SCOTTSDALE DESERT GREENBELT

Pima Road Drainage System

Basin Alternative

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The Desert Greenbelt
SCOTTSDALE, ARIZONA

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May 1996

Prepared for The City of Scottsdale

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REMARKS

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Executive Summary

As a result of an extensive study performed by Greiner, Inc. as part of the Scottsdale Desert Greenbelt Project for the City of Scottsdale, 30-percent design plans for a concrete lined channel along Pima Road were submitted on September 13, 1995. Subsequently, a preliminary design report was prepared by Pacific Advanced Civil Engineering (PACE) for Grayhawk Development, Scottsdale, Arizona, September 15, 1995, that presented an alternative detention basin drainage concept. This preliminary report prepared by PACE indicated the alternative drainage concept they had developed would reduce flowrates and flow velocities within the Pima channel, and provide a considerable cost savings to the City. Due to the significant interest generated within the City, the Flood Control District of Maricopa County, and the local developers regarding this alternative concept, and due to the conceptual nature of the report prepared by PACE, the City retained Greiner to further investigate the feasibility of this alternate detention basin drainage system.

This report is a summary of Greiner's investigation of this alternate system which generally consisted of several configurations of a drainage channel along Pima Road in conjunction with three detention basins located at: Happy Valley Road, Deer Valley Road, and the proposed Union Hills Road alignment. The findings of this study indicate that while the use of detention basins may reduce the flow velocities and flowrates within the Pima Road channel, the facilities required to produce these reductions, such as drop structures and energy dissipators are cost prohibitive to the project. These facilities were not included within the PACE conceptual report. Additionally, the hydraulic characteristics of the total system are quite different than those characteristics presented by PACE in their conceptual report. The extent of the channel lining materials required to meet the Flood Control District's minimum guidelines for this alternative also proved to be cost prohibitive. The least expensive alternative concept developed by Greiner, that addresses and meets the necessary hydraulic provisions of standard engineering practices, was $46.6 million; $7.7 million greater than the cost estimate for the Pima Road channel as designed for the 30-percent plans.

This report is a summary of Greiner's findings to date. After several meetings with the City of Scottsdale and the Flood Control District, it became apparent that the basin alternative would be more expensive than the original channel alternative. Under direction from the City of Scottsdale, Greiner discontinued its investigation in February 1996 awaiting further planning by the City of Scottsdale as to the future development of the Pima Road drainage system.

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1.0 Introduction

On September 13, 1995, Greiner, Inc. submitted the 30-percent design plans for a concrete lined channel along the Pima Road portion of the Desert Greenbelt Project, to the City of Scottsdale, Arizona. These 30-percent design plans were the result of an extensive study phase performed by Greiner, Inc. and City of Scottsdale staff (the design team) to determine the most cost effective drainage system for the Pima Road alignment. This study phase initially considered a single detention basin system alternative, but it was dismissed as an option because it was identified as being cost prohibitive.

In a Preliminary Design Report prepared for Grayhawk Development (Grayhawk), dated September 15, 1995, Pacific Advanced Civil Engineering (PACE) presented the results of their investigations into an alternative multiple detention basin system (basin alternative) for Pima Road. Within the Executive Summary of their report, PACE stated that the proposed detention design alternative has the support of the City of Scottsdale (COS), Maricopa County Flood Control District (FCDMC), Arizona State Land Department (ASLD), Arizona Department of Water Resources (ADWR), and the Arizona Department of Transportation (ADOT). However, the extent of the support for this concept was not identified and was diversive between, and within, the various agencies and departments. All parties, including the design team, were receptive to a system that might possibly reduce channel flowrates, velocities and cost. During the review of the PACE report by Greiner and COS staff, several concerns and questions were raised regarding the feasibility and the cost estimate for this basin alternative. Due to these questions, concerns and the conceptual nature of the PACE report, the City of Scottsdale requested that Greiner Inc. perform a detailed feasibility study for this basin alternative.

The purpose of this study is to investigate the hydraulic performance, cost, aesthetic possibilities and overall feasibility of this basin alternative for the Pima Road system incorporating multiple detention basins, drop structures and native invert channels as identified in the PACE report. This study also addresses the concerns and interests of the various involved parties identified above, and as stated below. Safety issues pertaining to supercritical flow and the associated high velocities are a primary concern of FCDMC. Grayhawk and the DC Ranch Development are concerned with the aesthetics and the total cost for the system. ASLD is particularly concerned with the alignment of the system and its impact to state owned properties. The conclusions of this study are the result of a collective effort conducted between COS staff, FCDMC staff and Greiner Inc. The approaches used to analyze the Basin Alternative, and the results thereof, are report herein.

1.1 Pima Road Drainage System

The Pima Road drainage basin extends, from north to south, from Jomax Road to the Tournament Players Club (TPC); and from east to west, from 104th Street to Hayden Road. The drainage basin includes the Grayhawk and DC Ranch development communities. The channel alternative and the Basin Alternative are both regional drainage facilities that will be used to remove the existing flooding potential and improve the potential for development along the Pima Road corridor.

The channel alternative consists of a concrete lined, trapezoidal channel from Jomax Road to the TPC, approximately 7 miles. The channel has been proposed to be placed at existing grade with

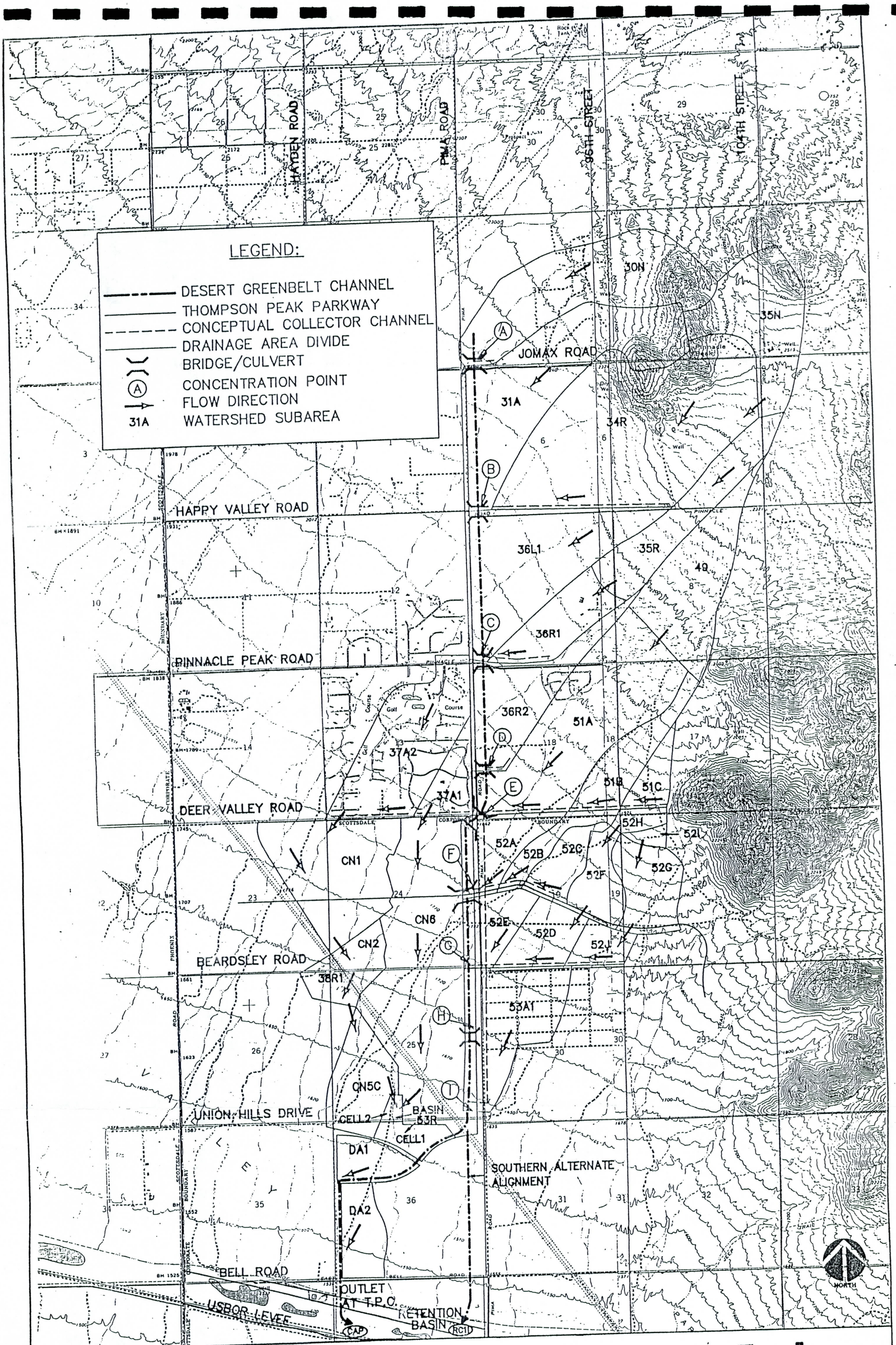
an average slope of approximately 2 percent. The proposed top width of the channel ranges from 40 feet, north of Jomax Road, to approximately 100 feet south of Bell Road. The depth of the channel is approximately 6 to 7 feet north of Deer Valley Road, and 10 feet south of Deer Valley Road. The depth of the channel increases to approximately 14 feet at the 5 bridge crossings south of Deer Valley Road. Figure 1.1 presents the proposed alignment and location of the channel alternative.

The basin alternative is based on the same drainage system analyzed for the channel alternative. This alternative consists of open channel facilities from Jomax to the TPC in conjunction with three in-line detention basins; one located at the northeast corner of Happy Valley Road (Happy Valley DB), one located at the northeast corner of Deer Valley Road alignment (Deer Valley DB), and the third located on the north side of the proposed Pima Freeway and adjacent to the proposed Union Hills Drive alignment (Union Hills DB). A large diameter pipe is also considered for the reach of open channel from the Union Hills Detention Basin to the TPC. Figure 1.2 depicts the overall layout of the Pima Road basin alternative.

1.2 Safety Concerns and Hydraulic Parameter Development

FCDMC was most notably concerned with the supercritical flow regime and high velocities, associated with the channel alternative, resulting from the peak flow of the 100-year storm for the Pima Road drainage basin. While the duration of the peak flow for this storm event is fairly short in relation to the overall storm duration, standard engineering practice for hydraulic structures dictates the use of this flowrate for design purposes. Peak flow velocities for the channel alternative range between 16 and 33 fps.

The analyses performed for this basin alternative study were based on recommended hydraulic parameters provided by the FCDMC Hydraulics Manual. This reference was used to establish acceptable parameters such as material roughness values, freeboard calculations, and permissible velocities. Cross-references from this publication were used to obtain other input parameters not provided within. Staff members from COS and FCDMC were an integral part of this study and review comments and recommendations provided to Greiner were used continually throughout the development of the basin alternative report. A total of four in-progress meetings were held during the months of January and February, between FCDMC, COS and Greiner personnel, to ensure all hydraulic requirements were met and that all feasible concepts for the basin alternative were addressed. The minutes from those meetings are provided in Appendix E.



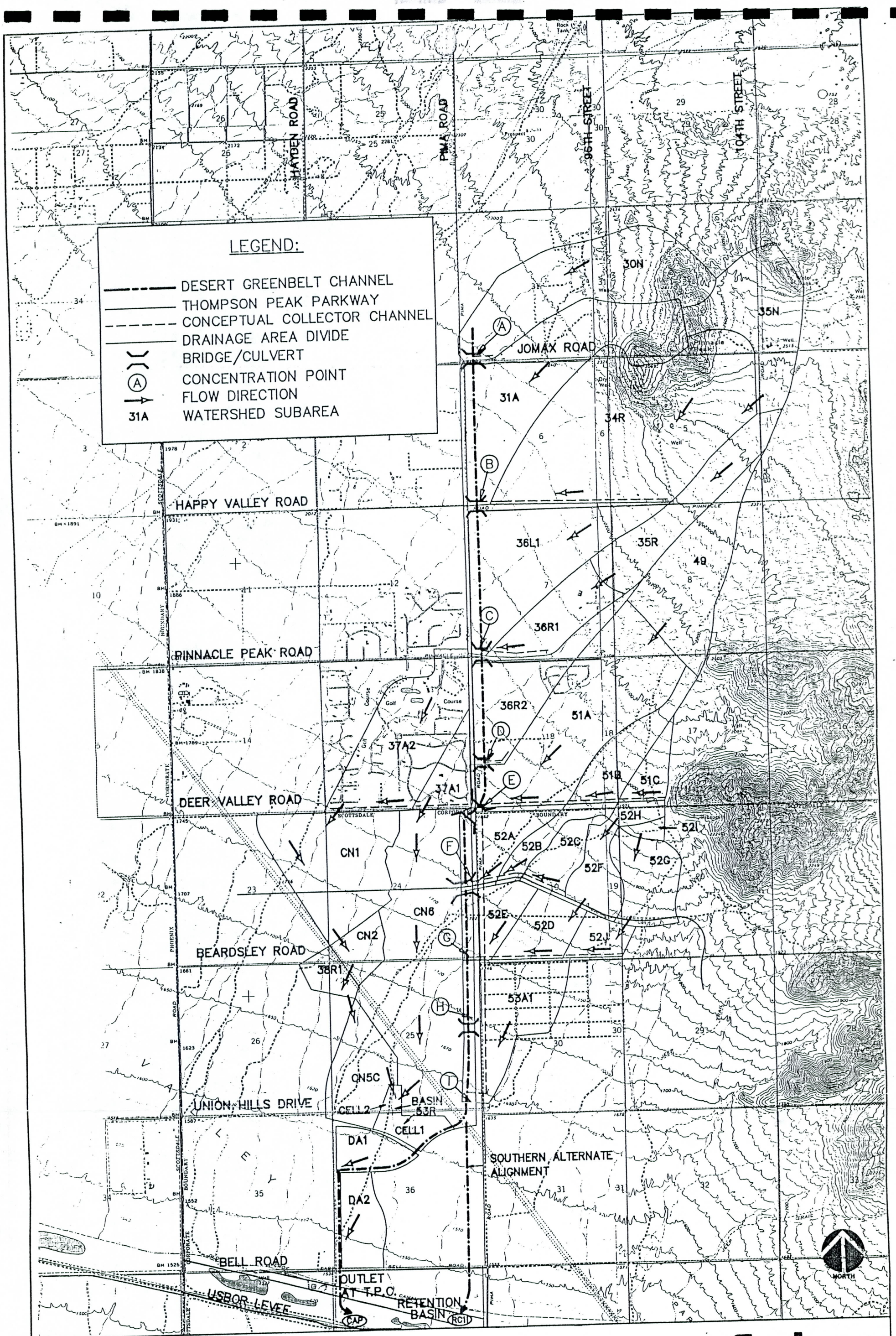
Pima Road Channel
Drainage Area Map
Overall View

Greiner

1" = 3000'

FIGURE 1-1

The Desert Greenbelt



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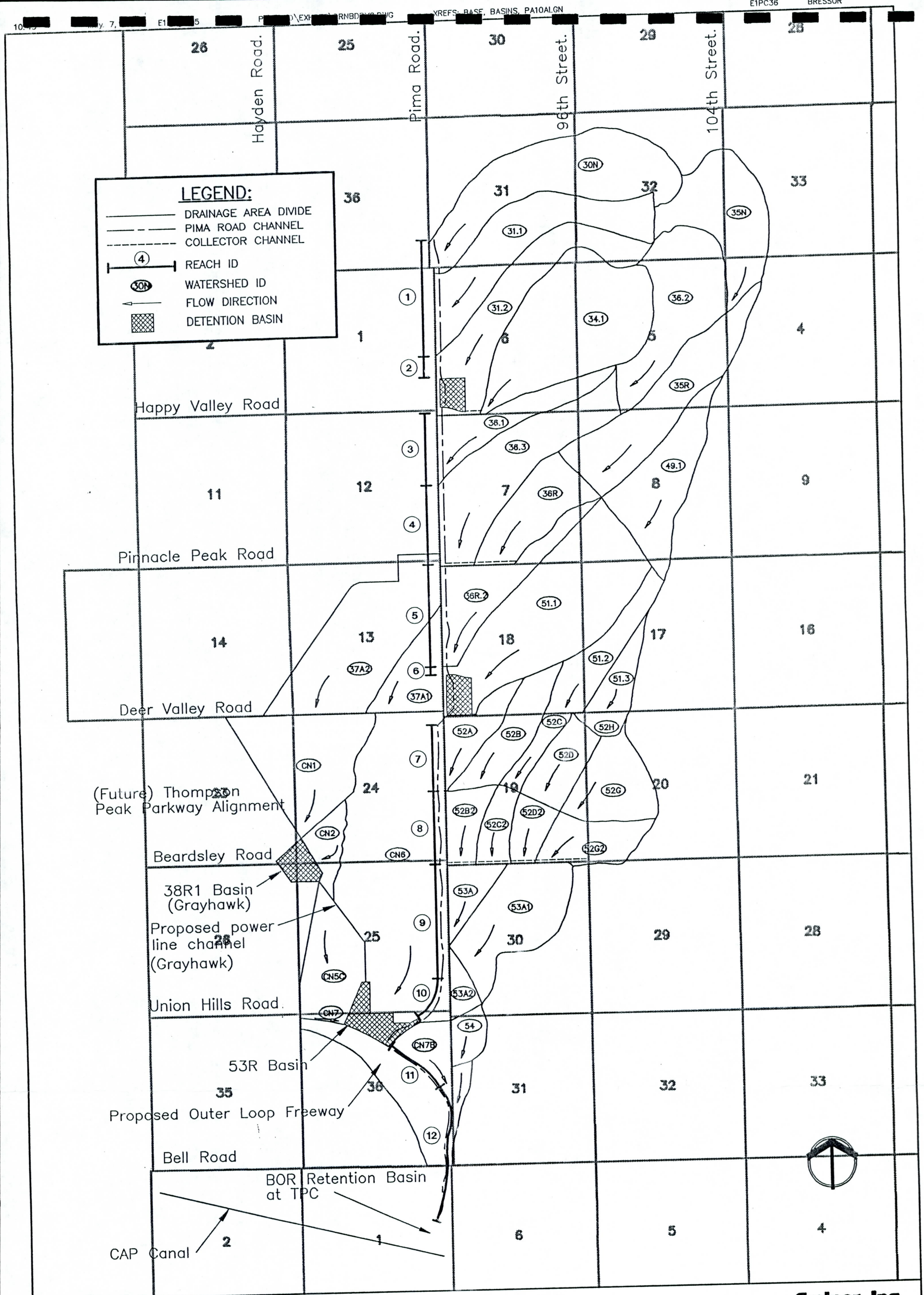


Greiner, Inc.

Pima Road Drainage Area Map Basin Alternative

1"=3000'

The Desert Greenbelt

Figure 1-2

2.0 Pima Road Basin Alternative Facilities

2.1 Detention Basins

The basin alternative includes three detention basins as discussed in Section 1.0. The locations of these basins were determined by land availability. Rapid private development has occurred in different areas along Pima Road for the full length of the system. Existing or planned development eliminates the inclusion of any additional basins as part of this drainage system.

A sensitivity analysis for basin sizing versus channel sizing was performed to determine basin storage volumes and channel flowrates. A considerable number of basin and channel geometric configurations have been investigated. Channel materials, bed slopes, channel geometry, bed widths and channel depths were investigated individually, and in conjunction with the detention basins, to determine an optimal design configuration that would meet the requirements of the FCDMC Hydraulics Manual. The combinations and variations of the parameters were used to determine the hydraulic characteristics of the system. Section 4.0 describes the results of the hydraulic analyses in detail.

The governing parameters used for sizing each basin included available land area, right-of-way impacts, easement requirements, surrounding development, embankment elevations, and the existing topography. The existing ground slope at each basin is steeply inclined from the northeast to the southwest and the grade differential between the existing high and low point for Happy Valley DB, Deer Valley DB and Union Hills DB is 32.1 feet, 53.4 feet and 31.1 feet; respectively. Ideally, the detention basins would be located below grade for aesthetic purposes and to avoid the perception of constructing dams within residential areas. Each basin was to meet non-jurisdictional dam requirements in accordance with governing statutes. Spatial confinement exists for each basin due to adjacent private development and City facilities or requirements. These area limitations will be discussed in detail for each basin.

The maximum excavated side slope for the basins is 4 horizontal to 1 vertical. This slope is necessary to eliminate the need for fencing and guardrails adjacent to the basins, and to improve the overall aesthetics. A 50-foot easement buffer was also required between a bordering property line and the top of the excavated basin slope. The configurations and invert elevations for each of the basins do not consider a tiered, sloped bottom which ultimately must be incorporated into the final configurations.

2.1.1 Happy Valley DB

The layout of the Happy Valley DB is provided in Appendix Figure A.1. This basin is confined on the north and the east by private development. Pima Road borders this basin on the west, and the future Happy Valley Road alignment borders it on the south. Three alternate configurations were considered based on depth and overall storage volume. The maximum storage elevation considered for each configuration was 2080. This elevation corresponds to the lowest existing grade elevation within the spatial limits established for the basin. Table 2.1 presents the invert elevations and storage volumes associated with the three alternatives.

Table 2.1
Happy Valley DB

Configuration Alternative	Depth (feet)	Basin Invert Elevation	Storage Volume (El. 2080) (Acre-ft)
1	10.0	2070.0	152.1
2	15.0	2065.0	216.9
3	20.0	2060.0	274.8

Basin inverts below 2060 were not considered practical because of the cost prohibitive increases resulting from additional excavation and the required additional length of the outlet structure in order to daylight downstream. Drawdown time requirements also limited the depth of the basin. The outlet structure invert was limited at a maximum of one foot above the basin invert to ensure the drawdown time requirement of 36 hours was met since evaporation and infiltration were not considered for the drainage of the basin.

2.1.2 Deer Valley DB

The layout of the Deer Valley DB is provided in Appendix Figure A.2. This basin is confined on the north, east and south by existing or planned private development. Pima Road borders this basin on the west. Three alternate configurations were also considered for the Deer Valley DB. The maximum storage elevation considered for each configuration was 1870. This elevation corresponds to the lowest existing grade elevation within the spatial limits established for the basin. Table 2.2 presents the invert elevations and storage volumes associated with the three alternatives.

Table 2.2
Deer Valley DB

Configuration Alternative	Depth (feet)	Basin Invert Elevation	Storage Volume (El. 1870) (Acre-ft)
1	11.0	1859.0	171.8
2	16.0	1854.0	237.8
3	20.0	1850.0	285.5

The aesthetics and overall appearance associated with the Deer Valley DB was a primary concern for the design. The basin is located just north of DC Ranch and will be adjacent to, and in view of, future residents of this development community. Executives in charge of the DC Ranch project have stated that they would not support this concept if a large embankment is part of this basin. Appendix Figure A.2 depicts the north slope of this basin at 4:1 and approximately 250 feet in length, but it will actually extend beyond 250 feet as the City has indicated that because of the length of slope benching will be required for aesthetic and safety purposes.

2.1.3 Union Hills DB

The layout of the Union Hills DB is provided in Appendix Figure A.3. This basin is confined by private development to the west and east; the proposed Pima Freeway to the south, and the City of Scottsdale water campus to the north. The maximum storage elevation considered for each alternate configuration was 1610. This elevation corresponds to the lowest existing grade elevation within the spatial limits established for the basin. Table 2.3 presents the invert elevations and storage volumes associated with the three alternatives.

Table 2.3
Union Hills DB

Configuration Alternative	Depth (feet)	Basin Invert Elevation	Storage Volume (El. 1870) (Acre-ft)
1	10.0	1600.0	348.2
2	15.0	1595.0	498.4
3	20.0	1590.0	633.7

ADOT has indicated that any facility used to store stormwater runoff must be located a minimum of 50 feet from the toe of the embankment for the proposed Pima Freeway. Because of this criteria, and the condition that the storage facility must not be a jurisdictional dam, the Union Hills DB was configured completely below grade. The placement of embankments would reduce the available storage area to be used for the basin as the embankments would have to be sufficiently high to recuperate the storage volume lost due to the areal reduction. Because the maximum embankment height is six feet for non-jurisdictional retention facilities, it is not high enough to make a sizeable contribution to the overall storage volume of the basin.

2.2 Open Channels and Enclosed Conduit Options

Open channels have been proposed to hydraulically connect the detention basins described in section 2.1. The open channels serve two primary functions in the overall system: convey the flow between the basins and collect the surface runoff between the basins. Large diameter pipes or concrete box culverts were not considered for conveying the flow between basins upstream of the Union Hills DB because of this requirement to collect surface runoff and also due to the magnitude of the peak flowrates to be conveyed for the 100-year storm. The cost of the structures required to convey these peak flows was prohibitive and separate interception of surface runoff and collector channel connections would also be difficult and costly.

The basin alternative includes the option of piping facilities from the outlet of the Union Hills DB at the proposed Pima Freeway to the TPC Bureau of Reclamation (BOR) retention basin. The drainage facilities from immediately downstream of the Union Hills DB to approximately 1300 feet downstream are required to convey the outflow from this basin and also to collect surface runoff from a minor subbasin located east and to the south of this basin (see Figure 1.2). Catch basins or a small collector channel are considered to collect the surface runoff in conjunction with the piping facilities for the detention basin outflow conveyance. Since the peak flowrates downstream can be sufficiently attenuated by the Union Hills DB, piping is preferred over the open channel option because of the reduced impact to area properties and the TPC golf course amenities and because of the enclosure of the high velocity flows.

3.0 Hydrology

The hydrology for the basin alternative was developed from the HEC-1 hydrology model used for the channel alternative and is the result of a consensus approval among the many agencies and groups involved in the Pima Road project. This hydrology model has been modified by including the three proposed detention basins, adjusting the geometric configuration of the channels, adjusting the length and location of proposed collector channels, and updating the original subbasins to accommodate the development and growth that had occurred since the model had been originally created. COS staff members were consulted regarding the changes made to the hydrology model, and their direction and review comments are reflected in the revised model for this basin alternative.

As mentioned above, the three proposed detention basins were incorporated into the hydrology model. These detention basins each had three alternative configurations (varying depths) as described in section 2.1. The stage-storage-discharge curve for each detention basin alternative configuration (9 total) was developed independently based on the invert depth, the storage volume, and the size of the outlet works. These curves were input into the revised HEC-1 model for the basin alternative.

The geometric configuration of the main routing channels and the location and length of the proposed collector channels were adjusted from the original model The main routing channels represent the channel reaches along Pima Road as shown in Figure 1.2. The geometry for these reaches was adjusted to accommodate the varying outflow from the detention basin alternative configurations and the localized surface runoff. The bottom width for these channels was varied between 20 and 80 feet. The side slopes considered for these channels varied from 2:1, to vertical walls. The lengths and the location of the collector channels proposed in the basin alternative model were substantially different from those proposed in the channel alternative model. This change in condition affected the routing of the contributing subbasins and impacted the peak flowrates throughout the model.

The areal delineation and routing of the subbasins used in the channel alternative HEC-1 model was adjusted for the basin alternative model. The subbasins were adjusted to reflect the updated conditions within the overall watershed. The DC Ranch development had been modified since the channel alternative model was developed. The basin alternative HEC-1 model reflects the most updated drainage conditions proposed by DC Ranch including the drainage requirements for their 404 Permit. Significant changes from the channel alternative include the redelineation of the drainage subbasins north of the Deer Valley Road alignment, the length of the Thompson Peak collector channel, and the subbasin routing scheme within the DC Ranch development.

3.1 Hydrology Modeling Variations

A number of HEC-1 models were developed for the many geometric variations associated with the basin alternative. In addition to the HEC-1 models, a number of independent programs were developed for the drainage system to optimize the size of the detention basin outlet structures and concurrently analyze the hydraulic characteristics of the system. The models and programs were

developed for the combinations of the detention basin alternative configurations and varying channel slopes within the system.

A total of 27 HEC-1 models were developed to analyze the three alternative geometric configurations for each of the three detention basins. The hydraulic characteristics for the ten separate channel reaches located upstream of the Union Hills DB were initially analyzed using channel bed slopes to match existing grade. The basin inverts and size of the outlet structures were adjusted until a minimum freeboard of one foot within each detention basin was attained for each of the 27 scenarios. The freeboard was provided in relation to the lowest top of bank elevation of the appropriate detention basin. As an example, a maximum water surface elevation of 1609 is allowable for the maximum storage elevation, or lowest top of bank elevation, of 1610 for the Union Hills DB. The three resulting basin invert elevations and corresponding storage volumes used for the 27 models are presented in Section 2.1.

The results from the project modeling and programs were used to establish preliminary hydraulic characteristics for the basin alternative and to select an optimal configuration for the entire system. The estimated cost of the system was a major factor that was considered throughout the optimization process.

The results of the 27 models indicated the performance of one basin was independent of the performance and sizing of the other basins. The sizing of the Happy Valley DB and its outlet works had little affect on the hydraulic performance of the Deer Valley DB. The subbasin runoff between the two detention basins predominated the peak flowrate entering the Deer Valley DB. For example, the peak flowrate into the Deer Valley DB was 3299 cfs using a shallow Happy Valley DB configuration where the flowrate into the Deer Valley DB was 3012 cfs using a deep Happy Valley DB configuration. And while the Happy Valley DB provides attenuation to the flow conveyed from the northern portion of the watershed, the impact of the attenuation has little affect on the hydraulic requirements of the Deer Valley DB. The same situation holds true between the Deer Valley DB and the Union Hills DB. Two combinations were selected from the 27 for further analysis and development were selected because they represented the maximum and minimum utilization conditions of the available combinations. The first overall system configuration consisted of a combination of the three shallowest basins with larger channels connecting the basins. The second overall system configuration consisted of a combination of the three deepest basins with smaller channels connecting the basins.

