FINAL REPORT

TIJERAS ARROYO

Flooding and Erosion Potential in the Hidden Valley Reach

Prepared for

Albuquerque Metropolitan Arroyo Flood Control Authority

Albuquerque, New Mexico

AYRES
ASSOCIATES

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TIJER7TX.DOC

July 1999

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1. INTRODUCTION

1.1 General

The purpose of this study is provide the Albuquerque Metropolitan Arroyo Flood Control Authority (AMAFCA) with an evaluation of flooding potential, erosion potential and conceptual countermeasure design along the Tijeras Arroyo. The study area is on the Tijeras Arroyo directly downstream of Four Hills Road in the vicinity of the Hidden Valley Subdivision as shown in **Figure 1.1**. The properties of interest through the study area are the Veretto Property, the Hidden Valley Subdivision and the undeveloped land between them. This study investigates potential adverse impaçts from flooding and arroyo channel instability.

The study was undertaken by Ayres Associates at the request of AMAFCA and consisted of four basic tasks as follows:

Task 1: Hydrology and Hydraulics Review
Task 2: Single Event Erosion Potential
Task 3: Long-Term Erosion Potential
Task 4: Conceptual Design of Countermeasures

The study utilizes existing hydrologic studies and includes a detailed hydraulic analysis to investigate flooding and erosion potential in the study area. Problems are identified and countermeasures concepts are recommended.

Data utilized for the analysis is listed below:

- Historical aerial photography
- Tijeras Arroyo Master Drainage Plan (Bovay Engineers 1981)
- Tijeras Arroyo Drainage Management Plan Phase II (Leedshill-Herkenoff Engineers 1990)
- Orthophoto/Topographic maps (1995) Numbers L-22 and L-23
- Sediment samples (including gradations)
- FEMA floodplain mapping and hydraulic models
- DTM of study area

A field reconnaissance of the study area was conducted on January 28, 1999 with AMAFCA staff. During the site visit features of interest in the study area were observed and photographs were taken (**Appendix A** attached - other Appendices are bound separately).

1.2 Description of Study Area

Tijeras Arroyo is located to the south and east of Albuquerque, New Mexico. The arroyo originates in the Cibola National Forest and flows west along the southern boundary of the City of Albuquerque into the Rio Grande. The study area includes the length of the arroyo from directly downstream of Four Hills Road to the western limit of the Hidden Valley Subdivision. The watershed above the study area is approximately 75 square-miles draining from the Sandia and Manzanita Mountains. The study area is on an historically unstable alluvial fan. In addition changes in climate and urbanization are altering the arroyo characteristics. The arroyo channel through this reach consists of a sinuous sand bed channel with rock formations to the north.

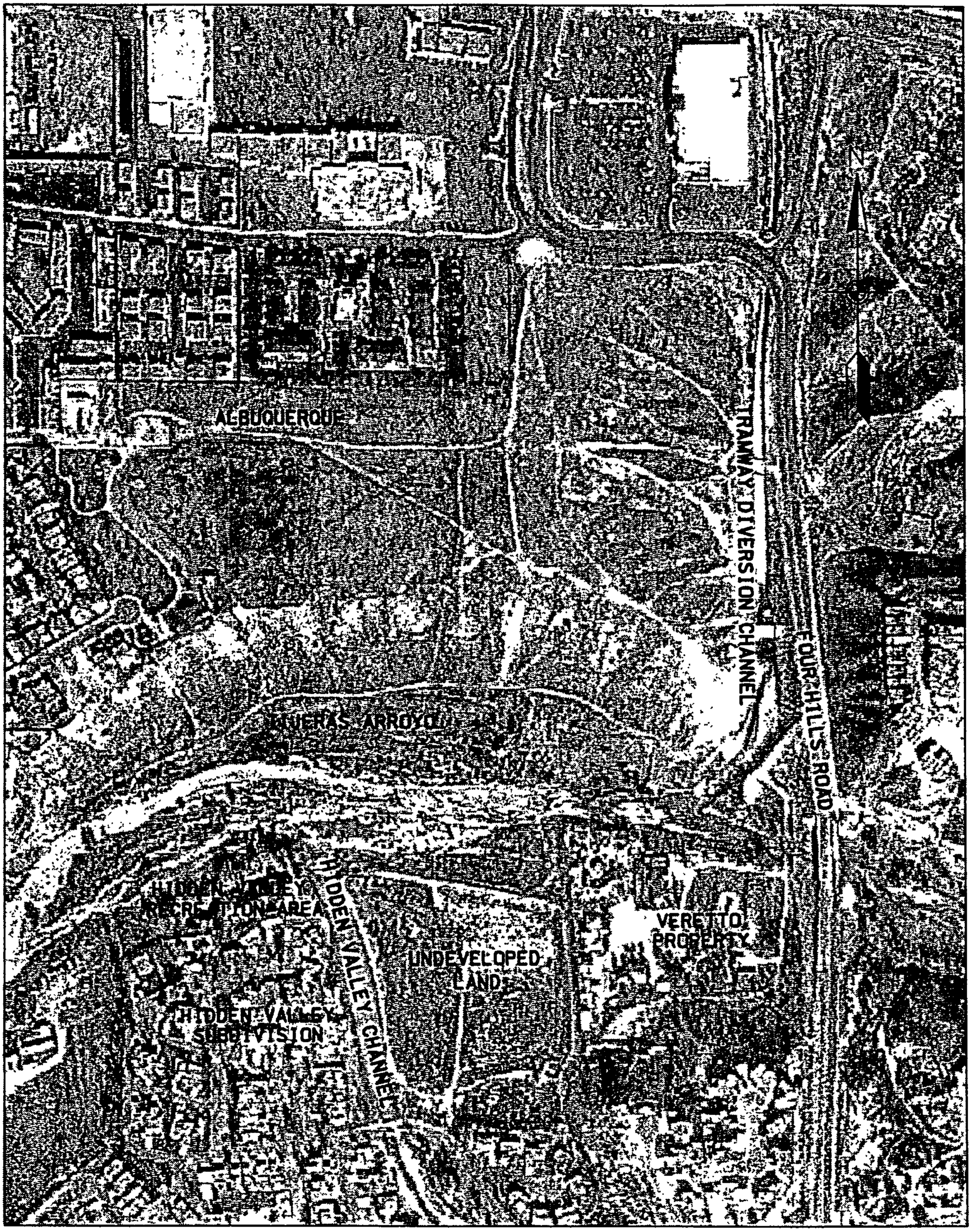


Figure 1.1. Study area location map.

2. HYDROLOGY AND HYDRAULICS

Hydrologic and hydraulic data were obtained from previous studies and reviewed for the detailed study. Hydrologic data was obtained from the Tijeras Arroyo Master Drainage Plan (Bovay Engineers 1981) and the Tijeras Arroyo Drainage Management Plan Phase II (Leedshill-Herkenoff Engineers 1990). The hydraulic analysis utilized the Federal Emergency Management Agency's (FEMA) regulatory HEC-2 model of the Tijeras Arroyo. The following sections describe the information used in the analysis.

2.1 Hydrology

Both of the drainage reports cited above reference a hydrologic study performed by the Army Corps of Engineers (USACE), Albuquerque District. The USACE study reports a 100-year discharge of 22,600 cfs for the Four Hills Area, assuming fully developed conditions within the watershed. The Phase II Drainage Report states that this value is consistent with findings from the Phase I Drainage Study (Leedshill- Herkenoff Engineers 1987). However this value differs from the peak discharge of 18,065 cfs used in the Phase II analysis and in the FEMA HEC-2 floodplain model. The Phase II Report states that the difference is due to the fact that the 22,600 cfs discharge was computed using an average from two separate hydrologic studies, and the 18,065 cfs value was based on a HEC-1 model for Tijeras Arroyo. Following personal correspondence with Don Dixon, AMAFCA Drainage Engineer (6/1999), the 18,065 cfs value was used for the single event erosion analysis to be consistent with the flow used in the FEMA analysis. A separate analysis using the value of 22,600 cfs was performed to evaluate the sensitivity of erosion and flooding to the variance in discharges. Hydrographs for the 2-, 5-, 10-, 25-, 50-, and 100-year 6-hour storms provided in the Phase II report were used for the analysis.

A stream gage maintained by the United States Geological survey (USGS) located approximately ½ mile upstream of the Four Hills Road Bridge (Station No. 08330500) was in operation from 1943 to 1948 and 1958 to 1996. A flood frequency analysis (FFA) was performed to verify the reasonableness of the discharges provided in the drainage reports. The maximum flow of record at this gage occurred on June 24,1967 with a magnitude of 6,500 cfs. The gage analysis results in a 100-year discharge of approximately 15,000 cfs and the reported 100-year discharges (18,065 and 22,600 cfs) were within the 5-95 percent confidence limits of the results from the flood frequency analysis. Therefore the reported values are considered reasonable for this study. Hydrologic data is presented in **Appendix B**.

Hydrologic data were also available for the tributary sources into the Hidden Valley reach of Tijeras Arroyo. The tributary channels were identified as the Tramway Diversion Channel to the north and the Hidden Valley Channel to the south (Figure 1.1). The Tijeras Arroyo Master Drainage Plan (Bovay Engineers 1981) indicated that the 100-year discharge through the Tramway Diversion Channel is 5,200 cfs. This 100-year flow would not coincide with the 100-year flow from Tijeras Arroyo due to the distance separating the drainage basins of these channels. For the Hidden Valley Channel to the south, the Tijeras Arroyo Drainage Management Plan Phase II (Leedshill-Herkenoff Engineers 1990) reported a 100-year discharge of 127 cfs. This discharge was based on a HEC-1 analysis of the contributing drainage basin.

2.2 Hydraulics

A hydraulic analysis was performed to determine flooding and erosion potential through the project reach. The hydraulic analysis for this study was performed using the HEC-RAS River Analysis System, ver. 2.2 (HEC 1998). The FEMA HEC-2 model of Tijeras Arroyo

was obtained from AMAFCA and reviewed for its adequacy for the detailed study of the Four Hills Area. The FEMA model extends approximately 3 miles downstream of the study area and approximately 5 miles upstream. Only a portion of the FEMA model was used for the detailed study. The FEMA model had a limited number of cross sections through the project reach. Therefore additional cross sections were developed to more accurately define the hydraulic characteristics of the arroyo through study area. Cross sections were developed from digital topographic mapping provided by AMAFCA. Map Nos. L-22 and L-23 of the Carnue Area, dated March 1995, were used to develop the cross sections. The location of the FEMA HEC-2 cross sections and the additional cross sections developed for the detailed HEC-RAS analysis are shown in **Figure 2.1.**

Hydraulic resistance and ineffective flow areas were represented in the model to appropriately account for energy losses through the system. Assuming upper flow regime and adjustments for cross section irregularity, a Manning's n value of 0.035 was used for the main channel of the arroyo. Overbank n values ranged from 0.04 to 0.1 depending on the ground cover, vegetation and the level of development. The arroyo main channel and overbank areas were identified using aerial photography and topographic mapping. The main channel was distinguished as that portion of the arroyo that is void of established vegetation. All areas beyond the main channel were defined as overbank in the hydraulic model.

As shown in Figure 2.1 the HEC-RAS model extended from an area approximately 1000 feet west of the Hidden Valley Subdivision to approximately 1 mile upstream of the Four Hills Road Bridge. The HEC-RAS cross section identifiers represent channel distance in feet from the downstream model boundary. The HEC-RAS model was run for a range of discharges that may occur up to and including the 100-year event. Discharges representative of the 2-, 5-, 10-, 25-, 50- and 100-year events were used for the analysis. Results from the hydraulic analysis are provided in the following sections and the model output is presented in **Appendix C.**

To determine the potential for flooding and erosion along the Hidden Valley Channel, a HEC-RAS model of this drainage was also developed. The model extends from the southern limit of the Hidden Valley Subdivision to the confluence with Tijeras Arroyo (Figure 2.1). Cross sections for this model were also developed from the digital topographic mapping provided by AMAFCA. Similar to Tijeras Arroyo, Manning's n values of 0.035 were used for the channel. Results from the hydraulic analysis of the Hidden Valley Channel are provided in the following sections and the model output is presented in Appendix C.

LEGEND

BL — REGULATORY FEMA HEC-2 CROSS SECTIONS

3313 — DETAILED STUDY HEC-RAS CROSS SECTIONS

CHANNEL THALWEG

Figure 2.1 Cross Section Locations

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ALBUQUERQUE METROPOLITAN ARROYO FLOOD CONTROL AUTHORITY

TIJERAS ARROYO HEC-RAS MODEL
CROSS SECTION LOCATIONS

Revisions | Date

Filename: F10A.dgn

Designed By: KSS
Drawn By: CAK
Checked By: LWZ
Approved By: PFL
Job #32-126.00
Date: 6-15-99

A

3. SINGLE EVENT EROSION POTENTIAL

A sediment continuity analysis was performed to estimate the channel morphology (aggradation/degradation) resulting from the erosion or deposition of sediment within the study reach during the 100-year storm event. Adjustment of the arroyo bed is related to the sediment supply and transport capacity through the study reach. Bed material sediment transport is dependent on the size of the bed material and the hydraulic characteristics of the flow. Results from the HEC-RAS model were used to estimate the bed material supply and transport capacity through the study reach.

For the sediment continuity analysis, the arroyo through the Hidden Valley area was divided into three alluvial subreaches, and an upstream supply reach was defined (**Figure 3.1**). The supply reach that extends approximately 1 mile upstream of the Four Hills Road was used to characterize the upstream sediment load. The three subreaches through the study area are described below:

Reach 1 - constricted section downstream of the Four Hills Road Bridge extending to the western limit of the Veretto Property.

