FINAL REPORT TO THE HYDROLOGIC TASK FORCE:

SANTA CRUZ RIVER

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MIXED POPULATION DISCHARGE-FREQUENCY ANALYSIS

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

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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 (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) currently being conducted by the COE in conjunction with local sponsors. A more complete hydrology report addressing the **mixed population** analysis will be included in the Feasibility Report. The purpose of this technical summary is to present some of the background, as well as a brief 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.

1.1 Phase 1: Reconnaissance Study - Plan Development.

1.1.1 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 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.

1.1.2 The PLAN, as proposed 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"[1] 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 Exhibit 14) was not revised to reflect this change.)
- 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).

1.2 Phase 2: Feasibility Study - Plan Implementation.

1.2.1 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[2]. Due to conflicting priorities, the COE was unable 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.

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[1] 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 completely 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).

[2] 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.

1.2.2 A follow-up meeting was held on 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 peak discharges) of peak discharges within Pima County. (Please refer to Exhibit 15 for summary tables comparing the results of the *Index Flood* routing.) 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 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[3], 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.

1.2.3 The results (Exhibit 15) showed[4]

"...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[5] 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."

1.2.4 In addition, the COE informed the participants that time/funding to develop a parallel **mixed**

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[3] 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*)

[4] Conclusion/quote excerpted from the memorandum entitled SANTA CRUZ RIVER-WATERSHED STUDY - EVALUATION OF IMPACTS OF CHANNEL CHANGES ON PEAK DISCHARGE, prepared for the Hydrologic Task Force, and provided at the July 27, 1999 meeting to participants.

[5] 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 applying the existing channel geometry, to alter the final **mixed population** results.

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.

1.2.5 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.

1.2.6 The final meeting of the Task Force was held in December, 1999. (A set of notes from that meeting, prepared by Doug Lantz, TTISG, are included in Exhibit 17.) 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 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.

2 MIXED POPULATION ANALYSIS

2.1 **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 16). The Tucson office of SLA/TTISG was contracted to develop subsets of "annual maxima" for each of the 3 seasons identified in the PLAN.

2.1.1 Flood Separation by Storm Type. The flood "seasons" were categorized according to the following storm "types" described in the USGS WSP 2379 (see references) 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[6]. As discussed in the SLA report;

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[6] *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).

"...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 been made in the references. 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[7], the collected data was thus "censored".

2.2 Estimated Data.

2.2.1 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 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

[7] 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.*

Cruz River at Tucson, Rillito Creek at La Cholla Boulevard[8], 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.

2.2.2 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[9]. 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.

2.2.2.1 *Steps*. Estimates of peak discharges below the base were made in the following sequence of steps[10]:

- Collect annual daily flow data for all stations (Hydrosphere CDROM, © 1999: see References).
- 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.
- Segregate any events characterized by daily flow results into appropriate seasons.

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[8] 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.

[9] 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.

[10] 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.

- 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 with input = "Raw Data" (Results are provided in Exhibit 1, attached tables).
- 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"[11] 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 Exhibit 2, attached tables, 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 (Flow records and estimates for each season and location are included in Exhibit 5 to Exhibit 7, attached HEC-FFA input data files. These records are included in the HEC-FFA input files. Exhibit 5 contains the *cyclonic* season data, Exhibit 6 contains the *monsoonal* season data, and Exhibit 7 contains the *frontal* season data.)

2.2.3 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. (Estimates of missing record are included in Exhibit 5 to Exhibit 7, attached HEC-FFA input data files).

2.3 Mixed population Discharge-Frequency Analysis.

2.3.1 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

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[11] 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.

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"[12]. 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 Exhibit 3, which contains the annual[13] as well as the seasonal/**mixed population** computed and adopted statistics.) No single distribution is correct for seasonal annual peaks. Observation of the data, however, convinced the investigator that an interpretation based upon log-normal (in this case log-Pearson Type III) distributions 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. 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. 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. It should be noted that 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.

2.3.2 Plotting Positions. Median plotting positions were used to graph 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:

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[12] 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.

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

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

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

2.3.3 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[14]. 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.

2.3.4 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[15] (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 provided a much better fit to the observed data (refer to Exhibit 3, MSE).

2.3.5 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 Exhibit 3, computed vs adopted skew).

2.4 **Annual Combined Curves**. The final *seasonal* discharge-frequency curves are included in this package (please refer to Exhibit 8 to Exhibit 10, 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 spreadsheets are provided in Exhibit 11). The input to the spreadsheet was a series of discharges to cover a wide range of likely frequencies for each seasonal sample/population,

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[14] 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. The difference between an 86- and 106-year historic period is not too significant for this location/season - refer to Exhibit 3 for a comparison of *winter* statistics.

[15] 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.

paired with the accompanying probability of exceedance for each station and season[16]. These calculations are also included. The general equation for combining multiple frequency curves from *independent series* is:

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

P_c is the exceedance probability of the combined annual frequency curve for a selected discharge;
$P_1, P_2, \ldots, P_n$ are the exceedance probabilities associated with the selected discharge from each of the separate sample 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:

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

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

where the 3 "seasons" are represented as
C = *cyclonic*, M = *monsoon*, and F = *frontal*. Refer to spreadsheet (Exhibit11 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[17] 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 *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 accompanying figures provided in Exhibit12. In addition, the combined annual discharge-frequency curves for each station (Nogales through Cortaro) are compared in Exhibit 13. Finally, a complete table of discharge-frequency values for each station is included in Exhibit 4.

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[16] The probability of exceedance was determined from the seasonal sample discharge-frequency curves shown in Exhibit 11.

[17] A list of references is included in Section 5 of this report.

2.5 **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 climate 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.

3 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.

LOCATION	D.A. (MI^2)	WATER YR, POR PEAK[a]	DISCHARGE (Ft^3/s) POR PEAK[a]	OCT 83 PEAK[b]	COE 100-YR[c]	PIMA 100-YR
Santa Cruz River nr. Nogales	533	1974	31,000	17,100	33,000	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 at Santa Cruz River.
[c] Mixed population analysis - 1999.
[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 results, in agreement with observation 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 in attachments as referenced within this report.

4. 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, Exhibit 4 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; the "expected" probability for this event 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 during the period 1977-1978. This synthetic, design-flood event was based 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 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 slightly greater. It is "typical" in Arizona, especially for large drainage basins, that the SPF have an approximate return interval between 200- and 500-years; i.e. $0.5 \leq Pr(Q \geq SPF) \leq 0.2$. Hence, the discharges associated with the more rare events, such as the 200-year are not obviously out-of-line.

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 (decreasing with 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 estimates 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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EXHIBIT 1

CORRELATION COEFFICIENTS

PEAK AND DAILY FLOWS

RAW DATA , 1940 - 1997

Prepared by Nick N. Adelmeyer, 26 January 2000
"C:\Projects\SANTCRUZ\1998I&II\TaskForce\TSK_FORCE_REPORT\FinalTechnical SummaryText_merge_HTF2.wpd"

CYCLONIC SEASON

1. 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

2. 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

3. 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

MONSOON SEASON

1. 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

2. 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

3. 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

WINTER SEASON

1. 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

2. 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

3. 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

EXHIBIT 2

CORRELATION COEFFICIENTS

PEAK AND DAILY FLOWS

MODIFIED DATA, 1940 - 1997

Prepared by Nick N. Adelmeyer, 26 January 2000
"C:\Projects\SANTCRUZ\1998I&II\TaskForce\TSK_FORCE_REPORT\FinalTechnical SummaryText_merge_IITF2.wpd"

CYCLONIC SEASON

1. 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

2. 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

3. 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

MONSOON SEASON

1. 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

2. 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

3. 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

WINTER SEASON

1. 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

2. 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

3. 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

EXHIBIT 3

STATISTICS

ANNUAL/SEASONAL

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.

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**)	2.6448	0.8513	-0.1606	-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

EXHIBIT 4

DISCHARGE-FREQUENCY RESULTS

COMBINED POPULATIONS
vs
ANNUAL MAXIMUM SERIES

RECOMMENDED RESULTS

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

EXHIBIT 5

HEC-FFA INPUT FILES

CYCLONIC SEASON

```
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          31000
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)
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       1e    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
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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
```

```
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
QR      09131975    2120     432
QR      09251976    7100    1140
QR      08151977    2660     354
```

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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
```

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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
QR      10101977   23000   12600
QR      10211978    2500e    419
QR      09061980    2000e    294
QR      09221981    4310     622
```

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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 6

HEC-FFA INPUT FILES

MONSOONAL SEASON

Prepared by Nick N. Adelmeyer, 26 January 2000
"C:\Projects\SANTCRUZ\1998H&H\TaskForce\TSK_FORCE_REPORT\FinalTechnical SummaryText_merge_HTF2.wpd

```
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 7

HEC-FFA INPUT FILES

FRONTAL SEASON

```
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	3.0	Fd-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
```

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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 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
```

