Appendix C: Channel Assessment and Classification Technical Memorandum

TECHNICAL MEMORANDUM

Stream Assessment and Classification

Prepared for:

San Bernardino County
Flood Control District

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1 INTRODUCTION

This technical memorandum is part of the larger study for San Bernardino County Flood Control District to develop the Watershed Action Plan as required by the current San Bernardino County MS4 Permit Order No. R8-2010-0036, NPDES No. CAS 618036. It discusses stream assessment and the delineation of existing drainages.

1.1 Background

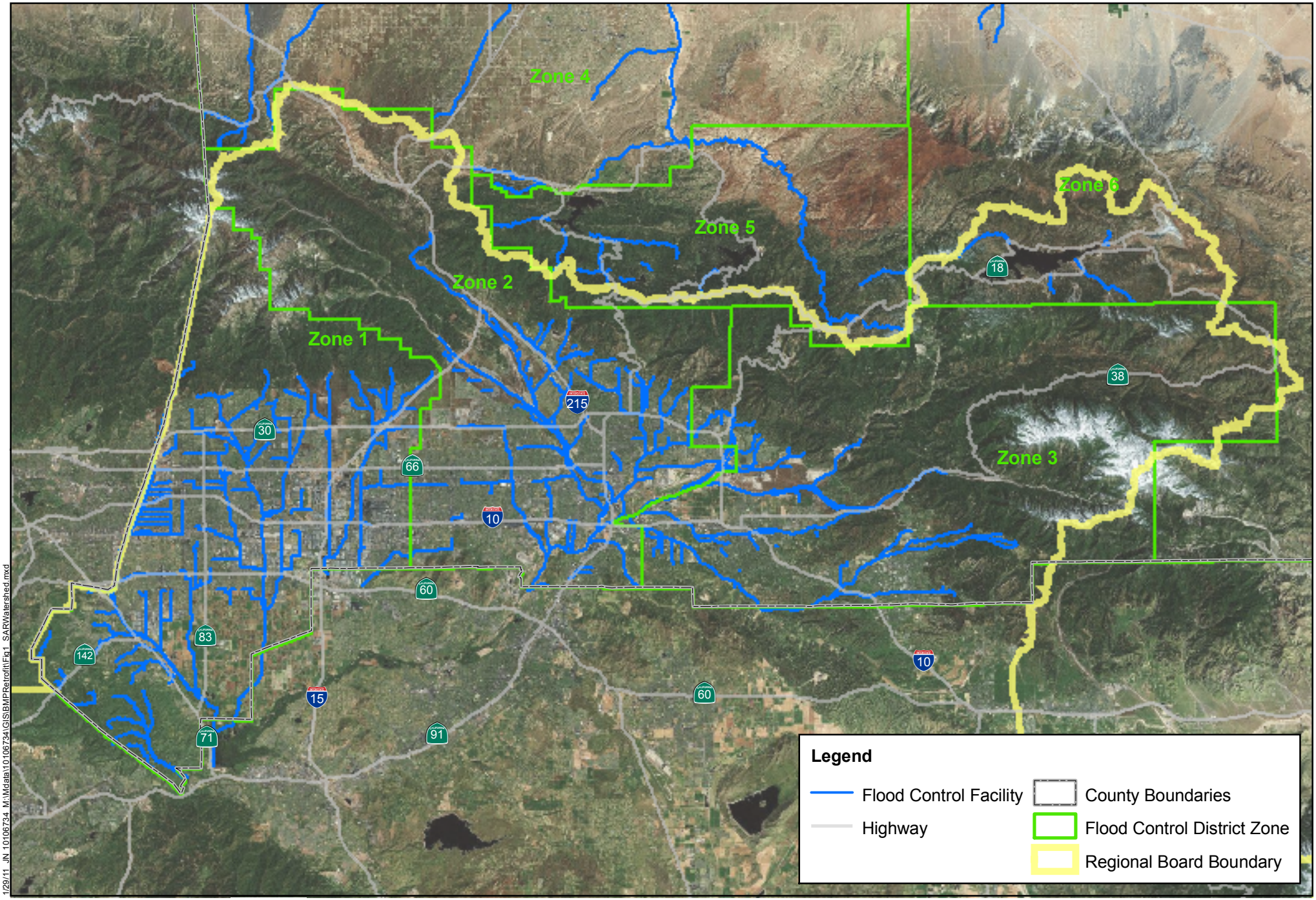
According to the County of San Bernardino (County) Stormwater Plan Proposal Summary, the County is a member of a broad, multi-stakeholder task force established to develop a regional Watershed Action Plan (WAP) that will assist its cities, water agencies, and watermasters, as well as its development and environmental communities to integrate water quality and water supply policies and encourage the capture and infiltration of stormwater into groundwater basins. The objective of the Watershed Action Plan is to improve integration of water quality, stream protection, storm water management, water conservation and re-use, and flood protection, with land use planning and development processes. The WAP builds upon the requirements of the recently adopted San Bernardino County Municipal Separate Storm Sewer System (MS4) permit for the county and its cities (permittees).

As part of the WAP, a Hydrologic Conditions of Concern (HCOC) Map/Watershed Geodatabase is required that incorporates the delineation of existing unarmored or soft-armored drainages in the permitted area that are vulnerable to geomorphology changes due to hydromodification and those channels and streams that are engineered, hardened, and maintained.

According to the MS4 permit, the permittees serve a population of approximately 1.5 million, occupying an area of approximately 620 square miles (see Figure 1: Santa Ana River Watershed). The permittees MS4 systems include an estimated 378 miles of above-ground channels and 485 miles of underground storm drain channels. The MS4 regulates urban and storm water runoff from the areas within the Santa Ana Regional Board's jurisdiction, which makes up approximately seven percent (7%) of the County. All other areas are under either the Colorado River Basin Regional Board or Lahontan Regional Board.

1.2 Purpose

The purpose of this technical memorandum is to summarize the methods used for delineating and assessing current physical conditions of the existing drainages. It will also present the results of the study.



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Sources: Caltrans; ESRI; SB DPW; SB Permittees; Microsoft Satellite Imagery

0 5 10
Miles

SAN BERNARDINO CHANNEL ASSESSMENT AND CLASSIFICATION

Figure 1: Santa Ana River Watershed - County of San Bernardino

2 METHODOLOGY

The existing drainages were delineated and assessed by the following methods: review of the San Bernardino County Flood Control District (SBCFCD) System Index, review of as-built plans and aerial photography, field investigations, and conducting Rapid Stream Risk Classifications using the method created by WEST Consultants, Inc (West) (see Appendix A).

2.1 SBCFCD System Index

The initial step of the study was to review the SBCFCD System Index (also known as the Red Book) to map out all facilities owned by the County. The SBCFCD System Index is a catalog of the County owned facilities. It provides the location and general information relating to each facility.

2.2 As-Built Plans, Aerial Photography and Field investigation

As-built plans provided by the SBCFCD were reviewed to determine the size and conveyance type of the facilities. If as-builts were not available, facilities were identified by use of aerial photography and verified by field investigation.

Based on the as-built plans and field investigations, the facilities were given one of two initial classifications:

1. Engineered, Hardened, and Maintained (EHM); or
2. Non-Engineered, Hardened, and Maintained (non-EHM).

EHM channels include channel reaches that have been approved (including CEQA review, and permitting by USACOE, RWQCB and California Dept. of Fish & Game as applicable) by June 1, 2004 for construction and stabilization to achieve design capacity.

Specifically, an EHM channel may meet either of the following criteria:

1. The channel reach has been stabilized using engineered linings with concrete, riprap, articulated concrete mat, soil cement, segmented materials (generally proprietary concrete blocks that interlock or are tied together with cable systems) on three sides, or an engineered closed conduit.
2. A channel section that has undergone an engineered stabilization project. This may include drop structures, channel bank lining (using materials from Item 1 above) and the use of geosynthetics or bio-stabilization. The project must have been designed and constructed as a 'stable' channel for the required design discharges. An engineered stable channel is designed not to overtop banks, and not scour either the bed or banks beyond the specified limits for the design event.

All channels that did not meet the EHM criteria were classified as non-EHM.

2.3 Rapid Stream Risk Classification

The next step of the study was to further assess the non-EHM facilities using the method created by WEST (see Appendix A). The Rapid Stream Risk Classification (RSRC) for Hydromodification Mapping assessed a channel segment based on 6 criteria:

1. Shear Ratio - An indicator of channel's bed shear stress sensitivity to increased discharge;
2. Entrainment Ratio - Represents the channel erosion potential;
3. Geotechnical Stability Number - measures the lateral channel stability;
4. Confinement Class – Measure of the amount of room that exists for the channel to actively move laterally and is a useful indicator of a channel's vulnerability to erosion;
5. Bank Conditions
6. Streambed Condition

Using aerials provided by Google Earth, thirty-six (36) sites were identified that had the potential for upstream development and future hydromodification. (Note four additional sites were analyzed by WEST).

All of the sites were observed from the field and were assessed using the six criteria. (See Map A for Field Visit Site Locations). A Stability Index (SI) was determined for each site, where the Stability Index is a weighted average of the six criteria. Based on the SI, the facilities were given a Risk Classification (RC) of Low, Medium, or High risk for hydromodification.

- If $0 < SI < 1/3$ then the RC = Low Risk;
- If $1/3 \leq SI < 2/3$ then the RC = Medium Risk, or
- If $2/3 \leq SI < 1.0$ then the RC = High Risk.

2.4 Final Classification

The goal of the study was to classify the County owned facilities as one of the following:

1. EHM - Engineered, Hardened, and Maintained;
2. Low Risk - Non-EHM with a low risk for Hydromodification ;
3. Medium Risk - Non-EHM with a medium risk for Hydromodification ;
4. High Risk - Non-EHM with a High risk for Hydromodification ;
5. Default High Risk – Non-EHM that was not evaluated;
6. Santa Ana River.

3 ASSESSMENT RESULTS

This section summarizes the Rapid Stream Risk Classifications for the 36 sites visited, the four sites visited by WEST Consultants and the classification of all the facilities that fall under MS4.

3.1 Rapid Stream Risk Classification

The following table summarizes the results found from the Rapid Stream Risk Classification. (See Appendix B for Calculation Summary Sheets).

Table 1: Rapid Stream Risk Classification Summary

FACILITY NAME	XSEC NO.	CLASSIFICATION
Zone 1		
Soquel Canyon Channel	1	Medium
	2	High
English Canyon	2	Medium
	3	High
Cypress Channel	1	Medium
Etiwanda Channel	1	Medium
San Antonio Channel	1	Medium
	2	High
Cucamonga Channel	1	Medium
San Sevaine Channel	1	Medium
Demens Creek Channel	1	High
24th St Storm Drain	1	High
Zone 2		
Baldridge Channel	2	High
Meecham Channel	1	Medium
	2	Medium
Cable Creek	1	Medium
Lytle Creek	1	Medium
Cajon Creek	1	Medium
	2	Medium
City Creek	WEST	High
Zone 3		
Glen Oak Creek	1	High
Live Oak Canyon	1	High
	2	High
	WEST	High
Mill Creek	1	High
Mission Channel	1	High
Morrey Arroyo	1	High

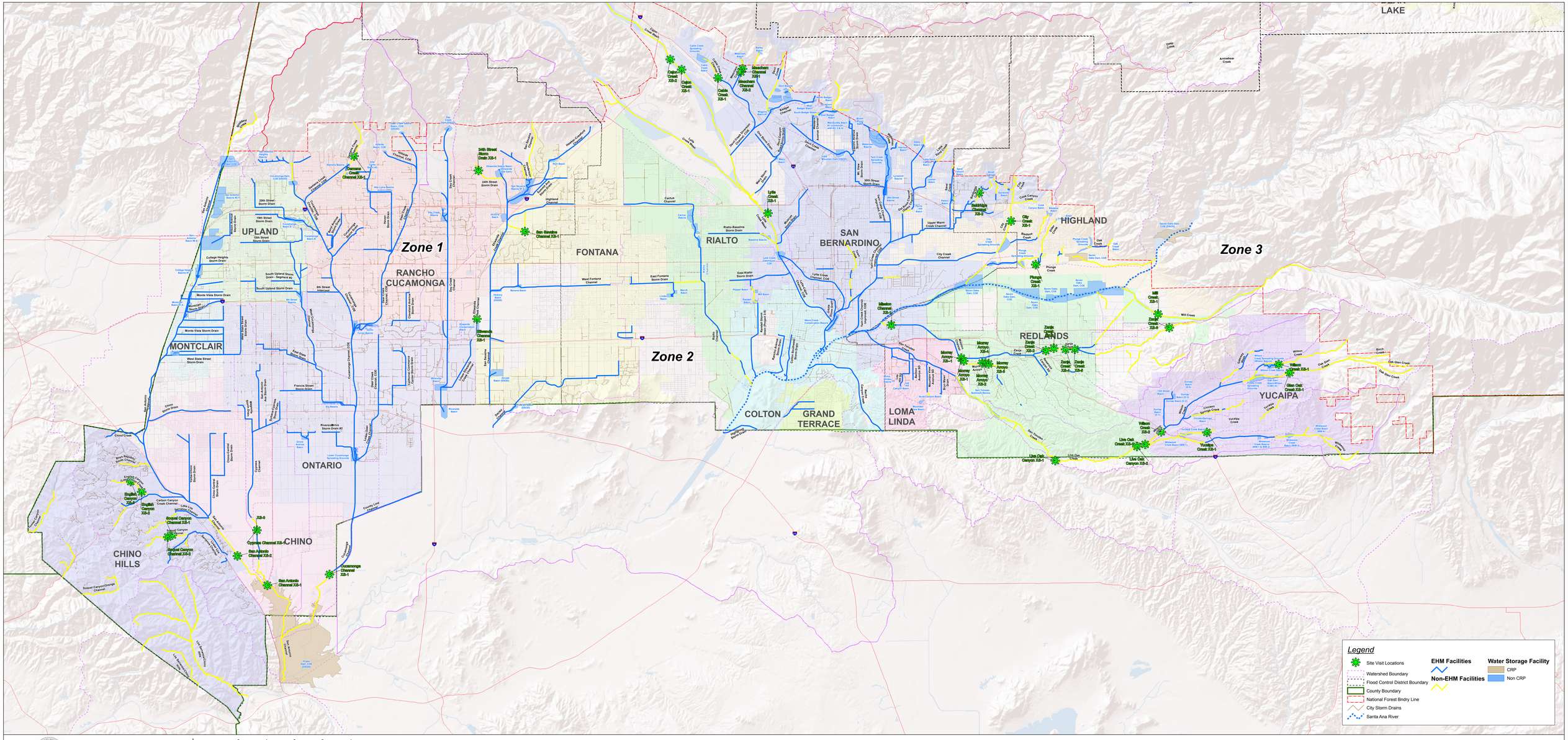
FACILITY NAME	XSEC NO.	CLASSIFICATION
Morrey Arroyo	1-1	High
	2	High
	3	High
	4	High
Wilson Creek	1	High
	2	High
Zanja Creek	2	High
	3	High
	4	High
	5	High
	6	High
Yucaipa Creek	WEST	Medium
Plunge Creek	WEST	Medium

3.2 Final Classifications

After all the facilities were classified as EHM, Non-EHM Low Risk, Non-EHM Medium Risk, Non-EHM High Risk, Non-EHM Default High Risk or the Santa Ana River, the geodatabase was updated. Facility classifications are shown on Map B – Channel Classification Map.

MAP A

Map of Field Visit Site Locations

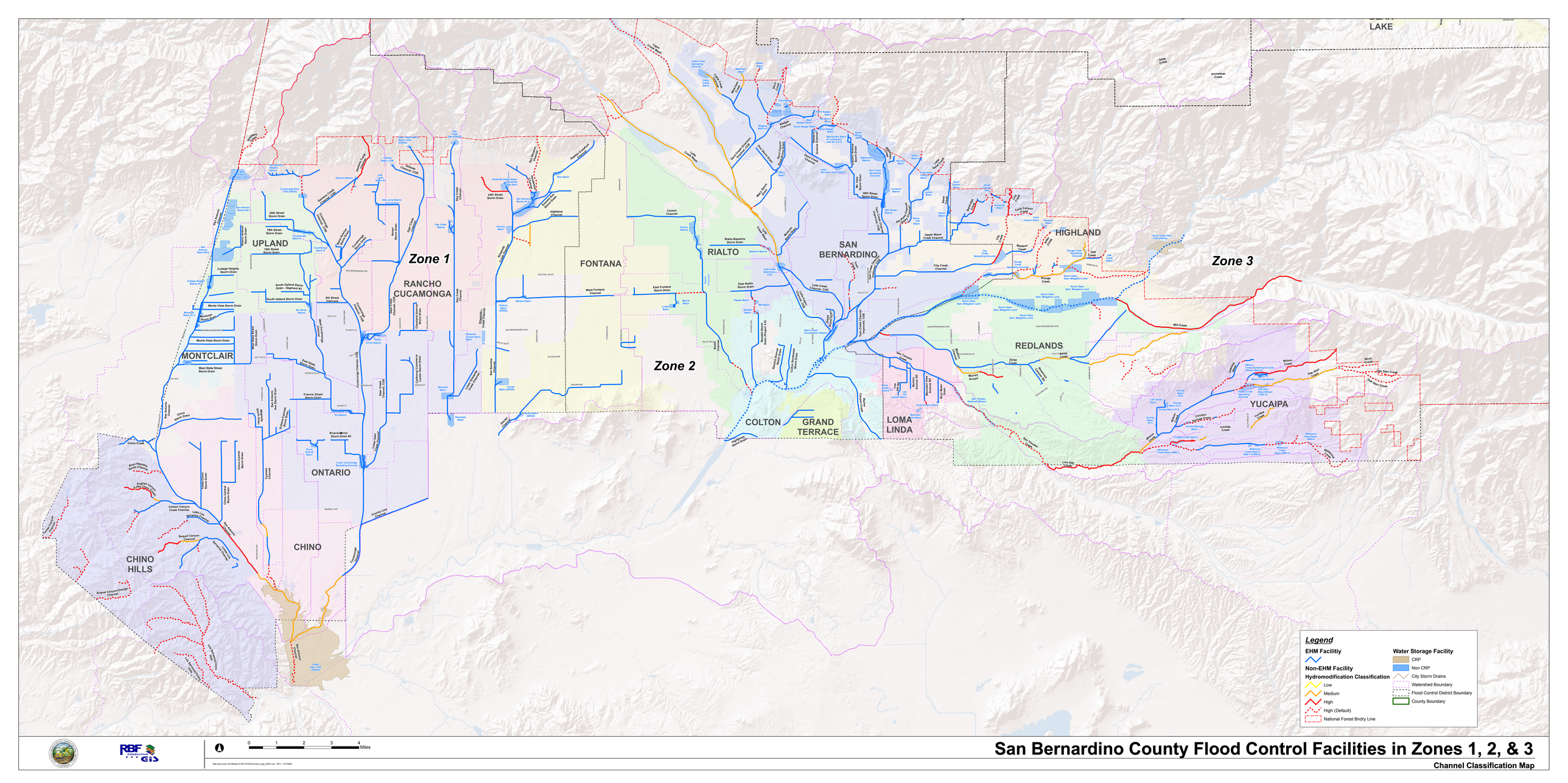


San Bernardino County Flood Control Facilities in Zones 1, 2, & 3

Stream Risk Classifcation Site Locations

MAP B

Channel Classification Map



San Bernardino County Flood Control Facilities in Zones 1, 2, & 3

Channel Classification Map

APPENDIX A

Rapid Stream Risk Classification for Hydromodification Mapping
By WEST Consultants, Inc.

Rapid Stream Risk Classification for Hydromodification Mapping

Stream Classification Methodology

1. Primary Criteria

1.1. Shear Ratio

Shear ratio SR is used as an indicator of a channel's bed shear stress sensitivity to increased discharge. The bed shear stress is first evaluated for bankfull discharge using the normal depth approximation for a given channel slope. The discharge is then doubled and the corresponding channel shear stress evaluated for a given distribution of flow conveyance between the main channel and the overbanks. The ratio of the increased shear stress to the bankfull shear stress is between 1.0 and 1.5 (can be proven theoretically for a rectangular shape). The lower range (SR from 1.0 to 1.3) is considered a medium-risk classification, while the upper range (SR from 1.3 to 1.5) is considered a high-risk classification. A low-risk classification applies only if the stream meets the criteria for a low-risk channel (aggrading channels, channels with continuous hardened beds and banks engineered to withstand erosive forces).

The approach adopted here provides a much better indicator of the channel's shear stress sensitivity to increased discharge than Rosgen's entrenchment ratio because the latter does not account for the actual distribution of flow conveyance between the main channel and the overbanks. The shear ratio methodology proposed here directly evaluates bed shear stress based on the geometry of a cross section (depth). The procedure can be easily carried out using the uniform flow option in HEC-RAS (Figure 1).

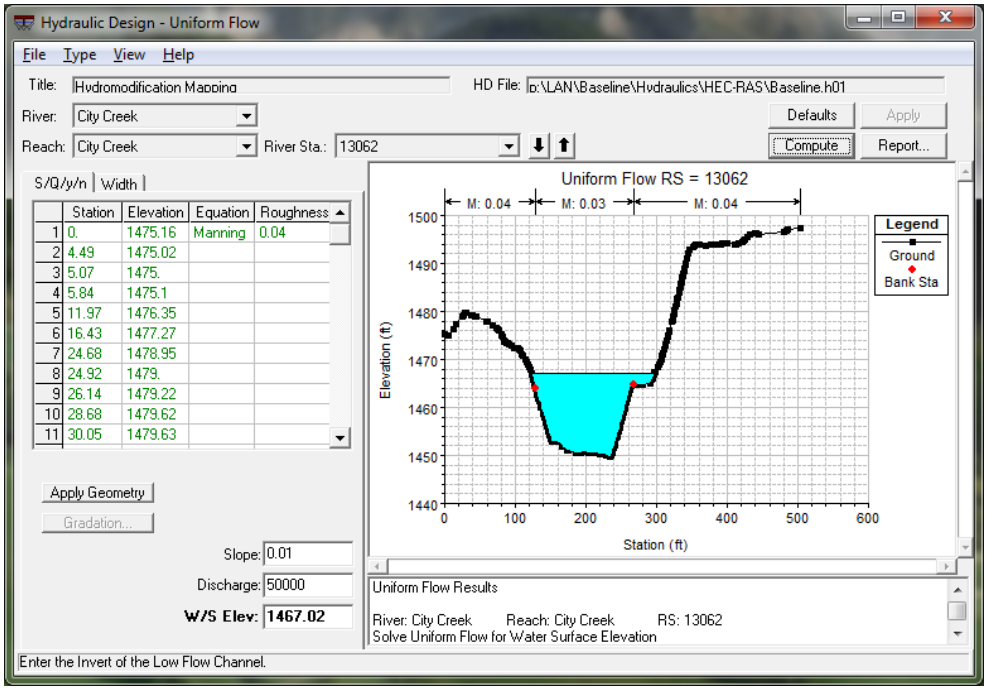


Figure 1. HEC-RAS Uniform Flow Module.

1.2. Entrainment Ratio

Entrainment ratio ER is the ratio between bankfull shear stress τ_o and critical shear stress τ_{cr} for a given grain size in the streambed. It represents the channel erosion potential. The procedure is to find bankfull shear stress and compare it to the critical shear stress that will entrain the median bed sediment size (D_{50}). If the bankfull shear stress is calculated as the total shear stress acting on the entire channel boundary (from a simple force balance), the incipient motion analysis for sand-bed channels usually shows that all particles in the bed material are capable of being moved (i.e. ER >> 1) for even very small discharges. Therefore, only the shear stress acting on individual particles in the streambed should be considered. An equation based on the vertical velocity profile is proposed here to find the bankfull shear stress (Mussetter et al., 1994):

$$\tau_o = \frac{\rho V^2}{\left[5.75 log\left(12.27 \frac{H_o}{k_s}\right)\right]^2}$$

where V = average channel velocity; H_o = bankfull depth; k_s = absolute roughness of the bed material (here approximated by $4D_{50}$); and ρ = water density. The critical shear stress is calculated as:

$$\tau_{cr} = (\gamma_s - \gamma) D_{50} \theta_{cr}$$

where γ_s and γ = specific weights of sediment and water, respectively; and θ_{cr} = dimensionless shear stress (Shields number) ≈1.9 for sand-bed channels carrying bankfull flow (Parker, 2004).

Based on this approach, a medium-risk classification is proposed for ER < 1.0, while a high-risk classification is proposed for ER ≥ 1.0. A low-risk classification applies only if the reach is aggrading or has a continuously hardened bed.

1.3. Geotechnical Stability Number

The first two criteria are mainly pertinent to longitudinal (streamwise) channel stability. The third criterion is a measure of lateral channel stability. Lateral migration and widening of natural channels occurs through bank retreat resulting from fluvial erosion at the toe of the bank and subsequent mass failure. Therefore, the goal is to evaluate the geotechnical stability number (GSN), which is the ratio of the actual bank height to the critical bank height, as an indicator of the stability of channel banks. It is proposed that the critical bank height be calculated for each bank separately using the Osman and Thorne (1988) model for wedge-type failures through the toe, similar to those that have been observed in incising channels in the Southwest (Figure 2). The lower range (GSN < 1) is considered a medium-risk classification, while the upper range (GSN > 1) is considered a high-risk classification. The high risk classification is also triggered if toe or bank erosion is observed in the field. A low-risk classification applies only if the channel banks are engineered to withstand erosive forces or in the case of a wide shallow channel. The geotechnical parameters for the critical bank height should be based on in-situ soil properties (internal friction angle ϕ and cohesion C). In the absence of in-situ soil properties, the average values of C = 300 psf and ϕ = 30° can be used.

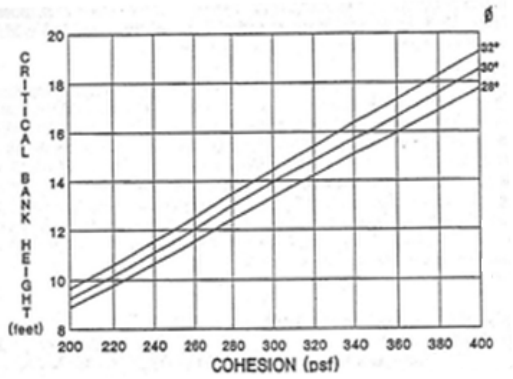


Figure 2. Critical Bank Height (Osman & Thorne, 1988).

2. Secondary Criteria

2.1. Confinement Class

Confinement is a measure of the amount of room that exists for the channel to actively move laterally. It can be a useful indicator of a channel's vulnerability to erosion. Confinement classes are assigned based on the width of the valley bottom W as a function of channel width B: a) Well confined (WC) channels are in valleys that are less than 2 channel widths wide. They usually have very limited meandering potential; b) Moderately confined (MC) channels are in valleys that are 2-4 channel widths wide. They tend to have minor amount of meandering, which commonly results in bank erosion that oscillates from side to side; c) Unconfined (UC) channels are in valleys with large floodplains, and exceed 4 channel widths wide. They are generally less influenced by hillslope processes and local sediment supply. It is proposed to classify WC and MC channels ($W/B \leq 4$) as high-risk, and UC channels ($W/B > 4$) as medium-risk. A low-risk classification applies only if the channel banks are fixed in place.

2.2. Bank Conditions

This criterion is based on detailed field observations. In general, the following factors that contribute to banks' resistance to erosion would classify as low-risk: bank stabilization in good condition, presence of bedrock, dense vegetation, highly consolidated bank material, no stratification, no signs of active erosion, toe in good condition. The opposite would classify as high-risk.

2.3. Streambed Conditions

This criterion is based on detailed field observations to assess the streambed sedimentation/erosion characteristics. A low-risk classification is triggered by the following factors: not braided or sand bed, highly armored, erosion resistant bedrock, no active headcuts, small degradation (< 1 ft), presence of downstream hard point in good condition (< 100 ft away), no widening, no aggradation, no obvious sources of sediments from bank failures of upstream sources. The opposite classifies as high-risk.

3. Stability Index

Each of the six criteria above are assigned a numerical value (low-risk = 0, medium-risk = 0.5, high-risk = 1) and a weighting factor (between 0 and 1). The weighted scores are added to find the total weighted score which determines the level of risk for future channel/reach instability (stability index). The weighting coefficients for the primary criteria should be larger than for the secondary ones because the latter are more subjective. Another option is to select weighting coefficients based on random sampling (Monte Carlo method) in order to incorporate elements of a risk-based analysis.

References

Mussetter R.A., P.F. Lagasse and M.D. Harvey, 1994, "Sediment and Erosion Design Guide," prepared for Albuquerque Metropolitan Arroyo Flood Control Authority (AMAFCA), Fort Colins, Colorado.

Osman, A.M. and C.R. Thorne, 1988, "Riverbank Stability Analysis I: Theory," *Journal of Hydraulic Engineering*, ASCE, HY2, v. 114, pp. 134-150.

Parker, G., 2004, "1D Sediment Transport Morphodynamics with Applications to Rivers and Turbidity Currents, Part 1, Chapter 3: Bankfull Characteristics of Rivers," e-book, University of Illinois at Urbana-Champaign.

