CASFM 2018 Annual Conference

Stream Restoration Sessions:

Session1: When Engineers Go Wild!

Richard Borchardt & Barb Chongtoua (UDFCD)

Session2: Urban Stream Design – How We Got to Now

Mary Powell (Corvus Environmental), Dave Skuodas (UDFCD)

Action & Reaction: Approaches for Understanding Sedimentation & Erosion

Matthew Johnson & Brinton Swift (HDR)

The Gunnison River and Riparian Habitat Rehabilitation Project Local Partnerships at Work

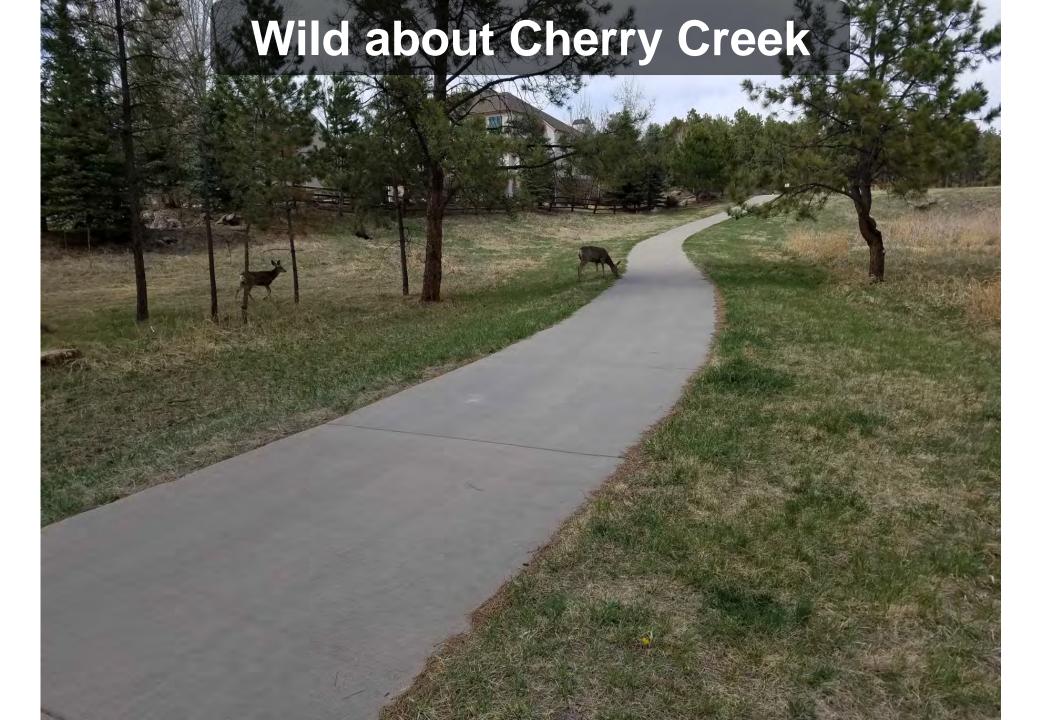
Dan Brauch & Steve Westbay (City of Gunnison)

Drone Based Riprap Imaging and Gradation Measurement

LeAndra Nelson (Kiewit Engineering Group)

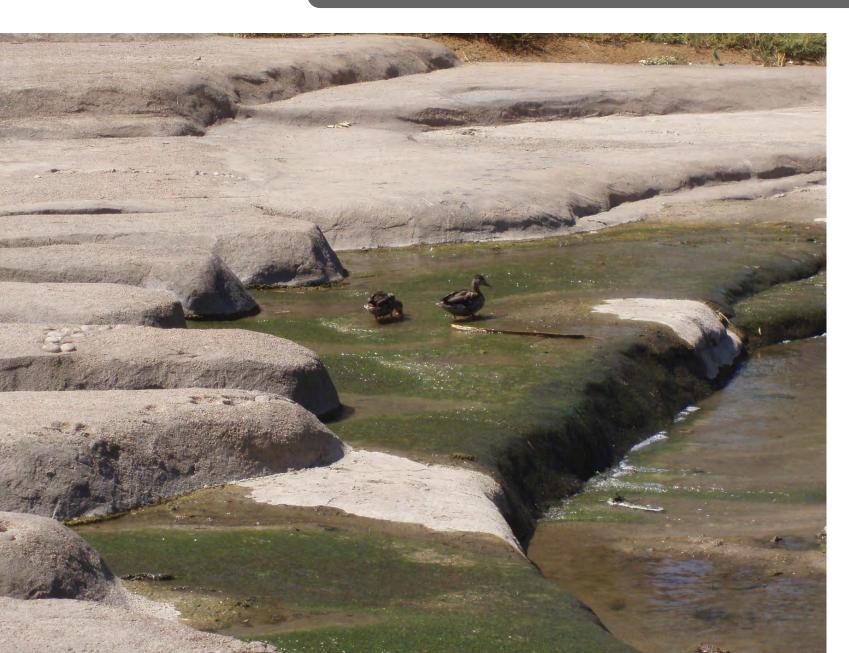








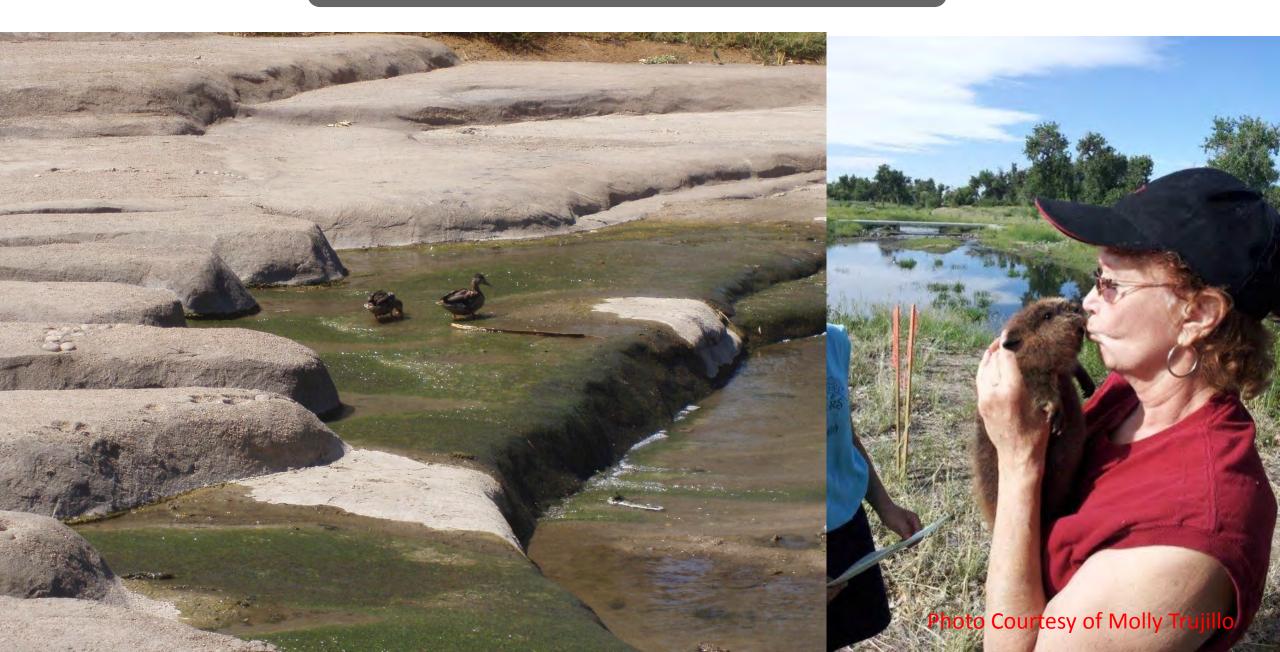
Wild about Cherry Creek







Wild about Cherry Creek





Wild about Streams







Have you ever wondered......

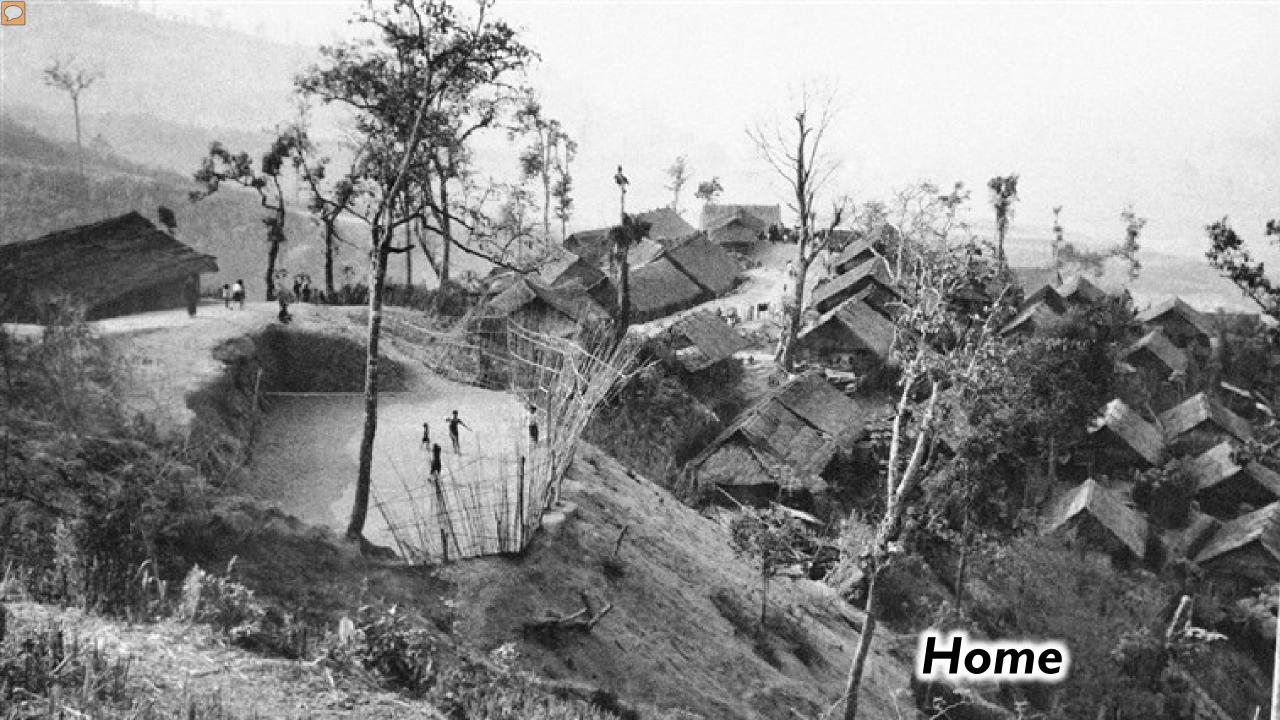
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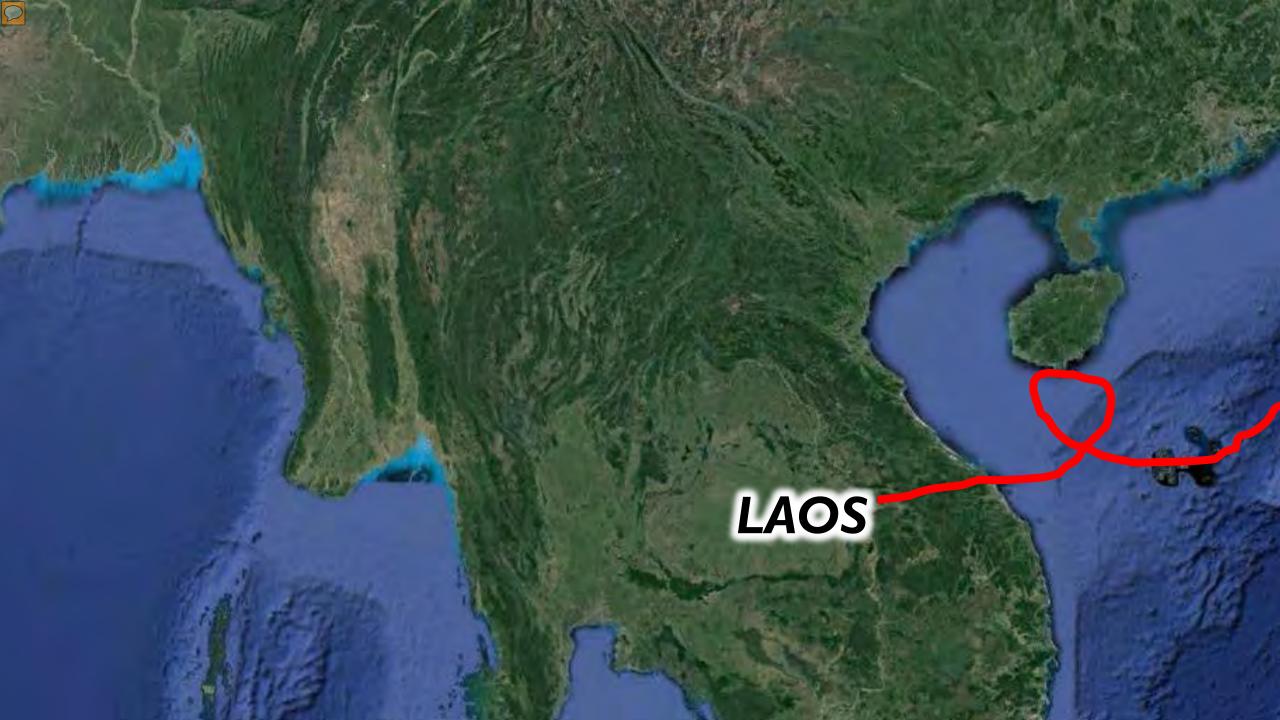
.....what events shaped you?

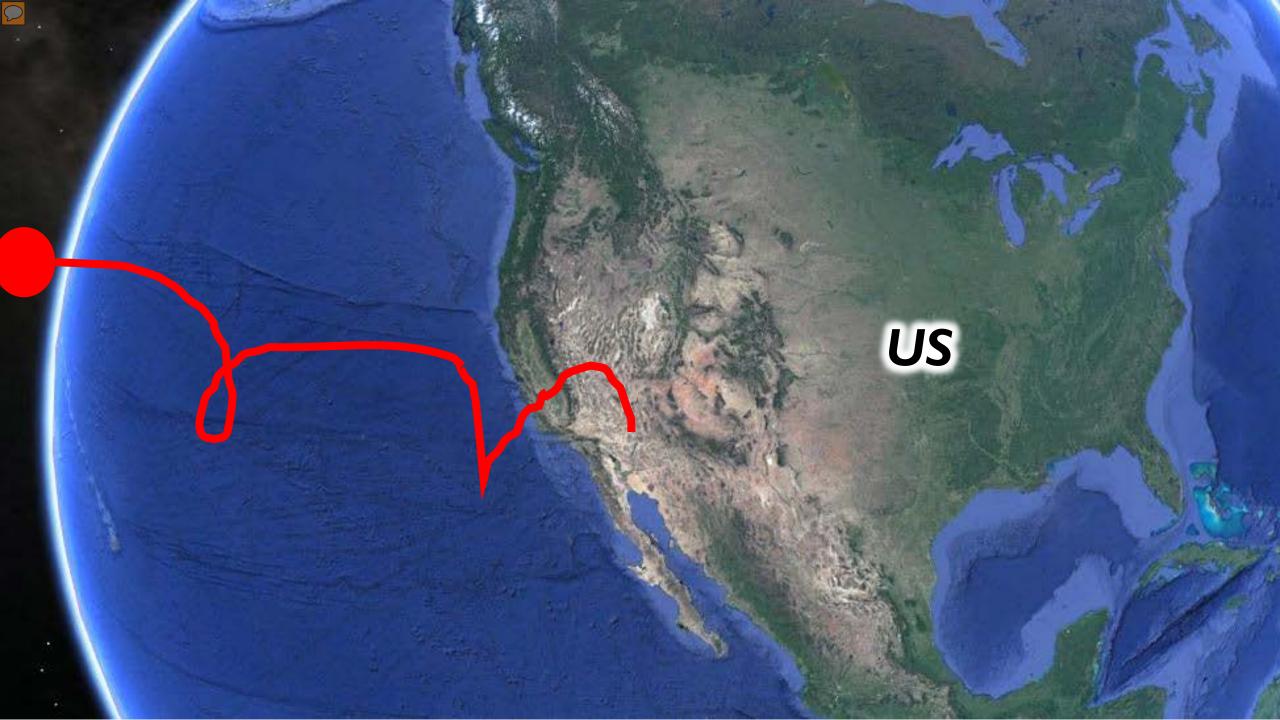
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War













Family



Failures





CASFM

Ben Urbonas Andrew Earles Brian Murphy

Luke Swan JoAnna Curran Will Harman

Georges Anastankes Doug Shields EWRI

Troy Thompson Chris Sturm Dan Baker **David Bidelspach**

John Schwartz

George Annandale Dave Rosgen Jim Wulliman

Brian Bledsoe Julie Ash Colorado Riparian Association

Have you ever wondered......

.....what events shaped streams?

Water





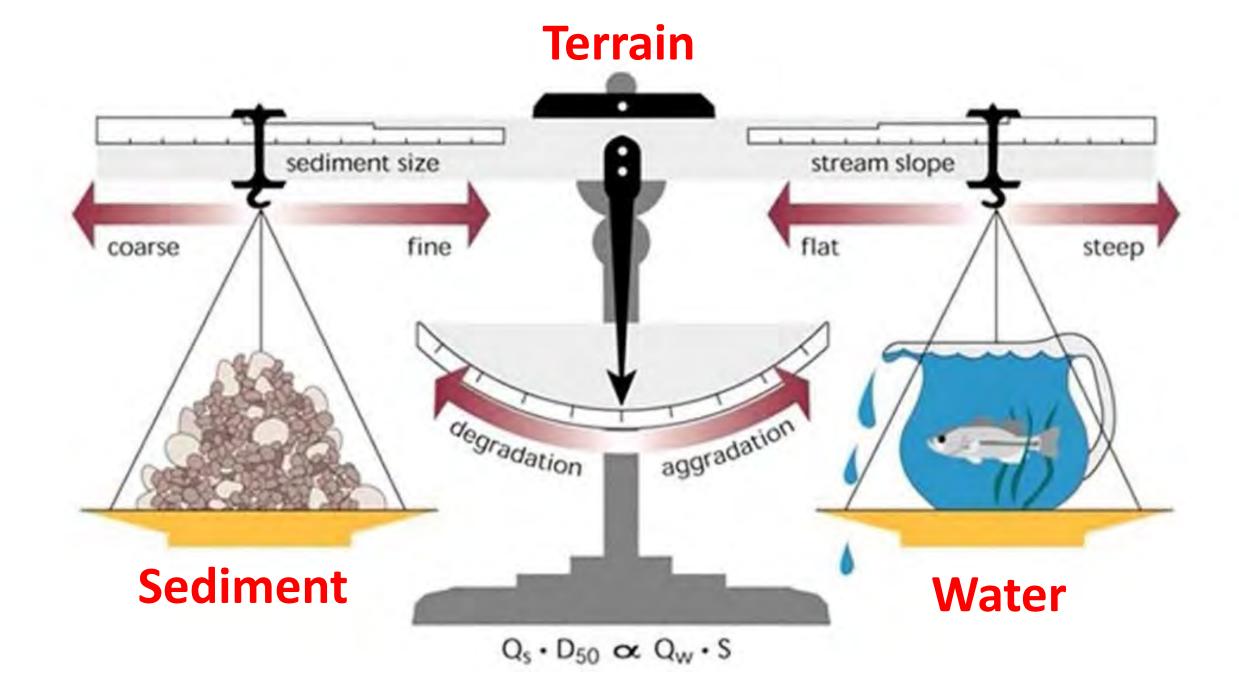
Sediment



Terrain



The stream living history these events



Stream
will change
if
one factor changes









Development starting to

occur in the

basin







Another reach improved.

1994 > 1999 > 2000 > 2001 > 2002



Downstream reaches near Santa Fe experiencing soil depoition due to upstream soil movement.





Improvements in upstream reaches completed.





The channel is coming apart.

Development starting to

occur in the

basin





Another reach improved.

2000

1994 > 1999 >

2001

2002



Downstream reaches near Santa Fe experiencing soil depoition due to upstream soil movement.





Improvements in upstream reaches completed.





