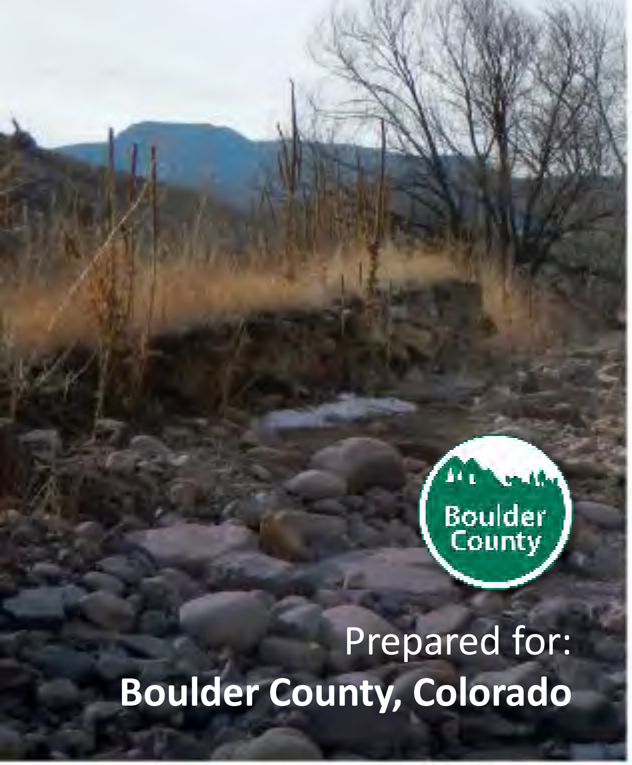
Flood Planning & Preliminary Design Services for South St. Vrain Creek Restoration at Hall Ranch

Presentation to Parks and Open Space Advisory Committee

September 22, 2016

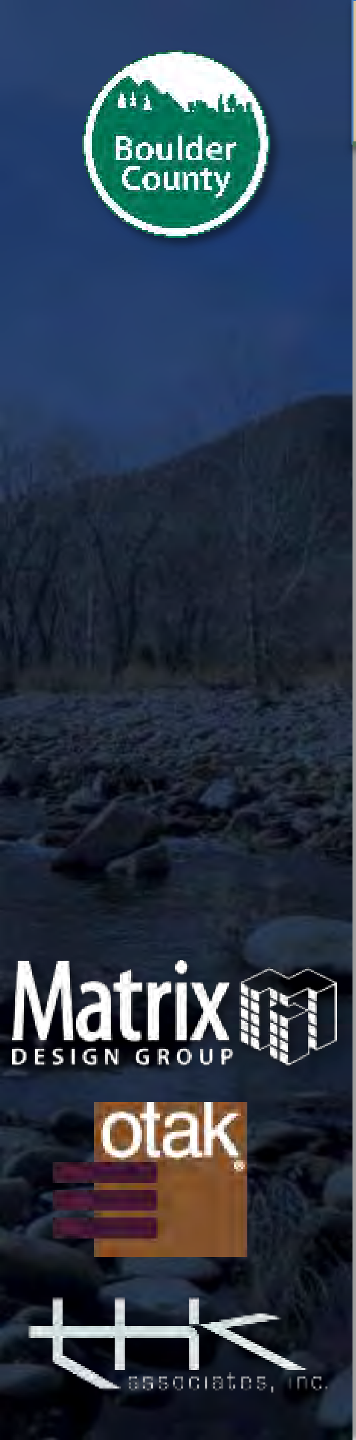


Boulder County

Prepared for:
Boulder County, Colorado

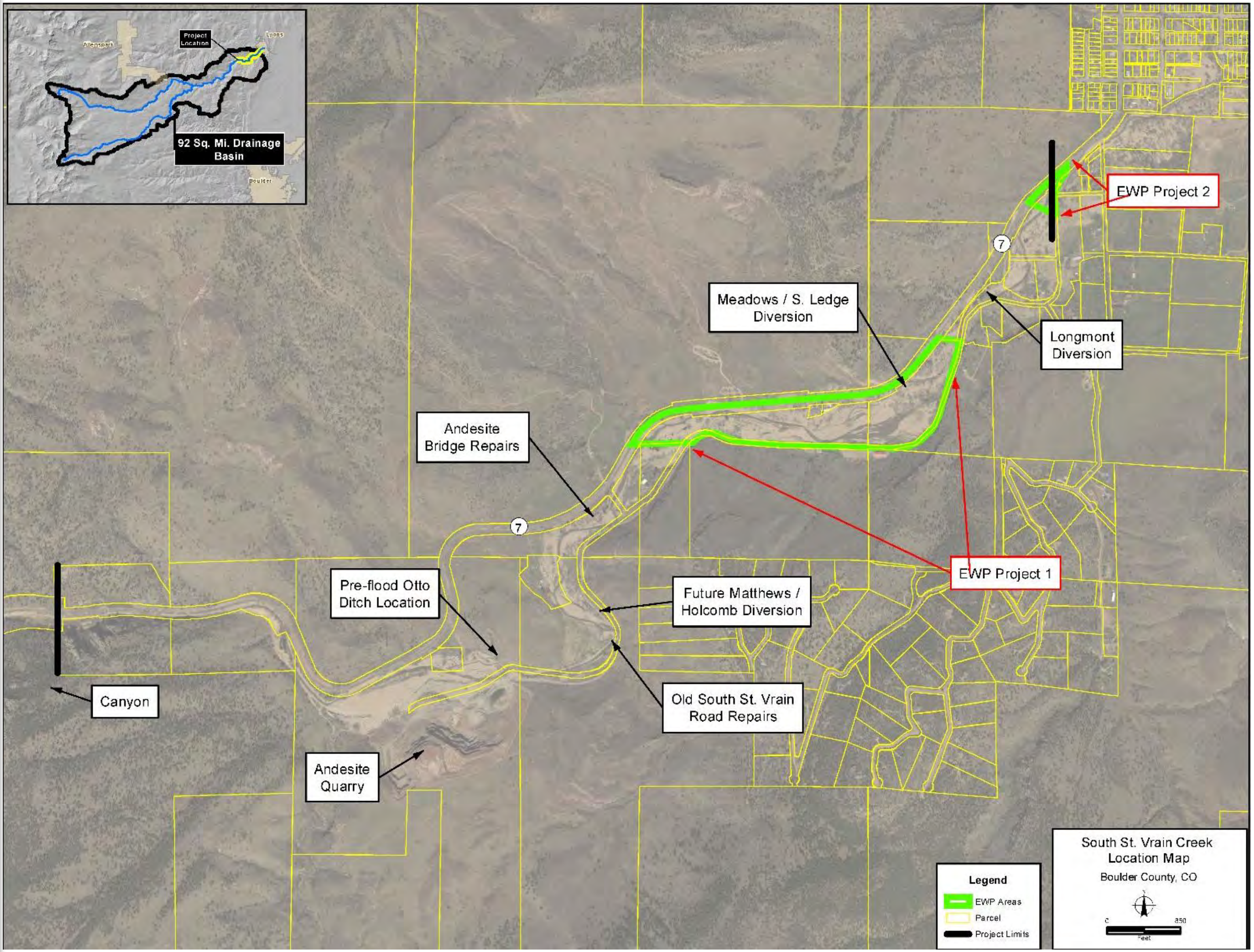
Matrix DESIGN GROUP

In association with:
Otak, THK, ERO, and Blue Mountain



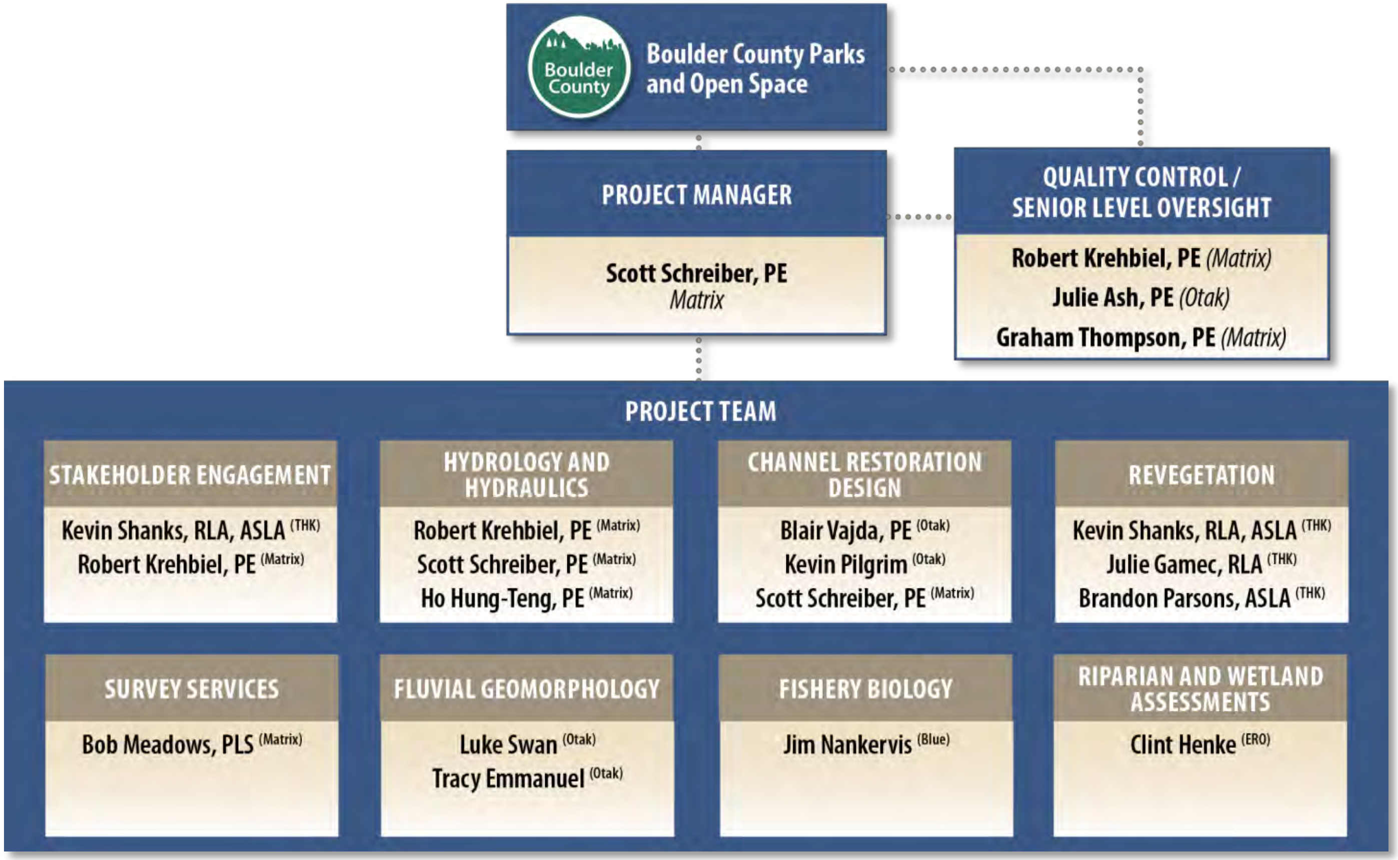
Introductions

- Introduction
- History of project
- Planning area: 3.2 Mile Reach from Canyon to Bridge
- Project sponsors and funding: DOLA/BCPOS
  - 30% Report and Designs
  - EWP Eligible Construction
- Project website
  - Information and comment
  - www.BoulderCountyOpenSpace.org/ssv


Project Location
Allenspark
Lyons
Boulder
92 Sq. Mi. Drainage Basin
EWP Project 2
7
Meadows / S. Ledge Diversion
Longmont Diversion
Andesite Bridge Repairs
7
EWP Project 1
Pre-flood Otto Ditch Location
Future Matthews / Holcomb Diversion
Old South St. Vrain Road Repairs
Canyon
Andesite Quarry
Legend
EWP Areas
Parcel
Project Limits
South St. Vrain Creek Location Map
Boulder County, CO
0
850
Feet

Boulder County

Matrix Team



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Boulder County Parks and Open Space

PROJECT MANAGER

Scott Schreiber, PE
Matrix

QUALITY CONTROL / SENIOR LEVEL OVERSIGHT

Robert Krehbiel, PE *(Matrix)*
Julie Ash, PE *(Otak)*
Graham Thompson, PE *(Matrix)*

PROJECT TEAM

STAKEHOLDER ENGAGEMENT

Kevin Shanks, RLA, ASLA (THK)
Robert Krehbiel, PE (Matrix)

HYDROLOGY AND HYDRAULICS

Robert Krehbiel, PE (Matrix)
Scott Schreiber, PE (Matrix)
Ho Hung-Teng, PE (Matrix)

CHANNEL RESTORATION DESIGN

Blair Vajda, PE (Otak)
Kevin Pilgrim (Otak)
Scott Schreiber, PE (Matrix)

REVEGETATION

Kevin Shanks, RLA, ASLA (THK)
Julie Gamec, RLA (THK)
Brandon Parsons, ASLA (THK)

SURVEY SERVICES

Bob Meadows, PLS (Matrix)

FLUVIAL GEOMORPHOLOGY

Luke Swan (Otak)
Tracy Emmanuel (Otak)

FISHERY BIOLOGY

Jim Nankervis (Blue)

RIPARIAN AND WETLAND ASSESSMENTS

Clint Henke (ERO)

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Project Schedule

- Design schedule
  - Notice to proceed: May 2016
  - Alternative analysis: June 2016
  - Preferred alternative: July 2016
  - 30% design: September 2016
  - EWP Permitting and 80% Design: Fall/Winter 2016
  - EWP Construction: Winter/Spring 2017

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Public Engagement

- Extensive Public Engagement
  - South St. Vrain Working Group – May 11
  - St. Vrain Creek Coalition – May 25, June 29, July 20, and August 17
  - General Public Meetings (Lyons) – May 24 and June 30
  - Individual Land Owner Meetings – June 22
  - Public Preferred Alternative Site Tour – July 28
  - Various on-line comments, phone calls, and field visits
- Comments since 2013

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Pre Flood Aerial: 2012

Post Flood Aerial: 2013

Post Flood Aerial: 2014

Post Flood Aerial: 2015

Pre Flood Aerial: 2012

Post Flood Aerial: 2013

Post Flood Aerial: 2014

Post Flood Aerial: 2015

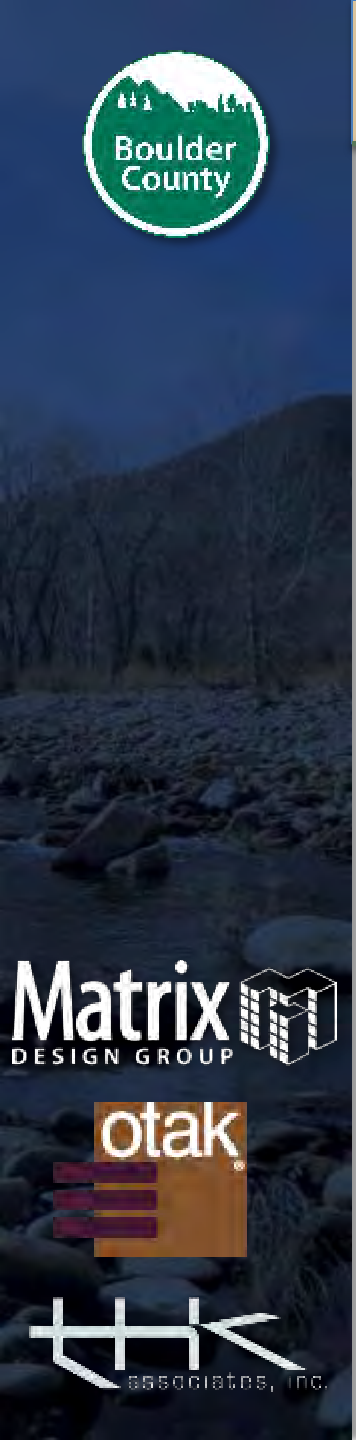
Pre Flood Aerial: 2012

Boulder County

Post Flood Aerial: 2013

Post Flood Aerial: 2014

Post Flood Aerial: 2015



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Project Goals Statement

- Provide a conceptual design for the entire South Saint Vrain Creek project area that restores and improves the channel and surrounding floodplain areas to a safe, natural, resilient, functioning, and ecologically rich habitat. This project will use qualitative research, quantitative data, and community input to inform resilient design that shall utilize natural system principles and onsite materials to expedite recovery from the 2013 floods and set up for better performance in future flood events. Components to meet goals include incorporating natural channel diversity and character, re-establishing floodplain benches for lateral connectivity, reducing longitudinal connectivity constraints, improving flow conveyance and sediment transport to maintain environmental values, promote naturally functioning stream processes, protect public and private infrastructure, improve public safety, repair unstable erosion scars in high-risk areas, and revegetate denuded areas.

