Maricopa County
Department of
Transportation

Bridge Scour Investigation
and
Design of Corrective Measures

Contract No. CY 1997-26
Work Order No. 80407

Final Report

Deer Valley Road Bridge at Wash (189th Avenue)

Submitted October 7, 1997

Registered Professional Engineer (Structural)
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Date Signed 10/7/97
ARIZONA, U.S.A.

Prepared By:
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INCA ENGINEERS, INC.
Wood/Patel & Associates
Maxim Technologies Inc.

TABLE OF CONTENTS

INTRODUCTION 1
Bridge Location and Description: 1

REVIEW OF PREVIOUS REPORT 1

SITE INVESTIGATION 3

HYDROLOGY RECOMMENDATIONS 6

HYDRAULICS RECOMMENDATIONS 6

SCOUR ANALYSIS 7

ALTERNATIVE COUNTERMEASURES 7
Alternative 1: 7
Alternative 2: 8
Alternatives not considered: 9

PREFERRED ALTERNATIVE 9

FIGURES

Location Map 2
Deer Valley Road Bridge @ 189th Avenue Aerial 4
USGS Quad Map Showing West Drainage Area 5

APPENDICES

Appendix A: Photographs
Appendix B: Alternative 1 Details
Appendix C: Alternative 2 Details
Appendix D: Hydraulic Calculations

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Bridge Scour Investigation and Design of Corrective Measures

FINAL REPORT

INTRODUCTION

The Maricopa County Department of Transportation retained two consultants in 1995 under Work Order Number 80407 to evaluate the scour potential during 100 and 500 year flood events for existing bridges in their jurisdiction over waterways. The results of that study classified some of the bridges as scour critical.

INCA Engineers, Inc. was retained by the County to review the previous reports for five bridges classified as scour critical, determine the extent of scour damage, recommend methods to prevent scour damage, and prepare contract documents for scour countermeasures.

The Deer Valley Road Bridge at Wash (189th Avenue) was evaluated as scour critical by Cannon and Associates, Inc. and documented in their report dated July 1996 (Revised November 1996).

Bridge Location and Description:

The Deer Valley Road Bridge crossing of an Unnamed Wash at 189th Avenue is located in north-central Maricopa County in Section 21, T4N, R2W, Gila and Salt River Baseline and Meridian. It is located on Deer Valley Road approximately 3 miles west of Grand Avenue (US Highway 60).

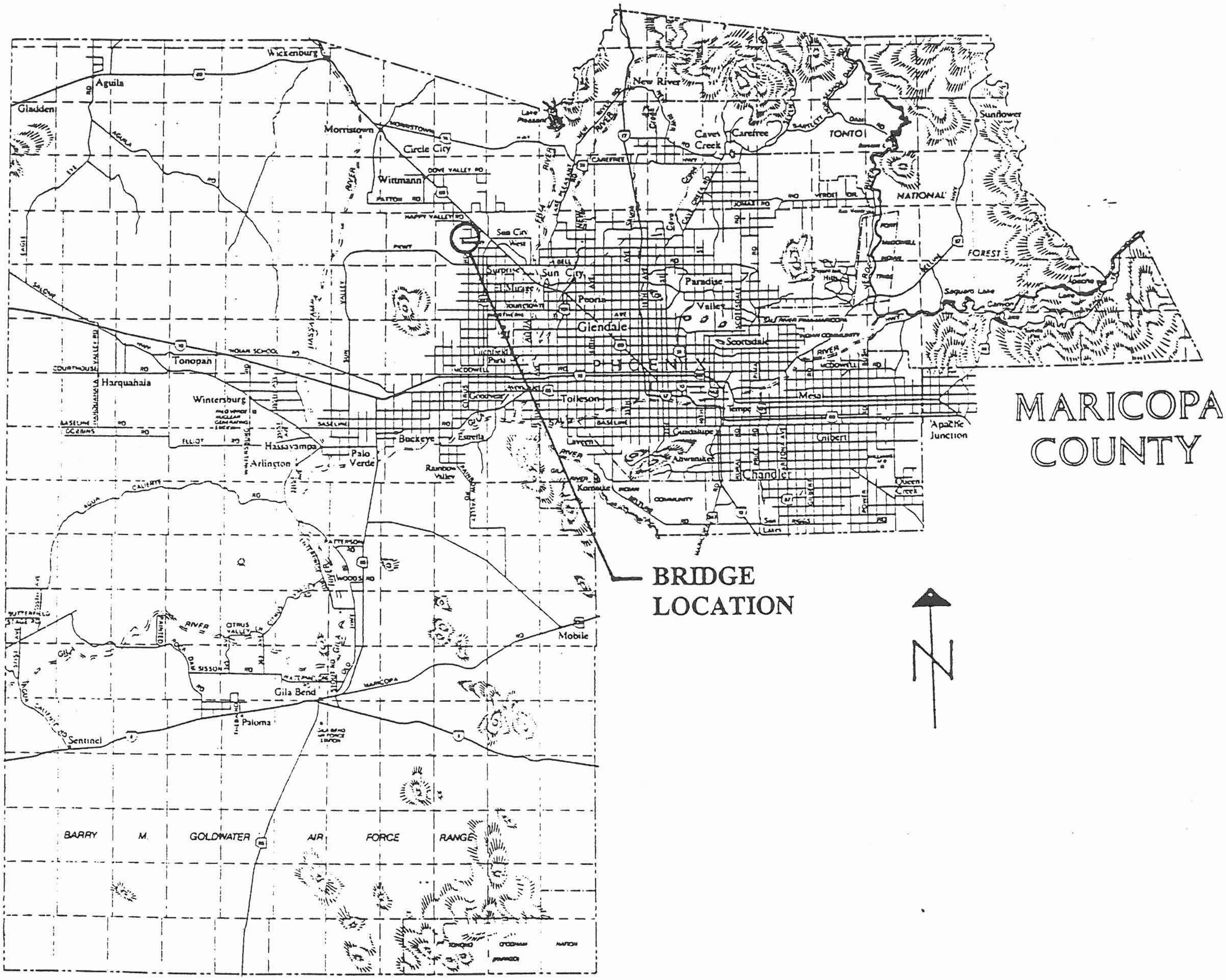
REVIEW OF PREVIOUS REPORT

Cannon & Associates, Inc. performed a scour investigation and structural stability analysis of this site and submitted a report in July 1996 (Revised November 1996) documenting their findings. Wood/Patel has reviewed this report and offers the following comments:

- The Report does not contain local ground elevations in order to determine if the larger flood flows will remain in the wash channel or sheet flow across the desert floor.

- There is a significant channel paralleling Deer Valley Road which diverts a significant amount of discharge from washes to the west of the bridge location. Although the existence of this channel and the fact that it diverts additional flow to the bridge site is noted in the report, no attempt seems to have been made to quantify this discharge. The discharge in this channel could significantly increase the west abutment scour. (See page 4)

Deer Valley Road Bridge at Wash (189th Avenue)
Location Map
Figure 1



SITE INVESTIGATION

On June 19, 1997, a review of the site conditions was conducted by Dennis Trefren, P.E. and Richard Bruesch, P.E. of INCA, Jeff Holzmeister, P.E. and Rick Hiner, P.E. of Wood/Patel, Dave Thomas, P.E. of Maxim Technologies and Tom Sonnemann, P.E. of MCDOT. Observations were noted as the following:

1. The upstream and downstream wash is very shallow. Additional survey work is needed to help determine the water surface elevation overtopping the Wash. It may not be possible to pass large flows through the bridge.

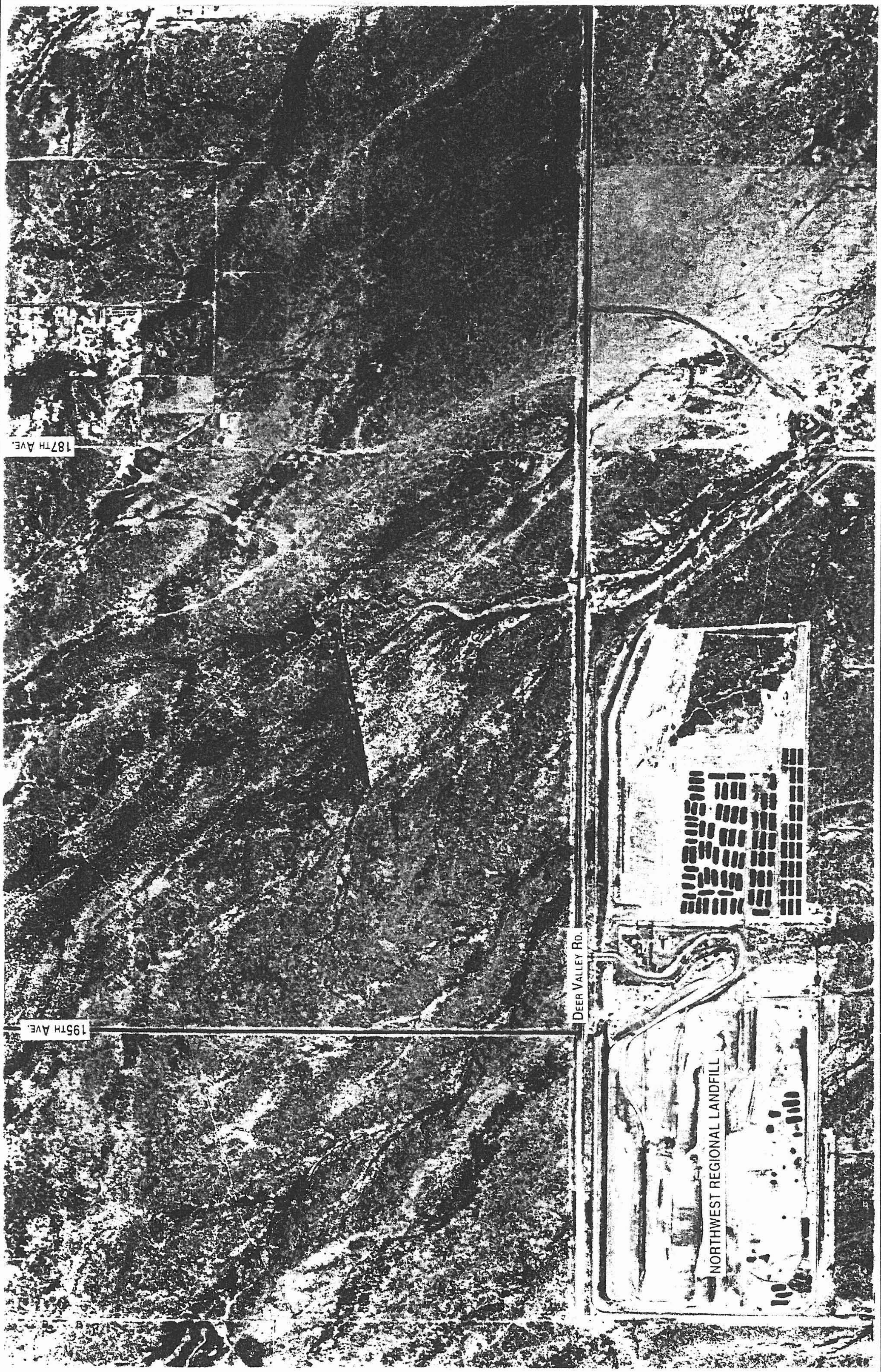
2. The channel paralleling Deer Valley Road appears to be subjected to significant discharge and it was decided that additional hydrologic investigation would be necessary to quantify this flow. For the purposes of this study, the contributing area was quantified and USGS regression equations were used to determine the flows and frequencies.

