Thomes Creek
Hydraulic Design Study

Thomes Creek / 99W
Bridge Replacement Project

Prepared for:
Tehama County, California

February 2014

HDR

Thomes Creek Hydraulic Design Study

Thomes Creek/99W
Bridge Replacement Project

Tehama County, California

February 24, 2014

2365 Iron Point Road, Suite 300
Folsom, CA 95630

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1.0 Introduction

1.1 General

The 99W Bridge crossing Thomes Creek (99W Bridge Replacement Project) is located in Tehama County, California approximately 5.0 miles west of the Sacramento River and Thomes Creek confluence and 1.5 miles east of Interstate 5 (I-5) (See Figure 1). The existing bridge has been approved for replacement through the Highway Bridge Program (HBP) by the Federal Highway Administration (FHWA). Tehama County as administered by the California Department of Transportation (Caltrans) contracted with HDR to conduct a detailed hydrologic and hydraulic analysis for the Bridge Replacement Project.

1.2 Purpose

This report summarizes the technical hydrologic and hydraulic information to determine water surface elevations and scour conditions at the existing 99W Bridge site. This information will be used in making decisions about the planning and design of the replacement 99W Bridge, including deck width and depth of foundation.

Specific design standards were provided by Tehama County and the California Department of Transportation (Caltrans). Tehama County specific design standards do not include freeboard criteria, but commonly use Caltrans hydraulic design freeboard standards for specific criteria. As such, the proposed bridge design will satisfy standards detailed in:

1. Tehama County Drainage Standards, dated March 1995, and
2. Caltrans Highway Design Standards, dated September 2006, which requires that:
    a) The proposed bridge must pass the 50-year flood without causing excessive backwater, excessive flow velocities, or encroaching on through-traffic lanes. Sufficient freeboard, typically a minimum of 2 feet is assumed for preliminary bridge design.
    b) The bridge should be able to convey the base flood (100-year flood).
    c) The bridge should be able to withstand scour effects for the base flood.

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THOMES CREEK AT 99W, TEHAMA COUNTY
BRIDGE REPLACEMENT PROJECT LOCATION

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0 0.5 1 2 Miles

Figure 1

2.0 Background

2.1 Previous Studies

HDR reviewed relevant previous studies in the vicinity of the 99W Bridge Replacement Project provided by the Tehama County Public Works Department for applicability to this analysis. This section describes the methodology used by these studies.

2.1.1 Federal Emergency Management Agency (FEMA) 2003 Flood Insurance Study (FIS) for Tehama County

A review of the FEMA FIS for Tehama County dated May 5, 2003 showed that the project site is within Zone A, where the floodplain delineation is based on approximate methods (FIRM Panel Number 0650640665B). Therefore, no base flood elevations are available for the study area.

2.1.2 Design Hydraulic Study, Rawson Road over Thomes Creek Bridge No. 08C-047, Tehama County (2003 Design Hydraulic Study)

The 2003 Design Hydraulic Study, dated April 10, 2003, summarizes a hydrologic and hydraulic assessment (performed by Pacific Hydrologic Inc. for Quincy Engineering) of the Rawson Road Bridge over Thomes Creek. The Rawson Road bridge is located approximately 2.8 miles west (upstream) of the 99W Bridge Replacement Project. The analysis included developing peak flows using a local gage in the watershed, and a hydraulic evaluation of existing and proposed bridge conditions. A scour analysis was performed for the proposed bridge design.

The 2003 Design Study evaluated five gaged basins (four in adjacent watersheds and one in the Thomes Creek watershed) to develop flood-frequency relationships. Characteristics of the five basins are summarized in Table 1.

Table 1. Characteristics of Basins Evaluated in the 2003 Design Hydraulic Study

Basin Description	USGS Gage No.	Basin Area (sq. mi.)	Ave. Annual Precipitation (in)	Elevation Index	Years of Record
Thomes Creek at Paskenta	11382000	194	35	2.7	76
Elder Creek at Gerber	11380500	136	38	1.8	30
Mill Creek near Los Molinos	11381500	131	35	1.5	70
Antelope Creek near Red Bluff	11379000	123	35	1.5	41
Paynes Creek near Red Bluff	11377500	93	35	1.5	27

Candidate peak flows for the Rawson Road Bridge project site were calculated using the characteristics and adjusted flood-frequency information of the Thomes Creek at Paskenta Basin. The 50-year and 100-year peak flows for the Rawson Road Bridge site are summarized in Table 2.

Table 2. Estimated Flood Peak Flows at the Thomes Creek Bridge at Rawson Road

Location	Basin Area (sq. mi.)	50-Year Flow (cfs)	100-Year Flow (cfs)
Adjustment from Thomes Creek near Paskenta	203	42,000	53,500

The potential scour for the proposed Rawson Road Bridge design was estimated to be approximately 16.0 feet at the piers and 6.0 feet and 16.5 feet respectively at the north and south abutments. Contraction scour was not evaluated in the 2003 Design Hydraulic Study as the proposed replacement Rawson Road Bridge would not cause contraction of the existing channel.

2.1.3 Thomes Creek Bridge #08-0085 Interstate 5; 12.6 miles north of Glen County Line and 13 miles south of Red Bluff (2006 Office of Structures Final Hydraulic Report)

A hydrologic and hydraulic assessment of the Thomes Creek Bridge on Interstate 5 was performed as part of the Bridge #08-0085 replacement project. The 2006 Office of Structures Final Hydraulic Report presented peak flows and scour conditions at the Bridge #08-0085 replacement project site.

The mean annual precipitation at the Bridge #08-0085 location was 760 mm (29.9 in). The 50- and 100-year peak flows at this location were calculated to be 1262 m^3/s (44,600 cfs) and 1402 m^3/s (49,500 cfs) respectively by applying a basin transfer equation to the peak flows from the USGS gage at Thomes Creek near Paskenta. A HEC-RAS model was developed to compute water surface elevations and scour at the proposed bridge location.

The degradation of the channel for an assumed bridge life span of 75 years was estimated to be 4.6 m (15.1 feet). Potential scour was estimated to be 4.6 m (15.1 feet) at the piers and 72.8 m (238.9 feet) at the abutments.

2.1.4 Preliminary Foundation Report Route 99W Bridge Replacement at Thomes Creek, Tehama County, California (2009 Preliminary Foundation Report)

The 2009 Preliminary Foundation Report details a preliminary geotechnical investigation conducted by Blackburn Consulting Inc. at the proposed 99W Replacement Bridge site. In development of the 2009 Preliminary Foundation Report, existing bridge data from Tehama County and Caltrans, and literature related to the geologic, hydrologic and seismic conditions of the project site were reviewed. The review indicated that the Thomes Creek stream channel has been scoured approximately 15-20 feet deep at the 99W Bridge location since the construction of the original bridge in 1920. The report mentions channel deposits of sand and gravel approximately 5 feet thick immediately upstream of the bridge and stiff to hard, yellowish brown clay within the channel immediately downstream of the bridge. This indicates some aggradation at the site. The 2009 Preliminary Foundation Report provided preliminary design recommendations for the foundation of the proposed 99W replacement bridge, and indicated that additional subsurface exploration and log bore testing would need to be performed for final design.

3.0 Hydrologic Model Development

3.1 General

Using a methodology similar to the 2003 Design Hydraulic Study, peak flows for the 99W replacement bridge were estimated using both the USGS regional flood-frequency equations and adjusting peak flows from the USGS gage on Thomes Creek near Paskenta, which is located approximately 30-miles west of the 99W Bridge Replacement Project site. Figure 2 presents the delineated Thomes Creek watersheds for the 99W study bridge location, the Rawson Road bridge location and the USGS gage near Paskenta.

Two scenarios were considered for existing conditions: Scenario1, using adjusted peak flows based on regression equation ratios and Scenario 2, using adjusted peak flows based on area ratios. Simulations were carried out for the 2-, 5-, 10-, 25-, 50-, 100- and 500-year peak flows through Thomes Creek at the 99W Bridge location.

3.2 USGS Regional Regression Equations

3.2.1 General

USGS Regional Regression Equations are used to determine the magnitude and frequency of floods. As at the Rawson Road Bridge and the gage near Paskenta, flood-frequency equations developed by the USGS for the North Coast California region were used to develop peak flows at the 99W Bridge Replacement Project site. Results from implementation of the Regional Regression Equations are summarized in Table 3. Regional Regression Equations were developed in the mid-1970s and have several limitations on their applicability, but the results provide a comparison to verify other detailed procedures. Table 3 provides the flood-frequency equations for the North Coast Region applicable to this study.

Table 3. USGS Regional Regression Equations for the North Coast Region

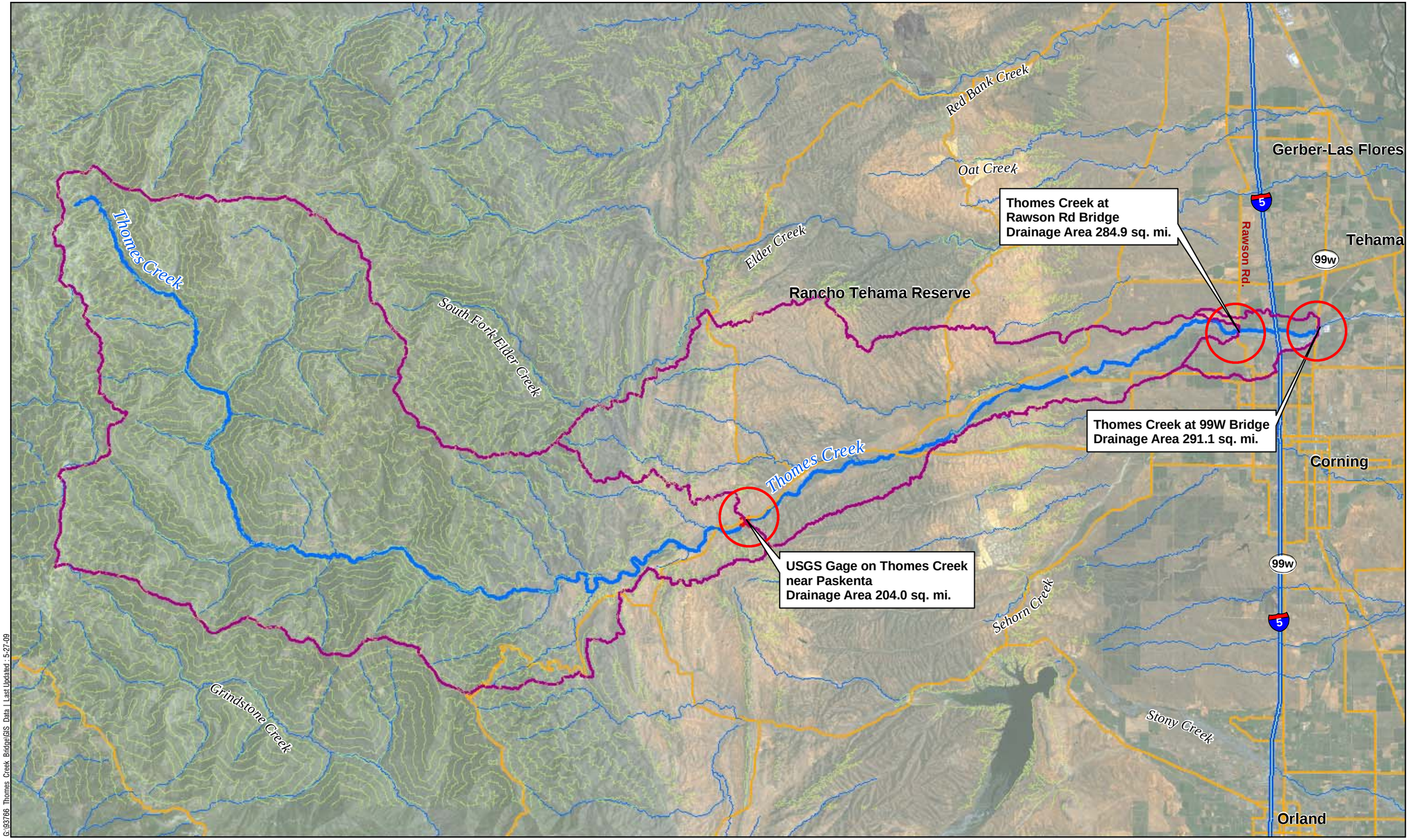
Recurrence Interval	Regional Regression Equations	Standard Error of Estimate ($\log_{10}$ units)	Number of Stations Used in Analysis
2-year	$Q = 3.52\ A^{0.90}\ p^{0.89}\ H^{-0.47}$	0.26	141
5-year	$Q = 5.04\ A^{0.89}\ p^{0.91}\ H^{-0.35}$	0.24	125
10-year	$Q = 6.21\ A^{0.88}\ p^{0.93}\ H^{-0.27}$	0.24	125
25-year	$Q = 7.64\ A^{0.87}\ p^{0.94}\ H^{-0.17}$	0.24	125
50-year	$Q = 8.57\ A^{0.87}\ p^{0.96}\ H^{-0.08}$	0.25	125
100-year	$Q = 9.23\ A^{0.87}\ p^{0.97}$	0.26	125

Q – Peak flow in cubic feet per second; A – Basin area in square miles; p – Mean annual precipitation in inches;
H – Altitude index of the basin in thousands of feet

3.2.2 Parameters

Mean annual precipitation values used in the equations were estimated using the Rantz rainfall map dated 1969 (See Figure 3). The Rantz rainfall map represents zones of mean annual precipitation values for California. The precipitation values for the Thomes Creek Basins at

99W, Rawson Road Bridge, and Paskenta site were estimated by computing an area-weighted average of values of different precipitation zones within that basin. The altitude index in thousands of feet was calculated at points located approximately 10% and 85% the distance from the project site along the main channel of the stream to the basin divide.



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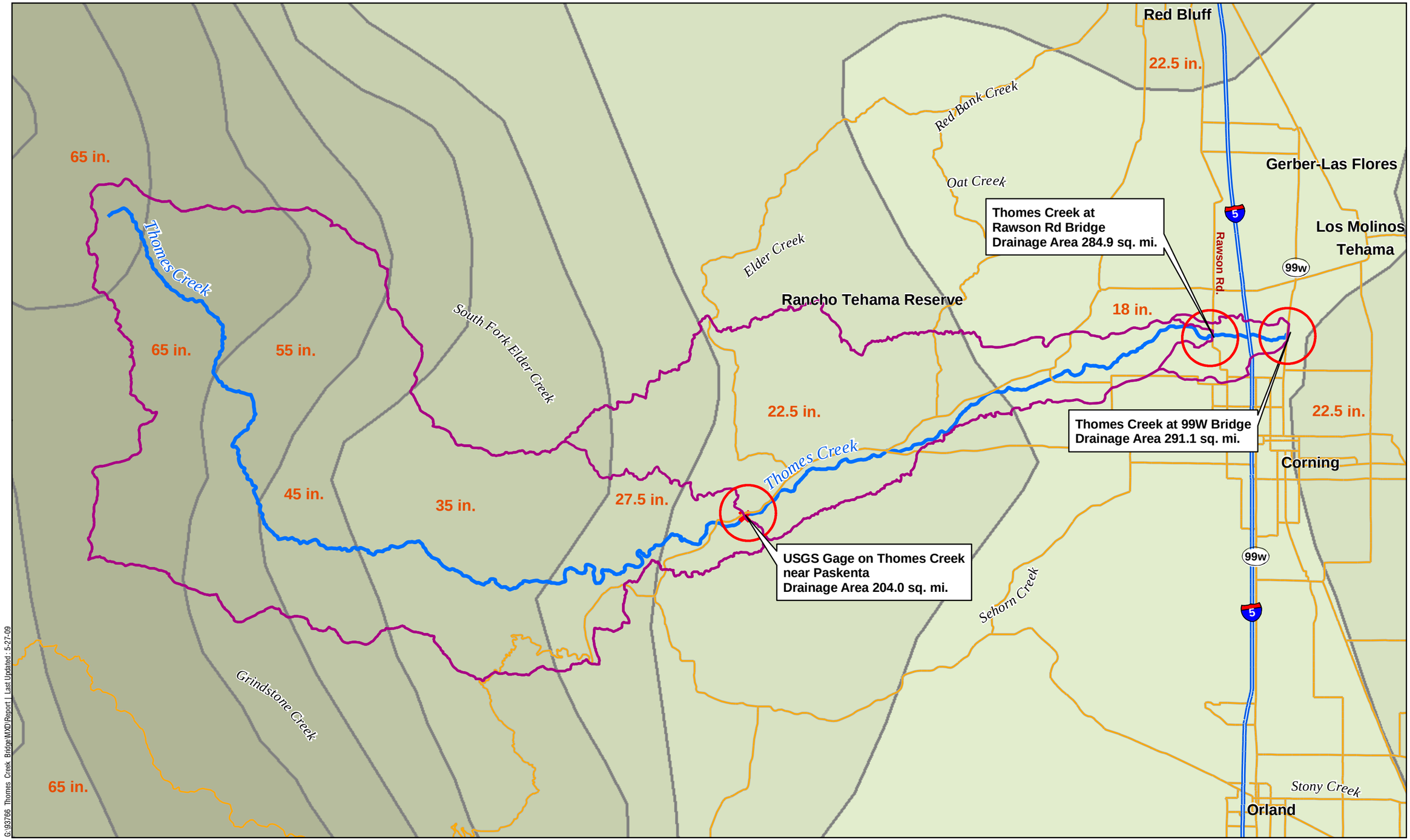
THOMES CREEK WATERSHED, TEHAMA COUNTY
BASIN DELINEATIONS

Figure 2



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THOMES CREEK WATERSHED, TEHAMA COUNTY
RANTZ RAINFALL MAP

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Figure 3

Table 4 lists the computed basin areas and the estimated precipitation and altitude index values developed by HDR.

Table 4. Precipitation and Altitude Index Values

Basin Description	Basin Area (sq. mi.)	Ave. Annual Precipitation (in)	Elevation Index (ft/1000)
Thomes Creek near Paskenta	204.0	47.3	2.50
Thomes Creek at Rawson Road	284.9	40.3	1.93
Thomes Creek at 99W	291.1	39.9	1.85

3.2.3 Results

Table 5 summarizes the regional regression equation peak flow results for the three Thomes Creek basins. Regional regression equations are not available for estimating 500-year flows; therefore the results were obtained from extrapolation on a flood frequency plot (See Figures 4 and 5).

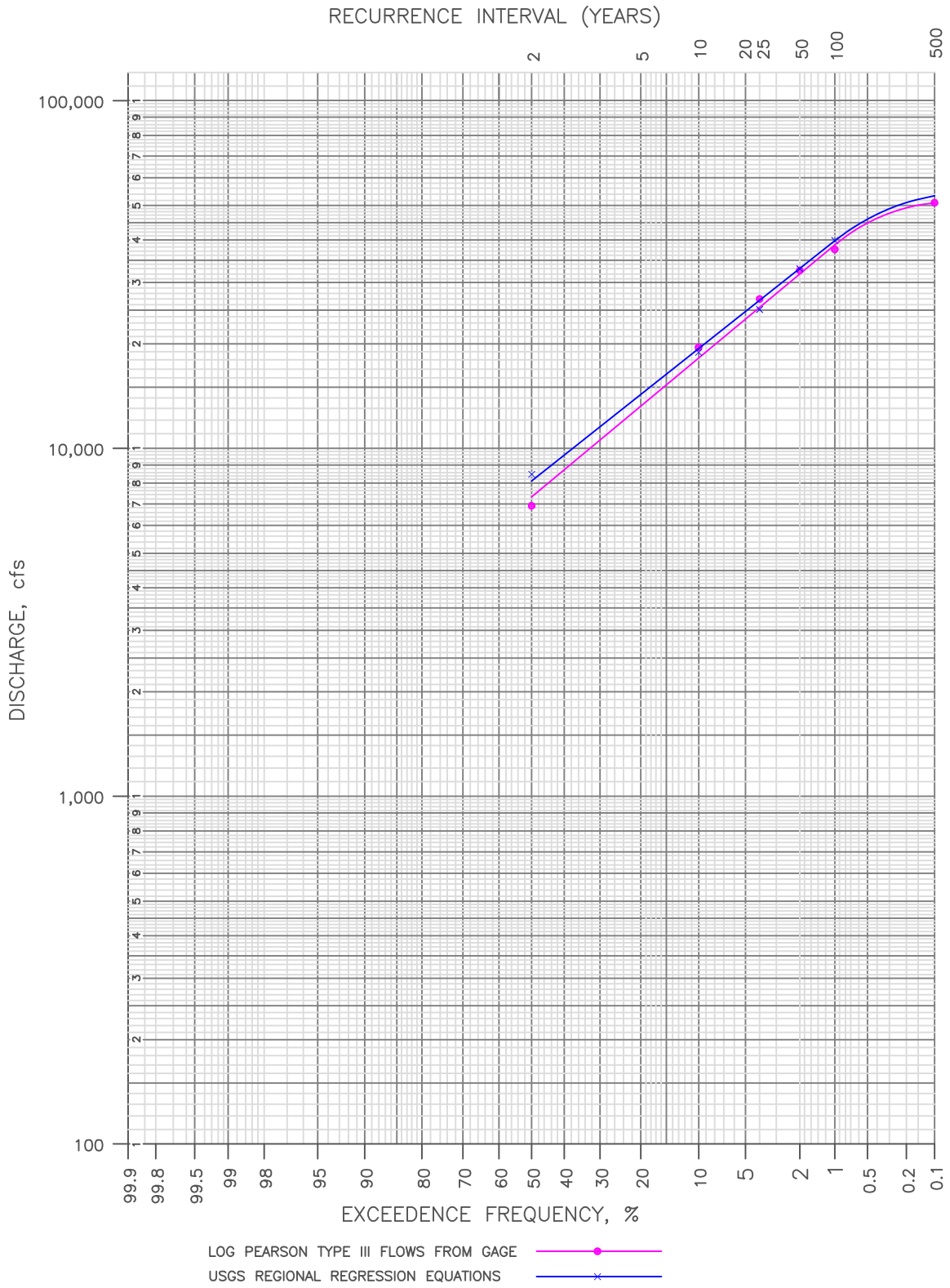
Table 5. USGS Regional Regression Peak Flow Results

Recurrence Interval	Peak Flow (cfs)		
	Thomes Creek Gage Location near Paskenta (Basin Area 204.0 sq.mi.)	Thomes Creek at Rawson Rd. (Basin Area 284.9 sq.mi.)	Thomes Creek at 99W (Basin Area 291.1 sq.mi.)
2-year	8,500	11,200	11,600
5-year	13,900	17,700	18,100
10-year	18,900	23,400	23,900
25-year	25,100	30,200	30,600
50-year	33,000	38,600	39,100
100-year	39,700	45,500	45,900
500-year	----------	----------	----------

3.3 Log-Pearson Type III Analysis

3.3.1 General

HDR utilized the HEC-SSP flood frequency program version 1.0 to estimate the 2-, 5-, 10-, 25-, 50-, 100- and 500-year peak flows for the gage location near Paskenta. Annual peak flow data for the recorded years 1920 - 2008 obtained from the USGS website and the flood-frequency relationship obtained as output from the program are presented in Appendix A. The results present the Weibull plotting positions, the computed Log Pearson III frequency curve, an expected probability frequency curve, and the 5% and 95% confidence limit curves.

