\Indxflds\FldRtng99\1998-5M.dat,05Jun99\nna\11:38 AM
[2] Source - C:\Projects\SANTCRUZ\1998h&h\Indxflds\FldRtng76\1976-500.dat,05Jun99\nna\11:38 AM

TABLE E1-1. (Continued) Santa Cruz River Flood Routing Comparison:
1998 Channel vs. 1976 Channel
N-year (Index) Floods
Continental Road to Pinal County Line

SANTA CRUZ RIVER Location	HEC-RAS Station	200-YR FLOOD			
		1998 Channel[1]		1976 Channel[2]	
		Peak Flow (cfs)	Time of Peak (hrs.)	Peak Flow (cfs)	Time of Peak (hrs.)
Continental Rd.	1	44602	41.75	44602	41.75
Near Nogales Hwy	814	43923	43.58	43811	43.58
Near Sahuarita Rd.	794	42759	45.50	41833	45.83
Near San Xavier Rd.	41.05	41736	49.08	41056	49.25
Near Valencia Rd.	38.82	41536	49.33	40899	49.50
Congress St.	32.61	41255	50.08	40562	50.25
Camino Del Cerro	25.8	41032	50.83	39210	52.33
Near Ina Rd.	21.64	40635	51.58	37999	54.58
Cortaro Rd.	20.2	40601	51.83	37175	54.92
Near Avra Valley Rd.	15.81	40459	52.83	37046	56.33
Near Sanders Rd.	9.47	40121	55.25	36697	58.75
Trico Marana Rd.	6.24	38129	57.67	35173	61.33
Trico Rd.	4.24	37596	59.42	34467	63.00
Pinal County Line	0.01	36355	62.75	339100	66.50

NOTES:
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[2] Source - C:\Projects\SANTCRUZ\1998h&h\Indxflds\FldRtng76\1976-200.dat,10Jun99\nna\10:21 AM

TABLE E1-1. (Continued) Santa Cruz River Flood Routing Comparison:
1998 Channel vs. 1976 Channel
N-year (Index) Floods
Continental Road to Pinal County Line

SANTA CRUZ RIVER Location	HEC-RAS Station	100-YR FLOOD			
		1998 Channel[1]		1976 Channel[2]	
		Peak Flow (cfs)	Time of Peak (hrs.)	Peak Flow (cfs)	Time of Peak (hrs.)
Continental Rd.	1	35800	39.75	35800	39.75
Near Nogales Hwy	814	32990	42.25	32734	43.92
Near Sahuarita Rd.	794	31554	45.75	30959	46.00
Near San Xavier Rd.	41.05	30317	50.00	30142	49.92
Near Valencia Rd.	38.82	30174	50.25	29987	50.17
Congress St.	32.61	29790	51.00	29783	50.92
Camino Del Cerro	25.8	29469	52.00	28796	53.00
Near Ina Rd.	21.64	29077	52.75	27864	55.25
Cortaro Rd.	20.2	28998	53.00	27195	55.67
Near Avra Valley Rd.	15.81	28778	54.00	27088	57.08
Near Sanders Rd.	9.47	28420	56.25	26878	59.25
Trico Marana Rd.	6.24	26769	58.75	25702	61.67
Trico Rd.	4.24	26466	60.50	25306	63.33
Pinal County Line	0.01	25647	64.25	24881	67.00

NOTES:
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[2] Source - C:\Projects\SANTCRUZ\1998h&h\Indxflds\FldRtng76\1976-50.dat,10:22 AM\nna\10:22 AM

TABLE E1-1. (Continued) Santa Cruz River Flood Routing Comparison:
1998 Channel vs. 1976 Channel
N-year (Index) Floods
Continental Road to Pinal County Line

SANTA CRUZ RIVER Location	HEC-RAS Station	50-YR FLOOD			
		1998 Channel[1]		1976 Channel[2]	
		Peak Flow (cfs)	Time of Peak (hrs.)	Peak Flow (cfs)	Time of Peak (hrs.)
Continental Rd.	1	26700	39.75	26700	39.75
Near Nogales Hwy	814	23662	42.50	23650	42.17
Near Sahuarita Rd.	794	21604	46.25	21028	46.17
Near San Xavier Rd.	41.05	20519	51.25	20317	50.75
Near Valencia Rd.	38.82	20433	51.50	20268	51.00
Congress St.	32.61	20139	52.50	20149	51.92
Camino Del Cerro	25.8	19939	53.25	19479	54.33
Near Ina Rd.	21.64	19694	54.00	19021	56.42
Cortaro Rd.	20.2	19631	54.25	18539	56.83
Near Avra Valley Rd.	15.81	19497	55.25	18477	58.17
Near Sanders Rd.	9.47	19271	57.50	18380	60.08
Trico Marana Rd.	6.24	18696	59.75	17904	62.00
Trico Rd.	4.24	18412	61.50	17638	63.50
Pinal County Line	0.01	17684	65.75	17254	67.75

NOTES:
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TABLE E1-1. (Continued) Santa Cruz River Flood Routing Comparison:
1998 Channel vs. 1976 Channel
N-year (Index) Floods
Continental Road to Pinal County Line

SANTA CRUZ RIVER Location	HEC-RAS Station	20-YR FLOOD			
		1998 Channel[1]		1976 Channel[2]	
		Peak Flow (cfs)	Time of Peak (hrs.)	Peak Flow (cfs)	Time of Peak (hrs.)
Continental Rd.	1	18000	39.75	18000	39.75
Near Nogales Hwy	814	15122	42.50	14529	42.25
Near Sahuarita Rd.	794	12714	46.25	12385	46.00
Near San Xavier Rd.	41.05	11947	52.25	11773	51.17
Near Valencia Rd.	38.82	11872	52.50	11744	51.42
Congress St.	32.61	11639	53.75	11675	52.50
Camino Del Cerro	25.8	11488	54.75	11332	54.58
Near Ina Rd.	21.64	11329	55.75	11114	56.58
Cortaro Rd.	20.2	11287	56.00	10806	57.08
Near Avra Valley Rd.	15.81	11196	57.00	10783	58.08
Near Sanders Rd.	9.47	11031	59.50	10730	59.92
Trico Marana Rd.	6.24	10746	61.50	10447	61.75
Trico Rd.	4.24	10692	62.25	10312	62.83
Pinal County Line	0.01	10298	67.25	10053	67.67

NOTES:
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TABLE E1-1. (Continued) Santa Cruz River Flood Routing Comparison:
1998 Channel vs. 1976 Channel
N-year (Index) Floods
Continental Road to Pinal County Line

SANTA CRUZ RIVER Location	HEC-RAS Station	10-YR FLOOD			
		1998 Channel[1]		1976 Channel[2]	
		Peak Flow (cfs)	Time of Peak (hrs.)	Peak Flow (cfs)	Time of Peak (hrs.)
Continental Rd.	1	12700	39.75	12700	39.75
Near Nogales Hwy	814	10106	41.50	10281	41.58
Near Sahuarita Rd.	794	7879	45.75	7615	45.58
Near San Xavier Rd.	41.05	7365	50.50	7311	50.17
Near Valencia Rd.	38.82	7309	50.75	7294	50.50
Congress St.	32.61	7163	52.25	7251	51.75
Camino Del Cerro	25.8	7053	53.50	7074	53.75
Near Ina Rd.	21.64	6930	54.75	6983	55.50
Cortaro Rd.	20.2	6897	55.00	6684	56.08
Near Avra Valley Rd.	15.81	6841	56.00	6662	57.25
Near Sanders Rd.	9.47	6754	58.25	6626	59.17
Trico Marana Rd.	6.24	6538	60.25	6432	61.17
Trico Rd.	4.24	6505	61.00	6349	61.92
Pinal County Line	0.01	6103	66.75	6034	66.58

NOTES:
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TABLE E1-1. (Continued) Santa Cruz River Flood Routing Comparison:
1998 Channel vs. 1976 Channel
N-year (Index) Floods
Continental Road to Pinal County Line

SANTA CRUZ RIVER Location	HEC-RAS Station	5-YR FLOOD			
		1998 Channel[1]		1976 Channel[2]	
		Peak Flow (cfs)	Time of Peak (hrs.)	Peak Flow (cfs)	Time of Peak (hrs.)
Continental Rd.	1	8381	39.75	8381	39.75
Near Nogales Hwy	814	6731	41.25	6687	41.50
Near Sahuarita Rd.	794	4460	46.25	4510	45.00
Near San Xavier Rd.	41.05	4132	52.00	4252	50.17
Near Valencia Rd.	38.82	4103	52.50	4236	50.58
Congress St.	32.61	4021	54.25	4200	52.08
Camino Del Cerro	25.8	3963	55.75	4095	54.17
Near Ina Rd.	21.64	3882	57.25	4007	56.42
Cortaro Rd.	20.2	3865	57.75	3754	57.17
Near Avra Valley Rd.	15.81	3840	59.00	3741	58.50
Near Sanders Rd.	9.47	3807	61.50	3722	60.75
Trico Marana Rd.	6.24	3662	63.75	3611	62.83
Trico Rd.	4.24	3645	64.50	3575	63.58
Pinal County Line	0.01	3430	70.75	3426	69.17

NOTES:
[1] Source - C:\Projects\SANTCRUZ\1998h&h\Indxflds\FldRtng99\1998-5M.dat,05Jun99\nna\11:38 AM
[2] Source - C:\Projects\SANTCRUZ\1998h&h\Indxflds\FldRtng76\1976-5.dat,11:05 AM\nna\11:05 AM

TABLE E1-1. (Continued) Santa Cruz River Flood Routing Comparison:
1998 Channel vs. 1976 Channel
N-year (Index) Floods
Continental Road to Pinal County Line

SANTA CRUZ RIVER Location	HEC-RAS Station	2-YR FLOOD			
		1998 Channel[1]		1976 Channel[2]	
		Peak Flow (cfs)	Time of Peak (hrs.)	Peak Flow (cfs)	Time of Peak (hrs.)
Continental Rd.	1	3800	39.75	3800	39.75
Near Nogales Hwy	814	2800	41.50	2878	41.50
Near Sahuarita Rd.	794	1543	46.50	1480	44.08
Near San Xavier Rd.	41.05	1510	50.75	1471	48.42
Near Valencia Rd.	38.82	1493	51.50	1460	49.25
Congress St.	32.61	1451	54.00	1423	52.33
Camino Del Cerro	25.8	1419	56.50	1336	55.83
Near Ina Rd.	21.64	1340	59.50	1271	59.83
Cortaro Rd.	20.2	1328	60.25	1176	60.92
Near Avra Valley Rd.	15.81	1315	62.50	1171	63.08
Near Sanders Rd.	9.47	1296	65.75	1161	66.83
Trico Marana Rd.	6.24	1250	68.00	1139	69.08
Trico Rd.	4.24	1237	69.00	1133	69.92
Pinal County Line	0.01	1136	76.25	1082	75.83

NOTES:
[1] Source - C:\Projects\SANTCRUZ\1998h&h\Indxflds\FldRtng99\1998-5M.dat,05Jun99\nna\11:38 AM
[2] Source - C:\Projects\SANTCRUZ\1998h&h\Indxflds\FldRtng76\1976-2.dat,11:16 AM\nna\11:16 AM

TABLE E1-2. CORRELATION COEFFICIENTS, PEAK AND DAILY FLOWS RAW DATA , 1940 - 1997

CYCLONIC SEASON

RAW DATA: Peak vs 1-Day Discharges				
1-DAY	**PEAK**			
	Nogales	Continental	Tucson	Cortaro
Nogales	0.977	0.629	0.529	0.482
Continental	0.603	0.983	0.827	0.764
Tucson	0.546	0.882	0.979	0.903
Cortaro	0.499	0.853	0.959	0.988

RAW DATA: 1-Day vs 1-Day Discharges				
1-DAY	**1-DAY**			
	Nogales	Continental	Tucson	Cortaro
Nogales	1.000	0.637	0.562	0.502
Continental	0.637	1.000	0.841	0.786
Tucson	0.562	0.841	1.000	0.917
Cortaro	0.502	0.786	0.917	1.000

RAW DATA: Peak vs Peak Discharges				
PEAK	**PEAK**			
	Nogales	Continental	Tucson	Cortaro
Nogales	1.000	0.603	0.530	0.464
Continental	0.603	1.000	0.882	0.864
Tucson	0.530	0.882	1.000	0.974
Cortaro	0.464	0.864	0.974	1.000

TABLE E1-3. CORRELATION COEFFICIENTS, PEAK AND DAILY FLOWS RAW DATA , 1940 - 1997

MONSOON SEASON

RAW DATA: Peak vs 1-Day Discharges				
1-DAY	**PEAK**			
	Nogales	Continental	Tucson	Cortaro
Nogales	0.815	0.536	0.477	0.390
Continental	0.370	0.856	0.699	0.679
Tucson	0.396	0.719	0.857	0.775
Cortaro	0.132	0.474	0.585	0.748

RAW DATA: 1-Day vs 1-Day Discharges				
1-DAY	**1-DAY**			
	Nogales	Continental	Tucson	Cortaro
Nogales	1.000	0.552	0.457	0.414
Continental	0.552	1.000	0.788	0.709
Tucson	0.457	0.788	1.000	0.830
Cortaro	0.414	0.709	0.830	1.000

RAW DATA: Peak vs Peak Discharges				
PEAK	**PEAK**			
	Nogales	Continental	Tucson	Cortaro
Nogales	1.000	0.462	0.405	0.138
Continental	0.462	1.000	0.631	0.446
Tucson	0.405	0.631	1.000	0.768
Cortaro	0.138	0.446	0.768	1.000

TABLE E1-4. CORRELATION COEFFICIENTS, PEAK AND DAILY FLOWS RAW DATA , 1940 - 1997

WINTER SEASON

RAW DATA: Peak vs 1-Day Discharges				
1-DAY	**PEAK**			
	Nogales	Continental	Tucson	Cortaro
Nogales	0.995	0.876	0.757	0.683
Continental	0.876	0.997	0.830	0.784
Tucson	0.812	0.888	0.986	0.812
Cortaro	0.818	0.898	0.904	0.975

RAW DATA: 1-Day vs 1-Day Discharges				
1-DAY	**1-DAY**			
	Nogales	Continental	Tucson	Cortaro
Nogales	1.000	0.870	0.759	0.674
Continental	0.870	1.000	0.835	0.780
Tucson	0.759	0.835	1.000	0.806
Cortaro	0.674	0.780	0.806	1.000

RAW DATA: Peak vs Peak Discharges				
PEAK	**PEAK**			
	Nogales	Continental	Tucson	Cortaro
Nogales	1.000	0.883	0.812	0.803
Continental	0.883	1.000	0.884	0.94
Tucson	0.812	0.884	1.000	0.905
Cortaro	0.803	0.894	0.905	1.000

TABLE E1-5. CORRELATION COEFFICIENTS, PEAK AND DAILY FLOWS MODIFIED DATA , 1940 - 1997

CYCLONIC SEASON

MODIFIED DATA: Peak vs 1-Day Discharges				
1-DAY	**PEAK**			
	Nogales	Continental	Tucson	Cortaro
Nogales	0.979	0.613	0.527	0.473
Continental	0.588	0.982	0.834	0.765
Tucson	0.520	0.850	0.981	0.929
Cortaro	0.435	0.737	0.926	0.961

MODIFIED DATA: 1-Day vs 1-Day Discharges				
1-DAY	**1-DAY**			
	Nogales	Continental	Tucson	Cortaro
Nogales	1.000	0.624	0.552	0.492
Continental	0.624	1.000	0.837	0.772
Tucson	0.552	0.837	1.000	0.940
Cortaro	0.492	0.772	0.940	1.000

MODIFIED DATA: Peak vs Peak Discharges				
PEAK	**PEAK**			
	Nogales	Continental	Tucson	Cortaro
Nogales	1.000	0.584	0.502	0.419
Continental	0.584	1.000	0.837	0.772
Tucson	0.502	0.837	1.000	0.940
Cortaro	0.419	0.772	0.940	1.000

TABLE E1-6. CORRELATION COEFFICIENTS, PEAK AND DAILY FLOWS MODIFIED DATA , 1940 - 1997

MONSOON SEASON

MODIFIED DATA: Peak vs 1-Day Discharges				
1-DAY	**PEAK**			
	Nogales	Continental	Tucson	Cortaro
Nogales	0.814	0.421	0.442	0.418
Continental	0.350	0.824	0.651	0.624
Tucson	0.390	0.585	0.845	0.789
Cortaro	0.412	0.405	0.667	0.824

MODIFIED DATA: 1-Day vs 1-Day Discharges				
1-DAY	**1-DAY**			
	Nogales	Continental	Tucson	Cortaro
Nogales	1.000	0.449	0.408	0.413
Continental	0.449	1.000	0.609	0.524
Tucson	0.408	0.609	1.000	0.853
Cortaro	0.413	0.524	0.853	1.000

MODIFIED DATA: Peak vs Peak Discharges				
PEAK	**PEAK**			
	Nogales	Continental	Tucson	Cortaro
Nogales	1.000	0.438	0.383	0.380
Continental	0.438	1.000	0.597	0.487
Tucson	0.383	0.597	1.000	0.730
Cortaro	0.380	0.487	0.730	1.000

TABLE E1-7. CORRELATION COEFFICIENTS, PEAK AND DAILY FLOWS MODIFIED DATA , 1940 - 1997

WINTER SEASON

MODIFIED DATA: Peak vs 1-Day Discharges				
1-DAY	**PEAK**			
	Nogales	Continental	Tucson	Cortaro
Nogales	0.995	0.876	0.757	0.683
Continental	0.876	0.997	0.830	0.784
Tucson	0.812	0.888	0.986	0.812
Cortaro	0.818	0.898	0.904	0.975

MODIFIED DATA: 1-Day vs 1-Day Discharges				
1-DAY	**1-DAY**			
	Nogales	Continental	Tucson	Cortaro
Nogales	1.000	0.870	0.759	0.674
Continental	0.870	1.000	0.835	0.780
Tucson	0.759	0.835	1.000	0.806
Cortaro	0.674	0.780	0.806	1.000

MODIFIED DATA: Peak vs Peak Discharges				
PEAK	**PEAK**			
	Nogales	Continental	Tucson	Cortaro
Nogales	1.000	0.883	0.812	0.803
Continental	0.883	1.000	0.884	0.94
Tucson	0.812	0.884	1.000	0.905
Cortaro	0.803	0.894	0.905	1.000

TABLE E1-8. STATISTICS - ANNUAL/MONSOON SEASONS

Location	Santa Cruz River: Annual Statistics (1940 -1997, H=1892)						
	Log Mean	Standard Deviation	Computed Skew	Adopted Skew[a]	MSE	Record Length, N	Historical Record, H
Nogales (**NogAnn-H.dat**)	3.5991	0.3318	0.0917	0.0000	.055	58	106[b]
Continental (**CntAnn-H.dat**)	3.5552	0.4072	0.0793	0.0000	.054	58	106[c]
Tucson (**TucAnn-H.dat**)	3.7106	0.3499	-0.1859	-0.1000	.059	58	106[c]
Cortaro (**CrtAnn-H.dat**)	3.8866	0.3151	-0.2348	-0.1000	.061	58	106[c]

NOTES: ***(File names in parentheses)***
[a] Regional skew set = 0.0 except Continental (0.10). MSE set = computed for all stations.
[b] Oct 1977 > 1892
[c] Oct 1983, Jan 1993 > 1892

Location	Santa Cruz River: Monsoon Season Statistics (1940 -1997)						
	Log Mean	Standard Deviation	Computed Skew	Adopted Skew[a]	MSE	Record Length, N	Historical Record, H[b]
Nogales (**NogMnsn1.dat**)	3.5024	0.3112	0.0417	-0.1000	.092	58	58
Continental (**CntMnsn1.dat**)	3.4352	0.3518	-0.3853	-0.1000	.115	58	58
Tucson (**TucMnsn1.dat**)	3.5787	0.3248	-0.3855	-0.2000	.115	58	58
Cortaro (**CrtMnsn1.dat**)	3.7116	0.3234	-0.3604	-0.2000	.113	58	58

NOTES: ***(File names in parentheses)***
[a] Regional skew set = 0.0 except Continental (0.10). MSE set = computed for all stations.
[b] No historic adjustment for systematic/estimated monsoon season data.

TABLE E1-9. STATISTICS - CYCLONIC/WINTER SEASONS

Location	Santa Cruz River: Cyclonic Season Statistics (1940 -1997, H=1892)						
	Log Mean	Standard Deviation	Computed Skew	Adopted Skew*	MSE	Record Length, N	Historical Record, H
Nogales (**NogCycH.dat**)	2.6099	0.7753	-0.6115	-0.3000	.083	58	106[a]
Continental (**CntCycH1.dat**)	2.6840	0.8280	-0.1633	-0.2000	.058	58	106[b]
Tucson (**TucCycH1.dat**)	3.1393	0.5935	-0.2622	0.1000	.063	58	106[c]
Cortaro (**CortCycH.dat**)	3.3089	0.5285	-0.0572	0.2000	.053	58	106[d]

NOTES: ***(File names in parentheses)***
Low outlier "adjustment" made for better data fit, more consistency at Continental - Q < 50 cfs
* Adopted skew adjusted to provide best fit and consistent results. MSE set = computed for all stations.
[a] Oct 1977 > 1892
[b, c, d] Oct 1983 > 1892

Location	Santa Cruz River: Winter Season Statistics (1940 -1997, H=1892)						
	Log Mean	Standard Deviation	Computed Skew	Adopted Skew	MSE	Record Length, N	Historical Record, H
Nogales (**NgFrntH1.dat**)	1.8379	1.1719	0.1631	-0.1000	.073	58	82[a]
(**NgFrntH3.dat**)	**1.8338**	**1.1645**	**0.1608**	**-0.2000**	**.058**	**58**	**106[aa]**
Continental* (**CntFrntH.dat**)	1.6506	1.2559	0.3972	-0.2000	.080	58	106[b]
Tucson (**TucFrntH.dat**)	1.7794	1.2747	-0.1505	-0.3000	.057	58	106[b]
Cortaro (**CrtFrntH.dat**)	2.6077	1.0307	-0.3880	-0.4000	.069	58	106[b]

NOTES: ***(File names in parentheses)***
Low outlier "adjustment" made to Nogales (Q<6cfs) and Continental (Q<5cfs) for better fit and consistency.
Regional skew varied to provide better fit and consistency. MSE set = computed for all stations.
* Low flow data adjusted. Low flows may NOT be measured. See note above.
[a] Dec 1967 > 1916
[aa] Dec 1967 > 1892, recommended for use in mixed population analysis due to consistency with d/s stations.
[b] Jan 1993 > 1892

TABLE E1-10. DISCHARGE-FREQUENCY ANALYSIS RESULTS COMBINED POPULATIONS vs ANNUAL MAXIMUM SERIES

RECOMMENDED

LOCATION	Drainage Area (sq.mi.)	500-YR	200-YR	100-YR	50-YR	20-YR	10-YR	5-YR	2-YR
		Discharges in ft^3/s							
SANTA CRUZ RIVER: MIXED POPULATION DISCHARGE-FREQUENCY ANALYSIS COMBINED RESULTS									
Nogales	533	84,000	49,000	32,000	22,000	14,000	9900	7000	3800
Continental	1662	115,000	72,000	45,000	30,000	17,000	12,000	7300	3500
Tucson	2222	120,000	75,000	55,000	35,000	20,000	14,000	9500	4900
Cortaro	3503	150,000	95,000	66,000	45,000	28,000	19,000	13,000	7000

FOR COMPARISON PURPOSES ONLY

LOCATION	Drainage Area (sq.mi.)	500-YR	200-YR	100-YR	50-YR	20-YR	10-YR	5-YR	2-YR
		Discharges in ft^3/s							
SANTA CRUZ RIVER: ANNUAL MAXIMUM SERIES DISCHARGE-FREQUENCY ANALYSIS "Expected" Probability Values									
Nogales	533	40,000	31,000	26,000	20,000	14,000	10,000	7500	4000
Continental	1662	60,000	45,000	35,000	26,000	17,500	12,000	8000	3600
Tucson	2222	52,000	41,000	33,500	25,000	19,500	14,500	10,200	5200
Cortaro	3503	62,000	50,000	42,000	35,000	26,000	20,000	14,200	7800

FIGURES

C:\Projects\SANTCRUZ\Report\All_Graphics_.wpd
NNA/28 September 2000

SANTA CRUZ RIVER MIXED POPULATION STUDY

Hydraulic Screening: Impacts of Channel Geometry on Attenuation of Peak Discharge

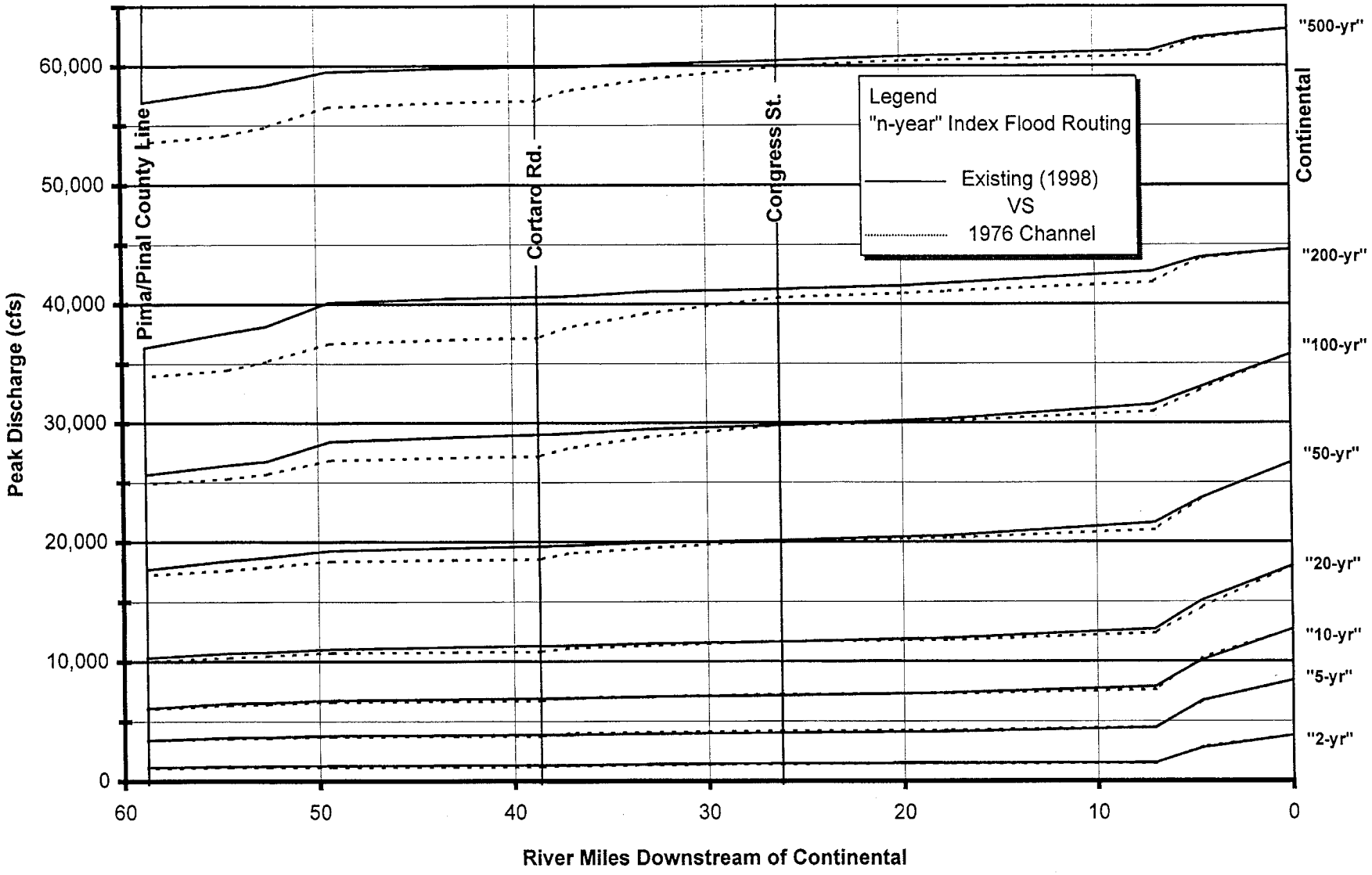


FIGURE E1-1

MIXED POPULATION ANALYSIS

Annual Seasonal Maxima - Cyclonic

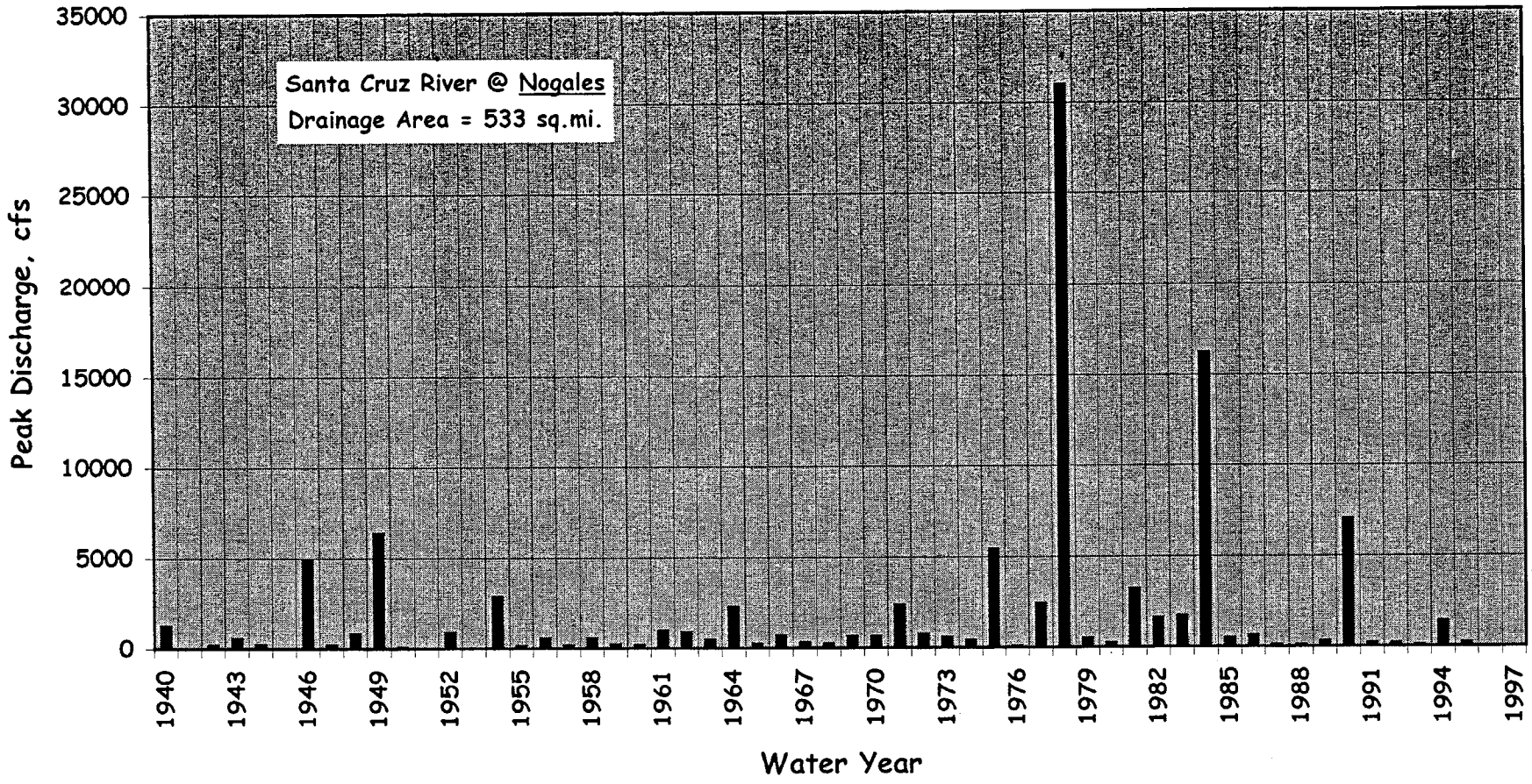


FIGURE E1-2a

MIXED POPULATION ANALYSIS

Annual Seasonal Maxima - Cyclonic

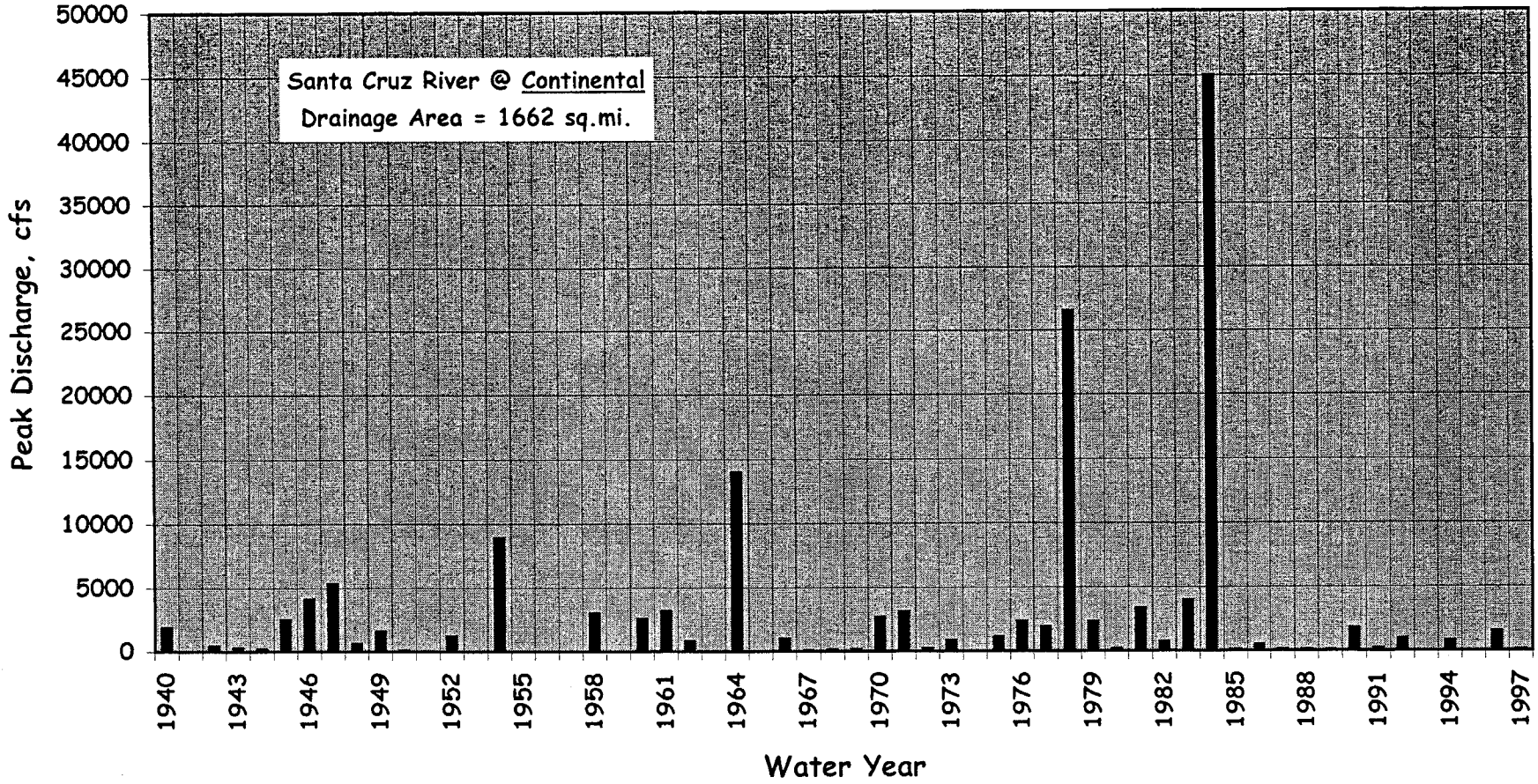


FIGURE E1-2b

MIXED POPULATION ANALYSIS

Annual Seasonal Maxima - Cyclonic

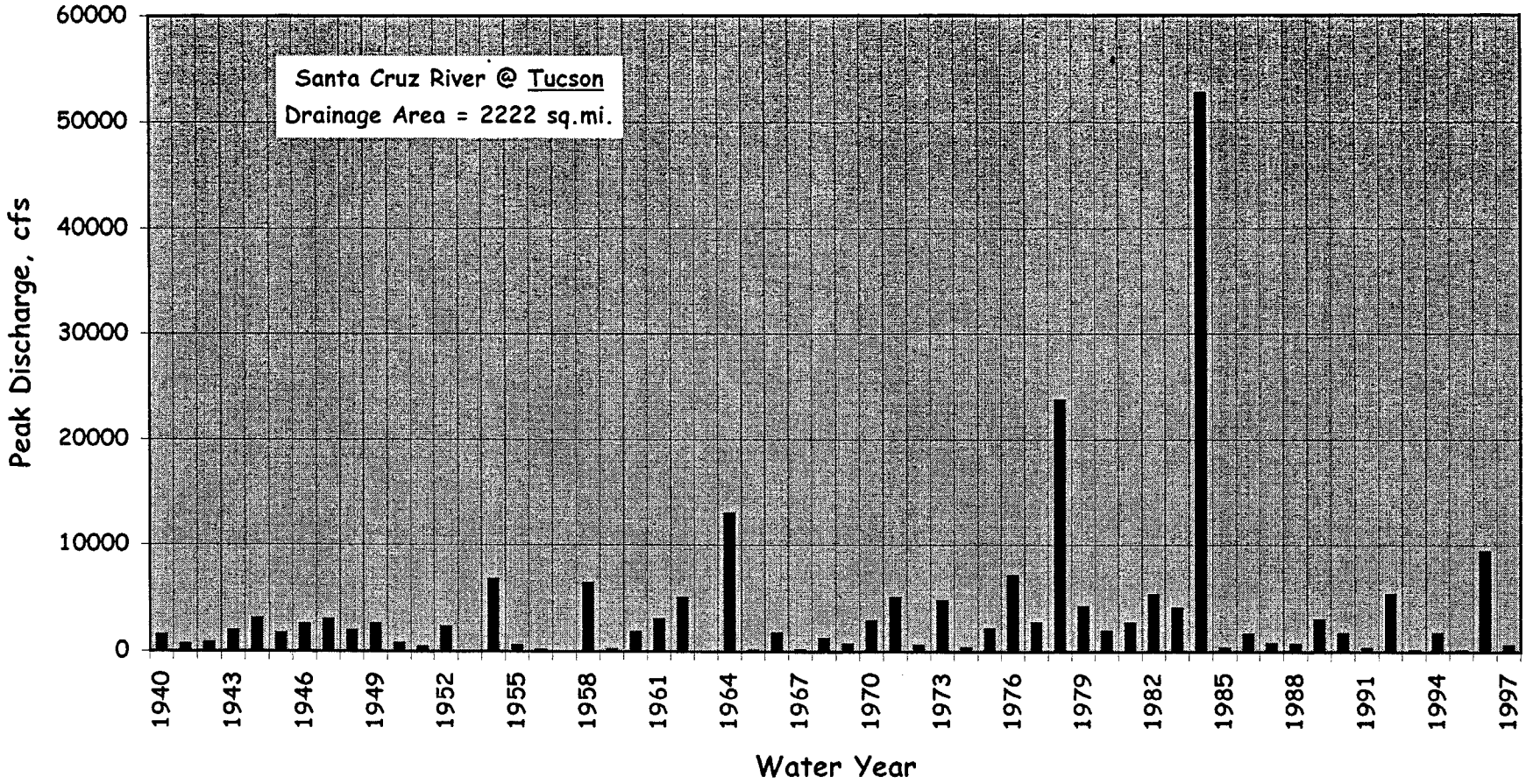


FIGURE E1-2c

MIXED POPULATION ANALYSIS

Annual Seasonal Maxima - Cyclonic

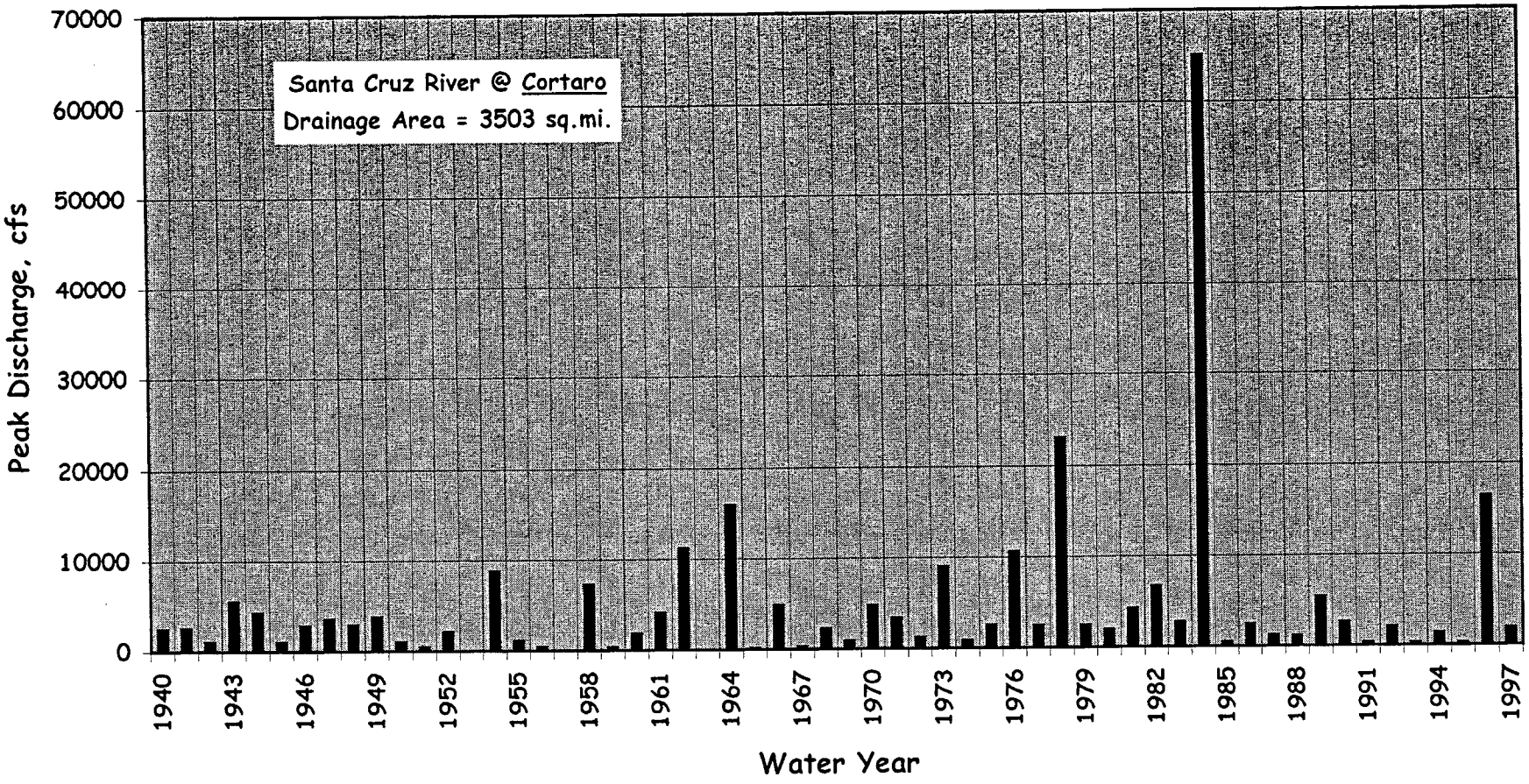


FIGURE E1-2d

MIXED POPULATION ANALYSIS

Annual Seasonal Maxima - Monsoonal

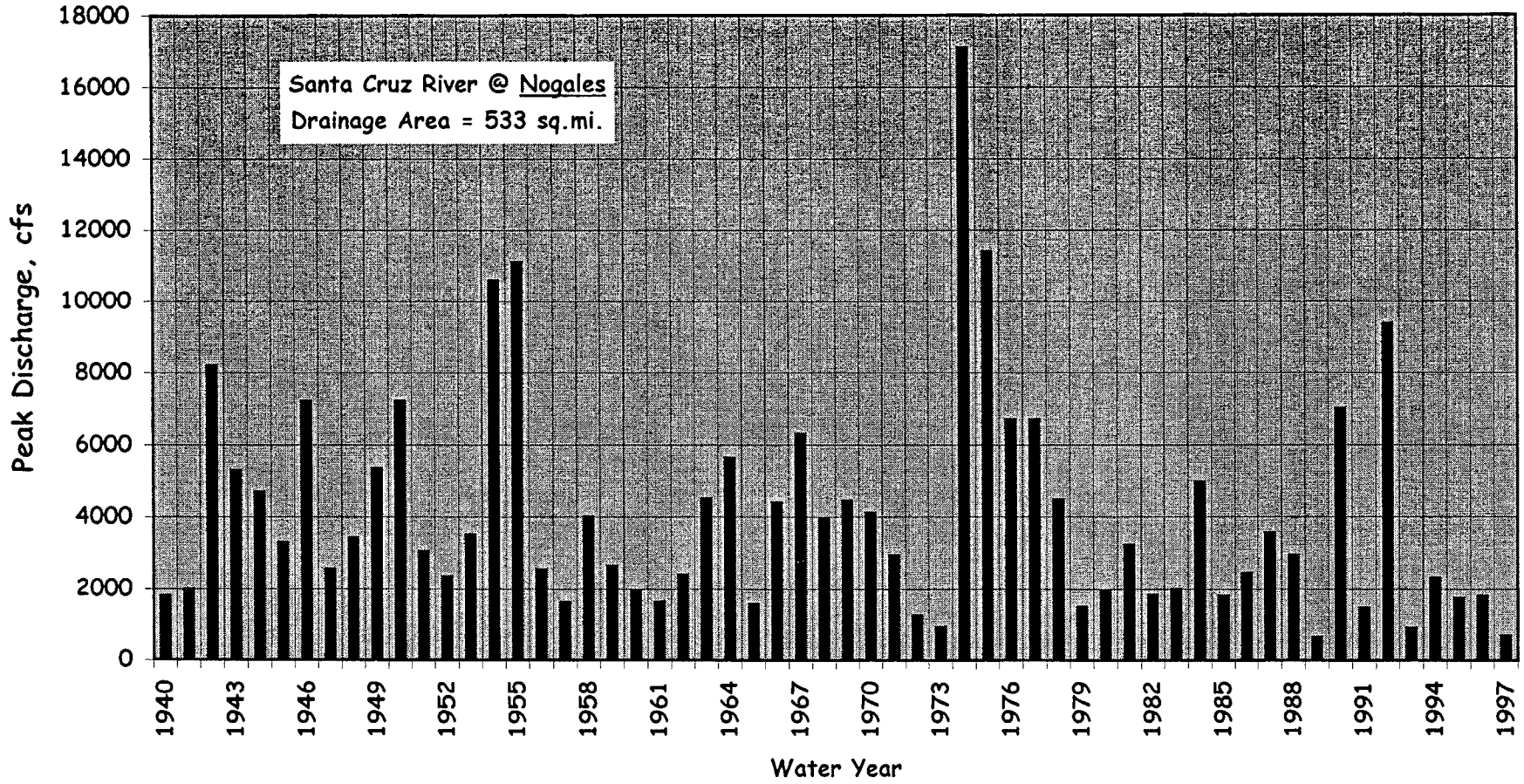


FIGURE E1-3a

MIXED POPULATION ANALYSIS

Annual Seasonal Maxima - Monsoonal

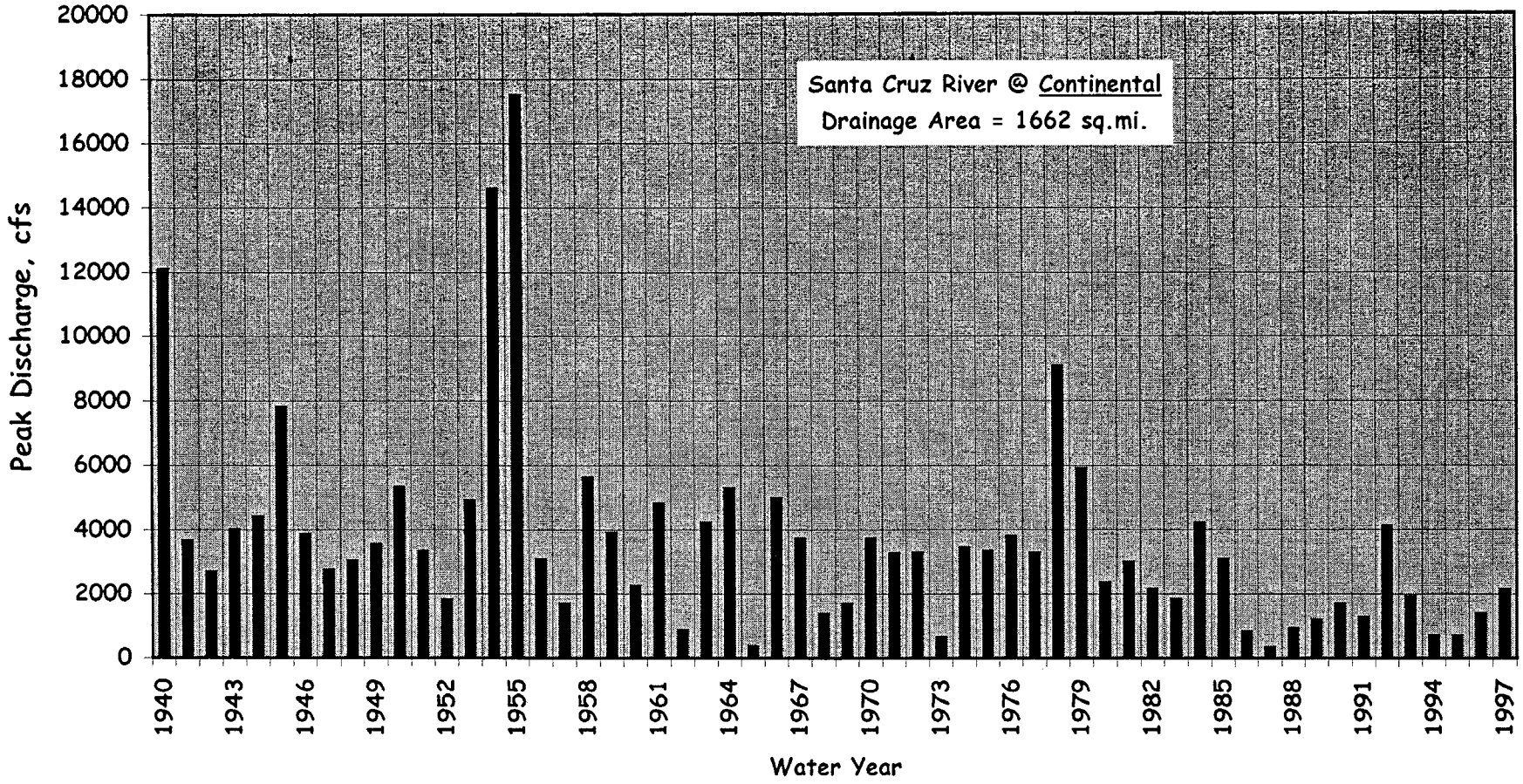


FIGURE E1-3b

MIXED POPULATION ANALYSIS

Annual Seasonal Maxima - Monsoonal

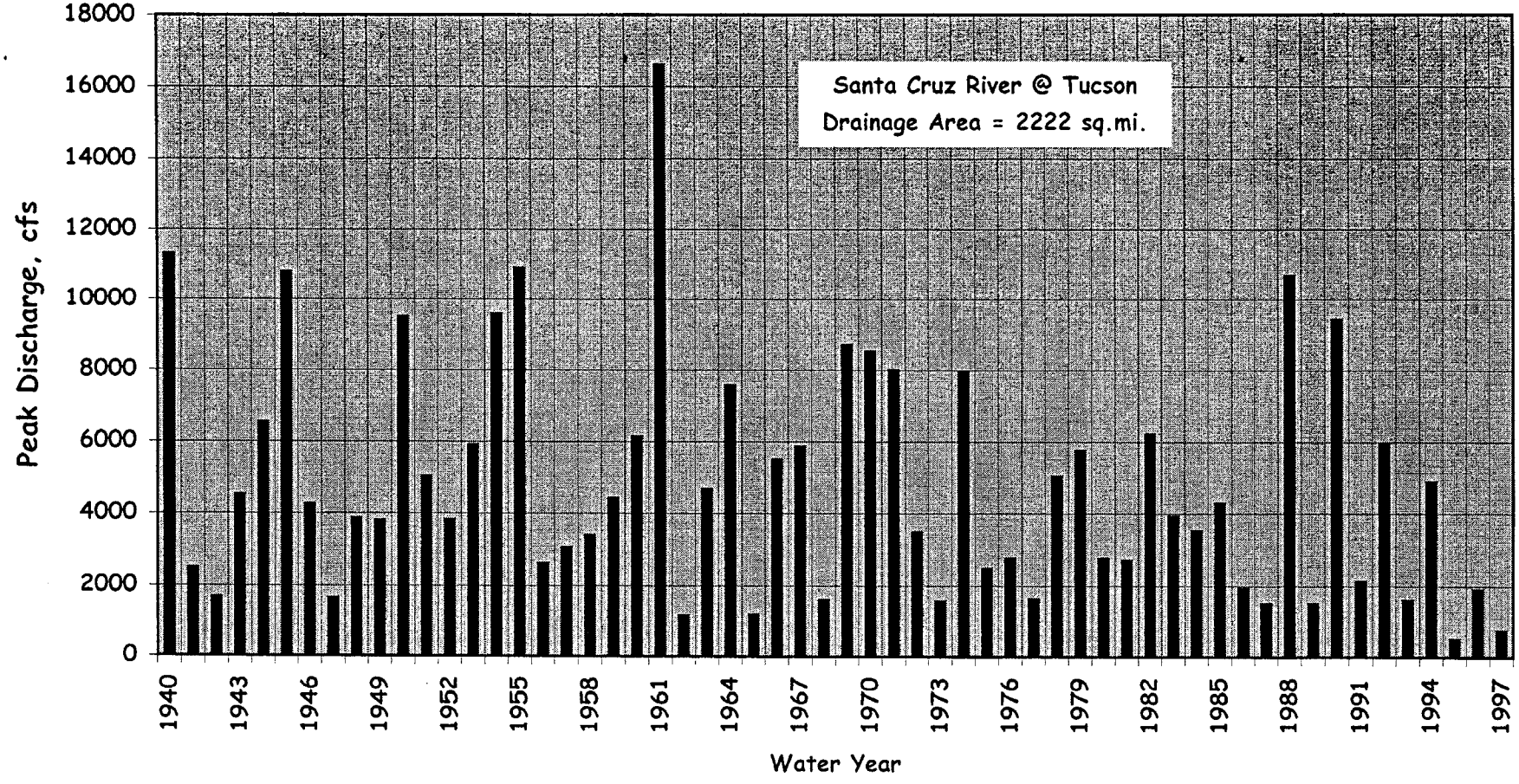


FIGURE E1-3c

MIXED POPULATION ANALYSIS

Annual Seasonal Maxima - Monsoonal

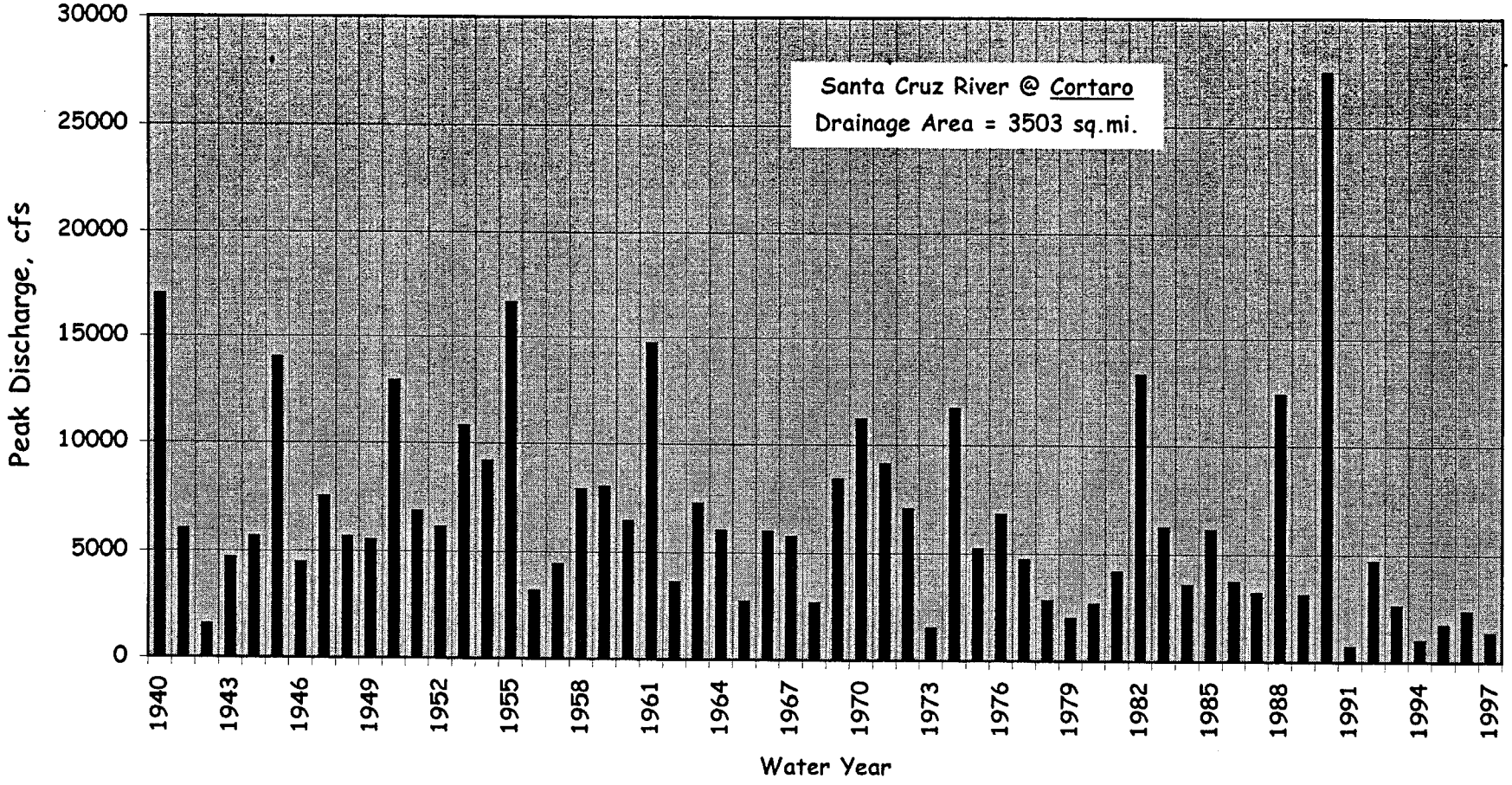


FIGURE E1-3d

MIXED POPULATION ANALYSIS

Annual Seasonal Maxima - Frontal

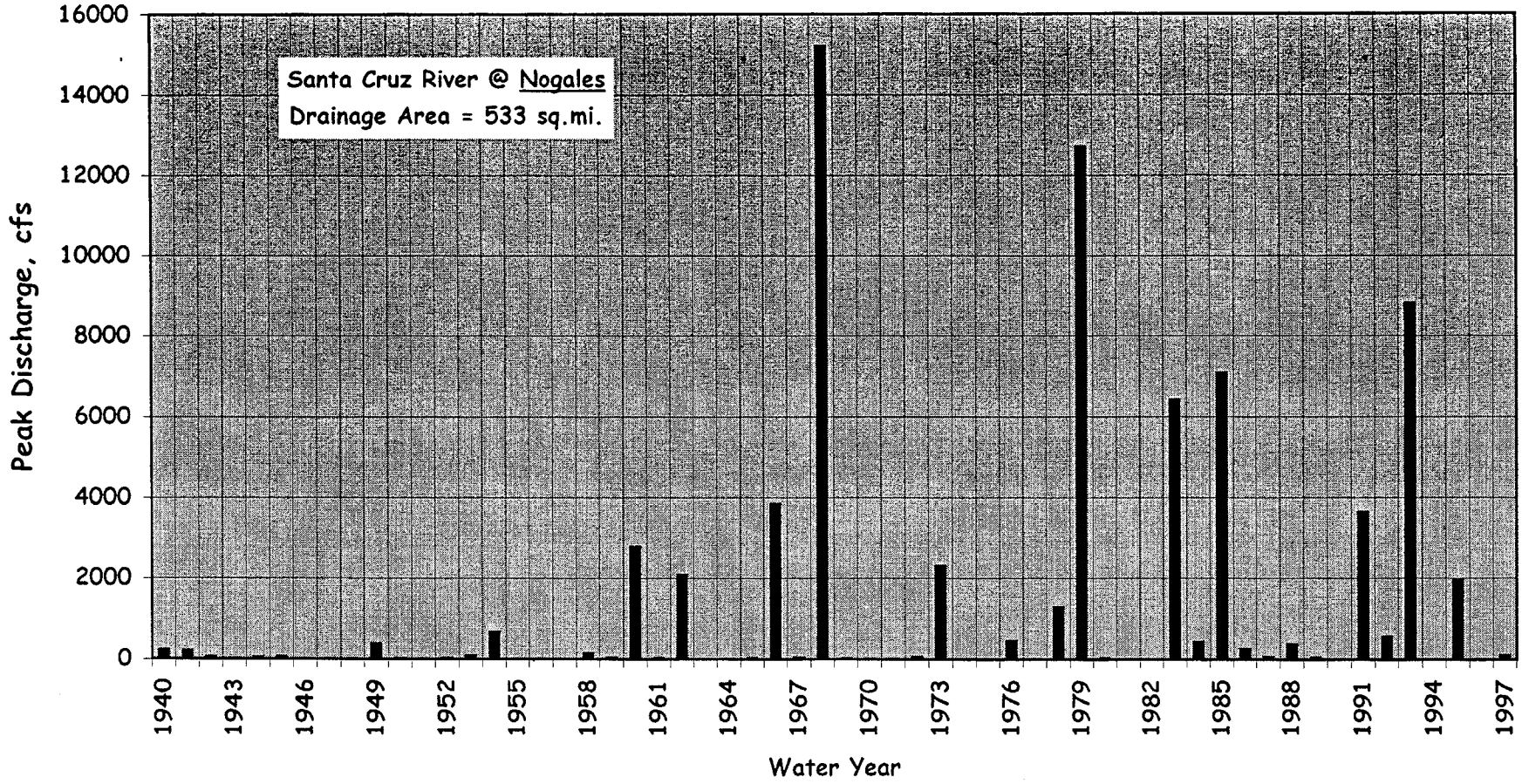


FIGURE E1-4a

MIXED POPULATION ANALYSIS

Annual Seasonal Maxima - Frontal

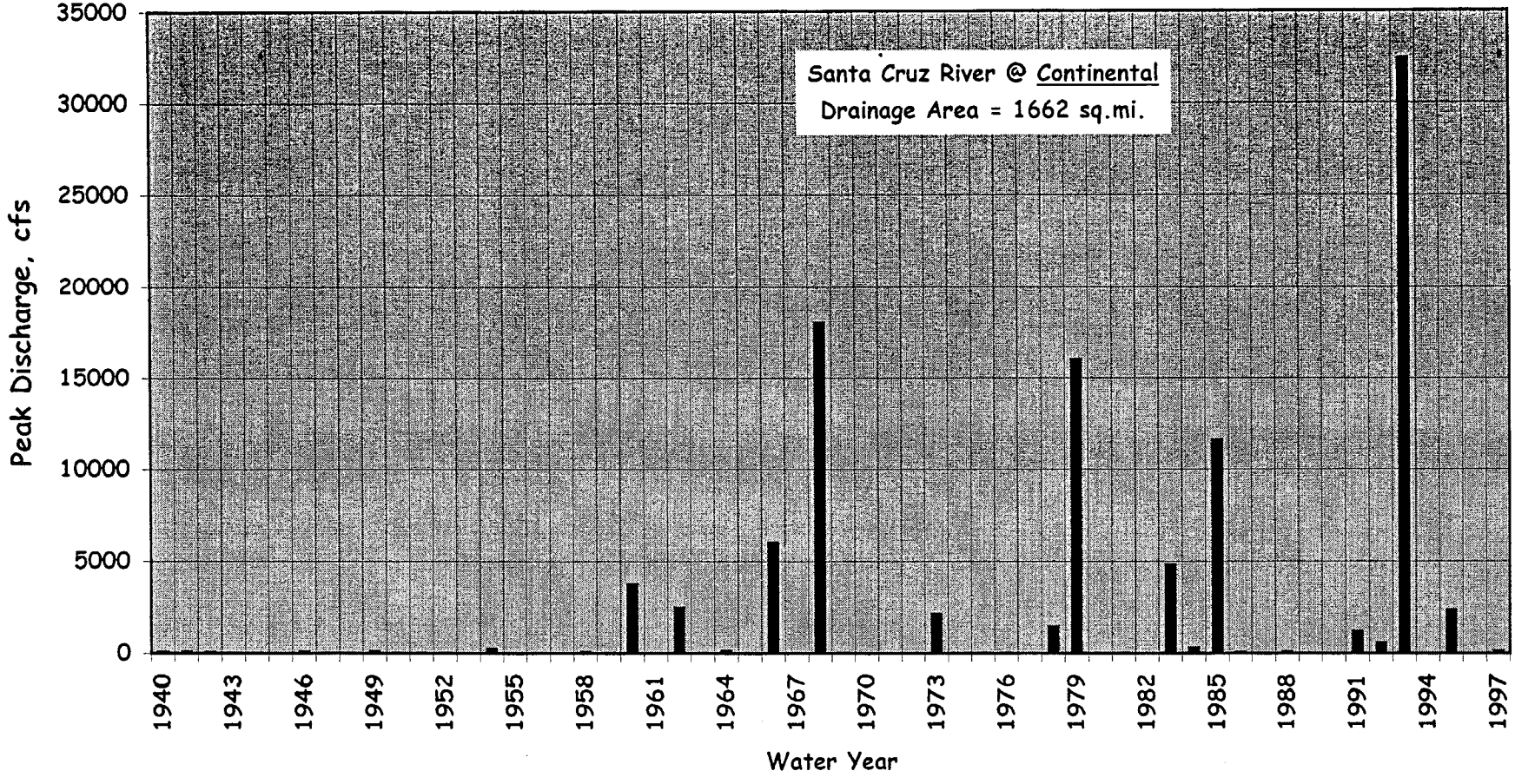


FIGURE E1-4b

MIXED POPULATION ANALYSIS

Annual Seasonal Maxima - Frontal

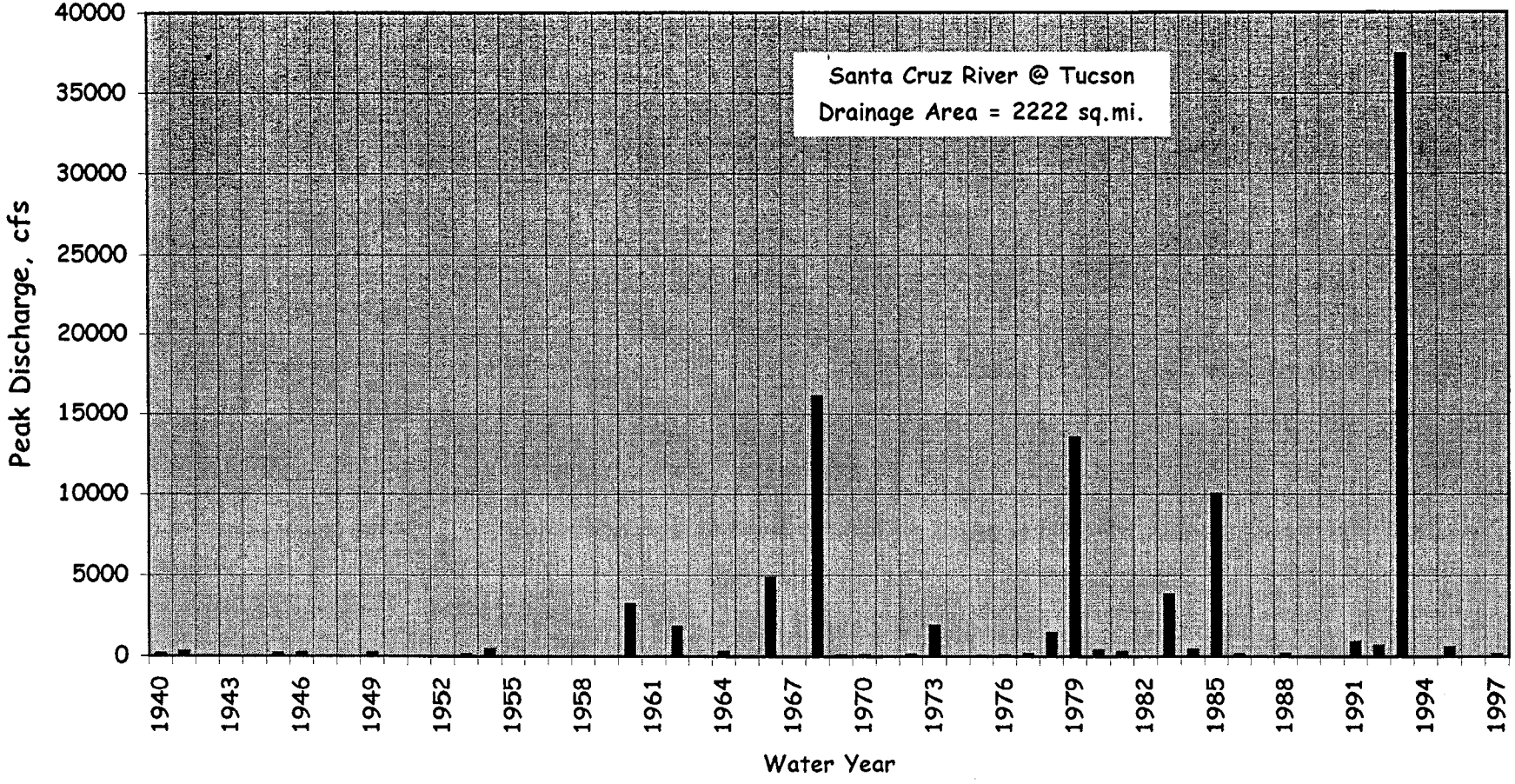


FIGURE E1-4c

MIXED POPULATION ANALYSIS

Annual Seasonal Maxima - Frontal

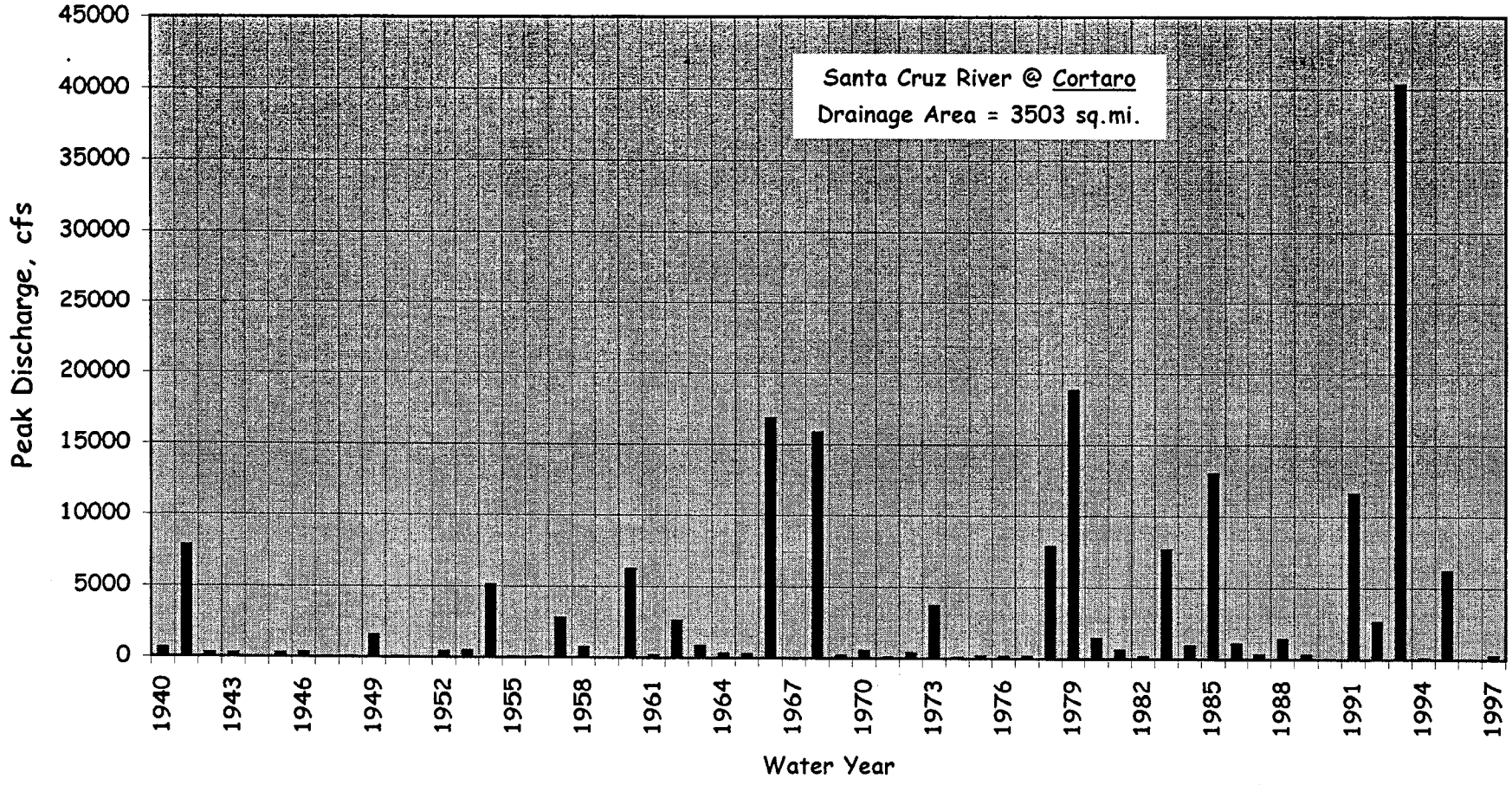


FIGURE E1-4d

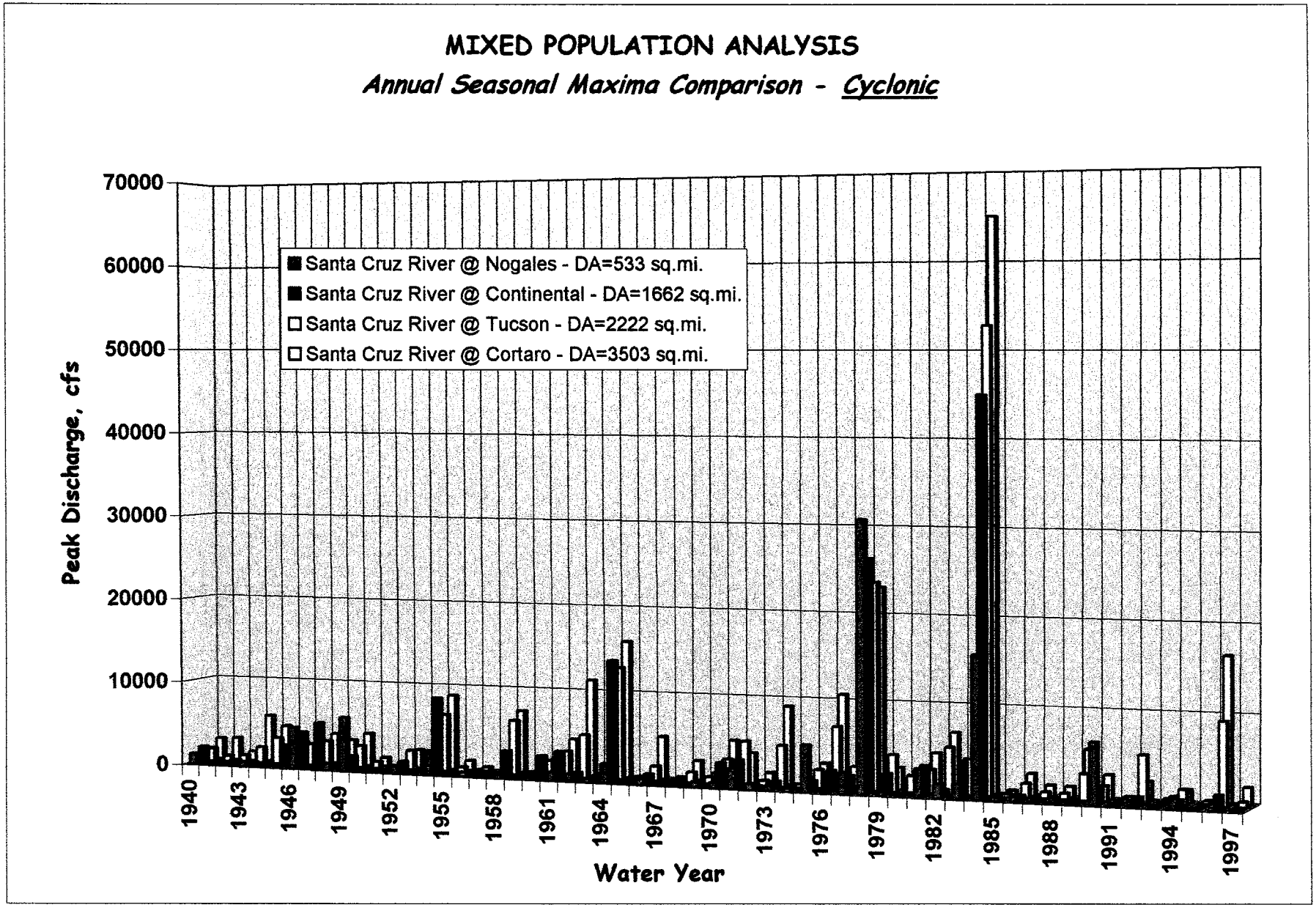

MIXED POPULATION ANALYSIS
Annual Seasonal Maxima Comparison - Cyclonic
Santa Cruz River @ Nogales - DA=533 sq.mi.
Santa Cruz River @ Continental - DA=1662 sq.mi.
Santa Cruz River @ Tucson - DA=2222 sq.mi.
Santa Cruz River @ Cortaro - DA=3503 sq.mi.
Peak Discharge, cfs
70000
60000
50000
40000
30000
20000
10000
0
1940
1943
1946
1949
1952
1955
1958
1961
1964
1967
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
Water Year