3. The existing pier scour protection is dumped riprap consisting of rounded river run stone. It was also noted that the riprap at the bridge abutments and in the vicinity of the piers has shifted from its original position and may be subject to significant movement in a major event.

4. There appears to be a dike or berm (about 200 feet in length) located approximately 2100 feet upstream of the bridge crossing. This dike is perpendicular to and centered on the main wash leading to the bridge crossing. From the aerial photographs and USGS Quad maps, it appears that this dike may allow the wash runoff to pond behind it, thus attenuating the peak runoff slightly (the amount of potential attenuation was not determined) but this may only be effective during smaller magnitude events (i.e. 2-5 year frequency). When full, it appears that the spillway is at the east end of the dike. Once over the spillway the runoff will continue to the bridge. Refer to the included copies of the Aerial Photograph and Quad map for additional information.

5. This site is not suitable for soil cement due to the low clearance under the bridge.

6. The selected countermeasure will have to incorporate the side channel at the northwest corner of the bridge.



DEER VALLEY ROAD BRIDGE @ 189TH AVENUE

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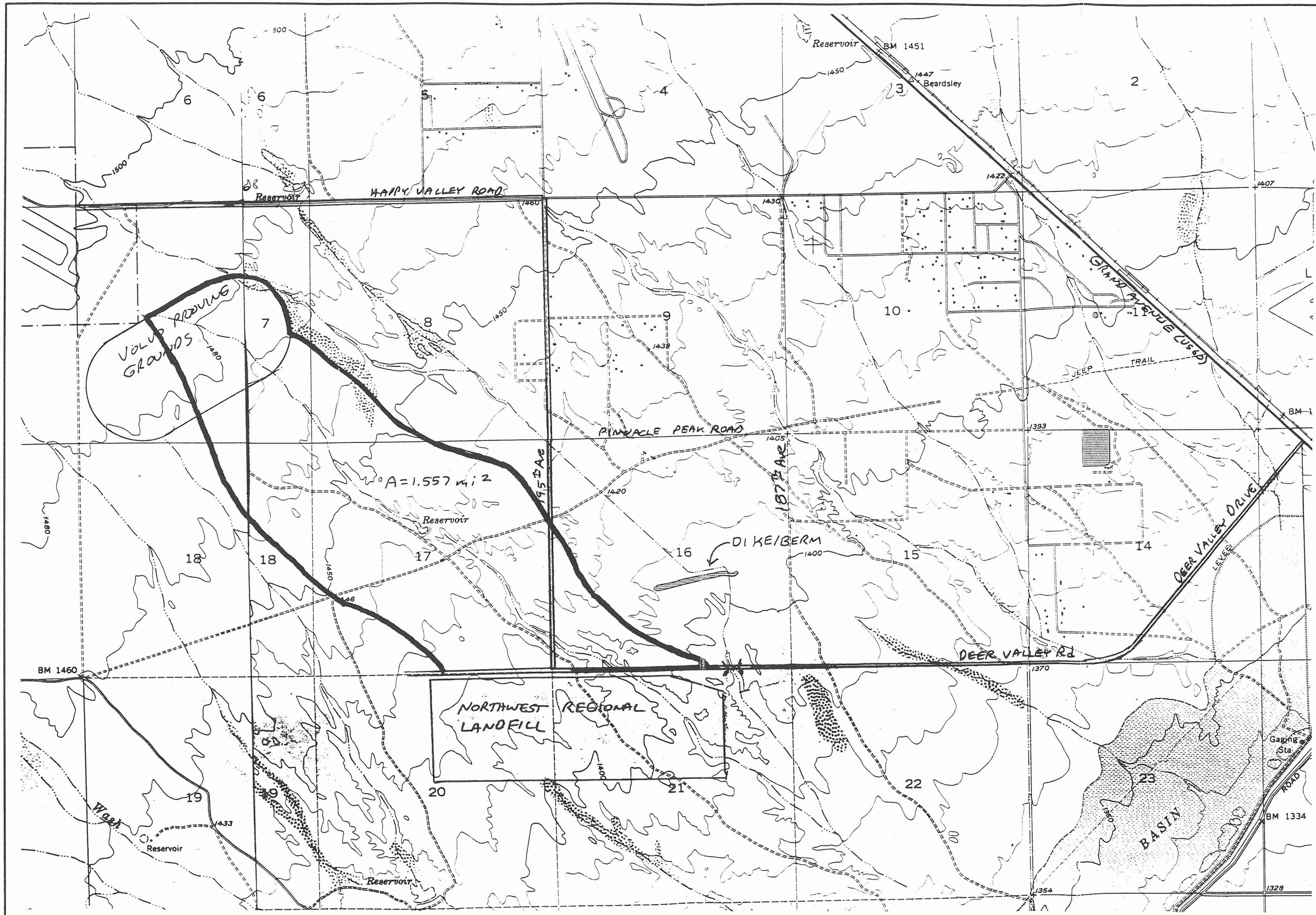
DESIGNER: R. HINER
CAD TECHNICIAN: -
SCALE (HORIZONTAL): 1" = 1200'
SCALE (VERTICAL):
DATE: 08-14-97
JOB NUMBER: 97629
TABLE/FIGURE NO.

USGS Quad Map Showing West Drainage Area



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DESIGNER R. HINER
CAD TECHNICIAN
SCALE (HORIZONTAL) 1"=2000'
SCALE (VERTICAL)
DATE 8-14-97
JOB NUMBER 97629
TABLE/FIGURE NO.

HYDROLOGY RECOMMENDATIONS

Wood/Patel reviewed the hydrology from the Final Bridge Scour Assessment Report prepared by Cannon & Associates, Inc. The 100-year discharge of 3925 cfs (Plans) and 500-year discharge of 8,600 cfs (FEMA Flood Insurance Maps) may not account for the flow intercepted by the drainage channel parallel to and north of the Deer Valley Road alignment. Regression calculations indicate that significant additional discharge may be redirected to the bridge site (See regression calculations). Since the contributing areas of the main watershed and this smaller diverted watershed are significantly different (by a factor of at least 10 times, if not more), it is unlikely that both watersheds would experience a peak event at the same time. In light of this, an assumption was made that when one of the watersheds was contributing 100% of its peak flow, the other watershed would only contribute 20% of its peak flow. This scenario was applied to both the 100-year event and the 500-year event and yielded the following peak discharges.

	USGS Regression Equation (Small Watershed)		Cannon & Associates Report (Main Watershed)		
100-year Q	2,876		3,925		
500-year Q	4,889		8,600		
Overtopping			9,420		
	% Contributing	Discharge (cfs)	% Contributing	Discharge (cfs)	Peak Flow
100-year(1)	100	2,876	20	785	3,661
100-year(2)	20	575	100	3,925	4,500
500-year(1)	100	4,889	20	1,720	6,609
500-year(2)	20	978	100	8,600	* 9,578

* Equals overtopping discharge.

HYDRAULICS RECOMMENDATIONS

The hydraulics performed in the Final Bridge Scour Assessment Report prepared by Cannon & Associates, Inc. used a single section to determine the hydraulic characteristics of the bridge crossing. Using this section, a HEC-RAS hydraulic model was constructed for the bridge site. The single cross-section (upstream bridge face) from the existing report was used for the upstream and downstream ends of the bridge and also copied upstream and downstream (modified as necessary based on field observations) to approximate the wash near the bridge. This should result in a more representative hydraulic model of the site.

Cross-sections were constructed for the channel along the Deer Valley Road embankment based on field observations. These were included in the HEC-RAS computer model to represent the flow that arrives at the bridge site from the west. HEC-RAS computes momentum losses at the junction where this side channel meets the main wash, which results in additional losses at the bridge site.

The results of this analysis are presented in Appendix D.

SCOUR ANALYSIS

The most recent version of the HEC-RAS program (v. 2.0) has incorporated HEC-18 scour methodology into its programming. This feature was used to verify the scour results from the Final Bridge Scour Assessment Report prepared by Cannon & Associates, Inc. The long-term/general scour estimate of 4.0 feet was used without modification in Wood/Patel's estimate of scour at this site since the field visit did not indicate that a greater value would be more appropriate. The 100-year and 500-year events both passed through the bridge and the results of these hydraulic analyses were used for the scour calculations. The results of this analysis are presented below:

	100-year(2)	**500-year(2)**
Contraction Scour	0.32 feet	0.57 feet
Pier Scour	18.23 feet	21.43 feet
Long-Term Scour	4.00 feet	4.00 feet
Abutment Scour (West)	10.82 feet	15.69 feet

This yields a total scour at the piers of 22.55 feet for the 100-year(2) event of 4500 cfs versus 16.8 feet in the prior 100-year analysis at 3925 cfs and 26.00 feet for the 500-year(2) event of 9578 cfs versus 19.1 feet in the prior 500-year analysis of 8600 cfs. The total scour at the west abutment for the 100-year(2) event is 15.14 feet and for the 500-year(2) event is 20.26 feet. No scour was computed at the east abutment (the spur dike at the east abutment will tend to align the flow). The prior analysis did not yield any contraction scour or abutment scour at this location.