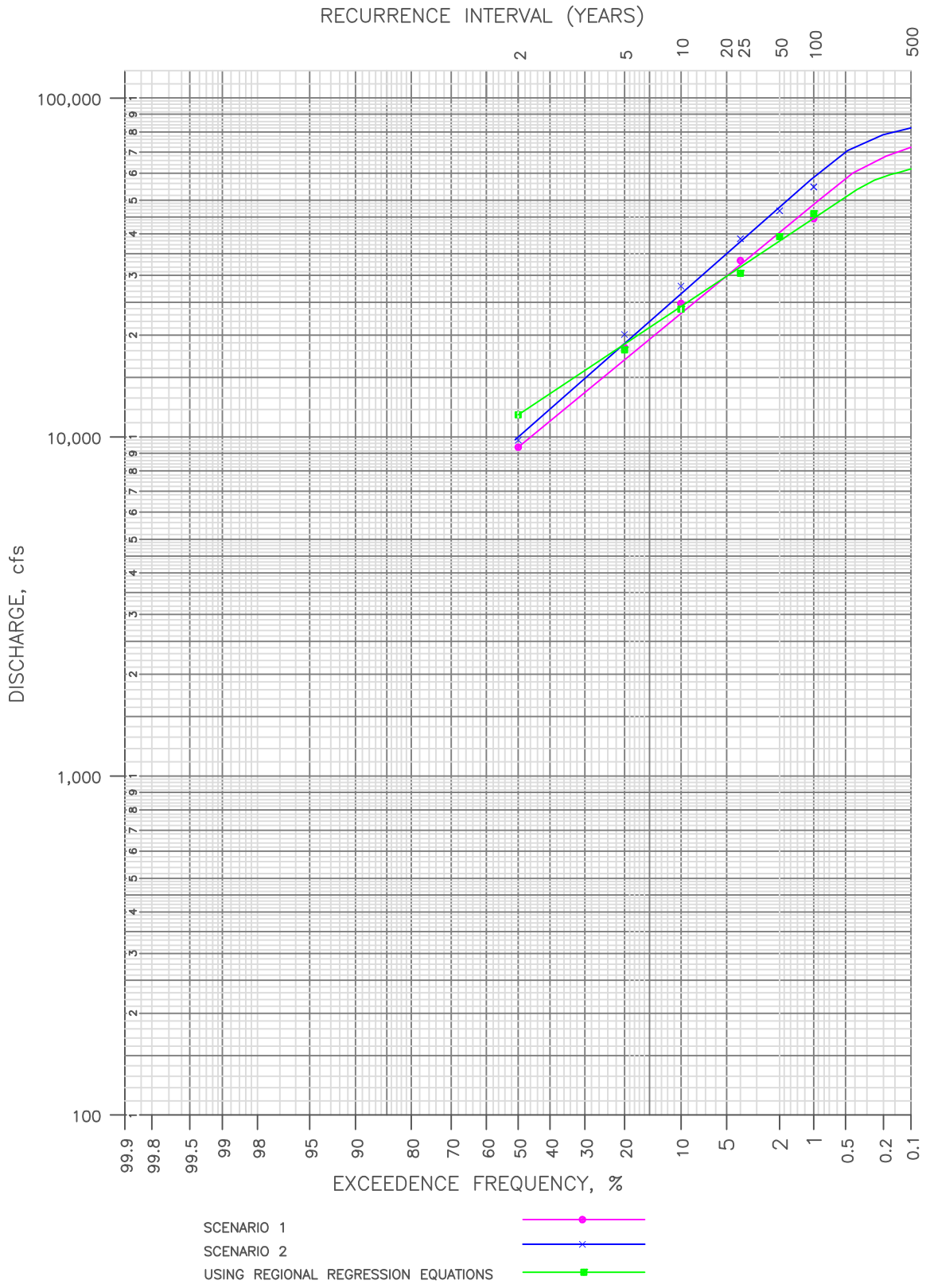


HDR Engineering, Inc.

FLOOD FREQUENCY PLOTS
THOMES CREEK AT USGS GAGE NEAR PASKENTA
TEHAMA COUNTY, CA
BASIN AREA = 204.0 SQUARE MILES

Date 06/09

Figure 4



HDR Engineering, Inc.

FLOOD FREQUENCY PLOTS

THOMES CREEK AT 99W BRIDGE, TEHAMA COUNTY, CA

BASIN AREA = 291.1 SQUARE MILES

Date 06/09

Figure 5

Peak flow results from the gage located near Paskenta were used to prorate and obtain peak flows for the hydraulic analysis for the 99W Bridge site. Scenario1 followed the 2003Design Hydraulic Study to adjust the peak flows based on the area, precipitation and altitude index exponents from the North Coast USGS Regression Equation. Scenario 2 followed the USGS Scientific Investigations Report 2004–5068 entitled "Evaluation of Methods Used for Estimating Selected Streamflow Statistics, and Flood Frequency and Magnitude, for Small Basins in North Coastal California" to adjust the peak flows using the ratio of basin areas. Table 6 provides the two scenarios. The 500-year peak flow values were obtained by extrapolation on a flood frequency plot (see Figure 5).

Table 6. Adjustments to Peak Flows from the Gage on Thomes Creek near Paskenta

Recurrence Interval	Scenario 1: Regression Equation Ratios	Scenario 2: Area Ratios
2-year	$(Q_1/Q_2)=(A_1/A_2)^{0.9}\,(p_1/p_2)^{0.89}(H_1/H_2)^{-0.47}$	$Q_1/Q_2 = A_1/A_2$
5-year	$(Q_1/Q_2)=(A_1/A_2)^{0.89}(p_1/p_2)^{0.91}(H_1/H_2)^{-0.35}$	$Q_1/Q_2 = A_1/A_2$
10-year	$(Q_1/Q_2)=(A_1/A_2)^{0.88}(p_1/p_2)^{0.93}(H_1/H_2)^{-0.27}$	$Q_1/Q_2 = A_1/A_2$
25-year	$(Q_1/Q_2)=(A_1/A_2)^{0.87}(p_1/p_2)^{0.94}(H_1/H_2)^{-0.17}$	$Q_1/Q_2 = A_1/A_2$
50-year	$(Q_1/Q_2)=(A_1/A_2)^{0.87}(p_1/p_2)^{0.96}(H_1/H_2)^{-0.08}$	$Q_1/Q_2 = A_1/A_2$
100-year	$(Q_1/Q_2)=(A_1/A_2)^{0.87}(p_1/p_2)^{0.97}$	$Q_1/Q_2 = A_1/A_2$
500-year	----------	----------

Q – Peak flow in cubic feet per second; A – Basin area in square miles; p – Mean annual precipitation in inches
H – Altitude index of the basin in thousands of feet; Subscripts 1 and 2 refer to the gaged and ungaged basins respectively

3.3.2 Results

Table 7 compares the peak flow results from the Log Pearson III analysis and the Regional Regression equations at the Paskenta gage location. The results indicate that the two sets of peak flows compare reasonably, thus justifying the use of the USGS Regression equation for flow adjustments.

Table 7. Paskenta Peak Flow Values Comparison

Return Period	Log Pearson III Peak Flows (cfs)	Regional Regression Peak Flows (cfs)	Percent Difference (%)
Thomes Creek at Paskenta (USGS Gage 11107745) (Basin Area 204.0 acres)			
2-Year	6,900	8,500	18.8
10-Year	19,600	18,900	3.6
25-Year	27,000	25,100	7.0
50-Year	32,700	33,000	0.9
100-Year	38,400	39,700	3.3
500-Year	51,500	----------	----------

3.3.3 Recommended Peak Flows

Table 8 shows the peak flow results for the 99W basin obtained from Regional Regression and prorated flows under Scenarios 1 and 2. The peak flows from Scenario 1 are closer to those estimated by the Regional Regression Equations and are recommended to be used for hydraulic analysis at the project location.

Table 8. Comparison of Estimated Peak Flows for the Thomes Creek Basin at 99W (Basin Area 291.1 sq. mi.)

Recurrence Interval	Regional Regression Peak Flows (cfs)	Scenario 1: LPIII Adjusted Peak Flows (cfs)	Percent Difference (%)	Scenario 2: LPIII Adjusted Peak Flows (cfs)	Percent Difference (%)
2-year	11,600	9,400	-19.0	9,800	-15.5
5-year	18,100	18,400	1.7	20,100	11.0
10-year	23,900	24,800	3.8	28,000	17.2
25-year	30,600	33,000	7.8	38,500	25.8
50-year	39,100	38,800	-0.8	46,700	19.4
100-year	45,900	44,400	-3.3	54,800	19.4
500-year	----------	72,000	----------	82,000	----------

Note: The Regional Regression Equations were developed in the 1970s and are subject to revision. Flows for Scenario 2 are closer to the peak flows used in the 2003 Design Hydraulic Study, and are more conservative. Hydraulic analysis for the 99 Replacement Bridge will be based on both Scenario 1 and Scenario 2 peak flow values. The water surface elevation and scour conditions calculations using Scenario 1 peak flows will be compared to those calculated from Scenario 2 peak flows.

4.0 Hydraulic Model Development

A steady-flow model was developed to simulate the existing conditions at the 99W Replacement Bridge site using the HEC-RAS 4.1 dated January 2010. Simulations were performed for the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year return periods. Hydraulic analysis results for existing conditions were used for the scour analysis.

4.1 Stream Channel Geometry Development

Information used for the hydraulic modeling was derived using the US Army Corps of Engineers HEC-GeoRAS 3.1 program in combination with ArcMap 9.2.

In general, HEC-RAS geometry is calculated using four sets of Geographic Information System (GIS) data layers: 1) stream centerline, 2) cross-section cut lines, 3) lines representing left and right banks, and 4) flow paths for each stream reach.

Topographic field survey data for the 99W Bridge Replacement Project area was provided by SDS Engineering. The field survey contained data for several cross-sections, including:

1. The existing 99W Bridge;
2. The adjacent railroad bridge; and
3. At respective locations upstream and downstream of each bridges perpendicular to the flow direction.

The stream centerline (thalweg of the channel) and cross-sections were digitized using a Triangulated Irregular Network (TIN) surface developed using one-foot contours and supplemented with the survey points. The TIN information was supplemented with the surveyed cross sections for hydraulic model development.

4.2 Bridge Modeling

4.2.1 99W Bridge

The geometric configuration of the existing 99W Bridge at Thomes Creek was determined using as-built drawings and point data obtained during the SDS Engineering field survey, which included point data for:

- The high and low chords of the bridge deck, including the soffit elevation of every arch.
- Elevations for several pier components, including around the base, top of the base and top of the piers.

The dimensions of the bridge were verified using as-built drawings (See Appendix C). A skew angle of 20 degrees was used to make adjustments to the bridge dimensions to define an equivalent cross section perpendicular to the direction of stream flow. No adjustment was made to increase the pier widths.

4.2.2 Railroad Bridge

The railroad bridge is located approximately 50 feet downstream of the 99W Bridge. The dimensions and spacing of the footings and the elevations of high chord of the bridge deck were all determined through the survey. The low chord elevations of the bridge deck were not established in the field survey; they were estimated from photographs taken during site visits. A skew angle of 20 degrees was used to make adjustments to the bridge dimensions to define an equivalent cross section perpendicular to the direction of stream flow. No adjustment was made to increase the pier widths.

4.2.3 Methodology

The procedures outlined in the HEC-RAS User's Manual and the Hydraulic Reference Manual for bridge and culvert modeling were followed to develop the hydraulic model. Modeling of hydraulic characteristics of the bridges used four user-defined cross-sections for computation of energy losses due to the structures. Cross section 1 is located sufficiently downstream from the structure so that flow is not affected by the structure. Cross section 2 is located immediately downstream from the structure. Cross section 3 is located just upstream from the structure. Cross section 4 is located sufficiently upstream so that the structure has no effect on flow. Additional cross-sections may be included, as deemed appropriate, between cross sections 1 and 2, and/or 3 and 4 to better define flow expansion and contraction transition zones.

HEC-RAS allows the use of several bridge loss methods (Energy, Momentum Balance, and Yarnell equations). If all the methods are selected, the model will evaluate each one and default to the one that computes the greatest energy loss through the bridge as the final solution. The Energy and Momentum methods are the most applicable to the widest range of bridges and flow situations. They provide the best results in situations where bridge piers are small obstructions to flow and friction losses are the predominate consideration. The Yarnell equation is an empirical formula and is more specific in its use. It is only applicable to sub-critical flow and in locations where bridge piers are the dominant contributor to energy losses and change in water surface. When neither the Momentum nor Yarnell equations can be solved, HEC-RAS defaults to the Energy equation.

The methods used for the bridge modeling are based on the flow conditions at the structures. The flows at the two existing bridge crossings were below the low chord of the bridge at the bridge openings. The bridge parameters used in the HEC-RAS model are summarized in Table 9.

Table 9. HEC-RAS Modeling Parameters for the Thomes Creek Bridges

Bridge Crossing	HEC-RAS River Station (ft)	Bridge Length (ft)	Bridge Width (ft)	Number of Piers	Low Chord Elevation (ft)
99W Bridge (Existing)	3425.5	530	31	8	272.2 (top of arch)
Railroad Bridge (Existing)	3325	600	23	14	269.4
Bridge (Proposed)	3424	605	42.83	4	267.7

4.3 Boundary Conditions

Boundary conditions are used in HEC-RAS to establish upstream and downstream water surface elevations for the river system. For this project, a steady flow analysis was done as the channel bed is relatively flat at the project location. A mixed flow regime, representing a combination of subcritical and supercritical flow conditions, was assumed.

HEC-RAS requires both upstream and downstream boundary conditions for mixed flow calculations. Critical depth was used as the upstream boundary condition and a normal depth with a slope of 0.005 feet/feet was used as the downstream boundary condition. The downstream boundary condition was determined by examining the channel slope obtained from the field survey. In general, the channel slope, so long as it is sufficiently downstream of the area in question, can be used as an estimate of the energy grade line slope. Once the slope of the energy grade line is established, Manning's equation is used by HEC-RAS to calculate the normal depth.

4.4 Losses

Manning's "n" Coefficients: The United States Geological Survey Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains (1989) was used to generate Manning's *n* values for the Thomes Creek site. Page 2 of the guide states:

"The most important factors that affect the selection of channel n-values are (1) the type and size of the materials that compose the bed and banks of the channel and (2) the shape of the channel. Cowan (1956) developed a procedure for estimating the effects of these factors to determine the value of n for a channel. The value of n may be computed by:

$$n = (n_b+n_1+n_2+n_3+n_4)m$$

where:

n_b = a base value of n for a straight, uniform, smooth channel in natural materials,

n_1 = a correction factor for the effect of surface irregularities,

n_2 = a value for variations in shape and size of the channel cross-section,

n_3 = a value for obstructions,

n_4= a value for vegetation and flow conditions, and

m = a correction factor for meandering of the channel.

Base n Values (n_b) for Channels: In determining the base n value (n_b) for the channel surface, the channel must be classified as either a stable channel or a sand channel. A stable channel is defined as a channel in which the bed is composed of firm soil, gravel, cobbles, boulders, or bedrock and the channel remains relatively unchanged throughout most of the range in flow. A sand channel is defined as a channel in which the bed has an unlimited supply of sand.

Irregularity (n_1): Where the ratio of width to depth is small, roughness caused by eroded and scalloped banks, projecting points, and exposed tree roots along the banks must be accounted for using the surface irregularity factor, n_1. The degree of surface irregularity is rated from smooth to severe.

Variation in Channel Cross Section (n_2): The value of n is not affected significantly by relatively large changes in the shape and size of cross-sections (n_2) if the changes are gradual and uniform. Greater roughness is associated with alternating large and small cross-sections and sharp bends, constrictions, and side-to-side shifting of the low-water channel. The degree of the effect of changes in the size of the channel depends primarily on the number of alterations of large and small sections and secondarily on the magnitude of the changes.

Obstructions (n_3): Obstructions such as logs, stumps, boulders, debris, pilings, and bridge piers disturb the flow pattern in the channel and increase roughness. The amount of increase depends on the shape of the obstruction; the size of the obstruction in relation to that of the cross-section; and the number, arrangement, and spacing of obstructions.

Vegetation (n_4): The extent to which vegetation affects n depends on the depth of flow, the percentage of the wetted perimeter covered by the vegetation, the density of vegetation below the high-water line, the degree to which the vegetation is flattened by high water, and the alignment of vegetation relative to the flow.

Meandering (m): The degree of meandering, m depends on the ratio of the total length of the meandering channel in the reach being considered to the straight length of the channel reach.

For this study, Manning's *n* values were computed based on observations made in the field during site visits (See Appendix D). The overbanks at the 99W Bridge site contain large amounts of gravel, while the main channel is composed of sand. Table 10 summarizes the calculated Manning's *n* values for the channel and left and right overbanks for the study reach.

Table 10. Summary of Estimated Manning's n Values for Thomes Creek Channel and Overbanks

Reach	Left Overbank n	Channel n	Right Overbank n
Thomes Creek - Entire Reach	0.055	0.03	0.055

Contraction/Expansion Coefficients: Contraction and expansion coefficients are used to reflect changes in flow due to energy loss within a reach between two cross-sections. Changes in cross sections are typically gradual for unconstructed stream reaches (i.e., stream reaches with no

bridges or culverts). Higher contraction and expansion coefficients are used at locations with abrupt changes in the channel configuration and at bridge locations.

For unconstricted reaches in the Thomes Creek model, contraction and expansion loss coefficients of 0.1 and 0.3 respectively were used. For the existing 99W Bridge and the railroad bridge, contraction and expansion loss coefficients of 0.3 and 0.5 were used to represent the transition of the channel through the bridge opening.

4.4.1 Ineffective Flow Locations

For upstream and downstream bridge cross sections, ineffective flow areas at the interior of the abutments were used to account for pooling of water immediately upstream and downstream of the bridge structures. It is recommended that ineffective flow areas be modeled to project upstream at a taper of 45 degrees (1:1) and downstream at approximately 14 degrees (4:1) from the interior of the abutments to account for the pooling of water. However, in the case of the existing bridge structures, the width of the bridge opening is approximately equal to the width of the channel and, hence, only minimal ineffective flow areas were assigned to the upstream and downstream cross sections. Ineffective flow areas were also used to eliminate conveyance through low-lying portions of the cross-section that exist outside of the main channel.

HEC-RAS evaluates each cross-section individually; therefore, the program assumes that the lowest points in that cross-section will convey flow. In order to account for this, the user must establish secondary channels as ineffective flow areas, because they do not contribute to the system's conveyance. However, these areas will become effective once the water surface elevation rises above the highest point separating them (i.e. the two channels are connected through an abnormally large flow area).

4.4.2 Verify Model Reasonableness

There are no stream stage gages or high water mark locations available within the study limits. Information from stream stage gages would have allowed for the developed models to be calibrated to specific events.

5.0 Modeling Results

5.1 Existing 99W Bridge

The modeling indicates that the channel maintains a fairly constant hydraulic depth throughout the study area; the water surface profiles are roughly parallel to the channel bed profile. This means that the obstructions presented by the bridges do not cause a significant increase in water surface elevations upstream of the bridge crossings. Consequently, there is no dramatic increase in velocities downstream of the bridges.

Tables 11 and 12 present the results from the modeling at the bridge location for the 2-, 5-, 10-, 25-, 50-, 100- and 500-year storm events for Scenarios 1 and 2 respectively. Based on these results, it can be concluded that water surface elevations for both modeled scenarios are not significantly different from each other. Sufficient freeboard is available at the existing 99W Bridge for all the storm events modeled. Freeboard has been measured from the low chord (soffit) elevation (top of the arch) of 272.2 ft.

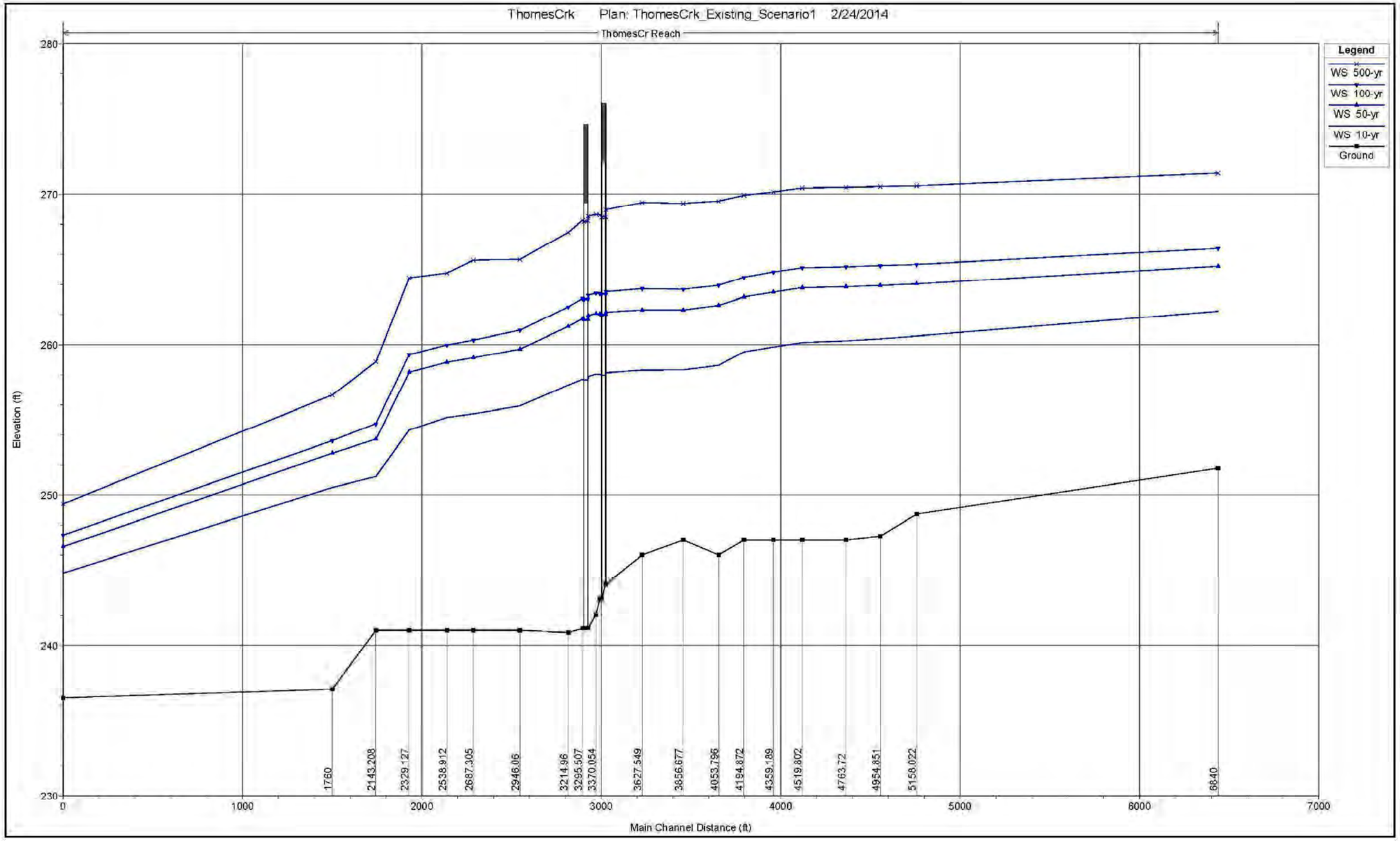
Table 11. Summary of Results at the Existing 99W Bridge on Thomes Creek for Scenario 1

Recurrence Interval	Estimated Peak Flows (cfs)	WSE (ft)	US Velocity (ft/s)	Freeboard (ft)
2-year	9,400	252.01	5.23	20.19
5-year	18,400	255.92	5.52	16.28
10-year	24,800	258.12	5.80	14.08
25-year	33,000	260.57	6.15	11.63
50-year	38,800	262.15	6.37	10.05
100-year	44,400	263.51	6.60	8.69
500-year	72,000	268.96	7.73	3.24

Table 12. Summary of Results at the Existing 99W Bridge on Thomes Creek for Scenario 2

Recurrence Interval	Estimated Peak Flows (cfs)	WSE (ft)	US Velocity (ft/s)	Freeboard (ft)
2-year	9,800	252.21	5.24	19.99
5-year	20,100	256.54	5.59	15.66
10-year	28,000	259.11	5.95	13.09
25-year	38,500	262.07	6.35	10.13
50-year	46,700	264.03	6.69	8.17
100-year	54,800	265.72	7.05	6.48
500-year	82,000	270.74	7.96	1.46

Figure 6 shows the 10-, 50-, 100- and 500-year water surface profiles estimated for existing conditions for Scenario 1. The 100- and 500-year floodplains for Scenario 1 are presented in Figure 7. The corresponding summary output tables from HEC-RAS are included in Appendix E.