Reach 2 - from the western limit of the Veretto Property to the northwestern limit of the Hidden Valley Subdivision.

Reach 3 – downstream of the Hidden Valley Subdivision.

The Hidden Valley Channel was not included in the sediment continuity analysis. The contribution of water and sediment load from the Hidden Valley Channel is considered negligible with respect to Tijeras Arroyo. However a separate analysis was conducted to evaluate the potential for erosion and flooding in this channel.

Hydraulic variables for the reaches described above were averaged and used to calculate sediment transport capacities. The reach averaged hydraulic results for the four reaches are summarized in **Tables 3.1. through 3.3.** The hydraulic variables are summarized for the arroyo main channel (CH), left overbank (LOB) and right overbank (ROB). In the following tables Q denotes discharge, EGS denotes energy grade slope, TW denotes top width, Y denotes depth and V denotes average velocity.



Figure 3.1 Sediment transport reach locations

B	Designed By: MSB Drawn By: CAK Checked By: LWZ Approved By: PFL Job #: 32-126.00 Date: 6-15-99	Revisions / Date	TIJERAS ARROYO SEDIMENT TRANSPORT REACH LOCATIONS	ALBUQUERQUE METROPOLITAN ARROYO FLOOD CONTROL AUTHORITY	AYRES ASSOCIATES Engineers/Scientists/Surveyors 3665 JFK Parkway, Building 2, Suite 300 P.O. Box 270460 Fort Collins, CO 80527 (970) 223-8556

Filename: F1G8.dgn

Table 3.1. Main Channel (CH) Reach Averaged Hydraulics						
100-Year Q Total (cfs)	Reach	Q CH (cfs)	EGS	TW CH (ft)	Y CH (ft)	V CH (ft)
18065	Supply	7712	0.00871	41.9	11.1	18.9
18065	Reach1	15857	0.00662	104.8	9.8	15.6
18065	Reach2	8210	0.01055	91.1	6.3	14.7
18065	Reach3	8411	0.01123	91.4	6.1	14.9
50-Year Q Total (cfs)	Reach	Q CH (cfs)	EGS	TW CH (ft)	Y CH (ft)	V CH (ft)
17210	Supply	7405	0.00872	41.9	10.9	18.6
17210	Reach1	15212	0.00673	104.8	9.5	15.4
17210	Reach2	7900	0.01051	91.1	6.1	14.4
17210	Reach3	8116	0.01151	91.4	6.0	14.9
25-Year Q Total (cfs)	Reach	Q CH (cfs)	EGS	TW CH (ft)	Y CH (ft)	V CH (ft)
11570	Supply	5356	0.00926	41.9	8.8	16.7
11570	Reach1	10671	0.00746	104.8	7.5	13.8
11570	Reach2	5796	0.01051	91.1	5.1	12.7
11570	Reach3	5933	0.01117	91.4	5.0	13.0
10-Year Q Total (cfs)	Reach	Q CH (cfs)	EGS	TW CH (ft)	Y CH (ft)	V CH (ft)
6285	Supply	3243	0.01059	41.9	6.4	14.0
6285	Reach1	6075	0.00836	104.8	5.2	11.4
6285	Reach2	3641	0.01019	91.1	3.9	10.5
6285	Reach3	3660	0.00943	90.9	3.9	10.2
5-Year Q Total (cfs)	Reach	Q CH (cfs)	EGS	TW CH (ft)	Y CH (ft)	V CH (ft)
3360	Supply	1931	0.01203	41.5	4.8	11.4
3360	Reach1	3338	0.00963	101.8	3.5	9.5
3360	Reach2	2281	0.00980	91.1	3.0	8.6
3360	Reach3	2249	0.00940	90.1	3.0	8.4
2-Year Q Total (cfs)	Reach	Q CH (cfs)	EGS	TW CH (ft)	Y CH (ft)	V CH (ft)
1560	Supply	1045	0.01231	41.0	3.2	9.0
1560	Reach1	1558	0.01125	96.5	2.2	7.5
1560	Reach2	1267	0.01025	89.8	2.1	6.9
1560	Reach3	1250	0.01046	88.1	2.0	6.9

Table 3.2. Left Overbank (LOB) Reach Averaged Hydraulics.						
100-Year Q Total (cfs)	Reach	Q LOB (cfs)	EGS	TW LOB (ft)	Y LOB (ft)	V LOB (fps)
18065	Supply	6949	0.00871	132.6	7.3	7.6
18065	Reach1	159	0.00662	16.5	3.2	3.1
18065	Reach2	6580	0.01055	264.1	3.6	6.6
18065	Reach3	5568	0.01123	319.7	3.4	5.3
50-Year Q Total (cfs)	Reach	Q LOB (cfs)	EGS	TW LOB (ft)	Y LOB (ft)	V LOB (fps)
17210	Supply	6598	0.00872	131.3	7.1	7.4
17210	Reach1	141	0.00673	16.0	3.0	3.0
17210	Reach2	6221	0.01051	262.8	3.5	6.4
17210	Reach3	5227	0.01151	309.0	3.3	5.2
25-Year Q Total (cfs)	Reach	Q LOB (cfs)	EGS	TW LOB (ft)	Y LOB (ft)	V LOB (fps)
11570	Supply	4265	0.00926	123.0	5.6	6.6
11570	Reach1	50	0.00746	10.3	1.9	2.3
11570	Reach2	3858	0.01051	241.0	2.7	5.5
11570	Reach3	3158	0.01117	279.5	2.6	4.4
10-Year Q Total (cfs)	Reach	Q LOB (cfs)	EGS	TW LOB (ft)	Y LOB (ft)	V LOB (fps)
6285	Supply	2160	0.01059	105.9	3.9	5.5
6285	Reach1	8	0.00836	3.6	0.8	1.3
6285	Reach2	1790	0.01019	204.8	1.9	4.2
6285	Reach3	1403	0.00943	246.4	1.7	3.3
5-Year Q Total (cfs)	Reach	Q LOB (cfs)	EGS	TW LOB (ft)	Y LOB (ft)	V LOB (fps)
3360	Supply	1058	0.01203	91.5	2.7	4.5
3360	Reach1	1	0.00963	0.8	0.2	0.5
3360	Reach2	767	0.00980	178.2	1.2	3.1
3360	Reach3	534	0.00940	190.7	1.0	2.8
2-Year Q Total (cfs)	Reach	Q LOB (cfs)	EGS	TW LOB (ft)	Y LOB (ft)	V LOB (fps)
1560	Supply	416	0.01231	74.0	1.7	3.4
1560	Reach1	0	0.01125	0.0	0.0	0.1
1560	Reach2	228	0.01025	115.1	0.6	2.0
1560	Reach3	140	0.01046	87.1	0.7	2.3

Table 3.3. Right Overbank (ROB) Reach Averaged Hydraulics.						
100-Year Q Total (cfs)	Reach	Q ROB (cfs)	EGS	TW ROB (ft)	Y ROB (ft)	V ROB (fps)
18065	Supply	3404	0.00871	67.2	5.8	6.7
18065	Reach1	2050	0.00662	133.4	3.7	4.5
18065	Reach2	3275	0.01055	166.8	3.5	5.1
18065	Reach3	4086	0.01123	172.3	3.8	5.4
50-Year Q Total (cfs)	Reach	Q ROB (cfs)	EGS	TW ROB (ft)	Y ROB (ft)	V ROB (fps)
17210	Supply	3208	0.00872	66.3	5.6	6.6
17210	Reach1	1857	0.00673	127.3	3.5	4.4
17210	Reach2	3090	0.01051	165.4	3.4	5.0
17210	Reach3	3867	0.01151	171.3	3.6	5.3
25-Year Q Total (cfs)	Reach	Q ROB (cfs)	EGS	TW ROB (ft)	Y ROB (ft)	V ROB (fps)
11570	Supply	1949	0.00926	59.0	4.3	5.6
11570	Reach1	848	0.00746	87.1	2.6	3.7
11570	Reach2	1916	0.01051	149.2	2.7	4.3
11570	Reach3	2479	0.01117	166.5	2.7	4.3
10-Year Q Total (cfs)	Reach	Q ROB (cfs)	EGS	TW ROB (ft)	Y ROB (ft)	V ROB (fps)
6285	Supply	883	0.01059	47.9	2.8	4.3
6285	Reach1	202	0.00836	48.4	1.3	2.3
6285	Reach2	854	0.01019	137.9	1.8	3.2
6285	Reach3	1222	0.00943	152.9	1.8	2.9
5-Year Q Total (cfs)	Reach	Q ROB (cfs)	EGS	TW ROB (ft)	Y ROB (ft)	V ROB (fps)
3360	Supply	371	0.01203	40.5	1.8	3.0
3360	Reach1	21	0.00963	18.1	0.6	1.3
3360	Reach2	313	0.00980	123.9	1.0	2.1
3360	Reach3	577	0.00940	131.8	1.2	2.1
2-Year Q Total (cfs)	Reach	Q ROB (cfs)	EGS	TW ROB (ft)	Y ROB (ft)	V ROB (fps)
1560	Supply	98	0.01231	25.8	0.9	1.9
1560	Reach1	2	0.01125	1.0	0.2	0.4
1560	Reach2	65	0.01025	80.0	0.4	1.2
1560	Reach3	170	0.01046	112.8	0.6	1.4

The hydraulic results were used to estimate the transport capacity and flow distributions for each reach. The distribution of flow between the main channel and overbank areas for the peak 100-year discharge is shown in **Figure 3.2.** To compute the flow distribution for discharges other than those modeled in HEC-RAS, discharge rating curves were developed for the main channel (CH), left overbank (LOB) and right overbank (ROB) in each reach. The discharge rating curves had the following form:

$$\%Q_i = \alpha Q^{\beta} \qquad \text{Eq. 3.1}$$

where:

$\%Q_i$ = percentage of flow in the main channel, left overbank or right overbank (cfs)
Q = total water discharge (cfs)
α and β = coefficient and exponent determined from regression

The computed water discharge coefficients and exponents for the four reaches in the study are listed in **Table 3.4.** The discharge rating curves were used to compute the distribution of flow, and concurrently, sediment supply for the sediment continuity analysis. Plots of the flow distributions are included in **Appendix D.**

Table 3.4. Flow Distribution Coefficients and Exponents.

Reach	Coeff./exp.	LOB	CH	ROB
Supply	α	9.9948	252.63	0.3717
	β	0.1382	-0.1814	0.4035
Reach 1	α	8.00E-15	163.05	5.00E-07
	β	3.3351	-0.0629	1.7461
Reach 2	α	1.3342	462.72	0.1075
	β	0.3399	-0.2369	0.5289
Reach 3	α	0.3416	397.89	1.9322
	β	0.4626	-0.2189	0.2506

Sediment discharge is related to water discharge. The total sediment load in an arroyo consists of bed material load and wash load. Wash load typically originates from overland runoff and is not directly related to the hydraulic conditions in the arroyo. Washload is an important factor in the design of detention and sedimentation basins, but is frequently omitted in sediment continuity studies for channels. Washload can be significant in channels at higher concentrations because it can change the viscosity of water and have an affect on the total transport capacity of the fluid. For this study the washload concentrations were considered low enough not to impact the results and only bed material load was used in the sediment continuity analysis.

The AMAFCA Sediment and Erosion Design Guide (RCE 1994) recommends the MPM-Woo method to estimate the bed material transport for arroyos in the Albuquerque area. The MPM-Woo power function is:

$$q_s = aV^b Y^c (1 - C_f / 10^6)^d \qquad \text{Eq. 3.2}$$



Figure 3.2 100-Year flow distribution

C	Designed By: MSB Drawn By: CAK Checked By: LWZ Approved By: PFL Job #: 32-126.00 Date: 6-15-99	Revisions / Date	TIJERAS ARROYO 100-YEAR FLOW DISTRIBUTION (CFS)	ALBUQUERQUE METROPOLITAN ARROYO FLOOD CONTROL AUTHORITY	AYRES ASSOCIATES Engineers/Scientists/Surveyors 3665 JFK Parkway, Building 2, Suite 300 P.O. Box 270460 Fort Collins, CO 80527 (970) 223-5556

Filename: FIGC.dgn

where:

q_s = bed material load (cfs/ft)
V = average velocity (fps)
Y = hydraulic depth (ft)
C_f = fine sediment (silt and clay) concentration by weight
a, b, c, d = coefficient and exponents which are a function of bed material size

Hydraulic modeling and reach averaged hydraulics provided values V and Y for each reach. Sediment samples taken from the arroyo bed upstream and downstream of the Four Hills Road bridge were averaged to provide a composite grain size distribution representative of the area. A total of five sediment samples were obtained from the arroyo bed for this study. The bed material distributions are included in Appendix D. The composite D_{50} of the bed material was determined to be 2.45 mm. Using the chart from the Sediment and Erosion Guide, the values of a, b, c, d were determined as Shown in **Figure 3.3**.

Using equation 3.2, sediment transport capacities for the supply channel and three subreaches were computed for the 2 through 100-year discharges. Transport capacities were computed for the main channel (CH), left overbank (LOB) and right overbank (ROB). For the supply reach upstream of Four Hills Road, it was assumed that sediment was only being transported from the main channel. The computed transport capacities were used to develop bed material rating curves of the following form:

$$Q_s = aQ_i^b \qquad \text{Eq. 3.3}$$

where:

Q_s = bed material load (lb/s)
Q_i = water discharge in the main channel or overbank areas (cfs)
a, b = coefficient and exponent determined from regression

The computed sediment load coefficients and exponents for the supply channel and three reaches in the study are listed in **Table 3.5**. Plots of the sediment load rating curves are presented in **Appendix D**.