The increase in pier scour depth during the 100-year(2) event over the prior 100-year analysis and the 500-year(2) event over the prior 500-year analysis is due to the following factors: A significant amount of discharge (which was not included in the prior analysis) enters the site from the roadside channel. This causes additional losses at the upstream face of the bridge, increases the angle of attack on the piers, and increases the total discharge through the bridge. The abutment scour at the west abutment is the result of the discharge entering the site from the roadside channel.

ALTERNATIVE COUNTERMEASURES

The following is a discussion of the most feasible countermeasures.

Alternative 1:

This alternative consists of constructing a reinforced concrete floor approximately five feet below the low point of the wash bed between the abutments. The reinforced concrete floor will be placed on the abutment slopes and all around the abutment and wingwalls.

Advantages of this alternative are:

- Provides a scour resistant floor around all piers.

- Protects the abutments from lateral erosion.
- Provides grade control within the existing right-of-way.
- Relatively easy to construct on the slopes under the bridge.
- Utilizes a proven material and construction method.
- The least costly alternative.

Disadvantages are the following:

- Rigid system that could be damaged if undercut.
- Sensitive to poor compaction of slopes.
- Requires a seal around the abutment and wingwalls to prevent water infiltration.

The estimated cost for this alternative is $214,000.

Alternative 2:

This alternative consists of constructing a wire tied riprap floor approximately five feet below the low point of the wash bed between the abutments. The wire tied riprap will be placed on the abutment slopes and all around the abutment and wingwalls. The layout geometry would be similar to the details for Alternative 1.

The advantages of this alternative are:

- Provides a scour resistant floor around all piers.
- Protects the abutments from lateral erosion.
- Provides grade control within the existing right-of-way.
- A flexible system that will settle if undercut.
- Utilizes a proven material and construction method.

Disadvantages are the following:

- Requires large excavations for toe-down sections.
- The wire is subject to abrasion and corrosion damage.

- Labor intensive system.
- Difficult to place against the abutment under the bridge due to limited vertical clearance.
- The upper portion of the slopes under the bridge deck need to be hand placed.
- The most costly alternative.

The estimated cost for this alternative is $272,000.

Alternatives not considered:

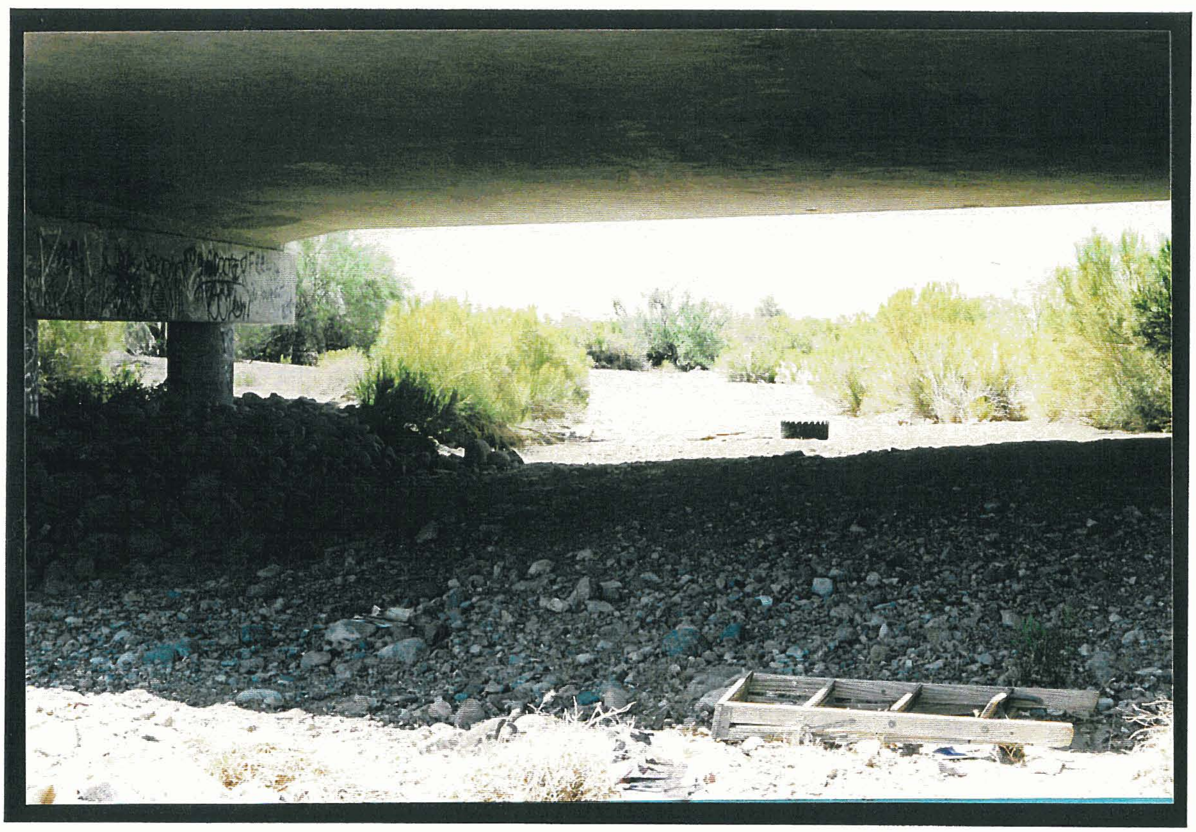
A soil cement floor was not considered due to the limited space available for the equipment to place the material. Practically all of the sloping sections would be constructed of a different material due to the lack of vertical clearance. Also, the soil cement quantities required at this site are too small to offset mobilization costs.

PREFERRED ALTERNATIVE

We prefer Alternative 2 to be constructed since it is a flexible system that will settle if undercut.

Appendix A
Photographs

Looking Downstream (Note: Shallow Wash)



