CONCEPT
DRAINAGE DESIGN REPORT
OUTER LOOP HIGHWAY
CAMELBACK WALK Channel TO THE ARIZONA CANAL

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DRAFT

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OUTER LOOP HIGHWAY
CAMELBACK WALK channel TO THE ARIZONA CANAL

Submitted To:

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AUGUST, 1989

DRAFT

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Registered Professional Engineer (Civil)
CERTIFICATE NO.
21560
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Date Signed 8-2-89
ARIZONA, U.S.A.

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I. INTRODUCTION

1.1 Project Location

This report pertains to a 2.9-mile-long segment of the Outer Loop Highway which will extend from the Camelback Walk Channel to the Arizona Canal (see Figure 1 of this report). This segment of the highway will be located entirely on the Salt River Indian Reservation. Legally, the project will occupy portions of Sections 6 and 7 within Township 2 North, and a portion of Section 30 within Township 3 South, all within Range 5 East of the Gila and Salt River Base and Meridian, Maricopa County, Arizona.

1.2 Purpose

The purpose of this report is to provide the approximate sizes and costs for the various elements of a stormwater-conveyance system that will intercept offsite runoff before it impacts the highway, and then convey this runoff to the vicinity of the Arizona Canal. The location where this channel will ultimately terminate will be established in a future phase of this project. The results of this analysis will allow for the selection of that alternative which most effectively meets the goals for the overall project. In addition, the results will assist in finalizing the right-of-way requirements associated with this segment of the Outer Loop. The scope-of-work associated with this concept drainage design is limited to those improvements that are required to accommodate offsite runoff, and therefore it does not address the pavement-drainage requirements.

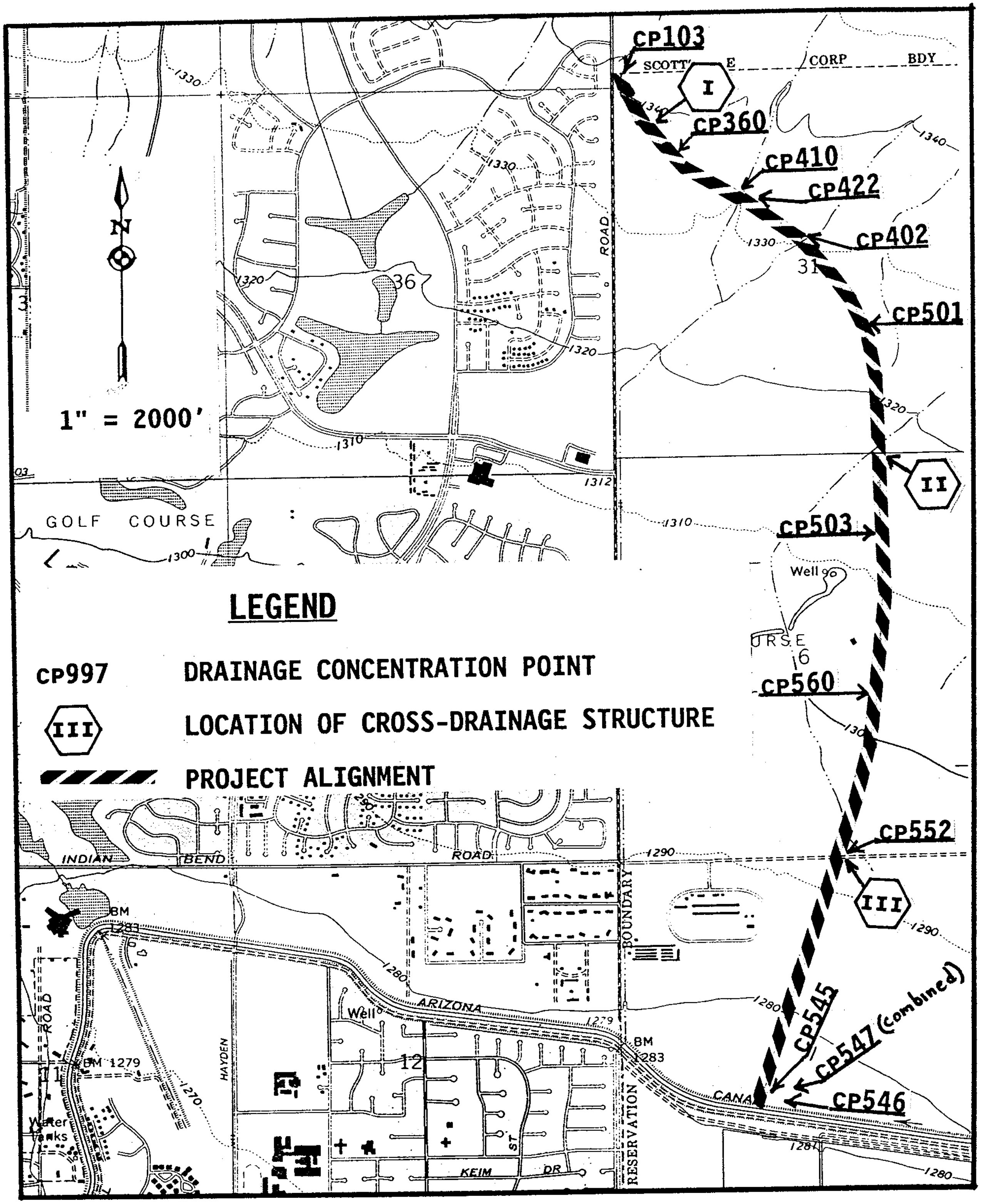


FIGURE 1

PROJECT LOCATION MAP

1.3 Hydrology

The drainage design alternatives presented in this report were formulated using both the 50-year and 100-year peak discharges. The runoff concentration points and discharge magnitudes were previously identified and defined in a hydrology report prepared by Simons, Li and Associates, Inc. (see Reference 1). Due to the physical characteristics of the contributing watershed, and those assumptions which were an integral part of the hydrology model, the peak discharges arriving at the respective concentration points are considered to be conservative. This fact was a major consideration in the analysis and recommendation process.

For ease of reference, Figure 1 of this report shows the location of the concentration points in relation to this study segment of the Outer Loop Highway. In addition, the peak-discharge summary sheet found in Reference 1 (Table 4.3) is provided as Table 1 of this report.

TABLE 1. PEAK-DISCHARGE SUMMARY ALONG OUTER LOOP ALIGNMENT

Concentration Point	Q100 (cfs)	Q50 (cfs)
(North-South Interceptor Channel)		
103	514	428
360	507	433
410	549	457
422	755	618
402	997	788
501	996	782
503	1314	971
560	1378	1023
552	3234	2453
545	3239	2485
(Arizona Canal Bridge)		
546	8120	6417
547	9326	7449

II. DESIGN METHODOLOGY

2.1 Design Criteria

The drainage design presented in this report is based on the standards and criteria as defined in the Arizona Department of Transportation (ADOT) publication entitled "Urban Highway Design Procedures Manual," and its designated references. Unless otherwise noted, there were no major deviations from the standards and procedures outlined in this manual. Specific criteria used in the design and the references consulted are described in more detail in the following sections of this report.

2.2 Project Approach

Typically, a design analysis of this type would consider all feasible drainage schemes, including those that are consistent with the existing drainage patterns and those that might suggest major deviations from the existing patterns. However, the nature of this particular project (i.e., location and watershed characteristics) dictates that all offsite runoff be intercepted before it impacts the highway. Therefore, the key design features associated with this project are (1) an interceptor channel that will parallel the eastern boundary of the highway, and (2) three cross-drainage structures (CDS) that will be required at the three major arterial intersections.

2.2.1 Interceptor Channel Design

The concept design of the interceptor channel considered two alternatives. The first design alternative assumes that a fully-lined concrete or gunite section would be provided along the entire project reach. The second design assumes that a fully-lined grass section would be provided along the entire project reach. The basic geometry of the two alternative designs (i.e., minimum bottom width and side-slope requirements) were based upon design criteria established by ADOT. Therefore, the concrete/gunite section (i.e., Alternative I) assumed a minimum bottom width of eight feet, and the steepness of the side-slopes were limited to 2H:1V. Likewise, the grass-lined section (i.e., Alternative II) also assumed a minimum bottom width of eight feet. However, the steepness of the side-slopes for Alternative II were limited to 4H:1V. Typical sections of the proposed interceptor channel are shown on Figure 2.

For Alternative I, the n-value was fixed at 0.018, as stipulated by the ADOT Design Procedures Manual. However, the n-value for the grass-lined section, which is a function of the retardance classification of grass used and the hydraulic radius of the affected section, was determined using the procedures outlined in Reference 2.

Since the hydraulic radius varies from section to section, the n-value also varies from section to section. Therefore, the final n-value for a particular Alternative-II section was determined through a trial-and-error analysis, where

INTERCEPTOR CHANNEL TYPICAL DESIGN SECTION

(LEFT TO RIGHT LOOKING UP STATION) N.T.S.