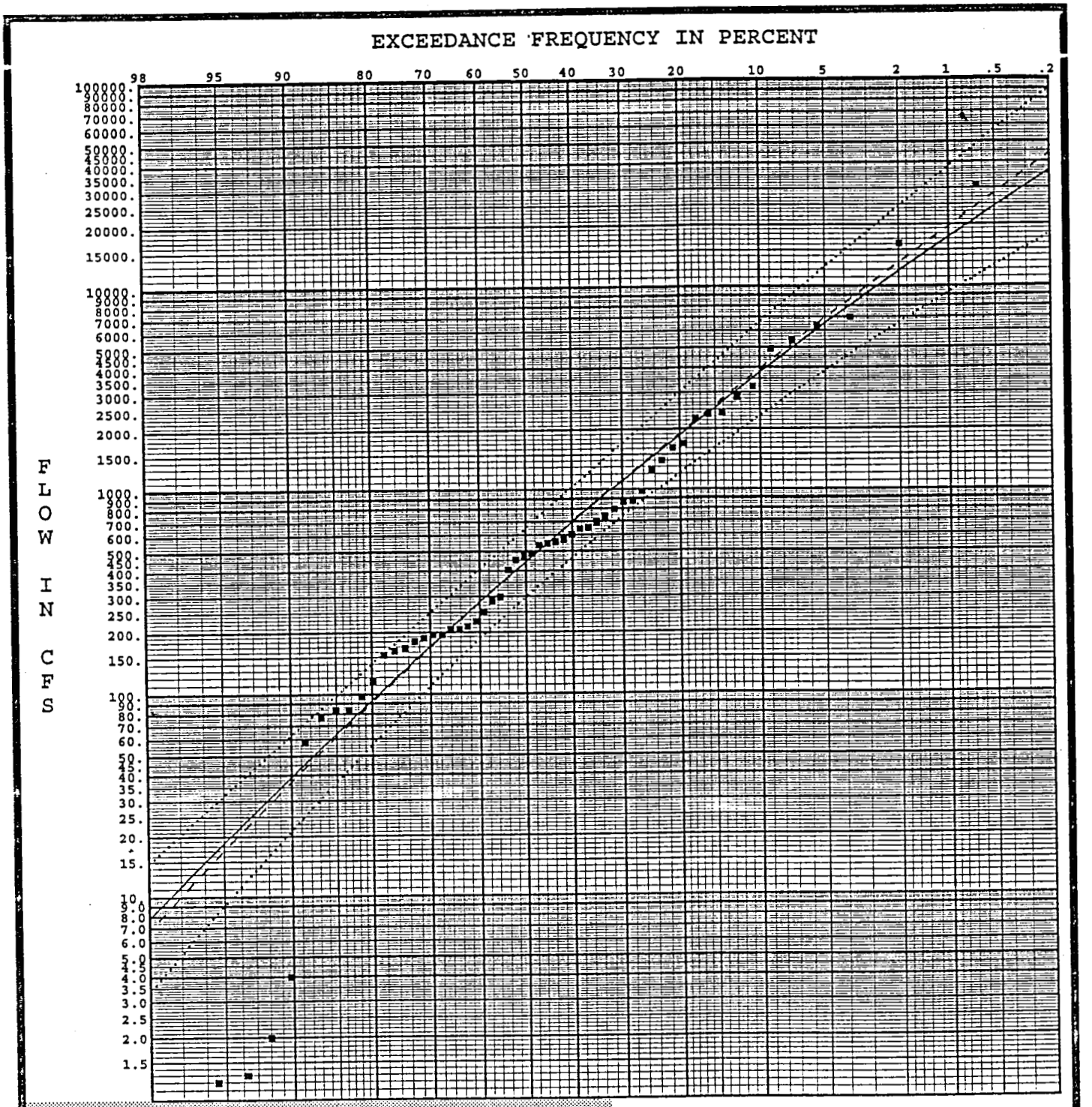
```
QR      03031981     603e    279
QR      03131982     149e    149
QR      02041983    7620    4020
QR      01101984     933e    244
QR      12281984   13000    7280
QR          1986    1068e    414e-Missing Year
QR          1987     308e    137e-Missing Year
QR          1988    1377e    529e-Missing 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
```

EXHIBIT 8

HEC-FFA OUTPUT GRAPHICS:

(HP- Plots, Discharge-frequency curves)

CYCLONIC SEASON



—— FLOW Frequency (without Exp. Prob.)

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

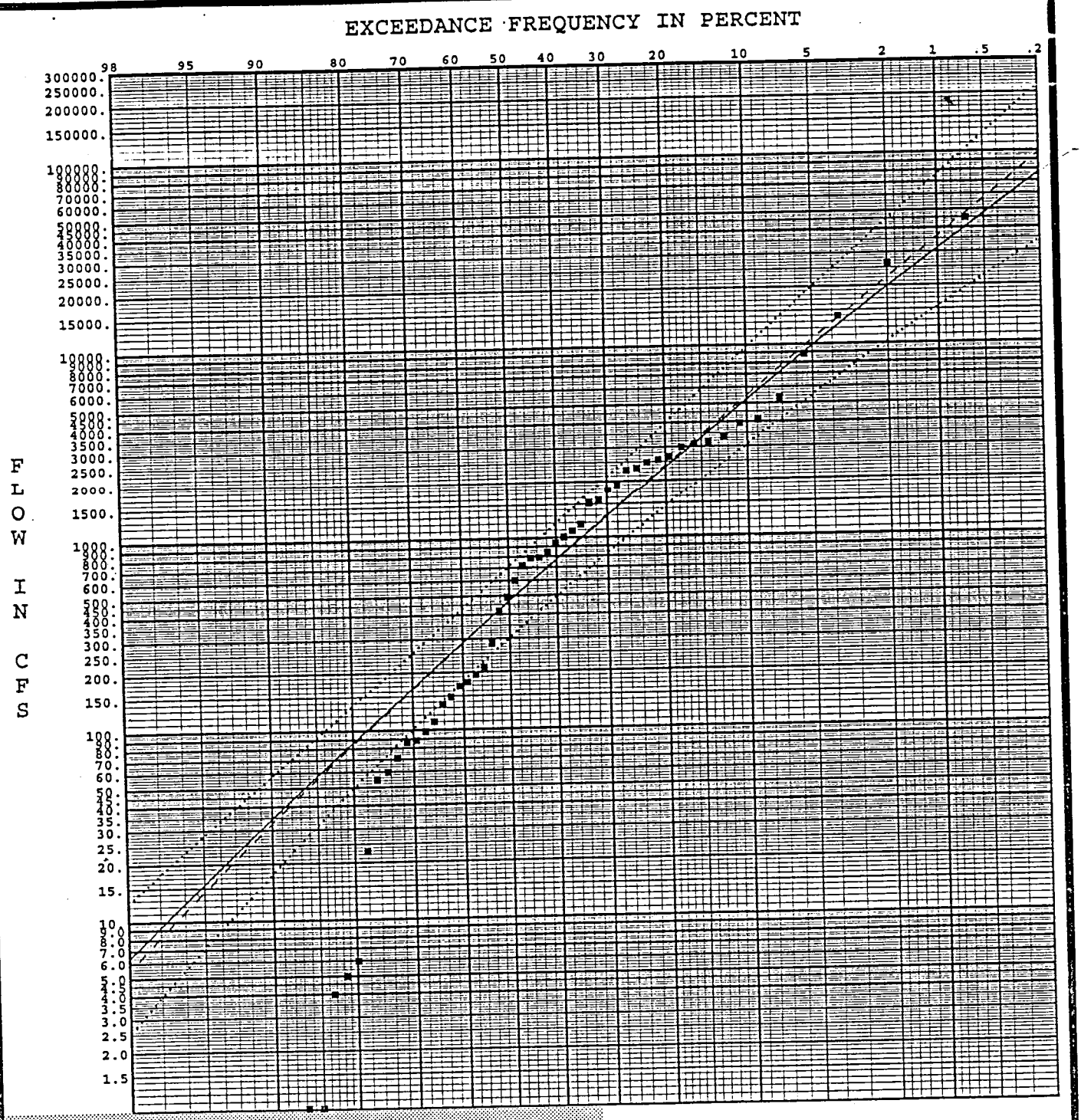
▪ Median Plotting Positions

..... 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



—— FLOW Frequency (without Exp. Prob.)

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

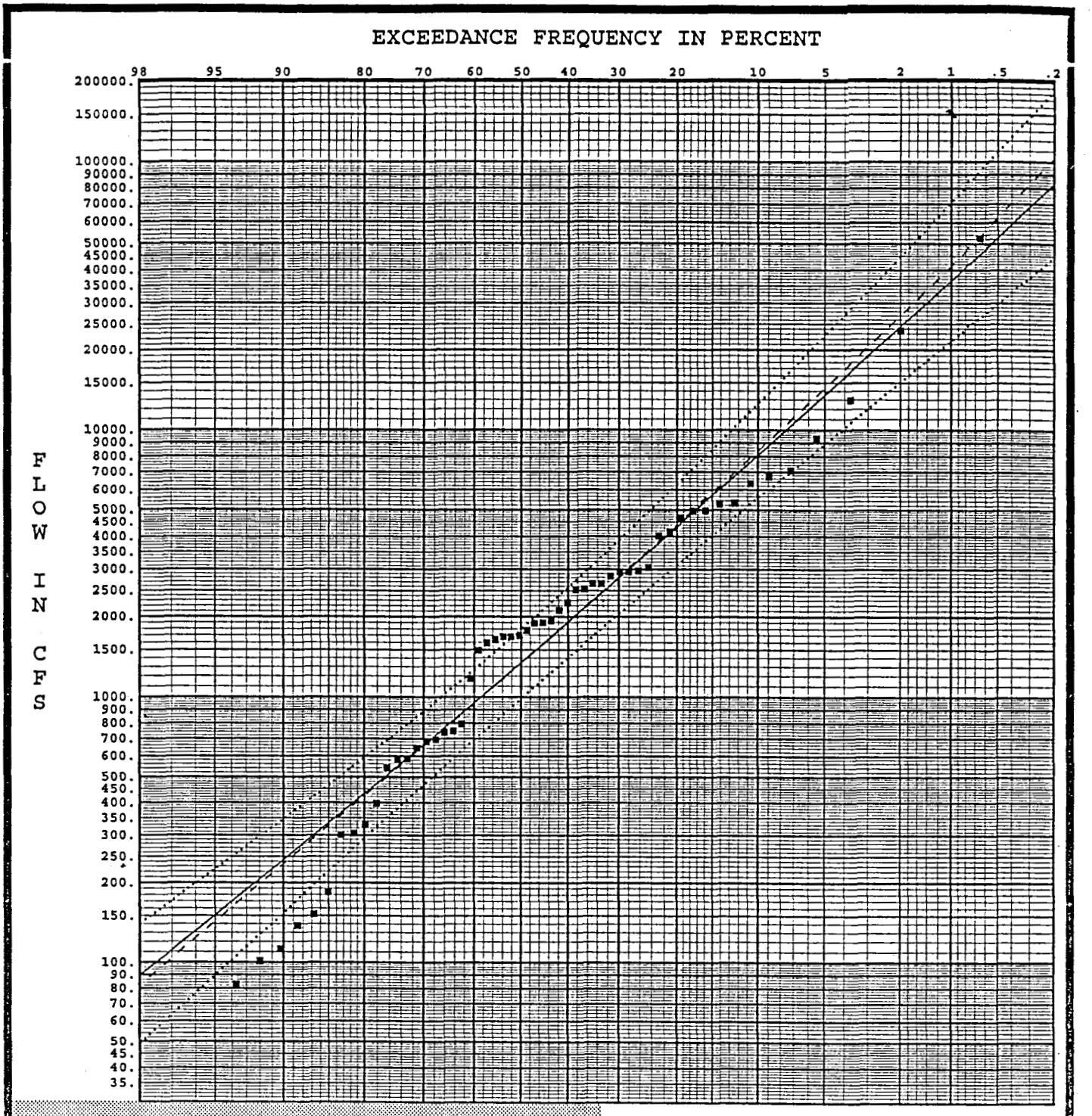
▪ Median Plotting Positions

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

FREQUENCY STATISTICS
LOG TRANSFORM OF FLOW, CFS

			NUMBER OF EVENTS
MEAN	2.6448	HISTORIC EVENTS	0
STANDARD DEV	.8513	HIGH OUTLIERS	1
SKEW	-.1606	LOW OUTLIERS	7
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



—— FLOW Frequency (without Exp. Prob.)