Shallow Wash and Erosion Near Pier 3

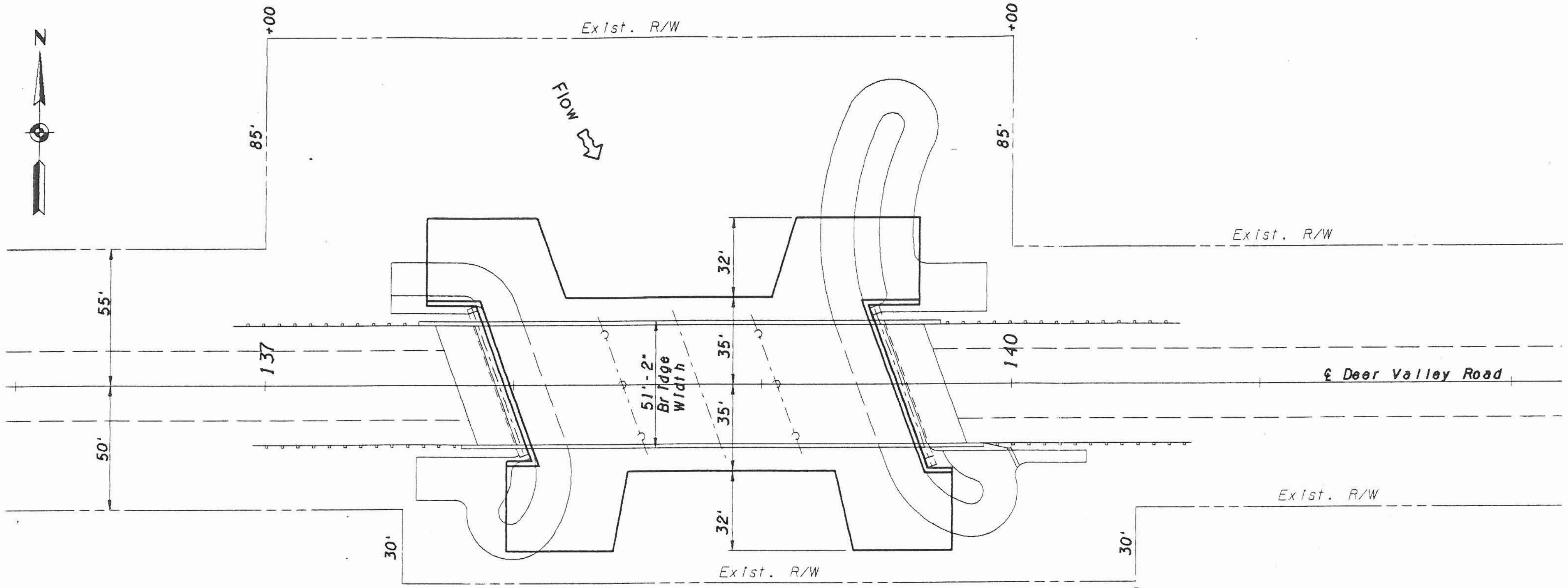
East Spur Dike Upstream

Drainage Channel North of Roadway and West of Bridge

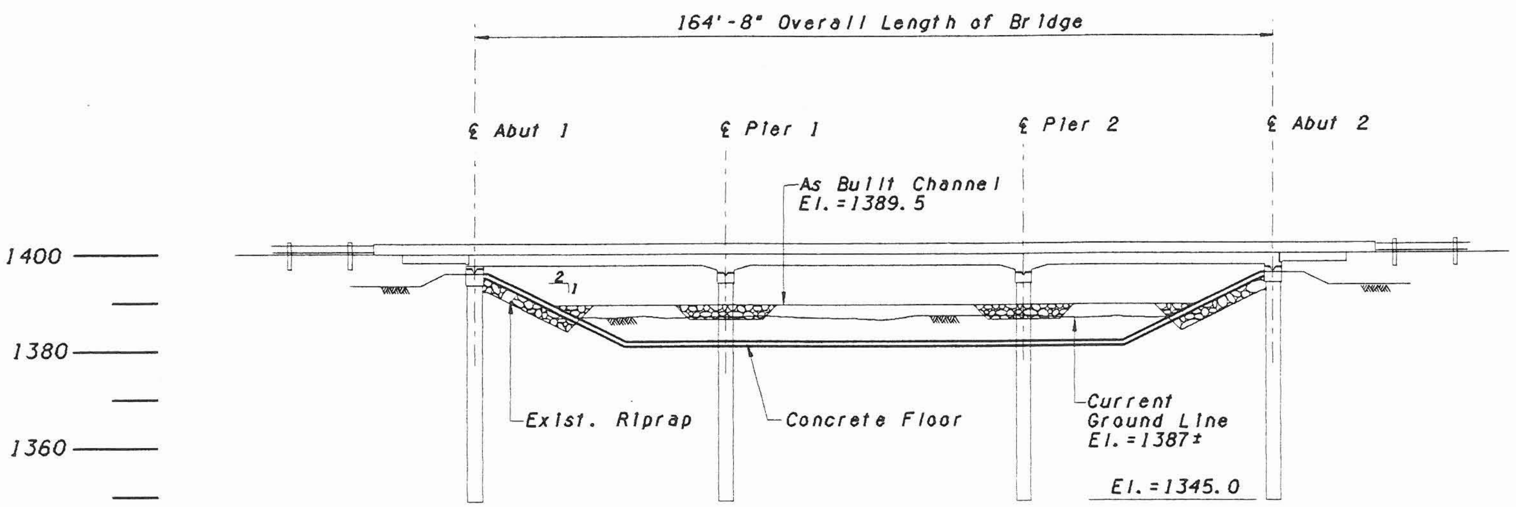
Looking Upstream of Bridge

Appendix B
Alternative 1 Details

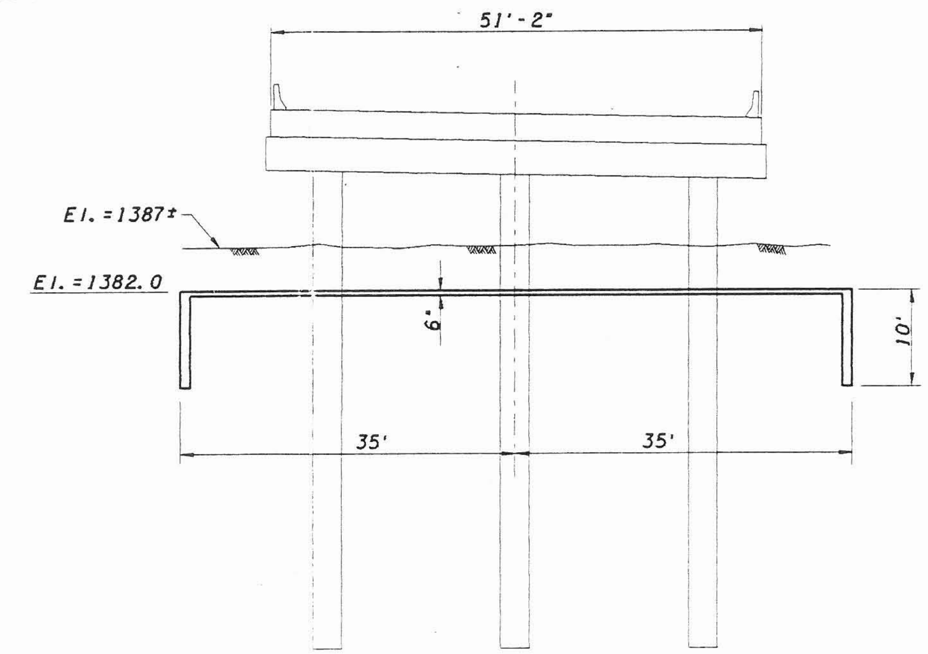
F.H.W.A. REGION	STATE	PROJECT NO.	SHEET NO.	TOTAL SHEETS	RECORD DRAWING
9	AZ.				



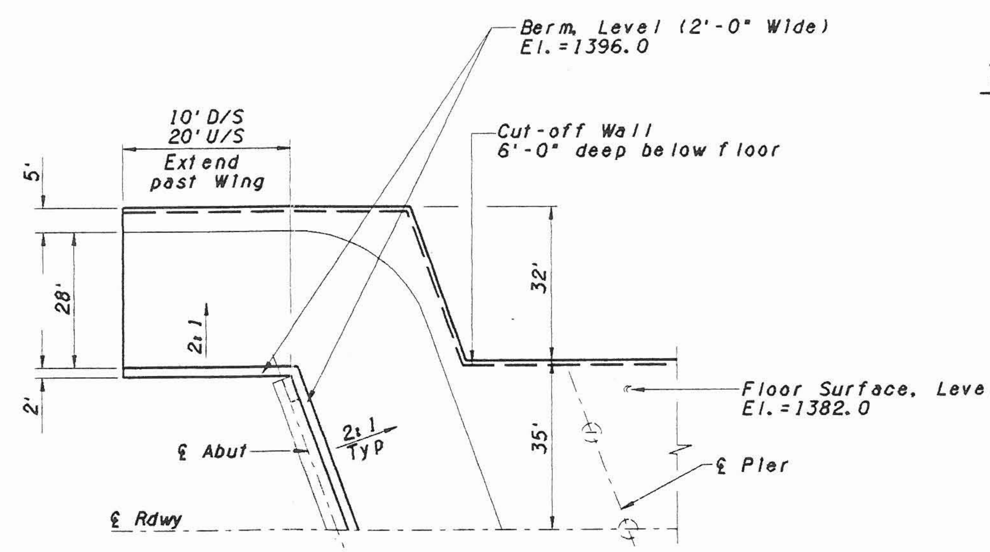
PLAN
SCALE: 1"=30'



SECTION ON ℄ OF ROADWAY
SCALE: 1"=20'



TYPICAL SECTION @ PIER (REINF. CONC)
SCALE: 1"=10'



PART PLAN - (NW CORNER)
NO SCALE

NO.	REVISION	BY	DATE
△			
△			
△			

MARICOPA COUNTY
DEPARTMENT OF TRANSPORTATION
ENGINEERING DIVISION

DEER VALLEY ROAD
@ 189TH AVE WASH

PRELIMINARY NOT FOR CONSTRUCTION		BY	DATE
	DESIGNED		
	DRAWN	RON WIETZEMA	8/12/97
	CHECKED		

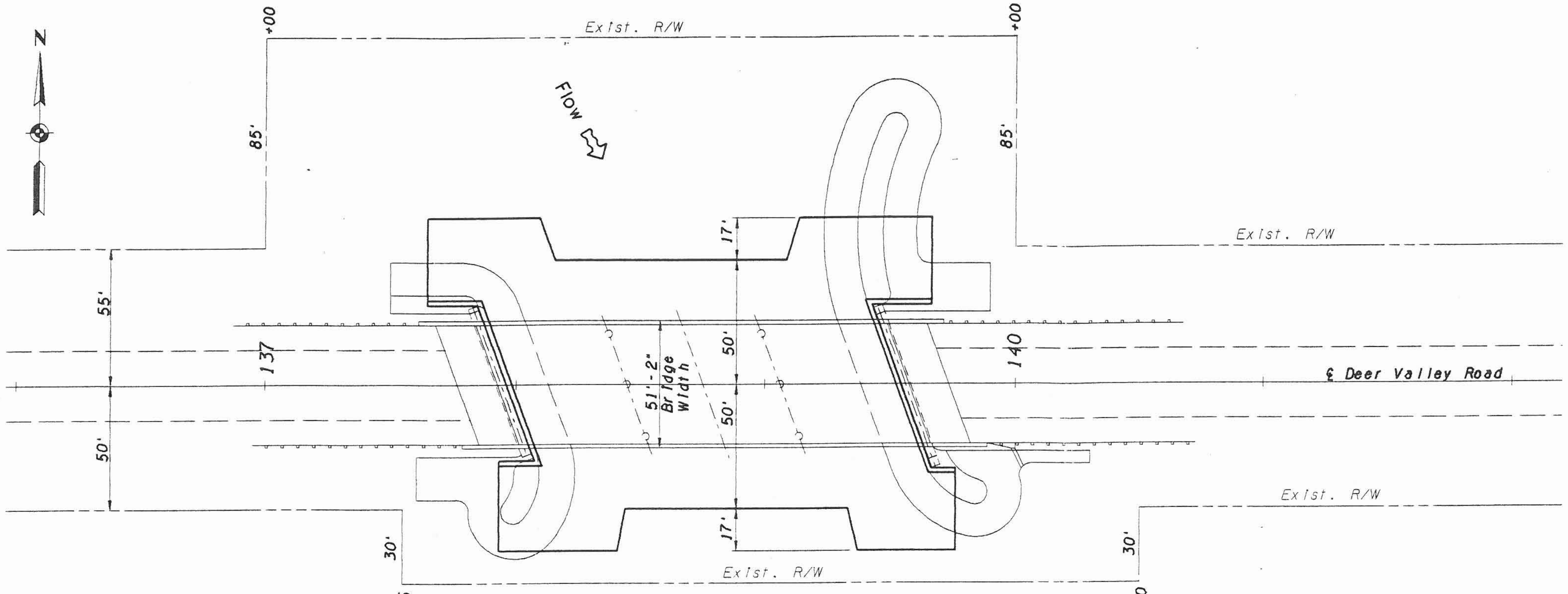
INCA
INCA ENGINEERS INC.