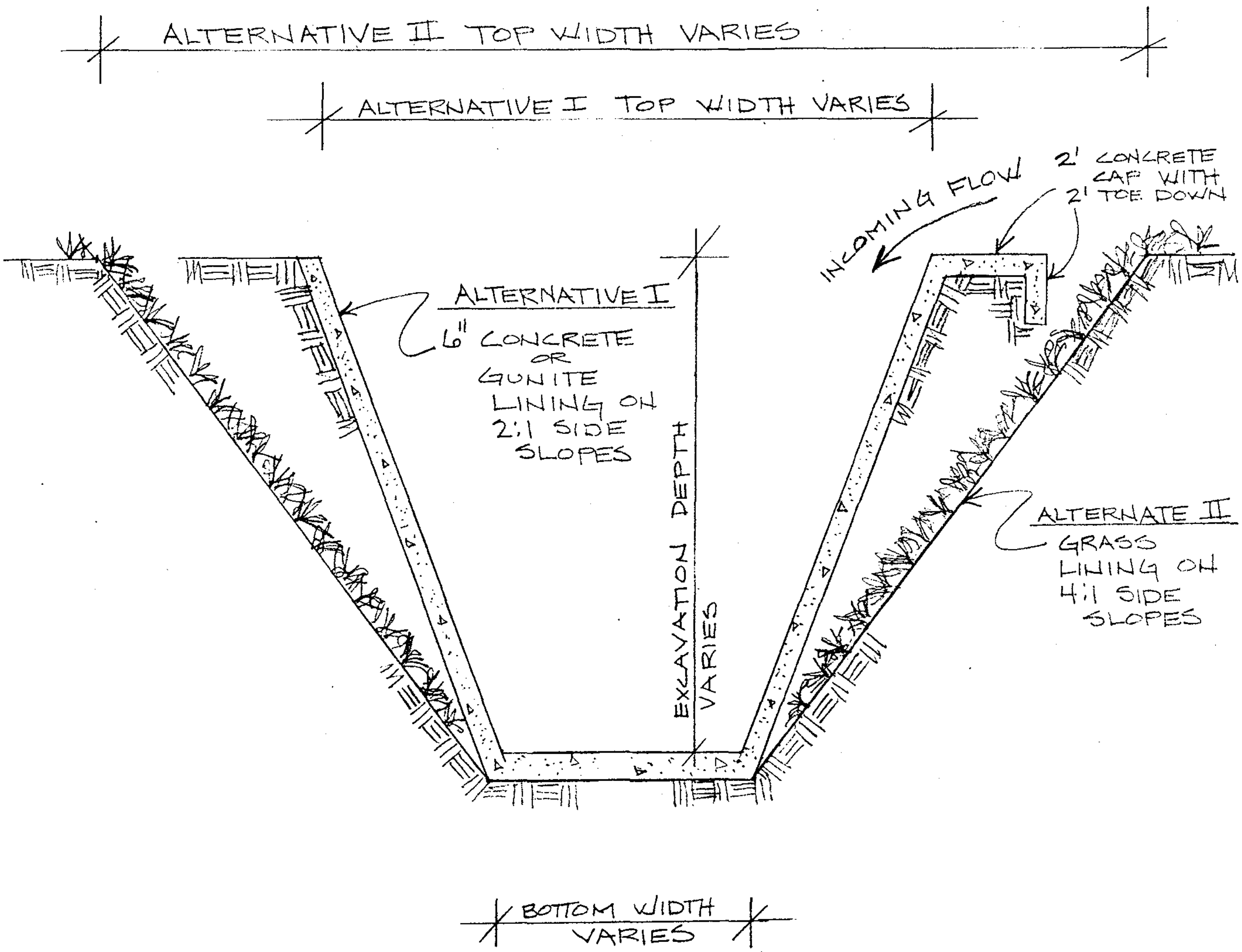


FIGURE 2

the bottom width of the section was varied as a function of the design discharge, depth, and slope.

The overall design is based on five design discharges. Since the design discharges gradually increase in the downstream direction, the bottom width and top width of the design section also increases in the downstream direction.

The design depth for both alternatives, which include the depth of flow plus freeboard, were held between four feet and seven feet. For the most part, both of these depths were based upon engineering judgment. In a effort to provide a hydraulically efficient section, the four-foot depth was selected as a minimum. Safety considerations played a major role in establishing the maximum design depth of seven feet. Therefore, the seven-foot depth is primarily a function of engineering judgement.

Since detailed topographic maps were not available to define the ground profile along the alignment of the proposed interceptor channel, the topographic information provided on USGS quadrangle maps (7.5-minute series) was used to establish the initial slopes in the trial-and-error analysis. Figure 3 provides a plot of the existing ground profile, which is based on 12 ground elevations obtained from the quad maps. It was assumed that the ground elevation adjacent to the Arizona Canal was equal to approximately 1274 feet (MSL). A point was then established at each contour interval which intersected the alignment of the proposed interceptor channel. This approach resulted in seven existing slope "breaks" along the project reach.

EXISTING AND DESIGN PROFILE ALONG INTERCEPTOR CHANNEL

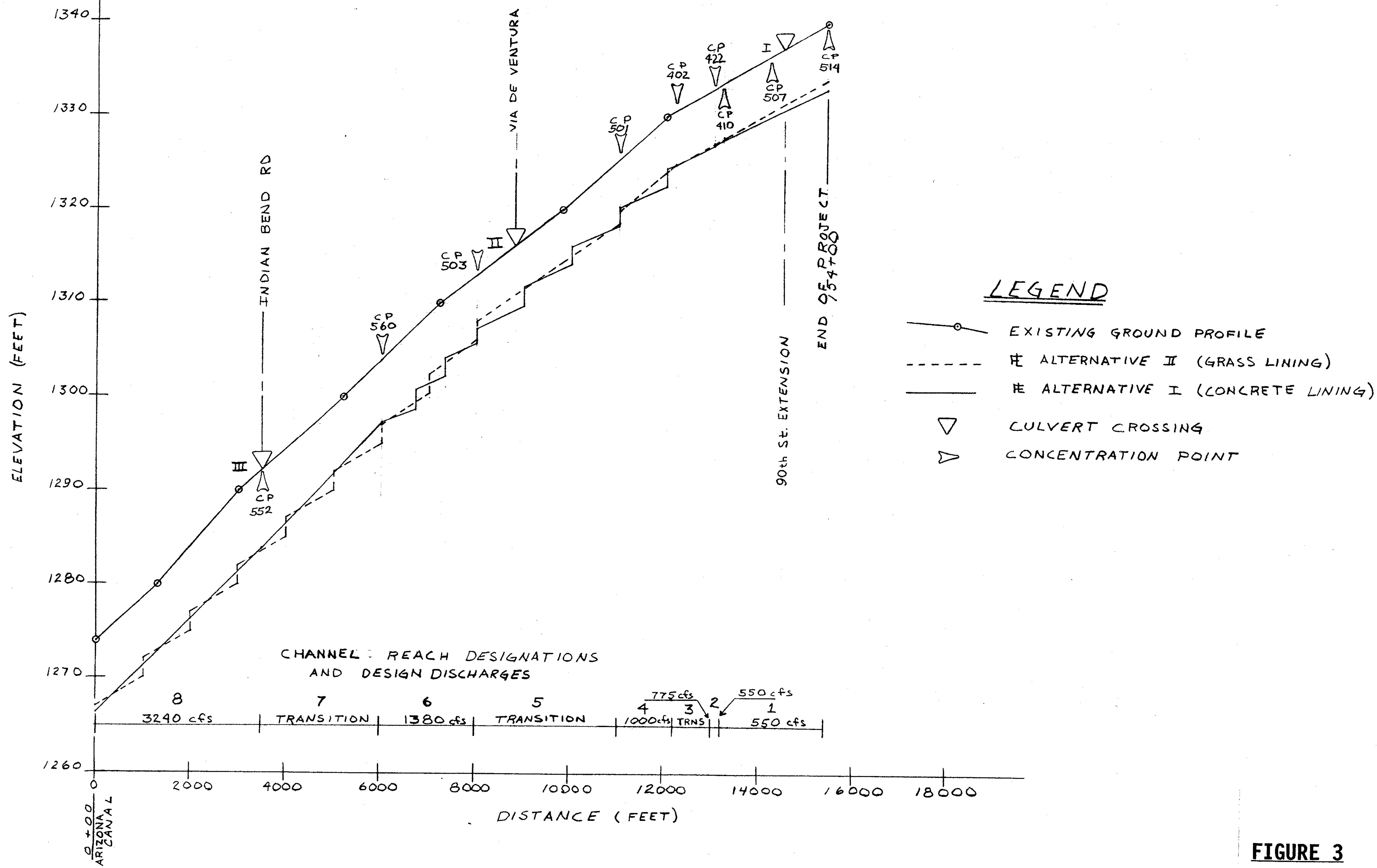


FIGURE 3

The initial design slopes (existing slopes) were then adjusted, along with the discharge, depth, and n-value (for the grass-lined section only), in a effort to maintain either a truly subcritical (i.e., Froude No. less than 0.86) or supercritical (i.e., Froude No. greater than 1.15) flow condition along the project reach. This trial-and-error analysis was based upon the assumption that uniform-flow conditions would prevail along the majority of the project reach. The design analysis proceeded from the upstream limit of what is subsequently referred to as Design Reach #1, which begins at Concentration Point 103 (CP 103).

The eight design reaches depicted on Figure 3 were established during the trial-and-error process. The design discharge and final design slopes controlled the establishment of these design reaches.

The erosion and sedimentation aspects associated with the interceptor channel were evaluated from both a qualitative and quantitative standpoint. However, since the physical characteristics of the watershed significantly limits the quantity of sediment that can be transported to the interceptor channel during a major runoff event, erosion/sedimentation considerations were limited to those conditions that are a function of the hydraulic conditions associated with a particular design reach and its proposed lining.

