2013 Colorado Flood Recovery: A Case Study in Riverine/Fluvial NNBF Applications

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Outline

- Background on Colorado's 2013 Floods
- The Colorado Stream Bioengineering Guide
- The Colorado Revegetation Matrix
- Example Restoration Projects
- Insights on NNBF Riverine/Fluvial Applications
- Insights on Community & Stakeholder Engagement

Colorado's Catastrophic 2013 Floods

- Nearly $4 billion in damage
- CO's costliest natural disaster
- Caused damage across 24 counties
- Displaced 18,000 people
- Destroyed 1,800 homes

Photos: J. Giordanengo & Denver Post

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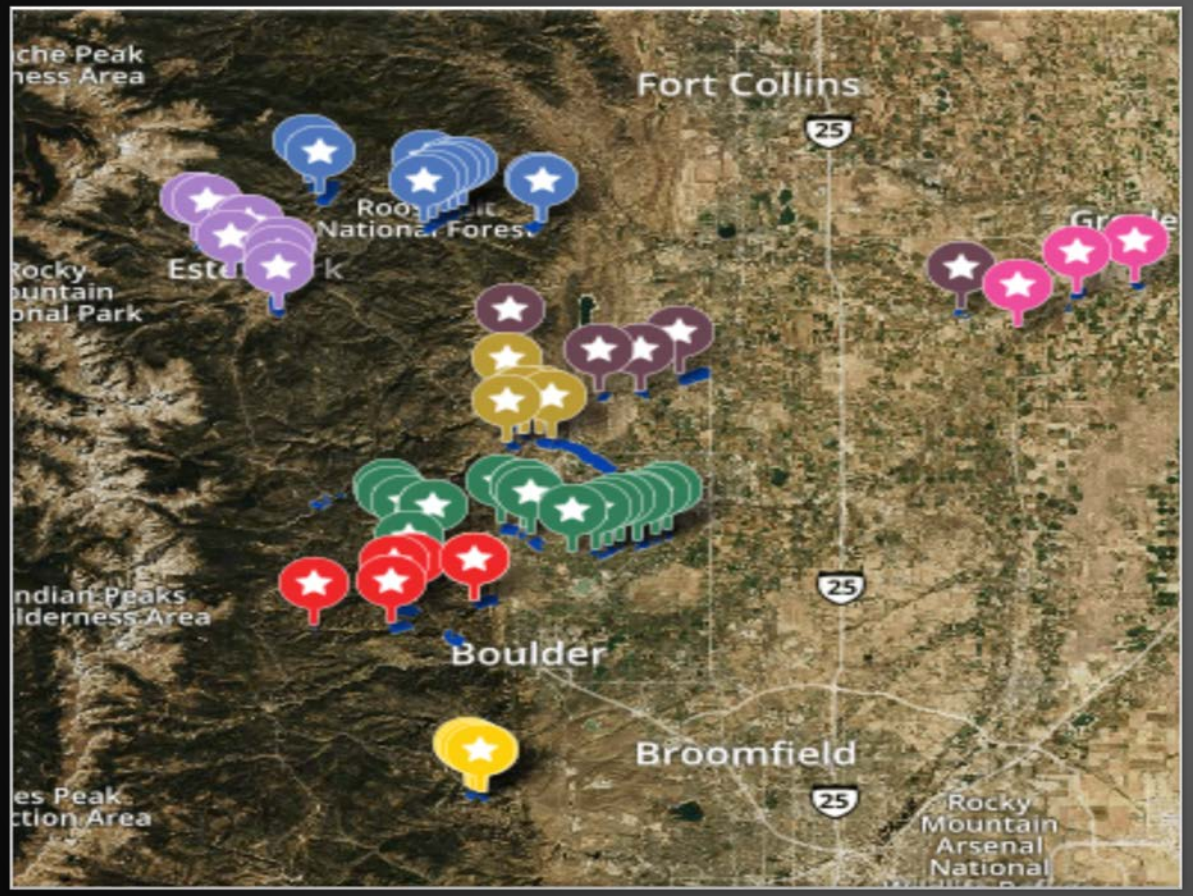
The Response: Colorado Water Conservation Board (CWCB)

"THIS WAS A NEW WAY OF DOING BUSINESS. WE TOOK A DIFFERENT, MORE HOLISTIC APPROACH AND WE'RE EXCITED TO SEE THE RESULTS ON THE GROUND."

-KEVIN HOUCK, CWCB

Colorado Emergency Watershed Protection (EWP) Program



- EWP funds were allocated to NRCS
- Program was administered and managed by CWCB
- Federal funds provided reimbursement for 75% of construction
- CWCB's management of the $70 million program begin in 2015 and ended in 2018

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The Response: A Bioengineering Guide for Colorado Streams

LIVING STREAMBANKS

A Manual of Bioengineering Treatments for Colorado Streams

Submitted To: State of Colorado, Colorado Water Conservation Board
1313 Sherman St, Room 718
Denver, CO 80201

Submitted By: AloTerra Restoration Services, LLC, and
Golder Associates, Inc.

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DRAFT Date: April 12, 2016

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A Bioengineering Guide for Colorado Streams

- **Bioengineering:** the integration of living woody and herbaceous materials along with organic and inorganic materials to increase the strength and structure of the soil
  - J. Chris Hoag (1998)

- **Purpose of Guide:** to provide restoration practitioners with guidelines for planning, design, and construction of streambank protection optimized for the conditions specific to Colorado's watersheds.

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A Bioengineering Guide for Colorado Streams

- Intent of Guide
  - Provide guidelines for comprehensive restoration strategy
  - Incorporate design elements that impart site stability
  - Include recommendations that minimize risks during vulnerable periods

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The Colorado Revegetation Matrix

- Includes prioritized woody, forb, and graminoid species based on feedback from multiple agencies and groups
- Incorporates 51 searchable parameters
  - Nomenclature
  - County
  - Hydrology/physiographic preference
  - Morphology
  - Germination data

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The Colorado Revegetation Matrix

- Included within morphology are root parameters that allow better incorporation in bioengineering techniques

- Also includes germination protocols, average seed weights, storage recommendations, and implementation preferences

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Plant Species in Flood Affected Areas - Colorado

Click "Enable Content" in the yellow bar below the ribbon when you first open the database.

Search Plant Species by:

- Nomenclature (Scientific and Common Name)
- Conservation (Status and C-Value)
- Occurrence
- Ecology
- Priority
- Implementation Plant Material
- Growth Form and Attributes
- Nursery Propagation
- Root System
- Wildlife and Livestock Attributes
- Wetland Status
- Notes

Reference Information:

- Citations
- Data Table Column Descriptions

Version 1.1, Updated May 2016

Close Database

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Search Plant Species by Occurrence

Return to Main Page

Search Criteria:

This form is used to search for plant species in flood affected areas that are found in Colorado by occurrence. Enter the search criteria in the boxes below. Click the filter button to apply the criteria. Click the remove filter button to remove all criteria values. If no criteria is applied for a specific topic, then all options for that topic will be included in the results. A list of the results is provided under Summary of Results and a table with all of data table columns can be exported to Excel by clicking "Export Results to Excel."

