US Army Corps
of Engineers
Los Angeles District

TANQUE VERDE CREEK, PIMA COUNTY, ARIZONA LIMITED REEVALUATION REPORT AND ENVIRONMENTAL ASSESSMENT

TECHNICAL APPENDICES

AUGUST 2002

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PLANNING DIVISION, WATER RESOURCES BRANCH
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HYDRAULICS

TANQUE VERDE CREEK
CRAYCROFT ROAD TO SABINO ROAD
BANK PROTECTION AND
RIPARIAN PRESERVE PROJECT
LIMITED REEVALUATION REPORT (LRR)
FEASIBILITY LEVEL ENGINEERING ANALYSIS

Prepared for:

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I. INTRODUCTION

This report summarizes the results of a hydraulic and geomorphic analysis of the Tanque Verde Creek from its confluence with the Rillito River, at Craycroft Road upstream to Sabino Canyon Road (see Figure 1). The study reach extends a short distance downstream of Craycroft Road and a short distance upstream of Sabino Canyon Road. The project reach is better defined as the unprotected portion of the Tanque Verde Creek located between Craycroft Road and Sabino Canyon Road. The project reach extends from Craycroft Road upstream approximately 8,000 feet, and represents the downstream three-quarters of the overall reach lying between Craycroft Road and Sabino Canyon Road.

1.1 Purpose

The purpose of this analysis was to investigate the impact of flooding during the 100-year event (peak discharge: 34,000 cfs) and to evaluate the erosion potential from both a qualitative and quantitative standpoint. It is intended that this document, either in whole or in part, be incorporated into a Limited Reevaluation Report (LRR) that will also address the results of the economic analysis and the issue of environmental acceptability. The purpose of the LRR is to determine the current economic feasibility of providing flood-control and erosion-control solutions within the study reach, in contrast to a 1987 Corps of Engineers report (Reference 1) that found no economically justified solutions to the area's problems. The LRR will specifically address the proposed Tanque Verde Creek bank stabilization and riparian area preserve project, as outlined in a preliminary report prepared by Pima County in December 1996 (Reference 2).

1.2 Project Formulation

The County's project report briefly discusses the recent history of flooding in the area, and provides the cost of repairs from damages sustained during the January 1993 flood. All of the damages are related to bank erosion (or lateral migration) and scour along the channel bed. There were no damages attributed to overbank flooding. In January 1993, two significant discharges impacted the study reach. On January 8th, the peak discharge was estimated to be approximately 24,500 cfs by the US Geological Survey (Reference 3). This discharge approximates the current 50-year peak discharge (24,000 cfs) as noted in Reference 4. On January 18th, the peak discharge was estimated to be 10,600 cfs. This discharge approximates the current 10-year peak discharge (10,500 cfs). The aerial photograph provided as Figure 2 was taken on January 9, 1993 (i.e., the day after the largest flow on record).

In addition to their concern of continued erosion along the study reach, the County expressed concern that the south approach to the Craycroft Road bridge could be washed out during a catastrophic event. According to the County, there is historic evidence of channel migration approximately 1000 feet south of the Craycroft Road bridge. They also attribute periodic repairs to both the roadway embankment and to a sewer interceptor in this area to

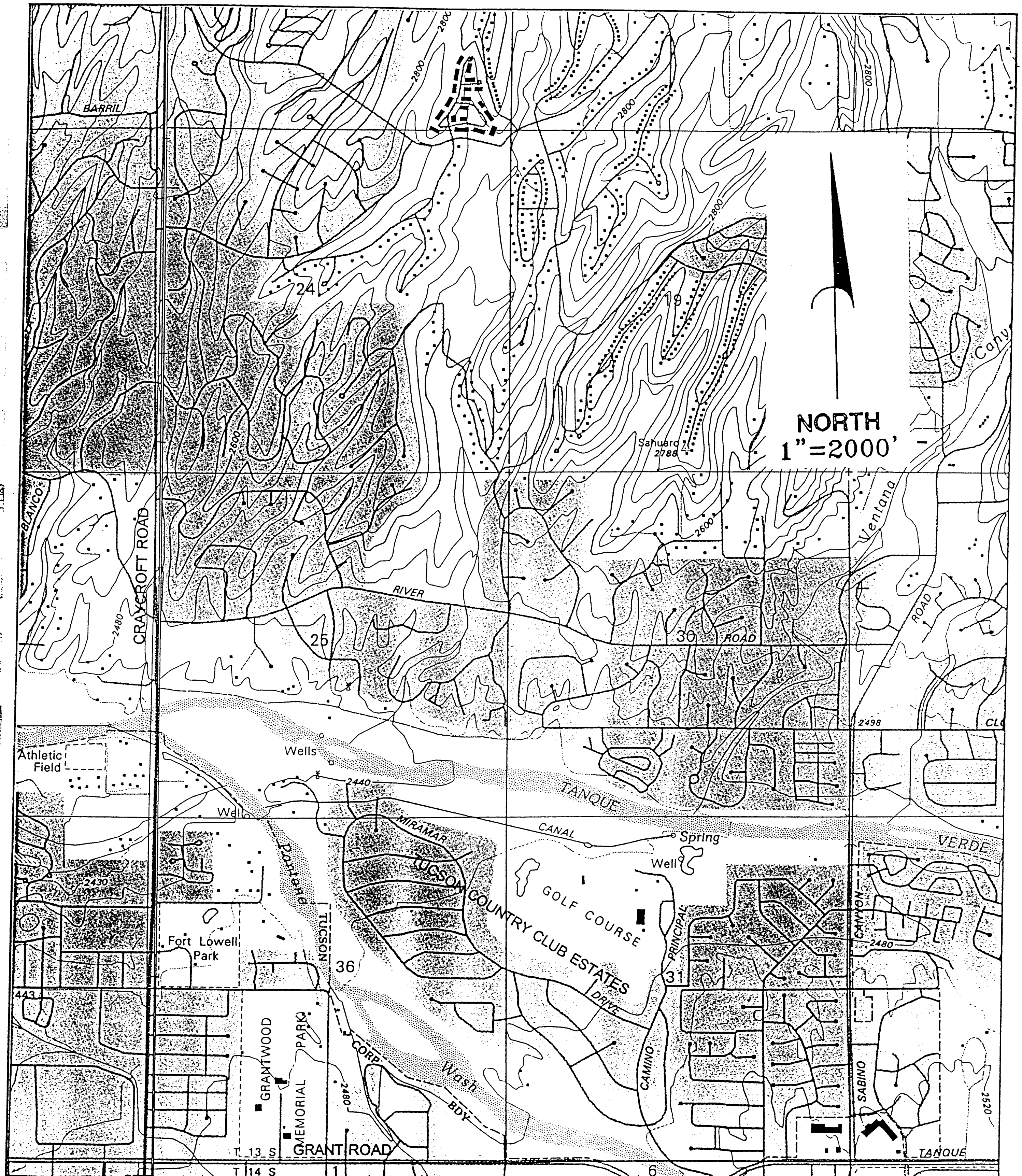

FIGURE 1

SITE LOCATION MAP

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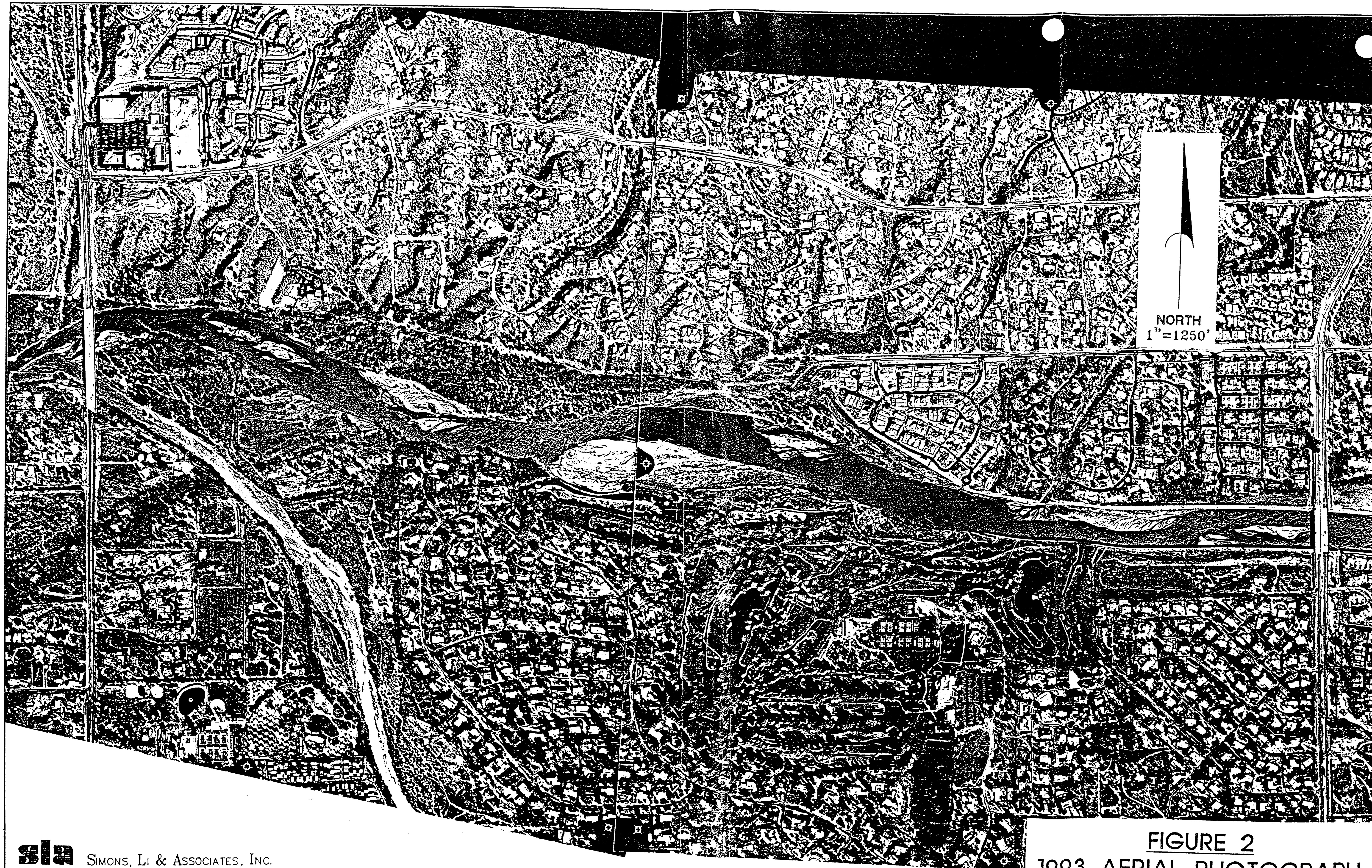

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FIGURE 2
1993 AERIAL PHOTOGRAPH

subsurface flows that follow this meander path. Since the meander scar lies within the 500-year flood plain, they are concerned that, during an extreme flow event, inundation and erosion along the study reach could impact several subdivisions and the Fort Lowell Historic District, which are located adjacent to the south approach of the Craycroft Road bridge.

The County's proposed solution to the problem requires the installation of approximately 8,600 linear feet of soil-cement bank protection and the establishment of a riparian preserve, which will act as an erosion buffer for the unprotected overbank areas. Figures 7 and 8 of the County's preliminary design report (Reference 2) shows the approximate location and the extent of these design features. Of the proposed 8,600 linear feet of bank protection, approximately 1,550 linear feet is required along the north bank immediately upstream of Craycroft Road in order to protect the north bridge abutment, and approximately 7,050 linear feet is required along the south bank to complete protection of the entire south bank. The riparian preserve will be located within the north overbank area between the upstream terminus of the proposed north abutment protection for Craycroft Road and the downstream terminus of the existing bank protection that extends approximately 4,550 feet upstream to Sabino Canyon Road. No grade stabilizers along the streambed were included in the County's proposed design.

1.3 Scope and Methodology

Collectively, the scope of the hydraulic and geomorphic analysis was formulated to address four major areas of concern. These four areas are (1) the potential for bank erosion, lateral migration, and channel migration along the project reach; (2) the relative stability of the Craycroft Road and Sabino Canyon Road bridges; (3) the flooding potential along the study reach during a 100-year event; and (4) the potential threat, if any, that the project might pose on the recently completed Rillito River bank stabilization project.

Using the methodology described in the Reference 1, an average-annual erosion rate relative to the existing bank was defined as the ratio of the recommended development set-back distance to the 50-year life of the proposed project. The development set-back distance was determined using the combined results of a qualitative and quantitative geomorphic analysis. The qualitative analysis compared changes in the location of the banks as documented by a series of photographs taken between 1936 and 1996. Flow records from the US Geological Survey were used to correlate noted changes in bank locations to a particular flow event. The quantitative analysis used empirical relationships to estimate the expected long-term migration distance (Reference 5) and the limiting width of channel meanders along the project reach (Reference 6).

In addition to evaluating the potential for bank erosion, migration, and channel meanders, scour calculations were performed to estimate adequate design toe-down depths for the proposed bank protection, and to verify the stability, under project conditions, of the existing bank protection and bridges. The scour components included in the analysis were general scour, bed-form scour, bend scour, local scour, and the potential for long-term degradation. The relationships provided in Reference 5 and Reference 7 were used for this purpose. A low-flow channel incisement component, which was assumed to be two feet, was also included in the analysis. The potential for long-term degradation was determined using the equilibrium slopes provided in Reference 8. For the most part, these procedures are consistent with the ones outlined in Reference 9.

The flooding potential along the study reach was determined using the HEC-2 water-surface profile model as described in Reference 9. The analysis was based on topographic information obtained in August 1993. To accurately model existing conditions, portions of the topography were revised to reflect the bank protection constructed by Pima County in 1994. With-project conditions were analyzed using the information provided on Figures 7 and 8 of Reference 2.

II. WITHOUT-PROJECT CONDITIONS

2.1 Erosion/Meander Potential

As previously noted, the qualitative geomorphic analysis of the study reach was based on an evaluation of 60 years of photographic records. The series of photographs used in the analysis were 1936, 1953, 1960, 1967, 1971, 1979, 1983, 1993, and 1996. USGS peak discharge records were used in an attempt to correlate movements of the channel or the banks to specific flow events. Table 2.1a summarizes the most significant discharges that occurred over the observed time period. Records obtained for the Rillito River and the Pantano Wash were also obtained to supplement missing records for the Tanque Verde Creek. Although the 1983 and 1993 photographs were taken immediately following the two largest flows on record for the Rillito River system, significant flow events also occurred in 1965 and 1978. In addition to bank erosion (or lateral migration), the photographs document other historical changes along the Tanque Verde Creek, including changes in land-use and vegetation—both of which have a significant influence on erosion potential. Land-use changes adjacent to and immediately upstream of the study reach have been especially dramatic during the last 45 years.

Prior to 1953, lands along the north and south banks of the Tanque Verde Creek between Craycroft Road and Sabino Canyon Road were mostly undeveloped, with the exception of agricultural uses. The 1936 photograph indicates that most of the geologic floodplain to the south was being farmed. However, on the north bank, only the confluence area between the Ventana Canyon Wash and the Tanque Verde Creek was being farmed. Immediately upstream of Sabino Canyon Road, most of the geologic flood plain was being farmed.

By 1953, development on the south bank began with the initial phases of the Tucson Country Club Estates. The golf course was already constructed, and the subdivision roads were being paved to make way for residential development. However, the north bank remained undeveloped until the late 1960's. By the early 1970's, development intensity increased on parcels adjacent to the east of the Country Club, along the north bank immediately upstream of Sabino Canyon Road. By 1979, developments spread to the north bank within the boundary of the study reach; however, most of this development was centered around the confluence region of the Ventana Canyon Wash.

Prior to the October 1983 flood, the Craycroft Road bridge was constructed at the downstream end of the study reach, and soil-cement bank protection was installed along both banks at the upstream end of the reach. In 1990, development began on another major subdivision that currently occupies a large portion of the northern bank immediately downstream of the Ventana Canyon confluence. Soil-cement bank protection also protects this subdivision and is currently a requirement for all subdivisions that encroach within 500 feet of the existing channel banks (i.e., the current setback requirement imposed by Pima County). However, the Tucson Country Club and the remaining residential properties located within 500-feet of the banks were permitted before the potential for channel migration along alluvial channels was fully recognized.

Table 2.1a Summary of Relevant Peak Discharges from USGS Gaging Stations

Date	Peak Discharge (cfs)				
	Tanque Verde Creek	Pantano Wash	Rillito River		
	Sabino Canyon Rd.	Tanque Verde Rd.	Dodge Blvd.	First Ave.	La Cholla Blvd.
13-Aug-40	6400	9200			13200
30-Dec-40	9000				
31-Dec-40					9900
03-Jul-50					9490
25-Jul-51					9500
12-Aug-58		20000			8930
01-Sep-64					9420
22-Dec-65	12200				12400
06-Sep-70	7340				7000
02-Aug-71					9290
1979 (1)		1530			16400
18-Dec-78	12700			16400	
01-Oct-83		11000			
02-Oct-83					29700
08-Jan-93	24500		24100		
11-Jan-93	9690				
13-Jan-93	4910				
18-Jan-93	10600				

(1) water year (01-Oct-78 to 30-Sep-79)

Aerial photographs taken prior to land-use changes reveal a geologic floodplain along the study reach that has an average width of approximately 3000 feet. The northern boundary is well defined where it meets the foothills of the Santa Catalina Mountain Range. With the exception of the developments that occupy the area near the Ventana Canyon Wash confluence, the majority of the area between the northern bank and the northern geologic boundary has remained undeveloped. However, the southern geologic boundary is not as well defined, and development of the area began with the establishment of Tucson Country Club Estates back in the early 1950's. At that time, the main channel remained very close to the northern geologic boundary of the flood plain.

From 1936 to 1993, the creek has been actively adjusting its channel geometry within the geologic floodplain. A comparison of the 1936 and 1993 photographs reveal that channel meanders and/or bank migrations have shifted the south bank by as much as 650 feet. However, movement of the north bank has been limited to approximately 200 feet over this same 60-year time period. In fact, prior to 1993, most of the north bank remained relatively unchanged. Consequently, channel migration and bank erosion has been most pronounced along the south bank.

A comparison of photographs from the successive years investigated reveal that the largest lateral shift occurred between 1960 and 1967. Evidence of this change first appears on the 1967 photographs. Sometime between 1960 and 1967, flows overtopped the south bank of the main channel and created a secondary channel that in essence resulted in the formation of a small island in the middle of the watercourse. It is likely that this shift probably occurred during the December 1965 flood. The 1967 photographs also reveal signs of excavation in the vicinity of the south bank, as well as the creation of a third channel through the center of the island. These efforts appear to be related to an attempt to minimize the erosion potential along the south bank by diverting flow towards the north.

As one might expect, the maximum change in channel geometry typically occurs during large flow events. Although there is no recorded flow data for the period 1953 to 1960, large flows were recorded in 1965, 1979, 1983 and 1993. The maximum lateral migration and/or erosion along the south bank occurred during these periods. The largest peaks on the Tanque Verde Creek occurred during the floods of October 1983 and January 1993.

In addition to lateral migration, the main channel throughout the study reach has widened considerably, and has correspondingly adjusted its profile through both aggradation and degradation. In 1953, the channel width ranged from 80 feet at its narrowest point to 260 feet at its widest point. By 1993, the channel width ranged from 200 to 850 feet. A review of river bed profiles from 1983 to 1993 indicates that the main channel has degraded approximately three feet at the upstream limit of the study reach. The trend towards degradation was evident within the upstream half of the reach, while the downstream half showed a tendency towards aggradation. The average depth of aggradation along the downstream reach was approximately 0.65 feet.

The following paragraphs provide a brief summary of the changes that occurred between the successive years of photographic record.

1936 - 1953 The most significant change noted during this period was the abandonment of some of the secondary low-flow channels that hugged the south bank in favor of the low-flow channels along the north bank. However, at one location—immediately downstream of Sabino Canyon Road—the south bank appears to have sifted in a southwesterly direction approximately 100 feet. This change could probably be attributed to the December 1940 flow event that approximated the 10-year flood by today's standards.

1953 - 1960 In 1953, the width of the main channel ranged from 80 feet to 260 feet along the study reach. In 1960, channel widths ranged from 80 feet to 400 feet. During this 7-year period, a portion of the south bank migrated approximately 200 feet. This shift occurred within the midsection of the study reach. The lower half of the study reach remained relatively unchanged. Although no recorded flow data is available for the Tanque Verde Wash during this period, it appears that several significant flow events occurred along the Pantano Wash.

1960 - 1967 Again, little or no change was noted along the north bank during this time period. However, increased development was occurring along the south bank. By 1967, the width of the main channel along the study reach ranged between 150 feet and 870 feet. The widest section was located in the midsection, where an island had formed due to overtopping flows from the main channel that existed in 1960. This bifurcation of the main channel relocated the active south bank approximately 650 feet from its original location. The lower half of the study reach remained relatively unchanged during this period. Flow records indicate only one significant flow event during this period. A peak discharge of 12,200 cfs was recorded on December 22, 1965.

1967 - 1971 Between 1967 and 1971, no significant change can be observed in the relative location of the respective banks. In addition, the relative width of the main channel remained unchanged. However, earlier attempts to straighten the active midsection proved successful in the sense that a well-defined straight channel predominated within this section of the study reach during the noted time period. Flow records indicate that no significant flow events occurred during this time period.

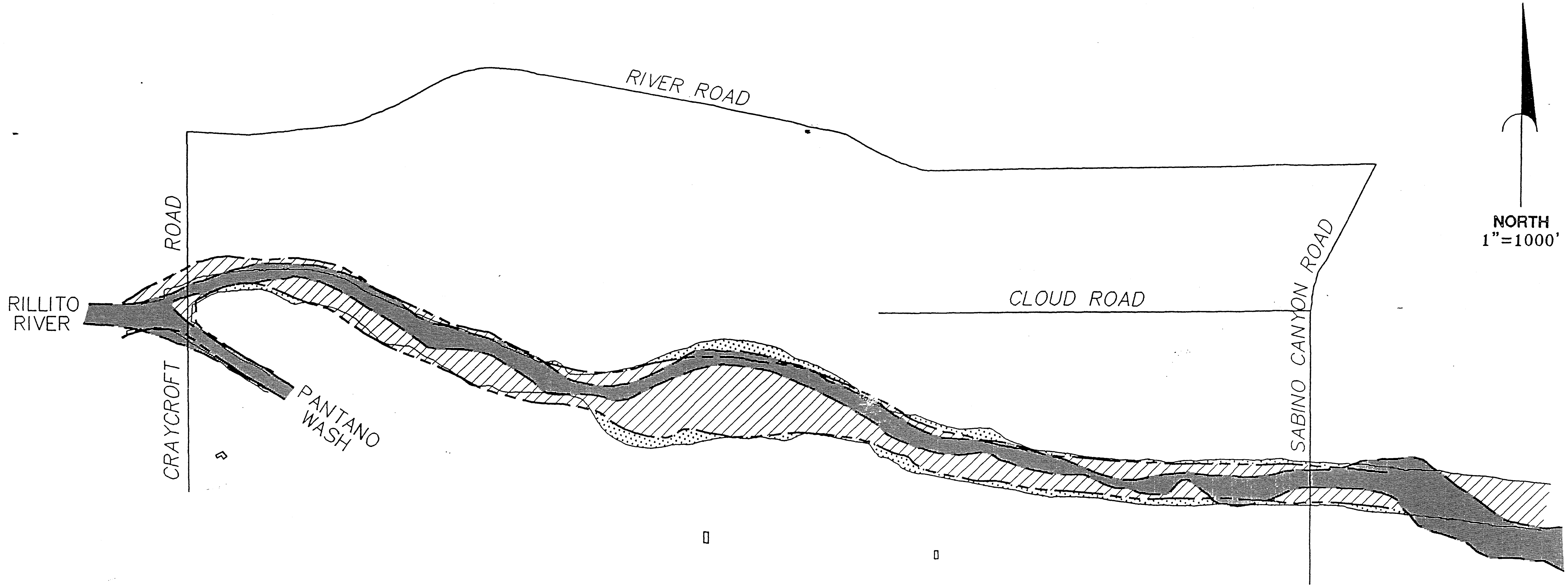
1971 - 1979 With the exception of a 100-foot lateral shift in the main channel at one isolated location, the channel geometry remained relatively unchanged during this time period. However, one significant flow event did take place on December 18, 1978. The peak discharge during this event was estimated to be approximately 12,700 cfs.

1979 - 1983 As previously mentioned, one of the largest events to impact the Rillito River system occurred during this time period (October 1983). Although no flow records were available for the Tanque Verde Creek, significant bank erosion was noted. A review of the flow records for the Rillito River and the Pantano Wash suggests that the peak discharge on the Tanque Verde Creek exceeded a 25-year event (i.e., ±17,000 cfs). Portions of the north and the south bank eroded between 100 and 200 feet. The largest shift occurred along the south bank adjacent to the Tucson Country Club Estates golf course. Since bank protection had been installed along the most upstream portion of the study reach, no erosion occurred in this area. However, the cause and effect relationship that typically surrounds piece-meal bank-protection projects probably contributed to the increased erosion that occurred along the unprotected downstream banks. Most of the damage from the October 1983 flood was isolated to the dynamic midsection, since the downstream one-third of study reach remained relatively unaffected by the flood. In 1983, the width of midsection channel increased to approximately 920 feet.

1983 - 1993 The largest flood on record (i.e., 24,500 cfs) occurred during this time period (January 1993). Although the most extensive erosion noted (approximately 150 feet) occurred on the north bank just upstream of Craycroft Road bridge, approximately 100 feet of bank was lost along a portion of the south bank that had been reclaimed after the October 1983 flood. Since the homes is this area were now located within 150 feet of the bank, and a major sewer line that traverses the area had been exposed, Pima County again reclaimed the bank and installed approximately 1600 feet of soil-cement bank protection. After the January 1993 flood, the most constrictive width in the main channel became 200 feet.

Figure 3 provides an illustrative summary of the changes that have occurred along the study reach between 1953 and 1993. The approximate location of the bank following the October 1983 flood is included, since some reclamation occurred between 1983 and 1993.

The results of the qualitative geomorphic analysis indicate that lateral shifts on the order of 650 feet in the banks of the main channel of the Tanque Verde Creek are not unusual over a 50-year time period. This distance correlates very closely to the long-term migration distance (652 feet) computed using the building setback relationship contained in Reference 5 in conjunction with a bank-full discharge of 17,000 cfs. Consequently, in contrast to the 500-foot building setback currently applied by Pima County, a 650-foot setback would seem more reasonable at some locations considering the dynamic nature of the main channel within the study reach. Likewise, over the 50-year project life, an average annual erosion rate of 13 feet per year appears to be a reasonable estimation of the erosion potential within the project area. Since the main channel along the study reach continues to occupy the northern third of the geologic flood plain, this erosion rate could result in 650 feet of erosion relative to the south bank. However, erosion to the north bank would be limited by the northern boundary of the geologic flood plain. For the most part, the northern boundary of the geologic flood plain corresponds to the northern boundary of the 100-year flood plain, as defined by this study.



LEGEND

- 1953 CHANNEL ALIGNMENT
- 1983 BANK AND CHANNEL ALIGNMENT
- 1993 BANK AND CHANNEL ALIGNMENT
- REDUCED (OR RECLAIMED) AREAS BETWEEN 1953 OR 1983 & 1993
- ENLARGED AREAS BETWEEN 1953 & 1993

FIGURE 3
CHANNEL MORPHOLOGY ALONG THE TANQUE VERDE CREEK BETWEEN 1953 AND 1993

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2.2 100-Year Flood Plain

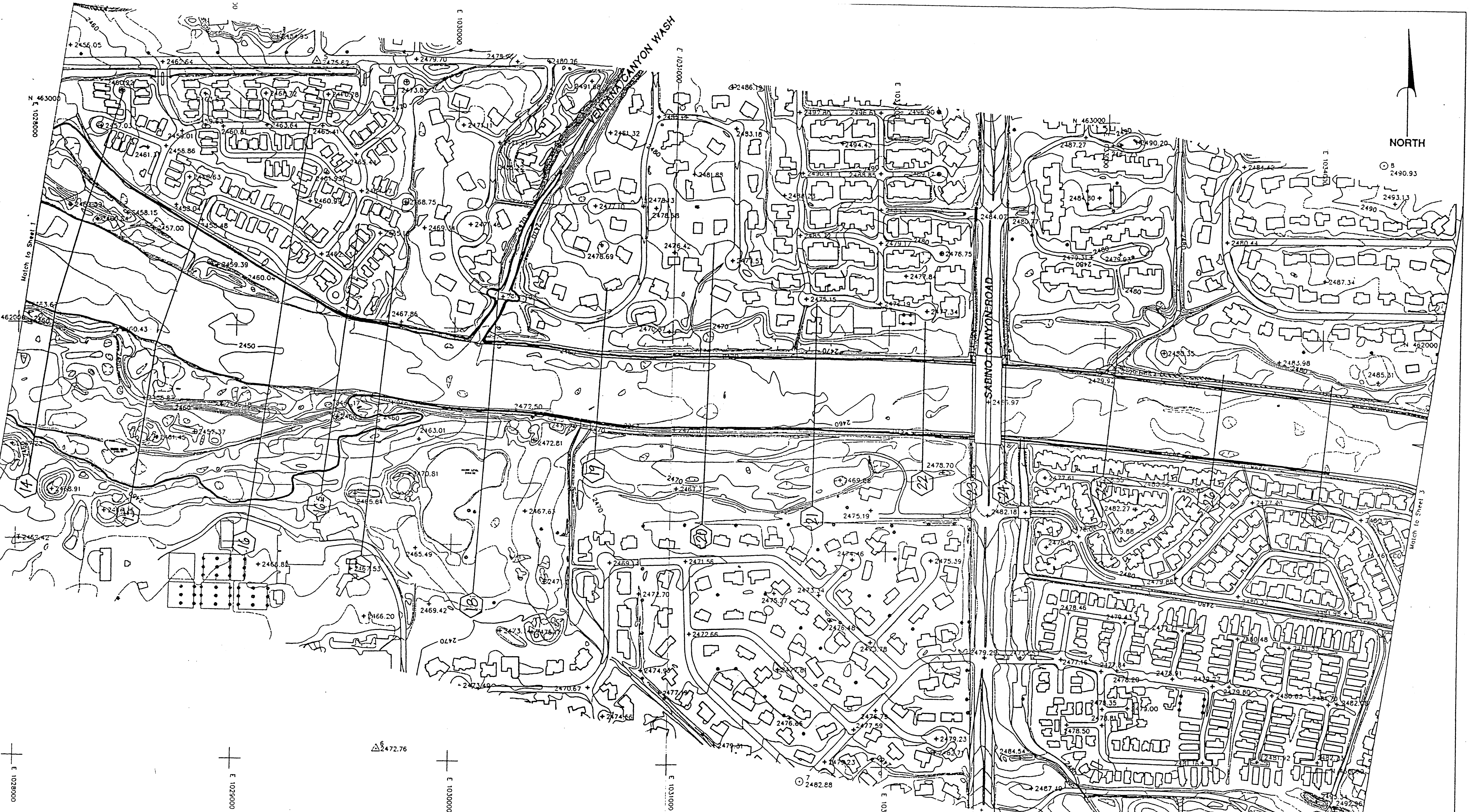
An analysis of the 100-year floodplain was conducted using a 1993 topographic base map provided by Pima County in conjunction with the HEC-2 water-surface profile model (Reference 10). The cross-sections used in the analysis are shown on Figure 4 (Sheets 1 and 2). The computed 100-year floodplain boundaries are also shown on Figure 4.

Two assumptions were made during the course of the analysis which have for the most part provided a conservative estimate of the 100-year flood plain and associated water-surface elevations. The first assumption is related to the starting water-surface elevation that was used in the analysis. This elevation was obtained using Reference 4 as a guide. Consequently, it is based on a backwater analysis relative to the confluence region that considers the combined effect of flows from the Pantano Wash and Tanque Verde Creek. However, this assumption only applies to the selected starting water-surface elevation at Cross Section 1. The entire floodplain model is based on a single discharge, 34,000 cfs, which is the current regulatory discharge for the Tanque Verde Creek. Although this assumption will produce higher water-surface elevations in the immediate vicinity of the confluence, the influence is limited to the extreme downstream portion of the study reach, which is currently undeveloped.

The second assumption applies to the unprotected levee that exists along a portion of the south bank. It appears that this levee was intended to protect the Tucson Country Club golf course from inundation during moderate flow events. However, the results of preliminary analyses indicate that the levees are high enough to contain the 100-year peak discharge under the assumption of stable levee conditions. Since the contained analysis produced higher water-surface elevations than the uncontained analysis, the flood plain was delineated using the water-surface elevations associated with the contained analysis. This approach provides the most conservative estimate of the limits of the 100-year flood plain.

The results of the 'without-project conditions' floodplain analysis are summarized in Table 2.2a. The complete HEC-2 input/output listing is provided in Appendix A.

With the exception of what appears to be a secondary structure to the primary residence on a single lot, there are no residential structures located within the 100-year flood plain of the Tanque Verde Creek. The Tucson Country Club Estates' golf course appears to be the only developed property located in the 100-year flood plain.



LEGEND

(2) CROSS-SECTION LOCATION

100-YEAR FLOOD PRONE LIMIT

Photo Date - August 10, 1993

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Contour Interval = 2 foot

200 100 0 200 400 600

FIGURE 4
100-YEAR FLOOD PLAIN MAP
TANQUE VERDE CREEK
CRAYCROFT ROAD TO SABINO CANYON ROAD
SHEET: 2 OF 2

Photo Date - August 10, 1993

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FIGURE 4
100-YEAR FLOOD PLAIN MAP
TANQUE VERDE CREEK
CRAYCROFT ROAD TO SABINO CANYON ROAD
SHEET: 1 OF 2

Table 2.2a Summary of Without-Project Floodplain Conditions

Section Number	Distance (1) (ft)	Water Surface Elevation (ft)	Max. Flow Depth (ft)	Top Width (ft)	Channel Velocity (fps)
1.0	100.0	2433.20	11.20	604	11.46
2.0	550.0	2434.04	10.04	910	13.79
3.0	1050.0	2437.17	10.67	1136	7.75
4.0	1550.0	2437.85	9.85	1293	8.01
5.0	2000.0	2438.54	9.04	1508	8.83
6.0	2500.0	2439.68	7.68	1118	11.22
7.0	3000.0	2442.22	8.22	1053	12.40
8.0	3500.0	2444.71	8.71	841	12.91
9.0	4000.0	2447.61	9.61	948	8.31
10.0	4500.0	2448.76	8.76	1049	6.43
11.0	5000.0	2449.46	8.16	1147	6.16
12.0	5500.0	2450.24	6.74	854	9.20
13.0	6000.0	2451.98	7.98	738	10.10
14.0	6470.0	2453.65	7.15	459	12.15
15.0	6970.0	2456.10	8.10	596	13.05
16.0	7490.0	2458.80	8.80	584	10.53
16.5	7790.0	2459.56	7.56	423	14.32
17.0	7990.0	2460.71	7.91	323	15.09
18.0	8490.0	2464.40	9.50	322	12.79
19.0	8990.0	2466.72	9.72	344	11.18
20.0	9490.0	2468.08	9.08	332	11.75
21.0	9990.0	2469.64	9.64	323	12.00
22.0	10490.0	2471.54	10.54	328	10.32
23.0	10710.0	2471.98	9.98	349	10.48
23.1	10730.0	2472.05	10.05	350	10.40
23.2	10850.0	2472.78	10.28	353	10.29
24.0	10870.0	2472.84	10.34	354	10.21
25.0	11370.0	2473.81	9.81	331	11.66
26.0	11870.0	2475.35	9.85	335	12.47
27.0	12370.0	2477.15	9.75	306	13.97

Notes: (1) Relative to the upstream face of the Craycroft Road bridge.

2.3 Scour/Stability Analysis

The scour/stability analysis was performed on a sub-reach-by-sub-reach basis. The study reach, excluding the bridge at Sabino Canyon Road, was broken down into six subreaches. The number of subreaches selected and the grouping of consecutive sections within a particular subreach are primarily a function of similarities in hydraulic properties and sediment transport characteristics. By grouping a number of cross sections together and considering their properties as a single unit, local effects surrounding a single cross section are reduced. The average hydraulic properties for each subreach were then used to compute the individual scour components. The total computed scour depth, which was used to estimate adequate design toe-down depths for the project's bank protection, represent the sum of the individual scour components times a safety factor (1.3) to account for irregularities in hydraulic properties and sediment distributions created by a nonuniform flow distribution.

Table 2.3a summarizes the results of the without-project scour analysis. As previously noted, the scour analysis was performed using empirical equations obtained from References 5 and 7. With the exception of the anticipated depth of the low-flow channel, all scour components, including general scour, were estimated using the appropriate relationship from these references. The depth of the low-flow channel was assumed to be two feet, which is consistent with observed conditions along the study reach. Since the results of the general scour analysis were consistent with the results of the detailed sediment routing analysis performed in conjunction with the Rillito River bank protection study (Reference 9), the computed values shown in Table 2.3a were used to estimate the total single-event scour depth. The individual scour computation sheets for each subreach, including a summary of the hydraulic properties used in the analysis, are provided in Appendix B. Each computation sheet shows the equation used and its source.