APPENDIX B

Calculation Summary Sheets

Calculation Summary Sheets

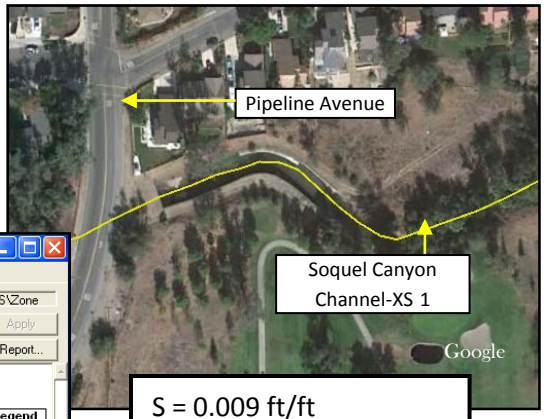
Zone 1

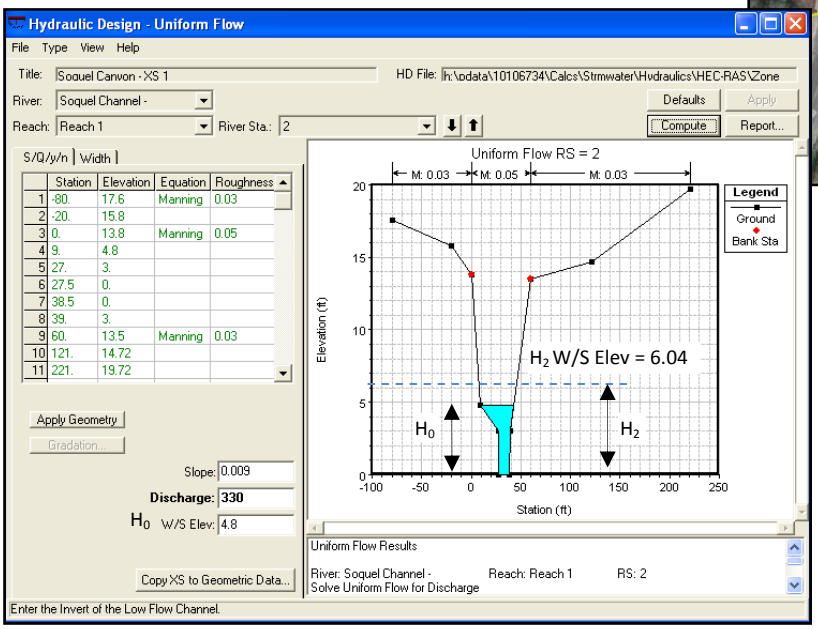
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Soquel Canyon Channel – XS 1 – Downstream of Pipeline Avenue

1) Shear Ratio SR (risk factor C_1)

$C_1 =$ { 1 *(high risk) 1.3 ≤ SR < 1.5*; 0.5 *(medium risk) 1.00 < SR ≤ 1.3*; 0 *(low risk) aggrading channel, hardened bed* }





S = 0.009 ft/ft

H_0 = 4.8 ft

Q_0 = 330 cfs

$Q_2 = 2Q_0$ = 660 cfs

H_2 = 6.04 ft

$SR = H_2/H_0$ = 1.26

C_1 = 0.5 (medium risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4 D_{50}} \right) \right]^2$$

$C_2 =$ { 1 *(high risk) ER > 1.0*; 0.5 *(medium risk) ER < 1.0*; 0 *(low risk) aggrading channel, hardened bed* }

V = 4.37fps

D_{50} = 1.5 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

ER = 0.10 < 1.0

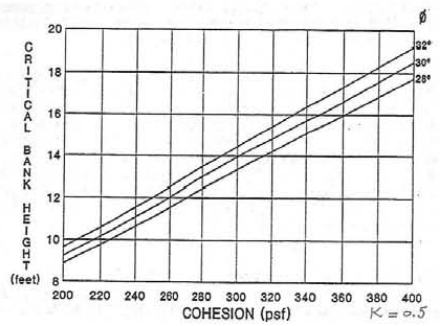
C = 399.47

C_2 = 0.5 (medium risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*
0.5 *(medium risk) GSN < 1.0*
0 *(low risk) engineered banks or wide shallow channel* }

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = .99 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*
0.5 *(medium risk) W/B > 4*
0 *(low risk) banks fixed in place* }

W = valley width, B = channel width

W = 166 ft, B = 60 ft, W/B = 2.77 ≤ 4.0, C_4 = 1.0 (high risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 1.0	C_{53} =0.0	C_{54} = 0.0	C_{55} = 1.0	C_{56} = 1.0

$$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6} = 0.67 \text{ (medium-high risk)}$$

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6) Streambed Conditions (risk factor C_6)

Braided	*Armored*	*Bedrock*	*Headcuts*	*Degradation*	*D/S Hardpoint*	*Sediment Source*
Yes = 0	*Yes = 0*	*Yes = 0*	*No = 0*	*< 1ft = 0*	*Yes = 0*	*No = 0*
No = 1	*No = 1*	*No = 1*	*Yes = 1*	*>1ft = 1*	*No = 1*	*Yes = 1*
C_{61} =0.0	C_{62} = 1.0	C_{63} =1.0	C_{54} = 0.0	C_{65} =1.0	C_{66} = 1.0	C_{67} = 0.0

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.57 (medium-high risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

SI = 2/9×(0.5+0.5+0.5) + 1/9×(1.0+0.67+0.57) = 0.58

Risk Classification RC

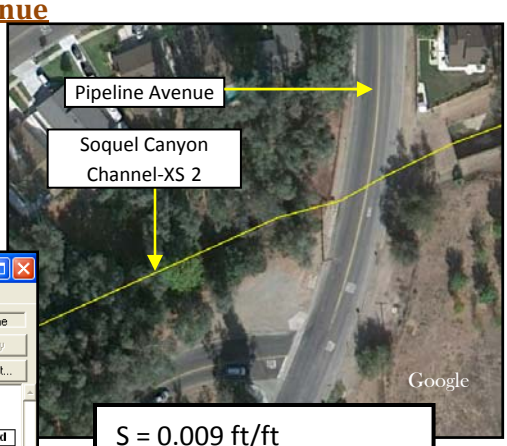
$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

SI =1/3 ≤ 0.58 < 2/3

RC = Medium

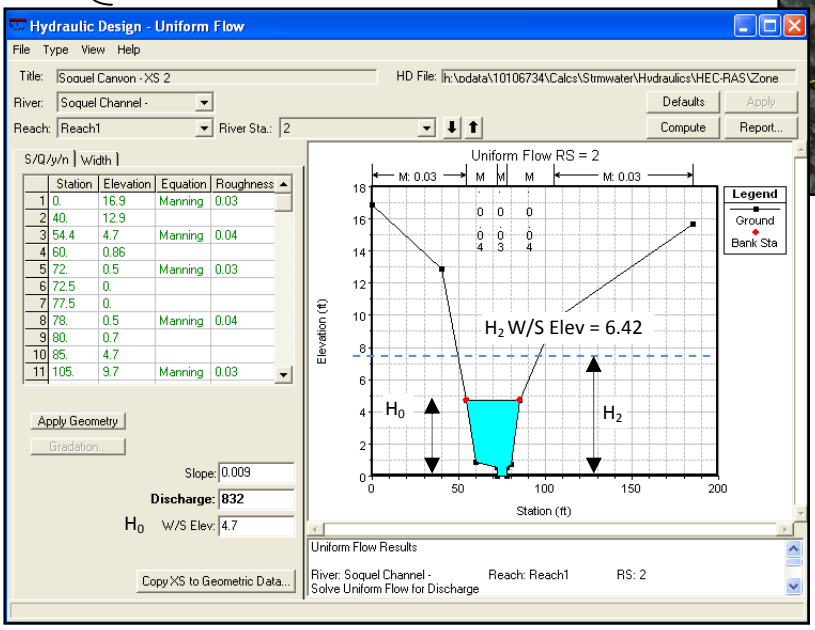
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Soquel Canyon Channel – XS 2 – Upstream of Pipeline Avenue



1) Shear Ratio SR (risk factor C_1)

$C_1 =$
- 1 *(high risk) 1.3 ≤ SR < 1.5*
- 0.5 *(medium risk) 1.00 < SR ≤ 1.3*
- 0 *(low risk) aggrading channel, hardened bed*



S = 0.009 ft/ft

H_0 = 4.7 ft

Q_0 = 832 cfs

$Q_2 = 2Q_0$ = 1664 cfs

H_2 = 6.42 ft

$SR = H_2/H_0$ = 1.37

C_1 = 1.0 (high risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4 D_{50}} \right) \right]^2$$

$C_2 =$
- 1 *(high risk) ER > 1.0*
- 0.5 *(medium risk) ER < 1.0*
- 0 *(low risk) aggrading channel, hardened bed*

V = 8.88 fps

D_{50} = 1.5 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

ER = 0.40 < 1.0

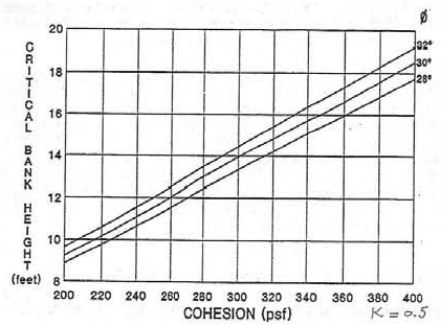
C = 397.37

C_2 = 0.5 (medium risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*; 0.5 *(medium risk) GSN < 1.0*; 0 *(low risk) engineered banks or wide shallow channel* }

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = .41 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*; 0.5 *(medium risk) W/B > 4*; 0 *(low risk) banks fixed in place* }

W = valley width, B = channel width

W = 100 ft, B = 30.6 ft, W/B = 3.27 ≤ 4.0, C_4 = 1.0 (high risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 1.0	C_{53} =0.0	C_{54} = 0.0	C_{55} = 0.0	C_{56} = 1.0

$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6}$ = *0.5 (medium risk)*

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6) Streambed Conditions (risk factor C_6)

Braided Yes = 0 No = 1	*Armored* Yes = 0 No = 1	*Bedrock* Yes = 0 No = 1	*Headcuts* No = 0 Yes = 1	*Degradation* < 1ft = 0 >1ft = 1	*D/S Hardpoint* Yes = 0 No = 1	*Sediment Source* No = 0 Yes = 1
C_{61} =0.0	C_{62} = 1.0	C_{63} =1.0	C_{54} = 0.0	C_{65} =1.0	C_{66} = 0.0	C_{67} = 1.0

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.57 (medium-high risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

SI = 2/9×(1.0+0.5+0.5) + 1/9×(1.0+0.5+0.57) = 0.67

Risk Classification RC

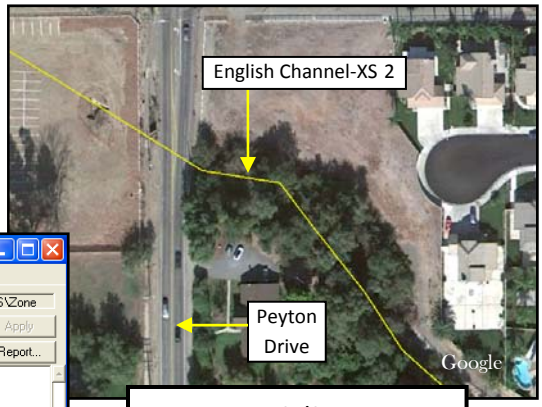
$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

SI = 2/3 ≤ 0.67 < 1

RC = High

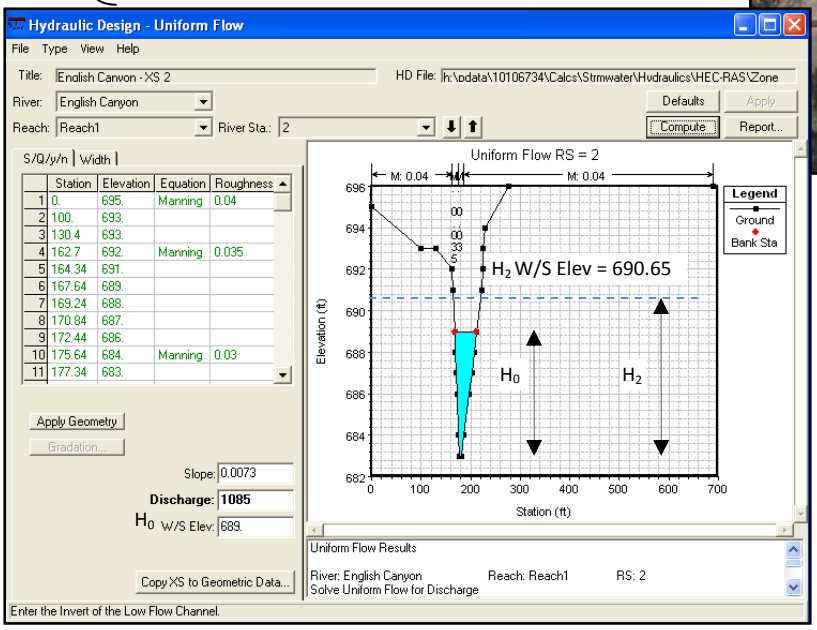
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

English Channel – XS 2 – Downstream of Peyton Drive



1) Shear Ratio SR (risk factor C_1)

$C_1 =$
- 1 *(high risk) 1.3 ≤ SR < 1.5*
- 0.5 *(medium risk) 1.00 < SR ≤ 1.3*
- 0 *(low risk) aggrading channel, hardened bed*



S = 0.0073 ft/ft

H_0 = 6.0 ft

Q_0 = 1085 cfs

$Q_2 = 2Q_0$ =2170 cfs

H_2 = 7.96 ft

$SR = H_2/H_0$ = 1.33

C_1 = 1.0 (high risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4 D_{50}} \right) \right]^2$$

$C_2 =$
- 1 *(high risk) ER > 1.0*
- 0.5 *(medium risk) ER < 1.0*
- 0 *(low risk) aggrading channel, hardened bed*

V = 7.37 fps

D_{50} = 1.5 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

ER = 0.26 < 1.0

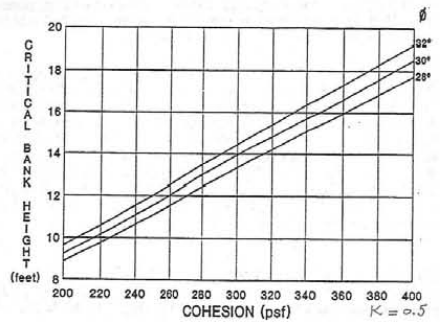
C = 422.05

C_2 = 0.5 (medium risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*; 0.5 *(medium risk) GSN < 1.0*; 0 *(low risk) engineered banks or wide shallow channel* }

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = .64 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*; 0.5 *(medium risk) W/B > 4*; 0 *(low risk) banks fixed in place* }

W = valley width, B = channel width

W = 277.54 ft, B = 61 ft, W/B = 4.55 > 4.0, C_4 = 0.5 (medium risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 1.0	C_{53} =0.0	C_{54} = 0.0	C_{55} = 1.0	C_{56} = 1.0

$$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6} = 0.67 \text{ (medium risk)}$$

RBF CONSULTING

6) Streambed Conditions (risk factor C_6)

Braided Yes = 0 No = 1	*Armored* Yes = 0 No = 1	*Bedrock* Yes = 0 No = 1	*Headcuts* No = 0 Yes = 1	*Degradation* < 1ft = 0 >1ft = 1	*D/S Hardpoint* Yes = 0 No = 1	*Sediment Source* No = 0 Yes = 1
C_{61} =0.0	C_{62} = 1.0	C_{63} =1.0	C_{54} = 0.0	C_{65} =1.0	C_{66} = 1.0	C_{67} = 1.0

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.71 (medium-high risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

SI = 2/9×(1.0+0.5+0.5) + 1/9×(0.5+0.67+0.71) = 0.65

Risk Classification RC

$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

SI = 1/3 ≤ 0.65 < 2/3

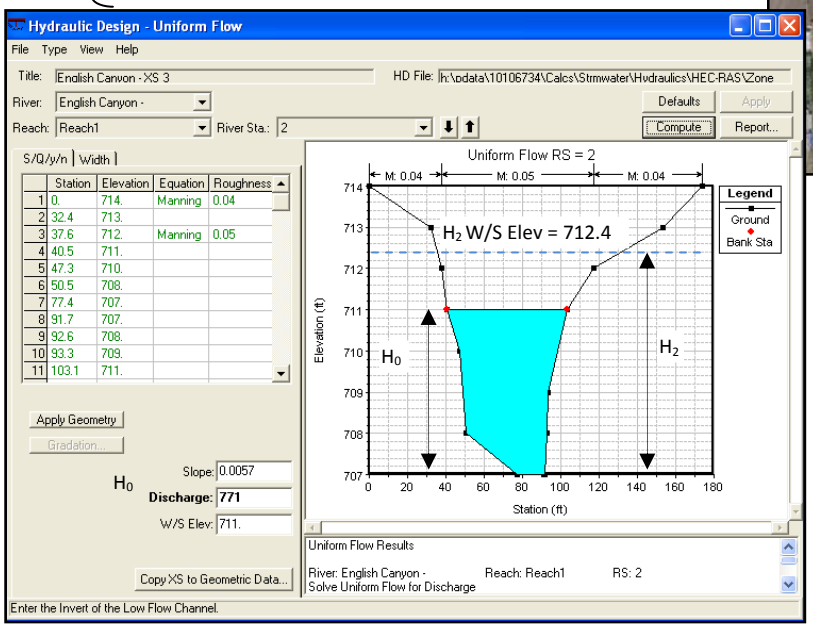
RC = Medium

RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

English Channel – XS 3 – Upstream of Peyton Drive

1) Shear Ratio SR (risk factor C_1)

$C_1 =$
- 1 *(high risk) 1.3 ≤ SR < 1.5*
- 0.5 *(medium risk) 1.00 < SR ≤ 1.3*
- 0 *(low risk) aggrading channel, hardened bed*



S = 0.0057 ft/ft

H_0 = 4.0 ft

Q_0 = 771 cfs

$Q_2 = 2Q_0$ = 1542 cfs

H_2 = 5.57 ft

$SR = H_2/H_0$ = 1.39

C_1 = 1.0 (high risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4 D_{50}} \right) \right]^2$$

$C_2 =$
- 1 *(high risk) ER > 1.0*
- 0.5 *(medium risk) ER < 1.0*
- 0 *(low risk) aggrading channel, hardened bed*

V = 4.38 fps

D_{50} = 1.5 mm

g = 32.2 ft/s^2

Θ_{cr} = 2.9

ER = 0.07 < 1.0

C = 381.48

C_2 = 0.5 (medium risk)

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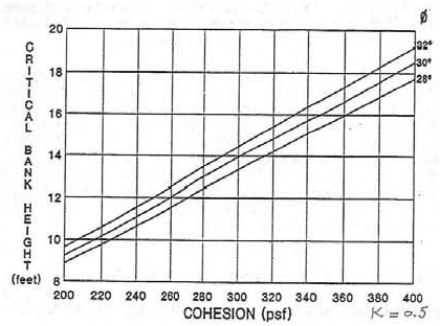
3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*; 0.5 *(medium risk) GSN < 1.0*; 0 *(low risk) engineered banks or wide shallow channel* }

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = 0.36 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*; 0.5 *(medium risk) W/B > 4*; 0 *(low risk) banks fixed in place* }

W = valley width, B = channel width

W = 173.9 ft, B = 79.6 ft, W/B = 2.18 ≤ 4.0, C_4 = 1.0 (high risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 1.0	C_{53} =0.0	C_{54} = 0.0	C_{55} = 1.0	C_{56} = 1.0

$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6}$ = *0.67 (medium risk)*

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6) Streambed Conditions (risk factor C_6)

Braided	*Armored*	*Bedrock*	*Headcuts*	*Degradation*	*D/S Hardpoint*	*Sediment Source*
Yes = 0	*Yes = 0*	*Yes = 0*	*No = 0*	*< 1ft = 0*	*Yes = 0*	*No = 0*
No = 1	*No = 1*	*No = 1*	*Yes = 1*	*>1ft = 1*	*No = 1*	*Yes = 1*
C_{61} *=0.0*	C_{62} *= 1.0*	C_{63} *=1.0*	C_{54} *= 0.0*	C_{65} *=1.0*	C_{66} *= 1.0*	C_{67} *= 1.0*

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.71 (low-medium risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

$SI = 2/9 \times (1.0+0.5+0.5) + 1/9 \times (1.0+0.67+0.71) =$ 0.71

Risk Classification RC

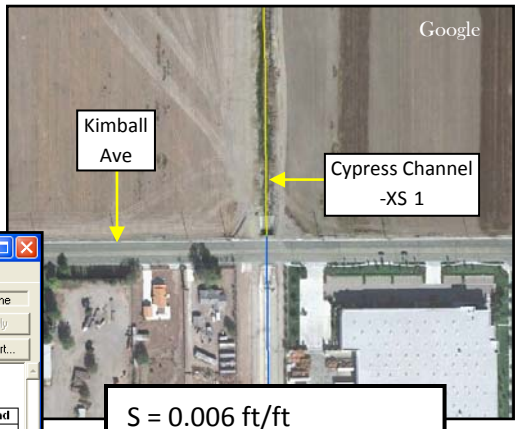
$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

$SI = 2/3 \le 0.71 < 1$

RC = High

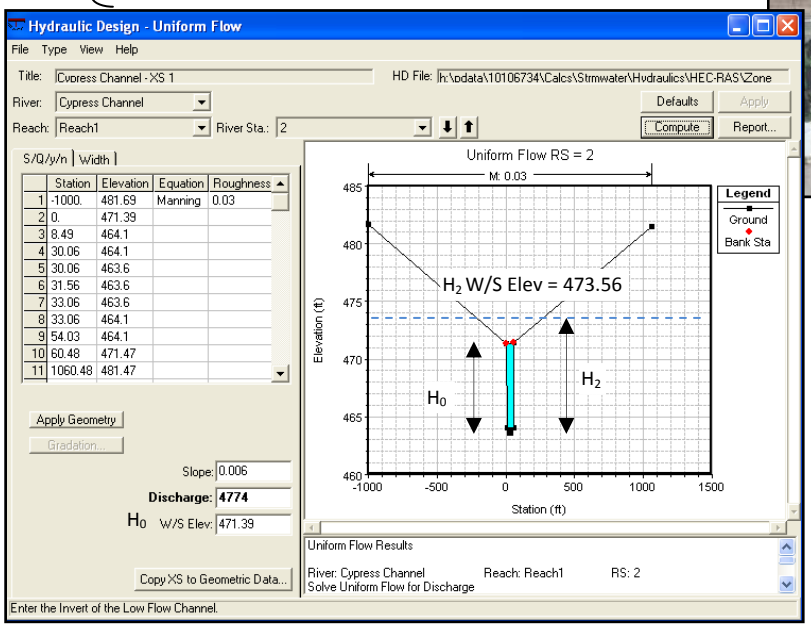
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Cypress Channel – XS 1 – Upstream of Kimball Avenue



1) Shear Ratio SR (risk factor C_1)

$C_1 =$
- 1 *(high risk) 1.3 ≤ SR < 1.5*
- 0.5 *(medium risk) 1.00 < SR ≤ 1.3*
- 0 *(low risk) aggrading channel, hardened bed*



S = 0.006 ft/ft

H_0 = 7.79 ft

Q_0 = 4774 cfs

$Q_2 = 2Q_0$ = 9548 cfs

H_2 = 9.96 ft

$SR = H_2/H_0$ = 1.28

C_1 = 0.5 (medium risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4 D_{50}} \right) \right]^2$$

$C_2 =$
- 1 *(high risk) ER > 1.0*
- 0.5 *(medium risk) ER < 1.0*
- 0 *(low risk) aggrading channel, hardened bed*

V =12.32 fps

D_{50} = 2.0 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

ER = 0.55 < 1.0

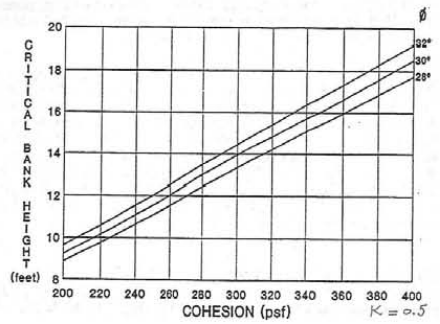
C = 419.33

C_2 = 0.5 (medium risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*; 0.5 *(medium risk) GSN < 1.0*; 0 *(low risk) engineered banks or wide shallow channel* }

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = 0.56 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*; 0.5 *(medium risk) W/B > 4*; 0 *(low risk) banks fixed in place* }

W = valley width, B = channel width

W = 500 ft, B = 60.48 ft, W/B = 8.27 > 4.0, C_4 = 0.5 (medium risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 1.0	C_{53} =1.0	C_{54} = 0.0	C_{55} = 1.0	C_{56} = 1.0

$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6}$ = *0.83 (medium-high risk)*

6) Streambed Conditions (risk factor C_6)

Braided	*Armored*	*Bedrock*	*Headcuts*	*Degradation*	*D/S Hardpoint*	*Sediment Source*
Yes = 0	*Yes = 0*	*Yes = 0*	*No = 0*	*< 1ft = 0*	*Yes = 0*	*No = 0*
No = 1	*No = 1*	*No = 1*	*Yes = 1*	*>1ft = 1*	*No = 1*	*Yes = 1*
C_{61} *=0.0*	C_{62} *= 1.0*	C_{63} *=1.0*	C_{54} *= 0.0*	C_{65} *=1.0*	C_{66} *= 0.0*	C_{67} *= 1.0*

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.57 (medium-high risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

$SI = 2/9 \times (0.5+0.5+0.5) + 1/9 \times (0.5+0.83+0.57) =$ 0.54

Risk Classification RC

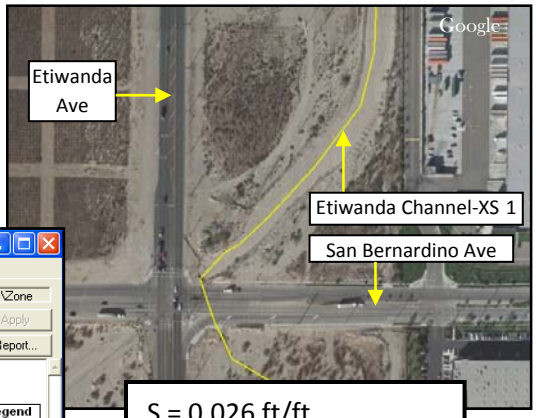
$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

$SI = 1/3 \le 0.54 < 2/3$

RC = Medium

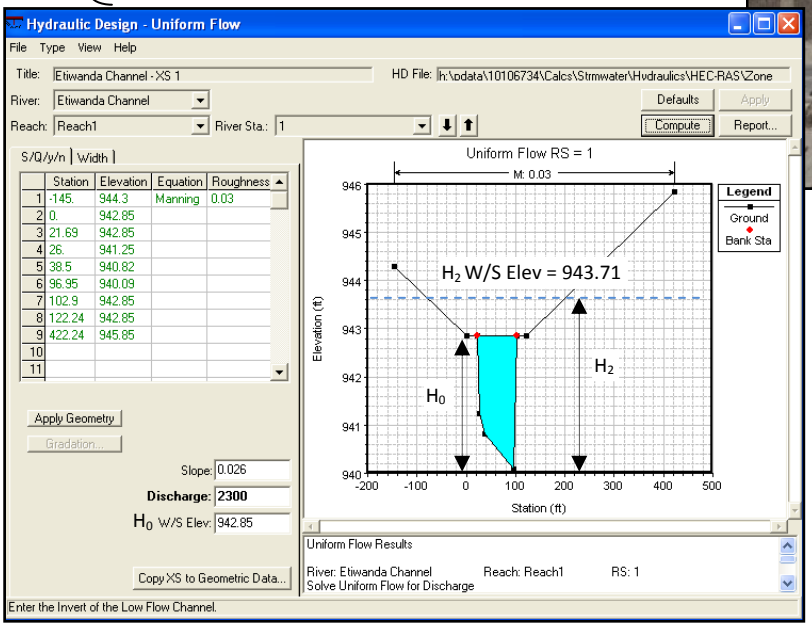
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Etiwanda Channel – XS 1 – Upstream of San Bernardino Avenue



1) Shear Ratio SR (risk factor C_1)

$C_1 =$
- 1 *(high risk) 1.3 ≤ SR < 1.5*
- 0.5 *(medium risk) 1.00 < SR ≤ 1.3*
- 0 *(low risk) aggrading channel, hardened bed*



S = 0.026 ft/ft

H_0 = 2.76 ft

Q_0 = 2300 cfs

$Q_2 = 2Q_0$ = 4600 cfs

H_2 = 3.62 ft

$SR = H_2/H_0$ = 1.31

C_1 = 1.0 (high risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4 D_{50}} \right) \right]^2$$

$C_2 =$
- 1 *(high risk) ER > 1.0*
- 0.5 *(medium risk) ER < 1.0*
- 0 *(low risk) aggrading channel, hardened bed*

V =13.19 fps

D_{50} = 2.0 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

ER = 0.82 < 1.0

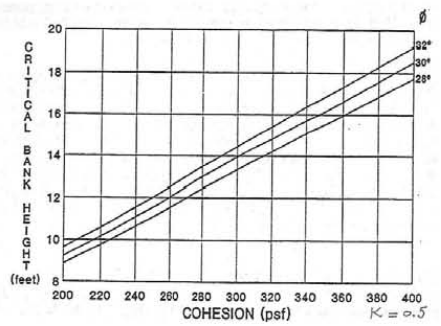
C = 319.92

C_2 = 0.5 (medium risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*; 0.5 *(medium risk) GSN < 1.0*; 0 *(low risk) engineered banks or wide shallow channel* }

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = 0.20 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*; 0.5 *(medium risk) W/B > 4*; 0 *(low risk) banks fixed in place* }

W = valley width, B = channel width

W = 620 ft, B = 81.21 ft, W/B = 7.63 > 4.0, C_4 = 0.5 (medium risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 1.0	C_{53} =1.0	C_{54} = 0.0	C_{55} = 1.0	C_{56} = 1.0

$$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6} = 0.83 \text{ (medium-high risk)}$$

6) Streambed Conditions (risk factor C_6)

Braided	*Armored*	*Bedrock*	*Headcuts*	*Degradation*	*D/S Hardpoint*	*Sediment Source*
Yes = 0	*Yes = 0*	*Yes = 0*	*No = 0*	*< 1ft = 0*	*Yes = 0*	*No = 0*
No = 1	*No = 1*	*No = 1*	*Yes = 1*	*>1ft = 1*	*No = 1*	*Yes = 1*
C_{61} *=0.0*	C_{62} *= 1.0*	C_{63} *=1.0*	C_{54} *= 0.0*	C_{65} *=0.0*	C_{66} *= 0.0*	C_{67} *= 1.0*

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.43 (low-medium risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

$SI = 2/9\times(1.0+0.5+0.5) + 1/9\times(0.5+0.83+0.43) =$ 0.64

Risk Classification RC

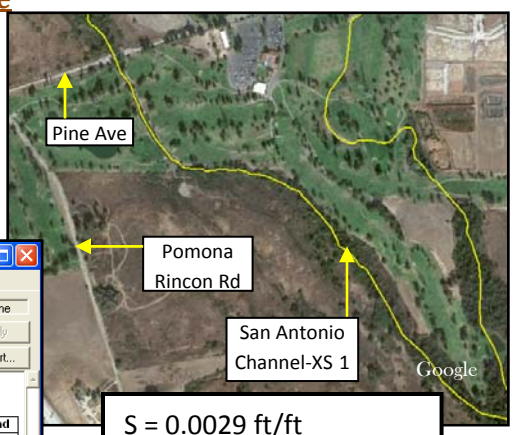
$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

$SI = 1/3 \le 0.64 < 2/3$

RC = Medium

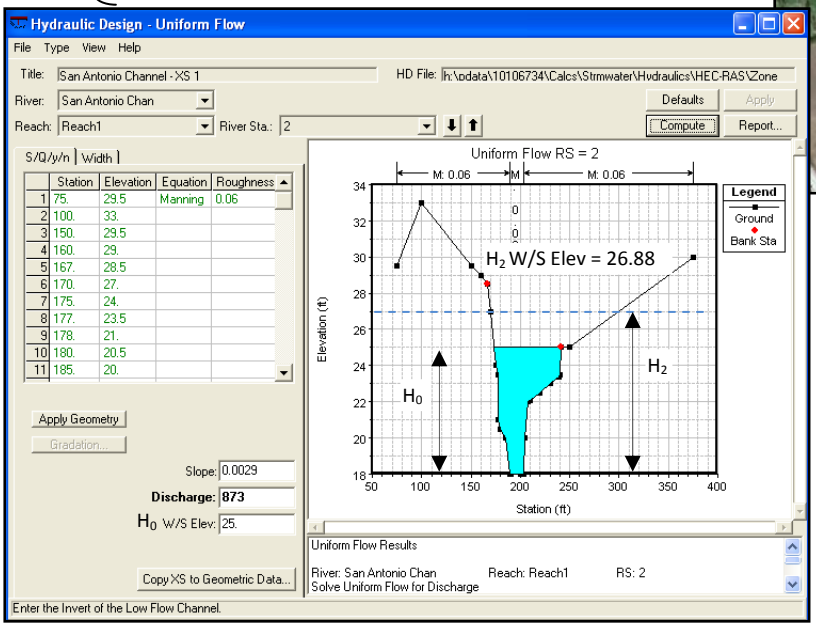
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

San Antonio Channel – XS 1 – Downstream of Pine Avenue



1) Shear Ratio SR (risk factor C_1)

$C_1 =$
- 1 *(high risk) 1.3 ≤ SR < 1.5*
- 0.5 *(medium risk) 1.00 < SR ≤ 1.3*
- 0 *(low risk) aggrading channel, hardened bed*



S = 0.0029 ft/ft

H_0 = 7.0 ft

Q_0 = 873 cfs

$Q_2 = 2Q_0$ = 1746 cfs

H_2 = 8.88 ft

$SR = H_2/H_0$ = 1.27

C_1 = 0.5 (medium risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4 D_{50}} \right) \right]^2$$

$C_2 =$
- 1 *(high risk) ER > 1.0*
- 0.5 *(medium risk) ER < 1.0*
- 0 *(low risk) aggrading channel, hardened bed*

V =3.36 fps

D_{50} = 2.0 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

ER = 0.04 < 1.0

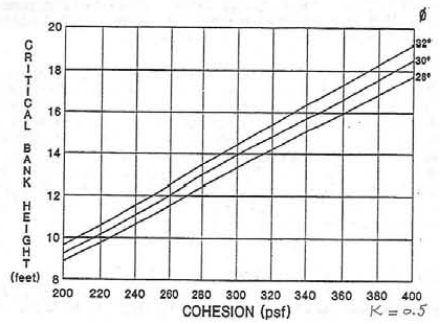
C = 408.46

C_2 = 0.5 (medium risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*; 0.5 *(medium risk) GSN < 1.0*; 0 *(low risk) engineered banks or wide shallow channel* }