ALTERNATIVE NO. 1

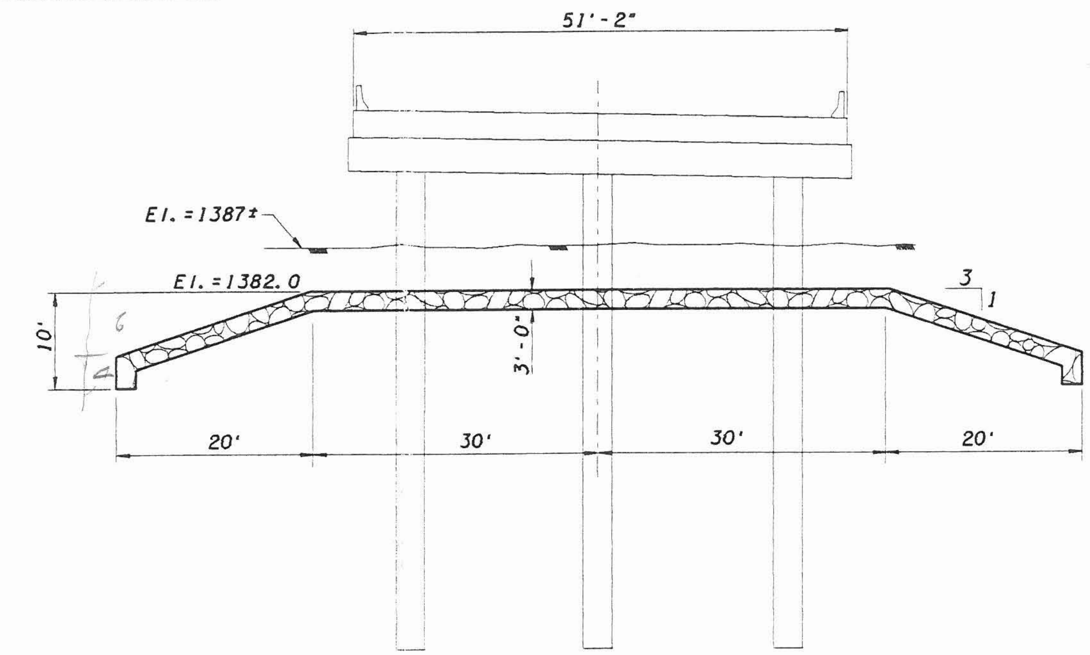
SHEET OF

Appendix C
Alternative 2 Details

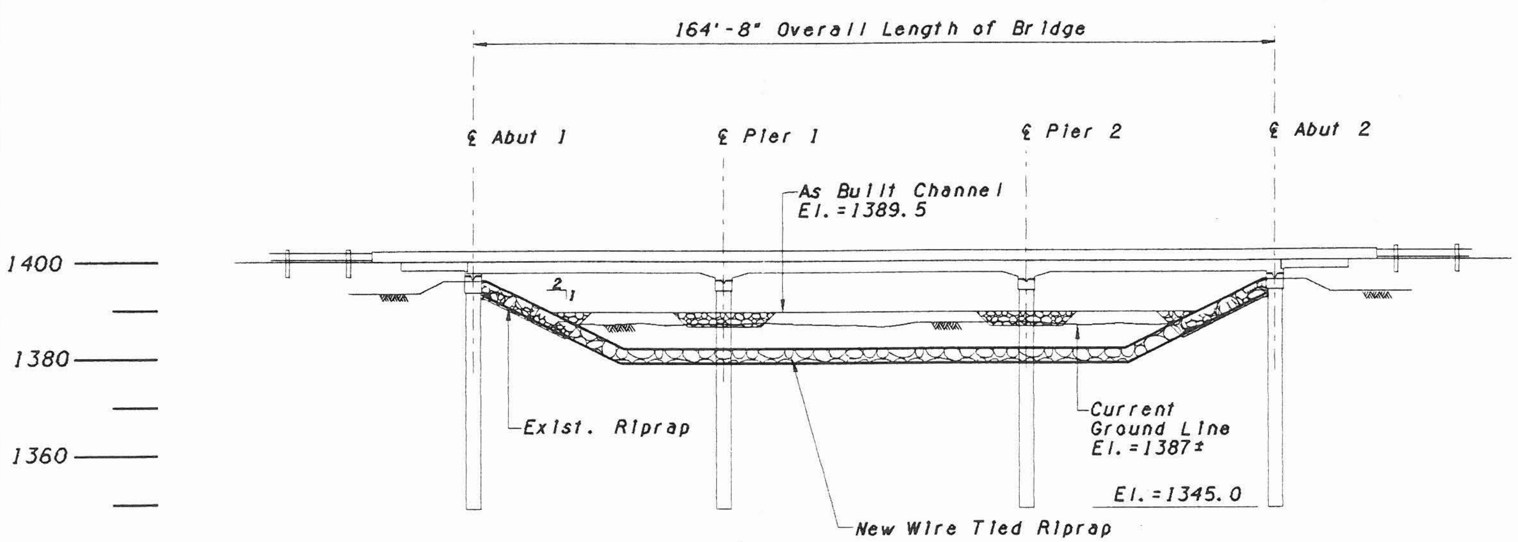
F.H.W.A. REGION	STATE	PROJECT NO.	SHEET NO.	TOTAL SHEETS	RECORD DRAWING
9	AZ.				



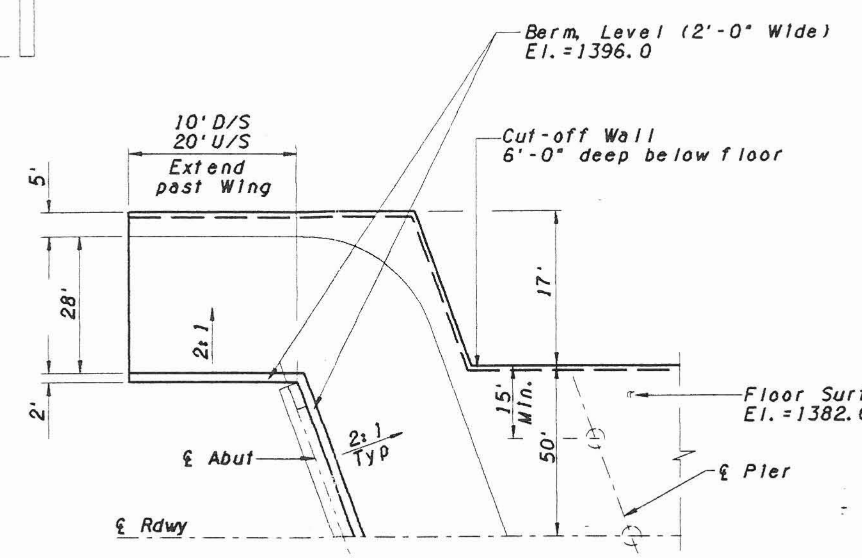
PLAN
SCALE: 1"=30'



TYPICAL SECTION @ PIER (WIRE TIED RIPRAP)
SCALE: 1"=10'



SECTION ON ℄ OF ROADWAY
SCALE: 1"=20'



PART PLAN - (NW CORNER)
NO SCALE

NO.	REVISION	BY	DATE

MARICOPA COUNTY
DEPARTMENT OF TRANSPORTATION
ENGINEERING DIVISION

DEER VALLEY ROAD
@ 189TH AVE WASH

		BY	DATE
PRELIMINARY NOT FOR CONSTRUCTION	DESIGNED		
	DRAWN	RON WIETZEMA	8/12/97
	CHECKED		

INCA
INCA ENGINEERS INC.

ALTERNATIVE NO. 2

SHEET OF

Appendix D
Hydraulic Calculations

Deer Valley Road Bridge over Unnamed Wash

100-year Scour Estimate Downstream of Floored Bridge Structure

Methodology from "Computing Degradation and Local Scour" by E. Pemberton and J. Lara, 1984,
Technical Guideline for Bureau of Reclamation, pages 40-45, equation type "D"

100-year Discharge =	4,500	cfs	4	ft Actual Long-Term Degradation
Total Flow Area =	556.95	ft^2	5	ft Assumed Long-Term Degradation
Total Top Width =	135.89	ft	4.5	ft Depth to Top of Soil-Cement
Mean Flow Depth =	4.10	ft	Existing Bed Elevation	1386.5 ft
Discharge per foot =	33.12	cfs/ft	Top of Floor Elevation	1382.0 ft

Schoklitsch (1932)

$$d_s = \frac{K(H)^{0.2} q^{0.57}}{D_{90}^{0.32}} - d_m$$

d_s = depth of scour (ft)		
K =	3.15	3.15 inch-pound units
H =	0.50	difference between U/S and D/S WSEL
q =	33.12	discharge per unit width (cfs per ft)
D_{90} =	5.00	particle size for which 90% is finer (mm)
d_m =	4.10	D/S mean water depth

ds = 7.9 ft

Veronese (1937)

$$d_s = KH_T^{0.225} q^{0.54} - d_m$$

d_s = depth of scour (ft)		
K =	1.32	1.32 inch-pound units
H_T =	0.50	head from U/S to D/S
q =	33.12	discharge per unit width (cfs per ft)
d_m =	4.10	D/S mean water depth

ds = 3.4 ft

Zimmerman & Maniak (1967)

$$d_s = K\left(\frac{q^{0.82}}{D_{85}^{0.23}}\right)\left(\frac{d_m}{q^{2/3}}\right)^{0.93} - d_m$$

d_s = depth of scour (ft)		
K =	1.95	1.95 inch-pound units
q =	33.12	discharge per unit width (cfs per ft)
D_{85} =	4.50	particle size for which 85% is finer (mm)
d_m =	4.10	D/S mean water depth

ds = 6.2 ft

Average Scour Depth at Toe = 5.8 ft

Recommended Downstream Toe-Down = 10 ft below channel bed

Height of Concrete Cut-Off Wall = 6 ft

Note: D_{85} and D_{90} estimated from field investigation and photographic data.

Note 2: 1-foot of additional long-term degradation was assumed in order to generate a scour value at the downstream toe. The actual long-term degradation was not sufficient to expose the floor.

