PRELIMINARY DESIGN REPORT

LANDSCAPED CHANNEL CONCEPT

OUTER LOOP HIGHWAY

VIA LINDA TO THE ARIZONA CANAL

Prepared For:

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Final Report
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1 INTRODUCTION

The purpose of this report is to summarize the technical assumptions and hydraulic performance characteristics from a preliminary analysis of a landscaped channelization concept. This concept has been tentatively adopted for carrying offsite drainage along that reach of the Outer Loop Highway from Via Linda to the Arizona Canal. The results of this report indicate that such a concept is feasible. However, the data is preliminary and subject to refinement during final design.

In recognition of the multiple offsite drainage concepts that have been evaluated for this reach of highway, a short chronological summary of previous drainage studies is presented in order to prevent any confusion as to which concept is being addressed in this report.

a. *Concept Drainage Design Report, Outer Loop Highway, Camelback Walk To The Arizona Canal*, Simons, Li & Associates, Inc. (SLA), September 1989. This is the first concept drainage study that evaluated both a fully lined concrete channel and a fully grass-lined channel section.

b. *Detention Basin Analysis, Outer Loop Highway, Camelback Walk to the Salt River*, memo from Robert L. Ward, P.E., Consulting Engineer, to Stan Polasik, P.E., DeLeuw, Cather & Company, November 2, 1989. This technical memorandum summarizes the results of a hydrologic and hydraulic study that was undertaken to examine changes in the SLA offsite drainage system costs that might accompany the construction of large detention basins at designated locations along the east side of the Outer Loop Highway. The large detention basin concept proved uneconomical and was not considered for further study.

c. *Outer Loop Highway, Analysis of 96th Street Drainage Channel Proposed by Evans, Kuhn & Associates, Inc. for the SRPMIC*, letter from Robert L. Ward, P.E., Consulting Engineer, to Wiley Smith, P.E., DeLeuw, Cather & Company, November 14, 1989. This letter summarizes the hydrologic, hydraulic, and financial impacts that would occur to the Outer Loop Highway offsite drainage channel (SLA concept) if a second interceptor channel were constructed by the Indian Community along 96th Street from the north boundary of the SRPMIC to the Arizona Canal. The results of this analysis indicated that the 96th Street channel would create a cost savings to the Outer Loop of approximately $312,000 for a concrete-lined channel, and about $387,000 for a grass-lined channel.

d. In December 1989, DeLeuw, Cather & Company commissioned an evaluation of a cascade-detention basin concept in lieu of the concrete and grass-lined channels that had previously been evaluated for this reach of the highway. This analysis was performed by Robert L. Ward, P.E., Consulting Engineer. This study was an effort to depart from the channelization concept and to provide long, relatively narrow detention basins that could be landscaped and located within the available highway right-of-way. The basins were all interconnected by culverts so that water could be transferred from one basin to the next. Connecting overflow spillways were also provided at the downstream end of each basin. The performance of such basins was found to be marginal, i.e., diversions at Via Linda were required to prevent the basins from spilling water beyond the highway right-of-way limits during routing of the 100-year event. Even with the Via Linda diversion, adequate freeboard was not attainable in several of the basins. The freeboard problem persisted even at the 50-year event.

However, the long, wide detention basin shape was found to perform satisfactorily if the dam embankments were eliminated, thus allowing each basin to freely discharge to the adjacent downstream basin. Accordingly, a channel invert profile was developed that closely paralleled the inverts of the cascade detention basins. In order to keep flow velocities in a non-erosive envelope, the channel slope was kept very flat. This required the use of several drop structures along the channel alignment.

The analysis of this wide, deep, landscaped channel concept is the focus of this report. Preliminary design assumptions, hydrology, hydraulic performance, and final design recommendations for this channel concept are presented in the following sections of this report.

2 HYDROLOGY

The peak discharges used for the channel design were based on several modifications to the HEC-1 model presented in the *Final Hydrology Report, Outer Loop Highway, Camelback Walk Channel to the Arizona Canal*, Simons, Li & Associates, Inc., May 1989. These modeling revisions are summarized as follows:

a. Several sub-basin boundaries were adjusted to reflect the most recent highway alignment adopted by DeLeuw, Cather & Company in 1989. This alignment change impacts Sub-Basins 360, 410, 420, 400, 430, and 500. These boundary adjustments created a need to revise drainage area sizes, curve numbers, overland flow parameters, and channel routing parameters.

b. In order to better define the drainage areas intercepted by the individual cascade-detention basins, nearly all the sub-basin boundaries along the Outer Loop Highway alignment were further subdivided, creating sub-basin designations such as 500A, 500B, etc. These revised drainage area subdivisions were retained in the HEC-1 model when the cascade-detention basin concept was abandoned in favor of the landscaped channel concept presented in this report.

c. Comment cards were added to the HEC-1 model to reference channel routing operations to the centerline stationing of the Outer Loop Highway.

d. All channel routing operations along the Outer Loop were converted from kinematic wave to modified Puls, using normal depth storage routing with an 8-point cross-section. This revision more accurately simulates the hydrograph attenuation that would be expected to occur (due to channel storage) within the large, low-velocity, landscaped channel cross-sections. For the purpose of HEC-1 routing operations, channel "n" values of 0.018

and 0.030 were used for the concrete and landscaped channels, respectively. The cross-sectional geometry that was used for each reach of the HEC-1 channel routings was based on an approximation of the average trapezoidal channel dimensions taken from the initial HEC-2 runs for the same corresponding reaches of channel. The channel geometry used for routing operations in the HEC-1 model were not updated to reflect subsequent channel geometry revisions in the HEC-2 models. The level of accuracy of hydrologic models does not warrant continued revision at such a refined level of detail.

e. At the request of DeLeuw, Cather, and Company, some additional flows were piped into the channel system at Via de Ventura (CP 503C). These flows, which originate from just north of the SRPMIC boundary, were routed to this location through 7000 L.F. of 4.5 foot diameter pipe. The maximum discharge of the input hydrograph is 120.6 cfs.

f. No westerly diversion of flow occurrs at the Via Linda/Outer Loop intersection, i.e., all water that enters this intersection is routed south through the Outer Loop drainage channel. This is not a change from the original SLA HEC-1 model; this assumption is stated herein to distinguish this analysis from other drainage system scenarios that did consider a westerly diversion of flow at this point.

g. For the purpose of the channel analysis presented in this report, it has been assumed that a north-south interceptor channel would be constructed along the extended alignment of 96th Street, from the north boundary of the SRPMIC to the Arizona Canal. This is an extremely important assumption since the proposed 96th Street channel will substantially reduce the peak inflows to the lower one-third of the subject reach of the Outer Loop Highway offsite drainage channel. The HEC-1 model used for this report

reflects the necessary revisions required to simulate the diversion of flow by the proposed 96th Street channel. **If the 96th Street channel is not constructed, the hydraulic analysis and water surface profiles presented in this report will not be valid**.

Appendix A contains a complete copy of the HEC-1 input and output data that was used as the basis for this report. The design event is the 100-year, 24-hour storm, using the HEC-1 hypothetical rainfall distribution. Plate 1 illustrates the revised HEC-1 sub-basin boundaries and concentration points.

It should be emphasized that Plate 1 only illustrates sub-basin boundaries and concentration points along the Outer Loop and 96th Street channel alignments, i.e., the total contributing drainage area is much larger than that portion shown on Plate 1. The interested reader is referred to Plate 3, *Final Hydrology Report, Outer Loop Highway, Camelback Walk Channel To The Arizona Canal*, Simons, Li & Associates, Inc., May 1989, for a complete schematic of the remaining, unrevised portions of the HEC-1 model.