FIGURE E1-5a

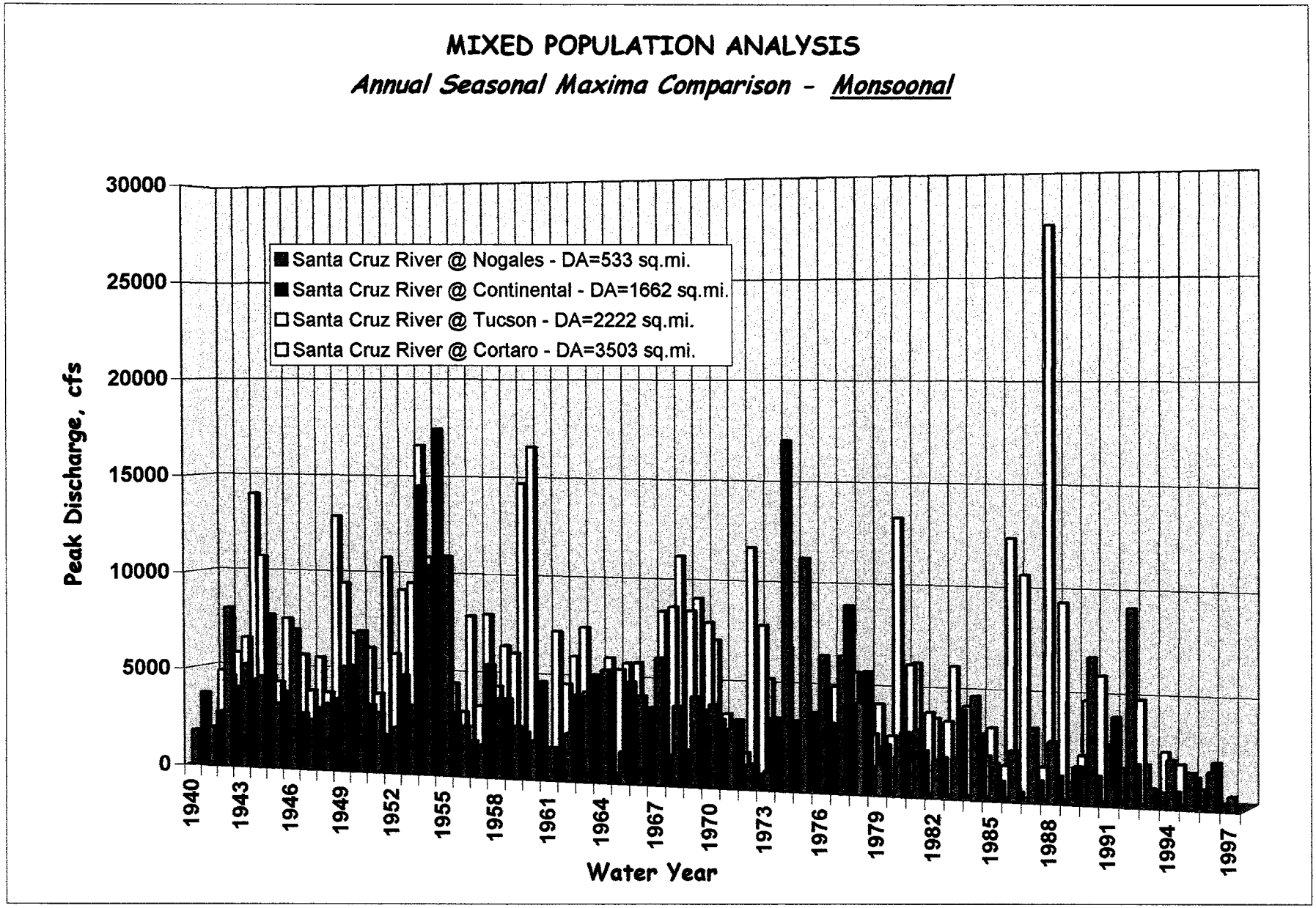

MIXED POPULATION ANALYSIS
Annual Seasonal Maxima Comparison - Monsoonal
Santa Cruz River @ Nogales - DA=533 sq.mi.
Santa Cruz River @ Continental - DA=1662 sq.mi.
Santa Cruz River @ Tucson - DA=2222 sq.mi.
Santa Cruz River @ Cortaro - DA=3503 sq.mi.
Peak Discharge, cfs
30000
25000
20000
15000
10000
5000
0
1940
1943
1946
1949
1952
1955
1958
1961
1964
1967
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
Water Year

FIGURE E1-5b

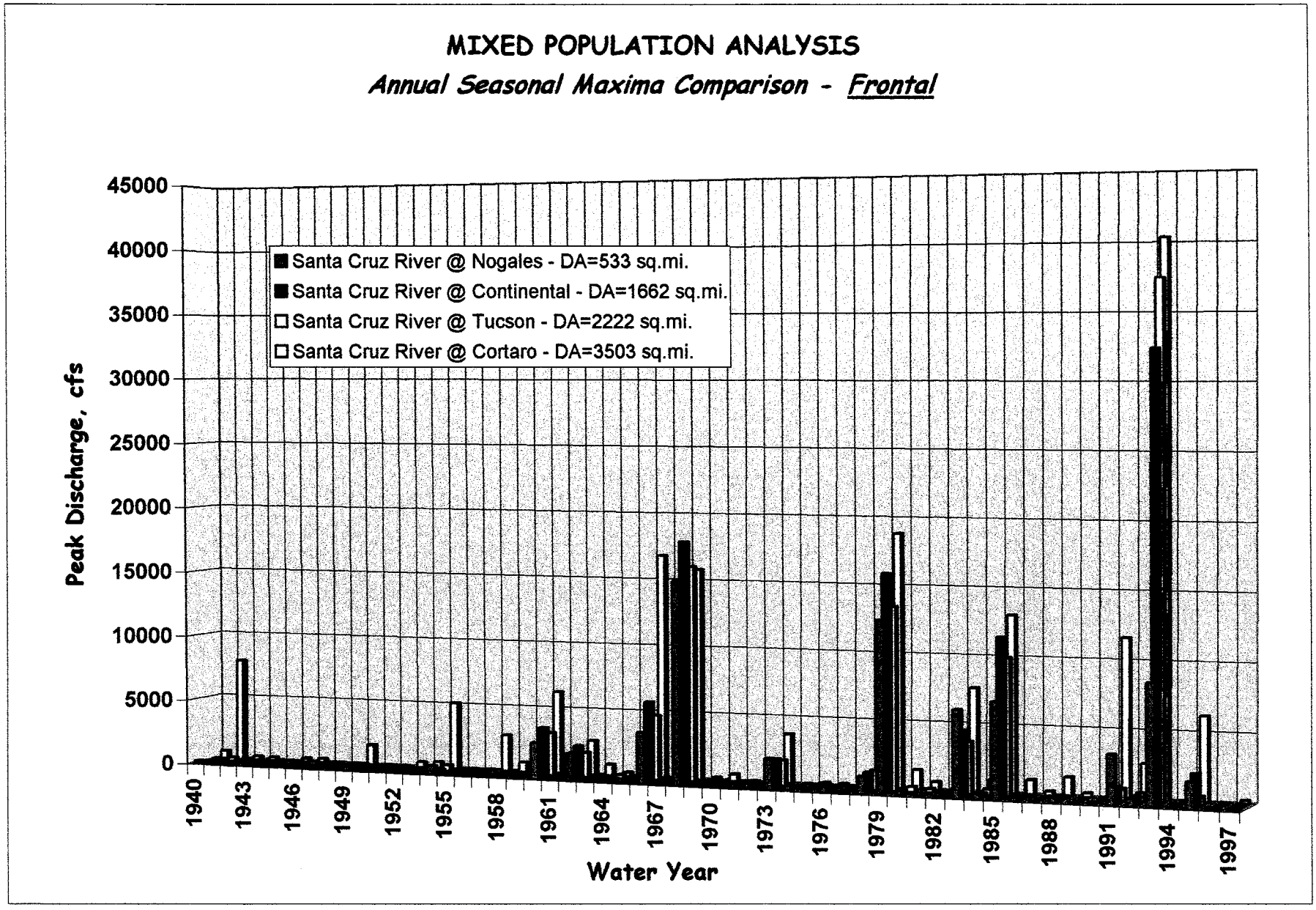
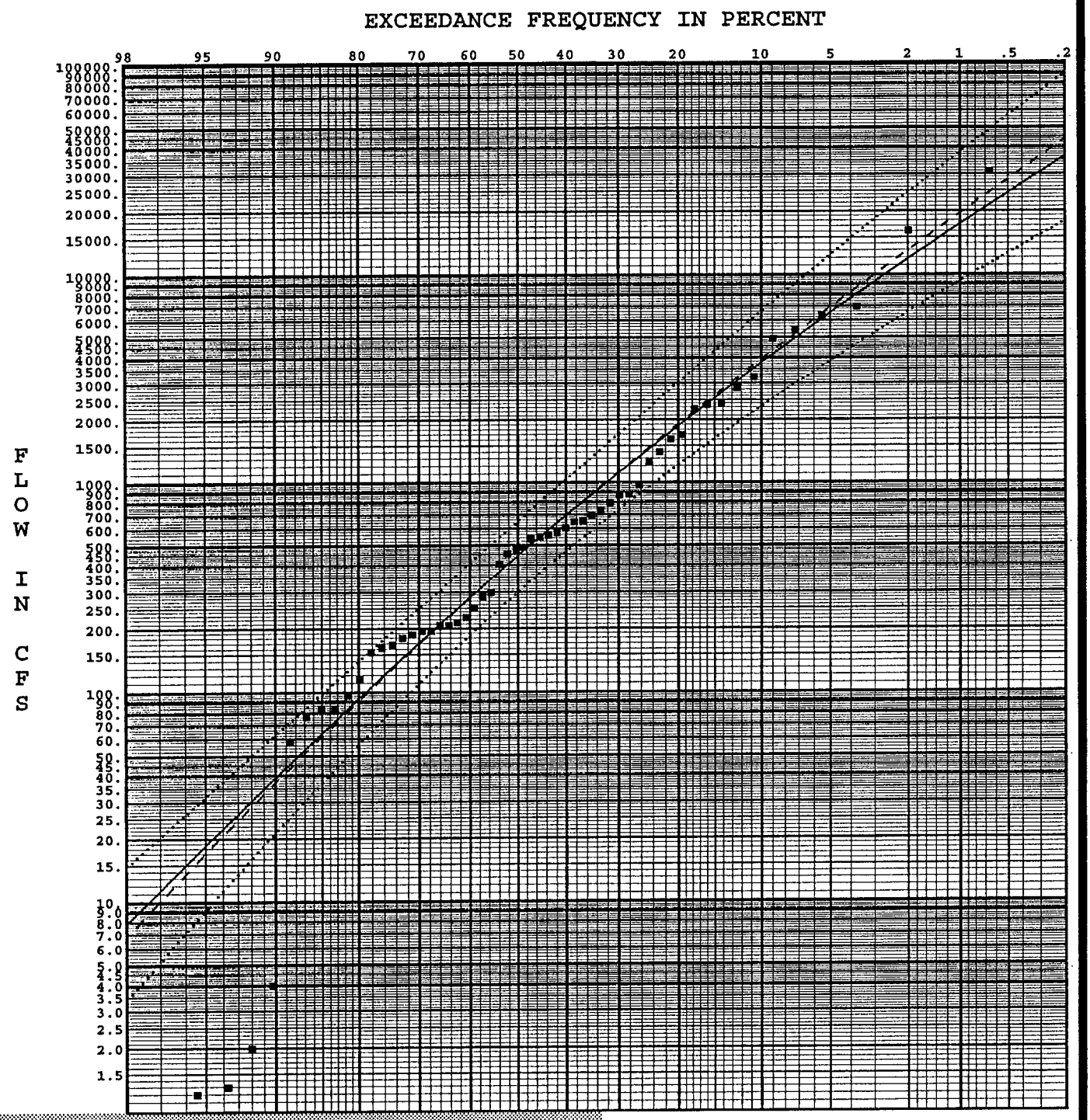

MIXED POPULATION ANALYSIS
Annual Seasonal Maxima Comparison - Frontal
Santa Cruz River @ Nogales - DA=533 sq.mi.
Santa Cruz River @ Continental - DA=1662 sq.mi.
Santa Cruz River @ Tucson - DA=2222 sq.mi.
Santa Cruz River @ Cortaro - DA=3503 sq.mi.
Peak Discharge, cfs
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
1940
1943
1946
1949
1952
1955
1958
1961
1964
1967
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
Water Year

FIGURE E1-5c



—— FLOW Frequency (without Exp. Prob.)

- - - FLOW Frequency (with Exp. Prob.)

■ Median Plotting Positions

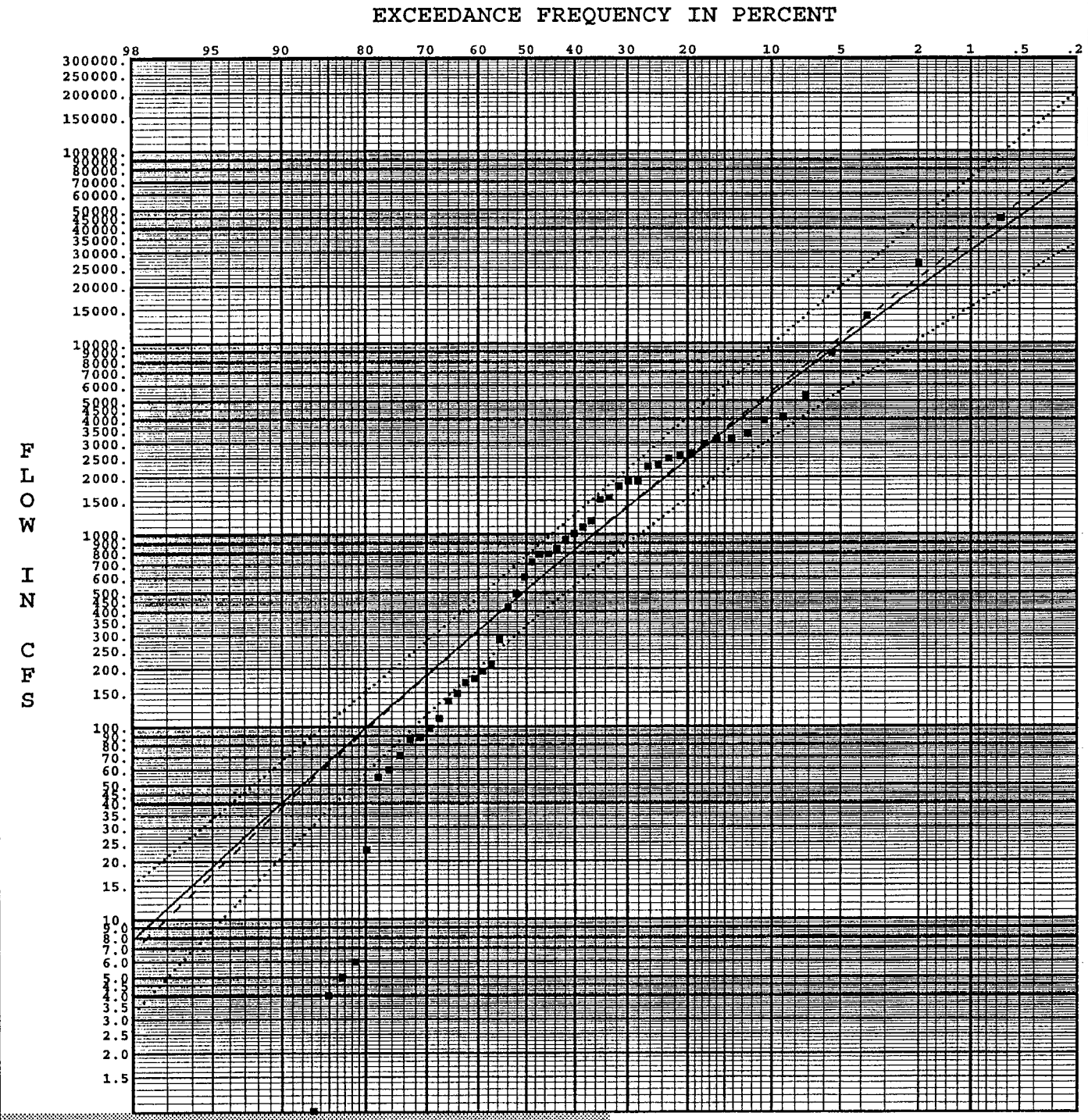
····· 5% and 95% Confidence Limits

FREQUENCY STATISTICS

LOG TRANSFORM OF FLOW, CFS		NUMBER OF EVENTS	
MEAN	2.6099	HISTORIC EVENTS	0
STANDARD DEV	.7753	HIGH OUTLIERS	1
SKEW	-.6115	LOW OUTLIERS	2
REGIONAL SKEW	.0000	ZERO OR MISSING	2
ADOPTED SKEW	-.3000	SYSTEMATIC EVENTS	58
		HISTORIC PERIOD(1892-1997)	106

W/ HISTORIC CRITERION:
Oct 1977 > 1892
SANTA CRUZ RIVER-NOGALES
CYCLONIC ANNUAL PEAKS
MSE Ajusted
BASIN AREA = 533 SQ.MI.
WATER YEARS IN RECORD
1940-1997

FIGURE E1-6a



—— FLOW Frequency (without Exp. Prob.)

- - - FLOW Frequency (with Exp. Prob.)

▪ Median Plotting Positions

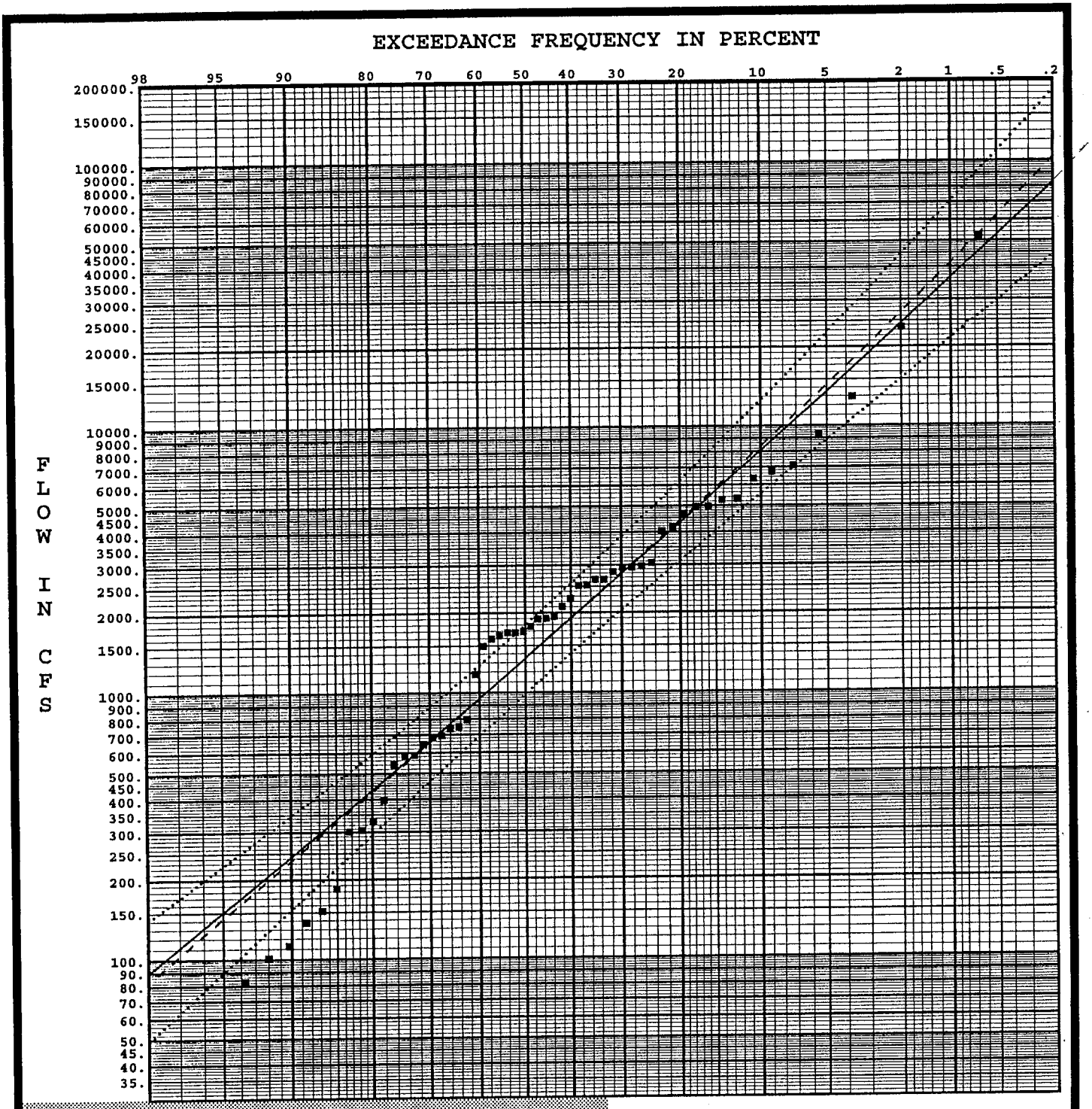
····· 5% and 95% Confidence Limits

FREQUENCY STATISTICS

LOG TRANSFORM OF FLOW, CFS		NUMBER OF EVENTS	
MEAN	2.6840	HISTORIC EVENTS	0
STANDARD DEV	.8280	HIGH OUTLIERS	1
SKEW	-.1633	LOW OUTLIERS	6
REGIONAL SKEW	-.2000	ZERO OR MISSING	6
ADOPTED SKEW	-.2000	SYSTEMATIC EVENTS	58
		HISTORIC PERIOD(1892-1997)	106

W/ HISTORIC CRITERION:
Oct 1983 > 1892
SANTA CRUZ RIVER-CONTINENTAL
CYCLONIC ANNUAL PEAKS
Low Flows < 50 cfs
MSE, Skew Adj
BASIN AREA = 1662 SQ.MI.
WATER YEARS IN RECORD
1940-1997

FIGURE E1-6b



—— FLOW Frequency (without Exp. Prob.)

- - - FLOW Frequency (with Exp. Prob.)

■ Median Plotting Positions

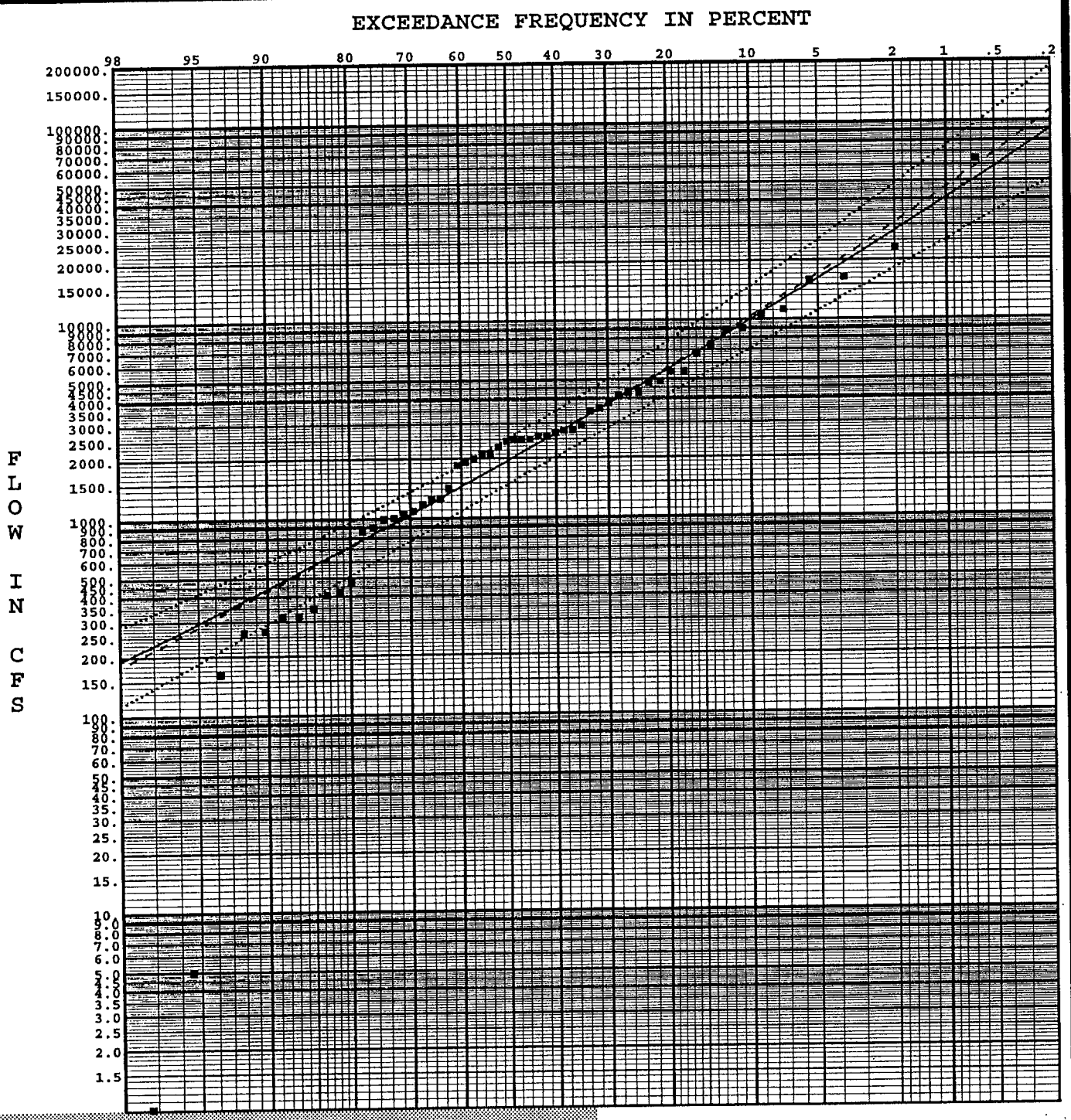
..... 5% and 95% Confidence Limits

FREQUENCY STATISTICS
LOG TRANSFORM OF FLOW, CFS

			NUMBER OF EVENTS
MEAN	3.1393	HISTORIC EVENTS	0
STANDARD DEV	.5935	HIGH OUTLIERS	1
SKEW	-.2622	LOW OUTLIERS	0
REGIONAL SKEW	.1000	ZERO OR MISSING	3
ADOPTED SKEW	.1000	SYSTEMATIC EVENTS	58
		HISTORIC PERIOD(1892-1997)	106

W/ HISTORIC CRITERION:
Oct 1983 > 1892
No Low Flows Specified
SANTA CRUZ RIVER-TUCSON
CYCLONIC ANNUAL PEAKS
Adjusted MSE, Skew
BASIN AREA = 2222 SQ.MI.
WATER YEARS IN RECORD
1940-1997

FIGURE E1-6c



—— FLOW Frequency (without Exp. Prob.)

- - - FLOW Frequency (with Exp. Prob.)

■ Median Plotting Positions

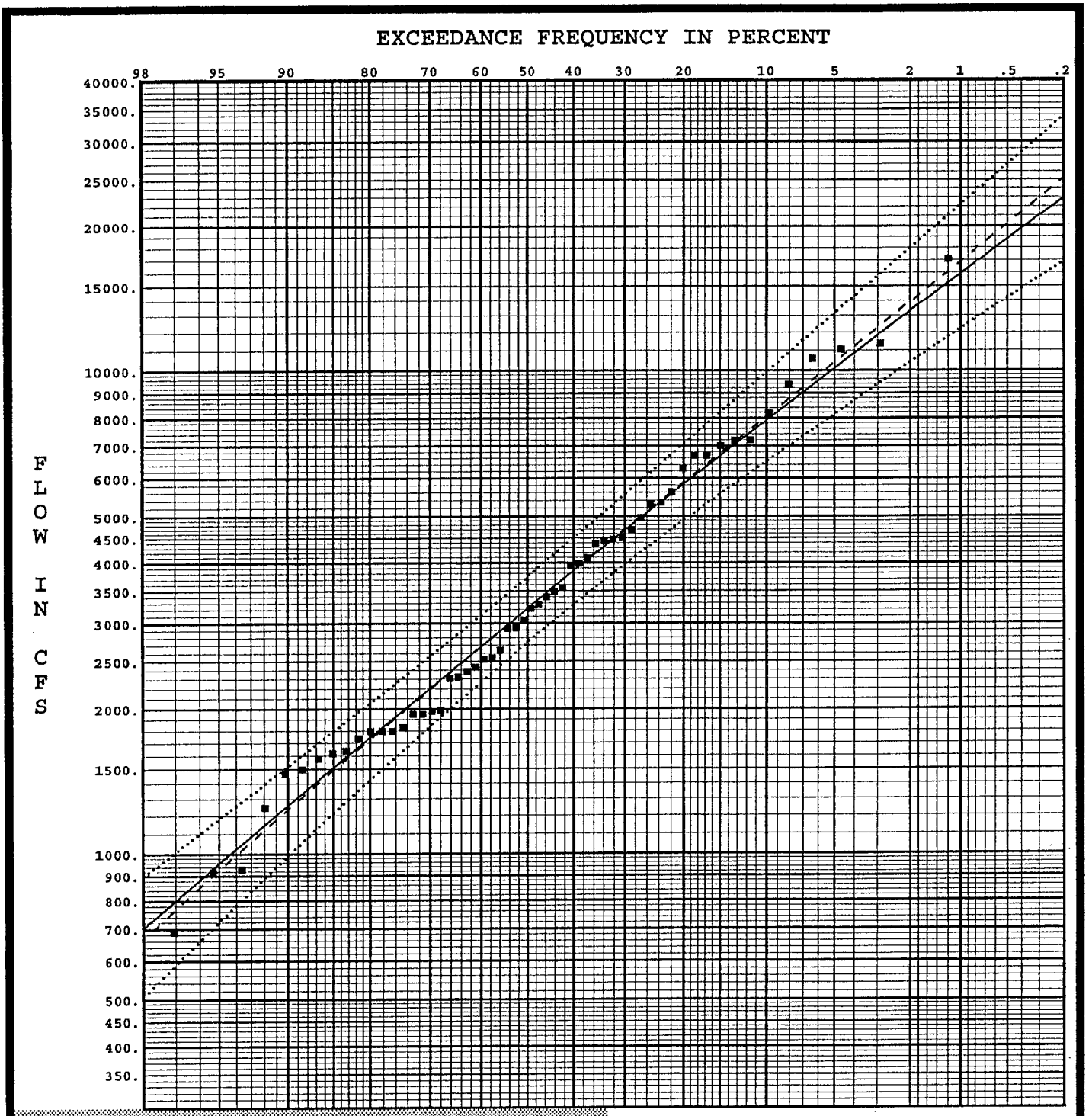
..... 5% and 95% Confidence Limits

FREQUENCY STATISTICS
LOG TRANSFORM OF FLOW, CFS

			NUMBER OF EVENTS
MEAN	3.3089	HISTORIC EVENTS	0
STANDARD DEV	.5285	HIGH OUTLIERS	1
SKEW	-.0572	LOW OUTLIERS	3
REGIONAL SKEW	.2000	ZERO OR MISSING	0
ADOPTED SKEW	.2000	SYSTEMATIC EVENTS	58
		HISTORIC PERIOD(1892-1997)	106

W/ HISTORIC CRITERION:
Oct 1977 > 1892
No Low Flows Specified
SANTA CRUZ RIVER-CORTARO
CYCLONIC ANNUAL PEAKS
BASIN AREA = 3503 SQ.MI.
WATER YEARS IN RECORD
1940-1997

FIGURE E1-6d



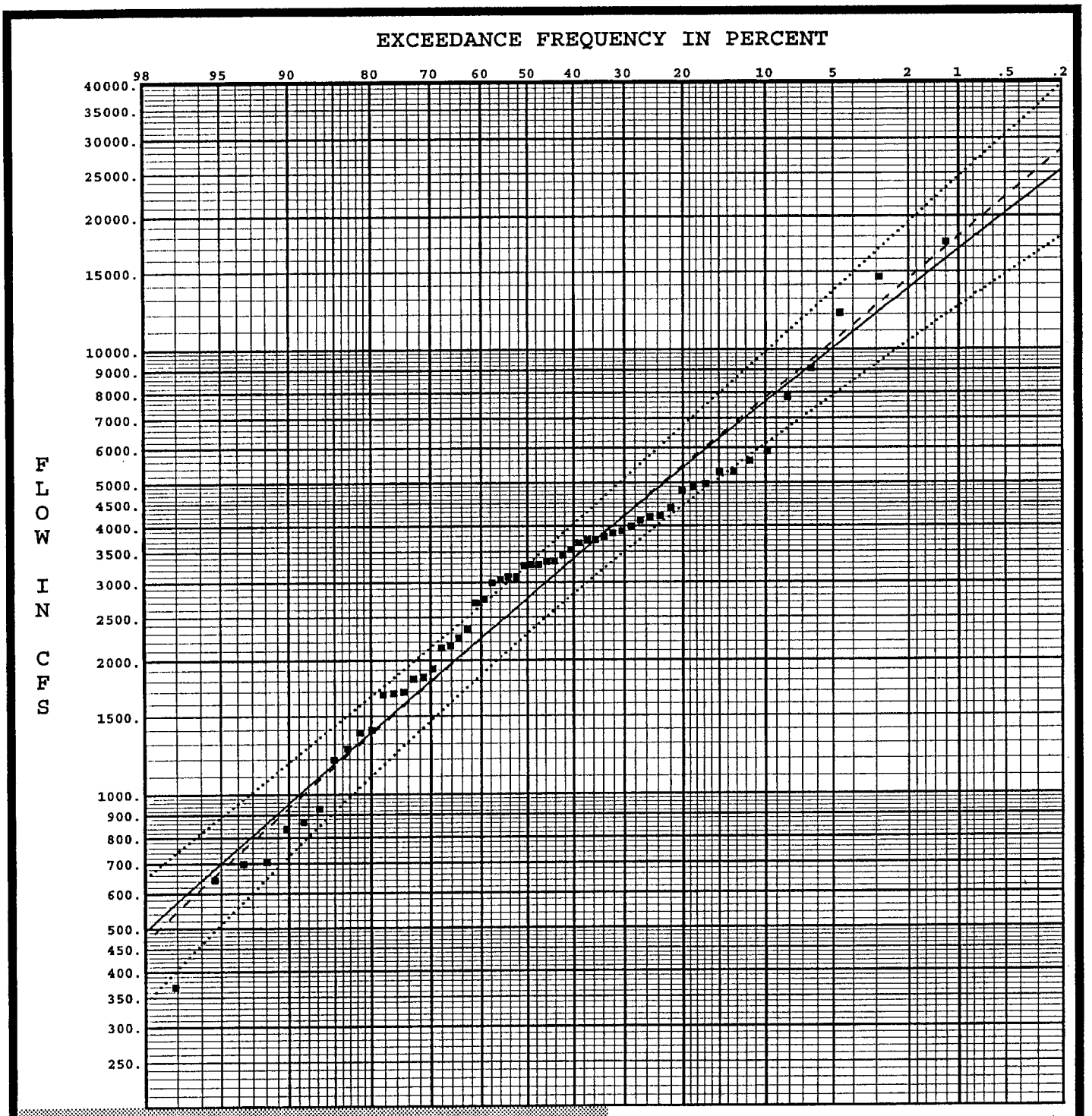
—— FLOW Frequency (without Exp. Prob.)
- - - FLOW Frequency (with Exp. Prob.)
▪ Median Plotting Positions
····· 5% and 95% Confidence Limits

FREQUENCY STATISTICS
LOG TRANSFORM OF FLOW, CFS

			NUMBER OF EVENTS
MEAN	3.5024	HISTORIC EVENTS	0
STANDARD DEV	.3112	HIGH OUTLIERS	0
SKEW	.0417	LOW OUTLIERS	0
REGIONAL SKEW	-.2000	ZERO OR MISSING	0
ADOPTED SKEW	-.1000	SYSTEMATIC EVENTS	58

W/O HISTORIC CRITERION
SANTA CRUZ RIVER-NOGALES
MONSOONAL ANNUAL PEAKS
Adjusted MSE
BASIN AREA = 533 SQ.MI.
WATER YEARS IN RECORD
1940-1997

FIGURE E1-7a



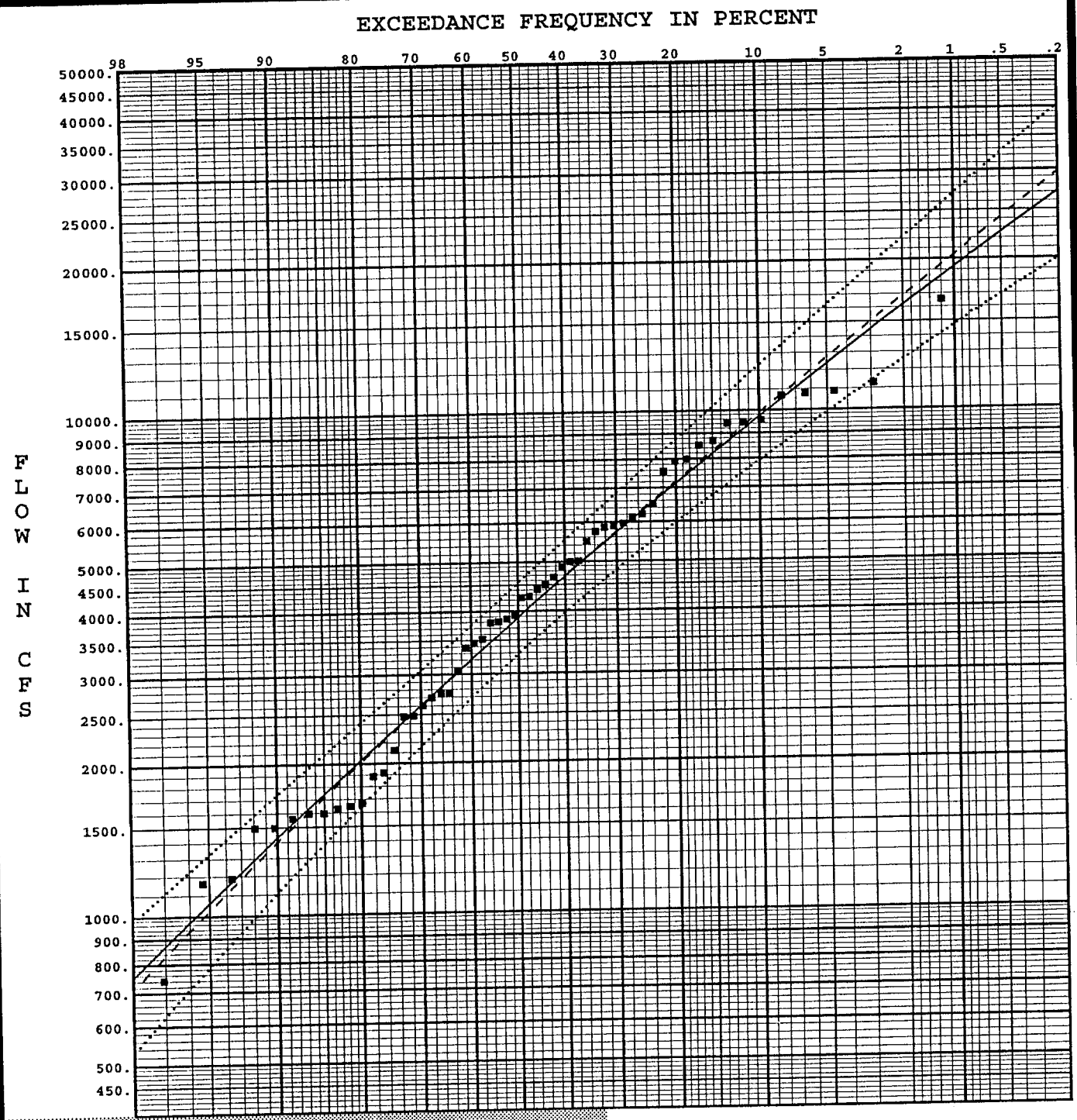
—— FLOW Frequency (without Exp. Prob.)
- - - FLOW Frequency (with Exp. Prob.)
▪ Median Plotting Positions
····· 5% and 95% Confidence Limits

FREQUENCY STATISTICS
LOG TRANSFORM OF FLOW, CFS

			NUMBER OF EVENTS
MEAN	3.4352	HISTORIC EVENTS	0
STANDARD DEV	.3518	HIGH OUTLIERS	0
SKEW	-.3853	LOW OUTLIERS	0
REGIONAL SKEW	.1000	ZERO OR MISSING	0
ADOPTED SKEW	-.1000	SYSTEMATIC EVENTS	58

W/O HISTORIC CRITERION
SANTA CRUZ RIVER-CONTINENTAL
Adjusted MSE, SKEW
MONSOON PEAKS
BASIN AREA = 1626 SQ.MI.
WATER YEARS IN RECORD
1940-1997

FIGURE E1-7b



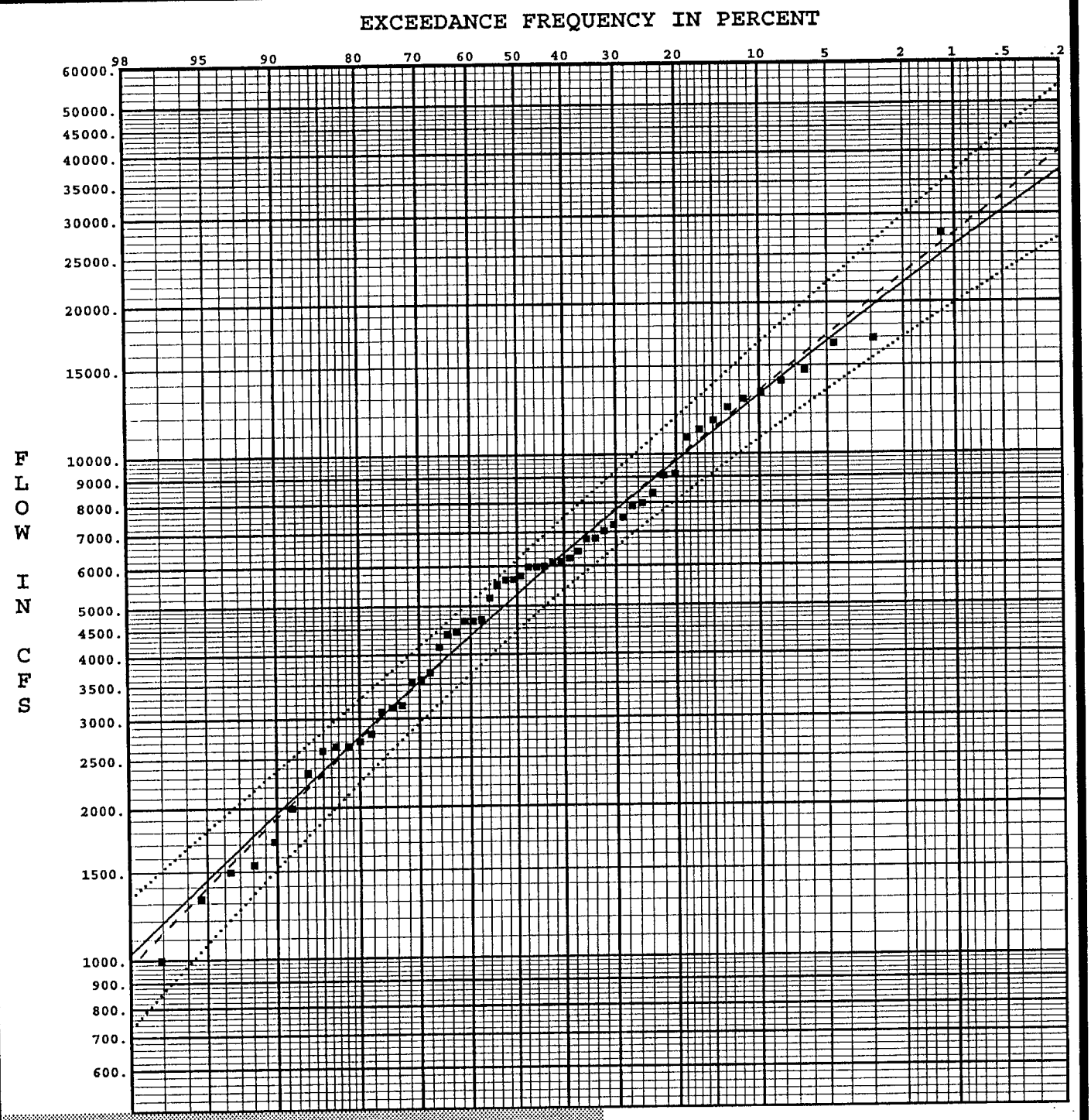
—— FLOW Frequency (without Exp. Prob.)
- - - FLOW Frequency (with Exp. Prob.)
■ Median Plotting Positions
..... 5% and 95% Confidence Limits

FREQUENCY STATISTICS
LOG TRANSFORM OF FLOW, CFS

			NUMBER OF EVENTS
MEAN	3.5787	HISTORIC EVENTS	0
STANDARD DEV	.3248	HIGH OUTLIERS	0
SKEW	-.3855	LOW OUTLIERS	0
REGIONAL SKEW	.0000	ZERO OR MISSING	0
ADOPTED SKEW	-.2000	SYSTEMATIC EVENTS	58

PLOTTUCM (MONSOONAL)
W/O HISTORIC CRITERION
SANTA CRUZ RIVER-TUCSON
MONSOONAL PEAKS
Adjusted MSE
BASIN AREA = 2222 SQ MI
WATER YEARS IN RECORD
1940-1997

FIGURE E1-7c



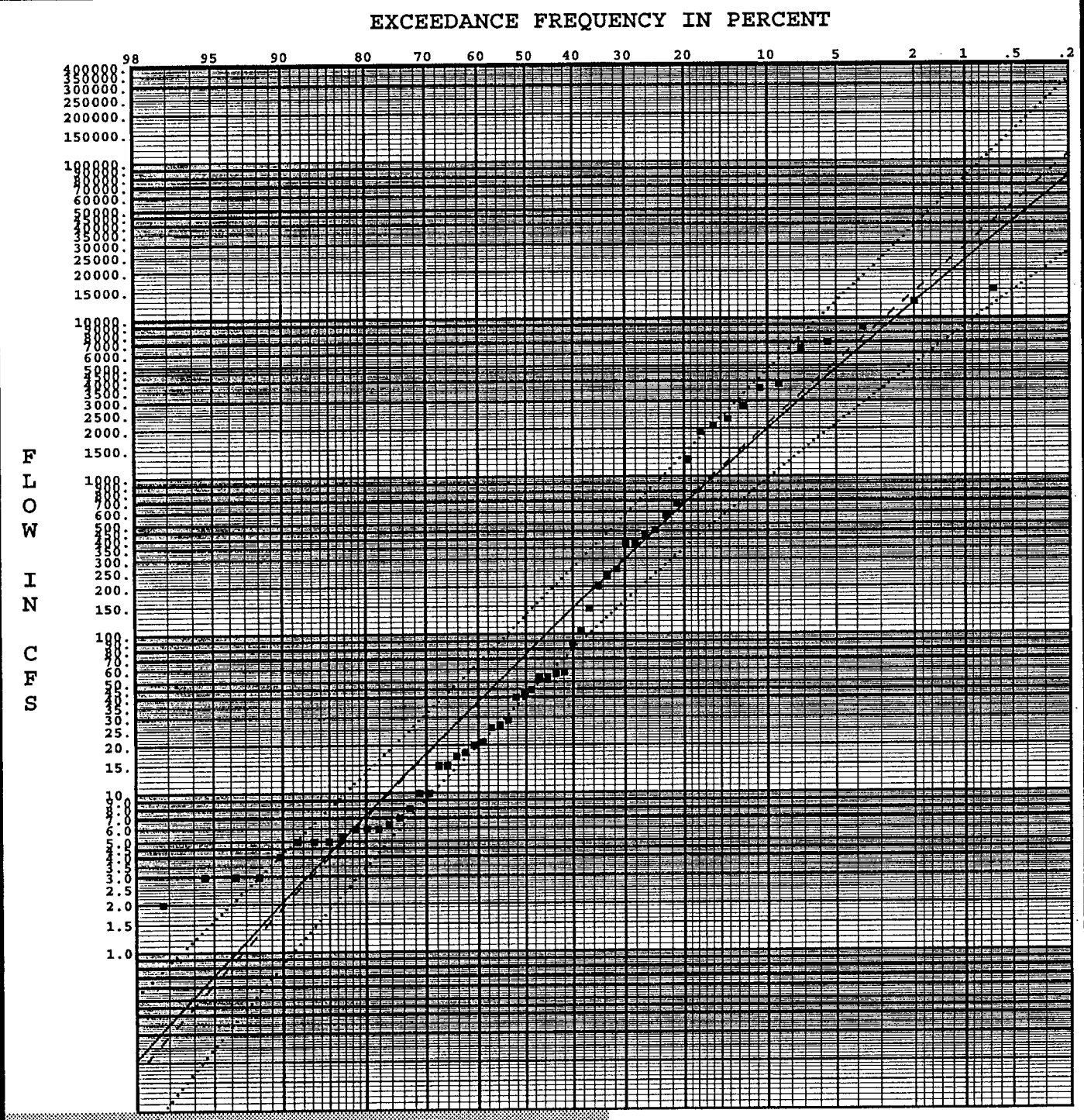
—— FLOW Frequency (without Exp. Prob.)
- - - FLOW Frequency (with Exp. Prob.)
▪ Median Plotting Positions
..... 5% and 95% Confidence Limits

FREQUENCY STATISTICS
LOG TRANSFORM OF FLOW, CFS

			NUMBER OF EVENTS
MEAN	3.7116	HISTORIC EVENTS	0
STANDARD DEV	.3234	HIGH OUTLIERS	0
SKEW	-.3604	LOW OUTLIERS	0
REGIONAL SKEW	.0000	ZERO OR MISSING	0
ADOPTED SKEW	-.2000	SYSTEMATIC EVENTS	58

W/O HISTORIC CRITERION
SANTA CRUZ RIVER-CORTARO
MONSOONAL SEASON ANNUAL PEAKS
Adjusted MSE
BASIN AREA = 3503 SQ.MI.
WATER YEARS IN RECORD
1940-1997

FIGURE E1-7d



—— FLOW Frequency (without Exp. Prob.)

- - - FLOW Frequency (with Exp. Prob.)

■ Median Plotting Positions

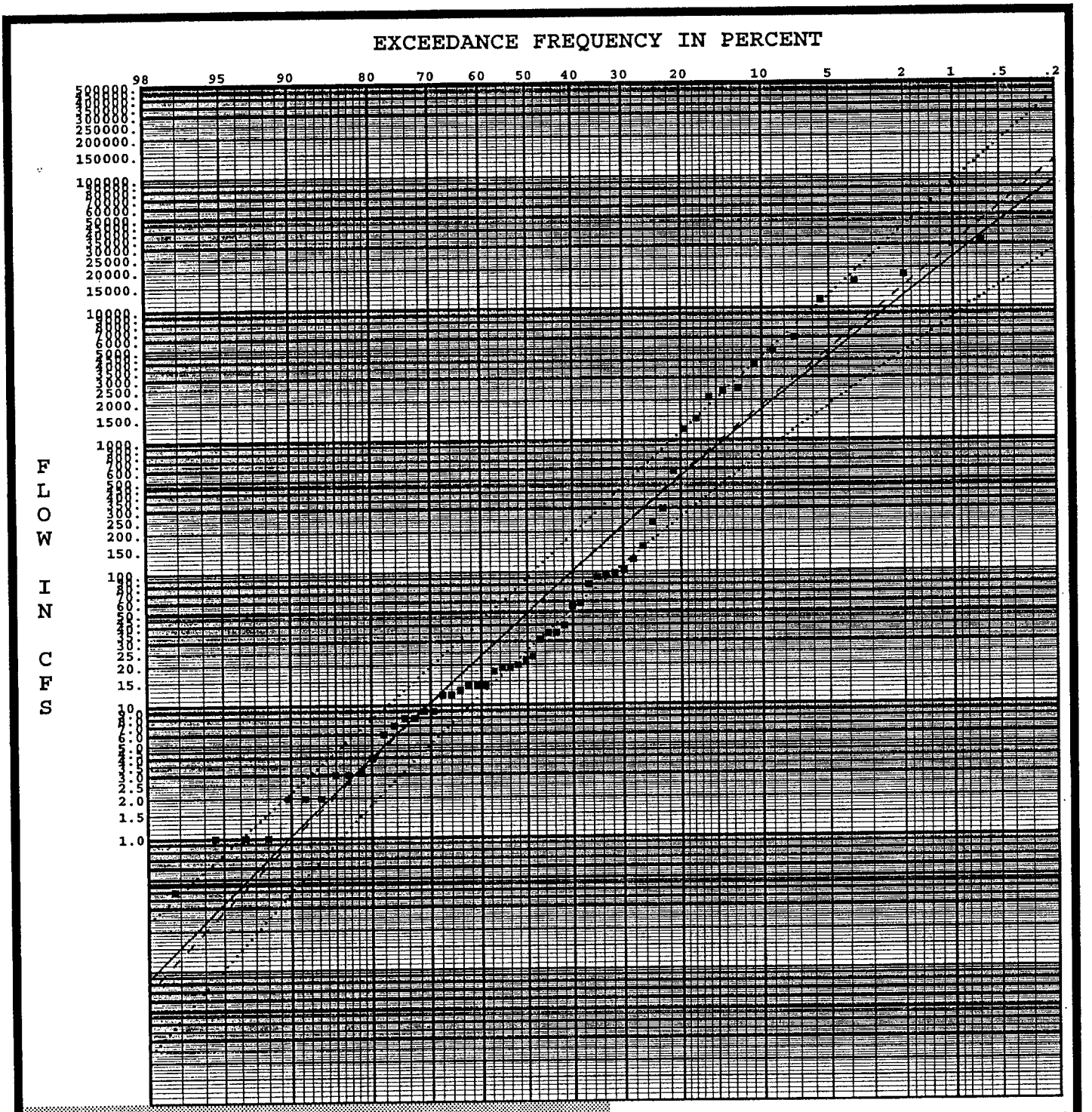
····· 5% and 95% Confidence Limits

FREQUENCY STATISTICS

LOG TRANSFORM OF FLOW, CFS		NUMBER OF EVENTS	
MEAN	1.8338	HISTORIC EVENTS	0
STANDARD DEV	1.1645	HIGH OUTLIERS	1
SKEW	.1608	LOW OUTLIERS	12
REGIONAL SKEW	-.5000	ZERO OR MISSING	1
ADOPTED SKEW	-.2000	SYSTEMATIC EVENTS	58
		HISTORIC PERIOD(1892-1997)	106

W/ HISTORIC CRITERION:
DEC 1967 > 1892
Low Outlier < 6 cfs
SANTA CRUZ RIVER-NOGALES
FRONTAL ANNUAL PEAKS
BASIN AREA = 533 SQ.MI.
WATER YEARS IN RECORD
1940-1997

FIGURE E1-8a



—— FLOW Frequency (without Exp. Prob.)

- - - FLOW Frequency (with Exp. Prob.)

■ Median Plotting Positions

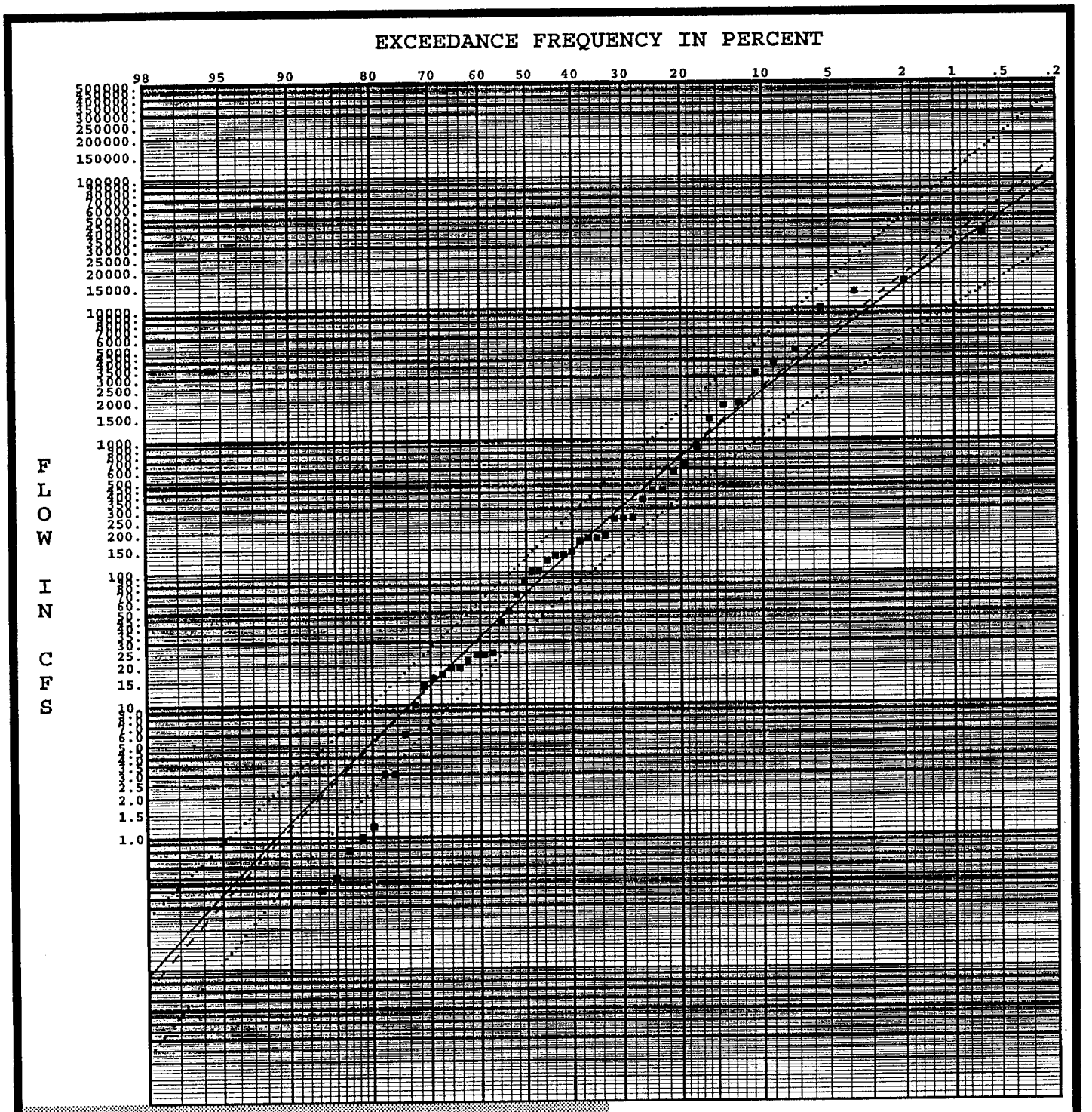
..... 5% and 95% Confidence Limits

FREQUENCY STATISTICS

LOG TRANSFORM OF FLOW, CFS		NUMBER OF EVENTS	
MEAN	1.6506	HISTORIC EVENTS	0
STANDARD DEV	1.2559	HIGH OUTLIERS	1
SKEW	.3972	LOW OUTLIERS	16
REGIONAL SKEW	-.2000	ZERO OR MISSING	0
ADOPTED SKEW	-.2000	SYSTEMATIC EVENTS	58
		HISTORIC PERIOD(1892-1997)	106

W/ HISTORIC CRITERION:
JAN 1993 > 1892
Low Outlier < 8cfs
SANTA CRUZ RIVER-CONTINENTAL
FRONTAL PEAKS
BASIN AREA = 1662 SQ.MI.
WATER YEARS IN RECORD
1940-1997

FIGURE E1-8b



—— FLOW Frequency (without Exp. Prob.)

- - - FLOW Frequency (with Exp. Prob.)

▪ Median Plotting Positions

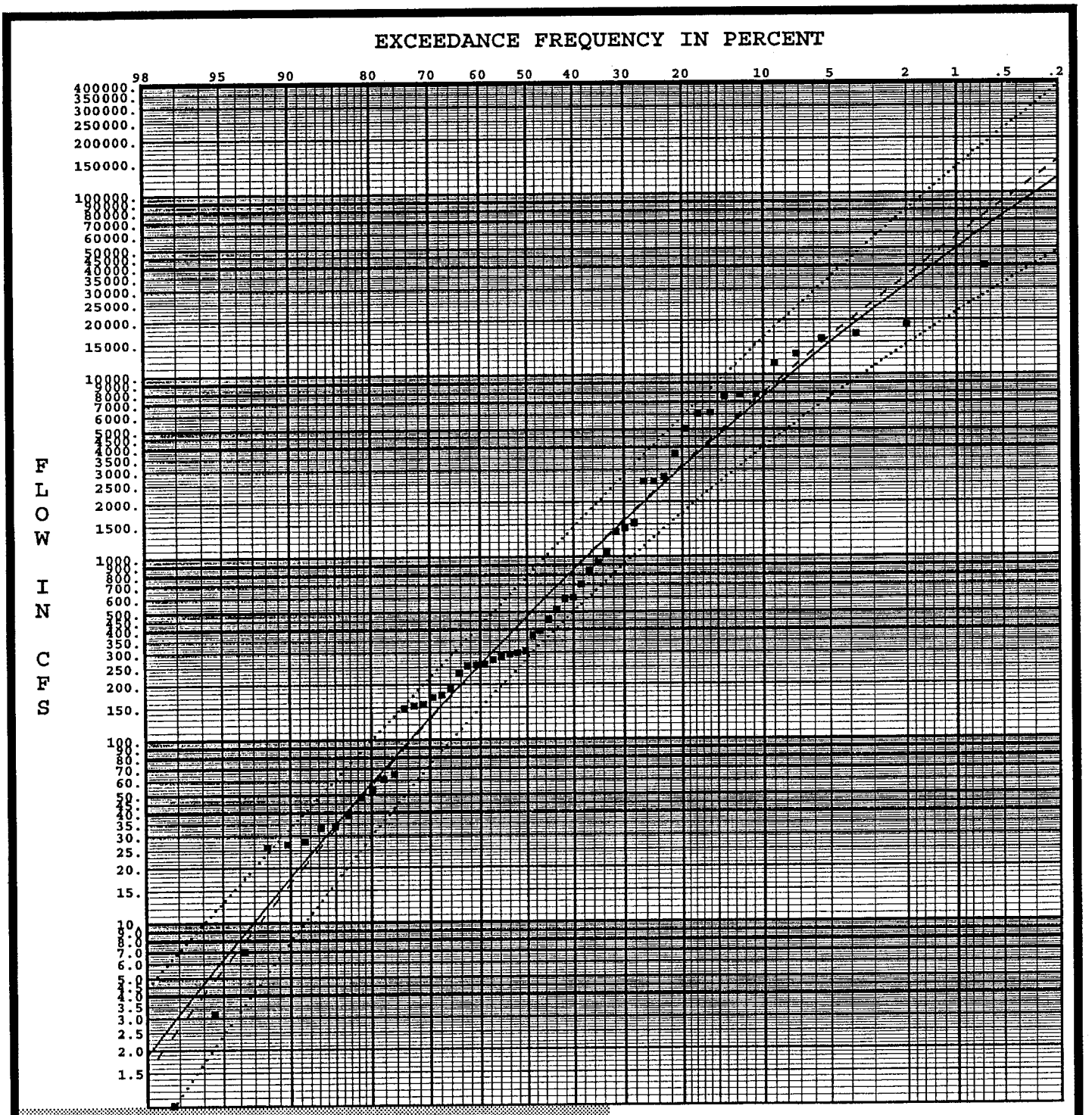
····· 5% and 95% Confidence Limits

FREQUENCY STATISTICS
LOG TRANSFORM OF FLOW, CFS

			NUMBER OF EVENTS
MEAN	1.7794	HISTORIC EVENTS	0
STANDARD DEV	1.2747	HIGH OUTLIERS	1
SKEW	-.1505	LOW OUTLIERS	0
REGIONAL SKEW	-.3000	ZERO OR MISSING	7
ADOPTED SKEW	-.3000	SYSTEMATIC EVENTS	58
		HISTORIC PERIOD(1892-1997)	106

W/ HISTORIC CRITERION:
JAN 1993 > 1892
SANTA CRUZ RIVER-TUCSON
FRONTAL PEAKS
BASIN AREA = 2222 SQ.MI.
WATER YEARS IN RECORD
1940-1997

FIGURE E1-8c



—— FLOW Frequency (without Exp. Prob.)

- - - FLOW Frequency (with Exp. Prob.)