Search for Plant(s) that meet the following criteria:

Native Status: *Leave blank if yes or no.*

Elevation Range (feet) to

County Occurrence:

Adams	Boulder	Costilla	Douglas	Gilpin	Jefferson	Las Animas	Montezuma	Phillips	Routt	Teller
Alamosa	Broomfield	Crowley	Eagle	Grand	Kiowa	Lincoln	Montrose	Pitkin	Saguache	Washington
Arapahoe	Chaffee	Custer	El Paso	Gunnison	Kit Carson	Logan	Morgan	Prowers	San Juan	Weld
Archuleta	Cheyenne	Delta	Elbert	Hinsdale	La Plata	Mesa	Otero	Pueblo	San Miguel	Yuma
Baca	Clear Creek	Denver	Fremont	Huerfano	Lake	Mineral	Ouray	Rio Blanco	Sedgwick	
Bent	Conejos	Dolores	Garfield	Jackson	Larimer	Moffat	Park	Rio Grande	Summit	

Summary of Results:

Export Results to Excel

The exported data table includes all columns of data, not just the subset of the table columns shown belo

Type	Scientific Name	Common Name	PLANTS Code	Native Status	Elevation Range (ft)	County Occurrence
woody species	Acer glabrum Torr.	Rocky Mountain maple	ACGL	yes	5,200 to 10,500	Alamosa, Archuleta, Boulder, Chaffee, Clear Creek, Conejos, Costilla, Custer, Delta, Denver, Dolores, Douglas, Eagle, El Paso, Fremont,
woody species	Acer negundo L. ssp. interius (Britton) Sarg.	boxelder	ACNEI2	yes or no,	4,800 to 7,900	Adams, Alamosa, Arapahoe, Archuleta, Baca, Bent, Boulder, Chaffee, Clear Creek, Costilla, Custer, Delta, Denver, Dolores, Douglas, Eagle,
forb	Achillea millefolium L. var. occidentalis DC.	western yarrow; common yarrow	ACMIO	yes	4,800 to 13,200	Adams, Alamosa, Arapahoe, Archuleta, Boulder, Chaffee, Cheyenne, Clear Creek, Conejos, Costilla, Custer, Denver, Dolores, Douglas,
graminoid	Achnatherum hymenoides (Roemer &	Indian ricegrass; Indian mountain	ACHY	yes	3,400 to 10,000	Adams, Alamosa, Arapahoe, Archuleta, Baca, Bent, Boulder, Chaffee, Cheyenne, Clear Creek, Conejos, Costilla, Crowley, Custer, Delta,
graminoid	Achnatherum lettermanii (Vasey)	Letterman's needlegrass	ACLE9	yes	6,000 to 12,500	Boulder, Chaffee, Costilla, Delta, Dolores, Eagle, Garfield, Gilpin, Grand, Gunnison, Hinsdale, Jackson, Larimer, Las Animas, Mesa,
graminoid	Achnatherum nelsonii	Columbia needlegrass	ACNE9	yes	6,000 to 13,000	Alamosa, Archuleta, Boulder, Chaffee, Clear Creek, Conejos, Costilla

Search Plant Species by Ecology

Return to Main Page

Search Criteria:

This form is used to search for plant species in flood affected areas that are found in Colorado by ecology. Enter the search criteria in the boxes below. Click the filter button to apply the criteria. Click the remove filter button to remove all criteria values. If no criteria is applied for a specific topic, then all options for that topic will be included in the results. A list of the results is provided under Summary of Results and a table with all of data table columns can be exported to Excel by clicking "Export Results to Excel."

Search for Plant(s) that meet the following criteria:

Habitat contains:

Hydrologic preference contains:

Soil texture contains:

pH Range (std. units): to

Nitrogen Fixer: *Leave blank if yes or no.*

Ecological Zone: bank, mesic to upland, overbank, toe, transitional, upland

Successional Tier: early-seral, mid-seral, late-seral, sub-dominant, co-dominant, dominant

Aspect Preference: No preference, all aspects, variable within range, south, north, west, east, non-specific

Acidic Tolerance: tolerant, moderate, medium, intolerant

Alkalinity Tolerance: tolerant, moderate, medium, intolerant

Sodicity Tolerance: tolerant, moderate, moderately intolerant, intolerant

Drought Tolerance: tolerant, moderate, highly tolerant, intolerant

Shade Tolerance: tolerant, moderate, medium, intolerant

Summary of Results:

Export Results to Excel

The exported data table includes all columns of data, not just the subset of the table columns shown belo

Type	Scientific Name	Common Name	PLANTS Code	Habitat	Ecological Zone	Hydrologic Preference	Successional Tier	pH preference	Aspect Preference	Soil Texture	Acidic Tolerance	Alkalinity Tolerance	Sodicity Tolerance	Drought Toleran
woody species	Acer glabrum Torr.	Rocky Mountain maple	ACGL	Along streams,	overbank zone;	mesic	early-seral sub-dominant	5.8 to 7.5	northern aspect optimal	Silty, loamy, sandy, gravely, and rocky	tolerant	moderate	intolerant	moderate
woody species	Acer negundo L. ssp. interius (Britton) Sarg.	boxelder	ACNEI2	Riparian areas,	overbank zone;	mesic	early-seral dominant, co-	5.2 to 7.0	non-specific	Gravely to clay soils, but prefers deep	moderate	moderate	intolerant	tolerant
forb	Achillea millefolium L. var. occidentalis DC.	western yarrow; common yarrow	ACMIO	Common in gravelly	transitional zone; upland	mesic to xeric	early-seral dominant or sub-	6.0 to 8.0	southern and western	Shallow, silty, gravelly, and silty	moderate	tolerant	moderate	tolerant
graminoid	Achnatherum hymenoides (Roemer &	Indian ricegrass; Indian mountain	ACHY	Desert, plains,	upland zone	xeric	early-seral, mid-seral or late-seral	6.6 to 8.6	southern and western	Coarse to medium-coarse textured	intolerant	tolerant	intolerant	tolerant
graminoid	Achnatherum lettermanii (Vasey)	Letterman's needlegrass	ACLE9	Common in	upland zone	xeric to mesic	early-seral, mid-seral or late-seral	6.0 to 7.6	non-specific	Medium coarse to silt loam, clay loam, or	intolerant	moderate	intolerant	tolerant

Search Plant Species by Growth Form and Attributes

Return to Main Page

Search Criteria:

This form is used to search for plant species in flood affected areas that are found in Colorado by growth form and attributes. Enter the search criteria in the boxes below. Click the filter button to apply the criteria. Click the remove filter button to remove all criteria values. If no criteria is applied for a specific topic, then all options for that topic will be included in the results. A list of the results is provided under Summary of Results and a table with all of data table columns can be exported to Excel by clicking "Export Results to Excel."