3 CHANNEL DESIGN PARAMETERS

As alluded to previously, the channelization concept presented in this report stresses maximum utilization of an unlined, desert landscaped cross-section. The cross-section is expected to be similar in appearance to the existing drainage channel located along the south side of Shea Boulevard, between Via Linda and 102nd Street. Appendix B presents photographs of the Shea Boulevard channel.

Where right-of-way restrictions prevented use of the landscaped cross-sections, a fully lined concrete section was used. The following sub-sections of this report discuss the design assumptions that were used for this preliminary hydraulic analysis.

3.1 Channel Geometry

The landscaped, unlined channel sections utilize a 4H:1V side-slope along the highway shoulder and a 3H:1V side-slope from the right-of-way line setback. Concrete cross-sections utilized both vertical walls and 2H:1V side-slopes, depending on location. The rectangular cross-section was used from Via Linda to about 500 feet south of the 90th Street (Pima Road) crossing of the Outer Loop. Available channel right-of-way was very limited in this reach and could not accommodate a trapezoidal section and still maintain an 8-foot channel bottomwidth. A complete summary of channel geometry, bottomwidths, channel lining, and side-slopes is presented in Table 3.1. Due to preliminary highway design revisions still in progress at the time this report was printed, there may be some channel locations where channel design data has been altered from that shown in Table 3.1. This will most likely occur through that reach from Via Linda to 90th Street.

A fifteen foot (15') offset was maintained from the highway right-of-way line along the east channel bank for the entire length of the proposed channel. A minimum fifteen foot (15') offset was also maintained between the west channel

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Table 3.1
Control Data For Channel Geometry
Outer Loop Highway, SRPMIC
Via Linda To The Arizona Canal

R-O-W Sideslope: 3.0 (except for concrete sections)
Roadway Sideslope: 4.0 (except for concrete sections)

OLH Station	R-O-W Setback Station (X1)	Roadway Setback Station (X2)	Controlling Station	Lower Elevation Of 2 End Points (E1)	Type Of Channel Lining	Sideslopes	Controlling Invert Elevation (E2)	Maximum Allowable Excavation Elevation (E3)	Maximum Excavation Elevation At 8 Ft Bottomwidth	Bottomwidth At Controlling Invert Elevation (B)	Channel Centerline Station At Controlling Invert Elevation
2369+70	N/A	131.2	131.2	1339.0	Concrete	Vertical	1333.21	1357.7	1358.9	20.0	141.2
2375+00	200.3	172.9	172.9	1339.1	Concrete	Vertical	1332.15	1335.2	1336.3	20.0	186.6
2380+00	234.1	204.9	234.1	1338.5	Concrete	Vertical	1331.15	1334.3	1335.5	20.0	219.5
2385+00	257.2	232.2	232.2	1336.6	Concrete	Vertical	1330.15	1333.0	1334.2	20.0	244.7
2390+00	264.3	224.4	224.4	1336.2	Concrete	Vertical	1329.15	1330.5	1331.6	20.0	244.4
2395+00	245.0	200.5	200.5	1333.2	Concrete	Vertical	1328.15	1326.8	1328.0	20.0	222.8
2400+00	225.2	151.4	151.4	1334.3	Earth	3:1, 4:1	1327.40	1323.8	1324.9	25.5	191.7
(D) 2405+00	212.0	90.3	90.3	1332.8	Earth	3:1, 4:1	1326.65	1315.4	1316.6	78.7	154.2
(D) 2405+00	212.0	90.3	90.3	1332.8	Earth	3:1, 4:1	1323.15	1315.4	1316.6	54.2	156.0
(D) 2410+00	213.1	98.9	98.9	1331.4	Earth	3:1, 4:1	1322.40	1315.1	1316.2	51.2	160.5
(D) 2410+00	213.1	98.9	98.9	1331.4	Earth	3:1, 4:1	1318.90	1315.1	1316.2	26.7	162.3
2415+00	224.4	91.8	91.8	1331.7	Earth	3:1, 4:1	1318.15	1312.8	1313.9	37.8	164.9
2420+00	217.5	103.3	103.3	1328.0	Earth	3:1, 4:1	1317.40	1311.7	1312.8	40.0	165.7
2425+00	220.0	103.6	220.0	1326.9	Earth	3:1, 4:1	1316.65	1310.3	1311.4	44.7	166.9
2430+00	229.0	136.2	136.2	1324.7	Earth	3:1, 4:1	1315.90	1311.4	1312.6	31.2	187.0
(D) 2435+00	281.0	183.3	183.3	1322.1	Concrete	2:1	1315.15	1308.1	1309.3	28.0	232.2
(D) 2435+00	281.0	183.3	183.3	1322.1	Concrete	2:1	1313.15	1308.1	1309.3	20.0	232.2
2440+00	274.7	234.5	234.5	1319.0	Concrete	2:1	1312.08	1313.3	1314.4	20.0	254.6
2445+00	260.0	218.0	218.0	1318.4	Concrete	2:1	1311.00	1312.4	1313.5	20.0	239.0
(D) 2450+00	245.0	166.5	166.5	1314.6	Earth	3:1, 4:1	1309.15	1303.4	1304.5	40.4	208.5
(D) 2450+00	245.0	166.5	166.5	1314.6	Earth	3:1, 4:1	1305.15	1303.4	1304.5	12.4	210.5
(D) 2455+00	235.0	121.9	121.9	1312.9	Earth	3:1, 4:1	1304.40	1296.7	1297.9	53.6	182.7
(D) 2455+00	235.0	121.9	121.9	1312.9	Earth	3:1, 4:1	1300.40	1296.7	1297.9	25.6	184.7
(D) 2460+00	220.0	94.0	94.0	1310.6	Earth	3:1, 4:1	1299.65	1292.6	1293.7	49.4	162.5