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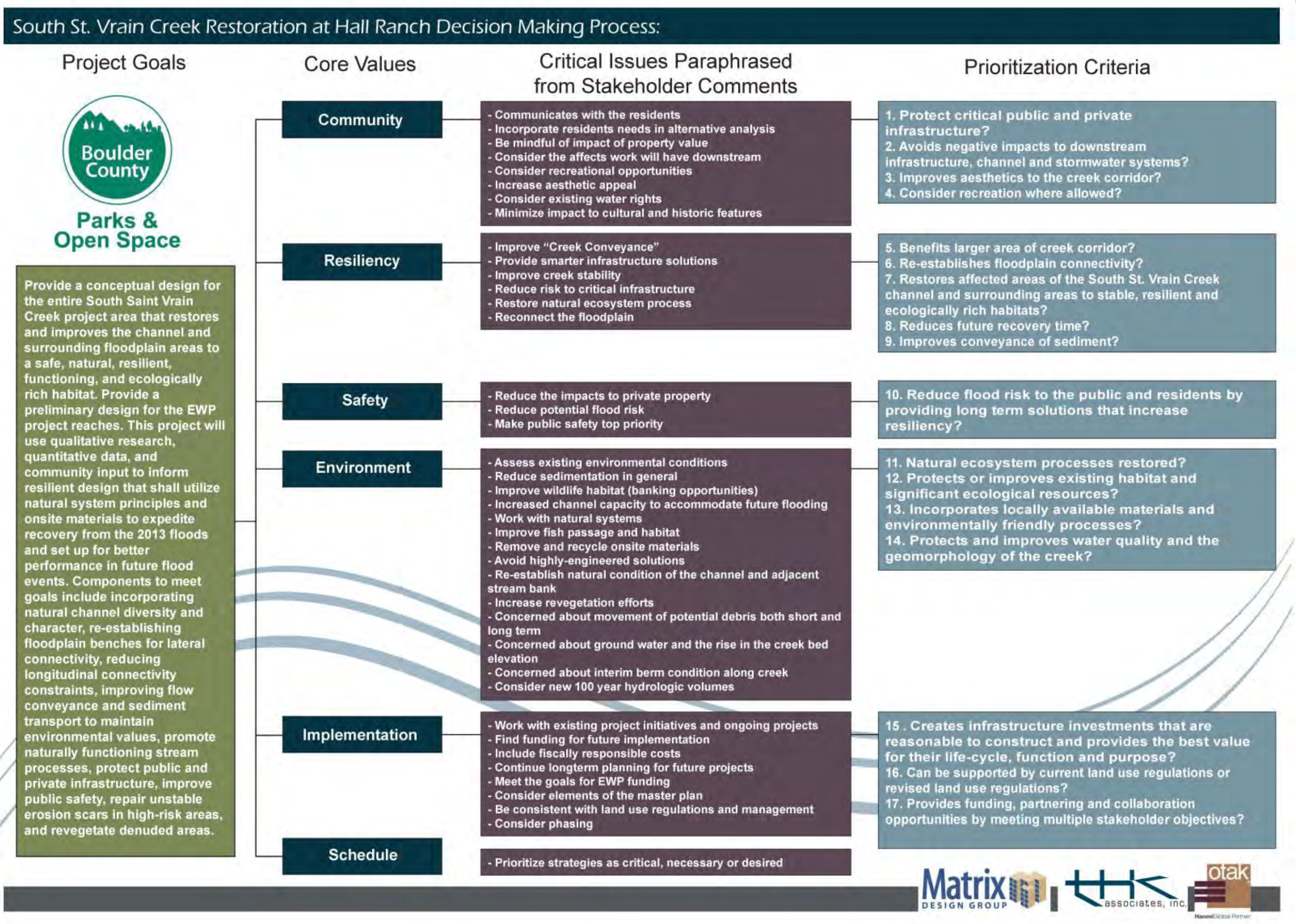
SAINT VRAIN CREEK COALITION

Decision Making Process



South St. Vrain Creek Restoration at Hall Ranch Decision Making Process:

Project Goals

Boulder County Parks & Open Space

Provide a conceptual design for the entire South Saint Vrain Creek project area that restores and improves the channel and surrounding floodplain areas to a safe, natural, resilient, functioning, and ecologically rich habitat. Provide a preliminary design for the EWP project reaches. This project will use qualitative research, quantitative data, and community input to inform resilient design that shall utilize natural system principles and onsite materials to expedite recovery from the 2013 floods and set up for better performance in future flood events. Components to meet goals include incorporating natural channel diversity and character, re-establishing floodplain benches for lateral connectivity, reducing longitudinal connectivity constraints, improving flow conveyance and sediment transport to maintain environmental values, promote naturally functioning stream processes, protect public and private infrastructure, improve public safety, repair unstable erosion scars in high-risk areas, and revegetate denuded areas.

Core Values	Critical Issues Paraphrased from Stakeholder Comments	Prioritization Criteria
Community	- Communicates with the residents - Incorporate residents needs in alternative analysis - Be mindful of impact of property value - Consider the affects work will have downstream - Consider recreational opportunities - Increase aesthetic appeal - Consider existing water rights - Minimize impact to cultural and historic features	1. Protect critical public and private infrastructure? 2. Avoids negative impacts to downstream infrastructure, channel and stormwater systems? 3. Improves aesthetics to the creek corridor? 4. Consider recreation where allowed?
Resiliency	- Improve "Creek Conveyance" - Provide smarter infrastructure solutions - Improve creek stability - Reduce risk to critical infrastructure - Restore natural ecosystem process - Reconnect the floodplain	5. Benefits larger area of creek corridor? 6. Re-establishes floodplain connectivity? 7. Restores affected areas of the South St. Vrain Creek channel and surrounding areas to stable, resilient and ecologically rich habitats? 8. Reduces future recovery time? 9. Improves conveyance of sediment?
Safety	- Reduce the impacts to private property - Reduce potential flood risk - Make public safety top priority	10. Reduce flood risk to the public and residents by providing long term solutions that increase resiliency?
Environment	- Assess existing environmental conditions - Reduce sedimentation in general - Improve wildlife habitat (banking opportunities) - Increased channel capacity to accommodate future flooding - Work with natural systems - Improve fish passage and habitat - Remove and recycle onsite materials - Avoid highly-engineered solutions - Re-establish natural condition of the channel and adjacent stream bank - Increase revegetation efforts - Concerned about movement of potential debris both short and long term - Concerned about ground water and the rise in the creek bed elevation - Concerned about interim berm condition along creek - Consider new 100 year hydrologic volumes	11. Natural ecosystem processes restored? 12. Protects or improves existing habitat and significant ecological resources? 13. Incorporates locally available materials and environmentally friendly processes? 14. Protects and improves water quality and the geomorphology of the creek?
Implementation	- Work with existing project initiatives and ongoing projects - Find funding for future implementation - Include fiscally responsible costs - Continue longterm planning for future projects - Meet the goals for EWP funding - Consider elements of the master plan - Be consistent with land use regulations and management - Consider phasing	15 . Creates infrastructure investments that are reasonable to construct and provides the best value for their life-cycle, function and purpose? 16. Can be supported by current land use regulations or revised land use regulations? 17. Provides funding, partnering and collaboration opportunities by meeting multiple stakeholder objectives?
Schedule	- Prioritize strategies as critical, necessary or desired	

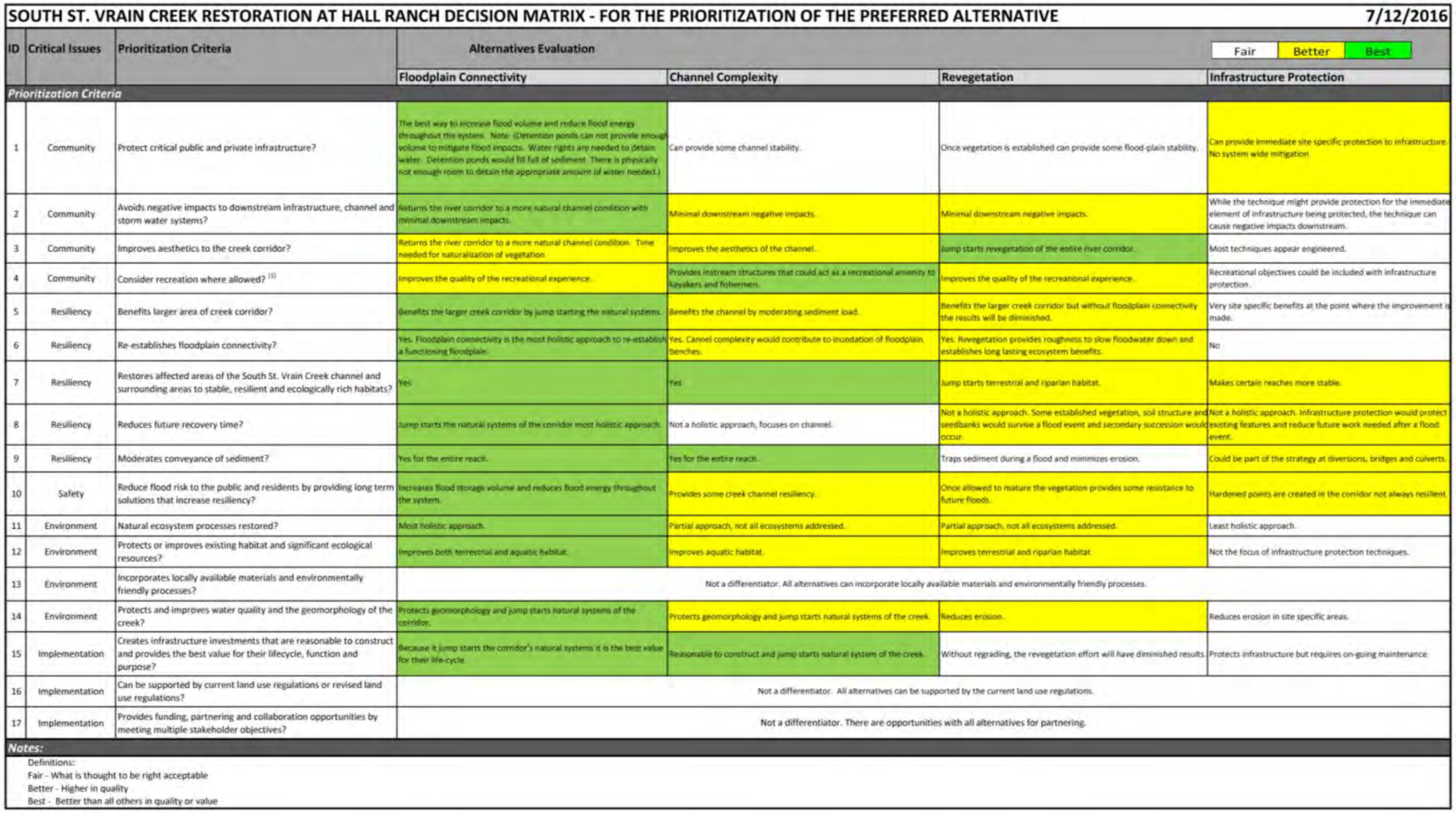
Comments/Concerns

Core Values

Project Goals

Prioritization Criteria

Prioritization Criteria



SOUTH ST. VRAIN CREEK RESTORATION AT HALL RANCH DECISION MATRIX - FOR THE PRIORITIZATION OF THE PREFERRED ALTERNATIVE 7/12/2016