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THOMES CREEK WATERSHED, TEHAMA COUNTY
WATER SURFACE PROFILES: SCENARIO 1

HDR
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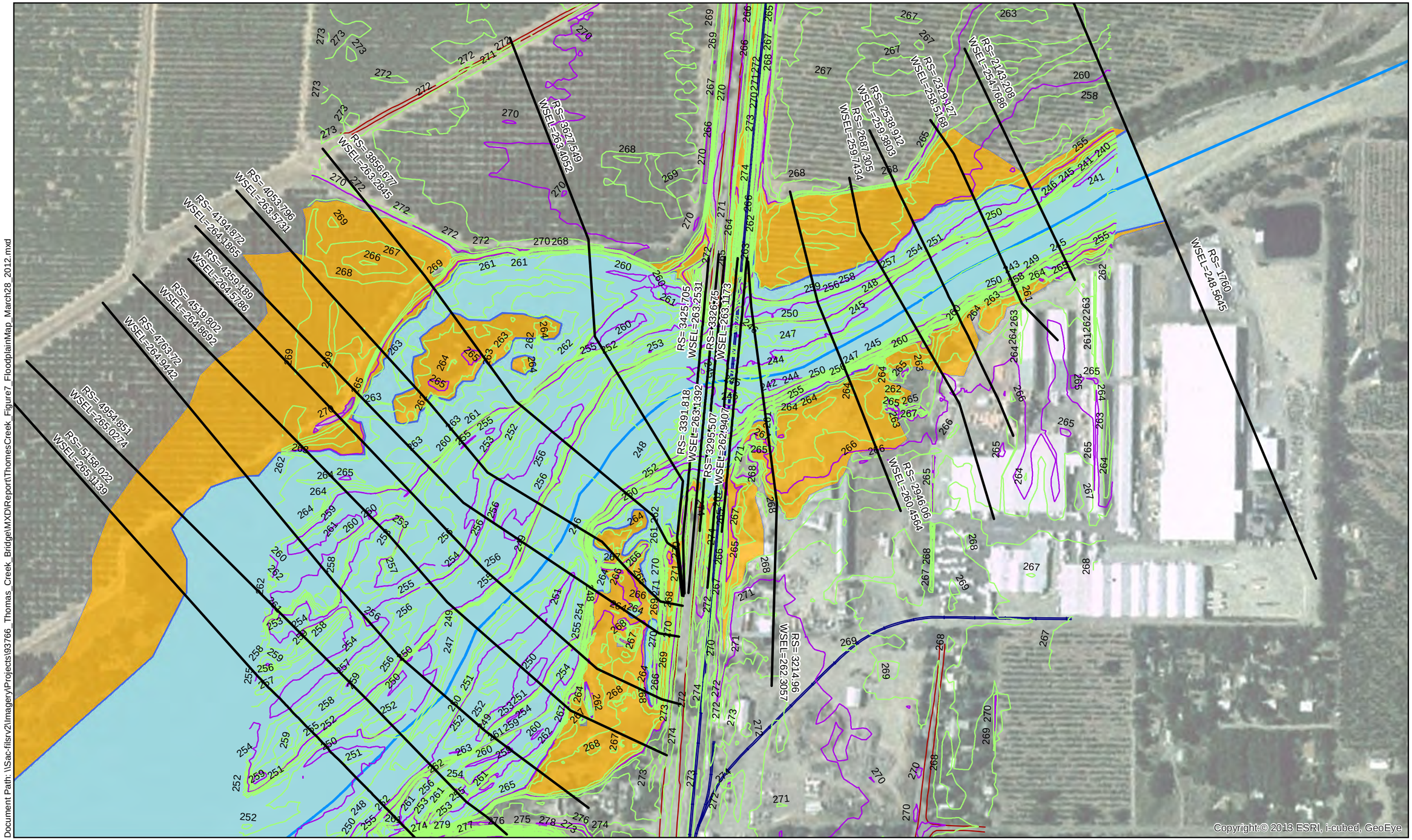
Note: Vertical Datum - NAVD 1988

Figure 6



N

0 300 600 Feet

Cross Sections
Stream Centerline
100-Year Floodplains
500-Year Floodplains

HDR
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THOMES CREEK WATERSHED, TEHAMA COUNTY
FLOODPLAINS: EXISTING CONDITIONS (SCENARIO 1)

Figure 7

5.2 Bridge Replacement

Tables 13 and 14 present the results from the modeling at the bridge replacement location for the 2-, 5-, 10-, 25-, 50-, 100- and 500-year storm events for Scenarios 1 and 2 respectively. Both scenarios provide more than 2.0 feet of freeboard for the 100-year event. Freeboard has been measured from the low chord (soffit) elevation of 267.73 ft. Results for the 500-year storm event do show surcharging of the bridge deck due to a lower soffit elevation than the existing bridge.

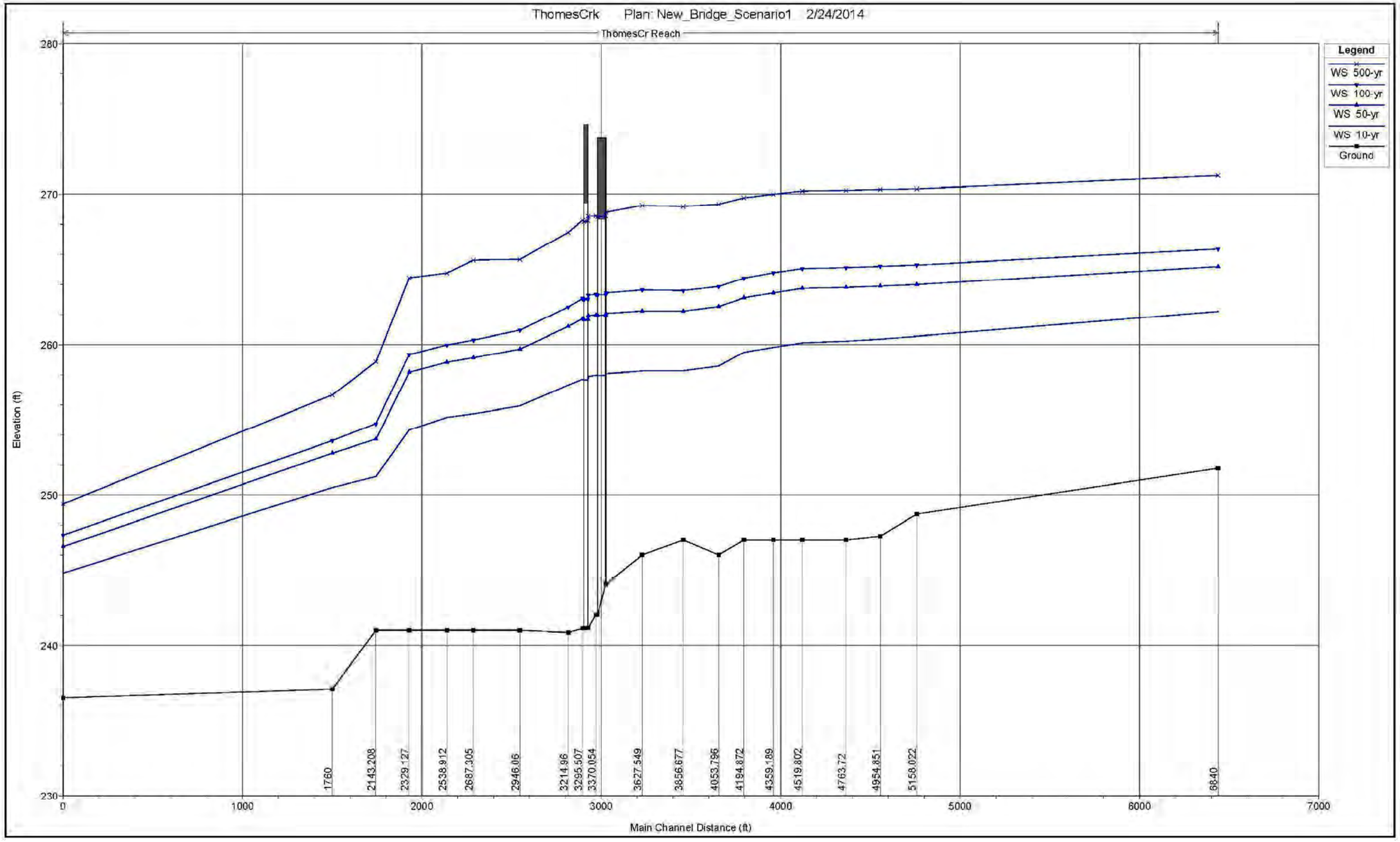
Table 13. Summary of Results at the Proposed 99W Bridge on Thomes Creek for Scenario 1

Recurrence Interval	Estimated Peak Flows (cfs)	WSE (ft)	US Velocity (ft/s)	Freeboard (ft)
2-year	9,400	251.97	5.26	15.76
5-year	18,400	255.87	5.55	11.86
10-year	24,800	258.06	5.84	9.67
25-year	33,000	260.50	6.19	7.23
50-year	38,800	262.08	6.42	5.65
100-year	44,400	263.42	6.65	4.31
500-year	72,000	268.78	7.75	Surcharging bridge deck (-1.05)

Table 14. Summary of Results at the Proposed 99W Bridge on Thomes Creek for Scenario 2

Recurrence Interval	Estimated Peak Flows (cfs)	WSE (ft)	US Velocity (ft/s)	Freeboard (ft)
2-year	9,800	252.17	5.28	15.56
5-year	20,100	256.48	5.63	11.25
10-year	28,000	259.05	5.98	8.68
25-year	38,500	262.00	6.41	5.73
50-year	46,700	263.94	6.75	3.79
100-year	54,800	265.58	7.11	2.15
500-year	82,000	270.53	8.07	Surcharging bridge deck (-2.80)

Figure 8 shows the 10-, 50-, 100- and 500-year water surface profiles estimated for proposed conditions for Scenario 1. The corresponding summary output tables from HEC-RAS are included in Appendix E.



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THOMES CREEK WATERSHED, TEHAMA COUNTY
WATER SURFACE PROFILES: SCENARIO 1

HDR
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Note: Vertical Datum - NAVD 1988

Figure 8

6.0 Scour Analysis

6.1 General

Scour analysis at bridges is performed using the methodology described in the Hydraulic Engineering Circular No. 18 (HEC-18), Evaluating Scour at Bridges, issued by the Federal Highway Administration (2001). The minimum design standard for bridge scour is the base flood (100-year flood).

The most common cause of bridge failure is from floods scouring the bed material around the bridge foundations. Scour is the result of the erosive action of flowing water, excavating and carrying away material from the bed and banks of streams, and from around the piers and abutments of bridges. Different materials scour at different rates. Loose granular soils are rapidly eroded by flowing water, while cohesive or cemented soils are more scour-resistant. However, ultimate scour in cohesive or cemented soils can be as deep as scour in sand-bed streams. Under constant flow conditions, scour will reach maximum depth in sand- and gravel-bed material in hours; cohesive bed material in days; glacial till, sandstones, and shale in months; limestone in years; and dense granite in centuries. Under flow conditions typical of actual bridge crossings, several floods may be needed to attain maximum scour. Determining the magnitude of scour is complicated by the cyclic nature of the scour process. Scour can be deepest near the peak of a flood, but hardly visible as floodwaters recede and scour holes refill with sediment.

6.2 Scour Analysis Methodology

According to the Preliminary Foundation Report prepared by Blackburn Consulting Inc. in February 2009 for the 99W Bridge site on Thomes Creek, a 1950 log of test borings available for this area from CALTRANS shows the presence of waxy yellow clay below coarse bedload deposits. The clay is now exposed on the channel at the bridge and downstream of it, with a veneer of gravelly bedload. Boring tests were performed at different depths by Blackburn Consulting Inc. in October 2009 at two locations within the channel at the bridge site. Grain size distribution analyses provided four sets of D50 and D95 values, which were used in the scour computations. Table 15 lists the D50 and D95 values and corresponding bore depths.

A scour analysis was done in HEC-RAS 4.1 using the hydraulic model developed for the proposed 99W Bridge on Thomes Creek based on the recommended peak flows (Scenario 1). Flow distribution was set for cross sections at the vicinity of the bridges by assigning a subsection distribution of 5 and 20 for overbanks and main channel respectively. HEC-RAS uses this information to get more detailed estimates of the depth and velocity at various locations within the cross-sections.

Table 15. D50 and D95 Values at the Existing Thomes Creek Bridge at 99W

Sample Number	Depth	D50 (mm)	D95 (mm)
B1-2	10.0-11.5”	2.86	16
B1-3	15.0’-16.5’	1.86	16.5
B1-5	25.0’-26.5’	0.075	0.38
B2-1	10.0’-11.5’	2.32	17

6.3 Long-term Aggradation and Degradation

Aggradation and degradation are long-term streambed elevation changes due to natural or anthropogenic forces that can affect the reach of the river where the structure is located. Aggradation involves a general and progressive buildup of the longitudinal profile of a channel bed due to sediment deposition. Degradation involves a general and progressive lowering of the channel bed due to erosion. Based on the 2009 Preliminary Foundation Report from Blackburn Consulting for the project location, the existing channel has experienced scour depths of approximately 15-20 feet since the construction of the bridge in 1920.

6.4 Contraction Scour

Contraction scour occurs when the flow of a stream is reduced significantly, either by natural contraction or by a bridge constricting the flow. There are two forms of contraction scour: live bed and clear water. Live-bed contraction occurs at a constriction in river channel when there is transport of bed material in the upstream reach into the constricted cross section. With live-bed contraction scour, the area of the contracted section increases until, in the limit, the transport of sediment out of the contracted section equals the sediment transported in. Clear water scour occurs when there is no movement of the bed material in the flow upstream of the crossing or the bed material being transported in the upstream reach is transported in suspension through the scour hole at the pier or abutment at less than the capacity of the flow.

The HEC-RAS program gives the user the option to choose from one of these forms of contraction or the default option where the program automatically determines the form of contraction based on the critical velocities and mean flow velocities in the channel and overbanks. To compute contraction scour, the user is only required to enter the D50 and a water temperature to compute the K1 factor. All the variables except D50 and K1 are obtained automatically from the HEC-RAS output file.

For this analysis, the default contraction scour method was chosen and water temperature was assumed to be 60 degrees Fahrenheit. Table 16 summarizes the contraction scour computation results for the four D50 values based on the hydraulic modeling results for the 100- and 500-year peak flows. The results show no contraction scour for the 500-year peak flow.

Table 16. Summary of Long Term Degradation and Contraction Scour at the Proposed Thomes Creek Bridge at 99W

Parameters	100-yr Peak Flow			500-yr Peak Flow		
	Left Overbank	Channel	Right Overbank	Left Overbank	Channel	Right Overbank
Long-term Bed Elevations Change (ft)	15-20	15-20	15-20	15-20	15-20	15-20
Contraction Scour for D50 = 2.86						
Scour Depth Ys (ft)	0.00	0.11	0.00	-	-	-
Critical Velocity (ft/s)	2.93	3.60	1.90	-	-	-
Equation	Clear	Live	Clear	-	-	-
Contraction Scour for D50 = 1.86						
Scour Depth Ys (ft)	0.43	0.11	0.00	-	-	-
Critical Velocity (ft/s)	2.54	3.12	1.64	-	-	-
Equation	Clear	Live	Clear	-	-	-
Contraction Scour for D50 = 0.075						
Scour Depth Ys (ft)	0.97	0.26	0.29	-	-	-
Critical Velocity (ft/s)	0.87	1.07	0.56	-	-	-
Equation	Live	Live	Clear	-	-	-
Contraction Scour for D50 = 2.32						
Scour Depth Ys (ft)	0.00	0.11	0.00	-	-	-
Critical Velocity (ft/s)	2.73	3.36	1.77	-	-	-
Equation	Clear	Live	Clear	-	-	-

6.5 Local Scour

Local scour consists of pier and abutment scour. Scour occurs at abutments and piers where the flow is obstructed. A horizontal vortex called the horseshoe vortex forms at the base of the obstruction, running along the obstruction, resulting in a vertical vortex called the wake vortex downstream of the obstruction. Both the horseshoe and wake vortices remove material from the base region of the obstruction

Pier scour can be computed using either the Colorado State University (CSU) equation or the Froehlich equation. The CSU equation is the default. In the case of the CSU equation, the user is required to enter the pier nose shape (K1), the angle of attack for flow hitting the piers, the condition of the bed (K3) and a D95 size fraction for the bed material. All other values are automatically obtained from the HEC-RAS output file. In the case of the Froehlich equation, the user is required to enter the projected pier width with respect to the direction of flow (a) and a correction factor for pier nose shape (Phi), which is automatically set when a pier nose shape is selected. For this analysis, the Froehlich equation was used. The pier nose shape was set to 'Circular Cylinder' and a projected pier width of 7 feet was used. Table 17 summarizes the pier

scour computation results for the four D50 values based on the hydraulic modeling results for the 100- and 500-year peak flows.

Table 17.Summary of Pier Scour at the Proposed Thomes Creek Bridge at 99W

Parameters	Piers			
	#1	#2	#3	#4
For D50 = 2.86 mm, 100-year Peak Flow				
Scour Depth Ys (ft)	12.00	12.00	12.00	12.00
Equation	Froehlich	Froehlich	Froehlich	Froehlich
For D50 = 2.86 mm, 500-year Peak Flow				
Scour Depth Ys (ft)	12.64	12.64	12.64	12.64
Equation	Froehlich	Froehlich	Froehlich	Froehlich
For D50 = 1.86 mm, 100-year Peak Flow				
Scour Depth Ys (ft)	12.20	12.20	12.20	12.20
Equation	Froehlich	Froehlich	Froehlich	Froehlich
For D50 = 1.86 mm, 500-year Peak Flow				
Scour Depth Ys (ft)	12.86	12.86	12.86	12.86
Equation	Froehlich	Froehlich	Froehlich	Froehlich
For D50 = 0.075 mm, 100-year Peak Flow				
Scour Depth Ys (ft)	13.94	13.94	13.94	13.94
Equation	Froehlich	Froehlich	Froehlich	Froehlich
For D50 = 0.075 mm, 500-year Peak Flow				
Scour Depth Ys (ft)	14.82	14.82	14.82	14.82
Equation	Froehlich	Froehlich	Froehlich	Froehlich
For D50 = 2.32 mm, 100-year Peak Flow				
Scour Depth Ys (ft)	12.10	12.10	12.10	12.10
Equation	Froehlich	Froehlich	Froehlich	Froehlich
For D50 = 2.32 mm, 500-year Peak Flow				
Scour Depth Ys (ft)	12.74	12.74	12.74	12.74
Equation	Froehlich	Froehlich	Froehlich	Froehlich

It can be seen from Table 17 that lower D50 values result in greater values of pier scour. In this analysis, the lowest value of D50 is 0.075 mm which gives scour values of 13.94 feet and 14.82 feet for the 100- and 500-year peak flows respectively.

Abutment scour can be computed using either the HIRE equation or Froehlich's equation. The use is required to enter the abutment type and skew angles. The program automatically selects values for all of the other variables based on the hydraulic output. The user can select one of the two equations or the default mode. When the default mode is selected, HEC-RAS will choose between the two equations based on the ratio of the wetted embankment length (L) and the approach flow depth (y1). When this ratio is greater than 25, the HIRE equation is used. When the ratio is less than or equal to 25, the Froehlich equation is used. For this analysis, the default mode was selected. Vertical abutment type with a skew angle of 90 degrees was used for both the left and right abutments. The computed scour values at the left and right abutments for the 100- and 500-year peak flows are presented in Table 18. The results show no abutment scour for the 100-year peak flow.

Table 18. Summary of Abutment Scour at the Proposed Thomes Creek Bridge at 99W

Parameters	100-yr Peak Flow		500-yr Peak Flow	
	Left	Right	Left	Right
Scour Depth Ys (ft)	-	-	19.22	20.37
Qe/Ae = Ve	-	-	2.57	1.33
Froude #	-	-	0.13	0.17
Equation	-	-	HIRE	HIRE

6.6 Estimated Total Scour

Total scour within the channel is a combination of long-term bed elevation changes, contraction scour, and the local scour at each pier and abutment. In the case of the 99W Bridge, contraction scour was not present in the cases of abutment scour. Therefore, the total abutment scour is the same as the local abutment scour. The total scour at the piers was computed as the sum of the pier scour and the contraction scour for the channel. Table 19 provides the total pier scour for the 100- and 500-year peak flows for D50 equal to 0.075 mm, which is the maximum total pier scour at the bridge. Figure 9 shows the HEC-RAS schematic of the total pier and abutment scour at the proposed 99W Bridge for the 500-year peak flow. HEC-RAS output reports for all the scour computations are included in Appendix E.

The maximum total scour for the proposed 99W Thomes Creek bridge location is the sum of the total pier scour and estimated maximum degradation at the site. Table 20 provides the estimated maximum total scour for the bridge location for the 100- and 500-year storm events.

Table 19. Total Pier Scour at the Proposed Thomes Creek Bridge at 99W

Total Pier Scour	Piers			
	#1	#2	#3	#4
For D50 = 0.075 mm, 100-year Peak Flow				
Scour Depth Ys (ft)	14.21	14.21	14.21	14.21
For D50 = 0.075 mm, 500-year Peak Flow				
Scour Depth Ys (ft)	14.82	14.82	14.82	14.82

Figure 9. Total Scour at the Proposed Thomes Creek Bridge at 99W for the 500-Year Peak Flow and D50 of 0.075 mm

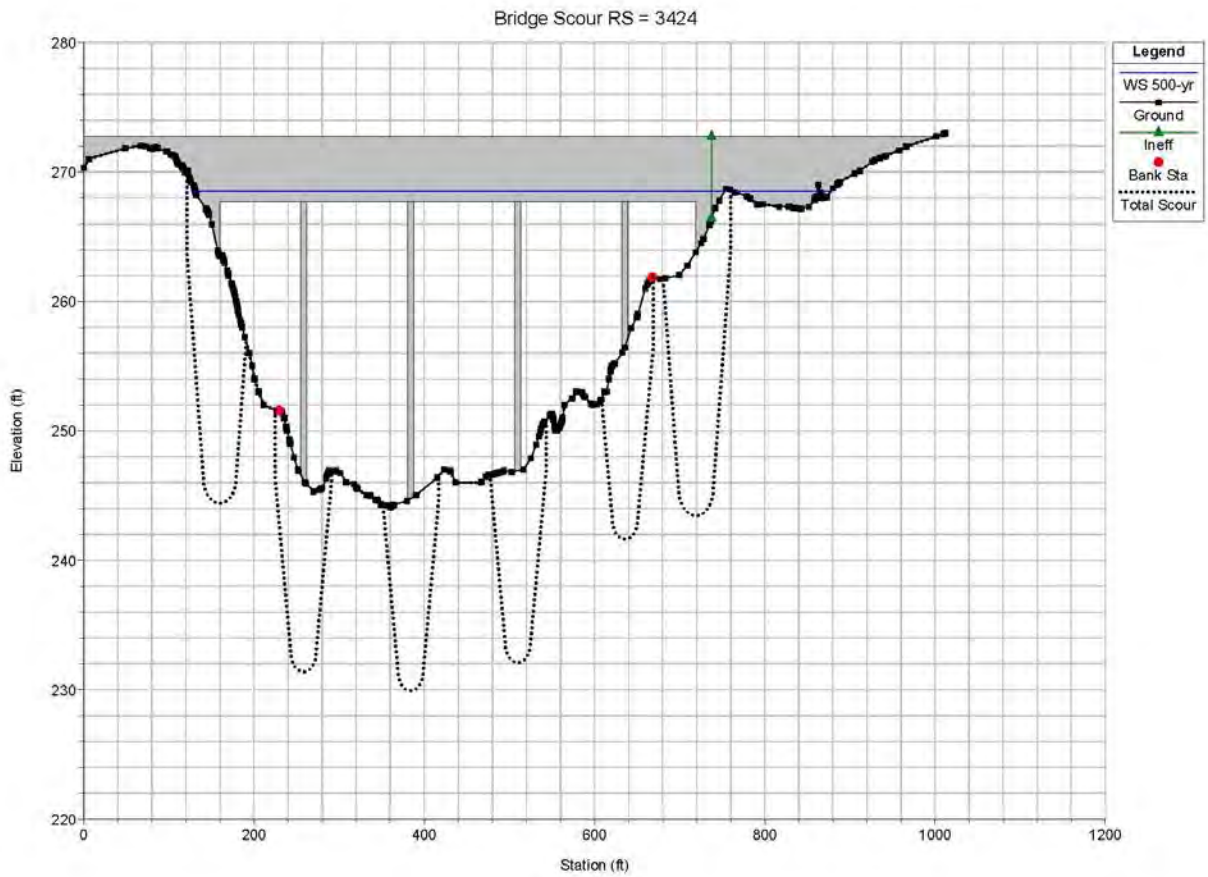

Table 20. Estimated Maximum Total Scour at the Proposed Thomes Creek Bridge at 99W

Recurrence Interval	Maximum Local Scour (at Piers) (ft)	Long-Term Degradation (ft)	Total Scour (ft)
100-year	14.21	20	34.21
500-year	14.82	20	34.82

7.0 Scour Analysis Conclusions and Recommendations

Values for contraction, pier, and abutment scour were estimated at the proposed 99W Bridge on Thomes Creek for the 100- and 500-year peak flows using HEC-RAS. An estimate of the long-term degradation in the channel is available from the 2003 Preliminary Foundation Report by Blackburn Consulting. The maximum total scour for the bridge location for the 100-year storm event was estimated as 34.21 feet, which is the sum of the maximum pier scour (sum of contraction and local scour at the piers) and long-term channel degradation. HDR recommends that the footing depth for the proposed bridge be at least equal to the estimated maximum total scour.