Table 3.5. Sediment Transport Coefficients and Exponents.

Reach	Coeff./exp.	LOB	CH	ROB
Supply	a	--	0.0101	--
	b	--	1.6602	--
Reach 1	a	*3.16E-01	0.0489	0.0001
	b	*-49.318	1.3627	1.6999
Reach 2	a	1.00E-04	0.0011	3.00E-05
	b	1.8319	1.8664	1.8997
Reach 3	a	3.20E-03	5.00E-04	2.00E-06
	b	1.3389	1.9615	2.2366

*a linear equation in the form of $Q_s = a*Q+b$ was used

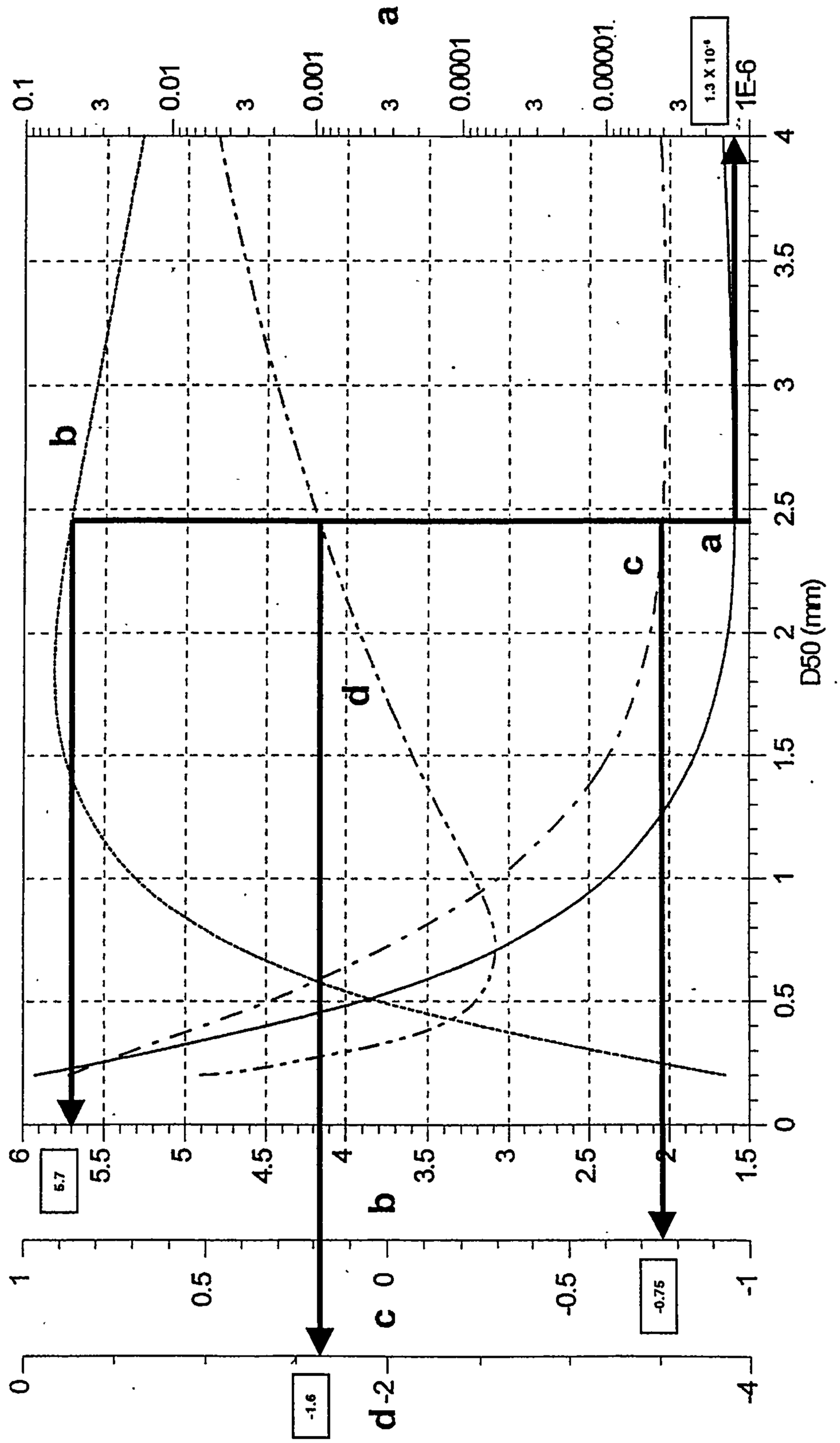


Figure 3.3. MPM-Woo coefficient/exponent nomograph.

Total sediment loads for each reach were computed by integrating the transport capacity over the 100-year hydrograph. The net erosion or deposition of sediment within the study reach was computed by performing a sediment continuity analysis for each reach. The sediment continuity can be expressed as:

$$\Delta V = V_{s(inflow)} - V_{s(outflow)} \qquad \text{Eq. 3.4}$$

where:

ΔV = volume of sediment stored (+) or lost (-) in the reach
$V_{s(inflow)}$ = volumetric sediment transport into the reach main channel or overbank area from upstream sources
$V_{s(outflow)}$ = volumetric sediment transport out of the reach main channel or overbank area

The sediment continuity is computed from one reach to the next. The transport capacity of the most upstream reach was used to estimate the supply to Reach 1. Then the transport capacity of Reach 1 was used for the supply to Reach 2, and so on. The continuity analysis included separate computations for the main channel and overbank areas. The supply from one reach to next was distributed to reflect the amount of sediment entering or leaving the main channel. It was assumed that sediment was not being delivered from the overbanks in the supply reach upstream of Four Hills Road. The average vertical response to the change in sediment volume was determined with the following equation:

$$\Delta Z = \frac{\Delta V}{WL(1-\eta)} \qquad \text{Eq. 3.5}$$

where:

ΔZ = average change in bed elevation in the reach
W = average flow width
L = length of the reach
η = porosity of bed material

When porosity is used in the above equation, the volume of sediment is an unbulked quantity (i.e., S.G. ≈ 2.65). A porosity (η) of 0.4 was used for the calculations. The results of the sediment continuity analysis for the 100-year discharge of 18,065 cfs are listed in **Tables 3.6 through 3.9**. Worksheets of the computations are provided in Appendix D.

Table 3.6. 100-Year Reach Total Sediment Continuity Results.

Qmax = 18,065	Reach Length (ft)	Reach Total Transport Volume (yd^3) (unbulked)	Volume Supplied from Upstream Supply to Reach (yd^3)	Reach Total Aggradation / Degradation Volume (yd^3)	Reach Total Width (ft)	Average Elevation Change (ft)
Supply	--	38318	--			
Reach1	716	35990	38318	2328	180	0.8
Reach2	1450	29978	35990	6012	439	0.4
Reach3	807	31750	29978	-1771	481	-0.2

Table 3.7. 100-Year Main Channel Sediment Continuity Results.						
Qmax = 18,065	Reach Length (ft)	Main Channel Transport Volume (yd^3) (unbulked)	Volume Supplied from Upstream Supply to Main Channel (yd^3)	Main Channel Aggradation / Degradation Volume (yd^3)	Main Channel Width (ft)	Average Main Channel Bed Elevation Change (ft)
Supply	--	38318	--	--	--	--
Reach1	716	35943	38318	2375	103	1.4
Reach2	1450	28844	20268	-8576	91	-2.9
Reach3	807	31162	26463	-4699	91	-2.9

Table 3.8. 100-Year Left Overbank Sediment Continuity Results.						
Qmax = 18,065	Reach Length (ft)	Left Overbank Transport Volume (yd^3) (unbulked)	Volume Supplied from Upstream Supply to Left Overbank (yd^3)	Left Overbank Aggradation / Degradation Volume (yd^3)	Left Overbank Width (ft)	Average Left Overbank Elevation Change (ft)
Supply	--	0	--	--	--	--
Reach1	716	7	0	-7	8	-0.1
Reach2	1450	994	12765	11771	211	1.7
Reach3	807	376	825	450	239	0.1

Table 3.9. 100-Year Right Overbank Sediment Continuity Results.						
Qmax = 18,065	Reach Length (ft)	Right Overbank Transport Volume (yd^3) (unbulked)	Volume Supplied from Upstream Supply to Right Overbank (yd^3)	Right Overbank Aggradation / Degradation Volume (yd^3)	Right Overbank Width (ft)	Average Right Overbank Elevation Change (ft)
Supply	--	0	--	--	--	--
Reach1	716	40	0	-40	69	0.0
Reach2	1450	140	2956	2817	137	0.6
Reach3	807	212	2690	2478	151	0.9

Figure 3.4 illustrates the expected bed elevation changes in feet during the 100-year storm event. A plus (+) sign indicates aggradation whereas a minus (-) indicates degradation.

The results indicate that the sediment supply from the canyon east of Four Hills Road exceeds the transport capacity of the arroyo west of Four Hills. Assuming the excess upstream supply is deposited in Reach 1, an increase in the main channel bed of 1.4 feet would be expected through Reach 1. The distribution of water and sediment through Reaches 2 and 3 could result in the channel bed lowering by approximately 3 feet during the 100-year event. The continuity analysis indicates that sediment would be deposited in the overbanks of Reaches 2 and 3. Negligible amounts of erosion and deposition can be expected in the overbanks of Reach 1.



Figure 3.4 100-Year Event Aggradation/degradation depths (ft)

D	Designed By: MSB Drawn By: CAK Checked By: LWZ Approved By: PFL Job #: 32-126.00 Date: 6-15-99	Revisions / Date	TIJERAS ARROYO 100-YEAR EVENT AGGRADATION/ DEGRADATION (FT)	ALBUQUERQUE METROPOLITAN ARROYO FLOOD CONTROL AUTHORITY	AYRES ASSOCIATES Engineers/Scientists/Surveyors 3653 JFK Parkway, Building 2, Suite 300 P.O. Box 270460 Fort Collins, CO 80527 (970) 223-5556

Filename: FIGD.dgn

A sediment continuity analysis for the 100-year discharge of 22,600 cfs was completed to test the sensitivity of the erosion potential to the variance in discharge. Using the 22,600 cfs value resulted in main channel lowering of 4.4 ft in Reaches 2 and 3 and a bed elevation increase of 2.5 feet through Reach 1. These values could be used as an upper limit to the expected change in the reach during an extreme event.

A sediment continuity analysis was performed to determine the impact of flows from the Tramway diversion channel on Tijeras Arroyo. The Tijeras Arroyo Master Drainage Plan (Bovay Engineers 1981) indicated that the 100-year discharge through the Tramway Diversion is 5,200 cfs and that this flow probably would not coincide with the 100-year flow from Tijeras Arroyo. To asses the amount of erosion on Tijeras Arroyo due to this flow, it was assumed that the discharge through the Tramway diversion would be sediment deficient (clear-water). The Tramway hydrograph was scaled from the 100-year hydrograph for Tijeras Arroyo. A sediment continuity analysis from this scenario resulted in less than 2 feet of channel lowering through Reach 2. Therefore, the 100-event channel lowering of 2.9 feet was more severe than that caused by the Tramway discharge.

Erosion potential in the Hidden Valley Drainage Channel was also investigated for this study. The Tijeras Arroyo Drainage Management Plan Phase II (Leedshill-Herkenoff Engineers 1990) reported a 100-year discharge for the channel of 127 cfs. The HEC-RAS model for the channel indicates that velocities on the order of 5 fps can be expected at the peak of the 100-year event. These velocities are certainly sufficient to erode the bed and bank material of the channel. However during the field reconnaissance (January 1999) no evidence of erosion or channel instability was observed. Therefore in lieu of performing a sediment continuity or stable slope analysis, it is recognized that there is an erosion potential in the channel at high flows. It is recommended that the channel be monitored for instability and countermeasures provided as needed.

4. SINGLE EVENT FLOODING POTENTIAL

Results from the HEC-RAS model were used to evaluate the potential for flooding through the study reach. Water surface elevations resulting from the 100-year event were used for the analysis. The focus was to identify locations on the south side of the arroyo where flooding could be a potential problem. The elevated topography on the north side of the arroyo eliminated the need to identify flood prone areas to the north. Potential problem areas were identified by comparison of computed water surface and energy grade elevations to the levee and embankment elevations along the south side of the arroyo. The locations of interest were the Veretto Property, the Hidden Valley Subdivision and the undeveloped land between them.

The limits of potential flooding are presented in **Figure 4.1.** Based on the 1995 DTM provided by AMAFCA, flooding is expected throughout the Veretto Property as water overtops the levee on south side of the arroyo. This flooding potential is also indicated on the preliminary FEMA Flood Insurance Rate Map (restudy) for this area (Panel 386 of 825). The preliminary FEMA map is included in Appendix B. The original FEMA FIS only showed limited flooding in the Veretto property and did not indicate that the dwellings on the property would be in the 100-year floodplain. At this location on the alluvial fan at the outlet from Tijeras Canyon, there might be little, if any, warning of a significant flood.