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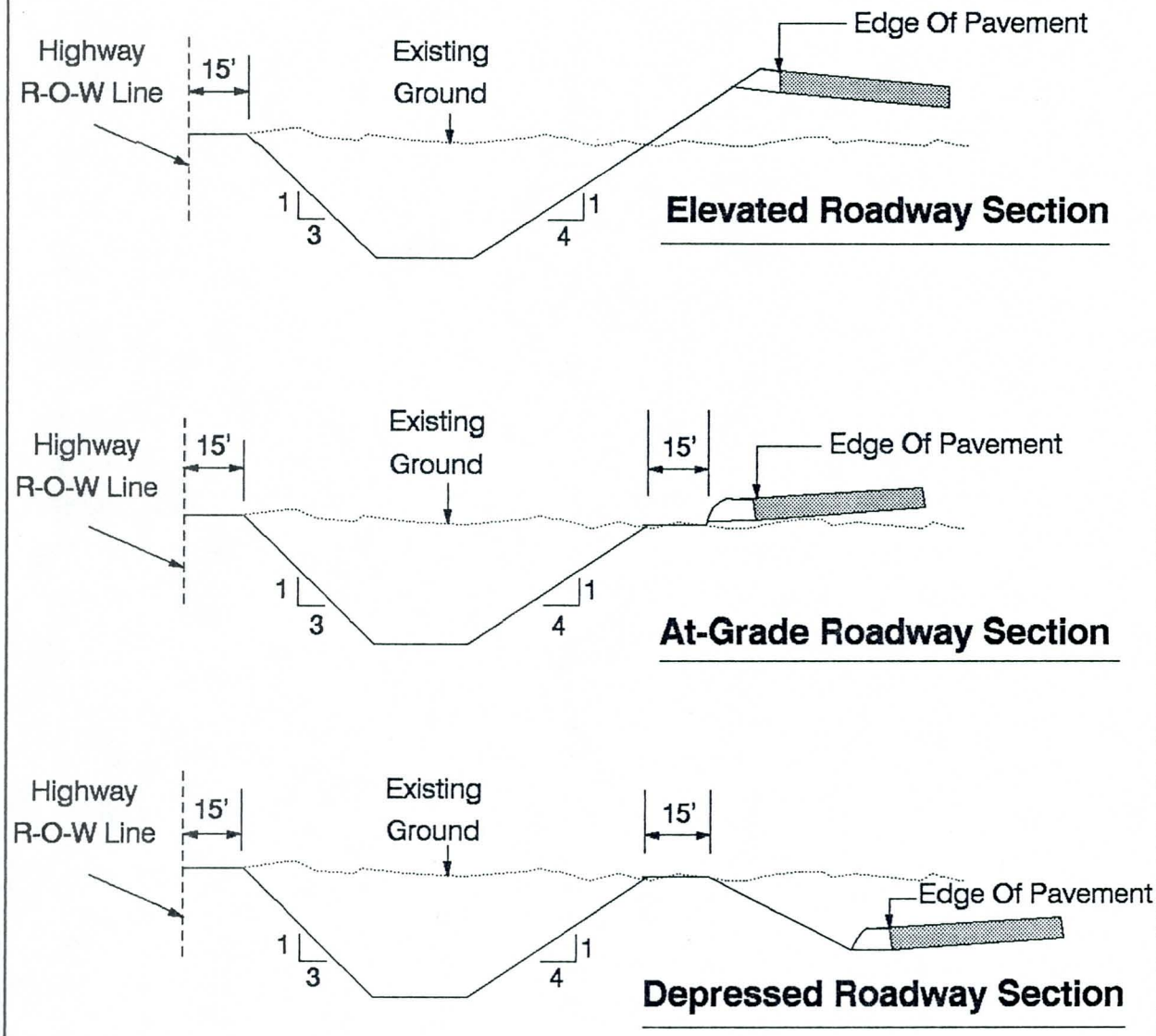
(D) 2460+00	220.0	94.0	94.0	1310.6	Earth	3:1, 4:1	1296.65	1292.6	1293.7	28.4	164.0
2465+00	214.0	86.7	86.7	1308.3	Earth	3:1, 4:1	1295.90	1290.1	1291.3	40.5	156.5
2470+00	214.6	88.8	88.8	1306.3	Earth	3:1, 4:1	1295.15	1288.3	1289.5	47.8	157.3
(D) 2475+00	214.9	93.3	93.3	1303.3	Earth	3:1, 4:1	1294.40	1285.9	1287.1	59.3	158.5
(D) 2475+00	214.9	93.3	93.3	1303.3	Earth	3:1, 4:1	1291.40	1285.9	1287.1	38.3	160.0
2480+00	214.9	86.9	86.9	1301.1	Earth	3:1, 4:1	1290.65	1282.8	1284.0	54.9	156.1
2485+00	225.0	127.3	225.0	1299.2	Earth	3:1, 4:1	1289.90	1285.2	1286.4	32.6	180.8
2490+00	255.0	165.1	255.0	1297.5	Earth	3:1, 4:1	1289.15	1284.7	1285.8	31.5	214.2
2495+00	279.0	218.0	218.0	1296.0	Concrete	2:1	1288.40	1287.3	1288.4	20.0	243.5
2500+00	273.0	216.5	216.5	1294.2	Concrete	2:1	1287.30	1286.1	1287.3	20.0	239.8
(D) 2505+00	254.7	179.0	179.0	1292.1	Earth	3:1, 4:1	1286.10	1281.3	1282.4	33.7	219.9
(D) 2505+00	254.7	179.0	179.0	1292.1	Earth	3:1, 4:1	1283.10	1281.3	1282.4	12.7	221.4
2510+00	235.5	137.0	137.0	1290.5	Earth	3:1, 4:1	1282.35	1276.4	1277.6	41.4	190.3
(D) 2515+00	225.0	95.9	225.0	1288.3	Earth	3:1, 4:1	1281.60	1269.9	1271.0	82.2	163.8
(D) 2515+00	225.0	95.9	225.0	1288.3	Earth	3:1, 4:1	1278.60	1269.9	1271.0	61.2	165.3
2520+00	224.9	113.0	113.0	1286.5	Earth	3:1, 4:1	1277.60	1270.5	1271.7	49.6	173.4
2525+00	225.0	110.8	225.0	1283.6	Earth	3:1, 4:1	1276.60	1267.3	1268.4	65.2	171.4
(D) 2529+00	220.5	162.8	162.8	1282.2	Earth	3:1, 4:1	1275.10	1274.0	1275.1	8.0	195.2

Notes: 1) (D) – Drop Structure Location
2) All channel cross-section stationing is referenced to the Outer Loop Highway General Plan & cross-sections provided by DeLeuw, Cather & Co.
3) Channel centerline is set at the middle of the channel bottomwidth.

bank and the roadway embankment slope for all depressed highway locations and some at-grade locations. Elevated highway sections simply extended the embankment slope at a 4H:1V angle to form the west side-slope of the channel. Figure 3.1 illustrates the typical offsets and side-slope extensions used to form the channel boundaries.

The channel geometry was coded into HEC-2 models with the use of the channel improvement (CHIMP) option. Only two GR (ground points) coordinate pairs were used at each cross-section. These two points represent a level ground line set at an elevation at which the channel would begin to overtop. These overtopping elevations were taken from the roadway cross-sections provided by DeLeuw, Cather & Company (DCCO). The horizontal coordinates of the GR points and the channel centerline on the CI card are referenced to the horizontal stationing used by DCCO for each highway cross-section. The channel centerline station is set at the midpoint of the channel bottomwidth.

In order to be consistent with the direction of the highway cross-section stationing, the left and right side-slopes (Fields 4 and 5 on the CI card) are referenced to a channel cross-section as it would be viewed looking in the <u>upstream</u> direction. This has no bearing on the hydraulic calculations, but allows starting and ending water surface elevation stations to use a conventional <u>left to right</u> format. The format of the highway cross-section stationing is from <u>right to left</u> (looking downstream) along the east side of the highway.



Typical Channel Geometry & Offsets
Landscaped Channel Cross-Section

Not To Scale

	Outer Loop Highway Via Linda to Arizona Canal	
Robert L. Ward, P.E., Consulting Engineer	Feb. 24, 1990	Figure 3.1

3.2 Channel Roughness Values

Manning's "n" values of 0.045 and 0.023 were used to develop an estimate of the maximum water surface profiles for landscaped and concrete channel sections, respectively. In order to assess the erosion potential to the earth/landscaped sections of channel, a second set of HEC-2 models was created with "n" values of 0.025 and 0.018 for landscaped and concrete channel sections, respectively.

This envelope of multiple "n" values allows a more accurate assessment of maximum water surface elevations and velocity profiles than can be achieved by relying on one set of values to evaluate both of these important hydraulic characteristics. The high "n" value scenario is an attempt to simulate a reduction in channel capacity due to debris build-up on vegetation and at culvert/bridge inlets. The low "n" value scenario is a simulation of a channel that might be stripped of vegetation (due to erosion), thus exposing the denuded channel banks to potentially erosive velocities.