Table 2.3a Summary of the Without-Project Single-Event Scour Analysis

Reach	Applicable	Scour Components (ft)							Total
	Sections	General	Bed-Form	Bend	Local	Subtotal	Low-Flow	Long-Term	Depth
1	1 - 4	1.2	1.4	0.0	18.3	27.2	2.0	0.0	29.2
2	5 - 9	1.0	1.6	3.4	0.0	7.7	2.0	0.0	9.7
3	10 - 13	0.4	0.9	1.7	0.0	3.8	2.0	0.0	5.8
4	14 - 18	1.4	2.3	1.9	0.0	7.3	2.0	0.0	9.3
5	19 - 23	1.4	1.7	0.0	0.0	4.0	2.0	0.0	6.0
6	24 - 27	1.5	2.0	0.0	18.2	28.2	2.0	0.0	30.2

Notes: The safety factor is included in the subtotal depth.
Local scour shown in reaches 1 and 6 would primarily occur in the vicinity of the bridges

It should be noted that the long-term degradation depth for all subreaches was assumed to be zero. Although this may appear to be contrary to the results of the qualitative geomorphic analysis, which noted a degradation depth of approximately 3.0 feet at the upstream limit, it is a function of the results of a comparison made between the existing bed slope and the projected equilibrium slope as presented in Reference 8. The existing bed slope between the observed pivot point (Section 18) and the upstream limit of the study reach (Section 27) is approximately 0.32 percent. The projected equilibrium slope was determined to be 0.35 percent. Consequently, it was assumed that the upstream reach has achieved a relative state of equilibrium, based on the most current information available. It is interesting to note that based on the results of the qualitative geomorphic analysis the downstream reach showed a tendency towards aggradation. The existing slope within the downstream reach (Section 1 to Section 18) was determined to be approximately 0.39 percent. The projected equilibrium slope for the downstream reach was 0.41 percent. Again, it appears that the bed profile along downstream reach has also obtained a relative state of equilibrium.

One additional component of the scour/stability analysis involved a determination of the limiting meander potential. The results of the qualitative geomorphic analysis indicate that a potential for erosion and/or migration of the channel banks exists within the boundary of the geologic flood plain. However, hydraulic engineers recognize that a limiting meander potential also exists. If the meander potential is not limited by a physical feature (i.e., rock formation or similar geologic feature), it will be limited from a geometric standpoint, as pointed out in Reference 6, in that an upper limit of development exists at which point a cutoff eliminates the meander. Using the bank-full discharge of 17,000 cfs and an average top width of 380 feet, the computed upper limit of meandering relative to the study reach was determined to be approximately 1,600 feet along either the north or south bank of the Tanque Verde Creek (i.e., a total meander width of $\pm$3,200 feet).

With respect to the stability of the Craycroft Road bridge and the Sabino Canyon Road bridge, the results of the scour analysis indicate that the total scour potential is approximately 29 feet and 30 feet, respectively. These values include the addition of local scour at the bridge piers, but do not include abutment scour, since conditions conducive to abutment scour were not applicable along the study reach. According to the as-built plans for the bridges, the bottom of the bridge piles are set at approximately 2375.0 feet and 2409.0 feet, respectively. The existing flow line elevation of the Tanque Verde Creek at Craycroft Road is approximately 2422.0 feet. At Sabino Canyon Road, the flow line elevation is approximately 2462.0 feet. Therefore, approximately 18 feet of the Craycroft Road bridge piles and approximately 23 feet of the Sabino Canyon Road bridge piles will be below the anticipated scour zone. If this depth is adequate to retain stability during the flood hydrograph, the bridges can be considered stable.

In should be noted that the existing bank-protected reaches within the study reach have toe-downs on the order of ten feet. Since the maximum computed scour depth outside the 'zone of influence' associated with the bridge piers was 9.7 feet, this toe-down depth is adequate.

However, based on a review of the as-built plans for both bridges, the toe-down depth for the bank protection at Craycroft Road was limited to 13 feet, and the toe-down depth for the bank protection at Sabino Canyon Road was limited to 10 feet. To ensure that these toe-down depths would be adequate, the local scour 'zone of influence' associated with the bridge piers was estimated. If the vertical plane of the bank protection enters this zone, the toe-down depths for the bank protection must be increased to consider the overlapping influence of local scour from the adjacent piers.

Typically, this zone is assumed to resemble an inverted cone surrounding the pier. Based on a 3:1 side slope for the cone, a minimum toe-down depth of 10 feet for the bank protection, a maximum pier diameter of nine feet (i.e., a five-foot pier, plus four feet of debris), and a maximum scour depth of 30 feet at the bridge piers, the radius of the inverted base of the cone would be approximately 73.5 feet. Therefore, if the vertical plane for the bank protection, adjacent to the abutment, is less than 73.5 feet from the center-line of the nearest pier, additional toe-down depths are required to ensure the stability of the bank protection. However, since this threshold value is exceeded at both locations (i.e., the bank protection is more than 73.5 feet from the piers), the overlapping influence of pier scour need not be considered. Therefore, the toe-down depths for the bank protection beneath the bridges are adequate under existing (without-project) conditions.

With respect to the Pima County's concern that channel migration could result in damage to (1) the south approach to the Craycroft Road bridge; (2) an adjacent sewer interceptor; and (3) the neighboring subdivisions, the results of the qualitative geomorphic analysis do not support this concern, since the width of the confluence region exceeds the projected 650-foot width to be applied over the life of the project. In addition, the historic meander scar mentioned in Reference 2 is located approximately 1600 feet south of the south bank for the Tanque Verde Creek at the bridge crossing. The 1000-foot distance mentioned in Reference 2 applies to the south bank of the Pantano Wash. In addition, if some of the damages noted under existing conditions are caused by subsurface flows from the Tanque Verde Creek, the proposed bank protection project will not eliminate subsurface flows unless the toe-down depths are increased to prevent the conveyance of flow along this subterrian channel. Even if this could be accomplished, the embankment would still be subject to flows conveyed along the Pantano Wash. Therefore, it appears that the project as proposed will do little to address this specific problem area.

III. WITH-PROJECT CONDITIONS

3.1 Impact on the 100-Year Flood Plain

Using the design information provided in Reference 2, the without-project conditions HEC-2 model was revised to reflect the approximate alignment and top-of-bank elevations associated with the proposed project. The results of the analysis are summarized in Table 3.1a. A complete input/output listing is provided in Appendix C. The relative impact of the project is summarized in Table 3.1b.

The results of the analysis indicate that the project will, for the most part, eliminate overbank flooding along the south bank between Sections 9 and 17, with little or no adverse impact on adjacent properties. In addition, the width of the flood plain will be reduced at several locations. Although the majority of the reductions are less than 55 feet, reductions in excess of 100 feet occur at four locations. The maximum reduction noted was approximately 250 feet. However, there are no significant increases in the width of the flood plain. Although the project will produce significant increases in the water-surface elevations at selected locations, sufficient freeboard exists at these locations to prevent overtopping of the main channel. However, it is recommended that Pima County "fine-tune" the final design to minimize the increase. This can be accomplished by eliminating the bottleneck condition created in the immediate vicinity of Section 16.5.

Table 3.1a Summary of With-Project Floodplain Conditions

Section Number	Distance (1) (ft)	Water Surface Elevation (ft)	Max. Flow Depth (ft)	Top Width (ft)	Channel Velocity (fps)
1.0	100.0	2433.20	11.20	604	10.42
2.0	550.0	2434.18	10.18	911	10.14
3.0	1050.0	2435.36	8.86	930	10.32
4.0	1550.0	2437.11	9.11	1238	8.83
5.0	2000.0	2438.03	8.53	1472	9.63
6.0	2500.0	2439.54	7.54	1104	12.31
7.0	3000.0	2442.57	8.57	1090	11.52
8.0	3500.0	2444.56	8.56	815	13.26
9.0	4000.0	2447.64	9.64	944	8.28
10.0	4500.0	2448.62	8.62	1040	7.59
11.0	5000.0	2449.56	8.26	902	6.96
12.0	5500.0	2450.45	6.95	839	8.94
13.0	6000.0	2452.01	8.01	746	9.96
14.0	6470.0	2453.60	7.10	442	12.49
15.0	6970.0	2456.16	8.16	600	12.83
16.0	7490.0	2458.44	8.44	394	14.61
16.5	7790.0	2460.15	8.15	309	15.13
17.0	7990.0	2462.51	9.71	327	11.98
18.0	8490.0	2464.15	9.25	321	13.18
19.0	8990.0	2466.71	9.71	344	11.20
20.0	9490.0	2468.08	9.08	332	11.76
21.0	9990.0	2469.64	9.64	323	12.00
22.0	10490.0	2471.55	10.55	328	10.32
23.0	10710.0	2471.98	9.98	349	10.48
23.1	10730.0	2472.05	10.05	350	10.40
23.2	10850.0	2472.78	10.28	353	10.29
24.0	10870.0	2472.85	10.35	354	10.21
25.0	11370.0	2473.81	9.81	331	11.66
26.0	11870.0	2475.35	9.85	335	12.47
27.0	12370.0	2477.14	9.74	306	13.97

Notes: (1) Relative to the upstream face of the Craycroft Road bridge.

Table 3.1b Summary of the Relative Impact of the Project on the 100-Year Floodplain

	Change in Primary Flow Characteristics taken from the HEC-2 Analysis		
Section Number	Water Surface Elevation Δ (ft)	Flood Plain Top Width Δ (ft)	Main Channel Velocity Δ (fps)
1.0	0.00	0	-1.04
2.0	0.14	0	-3.65
3.0	-1.81	-206	2.57
4.0	-0.74	-55	0.82
5.0	-0.51	-35	0.80
6.0	-0.14	-14	1.09
7.0	0.35	36	-0.88
8.0	-0.15	-27	0.35
9.0	0.03	-5	-0.03
10.0	-0.14	-9	1.16
11.0	0.10	-245	0.80
12.0	0.21	-15	-0.26
13.0	0.03	8	-0.14
14.0	-0.05	-17	0.34
15.0	0.06	4	-0.22
16.0	-0.36	-190	4.08
16.5	0.59	-114	0.81
17.0	1.80	5	-3.11
18.0	-0.25	-1	0.39
19.0	-0.01	-0	0.02
20.0	0.00	-0	0.01
21.0	0.00	0	0.00
22.0	0.01	0	0.00
23.0	0.00	0	0.00
23.1	0.00	0	0.00
23.2	0.00	0	0.00
24.0	0.01	0	0.00
25.0	0.00	0	0.00
26.0	0.00	0	0.00
27.0	-0.01	0	0.00

3.2 Scour/Stability Impact

A scour analysis consistent with the one described in Section 2.3 was again performed using the hydraulic conditions associated with the project to determine the relative impact of the project. In addition, the results were used to determine if the toe-down depth for the proposed bank protection is adequate to ensure the overall stability of the project.

The results of the single-event scour analysis are summarized in Table 3.2a. The individual scour-computation sheets, including a summary of the hydraulic properties used in the analysis, are provided in Appendix D.

Table 3.2a Summary of the With-Project Single-Event Scour Analysis

Reach	Applicable Sections	Scour Components (ft)							Total Depth
		General	Bed-Form	Bend	Local	Subtotal	Low-Flow	Long-Term	
1	1 - 4	1.2	1.4	0.0	17.8	26.4	2.0	0.0	28.4
2	5 - 9	1.1	1.7	3.4	0.0	7.9	2.0	0.0	9.9
3	10 - 13	0.5	1.0	1.7	0.0	4.2	2.0	0.0	6.2
4	14 - 18	1.5	2.5	2.0	0.0	7.8	2.0	0.0	9.8
5	19 - 23	1.4	1.7	0.0	0.0	4.0	2.0	0.0	6.0
6	24 - 27	1.5	2.0	0.0	18.2	28.2	2.0	0.0	30.2

Note: The safety factor is included in the subtotal depth.

Based on the results of the scour analysis, the minimum recommended toe-down depth for the bank protection would be ten feet. The average toe-down depth proposed by Pima County is eight feet. Since it is recommended that the ten-foot depth be applied, the estimated cost for the bank protection should be increased accordingly. However, the additional cost associated with the additional toe-down requirement could be offset somewhat by reducing the proposed top-of-bank elevation of the bank protection along the golf course. Since overbank flooding under existing (without-project) conditions does not result in the inundation of any residential structures along the south bank, it is not necessary to contain the 100-year discharge at this location. Consequently, the preliminary top-of-bank profile provided in Reference 2 could be lowered to reduce the quantity of material required for the bank protection. However, it is unlikely that a reduction in the top-of-bank profile will completely offset the additional quantity of material that will be required to accommodate the recommended toe-down depths.

Since the project will not significantly alter the flow characteristics along the study reach, the overall sediment-transport characteristics should remain essentially unchanged. Therefore, it is not anticipated that the project will increase the degradation or aggradation tendency either within or immediately upstream or downstream of the study reach.

3.3 Additional Stability Considerations

Overall, the proposed project will have little or no adverse impact on the stability of existing bank protection or channel features either upstream or downstream of the project reach. However, additional stability questions can be raised in conjunction with the proposed project. These include the increased erosion potential to the proposed riparian preserve and the potential for the project's bank protection to be outflanked at the downstream limit by bank erosion and/or migration along the Pantano Wash.

There are plenty of examples locally of the relative impact of piece-meal bank protection on the adjacent unprotected banks. Although the proposed riparian preserve will provide an adequate erosion buffer for neighboring properties, it is safe to assume that the erosion potential for the area will be increased as a result of the project. If it is intended that the area be maintained periodically to retain its natural character, then the cost of the project should be increased to include either maintenance of the area or any recreational features associated with the area. If preservation of the area, as it currently exists, is one of Pima County's project goals, then they should consider the possibility of providing, at some point in the immediate future, low-level bank protection along the channel side of the preserve in order to prevent its ultimate demise due to erosion.

Previous geomorphic studies of the Pantano Wash, including References 1 and 8, have determined that the erosion potential between the Rillito River confluence and Tanque Verde Road is somewhat similar to the erosion potential associated with the study reach. Therefore, it is safe to assume that the downstream limit of the proposed bank protection will ultimately be damaged as a result of bank erosion along the Pantano Wash. In lieu of providing bank protection along the entire south bank, including the confluence region, Pima County should consider the possibility of terminating the proposed bank protection project at the downstream limit of the properties that are currently developed. The adopted Rillito Corridor Study plan (Reference 1) indicates that the confluence region will ultimately be set aside as a regional park. Therefore, the confluence could be added to the project's overall riparian preserve area, in which case, it too would serve as an erosion buffer for the south approach to the Craycroft Road bridge.

IV. SUMMARY OF RESULTS

Based on the results of the qualitative geomorphic analysis, the average annual erosion rate for a fifty-year period is approximately 13 feet per year. The approach used in the determination of this rate is consistent with the methodology outlined in Reference 1. During any given flow event that approximates or exceeds the 10-year event, the unprotected banks can be expected to migrate on the order of 100 to 200 feet. The limiting meander potential was determined to be either the boundary of the geologic flood plain or a distance equal to approximately 1,600 feet from the projected centerline of the meander loop. Along the project reach, the centerline of the loop corresponds to a straight line projected upstream from the centerline of the Craycroft Road bridge crossing to the centerline of the channel at the downstream limit of the existing bank protection (i.e., Section 17 on Figure 4). Consequently, the limiting meander potential for the north bank corresponds to the northern boundary of the geologic flood plain. The limiting meander potential for the south bank is an imaginary line located approximately 1,600 feet south of the projected centerline of the meander loop. Since the south bank is located approximately 500 feet from this centerline, the limiting meander potential for the south bank is approximately 1,100 feet.

The results of the hydraulic analysis—in combination with the single-event scour analysis, the long-term degradation analysis, and the qualitative geomorphic analysis—indicate that the Craycroft Road bridge, the existing bank protection downstream of Craycroft Road, and the Sabino Canyon Road bridge are stable under both existing (without-project) and with-project conditions. In addition, the results of the 100-year overflow analysis indicate that little or no flood hazards exist within the study area for both existing (without-project) and with-project conditions. The extent of flooding noted is limited to the Tucson Country Club golf course, the rear yards of some developed lots within the associated subdivision, and the undeveloped properties that flank both sides of the existing watercourse.

The results of the overall analysis do not support Pima County's concern that the south approach to the Craycroft Road bridge will be undermined and damaged from channel migration along the Tanque Verde Creek. It appears that this area possess a greater risk of inundation and damage from erosion due to flows conveyed along the Pantano Wash than from the Tanque Verde Creek.

The proposed project will effectively curtail future damages from erosion along the unprotected banks and the proposed riparian preserve will act as an effective erosion buffer for properties located along the northern limit of the geologic flood plain. However, portions of the proposed project may be subject to failure from bank erosion along the Pantano Wash. In addition, if the riparian preserve is not afforded some protection from channel migration, any recreational amenities within the area will potentially be lost due to streambank erosion.

V. REFERENCES

1. U.S. Army Corps of Engineers, "Rillito River & Associated Streams, Survey Report & Environmental Assessment, Tucson, Arizona," Los Angeles District, Revised February 13, 1987.

2. Pima County, "Rillito River & Associated Streams, Bank Stabilization and Riparian Area Preserve, Tanque Verde Creek," Department of Transportation and Flood Control District, Flood Control Engineering Division, December 1996.

3. U.S. Geological Survey, "Water Resources Data - Arizona, Water Year 1993," Water-Data Report AZ 93-1, Water Resources Division, Tucson, Arizona.

4. Federal Emergency Management Agency, "Flood Insurance Study, Pima County, Arizona, Unincorporated Areas," Community Number - 040073, September 30, 1992.

5. City of Tucson, "Standards Manual for Drainage Design and Floodplain Management in Tucson, Arizona," Department of Transportation, Engineering Division, December 1989.

6. Morris, H.M., and Wiggert, J.M., Applied Hydraulics in Engineering, 2nd Edition, 1972.

7. Federal Highway Administration, "Evaluating Scour at Bridges," HEC-18, Second Edition, April 1993.

8. Simons, Li & Associates, Inc., "Sediment Transport Analysis of Rillito River and Tributaries for the Tucson Urban Study - Final Report," April 9, 1982.

9. U.S. Army Corps of Engineers, "Design Memorandum - Rillito River, Tucson, Arizona - Bank Protection," Los Angeles District, October 1992.

10. U.S. Army Corps of Engineers, "HEC-2: Water Surface Profiles, Users Manual," September, 1990.

APPENDIX A

HEC-2 INPUT/OUTPUT LISTING, EXISTING (WITHOUT-PROJECT) CONDITIONS

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 *********************************************                                   ****************************************
 *  HEC-2 WATER SURFACE PROFILES             *                                   *  U.S. ARMY CORPS OF ENGINEERS        *
 *********************************************                                   ****************************************

                                                  X     X  XXXXXXX   XXXXX           XXXXX
                                                  X     X  X        X     X         X     X
                                                  X     X  X        X                     X
                                                  XXXXXXX  XXXX     X         XXXXX   XXXXX
                                                  X     X  X        X               X
                                                  X     X  X        X     X         X
                                                  X     X  XXXXXXX   XXXXX          XXXXXXX
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                                                                          THIS RUN EXECUTED 14APR98    08:37:06
 **************************************
 HEC-2 WATER SURFACE PROFILES

 Version    4.6.2;  May 1991
 **************************************


 T1      LIMITED RE-EVALUATION REPORT FOR THE PROPOSED RILLITO RIVER AND
 T2      ASSOCIATED STREAMS, BANK STABILIZATION AND RIPARIAN AREA PRESERVE,
 T3      TANQUE VERDE CREEK (CRAYCROFT RD BRIDGE TO SABINO CANYON RD BRIDGE)
 T4      EXISTING CONDITIONS - APRIL 1998 - SLA JOB #: PAZ-COE32-TASK 2

 J1  ICHECK     INQ       NINV      IDIR      STRT      METRIC     HVINS      Q        WSEL       FQ

       -1         2         0         0     0.0000        0           0        0    2433.2        0

 J2  NPROF     IPLOT     PRFVS     XSECV     XSECH      FN       ALLDC      IBW      CHNIM      ITRACE

       1                  -1                                                                    15


 J3  VARIABLE CODES FOR SUMMARY PRINTOUT

      38         1        55        26        56        13        14        15         8         4
      53        54         0        38         1         2         3        11        12        42
       5        33        39        67        68

 J6  IHLEQ     ICOPY     SUBDIV    STRTDS    RMILE

       1


 NC     0.08      0.08     0.030       0.1       0.3
 QT        1     34000
 X1        1        11      1200      1490         0         0         0
 GR     2432       910      2432      1060      2430      1200      2422      1230      2422      1420
 GR     2424      1460      2432      1490      2434      1530      2436      1580      2440      1630
 GR     2450      1700

 X1        2        19      1430      1685       350       520       450
 X3                                  820
 GR     2430        40      2432       240      2434       525      2436       590      2438       600
 GR     2434       640      2428       660      2426       690      2426       800      2434       820
 GR     2434      1140      2432      1370      2430      1430      2424      1450      2424      1650
 GR     2430      1685      2432      1720      2434      1730      2440      1750
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 X1        3        27      1360      1790       420       500       500
 X3                                  670
 GR     2432       160      2434       340      2436       430      2440       450      2438       460
 GR     2436       490      2430       500      2428       530      2428       660      2430       665
 GR     2436       670      2436       830      2434       950      2434      1240      2433      1280
 GR     2433      1320      2432      1360      2430      1390      2428      1405      2427      1470
 GR   2426.5      1520      2428      1610      2427      1700      2427      1740      2428      1765
 GR     2432      1790      2440      1815

 X1        4        24      1330      1750       500       570       500
 X3                                  640
 GR     2434       320      2440       360      2440       380      2438       400      2430       420
 GR     2428       430      2428       540      2434       560      2436       570      2438       640
 GR     2436       780      2434       900      2434      1330      2430      1340      2428      1430
 GR     2429      1545    2429.5      1570      2429      1620      2429      1660      2430      1740
 GR     2434      1750      2434      1930      2440      1950      2450      1980

 X1        5        22      1290      1710       500       450       450
 X3                                  585
 GR     2441       420      2441       550      2440       600      2436       720      2435       750
 GR     2435      1100      2436      1250      2436      1290      2430      1310    2429.5      1330
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GR	2429.5	1450	2430	1485	2432	1650	2434	1710	2436	1750
GR	2436	1770	2436	1810	2436	1840	2436	1930	2436	2050
GR	2440	2210	2442	2260						
X1	6	16	900	1340	550	500	500			
GR	2444	200	2444	420	2442	570	2440	610	2438	680
GR	2434	900	2434	905	2432	930	2432	1060	2434	1180
GR	2436	1330	2438	1340	2438	1630	2440	1760	2442	1910
GR	2450	2020								
X1	7	20	740	1170	500	500	500			
GR	2446	210	2446	330	2444	420	2443.5	500	2443	560
GR	2442	660	2442	661	2440.5	740	2435	750	2434	850
GR	2434	890	2436	900	2437.2	950	2437.2	1040	2438	1090
GR	2438	1160	2440	1170	2440	1560	2440	1685	2450	1715
X1	8	19	790	1140	530	450	500			
GR	2450	380	2448	420	2446	560	2444	730	2443	740
GR	2443	790	2437	800	2436	880	2436	930	2436.5	970
GR	2436.5	1030	2438	1060	2440	1070	2442	1140	2442.2	1270
GR	2444	1450	2446	1620	2448	1770	2450	1780		
NC	.06	.08	.030	.1	.3					
X1	9	21	730	1180	500	500	500			
GR	2454	30	2452	380	2450	580	2448	700	2446	730
GR	2440	740	2440	930	2438	980	2438	1030	2438.5	1130
GR	2440	1170	2442	1175	2444	1180	2443.5	1270	2443.5	1430
GR	2443.5	1440	2444	1510	2446	1630	2448	1660	2450	1700
GR	2460	1750								

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X1	10	15	540	1310	500	500	500			
GR	2454	110	2452	380	2450	440	2448	540	2442	690
GR	2443	810	2443	940	2442	985	2440	1000	2440	1280
GR	2444	1310	2446	1460	2448	1540	2450	1570	2452	1600
X1	11	25	560	1420	500	500	500			
GR	2456	20	2454	200	2452	390	2450	410	2448	560
GR	2444	610	2444	650	2444	665	2444	675	2444	695
GR	2444	720	2444	870	2445	900	2445	930	2444	970
GR	2442	990	2441.3	1010	2442	1210	2441.5	1310	2441.5	1340
GR	2442	1400	2448	1420	2448	1510	2450	1630	2456	1660
X1	12	27	720	1430	500	500	500			
X3	10			720						
GR	2458	30	2456	180	2454	260	2452	290	2452	540
GR	2450	650	2450	720	2447	725	2447	900	2446	930
GR	2444	940	2444	1080	2444.5	1120	2444.5	1180	2444	1240
GR	2443.5	1300	2443.5	1350	2444	1390	2446	1410	2450	1430
GR	2450	1500	2450	1530	2450	1565	2450	1570	2452	1600
GR	2454	1710	2458	1730						
X1	13	21	800	1380	500	500	500			
X3	10			795						
GR	2458	0	2456	170	2454	285	2452	390	2450	430
GR	2450	620	2450	650	2452	680	2452	760	2456	790
GR	2456	800	2450	830	2448	920	2446	1010	2444	1100
GR	2444	1230	2446	1350	2450	1380	2452	1560	2454	1690
GR	2458	1850								
X1	14	20	690	1175	420	520	470			
X3	10			690						
GR	2460	120	2452	190	2452	540	2454	660	2460	690
GR	2450	730	2448	740	2447	830	2447	910	2448	950
GR	2448	1010	2446.5	1060	2446.5	1130	2448	1160	2454	1175
GR	2456	1200	2456	1340	2456	1460	2456	1480	2460	1800
X1	15	23	790	1160	500	500	500			
X3	10			590						
GR	2460	90	2454	130	2454	300	2456	310	2456	490
GR	2460	520	2460	560	2458	640	2456	760	2456	790
GR	2450	800	2448	860	2448	890	2449.5	950	2449.5	990
GR	2448	1050	2448	1080	2450	1150	2454	1160	2454	1290
GR	2456	1350	2458	1352	2460	1490				
X1	16	28	810	1205	550	480	520			
X3	10			700						
GR	2464	215	2460	260	2458	410	2456	430	2454	550
GR	2454	570	2454	590	2456	640	2460	660	2462	670
GR	2462	705	2460	710	2458	715	2458	810	2452	820
GR	2451	870	2451	930	2450	970	2450	1000	2451	1050
GR	2450.6	1100	2450.6	1120	2452	1200	2456	1205	2456	1290
GR	2460	1300	2462	1420	2464	1920				

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 X1     16.5          8        830       1190        300        300        300          0          0          0
 GR   2460.0      760.0     2458.0      770.0     2458.0      830.0     2452.5      850.0     2452.0      945.0
 GR   2453.0     1090.0     2454.0     1180.0     2464.0     1190.0

 X1       17         15        840       1190        200        200        200
 X3       10                             830
 GR     2464        180       2462        260       2462        690       2460        720       2460        760
 GR     2464        800       2466        820       2466        840       2464        855       2454        860
 GR   2452.8        920     2453.1       1050       2454       1110       2456       1170       2466       1190

   VENTANA CANYON WASH TRIBUTARY

 X1       18         15        850       1185        500        500        500
 X3       10                             845
 GR     2466          0       2466        500       2466        680       2464        730       2464        830
 GR     2468        840       2468        850       2462        860       2460        870       2456        875
 GR   2454.9        970     2454.9       1030       2456       1100       2458       1170       2470       1185

 X1       19         10        810       1180        500        500        500
 GR     2474        790       2472        810       2458        850       2457        860       2457       1080
 GR     2458       1100       2458       1150       2472       1180       2472       1370       2474       1460

 X1       20         22        820       1160        500        500        500
 X3       10                             810
 GR     2474        390       2472        510       2470        525       2468        540       2468        560
 GR     2470        580       2470        720       2472        720       2472        820       2460        840
 GR     2459        850       2459       1145       2460       1150       2470       1160       2472       1185
 GR     2470       1190       2472       1200       2472       1290       2470       1300       2474       1340
 GR     2476       1520       2478       1690

 X1       21         17        830       1170        500        500        500
 X3       10                             820
 GR     2474        490       2472        500       2472        760       2470        790       2470        800
 GR     2472        810       2472        830       2470        840       2460        860       2460       1000
 GR   2460.5       1010     2460.5       1140       2472       1170       2472       1185       2470       1200
 GR     2470       1230       2476       1280

 X1       22         13        830       1180        500        500        500
 X3       10                             825
 GR     2476        650       2474        700       2474        800       2476        820       2476        830
 GR     2462        850       2461        870       2461       1150       2476       1170       2476       1180
 GR     2474       1200       2474       1250       2476       1310

 X1       23          6        825       1160        220        220        220
 GR     2480        790       2470        825       2462        840       2462       1150       2470       1160
 GR     2478       1190

   SABINO CANYON RD BRIDGE
1
   14APR98     08:37:06                                                                                PAGE     5


 X1     23.1                                          20         20         20
 X3       10

 SB     1.25        1.6        2.6        400        315         24       5693          1     2462.5       2462
 X1     23.2          8        800       1160        120        120        120
 X2                              1     2480.9    2486.97
 X3       10
 GR     2480        760       2478        800       2463        830     2462.5        850     2462.5       1050
 GR     2464       1140       2472       1160       2480       1200

 X1       24                                          20         20         20

 X1       25          7        830       1170        500        500        500
 GR     2476        830       2466        840     2464.7        860     2464.9        940       2464       1110
 GR     2466       1150       2478       1170

 X1       26         11        820       1170        500        500        500
 GR     2482        800       2480        820       2468        840     2466.5       1025       2466       1060
 GR   2465.5       1080       2466       1115       2468       1150       2480       1170       2480       1190
 GR     2484       1200

 X1       27          9        840       1175        500        500        500
 GR     2482        790       2480        820       2480        840       2468        920     2467.4        960
 GR   2467.4       1030       2468       1080       2470       1150       2482       1175
1
   14APR98     08:37:06                                                                                PAGE     6


    SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
    Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
    TIME       VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
    SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST


 *PROF 1
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 IHLEQ = 1.  THEREFORE FRICTION LOSS (HL) IS CALCULATED AS A FUNCTION OF
 PROFILE TYPE, WHICH CAN VARY FROM REACH TO REACH.  SEE DOCUMENTATION FOR
 DETAILS.
0

 CCHV=     .100 CEHV=     .300
 *SECNO 1.000
 3280 CROSS SECTION      1.00 EXTENDED      1.20 FEET

      1.000     11.20   2433.20       .00   2433.20   2435.20      2.00       .00       .00   2430.00
    34000.0     671.4   33319.1       9.5     488.0    2908.0      14.4        .0        .0   2432.00
        .00      1.38     11.46       .66      .080      .030      .080      .000   2422.00    910.00
    .002499        0.        0.        0.         0         0         0       .00    604.00   1514.00


 FLOW DISTRIBUTION FOR SECNO=      1.00          CWSEL=   2433.20

 STA=      910.    1060.    1200.    1490.    1514.
   PER Q=        .6       1.4      98.0        .0
    AREA=    180.0    308.0    2908.0      14.4
     VEL=      1.0      1.6      11.5        .7
   DEPTH=      1.2      2.2      10.0        .6

 *SECNO 2.000

 3301 HV CHANGED MORE THAN HVINS


 3470 ENCROACHMENT STATIONS=      820.0    1750.0  TYPE=      1  TARGET=      -820.000
      2.000     10.04   2434.04   2433.09       .00   2436.90      2.87      1.44       .26   2430.00
    34000.0     729.8   32998.8     271.4     431.0    2393.8     116.6      31.9       6.8   2430.00
        .01      1.69     13.79      2.33      .080      .030      .080      .000   2424.00    820.00
    .003939      350.      450.      520.         4        11         0       .00    910.11   1730.11


 FLOW DISTRIBUTION FOR SECNO=      2.00          CWSEL=   2434.04

 STA=      820.    1370.    1430.    1685.    1720.    1730.
   PER Q=        .8       1.3      97.1        .8        .0
    AREA=    248.9    182.1    2393.8     106.2      10.3
     VEL=      1.1      2.4      13.8       2.4       1.2
   DEPTH=       .5      3.0       9.4       3.0       1.0

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     SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
     Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
     TIME       VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
     SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST


 *SECNO 3.000

 3301 HV CHANGED MORE THAN HVINS


 3302 WARNING:  CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE,  KRATIO =  1.79


 3470 ENCROACHMENT STATIONS=      670.0    1815.0  TYPE=      1  TARGET=      -670.000
      3.000     10.67   2437.17       .00       .00   2438.03       .86       .93       .20   2432.00
    34000.0    2564.8   31385.5      49.7    1867.1    4048.0      41.8      80.8      17.4   2432.00
        .03      1.37      7.75      1.19      .080      .030      .080      .000   2426.50    670.00
    .001235      420.      500.      500.         3         0         0       .00   1136.15   1806.15


 FLOW DISTRIBUTION FOR SECNO=      3.00          CWSEL=   2437.17

 STA=      670.     830.     950.    1240.    1280.    1320.    1360.    1790.    1806.
   PER Q=        .4        .8       3.8        .7        .8       1.0      92.3        .1
    AREA=    187.1    260.4     919.2     146.8     166.8     186.8    4048.0      41.8
     VEL=       .7      1.1       1.4       1.6       1.7       1.8       7.8       1.2
   DEPTH=      1.2      2.2       3.2       3.7       4.2       4.7       9.4       2.6

 *SECNO 4.000

 3470 ENCROACHMENT STATIONS=      640.0    1980.0  TYPE=      1  TARGET=      -640.000
      4.000      9.85   2437.85       .00       .00   2438.71       .86       .68       .00   2434.00
    34000.0    3470.3   29289.8    1239.8    2121.0    3658.0     718.8     152.9      31.5   2434.00
        .05      1.64      8.01      1.72      .080      .030      .080      .000   2428.00    650.12
    .001465      500.      500.      570.         2         0         0       .00   1292.73   1942.85


 FLOW DISTRIBUTION FOR SECNO=      4.00          CWSEL=   2437.85

 STA=      650.     780.     900.    1330.    1750.    1930.    1943.
   PER Q=        .2       1.4       8.5      86.1       3.6        .1
    AREA=    120.5    342.7    1657.9    3658.0     694.0      24.8
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     VEL=        .7        1.4        1.7        8.0        1.7        1.1
   DEPTH=        .9        2.9        3.9        8.7        3.9        1.9

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   14APR98       08:37:06                                                                                      PAGE      8

     SECNO       DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
     Q           QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
     TIME        VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
     SLOPE       XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST


 *SECNO 5.000

 3470 ENCROACHMENT STATIONS=       585.0     2260.0  TYPE=       1  TARGET=       -585.000
      5.000       9.04    2438.54        .00        .00    2439.57       1.03        .81        .05    2436.00
    34000.0     3659.9    28735.8     1604.3     1982.4     3254.1     1031.1      221.2       46.7    2434.00
        .06       1.85       8.83       1.56       .080       .030       .080       .000    2429.50     643.90
    .002079       500.       450.       450.          2          0          0        .00    1507.56    2151.46

 FLOW DISTRIBUTION FOR SECNO=       5.00           CWSEL=    2438.54

 STA=      644.      1100.      1290.      1710.      2050.      2151.
   PER Q=       7.9        2.8       84.5        4.3         .4
    AREA=    1425.4      557.0     3254.1      902.5      128.7
     VEL=       1.9        1.7        8.8        1.6        1.0
   DEPTH=       3.1        2.9        7.7        2.7        1.3

 *SECNO 6.000

 3301 HV CHANGED MORE THAN HVINS


 3302 WARNING:  CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE,  KRATIO =    .68

      6.000       7.68    2439.68    2439.18        .00    2441.45       1.77       1.66        .22    2434.00
    34000.0     2464.9    30572.5      962.6      859.3     2724.7      579.4      282.7       62.3    2438.00
        .08       2.87      11.22       1.66       .080       .030       .080       .000    2432.00     621.16
    .004516       550.       500.       500.          4         15          0        .00    1118.12    1739.27

 FLOW DISTRIBUTION FOR SECNO=       6.00           CWSEL=    2439.68

 STA=      621.       680.       900.      1340.      1630.      1739.
   PER Q=        .2        7.1       89.9        2.5         .3
    AREA=      49.5      809.9     2724.7      487.5       91.9
     VEL=       1.1        3.0       11.2        1.8        1.1
   DEPTH=        .8        3.7        6.2        1.7         .8

 *SECNO 7.000
 7185 MINIMUM SPECIFIC ENERGY
 3720 CRITICAL DEPTH ASSUMED
1
   14APR98       08:37:06                                                                                      PAGE      9

     SECNO       DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
     Q           QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
     TIME        VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
     SLOPE       XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST


      7.000       8.22    2442.22    2442.22        .00    2444.41       2.19       3.00       -.27    2440.50
    34000.0      108.2    31088.6     2803.2       78.9     2507.5     1148.8      328.0       74.8    2440.00
        .09       1.37      12.40       2.44       .080       .030       .080       .000    2434.00     638.37
    .006002       500.       500.       500.          2          8          0        .00    1053.28    1691.65

 FLOW DISTRIBUTION FOR SECNO=       7.00           CWSEL=    2442.22

 STA=      638.       740.      1170.      1560.      1685.      1692.
   PER Q=        .3       91.4        6.2        2.0         .0
    AREA=      78.9     2507.5      864.4      277.0        7.4
     VEL=       1.4       12.4        2.4        2.4        1.5
   DEPTH=        .8        5.8        2.2        2.2        1.1

 *SECNO 8.000
      8.000       8.71    2444.71    2444.45        .00    2447.19       2.47       2.69        .08    2443.00
    34000.0      192.3    32430.2     1377.5      119.4     2512.2      651.8      367.3       85.2    2442.00
        .10       1.61      12.91       2.11       .080       .030       .080       .000    2436.00     669.36
    .004941       530.       500.       450.          6          8          0        .00     841.27    1510.64