Erosion will not be a problem within the concrete/gunite lined section. From a qualitative standpoint, sedimentation should not be a problem since the quantity of sediment supplied by the watershed should be lower than the transport capacity of the interceptor channel.

However, in an effort to ensure that the quantity of sediment supplied by the watershed will not accumulate in the interceptor channel, and thus reduce its capacity, an attempt was made as part of the trial-and-error design process to ensure that the unit discharge and velocity within the design channel increased in the downstream direction for both alternatives. Since the sediment-transport capacity of a given section is proportional to its unit discharge, each successive downstream reach should be capable of conveying that quantity of sediment supplied from the adjacent upstream reach, plus any additional contribution from the watershed. Therefore, from a sedimentation standpoint, no special design considerations are warranted. Any sedimentation that might occur can be handled as part of a regular maintenance program.

To minimize the potential for erosion along the grass-lined channel (i.e., Alternative II), the permissible-tractive-force/permissible-velocity approaches outlined in Reference 2 were considered as part of the trial-and-error design of this alternative. The grass-lined section was designed such that the tractive force within a particular reach did not exceed, within practical limits, the empirical values used in Reference 2. The maximum tractive force associated with a particular section within a particular design reach was computed. The trial-and-error design also considered the permissible-velocity approach, which uses the permissible tractive-force value as a constant when computing the permissible velocity associated with a particular design section. The final design section was then selected if the permissible-tractive-force/permissible-velocity criteria were met within practical limits. Using this approach, the grass-lined channel can be considered stable if the protective mat or cover is properly maintained once established.

For design and cost-estimating purposes, it was assumed that the grass-lined channel would be hydro-seeded with a combination of exotic and natural grasses. The base or primary grass would be a bermuda hybrid. Bermuda grass was selected as the base grass, since it is very effective in stabilizing the soil once it is established. Bermuda is one of the few grasses that possesses all of the three reproductive mechanisms inherent in grasses (i.e., rhizomes, stolons, and seed). Therefore, the stabilizing effect of the soil is maintained by the rhizomes and roots, even when the surface material is dormant, but intact, during winter months or during long periods of drought. During the winter months, the secondary grasses could be selected in such a manner so as to ensure that a stable green mat is maintained when the bermuda is dormant. The only drawback to bermuda grass is that it requires a considerable amount of irrigation to retain a green, uniform cover. This overall approach would provide a protective mat or cover that would (1) act to stabilize the soil against erosion; (2) minimize the need for supplemental irrigation during excessive periods of sparse precipitation; and (3) have a relatively low flow-retardance factor, and thus minimize the amount of right-of-way required. Using Table 1 of Reference 2 as a guide, it was assumed that the selected grasses would fall within the Retardance C classification. This accommodates certain grasses that are allowed to grow up to 10-12 inches in height without significantly affecting the overall roughness of the channel section. However, this classification does assume that a regular maintenance program will be in operation; that is, one which attempts to maintain an average height of six inches for bermuda grass.

2.2.2 Culvert Design

Culvert crossings of the three major intersections (see Figure 2 of this report) were designed using the charts contained in HDS-5 (see Reference 3). In accordance with ADOT design procedures, the 50-year discharge was the design discharge and the 100-year discharge was the "check" discharge. The HDS-5 charts, which typically generate conservative headwater elevations under channelized conditions, were deemed appropriate for concept design purposes. However, during the final design stage, the U.S. Army Corps of Engineers computer program HEC-2 should be used to make the final selection.

The design height of the culvert opening was based on the available headwater elevation (i.e., existing ground elevation minus the proposed flow-line elevation) in the immediate vicinity of the crossing, assuming a minimum of one-foot of cover over the structure. The available headwater elevation was assumed to be approximately equal to the allowable headwater elevation for the design discharge and the "check" discharge. According to ADOT design procedures, the computed headwater elevation should be two feet below the minimum roadway elevation. Therefore, the roadway elevation was assumed equal to the available headwater elevation, plus two feet. The number of barrels and the width/diameter of each barrel was then adjusted to optimize the design.

The evaluation and selection process was based upon engineering judgement. As previously stated, an attempt was made to limit the headwater elevation for both the design discharge and the "check" discharge to the available headwater elevation. However, a particular culvert was not deemed acceptable if the headwater elevation for the design discharge exceeded the available elevation. If the headwater elevation for the "check" discharge exceeded the available elevation, the structure was not deemed acceptable if the overtopping depth exceeded one foot. This depth was selected to minimize any adverse flooding conditions within the right-of-way or adjacent properties.

When the final design is evaluated using more detailed topographic information, the HEC-2 special-bridge routine could be employed to evaluate the performance of the box culverts. This procedure is more appropriate than the HDS-5 procedure under channelized conditions. This is especially true under supercritical flow conditions. The design headwater elevation using HDS-5 is based on a comparison between the inlet-control headwater elevation and the outlet-control headwater elevation. Under supercritical flow conditions, the HDS-5 results will usually indicate that the inlet is the controlling section. However, under subcritical flow conditions, either section could control, depending on the elevation of the downstream tailwater.

When evaluating the outlet-control headwater elevation, the HDS-5 procedure approximates the hydraulic grade elevation at the outlet using either the $[(d_c + D)/2]$ criteria or computed tailwater elevation within the downstream channel section. In accordance with the energy equation, friction losses and entrance losses are then added to this elevation to define the headwater elevation at the inlet, with due consideration of the elevational change between the inlet and the outlet. This elevation is then compared to the inlet-control headwater elevation to establish the controlling section (higher elevation controls).

Without adjustment, the HDS-5 procedure assumes that ponded conditions always exist at the inlet, which is not usually the case when the upstream channel section approximates the width of the culvert/bridge opening. Under these conditions, entrance/pier losses are best evaluated using the momentum equation. The HEC-2 special-bridge routine uses the momentum equation to calculate inlet losses when piers exist. In addition, it computes the hydraulic grade elevation at the outlet using the downstream tailwater elevation. It also allows for the user to either compute an appropriate orifice coefficient when the relatively long culverts are required, or to select a value that is consistent with short culverts.

This latter approach provides site-specific headwater calculations which may reduce the size of the culvert required under design conditions in relation to that size selected using the HDS-5 procedure. Even if the size of the culvert is not reduced, the computed headwater elevation at the inlet is usually 0.5 to 1.5 feet lower using the HEC-2 routines than they are using the HDS-5 procedure, which may be useful information when determining the potential for overbank flooding.

However, as previously stated, for concept design purposes it is more appropriate to use the HDS-5 procedure, since the conservative results can account for the unknowns when evaluating the overall requirements and cost of this segment of the Outer Loop Highway. Considering this fact, it should be noted that the culvert evaluation process did not consider debris accumulation at the inlet. The primary reason for this fact is that, due to the characteristics of the watershed, it is not likely that a significant quantity of debris will be transported by surface runoff to the interceptor channel.

III. CONCEPT DESIGN

3.1 Alternative I

This alternative consists of eight design reaches, each assumed to be entirely lined with concrete. Reaches 1, 2 and 3 are subcritical, and on straight grades (i.e., no drop structures). Reaches 4, 5 and 6 are subcritical, with two-foot-high drop structures spaced at 600-foot to 1000-foot intervals. Reach 7 transitions from subcritical to supercritical, with no drop structures. Reach 8 is supercritical, also with no drop structures. Table 2 of this report provides a listing of the flow-line profile for Alternative I. Appendix A of this report provides hydraulic details for each cross section selected for this alternative.

The results of the HDS-5 analysis are summarized as follows:

CDS	Selected Structure	Concrete Quantities (Cubic Yards)
I	1-10X5 CBC	256
II	3-8X6 CBC	575
III	4-10X7 CBC	1035

The respective culvert computation sheets are contained in Appendix B of this report.

TABLE 2. FLOW-LINE PROFILE FOR ALTERNATIVE I		
Station	Elevation	Reach Number
0+00	1266.30	8
35+00	1283.80	
52+00	1293.00	7
60+00	1297.32	
66+66	1298.79	
	1300.79	
73+33	1302.25	6
	1304.25	
80+00	1305.72	
	1307.72	
90+00	1309.92	
	1311.92	5
100+00	1314.12	
	1316.12	
110+00	1318.32	
	1320.32	
120+00	1322.52	4
	1324.52	
122+00	1324.96	3
130+00	1326.96	2
132+00	1327.46	1
154+00	1332.95	

Note: Two elevations at a single station indicate the location of a grade-control structure.

3.2 Alternative II

Alternative II consists of eight design reaches, each assumed to be entirely lined with grass. All reaches are subcritical, and include a total of nine two-foot-high drop structures. These drop structures could be constructed of concrete, gabions, or soil cement; and would require adequate energy dissipators on their downstream sides. The details associated with these structures would need to be determined at the design phase. Table 3 of this report provides a flow-line profile for each reach within this alternative. A detailed listing of the individual hydraulic properties associated with each section is contained in Appendix A of this report. Also included within Appendix A are the tractive-force/permissible-velocity calculations for the grass lining.

The results of the HDS-5 analysis are summarized as follows:

CDS	Selected Structure	Concrete Quantities (Cubic Yards
I	2-6X4 CBC	267
2	6-6X4 CBC	725
3	4-10X7 CBC	1035

The respective culvert computation sheets are contained in Appendix B of this report.