Search for Plant(s) that meet the following criteria:

Growth Form: ☐ subshrub ☐ shrub ☐ shrub to small tree ☐ large shrub to small tree ☐ tree ☐ small tree ☐ graminoid ☐ herbaceous dicot ☐ herbaceous monocot

Duration: ☐ annual ☐ biennial ☐ perennial

Season: ☐ cool ☐ warm

Summary of Results:

Export Results to Excel

The exported data table includes all columns of data, not just the subset of the table columns shown belo

Type	Scientific Name	Common Name	PLANTS Code	Growth Form	Duration	Season
woody species	Acer glabrum Torr.	Rocky Mountain maple	ACGL	shrub to small tree	perennial	cool season
woody species	Acer negundo L. ssp. interius (Britton) Sarg.	boxelder	ACNEI2	tree	perennial	cool season
forb	Achillea millefolium L. var. occidentalis DC.	western yarrow; common yarrow	ACMIO	herbaceous dicot	perennial	cool season
graminoid	Achnatherum hymenoides (Roemer & J.A. Schultes) Barkworth	Indian ricegrass; Indian mountain ricegrass	ACHY	graminoid	perennial	cool season
graminoid	Achnatherum lettermanii (Vasey) Barkworth	Letterman's needlegrass	ACLE9	graminoid	perennial	cool season
graminoid	Achnatherum nelsonii (Scribn.) Barkworth	Columbia needlegrass	ACNE9	graminoid	perennial	cool season
graminoid	Achnatherum nelsonii (Scribn.) Barkworth ssp. dorei (Barkworth &	Dore's needlegrass; Columbia needlegrass	ACNED	graminoid	perennial	cool season
forb	Agastache urticifolia(Benth.) Kuntze	nettleleaf giant hyssop; field	AGUR	herbaceous dicot	perennial	cool season

Search Plant Species by Wetland Status

Return to Main Page

Search Criteria:

This form is used to search for plant species in flood affected areas that are found in Colorado by wetland status. Enter the search criteria in the boxes below. Click the filter button to apply the criteria. Click the remove filter button to remove all criteria values. If no criteria is applied for a specific topic, then all options for that topic will be included in the results. A list of the results is provided under Summary of Results and a table with all of data table columns can be exported to Excel by clicking "Export Results to Excel."

Search for Plant(s) that meet the following criteria:

Status:

- [ ] AW (FAC)
- [ ] AW (FACU)
- [ ] AW (FACW)
- [ ] AW (OBL)
- [ ] AW (UPL)
- [ ] AW (-)
- [ ] GP (FAC)
- [ ] GP (FACU)
- [ ] GP (FACW)
- [ ] GP (OBL)
- [ ] GP (UPL)
- [ ] GP (-)
- [ ] WMVC (FAC)
- [ ] WMVC (FACU)
- [ ] WMVC (FACW)
- [ ] WMVC (OBL)
- [ ] WMVC (UPL)
- [ ] not listed

USACE Regions:
AW = Arid West
GP = Great Plains
WMVC = Western Mountains, Valleys and Canyons

Indicator Codes:
OBL = Obligate Wetland (designated hydrophyte), almost always occurs in wetlands
FACW = Facultative Wetland (designated hydrophyte), usually occurs in wetlands, but may occur in non-wetlands
FAC = Facultative (designated hydrophyte), occurs in wetlands and non-wetlands
FACU = Facultative Upland (designated non-hydrophyte), usually occurs in non-wetlands, but may occur in wetlands

Summary of Results:

Export Results to Excel

The exported data table includes all columns of data, not just the subset of the table columns shown belo

Type	Scientific Name	Common Name	PLANTS Code	USACE National Wetland Plant List Indicator Stat
woody species	Acer glabrum Torr.	Rocky Mountain maple	ACGL	AW (FAC), GP (FAC), WMVC (FACU)
woody species	Acer negundo L. ssp. interius (Britton) Sarg.	boxelder	ACNEI2	AW (FACW), GP (FAC), WMVC (FAC)
forb	Achillea millefolium L. var. occidentalis DC.	western yarrow; common yarrow	ACMIO	AW (FACU), GP (FACU), WMVC (FACU)
graminoid	Achnatherum hymenoides (Roemer & J.A. Schultes) Barkworth	Indian ricegrass; Indian mountain ricegrass	ACHY	AW (UPL), GP (FACU), WMVC (UPL)
graminoid	Achnatherum lettermanii (Vasey) Barkworth	Letterman's needlegrass	ACLE9	not listed
graminoid	Achnatherum nelsonii (Scribn.)	Columbia needlegrass	ACNE9	AW (FACU), GP (UPL), WMVC (UPL)

Search Plant Species by Implementation Plant Material

Return to Main Page

Search Criteria:

This form is used to search for plant species in flood affected areas that are found in Colorado by project implementation plant material. Enter the search criteria in the boxes below. Click the filter button to apply the criteria. Click the remove filter button to remove all criteria values. If no criteria is applied for a specific topic, then all options for that topic will be included in the results. A list of the results is provided under Summary of Results and a table with all of data table columns can be exported to Excel by clicking "Export Results to Excel."

Search for Plant(s) that meet the following criteria:

Project Implementation Plant: ☐ container ☐ cutting ☐ rhizome ☐ seed ☐ vegetative planting

Summary of Results:

Export Results to Excel

The exported data table includes all columns of data, not just the subset of the table columns shown belo

Type	Scientific Name	Common Name	PLANTS Code	Project Implementation Plant Materials
woody species	Acer glabrum Torr.	Rocky Mountain maple	ACGL	container
woody species	Acer negundo L. ssp. interius (Britton) Sarg.	boxelder	ACNEI2	container
forb	Achillea millefolium L. var. occidentalis DC.	western yarrow; common yarrow	ACMIO	seed, container
graminoid	Achnatherum hymenoides (Roemer & J.A. Schultes) Barkworth	Indian ricegrass; Indian mountain ricegrass	ACHY	seed
graminoid	Achnatherum lettermanii (Vasey) Barkworth	Letterman's needlegrass	ACLE9	seed
graminoid	Achnatherum nelsonii (Scribn.) Barkworth	Columbia needlegrass	ACNE9	seed
graminoid	Achnatherum nelsonii (Scribn.) Barkworth ssp. dorei (Barkworth & Maze) Dorn	Dore's needlegrass; Columbia needlegrass	ACNED	seed
forb	Agastache urticifolia(Benth.) Kuntze var. urticifolia	nettleleaf giant hyssop; field horsemint	AGUR	container
forb	Allium acuminatum Hook.	tapertip onion	ALAC4	container

Search Plant Species by Root System

Return to Main Page

Search Criteria:

This form is used to search for plant species in flood affected areas that are found in Colorado by root system. Enter the search criteria in the box below. Click the filter button to apply the criteria. Click the remove filter button to remove all criteria values. If no criteria is applied, then all options for that topic will be included in the results. A list of the results is provided under Summary of Results and a table with all of data table columns can be exported to Excel by clicking "Export Results to Excel."