 FLOW DISTRIBUTION FOR SECNO=       8.00           CWSEL=    2444.71

 STA=      669.       730.       740.       790.      1140.      1270.      1450.      1511.
   PER Q=        .0         .1         .5       95.4        2.5        1.5         .0
    AREA=      21.6       12.1       85.7     2512.2      339.7      290.4       21.6
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    VEL=        .7       1.5       1.9      12.9       2.5       1.8        .7
  DEPTH=        .4       1.2       1.7       7.2       2.6       1.6        .4

 CCHV=     .100 CEHV=      .300
 *SECNO 9.000

 3301 HV CHANGED MORE THAN HVINS


 3302 WARNING:  CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE,  KRATIO =   1.71

     9.000      9.61   2447.61       .00       .00   2448.59       .98      1.26       .15   2446.00
   34000.0      17.1   30986.4    2996.5      19.5    3730.1    1649.6     417.2      95.5   2444.00
       .12       .88      8.31      1.82      .060      .030      .080      .000   2438.00    705.83
   .001689      500.      500.      500.         2         0         0       .00    948.34   1654.17
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1
     14APR98      08:37:06                                                                                              PAGE    10

      SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
      Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
      TIME       VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
      SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST

 FLOW DISTRIBUTION FOR SECNO=        9.00           CWSEL=    2447.61

 STA=      706.      730.     1180.     1270.     1430.     1440.     1510.     1630.     1654.
   PER Q=        .1      91.1       1.9       3.8        .2       1.5       1.3        .0
    AREA=      19.5    3730.1     347.5     657.8      41.1     270.3     313.4      19.5
     VEL=        .9       8.3       1.9       2.0       2.0       1.9       1.4        .7
   DEPTH=        .8       8.3       3.9       4.1       4.1       3.9       2.6        .8

 *SECNO 10.000
    10.000      8.76   2448.76       .00       .00   2449.38       .62       .75       .04   2448.00
   34000.0       6.9   32921.0    1072.1      14.4    5116.4     708.7     481.7     107.0   2444.00
       .14       .48      6.43      1.51      .060      .030      .080      .000   2440.00    502.08
   .001352      500.      500.      500.         2         0         0       .00   1049.29   1551.37

 FLOW DISTRIBUTION FOR SECNO=       10.00           CWSEL=    2448.76

 STA=      502.      540.     1310.     1460.     1540.     1551.
   PER Q=        .0      96.8       2.7        .4        .0
    AREA=      14.4    5116.4     563.7     140.7       4.3
     VEL=        .5       6.4       1.7       1.0        .4
   DEPTH=        .4       6.6       3.8       1.8        .4

 *SECNO 11.000
    11.000      8.16   2449.46       .00       .00   2450.05       .59       .67       .00   2448.00
   34000.0      58.4   33792.6     149.1      80.2    5484.9     195.8     548.3     119.6   2448.00
       .16       .73      6.16       .76      .060      .030      .080      .000   2441.30    450.30
   .001310      500.      500.      500.         2         0         0       .00   1147.46   1597.76

 FLOW DISTRIBUTION FOR SECNO=       11.00           CWSEL=    2449.46

 STA=      450.      560.     1420.     1510.     1598.
   PER Q=        .2      99.4        .3        .1
    AREA=      80.2    5484.9     131.6      64.2
     VEL=        .7       6.2        .9        .5
   DEPTH=        .7       6.4       1.5        .7

 *SECNO 12.000
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1
     14APR98      08:37:06                                                                                              PAGE    11

      SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
      Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
      TIME       VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
      SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST


 3301 HV CHANGED MORE THAN HVINS


 3302 WARNING:  CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE,  KRATIO =    .58


 3470 ENCROACHMENT STATIONS=       720.0     1730.0  TYPE=       1  TARGET=      -720.000
    12.000      6.74   2450.24       .00       .00   2451.56      1.31      1.29       .22   2450.00
   34000.0        .0   33984.9      15.1        .0    3693.1      34.1     602.7     131.1   2450.00
       .18       .00      9.20       .44      .000      .030      .080      .000   2443.50    720.00
   .003842      500.      500.      500.         2         0         0       .00    853.60   1573.60
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 FLOW DISTRIBUTION FOR SECNO=      12.00          CWSEL=   2450.24

 STA=      720.    1430.    1500.    1565.    1574.
   PER Q=     100.0        .0        .0        .0
    AREA=    3693.1      16.8      15.6       1.6
     VEL=       9.2        .4        .4        .4
   DEPTH=       5.2        .2        .2        .2

 *SECNO 13.000

 3470 ENCROACHMENT STATIONS=      795.0    1850.0  TYPE=      1  TARGET=     -795.000

 3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA=      2456.00 ELREA=      2450.00

     13.000       7.98   2451.98       .00       .00   2453.55      1.57      1.92       .08   2456.00
    34000.0         .0   33799.3     200.7        .0    3346.9     175.8     644.3     140.2   2450.00
        .19        .00     10.10      1.14      .000      .030      .080      .000   2444.00    820.12
    .003836       500.      500.      500.         2         0         0       .00    737.77   1557.89


 FLOW DISTRIBUTION FOR SECNO=      13.00          CWSEL=   2451.98

 STA=      820.    1380.    1558.
   PER Q=      99.4        .6
    AREA=    3346.9     175.8
     VEL=      10.1       1.1
   DEPTH=       6.0       1.0

1
    14APR98       08:37:06                                                                          PAGE    12


      SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
      Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
      TIME       VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
      SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST


 *SECNO 14.000

 3301 HV CHANGED MORE THAN HVINS


 3470 ENCROACHMENT STATIONS=      690.0    1800.0  TYPE=      1  TARGET=     -690.000

 3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA=      2460.00 ELREA=      2454.00

     14.000       7.15   2453.65       .00       .00   2455.95      2.29      2.18       .22   2460.00
    34000.0         .0   34000.0        .0        .0    2797.3        .0     678.5     146.7   2454.00
        .20        .00     12.15       .00      .000      .030      .000      .000   2446.50    715.39
    .005433       420.      470.      520.         2         0         0       .00    458.74   1174.13


 FLOW DISTRIBUTION FOR SECNO=      14.00          CWSEL=   2453.65

 STA=      715.    1175.
   PER Q=     100.0
    AREA=    2797.3
     VEL=      12.2
   DEPTH=       6.1

 *SECNO 15.000

 3470 ENCROACHMENT STATIONS=      590.0    1490.0  TYPE=      1  TARGET=     -590.000
     15.000       8.10   2456.10   2455.50       .00   2458.55      2.45      2.56       .05   2456.00
    34000.0        1.3   33326.0     672.7       3.5    2629.2     340.1     711.6     152.8   2454.00
        .21        .37     12.68      1.98      .060      .030      .080      .000   2448.00    753.64
    .004836       500.      500.      500.         4         8         0       .00    596.46   1350.11


 FLOW DISTRIBUTION FOR SECNO=      15.00          CWSEL=   2456.10

 STA=      754.     790.    1160.    1290.    1350.
   PER Q=        .0      98.0       1.7        .3
    AREA=       3.5    2629.2     273.8      66.4
     VEL=        .4      12.7       2.1       1.4
   DEPTH=        .1       7.1       2.1       1.1

1
    14APR98       08:37:06                                                                          PAGE    13


      SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
      Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
      TIME       VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
      SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST


 *SECNO 16.000
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 3301 HV CHANGED MORE THAN HVINS


 3470 ENCROACHMENT STATIONS=   `    700.0    1920.0  TYPE=       1  TARGET=       -700.000
      16.000       8.80    2458.80        .00        .00    2460.61       1.81       1.99        .06    2458.00
     34000.0       91.1    33403.2      505.6       76.4     3068.4      247.4      749.4      159.8    2456.00
         .23       1.19      10.89       2.04       .060       .030       .080       .000    2450.00     713.01
     .003172       550.       520.       480.          2          0          0        .00     583.98    1296.99


 FLOW DISTRIBUTION FOR SECNO=      16.00          CWSEL=    2458.80

 STA=      713.      810.     1205.     1290.     1297.
   PER Q=        .3      98.2       1.5        .0
    AREA=      76.4    3068.4     237.7       9.8
     VEL=       1.2      10.9       2.1       1.2
   DEPTH=        .8       7.8       2.8       1.4

 *SECNO 16.500

 3301 HV CHANGED MORE THAN HVINS

 7185 MINIMUM SPECIFIC ENERGY
 3720 CRITICAL DEPTH ASSUMED
      16.500       7.56    2459.56    2459.56        .00    2462.70       3.14       2.01       -.13    2458.00
     34000.0      265.1    33734.9         .0       99.5     2364.4         .0      769.5      163.2    2464.00
         .23       2.66      14.27        .00       .060       .030       .000       .000    2452.00     762.21
     .006710       300.       300.       300.          2         11          0        .00     423.35    1185.56


 FLOW DISTRIBUTION FOR SECNO=      16.50          CWSEL=    2459.56

 STA=      762.      770.      830.     1190.
   PER Q=        .0        .7      99.2
    AREA=       6.1      93.5    2364.4
     VEL=       1.7       2.7      14.3
   DEPTH=        .8       1.6       6.6

1
   14APR98      08:37:06                                                                                PAGE  14

     SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
     Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
     TIME       VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
     SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST


 *SECNO 17.000
 7185 MINIMUM SPECIFIC ENERGY
 3720 CRITICAL DEPTH ASSUMED

 3470 ENCROACHMENT STATIONS=       830.0    1190.0  TYPE=       1  TARGET=       -830.000

 3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA=       2466.00 ELREA=     100000.00

      17.000       7.91    2460.71    2460.71        .00    2464.25       3.54       1.42        .08    2466.00
     34000.0         .0    34000.0         .0         .0     2252.5         .0      780.4      164.9 100000.00
         .24        .00      15.09        .00       .000       .030       .000       .000    2452.80     856.65
     .007115       200.       200.       200.          2          8          0        .00     322.77    1179.42


 FLOW DISTRIBUTION FOR SECNO=      17.00          CWSEL=    2460.71

 STA=      857.     1190.
   PER Q=     100.0
    AREA=    2252.5
     VEL=      15.1
   DEPTH=       7.0

 *SECNO 18.000

 3301 HV CHANGED MORE THAN HVINS


 3470 ENCROACHMENT STATIONS=       845.0    1185.0  TYPE=       1  TARGET=       -845.000

 3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA=       2468.00 ELREA=     100000.00

      18.000       9.50    2464.40        .00        .00    2466.93       2.54       2.59        .10    2468.00
     34000.0         .0    34000.0         .0         .0     2659.9         .0      808.6      168.6 100000.00
         .25        .00      12.78        .00       .000       .030       .000       .000    2454.90     856.01
     .004063       500.       500.       500.          2          0          0        .00     321.99    1177.99


 FLOW DISTRIBUTION FOR SECNO=      18.00          CWSEL=    2464.40

 STA=      856.     1185.
   PER Q=     100.0
    AREA=    2659.9
```

VEL= 12.8
DEPTH= 8.3

1

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	L-BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	R-BANK ELEV
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

*SECNO 19.000

3301 HV CHANGED MORE THAN HVINS

19.000	9.72	2466.72	.00	.00	2468.66	1.94	1.66	.06	2472.00
34000.0	.0	34000.0	.0	.0	3041.3	.0	841.3	172.5	2472.00
.26	.00	11.18	.00	.000	.030	.000	.000	2457.00	825.08
.002820	500.	500.	500.	2	0	0	.00	343.60	1168.69

FLOW DISTRIBUTION FOR SECNO= 19.00 CWSEL= 2466.72

STA= 825. 1180.
PER Q= 100.0
AREA= 3041.3
VEL= 11.2
DEPTH= 8.9

*SECNO 20.000

3470 ENCROACHMENT STATIONS= 810.0 1690.0 TYPE= 1 TARGET= -810.000

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA= 2472.00 ELREA= 2470.00

20.000	9.08	2468.08	.00	.00	2470.22	2.14	1.51	.06	2472.00
34000.0	.0	34000.0	.0	.0	2893.9	.0	875.3	176.3	2470.00
.27	.00	11.75	.00	.000	.030	.000	.000	2459.00	826.54
.003202	500.	500.	500.	2	0	0	.00	331.54	1158.08

FLOW DISTRIBUTION FOR SECNO= 20.00 CWSEL= 2468.08

STA= 827. 1160.
PER Q= 100.0
AREA= 2893.9
VEL= 11.7
DEPTH= 8.7

*SECNO 21.000

3470 ENCROACHMENT STATIONS= 820.0 1280.0 TYPE= 1 TARGET= -820.000
1

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	L-BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	R-BANK ELEV
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA= 2472.00 ELREA= 2472.00

21.000	9.64	2469.64	.00	.00	2471.88	2.24	1.62	.03	2472.00
34000.0	.0	34000.0	.0	.0	2833.6	.0	908.2	180.1	2472.00
.28	.00	12.00	.00	.000	.030	.000	.000	2460.00	840.72
.003298	500.	500.	500.	2	0	0	.00	323.12	1163.84

FLOW DISTRIBUTION FOR SECNO= 21.00 CWSEL= 2469.64

STA= 841. 1170.
PER Q= 100.0
AREA= 2833.6
VEL= 12.0
DEPTH= 8.8

*SECNO 22.000

3301 HV CHANGED MORE THAN HVINS

3470 ENCROACHMENT STATIONS= 825.0 1310.0 TYPE= 1 TARGET= -825.000

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA= 2476.00 ELREA= 2476.00

```
      22.000      10.54    2471.54       .00        .00    2473.20       1.65       1.27        .06    2476.00
     34000.0         .0    34000.0        .0         .0     3293.4         .0      943.4      183.8    2476.00
         .30        .00      10.32       .00       .000       .030       .000       .000    2461.00     836.36
     .002056       500.       500.      500.          2          0          0        .00     327.70    1164.06

 FLOW DISTRIBUTION FOR SECNO=      22.00          CWSEL=    2471.54

 STA=      836.    1180.
   PER Q=     100.0
    AREA=    3293.4
     VEL=      10.3
   DEPTH=      10.1

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     14APR98      08:37:06                                                                                        PAGE  17

       SECNO      DEPTH      CWSEL      CRIWS      WSELK       EG         HV         HL         OLOSS      L-BANK ELEV
       Q          QLOB       QCH        QROB       ALOB        ACH        AROB       VOL        TWA        R-BANK ELEV
       TIME       VLOB       VCH        VROB       XNL         XNCH       XNR        WTN        ELMIN      SSTA
       SLOPE      XLOBL      XLCH       XLOBR      ITRIAL      IDC        ICONT      CORAR      TOPWID     ENDST


 *SECNO 23.000
      23.000       9.98    2471.98       .00        .00    2473.68       1.71        .47        .02    2470.00
     34000.0        7.7    33986.1       6.2        6.8     3242.5        7.3      959.9      185.5    2470.00
         .30       1.13      10.48       .85       .060       .030       .080       .000    2462.00     818.08
     .002212       220.       220.      220.          2          0          0        .00     349.34    1167.42

 FLOW DISTRIBUTION FOR SECNO=      23.00          CWSEL=    2471.98

 STA=      818.     825.    1160.    1167.
   PER Q=       .0     100.0       .0
    AREA=      6.8    3242.5      7.3
     VEL=      1.1      10.5       .8
   DEPTH=      1.0       9.7      1.0

 *SECNO 23.100
      23.100      10.05    2472.05       .00        .00    2473.73       1.68        .04        .00    2470.00
     34000.0        8.4    33984.8       6.8        7.4     3267.5        7.9      961.4      185.7    2470.00
         .30       1.14      10.40       .86       .060       .030       .080       .000    2462.00     817.82
     .002156        20.        20.       20.          2          0          0        .00     349.88    1167.70

 FLOW DISTRIBUTION FOR SECNO=      23.10          CWSEL=    2472.05

 STA=      818.     825.    1160.    1168.
   PER Q=       .0     100.0       .0
    AREA=      7.4    3267.5      7.9
     VEL=      1.1      10.4       .9
   DEPTH=      1.0       9.8      1.0

 SPECIAL BRIDGE

 SB  XK        XKOR       COFQ       RDLEN      BWC        BWP        BAREA      SS         ELCHU      ELCHD
       1.25       1.60       2.60     400.00     315.00      24.00    5693.00       1.00    2462.50    2462.00

 *SECNO 23.200
 CLASS A LOW FLOW

 3420 BRIDGE W.S.=     2471.79 BRIDGE VELOCITY=       11.86     CALCULATED CHANNEL AREA=        2788.
1
     14APR98      08:37:06                                                                                        PAGE  18

       SECNO      DEPTH      CWSEL      CRIWS      WSELK       EG         HV         HL         OLOSS      L-BANK ELEV
       Q          QLOB       QCH        QROB       ALOB        ACH        AROB       VOL        TWA        R-BANK ELEV
       TIME       VLOB       VCH        VROB       XNL         XNCH       XNR        WTN        ELMIN      SSTA
       SLOPE      XLOBL      XLCH       XLOBR      ITRIAL      IDC        ICONT      CORAR      TOPWID     ENDST


    EGPRS      EGLWC        H3       QWEIR       QLOW       BAREA    TRAPEZOID      ELLC       ELTRD      WEIRLN
                                                                        AREA
         .00    2474.42        .72         0.     34000.      5693.      5693.    2480.90    2486.97          0.


 3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA=       2478.00 ELREA=       2472.00

      23.200      10.28    2472.78       .00        .00    2474.42       1.64        .69        .00    2478.00
     34000.0         .0    33999.3        .7         .0     3303.9        1.5      970.5      186.7    2472.00
         .31        .00      10.29       .46       .000       .030       .080       .000    2462.50     810.45
     .002191       120.       120.      120.          0          0          0        .00     353.43    1163.88

 FLOW DISTRIBUTION FOR SECNO=      23.20          CWSEL=    2472.78
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```
STA=     810.    1160.    1164.
  PER Q=    100.0         .0
   AREA=   3303.9        1.5
    VEL=     10.3         .5
  DEPTH=      9.5         .4

*SECNO 24.000
   24.000     10.34   2472.84       .00       .00   2474.47      1.62       .04       .00   2478.00
  34000.0        .0   33999.1        .9        .0    3328.1       1.8     972.0     186.8   2472.00
      .31       .00     10.22       .48      .000      .030      .080      .000   2462.50    810.31
  .002140       20.       20.       20.         2         0         0       .00    353.91   1164.22


FLOW DISTRIBUTION FOR SECNO=     24.00          CWSEL=    2472.84

STA=     810.    1160.    1164.
  PER Q=    100.0         .0
   AREA=   3328.1        1.8
    VEL=     10.2         .5
  DEPTH=      9.5         .4

*SECNO 25.000
   25.000      9.81   2473.81       .00       .00   2475.92      2.11      1.31       .15   2476.00
  34000.0        .0   34000.0        .0        .0    2916.3        .0    1007.9     190.8   2478.00
      .32       .00     11.66       .00      .000      .030      .000      .000   2464.00    832.19
  .003110      500.      500.      500.         2         0         0       .00    330.84   1163.02
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    SECNO     DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS     L-BANK ELEV
    Q         QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA       R-BANK ELEV
    TIME      VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN     SSTA
    SLOPE     XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID    ENDST

FLOW DISTRIBUTION FOR SECNO=     25.00          CWSEL=    2473.81

STA=     832.    1170.
  PER Q=    100.0
   AREA=   2916.3
    VEL=     11.7
  DEPTH=      8.8

*SECNO 26.000
   26.000      9.85   2475.35       .00       .00   2477.76      2.41      1.75       .09   2480.00
  34000.0        .0   34000.0        .0        .0    2726.9        .0    1040.3     194.6   2480.00
      .33       .00     12.47       .00      .000      .030      .000      .000   2465.50    827.75
  .003925      500.      500.      500.         2         0         0       .00    334.50   1162.25


FLOW DISTRIBUTION FOR SECNO=     26.00          CWSEL=    2475.35

STA=     828.    1170.
  PER Q=    100.0
   AREA=   2726.9
    VEL=     12.5
  DEPTH=      8.2

*SECNO 27.000

3301 HV CHANGED MORE THAN HVINS

   27.000      9.75   2477.15       .00       .00   2480.17      3.03      2.23       .18   2480.00
  34000.0        .0   34000.0        .0        .0    2434.4        .0    1069.9     198.3   2482.00
      .34       .00     13.97       .00      .000      .030      .000      .000   2467.40    859.03
  .005053      500.      500.      500.         2         0         0       .00    305.85   1164.89


FLOW DISTRIBUTION FOR SECNO=     27.00          CWSEL=    2477.15

STA=     859.    1175.
  PER Q=    100.0
   AREA=   2434.4
    VEL=     14.0
  DEPTH=      8.0
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                                                               THIS RUN EXECUTED 14APR98     08:37:06
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HEC-2 WATER SURFACE PROFILES

Version   4.6.2;  May 1991
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NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

TANQUE VERDE CREEK (CRAY

SUMMARY PRINTOUT

	SECNO	CWSEL	VLOB	VCH	VROB	QLOB	QCH	QROB	DEPTH	TOPWID	SSTA	ENDST
	1.000	2433.20	1.38	11.46	.66	671.41	33319.09	9.50	11.20	604.00	910.00	1514.00
	2.000	2434.04	1.69	13.79	2.33	729.77	32998.81	271.41	10.04	910.11	820.00	1730.11
*	3.000	2437.17	1.37	7.75	1.19	2564.76	31385.55	49.69	10.67	1136.15	670.00	1806.15
	4.000	2437.85	1.64	8.01	1.72	3470.34	29289.83	1239.83	9.85	1292.73	650.12	1942.85
	5.000	2438.54	1.85	8.83	1.56	3659.85	28735.80	1604.34	9.04	1507.56	643.90	2151.46
*	6.000	2439.68	2.87	11.22	1.66	2464.92	30572.52	962.56	7.68	1118.12	621.16	1739.27
*	7.000	2442.22	1.37	12.40	2.44	108.24	31088.60	2803.17	8.22	1053.28	638.37	1691.65
	8.000	2444.71	1.61	12.91	2.11	192.33	32430.18	1377.48	8.71	841.27	669.36	1510.64
*	9.000	2447.61	.88	8.31	1.82	17.13	30986.40	2996.47	9.61	948.34	705.83	1654.17
	10.000	2448.76	.48	6.43	1.51	6.86	32920.99	1072.15	8.76	1049.29	502.08	1551.37
	11.000	2449.46	.73	6.16	.76	58.38	33792.55	149.07	8.16	1147.46	450.30	1597.76
*	12.000	2450.24	.00	9.20	.44	.00	33984.91	15.09	6.74	853.60	720.00	1573.60
	13.000	2451.98	.00	10.10	1.14	.00	33799.34	200.66	7.98	737.77	820.12	1557.89
	14.000	2453.65	.00	12.15	.00	.00	34000.00	.00	7.15	458.74	715.39	1174.13
	15.000	2456.10	.37	12.68	1.98	1.31	33325.99	672.70	8.10	596.46	753.64	1350.11
	16.000	2458.80	1.19	10.89	2.04	91.15	33403.23	505.62	8.80	583.98	713.01	1296.99
*	16.500	2459.56	2.66	14.27	.00	265.12	33734.88	.00	7.56	423.35	762.21	1185.56

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	SECNO	CWSEL	VLOB	VCH	VROB	QLOB	QCH	QROB	DEPTH	TOPWID	SSTA	ENDST
*	17.000	2460.71	.00	15.09	.00	.00	34000.00	.00	7.91	322.77	856.65	1179.42
	18.000	2464.40	.00	12.78	.00	.00	34000.00	.00	9.50	321.99	856.01	1177.99
	19.000	2466.72	.00	11.18	.00	.00	34000.00	.00	9.72	343.60	825.08	1168.69
	20.000	2468.08	.00	11.75	.00	.00	34000.00	.00	9.08	331.54	826.54	1158.08
	21.000	2469.64	.00	12.00	.00	.00	34000.00	.00	9.64	323.12	840.72	1163.84
	22.000	2471.54	.00	10.32	.00	.00	34000.00	.00	10.54	327.70	836.36	1164.06
	23.000	2471.98	1.13	10.48	.85	7.71	33986.08	6.21	9.98	349.34	818.08	1167.42
	23.100	2472.05	1.14	10.40	.86	8.40	33984.83	6.77	10.05	349.88	817.82	1167.70
	23.200	2472.78	.00	10.29	.46	.00	33999.31	.69	10.28	353.43	810.45	1163.88
	24.000	2472.84	.00	10.22	.48	.00	33999.15	.85	10.34	353.91	810.31	1164.22
	25.000	2473.81	.00	11.66	.00	.00	34000.00	.00	9.81	330.84	832.19	1163.02
	26.000	2475.35	.00	12.47	.00	.00	34000.00	.00	9.85	334.50	827.75	1162.25
	27.000	2477.15	.00	13.97	.00	.00	34000.00	.00	9.75	305.85	859.03	1164.89

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TANQUE VERDE CREEK (CRAY

SUMMARY PRINTOUT

SECNO	CWSEL	CRIWS	EG	HL	OLOSS	ELMIN	10*KS	K*CHSL	XLCH	SHEAR	FRCH

	1.000	2433.20	.00	2435.20	.00	.00	2422.00	24.99	.00	.00	1.56	.64
	2.000	2434.04	2433.09	2436.90	1.44	.26	2424.00	39.39	4.44	450.00	2.31	.79
*	3.000	2437.17	.00	2438.03	.93	.20	2426.50	12.35	5.00	500.00	.73	.45
	4.000	2437.85	.00	2438.71	.68	.00	2428.00	14.65	3.00	500.00	.80	.48
	5.000	2438.54	.00	2439.57	.81	.05	2429.50	20.79	3.33	450.00	1.01	.56
*	6.000	2439.68	2439.18	2441.45	1.66	.22	2432.00	45.16	5.00	500.00	1.75	.79
*	7.000	2442.22	2442.22	2444.41	3.00	-.27	2434.00	60.02	4.00	500.00	2.18	.90
	8.000	2444.71	2444.45	2447.19	2.69	.08	2436.00	49.41	4.00	500.00	2.21	.85
*	9.000	2447.61	.00	2448.59	1.26	.15	2438.00	16.89	4.00	500.00	.87	.51
	10.000	2448.76	.00	2449.38	.75	.04	2440.00	13.52	4.00	500.00	.56	.44
	11.000	2449.46	.00	2450.05	.67	.00	2441.30	13.10	2.60	500.00	.52	.43
*	12.000	2450.24	.00	2451.56	1.29	.22	2443.50	38.42	4.40	500.00	1.25	.71
	13.000	2451.98	.00	2453.55	1.92	.08	2444.00	38.36	1.00	500.00	1.43	.73
	14.000	2453.65	.00	2455.95	2.18	.22	2446.50	54.33	5.32	470.00	2.07	.87
	15.000	2456.10	2455.50	2458.55	2.56	.05	2448.00	48.36	3.00	500.00	2.14	.84
	16.000	2458.80	.00	2460.61	1.99	.06	2450.00	31.72	3.85	520.00	1.54	.69
*	16.500	2459.56	2459.56	2462.70	2.01	-.13	2452.00	67.10	6.67	300.00	2.78	.98
*	17.000	2460.71	2460.71	2464.25	1.42	.08	2452.80	71.15	4.00	200.00	3.10	1.01
	18.000	2464.40	.00	2466.93	2.59	.10	2454.90	40.63	4.20	500.00	2.09	.78
	19.000	2466.72	.00	2468.66	1.66	.06	2457.00	28.20	4.20	500.00	1.56	.66
	20.000	2468.08	.00	2470.22	1.51	.06	2459.00	32.02	4.00	500.00	1.74	.70
	21.000	2469.64	.00	2471.88	1.62	.03	2460.00	32.98	2.00	500.00	1.80	.71
	22.000	2471.54	.00	2473.20	1.27	.06	2461.00	20.56	2.00	500.00	1.29	.57
	23.000	2471.98	.00	2473.68	.47	.02	2462.00	22.12	4.55	220.00	1.34	.59

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SECNO	CWSEL	CRIWS	EG	HL	OLOSS	ELMIN	10*KS	K*CHSL	XLCH	SHEAR	FRCH
23.100	2472.05	.00	2473.73	.04	.00	2462.00	21.56	.00	20.00	1.31	.59
23.200	2472.78	.00	2474.42	.69	.00	2462.50	21.91	4.17	120.00	1.29	.59
24.000	2472.84	.00	2474.47	.04	.00	2462.50	21.40	.00	20.00	1.27	.58
25.000	2473.81	.00	2475.92	1.31	.15	2464.00	31.10	3.00	500.00	1.71	.69
26.000	2475.35	.00	2477.76	1.75	.09	2465.50	39.25	3.00	500.00	2.00	.77
27.000	2477.15	.00	2480.17	2.23	.18	2467.40	50.53	3.80	500.00	2.51	.87

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SUMMARY OF ERRORS AND SPECIAL NOTES

WARNING SECNO= 3.000 PROFILE= 1 CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

WARNING SECNO= 6.000 PROFILE= 1 CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

CAUTION SECNO= 7.000 PROFILE= 1 CRITICAL DEPTH ASSUMED
CAUTION SECNO= 7.000 PROFILE= 1 MINIMUM SPECIFIC ENERGY

WARNING SECNO= 9.000 PROFILE= 1 CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

WARNING SECNO= 12.000 PROFILE= 1 CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

CAUTION SECNO= 16.500 PROFILE= 1 CRITICAL DEPTH ASSUMED
CAUTION SECNO= 16.500 PROFILE= 1 MINIMUM SPECIFIC ENERGY

CAUTION SECNO= 17.000 PROFILE= 1 CRITICAL DEPTH ASSUMED
CAUTION SECNO= 17.000 PROFILE= 1 MINIMUM SPECIFIC ENERGY

APPENDIX B

SCOUR ANALYSIS SUMMARY SHEETS, EXISTING (WITHOUT-PROJECT) CONDITIONS

Existing (Without-Project) Conditions

Section Properties

Section No.	27	26	25	24	average	23.2	23.1	average	23	22	21	20	19	average
	Reach 6					Sabino Rd. Bridge			Reach 5					
W.S. Elev (ft)	2477.17	2475.37	2473.84	2472.89		2472.82	2472.05		2471.98	2471.55	2469.64	2468.08	2466.72	
E.G. Slope (ft/ft)	0.0050	0.0039	0.0031	0.0021	0.0035	0.0022	0.0022	0.0022	0.0022	0.0021	0.0033	0.0032	0.0028	0.0027
Max Chl Dpth (ft)	9.77	9.87	9.84	10.39	9.97	10.32	10.05	10.19	9.98	10.55	9.64	9.08	9.72	9.79
Min Ch El (ft)	2467.40	2465.50	2464.00	2462.50		2462.50	2462.00		2462.00	2461.00	2460.00	2459.00	2457.00	
Alpha	1.00	1.00	1.00	1.00		1.00	1.01		1.01	1.00	1.00	1.00	1.00	
Frctn Loss (ft)	2.22	1.75	1.30	0.04			0.04		0.47	1.27	1.62	1.51	1.67	
C & E Loss (ft)	0.18	0.09	0.15	0.00			0.00		0.01	0.06	0.03	0.06	0.06	
Main Channel Properties														
Wt. n-Val.	0.030	0.030	0.030	0.030		0.030	0.030		0.030	0.030	0.030	0.030	0.030	
Flow Area (sq ft)	2442	2735	2925	3343	2861	3320	3268	3294	3244	3293	2834	2895	3040	3061
Flow (cfs)	34000	34000	34000	33999	34000	33999	33985	33992	33986	34000	34000	34000	34000	33997
Top Width (ft)	306	335	331	350	330	350	335	342	335	328	323	332	344	332
Avg. Vel. (ft/s)	13.92	12.43	11.62	10.17	12.04	10.24	10.40	10.32	10.48	10.33	12.00	11.74	11.19	11.15
Hydr. Depth (ft)	7.98	8.17	8.84	9.56	8.64	9.49	9.75	9.62	9.68	10.05	8.77	8.73	8.85	9.22
Wetted Per. (ft)	308	339	336	354	334	354	340	347	340	334	327	337	347	337
Shear (lb/sq ft)	2.48	1.96	1.67	1.24	1.84	1.27	1.29	1.28	1.32	1.27	1.78	1.71	1.54	1.52
Stream Power (lb/ft s)	34.47	24.38	19.43	12.65	22.73	12.96	13.46	13.21	13.80	13.07	21.40	20.13	17.28	17.14

Section Properties

Section No.	18	17	16.5	16	15	14	average	13	12	11	10	average
	Reach 4							Reach 3				
W.S. Elev (ft)	2464.39	2460.72	2459.60	2458.80	2456.11	2453.65		2451.98	2450.24	2449.46	2448.76	
E.G. Slope (ft/ft)	0.0041	0.0071	0.0066	0.0032	0.0048	0.0054	0.0052	0.0038	0.0038	0.0013	0.0014	0.0026
Max Chl Dpth (ft)	9.49	7.92	7.60	8.80	8.11	7.15	8.18	7.98	6.74	8.16	8.76	7.91
Min Ch El (ft)	2454.90	2452.80	2452.00	2450.00	2448.00	2446.50		2444.00	2443.50	2441.30	2440.00	
Alpha	1.00	1.00	1.06	1.16	1.20	1.00		1.09	1.02	1.08	1.18	
Frctn Loss (ft)	2.59			1.99	2.57	2.18		1.92	1.29	0.66	0.75	
C & E Loss (ft)	0.10			0.06	0.05	0.22		0.08	0.22	0.00	0.04	
Main Channel Properties												
Wt. n-Val.	0.030	0.030	0.030	0.030	0.030	0.030		0.030	0.030	0.030	0.030	
Flow Area (sq ft)	2658	2255	2378	3069	2629	2797	2631	3348	3694	5487	5116	4411
Flow (cfs)	34000	34000	33726	33403	33326	34000	33742	33799	33985	33792	32921	33624
Top Width (ft)	322	323	356	395	370	459	371	560	710	860	770	725
Avg. Vel. (ft/s)	12.79	15.08	14.18	10.88	12.67	12.16	12.96	10.10	9.20	6.16	6.44	7.98
Hydr. Depth (ft)	8.26	6.99	6.69	7.77	7.11	6.10	7.15	5.98	5.20	6.38	6.64	6.05
Wetted Per. (ft)	327	328	359	398	373	461	374	560	712	861	771	726
Shear (lb/sq ft)	2.07	3.04	2.72	1.53	2.13	2.06	2.26	1.43	1.24	0.52	0.56	0.94
Stream Power (lb/ft s)	26.47	45.86	38.64	16.61	27.01	25.05	29.94	14.43	11.44	3.21	3.61	8.17

Section Properties

	Reach 2						Reach 1				
Section No.	9	8	7	6	5	average	4	3	2	1	average
W.S. Elev (ft)	2447.61	2444.69	2442.26	2439.68	2438.54		2437.85	2437.17	2434.04	2433.20	
E.G. Slope (ft/ft)	0.0017	0.0050	0.0058	0.0045	0.0021	0.0038	0.0015	0.0012	0.0039	0.0025	0.0023
Max Chl Dpth (ft)	9.61	8.69	8.26	7.68	9.04	8.66	9.85	10.67	10.04	11.20	10.44
Min Ch El (ft)	2438.00	2436.00	2434.00	2432.00	2429.50		2428.00	2426.50	2424.00	2422.00	
Alpha	1.59	1.48	1.71	1.71	2.26		2.03	1.71	1.38	1.29	
Frctn Loss (ft)	1.26	2.67		1.66	0.81		0.68	0.93	1.44		
C & E Loss (ft)	0.15	0.10		0.22	0.05		0.00	0.20	0.26		
Main Channel Properties											
Wt. n-Val.	0.030	0.030	0.030	0.030	0.030		0.030	0.030	0.030	0.030	
Flow Area (sq ft)	3732	2505	2528	2726	3255	2949	3654	4048	2394	2908	3251
Flow (cfs)	30984	32450	31024	30568	28731	30752	29300	31386	32997	33319	31750
Top Width (ft)	450	350	430	440	420	418	420	430	255	290	349
Avg. Vel. (ft/s)	8.30	12.96	12.27	11.21	8.83	10.71	8.02	7.75	13.78	11.46	10.25
Hydr. Depth (ft)	8.29	7.16	5.88	6.20	7.75	7.06	8.70	9.41	9.39	10.03	9.38
Wetted Per. (ft)	453	352	432	440	421	420	422	431	256	292	350
Shear (lb/sq ft)	0.87	2.22	2.13	1.74	1.00	1.59	0.80	0.72	2.29	1.55	1.34
Stream Power (lb/ft s)	7.21	28.77	26.10	19.53	8.85	18.09	6.38	5.62	31.62	17.79	15.35

SCOUR CALCULATIONS

Tanque Verde Creek Bank Protection and Riparian Preserve Project - Reach 1

HYDRAULIC PARAMETERS

Qmc, main channel discharge [1] =	31750	cfs
Se or So, energy/bed slope [2] =	0.0023	ft/ft
Yh, hydraulic depth =	9.38	ft.
Ym, maximum flow depth =	10.44	ft.
Vmc, main channel velocity =	10.25	fps
TW, top width of flow =	349.00	ft.
Amc, main channel flow area =	3097.56	sq. ft.
qmc, main channel unit discharge (mc) =	107.01	cfs/ft

note: [1] the discharge in the main channel (Qmc) and its hydraulic parameters are used if Qmc is less than the design discharge, otherwise the design discharge and its parameters are used.

[2] the bed slope (So) is used under uniform-flow conditions and the energy slope (Se) is used when the hydraulic parameters are obtained from a HEC-2 analysis.

GENERAL-SCOUR DEPTH

[Ys1 = Ym*(((0.0685*Vmc^0.8)/(Yh^0.4*So^0.3))-1), Reference 5]

for:	Se or So =	0.0023	ft/ft
	Yh =	9.38	ft.
	Ym =	10.44	ft.
	Vmc =	10.25	fps

	Ys1, general-scour depth =	1.1898	ft.

