Queen Creek Wash
Sossaman Bridge Replacement

SCOUR ANALYSIS REPORT

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BRIDGE SCOUR ANALYSIS

This section presents the procedures, methodology, and results of the scour analysis for the proposed Sossaman Road Bridge crossing at Queen CreekWash. Several scour components were considered in determining the total scour potential at the proposed bridge site during the design floods. The total scour at Sossaman Bridge was determined by adding the general (contraction) scour and local sour components. The local scour equation includes a correction factor for bed condition (bed-form scour). A 30% safety factor was applied to the total scour to account for non-uniform flow distributions that are typical of alluvial channels.

Scour depths were predicted for the 100-year design flood. As part of this analysis, scour depths were also predicted for the "Superflood" in order to help ensure that the proposed foundations will not fail due to scour during this larger event. Long-term aggradation/degradation was not included since there will be a grade-control structure located immediately downstream of the bridge. The supporting detailed scour calculations described below are provided in Appendix I.

1. General Scour

General scour refers to the vertical lowering of the channel bed over relatively short time periods (i.e., the scour in a given reach after passage of a single flood event). General scour was estimated using the methodology described in the Hydraulic Engineering Circular No. 18 (HEC-18), 4th Edition. The scour analysis predicted 1.0 feet and 1.3 feet of general scour for the 100-year and "Superflood" events, respectively. For the 100-year event, HEC-6T sedimentation results show a scour depth of 0.6 feet.

2. Local Scour

Local scour at the bridge piers was analyzed for both 100-year and "Superflood" design hydraulic conditions. The pier scour calculations were performed using Equation (6.1) in the Hydraulic Engineering Circular No. 18 (HEC-18), 4th edition.

Gradation data from the wash indicates that the D_{50} is less than 1 mm and bank and sub-bed materials are less than 0.1 mm. D_{90} and D_{95} sizes are less than 10 mm for both bed and bank samples with the exception of one bed sample which approached the 20 mm size range (1270' Above Power Road). Since the D_{95} size material found in this reach of the wash is less than 20 mm, the value of K4 was set to 1.0 for the local scour calculations.

Debris accumulation at the piers was accounted for by adding 4 feet of width to the 2.5-ft diameter columns. The results predict a pier scour of 10.6 feet and 9.0 feet for the 100-year and "Superflood" events, respectively. It should be noted that the "Superflood" event overtops the banks upstream from the bridge and will likely not all flow through the bridge. The factor used for the "Superflood" was 1.7 times the 100 year flood peak. A factor of 1.35 produces a flow approximately equal to the bank heights in the reach. This value is probably a more realistic of actual worst case flow conditions at the bridge. It also produced a higher pier scour value than that obtained for the "Superflood" – probably due to flow conditions associated with overtopping the bridge in the HEC-RAS model.

3. Total Pier Scour

The total expected scour at the proposed Sossaman Bridge piers was determined by first adding all the calculated scour components, and then applying a factor of safety. The factor of safety equals 30% of the sum of the general scour, and pier scour components. This safety factor is included to account for the non-uniform flow distribution that is typical of alluvial channels. A summary of these values is provided in Table 1.

Table 1. Pier Scour Depths at the Proposed Sossaman Road Bridge

Design Flood Event	General Scour (ft)	Local Scour (ft)	30% Factor of Safety (ft)	Total Pier Scour (ft)
100-Year	0.9	10.6	3.5	15
1.35*100-Year	1.5	11.4	3.9	17
"Superflood"	1.3	9.0	3.0	13

4. Abutment Scour

Classical abutment scour is the result of a change in local flow direction/velocity and increased flow turbulence caused either by (1) the abutment projecting into the flow of a watercourse; (2) overbank flow being intercepted and forced back into the channel by the abutment embankment; or by (3) a combination of these conditions. The length of embankment projected normal to the flow that is used in computing the abutment scour is determined from the results of HEC-RAS runs and HEC-18 guidelines. Table 2 summarizes the abutment scour for 100-year and "Superflood" events for both the left and right banks of the bridge location based on the location of the bridge shown in the 30% plans. Federal criteria requires evaluation for the "Superflood" condition (500 year flood or 1.7 times the 100 year flood peak. It appears, however, that the maximum flow in the wash is likely nearer 1.35 times the 100 year flood flow due to breakouts during the "Superflood" event.