8.0 Electronic Files

Table 20 lists the HEC-RAS file names and descriptions for Scenarios 1 and 2 of the existing and proposed conditions runs of the Thomes Creek HEC-RAS model. These files are provided in Appendix F.

Table 21. Electronic File Descriptions for the Thomes Creek HEC-RAS Model (Scenarios 1 and 2)

Type of File	File Description	File Name
Existing Bridge - Scenario 1		
HEC-RAS Project File	Thomes Creek	ThomesCrk.prj
Plan	Existing Conditions – Scenario 1	ThomesCrk.p03
Geometry File	Existing Geometry	ThomesCrk.g01
Steady Flow File	Flows – Scenario 1	ThomesCrk.f05
Existing Bridge - Scenario 2		
HEC-RAS Project File	Thomes Creek	ThomesCrk.prj
Plan	Existing Conditions – Scenario 2	ThomesCrk.p07
Geometry File	Existing Geometry	ThomesCrk.g01
Steady Flow File	Flows – Scenario 2	ThomesCrk.f06
Proposed Bridge - Scenario 1		
HEC-RAS Project File	Thomes Creek	ThomesCrk.prj
Plan	Proposed Conditions – Scenario 1	ThomesCrk.p01
Geometry File	Proposed Geometry	ThomesCrk.g03
Steady Flow File	Flows – Scenario 1	ThomesCrk.f05
Hydraulic Design File	Scour – Scenario 1	ThomesCrk.h06
Proposed Bridge – Scenario 2		
HEC-RAS Project File	Thomes Creek	ThomesCrk.prj
Plan	Proposed Conditions – Scenario 2	ThomesCrk.p08
Geometry File	Proposed Geometry	ThomesCrk.g03
Steady Flow File	Flows – Scenario 2	ThomesCrk.f06

9.0 References

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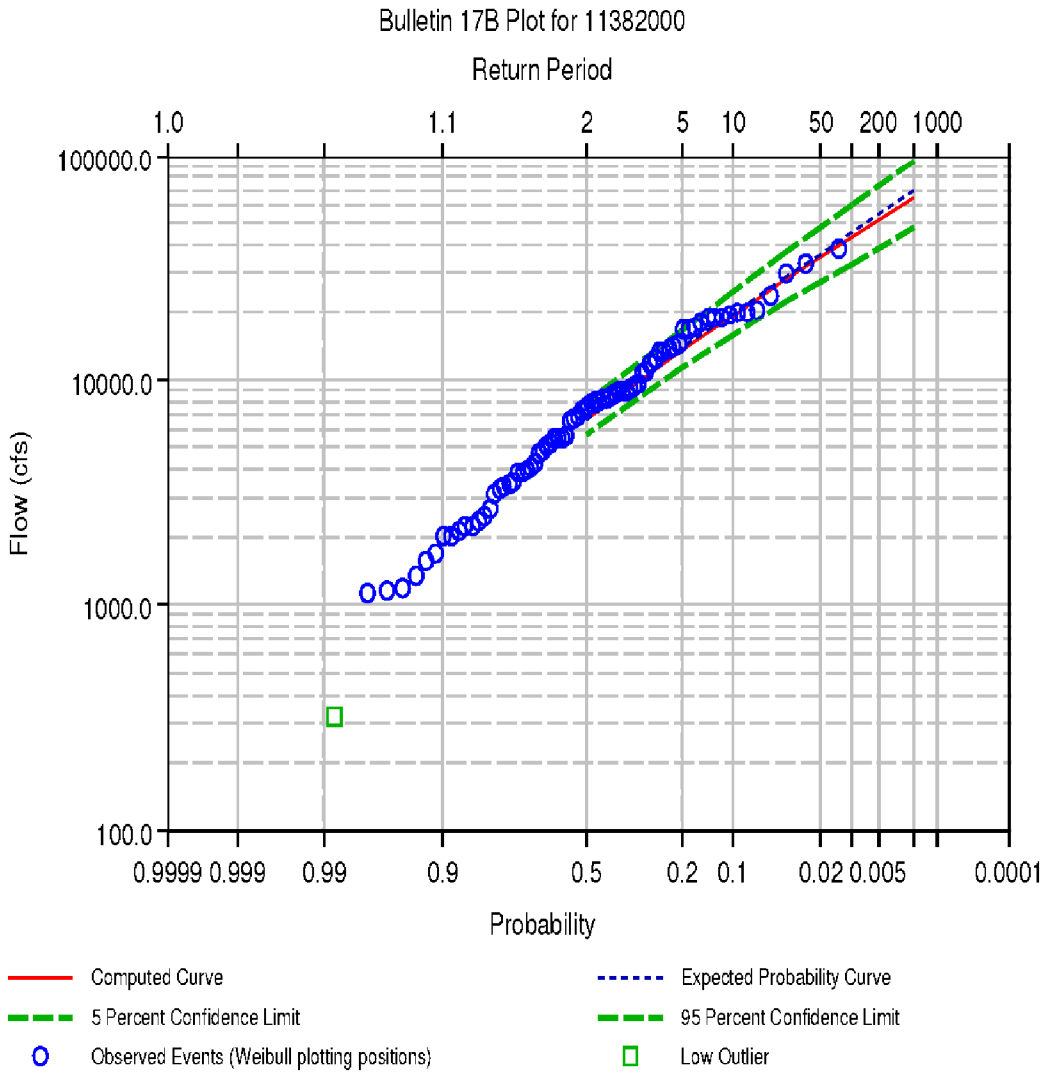
Appendix A: Hydrologic Data



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THOMES CREEK AT USGS GAGE NEAR PASEKENTA (Gage No. 11382000)
FLOOD FREQUENCY PLOT FROM HEC-SSP

USGS Peak Flow Data at USGS Gage 11382000 near Paskenta
(Used for HEC-SSP Log-Pearson Type III Analysis)

Date	Peak Flow (cfs)
November 18, 1920	13100
December 26, 1921	7100
December 28, 1922	3900
February 7, 1924	2000
February 4, 1925	13500
February 4, 1926	11700
February 20, 1927	13900
March 26, 1928	19600
December 25, 1928	2620
December 14, 1929	4750
January 23, 1931	3460
December 26, 1931	2080
April 4, 1933	1140
March 28, 1934	1970
April 8, 1935	3170
January 15, 1936	8290
March 12, 1937	2180
December 10, 1937	16500
December 3, 1938	1550
February 28, 1940	17000
February 28, 1941	13200
February 5, 1942	8120
January 21, 1943	18600
March 10, 1944	1160
February 8, 1945	2310
December 28, 1945	8990
February 12, 1947	5210
January 7, 1948	5470
March 18, 1949	1660
March 19, 1950	3040
February 4, 1951	7480
February 1, 1952	8860
January 9, 1953	10800
March 9, 1954	5390
November 15, 1954	2190
December 21, 1955	23500
February 24, 1957	7870
February 24, 1958	14300
January 12, 1959	5520
February 8, 1960	18700
January 31, 1961	4990
February 9, 1962	1330
January 31, 1963	19200
January 20, 1964	3390
December 22, 1964	37800
January 4, 1966	4180
January 29, 1967	8480
February 19, 1968	8740
January 20, 1969	9300
January 23, 1970	18000

USGS Peak Flow Data at USGS Gage 11382000 near Paskenta
(Used for HEC-SSP Log-Pearson Type III Analysis)

Date	Peak Flow (cfs)
March 26, 1971	9360
January 22, 1972	5400
January 16, 1973	7740
January 16, 1974	29400
March 7, 1975	10400
February 26, 1976	2410
March 16, 1977	315
January 14, 1978	7420
January 11, 1979	3800
January 13, 1980	18800
February 14, 1981	7890
February 15, 1982	16400
January 26, 1983	19500
November 24, 1983	8060
November 13, 1984	4020
February 17, 1986	32900
February 13, 1987	4720
December 10, 1987	6430
November 22, 1988	6850
January 8, 1990	3850
March 4, 1991	8760
March 15, 1992	3260
January 20, 1993	12100
December 8, 1993	1120
March 9, 1995	20100
December 12, 1995	6600

Appendix B: Hydraulic Data

Manning's n Computation Summary

Project Information:	Thomes Creek Drainage Analysis		Computed: RN	Date: 14-May-09
County:	Tehama County		Checked:	Date:
Stream Name:	Thomes Creek		Route:	Postmile:
Aerial Picture Attached:				
Photographs (#'s and locations)				

Summary of n-Values:

Reach	Left Overbank	Main Channel	Right Overbank
	0.055	0.035	0.055

Notes:

Manning's n Computation - Main Channel

Project Information	Thomes Creek Drainage Analysis		Computed: RN	Date: 14-May-09
County:	Tehama County		Checked:	Date:
Stream Name:	Thomes Creek		Route:	Postmile:
Aerial Picture Attached:				
Photographs (#'s and locations)				

Is roughness uniform throughout the reach? Yes

Note: If not, n-value should be assigned for the AVERAGE condition of the reach

Is roughness uniformly distributed along the cross section? Yes
Is a division between the channel and floodplain necessary? Yes

Calculation of n-value:
n = (nb + n1 + n2 + n3 + n4)m

where:	Description of Range
nb = base n value for surface	*median size btwn 1" and 2.5"=0.028 to 0.035, btwn 2.5" and 10"=0.030 to 0.050*
n1 = surface irregularity factor	*smooth = 0 up to severe at 0.020*
n2 = cross section variation factor	*gradual = 0 up to alternating frequently at 0.015*
n3 = obstructions factor	*negligible = 0 up to severe (over 50% of cross section) at 0.05*
n4 = vegetation factor	*small = 0.002 to very large (average depth of flow is less than 1/2 height of vegetation) at 0.100*
m = sinuosity/meandering factor	*minor = 1.0, appreciable = 1.15, Severe = 1.30*

Base n value for surface

nb: Sand channel? No If yes, median size of bed material?

nb =

median size (in)	nb
0.008	0.012
0.012	0.017
0.016	0.020
0.020	0.022
0.024	0.023
0.031	0.025
0.039	0.026

All other channels:

median size (in)	nb
.04 to .08	0.026 to 0.035
1 to 2.5	0.028 to 0.035
2.5 to 10	0.030 to 0.050
>10	0.040 to 0.070

Notes:

nb = 0.030

Surface Irregularity

n1:			
	Smooth	Is channel smooth? No	if yes, n1 = 0
	Minor	Is channel in good condition with slightly eroded or scoured side slopes?	if yes, n1 = 0.001 - 0.005
	Moderate	Is channel a dredged channel having moderate to considerable bed roughness and moderately sloughed or eroded side slopes in rock?	if yes, n1 = 0.006 - 0.010
	Severe	Is channel badly sloughed, scalloped banks or badly eroded or sloughed sides or jagged and irregular surface?	if yes, n1 = 0.011 - 0.020

n1 = 0.002

Notes:

Cross Section Variation Factor

n2:			
	Gradual	Does the size and shape of the channel cross section change gradually?	if yes, n2 = 0.000
	Alternately occasionally	Does the cross section alternate to large to small, *occasionally* or does the main flow *occasionally* shift from side to side?	if yes, n2 = 0.001 - 0.005
	Alternately frequently	Does the cross section alternate to large to small, *frequently* or does the main flow *frequently* shift from side to side?	if yes, n2 = 0.010 - 0.015

n2 = 0.001

Notes:

Manning's n Computation - Main Channel

Obstructions factor

n3:			
	Negligible	Does the stream have a few scattered obstructions that occupy < 5% of the cross-sectional area?	if yes, n3 = 0.000 - 0.004
	Minor	Obstructions occupy < 15% of the cross-sectional area and the spacing between obstructions is such that the sphere of influence doesn't extend to other obstructions?	if yes, n3 = 0.005 - 0.015
	Appreciable	Obstructions occupy 15% - 50% of the cross-sectional area and the spacing between obstructions is small enough to be additive?	if yes, n3 = 0.020 - 0.030
	Severe	Obstructions occupy more than 50% of the cross-sectional area or the spacing between obstructions causes turbulence?	if yes, n3 = 0.040 - 0.050
		n3 =	0.000

Notes:

Vegetation factor

n4:			
	Small	Does the channel have dense growth of flexible turf grass or weed growth where the flow is at least 2 times the height of the vegetation; tree seedlings of willows, cottonwoods, etc?	if yes, n4 = 0.002 - 0.010
	Medium	Does the channel have turf grass where the average depth of flow is 1 to 2 times the height of the vegetation; moderately stemmy grass, weeds or tree seedlings growing where the flow is 2 to 3 times the height of the vegetation?	if yes, n4 = 0.010 - 0.025
	Large	Does the channel where the average depth of flow is equal to the height of the vegetation; 8 to 10 years-old willows or cottonwoods intergrown with weeds and brush; where the hydraulic radius exceeds1.97 ft or bushy willows about 1 year old intergrown with some weeds along side slopes, and no significant vegetation exists along the channel bottom, where the hydraulic radius is greater than 2.0 ft.	if yes, n4 = 0.025 -0.050
	Very large	Does the channel have turf grass growing where the average depth of flow < 1/2 the height of the vegetation; bushy willows about 1 year old. with weeds intergrown on side slopes; dense cattails in channel bottom; trees intergrown with weeds and brush?	if yes, n4 = 0.050 - 0.100
		n4 =	0.002

Notes:

Sinuosity/meandering factor

m			
	Minor	Ratio of the channel length to valley length in 1.0 to 1.2	if yes, m = 1.00
	Appreciable	Ratio of the channel length to valley length in 1.2 to 1.5	if yes, m = 1.15
	Severe	Ratio of the channel length to valley length > 1.5	if yes, m = 1.30
		m =	1.00

Notes:

Manning's n - Main Channel n = 0.035

Manning's n Computation - Left Overbank

Project Information	Thomes Creek Drainage Analysis		Computed: RN	Date: 14-May-09
County:	Tehama County		Checked:	Date:
Stream Name:	Thomes Creek		Route:	Postmile:
Aerial Picture Attached:				
Photographs (#'s and locations)				

Is roughness uniform throughout the reach? Yes

Note: If not, n-value should be assigned for the AVERAGE condition of the reach

Is roughness uniformly distributed along the cross section? Yes
Is a division between the channel and floodplain necessary? Yes

Calculation of n-value:
n = (nb + n1 + n2 + n3 + n4)m

where:	Description of Range
nb = base n value for surface	*median size between 1" and 2.5"=0.028 to 0.035, between 2.5" and 10"=0.030 to 0.050*
n1 = surface irregularity factor	*smooth = 0 up to severe at 0.020*
n2 = cross section variation factor	*gradual = 0 up to alternating frequently at 0.015*
n3 = obstructions factor	*assumed to equal 0*
n4 = vegetation factor	*small = 0.002 to very large (average depth of flow is less than 1/2 height of vegetation) at 0.100*
m = sinuosity/meandering factor	*equals 0 for floodplains*

Base n value for surface

nb: Sand channel? _____ If yes, median size of bed material? _____

nb =

median size (in)	nb
0.008	0.012
0.012	0.017
0.016	0.020
0.020	0.022
0.024	0.023
0.031	0.025
0.039	0.026

All other channels:

median size (in)	nb
.04 to .08	0.026 to 0.035
1 to 2.5	0.028 to 0.035
2.5 to 10	0.030 to 0.050
>10	0.040 to 0.070

Notes:

nb = 0.035

Surface Irregularity

n1:

Smooth	Compares to the smoothest, flattest floodplain in a given bed material.	if yes, n1 = 0
Minor	Is the floodplain slightly irregular in shape. A few rises and dips or sloughs may be more visible on the floodplain.	if yes, n1 = 0.001 - 0.005
Moderate	Has more rises and dips. Sloughs and hummocks may occur.	if yes, n1 = 0.006 - 0.010
Severe	Floodplain very irregular in shape. Many rises and dips or sloughs are visible.	if yes, n1 = 0.011 - 0.020

n1 = 0.003

Notes:

Cross Section Variation Factor

n2 = 0.000

Notes: Not applicable to floodplains.

Obstructions factor

n3:

Negligible	Does the stream have a few scattered obstructions that occupy < 5% of the cross-sectional area?	if yes, n3 = 0.000 - 0.004
Minor	Obstructions occupy < 15% of the cross-sectional area and the spacing between obstructions is such that the sphere of influence doesn't extend to other obstructions?	if yes, n3 = 0.005 - 0.015
Appreciable	Obstructions occupy 15% - 50% of the cross-sectional area and the spacing between obstructions is small enough to be additive?	if yes, n3 = 0.020 - 0.030

n3 = 0.002

Notes:

Vegetation factor

n4:

Manning's n Computation - Left Overbank

Small	Does the channel have dense growth of flexible turf grass or weed growth where the flow is at least 2 times the height of the vegetation; tree seedlings of willows, cottonwoods, etc where the average depth of flow is at least three times the height of the vegetation?	if yes, n4 = 0.002 - 0.010
Medium	Does the channel have turf grass where the average depth of flow is 1-2 times the height of the vegetation; moderately stemmy grass, weeds or tree seedlings growing where the flow is 2-3 times the height of vegetation? Brushy, moderately dense vegetation, similar to 1-2 year old willow trees in dormant season.	if yes, n4 = 0.010 - 0.025
Large	Does the channel where the average. depth of flow is equal to the height of the vegetation; 8 to 10 year old. willows, cottonwoods intergrown with weeds and brush; where the R = 1.97 ft or bushy willows of 1 year old are in the channel bottom, where R =2.00 ft?	if yes, n4 = 0.025 -0.050
Very large	Does the channel have turf grass growing where the average depth of flow < 1/2 the height of the vegetation; bushy willows about 1 year old. with weeds intergrown on side slopes; dense cattails in channel bottom; trees intergrown with weeds and brush?	if yes, n4 = 0.050 - 0.100
Extreme	Does the channel have dense bushy willow, mesquite, and salt cedar (full foliage), or heavy stand of timber, few down trees, depth of reaching branches?	if yes, n4 = 0.100 - 0.200

n4 = 0.015

Notes:

Sinuosity/meandering factor

m = 1.00

Notes: Not applicable to floodplains.

Manning's n - Overbank n = 0.055

Manning's n Computation - Right Overbank

Project Information	Thomes Creek Drainage Analysis		Computed: RN	Date: 14-May-09
County:	Tehama County		Checked:	Date:
Stream Name:	Thomes Creek		Route:	Postmile:
Aerial Picture Attached:				
Photographs (#'s and locations)				

Is roughness uniform throughout the reach? Yes

Note: If not, n-value should be assigned for the AVERAGE condition of the reach

Is roughness uniformly distributed along the cross section? Yes
Is a division between the channel and floodplain necessary? Yes

Calculation of n-value:
n = (nb + n1 + n2 + n3 + n4)m

where:	Description of Range
nb = base n value for surface	*median size between 1" and 2.5"=0.028 to 0.035, between 2.5" and 10"=0.030 to 0.050*
n1 = surface irregularity factor	*smooth = 0 up to severe at 0.020*
n2 = cross section variation factor	*gradual = 0 up to alternating frequently at 0.015*
n3 = obstructions factor	*assumed to equal 0*
n4 = vegetation factor	*small = 0.002 to very large (average depth of flow is less than 1/2 height of vegetation) at 0.100*
m = sinuosity/meandering factor	*equals 0 for floodplains*

Base n value for surface

nb: Sand channel? _____ If yes, median size of bed material? _____

nb =

median size (in)	nb
0.008	0.012
0.012	0.017
0.016	0.020
0.020	0.022
0.024	0.023
0.031	0.025
0.039	0.026

All other channels:

median size (in)	nb
.04 to .08	0.026 to 0.035
1 to 2.5	0.028 to 0.035
2.5 to 10	0.030 to 0.050
>10	0.040 to 0.070

Notes:

nb = 0.035

Surface Irregularity

n1:			
	Smooth	Compares to the smoothest, flattest floodplain in a given bed material.	if yes, n1 = 0
	Minor	Is the floodplain slightly irregular in shape. A few rises and dips or sloughs may be more visible on the floodplain.	if yes, n1 = 0.001 - 0.005
	Moderate	Has more rises and dips. Sloughs and hummocks may occur.	if yes, n1 = 0.006 - 0.010
	Severe	Floodplain very irregular in shape. Many rises and dips or sloughs are visible.	if yes, n1 = 0.011 - 0.020

n1 = 0.003

Notes:

Cross Section Variation Factor

n2 = 0

Notes: Not applicable to floodplains.