BED-FORM OR ANTIDUNE-SCOUR DEPTH

[Ys2 = 0.0137*Vmc^2, Reference 5]

for:	Vmc =	10.25	fps

	Ys2, bedform or antidune-scour depth =	1.4372	ft.

BEND-SCOUR DEPTH

(computation of depth as a function of the impingement angle)

[Ys3 = (0.0685*Ym*Vmc^0.8*(2.1*((sin^2(Ai/2)/cos(Ai))^0.2)-1))/(Yh^0.4*So^0.3), Reference 5]

impingement angle =	0.00	degrees
Rc, radius of curvature =	straight reach	ft.
TW, top width of flow =	349.00	ft.
Rc/TW =	n/c	
Se or So, energy/bed slope [1] =	0.0023	ft/ft
Yh, hydraulic depth =	9.38	ft.
Ym, maximum flow depth =	10.44	ft.
Vmc, main channel velocity =	10.25	fps

Ys3, bend-scour depth =	0.0000	ft.

Note: The computations are limited to an Rc/TW ratio that is > 0.5, but < 10.21.
(that is, 0.5 < Rc/Tw < 10.21)

LOCAL-SCOUR DEPTH FOR BRIDGE PIERS AND SIMILAR OBSTRUCTIONS

[scour depth using CSU's equation, Ys = Y1*(2.0*K1*K2*(a/Y1)^0.65*Fr^0.43) , Reference 7]

Y1, maximum flow depth =	10.44	ft.
Fr, froude no. =	0.59	
a, width of obstruction =	9.00	ft.
K1, pier shape coefficient or correction factor =	1.10	
K2, correction factor for angle of attack =	1.00	
composite coefficient (2.0*K1*K2) =	2.20	

Ys, local-scour depth =	16.62	ft.

Pier Nose Shape	Coefficient (K1)
square nose	1.1
round nose	1.0
cylinder	1.0
sharp nose	0.9
group of cylinders	1.0

Angle of Attack (degrees)	Pier Length/Width Ratio (K2)		
	L/a = 4	L/a = 8	L/a = 12
0	1.0	1.0	1.0
15	1.5	2.0	2.5
30	2.0	2.75	3.5
45	2.3	3.3	4.3
90	2.5	3.9	5.0

<u>Comments</u>

a) If the obstruction width includes debris accumulation, use a pier shape coefficient (K1) of 1.1; otherwise use the appropriate coefficient listed above.

b) CSU's equation, as outlined above, was obtained from HEC-18. It is the same procedure used by ADWR and the City of Tucson. However, the ADWR and COT procedures are approached in a slightly different manner. A composite coefficient of 2.2 is the default condition. Reduction factors are then applied to adjust for different pier nose shapes. This table is provided below.

Pier Nose Shape	Reduction Factor
square nose	1.0
round nose	0.9
cylinder	0.9
sharp nose	0.8
group of cylinders	0.9

c) HEC-18 makes use of a third correction coefficient to account for variations in bed form and sediment transport. The associated factors are listed below. The computed scour depth obtained using this third correction factor is also provided.

Bed Condition	Dune Height, H (ft)	Coefficient (K3)
clear-water scour	n/a	1.1
plane bed and antidune flow	n/a	1.1
small dunes	10 > H < 2	1.1
medium dunes	30 > H > 10	1.1 to 1.2
large dunes	H > 30	1.3

K3, correction factor for bed condition =	1.10	
composite coefficient (2.0*K1*K2*K3) =	2.42	

Ys, local-scour depth =	18.28	ft.

SCOUR CALCULATIONS

Tanque Verde Creek Bank Protection and Riparian Preserve Project - Reach 2

HYDRAULIC PARAMETERS

Qmc, main channel discharge [1] =	30752	cfs
Se or So, energy/bed slope [2] =	0.0038	ft/ft
Yh, hydraulic depth =	7.06	ft.
Ym, maximum flow depth =	8.66	ft.
Vmc, main channel velocity =	10.71	fps
TW, top width of flow =	418.00	ft.
Amc, main channel flow area =	2871.34	sq. ft.
qmc, main channel unit discharge (mc) =	92.75	cfs/ft

note: [1] the discharge in the main channel (Qmc) and its hydraulic parameters are used if Qmc is less than the design discharge, otherwise the design discharge and its parameters are used.

[2] the bed slope (So) is used under uniform-flow conditions and the energy slope (Se) is used when the hydraulic parameters are obtained from a HEC-2 analysis.

GENERAL-SCOUR DEPTH

[Ys1 = Ym*(((0.0685*Vmc^0.8)/(Yh^0.4*So^0.3))-1), Reference 5]

for:	Se or So =	0.0038	ft/ft
	Yh =	7.06	ft.
	Ym =	8.66	ft.
	Vmc =	10.71	fps

	Ys1, general-scour depth =	0.9690	ft.

BED-FORM OR ANTIDUNE-SCOUR DEPTH

[Ys2 = 0.0137*Vmc^2, Reference 5]

for:	Vmc =	10.71	fps

	Ys2, bedform or antidune-scour depth =	1.5691	ft.

BEND-SCOUR DEPTH

(computation of depth as a function of the impingement angle)

[Ys3 = (0.0685*Ym*Vmc^0.8*(2.1*((sin^2(Ai/2)/cos(Ai))^0.2)-1))/(Yh^0.4*So^0.3), Reference 5]

impingement angle =	35.00	degrees
Rc, radius of curvature =	946.67	ft.
TW, top width of flow =	418.00	ft.
Rc/TW =	2.26	
Se or So, energy/bed slope [1] =	0.0038	ft/ft
Yh, hydraulic depth =	7.06	ft.
Ym, maximum flow depth =	8.66	ft.
Vmc, main channel velocity =	10.71	fps

Ys3, bend-scour depth =	3.3842	ft.

Note: The computations are limited to an Rc/TW ratio that is > 0.5, but < 10.21.
(that is, 0.5 < Rc/Tw < 10.21)

SCOUR CALCULATIONS

Tanque Verde Creek Bank Protection and Riparian Preserve Project - Reach 3

HYDRAULIC PARAMETERS

Qmc, main channel discharge [1] =	33624	cfs
Se or So, energy/bed slope [2] =	0.0026	ft/ft
Yh, hydraulic depth =	6.05	ft.
Ym, maximum flow depth =	7.91	ft.
Vmc, main channel velocity =	7.98	fps
TW, top width of flow =	725.00	ft.
Amc, main channel flow area =	4213.53	sq. ft.
qmc, main channel unit discharge (mc) =	63.12	cfs/ft

note: [1] the discharge in the main channel (Qmc) and its hydraulic parameters are used if Qmc is less than the design discharge, otherwise the design discharge and its parameters are used.

[2] the bed slope (So) is used under uniform-flow conditions and the energy slope (Se) is used when the hydraulic parameters are obtained from a HEC-2 analysis.

GENERAL-SCOUR DEPTH

[Ys1 = Ym*(((0.0685*Vmc^0.8)/(Yh^0.4*So^0.3))-1), Reference 5]

for: Se or So =	0.0026	ft/ft
Yh =	6.05	ft.
Ym =	7.91	ft.
Vmc =	7.98	fps

Ys1, general-scour depth =	0.3747	ft.

BED-FORM OR ANTIDUNE-SCOUR DEPTH

[Ys2 = 0.0137*Vmc^2, Reference 5]

for: Vmc =	7.98	fps

Ys2, bedform or antidune-scour depth =	0.8711	ft.

BEND-SCOUR DEPTH

(computation of depth as a function of the impingement angle)

[Ys3 = (0.0685*Ym*Vmc^0.8*(2.1*((sin^2(Ai/2)/cos(Ai))^0.2)-1))/(Yh^0.4*So^0.3), Reference 5]

impingement angle =	27.00	degrees
Rc, radius of curvature =	2963.39	ft.
TW, top width of flow =	725.00	ft.
Rc/TW =	4.09	
Se or So, energy/bed slope [1] =	0.0026	ft/ft
Yh, hydraulic depth =	6.05	ft.
Ym, maximum flow depth =	7.91	ft.
Vmc, main channel velocity =	7.98	fps

Ys3, bend-scour depth =	1.6646	ft.

Note: The computations are limited to an Rc/TW ratio that is > 0.5, but < 10.21.
(that is, 0.5 < Rc/Tw < 10.21)

SCOUR CALCULATIONS

Tanque Verde Creek Bank Protection and Riparian Preserve Project - Reach 4

HYDRAULIC PARAMETERS

Qmc, main channel discharge [1] =	33742	cfs
Se or So, energy/bed slope [2] =	0.0052	ft/ft
Yh, hydraulic depth =	7.15	ft.
Ym, maximum flow depth =	8.18	ft.
Vmc, main channel velocity =	12.96	fps
TW, top width of flow =	371.00	ft.
Amc, main channel flow area =	2603.55	sq. ft.
qmc, main channel unit discharge (mc) =	106.01	cfs/ft

note: [1] the discharge in the main channel (Qmc) and its hydraulic parameters are used if Qmc is less than the design discharge, otherwise the design discharge and its parameters are used.

[2] the bed slope (So) is used under uniform-flow conditions and the energy slope (Se) is used when the hydraulic parameters are obtained from a HEC-2 analysis.

GENERAL-SCOUR DEPTH

[Ys1 = Ym*(((0.0685*Vmc^0.8)/(Yh^0.4*So^0.3))-1), Reference 5]

for:	Se or So =	0.0052	ft/ft
	Yh =	7.15	ft.
	Ym =	8.18	ft.
	Vmc =	12.96	fps

	Ys1, general-scour depth =	1.4141	ft.

BED-FORM OR ANTIDUNE-SCOUR DEPTH

[Ys2 = 0.0137*Vmc^2, Reference 5]

for:	Vmc =	12.96	fps

	Ys2, bedform or antidune-scour depth =	2.2976	ft.

BEND-SCOUR DEPTH

(computation of depth as a function of the impingement angle)

[Ys3 = (0.0685*Ym*Vmc^0.8*(2.1*((sin^2(Ai/2)/cos(Ai))^0.2)-1))/(Yh^0.4*So^0.3), Reference 5]

impingement angle =	27.00	degrees
Rc, radius of curvature =	1516.44	ft.
TW, top width of flow =	371.00	ft.
Rc/TW =	4.09	
Se or So, energy/bed slope [1] =	0.0052	ft/ft
Yh, hydraulic depth =	7.15	ft.
Ym, maximum flow depth =	8.18	ft.
Vmc, main channel velocity =	12.96	fps

Ys3, bend-scour depth =	1.9277	ft.

Note: The computations are limited to an Rc/TW ratio that is > 0.5, but < 10.21. (that is, 0.5 < Rc/Tw < 10.21)

SCOUR CALCULATIONS

Tanque Verde Creek Bank Protection and Riparian Preserve Project - Reach 5

HYDRAULIC PARAMETERS

Qmc, main channel discharge [1] =	33997	cfs
Se or So, energy/bed slope [2] =	0.0027	ft/ft
Yh, hydraulic depth =	9.22	ft.
Ym, maximum flow depth =	9.79	ft.
Vmc, main channel velocity =	11.15	fps
TW, top width of flow =	332.00	ft.
Amc, main channel flow area =	3049.06	sq. ft.
qmc, main channel unit discharge (mc) =	109.16	cfs/ft

note: [1] the discharge in the main channel (Qmc) and its hydraulic parameters are used if Qmc is less than the design discharge, otherwise the design discharge and its parameters are used.

[2] the bed slope (So) is used under uniform-flow conditions and the energy slope (Se) is used when the hydraulic parameters are obtained from a HEC-2 analysis.

GENERAL-SCOUR DEPTH

[Ys1 = Ym*(((0.0685*Vmc^0.8)/(Yh^0.4*So^0.3))-1), Reference 5]

for: Se or So =	0.0027	ft/ft
Yh =	9.22	ft.
Ym =	9.79	ft.
Vmc =	11.15	fps

Ys1, general-scour depth =	1.4042	ft.

BED-FORM OR ANTIDUNE-SCOUR DEPTH

[Ys2 = 0.0137*Vmc^2, Reference 5]

for: Vmc =	11.15	fps

Ys2, bedform or antidune-scour depth =	1.7007	ft.

BEND-SCOUR DEPTH

(computation of depth as a function of the impingement angle)

[Ys3 = (0.0685*Ym*Vmc^0.8*(2.1*((sin^2(Ai/2)/cos(Ai))^0.2)-1))/(Yh^0.4*So^0.3), Reference 5]

impingement angle =	17.00	degrees
Rc, radius of curvature =	straight reach	ft.
TW, top width of flow =	332.00	ft.
Rc/TW =	n/c	
Se or So, energy/bed slope [1] =	0.0027	ft/ft
Yh, hydraulic depth =	9.22	ft.
Ym, maximum flow depth =	9.79	ft.
Vmc, main channel velocity =	11.15	fps

Ys3, bend-scour depth =	0.0000	ft.

Note: The computations are limited to an Rc/TW ratio that is > 0.5, but < 10.21. (that is, 0.5 < Rc/Tw < 10.21)

SCOUR CALCULATIONS

Tanque Verde Creek Bank Protection and Riparian Preserve Project - Reach 6

HYDRAULIC PARAMETERS

Qmc, main channel discharge [1] =	34000	cfs
Se or So, energy/bed slope [2] =	0.0035	ft/ft
Yh, hydraulic depth =	8.64	ft.
Ym, maximum flow depth =	9.97	ft.
Vmc, main channel velocity =	12.04	fps
TW, top width of flow =	334.00	ft.
Amc, main channel flow area =	2823.92	sq. ft.
qmc, main channel unit discharge (mc) =	120.04	cfs/ft

note: [1] the discharge in the main channel (Qmc) and its hydraulic parameters are used if Qmc is less than the design discharge, otherwise the design discharge and its parameters are used.

[2] the bed slope (So) is used under uniform-flow conditions and the energy slope (Se) is used when the hydraulic parameters are obtained from a HEC-2 analysis.

GENERAL-SCOUR DEPTH

[Ys1 = Ym*(((0.0685*Vmc^0.8)/(Yh^0.4*So^0.3))-1), Reference 5]

for:	Se or So =	0.0035	ft/ft
	Yh =	8.64	ft.
	Ym =	9.97	ft.
	Vmc =	12.04	fps

	Ys1, general-scour depth =	1.5396	ft.

BED-FORM OR ANTIDUNE-SCOUR DEPTH

[Ys2 = 0.0137*Vmc^2, Reference 5]

for:	Vmc =	12.04	fps

	Ys2, bedform or antidune-scour depth =	1.9830	ft.

BEND-SCOUR DEPTH

(computation of depth as a function of the impingement angle)

[Ys3 = (0.0685*Ym*Vmc^0.8*(2.1*((sin^2(Ai/2)/cos(Ai))^0.2)-1))/(Yh^0.4*So^0.3), Reference 5]

impingement angle =	17.00	degrees
Rc, radius of curvature =	straight reach	ft.
TW, top width of flow =	334.00	ft.
Rc/TW =	n/c	
Se or So, energy/bed slope [1] =	0.0035	ft/ft
Yh, hydraulic depth =	8.64	ft.
Ym, maximum flow depth =	9.97	ft.
Vmc, main channel velocity =	12.04	fps

Ys3, bend-scour depth =	0.0000	ft.

Note: The computations are limited to an Rc/TW ratio that is > 0.5, but < 10.21.
(that is, 0.5 < Rc/Tw < 10.21)

LOCAL-SCOUR DEPTH FOR BRIDGE PIERS AND SIMILAR OBSTRUCTIONS

[scour depth using CSU's equation, Ys = Y1*(2.0*K1*K2*(a/Y1)^0.65*Fr^0.43) , Reference 7]

Y1, maximum flow depth =	9.97	ft.
Fr, froude no. =	0.72	
a, width of obstruction =	8.00	ft.
K1, pier shape coefficient or correction factor =	1.10	
K2, correction factor for angle of attack =	1.00	
composite coefficient (2.0*K1*K2) =	2.20	

Ys, local-scour depth =	16.52	ft.

Pier Nose Shape	Coefficient (K1)
square nose	1.1
round nose	1.0
cylinder	1.0
sharp nose	0.9
group of cylinders	1.0

Angle of Attack (degrees)	Pier Length/Width Ratio (K2)		
	L/a = 4	L/a = 8	L/a = 12
0	1.0	1.0	1.0
15	1.5	2.0	2.5
30	2.0	2.75	3.5
45	2.3	3.3	4.3
90	2.5	3.9	5.0

Comments

a) If the obstruction width includes debris accumulation, use a pier shape coefficient (K1) of 1.1; otherwise use the appropriate coefficient listed above.

b) CSU's equation, as outlined above, was obtained from HEC-18. It is the same procedure used by ADWR and the City of Tucson. However, the ADWR and COT procedures are approached in a slightly different manner. A composite coefficient of 2.2 is the default condition. . Reduction factors are then applied to adjust for different pier nose shapes. This table is provided below.

Pier Nose Shape	Reduction Factor
square nose	1.0
round nose	0.9
cylinder	0.9
sharp nose	0.8
group of cylinders	0.9

c) HEC-18 makes use of a third correction coefficient to account for variations in bed form and sediment transport. The associated factors are listed below. The computed scour depth obtained using this third correction factor is also provided.

Bed Condition	Dune Height, H (ft)	Coefficient (K3)
clear-water scour	n/a	1.1
plane bed and antidune flow	n/a	1.1
small dunes	10 > H < 2	1.1
medium dunes	30 > H > 10	1.1 to 1.2
large dunes	H > 30	1.3

K3, correction factor for bed condition =	1.10	
composite coefficient (2.0*K1*K2*K3) =	2.42	

Ys, local-scour depth =	18.18	ft.

APPENDIX C

HEC-2 INPUT/OUTPUT LISTING, WITH-PROJECT CONDITIONS

```
 *********************************************                                  ***************************************
 *  HEC-2 WATER SURFACE PROFILES             *                                  *  U.S. ARMY CORPS OF ENGINEERS       *
 *********************************************                                  ***************************************

                                               X     X  XXXXXXX   XXXXX              XXXXX
                                               X     X  X        X     X            X     X
                                               X     X  X        X                        X
                                               XXXXXXX  XXXX     X          XXXXX    XXXXX
                                               X     X  X        X                  X
                                               X     X  X        X     X            X
                                               X     X  XXXXXXX   XXXXX             XXXXXXX
1
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                                                                        THIS RUN EXECUTED 13APR98    09:46:05
 ************************************
  HEC-2 WATER SURFACE PROFILES

  Version   4.6.2;  May 1991
 ************************************


 T1      LIMITED RE-EVALUATION REPORT FOR THE PROPOSED RILLITO RIVER AND
 T2      ASSOCIATED STREAMS, BANK STABILIZATION AND RIPARIAN AREA PRESERVE,
 T3      TANQUE VERDE CREEK (CRAYCROFT RD BRIDGE TO SABINO CANYON RD BRIDGE)
 T4      WITH-PROJECT CONDITIONS; SLA JOB #: PAZ-COE32; TASK 2

 J1  ICHECK     INQ      NINV      IDIR      STRT     METRIC     HVINS      Q        WSEL       FQ

       -1        2         0         0    0.0000        0           0       0    2433.2        0

 J2  NPROF     IPLOT     PRFVS     XSECV     XSECH      FN       ALLDC     IBW      CHNIM      ITRACE

       1                  -1                                                                  15


 J3  VARIABLE CODES FOR SUMMARY PRINTOUT

       38        1        55        26        56        13        14        15         8         4
       53       54         0        38         1         2         3        11        12        42
        5       33        39        67        68

 J6  IHLEQ     ICOPY     SUBDIV    STRTDS     RMILE

       1


 NC     0.08      0.08     0.030       0.1       0.3
 QT        1     34000
 X1        1        11      1180      1490         0         0         0
 GR     2432       910      2432      1060      2430      1180      2422      1190      2422      1420
 GR     2424      1460      2432      1490      2434      1530      2436      1580      2440      1630
 GR     2450      1700

 X1        2        19      1370      1705       350       520       450
 X3                                  820
 GR     2430        40      2432       240      2434       525      2436       590      2438       600
 GR     2434       640      2428       660      2426       690      2426       800      2434       820
 GR     2434      1140      2432      1370      2424      1380      2424      1440      2424      1650
 GR     2424      1695      2433      1705      2434      1730      2440      1750
1
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 X1        3        27      1390      1790       420       500       500
 X3                                  670
 GR     2432       160      2434       340      2436       430      2440       450      2438       460
 GR     2436       490      2430       500      2428       530      2428       660      2430       665
 GR     2436       670      2436       830      2434       950      2434      1240      2433      1280
 GR     2433      1320      2432      1360    2431.5      1390      2428      1400      2427      1470
 GR   2426.5      1520      2428      1610      2427      1700      2427      1740      2428      1780
 GR     2433      1790      2440      1815

 X1        4        24      1330      1750       500       570       500
 X3                                  640
 GR     2434       320      2440       360      2440       380      2438       400      2430       420
 GR     2428       430      2428       540      2434       560      2436       570      2438       640
 GR     2436       780      2434       900      2433      1330      2430      1340      2428      1430
 GR     2429      1545    2429.5      1570      2429      1620      2429      1660      2430      1740
 GR     2434      1750      2434      1930      2440      1950      2450      1980

 X1        5        22      1290      1710       500       450       450
 X3                                  585
 GR     2441       420      2441       550      2440       600      2436       720      2435       750
 GR     2435      1100      2436      1250      2436      1290      2430      1300    2429.5      1330
```

GR	2429.5	1450	2430	1485	2432	1650	2434	1710	2436	1750
GR	2436	1770	2436	1810	2436	1840	2436	1930	2436	2050
GR	2440	2210	2442	2260						
X1	6	18	900	1340	550	500	500			
GR	2444	200	2444	420	2442	570	2440	610	2438	680
GR	2438	885	2439	890	2439	900	2434	910	2432	930
GR	2432	1060	2434	1180	2436	1330	2438	1340	2438	1630
GR	2440	1760	2442	1910	2450	2020				
X1	7	20	740	1170	500	500	500			
GR	2446	210	2446	330	2444	420	2443.5	500	2443	560
GR	2442	660	2442	661	2440.5	740	2435	750	2434	850
GR	2434	890	2436	900	2437.2	950	2437.2	1040	2438	1090
GR	2438	1160	2440	1170	2440	1560	2440	1685	2450	1715
X1	8	19	790	1140	530	450	500			
GR	2450	380	2448	420	2446	560	2444	730	2443	740
GR	2443	790	2437	800	2436	880	2436	930	2436.5	970
GR	2436.5	1030	2438	1060	2440	1070	2442	1140	2442.2	1270
GR	2444	1450	2446	1620	2448	1770	2450	1780		
NC	.06	.08	.030	.1	.3					
X1	9	21	730	1180	500	500	500			
GR	2454	30	2452	380	2450	580	2448	700	2447	730
GR	2440	740	2440	930	2438	980	2438	1030	2438.5	1130
GR	2440	1170	2442	1175	2444	1180	2443.5	1270	2443.5	1430
GR	2443.5	1440	2444	1510	2446	1630	2448	1660	2450	1700
GR	2460	1750								

X1	10	16	700	1310	500	500	500			
GR	2454	110	2452	380	2450	440	2448	540	2448	690
GR	2448	700	2443	710	2443	940	2442	985	2440	1000
GR	2440	1280	2444	1310	2446	1460	2448	1540	2450	1570
GR	2452	1600								
X1	11	25	700	1420	500	500	500			
GR	2456	20	2454	200	2452	390	2450.5	410	2450.5	560
GR	2450.5	610	2450.5	650	2450.5	665	2450.5	675	2450.5	700
GR	2444	710	2444	870	2445	900	2445	930	2444	970
GR	2442	990	2441.3	1010	2442	1210	2441.5	1310	2441.5	1340
GR	2442	1400	2448	1420	2448	1510	2450	1630	2456	1660
X1	12	28	725	1430	500	500	500			
X3	10			725						
GR	2458	30	2456	180	2454	260	2452	290	2452	540
GR	2450	650	2450	720	2452	725	2452	735	2447	745
GR	2447	900	2444	940	2444	1080	2444.5	1120	2444.5	1180
GR	2444	1240	2443.5	1300	2443.5	1350	2444	1390	2446	1410
GR	2450	1430	2450	1500	2450	1530	2450	1565	2450	1570
GR	2452	1600	2454	1710	2458	1730				
X1	13	22	810	1380	500	500	500			
X3	10			810						
GR	2458	0	2456	170	2454	285	2452	390	2450	430
GR	2450	620	2450	650	2452	680	2452	760	2456	790
GR	2456	800	2454	810	2450	820	2448	920	2446	1010
GR	2444	1100	2444	1230	2446	1350	2450	1380	2452	1560
GR	2454	1690	2458	1850						
X1	14	20	690	1175	420	520	470			
X3	10			690						
GR	2460	120	2452	190	2452	540	2454	660	2460	690
GR	2455	730	2448	740	2447	830	2447	910	2448	950
GR	2448	1010	2446.5	1060	2446.5	1130	2448	1160	2454	1175
GR	2456	1200	2456	1340	2456	1460	2456	1480	2460	1800
X1	15	23	800	1160	500	500	500			
X3	10			590						
GR	2460	90	2454	130	2454	300	2456	310	2456	490
GR	2460	520	2460	560	2458	640	2456	760	2456	790
GR	2456	800	2449	810	2448	890	2449.5	950	2449.5	990
GR	2448	1050	2448	1080	2450	1150	2454	1160	2454	1290
GR	2456	1350	2458	1352	2460	1490				
X1	16	28	900	1205	550	480	520			
X3	10			900						
GR	2464	215	2460	260	2458	410	2456	430	2454	550
GR	2454	570	2454	590	2456	640	2460	660	2462	670
GR	2462	705	2460	710	2460	715	2460	810	2460	820
GR	2460	900	2451	910	2450	970	2450	1000	2451	1050
GR	2450.6	1100	2450.6	1120	2452	1200	2456	1205	2456	1290
GR	2460	1300	2462	1420	2464	1920				

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X1      16.5          11         875        1190         300         300         300           0           0           0
X3                                           870
GR    2460.0       760.0      2458.0       770.0      2458.0       830.0      2458.0         865      2462.5         870
GR    2462.5         875      2452.0       885.0      2452.0       945.0      2453.0      1090.0      2454.0      1180.0
GR    2464.0      1190.0

X1        17          15         840        1190         200         200         200
X3        10                                 830
GR      2464         180        2462         260        2462         690        2460         720        2460         760
GR      2464         800        2466         820        2466         840        2464         855        2454         860
GR    2452.8         920      2453.1        1050        2454        1110        2456        1170        2466        1190
  VENTANA CANYON WASH TRIBUTARY

X1        18          15         850        1185         500         500         500
X3        10                                 845
GR      2466           0        2466         500        2466         680        2464         730        2464         830
GR      2468         840        2468         850        2462         860        2460         870        2456         875
GR    2454.9         970      2454.9        1030        2456        1100        2458        1170        2470        1185

X1        19          10         810        1180         500         500         500
GR      2474         790        2472         810        2458         850        2457         860        2457        1080
GR      2458        1100        2458        1150        2472        1180        2472        1370        2474        1460

X1        20          22         820        1160         500         500         500
X3        10                                 810
GR      2474         390        2472         510        2470         525        2468         540        2468         560
GR      2470         580        2470         720        2472         720        2472         820        2460         840
GR      2459         850        2459        1145        2460        1150        2470        1160        2472        1185
GR      2470        1190        2472        1200        2472        1290        2470        1300        2474        1340
GR      2476        1520        2478        1690

X1        21          17         830        1170         500         500         500
X3        10                                 820
GR      2474         490        2472         500        2472         760        2470         790        2470         800
GR      2472         810        2472         830        2470         840        2460         860        2460        1000
GR    2460.5        1010      2460.5        1140        2472        1170        2472        1185        2470        1200
GR      2470        1230        2476        1280

X1        22          13         830        1180         500         500         500
X3        10                                 825
GR      2476         650        2474         700        2474         800        2476         820        2476         830
GR      2462         850        2461         870        2461        1150        2476        1170        2476        1180
GR      2474        1200        2474        1250        2476        1310

X1        23           6         825        1160         220         220         220
GR      2480         790        2470         825        2462         840        2462        1150        2470        1160
GR      2478        1190
 SABINO CANYON RD BRIDGE
1
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X1      23.1                                             20          20          20
X3        10

SB      1.25         1.6         2.6         400         315          24        5693           1      2462.5        2462
X1      23.2           8         800        1160         120         120         120
X2                                 1      2480.9     2486.97
X3        10
GR      2480         760        2478         800        2463         830      2462.5         850      2462.5        1050
GR      2464        1140        2472        1160        2480        1200

X1        24                                             20          20          20

X1        25           7         830        1170         500         500         500
GR      2476         830        2466         840      2464.7         860      2464.9         940        2464        1110
GR      2466        1150        2478        1170

X1        26          11         820        1170         500         500         500
GR      2482         800        2480         820        2468         840      2466.5        1025        2466        1060
GR    2465.5        1080        2466        1115        2468        1150        2480        1170        2480        1190
GR      2484        1200

X1        27           9         840        1175         500         500         500
GR      2482         790        2480         820        2480         840        2468         920      2467.4         960
GR    2467.4        1030        2468        1080        2470        1150        2482        1175
1
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     SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
     Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
     TIME       VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
     SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST


*PROF 1
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 IHLEQ = 1.  THEREFORE FRICTION LOSS (HL) IS CALCULATED AS A FUNCTION OF
 PROFILE TYPE, WHICH CAN VARY FROM REACH TO REACH.  SEE DOCUMENTATION FOR
 DETAILS.
0

 CCHV=      .100 CEHV=      .300
 *SECNO 1.000
 3280 CROSS SECTION       1.00 EXTENDED       1.20 FEET

      1.000      11.20    2433.20       .00    2433.20    2434.86       1.66        .00        .00    2430.00
    34000.0      537.5    33454.0       8.5      444.0     3212.0       14.4         .0         .0    2432.00
        .00       1.21      10.42       .59       .080       .030       .080       .000    2422.00     910.00
    .001990         0.         0.        0.          0          0          0        .00     604.00    1514.00

 FLOW DISTRIBUTION FOR SECNO=       1.00           CWSEL=    2433.20

 STA=      910.     1060.     1180.     1490.     1514.
   PER Q=       .5       1.1      98.4        .0
    AREA=    180.0     264.0    3212.0      14.4
     VEL=       .9       1.4      10.4        .6
   DEPTH=      1.2       2.2      10.4        .6

 *SECNO 2.000

 3470 ENCROACHMENT STATIONS=       820.0     1750.0  TYPE=       1  TARGET=      -820.000
      2.000      10.18    2434.18       .00        .00    2435.76       1.58        .90        .01    2432.00
    34000.0      267.4    33721.6      10.9      328.4     3324.9       17.0       37.1        6.9    2433.00
        .01        .81      10.14       .64       .080       .030       .080       .000    2424.00     820.00
    .002014       350.       450.      520.          2          0          0        .00     910.60    1730.60

 FLOW DISTRIBUTION FOR SECNO=       2.00           CWSEL=    2434.18

 STA=      820.     1140.     1370.     1705.     1730.
   PER Q=       .0        .7      99.2        .0
    AREA=     57.3     271.2    3324.9      17.0
     VEL=       .3        .9      10.1        .6
   DEPTH=       .2       1.2       9.9        .7

1
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     SECNO       DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
     Q           QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
     TIME        VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
     SLOPE       XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST


 *SECNO 3.000

 3470 ENCROACHMENT STATIONS=       670.0     1815.0  TYPE=       1  TARGET=      -670.000
      3.000       8.86    2435.36       .00        .00    2436.95       1.59       1.19        .00    2431.50
    34000.0     1263.2    32726.2      10.6      842.6     3172.4       10.0       80.1       16.5    2433.00
        .03       1.50      10.32      1.06       .080       .030       .080       .000    2426.50     868.26
    .002758       420.       500.      500.          2          0          0        .00     930.17    1798.44

 FLOW DISTRIBUTION FOR SECNO=       3.00           CWSEL=    2435.36

 STA=      868.      950.     1240.     1280.     1320.     1360.     1390.     1790.     1798.
   PER Q=       .1       1.4        .3        .5        .7        .7      96.3        .0
    AREA=     55.7     395.1      74.5      94.5     114.5     108.4    3172.4      10.0
     VEL=       .8       1.2       1.5       1.7       2.0       2.3      10.3       1.1
   DEPTH=       .7       1.4       1.9       2.4       2.9       3.6       7.9       1.2

 *SECNO 4.000

 3301 HV CHANGED MORE THAN HVINS


 3470 ENCROACHMENT STATIONS=       640.0     1980.0  TYPE=       1  TARGET=      -640.000
      4.000       9.11    2437.11       .00        .00    2438.17       1.06       1.16        .05    2433.00
    34000.0     3406.7    29584.5    1008.8     1848.5     3349.9      575.9      136.9       29.1    2434.00
        .04       1.84       8.83      1.75       .080       .030       .080       .000    2428.00     702.31
    .002002       500.       500.      570.          3          0          0        .00    1238.06    1940.37

 FLOW DISTRIBUTION FOR SECNO=       4.00           CWSEL=    2437.11

 STA=      702.      780.      900.     1330.     1750.     1930.     1940.
   PER Q=       .1       1.0       8.9      87.0       2.9        .1
    AREA=     43.1     253.2    1552.2    3349.9     559.8      16.1
     VEL=       .6       1.4       2.0       8.8       1.8       1.1
   DEPTH=       .6       2.1       3.6       8.0       3.1       1.6

 *SECNO 5.000

 3470 ENCROACHMENT STATIONS=       585.0     2260.0  TYPE=       1  TARGET=      -585.000
```

```
     5.000      8.53   2438.03       .00       .00   2439.29      1.26      1.06       .06   2436.00
   34000.0    3134.1   29602.1    1263.7    1660.9    3075.2     814.0     197.4      43.8   2434.00
       .06      1.89      9.63      1.55      .080      .030      .080      .000   2429.50    659.00
   .002670      500.      450.      450.         2         0         0       .00   1472.32   2131.33

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   13APR98     09:46:05                                                                                        PAGE    8

      SECNO     DEPTH     CWSEL     CRIWS     WSELK      EG        HV        HL        OLOSS     L-BANK ELEV
      Q         QLOB      QCH       QROB      ALOB       ACH       AROB      VOL       TWA       R-BANK ELEV
      TIME      VLOB      VCH       VROB      XNL        XNCH      XNR       WTN       ELMIN     SSTA
      SLOPE     XLOBL     XLCH      XLOBR     ITRIAL     IDC       ICONT     CORAR     TOPWID    ENDST

 FLOW DISTRIBUTION FOR SECNO=       5.00          CWSEL=    2438.03

 STA=      659.     1100.     1290.     1710.     2050.     2131.
   PER Q=       6.9       2.4      87.1       3.5        .2
    AREA=    1199.6     461.3    3075.2     731.3      82.7
     VEL=       1.9       1.7       9.6       1.6       1.0
   DEPTH=       2.7       2.4       7.3       2.2       1.0

 *SECNO 6.000

 3301 HV CHANGED MORE THAN HVINS

 7185 MINIMUM SPECIFIC ENERGY
 3720 CRITICAL DEPTH ASSUMED
     6.000      7.54   2439.54   2439.54       .00   2441.79      2.24      2.87      -.47   2439.00
   34000.0     654.4   32415.9     929.8     368.7    2634.0     524.9     250.6      59.1   2438.00
       .07      1.77     12.31      1.77      .080      .030      .080      .000   2432.00    625.99
   .005704      550.      500.      500.         2        11         0       .00   1104.32   1730.31

 FLOW DISTRIBUTION FOR SECNO=       6.00          CWSEL=    2439.54

 STA=      626.      680.      885.      890.      900.     1340.     1630.     1730.
   PER Q=        .1       1.7        .0        .0      95.3       2.5        .3
    AREA=      41.7     316.4       5.2       5.4    2634.0     447.5      77.4
     VEL=       1.2       1.9       1.4        .9      12.3       1.9       1.2
   DEPTH=        .8       1.5       1.0        .5       6.0       1.5        .8

 *SECNO 7.000
     7.000      8.57   2442.57   2442.23       .00   2444.43      1.86      2.60       .04   2440.50
   34000.0     170.5   30625.6    3203.9     120.9    2658.9    1332.6     294.5      71.7   2440.00
       .08      1.41     11.52      2.40      .080      .030      .080      .000   2434.00    603.16
   .004791      500.      500.      500.         4         8         0       .00   1089.54   1692.71

 FLOW DISTRIBUTION FOR SECNO=       7.00          CWSEL=    2442.57

 STA=      603.      660.      740.     1170.     1560.     1685.     1693.
   PER Q=        .0        .5      90.1       7.1       2.3        .0
    AREA=      16.2     104.7    2658.9    1001.7     321.0       9.9
     VEL=        .6       1.5      11.5       2.4       2.4       1.5
   DEPTH=        .3       1.3       6.2       2.6       2.6       1.3
1
   13APR98     09:46:05                                                                                        PAGE    9

      SECNO     DEPTH     CWSEL     CRIWS     WSELK      EG        HV        HL        OLOSS     L-BANK ELEV
      Q         QLOB      QCH       QROB      ALOB       ACH       AROB      VOL       TWA       R-BANK ELEV
      TIME      VLOB      VCH       VROB      XNL        XNCH      XNR       WTN       ELMIN     SSTA
      SLOPE     XLOBL     XLCH      XLOBR     ITRIAL     IDC       ICONT     CORAR     TOPWID    ENDST