Deer Valley Road Bridge over Unnamed Wash

500-year Scour Estimate Downstream of Floored Bridge Structure

Methodology from "Computing Degradation and Local Scour" by E. Pemberton and J. Lara, 1984,
Technical Guideline for Bureau of Reclamation, pages 40-45, equation type "D"

Overtopping Discharge	9,578	cfs	4	ft Actual Long-Term Degradation		
Total Flow Area =	741.21	ft^2	5	ft Long-Term Degradation		
Total Top Width =	141.85	ft	4.5	ft Depth to Top of Soil-Cement		
Mean Flow Depth =	5.23	ft	Existing Bed Elevation		1386.5	ft
Discharge per foot =	67.52	cfs/ft	Top of Floor Elevation		1382.0	ft

Schoklitsch (1932)

$$d_s = \frac{K(H)^{0.2} q^{0.57}}{D_{90}^{0.32}} - d_m$$

ds = 12.9 ft

d_s = depth of scour (ft)		
K =	3.15	3.15 inch-pound units
H =	0.5	difference between U/S and D/S WSEL
q =	67.52	discharge per unit width (cfs per ft)
D_{90} =	5.00	particle size for which 90% is finer (mm)
d_m =	5.23	D/S mean water depth

Veronese (1937)

$$d_s = KH_T^{0.225} q^{0.54} - d_m$$

ds = 5.8 ft

d_s = depth of scour (ft)		
K =	1.32	1.32 inch-pound units
H_T =	0.5	head from U/S to D/S
q =	67.52	discharge per unit width (cfs per ft)
d_m =	5.23	D/S mean water depth

Zimmerman & Maniak (1967)

$$d_s = K\left(\frac{q^{0.82}}{D_{85}^{0.23}}\right)\left(\frac{d_m}{q^{2/3}}\right)^{0.93} - d_m$$

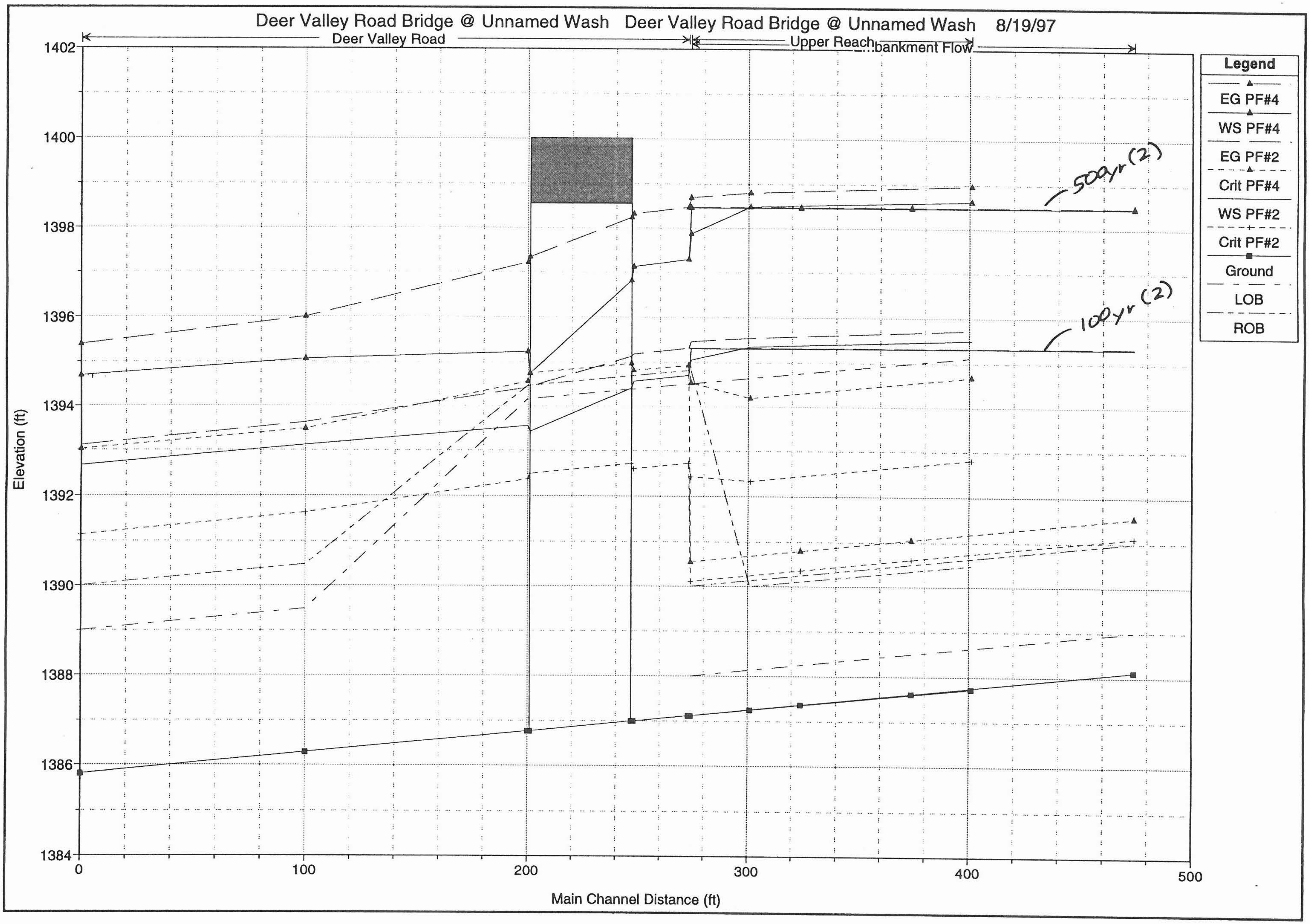
ds = 9.7 ft

d_s = depth of scour (ft)		
K =	1.95	1.95 inch-pound units
q =	67.52	discharge per unit width (cfs per ft)
D_{85} =	4.50	particle size for which 85% is finer (mm)
d_m =	5.23	D/S mean water depth

Average Scour Depth at Toe = 9.4 ft

Recommended Downstream Toe-Down = 14 ft below channel bed
Height of Concrete Cut-Off Wall = 10 ft

Note 1: D_{85} and D_{90} estimated from field investigation and photographic data.
Note 2: 1-foot of additional long-term degradation was assumed in order to generate a scour value at the downstream toe. The actual long-term degradation was not sufficient to expose the floor.


Deer Valley Road Bridge @ Unnamed Wash Deer Valley Road Bridge @ Unnamed Wash 8/19/97
Deer Valley Road
Upper Reach
Embankment Flow
Legend
EG PF#4
WS PF#4
EG PF#2
Crit PF#4
WS PF#2
Crit PF#2
Ground
LOB
ROB
500yr (2)
100yr (2)
Elevation (ft)
Main Channel Distance (ft)
1384
1386
1388
1390
1392
1394
1396
1398
1400
1402
0
100
200
300
400
500

100yr (2)

Plan: Deer Valley River: Unnamed Wash Reach:Deer Valley Road Riv Sta: 224 Profile: PF#2 Opening: Bridge #1

E.G. US. (ft)	1395.19	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	1394.57	E.G. Elev (ft)	1395.14	1394.44
Q Total (cfs)	4500.00	W.S. Elev (ft)	1394.42	1393.43
Q Bridge (cfs)	4500.00	Crit W.S. (ft)	1392.72	1392.49
Q Weir (cfs)		Max Chl Dpth (ft)	7.42	6.66
Weir Sta Lft (ft)		Vel Total (ft/s)	6.79	8.08
Weir Sta Rgt (ft)		Flow Area (sq ft)	662.33	556.95
Weir Submerg		Froude # Chl	0.55	0.70
Weir Max Depth (ft)		Specif Force (cu ft)	2698.77	2414.47
Min Top Rd (ft)	1400.02	Hydr Depth (ft)	4.70	4.10
Min El Prs (ft)	1398.56	W.P. Total (ft)	162.86	154.62
Delta EG (ft)	0.76	Conv. Total (cfs)	50155.1	38893.5
Delta WS (ft)	1.01	Top Width (ft)	140.84	135.89
BR Open Area (sq ft)	1192.69	Frctn Loss (ft)		
BR Open Vel (ft/s)	8.08	C & E Loss (ft)		
Coef of Q		Shear Total (lb/sq ft)	2.04	3.01
Br Sel Mthd	Momentum	Power Total (lb/ft s)	13.89	24.32

500 yr (2)

Plan: Deer Valley River: Unnamed Wash Reach:Deer Valley Road Riv Sta: 224 Profile: PF#4 Opening: Bridge #1

E.G. US. (ft)	1398.32	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	1397.13	E.G. Elev (ft)	1398.24	1397.34
Q Total (cfs)	9578.00	W.S. Elev (ft)	1396.82	1394.75
Q Bridge (cfs)	9578.00	Crit W.S. (ft)	1394.98	1394.75
Q Weir (cfs)		Max Chl Dpth (ft)	9.82	7.98
Weir Sta Lft (ft)		Vel Total (ft/s)	9.55	12.92
Weir Sta Rgt (ft)		Flow Area (sq ft)	1002.88	741.21
Weir Submerg		Froude # Chl	0.63	1.00
Weir Max Depth (ft)		Specif Force (cu ft)	6589.51	5983.91
Min Top Rd (ft)	1400.02	Hydr Depth (ft)	7.07	5.23
Min El Prs (ft)	1398.56	W.P. Total (ft)	178.03	166.97
Delta EG (ft)	1.10	Conv. Total (cfs)	95988.2	59704.3
Delta WS (ft)	1.89	Top Width (ft)	141.91	141.85
BR Open Area (sq ft)	1192.69	Frctn Loss (ft)		
BR Open Vel (ft/s)	12.92	C & E Loss (ft)		
Coef of Q		Shear Total (lb/sq ft)	3.50	7.13
Br Sel Mthd	Momentum	Power Total (lb/ft s)	33.44	92.17