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

▪ Median Plotting Positions

····· 5% and 95% Confidence Limits

FREQUENCY STATISTICS

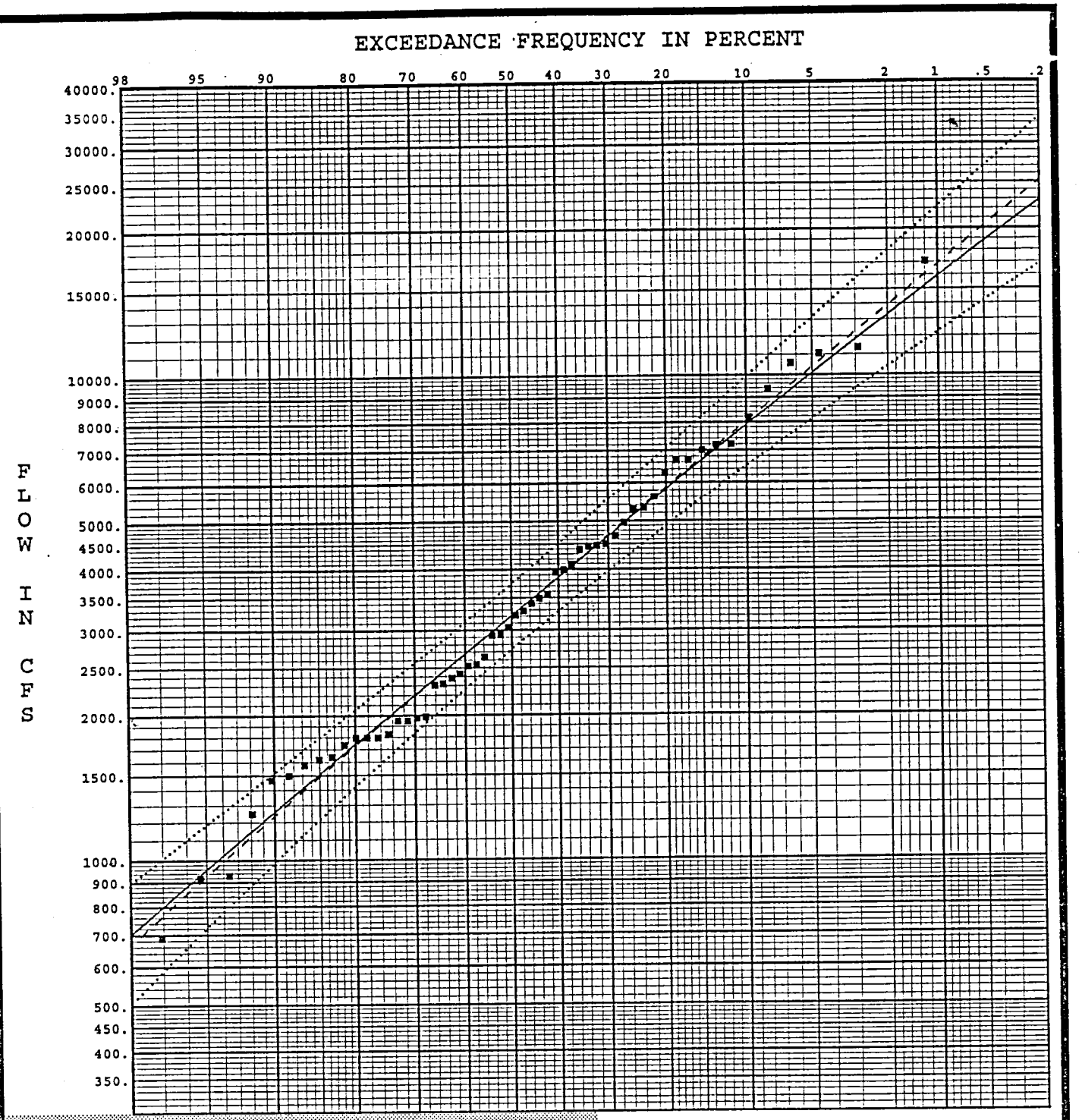
LOG TRANSFORM OF FLOW, CFS		NUMBER OF EVENTS	
MEAN	3.1393	HISTORIC EVENTS	0
STANDARD DEV	.5935	HIGH OUTLIERS	1
SKEW	-.2622	LOW OUTLIERS	0
REGIONAL SKEW	.1000	ZERO OR MISSING	3
ADOPTED SKEW	.1000	SYSTEMATIC EVENTS	58
		HISTORIC PERIOD(1892-1997)	106

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

EXHIBIT 9

HEC-FFA OUTPUT GRAPHICS:
(HP- Plots, Discharge-frequency curves)

MONSOONAL SEASON

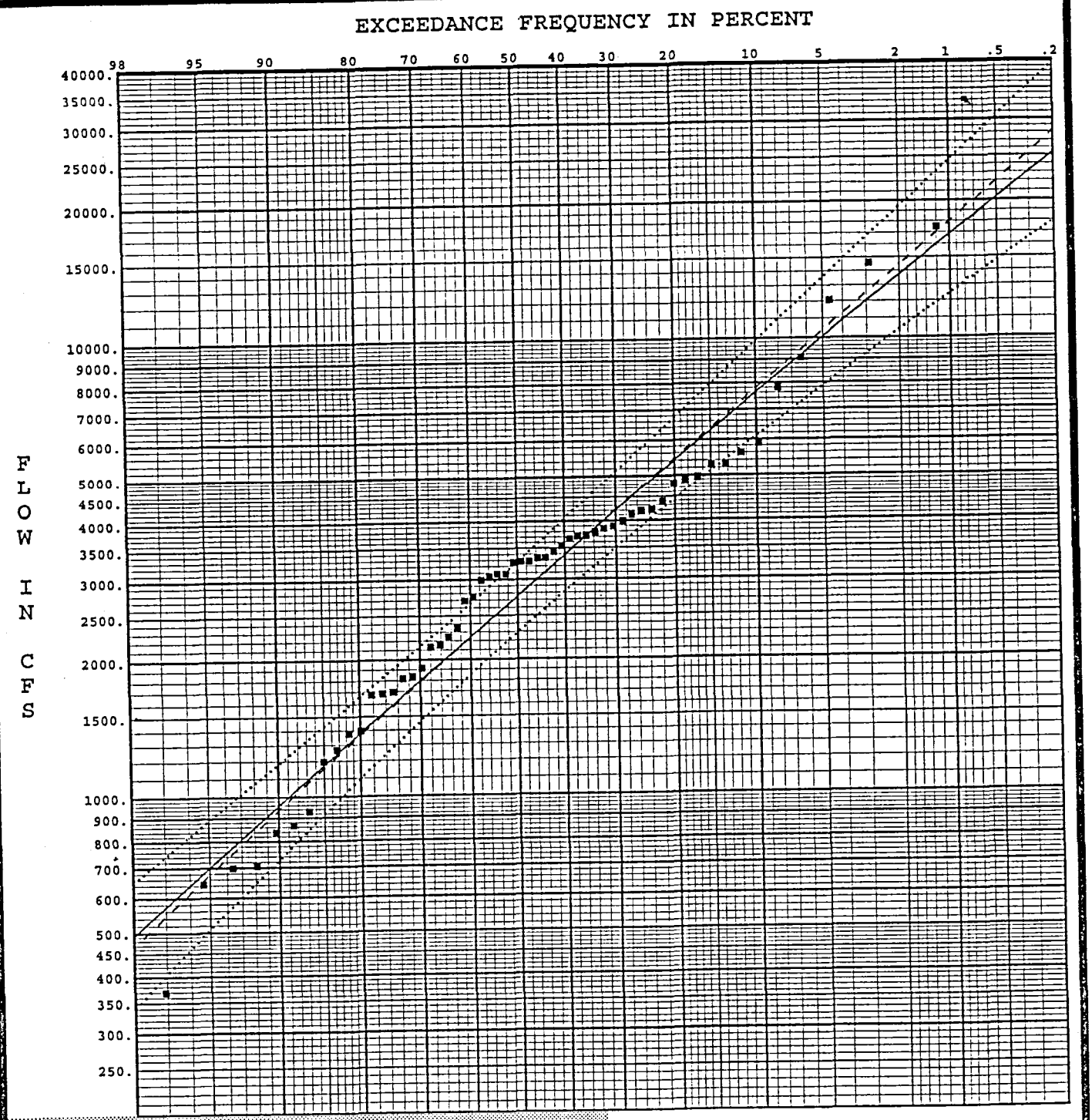


—— FLOW Frequency (without Exp. Prob.)
- - - FLOW Frequency (with Exp. Prob.)
▪ Median Plotting Positions
····· 5% and 95% Confidence Limits