Fair | Better | Best

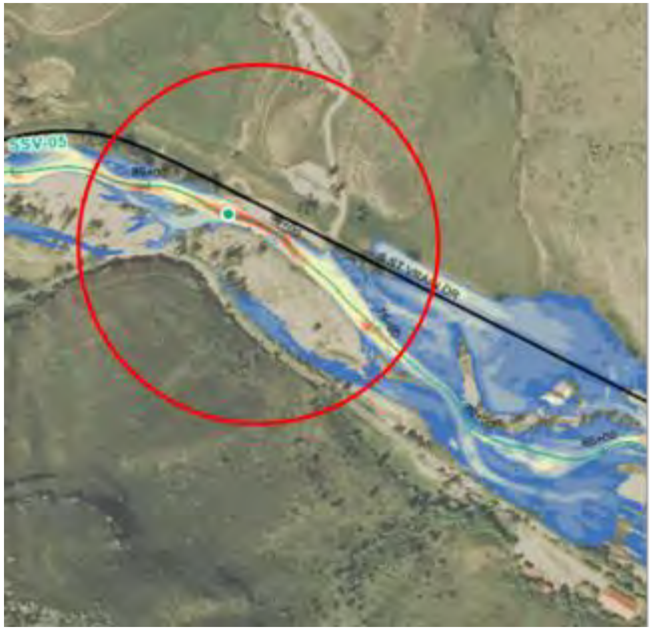
ID	Critical Issues	Prioritization Criteria	Alternatives Evaluation			
			Floodplain Connectivity	Channel Complexity	Revegetation	Infrastructure Protection
Prioritization Criteria						
1	Community	Protect critical public and private infrastructure?	The best way to increase flood volume and reduce flood energy throughout the system. Note: (Detention ponds can not provide enough volume to mitigate flood impacts. Water rights are needed to detain water. Detention ponds would fill full of sediment. There is physically not enough room to detain the appropriate amount of water needed.)	Can provide some channel stability.	Once vegetation is established can provide some flood-plain stability.	Can provide immediate site specific protection to infrastructure. No system wide mitigation
2	Community	Avoids negative impacts to downstream infrastructure, channel and storm water systems?	Returns the river corridor to a more natural channel condition with minimal downstream impacts.	Minimal downstream negative impacts.	Minimal downstream negative impacts.	While the technique might provide protection for the immediate element of infrastructure being protected, the technique can cause negative impacts downstream.
3	Community	Improves aesthetics to the creek corridor?	Returns the river corridor to a more natural channel condition. Time needed for naturalization of vegetation	Improves the aesthetics of the channel.	Jump starts revegetation of the entire river corridor.	Most techniques appear engineered.
4	Community	Consider recreation where allowed? [1]	Improves the quality of the recreational experience.	Provides instream structures that could act as a recreational amenity to kayakers and fishermen.	Improves the quality of the recreational experience.	Recreational objectives could be included with infrastructure protection.
5	Resiliency	Benefits larger area of creek corridor?	Benefits the larger creek corridor by jump starting the natural systems.	Benefits the channel by moderating sediment load.	Benefits the larger creek corridor but without floodplain connectivity the results will be diminished.	Very site specific benefits at the point where the improvement is made.
6	Resiliency	Re-establishes floodplain connectivity?	Yes. Floodplain connectivity is the most holistic approach to re-establish a functioning floodplain.	Yes. Cannel complexity would contribute to inundation of floodplain benches.	Yes. Revegetation provides roughness to slow floodwater down and establishes long lasting ecosystem benefits.	No
7	Resiliency	Restores affected areas of the South St. Vrain Creek channel and surrounding areas to stable, resilient and ecologically rich habitats?	Yes	Yes	Jump starts terrestrial and riparian habitat.	Makes certain reaches more stable.
8	Resiliency	Reduces future recovery time?	Jump starts the natural systems of the corridor most holistic approach.	Not a holistic approach, focuses on channel.	Not a holistic approach. Some established vegetation, soil structure and seedbanks would survive a flood event and secondary succession would occur.	Not a holistic approach. Infrastructure protection would protect existing features and reduce future work needed after a flood event.
9	Resiliency	Moderates conveyance of sediment?	Yes for the entire reach.	Yes for the entire reach.	Traps sediment during a flood and minimizes erosion.	Could be part of the strategy at diversions, bridges and culverts.
10	Safety	Reduce flood risk to the public and residents by providing long term solutions that increase resiliency?	Increases flood storage volume and reduces flood energy throughout the system.	Provides some creek channel resiliency.	Once allowed to mature the vegetation provides some resistance to future floods.	Hardened points are created in the corridor not always resilient.
11	Environment	Natural ecosystem processes restored?	Most holistic approach.	Partial approach, not all ecosystems addressed.	Partial approach, not all ecosystems addressed.	Least holistic approach.
12	Environment	Protects or improves existing habitat and significant ecological resources?	Improves both terrestrial and aquatic habitat.	Improves aquatic habitat.	Improves terrestrial and riparian habitat.	Not the focus of infrastructure protection techniques.
13	Environment	Incorporates locally available materials and environmentally friendly processes?	Not a differentiator. All alternatives can incorporate locally available materials and environmentally friendly processes.			
14	Environment	Protects and improves water quality and the geomorphology of the creek?	Protects geomorphology and jump starts natural systems of the corridor.	Protects geomorphology and jump starts natural systems of the creek.	Reduces erosion.	Reduces erosion in site specific areas.
15	Implementation	Creates infrastructure investments that are reasonable to construct and provides the best value for their lifecycle, function and purpose?	Because it jump starts the corridor's natural systems it is the best value for their life-cycle.	Reasonable to construct and jump starts natural system of the creek.	Without regrading, the revegetation effort will have diminished results.	Protects infrastructure but requires on-going maintenance.
16	Implementation	Can be supported by current land use regulations or revised land use regulations?	Not a differentiator. All alternatives can be supported by the current land use regulations.			
17	Implementation	Provides funding, partnering and collaboration opportunities by meeting multiple stakeholder objectives?	Not a differentiator. There are opportunities with all alternatives for partnering.			

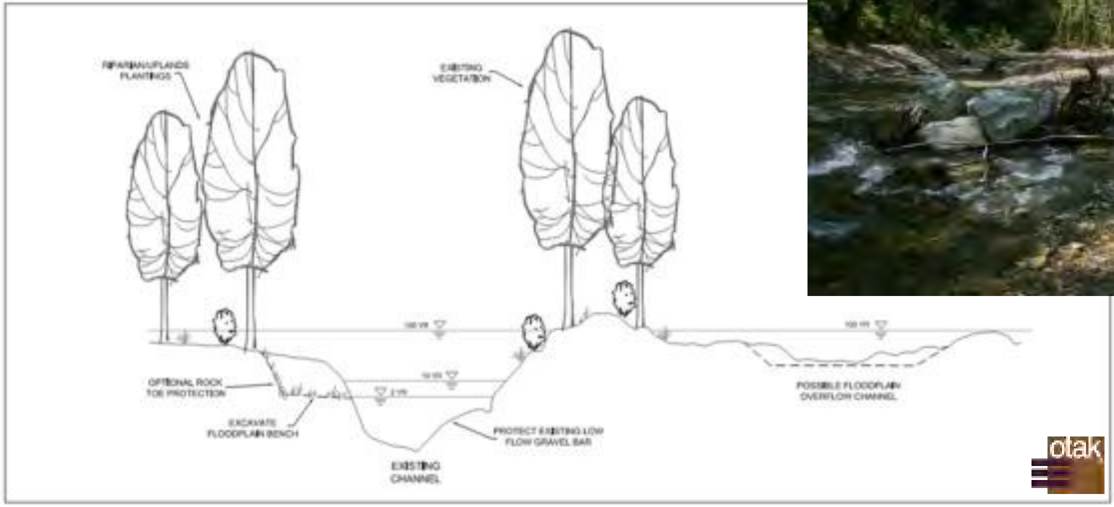
Notes:

Definitions:
Fair - What is thought to be right acceptable
Better - Higher in quality
Best - Better than all others in quality or value

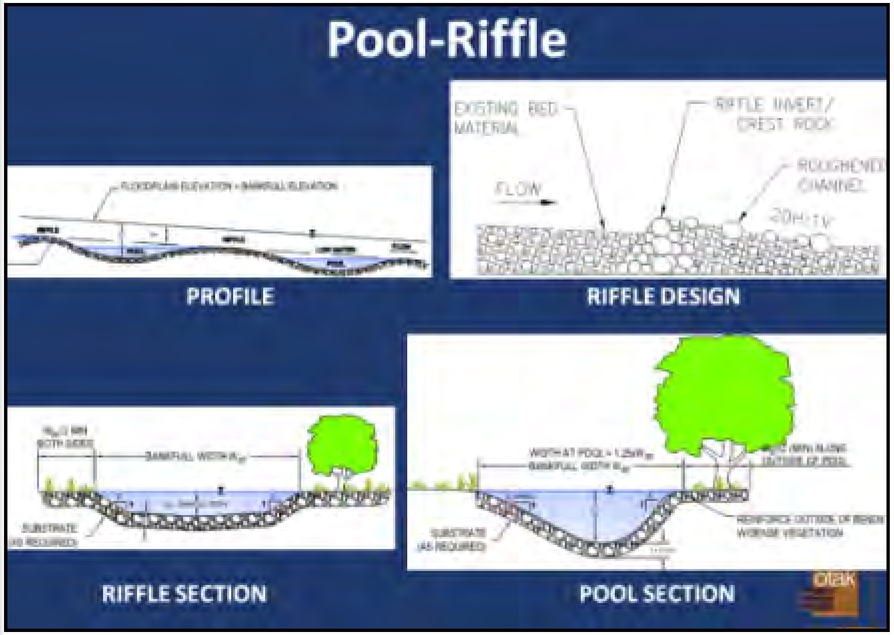
- Alternatives evaluated in matrices to determine most effect (preferred) alternative

Alternative: Floodplain Connectivity





Alternative: Channel Complexity



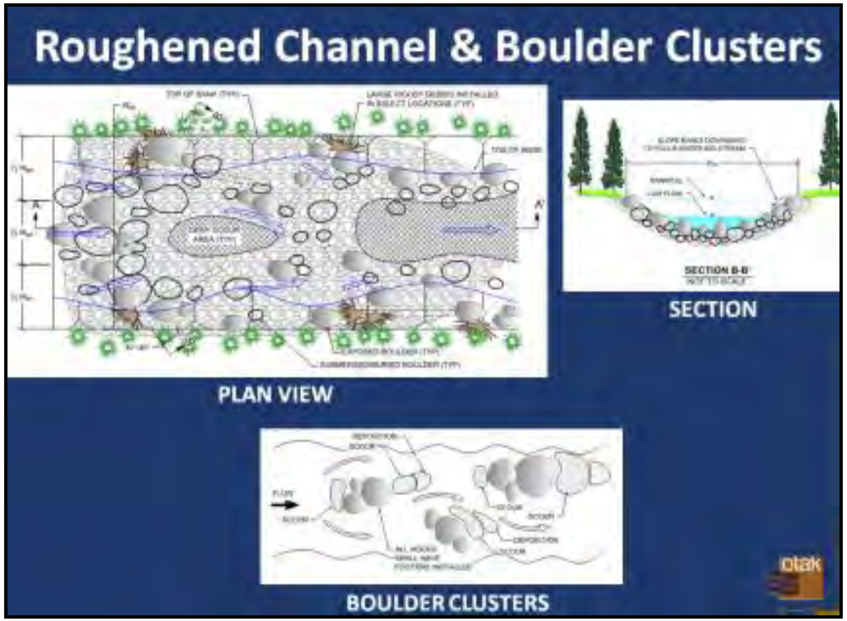
Pool-Riffle

PROFILE

RIFFLE DESIGN

RIFFLE SECTION

POOL SECTION



Roughened Channel & Boulder Clusters

PLAN VIEW

SECTION B-B

SECTION

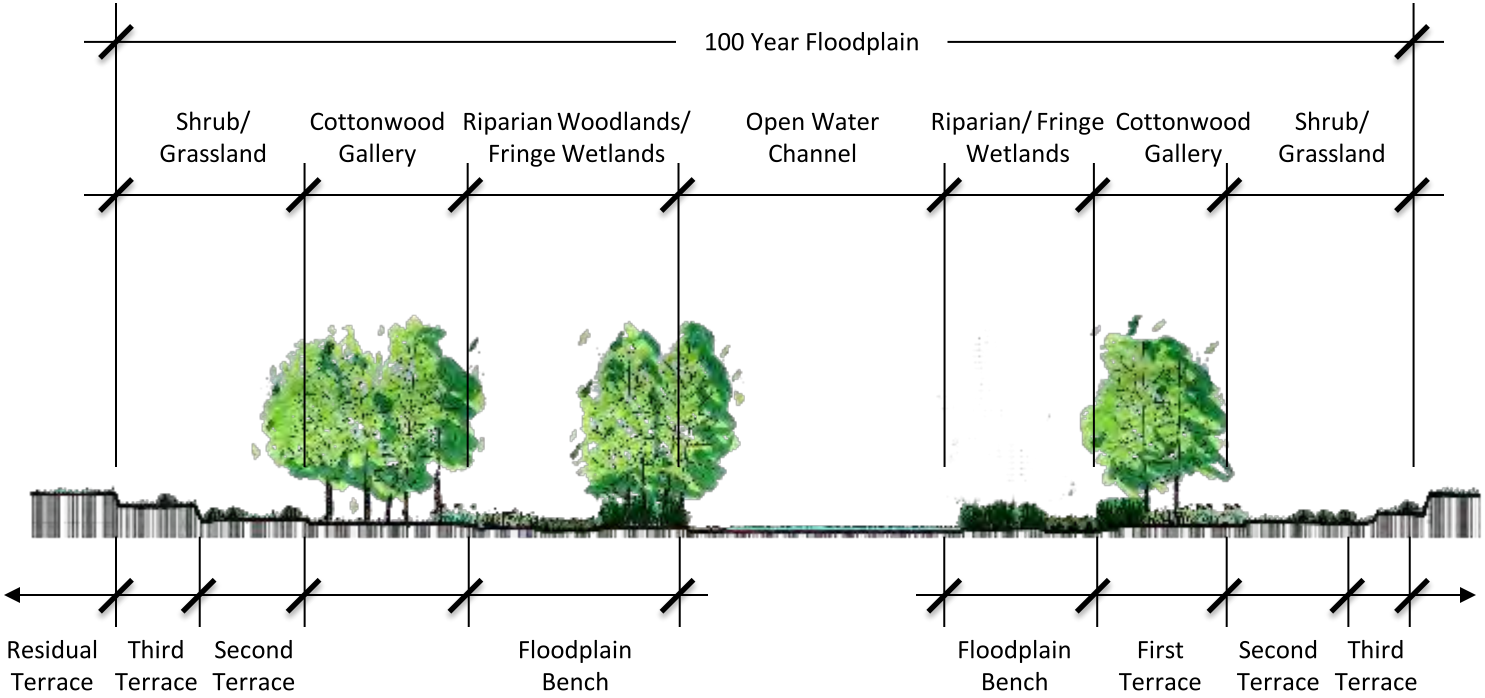
BOULDER CLUSTERS

Alternative: Revegetation

Cotton Wood Gallery

Wetland/Riparian Bench

Grassland Meadow



100 Year Floodplain

Shrub/ Grassland

Cottonwood Gallery

Riparian Woodlands/ Fringe Wetlands

Open Water Channel

Riparian/ Fringe Wetlands

Cottonwood Gallery

Shrub/ Grassland

Residual Terrace

Third Terrace

Second Terrace

Floodplain Bench

Floodplain Bench

First Terrace

Second Terrace

Third Terrace

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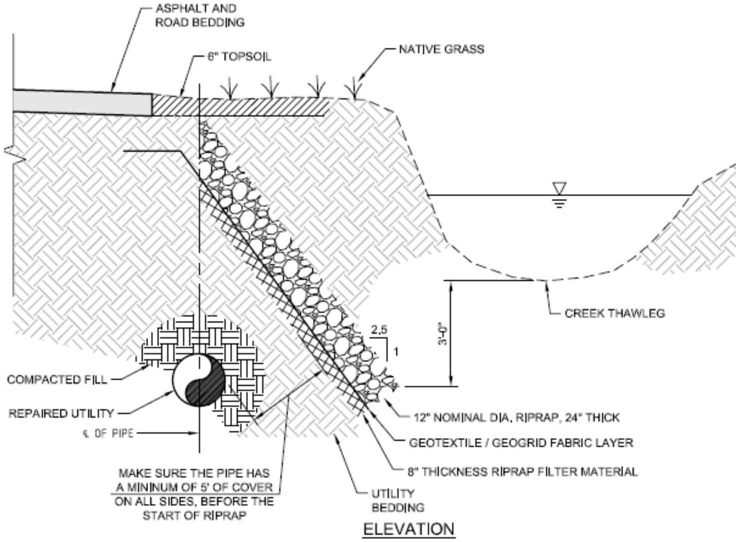
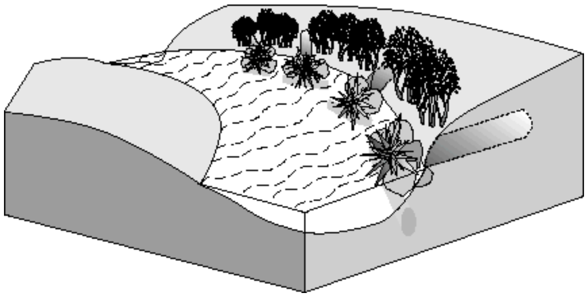
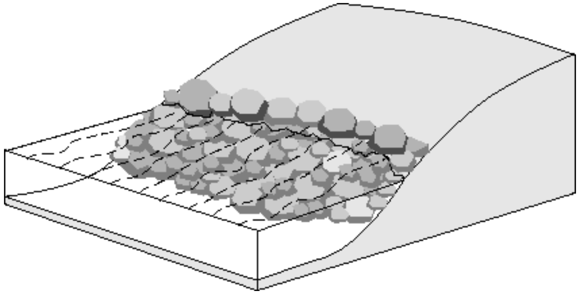
Alternative: Infrastructure Protection