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = 0.5 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*; 0.5 *(medium risk) W/B > 4*; 0 *(low risk) banks fixed in place* }

W = valley width, B = channel width

W = 520 ft, B = 31 ft, W/B = 16.77 > 4.0, C_4 = 0.5 (medium risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 1.0	C_{53} =0.0	C_{54} = 0.0	C_{55} = 1.0	C_{56} = 1.0

$$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6} = 0.67 \text{ (medium-high risk)}$$

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6) Streambed Conditions (risk factor C_6)

Braided	*Armored*	*Bedrock*	*Headcuts*	*Degradation*	*D/S Hardpoint*	*Sediment Source*
Yes = 0	*Yes = 0*	*Yes = 0*	*No = 0*	*< 1ft = 0*	*Yes = 0*	*No = 0*
No = 1	*No = 1*	*No = 1*	*Yes = 1*	*>1ft = 1*	*No = 1*	*Yes = 1*
C_{61} *=0.0*	C_{62} *= 1.0*	C_{63} *=1.0*	C_{54} *= 0.0*	C_{65} *=1.0*	C_{66} *= 1.0*	C_{67} *= 0.0*

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.57 (medium-high risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

$SI = 2/9 \times (0.5+0.5+0.5) + 1/9 \times (0.5+0.67+0.57) =$ 0.53

Risk Classification RC

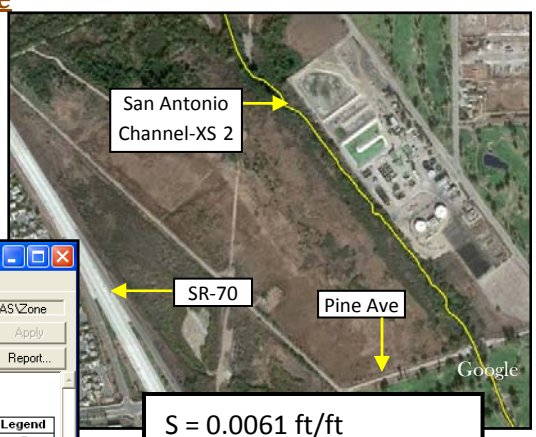
$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

$SI = 1/3 \le 0.53 < 2/3$

RC = Medium

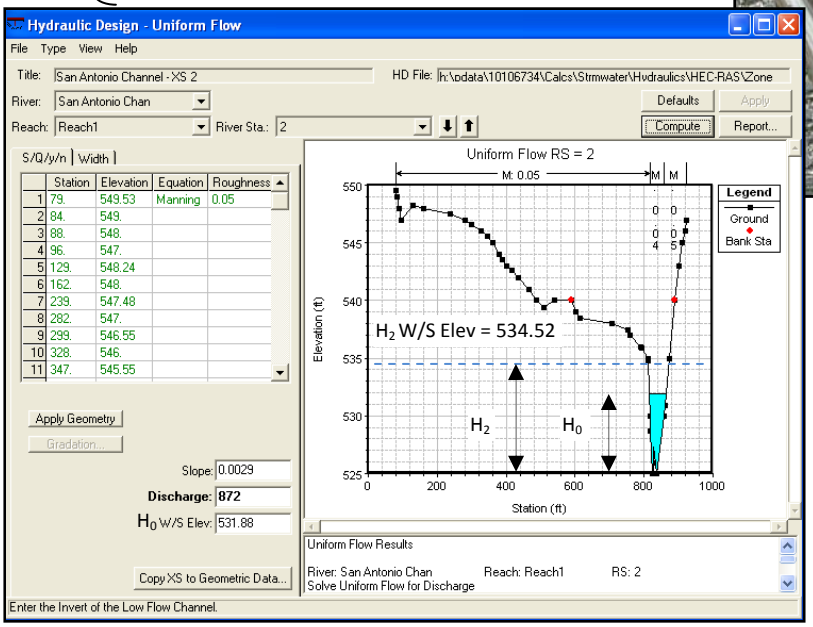
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

San Antonio Channel – XS 2 – Upstream of Pine Avenue



1) Shear Ratio SR (risk factor C_1)

$C_1 =$
- 1 *(high risk) 1.3 ≤ SR < 1.5*
- 0.5 *(medium risk) 1.00 < SR ≤ 1.3*
- 0 *(low risk) aggrading channel, hardened bed*



S = 0.0061 ft/ft

H_0 = 10.0 ft

Q_0 = 2833 cfs

$Q_2 = 2Q_0$ = 5666 cfs

H_2 = 14.36 ft

$SR = H_2/H_0$ = 1.44

C_1 = 1.0 (high risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4 D_{50}} \right) \right]^2$$

$C_2 =$
- 1 *(high risk) ER > 1.0*
- 0.5 *(medium risk) ER < 1.0*
- 0 *(low risk) aggrading channel, hardened bed*

V =7.94 fps

D_{50} = 2.0 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

ER = 0.21 < 1.0

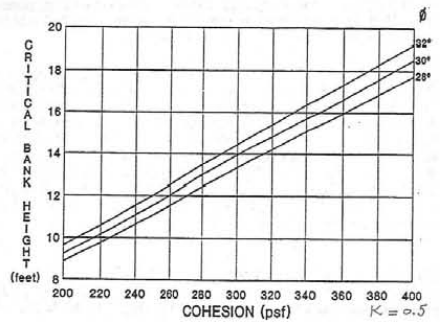
C =445.26

C_2 = 0.5 (medium risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*; 0.5 *(medium risk) GSN < 1.0*; 0 *(low risk) engineered banks or wide shallow channel* }

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = 1.07 < 1.0

C_3 = 1.0 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*; 0.5 *(medium risk) W/B > 4*; 0 *(low risk) banks fixed in place* }

W = valley width, B = channel width

W = 400 ft, B = 63 ft, W/B = 6.35 > 4.0, C_4 = 0.5 (medium risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 1.0	C_{53} =0.0	C_{54} = 0.0	C_{55} = 0.0	C_{56} = 1.0

$$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6} = 0.50 \text{ (medium risk)}$$

6) Streambed Conditions (risk factor C_6)

Braided *Yes = 0* *No = 1*	*Armored* *Yes = 0* *No = 1*	*Bedrock* *Yes = 0* *No = 1*	*Headcuts* *No = 0* *Yes = 1*	*Degradation* *< 1ft = 0* *>1ft = 1*	*D/S Hardpoint* *Yes = 0* *No = 1*	*Sediment Source* *No = 0* *Yes = 1*
C_{61} =0.0	C_{62} = 1.0	C_{63} =1.0	C_{54} = 0.0	C_{65} =1.0	C_{66} = 1.0	C_{67} = 0.0

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.57 (medium-high risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

$SI = 2/9 \times (1.0+0.5+1.0) + 1/9 \times (0.5+0.5+0.57) =$ 0.73

Risk Classification RC

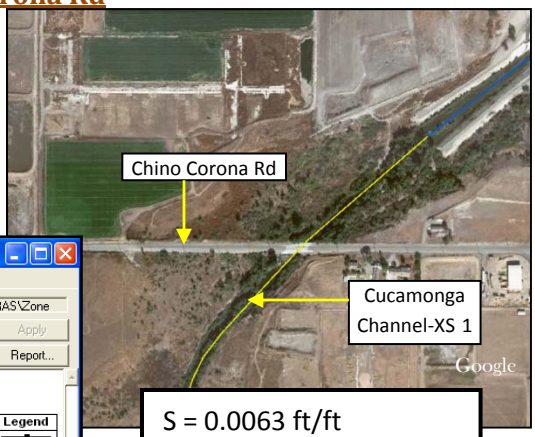
$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

$SI = 2/3 \le 0.73 < 1$

RC = High

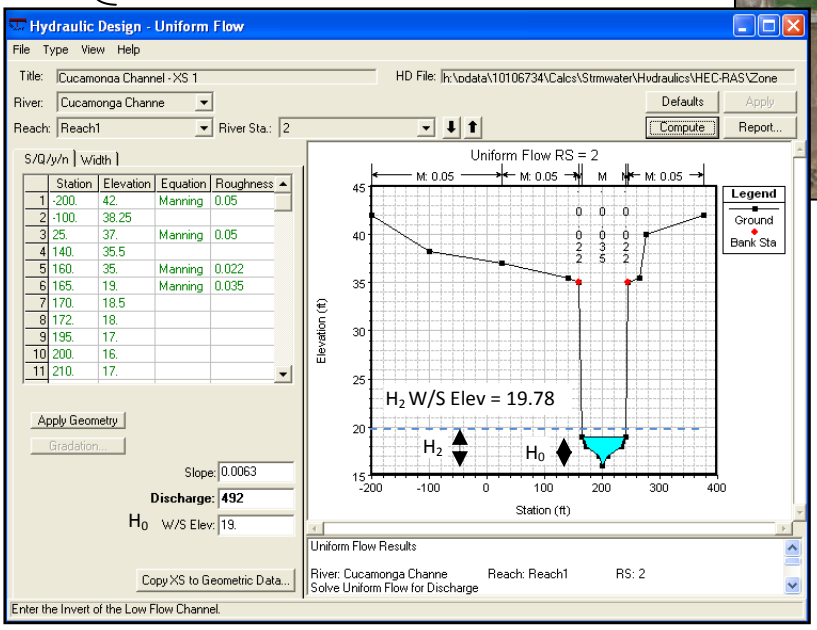
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Cucamonga Channel – XS 1 – Down stream of Chino Corona Rd



1) Shear Ratio SR (risk factor C_1)

$C_1 =$
- 1 *(high risk) 1.3 ≤ SR < 1.5*
- 0.5 *(medium risk) 1.00 < SR ≤ 1.3*
- 0 *(low risk) aggrading channel, hardened bed*



S = 0.0063 ft/ft

H_0 = 3.0 ft

Q_0 = 492 cfs

$Q_2 = 2Q_0$ = 984 cfs

H_2 = 3.78 ft

$SR = H_2/H_0$ = 1.26

C_1 = 0.5 (medium risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4 D_{50}} \right) \right]^2$$

$C_2 =$
- 1 *(high risk) ER > 1.0*
- 0.5 *(medium risk) ER < 1.0*
- 0 *(low risk) aggrading channel, hardened bed*

V =4.39 fps

D_{50} = 2.0 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

ER = 0.9 < 1.0

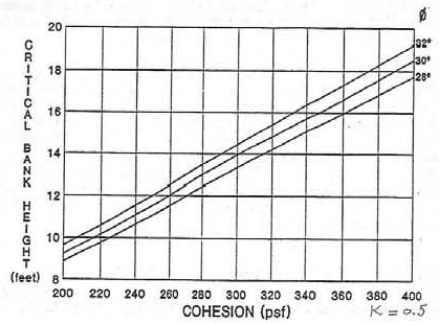
C = 327.42

C_2 = 0.5 (medium risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*; 0.5 *(medium risk) GSN < 1.0*; 0 *(low risk) engineered banks or wide shallow channel* }

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = 1.36 > 1.0

C_3 = 1.0 (high risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*; 0.5 *(medium risk) W/B > 4*; 0 *(low risk) banks fixed in place* }

W = valley width, B = channel width

W = 645 ft, B = 85 ft, W/B = 7.59 > 4.0, C_4 = 0.5 (medium risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 1.0	C_{53} =0.0	C_{54} = 0.0	C_{55} = 1.0	C_{56} = 1.0

$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6}$ = *0.67 (medium-high risk)*

6) Streambed Conditions (risk factor C_6)

Braided Yes = 0 No = 1	*Armored* Yes = 0 No = 1	*Bedrock* Yes = 0 No = 1	*Headcuts* No = 0 Yes = 1	*Degradation* < 1ft = 0 >1ft = 1	*D/S Hardpoint* Yes = 0 No = 1	*Sediment Source* No = 0 Yes = 1
C_{61} =0.0	C_{62} = 1.0	C_{63} =1.0	C_{54} = 0.0	C_{65} =1.0	C_{66} = 1.0	C_{67} = 0.0

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.57 (medium-high risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

SI = 2/9×(0.5+0.5+1.0) + 1/9×(0.5+0.67+0.57) = 0.64

Risk Classification RC

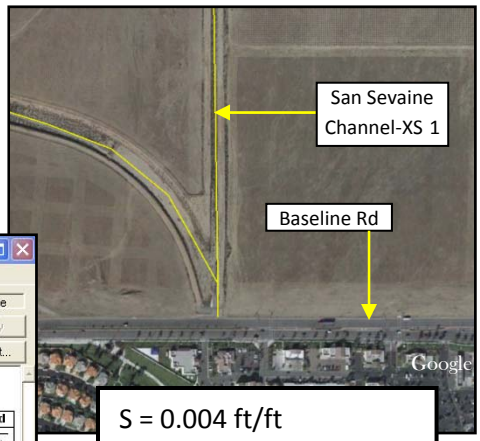
$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

SI = 1/3 ≤ 0.64 < 2/3

RC = Medium

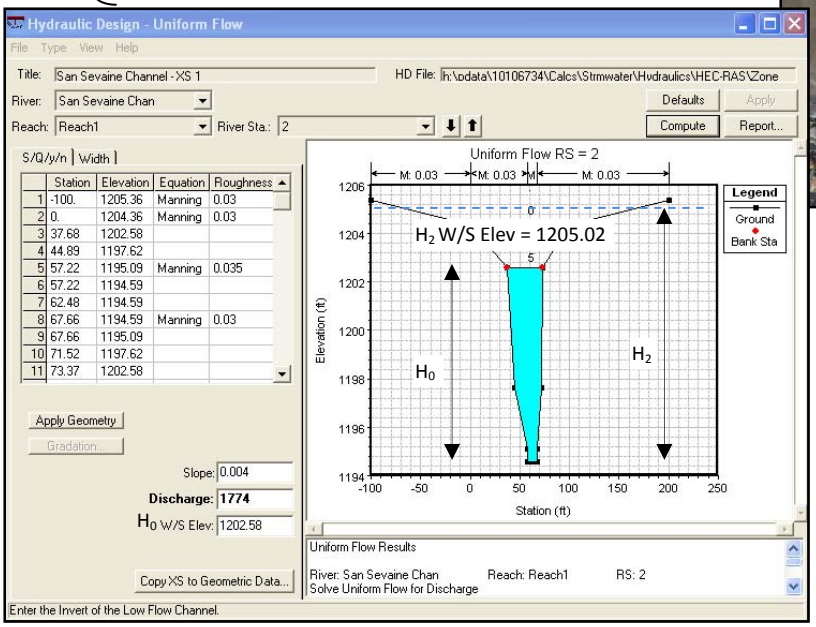
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

San Sevaine Channel – XS 1 – Upstream of Baseline Road



1) Shear Ratio SR (risk factor C_1)

$C_1 =$
- 1 *(high risk) 1.3 ≤ SR < 1.5*
- 0.5 *(medium risk) 1.00 < SR ≤ 1.3*
- 0 *(low risk) aggrading channel, hardened bed*



S = 0.004 ft/ft

H_0 = 7.99 ft

Q_0 = 1774 cfs

$Q_2 = 2Q_0$ = 3548 cfs

H_2 = 10.43 ft

$SR = H_2/H_0$ = 1.31

C_1 = 1.0 (high risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4 D_{50}} \right) \right]^2$$

$C_2 =$
- 1 *(high risk) ER > 1.0*
- 0.5 *(medium risk) ER < 1.0*
- 0 *(low risk) aggrading channel, hardened bed*

V =8.58 fps

D_{50} = 2.0 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

ER = 0.26 < 1.0

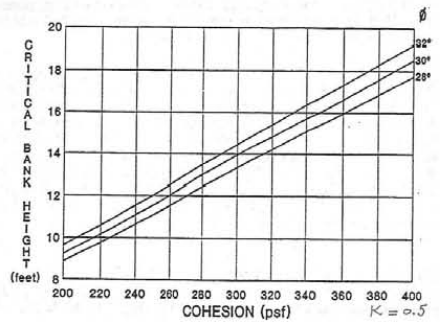
C = 421.93

C_2 = 0.5 (medium risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*; 0.5 *(medium risk) GSN < 1.0*; 0 *(low risk) engineered banks or wide shallow channel* }

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = 0.57 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*; 0.5 *(medium risk) W/B > 4*; 0 *(low risk) banks fixed in place* }

W = valley width, B = channel width

W = 470 ft, B = 35.69 ft, W/B = 13.17> 4.0, C_4 = 0.5 (medium risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 0.0	C_{53} =0.0	C_{54} = 0.0	C_{55} = 0.0	C_{56} = 0.0

$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6}$ = *0.17 (low-medium risk)*

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6) Streambed Conditions (risk factor C_6)

Braided Yes = 0 No = 1	*Armored* Yes = 0 No = 1	*Bedrock* Yes = 0 No = 1	*Headcuts* No = 0 Yes = 1	*Degradation* < 1ft = 0 >1ft = 1	*D/S Hardpoint* Yes = 0 No = 1	*Sediment Source* No = 0 Yes = 1
C_{61} =0.0	C_{62} = 1.0	C_{63} =1.0	C_{54} = 0.0	C_{65} =0.0	C_{66} = 1.0	C_{67} = 1.0

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.57 (medium-high risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

SI = 2/9×(1.0+0.5+0.5) + 1/9×(0.5+0.17+0.57) = 0.58

Risk Classification RC

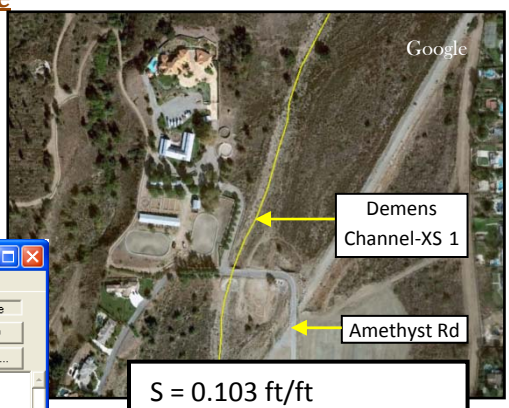
$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

SI = 1/3 ≤ 0.58 < 2/3

RC = Medium

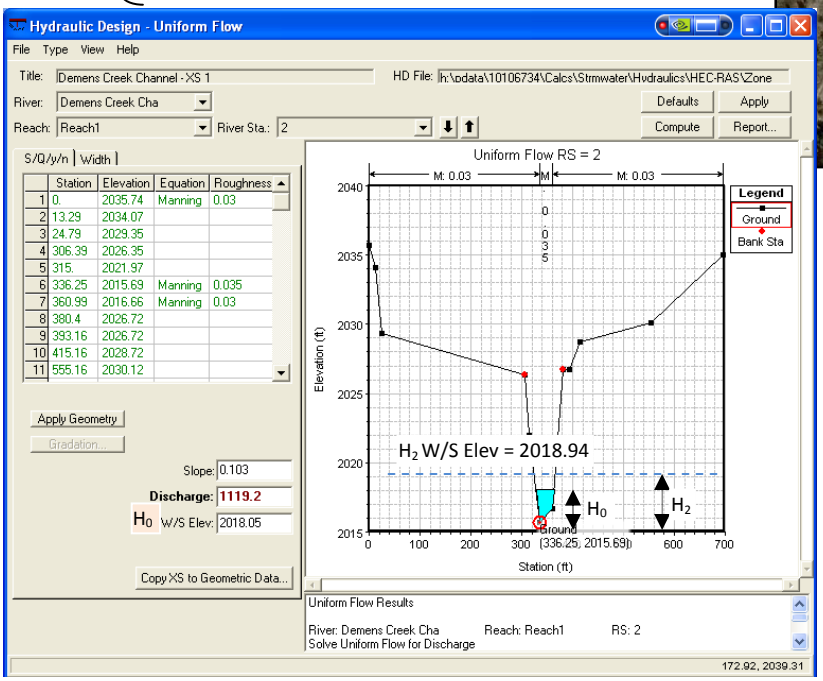
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Demens Channel – XS 1 – Upstream of Amethyst Avenue



1) Shear Ratio SR (risk factor C_1)

C_1 = { 1 *(high risk) 1.3 ≤ SR < 1.5*
0.5 *(medium risk) 1.00 < SR ≤ 1.3*
0 *(low risk) aggrading channel, hardened bed*



S = 0.103 ft/ft

H_0 = 2.36 ft

Q_0 = 1119.2 cfs

$Q_2 = 2Q_0$ = 2238.4 cfs

H_2 = 3.25 ft

$SR = H_2/H_0$ = 1.38

C_1 = 1.0 (high risk)

**Note: Q0 based on Q10*

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4 D_{50}} \right) \right]^2$$

C_2 = { 1 *(high risk) ER > 1.0*
0.5 *(medium risk) ER < 1.0*
0 *(low risk) aggrading channel, hardened bed*

V =19.45 fps

D_{50} = 2.0 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

ER = 1.87 > 1.0

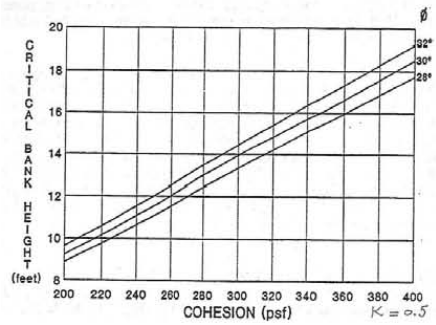
C = 306.09

C_2 = 1.0 (high risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*
0.5 *(medium risk) GSN < 1.0*
0 *(low risk) engineered banks or wide shallow channel*

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = 0.76 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*
0.5 *(medium risk) W/B > 4*
0 *(low risk) banks fixed in place*

W = valley width, B = channel width

W = 505ft, B = 74 ft, W/B = 6.82> 4.0, C_4 = 0.5 (medium risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 1.0	C_{53} =0.0	C_{54} = 0.0	C_{55} = 0.0	C_{56} = 0.0

$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6}$ = *0.33 (low-medium risk)*

6) Streambed Conditions (risk factor C_6)

Braided Yes = 0 No = 1	*Armored* Yes = 0 No = 1	*Bedrock* Yes = 0 No = 1	*Headcuts* No = 0 Yes = 1	*Degradation* < 1ft = 0 >1ft = 1	*D/S Hardpoint* Yes = 0 No = 1	*Sediment Source* No = 0 Yes = 1
C_{61} =0.0	C_{62} = 1.0	C_{63} =1.0	C_{54} = 0.0	C_{65} =1.0	C_{66} = 1.0	C_{67} = 1.0

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.71 (medium-high risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

$SI = 2/9 \times (1.0+1.0+0.5) + 1/9 \times (0.5+0.33+0.71) =$ 0.73

Risk Classification RC

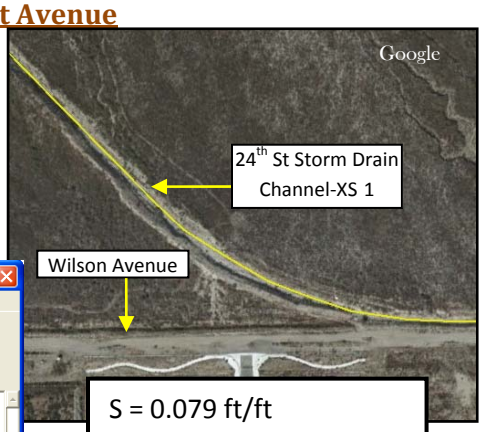
$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

$SI = 2/3 \le 0.73 < 1$

RC = High

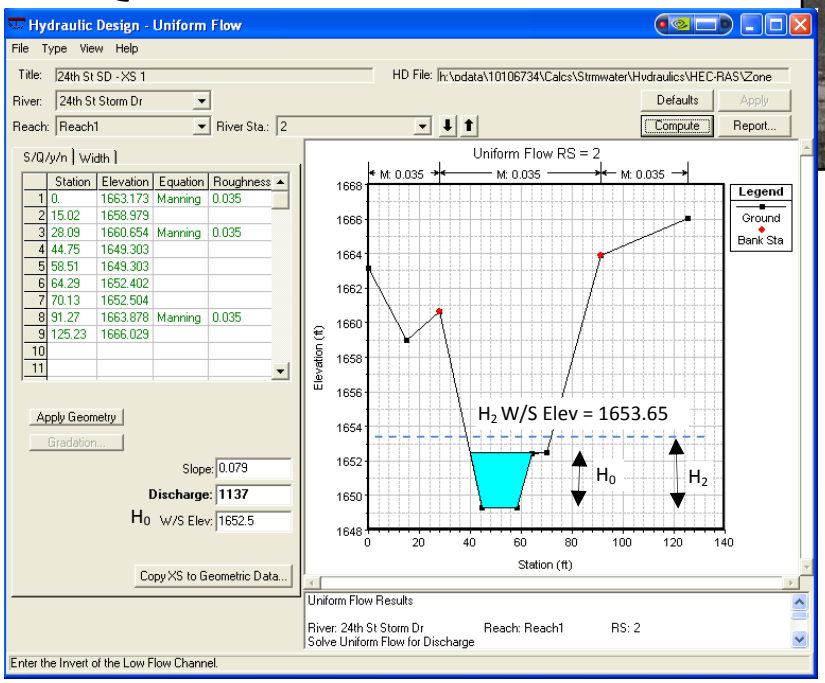
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

24th St Storm Drain Channel – XS 1 – Upstream of Amethyst Avenue



1) Shear Ratio SR (risk factor C_1)

$C_1 = \begin{cases} 1 \text{ (high risk) } 1.3 \le SR < 1.5 \\ 0.5 \text{ (medium risk) } 1.00 < SR \le 1.3 \\ 0 \text{ (low risk) aggrading channel, hardened bed} \end{cases}$



S = 0.079 ft/ft

H_0 = 3.2 ft

Q_0 = 1137 cfs

$Q_2 = 2Q_0$ = 2274 cfs

H_2 = 4.35 ft

$SR = H_2/H_0$ = 1.36

C_1 = 1.0 (high risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4 D_{50}} \right) \right]^2$$

$C_2 = \begin{cases} 1 \text{ (high risk) } ER > 1.0 \\ 0.5 \text{ (medium risk) } ER < 1.0 \\ 0 \text{ (low risk) aggrading channel, hardened bed} \end{cases}$

V =20.25 fps

D_{50} = 2.0 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

ER = 1.86 > 1.0

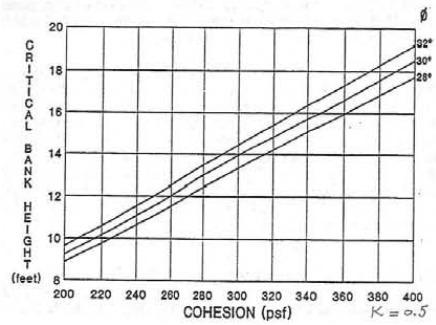
C = 333.27

C_2 = 1.0 (high risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*; 0.5 *(medium risk) GSN < 1.0*; 0 *(low risk) engineered banks or wide shallow channel* }

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = 0.81 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*; 0.5 *(medium risk) W/B > 4*; 0 *(low risk) banks fixed in place* }

W = valley width, B = channel width

W = 532ft, B = 63.2 ft, W/B = 8.42> 4.0, C_4 = 0.5 (medium risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 1.0	C_{53} =1.0	C_{54} = 0.0	C_{55} = 1.0	C_{56} = 1.0

$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6}$ = 0.83 (medium-high risk)

6) Streambed Conditions (risk factor C_6)

Braided *Yes = 0* *No = 1*	*Armored* *Yes = 0* *No = 1*	*Bedrock* *Yes = 0* *No = 1*	*Headcuts* *No = 0* *Yes = 1*	*Degradation* *< 1ft = 0* *>1ft = 1*	*D/S Hardpoint* *Yes = 0* *No = 1*	*Sediment Source* *No = 0* *Yes = 1*
C_{61} =0.0	C_{62} = 1.0	C_{63} =1.0	C_{54} = 1.0	C_{65} =0.0	C_{66} = 1.0	C_{67} = 1.0

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.71 (medium-high risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

$SI = 2/9 \times (1.0+1.0+0.5) + 1/9 \times (0.5+0.83+0.71) =$ 0.78

Risk Classification RC

$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

$SI = 2/3 \le 0.78 < 1$

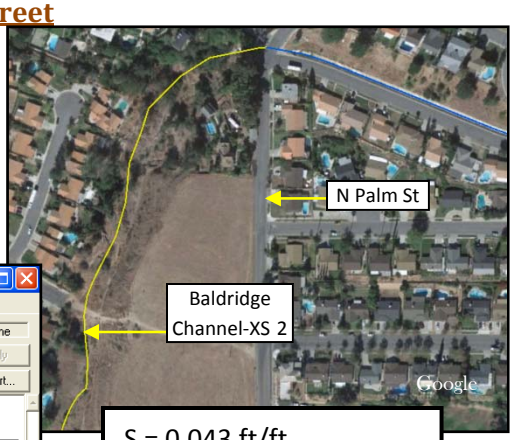
RC = High

Calculation Summary Sheets

Zone 2

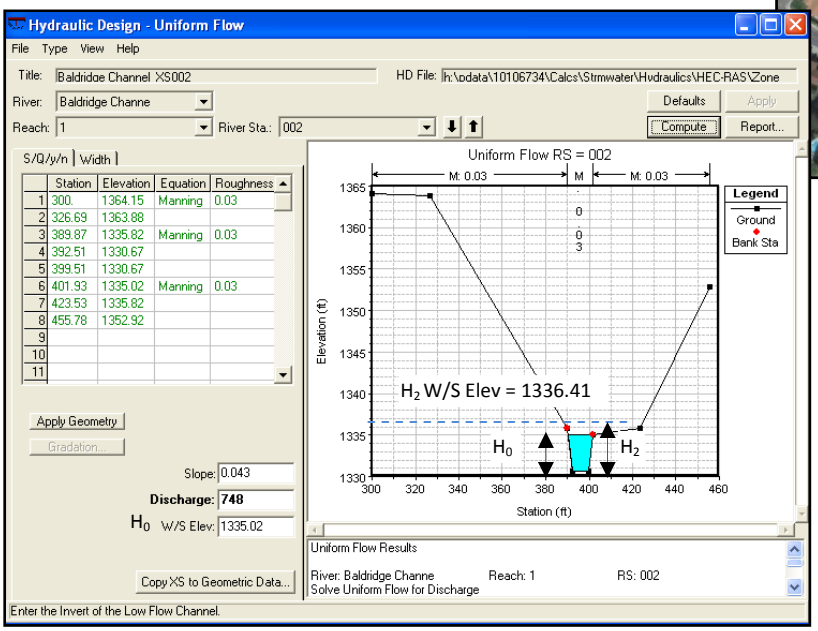
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Baldridge Channel – XS 1 – Downstreem of North Palm Street



1) Shear Ratio SR (risk factor C_1)

$C_1 =$
- 1 *(high risk) 1.3 ≤ SR < 1.5*
- 0.5 *(medium risk) 1.00 < SR ≤ 1.3*
- 0 *(low risk) aggrading channel, hardened bed*



S = 0.043 ft/ft

H_0 = 4.35 ft

Q_0 = 748 cfs

$Q_2 = 2Q_0$ = 1496 cfs

H_2 = 5.74 ft

$SR = H_2/H_0$ = 1.32

C_1 = 1.0 (high risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4 D_{50}} \right) \right]^2$$

$C_2 =$
- 1 *(high risk) ER > 1.0*
- 0.5 *(medium risk) ER < 1.0*
- 0 *(low risk) aggrading channel, hardened bed*