The bridge as drawn in the 30% plans is aligned to the north side of the channel leaving a longer south abutment which is more prone to scour. If the bridge were placed more to the south or the south bank tapered into the bridge the embankment scour for the left (south) abutment could likely be reduced.

Table 2. Embankment Scour

Design Flood Event	Left Embankment Scour (Looking Downstream) (ft)	Right Embankment Scour (Looking Downstream) (ft)
100-Year	16.5	15.0*
1.35*100-Year	20.0	17.0*
"Superflood"	26.0	13.0*

*Use maximum of total Pier Scour or Embankment Scour. Pier scour values shown for right abutment.

References

Hydraulic Engineering Circular No. 18 (HEC-18) 2001. Evaluating Scour At Bridges, 4th Edition, Federal Highway Administration Publication No. FHWA NHI 01-001.

Appendix I

Queen Creek Scour Data

100-Year Event

General and Pier Scour Data			
Variable	**Description**	**Value**	**Unit**
Q	Discharge	2832	cfs
y_1	Upstream Main Channel Water Depth	3.58	ft
V_1	Upstream Approach Velocity	7.00	ft/s
w'	Fall Velocity	0.036	ft/s
W_1	Upstream Main Channel Bottom Width	112.00	ft
W_2	Bottom Width of Contracted Channel Less Pier Widths	98.40	ft
S	Channel Slope	0.0098	ft/ft
a	Pier Width (Included Debris Width)	6.50	ft
y_0	Existing Depth in the Contracted Section Before Scour	2.98	ft
Fr	Froude Number	0.65	-
D_{50}	Mean Diameter	0.09	mm
D_{90}	90% Finer Diameter	0.23	mm
Left Abutment (Looking Downstream) Scour Data			
Variable	**Description**	**Value**	**Unit**
A_e	Flow Area of the Approach Cross Section Obstructed by the Embankment	117.00	ft^2
L	Length of Embankment Projected Normal to the Flow	54.00	ft
L'	Length of Active Flow Obstructed by Embankment	54.00	ft
K_1	Coefficient for Abutment Shape	1	-
θ	Embankment Angle	60	degrees
K_2	$(\theta/90)^{0.13}$	0.95	-
Right Abutment (Looking Downstream) Scour Data			
N/A			

$1.35*Q_{100}$ Event

General and Pier Scour Data			
Variable	Description	Value	Unit
Q	Discharge	3856	cfs
y_1	Upstream Main Channel Water Depth	4.10	ft
V_1	Upstream Approach Velocity	7.93	ft/s
w'	Fall Velocity	0.036	ft/s
W_1	Upstream Main Channel Bottom Width	112.00	ft
W_2	Bottom Width of Contracted Channel Less Pier Widths	98.40	ft
S	Channel Slope	0.0098	ft/ft
a	Pier Width (Included Debris Width)	6.50	ft
y_0	Existing Depth in the Contracted Section Before Scour	3.00	ft
Fr	Froude Number	0.69	-
D_{50}	Mean Diameter	0.09	mm
D_{90}	90% Finer Diameter	0.23	mm
Left Abutment (Looking Downstream) Scour Data			
Variable	Description	Value	Unit
A_e	Flow Area of the Approach Cross Section Obstructed by the Embankment	150.00	ft^2
L	Length of Embankment Projected Normal to the Flow	54.00	ft
L'	Length of Active Flow Obstructed by Embankment	54.00	ft
K_1	Coefficient for Abutment Shape	1.00	-
θ	Embankment Angle	60	degrees
K_2	$(\theta/90)^{0.13}$	0.95	-
Right Abutment (Looking Downstream) Scour Data			
N/A			