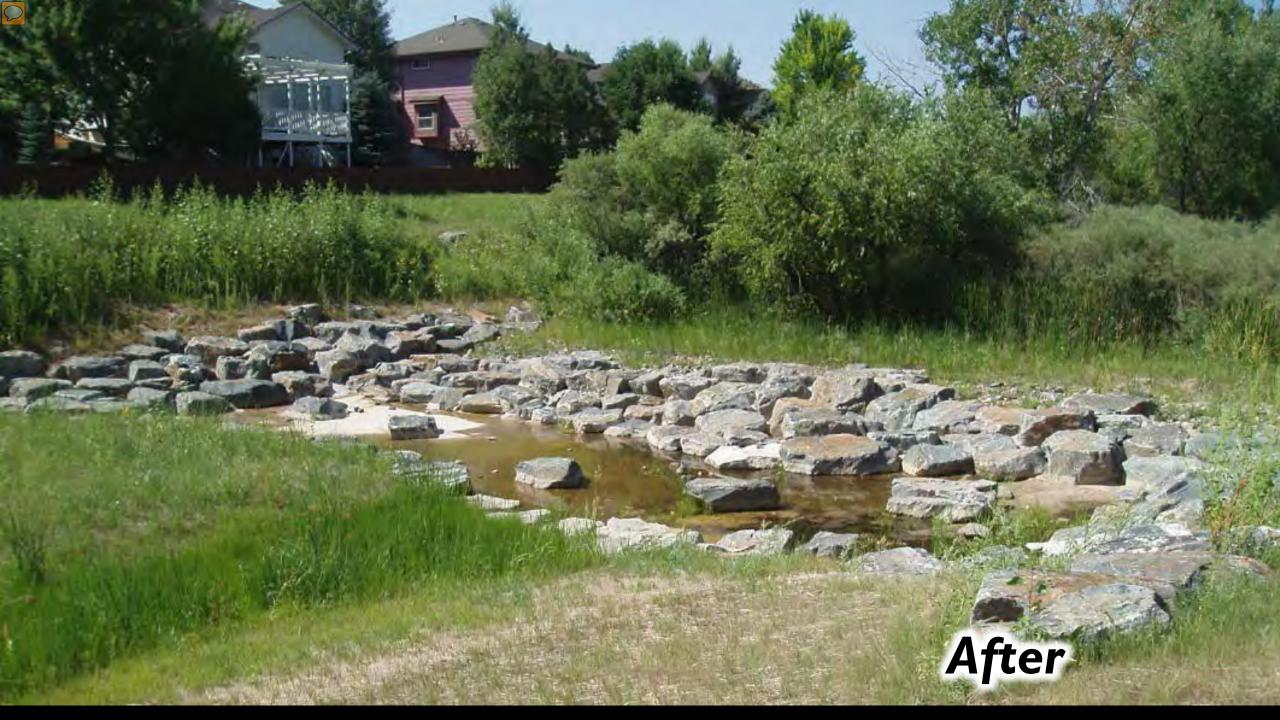






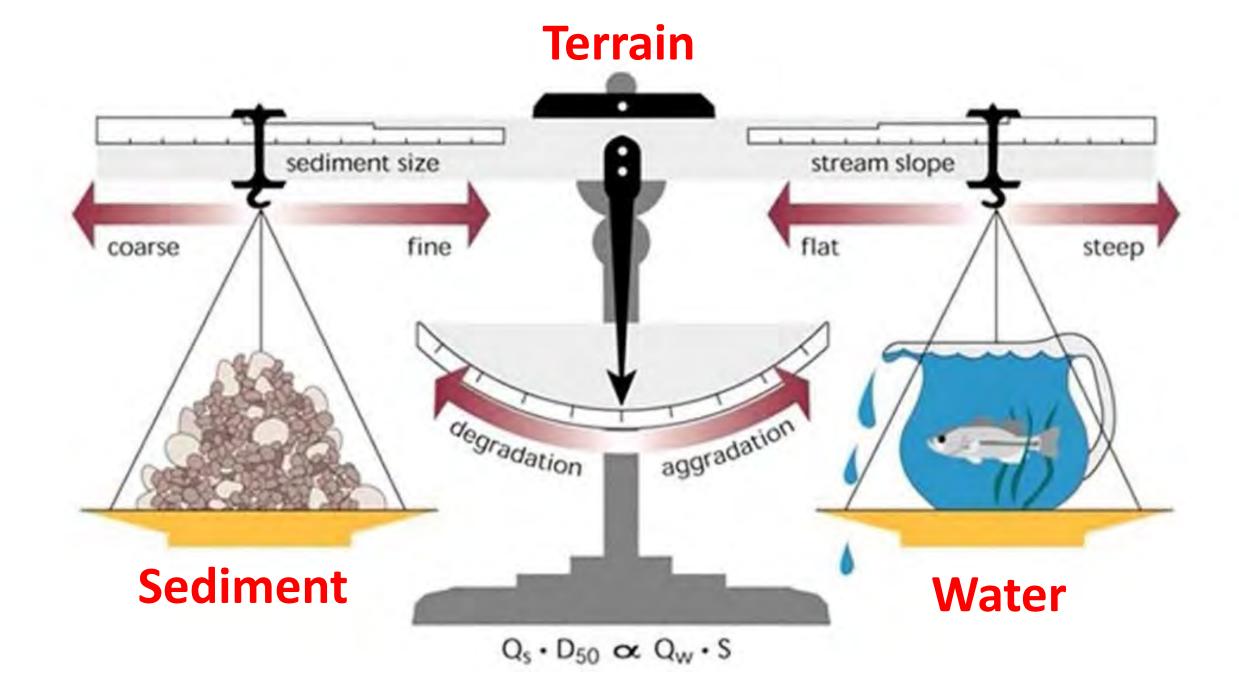












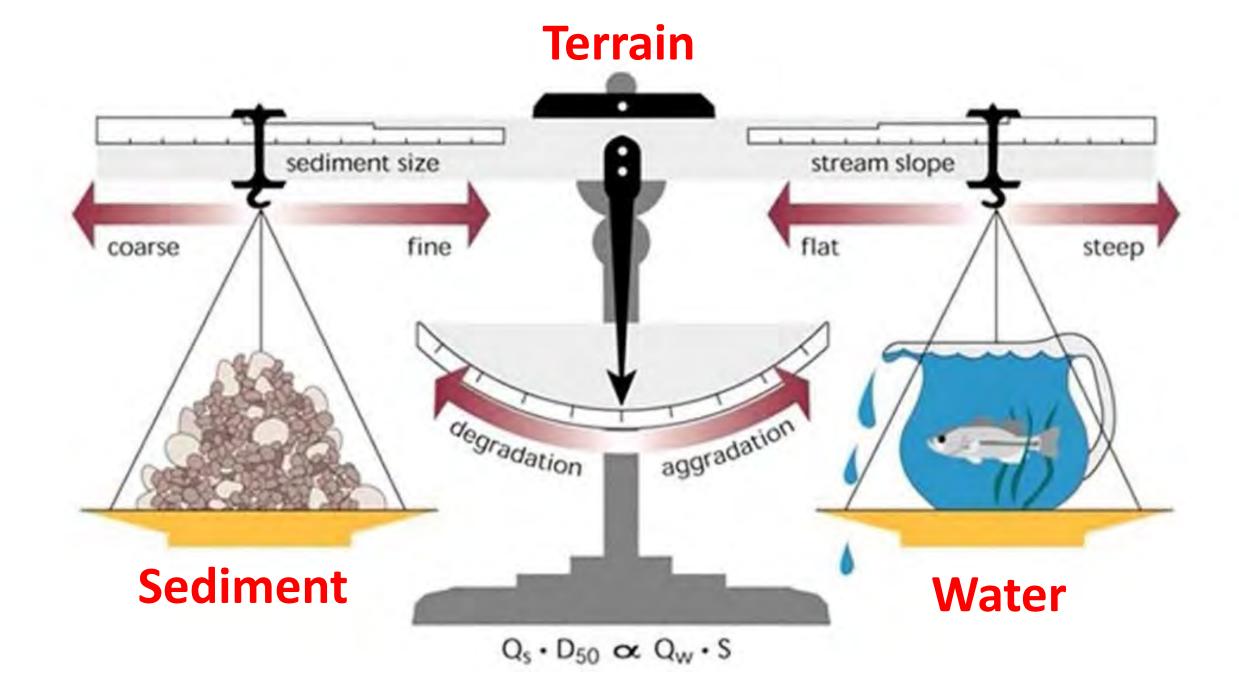


Be wild



Push beyond conventional bounds







Oak Gulch



Oak Gulch



Oak Gulch







Coyote Gulch









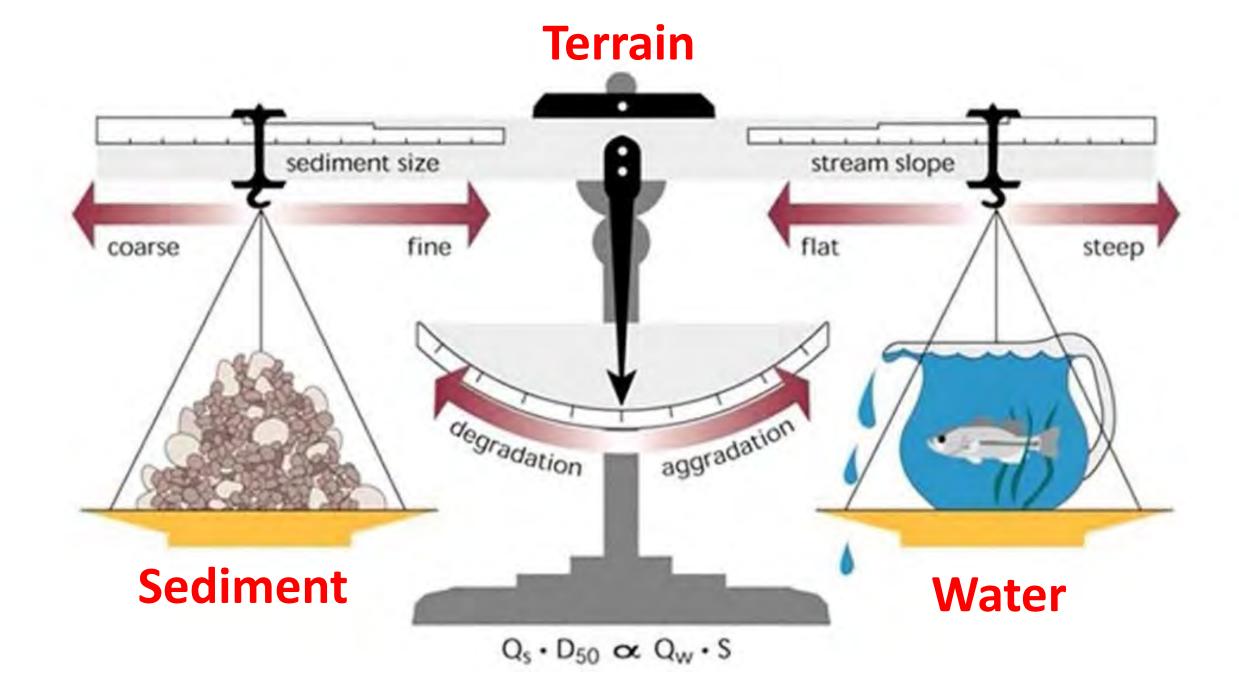












Water

Sediment



Terrain



Wild about Streams

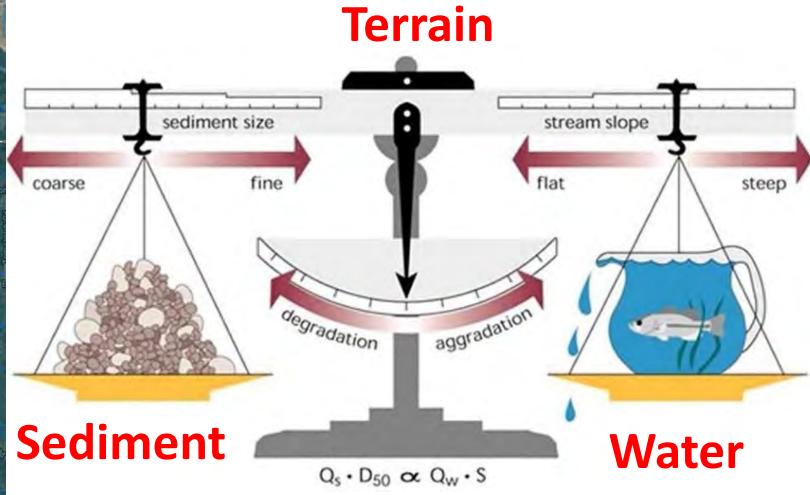




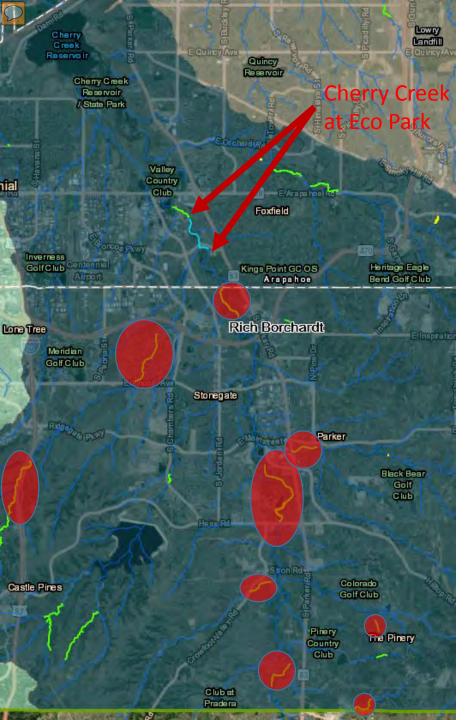
Lowry Reservoir Quincy Reservoir Cherry Creek **Cherry Creek** Reservoir /State Park at Eco Park Valley Country Foxfield Inverness Golf Club Heritage Eagle Bend Golf Club Kings Point GC OS Arapahoe Rich Borchardt Lone Tree Meridian Golf Club Stonegate Parker Black Bear Golf Club Colorado Golf Club The Pinery Clubat Pradera

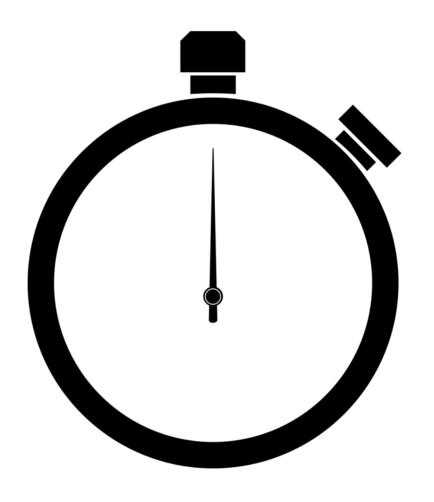


Lowry Quincy Reservoir Cherry Creek **Cherry Creek** Reservoir /State Park at Eco Park Valley Country Inverness GolfClub Heritage Eagle Bend Golf Club Kings Point GC OS Arapahoe Rich Borchardt Lone Tree Meridian Golf Club Stonegate Parker Black Bear Golf Club Colorado Golf Club The Pinery























Wild about Sediment Transport and Storage





Wild about Sediment Transport and Storage





Wild about Sediment Transport and Storage







Wild about Maintenance





Wild about Maintenance





Wild about Maintenance

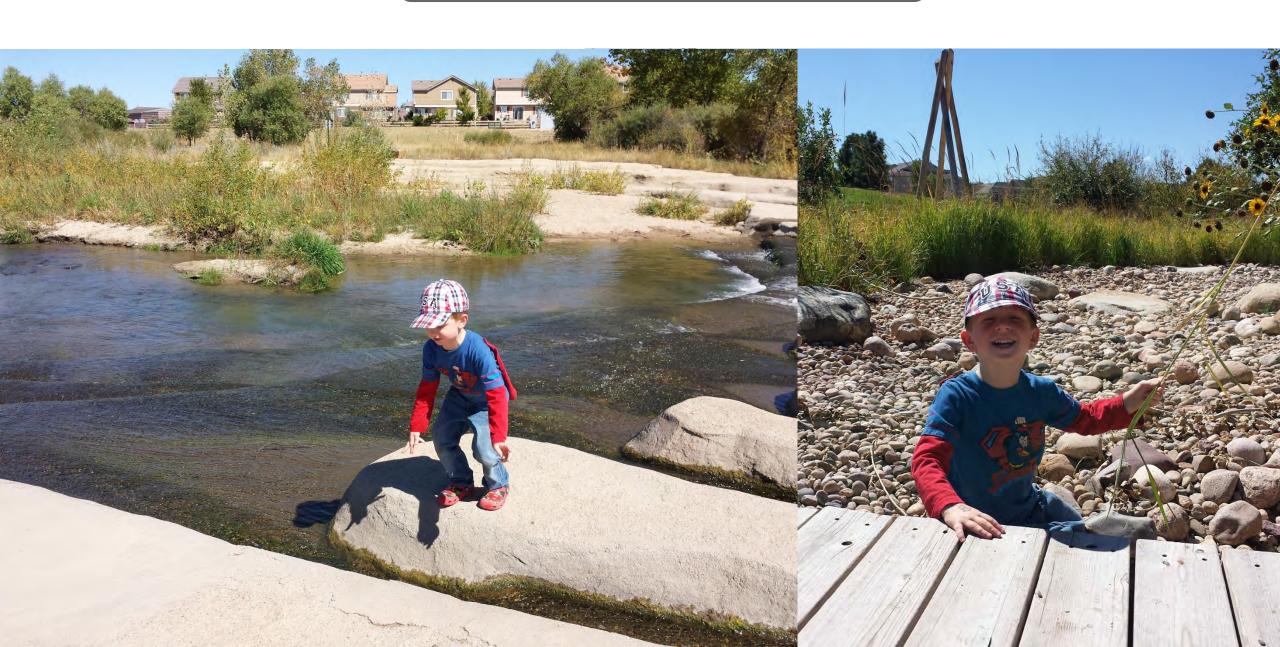


Lowry Charry Creek from Cherry Creek Valley Country Club to Reservoir /State Park Storm Soccer Inverness Golf Club Heritage Eagle Bend Golf Club Kings Point GC OS Arapahoe Rich Borchardt Lone Tree Happy Canyon Cree Meridian Golf Club Parker Black Bear Golf Club Colorado Golf Club Pinery Country The Pinery