TABLE 3. FLOW-LINE PROFILE FOR ALTERNATIVE II

Station	Elevation	Reach Number
0+00	1267.00	
10+00	1270.00	
	1272.00	
20+00	1275.00	
	1277.00	8
30+00	1280.00	
	1282.00	
35+00	1283.50	
40+00	1285.00	
	1287.00	
50+00	1290.00	7
	1292.00	
60+00	1295.00	
	1297.00	
70+00	1300.50	6
	1302.50	
80+00	1306.00	
	1308.00	5
110+00	1318.50	
	1320.00	4
122+00	1324.95	3
130+00	1327.19	2
132+00	1327.75	1
154+00	1333.91	

Note: Two elevations at a single station indicate the location of a grade-control structure.

IV. SUMMARY OF RESULTS

Based on the results of the hydraulic analysis of both channel alternatives (see Table 2), the grass-lined channel (Alternative II) will require approximately 24 additional acres of right-of-way compared to the concrete-lined channel. Overall, the top width of the cut section for the concrete-lined channel ranges from approximately 30 feet to approximately 60 feet. In contrast, the top width of the cut section for the grass-lined channel ranges from approximately 60 feet to 160 feet. These figures do not consider any additional widths that would be required to provide access to the channel for maintenance purposes.

Based on a comparison of the results of the HDS-5 analysis relative to each crossing, six cross-drainage structures were selected to be included in the cost analysis. The selected structures are similar for both alternatives. The grass-lined alternative (i.e., Alternative II) will require the design of outlet-protection structures at the outlet of each cross-drainage structure. Since the outlet structure could consist of either a simple, single-purpose plunge basin or a more sophisticated component of a linear park, its design was not included in this analysis. The total cost of the six culvert-outlet structures for Alternative II, as well as the nine drop structures, is included within the contingency factor.

V. COST ESTIMATES

Cost-tabulation sheets for each alternative are contained in Appendix C of this report. These estimates were prepared primarily for the purpose of comparing the two alternatives. Since there are several details associated with the final design that cannot be estimated at this time, these estimates are rough, and should therefore be considered as very preliminary in nature. However, they do provide relatively accurate estimates for the key elements associated with the two alternatives. Therefore, they should provide a clear distinction between the cost-effectiveness of each alterative. To ensure that all unknowns are approximated, a 30-percent contingency factor was included.

Earthwork quantities are based upon the design top width and bottom width (see Tables 3 and 6), which were applied over the length of each design-channel reach (see Figure 3) at the associated design depth for the eight distinct design reaches. A separate grading cost was added to the estimate associated with Alternative II to account for surface preparation. Landscape architects have indicated that rough grading is not adequate to accommodate a grass-lined channel.

Operation and maintenance costs were not included on the cost summary sheets. For the concrete-lined channel (i.e., Alternative I), it was assumed that these costs would be insignificant. For the grass-lined channel (i.e., Alternative II), it was assumed that the cost would be $5000.00 per acre per year. Since the total acreage of the grass-lined alternative is approximately 40 acres, this cost becomes $200,000 per year.

The total construction costs associated with Alternative I were determined to be approximately $3,785,000. The total construction costs associated with Alternative II were determined to be approximately $2,910,000.

With respect to Alternative II, if the present value of the operations and maintenance costs for Alternative II is computed assuming a 50-year design life with an average annual interest rate of 8 percent, additional costs associated with Alternative II would be approximately $2,447,000. This brings the total cost for Alternative II to $5,357,000. Therefore, under these assumptions, the total life-cycle cost of Alternative I is expected to be substantially less than the total life-cycle cost associated with Alternative II.

VI. RECOMMENDATIONS

Based on total costs associated with the two alternatives, and on the fact that considerably more right-of-way will be required for Alternative II, Alternative I is expected to be the most cost-effective alternative.

However, it should be noted that there are other considerations that will affect the selection of the final design alternative. An evaluation of these other considerations is beyond the scope of this analysis. Therefore, based solely upon the cost-effectiveness of the two alternatives analyzed, the concrete-lined channel (i.e., Alternative I) is the recommended alternative.

If Alternative I is selected, it is recommended that, at the time of final design, a seepage analysis be performed to determine whether or not a curtain wall is needed to prevent the piping of soil away from the interface between the concrete bank and the underlying support material during periods of side overflow of stormwater runoff into the interceptor channel.

VII. REFERENCES

1. Simons, Li and Associates, Inc., "Final Hydrology Report, Outer Loop Highway Camelback Walk Channel to the Arizona Canal," May, 1989.

2. U.S. Department of Transportation, Federal Highway Administration, "Design of Roadside Channels with Flexible Linings," Hydraulic Engineering Circular No. 15, April, 1988.

3. U.S. Department of Transportation, Federal Highway Administration, "Hydraulic Design of Highway Culverts," Hydraulic Design Series No. 5, September, 1985.

AZDC02/TC/sR04.WP5

(PAZ-DC-02.2)

APPENDIX A

HYDRAULIC PROPERTIES AND CALCULATIONS FOR DESIGN CROSS SECTIONS

NORMAL FLOW - HYDRAULIC PROPERTIES

REACH #1
Concrete Channel

discharge	=	550 cfs
n-value	=	0.0180
bottom width	=	8.0 ft.
slope	=	0.0025
side slope	=	2:1

depth	=	4.26 ft.
velocity	=	7.81 fps
Froude #	=	0.82
critical depth	=	3.85 ft.
sequent depth	=	------
hydraulic depth	=	2.81 ft.
velocity head	=	0.95 ft.
specific head	=	5.21 ft.
top width	=	25.05 ft.
x-sectional area	=	70.43 sq. ft.
wetted perimeter	=	27.06 ft.
hydraulic radius	=	2.60 ft.

freeboard = 1'
min. design depth = 5.3'

NORMAL FLOW - HYDRAULIC PROPERTIES

Downstream End of REACH #2
CP #422
Concrete Channel

discharge	=	755 cfs
n-value	=	0.0180
bottom width	=	8.0 ft.
slope	=	0.0025
side slope	=	2:1

depth	=	4.96 ft.
velocity	=	8.48 fps
Froude #	=	0.84
critical depth	=	4.53 ft.
sequent depth	=	------
hydraulic depth	=	3.19 ft.
velocity head	=	1.12 ft.
specific head	=	6.08 ft.
top width	=	27.86 ft.
x-sectional area	=	89.00 sq. ft.
wetted perimeter	=	30.20 ft.
hydraulic radius	=	2.95 ft.

freeboard = 1'

min design depth = 6.0'

NORMAL FLOW – HYDRAULIC PROPERTIES

REACH 4
Concrete Channel

discharge	=	1000 cfs
n-value	=	0.0180
bottom width	=	10.0 ft.
slope	=	0.0022
side slope	=	2:1

depth	=	5.50 ft.
velocity	=	8.65 fps
Froude #	=	0.80
critical depth	=	4.91 ft.
sequent depth	=	------
hydraulic depth	=	3.61 ft.
velocity head	=	1.16 ft.
specific head	=	6.66 ft.
top width	=	32.01 ft.
x-sectional area	=	115.59 sq. ft.
wetted perimeter	=	34.61 ft.
hydraulic radius	=	3.34 ft.

freeboard = 1'
min design depth = 6.5'

NORMAL FLOW - HYDRAULIC PROPERTIES
REACH #6
Concrete Channel

discharge	=	1380 cfs
n-value	=	0.0180
bottom width	=	13.0 ft.
slope	=	0.0022
side slope	=	2:1

depth	=	5.95 ft.
velocity	=	9.33 fps
Froude #	=	0.82
critical depth	=	5.35 ft.
sequent depth	=	------
hydraulic depth	=	4.02 ft.
velocity head	=	1.35 ft.
specific head	=	7.30 ft.
top width	=	36.78 ft.
x-sectional area	=	147.97 sq. ft.
wetted perimeter	=	39.59 ft.
hydraulic radius	=	3.74 ft.

freeboard = 1'
min. design depth = 7.0'

NORMAL FLOW - HYDRAULIC PROPERTIES

REACH #8

Concrete Channel

discharge	=	3240 cfs
n-value	=	0.0180
bottom width	=	30.0 ft.
slope	=	0.0050
side slope	=	2:1

depth	=	5.37 ft.
velocity	=	14.83 fps
Froude #	=	1.27
critical depth	=	6.17 ft.
sequent depth	=	7.04 ft.
hydraulic depth	=	4.25 ft.
velocity head	=	3.41 ft.
specific head	=	8.78 ft.
top width	=	51.46 ft.
x-sectional area	=	218.54 sq. ft.
wetted perimeter	=	54.00 ft.
hydraulic radius	=	4.05 ft.

freeboard = $\frac{1}{5}(D + V^2/2g)$ = 1.8'

design depth (min) = 7.2'

NORMAL FLOW - HYDRAULIC PROPERTIES

REACH #1

Grass Lined Channel

discharge	=	550 cfs
n-value	=	0.0520
bottom width	=	15.0 ft.
slope	=	0.0028
side slope	=	4:1

depth	=	4.93 ft.
velocity	=	3.21 fps
Froude #	=	0.32
critical depth	=	2.71 ft.
sequent depth	=	------
hydraulic depth	=	3.14 ft.
velocity head	=	0.16 ft.
specific head	=	5.09 ft.
top width	=	54.44 ft.
x-sectional area	=	171.14 sq. ft.
wetted perimeter	=	55.65 ft.
hydraulic radius	=	3.08 ft.