■ Median Plotting Positions

····· 5% and 95% Confidence Limits

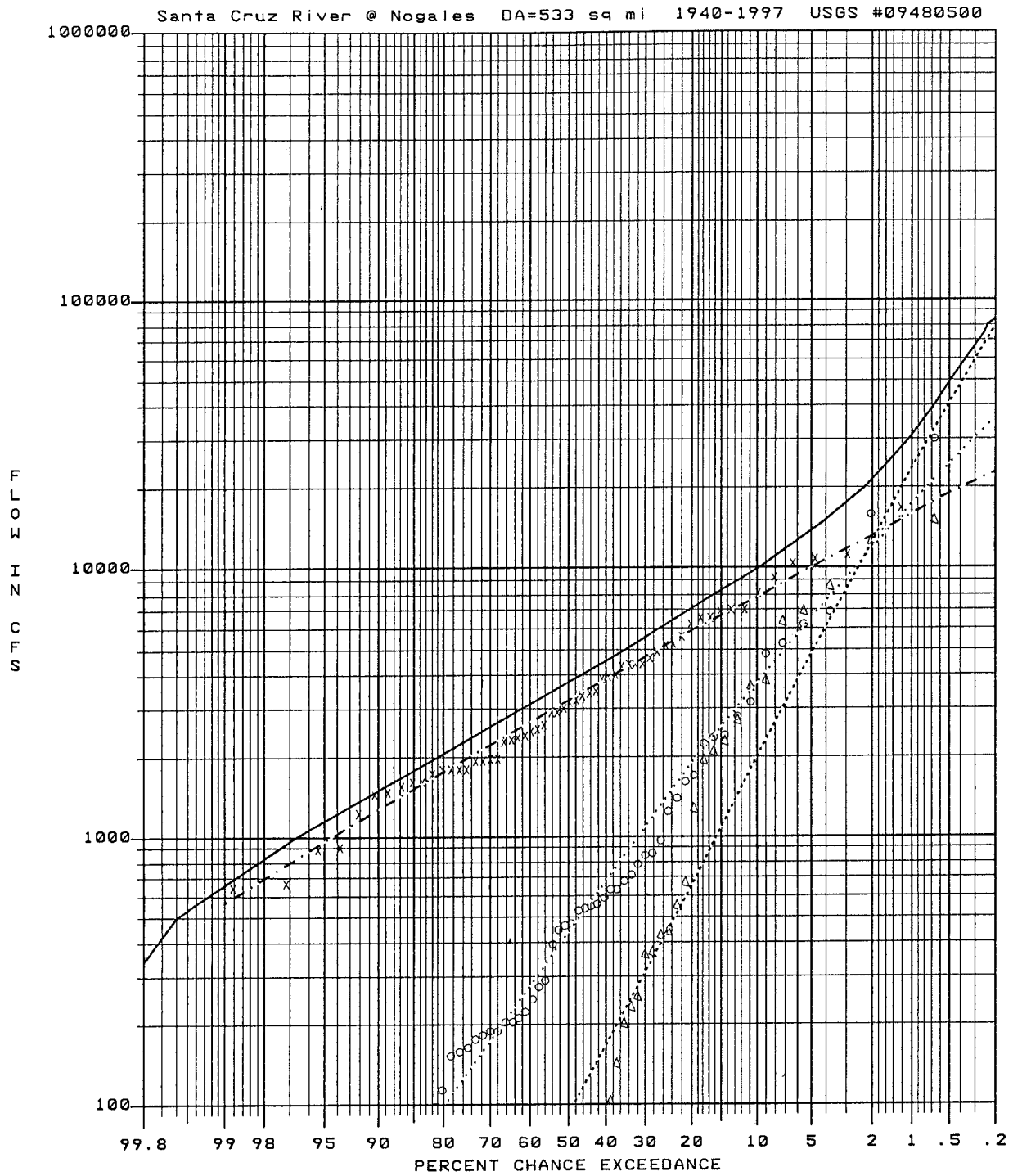
FREQUENCY STATISTICS

LOG TRANSFORM OF FLOW, CFS		NUMBER OF EVENTS	
MEAN	2.6077	HISTORIC EVENTS	0
STANDARD DEV	1.0307	HIGH OUTLIERS	1
SKEW	-.3880	LOW OUTLIERS	0
REGIONAL SKEW	-.4000	ZERO OR MISSING	0
ADOPTED SKEW	-.4000	SYSTEMATIC EVENTS	58
		HISTORIC PERIOD(1892-1997)	106

W/ HISTORIC CRITERION:
JAN 1993 > 1892
SANTA CRUZ RIVER-CORTARO
FRONTAL PEAKS
BASIN AREA = 3503 SQ.MI.
WATER YEARS IN RECORD
1940-1997

FIGURE E1-8d

30DEC99 13:36:05
MXDP_NOG.DSS



COMBINED MIXED POPULATION ANNUAL CURVE
o OBSERVED SEASONAL PEAKS - CYCLONIC
x OBSERVED SEASONAL PEAKS - MONSOON
Δ OBSERVED SEASONAL PEAKS - FRONTAL
COMPUTED SEASONAL CURVE - CYCLONIC
COMPUTED SEASONAL CURVE - MONSOON
COMPUTED SEASONAL CURVE - FRONTAL

FIGURE E1-9a

09FEB00 11:53:07
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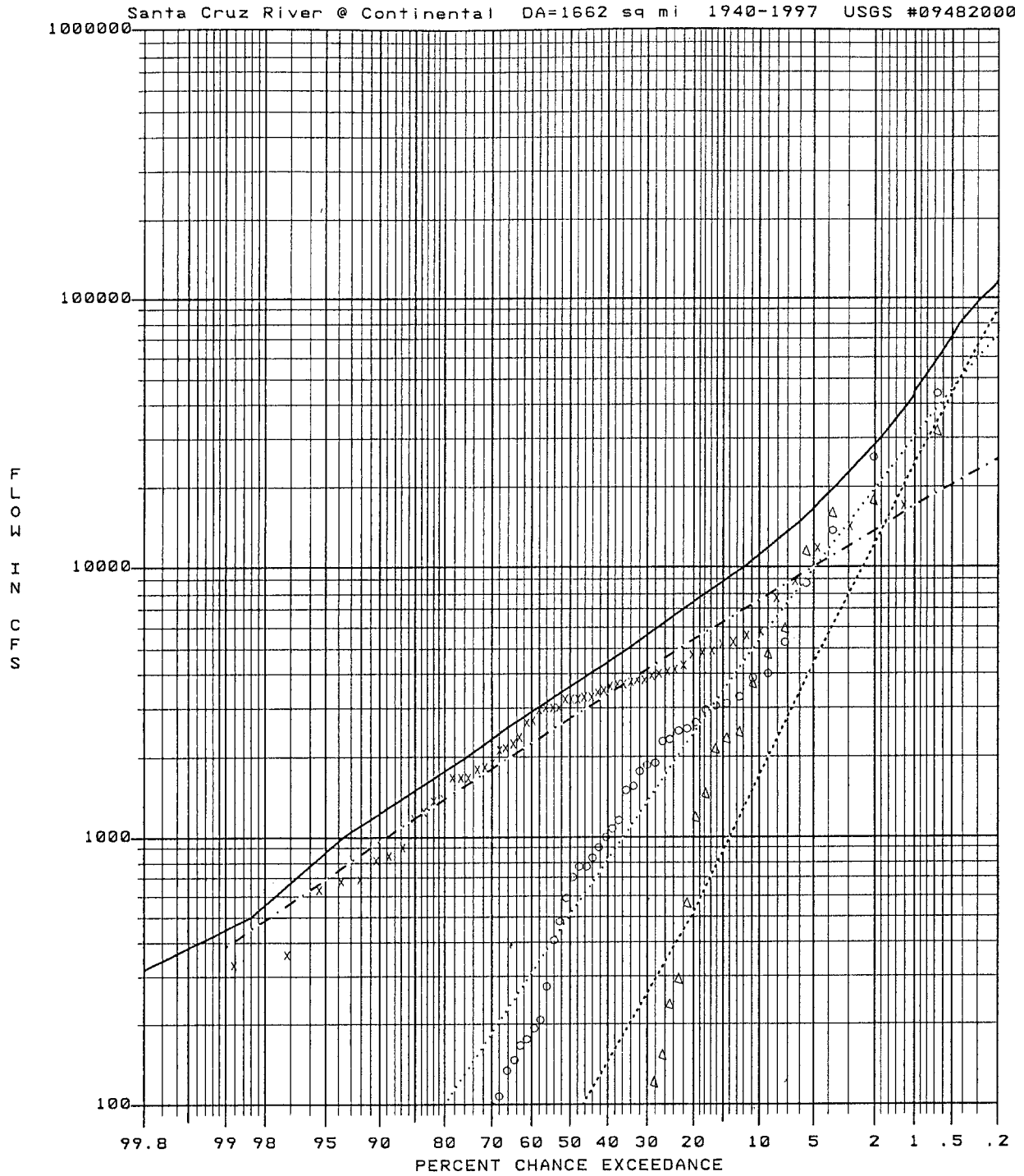
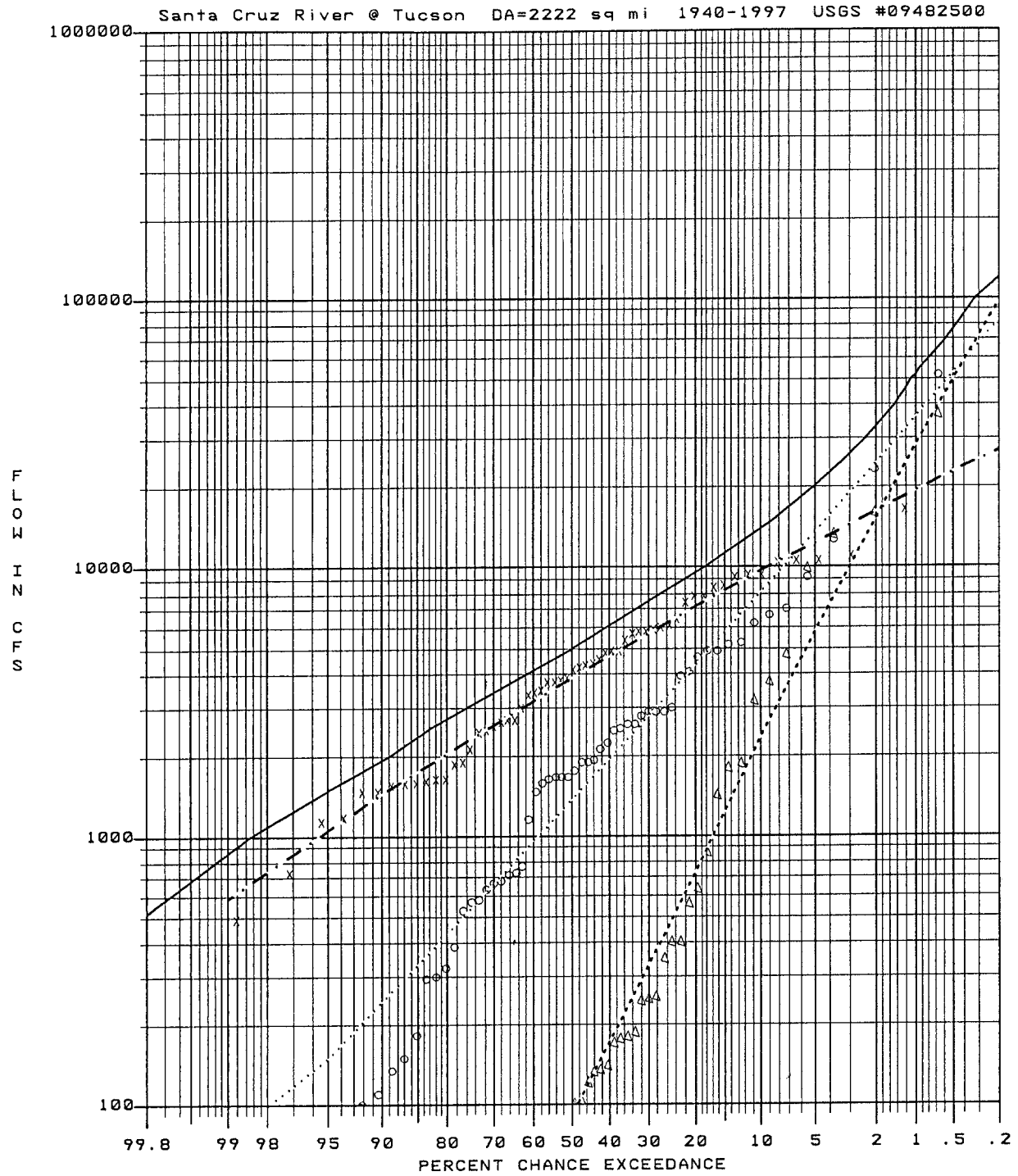


COMBINED MIXED POPULATION ANNUAL CURVE
o OBSERVED SEASONAL PEAKS - CYCLONIC
x OBSERVED SEASONAL PEAKS - MONSOON
Δ OBSERVED SEASONAL PEAKS - FRONTAL
COMPUTED SEASONAL CURVE - CYCLONIC
COMPUTED SEASONAL CURVE - MONSOON
COMPUTED SEASONAL CURVE - FRONTAL

FIGURE E1-9b

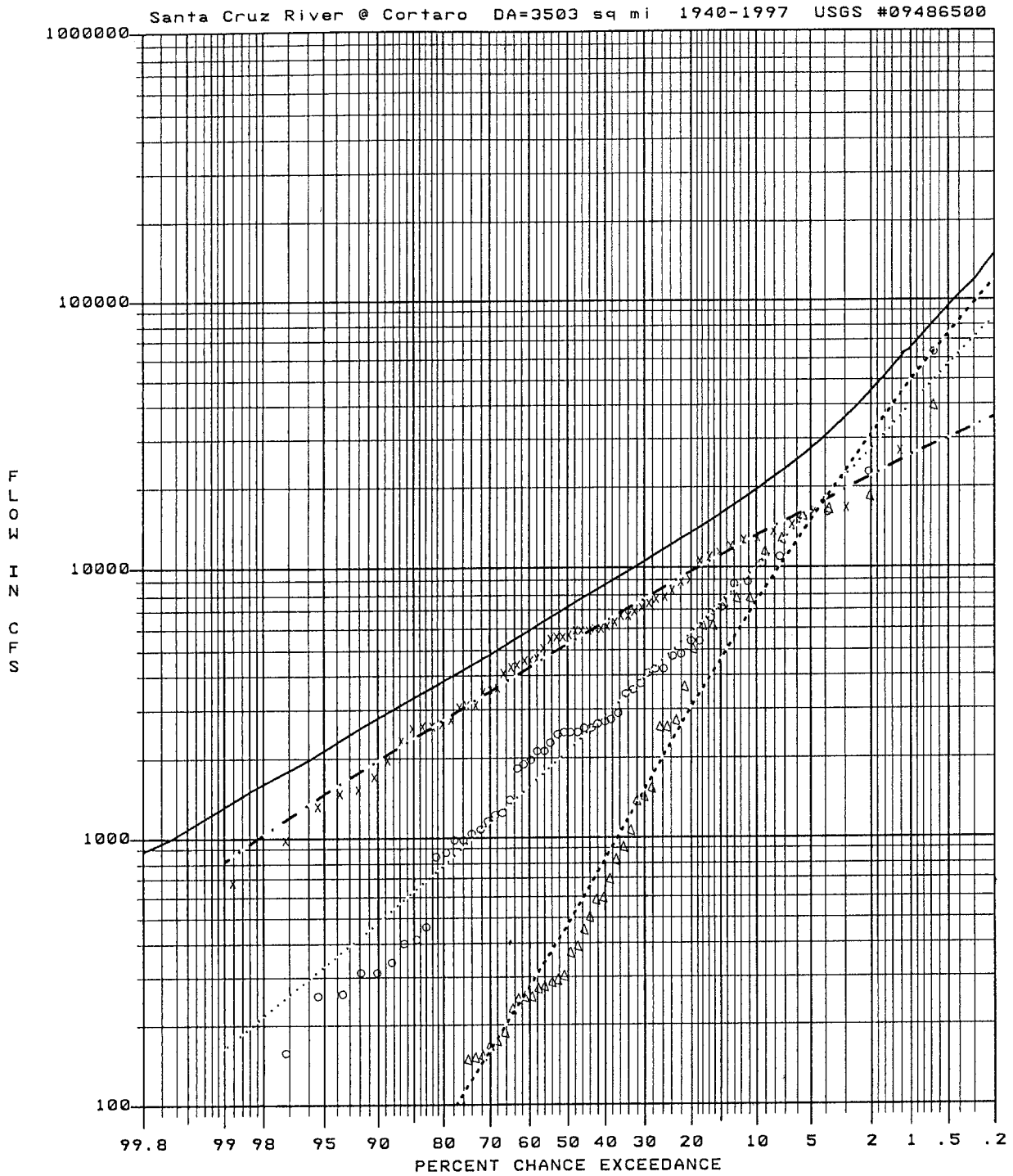
30DEC99 13:38:04
MXDP_TUC.DSS



COMBINED MIXED POPULATION ANNUAL CURVE
O OBSERVED SEASONAL PEAKS - CYCLONIC
X OBSERVED SEASONAL PEAKS - MONSOON
Δ OBSERVED SEASONAL PEAKS - FRONTAL
COMPUTED SEASONAL CURVE - CYCLONIC
COMPUTED SEASONAL CURVE - MONSOON
COMPUTED SEASONAL CURVE - FRONTAL

FIGURE E1-9c

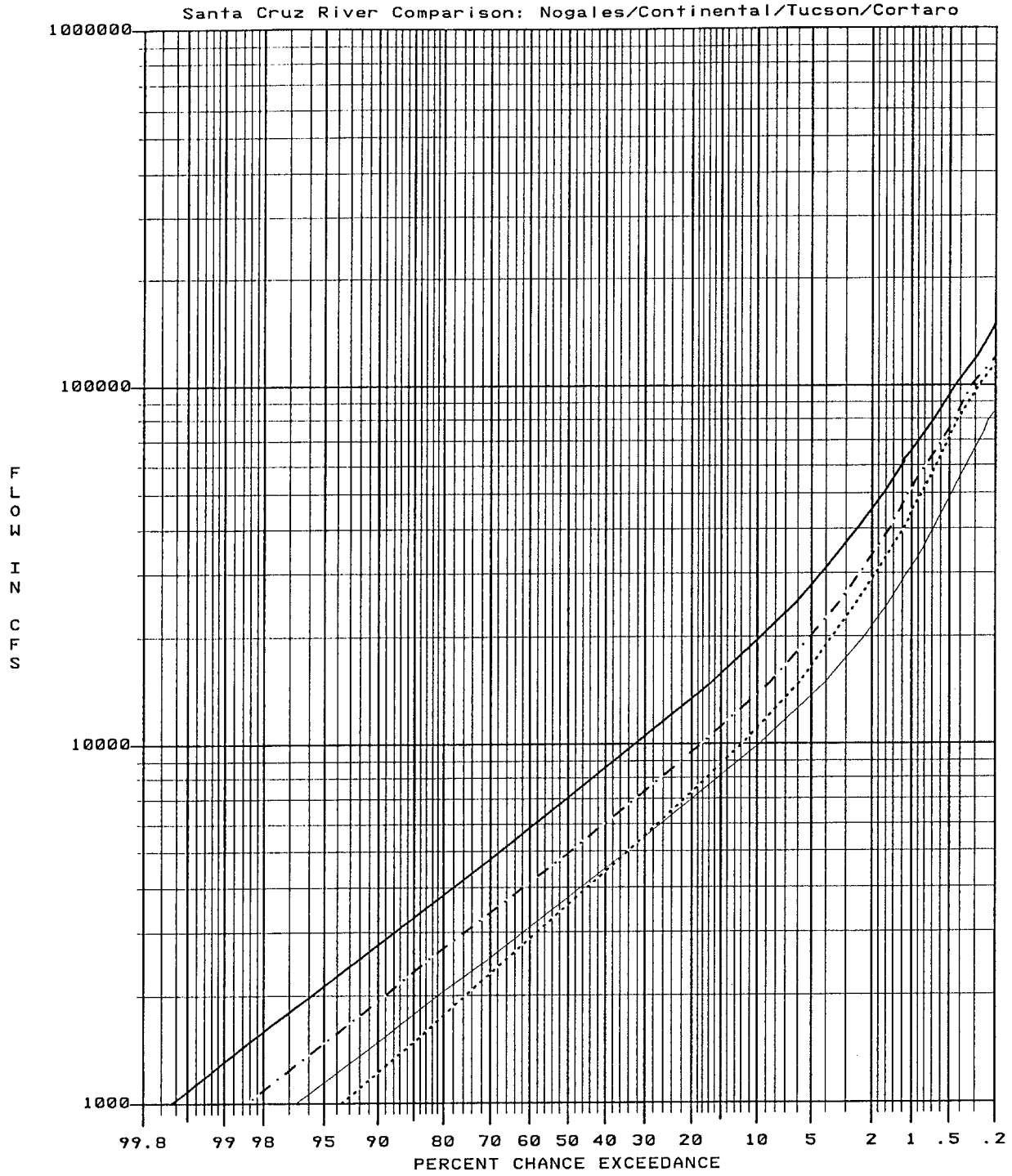
30DEC99 13:38:37
MXDP_COR.DSS



COMBINED MIXED POPULATION ANNUAL CURVE
o OBSERVED SEASONAL PEAKS - CYCLONIC
x OBSERVED SEASONAL PEAKS - MONSOON
Δ OBSERVED SEASONAL PEAKS - FRONTAL
COMPUTED SEASONAL CURVE - CYCLONIC
COMPUTED SEASONAL CURVE - MONSOON
COMPUTED SEASONAL CURVE - FRONTAL

FIGURE E1-9d

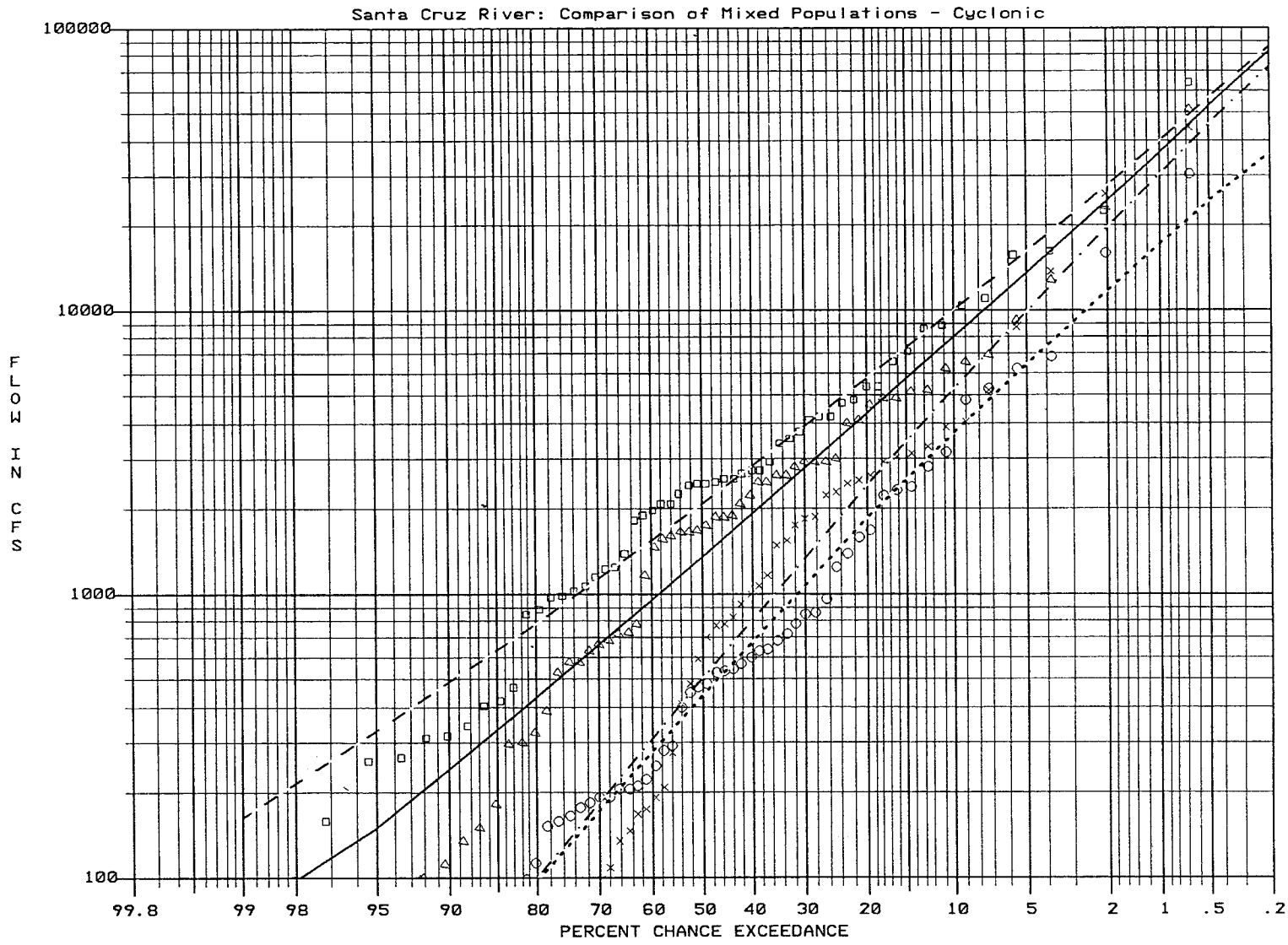
09FEB00 12:11:13
COMPARE.DSS



NOGALES COMBINED CURVE COMPUTED PEAK
CONTINENTAL COMBINED CURVE COMPUTED PEAK
TUCSON COMBINED CURVE COMPUTED PEAK
CORTARO COMBINED CURVE COMPUTED PEAK

FIGURE E1-10

09FEB00 13:30:22
COMPARE.DSS

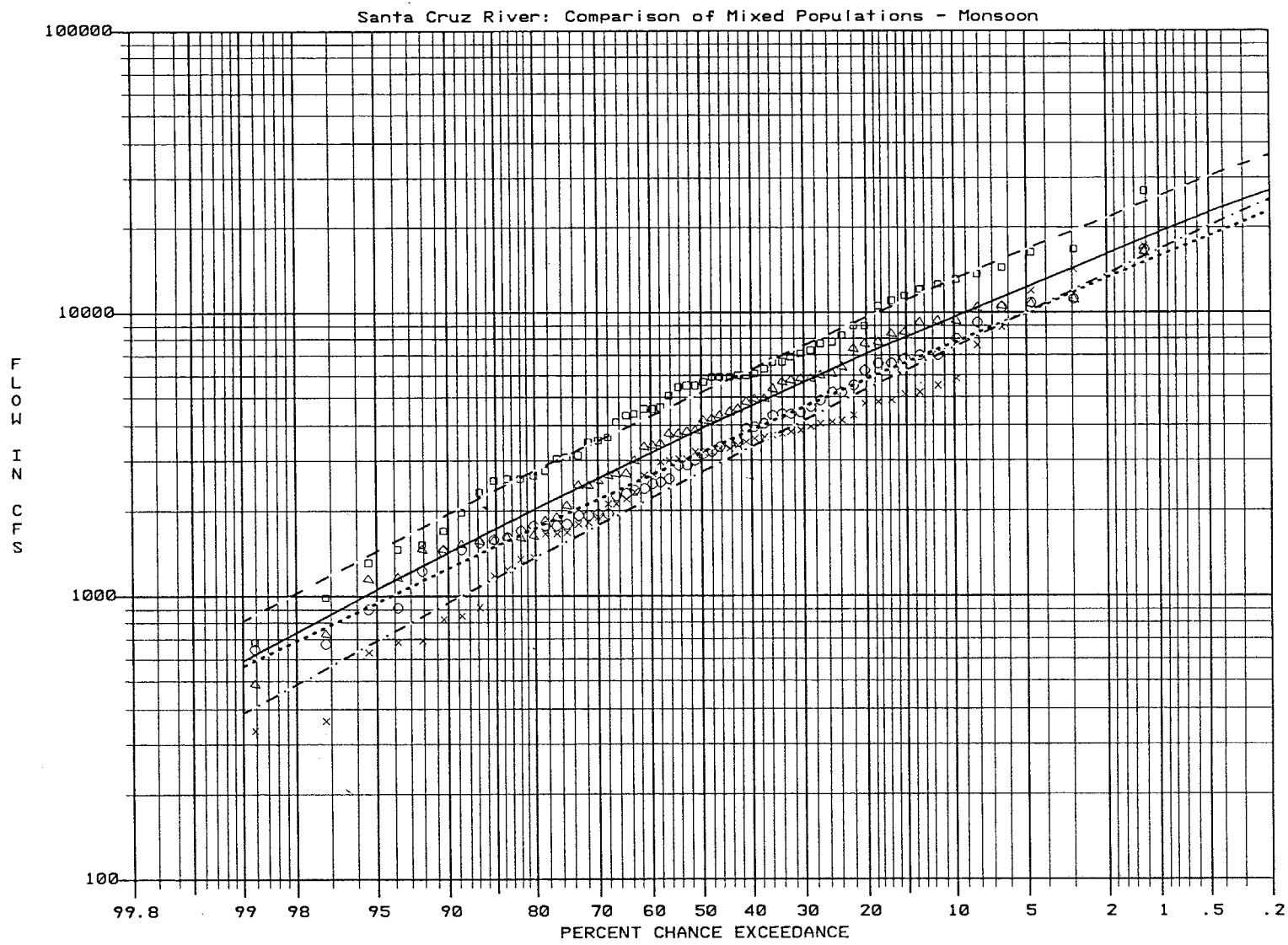


○ OBSERVED PEAKS-CYCLONIC - NOGALES
---------- COMPUTED CURVE-CYCLONIC - NOGALES
× OBSERVED PEAKS-CYCLONIC - CONTINENTAL
·-·-·-·- COMPUTED CURVE-CYCLONIC - CONTINENTAL

△ OBSERVED PEAKS-CYCLONIC - TUCSON
——— COMPUTED CURVE-CYCLONIC - TUCSON
□ OBSERVED PEAKS-CYCLONIC - CORTARO
- - - - - - - COMPUTED CURVE-CYCLONIC - CORTARO

FIGURE E1-11a

09FEB00 13:42:31
COMPARE.DSS

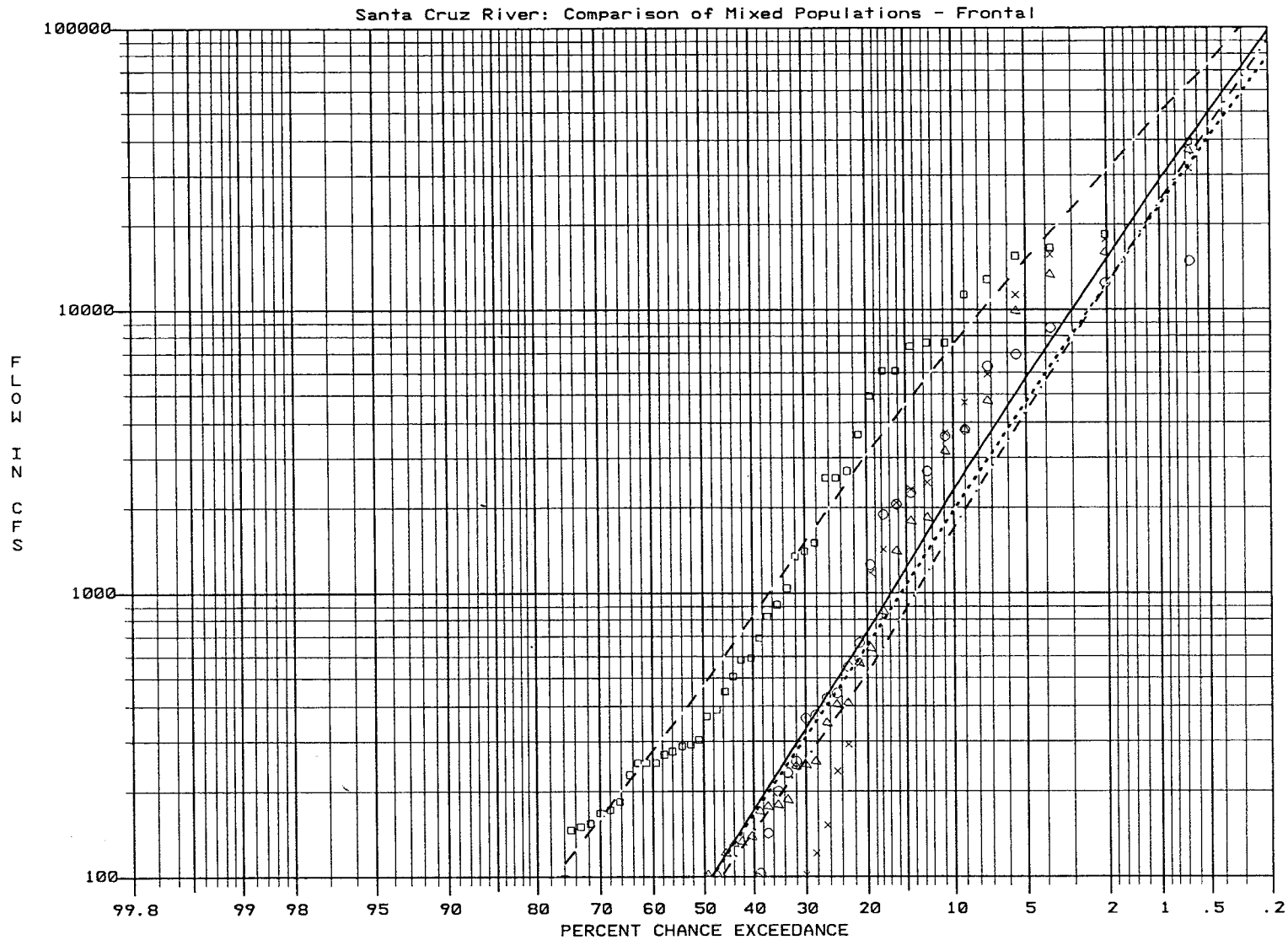


○ OBSERVED PEAKS-MONSOON - NOGALES
COMPUTED CURVE-MONSOON - NOGALES
× OBSERVED PEAKS-MONSOON - CONTINENTAL
COMPUTED CURVE-MONSOON - CONTINENTAL

△ OBSERVED PEAKS-MONSOON - TUCSON
COMPUTED CURVE-MONSOON - TUCSON
□ OBSERVED PEAKS-MONSOON - CORTARO
COMPUTED CURVE-MONSOON - CORTARO

FIGURE E1-11b

09FEB00 13:50:32
COMPARE.DSS



○ OBSERVED PEAKS-FRONTAL - NOGALES
COMPUTED CURVE-FRONTAL - NOGALES
× OBSERVED PEAKS-FRONTAL - CONTINENTAL
COMPUTED CURVE-FRONTAL - CONTINENTAL

△ OBSERVED PEAKS-FRONTAL - TUCSON
COMPUTED CURVE-FRONTAL - TUCSON
□ OBSERVED PEAKS-FRONTAL - CORTARO
COMPUTED CURVE-FRONTAL - CORTARO

FIGURE E1-11c

SANTA CRUZ RIVER MIXED POPULATION STUDY

Discharge-Frequency Profile: Discharge VS Drainage Area

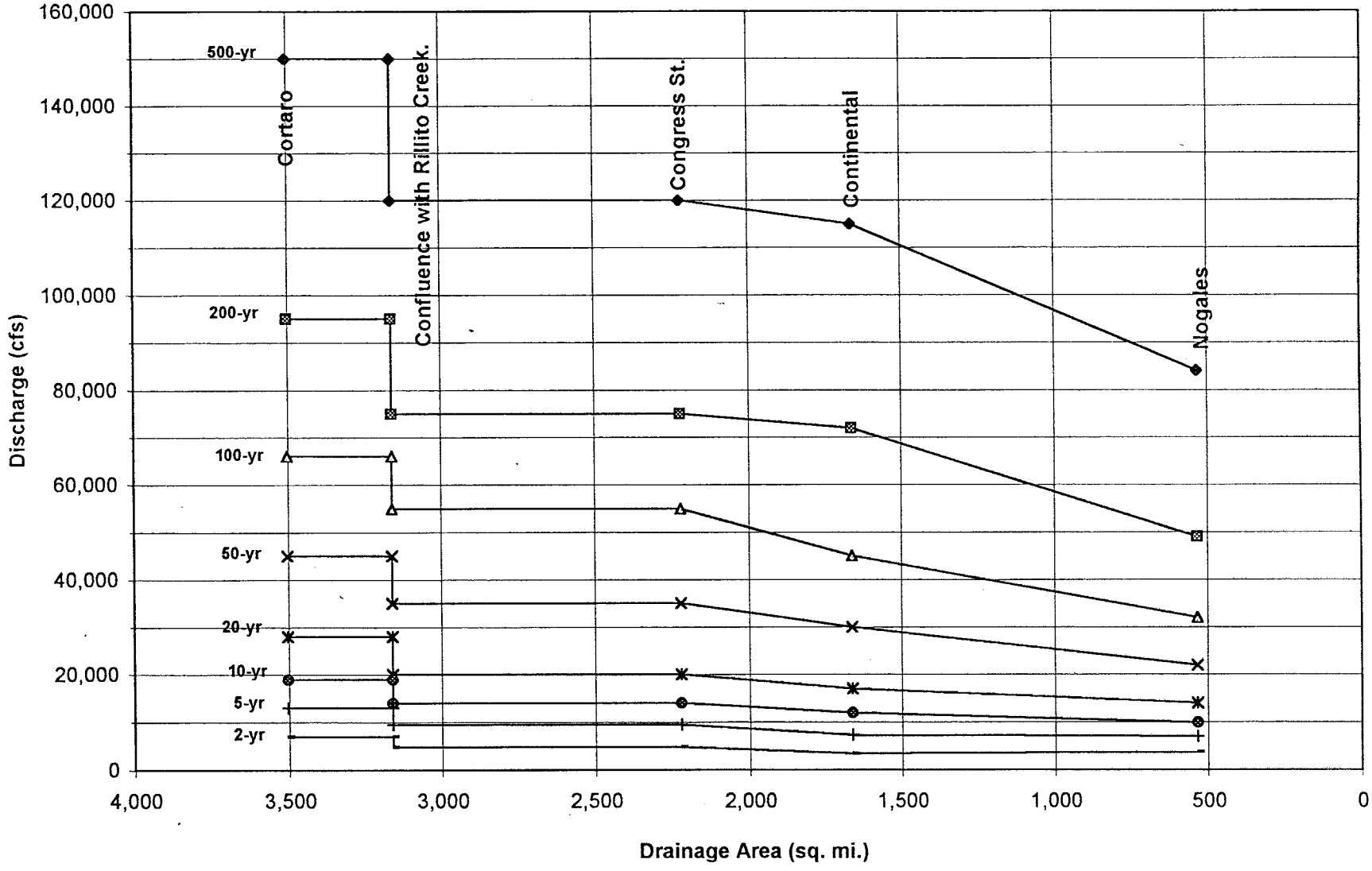


FIGURE E1-12

PLATES

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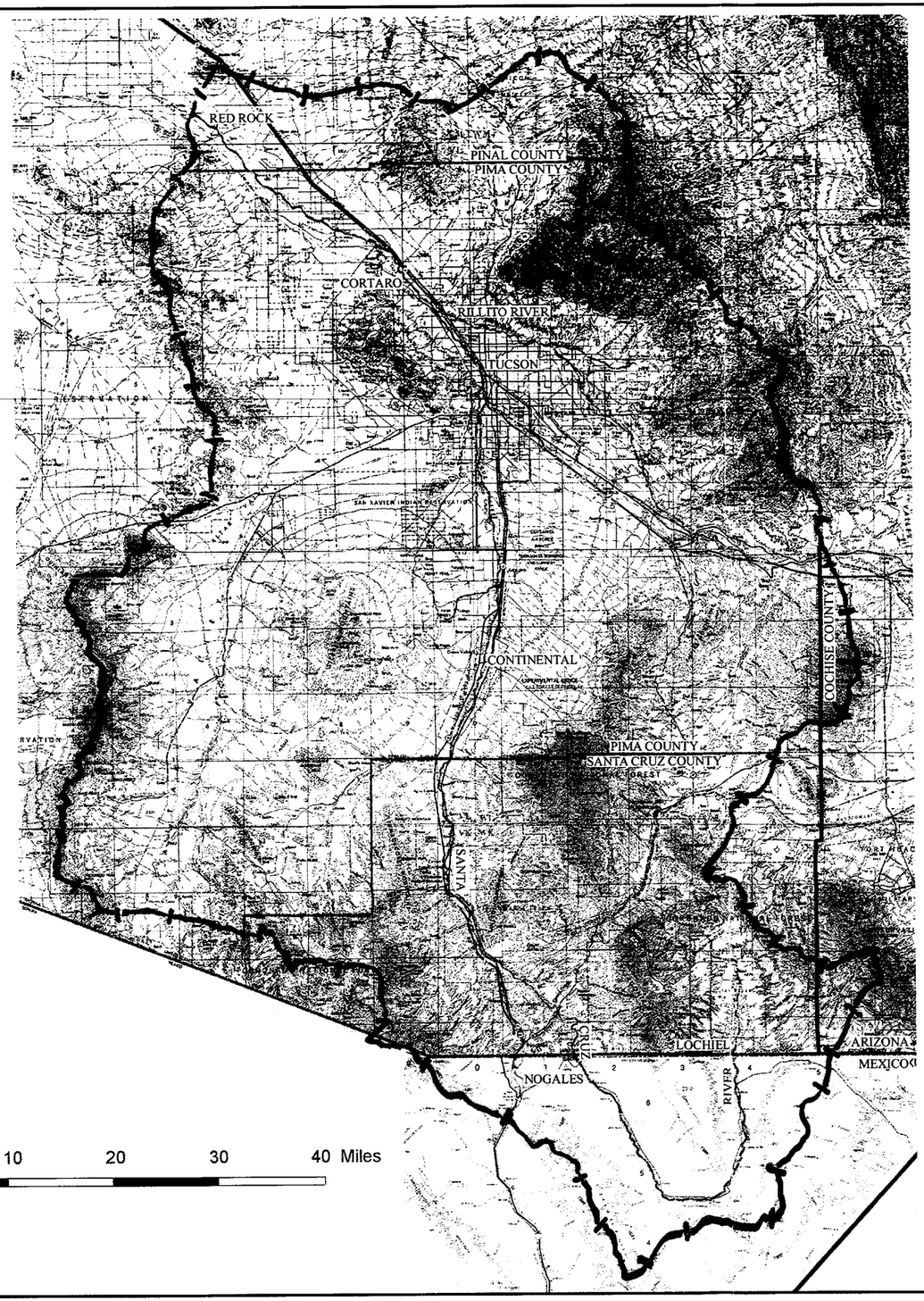
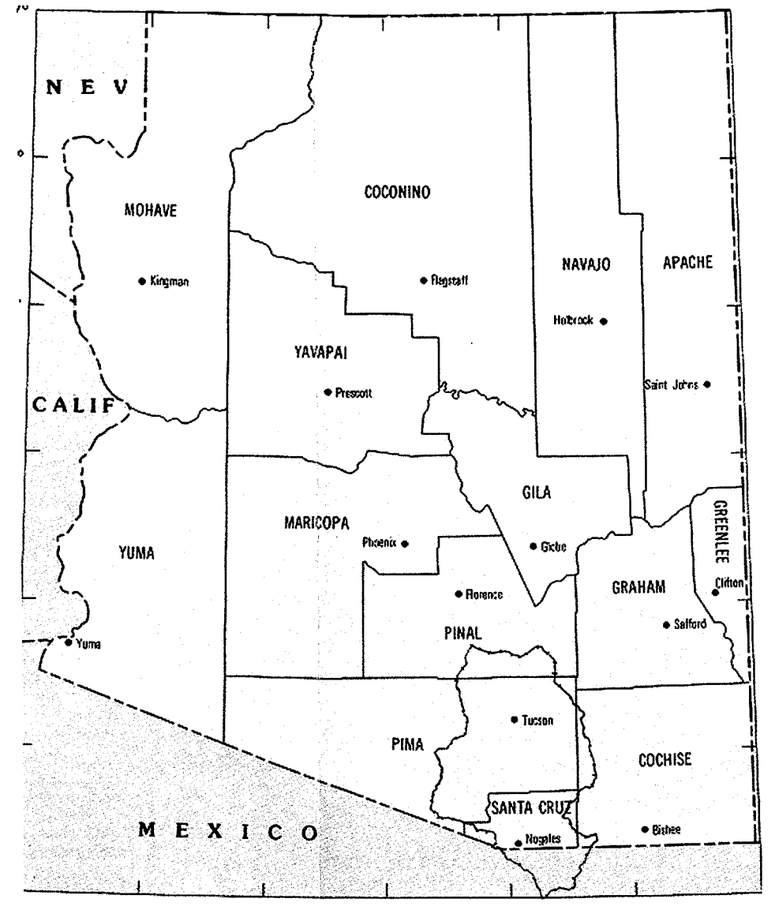
NNA/28 September 2000



N

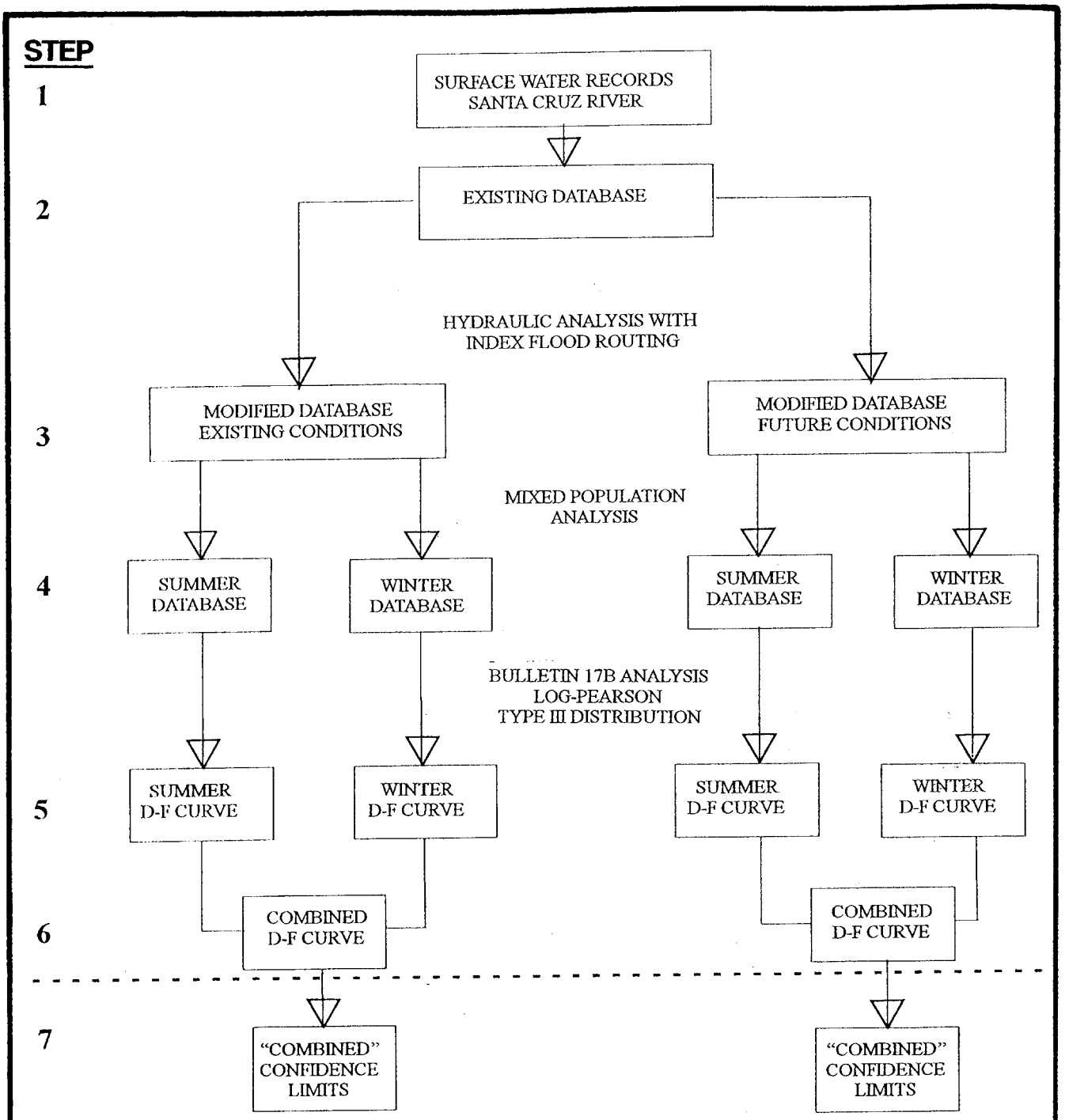
10 0 10 20 30 40 Miles



SCALE 1:100,000

GILA RIVER & TRIBUTARIES, AZ SANTA CRUZ RIVER
DRAINAGE AREA AND LOCATION MAP
U.S. ARMY CORPS OF ENGINEERS LOS ANGELES DISTRICT

PLATE E1-1



LEGEND

D-F = DISCHARGE FREQUENCY

GILA RIVER BASIN AND TRIBUTARIES
SANTA CRUZ RIVER

DRAFT PLAN
TECHNICAL APPROACH TO
DETERMINING MAINSTEM DISCHARGE
FREQUENCY RELATIONSHIPS

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

EXHIBIT E1-1

MIXED POPULATION DATA

CYCLONIC SEASON

C:\Projects\SANTCRUZ\Report\All_Graphics_.wpd
NNA/28 September 2000

MIXED POPULATION DATA: CYCLONIC MAXIMA (CFS)

Station name : Santa Cruz River at Nogales.....
Station number: 9480500.....
County..... SANTA CRUZ, AZ
Drainage area (square miles).....533

PERIOD OF RECORD.....1940 - 1997
File created on 19March1999, NNA.....
Data sources: "Hydrosphere CDROM", USGS WSP's and SLA data..NNA
BASE FLOW = 2000 CFS.....
FILE CHECKED AND EDITED 3APR99/NNA.....
REGFREQ estimated peaks merged into file on 30Apr1999.....nna
NOTE: Daily flows are entered alongside peaks, but NOT used...

Date	Peak Q	Associated Daily Maximum/Source
10081939	1,267	e 213
10291940	2	e 2
9101942	162	e 27
9251943	550	e 88-USGS
9151944	208	e 34-USGS
10281944	4	e 4
9091946	4,910	817
10011946	195	e 32-USGS
9271948	802	e 130
9141949	6,350	916
10021949	58	e 11
10041950	1	e 1.3
9221952	867	e 141
1953	0	-1
7121954	2,860	USGS (1D=637 cfs)
10081954	116	e 20
10031955	538	e 86
9071957	155	e 26
7291958	557	e 89-USGS
10051958	208	e 34
9101960	188	e 31-USGS
9121961	976	e 160
10311961	879	e 143
9151963	457	e 73
9111964	2,260	1080
10171964	227	e 37
9121966	696	e 112
10041966	285	e 46
9151968	253	e 41
9131969	654	e 105
9121970	648	104
8131971	2,370	USGS (1D=773cfs)
10251971	738	e 320
10201972	575	e 92
9221974	407	e 65
9131975	5,400	983

EXHIBIT E1-1

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9241976	84	e 15
8141977	2,430	USGS (1D=143 CFS)
10091977	31,000	13200
10211978	489	e 78
9071980	214	e 35-USGS
9031981	3,220	180
10021981	1,620	154
9231983	1,706	e 296
10021983	16,200	4860
10031984	476	e 76
10171985	606	e 97
10011986	97	e 17
10011987	84	e 15-USGS
10201988	298	e 48
9141990	7,010	USGS (1D=924 CFS)
10021990	181	e 30
9151992	168	e 28
9111993	77	e 14
8311994	1,407	e 238-USGS
9071995	195	e 32-USGS
10301995	1	e 1.2
1997	0	0

Station name : Santa Cruz River at Continental
Station number: 9482000
County..... Pima County, AZ
Drainage area (square miles)..... 1662

DATA EDITED AND FINAL RE: 6APR1999/NNA
BASE FLOW = 2000 CFS.....
1940 - 1997
REGFREQ estimated peaks merged into file on 30Apr1999.....nna
NOTE: Daily flows are entered alongside peaks, but NOT used...

Date	Peak Q	Associated Daily Maximum/Source
9121940	1,900	e 846
9181941	1	e 1Cd, Use as peak
9111942	418	e 102
9251943	283	e 50
9151944	196	e 30
10271944	2,510	SLA/USGS
9091946	4,120	SLA/USGS
10011946	5,330	
1948	601	e Missing Year
1949	1,564	e Missing Year
1950	86	e Missing Year
1951	23	e Missing Year
9211952	1,180	e 1D=145 CFS
1953	0	
7201954	8,900	SLA/USGS
10071954	4	e 3.8d, Use as peak
10041955	1	e 0.6d, Use as peak
1957	0	
7291958	2,990	USGS/SLA
1959	0	
9101960	2,580	SLA/USGS
9111961	3,190	SLA
9041962	791	e 130-SLA
9141963	6	e 6, Use as peak
9101964	14,000	rs to be a "" (yes, nna 5APR99)
1965	0	
9121966	1,014	e, 196
10051966	55	e, 15
10031967	137	e, 27-USGS
9161969	149	e, 32
9041970	2,680	SLA/USGS
8111971	3,110	SLA
10161971	211	e, 49
10191972	844	e, 142
1974	0	
9141975	1,090	e, 224-USGS
9251976	2,330	SLA/USGS
8151977	1,886	e, 394
10091977	26,500	SLA/USGS

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10211978	2,280	SLA/USGS
9071980	170	e, 30
9051981	3,350	SLA/USGS
9111982	720	e, 133
9221983	3,950	SLA/USGS
10021983	45,000	Peak of Reord.
10041984	60	e, 11
1986	494	thly record available. Peak <840
1987	111	e, Missing. Peak <340
1988	98	e, Missing. Peak <930
10201988	71	e, 12d. Peak <1200
10051989	1,790	HYDRODATA PEAK VALUES"
9011991	179	HYDRODATA PEAK VALUES"
10211991	936	e, 165-USGS
1993	0	
9031994	796	e, 158-USGS
9281995	5	e, 4.6-USGS
9031996	1,520	USGS, WSP
10261996	88	e, 17-USGS

Station name : Santa Cruz River at Tucson
Station number: 9482000
County..... Pima County, AZ
Drainage area (square miles)..... 2222

DATA EDITED AND FINAL RE: 6APR1999/NNA
ANNOTATIONS MADE ON 26MAR99.....NNA
1940 - 1997
BASE FOR PEAK DETERMINATION...(CFS).....1700
REGFREQ estimated peaks merged into file on 30Apr1999.....nna
NOTE: Daily flows are entered alongside peaks, but NOT used...

Date	Peak Q	Associated Daily Maximum/Source
9121940	1,500	e 241
9181941	645	e 153
9131942	796	e 92
9241943	1,900	358
9151944	3,070	688
10281944	1,650	e 183
9101946	2,530	369
10011946	2,960	1140
9271948	1,940	283
9151949	2,540	604
9071950	751	e 108
9071951	397	e 62
9201952	2,260	234
1953	0	0
7201954	6,730	1300
10081954	542	e 100
10041955	153	e 23
1957	0	0
7291958	6,350	1720e
10131958	185	e 33
9101960	1,780	301
10091960	2,980	491
9261962	4,980	1320
1963	0	0
9101964	13,000	6400
10161964	83	e 14
9121966	1,690	e 471
10041966	138	e 15
10031967	1,181	e 167
9151969	697	e 96
9051970	2,850	707
8121971	5,000	900
10171971	585	e 63
10191972	4,710	1410
9201974	332	e 65
9131975	2,120	432
9251976	7,100	1140
8151977	2,660	354

10101977	23,700		11,200	
10211978	4,180		1190	
9071980	1,910		297	
9051981	2,660		164	
1982	5,283		e, Missing Year	
1983	4,048		e, Missing Year	
10021983	52,700		29,000 (estimate)	
1985	307	e	40e, 1d <500 cfs	
1986	1,600	e	263e, 1d <500 cfs	
1987	739	e	102e, 1d <500 cfs	
1988	683	e	94e, 1d <500 cfs	
10201988	2,960		1010	
1990	1,690	e	451e, 1d <500 cfs	
1991	303	e	35e, 1d <500 cfs	
9131992	5,320	SLA/USGS.	1-D not published.	"Apparently" <500 cfs. This seems very doubtful.
1993	102	e	16e 1d <500 cfs	
1994	1,700	e	204e 1d <500 cfs	
1995	113	e	16e 1d <500 cfs	
9031996	9,370		965	
10261996	589		e 55	

Station name : Santa Cruz River at Cortaro
Station number: 9482000
County..... Pima County, AZ
Drainage area (square miles)..... 3503

DATA EDITED AND FINAL RE: 6APR1999/NNA
BASE FLOW 2700 CFS.....
1940 - 1997
REGFREQ estimated peaks merged into file on 30Apr1999.....nna
NOTE: Daily flows are entered alongside peaks, but NOT used...

Date	Peak Q	Associated Daily Maximum/Source
9131940	2,500	e 420
9181941	2,600	e 455
9141942	1,047	e 138
9241943	5,500	1040
9161944	4,310	1130
10281944	992	e 130
9101946	2,790	536
10011946	3,600	1190 Note: 1947 WSP indicat es peak of 3600 cfs on 1Oct for SCR@Rillito
1948	2,961	e 453e, Missing Year
1949	3,813	e 597e, Missing Year
9081950	1,006	e 116
9071951	427	e 39
9221952	2,135	e 230
1953	1	0
7201954	8,820	1980
10081954	1,092	e 119
10041955	410	e 69
1957	1	0
7291958	7,290	1660
10061958	321	e 40
9101960	1,855	e 188
10091960	4,180	741
9261962	11,200	2990
10191962	5	e 5
9101964	15,900	6900
10161964	162	e 21
9131966	4,900	1300
10041966	269	e 36
10031967	2,285	e 392
9151969	901	e 99
9061970	4,800	1680
8131971	3,450	966
10011971	1,246	207
10191972	9,000	3330
9201974	865	e 157
9131975	2,600	e 480
9251976	10,600	1170
8181977	2,515	e 243
10101977	23,000	12600

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10211978	2,500	e 419
9061980	2,000	e 294
9221981	4,310	622
9111982	6,720	2110
9221983	2,770	610
10021983	65,000	40000
10031984	475	e 54
1986	2,458	e 363e, Missing Year
1987	1,264	e 172e, Missing Year
1988	1,176	e 160e, Missing Year
1989	5,458	e 692e, Missing Year
9151990	2,690	e 520
9181991	350	e 32
9131992	2,121	e 82
10231992	318	e 41
9111994	1,420	e 115
9081995	265	e 32
9031996	16,400	4000
10271996	1,931	e 500

EXHIBIT E1-2

MIXED POPULATION DATA

MONSOONAL SEASON

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NNA/28 September 2000

MIXED POPULATION DATA: MONSOONAL MAXIMA (CFS)

Station name : Santa Cruz River at Nogales.....
Station number: 9480500.....
County..... SANTA CRUZ, AZ
Drainage area (square miles).....533

PERIOD OF RECORD.....1940 - 1997
File created on 19March1999, NNA.....
Data sources: "Hydrosphere CDROM", USGS WSP's and SLA data..NNA
BASE FLOW = 2000 CFS.....
FILE CHECKED AND EDITED 3APR99/NNA.....
REGFREQ estimated peaks merged into file on 30Apr1999.....nna
NOTE: Daily flows are entered alongside peaks, but NOT used...

Date	Peak Q		Associated Daily Maximum/Source
8041940	1,800		218 All data for Nogales:USGS/COE
7211941	1,980		167
7081942	8,200		589
7301943	5,300		376
8151944	4,700		373
7301945	3,290		207
7261946	7,200		791
8291947	2,550		225
8011948	3,410		306
8081949	5,350		331
7201950	7,210		963
8031951	3,040		653
7291952	2,330		295
7141953	3500		526
7101954	10,600		637
8201955	11,100		2680
6281956	2,530		152
8111957	1,620		350
8131958	4,000		810
8061959	2,640		364
8211960	1,950	e	219 E: PEAK; ADJUSTED
8151961	1,640	e	204
8191962	2,390		158
7101963	4,510		221
8141964	5,630		3410
9131965	1,580	e	192
8201966	4,400		1550
7271967	6,310		891
7221968	3,950		316
8021969	4,460		352
8161970	4,100		376
8201971	2,930		772
8091972	1,250	e	39
8011973	930	e	39
8011974	17,100		2320

EXHIBIT E1-2

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7221975	11,400			3500
7221976	6,700			1100
8181977	6,700			255
8011978	4,480			535
8041979	1,500	e	151	
8091980	1,950	e	166	
7291981	3,220			453
8211982	1,830	e	91d	
7221983	1,990	e	333d	
8131984	4,980			2170
8131985	1,800			249
8301986	2,440			824
8101987	3,560			555
9121988	2,940			934
8161989	663			87
9141990	7,010			924
7061991	1,470			84
8241992	9,370			2430
8281993	920	e	29 E: PEAK	
8211994	2,310			106
8191995	1,740	e	150	
7251996	1,800			183
9071997	689			55

Station name : Santa Cruz River at Continental
Station number: 9482000
County..... Pima County, AZ
Drainage area (square miles)..... 1662

DATA EDITED AND FINAL RE: 6APR1999/NNA
BASE FLOW = 2000 CFS.....
1940 - 1997
REGFREQ estimated peaks merged into file on 30Apr1999.....nna
NOTE: Daily flows are entered alongside peaks, but NOT used...

Date	Peak Q	Associated Daily Maximum/Source
8141940	12,100	sla
8091941	3,670	sla
7281942	2,700	sla
8011943	4,000	sla
8121944	4,400	sla
8091945	7,820	sla
7271946	3,860	sla Note: 1947-1951 Missing
1947	2,750	Missing Year e:COE
1948	3,050	Missing Year e:COE
1949	3,550	Missing Year e:COE
1950	5,320	Missing Year e:COE
1951	3,340	Missing Year e:COE
8151952	1,820	USGS "HYDRODATA PEAK VALUES"
7141953	4910	sla
8051954	14,600	sla
8191955	17,500	sla
7291956	3,090	sla
8211957	1690	USGS "HYDRODATA PEAK VALUES" (
8051958	5,620	sla
8171959	3900	sla
8141960	2,250	SLA/USGS
8231961	4,820	sla
8231962	870	e 19d
8061963	4,220	sla
8141964	5,290	sla
9121965	370	e 32d
8181966	4,980	SLA/USGS
7271967	3,730	sla
7221968	1,380	e 53d
8131969	1,680	USGS "HYDRODATA PEAK VALUES" (
7201970	3,720	sla
8201971	3,270	sla
7141972	3,290	sla
7141973	644	e 10d
9031974	3450	sla
9011975	3,350	sla
7121976	3,800	sla
7181977	3,290	sla
8111978	9,090	SLA/USGS

8161979	5,900	SLA/USGS
8251980	2,360	sla
7301981	3,000	e 470d USGS
8151982	2,160	sla
7211983	1,840	e 100d-USGS
7171984	4,200	USGS
7191985	3,090	SLA/USGS
7161986	840	SLA - USGS "HYDRODATA PEAK VAL
8051987	340	SLA - USGS "HYDRODATA PEAK VAL
7281988	930	SLA - USGS "HYDRODATA PEAK VAL
9031989	1,200	USGS "HYDRODATA PEAK VALUES"
1990	1,700	e Uncertain estimate. Pea
9011991	1,270	USGS "HYDRODATA PEAK VALUES"
8241992	4,120	sla
8281993	1920	e 119d
8221994	707	SLA - USGS "HYDRODATA PEAK VAL
8201995	700	e 13d-USGS
7081996	1,400	e 110d
9061997	2,140	sla

Station name : Santa Cruz River at Tucson
Station number: 9482000
County..... Pima County, AZ
Drainage area (square miles)..... 2222

DATA EDITED AND FINAL RE: 6APR1999/NNA
ANNOTATIONS MADE ON 26MAR99.....NNA
1940 - 1997
BASE FOR PEAK DETERMINATION...(CFS).....1700
REGFREQ estimated peaks merged into file on 30Apr1999.....nna
NOTE: Daily flows are entered alongside peaks, but NOT used...

Date	Peak Q		Associated Daily Maximum/Source	
8141940	11,300		4,270	sla
8141941	2,490		250	sla
8091942	1,670		536	sla
8021943	4,510		1,120	sla
8161944	6,530		2,740	sla
8101945	10,800		3,820	sla
8041946	4,260		1,340	sla
8101947	1,650	e	299	
8161948	3,860		1,130	sla
8081949	3,800		1,190	sla
7301950	9,490		2,080	sla
8021951	5,020		1,730	sla
8161952	3,820		495	sla
7151953	5900		1070	sla
7241954	9,570		1,280	sla
8031955	10,900		2,950	sla
7291956	2,610		234	sla
8311957	3050		356	sla
7291958	3,390		1,720	sla
8201959	4,420		349	sla
8101960	6,140		605	sla
8231961	16,600		4,570	sla
9051962	1,164	e	27	
8261963	4670		1580	sla
7241964	7,570		775	sla
7161965	1,190		121	sla
8191966	5,500		1,900	sla
7171967	5,860		1,600	sla
8041968	1,600	e	241	
8061969	8,710		1,120	sla
7201970	8,530		1,020	sla
8171971	8,000		300	sla
7151972	3,470		337	sla
7151973	1,562	e	62	
7081974	7,930		1,300	sla
7121975	2,480		273	sla
7121976	2,760		379	sla
7271977	1,630	e	290	

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8021978	5,030		1,040	sla
8151979	5,760		525	sla
8131980	2,760		378	sla
7271981	2,700		391	sla
1982	6,215	e	1162e Missing Year	
1983	3,922	e	530e Missing Year	
1984	3,521	e	629e Missing Year	
1985	4,283	e	875e Missing Year	
7211986	1,920	217e		
8021987	1,500	152e, d<500		
8231988	10,700		1,540	sla
1989	1,500	e	312e, d<500	
7241990	9,430		2,560	sla
8091991	2,130	247e, d<500		
8061992	5,970		2,240	sla
1993	1,600	e	404e, d<500	
7281994	4,890	490e, d<500		
1995	500	e	118e, d<500	
8221996	1,890		198	sla
8151997	743		75	sla

Station name : Santa Cruz River at Cortaro
Station number: 9482000
County..... Pima County, AZ
Drainage area (square miles)..... 3503

DATA EDITED AND FINAL RE: 6APR1999/NNA
BASE FLOW 2700 CFS.....
1940 - 1997
REGFREQ estimated peaks merged into file on 30Apr1999.....nna
NOTE: Daily flows are entered alongside peaks, but NOT used...

Date	Peak Q	Associated Daily Maximum/Source	
8141940	17,000	7,490	sla
8081941	6,000	682	sla
8091942	1,550	447	sla
9241943	4,670	1,040	sla
8161944	5,650	2,800	sla
8101945	14,000	5,210	sla
8041946	4,440	1,820	sla
8151947	7,500		
1948	5,640	MISSING	
1949	5,520	MISSING	
7301950	12,900	4,000	sla
7251951	6,820	648	sla
8141952	6,100	481	sla
7141953	10,800	1,430	sla
7241954	9,150	1,750	sla
8031955	16,600	2,670	sla
7291956	3,150	306	sla
9011957	4,400	458	sla
8121958	7,890	954	sla
8201959	8,000	647	sla
8111960	6,420	1,240	sla
8231961	14,700	5,380	sla
7311962	3,590	47	sla
8261963	7,240	1,800	sla
7241964	5,990	433	sla
7161965	2,710	201	sla
8191966	5,980	2,460	sla
7171967	5,740	2,090	sla
8201968	2,650	611	sla
8061969	8,400	1,110	sla
7201970	11,200	1,850	sla
8201971	9,100	2,240	sla
8121972	7,050	754	sla
7181973	1,500	120	sla
7081974	11,700	1,840	sla
7121975	5,200	649	sla
7091976	6,800	472	sla
9101977	4,700	413	sla
8021978	2,800	1,270	sla

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8151979	2,000	233	sla
7191980	2,650	179	sla
7251981	4,150	1,290	sla
8231982	13,300	2,490	sla
8071983	6,220	643	sla
7221984	3,540	642	sla
1985	6,110	MISSING	
1986	3,700	MISSING	
1987	3,190	MISSING	
1988	12,400	MISSING	
1989	3,100	MISSING	
7241990	27,500	6,660	sla
8091991	700	115	sla
8241992	4,670	1,710	sla
8301993	2,600	400	sla
7281994	1,000	82	sla
8111995	1,720	148	sla
8231996	2,350	250	sla
8181997	1,330	271	sla

EXHIBIT E1-3

MIXED POPULATION DATA

FRONTAL SEASON

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NNA/28 September 2000

MIXED POPULATION DATA: FRONTAL MAXIMA (CFS)

Station name : Santa Cruz River at Nogales.....
Station number: 9480500.....
County..... SANTA CRUZ, AZ
Drainage area (square miles).....533

PERIOD OF RECORD.....1940 - 1997
File created on 19March1999, NNA.....
Data sources: "Hydrosphere CDROM", USGS WSP's and SLA data..NNA
BASE FLOW = 2000 CFS.....
FILE CHECKED AND EDITED 3APR99/NNA.....
REGFREQ estimated peaks merged into file on 30Apr1999.....nna
NOTE: Daily flows are entered alongside peaks, but NOT used...

Date	Peak Q	Associated Daily Maximum/Source
2231940	236	e 146
2071941	204	e 127
12121941	56	e 37
2091943	5	e 5
2251944	43	e 29
1271945	54	e 36
3051946	5	e 5
12271946	8	e 8
2241948	5	e 5.4
1131949	378	e 229
12101949	15	e 11
4301951	10	e 9.8
1141952	21	e 15
3031953	88	e 57
3241954	680	e 402
1041955	10	e 9.7
11111955	15	e 11
1101957	6	e 6.4
3231958	146	e 92
11171958	27	e 19
1111960	2,760	1830
12301960	20	e 14
12151961	2,080	1060
2111963	3	e 2.7
11211963	6	e 6.4
11161964	26	e 18
12231965	3,840	2640
11091966	40	e 27
12201967	15,200	6160
12271968	18	e 13
12031969	17	e 12
11221970	7	e 7.1
12081971	54	e 36
2221973	2,300	1250
1974	-	0
1301975	3	2.6

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2101976	454	e 273
1231977	6	e 5.9
3021978	1,284	e 740
12181978	12,700	6010
2151980	29	e 20
3041981	5	e 5
1131982	3	e 3.0-USGS
2041983	6,410	3450
1061984	432	e 260
12271984	7,080	3400
2091986	259	e 159
2261987	58	e 38
12181987	372	e 225
1041989	45	e 30
1031990	2	e 1.6
3021991	3,640	2020
4031992	566	e 337
1181993	8,800	5880
2091994	6	e 6.4
11121994	1,940	628
11141995	4	e 3.7
3011997	105	e 67

Station name : Santa Cruz River at Continental
Station number: 9482000
County..... Pima County, AZ
Drainage area (square miles)..... 1662

DATA EDITED AND FINAL RE: 6APR1999/NNA
BASE FLOW = 2000 CFS.....
1940 - 1997
REGFREQ estimated peaks merged into file on 30Apr1999.....nna
NOTE: Daily flows are entered alongside peaks, but NOT used...

Date	Peak Q	Associated Daily Maximum/Source
1940	56	e
1011941	96	e 80
1942	40	* Peak Estimated manually
1943	12	* Peak Estimated manually
1944	22	* Peak Estimated manually
11061944	2	e 2d**use as peak also**
1946	98	* Peak Estimated manually
1947	14	* Peak Estimated manually
1948	3	* Peak Estimated manually
1949	104	e
1950	8	* Peak Estimated manually
1951	12	* Peak Estimated manually
1952	19	* Peak Estimated manually
2041953	1	e O.5d**use as peak also**
3241954	238	e 192
1955	6	* Peak Estimated manually
1956	8	* Peak Estimated manually
1957	4	* Peak Estimated manually
1958	81	* Peak Estimated manually
1959	14	* Peak Estimated manually
1121960	3,740	
1961	13	* Peak Estimated manually
1251962	2,480	
1963	14	* Peak Estimated manually
11211963	156	e 128
1965	18	* Peak Estimated manually
12231965	5,990	
1967	20	* Peak Estimated manually
12201967	18,000	
1969	35	* Peak Estimated manually
12031969	3	e 3.1d**use as peak also**
1971	7	* Peak Estimated manually
12131971	0	e 0.3d**use as peak also**
3141973	2,130	
1974	1	Peak Estimated manually set to
1975	23	* Peak Estimated manually
1221976	35	e 25
12291976	0	e 0.4d**use as peak also**
3021978	1,451	1030d (NOTE: estimated flow

12181978	16,000	
2141980	19	e 19
3021981	31	e 31
1982	2	* Peak Estimated manually
2041983	4,800	SLA/USGS
1081984	299	e 241
12281984	11,600	Note: record missing for 1986
1986	59	e 49e
1987	9	e 8e
1988	92	e 75e
12261988	9	e 8.6**use as peak also**
1990	1	0-1 REFER TO NOTE FOR ST
1991	1,200	05e -1 REFER TO NOTE FOR
3291992	574	e 452
1993	32400	14800d 2nd Greatest Peak of
1994	3	* Peak Estimated manually
1061995	2,350	SGS WSP (No daily record ava
1996	2	* Peak Estimated manually
1997	124	* Peak Estimated manually

Station name : Santa Cruz River at Tucson
Station number: 9482000
County..... Pima County, AZ
Drainage area (square miles)..... 2222

DATA EDITED AND FINAL RE: 6APR1999/NNA
ANNOTATIONS MADE ON 26MAR99.....NNA
1940 - 1997
BASE FOR PEAK DETERMINATION...(CFS).....1700
REGFREQ estimated peaks merged into file on 30Apr1999.....nna
NOTE: Daily flows are entered alongside peaks, but NOT used...

Date	Peak Q	Associated Daily Maximum/Source
2021940	134	e 134
1381941	251	e 251
12111941	24	e 24
3051943	19	e 19
1944	-	0e
11241944	173	e 173
1061946	190	e 190
3181947	19	e 19
3181948	1	e 1
2161949	182	e 17
1950	-	0e
4141951	14	e 14
12061951	17	e 17
11161952	104	e 104
3241954	415	e 58
1031955	3	e 2.9
1281956	0	e 0.4
1081957	3	e 2.6
2051958	16	e 16
11171958	1	e 0.5
1121960	3,220	2180
1271961	6	6
1251962	1,820	721
2101963	25	e 25
11211963	260	e 260
12281964	10	e 10
12231965	4,830	3680
4121967	1	e 0.8
12201967	16,100	7750
11141968	52	e 52
12031969	86	e 86
1971	-	0
12041971	103	e 103
3141973	1,890	1240
3091974	1	e 1.2
11081974	43	e 43
12231975	69	e 15
1221977	136	e 136

3021978	1,440	e	1090 (note: the flow 1090 <	< 1700 cfs)
12191978	13,500		9840	
2141980	355		e 355	
3031981	254		e 254	
1982	-		e 0e, Missing Year	
1983	3,831		e 2086e, Missing Year	
1984	413		e 364e, Missing Year	
12281984	10,000		4743e Note: 1986-1987 flow <	0 and 1500, respectively. No data available.
1986	124		e 124e	
1987	24		e 24e	
1988	181	e	179e Apparently daily flow	cfs.
1989	22	e	22e Apparently daily flow	cfs.
1990	-		e 0e	
1991	877	e	495e Apparently daily flow	cfs.
1992	651	e	495e Apparently daily flow	cfs.
1191993	37,400		24700	
1994	-		e 0e	
2161995	576		USGS HYDRODATA "INTERN	..NO DAILY FLOW > 500CFS.
1996	-		e 0 USGS	
4101997	142	e	142 (Refer to Monsoonal not	peak flow might have been 743 cfs)

Station name : Santa Cruz River at Cortaro
Station number: 9482000
County..... Pima County, AZ
Drainage area (square miles)..... 3503

DATA EDITED AND FINAL RE: 6APR1999/NNA
BASE FLOW 2700 CFS.....
1940 - 1997
REGFREQ estimated peaks merged into file on 30Apr1999.....nna
NOTE: Daily flows are entered alongside peaks, but NOT used...

Date	Peak Q	Associated Daily Maximum/Source
2021940	594	e 164
12311940	7,800	4000
12121941	258	e 130
3051943	233	e 167
11181943	1	0.7
11251944	255	e 82
1061946	299	e 135
11241946	39	e 20
1948	34	e 30e-Missing Year
1949	1,529	e 716e-Missing Year
1950	27	e 27e-Missing Year
4201951	7	e 6.6
3191952	395	e 358
11161952	456	e 189
3231954	5,060	2300
1041955	33	e 22
1291956	54	e 52
1091957	2,750	819
3221958	711	e 711
1959	3	e 3.2
1121960	6,220	4300
1121961	154	e 123
1251962	2,600	e 918
2171963	842	e 842
11221963	283	e 103
12291964	275	e 174
12221965	16,800	8460
11081966	1	e 1
12211967	15,800	8760
12151968	189	e 83
12031969	517	e 284
4081971	65	62
12271971	374	e 108
2221973	3,680	2350
11161973	61	e 61
11081974	171	e 115
12241975	157	e 31
1221977	176	e 72
3021978	7,820	5010

c:\projects\santcruz\report\tables\seasonaldata_cyclonic.xls

12181978	18,800		14,500
2141980	1,437		e 749
3031981	603		e 279
3131982	149		e 149
2041983	7,620		4020
1101984	933		e 244
12281984	13,000		7280
1986	1,068	e	414e-Missing Year
1987	308	e	137e-Missing Year
1988	1,377	e	529e-Missing Year
1989	294		e -1
1990	26		e -1
3011991	11,600		580
1131992	2,595		e 1000
1191993	40,300		25,000
2141994	49		e 41
2151995	6,175		3250
11051995	28		e 24
1031997	257		e 90

EXHIBIT E1-4

HEC-FFA INPUT FILES

CYCLONIC SEASON

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TT US GEOLOGICAL SURVEY
TT PEAK FLOW DATA - CYCLONIC ANNUAL MAXIMA...........NogCycH.DAT

TT Station name  : Santa Cruz River at Nogales . . . . . . . . . . . . . . .
TT Station number: 9480500.....................................

TT County..................................... SANTA CRUZ, AZ

TT Drainage area (square miles)..............................533

TT NNA/MARCH 1999/INITIAL EVALUATION OF Seasonal ANNUAL MAXIMA
TT PERIOD OF RECORD.................................1940 - 1997
TT File created on 19March1999, NNA............................