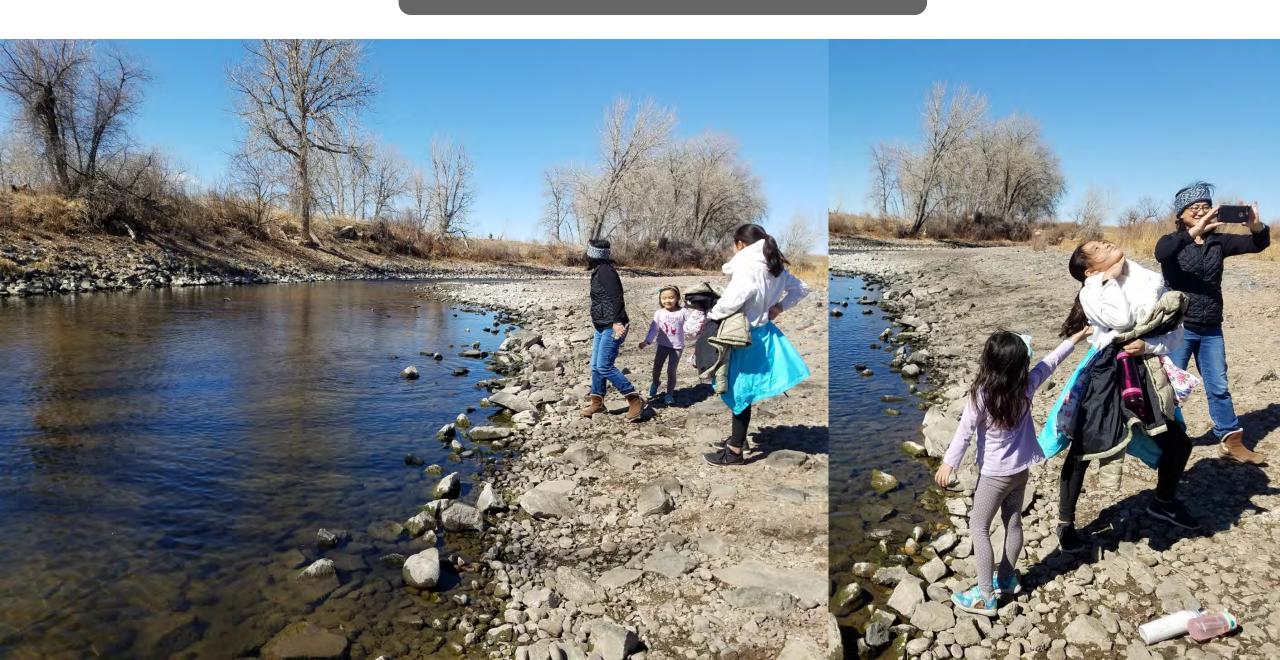
Wild about the Future



Wild about the Future



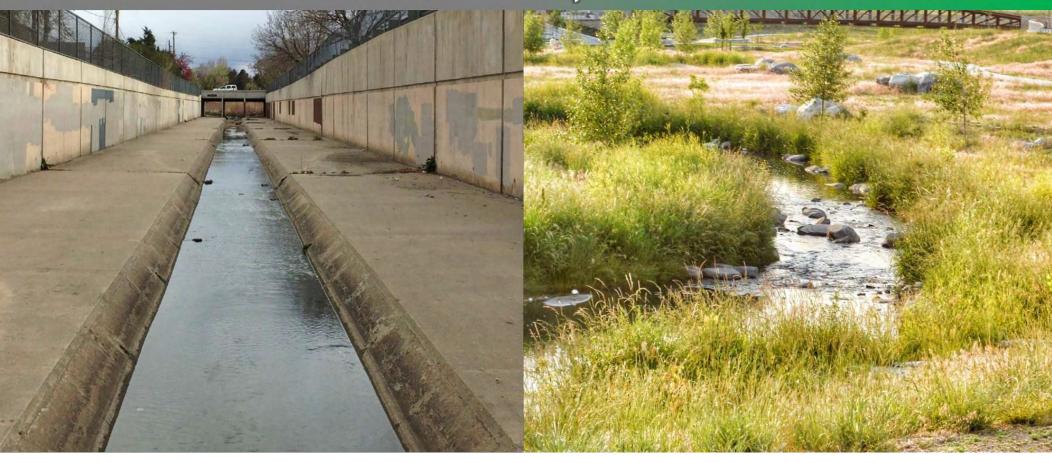
Wild about the Future

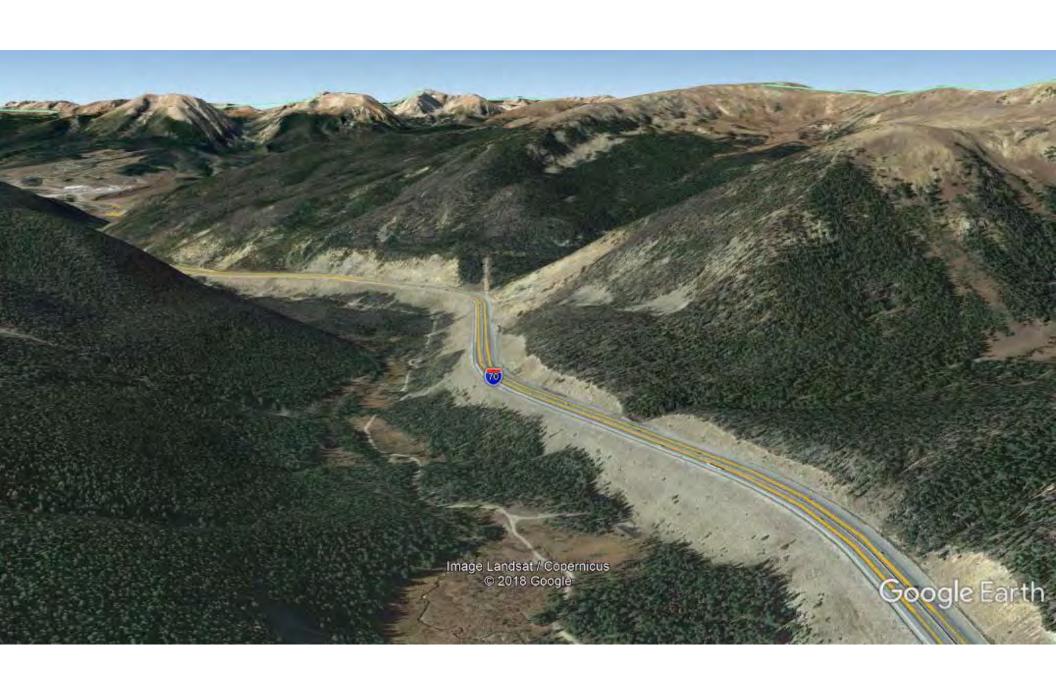


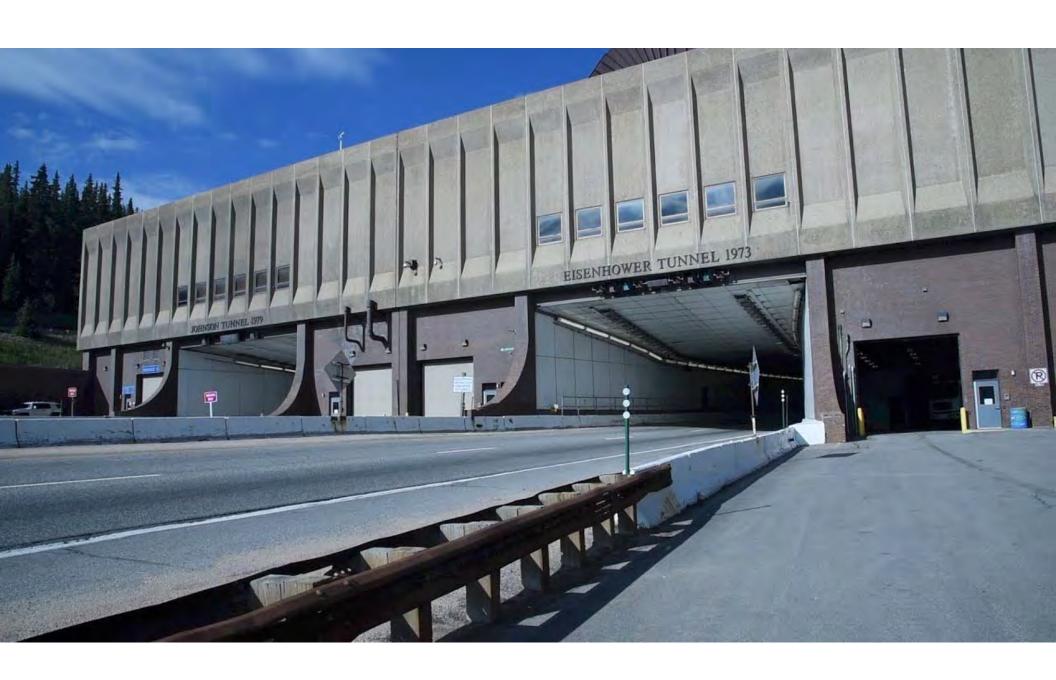


Urban Stream Design – How we Got to Now

Mary Powell, Corvus Environmental Dave Skuodas, UDFCD

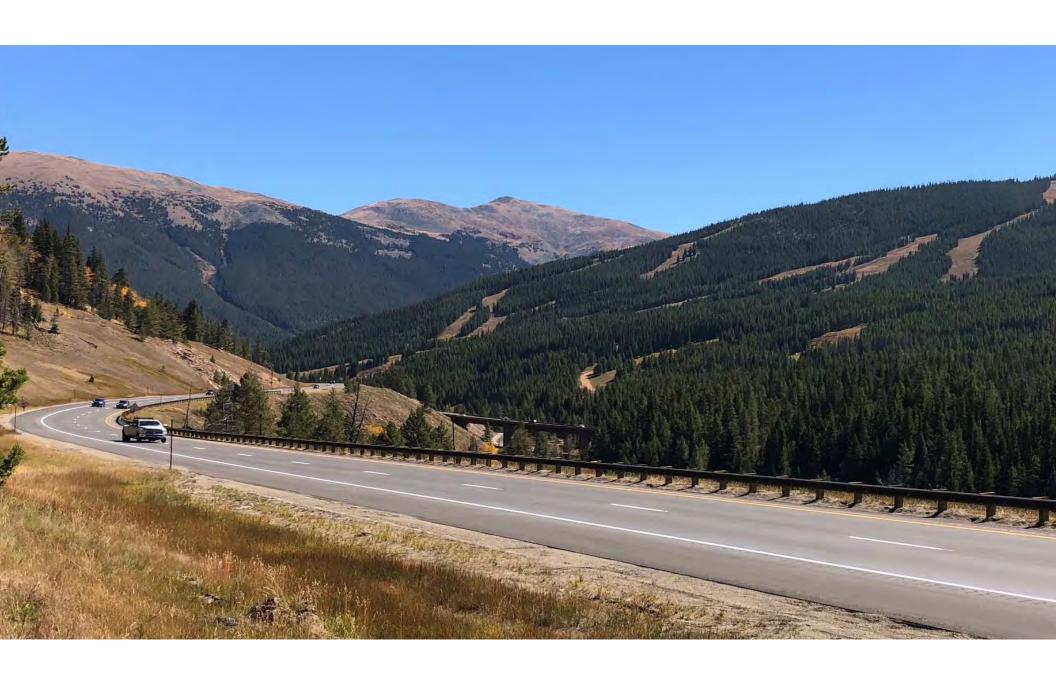


















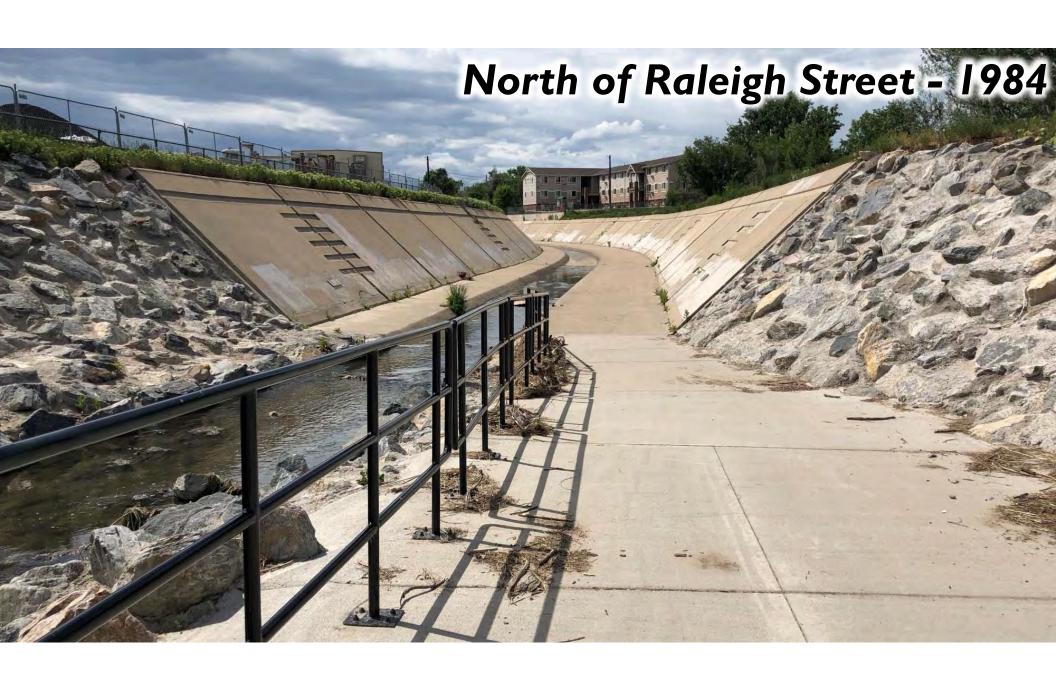


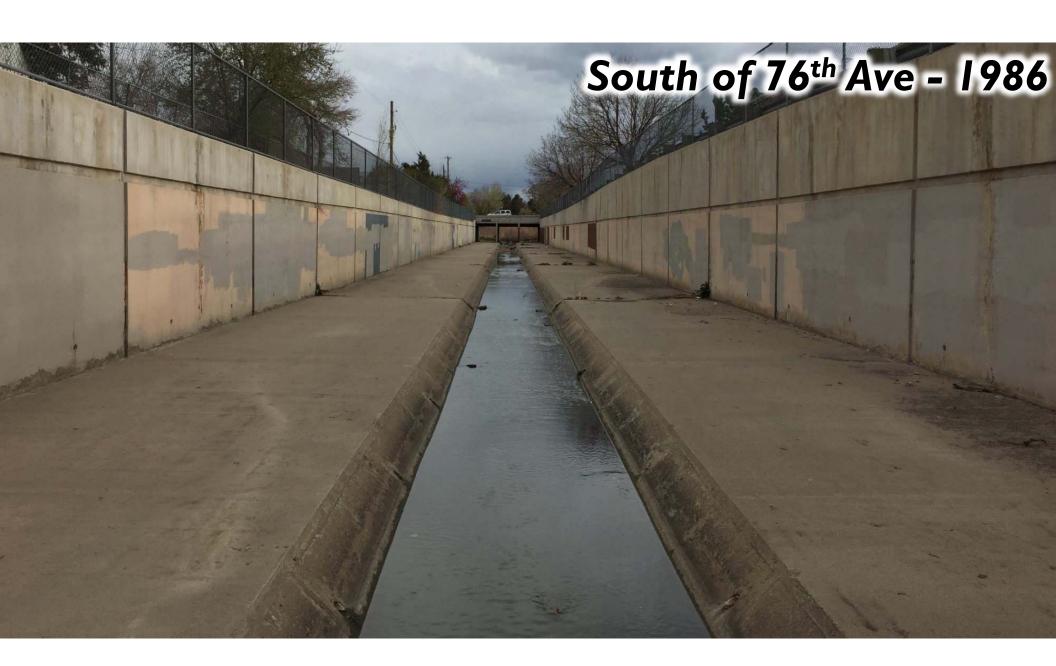




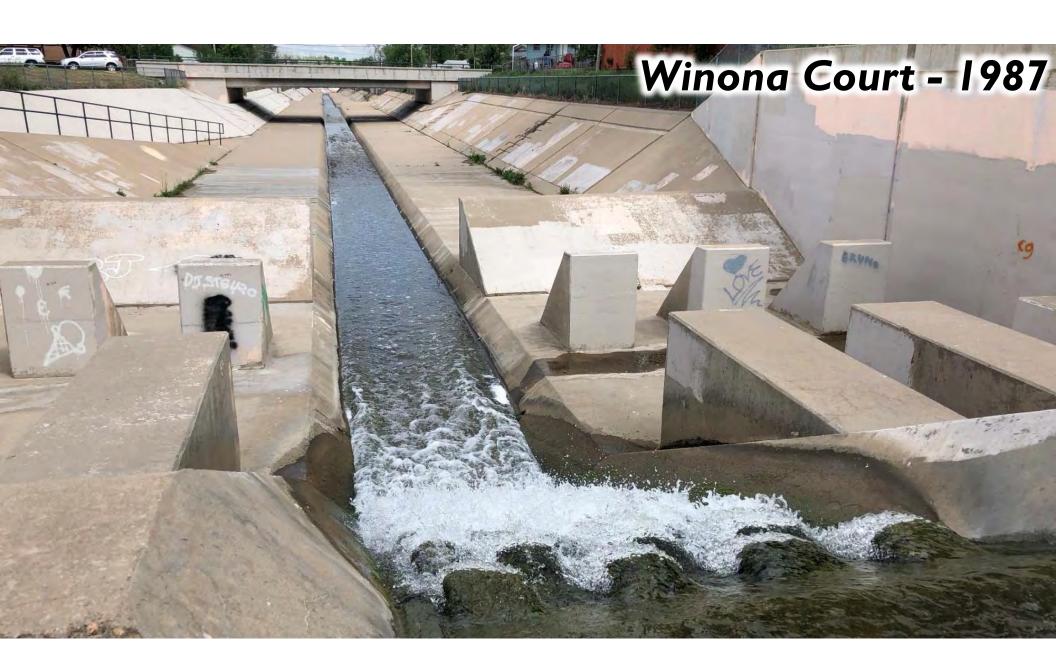










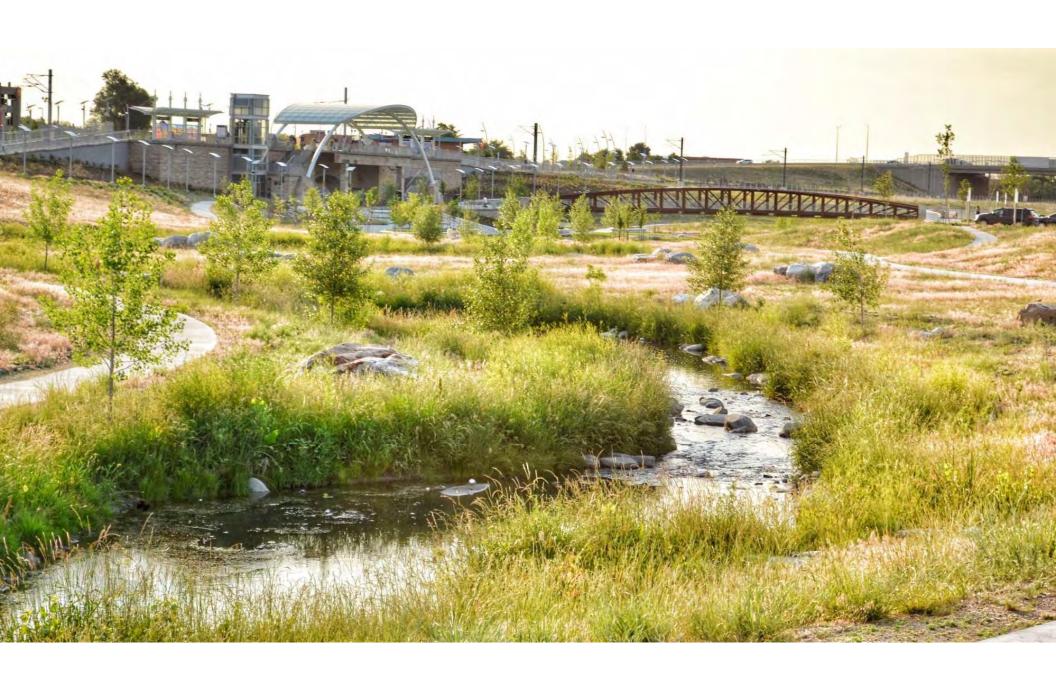


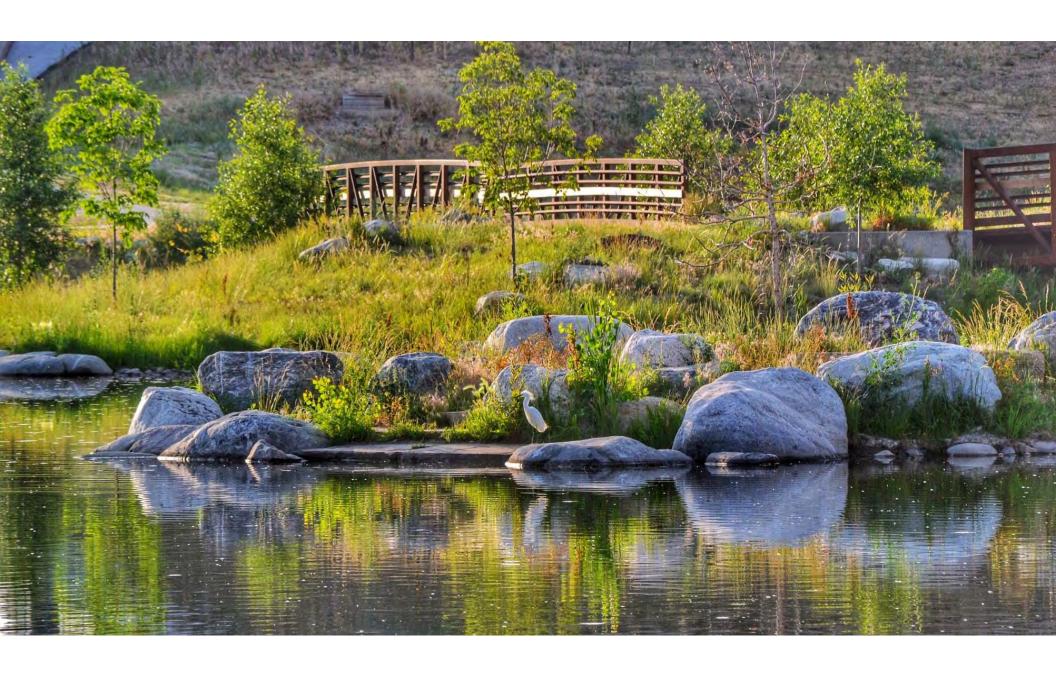


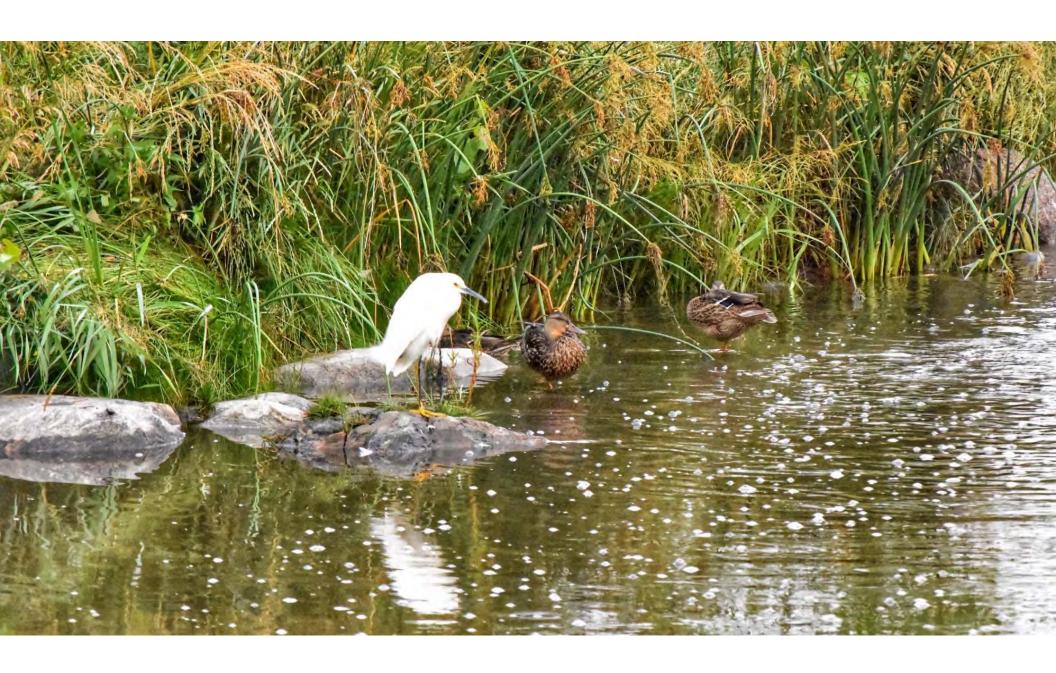




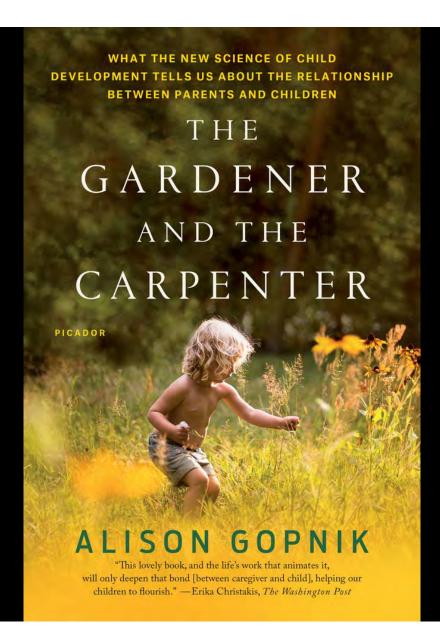


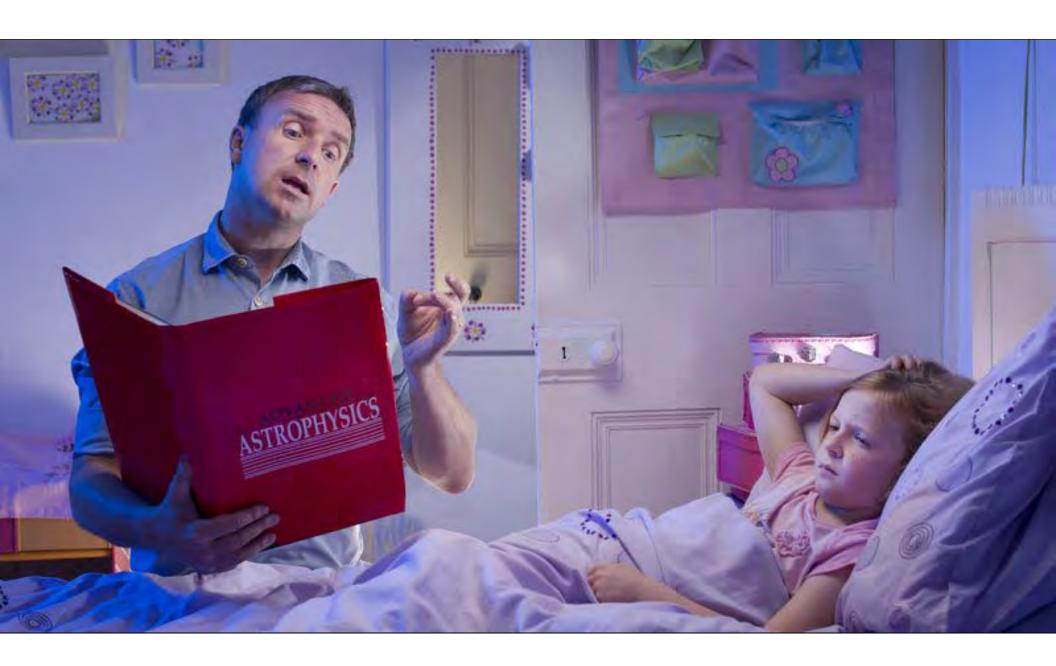












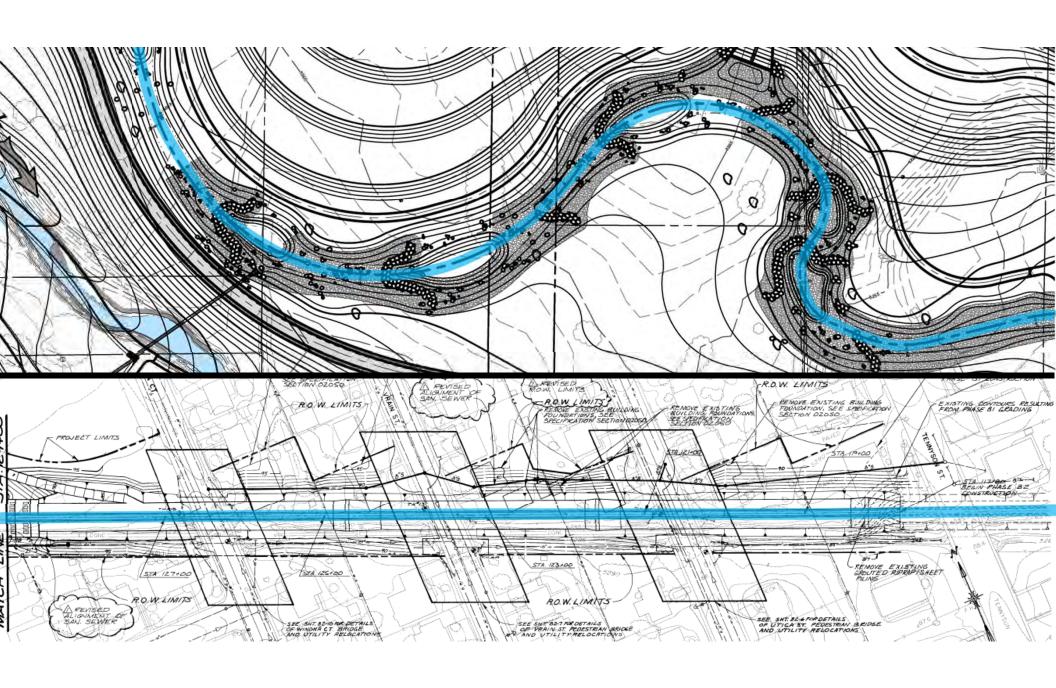






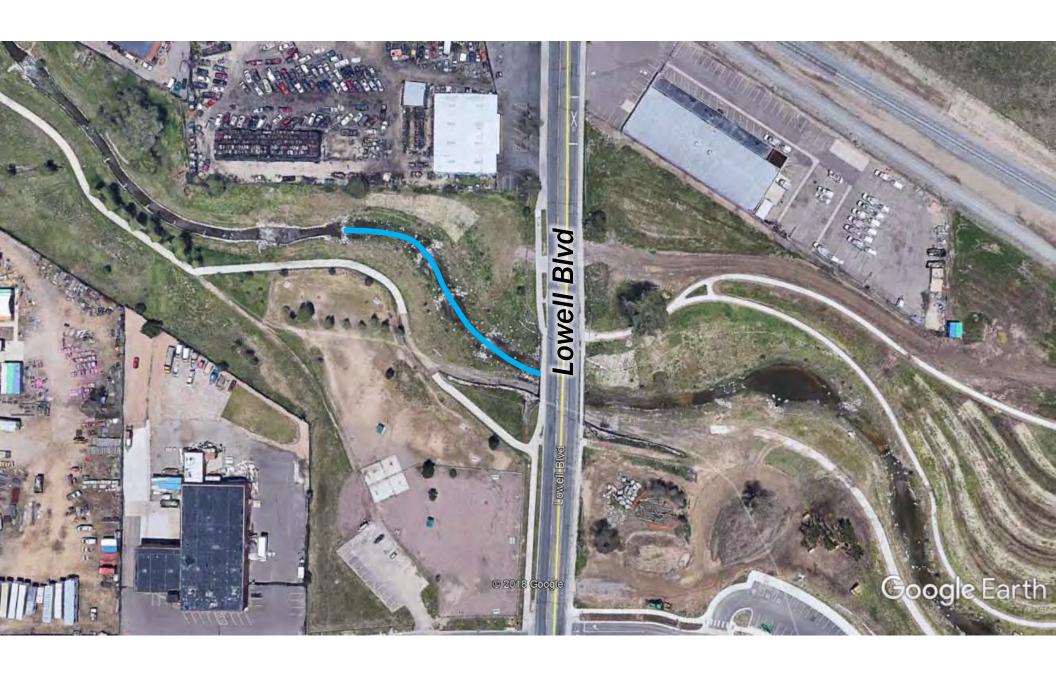
Plan Form









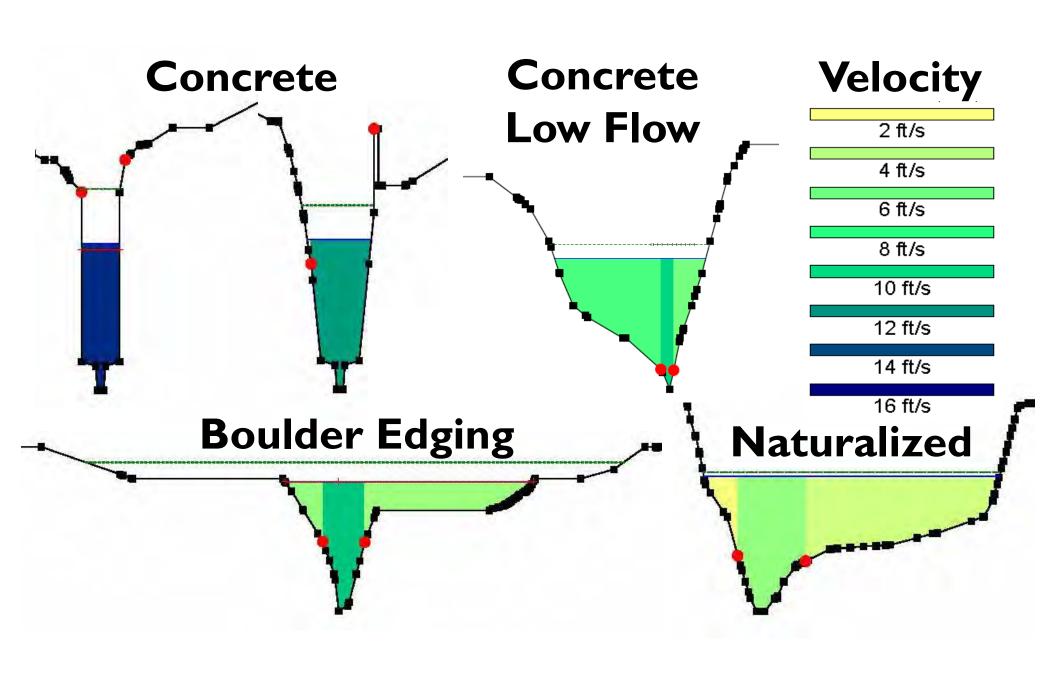




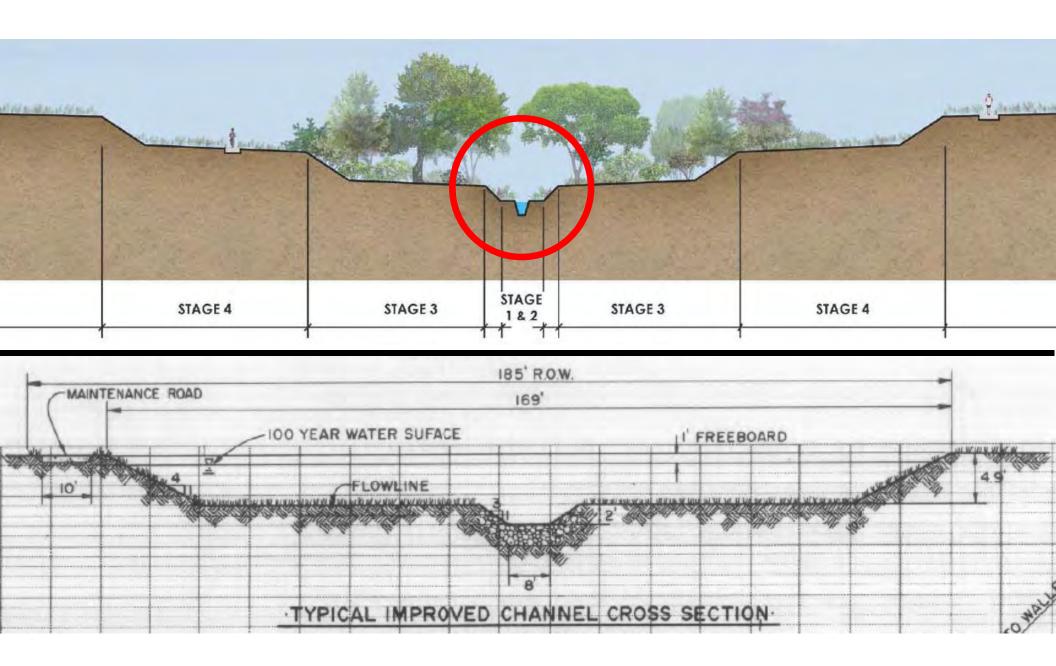
Cross Section









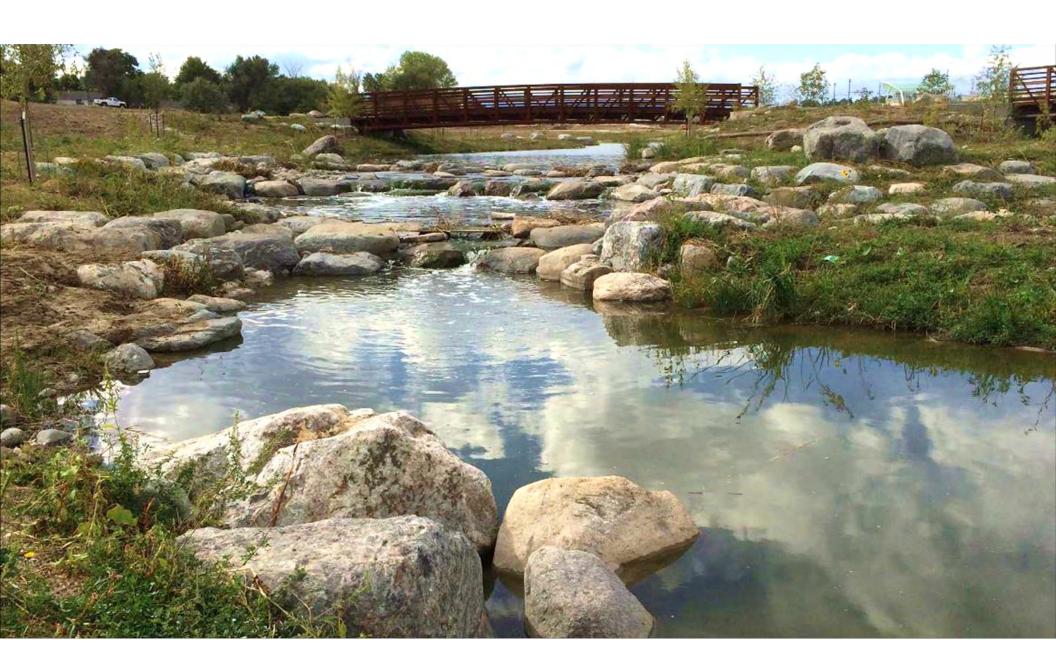








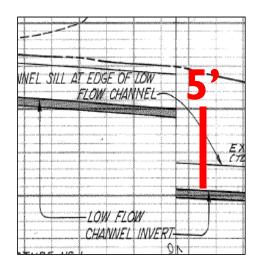


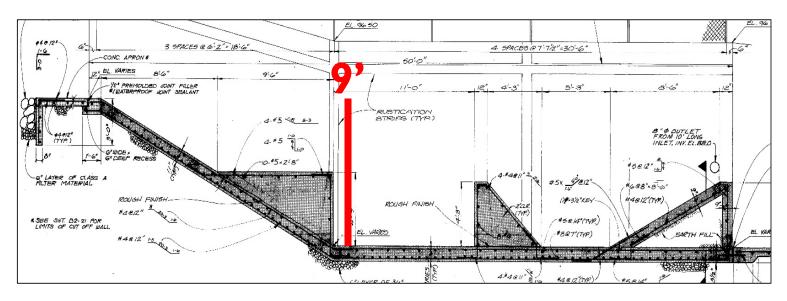


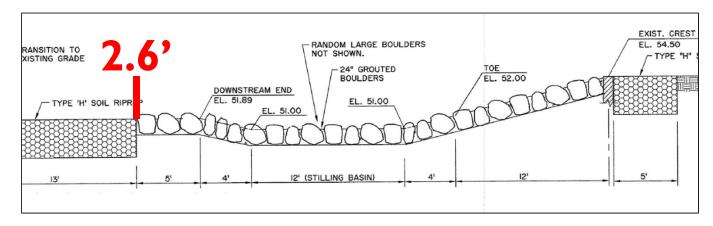