The two models selected for further analysis were revised by adjusting the bed slopes, providing drop structures at regular intervals, altering the channel invert widths and side slopes, and evaluating alternative construction materials for the channels. The revised HEC-1 models were used, along with a program established specifically for the basin alternative, to assess and adjust the model characteristics to ascertain the optimal hydraulic conditions for each of the two combinations. The development of these optimal models is discussed in Section 4.0.

4.0 Hydraulics

A number of issues surrounded the hydraulic development of the basin alternative. The main purpose of this study was to address the safety concerns and the flow characteristics for the Pima Road drainage alternative systems that had been developed, to date. The secondary purpose of the study was to assess the feasibility of a basin alternative, including the performance of the alternative as a regional drainage system and as a cost effective solution. A variety of safety parameters and targeted hydraulic characteristics were provided by FCDMC for the system. These parameters included the Bureau of Reclamation (BOR) standards, acceptable flow regimes within the primary channels, and allowable flow velocities for the channel materials selected. In addition to the safety and design concerns, FCDMC requested that Greiner identify similar drainage systems that were comparable with the proposed Pima Road drainage system.

4.1 BOR Standards

Prior to the start of the hydraulic analysis, the COS requested the FCDMC provide specific guidelines for flow depths, flow velocities and other safety parameters that would be acceptable to the District for the scenario that no fencing be provided along the open channels in order to meet the aesthetic goals established for the project. In response, the FCDMC provided a figure from a BOR design guideline publication (BOR, 1988) regarding depth-velocity relationships classified into low, judgement or high danger zones. While this reference pertains to the hazardous classification associated with dams and estimating the downstream area susceptible to flooding due to a dam failure, FCDMC indicated that they felt it was appropriate to design the channels to meet the conditions established for the 'Low Danger Zone'. The BOR figure is provided in Appendix B for reference.

Greiner developed a series of tables and graphs to compare the hydraulic characteristics of the channels for the basin alternative with the BOR guideline. These tables are presented in Appendix B. These tables were developed for specific channel bottom widths using normal flow calculations. The BOR danger zones were highlighted on each table for comparison with the flowrates and depths within the channels.

Greiner also developed a series of tables to address normal flow parameters for channels with varying bottom widths and bed slopes. Bottom widths ranged between 30 and 80 feet and bed slopes varied from 0.25 percent to 2.50 percent, the latter representing the maximum slope of the existing grade. These tables are also provided in Appendix B.

The BOR tables were established for channel invert widths as large as 1000 feet, but because of the right-of-way limitations of the project, a maximum invert width of 80 feet was considered feasible. Greiner developed a series of charts depicting the changing velocity-depth relationships for the specific channel reaches through the upper portion of the hydrograph. The figures are presented in Appendix B for the reaches upstream of the Union Hills DB. The figures were developed for the shallow basin and the deep basin system configuration and also for both the predominant storm (10-year frequency storm event) for ephemeral washes (ADOT, 1986) and the 100-year frequency storm.

The figures relating to the BOR guidelines were developed to demonstrate the hydraulic characteristics associated with the various channel reaches as a function of time for the routing of two different storm events. The deep basin configuration met the BOR standards better than the shallow basin configuration because the peak flows and the duration of the peak flows were less for the deep basin configuration. The differences between the two configurations were most notable within the channel reaches located immediately downstream from the basins. The differences were less noticeable in the reaches immediately upstream of the detention basins because of the impacts of the inflowing surface runoff described in Section 3. The figures also indicate that for many of the reaches, the BOR judgement zone is exceeded for less than two hours for the 100-year storm event. The time the judgement zones are exceeded for the predominant storm event is significantly less. The results from this investigation indicate that due to the project constraints, it would be very impractical and not cost effective to try to achieve velocities and depths within the BOR low danger and judgement zones for the peak flows.

It was requested that a range of acceptable velocities and depths be identified by FCDMC in which fencing would not be required on the channels. FCDMC staff, in response, asked that documentation be provided to identify existing channels in operation today that are not fenced and are in the BOR high danger zone to assist them in determining these ranges.

4.2 Drainage System Comparisons

Per FCDMC's request, Greiner and COS staff researched three active, unfenced drainage systems in Arizona for velocities and depths within the BOR high danger zone and for comparison with the proposed Pima Road drainage improvements. These three are the Indian Bend Wash (IBW) located in Scottsdale, the Canada del Oro Wash located in Tucson, and the Pantano Wash also located in Tucson. The hydraulic information for each wash was obtained from the appropriate flood insurance studies. BOR tables, similar to those developed for the Pima Road system, were developed for each of the three washes as shown in Tables 4.1, 4.2 and 4.3. These tables present the peak flow hydraulic characteristics for an upstream reach of the IBW at McDonald Road, a downstream reach of the IBW at McKellips Road, and two typical reaches for the Pantano Wash and the Canada del Oro Wash, respectively. Among these three washes, only pipe rail fencing is provided on the two Tucson washes, and no fencing is provided for the IBW.

The peak flowrate for both of the IBW reaches presented in Tables 4.1 and 4.2 fall within the BOR 'High Danger Zone' for the 100-year event. The upstream reach and the downstream reach are classified in the high danger zone when the flowrates exceed 3,375 cfs and 5,382 cfs, respectively.

Table 4.3 also indicates the peak flowrate for the Tucson washes fall within the BOR 'High Danger Zone' for the respective 100-year events. The peak flowrates and associated velocities for each of these washes is greater than those for the IBW. The flow within these washes would not be classified within the judgement zone until the flowrate was reduced to 1,832 cfs. Soil cement bank stabilization has been constructed on both of these washes, and the invert consists of native material. The improvements to each of these washes does not meet the design criteria guidelines and recommendations presented in the FCDMC design manual. The peak flow velocities for each channel exceed the permissible velocities for native channels as well as soil cement lining.

The improvements made to the Canada del Oro Wash included grade control structures, but the improvements to Pantano Wash did not. The Canada del Oro grade control structures consist of a large A-frame shape with a roller compacted concrete crown. The grade control structures were provided to prevent excessive bed erosion, and were not installed as drop structures to reduce the bed slope of the channel. The design bed slope for this channel is 1.56 percent.

Table 4.1 - Upstream Reach of Indian Bend Wash

BOR 'Low Danger Zone'
BOR 'Judgement Zone'
BOR 'High Danger Zone'

Flowrates - 348-feet Wide Channel											
	Velocity (fps)										
Depth (ft)	0	1	2	3	4	5	6	7	8	9	10
0.0	0	0	0	0	0	0	0	0	0	0	0
0.5	0	176	351	527	702	878	1053	1229	1404	1580	1755
1.0	0	354	708	1062	1416	1770	2124	2478	2832	3186	3540
1.5	0	536	1071	1607	2142	2678	3213	3749	4284	4820	5355
2.0	0	720	1440	2160	2880	3600	4320	5040	5760	6480	7200
2.5	0	908	1815	2723	3630	4538	5445	6353	7260	8168	9075
3.0	0	1098	2196	3294	4392	5490	6588	7686	8784	9882	10980
3.5	0	1292	2583	3875	5166	6458	7749	9041	10332	11624	12915
4.0	0	1488	2976	4464	5952	7440	8928	10416	11904	13392	14880
4.5	0	1688	3375	5063	6750	8438	10125	11813	13500	15188	16875
5.0	0	1890	3780	5670	7560	9450	11340	13230	15120	17010	18900
5.5	0	2096	4191	6287	8382	10478	12573	14669	16764	18860	20955
6.0	0	2304	4608	6912	9216	11520	13824	16128	18432	20736	23040
6.5	0	2516	5031	7547	10062	12578	15093	17609	20124	22640	25155
7.0	0	2730	5460	8190	10920	13650	16380	19110	21840	24570	27300
7.5	0	2948	5895	8843	11790	14738	17685	20633	23580	26528	29475
8.0	0	3168	6336	9504	12672	15840	19008	22176	25344	28512	31680
8.5	0	3392	6783	10175	13566	16958	20349	23741	27132	30524	33915
9.0	0	3618	7236	10854	14472	18090	21708	25326	28944	32562	36180

~ Sta. 380+00
~ McDonald
$S_0 = 0.002174$
V = 7.17 fps
y = 6 ft
$Q_{100} = 16,100$

Table 4.2 - Downstream Reach of Indian Bend Wash

BOR 'Low Danger Zone'
BOR 'Judgement Zone'
BOR 'High Danger Zone'

Flowrates - 580-feet Wide Channel											
	Velocity (fps)										
Depth (ft)	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
0.0	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
0.5	*0*	*292*	*583*	*875*	*1166*	*1458*	*1749*	*2041*	*2332*	*2624*	*2915*
1.0	*0*	*586*	*1172*	*1758*	*2344*	*2930*	*3516*	*4102*	*4688*	*5274*	*5860*
1.5	*0*	*884*	*1767*	*2651*	*3534*	*4418*	*5301*	*6185*	*7068*	*7952*	*8835*
2.0	*0*	*1184*	*2368*	*3552*	*4736*	*5920*	*7104*	*8288*	*9472*	*10656*	*11840*
2.5	*0*	*1488*	*2975*	*4463*	*5950*	*7438*	*8925*	*10413*	*11900*	*13388*	*14875*
3.0	*0*	*1794*	*3588*	*5382*	*7176*	*8970*	*10764*	*12558*	*14352*	*16146*	*17940*
3.5	*0*	*2104*	*4207*	*6311*	*8414*	*10518*	*12621*	*14725*	*16828*	*18932*	*21035*
4.0	*0*	*2416*	*4832*	*7248*	*9664*	*12080*	*14496*	*16912*	*19328*	*21744*	*24160*
4.5	*0*	*2732*	*5463*	*8195*	*10926*	*13658*	*16389*	*19121*	*21852*	*24584*	*27315*
5.0	*0*	*3050*	*6100*	*9150*	*12200*	*15250*	*18300*	*21350*	*24400*	*27450*	*30500*
5.5	*0*	*3372*	*6743*	*10115*	*13486*	*16858*	*20229*	*23601*	*26972*	*30344*	*33715*
6.0	*0*	*3696*	*7392*	*11088*	*14784*	*18480*	*22176*	*25872*	*29568*	*33264*	*36960*
6.5	*0*	*4024*	*8047*	*12071*	*16094*	*20118*	*24141*	*28165*	*32188*	*36212*	*40235*
7.0	*0*	*4354*	*8708*	*13062*	*17416*	*21770*	*26124*	*30478*	*34832*	*39186*	*43540*
7.5	*0*	*4688*	*9375*	*14063*	*18750*	*23438*	*28125*	*32813*	*37500*	*42188*	*46875*
8.0	*0*	*5024*	*10048*	*15072*	*20096*	*25120*	*30144*	*35168*	*40192*	*45216*	*50240*
8.5	*0*	*5364*	*10727*	*16091*	*21454*	*26818*	*32181*	*37545*	*42908*	*48272*	*53635*
9.0	*0*	*5706*	*11412*	*17118*	*22824*	*28530*	*34236*	*39942*	*45648*	*51354*	*57060*

~ Sta. 90+00
Low Flow Channel
120' bottom width
~ McKellips Road
$S_0 = 0.003137$
V = 8.86 fps
y = 6 ft
$Q_{100} = 23,500$

Table 4.3 - Canada del Oro Wash and Pantano Wash (Tucson, Arizona)

BOR 'Low Danger Zone'
BOR 'Judgement Zone'
BOR 'High Danger Zone'

Flowrates - 225-feet Wide Channel

	Velocity (fps)																				
Depth (ft)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.5	0	113	226	338	451	564	677	789	902	1015	1128	1240	1353	1466	1579	1691	1804	1917	2030	2142	2255
1.0	0	226	452	678	904	1130	1356	1582	1808	2034	2260	2486	2712	2938	3164	3390	3616	3842	4068	4294	4520
1.5	0	340	680	1019	1359	1699	2039	2378	2718	3058	3398	3737	4077	4417	4757	5096	5436	5776	6116	6455	6795
2.0	0	454	908	1362	1816	2270	2724	3178	3632	4086	4540	4994	5448	5902	6356	6810	7264	7718	8172	8626	9080
2.5	0	569	1138	1706	2275	2844	3413	3981	4550	5119	5688	6256	6825	7394	7963	8531	9100	9669	10238	10806	11375
3.0	0	684	1368	2052	2736	3420	4104	4788	5472	6156	6840	7524	8208	8892	9576	10260	10944	11628	12312	12996	13680
3.5	0	800	1600	2399	3199	3999	4799	5598	6398	7198	7998	8797	9597	10397	11197	11996	12796	13596	14396	15195	15995
4.0	0	916	1832	2748	3664	4580	5496	6412	7328	8244	9160	10076	10992	11908	12824	13740	14656	15572	16488	17404	18320
4.5	0	1033	2066	3098	4131	5164	6197	7229	8262	9295	10328	11360	12393	13426	14459	15491	16524	17557	18590	19622	20655
5.0	0	1150	2300	3450	4600	5750	6900	8050	9200	10350	11500	12650	13800	14950	16100	17250	18400	19550	20700	21850	23000
5.5	0	1268	2536	3803	5071	6339	7607	8874	10142	11410	12678	13945	15213	16481	17749	19016	20284	21552	22820	24087	25355
6.0	0	1386	2772	4158	5544	6930	8316	9703	11088	12474	13860	15246	16632	18018	19404	20790	22176	23562	24948	26334	27720
6.5	0	1505	3010	4514	6019	7524	9029	10533	12038	13543	15048	16552	18057	19562	21067	22571	24076	25581	27086	28590	30095
7.0	0	1624	3248	4872	6496	8120	9744	11368	12992	14616	16240	17864	19488	21112	22736	24360	25984	27608	29232	30856	32480
7.5	0	1744	3488	5231	6975	8719	10463	12206	13950	15694	17438	19181	20925	22669	24413	26156	27900	29644	31388	33131	34875
8.0	0	1864	3728	5592	7456	9320	11184	13048	14912	16776	18640	20504	22368	24232	26096	27960	29824	31688	33552	35416	37280
8.5	0	1985	3970	5954	7939	9924	11909	13893	15878	17863	19848	21832	23817	25802	27787	29771	31756	33741	35726	37710	39695
9.0	0	2106	4212	6318	8424	10530	12636	14742	16848	18954	21060	23166	25272	27378	29484	31590	33696	35802	37908	40014	42120

Pantano Wash
Main Channel
$S_0 = 0.0063$
V = 15 fps
y = 8 ft
Q_{100} = 27,900

Canada del Oro
Main Channel
$S_0 = 0.0156$
V = 20 fps
y = 6 ft
Q_{100} = 27,700

The proposed improvements for the Pima Road drainage system result in hydraulic characteristics that are somewhat comparable to the Tucson washes. Table 4.4 provides comparison information relative to peak flowrate, velocity and depth of flow for the IBW, the two Tucson washes, the Pima channel alternative and the Pima basin alternative. Also when compared to either of the proposed alternatives for the Pima Road drainage system, the flows within the Tucson washes fall within the high danger zones more often, and for longer durations.

Table 4.4
Hydraulic Parameter Comparisons

System	Channel Slope (feet/feet)	Peak Flowrate (cfs)	Peak Velocity (fps)	Peak Flow Depth (ft)
Indian Bend Wash (upstream)	.0022	16,000	7.2	6.0
Indian Bend Wash (downstream)	.0031	24,000	8.9	6.0
Canada del Oro Wash	.0156	27,700	20.0	6.0
Pantano Wash	.0063	27,900	15.0	8.0
Pima Road - channel alternative	~ .0200	9,300	33.0	5.0
Pima Road - basin alternative	~ .0200	4,000	20.0	4.0

Complete fencing, to prevent access into the channel, is not provided for any of these three existing drainage systems. Piperail fencing is provided along the Tucson washes and no fencing has been provided along the IBW.

FCDMC staff did not feel that these three examples were applicable for comparison because they were modifications to existing water courses and the Pima project would be wholly man-made. Hydraulic parameters were then established by FCDMC staff for both the unfenced condition and for the piperail protection. These parameters are discussed in section 4.3, below.

4.3 Flow Regimes

A number of analyses were performed for the Pima Road drainage system to address the hydraulic characteristics and the predominant flow regime of the proposed system. The existing slope throughout the project area varies from 1.6 to 2.2 percent. Proposed facilities installed at existing grade result in swift, supercritical flows. The velocity of such flows was as much as 33 fps for the channel alternative, and ranged between 13 and 20 fps for the basin alternative. The FCDMC required that, for piperail protection, the channel Froude number should be no greater than 0.85 and that 1H:1V, or flatter, side slopes would be acceptable. For a channel with no railing or fencing, the Froude number must be no greater than 0.85 and the channel side slopes should be no steeper than 4H:1V. Greiner developed several basin alternative scenarios in an effort to achieve a flow regime within the channels that would not require fencing and with peak flow characteristics that would be acceptable to FCDMC.

A number of charts and diagrams were developed to address the varying input parameters that affect the flowrate within the channel. The charts discussed herein are provided in Appendix C. These charts were developed to try to meet the BOR 'Judgement Zone' as discussed in Section 4.1 and were used as design aids to develop an optimal system that would best meet the needs of COS and FCDMC. The data provided in these charts was developed using the Manning's formula for normal, steady flow. The parameters that were adjustable for these charts included the channel bed slope, side slope, and invert width, and the Manning's roughness coefficient. The charts were developed holding two of these input parameters constant and varying the other two. The resulting flowrates and velocities were plotted versus one of the varying input parameters.

It again became quickly apparent that the BOR judgement zone could not be attained for the flowrates of the drainage system without adjusting the channel bed slope. The reduction of the channel bed slope was investigated considering two vertical drop structure scenarios: 1) moderately spaced, fairly large, vertical drops; or 2) frequently spaced, small vertical drops. Due to safety concerns, the COS and FCDMC agreed that a 3-foot high drop structure would be the upper height limit.

Greiner developed several scenarios, using 3-foot drop structures, to adjust the flow regime within the channels of the basin alternative. Based on normal flow calculations, Greiner developed several proposed systems with variable Froude numbers and different channel materials. A Froude number of 0.85 was targeted as the upper limit of permissible subcritical flow, in accordance with the FCDMC design manual. Lower Froude numbers within the subcritical regime were not initially considered due to the required increase in the frequency of the drop structures to attain the flatter slopes. Froude numbers within the supercritical range that were considered began at 1.13, the FCDMC design manual lower limit of permissible supercritical flow, and included values of 1.45 and 1.75. The number of drop structures required for these scenarios ranged from about 150 for the 0.85 Froude number scenario to as few as none for the 1.75 Froude number scenario. The 1.75 scenario was disregarded, however, because it could not meet the unfenced conditions.

The drop structures introduced into the system create a number of hydraulic situations that begin to deviate from the normal, steady flow computations. Steady, gradually varied flow ceases to exist within a vast majority of the channels, particularly with drops spaced as frequently as 150 feet apart. Immediately downstream from a drop structure, the flow is accelerated and requires a specific runout distance to develop the necessary friction losses before steady flow is once again established. The term tailrace is often used to describe this runout distance. When the runout length is longer than the spacing between the drop structures, the accelerated flow propagates down the channel. To prevent this propagation of the accelerated flow velocities, energy dissipators are required to provide the necessary energy loss at the drop structures.

The frequently spaced drop structures create other complications within the entire system. Without energy dissipators, the hydraulic characteristics of the accelerated flow downstream of the drop structures is substantially different than the hydraulic characteristics of normal flow for the associated average bed slope. The velocity of the accelerated flow is much greater than the velocity resulting from a normal flow calculation and is very close to the velocities for the basin alternative with no drop structures and channels at existing grade. However, unlike this basin alternative, the flow is unsteady throughout most of the system because of the drop structures. A safety issue surrounds unsteady flow as much as any other hydraulic characteristic.

Additionally, because the flow throughout most of the system is unsteady due to the presence of drop structures, normal water profile programs can not be used to model this system. Typical programs such as HEC-2 and HEC-RAS require the flow within the system to be steady and gradually varied. Greiner developed a series of tables for the various flow parameters and channel materials to develop the hydraulic characteristics within the reaches of the basin alternative. The tables are presented in Appendix C. These tables are used to address the hydraulic characteristics expected within the channel reaches and develop a water surface profile for the drop structure configuration.

4.4 Other Hydraulic Issues

A number of other hydraulic issues were raised during the course of the basin alternative development. Selected channel materials, roughness coefficients, scour depths, toe down depths of drop structures and stilling basins were discussed and considered during the many project development meetings between COS, FCDMC and Greiner. The FCDMC Design Manual was used to establish the acceptable range of hydraulic characteristics for these items, and other references were used where the FCDMC Design Manual did not address the issue.

The materials used to develop the various scenarios discussed in the previous section included reinforced concrete, soil cement/roller compacted concrete, shotcrete, native material, and cobbles. The scenarios were adjusted to attain peak flow velocities that were within the permissible ranges in accordance with the FCDMC Manual. Likewise, the roughness coefficients used for the various materials were also obtained from this manual.

Scour depths and the toe-down depths of the drop structures were estimated using standard equations provided in other references addressing the subject of sedimentation (AMAFCA, 1994). These values were calculated using the channel configuration and flow velocities associated with each reach of the system. These values were used to develop the cost estimates of the various scenarios discussed in Section 5.0.

The stilling basins were included for energy dissipation required to achieve the normal flow velocities associated with the targeted bed slope as discussed in Section 4.3. The stilling basins were designed using the BOR recommended design procedures for small outlet works and small spillways (BOR, 1984). The stilling basins were used to analyze the hydraulic characteristics of the overall system performance and establish an estimated unit cost for such structures.

5.0 Cost Analyses

In order to determine the overall feasibility of the proposed basin alternative, the total cost to construct the improvements was estimated. Preliminary studies performed by PACE estimated the total cost of construction for the basin alternative to be substantially less than the channel alternative. This was contradictory to what Greiner and COS had discovered during the initial study phase of the Pima Road drainage system. A basin alternative was considered during this study phase, but preliminary cost estimates indicated it would be more expensive and not cost effective.

After reviewing the project for local developers, the initial cost estimate developed by PACE was $13 million. This estimate was less than half the cost estimated for the channel alternative at that time. After several iterations, the initial cost estimate for the basin alternative was refined including modified unit costs, adjusted quantity calculations, and an overall redevelopment of the proposed drainage facilities. The revised cost estimate supplied to COS by PACE was roughly $26 million. This cost was still somewhat less than the channel alternative, but a review was performed by both COS staff and Greiner which resulted in an estimate of $35 million for the basin alternative. The principal discrepancy between these two estimates led to the analysis and results that are presented within this report. The following is a summary of the various cost estimates produced for the various basin alternative options.

5.1 Initial Cost Comparisons and Alternative Scenarios

Greiner initially developed cost estimates for four variations of the proposed basin alternative considering different channel linings. Three of the variations were developed for subcritical flow, and one was developed for supercritical flow. Each of these scenarios included three detention basin, using the deepest geometric configuration for each basin. The deep basins were selected because of the beneficial hydraulic performance of the systems as discussed in the previous sections. The cost estimates for these scenarios is presented in Appendix D.

Option 1 - Subcritical, Complete Soil Cement Lining

The first option considered for subcritical flow utilized channels that were completely lined with soil cement. For the purpose of a preliminary analysis, Greiner assumed that soil cement and roller compacted concrete could be constructed at essentially the same cost to avoid discussion of strength and erosion requirements at this initial stage. The characteristics of this option are as follows:

Froude number	= 0.85
Manning's roughness coefficient	= 0.022
Normal peak flow velocity	= 8-9 fps
3-foot drop structure spacing	= 165-170 feet
Average tailrace velocity for peak flow	= 13-14 fps
Total drop structures required	= 152

Energy dissipators and stilling basins were required for the drop structures since the tailrace runout length exceeded the drop structure spacing.

A completely lined channel alternative was considered to address the scour and lateral migration potential associated with this system. Side slope stabilization is provided to ensure containment and eliminate lateral migration. The potential for large scour depths exists throughout this system, particularly downstream of drop structures where localized scour holes could be substantial. The resulting foundation depths of the side slope structures could become excessive due to the scour depth potential, resulting in costly structures. A lined invert was considered for this alternative to address the scour issue.

The total estimated cost for construction using soil cement lining is $46.6 million.

Option 2 - Subcritical, Complete Shotcrete Lining

The second subcritical analysis used shotcrete channel lining for a wavy section (n = 0.022) rather than soil cement lining. The hydraulic characteristics were the same as the subcritical option above.

The total estimated cost for construction using shotcrete is $50.5 million.

Option 3 - Subcritical, Native Material Channel with Stilling Basins

The third subcritical flow scenario, was developed using energy dissipators and stilling basin drop structures connected with native, excavated channels. The stilling basins were provided to minimize the potential for scour holes and localized scour downstream from the drop structures. The total cost of construction for this scenario was considerably less at $37.2 million. However, because of the potential for lateral migration associated with this scenario, it was agreed side slope protection would be required throughout.

Option 4 - Supercritical, Complete Shotcrete Lining

The channels considered for the supercritical flow analysis were lined with shotcrete using a good section (n = 0.019). The characteristics for this supercritical flow option were:

Froude number	= 1.45
Manning's roughness coefficient	= 0.019
Normal peak flow velocity	= 12-13 fps
3-foot drop structure spacing	= 200-250 feet
Average tailrace velocity for peak flow	= 15-16 fps
Total drop structures required	= 105

Energy dissipators and stilling basins were required for most drop structure as the tailrace runout length exceeded the drop structure spacing.

The total estimated cost for construction for the supercritical flow analysis using shotcrete lining is $49.2 million.

The total estimated cost of the channel alternative is about $38.9 million. This cost estimate has been updated to reflect the quantities associated with the 30-percent plans, updated right-of-way costs, and the most recent utility relocation costs. This cost estimate also reflects $2.5 million for fencing. For comparative purposes, the cost estimate of the channel alternative continued to include engineering costs at 10 percent, and a contingency of 15 percent of the total cost estimate,

excluding right-of-way. The cost estimates developed for the Basin Alternatives are ultimately compared to the cost estimate of the channel alternative to determine the fiscal feasibility of basin alternative.

Of the options discussed above, and acceptable to COS and FCDMC, the soil cement, subcritical flow option was the most economical. However, the channel alternative at $38.9 million was less than the basin alternative at $46.6 million. In addition, FCDMC indicated that piperail fencing would still be required for the basin alternative, which was not initially included in the cost estimates for these scenarios.

Approximately $19 million of the total cost estimates for the Basin Alternatives was attributed to the construction of the detention basins. Considering the cost for engineering and contingencies, the overall cost of the basins was in excess of $23.5 million. COS asked Greiner to finalize the cost estimates for the Basin Alternatives to include the cost of piperail fencing, and to develop a combination scenario that would meld the basin alternative with the channel alternative. This combination alternative would incorporate the Union Hills DB into the 30 percent Pima Road Channel plans. The Union Hills DB provides the most hydraulic benefit for the drainage system by reducing the peak flows approximately 33 percent from the channel alternative for the reach below. The other benefit of the Union Hills DB was that it could be the only basin of the three used as a multi-purpose facility. The COS Parks Department had indicated that the Union Hills DB would be used for recreational facilities whereas the Happy Valley DB and the Deer Valley DB could not.

The finalized cost estimate for the combination alternative was developed and the cost estimate for the acceptable basin alternatives were revised to include piperail fencing. Each of these cost estimates was substantially greater than the channel alternative. These finalized cost estimates are presented in Appendix D.

6.0 Summary and Discussion

This study was conducted to address a number of outstanding issues that surrounded the Pima Road drainage system. The concern of high peak velocities, safety conditions, and the overall cost of the channel alternative that had been developed by Greiner and included in the 30 percent design plans was the impetus for this study. This study was conducted to address the outstanding issues described and determine the feasibility of constructing an alternative drainage system as it related to cost and aesthetics. While the study resolved some of the outstanding issues surrounding the project, the final result was that none of the proposed scenarios would meet the fiscal objectives initially established for the project. COS postponed further analysis and development of the Pima Road drainage system after the final project development meeting between FCDMC, COS and Greiner.

The channel alternative was the most cost effective scenario of those developed by Greiner. It became apparent, as it had during the initial study phase, that the costs associated with the construction of detention basins would nullify the cost benefits of the overall system. The cost estimates developed by PACE for the basin alternative were based on proposed facilities that neglected the appropriate design criteria established by the FCDMC Design Manual and other prudent design conditions common for engineering practices. Additionally, these cost estimates prepared by PACE based on their conceptual design did not consider the extenuating hydraulic situations that could potentially occur within the channels as investigated by Greiner. As the study performed by Greiner progressed, a number of options were disregarded because it was evident they would not meet the objectives of the project: reduce the peak flow rates, meet standard engineering design criteria for hydraulic systems, and be an economic alternative to the channel alternative.

The results from this study also provided insight into the overall hydraulic performance of the system when developed using drop structures. Most of the flow analyses conducted by others were based on an average bed slope using normal flow calculations to establish the predominant hydraulic characteristics for the channels within the drainage system. As described in section 4.0, drop structures induce accelerated flow conditions that are quite different from the normal flow conditions. When the drop structures are frequently spaced to reduce the average slope of the channel bed, the accelerated flows will propagate downstream resulting in much greater flow velocities than analyzed for normal conditions. Energy dissipators are required to prevent this adverse affect and avoid the propagation of accelerated flow velocities.

A number of complicating parameters surround the development of the Pima Road drainage system. The existing, natural grade of the project area varies between 1.6 and 2.2 percent and generally represent supercritical slopes. Drop structures have been used to reduce the existing grade and establish slopes conducive to subcritical flow. Since one of the primary objectives of the basin alternative was to establish a system that would not require fencing, the drop structures were limited to heights of 3 feet, or less. The frequency of the drop structures is directly dependent upon the desired average bed slope and the invert width for the channels. And since the invert width of the channels is also constrained by the project right-of-way limitations, the bed slope becomes the governing parameter for most of the flow characteristics. However, as the frequency of the drop

structures is increased to create the subcritical flow condition, the associated accelerated flow condition also becomes more prevalent within the channel.