TT Data sources: "Hydrosphere CDROM", USGS WSP's and SLA data..NNA
TT BASE FLOW = 2000 CFS.......................................
TT FILE CHECKED AND EDITED 3APR99/NNA.........................
TT REGFREQ estimated peaks merged into file on 30Apr1999......nna
TT NOTE: Daily flows are entered alongside peaks, but NOT used...
J1     2
ID SANTA CRUZ RIVER AT NOGALES DA=533 SQ MI,  #9480500
ZW /SANTACRUZ/NOGALES/FREQ-FLOW/1942-1997/CYCLONIC/PEAK/
HP  PLTNOGC.PCL                        3       0       0     533 SQ.MI.
HP W/ HISTORIC CRITERION:
HP Oct 1977 > 1892
HP No Low Outliers Specified
HP SANTA CRUZ RIVER-NOGALES
HP CYCLONIC ANNUAL PEAKS
HP MSE Adjusted
SI  1892           310005
GS          .083
QR      10081939    1267e    213
QR      10291940       2e      2
QR      09101942     162e     27
QR      09251943     550e     88Cd-USGS
QR      09151944     208e     34Cd-USGS
QR      10281944       4e      4
QR      09091946    4910     817
QR      10011946     195e     32Cd-USGS
QR      09271948     802e    130
QR      09141949    6350     916
QR      10021949      58e     11
QR      10041950     1.3e    1.3
QR      09221952     867e    141
QR          1953       0      -1
QR      07121954    2860C-USGS (1D=637 cfs)
QR      10081954     116e     20
QR      10031955     538e     86
QR      09071957     155e     26
QR      07291958     557e     89Cd-USGS
QR      10051958     208e     34
QR      09101960     188e     31Cd-USGS
QR      09121961     976e    160
QR      10311961     879e    143
QR      09151963     457e     73
QR      09111964    2260    1080
QR      10171964     227e     37
QR      09121966     696e    112
QR      10041966     285e     46
QR      09151968     253e     41
QR      09131969     654e    105
QR      09121970     648     104
QR      08131971    2370C-USGS (1D=773cfs)
```

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QR      10251971     738e    320
QR      10201972     575e     92
QR      09221974     407e     65
QR      09131975    5400     983
QR      09241976      84e     15
QR      08141977    2430C-USGS (1D=143 CFS)
QR      10091977   31000   13200
QR      10211978     489e     78
QR      09071980     214e     35Cd-USGS
QR      09031981    3220     180
QR      10021981    1620     154
QR      09231983    1706e    296
QR      10021983   16200    4860
QR      10031984     476e     76
QR      10171985     606e     97
QR      10011986      97e     17
QR      10011987      84e     15Cd-USGS
QR      10201988     298e     48
QR      09141990    7010C-USGS (1D=924 CFS)
QR      10021990     181e     30
QR      09151992     168e     28
QR      09111993      77e     14
QR      08311994    1407e    238Cd-USGS
QR      09071995     195e     32Cd-USGS
QR      10301995     1.2e    1.2
QR          1997       0       0
ED
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TT US GEOLOGICAL SURVEY
TT PEAK FLOW DATA seasonal analysis (mixed population)

TT Station name  : Santa Cruz River at Continental
TT Station number: 9482000
TT County..................................... Pima County, AZ

TT Drainage area (square miles)................. 1662

TT NNA/NOVEMBER 1998/INITIAL EVALUATION OF SEASONAL ANNUAL MAXIMA
TT DATA EDITED AND FINAL RE: 6APR1999/NNA
TT 1940 - 1997
TT REGFREQ estimated peaks merged into file on 30Apr1999......nna
TT NOTE: Daily flows are entered alongside peaks, but NOT used...
TT Note also: "low flow" adjustment used to de-emphasize very small
peaks...nna/20Oct1999...SI-card
TT "Trial" Skew adjustment
J1     2
ID SANTA CRUZ RIVER AT CONTINENTAL, DA=1662 SQ MI,  #9482000
ZW /SANTACRUZ/CONTINENTAL/FREQ-FLOW/1940-1994/CYCLONIC SEASON/PEAK/
HP  PLTContC.PCL                        3       0       0    1662 SQ.MI.
HP W/ HISTORIC CRITERION:
HP Oct 1983 > 1892
HP SANTA CRUZ RIVER-CONTINENTAL
HP CYCLONIC ANNUAL PEAKS
HP Low Flows < 50 cfs
HP MSE, Skew Adj
SI  1892           45000      50
GS  Cont    .058     -.2
QR      09121940    1900e    846Cd
QR      09181941       1e      1Cd, Use as peak
QR      09111942     418e    102Cd
QR      09251943     283e     50Cd
QR      09151944     196e     30Cd
QR      10271944    2510C-SLA/USGS
QR      09091946    4120C-SLA/USGS
QR      10011946    5330C
QR          1948     601e Missing Year
QR          1949    1564e Missing Year
QR          1950      86e Missing Year
QR          1951      23e Missing Year
QR      09211952    1180e 1D=145 CFS
QR          1953       0
QR      07201954    8900C-SLA/USGS
QR      10071954       4e 3.8d, Use as peak
QR      10041955     0.6e 0.6d, Use as peak
QR          1957       0
QR      07291958    2990C-USGS/SLA
QR          1959       0
QR      09101960    2580C-SLA/USGS
QR      09111961    3190C-SLA
QR      09041962     791e 130d-SLA
QR      09141963       6e 6d, Use as peak
QR      09101964   14000C Check: Based upon duration, appears to be a "C" (yes, nna 5APR99)
QR          1965       0
QR      09121966    1014e, 196d
QR      10051966      55e, 15d
QR      10031967     137e, 27d-USGS
QR      09161969     149e, 32d
QR      09041970    2680C-SLA/USGS
QR      08111971    3110C-SLA
QR      10161971     211e, 49d
QR      10191972     844e, 142d
```

```
QR          1974       0
QR      09141975    1090e, 224d-USGS
QR      09251976    2330C-SLA/USGS
QR      08151977    1886e, 394d
QR      10091977   26500C-SLA/USGS
QR      10211978    2280C-SLA/USGS
QR      09071980     170e, 30d
QR      09051981    3350C-SLA/USGS
QR      09111982     720e, 133d
QR      09221983    3950C-SLA/USGS
QR      10021983   45000C Peak of Record.
QR      10041984      60e, 11d
QR          1986     494e, No monthly record available. Peak <840
QR          1987     111e, Missing. Peak <340
QR          1988      98e, Missing. Peak <930
QR      10201988      71e, 12d. Peak <1200
QR      10051989    1790C SLA - USGS "HYDRODATA PEAK VALUES"
QR      09011991     179   No monthly record available...flow <1270Cfs!!SLA - USGS "HYDRODATA
PEAK VALUES"
QR      10211991     936e, 165d-USGS
QR          1993       0
QR      09031994     796e, 158d-USGS
QR      09281995       5e, 4.6d-USGS
QR      09031996    1520C-USGS, WSP
QR      10261996      88e, 17d-USGS
ED
```

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TT US GEOLOGICAL SURVEY
TT PEAK FLOW DATA seasonal analysis (mixed population)

TT Station name  : Santa Cruz River at Tucson
TT Station number: 9482000
TT County..................................... Pima County, AZ

TT Drainage area (square miles)................. 2222

TT NNA/NOVEMBER 1998/INITIAL EVALUATION OF SEASONAL ANNUAL MAXIMA
TT DATA EDITED AND FINAL RE: 6APR1999/NNA
TT ANNOTATIONS MADE ON 26MAR99.............................NNA
TT 1940 - 1997
TT BASE FOR PEAK DETERMINATION...(CFS).....................1700
TT REGFREQ estimated peaks merged into file on 30Apr1999......nna
TT NOTE: Daily flows are entered alongside peaks, but NOT used...
J1     2       3
ID SANTA CRUZ RIVER AT TUCSON, DA=2222 SQ MI,  #9482500
ZW /SANTACRUZ/TUCSON/FREQ-FLOW/1940-1997/CYCLONIC SEASON/PEAK/
HP  PLTTucC.PCL                        3       0       0    2222 SQ.MI.
HP W/ HISTORIC CRITERION:
HP Oct 1983 > 1892
HP No Low Flows Specified
HP SANTA CRUZ RIVER-TUCSON
HP CYCLONIC ANNUAL PEAKS
HP Adjusted MSE, Skew
SI  1892           52700
GS          .063      .1
QR      09121940    1500e    241
QR      09181941     645e    153
QR      09131942     796e     92
QR      09241943    1900     358
QR      09151944    3070     688
QR      10281944    1650e    183
QR      09101946    2530     369
QR      10011946    2960    1140
QR      09271948    1940     283
QR      09151949    2540     604
QR      09071950     751e    108
QR      09071951     397e     62
QR      09201952    2260     234
QR          1953       0       0
QR      07201954    6730    1300
QR      10081954     542e    100
QR      10041955     153e     23
QR          1957       0       0
QR      07291958    6350    1720e
QR      10131958     185e     33
QR      09101960    1780     301
QR      10091960    2980     491
QR      09261962    4980    1320
QR          1963       0       0
QR      09101964   13000    6400
QR      10161964      83e     14
QR      09121966    1690e    471
QR      10041966     138e     15
QR      10031967    1181e    167
QR      09151969     697e     96
QR      09051970    2850     707
QR      08121971    5000     900
QR      10171971     585e     63
QR      10191972    4710    1410
QR      09201974     332e     65
```

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QR      09131975    2120     432
QR      09251976    7100    1140
QR      08151977    2660     354
QR      10101977   23700  11,200
QR      10211978    4180    1190
QR      09071980    1910     297
QR      09051981    2660     164
QR          1982    5283e, Missing Year
QR          1983    4048e, Missing Year
QR      10021983   52700  29,000 (estimate)
QR          1985     307e     40e, 1d <500 cfs
QR          1986    1600e    263e, 1d <500 cfs
QR          1987     739e    102e, 1d <500 cfs
QR          1988     683e     94e, 1d <500 cfs
QR      10201988    2960    1010
QR          1990    1690e    451e, 1d <500 cfs
QR          1991     303e     35e, 1d <500 cfs
QR      09131992    5320C-SLA/USGS.  1-D not published.  "Apparently" <500 cfs.  This seems very
doubtful.
QR          1993     102e     16e 1d <500 cfs
QR          1994    1700e    204e 1d <500 cfs
QR          1995     113e     16e 1d <500 cfs
QR      09031996    9370     965
QR      10261996     589e     55
ED
```

```
TT US GEOLOGICAL SURVEY
TT PEAK FLOW DATA seasonal analysis (mixed population)...........CortCycH.dat

TT Station name  : Santa Cruz River at Cortaro
TT Station number: 9482000
TT County..................................... Pima County, AZ

TT Drainage area (square miles)................. 3503

TT NNA/NOVEMBER 1998/INITIAL EVALUATION OF SEASONAL ANNUAL MAXIMA
TT DATA EDITED AND FINAL RE: 6APR1999/NNA
TT BASE FLOW 2700 CFS.......................................................
TT 1940 - 1997
TT REGFREQ estimated peaks merged into file on 30Apr1999......nna
TT NOTE: Daily flows are entered alongside peaks, but NOT used...
J1     2       3
ID SANTA CRUZ RIVER AT CORTARO, DA=3503 SQ MI,  #9486500
ZW /SANTACRUZ/CORTARO/FREQ-FLOW/1940-1997/CYCLONIC SEASON/PEAK/
HP  PLTCortC.PCL                        3       0       0    3503 SQ.MI.
HP W/ HISTORIC CRITERION:
HP Oct 1977 > 1892
HP Low Flows < 6 cfs
HP SANTA CRUZ RIVER-CORTARO
HP CYCLONIC ANNUAL PEAKS
SI  1892           65000       6
GS          .053      .2
QR      09131940    2500e    420
QR      09181941    2600e    455
QR      09141942    1047e    138
QR      09241943    5500    1040
QR      09161944    4310    1130
QR      10281944     992e    130
QR      09101946    2790     536
QR      10011946    3600    1190 Note: 1947 WSP indicates peak of 3600 cfs on 1Oct for
SCR@Rillito
QR          1948    2961e    453e, Missing Year
QR          1949    3813e    597e, Missing Year
QR      09081950    1006e    116
QR      09071951     427e     39
QR      09221952    2135e    230
QR      07201954    8820    1980
QR      10081954    1092e    119
QR      10041955     410e     69
QR      07291958    7290    1660
QR      10061958     321e     40
QR      09101960    1855e    188
QR      10091960    4180     741
QR      09261962   11200    2990
QR      10191962       5e       5
QR      09101964   15900    6900
QR      10161964     162e     21
QR      09131966    4900    1300
QR      10041966     269e     36
QR      10031967    2285e    392
QR      09151969     901e     99
QR      09061970    4800    1680
QR      08131971    3450     966
QR      10011971    1246     207
QR      10191972    9000    3330
QR      09201974     865e    157
QR      09131975    2600e    480
QR      09251976   10600    1170
QR      08181977    2515e    243
```

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QR      10101977   23000   12600
QR      10211978    2500e    419
QR      09061980    2000e    294
QR      09221981    4310     622
QR      09111982    6720    2110
QR      09221983    2770     610
QR      10021983   65000   40000
QR      10031984     475e     54
QR          1986    2458e    363e, Missing Year
QR          1987    1264e    172e, Missing Year
QR          1988    1176e    160e, Missing Year
QR          1989    5458e    692e, Missing Year
QR      09151990    2690e    520
QR      09181991     350e     32
QR      09131992    2121e     82
QR      10231992     318e     41
QR      09111994    1420e    115
QR      09081995     265e     32
QR      09031996   16400    4000
QR      10271996    1931e    500
ED
* QR          1953       0       0
* QR          1957       0       0
```

EXHIBIT E1-5

HEC-FFA INPUT FILES

MONSOONAL SEASON

C:\Projects\SANTCRUZ\Report\All_Graphics_.wpd
NNA/28 September 2000

```
TT US GEOLOGICAL SURVEY
TT PEAK FLOW DATA - MONSOONAL ANNUAL MAXIMA...........NogMnsn1.DAT

TT Station name  : Santa Cruz River at Nogales..............
TT Station number: 9480500.....................................

TT County..................................... SANTA CRUZ, AZ

TT Drainage area (square miles)..............................533

TT NNA/MARCH 1999/INITIAL EVALUATION OF Seasonal ANNUAL MAXIMA
TT PERIOD OF RECORD.................................1940 - 1997
TT File created on 19March1999, NNA............................

TT Data sources: "Hydrosphere CDROM", USGS WSP's and SLA data..NNA
TT BASE FLOW = 2000 CFS........................................
TT NOTE: Daily flows are entered alongside peaks, but NOT used...
TT REGFREQ estimated peaks merged into file on 29Apr1999......nna
J1     2
ID SANTA CRUZ RIVER AT NOGALES DA=533 SQ MI,  #9480500
ZW /SANTACRUZ/NOGALES/FREQ-FLOW/1942-1997/Monsoonal/PEAK/
HP  PLTNOGM.PCL                        3       0       0     533 SQ.MI.
HP W/O HISTORIC CRITERION
HP SANTA CRUZ RIVER-NOGALES
HP MONSOONAL ANNUAL PEAKS
HP Adjusted MSE
GS          .092     -.2
QR      08041940    1800       218
QR      07211941    1980       167
QR      07081942    8200       589
QR      07301943    5300       376
QR      08151944    4700       373
QR      07301945    3290       207
QR      07261946    7200       791
QR      08291947    2550       225
QR      08011948    3410       306 (NOTE: ERROR FOUND. SHOULD HAVE USED VALUES INDICATED HERE)
QR      08081949    5350       331
QR      07201950    7210       963
QR      08031951    3040       653
QR      07291952    2330       295
QR      07141953    3500       526
QR      07101954   10600       637
QR      08201955   11100      2680
QR      06281956    2530       152
QR      08111957    1620       350
QR      08131958    4000       810
QR      08061959    2640       364
QR      08211960    1950e      219 E: PEAK; ADJUSTED
QR      08151961    1640e      204
QR      08191962    2390       158
QR      07101963    4510       221
QR      08141964    5630      3410
QR      09131965    1580e      192
QR      08201966    4400      1550
QR      07271967    6310       891
QR      07221968    3950       316
QR      08021969    4460       352
QR      08161970    4100       376
QR      08201971    2930       772
QR      08091972    1250e       39
QR      08011973     930e       39
QR      08011974   17100      2320
QR      07221975   11400      3500
```

QR	07221976	6700	1100	
QR	08181977	6700	255	
QR	08011978	4480	535	
QR	08041979	1500e	151	
QR	08091980	1950e	166	
QR	07291981	3220M	453	
QR	08211982	1830e	91d	
QR	07221983	1990e	333d	
QR	08131984	4980	2170	
QR	08131985	1800	249	
QR	08301986	2440	824	
QR	08101987	3560	555	
QR	09121988	2940	934	
QR	08161989	663	87	
QR	09141990	7010	924	
QR	07061991	1470	84	
QR	08241992	9370	2430	
QR	08281993	920e	29	E: PEAK
QR	08211994	2310	106	
QR	08191995	1740e	150	
QR	07251996	1800	183	
QR	09071997	689	55	
ED				

```
TT US GEOLOGICAL SURVEY
TT PEAK FLOW DATA seasonal analysis (mixed population)

TT Station name  : Santa Cruz River at Continental
TT Station number: 9482000
TT County..................................... Pima County, AZ

TT Drainage area (square miles)................. 1662

TT NNA/NOVEMBER 1998/INITIAL EVALUATION OF SEASONAL ANNUAL MAXIMA
TT DATA EDITED AND FINAL RE: 6APR1999/NNA
TT 1940 - 1997
TT REGFREQ estimated peaks merged into file on 29Apr1999......nna
TT NOTE: Daily flows are entered alongside peaks, but NOT used...
TT Skew adjusted for consistency w/ u/s and d/s stations
TT 15Oct1999/nna
J1     2
ID SANTA CRUZ RIVER AT CONTINENTAL, DA=1662 SQ MI,  #9482000
ZW /SANTACRUZ/CONTINENTAL/FREQ-FLOW/1940-1994/MONSOONAL SEASON/PEAK/
HP  PLTCONTM.PCL                        3       0       0    1626 SQ.MI.
HP W/O HISTORIC CRITERION
HP SANTA CRUZ RIVER-CONTINENTAL
HP Adjusted MSE, SKEW
HP MONSOON PEAKS
GS  Cont    .115     .1
QR      08141940   12100M
QR      08091941    3670M
QR      07281942    2700M
QR      08011943    4000M
QR      08121944    4400M
QR      08091945    7820M
QR      07271946    3860M-sla  Note: 1947-1951 Missing
QR          1947    2750 Missing Year
QR          1948    3050 Missing Year
QR          1949    3550 Missing Year
QR          1950    5320 Missing Year
QR          1951    3340 Missing Year
QR      08151952    1820M-USGS "HYDRODATA PEAK VALUES" (Note: 1d=311 CFS)
QR      07141953    4910M
QR      08051954   14600M
QR      08191955   17500M
QR      07291956    3090M
QR      08211957    1690M-USGS "HYDRODATA PEAK VALUES" (Note: 1d=53 CFS)
QR      08051958    5620M
QR      08171959    3900M
QR      08141960    2250M-SLA/USGS
QR      08231961    4820M
QR      08231962     870e    19d
QR      08061963    4220M
QR      08141964    5290M
QR      09121965     370e    32d
QR      08181966    4980M-SLA/USGS
QR      07271967    3730M
QR      07221968    1380e    53d
QR      08131969    1680M-USGS "HYDRODATA PEAK VALUES" (Note: 1d=341 CFS)
QR      07201970    3720M
QR      08201971    3270M
QR      07141972    3290M
QR      07141973     644e     10d
QR      09031974    3450M
QR      09011975    3350M
QR      07121976    3800M
QR      07181977    3290M
```

```
QR      08111978    9090M-SLA/USGS
QR      08161979    5900M-SLA/USGS
QR      08251980    2360M
QR      07301981    3000e    470d USGS
QR      08151982    2160M
QR      07211983    1840e    100d-USGS
QR      07171984    4200M-USGS
QR      07191985    3090M-SLA/USGS
QR      07161986     840M SLA - USGS "HYDRODATA PEAK VALUES"
QR      08051987     340M SLA - USGS "HYDRODATA PEAK VALUES"
QR      07281988     930M SLA - USGS "HYDRODATA PEAK VALUES" Note: Data for 1989-1991 is
crest-stage only, "???=-1"
QR      09031989    1200M-USGS "HYDRODATA PEAK VALUES"  Note for below: 1990 peak occurred in
October 1989.  Q must be <1790 cfs.
QR          1990    1700e        Uncertain estimate. Peak <1790.
QR      09011991    1270M-USGS "HYDRODATA PEAK VALUES"
QR      08241992    4120M
QR      08281993    1920e    119d
QR      08221994     707M SLA - USGS "HYDRODATA PEAK VALUES" (Note: 1d=89 CFS)
QR      08201995     700e     13d-USGS
QR      07081996    1400e    110d
QR      09061997    2140M
ED
```

```
TT US GEOLOGICAL SURVEY
TT PEAK FLOW DATA seasonal analysis (mixed population)

TT Station name  : Santa Cruz River at Tucson
TT Station number: 9482000
TT County..................................... Pima County, AZ

TT Drainage area (square miles)................. 2222

TT NNA/NOVEMBER 1998/INITIAL EVALUATION OF SEASONAL ANNUAL MAXIMA
TT DATA EDITED AND FINAL RE: 11FEB1999/NNA
TT 1940 - 1997
TT BASE FOR PEAK DETERMINATION...(CFS).......................1700
TT REGFREQ estimated peaks merged into file on 30Apr1999......nna
TT NOTE: Daily flows are entered alongside peaks, but NOT used...
J1     2
ID SANTA CRUZ RIVER AT TUCSON, DA=2222 SQ MI,  #9482000
ZW /SANTACRUZ/TUCSON/FREQ-FLOW/1940-1997/MONSOONAL SEASON/PEAK/
HP  PLOTTUCM.PCL                        3       0       0     2222 SQ MI
HP  PLOTTUCM (MONSOONAL)
HP W/O HISTORIC CRITERION
HP SANTA CRUZ RIVER-TUCSON
HP MONSOONAL PEAKS
HP Adjusted MSE
GS          .115
QR      08141940   11300     4270
QR      08141941    2490      250
QR      08091942    1670      536
QR      08021943    4510     1120
QR      08161944    6530     2740
QR      08101945   10800     3820
QR      08041946    4260     1340
QR      08101947    1650e     299
QR      08161948    3860     1130
QR      08081949    3800     1190
QR      07301950    9490     2080
QR      08021951    5020     1730
QR      08161952    3820      495
QR      07151953    5900     1070
QR      07241954    9570     1280
QR      08031955   10900     2950
QR      07291956    2610      234
QR      08311957    3050      356
QR      07291958    3390     1720
QR      08201959    4420      349
QR      08101960    6140      605
QR      08231961   16600     4570
QR      09051962    1164e      27
QR      08261963    4670     1580
QR      07241964    7570      775
QR      07161965    1190      121
QR      08191966    5500     1900
QR      07171967    5860     1600
QR      08041968    1600e     241
QR      08061969    8710     1120
QR      07201970    8530     1020
QR      08171971    8000      300
QR      07151972    3470      337
QR      07151973    1562e      62
QR      07081974    7930     1300
QR      07121975    2480      273
QR      07121976    2760      379
QR      07271977    1630e     290
```

```
QR      08021978    5030     1040
QR      08151979    5760      525
QR      08131980    2760      378
QR      07271981    2700      391
QR          1982    6215e    1162e Missing Year
QR          1983    3922e     530e Missing Year
QR          1984    3521e     629e Missing Year
QR          1985    4283e     875e Missing Year
QR      07211986    1920      217e
QR      08021987    1500      152e, d<500
QR      08231988   10700     1540
QR          1989    1500e     312e, d<500
QR      07241990    9430     2560
QR      08091991    2130      247e, d<500
QR      08061992    5970     2240
QR          1993    1600e     404e, d<500
QR      07281994    4890      490e, d<500
QR          1995     500e     118e, d<500
QR      08221996    1890      198
QR      08151997     743       75
ED
```

```
TT US GEOLOGICAL SURVEY
TT PEAK FLOW DATA seasonal analysis (mixed population)...........CorMnsn1.dat

TT Station name  : Santa Cruz River at Cortaro
TT Station number: 9482000
TT County..................................... Pima County, AZ

TT Drainage area (square miles)................. 3503

TT NNA/NOVEMBER 1998/INITIAL EVALUATION OF SEASONAL ANNUAL MAXIMA
TT DATA EDITED AND FINAL RE: 13Mar99/NNA
TT 1940 - 1997
TT NOTE: Daily flows are entered alongside peaks, but NOT used...
TT REGFREQ estimated peaks merged into file on 29Apr1999......nna

J1     2
ID SANTA CRUZ RIVER AT CORTARO, DA=3503 SQ MI,  #9486500
ZW /SANTACRUZ/CORTARO/FREQ-FLOW/1940-1997/MONSOONAL SEASON/PEAK/
HP  PLTCORTm.PCL                      3       0       0    3503 SQ.MI.
HP W/O HISTORIC CRITERION
HP SANTA CRUZ RIVER-CORTARO
HP MONSOONAL SEASON ANNUAL PEAKS
HP Adjusted MSE
GS          .113
QR      08141940   17000     7490
QR      08081941    6000      682
QR      08091942    1550      447
QR      09241943    4670     1040
QR      08161944    5650     2800
QR      08101945   14000     5210
QR      08041946    4440     1820
QR      08151947    7500
QR          1948    5640  MISSING
QR          1949    5520  MISSING
QR      07301950   12900     4000
QR      07251951    6820      648
QR      08141952    6100      481
QR      07141953   10800     1430
QR      07241954    9150     1750
QR      08031955   16600     2670
QR      07291956    3150      306
QR      09011957    4400      458
QR      08121958    7890      954
QR      08201959    8000      647
QR      08111960    6420     1240
QR      08231961   14700     5380
QR      07311962    3590       47
QR      08261963    7240     1800
QR      07241964    5990      433
QR      07161965    2710      201
QR      08191966    5980     2460
QR      07171967    5740     2090
QR      08201968    2650      611
QR      08061969    8400     1110
QR      07201970   11200     1850
QR      08201971    9100     2240
QR      08121972    7050      754
QR      07181973    1500      120
QR      07081974   11700     1840
QR      07121975    5200      649
QR      07091976    6800      472
QR      09101977    4700      413
QR      08021978    2800     1270
```

QR	08151979	2000	233
QR	07191980	2650	179
QR	07251981	4150	1290
QR	08231982	13300	2490
QR	08071983	6220	643
QR	07221984	3540	642
QR	1985	6110	MISSING
QR	1986	3700	MISSING
QR	1987	3190	MISSING
QR	1988	12400	MISSING
QR	1989	3100	MISSING
QR	07241990	27500	6660
QR	08091991	700	115
QR	08241992	4670	1710
QR	08301993	2600	400
QR	07281994	1000	82
QR	08111995	1720	148
QR	08231996	2350	250
QR	08181997	1330	271
ED			

EXHIBIT E1-6

HEC-FFA INPUT FILES

FRONTAL SEASON

C:\Projects\SANTCRUZ\Report\All_Graphics_.wpd
NNA/28 September 2000

```
TT US GEOLOGICAL SURVEY
TT PEAK FLOW DATA - FRONTAL/WINTER ANNUAL MAXIMA...........NgFrntH3.DAT

TT Station name  : Santa Cruz River at Nogales..............
TT Station number: 9480500.....................................

TT County..................................... SANTA CRUZ, AZ

TT Drainage area (square miles)..............................533

TT NNA/MARCH 1999/INITIAL EVALUATION OF Seasonal ANNUAL MAXIMA
TT PERIOD OF RECORD.................................1940 - 1997
TT File created on 19March1999, NNA............................

TT Data sources: "Hydrosphere CDROM", USGS WSP's and SLA data..NNA
TT BASE FLOW = 2000 CFS........................................
TT REGFREQ estimated peaks merged into file on 30Apr1999......nna
TT NOTE: Daily flows are entered alongside peaks, but NOT used...
J1     2
ID SANTA CRUZ RIVER AT NOGALES DA=533 SQ MI,  #9480500
ZW /SANTACRUZ/NOGALES/FREQ-FLOW/1940-1997/FRONTAL/PEAK/
HP  PLTNOGF.PCL                          3       0       0     533 SQ.MI.
HP W/ HISTORIC CRITERION:
HP DEC 1967 > 1892
HP Low Outlier < 6 cfs
HP SANTA CRUZ RIVER-NOGALES
HP FRONTAL ANNUAL PEAKS
GS          .058     -.5
SI  1892           15200       6
QR      02231940     236e    146
QR      02071941     204e    127
QR      12121941      56e     37
QR      02091943       5e      5
QR      02251944      43e     29
QR      01271945      54e     36
QR      03051946       5e      5
QR      12271946       8e      8
QR      02241948     5.4e    5.4
QR      01131949     378e    229
QR      12101949      15e     11
QR      04301951      10e    9.8
QR      01141952      21e     15
QR      03031953      88e     57
QR      03241954     680e    402
QR      01041955      10e    9.7
QR      11111955      15e     11
QR      01101957       6e    6.4
QR      03231958     146e     92
QR      11171958      27e     19
QR      01111960    2760    1830
QR      12301960      20e     14
QR      12151961    2080    1060
QR      02111963       3e    2.7
QR      11211963       6e    6.4
QR      11161964      26e     18
QR      12231965    3840    2640
QR      11091966      40e     27
QR      12201967   15200    6160
QR      12271968      18e     13
QR      12031969      17e     12
QR      11221970       7e    7.1
QR      12081971      54e     36
QR      02221973    2300    1250
```

```
QR          1974       0       0
QR      01301975       3     2.6
QR      02101976     454e    273
QR      01231977       6e    5.9
QR      03021978    1284e    740
QR      12181978   12700    6010
QR      02151980      29e     20
QR      03041981       5e      5
QR      01131982       3e    3.0Fd-USGS
QR      02041983    6410    3450
QR      01061984     432e    260
QR      12271984    7080    3400
QR      02091986     259e    159
QR      02261987      58e     38
QR      12181987     372e    225
QR      01041989      45e     30
QR      01031990       2e    1.6
QR      03021991    3640    2020
QR      04031992     566e    337
QR      01181993    8800    5880
QR      02091994     6.4e    6.4
QR      11121994    1940     628
QR      11141995       4e    3.7
QR      03011997     105e     67
ED
```

```
TT US GEOLOGICAL SURVEY
TT PEAK FLOW DATA seasonal analysis (mixed population)

TT Station name  : Santa Cruz River at Continental
TT Station number: 9482000
TT County..................................... Pima County, AZ

TT Drainage area (square miles)................. 1662

TT NNA/NOVEMBER 1998/INITIAL EVALUATION OF SEASONAL ANNUAL MAXIMA
TT DATA EDITED AND FINAL RE: 6APR1999/NNA...............CntFrntH.dat
TT 1940 - 1997
TT REGFREQ estimated peaks merged into file on 30Apr1999......nna
TT NOTE: Daily flows are entered alongside peaks, but NOT used...
TT Zero flows "adjusted manually" by interpolation: Nogales/Tucson
TT Note: tried to modify results by using "low flow" criterion - 20 cfs/nna/21Oct1999
J1     2
J2                              1
ID SANTA CRUZ RIVER AT CONTINENTAL, DA=1662 SQ MI,  #9482000
ZW /SANTACRUZ/CONTINENTAL/FREQ-FLOW/1940-1997/WINTER SEASON/PEAK/
HP  PLTCONTF.PCL                        3       0       0    1662 SQ.MI.
HP W/ HISTORIC CRITERION:
HP JAN 1993 > 1892
HP Low Outlier < 8cfs
HP SANTA CRUZ RIVER-CONTINENTAL
HP FRONTAL PEAKS
GS  CONT    .070     -.8
SI  1892           32400       8
QR          1940      56e
QR      01011941      96e      80d
QR          1942      40* Peak Estimated manually
QR          1943      12* Peak Estimated manually
QR          1944      22* Peak Estimated manually
QR      11061944       2e       2d**use as peak also**
QR          1946      98* Peak Estimated manually
QR          1947      14* Peak Estimated manually
QR          1948       3* Peak Estimated manually
QR          1949     104e
QR          1950       8* Peak Estimated manually
QR          1951      12* Peak Estimated manually
QR          1952      19* Peak Estimated manually
QR      02041953       1e     0.5d**use as peak also**
QR      03241954     238e     192d
QR          1955       6* Peak Estimated manually
QR          1956       8* Peak Estimated manually
QR          1957       4* Peak Estimated manually
QR          1958      81* Peak Estimated manually
QR          1959      14* Peak Estimated manually
QR      01121960    3740F
QR          1961      13* Peak Estimated manually
QR      01251962    2480F
QR          1963      14* Peak Estimated manually
QR      11211963     156e    128d
QR          1965      18* Peak Estimated manually
QR      12231965    5990F
QR          1967      20* Peak Estimated manually
QR      12201967   18000F
QR          1969      35* Peak Estimated manually
QR      12031969     3.1e    3.1d**use as peak also**
QR          1971       7* Peak Estimated manually
QR      12131971     0.3e    0.3d**use as peak also**
QR      03141973    2130F
QR          1974       1* Peak Estimated manually set to "non-zero"
```

```
QR          1975      23* Peak Estimated manually
QR      01221976      35e     25d
QR      12291976     0.4e    0.4d**use as peak also**
QR      03021978    1451e   1030d (NOTE: estimated flow must be > base!!!, Q=2000 cfs
QR      12181978   16000F
QR      02141980      19e     19d
QR      03021981      31e     31d
QR          1982       2* Peak Estimated manually
QR      02041983    4800F-SLA/USGS
QR      01081984     299e    241d
QR      12281984   11600F  Note: record missing for 1986, but 1987-1991 crest-stage gage...-1???)
QR          1986      59e      49e
QR          1987       9e       8e
QR          1988      92e      75e
QR      12261988       9e     8.6d**use as peak also**
QR          1990       1        0-1 REFER TO NOTE FOR STATION - crest-stage gage w/ no flow noted
for this period.
QR          1991    1200e     705e  -1 REFER TO NOTE FOR STATION - crest-stage gage w/ no flow
noted for this period.
QR      03291992     574e     452d
QR          1993   32400F   14800d 2nd Greatest Peak of record (1892); highest Winter event (F)
of record.
QR          1994       3* Peak Estimated manually
QR      01061995    2350F, USGS WSP (No daily record available from USGS WSP's...nna)
QR          1996       2* Peak Estimated manually
QR          1997     124* Peak Estimated manually
ED
```

```
TT US GEOLOGICAL SURVEY
TT PEAK FLOW DATA seasonal analysis (mixed population)

TT Station name  : Santa Cruz River at Tucson
TT Station number: 9482000
TT County..................................... Pima County, AZ

TT Drainage area (square miles)................. 2222

TT NNA/NOVEMBER 1998/INITIAL EVALUATION OF SEASONAL ANNUAL MAXIMA
TT DATA EDITED AND FINAL RE: 6APR1999/NNA
TT 1940 - 1997
TT BASE FOR PEAK DETERMINATION...(CFS).....................1700
TT REGFREQ estimated peaks merged into file on 01May1999......nna
TT NOTE: Daily flows are entered alongside peaks, but NOT used...
J1     2       3
ID SANTA CRUZ RIVER AT TUCSON, DA=1662 SQ MI,  #9482000
ZW /SANTACRUZ/TUCSON/FREQ-FLOW/1940-1996/WINTER SEASON/PEAK/
HP  PLOTTUCF.PCL                      3       0       0    2222 SQ.MI.
HP W/ HISTORIC CRITERION:
HP JAN 1993 > 1892
HP SANTA CRUZ RIVER-TUCSON
HP FRONTAL PEAKS
SI  1892            37400
GS          .057     -.3
QR      02021940     134e    134
QR      01381941     251e    251
QR      12111941      24e     24
QR      03051943      19e     19
QR          1944       0       0e
QR      11241944     173e    173
QR      01061946     190e    190
QR      03181947      19e     19
QR      03181948       1e      1
QR      02161949     182e     17
QR          1950       0       0e
QR      04141951      14e     14
QR      12061951      17e     17
QR      11161952     104e    104
QR      03241954     415e     58
QR      01031955       3e    2.9
QR      01281956     0.4e    0.4
QR      01081957       3e    2.6
QR      02051958      16e     16
QR      11171958     0.5e    0.5
QR      01121960    3220    2180
QR      01271961       6       6
QR      01251962    1820     721
QR      02101963      25e     25
QR      11211963     260e    260
QR      12281964      10e     10
QR      12231965    4830    3680
QR      04121967     0.8e    0.8
QR      12201967   16100    7750
QR      11141968      52e     52
QR      12031969      86e     86
QR          1971       0       0
QR      12041971     103e    103
QR      03141973    1890    1240
QR      03091974     1.2e    1.2
QR      11081974      43e     43
QR      12231975      69e     15
QR      01221977     136e    136
```

```
QR      03021978    1440e   1090 (note: the flow 1090 < peak < 1700 cfs)
QR      12191978   13500    9840
QR      02141980     355e    355
QR      03031981     254e    254
QR          1982       0e      0e, Missing Year
QR          1983    3831e   2086e, Missing Year
QR          1984     413e    364e, Missing Year
QR      12281984   10000    4743e Note: 1986-1987 flow < 1920 and 1500, respectively.  No data
available.
QR          1986     124e    124e
QR          1987      24e     24e
QR          1988     181e    179e Apparently daily flow <500 cfs.
QR          1989      22e     22e Apparently daily flow <500 cfs.
QR          1990       0e      0e
QR          1991     877e    495e Apparently daily flow <500 cfs.
QR          1992     651e    495e Apparently daily flow <500 cfs.
QR      01191993   37400   24700
QR          1994       0e      0e
QR      02161995     576F    475e USGS HYDRODATA "INTERNET"...NO DAILY FLOW > 500CFS.
QR          1996       0e      0 USGS
QR      04101997     142e    142 (Refer to Monsoonal note - peak flow might have been 743 cfs)
ED
```

```
TT US GEOLOGICAL SURVEY
TT PEAK FLOW DATA seasonal analysis (mixed population)...........CrtFrntH.dat

TT Station name  : Santa Cruz River at Cortaro
TT Station number: 9482000
TT County..................................... Pima County, AZ

TT Drainage area (square miles)................. 3503

TT NNA/MARCH 1999/INITIAL EVALUATION OF SEASONAL ANNUAL MAXIMA
TT DATA EDITED AND FINAL RE: 6APR1999/NNA
TT BASE FLOW.............................................2700CFS
TT 1940 - 1997
TT REGFREQ estimated peaks merged into file on 04May1999......nna
TT NOTE: Daily flows are entered alongside peaks, but NOT used...
J1     2       3
ZW /SANTACRUZ/CORTARO/FREQ-FLOW/1940-1997/WINTER SEASON/PEAK/
HP  PLTCORTF.PCL                      3       0       0    3503 SQ.MI.
HP W/ HISTORIC CRITERION:
HP JAN 1993 > 1892
HP No Low Outlier Specified
HP SANTA CRUZ RIVER-CORTARO
HP FRONTAL PEAKS
SI  1892           40300
GS          .069     -.4
QR      02021940     594e    164
QR      12311940    7800    4000
QR      12121941     258e    130
QR      03051943     233e    167
QR      11181943       1     0.7
QR      11251944     255e     82
QR      01061946     299e    135
QR      11241946      39e     20
QR          1948      34e     30e-Missing Year
QR          1949    1529e    716e-Missing Year
QR          1950      27e     27e-Missing Year
QR      04201951       7e    6.6
QR      03191952     395e    358
QR      11161952     456e    189
QR      03231954    5060    2300
QR      01041955      33e     22
QR      01291956      54e     52
QR      01091957    2750     819
QR      03221958     711e    711
QR          1959     3.2e    3.2
QR      01121960    6220    4300
QR      01121961     154e    123
QR      01251962    2600e    918
QR      02171963     842e    842
QR      11221963     283e    103
QR      12291964     275e    174
QR      12221965   16800    8460
QR      11081966       1e      1
QR      12211967   15800    8760
QR      12151968     189e     83
QR      12031969     517e    284
QR      04081971      65      62
QR      12271971     374e    108
QR      02221973    3680    2350
QR      11161973      61e     61
QR      11081974     171e    115
QR      12241975     157e     31
QR      01221977     176e     72
```

```
QR      03021978    7820    5010
QR      12181978   18800  14,500
QR      02141980    1437e    749
QR      03031981     603e    279
QR      03131982     149e    149
QR      02041983    7620    4020
QR      01101984     933e    244
QR      12281984   13000    7280
QR          1986    1068e    414e-Missing Year
QR          1987     308e    137e-Missing Year
QR          1988    1377e    529e-Missing Year
QR          1989     294e     -1
QR          1990      26e     -1
QR      03011991   11600     580
QR      01131992    2595e   1000
QR      01191993   40300  25,000
QR      02141994      49e     41
QR      02151995    6175    3250
QR      11051995      28e     24
QR      01031997     257e     90
ED
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EXHIBIT E1-7

COMBINED ANNUAL DISCHARGE-FREQUENCY COMPUTATIONS:

INTEGRATION OF MIXED POPULATION RESULTS

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NNA/28 September 2000

Santa Cruz River at Nogales: Seasonal Discharge-Frequency Analyis Results, based upon Log-Pearson Type III Distribution

Computed Probability

Includes Historic period, Dec 1967 > 1892, for Frontal Events also: Recommended for use based on consistency.

Q	Pr(C)	Pr(M)	Pr(F)	Pr(C)+Pr(M)+Pr(F)	Pr(C)xPr(M)	Pr(C)xPr(F)	Pr(M)xPr(F)	Pr(C)xPr(M)xPr(F)	Pr(Annual)	Pr, %
100,000	0.00016	0.00000001	0.00015	0.00031	1.6E-12	2.4E-08	1.5E-12	2.4E-16	0.00031	0.03
90,000	0.0002	0.00000005	0.00165	0.00185	1E-11	3.3E-07	8.25E-11	1.65E-14	0.0018497	0.18
80,000	0.0003	0.0000001	0.002	0.0023	3E-11	6E-07	2E-10	6E-14	0.0022995	0.23
75,000	0.00035	0.0000005	0.0022	0.002551	1.75E-10	7.7E-07	1.1E-09	3.85E-13	0.0025497	0.25
50,000	0.001	0.00005	0.0039	0.00495	5E-08	3.9E-06	1.95E-07	1.95E-10	0.0049459	0.49
40,000	0.0017	0.0001	0.005	0.0068	1.7E-07	8.5E-06	5E-07	8.5E-10	0.0067908	0.68
35,000	0.0022	0.00025	0.006	0.00845	5.5E-07	1.32E-05	1.5E-06	3.3E-09	0.0084348	0.84
33,000	0.0025	0.00029	0.0065	0.00929	7.25E-07	1.63E-05	1.89E-06	4.7125E-09	0.0092711	0.93
30,000	0.003	0.0005	0.0074	0.0109	1.5E-06	2.22E-05	3.7E-06	1.11E-08	0.0108726	1.09
25,000	0.0048	0.0012	0.0092	0.0152	5.76E-06	4.42E-05	1.1E-05	5.2992E-08	0.0151391	1.51
20,000	0.0073	0.0035	0.012	0.0228	2.56E-05	8.76E-05	0.000042	3.066E-07	0.0226452	2.26
15,000	0.013	0.0125	0.016	0.0415	0.000163	0.000208	0.0002	0.0000026	0.0409321	4.09
10,000	0.026	0.05	0.025	0.101	0.0013	0.00065	0.00125	0.0000325	0.0978325	9.78
7,500	0.041	0.115	0.034	0.19	0.004715	0.001394	0.00391	0.00016031	0.1801413	18.01
5,000	0.07	0.265	0.048	0.383	0.01855	0.00336	0.01272	0.0008904	0.3492604	34.93
2,500	0.15	0.63	0.083	0.863	0.0945	0.01245	0.05229	0.0078435	0.7116035	71.16
2,000	0.19	0.74	0.1	1.03	0.1406	0.019	0.074	0.01406	0.81046	81.05
1,500	0.24	0.85	0.124	1.214	0.204	0.02976	0.1054	0.025296	0.900136	90.01
1,000	0.32	0.943	0.157	1.42	0.30176	0.05024	0.148051	0.04737632	0.9673253	96.73
500	0.48	0.99	0.23	1.7	0.4752	0.1104	0.2277	0.109296	0.995996	99.60
250	0.62	0.995	0.32	1.935	0.6169	0.1984	0.3184	0.197408	0.998708	99.87
100	0.79	0.998	0.455	2.243	0.78842	0.35945	0.45409	0.3587311	0.9997711	99.98

Notes:

Pr(C) = probability that a *cyclonic* event will be >, = the reference discharge, Q

Pr(M) = probability that a *monsoonal* event will >, = the reference discharge, Q

Pr(F) = probability that a *frontal* event will >, = the reference discharge, Q

Pr(Annual) = probability that the combination of the seasonal events will be >, = the reference discharge, Q

Santa Cruz River at Continental: Seasonal Discharge-Frequency Analyis Results based upon Log-Pearson Type III Distribution

Computed Probability

*Test computation w/ Continental "Frontal" Skew set = -1**Recommended for Use*

Q	Pr(C)	Pr(M)	Pr(F)	Pr(C)+Pr(M)+Pr(F)	Pr(C)xPr(M)	Pr(C)xPr(F)	Pr(M)xPr(F)	Pr(C)xPr(M)xPr(F)	(G=-.1) Pr(Annual)	Pr, %
120,000	0.00065	0.000000001	0.0012	0.00185	6.5E-13	7.8E-07	1.2E-12	7.8E-16	0.0018492	0.18
110,000	0.0008	0.00000005	0.0014	0.0022	4E-11	1.12E-06	7E-11	5.6E-14	0.0021989	0.22
100,000	0.0011	0.0000001	0.0017	0.0028	1.1E-10	1.87E-06	1.7E-10	1.87E-13	0.0027982	0.28
80,000	0.0019	0.0000005	0.0025	0.004401	9.5E-10	4.75E-06	1.25E-09	2.375E-12	0.0043957	0.44
70,000	0.0023	0.00001	0.003	0.00531	2.3E-08	6.9E-06	3E-08	6.9E-11	0.005303	0.53
60,000	0.003	0.00002	0.0035	0.00652	6E-08	1.05E-05	7E-08	2.1E-10	0.0065094	0.65
50,000	0.0044	0.00006	0.0042	0.00866	2.64E-07	1.85E-05	2.52E-07	1.1088E-09	0.008641	0.86
45,000	0.005	0.00011	0.005	0.01011	5.5E-07	0.000025	5.5E-07	2.75E-09	0.0100839	1.01
43,000	0.0053	0.00015	0.0052	0.01065	7.95E-07	2.76E-05	7.8E-07	4.134E-09	0.0106209	1.06
40,000	0.006	0.0002	0.0055	0.0117	1.2E-06	0.000033	1.1E-06	6.6E-09	0.0116647	1.17
30,000	0.01	0.0009	0.008	0.0189	0.000009	0.00008	7.2E-06	0.000000072	0.0188039	1.88
25,000	0.014	0.0021	0.01	0.0261	2.94E-05	0.00014	0.000021	0.000000294	0.0259099	2.59
20,000	0.02	0.005	0.0125	0.0375	0.0001	0.00025	6.25E-05	0.00000125	0.0370888	3.71
15,000	0.029	0.015	0.016	0.06	0.000435	0.000464	0.00024	0.00000696	0.058868	5.89
10,000	0.05	0.05	0.024	0.124	0.0025	0.0012	0.0012	0.00006	0.11916	11.92
7,500	0.068	0.11	0.032	0.21	0.00748	0.002176	0.00352	0.00023936	0.1970634	19.71
5,000	0.11	0.23	0.044	0.384	0.0253	0.00484	0.01012	0.0011132	0.3448532	34.49
2,500	0.2	0.55	0.074	0.824	0.11	0.0148	0.0407	0.00814	0.66664	66.66
2,000	0.23	0.65	0.09	0.97	0.1495	0.0207	0.0585	0.013455	0.754755	75.48
1,500	0.27	0.77	0.11	1.15	0.2079	0.0297	0.0847	0.022869	0.850569	85.06
1,000	0.36	0.885	0.14	1.385	0.3186	0.0504	0.1239	0.044604	0.936704	93.67
500	0.5	0.96	0.204	1.664	0.48	0.102	0.19584	0.09792	0.98408	98.41
250	0.64	0.997	0.28	1.917	0.63808	0.1792	0.27916	0.1786624	0.9992224	99.92
100	0.795	0.9999	0.4	2.1949	0.794921	0.318	0.39996	0.3179682	0.9999877	100.00

Notes:

Pr(C) = probability that a *cyclonic* event will be >, = the reference discharge, Q

Pr(M) = probability that a *monsoonal* event will >, = the reference discharge, Q

Pr(F) = probability that a *frontal* event will >, = the reference discharge, Q

Pr(Annual) = probability that the combination of the seasonal events will be >, = the reference discharge, Q

Santa Cruz River at Tucson: Seasonal Discharge-Frequency Analyis Results, based upon Log-Pearson Type III Distribution

Computed Probability

Q	Pr(C)	Pr(M)	Pr(F)	Pr(C)+Pr(M)+Pr(F)	Pr(C)xPr(M)	Pr(C)xPr(F)	Pr(M)xPr(F)	Pr(C)xPr(M)xPr(F)	Pr(Annual)	Pr, %
120,000	0.0008	0.00000005	0.0012	0.002	4E-11	9.6E-07	6E-11	4.8E-14	0.0019991	0.20
110,000	0.001	0.0000001	0.0015	0.0025	1E-10	1.5E-06	1.5E-10	1.5E-13	0.0024986	0.25
100,000	0.0013	0.0000005	0.0019	0.003201	6.5E-10	2.47E-06	9.5E-10	1.235E-12	0.003198	0.32
80,000	0.0021	0.000001	0.0026	0.004701	2.1E-09	5.46E-06	2.6E-09	5.46E-12	0.0046955	0.47
70,000	0.0029	0.000005	0.003	0.005905	1.45E-08	8.7E-06	1.5E-08	4.35E-11	0.0058963	0.59
60,000	0.0039	0.00001	0.004	0.00791	3.9E-08	1.56E-05	4E-08	1.56E-10	0.0078943	0.79
55,000	0.0048	0.00006	0.0046	0.00946	2.88E-07	2.21E-05	2.76E-07	1.3248E-09	0.0094374	0.94
52,000	0.0051	0.0001	0.0049	0.0101	5.1E-07	2.5E-05	4.9E-07	2.499E-09	0.010074	1.01
50,000	0.0054	0.0005	0.005	0.0109	2.7E-06	0.000027	2.5E-06	1.35E-08	0.0108678	1.09
45,000	0.0066	0.0001	0.0058	0.0125	6.6E-07	3.83E-05	5.8E-07	3.828E-09	0.0124605	1.25
40,000	0.0084	0.0002	0.0065	0.0151	1.68E-06	5.46E-05	1.3E-06	1.092E-08	0.0150424	1.50
30,000	0.014	0.001	0.0095	0.0245	0.000014	0.000133	9.5E-06	0.000000133	0.0243436	2.43
25,000	0.019	0.003	0.012	0.034	0.000057	0.000228	0.000036	0.000000684	0.0336797	3.37
20,000	0.028	0.0084	0.015	0.0514	0.000235	0.00042	0.000126	0.000003528	0.0506223	5.06
15,000	0.042	0.027	0.02	0.089	0.001134	0.00084	0.00054	0.00002268	0.0865087	8.65
10,000	0.074	0.091	0.03	0.195	0.006734	0.00222	0.00273	0.00020202	0.183518	18.35
7,500	0.11	0.18	0.04	0.33	0.0198	0.0044	0.0072	0.000792	0.299392	29.94
5,000	0.17	0.36	0.055	0.585	0.0612	0.00935	0.0198	0.003366	0.498016	49.80
2,500	0.33	0.72	0.095	1.145	0.2376	0.03135	0.0684	0.022572	0.830222	83.02
2,000	0.39	0.8	0.11	1.3	0.312	0.0429	0.088	0.03432	0.89142	89.14
1,500	0.464	0.89	0.135	1.489	0.41296	0.06264	0.12015	0.0557496	0.9489996	94.90
1,000	0.58	0.957	0.17	1.707	0.55506	0.0986	0.16269	0.0943602	0.9850102	98.50
500	0.76	0.99	0.24	1.99	0.7524	0.1824	0.2376	0.180576	0.998176	99.82
250	0.895	0.995	0.32	2.21	0.890525	0.2864	0.3184	0.284968	0.999643	99.96
100	0.972	0.999	0.44	2.411	0.971028	0.42768	0.43956	0.42725232	0.9999843	100.00

Notes:

Pr(C) = probability that a *cyclonic* event will be >, = the reference discharge, Q
Pr(M) = probability that a *monsoonal* event will >, = the reference discharge, Q
Pr(F) = probability that a *frontal* event will >, = the reference discharge, Q
Pr(Annual) = probability that the combination of the seasonal events will be >, = the reference discharge, Q

Santa Cruz River at Cortaro: Seasonal Discharge-Frequency Analyis Results, based upon Log-Pearson Type III Distribution

Computed Probability

Q	Pr(C)	Pr(M)	Pr(F)	Pr(C)+Pr(M)+Pr(F)	Pr(C)xPr(M)	Pr(C)xPr(F)	Pr(M)xPr(F)	Pr(C)xPr(M)xPr(F)	Pr(Annual)	Pr, %
150,000	0.0006	1E-09	0.0014	0.002	6E-13	8.4E-07	1.4E-12	8.4E-16	0.0019992	0.20
130,000	0.0008	1E-08	0.0017	0.0025	8E-12	1.36E-06	1.7E-11	1.36E-14	0.0024986	0.25
120,000	0.0009	0.0000005	0.002	0.002901	4.5E-10	1.8E-06	1E-09	9E-13	0.0028987	0.29
100,000	0.0015	0.000001	0.003	0.004501	1.5E-09	4.5E-06	3E-09	4.5E-12	0.0044965	0.45
80,000	0.0026	0.000005	0.0044	0.007005	1.3E-08	1.14E-05	2.2E-08	5.72E-11	0.0069935	0.70
70,000	0.0035	0.00001	0.0057	0.00921	3.5E-08	2E-05	5.7E-08	1.995E-10	0.00919	0.92
65,000	0.004	0.00005	0.0065	0.01055	2E-07	0.000026	3.25E-07	1.3E-09	0.0105235	1.05
62,000	0.0045	0.00008	0.0069	0.01148	3.6E-07	3.11E-05	5.52E-07	2.484E-09	0.011448	1.14
60,000	0.0047	0.0001	0.0072	0.012	4.7E-07	3.38E-05	7.2E-07	3.384E-09	0.011965	1.20
50,000	0.007	0.0003	0.01	0.0173	2.1E-06	0.00007	0.000003	0.000000021	0.0172249	1.72
40,000	0.01	0.0012	0.014	0.0252	0.000012	0.00014	1.68E-05	0.000000168	0.0250314	2.50
30,000	0.018	0.005	0.021	0.044	0.00009	0.000378	0.000105	0.00000189	0.0434289	4.34
25,000	0.024	0.012	0.0275	0.0635	0.000288	0.00066	0.00033	0.00000792	0.0622299	6.22
20,000	0.035	0.028	0.036	0.099	0.00098	0.00126	0.001008	0.00003528	0.0957873	9.58
15,000	0.055	0.07	0.05	0.175	0.00385	0.00275	0.0035	0.0001925	0.1650925	16.51
10,000	0.1	0.19	0.075	0.365	0.019	0.0075	0.01425	0.001425	0.325675	32.57
7,500	0.14	0.32	0.1	0.56	0.0448	0.014	0.032	0.00448	0.47368	47.37
5,000	0.22	0.525	0.14	0.885	0.1155	0.0308	0.0735	0.01617	0.68137	68.14
2,500	0.42	0.83	0.23	1.48	0.3486	0.0966	0.1909	0.080178	0.924078	92.41
2,000	0.49	0.89	0.26	1.64	0.4361	0.1274	0.2314	0.113386	0.958486	95.85
1,500	0.59	0.945	0.31	1.845	0.55755	0.1829	0.29295	0.1728405	0.9844405	98.44
1,000	0.71	0.98	0.37	2.06	0.6958	0.2627	0.3626	0.257446	0.996346	99.63
500	0.875	0.998	0.49	2.363	0.87325	0.42875	0.48902	0.4278925	0.9998725	99.99
250	0.965	0.9998	0.6	2.5648	0.964807	0.579	0.59988	0.5788842	0.9999972	100.00
100	0.998	0.99995	0.735	2.73295	0.99795	0.73353	0.734963	0.733493324	1	100.00

Notes:

Pr(C) = probability that a *cyclonic* event will be >, = the reference discharge, Q

Pr(M) = probability that a *monsoonal* event will >, = the reference discharge, Q

Pr(F) = probability that a *frontal* event will >, = the reference discharge, Q

Pr(Annual) = probability that the combination of the seasonal events will be >, = the reference discharge, Q

EXHIBIT E1-8

HYDRAULIC SCREENING ANALYSIS

MEMORANDUM FOR RECORD:

Santa Cruz River Watershed Study-Hydraulic Results and Documentation in Support of Hydrologic Analysis

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NNA/28 September 2000

10 December 1999

CESPL-ED-HH

MEMORANDUM FOR RECORD

SUBJECT: Santa Cruz River Watershed Study-Hydraulic Results and Documentation in Support of Hydrologic Analysis

1. References:
   a. *Channel Change on the Santa Cruz River, Pima County, Arizona, 1936-86* by U. S. Geological survey, Open-File Report 93-41.
   b. *Floods of October 1977 in Southern Arizona and March 1978 in Central Arizona*, by the United States Department of the Interior-Geological Survey, Open-File Report 82-687.

2. As part of the ongoing Santa Cruz River Watershed Management Study, the Hydrology and Hydraulics Section was tasked to analyze the discharge-frequency relationships on the mainstem Santa Cruz River. This tasking objective focused upon the need to analyze the Santa Cruz River Watershed to determine if, over time, river geomorphic changes have had an affect on the discharge-frequency relationships presently being used. To facilitate the hydrologic analysis, the hydraulics group, within the Section, provided the hydraulic technical support. This Memorandum for Record summarizes the hydraulic work done in support of the hydrologic tasking effort.

3. In terms of the first step in the hydraulic support process, the initial effort began with the acquisition of a recently developed Pima County, Department of Transportation and Flood Control District (Pima County) HEC-2 Water Surface Profiles model. This model represented a reach of the Santa Cruz River from its downstream northern boundary with Pinal County to its upstream southern boundary with Santa Cruz County, a distance of about 70 miles. The model was geometrically described through approximately 670 cross sections spaced on an average of 550 feet. Note, much of the Pima County HEC-2 model was extracted from prior FEMA study(s). With the exception of the river reach upstream of Pima Mine Road Bridge, where the cross section information was based upon USGS 7.5 minute quadrangles at 1"=2000' and 10 foot contour intervals, most of the downstream reach was based on 1"=200' aerial topographic information with 2' contour intervals. The base mapping for this lower reach was compiled over a time period of 1984-1998. As stipulated by Pima County, their HEC-2 model was calibrated using USGS gage data at the Santa Cruz River stream stations located near Continental and Congress Street bridges for the January 1993 flood event. This particular event equated to a peak discharge of 37,400 cubic feet per second (cfs) being observed in the Santa Cruz River at Congress Street. Upon receipt of the Pima County HEC-2 model, it was subsequently reconfigured into an HEC-RAS based model because this "Windows" based program was determined to be more "user friendly", especially in the area of making changes in cross section geometry through a graphical display analysis. Finally, after the HEC-2 to HEC-RAS conversion process, the newly developed HEC-RAS model was further modified into another HEC-RAS model ("8-point"), in terms of cross sectional geometry, as input information into the hydrologic HEC-1 program. Specifically, what this last modification process entailed (while adhering to and preserving the hydraulic conveyance characteristics associated with the original HEC-2 and HEC-RAS models) was the following:

* removal of all bridge coding;
* reduction in the number of cross sections to 270;
* modification of each multi-point cross section to eight ground point data elements; and
* adjustment of the Manning's friction coefficient ("n") values to composite figures.

Note, during the initial conversion process from the HEC-2 to the HEC-RAS model, the HEC-RAS model was rectified (especially at the bridges) and further calibrated using the measured gage information at Cortaro Bridge. Finally, after the 8-point model river geometry had been input into an HEC-1 model, it was executed over a series of "Index Floods" over the study reach and the impact on the peak discharge figures observed. Index Floods here refers to an arbitrary range of synthetic floods which are based upon observed record, which are used to estimate relationships between upstream and downstream peak discharges.

4. The next step in the overall hydraulic support effort involved the reconstruction of another HEC-RAS Santa Cruz River model through the same study reach that approximately replicated the river system geomorphology for an earlier time period. The time period that was selected was 1976-1977. This time period was chosen because of the relative abundance of available data. In addition, the storm that occurred during the October 1977 event happened to be the flood of record up to that period in time. The earlier time frame model was developed by taking the modified (8-point) existing conditions model and adjusting the invert based on information provided in reference 1a. Corresponding gage height, discharge, and top width data were extracted from reference 1b. In short, this derived historic condition HEC-RAS model was developed with the intent to replicate, as much as possible, the 1976-1977 channel and floodplain geometry. In finalizing the 1976-1977 model, for consistency purposes, aerial photos of the storms of 1983 (largest storm of record) and 1993 were compared in order to determine if any topographic features had changed from the 1976-1977 time period to the present. As a consequence of that examination, it was determined that a number of bridges had been either washed out or damaged during the 1983 flood and that they had been improved in the interim. After the model was adjusted to reflect these past conditions and once again calibrated for the 1976-1977 time period, the base geometric information was incorporated into another HEC-1 model, where upon the same series of Index floods (used in the existing conditions model) were then routed through the same study reach.

5. The range of left overbank (LOB), channel (CH), and right overbank (ROB) "n" values that were used in the original Pima County HEC-2 model (file name MOD3A.IH2 and renamed MOD3B.DAT for the Corps), had the following respective values: 0.050-1.000, 0.025-0.040, and 0.050-10.000. The file name for the converted base HEC-RAS model is SNTACRUZ2.*. However, after further bridge modifications, an additional calibration process, and a conversion to an eight point cross section HEC-RAS model (file name SNTCRUZ21.*.), these corresponding LOB, CH, and ROB values needed to be adjusted to 0.040-1.000, 0.0250-0.057, and 0.080-10.000 respectively. Finally, for the 1976-1977 eight point HEC-RAS model (file name SNTCRUZ61.*.) its corresponding LOB, CH, and ROB "n" values were further adjusted to the following respective ranges 0.040-1.000, 0.025-0.200, and 0.050-1.000. Note, these files along with the above references and support materials are retained in the Hydrology and Hydraulics Section archives. In addition, a copy of the same materials will be made available to Pima County.

6. As indicated in the above, once the hydraulic base geometry was incorporated into the respective existing condition and 1976-1977 HEC-1 models, a hydrologic comparative Index Flood routing analysis was performed. The results of the hydraulic screening was to determine if man-made disturbances (bridge improvements, bank stabilization, etc.) to the natural channel conveyance would result in a decreased attenuation (hence greater peak discharges) of peak discharges within Pima County. The results showed that, in general, attenuation of peak flows for the 1976-1977 channel condition were slightly greater than for the present channel configuration. However, for some smaller floods, this same condition was somewhat moderately reversed. In any case, it appeared that the changes in the floodplain geometry, as reflected back to the 1976-1977 time period, were insignificant (generally less than 5% change) to warrant further investigation in this area. In addition, because of sparse geometric and commensurate flood data availability, which directly effect the reliability of a reconstructed historic channel condition, it was deemed not practicable to extend the analysis back further than 1976. A more detailed discussion of this subject is presented in the Corps' Hydrologic documentation report.

7. Note, there were some inherent limitations associated with the hydraulic support efforts. First of all, the Santa Cruz River functions under a movable bed stream condition. However, both the HEC-2 and HEC-RAS one-dimensional computer program models assume a fixed-bed system. For this level of analysis, it was assumed that the fixed-bed analysis would be sufficient in providing meaningful results. Finally, the changes that were made to the existing conditions model in order to replicate the 1976-1977-time period was limited by the available data. Specifically, the portions of the river channel system that were modified were limited to those locations where there were known geometric information documented within the targeted time period. Obviously other locations in the system could have been different in the 1976-1977 time frame, but there was no specific information available that would support this supposition.

ROBERT U. CASTLE, P.E.
Hydrology and Hydraulics Section

EXHIBIT E1-8a

HYDRAULIC SCREENING ANALYSIS

Santa Cruz River Watershed Study-Hydraulic Screening Documentation
July 1999 Task Force Meeting Presentation

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NNA/28 September 2000

SANTA CRUZ RIVER-WATERSHED STUDY – EVALUATION OF IMPACTS OF CHANNEL CHANGES ON PEAK DISCHARGE

1. **GENERAL.** The Los Angeles District (LAD) Hydrology and Hydraulics Section began an investigation to determine the impacts of channel changes in the Santa Cruz River on the magnitude of peak discharges. The investigation was limited to the reach within Pima County, where most of the channel changes have occurred. Hydraulic models of this reach of the Santa Cruz River were developed to reflect the present condition as well as a historic condition. The downstream limit of the study reach began at the Santa Cruz County line, and extended approximately 70 miles to the upstream limit at the Pinal County line. The basis for the development of this model was an HEC-2 model provided by the Pima County Department of Transportation and Flood Control District (Pima County). The general approach was to simulate the impacts of channel and overbank changes in the floodplain by routing a series of Index Floods through the present and historic configurations, and compare the results using HEC-1 models derived from the hydraulic models. If the historic channel configuration resulted in significant differences in simulated peak discharge, then modifications to the systematic recorded peak discharges would be necessary prior to performing a statistical analysis of peak discharges.

2. **PRESENT CONDITIONS (1998).**

The HEC-2 model provided by Pima County has approximately 670 cross sections. LAD engineers converted the HEC-2 model to HEC-RAS because it was anticipated that the cross sections would have to be modified numerous times to achieve the desired result. HEC-RAS allows multi-tasking, provides graphical information, and facilitates modifications to geometric properties. Subsequently the bridges were removed, the number of cross-sections was reduced to 270, and the cross sections were simplified to eight ground points. The eight ground-point cross sections are required for input into HEC-1. Gaging stations are located at the Continental, Congress, and Cortaro bridges. The Pima County provided us with gage heights and discharges at the Continental, Congress, and Cortaro bridges and aerial photos taken the day after the January 18, 1993 runoff event. The streamlined HEC-RAS model was then calibrated to the 1993 data to as much as possible represent present conditions. An HEC-1 model was developed utilizing the eight-point cross sections developed for the HEC-RAS model and the Index Floods were routed through the system.

3. **HISTORIC CONDITIONS (1976).**

The present condition HEC-RAS model was then modified to reflect conditions during an earlier period in time, namely 1976-77. This period was chosen for several reasons:

a) it was far enough back in time to provide both quantitative and qualitative information as to the relative impact of channel modifications – many improvements had been made after the October 1983 flood, so this condition (1976-1977) was likely to have been indicative of the channel for some period of time *prior* to the October 1983 flood;
b) in October 1977, the largest *known* flood to have occurred in the Santa Cruz took place, and considerable hydraulic/hydrologic information was available with which to compare the HEC-RAS model results;
c) and finally, because more geometric data appeared to be available than for earlier periods in time.

The invert of the HEC-RAS model was adjusted using data provided in the publication "Channel Change on the Santa Cruz River, Pima County, Arizona, 1936-86" by U. S. Geological Survey, Open-File Report 93-41. Gage height, discharge, and top width data were obtained from "Floods of October 1977 in Southern Arizona and March 1978 in Central Arizona", by the United States Department of the Interior-Geological Survey, Open-File Report 82-687. The HEC-RAS model was modified so the channel would, as nearly as possible, match the 1976-77 geometry. Aerial photos of the flood of October 1983 (largest of record) and January 1993 were compared in order to determine what topographic features had changed from the 1976-77 time period and the present. We discovered that a number of bridges were washed out or damaged during the 1983 flood and had been improved in the interim. The model was adjusted to reflect these past conditions, i.e. the earlier bridges were restored. The present conditions HEC-1 model was then modified to reflect the 1976-77 channel geometry, and the Index Floods were again routed through the system.

4. INDEX FLOODS.

A series of synthetic floods were developed utilizing data collected from the Continental, AZ. streamgage. Peak discharges as well as volumes for durations of 1 to 3 days were collected and a preliminary statistical analysis used to develop volume-frequency relationships. The flood of January 1983 was used as a "pattern" hydrograph to distribute the statistical results over time, and a series of n-year balanced flood hydrographs were then developed (n = 500-, 200-, 100-, 50-, 20-, 10-, 5-, and 2-year). These synthetic flood hydrographs were then used as Index Floods to compare the effects of channel changes during the periods of time for which hydraulic data had been developed.

5. RESULTS.

A summary and comparison of the HEC-1 simulated routings of the Index Floods is provided in the following tables (**Editor's note: The referenced tables are in the main portion of this Appendix, Table E1-1, pages E1-34 to E1-41**). There was no attempt to reproduce actual floods, including tributary inflow downstream from Continental, or flood history. Rather, the impacts of channel change were addressed merely by quantifying the affects of the channel changes on downstream discharges at the Tucson and Cortaro gages. The results show that, in general, attenuation of peak flows for the 1976-1977 channel condition was greater than for the present channel configuration. However, for some smaller floods, this condition is actually reversed. In any case, it does not appear that the changes are sufficient to merit further investigation of the period prior to 1976-1977, for which only sparse geometric and flood data is available from which to reliably reconstruct historic channel conditions. Furthermore, were such information available, it is unlikely that the results would have a significant impact on the subsequent evaluation of discharge-frequency relationships for the Santa Cruz River.

6. RECOMMENDATION.

Based upon our initial evaluation of the available hydraulic data for the Santa Cruz River in Pima County, AZ., it is our recommendation that discharge-frequency relationships be developed considering the streamflow data since 1940 to be homogeneous in character, at least based upon channel geometry. Hence, recorded streamflow data would be used without adjustment in order to pursue development of seasonal discharge-frequency relationships and the resulting annual discharge-frequency relationships.

EXHIBIT E1-9

HYDROLOGIC TASK FORCE

December 14, 1999 Meeting Notes

Santa Cruz Watershed Feasibility Study
Hydrologic Task Force

December 14, 1999 Meeting Notes

Background

The Corps of Engineers is continuing the hydrologic and hydraulic (H/H) analyses in connection with their efforts to resolve conflicting estimates of the discharge-frequency relation on the mainstem Santa Cruz River. The H/H work is part of the ongoing Santa Cruz River Watershed Feasibility Study that is being cost shared between the Corps of Engineers, the Pima County Department of Transportation and Flood Control District, the Pima County Department of Wastewater Management, the City of Tucson Department of Transportation, and the Tucson Water Department.

In an effort to coordinate a consensus, the Corps of Engineers initiated a Hydrologic Task Force (HTF) that includes federal, state, county, municipal and tribal government agencies with an interest in flood control or water resources. During the 1995-1996 reconnaissance phase of the study, the HTF worked with the Corps to develop the technical approach by which the agencies involved in floodplain regulation might reach an agreement on discharge-frequency relationships.

The HTF held the first feasibility phase meeting on January 22, 1998. The Corps presented a plan to resolve conflicting estimates of the discharge-frequency relation on the Santa Cruz River, and discussed some preliminary data gathering efforts.

The HTF held the second feasibility phase meeting on April 21, 1999. The Corps presented results and discussed their findings in regards to (1) peak discharge data collection and separation into storm types, (2) development of a series of index floods, and (3) development of a simplified and calibrated hydraulic (HEC-RAS) model using 8-point cross sections for the reach between Continental Road and Cortaro Road.

The HTF held the third feasibility phase meeting on July 27, 1999. The Corps discussed a short report entitled the "Santa Cruz River Watershed Study - Evaluation of Impacts of Channel Changes on Peak Discharge", which they had prepared and distributed prior to the meeting. In the report, the present and historic condition channels were compared by routing a series of index floods based on the 1983 flood event from Continental to Cortaro. When the routing results were compared, it was apparent that historic channel condition resulted in slightly more flood peak attenuation that the present condition channel. However, the difference is not significant enough to warrant an adjustment to the recorded peak discharges. The Corps recommended that the next phase of the analysis (discharge-frequency curves) be based on the peak discharges as recorded.

Current Meeting

On December 14, 1999 the fourth feasibility phase meeting of the HTF was held at the Public Works Building in Tucson, Arizona. Attendees included:

Joaquin Solis	City of Tucson
Zbig Osmolski	Pima County
Fazle Karim	Pima County
Steve Tineo	Pima County
Carl Larson	Pima County
Roger Baumann	Pinal County
John Hayes	Santa Cruz County
Chris Smith	USGS
Nick Adelmeyer	U.S. Army Corps of Engineers
Glenn Mashburn	U.S. Army Corps of Engineers

The Corps presented a draft technical summary report entitled "Santa Cruz River Mixed Population Discharge-Frequency Analysis" which summarized the discharge frequency results for three different storm types (frontal, monsoonal, and dissipating tropical cyclones) at four different gage locations (Nogales, Continental, Tucson, Cortaro) on the Santa Cruz River. An electronic copy of the document is available for downloading in the PDF format at Corps FTP site:

Host name/address:	"eml01.usace.army.mil"
user ID:	"anonymous"
password:	your email address
folder:	"pub\SantaCruz"

The Corps is accepting comments on the report from the HTF through Monday, December 21. Comments should be faxed or emailed to:

Nick Adelmeyer
US Army Corps of Engineers
Los Angeles District
911 Wilshire Blvd.
Los Angeles, California 90017
213-452-3570 (phone), 213-452-4202 (fax), nadelmeyer@spl.usace.army.mil

The discussion at the meeting revolved around a summary of the report. Mr. Adelmeyer discussed the differences between the original PLAN as envisioned during the reconnaissance phase, and the PLAN that was finally executed during the feasibility phase. The main differences are listed below.

- The PLAN originally envisioned a two-season analysis (monsoonal vs. frontal) but at the request of Pima County, was broadened to include a third storm type – dissipating tropical cyclone. Note that the frontal storm type is limited to winter events. Summer frontal storms, because of their meteorological association with dissipating tropical cyclones, were included in that population rather than with the winter events (with which they did not share a hydrologic similarity). There were only a few of these ill-fitted events, none of which ranked among the largest floods, and their inclusion/exclusion is not likely to bias the final results significantly.