 *SECNO 8.000

 3301 HV CHANGED MORE THAN HVINS

     8.000      8.56   2444.56   2444.43       .00   2447.17      2.62      2.52       .23   2443.00
   34000.0     164.9   32577.1    1258.0     101.6    2457.6     595.0     335.2      82.2   2442.00
       .09      1.62     13.26      2.11      .080      .030      .080      .000   2436.00    682.62
   .005365      530.      500.      450.         6         5         0       .00    814.75   1497.38

 FLOW DISTRIBUTION FOR SECNO=       8.00          CWSEL=    2444.56

 STA=      683.      730.      740.      790.     1140.     1270.     1450.     1497.
   PER Q=        .0        .0        .4      95.8       2.3       1.3        .0
    AREA=      13.2      10.6      77.9    2457.6     319.5     262.3      13.2
     VEL=        .6       1.4       1.8      13.3       2.5       1.7        .6
   DEPTH=        .3       1.1       1.6       7.0       2.5       1.5        .3

 CCHV=     .100 CEHV=     .300
 *SECNO 9.000
```

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 3301 HV CHANGED MORE THAN HVINS


 3302 WARNING:  CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE,  KRATIO =  1.79

        9.000      9.64   2447.64       .00       .00   2448.62       .98      1.28       .16   2447.00
      34000.0       2.9   30970.5    3026.6       6.2    3738.4    1663.6     384.3      92.3   2444.00
          .11       .47      8.28      1.82      .060      .030      .080      .000   2438.00    710.77
      .001677      500.      500.      500.         2         0         0       .00    943.84   1654.61


 FLOW DISTRIBUTION FOR SECNO=      9.00          CWSEL=   2447.64

 STA=     711.      730.     1180.     1270.     1430.     1440.     1510.     1630.     1655.
   PER Q=        .0      91.1       1.9       3.8        .2       1.5       1.4        .0
    AREA=       6.2    3738.4     350.2     662.5      41.4     272.4     316.9      20.2
     VEL=        .5       8.3       1.9       2.0       2.0       1.9       1.5        .7
   DEPTH=        .3       8.3       3.9       4.1       4.1       3.9       2.6        .8

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    13APR98     09:46:05                                                                                  PAGE    10


      SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
      Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
      TIME       VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
      SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST


 *SECNO 10.000
       10.000      8.62   2448.62       .00       .00   2449.48       .86       .85       .01   2448.00
      34000.0      77.9   32796.9    1125.2     108.0    4323.1     674.5     444.6     103.7   2444.00
          .13       .72      7.59      1.67      .060      .030      .080      .000   2440.00    509.21
      .001729      500.      500.      500.         3         0         0       .00   1040.02   1549.24


 FLOW DISTRIBUTION FOR SECNO=     10.00          CWSEL=   2448.62

 STA=     509.      540.      690.      700.     1310.     1460.     1540.     1549.
   PER Q=        .0        .2        .0      96.5       2.9        .4        .0
    AREA=       9.5      92.4       6.2    4323.1     542.4     129.3       2.8
     VEL=        .5        .7        .7       7.6       1.8       1.1        .4
   DEPTH=        .3        .6        .6       7.1       3.6       1.6        .3

 *SECNO 11.000
       11.000      8.26   2449.56       .00       .00   2450.31       .75       .82       .01   2450.50
      34000.0        .0   33816.5     183.5        .0    4858.4     213.4     503.0     114.9   2448.00
          .15       .00      6.96       .86      .000      .030      .080      .000   2441.30    701.45
      .001552      500.      500.      500.         2         0         0       .00    902.16   1603.60


 FLOW DISTRIBUTION FOR SECNO=     11.00          CWSEL=   2449.56

 STA=     701.     1420.     1510.     1604.
   PER Q=      99.5        .4        .1
    AREA=    4858.4     140.4      73.0
     VEL=       7.0       1.0        .6
   DEPTH=       6.8       1.6        .8

 *SECNO 12.000

 3302 WARNING:  CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE,  KRATIO =   .68


 3470 ENCROACHMENT STATIONS=      725.0     1730.0  TYPE=      1  TARGET=     -725.000

 3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA=      2452.00 ELREA=      2450.00

       12.000      6.95   2450.45       .00       .00   2451.69      1.24      1.23       .15   2452.00
      34000.0        .0   33959.9      40.1        .0    3798.1      64.1     554.3     124.9   2450.00
          .17       .00      8.94       .63      .000      .030      .080      .000   2443.50    738.11
      .003374      500.      500.      500.         2         0         0       .00    838.60   1576.71


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      SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
      Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
      TIME       VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
      SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST


 FLOW DISTRIBUTION FOR SECNO=     12.00          CWSEL=   2450.45

 STA=     738.     1430.     1500.     1530.     1565.     1577.
   PER Q=      99.9        .1        .0        .0        .0
    AREA=    3798.1      31.3      13.4      15.6       3.7
     VEL=       8.9        .6        .6        .6        .5
```

DEPTH= 5.5 .4 .4 .4 .3

*SECNO 13.000

3470 ENCROACHMENT STATIONS= 810.0 1850.0 TYPE= 1 TARGET= -810.000

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA= 2454.00 ELREA= 2450.00

13.000	8.01	2452.01	.00	.00	2453.54	1.53	1.77	.09	2454.00
34000.0	.0	33792.2	207.8	.0	3391.8	182.2	597.0	133.9	2450.00
.18	.00	9.96	1.14	.000	.030	.080	.000	2444.00	814.97
.003714	500.	500.	500.	2	0	0	.00	745.81	1560.78

FLOW DISTRIBUTION FOR SECNO= 13.00 CWSEL= 2452.01

STA=	815.	1380.	1560.
PER Q=	99.4	.6	
AREA=	3391.8	182.2	
VEL=	10.0	1.1	
DEPTH=	6.0	1.0	

*SECNO 14.000

3301 HV CHANGED MORE THAN HVINS

3470 ENCROACHMENT STATIONS= 690.0 1800.0 TYPE= 1 TARGET= -690.000

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA= 2460.00 ELREA= 2454.00

14.000	7.10	2453.60	.00	.00	2456.02	2.42	2.21	.27	2460.00
34000.0	.0	34000.0	.0	.0	2722.7	.0	631.1	140.5	2454.00
.19	.00	12.49	.00	.000	.030	.000	.000	2446.50	732.00
.005678	420.	470.	520.	2	0	0	.00	441.99	1173.99

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SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	L-BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	R-BANK ELEV
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

FLOW DISTRIBUTION FOR SECNO= 14.00 CWSEL= 2453.60

STA=	732.	1175.
PER Q=	100.0	
AREA=	2722.7	
VEL=	12.5	
DEPTH=	6.2	

*SECNO 15.000

3470 ENCROACHMENT STATIONS= 590.0 1490.0 TYPE= 1 TARGET= -590.000

15.000	8.16	2456.16	2455.58	.00	2458.67	2.50	2.62	.02	2456.00
34000.0	3.7	33285.3	711.0	7.4	2594.3	351.3	663.6	146.4	2454.00
.20	.50	12.83	2.02	.060	.030	.080	.000	2448.00	750.11
.004874	500.	500.	500.	4	8	0	.00	600.05	1350.16

FLOW DISTRIBUTION FOR SECNO= 15.00 CWSEL= 2456.16

STA=	750.	800.	1160.	1290.	1350.
PER Q=	.0	97.9	1.8	.3	
AREA=	7.4	2594.3	281.4	69.9	
VEL=	.5	12.8	2.2	1.4	
DEPTH=	.1	7.2	2.2	1.2	

*SECNO 16.000

3301 HV CHANGED MORE THAN HVINS

3470 ENCROACHMENT STATIONS= 900.0 1920.0 TYPE= 1 TARGET= -900.000

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA= 2460.00 ELREA= 2456.00

16.000	8.44	2458.44	2458.28	.00	2461.70	3.26	2.80	.23	2460.00
34000.0	.0	33448.6	551.4	.0	2289.2	214.7	696.0	152.3	2456.00
.21	.00	14.61	2.57	.000	.030	.080	.000	2450.00	901.73
.005987	550.	520.	480.	4	5	0	.00	394.36	1296.10

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     SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
     Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
     TIME       VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
     SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST


 FLOW DISTRIBUTION FOR SECNO=      16.00          CWSEL=   2458.44

 STA=      902.     1205.     1290.     1296.
   PER Q=      98.4       1.6        .0
    AREA=    2289.2     207.3       7.4
     VEL=      14.6       2.6       1.6
   DEPTH=       7.5       2.4       1.2

 *SECNO 16.500

 3470 ENCROACHMENT STATIONS=      870.0    1190.0  TYPE=       1  TARGET=      -870.000
     16.500       8.15   2460.15   2460.09        .00   2463.70       3.56       1.92        .09   2462.50
    34000.0         .0   34000.0        .0         .0    2247.0         .0      712.3      154.7 100000.00
        .22        .00     15.13       .00       .000      .030       .000       .000    2452.00    877.24
    .006794       300.      300.      300.          4         8          0        .00     308.91   1186.15


 FLOW DISTRIBUTION FOR SECNO=      16.50          CWSEL=   2460.15

 STA=      877.     1190.
   PER Q=     100.0
    AREA=    2247.0
     VEL=      15.1
   DEPTH=       7.3

 *SECNO 17.000

 3301 HV CHANGED MORE THAN HVINS


 3302 WARNING:  CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE,  KRATIO =  1.42


 3470 ENCROACHMENT STATIONS=      830.0    1190.0  TYPE=       1  TARGET=      -830.000

 3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA=       2466.00 ELREA=     100000.00

     17.000       9.71   2462.51        .00        .00   2464.74       2.23        .90        .13   2466.00
    34000.0         .0   34000.0        .0         .0    2838.2         .0      724.0      156.1 100000.00
        .22        .00     11.98       .00       .000      .030       .000       .000    2452.80    855.74
    .003374       200.      200.      200.          4         0          0        .00     327.28   1183.02


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   13APR98       09:46:05                                                                                 PAGE    14


     SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
     Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
     TIME       VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
     SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST


 FLOW DISTRIBUTION FOR SECNO=      17.00          CWSEL=   2462.51

 STA=      856.     1190.
   PER Q=     100.0
    AREA=    2838.2
     VEL=      12.0
   DEPTH=       8.7

 *SECNO 18.000

 3470 ENCROACHMENT STATIONS=      845.0    1185.0  TYPE=       1  TARGET=      -845.000

 3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA=       2468.00 ELREA=     100000.00

     18.000       9.25   2464.15        .00        .00   2466.84       2.70       1.96        .14   2468.00
    34000.0         .0   34000.0        .0         .0    2579.8         .0      755.1      159.9 100000.00
        .23        .00     13.18       .00       .000      .030       .000       .000    2454.90    856.42
    .004482       500.      500.      500.          3         0          0        .00     321.26   1177.68


 FLOW DISTRIBUTION FOR SECNO=      18.00          CWSEL=   2464.15

 STA=      856.     1185.
   PER Q=     100.0
    AREA=    2579.8
     VEL=      13.2
   DEPTH=       8.0

 *SECNO 19.000

 3301 HV CHANGED MORE THAN HVINS
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   19.000      9.71   2466.71       .00       .00   2468.65      1.95      1.74       .08   2472.00
  34000.0        .0   34000.0        .0        .0    3036.9        .0     787.3     163.7   2472.00
      .25       .00     11.20       .00      .000      .030      .000      .000   2457.00    825.12
  .002832      500.      500.      500.         3         0         0       .00    343.54   1168.66

 FLOW DISTRIBUTION FOR SECNO=     19.00          CWSEL=   2466.71
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   SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
   Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
   TIME       VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
   SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST


 STA=      825.    1180.
   PER Q=     100.0
    AREA=    3036.9
     VEL=      11.2
   DEPTH=       8.8

 *SECNO 20.000

 3470 ENCROACHMENT STATIONS=      810.0    1690.0  TYPE=       1  TARGET=     -810.000

 3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA=      2472.00 ELREA=      2470.00

   20.000      9.08   2468.08       .00       .00   2470.22      2.15      1.51       .06   2472.00
  34000.0        .0   34000.0        .0        .0    2891.9        .0     821.3     167.6   2470.00
      .26       .00     11.76       .00      .000      .030      .000      .000   2459.00    826.55
  .003210      500.      500.      500.         2         0         0       .00    331.53   1158.07

 FLOW DISTRIBUTION FOR SECNO=     20.00          CWSEL=   2468.08

 STA=      827.    1160.
   PER Q=     100.0
    AREA=    2891.9
     VEL=      11.8
   DEPTH=       8.7

 *SECNO 21.000

 3470 ENCROACHMENT STATIONS=      820.0    1280.0  TYPE=       1  TARGET=     -820.000

 3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA=      2472.00 ELREA=      2472.00

   21.000      9.64   2469.64       .00       .00   2471.88      2.23      1.63       .03   2472.00
  34000.0        .0   34000.0        .0        .0    2834.4        .0     854.2     171.3   2472.00
      .27       .00     12.00       .00      .000      .030      .000      .000   2460.00    840.71
  .003295      500.      500.      500.         2         0         0       .00    323.14   1163.85

 FLOW DISTRIBUTION FOR SECNO=     21.00          CWSEL=   2469.64
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   SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
   Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
   TIME       VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
   SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST


 STA=      841.    1170.
   PER Q=     100.0
    AREA=    2834.4
     VEL=      12.0
   DEPTH=       8.8

 *SECNO 22.000

 3301 HV CHANGED MORE THAN HVINS


 3470 ENCROACHMENT STATIONS=      825.0    1310.0  TYPE=       1  TARGET=     -825.000

 3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA=      2476.00 ELREA=      2476.00

   22.000     10.55   2471.55       .00       .00   2473.20      1.65      1.27       .06   2476.00
  34000.0        .0   34000.0        .0        .0    3293.8        .0     889.4     175.0   2476.00
      .28       .00     10.32       .00      .000      .030      .000      .000   2461.00    836.36
  .002055      500.      500.      500.         2         0         0       .00    327.70   1164.06


 FLOW DISTRIBUTION FOR SECNO=     22.00          CWSEL=   2471.55
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 STA=      836.    1180.
   PER Q=     100.0
    AREA=   3293.8
     VEL=     10.3
   DEPTH=     10.1

 *SECNO 23.000
     23.000       9.98   2471.98       .00       .00   2473.69     1.70      .47      .02   2470.00
    34000.0        7.7   33986.1       6.2       6.9    3242.8      7.3    905.9    176.8   2470.00
        .29       1.13     10.48       .85      .060      .030     .080     .000  2462.00    818.08
    .002211       220.      220.      220.         2         0        0      .00   349.34   1167.42


 FLOW DISTRIBUTION FOR SECNO=     23.00         CWSEL=    2471.98

 STA=      818.     825.    1160.    1167.
   PER Q=        .0    100.0        .0
    AREA=       6.9   3242.8       7.3
     VEL=       1.1     10.5        .8
   DEPTH=       1.0      9.7       1.0
```



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     SECNO     DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS     L-BANK ELEV
     Q         QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA       R-BANK ELEV
     TIME      VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN     SSTA
     SLOPE     XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID    ENDST


 *SECNO 23.100
     23.100      10.05   2472.05       .00       .00   2473.73     1.68      .04      .00   2470.00
    34000.0        8.4   33984.8       6.8       7.4    3267.7      7.9    907.4    176.9   2470.00
        .29       1.14     10.40       .86      .060      .030     .080     .000  2462.00    817.82
    .002156        20.       20.       20.         2         0        0      .00   349.88   1167.70


 FLOW DISTRIBUTION FOR SECNO=     23.10         CWSEL=    2472.05

 STA=      818.     825.    1160.    1168.
   PER Q=        .0    100.0        .0
    AREA=       7.4   3267.7       7.9
     VEL=       1.1     10.4        .9
   DEPTH=       1.0      9.8       1.0


 SPECIAL BRIDGE

 SB  XK        XKOR      COFQ      RDLEN     BWC       BWP       BAREA     SS        ELCHU     ELCHD
      1.25      1.60      2.60    400.00    315.00     24.00   5693.00      1.00   2462.50   2462.00

 *SECNO 23.200
 CLASS A LOW FLOW

 3420 BRIDGE W.S.=    2471.79 BRIDGE VELOCITY=      11.86    CALCULATED CHANNEL AREA=      2788.

   EGPRS     EGLWC       H3      QWEIR      QLOW      BAREA   TRAPEZOID     ELLC     ELTRD    WEIRLN
                                                                AREA
       .00   2474.42      .72        0.    34000.     5693.     5693.   2480.90   2486.97        0.


 3495 OVERBANK AREA ASSUMED NON-EFFECTIVE, ELLEA=     2478.00 ELREA=     2472.00

     23.200      10.28   2472.78       .00       .00   2474.42     1.64      .69      .00   2478.00
    34000.0         .0   33999.3        .7        .0    3304.1      1.5    916.5    177.9   2472.00
        .29        .00     10.29       .46      .000      .030     .080     .000  2462.50    810.45
    .002191       120.      120.      120.         0         0        0      .00   353.43   1163.88


 FLOW DISTRIBUTION FOR SECNO=     23.20         CWSEL=    2472.78

 STA=      810.    1160.    1164.
   PER Q=    100.0       .0
    AREA=   3304.1      1.5
     VEL=     10.3       .5
   DEPTH=      9.5       .4
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     SECNO     DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS     L-BANK ELEV
     Q         QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA       R-BANK ELEV
     TIME      VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN     SSTA
     SLOPE     XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID    ENDST


 *SECNO 24.000
```

24.000	10.35	2472.85	.00	.00	2474.47	1.62	.04	.00	2478.00
34000.0	.0	33999.1	.9	.0	3328.5	1.8	918.0	178.0	2472.00
.29	.00	10.21	.48	.000	.030	.080	.000	2462.50	810.31
.002139	20.	20.	20.	2	0	0	.00	353.92	1164.23

FLOW DISTRIBUTION FOR SECNO= 24.00 CWSEL= 2472.85

STA=	810.	1160.	1164.
PER Q=	100.0	.0	
AREA=	3328.5	1.8	
VEL=	10.2	.5	
DEPTH=	9.5	.4	

*SECNO 25.000

25.000	9.81	2473.81	.00	.00	2475.92	2.11	1.31	.15	2476.00
34000.0	.0	34000.0	.0	.0	2916.3	.0	953.9	182.0	2478.00
.30	.00	11.66	.00	.000	.030	.000	.000	2464.00	832.19
.003109	500.	500.	500.	2	0	0	.00	330.84	1163.02

FLOW DISTRIBUTION FOR SECNO= 25.00 CWSEL= 2473.81

STA=	832.	1170.
PER Q=	100.0	
AREA=	2916.3	
VEL=	11.7	
DEPTH=	8.8	

*SECNO 26.000

26.000	9.85	2475.35	.00	.00	2477.76	2.41	1.75	.09	2480.00
34000.0	.0	34000.0	.0	.0	2727.1	.0	986.3	185.8	2480.00
.32	.00	12.47	.00	.000	.030	.000	.000	2465.50	827.75
.003924	500.	500.	500.	2	0	0	.00	334.50	1162.25

FLOW DISTRIBUTION FOR SECNO= 26.00 CWSEL= 2475.35

STA=	828.	1170.
PER Q=	100.0	
AREA=	2727.1	
VEL=	12.5	
DEPTH=	8.2	

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	L-BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	R-BANK ELEV
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

*SECNO 27.000

3301 HV CHANGED MORE THAN HVINS

27.000	9.74	2477.14	.00	.00	2480.17	3.03	2.23	.18	2480.00
34000.0	.0	34000.0	.0	.0	2434.2	.0	1015.9	189.5	2482.00
.33	.00	13.97	.00	.000	.030	.000	.000	2467.40	859.03
.005054	500.	500.	500.	2	0	0	.00	305.85	1164.89

FLOW DISTRIBUTION FOR SECNO= 27.00 CWSEL= 2477.14

STA=	859.	1175.
PER Q=	100.0	
AREA=	2434.2	
VEL=	14.0	
DEPTH=	8.0	

THIS RUN EXECUTED 13APR98 09:46:05

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HEC-2 WATER SURFACE PROFILES

Version   4.6.2;  May 1991
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NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

TANQUE VERDE CREEK (CRAY

SUMMARY PRINTOUT

	SECNO	CWSEL	VLOB	VCH	VROB	QLOB	QCH	QROB	DEPTH	TOPWID	SSTA	ENDST
	1.000	2433.20	1.21	10.42	.59	537.52	33454.00	8.48	11.20	604.00	910.00	1514.00
	2.000	2434.18	.81	10.14	.64	267.43	33721.65	10.93	10.18	910.60	820.00	1730.60
	3.000	2435.36	1.50	10.32	1.06	1263.21	32726.19	10.59	8.86	930.17	868.26	1798.44
	4.000	2437.11	1.84	8.83	1.75	3406.67	29584.50	1008.84	9.11	1238.06	702.31	1940.37
	5.000	2438.03	1.89	9.63	1.55	3134.11	29602.14	1263.75	8.53	1472.32	659.00	2131.33
*	6.000	2439.54	1.77	12.31	1.77	654.37	32415.86	929.78	7.54	1104.32	625.99	1730.31
	7.000	2442.57	1.41	11.52	2.40	170.45	30625.61	3203.93	8.57	1089.54	603.16	1692.71
	8.000	2444.56	1.62	13.26	2.11	164.89	32577.15	1257.96	8.56	814.75	682.62	1497.38
*	9.000	2447.64	.47	8.28	1.82	2.92	30970.46	3026.61	9.64	943.84	710.77	1654.61
	10.000	2448.62	.72	7.59	1.67	77.87	32796.89	1125.23	8.62	1040.02	509.21	1549.24
	11.000	2449.56	.00	6.96	.86	.00	33816.54	183.47	8.26	902.16	701.45	1603.60
*	12.000	2450.45	.00	8.94	.63	.00	33959.93	40.07	6.95	838.60	738.11	1576.71
	13.000	2452.01	.00	9.96	1.14	.00	33792.16	207.84	8.01	745.81	814.97	1560.78
	14.000	2453.60	.00	12.49	.00	.00	34000.00	.00	7.10	441.99	732.00	1173.99
	15.000	2456.16	.50	12.83	2.02	3.69	33285.30	711.01	8.16	600.05	750.11	1350.16
	16.000	2458.44	.00	14.61	2.57	.00	33448.59	551.41	8.44	394.36	901.73	1296.10
	16.500	2460.15	.00	15.13	.00	.00	34000.00	.00	8.15	308.91	877.24	1186.15

	SECNO	CWSEL	VLOB	VCH	VROB	QLOB	QCH	QROB	DEPTH	TOPWID	SSTA	ENDST
*	17.000	2462.51	.00	11.98	.00	.00	34000.00	.00	9.71	327.28	855.74	1183.02
	18.000	2464.15	.00	13.18	.00	.00	34000.00	.00	9.25	321.26	856.42	1177.68
	19.000	2466.71	.00	11.20	.00	.00	34000.00	.00	9.71	343.54	825.12	1168.66
	20.000	2468.08	.00	11.76	.00	.00	34000.00	.00	9.08	331.53	826.55	1158.07
	21.000	2469.64	.00	12.00	.00	.00	34000.00	.00	9.64	323.14	840.71	1163.85
	22.000	2471.55	.00	10.32	.00	.00	34000.00	.00	10.55	327.70	836.36	1164.06
	23.000	2471.98	1.13	10.48	.85	7.72	33986.06	6.22	9.98	349.34	818.08	1167.42
	23.100	2472.05	1.14	10.40	.86	8.40	33984.82	6.78	10.05	349.88	817.82	1167.70
	23.200	2472.78	.00	10.29	.46	.00	33999.31	.69	10.28	353.43	810.45	1163.88
	24.000	2472.85	.00	10.21	.48	.00	33999.15	.85	10.35	353.92	810.31	1164.23
	25.000	2473.81	.00	11.66	.00	.00	34000.00	.00	9.81	330.84	832.19	1163.02
	26.000	2475.35	.00	12.47	.00	.00	34000.00	.00	9.85	334.50	827.75	1162.25
	27.000	2477.14	.00	13.97	.00	.00	34000.00	.00	9.74	305.85	859.03	1164.89

TANQUE VERDE CREEK (CRAY

SUMMARY PRINTOUT

SECNO	CWSEL	CRIWS	EG	HL	OLOSS	ELMIN	10*KS	K*CHSL	XLCH	SHEAR	FRCH
1.000	2433.20	.00	2434.86	.00	.00	2422.00	19.90	.00	.00	1.29	.57
2.000	2434.18	.00	2435.76	.90	.01	2424.00	20.14	4.44	450.00	1.25	.57
3.000	2435.36	.00	2436.95	1.19	.00	2426.50	27.58	5.00	500.00	1.37	.65
4.000	2437.11	.00	2438.17	1.16	.05	2428.00	20.02	3.00	500.00	1.00	.55

	5.000	2438.03	.00	2439.29	1.06	.06	2429.50	26.70	3.33	450.00	1.22	.63
*	6.000	2439.54	2439.54	2441.79	2.87	-.47	2432.00	57.04	5.00	500.00	2.13	.89
	7.000	2442.57	2442.23	2444.43	2.60	.04	2434.00	47.91	4.00	500.00	1.85	.82
	8.000	2444.56	2444.43	2447.17	2.52	.23	2436.00	53.65	4.00	500.00	2.35	.88
*	9.000	2447.64	.00	2448.62	1.28	.16	2438.00	16.77	4.00	500.00	.87	.51
	10.000	2448.62	.00	2449.48	.85	.01	2440.00	17.29	4.00	500.00	.76	.50
	11.000	2449.56	.00	2450.31	.82	.01	2441.30	15.52	2.60	500.00	.65	.47
*	12.000	2450.45	.00	2451.69	1.23	.15	2443.50	33.74	4.40	500.00	1.16	.67
	13.000	2452.01	.00	2453.54	1.77	.09	2444.00	37.14	1.00	500.00	1.39	.72
	14.000	2453.60	.00	2456.02	2.21	.27	2446.50	56.78	5.32	470.00	2.18	.89
	15.000	2456.16	2455.58	2458.67	2.62	.02	2448.00	48.74	3.00	500.00	2.19	.84
	16.000	2458.44	2458.28	2461.70	2.80	.23	2450.00	59.87	3.85	520.00	2.82	.94
	16.500	2460.15	2460.09	2463.70	1.92	.09	2452.00	67.94	6.67	300.00	3.08	.99
*	17.000	2462.51	.00	2464.74	.90	.13	2452.80	33.74	4.00	200.00	1.83	.72
	18.000	2464.15	.00	2466.84	1.96	.14	2454.90	44.82	4.20	500.00	2.25	.82
	19.000	2466.71	.00	2468.65	1.74	.08	2457.00	28.32	4.20	500.00	1.56	.66
	20.000	2468.08	.00	2470.22	1.51	.06	2459.00	32.10	4.00	500.00	1.75	.70
	21.000	2469.64	.00	2471.88	1.63	.03	2460.00	32.95	2.00	500.00	1.80	.71
	22.000	2471.55	.00	2473.20	1.27	.06	2461.00	20.55	2.00	500.00	1.29	.57
	23.000	2471.98	.00	2473.69	.47	.02	2462.00	22.11	4.55	220.00	1.34	.59

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SECNO	CWSEL	CRIWS	EG	HL	OLOSS	ELMIN	10*KS	K*CHSL	XLCH	SHEAR	FRCH
23.100	2472.05	.00	2473.73	.04	.00	2462.00	21.56	.00	20.00	1.31	.59
23.200	2472.78	.00	2474.42	.69	.00	2462.50	21.91	4.17	120.00	1.29	.59
24.000	2472.85	.00	2474.47	.04	.00	2462.50	21.39	.00	20.00	1.27	.58
25.000	2473.81	.00	2475.92	1.31	.15	2464.00	31.09	3.00	500.00	1.71	.69
26.000	2475.35	.00	2477.76	1.75	.09	2465.50	39.24	3.00	500.00	2.00	.77
27.000	2477.14	.00	2480.17	2.23	.18	2467.40	50.54	3.80	500.00	2.51	.87

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SUMMARY OF ERRORS AND SPECIAL NOTES

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CAUTION SECNO=     6.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=     6.000  PROFILE=  1  MINIMUM SPECIFIC ENERGY

WARNING SECNO=     9.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

WARNING SECNO=    12.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

WARNING SECNO=    17.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE
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APPENDIX D

SCOUR ANALYSIS SUMMARY SHEETS, WITH-PROJECT CONDITIONS

With-Project Conditions

Section Properties

	Reach 6					Sabino Rd. Bridge			Reach 5					
Section No.	27	26	25	24	average	23.2	23.1	average	23	22	21	20	19	average
W.S. Elev (ft)	2477.17	2475.37	2473.84	2472.89		2472.82	2472.05		2471.98	2471.55	2469.64	2468.08	2466.71	
E.G. Slope (ft/ft)	0.0050	0.0039	0.0031	0.0021	0.0035	0.0022	0.0022	0.0022	0.0022	0.0021	0.0033	0.0032	0.0028	0.0027
Max Chl Dpth (ft)	9.77	9.87	9.84	10.39	9.97	10.32	10.05	10.19	9.98	10.55	9.64	9.08	9.71	9.79
Min Ch El (ft)	2467.40	2465.50	2464.00	2462.50		2462.50	2462.00		2462.00	2461.00	2460.00	2459.00	2457.00	
Alpha	1.00	1.00	1.00	1.00		1.00	1.01		1.01	1.00	1.00	1.00	1.00	
Frctn Loss (ft)	2.22	1.75	1.30	0.04			0.04		0.47	1.27	1.63	1.51	1.73	
C & E Loss (ft)	0.18	0.09	0.15	0.00			0.00		0.01	0.06	0.03	0.06	0.08	
Main Channel Properties														
Wt. n-Val.	0.030	0.030	0.030	0.030		0.030	0.030		0.030	0.030	0.030	0.030	0.030	
Flow Area (sq ft)	2442	2735	2925	3343	2861	3320	3268	3294	3244	3293	2834	2894	3037	3060
Flow (cfs)	34000	34000	34000	33999	34000	33999	33985	33992	33986	34000	34000	34000	34000	33997
Top Width (ft)	306	335	331	350	330	350	335	342	335	328	323	332	344	332
Avg. Vel. (ft/s)	13.92	12.43	11.62	10.17	12.04	10.24	10.40	10.32	10.48	10.33	12.00	11.75	11.19	11.15
Hydr. Depth (ft)	7.98	8.17	8.84	9.56	8.64	9.49	9.75	9.62	9.68	10.05	8.77	8.73	8.84	9.21
Wetted Per. (ft)	308	339	336	354	334	354	340	347	340	334	327	337	347	337
Shear (lb/sq ft)	2.48	1.96	1.67	1.24	1.84	1.27	1.29	1.28	1.32	1.27	1.78	1.72	1.55	1.53
Stream Power (lb/ft s)	34.47	24.38	19.43	12.66	22.74	12.96	13.46	13.21	13.80	13.07	21.41	20.15	17.32	17.15

Section Properties

	Reach 4							Reach 3				
Section No.	18	17	16.5	16	15	14	average	13	12	11	10	average
W.S. Elev (ft)	2464.39	2460.72	2459.60	2458.80	2456.11	2453.65		2451.98	2450.24	2449.46	2448.76	
E.G. Slope (ft/ft)	0.0041	0.0071	0.0066	0.0032	0.0048	0.0054	0.0052	0.0038	0.0038	0.0013	0.0014	0.0026
Max Chl Dpth (ft)	9.49	7.92	7.60	8.80	8.11	7.15	8.18	7.98	6.74	8.16	8.76	7.91
Min Ch El (ft)	2454.90	2452.80	2452.00	2450.00	2448.00	2446.50		2444.00	2443.50	2441.30	2440.00	
Alpha	1.00	1.00	1.06	1.16	1.20	1.00		1.09	1.02	1.08	1.18	
Frctn Loss (ft)	2.59			1.99	2.57	2.18		1.92	1.29	0.66	0.75	
C & E Loss (ft)	0.10			0.06	0.05	0.22		0.08	0.22	0.00	0.04	
Main Channel Properties												
Wt. n-Val.	0.030	0.030	0.030	0.030	0.030	0.030		0.030	0.030	0.030	0.030	
Flow Area (sq ft)	2658	2255	2378	3069	2629	2797	2631	3348	3694	5487	5116	4411
Flow (cfs)	34000	34000	33726	33403	33326	34000	33742	33799	33985	33792	32921	33624
Top Width (ft)	322	323	356	395	370	459	371	560	710	860	770	725
Avg. Vel. (ft/s)	12.79	15.08	14.18	10.88	12.67	12.16	12.96	10.10	9.20	6.16	6.44	7.98
Hydr. Depth (ft)	8.26	6.99	6.69	7.77	7.11	6.10	7.15	5.98	5.20	6.38	6.64	6.05
Wetted Per. (ft)	327	328	359	398	373	461	374	560	712	861	771	726
Shear (lb/sq ft)	2.07	3.04	2.72	1.53	2.13	2.06	2.26	1.43	1.24	0.52	0.56	0.94
Stream Power (lb/ft s)	26.47	45.86	38.64	16.61	27.01	25.05	29.94	14.43	11.44	3.21	3.61	8.17

Section Properties

Section No.	9	8	7	6	5	average	4	3	2	1	average
	Reach 2						Reach 1				
W.S. Elev (ft)	2447.61	2444.69	2442.26	2439.68	2438.54		2437.85	2437.17	2434.04	2433.20	
E.G. Slope (ft/ft)	0.0017	0.0050	0.0058	0.0045	0.0021	0.0038	0.0015	0.0012	0.0039	0.0025	0.0023
Max Chl Dpth (ft)	9.61	8.69	8.26	7.68	9.04	8.66	9.85	10.67	10.04	11.20	10.44
Min Ch El (ft)	2438.00	2436.00	2434.00	2432.00	2429.50		2428.00	2426.50	2424.00	2422.00	
Alpha	1.59	1.48	1.71	1.71	2.26		2.03	1.71	1.38	1.29	
Frctn Loss (ft)	1.26	2.67		1.66	0.81		0.68	0.93	1.44		
C & E Loss (ft)	0.15	0.10		0.22	0.05		0.00	0.20	0.26		
Main Channel Properties											
Wt. n-Val.	0.030	0.030	0.030	0.030	0.030		0.030	0.030	0.030	0.030	
Flow Area (sq ft)	3732	2505	2528	2726	3255	2949	3654	4048	2394	2908	3251
Flow (cfs)	30984	32450	31024	30568	28731	30752	29300	31386	32997	33319	31750
Top Width (ft)	450	350	430	440	420	418	420	430	255	290	349
Avg. Vel. (ft/s)	8.30	12.96	12.27	11.21	8.83	10.71	8.02	7.75	13.78	11.46	10.25
Hydr. Depth (ft)	8.29	7.16	5.88	6.20	7.75	7.06	8.70	9.41	9.39	10.03	9.38
Wetted Per. (ft)	453	352	432	440	421	420	422	431	256	292	350
Shear (lb/sq ft)	0.87	2.22	2.13	1.74	1.00	1.59	0.80	0.72	2.29	1.55	1.34
Stream Power (lb/ft s)	7.21	28.77	26.10	19.53	8.85	18.09	6.38	5.62	31.62	17.79	15.35

SCOUR CALCULATIONS

Tanque Verde Creek Bank Protection and Riparian Preserve Project - Reach 1 (w/ Project)

HYDRAULIC PARAMETERS

Qmc, main channel discharge [1] =	32371	cfs
Se or So, energy/bed slope [2] =	0.0022	ft/ft
Yh, hydraulic depth =	9.05	ft.
Ym, maximum flow depth =	9.84	ft.
Vmc, main channel velocity =	9.93	fps
TW, top width of flow =	366.00	ft.
Amc, main channel flow area =	3259.92	sq. ft.
qmc, main channel unit discharge (mc) =	97.71	cfs/ft

note: [1] the discharge in the main channel (Qmc) and its hydraulic parameters are used if Qmc is less than the design discharge, otherwise the design discharge and its parameters are used.

[2] the bed slope (So) is used under uniform-flow conditions and the energy slope (Se) is used when the hydraulic parameters are obtained from a HEC-2 analysis.

GENERAL-SCOUR DEPTH

[Ys1 = Ym*(((0.0685*Vmc^0.8)/(Yh^0.4*So^0.3))-1), Reference 5]

for:	Se or So =	0.0022	ft/ft
	Yh =	9.05	ft.
	Ym =	9.84	ft.
	Vmc =	9.93	fps

Ys1, general-scour depth =		1.1465	ft.

BED-FORM OR ANTIDUNE-SCOUR DEPTH

[Ys2 = 0.0137*Vmc^2, Reference 5]

for:	Vmc =	9.93	fps

Ys2, bedform or antidune-scour depth =		1.3489	ft.

BEND-SCOUR DEPTH

(computation of depth as a function of the impingement angle)

[Ys3 = (0.0685*Ym*Vmc^0.8*(2.1*((sin^2(Ai/2)/cos(Ai))^0.2)-1))/(Yh^0.4*So^0.3), Reference 5]

impingement angle =	0.00	degrees
Rc, radius of curvature =	straight reach	ft.
TW, top width of flow =	366.00	ft.
Rc/TW =	n/c	
Se or So, energy/bed slope [1] =	0.0022	ft/ft
Yh, hydraulic depth =	9.05	ft.
Ym, maximum flow depth =	9.84	ft.
Vmc, main channel velocity =	9.93	fps

Ys3, bend-scour depth =	0.0000	ft.

Note: The computations are limited to an Rc/TW ratio that is > 0.5, but < 10.21.
(that is, 0.5 < Rc/Tw < 10.21)

SCOUR CALCULATIONS

LOCAL-SCOUR DEPTH FOR BRIDGE PIERS AND SIMILAR OBSTRUCTIONS

[scour depth using CSU's equation, Ys = Y1*(2.0*K1*K2*(a/Y1)^0.65*Fr^0.43) , Reference 7]

Y1, maximum flow depth =	9.84 ft.
Fr, froude no. =	0.58
a, width of obstruction =	9.00 ft.
K1, pier shape coefficient or correction factor =	1.10
K2, correction factor for angle of attack =	1.00
composite coefficient (2.0*K1*K2) =	2.20

Ys, local-scour depth =	16.18 ft.