$\tau_p = 1 \text{ lb/ft}^2$

$\tau_{max} = \gamma D S = 0.86$ ok

$V_p = \frac{0.189}{n} Y_h^{1/6} \tau_p^{1/2} = 4.4$ fps ok

freeboard = 1 foot

min design depth = 6.0'

NORMAL FLOW - HYDRAULIC PROPERTIES
Downstream End of Reach #2
Grass Lined Channel

discharge	=	755 cfs
n-value	=	0.0500
bottom width	=	25.0 ft.
slope	=	0.0028
side slope	=	4:1

depth	=	4.84 ft.
velocity	=	3.51 fps
Froude #	=	0.34
critical depth	=	2.63 ft.
sequent depth	=	------
hydraulic depth	=	3.37 ft.
velocity head	=	0.19 ft.
specific head	=	5.04 ft.
top width	=	63.76 ft.
x-sectional area	=	214.99 sq. ft.
wetted perimeter	=	64.95 ft.
hydraulic radius	=	3.31 ft.

$\tau_p = 1 \ lb/ft^2$

$\tau_{max} = \gamma DS = 0.85 \ lb/ft^2$ ok

$V_p = \frac{0.189}{n} R_h^{1/6} \tau_p^{1/2} = 4.63$ fps ok

freeboard = 1'

min design depth 5.8'

NORMAL FLOW - HYDRAULIC PROPERTIES
REACH #4
Grass Lined Channel

discharge	=	1000 cfs
n-value	=	0.0480
bottom width	=	50.0 ft.
slope	=	0.0041
side slope	=	4:1

depth	=	3.73 ft.
velocity	=	4.13 fps
Froude #	=	0.42
critical depth	=	2.18 ft.
sequent depth	=	------
hydraulic depth	=	3.03 ft.
velocity head	=	0.26 ft.
specific head	=	3.99 ft.
top width	=	79.83 ft.
x-sectional area	=	242.08 sq. ft.
wetted perimeter	=	80.75 ft.
hydraulic radius	=	3.00 ft.

$\tau_p = 1 \ lb/ft^2$

$\tau_{max} = \gamma DS = 0.95 \ lb/ft^2$ ok

$V_p = \frac{0.189}{n} Y_h^{1/6} \tau_p^{1/2} = 4.74$ fps

freeboard = 1'

min. design depth = 4.7'

NORMAL FLOW - HYDRAULIC PROPERTIES
REACH #6
Grass Lined Channel

discharge	=	1380 cfs
n-value	=	0.0480
bottom width	=	60.0 ft.
slope	=	0.0035
side slope	=	4:1

depth	=	4.27 ft.
velocity	=	4.19 fps
Froude #	=	0.39
critical depth	=	2.40 ft.
sequent depth	=	------
hydraulic depth	=	3.50 ft.
velocity head	=	0.27 ft.
specific head	=	4.55 ft.
top width	=	94.19 ft.
x-sectional area	=	329.43 sq. ft.
wetted perimeter	=	95.24 ft.
hydraulic radius	=	3.46 ft.

$\tau_p = 1 \text{ lb/ft}^2$

$\tau_{max} = \gamma D S = 0.93 \text{ lb/ft}^2$ OK

$V_p = \frac{0.189}{n} Y_h^{1/6} \tau_p^{1/2} = 4.85$ fps OK

Freeboard = 1'
min design depth = 5.3'

NORMAL FLOW - HYDRAULIC PROPERTIES

REACH #8

Grass Lined Channel

discharge	=	3240 cfs
n-value	=	0.0460
bottom width	=	110.0 ft.
slope	=	0.0030
side slope	=	4:1

depth	=	5.18 ft.
velocity	=	4.78 fps
Froude #	=	0.40
critical depth	=	2.89 ft.
sequent depth	=	------
hydraulic depth	=	4.47 ft.
velocity head	=	0.35 ft.
specific head	=	5.54 ft.
top width	=	151.47 ft.
x-sectional area	=	677.76 sq. ft.
wetted perimeter	=	152.75 ft.
hydraulic radius	=	4.44 ft.

$\tau_p = 1 \ lb/ft^2$

$\tau_{max} = \gamma D S = 0.97$ ok

$V_p = \frac{0.189}{n} Y_h^{1/6} \tau_p^{1/2} = 5.27$ ok

freeboard = 1'

min design depth = 6.2'

APPENDIX B

CULVERT COMPUTATION SHEETS

PROJECT: OUTER LOOP HIGHWAY
PAZ-DC-02 T2

STATION: 145+00
SHEET 1 **OF** 6

CULVERT DESIGN FORM

DESIGNER / DATE: RJS / 7/28/89
REVIEWER / DATE: JMT / 7/28/89

HYDROLOGICAL DATA

SEE ADD'L SHTS.

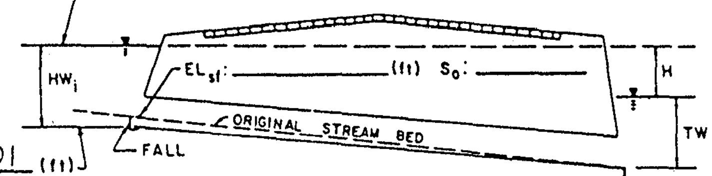
- ☐ METHOD:
- ☐ DRAINAGE AREA: ☐ STREAM SLOPE:
- ☐ CHANNEL SHAPE:
- ☐ ROUTING: ☐ OTHER:

DESIGN FLOWS/TAILWATER

R.I. (YEARS)	FLOW (cfs)	TW (ft)
50	428	3.77
100	514	4.26

EL_{hd}: 1337.51 (ft)

ROADWAY ELEVATION: 1339.51 (ft)



EL_i: 1331.01 (ft)

EL_o: 1330.39 (ft)

$S = S_o - FALL / L_o$
S = 0.0025
L_o = 250'

CULVERT DESCRIPTION: MATERIAL - SHAPE - SIZE - ENTRANCE	TOTAL FLOW Q (cfs)	FLOW PER BARREL Q/N (1)	HEADWATER CALCULATIONS: INLET CONTROL HW_i/D (2)	HW_i	FALL (3)	EL_{hi} (4)	OUTLET CONTROL TW (5)	d_c	$\frac{d_c+D}{2}$	h_o (6)	k_e	H (7)	EL_{ho} (8)	CONTROL HEADWATER ELEVATION	OUTLET VELOCITY	COMMENTS
1 - 10'X5' CBC	428	428	1.3	6.5	0	37.51	3.77	3.37	4.19	4.19	0.2	1.97	36.6	37.51	10.2	OK, IC
	514	514	1.5	7.5	0	38.51	4.26	3.71	4.36	4.36	0.2	2.84	37.6	38.7	11.8	OK, IC

TECHNICAL FOOTNOTES:

(1) USE Q/NB FOR BOX CULVERTS

(2) $HW_i/D = HW/D$ OR HW_i/D FROM DESIGN CHARTS

(3) $FALL = HW_i - (EL_{hd} - EL_{sf})$; FALL IS ZERO FOR CULVERTS ON GRADE

(4) $EL_{hi} = HW_i + EL_i$ (INVERT OF INLET CONTROL SECTION)

(5) TW BASED ON DOWN STREAM CONTROL OR FLOW DEPTH IN CHANNEL.

(6) $h_o = TW$ or $(d_c + D/2)$ (WHICHEVER IS GREATER)

(7) $H = \left[1 + k_e + (29 n^2 L) / R^{1.33}\right] v^2 / 2g$

(8) $EL_{ho} = EL_o + H + h_o$

SUBSCRIPT DEFINITIONS:

- a. APPROXIMATE
- f. CULVERT FACE
- hd. DESIGN HEADWATER
- hi. HEADWATER IN INLET CONTROL
- ho. HEADWATER IN OUTLET CONTROL
- i. INLET CONTROL SECTION
- o. OUTLET
- sf. STREAMBED AT CULVERT FACE
- tw. TAILWATER

COMMENTS / DISCUSSION:

90th Street Extension - CULVERT I
Alternative I - Concrete lined channel

CULVERT BARREL SELECTED:

SIZE: 1-10X5
SHAPE: Rectangular
MATERIAL: CBC n0.012
ENTRANCE: wingwalls

PROJECT: OUTER LOOP HIGHWAY PAZ-DC-02

STATION: 145+00

SHEET 2 **OF** 6

CULVERT DESIGN FORM

DESIGNER / DATE: RJS / 7/28/89

REVIEWER / DATE: JMT / 7/28/89

HYDROLOGICAL DATA

SEE ADD'L. SHTS.