A degree of uncertainty remains regarding the best alternative for the Pima Road drainage system. While the channel alternative appears to be the least costly, FCDMC would require complete fencing of the channels. Fencing does not meet the aesthetic project objectives established by COS. None of the cost estimates established for the basin alternative were economically more attractive than the channel alternative. The combination alternative developed as a result of the study was more cost effective than the basin alternatives, reduced the peak flowrates approximately 33 percent from the channel alternative, but would still require fencing due to the peak flow velocities.

References

US Department of the Interior, Bureau of Reclamation, "Downstream Hazard Classification Guidelines," 1988.

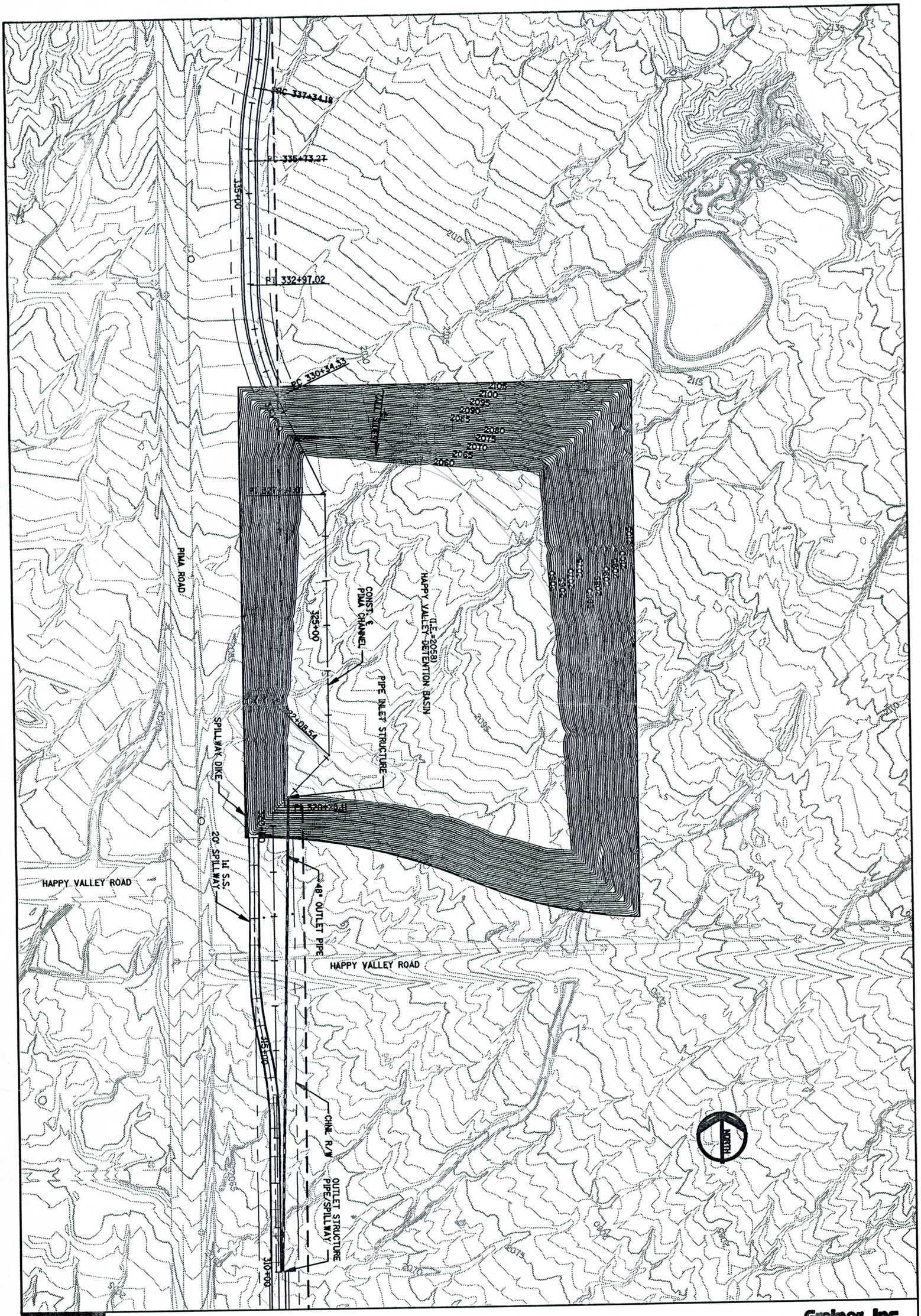
Arizona Department of Transportation, Research Center, "Engineering Analysis of Fluvial Systems," July 1986.

Albuquerque Metropolitan Arroyo Flood Control Authority, Mussetter, Lagasse, and Harvey, "Sediment and Erosion Design Guide," March 1994.

US Department of the Interior, Bureau of Reclamation, "Hydraulic Design of Stilling Basins and Energy Dissipators," Engineering Monograph No. 25, May 1984.

Appendix A

Basin Schematics



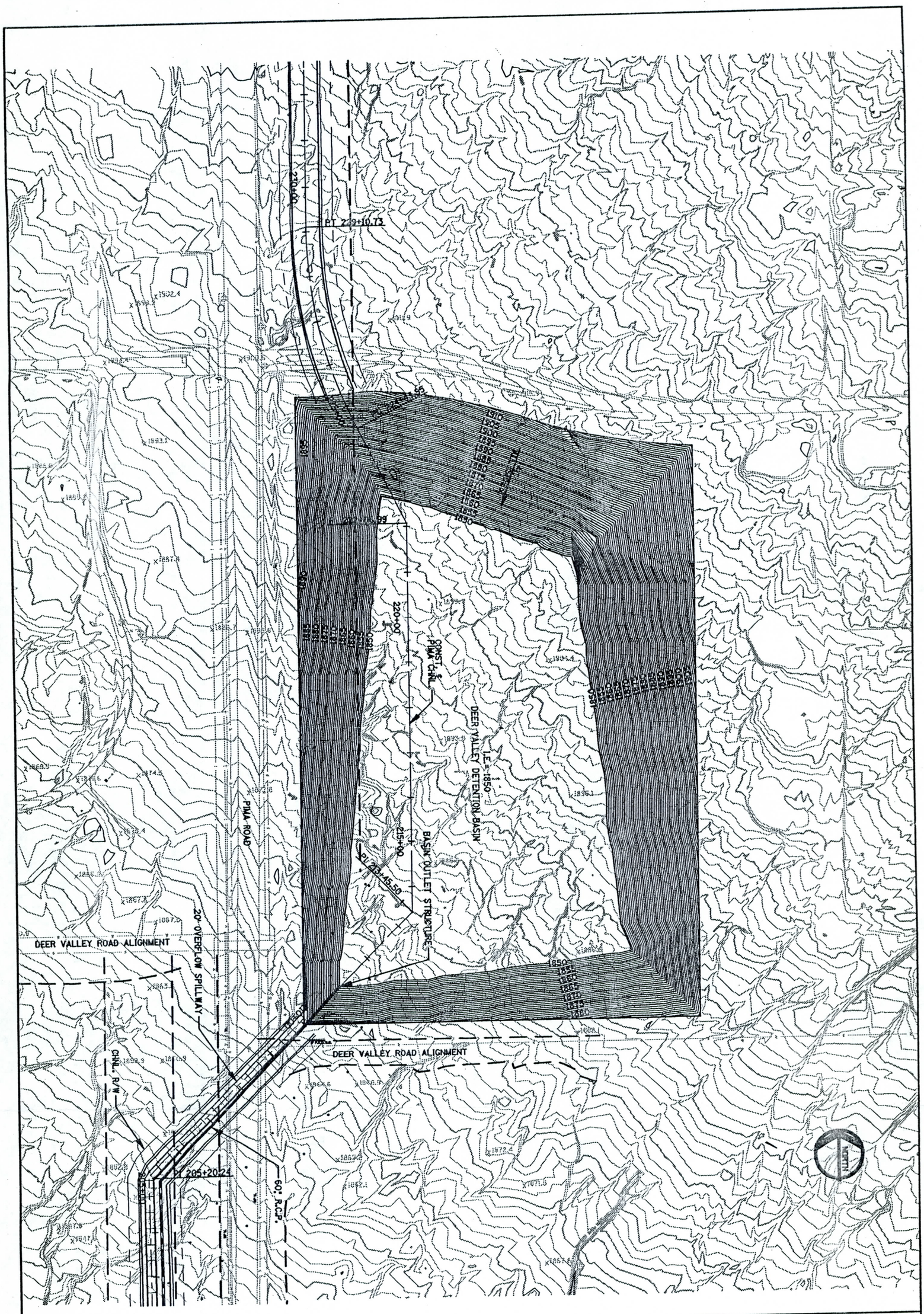
The Desert Greenbelt

Pima Road Basin Alternative
Happy Valley Detention Basin

Greiner, Inc.

Scale 1"=200'

Figure A.1



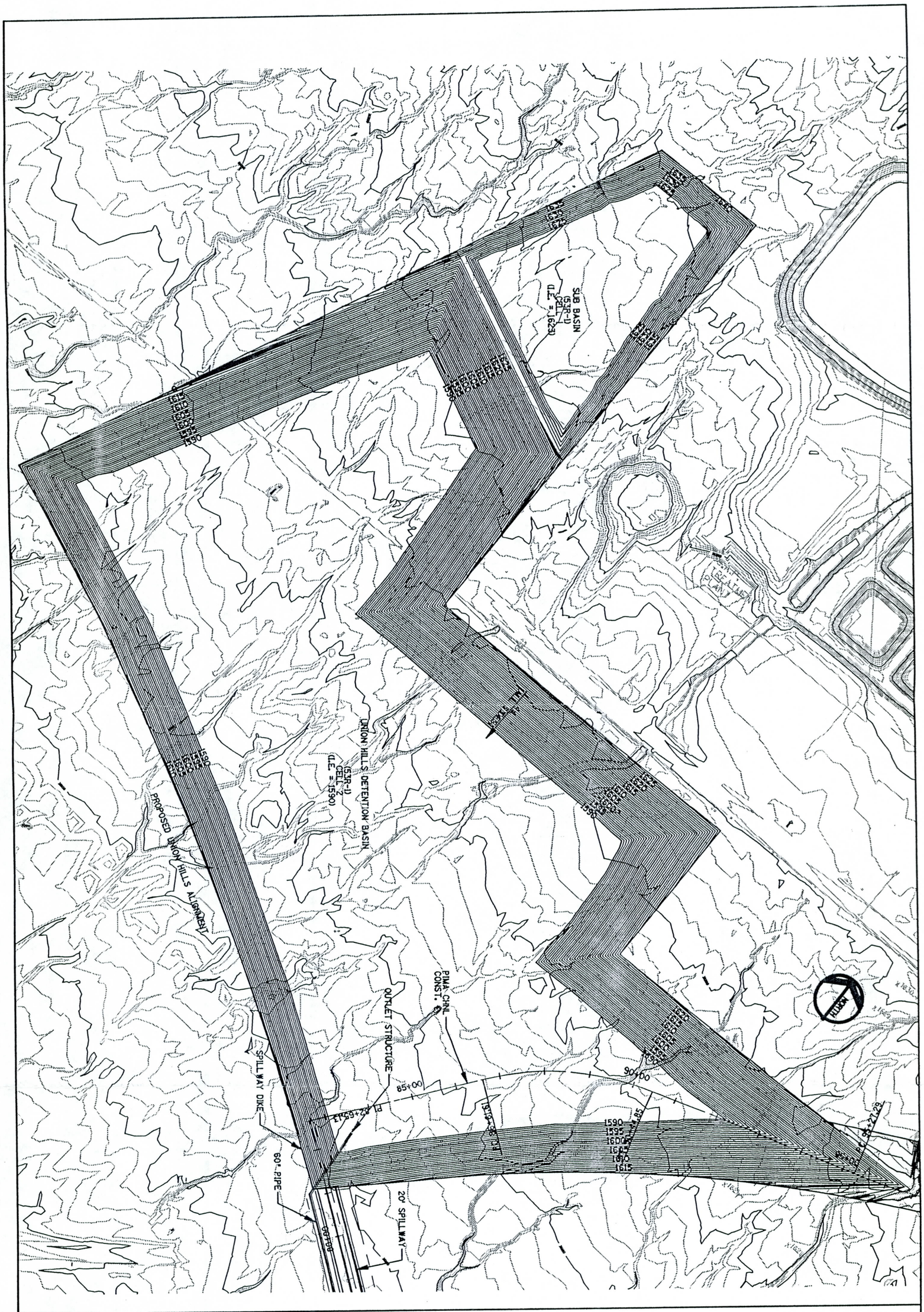
Greiner, Inc.

Pima Road Basin Alternative
Deer Valley Detention Basin

The Desert Greenbelt

Scale 1"=200'

Figure A.2



The Desert Greenbelt

Pima Road Channel
Union Hills Detention Basin
Overall View

Greiner, Inc.

Scale 1"=200'

Figure A.3

Appendix B

Bureau of Reclamation Downstream Hazardous Classifications

Hydraulic Parameters
100-year/24-hour Storm Event
Froude Number = 0.85

Channel Reach	Reach Identifier	Reach Length (ft)	Existing Grade Slope (ft/ft)	Proposed Channel Slope (ft/ft)	Proposed Channel Invert Width (ft)	n	Peak Channel Flowrate (cfs)	Peak Channel Velocity (fps)	Peak Flow Depth (ft)	3' Drop Structure Spacing (ft)	Approx. Tailrace Length (ft)	Average Tailrace Velocity (fps)	Average Tailrace Depth (ft)	Nappe Velocity (fps)	Nappe Depth (ft)	Approx. Number of Drops	Stilling Basins Required
1	R31.1	4200	0.0220	0.0039	30	0.022	894	8.3	3.2	166	173	13.3	2.2	16.2	1.7	26	*yes*
2	R31.2	1000	0.0200	0.0037	50	0.022	1618	8.7	3.5	184	173	13.7	2.4	16.4	1.9	6	*yes*
3	R36.1	2600	0.0160	0.0069	20	0.022	28	3.1	0.4	330	25	9.1	0.2	14.3	0.1	8	*yes*
4	R36.3A	2600	0.0180	0.0046	20	0.022	274	6.4	1.9	224	116	11.7	1.2	15.3	0.9	12	*yes*
5	R36R2	3600	0.0220	0.0035	80	0.022	2770	9.0	3.7	162	173	14.0	2.5	16.6	2.0	23	*yes*
6	R51.1A	400	0.0220	0.0035	80	0.022	2990	9.3	3.9	162	179	14.2	2.6	16.7	2.2	3	*yes*
7	R52A2	2600	0.0220	0.0042	20	0.022	516	7.7	2.9	169	166	12.9	1.9	15.9	1.5	16	*yes*
8	R52B2A	2600	0.0220	0.0042	20	0.022	527	7.8	2.9	169	168	12.9	2.0	15.9	1.5	16	*yes*
9	R53A	3900	0.0220	0.0036	80	0.022	2387	8.6	3.3	163	163	13.6	2.2	16.4	1.8	24	*yes*
10	R53A2	1300	0.0180	0.0034	80	0.022	3070	9.3	3.9	205	180	14.2	2.7	16.7	2.2	7	*yes*
11	CPX	2300	0.0180	0.0043	20	0.022	397	7.2	2.5	219	143	12.4	1.6	15.7	1.2	11	*yes*

Hydraulic Parameters
100-year/24-hour Storm Event
Froude Number = 1.45

Channel Reach	Reach Identifier	Reach Length (ft)	Existing Grade Slope (ft/ft)	Proposed Channel Slope (ft/ft)	Proposed Channel Invert Width (ft)	n	Peak Channel Flowrate (cfs)	Peak Channel Velocity (fps)	Peak Flow Depth (ft)	3' Drop Structure Spacing (ft)	Approx. Tailrace Length (ft)	Average Tailrace Velocity (fps)	Average Tailrace Depth (ft)	Nappe Velocity (fps)	Nappe Depth (ft)	Approx. Number of Drops	Stilling Basins Required
1	R31.1	4200	0.0220	0.0092	30	0.019	894	12.0	2.3	234	355	15.2	1.9	18.4	1.5	18	*yes*
2	R31.2	1000	0.0200	0.0087	50	0.019	1618	12.6	2.5	265	357	15.7	2.1	18.8	1.7	4	*yes*
3	R36.1	2600	0.0160	0.0168	20	0.019	28	4.5	0.3	2600	29	9.6	0.2	14.6	0.1	1	*no*
4	R36.3A	2600	0.0180	0.0109	20	0.019	274	9.3	1.4	423	181	13.1	1.1	16.8	0.8	7	*yes*
5	R36R2	3600	0.0220	0.0084	80	0.019	2770	13.0	2.6	221	362	16.0	2.2	19.0	1.8	17	*yes*
6	R51.1A	400	0.0220	0.0083	80	0.019	2990	13.3	2.7	219	387	16.3	2.3	19.3	1.9	2	*yes*
7	R52A2	2600	0.0220	0.0098	20	0.019	516	11.3	2.1	246	329	14.6	1.7	17.9	1.4	11	*yes*
8	R52B2A	2600	0.0220	0.0098	20	0.019	527	11.4	2.1	246	337	14.7	1.7	18.0	1.4	11	*yes*
9	R53A	3900	0.0220	0.0087	80	0.019	2387	12.4	2.3	226	319	15.5	2.0	18.6	1.6	18	*yes*
10	R53A2	1300	0.0180	0.0083	80	0.019	3070	13.4	2.8	309	396	16.4	2.4	19.3	1.9	5	*yes*
11	CPX	2300	0.0180	0.0043	20	0.019	397	10.5	1.7	219	254	13.9	1.4	17.4	1.1	11	*yes*

Hydraulic Parameters
100-year/24-hour Storm Event
@ Existing Grade

Channel Reach	Reach Identifier	Reach Length (ft)	Existing Grade Slope (ft/ft)	Proposed Channel Slope (ft/ft)	Proposed Channel Invert Width (ft)	n	Peak Channel Flowrate (cfs)	Peak Channel Velocity (fps)	Peak Flow Depth (ft)	3' Drop Structure Spacing (ft)	Approx. Tailrace Length (ft)	Average Tailrace Velocity (fps)	Average Tailrace Depth (ft)	Nappe Velocity (fps)	Nappe Depth (ft)	Approx. Number of Drops	Stilling Basins Required
1	R31.1	4200	0.0220	0.0220	30	0.022	899	14.5	1.9	-	-	-	-	-	-	-	-
2	R31.2	1000	0.0200	0.0200	30	0.022	1621	17.4	2.8	-	-	-	-	-	-	-	-
3	R36.1	2600	0.0160	0.0160	40	0.022	28	8.7	0.1	-	-	-	-	-	-	-	-
4	R36.3A	2600	0.0180	0.0180	40	0.022	274	9.2	0.7	-	-	-	-	-	-	-	-
5	R36R2	3600	0.0220	0.0220	40	0.022	2764	20.1	3.2	-	-	-	-	-	-	-	-
6	R51.1A	400	0.0220	0.0220	40	0.022	3012	20.8	3.3	-	-	-	-	-	-	-	-
7	R52A2	2600	0.0220	0.0220	60	0.022	531	8.7	1.0	-	-	-	-	-	-	-	-
8	R52B2A	2600	0.0220	0.0220	60	0.022	556	8.8	1.0	-	-	-	-	-	-	-	-
9	R53A	3900	0.0220	0.0220	60	0.022	2154	13.3	2.6	-	-	-	-	-	-	-	-
10	R53A2	1300	0.0180	0.0180	60	0.022	2969	14.0	3.3	-	-	-	-	-	-	-	-

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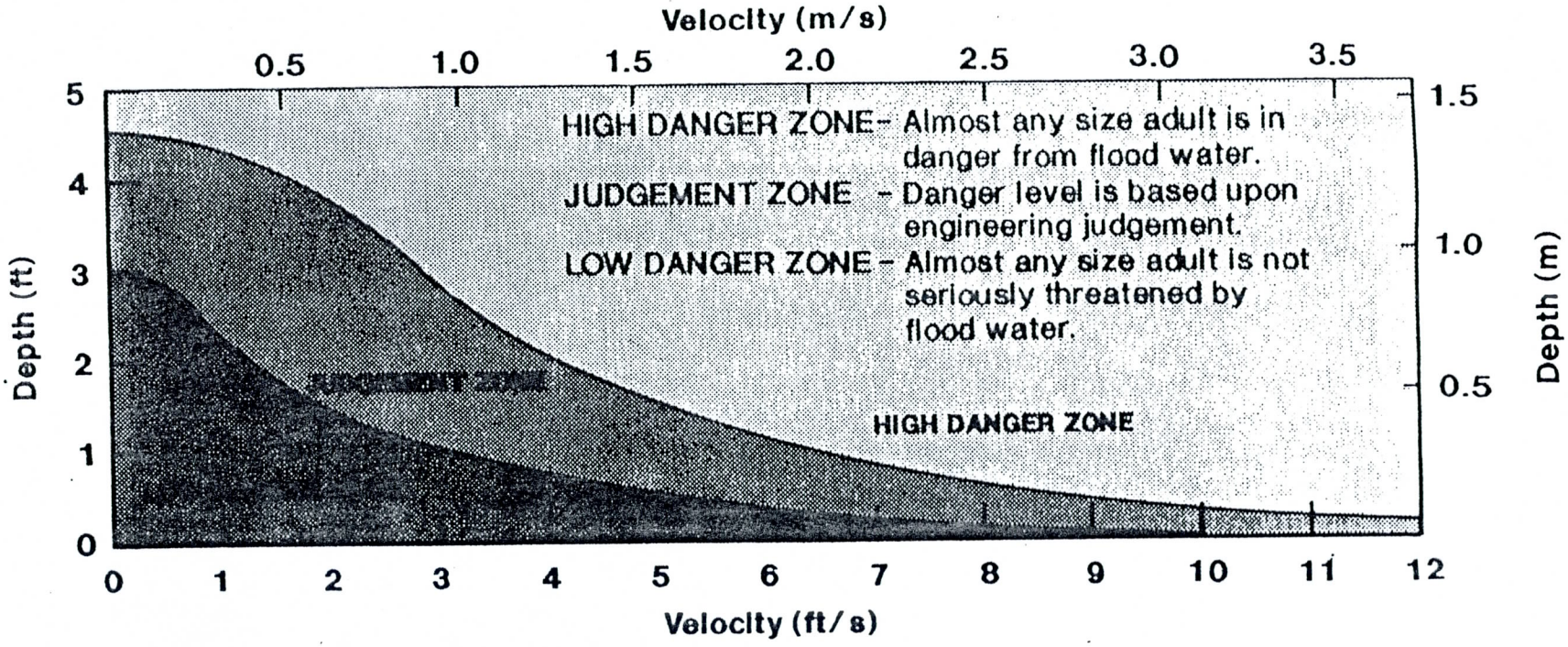


Figure 5. – Depth–velocity flood danger level relationship for adults.

Side Slope = 1

BOR 'Low Danger Zone'
BOR 'Judgement Zone'
BOR 'High Danger Zone'

Flowrate - 30' CHANNEL

Depth (ft)	Velocity (fps) 0	1	2	3	4	5	6	7	8	9	10
0.0	0	0	0	0	0	0	0	0	0	0	0
0.5	0	15	31	46	61	76	92	107	122	137	153
1.0	0	31	62	93	124	155	186	217	248	279	310
1.5	0	47	95	142	189	236	284	331	378	425	473
2.0	0	64	128	192	256	320	384	448	512	576	640
2.5	0	81	163	244	325	406	488	569	650	731	813
3.0	0	99	198	297	396	495	594	693	792	891	990
3.5	0	117	235	352	469	586	704	821	938	1055	1173
4.0	0	136	272	408	544	680	816	952	1088	1224	1360
4.5	0	155	311	466	621	776	932	1087	1242	1397	1553
5.0	0	175	350	525	700	875	1050	1225	1400	1575	1750

Flowrate - 40' CHANNEL

Depth (ft)	Velocity (fps) 0	1	2	3	4	5	6	7	8	9	10
0.0	0	0	0	0	0	0	0	0	0	0	0
0.5	0	20	41	61	81	101	122	142	162	182	203
1.0	0	41	82	123	164	205	246	287	328	369	410
1.5	0	62	125	187	249	311	374	436	498	560	623
2.0	0	84	168	252	336	420	504	588	672	756	840
2.5	0	106	213	319	425	531	638	744	850	956	1063
3.0	0	129	258	387	516	645	774	903	1032	1161	1290
3.5	0	152	305	457	609	761	914	1066	1218	1370	1523
4.0	0	176	352	528	704	880	1056	1232	1408	1584	1760
4.5	0	200	401	601	801	1001	1202	1402	1602	1802	2003
5.0	0	225	450	675	900	1125	1350	1575	1800	2025	2250

Flowrate - 50' CHANNEL

Depth (ft)	Velocity (fps) 0	1	2	3	4	5	6	7	8	9	10
0.0	0	0	0	0	0	0	0	0	0	0	0
0.5	0	25	51	76	101	126	152	177	202	227	253
1.0	0	51	102	153	204	255	306	357	408	459	510
1.5	0	77	155	232	309	386	464	541	618	695	773
2.0	0	104	208	312	416	520	624	728	832	936	1040
2.5	0	131	263	394	525	656	788	919	1050	1181	1313
3.0	0	159	318	477	636	795	954	1113	1272	1431	1590
3.5	0	187	375	562	749	936	1124	1311	1498	1685	1873
4.0	0	216	432	648	864	1080	1296	1512	1728	1944	2160
4.5	0	245	491	736	981	1226	1472	1717	1962	2207	2453
5.0	0	275	550	825	1100	1375	1650	1925	2200	2475	2750

Flowrate - 60' CHANNEL

Depth (ft)	Velocity (fps) 0	1	2	3	4	5	6	7	8	9	10
0.0	0	0	0	0	0	0	0	0	0	0	0
0.5	0	30	61	91	121	151	182	212	242	272	303
1.0	0	61	122	183	244	305	366	427	488	549	610
1.5	0	92	185	277	369	461	554	646	738	830	923
2.0	0	124	248	372	496	620	744	868	992	1116	1240
2.5	0	156	313	469	625	781	938	1094	1250	1406	1563
3.0	0	189	378	567	756	945	1134	1323	1512	1701	1890
3.5	0	222	445	667	889	1111	1334	1556	1778	2000	2223
4.0	0	256	512	768	1024	1280	1536	1792	2048	2304	2560
4.5	0	290	581	871	1161	1451	1742	2032	2322	2612	2903
5.0	0	325	650	975	1300	1625	1950	2275	2600	2925	3250

Flowrate - 70' CHANNEL

Depth (ft)	Velocity (fps) 0	1	2	3	4	5	6	7	8	9	10
0.0	0	0	0	0	0	0	0	0	0	0	0
0.5	0	35	71	106	141	176	212	247	282	317	353
1.0	0	71	142	213	284	355	426	497	568	639	710
1.5	0	107	215	322	429	536	644	751	858	965	1073
2.0	0	144	288	432	576	720	864	1008	1152	1296	1440
2.5	0	181	363	544	725	906	1088	1269	1450	1631	1813
3.0	0	219	438	657	876	1095	1314	1533	1752	1971	2190
3.5	0	257	515	772	1029	1286	1544	1801	2058	2315	2573
4.0	0	296	592	888	1184	1480	1776	2072	2368	2664	2960
4.5	0	335	671	1006	1341	1676	2012	2347	2682	3017	3353
5.0	0	375	750	1125	1500	1875	2250	2625	3000	3375	3750

Flowrate - 80' CHANNEL

Depth (ft)	Velocity (fps) 0	1	2	3	4	5	6	7	8	9	10
0.0	0	0	0	0	0	0	0	0	0	0	0
0.5	0	40	81	121	161	201	242	282	322	362	403
1.0	0	81	162	243	324	405	486	567	648	729	810
1.5	0	122	245	367	489	611	734	856	978	1100	1223
2.0	0	164	328	492	656	820	984	1148	1312	1476	1640
2.5	0	206	413	619	825	1031	1238	1444	1650	1856	2063
3.0	0	249	498	747	996	1245	1494	1743	1992	2241	2490
3.5	0	292	585	877	1169	1461	1754	2046	2338	2630	2923
4.0	0	336	672	1008	1344	1680	2016	2352	2688	3024	3360
4.5	0	380	761	1141	1521	1901	2282	2662	3042	3422	3803
5.0	0	425	850	1275	1700	2125	2550	2975	3400	3825	4250

Flowrate - 100' CHANNEL

Depth (ft)	Velocity (fps) 0	1	2	3	4	5	6	7	8	9	10
0.0	0	0	0	0	0	0	0	0	0	0	0
0.5	0	50	101	151	201	251	302	352	402	452	503
1.0	0	101	202	303	404	505	606	707	808	909	1010
1.5	0	152	305	457	609	761	914	1066	1218	1370	1523
2.0	0	204	408	612	816	1020	1224	1428	1632	1836	2040
2.5	0	256	513	769	1025	1281	1538	1794	2050	2306	2563
3.0	0	309	618	927	1236	1545	1854	2163	2472	2781	3090
3.5	0	362	725	1087	1449	1811	2174	2536	2898	3260	3623
4.0	0	416	832	1248	1664	2080	2496	2912	3328	3744	4160
4.5	0	470	941	1411	1881	2351	2822	3292	3762	4232	4703
5.0	0	525	1050	1575	2100	2625	3150	3675	4200	4725	5250