500-Year Event

General and Pier Scour Data			
Variable	**Description**	**Value**	**Unit**
Q	Discharge	4855	cfs
y_1	Upstream Main Channel Water Depth	7.28	ft
V_1	Upstream Approach Velocity	3.71	ft/s
w'	Fall Velocity	0.036	ft/s
W_1	Upstream Main Channel Bottom Width	112.00	ft
W_2	Bottom Width of Contracted Channel Less Pier Widths	98.40	ft
S	Channel Slope	0.0098	ft/ft
a	Pier Width (Included Debris Width)	6.50	ft
y_0	Existing Depth in the Contracted Section Before Scour	6.60	ft
Fr	Froude Number	0.24	-
D_{50}	Mean Diameter	0.09	mm
D_{90}	90% Finer Diameter	0.23	mm
Left Abutment (Looking Downstream) Scour Data			
Variable	**Description**	**Value**	**Unit**
A_e	Flow Area of the Approach Cross Section Obstructed by the Embankment	476.00	ft^2
L	Length of Embankment Projected Normal to the Flow	54.00	ft
L'	Length of Active Flow Obstructed by Embankment	54.00	ft
K_1	Coefficient for Abutment Shape	1	-
θ	Embankment Angle	60	degrees
K_2	$(\theta/90)^{0.13}$	0.95	-
Right Abutment (Looking Downstream) Scour Data			
A_e	Flow Area of the Approach Cross Section Obstructed by the Embankment	14.00	ft^2
L	Length of Embankment Projected Normal to the Flow	5.00	ft
L'	Length of Active Flow Obstructed by Embankment	5.00	ft
K_1	Coefficient for Abutment Shape	1.00	-
θ	Embankment Angle	120	degrees
K_2	$(\theta/90)^{0.13}$	1.04	-

GENERAL (CONTRACTION) SCOUR

EQUATION - 5.2 (HEC-18, 4th EDITION)

$$\frac{y_2}{y_1} = \left(\frac{Q_2}{Q_1}\right)^{6/7}\left(\frac{W_1}{W_2}\right)^{K_1}$$

EQUATION - 5.3 (HEC-18, 4th EDITION)

$$y_s = y_2 - y_0 = \text{(AVERAGE CONTRACTION SCOUR DEPTH)}$$

WHERE: y_1 = AVERAGE DEPTH IN THE UPSTREAM MAIN CHANNEL, ft. (HEC-RAS CROSS SECTION: 5.119)

y_2 = AVERAGE DEPTH IN CONTRACTED SECTION, ft.

y_0 = EXISTING DEPTH IN THE CONTRACTED SECTION BEFORE SCOUR, ft

Q_1 = FLOW IN UPSTREAM CHANNEL, ft^3/s

Q_2 = FLOW IN THE CONTRACTED CHANNEL, ft^3/s.

W_1 = BOTTOM WIDTH OF THE UPSTREAM MAIN CHANNEL, ft.

W_2 = BOTTOM WIDTH OF THE MAIN CHANNEL IN THE CONTRACTED SECTION LESS PIER WIDTH(S), ft.

K_1 = EXPONENT BASED ON V^*/ω

WHERE: $V^* = \sqrt{g y_1 S_1}$ = SHEAR VELOCITY

$g = 32.2$ ft/s

S_1 = CHANNEL SLOPE

ω = FALL VELOCITY BASED ON D_{50}.

100-YEAR EVENT CALCULATIONS:

$y_1 = 3.58$ ft

$y_0 = 2.98$ ft

$W_1 = 112$ ft

$W_2 = 98.4$ ft

$Q_1 = Q_2 = 2832$ cfs

$K_1 = 0.69$ (SEE HEC-18, 4th Ed., Pg # 5.11)

SINCE $V^* = \sqrt{g\, y_1\, S_1}$

$= \sqrt{32.2 \times 3.58 \times 0.0098}$

$\Rightarrow V^* = 1.06$ ft/s.