Grade Control

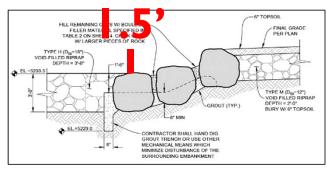




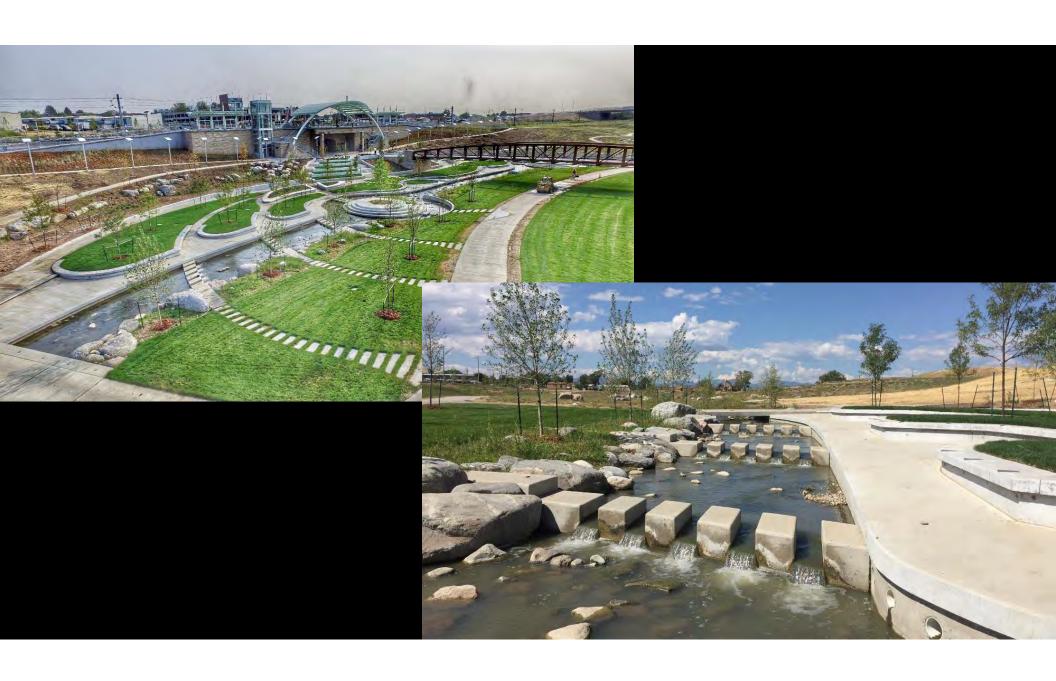












Maintenance















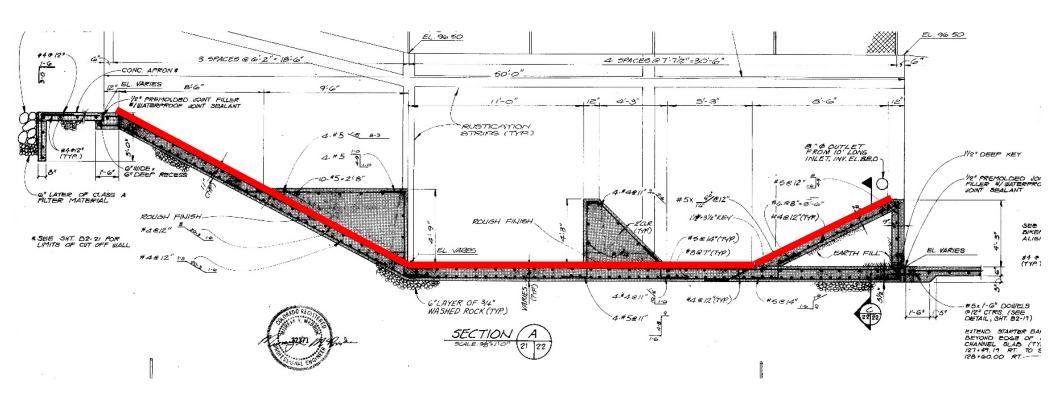


Uses



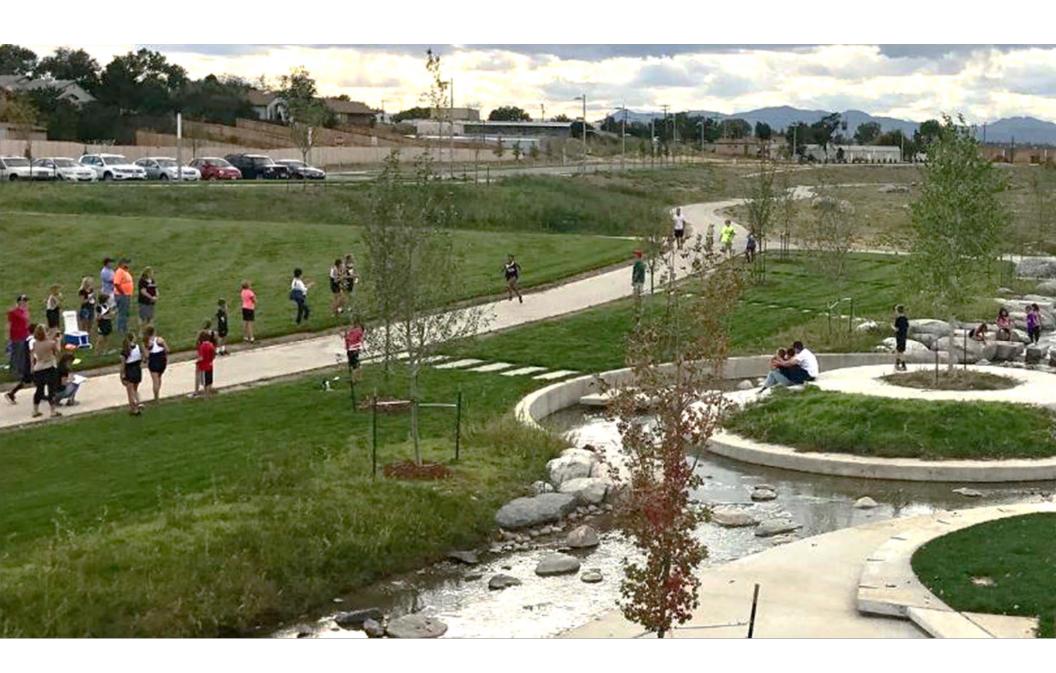


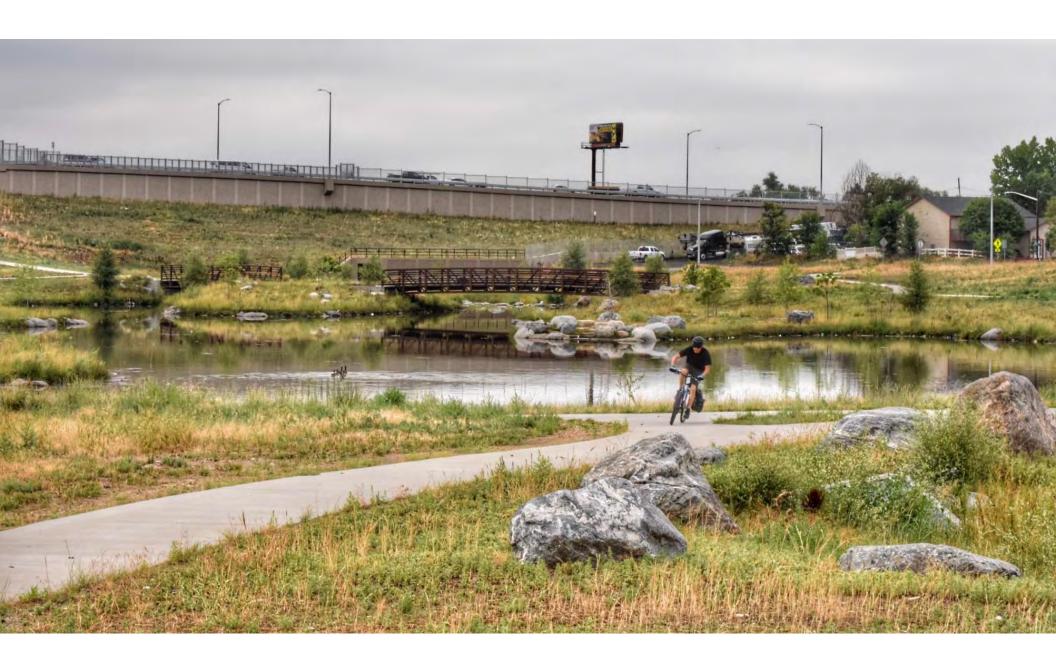






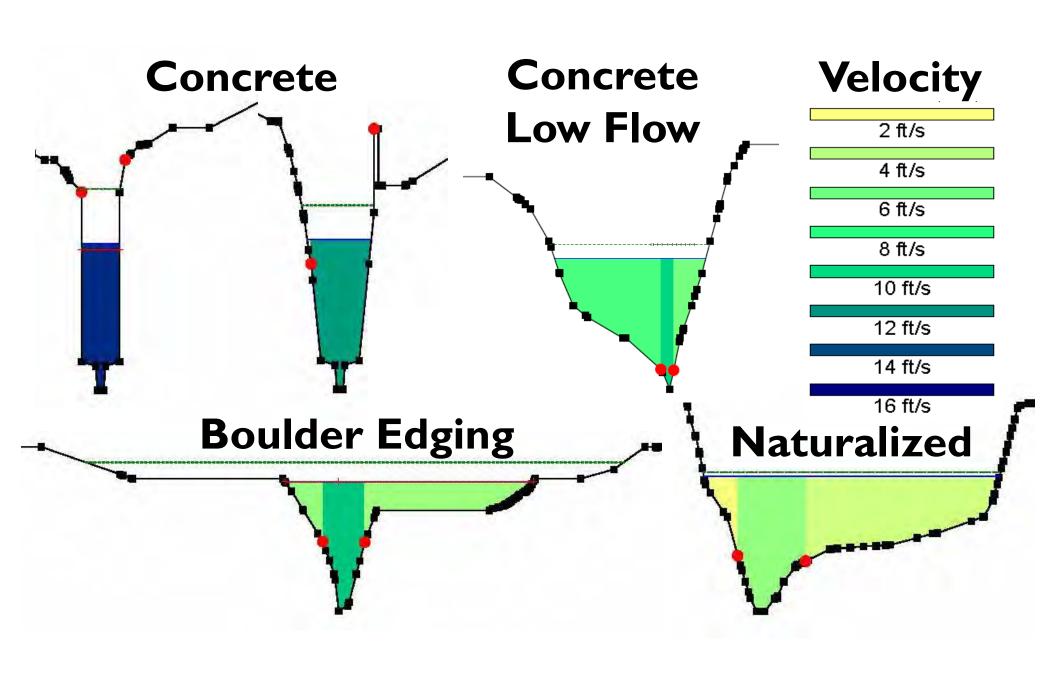










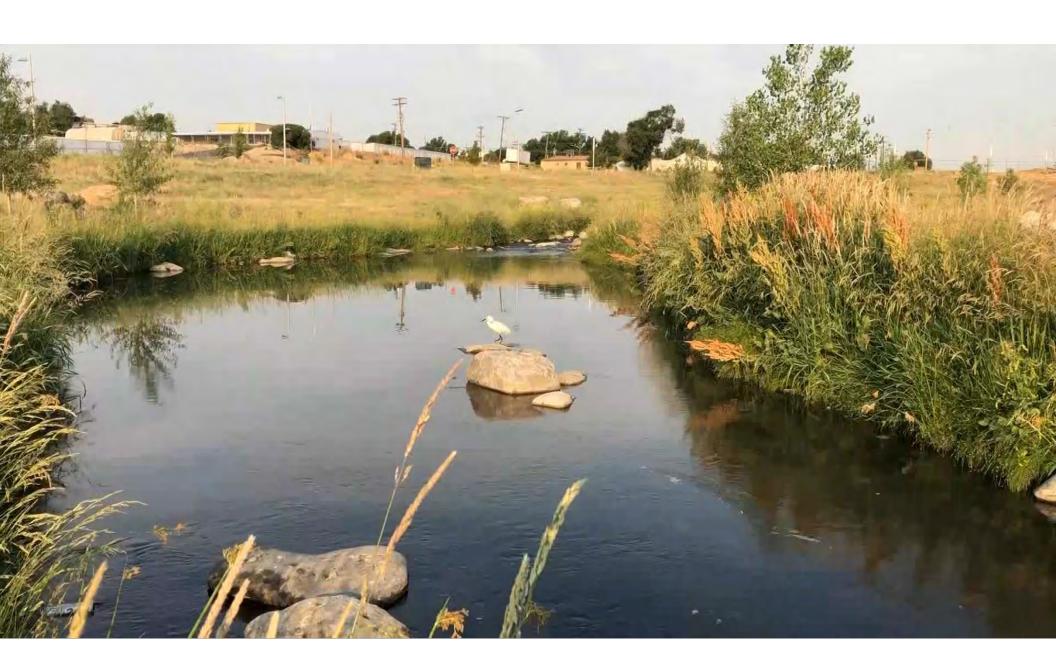












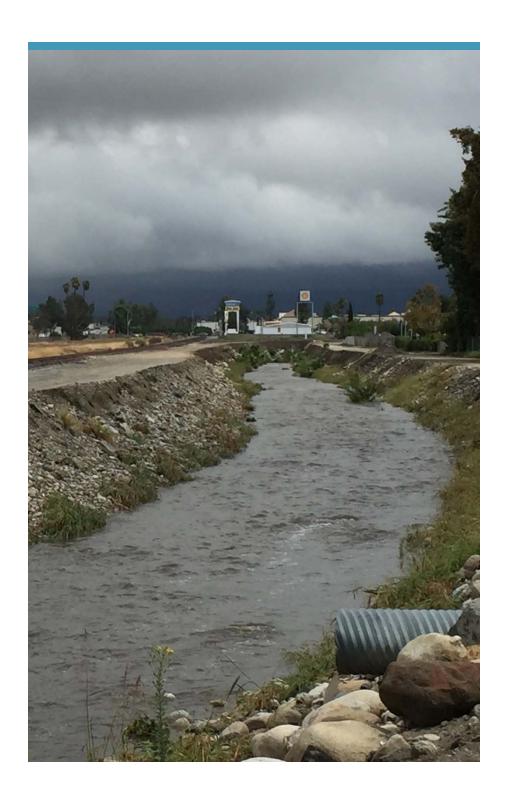


Action & Reaction: Approaches for Understanding Sedimentation & Erosion

Matthew Johnson, PE, CFM Brinton Swift, PE, CFM







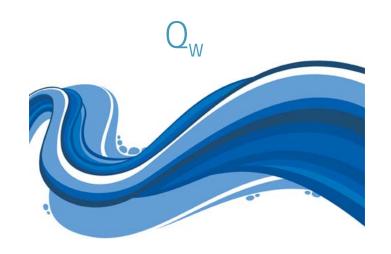
- Channel Stability Theory
- **2** Analysis Considerations
- Simplified Sediment Approaches
- Design Examples

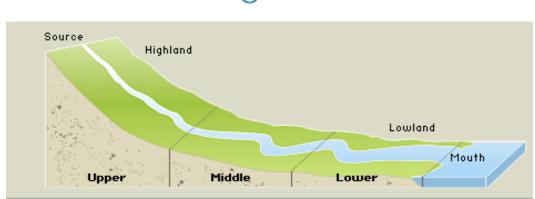
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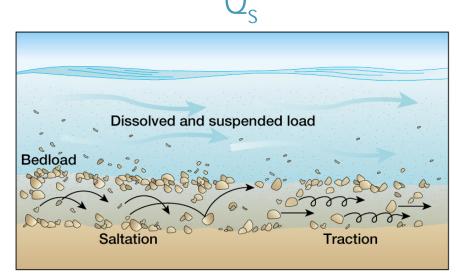
Channel Stability Theory

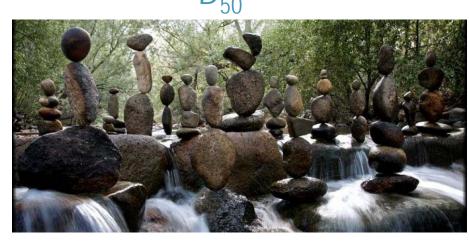


Channel Stability Theory

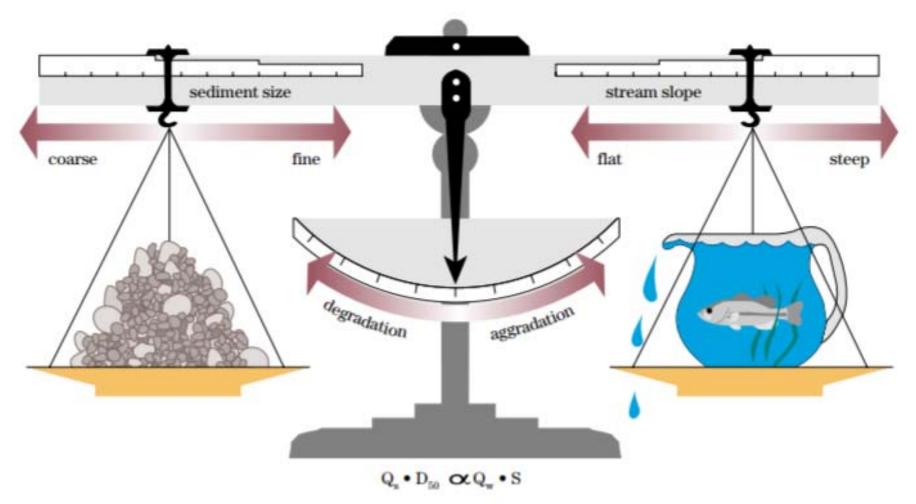








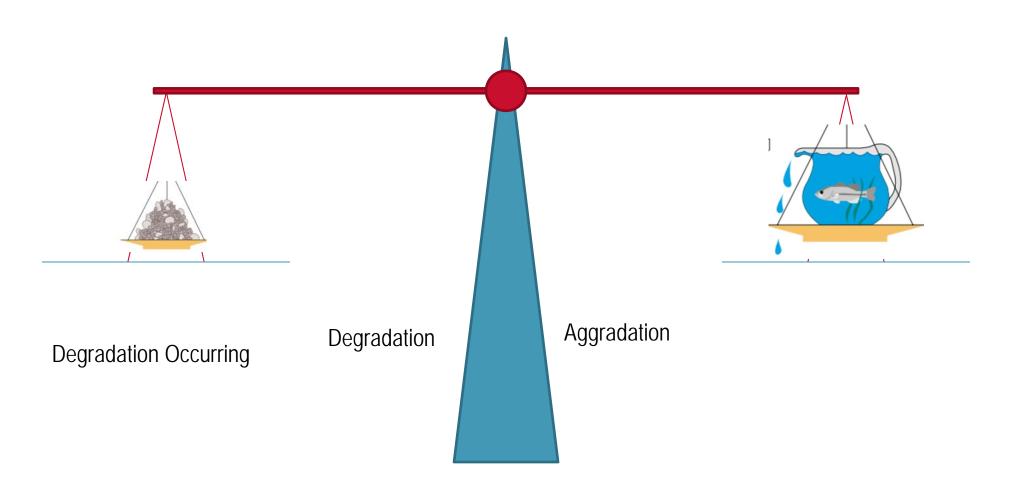




From Rosgen (1996), from Lane, Proceedings, 1955. Published with the permission of American Society of Civil Engineers.