Flowrate - 200' CHANNEL

Depth (ft)	Velocity (fps) 0	1	2	3	4	5	6	7	8	9	10
0.0	0	0	0	0	0	0	0	0	0	0	0
0.5	0	100	201	301	401	501	602	702	802	902	1003
1.0	0	201	402	603	804	1005	1206	1407	1608	1809	2010
1.5	0	302	605	907	1209	1511	1814	2116	2418	2720	3023
2.0	0	404	808	1212	1616	2020	2424	2828	3232	3636	4040
2.5	0	506	1013	1519	2025	2531	3038	3544	4050	4556	5063
3.0	0	609	1218	1827	2436	3045	3654	4263	4872	5481	6090
3.5	0	712	1425	2137	2849	3561	4274	4986	5698	6410	7123
4.0	0	816	1632	2448	3264	4080	4896	5712	6528	7344	8160
4.5	0	920	1841	2761	3681	4601	5522	6442	7362	8282	9203
5.0	0	1025	2050	3075	4100	5125	6150	7175	8200	9225	10250

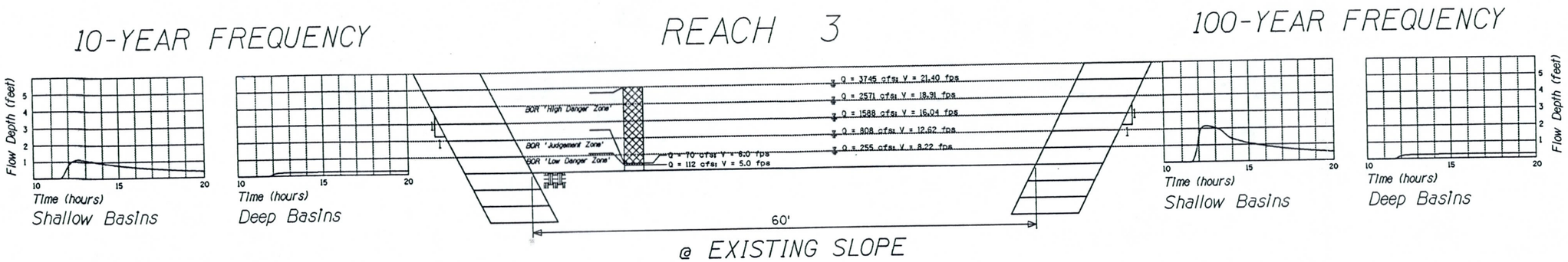
Flowrate - 500' CHANNEL

Depth (ft)	Velocity (fps) 0	1	2	3	4	5	6	7	8	9	10
0.0	0	0	0	0	0	0	0	0	0	0	0
0.5	0	250	501	751	1001	1251	1502	1752	2002	2252	2503
1.0	0	501	1002	1503	2004	2505	3006	3507	4008	4509	5010
1.5	0	752	1505	2257	3009	3761	4514	5266	6018	6770	7523
2.0	0	1004	2008	3012	4016	5020	6024	7028	8032	9036	10040
2.5	0	1256	2513	3769	5025	6281	7538	8794	10050	11306	12563
3.0	0	1509	3018	4527	6036	7545	9054	10563	12072	13581	15090
3.5	0	1762	3525	5287	7049	8811	10574	12336	14098	15860	17623
4.0	0	2016	4032	6048	8064	10080	12096	14112	16128	18144	20160
4.5	0	2270	4541	6811	9081	11351	13622	15892	18162	20432	22703
5.0	0	2525	5050	7575	10100	12625	15150	17675	20200	22725	25250

Flowrate - 1000' CHANNEL

Depth (ft)	Velocity (fps) 0	1	2	3	4	5	6	7	8	9	10
0.0	0	0	0	0	0	0	0	0	0	0	0
0.5	0	500	1001	1501	2001	2501	3002	3502	4002	4502	5003
1.0	0	1001	2002	3003	4004	5005	6006	7007	8008	9009	10010
1.5	0	1502	3005	4507	6009	7511	9014	10516	12018	13520	15023
2.0	0	2004	4008	6012	8016	10020	12024	14028	16032	18036	20040
2.5	0	2506	5013	7519	10025	12531	15038	17544	20050	22556	25063
3.0	0	3009	6018	9027	12036	15045	18054	21063	24072	27081	30090
3.5	0	3512	7025	10537	14049	17561	21074	24586	28098	31610	35123
4.0	0	4016	8032	12048	16064	20080	24096	28112	32128	36144	40160
4.5	0	4520	9041	13561	18081	22601	27122	31642	36162	40682	45203
5.0	0	5025	10050	15075	20100	25125	30150	35175	40200	45225	50250

REACH 3



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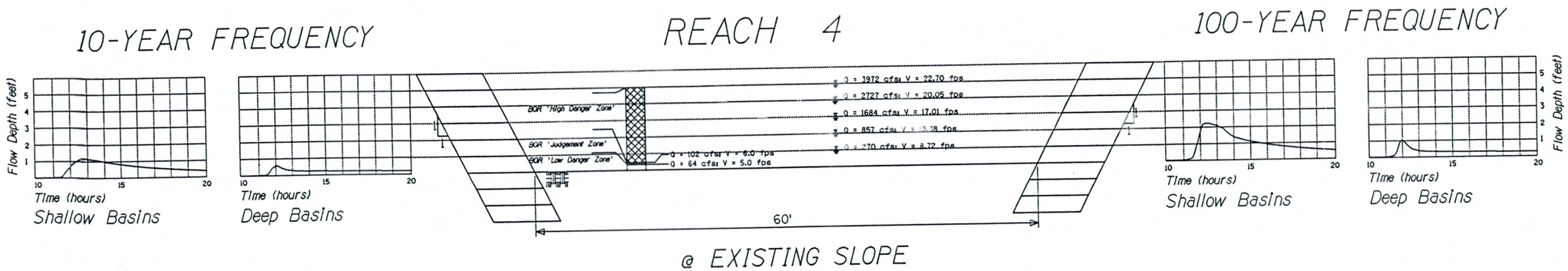

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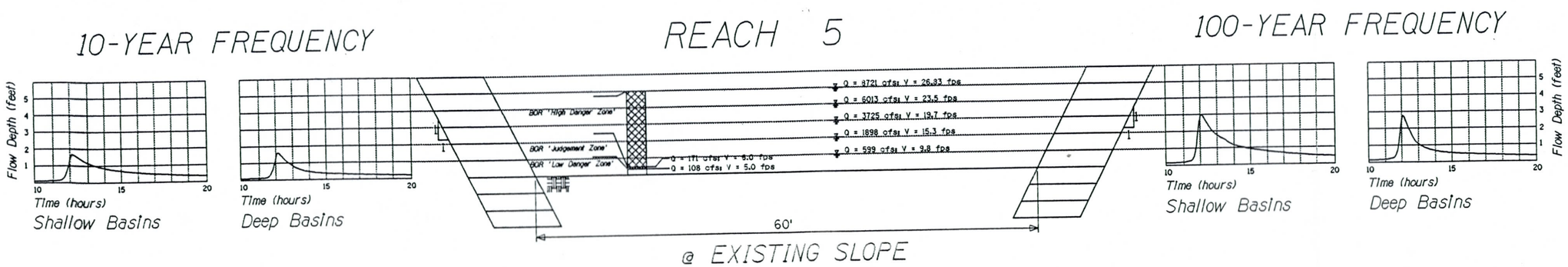


Greiner, Inc.

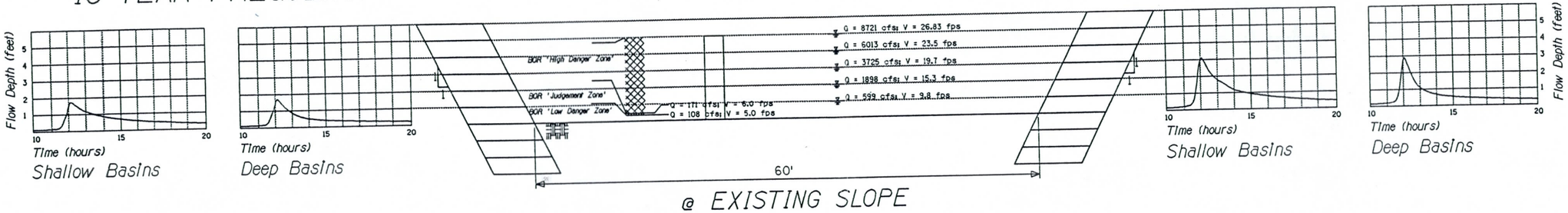
Pima Road Basin Alternative

B.O.R. Safety Graphs

The Desert Greenbelt

REACH 6

10-YEAR FREQUENCY

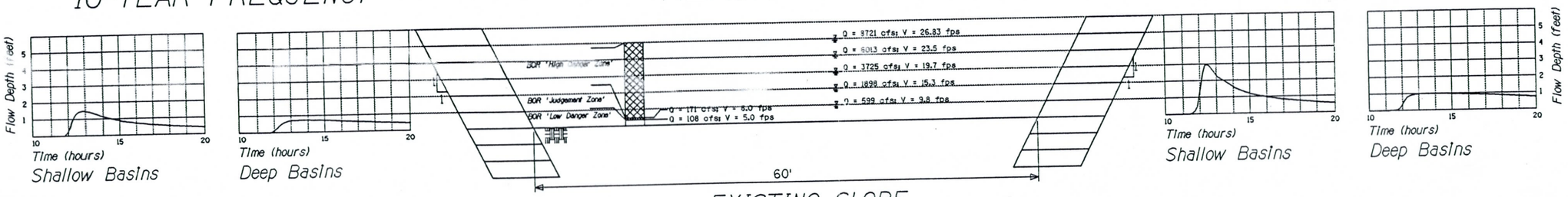


100-YEAR FREQUENCY

@ EXISTING SLOPE

REACH 7

10-YEAR FREQUENCY

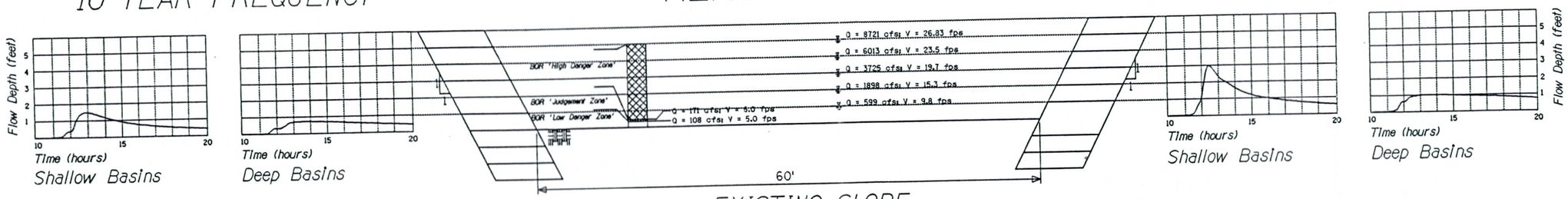


100-YEAR FREQUENCY

@ EXISTING SLOPE

REACH 8

10-YEAR FREQUENCY



100-YEAR FREQUENCY

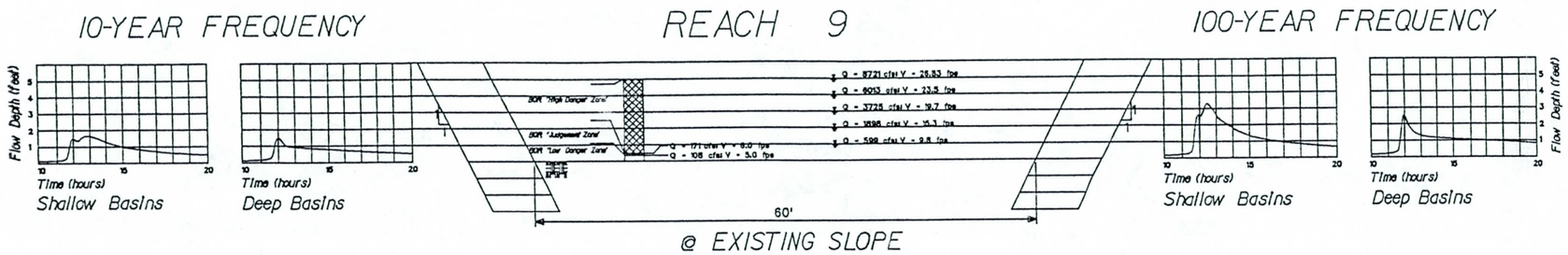
@ EXISTING SLOPE

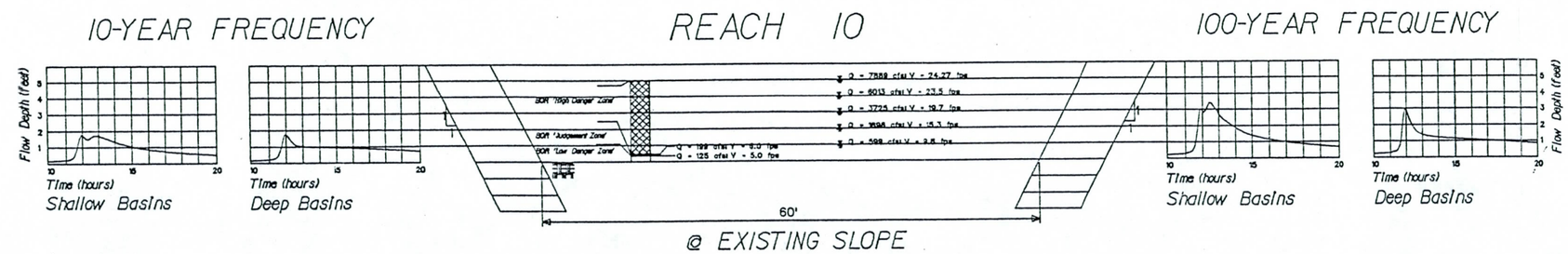
Gardner, Inc.

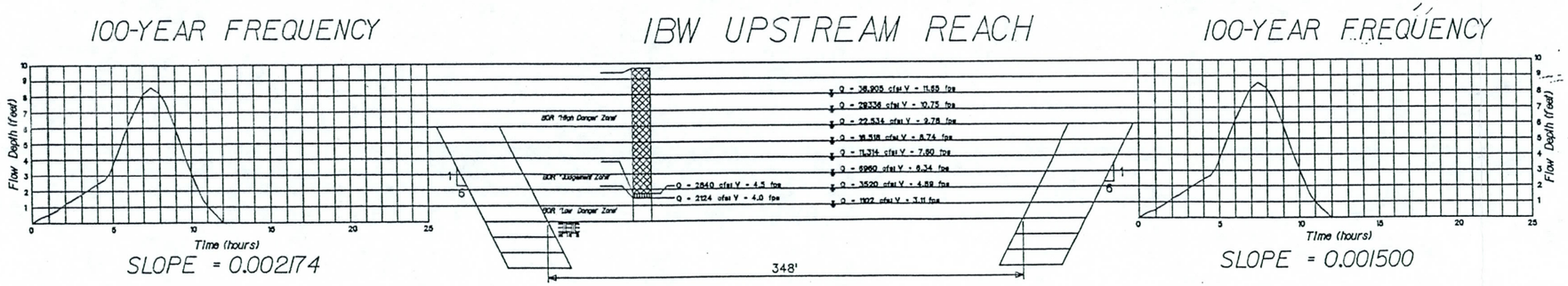
Pima Road Basin Alternative

B.O.R. Safety Graphs

The Desert Greenbelt







Greiner, Inc.

Figure B-3

Pima Road Basin Alternative
B.O.R. Safety Graphs

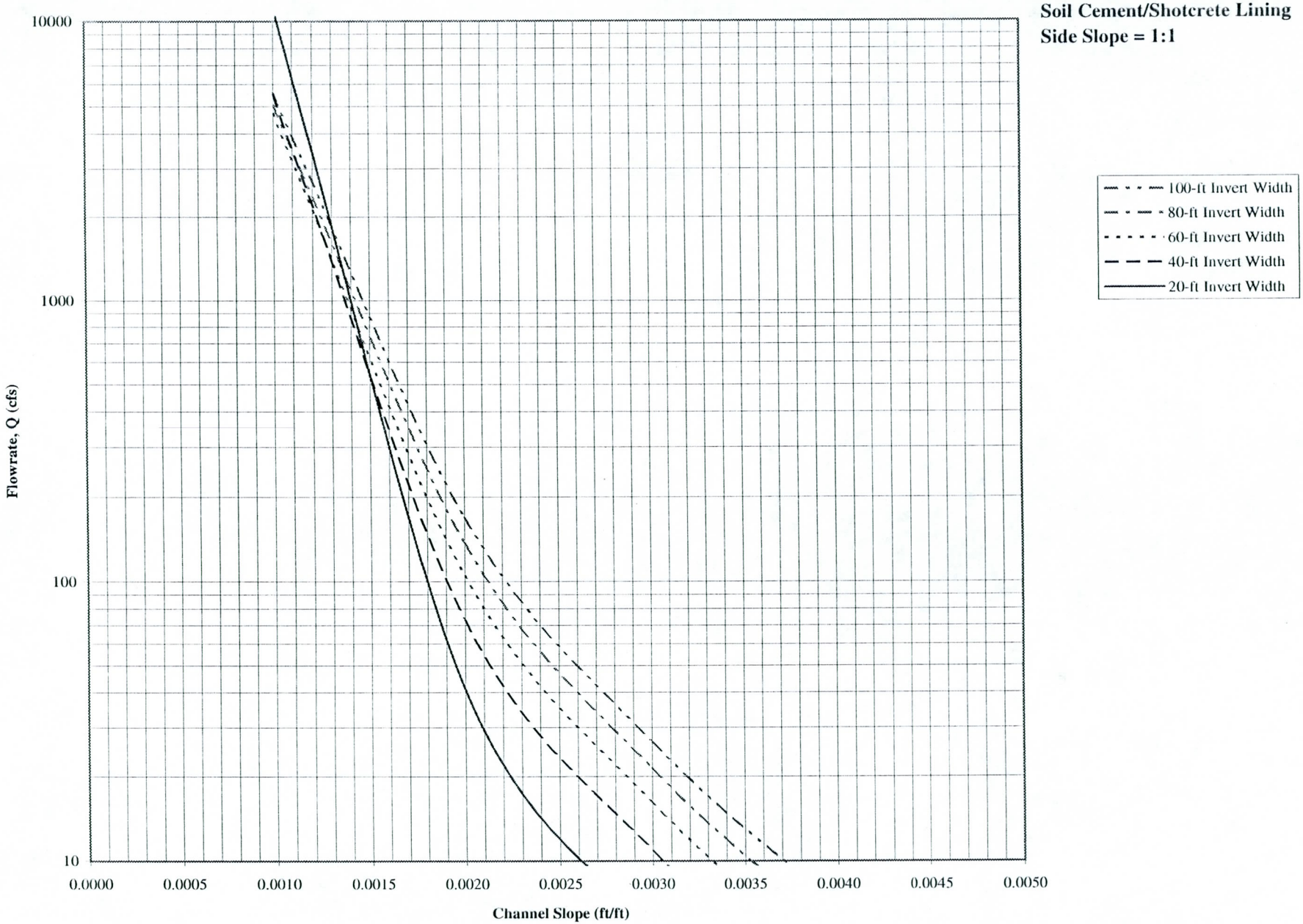
The Desert Greenbelt

Appendix C

Hydraulic Parameters and Sensitivity Figures

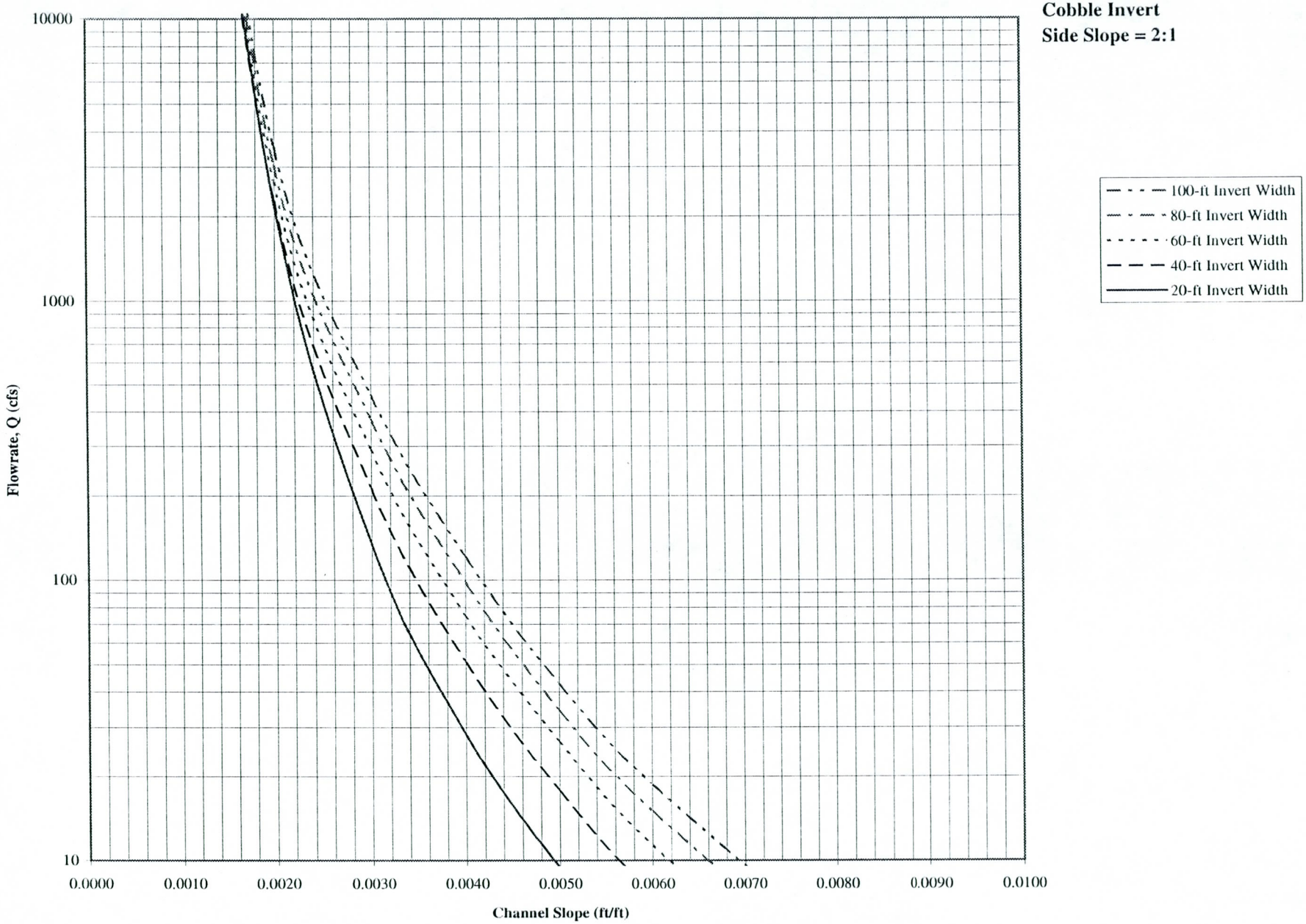
Flowrate- Bed Slope Relationships
for F = 0.50

Manning's 'n' = 0.022
Soil Cement/Shotcrete Lining
Side Slope = 1:1



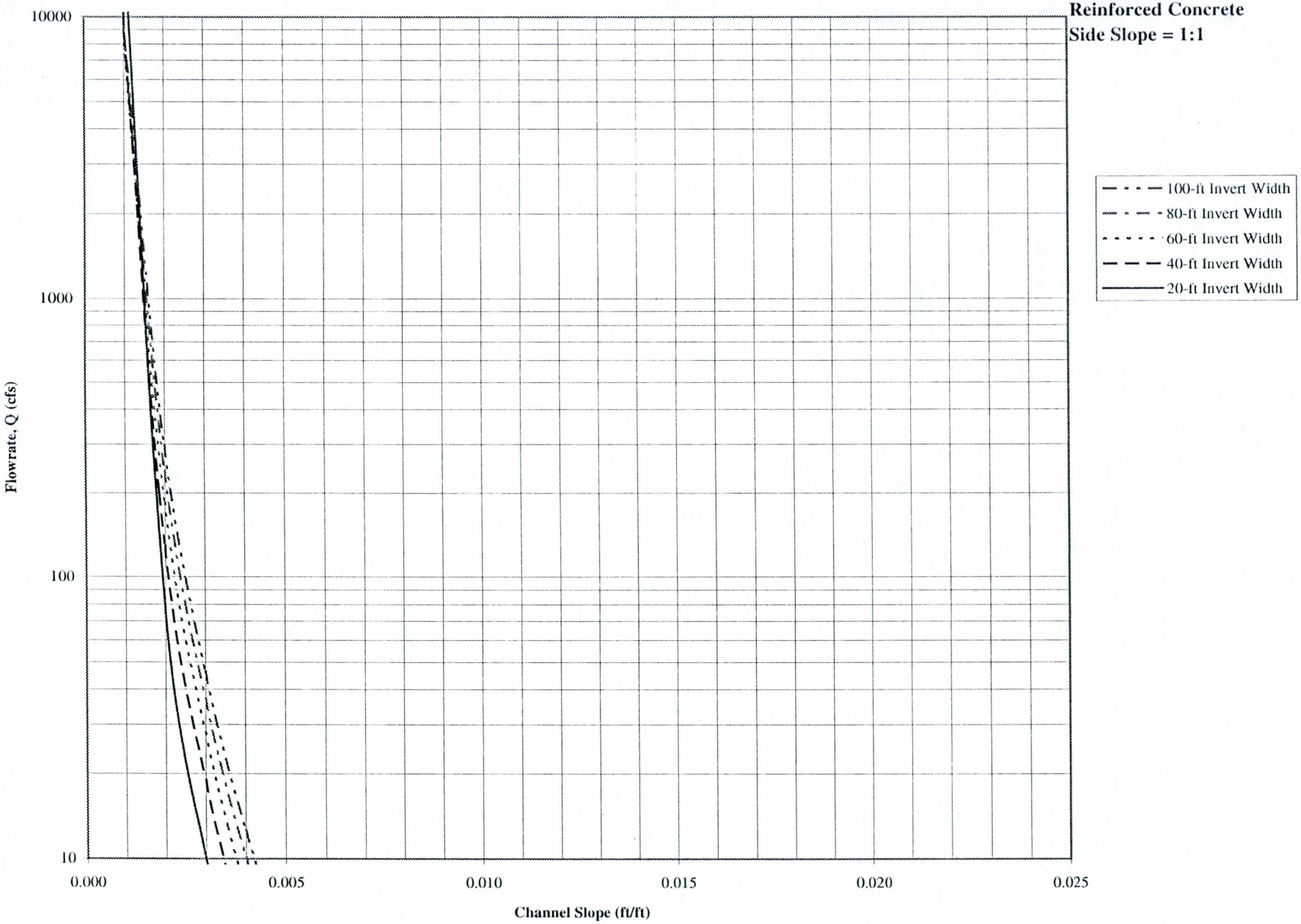
Flowrate- Bed Slope Relationships
for F = 0.50

Manning's 'n' = 0.030
Cobble Invert
Side Slope = 2:1



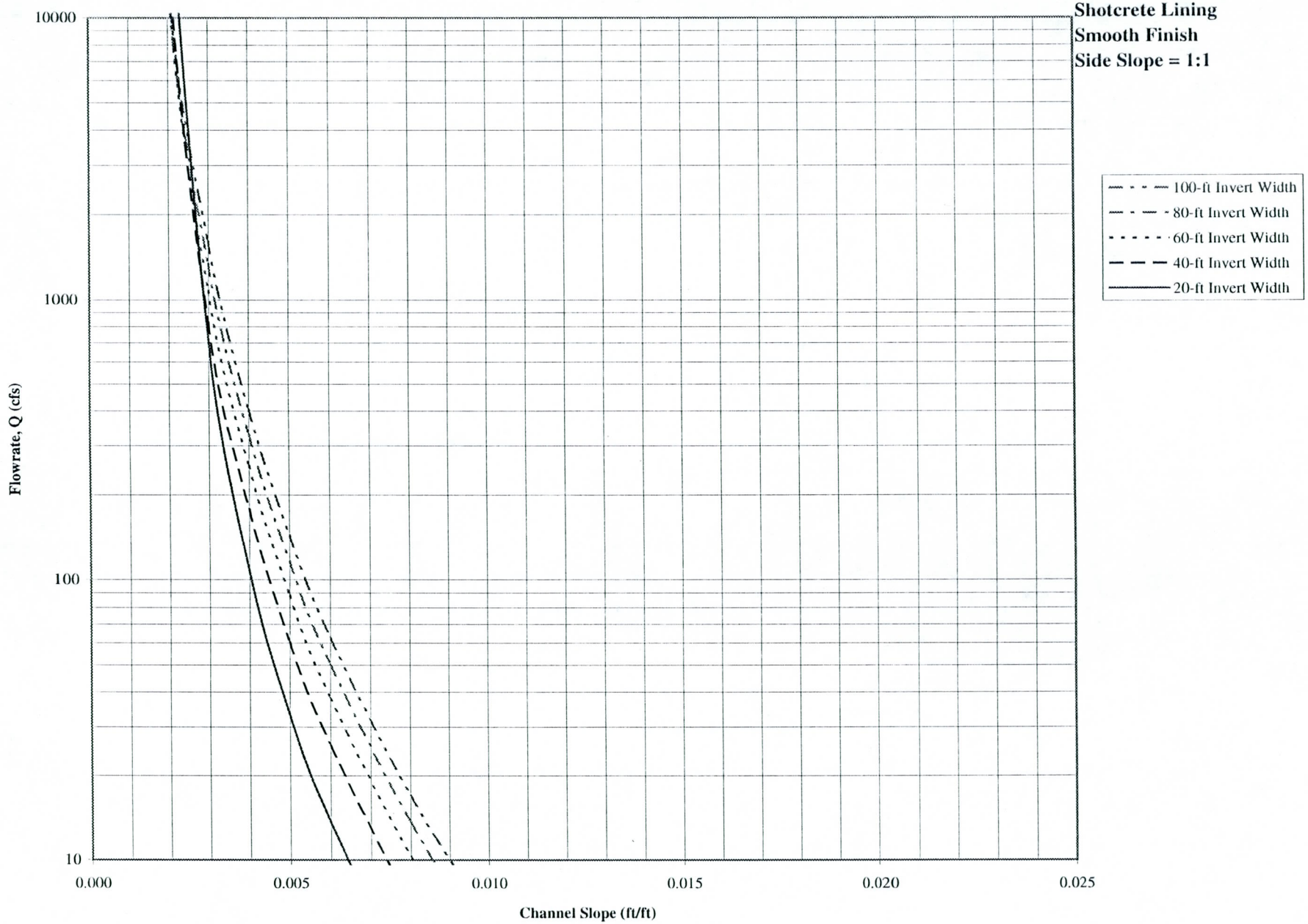
Flowrate- Bed Slope Relationships
for F = 0.85