$\omega = 0.036$ ft/s

$V^*/\omega = 29.4 > 2 \Rightarrow K_1 = \underline{\underline{0.69}}$

$$y_2 = y_1 \left(\frac{W_1}{W_2} \right)^{K_1} = 3.58 \times \left(\frac{112}{98.4} \right)^{0.69}$$

$\Rightarrow y_2 = 3.91$ ft

y_s = GENERAL (CONTRACTION) SCOUR

$= y_2 - y_0 = 3.91 - 2.98$

$\Rightarrow \boxed{y_s = 0.9 \text{ ft}}$

PIER SCOUR: (CSU EQUATION, HEC-18)

EQUATION-6.1 (HEC-18, 4th EDITION)

$$\frac{y_s}{y_1} = 2.0 \; K_1 \, K_2 \, K_3 \, K_4 \left(\frac{a}{y_1}\right)^{0.65} Fr_1^{\;0.43}$$

WHERE: y_s = PIER SCOUR DEPTH, ft

y_1 = UPSTREAM FLOW DEPTH, ft

K_1 = CORRECTION FACTOR FOR PIER SHAPE

K_2 = CORRECTION FACTOR FOR FLOW ANGLE OF ATTACK

K_3 = CORRECTION FACTOR FOR BED CONDITION

K_4 = CORRECTION FACTOR FOR ARMORING BY BED MATERIAL SIZE

a = EFFECTIVE PIER WIDTH, ft

Fr = FROUDE NUMBER

100-YEAR EVENT CALCULATIONS:

$y_1 = 3.58$ ft $= 1.09$ m ; $V_1 = 7$ ft/s $= 2.13$ m/s

$K_1 = 1.1$ SQUARE NOSE SHAPE FACTOR CONSIDERING DEBRIS LOADING ON THE PIER COLUMN.

$K_2 = 1.0$ PIERS ARE ALIGNED WITH THE FLOW

$K_3 = 1.1$ (TABLE 6.3, HEC-18)

K_4 FACTOR CALCULATIONS: (BASED ON HEC-18, 3rd EDITION)

$$V_R = \left[\frac{V_1 - V_i}{V_{c90} - V_i}\right] \quad \text{- EQN 24a}$$

$$V_i = 0.645 \left[\frac{D_{50}}{a}\right]^{0.053} V_{c50} \quad \text{- EQN 24b}$$

WHERE: V_R = VELOCITY RATIO

V_1 = APPROACH VELOCITY, m/s

V_i = APPROACH VELOCITY WHEN PARTICLES AT A PIER BEGIN TO MOVE, m/s

V_{c90} = CRITICAL VELOCITY FOR D_{90} BED MATERIAL SIZE, m/s

V_{c50} = CRITICAL VELOCITY FOR D_{50} BED MATERIAL SIZE, m/s

a = EFFECTIVE PIER WIDTH, m

$$V_c = 6.19\ y^{1/6}\ D_c^{1/3}$$

WHERE: D_c = CRITICAL PARTICLE SIZE FOR THE CRITICAL VELOCITY V_c, m

$$D_{50} = 0.09\ \text{mm} = 0.00009\ \text{m}$$

$$D_{90} = 0.23\ \text{mm} = 0.00023\ \text{m}$$

$$a = 6.5\ \text{ft}$$

$$V_{c50} = 6.19\ (1.09)^{1/6}\ (0.00009)^{1/3}$$

$$= 0.28\ \text{m/s}$$

$$V_{c90} = 6.19\ (1.09)^{1/6}\ (0.00023)^{1/3}$$

$$= 0.38\ \text{m/s}$$

$$V_i = 0.645 \left[\frac{0.00009}{6.5}\right]^{0.053} (0.28)$$

$$= 0.10\ \text{m/s}$$

$$V_R = \left[\frac{V_1 - V_i}{V_{c90} - V_i}\right] = \frac{2.13 - 0.10}{0.38 - 0.10}$$

$$\Rightarrow V_R = 7.25$$

BASED ON TABLE-5 (HEC-18, 3rd EDITION)