Pier Nose Shape	Coefficient (K1)
square nose	1.1
round nose	1.0
cylinder	1.0
sharp nose	0.9
group of cylinders	1.0

Angle of Attack (degrees)	Pier Length/Width Ratio (K2)		
	L/a = 4	L/a = 8	L/a = 12
0	1.0	1.0	1.0
15	1.5	2.0	2.5
30	2.0	2.75	3.5
45	2.3	3.3	4.3
90	2.5	3.9	5.0

Comments

a) If the obstruction width includes debris accumulation, use a pier shape coefficient (K1) of 1.1; otherwise use the appropriate coefficient listed above.

b) CSU's equation, as outlined above, was obtained from HEC-18. It is the same procedure used by ADWR and the City of Tucson. However, the ADWR and COT procedures are approached in a slightly different manner. A composite coefficient of 2.2 is the default condition. Reduction factors are then applied to adjust for different pier nose shapes. This table is provided below.

Pier Nose Shape	Reduction Factor
square nose	1.0
round nose	0.9
cylinder	0.9
sharp nose	0.8
group of cylinders	0.9

c) HEC-18 makes use of a third correction coefficient to account for variations in bed form and sediment transport. The associated factors are listed below. The computed scour depth obtained using this third correction factor is also provided.

Bed Condition	Dune Height, H (ft)	Coefficient (K3)
clear-water scour	n/a	1.1
plane bed and antidune flow	n/a	1.1
small dunes	10 > H < 2	1.1
medium dunes	30 > H > 10	1.1 to 1.2
large dunes	H > 30	1.3

K3, correction factor for bed condition =	1.10
composite coefficient (2.0*K1*K2*K3) =	2.42

Ys, local-scour depth =	17.80 ft.

SCOUR CALCULATIONS

Tanque Verde Creek Bank Protection and Riparian Preserve Project - Reach 2 (w/ Project)

HYDRAULIC PARAMETERS

Qmc, main channel discharge [1] =	31234	cfs
Se or So, energy/bed slope [2] =	0.0040	ft/ft
Yh, hydraulic depth =	6.97	ft.
Ym, maximum flow depth =	8.57	ft.
Vmc, main channel velocity =	10.99	fps
TW, top width of flow =	420.00	ft.
Amc, main channel flow area =	2842.04	sq. ft.
qmc, main channel unit discharge (mc) =	94.18	cfs/ft

note: [1] the discharge in the main channel (Qmc) and its hydraulic parameters are used if Qmc is less than the design discharge, otherwise the design discharge and its parameters are used.

[2] the bed slope (So) is used under uniform-flow conditions and the energy slope (Se) is used when the hydraulic parameters are obtained from a HEC-2 analysis.

GENERAL-SCOUR DEPTH

[Ys1 = Ym*(((0.0685*Vmc^0.8)/(Yh^0.4*So^0.3))-1), Reference 5]

for:	Se or So =	0.0040	ft/ft
	Yh =	6.97	ft.
	Ym =	8.57	ft.
	Vmc =	10.99	fps

	Ys1, general-scour depth =	1.0585	ft.

BED-FORM OR ANTIDUNE-SCOUR DEPTH

[Ys2 = 0.0137*Vmc^2, Reference 5]

for:	Vmc =	10.99	fps

	Ys2, bedform or antidune-scour depth =	1.6522	ft.

BEND-SCOUR DEPTH

(computation of depth as a function of the impingement angle)

[Ys3 = (0.0685*Ym*Vmc^0.8*(2.1*((sin^2(Ai/2)/cos(Ai))^0.2)-1))/(Yh^0.4*So^0.3), Reference 5]

impingement angle =	35.00	degrees
Rc, radius of curvature =	951.20	ft.
TW, top width of flow =	420.00	ft.
Rc/TW =	2.26	
Se or So, energy/bed slope [1] =	0.0040	ft/ft
Yh, hydraulic depth =	6.97	ft.
Ym, maximum flow depth =	8.57	ft.
Vmc, main channel velocity =	10.99	fps

Ys3, bend-scour depth =	3.3840	ft.

Note: The computations are limited to an Rc/TW ratio that is > 0.5, but < 10.21.
(that is, 0.5 < Rc/Tw < 10.21)

SCOUR CALCULATIONS

Tanque Verde Creek Bank Protection and Riparian Preserve Project - Reach 3 (w/ Project)

HYDRAULIC PARAMETERS

Qmc, main channel discharge [1] =	33592	cfs
Se or So, energy/bed slope [2] =	0.0026	ft/ft
Yh, hydraulic depth =	6.34	ft.
Ym, maximum flow depth =	7.96	ft.
Vmc, main channel velocity =	8.36	fps
TW, top width of flow =	646.00	ft.
Amc, main channel flow area =	4018.18	sq. ft.
qmc, main channel unit discharge (mc) =	66.55	cfs/ft

note: [1] the discharge in the main channel (Qmc) and its hydraulic parameters are used if Qmc is less than the design discharge, otherwise the design discharge and its parameters are used.

[2] the bed slope (So) is used under uniform-flow conditions and the energy slope (Se) is used when the hydraulic parameters are obtained from a HEC-2 analysis.

GENERAL-SCOUR DEPTH

[Ys1 = Ym*(((0.0685*Vmc^0.8)/(Yh^0.4*So^0.3))-1), Reference 5]

for:	Se or So =	0.0026	ft/ft
	Yh =	6.34	ft.
	Ym =	7.96	ft.
	Vmc =	8.36	fps

	Ys1, general-scour depth =	0.5326	ft.

BED-FORM OR ANTIDUNE-SCOUR DEPTH

[Ys2 = 0.0137*Vmc^2, Reference 5]

for:	Vmc =	8.36	fps

	Ys2, bedform or antidune-scour depth =	0.9560	ft.

BEND-SCOUR DEPTH

(computation of depth as a function of the impingement angle)

[Ys3 = (0.0685*Ym*Vmc^0.8*(2.1*((sin^2(Ai/2)/cos(Ai))^0.2)-1))/(Yh^0.4*So^0.3), Reference 5]

impingement angle =	27.00	degrees
Rc, radius of curvature =	2640.48	ft.
TW, top width of flow =	646.00	ft.
Rc/TW =	4.09	
Se or So, energy/bed slope [1] =	0.0026	ft/ft
Yh, hydraulic depth =	6.34	ft.
Ym, maximum flow depth =	7.96	ft.
Vmc, main channel velocity =	8.36	fps

Ys3, bend-scour depth =	1.7064	ft.

Note: The computations are limited to an Rc/TW ratio that is > 0.5, but < 10.21.
(that is, 0.5 < Rc/Tw < 10.21)

SCOUR CALCULATIONS

Tanque Verde Creek Bank Protection and Riparian Preserve Project - Reach 4 (w/ Project)

HYDRAULIC PARAMETERS

Qmc, main channel discharge [1] =	33788	cfs
Se or So, energy/bed slope [2] =	0.0052	ft/ft
Yh, hydraulic depth =	7.49	ft.
Ym, maximum flow depth =	8.47	ft.
Vmc, main channel velocity =	13.37	fps
TW, top width of flow =	344.00	ft.
Amc, main channel flow area =	2527.15	sq. ft.
qmc, main channel unit discharge (mc) =	113.24	cfs/ft

note: [1] the discharge in the main channel (Qmc) and its hydraulic parameters are used if Qmc is less than the design discharge, otherwise the design discharge and its parameters are used.

[2] the bed slope (So) is used under uniform-flow conditions and the energy slope (Se) is used when the hydraulic parameters are obtained from a HEC-2 analysis.

GENERAL-SCOUR DEPTH

[Ys1 = Ym*(((0.0685*Vmc^0.8)/(Yh^0.4*So^0.3))-1), Reference 5]

for:	Se or So =	0.0052	ft/ft
	Yh =	7.49	ft.
	Ym =	8.47	ft.
	Vmc =	13.37	fps

	Ys1, general-scour depth =	1.5274	ft.

BED-FORM OR ANTIDUNE-SCOUR DEPTH

[Ys2 = 0.0137*Vmc^2, Reference 5]

for:	Vmc =	13.37	fps

	Ys2, bedform or antidune-scour depth =	2.4453	ft.

BEND-SCOUR DEPTH

(computation of depth as a function of the impingement angle)

[Ys3 = (0.0685*Ym*Vmc^0.8*(2.1*((sin^2(Ai/2)/cos(Ai))^0.2)-1))/(Yh^0.4*So^0.3), Reference 5]

impingement angle =	27.00	degrees
Rc, radius of curvature =	1406.08	ft.
TW, top width of flow =	344.00	ft.
Rc/TW =	4.09	
Se or So, energy/bed slope [1] =	0.0052	ft/ft
Yh, hydraulic depth =	7.49	ft.
Ym, maximum flow depth =	8.47	ft.
Vmc, main channel velocity =	13.37	fps

Ys3, bend-scour depth =	2.0088	ft.

Note: The computations are limited to an Rc/TW ratio that is > 0.5, but < 10.21.
(that is, 0.5 < Rc/Tw < 10.21)

SCOUR CALCULATIONS

Tanque Verde Creek Bank Protection and Riparian Preserve Project - Reach 5 (w/ Project)

HYDRAULIC PARAMETERS

Qmc, main channel discharge [1] =	33997	cfs
Se or So, energy/bed slope [2] =	0.0027	ft/ft
Yh, hydraulic depth =	9.21	ft.
Ym, maximum flow depth =	9.79	ft.
Vmc, main channel velocity =	11.15	fps
TW, top width of flow =	332.00	ft.
Amc, main channel flow area =	3049.06	sq. ft.
qmc, main channel unit discharge (mc) =	109.16	cfs/ft

note: [1] the discharge in the main channel (Qmc) and its hydraulic parameters are used if Qmc is less than the design discharge, otherwise the design discharge and its parameters are used.

[2] the bed slope (So) is used under uniform-flow conditions and the energy slope (Se) is used when the hydraulic parameters are obtained from a HEC-2 analysis.

GENERAL-SCOUR DEPTH

[Ys1 = Ym*(((0.0685*Vmc^0.8)/(Yh^0.4*So^0.3))-1), Reference 5]

for:	Se or So =	0.0027	ft/ft
	Yh =	9.21	ft.
	Ym =	9.79	ft.
	Vmc =	11.15	fps

Ys1, general-scour depth =		1.4090	ft.

BED-FORM OR ANTIDUNE-SCOUR DEPTH

[Ys2 = 0.0137*Vmc^2, Reference 5]

for:	Vmc =	11.15	fps

Ys2, bedform or antidune-scour depth =		1.7007	ft.

BEND-SCOUR DEPTH

(computation of depth as a function of the impingement angle)

[Ys3 = (0.0685*Ym*Vmc^0.8*(2.1*((sin^2(Ai/2)/cos(Ai))^0.2)-1))/(Yh^0.4*So^0.3), Reference 5]

impingement angle =	17.00	degrees
Rc, radius of curvature =	straight reach	ft.
TW, top width of flow =	332.00	ft.
Rc/TW =	n/c	
Se or So, energy/bed slope [1] =	0.0027	ft/ft
Yh, hydraulic depth =	9.21	ft.
Ym, maximum flow depth =	9.79	ft.
Vmc, main channel velocity =	11.15	fps

Ys3, bend-scour depth =	0.0000	ft.

Note: The computations are limited to an Rc/TW ratio that is > 0.5, but < 10.21.
(that is, 0.5 < Rc/Tw < 10.21)

SCOUR CALCULATIONS

Tanque Verde Creek Bank Protection and Riparian Preserve Project - Reach 6 (w/ Project)

HYDRAULIC PARAMETERS

Qmc, main channel discharge [1] =	34000	cfs
Se or So, energy/bed slope [2] =	0.0035	ft/ft
Yh, hydraulic depth =	8.64	ft.
Ym, maximum flow depth =	9.97	ft.
Vmc, main channel velocity =	12.04	fps
TW, top width of flow =	330.00	ft.
Amc, main channel flow area =	2823.92	sq. ft.
qmc, main channel unit discharge (mc) =	120.04	cfs/ft

note: [1] the discharge in the main channel (Qmc) and its hydraulic parameters are used if Qmc is less than the design discharge, otherwise the design discharge and its parameters are used.

[2] the bed slope (So) is used under uniform-flow conditions and the energy slope (Se) is used when the hydraulic parameters are obtained from a HEC-2 analysis.

GENERAL-SCOUR DEPTH

[Ys1 = Ym*(((0.0685*Vmc^0.8)/(Yh^0.4*So^0.3))-1), Reference 5]

for:	Se or So =	0.0035	ft/ft
	Yh =	8.64	ft.
	Ym =	9.97	ft.
	Vmc =	12.04	fps

	Ys1, general-scour depth =	1.5396	ft.

BED-FORM OR ANTIDUNE-SCOUR DEPTH

[Ys2 = 0.0137*Vmc^2, Reference 5]

for:	Vmc =	12.04	fps

	Ys2, bedform or antidune-scour depth =	1.9830	ft.

BEND-SCOUR DEPTH

(computation of depth as a function of the impingement angle)

[Ys3 = (0.0685*Ym*Vmc^0.8*(2.1*((sin^2(Ai/2)/cos(Ai))^0.2)-1))/(Yh^0.4*So^0.3), Reference 5]

impingement angle =	17.00	degrees
Rc, radius of curvature =	straight reach	ft.
TW, top width of flow =	330.00	ft.
Rc/TW =	n/c	
Se or So, energy/bed slope [1] =	0.0035	ft/ft
Yh, hydraulic depth =	8.64	ft.
Ym, maximum flow depth =	9.97	ft.
Vmc, main channel velocity =	12.04	fps

Ys3, bend-scour depth =	0.0000	ft.

Note: The computations are limited to an Rc/TW ratio that is > 0.5, but < 10.21.
(that is, 0.5 < Rc/Tw < 10.21)

SCOUR CALCULATIONS

LOCAL-SCOUR DEPTH FOR BRIDGE PIERS AND SIMILAR OBSTRUCTIONS

[scour depth using CSU's equation, Ys = Y1*(2.0*K1*K2*(a/Y1)^0.65*Fr^0.43) , Reference 7]

Y1, maximum flow depth =	9.97 ft.
Fr, froude no. =	0.72
a, width of obstruction =	8.00 ft.
K1, pier shape coefficient or correction factor =	1.10
K2, correction factor for angle of attack =	1.00
composite coefficient (2.0*K1*K2) =	2.20

Ys, local-scour depth =	16.52 ft.

Pier Nose Shape	Coefficient (K1)
square nose	1.1
round nose	1.0
cylinder	1.0
sharp nose	0.9
group of cylinders	1.0

Angle of Attack (degrees)	Pier Length/Width Ratio (K2)		
	L/a = 4	L/a = 8	L/a = 12
0	1.0	1.0	1.0
15	1.5	2.0	2.5
30	2.0	2.75	3.5
45	2.3	3.3	4.3
90	2.5	3.9	5.0

Comments

a) If the obstruction width includes debris accumulation, use a pier shape coefficient (K1) of 1.1; otherwise use the appropriate coefficient listed above.

b) CSU's equation, as outlined above, was obtained from HEC-18. It is the same procedure used by ADWR and the City of Tucson. However, the ADWR and COT procedures are approached in a slightly different manner. A composite coefficient of 2.2 is the default condition. Reduction factors are then applied to adjust for different pier nose shapes. This table is provided below.

Pier Nose Shape	Reduction Factor
square nose	1.0
round nose	0.9
cylinder	0.9
sharp nose	0.8
group of cylinders	0.9

c) HEC-18 makes use of a third correction coefficient to account for variations in bed form and sediment transport. The associated factors are listed below. The computed scour depth obtained using this third correction factor is also provided.

Bed Condition	Dune Height, H (ft)	Coefficient (K3)
clear-water scour	n/a	1.1
plane bed and antidune flow	n/a	1.1
small dunes	10 > H < 2	1.1
medium dunes	30 > H > 10	1.1 to 1.2
large dunes	H > 30	1.3

K3, correction factor for bed condition =	1.10
composite coefficient (2.0*K1*K2*K3) =	2.42

Ys, local-scour depth =	18.18 ft.

LATERAL MIGRATION

TANQUE VERDE CREEK
CRAYCROFT ROAD TO SABINO ROAD
BANK PROTECTION AND
RIPARIAN PRESERVE PROJECT

LATERAL MIGRATION ANALYSIS

Prepared for:

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I. INTRODUCTION

This report presents the results of a lateral migration analysis conducted for four proposed bank-protection alternatives located a study reach of the Tanque Verde Creek which lies between Craycroft Road and Sabino Canyon Road in Pima County, Arizona. This particular reach of Tanque Verde Creek contains approximately 9,500 linear feet of existing bank protection located along four isolated channel segments which lie between the Craycroft Road bridge and the Sabino Canyon Road bridge. Approximately 12,500 linear feet of channel banks are currently unprotected within the study reach. Figure 1, Location Map, shows the study reach and the existing bank protection within the study reach.

Three bank-protection alternatives have been defined to include varying lengths of bank protection within the study reach—all in conjunction with the creation of a Riparian Preserve along a portion of the north bank of the Tanque Verde Creek. All of the proposed bank protection would be located along the alignment of the existing channel banks. The three bank-protection alternatives, along with a "no-action" alternative, have been defined as follows:

Alternative 1: No action.

Alternative 2: Bank protection in the existing gaps along the south bank (5,900 linear feet);

Bank protection upstream of the Craycroft bridge on the north bank (1,600 linear feet); and

Riparian Preserve along the north bank.

Alternative 3: Bank protection along the south bank adjacent, to the golf course (4,200 linear feet);

Bank protection upstream of the Craycroft bridge on the north bank (1,600 linear feet); and

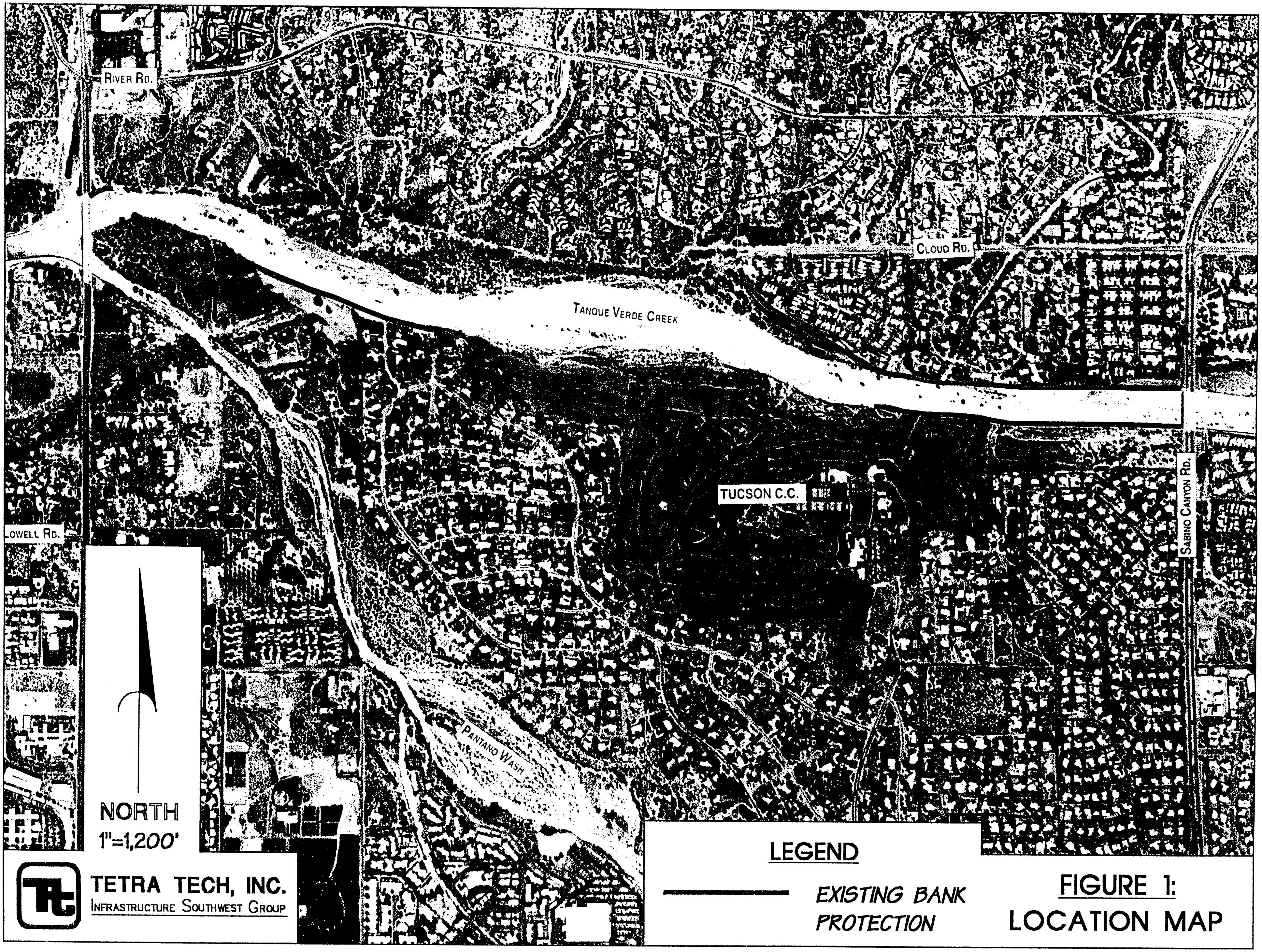
Riparian Preserve along the north bank.

Alternative 4: Bank protection in the existing gaps along the south bank (5,900 linear feet);

Bank protection upstream of the Craycroft bridge on the north bank (1,600 linear feet);

Riparian Preserve along the north bank, and

Bank protection (low flow) along the Riparian Preserve (5,000 linear feet).



TETRA TECH, INC.
INFRASTRUCTURE SOUTHWEST GROUP

FIGURE 1:
LOCATION MAP

II. PREVIOUS STUDIES

In 1996 the Pima County Flood Control District (District) asked the U.S. Army Corp of Engineers to evaluate flooding and erosion hazards along the study reach of the Tanque Verde Creek. (Pima County, 1996). The District outlined the existing flooding and erosion hazards, and prepared preliminary cost estimates for their proposed solution. The District's 1996 proposal has been included as Alternative 2 in this report.

Subsequently, a hydraulic and geomorphic analysis was completed for the study reach of the Tanque Verde Creek (SLA, 1998) which addressed four major areas of concern. The four areas of concern were (1) the potential for bank erosion, lateral migration, and channel migration along the project reach; (2) the relative stability of the Craycroft Road and Sabino Road bridges; (3) the flooding potential along the study reach during the 100-year event; and (4) the potential threat, if any, that the project might pose on the recently completed Rillito Creek bank stabilization project. For the purpose of the analysis presented within this report, the results of the 1998 SLA analysis regarding the first area of concern—bank erosion, lateral migration, and channel migration—will be examined in further detail and expanded upon in order to assess the impacts that bank stabilization might create along the proposed Riparian Preserve which is to be located along a portion of the north bank of the study reach.

III. QUALITATIVE GEOMORPHIC ANALYSIS

A. Historical Geomorphic Analysis

The 1998 SLA analysis incorporated a fluvial geomorphologic assessment which included an evaluation of aerial photographs of the study reach for the years 1936, 1953, 1960, 1967, 1971, 1979, 1983, 1993, and 1996. Using these historical aerial photographs and USGS flow records, movements of channel banks along the study reach were documented and correlated to flow events over the 60-year time period of the aerial photographs. In addition, changes in land uses and vegetation location and volume were also documented and correlated to the movements of the channel banks. The 1998 analysis presented summaries of the movements of channel banks, land-use changes, and vegetation changes which occurred during the intervening time periods between each successive aerial photograph.

The results of the 1998 fluvial geomorphologic analysis revealed that 650 feet was the maximum lateral movement of the channel banks which occurred during the 60-year time period of 1936 to 1996. A review of historic flow records indicates that a flow event of 12,200 cfs in December of 1965 was responsible for the majority of this severe bank erosion. While the peak flow rate for this event was much less than the adopted 100-year discharge of 34,000 cfs, the extensive bank erosion which occurred during the 1965 event was considered to be primarily due to the prolonged duration of flow (Pearthree and Baker, 1987). Another primary factor was that the flow was directed toward the outside of a appreciable meander bend which existed at the time.

B. Localized Bank Protection along Regional Watercourses

Each of the proposed alternatives would result in varying levels of bank protection along the study reach. The alternatives range from Alternative 1, with no new bank protection, to Alternative 4, with complete bank protection. Alternatives 1, 2, and 3 would all result in localized, or "piecemeal," areas of bank protection within the study reach, with unprotected channel banks located between, and adjacent to, protected channel banks.

The occurrence of increased bank erosion adjacent to localized bank protection has been well documented for regional watercourses within the Tucson basin such as the Tanque Verde Creek, the Rillito Creek, and the Santa Cruz River. During the October, 1983, flow events on these regional watercourses, a systematic pattern of erosion at meander bends was documented that appeared to be *directed or otherwise facilitated by existing localized bank protection* [emphasis added] (Pearthree and Baker, 1987). Localized bank protection, such as is proposed with Alternatives 1, 2, and 3, clearly will concentrate potential bank erosion and focus it upon those unprotected banks which remain within the study reach.

IV. ENGINEERING GEOMORPHIC ANALYSIS

A. Sediment Transport Continuity and Equilibrium Slopes

In order to determine the effect of any proposed channel improvements on channel stability, a quantitative engineering-geomorphic analysis can be conducted to determine both existing and with-project characteristics (ADWR, 1985). That is, an analysis of sediment transport rates and equilibrium slopes can be used to determine the effect of a proposed alternative on the stability of both the channel bed and banks of an alluvial watercourse.

Hydraulic models for both existing and with-project conditions were completed as part of the 1998 SLA analysis. Using hydraulic parameters (i.e., depth, velocity, width) obtained from these hydraulic models for both existing and with-project conditions, sediment transport rates can be calculated and compared to one another in order to identify any changes in sediment transport continuity within the study reach. Such a comparison showed little predicted change, however, since the proposed bank protection for each alternative will generally be located along the existing alignment of channel banks, and therefore existing flow hydraulics and corresponding sediment transport rates will remain essentially unchanged. Consequently, comparison of existing versus with-project sediment transport rates does not predict the occurrence of any substantive change in sediment transport continuity within the study reach.

Any instability in the sediment transport continuity of the study reach can also be identified through an analysis of equilibrium slopes—a procedure which can be used to determine long-term trends toward aggradation or degradation of the streambed. In the 1998 SLA analysis, equilibrium slopes were calculated for the study reach (SLA, 1982) and were compared to existing slopes. Differences in the two slopes were small, between 0.0002 ft./ft. and 0.0003 ft./ft. (i.e., 1.1 ft./mile to 1.6 ft./mile), with a slight trend towards aggradation indicated. Consequently, instability in the sediment transport continuity of the study reach due to either streambed aggradation or degradation is not predicted to occur for either existing or with-project conditions.

B. Shear Stress Analysis at Bendways

The occurrence of lateral migration and bank erosion is not exclusively a function of system sediment imbalances or long-term equilibrium slopes. Localized bank movement along the outside of meander bends will also occur. The extent of this localized bank-erosion process can be predicted by calculating the change in shear stress which occurs on the outside of meander bends during the progression of a flood hydrograph (SLA, 1997). Increased shear stress on the outside of a meander bend is created by the curvature effect induced in the flow as it passes through the bend. Physical model studies have shown that "bend shear stresses" can be more than four times as great as the shear stresses which occur along a straight channel segment.

Single-event bank erosion distance along the outside of an existing meander bend can be predicted by (1) utilizing representative cross sections along the study reach for both a straight approach channel and a meander bend; by (2) adjusting channel hydraulics to represent the outer portion of flow within the representative cross sections; by (3) computing corresponding sediment transport rates; by (4) considering the geometry of existing meander bends along the study reach; by (5) accounting for the increased shear stress on the outside of the meander bend; and by (6) considering the sediment composition of the eroding bank. Two existing meander bends located along the north bank of the study reach were evaluated for single-event bank erosion using this approach. Results, provided in the appendix to this report, indicate that for current conditions within the study reach, the maximum northward lateral movement of the north bank of the Tanque Verde Creek is predicted to be in the range of 200 feet to 300 feet during the occurrence of a 100-year flow event.

An earlier fluvial geomorphologic assessment (SLA, 1998) of the study reach of the Tanque Verde Creek recommended 650 feet as a reasonable prediction of long-term lateral migration potential. On an average-annual basis, this represents only a few feet of migration per year. However, the amount of lateral migration predicted to occur during a major single event, such as a 100-year flood, accounts for a significant portion of the total lateral migration that is anticipated to occur within the study reach over the long term. Consequently, the ability to passively monitor erosion impacts along the proposed Riparian Preserve—and then take appropriate mitigation measures, as necessary, to preserve the integrity of the Preserve—can be severely compromised since the passage of a major single event can cause several hundred feet of lateral bank movement to occur along the study reach of the Tanque Verde Creek in a matter of only a few hours time.

V. RESULTS

All of the proposed alternatives incorporate installation of varying levels of bank protection for the unprotected channel banks along the study reach. The alternatives range from Alternative 1, with no new bank protection, to Alternative 4, with complete bank protection. Alternatives 1, 2, and 3 would all result in localized, or "piecemeal," areas of bank protection within the study reach, with unprotected channel banks located between, and adjacent to, the protected channel banks. As a result, the potential for erosion along the unprotected segments of channel banks is expected to be high for Alternatives 1, 2, and 3, due to the "piecemeal" nature of the existing and proposed bank protection.

The occurrence of increased bank erosion for unprotected banks located adjacent to localized protected banks has been well documented for regional watercourses within the Tucson basin. Erosion at meander bends has either been caused, or exacerbated by, existing localized bank protection. Localized bank protection, such as is proposed with Alternatives 1, 2, and 3, will clearly concentrate potential bank erosion along those segments of unprotected banks located within the study reach.

Existing fluvial-geomorphic and engineering-geomorphic analyses of the study reach of the Tanque Verde Creek were evaluated for the purpose of determining the effects, if any, of the proposed bank-protection alternatives on lateral migration. Using existing and with-project hydraulic parameters, it was determined that sediment transport rates, and thus overall sediment transport continuity, will not be altered by any of the proposed alternatives. Similarly, a comparison of existing and equilibrium slopes in the study reach indicates that the channel bed profile is approaching long-term equilibrium conditions. These two quantitative methodologies indicate that no substantive change in sediment continuity results from the proposed alternatives.

Using a quantitative methodology which considers the hydraulics and shear stress of flow on the outside of a meander bend, single-event bank erosion estimates were determined along the study reach to range between 200 feet to 300 feet for the two meander bends located within the study reach. Although these estimates are less than historical single-event bank movements that have been recorded, the estimate is considered to be reliable for the geomorphology of the Tanque Verde Creek as it exists today along the study reach (i.e., the existing channel alignment is straighter than in the past, and the ability of the channel to meander has been reduced significantly due to the presence of two bridges and 9,500 linear feet of existing bank protection).

Because the amount of lateral migration predicted to occur during a major single event, such as a 100-year flood, accounts for a significant portion of the total lateral migration that is anticipated to occur within the study reach over the long term, the ability to passively monitor erosion impacts along the proposed Riparian Preserve—and then take appropriate mitigation measures, as necessary, to preserve the integrity of the Preserve—can be severely compromised since the passage of a major single event can cause several hundred feet of lateral bank movement to occur along the study reach of the Tanque Verde Creek in a matter of only a few hours time.

Results of the historical geomorphic analysis indicate that 650 feet represents the maximum long-term lateral movement of the channel banks during the 60-year period of record analyzed (1936 to 1996). As noted in the 1998 SLA analysis of the study reach, this maximum observed lateral migration distance correlates closely to a building setback distance of 652 feet which was calculated using local City of Tucson standards (City of Tucson, 1989). Therefore, while lateral bank movements of this magnitude are less likely today, due to the limiting effect of recent bridge construction and bank protection within the study reach, 650 feet is still considered to be a conservative estimate of worst-case channel movement within the study reach over the long term.

In order to quantify the erosion hazards that are associated with each alternative, unprotected sections of channel bank were tabulated and potential areas of bank erosion were calculated. The results, shown in Table 1 and Figure 2, indicate the relative erosion hazards for each alternative. With the exception of Alternative 4, all of the alternatives are predicted to result in a high risk of erosion along the proposed Riparian Preserve.

TABLE 1: EROSION HAZARDS FOR PROPOSED ALTERNATIVES

Alternative	Proposed Bank Protection (linear feet)	Unprotected Banks (linear feet)	Acreage at Risk (acres)	Structures at Risk
1	0	12,500	187	21 homes, the north and south approaches to the Craycroft bridge, a golf course, and the Riparian Preserve
2	7,500	5,000	75	15 homes, along with the Riparian Preserve
3	5,800	6,700	100	15 homes, the Riparian Preserve, and the south approach to the Craycroft bridge
4	12,500	0	0	None

VI. RECOMMENDATION

Based upon the lateral migration assessment conducted under this study effort, it is recommended that Alternative 4—bank protection in the existing gaps along the south bank (5,900 linear feet); bank protection upstream of the Craycroft bridge on the north bank (1,600 linear feet); Riparian Preserve along the north bank, and Bank protection (low flow) along the Riparian Preserve (5,000 linear feet), be adopted as the preferred alternative for the project.

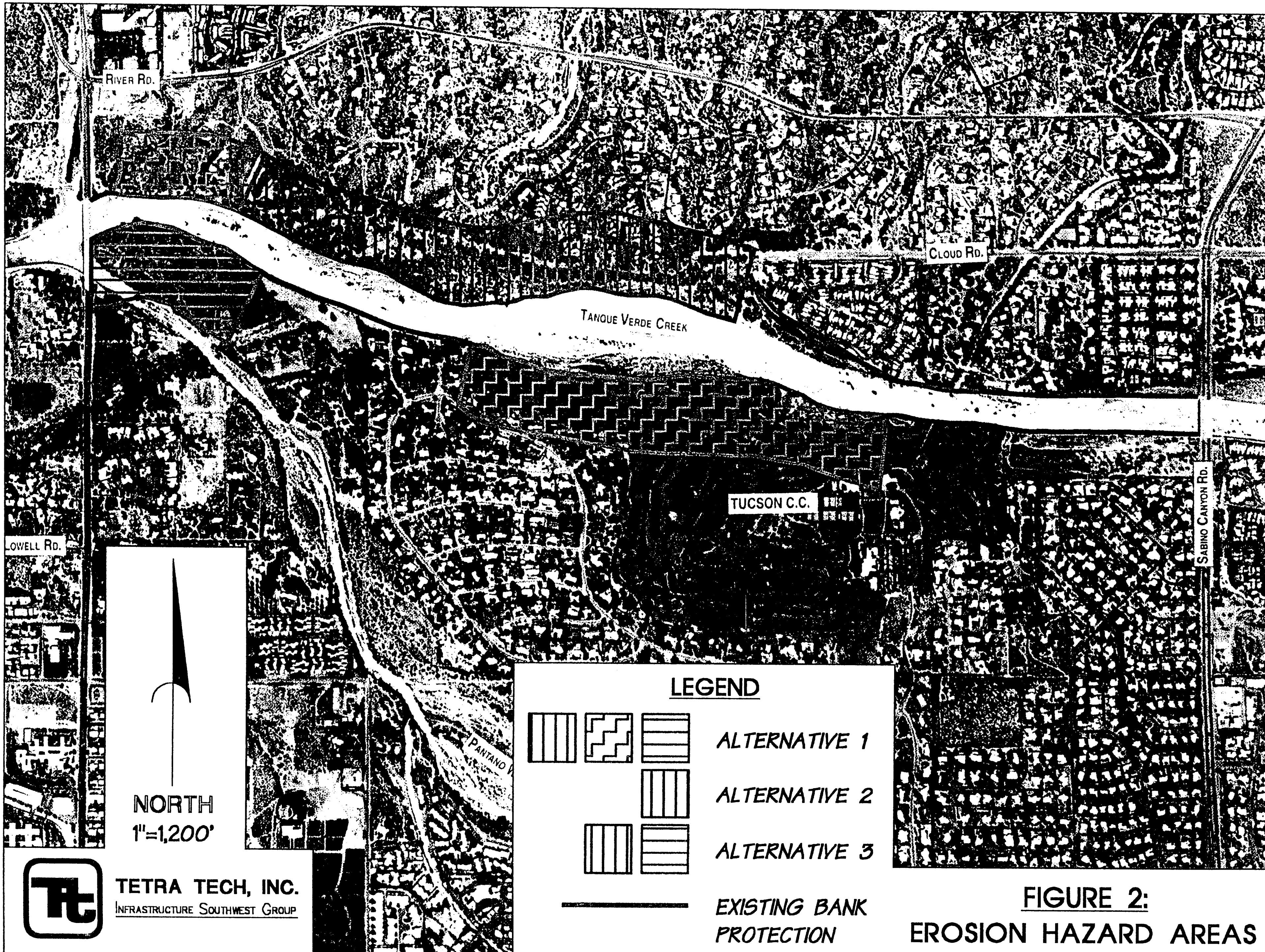


FIGURE 2:
EROSION HAZARD AREAS

VII. REFERENCES

1. *Sediment Transport Analysis of Rillito River and Tributaries for the Tucson Urban Study*; a report by Simons, Li & Associates, Inc., Fort Collins, Colorado & Tucson, Arizona; April 9, 1982.