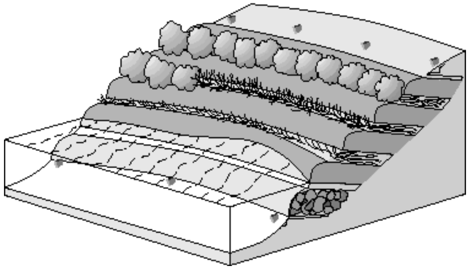
Utility Armoring



Root Wad Stabilization



Boulder Toe Protection



Vegetated Geogrid

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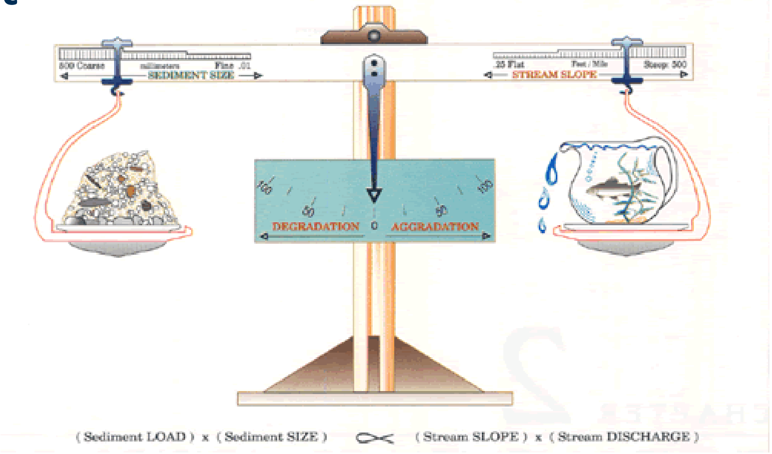
Additional Design Aspects Evaluated

Existing infrastructure aspects investigated to provide future recommendations

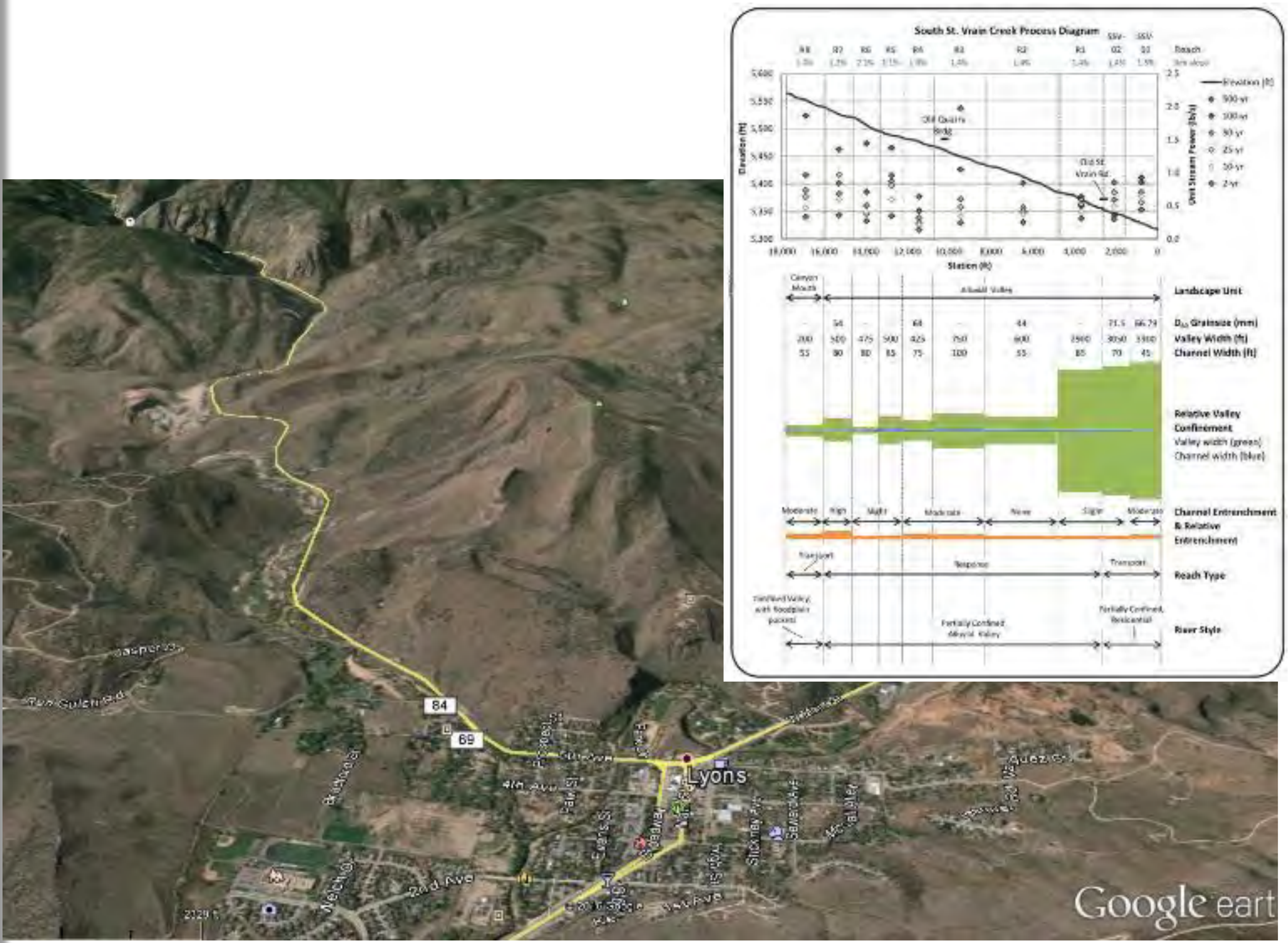
- Old St Vrain Road Bridge
  - Required capacity and road overtopping
- Longmont Diversion
  - Relocation of diversion and floodplain conveyance
- South Ledge/Meadows Ditch
  - Sedimentation issues
- Woody Vegetation Management

Geomorphology

- Geomorphic Assessment
  - Data Review
  - Desktop Analysis
  - Field Assessment
- Sediment Transport
  - Stability Analyses
  - Trajectory determination
  - Structure design
- What questions are we trying to answer?
  - What are prevailing processes and how do we use them to achieve the project goals?
  - What is the channel trajectory and what does that mean for the project goals?
  - Is the channel stable? Is the design stable?



Geomorphology - Assessment



	R8	R7	R6	R5	R4	R3	R2	R1	SSV-02	SSV-03
D50 Grainsize (mm)	-	54	-		68	-	44	-	71.5	66.79
Valley Width (ft)	200	500	475	500	425	750	600	2500	3050	3300
Channel Width (ft)	55	80	80	85	75	100	55	85	70	45

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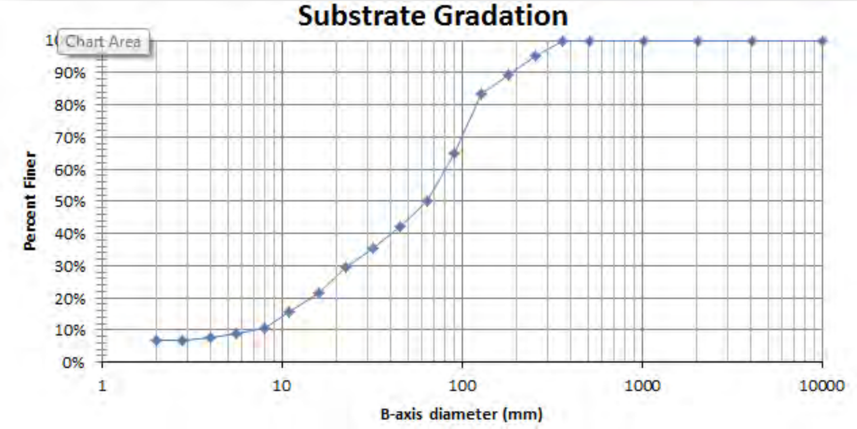
Geomorphology - Assessment



Substrate Gradation

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Geomorphology - Assessment

- River Styles

Partially Confined, Alluvial Valley (PCAV)

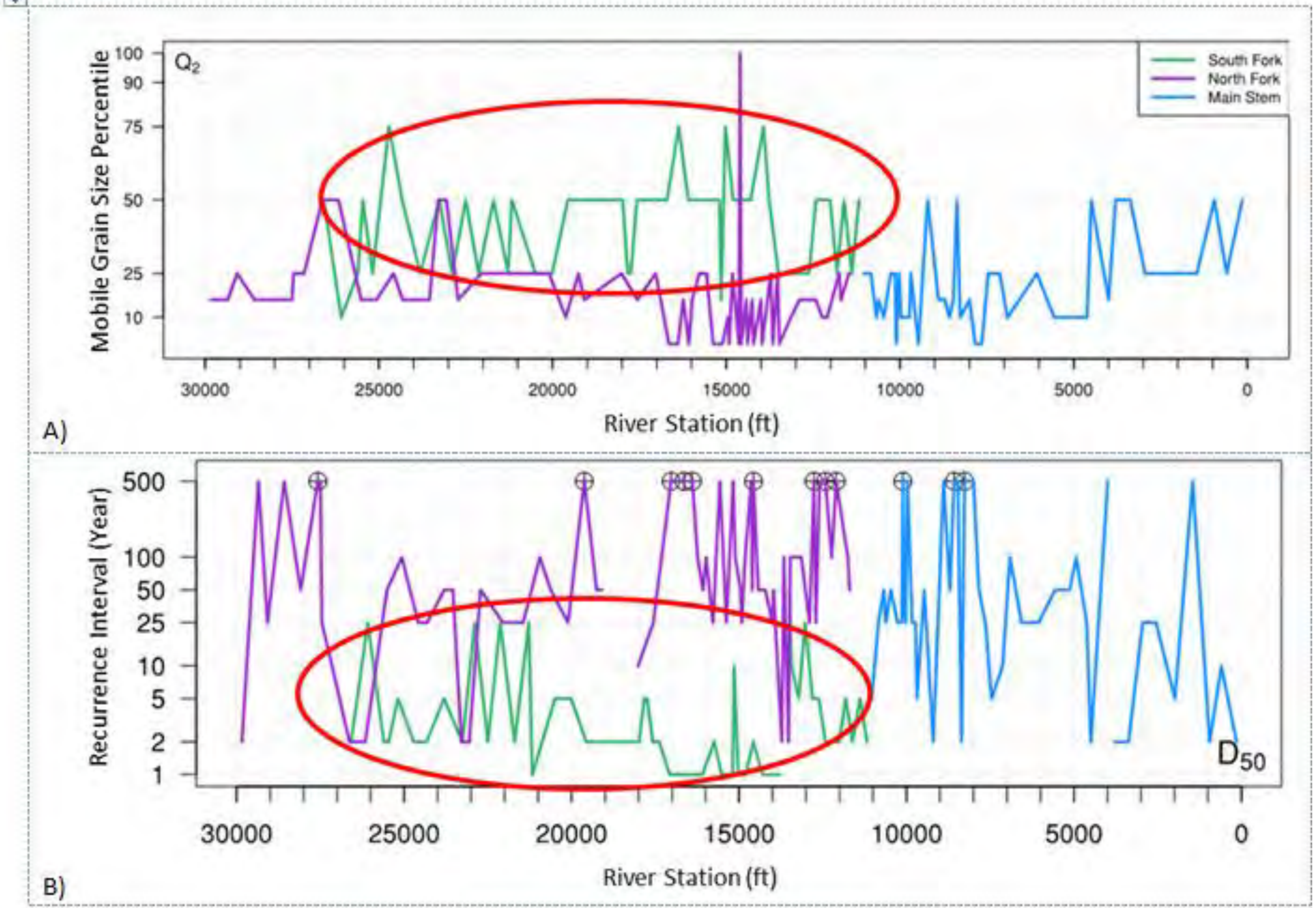
Properties:
The majority of the reaches in the study area are classified under this stream style. They occupy the transition from the canyons through the hogbacks to the alluvial plain landscape units. Slopes are steep, but milder than the confined reaches (observed slopes ranged from 0.3% to 2.1%). As a result of this relative steepness, relative lack of confinement, and position downstream of confined reaches directly coupled with hillslope sediment supplies, these reaches exhibit the most geomorphic response to floods. Because these reaches experienced the most geomorphic change, many channels of this style are still evolving in response to the floods. In some cases, channels are beginning to narrow and some side channels are slowly filling in with sediment. Nevertheless, a large amount of unstable sediment ranging from sand to cobble material exists in the banks and floodplains of these reaches and will continue to be a net sediment supply to downstream reaches for some time.