Obstructions factor

n3:			
	Negligible	Does the stream have a few scattered obstructions that occupy < 5% of the cross-sectional area?	if yes, n3 = 0.000 - 0.004
	Minor	Obstructions occupy < 15% of the cross-sectional area and the spacing between obstructions is such that the sphere of influence doesn't extend to other obstructions?	if yes, n3 = 0.005 - 0.015
	Appreciable	Obstructions occupy 15% - 50% of the cross-sectional area and the spacing between obstructions is small enough to be additive?	if yes, n3 = 0.020 - 0.030

n3 = 0.002

Notes:

Vegetation factor

n4:

Manning's n Computation - Right Overbank

Small	Does the channel have dense growth of flexible turf grass or weed growth where the flow is at least 2 times the height of the vegetation; tree seedlings of willows, cottonwoods, etc where the average depth of flow is at least three times the height of the vegetation?	if yes, n4 = 0.002 - 0.010
Medium	Does the channel have turf grass where the average depth of flow is 1-2 times the height of the vegetation; moderately stemmy grass, weeds or tree seedlings growing where the flow is 2-3 times the height of vegetation? Brushy, moderately dense vegetation, similar to 1-2 year old willow trees in dormant season.	if yes, n4 = 0.010 - 0.025
Large	Does the channel where the average. depth of flow is equal to the height of the vegetation; 8 to 10 year old. willows, cottonwoods intergrown with weeds and brush; where the R = 1.97 ft or bushy willows of 1 year old are in the channel bottom, where R =2.00 ft?	if yes, n4 = 0.025 -0.050
Very large	Does the channel have turf grass growing where the average depth of flow < 1/2 the height of the vegetation; bushy willows about 1 year old. with weeds intergrown on side slopes; dense cattails in channel bottom; trees intergrown with weeds and brush?	if yes, n4 = 0.050 - 0.100
Extreme	Does the channel have dense bushy willow, mesquite, and salt cedar (full foliage), or heavy stand of timber, few down trees, depth of reaching branches?	if yes, n4 = 0.100 - 0.200

n4 = 0.015

Notes:

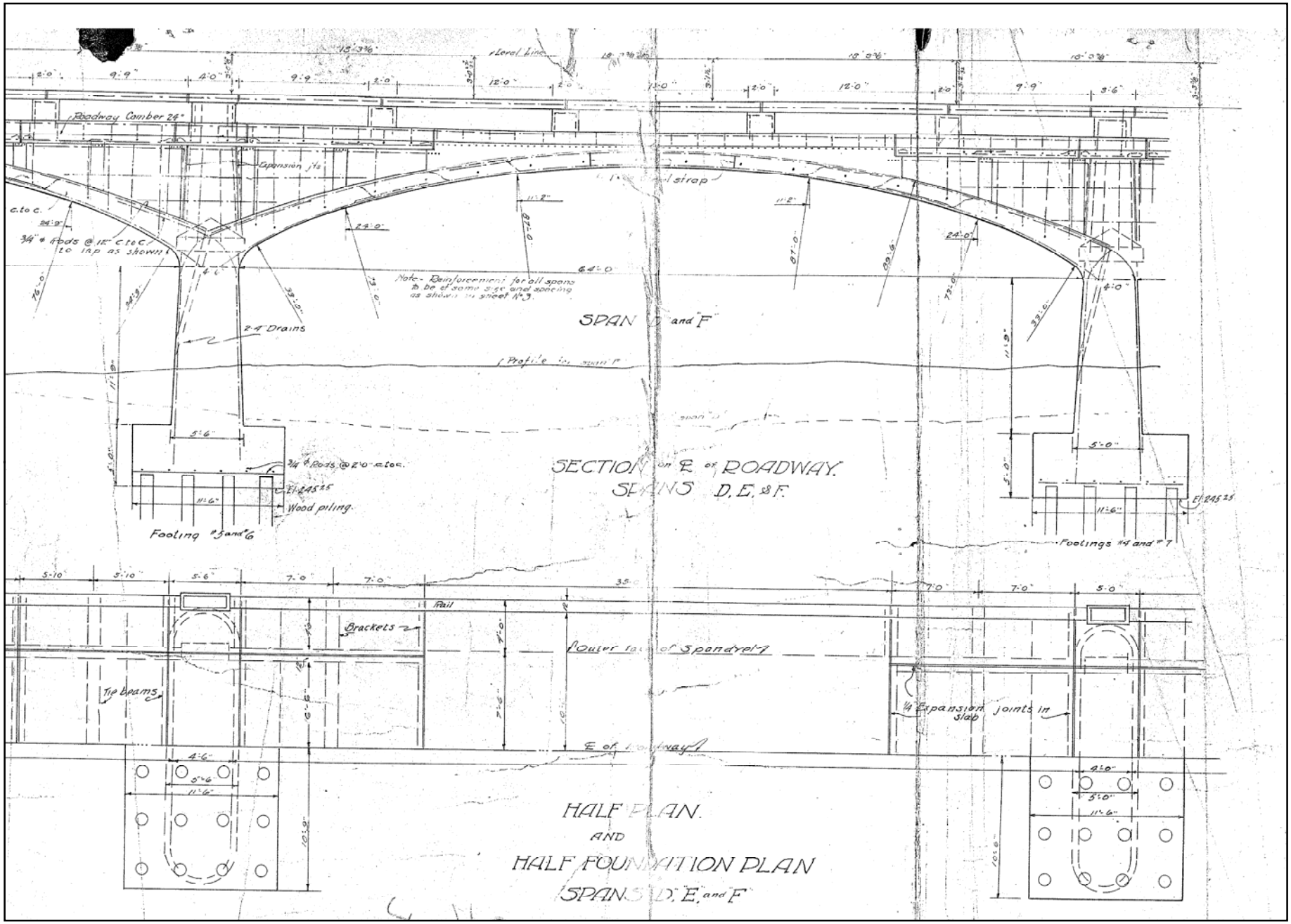
Sinuosity/meandering factor

m = 1.00

Notes: Not applicable to floodplains.

Manning's n - Overbank n = 0.055

Appendix C. Bridge Data



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THOMES CREEK BRIDGE
AS BUILTS SHEET

Appendix D: Site Visit Photo Log

Looking East Photo 1

Looking North Between 99W and Railroad Photo 2

Looking South Between 99W and Railroad Photo 3

Looking East at Railroad Photo 4

Looking West Photo 5

Appendix E. HEC-RAS Output

HEC-RAS Results - Existing Scenario 1

HEC-RAS Plan: Scenario 1 Exist River: ThomesCr Reach: Reach

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach	6840	2-yr	9400.00	251.77	258.20	255.99	258.39	0.001150	3.67	2772.94	742.67	0.32
Reach	6840	5-yr	18400.00	251.77	260.78	257.17	261.02	0.000789	4.18	5239.87	1314.22	0.29
Reach	6840	10-yr	24800.00	251.77	262.21	257.79	262.48	0.000698	4.45	7285.78	1455.56	0.28
Reach	6840	25-yr	33000.00	251.77	263.98	258.54	264.24	0.000542	4.46	9870.05	1472.86	0.25
Reach	6840	50-yr	38800.00	251.77	265.22	259.05	265.46	0.000465	4.47	11690.08	1511.67	0.24
Reach	6840	100-yr	44400.00	251.77	266.38	259.51	266.62	0.000407	4.46	13425.53	1521.48	0.23
Reach	6840	500-yr	72000.00	251.77	271.38	261.09	271.63	0.000285	4.63	21256.43	1691.79	0.20
Reach	5158.022	2-yr	9400.00	248.72	255.97	253.06	256.32	0.001309	4.77	2048.43	500.19	0.36
Reach	5158.022	5-yr	18400.00	248.72	258.98	254.77	259.39	0.001194	5.35	3914.58	712.44	0.36
Reach	5158.022	10-yr	24800.00	248.72	260.57	255.96	261.02	0.001080	5.65	5087.60	770.58	0.35
Reach	5158.022	25-yr	33000.00	248.72	262.58	257.34	263.07	0.000889	5.93	6977.44	1044.59	0.33
Reach	5158.022	50-yr	38800.00	248.72	264.03	258.15	264.48	0.000719	5.84	8496.49	1050.02	0.30
Reach	5158.022	100-yr	44400.00	248.72	265.33	258.65	265.77	0.000618	5.80	9863.45	1054.91	0.28
Reach	5158.022	500-yr	72000.00	248.72	270.54	260.70	271.01	0.000451	6.21	16085.93	1319.60	0.26
Reach	4954.851	2-yr	9400.00	247.25	255.68	252.84	256.04	0.001392	4.94	2164.40	594.62	0.37
Reach	4954.851	5-yr	18400.00	247.25	258.76	254.91	259.15	0.001089	5.38	4296.61	794.38	0.34
Reach	4954.851	10-yr	24800.00	247.25	260.38	256.02	260.80	0.000997	5.65	5654.86	886.19	0.34
Reach	4954.851	25-yr	33000.00	247.25	262.44	257.10	262.88	0.000833	5.87	7713.38	1119.39	0.32
Reach	4954.851	50-yr	38800.00	247.25	263.93	257.75	264.33	0.000666	5.73	9389.97	1136.66	0.29
Reach	4954.851	100-yr	44400.00	247.25	265.25	258.27	265.63	0.000569	5.68	10898.27	1148.85	0.27
Reach	4954.851	500-yr	72000.00	247.25	270.50	260.26	270.90	0.000416	6.06	17652.78	1415.16	0.25
Reach	4763.72	2-yr	9400.00	247.00	255.52	252.42	255.79	0.001049	4.19	2397.50	589.59	0.32
Reach	4763.72	5-yr	18400.00	247.00	258.63	254.00	258.95	0.000829	4.73	4485.31	746.94	0.30
Reach	4763.72	10-yr	24800.00	247.00	260.25	255.16	260.62	0.000758	5.12	5846.47	957.04	0.30
Reach	4763.72	25-yr	33000.00	247.00	262.35	256.23	262.72	0.000612	5.26	8032.83	1073.39	0.28
Reach	4763.72	50-yr	38800.00	247.00	263.84	256.87	264.20	0.000525	5.29	9727.73	1187.10	0.26
Reach	4763.72	100-yr	44400.00	247.00	265.17	257.47	265.52	0.000456	5.27	11319.25	1200.99	0.25
Reach	4763.72	500-yr	72000.00	247.00	270.44	259.72	270.82	0.000347	5.67	18516.22	1538.45	0.23
Reach	4519.802	2-yr	9400.00	247.00	255.28	252.03	255.53	0.001035	4.03	2496.28	605.81	0.31
Reach	4519.802	5-yr	18400.00	247.00	258.49	253.62	258.74	0.000698	4.19	5039.31	863.76	0.27
Reach	4519.802	10-yr	24800.00	247.00	260.14	254.73	260.43	0.000628	4.55	6505.86	1001.30	0.27
Reach	4519.802	25-yr	33000.00	247.00	262.27	256.00	262.57	0.000491	4.65	8675.75	1030.09	0.25
Reach	4519.802	50-yr	38800.00	247.00	263.78	256.68	264.07	0.000419	4.68	10265.87	1113.56	0.23
Reach	4519.802	100-yr	44400.00	247.00	265.10	257.14	265.41	0.000390	4.82	11818.55	1206.27	0.23
Reach	4519.802	500-yr	72000.00	247.00	270.40	259.04	270.73	0.000288	5.15	19414.22	1607.16	0.21
Reach	4359.189	2-yr	9400.00	247.00	254.97	251.81	255.33	0.001328	4.78	1978.82	382.57	0.36
Reach	4359.189	5-yr	18400.00	247.00	258.17	253.58	258.59	0.000998	5.40	4026.45	765.10	0.33
Reach	4359.189	10-yr	24800.00	247.00	259.84	254.81	260.29	0.000884	5.71	5319.93	782.92	0.32
Reach	4359.189	25-yr	33000.00	247.00	261.99	256.41	262.45	0.000732	5.90	7044.19	823.27	0.30
Reach	4359.189	50-yr	38800.00	247.00	263.48	257.23	263.97	0.000671	6.08	8329.61	945.32	0.30
Reach	4359.189	100-yr	44400.00	247.00	264.83	257.84	265.31	0.000605	6.14	9673.41	1041.47	0.28
Reach	4359.189	500-yr	72000.00	247.00	270.14	260.06	270.65	0.000460	6.57	16850.14	1662.16	0.26
Reach	4194.872	2-yr	9400.00	247.00	254.68	251.27	255.11	0.001287	5.23	1815.32	321.93	0.36
Reach	4194.872	5-yr	18400.00	247.00	257.85	253.25	258.41	0.001116	6.24	3623.18	656.20	0.36
Reach	4194.872	10-yr	24800.00	247.00	259.51	254.53	260.13	0.001053	6.71	4724.88	671.39	0.36
Reach	4194.872	25-yr	33000.00	247.00	261.68	256.59	262.31	0.000909	6.97	6208.87	698.00	0.34
Reach	4194.872	50-yr	38800.00	247.00	263.16	257.36	263.83	0.000860	7.24	7292.64	830.59	0.34
Reach	4194.872	100-yr	44400.00	247.00	264.47	258.01	265.18	0.000842	7.51	8517.69	1106.95	0.34
Reach	4194.872	500-yr	72000.00	247.00	269.92	260.53	270.56	0.000593	7.65	15696.69	1596.64	0.30
Reach	4053.796	2-yr	9400.00	246.00	253.50	252.09	254.72	0.004510	8.90	1098.58	244.18	0.66
Reach	4053.796	5-yr	18400.00	246.00	256.53	254.82	258.03	0.004736	10.16	2145.42	527.18	0.70
Reach	4053.796	10-yr	24800.00	246.00	258.61	256.86	259.84	0.002922	9.49	3259.30	538.74	0.57
Reach	4053.796	25-yr	33000.00	246.00	261.00	257.95	262.09	0.002004	9.15	4558.00	549.43	0.49
Reach	4053.796	50-yr	38800.00	246.00	262.60	258.63	263.63	0.001671	9.05	5527.39	678.32	0.46
Reach	4053.796	100-yr	44400.00	246.00	263.93	259.22	264.99	0.001580	9.25	6587.30	905.56	0.45
Reach	4053.796	500-yr	72000.00	246.00	269.53	261.82	270.44	0.000956	9.12	13762.07	1674.93	0.37
Reach	3856.677	2-yr	9400.00	247.00	252.63	251.60	253.72	0.005263	8.38	1138.85	291.53	0.70
Reach	3856.677	5-yr	18400.00	247.00	256.14	253.84	257.19	0.002736	8.44	2487.02	459.69	0.55
Reach	3856.677	10-yr	24800.00	247.00	258.31	254.98	259.28	0.001991	8.31	3499.99	478.20	0.48
Reach	3856.677	25-yr	33000.00	247.00	260.74	256.50	261.69	0.001550	8.31	4689.73	498.69	0.44
Reach	3856.677	50-yr	38800.00	247.00	262.30	257.25	263.31	0.001452	8.61	5541.65	722.88	0.43
Reach	3856.677	100-yr	44400.00	247.00	263.67	257.93	264.68	0.001317	8.72	6749.76	947.85	0.42
Reach	3856.677	500-yr	72000.00	247.00	269.38	260.71	270.24	0.000804	8.61	13786.37	1603.27	0.35
Reach	3627.549	2-yr	9400.00	246.00	252.34	250.19	252.82	0.002080	5.54	1703.59	376.50	0.44
Reach	3627.549	5-yr	18400.00	246.00	256.12	251.87	256.62	0.001202	5.75	3327.97	460.41	0.36
Reach	3627.549	10-yr	24800.00	246.00	258.29	253.02	258.83	0.000966	5.97	4346.93	476.25	0.34
Reach	3627.549	25-yr	33000.00	246.00	260.72	254.13	261.32	0.000845	6.32	5584.95	553.31	0.33
Reach	3627.549	50-yr	38800.00	246.00	262.30	254.82	262.93	0.000867	6.52	6667.14	865.01	0.33
Reach	3627.549	100-yr	44400.00	246.00	263.71	255.57	264.32	0.000788	6.46	7954.34	1008.00	0.32
Reach	3627.549	500-yr	72000.00	246.00	269.43	258.27	270.01	0.000486	6.51	14010.83	1146.92	0.27

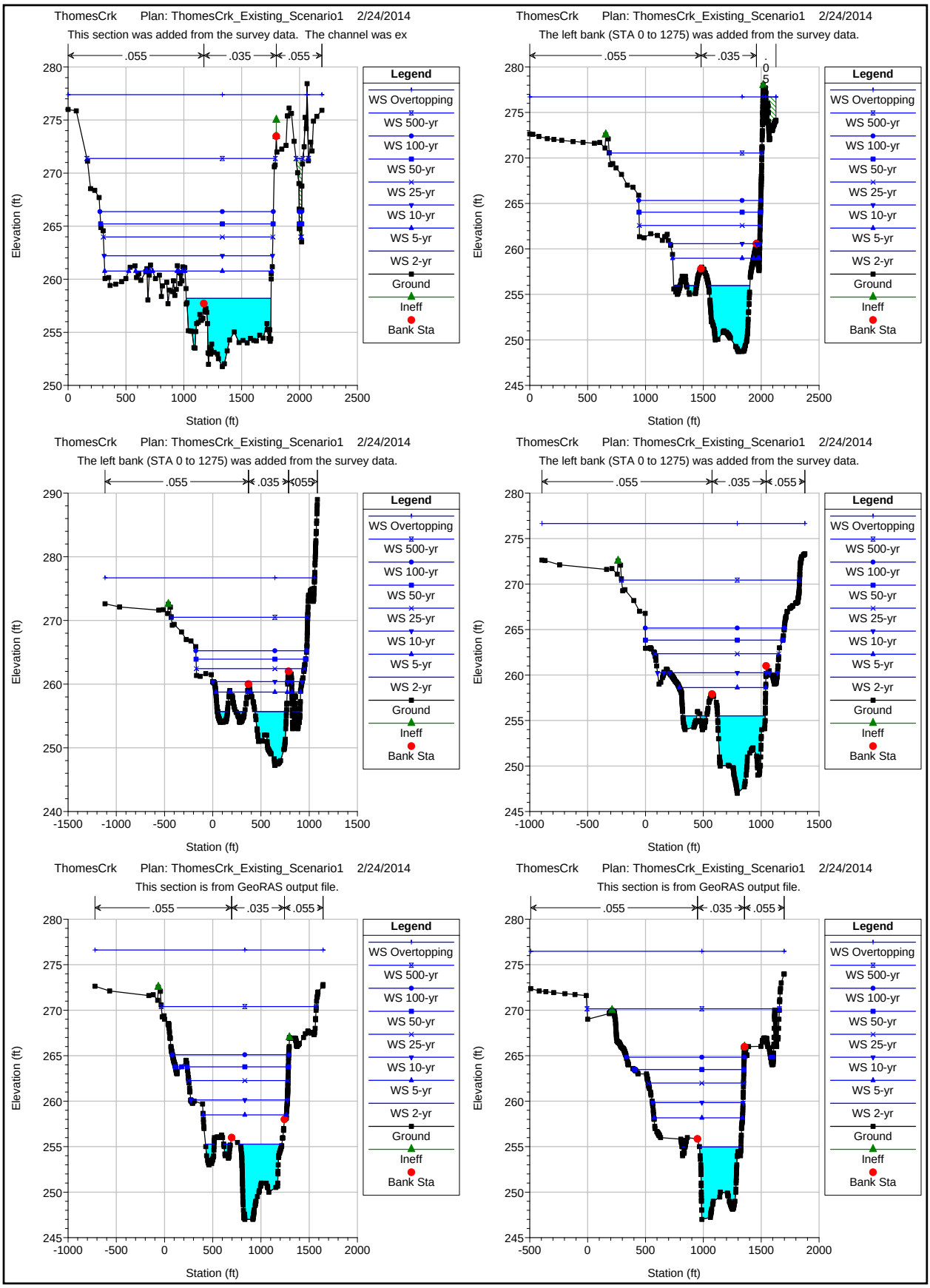
HEC-RAS Plan: Scenario 1 Exist River: ThomesCr Reach: Reach (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach	3425.705	2-yr	9400.00	244.07	252.01	249.23	252.43	0.001631	5.23	1803.36	354.47	0.40
Reach	3425.705	5-yr	18400.00	244.07	255.92	251.12	256.38	0.001029	5.52	3409.94	436.73	0.34
Reach	3425.705	10-yr	24800.00	244.07	258.12	252.31	258.64	0.000862	5.80	4398.95	459.06	0.32
Reach	3425.705	25-yr	33000.00	244.07	260.57	253.54	261.15	0.000752	6.15	5545.54	480.47	0.31
Reach	3425.705	50-yr	38800.00	244.07	262.15	254.25	262.77	0.000706	6.37	6310.10	531.67	0.31
Reach	3425.705	100-yr	44400.00	244.07	263.51	254.90	264.17	0.000667	6.59	6996.87	554.05	0.30
Reach	3425.705	500-yr	72000.00	244.07	268.96	257.72	269.86	0.000604	7.73	9747.64	754.48	0.30
Reach	3425.5		Bridge									
Reach	3391.818	2-yr	9400.00	243.11	251.88	249.03	252.23	0.001437	4.76	1974.62	386.96	0.37
Reach	3391.818	5-yr	18400.00	243.11	255.81	250.81	256.22	0.000859	5.15	3574.78	422.28	0.31
Reach	3391.818	10-yr	24800.00	243.11	258.02	251.81	258.48	0.000760	5.48	4529.64	444.50	0.30
Reach	3391.818	25-yr	33000.00	243.11	260.46	252.90	260.99	0.000700	5.84	5649.54	472.07	0.30
Reach	3391.818	50-yr	38800.00	243.11	262.04	253.63	262.61	0.000669	6.06	6406.81	490.09	0.30
Reach	3391.818	100-yr	44400.00	243.11	263.39	254.27	264.00	0.000638	6.28	7071.52	508.35	0.29
Reach	3391.818	500-yr	72000.00	243.11	268.61	257.10	269.47	0.000599	7.45	9666.10	555.06	0.30
Reach	3370.054	2-yr	9400.00	242.04	251.88	248.61	252.17	0.001063	4.33	2170.47	390.94	0.32
Reach	3370.054	5-yr	18400.00	242.04	255.82	250.28	256.18	0.000752	4.81	3828.38	453.84	0.29
Reach	3370.054	10-yr	24800.00	242.04	258.03	251.28	258.44	0.000661	5.10	4858.93	477.29	0.28
Reach	3370.054	25-yr	33000.00	242.04	260.48	252.40	260.94	0.000608	5.44	6070.53	508.90	0.28
Reach	3370.054	50-yr	38800.00	242.04	262.06	253.14	262.55	0.000584	5.63	6890.46	531.34	0.28
Reach	3370.054	100-yr	44400.00	242.04	263.41	253.83	263.94	0.000562	5.83	7621.08	586.43	0.27
Reach	3370.054	500-yr	72000.00	242.04	268.66	256.65	269.39	0.000515	6.87	10477.11	606.02	0.28
Reach	3326.75	2-yr	9400.00	241.16	251.76	248.64	252.11	0.001332	4.77	1971.24	362.09	0.36
Reach	3326.75	5-yr	18400.00	241.16	255.70	250.51	256.14	0.000840	5.31	3497.87	403.30	0.31
Reach	3326.75	10-yr	24800.00	241.16	257.89	251.56	258.40	0.000761	5.74	4400.25	427.45	0.31
Reach	3326.75	25-yr	33000.00	241.16	260.34	252.74	260.90	0.000785	6.06	5603.86	524.14	0.31
Reach	3326.75	50-yr	38800.00	241.16	261.92	253.47	262.51	0.000726	6.24	6458.73	576.85	0.31
Reach	3326.75	100-yr	44400.00	241.16	263.28	254.13	263.90	0.000673	6.42	7222.85	689.50	0.30
Reach	3326.75	500-yr	72000.00	241.16	268.52	257.05	269.36	0.000598	7.46	10179.80	733.35	0.30
Reach	3325		Bridge									
Reach	3295.507	2-yr	9400.00	241.12	251.61	248.11	251.93	0.001071	4.55	2066.24	344.57	0.33
Reach	3295.507	5-yr	18400.00	241.12	255.53	249.99	255.96	0.000789	5.26	3554.87	410.66	0.30
Reach	3295.507	10-yr	24800.00	241.12	257.70	251.03	258.20	0.000730	5.70	4502.22	459.33	0.30
Reach	3295.507	25-yr	33000.00	241.12	260.13	252.21	260.69	0.000727	6.10	5664.99	513.42	0.30
Reach	3295.507	50-yr	38800.00	241.12	261.71	253.01	262.31	0.000708	6.29	6475.80	546.09	0.30
Reach	3295.507	100-yr	44400.00	241.12	263.06	253.76	263.70	0.000689	6.49	7199.00	591.27	0.30
Reach	3295.507	500-yr	72000.00	241.12	268.26	256.90	269.11	0.000624	7.55	10108.85	722.35	0.30
Reach	3214.96	2-yr	9400.00	240.85	251.36	247.94	251.80	0.001319	5.32	1767.88	273.27	0.37
Reach	3214.96	5-yr	18400.00	240.85	255.19	250.00	255.82	0.001182	6.39	2881.41	311.27	0.37
Reach	3214.96	10-yr	24800.00	240.85	257.30	251.24	258.05	0.001111	6.95	3622.95	394.40	0.37
Reach	3214.96	25-yr	33000.00	240.85	259.66	252.64	260.53	0.001029	7.54	4547.67	421.82	0.37
Reach	3214.96	50-yr	38800.00	240.85	261.20	253.56	262.14	0.001004	7.87	5161.42	434.17	0.37
Reach	3214.96	100-yr	44400.00	240.85	262.50	254.41	263.52	0.000993	8.19	5706.16	481.42	0.37
Reach	3214.96	500-yr	72000.00	240.85	267.45	258.09	268.87	0.000978	9.79	7928.47	791.36	0.38
Reach	2946.06	2-yr	9400.00	241.00	250.34	247.81	251.26	0.002678	7.69	1222.64	183.73	0.53
Reach	2946.06	5-yr	18400.00	241.00	253.87	250.47	255.26	0.003065	9.48	1941.30	235.53	0.58
Reach	2946.06	10-yr	24800.00	241.00	255.93	252.13	257.51	0.002893	10.12	2451.70	258.09	0.58
Reach	2946.06	25-yr	33000.00	241.00	258.22	254.15	260.02	0.002665	10.77	3062.70	275.29	0.57
Reach	2946.06	50-yr	38800.00	241.00	259.70	255.23	261.63	0.002620	11.14	3482.86	294.12	0.57
Reach	2946.06	100-yr	44400.00	241.00	260.95	256.17	263.00	0.002699	11.48	3867.02	322.35	0.58
Reach	2946.06	500-yr	72000.00	241.00	265.66	260.34	268.36	0.002398	13.22	5616.99	906.71	0.58
Reach	2687.305	2-yr	9400.00	241.00	249.85		250.59	0.002131	6.93	1355.58	201.90	0.47
Reach	2687.305	5-yr	18400.00	241.00	253.35		254.53	0.002206	8.70	2114.52	229.12	0.50
Reach	2687.305	10-yr	24800.00	241.00	255.40		256.81	0.002184	9.54	2599.21	242.98	0.51
Reach	2687.305	25-yr	33000.00	241.00	257.67		259.35	0.002222	10.40	3172.48	262.59	0.53
Reach	2687.305	50-yr	38800.00	241.00	259.12		260.95	0.002407	10.86	3571.61	293.57	0.55
Reach	2687.305	100-yr	44400.00	241.00	260.30		262.28	0.002722	11.27	3938.23	336.10	0.58
Reach	2687.305	500-yr	72000.00	241.00	265.61		267.51	0.002288	11.24	7037.45	821.70	0.54
Reach	2538.912	2-yr	9400.00	241.00	249.61		250.27	0.001875	6.53	1439.12	212.66	0.44
Reach	2538.912	5-yr	18400.00	241.00	253.12		254.19	0.001891	8.31	2213.07	227.85	0.47
Reach	2538.912	10-yr	24800.00	241.00	255.16		256.49	0.001898	9.23	2687.20	236.36	0.48
Reach	2538.912	25-yr	33000.00	241.00	257.40		259.01	0.002131	10.18	3242.40	268.50	0.52
Reach	2538.912	50-yr	38800.00	241.00	258.82		260.58	0.002336	10.64	3648.02	303.26	0.54
Reach	2538.912	100-yr	44400.00	241.00	259.98		261.88	0.002332	11.08	4019.41	339.46	0.55
Reach	2538.912	500-yr	72000.00	241.00	264.76		267.13	0.002082	12.56	6410.14	684.38	0.54
Reach	2329.127	2-yr	9400.00	241.00	248.81	246.59	249.75	0.002947	7.80	1205.30	191.60	0.55
Reach	2329.127	5-yr	18400.00	241.00	252.18	249.13	253.65	0.003215	9.70	1896.74	231.38	0.60