- A future-conditions analysis was not performed. Based upon information on channel migration and arroyo-cutting provided by the USGS (John T. Parker) and the degree of channelization/regulation of the river within Pima County, the affects of future activity and growth on channel changes in the Santa Cruz River between Continental and Cortaro is not expected to significantly affect peak discharges.

The Corps results generally support the regulatory discharges currently in use by Pima County. As a result, the Corps and Pima County agreed that there was no reason to attempt to determine confidence limits for the combined analytical curves. Further, there is no theoretical method for determining confidence limits for a mixed population analysis. Graphical/quasi-analytical procedures are suggested (see " Mixed-Population Frequency Analysis", USACE, Training Document 17, Apr 82) but Mr. Adelmeyer does not endorse using graphical confidence limits to support regulatory or engineering decisions because of the high-degree of uncertainty (reflected in an extremely wide range within the confidence limits) which would accompany the composite discharge-frequency curves.

Mr. Adelmeyer pointed out that in many ways the Corps analysis appeared to be similar to the 1992 "Climate Variability and Flood Frequency of the Santa Cruz River, Pima County, Arizona", USGS Water Supply Paper 2379. That report also separated the flood record into the monsoonal, frontal, and cyclonic storm types and developed different discharge frequency relations for each. However, he cited a number of differences between the work done by the Corps and the previous study by the USGS.

- The USGS study was based on data through 1986. COE analysis was based on data through 1997 And thus included the January 1993 and July 1990 events – both of which were significant on the Santa Cruz River (the latter event produced a large flow in a major tributary of the Santa Cruz River – Rillito Creek – and was reflected most strongly at the Cortaro gage).

- In order to develop a more complete annual series for each storm type, the COE estimated the magnitude of peak discharges below the base by correlation with published daily flows for the station of interest, and by cross-correlation with both peak and daily flows at the other mainstem Santa Cruz River stations. The actual peak data for flows below base could have been retrieved from the USGS archived records, but such efforts were beyond the scope and budget of the present study. The USGS study relied on censored data and used the method of "maximum likelihood" to perform the statistical analysis. While the original plan called for analysis of the Continental, Tucson and Cortaro gages, the Corps later added the Nogales record to better define conditions at the upper end of the watershed.

- The log-Pearson Type III distribution, which the Corps assumed could reasonably apply to each of the seasons, can accommodate "censored data" by use of conditional probability adjustments. However, because the number of "missing" events (i.e. discharges below the base) for the cyclonic and frontal seasons was greater than 25% of the record, the conditional probability adjustment algorithm could not be used. Hence, the estimated flows were used to complete the record wherever these values were considered to reasonably portray the actual missing flows. The log-Pearson Type III flood frequency distribution was then used to develop statistics (mean, standard deviation, and skew) from the recorded and estimated data.

- The Corps results are more heavily influenced by the frontal events. The inclusion of the non-censored data (which affects the lower end of the curve), and the January 1993 event (which affects the higher end) leads to an overall higher standard deviation for this storm type.

- The Corps considered the largest events within the systematic record for all stations during the cyclonic and frontal seasons to be greater than any event since the February 1891 flood. The statistics were adjusted to reflect this historical period. No statement could be made about the monsoon season as to historical perspective, so only the systematic period was considered.

- Mr. Adelmeyer felt that the USGS study tacitly supported the concept of long term climate change and its affect on the Santa Cruz flood record. He pointed out that the Corps does endorse climate variability, and acknowledges that the more recent record shows significantly higher flood peaks. However, the Corps does not endorse the concept of climate change as applied to Federal involvement and/or development of Federal projects. These typically have a lifespan of only 50-100 years, which is considered to be too short to reflect the effects of long-term climate processes and changes.

In closing, Mr. Adelmeyer will review and address the comments as necessary and will prepare a revised report that incorporates the necessary changes. It will also include (as appendices) the previously mentioned document on channel changes "Santa Cruz River Watershed Study - Evaluation of Impacts of Channel Changes on Peak Discharge" and a summary of the peak discharge data that was collected and estimated for use in the study. The revised report will be distributed to all members on the current HTF distribution list. This will mark the end of the technical analyses and thus completes the work of the HTF. No further review, and no further meetings are anticipated. If there are questions or comments, please feel free to call Doug Lantz (206-728-9655), Nick Adelmeyer (213-453-3570) or Glenn Mashburn (213-452-3549).

EXHIBIT E1-10

INDEX FLOOD HYDROGRAPHS:

Santa Cruz River at Continental
"Balanced Hydrographs vs. Oct 83 Flood

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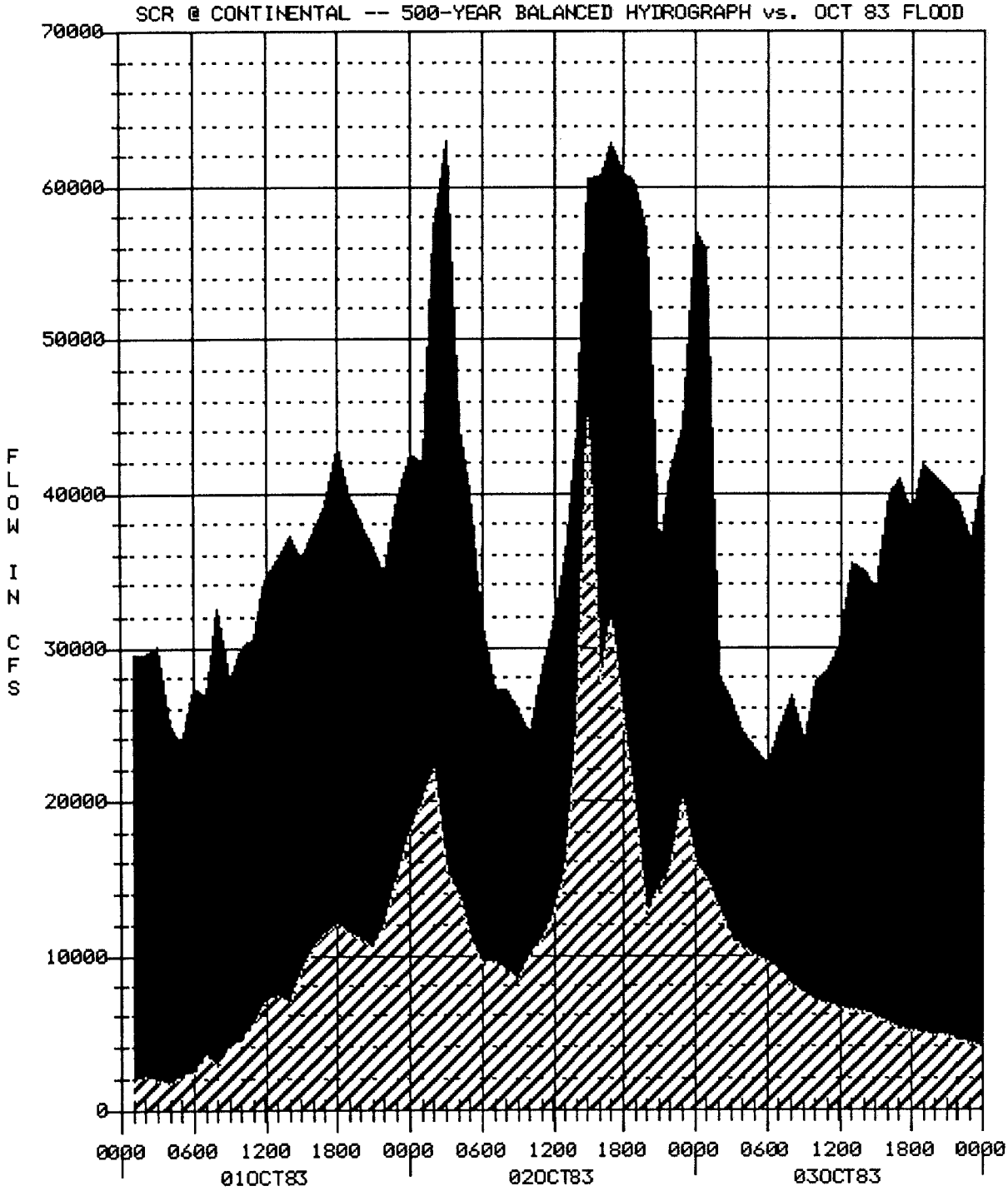

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SCRATCON OCT83 FLOW

EXHIBIT E1-10
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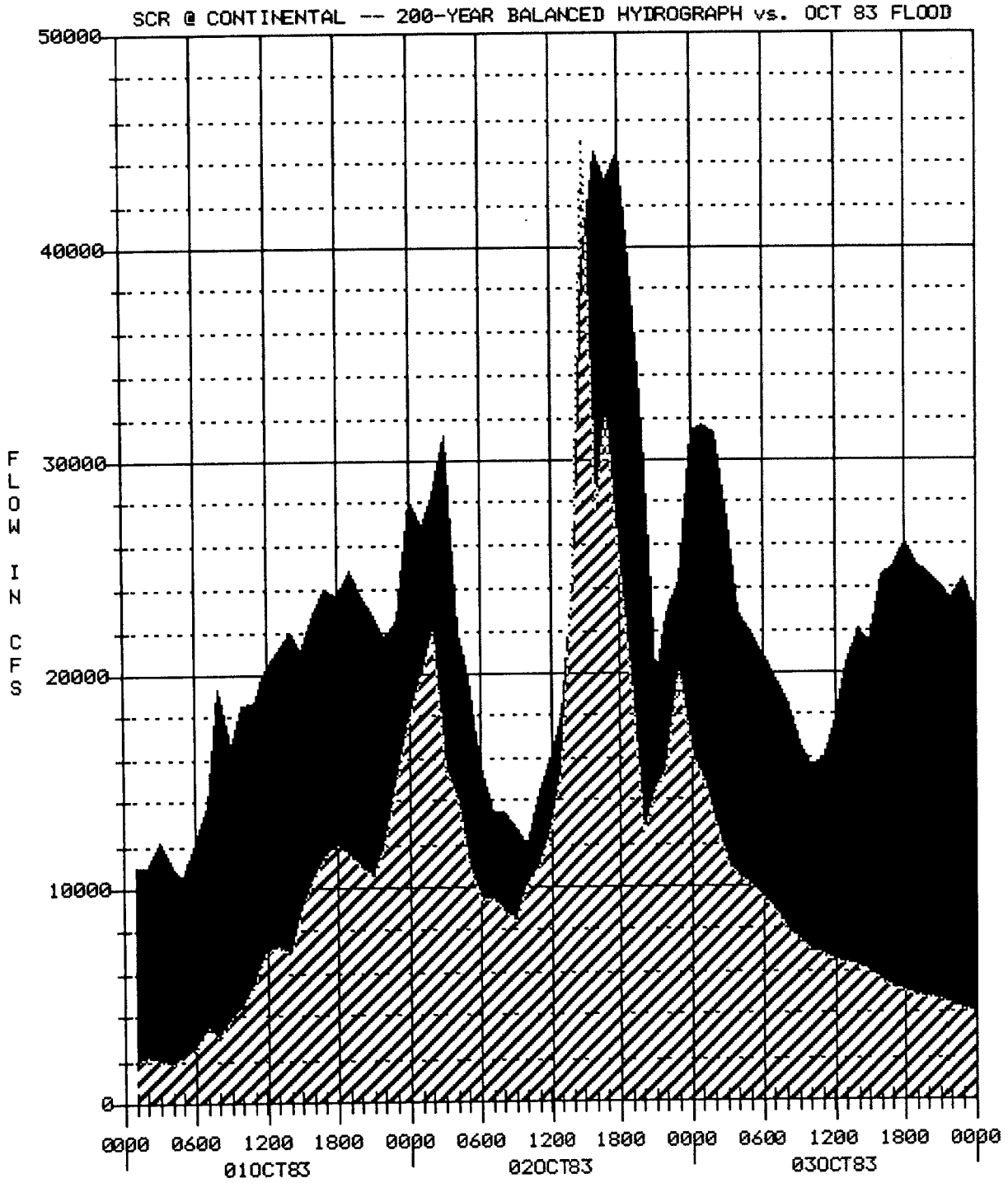

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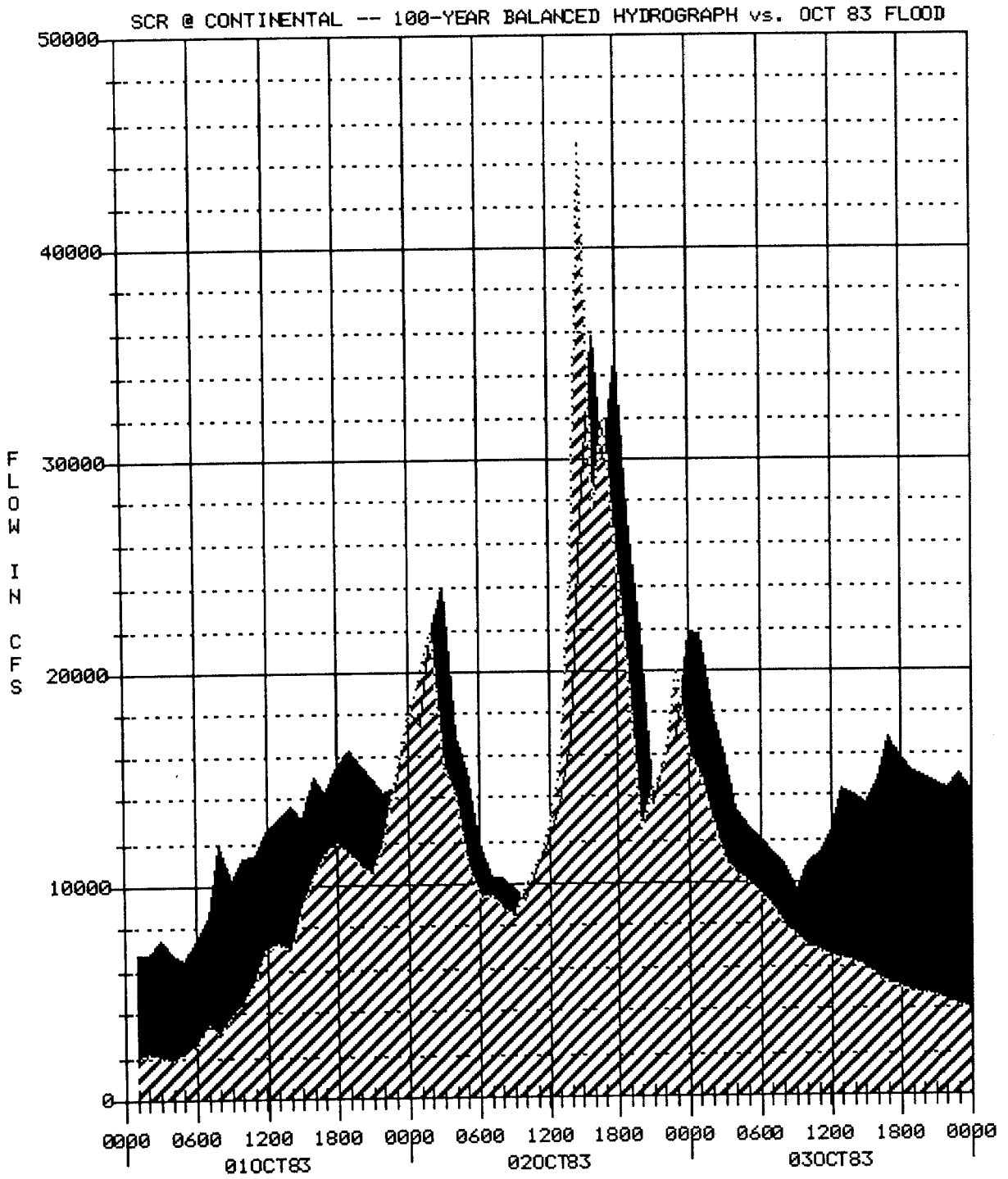

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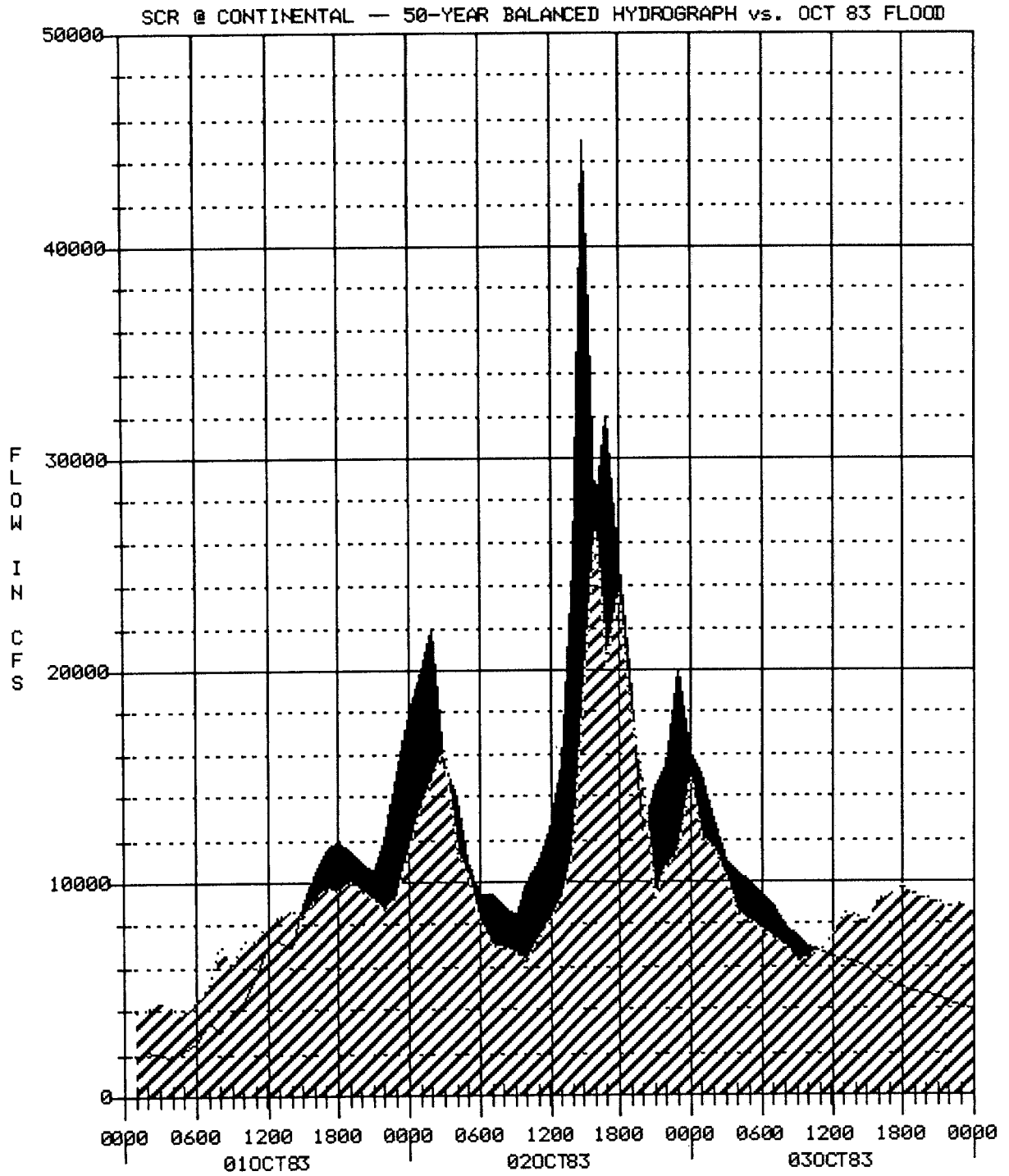

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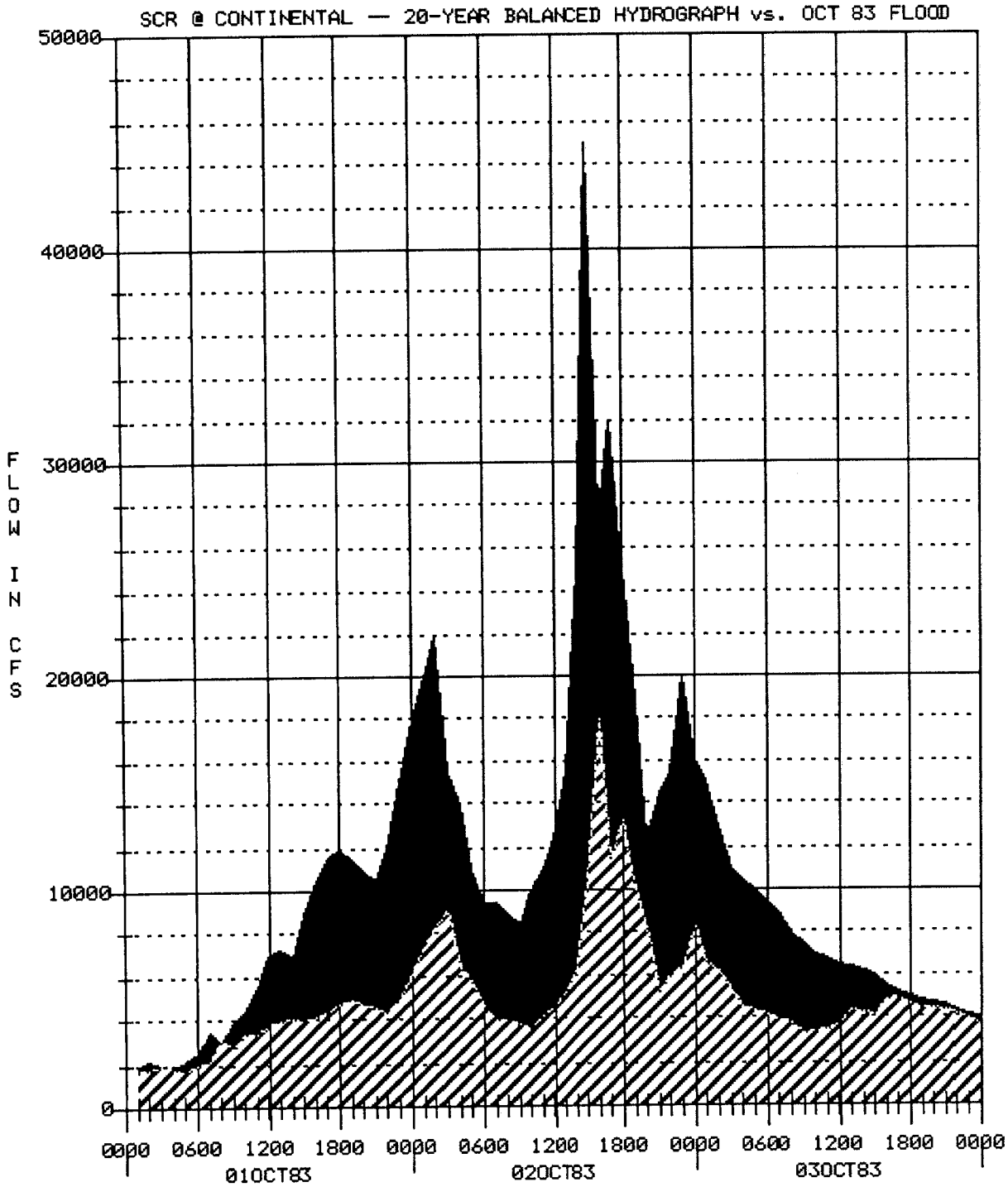

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CONTBLNCD 20-YR FLOW

EXHIBIT E1-10
Page 5 of 8

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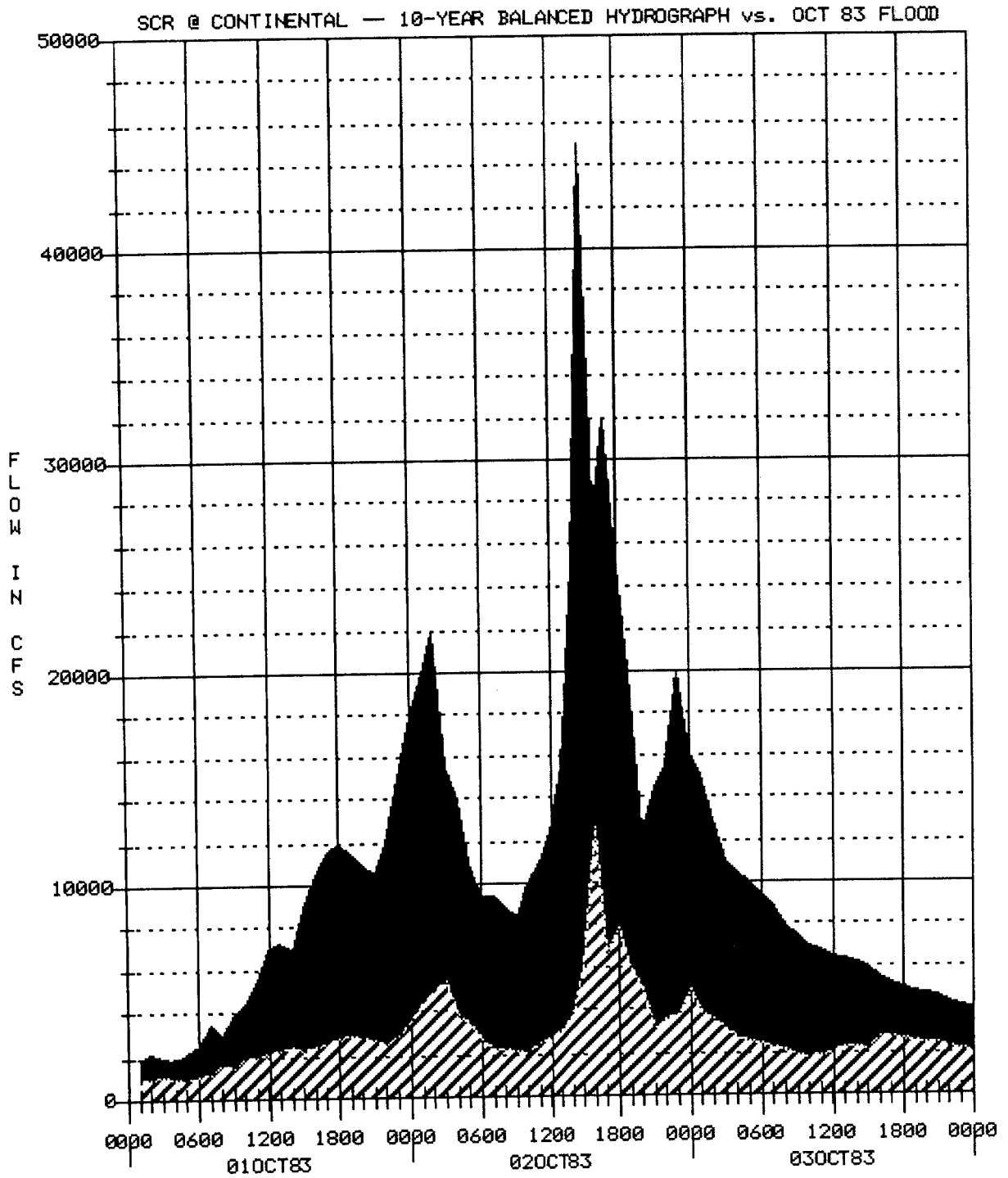

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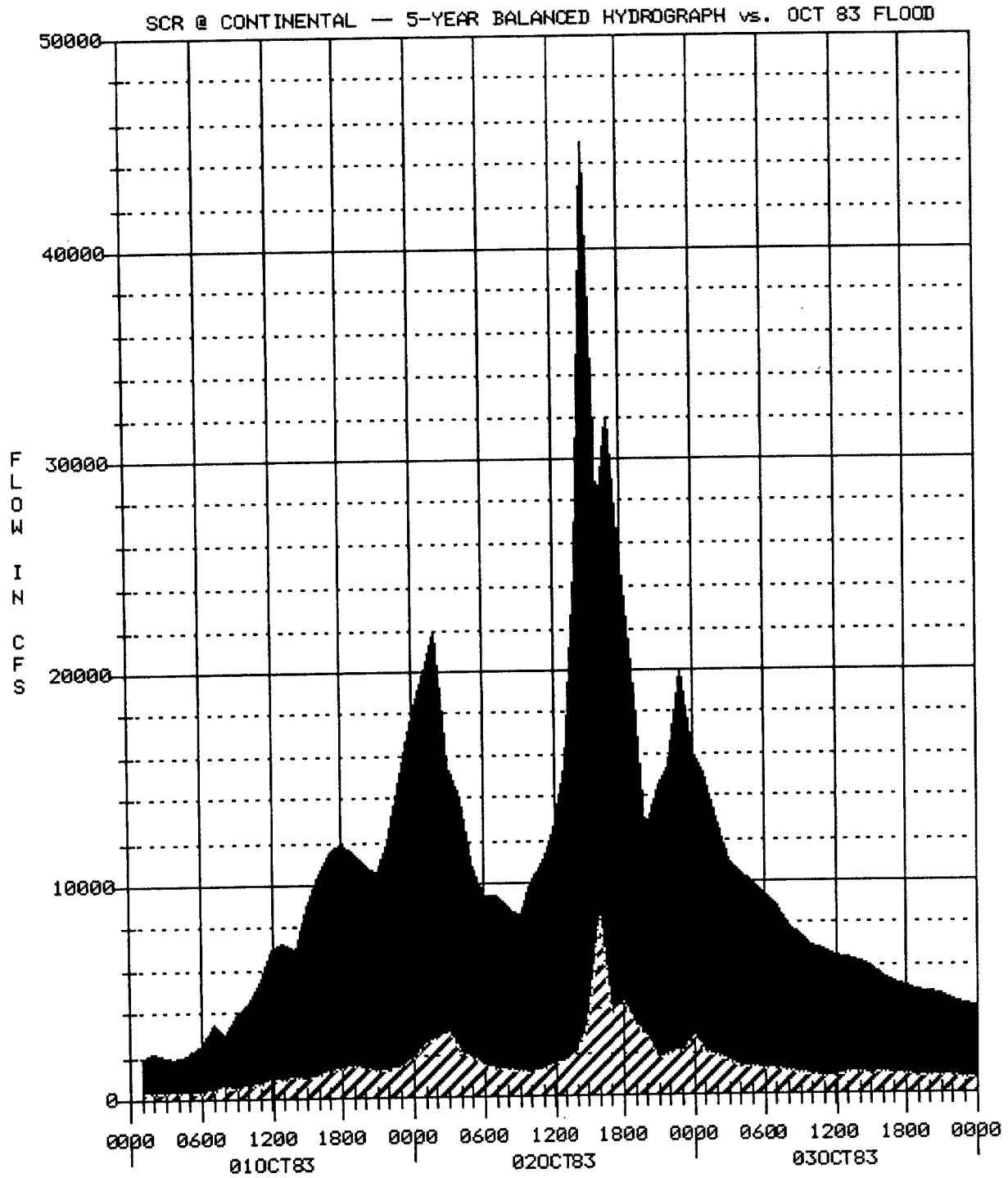

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Page 7 of 8

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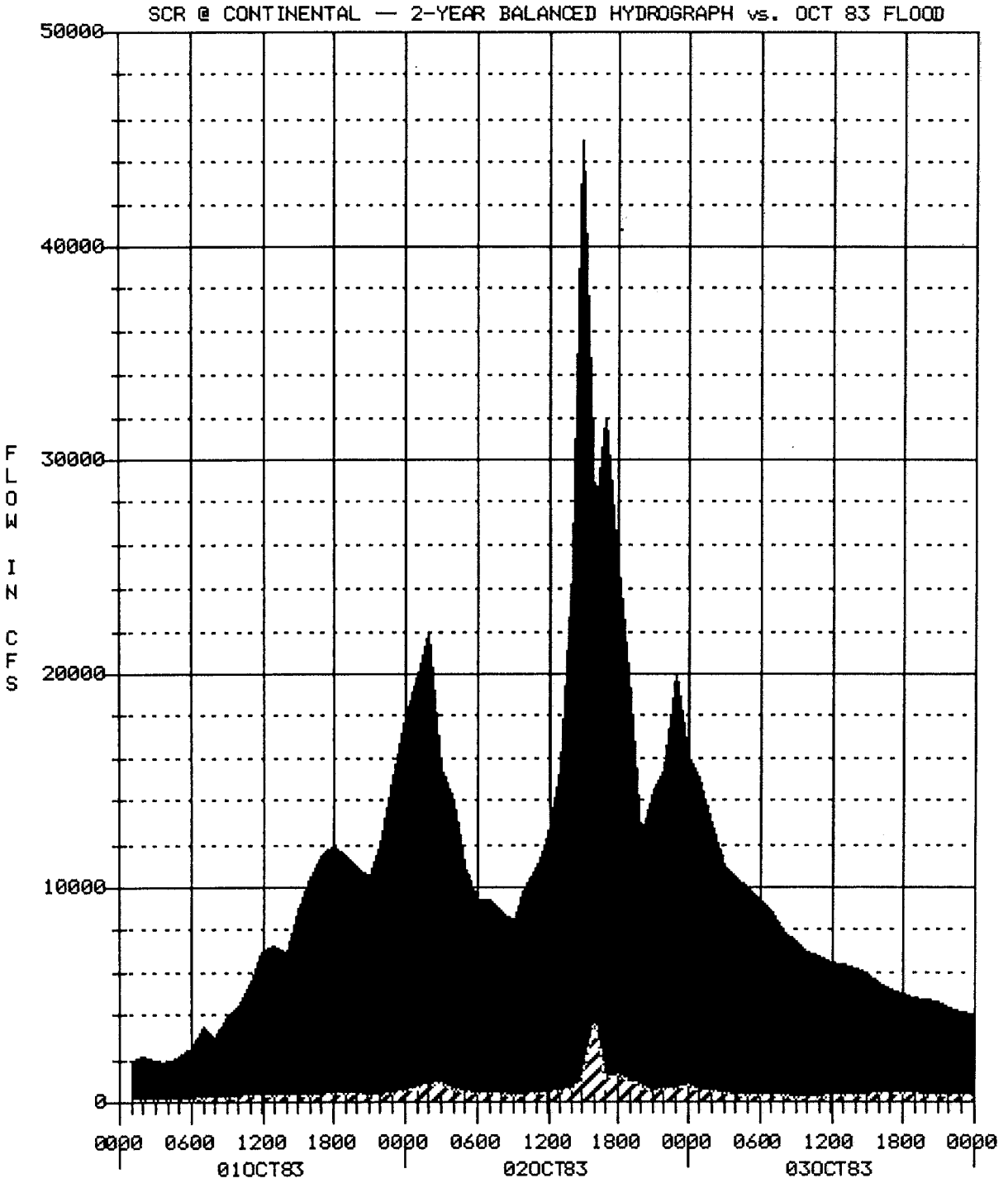

SCRATCON OCT83 FLOW
CONTBLNCD 2-YR FLOW

EXHIBIT E1-10
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EXHIBIT E1-11

VOLUME-FREQUENCY RELATIONSHIPS FOR

INDEX FLOOD DEVELOPMENT

Santa Cruz River at Continental
(based upon annual maximum series)

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NNA/28 September 2000

VOLUME-FREQUENCY RELATIONSHIPS FOR INDEX FLOOD DEVELOPMENT:
Santa Cruz River at Continental

Return Period (years)	500	200	100	50	20	10	5	2
Duration	*Note: discharges for all durations are in ft^3/s.*							
Peak	60,400	44,600	34,800	26,700	18,000	12,700	8400	3800
1-day	42,000	26,900	18,800	12,800	7300	4400	2500	820
2-day	39,000	24,100	16,400	10,800	5900	3500	1900	600
3-day	37,400	22,500	15,000	9700	5100	3000	1500	500
5-day	34,600	20,100	13,000	8100	4100	2300	1100	300

Note: annual maximum series results for record to 1993, expected probability. Index floods were NOT generated from *mixed population* analysis, but tools used to evaluate impacts of channel changes on peak discharge attenuation.

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NNA/25 September 2000

EXHIBIT E1-12

SANTA CRUZ RIVER AT CORTARO:

1993 FLOOD HYDROGRAPH DEVELOPMENT

Santa Cruz River Component Hydrographs,
Tucson to Cortaro

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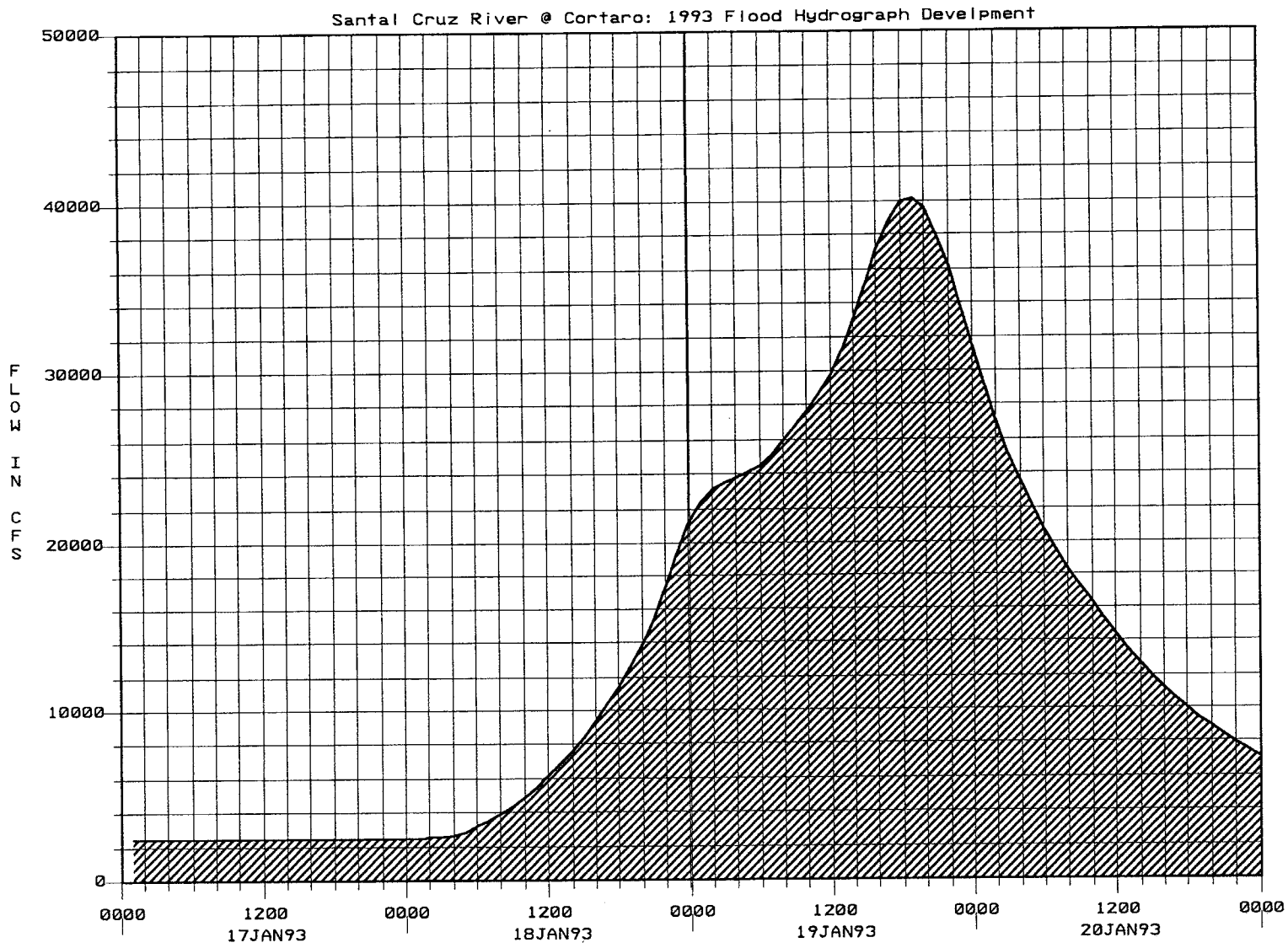

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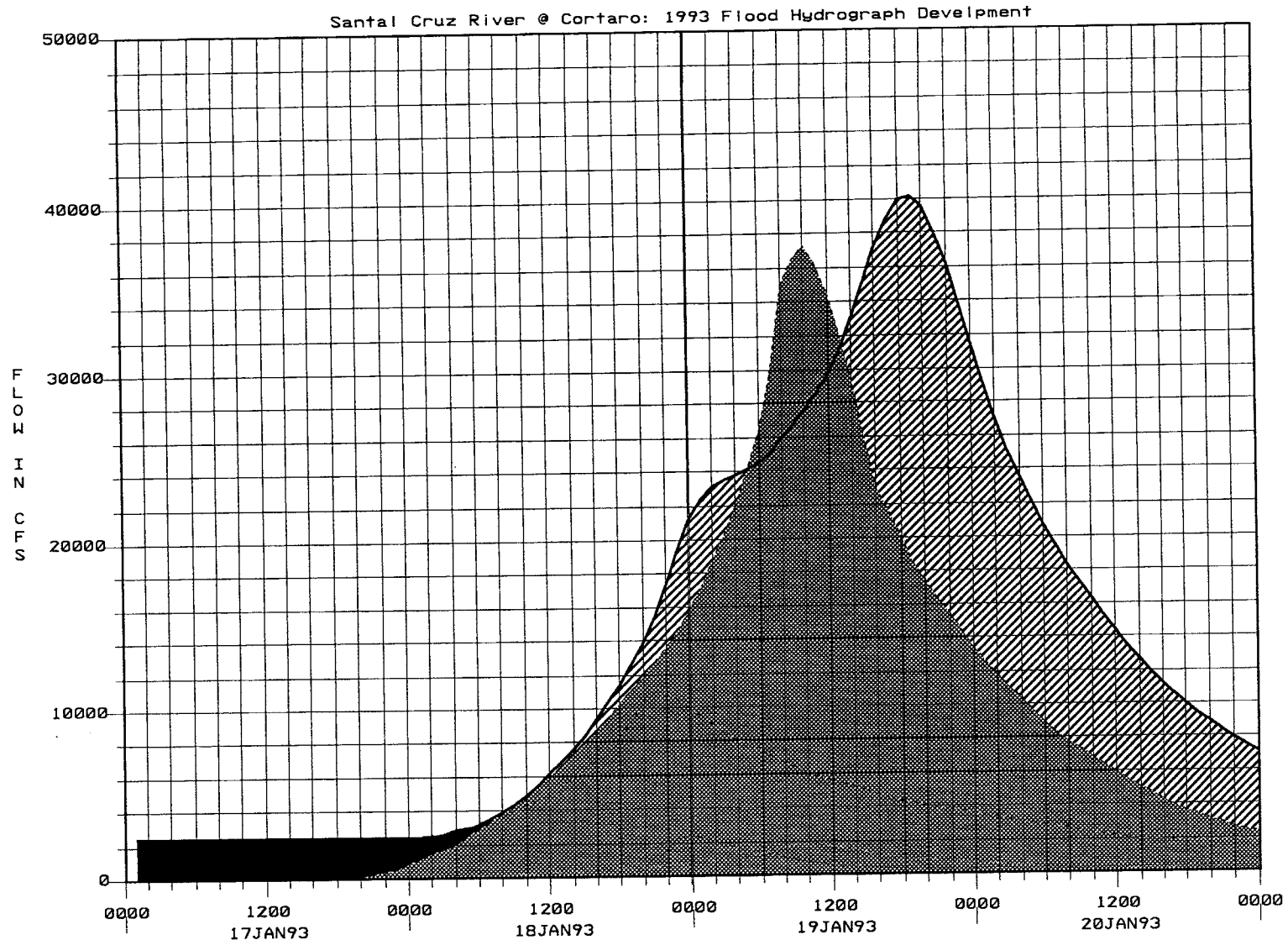

SCRATCORT JAN93 FLOW
LOCSCRC JAN93 FLOW-LOC INC
RCABSCR JAN93 FLOW
CDOABSCR JAN93 FLOW
SCRATTUC JAN93 FLOW

EXHIBIT E1-12
Page 2 of 2

U.S. Army Corps
of Engineers
South Pacific Division
Los Angeles District

SANTA CRUZ RIVER WATERSHED MANAGEMENT STUDY

PIMA COUNTY, ARIZONA

Appendix E2
Low Flow Analysis

August 2001

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Introduction

The natural and effluent baseflow conditions in the Santa Cruz River are an important consideration in terms of river management and potential restoration projects. In the reach downstream of the Roger Road Wastewater Treatment Facility (WWTF) and Ina Road Water Pollution Control Facilities (WPCF), the constant flow of effluent has induced a lush riparian corridor that provides wildlife habitat, but also reduces the flow capacity of the main channel. Upstream of the treatments plants, where base flow is nonexistent, the intermittent low flows that result from storm events may represent a usable resource in desert riparian restoration projects. This appendix characterizes the low flow regime of the Santa Cruz River in terms of average daily discharges recorded at USGS gages, and in the expected discharges from wastewater treatment facilities.

Stream Gaging

Average daily discharges for the Santa Cruz River were available at four USGS gaging stations shown in Figure 1 and listed in Table 1. The complete period of record at each gage is tabulated in Table 2.

Table 1 – Stream Gage Locations

Gage Name	Gage #	Latitude (DMS)	Longitude (DMS)	Elevation (ft)	Drainage Area (mi^2)	Period of Record
SCR at Nogales	9480500	31:20:40	110:51:03	3702.54	533	1913 – 1999
SCR at Continental	9482000	31:51:12	110:58:40	2832.28	1682	1940 – 1999
SCR at Tucson	9482500	32:13:16	110:58:52	2317.82	2222	1906 – 1999
SCR at Cortaro	9486500	32:21:04	111:05:38	2133.13	3503	1940 – 1999

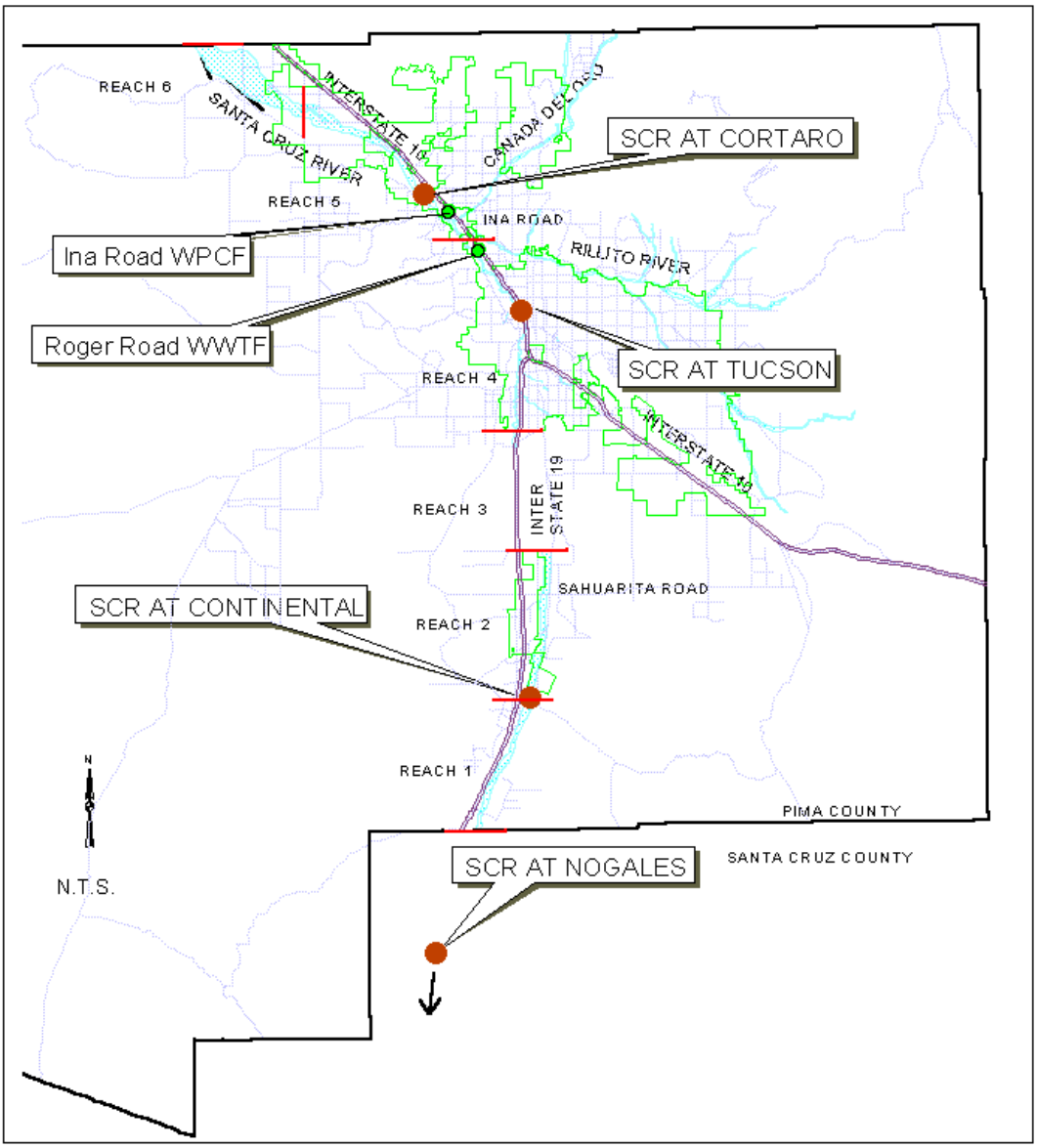

Figure 1 – Stream Gage and Wastewater Treatment Facility Locations

Table 2 – Stream Gage Data Availability	
Gaging Station	**Available Flow Data**
Nogales	1/1/13-12/18/14, 12/25/14-6/30/20, 4/28/21-6/30/22, 5/1/30-12/31/33 7/1/35-9/30/99
Continental	6/1/40-12/31/46, 10/1/51-9/30/85, 10/1/88-7/20/89, 10/1/91-9/30/99
Tucson	10/0/5-12/31/6, 10/1/12-12/31/13, 10/1/14-9/30/81 8/23/88, 10/20/88, 7/7/90, 7/15/90, 7/20/90, 7/24/90 8/24/92, 8/25/92, 1/8/93, 1/9/93, 1/11/93-1/13/93,1/18/93-1/22/93 10/1/95-9/30/99
Cortaro	10/1/39-6/30/47, 7/8/50-9/30/82, 12/1/82, 12/10/82, 12/11/82 1/30/83-2/1/83, 2/3/83-2/7/83, 3/4/83-3/8/83 3/19/83, 3/20/83, 3/22/83, 3/25/83, 3/26/83, 8/7/83 8/9/83-8/11/83 8/16/83, 8/17/83, 8/22/83-8/24/83, 9/28/83-10/7/83 11/21/83, 1/9/84, 1/10/84, 6/29/84, 7/17/84-7/22/84, 8/10/84-8/19/84 9/26/84, 9/27/84, 9/30/84-12/28/84, 4/25/90-9/30/99

The Nogales, Arizona gage is located approximately 30 miles upstream of the study reach but is included for reference (Figure 1). The Continental gage is located near the Continental Road bridge on the boundary between study Reaches 1 and 2. The Tucson gage is located near the Congress Street bridge and is in study Reach 4. The Cortaro gage is located the Cortaro Road bridge and is Study Reach 5.

Mean daily flow data from the four gaging stations were downloaded from the USGS website at http://waterdata.usgs.gov/nwis-w/AZ/. Table 3 shows the minimum, maximum and mean daily flows for the entire period of record for each station.

Table 3 – Stream Gage Daily Flow Summary Statistics				
Gage Name	Minimum (cfs)	Mean (cfs)	Maximum (cfs)	Date of Max Discharge
SCR at Nogales	0	27.5	13,200	10/9/77
SCR at Continental	0	26.3	17,800	10/2/83
SCR at Tucson	0	24.4	24,700	1/19/93
SCR at Cortaro (1939 – 1969)	0	32.0	8760	12/20/67
SCR at Cortaro (1969-1999)	0	99.5	40,000	10/2/83

The record at Cortaro is divided into a pre-1969 record and a post 1969 record. The two parts represent the regime before and after the introduction of effluent flows from the Roger Road, and later the Ina Road facilities.

Effluent Flows

Wastewater is collected and treated at a number of wastewater treatment plants through out the study area. Only two, the Roger Road WWTF and the Ina Road WPCF discharge directly to the Santa Cruz River. The historic and projected discharges for each are given in Table 4.

Table 4 – Average Annual Projected Flows at the Roger Road and Ina Road Facilities

	1996 (actual)	2000	2005	2010	2015	2020	2025
Ina Road WPCF	25.2	27.5	30.4	33.2	36.1	38.8	41.6
Roger Road WWTF	34.8	38.1	42.1	46.0	50.0	53.8	57.6
TOTAL MGD	60.0	65.6	72.5	79.3	86.0	92.6	99.1
TOTAL (CFS)	93	102	112	123	133	143	153

(1) The Pima Association of Governments 1997 Population Handbook used as reference.

A portion of the treated secondary effluent is further treated to provide reclaimed water that is usable for irrigation and industry. The Tucson Water department began delivery of reclaimed water through its metropolitan reclaimed water system in 1984. The reclaimed system currently uses City-owned pressure filtration and chlorination facilities, an underground storage and recovery facility, a wetlands treatment system, and a reservoir and pump station located adjacent to the Roger Road WWTF (study reach 4). The City facilities receive secondary effluent from the WWTF and treat it to State of Arizona reclaimed water standards for reuse as irrigation water primarily for golf courses and parks.

Demand for reclaimed water is projected to reach 20.5 MGD (23,000 acre-feet/year) by 2025 (Table 5), and is generally used for turf irrigation. Thus over the next 25 years, reclaimed usage will only account for roughly 20% of the total effluent. Agricultural use is projected to stay constant at around 2.7 MGD (3,000 acre-feet/year) unless a regional distribution system is developed to deliver to agricultural users. Industrial use is projected to climb to 2.7 MGD (3,000 acre-feet/year) by 2025, based on potential use by gravel facilities and cooling towers.

Table 5 - Projected Effluent Production and Reclaimed Water Usage				
	Total Effluent from Roger Road and Ina Road Facilities		Reclaimed Usage	
Year	MGD	CFS	MGD	CFS
2000	65.6	101	11.4	18
2005	72.5	112	13.5	21
2010	79.3	123	14.6	23
2025	99.1	153	20.5	32

Low Flow Analyses

The low flow regime in the Santa Cruz River is characterized in terms of (1) cumulative volumes, (2) percent exceedance for a given discharge on an annual basis, and (3) percent exceedance of a given discharge on a monthly basis.

Cumulative Discharges

Cumulative discharges were determined by converting average daily flow values (cfs) to acre feet and summing the record sequentially. When the cumulative values are plotted against time (Figure 2) the trends within the record are readily apparent. In wet periods the slope of the line steepens and in dry periods it flattens out. Flood events appear as sudden jumps and are visible in 1955, 1967, 1977, 1983, and 1993. Gaps indicate missing data.

The upstream-most record at Nogales shows a steady slope with few sudden jumps through the mid 50's. The latter portion of the record is marked by a steeper slope with noticeable increases during the flood years of 1977 and 1983. The flood of 1993 is apparent, but is not as dramatic as at the gages further downstream. The Continental flow record shows a flatter slope than the Nogales gage from the mid 50's through the mid 70's, but has also shown a marked increase in the latter part of the record. It's possible that the Continental gage is missing some of the low flows. The Tucson flow record shows a very steady slope, with the exception of the two major flood events in 1977 and 1993 that produced major jumps in the curve. The Cortaro flow record shows a significant increase in the slope of the curve beginning in 1969 when the treatment plant began discharging to the river. With the exception of the vertical jumps resulting from the floods in 1977, 1983, and 1993, the curve since 1969 is very smooth, indicating that the bulk of the flow volume results from these regular daily flows.

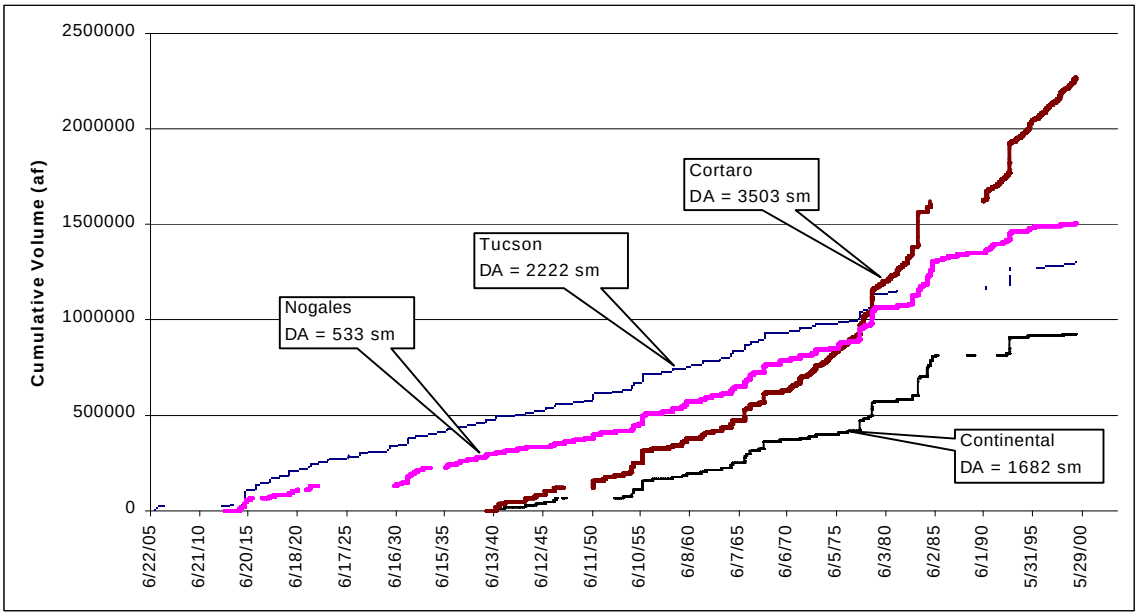

Figure 2 – Cumulative Flow Volumes

Exceedance Probabilities

Exceedance probabilities were determined by counting the number of days in which the average daily discharge exceeded a given value, and dividing by the total number of days in the record. Plots of exceedances for each gage are shown in Figure 3.

Exceedance probabilities for the Continental, Tucson, and Cortaro prior to 1969 gages are very similar. Approximately 85% of the record has a discharge less than 0.1 cfs (i.e., zero). A discharge of 1 cfs is exceeded in 13% of the record and a discharge of 10 cfs is exceeded roughly 9% of the record. At Nogales, flows less than 0.1 cfs occur in only 20% of the record. A discharge of 1 cfs is exceeded in 60% of the record and a discharge of 10 cfs is exceeded in less than 26% of the record. The post 1969 Cortaro record shows very few zero flows. Roughly 98% of the record is greater than or equal to 1 cfs, and 94% of the record is greater than 10 cfs. The median (50%) exceedance (50%) has a discharge of 43 cfs.

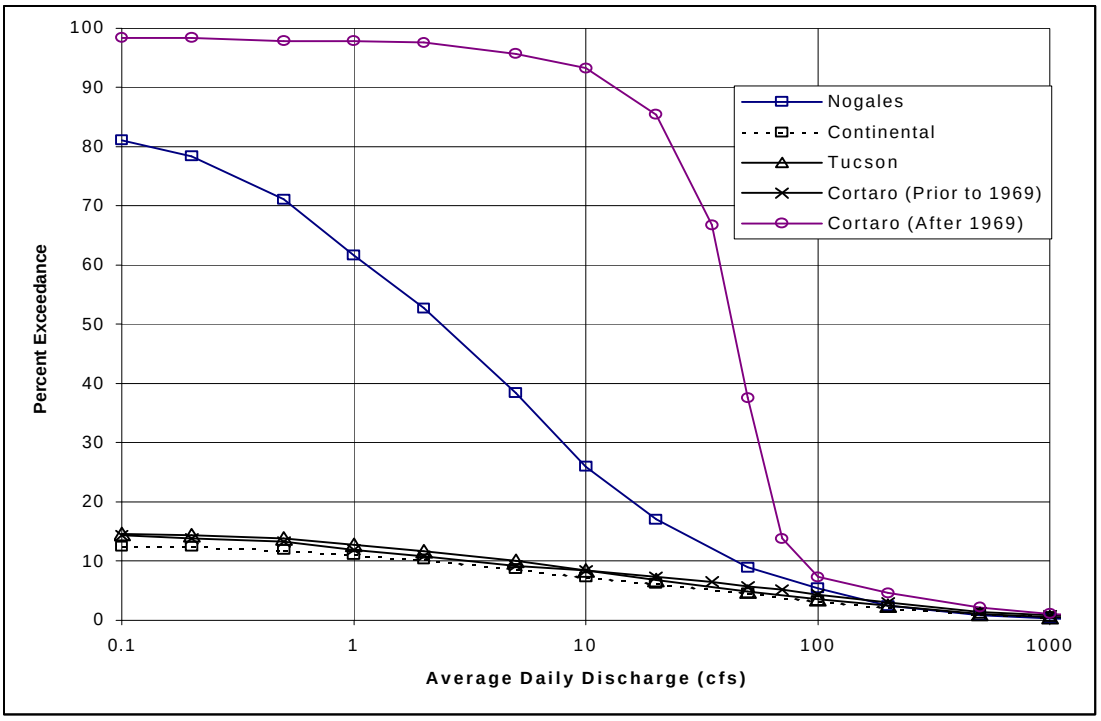

Figure 3 - Percent Exceedance for a given Average Daily Flow

Monthly Exceedance Probabilities

Seasonal variation in flow values was evaluated by dividing each record into individual months. Summaries are given in Table 6.

The statistics at Nogales, Continental, Tucson, and Cortaro prior-to-1969 reflect the seasonal climate regime that characterizes the Sonoran Desert. The means are highest in the winter months (December through March), during the summer monsoon (July – September), and on into October, which is a season of dissipating tropical cyclones (Appendix E1). As a result of the October 1983 flood (from dissipating tropical storm Octave) October is the month of maximum daily flows at all gages.

Table 6 – Stream Gage Daily Flow Summary Statistics by Month													
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Total
Santa Cruz River at Nogales													
Min	0	0	0	0	0	0	0	0	0	0	0	0	0
Max	5880	3450	3340	337	56	300	3500	3410	2390	13200	1710	6160	13200
Mean	40.8	33.5	24.3	7.7	1.8	1.3	40.4	86.2	26.0	23.7	8.6	34.8	27.5
Santa Cruz River at Continental													
Min	0	0	0	0	0	0	0	0	0	0	0	0	
Max	14800	2290	2450	291	31	180	1720	4290	6110	17800	3000	9800	17800
Mean	52.7	16.9	11.1	0.7	0.0	0.4	30.8	83.3	19.5	49.4	3.0	43.3	26.3
Santa Cruz River at Tucson													
Min	0	0	0	0	0	0	0	0	0	0	0	0	0
Max	24700	1580	1240	142	70	324	3120	4570	6400	11200	3200	9840	24700
Mean	42.7	10.9	4.8	0.6	0.1	1.3	52.9	92.3	32.1	12.8	6.1	33.6	24.4
Santa Cruz River at Cortaro (Pre-Effluent)													
Min	0	0	0	0	0	0	0	0	0	0	0	0	0
Max	4300	1490	2300	127	64	399	4000	7490	6900	1190	350	8760	8760
Mean	15	14	10	0	0	2	86	140	37	6	2	67	32.0
Santa Cruz River at Cortaro (Post-Effluent)													
Min	0	1	0	0	0	0	0	0	1	0	0	0	0
Max	25000	4020	5010	608	103	334	3700	2490	6660	40000	3340	14500	40000
Mean	214	102	88	39	37	37	86	106	115	194	53	118	99.5

Exceedance probabilities were determined on a monthly basis by counting the number of days in which the average daily discharge exceeded a given value, and dividing by the total number of days in the record, for a given month. Plots of exceedances for the Tucson and Cortaro (Pre and Post 1969) records are shown in Figures 4 through 6.

The low flow record a Tucson reflects a more bi-seasonal flow regime. The early fall tropical storms, which do affect the extreme statistics and thus the overall mean do not occur frequently enough to significantly affect the low flow exceedance, and the months of October-November show up as a trough between the summer flow and winter flow seasons. The Tucson record shows that the summer monsoon flows are more reliable, with the best month being August.

The monthly exceedances at Cortaro prior to 1969 show the same summer flow regime as the Tucson gage with higher exceedances for a given flow value. For flows up to 20 cfs, the remainder of the months leveled off with exceedances on the order of 40% to 50%. For flows on the order of 50-100 cfs, the bi-seasonal regime is again more apparent. In the post-1969 record at Cortaro, the effluent discharges have increased the exceedances to over 90% for flows up to 10 cfs, and to roughly 80% for flows up to 20 cfs. Exceedances for flows on the

order of 50 cfs are higher than those in the pre-1969 record, but exceedances for flows on the order of 100 cfs are roughly the same.

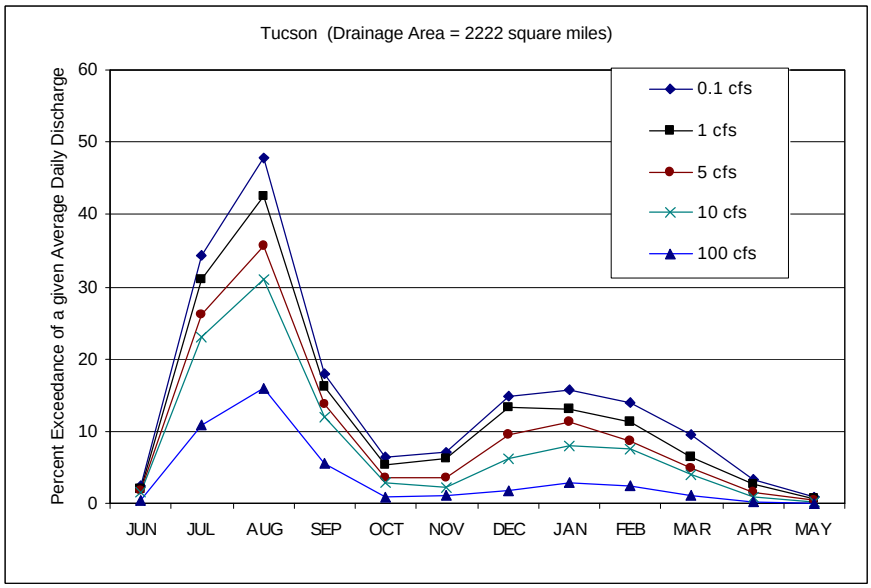

Figure 4 – Monthly Exceedances at Tucson

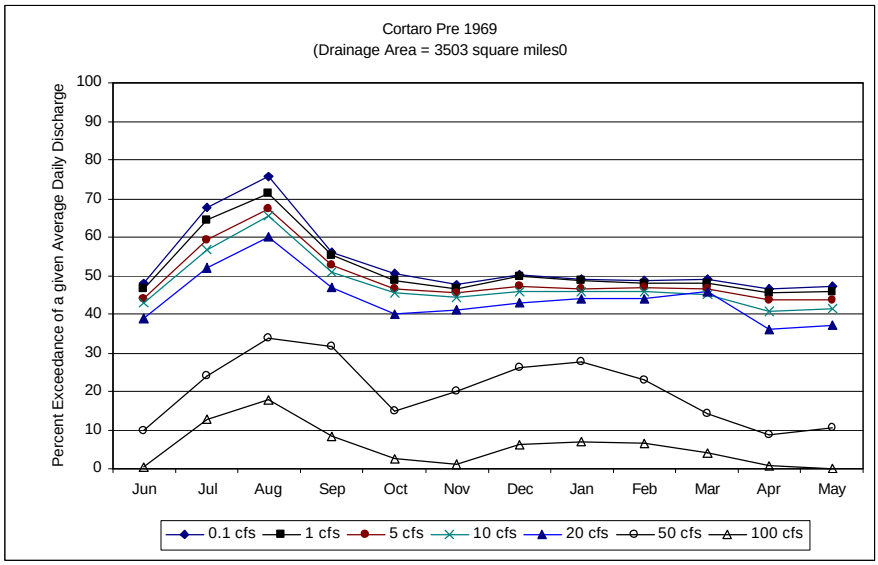

Figure 5 - Exceedance Flows at Cortaro Pre-1969

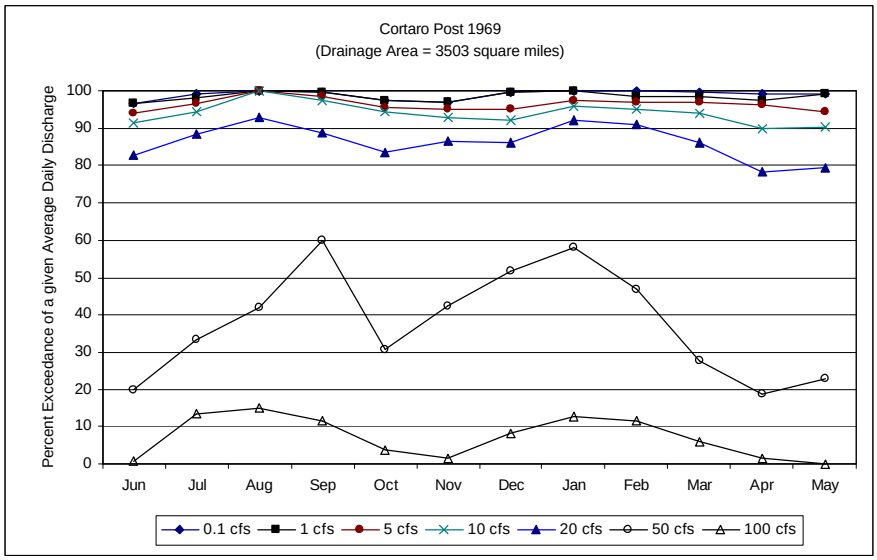

Figure 6 - Exceedance Flows at Cortaro Post 1969

Summary and Conclusions

The Watershed Study includes a number of restoration and seasonal flow concepts in the Santa Cruz River. Most are concentrated in the area between the southern Tucson area (Valencia Road) and the Marana Area near Avra Valley Road (study reaches 4 and 5). In the Santa Cruz River near Tucson (Reach 4), an average daily flow of I cfs was exceeded during 17% to 43% of the record during the summer season (July-August-September). Average daily flows of 10 cfs, have been exceeded from 12% to 30% of the record. In the winter months (December through March) average daily flows of 1 cfs were exceeded in 7% to 14% of record. Average daily flows of 10 cfs were exceeded in 5% to 8% of the record During the remaining months (October-November, April-June) there are zero flows in upwards of 92% of the record.

At Cortaro (Reach 5), under the current effluent dominated regime, average daily flows of 10 cfs have been exceeded 90% of the time. If all treated effluent were converted and distributed as reclaimed water, the flows at Cortaro would likely return back to the pre-1969 regime, barring long term climate change. However over the next 25-year, the expected reclaimed water use is expected to be only 20% of the total effluent produced. In terms of natural water availability, flows of 1 cfs have been exceeded from 50%-75% of the time during the summer monsoon (July-September) and then level off to between 45%-50% of the record for the remainder of the year.

U.S. Army Corps
of Engineers
South Pacific Division
Los Angeles District

SANTA CRUZ RIVER WATERSHED MANAGEMENT STUDY

PIMA COUNTY, ARIZONA

Appendix E3
Historic Profile and
Cross Section Analysis

August 2001

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INTRODUCTION

This section summarizes a qualitative analysis of the historical profile and channel morphology of the mainstem Santa Cruz River within Pima County. Thalweg profiles and cross sections at selected locations were developed using current and historic topographic data collected from federal, state, and local agencies. The data are compared on common scales to highlight channel changes over the last 85 years.

The available topo ranged from 60' quad sheets published between 1915 and 1918 to 2' digital contours that were mapped in 1998. In between, mapping include USGS 15' and 7.5' quads, and locally developed topography with scales between 1" = 50' and 1" = 200' (with 1' and 2' contour intervals) that have been used in floodplain mapping and design of flood control projects. Topographic mapping used in this analysis is summarized in Tables 1 and 2. It is important to note that the contours from the USGS mapping are often in excess of 20 feet with questionable accuracy at the scale of interest. Caution must be used in interpreting channel changes based on this data.