3.3 Channel Profile

Plate 2 presents a profile of the channel invert, the estimated water surface profile associated with the 100-year event, and the ground elevation at which channel overtopping would occur. Plate 2 is a copy of a work map and, in an effort to reduce costs, has not been re-drafted into a more formal format. Additionally, this profile is preliminary and will, undoubtedly, be revised during final design. The purpose of Plate 2, as well the results of this report, is to provide the final design team with a starting point from which the final channel design may proceed. The water surface profile on Plate 2 is based on "n" values of 0.045 and 0.023 for earth and concrete linings, respectively.

The preliminary channel profile contains several drop structures. These structures are required to keep the channel bed-slopes sufficiently flat to prevent the occurrence of erosive velocities through the unlined channel sections. It is anticipated that these drops will be constructed of either reinforced concrete or soil-cement. Both vertical and sloping drop faces may be considered during final design.

The majority of the unlined channel sections employ bed-slopes of 0.0015 ft/ft. This is less than the minimum slope of 0.0020 ft/ft specified by ADOT for unlined channels. The use of a steeper slope might be considered during final design. However, special attention should be devoted to the possiblity of erosive velocities that may be generated by such slopes.

3.4 Starting Water Surface Profile Assumptions

To acknowledge the hydraulic impact of the proposed drop structures, the highway interceptor channel was divided into 10 reaches, with a separate HEC-2 model created for each reach.

The downstream terminus of the channel is just north of the north side of the Arizona Canal. Based on topographic data provided by DeLeuw, Cather & Company, the north canal embankment has a crest elevation of approximately 1282.0 feet MSL. Accordingly, the HEC-2 model for this initial channel reach utilized a starting water surface elevation of 1281.0 feet MSL. This assumes water would be ponded to within 1 foot of the top of the north canal bank.

The remaining upstream channel reaches were initially analyzed under an assumption that the starting water surface elevation would be equal to critical depth at the brink of each drop structure. The results of the initial HEC-2 runs were reviewed to see if the downstream water surface profiles would submerge

the drop structures at the upstream end of each channel reach. Such submergence could invalidate the assumption of critical depth for the starting condition of the water surface profile upstream of the drop structures. Table 3.2 summarizes the results of this analysis. All of the drops were submerged to some degree, while four of the drops were submerged to a depth greater than critical depth.

Although critical depth would probably still be a reasonable starting condition for those drops submerged to a depth less than critical depth, it would not be a sound assumption for those drops submerged deeper than critical depth.

To provide more realism to the hydraulic analysis, an approximate friction slope was computed for the flow over the submerged drop structures. This slope was computed as the difference between the energy gradelines, upstream and downstream of a drop, divided by a length of 100 feet, i.e., the friction slope is assumed applicable over a 100 foot transition distance, centered somewhere near the drop structure location. The HEC-2 models were then re-run with the computations initialized by the slope-area method, using the friction slopes in Table 3.3 as the estimated starting energy slopes at each drop structure. All the HEC-2 models presented in this report utilize these friction slopes, with the exception of the most downstream model, which uses a starting water surface elevation of 1281.0 feet MSL.

Table 3.2

Drop Structure Data
Outer Loop Highway
Via Linda to Arizona Canal

Drop Location	Elevation, Top of Drop (ft, MSL)	Elevation, Bottom of Drop (ft, MSL)	* D/S Water Surface Elevation (ft, MSL)	Submergence Depth (ft)	Critical Depth (ft)	Q100 (cfs)
2405+00	1326.65	1323.15	1327.45	0.80	1.59	930
2410+00	1322.40	1318.90	1324.43	2.03	2.06	930
2435+00	1315.15	1313.15	1318.65	3.50	3.36	1112
2450+00	1309.15	1305.15	1311.69	2.54	2.79	1220
2455+00	1304.40	1300.40	1306.21	1.81	2.40	1230
2460+00	1299.65	1296.65	1302.32	2.67	2.46	1183
2475+00	1294.40	1291.40	1297.39	2.99	2.25	1226
2505+00	1286.10	1283.10	1289.18	3.08	3.14	1271
2515+00	1281.60	1278.60	1283.78	2.18	1.89	1271

** Based on water surface profiles starting at critical depth at drop structures. No interpolated cross-sections.*

Table 3.3

Approximation of Energy Slope Over Drop Structures

Outer Loop Highway
Via Linda to Arizona Canal

Drop Location	* Upstream Energy Gradeline (ft, MSL)	* Downstream Energy Gradeline (ft, MSL)	Assumed Transition Length (ft)	Computed Friction Slope (ft/ft)
2405+00	1328.99	1327.60	100	0.0139
2410+00	1325.39	1324.64	100	0.0075
2435+00	1319.92	1319.31	100	0.0061
2450+00	1313.12	1312.13	100	0.0099
2455+00	1307.86	1306.54	100	0.0132
2460+00	1303.18	1302.61	100	0.0057
2475+00	1297.67	1297.58	100	0.0009
2505+00	1290.51	1289.77	100	0.0074
2515+00	1284.38	1283.93	100	0.0045

** Based on water surface profiles starting at critical depth at drop structures. No interpolated cross-sections.*

3.5 Hydraulic Analysis

As discussed previously, the Corps of Engineers *Water Surface Profile Program, HEC-2*, was used for the hydraulic calculations presented in this report. All models were run in a sub-critical mode.

Cross-section numbers are referenced to stationing along the centerline of the Outer Loop Highway. Cross-section spacing was maintained at 500 feet. This distance was controlled by the highway cross-sectioning provided by DeLeuw, Cather & Company, i.e., sections were provided to the consultant at 500 foot intervals. In order to improve the accuracy of the water surface profiles, the final HEC-2 models were executed with the option activated for the program to insert interpolated cross-sections if the velocity head between adjacent sections exceeded 0.1 feet. The initial HEC-2 models, with critical depth starting assumptions, did not use interpolated cross-sections.

Two water surface profiles were developed for each channel reach. The first profile was based on the 100-year event, while the second profile utilized a discharge equal to 1.2 x Q_{100}. This second profile was executed in order to comply with ADOT criteria that *"All channels shall be able to convey 120 percent of the design flow at bank-full elevation"* (Reference: Design Procedures Manual, Section 3.7.8, sub-paragraph 6.)

The HEC-2 models presented in this report <u>do not</u> address the impact of any bridges, culverts, or siphons that may ultimately be included in the final roadway and channel design for cross-streets such as Via de Ventura, Indian Bend Road, etc. All water surface profiles are based on open channel flow, using the channel geometries listed in Table 3.1.

The input and output data for the HEC-2 Models are presented in Appendices C and D. Appendix C presents the high "n" value models that were used to plot the water surface profile on Plate 2, while Appendix D includes the low "n" value models that were used for the maximum velocity analysis. Tabular summary printouts are included with each HEC-2 model to provide a convenient reference to key hydraulic parameters.

3.6 Bank Erosion Potential

As stated previously, both high and low "n" value envelopes were modeled in order to investigate maximum water surface profiles, as well as maximum channel velocities. Table 3.4 summarizes the maximum and minimum velocities that occur at the extreme ends of the "n" value envelope. The majority of the landscaped earth sections experience velocities in the 2 to 5 fps range, although some sections reach values as high as 7 to 9 fps under the low "n" value scenario.