V = 18.43 fps

D_{50} = 2 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

ER = 1.42 > 1.0

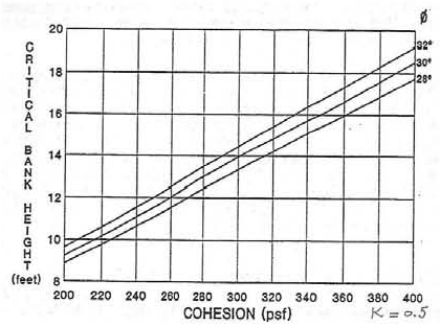
C = 361.86

C_2 = 1.0 (high risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*; 0.5 *(medium risk) GSN < 1.0*; 0 *(low risk) engineered banks or wide shallow channel* }

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = .31 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*; 0.5 *(medium risk) W/B > 4*; 0 *(low risk) banks fixed in place* }

W = valley width, B = channel width

W = 130 ft, B = 7 ft, W/B = 18.6 >4.0, C_4 = 0.5 (medium risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 1.0	C_{53} =0.0	C_{54} = 0.0	C_{55} = 1.0	C_{56} = 1.0

$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6}$ = *0.67 (medium-high risk)*

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6) Streambed Conditions (risk factor C_6)

Braided Yes = 0 No = 1	*Armored* Yes = 0 No = 1	*Bedrock* Yes = 0 No = 1	*Headcuts* No = 0 Yes = 1	*Degradation* < 1ft = 0 >1ft = 1	*D/S Hardpoint* Yes = 0 No = 1	*Sediment Source* No = 0 Yes = 1
C_{61} =0.0	C_{62} = 1.0	C_{63} =1.0	C_{54} = 1.0	C_{65} =1.0	C_{66} = 1.0	C_{67} = 1.0

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.86 (medium-high risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

$SI = 2/9 \times (1.0+1.0+0.5) + 1/9 \times (0.5+0.67+0.86) =$ 0.78

Risk Classification RC

$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

$SI = 2/3 \le 0.78 < 1$

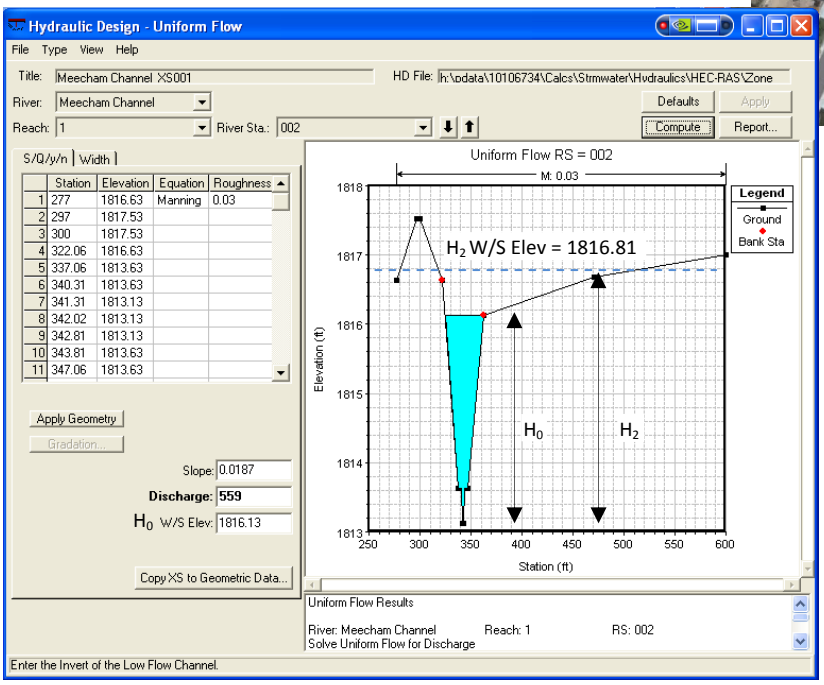
RC = High

RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Meecham Channel – XS 1 – Upstream of Ohio Avenue

1) Shear Ratio SR (risk factor C_1)

$C_1 = \begin{cases} 1 \text{ (high risk) } 1.3 \le SR < 1.5 \\ 0.5 \text{ (medium risk) } 1.00 < SR \le 1.3 \\ 0 \text{ (low risk) aggrading channel, hardened bed} \end{cases}$



S = 0.0187 ft/ft

H_0 = 2.50 ft

Q_0 = 559 cfs

$Q_2 = 2Q_0$ = 1118 cfs

H_2 = 3.16 ft

$SR = H_2/H_0$ = 1.26

C_1 = 0.5 (medium risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4 D_{50}} \right) \right]^2$$

$C_2 = \begin{cases} 1 \text{ (high risk) } ER > 1.0 \\ 0.5 \text{ (medium risk) } ER < 1.0 \\ 0 \text{ (low risk) aggrading channel, hardened bed} \end{cases}$

V = 9.23 fps

D_{50} = 2 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

ER = 0.41 < 1.0

C = 311.15

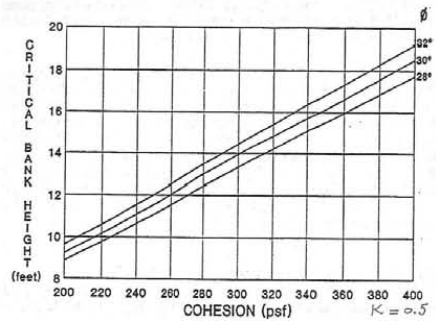
C_2 = 0.5 (medium risk)

RBF CONSULTING

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*
0.5 *(medium risk) GSN < 1.0*
0 *(low risk) engineered banks or wide shallow channel* }

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = 0.18 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*
0.5 *(medium risk) W/B > 4*
0 *(low risk) banks fixed in place* }

W = valley width, B = channel width

W = 117 ft, B = 40 ft, W/B = 2.9 ≤4.0, C_4 = 1.0 (high risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 1.0	C_{53} =1.0	C_{54} = 0.0	C_{55} = 0.0	C_{56} = 1.0

$$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6} = 0.67 \text{ (medium-high risk)}$$

6) Streambed Conditions (risk factor C_6)

Braided *Yes = 0* *No = 1*	*Armored* *Yes = 0* *No = 1*	*Bedrock* *Yes = 0* *No = 1*	*Headcuts* *No = 0* *Yes = 1*	*Degradation* *< 1ft = 0* *>1ft = 1*	*D/S Hardpoint* *Yes = 0* *No = 1*	*Sediment Source* *No = 0* *Yes = 1*
C_{61} =0.0	C_{62} = 1.0	C_{63} =1.0	C_{54} = 0.0	C_{65} =1.0	C_{66} = 0.0	C_{67} =0.0

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.43 (low-medium risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

SI = 2/9×(0.5+0.5+0.5) + 1/9×(1.0+0.67+0.43) = 0.57

Risk Classification RC

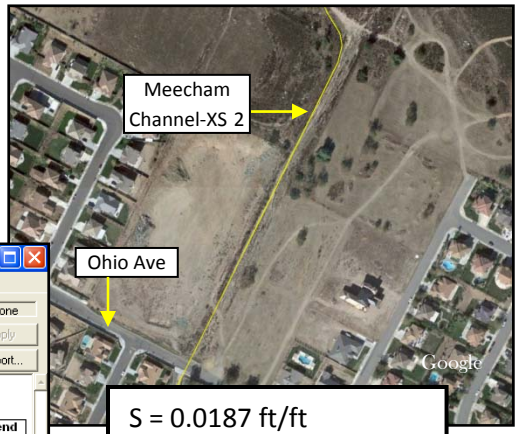
$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

SI =1/3≤ 0.57 < 2/3

RC = Medium

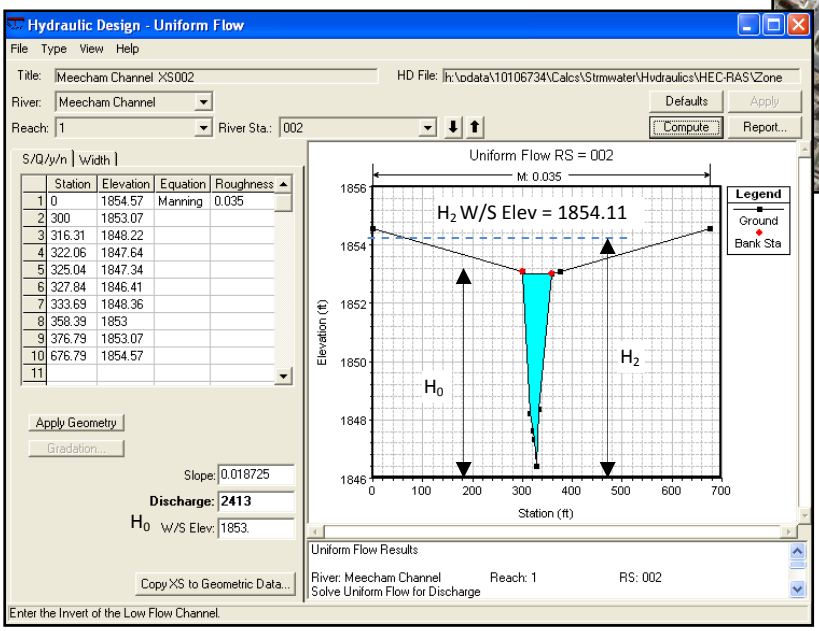
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Meecham Channel – XS 2 – Upstream of Ohio Avenue



1) Shear Ratio SR (risk factor C_1)

$C_1 =$
- 1 *(high risk) 1.3 ≤ SR < 1.5*
- 0.5 *(medium risk) 1.00 < SR ≤ 1.3*
- 0 *(low risk) aggrading channel, hardened bed*



S = 0.0187 ft/ft

H_0 = 6.59 ft

Q_0 = 2413 cfs

$Q_2 = 2Q_0$ = 4826 cfs

H_2 = 7.70 ft

$SR = H_2/H_0$ = 1.17

C_1 = 0.5 (medium risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4 D_{50}} \right) \right]^2$$

$C_2 =$
- 1 *(high risk) ER > 1.0*
- 0.5 *(medium risk) ER < 1.0*
- 0 *(low risk) aggrading channel, hardened bed*

V = 12.68 fps

D_{50} = 2 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

ER = 0.60 < 1.0

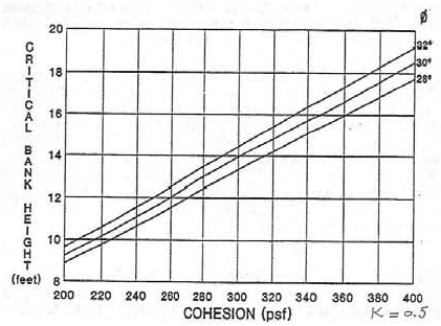
C = 402.39

C_2 = 0.5 (medium risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*; 0.5 *(medium risk) GSN < 1.0*; 0 *(low risk) engineered banks or wide shallow channel* }

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = 0.47 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*; 0.5 *(medium risk) W/B > 4*; 0 *(low risk) banks fixed in place* }

W = valley width, B = channel width

W = 450 ft, B =58 ft, W/B =7.8 >4.0, C_4 = 0.5 (medium risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 1.0	C_{53} =0.0	C_{54} = 0.0	C_{55} = 0.0	C_{56} = 0.0

$$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6} =$$ *0.33 (low-medium risk)*

RBF CONSULTING

6) Streambed Conditions (risk factor C_6)

Braided Yes = 0 No = 1	*Armored* Yes = 0 No = 1	*Bedrock* Yes = 0 No = 1	*Headcuts* No = 0 Yes = 1	*Degradation* < 1ft = 0 >1ft = 1	*D/S Hardpoint* Yes = 0 No = 1	*Sediment Source* No = 0 Yes = 1
C_{61} =0.0	C_{62} = 1.0	C_{63} =1.0	C_{54} = 0.0	C_{65} =0.0	C_{66} = 1.0	C_{67} =1.0

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.57 (medium-high risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

SI = 2/9×(0.5+0.5+0.5) + 1/9×(0.5+0.33+0.57) = 0.49

Risk Classification RC

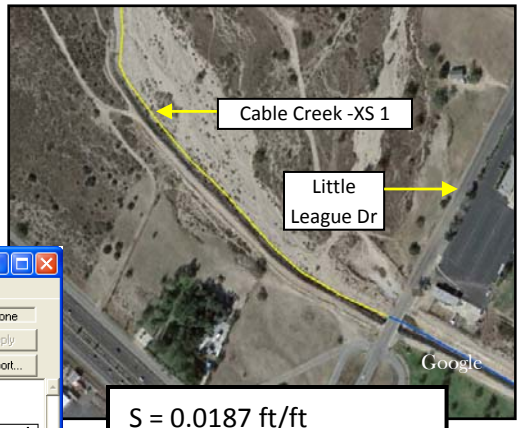
$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

SI =1/3≤ 0.49 < 2/3

RC = Medium

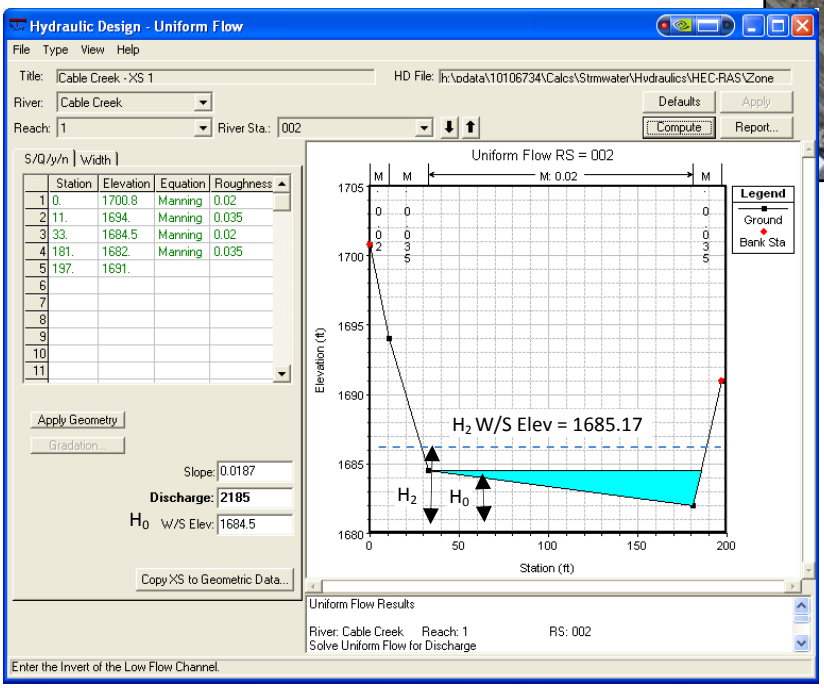
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Cable Creek – XS 1 – Upstream of Ohio Avenue



1) Shear Ratio SR (risk factor C_1)

$C_1 =$
- 1 *(high risk) 1.3 ≤ SR < 1.5*
- 0.5 *(medium risk) 1.00 < SR ≤ 1.3*
- 0 *(low risk) aggrading channel, hardened bed*



S = 0.0187 ft/ft

H_0 = 2.5 ft

Q_0 = 2,185 cfs

$Q_2 = 2Q_0$ = 4,370 cfs

H_2 = 3.17 ft

$SR = H_2/H_0$ = 1.27

C_1 = 0.5 (medium risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4 D_{50}} \right) \right]^2$$

$C_2 =$
- 1 *(high risk) ER > 1.0*
- 0.5 *(medium risk) ER < 1.0*
- 0 *(low risk) aggrading channel, hardened bed*

V = 11.44 fps

D_{50} = 2 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

ER = 0.64 < 1.0

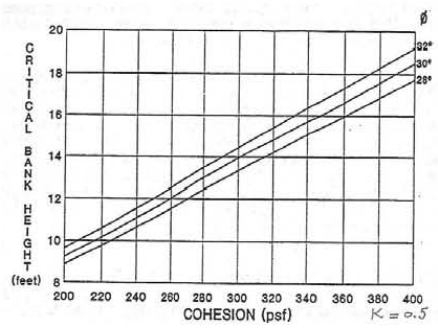
C = 311.15

C_2 = 0.5 (medium risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*; 0.5 *(medium risk) GSN < 1.0*; 0 *(low risk) engineered banks or wide shallow channel* }

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = 0.84 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*; 0.5 *(medium risk) W/B > 4*; 0 *(low risk) banks fixed in place* }

W = valley width, B = channel width

W = 600 ft, B = 129 ft, W/B = 4.7 >4.0, C_4 = 0.5 (medium risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	*C_{52} = 1.0*	*C_{53} =1.0*	*C_{54} = 0.0*	*C_{55} = 0.0*	*C_{56} = 0.0*

$$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6} = 0.50 \text{ (medium risk)}$$

RBF CONSULTING

6) Streambed Conditions (risk factor C_6)

Braided *Yes = 0* *No = 1*	*Armored* *Yes = 0* *No = 1*	*Bedrock* *Yes = 0* *No = 1*	*Headcuts* *No = 0* *Yes = 1*	*Degradation* *< 1ft = 0* *>1ft = 1*	*D/S Hardpoint* *Yes = 0* *No = 1*	*Sediment Source* *No = 0* *Yes = 1*
C_{61} *=0.0*	C_{62} *= 1.0*	C_{63} *=1.0*	C_{54} *= 0.0*	C_{65} *=0.0*	C_{66} *= 0.0*	C_{67} *=1.0*

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.43 (low-medium risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

$SI = 2/9\times(0.5+1.0+0.5) + 1/9\times(0.5+0.5+0.43) =$ 0.49

Risk Classification RC

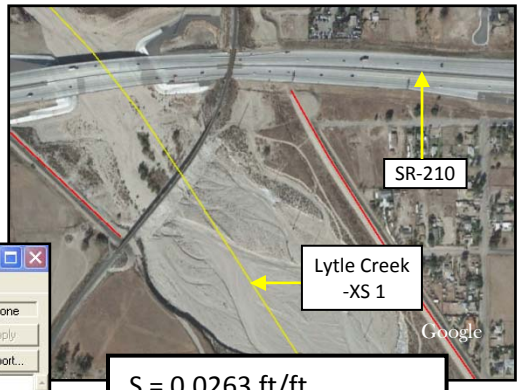
$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

$SI = 1/3 \le 0.49 < 2/3$

RC = Medium

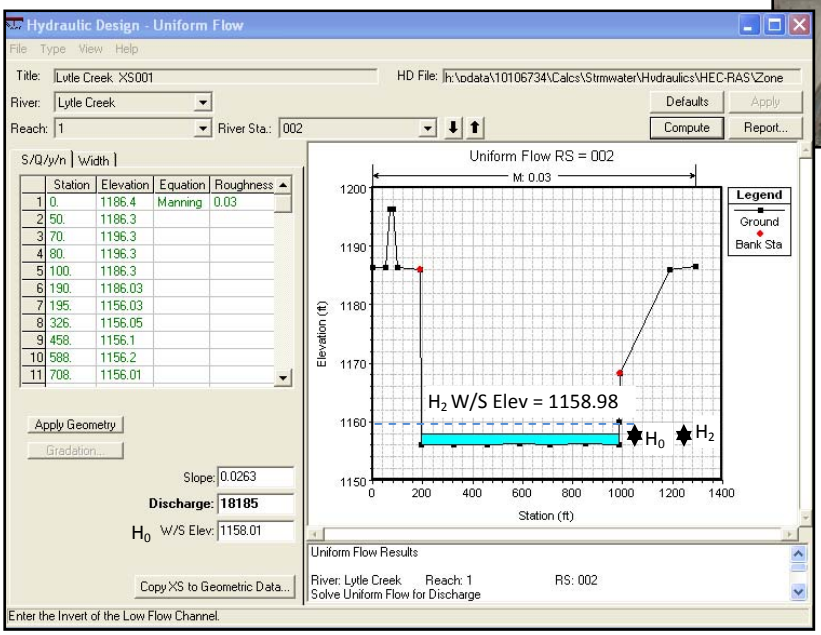
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Lytle Creek – XS 1 – Upstream of Ohio Avenue



1) Shear Ratio SR (risk factor C_1)

$C_1 =$
- 1 *(high risk) 1.3 ≤ SR < 1.5*
- 0.5 *(medium risk) 1.00 < SR ≤ 1.3*
- 0 *(low risk) aggrading channel, hardened bed*



Station	Elevation	Equation	Roughness
0.	1186.4	Manning	0.03
50.	1186.3		
70.	1196.3		
80.	1196.3		
100.	1186.3		
190.	1186.03		
195.	1156.03		
326.	1156.05		
458.	1156.1		
588.	1156.2		
708.	1156.01		

S = 0.0263 ft/ft

H_0 = 2.0 ft

Q_0 = 18185 cfs

$Q_2 = 2Q_0$ = 36370 cfs

H_2 = 2.97 ft

$SR = H_2/H_0$ = 1.49

C_1 = 1.0 (high risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4 D_{50}} \right) \right]^2$$

$C_2 =$
- 1 *(high risk) ER > 1.0*
- 0.5 *(medium risk) ER < 1.0*
- 0 *(low risk) aggrading channel, hardened bed*

V = 12.22 fps

D_{50} = 2 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

ER = 0.77 < 1.0

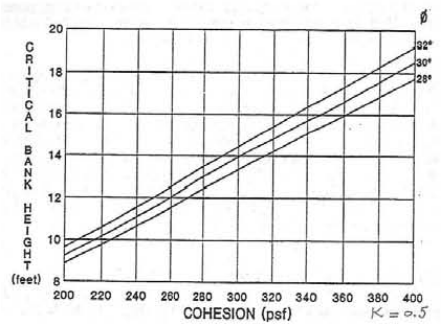
C = 291.80

C_2 = 0.5 (medium risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*; 0.5 *(medium risk) GSN < 1.0*; 0 *(low risk) engineered banks or wide shallow channel* }

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = 0.14< 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*; 0.5 *(medium risk) W/B > 4*; 0 *(low risk) banks fixed in place* }

W = valley width, B = channel width

W = 1090 ft, B = 1090 ft, W/B = 1 ≤ 4.0, C_4 = 0.0 (low risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 1.0	C_{53} =1.0	C_{54} = 0.0	C_{55} = 0.0	C_{56} = 0.0

$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6}$ = 0.50 (medium risk)

6) Streambed Conditions (risk factor C_6)

Braided Yes = 0 No = 1	*Armored* Yes = 0 No = 1	*Bedrock* Yes = 0 No = 1	*Headcuts* No = 0 Yes = 1	*Degradation* < 1ft = 0 >1ft = 1	*D/S Hardpoint* Yes = 0 No = 1	*Sediment Source* No = 0 Yes = 1
C_{61} =0.0	C_{62} = 1.0	C_{63} =1.0	C_{54} = 0.0	C_{65} =0.0	C_{66} = 1.0	C_{67} =1.0

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.57 (medium-high risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

SI = 2/9×(1.0+0.5+0.5) + 1/9×(0.0+0.5+0.57) = 0.56

Risk Classification RC

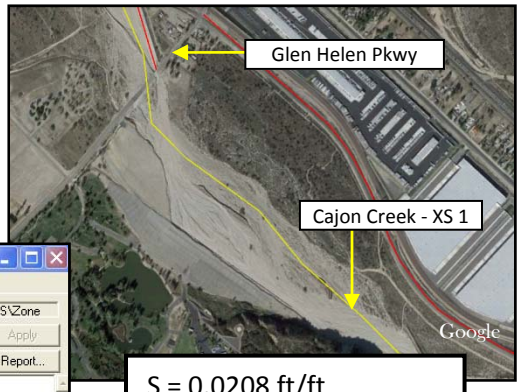
$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

$SI = 1/3 \le 0.56 < 2/3$

RC = Medium

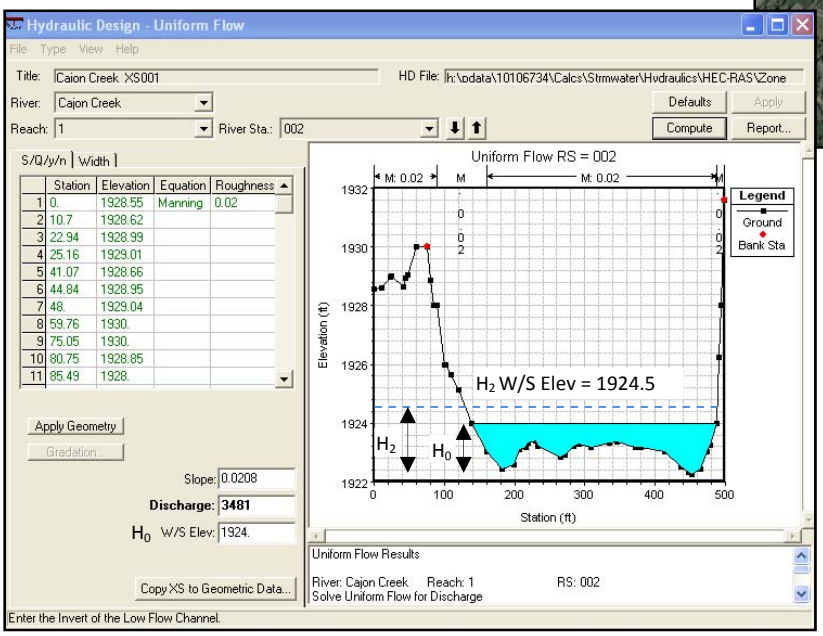
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Cajon Creek – XS 1 – Downstream of Glen Helen Pkwy



1) Shear Ratio SR (risk factor C_1)

$C_1 =$
- 1 *(high risk) 1.3 ≤ SR < 1.5*
- 0.5 *(medium risk) 1.00 < SR ≤ 1.3*
- 0 *(low risk) aggrading channel, hardened bed*



S = 0.0208 ft/ft

H_0 = 1.75 ft

Q_0 = 3481 cfs

$Q_2 = 2Q_0$ = 6962 cfs

H_2 = 2.25 ft

SR = H_2/H_0 = 1.29

C_1 = 0.5 (medium risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4 D_{50}} \right) \right]^2$$

$C_2 =$
- 1 *(high risk) ER > 1.0*
- 0.5 *(medium risk) ER < 1.0*
- 0 *(low risk) aggrading channel, hardened bed*

V = 10.42 fps

D_{50} = 2 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

ER = 0.58 < 1.0

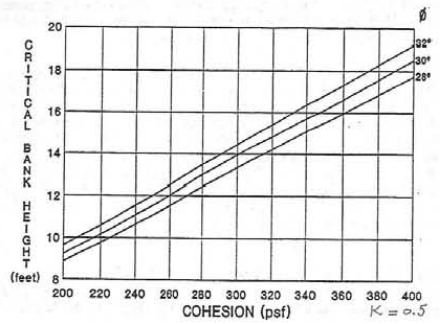
C = 280.52

C_2 = 0.5 (medium risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*; 0.5 *(medium risk) GSN < 1.0*; 0 *(low risk) engineered banks or wide shallow channel* }

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = 0.13 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*; 0.5 *(medium risk) W/B > 4*; 0 *(low risk) banks fixed in place* }

W = valley width, B = channel width

W = 1424 ft, B = 1424 ft, W/B = 1 ≤ 4.0, C_4 = 1.0 (high risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 1.0	C_{53} =1.0	C_{54} = 0.0	C_{55} = 0.0	C_{56} = 0.0

$$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6} = \text{0.50 (medium risk)}$$

6) Streambed Conditions (risk factor C_6)

Braided Yes = 0 No = 1	*Armored* Yes = 0 No = 1	*Bedrock* Yes = 0 No = 1	*Headcuts* No = 0 Yes = 1	*Degradation* < 1ft = 0 >1ft = 1	*D/S Hardpoint* Yes = 0 No = 1	*Sediment Source* No = 0 Yes = 1
C_{61} =0.0	C_{62} = 1.0	C_{63} =1.0	C_{54} = 0.0	C_{65} =0.0	C_{66} = 1.0	C_{67} =1.0

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.57 (medium-high risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

SI = 2/9×(0.5+0.5+0.5) + 1/9×(1.0+0.5+0.57) = 0.56

Risk Classification RC

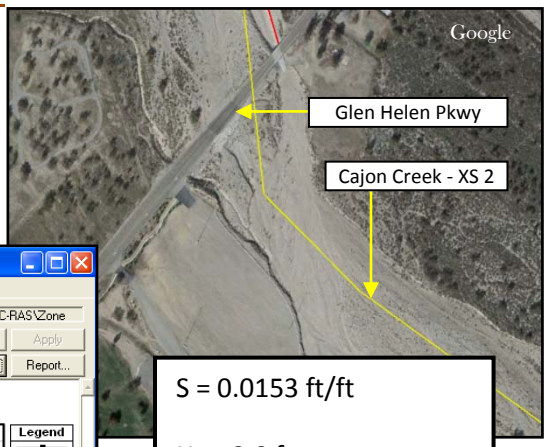
$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

$SI = 1/3 \le 0.56 < 2/3$

RC = Medium

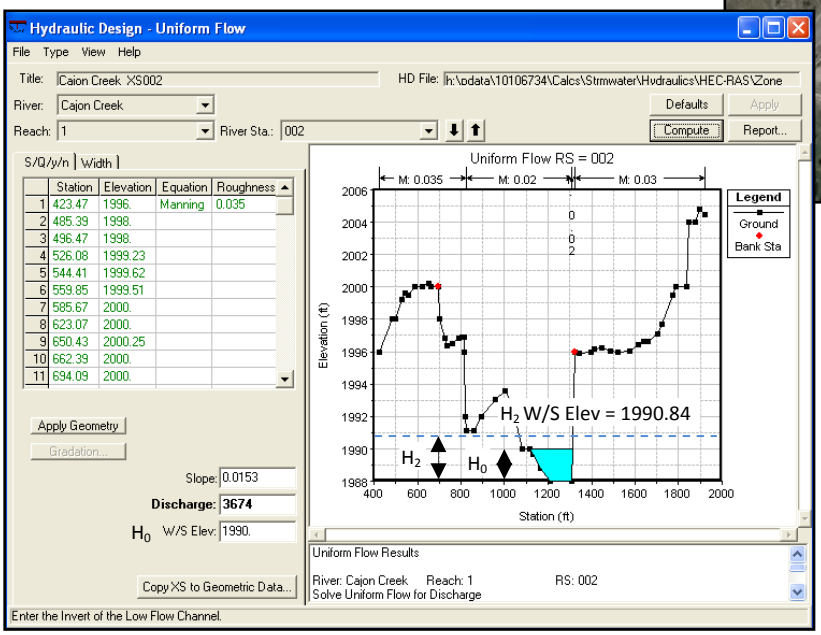
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Cajon Creek – XS 2 – Downstream of Glen Helen Pkwy



1) Shear Ratio SR (risk factor C_1)

$C_1 =$
- 1 *(high risk) 1.3 ≤ SR < 1.5*
- 0.5 *(medium risk) 1.00 < SR ≤ 1.3*
- 0 *(low risk) aggrading channel, hardened bed*



S = 0.0153 ft/ft

H_0 = 2.0 ft

Q_0 = 3674 cfs

$Q_2 = 2Q_0$ = 7348 cfs

H_2 = 2.84 ft

$SR = H_2/H_0$ = 1.42

C_1 = 1.0 (high risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4 D_{50}} \right) \right]^2$$

$C_2 =$
- 1 *(high risk) ER > 1.0*
- 0.5 *(medium risk) ER < 1.0*
- 0 *(low risk) aggrading channel, hardened bed*

V = 11.4 fps

D_{50} = 2 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

ER = 0.67 < 1.0

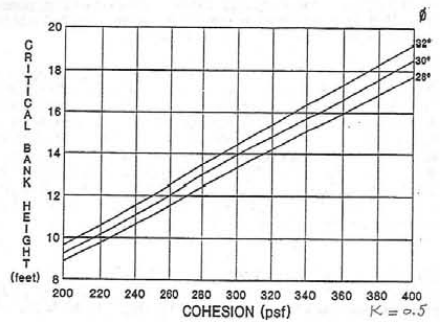
C = 291.80

C_2 = 0.5 (medium risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*; 0.5 *(medium risk) GSN < 1.0*; 0 *(low risk) engineered banks or wide shallow channel* }

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = 0.14 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*; 0.5 *(medium risk) W/B > 4*; 0 *(low risk) banks fixed in place* }