Table 1 – Historical Topographic Mapping

Source	Name	Date of Topo	Extents	Vertical Datum	Horizontal Datum	Contour Interval	Scale	Description/ Comments
USGS	Helvetica Samaniego Peak	1915	Upstream portion of Reach 1			100'	1:62,500	11x17 photocopy
	Patagonia	1919		MSL		100'	1:125,000	11x17 photocopy
USGS 15' Quads	Red Rock	1946 r1963	Santa Cruz Co. Line to Pinal County Line	msl	NAD 1927	25	1:62,500	BW Photocopy
	Silver Bell	1958		ngvd 1929	1927	40 (20)	1:62,500	BW Photocopy
	Cortaro	1946		msl	1927	50	1:62,500	BW Photocopy
	Mount Lemon	1953-1954		msl	1927	80 (40)	1:62,500	BW Photocopy
	Tucson	1946		msl	1927	25	1:62,500	BW Photocopy
	Sahuarita	1955-1956		msl	1927	40	1:62,500	BW Photocopy
	Twin Buttes	1938-1939		msl	1927	50	1:62,500	BW Photocopy
	Tubac	1939		msl	1927	50	1:62,500	BW Photocopy
USGS 7.5' Quads	Green Valley	1975	Santa Cruz Co. Line to Pinal County Line	NGVD 1929	NAD 1927	20 (10)	1:24000	Color Original
	Esperanza Mill	1975		NGVD 1929	NAD 1927	20 (10)	1:24000	Color Original
	Sahuarita	1975		NGVD 1929	NAD 1927	20 (10)	1:24000	Color Original
	Red Rock	1976		NGVD 1929	NAD 1927	10 (5)	1:24000	Color Original

Table 1 – Historical Topographic Mapping

Source	Name	Date of Topo	Extents	Vertical Datum	Horizontal Datum	Contour Interval	Scale	Description/ Comments
	Marana	1966 (1967)		NGVD 1929	NAD 1983	20 (10)	1:24000	Color Original
	Ruelas Canyon	1966 (1968)		NGVD 1929	NAD 1983	20 (10)	1:24000	Color Original
	West of Marana	1958		NGVD 1929	NAD 1927	10	1:24000	Color Original
	Samiengo Hills	1976		NGVD 1929	NAD 1927	20 (5)	1:24000	Color Original
	Cat Mountain	1966 (1968)		NGVD 1929	NAD 1983	20 (10)	1:24000	Color Original
	Tucson SW	1966		NGVD 1929	NAD 1983	10	1:24000	Color Original
	Tucson	1954 (1981)		NGVD 1929	NAD 1983	10	1:24000	Color Original
	Amado	1975		NGVD 1929	NAD 1927	20 (10)	1:24000	Color Original
	Jaynes	1966 (1968)		NGVD 1929	NAD 1983	20 (10)	1:24000	Color Original
Pima County	Rillito River FIS	August-79	Rillito Confluence Reach 5					2 sheets, Panels 80-81
Pima County	Cooper	1984	Avra Valley to Valencia		NAD 1927	2'	1"=400'	Contours on Aerial Photos
PCDOT	---	2/5/1986	Trico Road to CAP Aqueduct		NAD 1927	2'	1"=200'	Avra Valley Project
PCDOT	---	10/30/1987	Grant Road to St. Mary's			1' contour interval	1"=100'	9 e-size blueline copies
PCDOT	Santa Cruz River	5/12/1989	Silvercroft Wash to Camino del Cerro			1' contour interval	1"=100'	7 d-size blueline copies
FEMA	McClain Harbors	1/28/92	Pima Mine Road Reach 2			2' contour	1"=200 1"=400'	6 oversize copies reduced 50%
Pima County	---	1992	CDO Confluence Reach 5	NAVD 1988		1' contour	1"=50'	3 oversize sheets, Panels 42-44
Pima County	---	1993	Rillito Confluence Reach 5	NAVD 1988		1' contour	1"=50'	3 oversize sheets, Panels 45-46
USBR	San Xavier	11/15/1994	Reach 3	NAVD 1929	NAD 1983	2' contour interval	1"=200'	Set of 17 oversize sheets
PCDOT	McClain Harbors Levee Plans	1995	Sanders Road to Avra Valley	NAVD 1988		1' contour	1"=100'	Set of 18 oversize blueline copies
FEMA	---	1995	Sanders Road to Avra Valley					Floodplain Mapping
PCDOT	Santa Cruz River Grant to Fort Lowell	Feb-96	Reach 4				1"=100'	4 D-size blueline copies
Pima County	---	1998	Reaches 4 and 5			2' contour		Digital Topo, ArcviewShape File

Table 2 – Mapping by Reaches		
	Reach	Mapping/Survey used in profiles
1	Santa Cruz County Line to Continental Road Bridge	USGS quads: 60' (1915-19), 15' (1939-1956), 7.5' (1975) FEMA 1"=200' topo (1992)
2	Continental Road Bridge to Pima Mine Road	USGS quads: 60' (1915-19), 15' (1939-1956), 7.5' (1975-76) AFCWS 1"=200' topo (1992)
3	Pima Mine Road to Los Reales Road	USGS quads: 15' (1939-56), 7.5' (1975) 1"=200', 2' CI (1984), 1"=200', 2' CI (1994)
4	Los Reales Road to Sunset Road	USGS quads: 15' (1946), 7.5' (1981) 1"=200', 2' CI (1984), 1"=100', 1' CI (1987), 1"=50', 1' CI (1992) 1"=100', 1' CI (1996) Digital topo Mapping (1998)
5	Sunset Road to Sanders Road	USGS quads: 15' (1946-58), 7.5' (1968-1976) 1"=200', 2' CI (1984), 1"=200', 2' CI (1986) Ground Survey 1999
6	Sanders Road to the Pinal County Line	USGS quads: 15' (1958-63), 7.5' (1968) 1"=200', 2' CI (1986) Topo as coded in PCDOT HEC-RAS model

PREVIOUS STUDIES

Previous studies that were used to provided descriptive information and profile data are listed below.

Pima County DOT&FCD. 2000. Continuous HEC-RAS Watersurface Profile for the Santa Cruz Watershed Study.

Pima County prepared a continuous watersurface profile that extends from the Pinal County line to the Santa Cruz County Line. The geometric data is based on a collection of existing flood insurance studies and flood control design studies using mapping bases that extend back to 1984. Geometries based on different vertical data were converted to the NGVD 29 for consistency.

Pima County DOT&FCD. 1999. Recent Channel Bed Changes in the Santa Cruz River reach from Ina Road to Continental Ranch.

Pima County prepared a detailed survey and sediment modeling effort that examined the effects of a low flow effluent channel on the toe of existing bank

protection. Included 1986 topography developed from bank protection drawings and 1999 ground survey profiles from Pima County Survey.

Arizona State Land Department. 1996. Arizona Stream Navigability Study for the Santa Cruz River, Section 4 Historical Geomorphology and Hydrology of the Santa Cruz River.

The report provides descriptive overview of how the Santa Cruz River has changed since the time of Statehood with special focus on the stream flow conditions and geomorphic changes.

Simons, Li and Associates. 1986. Santa Cruz River Management Study Technical Report
This report, prepared for the Pima County DOT&FCD included Historic profiles using 1963, 1976, and 1984 topography from 6000 feet upstream of Valencia Road to 18,000 feet downstream of Avra Valley Road.

Parker, J.T. 1993. Channel Change on the Santa Cruz River, Pima County Arizona, 1936-1986, US Geological Survey Open File Report 93-41.

This study used aerial photographs; interpretations of filed observations, published and unpublished geomorphic, topographic, geotechnical and historical data to investigate channel change from 1936 through 1986 along the Santa Cruz River in Pima County

CHANNEL CHANGES

The historic profiles are shown in Figures 1 through 8 and cross sections (with a location map) are shown in Figures 9 –20. To maintain a downstream-to-upstream continuity, the study reach order is reversed.

REACH 6

Reach 6, between the Pinal County line and Sanders Road has been historically aggradational (State Land Department, 1996). Prior to 1970, the channel was highly unstable and experienced meander cutoffs, and large shifts in the lateral location. After 1970, the vegetation density increased because of perennial effluent discharges and the channel became narrower and more sinuous. The large flood events in 1977, 1983 produced large lateral shifts (Parker, 1993).

The plotted profiles (Figure 1) have been relatively stable from 1958 through 1986. The invert has not changed appreciably and the overall channel morphology (allowing for the large contour intervals) appears to be stable. (Mapping that documents more recent changes, such as the channel avulsion at Trico Road during the 1993 flood is not available.)

Cross section #1 (Figure 10) was taken upstream of the Trico Road Bridge using USGS topographic mapping for 1958 and 1967 and the cross section from the 1986 topo was taken directly from Pima County's continuous HEC-RAS model. The section from 1986 appears to support the channel narrowing cited by Parker but the differences in the cross-sectional shape may be attributed to the relatively large contour interval of the USGS quad maps. Cross Section #2 (Figure 11) was taken upstream of Trico Marana Road Bridge using USGS topographic maps from 1958 and 1967, and 1"=200' topo, 2' contour interval topo mapping from 1986. There is little change in invert or overall section though the low flow invert has shifted by more than 1000 feet between 1967 and 1986.

REACH 5

The downstream end of Reach 5, between Sander's Road and Avra Valley Road has many of the same characteristics as Reach 6. The upper portion, between Avra Valley Road and Sunset Road begins to take on the more arroyo like morphology that characterizes the river in southern portion of the study reach.

The plotted profiles (Figures 2 and 3) show that since the early 60's (i.e. since the USGS 7.5 minute quad) the overall channel profile has been fairly stable. The downcutting shown in the 1999 field survey has resulted from the continuous flow of effluent from the Roger Road Wastewater Treatment Facility (WWTF) and the Ina Road Water Pollution Control Facility (WPCF). The effluent channel is 5 to 7 feet deep and 20 to 30 feet wide. The degraded invert has probably been in place there for some time but has never been picked up by aerial surveys since it has always been underwater.

Cross section #3 (Figure 12) was taken at a location between Ina and Cortaro Road using 1946 and 1967 USGS mapping. It appears that the channel has degraded by approximately 6 feet and the overall channel size is approximately the same. However, the large contour interval of the 1946 mapping makes it difficult to compare with the others.

Cross Section #4 (Figure 13) was taken at a location between the Rillito River and Canada del Oro confluences using USGS mapping from 1946 and 1967, and 2' contour mapping from 1984 and 1998. The most significant change in cross section is the gravel pit, which reaches a depth of almost 65 feet below the channel invert in the 1998 survey. The channel invert has remained at a fairly steady elevation since 1946; however, there has been an apparent lateral shift that may be related to man-made gravel mining operations.

Cross Section #5 (Figure 14) was taken near Sunset Road using USGS mapping from 1946 and 1967, and 2-foot contour mapping from 1998. The channel invert has been fairly steady since 1946. However, from 1967 to 1998, there appears to have been a significant shift in the thalweg while the overall section remained fairly stable.

REACH 4

Reach 4 is part of what the Stream Navigability Study calls the “upper Santa Cruz Reach (I.e., upstream of Marana). It is characterized as an arroyo in which meander migration, cutoffs, widening, channelization, and increasing vegetation due to effluent have all had an effect on the morphology (State Land Department, 1996). Parker (1993) identifies vertical degradation and extensive widening of the arroyo since 1915 with some width stability apparent after 1960. Manmade bank stabilization and grade control constructed in the 1980’s and 1990’s have fixed the channel morphology throughout much of the reach. Currently unprotected sections, like the one between Grant Road and Fort Lowell Road, continue to widen and shift laterally.

The plotted profiles (Figures 3 to 5) show general invert degradation form the 40’s (USGS 15-minute quads) and 1998, especially between Grant Road and Irvington Road. Comparison of the 1984 and 1998 profiles show that with the exception of localized changes (e.g., St. Mary’s Road) the invert appears to be fairly stable.

Cross section #6 (Figure 15) was taken at the bend between Grant Road and Fort Lowell using USGS mapping from 1946 and 1966, and 1-foot to 2-foot contour interval mapping from 1984, 1987, and 1998. This section shows approximately 8 feet of degradation from 1946 to 1984. From 1984 to 1998, the invert has been relatively constant (1 foot of degradation) while the right bank (looking downstream) has shifted roughly 300 feet toward the outside of the bend.
Cross section #7 (Figure 16) was taken somewhat further upstream between Grant Road and Fort Lowell using USGS mapping from 1946 and 1967, and 1-foot to 2-foot contour interval mapping from 1984, 1987, 1996, and 1998. In contrast to section #6, this section shows no change in invert elevation between 1946 and 1984. The left bank has shifted somewhat to the outside of the bend and has remained fairly steep since 1984, with the invert dropping 4 feet between 1984 and 1996. The 1998 topography shows a slight recovery.

Cross section #8 (Figure 17) was taken between Ajo Way and Silverlake using USGS mapping from 1946 and 1967. The comparison shows approximately 4 feet of degradation between 1946 and 1967, but the overall channel morphology is roughly the same.

Cross section #9 (Figure 18) was taken between Drexler Road and Valencia Road using the USGS mapping from 1946 and 1967 and the 2-foot contour interval mapping from 1984 and 1998. The comparison shows that the channel was remarkably stable between 1946 and 1984, but widened by more than 400 feet between 1984 and 1998.

REACH 3

Reach 3 is very much characterized as an arroyo in which meander migration, cutoffs, widening, channelization, and the loss of riparian vegetation have all had a part in the channel morphology. Parker (1993) identifies headcut migration and cienega destruction in 1914-15 and

arroyo entrenchment through 1929. From 1930 to 1986 the arroyo widened, with large especially width during the floods of 1977 and 1983.

The plotted profiles (Figures 5 and 6) show large changes in the profile between the 15-minute USGS quads (1939-1957) to the 7.5-minute USGS quads (1958-1967). This may in part be attributable to the large contour intervals in the 15-minute mapping. The profiles from 1984, 1994, and 1998 appear to be consistent in the downstream end of the reach but in the upstream end, near Pima Mine Road, there was roughly 10 feet of degradation between the mid 70's and 1992.

Cross section 10 (Figure 19) was taken in the San Xavier Reservation using USGS mapping from 1946 and 1967 and 2-foot contour interval mapping from 1994. The comparison shows invert degradation of approximately six feet. The apparent changes in width shown here are consistent with the historical record but may be more attributable to the large contour interval on the USGS mapping.

Cross section 11 (Figure 20) was taken in the San Xavier Reservation using USGS mapping from 1946 and 1967, and 2-foot contour interval topo from 1994. The channel morphology appears to have been remarkably stable similar over a 50-year period.

REACH 2

Reach 2 has been characterized by headcutting, meander cutoff, and widening, but has shown little natural change in channel position from 1960-86 (Parker, 1993).

The plotted profiles (Figures 6 and 7) show a relatively stable profile (given the limits of the mapping) from 1915 to the mid 50's. From the mid 50's, the invert aggraded by up to 15 feet though the mid 70's (7.5 minute USGS mapping) and then degraded back to its earlier profile in the 90's.,

Section 12 (Figure 21) was taken just upstream of Pima Road Bridge using USGS mapping from 1955 and 1967, and the 2-foot contour interval mapping from 1992. The section shows a fairly stable invert from 1955 to 1967, but the invert shows almost 15 feet of degradation between 1967 and 1992. The degradation extends downstream though Reach 3, but does not continue further upstream because of a grade control structure.

Section 13 was taken between the Southern Pacific Railroad crossing and Nogales Highway using USGS mapping from 1915, 1955, and 1967, and the 2-foot contour interval mapping from 1992. The section shows overall aggradation from 1915 to 1967 but the section has been relatively stable since.

REACH 1

Reach 1 has been characterized by widening and artificial channelization, with unchannelized parts of the reach generally stable. During the 1977 and 1983 floods the mean channel width increased by more than 50%, and 25% respectively (Parker, 1993).

In the downstream portion of the reach, the plotted profiles (Figure 7) show aggradation from 1915 to mid 50's (USGS 15-minute mapping), degradation though the mid 70's, and relative stability though 1992. In the upstream portion of the reach, the plotted profiles (Figure 8) show degradation from the mid 50's to the mid 70's, followed by aggradation through 1992. The apparent oscillations may be due to large contour intervals in the USGS mapping. It is interesting to note that the 1915 and 1992 profiles follow quite closely.

Section 14 (Figure 23) was taken upstream of Green Valley using USGS mapping from 1915, 1939, and 1967, and the 2-foot contour interval mapping from. The invert and channel morphology appear to be fairly stable. The apparent change from the 1915, mapping is likely attributable to the large contour interval.

Section 15 (Figure 24) was taken 600 feet upstream of Elephant Head Road Bridge. Mapping was available for 1915, 1939, 1967, and the 2-foot contour interval mapping from 1992. The inverts appear to be stable over time. The apparent widening of the channel bottom from 1939 to 1967 may be attributable to the large contour intervals. From 1967 to 1992, the channel has changed very little.