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

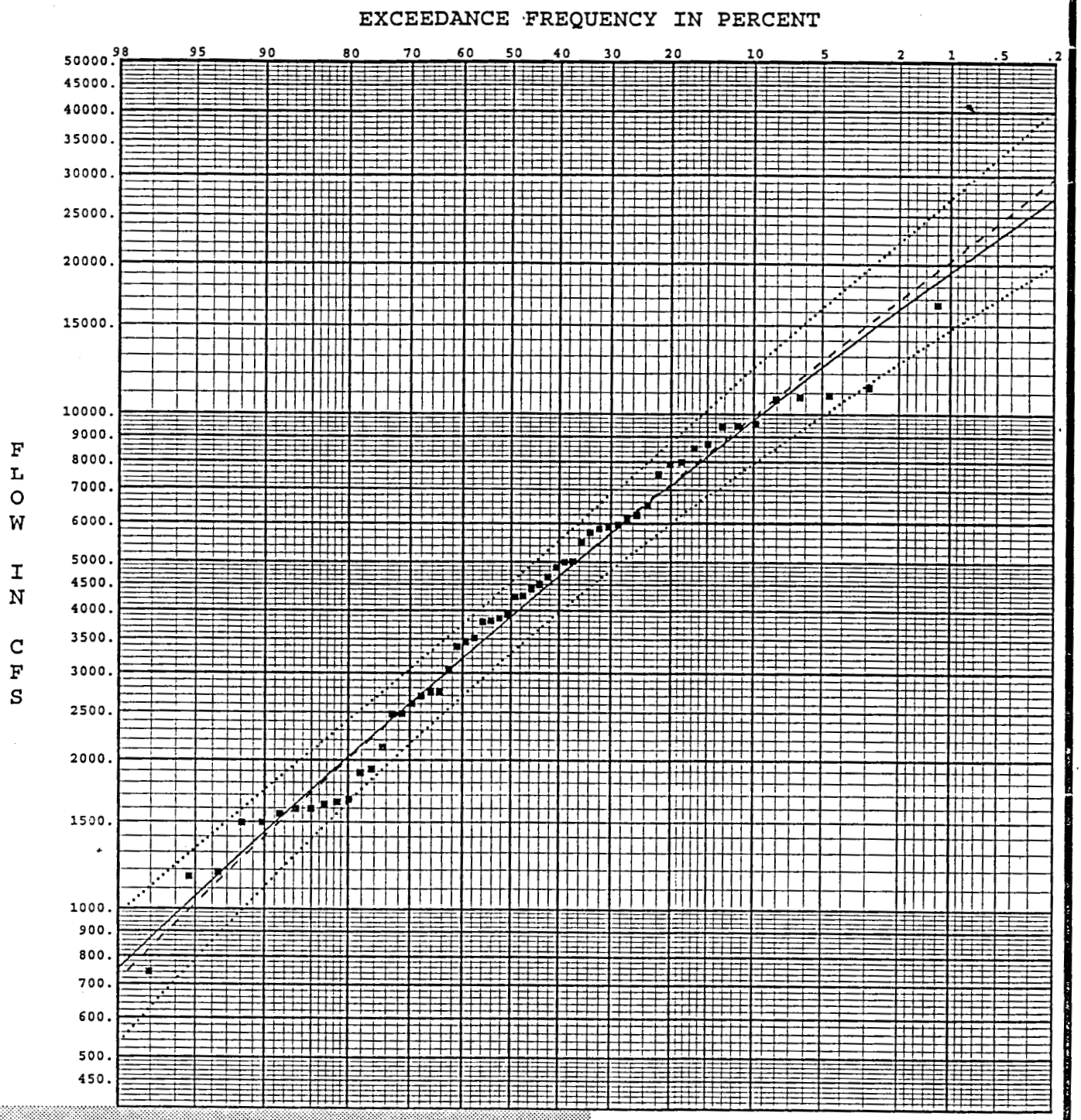


—— FLOW Frequency (without Exp. Prob.)
- - - FLOW Frequency (with Exp. Prob.)
■ Median Plotting Positions
..... 5% and 95% Confidence Limits

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

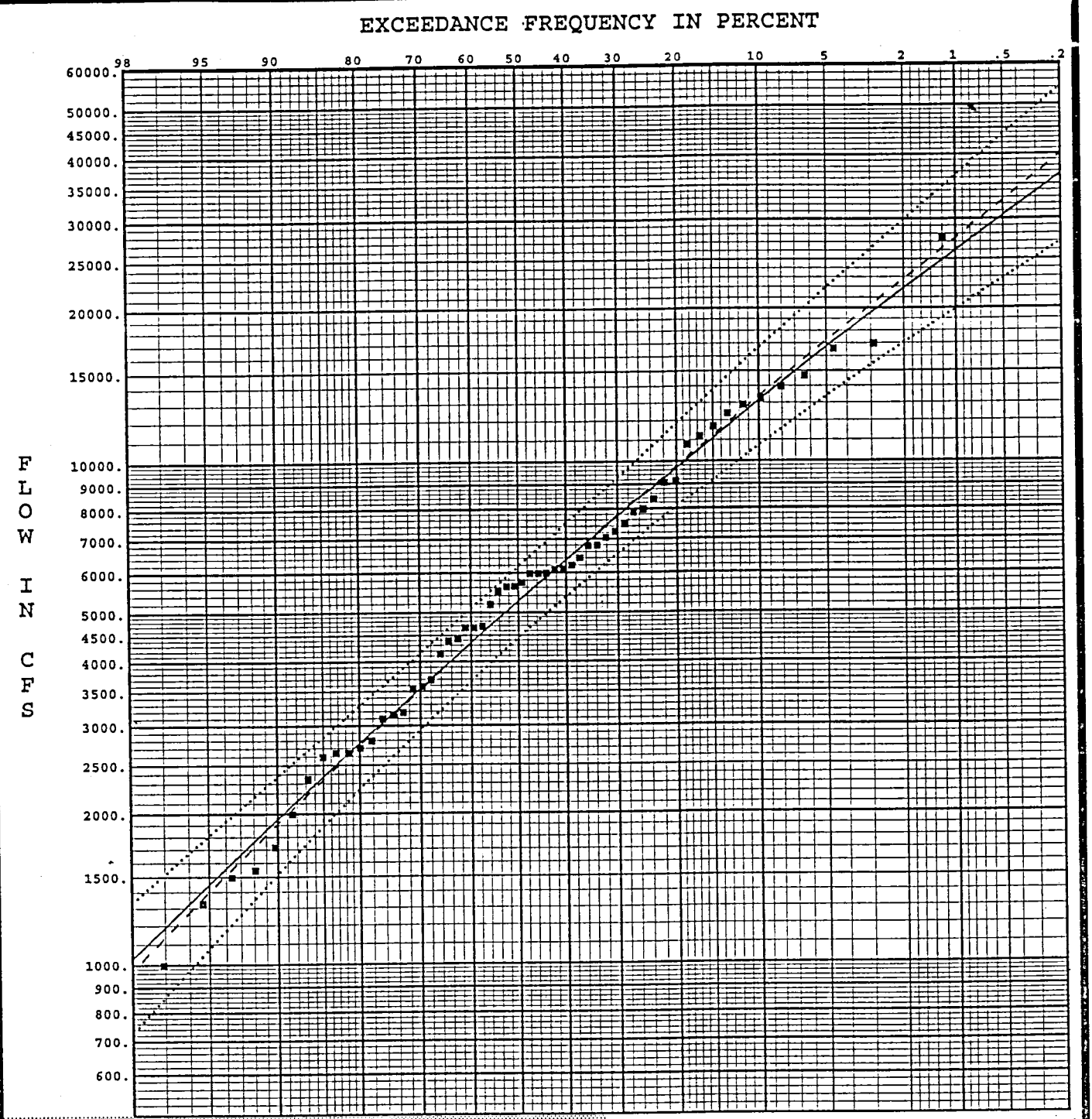


—— FLOW Frequency (without Exp. Prob.)
- - - FLOW Frequency (with Exp. Prob.)
▪ Median Plotting Positions
····· 5% and 95% Confidence Limits

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



—— 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

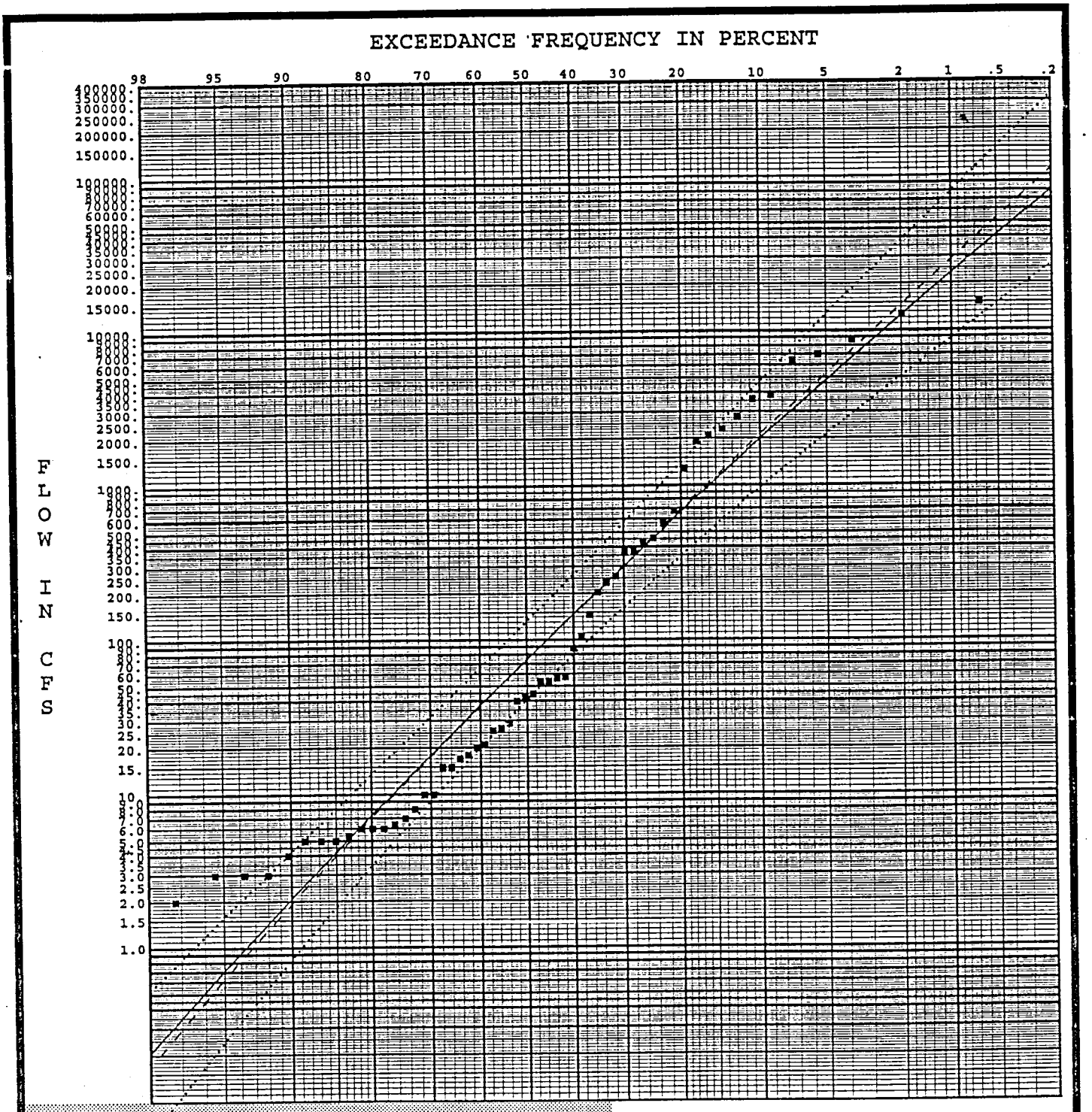
			NUMBER OF EVENTS
MEAN	3.7116	HISTORIC EVENTS	0
STANDARD DEV	.3234	HIGH OUTLIERS	0
SKEW	-.3604	LOW OUTLIERS	0
REGIONAL SKEW	.0000	ZERO OR MISSING	0
ADOPTED SKEW	-.2000	SYSTEMATIC EVENTS	58

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

EXHIBIT 10

HEC-FFA OUTPUT GRAPHICS:
(HP- Plots, Discharge-frequency curves)

FRONTAL SEASON



—— FLOW Frequency (without Exp. Prob.)