Another potential overtopping location is a small area along the embankment at the Hidden Valley Subdivision. Although the average computed water surface elevation is below the embankment elevation, the computed energy grade line exceeds the embankment elevation in this area. The water surface computed with a 1-dimensional model such as HEC-2 or HEC-RAS represents the average water surface elevation across the cross section. There could be localized water surfaces that are higher or lower than this elevation across the channel cross section. The maximum potential water surface locally could reach the energy grade line. Profiles of the top of levee/embankment, critical and computed water surface and energy grade line are presented in **Figure 4.2.** Tabulated values are listed in **Table 4.1**.

If water were to enter the subdivision at this location, it is likely that the magnitude of flooding would be of relatively short duration due to the flashy nature of runoff through the arroyo. Due to these uncertainties, the ability of the 100-year event to flood the Hidden Valley Subdivision is somewhat questionable, but should not be neglected as a potential problem.

As was done to evaluate erosion potential, an additional analysis using the 100-year discharge of 22,600 cfs was performed to test the sensitivity of the computed water surface and energy grade elevations to the variance in discharges. The hydraulic analysis resulted in higher water surface elevations throughout the study area, but there were no additional problem areas identified at the higher discharge.

Flooding potential along the Hidden Valley Channel which flows north into Tijeras Arroyo was investigated as another source of flooding to the surrounding properties. To be conservative with respect to flooding, it was assumed that the 100-year discharge through the drainage channel would coincide with the 100-year maximum flow on Tijeras Arroyo. Therefore the downstream tailwater for the channel was set at the 100-year water surface elevation on Tijeras Arroyo at the confluence location. The results from the HEC-RAS model indicate that flooding outside of the channel banks is not expected for the reported discharge of 127 cfs in the Hidden Valley Channel.



Figure 4.1 100-Year Limits

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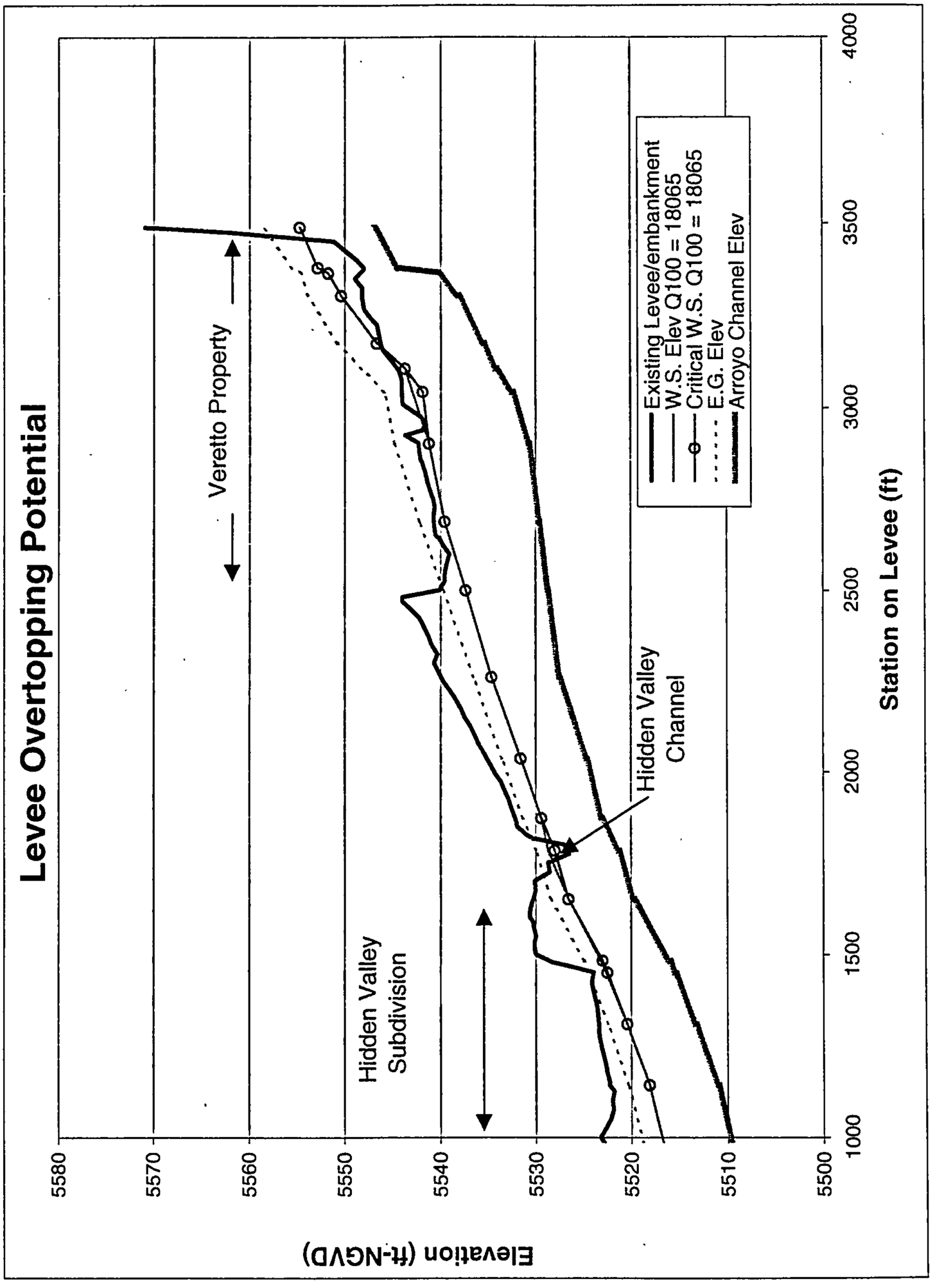


Figure 4.2. Hydraulic profiles.

Table 4.1. Hydraulic Profiles.						
Station on Existing Levee/ Embankment (ft)	Corresponding HEC-RAS Cross Section	Arroyo Channel Elev. (ft-NGVD)	Existing Levee/ Embankment Elevation	W.S. Elev Q_{100} = 18065 (ft-NGVD)	Critical W.S. Q_{100} = 18065 (ft-NGVD)	E.G. Elev Q_{100} = 18065 (ft-NGVD)
328	329	5504.90	5522.23	5510.96	5510.87	5512.66
621	499	5506.49	5523.47	5513.76	5513.76	5515.50
923	692	5509.09	5521.38	5516.17	5516.17	5518.20
1143	879	5511.00	5522.34	5518.12	5518.12	5520.28
1309	1063	5513.37	5523.45	5520.40	5520.40	5522.48
1450	(1273)	5515.48	5523.95	5522.68	5522.53	5524.51
1483	1322	5515.98	5528.70	5523.21	5523.03	5524.99
1651	1620	5519.76	5530.23	5526.62	5526.62	5528.46
1784	1794	5521.26	5526.73	5528.75	5528.02	5529.96
1873	1909	5523.16	5532.16	5529.40	5529.40	5531.34
2037	2076	5524.72	5535.11	5531.57	5531.57	5533.54
2261	2310	5527.57	5539.97	5534.60	5534.60	5536.56
2500	(2433)	5528.72	5540.11	5537.39	5537.39	5539.75
2689	2531	5529.63	5540.75	5539.59	5539.59	5542.27
2902	2708	5530.69	5542.38	5541.27	5541.27	5544.92
3044	2851	5532.40	5544.14	5543.01	5541.92	5545.89
3107	2913	5534.17	5544.62	5543.81	5543.81	5548.26
3176	2981	5535.50	5546.35	5546.72	5546.72	5550.81
3305	3109	5538.17	5548.26	5550.41	5550.41	5553.91
3366	3164	5540.30	5548.41	5551.77	5551.77	5554.61
3380	3169	5544.50	5548.11	5552.86	5552.86	5555.54
3489	3243	5547.00	5570.96	5554.76	5554.76	5558.56

5. LONG-TERM EROSION POTENTIAL

The analysis of long-term erosion included an investigation the potential for lateral and vertical changes in the arroyo. The analysis of lateral migration potential utilized historical aerial photography. The vertical stability analysis was based on geomorphic trends observed in the arroyo and a long-term sediment continuity analysis.

5.1 Lateral Migration Potential

To identify trends with respect to lateral migration, historical aerial photographs were obtained from AMAFCA. Aerial photography from 1951, 1961, 1967, and 1995 were used to identify historical channel patterns and active overbank areas. To compare historical channel patterns, the photographs were scaled and aligned using CAD/GIS software. Then the channel banks and active portions of the overbanks were delineated as shown in **Figure 5.1.** Comparison of the channel alignments indicates that the arroyo channel has shifted within an approximate 300 ft band throughout the study area within the last 50 years.

It is evident that in 1961 active overbank areas existed further south before the levees and the Four Hills Road bridge were constructed. Since construction of these features within the last 40 years the channel has migrated significantly between the levees and the north side of the arroyo. The 1967 channel and some active portion of the 1995 overbanks have run adjacent to the levee and appear to impinge on the embankment at the northeastern tip of the Hidden Valley Subdivision. The 1995 channel is significantly narrower than that in the previous years. This narrowing could indicate some potential for incision. This would be consistent with results from the sediment continuity analysis where channel erosion and overbank deposition were computed. The comparison of historical photographs clearly indicates that there is a potential for channel migration that could undermine levees and embankments on the south side of the arroyo. **Figure 5.2** illustrates the limits of long-term main channel migration observed from the historical aerial photographs.

5.2 Vertical Stability Analysis

The Tijeras Arroyo Drainage Management Plan Phase II (Leedshill-Herkenoff Engineers 1990) provided a comparison of longitudinal profiles along the arroyo thalweg using topographic maps from 1954 to 1987. The Phase II report indicated that the arroyo in the study area has aggraded by as much as 3 to 5 feet since 1954. However the Phase II Report notes that the arroyo has experienced severe incision and degradation by as much as 12 feet approximately 11 miles downstream. The Phase II Report indicates that the channel has degraded by as much as 4 feet since 1954 as near as 8 miles downstream. There is a potential for this incision to work its way upstream and it is recommended that the downstream reach be monitored for potential headcutting that would impact the Hidden Valley area. Visual inspection annually or after high flow events is recommended.

To quantify the long-term vertical changes (aggradation/degradation) in the arroyo, a sediment continuity analysis was conducted. The Sediment and Erosion Design Guide (RCE 1994) provides a procedure for computing an average annual sediment yield. The analysis is performed by integrating the sediment yield for the 2-, 5-, 10-, 25-, 50-, and 100-year events over their probability of occurrence in any one year. The resulting equation for computing the annual sediment yield is:

FLOW

FOUR HILLS ROAD

FLOW

N

400 200 0 400

APPROX. SCALE IN FEET

CHANNEL
1951
1961
1967
1995

Dashed areas are areas with active overbank flow.

Figure 5.1 Historical Bankline Comparisons

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ALBUQUERQUE METROPOLITAN ARROYO FLOOD CONTROL AUTHORITY

TIJERAS ARROYO
HISTORIAL BANKLINE
COMPARISONS

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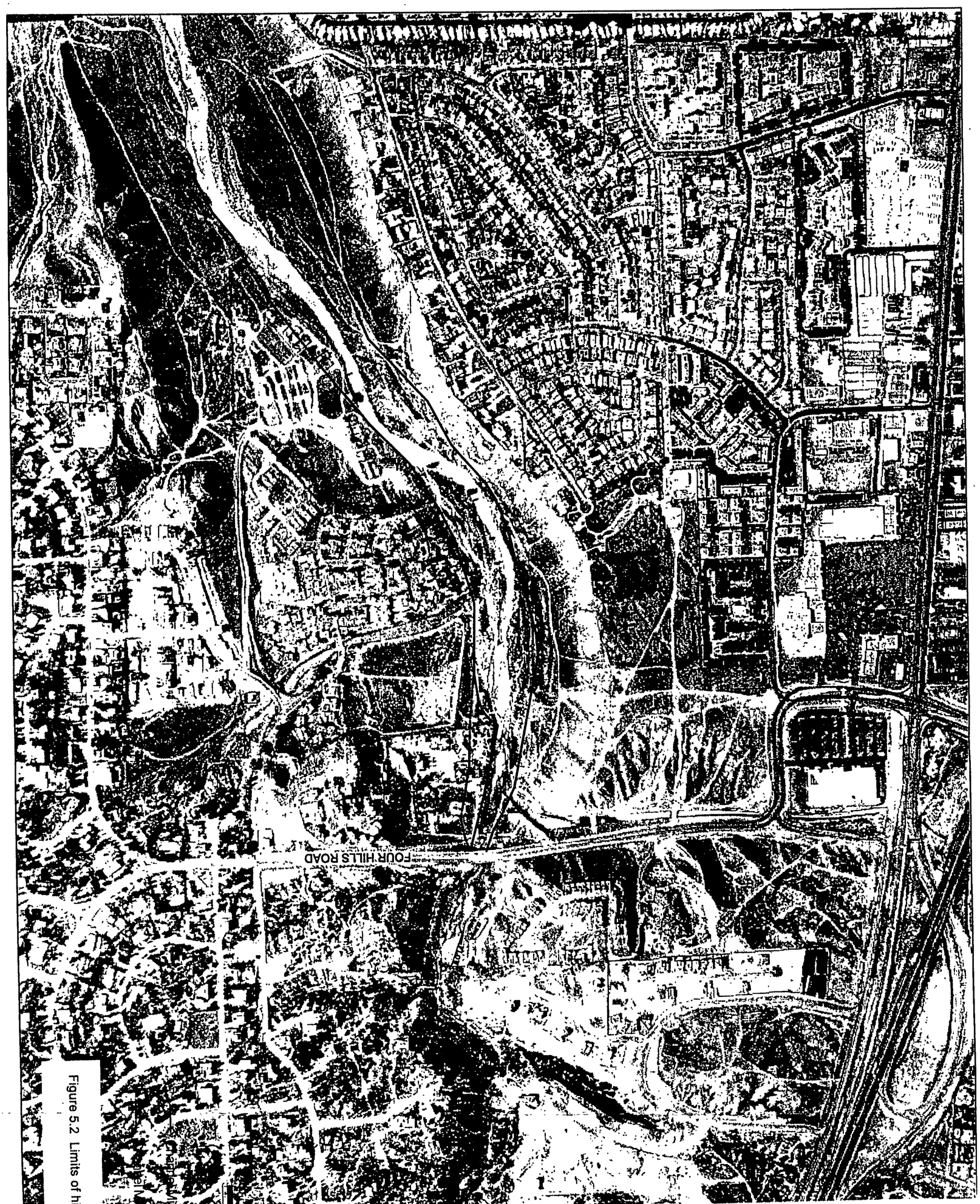