W = valley width, B = channel width

W = 1096 ft, B = 200 ft, W/B = 5.5> 4.0, C_4 = 0.5 (medium risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 1.0	C_{53} =1.0	C_{54} = 0.0	C_{55} = 0.0	C_{56} = 0.0

$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6}$ = *0.50 (medium risk)*

6) Streambed Conditions (risk factor C_6)

Braided Yes = 0 No = 1	*Armored* Yes = 0 No = 1	*Bedrock* Yes = 0 No = 1	*Headcuts* No = 0 Yes = 1	*Degradation* < 1ft = 0 >1ft = 1	*D/S Hardpoint* Yes = 0 No = 1	*Sediment Source* No = 0 Yes = 1
C_{61} =0.0	C_{62} = 1.0	C_{63} =1.0	C_{54} = 0.0	C_{65} =0.0	C_{66} = 1.0	C_{67} =1.0

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.57 (medium-high risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

SI = 2/9×(1.0+0.5+0.5) + 1/9×(0.5+0.5+0.57) = 0.62

Risk Classification RC

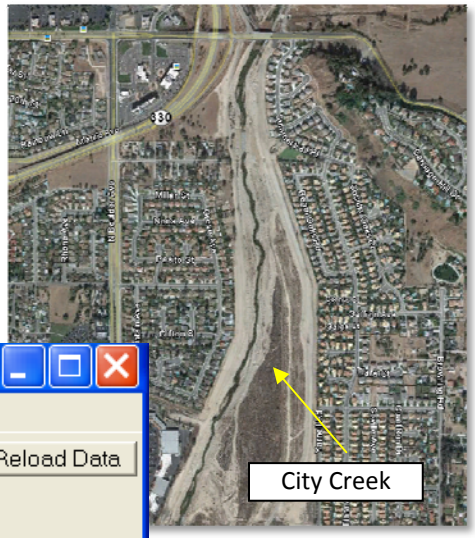
$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

$SI = 1/3 \le 0.62 < 2/3$

RC = Medium

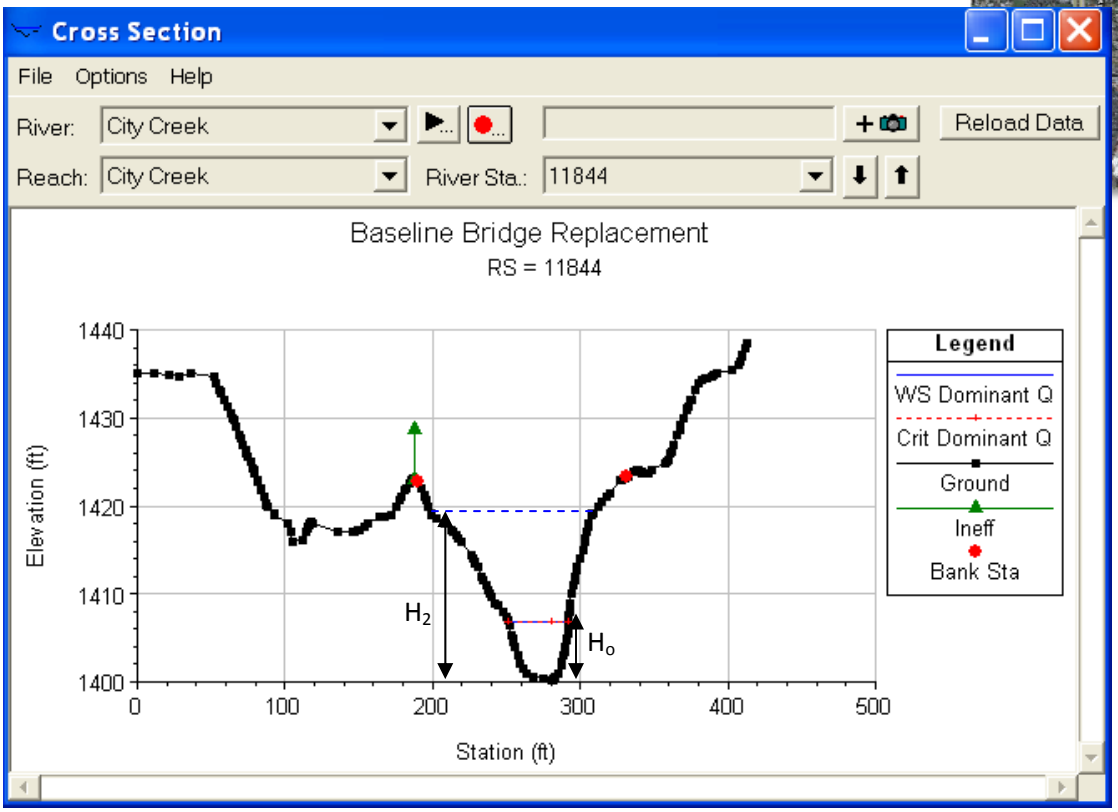
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

City Creek - Downstream of Highland Ave



1) Shear Ratio SR (risk factor C_1)

$$C_1 = \begin{cases} 1\,(high\ risk) & 1.3 \le SR < 1.5 \\ 0.5\,(medium\ \ risk) & 1.00 < SR < 1.3 \\ 0\,(low\ risk) & aggrading\ channel,\ hardened\ bed \end{cases}$$



S = 3.1%

H_o = 6.67 ft

Q_o = 2,600 cfs (10-yr)

$Q_2 = 2\ Q_o$ = 5,200 cfs

H_2 = 9.93 ft

$SR = H_2/H_o$ = 1.49 > 1.3

C_1 = 1.0 (high risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{cr}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{cr}} = \frac{V^2}{1.65 g D_{50} \Theta_{cr} C} \qquad C = \left[5.75 \log\left(12.27 \frac{H_o}{4 D_{50}} \right) \right]^2$$

$$C_2 = \begin{cases} 1\,(high\ risk) & ER > 1.0 \\ 0.5\,(medium\ \ risk) & ER < 1.0 \\ 0\,(low\ risk) & aggrading\ channel, hardened\ bed \end{cases}$$

V = 12.7 ft/s

D_{50} = 2 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

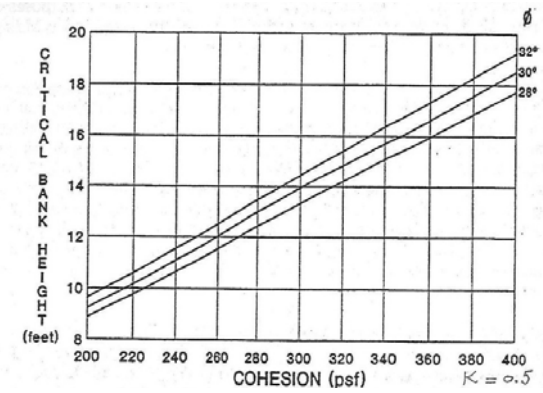
ER = 0.61 < 1.0

C = 404

C_2 = 0.5 (medium risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

$$C_3 = \begin{cases} 1\,(high\ risk) & GSN > 1.0 \text{ or toe/bank erosion observed} \\ 0.5\,(medium\ \ risk) & GSN < 1.0 \\ 0\,(low\ risk) & \text{engineered banks or wide shallow channel} \end{cases}$$



$GSN = \frac{H_o}{H_c}$, H_c = critical bank height

Assumed cohesion = 200 psf, H_c = 10 ft, *GSN* = .67 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

$$C_4 = \begin{cases} 1\,(high\ risk) & W/B \le 4 \\ 0.5\,(medium\ \ risk) & W/B > 4 \\ 0\,(low\ risk) & banks\ \ fixed\ in\ \ place \end{cases}$$

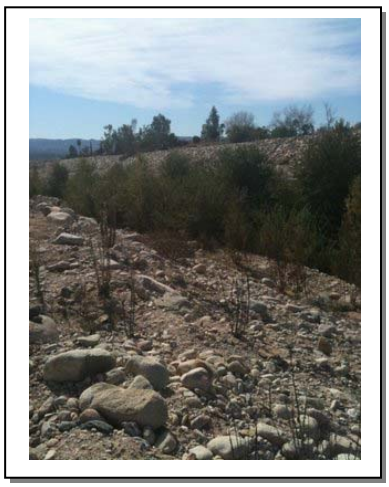
W = valley width, B = channel width

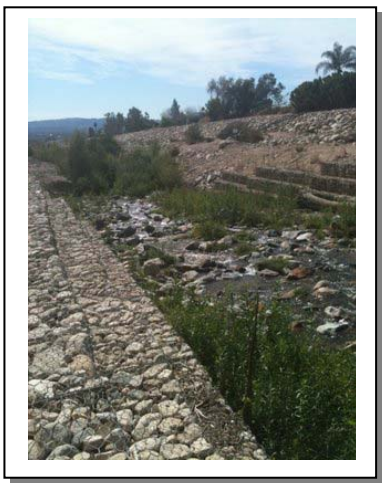
W = 320 ft, B = 100 ft, W/B = 3.2 < 4.0, C_4 = 1.0 (high risk)

5) Bank Conditions (risk factor C_5)

Bedrock yes = 0 no = 1	*Bank Protection* good condition = 0 bad condition or no = 1	*Vegetation* dense = 0 sparse or no = 1	*Stratification* no = 0 yes = 1	*Bank Erosion* no = 0 yes = 1	*Toe Erosion* no = 0 yes = 1
C_{51} = 0.5	C_{52} = 1.0	C_{53} = 1.0	C_{54} = 0.0	C_{55} = 1.0	C_{56} = 1.0

$$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6} = 0.75 \text{ (high risk)}$$





6) Streambed Conditions (risk factor C_6)

Braided no = 0 yes = 1	*Armored* yes = 0 no = 1	*Bedrock* yes = 0 no = 1	*Headcuts* no = 0 yes = 1	*Degradation* < 1ft = 0 > 1 ft = 1	*D/S Hardpoint* yes = 0 no = 1	*Sediment Source* no = 0 yes = 1
$C_{61} = 0.0$	$C_{62} = 0.5$	$C_{63} = 1.0$	$C_{64} = 0.0$	$C_{65} = 1.0$	$C_{66} = 1.0$	$C_{67} = 1.0$

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = 0.64 \text{ (medium risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i \,, \quad \sum_{1}^{6} w_i = 1$$

Primary criteria: $w_1 = w_2 = w_3 = 2/9$

Secondary criteria: $w_4 = w_5 = w_6 = 1/9$

$SI = 2/9 \cdot (1.0 + 0.5 + 0.5) + 1/9 \cdot (1.0 + 0.75 + 0.64) = 0.71 > 0.67$

Risk Classification RC

$$RC = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

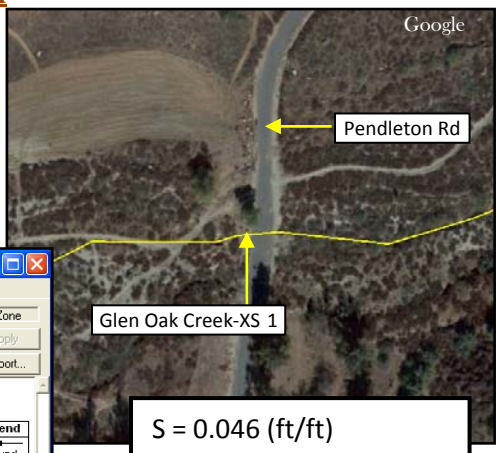
RC = High

Calculation Summary Sheets

Zone 3

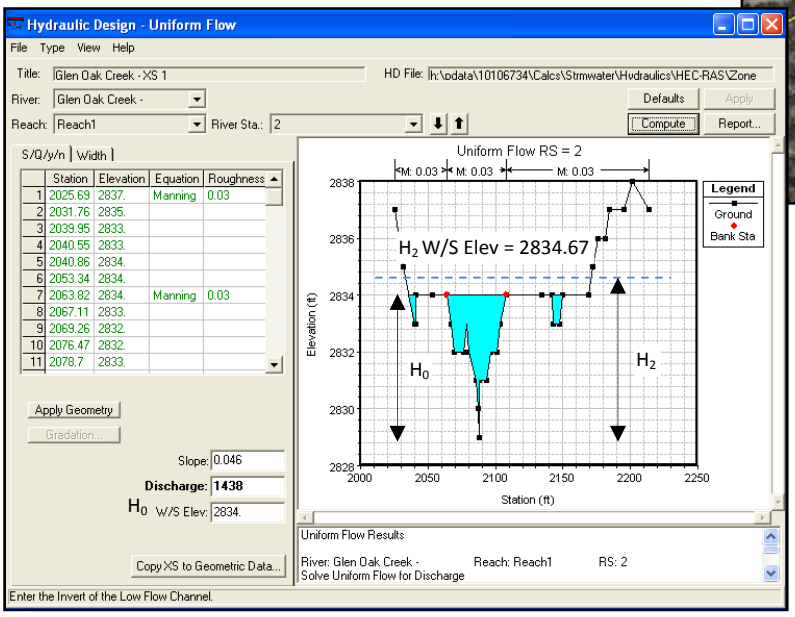
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Glen Oak Creek– XS 1 – Downstream of Pendleton Road



1) Shear Ratio SR (risk factor C_1)

$C_1 =$
- 1 *(high risk) 1.3 ≤ SR < 1.5*
- 0.5 *(medium risk) 1.00 < SR ≤ 1.3*
- 0 *(low risk) aggrading channel, hardened bed*



S = 0.046 (ft/ft)

H_0 = 5.00 ft

Q_0 = 1438 cfs

$Q_2 = 2Q_0$ = 2876 cfs

H_2 = 5.67 ft

$SR = H_2/H_0$ = 1.13

C_1 = 0.5 (medium risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4D_{50}} \right) \right]^2$$

$C_2 =$
- 1 *(high risk) ER > 1.0*
- 0.5 *(medium risk) ER < 1.0*
- 0 *(low risk) aggrading channel, hardened bed*

V = 15.71 fps

D_{50} = 2.0 mm

g = 32.2 ft/s^2

Θ_{cr} = 2.9

ER = 0.65 < 1.0

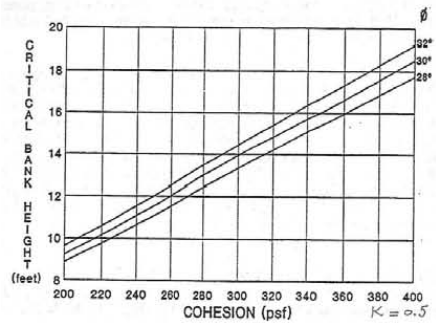
C = 375.21

C_2 = 0.5 (medium risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*; 0.5 *(medium risk) GSN < 1.0*; 0 *(low risk) engineered banks or wide shallow channel* }

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = 0.36 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*; 0.5 *(medium risk) W/B > 4*; 0 *(low risk) banks fixed in place* }

W = valley width, B = channel width

W = 451 ft, B = 45 ft, W/B = 10 > 4.0, C_4 = 0.5 (medium risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 1.0	C_{53} =0.0	C_{54} = 0.0	C_{55} = 0.0	C_{56} = 0.0

$$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6} = 0.33 \text{(low-medium risk)}$$

6) Streambed Conditions (risk factor C_6)

Braided *Yes = 0* *No = 1*	*Armored* *Yes = 0* *No = 1*	*Bedrock* *Yes = 0* *No = 1*	*Headcuts* *No = 0* *Yes = 1*	*Degradation* *< 1ft = 0* *>1ft = 1*	*D/S Hardpoint* *Yes = 0* *No = 1*	*Sediment Source* *No = 0* *Yes = 1*
C_{61} =0.0	C_{62} = 1.0	C_{63} =1.0	C_{54} = 0.0	C_{65} = 0.0	C_{66} = 1.0	C_{67} = 1.0

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.57 (medium-high risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

$SI = 2/9 \times (0.5+0.5+0.5) + 1/9 \times (0.5+0.33+0.57) =$ 0.49

Risk Classification RC

$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

$SI = 1/3 \le 0.49 < 2/3$

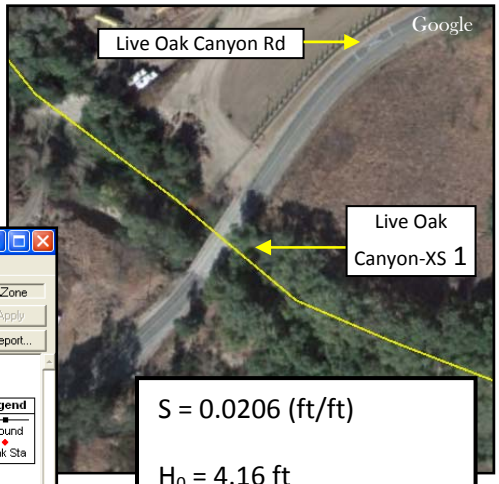
RC = Medium

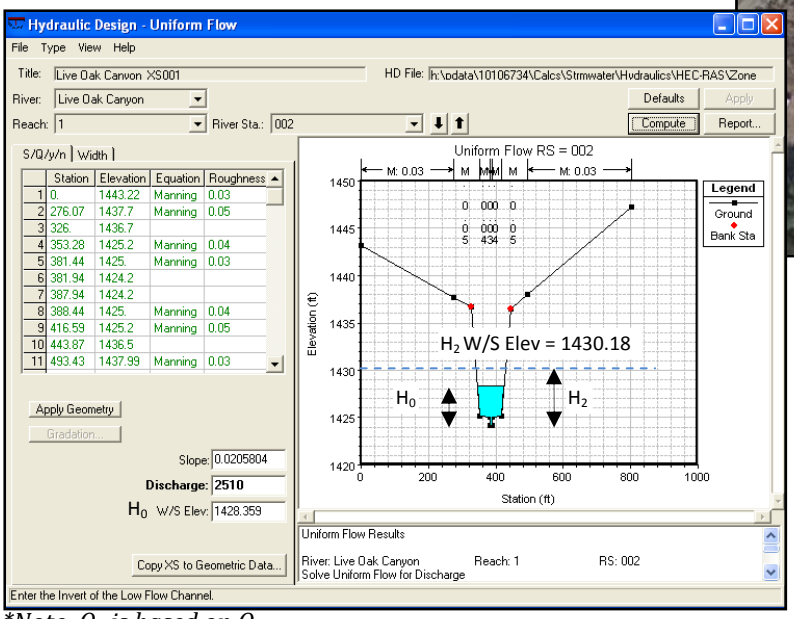
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Live Oak Canyon – XS 1 – Upstream of Live Oak Canyon Road

1) Shear Ratio SR (risk factor C_1)

$C_1 = \begin{cases} 1 \text{ (high risk) } 1.3 \le SR < 1.5 \\ 0.5 \text{ (medium risk) } 1.00 < SR \le 1.3 \\ 0 \text{ (low risk) aggrading channel, hardened bed} \end{cases}$





**Note: Q_0 is based on Q_{10}.*

S = 0.0206 (ft/ft)

H_0 = 4.16 ft

Q_0 = 2510 cfs

$Q_2 = 2Q_0$ = 5020 cfs

H_2 = 5.88 ft

$SR = H_2/H_0$ = 1.41

C_1 = 1.0 (high risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4 D_{50}} \right) \right]^2$$

$C_2 = \begin{cases} 1 \text{ (high risk) } ER > 1.0 \\ 0.5 \text{ (medium risk) } ER < 1.0 \\ 0 \text{ (low risk) aggrading channel, hardened bed} \end{cases}$

V = 10.6 fps

D_{50} = 2.0 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

ER = 0.47 > 1.0

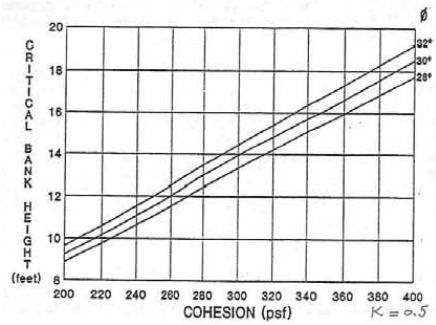
C = 357.62

C_2 = 0.5 (medium risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*; 0.5 *(medium risk) GSN < 1.0*; 0 *(low risk) engineered banks or wide shallow channel* }

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = 0.30 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*; 0.5 *(medium risk) W/B > 4*; 0 *(low risk) banks fixed in place* }

W = valley width, B = channel width

W = 300 ft, B = 117.87 ft, W/B = 2.5 ≤ 4.0, C_4 = 1.0 (high risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 1.0	C_{53} =0.0	C_{54} = 0.0	C_{55} = 0.0	C_{56} = 0.0

$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6}$ = *0.33 (low-medium risk)*

6) Streambed Conditions (risk factor C_6)

Braided *Yes = 0* *No = 1*	*Armored* *Yes = 0* *No = 1*	*Bedrock* *Yes = 0* *No = 1*	*Headcuts* *No = 0* *Yes = 1*	*Degradation* *< 1ft = 0* *>1ft = 1*	*D/S Hardpoint* *Yes = 0* *No = 1*	*Sediment Source* *No = 0* *Yes = 1*
C_{61} =0.0	C_{62} = 1.0	C_{63} =1.0	C_{54} = 0.0	C_{65} = 1.0	C_{66} = 1.0	C_{67} = 1.0

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.71 (medium-high risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

$SI = 2/9 \times (1.0+0.5+0.5) + 1/9 \times (1.0+0.33+0.71) =$ 0.67

Risk Classification RC

$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

$SI = 2/3 \le 0.67 < 1$

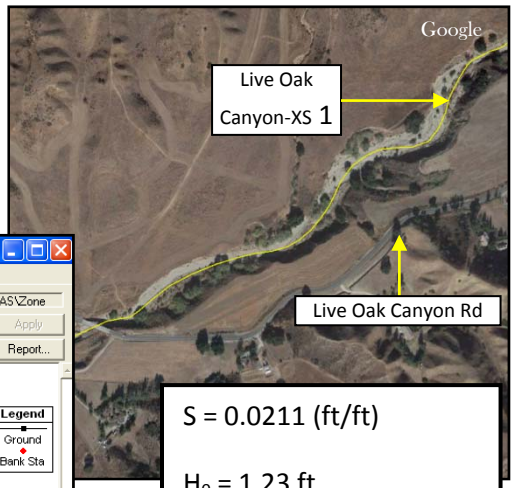
RC = High

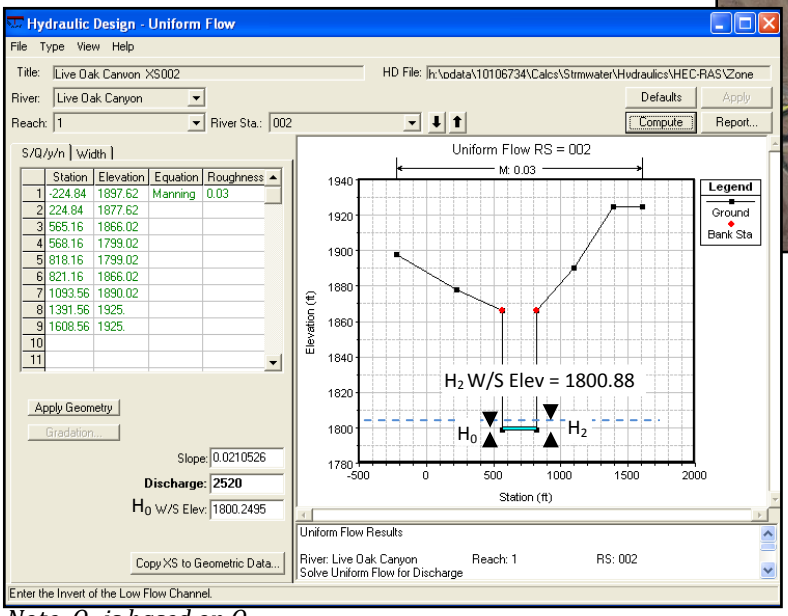
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Live Oak Canyon – XS 2 – Upstream of Live Oak Canyon Road

1) Shear Ratio SR (risk factor C_1)

$C_1 =$ { 1 *(high risk) 1.3 ≤ SR < 1.5*; 0.5 *(medium risk) 1.00 < SR ≤ 1.3*; 0 *(low risk) aggrading channel, hardened bed* }





Note: Q_0 is based on Q_{10}.

S = 0.0211 (ft/ft)

H_0 = 1.23 ft

Q_0 = 2510 cfs

$Q_2 = 2Q_0$ = 5020 cfs

H_2 = 1.86 ft

$SR = H_2/H_0$ = 1.51

C_1 = 1.0 (high risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4 D_{50}} \right) \right]^2$$

$C_2 =$ { 1 *(high risk) ER > 1.0*; 0.5 *(medium risk) ER < 1.0*; 0 *(low risk) aggrading channel, hardened bed* }

V = 8.12 fps

D_{50} = 2.0 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

ER = 0.40 > 1.0

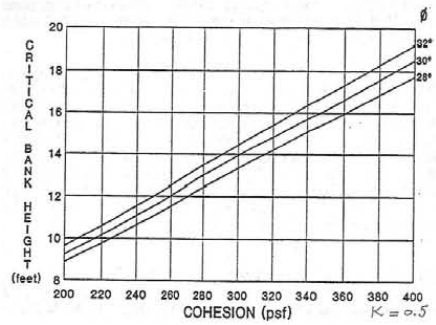
C = 251.80

C_2 = 0.5 (medium risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*
0.5 *(medium risk) GSN < 1.0*
0 *(low risk) engineered banks or wide shallow channel* }

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = 0.09 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*
0.5 *(medium risk) W/B > 4*
0 *(low risk) banks fixed in place* }

W = valley width, B = channel width

W = 868 ft, B = 256 ft, W/B = 3.4 ≤ 4.0, C_4 = 1.0 (high risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 1.0	C_{53} =1.0	C_{54} = 0.0	C_{55} = 1.0	C_{56} = 1.0

$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6}$ = *0.83 (medium-high risk)*

6) Streambed Conditions (risk factor C_6)

Braided *Yes = 0* *No = 1*	*Armored* *Yes = 0* *No = 1*	*Bedrock* *Yes = 0* *No = 1*	*Headcuts* *No = 0* *Yes = 1*	*Degradation* *< 1ft = 0* *>1ft = 1*	*D/S Hardpoint* *Yes = 0* *No = 1*	*Sediment Source* *No = 0* *Yes = 1*
C_{61} =0.0	C_{62} = 1.0	C_{63} =1.0	C_{54} = 1.0	C_{65} = 1.0	C_{66} = 1.0	C_{67} = 1.0

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.86 (medium-high risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

$SI = 2/9 \times (1.0+0.5+0.5) + 1/9 \times (1.0+0.83+0.86) =$ 0.74

Risk Classification RC

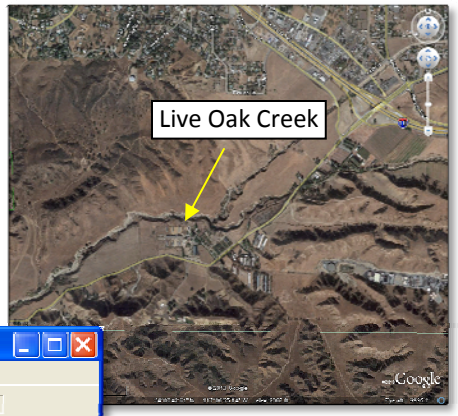
$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

$SI = 2/3 \le 0.74 < 1$

RC = High

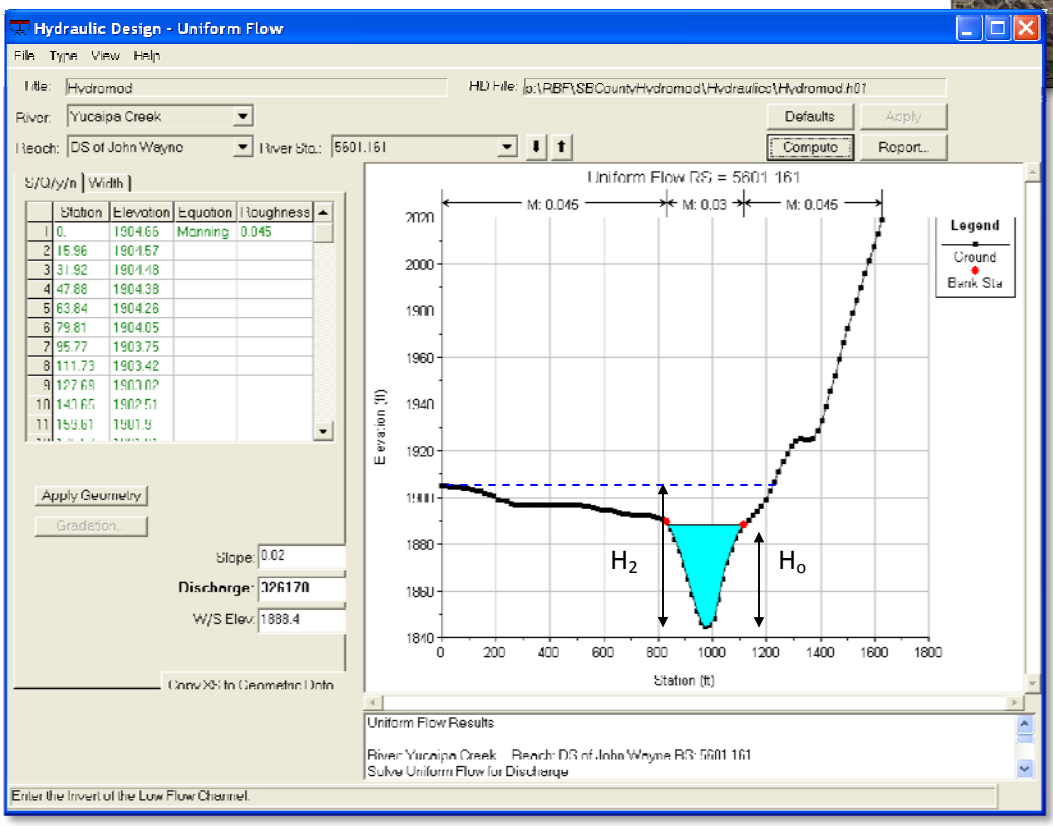
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Live Oak Creek - Downstream of Highway 10



1) Shear Ratio SR (risk factor C_1)

$$C_1 = \begin{cases} 1\,(high\ risk) & 1.3 \le SR < 1.5 \\ 0.5\,(medium\ \ risk) & 1.00 < SR < 1.3 \\ 0\,(low\ risk) & aggrading\ channel,\ hardened\ bed \end{cases}$$



S = 2.0%

H_o = 43.8ft

Q_o = 326,178 cfs

$Q_2 = 2\,Q_o$ = 652,356 cfs

H_2 = 54.13 ft

$SR = H_2/H_o = 1.24 < 1.3$

C_1 = 0.5 (medium risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{cr}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{cr}} = \frac{V^2}{1.65 g D_{50} \Theta_{cr} C} \qquad C = \left[5.75 \log\left(12.27 \frac{H_o}{4 D_{50}} \right) \right]^2$$

$$C_2 = \begin{cases} 1\,(high\ risk) & ER > 1.0 \\ 0.5\,(medium\ \ risk) & ER < 1.0 \\ 0\,(low\ risk) & aggrading\ channel, hardened\ bed \end{cases}$$

V = 27.4 ft/s

D_{50} = 2 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

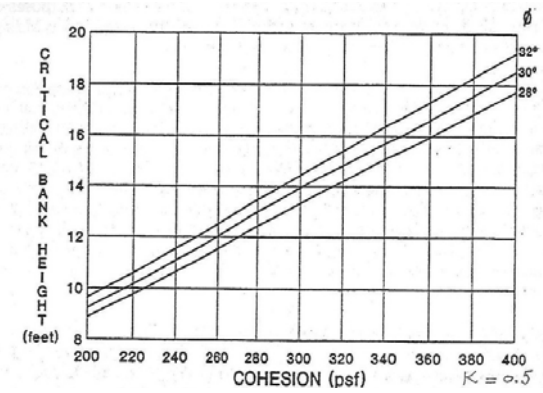
ER = 1.84 > 1.0

C = 615

C_2 = 1.0 (high risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

$$C_3 = \begin{cases} 1\,(high\ risk) & GSN > 1.0 \text{ or } toe/bank\ erosion\ observed \\ 0.5\,(medium\ \ risk) & GSN < 1.0 \\ 0\,(low\ risk) & engineered\ banks\ or\ wide\ shallow\ channel \end{cases}$$