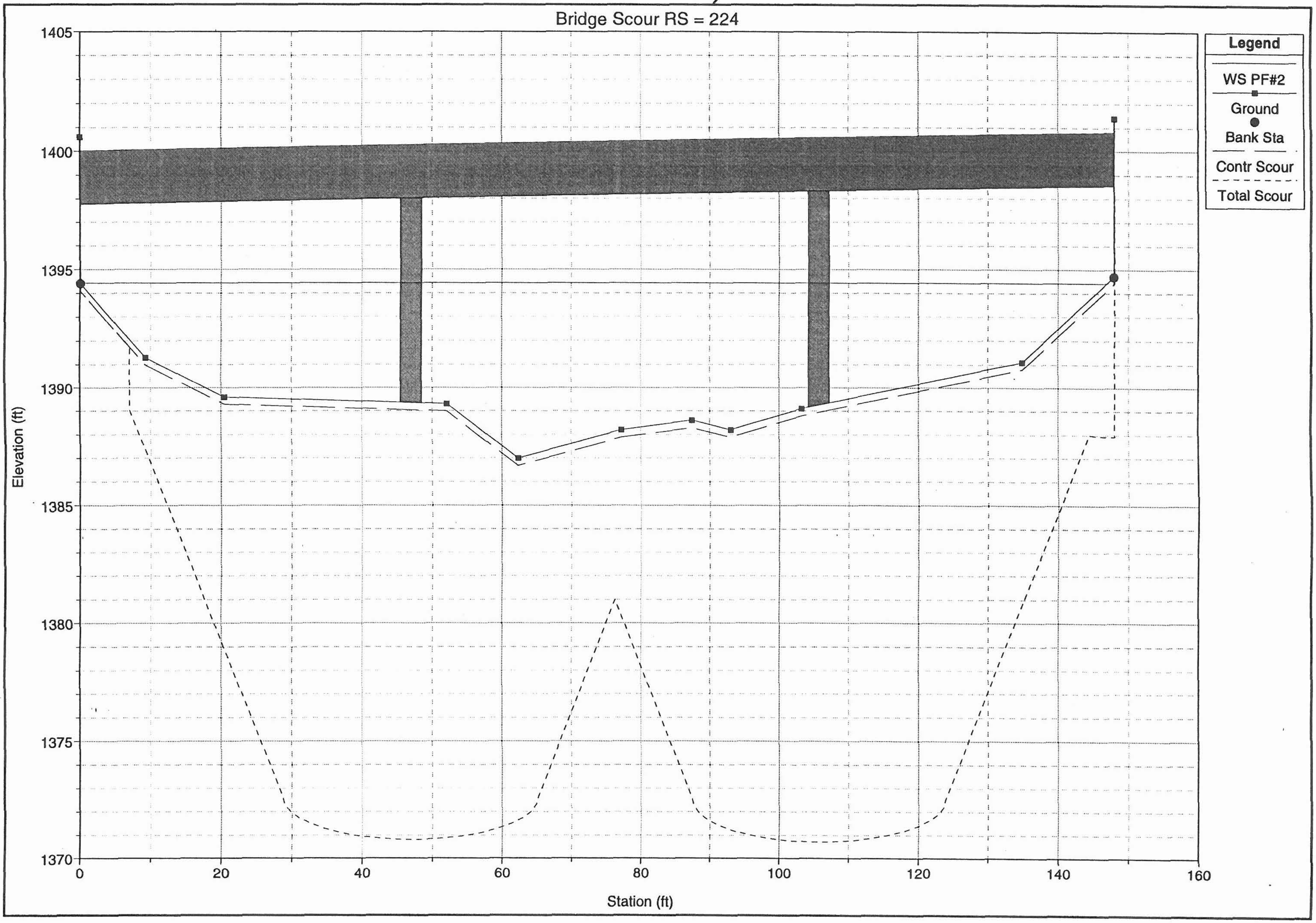
HEC-RAS Plan: Deer Valley

River	Reach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Hydr Depth C	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	(ft)	
Embankment Flow	Embankment Flow	200	2876.00	1388.12	1395.39	1393.02	1395.79	0.002333	6.59	593.43	7.19	117.57	0.43
Embankment Flow	Embankment Flow	200	575.00	1388.12	1395.32	1391.11	1395.34	0.000097	1.34	585.13	7.12	117.29	0.09
Embankment Flow	Embankment Flow	200	4889.00	1388.12	1397.62	1394.23	1398.16	0.002151	7.58	864.32	9.41	124.00	0.44
Embankment Flow	Embankment Flow	200	978.00	1388.12	1398.47	1391.55	1398.49	0.000060	1.34	969.74	10.26	124.00	0.07
Embankment Flow	Embankment Flow	100	2876.00	1387.62	1395.21	1392.52	1395.57	0.001931	6.17	631.42	7.51	118.86	0.40
Embankment Flow	Embankment Flow	100	575.00	1387.62	1395.32	1390.61	1395.33	0.000073	1.21	643.51	7.61	119.26	0.08
Embankment Flow	Embankment Flow	100	4889.00	1387.62	1397.45	1393.73	1397.95	0.001861	7.21	905.87	9.75	124.00	0.41
Embankment Flow	Embankment Flow	100	978.00	1387.62	1398.47	1391.05	1398.48	0.000050	1.26	1031.24	10.76	124.00	0.07
Embankment Flow	Embankment Flow	50	2876.00	1387.37	1395.14	1392.27	1395.47	0.001751	5.97	652.11	7.68	119.55	0.38
Embankment Flow	Embankment Flow	50	575.00	1387.37	1395.31	1390.36	1395.33	0.000064	1.15	673.15	7.86	120.25	0.07
Embankment Flow	Embankment Flow	50	4889.00	1387.37	1397.38	1393.48	1397.85	0.001728	7.04	927.81	9.93	124.00	0.39
Embankment Flow	Embankment Flow	50	978.00	1387.37	1398.46	1390.80	1398.48	0.000046	1.22	1062.01	11.01	124.00	0.06
Embankment Flow	Embankment Flow	0	2876.00	1387.12	1395.07	1392.02	1395.38	0.001585	5.77	673.90	7.86	120.28	0.36
Embankment Flow	Embankment Flow	0	575.00	1387.12	1395.31	1390.11	1395.32	0.000056	1.10	703.07	8.11	121.24	0.07
Embankment Flow	Embankment Flow	0	4889.00	1387.12	1397.31	1393.23	1397.76	0.001604	6.86	950.45	10.11	124.00	0.38
Embankment Flow	Embankment Flow	0	978.00	1387.12	1398.46	1390.55	1398.48	0.000042	1.19	1092.81	11.26	124.00	0.07
Unnamed Wash	Upper Reach	400	785.00	1387.73	1395.09	1390.75	1395.10	0.000105	0.90	982.98	5.09	249.78	0.07
Unnamed Wash	Upper Reach	400	3925.00	1387.73	1395.50	1392.81	1395.72	0.001920	4.04	1087.03	5.50	249.91	0.30
Unnamed Wash	Upper Reach	400	1720.00	1387.73	1397.35	1391.55	1397.37	0.000120	1.22	1548.05	7.35	249.94	0.08
Unnamed Wash	Upper Reach	400	8600.00	1387.73	1398.62	1394.68	1398.96	0.001635	5.03	1865.61	8.62	249.96	0.30
Unnamed Wash	Upper Reach	300	785.00	1387.25	1395.08	1390.27	1395.09	0.000074	0.80	1101.16	5.56	249.91	0.06
Unnamed Wash	Upper Reach	300	3925.00	1387.25	1395.36	1392.33	1395.54	0.001523	3.74	1169.89	5.83	249.92	0.27
Unnamed Wash	Upper Reach	300	1720.00	1387.25	1397.34	1391.06	1397.36	0.000094	1.13	1665.85	7.82	249.95	0.07
Unnamed Wash	Upper Reach	300	8600.00	1387.25	1398.49	1394.20	1398.80	0.001409	4.79	1953.09	8.97	249.96	0.28
Unnamed Wash	Upper Reach	273	785.00	1387.12	1395.07	1390.18	1395.09	0.000132	1.02	770.72	5.21	147.85	0.08
Unnamed Wash	Upper Reach	273	3925.00	1387.12	1395.06	1392.43	1395.46	0.003315	5.10	769.24	5.20	147.85	0.39
Unnamed Wash	Upper Reach	273	1720.00	1387.12	1397.31	1391.04	1397.35	0.000192	1.56	1102.62	7.46	147.92	0.10
Unnamed Wash	Upper Reach	273	8600.00	1387.12	1397.88	1394.54	1398.69	0.003765	7.25	1185.64	8.02	147.93	0.45
Unnamed Wash	Deer Valley Road	273	3661.00	1387.12	1394.18	1392.29	1394.68	0.005172	5.72	639.56	4.43	144.49	0.48
Unnamed Wash	Deer Valley Road	273	4500.00	1387.12	1394.71	1392.73	1395.32	0.005466	6.27	717.94	4.87	147.45	0.50
Unnamed Wash	Deer Valley Road	273	6609.00	1387.12	1395.85	1393.75	1396.72	0.005854	7.45	886.67	6.00	147.87	0.54
Unnamed Wash	Deer Valley Road	273	9578.00	1387.12	1397.30	1394.94	1398.48	0.005988	8.71	1100.36	7.44	147.92	0.56
Unnamed Wash	Deer Valley Road	248	3661.00	1387.00	1394.04	1392.17	1394.56	0.005214	5.74	637.83	4.42	144.41	0.48
Unnamed Wash	Deer Valley Road	248	4500.00	1387.00	1394.57	1392.60	1395.19	0.005543	6.30	714.75	4.85	147.38	0.50
Unnamed Wash	Deer Valley Road	248	6609.00	1387.00	1395.69	1393.63	1396.57	0.005991	7.51	880.56	5.96	147.87	0.54
Unnamed Wash	Deer Valley Road	248	9578.00	1387.00	1397.13	1394.82	1398.32	0.006120	8.76	1093.21	7.39	147.92	0.57