Figure 5.2 Limits of historical channel migration

F.a	Designed By: NSB Drawn By: CAK Checked By: LWZ Approved By: PFL Job #: 32-126.00 Date: 6-15-99	Revisions / Date Filename: FIGF.dgn	TIJERAS ARROYO LIMITS OF HISTORICAL CHANNEL MIGRATION	ALBUQUERQUE METROPOLITAN ARROYO FLOOD CONTROL AUTHORITY	AYRES ASSOCIATES Engineers/Scientists/Surveyors 3665 JFK Parkway, Building 2, Suite 300 P.O. Box 270460 Fort Collins, CO 80527 (970) 223-5556

$$Y_{s_m} = 0.015Y_{s_{100}} + 0.015Y_{s_{50}} + 0.04Y_{s_{25}}\ 0.08Y_{s_{10}}\ 0.2Y_{s_5} + 0.4Y_{s_2} \qquad \text{Eq. 5.1}$$

where:

Y_{si} = computed sediment yield for the 2-, 5-, 10-, 25-, 50-, 100-year events
Y_{sm} = annual sediment yield

The vertical response to changes in sediment volume were computed as was done for the short-term erosion analysis (Eq. 3.5). The annual value can be extrapolated to provide a long-term estimate of sedimentation or erosion. The Sediment and Erosion Guide recommends 30-years as a reasonable extrapolation period for urban areas. Results of the long-term analysis are listed in **Tables 5.1 through 5.4**. Worksheets of the computations are provided in Appendix D.

Table 5.1 Long-Term Reach Total Sediment Continuity Results.

	Reach Total Aggradation / Degradation Volumes (yd^3) (Sediment Yield)										
Q_2 - Q_{100}	2-Year (yd^3)	5-Year (yd^3)	10-Year (yd^3)	25-Year (yd^3)	50-Year (yd^3)	100-Year (yd^3)	Annual (yd^3)	Reach Length (ft)	Reach Total Width (ft)	Annual Reach Total Bed Elevation Change (ft)	30-year Reach Total Bed Elevation Change (ft)
REACH1	-256	-337	-215	591	2122	2328	-96	716	180	-0.03	-1.0
REACH2	895	1782	3041	4799	5994	6012	1330	1450	439	0.09	2.8
REACH3	193	297	265	-319	-1587	-1771	95	807	481	0.01	0.3

Table 5.2 Long-Term Main Channel Sediment Continuity Results.

	Main Channel Aggradation / Degradation Volumes (yd^3) (Sediment Yield)										
Q_2 - Q_{100}	2-Year (yd^3)	5-Year (yd^3)	10-Year (yd^3)	25-Year (yd^3)	50-Year (yd^3)	100-Year (yd^3)	Annual (yd^3)	Reach Length (ft)	Main Channel Width (ft)	Annual Main Channel Bed Elevation Change (ft)	30-year Main Channel Bed Elevation Change (ft)
REACH1	-256	-337	-214	596	2157	2375	-95	716	103	-0.06	-1.7
REACH2	536	610	-56	-3077	-7986	-8576	-40	1450	91	-0.01	-0.4
REACH3	105	14	-453	-2016	-4413	-4699	-209	807	91	-0.13	-3.8

Table 5.3 Long-Term Left Overbank Sediment Continuity Results.

	Left Overbank Aggradation / Degradation Volumes (yd^3) (Sediment Yield)										
Q_2 - Q_{100}	2-Year (yd^3)	5-Year (yd^3)	10-Year (yd^3)	25-Year (yd^3)	50-Year (yd^3)	100-Year (yd^3)	Annual (yd^3)	Reach Length (ft)	Left Overbank Width (ft)	Annual Left Overbank Bed Elevation Change (ft)	30-year Left Overbank Bed Elevation Change (ft)
REACH1	0	0	0	0	-2	-7	0	716	8	0.00	-0.0
REACH2	275	877	2296	5966	11175	11771	1052	1450	211	0.15	4.6
REACH3	-2	-4	8	109	400	450	16	807	239	0.00	0.1

Table 5.4 Long-Term Right Overbank Sediment Continuity Results.											
	Right Overbank Aggradation / Degradation Volumes (yd^3) (Sediment Yield)										
Q_2 - Q_{100}	2-Year (yd^3)	5-Year (yd^3)	10-Year (yd^3)	25-Year (yd^3)	50-Year (yd^3)	100-Year (yd^3)	Annual (yd^3)	Reach Length (ft)	Right Overbank Width (ft)	Annual Right Overbank Bed Elevation Change (ft)	30-year Right Overbank Bed Elevation Change (ft)
REACH1	0	0	0	-5	-33	-40	-1	716	69	0.00	-0.0
REACH2	84	296	801	1910	2805	2817	318	1450	137	0.07	2.2
REACH3	90	287	711	1587	2427	2478	287	807	151	0.11	3.2

Figure 5.3 illustrates the computed bed elevation changes for the 30 year analysis. A plus (+) sign indicates an increase in elevation whereas a minus (-) indicates lowering of the channel.

The long-term sediment continuity analysis indicates that in Reach 1 near the Veretto Property there is a potential for long-term degradation on the order of 1 to 2 feet in 30 years. Downstream through Reaches 2 and 3 there is a potential for long-term aggradation. On a reach total basis, Reach 2 is expected to aggrade by as much as 2.8 feet in 30 years. Similar to the short-term erosion results, the continuity analysis indicates some channel erosion and overbank deposition in Reaches 2 and 3 when sediment transfer between the main channel and overbanks is considered. However considering long-term channel forming processes, it is more likely that the channel would also eventually aggrade following sediment deposition in the overbanks. Therefore the reach total results presented in Table 5.1 are more reasonable estimates of the 30-year aggradation expected for the Hidden Valley Subdivision and the undeveloped land.



Figure 5.3 Long-term Aggradation/degradation depths (ft)

D.a	Designed By: MSB Drawn By: CAK Checked By: LWZ Approved By: PFL Job #: 32-126.00 Date: 6-15-99	Revisions / Date	TIJERAS ARROYO LONG-TERM (30 YEAR) AGGRADATION/ DEGRADATION (FT)	ALBUQUERQUE METROPOLITAN ARROYO FLOOD CONTROL AUTHORITY	AYRES ASSOCIATES Engineers/Scientists/Surveyors 3665 JFK Parkway, Building 2, Suite 300 P.O. Box 270460 Fort Collins, CO 80527 (970) 223-6556

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6. CONCEPTUAL COUNTERMEASURE DESIGN

Based on findings from the single event and long term-erosion analyses the following problem areas have been identified:

- Flooding potential along the Veretto Property and the Hidden Valley Subdivision levees
- Potential for levee/embankment undermining due to lateral channel migration and arroyo channel lowering

The potential problems listed above can be mitigated with countermeasures. Several methods are suggested in the following section. Recommended countermeasures include:

- Raise the levee along the Veretto Property and provide additional flood protection along the Hidden Valley Subdivision to an elevation which exceeds the freeboard requirements
- Provide levee and berm revetment with riprap or other armor along the south side of the arroyo at the Veretto Property, the Hidden Valley Subdivision and the undeveloped land between them.

Alternatives considering the extent of revetment and the method of toe down are provided in the following sections. Raising the levee for flood protection is recommended for all alternatives.

6.1 Levee Improvement

The levee along the Veretto Property should be raised to prevent flooding during the 100-year event. Following inspection, if the upper embankment along the Hidden Valley Subdivision appears to be inadequate, a portion of it should be raised to prevent potential flooding. The height of the design levee or embankment should provide enough freeboard (above the critical water surface or energy grade line) to account for increases in water surface due to sediment deposition. The long-term erosion analysis predicted as much as 2.8 feet of deposition in Reach 2. The single event erosion analysis predicted up to 1.4 feet of deposition in Reach 1 near the Veretto Property. This could potentially cause a rise in the water surface during a flood. For the conceptual design 3 feet of freeboard above the critical water surface or 1 foot above the computed energy gradeline (whichever is greater) was assumed. **Figure 6.1** represents the design levee profile and tabulated values are listed in **Table 6.1**. The levee improvements could be constructed from compacted fill material and the facing should be armored with revetment.

6.2 Levee Revetment

The levees and embankments that are impacted by floodwaters should be protected with armoring material such as riprap, gabions, soil cement etc. Riprap may prove to be the most cost effective treatment. Some of the design considerations for revetments include material sizing for stability, toe down depth, riprap thickness, gradation and filter requirements. A stability analysis for riprap sizing was performed using the HEC-11 equation (Brown and Clyde 1988). The maximum reach averaged main channel velocity through the study area and a levee sideslope of 2H:1V were used for the analysis. The following riprap sizes were computed as shown in **Table 6.2**.

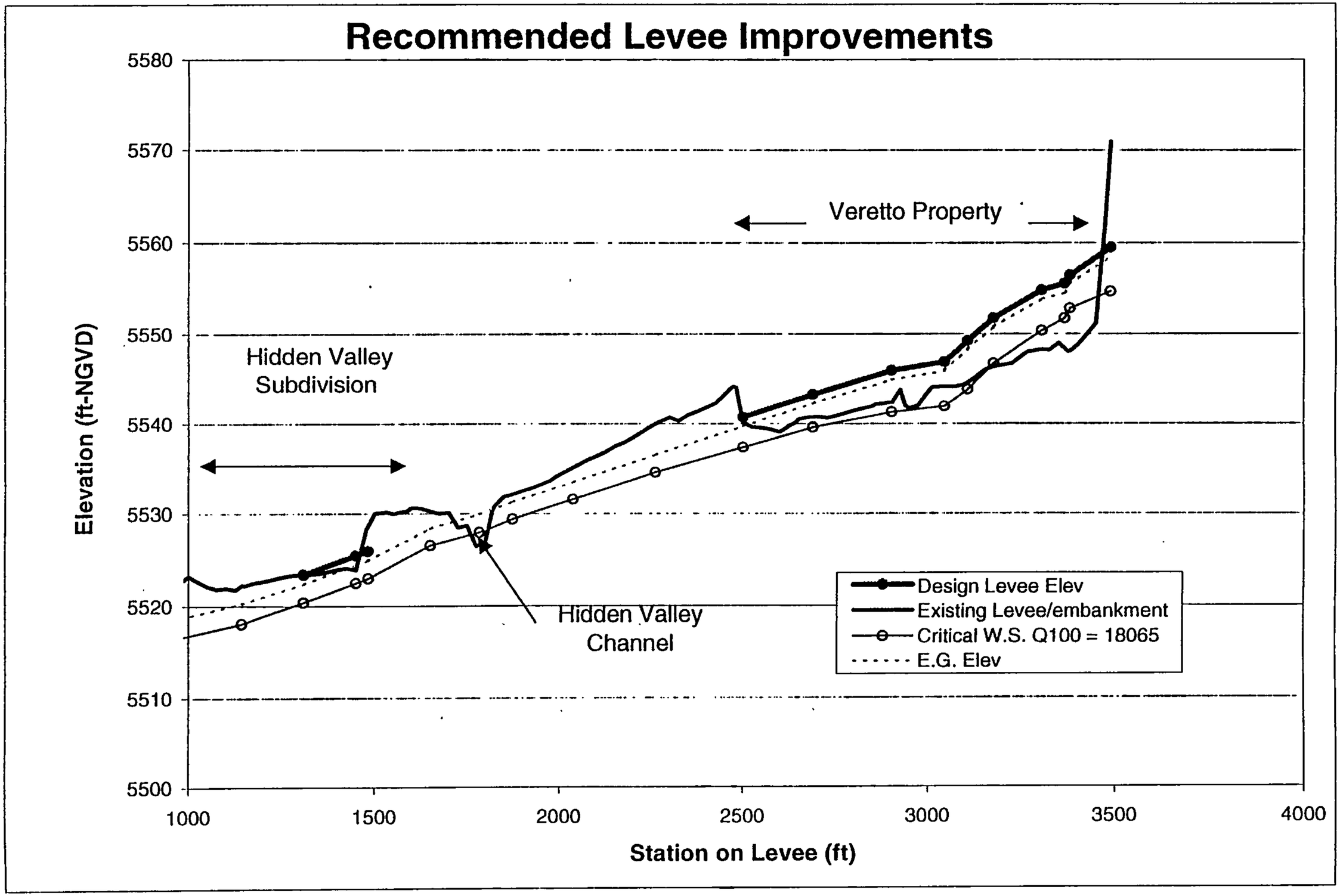


Figure 6.1. Levee improvement profile.