☐ METHOD:

☐ DRAINAGE AREA: ☐ STREAM SLOPE:

☐ CHANNEL SHAPE:

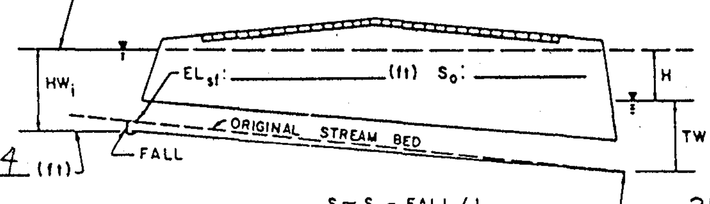
☐ ROUTING: ☐ OTHER:

DESIGN FLOWS/TAILWATER

R.I. (YEARS)	FLOW (cfs)	TW (ft)
50	428	4.39
100	514	4.79

EL_{hd}: 37.51 (ft)

ROADWAY ELEVATION: 39.51 (ft)



EL_i 31.74 (ft)

EL_o: 31.04 (ft)

$S = S_o - FALL / L_o$

S = 0.0028

L_o = 250'

HEADWATER CALCULATIONS

CULVERT DESCRIPTION: MATERIAL - SHAPE - SIZE - ENTRANCE	TOTAL FLOW Q (cfs)	FLOW PER BARREL Q/N (1)	INLET CONTROL: HW_i/D (2)	INLET CONTROL: HW_i	INLET CONTROL: FALL (3)	INLET CONTROL: EL_{hi} (4)	OUTLET CONTROL: TW (5)	OUTLET CONTROL: d_c	OUTLET CONTROL: $\frac{d_c+D}{2}$	OUTLET CONTROL: h_o (6)	OUTLET CONTROL: k_e	OUTLET CONTROL: H (7)	OUTLET CONTROL: EL_{ho} (8)	CONTROL HEADWATER ELEVATION	OUTLET VELOCITY	COMMENTS
2 - 6X4 CBC	428	214	1.4	5.6	0	37.3	4.39	3.4	3.7	4.39	0.2	2.98	37.9	37.9	8.9	close enough o.c.
	514	257	1.73	6.9	0	38.6	4.79	3.85	3.9	4.79	0.2	3.60	39.4	39.4	10.7	OK o.c.

TECHNICAL FOOTNOTES:

(1) USE Q/NB FOR BOX CULVERTS

(2) $HW_i/D = HW/D$ OR HW_i/D FROM DESIGN CHARTS

(3) $FALL = HW_i - (EL_{hd} - EL_{sf})$; FALL IS ZERO FOR CULVERTS ON GRADE

(4) $EL_{hi} = HW_i + EL_i$ (INVERT OF INLET CONTROL SECTION)

(5) TW BASED ON DOWN STREAM CONTROL OR FLOW DEPTH IN CHANNEL.

(6) h_o = TW or $(d_c + D/2)$ (WHICHEVER IS GREATER)

(7) $H = \left[1 + k_e + (29 n^2 L) / R^{1.33}\right] V^2/2g$

(8) $EL_{ho} = EL_o + H + h_o$

SUBSCRIPT DEFINITIONS:

a. APPROXIMATE
f. CULVERT FACE
hd. DESIGN HEADWATER
hi. HEADWATER IN INLET CONTROL
ho. HEADWATER IN OUTLET CONTROL
i. INLET CONTROL SECTION
o. OUTLET
sf. STREAMBED AT CULVERT FACE
tw. TAILWATER

COMMENTS / DISCUSSION:

90th Street Extension - CULVERT I
Alternative II, Grass Lined Channel

CULVERT BARREL SELECTED:

SIZE: 2-6X4 CBC

SHAPE: Rectangular

MATERIAL: CBC n 0.012

ENTRANCE: Wingwalls

PROJECT: OUTER LOOP HIGHWAY PAZ-DC-02 T2

STATION: 88+00

SHEET 3 **OF** 6

CULVERT DESIGN FORM

DESIGNER / DATE: RJS / 7-28-89

REVIEWER / DATE: JMT / 7-28-89

HYDROLOGICAL DATA

SEE ADD'L SHTS.

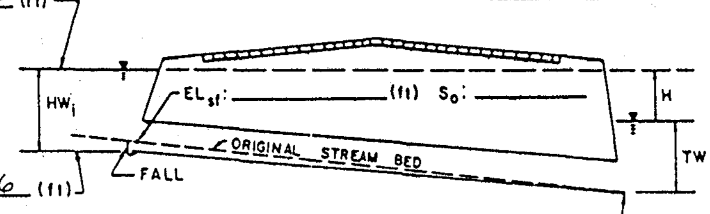
- ☐ METHOD:
- ☐ DRAINAGE AREA: ☐ STREAM SLOPE:
- ☐ CHANNEL SHAPE:
- ☐ ROUTING: ☐ OTHER:

DESIGN FLOWS/TAILWATER

R.I. (YEARS)	FLOW (cfs)	TW (ft)
50	971	4.98
100	1314	5.80

EL_{hd}: 16.76 (ft)

ROADWAY ELEVATION: 18.76 (ft)



EL_i: 09.76 (ft)

EL_o: 09.21 (ft)

$S = S_o - FALL / L_o$

S = 0.0022

L_o = 250

CULVERT DESCRIPTION: MATERIAL - SHAPE - SIZE - ENTRANCE	TOTAL FLOW Q (cfs)	FLOW PER BARREL Q/N (1)	HEADWATER CALCULATIONS – INLET CONTROL: HW_i/D (2)	HW_i	FALL (3)	EL_{hi} (4)	OUTLET CONTROL: TW (5)	d_c	$\frac{d_c+D}{2}$	h_o (6)	k_e	H (7)	EL_{ho} (8)	CONTROL HEADWATER ELEVATION	OUTLET VELOCITY	COMMENTS
3 - 8'x6' CBC	971	324	.93	5.6	0	15.3	4.98	3.71	4.86	4.98	0.2	1.2	15.4	15.4	8.1	OK O.C.
	1314	438	1.22	7.3	0	17.1	5.80	4.53	5.27	5.80	0.2	2.1	17.1	17.1	9.4	OK O.C.

TECHNICAL FOOTNOTES:

(1) USE Q/NB FOR BOX CULVERTS

(2) $HW_i/D = HW/D$ OR HW_i/D FROM DESIGN CHARTS

(3) $FALL = HW_i - (EL_{hd} - EL_{sf})$; FALL IS ZERO FOR CULVERTS ON GRADE

(4) $EL_{hi} = HW_i + EL_i$ (INVERT OF INLET CONTROL SECTION)

(5) TW BASED ON DOWN STREAM CONTROL OR FLOW DEPTH IN CHANNEL.

(6) $h_o = TW$ or $(d_c + D/2)$ (WHICHEVER IS GREATER)

(7) $H = \left[1 + k_e + (29 n^2 L)/R^{1.33}\right] V^2/2g$

(8) $EL_{ho} = EL_o + H + h_o$

SUBSCRIPT DEFINITIONS:

- a. APPROXIMATE
- f. CULVERT FACE
- hd. DESIGN HEADWATER
- hi. HEADWATER IN INLET CONTROL
- ho. HEADWATER IN OUTLET CONTROL
- i. INLET CONTROL SECTION
- o. OUTLET
- sf. STREAMBED AT CULVERT FACE
- tw. TAILWATER

COMMENTS / DISCUSSION:

Via De Ventura - CULVERT II

Alternative I, Concrete lined channel

CULVERT BARREL SELECTED:

SIZE: 3-8'X6' CBC

SHAPE: RECTANGULAR

MATERIAL: CBC n 0.012

ENTRANCE: Wing wall

PROJECT: OUTER LOOP HIGHWAY PAZ-DC-02 T2

STATION: 88+00

SHEET 4 **OF** 6

CULVERT DESIGN FORM

DESIGNER / DATE: RJS / 7-28-89

REVIEWER / DATE: JMT / 7-28-89

HYDROLOGICAL DATA

SEE ADD'L. SHTS.

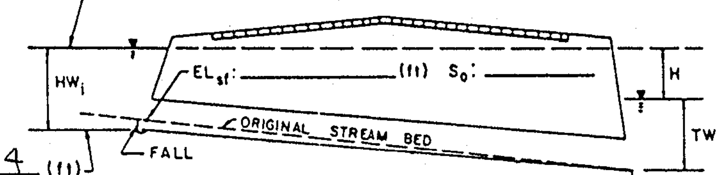
- ☐ METHOD:
- ☐ DRAINAGE AREA: ☐ STREAM SLOPE:
- ☐ CHANNEL SHAPE:
- ☐ ROUTING: ☐ OTHER:

DESIGN FLOWS/TAILWATER

R.I. (YEARS)	FLOW (cfs)	TW (ft)
50	971	3.51
100	1314	4.16

EL_{hd}: 16.76 (ft)

ROADWAY ELEVATION: 18.76 (ft)



EL_i: 11.24 (ft)

EL_o: 10.36 (ft)

$S = S_o - FALL / L_o$

S = 0.0035

L_o = 250

CULVERT DESCRIPTION: MATERIAL - SHAPE - SIZE - ENTRANCE	TOTAL FLOW Q (cfs)	FLOW PER BARREL Q/N (1)	HEADWATER CALCULATIONS: INLET CONTROL HW_i/D (2)	HW_i	FALL (3)	EL_{hi} (4)	OUTLET CONTROL: TW (5)	d_c	$\frac{d_c+D}{2}$	h_o (6)	k_e	H (7)	EL_{ho} (8)	CONTROL HEADWATER ELEVATION	OUTLET VELOCITY	COMMENTS
6 - 6'X4' CBC	971	162	1.11	4.4	0	15.7	3.51	2.83	3.42	3.51	0.2	1.43	15.3	15.7	7.7	OK
	1314	219	1.5	6.0	0	17.2	4.16	3.46	3.73	4.16	0.2	2.60	17.1	17.2	8.8	OK

TECHNICAL FOOTNOTES:

(1) USE Q/NB FOR BOX CULVERTS

(2) $HW_i/D = HW/D$ OR HW_i/D FROM DESIGN CHARTS

(3) $FALL = HW_i - (EL_{hd} - EL_{sf})$; FALL IS ZERO FOR CULVERTS ON GRADE

(4) $EL_{hi} = HW_i + EL_i$ (INVERT OF INLET CONTROL SECTION)

(5) TW BASED ON DOWN STREAM CONTROL OR FLOW DEPTH IN CHANNEL.