Search for Plant(s) that meet the following criteria:

Root System: ☐ cespitose (non-spreading) ☐ spreading ☐ rhizomatous/rhizomes/stoloniferous ☐ taproot/caudex ☐ hemiparasitic ☐ bulb ☐ unknown

Summary of Results:

Export Results to Excel

The exported data table includes all columns of data, not just the subset of the table columns shown belo

Type	Scientific Name	Common Name	PLANTS Code	Root System
woody species	Acer glabrum Torr.	Rocky Mountain maple	ACGL	Wide-spreading root system with combination of deep and lateral roots. Readily sprouts from root crown.
woody species	Acer negundo L. ssp. interius (Britton) Sarg.	boxelder	ACNEI2	Wide-spreading root system with combination of deep and lateral roots. Readily sprouts from root crown. Produces many suckers.
forb	Achillea millefolium L. var. occidentalis DC.	western yarrow; common yarrow	ACMIO	Shallow with extensive rhizomes.
graminoid	Achnatherum hymenoides (Roemer & J.A. Schultes) Barkworth	Indian ricegrass; Indian mountain ricegrass	ACHY	Cespitose with extensive fibrous roots.
graminoid	Achnatherum lettermanii (Vasey) Barkworth	Letterman's needlegrass	ACLE9	Cespitose with extensive fibrous roots (up to 3 ft in depth).
graminoid	Achnatherum nelsonii (Scribn.) Barkworth	Columbia needlegrass	ACNE9	Cespitose with extensive fibrous roots (up to 3 ft in depth).
graminoid	Achnatherum nelsonii (Scribn.) Barkworth ssp. dorei (Barkworth &	Dore's needlegrass; Columbia needlegrass	ACNED	Cespitose with extensive fibrous roots (up to 3 ft in depth).
forb	Agastache urticifolia(Benth.) Kuntze var. urticifolia	nettleleaf giant hyssop; field horsemint	AGUR	Lateral, spreading roots.
forb	Allium acuminatum Hook.	tapertip onion	ALAC4	Lateral, spreading roots.

Search Plant Species by Nursery Propagation

Return to Main Page

Search Criteria:

This form is used to search for plant species in flood affected areas that are found in Colorado by nursery propagation. Enter the search criteria in the boxes below. Click the filter button to apply the criteria. Click the remove filter button to remove all criteria values. If no criteria is applied for a specific topic, then all options for that topic will be included in the results. A list of the results is provided under Summary of Results and a table with all of data table columns can be exported to Excel by clicking "Export Results to Excel."

Search for Plant(s) that meet the following criteria:

Nursery Propagule: ☐ cutting ☐ division ☐ rhizome ☐ seed ☐ plantlet

Relative Difficulty to Propagate: ☐ easy ☐ moderate ☐ intermediate ☐ difficult

Project Implementation Plant Materials Type: ☐ container ☐ cutting ☐ rhizome ☐ seed ☐ vegetative planting

Seed Collection Time: [ ] to [ ]

Seed Periodicity (years): [ ] to [ ] *Values range from 0 to 10 years.*

Average Cleaned Seed Weight (seeds/lb): [ ] to [ ]

Minimum Seed Viability in Proper Storage* (years): [ ] **approx. 40°F and under 10% humidity*

Germination/Vegetative Protocol contains: [ ]

*approx. 40°F and under 10% humidity

Summary of Results:

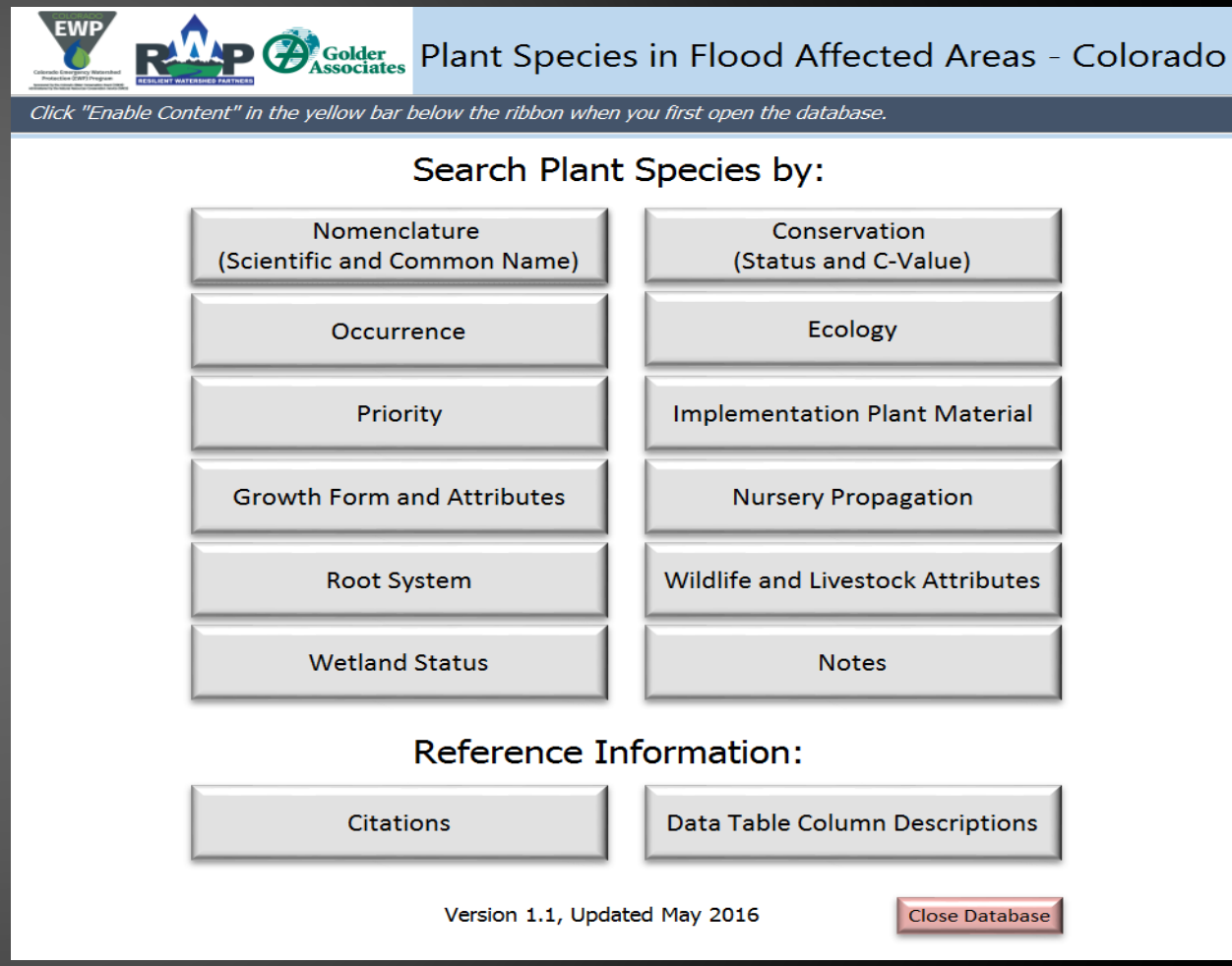
Export Results to Excel

The exported data table includes all columns of data, not just the subset of the table columns shown belo