Table 6.1. Levee Improvement Profile.					
Station on Existing Levee/ Embankment (ft)	Corresponding HEC-RAS Cross Section	Existing Levee/ Embankment Elevation (ft-NGVD)	Critical W.S. Q_{100} = 18065 (ft-NGVD)	E.G. Elev Q_{100} = 18065 (ft-NGVD)	Design Levee Elevation (ft-NGVD)
328	329	5522.23	5510.87	5512.66	
621	499	5523.47	5513.76	5515.50	
923	692	5521.38	5516.17	5518.20	
1143	879	5522.34	5518.12	5520.28	
1309	1063	5523.45	5520.40	5522.48	5523.48
1450	(1273)	5523.95	5522.53	5524.51	5525.53
1483	1322	5528.70	5523.03	5524.99	5526.03*
1651	1620	5530.23	5526.62	5528.46	
1784	1794	5526.73	5528.02	5529.96	
1873	1909	5532.16	5529.40	5531.34	
2037	2076	5535.11	5531.57	5533.54	
2261	2310	5539.97	5534.60	5536.56	
2500	(2433)	5540.11	5537.39	5539.75	5540.75
2689	2531	5540.75	5539.59	5542.27	5543.27
2902	2708	5542.38	5541.27	5544.92	5545.92
3044	2851	5544.14	5541.92	5545.89	5546.89
3107	2913	5544.62	5543.81	5548.26	5549.26
3176	2981	5546.35	5546.72	5550.81	5551.81
3305	3109	5548.26	5550.41	5553.91	5554.91
3366	3164	5548.41	5551.77	5554.61	5555.61
3380	3169	5548.11	5552.86	5555.54	5556.54
3489	3243	5570.96	5554.76	5558.56	5559.56*
*tie into existing levee					

Table 6.2. Required Riprap Sizes for Levee Revetment.		
Event	Velocity (fps)	D_{50} Riprap (ft)
100-year	15.6	2.0
50-year	15.4	1.9
25-year	13.8	1.6
10-year	11.4	1.1
5-year	11.4	1.1
2-year	7.5	0.5

The maximum reach averaged main channel velocities were computed in Reach 1 where the flow is more constricted. Although there could be local velocities that exceed the reach averaged values, it was assumed that the reach averaged velocities were adequate for design. Riprap sizing computations are included in **Appendix E.**

The levee revetment should be keyed into the arroyo bed to prevent undermining of the levee toe. The revetment could extend into the arroyo bed or alternatively a revetment toe trench could be provided so that the riprap would launch into the scour hole as flow impinges on the levee. The revetment toe design should include the consideration for channel migration and scour within the channel as it impinges on the levee.

Results from the long-term erosion analysis indicate that the channel could migrate to the toe of levee for all properties within the study area. Results from the single event erosion analysis indicate that the main channel could lower by as much as 2.9 feet (Q_{100} = 18,065 cfs) to 4.4 feet (Q_{100} = 22,600 cfs) near the Hidden Valley subdivision and the undeveloped land to the east during the 100-year event. The long-term analysis resulted in an additional 0.4 foot of channel degradation in this area. Summing the results from the long-term and single event analyses indicates 3.3 to 4.8 feet of potential channel scour for the Hidden Valley subdivision and the undeveloped land. Therefore the revetment should provide toe down to account for the main channel shifting and the anticipated scour within the main channel. The existing main channel invert is currently between 2 to 5 feet below the toe of levee depending on the location within the study area. With the additional channel scour, the required toe down could be as much as 10 feet. The toe of the upper embankment at the Hidden Valley Subdivision is as much as 8 feet above the channel invert. However, a lower terrace berm protecting the duck ponds exists to the north of this fill. This lower berm acts as a buffer and the trees along the berm provide additional stability. It is unlikely the arroyo channel could migrate into the filled portion of the Hidden Valley Subdivision. Consequently, this upper section does not require revetment.

The long-term analysis shows as much as 1.7 feet of degradation at the Veretto Property. Therefore, approximately 2 feet of toe down for levee revetment in this reach is recommended.

Alternative 1

This alternative includes raising the levee along the Veretto Property and the embankment at the Hidden Valley Subdivision to an elevation which exceeds the computed freeboard requirements. The levee revetment would extend along the length of the levee at Veretto

Property and along portions of the low berm protecting the Hidden Valley Subdivision and the undeveloped land. The extent of the revetment for the latter two locations would include only that portion of the levee/berm that would presumably be impacted by channel migration. Based on a review of historical aerial photographs, the western half of the undeveloped land and the northeastern tip of the Hidden Valley Recreation Area are most susceptible to impinging flow patterns from channel migration. **Figure 6.2** illustrates in planform the recommendations for Alternative 1.

Alternative 2

This alternative includes raising the levee along the Veretto Property and the embankment along the Hidden Valley Subdivision to an elevation which exceeds the computed freeboard requirements. In addition this alternative provides revetment for all of the levee and embankment on the south side of the arroyo that would be impacted by floodwaters. This alternative would be more costly than Alternative 1, but would provide a more robust levee system. The levee revetment would extend the full length of the Veretto property, the undeveloped land and the low berm at the Hidden Valley Subdivision. **Figure 6.3** illustrates in planform the recommendations for Alternative 2.

For the levee revetment locations recommended in Alternatives 1 and 2, options for the treatment of revetment at the toe of the levees are describe below.

Option A: Bury the revetment to the anticipated scour depth. This depth includes the arroyo channel thalweg plus the scour depth computed for the main channel in the long-term 100-year event. **Figure 6.4** illustrates in cross-section, the recommended levee improvements, revetment layout and toe down depth suggested for the Veretto Property and the undeveloped property. The embankment along the undeveloped property to the west does not need to be raised but should have similar revetment protection. **Figure 6.5** illustrates in cross section, the recommended improvements for the Hidden Valley Subdivision.

Option B: Provide a toe trench of sufficient volume so that the riprap will launch into the scour hole as it develops. This method may provide a cost savings over Option A in that the depth of excavation would be less. **Figure 6.6** illustrates in cross-section, the recommended levee improvements, revetment layout and toe trench depth suggested for the Veretto Property and the undeveloped property. Again, the embankment along the undeveloped property to the west does not need to be raised but should have similar revetment protection. **Figure 6.7** illustrates in cross section, the recommended improvements for the Hidden Valley Subdivision.

For both Options A and B, the thickness of the levee revetment should be 1.5 times the D_{50} of the material used. The riprap should be well graded throughout the revetment layer to provide interlocking between the stones. The gradation curve provided in HEC-11(Brown and Clyde 1988) is recommended for the levee protection in Tijeras arroyo. The gradation curve is provided in Appendix E.

Providing a filter between the revetment and the subgrade prevents the migration of fine materials between the voids in the revetment. A filter provides a transitional layer between the subgrade and the revetment. Synthetic geotextile fabric or granular filters may be used. For granular filters the HEC-11 (Brown and Clyde 1988) criteria was used. Using a riprap size of D_{50} = 2 ft and D_{15} = 1 ft (100-year) a filter would be required with the existing subgrade. Using the HEC-11 criteria a gravel filter with a D_{85} of 3.6 inches would be required. The filter gradation should be such that the D_{15} is no larger than 0.7 inches. Otherwise two filter layers may be required.

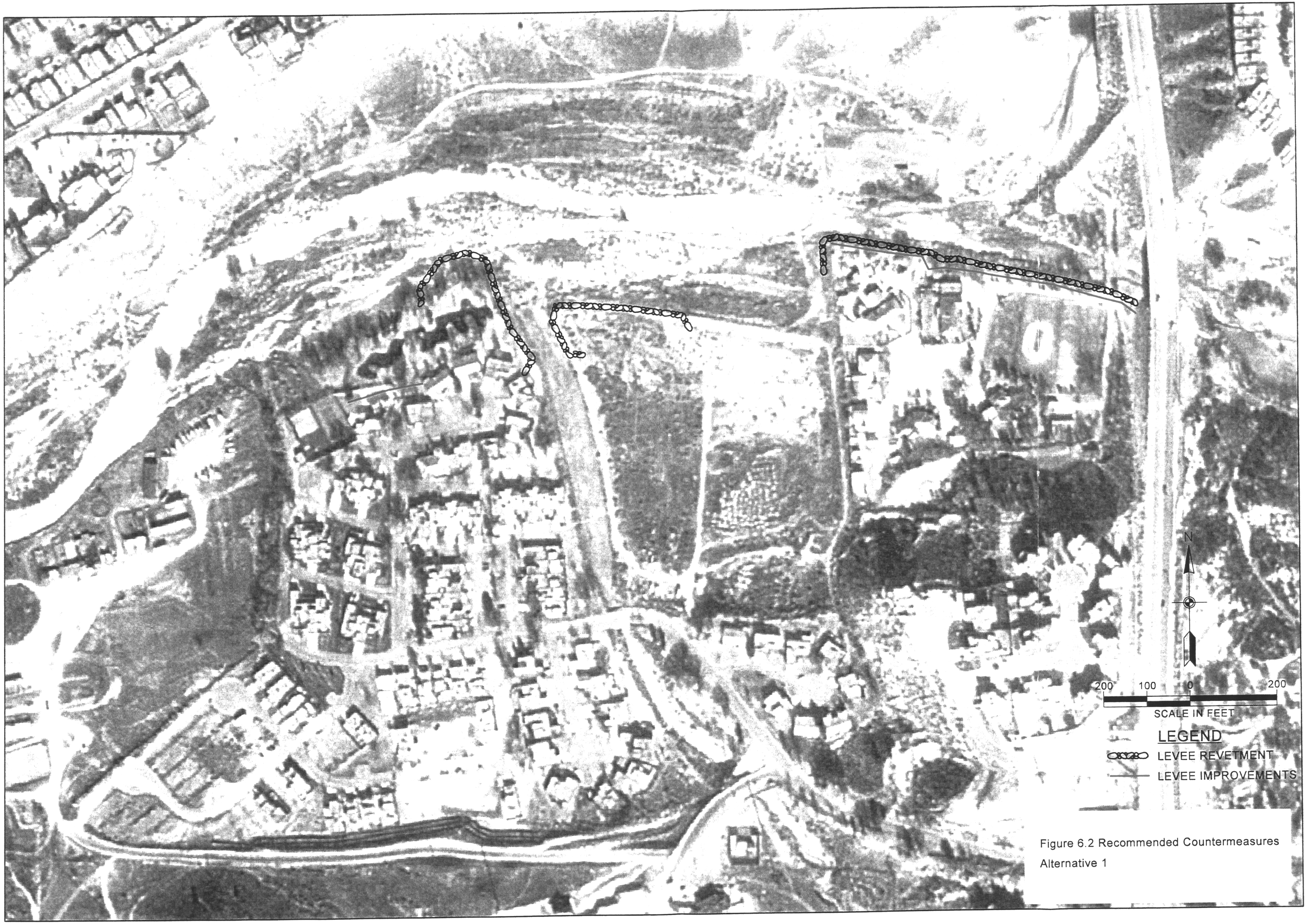


Figure 6.2 Recommended Countermeasures Alternative 1

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ALBUQUERQUE METROPOLITAN ARROYO FLOOD CONTROL AUTHORITY

TIJERAS ARROYO
RECOMMENDED IMPROVEMENTS
ALTERNATIVE 1

Revisions | Date

Designed By: MSB
Drawn By: CAK
Checked By: LWZ
Approved By: PFL
Job #32-126.00

G.1



Figure 6.3 Recommended Countermeasures
Alternative 2

G.2	Designed By: MSB Drawn By: CAK Checked By: LWZ Approved By: PFL Job #: 32-126.00 Date: 6-15-99	Revisions / Date	TIJERAS ARROYO RECOMMENDED IMPROVEMENTS ALTERNATIVE 2	ALBUQUERQUE METROPOLITAN ARROYO FLOOD CONTROL AUTHORITY	AYRES ASSOCIATES Engineers/Scientists/Surveyors 3665 JFK Parkway, Building 2, Suite 300 P.O. Box 270460 Fort Collins, CO 80527 (970) 223-5556