Reaches:
SVC-03, SVC-04, SVC-05 / NSV-04, NSV-05, NSV-06 / SSV-03, SSV-04, SSV-05, SSV-06, SSV-07, SSV-08, SSV-09

RIVER CHARACTERISTICS	
Valley Setting	Partially confined. Observed confinement ratio ranging from 3 to 35
Channel Planform	Meandering channel with low sinuosity, braided in some areas after flood. High flow, side channels present.
Bed Morphology	Typical: pool-riffle, boulder clusters, large wood jams and roughness elements; lateral and mid-channel bars Observed: pool-riffle, plane bed, riffle-run, mid-channel/point/lateral bars, instream large wood
RIVER BEHAVIOR	
Current Stream Evolution Stage	Majority of reaches are in the Aggradation and Widening stage, with a few in the Degradational stage and a few in the Quasi Equilibrium stage (post-restoration)
Flood Response	Flood response ranged from channel widening throughout, downstream lateral migration of meander bends, channel avulsion, and braiding.
Stage Behavior	Low flows are generally single thread with splits around mid-channel bars. Sediment is stored in bar complexes at the channel margin. Bankfull flows activate side channels and re-work in-channel bars. Large wood has significant influence on bank erosion and sediment accumulation. At flood stages, extremely high stream power values are generated before flows can spill into extensive floodplains, dissipating stream energy. Side channels are activated through inundation and channel avulsions will likely occur. Large wood is recruited into the channel as banks and terraces become undercut and may have significant influence over channel behavior as additional wood is racked up.

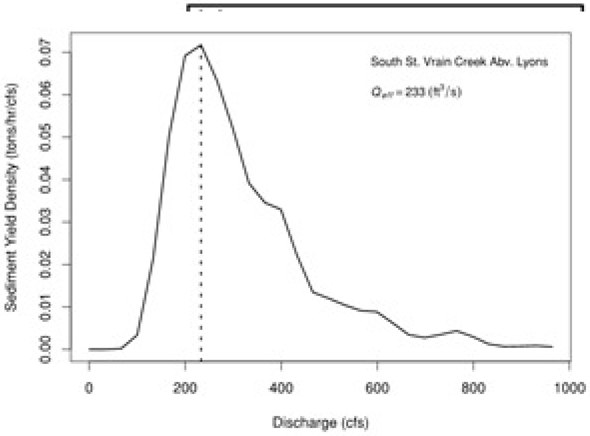
Geomorphology – Sediment Transport

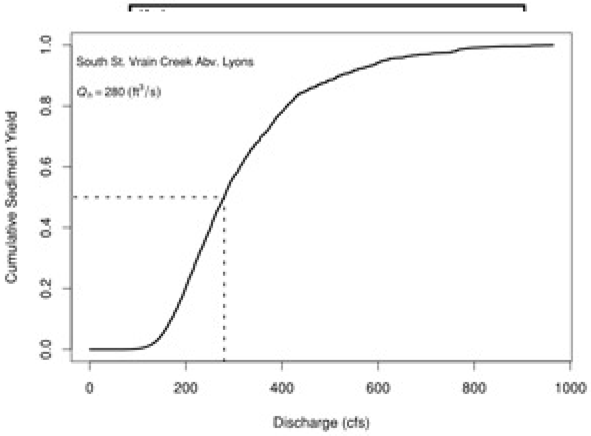
- Base Bed Mobility



Geomorphology – Sediment Transport

- Effective Discharge
  - Q_{eff} – flow that transports most sediment over time
  - Q_h – discharge associated with cumulative 50% of sediment yield





Geomorphology – Sediment Transport

Sediment Transport Capacity and Balance

Stream Power

$$q_s = 4.610^{-7}\Omega^{1.75}D_{50}^{-0.56}$$

$$\Omega = \frac{\omega^{1.5}}{R^{\frac{2}{3}}} \qquad \omega = \frac{\rho g Q S}{b}$$

Meyer-Peter Muller

$$\left(\frac{k_r}{k_r'}\right)^{3/2}\gamma RS = 0.047(\gamma_s - \gamma)d_m + 0.25\left(\frac{\gamma}{g}\right)^{1/3}\left(\frac{\gamma_s - \gamma}{\gamma_s}\right)^{2/3} g_s^{2/3}$$

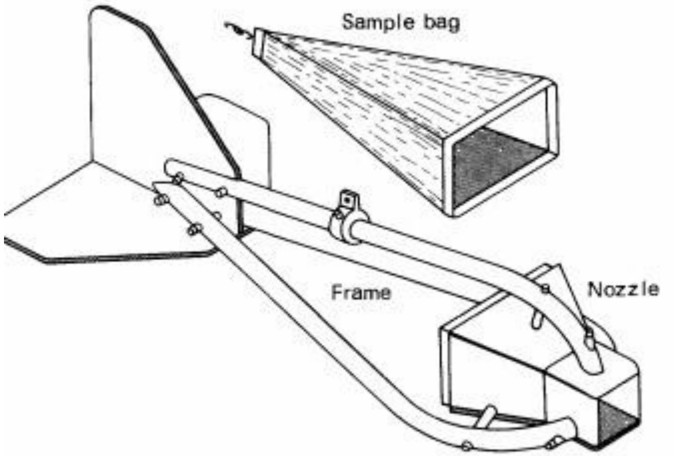
Where: g_s = Unit sediment transport rate in weight/time/
k_r = A roughness coefficient
k_r' = A roughness coefficient based on grains
γ = Unit weight of water
γ_s = Unit weight of the sediment
g = Acceleration of gravity
d_m = Median particle diameter
R = Hydraulic radius
S = Energy gradient

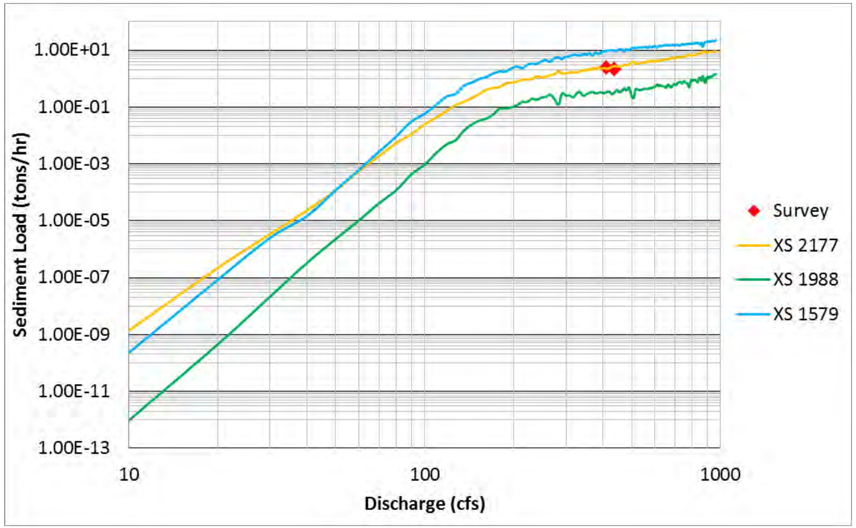
Capacity-Supply Ratio (CSR)

- Reach capacity/supply
- 1 is good

Geomorphology – Sediment Transport

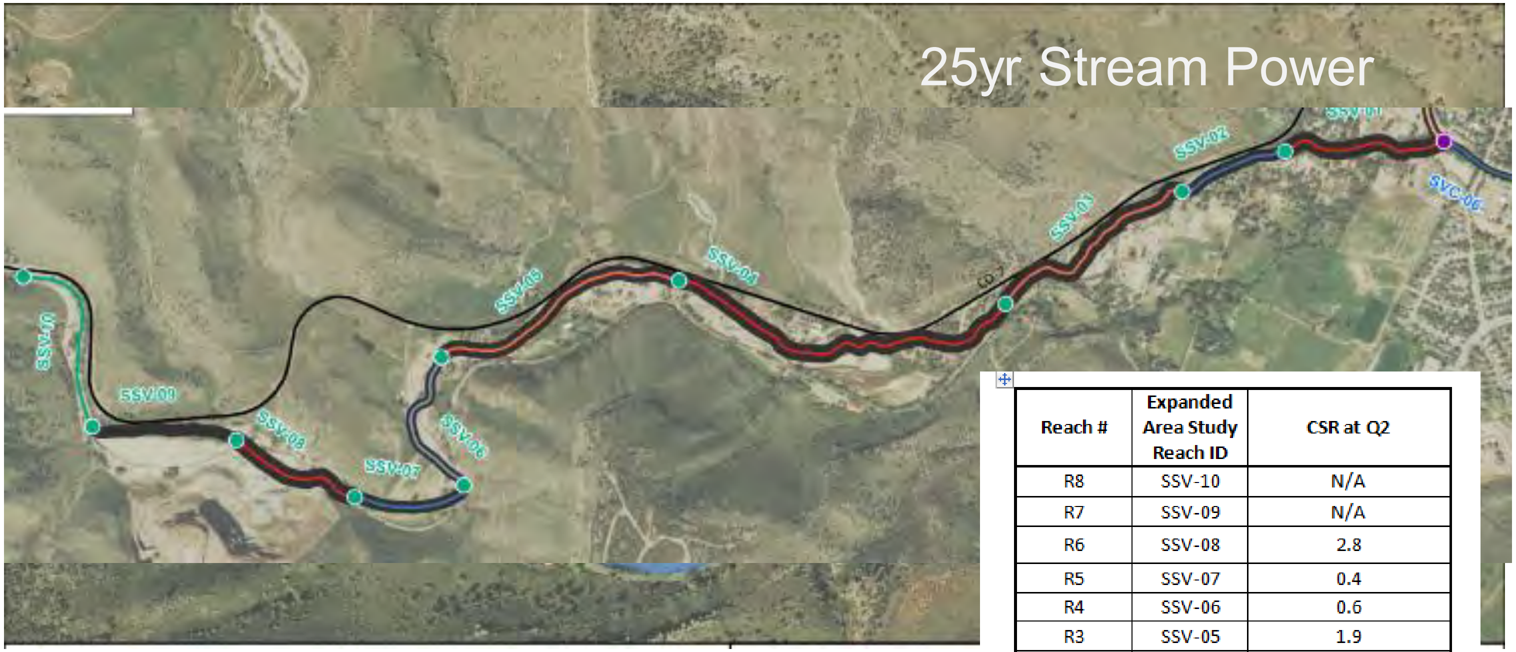
- Sediment Transport Capacity and Balance





Geomorphology – Sediment Transport

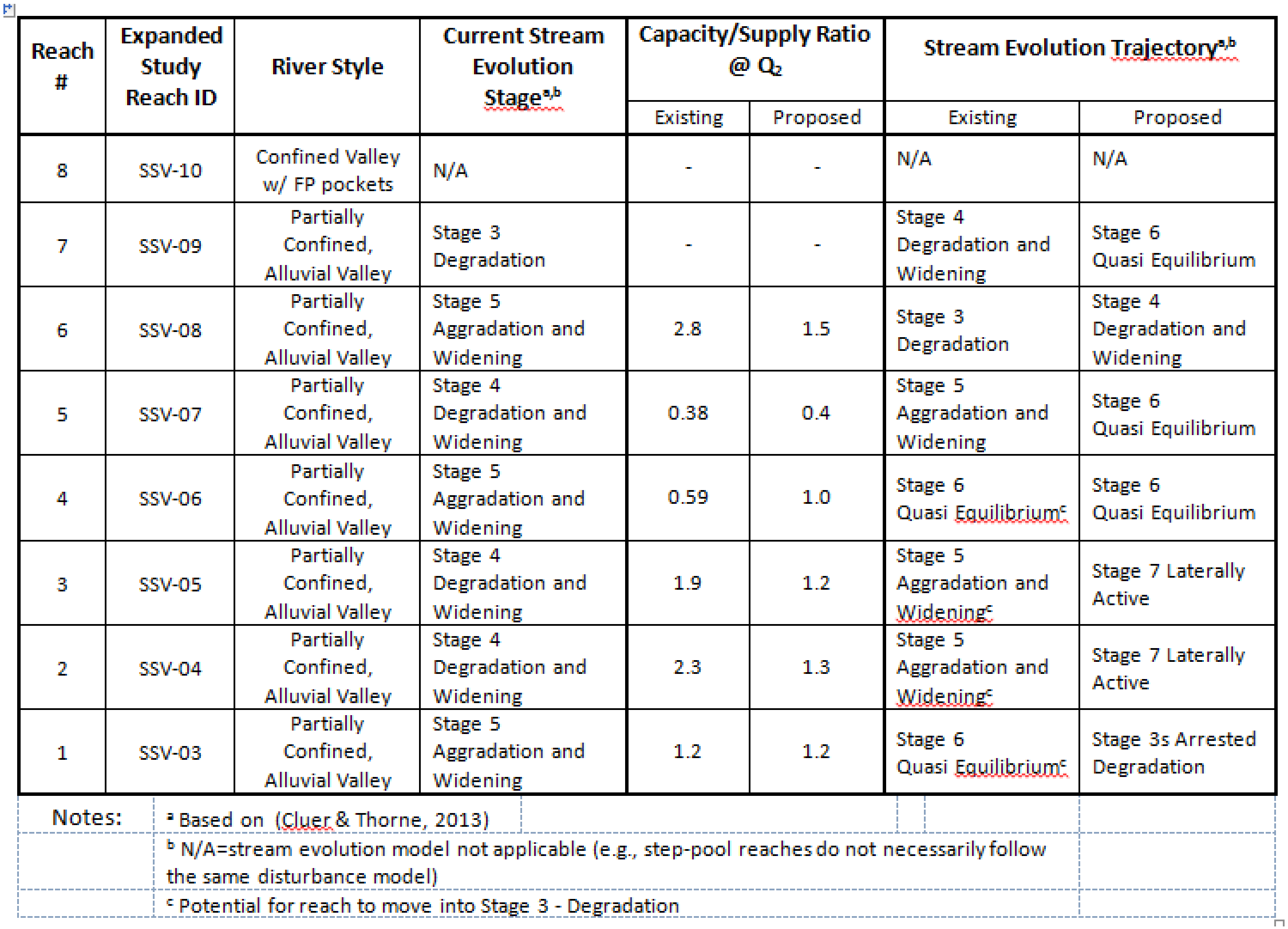
- Sediment Transport Capacity and Balance



Reach #	Expanded Area Study Reach ID	CSR at Q2
R8	SSV-10	N/A
R7	SSV-09	N/A
R6	SSV-08	2.8
R5	SSV-07	0.4
R4	SSV-06	0.6
R3	SSV-05	1.9
R2	SSV-04	2.3
R1	SSV-03	1.2
-	SSV-02	0.2
-	SSV-01	3.4