2. *An Approach to Estimating Single-Event and Long-Term Lateral Migration Distances Along Alluvial Channels;* a paper by Michael Zeller, Simons, Li & Associates, Inc., Tucson, Arizona; November, 1997.

3. *Tanque Verde Creek, Craycroft Road to Sabino Road, Bank Protection and Riparian Preserve Project Limited Reevaluation Report (LRR), Feasibility Level Engineering Analysis*; a report by Simons, Li & Associates, Inc., Tucson, Arizona; May 4, 1998.

4. *Standards Manual for Drainage Design and Floodplain Management in Tucson, Arizona*; by Simons, Li & Associates, Inc., Tucson, Arizona; December, 1989.

5. *Design Manual for Engineering Analysis of Fluvial Systems*; Arizona Department of Water Resources; 1985.

6. *Rillito River and Associated Streams, Bank Stabilization and Riparian Area Preserve, Tanque Verde Creek, Craycroft Road to Sabino Canyon Road*; Pima County Department of Transportation and Flood Control District, Flood Control Engineering Division; December, 1996.

7. *Channel Change Along the Rillito Creek System of Southeastern Arizona, 1941 through 1983*; Marie Slezak Pearthree and Victor R. Baker, Special Paper 6, Arizona Bureau of Geology and Mineral Technology Geological Survey Branch, 1987.

APPENDIX

CALCULATIONS FOR BANK EROSION IN BENDS DUE TO INCREASED SHEAR STRESS

TANQUE VERDE CREEK - CRAYCROFT ROAD TO SABINO ROAD
100-YEAR LATERAL MIGRATION ANALYSIS
WEST MEANDER NEAR CRAYCROFT ROAD

Hydraulics from HEC-2 Design Run (SLA, 98)
Unit Sediment Discharge from Tucson Urban Study (SLA, 82)

$qs = (2.75x10^{-6}) * v^{4.29} * y^{-0.261}$

Total Sediment Discharge for Shear Stress Analysis (1/2 section)

$Qs = qs * (width/2)$

420	Supply channel width
400	Bend channel width
32	Angle of curvature
7	Average height of outer bank
0.7	Fraction of bed material found in bank
0.4	Porosity
5.5	Shape factor

Hydrograph		Supply Reach (XS-5)				Bend Reach (XS-3)					
Time Increment (hr)	Discharge (cfs)	Velocity (ft)	Depth (ft)	Sediment Discharge (cfs)	Sediment Volume (cf) (bulked)	Velocity (ft)	Depth (ft)	Adjusted Velocity (ft)	Adjusted Depth (ft)	Sediment Discharge (cfs)	Sediment Volume (cf) (bulked)
1.5	2200	1.98	3.83	0.0762	686	1.0	6.7	1.13	6.72	0.0056	51
1	8600	5.66	4.83	6.4957	38974	3.6	6.9	4.28	6.97	1.6931	10159
1	15700	7.77	5.98	23.9188	143513	6.2	7.2	7.33	7.54	16.7344	100407
1	26400	9.21	7.52	46.7232	280339	9.1	8.1	10.77	8.73	83.7157	502294
1	33800	9.62	8.51	54.5333	327200	10.3	8.8	12.23	9.67	140.7046	844227
1	27200	9.27	7.63	47.8614	287168	9.2	8.2	10.96	8.82	89.9955	539973
1	20200	8.59	6.64	35.7929	214757	7.6	7.6	8.97	8.00	39.1727	235036
1	17700	8.17	6.28	29.2898	175739	6.8	7.4	8.09	7.73	25.3857	152314
1	13800	7.33	5.69	18.8696	113218	5.5	7.1	6.57	7.36	10.5269	63161
1	10200	6.25	5.1	9.7994	58797	4.2	6.9	5.02	7.08	3.3343	20006
1	7600	5.24	4.66	4.7101	28261	3.2	6.8	3.80	6.91	1.0239	6143
1	5700	4.33	4.34	2.1169	12701	2.4	6.8	2.89	6.83	0.3154	1892
1	4200	3.45	4.09	0.8112	4867	1.8	6.7	2.14	6.77	0.0872	523
1	3300	2.83	3.96	0.3497	2098	1.4	6.7	1.69	6.75	0.0316	189
1	2500	2.22	3.86	0.1243	746	1.1	6.7	1.28	6.73	0.0098	59
2	1700	1.56	3.78	0.0275	330	0.7	6.7	0.87	6.71	0.0018	22
2.5	900	0.84	3.72	0.0019	29	0.4	6.7	0.46	6.70	0.0001	2
Total Sediment Volume (bulked cf)					*1689423*						*2476459*
Sediment Deficit (bulked cf)									*787036*		
Lateral Migration Potential (ft)									***209***		

TANQUE VERDE CREEK - CRAYCROFT ROAD TO SABINO ROAD
100-YEAR LATERAL MIGRATION ANALYSIS
EAST MEANDER NEAR SABINO ROAD

Hydraulics from HEC-2 Design Run (SLA, 98)
Unit Sediment Discharge from Tucson Urban Study (SLA, 82)
qs = (2.75x10^-6) * v^4.29 * y^-0.261

Total Sediment Discharge for Shear Stress Analysis (1/2 section)
Qs = qs * (width/2)

360	Supply channel width
705	Bend channel width
35	Angle of curvature
7	Average height of outer bank
0.7	Fraction of bed material found in bank
0.4	Porosity
6.1	Shape factor

Hydrograph		Supply Reach (XS-15)				Bend Reach (XS-12)					
Time Increment (hr)	Discharge (cfs)	Velocity (ft)	Depth (ft)	Sediment Discharge (cfs)	Sediment Volume (cf) (bulked)	Velocity (ft)	Depth (ft)	Adjusted Velocity (ft)	Adjusted Depth (ft)	Sediment Discharge (cfs)	Sediment Volume (cf) (bulked)
1.5	2200	3.66	2.53	1.0156	9140	4.0	1.7	4.90	1.86	7.5432	67889
1	8600	7.06	4.3	14.8130	88878	6.3	3.4	7.67	3.75	42.9264	257558
1	15700	9.27	5.65	44.3703	266222	7.1	4.6	8.73	5.15	68.6535	411921
1	26400	11.6	7.22	108.9060	653436	8.3	6.0	10.21	6.75	125.4274	752564
1	33800	12.8	8.14	161.0138	966083	8.9	6.9	10.94	7.74	163.1262	978757
1	27200	11.74	7.32	114.2468	685481	8.4	6.1	10.29	6.87	129.4549	776729
1	20200	10.36	6.36	69.3101	415860	7.7	5.2	9.44	5.85	92.9302	557581
1	17700	9.78	5.98	55.0098	330059	7.4	4.9	9.06	5.47	79.2813	475688
1	13800	8.74	5.33	34.9956	209974	6.8	4.4	8.36	4.83	58.0495	348297
1	10200	7.62	4.65	20.1366	120820	6.2	3.8	7.55	4.20	38.9012	233407
1	7600	6.66	4.09	11.6856	70113	6.0	3.2	7.29	3.52	35.0940	210564
1	5700	5.82	3.62	6.7655	40593	5.4	2.8	6.56	3.04	23.1090	138654
1	4200	5.04	3.2	3.7687	22612	4.8	2.4	5.89	2.61	15.2435	91461
1	3300	4.51	2.9	2.4007	14404	4.6	2.0	5.65	2.26	13.1905	79143
1	2500	3.97	2.61	1.4278	8567	4.2	1.8	5.12	1.98	8.9696	53817
2	1700	3.33	2.26	0.6974	8369	3.8	1.5	4.61	1.64	5.9860	71832
2.5	900	2.47	1.83	0.2045	3068	2.9	1.2	3.55	1.28	2.0958	31437

Total Sediment Volume (bulked cf): Supply Reach *3913678*; Bend Reach *5537301*
Sediment Deficit (bulked cf): *1623623*

Lateral Migration Potential (ft): *285*

COST ESTIMATING - MCACES

Tanque Verde

Designed By: TTISG
Estimated By: Mike Gorecki

Prepared By: ED-TB-CE

Preparation Date: 05/12/00
Effective Date of Pricing: 05/12/00
Est Construction Time: 360 Days

Sales Tax: 0.0%

Note No. 1 - M,D,CA&F includes the following. 3% for Mobilization, 6% for Design Engineering, and 15% for Construction Administration & Field Inspection

** PROJECT SETTINGS **

ESTIMATE TYPE : A-Crews with Auto Reprice

SALES TAX : 0.0%

DATE OF ESCALATION SCHEDULE : 05/12/00

PROJECT DIRECT COST COLUMNS

Col Type	H	L	E	M	U
Rep Width	8	9	9	9	8
Title	MANHRS	LABOR	EQUIPMNT	MATERIAL	OTHER

PROJECT INDIRECT COST COLUMNS

Col Type	O	U	P	B	X
Rep Width	12	12	12	12	0
Title	OVERHEAD	HOME OFC	PROFIT	BOND	<Unused>

PROJECT OWNER COST COLUMNS

Col Type	C	U	X	X	X
Rep Width	12	12	0	0	0
Title	CONTINGN	M,D,CA&F	<Unused>	<Unused>	<Unused>

PROJECT BREAKDOWN

PROJECT ID	Length	Trail Sep	Level Title	2nd View Order
Level 1 ID :	4	.	Scope	1
Level 2 ID :	3	.	Facility	2
Level 3 ID :	2	.	System	3
Level 4 ID :	2	.	SubSystm	0
Level 5 ID :	2	.	Assm Cat	0
Level 6 ID :	2	.	Assembly	0

Owner Cost Level : 1

** PROJECT SETTINGS **

2ND VIEW COLUMNS

Quantity Column Width : 10

Col Type	E	X	X	X	X
Rep Width	25	0	0	0	0
Title	ESC COST	(Unused)	(Unused)	(Unused)	(Unused)
Shadow	L	X	X	X	X

DETAIL REPORT FORMATTING

PAGE OPTIONS
Page Break Levels : 0
Table of Contents Levels : 6

		0	1	2	3	4	5	6	7
ROW OPTIONS	Print Titles at Levels :		Y	Y	Y	Y	Y	Y	
	Print Totals at Levels :		Y	Y	Y	Y	Y	Y	
	Print Notes at Levels :	Y	Y	Y	Y	Y	Y	Y	Y

Print Unit Cost Row : N
Print Page Footer : Y
Show Cost Codes : Y

COLUMNS OPTIONS
Print Crew Id : Y
Crew Output : Y
Unit Cost : Y

UPB TITLES
No. of Levels to Print : 0
Bracket Titles With : N N
Include titles Notes : N

** PROJECT SETTINGS **

OTHER REPORT FORMATTING

COLUMN TITLES FOR SUMMARY REPORTS

Column 1 OVERHEAD : Contractor's Overhead
Column 2 HOME OFC : Home Office Expense
Column 3 PROFIT : Contractor's Profit
Column 4 BOND : Contractor's Bond
Column 5 <Unused> :

Column 1 CONTINGN : Contingency
Column 2 M,D,CA&F : Mob., Design, and Const. Admin
Column 3 <Unused> :
Column 4 <Unused> : (Unused)
Column 5 <Unused> : (Unused)

STANDARD COLUMN WIDTHS		SUMMARY FEATURES	
Quantity Columns	10	Round Totals Column	T-Tens
Total cost Columns	12	Contingency Notes	Yes
Unit Cost Columns	10	Show Project Totals	Yes

SPECIAL REPORT FORMATTING OPTIONS

First Alternate ID : (None)
Show Markup at Level : 0
Display Indirect/Owner Markup as : A - Unit Costs Only
CSI Sort at Level : (None)

** PROJECT SETTINGS **

REPORT SELECTION

Project Settings : Y   Profit Guidelines : N
Contractor Settings : N
Link Listing : N   Measurement Units : Original

	Direct	Indirect	Owner	0	1	2	3	4	5	6
Detail :	Y									
Project :	Y	Y	Y		Y	Y	Y	Y	Y	Y
Contractor :	N	N		N	N	N	N	N	N	N
Division :	N	N	N	N	N	N	N	N	N	N
System :	N	N	N	N	N	N	N	N	N	N
2nd View :	N									
Crew :	N			N	N	N	N	N	N	N
Labor :	N									
Equipment :	N									
Prime Labor Cost Level :	N									

(REPORT FORMAT TYPE: Direct, Indirect, Owner; FOR LEVEL (S): 0–6)

** OWNER, OVERTIME, AND ADJUSTMENTS SETTINGS **

		AMOUNT	PERCENT	*ESCALATN DATE* BEGIN	END	*ESCALATN INDEX* BEGIN	END
01 Diversion and Control of Water							
Contingency	P		20.00				
Mob., Design, and Const. Admin	P		24.00				
02 Clearing and Grubbing							
Contingency	P		20.00				
Mob., Design, and Const. Admin	P		24.00				
03 Removal of Structures and Obstru							
Contingency	P		20.00				
Mob., Design, and Const. Admin	P		24.00				
06 Dewatering							
Contingency	P		20.00				
Mob., Design, and Const. Admin	P		24.00				
10 Drainage Excavation							
Contingency	P		20.00				
Mob., Design, and Const. Admin	P		24.00				
12 Compacted Fill							
Contingency	P		20.00				
Mob., Design, and Const. Admin	P		24.00				
15 Soil Cement							
Contingency	P		20.00				
Mob., Design, and Const. Admin	P		24.00				
18 Pozzolan, For Soil Cement							
Contingency	P		20.00				
Mob., Design, and Const. Admin	P		24.00				
20 Miscellaneous							
Contingency	P		20.00				
Mob., Design, and Const. Admin	P		24.00				
25 Right of Way							
Contingency	P		0.00				
Mob., Design, and Const. Admin	P		0.00				
30 Mitigation							
Contingency	P		0.00				
Mob., Design, and Const. Admin	P		0.00				

		QUANTY	UOM	CREW ID	OUTPUT	MANHRS	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
	TOTAL Diversion and Control					0	0	0	0	40,000	40,000	
	TOTAL Clearing and Grubbing					0	0	0	0	20,000	20,000	
	TOTAL Removal of Structures					0	0	0	0	20,000	20,000	
	TOTAL Dewatering	2.00	EA			0	0	0	0	40,000	40,000	20000.00
	10. Drainage Excavation											
USR	Excavate	29000	CY		0.00	0	0	0	0	87,000	87,000	3.00
	TOTAL Drainage Excavation	1.00	EA			0	0	0	0	87,000	87,000	87000.00
	12. Compacted Fill											
USR	Backfill, dozer, comp acted	29000	CY		0.00	0	0	0	0	101,500	101,500	3.50
	TOTAL Compacted Fill	1.00	EA			0	0	0	0	101,500	101,500	101500.00
	TOTAL Soil Cement	1.00	EA			0	0	0	0	573,300	573,300	573300.00
	18. Pozzolan, For Soil Cement											
M USR	Pozzolan, plain, truc ked in bulk	12500	TON	N/A	0.00	0	0	0	1375000	0	1,375,000	110.00
	TOTAL Pozzolan, For Soil Ce	12500	TON			0	0	0	1375000	0	1,375,000	110.00
	20. Miscellaneous											
M RSM	Railing, pipe, alumin um, 2 rail, satin finish, 1.25" dia Modified per discussion to reflect unit price of Railing	8250.00	LF	SIWSE4	20.00	1,650	69,849	4,145	24,998	0	98,992	12.00
	TOTAL Miscellaneous	1.00	EA			1,650	69,849	4,145	24,998	0	98,992	98991.75
	25. Right of Way											
	TOTAL Right of Way					0	0	0	0	295,610	295,610	
	TOTAL Right of Way					0	0	0	0	295,610	295,610	

	QUANTY	UOM	CREW ID	OUTPUT	MANHRS	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
30. Mitigation											
TOTAL Mitigation Land					0	0	0	0	780,560	780,560	
TOTAL Mitigation					0	0	0	0	780,560	780,560	
TOTAL Tanque Verde	1.00	EA			1,650	69,849	4,145	1399998	1957970	3,431,962	3431962

** PROJECT OWNER SUMMARY - Scope (Rounded to 10's) **

		QUANTITY	UOM	CONTRACT	CONTINGN	M,D,CA&F	TOTAL COST	UNIT COST	NOTES
01	Diversion and Control of Water			40,000	8,000	11,520	59,520		1
02	Clearing and Grubbing			20,000	4,000	5,760	29,760		1
03	Removal of Structures and Obstru			20,000	4,000	5,760	29,760		1
06	Dewatering	2.00	EA	40,000	8,000	11,520	59,520	29760.00	1
10	Drainage Excavation	1.00	EA	87,000	17,400	25,060	129,460	129456.00	1
12	Compacted Fill	1.00	EA	101,500	20,300	29,230	151,030	151032.00	1
15	Soil Cement	1.00	EA	573,300	114,660	165,110	853,070	853070.40	1
18	Pozzolan, For Soil Cement	12500.00	TON	1,375,000	275,000	396,000	2,046,000	163.68	1
20	Miscellaneous	1.00	EA	98,990	19,800	28,510	147,300	147299.72	1
25	Right of Way			295,610	0	0	295,610		
30	Mitigation			780,560	0	0	780,560		
TOTAL	Tanque Verde	1.00	EA	3,431,960	471,160	678,470	4,581,590	4581588	

** PROJECT OWNER SUMMARY - Facility (Rounded to 10's) **

	QUANTITY	UOM	CONTRACT	CONTINGN	M,D,CA&F	TOTAL COST	UNIT COST	NOTES
01 Diversion and Control of Water			40,000	8,000	11,520	59,520		1
02 Clearing and Grubbing			20,000	4,000	5,760	29,760		1
03 Removal of Structures and Obstru			20,000	4,000	5,760	29,760		1
06 Dewatering	2.00	EA	40,000	8,000	11,520	59,520	29760.00	1
10 Drainage Excavation	1.00	EA	87,000	17,400	25,060	129,460	129456.00	1
12 Compacted Fill	1.00	EA	101,500	20,300	29,230	151,030	151032.00	1
15 Soil Cement	1.00	EA	573,300	114,660	165,110	853,070	853070.40	1
18 Pozzolan, For Soil Cement	12500.00	TON	1,375,000	275,000	396,000	2,046,000	163.68	1
20 Miscellaneous	1.00	EA	98,990	19,800	28,510	147,300	147299.72	1
25 Right of Way								
25. 5 Right of Way			295,610	0	0	295,610		
TOTAL Right of Way			295,610	0	0	295,610		
30 Mitigation								
30. 5 Mitigation Land			780,560	0	0	780,560		
TOTAL Mitigation			780,560	0	0	780,560		
TOTAL Tanque Verde	1.00	EA	3,431,960	471,160	678,470	4,581,590	4581588	

** PROJECT INDIRECT SUMMARY - Scope (Rounded to 10's) **

		QUANTITY	UOM	DIRECT	OVERHEAD	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT COST
01	Diversion and Control of			40,000	0	0	0	0	40,000	
02	Clearing and Grubbing			20,000	0	0	0	0	20,000	
03	Removal of Structures and			20,000	0	0	0	0	20,000	
06	Dewatering	2.00	EA	40,000	0	0	0	0	40,000	20000.00
10	Drainage Excavation	1.00	EA	87,000	0	0	0	0	87,000	87000.00
12	Compacted Fill	1.00	EA	101,500	0	0	0	0	101,500	101500.00
15	Soil Cement	1.00	EA	573,300	0	0	0	0	573,300	573300.00
18	Pozzolan, For Soil Cement	12500.00	TON	1,375,000	0	0	0	0	1,375,000	110.00
20	Miscellaneous	1.00	EA	98,990	0	0	0	0	98,990	98991.75
25	Right of Way			295,610	0	0	0	0	295,610	
30	Mitigation			780,560	0	0	0	0	780,560	
TOTAL	Tanque Verde	1.00	EA	3,431,960	0	0	0	0	3,431,960	3431962
	Contingency								471,160	
	SUBTOTAL								3,903,120	
	Mob., Design, and Const. Admin								678,470	
	TOTAL INCL OWNER COSTS								4,581,590	

** PROJECT INDIRECT SUMMARY - Facility (Rounded to 10's) **

	QUANTITY	UOM	DIRECT	OVERHEAD	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT COST
01 Diversion and Control of			40,000	0	0	0	0	40,000	
02 Clearing and Grubbing			20,000	0	0	0	0	20,000	
03 Removal of Structures and			20,000	0	0	0	0	20,000	
06 Dewatering	2.00	EA	40,000	0	0	0	0	40,000	20000.00
10 Drainage Excavation	1.00	EA	87,000	0	0	0	0	87,000	87000.00
12 Compacted Fill	1.00	EA	101,500	0	0	0	0	101,500	101500.00
15 Soil Cement	1.00	EA	573,300	0	0	0	0	573,300	573300.00
18 Pozzolan, For Soil Cement	12500.00	TON	1,375,000	0	0	0	0	1,375,000	110.00
20 Miscellaneous	1.00	EA	98,990	0	0	0	0	98,990	98991.75
25 Right of Way									
25. 5 Right of Way			295,610	0	0	0	0	295,610	
TOTAL Right of Way			295,610	0	0	0	0	295,610	
30 Mitigation									
30. 5 Mitigation Land			780,560	0	0	0	0	780,560	
TOTAL Mitigation			780,560	0	0	0	0	780,560	
TOTAL Tanque Verde	1.00	EA	3,431,960	0	0	0	0	3,431,960	3431962
Contingency								471,160	
SUBTOTAL								3,903,120	
Mob., Design, and Const. Admin								678,470	
TOTAL INCL OWNER COSTS								4,581,590	

** PROJECT DIRECT SUMMARY - Scope (Rounded to 10's) **

		QUANTITY	UOM	MANHRS	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
01	Diversion and Control of Water			0	0	0	0	40,000	40,000	
02	Clearing and Grubbing			0	0	0	0	20,000	20,000	
03	Removal of Structures and Obstru			0	0	0	0	20,000	20,000	
06	Dewatering	2.00	EA	0	0	0	0	40,000	40,000	20000.00
10	Drainage Excavation	1.00	EA	0	0	0	0	87,000	87,000	87000.00
12	Compacted Fill	1.00	EA	0	0	0	0	101,500	101,500	101500.00
15	Soil Cement	1.00	EA	0	0	0	0	573,300	573,300	573300.00
18	Pozzolan, For Soil Cement	12500.00	TON	0	0	0	1375000	0	1,375,000	110.00
20	Miscellaneous	1.00	EA	1,650	69,850	4,140	25,000	0	98,990	98991.75
25	Right of Way			0	0	0	0	295,610	295,610	
30	Mitigation			0	0	0	0	780,560	780,560	
TOTAL	Tanque Verde	1.00	EA	1,650	69,850	4,140	1400000	1957970	3,431,960	3431962
	Contingency								471,160	
	SUBTOTAL								3,903,120	
	Mob., Design, and Const. Admin								678,470	
	TOTAL INCL OWNER COSTS								4,581,590	

** PROJECT DIRECT SUMMARY - Facility (Rounded to 10's) **

	QUANTITY	UOM	MANHRS	LABOR	EQUIPMNT	MATERIAL	OTHER	TOTAL COST	UNIT COST
01 Diversion and Control of Water			0	0	0	0	40,000	40,000	
02 Clearing and Grubbing			0	0	0	0	20,000	20,000	
03 Removal of Structures and Obstru			0	0	0	0	20,000	20,000	
06 Dewatering	2.00	EA	0	0	0	0	40,000	40,000	20000.00
10 Drainage Excavation	1.00	EA	0	0	0	0	87,000	87,000	87000.00
12 Compacted Fill	1.00	EA	0	0	0	0	101,500	101,500	101500.00
15 Soil Cement	1.00	EA	0	0	0	0	573,300	573,300	573300.00
18 Pozzolan, For Soil Cement	12500.00	TON	0	0	0	1375000	0	1,375,000	110.00
20 Miscellaneous	1.00	EA	1,650	69,850	4,140	25,000	0	98,990	98991.75
25 Right of Way									
25. 5 Right of Way			0	0	0	0	295,610	295,610	
TOTAL Right of Way			0	0	0	0	295,610	295,610	
30 Mitigation									
30. 5 Mitigation Land			0	0	0	0	780,560	780,560	
TOTAL Mitigation			0	0	0	0	780,560	780,560	
TOTAL Tanque Verde	1.00	EA	1,650	69,850	4,140	1400000	1957970	3,431,960	3431962
Contingency								471,160	
SUBTOTAL								3,903,120	
Mob., Design, and Const. Admin								678,470	
TOTAL INCL OWNER COSTS								4,581,590	

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SUMMARY REPORTS SUMMARY PAGE

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ECONOMICS

US Army Corps
of Engineers
Los Angeles District

TANQUE VERDE CREEK, ARIZONA
LIMITED REEVALUATION REPORT
ECONOMIC ASSESSMENT

Prepared for:

U.S. Army Corps of Engineers
Los Angeles District
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17770 Cartwright Road, Suite 500
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August 2002

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I. THE STUDY

A. Study Area Location

The study area is located approximately 6 miles east-northeast of downtown Tucson in an unincorporated area generally known as the Tucson Country Club Estates. On the southern side of Tanque Verde Creek, the study area is defined as the area from approximately 2,800 feet west of Sabino Canyon Road to Craycroft Road and for a distance of approximately 1,000 feet south of the Tanque Verde Creek. The northern study area extends from the base of the bluff south to the Tanque Verde Creek between Craycroft Road and approximately 4,200 feet west of Sabino Canyon Road. The study area is essentially fully developed and no future development is anticipated.

B. Authority

This study is being conducted under the authority of the Water Resources Development Act of 1986, Public Law 99-662, 99^{th} Congress.

C. Study Purpose and Scope

The purpose of this Limited Reevaluation Report (LRR) is to determine if the improvements proposed by Pima County, Arizona are economically justified under the existing Rillito River and Associated Streams study authority. These improvements are identified in the report titled "*Rillito River and Associated Streams Bank Stabilization and Riparian Area Preserve - Tanque Verde Creek*," dated December 1996, as prepared by the Pima County Department of Transportation and Flood Control District. This assessment is to present the economic analysis used to measure beneficial contributions to National Economic Development (NED) from erosion damage reduction.

II. EXISTING CONDITIONS

A. Flood Inundation - 100-Year Flood Plain

There are no residential structures located within the 100-year flood plain of the Tanque Verde Creek, with the exception of a secondary structure to a primary, single lot residence. The Tucson Country Club golf course appears to be the only developed property located in the 100-year flood plain. Since streambank stabilization and protection would not provide any additional flood control protection to the study reach of Tanque Verde Creek, further analysis of flood inundation damage reduction in this study is omitted.

B. Erosion Zone Limit

The hydraulic analysis indicates an average annual erosion rate of approximately 13 feet per year and a limiting meander potential for the north bank corresponding to the northern boundary of the geologic flood plain. The limiting meander potential for the south bank is an imaginary line located approximately 1,600 feet south of the projected centerline of the meander loop. Since the south bank is located approximately 500 feet from this centerline, the limiting meander potential for the south bank is approximately 1,100 feet.

III. METHODOLOGY OVERVIEW

A. Guidance and Regulations

This economic assessment is formulated to be in accordance with ER 1105-2-100 (22 April 2000) and the Risk & Uncertainty guidance of ER 1105-2-205. Further, benefits and costs expressed as annual values are calculated utilizing the FY00 discount rate of $6^{5}/_{8}$ percent with a project life of 50 years. All benefits and costs are expressed at a February 2000 price level. The base operational year is 2004.

The following analysis attempts to extend the implicit risk-neutrality of ER 1105-2-100's Chapter 6, Section IV, to urban streambank erosion. Previous Corps studies have dealt with erosion in differing manners, each with its own implied level of risk-taking behavior. In the Corps study *"Rillito River & Associated Streams Feasibility Report,"* dated 1987, the interactions between market price, damage value, and the timing of loss imply a high level of risk-taking behavior on the part of property owners. In contrast, the Corps' study *"Norco Bluffs, California"* a constant erosion rate and the net present modeling (NPV) of the expectation of loss shifts the analysis from risk-neutrality toward risk-averse. This study's analytical approach is to merge the randomness of annual erosion with the long-term expectation of erosion loss in an attempt to bring streambank erosion analysis closer to a true risk-neutral state. This analytical approach is discussed in greater detail in the next section.

B. Computer-based Models and Reference Sources

The following items were utilized for the economic assessment of Tanque Verde Creek:

Models:
(1) HEC-EAD Expected Annual Flood Damage Computation Model

Software:
(1) Microsoft Excel, Version 8
(2) Paradise @RISK, Version 3.05.0006
(3) MicroStation 95

References:
(1) Marshall & Swift Evaluation Services
(2) TRW Redi Real Estate data base
(3) Pima County study area digital CADD files
(4) DATA**QUICK**

C. Database Field Survey

Average structure value, residential land value and the average per acre land value for the Tucson Country Club were prepared by the Real Estate Division of the Corps of Engineers and employed in this analysis.

D. Topographic Mapping

Structure distance from the Tanque Verde Creek streambank was measured using MicroStation 95 and the Pima County CADD files.

IV. RISK & UNCERTAINTY MODELING

A. Synthetic Frequency-Erosion Function

Although the exact nature of the frequency-erosion function is unknown and is dependent upon numerous variables, it is still possible to develop a synthetic representation of the function. While there is still considerable uncertainty in the synthetic function, it is still a valuable tool with which to predict erosion behavior on the creek, especially when combined with a sensitivity analysis.

Development of the synthetic frequency-erosion function begins with identification of several points to be used as the backbone of the frequency-erosion function and the estimated long-term average annual erosion rate. The long-term average annual erosion rate serves as the control point for the HEC-EAD synthesis of the frequency-erosion function. The HEC-EAD model is used in this process as a tool for the integration of data points for their comparison to the control point of long-term average annual erosion. Within the HEC-EAD model a subroutine exists for the identification of the model's internal calculations of intermediate points between the backbone points. The manipulation of these intermediate points to control the expected annual rate generated by HEC-EAD to the estimated long-term average annual rate is possible through expansion of the data points beyond the initial backbone data set. Through this manipulation of intermediate data points it is possible to construct a synthetic frequency-erosion function with a historical basis that approximates the long-term average annual erosion rate.

The engineering analysis indicates that the greatest historical erosion event observed was on the order of 200 feet. Conservatively capping erosion at 195 feet for the frequency event of 0.0001 sets the upper backbone limit for the synthetic frequency-erosion function. The engineering analysis also indicates that an erosion rate of 90 feet for the .01 frequency event is consistent with the observed data and a non-erosion frequency could be defined as the 3-year event. These points serve as the backbone events for the HEC-EAD model for the derivation of the initial frequency-erosion function along with the engineering analysis' estimate of the long-term annual erosion rate at 13 feet. Through a process of intermediate point additions and manipulations within the HEC-EAD model, Table 1 shows the HEC-EAD model inputs of frequency-erosion pairings that yield an expected annual erosion rate of 13.02 feet.

Table 1
Derivation of Synthetic Frequency-Erosion Function
HEC-EAD Frequency-Erosion Pairings

Frequency	Erosion (feet)
.30	0
.29	5
.25	20
.10	50
.01	90
.005	130
.0001	195

Although the HEC-EAD model produces a reasonable estimate of the frequency-erosion function, it is not in a form readily accessible for risk-based computer modeling. The HEC-EAD relationships must be transformed into a usable modeling form. This transformation was accomplished through the use of the expanded output matrix of HEC-EAD and the CUMUL function of @RISK. The CUMUL function takes the following form where x denotes lateral erosion and p the cumulative probability.

CUMUL(min,max,$\{x_1,...,x_n\}$,$\{p_1,...,p_n\}$)

The Excel data matrix for the CUMUL function is,

RiskCumul(0,210,{0.000001,0.62,2.66,4.51,5,6.93,13.34,18.74,20,24.06,34.72,45.71,50,52.76,63.63, 82.15,90,91.22,104.29,124.21,130,135.78,159.14,186.54,195},{0.7,0.70113,0.705,0.70887,0.71,0.71451, 0.73,0.74549,0.75,0.76691,0.825,0.88309,0.9,0.91014,0.945,0.97986,0.99,0.99056,0.9925,0.99444, 0.995,0.99555,0.99745,0.99935,0.9999})

The expected value of the RiskCumul function is 13.07.

B. Expectation of Erosion

At any given point in time, it is assumed that a property owner perceives risk based on the position of the property in relation to the current position of the streambank and the long-term average erosion rate. Under this concept, the property owner experiences the random fluctuations in erosion but does not alter his risk factor by this randomness.

Calculation of damage employs the Net Present Value (NPV) technique with the modification that erosion is a random annual event rather than using a constant, average annual rate as in the case of the Norco Bluffs study.

C. R&U Model Process

The R&U process is modeled in Excel employing @RISK add-ins. First, the model produces a random erosion rate based on the RiskCumul function and uniformly shifts the streambank toward the structures by this amount. Second, the NPV of the property owners' expected future loss is estimated based on the current existing condition of the streambank in relation to the long-term erosion rate. This process is then repeated annually for the duration of the study life. The individual losses are summed by year and the change in the annual total is computed, producing a stream of net annual losses. This stream of future net annual losses is transformed using the NPV technique to an equivalent current dollar loss. Finally, this equivalent current dollar loss is amortized, producing an equivalent annual dollar loss.

This process was repeated 5,000 times generating a distribution of potential outcomes for statistical analysis.

1. Residential Structure and Land Loss

The NPV random erosion process above applies to residential structures and land. The only modification to the process described above is the assumption of a 13-foot condemnation zone around the structure. In the analysis, if erosion has proceeded within 13 feet of the structure but has not yet destroyed the structure, the structure is deemed uninhabitable and lost.

2. Residential Content Loss

Residential content loss applies the basic principles of the R&U model with one major exception. This exception is that a loss only occurs when the streambank's annual erosion extends from outside the 13-foot condemnation zone beyond the structure's starting location. This assures that contents are only lost when the structure is destroyed and not by condemnation.

3. Sewer Line Loss

Sewer line loss applies the same principles of residential content loss in that damage to the sewer line occurs when the random erosion process proceeds past the location of the sewer line.

V. RESIDENTIAL CONTENT VALUE

Chapter 6, Section 6-45 (2) (a) of ER 1105-2-100 requires that, for feasibility studies, all content-to-structure ratios must be based on either site-specific surveys or surveys of comparable floodplains. It also requires that in areas where surveys of comparable floodplains are used, at a minimum, a qualitative rationale must be provided to demonstrate comparability of the survey to the study floodplain. For this study, the results of the "*Tucson Area Drainage Feasibility Study, Arizona*" will be used, since they are qualitatively very similar due to their proximity to a nearby golf course and their proximity to each other. Therefore, the residential content-to-structure value percentage is 50%.

VI. EROSION ZONE INVENTORY

The erosion zone consists of residential properties, an existing sewer line, a proposed sewer line, and the Tucson Country Club. There are 56 residential structures within the 1,100-foot maximum erosion zone. Real estate values were determined by the Real Estate Division of the US Army Corps of Engineers, Los Angeles District. The estimate for total value (structure plus land) is $125 per square foot of structure. The estimated structure-only portion of total value is $85 per square foot. Content value was assumed to be 50 percent of structure value. Individual structure square footage measures were obtained from DATA**QUICK**, a real estate service. Residential structures in the study area range from 1,800 to more than 6,000 square feet in size, with the average being 3,439 square feet. The total value of residential property subject to the erosion threat is shown in Table 2. Potential Tucson Country Club golf course erosion damages are detailed in Table 3.

Table 2 **Erosion Zone Residential Inventory**	
Number of Structures	56
Average Structure Value	$292,315
Average Residential Lot Value	$137,560
Average Content Value	$146,158
Total Structure Value	$16,368,195
Total Lot Value	$7,702,680
Total Content Value	$8,184,098
Total Residential Inventory Value	**$32,254,973**

Table 3
Potential Damages to Tucson Country Club

Structures & Facilities:
Pool House & Pool
Pavilion Banquet Hall
4 Maintenance Buildings
Tennis House & 12 Courts

Golf Course Hole:	Potential for Erosion Damage		
	Green	Tee	Fairway
2	X		X
3	X	X	X
4	X	X	X
5	X	X	X
6	X	X	X
7		X	X
11	X		X
12	X	X	X
13		X	X
16	X	X	X
17		X	X

The North Rillito Interceptor, a 30" sewer line, runs along the base of the bluff on the north side of Tanque Verde Creek. For the most part, the North Rillito Interceptor ranges from 300 to 600 feet from the Tanque Verde Creek. However, immediately upstream of Craycroft Road and for a distance of approximately 1,550 feet, the North Rillito Interceptor is within 100 feet of the creek. If a line break should occur, it is impossible to close down flow without inducing sewer back-flow into residential properties due to the interceptor's gravity flow design. According to the Pima County Wastewater Management Department, it is likely that a line break during a storm event could produce a 20 million-gallon release of wastewater prior to its containment. On the south side of the Tanque Verde Creek, Pima County has awarded an engineering and design contract for the construction of the new 36" Tanque Verde Interceptor Extension sewer line. This interceptor will parallel the Tanque Verde Creek from Craycroft Road east to the Tucson Country Club. This project was approved with the 1997 sewer system revenue bond ballot initiative. Bond funding for this project is $4,050,000. Erosion protection for this project is estimated to increase its overall cost to $5,800,000.