Lane' Balance





Sediment Supply, Capacity, and Transport

Sediment Supply – The amount of sediment conveyed into a reach for a given flow

Sediment Capacity – The amount of sediment that can be conveyed by a given flow in a reach

Sediment Transport – A comparison of sediment supply and sediment capacity to identify changes in bed and bank in a reach.

IN SIMPLE TERMS

Sediment Supply > Sediment Capacity = Aggredation

Sediment Supply < Sediment Capacity = Degradation



Stream Response Potential (SPR)

 Design Hydrology for Stream Restoration and Channel Stability at Stream Crossings (Bledsoe, September 2016)

Fine-bed river system have greater susceptibility to change with a greater range of flow regimes transporting sediment; high SPR

Coarse-bed river systems have lower variability with a small range of flow regimes transporting sediment; lower SPR Stream Response Potential







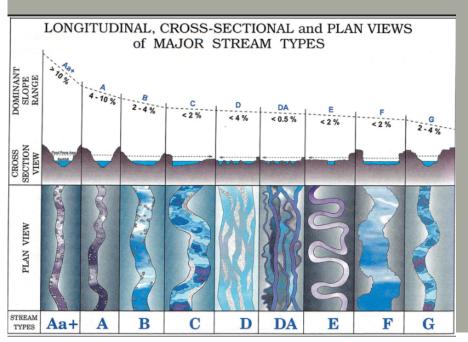
02

Analysis Considerations

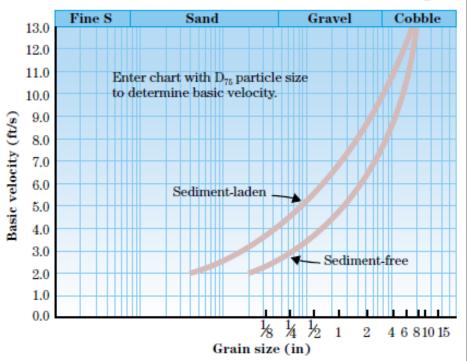


Channel Stability Analysis

- Reference Channel Approaches
 - Comparison of similar channel properties (Rosgen)
- Historic Channel Behavior
 - Review of previous channel trends
- Channel Threshold Methods
 - Critical Shear Stress
 - Critical Velocities
- Empirical Channel Form Equations
 - o Julien, etc.



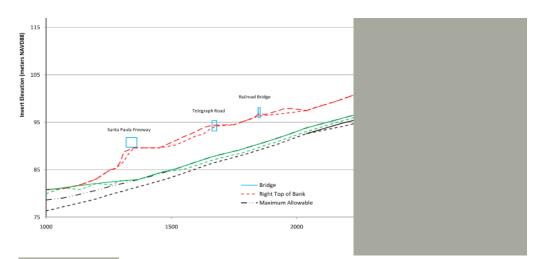
Basic velocity for discrete particles of earth materials, vb

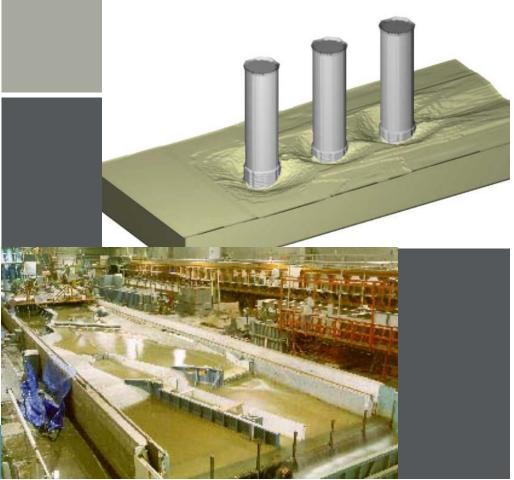




Channel Stability Analysis Methods

- Sediment Budget Analyses
 - Segmented sediment accounting
- Numerical Sediment Transport Models
 - o HEC-RAS, SRH-2D, etc
- Computational Fluid Dynamic Models
 - o FLOW3D, Fluent, etc
- Physical Models







Analysis Selection Considerations

Purpose of the Analysis

- Feasibility Studies
 - Coarser detail
 - General comparisons
 - Often qualitative
- Permitting Support
 - More detail
 - Stability trends
 - Comparative analyses
 - Qualitative or quantitative
- Design Support
 - Significant detail
 - Accurate quantitative



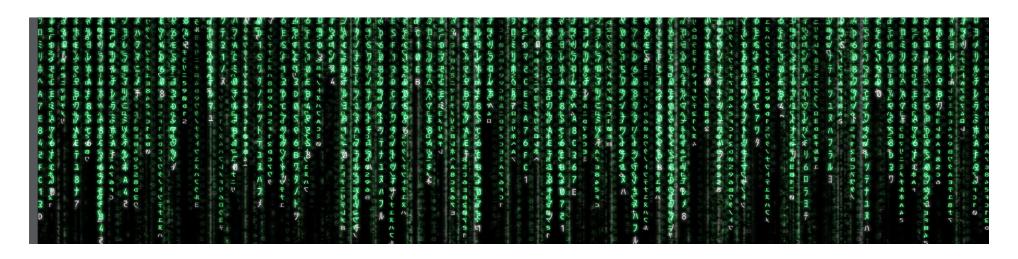




Analysis Selection Considerations

- Historical Data
 - Aerial Imagery
 - Previous hydrology, hydraulic, sediment, and geomorphic studies
- Topography/Bathymetry
- Hydrology
 - Previous Studies
 - Regression, Deterministic Models, Stochastic Models
 - Reservoir Operational Data
- Hydraulics
 - Normal Depth
 - Hydraulic Model

- Geotechnical/Sediment Information
 - Grain size distributions or Erosion Resistance
 - Geologic formations
 - Inflowing sediment/gradations
- Future Conditions
 - Land use
 - Geometry
 - Weather patterns



03 Simplified Sediment Approaches

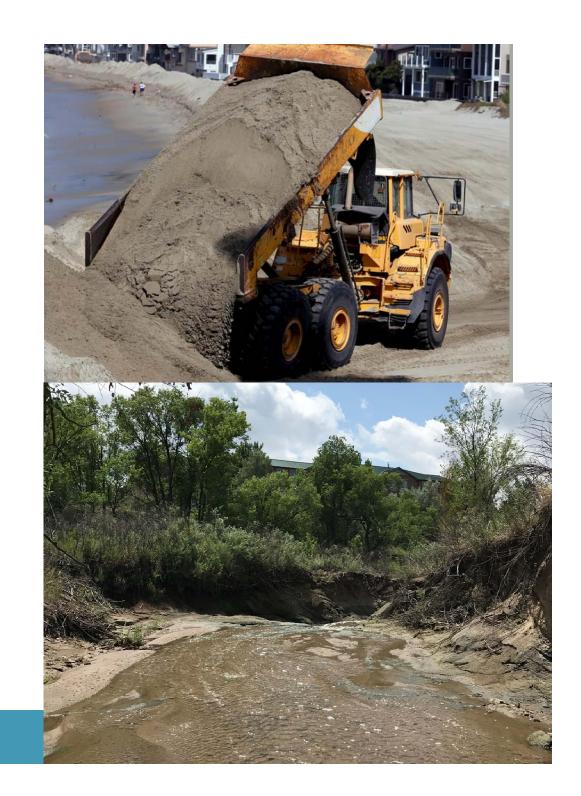


Sediment Supply

- Equilibrium Load
 - Supply = Capacity
- Sediment Yield Calculations
- Gage Data
- Historical
- Upstream Supply Reach Capacity

Sediment Capacity

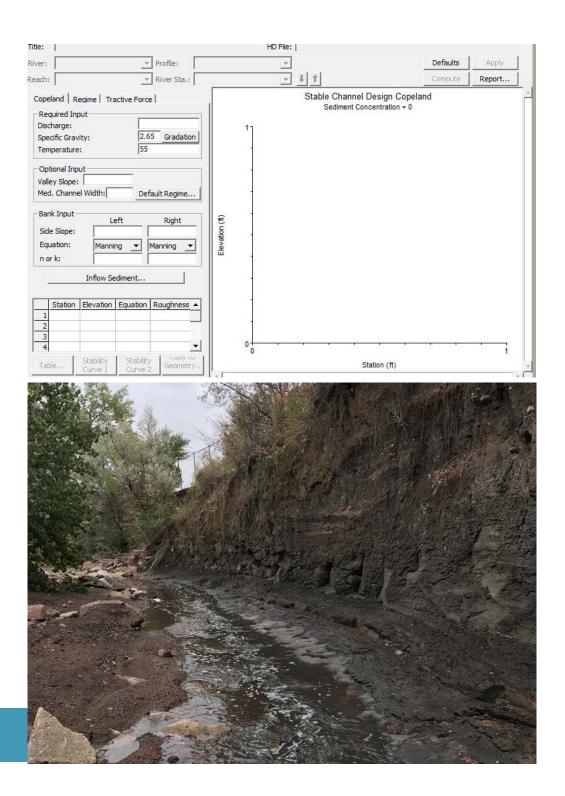
- Transport Equations
- Stable Slope
- Historical Behavior





Stable Channel Design Trends

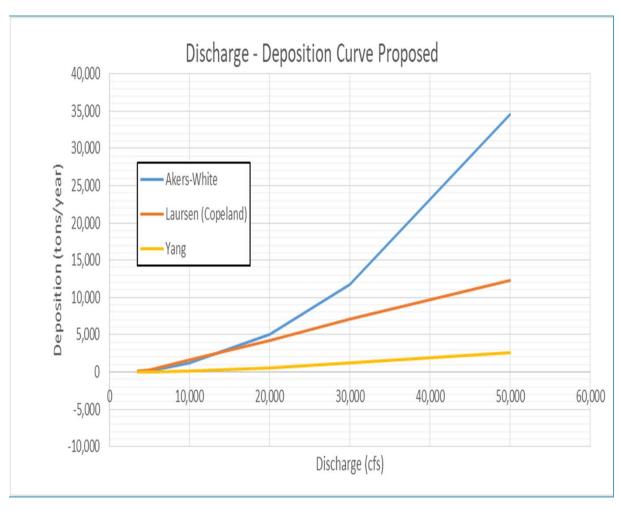
- Use Copeland Method
 - Stability curve slope/width
 - o Aggradation or degradation is expected
 - Based on supply reach
- Regime Method
 - o Stable slope for a given geometry
- Tractive Force
 - o Critical Shear vs Applied Shear





Sediment Transport Capacity

Quantity



- Sediment Transport Capacity
 - Calculation of capacity of crosssection not actually sediment transported
- Compare ability of section to transport sediment between existing and proposed conditions
- Compare upstream, downstream, and design reaches

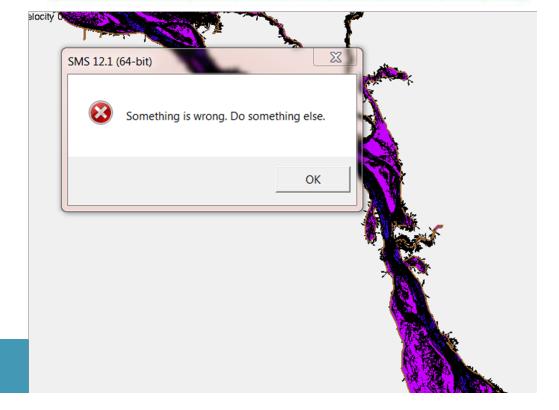


Sediment Transport Capacity

- Transport Equations
 - o Ackers-White
 - o Engelund-Hansen
 - Laursen
 - o Meyer-Peter-Muller
 - Toffaleti
 - o Yang
- Suspended Load
- Bed Load
- Wash Load

Table 12-8 Range of input values for sediment transport functions (Sam User's Manual, 1998)

Function	d	dm	s	V	D	s	W	T
Ackers-White (flume)	0.04 - 7.0	NA	1.0 - 2.7	0.07 - 7.1	0.01 - 1.4	0.00006 - 0.037	0.23 - 4.0	46 - 89
Englund-Hansen (flume)	NA	0.19 - 0.93	NA	0.65 – 6.34	0.19 – 1.33	0.000055 - 0.019	NA	45 - 93
Laursen (field)	NA	0.08-0.7	NA	0.068 – 7.8	0.67 - 54	0.0000021 - 0.0018	63 – 3640	32 - 93
Laursen (flume)	NA	0.011 - 29	NA	0.7 - 9.4	0.03 - 3.6	0.00025 - 0.025	0.25 - 6.6	46 - 83
Meyer-Peter Muller (flume)	0.4 – 29	NA	1.25 - 4.0	1.2 – 9.4	0.03 – 3.9	0.0004 - 0.02	0.5 – 6.6	NA
Tofaletti (field)	0.062 – 4.0	0.095 – 0.76	NA	0.7 - 7.8	0.07 – 56.7 (R)	0.000002 - 0.0011	63 - 3640	32 – 93
Tofaletti (flume)	0.062 - 4.0	0.45 – 0.91	NA	0.7 - 6.3	0.07 - 1.1 (R)	0.00014 - 0.019	0.8 - 8	40 - 93
Yang (field-sand)	0.15 – 1.7	NA	NA	0.8 - 6.4	0.04 - 50	0.000043 - 0.028	0.44 – 1750	32 - 94
Yang (field-gravel)	2.5 – 7.0	NA	NA	1.4 - 5.1	0.08 - 0.72	0.0012 - 0.029	0.44 – 1750	32 - 94

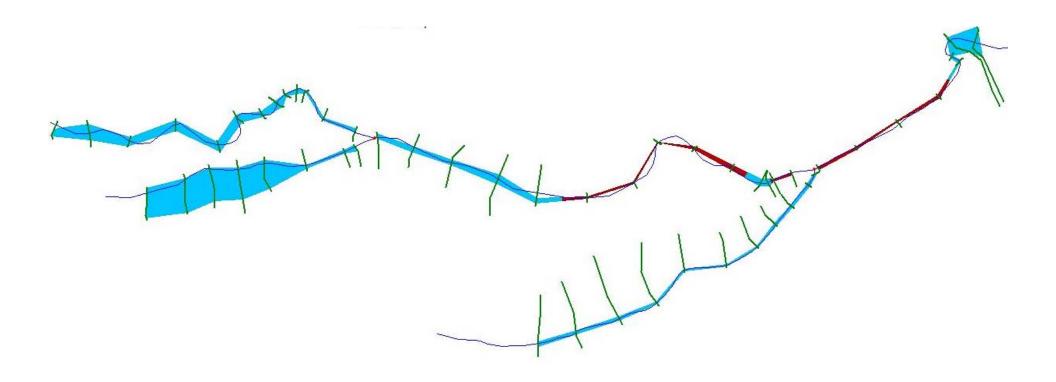




Sediment Impact Analysis Methods (SIAM)

System Changes

- Sediment Budget Tool comparing annualized sediment reach transport capacities
- Indicates overall sediment surplus or budget
- Screening level tool





Limitations

- Risk
- Complex Hydraulics
- Complex Geotechnical Conditions

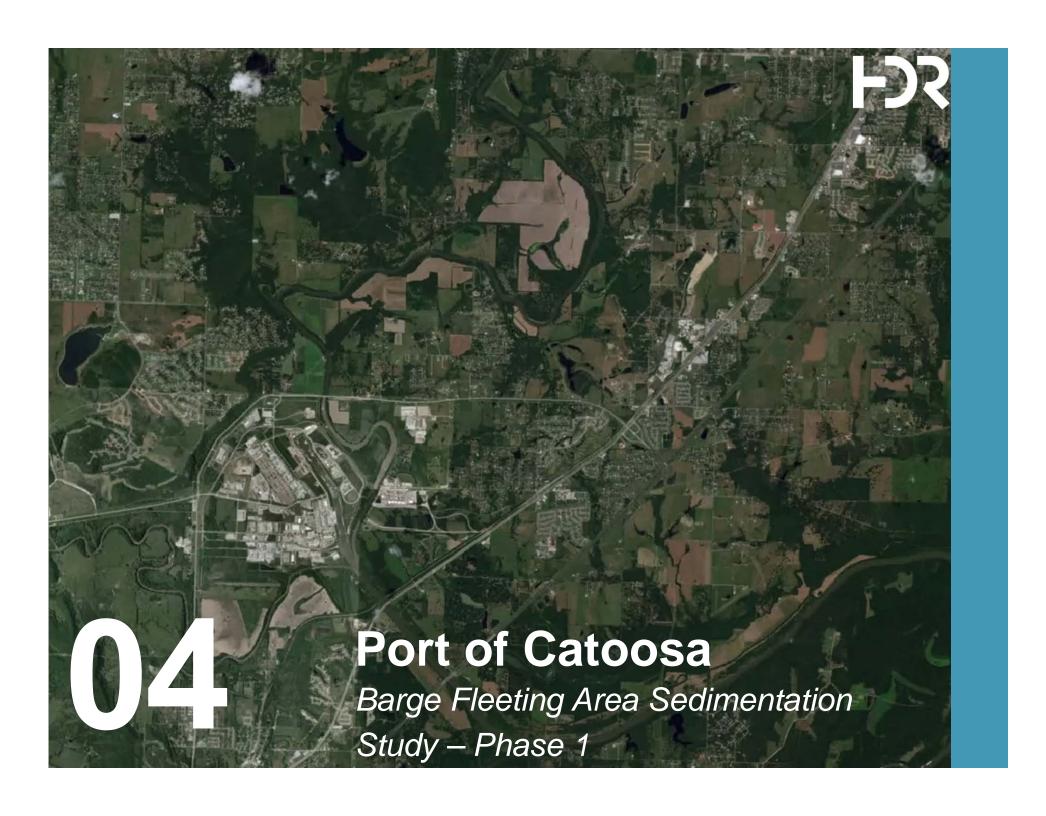


Stable Channel = Trends

Sediment Transport Capacity = Quantity

SIAM = System Changes





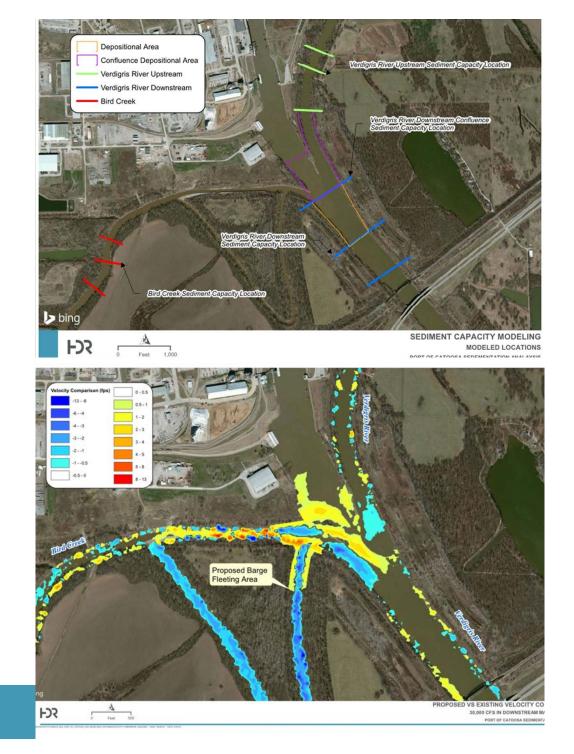
Port of Catoosa Sedimentation Analysis

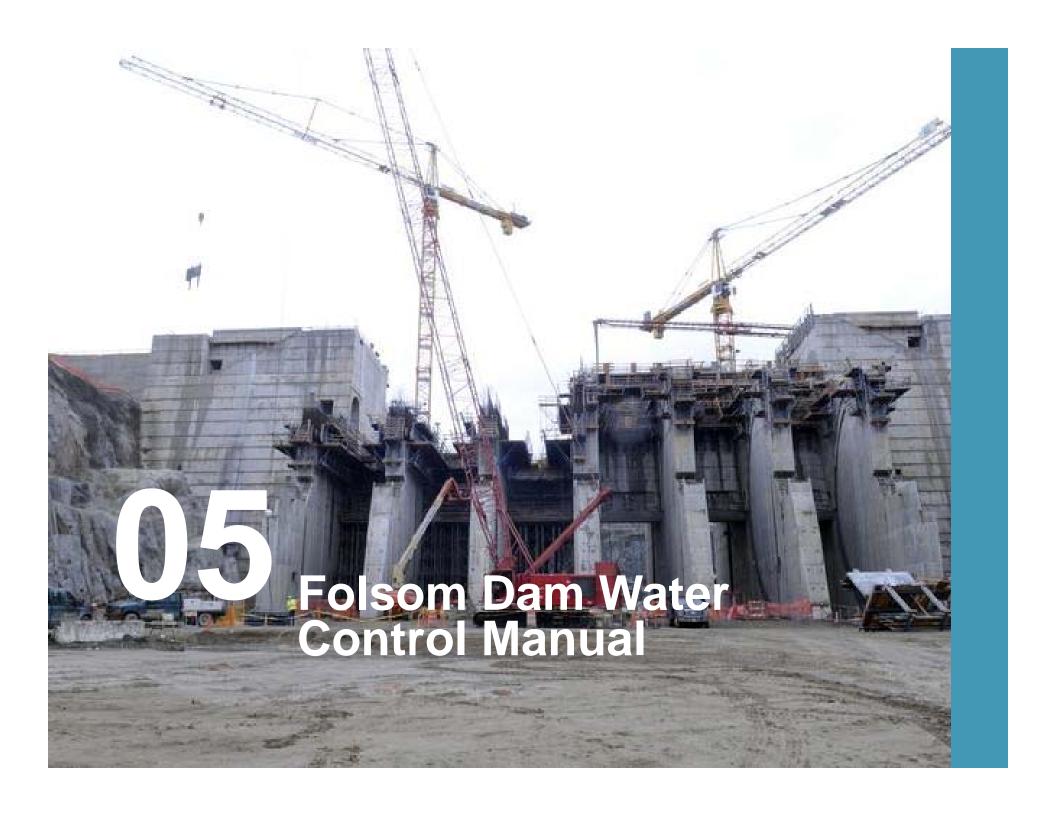
- Objectives
 - Screening Level Tool for Port Improvements
 - Dredging Requirements
- Data
 - o 2D Hydrodynamic Model
 - Geotechnical Gradations
 - o Limited Dredging Information
 - o Gage Data
- Analysis
 - HEC-RAS Sediment Transport Capacity Comparison
 - o 2D Hydrodynamic Model Velocity Comparison