Type	Scientific Name	Common Name	PLANTS Code	Nursery Propagule	Relative Difficulty to	Project Impl. Plant Materials	Seed Collection	Seed Periodicity	Average Cleaned Seed Weight	Seed Viability in Proper Storage*	Germination/ Vegetative Protoc
woody species	Acer glabrum Torr.	Rocky Mountain maple	ACGL	seed	intermediate	container	mid-September to late-October	1 to 3 years	7,820 to 20,300 seeds/lb (avg. 13,430	2 years	Seed: 75°F distilled H2O (4h); 70°F
woody species	Acer negundo L. ssp. interius (Britton) Sarg.	boxelder	ACNEI2	seed	easy	container	mid-September	annually	8,200 to 20,400 seeds/lb (avg. 13,400	2 years	Seed: 75°F distilled H2O (4h); 40°F cold
forb	Achillea millefolium L. var. occidentalis DC.	western yarrow; common yarrow	ACMIO	seed	easy	seed, container	August through September	annually	2,740,670 to 4,124,000 seeds/lb	2 years	Seed: Dry sow seed; 80°F
graminoid	Achnatherum hymenoides (Roemer & J.A. Schultes)	Indian ricegrass; Indian mountain ricegrass	ACHY	seed	difficult	seed	July through August	annually	128,482 to 235,000 seeds/lb	5 to 10 years	Seed: 212F distilled H2O (20s); 75°F

The Colorado Revegetation Matrix

- Matrix incorporates over 419 documents:
  - PLANTS Database
  - Biota of North America Project (BONAP)
  - NWPL/Lichvar/Army Corps of Engineers
  - Flora of Colorado (Ackerfield)
  - Colorado Flora (Weber and Whitman)



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Stream Bioengineering Equations

Root parameters can be applied to:

- **Annandale Erodibility Index (2006)**

$$K = M_s * K_b * K_d * J_a$$

Where: M_s - mass strength; K_b - block size; K_d - discontinuity bond shear strength; and J_a - relative ground structure.

$$K_b = 1000D^3$$

Block size = 1000 * root dimension^3

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Stream Bioengineering Equations

The simple perpendicular model is based on the Coulomb equation:

$$S_r = \acute{c} + (\sigma - \mu) \tan \varphi'$$

Root paramaters can be applied to:

- **<u>Waldron Model (1977), as modified by Wu, McKinnell, & Swanston (1979) (as described in Simon et al. 2006)</u>**

- **Where: S_r = shear strength (kPa), $\acute{C}$ = effective cohesion (kPa), σ = normal stress (kPa), μ = pore pressure (kPa), and φ' = angle of internal friction in degrees**

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Stream Bioengineering Equations

Waldron Model (1977), as modified by Wu, McKinnell, & Swanston (continued):

$$\Delta S = T_r (A_R/A)\ 1.2$$

- As such, the shear strength of the roots (ΔS) is calculated through use of the root tensile strength and the cross section of the roots relative to the area of the shear surface

- Where: T_r = root tensile strength (kPa), A_R/A = root area ratio (dimensionless), A = soil area (m^2), A_R = root area (m^2), and *1.2* = value that accounts for the angle of shear distortion and soil friction in degrees (Wu et al., 1979; Simon et al., 2006)

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Development of the Germination Protocols

Photo courtesy of E. Schmidt

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U68 container, vegetative planting

	A	U	V	W	X	Y	Z	AA	AB	AC	AD
1	**Scientific Name** (A)	**Project Implementation Plant Materials Type** (U)	**Seed Collection Time** (V)	**Seed Periodicity** (W)	**Average Cleaned Seed Weight** (X)	**Seed Viability in Proper Storage (approx. 40°F and under 10% humidity)** (Y)	**Germination/ Vegetative Protocol** (Z)	**C-Value** (AA)	**pH preference** (AB)	**Aspect Preference** (AC)	**Soil Texture** (AD)
68	*Salix geyeriana* Anderss.	container, vegetative planting	mid-spring as cotton is appearing on female catkins (April through May)	annually	estimated at 11,500,000 cleaned seeds/lb	recalcitrant (little to no shelf-life)	Seed: Seed must be fresh-collected and direct sowed, as it has minimal shelf life. 75°F distilled H20(2h); 80°F greenhouse (8-10d emergence). Seed should be lightly covered with germination mix. Cutting - semi-hardwood: no pre-soak; gel rooting mix 70°F greenhouse (30d). Cutting - hardwood: (dormant stems ½ to 1¼" width, 12-24" length, bottom diagonally cut); soak 5-10d; gel rooting mix 55-60°F (30d).	6	6.5 to 7.5	non-specific	Cobbles and grav sandy or clay loa Alluvial soils.
	Salix glauca L.	container	mid- to late-spring as cotton is appearing on female catkins (mid-April through mid-June)	annually	10,000,000 cleaned seeds/lb	recalcitrant (little to no shelf-life)	Seed: Seed must be fresh-collected and direct sowed, as it has minimal shelf life. 75°F distilled H20(2h); 80°F greenhouse (8-10d emergence). Seed should be lightly covered with germination mix. Cutting - semi-hardwood: no pre-soak; gel rooting mix 70°F greenhouse (30d). Cutting - hardwood: (dormant stems ½ to 1¼" width, 12-24" length, bottom	8	5.5 to 7.5	non-specific	Cobbles and grav sandy or clay loa Alluvial soils.