VII. WITHOUT-PROJECT EROSION DAMAGE

A. North Rillito Interceptor

The North Rillito Interceptor (NRI) runs parallel to Tanque Verde Creek in the vicinity of Craycroft Road. Erosion has the potential to undercut NRI's supporting land and subject the sewer line to failure. NRI has a replacement value of $4,611,600 as estimated by the Wastewater Management Department of Pima County. Only the first 1,550 feet of the NRI east of Craycroft Road are considered subject to erosion in this analysis. It is estimated that the sewer line is 65 feet from the creek bank within this 1,550-foot zone. Further, it is assumed that the value of the first 1,550 feet is proportionate to the overall value of the interceptor. Under this assumption, the value of the sewer line in the 1,550-foot zone is $1,235,900. With a base year of 2004, under the R&U model of random annual erosion, there is a 9% chance that the sewer line would be damaged prior to the provision of streambank protection (based on 30,000 iterations of a 50-year study horizon). It is further assumed that if the sewer line is damaged prior to the project, the entire 1,550-foot zone will be protected from future erosion damage. Under these assumptions, the mean unweighted NPV of the damage to the sewer line is $785,700. Thus, the weighted NPV of sewer line damage is $715,000. The amortized value of the weighted damage is $49,400.

When the sewer line fails, wastewater is released into the environment. Previous Corps studies (most notably the Emergency Streambank Protection report on Walnut Canyon Creek, City of Anaheim, California) have estimated the cleanup cost from a sewer line failure in the range of 1 to 66 cents per gallon. For the purposes of this analysis, a cost of 6.4 cents per gallon is assumed. It is estimated that a sewer line failure would release 20,000,000 gallons of wastewater before containment, as previously reported. Using the random annual erosion model and the NPV technique of converting future damage at the occurrence of a sewer line break to current dollars, the unweighted mean damage estimate is $812,000. Its weighted mean value is $738,900 with an amortized value of $51,000.

B. Tanque Verde Interceptor Extension

The Tanque Verde Interceptor Extension project should be considered implemented for the without-project condition. The potential "damage" reduction for the extension project in a with-project condition is an avoided cost saving. With a base year of 2004, a Corps project would be in place prior to the construction of the extension project avoiding the need for the $1.74 million cost of erosion protection for the extension project. On an annual basis the avoided cost savings has a value of $120,100.

C. Tucson Country Club

The Tucson Country Club was incorporated in 1947 under the laws of Arizona. The club was organized in conjunction with one of the most prestigious subdivisions in Tucson. The clubhouse, tennis courts, swimming pool, and golf course cover approximately 200 acres. The golf course is unique to central and southern Arizona not only because of its size, but because of the significant number of trees which line the fairways. The 2000 trees estimated on the course make it unique in southern Arizona. The golf course could not be replaced elsewhere because water laws now limit the number of acre-feet of water that new golf courses can utilize. Tucson Country Club is exempt from these stringent water use requirements.

The economic analysis related to the Tucson Country Club considers the impact of erosion on the corporation. Traditional approaches of evaluating changes to potential net income fail because private organizations are not structured to respond to the market forces of supply and demand as are other free market corporations. The Country Club's purpose is not to maximize profits. The Tucson Country Club has 425 Regular class members. Regular class members represent the only classification which has equity in the corporation. Recent transactions of membership certificate exchanges place the value at $30,000. At this value, the indicated nonmarket value of the Country Club would be $12,750,000. Although this is a nonmarket evaluation, a measure of the impact of erosion on the corporation is the change in membership value. Past, direct experience with flooding and erosion at the Country Club helps to define changes in membership value, as follows.

Examination of the response in membership value to the 1983 flood and erosion to one fairway will shed some light on the loss of corporate value. Membership sales averaged $14,313 in the four months prior to the flood of 1983. There were 21 sales, not including transfers to relatives, during this period. In the seven months subsequent to the 1983 flood, through July 1984, there were only 13 sales, not including transfers to relatives. During this period, the average price dropped to $9,958. This 30% decline in membership value occurred even though there was sufficient land to move the fairway slightly without rebuilding the entire hole.

Although membership value has recovered and no permanent loss occurred, it is expected that this will not be the case following an erosive event in the future. The erosion of 1983 has left the golf course without any flexibility to realign holes immediately adjacent to Tanque Verde Creek since sufficient land near the creek is no longer available and the Country Club is land locked by development. Future erosion left unabated will require redesign and reconstruction of the golf course to a less desirable "executive" course. In this case, it is reasonable to assume the corporation's value would greatly decrease given the historical response to the 1983 flood. However, unlike the long-term response to the 1983 flood, membership value would likely not recover since the effects would be permanent.

Erosion left unabated would damage the facilities and golf course holes shown in Table 3. Given the extent of this potential damage, the use of the decline experienced in 1983, 30 percent, may be considered conservatively low. An irreversible 30 percent loss in the "market value" of the Tucson County Club would be $3,825,000.

Economic reasonableness dictates the limiting of damages from the Country Club to the cost of streambank erosion protection since the existing condition on Tanque Verde Creek would allow for construction to solely protect the Country Club. It is estimated that the cost of streambank stabilization for the area of the Country Club would be approximately $2,100,000. Economically, it would be more rational for the Tucson Country Club to expend $2.1 million to protect itself rather than to suffer the $3.83 million loss to erosion. Therefore, erosion damages to the Tucson Country Club on a National Economic Development basis are $2.1 million. On an annual basis, this loss is $144,500.

It should be noted that others would derive benefits from the actions of the Tucson Country Club if it were to provide streambank erosion protection for the Club. Namely, the residential damages discussed in the following section would be eliminated with this construction and the protection of the Tanque Verde Interceptor would not be necessary in the area of the Country Club.

D. Residential Structures

The results of the 5,000 iteration runs for the R&U model for structures and land[1], and contents, as outlined in Section IV of this report, indicated a mean NPV for structure and land damage of $4,620,091 and a mean NPV of $436,402 for content damage. The respective standard deviations were $1,432,916 and $298,717. The NPV distribution for structures and land damage is shown in Figure 1. Figure 2 shows the distribution of content NPV damage. Amortizing the NPVs at $6^5/_8$ percent over 50 years yields the following annual damages:

- Annual Structure & Land Damage: $319,000
- Annual Content Damage $30,100

[1]Loss of land value occurs only at the time of structure loss. No accounting is made for incremental land losses before the loss of structure.

Total annual damage to residential structures is $349,100.

FIGURE 1

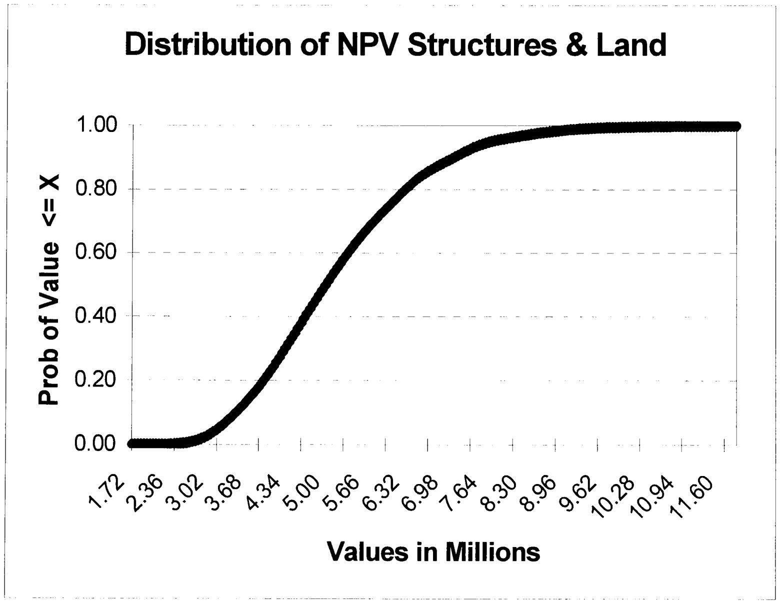
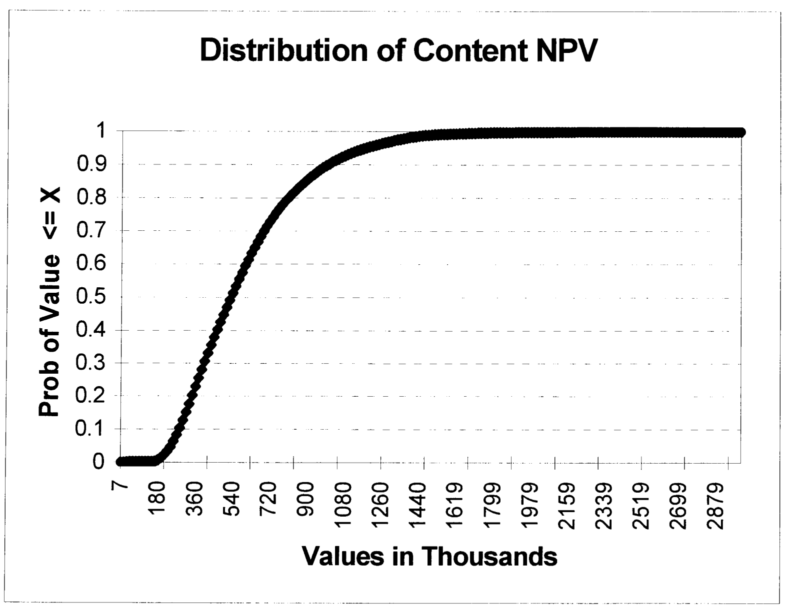


FIGURE 2



E. Without-Project Equivalent Annual Damage Summary

Table 4 presents a summary of the equivalent annual damages of the without-project condition.

Table 4
WITHOUT-PROJECT EQUIVALENT ANNUAL DAMAGES

Category	Equivalent Damage
Residential Structures & Land	$319,000
Residential Contents	$30,100
North Rillito Interceptor	$49,400
Sewer Spill Cleanup Costs	$51,000
Tanque Verde Interceptor	$120,100
Tucson Country Club	$144,500
Total	$714,100

VIII. WITH-PROJECT DAMAGE REDUCTION

The effect of the proposed streambank protection is to preclude the damages outlined above. Therefore, the annual benefit of providing streambank protection is $714,100.

A. With-Project Economics

Proposed streambank protection consists of four (4) alternatives. These alternatives are as follows.

Alternative 1: The no-action plan;

Alternative 2: The recommended plan and preferred by Pima County. This alternative fully addresses the identified problems along the Tanque Verde Creek between Sabino Canyon Road and Craycroft Road. The structural measures include installing soil cement bank protection in the existing gaps in bank protection on the south bank, and installing approximately 1,550 feet of bank protection upstream of the Craycroft Road Bridge on the north bank. The horizontal alignment of the proposed bank protection would be along smooth curves that generally follow the existing bank. Where applicable, the ends would match the existing soil cement. On the south bank, at the downstream end, the proposed soil cement would key into the bank just upstream of the confluence with Pantano Wash.

On the north bank, at the upstream end, the soil cement would key into the existing bank and be tied back to high ground. The soil cement would match the top of the existing bank, and the toedown would extend 10 feet below the existing thalweg.

The soil cement layer would be an 8-foot thick layer of soil and portland cement that is mixed and placed in 6-inch to 1-foot thick lifts. The lifts are successively placed until the desired bank protection height is reached. Once compacted, the soil cement mixture provides a hard and durable surface that is expected to last well over the project life of 50 years.

The mitigation component of the proposed plan includes acquiring the rights-of-way to establish a permanent 500-foot buffer along the north bank. Public ownership of this land would prevent additional development and the associated flood damages, while preserving the riparian values of this heavily vegetated area.

Alternative 3: This plan would be identical to Alternative 2 except approximately 2,830 feet on the south bank just upstream of the Craycroft Road bridge would not receive bank protection. The protection on the south bank would instead tie into the existing protection upstream of the golf course and continue to just downstream of the golf course, to beyond the site of the historic meander. The unprotected portion of the south bank would be allowed to erode naturally.

Alternative 4: This plan would be identical to Alternative 2 except that the habitat area would receive erosion protection to reduce the rate of erosion and thereby increase environmental benefits. This would be accomplished by constructing a low soil cement berm adjacent to the bank of the habitat area. The berm would stabilize the slope yet be sized to allow overtopping from the 5-10 year flood so as to allow flushing flows. It is estimated that the berm would be approximately 2 feet above ground with toe-down depths the same as with the upstream and downstream slope protection (approximately 10 feet).

Alternative 2

Alternative 2 is preliminarily estimated to have a total construction cost of $3,560,400. Interest during construction (IDC), based on a one-year time frame, is $117,900. Amortization of the total economic cost ($3,678,300) yields an annual economic cost of $253,965. The annual OMRR&R cost for Alternative 2 is estimated to be $17,900. Therefore, the total annual economic cost for Alternative 2 is estimated to be $271,865. Alternative 2 would prevent all damages and has annual NED benefits of $714,100. The NED economics of Alternative 2 are shown in Table 5 below.

Table 5 **ALTERNATIVE 2 NED ECONOMICS** Annual Costs & Benefits February 2000 price level			
NED Costs	NED Benefits	B/C Ratio	Net Benefits
$271,865	$714,100	2.63	$442,235

Preliminary Cost Estimate - Alternative 2

Item	Units	Quantity	Unit Cost	Cost
Clearing and Grubbing	L.S.	1	$20,000.00	$20,000
Removal of Structures & Obstructions	L.S.	1	$20,000.00	$20,000
Diversion and Control of Water	L.S.	1	$20,000.00	$20,000
Dewatering	L.S.	1	$20,000.00	$20,000
Drainage Excavation	C.Y.	26,000	$3.00	$78,000
Compacted Fill	C.Y.	29,000	$3.50	$101,500
Soil Cement Bank Protection	C.Y.	43,000	$9.00	$387,000
Stabilizer for Soil Cement	Ton	8,400	$110.00	$924,000
Safety Hand Rail	L.F.	8,250	$12.00	$99,000
Subtotal				**$1,669,500**
Contingency (20% of Subtotal)				$333,900
Total Construction Cost				**$2,003,400**
Mobilization (3%)				$60,102
Design Engineering Cost (6%)				$120,204
Construction Admin. & Field Inspection (15%)				$300,510
Right-of-Way			$295,610.00	$295,610
Mitigation Land			$780,560.00	$780,560
TOTAL PROJECT COST				**$3,560,386**

Alternative 3

Alternative 3 deletes bank protection for a 2,830-foot segment on the south bank upstream of the Craycroft Road Bridge from Alternative 2. This bank protection deletion subjects the Tanque Verde Interceptor Extension project to erosion in this area reducing the avoided cost savings benefit. The estimated cost to provide erosion protection to the interceptor extension in this area is $1,052,600. At this cost level, the Tanque Verde Interceptor avoided cost benefits would be reduced by $72,700 to an annual equivalent of $47,400. Overall annual NED benefits for Alternative 3 would be $641,400. Alternative 3 is estimated to have a total construction cost of $2,710,840. Interest during construction (IDC), based on a one-year time frame, is $89,800.

Amortization of the total economic cost ($2,800,640) yields an annual economic cost of $193,400. The annual OMRR&R cost for Alternative 3 is estimated to be $17,900. Therefore, the total annual economic cost for Alternative 3 is estimated to be $211,300. The NED economics of Alternative 3 are shown in Table 6 below.

Table 6
ALTERNATIVE 3 NED ECONOMICS
Annual Costs & Benefits
February 2000 price level

NED Costs	NED Benefits	B/C Ratio	Net Benefits
$211,300	$641,400	3.04	$430,100

Preliminary Cost Estimate - Alternative 3

Item	Units	Quantity	Unit Cost	Cost
Clearing and Grubbing	L.S.	1	$20,000.00	$20,000
Removal of Structures & Obstructions	L.S.	1	$20,000.00	$20,000
Diversion and Control of Water	L.S.	1	$20,000.00	$20,000
Dewatering	L.S.	1	$20,000.00	$20,000
Drainage Excavation	C.Y.	17,445	$3.00	$52,336
Compacted Fill	C.Y.	17,364	$3.50	$60,773
Soil Cement Bank Protection	C.Y.	29,600	$9.00	$266,400
Stabilizer for Soil Cement	Ton	5,800	$110.00	$638,000
Safety Hand Rail	L.F.	5,536	$12.00	$66,426
Subtotal				**$1,163,935**
Contingency (20% of Subtotal)				$232,787
Total Construction Cost				**$1,396,722**
Mobilization (3%)				$41,902
Design Engineering Cost (6%)				$83,803
Construction Admin. & Field Inspection (15%)				$209,508
Right-of-Way			$198,345.00	$198,345
Mitigation Land			$780,560.00	$780,560
TOTAL PROJECT COST				**$2,710,840**

Alternative 4

Alternative 4 is identical to Alternative 2 with the addition of low-flow bank stabilization for the habitat area. This alternative would prevent all damages as like Alternative 2. The additional cost of low-flow bank protection is estimated at $1,021,200, resulting in a total construction cost of $4,581,600. IDC for this alternative is estimated at $151,800 which yields an economic cost of this alternative of $4,733,400. The amortized cost of this alternative is $326,800. The annual OMRR&R cost for Alternative 4 is estimated to be $17,900. Therefore, the total annual economic cost for Alternative 4 is estimated to be $344,700. The NED economics of Alternative 4 are shown in Table 7 below.

Table 7
ALTERNATIVE 4 NED ECONOMICS
Annual Costs & Benefits
February 2000 price level

NED Costs	NED Benefits	B/C Ratio	Net Benefits
$344,700	$714,100	2.07	$369,400

Preliminary Cost Estimate - Alternative 4

Item	Units	Quantity	Unit Cost	Cost
Clearing and Grubbing	L.S.	1	$20,000.00	$20,000
Removal of Structures & Obstructions	L.S.	1	$20,000.00	$20,000
Diversion and Control of Water	L.S.	2	$20,000.00	$40,000
Dewatering	L.S.	2	$20,000.00	$40,000
Drainage Excavation	C.Y.	29,000	$3.00	$87,000
Compacted Fill	C.Y.	29,000	$3.50	$101,500
Soil Cement Bank Protection	C.Y.	63,700	$9.00	$573,300
Stabilizer for Soil Cement	Ton	12,500	$110.00	$1,375,000
Safety Hand Rail	L.F.	8,250	$12.00	$99,000
Subtotal				**$2,355,800**
Contingency (20% of Subtotal)				$471,160
Total Construction Cost				**$2,826,960**
Mobilization (3%)				$84,809
Design Engineering Cost (6%)				$169,618
Construction Admin. & Field Inspection (15%)				$424,044
Right-of-Way			$295,610.00	$295,610
Mitigation Land			$780,560.00	$780,560
TOTAL PROJECT COST				**$4,581,600**

Summary of Alternatives

Table 8 summarizes the findings on the soil cement revetment alternatives.

Table 8
Summary - Soil Cement Revetment Alternatives

Alternative	Annual			
	NED Costs	NED Benefits	B/C Ratio	Net Benefits
Alternative 2	$271,865	$714,100	2.63	$442,235
Alternative 3	$211,300	$641,400	3.04	$430,100
Alternative 4	$344,700	$714,100	2.07	$369,400

Each alternative displays positive net benefits and will be a candidate for the NED plan if it satisfies the other constraints of plan formulation, especially those regarding environmental mitigation.

Incremental Analysis of Components

The Tanque Verde system consists of three elements: (1) a 4,220' bank stabilization element along the golf course on the south bank of the river, (2) a stabilization element connecting Craycroft Road to the existing bank stabilization 2,830 feet upstream on the south side of the river and, (3) a bank stabilization element on the north bank of the river stretching upstream from Craycroft Road 1,550 feet. The first element, the golf course alignment, is not incrementally analyzed as it covers virtually all of the residential structures in the study area. The second and third elements are incrementally analyzed under the following assumptions, (1) no IDC accrues and (2) element costs are proportionate to the total construction cost based on element length.

North Bank Protection - North Rillito Interceptor

Benefits for this element are the previously discussed benefit categories of (1) North Rillito Interceptor and (2) Sewer Spill Cleanup Costs. Table 4 indicates that the without project annual damages are $49,400 and $51,000, respectively. Annual benefits are $100,400, given that this element would prevent these damages. The length of the element is 1,550 feet, 19% of all non-habitat construction. The proportionate share of total construction cost (Table 5) is $380,600, having an amortized annual value of $26,300. Net annual benefits are $74,100 and with a B/C ratio of 3.8.

South Side - Craycroft Road to Existing Protection

The benefits for the bank stabilization element from Craycroft Road to 2,830 feet upstream where protection currently exists take the form of an avoided cost savings in the design of the Tanque Verde Interceptor (TVI). If no erosion protection is provided, the Sewer

Department will expend $1.75 million to protect TVI from erosion. The annual cost of this expenditure is $120,800.

The prorated total construction cost of the Corps plan for the 2,830 feet of TVI protection is $667,800. The annualized value of this expenditure is $46,100. Thus, implementing the Corps plan would produce a net avoided annual cost savings of $74,700 with a benefit/cost ratio of 2.6.

B. Plan Selection

Table 8 indicates that the addition of the 2830-foot segment on the south bank of the Tanque Verde Creek is incrementally justified. A detailed analysis of this fact is presented above, as well as, the incremental justification of the northern bank component. As described earlier, the difference between Alternative 2 and 3 is that Alternative 2 contains the 2830-foot protection on the southern bank. An examination of the change in net benefits between Alternatives 2 and 3 reveals a net benefit increase of $12,135 with the change in project scope from Alternative 3 to Alternative 2. These added positive net benefits are attributable to the 2830-foot segment.

If the incremental justification of the 2830-foot south bank segment is acknowledged, further detailed analysis of Alternative 3 would not be warranted as NED requirements would dictate plan selection towards Alternative 2, unless there was a locally preferred exception. Given the absence of a locally preferred exception, further detailed analysis of Alternative 3 has not been conducted for this economic assessment.

As a result of the preliminary findings on costs and benefits, Alternatives 2 and 4 remain as potential NED candidates. However, the environmental assessment of these plans, as detailed in Appendix B-5: Incremental Cost Analysis and Habitat Evaluation of the Environmental Assessment (EA), indicates that the acquisition of the 48-acre preserve area will not fully mitigate the environmental impacts associated with the construction of Alternative 2. Specifically, the EA states:

> *"The mitigation goal for the Recommended plan is to maintain a minimum of 40.46 AAHUs [average annual habitat units]. With the preserve, a deficiency of 1.6 AAHUs remains. The 48-acre preserve is, therefore, not adequate mitigation for Alternative 2."*

The EA further indicates that Alternative 4 exceeds the minimum goal of 40.46 AAHUs by 4.43 AAHUs (44.48 AAHUs in total) making Alternative 4 consistent with the goals of plan formulation. Alternative 4 is identified as the NED plan, for the above reasons, and is the plan selected for detailed cost (M-CACES) and benefit analysis.

C. Selected Plan

The plan selected for recommendation is Alternative 4. This plan was selected because it most closely meets the planning objectives identified for this study, including:

- Provides reduction of flood hazards and associated inundation damages along Tanque Verde Creek;

- Provides protection and, where appropriate, enhancement of existing riparian and wildlife resources of the existing stream environments;

- The selected plan is complete in and of itself and should not require additional improvements in the future;

- The selected plan is "justified" in the sense that total beneficial effects associated with the objectives are equal to or exceed the total adverse effects associated with the objectives; and

- The plan is generally acceptable to the public.

The following discussion presents Alternative 2 at a higher level of consideration, M-CACES level, for analysis of its benefits and costs.

Project Description

The selected plan, Alternative 4, fully addresses the identified problems along the Tanque Verde Creek between Sabino Canyon Road and Craycroft Road while including both structural and non-structural measures. The structural measures include installing soil cement bank protection in the existing gaps in bank protection on the south bank, and installing approximately 1,550 feet of bank protection upstream of the Craycroft Road Bridge on the north bank. The horizontal alignment of the proposed bank protection would be along smooth curves that generally follow the existing bank. Where applicable, the ends would match the existing soil cement. On the south bank, at the downstream end, the proposed soil cement would key into the bank just upstream of the confluence with Pantano Wash.

On the north bank, at the upstream end, the soil cement would key into the existing bank and be tied back to high ground. The soil cement would match the top of the existing bank, and the toedown would extend 10 feet below the existing thalweg. In addition, limited bank protection will be constructed for the preserve area. This limited bank protection will be a low soil cement berm (approximately 5,000 feet in length) with "weep holes" to maintain the hydrologic connection between the creek and the preserve. The berm will stabilize the slope and allow for the continued overtopping of flood waters with events greater than approximately 10-years in size by its low 2-foot height.

The soil cement layer would be an 8-foot thick layer of soil and portland cement that is mixed and placed in 6-inch to 1-foot thick "lifts." The lifts are successively placed until the desired bank protection height is reached. Once compacted, the soil cement mixture provides a hard and durable surface that is expected to last well over the project life of 50 years.

The proposed action would affect desert riparian habitat, including mesquite bosque habitat, along Tanque Verde Creek. A total of approximately 9.9 acres of habitat would be lost, including approximately 1.9 acres of moderate to high quality mesquite bosque habitat and 8.0 acres of disturbed desert wash habitat. Impacts to wildlife in the disturbed desert wash area will be minor because relatively few species inhabit these areas, and most are relatively common. Impacts to wildlife found in the mesquite bosque habitats would include temporary and permanent displacement and mortality of some wildlife that is unable to escape.

Mitigation of the proposed plan, in addition to the berm, involves acquiring the rights-of-way to establish a permanent 500-foot buffer along the north bank. Public ownership of this land (approximately 48 acres) would prevent additional development and the associated flood damages, while preserving the riparian values of this heavily vegetated area.

Project Performance and Residual Flooding

The soil cement bank stabilization will provide a hard and durable surface that is expected to last well over the project life of 50 years and will prevent future movement of the banks in the protected areas. Alternative 4 will not increase nor decrease the current level of overbank flood protection. The 100- and 500-year overflows for the Tanque Verde Wash will remain as present.

Plan Benefits

The Selected Plan would prevent erosion damage to residential structures, the North Rillito Interceptor, and the Tucson Country Club; while providing for an avoid cost saving benefit to the construction of the Tanque Verde Interceptor Extension project and the prevention of damage from sewage releases. The equivalent annual damage prevented by the plan is $714,100, as shown below.

Table 9 **Equivalent Annual Damage Prevention** (February 2000, price level)	
Category	**Damage Prevention**
Residential Structures & Land	$319,000
Residential Contents	$30,100
North Rillito Interceptor	$49,400
Sewer Spill Cleanup Costs	$51,000
Tanque Verde Interceptor	$120,100
Tucson Country Club	$144,500
Total	**$714,100**

Detailed Cost Estimate

Table 10 presents a summary of the detailed M-CACES cost estimate for the selected plan. The costs for all structural flood control elements, right-of-way, mitigation, and costs associated with operating, maintaining, replacing, repairing, and rehabilitating (OMRR&R) the selected plan are included.

Table 10 Summary of Detailed Cost Estimate

(May 2000, price level)

Item	Cost
Clearing and Grubbing	$20,000
Removal of Structures & Obstructions	$20,000
Diversion and Control of Water	$40,000
Dewatering	$40,000
Drainage Excavation	$87,000
Compacted Fill	$101,500
Soil Cement	$573,300
Pozzolan, for Soil Cement	$1,375,000
Safety Hand Rail	$98,990
Subtotal	$2,355,790
Contingency (20% of Subtotal)	$471,160
Total Construction Cost	$2,826,950
Mobilization	$54,610
Design Engineering Cost	$170,916
Construction Admin. & Field Inspection	$452,944
Right-of-Way	$295,610
Mitigation Lands	$780,560
TOTAL PROJECT COST	$4,581,590
IDC	$151,765
Gross Investment	$4,733,355
Annualized Cost (50-yrs, $6^{5}/_{8}$%)	$326,800
OMRR&R	$17,900
Total Annual Cost	**$344,700**

The B/C ratio for the Selected plan ($714,100/$344,700) is 2.07 with net positive NED benefits of $369,400.

REAL ESTATE

Real Estate Appendix
Tanque Verde Limited Reevaluation Report
(Revised May 1, 2002)

1. Abstract of Project Data:	
Project Name: Tanque Verde Creek.	
Location: Pima County, Arizona	
Project Purposes: Flood Control	
Acreage	
South Bank	10.57 Easement
North Bank	48.38 Mitigation Area- Fee
Channel bottom	76.05 Easement
Project Sponsor: Pima County Transportation and Flood Control District.	

2. Introduction and Purpose

This project is a continuance of the Rillito River Flood Control project. The plan description for the Tanque Verde section involves installing bank protection along the north bank in the form of a soil cement levee upstream of Craycroft Avenue. On the south bank two sections of new levee length would tie in existing bank protection works creating a continuous levee from Craycroft to Sabino Canyon Road. The new sections would front the Tucson Country Club and a residential subdivision known as Tucson Country Club Estates.

3. Authority:

The statutory authority for this project is contained in the following enacted laws:

Section 6, Public Law 761, Seventy-fifth Congress, dated June 28, 1938, which reads, "The Secretary of War is hereby authorized and directed to cause preliminary examination and surveys at the following locations..... Gila River and Tributaries, Arizona."

Additional authority was provided in Section 601 (b) of the Water Resources Development Act of 1986 (PL 99-662) which authorizes a project for the Rillito River in Tucson Arizona {Rillito River accepts the inflow from Tanque Verde Creek which is within the original study area of the project defined as "Rillito River"}

Additional authority was enacted in the Energy and Water Resources Appropriation Act of 1998 " to accomplish a Limited Re-evaluation Report of Tanque Creek immediately upstream and including Craycroft Road Bridge to determine the advisability of extending bank protection and related measures…"

4. Purpose of this Report:

This report is submitted as the Real Estate Plan to support the decision to authorize construction of the Tanque Verde portion of this project.

5. Recommended/Selected Plan

The recommended/selected plan fully addresses the identified problems along the Tanque Verde Creek between Sabino Canyon Road and Craycroft Road while including both structural and non-structural measures. The structural measures include installing soil cement bank protection in the existing gaps in bank protection on the south bank (two segments of approximately 4,220 and 2,830 linear feet), and installing approximately 1,550 feet of bank protection upstream of the Craycroft Road Bridge on the north bank. The horizontal alignment of the proposed bank protection would be along smooth curves that generally follow the existing bank. On the south bank, at the downstream end, the proposed soil cement would key into the bank just upstream of the confluence with Pantano Wash. On the north bank, at the upstream end, the soil cement would key into the existing bank and be tied back to high ground. The soil cement would match the top of the existing bank, and the toedown would extend 10 feet below the existing thalweg.

The soil cement layer would be an 8-foot thick layer of soil and portland cement that is mixed and placed in 6-inch to 1-foot thick "lifts." The lifts are successively placed until the desired bank protection height is reached. Once compacted, the soil cement mixture provides a hard and durable surface .

The recommended and selected Federal plan of improvement, the Federal Project, has no active recreation component.

The mitigation component of the proposed plan involves acquiring the rights-of-way to establish a permanent 500-foot buffer along the north bank. Public ownership of this land (48.38 acres) would prevent additional development, while preserving the riparian values of this vegetated area.

Description of Section 104 Work: as excerpted from main report:

The Pima County Department of Transportation and Flood Control submitted to the Los Angeles District an application, dated June 5, 1998, for credit for implementing flood damage reduction measures pursuant to Section 104 of the Water Resources Development Act (WRDA) of 1986 (Appendix A). The application is for a credit to construct approximately 4,220 linear feet of soil cement bank protection along the south bank of the Tanque Verde Creek, beginning from the existing bank protection west of Sabino Canyon Road to the existing bank protection at the downstream end (gap on the upstream end of the south bank). As shown on Exhibit 6 - Plan Sheets 1 &2 found at the end of the Main Report, this reach would begin at Station 39+67 and would end at Station 81+87.

On June 7, 1999, the Assistant Secretary of the Army for Civil Works granted conditional approval for the credit. Final approval and credit determination will be subject to the results of the LRR, Administration review and approval, project authorization, and other requirements of Section 104 of WRDA 1986.

6.: Land Use and Acreage Allocations.

Channel Bottom (wash influence)	Channel Improv. Easement)	76.05 acres
Levee/Bank Protection	Levee Easement	10.57 acres
North Bank Environmental Mitigation Area	Fee	48.38 acres

Estimate of Non-Federal "LERRD's"

Land Category	Acres		Value Estimate
Component 1			
Levee Easement	10.57		$84,560
Along Bank			
Bottom of Channel			
Inside Wash (Easement)	76.05		$76,050
			$160,610
Added Contingencies			$60,000
Admin and Inc Costs			$75,000
Flood Control Total	**Non Federal**	**"LERRD's"**	**$295,610**
Component 2 Mitigation Riparian Habitat			
Above top of Bank	48.38	12,000	$580,560
Fee Acquisition			
Contingencies			$100,000

Admin and Incidental			$100,000
Component 2 Total	**Non-Federal**	**"LERRDs"**	$780,560

7. Federal Lands, Interests or Reservations:

There are no Federally owned lands within the study area.

8. Navigational Servitude:

Neither Tanque Verde Creek nor the main stem Rillito River are navigable waterways, these waters are ephemeral and intermittent and therefore do not support commercial purposes of navigation under either the Federal or State doctrines.

9. Description of Lands.

The study area is within metropolitan Tucson on Craycroft Road located in the North-Central sector of the City. Tanque Verde Creek and the Rillito River run along the alluvial slope that skirts the north of Tucson along the pediment of Santa Catalina Mountains. The Creek and Rillito River deliver the runoff to the Santa Cruz River
The Rillito River Flood Control project has been successfully implemented in this area. This opportunity has given us much data on the performance of soil cement levee as well as real estate acquisition issues and values in the project area.

The project environs consist of a dry or ephemeral wash known as Tanque Verde Creek. Residential subdivisions are populated along the north bank but on an upper bench and outside the designated floodplain. Along the south bank is the Tucson Country Club and an associated subdivision.

10. Acquisition Authorities:

The sponsor is a duly organized municipal corporation in the State of Arizona and is vested with sufficient power to acquire and hold title, and to condemn lands as needed for public purposes. The sponsor does have "quick take" authority, which is the right to obtain possession based upon application of due process and a deposit of just compensation. The sponsor has performed successfully in implementation of the Rillito project and numerous other civil works projects.

11. Project Maps:

Project maps are included in the main body of this report.

12. Crediting for LERRD's:

Crediting will follow standard procedures as set out in a model Project Cooperation Agreement.

13. Facility Relocations:

Because the project lies in a vacated area, a wash and riverbed, no utilities or roads will be affected requiring relocation. There is a sanitary sewer intercept in the project area, that has been partially exposed due to past erosion, but this will be covered over and "protected in place" as an incident of project construction by the project and is not to be considered a facility relocation for LERRD purposes.. This will be done as part of project construction in back filling and grading the area behind the new levee. Thus, it is part of ordinary project construction.

Note: The following policy statement and disclaimer concerning any potential facility relocations prevails over any other statement, description or presentation in this report. Any conclusion or categorization contained in this report that an item is a utility or facility relocation to be performed by the Non Federal Sponsor as part of its LERRD responsibilities is preliminary only. The Government will make a final determination of the relocations necessary for the construction, operation and maintenance of the project after further analysis. A Final Attorney's Opinion of Compensability would be provided if necessary to address any such relocations added to the project as a result of this analysis.

14. Mineral Activity:

There is no known mineral activity currently occurring inside the project area.

15. Estates:

Acquisition of real estate for the mitigation purposes will be in fee simple title. The estate recommended for Federal cost sharing and crediting purposes for flood control will be by the standard permanent Flood Protection Levee Easement. The recommended estate for the wash area will be a standard permanent channel improvement easement. These are the recommended estate needed to implement the Federal plan of improvements for the recommended project, including operation, maintenance, repair, replacement and sustainability.

16. Construction Induced Flooding

As this creek is a dry wash most of the time appropriate measures will be taken for the care and diversion of water during construction and there will be no construction induced flooding outside the project take areas.

17. Cost Estimate.

The Flood Control cost estimate is $295,610

The cost for the "Riparian Habitat Preserve" Mitigation Land is $780, 560

The Total Estimate is $1,076,170

18. Relocation Assistance (URA Relocations):

The Pima County Department of Transportation will accomplish all property acquisitions in accordance with Public Law 91-646, as amended, and the Uniform Regulations as promulgated by the U.S. Department of Transportation. The property is largely unimproved and it does not appear that any displacements of businesses or residences will be required due to the design and configuration of the project.

19. Other Matters:

No timber activity affects these lands. The sponsor is not using any zoning ordinances in lieu of acquisitions of lands or easements within the project take areas.

20. Hazardous Waste Assessments:

The sponsor fully understands its responsibilities for assessing the properties for any potential or presence of hazardous waste materials as defined and regulated under CERRLA. There are no known "Superfund" sites or sites presently under CERRCLA remediation or response orders identified in the project area. The PCA conditions contain specific terms and conditions governing the sponsor's responsibility for environmental cleanup for CERRCLA regulated substances. Hazardous Waste Assessments are covered as a project cost under the model PCA.

21. Recreation:

There are no separable recreation lands. Recreation is not part of the Federally authorized purpose. The authorized Federal project will be for the purposes of flood control and related environmental mitigation for that flood control project. Recreration is not part of the Federal plan or plan formulation of this project. Passive recreation such as wildlife and nature appreciation, "bird watching" may occur in the riparian habitat mitigation preserve, but active recreation as a project purpose or project feature IS NOT part of the Federal project or plan of improvements.

22. Attitude of Landowners:

There is not expected to be a high degree of landowner opposition to the project. On the south Bank levee works and for the 1700 feet of north bank levee works the acquisition of easement rights only for flood control is expected to encounter no opposition. The properties will be protected from erosion and flood control and these rights will not be detrimental at all to the owners' property interests. In fact there may be offsetting benefits to the owners of the Tucson Country Club, beyond "general benefits" for protecting their specific property from floods and losses due to erosion. Indeed, the majority of economics benefits on the south shore accrue to damages prevented on the Golf Course. Therefore an easement acquisition for a flood control levee purposes should present the Country Club with no reason to oppose the project or grant the necessary easement.

23. Report Content.

This report follows the requirements of ER-405-1-12, Chapter 12, and addresses several itinerations of review comments, most recently those provided by telephone conference of April 29, 2002.