Geomorphology - SEM

Stream Evolution Model



Reach #	Expanded Study Reach ID	River Style	Current Stream Evolution Stage[a,b]	Capacity/Supply Ratio @ Q_2		Stream Evolution Trajectory[a,b]	
				Existing	Proposed	Existing	Proposed
8	SSV-10	Confined Valley w/ FP pockets	N/A	-	-	N/A	N/A
7	SSV-09	Partially Confined, Alluvial Valley	Stage 3 Degradation	-	-	Stage 4 Degradation and Widening	Stage 6 Quasi Equilibrium
6	SSV-08	Partially Confined, Alluvial Valley	Stage 5 Aggradation and Widening	2.8	1.5	Stage 3 Degradation	Stage 4 Degradation and Widening
5	SSV-07	Partially Confined, Alluvial Valley	Stage 4 Degradation and Widening	0.38	0.4	Stage 5 Aggradation and Widening	Stage 6 Quasi Equilibrium
4	SSV-06	Partially Confined, Alluvial Valley	Stage 5 Aggradation and Widening	0.59	1.0	Stage 6 Quasi Equilibrium[c]	Stage 6 Quasi Equilibrium
3	SSV-05	Partially Confined, Alluvial Valley	Stage 4 Degradation and Widening	1.9	1.2	Stage 5 Aggradation and Widening[c]	Stage 7 Laterally Active
2	SSV-04	Partially Confined, Alluvial Valley	Stage 4 Degradation and Widening	2.3	1.3	Stage 5 Aggradation and Widening[c]	Stage 7 Laterally Active
1	SSV-03	Partially Confined, Alluvial Valley	Stage 5 Aggradation and Widening	1.2	1.2	Stage 6 Quasi Equilibrium[c]	Stage 3s Arrested Degradation

Notes:

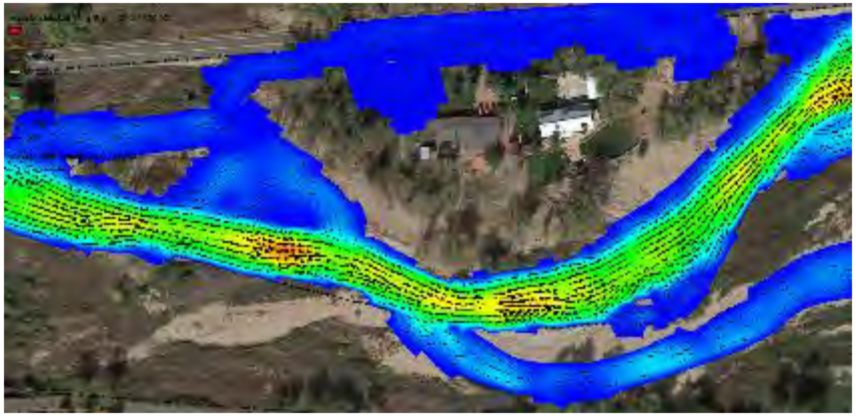
[a] Based on (Cluer & Thorne, 2013)

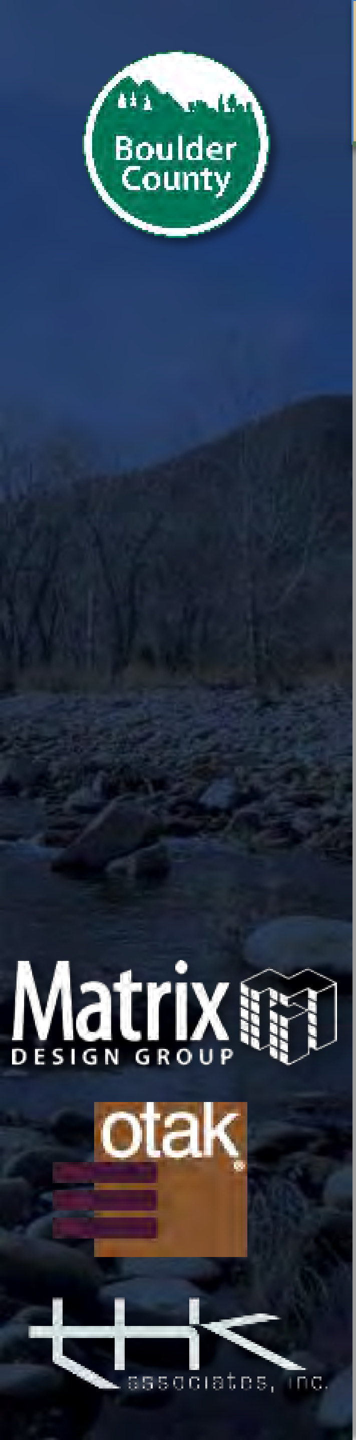
[b] N/A=stream evolution model not applicable (e.g., step-pool reaches do not necessarily follow the same disturbance model)

[c] Potential for reach to move into Stage 3 - Degradation

Geomorphology - Summary

- Stream is generally featureless, over-widened and likely to degrade disconnecting further from the existing floodplain
- Restoration and Flood Mitigation Strategies:
  - Establish equilibrium channel geometries that promote/maintain floodplain connection
  - Control sediment supply with aggressive revegetation
  - Establish geomorphic complexity to manage sediment load, improve habitat



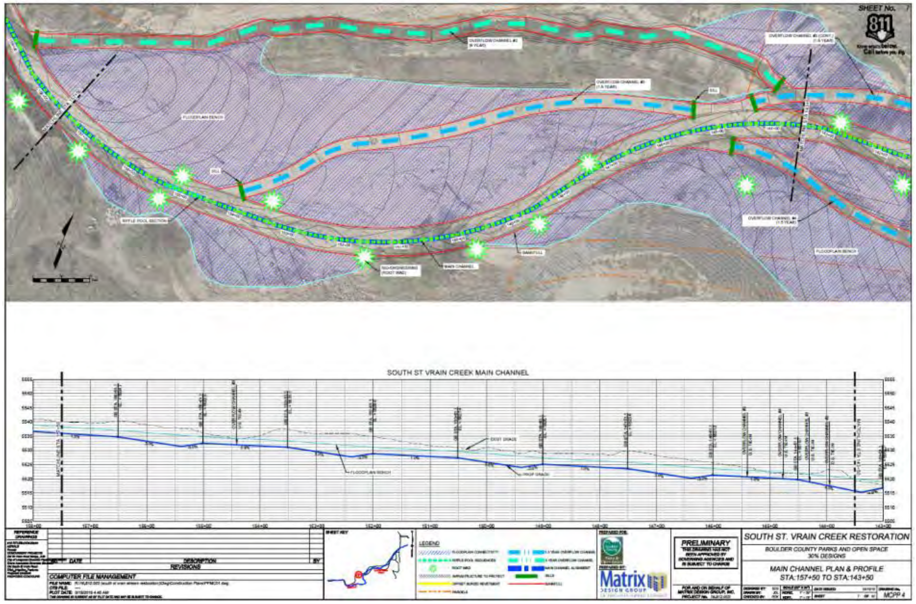


Design Process

- Understand Hydraulics with Development of Design Models
  - 1-D HEC-RAS
    - Regulatory floodplain modeling
  - 2-D Sedimentation and River Hydraulics
    - Final design parameters and sediment transport
- Iterative Process
  - EC Topography and Modeling
  - PC Grading and PC Modeling
  - Refine PC Topography
  - Verify Capacity-Supply Ratio
  - Structure and Revegetation Design

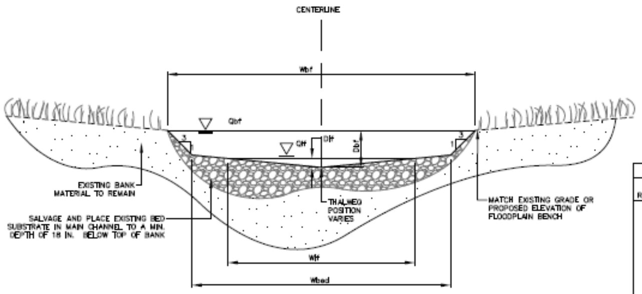
30% Design

- Channel Geometry
  - Function of hydraulic geometry, and constraints
- Main Channel and Overflow Planform
  - Pre-Flood or Existing Alignments
- Channel Profile
  - Equilibrium bed slope analysis (0.8 – 2% range)



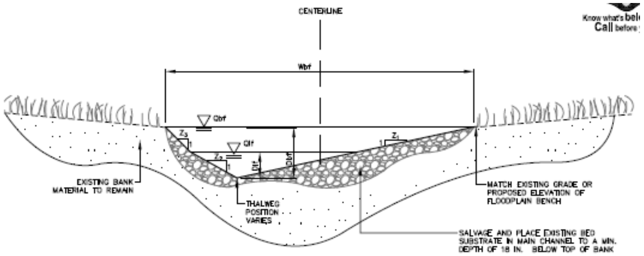
30% Design

- Channel and Floodplain Dimensions
  - Multi-Stage Channel

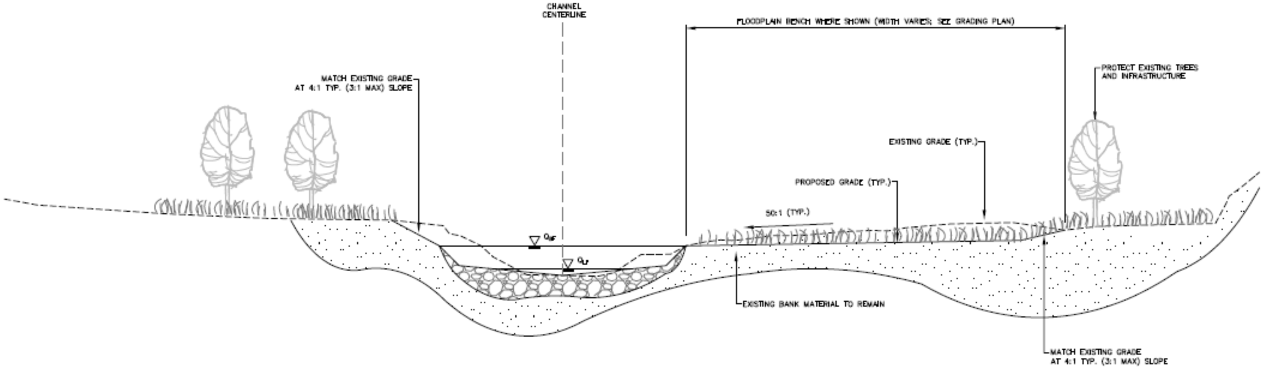


TYPICAL MAIN CHANNEL GRADING SECTION FOR STRAIGHT REACHES
NOT TO SCALE

TYPICAL MAIN CHANNEL GEOMETRY (ft)				
REACH TYPE	DIMENSION	NARROW	TYP	WIDE
STRAIGHT REACH	Wbf	40	48	55
	Wbed	31	38	44
	Wff	26	29	32
	Dbf	2.5	2.25	2.1
	Dff	0.84	0.76	0.73
	Z1	15.5	19	22
	Z2	3	4	5
MEANDER REACH	Wbf	40	48	55
	Dbf	4.4	4.0	3.6
	Dff,pool	2.75	2.5	2.25
	Z1	6.2	8.3	10.8
	Z2	3	4	5
	Z3	2.5	3	3



TYPICAL MAIN CHANNEL GRADING SECTION FOR MEANDER REACHES
NOT TO SCALE

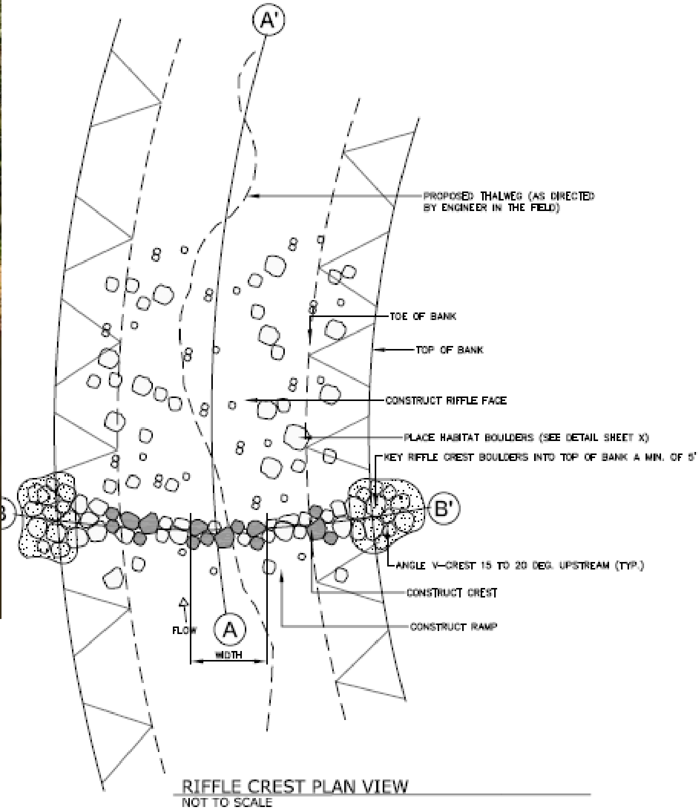


TYPICAL FLOODPLAIN GRADING SECTION
NOT TO SCALE

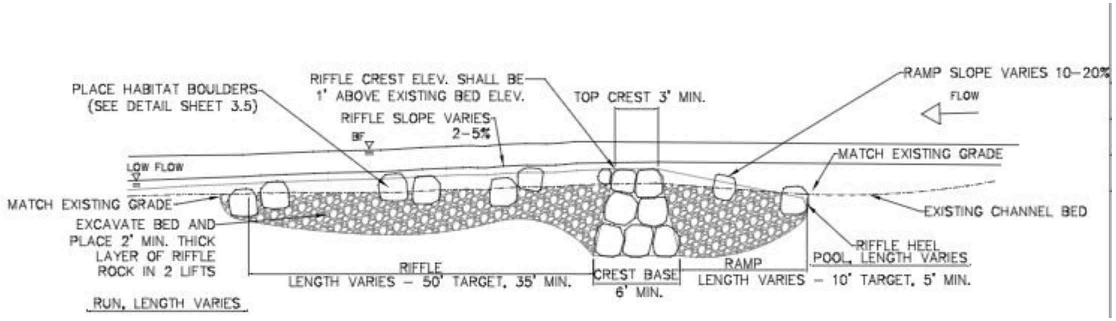
1.5 and 5 Year Overflow Channels

- Along Existing and/or Pre-Flood Channel Alignments to stretch implementation funds
- On Average 25’ Bottom Width with Gentle Side Slopes
- Vegetation Lined and/or Stream Substrate

Riffle Structure Design



RIFFLE CREST PLAN VIEW
NOT TO SCALE



Boulder County

Matrix DESIGN GROUP

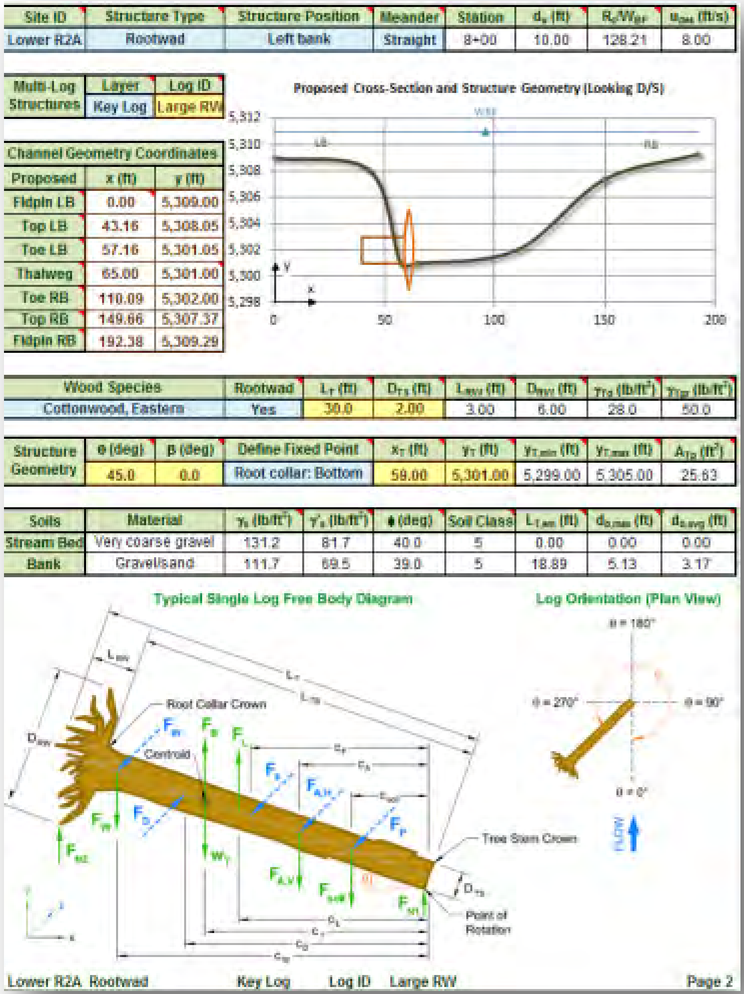
otak

associates, inc.