(6) h_o = TW or $(d_c + D/2)$ (WHICHEVER IS GREATER)

(7) $H = \left[1 + k_e + (29 n^2 L) / R^{1.33}\right] V^2 / 2g$

(8) $EL_{ho} = EL_o + H + h_o$

SUBSCRIPT DEFINITIONS:

- a. APPROXIMATE
- f. CULVERT FACE
- hd. DESIGN HEADWATER
- hi. HEADWATER IN INLET CONTROL
- ho. HEADWATER IN OUTLET CONTROL
- i. INLET CONTROL SECTION
- o. OUTLET
- sf. STREAMBED AT CULVERT FACE
- tw. TAILWATER

COMMENTS / DISCUSSION:

Via De Ventura - CULVERT II

Alternative II, Grass-Lined Channel

CULVERT BARREL SELECTED:

SIZE: 6-6X4 CBC

SHAPE:

MATERIAL: CBC n 0.012

ENTRANCE: Wing wall

PROJECT: OUTER LOOP HIGHWAY
PAZ-DC-02 T2

STATION: 35+00
SHEET 5 OF 6

CULVERT DESIGN FORM
DESIGNER / DATE: RJS / 7-28-89
REVIEWER / DATE: JMT / 7-28-89

HYDROLOGICAL DATA

SEE ADD'L. SHTS.

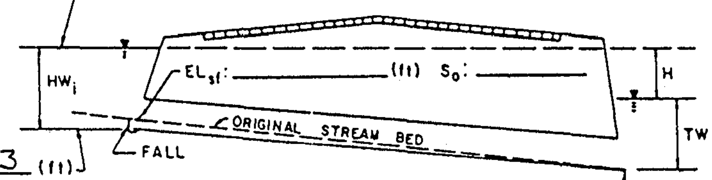
- ☐ METHOD:
- ☐ DRAINAGE AREA: ☐ STREAM SLOPE:
- ☐ CHANNEL SHAPE:
- ☐ ROUTING: ☐ OTHER:

DESIGN FLOWS/TAILWATER

R.I. (YEARS)	FLOW (cfs)	TW (ft)
50	2453	4.60
100	3234	5.36

EL_{hd}: 92.63 (ft)

ROADWAY ELEVATION: 94.63 (ft)



EL_i: 84.43 (ft)

EL_o: 83.18 (ft)

$S = S_o - FALL / L_o$
S = 0.005
L_o = 250

CULVERT DESCRIPTION: MATERIAL - SHAPE - SIZE - ENTRANCE	TOTAL FLOW Q (cfs)	FLOW PER BARREL Q/N (1)	HEADWATER CALCULATIONS: INLET CONTROL: HW_i/D (2)	HW_i	FALL (3)	EL_{hi} (4)	OUTLET CONTROL: TW (5)	d_c	$\frac{d_c+D}{2}$	h_o (6)	k_e	H (7)	EL_{ho} (8)	CONTROL HEADWATER ELEVATION	OUTLET VELOCITY	COMMENTS
4-10'X7' CBC	2453	614	1.1	7.7	0	92.1	4.60	4.89	5.95	5.95	0.2	1.90	91.0	92.1	10.3	OK I.C.
	3234	809	1.45	10.2	0	94.6	5.36	5.88	6.44	6.44	0.2	3.31	92.9	94.6	12.6	OK I.C.

TECHNICAL FOOTNOTES:

(1) USE Q/NB FOR BOX CULVERTS

(2) HW_i/D = HW /D OR HW_i/D FROM DESIGN CHARTS

(3) FALL = $HW_i - (EL_{hd} - EL_{sf})$; FALL IS ZERO FOR CULVERTS ON GRADE

(4) $EL_{hi} = HW_i + EL_i$ (INVERT OF INLET CONTROL SECTION)

(5) TW BASED ON DOWN STREAM CONTROL OR FLOW DEPTH IN CHANNEL.

(6) h_o = TW or $(d_c + D/2)$ (WHICHEVER IS GREATER)

(7) $H = \left[1 + k_e + (29 n^2 L) / R^{1.33}\right] V^2 / 2g$

(8) $EL_{ho} = EL_o + H + h_o$

SUBSCRIPT DEFINITIONS:

- o. APPROXIMATE
- f. CULVERT FACE
- hd. DESIGN HEADWATER
- hi. HEADWATER IN INLET CONTROL
- ho. HEADWATER IN OUTLET CONTROL
- i. INLET CONTROL SECTION
- o. OUTLET
- sf. STREAMBED AT CULVERT FACE
- tw. TAILWATER

COMMENTS / DISCUSSION:

Indian Bend Rd. - CULVERT III

Alternative I, Concrete lined channel

CULVERT BARREL SELECTED:

SIZE: 4-10'X7' CBC
SHAPE:
MATERIAL: CBC n 0.012
ENTRANCE: Wingwalls

PROJECT: OUTER LOOP HIGHWAY PAZ-DC-02 T2

STATION: 35+00

SHEET 6 OF 6

CULVERT DESIGN FORM

DESIGNER / DATE: RJS / 7-29-89

REVIEWER / DATE: JMT / 7-29-89

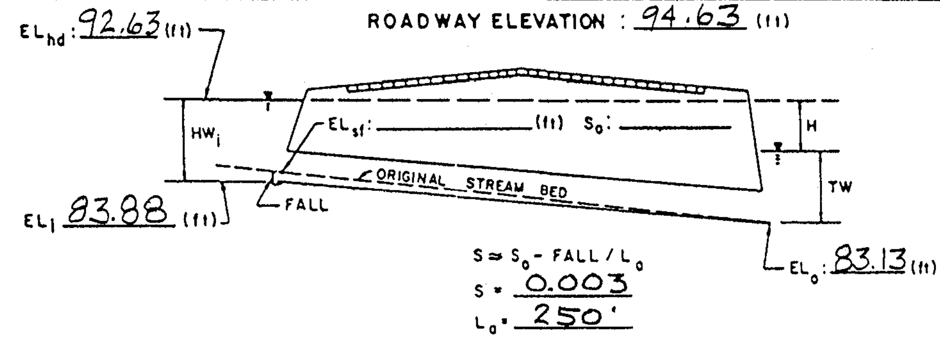
HYDROLOGICAL DATA

SEE ADD'L. SHTS.

- ☐ METHOD:
- ☐ DRAINAGE AREA: ☐ STREAM SLOPE:
- ☐ CHANNEL SHAPE:
- ☐ ROUTING: ☐ OTHER:

DESIGN FLOWS/TAILWATER

R.I. (YEARS)	FLOW (cfs)	TW (ft)
50	2453	4.42
100	3234	5.18



CULVERT DESCRIPTION: MATERIAL - SHAPE - SIZE - ENTRANCE	TOTAL FLOW Q (cfs)	FLOW PER BARREL Q/N (1)	HEADWATER CALCULATIONS – INLET CONTROL HW_i/D (2)	HW_i	FALL (3)	EL_{hi} (4)	OUTLET CONTROL TW (5)	d_c	$\frac{d_c+D}{2}$	h_o (6)	k_e	H (7)	EL_{ho} (8)	CONTROL HEADWATER ELEVATION	OUTLET VELOCITY	COMMENTS
4-10'x7' CBC	2453	614	1.1	7.7	0	91.6	4.42	4.89	5.95	5.95	0.2	1.90	91.0	91.6	10.3	OK
	3234	809	1.45	10.2	0	94.1	5.18	5.88	6.44	6.44	0.2	3.31	92.88	94.1	12.6	OK

TECHNICAL FOOTNOTES:

(1) USE Q/NB FOR BOX CULVERTS

(2) $HW_i/D = HW/D$ OR HW_f/D FROM DESIGN CHARTS

(3) FALL = $HW_i - (EL_{hd} - EL_{sf})$; FALL IS ZERO FOR CULVERTS ON GRADE

(4) $EL_{hi} = HW_i + EL_i$ (INVERT OF INLET CONTROL SECTION)

(5) TW BASED ON DOWN STREAM CONTROL OR FLOW DEPTH IN CHANNEL.

(6) h_o = TW or $(d_c + D/2)$ (WHICHEVER IS GREATER)

(7) $H = \left[1 + k_e + (29 n^2 L)/R^{1.33}\right] V^2/2g$

(8) $EL_{ho} = EL_o + H + h_o$

SUBSCRIPT DEFINITIONS:

- a. APPROXIMATE
- f. CULVERT FACE
- hd. DESIGN HEADWATER
- hi. HEADWATER IN INLET CONTROL
- ho. HEADWATER IN OUTLET CONTROL
- i. INLET CONTROL SECTION
- o. OUTLET
- sf. STREAMBED AT CULVERT FACE
- tw. TAILWATER

COMMENTS / DISCUSSION:

Indian Bend Rd. - CULVERT III

Alternative II, Grass lined channel

CULVERT BARREL SELECTED:

SIZE: 4-10'x7' CBC

SHAPE:

MATERIAL:

ENTRANCE: Wingwalls

APPENDIX C

QUANTITY CALCULATIONS AND COST ESTIMATES

Alternative I - Concrete lined channel

Excavation:

Reach 1

bottom width = 8'
depth = 5.3'
top width = 29.2'

X-sec Area = (8 + 29.2)/2 x 5.3 = 98.6 ft^2

length = 2200

Volume = 8,035 cy

Reach 2

upstream end X-sec Area = 98.6 ft^2

downstream end X-sec Area
B = 8'
d = 6'
T = 32'
A = (8+32)/2 x 6 = 120.0 ft^2

length = 200'

V = [(98.6+120.0)/2 x 200]/27 = 810 cy

Reach 3

upstream end X-sec Area = 120.0 ft^2

d/s end X-sec Area
B = 10'
d = 6.5'
T = 36'
A = (10 +36)/2 x 6.5 = 149.5 ft^2
length = 800'

V = [(120.0+149.5)/2 * 800]/27 = 3993 cy

Alternative I cont

Reach 4

X-sec Area = 149.5
length = 1200

V = 149.5 * 1200 / 27 = 6645 cy

Reach 5

U/s end X-sec Area = 149.5

d/s end X-sec Area
B = 13'
d = 7'
T = 41'
A = (41 + 13)/2 * 7.0 = 189 ft^2
length = 3000'

V = [(149.5 + 189)/2 * 3000]/27 = 18,806 cy

Reach 6

X-sec Area = 189 ft^2
length = 2000'

V = 189 * 2000 /27 = 14,000 cy

Reach 7

U/s end X-sec Area = 189 ft^2

d/s end X-sec Area
B = 30', d = 7.2', T = 58.8'

A = (30 + 58.8)/2 * 7.2 = 320 ft^2

V = [(189 + 320)/2 * 2500'] /27 = 23,565 cy

Alternative I cont.