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

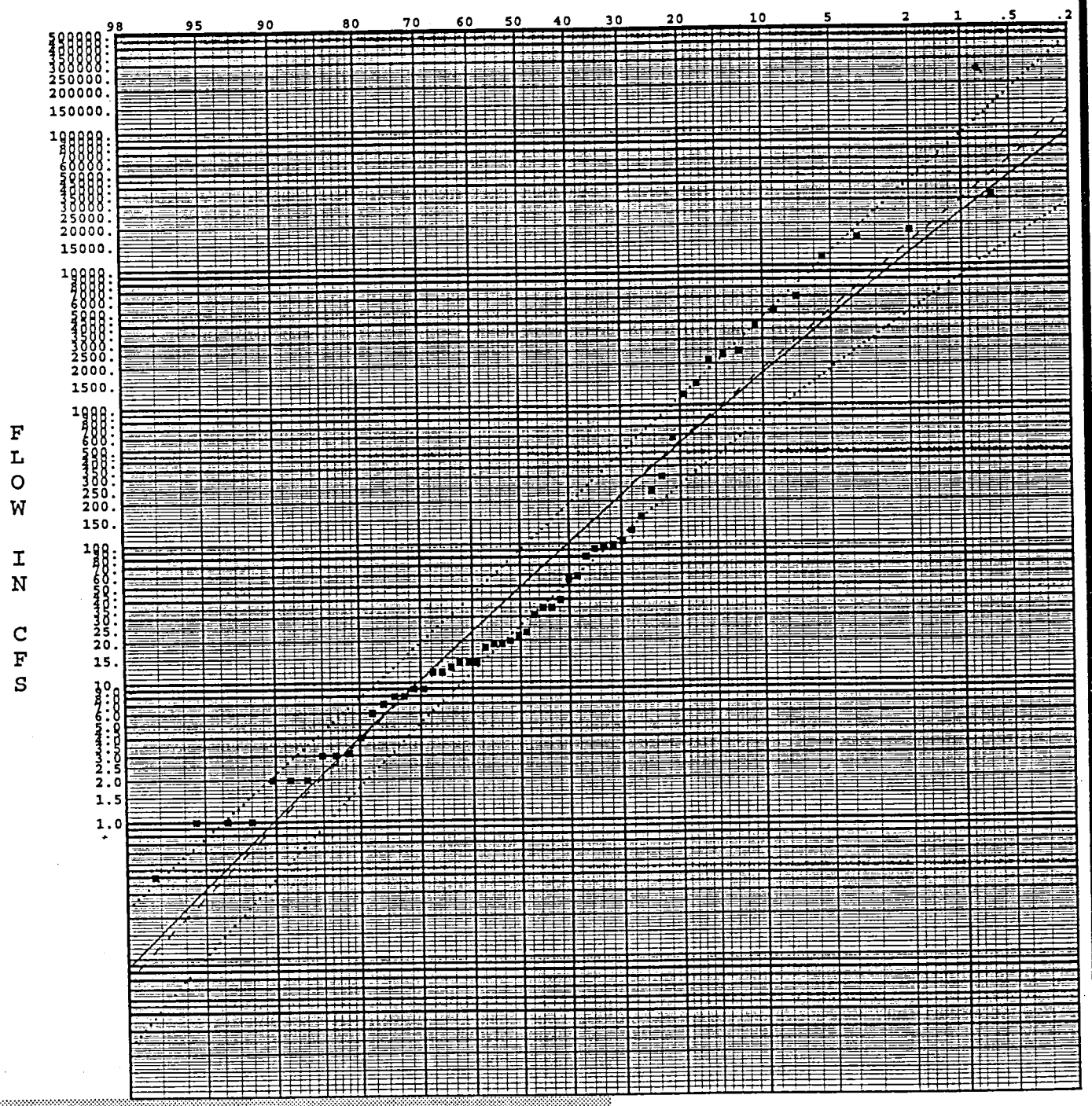
■ Median Plotting Positions

····· 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



—— FLOW Frequency (without Exp. Prob.)

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

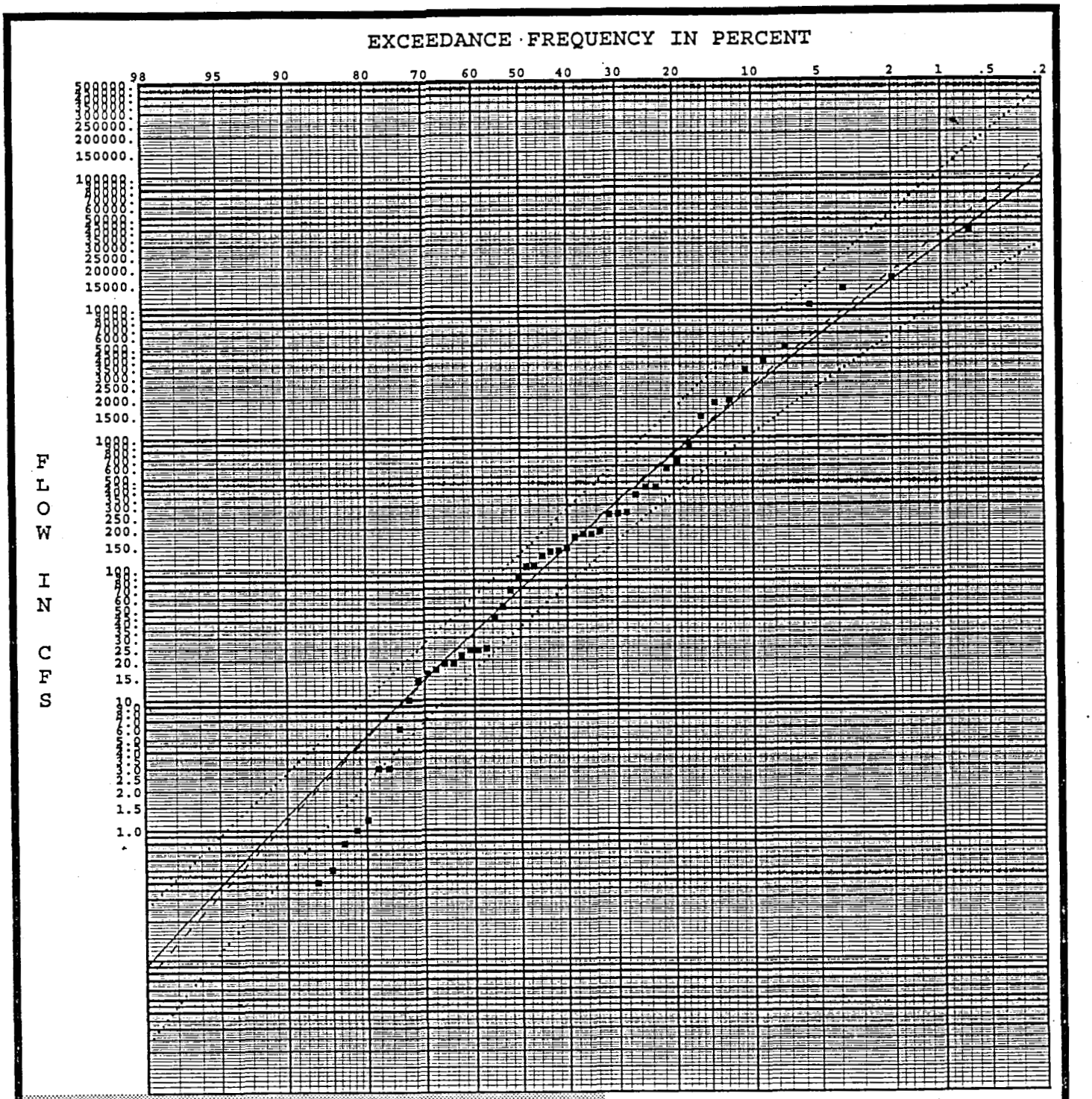
■ Median Plotting Positions

····· 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



—— FLOW Frequency (without Exp. Prob.)

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

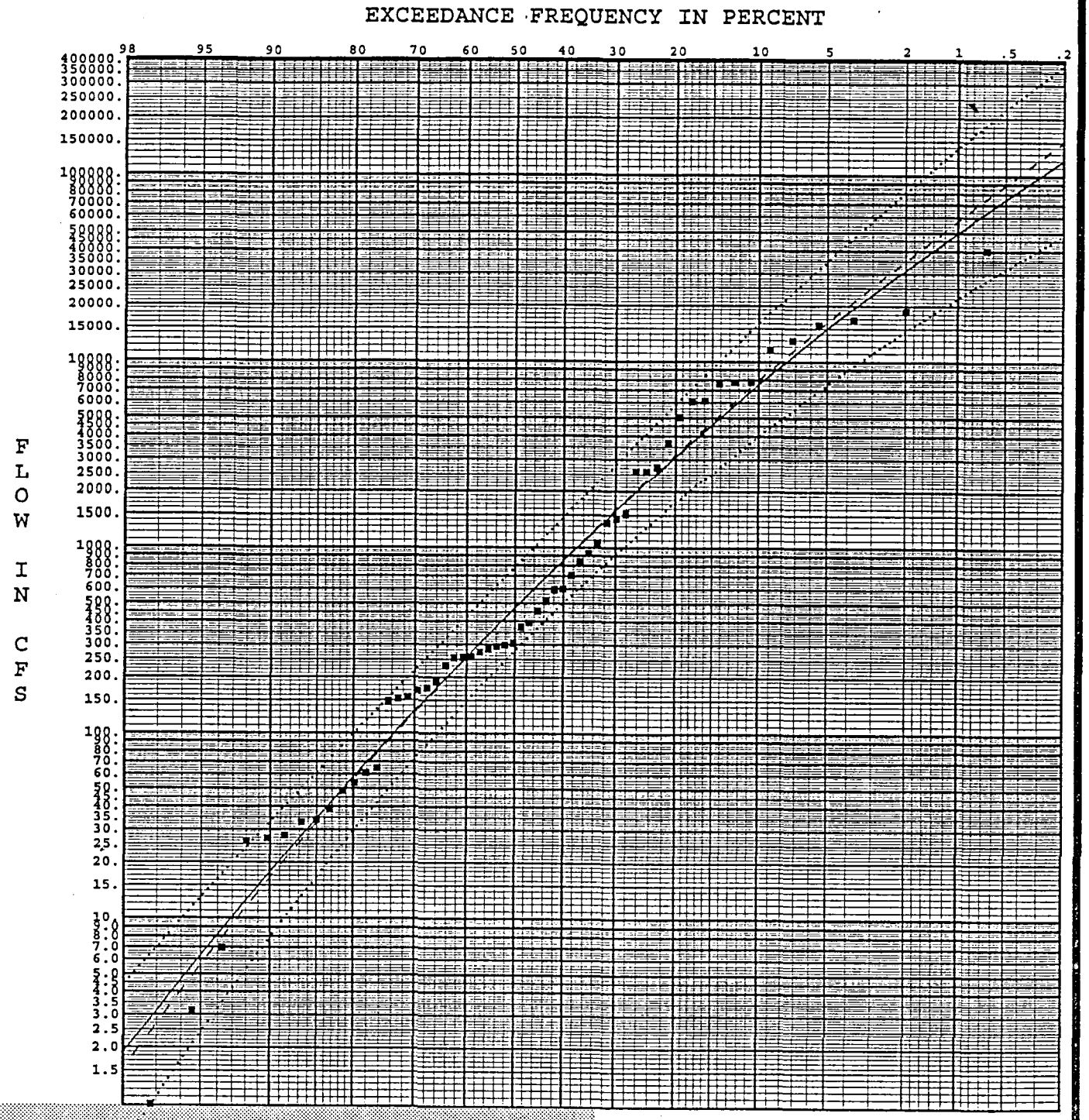
▪ Median Plotting Positions

····· 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



—— 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

EXHIBIT 11

COMBINED ANNUAL DISCHARGE-FREQUENCY COMPUTATIONS:

INTEGRATION OF MIXED POPULATION RESULTS

Prepared by Nick N. Adelmeyer, 26 January 2000
"C:\Projects\SANTCRUZ\1998H&H\TaskForce\TSK_FORCE_REPORT\FinalTechnical SummaryText_merge_HTF2.wpd

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	0.0032	0.00002	0.0035	0.00672	6.4E-08	1.12E-05	7E-08	2.24E-10	0.0067087	0.67
50,000	0.0046	0.00006	0.0042	0.00886	2.76E-07	1.93E-05	2.52E-07	1.1592E-09	0.0088402	0.88
45,000	0.0053	0.00011	0.005	0.01041	5.83E-07	2.65E-05	5.5E-07	2.915E-09	0.0103824	1.04
43,000	0.006	0.00015	0.0052	0.01135	9E-07	3.12E-05	7.8E-07	4.68E-09	0.0113171	1.13
40,000	0.0065	0.0002	0.0055	0.0122	1.3E-06	3.58E-05	1.1E-06	7.15E-09	0.0121619	1.22
30,000	0.011	0.0009	0.008	0.0199	9.9E-06	0.000088	7.2E-06	7.92E-08	0.019795	1.98
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	0.1	0.23	0.044	0.374	0.023	0.0044	0.01012	0.001012	0.337492	33.75
2,500	0.19	0.55	0.074	0.814	0.1045	0.01406	0.0407	0.007733	0.662473	66.25
2,000	0.225	0.65	0.09	0.965	0.14625	0.02025	0.0585	0.0131625	0.7531625	75.32
1,500	0.27	0.77	0.11	1.15	0.2079	0.0297	0.0847	0.022869	0.850569	85.06
1,000	0.35	0.885	0.14	1.375	0.30975	0.049	0.1239	0.043365	0.935715	93.57
500	0.485	0.96	0.204	1.649	0.4656	0.09894	0.19584	0.0949824	0.9836024	98.36
250	0.62	0.997	0.28	1.897	0.61814	0.1736	0.27916	0.1730792	0.9991792	99.92
100	0.78	0.9999	0.4	2.1799	0.779922	0.312	0.39996	0.3119688	0.9999868	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 12

COMBINED ANNUAL DISCHARGE-FREQUENCY CURVES

INCLUDING MIXED POPULATION RESULTS

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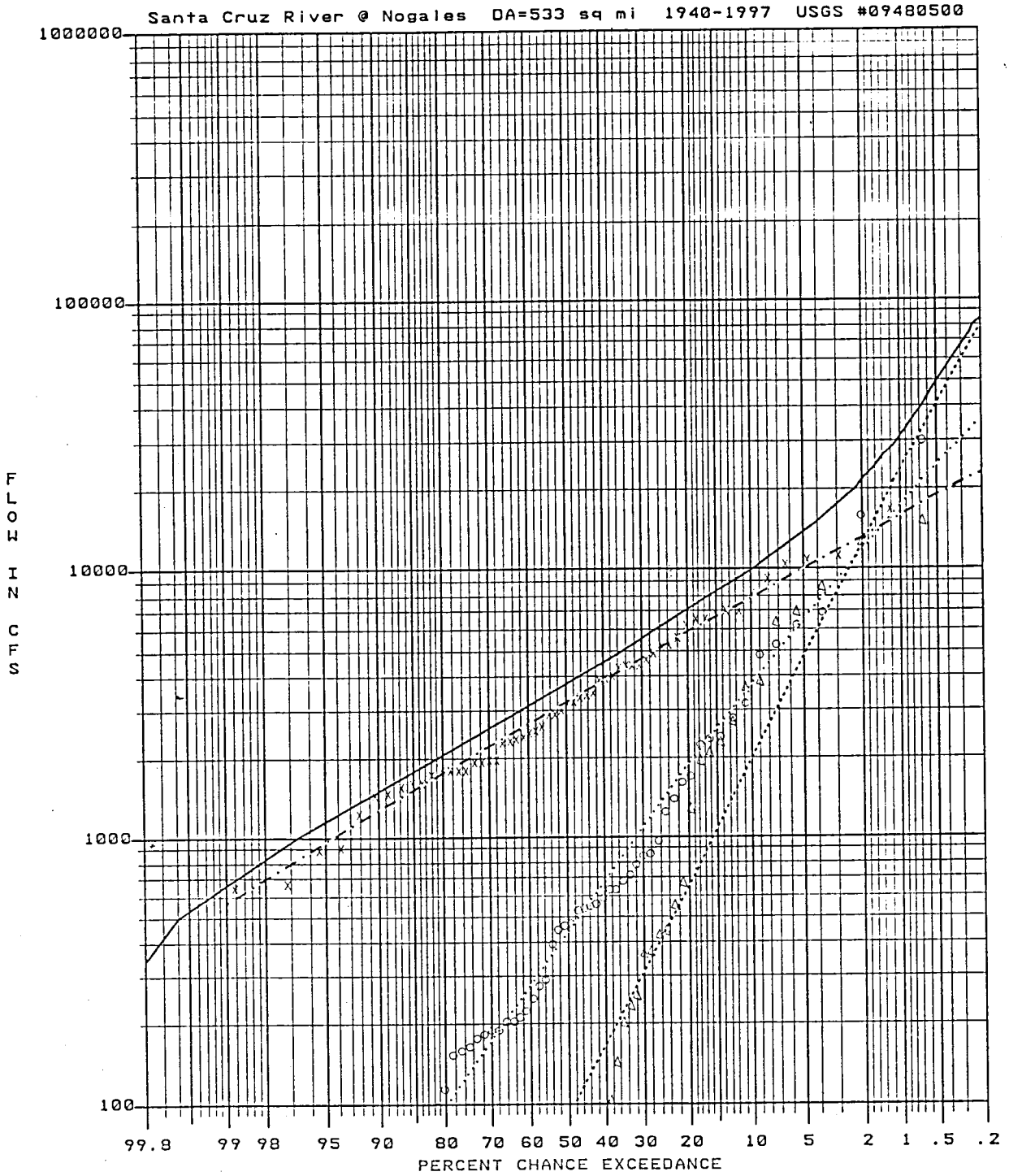

COMBINED MIXED POPULATION ANNUAL CURVE
o OBSERVED SEASONAL PEAKS - CYCLONIC
x OBSERVED SEASONAL PEAKS - MONSOON
Δ OBSERVED SEASONAL PEAKS - FRONTAL

COMPUTED SEASONAL CURVE - CYCLONIC
COMPUTED SEASONAL CURVE - MONSOON
COMPUTED SEASONAL CURVE - FRONTAL

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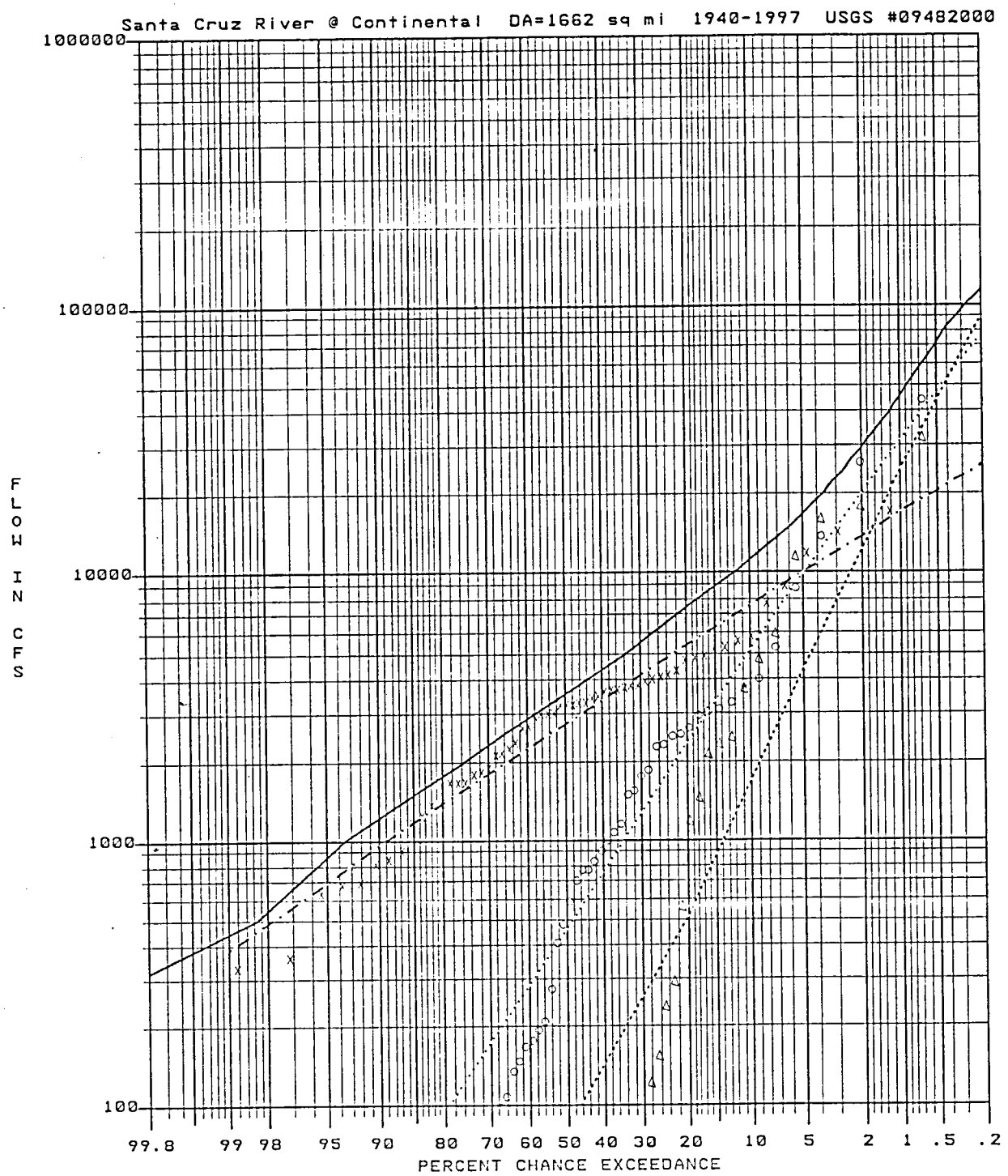