Port of Catoosa Sedimentation Analysis

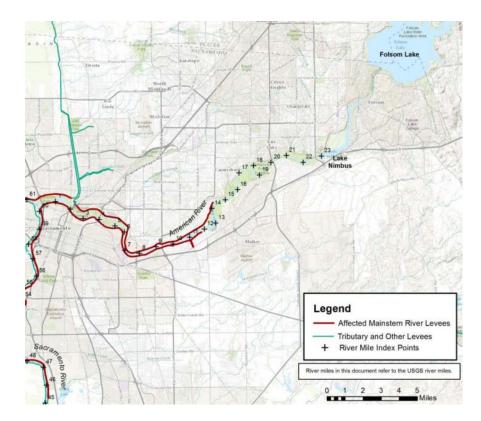
- Limitations
 - Limited Resolution
 - Relative Changes Only
 - No Calibration
- Benefits
 - High Level Screening Tool
 - o Easy to Understand Results
 - o Efficient Analysis

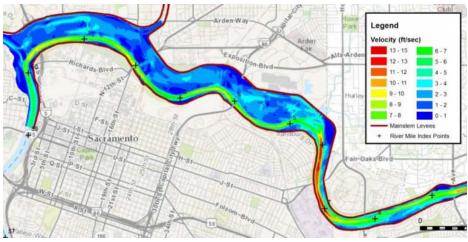




Folsom Dam WCM

- Support Permitting of New Folsom Dam Gates
- Objectives
 - o Understand Horizontal Stability
 - Understand Vertical Stability
 - Understand Gravel Habitat Mobility
- Challenges
 - o 22-Mile Reach
 - Limited Bed Sediment Data
 - o Highly Variable Bed Material
 - Long Term Reservoir Operations
- Analyses
 - o HEC-RAS Hydraulic Model
 - o Threshold Analysis





Folsom Dam WCM

- Support Permitting of New Folsom Dam Gates
- Approach for 6 Alternatives
 - 1. Identify Erosion Critical Sites
 - 2. HEC-RAS results (1930-2002)
 - 3. Critical Shear vs. Applied Shear
 - 4. Identify Periods of Erosion (1930-2002)
 - 5. Determine Overall Erosion Magnitude
 - 6. Compare Existing and Proposed Erosion

	J604 FLD Average Applied Shear Above Critical Shear	J602F3 FLD Average Applied Shear Above Critical Shear	Change in Average Shear Above Critical Shear
Site	(<u>lb</u> /ft ²)	(lb/ft²)	(\underline{lb}/ft^2)
Site 1	*	*	*
Site 3	*	*	*
Site 4a	*	*	*
Site 4b	*	*	*
Site 5	*	*	*
Site 6	*	*	*
Site 7	*	*	*
Site 8a	*	*	*
Site 8b	*	*	*
Site 9a	*	*	*
Site 9b	*	*	*
Site 10	0.20	0.20	0.0
Site 11a	*	*	*
Site 11b	*	*	*
Site 12	*	*	*
Site 13	0.20	0.21	0.01
Site 14	*	*	*

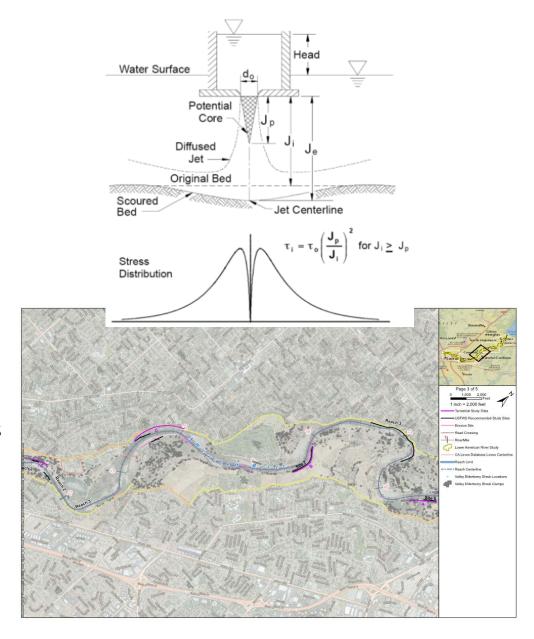
^{*} Shear stresses would not exceed critical shear. Negative values represent a reduction in average applied shear.

Comparison	Type of Analysis	Number of Sites where Average Shear is above Critical Shear	Increase or Decrease in Average Shear Stresses <u>above</u> Critical Shear	Maximum Total Change in Erosion Over Period of Record (ft)	
E504 ELD vs J604 FLD	Horizontal Erosion Average overbank Shear	2		0.13	
E504 ELD vs J602p ELD	Horizontal Erosion Channel Shear	11	Increase	0.029 ft/day*	
E504 ELD vs J602F3 ELD	Horizontal Erosion Average overbank Shear	2	No Change in Shear Stresses	0.5	
J604 FLD vs J602p FLD	Horizontal Erosion Channel Shear	11	Increase	0.029 ft/day*	
J604 FLD vs J602F3 FLD	Horizontal Erosion Average overbank Shear	2	Increase	0.27	
E503p ELD vs J602F3 ELD Horizontal Ero- Average overb Shear		2	No Change in Shear Stresses	0.3	

^{*} Values are erosion rates

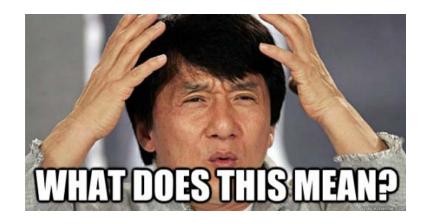
Folsom Dam WCM

- Limitations
 - o Generalized Bed Properties
 - Huge Variability in Erosion Rate Information
 - o Average Shear From Model
 - Limited Resolution
- Benefits
 - Understanding of Huge Period of Flows
 - Repeatable Comparison of Alternatives
 - Easy to Understand Results
 - Easily Incorporated into Other Analyses
 - Efficient Analysis





Take Away



- Why is this important?
 - Much can be learned from even simple analyses with comprehensive sensitivities
 - o You don't always need the most complicated analysis
 - All the information needed for a detailed analysis is not always available
 - o Some analyses can be too complicated for general consumption
- However...
 - A combination of multiple approaches should always be considered
 - Detailed analyses are an essential tool for many designs
- Always...
 - Complete a sensitivity analysis.
 - o Professional judgement and experience is the most important component of any analysis

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Brinton Swift, PE, CFM Brinton.swift@hdrinc.com



Questions?

The Gunnison River and Riparian Habitat Rehabilitation Project Local Partnerships at Work

Dan Brauch – CPW Aquatic Biologist Steve Westbay – City of Gunnison –





COLORADO

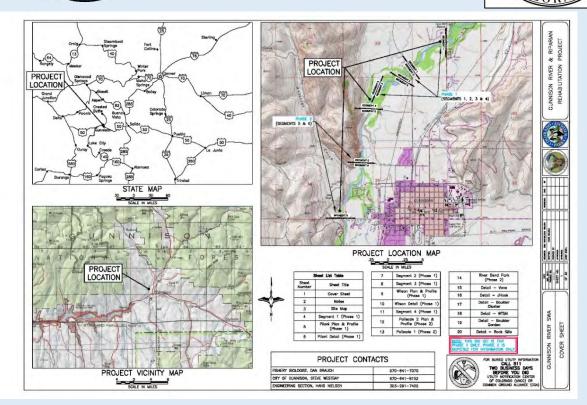
Colorado Water Conservation Board

Department of Natural Resources

GUNNISON ANGLING SOCIETY

THE GUNNISON CHAPTER OF TROUT UNLIMITED





Goddard Ranch

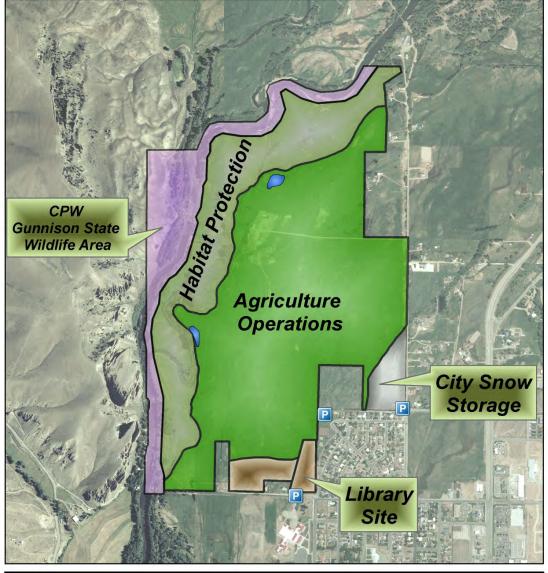




Background VanTuyl Ranch & Gunnison River State Wildlife Area

A Project 25 Years in the Making

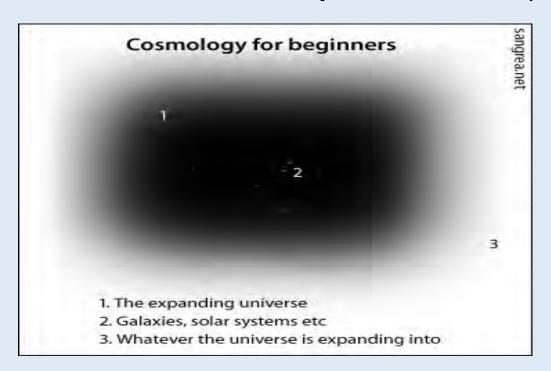
- > Property purchased 1993 by the Trust for Public Lands
- > Titles conveyed to Bureau of Reclamation (BOR) & the City
- > State Wildlife Area deed transfer from BOR to CPW in 1994
- ➤ City took over ranch operations in 2008 after lifetime resident Ray VanTuyl passed away
- Ranch Annexed in 2011
 - Regulated by an Adaptive Resource Management Plan
 - Alluvial Aquifer Recharge City domestic water source
 - Watershed Protection Septic system proliferation
 - Prescribed Agricultural Operations & community garden
 - Public Open Space 5K trail system
 - Flood Control
 - Habitat Protection





Rehabilitation Project - It Starts with an IDEA in 2001

- > Fluvial Morphology & River Restoration Assessment, 2001
- > Partners: CWCB, Trout Unlimited, UGRWCD, CPW, City, 2012
- > Championing the Cause: CPW & City, 2012
- > Funding: 2014 CWCB Grant (\$440K); Private Donations (\$150K)
- ➤ Design Programming 2014 through 2017
- ➤ Scope Modification 2016 Project Cost Overruns
- > Permitting: ACOE 404; Fish & Wildlife Service 2017
- > Project Bid Award September 2017 & Construction through May 2018









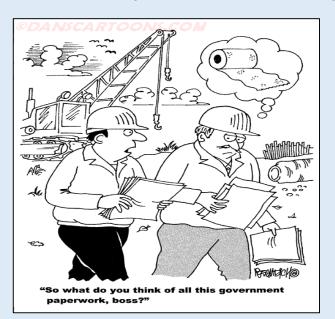
PROJECT GOALS

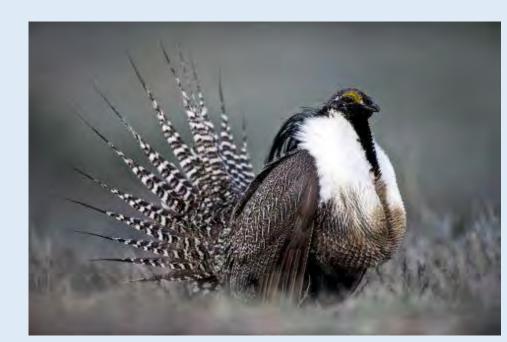
- Improve diversions- H2O rights due diligence
- Reconnect floodplains
- Improve channel habitat
- Increase trout biomass
- Improve trout size
- Improve riparian habitat
- Improve public river access

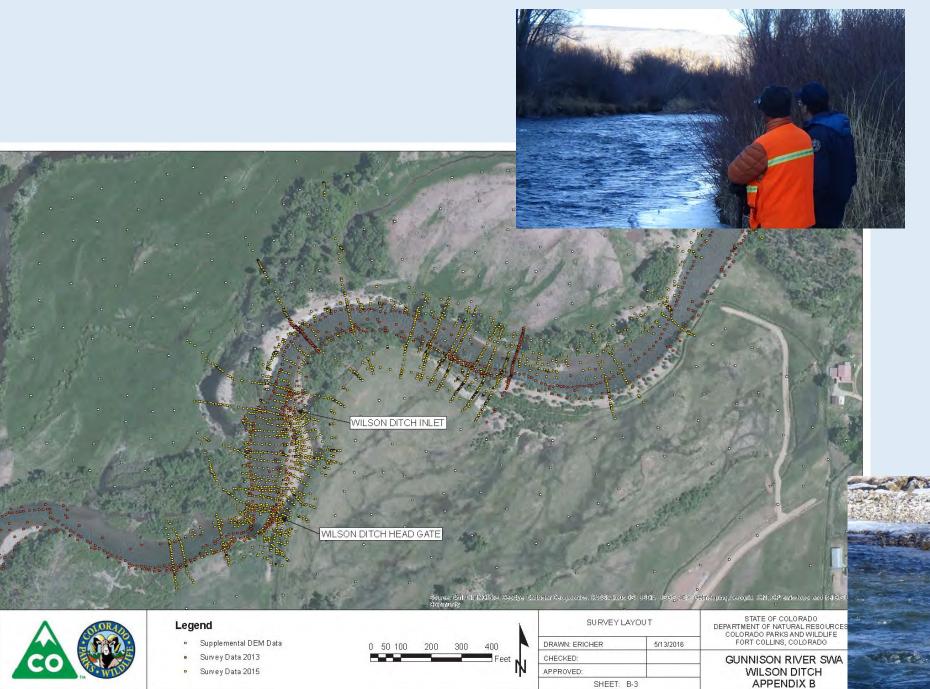


Permitting Overview

- ➤ Gunnison Sage-grouse Listing Decision November 12, 2014 US Fish and Wildlife Service
- > ACOE Nationwide Permit 33:Temporary Access Construction and Dewatering agricultural diversions
- > ACOE Regional General Permit 12: Aquatic Habitat Improvement for Stream Channels in Colorado
- ➤ Endangered Species Act, Section 7 Consultation, ACOE/FWS
 - Cultural Resource Inventory
 - Wetland Inventory
 - ESA Gunnison Sage-grouse Critical Habitat Biological Assessment
 - Special Conditions for season of operations, equipment access, et AL
- ➤ Coordination & Approvals from the Bureau of Reclamation
- County Flood Hazard Application







Project engineering and design was done by the CPW's engineering staff.
These in kind design services, along with permit administration by local agencies added significant project value.

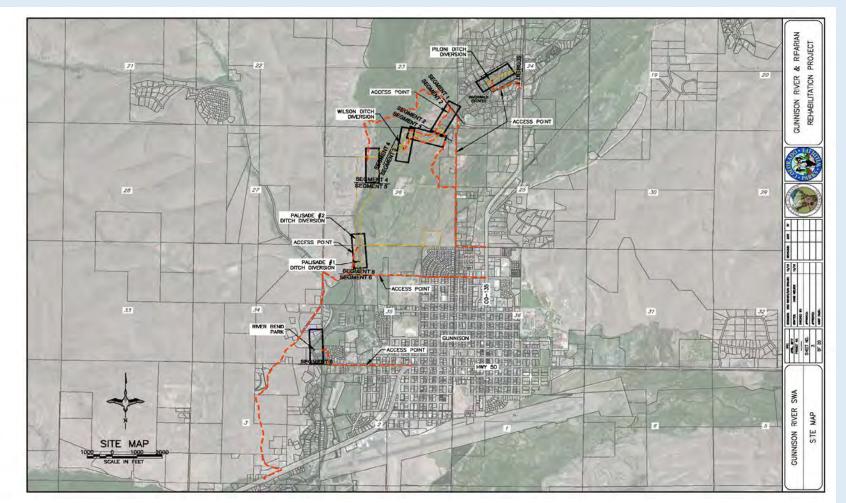


KEY DESIGN CONSIDERATIONS

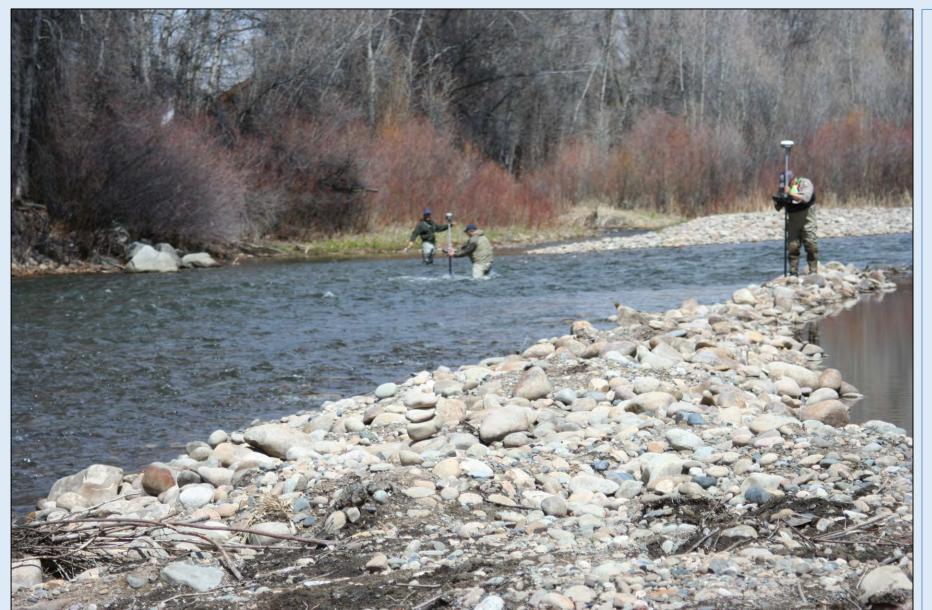
Design Improvements on 7 Channel Segments along a 3.75 mile reach

- ➤ Abate historic channelization where practical
- Reestablish morphological function
- Improving fish habitat
- Emphasize low profile channel features

- > Improve Riparian Function w/ vegetation treatment
- Reconnect floodplains where possible
- ➤ Use native vegetation: willow transplants; sod mat



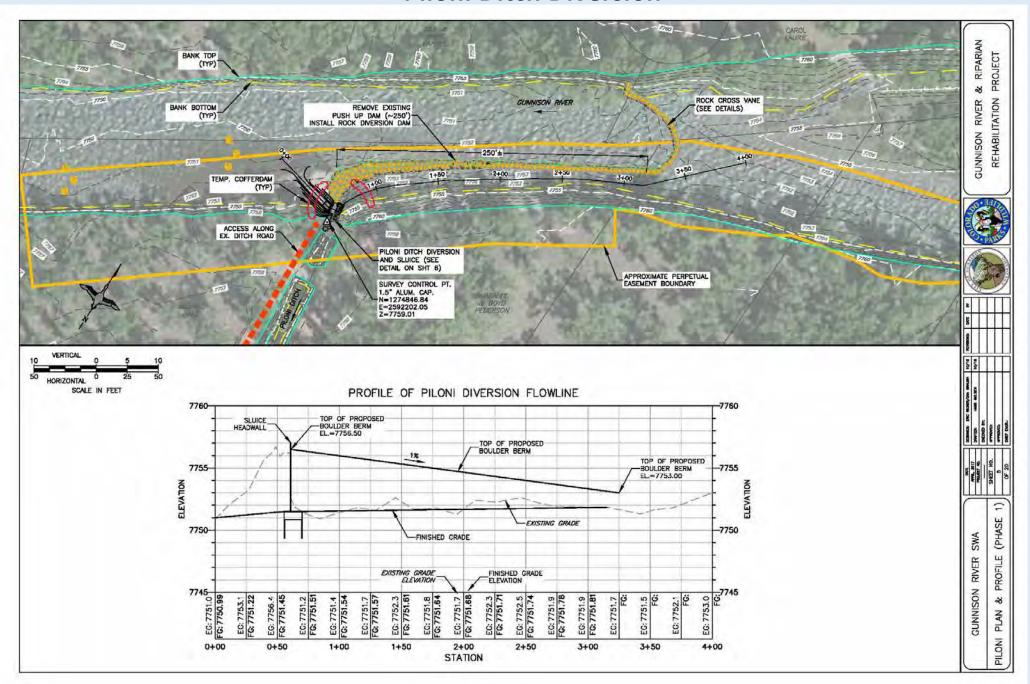
Pre-Construction Conditions – Hydraulic Modelling



Hydraulic modeling indicated that the initial designs of one channel feature would cause flood elevation rise & final design alterations were made to ensure norise would occur.

Elevation grade change between the head gates and diversion points were critical functions of the final design to ensure adequate water delivery and sediment control.

Piloni Ditch Diversion



Piloni Ditch – Major Diversion & Habitat Improvements





Frozen soil conditions experienced in early January 2018 finally chased the crew off for the season. Construction began again the past week – estimated completion date May 2018.

A \$100,000 grant from the LOR Foundation allowed for constructing a new headworks on the Piloni Ditch & the construction of additional fish habitat structures in all reaches of the river project area.

Piloni Ditch – March 27, 2018 Ongoing Construction

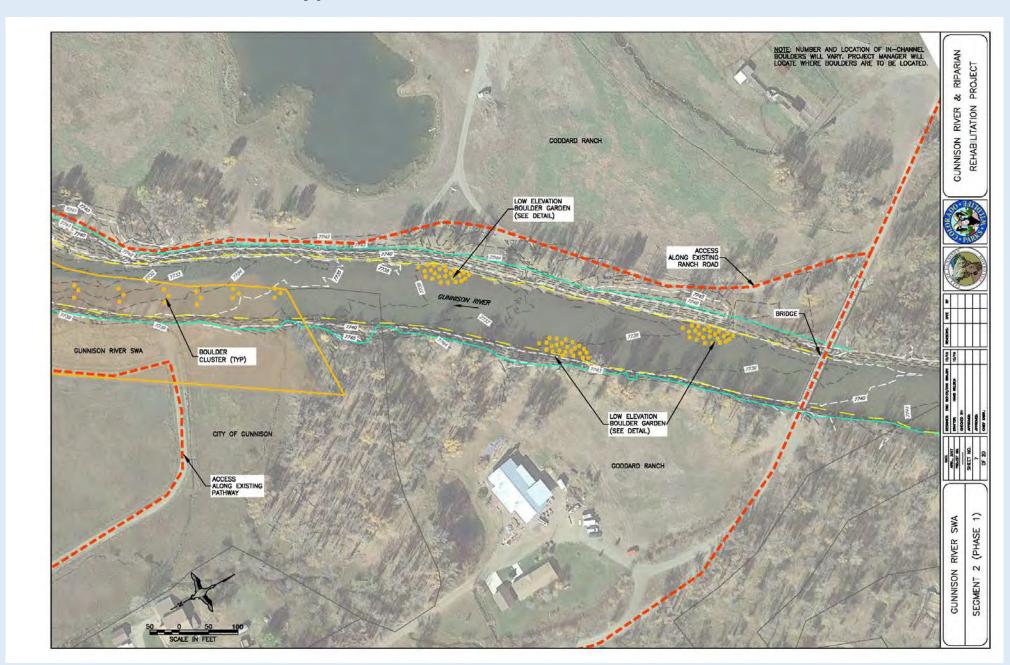




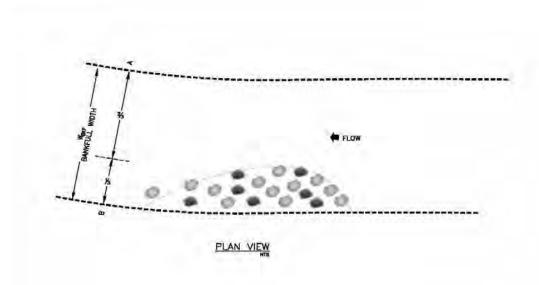




Typical Fish Habit Channel Features



Boulder Garden Details



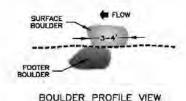
BANKFULL ELEV.