Filename: FIGG.dgn

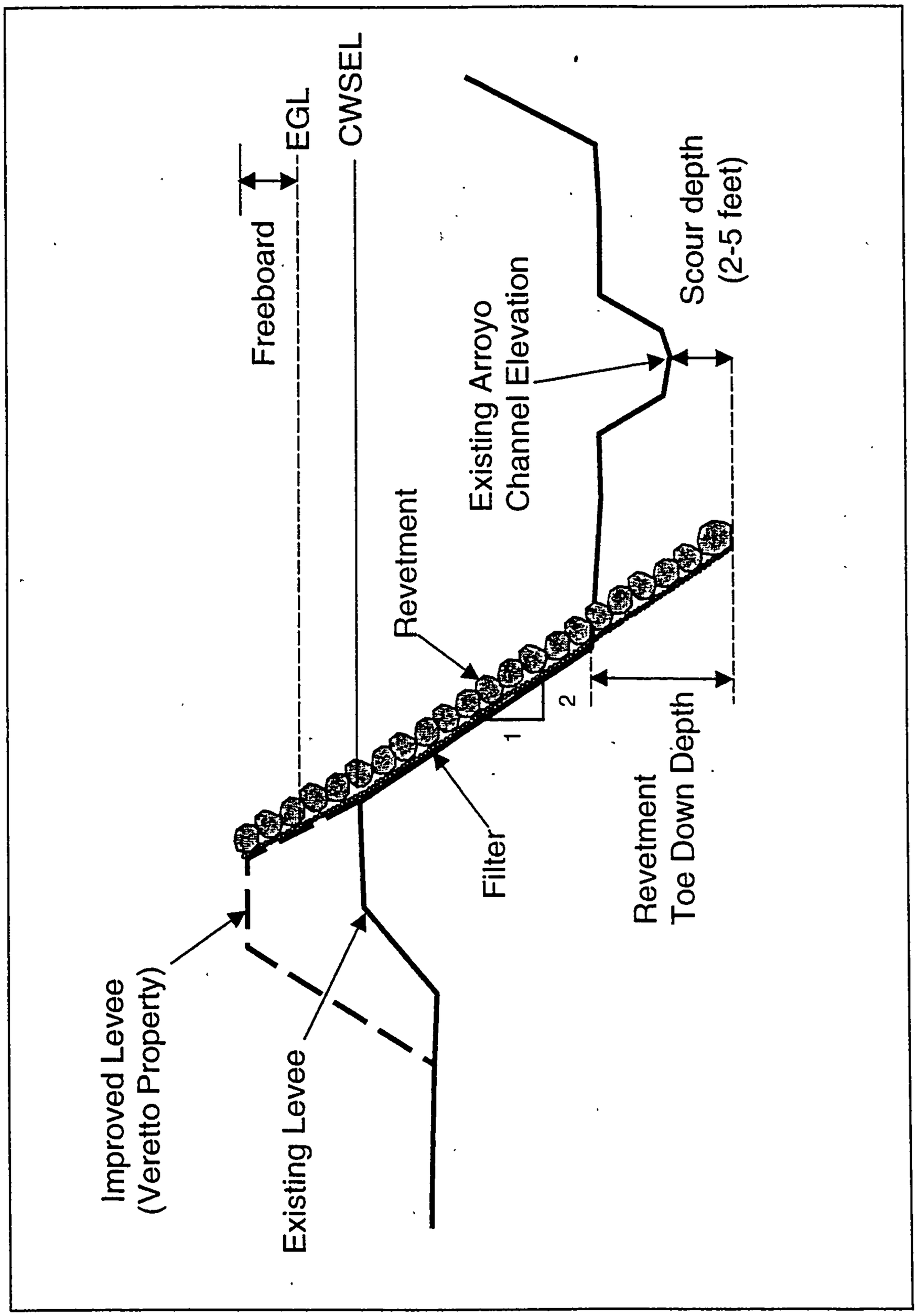


Figure 6.4. Alternatives 1 and 2 - Option A. Recommended countermeasures for the Veretto property and the undeveloped land.

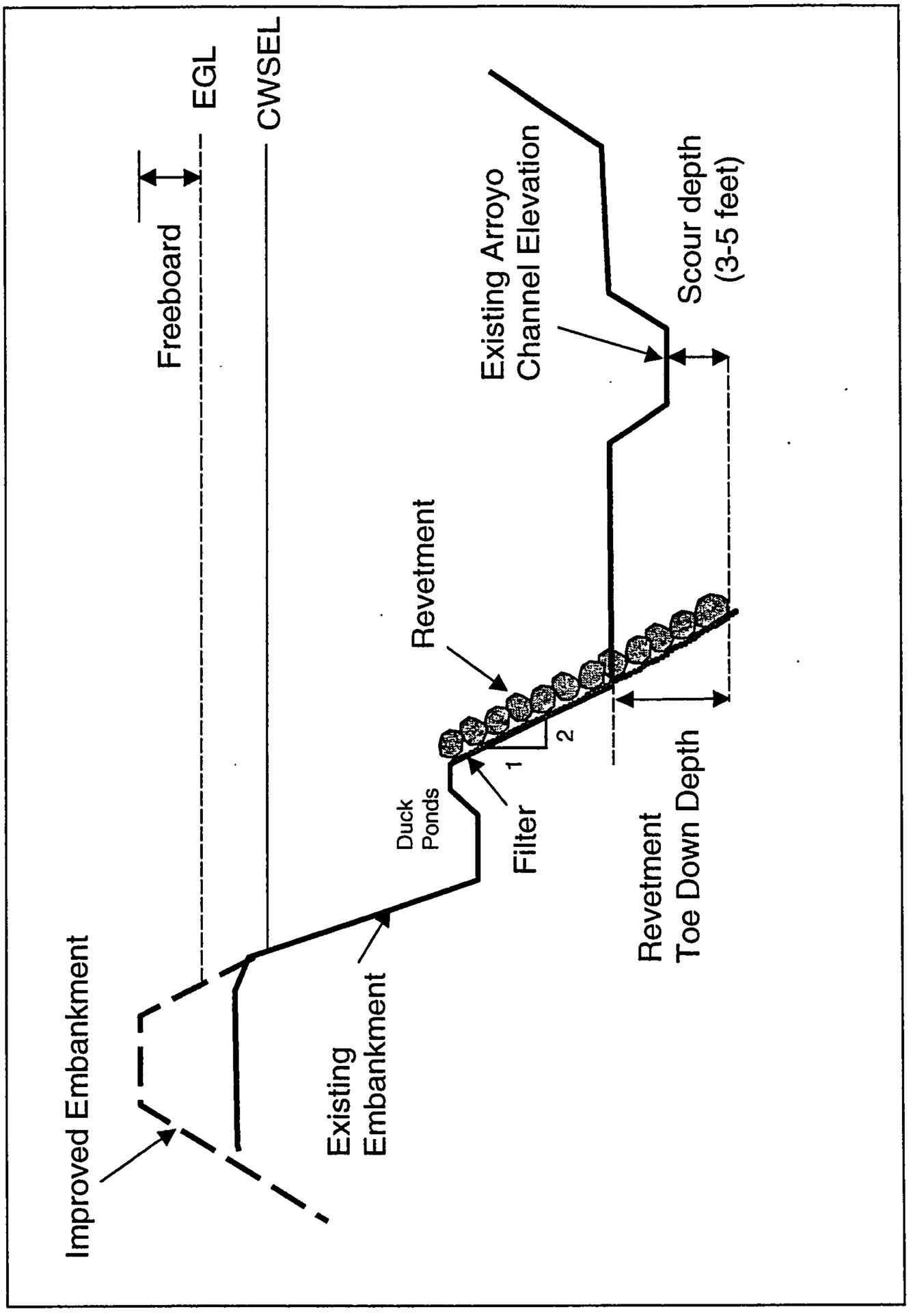


Figure 6.5. Alternatives 1 and 2 - Option A. Recommended countermeasures for the Hidden Valley Subdivision.

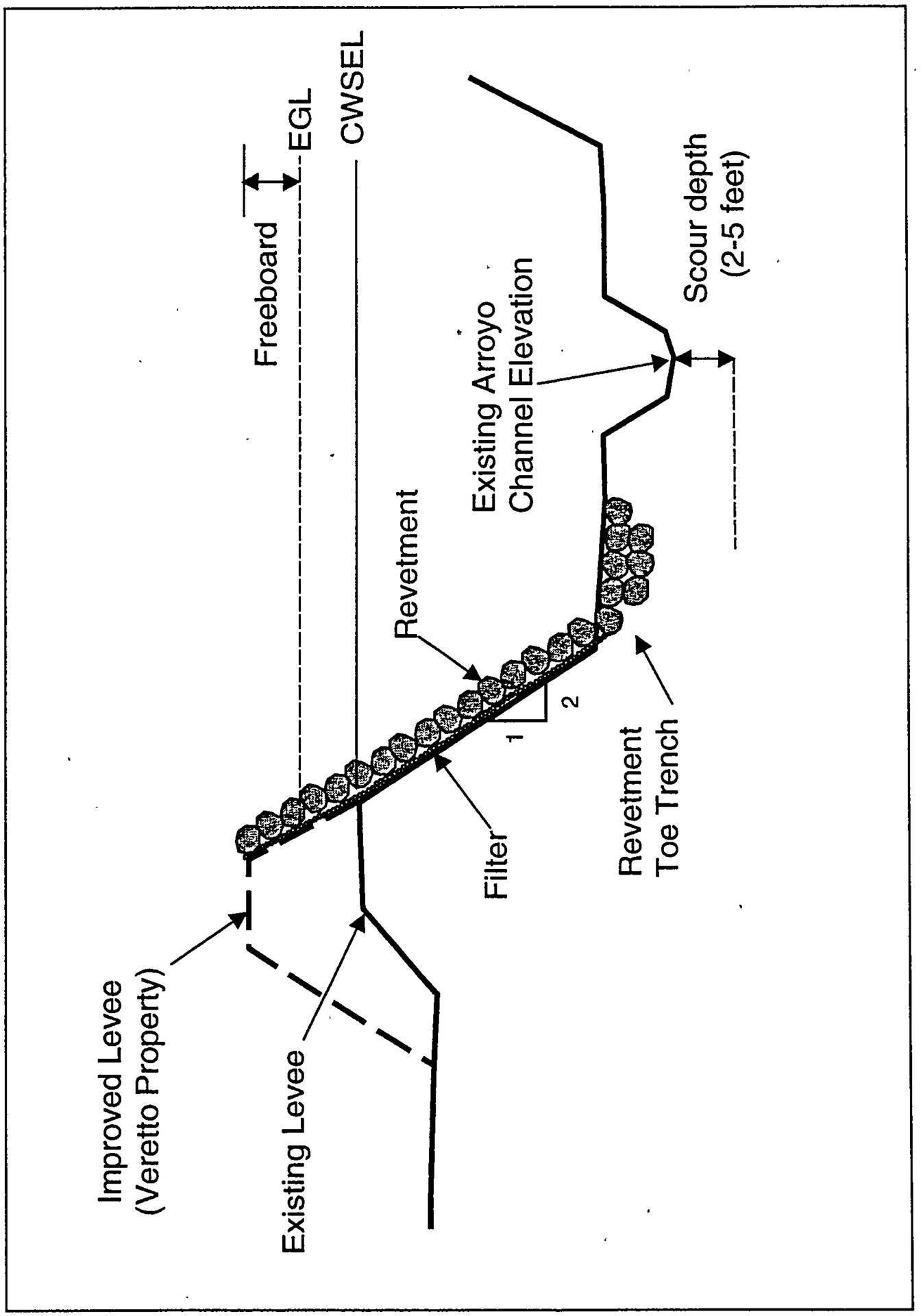


Figure 6.6. Alternatives 1 and 2 - Option B. Recommended countermeasures for the Veretto property and undeveloped land.

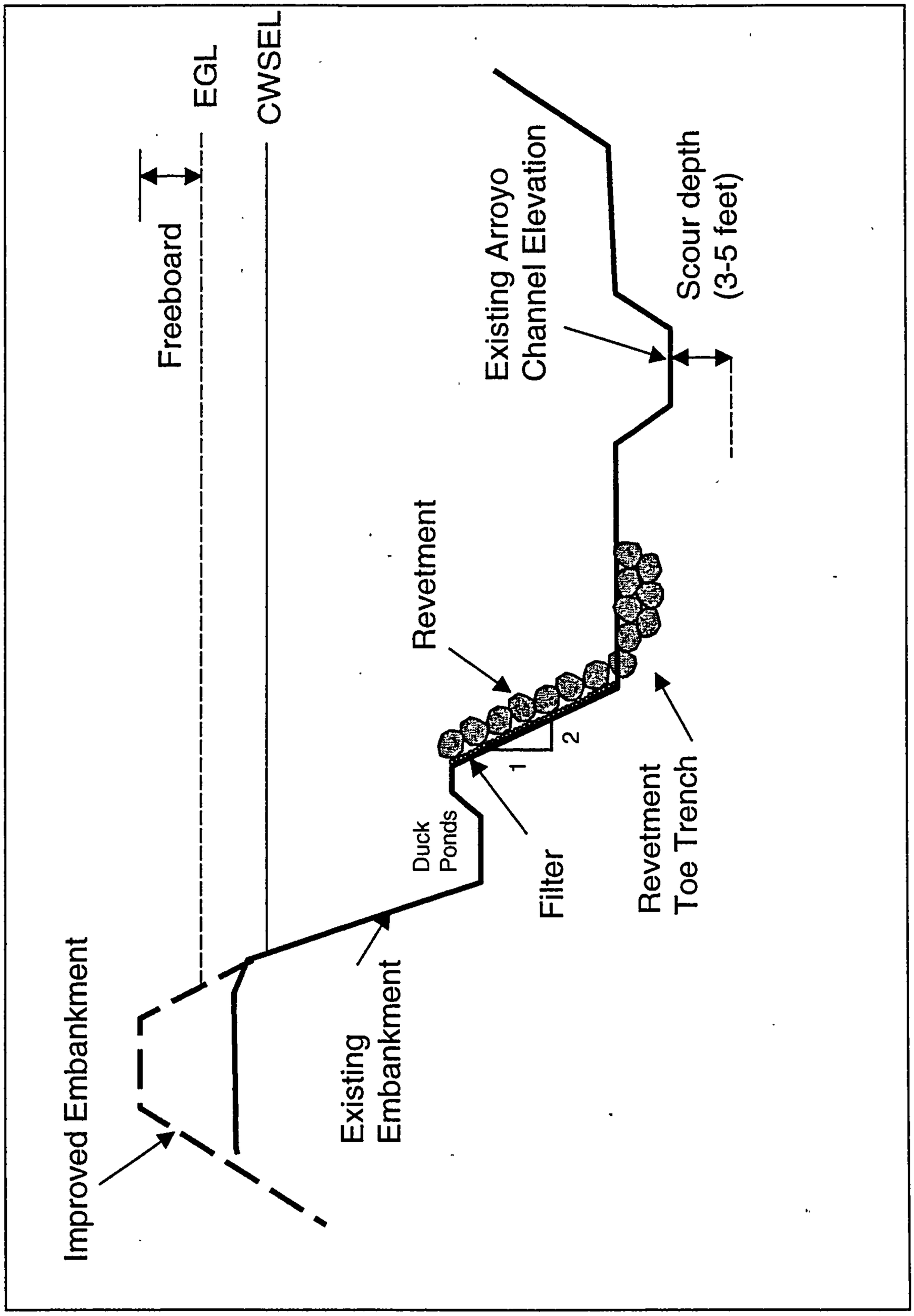


Figure 6.7. Alternatives 1 and 2 - Option B. Recommended countermeasures for the Hidden Valley Subdivision.