COMBINED MIXED POPULATION ANNUAL CURVE
o OBSERVED SEASONAL PEAKS - CYCLONIC
x OBSERVED SEASONAL PEAKS - MONSOON
Δ OBSERVED SEASONAL PEAKS - FRONTAL
COMPUTED SEASONAL CURVE - CYCLONIC
COMPUTED SEASONAL CURVE - MONSOON
COMPUTED SEASONAL CURVE - FRONTAL

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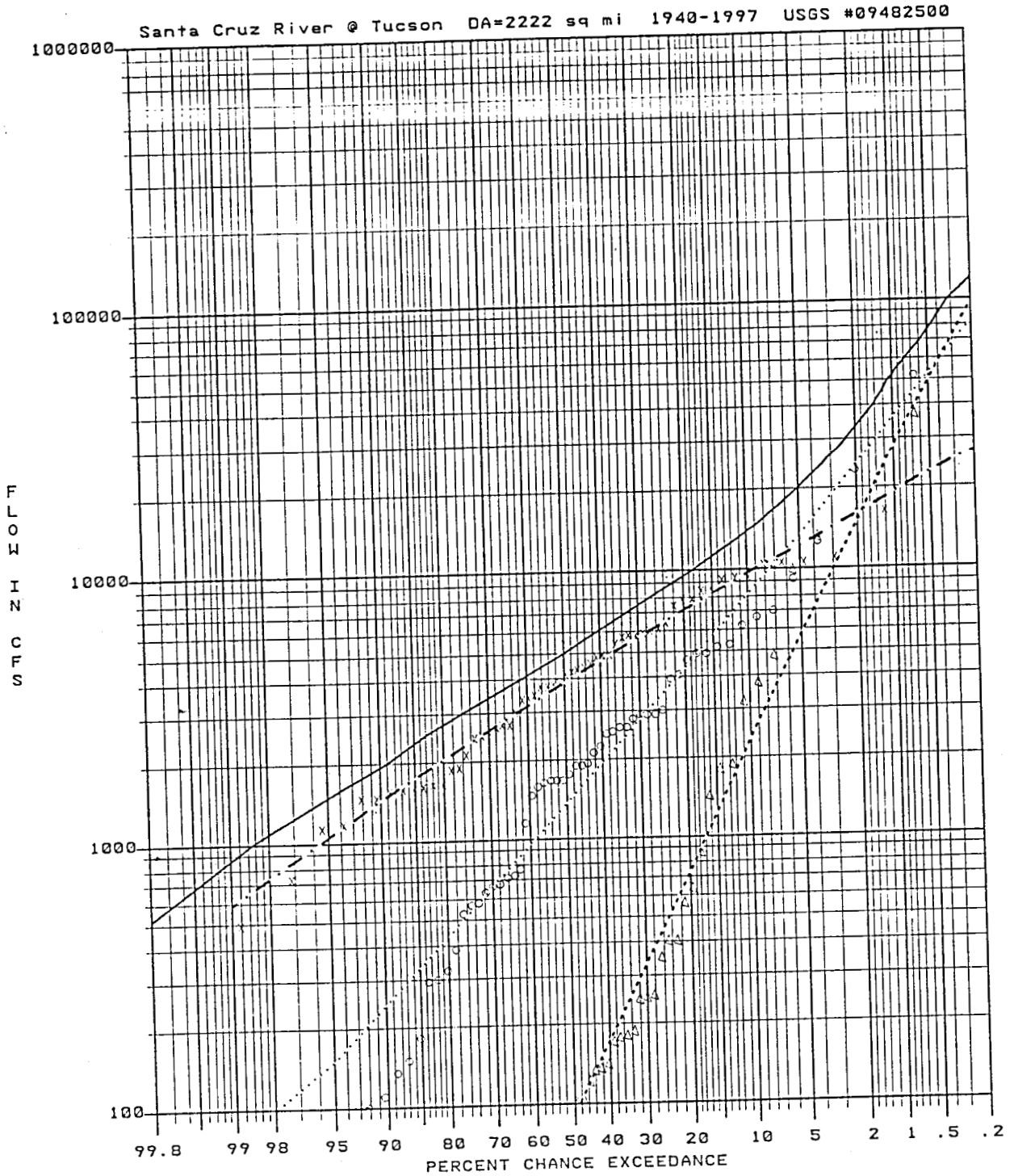
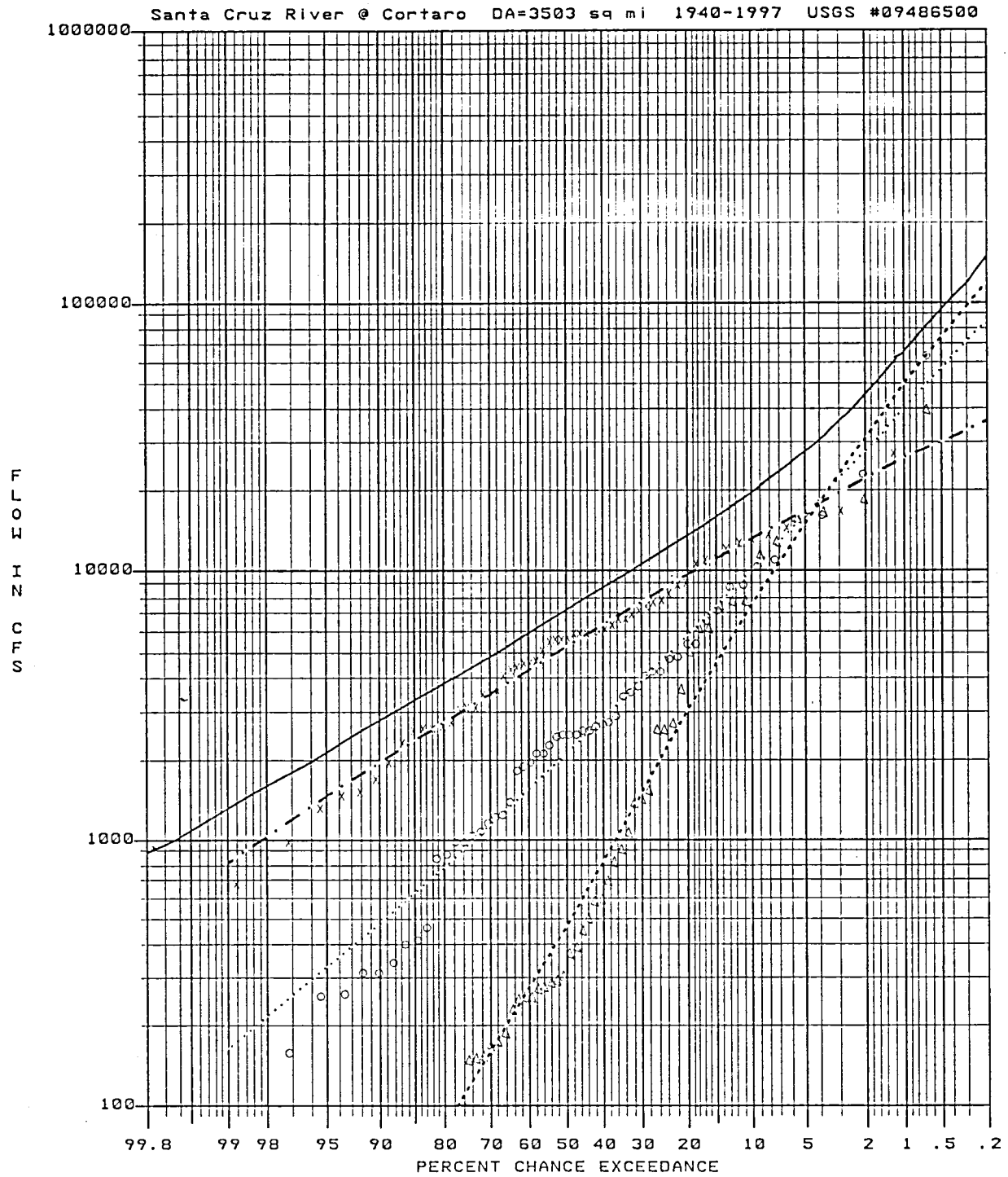


COMBINED MIXED POPULATION ANNUAL CURVE
OBSERVED SEASONAL PEAKS - CYCLONIC
OBSERVED SEASONAL PEAKS - MONSOON
OBSERVED SEASONAL PEAKS - FRONTAL

COMPUTED SEASONAL CURVE - CYCLONIC
COMPUTED SEASONAL CURVE - MONSOON
COMPUTED SEASONAL CURVE - FRONTAL



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

EXHIBIT 13

COMBINED ANNUAL DISCHARGE-FREQUENCY CURVES

STATION COMPARISON

Prepared by Nick N. Adelmeyer, 26 January 2000
"C:\Projects\SANTCRUZ\1998I&II\TaskForce\TSK_FORCE_REPORT\FinalTechnical SummaryText_merge_HTF2.wpd