An "n" of 0.025 for a well-landscaped channel is conservatively low. Accordingly, there should be little risk that these higher velocities will ever be achieved. However, a detailed bank erosion analysis should be performed during final channel design. It may be found neccessary to flatten some of the channel slopes to force a slight velocity reduction from those shown in Table 3.4.

Table 3.4
Summary of Flow Velocities
Outer Loop Highway Drainage Channel
Via Linda to the Arizona Canal

OLH Station	* Low Velocity (fps)	** High Velocity (fps)	Type of Lining
2369+70	5.96	7.07	Concrete
2375+00	5.87	6.96	Concrete
2380+00	5.69	6.67	Concrete
2385+00	5.39	6.13	Concrete
2390+00	5.62	6.15	Concrete
2395+00	9.18	10.50	Concrete
2400+00	4.19	5.40	Earth
(D) 2405+00	5.68	6.96	Earth
(D) 2405+00	3.35	4.55	Earth
(D) 2410+00	5.19	7.65	Earth
(D) 2410+00	3.71	5.68	Earth
2415+00	3.13	4.64	Earth
2420+00	2.94	4.17	Earth
2425+00	2.57	3.40	Earth
2430+00	3.78	4.90	Earth
(D) 2435+00	9.52	9.52	Concrete
(D) 2435+00	6.58	7.63	Concrete
2440+00	7.44	8.67	Concrete
2445+00	10.24	10.21	Concrete
(D) 2450+00	3.63	8.72	Earth
(D) 2450+00	5.32	6.74	Earth
(D) 2455+00	6.84	8.28	Earth
(D) 2455+00	5.16	7.35	Earth
(D) 2460+00	5.16	7.68	Earth
(D) 2460+00	4.21	6.48	Earth
2465+00	3.60	5.56	Earth
2470+00	3.22	4.96	Earth
(D) 2475+00	2.71	4.03	Earth

Table 3.4
Summary of Flow Velocities
Outer Loop Highway Drainage Channel
Via Linda to the Arizona Canal

OLH Station	* Low Velocity (fps)	** High Velocity (fps)	Type of Lining
(D) 2475+00	3.38	4.83	Earth
2480+00	2.47	3.28	Earth
2485+00	3.32	4.38	Earth
2490+00	3.32	4.07	Earth
2495+00	7.51	8.84	Concrete
2500+00	10.38	10.10	Concrete
(D) 2505+00	6.19	9.07	Earth
(D) 2505+00	5.97	7.90	Earth
2510+00	4.95	6.55	Earth
(D) 2515+00	4.35	6.38	Earth
(D) 2515+00	3.08	4.09	Earth
2520+00	3.40	4.14	Earth
2525+00	2.46	2.73	Earth
2529+00	7.52	7.52	Earth

* n=.045 – earth/landscape
* n=.023 – concrete
** n=.025 – earth/landscape
** n=.018 – concrete

File: VEL.WK1

Notes: 1) All velocities are for Q100
2) (D) – Drop Structure Location

3.7 Channel Freeboard Summary

Table 3.5 summarizes the freeboard dimensions that occur with both the 100-year event and 1.2 x Q_{100}. Freeboard is listed for those HEC-2 Models that employ critical depth as the starting condition at each drop structure, as well as for those models that use an approximate energy slope at the drops to simulate drop structure submergence.

A review of Table 3.5 indicates that the proposed channel concept provides the required 1 foot of freeboard during the 100-year event at all cross-sections for an assumed starting condition of critical depth. However, when the estimated energy slope option is used, Station 2450+00 experiences an overtop condition of 0.05 feet. All other channel stations exhibit 1.00 feet, or more, of freeboard for the 100-year event with the energy slope starting option.

The freeboard criteria for the 1.2 x Q_{100} event is zero, i.e., this event simply has to be contained within the channel banks. A review of Table 3.5 indicates that this criteria is met at all stations for an assumed starting condition of critical depth at the drop structures. When the starting energy slope option is used at the drops, minor overtopping occurs at Stations 2450+00 and 2525+00; the flow is adequately contained at all other stations.

The minor freeboard and overtopping violations that are shown in Table 3.5 could be eliminated through adjustment of drop structure heights, or by the use of wider bottomwidths and steeper side-slopes. Channel bed-slopes could also be increased (may cause erosive velocities), or as a last resort, the entire channel reach could be lined with concrete. These minor discrepancies should be easily resolved during final channel design.

Revised: 3/18/90
File: CHNLFB.WK1

Table 3.5
Channel Freeboard Summary
Outer Loop Highway, SRPMIC
Via Linda To The Arizona Canal
(all CWSEL based on n=.045 & .023)

	R-O-W Sideslope:	3.0	100-Year Event					1.2 x 100-Year Event				
	Roadway Sideslope:	4.0										
OLH Station	Channel Invert Elevation (ft)	Channel Overtop Elevation (ft)	Q100 (cfs)	CWSEL, Starting With CRIWS (ft)	CWSEL, Starting With Energy Slope (ft)	Freeboard With CRIWS (ft)	Freeboard With Energy Slope (ft)	1.2 x Q100 (cfs)	CWSEL, Starting With CRIWS (ft)	CWSEL, Starting With Energy Slope (ft)	Freeboard With CRIWS (ft)	Freeboard With Energy Slope (ft)
2369+70	1333.21	1339.0	517	1337.56	1337.54	1.44	1.46	620	1338.16	1338.14	0.84	0.86
2375+00	1332.15	1339.1	517	1336.59	1336.55	2.51	2.55	620	1337.22	1337.17	1.88	1.93
2380+00	1331.15	1338.5	517	1335.76	1335.68	2.74	2.82	620	1336.41	1336.33	2.09	2.17
2385+00	1330.15	1336.6	517	1335.07	1334.94	1.53	1.66	620	1335.73	1335.59	0.87	1.01
2390+00	1329.15	1336.2	564	1334.37	1334.15	1.83	2.05	677	1335.00	1334.79	1.20	1.41
2395+00	1328.15	1334.5	716	1332.95	1332.04	1.55	2.46	859	1333.35	1332.31	1.15	2.19
2400+00	1327.40	1334.9	716	1332.13	1331.64	2.77	3.26	859	1332.50	1332.02	2.40	2.88
(D) 2405+00	1326.65	1333.7	930	1328.24	1328.57	5.46	5.13	1116	1328.43	1328.78	5.27	4.92
(D) 2405+00	1323.15	1333.7	930	1327.45	1327.21	6.25	6.49	1116	1327.85	1327.61	5.85	6.09
(D) 2410+00	1322.40	1331.8	930	1324.46	1325.32	7.34	6.48	1116	1324.71	1325.63	7.09	6.17
(D) 2410+00	1318.90	1331.8	930	1324.36	1324.37	7.44	7.43	1116	1324.90	1324.92	6.90	6.88
2415+00	1318.15	1331.8	959	1323.52	1323.55	8.28	8.25	1151	1324.07	1324.11	7.73	7.69
2420+00	1317.40	1328.0	959	1322.85	1322.90	5.15	5.10	1151	1323.41	1323.47	4.59	4.53
2425+00	1316.65	1326.9	959	1322.34	1322.41	4.56	4.49	1151	1322.90	1322.98	4.00	3.92
2430+00	1315.90	1325.0	1112	1321.50	1321.64	3.50	3.36	1334	1322.02	1322.18	2.98	2.82
(D) 2435+00	1315.15	1322.1	1112	1318.51	1318.51	3.59	3.59	1334	1318.90	1318.90	3.20	3.20
(D) 2435+00	1313.15	1322.1	1112	1318.65	1318.61	3.45	3.49	1334	1319.22	1319.17	2.88	2.93
2440+00	1312.08	1319.0	1220	1317.51	1317.42	1.49	1.58	1464	1318.06	1317.95	0.94	1.05
2445+00	1311.00	1318.4	1220	1315.69	1315.20	2.71	3.20	1464	1316.10	1315.66	2.30	2.74
(D) 2450+00	1309.15	1314.6	1220	1311.94	1314.65	2.66	-0.05	1464	1312.27	1314.72	2.33	-0.12
(D) 2450+00	1305.15	1314.6	1220	1311.69	1311.67	2.91	2.93	1464	1312.16	1312.19	2.44	2.41
(D) 2455+00	1304.40	1312.9	1230	1306.80	1307.23	6.10	5.67	1476	1307.10	1307.55	5.80	5.35
(D) 2455+00	1300.40	1312.9	1230	1306.21	1305.77	6.69	7.13	1476	1306.69	1306.23	6.21	6.67
(D) 2460+00	1299.65	1310.6	1183	1302.11	1303.33	8.49	7.27	1420	1302.40	1303.71	8.20	6.89