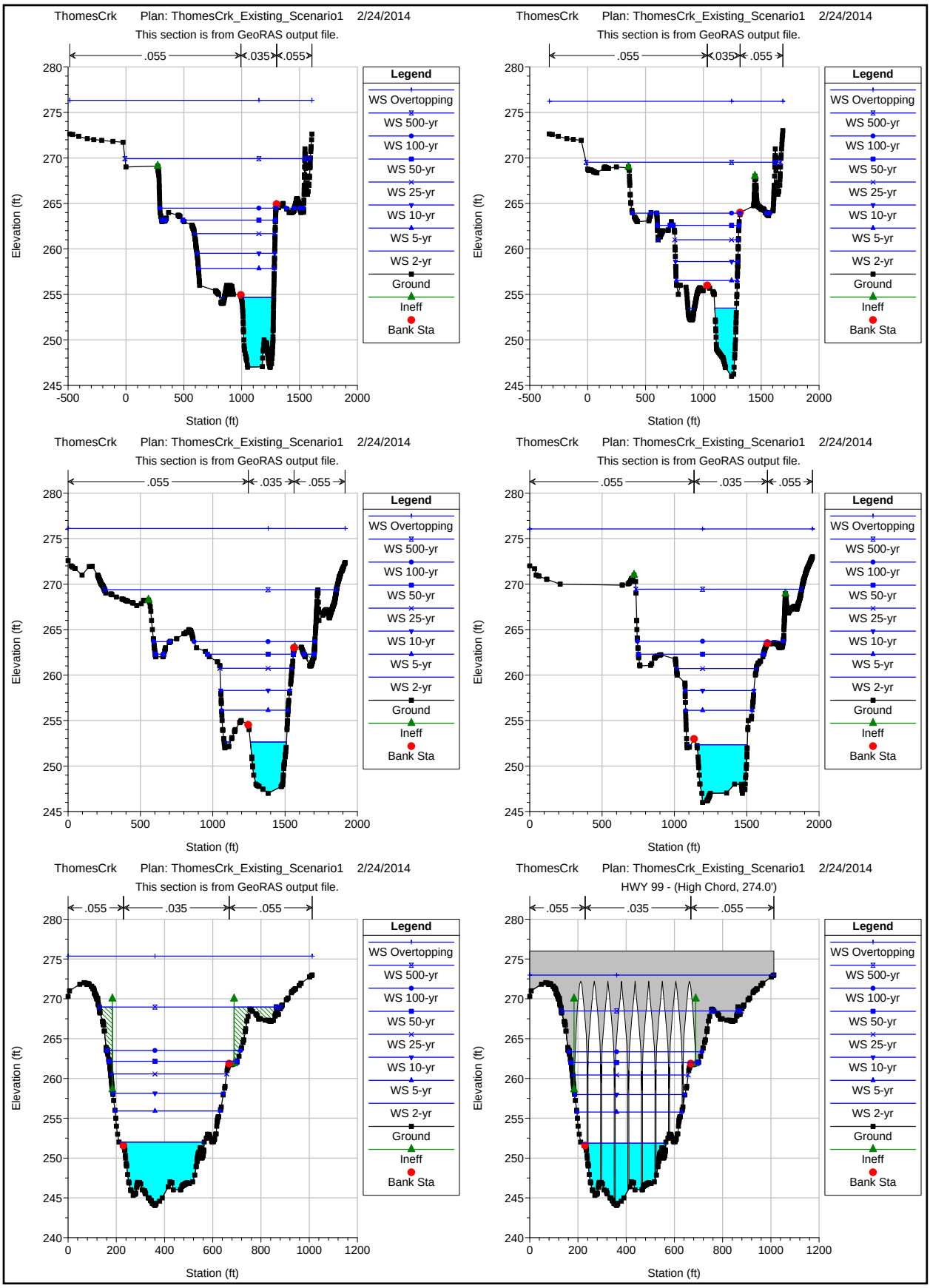
HEC-RAS Plan: Scenario 1 Exist River: ThomesCr Reach: Reach (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach	2329.127	10-yr	24800.00	241.00	254.32	250.66	255.96	0.003068	10.25	2418.39	261.96	0.59
Reach	2329.127	25-yr	33000.00	241.00	256.70	252.60	258.48	0.002843	10.72	3079.53	294.96	0.58
Reach	2329.127	50-yr	38800.00	241.00	258.15	253.79	260.03	0.002724	11.02	3522.11	325.24	0.58
Reach	2329.127	100-yr	44400.00	241.00	259.33	254.79	261.34	0.002734	11.38	3902.16	347.34	0.58
Reach	2329.127	500-yr	72000.00	241.00	264.43	258.81	266.66	0.002055	12.20	6711.82	698.17	0.53
Reach	2143.208	2-yr	9400.00	241.00	247.46		248.89	0.005328	9.60	979.57	177.41	0.72
Reach	2143.208	5-yr	18400.00	241.00	249.85		252.47	0.006502	13.00	1415.11	187.65	0.83
Reach	2143.208	10-yr	24800.00	241.00	251.22	250.57	254.59	0.007472	14.74	1683.06	205.34	0.91
Reach	2143.208	25-yr	33000.00	241.00	252.72	252.51	256.91	0.008414	16.43	2008.24	227.56	0.97
Reach	2143.208	50-yr	38800.00	241.00	253.70	253.70	258.37	0.008797	17.33	2239.22	242.40	1.00
Reach	2143.208	100-yr	44400.00	241.00	254.75	254.75	259.64	0.008642	17.75	2500.95	257.72	1.00
Reach	2143.208	500-yr	72000.00	241.00	258.84	258.84	264.85	0.007768	19.69	3692.68	339.16	0.99
Reach	1760	2-yr	9400.00	237.09	246.87	244.34	247.45	0.002047	6.13	1532.53	264.86	0.45
Reach	1760	5-yr	18400.00	237.09	249.18	246.36	250.31	0.002686	8.53	2158.01	278.28	0.54
Reach	1760	10-yr	24800.00	237.09	250.49	247.57	251.98	0.003034	9.80	2530.84	290.09	0.58
Reach	1760	25-yr	33000.00	237.09	251.94	248.98	253.87	0.003377	11.14	2961.28	303.24	0.63
Reach	1760	50-yr	38800.00	237.09	252.77	249.92	255.03	0.003647	12.06	3215.93	309.56	0.66
Reach	1760	100-yr	44400.00	237.09	253.60	250.77	256.14	0.003768	12.78	3475.18	314.36	0.68
Reach	1760	500-yr	72000.00	237.09	256.65	254.53	260.61	0.005136	15.96	4510.25	368.83	0.80
Reach	260	2-yr	9400.00	236.51	242.26	241.38	242.87	0.005000	6.26	1501.36	497.17	0.63
Reach	260	5-yr	18400.00	236.51	243.83	242.71	244.83	0.005009	7.99	2301.99	528.58	0.67
Reach	260	10-yr	24800.00	236.51	244.79	243.54	245.99	0.004994	8.79	2821.88	560.61	0.69
Reach	260	25-yr	33000.00	236.51	245.95	244.46	247.30	0.005001	9.34	3531.51	640.78	0.70
Reach	260	50-yr	38800.00	236.51	246.55	245.18	248.07	0.005001	9.89	3922.80	653.52	0.71
Reach	260	100-yr	44400.00	236.51	247.32	245.71	248.85	0.005006	9.91	4478.53	744.32	0.71
Reach	260	500-yr	72000.00	236.51	249.40	247.92	251.60	0.005006	11.91	6043.81	762.09	0.75

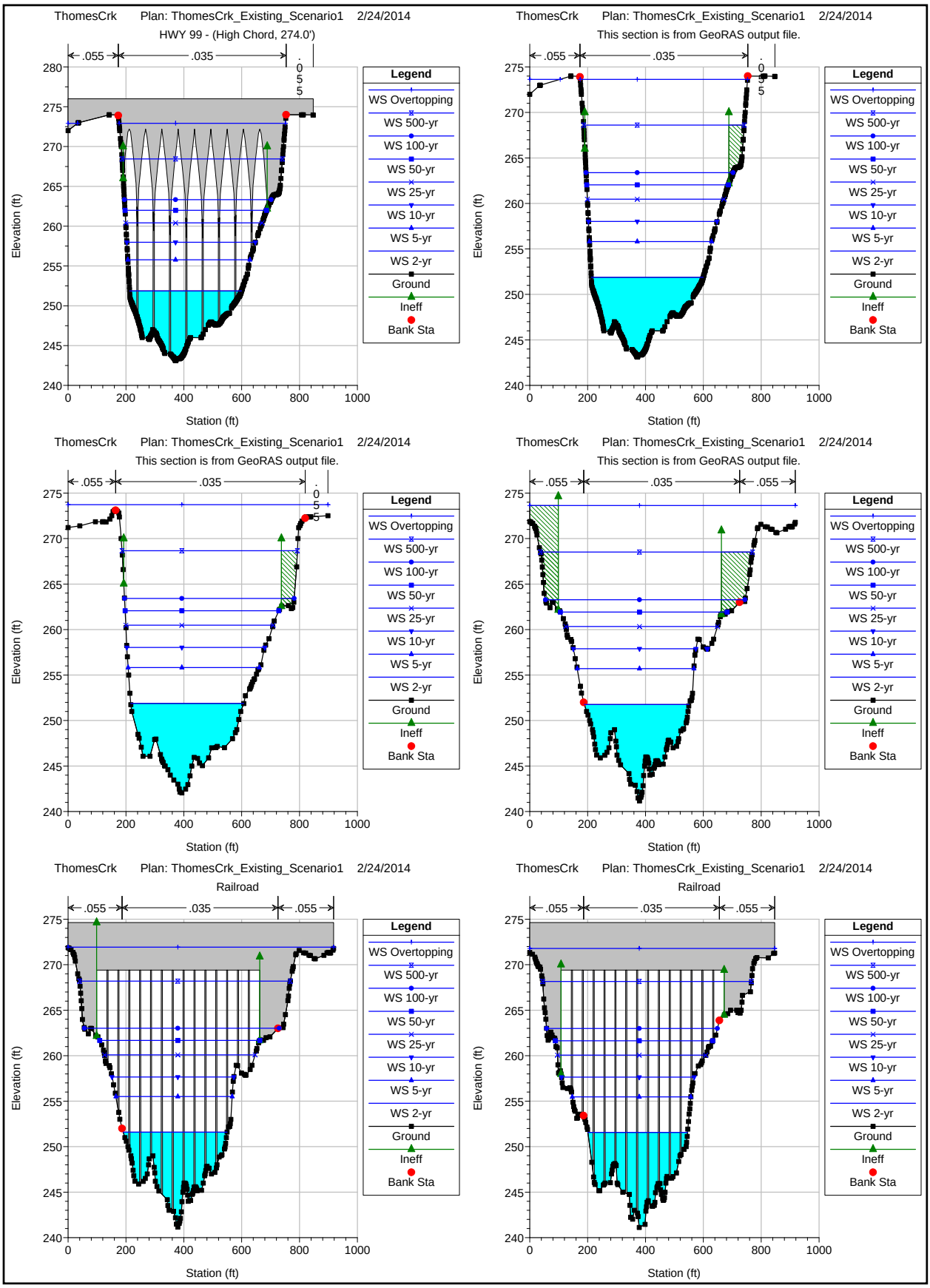
Cross Sections - Existing Scenario 1 (Sheet 1 of 5)



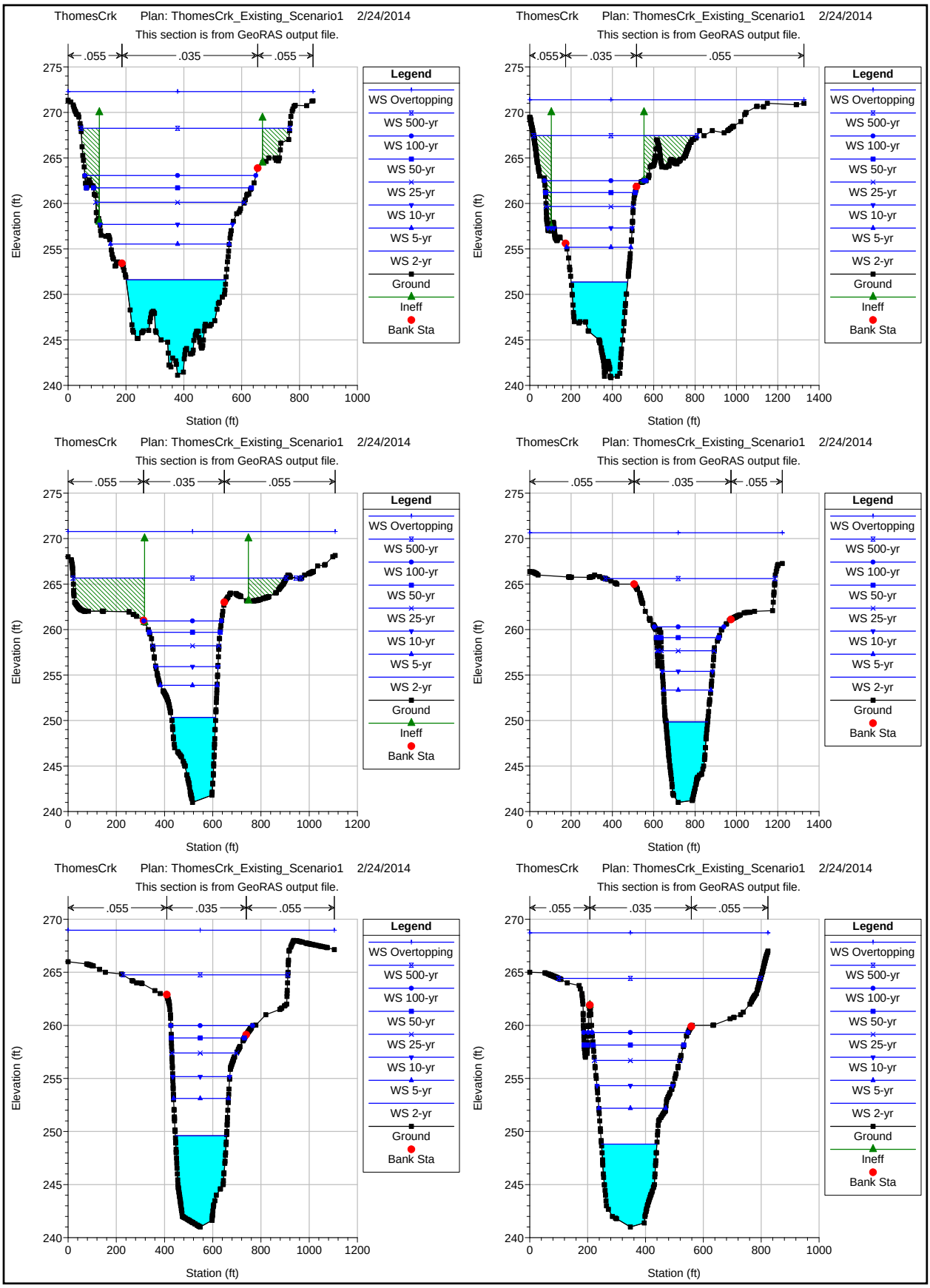
Cross Sections - Existing Scenario 1 (Sheet 2 of 5)



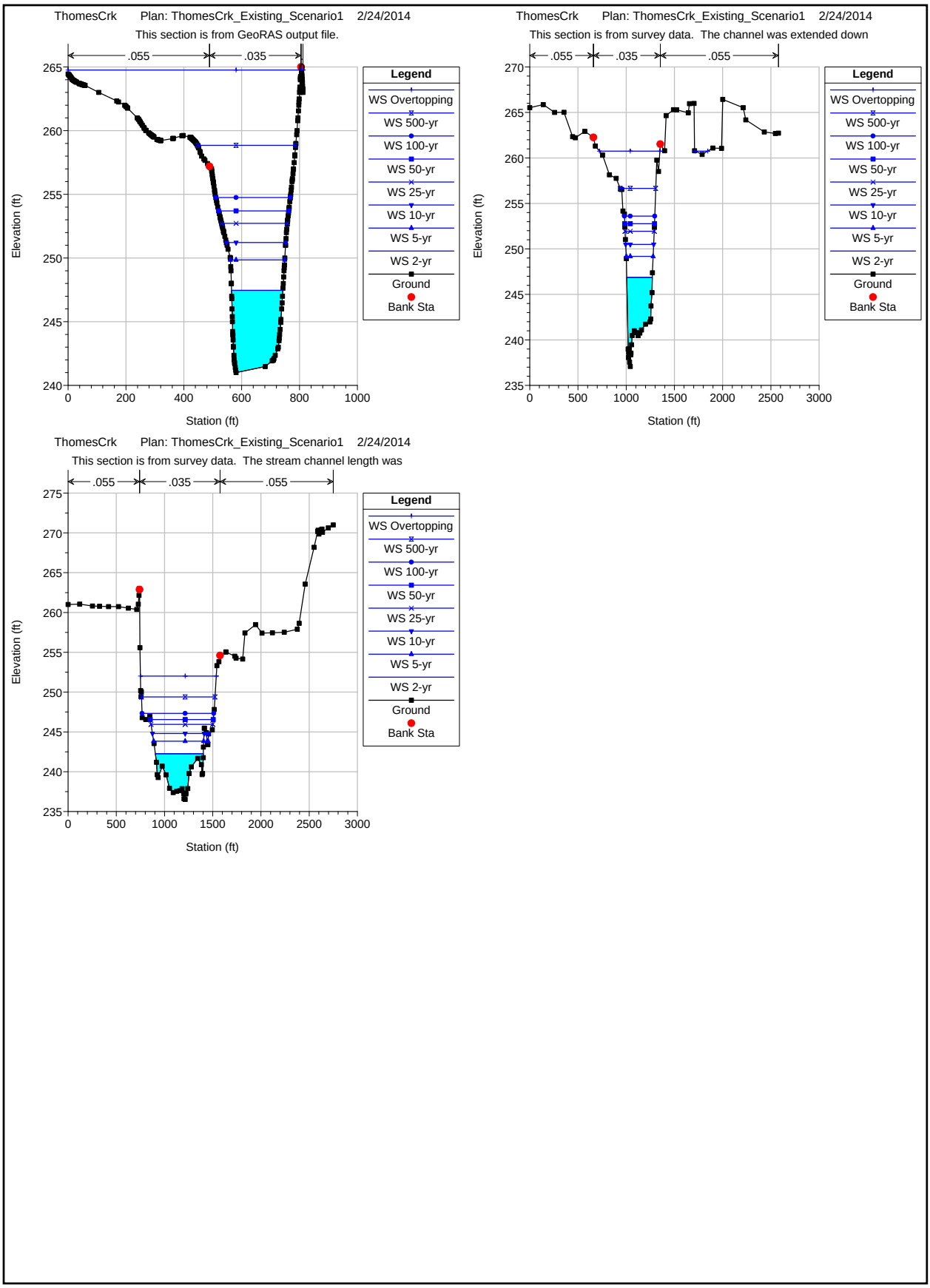
Cross Sections - Existing Scenario 1 (Sheet 3 of 5)



Cross Sections - Existing Scenario 1 (Sheet 4 of 5)



Cross Sections - Existing Scenario 1 (Sheet 5 of 5)