Sheet1 Sheet2 Sheet3

U68 container, vegetative planting

	A	U	V	W	X	Y	Z	AA	AB	AC	AD
1	**Scientific Name** (A)	**Project Implementation Plant Materials Type** (U)	**Seed Collection Time** (V)	**Seed Periodicity** (W)	**Average Cleaned Seed Weight** (X)	**Seed Viability in Proper Storage (approx. 40°F and under 10% humidity)** (Y)	**Germination/ Vegetative Protocol** (Z)	**C-Value** (AA)	**pH preference** (AB)	**Aspect Preference** (AC)	**Soil Texture** (AD)
23	*Carex nebrascensis* Dewey	container	August to early-October	annually	450,000 seeds/lb with perigynia intact; 800,000 to 912,000 seeds/lb with perigynia removed	2 to 3 years	Seed: 75°F distilled H20(24h); 40°F cold stratification (85d or until radical emergence); 90°F greenhouse (emergence 8-12d). Seed should be covered with germination mix (1/16" depth). Division: Divide in a manner that maintains the maximum amount of root material without compromising the integrity of root culm through over-division. Materials should be divided while young, such as that culms are small and easily transplantable. Once divided, materials should be maintained at 65-70°F within the greenhouse for 12 to 15 weeks until no soil sloughs from the plug upon removal from the container.	5	5.7 to 8.5	non-specific	Medium coarse moderately fine soils.
	Carex pellita Muhl. ex Willd.	container	mid-August through early October	every 2 years	236,000 to 312,075 seeds/lb	2 to 3 years	Seed: 75°F distilled H20(24h); 40°F cold stratification (100d or until radical emergence); 90°F greenhouse	6	6.0 to 8.5	non-specific	Medium coarse medium fine soil

Sheet1 Sheet2 Sheet3

U68 container, vegetative planting

	A	U	V	W	X	Y	Z	AA	AB	AC	AD
1	**Scientific Name** (A)	**Project Implementation Plant Materials Type** (U)	**Seed Collection Time** (V)	**Seed Periodicity** (W)	**Average Cleaned Seed Weight** (X)	**Seed Viability in Proper Storage (approx. 40°F and under 10% humidity)** (Y)	**Germination/ Vegetative Protocol** (Z)	**C-Value** (AA)	**pH preference** (AB)	**Aspect Preference** (AC)	**Soil Texture** (AD)
127	*Delphinium x occidentale* (S. Wats.) S. Wats. (pro sp.) [*barbeyi x glacum*]	container	August through September	annually	500,000 seeds/lb	1 to 2 years	Seed: Most successful protocol to date is to sew seed directly to 10 ci plugs in November that are filled with 3:1:1 peat:vermiculite:perlite blend and treated with rootguard. Once seed is sewn top with light cover of pea gravel and store outside. Germination begins in March. Containers are watered only during dry periods. Plants are moved to the lath house in June and allowed to grow until the following season. Plants should be lightly insulated with reemay over second winter season, then are ready for planting by the beginning of the second growing season.	5	6.5 to 8.5	non-specific	Medium coarse medium fine loa
	Dodecatheon pulchellum (Raf.) Merr.	container	July through mid-August	2 to 3 years	4,303,920 seeds/lb	2 to 3 years	Seed: 75°F distilled H20(1h); 40°F cold stratification (60 to 120d or until radical emergence); 80°F greenhouse (emergence 30d). Seed should be covered with germination mix (1/16" depth).	8	6.5 to 8.5	non-specific	Sandy to mediur soils.

Sheet1 Sheet2 Sheet3

The Colorado Revegetation Matrix

Application:

- NRCS/CWCB Emergency Watershed Protection
- 2013 Flood Impacted Areas
- 68 / 117 Projects Implemented by 2018
- Revegetation Guides / Planting Plans

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Broadview Estimated Planting Requirements

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Revegetation Area Poles and Stakes							
Scientific Name	Common Name	Percent of Mix	Material Type	Container Size	Plant Spacing	Number of Plants	
						Broadview 1	Broadview 2
Woody Species							
Populus angustifolia	narrowleaf cottonwood	15	Cutting	60-inch cutting	6-foot spacing	10	22
Salix exigua	narrowleaf willow	25	Cutting	48-inch cutting	6-foot spacing	16	37
Salix geyeriana	Geyer's willow	20	Cutting	48-inch cutting	6-foot spacing	13	30
Salix monticola	Rocky Mountain willow	20	Cutting	48-inch cutting	6-foot spacing	13	30
Salix ligulifolia	strapleaf willow	10	Cutting	48-inch cutting	6-foot spacing	7	15
Salix lucida ssp. caudata	whiplash willow	10	Cutting	48-inch cutting	6-foot spacing	7	15
Total		100				56	127

Broadview Seed							
Scientific Name	Common Name	Percent of mix	Seed number using 150 seeds/sq ft	Pure Live Seed (PLS) Weight	PLS lb Required per	PLS lbs Required Per	
						Broadview 1	Broadview 2
Herbaceous Dicot							
Campanula rotundifolia	harebell	2	3	7,250,000	0.02	0.10	0.10
Cleome serrulata	Rocky Mountain beeplant	2	3	87,250	1.50	0.11	0.32
Gaillardia aristata	blanketflower	2	3	217,000	0.60	0.04	0.13
Helianthus nuttallii	Nuttall's sunflower	2	3	217,000	0.60	0.04	0.13
Mertensia ciliata	alpine bluebells	2	3	1,000,000	0.13	0.10	0.10
Monarda fistulosa	wild bergamot	2	3	1,250,625	0.10	0.10	0.10
Solidago missouriensis	Missouri goldenrod	2	3	1,350,000	0.10	0.10	0.10
Graminoids							
Achnatherum hymenoides	Indian ricegrass	5	7.5	155,350	2.10	0.16	0.45
Elymus lanceolatus ssp. lanceolatus	thickspike wheatgrass	12	18	155,350	5.05	0.37	1.07
Elymus trachycaulus ssp. trachycaul	slender wheatgrass	4	6	147,500	1.77	0.13	0.38
Deschampsia caespitosa	tufted hairgrass	8	12	1,812,500	0.29	0.10	0.10
Glyceria striata	fowl mannagrass	8	12	170,000	3.07	0.23	0.65
Juncus arcticus ssp. littoralis	mountain rush	8	12	6,950,000	0.08	0.10	0.10
Juncus torreyi	Torrey rush	5	7.5	12,150,000	0.03	0.10	0.10
Nassella viridula	green needlegrass	8	12	152,117	3.44	0.25	0.73
Pascopyron smithii	western wheatgrass	10	15	133,000	4.91	0.36	1.04
Poa palustris	fowl bluegrass	10	15	2,078,000	0.31	0.10	0.07
Poa secunda	Sandberg bluegrass	8	12	902,500	0.58	0.20	0.12
Total		100	150		24.68	2.70	5.78

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RESILIENT WATERSHED PARTNERS

COLORADO EWP

Colorado Emergency Watershed Protection (EWP) Program

Sponsored by the Colorado Water Conservation Board (CWCB)
Administered by the Natural Resources Conservation Service (NRCS)

REVEGETATION AND BIOSTABLIZATION RECOMMENDATIONS FOR UPPER BIG THOMPSON RIVER RESTORATION AT ROCK AND ROLL

TECHNICAL MEMORANDUM

Submitted to:

Natural Resources Conservation Service
Denver Federal Center
Building 56, Room 2604
P.O. Box 25426
Denver, Colorado 80225

Date:

December 2, 2016

Prepared by

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BACKGROUND

The 2013 floods resulted in ongoing streambank erosions and sedimentation that are impacting residences, lodges, business, and bridges on this reach of the Upper Big Thompson River. The project proposes to remove and rework unstable sediment to reduce flood surfaces and store future sediment. Additionally, the project proposes to remove flood debris that has been left in the channel. It will provide and enhance bioengineering and existing rock toe protection to stabilize streambanks. A low-flow channel and rock clusters will be created to increase channel complexity and enhance fish habitat. Disturbed areas will be revegetated to enhance streambank stabilization.