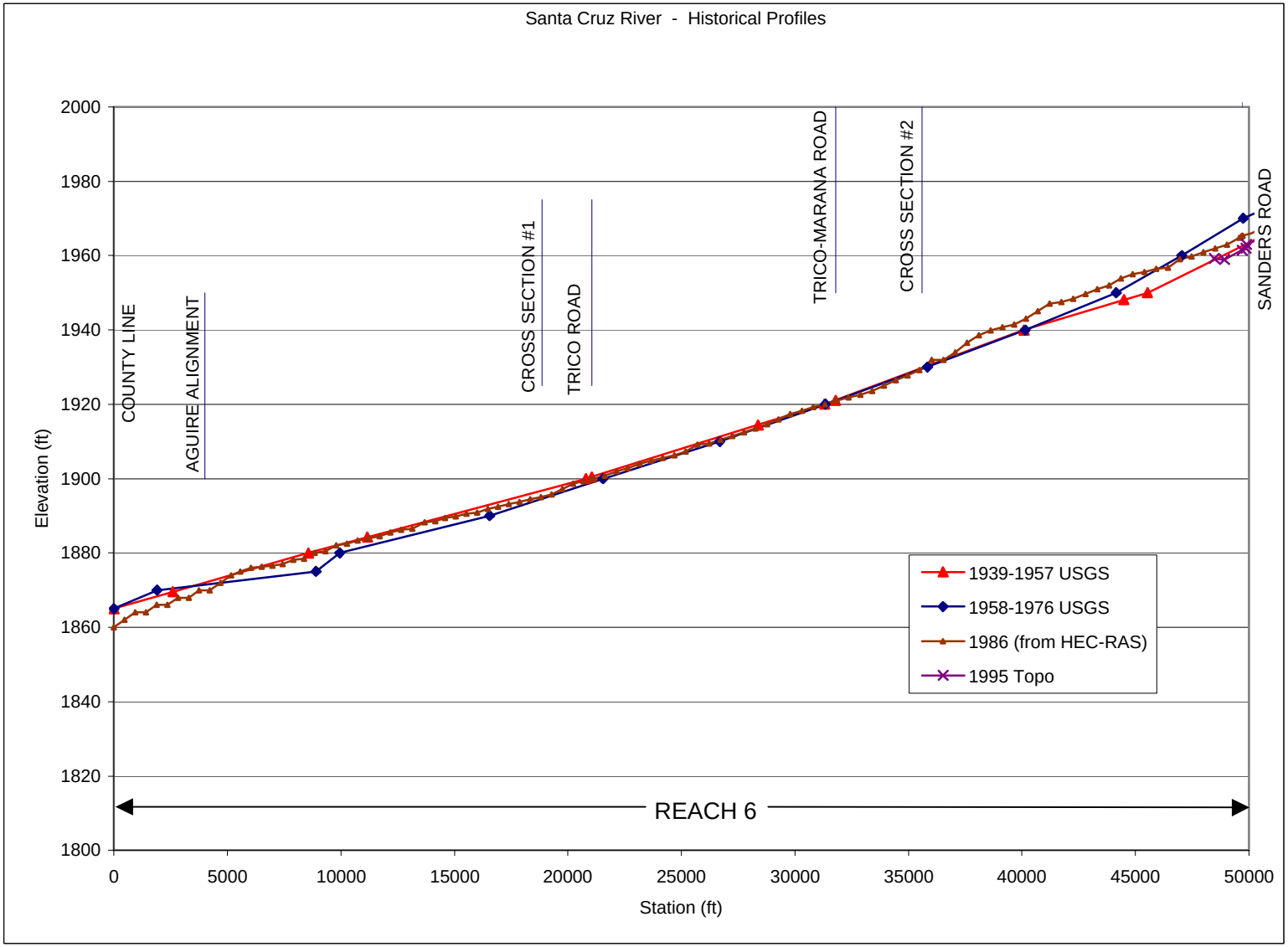

Figure 1 – Historical Profile Reach 6

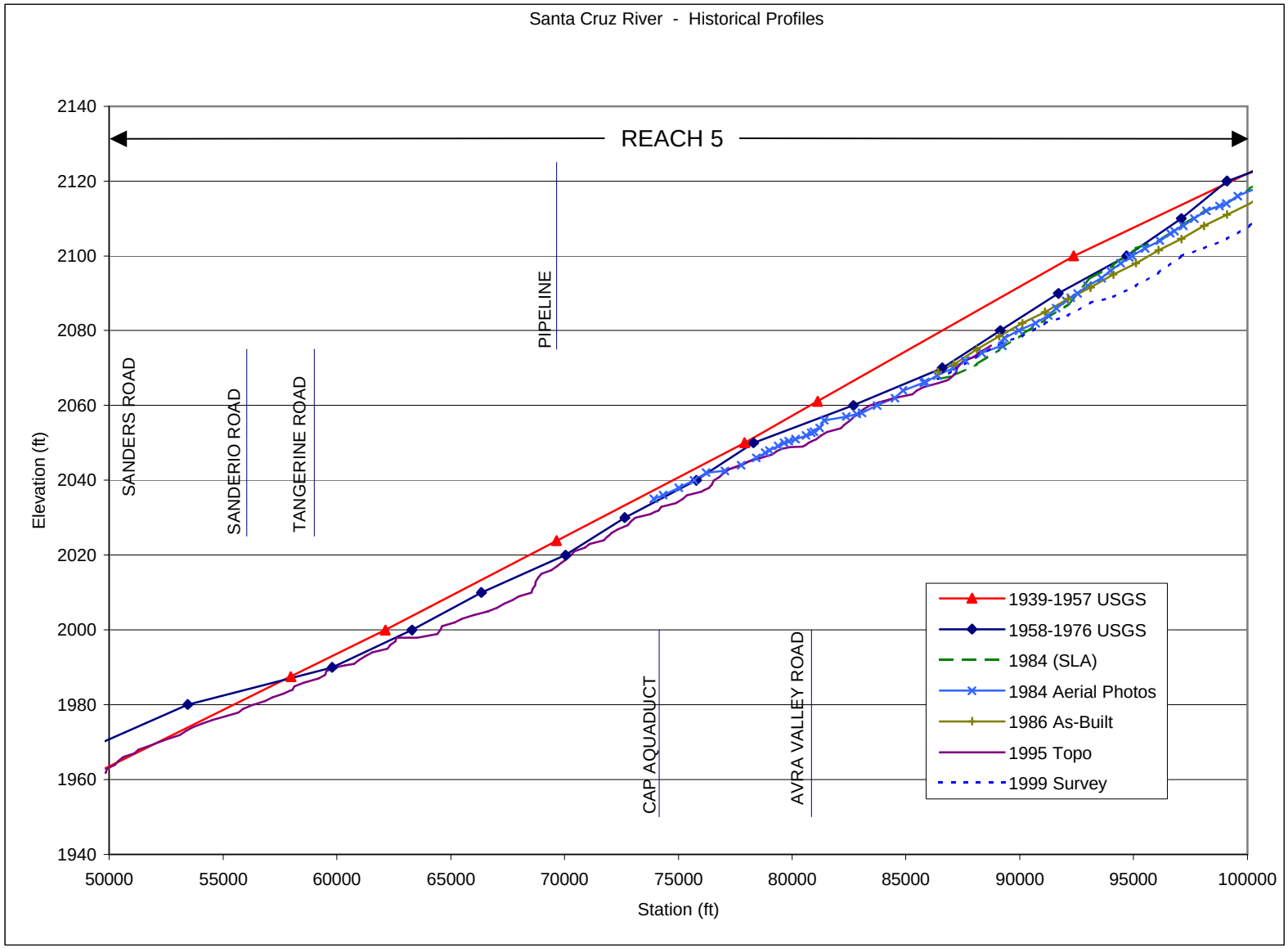

Figure 2 – Historical Profile Reach 5

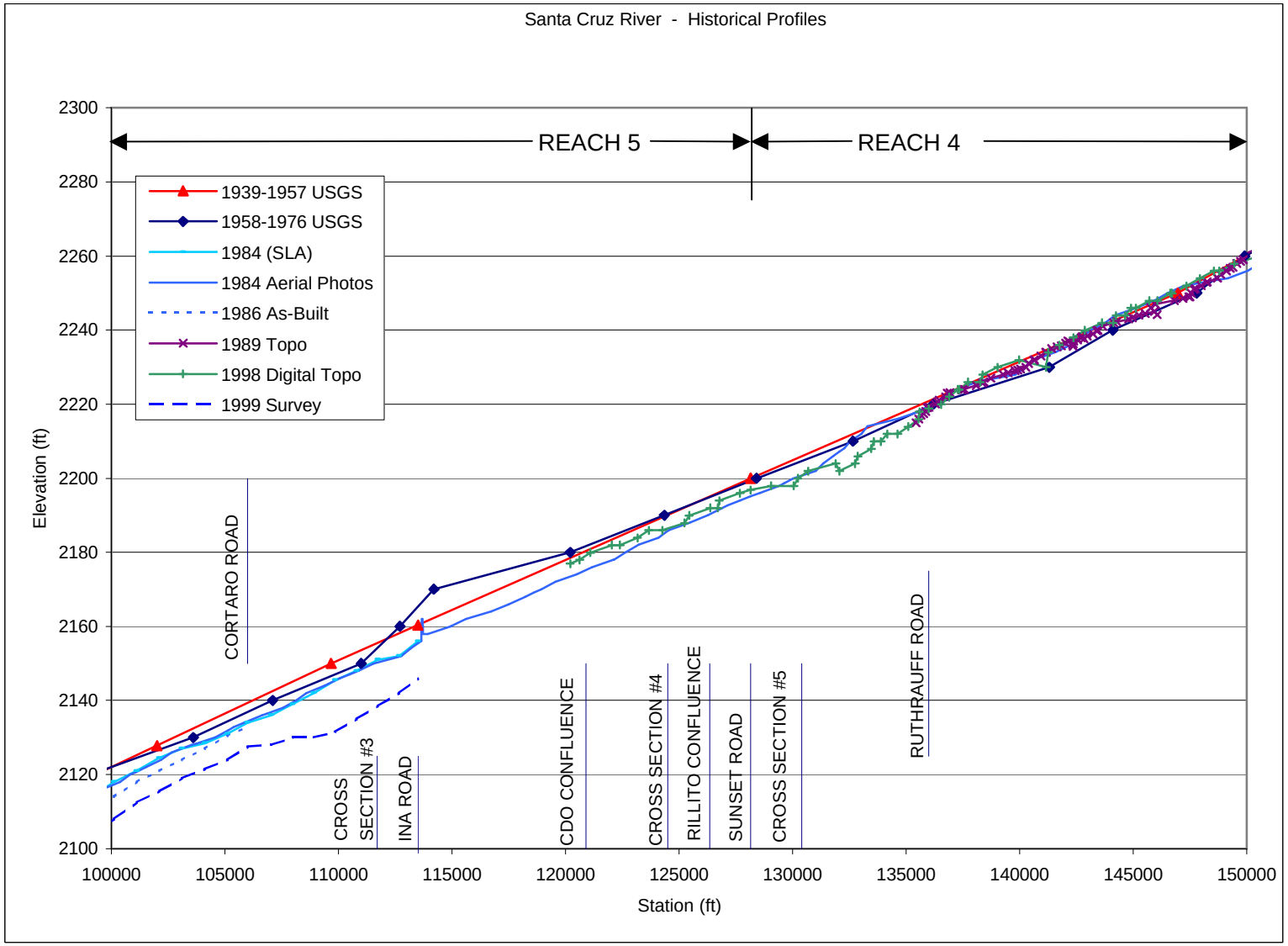

Figure 3 – Historical Profile Reaches 4 and 5

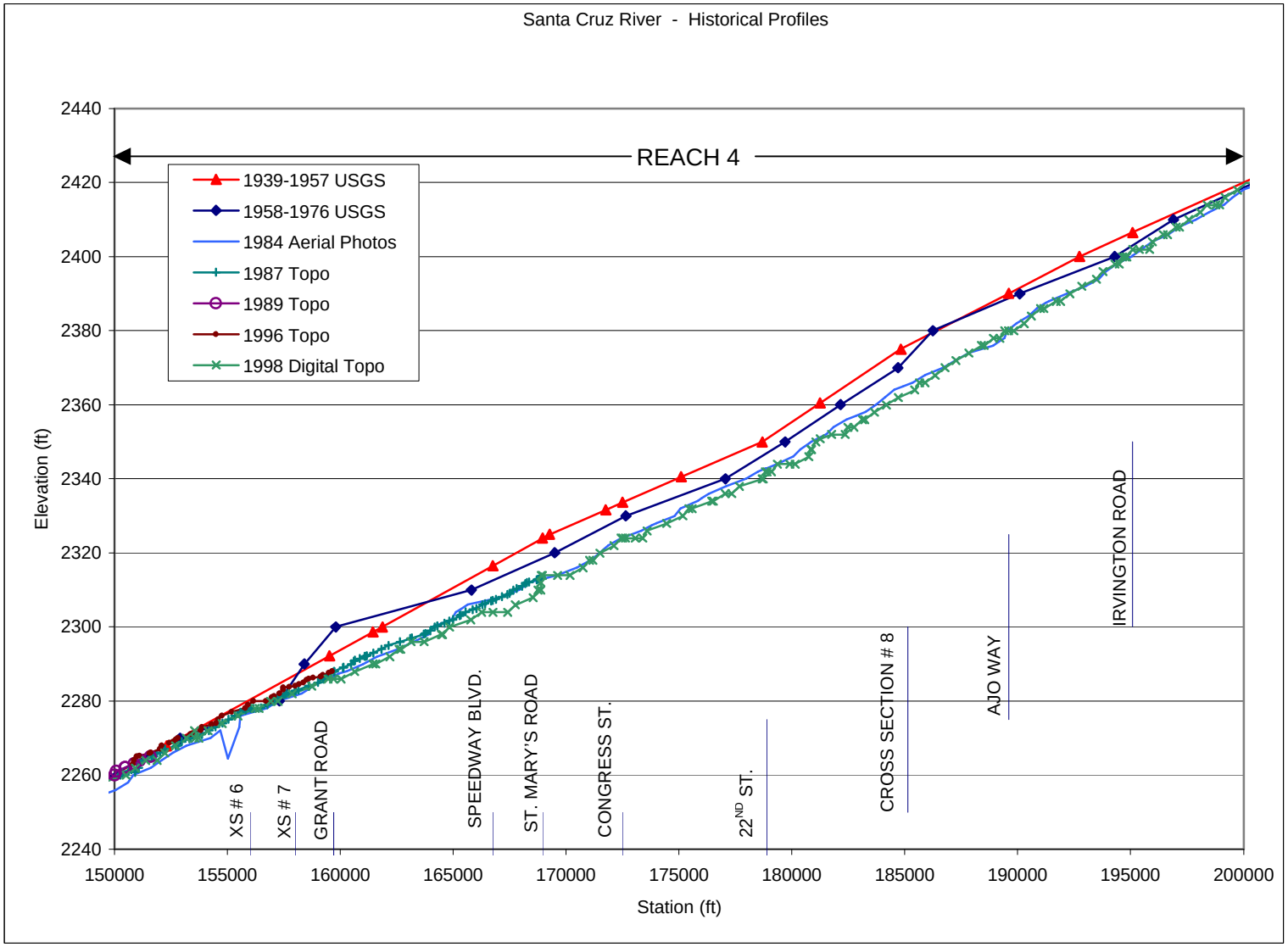

Figure 4 – Historical Profile Reach 4

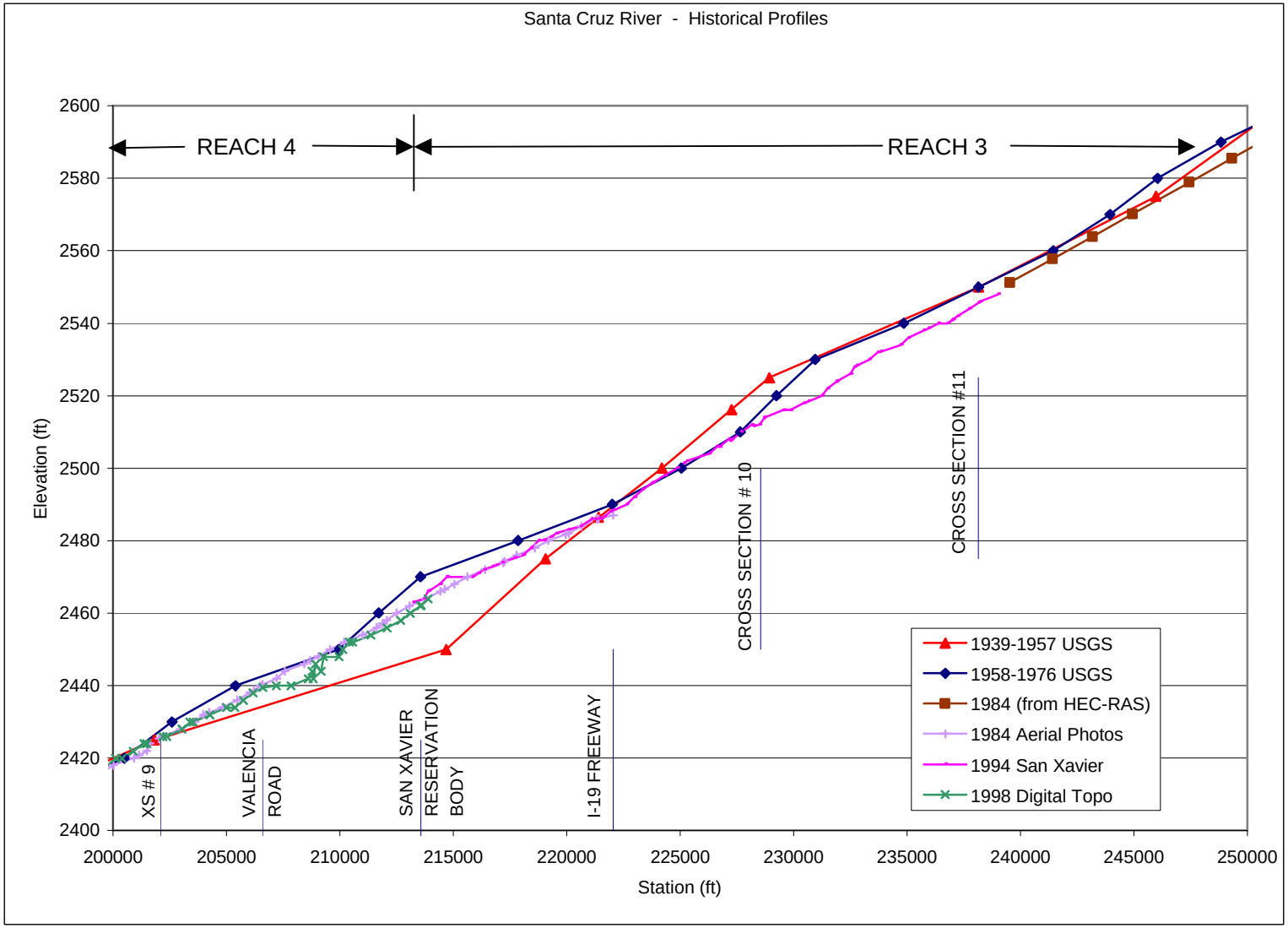

Figure 5 – Historical Profile Reaches 3 and 4

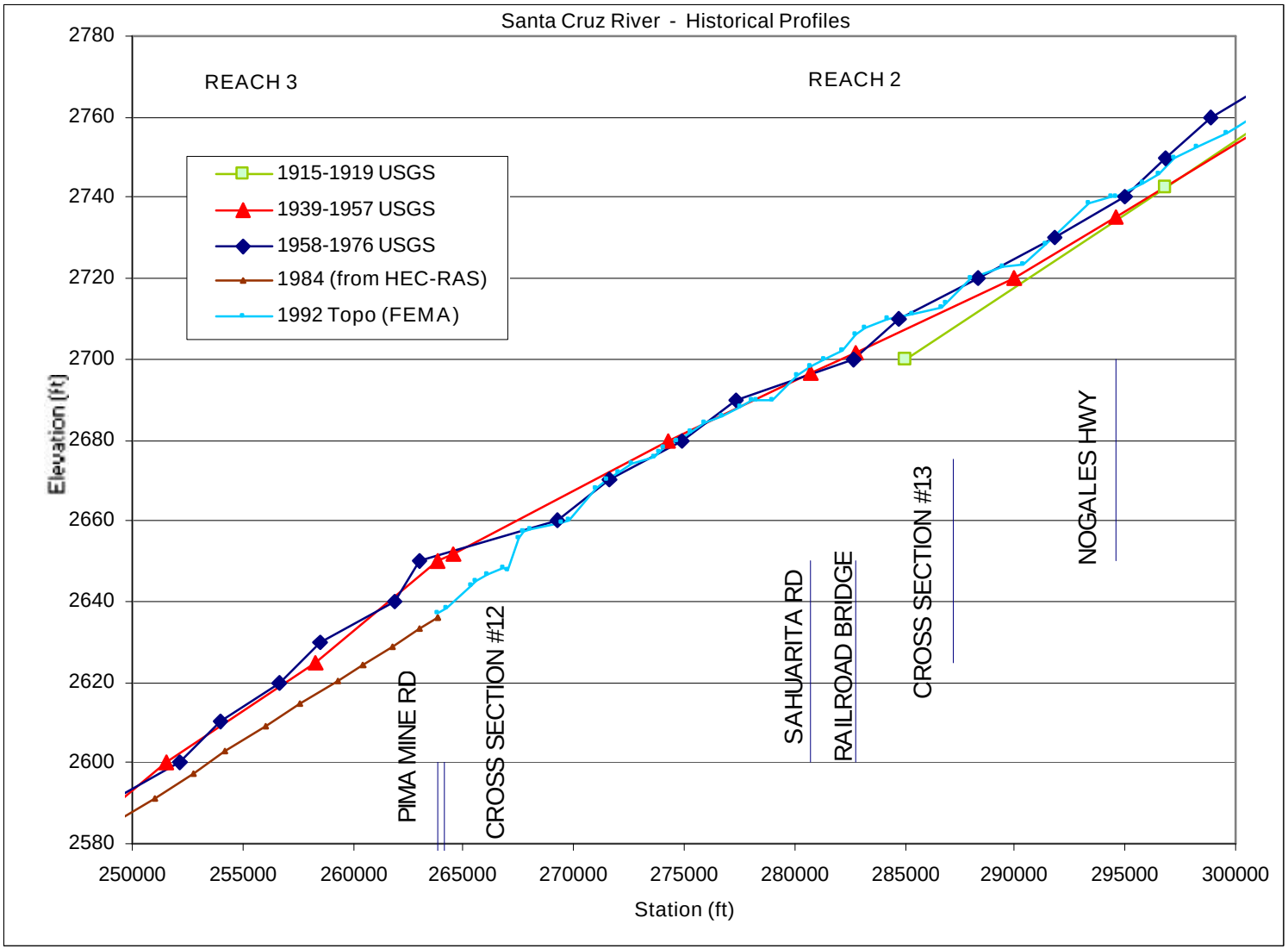

Figure 6 – Historical Profile Reaches 2 and 3

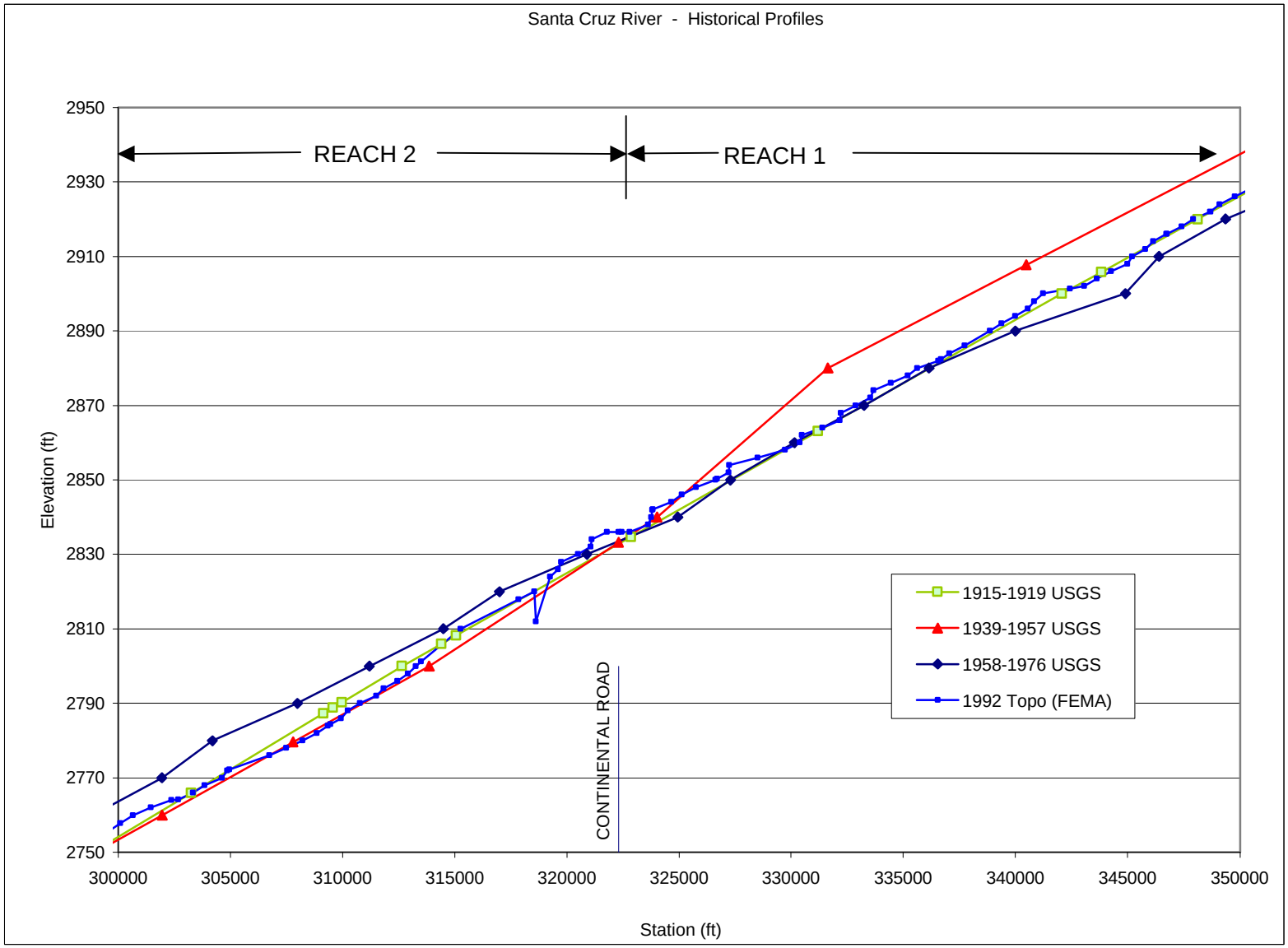

Figure 7 – Historical Profile Reaches 1 and 2

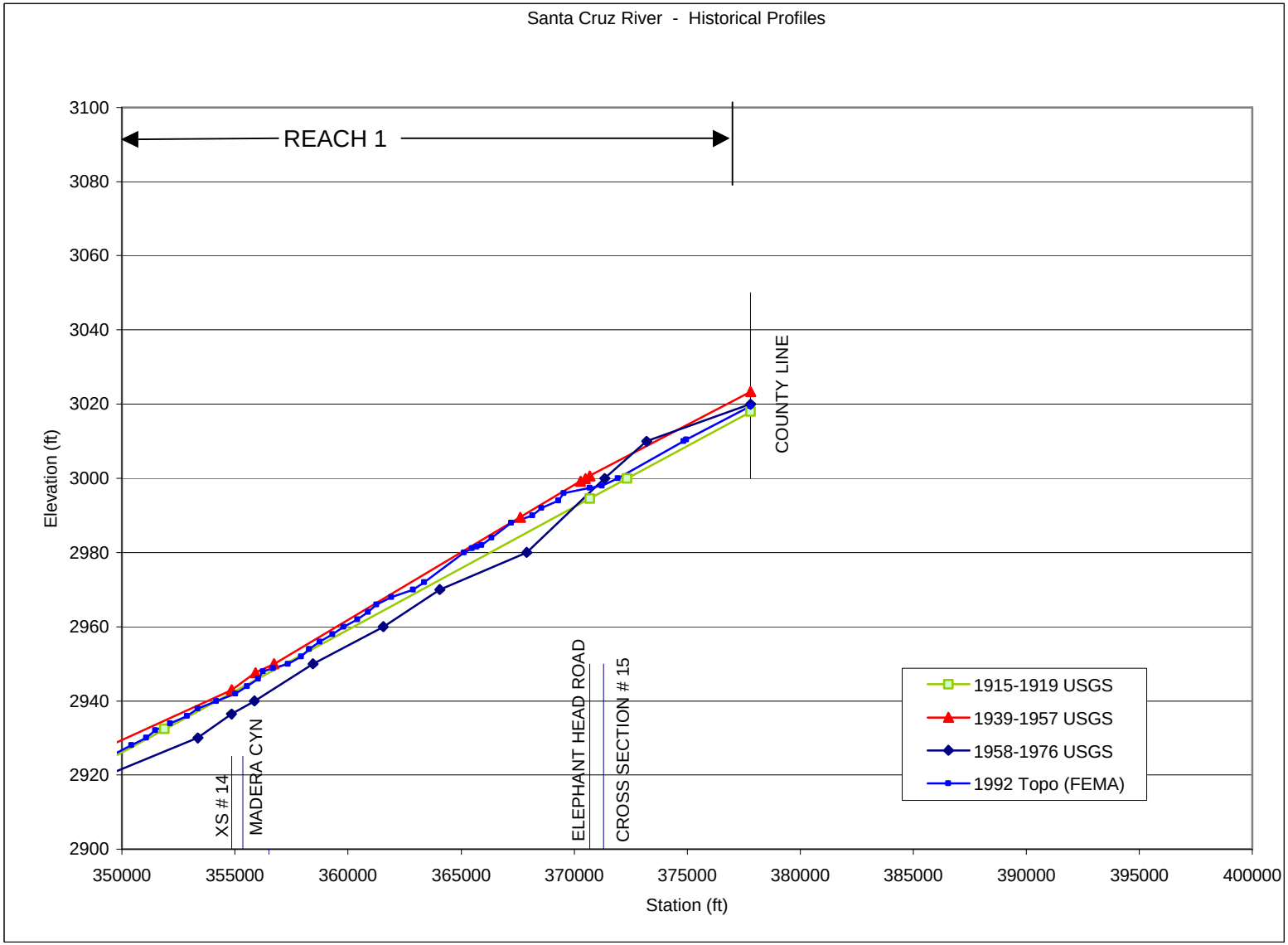

Figure 8 – Historical Profile Reach 1

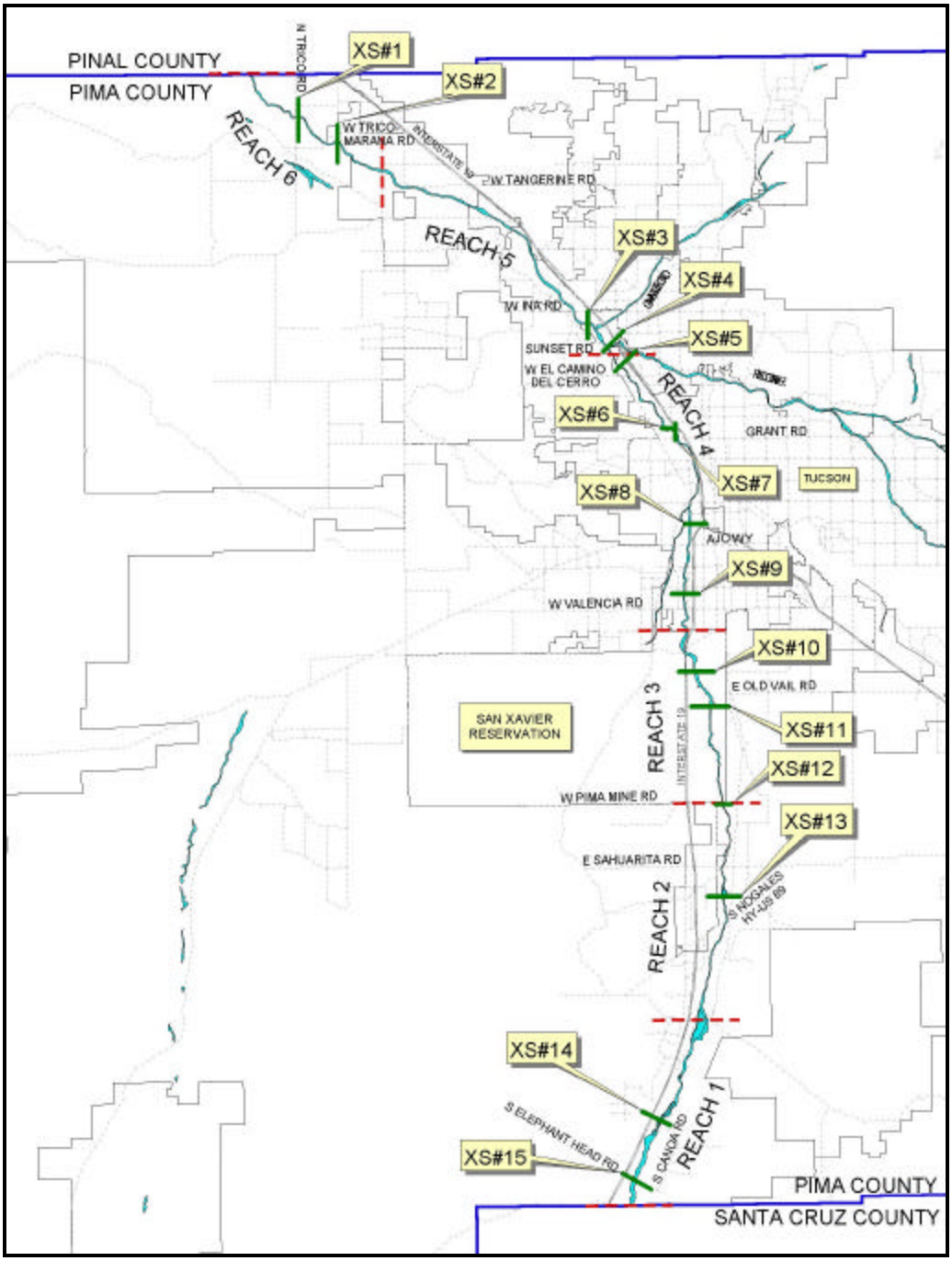

Figure 9 - Historic Cross Section Location Map

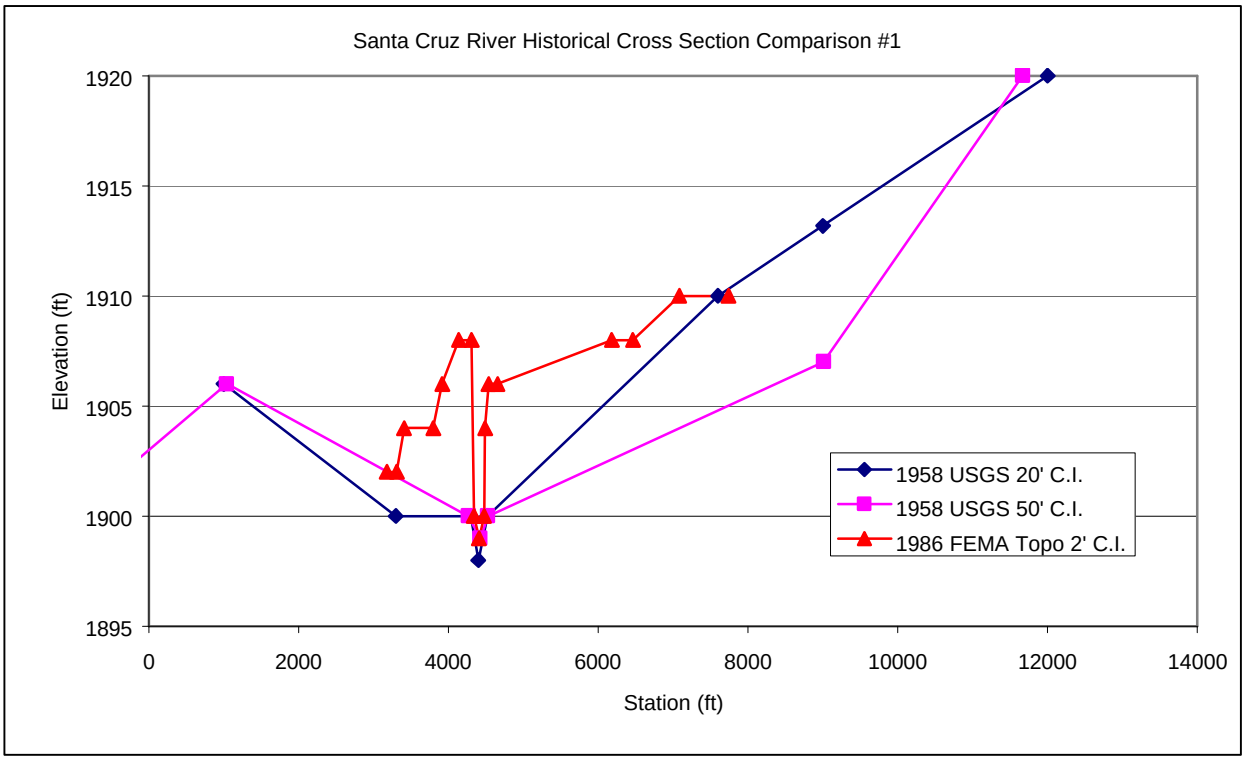

Figure 10 – Historic Cross Section #1

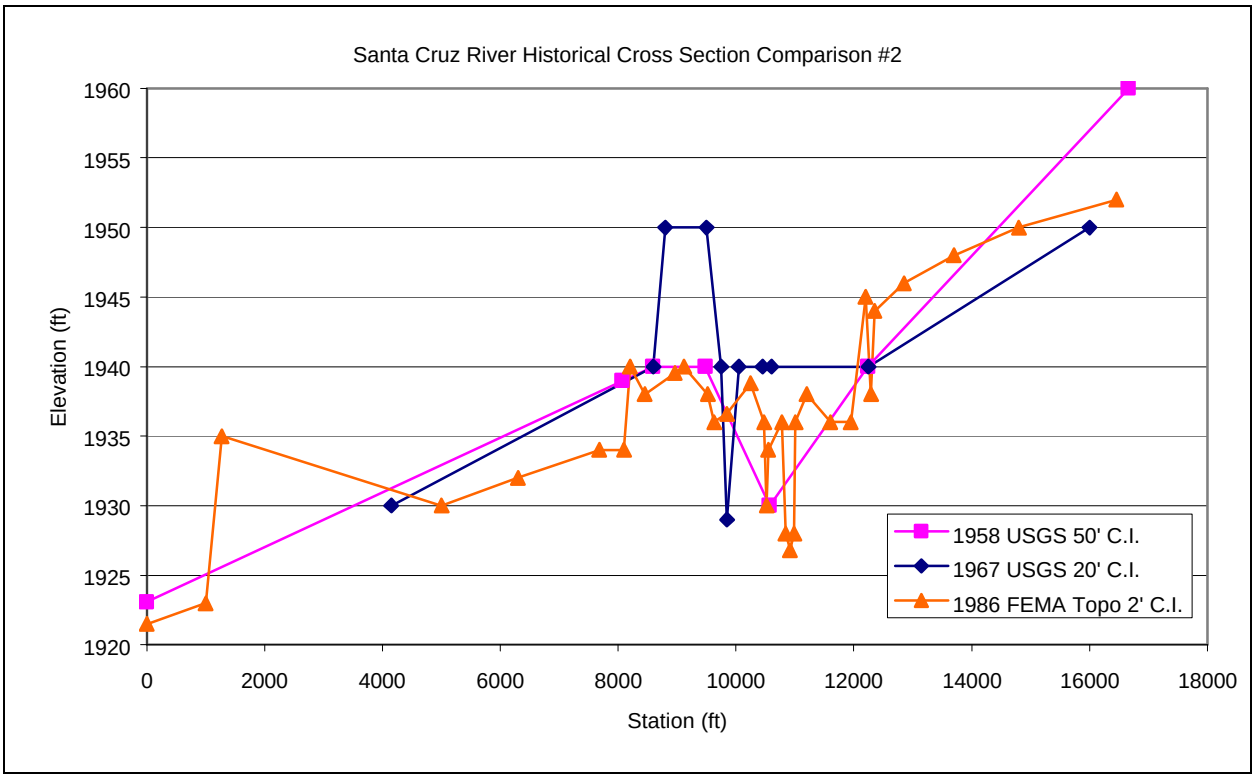

Figure 11 – Historic Cross Section #2

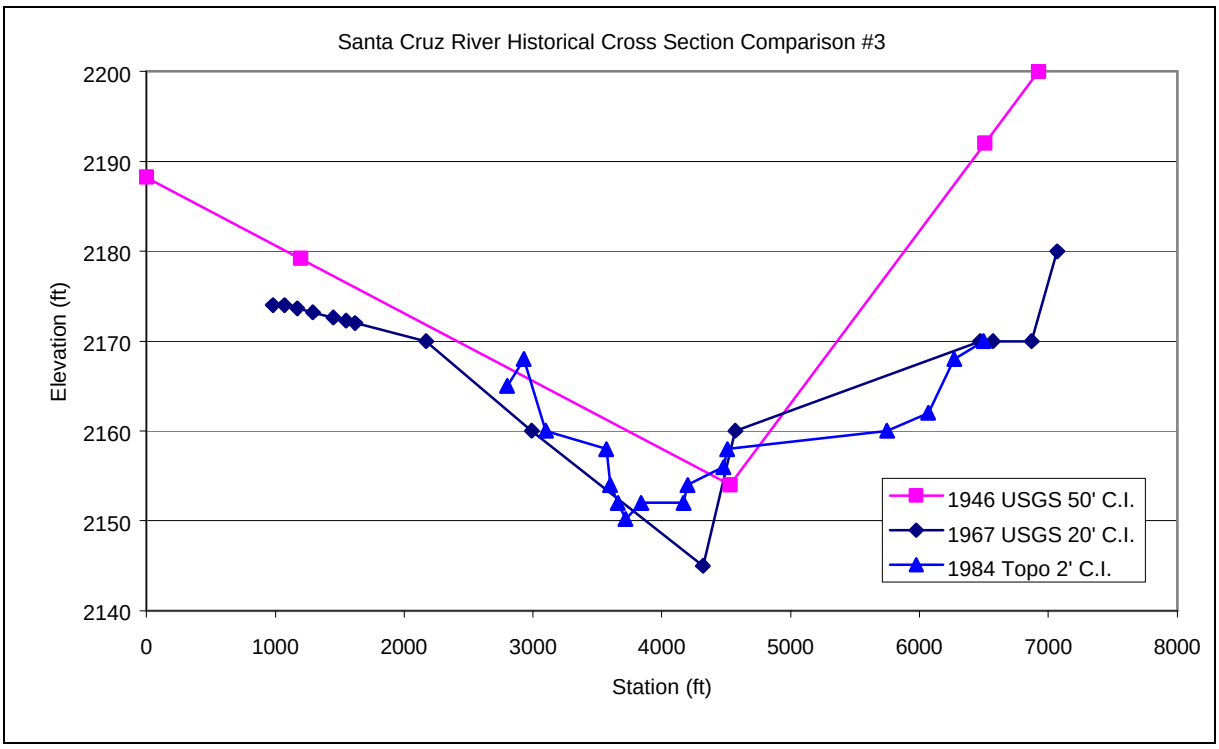

Figure 12 – Historic Cross Section #3

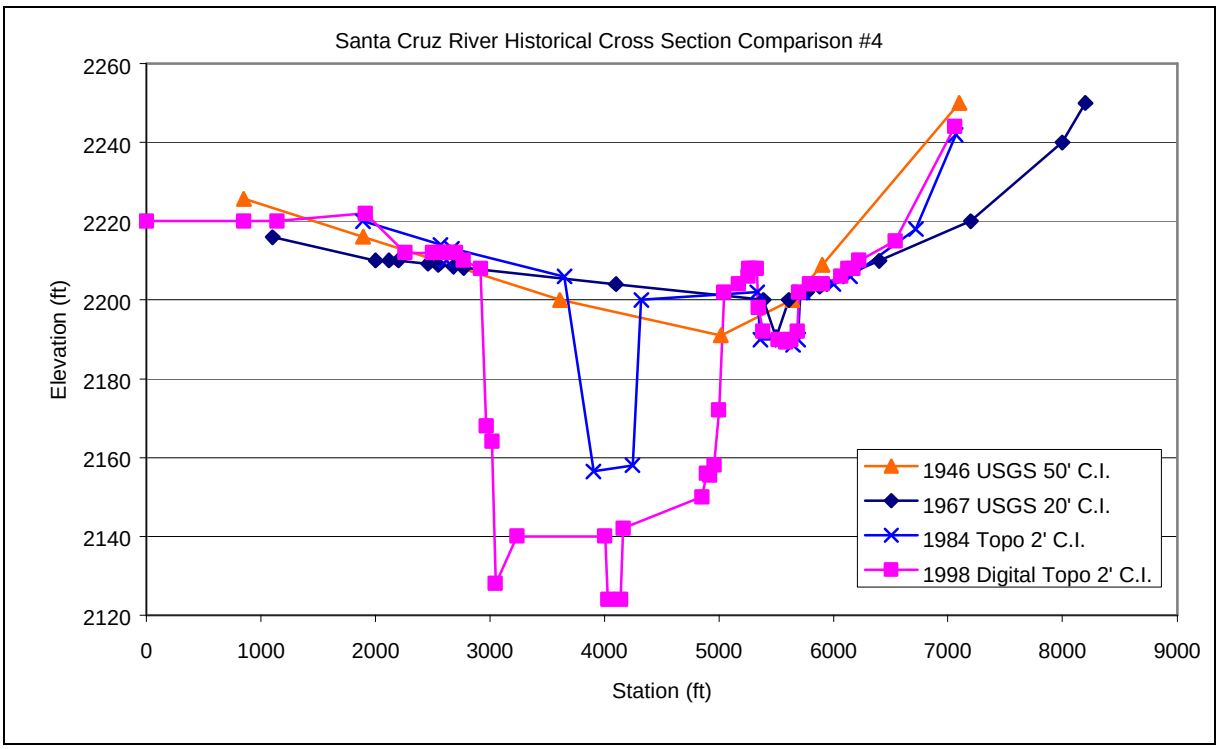

Figure 13 – Historic Cross Section #4

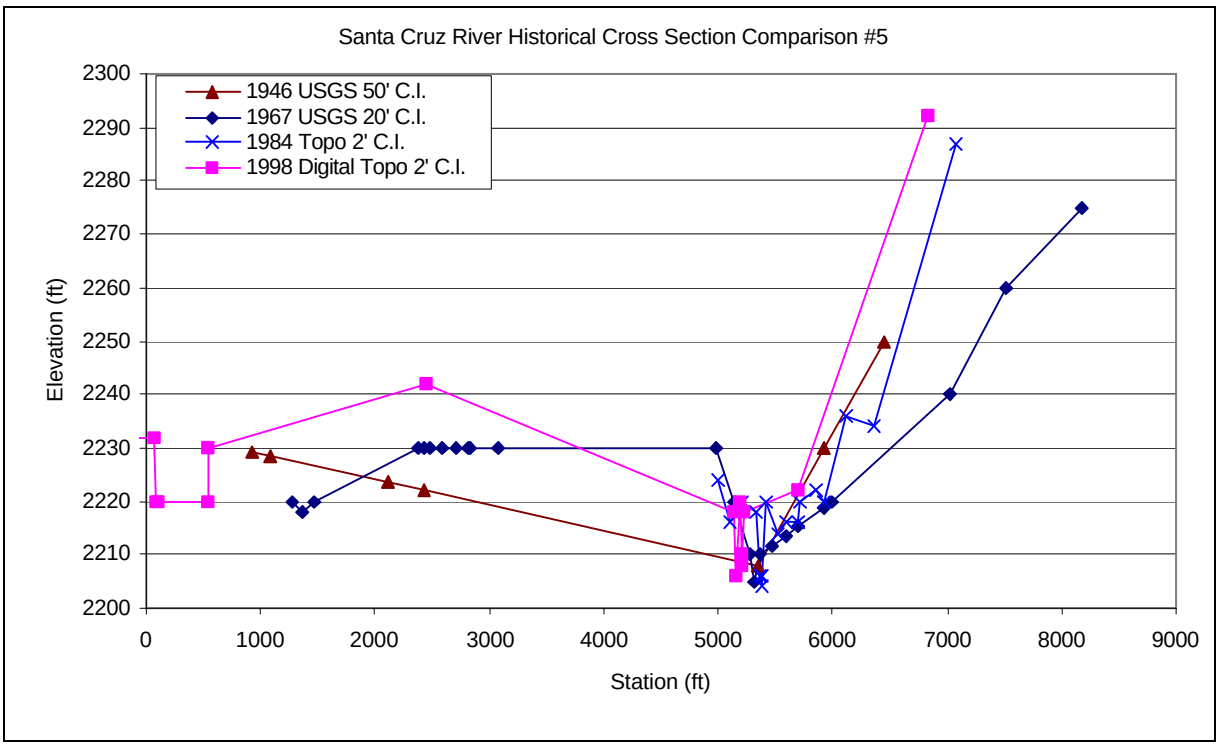

Figure 14 – Historic Cross Section #5

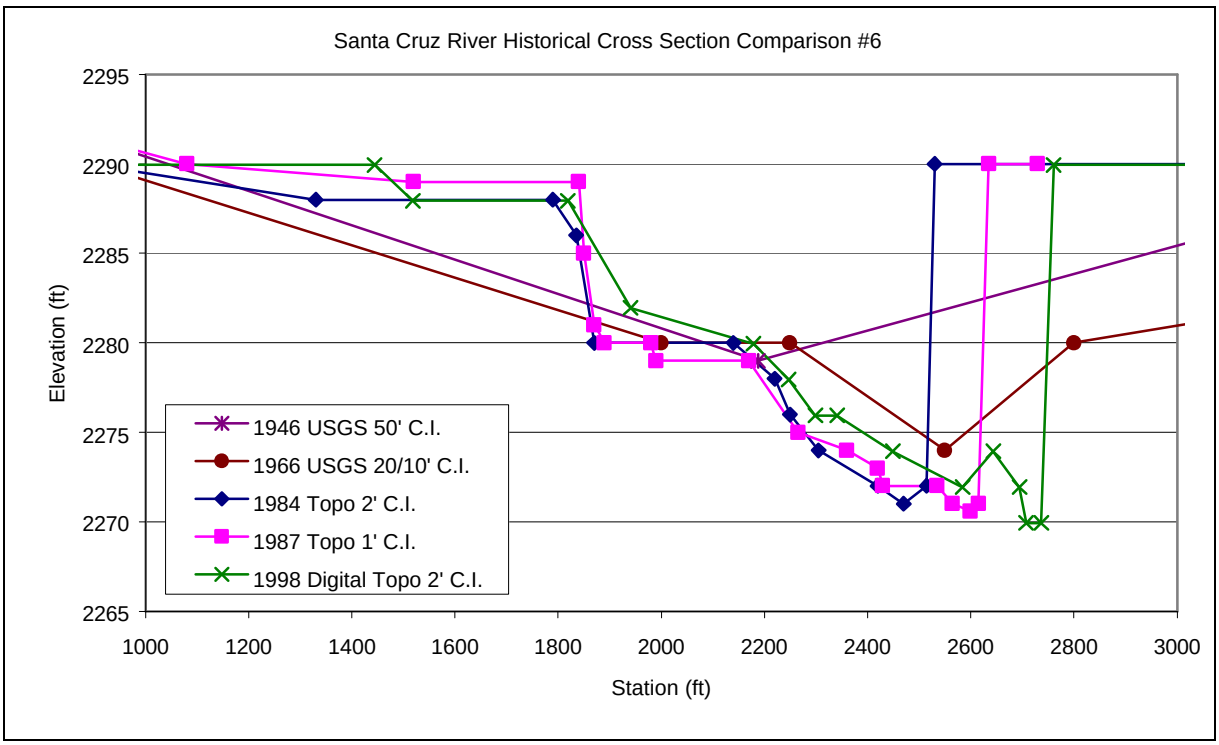

Figure 15 – Historic Cross Section #6

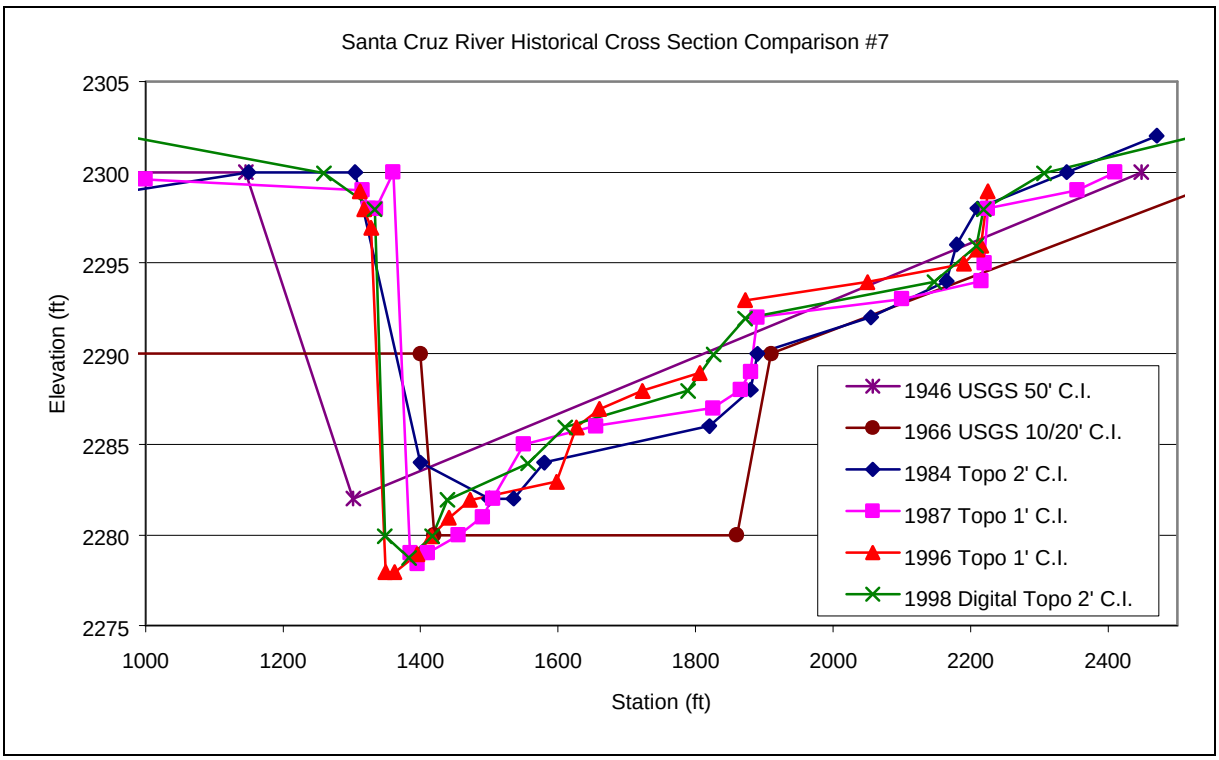

Figure 16 – Historic Cross Section #7

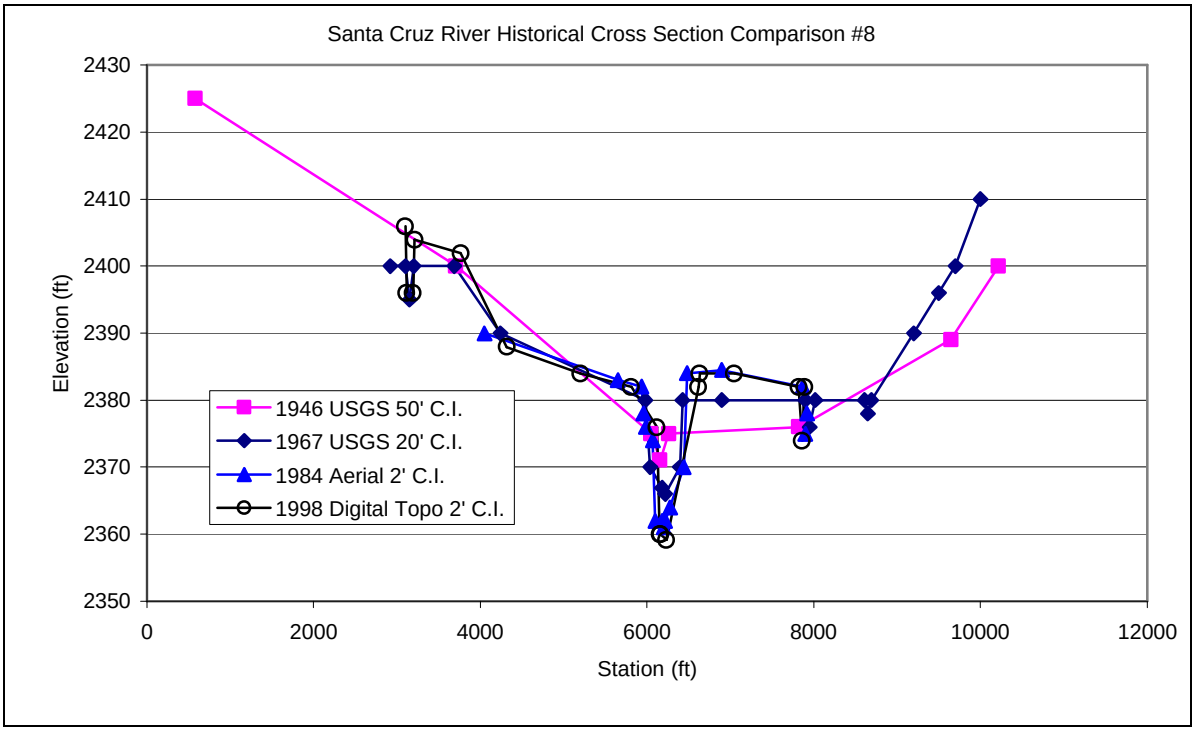

Figure 17 – Historic Cross Section #8

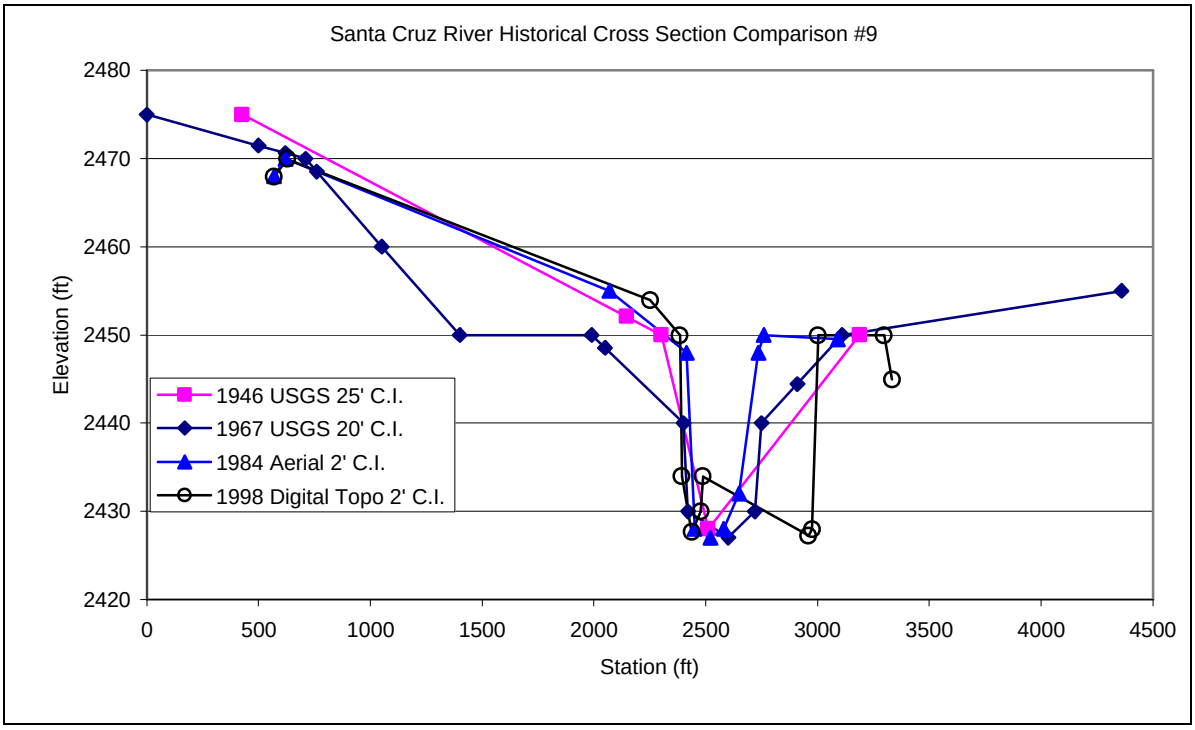

Figure 18 – Historic Cross Section #9

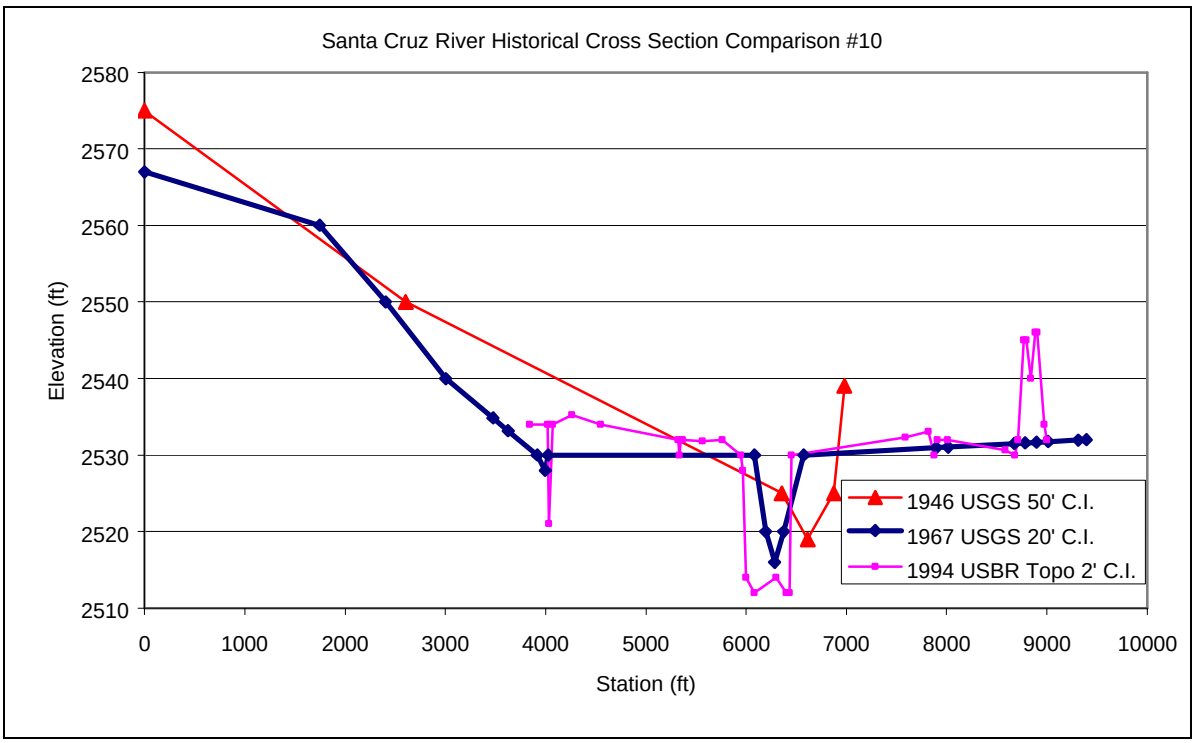

Figure 19 – Historic Cross Section #10

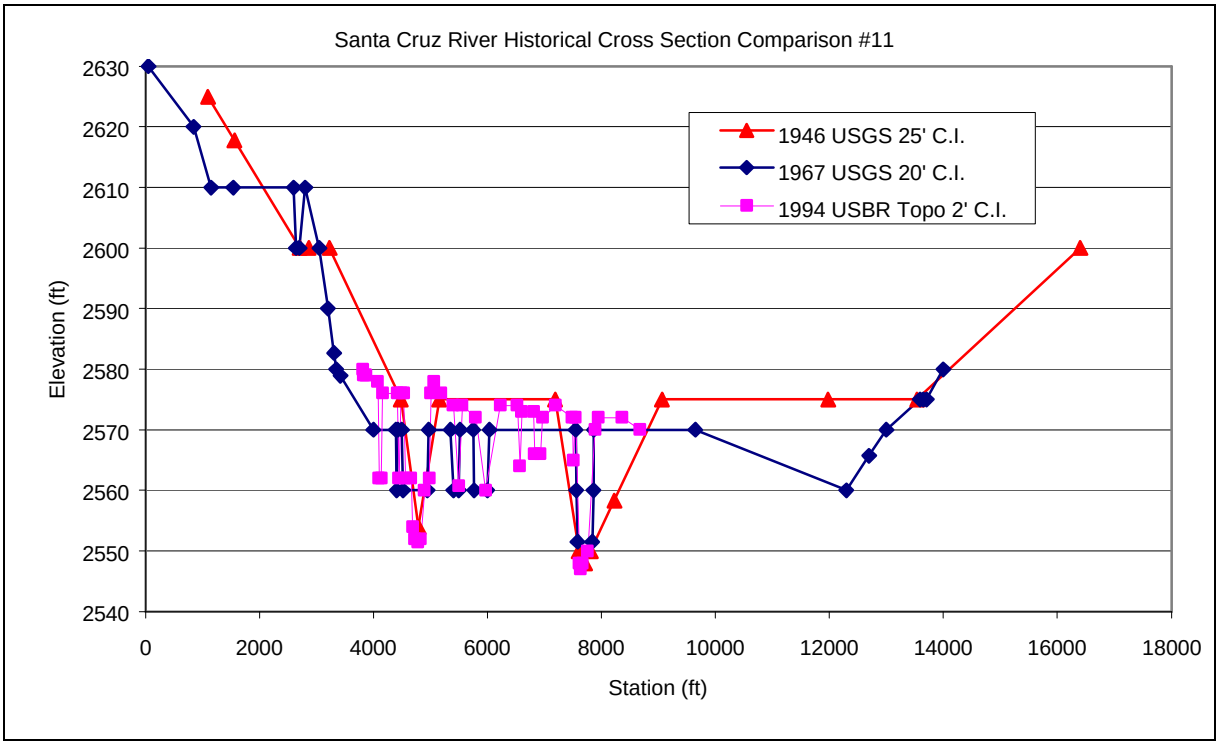

Figure 20 – Historic Cross Section #11

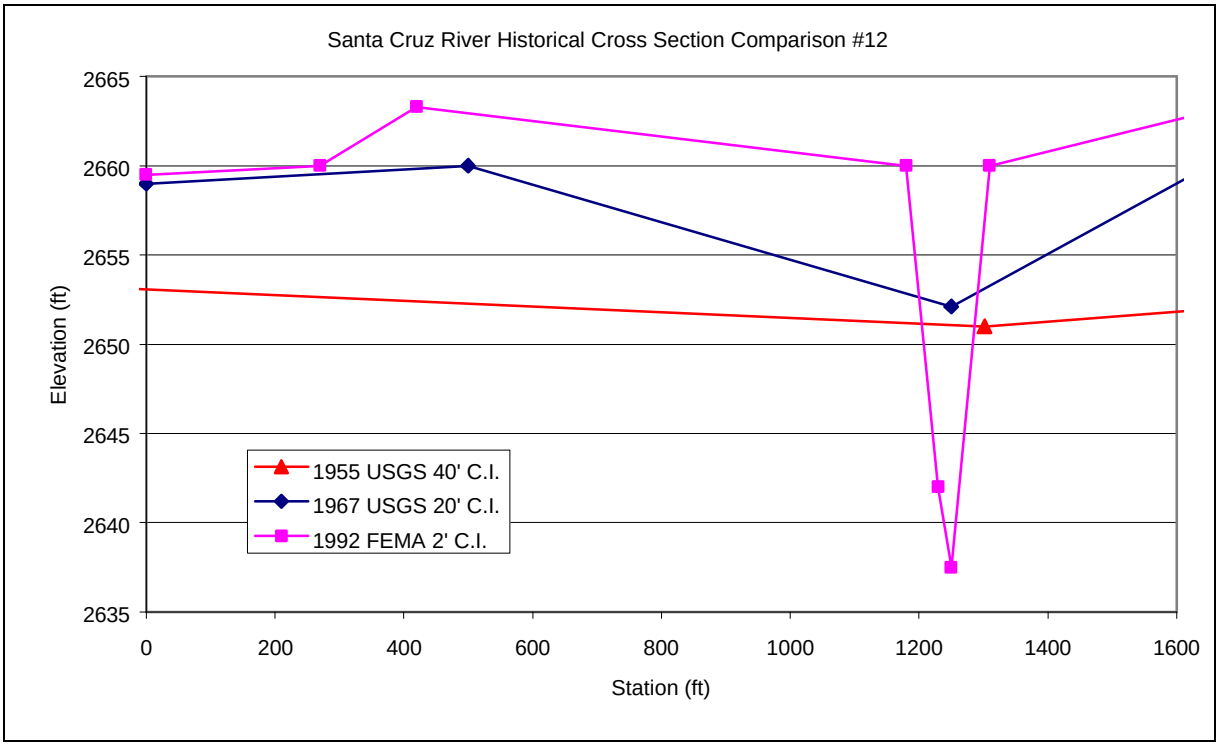

Figure 21 - Historic Cross Section #12

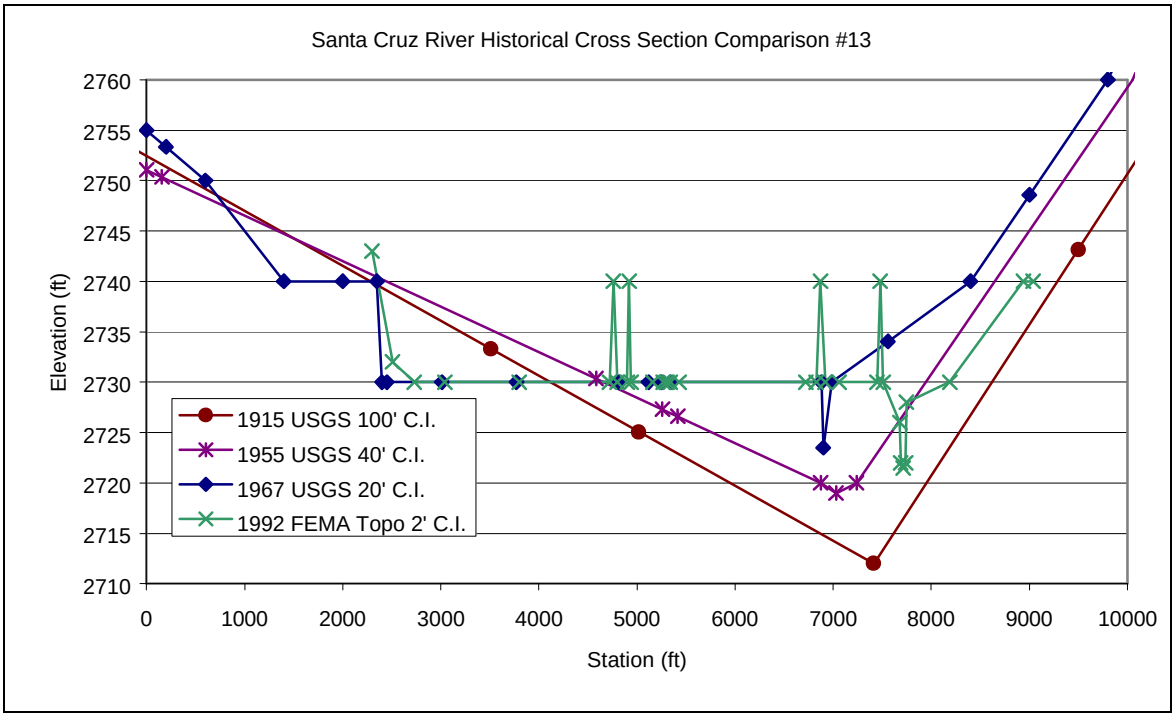

Figure 22 - Historic Cross Section #13

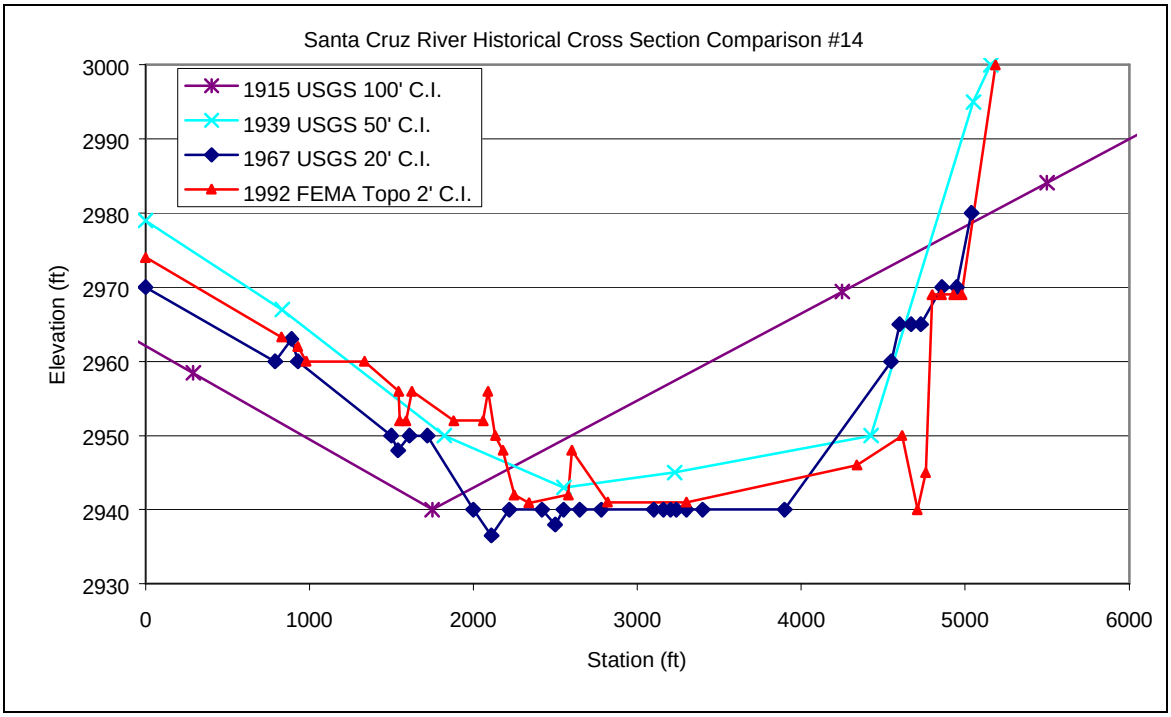

Figure 23 - Historic Cross Section #14

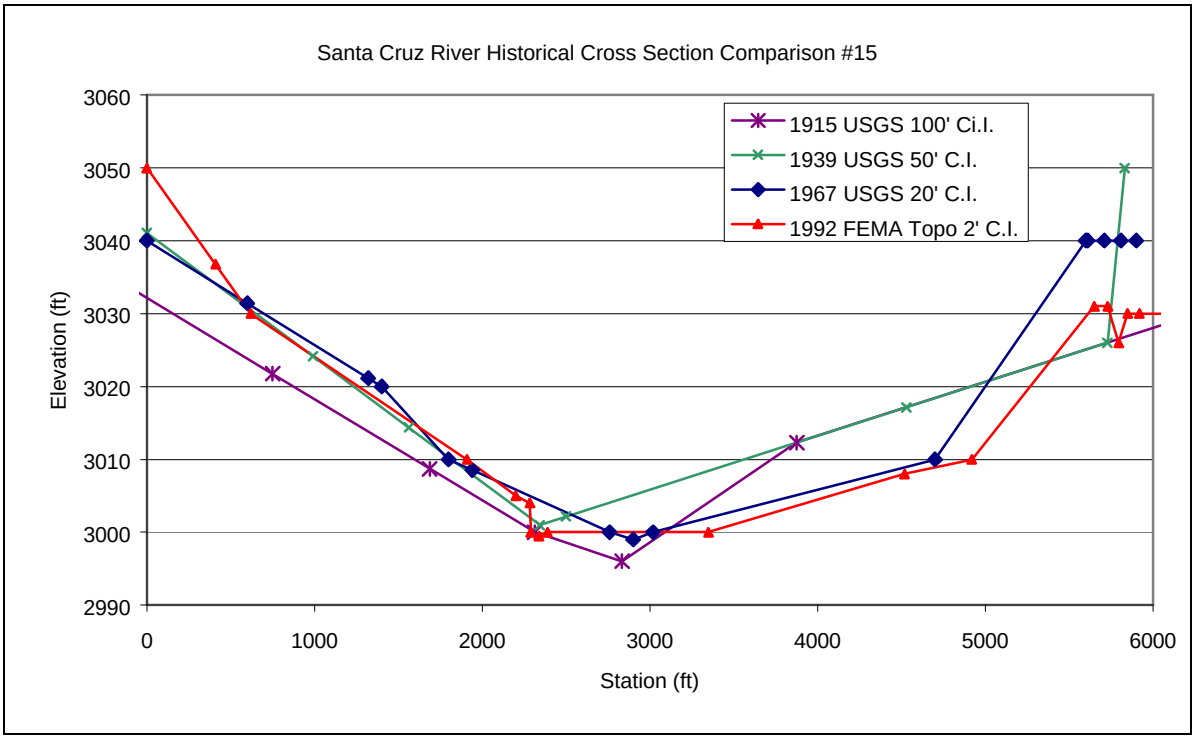

Figure 24 - Historic Cross Section #15

U.S. Army Corps
of Engineers
South Pacific Division
Los Angeles District

SANTA CRUZ RIVER WATERSHED MANAGEMENT STUDY

PIMA COUNTY, ARIZONA

Appendix E4
HEC-RAS Watersurface Profiles

August 2001

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
0	66000	1863	1865.34	1865.43	0.002003	2.39	29233.97	6178.62	0.32
0	70000	1863	1865.53	1865.62	0.002003	2.49	30402.72	6223.51	0.32
0.1	66000	1864	1866.44	1866.54	0.002452	2.82	27522.48	6554.76	0.36
0.1	70000	1864	1866.62	1866.72	0.002435	2.92	28739.01	6610.14	0.36
0.19	66000	1865	1867.64	1867.73	0.00231	2.8	28705.43	6560.53	0.35
0.19	70000	1865	1867.81	1867.91	0.002301	2.89	29884.56	6617.51	0.35
0.28	66000	1866.1	1868.68	1868.75	0.001822	2.59	32651.37	7306.54	0.31
0.28	70000	1866.1	1868.86	1868.93	0.001817	2.69	33942.45	7352.63	0.32
0.38	66000	1867	1869.63	1869.7	0.001974	2.45	31989.9	7358.17	0.32
0.38	70000	1867	1869.8	1869.88	0.001977	2.54	33285.09	7439.88	0.32
0.47	66000	1868	1870.73	1870.82	0.002528	2.99	29452.63	7346.28	0.37
0.47	70000	1868	1870.9	1870.99	0.00251	3.08	30723.91	7404.78	0.37
0.57	66000	1869.5	1871.96	1872.04	0.00238	2.97	30824.52	7974.43	0.36
0.57	70000	1869.5	1872.13	1872.21	0.002367	3.07	32141.76	8032.91	0.36
0.66	66000	1871.8	1872.96	1873.02	0.001635	1.56	34368.32	7871.14	0.27
0.66	70000	1871.8	1873.13	1873.19	0.001658	1.71	35695.36	8035.05	0.27
0.76	66000	1872.5	1873.71	1873.76	0.001335	1.48	37140.98	7960.88	0.24
0.76	70000	1872.5	1873.88	1873.94	0.001346	1.62	38527.58	8037.72	0.25
0.85	66000	1873	1874.46	1874.51	0.001696	1.86	35969.87	7686.6	0.28
0.85	70000	1873	1874.64	1874.7	0.001711	2.01	37364.61	7826.92	0.29
0.95	66000	1873.6	1875.36	1875.42	0.001933	2.24	34307.64	7749.7	0.31
0.95	70000	1873.6	1875.54	1875.61	0.001927	2.37	35730.1	7860.35	0.31
1.04	66000	1874.3	1876.39	1876.46	0.002219	2.72	32969.25	8883.69	0.34
1.04	70000	1874.3	1876.57	1876.64	0.002202	2.84	34562.25	9070.09	0.35
1.14	66000	1875	1877.57	1877.64	0.002725	2.78	30641.67	7032.47	0.37
1.14	70000	1875	1877.74	1877.81	0.002715	2.87	31892.99	7695.7	0.38
1.23	66000	1876	1878.69	1878.76	0.002391	2.75	32458.47	8589.84	0.35
1.23	70000	1876	1878.86	1878.93	0.002383	2.83	33897.63	8684.38	0.36
1.33	66000	1876.3	1879.81	1879.86	0.002805	3.6	37835.59	7193.66	0.4
1.33	70000	1876.3	1879.98	1880.03	0.002847	3.73	39113.69	7501.38	0.41
1.42	66000	1876.6	1881.14	1881.21	0.003042	4.38	34057.48	7706.44	0.44
1.42	70000	1876.6	1881.32	1881.39	0.003024	4.5	35462.18	7822.96	0.44
1.52	66000	1877	1882.04	1882.1	0.002826	4.61	39595.98	8435.21	0.43

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1.52	70000	1877	1882.22	1882.28	0.002819	4.74	41120.79	8536.65	0.44
1.61	66000	1878.1	1882.98	1883.02	0.001784	4.1	46358.56	9533.76	0.35
1.61	70000	1878.1	1883.16	1883.2	0.001794	4.2	48109.62	9630.79	0.35
1.7	66000	1878.5	1883.78	1883.84	0.002315	5.12	42379.56	9250	0.41
1.7	70000	1878.5	1883.96	1884.03	0.00231	5.22	44092.14	9381.44	0.41
1.8	66000	1880	1884.59	1884.64	0.001616	3.54	39342.7	9216.48	0.33
1.8	70000	1880	1884.77	1884.82	0.001599	3.61	40997.91	9256.97	0.33
1.89	66000	1880.5	1885.62	1885.68	0.002304	4.77	35585.17	9789.07	0.4
1.89	70000	1880.5	1885.78	1885.85	0.002275	4.83	37209.95	9929.71	0.4
1.99	66000	1882	1886.6	1886.64	0.001717	3.75	41029.05	11366.17	0.34
1.99	70000	1882	1886.75	1886.8	0.001707	3.79	42823.08	11454.79	0.34
2.08	66000	1882.5	1887.48	1887.52	0.001627	3.88	44543.04	12272.49	0.33
2.08	70000	1882.5	1887.63	1887.67	0.001615	3.94	46401.59	12363.88	0.33
2.18	66000	1883.4	1888.25	1888.29	0.001514	3.85	45393.03	12380.46	0.34
2.18	70000	1883.4	1888.39	1888.44	0.001507	3.91	47208.52	12427.65	0.35
2.27	66000	1884	1888.95	1888.99	0.001384	3.73	47103.63	12774.72	0.31
2.27	70000	1884	1889.09	1889.13	0.001379	3.79	48938.62	12790.24	0.31
2.37	66000	1884.5	1889.53	1889.58	0.001065	3.27	38521.96	12968.73	0.27
2.37	70000	1884.5	1889.66	1889.71	0.001039	3.28	40271.48	12995.24	0.27
2.46	66000	1885.5	1890.28	1890.39	0.003284	5.41	27559.97	13444.66	0.47
2.46	70000	1885.5	1890.39	1890.5	0.003135	5.36	29042.82	13459.98	0.46
2.56	66000	1886.2	1892.05	1892.14	0.002971	4.97	30043.56	15382.1	0.46
2.56	70000	1886.2	1892.12	1892.21	0.002986	5.03	31156.05	15406.85	0.46
2.65	66000	1886.5	1893.07	1893.16	0.001717	4.71	32949.59	14119.81	0.43
2.65	70000	1886.5	1893.15	1893.24	0.001745	4.75	34105.46	14188.14	0.43
2.75	66000	1888.2	1893.83	1893.9	0.001566	4.37	36115.46	15087.18	0.34
2.75	70000	1888.2	1893.92	1893.99	0.001584	4.44	37432.88	15143.18	0.34
2.84	66000	1888.6	1894.52	1894.61	0.001582	4.6	33867.76	14523.58	0.36
2.84	70000	1888.6	1894.61	1894.7	0.001596	4.66	35224.68	14613.93	0.36
2.94	66000	1889.4	1895.33	1895.43	0.001816	4.66	32873.17	15317.8	0.39
2.94	70000	1889.4	1895.43	1895.52	0.001803	4.68	34367.09	15354.49	0.39
3.03	66000	1889.9	1896.32	1896.41	0.002161	3.86	32039.1	17444.91	0.44
3.03	70000	1889.9	1896.42	1896.5	0.002135	3.83	33662.7	17464.59	0.43

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
3.13	66000	1890.5	1897.31	1897.44	0.001847	5.16	30018.52	12663.6	0.41
3.13	70000	1890.5	1897.4	1897.53	0.001872	5.22	31196.02	12889.17	0.41
3.22	66000	1890.9	1898.23	1898.38	0.0019	5.85	33163.36	17580.41	0.39
3.22	70000	1890.9	1898.33	1898.47	0.001877	5.87	34851.34	17605.12	0.39
3.31	66000	1891.8	1899.27	1899.37	0.001681	5.2	32119.95	12656.74	0.36
3.31	70000	1891.8	1899.36	1899.47	0.001705	5.28	33323.15	12878.64	0.37
3.41	66000	1892.5	1900.22	1900.36	0.002249	6.28	31515.1	17399.18	0.43
3.41	70000	1892.5	1900.32	1900.46	0.0022	6.27	33260.86	17439.52	0.42
3.5	66000	1893.1	1900.85	1900.93	0.000879	2.98	38615.45	16022.34	0.25
3.5	70000	1893.1	1900.94	1901.02	0.000894	3.04	40115.34	16185.07	0.25
3.6	66000	1893.7	1901.56	1901.79	0.004839	8.41	23934.59	13847.36	0.61
3.6	70000	1893.7	1901.66	1901.89	0.004662	8.32	25356.15	14112.72	0.6
3.69	66000	1894.4	1902.75	1902.86	0.002179	6.27	31955.51	15910.63	0.42
3.69	70000	1894.4	1902.83	1902.94	0.002206	6.36	33201.18	15978.4	0.42
3.79	66000	1895	1903.98	1904.15	0.002984	7.15	27696.64	13720.46	0.49
3.79	70000	1895	1904.07	1904.24	0.002966	7.19	29024.25	15447.71	0.49
3.88	66000	1895.7	1905.23	1905.45	0.002887	7.75	27208.67	14558.12	0.49
3.88	70000	1895.7	1905.32	1905.54	0.002876	7.78	28501.99	14628.84	0.49
3.98	66000	1897.2	1906.1	1906.23	0.001808	5.61	30827.39	15907.65	0.38
3.98	70000	1897.2	1906.18	1906.32	0.001839	5.71	32193.11	16012.33	0.38
4.07	66000	1898.7	1907.22	1907.34	0.002167	6.44	32339.07	16186.75	0.42
4.07	70000	1898.7	1907.31	1907.44	0.002164	6.5	33856.14	16432.19	0.42
4.17	66000	1899.3	1908.09	1908.23	0.001958	6.1	32937.32	18205.22	0.4
4.17	70000	1899.3	1908.18	1908.31	0.001956	6.13	34493.98	18229.44	0.4
4.24	66000	1899.8	1908.48	1908.62	0.001906	6.44	34000.98	17567.37	0.4
4.24	70000	1899.8	1908.57	1908.71	0.001904	6.47	35474.59	17627.41	0.4
4.25	Bridge								
4.26	66000	1900	1908.75	1908.87	0.001543	5.84	35296.04	15978.46	0.36
4.26	70000	1900	1908.84	1908.95	0.001568	5.92	36620.52	16075.21	0.36
4.36	66000	1900.86	1909.35	1909.48	0.0017	5.97	33211.15	14367.29	0.37
4.36	70000	1900.86	1909.44	1909.57	0.001716	6.03	34504.14	14454.94	0.38
4.45	66000	1901.96	1910.16	1910.34	0.002447	6.99	32056.37	18001.61	0.45
4.45	70000	1901.96	1910.25	1910.43	0.002396	6.97	33698.04	18053.6	0.44

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
4.55	66000	1902.86	1911.25	1911.46	0.002319	6.9	31515.82	17386.47	0.44
4.55	70000	1902.86	1911.33	1911.54	0.002334	6.97	32906.43	17504.22	0.44
4.64	66000	1903.9	1912.37	1912.57	0.002242	6.88	31314.07	17232.82	0.43
4.64	70000	1903.9	1912.46	1912.66	0.002237	6.92	32795.42	17291.41	0.43
4.74	66000	1904.9	1913.52	1913.85	0.00299	8.12	24033.4	14264.14	0.5
4.74	70000	1904.9	1913.61	1913.94	0.003019	8.22	25336.75	14553.87	0.5
4.83	66000	1905.5	1914.8	1915	0.002414	7.19	26805.41	14512.57	0.45
4.83	70000	1905.5	1914.9	1915.1	0.002429	7.28	28283.48	15310.9	0.45
4.92	66000	1906.3	1915.97	1916.4	0.004307	9.68	19377.3	12345.73	0.6
4.92	70000	1906.3	1916.08	1916.5	0.004328	9.78	20935.22	15641.51	0.6
5.02	66000	1907.3	1917.52	1917.71	0.001985	6.93	28129.47	14176.83	0.41
5.02	70000	1907.3	1917.63	1917.82	0.001987	6.99	29636.39	14565.02	0.42
5.11	66000	1909.1	1918.63	1918.86	0.002631	7.57	26438.46	13626.48	0.47
5.11	70000	1909.1	1918.73	1918.96	0.002623	7.62	27838.06	13835.8	0.47
5.21	66000	1909.5	1920	1920.53	0.004087	10.47	20037.95	7759.65	0.6
5.21	70000	1909.5	1920.1	1920.63	0.004093	10.56	21667.58	15968.81	0.6
5.3	66000	1910.5	1922.11	1922.29	0.002932	8.41	29148.24	16326.72	0.49
5.3	70000	1910.5	1922.2	1922.37	0.002898	8.42	30626.72	16407.75	0.49
5.4	66000	1911.5	1923.48	1924.02	0.003472	10.62	25425.59	15602.22	0.57
5.4	70000	1911.5	1923.56	1924.09	0.003452	10.64	26814.71	15707.72	0.57
5.49	66000	1912.5	1925.06	1925.53	0.002736	9.8	30272.49	15635.55	0.51
5.49	70000	1912.5	1925.14	1925.6	0.002784	9.93	31478.46	15677.48	0.51
5.59	66000	1913.5	1926.42	1927.01	0.003125	10.49	31618.23	15602.97	0.55
5.59	70000	1913.5	1926.52	1927.1	0.003145	10.59	33179.21	15693.47	0.55
5.68	66000	1914.7	1927.95	1928.46	0.002788	10.07	34144.1	16074.74	0.52
5.68	70000	1914.7	1928.06	1928.55	0.002791	10.13	35842.29	16191.09	0.52
5.78	66000	1916	1929.3	1929.79	0.002767	9.99	33041.07	15688.87	0.51
5.78	70000	1916	1929.4	1929.89	0.002785	10.08	34693.53	15828.99	0.51
5.87	66000	1917.3	1930.73	1931.33	0.003156	10.65	27831.4	14848.46	0.55
5.87	70000	1917.3	1930.84	1931.43	0.003176	10.75	29555.84	14986.06	0.55
5.97	66000	1918.3	1932.15	1932.61	0.001942	7.17	26190.03	12403.67	0.42
5.97	70000	1918.3	1932.27	1932.74	0.002006	7.35	27671.55	12828.23	0.42
6.06	66000	1919.3	1933.49	1934.8	0.004066	12.14	17888.14	8603.06	0.63
6.06	70000	1919.3	1933.82	1934.94	0.00359	11.62	21932.35	12591.56	0.59

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
6.16	66000	1920	1935.49	1935.72	0.000862	6.64	38234.73	13046.68	0.3
6.16	70000	1920	1935.59	1935.83	0.000911	6.86	39614.62	13150.45	0.31
6.24	66000	1921	1935.49	1936.39	0.001992	9.15	18272.44	7934.5	0.43
6.24	70000	1921	1935.59	1936.55	0.002132	9.51	19054.19	8055.65	0.45
6.245	Bridge								
6.25	66000	1921	1938.75	1938.93	0.000569	4.9	48714.54	14022.84	0.21
6.25	70000	1921	1936.63	1937.83	0.002165	10.02	21637.12	11728.84	0.46
6.34	66000	1921.8	1939.04	1939.21	0.000544	4.68	49920.8	13557.85	0.2
6.34	70000	1921.8	1938.29	1938.6	0.000972	6.06	39816.09	13309.99	0.27
6.44	66000	1922.5	1939.2	1939.7	0.001203	8.23	36001.06	12458.72	0.36
6.44	70000	1922.5	1938.61	1939.43	0.001869	10.01	29000.02	11306.64	0.44
6.53	66000	1923.5	1939.63	1940.52	0.002296	10.51	26349.05	9504.86	0.49
6.53	70000	1923.5	1939.38	1940.54	0.002967	11.81	24139.21	8413.96	0.55
6.63	66000	1925	1940.88	1941.17	0.000986	7.03	40800.11	11910.87	0.32
6.63	70000	1925	1941.01	1941.3	0.001033	7.24	42312.89	12013.26	0.33
6.72	66000	1926.5	1941.27	1941.63	0.001253	7.37	34918.1	10186.6	0.36
6.72	70000	1926.5	1941.42	1941.78	0.001302	7.57	36404.49	10504.12	0.36
6.82	66000	1927.7	1941.74	1942.59	0.003517	11.38	24178.23	8024.17	0.58
6.82	70000	1927.7	1941.91	1942.76	0.003544	11.53	25596.86	8413.51	0.59
6.91	66000	1929.2	1943.16	1944.26	0.003706	12.6	21601.63	7573.74	0.61
6.91	70000	1929.2	1943.35	1944.43	0.003712	12.73	23025.09	7890.57	0.61
7.01	66000	1932	1945.11	1946.38	0.004368	13.21	17857.15	7876.92	0.66
7.01	70000	1932	1945.3	1946.57	0.004392	13.38	19387.01	8118.72	0.66
7.1	66000	1932	1947.09	1948.58	0.00405	12.96	17417.98	9564.19	0.63
7.1	70000	1932	1947.3	1948.75	0.004	13.02	19501.44	10042.59	0.63
7.2	66000	1934	1949.39	1950.83	0.004875	10.16	12794.72	9260.35	0.64
7.2	70000	1934	1949.55	1951	0.004945	10.33	14306.69	10183.97	0.65
7.29	66000	1936.5	1951.81	1953.11	0.004281	14.25	23864.04	13332.32	0.66
7.29	70000	1936.5	1952.04	1953.26	0.004111	14.12	27060.88	13886.17	0.65
7.39	66000	1938.5	1954.03	1954.37	0.001727	9.32	37939.43	14484.95	0.42
7.39	70000	1938.5	1954.15	1954.49	0.001745	9.42	39744.79	14571.11	0.43
7.48	66000	1939.8	1954.89	1955.2	0.001657	8.5	35744.11	14007.4	0.41
7.48	70000	1939.8	1955.02	1955.33	0.001695	8.65	37549.27	14106.39	0.41

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
7.58	66000	1940.7	1955.8	1956.85	0.004037	13.13	24349.46	12470.08	0.63
7.58	70000	1940.7	1955.96	1956.97	0.003989	13.15	26371.98	13138.11	0.62
7.67	66000	1941.5	1957.35	1957.76	0.00111	6.75	33621.54	13385.64	0.33
7.67	70000	1941.5	1957.47	1957.89	0.001158	6.94	35214.17	13459.8	0.34
7.77	66000	1943	1957.83	1958.49	0.002067	9.29	25335.38	9106.13	0.45
7.77	70000	1943	1957.97	1958.65	0.002147	9.54	26660.09	9588.23	0.46
7.86	66000	1945	1958.82	1959.24	0.001517	7.71	27987.85	8510.19	0.39
7.86	70000	1945	1959	1959.42	0.001557	7.88	29666.23	10389.18	0.39
7.95	66000	1947	1959.38	1960.01	0.001964	8.05	21199.45	8572.77	0.43
7.95	70000	1947	1959.57	1960.21	0.002008	8.23	22853.29	9021.62	0.44
8.05	66000	1947.5	1960.26	1961.34	0.002891	9.77	14483.33	6019.03	0.52
8.05	70000	1947.5	1960.45	1961.58	0.002978	10.03	15914.45	8472.59	0.53
8.14	66000	1948.3	1961.94	1962.85	0.003423	11.63	23000.34	9726.33	0.58
8.14	70000	1948.3	1962.25	1963.04	0.00309	11.23	26068.03	10251.3	0.55
8.24	66000	1949.7	1963.56	1964.12	0.002089	8.81	26551.26	9910.21	0.45
8.24	70000	1949.7	1963.69	1964.27	0.002168	9.04	27867.54	10396.65	0.46
8.33	66000	1951	1964.56	1965.18	0.002134	8.89	24857.43	9376.42	0.46
8.33	70000	1951	1964.73	1965.35	0.002171	9.05	26405.74	9554.56	0.46
8.43	66000	1952	1965.52	1966.21	0.002436	9.63	23531.76	8805.77	0.49
8.43	70000	1952	1965.7	1966.39	0.002468	9.79	25092.64	8990.66	0.49
8.52	66000	1953.8	1966.66	1967.08	0.001487	7.58	29538.63	8623.59	0.38
8.52	70000	1953.8	1966.85	1967.27	0.001505	7.7	31135.93	8661.84	0.39
8.62	66000	1955	1967.48	1968.16	0.002542	9.59	23267.94	7496.01	0.5
8.62	70000	1955	1967.68	1968.36	0.002561	9.73	24762.44	7712.68	0.5
8.71	66000	1955.5	1968.66	1969.32	0.00233	9.62	24312.96	7733.74	0.48
8.71	70000	1955.5	1968.86	1969.52	0.002343	9.75	25896.19	7911.39	0.48
8.81	66000	1956.5	1969.8	1970.49	0.002459	8.31	18943.75	5300.24	0.47
8.81	70000	1956.5	1970	1970.71	0.002512	8.51	20014.83	5565.73	0.48
8.9	66000	1956.7	1970.91	1971.53	0.001746	7.63	19554.68	4513.66	0.41
8.9	70000	1956.7	1971.13	1971.78	0.001792	7.84	20564.85	4645.54	0.41
9	66000	1959	1971.67	1972.72	0.002803	10.29	16649.87	2600.45	0.52
9	70000	1959	1971.91	1973	0.002877	10.56	17263.21	2606.28	0.53
9.09	66000	1959.8	1973.57	1973.96	0.002085	6.47	20585.45	3142.91	0.34

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
9.09	70000	1959.8	1973.86	1974.26	0.002106	6.59	21773.17	4999.16	0.34
9.19	66000	1960.94	1974.21	1974.78	0.001362	7.13	19208.85	2589.47	0.36
9.19	70000	1960.94	1974.5	1975.1	0.001384	7.3	19965.45	2592.88	0.37
9.28	66000	1961.9	1974.83	1975.6	0.001799	8.02	16452.52	2360.32	0.42
9.28	70000	1961.9	1975.13	1975.92	0.001819	8.21	17159.98	2364.93	0.42
9.38	66000	1962.94	1975.81	1976.72	0.002734	8.82	12449.56	1852.2	0.48
9.38	70000	1962.94	1976.12	1977.05	0.002728	8.97	13019.55	1856.68	0.48
9.47	66000	1964.84	1977.36	1978.31	0.003592	9.4	11977.46	1728.24	0.52
9.47	70000	1964.84	1977.66	1978.64	0.003597	9.56	12507.9	1732.84	0.52
9.48	66000	1965.24	1977.41	1978.88	0.005348	12.33	10600.57	1807.17	0.67
9.48	70000	1965.24	1977.72	1979.2	0.005286	12.45	11171.6	1819.06	0.68
9.485	Bridge								
9.49	66000	1965.34	1978.68	1979.53	0.003938	9.77	12807.37	1834.43	0.53
9.49	70000	1965.34	1978.98	1979.84	0.003963	9.95	13345.01	1837.72	0.53
9.56	66000	1965.94	1979.7	1980.12	0.000955	5.91	18134.25	2117.28	0.3
9.56	70000	1965.94	1980	1980.44	0.000975	6.07	18776.65	2118.13	0.31
9.66	66000	1967.24	1980.14	1980.65	0.001429	6.45	16391.31	2314.03	0.36
9.66	70000	1967.24	1980.45	1980.98	0.001428	6.58	17110.89	2320.24	0.36
9.75	66000	1968.74	1980.85	1981.34	0.001527	6.37	16414.54	2398.75	0.36
9.75	70000	1968.74	1981.16	1981.67	0.001519	6.49	17160.29	2402.21	0.36
9.85	66000	1969.94	1981.55	1982.07	0.001702	6.38	15190.42	2256.82	0.38
9.85	70000	1969.94	1981.85	1982.39	0.00169	6.49	15877.91	2257.74	0.38
9.94	66000	1971.04	1982.42	1982.99	0.002227	6.45	13104.27	2108.85	0.43
9.94	70000	1971.04	1982.71	1983.3	0.002177	6.55	13717.97	2110.6	0.42
10.04	66000	1974.74	1983.56	1984.42	0.003567	7.67	10169.81	1759.04	0.53
10.04	70000	1974.74	1983.81	1984.71	0.003516	7.81	10618.84	1767.7	0.53
10.13	66000	1975.84	1985.43	1986.57	0.004872	8.99	9234.13	1662.97	0.6
10.13	70000	1975.84	1985.66	1986.85	0.004886	9.2	9615.07	1663.89	0.6
10.23	66000	1977.34	1987.49	1988.34	0.0026	7.67	10981.06	1652.01	0.47
10.23	70000	1977.34	1987.74	1988.63	0.002633	7.88	11393.88	1657	0.48
10.32	66000	1978.84	1988.89	1989.67	0.002654	7.42	12247.63	2320.56	0.47
10.32	70000	1978.84	1989.16	1989.96	0.002631	7.56	12884.13	2364.13	0.47
10.42	66000	1979.64	1990.33	1990.99	0.002568	7.92	15632.05	2751.58	0.47

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
10.42	70000	1979.64	1990.6	1991.28	0.002548	8.05	16382.86	2759.75	0.47
10.51	66000	1980.74	1991.6	1992.68	0.004048	9.79	14695.92	3001.52	0.59
10.51	70000	1980.74	1991.86	1992.95	0.003996	9.92	15481.96	3008.06	0.59
10.61	66000	1981.94	1993.66	1994.14	0.002074	7.19	18303.57	3173.1	0.42
10.61	70000	1981.94	1993.92	1994.41	0.002064	7.31	19108.49	3179.44	0.43
10.7	66000	1983.54	1994.82	1995.49	0.002993	8.27	15326.13	2788.99	0.5
10.7	70000	1983.54	1995.07	1995.75	0.00298	8.4	16012.65	2796.64	0.5
10.8	66000	1984.34	1995.92	1996.56	0.00282	7.95	15339.55	2727.55	0.48
10.8	70000	1984.34	1996.16	1996.81	0.002832	8.11	15974.6	2734.28	0.48
10.89	66000	1985.64	1997.22	1997.81	0.002192	7.36	16092.29	2830.24	0.44
10.89	70000	1985.64	1997.46	1998.06	0.002202	7.51	16768.66	2838.11	0.44
10.98	66000	1986.64	1998.37	1999.26	0.00319	8.66	12858.06	2488.3	0.53
10.98	70000	1986.64	1998.6	1999.53	0.003192	8.83	13453.92	2500.25	0.53
11.08	66000	1987.64	2000.07	2001.12	0.003924	9.49	11685.88	2130.18	0.57
11.08	70000	1987.64	2000.31	2001.39	0.003943	9.67	12199.65	2136.2	0.58
11.17	66000	1988.74	2002.02	2003.19	0.004039	10	11894.5	2351.52	0.57
11.17	70000	1988.74	2002.28	2003.47	0.004039	10.17	12492.54	2368.24	0.57
11.27	66000	1990.74	2003.94	2005.15	0.004123	10.75	12640.8	2374.73	0.6
11.27	70000	1990.74	2004.19	2005.43	0.00415	10.95	13249.86	2406.89	0.6
11.36	66000	1992.44	2006.03	2007.14	0.004045	10.68	13510.06	2534.47	0.54
11.36	70000	1992.44	2006.3	2007.42	0.004011	10.8	14216.89	2542.55	0.54
11.46	66000	1993.94	2007.64	2009.39	0.004519	11.99	10936.17	2611.87	0.63
11.46	70000	1993.94	2007.9	2009.66	0.004515	12.14	11615.06	2622.5	0.63
11.55	66000	1993.94	2009.76	2011.25	0.003032	10.73	11439.54	2692.59	0.53
11.55	70000	1993.94	2010.01	2011.54	0.003087	10.97	12102.07	2699.18	0.54
11.65	66000	1995.84	2011.94	2012.68	0.002452	7.68	14327.91	2766.02	0.38
11.65	70000	1995.84	2012.23	2012.97	0.002456	7.8	15124.47	2778.08	0.38
11.74	66000	1996.74	2013.05	2014.05	0.00292	8.72	12212.29	2611.28	0.45
11.74	70000	1996.74	2013.34	2014.35	0.002925	8.86	12955.66	2627.18	0.45
11.84	66000	1997.74	2014.3	2015.78	0.003437	11.41	12529.98	2582.94	0.54
11.84	70000	1997.74	2014.59	2016.07	0.00343	11.53	13297.09	2597.75	0.54
11.93	66000	1999.34	2016.28	2017.57	0.003395	10.81	12918.34	2511.15	0.53
11.93	70000	1999.34	2016.57	2017.86	0.003386	10.92	13656.41	2519.07	0.53

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
12.03	66000	2000.74	2018.15	2018.95	0.002412	9.36	15814.79	2764.83	0.45
12.03	70000	2000.74	2018.44	2019.23	0.002412	9.46	16597.85	2769.92	0.45
12.12	66000	2002.24	2018.78	2021.73	0.005498	15.94	9587.46	2481.16	0.75
12.12	70000	2002.24	2019.05	2021.99	0.005495	16.14	10248.55	2494.19	0.75
12.22	66000	2003.34	2021.65	2024.04	0.003973	14.75	11110.43	2404.29	0.65
12.22	70000	2003.34	2021.86	2024.32	0.004108	15.12	11611.88	2414.28	0.66
12.31	66000	2003.84	2024.19	2025.56	0.002135	10.74	12633.97	2173.75	0.47
12.31	70000	2003.84	2024.48	2025.88	0.002174	10.97	13265.1	2174.62	0.48
12.41	66000	2004.84	2025.14	2026.93	0.002979	11.9	10496.45	2008.81	0.55
12.41	70000	2004.84	2025.46	2027.27	0.002994	12.1	11124.16	2010.06	0.56
12.5	66000	2006.94	2026.67	2028.27	0.002317	10.96	10312.2	1771.47	0.49
12.5	70000	2006.94	2026.97	2028.63	0.00237	11.22	10844.47	1772.17	0.5
12.59	66000	2010.24	2028.09	2029.54	0.002578	10.19	9687.32	1683.46	0.5
12.59	70000	2010.24	2028.44	2029.92	0.002587	10.38	10265.57	1684.49	0.5
12.69	66000	2011.34	2029.76	2030.7	0.001931	8.55	13640.37	2740	0.43
12.69	70000	2011.34	2030.14	2031.07	0.001871	8.58	14679.24	2740	0.42
12.78	66000	2012.84	2030.77	2031.59	0.001641	8.1	14653.83	2575	0.4
12.78	70000	2012.84	2031.11	2031.93	0.001627	8.2	15528.3	2575	0.4
12.88	66000	2014.74	2031.69	2032.37	0.001477	7.46	15263.73	2410	0.38
12.88	70000	2014.74	2032.01	2032.71	0.001473	7.58	16052.75	2410	0.38
12.97	66000	2016.04	2032.4	2033.22	0.001879	7.97	13501.46	2270	0.4
12.97	70000	2016.04	2032.72	2033.55	0.001877	8.09	14234.39	2270	0.41
13.07	66000	2018.64	2033.25	2034.02	0.001462	7.51	13246.96	2160	0.38
13.07	70000	2018.64	2033.57	2034.36	0.001475	7.67	13923.54	2160	0.38
13.16	66000	2020.64	2034.01	2034.91	0.002041	7.86	11029.15	2020	0.43
13.16	70000	2020.64	2034.33	2035.25	0.002036	8.01	11665.33	2020	0.43
13.26	66000	2021.74	2035.08	2036.03	0.002397	8.15	10665.28	1900	0.46
13.26	70000	2021.74	2035.39	2036.37	0.002381	8.3	11254.39	1900	0.46
13.35	66000	2022.94	2036.25	2037.31	0.002563	8.67	10459.07	1840	0.48
13.35	70000	2022.94	2036.55	2037.64	0.002559	8.84	11015.21	1840	0.48
13.45	66000	2025.14	2037.58	2039.34	0.005589	11.15	7999.37	1675	0.69
13.45	70000	2025.14	2037.87	2039.66	0.005478	11.29	8482.52	1675	0.68
13.54	66000	2026.94	2040.18	2041.51	0.003338	9.61	8915.87	1550	0.55
13.54	70000	2026.94	2040.43	2041.82	0.003393	9.86	9308.29	1550	0.55

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
13.64	66000	2028.64	2041.89	2043.18	0.003368	9.48	8890.03	1425	0.55
13.64	70000	2028.64	2042.17	2043.51	0.003386	9.69	9290.46	1425	0.55
13.73	66000	2030.14	2043.53	2044.72	0.002705	8.91	8658.32	1295	0.49
13.73	70000	2030.14	2043.82	2045.07	0.002743	9.14	9032.02	1295	0.5
13.83	66000	2031.74	2044.9	2045.84	0.001731	7.86	9405.81	1160	0.41
13.83	70000	2031.74	2045.22	2046.2	0.00177	8.09	9769.73	1160	0.41
13.92	66000	2033.34	2045.76	2046.9	0.002241	8.75	8711.67	1085	0.46
13.92	70000	2033.34	2046.09	2047.29	0.002271	8.98	9069.28	1085	0.47
14.02	66000	2034.74	2046.8	2048.49	0.003755	10.57	7486.68	1653.24	0.58
14.02	70000	2034.74	2047.15	2048.88	0.003718	10.75	8073.26	1745	0.59
14.11	66000	2036.54	2048.76	2050.29	0.003392	10.39	9520.87	2305	0.56
14.11	70000	2036.54	2049.12	2050.64	0.003272	10.43	10366.11	2305	0.55
14.2	66000	2038.34	2050.35	2052.83	0.005886	13.27	7870.83	2342.65	0.73
14.2	70000	2038.34	2050.64	2053.11	0.005798	13.41	8533.29	2343.78	0.73
14.29	66000	2039.84	2053.57	2054.54	0.001942	8.21	11524.11	2387.26	0.43
14.29	70000	2039.84	2053.83	2054.83	0.001985	8.42	12134.98	2387.77	0.43
14.39	66000	2041.14	2054.7	2055.54	0.002014	7.93	12846.88	2338.88	0.41
14.39	70000	2041.14	2054.98	2055.85	0.002031	8.09	13517.7	2345.5	0.42
14.48	66000	2042.64	2055.75	2056.81	0.002969	8.85	11188.68	2157	0.5
14.48	70000	2042.64	2056.05	2057.12	0.002954	8.98	11821.67	2157	0.5
14.58	66000	2043.74	2057.26	2058.05	0.002024	7.44	11702.78	1910	0.42
14.58	70000	2043.74	2057.55	2058.36	0.002044	7.6	12246.96	1910	0.42
14.67	66000	2045.44	2058.36	2059.12	0.002271	7.09	10565.62	1653.69	0.41
14.67	70000	2045.44	2058.66	2059.45	0.0023	7.25	11051.08	1654.87	0.41
14.77	66000	2046.74	2059.38	2060.45	0.002814	9	9080.64	1380	0.51
14.77	70000	2046.74	2059.68	2060.79	0.002833	9.21	9490.33	1380	0.51
14.86	66000	2047.74	2060.62	2062.35	0.004274	11.06	7804.04	1233	0.62
14.86	70000	2047.74	2060.92	2062.71	0.004295	11.3	8164.37	1233	0.63
14.93	66000	2048.74	2062.2	2064	0.007162	11.39	7014.77	1035.39	0.67
14.93	70000	2048.74	2062.51	2064.36	0.007178	11.59	7332.71	1036.66	0.67
14.9325	Bridge								
14.935	66000	2048.74	2062.56	2064.19	0.006305	10.88	7339.79	1026.85	0.63
14.935	70000	2048.74	2062.86	2064.55	0.006359	11.09	7653.61	1028.12	0.63

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
14.965	66000	2050.44	2063.91	2065.7	0.004369	11.49	7125.23	870	0.64
14.965	70000	2050.44	2064.21	2066.08	0.004411	11.77	7387.12	870	0.64
15.09	66000	2051.44	2066.1	2067.28	0.001647	8.71	7574.75	530	0.41
15.09	70000	2051.44	2066.44	2067.71	0.001716	9.03	7755.39	530	0.42
15.18	66000	2052.74	2066.65	2068.57	0.002917	11.12	5937.67	443.07	0.54
15.18	70000	2052.74	2067.01	2069.06	0.00302	11.48	6095.16	444.22	0.55
15.185	Bridge								
15.19	66000	2052.84	2067.01	2068.86	0.002736	10.91	6048.3	441.58	0.52
15.19	70000	2052.84	2067.4	2069.37	0.002812	11.25	6221.42	442.6	0.53
15.34	66000	2055.61	2069.36	2070.99	0.002551	10.28	6586.08	548.34	0.5
15.34	70000	2055.61	2069.83	2071.54	0.002554	10.52	6842.86	555.32	0.5
15.44	66000	2056.84	2070.68	2072.25	0.002448	10.07	6688.78	552.13	0.49
15.44	70000	2056.84	2071.15	2072.79	0.002449	10.31	6950.05	559.18	0.49
15.53	66000	2058.72	2072.02	2073.56	0.002811	10.09	7002.63	644.08	0.51
15.53	70000	2058.72	2072.5	2074.1	0.002774	10.27	7315.04	644.56	0.51
15.63	66000	2059.94	2073.57	2074.83	0.00221	9.23	8387.82	899.63	0.46
15.63	70000	2059.94	2074.05	2075.34	0.002165	9.37	8826.12	900.23	0.46
15.71	66000	2060.94	2074.68	2075.92	0.002166	9.29	9349.29	1314.71	0.46
15.71	70000	2060.94	2075.16	2076.41	0.002098	9.37	9985	1316.45	0.46
15.81	66000	2061.94	2075.81	2077.03	0.002239	9.37	10051	1566.38	0.47
15.81	70000	2061.94	2076.27	2077.49	0.00217	9.45	10789.45	1658.88	0.46
15.91	66000	2063.84	2077.21	2078.09	0.001913	8.46	13689.8	2441.9	0.43
15.91	70000	2063.84	2077.65	2078.51	0.001817	8.44	14770.48	2449.19	0.42
16	66000	2065.74	2078.14	2079.32	0.00275	9.66	11856.52	2329.2	0.51
16	70000	2065.74	2078.53	2079.69	0.002629	9.67	12765.3	2329.59	0.5
16.1	66000	2066.94	2079.79	2081.48	0.006313	11.17	8607.13	2044.96	0.64
16.1	70000	2066.94	2080.09	2081.78	0.006173	11.26	9228.91	2052.7	0.64
16.19	66000	2069.44	2082.29	2083.7	0.003216	10.24	10071.89	1885.37	0.55
16.19	70000	2069.44	2082.54	2084	0.003277	10.49	10540	1888.95	0.55
16.27	66000	2070.64	2083.76	2084.85	0.002253	8.99	11369.73	2547.35	0.47
16.27	70000	2070.64	2083.98	2085.21	0.00245	9.49	11940.48	2958.81	0.49
16.39	66000	2071.94	2085.19	2086.06	0.001638	8.11	11816.23	3465.76	0.45
16.39	70000	2071.94	2085.6	2086.42	0.001507	7.98	13297.31	3692.39	0.43

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
16.47	66000	2071.94	2085.88	2086.78	0.001929	8.5	11654.42	3165.58	0.48
16.47	70000	2071.94	2086.23	2087.1	0.001815	8.44	12819.86	3356.69	0.47
16.53	66000	2073.94	2086.47	2087.47	0.002221	9.31	11533.97	3034.92	0.52
16.53	70000	2073.94	2086.8	2087.75	0.002104	9.25	12518.63	3099.13	0.5
16.59	66000	2074.94	2087.35	2088.19	0.002081	8.97	12073.52	3483.05	0.5
16.59	70000	2074.94	2087.62	2088.44	0.002029	9.02	12995.36	3535.3	0.49
16.69	66000	2076.94	2088.38	2089.59	0.00308	10.44	9829.33	2841.21	0.6
16.69	70000	2076.94	2088.61	2089.83	0.003062	10.58	10497.49	3069.77	0.6
16.79	66000	2078.44	2090.13	2090.83	0.001988	8.66	14258.17	4444.46	0.49
16.79	70000	2078.44	2090.31	2091.14	0.002264	9.35	15064.38	4477.96	0.52
16.9	66000	2079.74	2091.44	2093.45	0.004711	12.94	8277.07	2457.41	0.74
16.9	70000	2079.74	2091.61	2093.69	0.00482	13.25	8710.27	2547.82	0.76
16.98	66000	2080.94	2093.94	2094.93	0.002478	9.72	11139.43	2225.55	0.54
16.98	70000	2080.94	2094.16	2095.18	0.002516	9.94	11628.32	2274.44	0.55
17.07	66000	2083	2094.94	2095.54	0.001279	7.84	13673.63	2455.83	0.4
17.07	70000	2083	2094.9	2095.59	0.001465	8.37	13572.13	2435.34	0.43
17.17	66000	2084.6	2095.49	2096.36	0.001974	9.17	11801.17	2425.57	0.49
17.17	70000	2084.6	2095.54	2096.49	0.002169	9.64	11917.93	2429.73	0.52
17.26	66000	2086	2096.24	2097.4	0.002746	10.38	10304.64	2035.94	0.57
17.26	70000	2086	2096.38	2097.6	0.002885	10.73	10600.81	2388.86	0.59
17.33	66000	2087.1	2097.16	2098.42	0.003047	10.78	9937.7	2054.16	0.6
17.33	70000	2087.1	2097.34	2098.64	0.00311	11.03	10314.46	2055.64	0.61
17.43	66000	2088.8	2098.48	2100.33	0.004311	12.52	8382.74	2015.39	0.71
17.43	70000	2088.8	2098.69	2100.56	0.004324	12.71	8796.71	2017.04	0.71
17.53	66000	2090.5	2101.01	2102.11	0.002531	10.13	10514.85	2021.36	0.55
17.53	70000	2090.5	2101.22	2102.35	0.002561	10.33	10944.88	2023.21	0.56
17.61	66000	2091.7	2102.1	2103.17	0.00253	10.05	10559.74	1990.99	0.55
17.61	70000	2091.7	2102.33	2103.42	0.002538	10.21	11019.3	1992.84	0.55
17.71	66000	2093.6	2103.16	2105.22	0.004783	13.08	7938.18	1958.91	0.75
17.71	70000	2093.6	2103.4	2105.45	0.004712	13.19	8398.47	1960.79	0.75
17.81	66000	2095.4	2105.77	2107.16	0.003059	11.1	9532.03	1946.97	0.61
17.81	70000	2095.4	2105.95	2107.39	0.003139	11.38	9881.53	1948.41	0.62
17.91	66000	2097	2107.28	2108.67	0.003134	11.12	9441.32	1926.26	0.61

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
17.91	70000	2097	2107.51	2108.92	0.003144	11.3	9872.77	1928.05	0.62
17.99	66000	2098.1	2108.22	2110.16	0.004147	12.61	8143.72	1925.86	0.7
17.99	70000	2098.1	2108.44	2110.41	0.004135	12.78	8580.25	1927.69	0.7
18.02	66000	2098.8	2108.49	2111.23	0.005749	14.41	6822.15	1900.38	0.82
18.02	70000	2098.8	2108.72	2111.46	0.005685	14.56	7265.01	1902.46	0.82
18.11	66000	2100.2	2111.88	2113	0.002097	9.9	10513.25	1882.24	0.51
18.11	70000	2100.2	2112.08	2113.24	0.002155	10.16	10892.53	1883.86	0.52
18.21	66000	2101.52	2113.22	2113.93	0.001463	8.28	12527.99	1870.38	0.43
18.21	70000	2101.52	2113.46	2114.19	0.001489	8.47	12978.41	1871.81	0.43
18.31	66000	2103.15	2113.93	2114.88	0.002153	9.51	10987.6	1893.52	0.51
18.31	70000	2103.15	2114.18	2115.15	0.002154	9.66	11465.85	1895.41	0.51
18.41	66000	2104.6	2114.94	2116.09	0.002698	10.34	10172.22	1924.99	0.57
18.41	70000	2104.6	2115.19	2116.35	0.002678	10.46	10658.41	1926.9	0.57
18.51	66000	2106.3	2116.46	2117.52	0.002619	10.07	10534.32	1984.02	0.56
18.51	70000	2106.3	2116.7	2117.77	0.00261	10.21	11011.16	1985.81	0.56
18.61	66000	2107.9	2117.79	2118.98	0.003006	10.6	10037.72	1992.98	0.6
18.61	70000	2107.9	2118.02	2119.23	0.002991	10.74	10503.58	1994.86	0.6
18.71	66000	2109.55	2119.41	2120.64	0.003095	10.74	9946.78	2023	0.6
18.71	70000	2109.55	2119.64	2120.89	0.003086	10.89	10405.33	2024.82	0.61
18.81	66000	2111.12	2121.06	2122.27	0.003	10.63	10059.07	2032.44	0.6
18.81	70000	2111.12	2121.29	2122.51	0.002999	10.79	10513.31	2034.37	0.6
18.91	66000	2112.79	2122.78	2123.97	0.002946	10.57	10046.17	1983.43	0.59
18.91	70000	2112.79	2123.01	2124.22	0.002948	10.73	10493.82	1985.37	0.59
19.01	66000	2114.32	2124.32	2125.61	0.003107	10.86	9560.09	1842.57	0.61
19.01	70000	2114.32	2124.54	2125.86	0.003119	11.05	9974.17	1844.53	0.61
19.11	66000	2116	2125.91	2127.34	0.003433	11.33	8887.8	1662.19	0.64
19.11	70000	2116	2126.13	2127.61	0.003455	11.54	9261.76	1664.1	0.64
19.22	66000	2117.8	2127.75	2129.25	0.003479	11.46	8514.13	1494.02	0.64
19.22	70000	2117.8	2127.98	2129.53	0.003509	11.68	8860.13	1495.88	0.65
19.31	66000	2119.35	2129.44	2131.1	0.003621	11.8	7900.65	1284.88	0.66
19.31	70000	2119.35	2129.68	2131.39	0.003662	12.06	8209.56	1286.81	0.66
19.39	66000	2120.6	2130.79	2132.67	0.003887	12.31	7265.82	1120.55	0.68
19.39	70000	2120.6	2131.04	2132.99	0.003939	12.59	7543.74	1122.53	0.69

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
19.49	66000	2122.26	2132.72	2134.7	0.003821	12.42	6831.56	934.19	0.68
19.49	70000	2122.26	2132.99	2135.05	0.003883	12.73	7077.7	936.29	0.69
19.52	66000	2122.7	2133.32	2135.4	0.003857	12.6	6594.15	874.03	0.68
19.52	70000	2122.7	2133.59	2135.77	0.003924	12.93	6828.95	876.18	0.69
19.59	66000	2124.12	2134.81	2136.54	0.002922	11.04	6840.28	795.91	0.6
19.59	70000	2124.12	2135.11	2136.92	0.002972	11.34	7075.34	798.12	0.6
19.69	66000	2126	2136.57	2137.82	0.001972	9.02	7494.79	758.7	0.49
19.69	70000	2126	2136.91	2138.22	0.001994	9.27	7750.34	761.56	0.5
19.73	66000	2126.8	2137.17	2138.25	0.001761	8.32	7933.04	779.22	0.46
19.73	70000	2126.8	2137.53	2138.66	0.001772	8.53	8208.87	780.2	0.46
19.79	66000	2127	2137.76	2138.8	0.001624	8.17	8080.49	767.48	0.44
19.79	70000	2127	2138.12	2139.21	0.001638	8.38	8355.37	768.53	0.45
19.89	66000	2129.3	2138.62	2139.97	0.002538	9.33	7073.54	768.63	0.54
19.89	70000	2129.3	2138.97	2140.38	0.002519	9.53	7348.02	769.35	0.54
19.99	66000	2130.7	2139.98	2141.34	0.002575	9.37	7042.39	768.55	0.55
19.99	70000	2130.7	2140.32	2141.75	0.002564	9.58	7308.76	769.24	0.55
20.1	66000	2132	2141.41	2142.73	0.00247	9.24	7146.34	773.49	0.54
20.1	70000	2132	2141.75	2143.13	0.002466	9.45	7410.84	774.22	0.54
20.16	66000	2133.2	2142.16	2143.61	0.002916	9.68	6817.37	778.33	0.58
20.16	70000	2133.2	2142.5	2144.01	0.002897	9.89	7080.09	779.02	0.58
20.18	Bridge								
20.2	66000	2133.2	2142.41	2143.79	0.002654	9.41	7015.62	778.85	0.55
20.2	70000	2133.2	2142.76	2144.19	0.002634	9.61	7287.67	779.58	0.55
20.27	66000	2135	2142.81	2146.34	0.00594	15.1	4388.25	633.1	0.98
20.27	70000	2135	2143.07	2146.78	0.005949	15.46	4556.18	647.79	0.98
20.36	66000	2136	2146.68	2147.68	0.001108	8.08	9434.38	2445.78	0.51
20.36	70000	2136	2147.1	2148.08	0.001039	8.05	10465.37	2461.75	0.49
20.46	66000	2138	2147.26	2148.29	0.001356	8.58	9208.65	1395.45	0.54
20.46	70000	2138	2147.63	2148.68	0.001318	8.68	9726.37	1447.15	0.54
20.55	66000	2140	2148.53	2150.18	0.004379	15.16	8276.9	2352.44	0.97
20.55	70000	2140	2148.68	2150.37	0.00445	15.45	8617.78	2356.64	0.98
20.65	66000	2142	2150.5	2152.59	0.004959	13.6	7497.64	1966.11	0.99
20.65	70000	2142	2150.64	2152.87	0.005131	14.04	7781.8	2019.97	1.01

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
20.74	66000	2144	2154.12	2154.75	0.003344	7.4	11467.59	2832.1	0.54
20.74	70000	2144	2154.38	2155.01	0.003161	7.4	12210.89	2848.02	0.53
20.83	66000	2145	2155.4	2155.77	0.00124	5.8	14877.33	2985.32	0.46
20.83	70000	2145	2155.61	2156	0.001227	5.94	15509.71	3010.58	0.46
20.93	66000	2147	2156.31	2156.69	0.002396	4.96	13453.47	2443.01	0.38
20.93	70000	2147	2156.51	2156.91	0.002402	5.07	13954.66	2444.78	0.38
21.02	66000	2148	2157.35	2157.89	0.001852	6.26	11948.08	2684.97	0.52
21.02	70000	2148	2157.56	2158.12	0.001869	6.35	12512.19	2688.54	0.51
21.12	66000	2150	2158.05	2159.39	0.003647	9.75	7823.24	2459.14	0.81
21.12	70000	2150	2158.25	2159.61	0.003515	9.86	8323.93	2494.52	0.8
21.21	66000	2151	2159.31	2161.59	0.003676	12.18	5953.18	2047.77	0.86
21.21	70000	2151	2159.4	2161.88	0.003923	12.7	6155.3	2102.08	0.89
21.31	66000	2151.5	2160.55	2164.09	0.004862	15.14	4724.12	1909.08	1.01
21.31	70000	2151.5	2160.8	2164.42	0.004806	15.38	5199.83	1953.21	1.01
21.41	66000	2152	2163.47	2165.98	0.00278	13.1	6845.65	2093.78	0.79
21.41	70000	2152	2163.76	2166.27	0.002706	13.22	7457.47	2135.73	0.78
21.5	66000	2155	2164.51	2167.69	0.003338	14.4	5435.59	1882.73	0.86
21.5	70000	2155	2164.62	2168.1	0.0036	15.08	5637.52	1885.41	0.9
21.54	66000	2156	2166.99	2168.55	0.001222	10.04	7613.17	1310.96	0.54
21.54	70000	2156	2167.42	2169.05	0.001207	10.24	8206.99	1414.27	0.54
21.545	Bridge								
21.55	66000	2156	2167.72	2169.1	0.00099	9.43	7599.68	1309	0.49
21.55	70000	2156	2168.15	2169.59	0.000989	9.64	8192.24	1467.07	0.49
21.64	66000	2157	2166.85	2170.71	0.003803	15.78	5572.92	1776.44	0.93
21.64	70000	2157	2167.22	2171.22	0.003737	16.07	6249.34	1910.38	0.93
21.74	66000	2158	2167.68	2174.13	0.006491	20.64	8444.29	1718.38	1.21
21.74	70000	2158	2168	2174.73	0.006495	21.11	8992.02	1719.98	1.22
21.83	66000	2159	2171.83	2176.79	0.003982	18.11	9769.42	1628.52	0.97
21.83	70000	2159	2172.26	2177.38	0.003905	18.41	10481.35	1642.45	0.97
21.93	66000	2161	2176.48	2177.98	0.000937	9.91	13006.71	1478.5	0.49
21.93	70000	2161	2177.01	2178.56	0.000921	10.07	13799.54	1481.78	0.49
22.02	66000	2162	2177.48	2178.37	0.000501	7.64	14369.73	1471	0.36
22.02	70000	2162	2178.03	2178.95	0.000493	7.78	15181.22	1480.88	0.36

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
22.12	66000	2163	2177.68	2178.68	0.000593	8.08	12073.24	1202.84	0.39
22.12	70000	2163	2178.22	2179.26	0.000581	8.22	12729.29	1211.54	0.39
22.21	66000	2164	2177.53	2179.34	0.00129	11.01	6891.16	854.11	0.57
22.21	70000	2164	2178.08	2179.9	0.001227	11.07	7362.03	861.43	0.56
22.31	66000	2165	2177.86	2180.3	0.001859	12.62	5722.45	865.96	0.67
22.31	70000	2165	2178.36	2180.83	0.00178	12.72	6187.35	944.78	0.66
22.4	66000	2166	2177.93	2182.01	0.003352	16.26	4147.53	419.62	0.89
22.4	70000	2166	2178.23	2182.61	0.00346	16.83	4405.69	1004.81	0.91
22.5	66000	2167.5	2177.98	2184.6	0.00621	20.65	3196.72	337.97	1.18
22.5	70000	2167.5	2178.67	2185.13	0.00582	20.4	3438.66	431.48	1.15
22.59	66000	2169	2183.13	2186.82	0.002628	15.64	5172.61	1193.78	0.81
22.59	70000	2169	2183.58	2187.25	0.002537	15.72	5714.88	1208.74	0.8
22.69	66000	2170	2186.05	2187.86	0.001187	11.65	8825.02	1492.93	0.55
22.69	70000	2170	2186.46	2188.27	0.00117	11.76	9434.07	1496.49	0.55
22.78	66000	2171	2186.54	2188.48	0.001164	11.65	8248.86	1687.93	0.55
22.78	70000	2171	2186.93	2188.88	0.001154	11.81	8911.39	1736.3	0.55
22.87	66000	2173	2188.09	2189.06	0.000841	8.11	10237.25	1835.17	0.4
22.87	70000	2173	2188.48	2189.46	0.000833	8.24	10946.53	1856.3	0.4
22.97	66000	2174	2188.17	2189.67	0.000954	10	8308.53	1798.61	0.49
22.97	70000	2174	2188.53	2190.07	0.000952	10.18	8965.34	1802.87	0.5
23.06	66000	2176	2190.15	2192.99	0.002103	14.2	7107.35	1813.64	0.72
23.06	70000	2176	2190.46	2193.33	0.002094	14.41	7658.82	1820.84	0.72
23.16	66000	2177	2191.97	2193.76	0.001138	11.19	7908.27	1432.22	0.54
23.16	70000	2177	2192.19	2194.19	0.001236	11.78	8227.37	1504.47	0.56
23.25	66000	2179	2193.75	2194.11	0.000221	4.86	14115.75	1555.18	0.24
23.25	70000	2179	2194.18	2194.56	0.000221	4.97	14803.71	1615.92	0.24
23.35	66000	2180	2193.64	2194.45	0.000938	7.23	9130.49	1071	0.44
23.35	70000	2180	2194.07	2194.9	0.000912	7.3	9594.19	1085.67	0.43
23.44	66000	2181	2194.05	2194.86	0.000729	7.21	9148.98	955	0.41
23.44	70000	2181	2194.46	2195.3	0.000716	7.34	9541.45	958.74	0.41
23.54	66000	2183	2194.21	2195.51	0.001476	9.16	7203.09	892.1	0.57
23.54	70000	2183	2194.61	2195.94	0.001429	9.26	7560.53	899.88	0.56
23.63	66000	2184	2194.88	2196.79	0.003549	11.09	5952.85	814.39	0.72
23.63	70000	2184	2195.23	2197.18	0.003426	11.22	6238.27	816.14	0.72