HEC-RAS Results - Proposed Scenario 1

HEC-RAS Plan: New_Bridge_S River: ThomesCr Reach: Reach

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach	6840	2-yr	9400.00	251.77	258.20	255.99	258.39	0.001150	3.67	2772.81	742.67	0.32
Reach	6840	5-yr	18400.00	251.77	260.77	257.17	261.02	0.000789	4.18	5237.74	1313.92	0.29
Reach	6840	10-yr	24800.00	251.77	262.20	257.79	262.47	0.000701	4.46	7273.35	1455.51	0.28
Reach	6840	25-yr	33000.00	251.77	263.96	258.54	264.22	0.000546	4.47	9843.62	1472.47	0.25
Reach	6840	50-yr	38800.00	251.77	265.19	259.05	265.44	0.000470	4.48	11646.92	1511.43	0.24
Reach	6840	100-yr	44400.00	251.77	266.34	259.51	266.58	0.000411	4.48	13372.78	1521.19	0.23
Reach	6840	500-yr	72000.00	251.77	271.22	261.09	271.47	0.000296	4.68	20995.87	1682.60	0.20
Reach	5158.022	2-yr	9400.00	248.72	255.97	253.06	256.32	0.001310	4.77	2047.73	500.09	0.36
Reach	5158.022	5-yr	18400.00	248.72	258.97	254.77	259.39	0.001197	5.35	3911.32	712.34	0.36
Reach	5158.022	10-yr	24800.00	248.72	260.55	255.96	261.00	0.001089	5.67	5073.29	768.73	0.35
Reach	5158.022	25-yr	33000.00	248.72	262.55	257.34	263.04	0.000900	5.96	6942.73	1044.47	0.33
Reach	5158.022	50-yr	38800.00	248.72	263.98	258.15	264.44	0.000731	5.87	8449.39	1049.84	0.30
Reach	5158.022	100-yr	44400.00	248.72	265.28	258.65	265.72	0.000627	5.83	9811.53	1054.73	0.29
Reach	5158.022	500-yr	72000.00	248.72	270.34	260.70	270.83	0.000472	6.31	15828.91	1317.63	0.26
Reach	4954.851	2-yr	9400.00	247.25	255.68	252.84	256.04	0.001393	4.94	2163.33	594.47	0.37
Reach	4954.851	5-yr	18400.00	247.25	258.76	254.91	259.15	0.001091	5.38	4292.54	793.98	0.34
Reach	4954.851	10-yr	24800.00	247.25	260.36	256.02	260.78	0.001002	5.65	5638.04	880.22	0.34
Reach	4954.851	25-yr	33000.00	247.25	262.41	257.10	262.85	0.000845	5.89	7673.59	1119.00	0.32
Reach	4954.851	50-yr	38800.00	247.25	263.88	257.75	264.29	0.000677	5.76	9336.81	1136.16	0.29
Reach	4954.851	100-yr	44400.00	247.25	265.20	258.27	265.58	0.000578	5.71	10839.94	1148.49	0.28
Reach	4954.851	500-yr	72000.00	247.25	270.30	260.26	270.72	0.000436	6.15	17373.44	1413.08	0.25
Reach	4763.72	2-yr	9400.00	247.00	255.52	252.42	255.78	0.001050	4.19	2396.29	589.50	0.32
Reach	4763.72	5-yr	18400.00	247.00	258.62	254.00	258.94	0.000831	4.73	4481.30	746.75	0.30
Reach	4763.72	10-yr	24800.00	247.00	260.23	255.16	260.60	0.000764	5.13	5826.48	955.02	0.30
Reach	4763.72	25-yr	33000.00	247.00	262.31	256.23	262.69	0.000620	5.28	7993.57	1072.46	0.28
Reach	4763.72	50-yr	38800.00	247.00	263.79	256.87	264.16	0.000533	5.32	9670.53	1185.38	0.26
Reach	4763.72	100-yr	44400.00	247.00	265.12	257.47	265.48	0.000463	5.30	11256.73	1200.58	0.25
Reach	4763.72	500-yr	72000.00	247.00	270.24	259.72	270.64	0.000363	5.76	18207.95	1536.14	0.23
Reach	4519.802	2-yr	9400.00	247.00	255.28	252.03	255.52	0.001036	4.03	2494.85	605.50	0.31
Reach	4519.802	5-yr	18400.00	247.00	258.49	253.62	258.74	0.000700	4.19	5034.27	863.71	0.27
Reach	4519.802	10-yr	24800.00	247.00	260.11	254.73	260.41	0.000634	4.57	6483.56	1001.01	0.27
Reach	4519.802	25-yr	33000.00	247.00	262.23	256.00	262.53	0.000498	4.67	8636.91	1029.64	0.25
Reach	4519.802	50-yr	38800.00	247.00	263.73	256.68	264.02	0.000426	4.70	10211.37	1109.01	0.23
Reach	4519.802	100-yr	44400.00	247.00	265.05	257.14	265.36	0.000396	4.85	11754.61	1204.73	0.23
Reach	4519.802	500-yr	72000.00	247.00	270.20	259.04	270.54	0.000302	5.23	19089.37	1604.42	0.21
Reach	4359.189	2-yr	9400.00	247.00	254.97	251.81	255.32	0.001330	4.78	1977.78	382.51	0.36
Reach	4359.189	5-yr	18400.00	247.00	258.16	253.58	258.59	0.001001	5.41	4021.24	765.02	0.33
Reach	4359.189	10-yr	24800.00	247.00	259.81	254.81	260.27	0.000892	5.73	5300.49	782.59	0.32
Reach	4359.189	25-yr	33000.00	247.00	261.95	256.41	262.42	0.000741	5.92	7010.78	821.84	0.30
Reach	4359.189	50-yr	38800.00	247.00	263.43	257.23	263.92	0.000680	6.11	8280.36	940.59	0.30
Reach	4359.189	100-yr	44400.00	247.00	264.77	257.84	265.26	0.000615	6.17	9615.28	1039.33	0.29
Reach	4359.189	500-yr	72000.00	247.00	269.98	260.06	270.47	0.000444	6.42	16452.56	1655.87	0.26
Reach	4194.872	2-yr	9400.00	247.00	254.68	251.27	255.10	0.001289	5.23	1814.32	321.76	0.36
Reach	4194.872	5-yr	18400.00	247.00	257.85	253.25	258.40	0.001120	6.25	3617.94	656.13	0.36
Reach	4194.872	10-yr	24800.00	247.00	259.49	254.53	260.10	0.001064	6.73	4706.03	671.07	0.36
Reach	4194.872	25-yr	33000.00	247.00	261.64	256.59	262.27	0.000921	7.00	6177.65	697.41	0.34
Reach	4194.872	50-yr	38800.00	247.00	263.11	257.36	263.78	0.000872	7.28	7245.90	823.35	0.34
Reach	4194.872	100-yr	44400.00	247.00	264.41	258.01	265.13	0.000857	7.56	8451.92	1100.21	0.34
Reach	4194.872	500-yr	72000.00	247.00	269.74	260.53	270.41	0.000619	7.78	15419.25	1593.72	0.30
Reach	4053.796	2-yr	9400.00	246.00	253.49	252.09	254.71	0.004529	8.91	1096.83	243.97	0.67
Reach	4053.796	5-yr	18400.00	246.00	256.49	254.82	258.02	0.004832	10.23	2127.51	526.92	0.71
Reach	4053.796	10-yr	24800.00	246.00	258.57	256.86	259.81	0.002987	9.56	3233.46	538.50	0.58
Reach	4053.796	25-yr	33000.00	246.00	260.94	257.95	262.04	0.002045	9.22	4525.96	549.14	0.50
Reach	4053.796	50-yr	38800.00	246.00	262.53	258.63	263.58	0.001704	9.11	5481.34	674.37	0.46
Reach	4053.796	100-yr	44400.00	246.00	263.85	259.22	264.94	0.001618	9.33	6517.34	892.63	0.46
Reach	4053.796	500-yr	72000.00	246.00	269.32	261.82	270.28	0.001016	9.33	13414.71	1669.36	0.38
Reach	3856.677	2-yr	9400.00	247.00	252.61	251.60	253.71	0.005343	8.42	1132.64	290.65	0.70
Reach	3856.677	5-yr	18400.00	247.00	256.10	253.84	257.16	0.002795	8.50	2466.72	459.39	0.55
Reach	3856.677	10-yr	24800.00	247.00	258.25	254.98	259.24	0.002032	8.37	3473.91	477.69	0.49
Reach	3856.677	25-yr	33000.00	247.00	260.68	256.50	261.64	0.001581	8.37	4658.11	498.14	0.44
Reach	3856.677	50-yr	38800.00	247.00	262.22	257.25	263.25	0.001480	8.67	5493.77	714.55	0.44
Reach	3856.677	100-yr	44400.00	247.00	263.58	257.93	264.62	0.001351	8.79	6668.75	939.47	0.42
Reach	3856.677	500-yr	72000.00	247.00	269.18	260.71	270.07	0.000840	8.74	13464.96	1594.94	0.35
Reach	3627.549	2-yr	9400.00	246.00	252.31	250.19	252.79	0.002116	5.57	1692.42	374.50	0.45
Reach	3627.549	5-yr	18400.00	246.00	256.07	251.87	256.58	0.001225	5.79	3307.14	460.05	0.37
Reach	3627.549	10-yr	24800.00	246.00	258.24	253.02	258.78	0.000984	6.00	4320.81	475.85	0.34
Reach	3627.549	25-yr	33000.00	246.00	260.65	254.13	261.26	0.000860	6.36	5549.49	552.24	0.33
Reach	3627.549	50-yr	38800.00	246.00	262.23	254.82	262.87	0.000873	6.53	6610.18	860.14	0.33
Reach	3627.549	100-yr	44400.00	246.00	263.63	255.57	264.25	0.000808	6.52	7867.74	1006.71	0.32
Reach	3627.549	500-yr	72000.00	246.00	269.24	258.27	269.82	0.000507	6.60	13783.55	1144.35	0.27

HEC-RAS Plan: New_Bridge_S River: ThomesCr Reach: Reach (Continued)

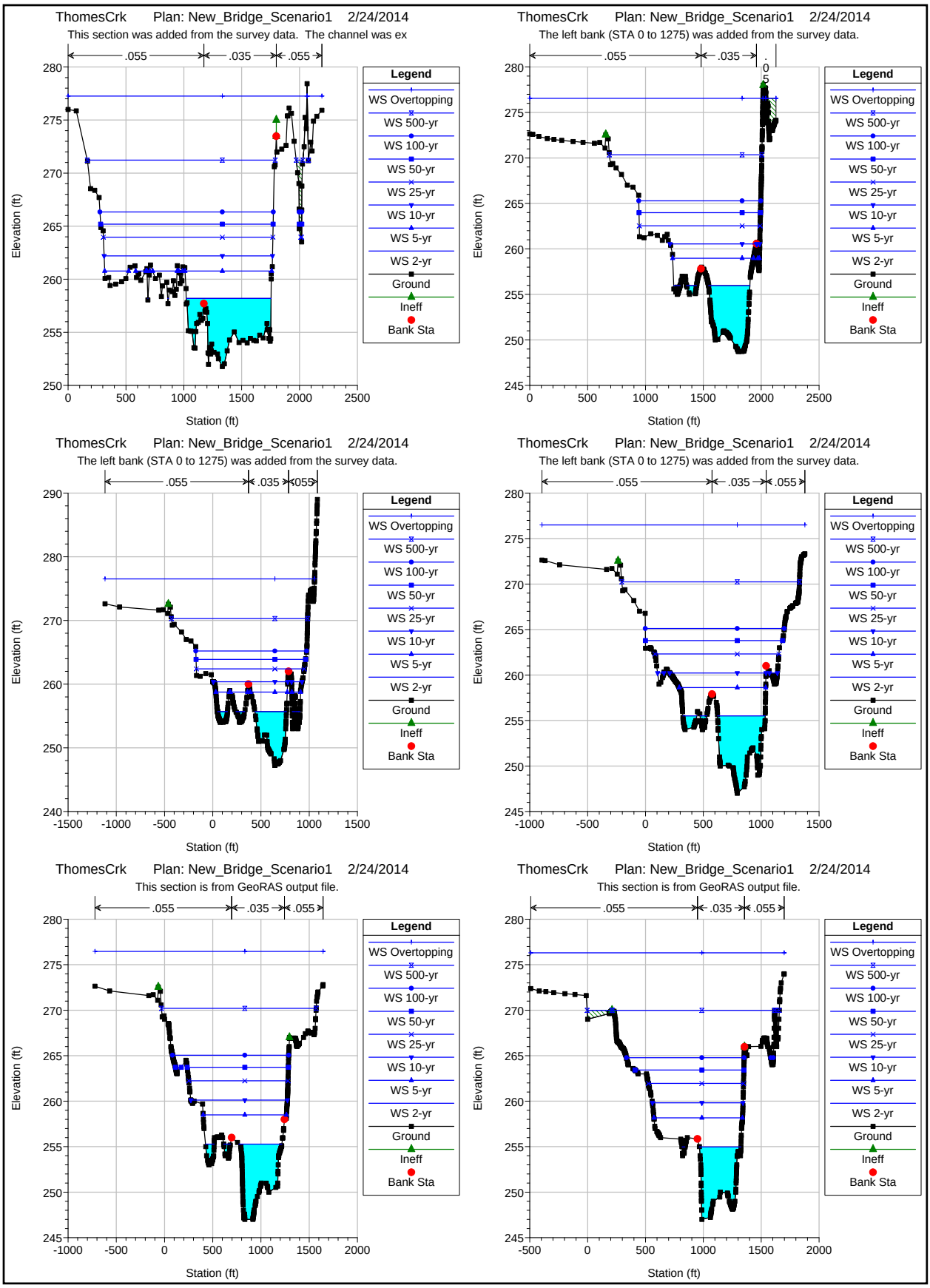
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach	3425.705	2-yr	9400.00	244.07	251.97	249.23	252.40	0.001663	5.26	1790.41	352.62	0.40
Reach	3425.705	5-yr	18400.00	244.07	255.87	251.11	256.34	0.001048	5.55	3388.44	436.08	0.34
Reach	3425.705	10-yr	24800.00	244.07	258.06	252.30	258.59	0.000878	5.84	4372.56	458.45	0.32
Reach	3425.705	25-yr	33000.00	244.07	260.50	253.55	261.09	0.000768	6.19	5519.65	479.96	0.31
Reach	3425.705	50-yr	38800.00	244.07	262.08	254.24	262.70	0.000723	6.42	6294.89	530.38	0.31
Reach	3425.705	100-yr	44400.00	244.07	263.42	254.90	264.09	0.000684	6.65	7024.35	551.99	0.31
Reach	3425.705	500-yr	72000.00	244.07	268.78	257.73	269.68	0.000614	7.75	10159.63	749.90	0.30
Reach	3424		Bridge									
Reach	3370.054	2-yr	9400.00	242.04	251.84	248.73	252.17	0.001234	4.65	2023.45	366.81	0.35
Reach	3370.054	5-yr	18400.00	242.04	255.76	250.48	256.18	0.000856	5.17	3572.32	425.40	0.31
Reach	3370.054	10-yr	24800.00	242.04	257.96	251.51	258.43	0.000751	5.51	4534.89	447.64	0.30
Reach	3370.054	25-yr	33000.00	242.04	260.40	252.66	260.93	0.000693	5.88	5665.46	477.43	0.30
Reach	3370.054	50-yr	38800.00	242.04	261.97	253.43	262.55	0.000666	6.10	6430.64	497.97	0.30
Reach	3370.054	100-yr	44400.00	242.04	263.32	254.13	263.93	0.000644	6.32	7143.90	550.71	0.29
Reach	3370.054	500-yr	72000.00	242.04	268.54	257.06	269.38	0.000586	7.42	10070.57	569.06	0.30
Reach	3326.75	2-yr	9400.00	241.16	251.76	248.64	252.11	0.001332	4.77	1971.23	362.09	0.36
Reach	3326.75	5-yr	18400.00	241.16	255.70	250.51	256.14	0.000840	5.31	3497.84	403.30	0.31
Reach	3326.75	10-yr	24800.00	241.16	257.89	251.56	258.40	0.000761	5.74	4400.31	427.46	0.31
Reach	3326.75	25-yr	33000.00	241.16	260.34	252.74	260.90	0.000785	6.06	5603.63	524.13	0.31
Reach	3326.75	50-yr	38800.00	241.16	261.92	253.47	262.51	0.000726	6.24	6458.70	576.85	0.31
Reach	3326.75	100-yr	44400.00	241.16	263.28	254.13	263.90	0.000673	6.42	7222.85	689.50	0.30
Reach	3326.75	500-yr	72000.00	241.16	268.52	257.05	269.36	0.000598	7.46	10179.76	733.35	0.30
Reach	3325		Bridge									
Reach	3295.507	2-yr	9400.00	241.12	251.61	248.11	251.93	0.001071	4.55	2066.23	344.57	0.33
Reach	3295.507	5-yr	18400.00	241.12	255.53	249.99	255.96	0.000789	5.26	3554.86	410.66	0.30
Reach	3295.507	10-yr	24800.00	241.12	257.70	251.03	258.20	0.000730	5.70	4502.29	459.33	0.30
Reach	3295.507	25-yr	33000.00	241.12	260.13	252.21	260.69	0.000727	6.10	5664.80	513.41	0.30
Reach	3295.507	50-yr	38800.00	241.12	261.71	253.01	262.31	0.000708	6.29	6475.78	546.09	0.30
Reach	3295.507	100-yr	44400.00	241.12	263.06	253.76	263.70	0.000689	6.49	7198.98	591.27	0.30
Reach	3295.507	500-yr	72000.00	241.12	268.26	256.90	269.11	0.000624	7.55	10108.82	722.35	0.30
Reach	3214.96	2-yr	9400.00	240.85	251.36	247.94	251.80	0.001319	5.32	1767.87	273.27	0.37
Reach	3214.96	5-yr	18400.00	240.85	255.19	250.00	255.82	0.001182	6.39	2881.39	311.27	0.37
Reach	3214.96	10-yr	24800.00	240.85	257.31	251.24	258.05	0.001111	6.95	3623.02	394.40	0.37
Reach	3214.96	25-yr	33000.00	240.85	259.66	252.64	260.53	0.001029	7.54	4547.50	421.82	0.37
Reach	3214.96	50-yr	38800.00	240.85	261.20	253.56	262.14	0.001004	7.87	5161.41	434.17	0.37
Reach	3214.96	100-yr	44400.00	240.85	262.50	254.41	263.52	0.000993	8.19	5706.14	481.42	0.37
Reach	3214.96	500-yr	72000.00	240.85	267.45	258.09	268.87	0.000978	9.80	7928.45	791.36	0.38
Reach	2946.06	2-yr	9400.00	241.00	250.34	247.81	251.26	0.002678	7.69	1222.63	183.73	0.53
Reach	2946.06	5-yr	18400.00	241.00	253.87	250.47	255.26	0.003065	9.48	1941.28	235.53	0.58
Reach	2946.06	10-yr	24800.00	241.00	255.93	252.13	257.51	0.002892	10.12	2451.77	258.09	0.58
Reach	2946.06	25-yr	33000.00	241.00	258.22	254.15	260.02	0.002665	10.78	3062.52	275.28	0.57
Reach	2946.06	50-yr	38800.00	241.00	259.70	255.23	261.63	0.002620	11.14	3482.82	294.11	0.57
Reach	2946.06	100-yr	44400.00	241.00	260.95	256.17	263.00	0.002699	11.48	3866.99	322.35	0.58
Reach	2946.06	500-yr	72000.00	241.00	265.66	260.34	268.36	0.002398	13.22	5616.95	906.68	0.58
Reach	2687.305	2-yr	9400.00	241.00	249.85	246.88	250.59	0.002131	6.93	1355.58	201.90	0.47
Reach	2687.305	5-yr	18400.00	241.00	253.35	249.45	254.53	0.002206	8.70	2114.50	229.12	0.50
Reach	2687.305	10-yr	24800.00	241.00	255.40	250.99	256.81	0.002184	9.54	2599.30	242.99	0.51
Reach	2687.305	25-yr	33000.00	241.00	257.67	252.68	259.35	0.002222	10.40	3172.29	262.58	0.53
Reach	2687.305	50-yr	38800.00	241.00	259.12	253.77	260.95	0.002407	10.86	3571.56	293.57	0.55
Reach	2687.305	100-yr	44400.00	241.00	260.30	254.75	262.28	0.002722	11.27	3938.21	336.10	0.58
Reach	2687.305	500-yr	72000.00	241.00	265.61	259.30	267.51	0.002288	11.24	7037.38	821.69	0.54
Reach	2538.912	2-yr	9400.00	241.00	249.61	246.56	250.27	0.001875	6.53	1439.10	212.66	0.44
Reach	2538.912	5-yr	18400.00	241.00	253.12	248.93	254.19	0.001891	8.31	2213.04	227.85	0.47
Reach	2538.912	10-yr	24800.00	241.00	255.16	250.34	256.49	0.001897	9.23	2687.29	236.36	0.48
Reach	2538.912	25-yr	33000.00	241.00	257.40	251.99	259.01	0.002131	10.18	3242.18	268.48	0.52
Reach	2538.912	50-yr	38800.00	241.00	258.82	253.05	260.58	0.002336	10.64	3647.96	303.25	0.54
Reach	2538.912	100-yr	44400.00	241.00	259.98	254.00	261.88	0.002332	11.08	4019.38	339.46	0.55
Reach	2538.912	500-yr	72000.00	241.00	264.76	258.84	267.13	0.002082	12.56	6410.08	684.37	0.54
Reach	2329.127	2-yr	9400.00	241.00	248.81	246.59	249.75	0.002948	7.80	1205.29	191.60	0.55
Reach	2329.127	5-yr	18400.00	241.00	252.18	249.13	253.65	0.003216	9.70	1896.70	231.38	0.60
Reach	2329.127	10-yr	24800.00	241.00	254.32	250.66	255.96	0.003068	10.25	2418.52	261.97	0.59
Reach	2329.127	25-yr	33000.00	241.00	256.69	252.60	258.48	0.002844	10.72	3079.22	294.95	0.58
Reach	2329.127	50-yr	38800.00	241.00	258.15	253.79	260.03	0.002724	11.02	3522.07	325.24	0.58
Reach	2329.127	100-yr	44400.00	241.00	259.33	254.79	261.34	0.002734	11.38	3902.12	347.34	0.58
Reach	2329.127	500-yr	72000.00	241.00	264.43	258.81	266.66	0.002055	12.20	6711.73	698.16	0.53
Reach	2143.208	2-yr	9400.00	241.00	247.46	246.30	248.89	0.005328	9.60	979.58	177.41	0.72
Reach	2143.208	5-yr	18400.00	241.00	249.85	248.93	252.47	0.006501	13.00	1415.18	187.65	0.83

HEC-RAS Results - Proposed Scenario 1

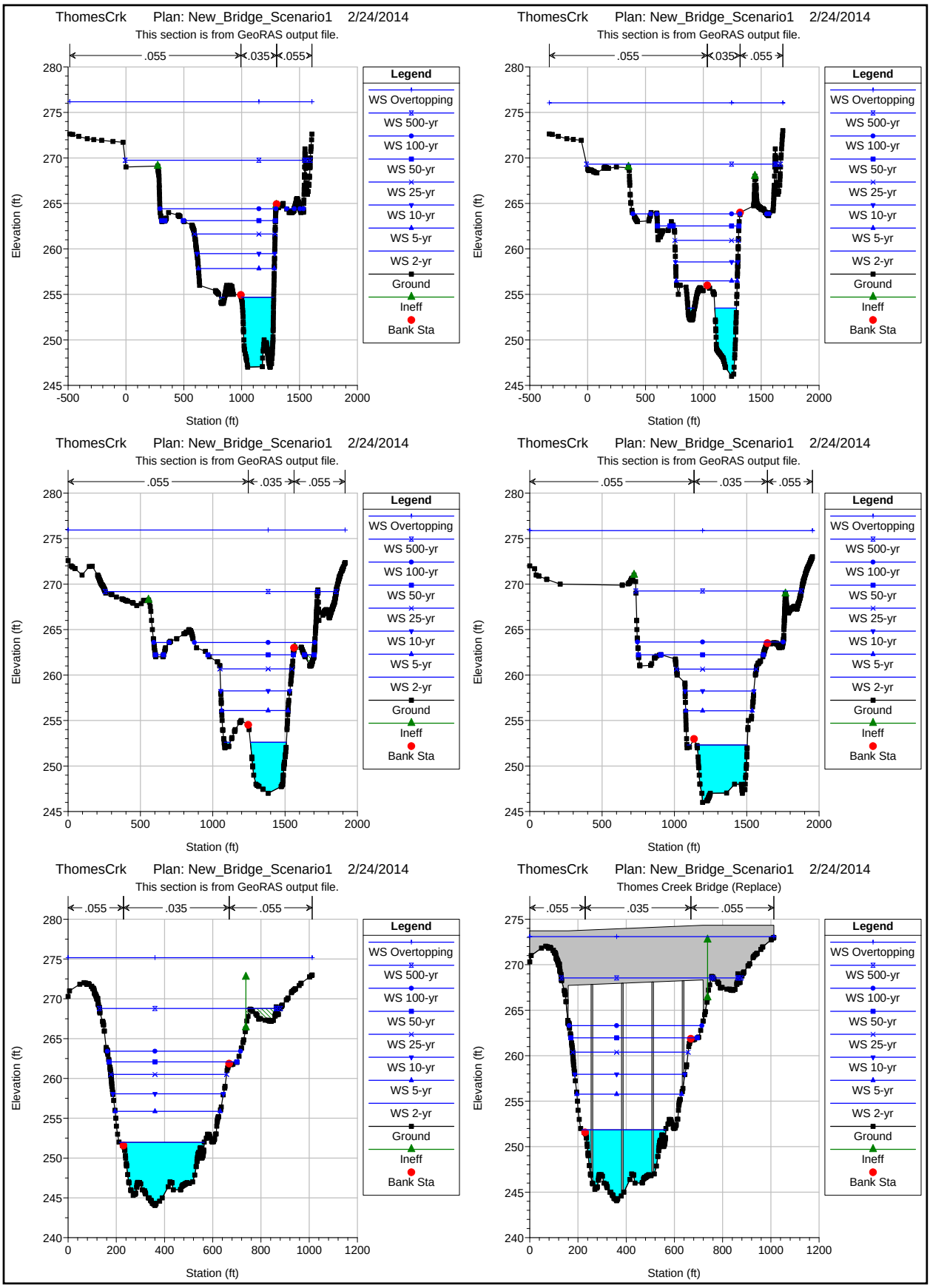
HEC-RAS Plan: New_Bridge_S River: ThomesCr Reach: Reach (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach	2143.208	10-yr	24800.00	241.00	251.21	250.57	254.59	0.007479	14.74	1682.52	205.31	0.91
Reach	2143.208	25-yr	33000.00	241.00	252.72	252.51	256.91	0.008409	16.43	2008.68	227.58	0.97
Reach	2143.208	50-yr	38800.00	241.00	253.70	253.70	258.37	0.008797	17.33	2239.22	242.40	1.00
Reach	2143.208	100-yr	44400.00	241.00	254.75	254.75	259.64	0.008642	17.75	2500.95	257.72	1.00
Reach	2143.208	500-yr	72000.00	241.00	258.84	258.84	264.85	0.007768	19.69	3692.68	339.16	0.99
Reach	1760	2-yr	9400.00	237.09	246.87	244.34	247.45	0.002047	6.13	1532.53	264.86	0.45
Reach	1760	5-yr	18400.00	237.09	249.18	246.36	250.31	0.002686	8.53	2158.11	278.28	0.54
Reach	1760	10-yr	24800.00	237.09	250.49	247.57	251.98	0.003038	9.80	2529.75	290.06	0.58
Reach	1760	25-yr	33000.00	237.09	251.94	248.98	253.87	0.003375	11.14	2962.04	303.26	0.63
Reach	1760	50-yr	38800.00	237.09	252.77	249.92	255.03	0.003647	12.06	3215.93	309.56	0.66
Reach	1760	100-yr	44400.00	237.09	253.60	250.77	256.14	0.003768	12.78	3475.18	314.36	0.68
Reach	1760	500-yr	72000.00	237.09	256.65	254.53	260.61	0.005136	15.96	4510.25	368.83	0.80
Reach	260	2-yr	9400.00	236.51	242.26	241.38	242.87	0.005000	6.26	1501.36	497.17	0.63
Reach	260	5-yr	18400.00	236.51	243.83	242.71	244.83	0.005009	7.99	2301.99	528.58	0.67
Reach	260	10-yr	24800.00	236.51	244.79	243.54	245.99	0.004994	8.79	2821.88	560.61	0.69
Reach	260	25-yr	33000.00	236.51	245.95	244.46	247.30	0.005001	9.34	3531.51	640.78	0.70
Reach	260	50-yr	38800.00	236.51	246.55	245.18	248.07	0.005001	9.89	3922.80	653.52	0.71
Reach	260	100-yr	44400.00	236.51	247.32	245.71	248.85	0.005006	9.91	4478.53	744.32	0.71
Reach	260	500-yr	72000.00	236.51	249.40	247.92	251.60	0.005006	11.91	6043.81	762.09	0.75