CROSS-SECTION VIEW

BANK FULL ELEVATION

36 BANKFULL ELEV. MAX.

& BANKFULL ELEV. MAX.



CONSTRUCTION NOTES:

- STRUCTURE SHALL BE FIELD LOCATED BY CPW PROJECT MANAGER OR DESIGNATED REPRESENTATIVE.
- SURFACE BOULDERS ARE THE TOP COURSE OF BOULDERS, SURFACE BOULDERS SHALL VARY IN DEPTH BETWEEN 1/3 BANK FULL DEPTH AND 2/3 BANK FULL DEPTH.
- 3. FOOTING BOULDERS ARE PLACED TO PROMDE A FOUNDATION FOR THE SURFACE BOULDERS. TYPICALLY FOOTER BOULDERS SHALL BE BURIED IN THE CHANNEL BOTTOM AND NOT SEEN WHEN THE STRUCTURE IS COMPLETED. ALL SURFACE BOULDERS SHALL REQUIRED FOOTERS AND SHALL BE OMITTED ONLY AT THE DISCRETION OF CPW PROJECT MANAGER, OR DESIGNATED REPRESENTATIVE, ON A STRUCTURE BY STRUCTURE BASIS.
- 4. BOULDERS SHALL BE PLACED AT AN IRREGULAR SPACING.
- BOULDERS SHALL BE PLACED APPROXIMATELY 2-4 x BOULDER DIAMETER APART.
- 5. CONTRACTOR SHALL USE AN EXCAVATOR OF SUITABLE CAPACITY WITH HYDRAULIC THUMB TO CONSTRUCT THE STRUCTURE.
- CONTRACTOR SHALL ANTICIPATE THAT HANDLING OF INDIVIDUAL ROCK (ESPECIALLY BOULDERS) AFTER INITIAL PLACEMENT WILL BE REQUIRED TO ACHIEVE REQUIRED SLOPES, GRADES, ELEVATIONS, AND POSITION.
- 8. REFER TO PROJECT TECHNICAL SPECIFICATIONS FOR ROCK AND OTHER REQUIREMENTS FOR INSTALLING STRUCTURES

BOULDER GARDEN

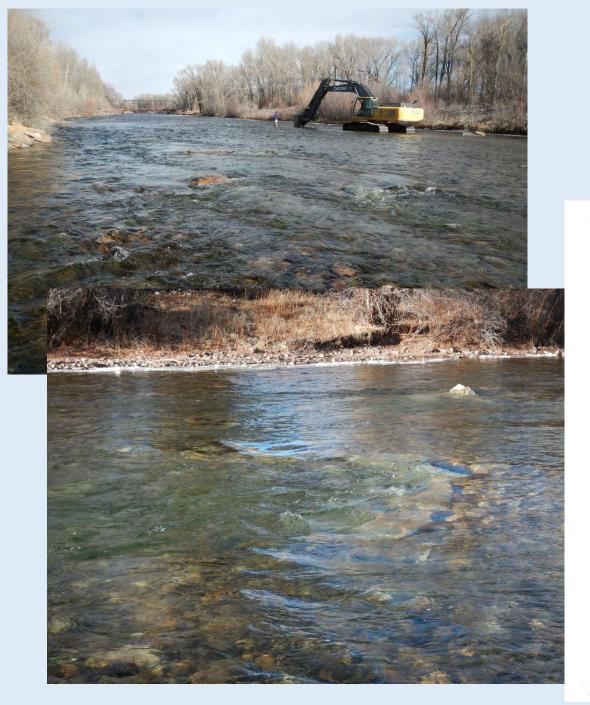
GUNNISON RIVER & RIPARIAN REHABILITATION PROJECT



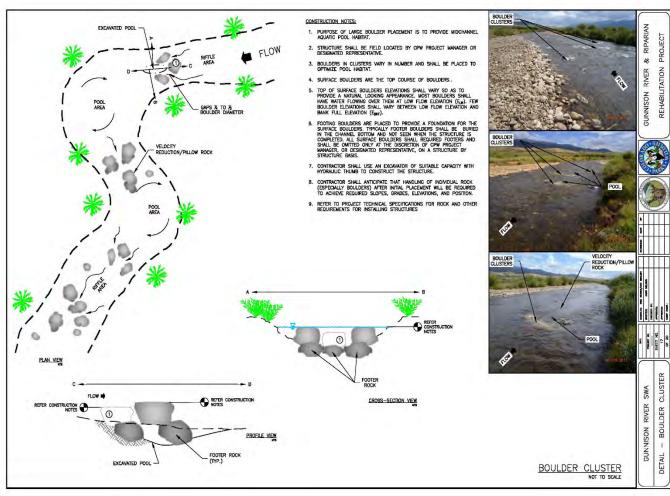


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GUNNISON RIVER SWA DETAIL - BOULDER GARDEN



Fishery habitat improvements include construction boulder gardens and boulder clusters on all project area river reaches.



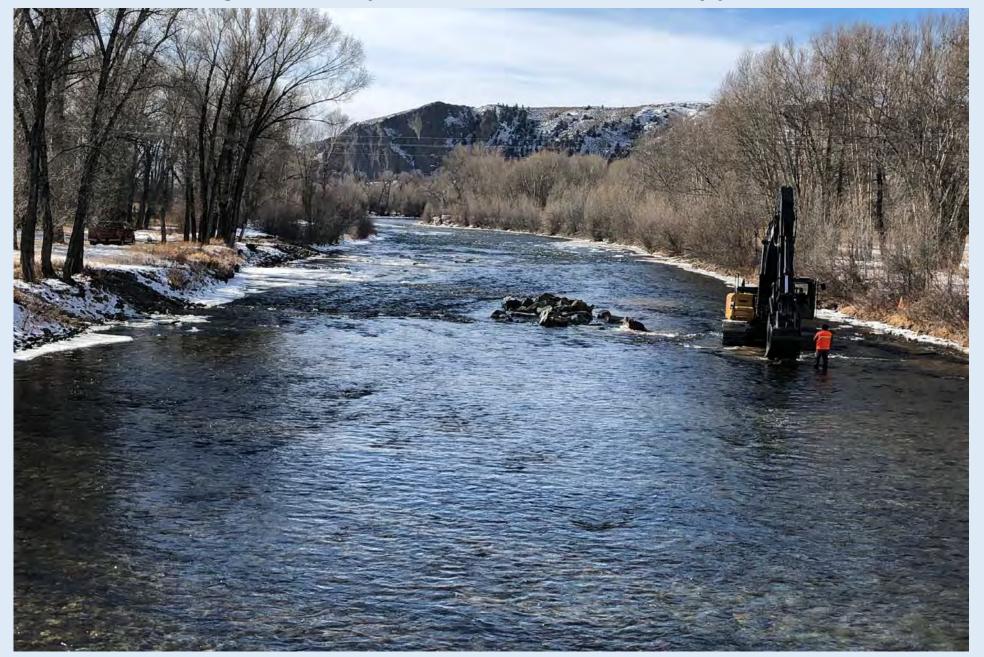
Low Profile Boulders Clusters at Work



Channelization Challenges Establishing Thalweg & Sinuosity



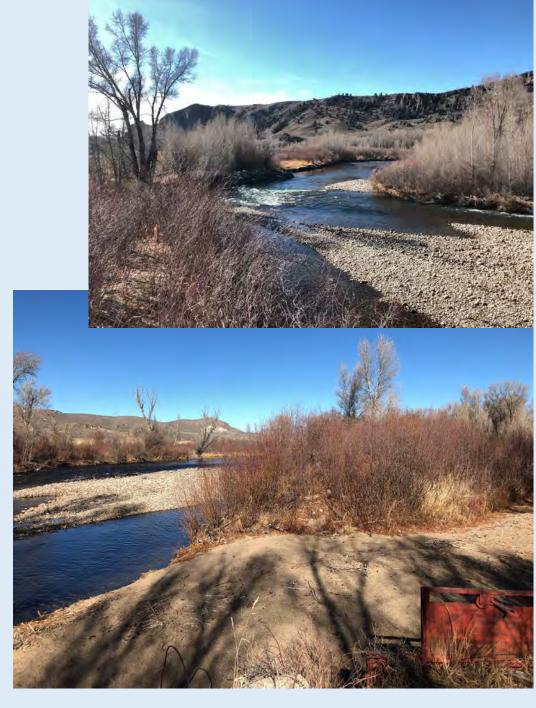
Thalweg & Sinuosity- Boulder Gardens in lieu of point bars



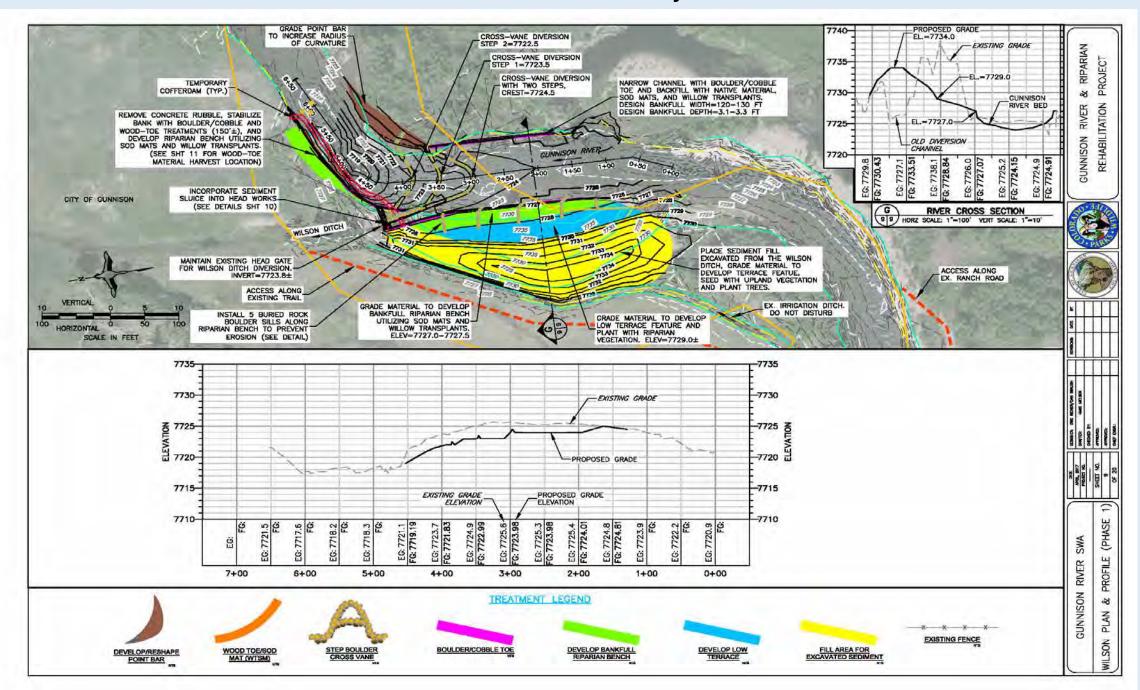


Wilson Diversion Pre-Construction Conditions

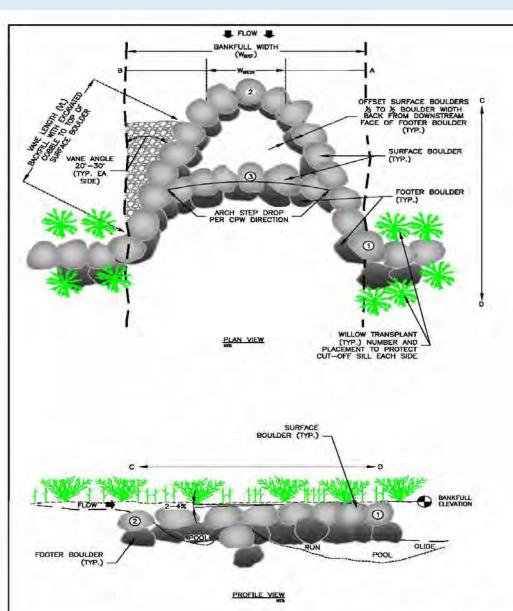


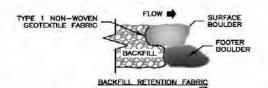


Wilson Diversion Plan and Profile



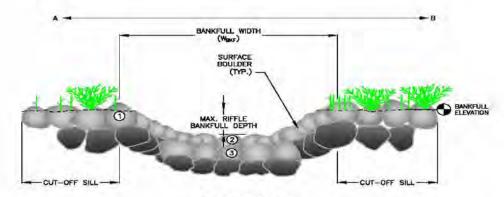
Low Profile Cross Vanes





BACKFILL RETENTION FABRIC NOTES:

- THE PURPOSE OF THE BACKFILL RETENTION FABRIC IS TO INHIBIT THE PASSING OF BACKFILL MATERIAL (I.E. CHANNEL BED MATERIAL) THROUGH OR UNDER THE STRUCTURE.
- FABRIC SHALL BE USED ON THE VANE OF ALL STRUCTURES AND SHALL BE OMITTED ONLY AT THE DISCRETION OF CPW PROJECT MANAGER, OR DESIGNATED REPRESENTATIVE, ON A STRUCTURE BY STRUCTURE BASIS.
- FABRIC MANUFACTURER'S ROLL WIDTH SHALL GO FROM SURFACE BOULDER, ALONG FACE OF BOULDERS AND EXTEND UPSTREAM UNDERNEATH BACKFILL. ROLL WIDTH SHALL NOT BE CUT.



CROSS-SECTION VIEW

CONSTRUCTION NOTES:

- I. STRUCTURE SHALL BE FIELD LOCATED BY CPW PROJECT MANAGER OR DESIGNATED REPRESENTATIVE.
- SURFACE BOULDERS ARE THE TOP COURSE OF BOULDERS, ALL SURFACE BOULDERS CAN BE SEEN PROTRUDING FROM THE WATER SURFACE ONLY DURING LOW FLOWS.
- 3. FOOTING BOULDERS ARE PLACED TO PROVIDE A FOUNDATION FOR THE SURFACE BOULDERS, TYPICALLY FOOTER BOULDERS SHALL BE BURIED IN THE CHANNEL BOTTOM AND NOT SEEN WHEN THE STRUCTURE IS COMPLETED. ALL SURFACE BOULDERS SHALL REQUIRED FOOTERS AND SHALL BE OMITTED ONLY AT THE DISCRETION OF CPW PROJECT MANAGER, OR DESIGNATED REPRESENTATIVE, ON A STRUCTURE BY STRUCTURE BASIS.
- 4. THE SURFACE OF THE CROSS-VANE SHALL BE FINISHED TO A SMOOTH AND COMPACT SURFACE IN ACCORDANCE

WITH THE LINES, GRADES AND CROSS—SECTIONS OR ELEVATIONS SHOWN ON THE DRAWINGS. THE DEGREE OF FINISH FOR INVERT ELEVATIONS SHALL BE WITHIN ± ONE—INCH OF THE GRADES AND ELEVATIONS INDICATED PROVIDED ANY HEIGHT DOES NOT EXCEED 1.5 INCHES. ALL GAPS AND/OR VOIDS ALONG THE VANE SHALL BE PLUGGED WITH ROCK TO FORM A TIGHT FITTING SEAL TO 2 — 4 INCHES BELOW THE HEAD ROCK ELEVATION.

- CONTRACTOR SHALL USE AN EXCAVATOR OF SUITABLE CAPACITY WITH HYDRAULIC THUMB TO CONSTRUCT THE STRUCTURE.
- CONTRACTOR SHALL ANTICIPATE THAT HANDLING OF INDMIDUAL ROCK (ESPECIALLY BOULDERS) AFTER INITIAL PLACEMENT WILL BE REQUIRED TO ACHIEVE REQUIRED SLOPES, GRADES, ELEVATIONS, AND POSITION.
- REFER TO PROJECT TECHNICAL SPECIFICATIONS FOR ROCK AND OTHER REQUIREMENTS FOR INSTALLING STRUCTURES

CUNNISON RIVER & RIPARIAN REHABILITATION PROJECT



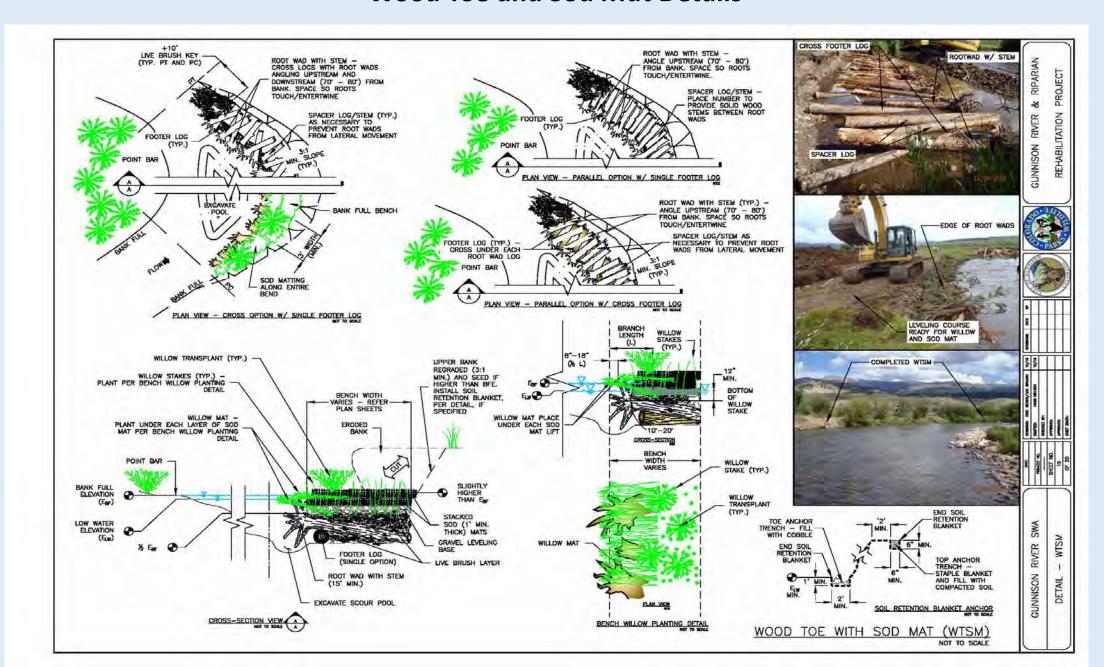




GUNNISON RIVER SWA. DETAIL — VANE

STEP BOULDER CROSS-VANE

Wood Toe and Sod Mat Details









Local contactor Spallone
Construction was awarded the
Bid in August 2017. CSI
Concrete was a subcontractor
for the project.

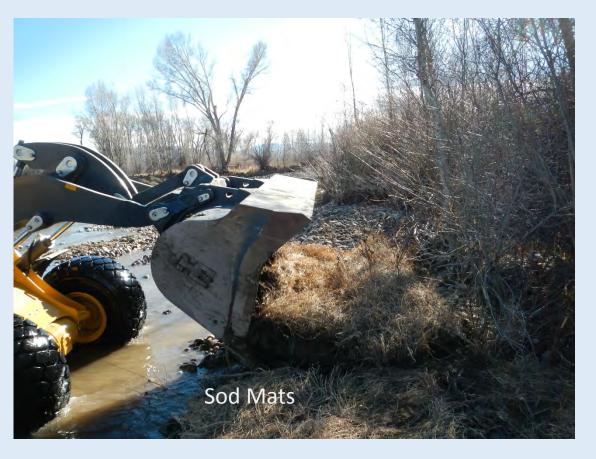
Work on the Wilson diversion began in late October 2017. Favorable weather conditions allowed for completion of all rock structures & concrete work. The majority of vegetation work was also complete during the warm fall season.





Riparian Habitat Treatments

Bank stabilization, willow transplanting & other work will improve riparian habitat. Reconnection of the floodplain, where appropriate, was also a project goal



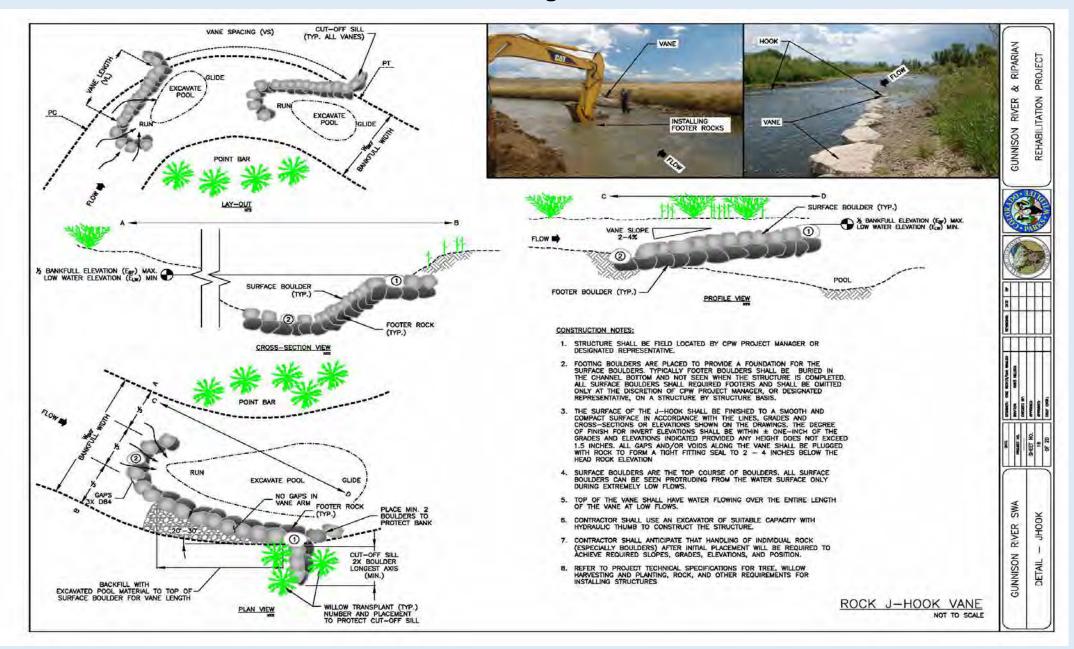
Floodplain Connection
Terrace & Floodplain Riparian Habitat Treatment







J-Hook Design Details





While equipment was staged at the Wilson Diversion, work to stabilize the Ohio Creek/Gunnison confluence was accomplished.

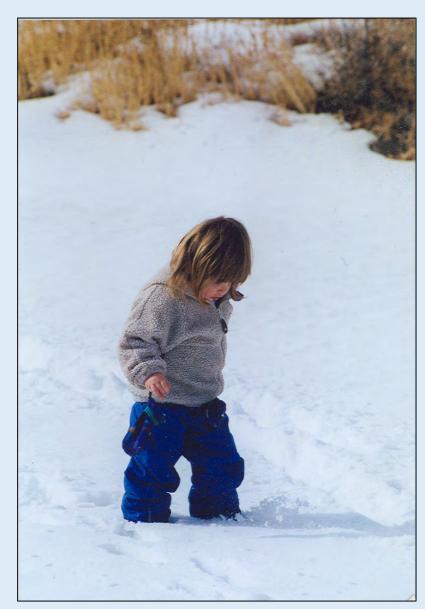
A J-Hook structure and boulder cluster habitat features were constructed at the confluence.

Observations – Lessons Learned

- > Develop partnerships & allies focus on possible stakeholders
- Be a champion of Great Projects
- ➤ Good ideas take time do not loose focus
- ➤ Be a steward of natural resources it is what *sustainability* requires

'A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise.'