PROJECT AREA DESCRIPTION

The Upper Big Thompson River Restoration at Rock and Roll is located in Larimer County, in the Estes Valley Watershed, just south of Highway 36 and directly abutting a business and residences. It is approximately 150 west of the Upper Big Thompson Livingston site. The project reach spans approximately 180 feet.

SEEDING, PLANTING, AND MULCHING

All seed and woody plant material recommendations were based on site elevation, county occurrence, hydrologic preference, topography, aspect preference, successional tier, habitat preference, soil texture, shade tolerance, and growth form, as well as attributes including root system structure and dimension (Ackerfield 2015, Mandel 2016). To maximize ecological fitness, all plant materials will be as ecotypic as possible. Ecotypic vegetation is beneficial in restoration efforts as it has co-evolved to live in local climates, soil types, and with local environmental pressures.

All seed should be from ecotypic sources, if possible, and should represent the species and quantities presented in TABLE 1. Any deviation from the recommended species and quantities should be cleared through the project restoration ecologist (R. Mandel and/or S. Copp Franz, Great Ecology). The contractor should apply the mix to all areas disturbed by restoration activities through broadcast seeding at a rate of 24.68 Pure Live Seed (PLS) lbs/ac, hand-raked to ⅛-to ¼-inch depth to minimize seed loss, then surface-pressed through a water-filed press-wheel to facilitate good seed-to-soil contact. All seed must be labeled as "certified" and should not include the presence of noxious or invasive species prohibited under the Colorado Seed Act (as indicated on the tag by the Colorado Seed Growers Association approved labeling). All seed should be inspected by the restoration ecologist and/or watershed coordinator prior to installation and all tags must be maintained for documentation by the watershed coordinator, or their designee. Prior to delivery, seed should be processed by the seed provider on a "gravity-table" to remove non-target seed types, such as yellow sweetclover (*Melilotus officinalis*), alfalfa (*Medicago sativa*), wood sorrel (*Oxalis acetosella*), and other potentially invasive species.

All seed recommendations are based on the 150 PLS per square foot, as determined on a percentage basis by species to facilitate ecological functionality, to minimize interspecific competition, and to promote proper revegetation. Once the seed has been properly applied to the site, the contractor should apply woodstraw or 24-moth biodegradable erosion control blankets within 24 hours of seed application as necessary. Biodegradable erosion control blanketing will be placed on graded portions of all zones. The remainder of the site will be applied with a 75% cover (5,000 lbs/ac) of woodstraw.

In addition to the seed mix, the contractor should install woody plant materials within the designated "Revegetation Area" (0.04 acre) located on the site. Woody plant materials will be planted in suites to create a mosaic based on site condition and submitted plan by the contractor. Recommended species and percentages are presented in TABLE 2. The exact location of live plant material will be based on final grading, as determined by Emergency Watershed Protection vegetation experts who will be onsite

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Ecotypic Plant Materials Are Key

- Ecotype: a genetically distinct geographic variety, population, or race within a species which is adapted to specific environmental conditions.

- Native: a species that occurs naturally in a particular site as determined by living (biotic) and non-living (abiotic) factors and was not introduced by human activities.

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Ecotypic Plant Materials Are Key

- Ecotypic plant materials are important because these plants:
  - Have improved site adaptability;
  - Improve water conservation;
  - Are less likely to become invasive;
  - Co-evolved with local site conditions such as hydrology and biophysiology, therefore tend to have greater resiliency to stress;
  - Tend to be more aesthetically aligned (display sense of place);
  - May be required by law, policy, or covenant; and
  - Tend to impart long-term improved economics through reduced maintenance and irrigation costs.

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Restoration Requirements

- Species were grouped by hydrologic and elevational preference.
- For the purposes of restoration design, a total of five distinct ecological zones were recognized:
  - Zone 1: Wetland (0 - 1 ft above low-flow water surface, 70 – 100% wet annually);
  - Zone 2: Riparian (1 - 3 ft above low-flow water surface, bankful, 40 – 70% wet annually);
  - Zone 3: Transitional (2 – 4 ft above low-flow water surface; 100 yr flood elevational 40% wet annually to bankful height);
  - Zone 4: Upland (4+ ft above low-flow water surface);
  - Zone 5: Overbank or swale.

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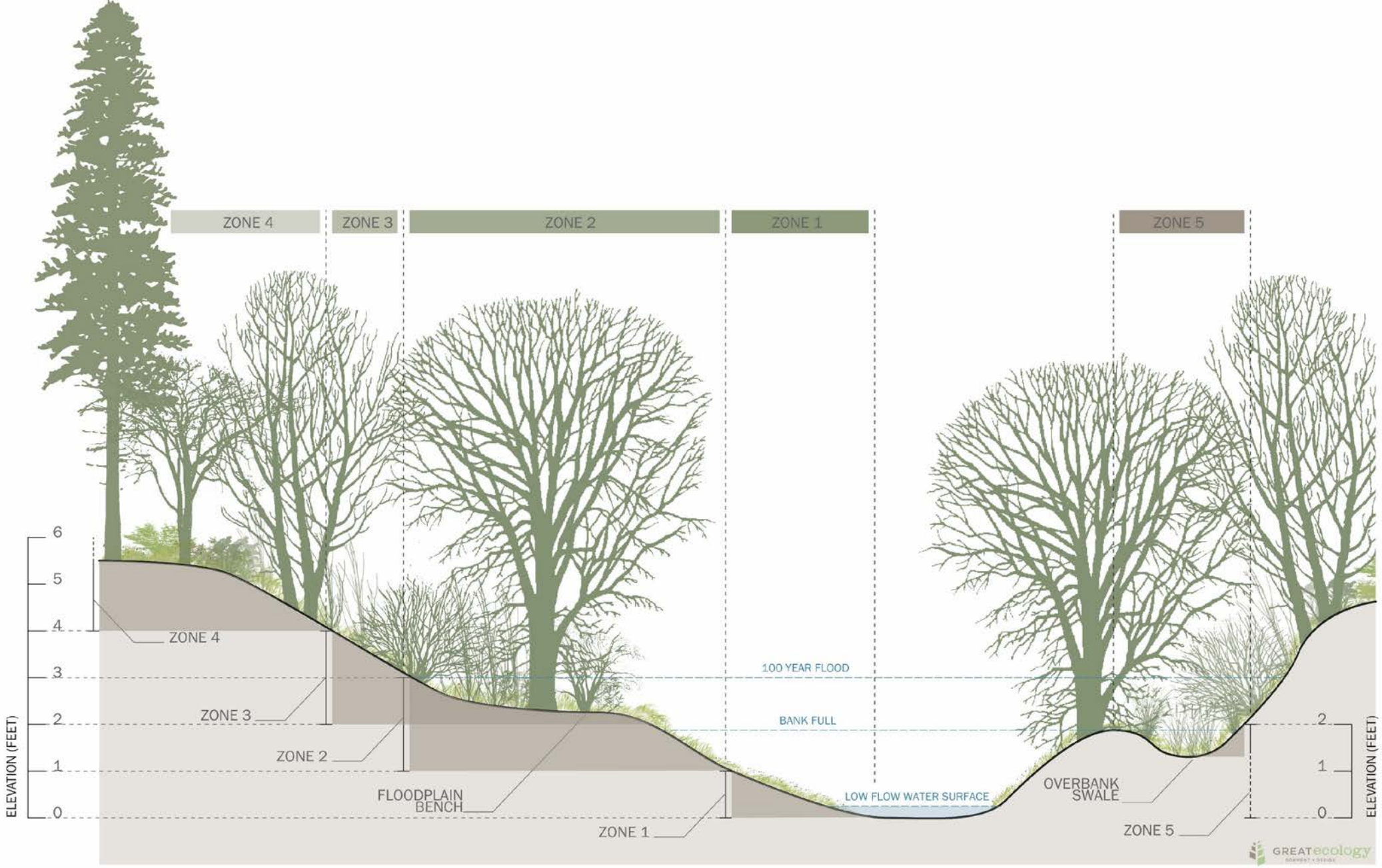