$GSN = \frac{H_o}{H_c}$, H_c = critical bank height

Assumed cohesion = 300 psf, H_c = 14 ft, *GSN* = 3.13 >> 1.0

C_3 = 1.0 (high risk)

4) Confinement Class (risk factor C_4)

$$C_4 = \begin{cases} 1\,(high\ risk) & W/B \le 4 \\ 0.5\,(medium\ \ risk) & W/B > 4 \\ 0\,(low\ risk) & banks\ \ fixed\ in\ \ place \end{cases}$$

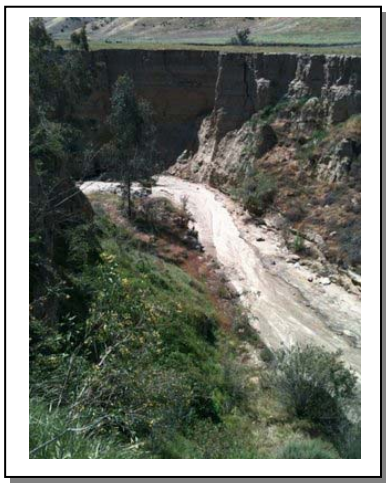
W = valley width, B = channel width

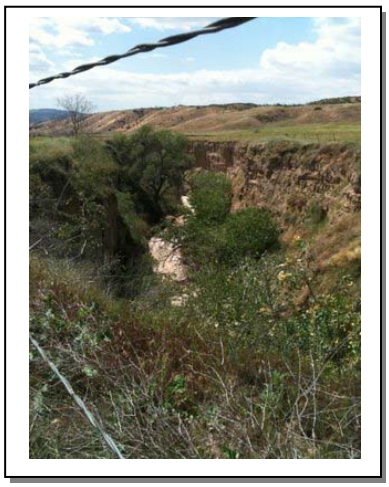
W = 1800ft, B = 300 ft, W/B = 6.0 > 4.0, C_4 = 0.5 (medium risk)

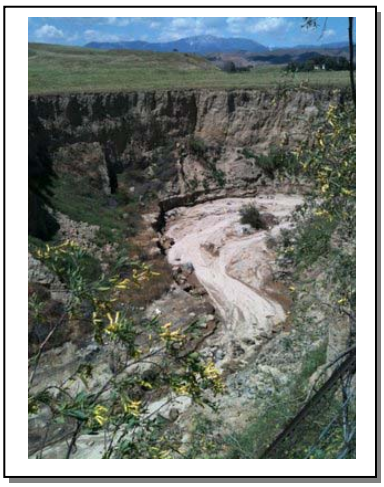
5) Bank Conditions (risk factor C_5)

Bedrock yes = 0 no = 1	*Bank Protection* good condition = 0 bad condition or no = 1	*Vegetation* dense = 0 sparse or no = 1	*Stratification* no = 0 yes = 1	*Bank Erosion* no = 0 yes = 1	*Toe Erosion* no = 0 yes = 1
C_{51} = 1.0	C_{52} = 1.0	C_{53} = 0.0	C_{54} = 0.0	C_{55} = 1.0	C_{56} = 1.0

$$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6} = 0.67 \text{ (medium-high risk)}$$







6) Streambed Conditions (risk factor C_6)

Braided no = 0 yes = 1	*Armored* yes = 0 no = 1	*Bedrock* yes = 0 no = 1	*Headcuts* no = 0 yes = 1	*Degradation* < 1ft = 0 > 1 ft = 1	*D/S Hardpoint* yes = 0 no = 1	*Sediment Source* no = 0 yes = 1
$C_{61} = 0.0$	$C_{62} = 1.0$	$C_{63} = 1.0$	$C_{64} = 0.0$	$C_{65} = 1.0$	$C_{66} = 1.0$	$C_{67} = 0.5$

$$C_6 = \frac{\sum_1^7 C_{6i}}{7} = 0.57 \text{ (medium risk)}$$

Stability Index SI

$$SI = \sum_1^6 w_i C_i \,, \quad \sum_1^6 w_i = 1$$

Primary criteria: $w_1 = w_2 = w_3 = 2/9$

Secondary criteria: $w_4 = w_5 = w_6 = 1/9$

$SI = 2/9 \cdot (0.5 + 1.0 + 1.0) + 1/9 \cdot (0.5 + 0.67 + 0.57) = 0.75 > 0.67$

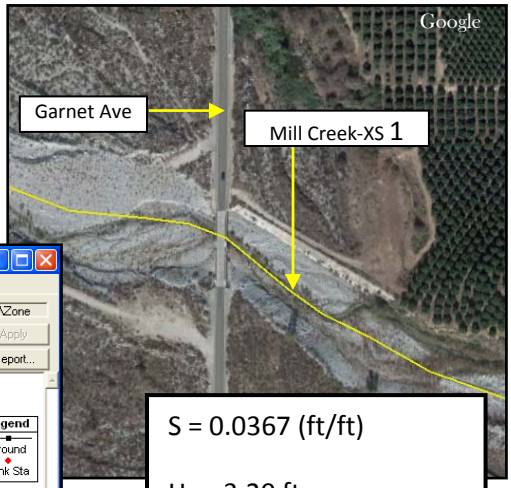
Risk Classification RC

$$RC = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

RC = High

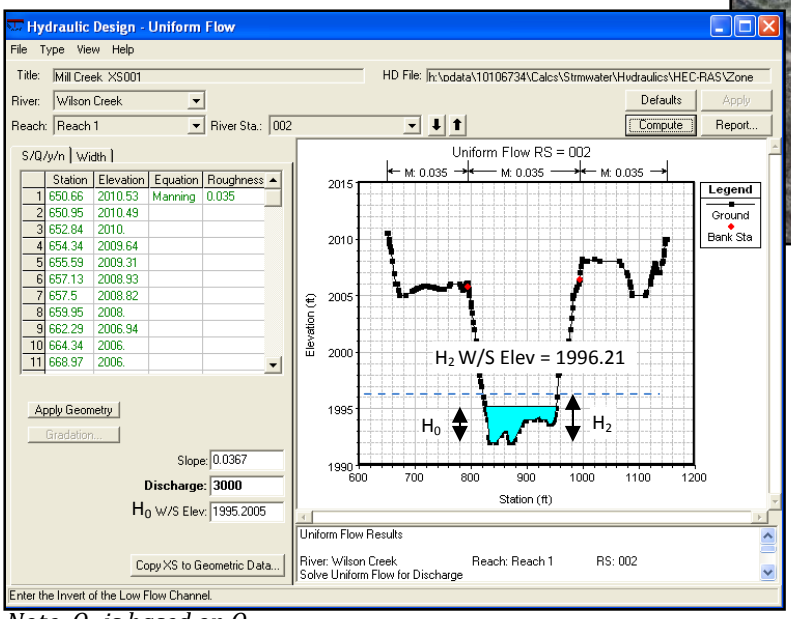
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Mill Creek – XS 1 – Upstream of Garnet Avenue



1) Shear Ratio SR (risk factor C_1)

$C_1 =$
- 1 *(high risk) 1.3 ≤ SR < 1.5*
- 0.5 *(medium risk) 1.00 < SR ≤ 1.3*
- 0 *(low risk) aggrading channel, hardened bed*



Note: Q_0 is based on Q_{10}.

S = 0.0367 (ft/ft)

H_0 = 3.20 ft

Q_0 = 3000 cfs

$Q_2 = 2Q_0$ = 6000 cfs

H_2 = 4.21 ft

$SR = H_2/H_0$ = 1.32

C_1 = 1.0 (high risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4 D_{50}} \right) \right]^2$$

$C_2 =$
- 1 *(high risk) ER > 1.0*
- 0.5 *(medium risk) ER < 1.0*
- 0 *(low risk) aggrading channel, hardened bed*

V = 12.42 fps

D_{50} = 40.0 mm

g = 32.2 ft/s^2

Θ_{cr} = 2.9

ER = 0.46 < 1.0

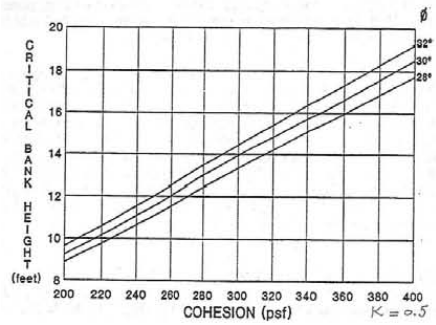
C = 333.27

C_2 = 0.5 (medium risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*
0.5 *(medium risk) GSN < 1.0*
0 *(low risk) engineered banks or wide shallow channel*

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = 0.23 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*
0.5 *(medium risk) W/B > 4*
0 *(low risk) banks fixed in place*

W = valley width, B = channel width

W = 496 ft, B = 198 ft, W/B = 2.5 ≤ 4.0, C_4 = 1.0 (high risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 1.0	C_{53} =1.0	C_{54} = 0.0	C_{55} = 1.0	C_{56} = 1.0

$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6}$ = *0.83 (medium-high risk)*

6) Streambed Conditions (risk factor C_6)

Braided *Yes = 0* *No = 1*	*Armored* *Yes = 0* *No = 1*	*Bedrock* *Yes = 0* *No = 1*	*Headcuts* *No = 0* *Yes = 1*	*Degradation* *< 1ft = 0* *>1ft = 1*	*D/S Hardpoint* *Yes = 0* *No = 1*	*Sediment Source* *No = 0* *Yes = 1*
C_{61} =0.0	C_{62} = 1.0	C_{63} =1.0	C_{54} = 0.0	C_{65} = 1.0	C_{66} = 1.0	C_{67} = 1.0

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.71 (medium-high risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

$SI = 2/9 \times (1.0+0.5+0.5) + 1/9 \times (1.0+0.83+0.71) =$ 0.73

Risk Classification RC

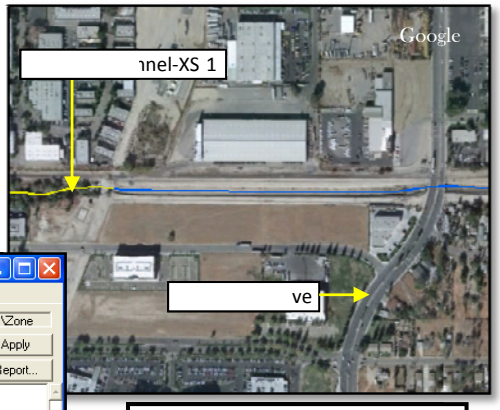
$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

$SI = 2/3 \le 0.73 < 1$

RC = High

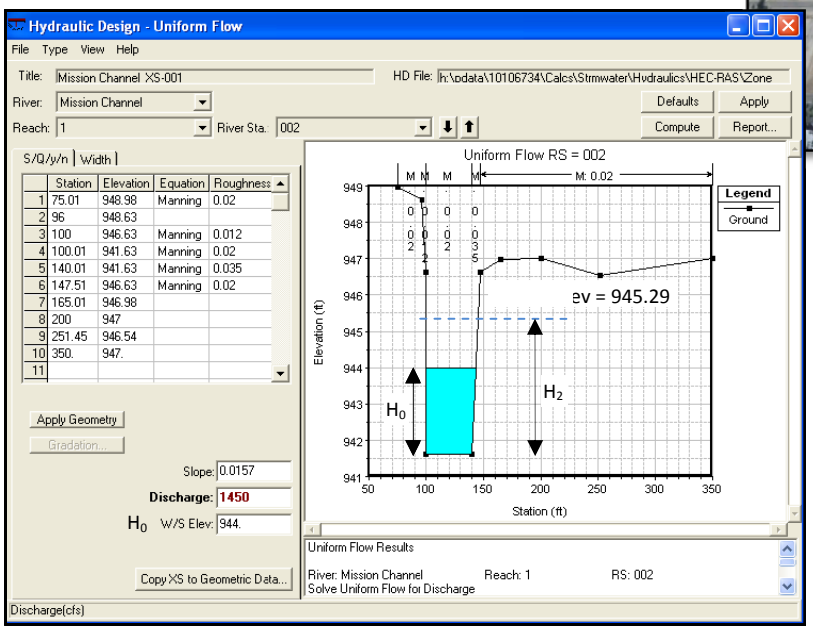
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Mission Channel – XS 1 – Downstream of Ward Way



1) Shear Ratio SR (risk factor C_1)

$C_1 = \begin{cases} 1 \text{ (high risk) } 1.3 \le SR < 1.5 \\ 0.5 \text{ (medium risk) } 1.00 < SR \le 1.3 \\ 0 \text{ (low risk) aggrading channel, hardened bed} \end{cases}$



Note: Q_0 is based on Q_{10}.

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4 D_{50}} \right) \right]^2$$

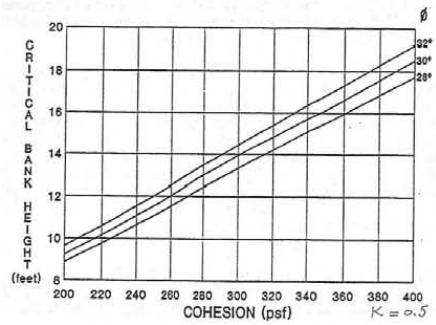
$C_2 = \begin{cases} 1 \text{ (high risk) } ER > 1.0 \\ 0.5 \text{ (medium risk) } ER < 1.0 \\ 0 \text{ (low risk) aggrading channel, hardened bed} \end{cases}$

RBF CONSULTING

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*
0.5 *(medium risk) GSN < 1.0*
0 *(low risk) engineered banks or wide shallow channel* }

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = 0.23 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*
0.5 *(medium risk) W/B > 4*
0 *(low risk) banks fixed in place* }

W = valley width, B = channel width

W = 130 ft, B = 47.52 ft, W/B = 2.7 ≤ 4.0, C_4 = 1.0 (high risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 1.0	C_{53} =1.0	C_{54} = 0.0	C_{55} = 1.0	C_{56} = 1.0

$$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6} = 0.83 \text{ (medium-high risk)}$$

6) Streambed Conditions (risk factor C_6)

Braided *Yes = 0* *No = 1*	*Armored* *Yes = 0* *No = 1*	*Bedrock* *Yes = 0* *No = 1*	*Headcuts* *No = 0* *Yes = 1*	*Degradation* *< 1ft = 0* *>1ft = 1*	*D/S Hardpoint* *Yes = 0* *No = 1*	*Sediment Source* *No = 0* *Yes = 1*
C_{61} =0.0	C_{62} = 1.0	C_{63} =1.0	C_{54} = 1.0	C_{65} = 1.0	C_{66} = 1.0	C_{67} = 1.0

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.86 (medium-high risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

$SI = 2/9 \times (1.0+0.5+0.5) + 1/9 \times (1.0+0.83+0.86) =$ 0.74

Risk Classification RC

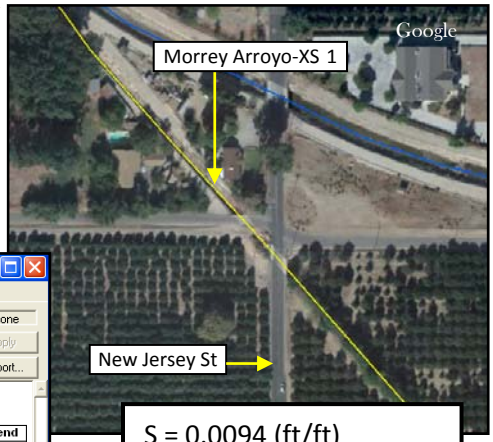
$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

$SI = 2/3 \le 0.74 < 1$

RC = High

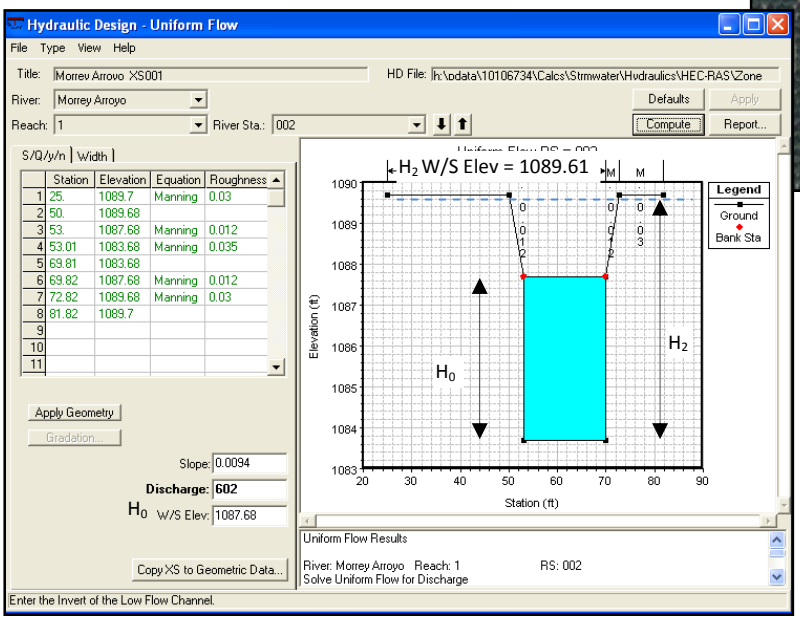
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Morrey Arroyo– XS 1 – Downstream of New Jersy Street



1) Shear Ratio SR (risk factor C_1)

$C_1 =$ { 1 *(high risk) 1.3 ≤ SR < 1.5*; 0.5 *(medium risk) 1.00 < SR ≤ 1.3*; 0 *(low risk) aggrading channel, hardened bed*



S = 0.0094 (ft/ft)

H_0 = 4.00 ft

Q_0 = 602 cfs

$Q_2 = 2Q_0$ = 1204 cfs

H_2 = 5.93 ft

$SR = H_2/H_0$ = 1.48

C_1 = 1.0 (high risk)

Note: Q_0 is based on Q_{10}.

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4 D_{50}} \right) \right]^2$$

$C_2 =$ { 1 *(high risk) ER > 1.0*; 0.5 *(medium risk) ER < 1.0*; 0 *(low risk) aggrading channel, hardened bed*

V = 8.85 fps

D_{50} = 1.5 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

ER = 0.33 < 1.0

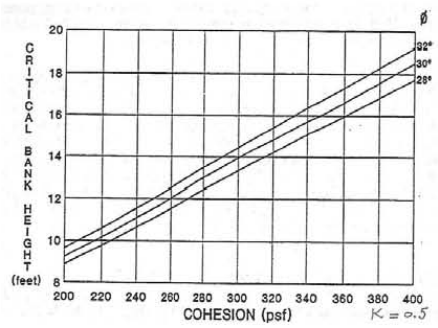
C = 353.93

C_2 = 0.5 (medium risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*; 0.5 *(medium risk) GSN < 1.0*; 0 *(low risk) engineered banks or wide shallow channel* }

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = 0.29 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*; 0.5 *(medium risk) W/B > 4*; 0 *(low risk) banks fixed in place* }

W = valley width, B = channel width

W = 53 ft, B = 16.8 ft, W/B = 3.2 ≤ 4.0, C_4 = 1.0 (high risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 0.0	C_{53} =1.0	C_{54} = 0.0	C_{55} = 0.0	C_{56} = 0.0

$$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6} = 0.33 \text{ (low-medium risk)}$$

6) Streambed Conditions (risk factor C_6)

Braided *Yes = 0* *No = 1*	*Armored* *Yes = 0* *No = 1*	*Bedrock* *Yes = 0* *No = 1*	*Headcuts* *No = 0* *Yes = 1*	*Degradation* *< 1ft = 0* *>1ft = 1*	*D/S Hardpoint* *Yes = 0* *No = 1*	*Sediment Source* *No = 0* *Yes = 1*
C_{61} =0.0	C_{62} = 0.0	C_{63} =1.0	C_{54} = 0.0	C_{65} = 0.0	C_{66} = 1.0	C_{67} = 0.0

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.29 (low-medium risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

SI = 2/9×(1.0+0.5+0.5) + 1/9×(1.0+0.33+0.29) = 0.62

Risk Classification RC

$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

SI = 1/3 ≤ 0.62 < 2/3

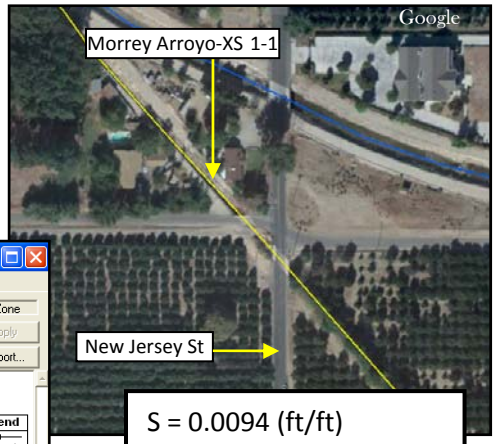
RC = Medium

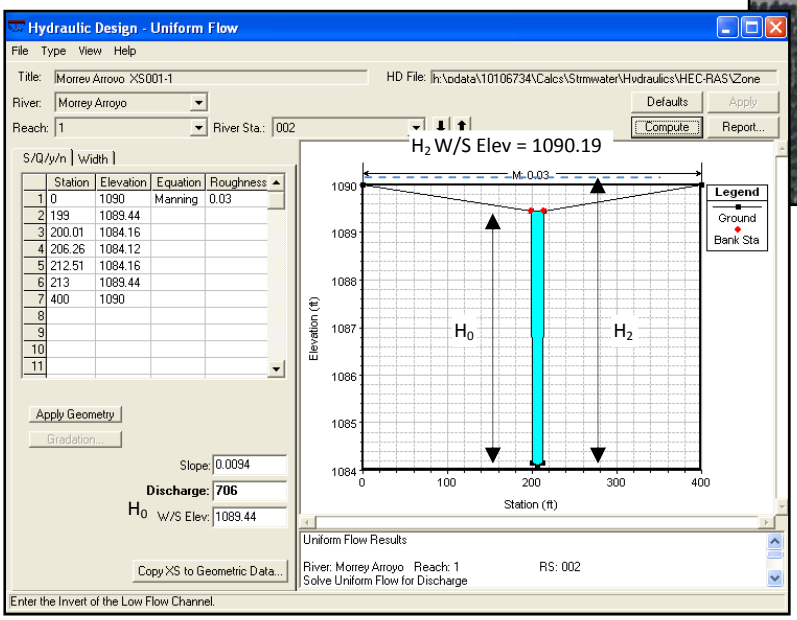
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Morrey Arroyo– XS 1-1 – Downstream of New Jersey Street

1) Shear Ratio SR (risk factor C_1)

$C_1 =$ { 1 *(high risk) 1.3 ≤ SR < 1.5*; 0.5 *(medium risk) 1.00 < SR ≤ 1.3*; 0 *(low risk) aggrading channel, hardened bed* }





S = 0.0094 (ft/ft)

H_0 = 5.32 ft

Q_0 = 706 cfs

$Q_2 = 2Q_0$ = 1412 cfs

H_2 = 6.07 ft

$SR = H_2/H_0$ = 1.14

C_1 = 0.5 (medium risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4D_{50}} \right) \right]^2$$

$C_2 =$ { 1 *(high risk) ER > 1.0*; 0.5 *(medium risk) ER < 1.0*; 0 *(low risk) aggrading channel, hardened bed* }

V = 10.06 fps

D_{50} = 1.5 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

ER = 0.50 < 1.0

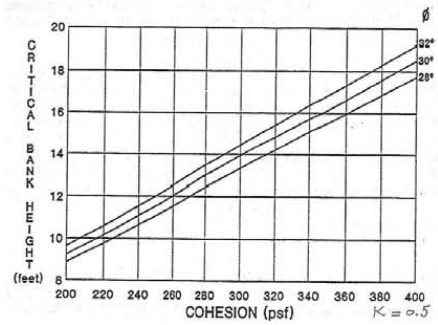
C = 409.80

C_2 = 0.5 (medium risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*
0.5 *(medium risk) GSN < 1.0*
0 *(low risk) engineered banks or wide shallow channel*

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = 0.38 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*
0.5 *(medium risk) W/B > 4*
0 *(low risk) banks fixed in place*

W = valley width, B = channel width

W = 400 ft, B = 12.5 ft, W/B = 32.0 > 4.0, C_4 = 0.5 (medium risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 0.0	C_{53} =0.0	C_{54} = 0.0	C_{55} = 1.0	C_{56} = 1.0

$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6}$ = *0.50 (medium risk)*

6) Streambed Conditions (risk factor C_6)

Braided *Yes = 0* *No = 1*	*Armored* *Yes = 0* *No = 1*	*Bedrock* *Yes = 0* *No = 1*	*Headcuts* *No = 0* *Yes = 1*	*Degradation* *< 1ft = 0* *>1ft = 1*	*D/S Hardpoint* *Yes = 0* *No = 1*	*Sediment Source* *No = 0* *Yes = 1*
C_{61} =0.0	C_{62} = 1.0	C_{63} =1.0	C_{54} = 0.0	C_{65} = 0.0	C_{66} = 1.0	C_{67} = 1.0

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.57 (low-medium risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

$SI = 2/9\times(0.5+0.5+0.5) + 1/9\times(0.5+0.5+0.57) =$ 0.51

Risk Classification RC

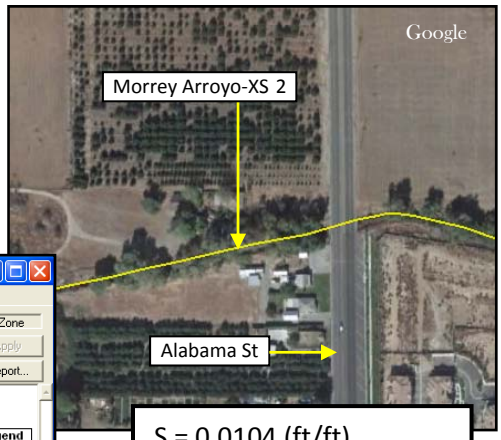
$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

$SI = 1/3 \le 0.51 < 2/3$

RC = Medium

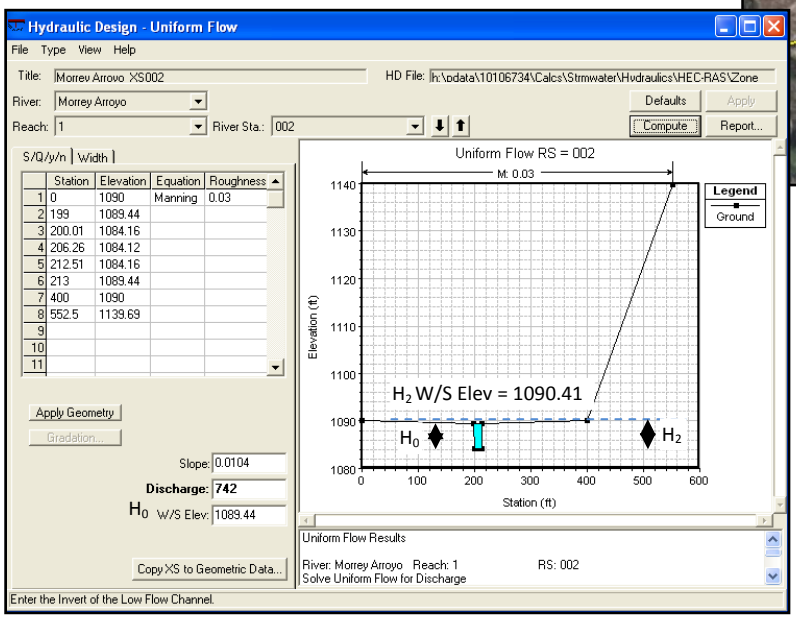
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Morrey Arroyo– XS 2 – Downstream of Alabama Street



1) Shear Ratio SR (risk factor C_1)

$C_1 =$
- 1 *(high risk) 1.3 ≤ SR < 1.5*
- 0.5 *(medium risk) 1.00 < SR ≤ 1.3*
- 0 *(low risk) aggrading channel, hardened bed*



S = 0.0104 (ft/ft)

H_0 = 5.32 ft

Q_0 = 742 cfs

$Q_2 = 2Q_0$ = 1484 cfs

H_2 = 6.25 ft

$SR = H_2/H_0$ = 1.17

C_1 = 0.5 (medium risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4 D_{50}} \right) \right]^2$$

$C_2 =$
- 1 *(high risk) ER > 1.0*
- 0.5 *(medium risk) ER < 1.0*
- 0 *(low risk) aggrading channel, hardened bed*

V = 9.3 fps

D_{50} = 1.5 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

ER = 0.42 < 1.0

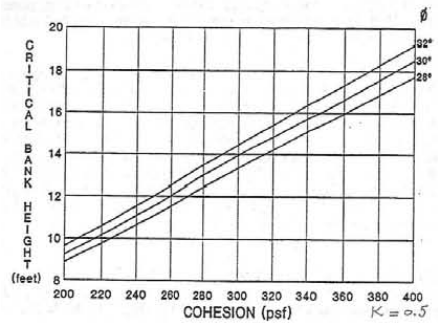
C = 409.80

C_2 = 0.5 (medium risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*; 0.5 *(medium risk) GSN < 1.0*; 0 *(low risk) engineered banks or wide shallow channel* }

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = 0.38 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*; 0.5 *(medium risk) W/B > 4*; 0 *(low risk) banks fixed in place* }

W = valley width, B = channel width

W = 552 ft, B = 35.76 ft, W/B = 15.4 > 4.0, C_4 = 0.5 (medium risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 1.0	C_{53} =1.0	C_{54} = 0.0	C_{55} = 1.0	C_{56} = 0.0

$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6}$ = 0.67 (medium-high risk)

6) Streambed Conditions (risk factor C_6)

Braided *Yes = 0* *No = 1*	*Armored* *Yes = 0* *No = 1*	*Bedrock* *Yes = 0* *No = 1*	*Headcuts* *No = 0* *Yes = 1*	*Degradation* *< 1ft = 0* *>1ft = 1*	*D/S Hardpoint* *Yes = 0* *No = 1*	*Sediment Source* *No = 0* *Yes = 1*
C_{61} =0.0	C_{62} = 1.0	C_{63} =1.0	C_{54} = 0.0	C_{65} = 1.0	C_{66} = 1.0	C_{67} = 0.0

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.57 (medium-high risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

$SI = 2/9 \times (0.5+0.5+0.5) + 1/9 \times (0.5+0.67+0.57) =$ 0.53

Risk Classification RC

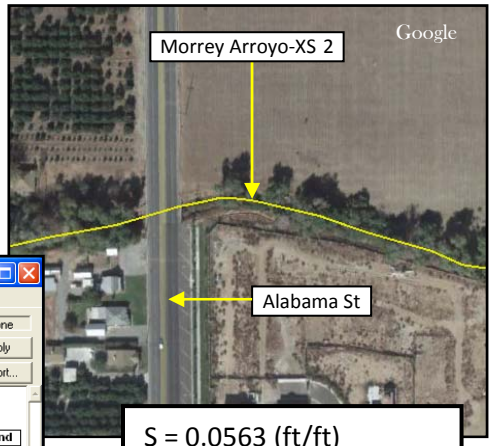
$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

$SI = 1/3 \le 0.53 < 2/3$

RC = Medium

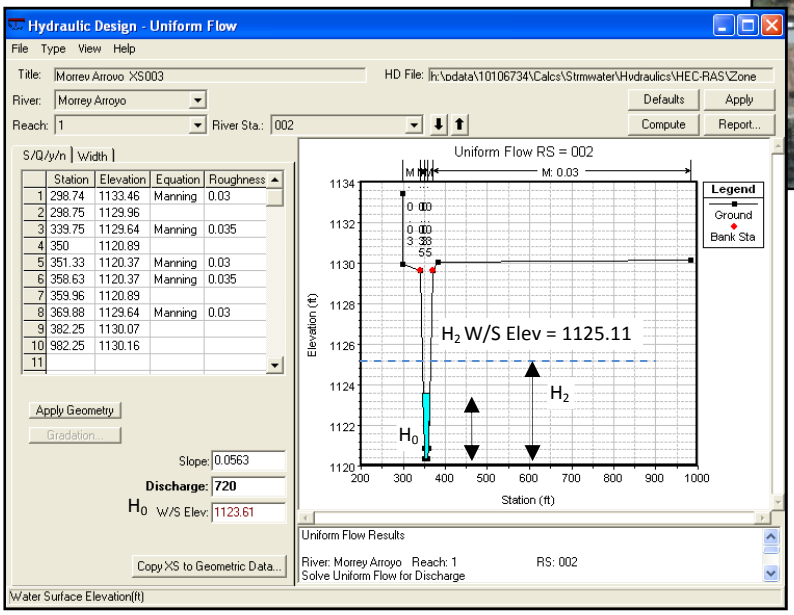
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Morrey Arroyo– XS 3 – Upstream of Alabama Street



1) Shear Ratio SR (risk factor C_1)

$C_1 =$
- 1 *(high risk) 1.3 ≤ SR < 1.5*
- 0.5 *(medium risk) 1.00 < SR ≤ 1.3*
- 0 *(low risk) aggrading channel, hardened bed*



S = 0.0563 (ft/ft)

H_0 = 3.24 ft

Q_0 = 720 cfs

$Q_2 = 2Q_0$ = 1440 cfs

H_2 = 4.74 ft

$SR = H_2/H_0$ = 1.46

C_1 = 1.0 (high risk)

Note: Q_0 is based on Q_{10}.