Aldo Leopold





Drone Based Riprap Imaging and Gradation Measurement

LeAndra Nelson, PE - Kiewit Engineering Group











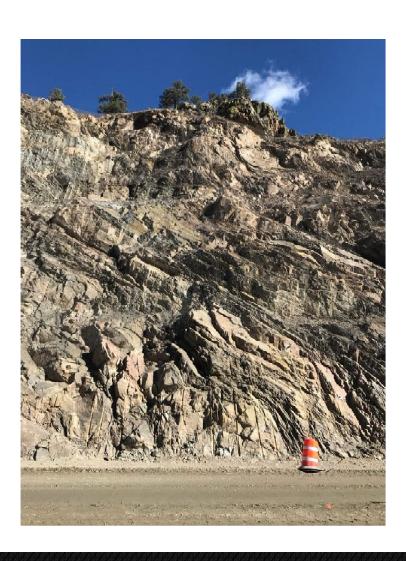


Kiewit Engineering Group

- 1,400 Engineers
 - Construction Engineering Services
 - Permanent Design Services
- Power & Energy
- Roadway
- Railway
- Structures
- Hydraulics
- Geotechnical



Purpose



- Limited processes for measuring rock gradation
- Build on use of drones
- Independent quality check



US-34 Permanent Repair Project *An Opportunity for Innovation*



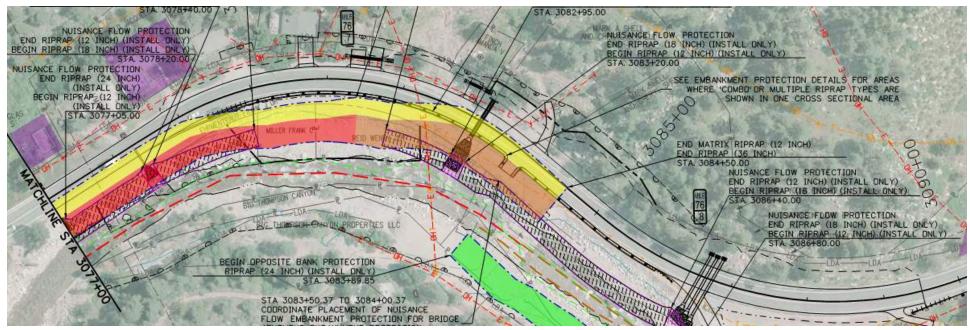


State-of-the-Industry Geomatics

- GPS Coverage
- RTK Equipped Survey Crews
- Machine Control
- Drone Based Remote Sensing
 - Topographic Models
 - Construction Work Planning
 - Quantity Determination







*Plans Provided Courtesy of CDOT

Embankment Protection

- Challenging River Hydraulics
- Environmental Requirements
- Varying size/type of riprap



Quality Concerns



- 100,000 CY riprap placed
- Difficult placement
- Varying gradations
- Potential to fail inspection
- QC Methods

Accepted Quality Methods

Visual Inspection

Bulk Weigh

Random Sampling



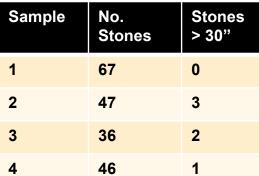
Visual Inspection

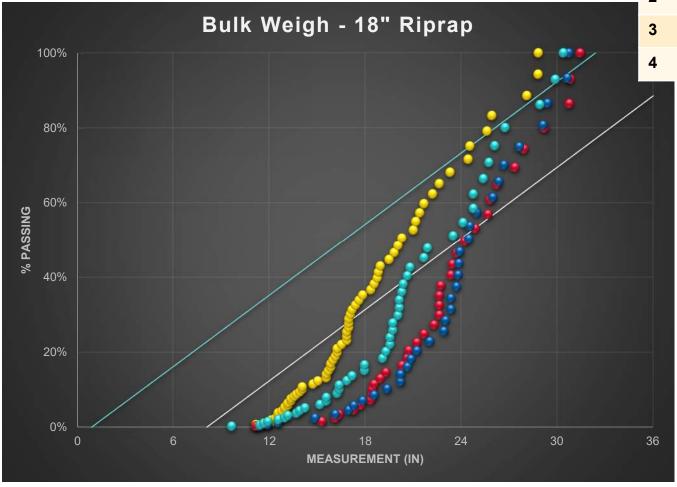




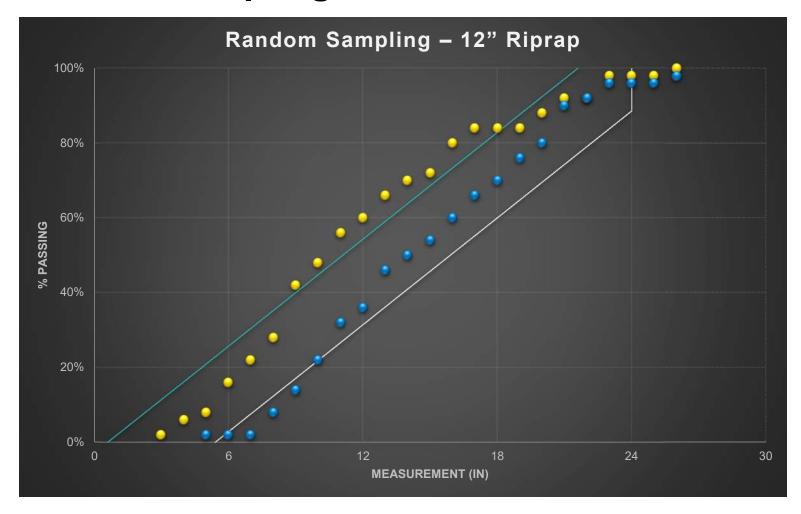


Bulk Weigh



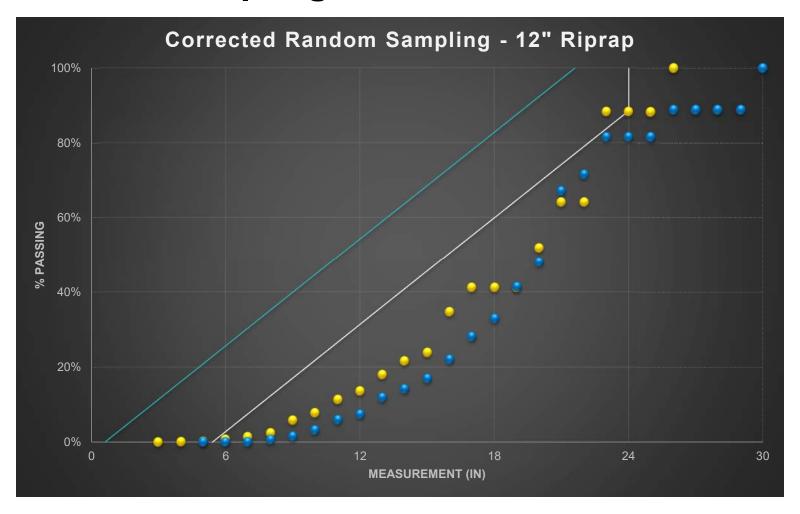


Random Sampling



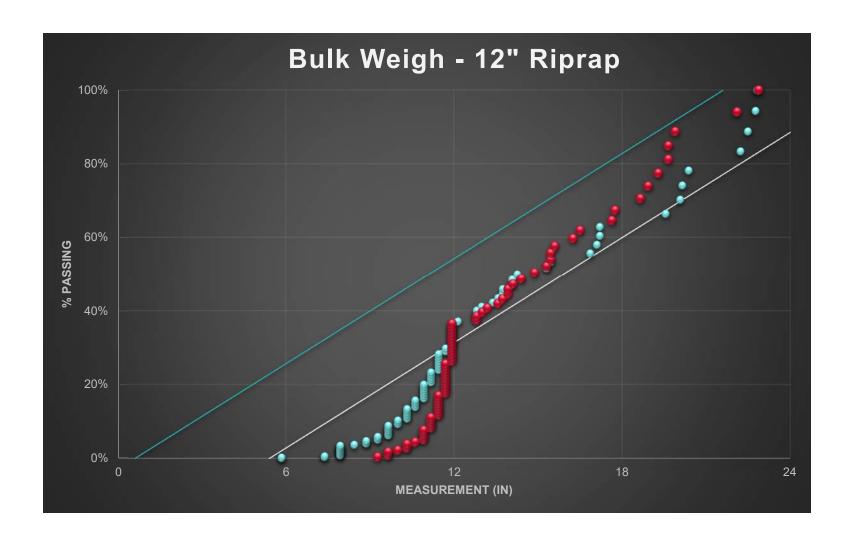


Random Sampling





Random Sampling vs. Bulk Weigh





Current Quality Method Drawbacks

Method	Drawbacks
Visual Inspection	Requires experienced inspectorSubjective
Mass Weigh	Time consumingLarge massSample size too small
Random Sampling	Volumetric correctionSample size too small



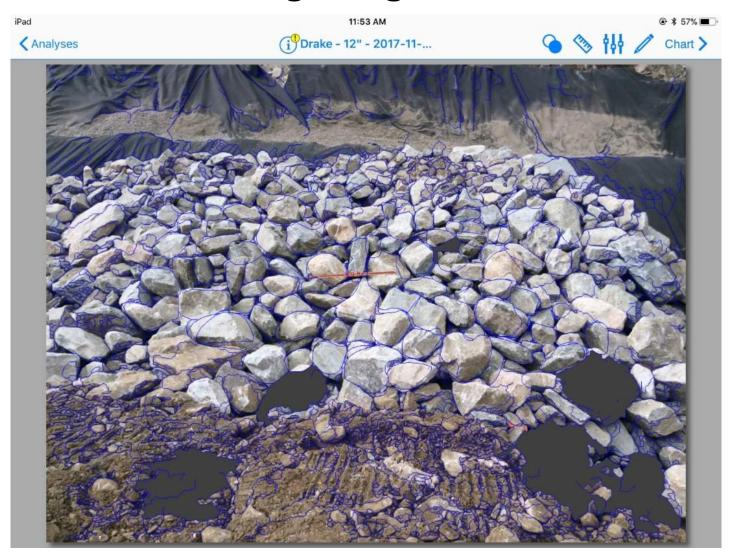
Independent Quality Methods

Ground Level Image Segmentation

Drone Image Segmentation

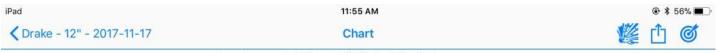


Ground Level Image Segmentation

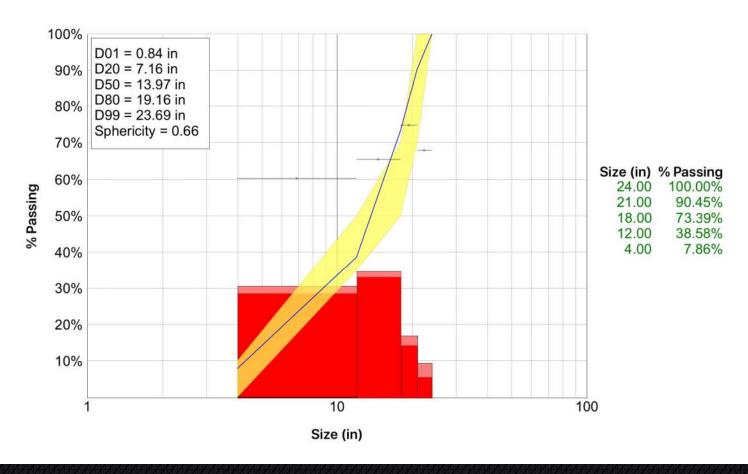




Ground Level Image Segmentation

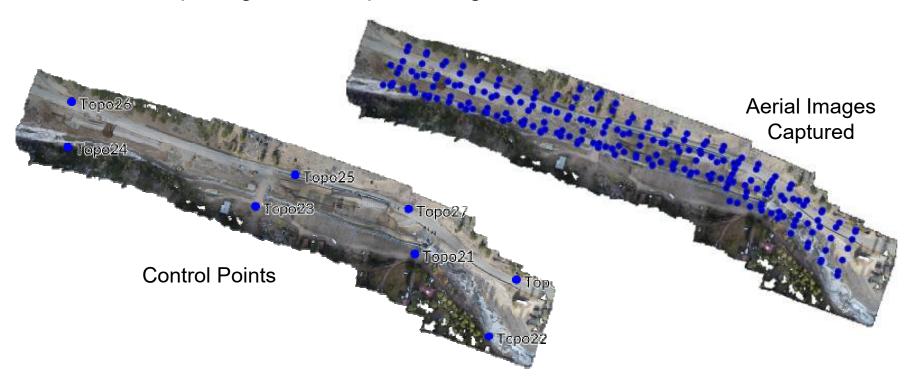


Drake - 12" - 2017-11-17



Drone Image Segmentation

- Comprehensive GPS network
- Controlled drone flights
- Automated photogrammetric processing



Drone Tasking

- Typical flight height
 - 80 meters (250 feet)
 - 120 meters (400 feet)



40 m Flight Height



80 m Flight Height



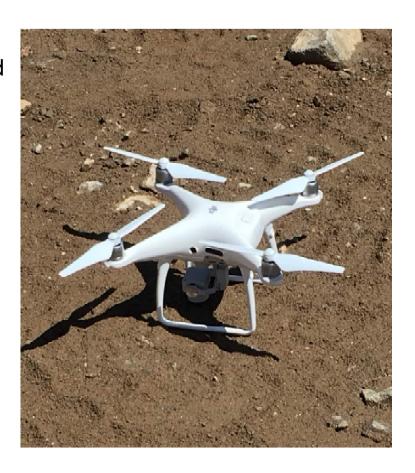
120 m Flight Height

Drone Tasking

Constraints

- Operator with surveying background
- 3" 4" Accuracy
- FAA licensed pilot
- Light and weather conditions
- Flight lines and programming
- Overlapping images
- Ground Control







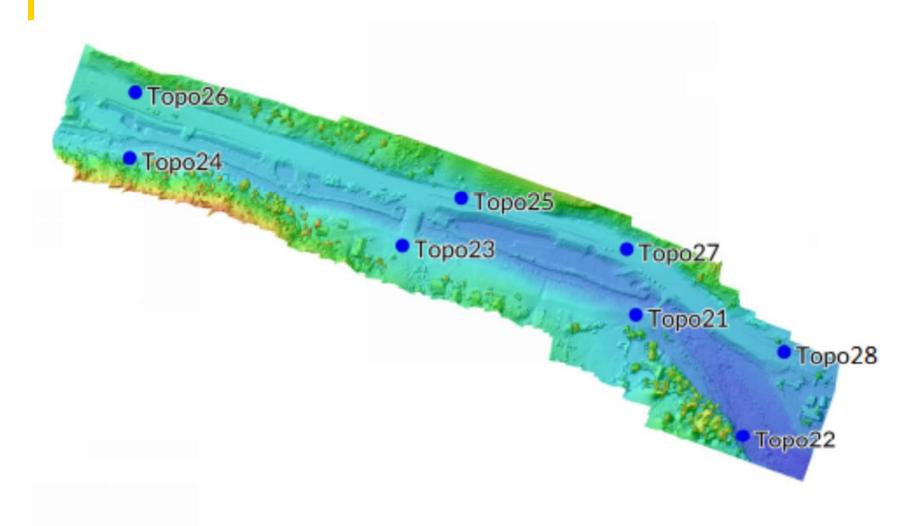
From Riprap Quantity to Gradation Quality

- Photogrammetric processing results
- Gradation Classes

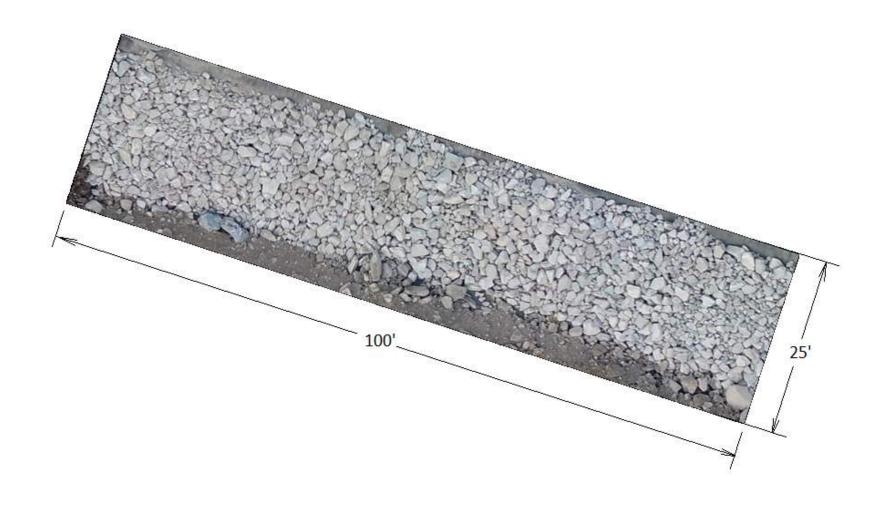
Photogrammetric Processing Report



Photogrammetric Processing Report

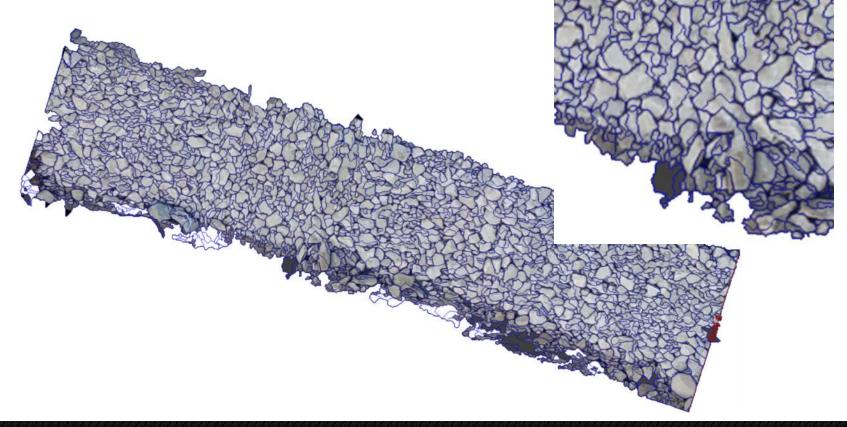


Photogrammetric Processing Report



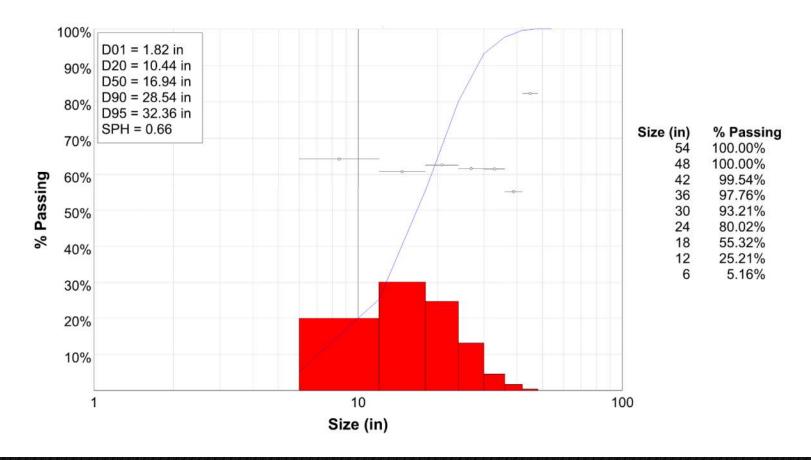
Drone Image Segmentation

- 2,500 sq. ft Sample Area (100' x 25')
- Contains over 1,000 stones

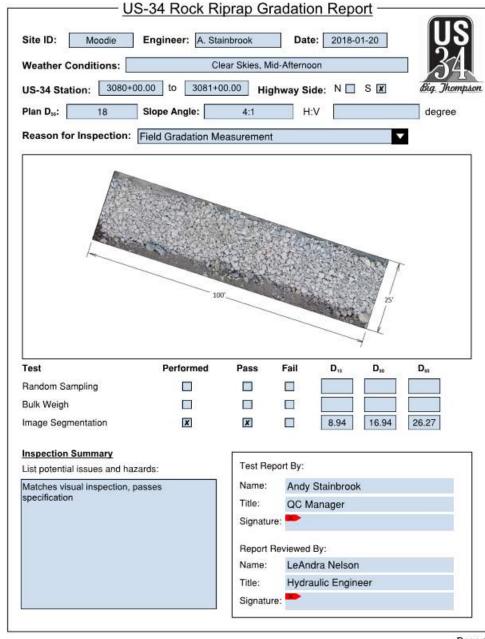


Gradation Analysis

• 18" Riprap Gradation Moodie East



KieTrac Documentation Form

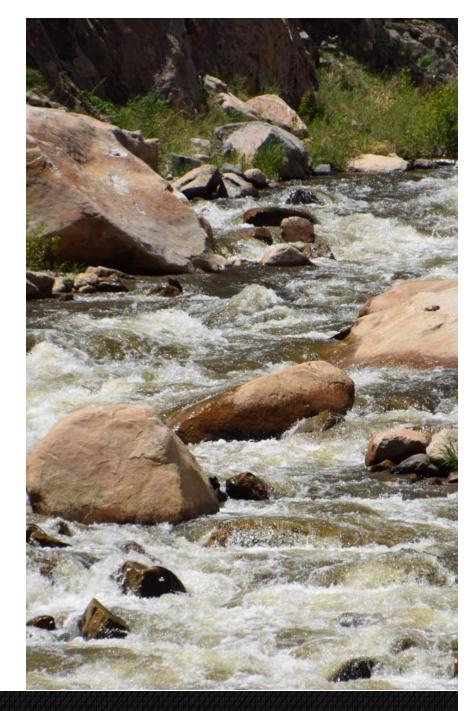


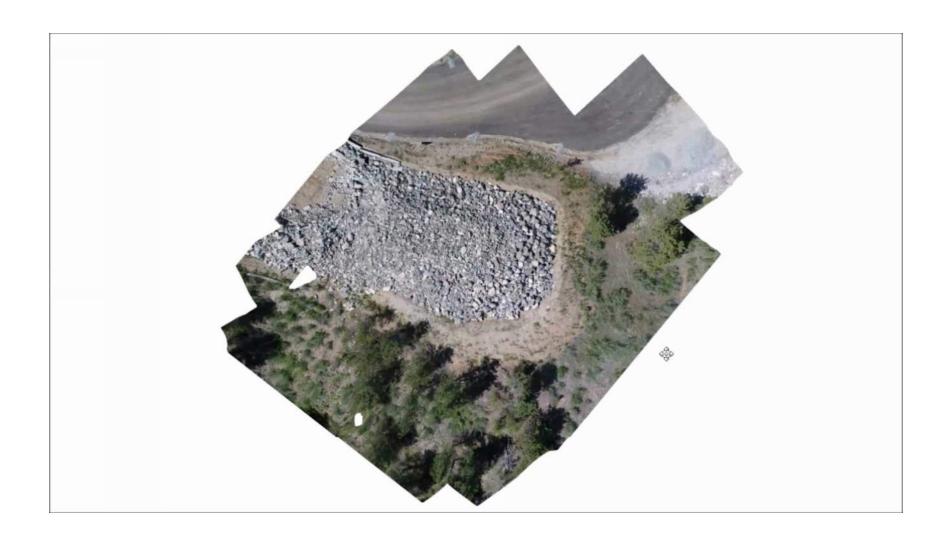
Page 1



Image Segmentation Conclusions

- Larger sample size
- Better gradation analysis
- Easy to integrate with drone survey
- Independent QC met
- Build right the first time
- Reduce risk
- Safety







Point Cloud Applications

- Quantity take-off
- Quality assurance
- Work planning
- Bridge clearances
- Automatic object identification



"Growth and improvement are not likely to occur unless we are willing to try something we have not done before. Sometimes the effort fails – but it is the reaching, the striving, the divine discontent that builds confidence and generates greater strength and knowledge."

Peter Kiewit



Acknowledgements

- George Cotton, PE Kiewit Engineering Group / Chief Hydraulic Engineer
- Ben Constable Kiewit Engineering Group / VDC Coordination Manager
- Jim Brinkman Kiewit Engineering Group / VDC Civil Designer
- Karl Pearson Kiewit Central District / US-34 Survey Chief





Questions?