riparian planting zones 1 - 5 section view

EWP Restoration - not to scale

11.03.2016

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Plant Material Increase and Storage

Photos courtesy of R. Mandel

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Restoration Implementation

- The greatest challenges to date have been:
  - Timing and budget (always too tight and never enough);
  - Irrigation (plants like water);
  - Noxious and/or invasive species (limited budgets for control; water nexus);
  - Availability for some key species and need for cultural studies to improve production capabilities;
  - Availability of trained installation crews with consistent attention to planting detail; and
  - Long-term monitoring and its funding.

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2013 Flood Restoration: The Before

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The Implementation

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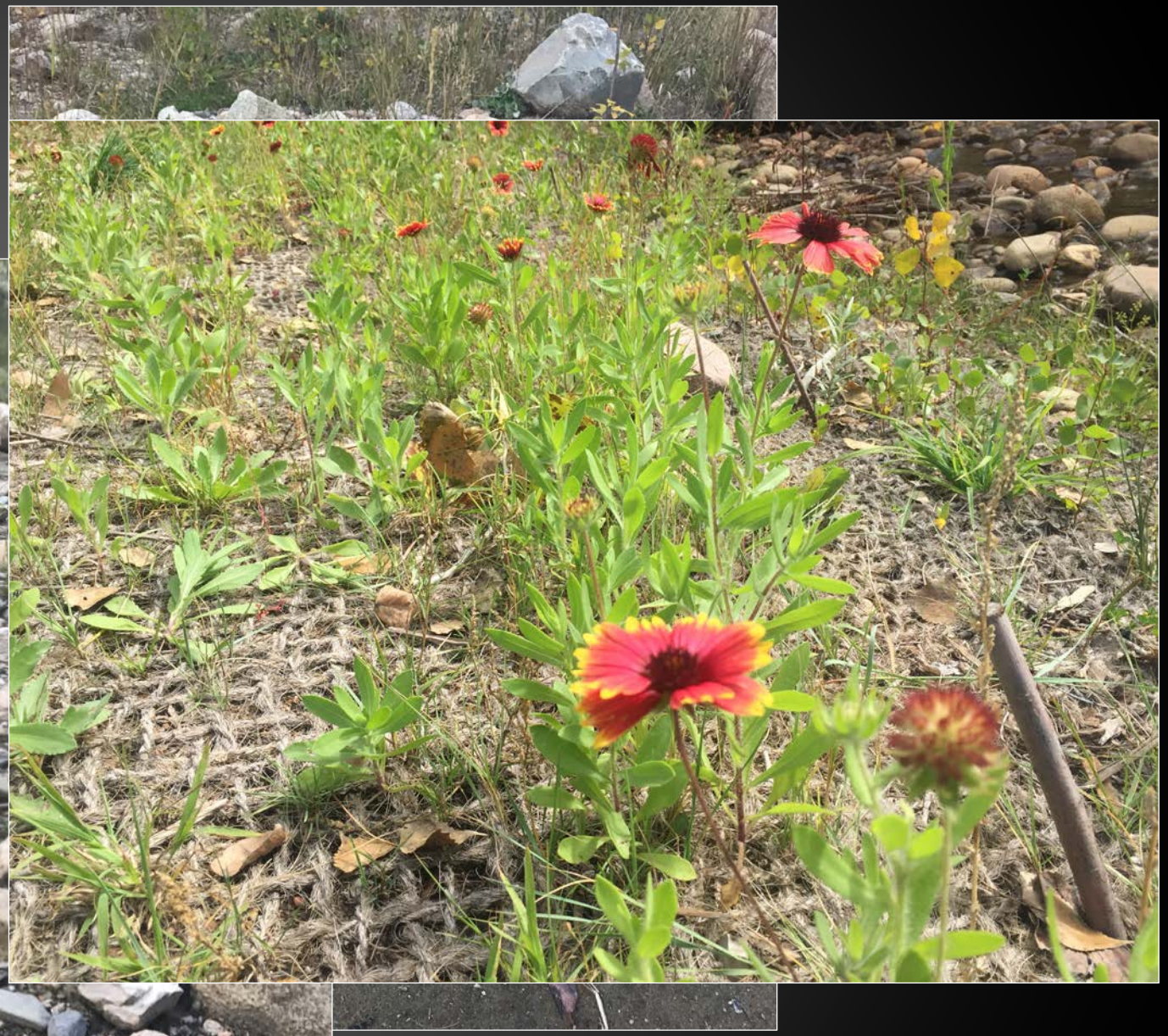
The Implementation



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2013 Flood Restoration: The After

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NNBF Riverine & Fluvial Application Summary

- Nature-Based Design
- Watershed Context
- Proactive Groundwater Measurement
- Hydrology-Based Grading
- Ecotypic Plant Materials
- Planting Techniques
  - By Hydrologic Zone
  - Bioengineering
  - Staking
  - Planting
  - Seeding
- Irrigation (Transitional/Upland)
- Iterative Management

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The Important Role of Community & Stakeholder Engagement

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Great Ecology:

Great Ecology specializes in the design, restoration, and enhancement of ecosystems throughout the United States and abroad. We bring higher ecological thought to leading organizations, corporations, and governments throughout the world. With offices in San Diego, Denver, Manhattan, and Soda Springs, we integrate ecological project design with biological and financial assessment, project implementation, and iterative management.

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Questions?

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