Revised: 3/15/90
File: CHNLFB.WK1

Table 3.5
Channel Freeboard Summary
Outer Loop Highway, SRPMIC
Via Linda To The Arizona Canal
(all CWSEL based on n=.045 & .023)

	R-O-W Sideslope:	3.0	100-Year Event					1.2 x 100-Year Event				
	Roadway Sideslope:	4.0										
OLH Station	Channel Invert Elevation (ft)	Channel Overtop Elevation (ft)	Q100 (cfs)	CWSEL, Starting With CRIWS (ft)	CWSEL, Starting With Energy Slope (ft)	Freeboard With CRIWS (ft)	Freeboard With Energy Slope (ft)	1.2 x Q100 (cfs)	CWSEL, Starting With CRIWS (ft)	CWSEL, Starting With Energy Slope (ft)	Freeboard With CRIWS (ft)	Freeboard With Energy Slope (ft)
(D) 2460+00	1296.65	1310.6	1183	1302.32	1302.43	8.28	8.17	1420	1302.84	1303.00	7.76	7.60
2465+00	1295.90	1308.5	1183	1301.13	1301.40	7.37	7.10	1420	1301.62	1301.99	6.88	6.51
2470+00	1295.15	1306.6	1183	1300.08	1300.63	6.52	5.97	1420	1300.52	1301.24	6.08	5.36
(D) 2475+00	1294.40	1303.5	1226	1296.65	1300.11	6.85	3.39	1471	1296.93	1300.73	6.57	2.77
(D) 2475+00	1291.40	1303.5	1226	1297.39	1297.49	6.11	6.01	1471	1298.03	1298.13	5.47	5.37
2480+00	1290.65	1301.3	1226	1296.94	1297.07	4.36	4.23	1471	1297.58	1297.72	3.72	3.58
2485+00	1289.90	1299.2	1226	1296.34	1296.52	2.86	2.68	1471	1296.97	1297.16	2.23	2.04
2490+00	1289.15	1297.5	1226	1295.56	1295.86	1.94	1.64	1471	1296.20	1296.49	1.30	1.01
2495+00	1288.40	1296.0	1271	1293.89	1293.87	2.11	2.13	1525	1294.44	1294.41	1.56	1.59
2500+00	1287.30	1294.2	1271	1292.53	1291.59	1.67	2.61	1525	1292.97	1292.06	1.23	2.14
(D) 2505+00	1286.10	1292.2	1271	1289.24	1290.33	2.96	1.87	1525	1289.60	1290.79	2.60	1.41
(D) 2505+00	1283.10	1292.2	1271	1289.18	1289.28	3.02	2.92	1525	1289.69	1289.79	2.51	2.41
2510+00	1282.35	1290.5	1271	1287.36	1286.86	3.14	3.64	1525	1287.78	1287.25	2.72	3.25
(D) 2515+00	1281.60	1288.3	1271	1283.49	1284.73	4.81	3.57	1525	1283.73	1285.06	4.57	3.24
(D) 2515+00	1278.60	1288.3	1271	1283.78	1283.79	4.52	4.51	1525	1284.36	1284.79	3.94	3.51
2520+00	1277.60	1286.5	1271	1283.02	1283.04	3.48	3.46	1525	1283.60	1284.25	2.90	2.25
2525+00	1276.60	1283.6	1271	1282.57	1282.60	1.03	1.00	1525	1283.15	1283.68	0.45	-0.08
2529+00	1275.10	1282.2	1271	1281.00	1281.00	1.20	1.20	1525	1281.50	1281.50	0.70	0.70

Notes: 1) (D) - Drop structure location
2) CWSEL - Calculated water surface elevation from HEC-2 models.
3) CRIWS - Water surface profile is initiated at critical depth.

4 CONCLUSIONS & RECOMMENDATIONS FOR FINAL DESIGN

As stated previously, it is the purpose of this report to determine the feasibility of a landscaped channel concept for this section of the Outer Loop Highway. The preliminary hydraulic information presented in this report indicates that such a concept is feasible for the majority of this reach of the highway interceptor channel.

Should this concept be carried into final design, the following issues should be studied in more detail:

* The starting water surface elevation at the north embankment of the Arizona Canal should be confirmed. There are ongoing discussions with the Indian Community relative to the design of an east-west channel along the north side of the canal. Such a structure could have a significant influence on the starting water surface elevation for the north-south Outer Loop channel.

* The channel invert profile presented on Plate 2 is very preliminary. Final channel design should consider the requirements for highway fill. There are several channel reaches that could be raised or lowered, depending on the requirement to balance cut and fill between road construction and channel excavation.

* As presently sized, the channel experiences wide variations in bottomwidth, both within the earth-lined sections and in the transitions from earth to concrete lining. The final hydraulic analysis might want to consider the use of higher expansion and contraction coefficients to model energy losses through some of these transitions.

* No transition geometries were evaluated as part of this study. Changes in cross-section geometry will be required at transitions between earth and concrete lined sections, and at any culvert or bridge locations.

* The entrance and outlets to drop structures will require bank lining. An appropriate distance for this lining, both upstream and downstream of the drops, must be determined during final design. The bank-lining design must also include allowances for scour protection along the toe of slope, unless the channel bottom is also lined. Some type of energy dissipation design will also be required for the downstream side of the drops. Soil-cement should be considered as a viable candidate for drop structure construction.

* The ADOT Design Procedures Manual requires a minimum channel bottomwidth of 8 feet, and a 2 percent cross-slope to one side. The 8 foot bottomwidth has been complied with in this report, but no cross-slope was included in the cross-sectional geometry.

* The cross-section spacing used in the final design HEC-2 models should be closer than the 500 feet used in this preliminary analysis. This will promote more accuracy in the water surface profiles, especially through transition sections.

* The analysis presented in this report does not include the impact of any bridges, culverts, or siphons. The hydraulic impact of such structures will have to be evaluated during final design. All water surface profiles are based on the channel geometries listed in Table 3.1.

* At the time this report was being prepared, details on the 90th Street (Pima Road) crossing were in a state of revision by DeLeuw, Cather & Company. Accordingly, the final channel profile from Via Linda to 90th Street will probably be different from what is presented in this report.