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
23.73	66000	2186	2196.48	2198.51	0.003223	11.44	5769.51	699.88	0.7
23.73	70000	2186	2196.77	2198.9	0.003245	11.72	5971.24	701.8	0.71
23.82	66000	2186.9	2197.7	2202.5	0.006826	17.59	3752.09	417.52	1.03
23.82	70000	2186.9	2197.73	2203.09	0.007577	18.58	3767.89	417.72	1.09
23.92	66000	2188	2200.49	2205.88	0.006135	18.63	3543.05	332.1	1.01
23.92	70000	2188	2200.97	2206.52	0.006015	18.9	3704.12	334.63	1
24.01	66000	2189.2	2205.95	2207.32	0.001029	9.42	7351.15	856.72	0.43
24.01	70000	2189.2	2206.54	2207.95	0.001008	9.56	7868.9	872.23	0.43
24.11	66000	2191	2206.84	2207.77	0.000663	7.77	9082.91	1126.32	0.4
24.11	70000	2191	2207.46	2208.39	0.000622	7.78	9791.09	1148.73	0.39
24.2	55000	2193	2208.36	2211.59	0.002975	14.69	4684.75	1164.19	0.83
24.2	60000	2193	2208.95	2212.14	0.002788	14.79	5386.6	1250.56	0.81
24.29	55000	2194	2209.97	2212.75	0.001746	13.93	5748.64	1277.34	0.67
24.29	60000	2194	2210.2	2213.29	0.001919	14.77	6042.81	1286.36	0.7
24.39	55000	2194.6	2207.42	2214.47	0.005664	21.3	2582.26	242.18	1.15
24.39	60000	2194.6	2209.5	2215.33	0.003845	19.39	3162.99	535.7	0.97
24.48	55000	2196	2210.25	2217.23	0.005394	21.62	3104.45	876.01	1.13
24.48	60000	2196	2210.94	2217.8	0.005023	21.69	3756.52	1028.38	1.1
24.58	55000	2197	2215.91	2218.99	0.001685	15.38	6588.54	1401.5	0.67
24.58	60000	2197	2216.44	2219.52	0.001672	15.65	7336.8	1426.08	0.67
24.67	55000	2198.3	2216.72	2219.97	0.002038	14.88	4917.52	943.16	0.72
24.67	60000	2198.3	2217.06	2220.61	0.002181	15.65	5241.22	974.23	0.75
24.77	55000	2200.2	2218.07	2221.85	0.002567	16.07	4509.12	916.76	0.8
24.77	60000	2200.2	2218.7	2222.5	0.002474	16.3	5090.95	941.49	0.8
24.86	55000	2202	2221.77	2222.69	0.000613	8.42	9148.73	1062.03	0.4
24.86	60000	2202	2222.36	2223.34	0.00062	8.71	9789.67	1100.47	0.4
24.96	55000	2204	2221.73	2223.43	0.001985	11.13	5952.79	799.83	0.66
24.96	60000	2204	2222.16	2224.18	0.002163	12	6347.67	1089.81	0.7
25.05	55000	2206	2221.44	2225.89	0.010206	18.28	3757.17	843.96	1.39
25.05	60000	2206	2221.75	2226.4	0.010127	18.73	4021.61	872.65	1.39
25.15	55000	2208	2225.82	2228.64	0.00311	15.14	5851.41	1150.07	0.84
25.15	60000	2208	2226.26	2229.13	0.003049	15.43	6356.77	1155.04	0.84
25.24	55000	2211.1	2226.9	2229.96	0.002077	14.51	5016.19	943.12	0.72

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
25.24	60000	2211.1	2227.18	2230.57	0.002247	15.32	5291.06	958.66	0.75
25.34	55000	2214	2228.97	2230.82	0.001109	11.24	6336.85	984.94	0.53
25.34	60000	2214	2229.54	2231.48	0.001126	11.6	6913.05	1034.86	0.54
25.43	55000	2215.5	2229.31	2231.57	0.001443	12.39	5769.44	1047.1	0.6
25.43	60000	2215.5	2229.89	2232.23	0.001434	12.72	6398.42	1116.97	0.61
25.53	55000	2215.8	2230.03	2232.27	0.001369	12.27	5723.2	1159.92	0.59
25.53	60000	2215.8	2230.62	2232.92	0.001353	12.55	6421.76	1186.34	0.59
25.62	55000	2216.6	2230.49	2233.13	0.001622	13.03	4221.77	322.68	0.63
25.62	60000	2216.6	2230.95	2233.88	0.001735	13.74	4367.31	323.9	0.66
25.72	55000	2217.9	2231.21	2234.05	0.001848	13.53	4065.98	324.81	0.67
25.72	60000	2217.9	2231.73	2234.85	0.001936	14.17	4233.92	326.31	0.69
25.8	55000	2219.2	2231.93	2235.03	0.002155	14.13	3891.75	325.57	0.72
25.8	60000	2219.2	2232.49	2235.85	0.002221	14.73	4073.94	327.31	0.74
25.805	Bridge								
25.81	55000	2219.6	2233.15	2235.86	0.001744	13.2	4165.95	328.85	0.65
25.81	60000	2219.6	2233.83	2236.73	0.00176	13.66	4390.85	331.01	0.66
25.91	55000	2221.2	2233.69	2237.06	0.002339	14.75	3784.14	436.98	0.75
25.91	60000	2221.2	2234.37	2237.94	0.002312	15.18	4099.04	485.96	0.75
26	55000	2222.8	2230.82	2238.59	0.009512	22.37	2458.98	319.97	1.42
26	60000	2222.8	2231.19	2239.61	0.009727	23.27	2578.03	321.22	1.45
26.09	55000	2224.4	2234.9	2242.54	0.006708	22.19	2491.61	260.32	1.24
26.09	60000	2224.4	2235.56	2243.54	0.006456	22.69	2664.3	265.53	1.24
26.19	55000	2225.8	2240.04	2245.39	0.004178	18.55	2964.2	296.69	1
26.19	60000	2225.8	2240.73	2246.35	0.004129	19.03	3160.53	325.92	0.99
26.28	55000	2226.5	2243.89	2247.2	0.002578	14.69	4037.9	825.49	0.79
26.28	60000	2226.5	2244.88	2248.08	0.002259	14.51	4635.31	893.08	0.75
26.38	55000	2227.5	2246.77	2248.02	0.000709	9.27	7358.41	1486.46	0.43
26.38	60000	2227.5	2247.55	2248.84	0.000692	9.46	8024.62	1513.88	0.43
26.47	55000	2228	2246.07	2249.09	0.00196	14.15	4418.6	1106.37	0.7
26.47	60000	2228	2246.8	2249.92	0.001931	14.46	4816.18	1172.99	0.7
26.57	55000	2229	2246.69	2250.48	0.002775	15.67	3614.05	1054.04	0.82
26.57	60000	2229	2247.31	2251.34	0.002769	16.15	3868.4	1093.36	0.82
26.66	55000	2232	2248.26	2251.87	0.002688	15.28	3681.37	1001.6	0.81

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
26.66	60000	2232	2248.91	2252.72	0.002657	15.7	3945.01	1023.55	0.81
26.76	55000	2232.9	2250.44	2252.98	0.001554	12.9	4765.52	1533.4	0.63
26.76	60000	2232.9	2251.29	2253.82	0.001482	12.99	5615.14	1664.3	0.61
26.85	55000	2234	2250.44	2254.4	0.00263	16.12	3868.51	787.99	0.81
26.85	60000	2234	2248.78	2255.36	0.005082	20.61	2997.01	403.76	1.1
26.95	55000	2235.3	2252.39	2256.77	0.003284	16.99	3701.4	1070.24	0.89
26.95	60000	2235.3	2253.17	2257.53	0.00307	17.09	4228.19	1199.54	0.87
27.04	55000	2237.4	2255.92	2257.95	0.001225	11.98	6467.09	1022.23	0.56
27.04	60000	2237.4	2256.65	2258.67	0.001178	12.09	7223.89	1044.29	0.56
27.14	55000	2239.5	2256.94	2258.55	0.001015	10.53	6933.27	1166.3	0.51
27.14	60000	2239.5	2257.62	2259.25	0.000987	10.69	7746.69	1219.48	0.5
27.23	55000	2242	2251.22	2260.79	0.011629	24.83	2215.09	288	1.58
27.23	60000	2242	2251.88	2261.53	0.010715	24.93	2406.72	292.33	1.53
27.33	55000	2242.4	2259.8	2263.61	0.002361	16.03	4479.42	962	0.77
27.33	60000	2242.4	2260.49	2264.27	0.002254	16.17	5153.97	980.28	0.76
27.42	55000	2243.3	2261.63	2264.76	0.001962	14.54	4617.08	649.7	0.71
27.42	60000	2243.3	2261.84	2265.41	0.002192	15.54	4759.43	659.03	0.75
27.51	55000	2244.6	2262.41	2265.74	0.001745	14.68	3990.89	904.57	0.67
27.51	60000	2244.6	2262.74	2266.48	0.001912	15.59	4304.63	997.87	0.7
27.61	55000	2247	2263.67	2266.71	0.002025	14.03	4015.17	1114.53	0.71
27.61	60000	2247	2264.19	2267.53	0.002108	14.69	4359.44	2060.62	0.72
27.7	55000	2248.2	2263.34	2269.54	0.005107	20.01	2774.54	279.86	1.09
27.7	60000	2248.2	2264.7	2270.31	0.003993	19.11	3513.36	824.15	0.98
27.8	55000	2250	2268.18	2271.39	0.002106	15.52	5920.81	1288.53	0.73
27.8	60000	2250	2268.71	2271.94	0.002077	15.8	6622.13	1344.47	0.73
27.89	55000	2251.3	2269.45	2272.31	0.001562	14.34	5358.99	834.59	0.64
27.89	60000	2251.3	2263.9	2274.44	0.008981	26.38	2456.9	283.34	1.44
27.99	55000	2252.7	2269.42	2276.17	0.003938	20.88	2681.17	212.16	0.99
27.99	60000	2252.7	2272.28	2277.04	0.002291	17.95	4683.86	1147.62	0.78
28.08	55000	2254	2274.64	2277.62	0.001341	14.6	5940.31	1169.92	0.61
28.08	60000	2254	2273.85	2278.15	0.001987	17.26	5043.55	1088.56	0.73
28.18	55000	2255.5	2277.26	2278.13	0.000336	7.99	10745.33	1266.62	0.31
28.18	60000	2255.5	2277.93	2278.83	0.000344	8.26	11596.03	1283.3	0.32

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
28.27	55000	2256.6	2277.42	2278.31	0.000372	8.04	10252.75	1269.05	0.32
28.27	60000	2256.6	2278.08	2279.03	0.000385	8.37	11133.3	1399.88	0.33
28.37	55000	2258.7	2276.81	2278.99	0.00106	12.16	5739.14	783.09	0.53
28.37	60000	2258.7	2277.43	2279.74	0.001082	12.59	6230.88	796.63	0.54
28.46	55000	2260.8	2276.88	2279.87	0.001547	13.94	4233.88	493.59	0.63
28.46	60000	2260.8	2277.41	2280.69	0.001628	14.63	4512.8	564.74	0.65
28.56	55000	2262.1	2278.6	2280.59	0.001014	11.36	5088.67	478.18	0.52
28.56	60000	2262.1	2279.31	2281.44	0.001027	11.79	5434.71	497.33	0.52
28.65	55000	2266	2279.74	2284.14	0.003233	17.01	3722.25	738.26	0.88
28.65	60000	2266	2280.78	2284.85	0.002755	16.58	4547.09	812.43	0.82
28.75	55000	2266	2283.47	2285.32	0.001162	11.84	7943.13	1606.55	0.55
28.75	60000	2266	2284.16	2285.91	0.001084	11.79	9044.22	1611.46	0.53
28.84	55000	2268	2282.32	2287.14	0.003401	17.63	3218.49	641.02	0.91
28.84	60000	2268	2284.2	2287.96	0.002268	15.89	5007.94	1228.89	0.76
28.94	55000	2268.9	2284.77	2288.56	0.002101	15.7	3907.44	815.48	0.73
28.94	60000	2268.9	2284.94	2289.3	0.002389	16.87	4048.94	847.67	0.78
29.03	55000	2270	2288.06	2289.43	0.000804	9.54	7072.98	1342.19	0.45
29.03	60000	2270	2288.89	2290.24	0.000754	9.58	8205.32	1392.5	0.44
29.17	55000	2272	2289.16	2289.96	0.000578	7.24	8843.69	1595.69	0.38
29.17	60000	2272	2289.94	2290.73	0.000533	7.26	10100.45	1627.66	0.37
29.3	55000	2274	2288.98	2290.88	0.001378	11.14	5484.41	1159.03	0.58
29.3	60000	2274	2289.7	2291.62	0.001305	11.26	6382.57	1336.8	0.57
29.4	55000	2276	2289.3	2292	0.002035	13.21	4233.92	441.31	0.7
29.4	60000	2276	2289.87	2292.76	0.002053	13.68	4488.35	446.75	0.71
29.5	55000	2276.9	2290.58	2293.14	0.002328	12.86	4301.81	501.58	0.73
29.5	60000	2276.9	2291.22	2293.9	0.002226	13.13	4642.95	555.79	0.72
29.59	55000	2278	2292.04	2294.35	0.002382	12.23	4650.88	680.75	0.73
29.59	60000	2278	2292.68	2295.04	0.00222	12.38	5102.97	722.1	0.71
29.69	55000	2280	2293.44	2295.42	0.001812	11.52	5557.71	996.85	0.65
29.69	60000	2280	2294.03	2296.05	0.001732	11.71	6180.37	1111.37	0.64
29.78	55000	2281	2293.27	2299.22	0.005678	20.36	3641.18	824.72	1.14
29.78	60000	2281	2293.56	2300	0.005972	21.29	3889.08	855.05	1.18
29.88	55000	2283	2296.06	2301.71	0.004276	19.09	2989.88	771.14	1
29.88	60000	2283	2296.69	2302.53	0.004162	19.52	3489.06	831.86	1

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
29.97	55000	2284.2	2298.81	2303.48	0.002808	17.41	3528.69	933.16	0.83
29.97	60000	2284.2	2300.13	2304.21	0.002303	16.6	4772.63	947.31	0.76
30.06	55000	2285.4	2302.52	2304.61	0.001211	12.56	6787.35	991.32	0.56
30.06	60000	2285.4	2303.03	2305.22	0.001252	12.99	7295.58	1011.32	0.57
30.16	55000	2287.5	2301.69	2308.46	0.004265	20.87	2635.13	193.29	1
30.16	60000	2287.5	2301.21	2309.86	0.005683	23.61	2541.72	192.77	1.15
30.17	Bridge								
30.18	55000	2287.5	2307.5	2310.29	0.001215	13.63	5318.63	1231.48	0.54
30.18	60000	2287.5	2305.97	2310.29	0.001995	16.67	3599.24	198.72	0.69
30.28	55000	2288	2309.08	2310.85	0.000736	11.05	8104.94	1487.84	0.44
30.28	60000	2288	2308.99	2311.14	0.000893	12.14	7976.65	1481.02	0.49
30.37	55000	2289	2309.25	2311.37	0.00093	12.08	7439.25	1476.03	0.5
30.37	60000	2289	2309.22	2311.76	0.001115	13.21	7389.57	1473.18	0.54
30.48	55000	2290.4	2309.96	2311.94	0.00091	11.77	7976.71	1451.87	0.49
30.48	60000	2290.4	2310.2	2312.44	0.001023	12.57	8323.42	1463.68	0.52
30.58	55000	2291.5	2310.1	2312.61	0.001172	12.98	6143.38	1175.75	0.55
30.58	60000	2291.5	2310.35	2313.19	0.001318	13.86	6433.28	1187.27	0.59
30.67	55000	2292.5	2310.39	2313.41	0.001426	13.98	4368.78	676.11	0.61
30.67	60000	2292.5	2310.65	2314.1	0.001611	14.98	4543.15	692.12	0.65
30.77	55000	2294	2310.96	2314.27	0.001682	14.72	3994.34	271.13	0.65
30.77	60000	2294	2311.28	2315.07	0.001877	15.72	4083.98	273.24	0.69
30.86	55000	2295	2311.93	2315.12	0.001645	14.54	4116.47	315.27	0.65
30.86	60000	2295	2312.45	2316	0.001765	15.34	4293.86	362.26	0.67
30.96	55000	2296.3	2312.64	2316.06	0.001844	15.08	4151.89	449.55	0.68
30.96	60000	2296.3	2313.25	2316.98	0.001929	15.76	4453.17	529.48	0.7
31.05	55000	2297.8	2314.03	2317.12	0.001743	14.59	4651.23	527.33	0.66
31.05	60000	2297.8	2314.68	2317.95	0.001777	15.08	5030.99	637.4	0.67
31.15	55000	2298.8	2314.44	2318.34	0.002183	15.97	3780.13	411.46	0.74
31.15	60000	2298.8	2315.03	2319.24	0.002269	16.65	4025.41	422.64	0.76
31.24	55000	2300	2315.33	2319.6	0.002414	16.6	3357.02	250.99	0.77
31.24	60000	2300	2315.89	2320.59	0.002544	17.42	3499.17	254.23	0.8
31.34	55000	2301	2316.34	2320.96	0.002636	17.25	3188.55	215.66	0.79
31.34	60000	2301	2316.95	2322.02	0.002762	18.07	3320.84	216.28	0.81

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
31.43	55000	2302.3	2320.53	2321.84	0.000601	9.19	6020.7	500.23	0.4
31.43	60000	2302.3	2321.57	2322.94	0.000581	9.39	6676.73	764.17	0.4
31.52	55000	2303.8	2318.63	2324.94	0.004146	20.17	2727.03	214.95	1
31.52	60000	2303.8	2319.42	2326.08	0.004081	20.7	2897.94	216.39	1
31.53	Bridge								
31.54	55000	2304.2	2326.34	2328.43	0.000816	11.98	6617.23	1252.18	0.47
31.54	60000	2304.2	2326.36	2328.83	0.000966	13.05	6645.09	1255.72	0.51
31.63	55000	2306	2325.4	2329.68	0.001906	16.61	3336.65	220.52	0.7
31.63	60000	2306	2325.14	2330.39	0.002382	18.41	3278.53	215.86	0.78
31.73	55000	2308	2325.8	2331.1	0.002616	18.47	2986.35	214.71	0.81
31.73	60000	2308	2323.16	2332.13	0.005357	24.04	2496.25	179.38	1.14
31.82	55000	2309.8	2326.08	2333.26	0.003974	21.51	2556.59	170.15	0.98
31.82	60000	2309.8	2326.73	2334.58	0.004154	22.49	2667.76	171.2	1
31.95	55000	2313	2330.65	2335.65	0.002714	17.93	3067.49	212.51	0.83
31.95	60000	2313	2332.02	2336.97	0.002474	17.84	3362.61	218.52	0.8
31.955	Bridge								
31.96	55000	2313	2337.39	2339.63	0.000812	12.03	5883.12	1109.93	0.47
31.96	60000	2313	2337.34	2340.03	0.000973	13.16	5833.7	1102.41	0.52
32.06	55000	2314	2338.03	2340.02	0.00065	11.36	8425.21	1146.7	0.44
32.06	60000	2314	2338.15	2340.49	0.000759	12.32	8562.65	1160.4	0.47
32.15	55000	2314.9	2338.82	2340.39	0.000673	10.08	7498.71	1209.36	0.43
32.15	60000	2314.9	2339.11	2340.92	0.000755	10.8	7861.59	1249.51	0.46
32.25	55000	2317	2338.13	2341.32	0.001212	14.34	4853.9	490.13	0.58
32.25	60000	2317	2338.27	2342	0.001408	15.53	4920.82	503.02	0.63
32.34	55000	2318	2339.36	2341.98	0.001228	13	5202.76	1030.98	0.57
32.34	60000	2318	2339.83	2342.77	0.001327	13.77	5761.01	1381.04	0.6
32.44	55000	2322	2337.95	2344.09	0.004059	19.89	2959.72	346.25	1
32.44	60000	2322	2338.7	2345.18	0.003961	20.44	3299.64	478.81	1
32.53	55000	2323.5	2341.86	2345.71	0.002036	15.75	3984.44	690.52	0.73
32.53	60000	2323.5	2342.71	2346.79	0.002004	16.23	4612.31	785.67	0.73
32.61	55000	2324	2341.24	2348.15	0.004055	21.11	2605.81	187.2	1
32.61	60000	2324	2340.85	2349.56	0.005231	23.67	2534.69	185.77	1.13

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
32.615	Bridge								
32.62	55000	2324	2345.29	2348.76	0.001481	14.94	3681.46	652.86	0.62
32.62	60000	2324	2347.16	2350.52	0.001287	14.72	5923.94	1204.41	0.58
32.72	55000	2325.5	2347.2	2349.49	0.001034	12.17	6648.08	852.65	0.53
32.72	60000	2325.5	2348.96	2351.17	0.000891	11.94	8391.56	1247.52	0.5
32.81	55000	2327	2347.54	2350.16	0.001266	13.01	5444.23	733.39	0.58
32.81	60000	2327	2349.22	2351.75	0.001067	12.78	6861.84	962.46	0.54
32.9	55000	2329	2347.98	2351.02	0.001697	13.99	3930.58	282.66	0.66
32.9	60000	2329	2349.75	2352.5	0.001811	13.31	4506.7	367.88	0.67
33	55000	2330	2349.46	2351.84	0.001337	12.37	4446.76	323.36	0.59
33	60000	2330	2351.03	2353.26	0.001122	12.01	5377.68	757.25	0.55
33.09	55000	2331	2350.25	2352.49	0.001208	11.99	4587.25	321.52	0.56
33.09	60000	2331	2351.6	2353.82	0.001099	11.93	5027.73	330.4	0.54
33.19	55000	2332.1	2348.58	2354.54	0.003264	19.59	2808.03	190.79	0.9
33.19	60000	2332.1	2349.77	2355.83	0.003067	19.76	3036.86	193.74	0.88
33.28	55000	2333.2	2350.44	2356.11	0.002919	19.1	2879.05	183.97	0.85
33.28	60000	2333.2	2351.26	2357.35	0.002971	19.79	3031.17	185.59	0.86
33.38	55000	2334.3	2352.45	2357.5	0.002456	18.04	3048.42	185.94	0.79
33.38	60000	2334.3	2353.39	2358.77	0.002467	18.61	3224.2	187.8	0.79
33.47	55000	2335.2	2354.35	2358.68	0.001982	16.69	3294.7	193.13	0.71
33.47	60000	2335.2	2355.36	2359.95	0.001977	17.19	3491.86	208.42	0.72
33.57	55000	2336.2	2356.94	2359.6	0.001206	13.09	4204.22	260.54	0.56
33.57	60000	2336.2	2358.1	2360.87	0.001148	13.35	4515.61	277.74	0.56
33.66	55000	2337.4	2356.97	2360.57	0.001568	15.22	3612.94	202.23	0.63
33.66	60000	2337.4	2358.03	2361.85	0.001549	15.67	3840.08	240.08	0.64
33.75	55000	2341.8	2353.97	2362.38	0.00661	23.27	2363.35	213.32	1.23
33.75	60000	2341.8	2354.63	2363.53	0.006544	23.95	2505.44	214.48	1.23
33.755	Bridge								
33.76	55000	2342	2358.05	2362.8	0.002633	17.48	3145.81	209.71	0.8
33.76	60000	2342	2358.96	2363.98	0.002606	17.98	3336.79	210.52	0.8
33.86	55000	2343	2359.78	2364.05	0.002197	16.58	3316.31	214.38	0.74
33.86	60000	2343	2360.7	2365.22	0.002187	17.07	3515	216.22	0.75
33.95	55000	2344	2363.23	2364.87	0.000679	10.27	5353	296.71	0.43

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
33.95	60000	2344	2364.32	2366.06	0.000671	10.57	5680.73	313.83	0.43
34.05	55000	2345.3	2361.26	2366.6	0.002938	18.54	2967.29	201.77	0.85
34.05	60000	2345.3	2362.24	2367.82	0.002867	18.95	3165.68	203.72	0.85
34.14	55000	2346.4	2357.95	2368.7	0.008684	26.32	2090.05	191.9	1.41
34.14	60000	2346.4	2358.68	2369.91	0.008429	26.9	2230.73	193.28	1.4
34.24	55000	2351	2365.55	2372.02	0.004065	20.42	2693.81	206.37	1
34.24	60000	2351	2366.38	2373.18	0.004003	20.93	2866.67	208.79	1
34.245	Bridge								
34.25	55000	2351	2373.94	2376.16	0.000798	11.96	4619.97	269.59	0.47
34.25	60000	2351	2374.04	2376.66	0.000935	12.99	4646.13	274.58	0.5
34.34	55000	2354	2375.09	2376.59	0.000648	9.83	5592.3	330.16	0.42
34.34	60000	2354	2375.44	2377.16	0.000726	10.51	5708.29	332.03	0.45
34.43	55000	2356	2374.96	2377.28	0.001289	12.33	7917.5	634.2	0.58
34.43	60000	2356	2375.29	2377.93	0.001426	13.14	8127.97	636.39	0.61
34.53	55000	2357	2375.91	2377.91	0.001093	11.41	7763.3	660.8	0.53
34.53	60000	2357	2376.39	2378.61	0.001168	12.03	8080.57	661.88	0.55
34.62	55000	2358.2	2373.95	2380.02	0.003414	19.87	4509.42	468.24	0.93
34.62	60000	2358.2	2374.19	2381.17	0.003849	21.3	4621.02	469.47	0.99
34.72	55000	2361	2380.1	2381.17	0.000673	8.28	6644.47	529.38	0.41
34.72	60000	2361	2381.33	2382.38	0.0006	8.22	7298.77	539	0.39
34.81	55000	2364	2380.1	2381.76	0.001048	10.91	6062.52	514	0.52
34.81	60000	2364	2381.29	2382.92	0.000936	10.84	6677.82	519.11	0.5
34.91	55000	2366	2381.56	2382.27	0.000685	8.98	11044.6	1083.19	0.42
34.91	60000	2366	2382.68	2383.39	0.000618	8.99	12285.15	1136.56	0.41
35	55000	2367	2380.93	2383.36	0.002094	13.48	5252.1	581.17	0.71
35	60000	2367	2382.09	2384.36	0.001749	13.08	5933.96	586.42	0.66
35.1	55000	2368	2382.69	2384.3	0.001418	10.44	5858.78	647.9	0.58
35.1	60000	2368	2383.54	2385.17	0.001303	10.53	6426.27	691.05	0.56
35.19	55000	2370	2383.85	2384.92	0.000932	8.53	7345.75	846.69	0.47
35.19	60000	2370	2384.69	2385.75	0.000845	8.54	8050.97	851.98	0.45
35.29	55000	2372	2383.26	2386.58	0.003526	15.15	4520.07	800.86	0.89
35.29	60000	2372	2383.82	2387.19	0.003357	15.36	4979.46	844.66	0.88
35.38	55000	2374	2386.68	2387.69	0.001076	9.68	9435.29	1222.33	0.51

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
35.38	60000	2374	2387.24	2388.27	0.001048	9.85	10122.06	1225.9	0.51
35.47	55000	2375	2385.32	2392	0.008397	21.58	3187.15	606.89	1.35
35.47	60000	2375	2385.52	2392.95	0.009109	22.83	3306.95	607.67	1.41
35.57	55000	2376	2388.98	2394.97	0.004265	19.65	2799.64	234.45	1
35.57	60000	2376	2389.71	2396.04	0.004202	20.18	2973.29	235.96	1
35.66	55000	2377	2387.32	2397.8	0.013383	25.98	2117.12	282.57	1.67
35.66	60000	2377	2387.73	2398.94	0.01339	26.86	2233.88	283.4	1.69
35.77	55000	2381	2394.34	2403.15	0.007046	23.82	2308.89	213.36	1.28
35.77	60000	2381	2395.08	2404.26	0.006823	24.31	2467.89	215.53	1.27
35.775	Bridge								
35.78	55000	2382	2399.63	2403.46	0.002025	15.71	3501.19	237.67	0.72
35.78	60000	2382	2400.53	2404.58	0.002017	16.14	3716.61	241.08	0.72
35.87	55000	2382.6	2400.87	2404.41	0.001642	15.1	3642.97	215.86	0.65
35.87	60000	2382.6	2401.69	2405.52	0.001684	15.7	3822.42	220.34	0.66
35.97	55000	2385	2400.8	2405.96	0.002873	18.23	3016.38	207.85	0.84
35.97	60000	2385	2401.6	2407.11	0.002898	18.85	3183.41	209.57	0.85
36.06	55000	2387.3	2403.27	2407.32	0.002181	16.15	3404.84	229.49	0.74
36.06	60000	2387.3	2404.23	2408.48	0.002135	16.54	3626.65	231.45	0.74
36.16	55000	2389	2404.96	2408.38	0.001819	14.83	3709.56	249.74	0.68
36.16	60000	2389	2405.94	2409.51	0.001775	15.17	3954.12	251.87	0.67
36.25	55000	2390	2406.2	2409.26	0.001593	14.05	3914.52	258.35	0.64
36.25	60000	2390	2407.16	2410.38	0.001562	14.41	4163.66	266.88	0.63
36.35	55000	2391.3	2406.56	2410.43	0.002189	15.79	3484.15	246.56	0.74
36.35	60000	2391.3	2407.48	2411.54	0.002141	16.16	3712.04	248.76	0.74
36.44	55000	2392.5	2407.69	2411.52	0.002161	15.71	3502.04	245.98	0.73
36.44	60000	2392.5	2408.56	2412.61	0.002136	16.14	3716.96	247.76	0.73
36.54	55000	2394	2410.94	2412.31	0.000642	9.37	5869.64	364.79	0.41
36.54	60000	2394	2411.96	2413.4	0.000626	9.61	6243.21	370.04	0.41
36.63	55000	2396	2410.1	2413.43	0.002052	14.63	3758.42	288.08	0.71
36.63	60000	2396	2411.09	2414.5	0.001945	14.84	4043.62	291.09	0.7
36.72	55000	2398.2	2409.84	2415.56	0.004407	19.19	2866.34	257.36	1.01
36.72	60000	2398.2	2410.79	2416.57	0.00404	19.28	3112.06	259.18	0.98
36.82	55000	2400	2411.61	2418.5	0.006554	21.07	2610.73	279.01	1.21

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
36.82	60000	2400	2412.18	2419.46	0.006445	21.65	2771.69	280.45	1.21
36.825	Bridge								
36.83	55000	2400	2416.87	2419.15	0.001114	12.11	4541.43	288.34	0.54
36.83	60000	2400	2417.39	2419.93	0.001199	12.79	4690.06	289.51	0.56
36.93	55000	2403	2417.44	2422	0.004544	17.15	3206.76	357.77	1.01
36.93	60000	2403	2418.03	2422.81	0.004422	17.55	3418.87	360.85	1
37.02	55000	2405	2420.75	2423.59	0.001911	13.98	4688.08	497.65	0.69
37.02	60000	2405	2421.41	2424.39	0.001908	14.37	5019.06	505.84	0.69
37.12	55000	2406	2421.65	2424.68	0.002262	13.97	3938.41	354.37	0.74
37.12	60000	2406	2422.28	2425.51	0.002313	14.4	4165.26	363.69	0.75
37.21	55000	2408	2422.58	2426.01	0.002602	14.86	3700.49	337.65	0.79
37.21	60000	2408	2423.21	2426.86	0.002604	15.33	3913.56	340.73	0.8
37.31	55000	2409.7	2423.59	2427.77	0.003686	16.41	3351.96	338.27	0.92
37.31	60000	2409.7	2424.2	2428.62	0.003625	16.87	3556.94	339.66	0.92
37.4	55000	2412	2425.89	2429.5	0.002856	16.23	4661.23	657.36	0.83
37.4	60000	2412	2426.97	2430.24	0.002395	15.69	5369.57	659.36	0.77
37.5	55000	2413	2428.48	2430.71	0.001697	12.28	5035.61	524.69	0.64
37.5	60000	2413	2428.9	2431.34	0.001781	12.87	5255.74	526.16	0.66
37.59	55000	2416	2428.88	2432.1	0.002981	14.39	3821.46	407.03	0.83
37.59	60000	2416	2429.29	2432.8	0.003114	15.04	3990.67	411.27	0.85
37.69	55000	2418	2430.28	2434.41	0.00469	16.32	3369.44	416.83	1.01
37.69	60000	2418	2430.79	2435.14	0.004542	16.74	3585.97	420.28	1
37.78	55000	2419	2433.25	2436.18	0.002438	13.73	4007.27	389.76	0.75
37.78	60000	2419	2433.73	2436.91	0.002508	14.31	4193.74	391.19	0.77
37.87	55000	2420.3	2435.63	2437.11	0.00111	9.79	5616.95	504.94	0.52
37.87	60000	2420.3	2436.29	2437.86	0.001098	10.08	5952	507.52	0.52
37.97	55000	2422	2435.96	2437.91	0.001601	11.2	4909.67	474.96	0.61
37.97	60000	2422	2436.61	2438.66	0.001577	11.5	5215.78	479.26	0.61
38.06	55000	2424.6	2433.44	2442.99	0.016193	24.79	2218.26	372.5	1.79
38.06	60000	2424.6	2433.75	2444	0.016544	25.69	2335.41	377.81	1.82
38.16	55000	2427	2441.3	2447.04	0.004146	19.23	2866.01	258.98	1
38.16	60000	2427	2442	2448.07	0.004054	19.78	3047.74	264.3	1
38.25	55000	2428	2446.81	2448.14	0.000619	9.7	6838.27	507.8	0.41

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
38.25	60000	2428	2447.79	2449.17	0.000603	9.94	7339.08	516.82	0.41
38.35	55000	2429.4	2446.87	2448.62	0.000917	11.22	6100	495.14	0.5
38.35	60000	2429.4	2447.84	2449.64	0.000878	11.42	6582.63	499.75	0.49
38.44	55000	2431.6	2440.6	2452.98	0.017011	28.23	1948.08	276.35	1.87
38.44	60000	2431.6	2441.01	2454.15	0.017154	29.09	2062.61	281.43	1.89
38.54	55000	2433	2450.39	2457.18	0.004064	20.92	2638.77	225.77	1
38.54	60000	2433	2452.12	2458.34	0.004043	20.05	3104.88	358.46	0.99
38.63	55000	2434.2	2456.55	2458.38	0.000706	10.9	5552.33	950.26	0.45
38.63	60000	2434.2	2457.6	2459.46	0.000676	11.07	6741.35	1318.66	0.44
38.73	55000	2434.3	2457.45	2458.72	0.000454	9.14	6630.36	518.26	0.36
38.73	60000	2434.3	2458.4	2459.78	0.000462	9.51	7222.24	759.03	0.37
38.82	55000	2435.4	2457.65	2458.96	0.000457	9.19	6124.15	391.21	0.36
38.82	60000	2435.4	2458.61	2460.02	0.000463	9.54	6515.23	419.45	0.37
38.96	55000	2440	2457.51	2459.7	0.001039	11.87	4631.98	289.02	0.52
38.96	60000	2440	2458.46	2460.78	0.001036	12.23	4906.52	291.67	0.53
38.965	Bridge								
38.97	55000	2440	2457.95	2459.97	0.000953	11.4	4823.25	302.28	0.5
38.97	60000	2440	2458.92	2461.06	0.000947	11.73	5117.17	305.9	0.51
39.06	55000	2442.5	2455.09	2462.77	0.006443	22.24	2473.14	239.89	1.22
39.06	60000	2442.5	2455.64	2463.87	0.006537	23.02	2606.54	242.38	1.24
39.16	55000	2444.9	2459.09	2465.45	0.00417	20.23	2718.57	214.55	1
39.16	60000	2444.9	2459.85	2466.58	0.004137	20.83	2881.15	215.76	1
39.25	55000	2446.5	2465.06	2466.66	0.000737	10.14	5473.15	362.78	0.45
39.25	60000	2446.5	2466.14	2467.8	0.000705	10.36	5865.09	367.61	0.44
39.35	55000	2448.6	2466.24	2466.99	0.000351	6.99	8577.66	788.91	0.31
39.35	60000	2448.6	2467.36	2468.12	0.000327	7.06	9498.24	853.37	0.3
39.44	55000	2450.7	2465.21	2467.91	0.001711	13.25	4383.14	445.89	0.65
39.44	60000	2450.7	2466.34	2469	0.001525	13.2	4898.44	469.2	0.62
39.54	55000	2452.5	2466.25	2470.87	0.004477	17.25	3196.19	354.36	1
39.54	60000	2452.5	2468.26	2471.9	0.002799	15.34	4315.69	1885.05	0.82
39.63	55000	2454	2470.99	2471.86	0.000565	7.64	9219.23	1851.72	0.38
39.63	60000	2454	2471.85	2472.68	0.000507	7.56	10824.58	1870.62	0.36
39.73	55000	2456.2	2471.65	2472.1	0.000317	5.58	13556.09	2529.54	0.28

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
39.73	60000	2456.2	2472.47	2472.9	0.000284	5.52	15630.35	2536.74	0.27
39.82	55000	2458.4	2471.55	2472.5	0.001056	8.49	10084.63	2267.11	0.49
39.82	60000	2458.4	2472.41	2473.22	0.000837	8.02	12038.36	2273.28	0.44
39.92	55000	2461.1	2471.82	2474.02	0.003746	13.27	6368.38	1497.89	0.88
39.92	60000	2461.1	2472.18	2474.4	0.003627	13.48	6905.58	1512.17	0.88
40.01	55000	2462.8	2474.1	2474.98	0.00086	7.86	8561.65	1216.2	0.45
40.01	60000	2462.8	2474.42	2475.39	0.000908	8.24	8956.23	1221.51	0.46
40.11	55000	2464.4	2474.79	2475.38	0.000621	6.16	8965.66	1061.66	0.37
40.11	60000	2464.4	2475.16	2475.8	0.000643	6.44	9358.77	1063.98	0.38
40.2	55000	2466.4	2475.01	2475.91	0.001343	7.58	7254.78	1115.1	0.52
40.2	60000	2466.4	2475.39	2476.34	0.00133	7.82	7673.71	1117.73	0.53
40.29	55000	2468.7	2475.65	2476.98	0.002806	9.25	5946.7	1179.02	0.73
40.29	60000	2468.7	2476	2477.38	0.00267	9.43	6365.07	1181.35	0.72
40.39	55000	2471.1	2476.42	2479.63	0.008711	14.37	3826.94	916.82	1.24
40.39	60000	2471.1	2476.6	2480.11	0.009068	15.05	3986.92	918.6	1.27
40.48	55000	2472	2479.94	2482.93	0.005119	13.88	3961.83	669.64	1.01
40.48	60000	2472	2480.29	2483.46	0.005034	14.29	4198.29	670.72	1.01
40.58	55000	2474	2483.33	2484.34	0.001412	8.05	6828.53	994.16	0.54
40.58	60000	2474	2483.81	2484.85	0.001369	8.22	7302.74	1008.25	0.54
40.67	55000	2476	2484.06	2485.47	0.003105	9.52	5779.17	1184.06	0.76
40.67	60000	2476	2484.5	2485.91	0.002783	9.52	6299.37	1187.38	0.73
40.77	55000	2478	2485.53	2487.69	0.005338	11.79	4666.65	1039.92	0.98
40.77	60000	2478	2485.75	2488.09	0.005488	12.26	4892.81	1048.8	1
40.86	55000	2480	2488.28	2489.53	0.002456	8.96	6140.21	1152.81	0.68
40.86	60000	2480	2488.61	2489.93	0.002397	9.2	6522.51	1155.06	0.68
40.96	55000	2482	2489.65	2492.04	0.005477	12.4	4433.85	931.65	1
40.96	60000	2482	2490.15	2492.46	0.005636	12.19	4923.08	1085.67	1.01
41.05	55000	2484	2492.45	2494.43	0.004058	11.3	4869.56	944.53	0.88
41.05	60000	2484	2492.74	2494.85	0.004046	11.66	5148.07	950.48	0.88
41.19	55000	2486	2495.04	2501.37	0.010666	20.18	2725.25	452.6	1.45
41.19	60000	2486	2495.44	2502.06	0.010309	20.66	2904.13	453.59	1.44
41.195	Bridge								
41.2	55000	2486.2	2499.35	2501.49	0.001843	11.74	4682.9	469.41	0.66

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
41.2	60000	2486.2	2499.93	2502.21	0.001826	12.1	4958.51	471.74	0.66
41.32	55000	2487.5	2497.02	2504.66	0.009513	22.18	2479.45	325.15	1.42
41.32	60000	2487.5	2497.55	2505.49	0.009086	22.62	2652.98	326.02	1.4
41.33	Bridge								
41.34	55000	2488	2503.8	2506.36	0.001782	12.87	4324.97	406.07	0.66
41.34	60000	2488	2504.49	2507.2	0.001747	13.24	4610.04	417.66	0.66
41.43	55000	2493.1	2505.04	2507.52	0.003011	12.7	4444.15	614.83	0.81
41.43	60000	2493.1	2505.92	2508.28	0.002482	12.4	4988.05	618.78	0.75
41.62	55000	2496	2507.77	2509.79	0.001734	11.8	5550.38	712.51	0.64
41.62	60000	2496	2508.19	2510.38	0.001795	12.32	5850.65	745.42	0.66
41.71	55000	2500	2509.94	2510.25	0.000301	4.48	12280.44	1344.57	0.26
41.71	60000	2500	2510.52	2510.85	0.000292	4.6	13062.18	1345.07	0.26
41.84	55000	2501.5	2510.17	2510.59	0.000731	6.18	13256.01	2103.04	0.4
41.84	60000	2501.5	2510.74	2511.16	0.000664	6.18	14472.34	2108.36	0.38
41.93	55000	2502.6	2512.61	2515.69	0.003319	14.8	4901.93	887.2	0.86
41.93	60000	2502.6	2513.01	2516.23	0.003328	15.24	5260.1	887.87	0.87
42.03	55000	2504	2515.86	2516.63	0.00076	7.21	8655.28	1117.25	0.42
42.03	60000	2504	2516.37	2517.18	0.000748	7.41	9224.81	1118.32	0.42
42.12	55000	2506	2515.36	2517.79	0.003123	13.1	5206.23	969.77	0.82
42.12	60000	2506	2515.84	2518.33	0.00299	13.33	5673.54	992.4	0.81
42.22	55000	2509.6	2516.41	2523.47	0.011703	21.31	2580.49	424	1.52
42.22	60000	2509.6	2516.69	2524.37	0.012028	22.23	2698.81	424.7	1.55
42.31	55000	2510	2521.82	2527	0.004366	18.26	3012.35	295.02	1.01
42.31	60000	2510	2522.44	2527.92	0.004279	18.78	3196.82	300.68	1
42.41	55000	2512	2525.23	2528.79	0.002501	15.15	3629.45	303.94	0.77
42.41	60000	2512	2525.91	2529.71	0.002499	15.64	3836.65	305.72	0.78
42.5	55000	2514	2528.34	2529.74	0.000922	9.49	5794.68	468.78	0.48
42.5	60000	2514	2529.19	2530.65	0.000887	9.68	6196.62	471.98	0.47
42.6	55000	2515	2529.03	2530.18	0.000754	8.6	6393.79	519.39	0.43
42.6	60000	2515	2529.88	2531.07	0.000723	8.78	6835.27	521.36	0.43
42.69	55000	2516	2529.8	2530.52	0.000477	6.8	8201.1	744.05	0.35
42.69	60000	2516	2530.66	2531.4	0.00045	6.91	8843.52	747.51	0.34
42.78	55000	2519	2529.25	2531.35	0.002286	11.63	4728.98	569.08	0.71

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
42.78	60000	2519	2530.14	2532.18	0.001969	11.46	5236.81	576.02	0.67
42.88	55000	2520	2531.08	2532.12	0.000906	8.18	6742.73	701.24	0.46
42.88	60000	2520	2531.8	2532.87	0.000851	8.31	7250.09	704.81	0.45
42.96	55000	2520	2530.49	2533.87	0.004647	14.77	3779.59	587.62	0.99
42.96	60000	2520	2530.84	2534.47	0.004693	15.33	3985.48	602.56	1
43.05	55000	2523.2	2533.42	2535.47	0.002018	11.48	4824.89	558.97	0.68
43.05	60000	2523.2	2533.9	2536.09	0.002019	11.88	5094.52	573.76	0.68
43.15	55000	2524	2534.79	2536.37	0.001485	10.07	5464.14	585.9	0.58
43.15	60000	2524	2535.31	2536.99	0.001479	10.4	5768.47	586.74	0.58
43.22	55000	2526	2532.86	2539.01	0.010599	19.91	2762.71	468.06	1.44
43.22	60000	2526	2533.19	2539.75	0.010525	20.55	2919.39	468.81	1.45
43.31	55000	2530	2538.52	2542.55	0.004712	16.1	3416.54	428.43	1
43.31	60000	2530	2539	2543.26	0.004632	16.56	3622.25	429.17	1
43.41	55000	2530.7	2542.48	2543.89	0.001232	9.51	5795.82	602.76	0.54
43.41	60000	2530.7	2543.11	2544.59	0.00119	9.75	6178.27	605.97	0.53
43.57	55000	2534	2543.42	2545.51	0.002379	11.61	4738.13	586.38	0.72
43.57	60000	2534	2543.99	2546.16	0.002264	11.83	5071.02	588.05	0.71
43.66	55000	2536	2545.13	2548.74	0.004741	15.26	3606.22	507.49	1
43.66	60000	2536	2545.58	2549.39	0.004632	15.67	3836.26	517.79	1
43.84	55000	2538.68	2549.95	2551.37	0.001597	9.54	5767.9	711.03	0.59
43.84	60000	2538.68	2550.48	2551.96	0.001556	9.77	6143.54	716.08	0.59
43.95	55000	2540	2551.84	2555.5	0.004863	15.35	3583.07	499.67	1.01
43.95	60000	2540	2552.27	2556.14	0.00478	15.78	3802.05	501.97	1.01
44.21	45000	2547.17	2559.18	2560.32	0.002132	10.02	5716.22	746.14	0.66
44.21	45000	2547.17	2559.61	2560.64	0.001802	9.53	6043.08	762.39	0.62
44.49	45000	2551.2	2563.8	2567.63	0.004132	20.11	4101.3	509.71	1
44.49	45000	2551.2	2563.8	2567.63	0.004132	20.11	4101.3	509.71	1
44.83	45000	2557.7	2570.21	2571.35	0.001173	10.84	8923.64	1611.02	0.54
44.83	45000	2557.7	2570.21	2571.35	0.001173	10.84	8923.64	1611.02	0.54
45.15	45000	2563.9	2577.32	2582.3	0.007088	23.06	2989.33	288.81	1.21
45.15	45000	2563.9	2577.32	2582.3	0.007088	23.06	2989.33	288.81	1.21
45.47	45000	2570.2	2585.08	2587.35	0.001375	12.99	4528.32	405.83	0.6
45.47	45000	2570.2	2585.08	2587.35	0.001375	12.99	4528.32	405.83	0.6

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
45.93	45000	2578.9	2598.6	2605.15	0.002995	22.18	2857.98	261.38	0.9
45.93	45000	2578.9	2598.6	2605.15	0.002995	22.18	2857.98	261.38	0.9
46.27	45000	2585.5	2606.77	2608.41	0.000975	13.37	6954.86	698.84	0.52
46.27	45000	2585.5	2606.77	2608.41	0.000975	13.37	6954.86	698.84	0.52
46.57	45000	2591.4	2609.09	2609.82	0.00072	10.23	10236.42	1162.63	0.43
46.57	45000	2591.4	2609.09	2609.82	0.00072	10.23	10236.42	1162.63	0.43
46.89	45000	2597.6	2612.92	2617.01	0.004125	21.38	5000.27	914.32	0.99
46.89	45000	2597.6	2612.92	2617.01	0.004125	21.38	5000.27	914.32	0.99
47.16	45000	2602.7	2620.21	2623.23	0.004255	14.04	3503.04	833.74	0.93
47.16	45000	2602.7	2620.21	2623.23	0.004255	14.04	3503.04	833.74	0.93
47.49	45000	2609.1	2615.14	2630.36	0.026794	31.3	1437.53	244.08	2.27
47.49	45000	2609.1	2615.14	2630.36	0.026794	31.3	1437.53	244.08	2.27
47.78	45000	2614.6	2635.79	2639.59	0.002241	19.05	6686.22	2517.44	0.76
47.78	45000	2614.6	2635.79	2639.59	0.002241	19.05	6686.22	2517.44	0.76
48.08	45000	2620.4	2637.29	2646.67	0.005678	26.01	2788.77	631.77	1.17
48.08	45000	2620.4	2637.29	2646.67	0.005678	26.01	2788.77	631.77	1.17
48.29	45000	2624.4	2645.03	2651.91	0.003631	23.56	4644.69	2359.16	0.95
48.29	45000	2624.4	2645.03	2651.91	0.003631	23.56	4644.69	2359.16	0.95
48.52	45000	2628.9	2649.63	2656.53	0.003686	23.63	5393.5	2970.64	0.96
48.52	45000	2628.9	2649.63	2656.53	0.003686	23.63	5393.5	2970.64	0.96
48.75	45000	2633.4	2653.84	2662.35	0.005505	26.23	4103.46	1508.12	1.12
48.75	45000	2633.4	2653.84	2662.35	0.005505	26.23	4103.46	1508.12	1.12
772	45000	2636.3	2662.8	2664.1	0.002933	11.77	36189.48	7842.56	0.53
772	45000	2636.3	2662.8	2664.1	0.002933	11.77	36189.48	7842.56	0.53
772.5	Bridge								
773	45000	2636.3	2665.91	2665.92	0.000041	1.42	61551.57	8550.5	0.06
773	45000	2636.3	2665.91	2665.92	0.000041	1.42	61551.57	8550.5	0.06
773.1	45000	2636	2665.91	2665.92	0.00006	1.99	54299.05	8814.21	0.08
773.1	45000	2636	2665.91	2665.92	0.00006	1.99	54299.05	8814.21	0.08
773.15	Bridge								
773.2	45000	2636	2668.76	2668.77	0.000017	1.55	80655.39	9637.35	0.06
773.2	45000	2636	2668.76	2668.77	0.000017	1.55	80655.39	9637.35	0.06
774	45000	2638	2668.72	2668.79	0.000174	3.75	86125.13	9655.14	0.14

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
774	45000	2638	2668.72	2668.79	0.000174	3.75	86125.13	9655.14	0.14
775	45000	2640.9	2668.91	2669.05	0.0006	5.94	58387.16	8679.29	0.25
775	45000	2640.9	2668.91	2669.05	0.0006	5.94	58387.16	8679.29	0.25
776	45000	2648	2669.54	2669.66	0.000467	5.17	55327.36	8809.48	0.22
776	45000	2648	2669.54	2669.66	0.000467	5.17	55327.36	8809.48	0.22
778	45000	2660	2672.92	2673.92	0.005683	12.58	36868.04	8667.15	0.71
778	45000	2660	2672.92	2673.92	0.005683	12.58	36868.04	8667.15	0.71
780	45000	2660	2677.65	2678.16	0.00235	8.74	41170.75	9399.78	0.47
780	45000	2660	2677.65	2678.16	0.00235	8.74	41170.75	9399.78	0.47
781	45000	2664.9	2680.6	2680.74	0.001998	6.4	39670.51	8917.17	0.4
781	45000	2664.9	2680.6	2680.74	0.001998	6.4	39670.51	8917.17	0.4
782	45000	2672	2683.55	2683.65	0.002625	5.98	42938.45	8663.71	0.44
782	45000	2672	2683.55	2683.65	0.002625	5.98	42938.45	8663.71	0.44
783	45000	2676	2686.79	2687.15	0.00281	7.87	37219.52	8114.98	0.49
783	45000	2676	2686.79	2687.15	0.00281	7.87	37219.52	8114.98	0.49
784	45000	2676.1	2688.46	2689.07	0.00325	9.2	35189.23	8000.36	0.54
784	45000	2676.1	2688.46	2689.07	0.00325	9.2	35189.23	8000.36	0.54
785	45000	2674.7	2690.77	2691.34	0.002187	7.86	25591.51	7425.39	0.44
785	45000	2674.7	2690.77	2691.34	0.002187	7.86	25591.51	7425.39	0.44
786	45000	2678.2	2693.24	2694.27	0.004047	10.68	22448.89	6854.13	0.6
786	45000	2678.2	2693.24	2694.27	0.004047	10.68	22448.89	6854.13	0.6
787	45000	2682.2	2695.34	2696.16	0.002266	8.55	25006.42	6407.12	0.46
787	45000	2682.2	2695.34	2696.16	0.002266	8.55	25006.42	6407.12	0.46
788	45000	2684	2698.11	2698.28	0.001508	5.33	34888.13	6647.47	0.35
788	45000	2684	2698.11	2698.28	0.001508	5.33	34888.13	6647.47	0.35
789	45000	2689.3	2699.74	2699.94	0.001858	5.33	30039.74	6182.81	0.38
789	45000	2689.3	2699.74	2699.94	0.001858	5.33	30039.74	6182.81	0.38
790	45000	2689.8	2702	2702.46	0.003791	8.17	26714.02	5928.56	0.55
790	45000	2689.8	2702	2702.46	0.003791	8.17	26714.02	5928.56	0.55
791	45000	2696	2705.19	2705.4	0.00262	7.39	30664.05	6884.99	0.47
791	45000	2696	2705.19	2705.4	0.00262	7.39	30664.05	6884.99	0.47
792	45000	2698	2707.48	2707.7	0.002612	7.23	34462.55	7444.11	0.47
792	45000	2698	2707.48	2707.7	0.002612	7.23	34462.55	7444.11	0.47

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
793	45000	2698.3	2708.31	2709.53	0.007689	12.42	24512.53	7102.28	0.79
793	45000	2698.3	2708.31	2709.53	0.007689	12.42	24512.53	7102.28	0.79
793.5	Bridge								
794	45000	2698.3	2710.51	2710.81	0.001828	7.16	41207.69	7938.07	0.4
794	45000	2698.3	2710.51	2710.81	0.001828	7.16	41207.69	7938.07	0.4
796	45000	2700	2711.07	2711.15	0.00095	4.38	44429.67	7628.38	0.28
796	45000	2700	2711.07	2711.15	0.00095	4.38	44429.67	7628.38	0.28
797	45000	2702	2711.65	2711.7	0.001248	4.22	47457.23	7310.13	0.31
797	45000	2702	2711.65	2711.7	0.001248	4.22	47457.23	7310.13	0.31
798	45000	2704	2712.39	2712.45	0.00197	5	42424.45	6972.89	0.38
798	45000	2704	2712.39	2712.45	0.00197	5	42424.45	6972.89	0.38
799	45000	2704.6	2713.08	2713.28	0.002386	6.4	38462.93	6681.7	0.44
799	45000	2704.6	2713.08	2713.28	0.002386	6.4	38462.93	6681.7	0.44
799.1	45000	2704.8	2716.01	2716.06	0.000657	4.16	55115.81	7127.32	0.24
799.1	45000	2704.8	2716.01	2716.06	0.000657	4.16	55115.81	7127.32	0.24
799.15	Bridge								
799.2	45000	2704.8	2716.05	2716.1	0.000645	4.14	55416.92	7130.94	0.24
799.2	45000	2704.8	2716.05	2716.1	0.000645	4.14	55416.92	7130.94	0.24
800	45000	2705	2716.07	2716.14	0.000586	3.89	53305.2	7014.2	0.23
800	45000	2705	2716.07	2716.14	0.000586	3.89	53305.2	7014.2	0.23
804	45000	2706	2716.64	2716.72	0.001118	3.66	44576.68	6904.62	0.29
804	45000	2706	2716.64	2716.72	0.001118	3.66	44576.68	6904.62	0.29
805	45000	2710	2718.5	2718.71	0.003863	5.17	24209.41	6488.48	0.5
805	45000	2710	2718.5	2718.71	0.003863	5.17	24209.41	6488.48	0.5
806	45000	2714	2722.96	2723.19	0.00294	5.32	19993.16	6311.73	0.45
806	45000	2714	2722.96	2723.19	0.00294	5.32	19993.16	6311.73	0.45
807	45000	2718	2727.9	2728.24	0.003085	5.56	18694.73	6027.74	0.47
807	45000	2718	2727.9	2728.24	0.003085	5.56	18694.73	6027.74	0.47
808	45000	2720	2730.36	2730.82	0.003457	5.94	14673.29	5568.75	0.49
808	45000	2720	2730.36	2730.82	0.003457	5.94	14673.29	5568.75	0.49
809	45000	2726	2733.36	2733.74	0.003117	6.33	11326.96	4355.51	0.48
809	45000	2726	2733.36	2733.74	0.003117	6.33	11326.96	4355.51	0.48
810	45000	2723.9	2738.14	2739.01	0.005387	8.55	11439.51	5219.97	0.64

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
810	45000	2723.9	2738.14	2739.01	0.005387	8.55	11439.51	5219.97	0.64
811	45000	2729.3	2741.34	2741.63	0.002166	5.83	18011.22	5595.73	0.41
811	45000	2729.3	2741.34	2741.63	0.002166	5.83	18011.22	5595.73	0.41
812	45000	2731.2	2743.25	2743.63	0.002535	5.67	14211.14	4830.92	0.43
812	45000	2731.2	2743.25	2743.63	0.002535	5.67	14211.14	4830.92	0.43
813	45000	2738	2747.55	2748.04	0.004246	7.18	14885.14	4752.94	0.56
813	45000	2738	2747.55	2748.04	0.004246	7.18	14885.14	4752.94	0.56
814	45000	2740	2749.48	2749.85	0.002562	7.18	18611.93	5193.86	0.46
814	45000	2740	2749.48	2749.85	0.002562	7.18	18611.93	5193.86	0.46
815	45000	2740.4	2750.58	2751.74	0.00391	10.4	15761.87	5536.14	0.59
815	45000	2740.4	2750.58	2751.74	0.00391	10.4	15761.87	5536.14	0.59
815.5	Bridge								
816	45000	2740.4	2750.98	2751.94	0.003237	9.68	17070.01	5672.71	0.54
816	45000	2740.4	2750.98	2751.94	0.003237	9.68	17070.01	5672.71	0.54
817	45000	2741.2	2752.06	2752.59	0.002806	7.44	18681.07	5757.51	0.48
817	45000	2741.2	2752.06	2752.59	0.002806	7.44	18681.07	5757.51	0.48
820	45000	2742	2753.27	2754.15	0.005771	8.98	14272.1	5280.93	0.66
820	45000	2742	2753.27	2754.15	0.005771	8.98	14272.1	5280.93	0.66
821	45000	2748	2758.12	2758.51	0.002249	6.42	22960.56	4822.26	0.43
821	45000	2748	2758.12	2758.51	0.002249	6.42	22960.56	4822.26	0.43
822	45000	2752	2759.87	2760.26	0.00284	6.22	18546.95	4845.26	0.46
822	45000	2752	2759.87	2760.26	0.00284	6.22	18546.95	4845.26	0.46
823	45000	2754.1	2763.5	2764	0.003771	8.21	11286.4	3978.01	0.55
823	45000	2754.1	2763.5	2764	0.003771	8.21	11286.4	3978.01	0.55
824	45000	2757.3	2766.97	2767.34	0.002867	7.15	12763.64	4028.8	0.48
824	45000	2757.3	2766.97	2767.34	0.002867	7.15	12763.64	4028.8	0.48
825	45000	2764	2773.8	2774.4	0.004228	10.11	12357.19	3753.21	0.6
825	45000	2764	2773.8	2774.4	0.004228	10.11	12357.19	3753.21	0.6
827	45000	2766	2780.2	2781.21	0.00378	10.8	12029.93	4170.11	0.58
827	45000	2766	2780.2	2781.21	0.00378	10.8	12029.93	4170.11	0.58
829	45000	2770.1	2784.42	2786.13	0.003898	12.06	8986.29	3971.89	0.61
829	45000	2770.1	2784.42	2786.13	0.003898	12.06	8986.29	3971.89	0.61
831	45000	2774	2788.4	2788.67	0.001549	6.94	19603.97	5428.47	0.38

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
831	45000	2774	2788.4	2788.67	0.001549	6.94	19603.97	5428.47	0.38
832	45000	2776	2790.44	2791.81	0.007226	14.09	14184.83	5228.25	0.8
832	45000	2776	2790.44	2791.81	0.007226	14.09	14184.83	5228.25	0.8
833	45000	2780	2795.43	2795.87	0.002399	8.43	17032.29	5257.87	0.47
833	45000	2780	2795.43	2795.87	0.002399	8.43	17032.29	5257.87	0.47
835	45000	2786	2803.4	2804.69	0.004144	11.56	10923.57	4272.48	0.62
835	45000	2786	2803.4	2804.69	0.004144	11.56	10923.57	4272.48	0.62
836	45000	2790	2806.06	2808.11	0.006979	14.68	10677.93	4208.55	0.79
836	45000	2790	2806.06	2808.11	0.006979	14.68	10677.93	4208.55	0.79
837	45000	2794	2811.46	2811.73	0.001683	7.15	23235.26	5930.85	0.39
837	45000	2794	2811.46	2811.73	0.001683	7.15	23235.26	5930.85	0.39
838	45000	2798	2813.9	2815.39	0.006285	14.2	10343.42	4540.87	0.75
838	45000	2798	2813.9	2815.39	0.006285	14.2	10343.42	4540.87	0.75
840	45000	2802	2817.49	2817.97	0.002382	8.87	13801.95	4331.3	0.47
840	45000	2802	2817.49	2817.97	0.002382	8.87	13801.95	4331.3	0.47
841	45000	2810	2825.07	2825.97	0.004114	11.58	16328.38	5189.98	0.61
841	45000	2810	2825.07	2825.97	0.004114	11.58	16328.38	5189.98	0.61
842	45000	2809.3	2826.84	2827.14	0.00066	5	19903.02	5916.89	0.25
842	45000	2809.3	2826.84	2827.14	0.00066	5	19903.02	5916.89	0.25
843	45000	2815.1	2827.52	2829.06	0.004208	10.19	5307.15	1566.95	0.61
843	45000	2815.1	2827.52	2829.06	0.004208	10.19	5307.15	1566.95	0.61
844	45000	2820	2832.63	2834.31	0.004461	10.42	4418.26	669.88	0.62
844	45000	2820	2832.63	2834.31	0.004461	10.42	4418.26	669.88	0.62
846	45000	2826	2838.24	2839.13	0.002468	7.55	5962.62	1670.75	0.46
846	45000	2826	2838.24	2839.13	0.002468	7.55	5962.62	1670.75	0.46
847	45000	2830	2840.88	2841.98	0.006014	8.43	5341.22	1778.98	0.66
847	45000	2830	2840.88	2841.98	0.006014	8.43	5341.22	1778.98	0.66
850	45000	2836	2847.2	2848.65	0.004304	10.12	5911.23	2774.18	0.61
850	45000	2836	2847.2	2848.65	0.004304	10.12	5911.23	2774.18	0.61
855	45000	2838	2848.27	2849.36	0.002491	8.37	5374.42	1311.9	0.47
855	45000	2838	2848.27	2849.36	0.002491	8.37	5374.42	1311.9	0.47
855.05	Bridge								
855.1	45000	2838	2849.85	2850.65	0.001543	7.19	6261.94	1697.91	0.38

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
855.1	45000	2838	2849.85	2850.65	0.001543	7.19	6261.94	1697.91	0.38
855.2	45000	2839.3	2850.66	2851.06	0.00098	5.53	10733.05	2194.86	0.3
855.2	45000	2839.3	2850.66	2851.06	0.00098	5.53	10733.05	2194.86	0.3
856	45000	2836.6	2851.11	2851.59	0.001166	5.76	9882.86	2746.7	0.33
856	45000	2836.6	2851.11	2851.59	0.001166	5.76	9882.86	2746.7	0.33
857	45000	2844	2854.73	2855.9	0.006254	11.61	7401.31	2690.84	0.73
857	45000	2844	2854.73	2855.9	0.006254	11.61	7401.31	2690.84	0.73
858	45000	2846	2857.7	2857.88	0.000805	4.1	14566.5	2895.54	0.26
858	45000	2846	2857.7	2857.88	0.000805	4.1	14566.5	2895.54	0.26
861	45000	2852	2860.05	2861.27	0.013228	10.47	5756.88	2464.73	0.94
861	45000	2852	2860.05	2861.27	0.013228	10.47	5756.88	2464.73	0.94
862	45000	2856	2864.66	2864.86	0.001545	4.56	14182.38	4113.62	0.34
862	45000	2856	2864.66	2864.86	0.001545	4.56	14182.38	4113.62	0.34
865	45000	2859.2	2869.03	2869.99	0.00591	10.81	8047.8	3663.6	0.7
865	45000	2859.2	2869.03	2869.99	0.00591	10.81	8047.8	3663.6	0.7
866	45000	2864	2873.04	2873.58	0.003005	7.74	9924.6	3045.08	0.5
866	45000	2864	2873.04	2873.58	0.003005	7.74	9924.6	3045.08	0.5
867	45000	2866	2875.69	2876.54	0.00286	8.11	8221.51	2540.03	0.5
867	45000	2866	2875.69	2876.54	0.00286	8.11	8221.51	2540.03	0.5
868	45000	2870	2878.15	2878.92	0.002585	7.5	8069.14	2491.16	0.47
868	45000	2870	2878.15	2878.92	0.002585	7.5	8069.14	2491.16	0.47
870	45000	2872	2883.29	2884.71	0.005704	10.83	6432.43	2242.09	0.69
870	45000	2872	2883.29	2884.71	0.005704	10.83	6432.43	2242.09	0.69
871	45000	2877.4	2888.08	2889.06	0.003202	9.08	8010.27	2589.63	0.53
871	45000	2877.4	2888.08	2889.06	0.003202	9.08	8010.27	2589.63	0.53
872	45000	2881.1	2890.3	2891.12	0.002549	7.41	6961.51	2420.45	0.46
872	45000	2881.1	2890.3	2891.12	0.002549	7.41	6961.51	2420.45	0.46
873	45000	2882.4	2893.39	2894.04	0.002454	6.89	8331.35	2156.35	0.45
873	45000	2882.4	2893.39	2894.04	0.002454	6.89	8331.35	2156.35	0.45
874	45000	2886	2895.62	2896.63	0.003777	8.15	5911.56	1459.08	0.55
874	45000	2886	2895.62	2896.63	0.003777	8.15	5911.56	1459.08	0.55
875	45000	2890.8	2899.89	2901.29	0.006697	10.24	5520.28	1480.52	0.73
875	45000	2890.8	2899.89	2901.29	0.006697	10.24	5520.28	1480.52	0.73

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
876	45000	2895.8	2905.51	2906.21	0.002241	7.56	8037.32	1621.34	0.45
876	45000	2895.8	2905.51	2906.21	0.002241	7.56	8037.32	1621.34	0.45
878	45000	2902	2912.29	2913.86	0.005645	12.02	6520.27	2217.31	0.71
878	45000	2902	2912.29	2913.86	0.005645	12.02	6520.27	2217.31	0.71
880	45000	2906	2916.57	2917	0.001797	6.35	10605.44	2578.24	0.39
880	45000	2906	2916.57	2917	0.001797	6.35	10605.44	2578.24	0.39
881	45000	2908	2917.68	2919.87	0.007468	14.02	5314.34	1556.06	0.82
881	45000	2908	2917.68	2919.87	0.007468	14.02	5314.34	1556.06	0.82
882	45000	2912	2923.93	2924.32	0.00213	5.31	9305.35	1812.53	0.4
882	45000	2912	2923.93	2924.32	0.00213	5.31	9305.35	1812.53	0.4
883	45000	2918	2926.96	2927.33	0.002455	5.1	9457.56	2232.69	0.42
883	45000	2918	2926.96	2927.33	0.002455	5.1	9457.56	2232.69	0.42
884	45000	2924	2932.22	2932.56	0.004084	4.74	10006.96	4055.93	0.5
884	45000	2924	2932.22	2932.56	0.004084	4.74	10006.96	4055.93	0.5
885	45000	2925.8	2935.37	2935.6	0.001603	3.99	12077.27	3085.81	0.34
885	45000	2925.8	2935.37	2935.6	0.001603	3.99	12077.27	3085.81	0.34
886	45000	2930.2	2937.61	2938.03	0.004225	5.32	8798.17	2798.38	0.52
886	45000	2930.2	2937.61	2938.03	0.004225	5.32	8798.17	2798.38	0.52
887	45000	2932.2	2940.76	2941.23	0.004843	5.7	8297.1	2559.26	0.55
887	45000	2932.2	2940.76	2941.23	0.004843	5.7	8297.1	2559.26	0.55
888	45000	2936	2946.39	2946.65	0.002296	4.37	11299.84	3170.82	0.39
888	45000	2936	2946.39	2946.65	0.002296	4.37	11299.84	3170.82	0.39
890	45000	2938.8	2948.17	2948.72	0.003986	6.39	8036.81	2134.49	0.53
890	45000	2938.8	2948.17	2948.72	0.003986	6.39	8036.81	2134.49	0.53
891	45000	2940	2952.46	2953.2	0.005417	7.16	6671.94	1654.96	0.61
891	45000	2940	2952.46	2953.2	0.005417	7.16	6671.94	1654.96	0.61
892	45000	2940	2955	2955.57	0.002958	6.15	7725.38	1748.26	0.47
892	45000	2940	2955	2955.57	0.002958	6.15	7725.38	1748.26	0.47
893	45000	2950	2958.16	2959.08	0.006258	7.68	5857.96	1399.97	0.66
893	45000	2950	2958.16	2959.08	0.006258	7.68	5857.96	1399.97	0.66
895	45000	2956	2964.66	2965.01	0.002271	4.91	9852.37	2329.97	0.4
895	45000	2956	2964.66	2965.01	0.002271	4.91	9852.37	2329.97	0.4
896	45000	2960	2968.05	2968.48	0.002866	5.49	9294.5	2769.37	0.45
896	45000	2960	2968.05	2968.48	0.002866	5.49	9294.5	2769.37	0.45

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
898	45000	2968	2974.04	2974.48	0.003945	5.39	8649.22	3027.29	0.51
898	45000	2968	2974.04	2974.48	0.003945	5.39	8649.22	3027.29	0.51
900	45000	2971.6	2978.66	2978.96	0.002274	4.41	10201.78	2586.3	0.39
900	45000	2971.6	2978.66	2978.96	0.002274	4.41	10201.78	2586.3	0.39
901	45000	2975.8	2982.32	2982.98	0.006632	6.48	6949.63	2213.26	0.64
901	45000	2975.8	2982.32	2982.98	0.006632	6.48	6949.63	2213.26	0.64
902	45000	2979.7	2988.03	2988.34	0.00206	4.53	9943.62	2256.59	0.38
902	45000	2979.7	2988.03	2988.34	0.00206	4.53	9943.62	2256.59	0.38
903	45000	2982.2	2990.14	2990.69	0.003427	5.9	7624.95	1698.04	0.49
903	45000	2982.2	2990.14	2990.69	0.003427	5.9	7624.95	1698.04	0.49
904	45000	2984.9	2993.02	2993.48	0.003452	5.46	8260.12	2120.47	0.48
904	45000	2984.9	2993.02	2993.48	0.003452	5.46	8260.12	2120.47	0.48
905	45000	2992	2998.53	2999.09	0.004582	6.38	8066.83	2471.44	0.56
905	45000	2992	2998.53	2999.09	0.004582	6.38	8066.83	2471.44	0.56
906	45000	2994	3001.55	3002.21	0.003944	7.1	7590.96	1928.21	0.54
906	45000	2994	3001.55	3002.21	0.003944	7.1	7590.96	1928.21	0.54
907	45000	2998	3005.14	3006.55	0.007668	10.79	5565.53	1484.04	0.77
907	45000	2998	3005.14	3006.55	0.007668	10.79	5565.53	1484.04	0.77
907.05	Bridge								
907.1	45000	2998	3006.53	3007.26	0.003391	8.01	7923.88	1911.36	0.53
907.1	45000	2998	3006.53	3007.26	0.003391	8.01	7923.88	1911.36	0.53
907.2	45000	2998.4	3007.56	3007.74	0.000761	4.09	13869.78	2631.53	0.25
907.2	45000	2998.4	3007.56	3007.74	0.000761	4.09	13869.78	2631.53	0.25
908	45000	3000.8	3008.71	3009.19	0.002373	5.83	8533.66	2193.34	0.43
908	45000	3000.8	3008.71	3009.19	0.002373	5.83	8533.66	2193.34	0.43
909	45000	3006	3011.64	3012.56	0.005251	7.83	6249.74	1765.51	0.62
909	45000	3006	3011.64	3012.56	0.005251	7.83	6249.74	1765.51	0.62
910	45000	3010	3017.16	3017.57	0.00225	5.3	9063.93	1948.03	0.41
910	45000	3010	3017.16	3017.57	0.00225	5.3	9063.93	1948.03	0.41
911	45000	3014	3020.44	3020.96	0.004243	5.81	7748.73	2083.06	0.53
911	45000	3014	3020.44	3020.96	0.004243	5.81	7748.73	2083.06	0.53
912	45000	3020	3027.22	3027.83	0.004999	6.3	7334.3	2054.24	0.58
912	45000	3020	3027.22	3027.83	0.004999	6.3	7334.3	2054.24	0.58

HEC-RAS Profiles

Profile #1 – Discharges from Modified Discharge Frequency Relation (Appendix E1)
Profile #2 – Pima County DOT&FCD Regulatory Discharges

River Sta	Q Total	Min Ch El	W.S. Elev	E.G. Elev	E.G.Slope	Vel Chnl	Flow Area	Top Width	Fr # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
913	45000	3028	3034.41	3035	0.004892	6.2	7478.01	2154.65	0.57
913	45000	3028	3034.41	3035	0.004892	6.2	7478.01	2154.65	0.57
914	45000	3027.5	3038.67	3039.01	0.00209	4.67	9772.9	2180.69	0.38
914	45000	3027.5	3038.67	3039.01	0.00209	4.67	9772.9	2180.69	0.38