Reach 8

X-sec Area = 320 ft^2
length = 3500

V = 320 * 3500 / 27 = 41,482 cy

Total excavation

V_T = 8035 + 810 + 3993 + 6645 + 18806 + 14000 + 23565 + 41482 = **117,336 cy**

Channel lining (5" thick)

NOTE: all channel lining will be 5" thick except floor on reach #08 which will be 6".

Reach 1:

P = 8 (B) + (2.24 * 5.3) 2 (side slopes) = 32' ft^2 per foot of channel

SA = 2200 * 32 / 9 = 7823 sy surface area

Reach 2:

u/s P = 32'

d/s P = 8 + (2.24 * 6) 2 = 35'

SA = [200' * (32+35)/2] / 9 = 745 sy

Alternative I cont

Reach 3 :

u/s P = 35'

d/s P = 10 + (2.24 * 6.5) 2 = 40'

SA = [800 * (35+40)/2] / 9 = 3334 sy

Reach 4 :

P = 40'

SA = 1200 * 40/9 = 5334 sy

Reach 5 :

u/s P = 40'

d/s P = 13 + (2.24 * 7) 2 = 45'

SA = [3000 * (40+45)/2]/9 = 14,167 sy

Reach 6 :

P = 45'

SA = 45 * 2000'/9 = 10,000 sy

Reach 7 :

u/s P = 45'

d/s P = 30 + (2.24 * 7.2) 2 = 63'

SA = [2500 * (45+63)/2] /9 = 15,000 sy

Alternative I cont

Reach 8 :

side slopes only w/ 5" thick

P = (2.24 x 7.2) 2 = 33'

SA = 3500 * 33 / 9 = 12,834 sy

total channel lining (5" thick) =

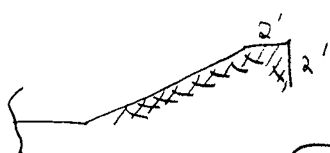
7823 + 745 + 3334 + 5334 + 14167 + 10000 +

15000 + 12834 = **69,237 sy**

total channel lining (6" thick) =
(bottom of Reach 8 only)

3500 * 30 / 9 = **393 sy**

concrete cap and toe down along u/s side of channel :
(5" thick)



4' x 15400' / 9 = **6845 sy**

Alternative I cont.

Culverts

Culvert I

1-10'x5' CBC L=250'

250' x 1.023 cy/ft = 256 cy

Culvert II

3- 8'x 6' CBC L= 250'

250' x 2.298 cy/ft = 575 cy

Culvert III

4-10'x7' CBC L=250'

250' x 4.140 cy/ft = 1035 cy

total concrete for culverts =

256 + 575 + 1035 = 1866 cy

Alternative II - grass-lined channel

Excavation :

Reach 1

B = 15', d = 6', T = 63'

A = (15 + 63)/2 * 6 = 234.0 ft^2

V = 2200 * 234 /27 = 19067 cy

Reach 2

u/s A = 234.0 ft^2

d/s A

B = 25', d = 5.8', T = 71.4

A = (25 + 71.4)/2 * 5.8 = 279.6 ft^2

L = 200'

V = [(234 + 279.6)/2 x 200] /27 = 3804 cy

Reach 3

u/s A = 279.6

d/s A

B = 50', d = 5', T = 90'

A = (50+90)/2 * 5 = 350 ft^2

L = 800'

V = [(279.6 + 350)/2 * 800] /27 = 9327 cy

Alternative II cont.

Reach 4

$A = 350\ ft^2$

$L = 1200'$

$V = 350 \times 1200 / 27 = \underline{15556\ cy}$

Reach 5

u/s $A = 350\ ft^2$

d/s A
$B = 60'$ $D = 5.3'$ $T = 102.4'$

$A = (60 + 102.4)/2 * 5.3 = 430.4\ ft^2$

$V = [(350 + 430.4)/2 * 3000]/27 = \underline{43,356\ cy}$

Reach 6

$V = 2000' * 430.4 ft^2 /27 = \underline{31,882\ cy}$

Reach 7

u/s $A = 430.4\ ft^2$

d/s A
$B = 110'$ $d = 6.2'$ $T = 159.6$

$A = (110 + 159.6)/2 * 6.2 = \underline{836\ ft^2}$

$V = [(430.4 + 836)/2 * 2500']/27 = \underline{58,630\ cy}$

Alternative II cont

Reach 8

$V = 836\ ft^2 * 3500' / 27 =$ 108 370 cy

Total excavation:

V_T 19067 + 3804 + 9327 + 15,556 + 31,882 +
58,630 + 108370 = 246,636 cy

Grass lining (calc surface area)

Reach 1:

P = 15 + (4.12 * 6) 2 = 64.4'

SA = 2200 × 64.4 = 141,680 sf

Reach 2:

u/s P = 64.4'

d/s P = 25 + (4.12 * 5.8) 2 = 72.8'

SA = 200 × 72.8 = 12880 sf

Reach 3

u/s P = 72.8

d/s P = 50 + (4.12 * 5) 2 = 91.2'

SA = 800 * 91.2 = 72,960 sf

Alternative II cont

Reach 4

P = 91.2'

SA = 1200 * 91.2 = 109,440 sf

Reach 5

u/s P = 91.2

d/s P = 60 + (4.12 * 5.3) 2 = 103.7'

SA = (91.2 + 103.7)/2 * 3000 = 292,350 sf

Reach 6

SA = 103.7 * 2000' = 207,400 sf

Reach 7

u/s P = 103.7'

d/s P = 110 + (4.12 * 6.2) 2 = 161'

SA = (103.7 + 161) 2 * 2500 = 329,625 sf

Reach 8

SA = 161 * 3500 = 563,500 sf

Total Surface Area =

141,680 + 12,880 + 72,960 + 109,440 + 292,350 +
207,400 + 329,625 + 563,500 = 1,729,835 sf
39.7 acres

Alternative II cont.

Culverts

Culvert I

2-6X4 CBC L=250'

250 X 1.068 cy/ft = 267 cy

Culvert II

6-6'X4' CBC L=250'

250 X 2.899 cy/ft = 725 cy

Culvert III

4-10'X7' CBC L=250'

250 X 4.140 cy/ft = 1035 cy

Total concrete for culverts

267 + 725 + 1035 = 2027

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CLIENT De Leuw Cather JOB NO. PAZ-DC-02.2 PAGE 12
PROJECT Outer Loop Highway DATE CHECKED ______ DATE 7-31-89
DETAIL Cost Estimate CHECKED BY ______ COMPUTED BY RJS

COST ESTIMATE

ALTERNATIVE I

CONCRETE-LINED CHANNEL

Item	Unit	Quantity	$ Unit Price	$ Amount
Channel Excavation	CY	117,336	3.75	440,010
Channel lining (6")	SY	69,630	25.00	1,740,750
Culverts, includes concrete, steel, excavation for box and wingwalls	CY	1866	300.00	559,800
Concrete cap & toe down alon u/s side of collector channel	SY	6845	25.00	171,125
		SUBTOTAL		2,911,685
		Contingencies (30%)		873,506
		TOTAL		$3,785,191

sla
SIMONS, LI & ASSOCIATES, INC.

CLIENT De Leuw Cather JOB NO. PAZ-DC-02.2 PAGE 13
PROJECT Outer Loop Highway DATE CHECKED ______ DATE 7-31-89
DETAIL Cost Estimate CHECKED BY ______ COMPUTED BY RJS

COST ESTIMATE

ALTERNATIVE II

GRASS-LINED CHANNEL

Item	UNIT	QUANTITY	$ UNIT PRICE	$ AMOUNT
Channel Excavation	CY	246,636	3.75	924,885
Channel Lining - Hydro seeded w/ bermuda, and other native & exotic species				
a) Hydro seeding	Acres	40	1200	48,000
b) Grading	SF	1,729,835	0.03	51,895
c) Irrigation System	SF	1,729,835	0.35	605,442
Culverts, includes concrete, steel & excavation for box and wingwalls	CY	2,027	300	608,100
		SUBTOTAL		2,238,322
		Contingencies (30%)		671,497
		TOTAL		$2,909,819