* Information on the location and type of channel inlet structure at Via Linda was not available at the time this report was prepared. When available, this information, in conjunction with new details on the 90th Street crossing, will almost certainly require revisions in the channel profile between Via Linda and the 90th Street crossing of the Outer Loop. For the purpose of this report, this reach of channel has been analyzed as a concrete lined section, with vertical side-walls.

* The requirement for a 15 foot channel offset along the highway embankment at stations 2460+00, 2490+00, and 2515+00 needs to be further investigated during final design. For the purpose of this study, a 15 foot offset was used at stations 2460+00 and 2515+00, but not at station 2490+00.

* A bank erosion analysis needs to be performed as part of the final channel design. The sediment transport continuity of the channel should also be investigated.

* The east side of the channel bank will be subject to receiving substantial amounts of lateral inflow. Some type of concrete cutoff wall, or apron, should be constructed along the top of the channel bank to stabilize the bankline and prevent bank rilling (headcutting) from propagating beyond the highway right-of-way. Controlled inflow points for major flows should also be considered.

This concludes the preliminary hydraulic analysis for the Outer Loop Highway offsite drainage channel between Via Linda and the Arizona Canal. It should be re-emphasized that this report is based on preliminary design information that was still undergoing some revision at the time this report was printed. Accordingly, the final design team should verify all information presented in this report.

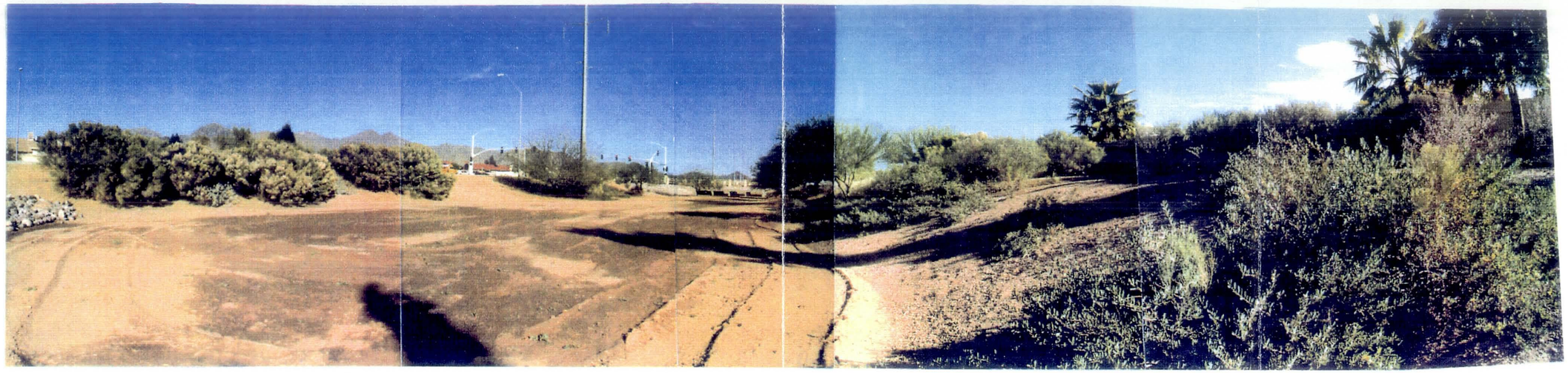
APPENDIX B

Photographs of Shea Boulevard Channel

DeLEUW CATHER

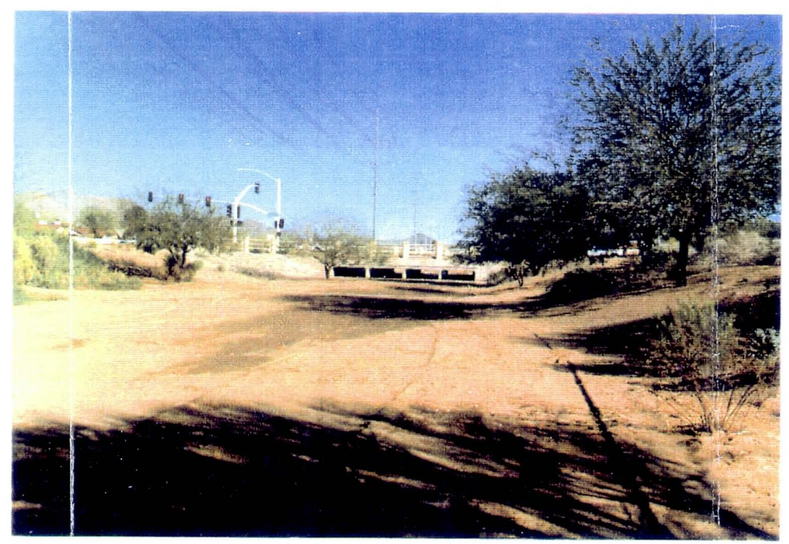
De Leuw, Cather & Company
Engineers and Planners

SUBJECT Drainage Channel Photos, Section 10 JOB NO. SHEET NO. OF
MADE BY RSB DATE 31 Jan 90 CHECKED BY DATE



Unlined drainage channel on south side of Shea Blvd. Panorama is looking east toward Via Linda crossing.

Vegetation in unlined channel (Shea Blvd) in the proximity of 100th St.

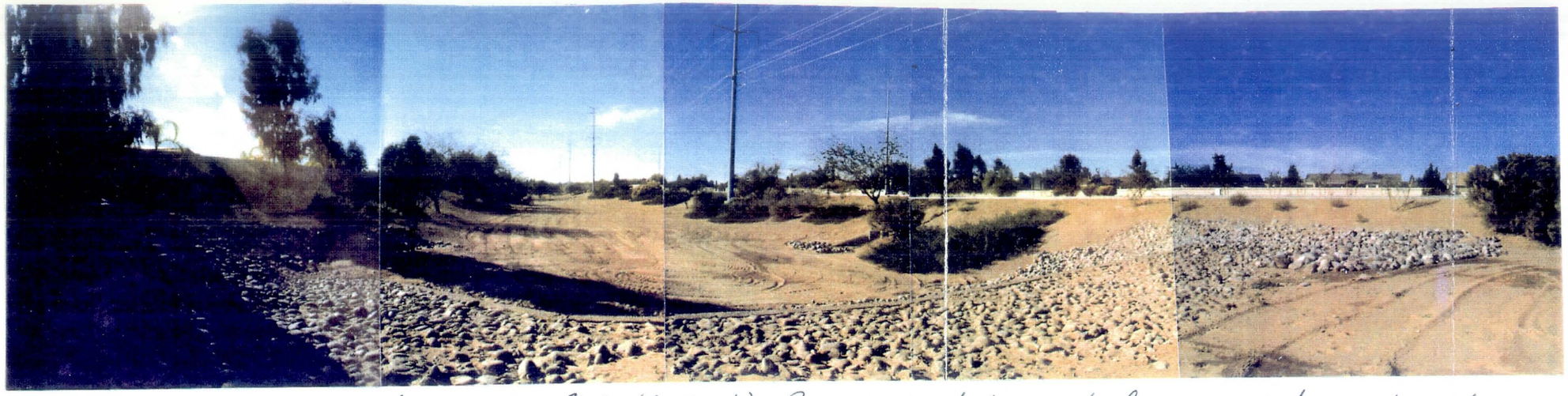


Looking east along Shea Blvd drainage channel at Via Linda Crossing.