Manning's 'n' = 0.015
Reinforced Concrete
Side Slope = 1:1



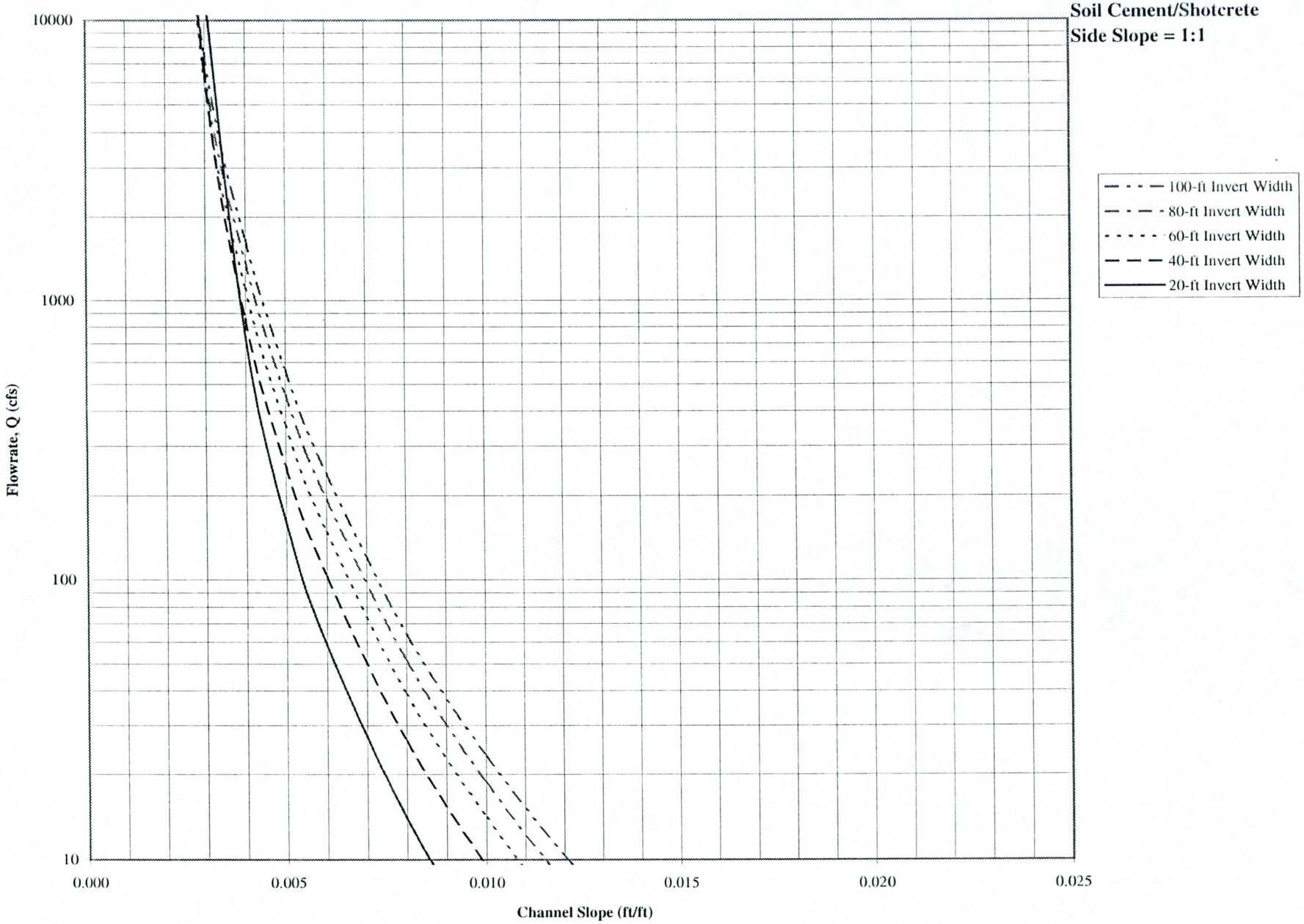
Flowrate- Bed Slope Relationships
for F = 0.85

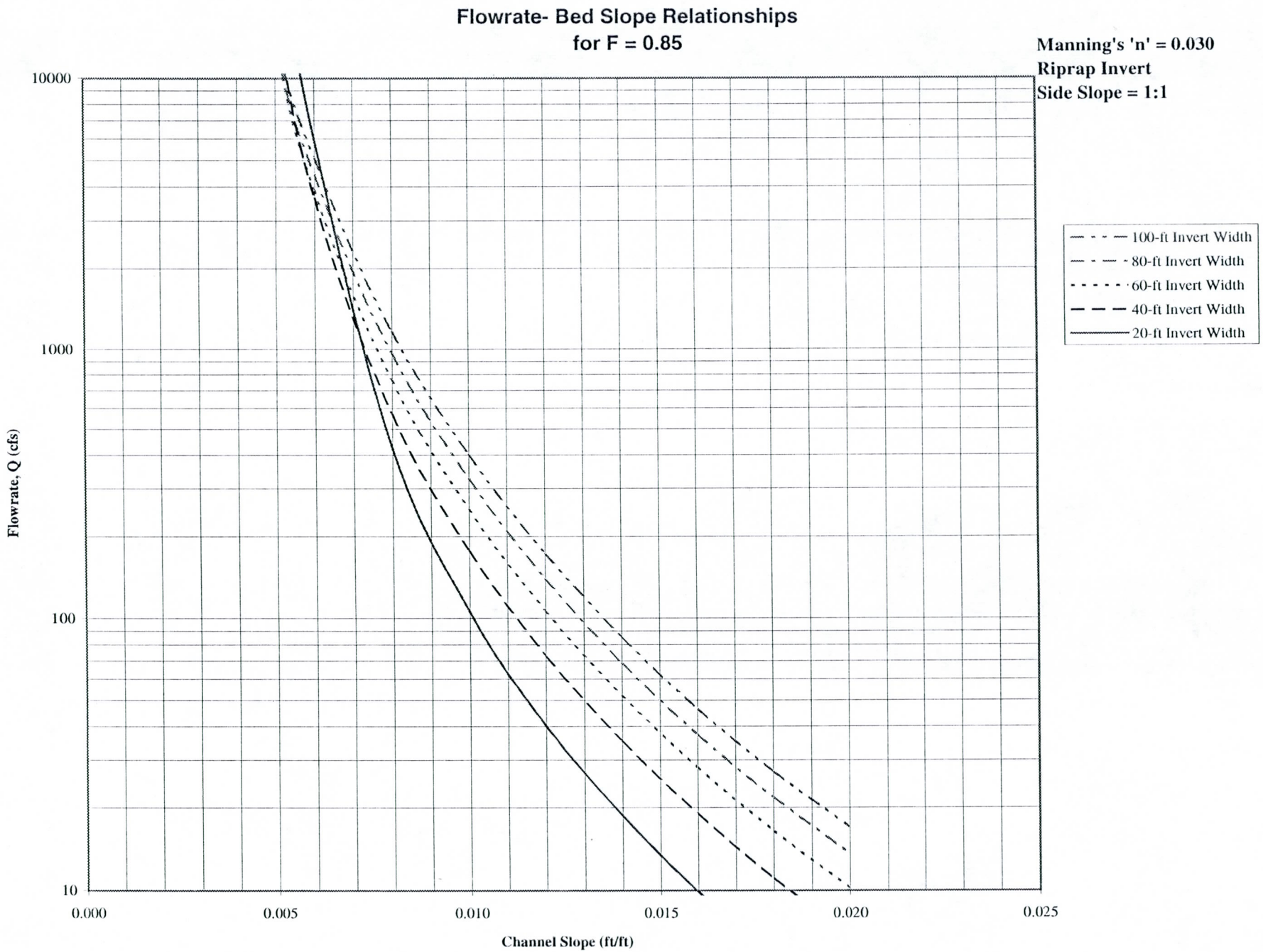
Manning's 'n' = 0.019
Shotcrete Lining
Smooth Finish
Side Slope = 1:1



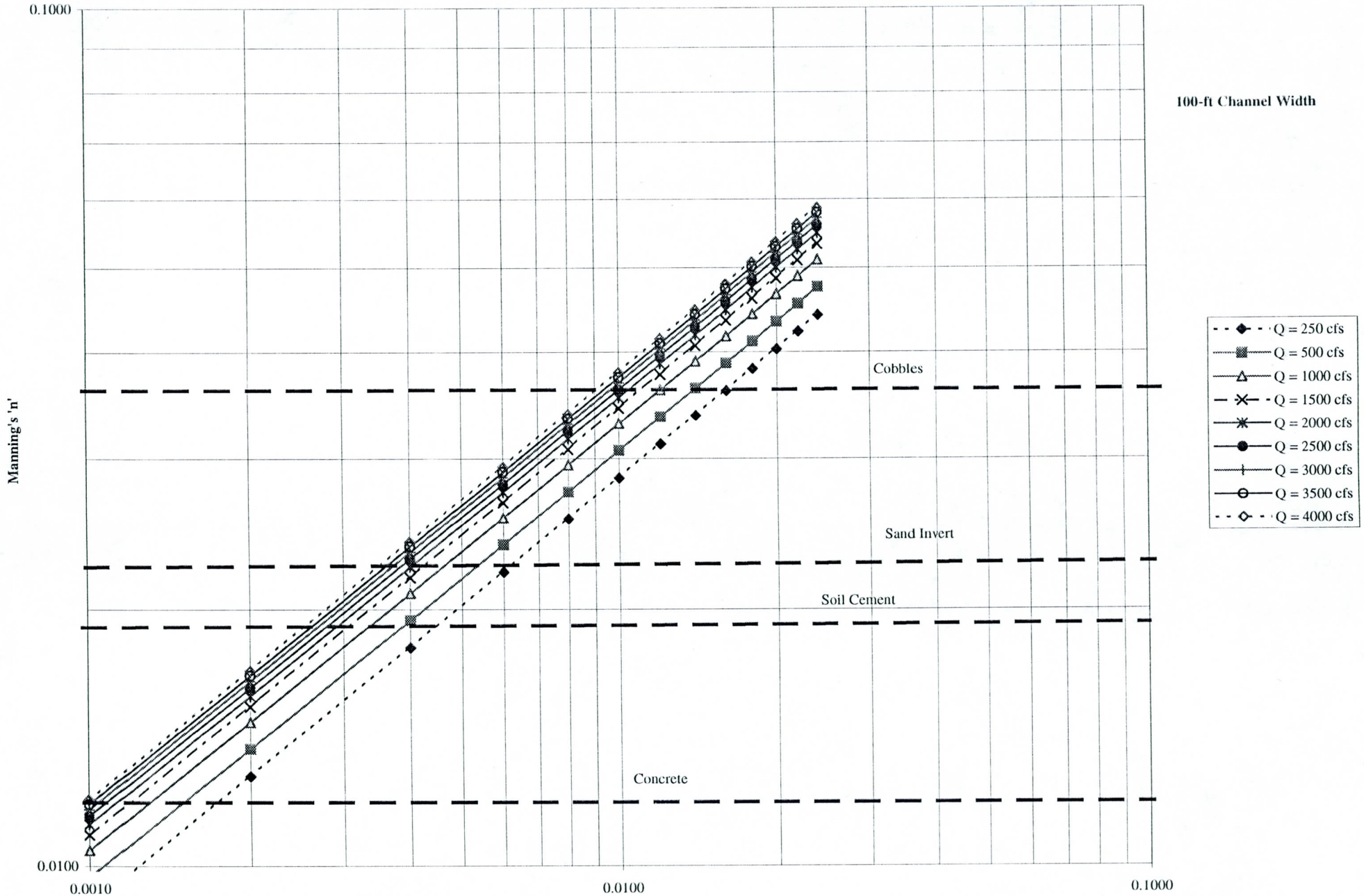
Flowrate- Bed Slope Relationships
for F = 0.85

Manning's 'n' = 0.022
Soil Cement/Shotcrete
Side Slope = 1:1




Flowrate- Bed Slope Relationships
for F = 0.85
Manning's 'n' = 0.030
Riprap Invert
Side Slope = 1:1
100-ft Invert Width
80-ft Invert Width
60-ft Invert Width
40-ft Invert Width
20-ft Invert Width
Flowrate, Q (cfs)
10000
1000
100
10
0.000
0.005
0.010
0.015
0.020
0.025
Channel Slope (ft/ft)

Manning's 'n' - Bed Slope Relationships
for F = 0.85



GREINER, INC.

E10060115 \hydraul\db*Subcritical Chart 23

Table 4.1 - Upstream Reach of Indian Bend Wash

BOR 'Low Danger Zone'
BOR 'Judgement Zone'
BOR 'High Danger Zone'

Flowrates - 348' CHANNEL											
	Velocity (fps)										
Depth (ft)	0	1	2	3	4	5	6	7	8	9	10
0.0	0	0	0	0	0	0	0	0	0	0	0
0.5	0	176	351	527	702	878	1053	1229	1404	1580	1755
1.0	0	354	708	1062	1416	1770	2124	2478	2832	3186	3540
1.5	0	536	1071	1607	2142	2678	3213	3749	4284	4820	5355
2.0	0	720	1440	2160	2880	3600	4320	5040	5760	6480	7200
2.5	0	908	1815	2723	3630	4538	5445	6353	7260	8168	9075
3.0	0	1098	2196	3294	4392	5490	6588	7686	8784	9882	10980
3.5	0	1292	2583	3875	5166	6458	7749	9041	10332	11624	12915
4.0	0	1488	2976	4464	5952	7440	8928	10416	11904	13392	14880
4.5	0	1688	3375	5063	6750	8438	10125	11813	13500	15188	16875
5.0	0	1890	3780	5670	7560	9450	11340	13230	15120	17010	18900
5.5	0	2096	4191	6287	8382	10478	12573	14669	16764	18860	20955
6.0	0	2304	4608	6912	9216	11520	13824	16128	18432	20736	23040
6.5	0	2516	5031	7547	10062	12578	15093	17609	20124	22640	25155
7.0	0	2730	5460	8190	10920	13650	16380	19110	21840	24570	27300
7.5	0	2948	5895	8843	11790	14738	17685	20633	23580	26528	29475
8.0	0	3168	6336	9504	12672	15840	19008	22176	25344	28512	31680
8.5	0	3392	6783	10175	13566	16958	20349	23741	27132	30524	33915
9.0	0	3618	7236	10854	14472	18090	21708	25326	28944	32562	36180

~ Sta. 380+00
~ McDonald
$S_0 = 0.002174$
V = 7.17 fps
y = 6 ft

Table 4.2 - Downstream Reach of Indian Bend Wash

BOR 'Low Danger Zone'
BOR 'Judgement Zone'
BOR 'High Danger Zone'

Flowrates - 580' CHANNEL											
	Velocity (fps)										
Depth (ft)	0	1	2	3	4	5	6	7	8	9	10
0.0	0	0	0	0	0	0	0	0	0	0	0
0.5	0	292	583	875	1166	1458	1749	2041	2332	2624	2915
1.0	0	586	1172	1758	2344	2930	3516	4102	4688	5274	5860
1.5	0	884	1767	2651	3534	4418	5301	6185	7068	7952	8835
2.0	0	1184	2368	3552	4736	5920	7104	8288	9472	10656	11840
2.5	0	1488	2975	4463	5950	7438	8925	10413	11900	13388	14875
3.0	0	1794	3588	5382	7176	8970	10764	12558	14352	16146	17940
3.5	0	2104	4207	6311	8414	10518	12621	14725	16828	18932	21035
4.0	0	2416	4832	7248	9664	12080	14496	16912	19328	21744	24160
4.5	0	2732	5463	8195	10926	13658	16389	19121	21852	24584	27315
5.0	0	3050	6100	9150	12200	15250	18300	21350	24400	27450	30500
5.5	0	3372	6743	10115	13486	16858	20229	23601	26972	30344	33715
6.0	0	3696	7392	11088	14784	18480	22176	25872	29568	33264	36960
6.5	0	4024	8047	12071	16094	20118	24141	28165	32188	36212	40235
7.0	0	4354	8708	13062	17416	21770	26124	30478	34832	39186	43540
7.5	0	4688	9375	14063	18750	23438	28125	32813	37500	42188	46875
8.0	0	5024	10048	15072	20096	25120	30144	35168	40192	45216	50240
8.5	0	5364	10727	16091	21454	26818	32181	37545	42908	48272	53635
9.0	0	5706	11412	17118	22824	28530	34236	39942	45648	51354	57060

~ Sta. 90+00
Low Flow Channel
120' bottom width
~ McKellips Road
$S_0 = 0.003137$
V = 8.86 fps
y = 6 ft

Table 4.3 - Canada del Oro Wash and Pantano Wash (Tucson, Arizona)

BOR 'Low Danger Zone'
BOR 'Judgement Zone'
BOR 'High Danger Zone'

Flowrates - 225' CHANNEL

	Velocity (fps)																				
Depth (ft)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.5	0	113	226	338	451	564	677	789	902	1015	1128	1240	1353	1466	1579	1691	1804	1917	2030	2142	2255
1.0	0	226	452	678	904	1130	1356	1582	1808	2034	2260	2486	2712	2938	3164	3390	3616	3842	4068	4294	4520
1.5	0	340	680	1019	1359	1699	2039	2378	2718	3058	3398	3737	4077	4417	4757	5096	5436	5776	6116	6455	6795
2.0	0	454	908	1362	1816	2270	2724	3178	3632	4086	4540	4994	5448	5902	6356	6810	7264	7718	8172	8626	9080
2.5	0	569	1138	1706	2275	2844	3413	3981	4550	5119	5688	6256	6825	7394	7963	8531	9100	9669	10238	10806	11375
3.0	0	684	1368	2052	2736	3420	4104	4788	5472	6156	6840	7524	8208	8892	9576	10260	10944	11628	12312	12996	13680
3.5	0	800	1600	2399	3199	3999	4799	5598	6398	7198	7998	8797	9597	10397	11197	11996	12796	13596	14396	15195	15995
4.0	0	916	1832	2748	3664	4580	5496	6412	7328	8244	9160	10076	10992	11908	12824	13740	14656	15572	16488	17404	18320
4.5	0	1033	2066	3098	4131	5164	6197	7229	8263	9295	10328	11360	12393	13426	14459	15491	16524	17557	18590	19622	20655
5.0	0	1150	2300	3450	4600	5750	6900	8050	9200	10350	11500	12650	13800	14950	16100	17250	18400	19550	20700	21850	23000
5.5	0	1268	2536	3803	5071	6339	7607	8874	10142	11410	12678	13945	15213	16481	17749	19016	20284	21552	22820	24087	25355
6.0	0	1386	2772	4158	5544	6930	8316	9702	11088	12474	13860	15246	16632	18018	19404	20790	22176	23562	24948	26334	27720
6.5	0	1505	3010	4514	6019	7524	9029	10533	12038	13543	15048	16552	18057	19562	21067	22571	24076	25581	27086	28590	30095
7.0	0	1624	3248	4872	6496	8120	9744	11368	12992	14616	16240	17864	19488	21112	22736	24360	25984	27608	29232	30856	32480
7.5	0	1744	3488	5231	6975	8719	10463	12206	13950	15694	17438	19181	20925	22669	24413	26156	27900	29644	31388	33131	34875
8.0	0	1864	3728	5592	7456	9320	11184	13048	14912	16776	18640	20504	22368	24232	26096	27960	29824	31688	33552	35416	37280
8.5	0	1985	3970	5954	7939	9924	11909	13893	15878	17863	19848	21832	23817	25802	27787	29771	31756	33741	35726	37710	39695
9.0	0	2106	4212	6318	8424	10530	12636	14742	16848	18954	21060	23166	25272	27378	29484	31590	33696	35802	37908	40014	42120

Pantano Wash
Main Channel
$S_0 = 0.0063$
V = 15 fps
y = 8 ft

Canada del Oro
Main Channel
$S_0 = 0.0156$
V = 20 fps
y = 6 ft

S = 0.25%

side slope 'n' =	0.019
invert 'n' =	0.022
Average Channel slope	0.0025
Channel side slope =	1.0

CHANNEL WIDTH=	30								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	30.7	31.4	32.1	32.8	35.7	38.5	41.3	44.1	47.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.021	0.021	0.021	0.021
flow area =	7.6	15.3	23.1	31.0	64.0	99.0	136.0	175.0	216.0
hyd. radius =	0.25	0.49	0.72	0.94	1.79	2.57	3.29	3.96	4.60
V =	1.33	2.10	2.73	3.29	5.10	6.54	7.76	8.85	9.82
Q =	10	32	63	102	326	647	1056	1548	2122

CHANNEL WIDTH=	40								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	40.7	41.4	42.1	42.8	45.7	48.5	51.3	54.1	57.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.021	0.021	0.021	0.021
flow area =	10.1	20.3	30.6	41.0	84.0	129.0	176.0	225.0	276.0
hyd. radius =	0.25	0.49	0.73	0.96	1.84	2.66	3.43	4.16	4.84
V =	1.33	2.11	2.75	3.31	5.16	6.64	7.92	9.05	10.08
Q =	13	43	84	136	433	857	1394	2037	2782

CHANNEL WIDTH=	50								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	50.7	51.4	52.1	52.8	55.7	58.5	61.3	64.1	67.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.021	0.021	0.021
flow area =	12.6	25.3	38.1	51.0	104.0	159.0	216.0	275.0	336.0
hyd. radius =	0.25	0.49	0.73	0.97	1.87	2.72	3.52	4.29	5.02
V =	1.33	2.11	2.75	3.32	5.20	6.71	8.02	9.19	10.25
Q =	17	53	105	169	540	1067	1733	2527	3445

CHANNEL WIDTH=	60								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	60.7	61.4	62.1	62.8	65.7	68.5	71.3	74.1	77.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.021	0.021
flow area =	15.1	30.3	45.6	61.0	124.0	189.0	256.0	325.0	396.0
hyd. radius =	0.25	0.49	0.73	0.97	1.89	2.76	3.59	4.38	5.14
V =	1.34	2.11	2.76	3.33	5.22	6.76	8.09	9.29	10.38
Q =	20	64	126	203	647	1277	2072	3018	4109

CHANNEL WIDTH=	70								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	70.7	71.4	72.1	72.8	75.7	78.5	81.3	84.1	87.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.021	0.021
flow area =	17.6	35.3	53.1	71.0	144.0	219.0	296.0	375.0	456.0
hyd. radius =	0.25	0.49	0.74	0.97	1.90	2.79	3.64	4.46	5.24
V =	1.34	2.12	2.76	3.34	5.24	6.79	8.15	9.36	10.47
Q =	23	75	147	237	755	1488	2411	3510	4775

CHANNEL WIDTH=	80								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	80.7	81.4	82.1	82.8	85.7	88.5	91.3	94.1	97.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.021
flow area =	20.1	40.3	60.6	81.0	164.0	249.0	336.0	425.0	516.0
hyd. radius =	0.25	0.49	0.74	0.98	1.91	2.81	3.68	4.51	5.32
V =	1.34	2.12	2.77	3.34	5.25	6.82	8.19	9.42	10.55
Q =	27	85	168	271	862	1698	2751	4003	5441

S = 0.50%

side slope '*n*' =	0.019
invert '*n*' =	0.022
Average Channel slope	0.0050
Channel side slope =	1.0

CHANNEL WIDTH=	30								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	30.7	31.4	32.1	32.8	35.7	38.5	41.3	44.1	47.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.021	0.021	0.021	0.021
flow area =	7.6	15.3	23.1	31.0	64.0	99.0	136.0	175.0	216.0
hyd. radius =	0.25	0.49	0.72	0.94	1.79	2.57	3.29	3.96	4.60
V =	1.88	2.97	3.86	4.65	7.21	9.24	10.98	12.51	13.89
Q =	14	45	89	144	461	915	1493	2189	3001

CHANNEL WIDTH=	40								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	40.7	41.4	42.1	42.8	45.7	48.5	51.3	54.1	57.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.021	0.021	0.021	0.021
flow area =	10.1	20.3	30.6	41.0	84.0	129.0	176.0	225.0	276.0
hyd. radius =	0.25	0.49	0.73	0.96	1.84	2.66	3.43	4.16	4.84
V =	1.89	2.98	3.88	4.68	7.29	9.39	11.20	12.80	14.25
Q =	19	60	119	192	613	1212	1971	2880	3934

CHANNEL WIDTH=	50								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	50.7	51.4	52.1	52.8	55.7	58.5	61.3	64.1	67.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.021	0.021	0.021
flow area =	12.6	25.3	38.1	51.0	104.0	159.0	216.0	275.0	336.0
hyd. radius =	0.25	0.49	0.73	0.97	1.87	2.72	3.52	4.29	5.02
V =	1.89	2.98	3.89	4.70	7.35	9.49	11.34	13.00	14.50
Q =	24	75	148	240	764	1509	2450	3574	4872

CHANNEL WIDTH=	60								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	60.7	61.4	62.1	62.8	65.7	68.5	71.3	74.1	77.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.021	0.021
flow area =	15.1	30.3	45.6	61.0	124.0	189.0	256.0	325.0	396.0
hyd. radius =	0.25	0.49	0.73	0.97	1.89	2.76	3.59	4.38	5.14
V =	1.89	2.99	3.90	4.71	7.38	9.56	11.45	13.13	14.68
Q =	28	90	178	287	916	1807	2930	4269	5811

CHANNEL WIDTH=	70								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	70.7	71.4	72.1	72.8	75.7	78.5	81.3	84.1	87.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.021	0.021
flow area =	17.6	35.3	53.1	71.0	144.0	219.0	296.0	375.0	456.0
hyd. radius =	0.25	0.49	0.74	0.97	1.90	2.79	3.64	4.46	5.24
V =	1.89	2.99	3.91	4.72	7.41	9.61	11.52	13.24	14.81
Q =	33	105	207	335	1067	2104	3410	4964	6753

CHANNEL WIDTH=	80								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	80.7	81.4	82.1	82.8	85.7	88.5	91.3	94.1	97.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.021
flow area =	20.1	40.3	60.6	81.0	164.0	249.0	336.0	425.0	516.0
hyd. radius =	0.25	0.49	0.74	0.98	1.91	2.81	3.68	4.51	5.32
V =	1.89	2.99	3.91	4.73	7.43	9.65	11.58	13.32	14.91
Q =	38	120	237	383	1219	2402	3891	5661	7695

S = 0.75%

side slope '*n*' =	0.019
invert '*n*' =	0.022
Average Channel slope	0.0075
Channel side slope =	1.0

CHANNEL WIDTH=	30								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	30.7	31.4	32.1	32.8	35.7	38.5	41.3	44.1	47.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.021	0.021	0.021	0.021
flow area =	7.6	15.3	23.1	31.0	64.0	99.0	136.0	175.0	216.0
hyd. radius =	0.25	0.49	0.72	0.94	1.79	2.57	3.29	3.96	4.60
V =	2.31	3.64	4.73	5.70	8.83	11.32	13.45	15.32	17.01
Q =	17	55	109	177	565	1121	1829	2681	3675

CHANNEL WIDTH=	40								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	40.7	41.4	42.1	42.8	45.7	48.5	51.3	54.1	57.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.021	0.021	0.021	0.021
flow area =	10.1	20.3	30.6	41.0	84.0	129.0	176.0	225.0	276.0
hyd. radius =	0.25	0.49	0.73	0.96	1.84	2.66	3.43	4.16	4.84
V =	2.31	3.65	4.76	5.73	8.93	11.51	13.72	15.68	17.46
Q =	23	74	145	235	750	1484	2414	3528	4818

CHANNEL WIDTH=	50								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	50.7	51.4	52.1	52.8	55.7	58.5	61.3	64.1	67.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.021	0.021	0.021
flow area =	12.6	25.3	38.1	51.0	104.0	159.0	216.0	275.0	336.0
hyd. radius =	0.25	0.49	0.73	0.97	1.87	2.72	3.52	4.29	5.02
V =	2.31	3.65	4.77	5.76	9.00	11.62	13.89	15.92	17.76
Q =	29	92	182	294	936	1848	3001	4377	5966

CHANNEL WIDTH=	60								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	60.7	61.4	62.1	62.8	65.7	68.5	71.3	74.1	77.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.021	0.021
flow area =	15.1	30.3	45.6	61.0	124.0	189.0	256.0	325.0	396.0
hyd. radius =	0.25	0.49	0.73	0.97	1.89	2.76	3.59	4.38	5.14
V =	2.31	3.66	4.78	5.77	9.04	11.71	14.02	16.09	17.97
Q =	35	111	218	352	1121	2213	3588	5228	7117