Large Woody Material and Vegetation

- Geomorphic, Biologic and Ecologic Benefits
- Implementation Guidance
  - Site Visit with Boulder County Emergency Management (OEM)
    - OEM Decision Process
    - Focused on hazard trees in the vicinity of infrastructure
  - National Guidance Documents on the Design of Engineered Log Structures

Large Wood Structure Design



Site ID	Structure Type	Structure Position	Meander	Station	d_a (ft)	R_c/W_{BF}	u[illegible] (ft/s)
Lower R2A	Rootwad	Left bank	Straight	8+00	10.00	128.21	8.00

Multi-Log Structures	Layer	Log ID
	Key Log	Large RW

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	0.00	5,309.00
Top LB	43.16	5,308.05
Toe LB	57.16	5,301.05
Thalweg	65.00	5,301.00
Toe RB	110.09	5,302.00
Top RB	149.66	5,307.37
Fldpln RB	192.38	5,309.29

Proposed Cross-Section and Structure Geometry (Looking D/S)

Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft³)	γ_{Tg} (lb/ft³)
Cottonwood, Eastern	Yes	30.0	2.00	3.00	6.00	28.0	50.0

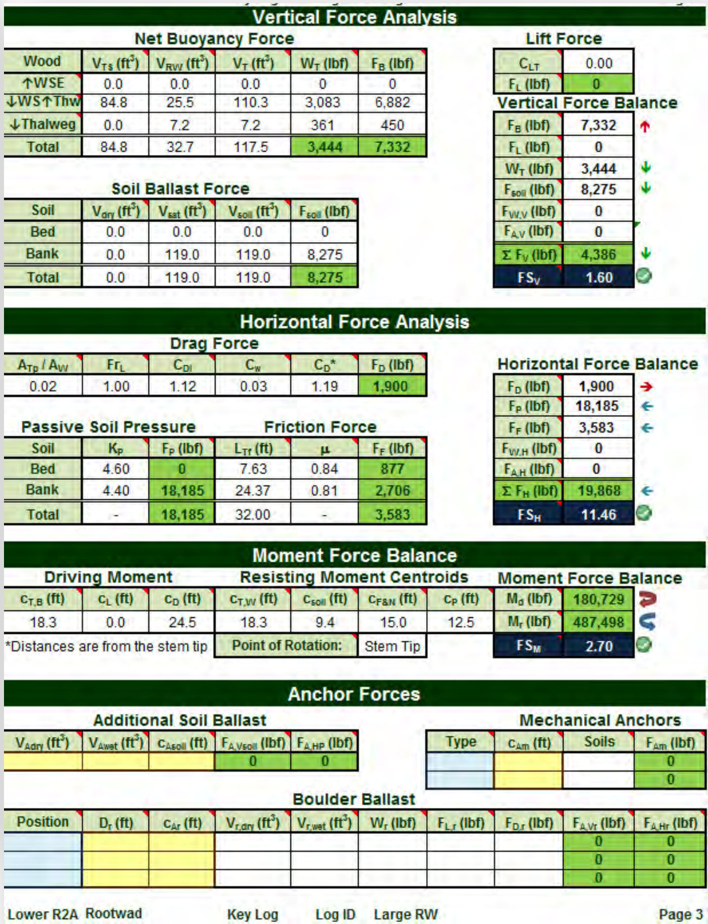
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	$y_{T,min}$ (ft)	$y_{T,max}$ (ft)	A_{Tp} (ft²)
	45.0	0.0	Root collar: Bottom	59.00	5,301.00	5,299.00	5,305.00	25.63

Soils	Material	γ_s (lb/ft³)	γ'_s (lb/ft³)	ϕ (deg)	Soil Class	$L_{T,aa}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Very coarse gravel	131.2	81.7	40.0	5	0.00	0.00	0.00
Bank	Gravel/sand	111.7	69.5	39.0	5	18.89	5.13	3.17

Typical Single Log Free Body Diagram

Log Orientation (Plan View)

Lower R2A Rootwad Key Log Log ID Large RW Page 2



Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft³)	V_{RW} (ft³)	V_T (ft³)	W_T (lbf)	F_B (lbf)
↑WSE	0.0	0.0	0.0	0	0
↓WS↑Thw	84.8	25.5	110.3	3,083	6,882
↓Thalweg	0.0	7.2	7.2	361	450
Total	84.8	32.7	117.5	3,444	7,332

Lift Force

C_{LT}	0.00
F_L (lbf)	0

Vertical Force Balance

F_B (lbf)	7,332	↑
F_L (lbf)	0	
W_T (lbf)	3,444	↓
F_{soil} (lbf)	8,275	↓
$F_{W,V}$ (lbf)	0	
$F_{A,V}$ (lbf)	0	
Σ F_V (lbf)	4,386	↓
FS_V	1.60	✓

Soil Ballast Force

Soil	V_{dry} (ft³)	V_{sat} (ft³)	V_{soil} (ft³)	F_{soil} (lbf)
Bed	0.0	0.0	0.0	0
Bank	0.0	119.0	119.0	8,275
Total	0.0	119.0	119.0	8,275

Horizontal Force Analysis

Drag Force

A_{Tp} / A_W	Fr_L	C_{DI}	C_w	C_D*	F_D (lbf)
0.02	1.00	1.12	0.03	1.19	1,900

Horizontal Force Balance

F_D (lbf)	1,900	→
F_P (lbf)	18,185	←
F_F (lbf)	3,583	←
$F_{W,H}$ (lbf)	0	
$F_{A,H}$ (lbf)	0	
Σ F_H (lbf)	19,868	←
FS_H	11.46	✓

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	4.60	0	7.63	0.84	877
Bank	4.40	18,185	24.37	0.81	2,706
Total	-	18,185	32.00	-	3,583

Moment Force Balance

Driving Moment			Resisting Moment Centroids			
$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
18.3	0.0	24.5	18.3	9.4	15.0	12.5

*Distances are from the stem tip

Point of Rotation: Stem Tip

Moment Force Balance

M_d (lbf)	180,729
M_r (lbf)	487,498
FS_M	2.70 ✓

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft³)	V_{Awet} (ft³)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

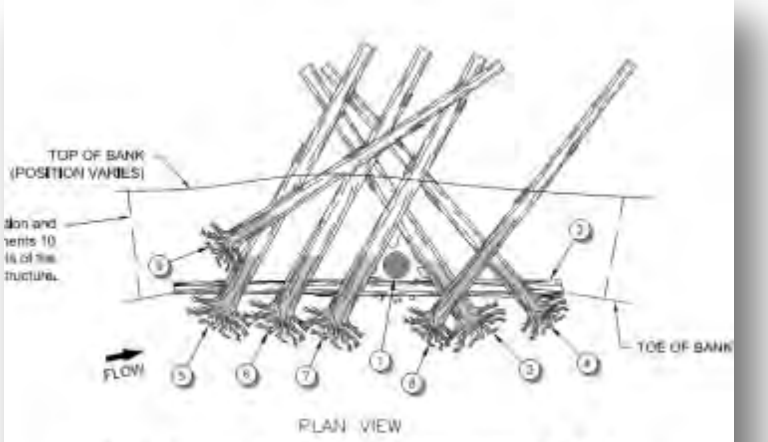
Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
			0
			0

Boulder Ballast

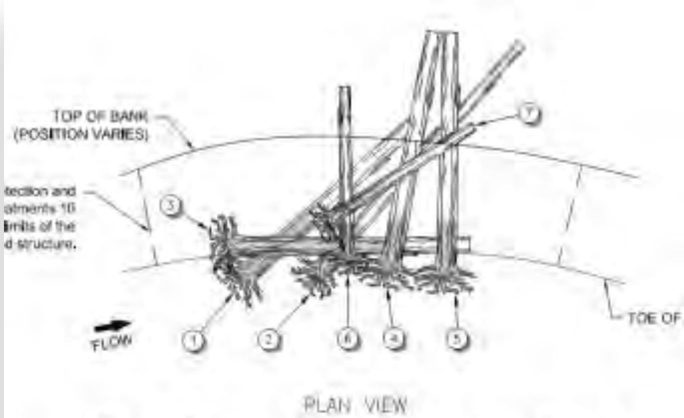
Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft³)	$V_{r,wet}$ (ft³)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
								0	0
								0	0
								0	0

Lower R2A Rootwad Key Log Log ID Large RW Page 3

Large Wood Structure Design

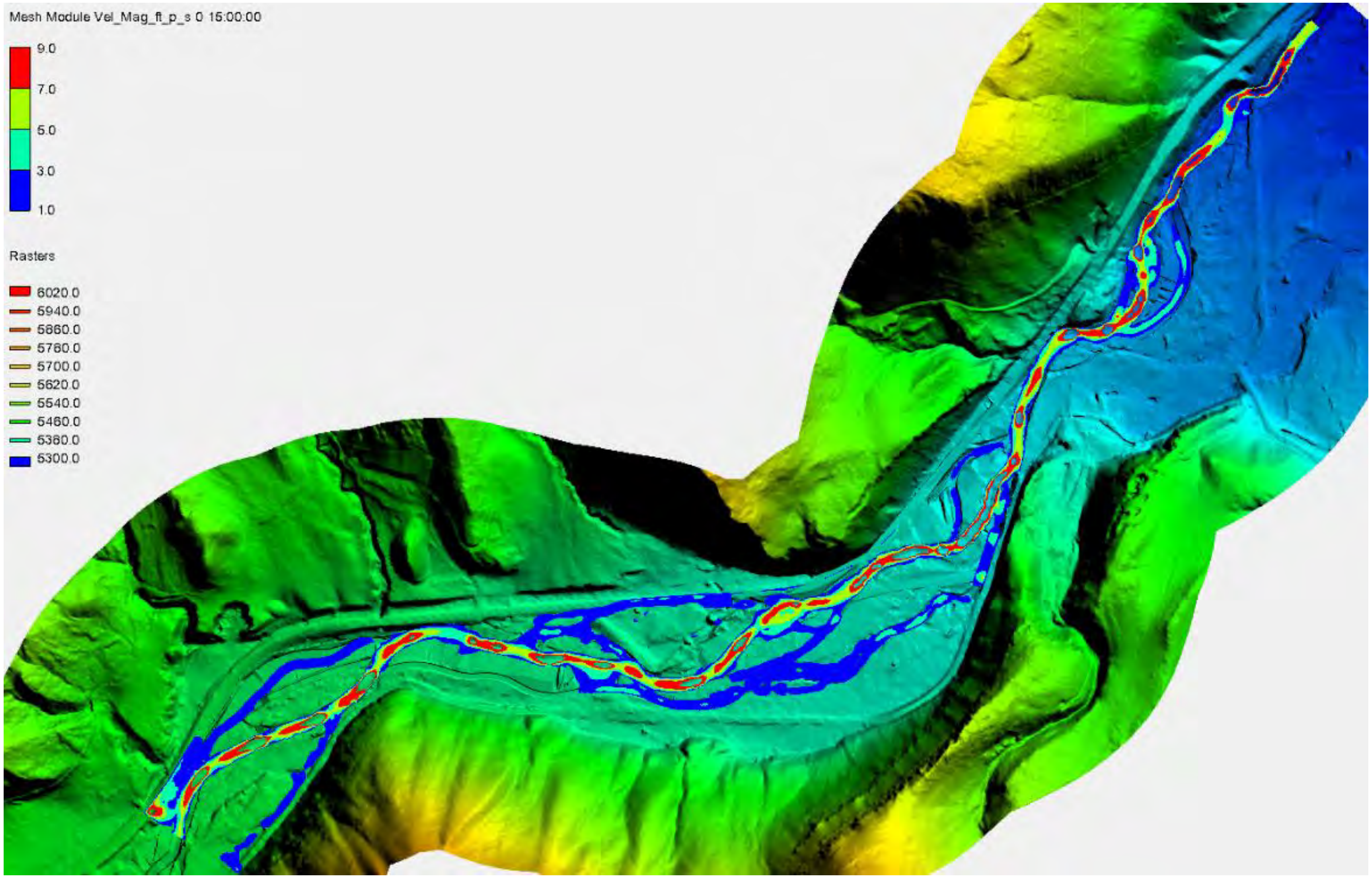


Type A Large Wood Structure Detail



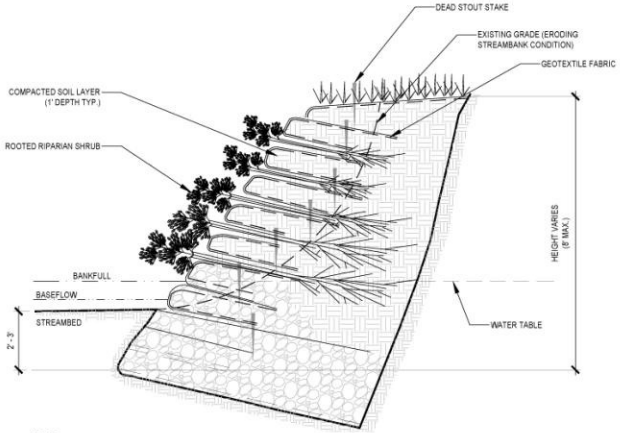
Type B Large Wood Structure Detail

Bank Stabilization



Bank Stabilization

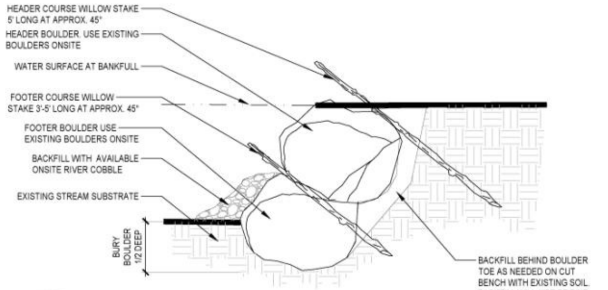
Boulder County



NOTES:
1. INTEGRATE STAKE PLANTING TECHNIQUES DURING ROCK PLACEMENT TO ENSURE CONTACT WITH NATIVE GROUND.
2. PLACE SOIL FILL AROUND CUTTINGS AND 'WATER IN' IF NEEDED.
3. ASSUME 15 STAKES PER LINEAR FOOT OF VEGETATED REINFORCED SOIL SLOPES