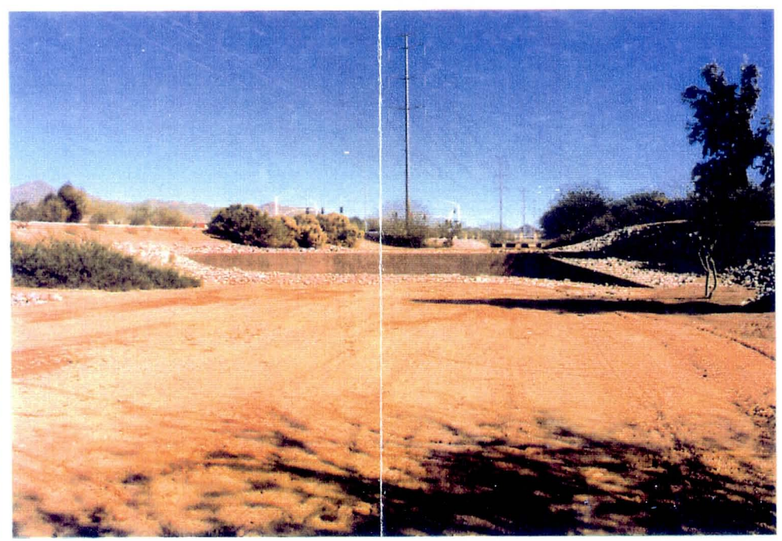
DeLEUW CATHER

De Leuw, Cather & Company
Engineers and Planners

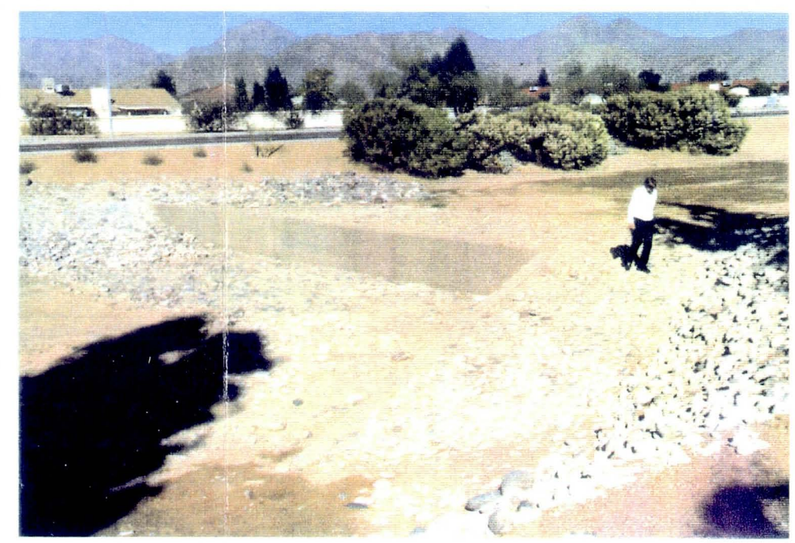
SUBJECT Drainage Channel Photos, Section 10 JOB NO. SHEET NO. OF
MADE BY RSB DATE 31 Jan 90 CHECKED BY DATE



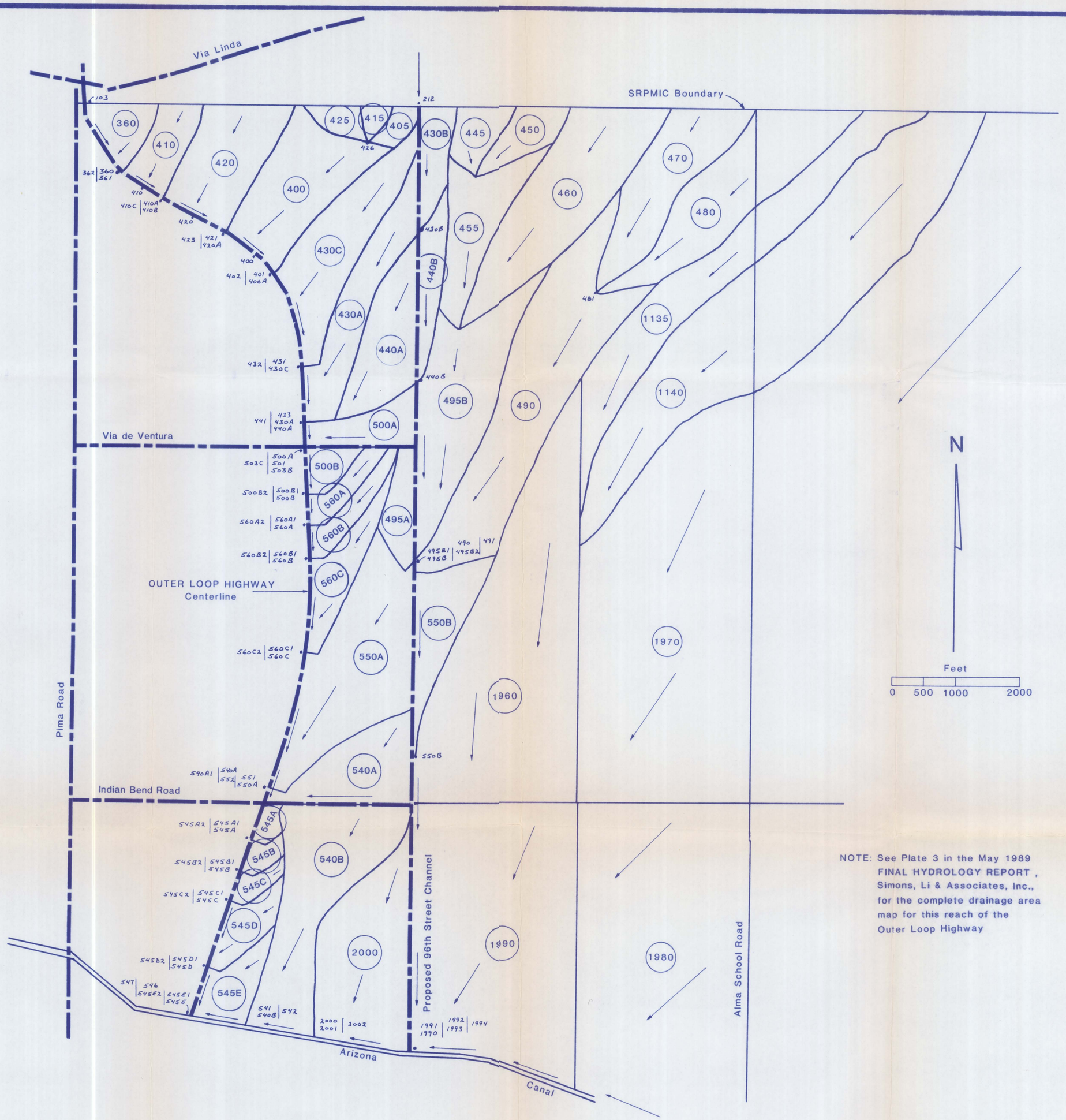
Unlined drainage channel following Shea Blvd (South side). Panorama is looking west from Via Linda, just upstream of a drop structure.



Two views looking east along Shea Blvd drainage channel toward drop structure and box culverts crossing Via Linda.



Drop structure and rip-rap in Shea Blvd drainage channel.



NOTE: See Plate 3 in the May 1989 FINAL HYDROLOGY REPORT, Simons, Li & Associates, Inc., for the complete drainage area map for this reach of the Outer Loop Highway

HEC-1 ROUTING SCHEMATIC
OUTER LOOP HIGHWAY
WITH PROPOSED 96th STREET CHANNEL

Robert L. Ward, P.E. Consulting Engineer	March 16,1990
	PLATE 1