The Hidden Valley Drainage Channel that flows north into Tijeras Arroyo could potentially require some channel and bank protection in the future if erosion/degradation is observed. Although the computed 100-year velocities are sufficient to erode the bed and bank material from this channel, no evidence of channel instability has been observed. Therefore a reasonable countermeasure is to monitor the channel and repair any localized erosion on an as needed basis.

If significant degradation is observed on the Hidden Valley drainage channel in the future, channel or embankment revetment should be implemented. Similar to the levee protection recommended on Tijeras Arroyo, the armor should be well graded, include a filter and have a thickness which is 1.5 D_{50} of the revetment material. Using the HEC-11 equation for sizing riprap the required rock size to remain stable during the 100-year event would be 0.3 ft (3.6 inches). Based on the HEC-11 criteria, a gravel filter with a D_{85} of 0.5 inches would be required for the Hidden Valley Channel.

For all of the conceptual countermeasure alternatives described above, additional engineering design would be required to develop cost estimates and documents suitable for bidding and construction. Revetment alternatives such as soil cement would not appear justified considering the existence of a serviceable levee or embankment on the south bank of the arroyo in the study reach.

7. REFERENCES

Bovay Engineers, Inc., 1981. Tijeras Arroyo Drainage Management Plan, prepared for the Albuquerque Metropolitan Flood Control Authority, January.

Leedshill-Herkenoff Engineers, Inc., 1987. Tijeras Arroyo Drainage Management Plan Phase I, prepared for the City of Albuquerque.

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RCE, Inc., 1994. Sediment and Erosion Design Guide, prepared for the Albuquerque Metropolitan Flood Control Authority, March.

Brown, S.A., E.S. Clyde, 1989, "Design of Riprap Revetment," Hydraulic Engineering Circular No. 11, FHWA-IP-016, prepared for FHWA, Washington, D.C.

APPENDIX A
Field Reconnaissance Photographs



Hidden Valley Channel looking D/S toward Tijeras Arroyo



Hidden Valley Channel looking U/S



Looking U/S on Tijeras Arroyo, south side along AMAFCA low dike



Looking D/S on Tijeras Arroyo at Hidden Valley Recreation Area



Looking D/S on Tijeras Arroyo at Hidden Valley Recreation Area



Looking U/S on Tijeras Arroyo from Hidden Valley Area



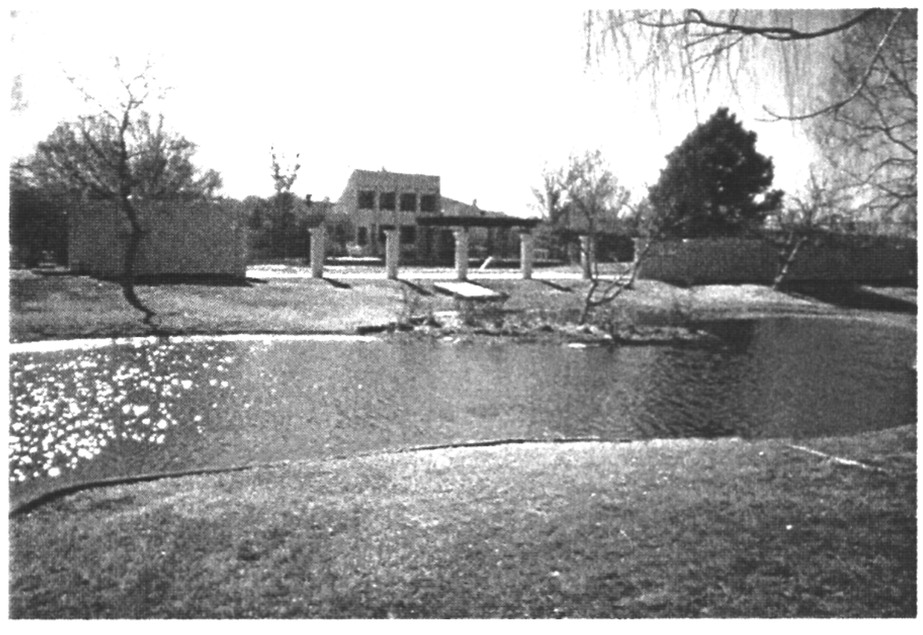
Looking U/S on Tijeras Arroyo from horse farm



Bank protection at horse farm, south bank



Hidden Valley Recreation Area club house



Hidden Valley Recreation Area club house



Looking U/S on Tijeras Arroyo at "T" dike



Looking D/S on Tijeras Arroyo - note perennial flow



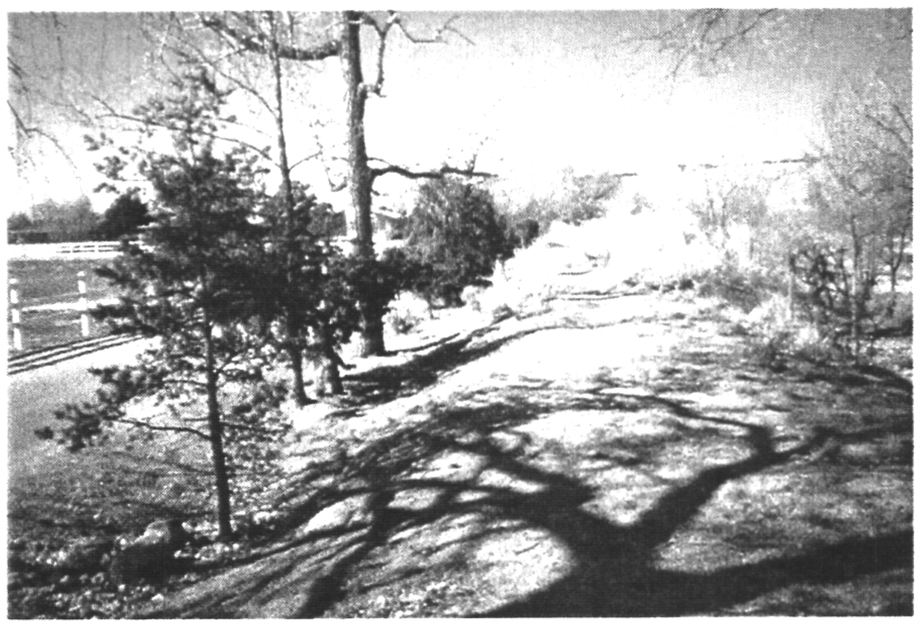
Looking U/S on Tijeras Arroyo at Four Hills Road Bridge – note drop structure



Looking D/S on Tijeras Arroyo from Four Hills Road Bridge



AMAFCA riprap on south bank below Four Hills Road Bridge



Looking west along dike below Four Hills Road Bridge



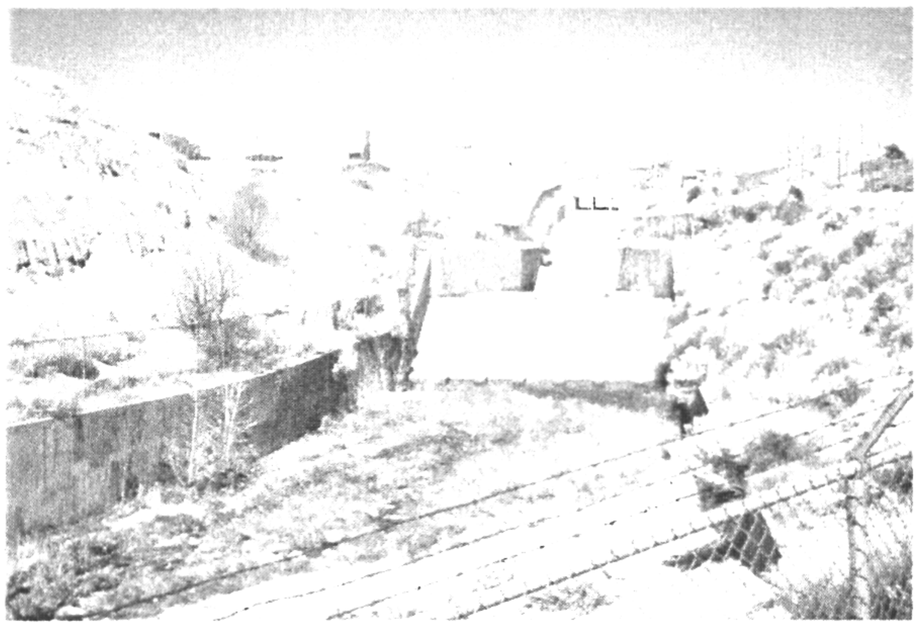
Looking southwest along dike below Four Hills Road Bridge into Veretto Property



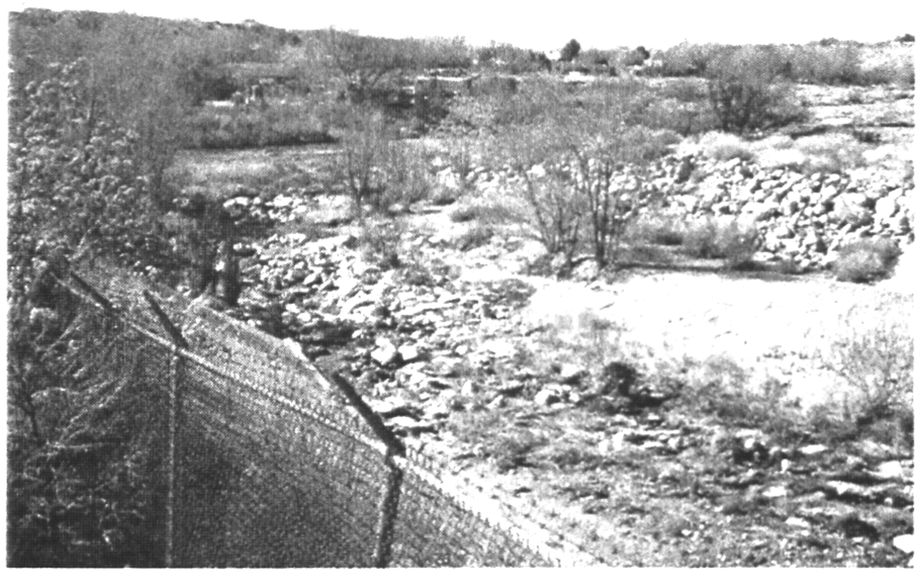
Looking U/S on Tijeras Arroyo through Four Hills Road Bridge



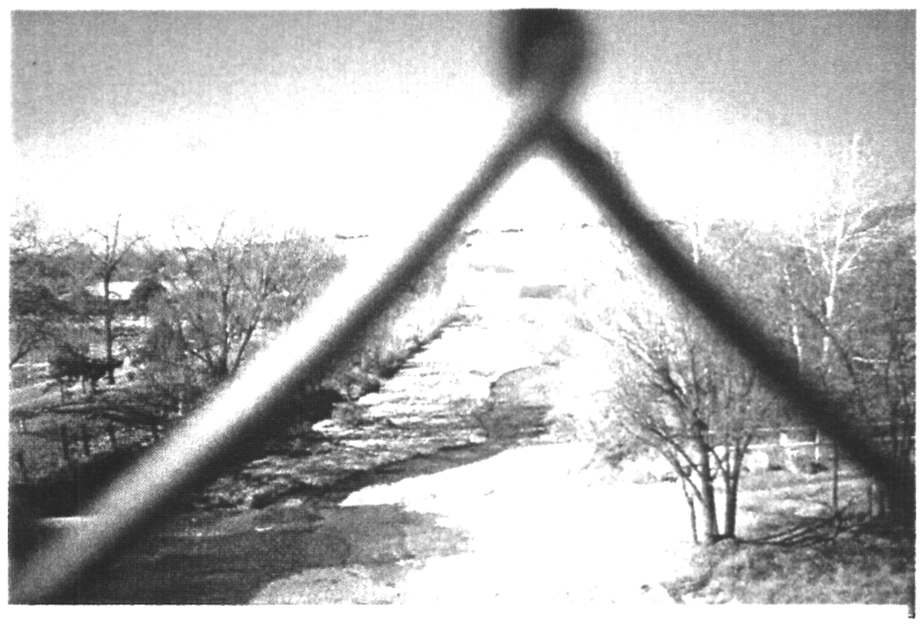
Looking D/S on Tijeras Arroyo from Four Hills Road Bridge



Looking U/S on Tramway Diversion Channel



Looking D/S on Tramway Diversion Channel to confluence with Tijeras Arroyo



Looking D/S at Tijeras Arroyo from Four Hills Road Bridge



Looking D/S at Veretto Property and Tijeras Arroyo from Four Hills Road Bridge



Looking U/S on Tijeras Arroyo from Four Hills Road Bridge