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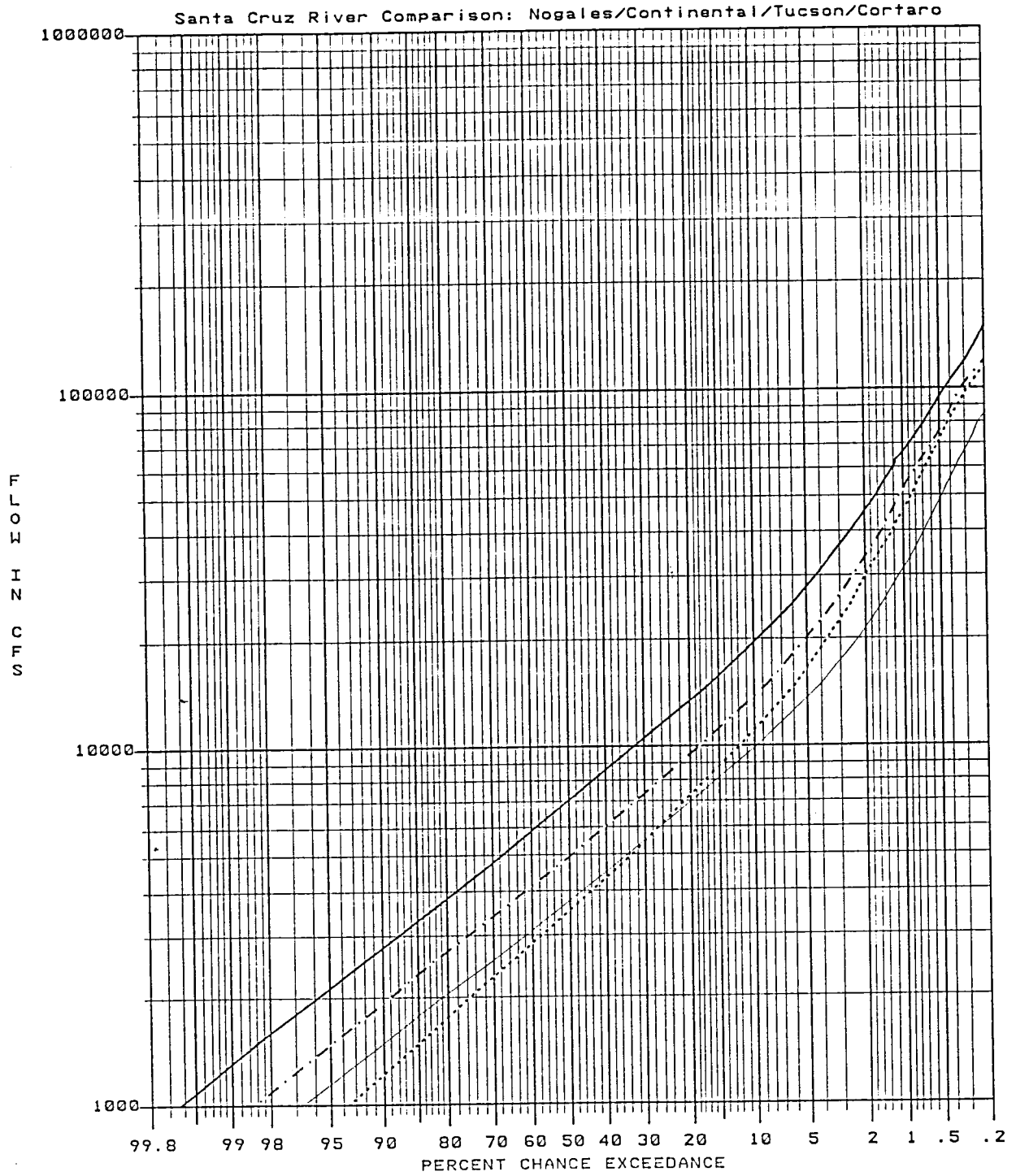
COMPARE.DSS

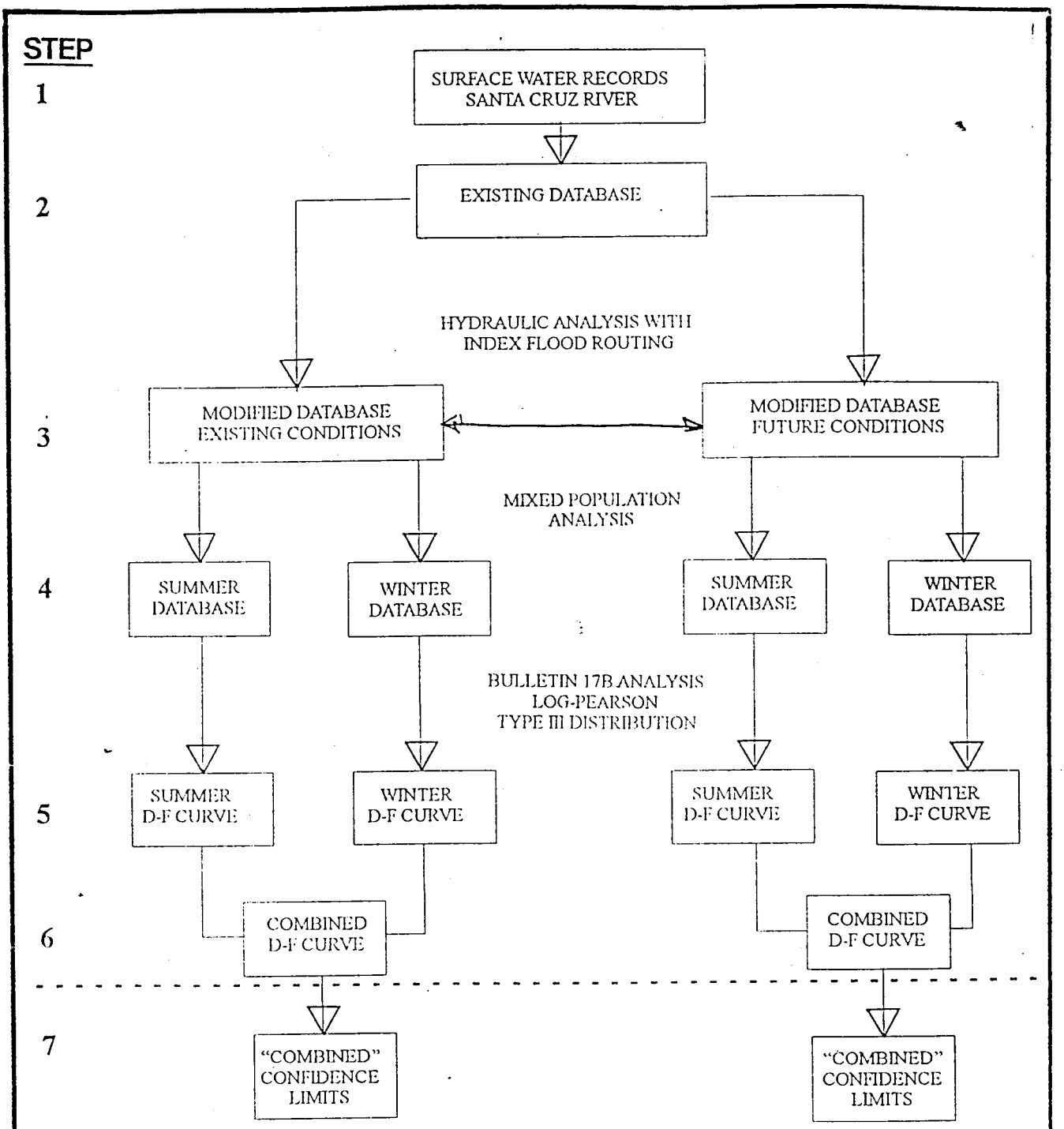


NOGALES COMBINED CURVE COMPUTED PEAK
CONTINENTAL COMBINED CURVE COMPUTED PEAK
TUCSON COMBINED CURVE COMPUTED PEAK
CORTARO COMBINED CURVE COMPUTED PEAK

EXHIBIT 14

"PLAN"

SCHEMATIC



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 15

HYDRAULIC SCREENING ANALYSIS

ROUTING COMPARISON, 1998 V.S. 1976 CHANNEL CONDITIONS

Prepared by Nick N. Adelmeyer, 26 January 2000
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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

N-year Index Flood is simply a synthetic "reference" flood used to compare the degree of attenuation for a range of flood events.

[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

Prepared by Nick N. Adelmeyer, 26 January 2000
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Santa Cruz River Flood Routing Comparison:
1998 Channel vs. 1976 Channel
N-year (Index) Floods
Continental Road to Pinal County Line (continued)

SANTA CRUZ RIVER Location	HEC-RAS Station	"200-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*	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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*** 51.85 miles u/s of Pinal County Line

N-year Index Flood is simply a synthetic "reference" flood used to compare the degree of attenuation for a range of flood events.

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

SANTA CRUZ RIVER Location	HEC-RAS Station	"100-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*	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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N-year Index Flood is simply a synthetic "reference" flood used to compare the degree of attenuation for a range of flood events.

[1] Source - C:\Projects\SANTCRUZ\1998h&h\Indxflds\FldRtng99\1998-15M.dat,05Jun99\nna\11:38 AM
[2] Source - C:\Projects\SANTCRUZ\1998h&h\Indxflds\FldRtng76\1976-50.dat,10:22 AM\nna\10:22 AM

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

SANTA CRUZ RIVER Location	HEC-RAS Station	"50-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*	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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N-year Index Flood is simply a synthetic "reference" flood used to compare the degree of attenuation for a range of flood events.

[1] Source - C:\Projects\SANTCRUZ\1998h&h\Indxflds\FldRtng99\1998-15M.dat,05Jun99\nna\11:38 AM
[2] Source - C:\Projects\SANTCRUZ\1998h&h\Indxflds\FldRtng76\1976-50.dat,10:45 AM\nna\10:45 AM

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

SANTA CRUZ RIVER Location	HEC-RAS Station	"20-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*	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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*** 51.85 miles u/s of Pinal County Line

N-year Index Flood is simply a synthetic "reference" flood used to compare the degree of attenuation for a range of flood events.

[1] Source - C:\Projects\SANTCRUZ\1998h&h\Indxflds\FldRtng99\1998-15M.dat,05Jun99\nna\11:38 AM
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Santa Cruz River Flood Routing Comparison:
1998 Channel vs. 1976 Channel
N-year (Index) Floods
Continental Road to Pinal County Line (continued)

SANTA CRUZ RIVER Location	HEC-RAS Station	"10-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*	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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N-year Index Flood is simply a synthetic "reference" flood used to compare the degree of attenuation for a range of flood events.

[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\1976-10.dat,10Jun99\nna\10:59 AM

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

SANTA CRUZ RIVER Location	HEC-RAS Station	"5-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*	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:
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*** 51.85 miles u/s of Pinal County Line

N-year Index Flood is simply a synthetic "reference" flood used to compare the degree of attenuation for a range of flood events.

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

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

SANTA CRUZ RIVER Location	HEC-RAS Station	"2-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*	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:
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N-year Index Flood is simply a synthetic "reference" flood used to compare the degree of attenuation for a range of flood events.

[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

EXHIBIT 16

HYDRAULIC SCREENING ANALYSIS

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

Prepared by Nick N. Adelmeyer, 26 January 2000
"C:\Projects\SANTCRUZ\1998H&H\TaskForce\TSK_FORCE_REPORT\FinalTechnical SummaryText_merge_HTF2.wpd

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 17

HYDROLOGIC TASK FORCE

December 14, 1999 Meeting Notes

Prepared by Nick N. Adelmeyer, 26 January 2000
"C:\Projects\SANTCRUZ\1998H&H\TaskForce\TSK_FORCE_REPORT\FinalTechnical SummaryText_merge_HTF2.wpd

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:

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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).