CHANNEL WIDTH=	70								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	70.7	71.4	72.1	72.8	75.7	78.5	81.3	84.1	87.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.021	0.021
flow area =	17.6	35.3	53.1	71.0	144.0	219.0	296.0	375.0	456.0
hyd. radius =	0.25	0.49	0.74	0.97	1.90	2.79	3.64	4.46	5.24
V =	2.31	3.66	4.79	5.78	9.08	11.77	14.11	16.21	18.14
Q =	41	129	254	411	1307	2577	4177	6080	8271

CHANNEL WIDTH=	80								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	80.7	81.4	82.1	82.8	85.7	88.5	91.3	94.1	97.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.021
flow area =	20.1	40.3	60.6	81.0	164.0	249.0	336.0	425.0	516.0
hyd. radius =	0.25	0.49	0.74	0.98	1.91	2.81	3.68	4.51	5.32
V =	2.32	3.67	4.79	5.79	9.10	11.81	14.18	16.31	18.27
Q =	46	148	290	469	1493	2942	4765	6933	9425

S = 1.00%

side slope '*n*' = 0.019
invert '*n*' = 0.022
Average Channel slope 0.0100
Channel side slope = 1.0

CHANNEL WIDTH=	30								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	30.7	31.4	32.1	32.8	35.7	38.5	41.3	44.1	47.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.021	0.021	0.021	0.021
flow area =	7.6	15.3	23.1	31.0	64.0	99.0	136.0	175.0	216.0
hyd. radius =	0.25	0.49	0.72	0.94	1.79	2.57	3.29	3.96	4.60
V =	2.66	4.20	5.47	6.58	10.20	13.07	15.53	17.69	19.65
Q =	20	64	126	204	653	1294	2112	3096	4244

CHANNEL WIDTH=	40								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	40.7	41.4	42.1	42.8	45.7	48.5	51.3	54.1	57.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.021	0.021	0.021	0.021
flow area =	10.1	20.3	30.6	41.0	84.0	129.0	176.0	225.0	276.0
hyd. radius =	0.25	0.49	0.73	0.96	1.84	2.66	3.43	4.16	4.84
V =	2.67	4.21	5.49	6.62	10.32	13.29	15.84	18.10	20.16
Q =	27	85	168	271	867	1714	2788	4073	5564

CHANNEL WIDTH=	50								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	50.7	51.4	52.1	52.8	55.7	58.5	61.3	64.1	67.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.021	0.021	0.021
flow area =	12.6	25.3	38.1	51.0	104.0	159.0	216.0	275.0	336.0
hyd. radius =	0.25	0.49	0.73	0.97	1.87	2.72	3.52	4.29	5.02
V =	2.67	4.22	5.51	6.65	10.39	13.42	16.04	18.38	20.50
Q =	34	107	210	339	1081	2134	3465	5054	6889

CHANNEL WIDTH=	60								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	60.7	61.4	62.1	62.8	65.7	68.5	71.3	74.1	77.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.021	0.021
flow area =	15.1	30.3	45.6	61.0	124.0	189.0	256.0	325.0	396.0
hyd. radius =	0.25	0.49	0.73	0.97	1.89	2.76	3.59	4.38	5.14
V =	2.67	4.23	5.52	6.66	10.44	13.52	16.19	18.57	20.75
Q =	40	128	251	406	1295	2555	4144	6037	8219

CHANNEL WIDTH=	70								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	70.7	71.4	72.1	72.8	75.7	78.5	81.3	84.1	87.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.021	0.021
flow area =	17.6	35.3	53.1	71.0	144.0	219.0	296.0	375.0	456.0
hyd. radius =	0.25	0.49	0.74	0.97	1.90	2.79	3.64	4.46	5.24
V =	2.67	4.23	5.53	6.68	10.48	13.59	16.29	18.72	20.94
Q =	47	149	293	474	1509	2976	4823	7021	9550

CHANNEL WIDTH=	80								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	80.7	81.4	82.1	82.8	85.7	88.5	91.3	94.1	97.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.021
flow area =	20.1	40.3	60.6	81.0	164.0	249.0	336.0	425.0	516.0
hyd. radius =	0.25	0.49	0.74	0.98	1.91	2.81	3.68	4.51	5.32
V =	2.67	4.23	5.53	6.69	10.51	13.64	16.38	18.84	21.09
Q =	54	170	335	542	1724	3397	5502	8005	10883

S = 1.25%

side slope '*n*' =	0.019
invert '*n*' =	0.022
Average Channel slope	0.0125
Channel side slope =	1.0

CHANNEL WIDTH=	30								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	30.7	31.4	32.1	32.8	35.7	38.5	41.3	44.1	47.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.021	0.021	0.021	0.021
flow area =	7.6	15.3	23.1	31.0	64.0	99.0	136.0	175.0	216.0
hyd. radius =	0.25	0.49	0.72	0.94	1.79	2.57	3.29	3.96	4.60
V =	2.98	4.69	6.11	7.36	11.40	14.62	17.36	19.78	21.97
Q =	23	72	141	228	730	1447	2361	3462	4745

CHANNEL WIDTH=	40								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	40.7	41.4	42.1	42.8	45.7	48.5	51.3	54.1	57.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.021	0.021	0.021	0.021
flow area =	10.1	20.3	30.6	41.0	84.0	129.0	176.0	225.0	276.0
hyd. radius =	0.25	0.49	0.73	0.96	1.84	2.66	3.43	4.16	4.84
V =	2.98	4.71	6.14	7.40	11.53	14.85	17.71	20.24	22.54
Q =	30	95	188	303	969	1916	3117	4554	6220

CHANNEL WIDTH=	50								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	50.7	51.4	52.1	52.8	55.7	58.5	61.3	64.1	67.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.021	0.021	0.021
flow area =	12.6	25.3	38.1	51.0	104.0	159.0	216.0	275.0	336.0
hyd. radius =	0.25	0.49	0.73	0.97	1.87	2.72	3.52	4.29	5.02
V =	2.98	4.72	6.16	7.43	11.62	15.01	17.94	20.55	22.92
Q =	37	119	234	379	1208	2386	3874	5651	7703

CHANNEL WIDTH=	60								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	60.7	61.4	62.1	62.8	65.7	68.5	71.3	74.1	77.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.021	0.021
flow area =	15.1	30.3	45.6	61.0	124.0	189.0	256.0	325.0	396.0
hyd. radius =	0.25	0.49	0.73	0.97	1.89	2.76	3.59	4.38	5.14
V =	2.99	4.72	6.17	7.45	11.68	15.11	18.10	20.77	23.20
Q =	45	143	281	454	1448	2856	4633	6749	9189

CHANNEL WIDTH=	70								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	70.7	71.4	72.1	72.8	75.7	78.5	81.3	84.1	87.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.021	0.021
flow area =	17.6	35.3	53.1	71.0	144.0	219.0	296.0	375.0	456.0
hyd. radius =	0.25	0.49	0.74	0.97	1.90	2.79	3.64	4.46	5.24
V =	2.99	4.73	6.18	7.46	11.72	15.19	18.22	20.93	23.41
Q =	52	167	328	530	1687	3327	5392	7849	10677

CHANNEL WIDTH=	80								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	80.7	81.4	82.1	82.8	85.7	88.5	91.3	94.1	97.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.021
flow area =	20.1	40.3	60.6	81.0	164.0	249.0	336.0	425.0	516.0
hyd. radius =	0.25	0.49	0.74	0.98	1.91	2.81	3.68	4.51	5.32
V =	2.99	4.73	6.19	7.48	11.75	15.25	18.31	21.06	23.58
Q =	60	190	375	605	1927	3798	6152	8950	12167

S = 1.50%

side slope '*n*' =	0.019
invert '*n*' =	0.022
Average Channel slope	0.0150
Channel side slope =	1.0

CHANNEL WIDTH=	30								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	30.7	31.4	32.1	32.8	35.7	38.5	41.3	44.1	47.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.021	0.021	0.021	0.021
flow area =	7.6	15.3	23.1	31.0	64.0	99.0	136.0	175.0	216.0
hyd. radius =	0.25	0.49	0.72	0.94	1.79	2.57	3.29	3.96	4.60
V =	3.26	5.14	6.69	8.06	12.49	16.01	19.02	21.67	24.06
Q =	25	78	154	250	799	1585	2586	3792	5197

CHANNEL WIDTH=	40								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	40.7	41.4	42.1	42.8	45.7	48.5	51.3	54.1	57.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.021	0.021	0.021	0.021
flow area =	10.1	20.3	30.6	41.0	84.0	129.0	176.0	225.0	276.0
hyd. radius =	0.25	0.49	0.73	0.96	1.84	2.66	3.43	4.16	4.84
V =	3.27	5.16	6.73	8.11	12.63	16.27	19.40	22.17	24.69
Q =	33	104	206	332	1061	2099	3414	4989	6814

CHANNEL WIDTH=	50								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	50.7	51.4	52.1	52.8	55.7	58.5	61.3	64.1	67.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.021	0.021	0.021
flow area =	12.6	25.3	38.1	51.0	104.0	159.0	216.0	275.0	336.0
hyd. radius =	0.25	0.49	0.73	0.97	1.87	2.72	3.52	4.29	5.02
V =	3.27	5.17	6.75	8.14	12.73	16.44	19.65	22.51	25.11
Q =	41	131	257	415	1324	2614	4244	6190	8438

CHANNEL WIDTH=	60								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	60.7	61.4	62.1	62.8	65.7	68.5	71.3	74.1	77.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.021	0.021
flow area =	15.1	30.3	45.6	61.0	124.0	189.0	256.0	325.0	396.0
hyd. radius =	0.25	0.49	0.73	0.97	1.89	2.76	3.59	4.38	5.14
V =	3.27	5.18	6.76	8.16	12.79	16.56	19.82	22.75	25.42
Q =	49	157	308	498	1586	3129	5075	7393	10066

CHANNEL WIDTH=	70								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	70.7	71.4	72.1	72.8	75.7	78.5	81.3	84.1	87.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.021	0.021
flow area =	17.6	35.3	53.1	71.0	144.0	219.0	296.0	375.0	456.0
hyd. radius =	0.25	0.49	0.74	0.97	1.90	2.79	3.64	4.46	5.24
V =	3.27	5.18	6.77	8.18	12.84	16.64	19.95	22.93	25.65
Q =	57	183	359	581	1848	3645	5907	8598	11696

CHANNEL WIDTH=	80								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	80.7	81.4	82.1	82.8	85.7	88.5	91.3	94.1	97.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.021
flow area =	20.1	40.3	60.6	81.0	164.0	249.0	336.0	425.0	516.0
hyd. radius =	0.25	0.49	0.74	0.98	1.91	2.81	3.68	4.51	5.32
V =	3.27	5.18	6.78	8.19	12.87	16.71	20.06	23.07	25.83
Q =	66	209	410	663	2111	4160	6739	9804	13329

S = 1.75%

side slope '*n*' =	0.019
invert '*n*' =	0.022
Average Channel slope	0.0175
Channel side slope =	1.0

CHANNEL WIDTH=	30								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	30.7	31.4	32.1	32.8	35.7	38.5	41.3	44.1	47.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.021	0.021	0.021	0.021
flow area =	7.6	15.3	23.1	31.0	64.0	99.0	136.0	175.0	216.0
hyd. radius =	0.25	0.49	0.72	0.94	1.79	2.57	3.29	3.96	4.60
V =	3.52	5.55	7.23	8.70	13.49	17.30	20.54	23.40	25.99
Q =	27	85	167	270	863	1712	2793	4096	5614

CHANNEL WIDTH=	40								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	40.7	41.4	42.1	42.8	45.7	48.5	51.3	54.1	57.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.021	0.021	0.021	0.021
flow area =	10.1	20.3	30.6	41.0	84.0	129.0	176.0	225.0	276.0
hyd. radius =	0.25	0.49	0.73	0.96	1.84	2.66	3.43	4.16	4.84
V =	3.53	5.57	7.26	8.76	13.65	17.58	20.95	23.95	26.67
Q =	35	113	222	359	1146	2267	3688	5389	7360

CHANNEL WIDTH=	50								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	50.7	51.4	52.1	52.8	55.7	58.5	61.3	64.1	67.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.021	0.021	0.021
flow area =	12.6	25.3	38.1	51.0	104.0	159.0	216.0	275.0	336.0
hyd. radius =	0.25	0.49	0.73	0.97	1.87	2.72	3.52	4.29	5.02
V =	3.53	5.58	7.29	8.79	13.75	17.76	21.22	24.31	27.12
Q =	44	141	277	448	1430	2823	4584	6686	9114

CHANNEL WIDTH=	60								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	60.7	61.4	62.1	62.8	65.7	68.5	71.3	74.1	77.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.021	0.021
flow area =	15.1	30.3	45.6	61.0	124.0	189.0	256.0	325.0	396.0
hyd. radius =	0.25	0.49	0.73	0.97	1.89	2.76	3.59	4.38	5.14
V =	3.53	5.59	7.30	8.82	13.81	17.88	21.41	24.57	27.45
Q =	53	169	333	538	1713	3380	5481	7986	10872

CHANNEL WIDTH=	70								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	70.7	71.4	72.1	72.8	75.7	78.5	81.3	84.1	87.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.021	0.021
flow area =	17.6	35.3	53.1	71.0	144.0	219.0	296.0	375.0	456.0
hyd. radius =	0.25	0.49	0.74	0.97	1.90	2.79	3.64	4.46	5.24
V =	3.54	5.60	7.31	8.83	13.86	17.98	21.55	24.77	27.70
Q =	62	197	388	627	1997	3937	6380	9287	12633

CHANNEL WIDTH=	80								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	80.7	81.4	82.1	82.8	85.7	88.5	91.3	94.1	97.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.021
flow area =	20.1	40.3	60.6	81.0	164.0	249.0	336.0	425.0	516.0
hyd. radius =	0.25	0.49	0.74	0.98	1.91	2.81	3.68	4.51	5.32
V =	3.54	5.60	7.32	8.84	13.90	18.05	21.66	24.92	27.90
Q =	71	225	443	716	2280	4493	7279	10590	14397

S = 2.00%

side slope '*n*' =	0.019
invert '*n*' =	0.022
Average Channel slope	0.0200
Channel side slope =	1.0

CHANNEL WIDTH=	30								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	30.7	31.4	32.1	32.8	35.7	38.5	41.3	44.1	47.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.021	0.021	0.021	0.021
flow area =	7.6	15.3	23.1	31.0	64.0	99.0	136.0	175.0	216.0
hyd. radius =	0.25	0.49	0.72	0.94	1.79	2.57	3.29	3.96	4.60
V =	3.76	5.94	7.73	9.30	14.42	18.49	21.96	25.02	27.78
Q =	28	91	178	288	923	1830	2986	4379	6001

CHANNEL WIDTH=	40								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	40.7	41.4	42.1	42.8	45.7	48.5	51.3	54.1	57.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.021	0.021	0.021	0.021
flow area =	10.1	20.3	30.6	41.0	84.0	129.0	176.0	225.0	276.0
hyd. radius =	0.25	0.49	0.73	0.96	1.84	2.66	3.43	4.16	4.84
V =	3.77	5.96	7.77	9.36	14.59	18.79	22.40	25.60	28.51
Q =	38	121	237	384	1225	2424	3942	5761	7868

CHANNEL WIDTH=	50								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	50.7	51.4	52.1	52.8	55.7	58.5	61.3	64.1	67.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.021	0.021	0.021
flow area =	12.6	25.3	38.1	51.0	104.0	159.0	216.0	275.0	336.0
hyd. radius =	0.25	0.49	0.73	0.97	1.87	2.72	3.52	4.29	5.02
V =	3.78	5.97	7.79	9.40	14.70	18.98	22.69	25.99	29.00
Q =	47	151	296	479	1528	3018	4900	7148	9743

CHANNEL WIDTH=	60								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	60.7	61.4	62.1	62.8	65.7	68.5	71.3	74.1	77.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.021	0.021
flow area =	15.1	30.3	45.6	61.0	124.0	189.0	256.0	325.0	396.0
hyd. radius =	0.25	0.49	0.73	0.97	1.89	2.76	3.59	4.38	5.14
V =	3.78	5.98	7.81	9.42	14.77	19.12	22.89	26.27	29.35
Q =	57	181	356	575	1831	3613	5860	8537	11623

CHANNEL WIDTH=	70								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	70.7	71.4	72.1	72.8	75.7	78.5	81.3	84.1	87.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.021	0.021
flow area =	17.6	35.3	53.1	71.0	144.0	219.0	296.0	375.0	456.0
hyd. radius =	0.25	0.49	0.74	0.97	1.90	2.79	3.64	4.46	5.24
V =	3.78	5.98	7.82	9.44	14.82	19.22	23.04	26.48	29.62
Q =	66	211	415	670	2134	4208	6820	9929	13506

CHANNEL WIDTH=	80								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	80.7	81.4	82.1	82.8	85.7	88.5	91.3	94.1	97.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.021
flow area =	20.1	40.3	60.6	81.0	164.0	249.0	336.0	425.0	516.0
hyd. radius =	0.25	0.49	0.74	0.98	1.91	2.81	3.68	4.51	5.32
V =	3.78	5.99	7.82	9.46	14.86	19.29	23.16	26.64	29.83
Q =	76	241	474	766	2437	4804	7781	11321	15391

S = 2.25%

side slope 'n' =	0.019
invert 'n' =	0.022
Average Channel slope	0.0225
Channel side slope =	1.0

CHANNEL WIDTH=	30								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	30.7	31.4	32.1	32.8	35.7	38.5	41.3	44.1	47.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.021	0.021	0.021	0.021
flow area =	7.6	15.3	23.1	31.0	64.0	99.0	136.0	175.0	216.0
hyd. radius =	0.25	0.49	0.72	0.94	1.79	2.57	3.29	3.96	4.60
V =	3.99	6.30	8.20	9.87	15.29	19.61	23.29	26.54	29.47
Q =	30	96	189	306	979	1942	3168	4644	6366

CHANNEL WIDTH=	40								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	40.7	41.4	42.1	42.8	45.7	48.5	51.3	54.1	57.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.021	0.021	0.021	0.021
flow area =	10.1	20.3	30.6	41.0	84.0	129.0	176.0	225.0	276.0
hyd. radius =	0.25	0.49	0.73	0.96	1.84	2.66	3.43	4.16	4.84
V =	4.00	6.32	8.24	9.93	15.47	19.93	23.76	27.16	30.24
Q =	40	128	252	407	1300	2571	4181	6110	8345

CHANNEL WIDTH=	50								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	50.7	51.4	52.1	52.8	55.7	58.5	61.3	64.1	67.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.021	0.021	0.021
flow area =	12.6	25.3	38.1	51.0	104.0	159.0	216.0	275.0	336.0
hyd. radius =	0.25	0.49	0.73	0.97	1.87	2.72	3.52	4.29	5.02
V =	4.00	6.33	8.26	9.97	15.59	20.13	24.06	27.57	30.76
Q =	50	160	314	508	1621	3201	5198	7581	10334

CHANNEL WIDTH=	60								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	60.7	61.4	62.1	62.8	65.7	68.5	71.3	74.1	77.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.021	0.021
flow area =	15.1	30.3	45.6	61.0	124.0	189.0	256.0	325.0	396.0
hyd. radius =	0.25	0.49	0.73	0.97	1.89	2.76	3.59	4.38	5.14
V =	4.01	6.34	8.28	10.00	15.66	20.28	24.28	27.86	31.13
Q =	60	192	377	610	1942	3832	6215	9055	12328

CHANNEL WIDTH=	70								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	70.7	71.4	72.1	72.8	75.7	78.5	81.3	84.1	87.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.021	0.021
flow area =	17.6	35.3	53.1	71.0	144.0	219.0	296.0	375.0	456.0
hyd. radius =	0.25	0.49	0.74	0.97	1.90	2.79	3.64	4.46	5.24
V =	4.01	6.35	8.29	10.01	15.72	20.38	24.44	28.08	31.41
Q =	70	224	440	711	2264	4464	7234	10531	14325

CHANNEL WIDTH=	80								
DEPTH	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0
wetted perim. =	80.7	81.4	82.1	82.8	85.7	88.5	91.3	94.1	97.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.021
flow area =	20.1	40.3	60.6	81.0	164.0	249.0	336.0	425.0	516.0
hyd. radius =	0.25	0.49	0.74	0.98	1.91	2.81	3.68	4.51	5.32
V =	4.01	6.35	8.30	10.03	15.76	20.46	24.56	28.25	31.64
Q =	80	256	503	812	2585	5095	8253	12008	16324

S = 2.50%

side slope '*n*' =	0.019
invert '*n*' =	0.022
Average Channel slope	0.0250
Channel side slope =	1.0

CHANNEL WIDTH=	30								
DEPTH	**0.25**	**0.50**	**0.75**	**1.0**	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**
wetted perim. =	30.7	31.4	32.1	32.8	35.7	38.5	41.3	44.1	47.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.021	0.021	0.021	0.021
flow area =	7.6	15.3	23.1	31.0	64.0	99.0	136.0	175.0	216.0
hyd. radius =	0.25	0.49	0.72	0.94	1.79	2.57	3.29	3.96	4.60
V =	4.21	6.64	8.64	10.40	16.12	20.67	24.55	27.97	31.06
Q =	**32**	**101**	**199**	**322**	**1032**	**2047**	**3339**	**4895**	**6710**

CHANNEL WIDTH=	40								
DEPTH	**0.25**	**0.50**	**0.75**	**1.0**	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**
wetted perim. =	40.7	41.4	42.1	42.8	45.7	48.5	51.3	54.1	57.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.021	0.021	0.021	0.021
flow area =	10.1	20.3	30.6	41.0	84.0	129.0	176.0	225.0	276.0
hyd. radius =	0.25	0.49	0.73	0.96	1.84	2.66	3.43	4.16	4.84
V =	4.22	6.66	8.68	10.47	16.31	21.01	25.04	28.63	31.87
Q =	**42**	**135**	**265**	**429**	**1370**	**2710**	**4407**	**6441**	**8797**

CHANNEL WIDTH=	50								
DEPTH	**0.25**	**0.50**	**0.75**	**1.0**	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**
wetted perim. =	50.7	51.4	52.1	52.8	55.7	58.5	61.3	64.1	67.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.021	0.021	0.021
flow area =	12.6	25.3	38.1	51.0	104.0	159.0	216.0	275.0	336.0
hyd. radius =	0.25	0.49	0.73	0.97	1.87	2.72	3.52	4.29	5.02
V =	4.22	6.67	8.71	10.51	16.43	21.22	25.36	29.06	32.42
Q =	**53**	**168**	**331**	**536**	**1709**	**3374**	**5479**	**7991**	**10893**

CHANNEL WIDTH=	60								
DEPTH	**0.25**	**0.50**	**0.75**	**1.0**	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**
wetted perim. =	60.7	61.4	62.1	62.8	65.7	68.5	71.3	74.1	77.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.021	0.021
flow area =	15.1	30.3	45.6	61.0	124.0	189.0	256.0	325.0	396.0
hyd. radius =	0.25	0.49	0.73	0.97	1.89	2.76	3.59	4.38	5.14
V =	4.22	6.68	8.73	10.54	16.51	21.37	25.59	29.37	32.81
Q =	**64**	**202**	**398**	**643**	**2047**	**4040**	**6552**	**9545**	**12995**

CHANNEL WIDTH=	70								
DEPTH	**0.25**	**0.50**	**0.75**	**1.0**	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**
wetted perim. =	70.7	71.4	72.1	72.8	75.7	78.5	81.3	84.1	87.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.021	0.021
flow area =	17.6	35.3	53.1	71.0	144.0	219.0	296.0	375.0	456.0
hyd. radius =	0.25	0.49	0.74	0.97	1.90	2.79	3.64	4.46	5.24
V =	4.23	6.69	8.74	10.56	16.57	21.48	25.76	29.60	33.11
Q =	**74**	**236**	**464**	**749**	**2386**	**4705**	**7625**	**11101**	**15100**

CHANNEL WIDTH=	80								
DEPTH	**0.25**	**0.50**	**0.75**	**1.0**	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**
wetted perim. =	80.7	81.4	82.1	82.8	85.7	88.5	91.3	94.1	97.0
weighted n =	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.021
flow area =	20.1	40.3	60.6	81.0	164.0	249.0	336.0	425.0	516.0
hyd. radius =	0.25	0.49	0.74	0.98	1.91	2.81	3.68	4.51	5.32
V =	4.23	6.69	8.75	10.57	16.62	21.57	25.89	29.78	33.35
Q =	**85**	**269**	**530**	**856**	**2725**	**5371**	**8700**	**12657**	**17207**

Appendix D

Cost Estimates

JOB NUMBER: E10060102
LOCATION: SCOTTSDALE, AZ
CLIENT: CITY OF SCOTTSDALE

		PIMA CHANNEL				PIMA CHANNEL w/ UNION HILLS DB				DIFFERENCE
ITEM NUMBER	DESCRIPTION	BID QUANTITY	UNIT	UNIT PRICE	TOTAL PRICE	BID QUANTITY	UNIT	UNIT PRICE	TOTAL PRICE	BID QUANTITY
104150	PROJECT SIGNAGE	1	LS	$ 77,000.00	$ 77,000	1	LS	$ 77,000.00	$ 77,000	-
105801	CONSTRUCTION SURVEY AND "AS-BUILTS"	1	LS	$ 29,000.00	$ 29,000	1	LS	$ 29,000.00	$ 29,000	$ -
202801	MOBILIZATION	1	LS	$ 58,000.00	$ 58,000	1	LS	$ 58,000.00	$ 58,000	-
205001	ROADWAY EXCAVATION (SHORT HAUL)	178,741	CY	$ 2.00	$ 357,482	5,731	CY	$ 2.00	$ 11,462	$ (346,020)
206001	STRUCTURAL EXCAVATION (SANDY GRAVEL)	543,483	CY	$ 3.00	$ 1,630,449	358,142	CY	$ 3.00	$ 1,074,425	$ (556,024)
211001	COMPACTED BACKFILL	7,246	CY	$ 4.00	$ 28,984	8,190	CY	$ 4.00	$ 32,760	3,776
220802	8" REINFORCED CONCRETE LINING	1,995,099	SF	$ 6.00	$ 11,970,594	1,994,031	SF	$ 6.00	$ 11,964,185	$ (6,409)
220810	TURF LANDSCAPING AND IRRIGATION	34,679	SY	$ 9.00	$ 312,111					$ (312,111)
220811	GEOSYNTHETIC REINFORCEMENT	29,467	SY	$ 7.00	$ 206,269					$ (206,269)
220812	GRADE CONTROL STRUCTURES	9	EA	$ 12,588.00	$ 113,292	7	EA	$ 12,588.00	$ 88,116	$ (25,176)
340214	MULTI-USE CONCRETE PATH	20,550	LF	$ 15.00	$ 308,250	20,550	LF	$ 15.00	$ 308,250	-
340405	MAINTENANCE ROAD/TRAIL ACCESS	6	EA	$ 20,000.00	$ 120,000	6	EA	$ 20,000.00	$ 120,000	-
430801	HORSE TRAIL	20,550	LF	$ 0.25	$ 5,138	20,550	LF	$ 0.25	$ 5,138	-
430802	REVEGETATION	844,500	SF	$ 1.00	$ 844,500	837,000	SF	$ 1.00	$ 837,000	$ (7,500)
430803	SALVAGE	3,856,567	SF	$ 0.50	$ 1,928,284	2,630,500	SF	$ 0.50	$ 1,315,250	$ (613,034)
430804	AESTHETIC TREATMENT	1.00	LS	$ 3,777,383.00	$ 3,777,383	0.81	LS	$ 3,777,383.00	$ 3,075,869	$ (701,514)
621072	72" RGRCP STORM DRAIN					4,400	LF	$ 160.00	$ 704,000	$ 704,000
631001	STEEL FENCING	70,000	LF	$ 35.00	$ 2,450,000	55,800	LF	$ 35.00	$ 1,953,000	$ (497,000)
650101	BELL ROAD BRIDGE	1	LS	$ 641,831.00	$ 641,831					$ (641,831)
650102	SOUTH PIMA ROAD BRIDGE	1	LS	$ 793,234.00	$ 793,234					$ (793,234)
650103	UNION HILLS ROAD BRIDGE	1	LS	$ 253,656.00	$ 253,656	1	LS	$ 253,656.00	$ 253,656	-
650104	THOMPSON PEAK PARKWAY BRIDGE	1	LS	$ 273,270.00	$ 273,270	1	LS	$ 273,270.00	$ 273,270	-
650105	NORTH PIMA ROAD BRIDGE	1	LS	$ 969,117.00	$ 969,117	1	LS	$ 969,117.00	$ 969,117	-
650106	PHASE II BRIDGES[4]	28,854	SF	$ 45.00	$ 1,298,409	28,854	SF	$ 45.00	$ 1,298,409	-
660101	UTILITY RELOCATIONS	1	LS	$ 705,855.00	$ 705,855	1	LS	$ 705,855.00	$ 705,855	-
660201	ROADWAY CROSSINGS	1	LS	$ 399,997.00	$ 399,997	1	LS	$ 399,997.00	$ 399,997	-
700000	UNION HILLS DETENTION BASIN					1	LS	$ 9,212,421.00	$ 9,212,421	$ 9,212,421
	SUBTOTAL				**$ 29,552,104**				**$ 34,766,180**	**$ 5,214,076**
										-
900000	CONTINGENCY (EXCLUDING R/W)	15	PCT	$ 29,552,104	$ 4,432,816	15	PCT	$ 34,766,180	$ 5,214,927	$ 782,111
900001	ENGINEERING (EXCLUDING R/W)	10	PCT	$ 29,552,104	$ 2,955,210	10	PCT	$ 34,766,180	$ 3,476,618	$ 521,408
800000	RIGHT-OF-WAY (PURCHASE/PERIMETER CENTER)	3.90	AC	$ 348,480.00	$ 1,360,000	1.38	AC	$ 348,480.00	$ 480,000	$ (880,000)
800100	RIGHT-OF-WAY (PURCHASE EASEMENT)	5.27	AC	$ 32,000.00	$ 168,595	54.86	AC	$ 32,000.00	$ 1,755,504	$ 1,586,909
800100	RIGHT-OF-WAY (LEASE ACREAGE)	59.71	AC	$ 6,500.00	$ 388,120	54.57	AC	$ 6,500.00	$ 354,732	$ (33,388)
										-
	TOTAL ESTIMATED COST				**$ 38,856,845**				**$ 46,047,961**	**$ 7,191,116**
										-