SINCE $V_R > 1.0 \Rightarrow \boxed{K_4 = 1.0}$

Fr_1 = FROUDE NUMBER $= V_1 / \sqrt{g\, y_1}$

$$= \frac{7.0}{\sqrt{32.2 \times 3.58}} = 0.65$$

FROM EQUATION - 6.1 (HEC-18, 4th EDITION)

$$y_s = \left[2.0\, K_1 K_2 K_3 K_4 \left(\frac{a}{y_1}\right)^{0.65} Fr_1^{\,0.43}\right] \times y_1$$

$$\Rightarrow y_s = \left[(2.0)(1.1)(1.0)(1.1)(1.0)\left(\frac{6.5}{3.58}\right)^{0.65} (0.65)^{0.43}\right] \times 3.58$$

$$\Rightarrow \boxed{y_s = 10.62 \text{ ft}}$$

ABUTMENT SCOUR (LIVE-BED):

FROEHLICK'S LIVE-BED ABUTMENT SCOUR EQUATION (HEC-18, 4th EDITION)

$$\frac{y_s}{y_a} = 2.27\, K_1 K_2 \left(\frac{L'}{y_a}\right)^{0.43} Fr^{0.61} + 1 \qquad \text{EQN. (7.1)}$$

WHERE:

K_1 = COEFFICIENT FOR ABUTMENT SHAPE

K_2 = COFFICIENT FOR ANGLE OF EMBANKMENT TO FLOW

$K_2 = (\theta/90)^{0.13}$ (SEE FIGURE 7.4, HEC-18)

$\theta < 90°$ IF EMBANKMENT POINTS DOWNSTREAM

$\theta > 90°$ IF EMBANKMENT POINTS UPSTREAM

L' = LENGTH OF ACTIVE FLOW OBSTRUCTED BY EMBANKMENT, ft.

A_e = FLOW AREA OF THE APPROACH CROSS SECTION OBSTRUCTED BY THE EMBANKMENT, ft^2

Fr = FROUDE NUMBER OF APPROACH FLOW UPSTREAM OF THE ABUTMENT

$= V_e/\sqrt{g y_a}$

$V_e = Q_e/A_e$ ft/s.

Q_e = FLOW cfs.

y_a = AVERAGE DEPTH OF FLOW (A_e/L), ft.

L = LENGTH OF EMBANKMENT PROJECTED NORMAL TO THE FLOW, ft.

y_s = SCOUR DEPTH, ft.

100-YEAR EVENT CALCULATIONS:

LEFT ABUTMENT:-

$A_e = 110 \ ft^2$

$L = 54 \ ft.$

$L' = 54 \ ft.$

$K(1) = 1.00$ (VERTICAL WALL ABUTMENT ASSUMED)

$\theta = 60°$ (ABUTMENT POINTING DOWNSTREAM)

$K(2) = (\theta/90)^{0.13} = (60/90)^{0.13} = 0.95$

$y_a = A_e/L = 110/54 = 2.04 \ ft$

$F_r = 0.65$

$y_s = 2.04 \times \left[(2.27)(1)(0.95)\left(\frac{54}{2.04}\right)^{0.43}(0.65)^{0.61} + 1\right]$

$\Rightarrow \boxed{y_s = 16.5 \ ft}$

RIGHT ABUTMENT:-

$A_e = 0 \ ft^2$

$L = 5 \ ft$

$L' = 0 \ ft$ (FLOW-DEPTH DOES NOT REACH ABUTMENT)

$\boxed{y_s = 0 \ ft}$