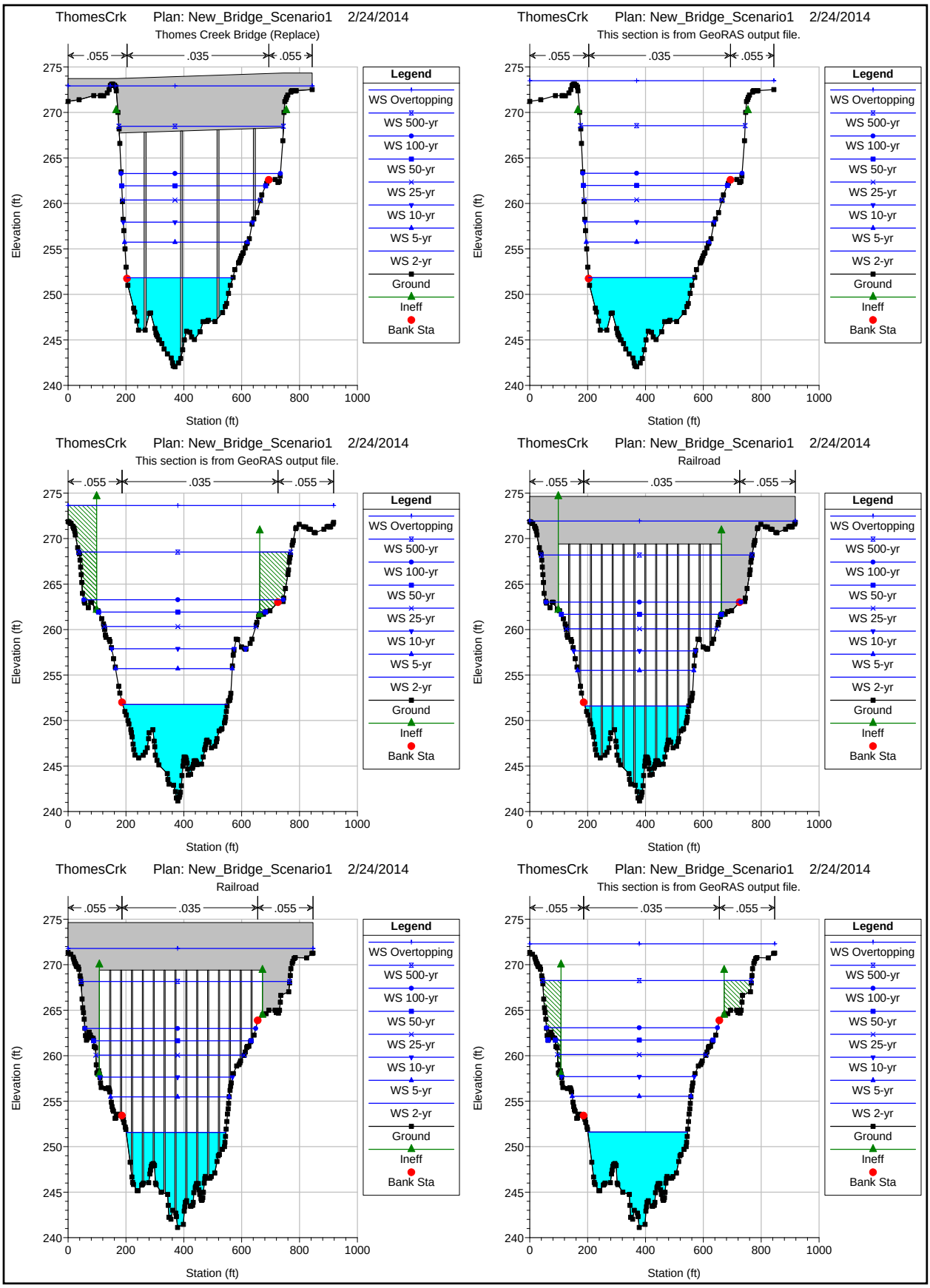
Cross Sections - Proposed Scenario 1 (Sheet 1 of 5)



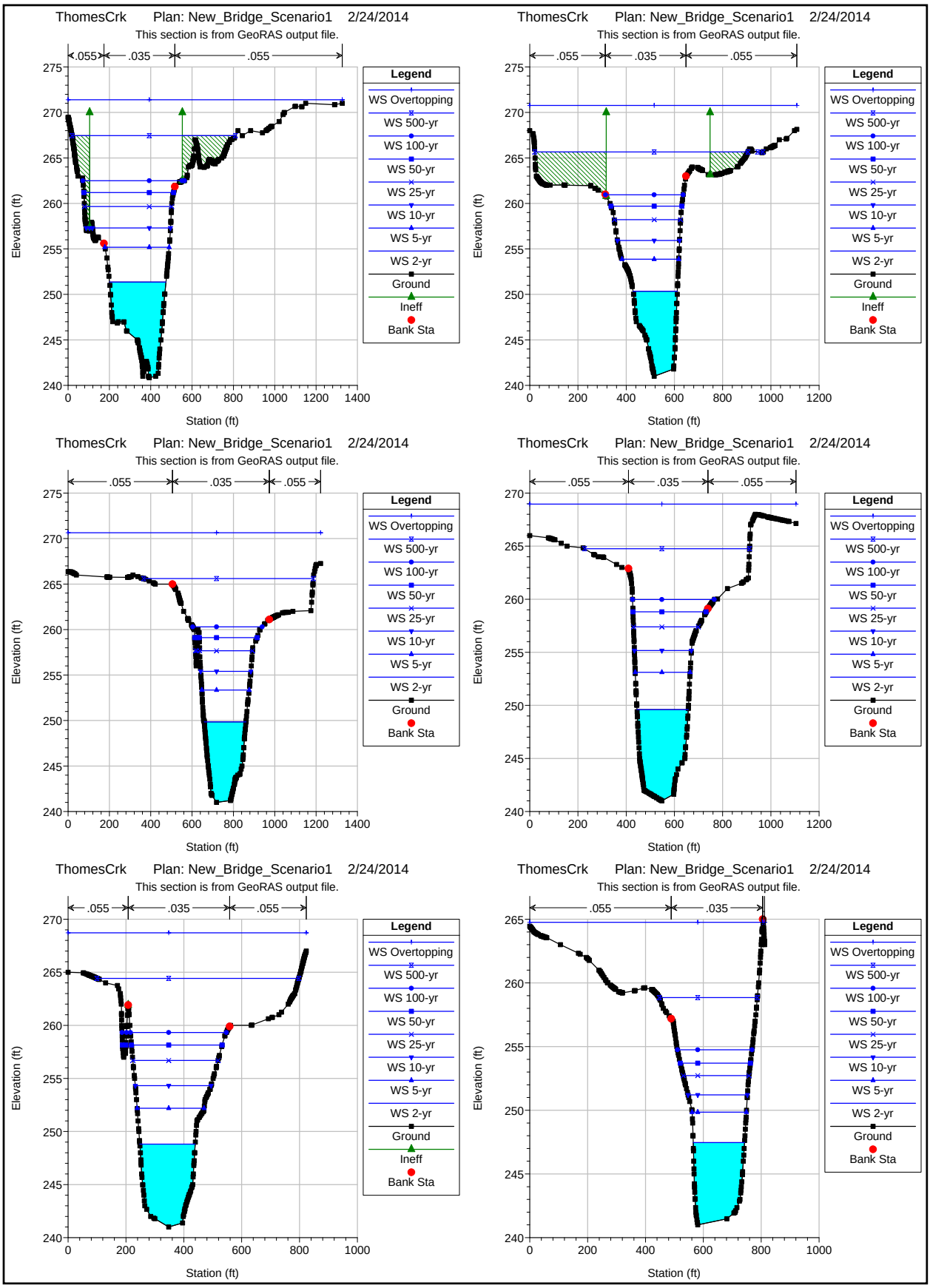
Cross Sections - Proposed Scenario 1 (Sheet 2 of 5)



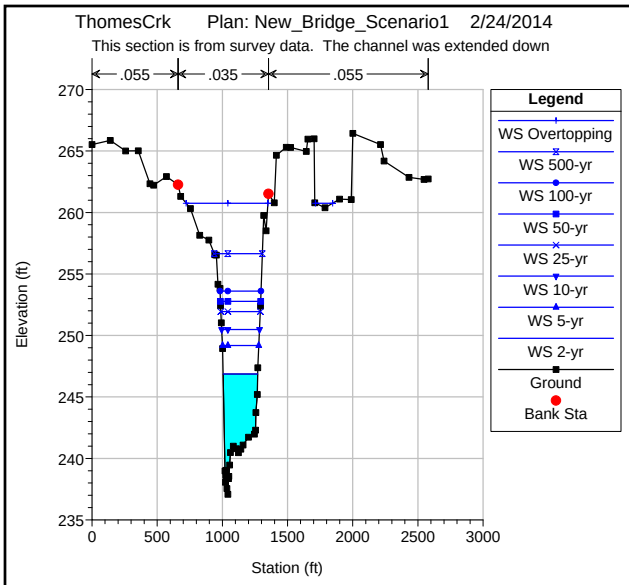
Cross Sections - Proposed Scenario 1 (Sheet 3 of 5)

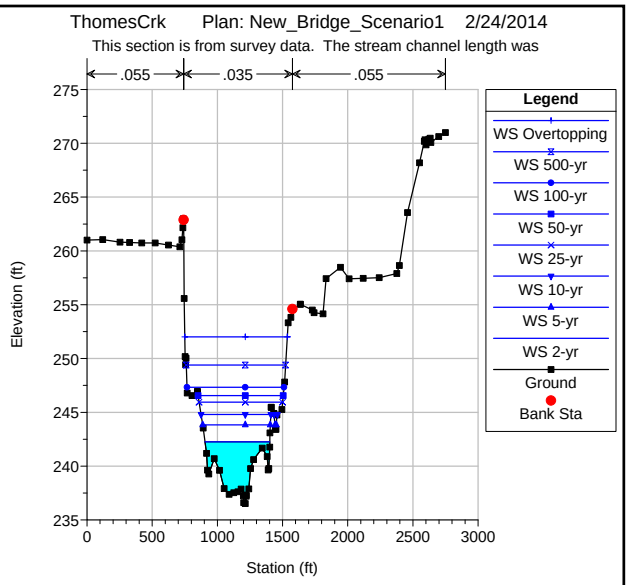


Cross Sections - Proposed Scenario 1 (Sheet 4 of 5)



Cross Sections - Proposed Scenario 1 (Sheet 5 of 5)





Scour Results for 100-Year Peak Flow and D50 = 2.86

Contraction Scour

		Left	Channel	Right
Input Data				
	Average Depth (ft):	3.66	12.62	0.27
	Approach Velocity (ft/s):	1.82	6.52	0.32
	Br Average Depth (ft):	7.30	14.64	1.21
	BR Opening Flow (cfs):	1603.98	42739.66	56.36
	BR Top WD (ft):	65.93	410.49	45.89
	Grain Size D50 (mm):	2.86	2.86	2.86
	Approach Flow (cfs):	2596.45	41794.32	9.22
	Approach Top WD (ft):	390.48	508.10	108.13
	K1 Coefficient:	0.590	0.640	0.590
Results				
	Scour Depth Ys (ft):	0.00	0.11	0.00
	Critical Velocity (ft/s):	2.93	3.60	1.90
	Equation:	Clear	Live	Clear

Pier Scour

All piers have the same scour depth

Input Data		
	Pier Shape:	Circulare cylinder
	Pier Width (ft):	7.00
	Grain Size D50 (mm):	2.86000
	Depth Upstream (ft):	19.03
	Velocity Upstream (ft/s):	7.53
	Projected Width (ft):	7.00
	Pier shape Coeff:	1.00
Results		
	Scour Depth Ys (ft):	12.00
	Froude #:	0.30
	Equation:	Froehlich's equation

Combined Scour Depths

Pier Scour + Contraction Scour (ft):

Channel:	12.11

Scour Results for 100-Year Peak Flow and D50 = 1.86

Contraction Scour

		Left	Channel	Right
Input Data				
	Average Depth (ft):	3.66	12.62	0.27
	Approach Velocity (ft/s):	1.82	6.52	0.32
	Br Average Depth (ft):	7.30	14.64	1.21
	BR Opening Flow (cfs):	1603.98	42739.66	56.36
	BR Top WD (ft):	65.93	410.49	45.89
	Grain Size D50 (mm):	1.86	1.86	1.86
	Approach Flow (cfs):	2596.45	41794.32	9.22
	Approach Top WD (ft):	390.48	508.10	108.13
	K1 Coefficient:	0.590	0.640	0.590
Results				
	Scour Depth Ys (ft):	0.43	0.11	0.00
	Critical Velocity (ft/s):	2.54	3.12	1.64
	Equation:	Clear	Live	Clear

Pier Scour

All piers have the same scour depth

Input Data		
	Pier Shape:	Circulare cylinder
	Pier Width (ft):	7.00
	Grain Size D50 (mm):	1.86000
	Depth Upstream (ft):	19.03
	Velocity Upstream (ft/s):	7.53
	Projected Width (ft):	7.00
	Pier shape Coeff:	1.00
Results		
	Scour Depth Ys (ft):	12.20
	Froude #:	0.30
	Equation:	Froehlich's equation

Combined Scour Depths

Pier Scour + Contraction Scour (ft):

Channel:	12.31

Scour Results for 100-Year Peak Flow and D50 = 0.075

Contraction Scour

		Left	Channel	Right
Input Data				
	Average Depth (ft):	3.66	12.62	0.27
	Approach Velocity (ft/s):	1.82	6.52	0.32
	Br Average Depth (ft):	7.30	14.64	1.21
	BR Opening Flow (cfs):	1603.98	42739.66	56.36
	BR Top WD (ft):	65.93	410.49	45.89
	Grain Size D50 (mm):	0.075	0.075	0.075
	Approach Flow (cfs):	2596.45	41794.32	9.22
	Approach Top WD (ft):	390.48	508.10	108.13
	K1 Coefficient:	0.690	0.690	0.690
Results				
	Scour Depth Ys (ft):	0.97	0.26	0.29
	Critical Velocity (ft/s):	0.87	1.07	0.56
	Equation:	Live	Live	Clear

Pier Scour

All piers have the same scour depth

Input Data		
	Pier Shape:	Circulare cylinder
	Pier Width (ft):	7.00
	Grain Size D50 (mm):	0.07500
	Depth Upstream (ft):	19.03
	Velocity Upstream (ft/s):	7.53
	Projected Width (ft):	7.00
	Pier shape Coeff:	1.00
Results		
	Scour Depth Ys (ft):	13.94
	Froude #:	0.30
	Equation:	Froehlich's equation

Combined Scour Depths

Pier Scour + Contraction Scour (ft):

Channel:	14.21

Scour Results for 100-Year Peak Flow and D50 = 2.32

Contraction Scour

		Left	Channel	Right
Input Data				
	Average Depth (ft):	3.66	12.62	0.27
	Approach Velocity (ft/s):	1.82	6.52	0.32
	Br Average Depth (ft):	7.30	14.64	1.21
	BR Opening Flow (cfs):	1603.98	42739.66	56.36
	BR Top WD (ft):	65.93	410.49	45.89
	Grain Size D50 (mm):	2.32	2.32	2.32
	Approach Flow (cfs):	2596.45	41794.32	9.22
	Approach Top WD (ft):	390.48	508.10	108.13
	K1 Coefficient:	0.590	0.640	0.590
Results				
	Scour Depth Ys (ft):	0.00	0.11	0.00
	Critical Velocity (ft/s):	2.73	3.36	1.77
	Equation:	Clear	Live	Clear

Pier Scour

All piers have the same scour depth

Input Data		
	Pier Shape:	Circulare cylinder
	Pier Width (ft):	7.00
	Grain Size D50 (mm):	2.32000
	Depth Upstream (ft):	19.03
	Velocity Upstream (ft/s):	7.53
	Projected Width (ft):	7.00
	Pier shape Coeff:	1.00
Results		
	Scour Depth Ys (ft):	12.10
	Froude #:	0.30
	Equation:	Froehlich's equation

Combined Scour Depths

Pier Scour + Contraction Scour (ft):

Channel:	12.20

Scour Results for 500-Year Peak Flow and D50 = 2.86

Pier Scour

All piers have the same scour depth

Input Data

Pier Shape:	Group of Cylinders
Pier Width (ft):	7.00
Grain Size D50 (mm):	2.86000
Depth Upstream (ft):	24.43
Velocity Upstream (ft/s):	8.59
Projected Width (ft):	7.00
Pier shape Coeff:	1.00

Results

Scour Depth Ys (ft):	12.64
Froude #:	0.31
Equation:	Froehlich's equation

Abutment Scour

	Left	Right
Input Data		
Station at Toe (ft):	159.65	718.97
Toe Sta at appr (ft):	1065.52	1694.45
Abutment Length (ft):	332.14	183.89
Depth at Toe (ft):	5.23	5.03
K1 Shape Coef:	1.00 - Vertical abutment	
Degree of Skew (degrees):	90.00	90.00
K2 Skew Coef:	1.00	1.00
Projected Length L' (ft):	310.41	184.20
Avg Depth Obstructed Ya (ft):	8.80	3.17
Flow Obstructed Qe (cfs):	7501.55	778.34
Area Obstructed Ae (sq ft):	2922.17	583.23
Results		
Scour Depth Ys (ft):	19.22	20.37
Froude #:	0.13	0.17
Equation:	HIRE	HIRE

Scour Results for 500-Year Peak Flow and D50 = 1.86

Pier Scour

All piers have the same scour depth

Input Data

Pier Shape:	Circulare cylinder
Pier Width (ft):	7.00
Grain Size D50 (mm):	1.86000
Depth Upstream (ft):	24.43
Velocity Upstream (ft/s):	8.59
Projected Width (ft):	7.00
Pier shape Coeff:	1.00

Results

Scour Depth Ys (ft):	12.86
Froude #:	0.31
Equation:	Froehlich's equation

Abutment Scour

	Left	Right
Input Data		
Station at Toe (ft):	159.65	718.97
Toe Sta at appr (ft):	1065.52	1694.45
Abutment Length (ft):	332.14	183.89
Depth at Toe (ft):	5.23	5.03
K1 Shape Coef:	1.00 - Vertical abutment	
Degree of Skew (degrees):	90.00	90.00
K2 Skew Coef:	1.00	1.00
Projected Length L' (ft):	310.41	184.20
Avg Depth Obstructed Ya (ft):	8.80	3.17
Flow Obstructed Qe (cfs):	7501.55	778.34
Area Obstructed Ae (sq ft):	2922.17	583.23
Results		
Scour Depth Ys (ft):	19.22	20.37
Froude #:	0.13	0.17
Equation:	HIRE	HIRE

Scour Results for 500-Year Peak Flow and D50 = 0.075

Pier Scour

All piers have the same scour depth

Input Data

Pier Shape:	Circulare cylinder
Pier Width (ft):	7.00
Grain Size D50 (mm):	0.07500
Depth Upstream (ft):	24.43
Velocity Upstream (ft/s):	8.59
Projected Width (ft):	7.00
Pier shape Coeff:	1.00

Results

Scour Depth Ys (ft):	14.82
Froude #:	0.31
Equation:	Froehlich's equation

Abutment Scour

	Left	Right
Input Data		
Station at Toe (ft):	159.65	718.97
Toe Sta at appr (ft):	1065.52	1694.45
Abutment Length (ft):	332.14	183.89
Depth at Toe (ft):	5.23	5.03
K1 Shape Coef:	1.00 - Vertical abutment	
Degree of Skew (degrees):	90.00	90.00
K2 Skew Coef:	1.00	1.00
Projected Length L' (ft):	310.41	184.20
Avg Depth Obstructed Ya (ft):	8.80	3.17
Flow Obstructed Qe (cfs):	7501.55	778.34
Area Obstructed Ae (sq ft):	2922.17	583.23
Results		
Scour Depth Ys (ft):	19.22	20.37
Froude #:	0.13	0.17
Equation:	HIRE	HIRE

Scour Results for 500-Year Peak Flow and D50 = 2.32

Pier Scour

All piers have the same scour depth

Input Data

Pier Shape:	Circulare cylinder
Pier Width (ft):	7.00
Grain Size D50 (mm):	2.32000
Depth Upstream (ft):	24.43
Velocity Upstream (ft/s):	8.59
Projected Width (ft):	7.00
Pier shape Coeff:	1.00

Results

Scour Depth Ys (ft):	12.74
Froude #:	0.31
Equation:	Froehlich's equation

Abutment Scour

	Left	Right
Input Data		
Station at Toe (ft):	159.65	718.97
Toe Sta at appr (ft):	1065.52	1694.45
Abutment Length (ft):	332.14	183.89
Depth at Toe (ft):	5.23	5.03
K1 Shape Coef:	1.00 - Vertical abutment	
Degree of Skew (degrees):	90.00	90.00
K2 Skew Coef:	1.00	1.00
Projected Length L' (ft):	310.41	184.20
Avg Depth Obstructed Ya (ft):	8.80	3.17
Flow Obstructed Qe (cfs):	7501.55	778.34
Area Obstructed Ae (sq ft):	2922.17	583.23
Results		
Scour Depth Ys (ft):	19.22	20.37
Froude #:	0.13	0.17
Equation:	HIRE	HIRE

Appendix F. Electronic Files