Notes:

1. Unit costs provided by the Flood Control District have been used
2. Right-of-way costs based on recent land sales in the area
3. Quantities for the detention basin calculated separately
4. Phase II bridge costs from Greiner's 10-percent Study Phase

Union Hills Detention Basin for Channel Alternative

#	Sub #	Description	Quantity	Unit	Unit Cost $	Total $
A		**Detention Basin Construction**				
	1	Clear & Grub	50	AC	1,600.00	$ 80,000
	2	Prewetting Operation				
	a	Develop water supply	1	LS	40,000.00	40,000
	b	Water for embankments	-	MGA	2.00	-
	3	Excavation (short haul)				
		Embankment	-	CY	1.60	-
		Short Haul (to ADOT)	1,200,000	CY	2.00	2,400,000
		Export	885,717	CY	3.00	2,657,151
	4	Finish Grading	246,840	SY	0.25	61,710
	5	Slope protection (Dumped Riprap w/geotext)	10,000	SY	25.00	250,000
B		**Earth Dam Embankment Construction**				
	1	Earth Embankment Construction				
	a	Soil cement core	-	CY	30.00	-
	b	Spread fill & compaction	-	CY	2.75	-
	c	Finish grading	-	SY	0.25	-
C		**Spillway**				
	1	300 LF soil cement cutoff wall (see B1a)				
	2	Low Flow Outlet - 66" RGRCP	2,900	LF	140.00	406,000
D		**Downstream Improvements - Spillway**				
		Soil Cement	-	CY	30.00	-
		Excavation	-	CY	2.00	-
		Salvage	-	SF	0.50	-
	1	Revegetation	-	SF	1.00	-
E		**Site Development and Landscaping**				
	1	Landscaping				
	a	Salvage	50	AC	21,780.00	1,089,000
	b	Exterior slopes	-	AC	43,560.00	-
	c	Basin revegetation	51	AC	43,560.00	2,221,560
	2	Archaeological Site Investigation	1	LS	7,000.00	7,000
		SUBTOTAL				$ 9,212,421
F						
		10% Overhead, bonds & insurance	10	PCT		313,230.00
		TOTAL				$ 9,525,651

Notes

1. Unit costs provided by the Flood Control District have been used
2. Right-of-way costs based on PACE submittal and Greiner 10% Cost Estimate
3. Most quantities for the Detention Basins are based on the PACE submittals
4. Shaded areas represent adjustments to the 1/29/96 Meeting attachments

Estimate F = 0.85 Scement Lined
Soil Cement Lining
8-ft Wide Side Slopes
2-ft Thick Invert

5/8/96

Pima Road Detention Basin

JOB NUMBER: E060102
LOCATION: SCOTTSDALE, AZ
CLIENT: CITY OF SCOTTSDALE

Item #	Sub-item #	Description	Quantity	Unit	Unit Cost $	Total $
J2-0101		Channel Excavation	453,552	CY	$ 2.00	$ 907,104
J2-0208		Shotcrete	-	SF	6.00	0
J2-0210		Soil Cement	194,533	CY	30.00	5,836,000
J2-0216		Concrete Stilling Basins (Drop) Structures	152	EA	17,860.00	2,714,720
J2-0401		Multi-use Concrete Path	27,850	LF	15.00	417,750
J2-0402		Signage	1	LS	75,000.00	75,000
J2-0403		Horse Trail	27,850	LF	0.25	6,963
J2-0501		Revegetation	271,000	SF	1.00	271,000
J2-0502		Salvage Vegetation	2,411,000	SF	0.50	1,205,500
J2-0701		Concrete Box Culverts	10	EA	37,000.00	370,000
J2-1002		Pedestrian & Equestrian Undercrossings	7	EA	200,000.00	1,400,000
J2-1201		Utility Relocation (Drop Existing Line)	7	EA	15,000.00	105,000
J2-1202		Utility Relocation (Drop Stubout)	8	EA	2,000.00	16,000
		72" RGRCP	4,735	LF	160.00	757,600
		Pipe Rail Fencing	**50,000**	**LF**	**12.00**	**600,000**
		Collector Channels				
	a	Happy Valley	-	LS	240,000.00	0
	b	Deer Valley	-	LS	75,000.00	0
	a	Happy Valley Road Dam/detention	1	LS	4,529,741.00	4,529,741
	b	Deer Valley Road Dam/detention	1	LS	6,038,089.55	6,038,090
	c	Union Hills Dam/detention	1	LS	8,295,074.03	8,295,074
		SUBTOTAL				$ 33,545,541
J2-7000		Engineering (10 %)				3,354,554
J2-9000		Contingency (15%)				5,031,831
J2-8000		Right-of-way (Purchase)	**110.74**	AC	32,000.00	**3,543,680**
J2-8001		Right-of-way (Lease)	**54.57**	AC	6,500.00	**354,705**
J2-6000		Aesthetic Treatment (10% of original value)	1	LS	755,000.00	755,000
		TOTAL ESTIMATED COST				**$ 46,585,311**

Notes

1. Unit costs provided by the Flood Control District have been used
2. Right-of-way costs based on recent land sales in the area
3. Quantities for the Detention Basins are based on the "Deep" Basin Option
4. Shaded areas represent adjustments to the 2/12/96 Meeting attachments

Estimate F = 0.85 Lined
Shotcrete Lining
8-in Thick with #5 Reinforcement

5/8/96

Pima Road Detention Basin

JOB NUMBER: E060102
LOCATION: SCOTTSDALE, AZ
CLIENT: CITY OF SCOTTSDALE

Item #	Sub-item #	Description	Quantity	Unit	Unit Cost $	Total $
J2-0101		Channel Excavation	302,490	CY	$ 2.00	$ 604,980
J2-0208		Shotcrete	1,602,321	SF	6.00	9,613,923
J2-0210		Soil Cement	-	CY	30.00	0
J2-0216		Concrete Stilling Basin (Drop) Structures	152	EA	17,860.00	2,714,720
J2-0401		Multi-use Concrete Path	27,850	LF	15.00	417,750
J2-0402		Signage	1	LS	75,000.00	75,000
J2-0403		Horse Trail	27,850	LF	0.25	6,963
J2-0501		Revegetation	271,000	SF	1.00	271,000
J2-0502		Salvage Vegetation	1,761,400	SF	0.50	880,700
J2-0701		Concrete Box Culverts	10	EA	37,000.00	370,000
J2-1002		Pedestrian & Equestrian Undercrossings	7	EA	200,000.00	1,400,000
J2-1201		Utility Relocation (Drop Existing Line)	7	EA	15,000.00	105,000
J2-1202		Utility Relocation (Drop Stubout)	8	EA	2,000.00	16,000
		72" RGRCP	4,735	LF	160.00	757,600
		Pipe Rail Fencing	**50,000**	**LF**	**12.00**	**600,000**
		Collector Channels				
	a	Happy Valley	-	LS	240,000.00	0
	b	Deer Valley	-	LS	75,000.00	0
	a	Happy Valley Road Dam/detention	1	LS	4,529,741.00	4,529,741
	b	Deer Valley Road Dam/detention	1	LS	6,038,089.55	6,038,090
	c	Union Hills Dam/detention	1	LS	8,295,074.03	8,295,074
		SUBTOTAL				$ 36,696,540
J2-7000		Engineering (10 %)				3,669,654
J2-9000		Contingency (15%)				5,504,481
J2-8000		Right-of-way (Purchase)	**110.74**	AC	32,000.00	**3,543,680**
J2-8001		Right-of-way (Lease)	**54.57**	AC	6,500.00	**354,705**
J2-6000		Aesthetic Treatment (10% of original value)	1	LS	755,000.00	755,000
		TOTAL ESTIMATED COST				**$ 50,524,060**

Notes

1. Unit costs provided by the Flood Control District have been used
2. Right-of-way costs based on recent land sales in the area
3. Quantities for the Detention Basins are based on the "Deep" Basin Option
4. Shaded areas represent adjustments to the 2/12/96 Meeting attachments

Estimate F = 1.45
Shotcrete Lined
8-in Thick with #5 Reinforcement

5/8/96

Pima Road Detention Basin

JOB NUMBER: E060102
LOCATION: SCOTTSDALE, AZ
CLIENT: CITY OF SCOTTSDALE

Item #	Sub-item #	Description	Quantity	Unit	Unit Cost $	Total $
J2-0101		Channel Excavation	255,883	CY	$ 2.00	$ 511,766
J2-0208		Shotcrete	1,601,508	SF	6.00	9,609,046
J2-0210		Soil Cement	-	CY	30.00	0
J2-0216		Concrete Stilling Basin (Drop) Structures	105	EA	17,250.00	1,811,250
J2-0401		Multi-use Concrete Path	27,850	LF	15.00	417,750
J2-0402		Signage	1	LS	75,000.00	75,000
J2-0403		Horse Trail	27,850	LF	0.25	6,963
J2-0501		Revegetation	271,000	SF	1.00	271,000
J2-0502		Salvage Vegetation	1,722,500	SF	0.50	861,250
J2-0701		Concrete Box Culverts	10	EA	37,000.00	370,000
J2-1002		Pedestrian & Equestrian Undercrossings	7	EA	200,000.00	1,400,000
J2-1201		Utility Relocation (Drop Existing Line)	7	EA	15,000.00	105,000
J2-1202		Utility Relocation (Drop Stubout)	8	EA	2,000.00	16,000
		72" RGRCP	4,735	LF	160.00	757,600
		Pipe Rail Fencing	**50,000**	**LF**	**12.00**	**600,000**
		Collector Channels				
	a	Happy Valley	-	LS	240,000.00	0
	b	Deer Valley	-	LS	75,000.00	0
	a	Happy Valley Road Dam/detention	1	LS	4,529,741.00	4,529,741
	b	Deer Valley Road Dam/detention	1	LS	6,038,089.55	6,038,090
	c	Union Hills Dam/detention	1	LS	8,295,074.03	8,295,074
		SUBTOTAL				$ 35,675,529
J2-7000		Engineering (10 %)				3,567,553
J2-9000		Contingency (15%)				5,351,329
J2-8000		Right-of-way (Purchase)	**110.74**	AC	32,000.00	**3,543,680**
J2-8001		Right-of-way (Lease)	**54.57**	AC	6,500.00	**354,705**
J2-6000		Aesthetic Treatment (10% of original value)	1	LS	755,000.00	755,000
		TOTAL ESTIMATED COST				**$ 49,247,796**

Notes

1. Unit costs provided by the Flood Control District have been used
2. Right-of-way costs based on recent land sales in the area
3. Quantities for the Detention Basins are based on the "Deep" Basin Option
4. Shaded areas represent adjustments to the 2/12/96 Meeting attachments

Happy Valley Detention Basin for Basin Alternatives

#	Sub #	Description	Quantity	Unit	Unit Cost $	Total $
A		**Detention Basin Construction**				
	1	Clear & Grub	22	AC	1,600.00	$ 35,200
	2	Prewetting Operation				
	a	Develop water supply	1	LS	40,000.00	40,000
	b	Water for embankments	-	MGA	2.00	-
	3	Excavation (short haul)				
		Embankment	-	CY	1.60	-
		Short Haul (to ADOT)	-	CY	2.00	-
		Export	**951,273**	CY	3.00	**2,853,819**
	4	Finish Grading	108,900	SY	0.25	27,225
	5	Slope protection (Dumped Riprap w/geotext)	10,000	SY	25.00	250,000
B		**Earth Dam Embankment Construction**				
	1	Earth Embankment Construction				
	a	Soil cement core	-	CY	30.00	-
	b	Spread fill & compaction	-	CY	2.75	-
	c	Finish grading	-	SY	0.25	-
C		**Spillway**				
	1	300 LF soil cement cutoff wall (see B1a)				
	2	Low Flow Outlet - 48" RGRCP	1,065	LF	80.00	85,200
D		**Downstream Improvements - Spillway**				
		Soil Cement	2,876	CY	30.00	86,280
		Excavation	1,406	CY	2.00	2,812
		Salvage	52,350	SF	0.50	26,175
	1	Revegetation	29,370	SF	1.00	29,370
E		**Site Development and Landscaping**				
	1	Landscaping				
	a	Salvage	22	AC	21,780.00	479,160
	b	Exterior slopes	-	AC	43,560.00	-
	c	Basin revegetation	23	AC	27,000.00	607,500
	2	Archaeological Site Investigation	1	LS	7,000.00	7,000
		SUBTOTAL				**$ 4,529,741**
F						
		10% Overhead, bonds & insurance	10	PCT		313,230.00
		TOTAL				**$ 4,842,971**

Notes

1. Unit costs provided by the Flood Control District have been used
2. Right-of-way costs based on PACE submittal and Greiner 10% Cost Estimate
3. Most quantities for the Detention Basins are based on the PACE submittals
4. Shaded areas represent adjustments to the 1/29/96 Meeting attachments

Deer Valley Detention Basin for Basin Alternatives

#	Sub #	Description	Quantity	Unit	Unit Cost $	Total $
A		**Detention Basin Construction**				
	1	Clear & Grub	27	AC	1,600.00	$ 43,200
	2	Prewetting Operation				
	a	Develop water supply	1	LS	40,000.00	40,000
	b	Water for embankments	-	MGA	2.00	-
	3	Excavation (short haul)				
		Embankment	-	CY	1.60	-
		Short Haul (to ADOT)	-	CY	2.00	-
		Export	**1,352,413**	CY	3.00	**4,057,239**
	4	Finish Grading	141,126	SY	0.25	35,281
	5	Slope protection (Dumped Riprap w/geotext)	10,000	SY	25.00	250,000
B		**Earth Dam Embankment Construction**				
	1	Earth Embankment Construction				
	a	Soil cement core	-	CY	30.00	-
	b	Spread fill & compaction	-	CY	2.75	-
	c	Finish grading	-	SY	0.25	-
C		**Spillway**				
	1	300 LF soil cement cutoff wall (see B1a)				
	2	Low Flow Outlet - 60" RGRCP	1,000	LF	120.00	120,000
D		**Downstream Improvements - Spillway**				
		Soil Cement	1,927	CY	30.00	57,810
		Excavation	536	CY	2.00	1,072
		Salvage	47,233	SF	0.50	23,617
	1	Revegetation	27,540	SF	1.00	27,540
E		**Site Development and Landscaping**				
	1	Landscaping				
	a	Salvage	27	AC	21,780.00	588,060
	b	Exterior slopes	-	AC	43,560.00	-
	c	Basin revegetation	29	AC	27,000.00	787,271
	2	Archaeological Site Investigation	1	LS	7,000.00	7,000
		SUBTOTAL				**$ 6,038,090**
F						
		10% Overhead, bonds & insurance	10	PCT		313,230.00
		TOTAL				**$ 6,351,320**

Notes

1. Unit costs provided by the Flood Control District have been used
2. Right-of-way costs based on PACE submittal and Greiner 10% Cost Estimate
3. Most quantities for the Detention Basins are based on the PACE submittals
4. Shaded areas represent adjustments to the 1/29/96 Meeting attachments

Union Hills Detention Basin for Basin Alternatives

#	Sub #	Description	Quantity	Unit	Unit Cost $	Total $
A		**Detention Basin Construction**				
	1	Clear & Grub	50	AC	1,600.00	$ 80,000
	2	Prewetting Operation				
	a	Develop water supply	1	LS	40,000.00	40,000
	b	Water for embankments	-	MGA	2.00	-
	3	Excavation (short haul)				
		Embankment	-	CY	1.60	-
		Short Haul (to ADOT)	1,200,000	CY	2.00	2,400,000
		Export	**910,522**	CY	3.00	**2,731,566**
	4	Finish Grading	244,733	SY	0.25	61,183
	5	Slope protection (Dumped Riprap w/geotext)	10,000	SY	25.00	250,000
B		**Earth Dam Embankment Construction**				
	1	Earth Embankment Construction				
	a	Soil cement core	-	CY	30.00	-
	b	Spread fill & compaction	-	CY	2.75	-
	c	Finish grading	-	SY	0.25	-
C		**Spillway**				
	1	300 LF soil cement cutoff wall (see B1a)				
	2	Low Flow Outlet - 60" RGRCP	2,259	LF	120.00	271,080
D		**Downstream Improvements - Spillway**				
		Soil Cement	-	CY	30.00	-
		Excavation	-	CY	2.00	-
		Salvage	-	SF	0.50	-
	1	Revegetation	-	SF	1.00	-
E		**Site Development and Landscaping**				
	1	Landscaping				
	a	Salvage	50	AC	21,780.00	1,089,000
	b	Exterior slopes	-	AC	43,560.00	-
	c	Basin revegetation	51	AC	27,000.00	1,365,245
	2	Archaeological Site Investigation	1	LS	7,000.00	7,000
		SUBTOTAL				**$ 8,295,074**
F						
		10% Overhead, bonds & insurance	10	PCT		313,230.00
		TOTAL				**$ 8,608,304**

Notes

1. Unit costs provided by the Flood Control District have been used
2. Right-of-way costs based on PACE submittal and Greiner 10% Cost Estimate
3. Most quantities for the Detention Basins are based on the PACE submittals
4. Shaded areas represent adjustments to the 1/29/96 Meeting attachments

Study Phase Right - of - Way

THE DESERT GREENBELT
CITY OF SCOTTSDALE
Right-of-Way
PIMA ROAD CHANNEL

SUMMARY

Date: 08-May-96

Project No.: E0601.15

STATUS	OWNER	PARCEL	STATION	TO	STATION	LENGTH	x	WIDTH	=	TOTAL	DONATE ACREAGE	LEASE ACREAGE	PURCHASE ACREAGE
DONATE	BUREAU OF RECLAMATION	215 - 50 - 002A	0+00	TO	10+00	1,000.00	x	0.00	=	0.00 SF	0.0000 AC	0.0000 AC	0.0000 AC
DONATE	CITY OF SCOTTSDALE	215 - 50 - 004G	10+00	TO	16+50	650.00	x	60.00	=	39,000.00 SF	0.8953 AC	0.0000 AC	0.0000 AC
PURCHASE	PRIVATE	215 - 50 - 004F	16+50	TO	30+00	1,350.00	x	60.00	=	81,000.00 SF	0.0000 AC	0.0000 AC	1.8595 AC
PURCHASE	PERIMETER CENTER	215 - 50 - 001B	30+00	TO	40+00	1,000.00	x	60.00	=	60,000.00 SF	0.0000 AC	0.0000 AC	1.3774 AC
LEASE	STATE LAND	215 - 50 - 021	40+00	TO	48+50	850.00	x	60.00	=	51,000.00 SF	0.0000 AC	1.1708 AC	0.0000 AC
LEASE	STATE LAND	216 - 50 - 019	48+50	TO	75+00	2,650.00	x	60.00	=	159,000.00 SF	0.0000 AC	3.6501 AC	0.0000 AC
DONATE	COS WATER CAMPUS	212 - 31 - 056	75+00	TO	82+00 ***	700.00	x	250.00	=	175,000.00 SF	4.0174 AC	0.0000 AC	0.0000 AC
DONATE	COS WATER CAMPUS	212 - 31 - 056	92+75	TO	115+00	2,225.00	x	250.00	=	556,250.00 SF	12.7697 AC	0.0000 AC	0.0000 AC
LEASE	STATE LAND	212 - 31 - 108	115+00	TO	120+25	525.00	x	250.00	=	131,250.00 SF	0.0000 AC	3.0131 AC	0.0000 AC
DONATE	GRAYHAWK	212 - 31 - 103	120+25	TO	162+00	4,175.00	x	250.00	=	1,043,750.00 SF	23.9612 AC	0.0000 AC	0.0000 AC
LEASE	STATE LAND	212 - 31 - 084	162+00	TO	167+00	500.00	x	250.00	=	125,000.00 SF	0.0000 AC	2.8696 AC	0.0000 AC
DONATE	GRAYHAWK	213 - 31 - 096	167+00	TO	189+88	2,288.00	x	250.00	=	572,000.00 SF	13.1313 AC	0.0000 AC	0.0000 AC
DONATE	DC RANCH	217 - 07 - 009	189+88	TO	193+00	312.00	x	150.00	=	46,800.00 SF	1.0744 AC	0.0000 AC	0.0000 AC
LEASE	STATE LAND	###	193+00	TO	219+40	2,640.00	x	150.00	=	396,000.00 SF	0.0000 AC	9.0909 AC	0.0000 AC
DONATE	MONTEREY HOMES	2A	219+40	TO	232+60	1,320.00	x	150.00	=	198,000.00 SF	4.5455 AC	0.0000 AC	0.0000 AC
DONATE	HEYLCORP	4	232+60	TO	245+80	1,320.00	x	150.00	=	198,000.00 SF	4.5455 AC	0.0000 AC	0.0000 AC
DONATE	NELSON	3	245+80	TO	259+00	1,320.00	x	150.00	=	198,000.00 SF	4.5455 AC	0.0000 AC	0.0000 AC
LEASE	STATE LAND	###	259+00	TO	299+00	4,000.00	x	150.00	=	600,000.00 SF	0.0000 AC	13.7741 AC	0.0000 AC
LEASE	STATE LAND	###	299+00	TO	360+00	6,100.00	x	150.00	=	915,000.00 SF	0.0000 AC	21.0055 AC	0.0000 AC
PURCHASE	STATE LAND	###	HAPPY VALLEY DB							1,045,440.00 SF	0.0000 AC	0.0000 AC	24.0000 AC
PURCHASE	STATE LAND	###	DEER VALLEY DB							1,328,580.00 SF	0.0000 AC	0.0000 AC	30.5000 AC
PURCHASE	STATE LAND	###	UNION HILLS DB							2,308,680.00 SF	0.0000 AC	0.0000 AC	53.0000 AC
	SUBTOTAL ACREAGE									10,227,750.00 SF	69.4858 AC	54.5742 AC	110.7369 AC
	GRAND TOTAL ACREAGE											Total	234.7968 AC

PACE Cost Estimate
Latest Cost Estimate for Basin Alternative

Item #	Sub-item #	Description	Quantity	Unit	Unit Cost $	Total $
J2-0101		Channel Excavation	260,628	CY	$ 2.00	$ 521,256
J2-0208		Concrete	1,100	SF	16.00	17,600
J2-0210		Soil Cement	64,641	CY	30.00	1,939,230
J2-0216		Grade Control (Drop) Structures	39	EA	11,600.00	454,720
J2-0401		Multi-use Concrete Path	15,596	LF	15.00	233,940
J2-0402		Signage	0.56	LS	75,000.00	42,000
J2-0403		Horse Trail	15,596	LF	0.25	3,899
J2-0501		Revegetation	971,477	LF	1.00	971,477
J2-0502		Salvage Vegetation	1,561,045	LF	0.50	780,522
J2-0701		Concrete Box Culverts	6	EA	37,000.00	222,000
J2-1002		Pedestrian & Equestrian Undercrossings	4	EA	150,000.00	600,000
J2-1201		Utility Relocation (Drop Existing Line)	7	EA	15,000.00	105,000
J2-1202		Utility Relocation (Drop Stubout)	8	EA	2,000.00	16,000
		Collector Channels				
	a	Happy Valley	1	LS	240,000.00	240,000
	b	Deer Valley	1	LS	75,000.00	75,000
	a	Happy Valley Road Dam/detention	1	LS	4,661,610.00	4,661,610
	b	Deer Valley Road Dam/detention	1	LS	4,013,719.00	4,013,719
	c	Union Hills Dam/detention	1	LS	5,358,813.00	5,358,813
		SUBTOTAL				**$ 20,256,787**
J2-7000		Engineering (10 %)				2,025,679
J2-9000		Contingency (15%)				3,038,518
J2-8000		Right-of-way (Purchase)	59.37	AC	25,000.00	1,484,250
J2-8001		Right-of-way (Lease)	15.00	AC	5,000.00	75,000
J2-6000		Aesthetic Treatment (10% of original value)	1	LS	755,000.00	755,000
		TOTAL ESTIMATED COST				**$ 27,635,233**

Notes

1. Unit costs provided by the Flood Control District have been used
2. Right-of-way costs based on PACE submittal and Greiner 10% Cost Estimate
3. Most quantities for the Detention Basins are based on the PACE submittals

PACE Estimates

Happy Valley Detention Basin for Basin Alternatives

#	Sub #	Description	Quantity	Unit	Unit Cost $	Total $
A		**Detention Basin Construction**				
	1	Clear & Grub	25	AC	1,600.00	$ 40,000
	2	Prewetting Operation				
	a	Develop water supply	1	LS	40,000.00	40,000
	b	Water for embankments	250	MGA	2.00	500
	3	Excavation (short haul)				
		Embankment	50,000	CY	1.60	80,000
		Short Haul (to ADOT)	-	CY	2.00	-
		Export	600,000	CY	3.00	1,800,000
	4	Finish Grading	50,000	SY	0.25	12,500
	5	Slope protection (Dumped Riprap w/geotext)	10,000	SY	25.00	250,000
B		**Earth Dam Embankment Construction**				
	1	Earth Embankment Construction				
	a	Soil cement core	18,000	CY	30.00	540,000
	b	Spread fill & compaction	50,000	CY	2.75	137,500
	c	Finish grading	30,000	SY	0.25	7,500
C		**Spillway**				
	1	300 LF soil cement cutoff wall (see B1a)				
	2	Low Flow Outlet - 36" RCP	1,200	LF	75.00	90,000
D		**Downstream Improvements**				
		Downstream Improvements	1	LS	15,000.00	15000
	1	Reno Mattress	5,216	SF	5.00	26,080
E		**Site Development and Landscaping**				
	1	Landscaping				
	a	Salvage	25	AC	21,780.00	544,500
	b	Exterior slopes	5	AC	43,560.00	217,800
	c	Basin revegetation	20	AC	27,000.00	540,000
	2	Archaeological Site Investigation	1	LS	7,000.00	7,000
		SUBTOTAL				$ 4,348,380
F						
		10% Overhead, bonds & insurance	10	PCT		313,230.00
		TOTAL				$ 4,661,610

Notes

1. Unit costs provided by the Flood Control District have been used
2. Right-of-way costs based on PACE submittal and Greiner 10% Cost Estimate
3. Most quantities for the Detention Basins are based on the PACE submittals

PACE Estimates

Deer Valley Detention Basin for Basin Alternatives

#	Sub #	Description	Quantity	Unit	Unit Cost $	Total $
A		**Detention Basin Construction**				
	1	Clear & Grub	23	AC	1,600.00	$ 36,800
	2	Prewetting Operation				
	a	Develop water supply	1	LS	40,000.00	40,000
	b	Water for embankments	500	MGA	2.00	1,000
	3	Excavation (short haul)				
		Embankment	115,000	CY	1.60	184,000
		Short Haul (to ADOT)	485,000	CY	2.00	970,000
		Export	-	CY	3.00	-
	4	Finish Grading	55,000	SY	0.25	13,750
	5	Slope protection (Dumped Riprap w/geotext)	10,000	SY	25.00	250,000
B		**Earth Dam Embankment Construction**				
	1	Earth Embankment Construction				
	a	Soil cement core	20,000	CY	30.00	600,000
	b	Spread fill & compaction	95,000	CY	2.75	261,250
	c	Finish grading	50,000	SY	0.25	12,500
C		**Spillway**				
	1	300 LF soil cement cutoff wall (see B1a)				
	2	Low Flow Outlet - 48" RCP	800	LF	90.00	72,000
D		**Downstream Improvements**				
		Downstream Improvements	1	LS	15,000.00	15000
	1	Reno Mattress	6,955	SF	5.00	34,775
E		**Site Development and Landscaping**				
	1	Landscaping				
	a	Salvage	23	AC	21,780.00	500,940
	b	Exterior slopes	5	AC	43,560.00	217,800
	c	Basin revegetation	18	AC	27,000.00	486,000
	2	Archaeological Site Investigation	1	LS	7,000.00	7,000
		SUBTOTAL				$ 3,702,815
F						
		10% Overhead, bonds & insurance	10	PCT		310,904.00
		TOTAL				$ 4,013,719

Notes

1. Unit costs provided by the Flood Control District have been used
2. Right-of-way costs based on PACE submittal and Greiner 10% Cost Estimate
3. Most quantities for the Detention Basins are based on the PACE submittals

PACE Estimates
Union Hills Detention Basin for Basin Alternatives

#	Sub #	Description	Quantity	Unit	Unit Cost $	Total $
A		**Detention Basin Construction**				
	1	Clear & Grub	30	AC	1,600.00	$ 48,000
	2	Prewetting Operation				
	a	Develop water supply	1	LS	40,000.00	40,000
	b	Water for embankments	500	MGA	2.00	1,000
	3	Excavation (short haul)				
		Embankment	100,000	CY	1.60	160,000
		Short Haul (to ADOT)	715,000	CY	2.00	1,430,000
		Export	85,000	CY	3.00	255,000
	4	Finish Grading	70,000	SY	0.25	17,500
	5	Slope protection (Dumped Riprap w/geotext)	10,000	SY	25.00	250,000
B		**Earth Dam Embankment Construction**				
	1	Earth Embankment Construction				
	a	Soil cement core	25,000	CY	30.00	750,000
	b	Spread fill & compaction	110,000	CY	2.75	302,500
	c	Finish grading	70,000	SY	0.25	17,500
C		**Spillway**				
	1	300 LF soil cement cutoff wall (see B1a)				
	2	Low Flow Outlet - 48" RCP	1,200	LF	90.00	108,000
D		**Downstream Improvements**				
		Downstream Improvements	1	LS	15,000.00	15000
	1	Reno Mattress	6,955	SF	5.00	34,775
E		**Site Development and Landscaping**				
	1	Landscaping				
	a	Salvage	30	AC	21,780.00	653,400
	b	Exterior slopes	3	AC	43,560.00	130,680
	c	Basin revegetation	27	AC	27,000.00	729,000
	2	Archaeological Site Investigation	1	LS	7,000.00	7,000
		SUBTOTAL				$ 4,949,355
F						
		10% Overhead, bonds & insurance	10	PCT		409,458.00
		TOTAL				$ 5,358,813

Notes

1. Unit costs provided by the Flood Control District have been used
2. Right-of-way costs based on PACE submittal and Greiner 10% Cost Estimate
3. Most quantities for the Detention Basins are based on the PACE submittals

Appendix E

Minutes of Meetings

Greiner

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Project No. E10060102

CITY OF SCOTTSDALE
Desert Greenbelt Project — Phase One Design

Pima Channel, Detention Basin Alternative – January 9, 1996

MINUTES OF MEETING

ATTENDEES:

Mark Landsiedel	City of Scottsdale	Afshin Ahouraiyan	Flood Control District
Bill Erickson	City of Scottsdale	Raju Shah	Flood Control District
Collis Lovely	City of Scottsdale	Shi-En Shiau	Primatech
Russ Miracle	Flood Control District	Ron Price	Greiner
Ed Raleigh	Flood Control District	Vince Gibbons	Greiner
Pedro Calza	Flood Control District	Marty Bressor	Greiner

- The purpose of the meeting was to specifically address several outstanding concerns the Flood Control District had regarding the proposed Pima Road drainage facility and continue the technical discussion of the hydrology and hydraulic parameters for the system.