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4 D_{50}} \right) \right]^2$$

$C_2 =$
- 1 *(high risk) ER > 1.0*
- 0.5 *(medium risk) ER < 1.0*
- 0 *(low risk) aggrading channel, hardened bed*

V = 17.91 fps

D_{50} = 1.5 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

ER = 1.79 > 1.0

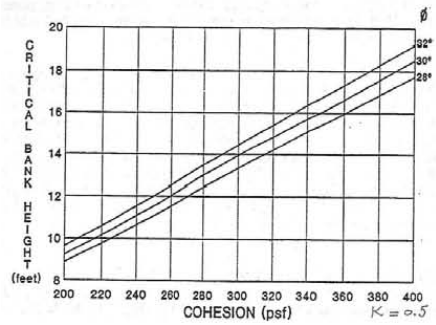
C = 361.20

C_2 = 1.0 (high risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*; 0.5 *(medium risk) GSN < 1.0*; 0 *(low risk) engineered banks or wide shallow channel* }

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = 0.23 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*; 0.5 *(medium risk) W/B > 4*; 0 *(low risk) banks fixed in place* }

W = valley width, B = channel width

W = 90 ft, B = 30.13 ft, W/B = 3.0 ≤ 4.0, C_4 = 1.0 (high risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 1.0	C_{53} =0.0	C_{54} = 0.0	C_{55} = 1.0	C_{56} = 1.0

$$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6} = 0.67 \text{ (medium-high risk)}$$

6) Streambed Conditions (risk factor C_6)

Braided *Yes = 0* *No = 1*	*Armored* *Yes = 0* *No = 1*	*Bedrock* *Yes = 0* *No = 1*	*Headcuts* *No = 0* *Yes = 1*	*Degradation* *< 1ft = 0* *>1ft = 1*	*D/S Hardpoint* *Yes = 0* *No = 1*	*Sediment Source* *No = 0* *Yes = 1*
C_{61} =0.0	C_{62} = 1.0	C_{63} =1.0	C_{54} = 0.0	C_{65} = 1.0	C_{66} = 0.0	C_{67} = 0.0

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.43 (low-medium risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

$SI = 2/9 \times (1.0+1.0+0.5) + 1/9 \times (1.0+0.67+0.43) =$ 0.79

Risk Classification RC

$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

$SI = 2/3 \le 0.79 < 1$

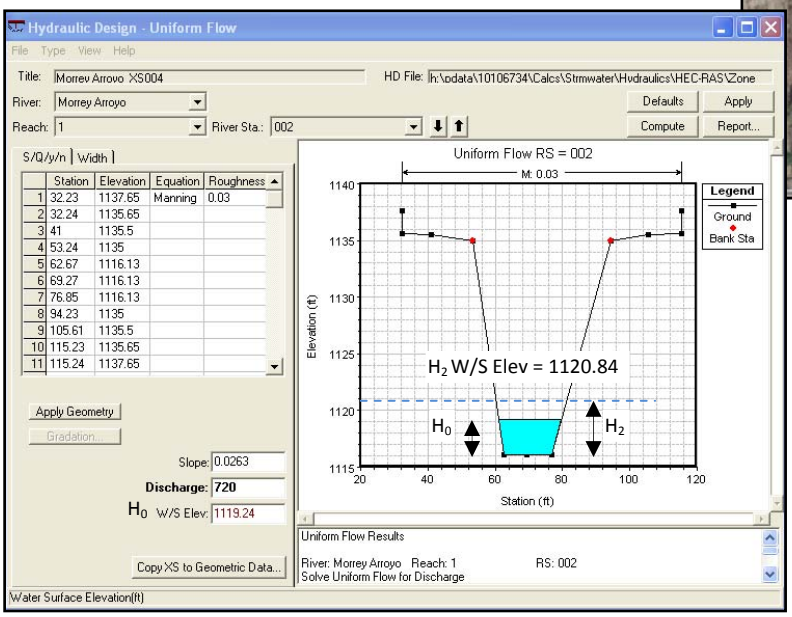
RC = High

RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Morrey Arroyo– XS 4 – Upstream of Alabama Street

1) Shear Ratio SR (risk factor C_1)

$C_1 =$
- 1 *(high risk) 1.3 ≤ SR < 1.5*
- 0.5 *(medium risk) 1.00 < SR ≤ 1.3*
- 0 *(low risk) aggrading channel, hardened bed*



S = 0.0263 (ft/ft)

H_0 = 3.11 ft

Q_0 = 720 cfs

$Q_2 = 2Q_0$ = 1440 cfs

H_2 = 4.71 ft

$SR = H_2/H_0$ = 1.51

C_1 = 1.0 (high risk)

Note: Q0 is based on Q10.

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4 D_{50}} \right) \right]^2$$

$C_2 =$
- 1 *(high risk) ER > 1.0*
- 0.5 *(medium risk) ER < 1.0*
- 0 *(low risk) aggrading channel, hardened bed*

V = 14.12 fps

D_{50} = 1.5 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

ER = 1.12 > 1.0

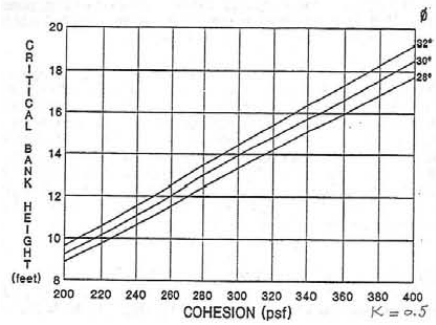
C = 357.32

C_2 = 1.0 (high risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*; 0.5 *(medium risk) GSN < 1.0*; 0 *(low risk) engineered banks or wide shallow channel* }

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = 0.22 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*; 0.5 *(medium risk) W/B > 4*; 0 *(low risk) banks fixed in place* }

W = valley width, B = channel width

W = 83 ft, B = 41 ft, W/B = 2.0 ≤ 4.0, C_4 = 1.0 (high risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 1.0	C_{53} =1.0	C_{54} = 0.0	C_{55} = 1.0	C_{56} = 1.0

$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6}$ = *0.83 (medium-high risk)*

6) Streambed Conditions (risk factor C_6)

Braided *Yes = 0* *No = 1*	*Armored* *Yes = 0* *No = 1*	*Bedrock* *Yes = 0* *No = 1*	*Headcuts* *No = 0* *Yes = 1*	*Degradation* *< 1ft = 0* *>1ft = 1*	*D/S Hardpoint* *Yes = 0* *No = 1*	*Sediment Source* *No = 0* *Yes = 1*
C_{61} =0.0	C_{62} = 1.0	C_{63} =1.0	C_{54} = 0.0	C_{65} = 1.0	C_{66} = 1.0	C_{67} = 1.0

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.71 (medium-high risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

$SI = 2/9 \times (1.0+1.0+0.5) + 1/9 \times (1.0+0.83+0.71) =$ 0.84

Risk Classification RC

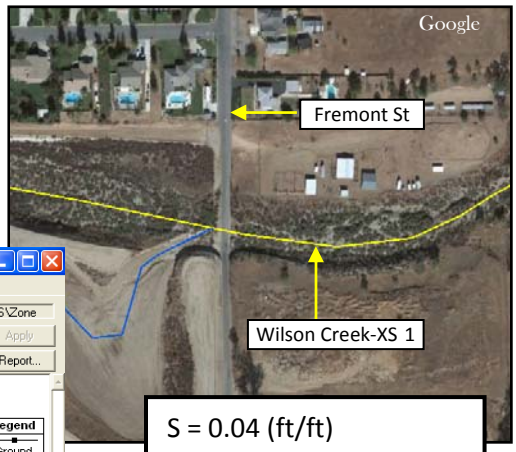
$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

$SI = 2/3 \le 0.84 < 1$

RC = High

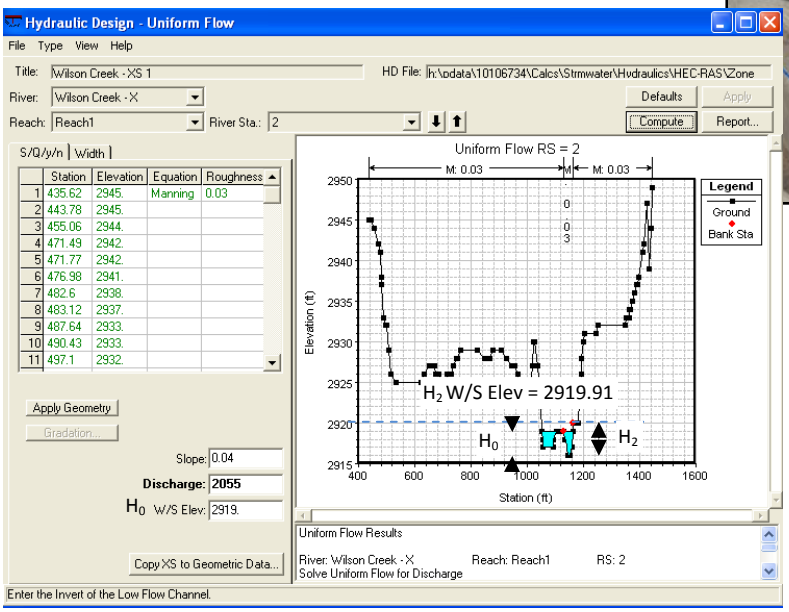
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Wilson Creek– XS 1 – Upstream of Fremont St



1) Shear Ratio SR (risk factor C_1)

$C_1 =$ { 1 *(high risk) 1.3 ≤ SR < 1.5*; 0.5 *(medium risk) 1.00 < SR ≤ 1.3*; 0 *(low risk) aggrading channel, hardened bed*



S = 0.04 (ft/ft)

H_0 = 3.00 ft

Q_0 = 2055 cfs

$Q_2 = 2Q_0$ = 4110 cfs

H_2 = 3.91 ft

$SR = H_2/H_0$ = 1.30

C_1 = 1.0 (high risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4 D_{50}} \right) \right]^2$$

$C_2 =$ { 1 *(high risk) ER > 1.0*; 0.5 *(medium risk) ER < 1.0*; 0 *(low risk) aggrading channel, hardened bed*

V = 15.24 fps

D_{50} = 2.0 mm

g = 32.2 ft/s^2

Θ_{cr} = 2.9

ER = 0.70 < 1.0

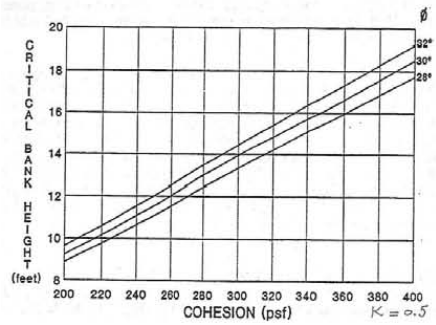
C = 327.42

C_2 = 1.0 (high risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*; 0.5 *(medium risk) GSN < 1.0*; 0 *(low risk) engineered banks or wide shallow channel* }

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = 0.21 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*; 0.5 *(medium risk) W/B > 4*; 0 *(low risk) banks fixed in place* }

W = valley width, B = channel width

W = 465 ft, B = 152 ft, W/B = 3.1 ≤ 4.0, C_4 = 1.0 (high risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 1.0	C_{53} =0.0	C_{54} = 0.0	C_{55} = 1.0	C_{56} = 1.0

$$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6} = 0.67 \text{(medium-high risk)}$$

6) Streambed Conditions (risk factor C_6)

Braided *Yes = 0* *No = 1*	*Armored* *Yes = 0* *No = 1*	*Bedrock* *Yes = 0* *No = 1*	*Headcuts* *No = 0* *Yes = 1*	*Degradation* *< 1ft = 0* *>1ft = 1*	*D/S Hardpoint* *Yes = 0* *No = 1*	*Sediment Source* *No = 0* *Yes = 1*
C_{61} =0.0	C_{62} = 1.0	C_{63} =1.0	C_{54} = 1.0	C_{65} =1.0	C_{66} = 1.0	C_{67} = 1.0

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.86 (medium-high risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

$SI = 2/9 \times (1.0+0.5+0.5) + 1/9 \times (1.0+0.67+0.86) =$ 0.84

Risk Classification RC

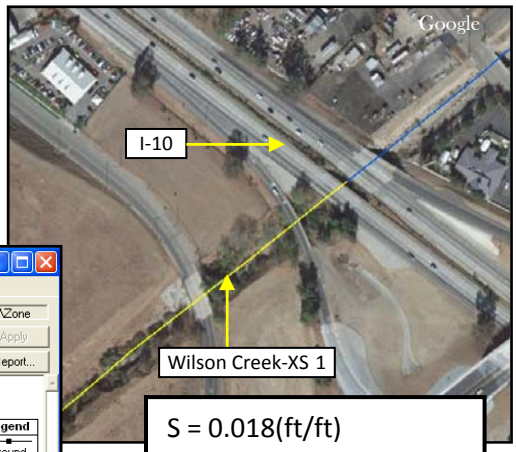
$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

$SI = 2/3 \le 0.84 < 1$

RC = High

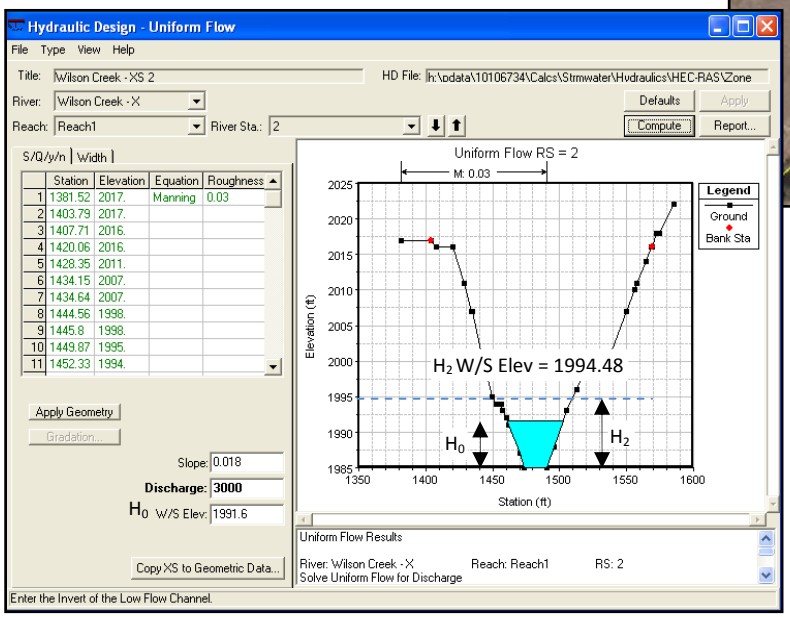
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Wilson Creek– XS 2 – Downstream of Interstate-10



1) Shear Ratio SR (risk factor C_1)

$C_1 =$ { 1 *(high risk) 1.3 ≤ SR < 1.5*; 0.5 *(medium risk) 1.00 < SR ≤ 1.3*; 0 *(low risk) aggrading channel, hardened bed* }



S = 0.018(ft/ft)

H_0 = 6.60 ft

Q_0 = 3000 cfs

$Q_2 = 2Q_0$ = 6000 cfs

H_2 = 9.48 ft

$SR = H_2/H_0$ = 1.44

C_1 = 1.0 (high risk)

Note: Q_0 is based on Q_{10}.

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4 D_{50}} \right) \right]^2$$

$C_2 =$ { 1 *(high risk) ER > 1.0*; 0.5 *(medium risk) ER < 1.0*; 0 *(low risk) aggrading channel, hardened bed* }

V = 15.24 fps

D_{50} = 2.0 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

ER = 0.92 < 1.0

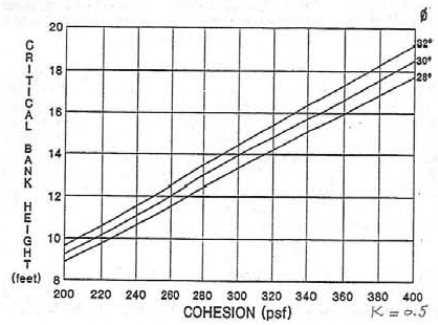
C = 402.55

C_2 = 0.5 (medium risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*
0.5 *(medium risk) GSN < 1.0*
0 *(low risk) engineered banks or wide shallow channel* }

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = 0.47 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*
0.5 *(medium risk) W/B > 4*
0 *(low risk) banks fixed in place* }

W = valley width, B = channel width

W = 900 ft, B = 107 ft, W/B = 8.4 > 4.0, C_4 = 0.5 (high risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 1.0	C_{53} =1.0	C_{54} = 0.0	C_{55} = 1.0	C_{56} = 0.0

$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6}$ = *0.67(medium-high risk)*

6) Streambed Conditions (risk factor C_6)

Braided *Yes = 0* *No = 1*	*Armored* *Yes = 0* *No = 1*	*Bedrock* *Yes = 0* *No = 1*	*Headcuts* *No = 0* *Yes = 1*	*Degradation* *< 1ft = 0* *>1ft = 1*	*D/S Hardpoint* *Yes = 0* *No = 1*	*Sediment Source* *No = 0* *Yes = 1*
C_{61} =0.0	C_{62} = 1.0	C_{63} =1.0	C_{54} = 1.0	C_{65} =0.0	C_{66} = 0.0	C_{67} = 1.0

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.57 (medium-high risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

$SI = 2/9 \times (1.0+0.5+0.5) + 1/9 \times (0.5+0.67+0.57) =$ 0.64

Risk Classification RC

$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

$SI = 1/3 \le 0.64 < 2/3$

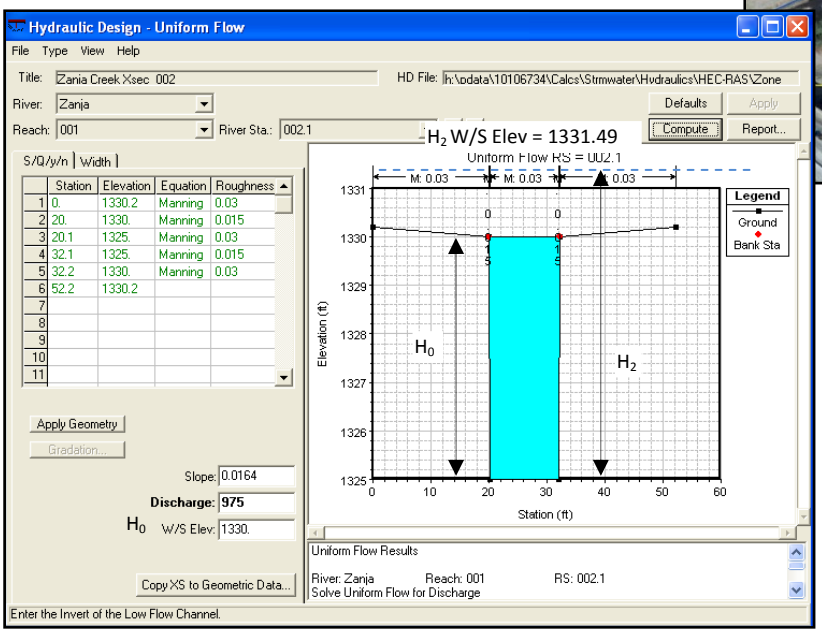
RC = Medium

RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Zanja Creek – XS 2 – Upstream of Division St

1) Shear Ratio SR (risk factor C_1)

C_1 =
- 1 *(high risk) 1.3 ≤ SR < 1.5*
- 0.5 *(medium risk) 1.00 < SR ≤ 1.3*
- 0 *(low risk) aggrading channel, hardened bed*



S = 0.0164 ft/ft

H_0 = 5.00 ft

Q_0 = 975 cfs

$Q_2 = 2Q_0$ = 1950 cfs

H_2 = 6.49 ft

$SR = H_2/H_0$ = 1.30

C_1 = 0.5 (medium risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4D_{50}} \right) \right]^2$$

C_2 =
- 1 *(high risk) ER > 1.0*
- 0.5 *(medium risk) ER < 1.0*
- 0 *(low risk) aggrading channel, hardened bed*

V = 15.87 fps

D_{50} = 1.5 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

ER = 1.26 > 1.0

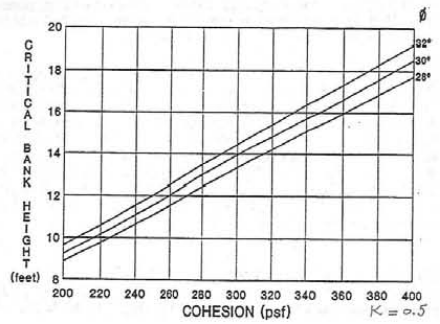
C = 403.55

C_2 = 1.0 (high risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*; 0.5 *(medium risk) GSN < 1.0*; 0 *(low risk) engineered banks or wide shallow channel* }

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = 0.36 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*; 0.5 *(medium risk) W/B > 4*; 0 *(low risk) banks fixed in place* }

W = valley width, B = channel width

W = 85 ft, B = 12 ft, W/B = 7.1 > 4.0, C_4 = 0.5 (medium risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 0.0	C_{53} =1.0	C_{54} = 0.0	C_{55} = 0.0	C_{56} = 0.0

$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6}$ = *0.33 (low-medium risk)*

6) Streambed Conditions (risk factor C_6)

Braided Yes = 0 No = 1	*Armored* Yes = 0 No = 1	*Bedrock* Yes = 0 No = 1	*Headcuts* No = 0 Yes = 1	*Degradation* < 1ft = 0 >1ft = 1	*D/S Hardpoint* Yes = 0 No = 1	*Sediment Source* No = 0 Yes = 1
C_{61} =0.0	C_{62} = 1.0	C_{63} =1.0	C_{54} = 0.0	C_{65} = 0.0	C_{66} = 0.0	C_{67} = 1.0

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.43 (low-medium risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

SI = 2/9×(0.5+1.0+0.5) + 1/9×(0.5+0.33+0.43) = 0.58

Risk Classification RC

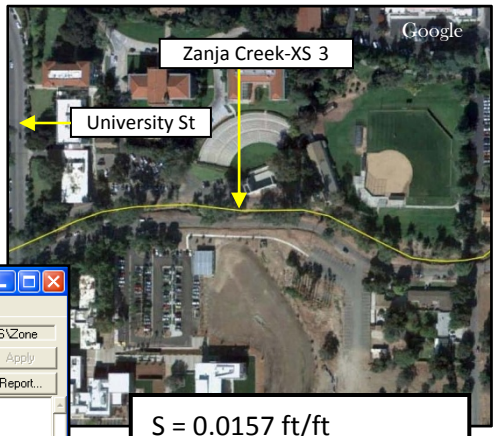
$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

SI = 1/3 ≤ 0.58 < 2/3

RC = Medium

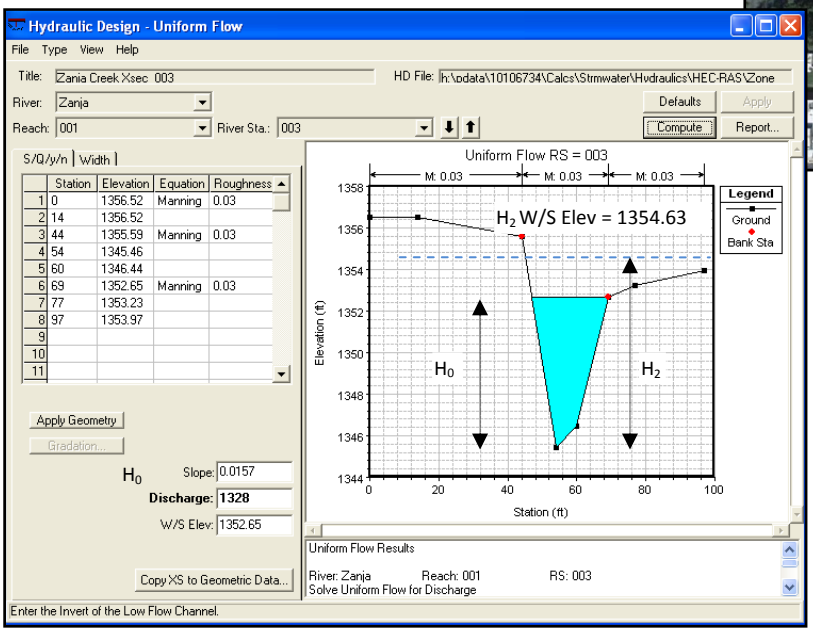
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Zanja Creek – XS 3 – Upstream of University St



1) Shear Ratio SR (risk factor C_1)

$C_1 =$
- 1 *(high risk) 1.3 ≤ SR < 1.5*
- 0.5 *(medium risk) 1.00 < SR ≤ 1.3*
- 0 *(low risk) aggrading channel, hardened bed*



S = 0.0157 ft/ft

H_0 = 7.19 ft

Q_0 = 1328 cfs

$Q_2 = 2Q_0$ = 2656 cfs

H_2 = 9.17 ft

$SR = H_2/H_0$ = 1.28

C_1 = 0.5 (medium risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4 D_{50}} \right) \right]^2$$

$C_2 =$
- 1 *(high risk) ER > 1.0*
- 0.5 *(medium risk) ER < 1.0*
- 0 *(low risk) aggrading channel, hardened bed*

V = 14.19 fps

D_{50} = 2 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

ER = 0.74 < 1.0

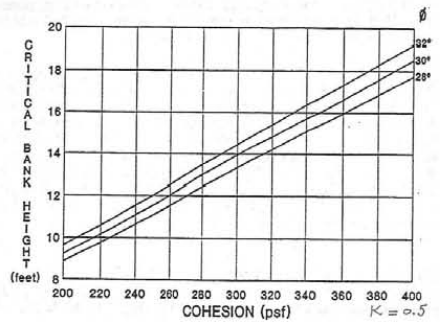
C = 411.17

C_2 = 0.5 (medium risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*; 0.5 *(medium risk) GSN < 1.0*; 0 *(low risk) engineered banks or wide shallow channel* }

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = 0.51 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*; 0.5 *(medium risk) W/B > 4*; 0 *(low risk) banks fixed in place* }

W = valley width, B = channel width

W = 90 ft, B = 25 ft, W/B = 3.6 ≤ 4.0, C_4 = 1.0 (high risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 0.0	C_{53} =1.0	C_{54} = 0.0	C_{55} = 0.0	C_{56} = 0.0

$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6}$ = *0.33 (low-medium risk)*

6) Streambed Conditions (risk factor C_6)

Braided	*Armored*	*Bedrock*	*Headcuts*	*Degradation*	*D/S Hardpoint*	*Sediment Source*
Yes = 0	*Yes = 0*	*Yes = 0*	*No = 0*	*< 1ft = 0*	*Yes = 0*	*No = 0*
No = 1	*No = 1*	*No = 1*	*Yes = 1*	*>1ft = 1*	*No = 1*	*Yes = 1*
C_{61} =0.0	C_{62} = 0.0	C_{63} =1.0	C_{54} = 0.0	C_{65} = 0.0	C_{66} = 1.0	C_{67} = 0.0

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = 0.29 \text{ (low-medium risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

$SI = 2/9 \times (0.5+0.5+0.5) + 1/9 \times (1.0+0.33+0.29) =$ 0.51

Risk Classification RC

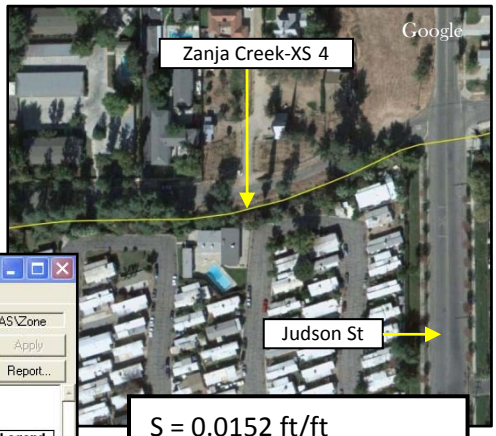
$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

$SI = 1/3 \le 0.51 < 2/3$

RC = Medium

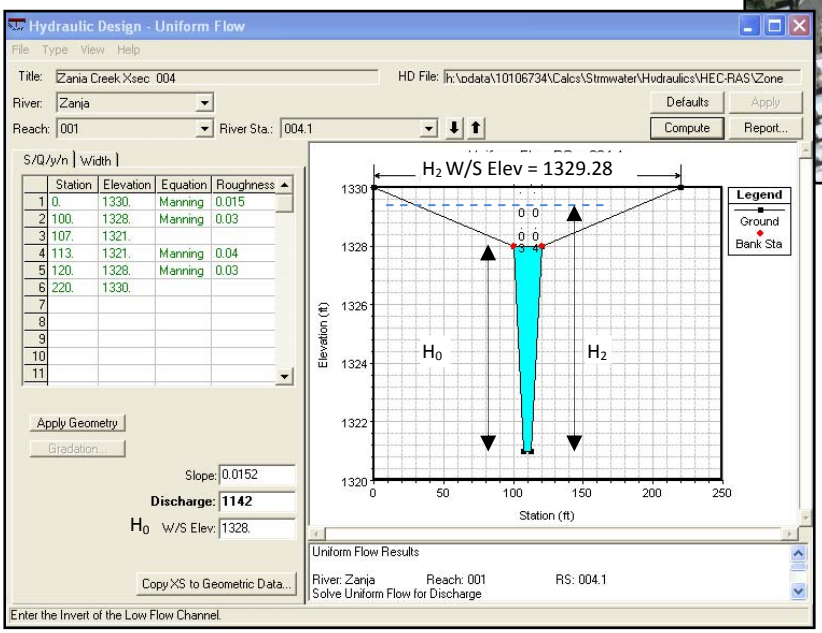
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Zanja Creek – XS 4 – Downstream of Judson St



1) Shear Ratio SR (risk factor C_1)

$C_1 =$
- 1 *(high risk) 1.3 ≤ SR < 1.5*
- 0.5 *(medium risk) 1.00 < SR ≤ 1.3*
- 0 *(low risk) aggrading channel, hardened bed*



S = 0.0152 ft/ft

H_0 = 7.00 ft

Q_0 = 1142 cfs

$Q_2 = 2Q_0$ = 2284 cfs

H_2 = 8.28 ft

$SR = H_2/H_0$ = 1.18

C_1 = 0.5 (medium risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4 D_{50}} \right) \right]^2$$

$C_2 =$
- 1 *(high risk) ER > 1.0*
- 0.5 *(medium risk) ER < 1.0*
- 0 *(low risk) aggrading channel, hardened bed*