VEGETATED REINFORCED SOIL SLOPES

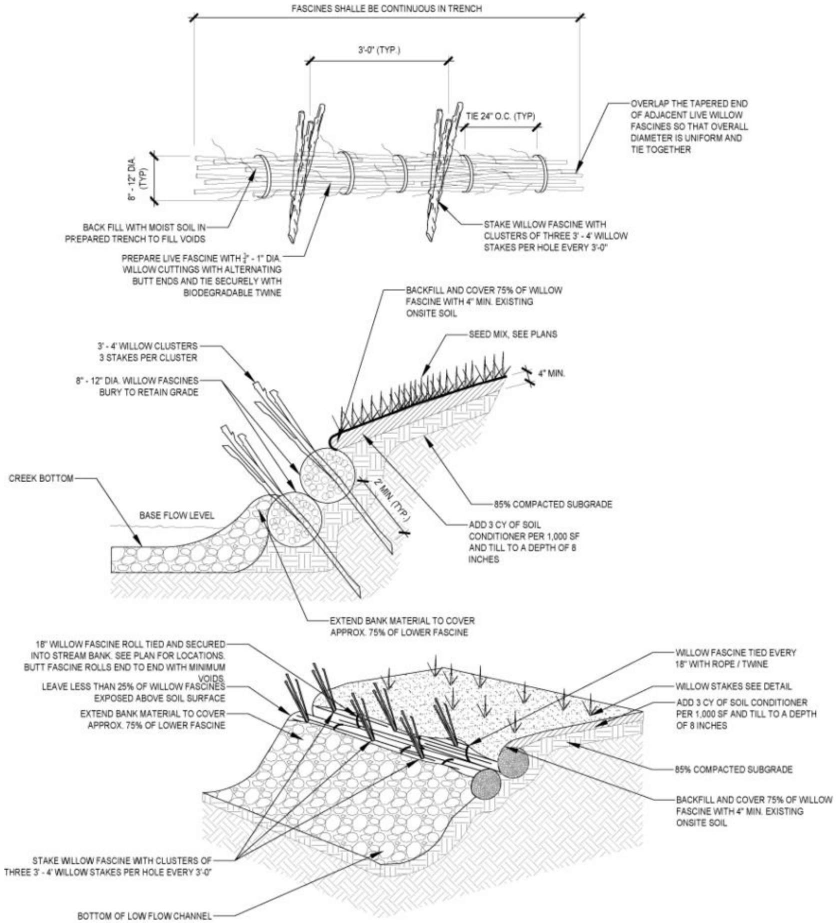
SCALE: N.T.S.



NOTES:
1. SEE REVEGETATION PLANS FOR LOCATIONS.

BOULDER TOE WILLOW PLANTING

SCALE: N.T.S.



NOTES:
1. MAKE CLEAN CUTS AND DO NOT DAMAGE STAKES OR SPLIT ENDS
2. DURING INSTALLATION USE A PILOT BAR IN FIRM SOILS.
3. TAMP THE SOIL AROUND THE STAKE / OR BACK FILL WITH MUD SLURRY.
4. COLLECT WILLOWS FROM ONSITE TO CONSTRUCT WILLOW FASCINES.

LIVE WILLOW FASCINE

SCALE: N.T.S.

Matrix DESIGN GROUP

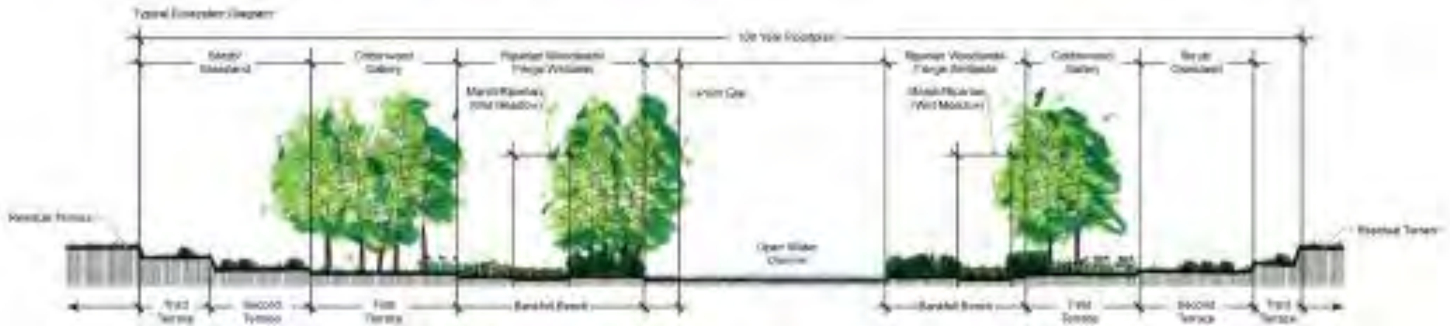
otak

THK associates, inc.

Bank Stabilization

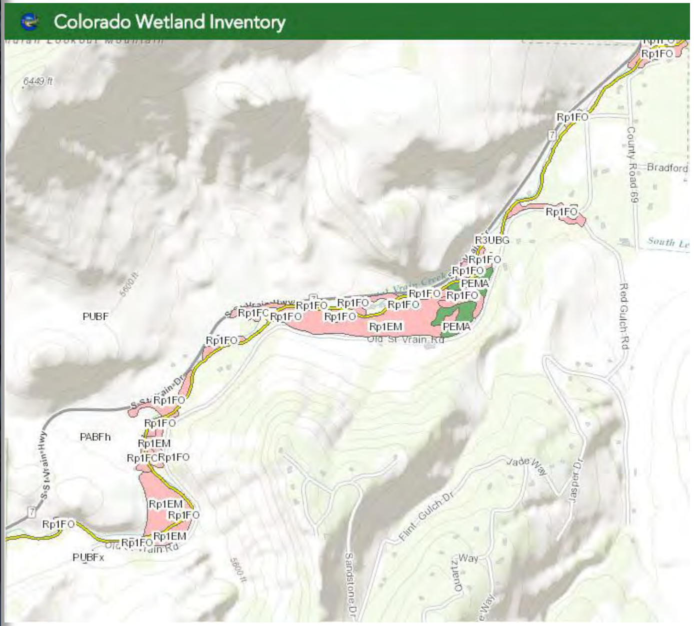
Revegetation: Goals

- Preserve Existing Vegetation
- Planting Diversity Based Upon Proximity to Water Table (Iterative Design Process)
- Match existing plant species and ecosystem types to historical character and onsite conditions.



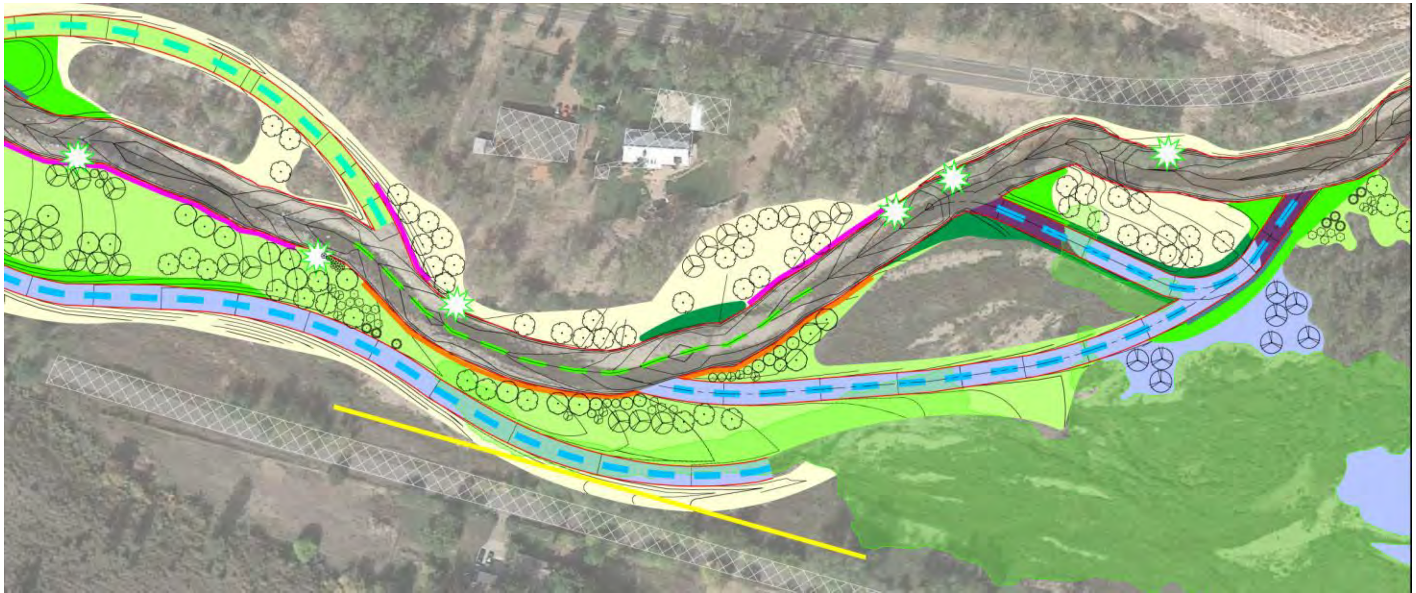
Revegetation Assessment

- Evaluate onsite plant communities
- Utilize State and National Resources
  - National Wetland Inventory Wetlands Mapper
  - Colorado Wetland Inventory Mapping Tool
  - The CNHP Field Guide to Wetland and Riparian Plant Associates



Revegetation Recommendations

- Re-establish upland, riparian, wetland environments through:
    - Seeding (Riparian and Upland)
    - Perennial Tubelings
    - Wetland Sod
    - Tree and Shrub Plantings
    - Willow Staking



Boulder County

Revegetation Results

Matrix
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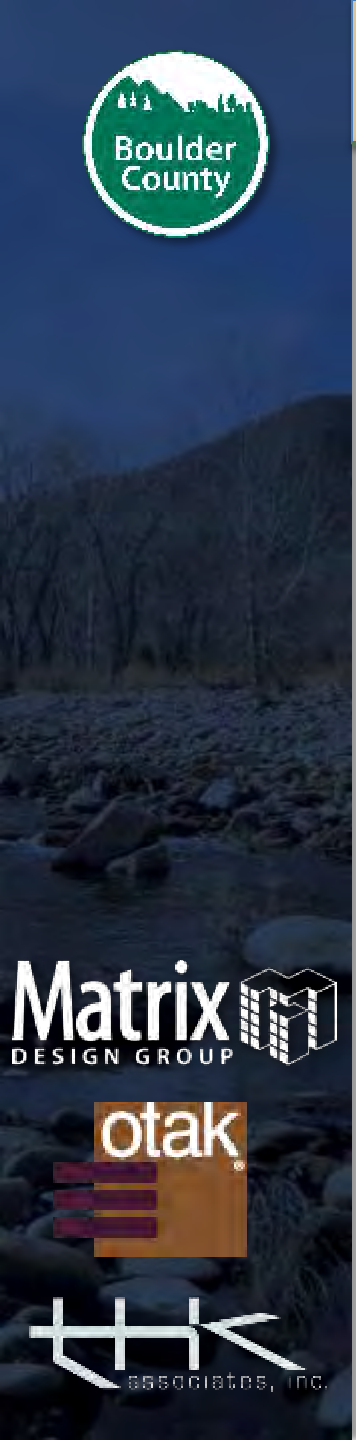
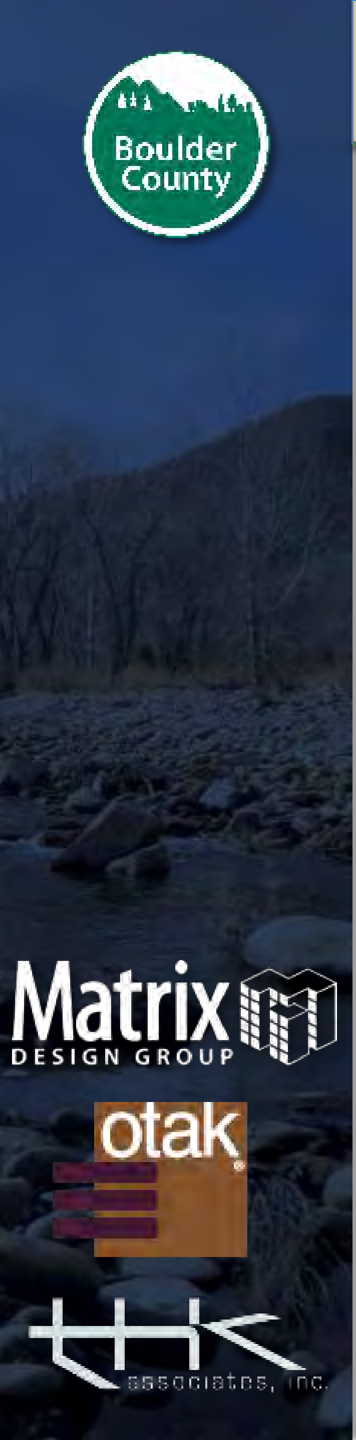


30% Design Plans and Report

- Posted to Boulder County Project Website
    - http://www.bouldercounty.org/ssv
- 30% Design Plans
    - 62 Sheets
        - Plan and Profile of Main and Overflow Channels
        - Channel Design Details
        - Revegetation Plans
        - Revegetation and Bio-Engineering Details
        - Additional Planning Elements
- 30% Preliminary Basis of Design Report
    - 299 Pages

Next Steps



- 80% Design Drawings
  - Working with EWP and Boulder County Currently to contract for additional services
- Permitting
  - 404 CWA, Floodplain, Land Use, Stormwater
- Construction
  - Bid Support
  - Construction Oversight and Closeout