- An exhibit package prepared by Greiner was distributed to the group including hydrographs for specific channel reaches for the 10-year and 100-year storms, typical cross-sections for the Indian Bend Wash (IBW) and a revised BOR guide for the IBW, typical cross-sections for the Canada del Oro Wash and the Pantano Wash located near Tucson and a revised BOR guide for the Tucson washes.

- Marty gave Afshin a disk containing the revised hydrology model and HEC-1 output for the consensus hydrology resulting from Friday's (January 5, 1996) meeting.

- Marty described the hydrograph exhibits. The exhibits were presented to display the duration of the flow depth within the various channel reaches for the 10-year and 100-year storms using a shallow basin configuration and a deep basin configuration. The exhibits demonstrate that reaches 5, 6, 9 and 10 are essentially unaffected by the basin configurations. The District proposed that Greiner investigate the feasibility of constructing additional basins at Pinnacle Peak Road and Beardsley Road, which could possibly result in reducing the flows to a point where large diameter pipe or box culverts could be considered as an alternative to the open channel reaches. Greiner, and the City pointed out that a closed conduit system would require a separate north-south collector channel with catch basin inlets in order to intercept the braided overland flow along the corridor.

Mark indicated that locating detention basins at Pinnacle Peak and Beardsley is not possible due to the current land uses. ASLD has sold the parcels at Pinnacle Peak Road and development plans are well under way. A detention basin located upstream of those parcels would be basically useless. Mark also stated that the area near Beardsley Road belongs to the DC Ranch development, and it is not feasible to locate a detention basin within the DC Ranch property.

- Marty presented the cross-sections and the corresponding BOR guide for the IBW and the Tucson washes. Pedro had requested that Scottsdale furnish documented storm routing facilities that have similar characteristics to the proposed Pima Road drainage facility. The facilities were to have minimum or no fencing, be constructed using natural materials for the channel invert, and have similar flowrates, flow depths and flow velocities. The parameters for the various washes are presented below:

Channel	*Peak Flow (cfs)*	*Peak Velocity (fps)*	*Peak Depth (ft)*
Pima Road Channel	<3,070	~18	<3
IBW Upstream	30,000	~7	<8
IBW Downstream	30,000	~9	<10
Canada del Oro	28,000	~20	<6
Pantano	26,000	~15	<8

Ed stated that he did not believe these projects were similar to the Pima Road project because the Pima Road project would be a man-made watercourse whereas these other projects were modifications to existing watercourses. Ed said that he believed these differences would result in a different form of liability for both the District and the City. Mark, Bill and Collis all disagreed and felt that, regardless if the IBW and the Tucson Projects are along an existing watercourse, they are all man-made channels with high velocities and depths and that the issue of being a natural watercourse did not have any bearing on the liability.

Ed said the District was not comfortable with the condition of an unfenced channel given the steepness of the channel side slopes (1H:1V), and the flow velocities and depths as presented by Greiner for the existing slope condition. Mark said that he felt pipe-railing, similar to that used at the Tucson channels, would be acceptable to the City, but if fencing was required, the project would die and not be constructed. Mark asked Ed what hydraulic parameters the District would require for the Pima Road channel if pipe-railing was installed. Ed responded that, for pipe-rail protection, the channel Froude Number should be no greater than 0.85 and that 1H:1V side slopes would be acceptable. Ed also stated that for a channel with no railing or fencing, the Froude Number must also be no greater than 0.85 and the channel side slopes should be no steeper than 4H:1V. Mark instructed Greiner to investigate the feasibility of meeting these subcritical parameters.

- Ed additionally stated that he did not feel the channel system, constructed using a natural invert at steep slopes, would be stable in regard to sediment transport and long-term scour. If it is not feasible to reduce the channel slopes and resulting high velocities, Ed feels it may be necessary to line the entire channel.

- Vince presented Greiner's preliminary findings regarding the requirements and overall performance of drop structures. Vince stated that, given the existing grade, drop structures would be required at frequent intervals to attain moderate channel slopes capable of meeting the lower velocity parameters established by the District. However, as the frequency of the drop structures increases, and the resulting spacing between the structures decreases, the ability to predict the performance of the overall system using normal flow conditions alone, as originally presented by PACE, is compromised. Vince explained that the length of the tailrace required to dissipate the energy from the drop structure and attain the normal flow conditions generally exceeded the spacing of the drop structures required to achieve the necessary channel slope. The resulting effect is a continually increasing flow velocity that propagates downstream and negates the intended impact of the drop structure installation. To alleviate this propagating effect downstream, energy dissipators or alternate channel materials will be required. As these conditions were neglected by PACE in their original analysis, the costs associated with the energy dissipators or alternative channel material would be added to the overall cost estimate for the Detention Basin Alternative. Greiner will continue to investigate various solutions to reduce the existing slopes.

- A follow-up meeting is scheduled for January 16, 1996, at 1:00 P.M.

cc: Attendees
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Project No. E10060102

CITY OF SCOTTSDALE
Desert Greenbelt Project — Phase One Design

Pima Channel, Detention Basin Alternative – January 16, 1996

MINUTES OF MEETING

ATTENDEES:

Mark Landsiedel	City of Scottsdale	Raju Shah	Flood Control District
Collis Lovely	City of Scottsdale	Pedro Calza	Flood Control District
Alex McLaren	City of Scottsdale	Shi-En Shiau	Primatech, LLC
Ed Raleigh	Flood Control District	Marty Bressor	Greiner, Inc.
Amir Motamedi	Flood Control District	Vince Gibbons	Greiner, Inc.
Russ Miracle	Flood Control District		

- The purpose of this meeting was to continue discussions on the range of allowable velocities and depths to be used in the design of the channels for the Detention Basin Alternative for the Pima Channel and the corresponding safety and liability issues. This is a follow-up meeting to the meeting conducted on January 9, 1996.

- Marty made a presentation on the results of Greiner's investigation into the channel parameters required to achieve a Froude number of 0.85. A handout showing the results of this investigation was distributed which contained tables, graphs and charts relative to the hydraulic performance of the 10 separate channel reaches using various channel materials (n = 0.013 – concrete lined, 0.019 – soil cement lined, 0.022 – soil cement side slopes with native invert, 0.030 – soil cement side slopes with riprap invert, and 0.035 – same as 0.030 but with a meandering channel). The analysis was based on a constant channel bottom width of 100 feet with 3-foot drop structures and considered both 1:1 and 4:1 side slopes. The results of the analysis show that frequent drop structures are required to achieve slopes necessary for the 0.85 Froude number and that, for most cases, either energy dissipators at the drops, or downstream channel armoring extended to the end of the calculated tail race, are required.

- As part of the analysis Greiner prepared and presented a preliminary cost comparison that considered only channel excavation and channel material. This comparison indicates that the n = 0.022 alternative (soil cement side slopes with native bottom) is the most cost effective for a Froude number of 0.85. It was stated that this comparison did not take into account the cost of the drop structures. In evaluating the required number of drop structures, the two most cost-effective alternatives appear to be soil cement side slopes

with native invert (n = 0.022) and soil cement side slopes with riprap invert (n = 0.030). Mark stated that a riprap invert would not be aesthetically acceptable for the project. Greiner will develop a rough cost estimate for the entire system based on the n = 0.022 alternative (soil cement side slopes with native invert), using a maximum top width of 100 feet. Greiner will evaluate scour and sediment transport as part of the cost estimate development.

- Russ asked what Greiner had in mind for the drop structures and the energy dissipators. Vince said that the analysis had been performed for vertical drops and that construction materials considered would be soil cement and concrete. Energy dissipators would be either plunge pools or stilling basins with baffle blocks. Vince stated that it may be possible to incorporate either natural or man-made (Larson Treatment) boulders into the energy dissipators in place of the less aesthetically pleasing baffle blocks. Greiner has not performed an in-depth investigation into the drops at this point due to the preliminary state of the review and selection phase for the channel alternatives. Russ requested that Greiner develop a preliminary sketch of the anticipated drop structures and energy dissipators.

- Marty presented additional tables reflecting the results of a parallel analysis of the channel sections for Froude numbers of 1.13, 1.45 and 1.75, which were also based on the 100-foot bottom width and 3-foot drop structures. The Froude number of 1.75 was investigated for both 1:1 and 4:1 side slopes, and the other two (1.13 and 1.45) for 1:1 side slopes only. The resulting velocities of the 1.45 Froude number are in the same general range as those presented in the PACE Report. Vince stated that it would be a good idea to prepare a cost estimate for one of these supercritical alternatives for comparison to the cost estimate for the subcritical (Froude number 0.85) alternative as previously discussed. All agreed. Ed said that Greiner should evaluate the channel lining requirements for these higher velocities and take this factor into account when developing the cost estimate.

- A discussion on the detention basins was initiated and included items such as outlet structure length and configuration, overtopping protection and routing, and the fact that the deep basins were identified as the most cost effective and will be used for future analysis and cost estimates. Mark requested that Greiner produce sketches of the detention basins for the next meeting.

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Project No. E10060102

CITY OF SCOTTSDALE
Desert Greenbelt Project — Phase One Design

Pima Channel, Detention Basin Alternative – January 29, 1996

MINUTES OF MEETING

ATTENDEES:

Mark Landsiedel	City of Scottsdale	Raju Shah	Flood Control District
Collis Lovely	City of Scottsdale	Pedro Calza	Flood Control District
Alex McLaren	City of Scottsdale	John Rodriguez	Flood Control District
Ed Raleigh	Flood Control District	Marty Bressor	Greiner, Inc.
Afshin Ahouraiyan	Flood Control District	Vince Gibbons	Greiner, Inc.
Russ Miracle	Flood Control District	Bill Lace	Greiner, Inc.

GENERAL

- The purpose of this meeting was to continue discussions on the design of the channels for the Detention Basin Alternative for the Pima Channel and the corresponding safety and liability issues. This is a follow-up meeting to the meeting conducted on January 16, 1996.

- Vince gave a review summary of the information that was presented, the items that were discussed, and the resulting decisions, directions and requests made at the prior meeting held on January 16, 1996.

- Marty presented a review of the overall system components and introduced the latest development of adding Reach 11 from the outlet of the detention basin at Union Hills, along the north side of the Pima Freeway, for a distance of approximately 2,300 feet. This reach consists of both a 60-inch pipe and a surface channel to convey the flow out of the detention basin to daylight and to collect surface flow from the north. Both the 60-inch pipe and the surface channel would combine at the end of this reach and transition into a 72-inch pipe which would then extend to the outfall at the BOR basin at the TPC to the south (approximately 4,735 L.F.). Marty stated that utilizing the 72-inch pipe could eliminate the need for the bridges at the Pima Freeway and Bell Road and also eliminate the wide, reinforced grass-lined channel that adversely impacts the TPC golf course features.

DETENTION BASINS

- A preliminary plan view layout of each of the three detention basins was distributed. Marty discussed the various features associated with each basin such as invert elevation, top elevation, storage volume, excavation volume, setback, outlet requirements and configuration. The Union Hills basin is depicted as a two-cell system with the upper cell receiving flow from the Grayhawk development via the proposed "power line channel" and the lower cell receiving flow from the Pima channel and also from the upper cell when its capacity is exceeded. FCD and COS expressed the desire to armor the dike between the upper and lower cells to protect it from failure and thus prevent costly maintenance to the dike and the loss of the outlet pipe that would connect the two cells through the dike.

OPTION #1 — F=0.85 – SUBCRITICAL FLOW

- Vince made a presentation on the material contained in the handout packet for Option #1 (subcritical flow, F=0.85, n=0.022 and soil cement side slopes with native invert). The first page in the packet was a spreadsheet showing a summary of the hydraulic parameters for this option. The important items on this summary that were discussed were as follows:

  1. Velocities = 8 to 9 fps (average).
  2. 3-foot drop structure spacing = 165 feet to 170 feet (average).
  3. The calculated tailrace length exceeded or roughly equaled the drop spacing for all reaches except for Reach No. 3.
  4. Average tailrace velocities are mainly in the 13 to 14 fps range.
  5. Nappe velocities fall mainly in the 16 to 17 fps range.
  6. 152 drop structures are required for the F=0.85 slopes.
  7. Stilling basins are required for all reaches.

  Vince pointed out that stilling basins are required due to the fact that the tailrace length exceeds the drop spacing distance and, without energy dissipation at the drops, the effect would be a continually increasing velocity that propagates downstream as each successive drop is encountered. Also stilling basins are needed to eliminate the increased velocities through the tailrace length which exceed the recommended maximums for the specified channel materials as listed in the FCD's hydraulics manual.

  Vince stated that, based on the maximum velocity of 3 fps recommended in the FCD manual for earthen channels (silt loam) and considering the calculated normal flow velocities being in the 8 to 9 fps range, it will necessary to completely line the channel. Therefore, both soil cement lined channels and shotcrete lined channels were evaluated. It was determined that the stilling basins are still required in both cases. This determination is based on the fact that the tailrace lengths do not change and therefore still exceed the drop spacing distance and that, in most of the reaches, the tailrace velocities exceed the maximum recommended in the FCD manual for these channel lining materials (soil cement – 9 fps, shotcrete – 15 fps).

- A preliminary sketch of the proposed reinforced concrete stilling basins based on the HEC-14 procedure was the next page in the Option #1 packet. This sketch included a table listing all the required dimensions for the basins broken down by channel reaches. The average depth and length required for the basins is 6 feet and 20 feet, respectively. Vince said that the cost estimate for the basins ranged from $5,000 to $31,000 per basin for the various reaches and that an average unit cost of $17,860 was used.

- Two preliminary, itemized cost estimates were presented for Option #1. The first was for soil cement lining using a 2-foot thick invert and 8-foot wide side slopes. Total estimated cost for this soil cement alternative is $40,225,832. The second was for shotcrete lining using an 8-inch thick section with #5 bars both ways. Total estimated cost for this alternative is $44,164,582.

OPTION #2 — F=1.45 – SUPERCRITICAL FLOW

- Vince made a presentation on the material contained in the handout packet for Option #2 (supercritical flow, F=1.45, n=0.019, and a concrete or shotcrete lined channel). The first page in the packet was a spreadsheet showing a summary of the hydraulic parameters for this option. The important items on this summary that were discussed were as follows:

  1. Velocities = 12 to 13 fps (average).
  2. 3-foot drop structure spacing = 200 feet to 250 feet (average).
  3. The calculated tailrace length exceeded or roughly equaled the drop spacing for all reaches except for Reach No. 3 and Reach No. 4.
  4. Average tailrace velocities fall mainly in the 15 to 16 fps range.
  5. Nappe velocities are mainly in the 18 to 19 fps range.
  6. 105 drop structures are required for F=1.45 slopes.
  7. Stilling basins are required for all reaches except reach No. 3.

  Vince pointed out that stilling basins are required due to the fact that the tailrace length exceeds the drop spacing distance and, without energy dissipation at the drops, the effect would be a continually increasing velocity that propagates downstream as each successive drop is encountered. Also stilling basins are needed to eliminate the increased velocities through the tailrace length which would exceed the recommended maximums for the concrete lined channel (15 fps), as listed in the FCD's hydraulics manual. Vince stated that the stilling basins required for this option would be the same as for Option #1 but would be shallower (3 to 4 feet deep) and shorter (17 to 18 feet long) on average.

- A preliminary, itemized cost estimate was presented for Option #2. This estimate was based on using an 8-inch thick shotcrete or concrete section with #5 bars both ways. Total estimated cost for this option is $42,953,005.

DISCUSSIONS REGARDING THE INFORMATION PRESENTED

- Pedro commented that the cost estimate difference between obtaining subcritical flow and supercritical flow is minor for the shotcrete alternative ($1.2 million more for subcritical) and that the soil cement alternative for subcritical is less expensive than the shotcrete supercritical by $2.7 million. FCD would prefer the subcritical flow option.

- Mark asked FCD if they had a chance to discuss the railing versus fencing issue since the last meeting and if they had come to any conclusions on what were acceptable channel velocities for both. Russ stated that the District feels that the pipe railing would be acceptable for the two options (F=0.85 and F=1.45) as presented today.

- Mark asked Greiner what a rough cost estimate would be for the concrete channel alternative (as shown in the 30 percent plans), including the portion from Deer Valley to north of Jomax as concrete channel. Marty stated that it would probably fall within the $31 to $32 million range plus the cost of the fencing. Mark requested that Greiner prepare a cost estimate for this alternative but with a change consisting of including the detention basin at Union Hills to the system. This estimate is to include the cost for fencing both sides of the open channel reaches. It was decided that, as soon as this cost estimate was complete, another meeting will be scheduled to discuss how it compares to the other two options presented at today's meeting.

TOTALLY UNLINED ALTERNATIVE TO OPTION #1

- Vince said that a cost saving alternative to the subcritical Option #1 was discussed at the last project biweekly meeting which would relatively be the same system, but instead of lined channel sections between the stilling basins (drops), use completely native (excavated) channel sections, the rationale being that, because the distance between the stilling basins is so short, you would not expect significant lateral migration of the alignment as the scour reduced the longitudinal slope between the stilling basins. A preliminary cost estimate for this alternative shows a significant cost savings over the lined versions for Option #1 with a total cost at approximately $32.8 million. Ed said that this would be a similar design to what is done in Colorado and that he could provide Greiner with a copy of the manual that addresses this design that was prepared for the Flood Control District in Denver. Ed said that he could agree with the idea of the milder slope being produced from the scour, but that the Flood Control would not feel comfortable with unprotected side slopes and that soil cement, toed down below anticipated scour depth would be necessary. Greiner roughly estimated that the cost would increase to approximately $38 to $40 million with the addition of the soil cement side slopes.

FEMA CLOMR AND HEC-6

- Bill passed around a handout that contained four pages from the HEC-6 manual and a copy of a portion of a HEC-6 model printout. Bill explained that the HEC-6 model uses critical depth to establish the water surface profile, which is conservative for a supercritical flow regime. Bill also explained that the HEC-6 model uses super-normal depth to calculate scour as evident on the sediment output portion of the HEC-6 model printout. Bill said that he wanted to bring this to light because it appears that some of the comments from FEMA and the District were related to the perception that the model was using critical depth to calculate the scour and resulting sediment load.

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Project No. E10060102

CITY OF SCOTTSDALE
Desert Greenbelt Project — Phase One Design

Pima Channel, Detention Basin Alternative – February 12, 1996

MINUTES OF MEETING

ATTENDEES:

Mark Landsiedel	City of Scottsdale	Kofi Awumah	Flood Control District
Collis Lovely	City of Scottsdale	John Rodriguez	Flood Control District
Alex McLaren	City of Scottsdale	Shi-en Shiau	Primatech, LLC
Ed Raleigh	Flood Control District	Marty Bressor	Greiner, Inc.
Russ Miracle	Flood Control District	Vince Gibbons	Greiner, Inc.
Raju Shah	Flood Control District	Keith Dahlen	AGRA, Inc.

GENERAL

- The purpose of this meeting was to continue discussions on the design of the channels for the Detention Basin Alternative for the Pima Channel and the corresponding safety and liability issues. This is a follow up meeting to the meeting conducted on 1/29/96.

- Vince gave a review summary of the information that was presented, the items that were discussed, and the resulting decisions, directions and requests made at the prior meeting held on 1/29/96.

ADDITIONAL SOIL SAMPLES

- A copy of the letter from AGRA dated 1/26/96, addressing the additional soil sampling requested by FCD was distributed. Ed asked Keith if the letter was basically stating that AGRA felt that no additional borings were needed. Keith discussed the river morphology for this alluvial area and said that with additional borings, he would not expect to find a subsurface composition different than that discovered with the borings performed to date. Keith said that he was not concerned with the consistency of the subsurface datum, but that his concern lies in the depth achieved during the initial investigations. Keith felt that either some track-hoe test pits or borings using a large drill rig will be needed to get down to the 17 to 20 levee toe down depths or that seismic testing might be another option to consider to obtain the information at these depths. Ed asked where along the corridor were the AGRA borings performed? Keith stated that the locations were established from the centerline staking provided by Greiner and that approximately 2/3 of the samples were taken down in the wash, while approximately 1/3 of the samples were taken at the overburden area (banks). Samples taken indicate that the upper 3' to 4' is fine material with the portion below consisting of an armoring layer of cobbles.

- Ed requested that samples be taken at the actual locations where the levees will be constructed as has been the case for previous projects that FCD has been involved with. Ed also requested that bearing capacity for the soil cement foundations be addressed. Raj had some questions regarding how the soil samples were applied to the HEC-6 model and if the AGRA information was used. It was determined that Marty would look through the CLOMR binders that were submitted to FCD to answer these questions and if required, Bill Lace will call Raj as a follow-up.

- It was decided that additional sampling would be performed at the actual levee locations and at the same stations where the initial sampling was taken for comparative purposes. The additional samples will be analyzed to address sediment loading in the HEC-6 model, suitability for soil cement production and for structural applications. Greiner and AGRA will meet to determine the optimum locations for these additional samples and submit to both COS and FCD for review. The additional sampling will include the area south of Bell Road which is now accessible due to the property purchases COS has made in that area.

COMPARISON OF GREINER'S INVESTIGATIONS TO THE PACE PROPOSAL

- Mark said that there had been concern expressed to him by the District that the current evaluations of the detention basin system were not similar to the alternative presented in the PACE Report. Vince stated that Option #2 (F=1.45, supercritical flow) is very close to the alternative as presented in the PACE Report. Some of the PACE hydraulic parameters mentioned were velocities in the 11 fps to 12 fps range, Froude #s averaging 1.3 to 1.4, and most of the reaches in supercritical flow. PACE had presented a channel section consisting of soil cement side slopes with native invert which is unacceptable to the District for velocities over 3 fps. PACE had also planned on using concrete drop structures but had not evaluated the increased velocities or the need for energy dissipation and therefore underestimated the cost. Considering the high velocity ranges and the similarity to Option #2, the actual estimate for the PACE alternative would be very close to the estimated cost of Option #2 (approximately 46.8 million). PACE estimated the cost of their alternative at 27 million. Everyone was in agreement that Option #2 was similar to the alternative presented in the PACE Report.

OPTION #1 - F=0.85 - SUBCRITICAL FLOW

- A revised cost estimate for the soil cement lined channel was presented with the new total at $45,974,726. A revised cost estimate for the shotcrete lined channel was presented with the new total at $49,913,475. Revisions were highlighted and included the addition of 50,000 L.F. of pipe rail fencing, and the corrected cost for the three detention basins. Individual cost item breakdowns for the three detention basins indicated the corrected excavation quantities and associated cost. Mark pointed out that the right-of-way costs for the detention basins was not correct and would need to be adjusted and added to the total cost estimates. Greiner will revise the estimates to include these adjusted right-of-way costs. It was mentioned that a portion of the excavated soil from the Union Hills basin will be used for fill for the Pima Freeway and the details of how and when this will happen need to be further discussed with ADOT.

OPTION #2 - F=1.45 - SUPERCRITICAL FLOW

- A revised cost estimate for the concrete/shotcrete lined channel was presented with the new total at $48,637,211. Revisions were highlighted and included the addition of 50,000 L.F. of pipe rail fencing, and the corrected cost for the three detention basins. Right-of-way cost adjustments as discussed above will also be added to the total cost estimate for this option.

OPTION #3 - 30% DESIGN WITH UNION HILLS DETENTION BASIN

- A spreadsheet was distributed showing the estimated cost for the concrete channel as depicted in the 30 % plans. This spreadsheet was divided into three columns with the first indicating the cost of the system as presented in the 30% plans plus adding phase 2 (concrete lined channel from Deer Valley to north of Jomax) and 70,000 L.F. of steel picket fencing. The total estimated cost is $38,856,845. The second column reflected the items associated with adding the detention basin at Union Hills to the system. The total estimated cost is $44,347,241. The third column listed the differences between the two. Vince pointed out that the steel fencing added 2.5 million to the cost of the 30% design and that the main factor contributing to the higher cost of the system with the Union Hills basin added in was the cost of the basin itself at 9.2 million. Utilizing this basin in the system eliminates the need for the reinforced, grass lined channel south of the freeway and through the TPC which would mean less impact to the golf course amenities. It also eliminates the bridges at Bell Road, South Pima Road and at the Pima Freeway crossing. The decrease in cost associated with the elimination of the Pima Freeway bridge is not included in the spreadsheet because this decrease would be realized by the ADOT project, not the Greenbelt Project.

- Raj asked what the velocities were at the channel section with the reinforced grass lining. Marty said that the velocity in that reach was about 18 fps. FCD would not feel comfortable with this lining for flows at 18 fps. Vince said that the manufacture had provided testing information showing that the lining could withstand this velocity for a certain duration. Collis said that he did not accept this lining and that the velocities of the flow leaving the concrete lined section and entering this section will be higher than 18 fps, and thus require some type of energy dissipation to get it down to 18 fps. Marty said that Greiner was planning on addressing the energy dissipation during the 60% design phase and that more research was anticipated on the acceptability of the lining. Vince stated that the reinforced grass lining was developed to try to meet the aesthetic requirements of the open channel reach through the Perimeter Center and the TPC as established during the study phase. This section may need to be designed as a concrete lined channel which would not fit with the aesthetic goals and would increase the cost of this option.

- Ed asked what Greiner had used for an "n" value for the concrete lined channel and if Greiner had considered the anticipated sediment deposit when establishing this "n" value. Marty said that the n value used was 0.015 and that the sediment deposit was not included because it would become suspended during the design storm flows. Ed requested that Greiner conduct a literature search for info on how the sediment would impact the "n" value if this alternative is further developed.

LOWER VELOCITY DETENTION BASIN ALTERNATIVE OPTIONS

- Raj said that he had been investigating the parameters required to achieve velocities of around 4 to 6 fps in the channel reaches in order to utilize a native invert, as previous discussed with Greiner. Raj targeted a new slope of 0.0012 ft/ft which required approximately 165 drop structures (3' drops) spaced at around 140'. Rather than use the HEC-14 type stilling basin, Raj looked at a concrete apron without baffle blocks, but with an end sill depressed to create a tailwater depth equal to the required sequent depth. The resulting length required to contain the hydraulic jump on the concrete apron averaged 30' to 40'. Raj also investigated the possibility of using "A" shaped soil cement grade control (drop) structures with riprap at the bottom of the sloped drop (3:1) to dissipate the energy. Channel widths were around 70' to 84' and depth of flow at 2' to 5'. Raj estimated the cost of the drops at $25,000 per each. Scour calculations were not performed so the extent of the riprap protection was not determined. Shi-En stated that generally you would extend the riprap protection for a distance equal to 7 times the depth of the scour hole.

  In comparing this scenario with the soil cement lined channel of Option #1, the cost of 165 drops at $25,000 would be 4.1 million which is 1.4 million more, but by eliminating the soil cement invert the cost for this item would decrease by 3.2 million resulting in a total difference of about 1.8 million less for this scenario. This does not take into consideration the cost of the riprap protection for the "A" shaped soil cement drops alternative. The cost estimate for these two new scenarios would fall somewhere in the 44 to 46 million range which is close to all the other options investigated to date.

DISCUSSIONS REGARDING THE INFORMATION PRESENTED

- Mark stated that it is obvious that the costs presented in the PACE report are very low and did not consider all the requirements necessary to make the system work. He also said that all of the options are very expensive and above what was anticipated when the project was started. Items such as reducing the design storm or requiring the developers to provide more retention were discussed. It was decided that the City will need to re-evaluate its position on the Pima Channel and that the information developed to date will need to be presented to the State Land Department, Grayhawk and DC Ranch.

- Greiner is to finalize all of the cost estimates by making the changes identified and discussed during this meeting. A date for a follow-up meeting was not set.

cc: Attendees
Correspondence File