V = 12.51 fps

D_{50} = 1.5 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

ER = 0.72 < 1.0

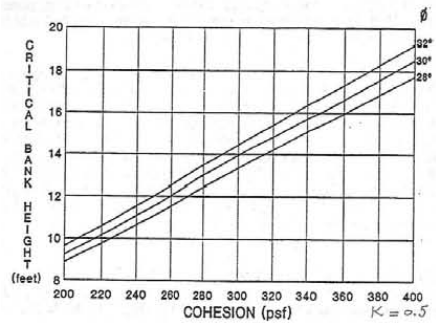
C = 438.02

C_2 = 0.5 (medium risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*
0.5 *(medium risk) GSN < 1.0*
0 *(low risk) engineered banks or wide shallow channel*

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = 0.5 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*
0.5 *(medium risk) W/B > 4*
0 *(low risk) banks fixed in place*

W = valley width, B = channel width

W = 94 ft, B = 20 ft, W/B = 4.7> 4.0, C_4 = 0.5 (medium risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 1.0	C_{53} =0.0	C_{54} = 0.0	C_{55} = 0.0	C_{56} = 0.0

$$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6} = \text{0.33 (low-medium risk)}$$

6) Streambed Conditions (risk factor C_6)

Braided *Yes = 0* *No = 1*	*Armored* *Yes = 0* *No = 1*	*Bedrock* *Yes = 0* *No = 1*	*Headcuts* *No = 0* *Yes = 1*	*Degradation* *< 1ft = 0* *>1ft = 1*	*D/S Hardpoint* *Yes = 0* *No = 1*	*Sediment Source* *No = 0* *Yes = 1*
C_{61} =0.0	C_{62} = 1.0	C_{63} =1.0	C_{54} = 0.0	C_{65} = 0.0	C_{66} = 1.0	C_{67} = 1.0

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.57 (medium-high risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

$SI = 2/9\times(0.5+0.5+0.5) + 1/9\times(0.5+0.33+0.14) =$ 0.49

Risk Classification RC

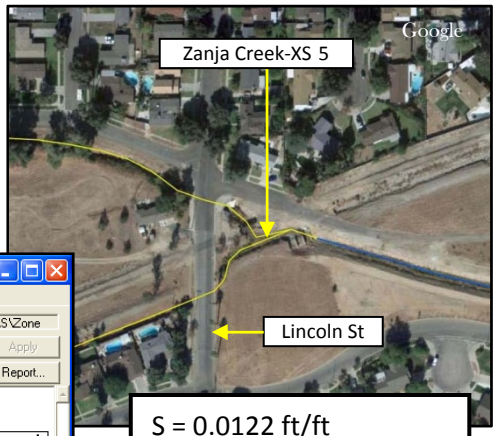
$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

$SI = 1/3 \le 0.49 < 2/3$

RC = Medium

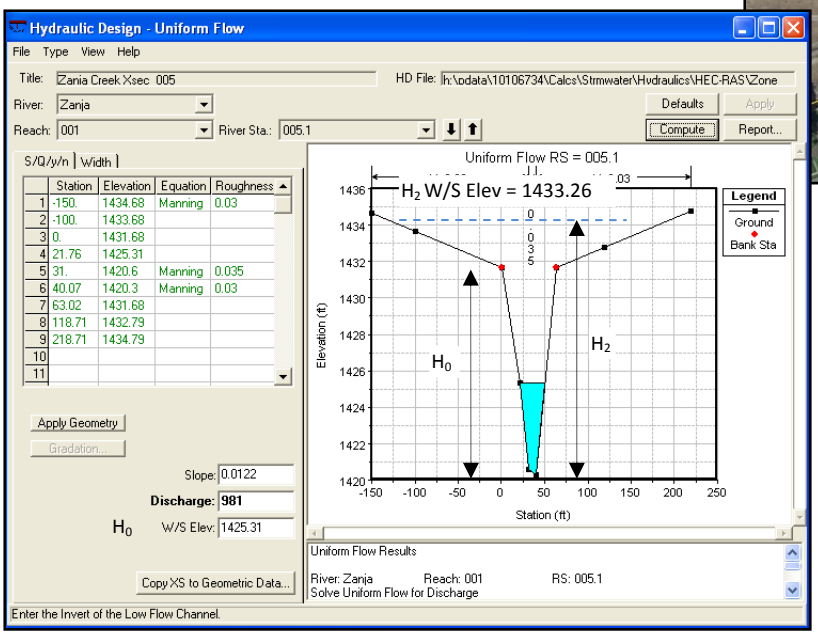
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Zanja Creek – XS 5 – Upstream of Lincoln St



1) Shear Ratio SR (risk factor C_1)

$C_1 =$
- 1 *(high risk) 1.3 ≤ SR < 1.5*
- 0.5 *(medium risk) 1.00 < SR ≤ 1.3*
- 0 *(low risk) aggrading channel, hardened bed*



S = 0.0122 ft/ft

H_0 = 5.01 ft

Q_0 = 981 cfs

$Q_2 = 2Q_0$ = 1962 cfs

H_2 = 6.91 ft

$SR = H_2/H_0$ = 1.38

C_1 = 1.0 (high risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4 D_{50}} \right) \right]^2$$

$C_2 =$
- 1 *(high risk) ER > 1.0*
- 0.5 *(medium risk) ER < 1.0*
- 0 *(low risk) aggrading channel, hardened bed*

V = 10.75 fps

D_{50} = 1.5 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

ER = 0.58 < 1.0

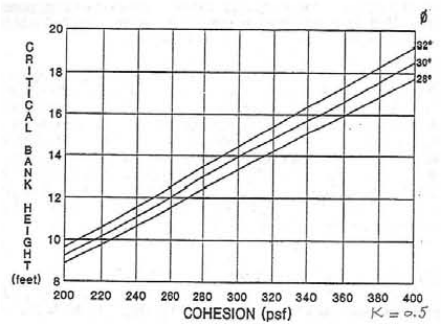
C =403.75

C_2 = 0.5 (medium risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*; 0.5 *(medium risk) GSN < 1.0*; 0 *(low risk) engineered banks or wide shallow channel* }

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = 0.36 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*; 0.5 *(medium risk) W/B > 4*; 0 *(low risk) banks fixed in place* }

W = valley width, B = channel width

W = 219 ft, B = 63 ft, W/B = 3.5 ≤4.0, C_4 = 1.0 (high risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 0.0	C_{53} =1.0	C_{54} = 0.0	C_{55} = 0.0	C_{56} = 0.0

$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6}$ = *0.33 (low-medium risk)*

6) Streambed Conditions (risk factor C_6)

Braided Yes = 0 No = 1	*Armored* Yes = 0 No = 1	*Bedrock* Yes = 0 No = 1	*Headcuts* No = 0 Yes = 1	*Degradation* < 1ft = 0 >1ft = 1	*D/S Hardpoint* Yes = 0 No = 1	*Sediment Source* No = 0 Yes = 1
C_{61} =0.0	C_{62} = 0.0	C_{63} =1.0	C_{54} = 0.0	C_{65} = 0.0	C_{66} = 0.0	C_{67} = 0.0

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.14 (low-medium risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

SI = 2/9×(1.0+0.5+0.5) + 1/9×(1.0+0.33+0.14) = 0.61

Risk Classification RC

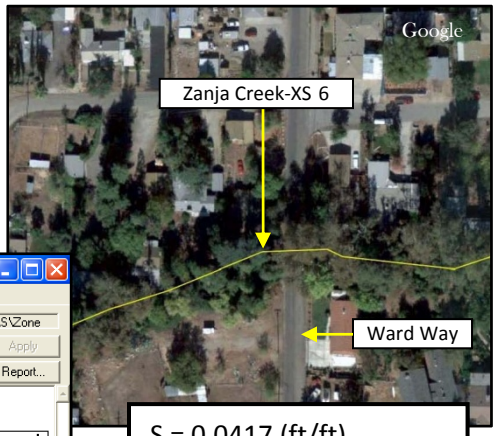
$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

SI = 1/3 ≤ 0.61 < 2/3

RC = Medium

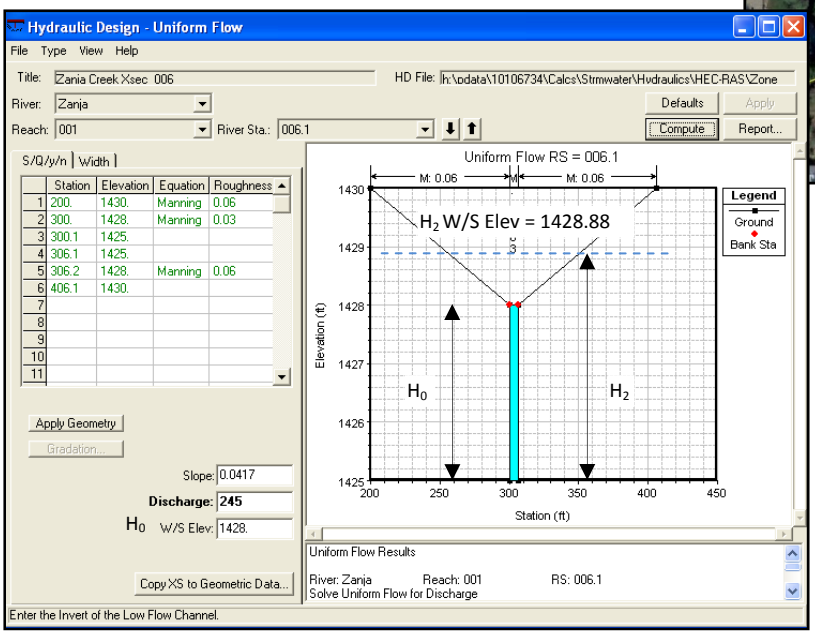
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Zanja Creek – XS 6 – Downstream of Ward Way



1) Shear Ratio SR (risk factor C_1)

$C_1 =$
- 1 *(high risk) 1.3 ≤ SR < 1.5*
- 0.5 *(medium risk) 1.00 < SR ≤ 1.3*
- 0 *(low risk) aggrading channel, hardened bed*



S = 0.0417 (ft/ft)

H_0 = 3.00 ft

Q_0 = 245 cfs

$Q_2 = 2Q_0$ = 490 cfs

H_2 = 3.88 ft

$SR = H_2/H_0$ = 1.29

C_1 = 0.5 (medium risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{CR}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{CR} C}$$

$$C = \left[5.75 \log \left(12.27 \frac{H_0}{4D_{50}} \right) \right]^2$$

$C_2 =$
- 1 *(high risk) ER > 1.0*
- 0.5 *(medium risk) ER < 1.0*
- 0 *(low risk) aggrading channel, hardened bed*

V = 13.4 fps

D_{50} = 1.5 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

ER = 1.02 > 1.0

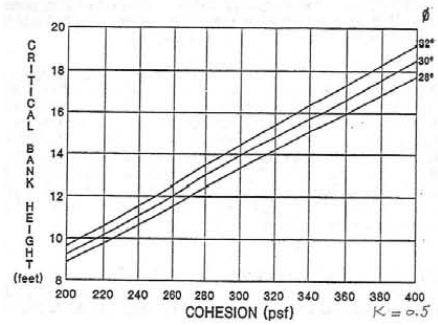
C = 353.93

C_2 = 1.0 (high risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

C_3 = { 1 *(high risk) GSN > 1.0 or toe/bank erosion observed*
0.5 *(medium risk) GSN < 1.0*
0 *(low risk) engineered banks or wide shallow channel*

GSN = $\frac{H_0}{H_C}$, Hc = critical bank height



Assumed cohesion = 300 psf, H_c=14 ft, GSN = 0.21 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

C_3 = { 1 *(high risk) W/B ≤ 4*
0.5 *(medium risk) W/B > 4*
0 *(low risk) banks fixed in place*

W = valley width, B = channel width

W = 55 ft, B = 6 ft, W/B = 9.2 > 4.0, C_4 = 0.5 (medium risk)

5) Bank Conditions (risk factor C_5)

Bedrock *Yes = 0* *No = 1*	*Bank Protection* *Good condition = 0* *Bad condition =1*	*Vegetation* *Dense = 0* *Sparse or no =1*	*Stratication* *No = 0* *Yes = 1*	*Bank Erosion* *No = 0* *Yes = 1*	*Toe Erosion* *No = 0* *Yes = 1*
C_{51} =1.0	C_{52} = 1.0	C_{53} =0.0	C_{54} = 0.0	C_{55} = 0.0	C_{56} = 0.0

$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6}$ = *0.33 (low-medium risk)*

6) Streambed Conditions (risk factor C_6)

Braided *Yes = 0* *No = 1*	*Armored* *Yes = 0* *No = 1*	*Bedrock* *Yes = 0* *No = 1*	*Headcuts* *No = 0* *Yes = 1*	*Degradation* *< 1ft = 0* *>1ft = 1*	*D/S Hardpoint* *Yes = 0* *No = 1*	*Sediment Source* *No = 0* *Yes = 1*
C_{61} =0.0	C_{62} = 1.0	C_{63} =1.0	C_{54} = 0.0	C_{65} = 0.0	C_{66} = 1.0	C_{67} = 0.0

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = \text{0.43 (low-medium risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i, \sum_{1}^{6} w_i = 1$$

Primary criteria = $w_1 = w_2 = w_3 = 2/9$

Secondary criteria = $w_4 = w_5 = w_6 = 1/9$

$SI = 2/9 \times (0.5+1.0+0.5) + 1/9 \times (0.5+0.33+0.43) =$ 0.58

Risk Classification RC

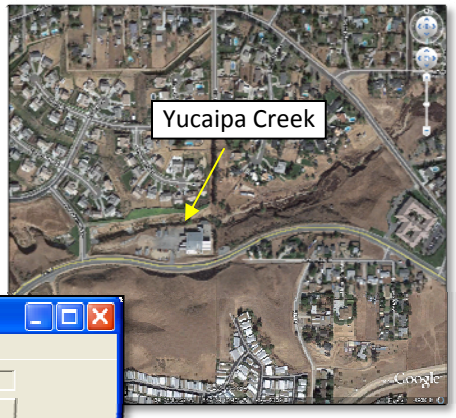
$$C_3 = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

$SI = 1/3 \le 0.58 < 2/3$

RC = Medium

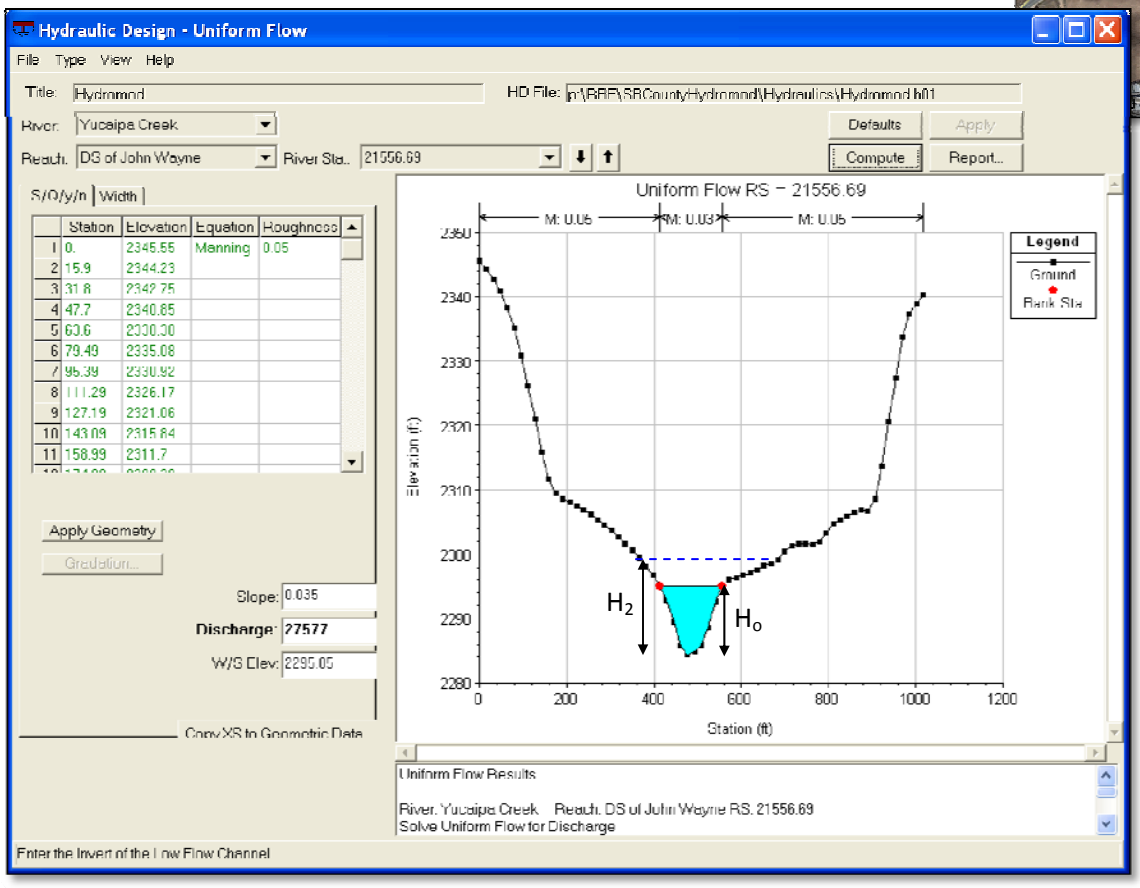
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Yucaipa Creek - Upstream of John Wayne Way



1) Shear Ratio SR (risk factor C_1)

$$C_1 = \begin{cases} 1\,(high\ risk) & 1.3 \le SR < 1.5 \\ 0.5\,(medium\ \ risk) & 1.00 < SR < 1.3 \\ 0\,(low\ risk) & aggrading\ channel,\ hardened\ bed \end{cases}$$



S = 3.5%

H_o = 10.64 ft

Q_o = 27,577 cfs

$Q_2 = 2\ Q_o$ = 55,154 cfs

H_2 =13.72 ft

$SR = H_2/H_o$ = 1.29 < 1.3

C_1 = 0.5 (medium risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{cr}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{cr}} = \frac{V^2}{1.65 g D_{50} \Theta_{cr} C} \qquad C = \left[5.75 \log\left(12.27 \frac{H_o}{4 D_{50}} \right) \right]^2$$

$$C_2 = \begin{cases} 1\,(high\ risk) & ER > 1.0 \\ 0.5\,(medium\ \ risk) & ER < 1.0 \\ 0\,(low\ risk) & aggrading\ channel, hardened\ bed \end{cases}$$

V = 14.1 ft/s

D_{50} = 1 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

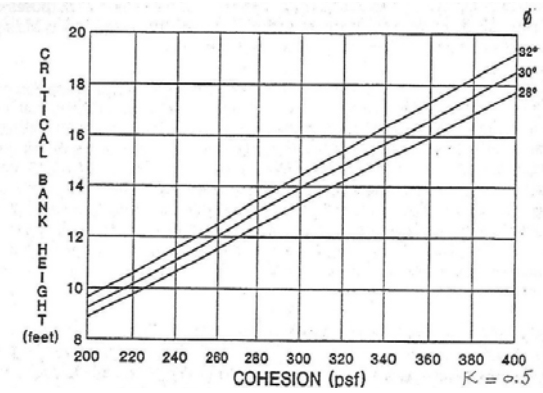
ER = 1.14 > 1.0

C = 528

C_2 = 1.0 (high risk)

3) Geotechnical Stability Number *GSN* (risk factor C_3)

$$C_3 = \begin{cases} 1\,(high\ risk) & GSN > 1.0 \text{ or toe/bank erosion observed} \\ 0.5\,(medium\ \ risk) & GSN < 1.0 \\ 0\,(low\ risk) & \text{engineered banks or wide shallow channel} \end{cases}$$



$GSN = \frac{H_o}{H_c}$, H_c = critical bank height

Assumed cohesion = 300 psf, H_c = 14 ft, *GSN* = 0.76 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

$$C_4 = \begin{cases} 1\,(high\ risk) & W/B \le 4 \\ 0.5\,(medium\ \ risk) & W/B > 4 \\ 0\,(low\ risk) & banks\ \ fixed\ in\ \ place \end{cases}$$

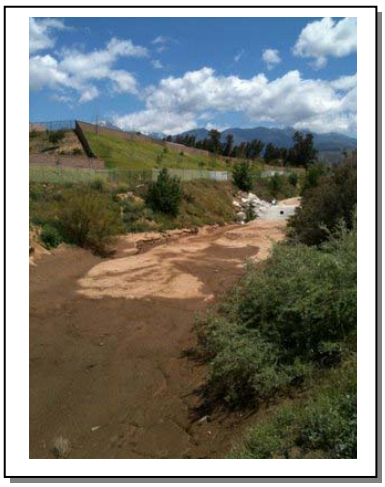
W = valley width, B = channel width

W = 700 ft, B = 150 ft, W/B = 4.7 > 4.0, C_4 = 0.5 (medium risk)

5) Bank Conditions (risk factor C_5)

Bedrock yes = 0 no = 1	*Bank Protection* good condition = 0 bad condition or no = 1	*Vegetation* dense = 0 sparse or no = 1	*Stratification* no = 0 yes = 1	*Bank Erosion* no = 0 yes = 1	*Toe Erosion* no = 0 yes = 1
C_{51} = 1.0	C_{52} = 1.0	C_{53} = 0.0	C_{54} = 0.0	C_{55} = 0.0	C_{56} = 0.5

$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6}$ = 0.42 (medium risk)



6) Streambed Conditions (risk factor C_6)

Braided no = 0 yes = 1	*Armored* yes = 0 no = 1	*Bedrock* yes = 0 no = 1	*Headcuts* no = 0 yes = 1	*Degradation* < 1ft = 0 > 1 ft = 1	*D/S Hardpoint* yes = 0 no = 1	*Sediment Source* no = 0 yes = 1
$C_{61} = 0.0$	$C_{62} = 1.0$	$C_{63} = 1.0$	$C_{64} = 0.0$	$C_{65} = 0.0$	$C_{66} = 0.0$	$C_{67} = 0.0$

$$C_6 = \frac{\sum_1^7 C_{6i}}{7} = 0.29 \text{ (medium-low risk)}$$

Stability Index SI

$$SI = \sum_1^6 w_i C_i \,, \quad \sum_1^6 w_i = 1$$

Primary criteria: $w_1 = w_2 = w_3 = 2/9$

Secondary criteria: $w_4 = w_5 = w_6 = 1/9$

$SI = 2/9 \cdot (0.5 + 1.0 + 0.5) + 1/9 \cdot (0.5 + 0.42 + 0.29) = 0.58 < 0.67$

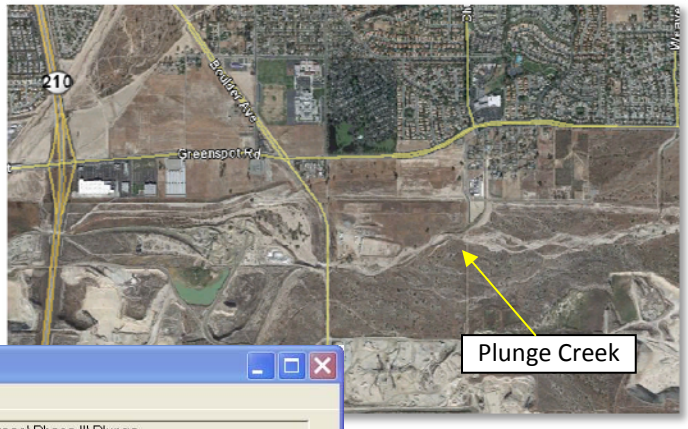
Risk Classification RC

$$RC = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

RC = Medium

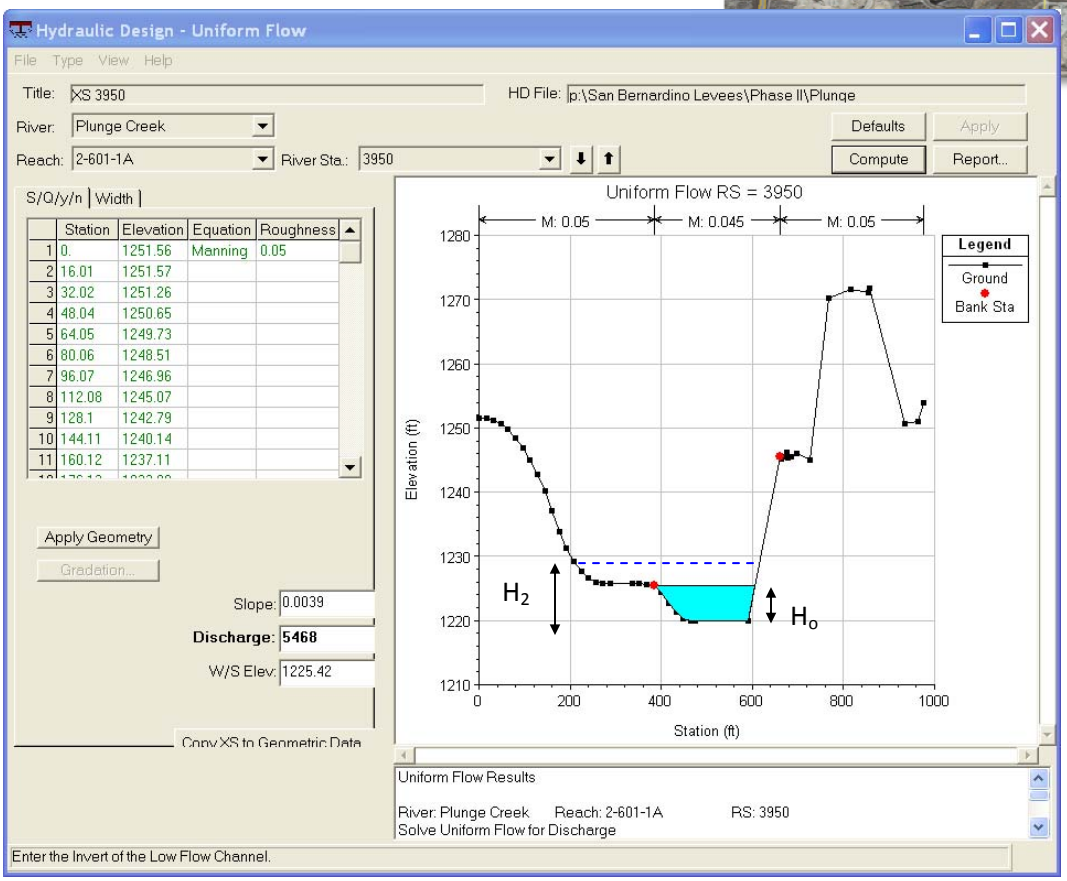
RAPID STREAM RISK CLASSIFICATION FOR HYDROMODIFICATION MAPPING IN SAN BERNARDINO COUNTY

Plunge Creek - Downstream of Boulder Ave



1) Shear Ratio SR (risk factor C_1)

$$C_1 = \begin{cases} 1\,(high\ risk) & 1.3 \le SR < 1.5 \\ 0.5\,(medium\ \ risk) & 1.00 < SR < 1.3 \\ 0\,(low\ risk) & aggrading\ channel,\ hardened\ bed \end{cases}$$



S = 0.4%

H_o = 5.44 ft

Q_o = 5,468 cfs

$Q_2 = 2\ Q_o$ = 10,936 cfs

H_2 = 7.54 ft

$SR = H_2/H_o$ = 1.39 > 1.3

C_1 = 1.0 (high risk)

2) Entrainment Ratio ER (risk factor C_2)

$$ER = \frac{\tau_0}{\tau_{cr}} = \frac{\rho V^2 / C}{(\gamma_s - \gamma) D_{50} \Theta_{cr}} = \frac{V^2}{1.65 g D_{50} \Theta_{cr} C} \qquad C = \left[5.75 \log\left(12.27 \frac{H_o}{4 D_{50}} \right) \right]^2$$

$$C_2 = \begin{cases} 1\,(high\ risk) & ER > 1.0 \\ 0.5\,(medium\ \ risk) & ER < 1.0 \\ 0\,(low\ risk) & aggrading\ channel, hardened\ bed \end{cases}$$

V = 4.8 ft/s

D_{50} = 1 mm

g = 32.2 ft/s^2

Θ_{cr} = 1.9

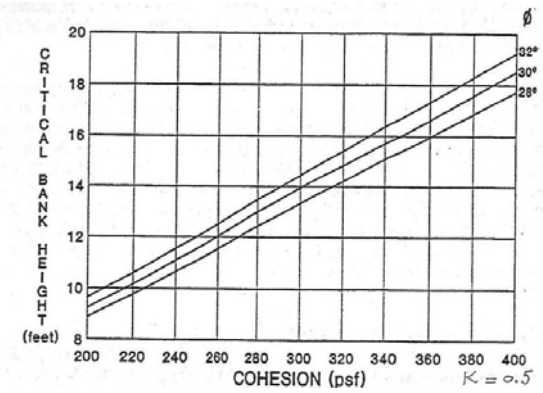
ER = 0.16 < 1.0

C = 454

C_2 = 0.5 (medium risk)

3) Geotechnical Stability Number GSN (risk factor C_3)

$$C_3 = \begin{cases} 1\,(high\ risk)\ \ GSN > 1.0\ or\ toe/bank\ erosion\ observed \\ 0.5\,(medium\ \ risk)\ \ GSN < 1.0 \\ 0\,(low\ risk)\ \ engineered\ banks\ or\ \ wide\ shallow\ channel \end{cases}$$



$GSN = \frac{H_o}{H_c}$, H_c = critical bank height

Assumed cohesion = 200 psf, H_c = 10 ft, *GSN* = 0.54 < 1.0

C_3 = 0.5 (medium risk)

4) Confinement Class (risk factor C_4)

$$C_4 = \begin{cases} 1\,(high\ risk)\ \ W/B \le 4 \\ 0.5\,(medium\ \ risk)\ \ W/B > 4 \\ 0\,(low\ risk)\ \ banks\ \ fixed\ in\ \ place \end{cases}$$

W = valley width, B = channel width

W = 550 ft, B = 220 ft, W/B = 2.5 < 4.0, C_4 = 1.0 (high risk)

5) Bank Conditions (risk factor C_5)

Bedrock yes = 0 no = 1	*Bank Protection* good condition = 0 bad condition or no = 1	*Vegetation* dense = 0 sparse or no = 1	*Stratification* no = 0 yes = 1	*Bank Erosion* no = 0 yes = 1	*Toe Erosion* no = 0 yes = 1
C_{51} = 0.5	C_{52} = 1.0	C_{53} = 0.0	C_{54} = 0.0	C_{55} = 0.0	C_{56} = 0.0

$$C_5 = \frac{\sum_{1}^{6} C_{5i}}{6} = 0.25 \text{ (low risk)}$$

6) Streambed Conditions (risk factor C_6)

Braided no = 0 yes = 1	*Armored* yes = 0 no = 1	*Bedrock* yes = 0 no = 1	*Headcuts* no = 0 yes = 1	*Degradation* < 1ft = 0 > 1 ft = 1	*D/S Hardpoint* yes = 0 no = 1	*Sediment Source* no = 0 yes = 1
C_{61} = 1.0	C_{62} = 0.5	C_{63} = 1.0	C_{64} = 0.0	C_{65} = 0.0	C_{66} = 1.0	C_{67} = 1.0

$$C_6 = \frac{\sum_{1}^{7} C_{6i}}{7} = 0.64 \text{ (medium risk)}$$

Stability Index SI

$$SI = \sum_{1}^{6} w_i C_i \,, \quad \sum_{1}^{6} w_i = 1$$

Primary criteria: $w_1 = w_2 = w_3 = 2/9$

Secondary criteria: $w_4 = w_5 = w_6 = 1/9$

$SI = 2/9 \cdot (1.0 + 0.5 + 0.5) + 1/9 \cdot (1.0 + 0.25 + 0.64) = 0.65 < 0.67$

Risk Classification RC

$$RC = \begin{cases} low & 0 < SI < 1/3 \\ medium & 1/3 \le SI < 2/3 \\ high & 2/3 \le SI < 1 \end{cases}$$

RC = Medium