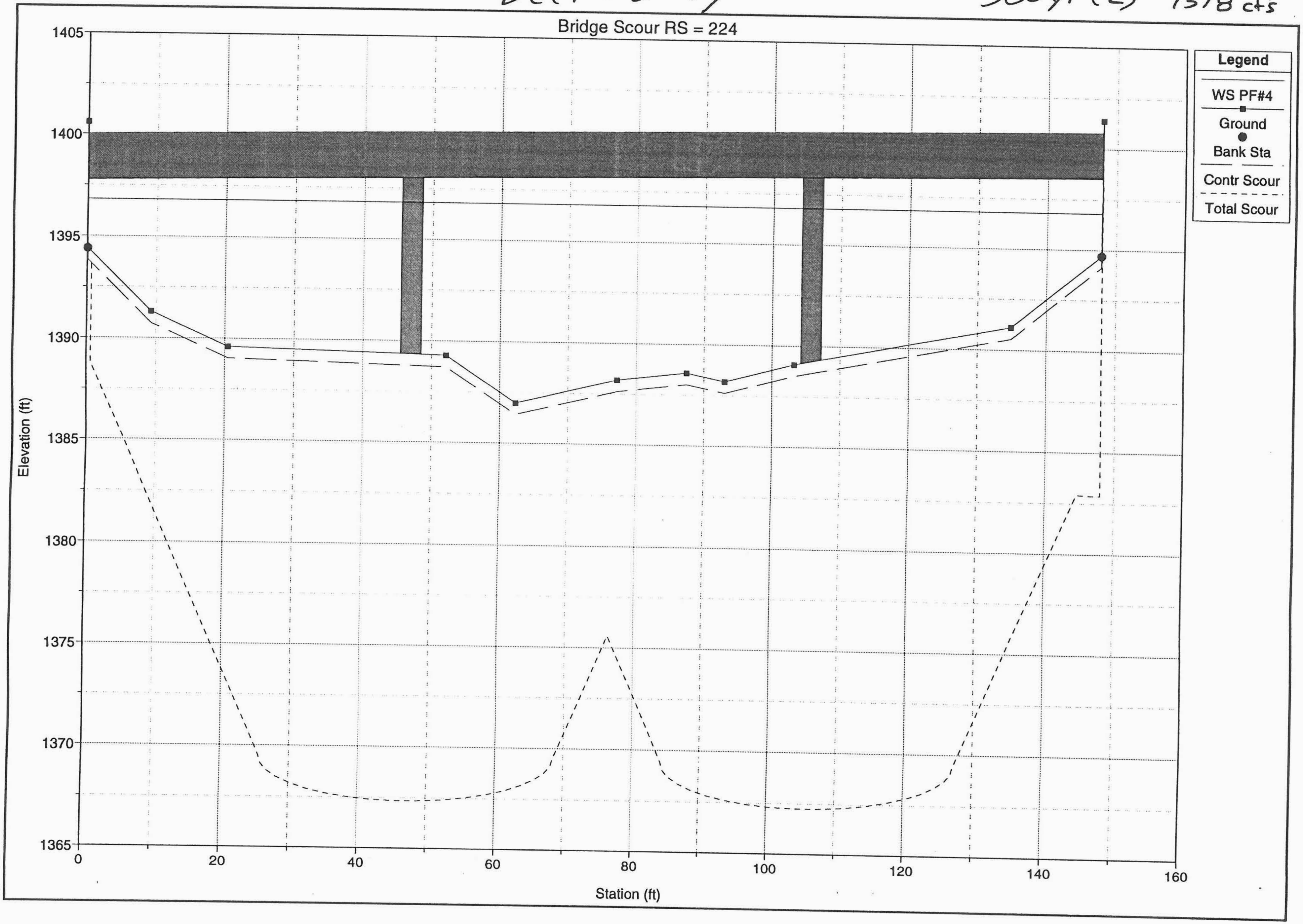
HEC-RAS Plan: Deer Valley (Continued)

River	Reach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Hydr Depth C	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	(ft)	
Unnamed Wash	Deer Valley Road	224	Bridge										
Unnamed Wash	Deer Valley Road	200	3661.00	1386.77	1393.15	1391.94	1393.85	0.008552	6.74	542.84	3.88	140.01	0.60
Unnamed Wash	Deer Valley Road	200	4500.00	1386.77	1393.56	1392.37	1394.43	0.009433	7.48	601.38	4.21	142.74	0.64
Unnamed Wash	Deer Valley Road	200	6609.00	1386.77	1394.39	1393.37	1395.69	0.011606	9.16	721.49	4.89	147.54	0.73
Unnamed Wash	Deer Valley Road	200	9578.00	1386.77	1395.24	1394.56	1397.22	0.014304	11.30	847.33	5.73	147.87	0.83
Unnamed Wash	Deer Valley Road	100	3661.00	1386.29	1392.68	1391.24	1393.12	0.005094	5.53	721.37	4.22	242.66	0.47
Unnamed Wash	Deer Valley Road	100	4500.00	1386.29	1393.12	1391.63	1393.63	0.005245	5.99	821.85	4.66	261.60	0.49
Unnamed Wash	Deer Valley Road	100	6609.00	1386.29	1394.02	1392.56	1394.72	0.005712	7.03	1031.23	5.56	299.79	0.53
Unnamed Wash	Deer Valley Road	100	9578.00	1386.29	1395.07	1393.49	1396.01	0.006175	8.21	1280.41	6.61	329.24	0.56
Unnamed Wash	Deer Valley Road	0	3661.00	1385.81	1392.21	1390.77	1392.62	0.004809	5.38	774.79	4.23	277.89	0.46
Unnamed Wash	Deer Valley Road	0	4500.00	1385.81	1392.66	1391.14	1393.11	0.004808	5.75	903.26	4.68	303.69	0.47
Unnamed Wash	Deer Valley Road	0	6609.00	1385.81	1393.59	1391.99	1394.15	0.004813	6.50	1176.41	5.61	355.40	0.48
Unnamed Wash	Deer Valley Road	0	9578.00	1385.81	1394.69	1393.02	1395.39	0.004804	7.31	1507.21	6.71	396.65	0.50

Deer Valley 100 yr (2) 4,500 cfs



Deer Valley 500yr (2) 9578 cfs



100 yr Discharge

HEC-RAS

Contraction Scour

Input Data

	Channel
Average Depth (ft): 0.10	4.87
Approach Velocity (ft/s):	6.27
Br Average Depth (ft):	4.70
BR Opening Flow (cfs):	4500.00
BR Top WD (ft):	140.84
Grain Size D50 (ft):	0.0164
Approach Flow (cfs):	4500.00
Approach Top WD (ft):	147.45
K1 Coefficient:	0.640

Results

Scour Depth Ys (ft):	0.32
Critical Velocity (ft/s):	
Equation:	Live

Pier Scour

All piers have the same scour depth

Input Data

Pier Shape:	Square nose
Pier Width (ft):	7.00
Grain Size D50 (ft):	0.01640
Depth Upstream (ft):	7.46
Velocity Upstream (ft/s):	7.86
K1 Nose Shape:	1.00
Pier Angle:	10.00
Pier Length (ft):	46.00
K2 Angle Coef:	1.55
K3 Bed Cond Coef:	1.10
Grain Size D90 (ft):	0.33000
K4 Armouring Coef:	1.00

Set K1 value to 1.0 because angle > 5 degrees

Results

Scour Depth Ys (ft):	18.23
Froude #:	0.51
Equation:	CSU equation

Abutment Scour

Input Data

	Right
Station at Toe (ft):	147.99
Toe Sta at appr (ft):	147.99
Abutment Length (ft):	0.00
Depth at Toe (ft):	-3.98
K1 Shape Coef: 0.55 – Spill-through	abutment
Degree of Skew (degrees):	90.00
K2 Skew Coef:	1.00
Projected Length L' (ft):	0.00
Avg Depth Obstructed Ya (ft):	6.34
Flow Obstructed Qe (cfs):	575.00
Area Obstructed Ae (sq ft):	715.34

Results

Scour Depth Ys (ft):	10.82
Qe/Ae = Ve:	0.80
Froude #:	0.06
Equation:	Froehlich

Long-Term Degradation/Scour (ft) **4.00**

Combined Scour Depths

Pier + Contraction + Long-Term Scour (ft): **22.54**

Rt abutment + contr + Long-Term scour (ft): **15.14**

500 yr Discharge

HEC-RAS

Contraction Scour

Input Data

	Channel
Average Depth (ft):	7.44
Approach Velocity (ft/s):	0.17
Br Average Depth (ft):	1.21
BR Opening Flow (cfs):	9577.99
BR Top WD (ft):	141.84
Grain Size D50 (ft):	0.0164
Approach Flow (cfs):	9577.98
Approach Top WD (ft):	147.84
K1 Coefficient:	0.640

Results

Scour Depth Ys (ft):	0.57
Critical Velocity (ft/s):	
Equation: Live	Live

Pier Scour

All piers have the same scour depth

Input Data

Pier Shape:	Square nose
Pier Width (ft):	7.00
Grain Size D50 (ft):	0.01640
Depth Upstream (ft):	10.01
Velocity Upstream (ft/s):	10.44
K1 Nose Shape:	1.00
Pier Angle:	10.00
Pier Length (ft):	46.00
K2 Angle Coef:	1.55
K3 Bed Cond Coef:	1.10
Grain Size D90 (ft):	0.33000
K4 Armouring Coef:	1.00

Set K1 value to 1.0 because angle > 5 degrees

Results

Scour Depth Ys (ft):	21.43
Froude #:	0.58
Equation:	CSU equation

Abutment Scour

Input Data

	Right
Station at Toe (ft):	147.99
Toe Sta at appr (ft):	147.99
Abutment Length (ft):	100
Depth at Toe (ft):	10.26
K1 Shape Coef: 0.55 – Spill-through	abutment
Degree of Skew (degrees):	90.00
K2 Skew Coef:	1.00
Projected Length L' (ft):	100
Avg Depth Obstructed Ya (ft):	10.26
Flow Obstructed Qe (cfs):	978
Area Obstructed Ae (sq ft):	1092.81

Results

Scour Depth Ys (ft):	15.69
Qe/Ae = Ve:	0.89
Froude #:	0.05
Equation:	Froehlich

Long-Term Degradation/Scour (ft) **4.00**

Combined Scour Depths

Pier + Contraction + Long-Term Scour (ft): **26.00**

Rt abutment + contr + Long-Term scour (ft): **20.26**