Green Ditch Diversion Rehabilitation and Fish Passage Project
Final Report

Prepared for:
WSRF Grant
Attn: Chris Sturm

April 12, 2018

Grant Recipient: The Green Ditch Company
Grant Amount: $245,000
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City of Boulder Open Space and Mountain Parks Department

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Introduction

Boulder Creek and its riparian corridor, particularly from the mouth of Boulder Canyon to the creek's confluence with the St. Vrain River, have been heavily impacted by current and historic land use. Within the city limits of Boulder, the creek itself has been straightened and its riparian corridor narrowed to accommodate development of the city and recreational opportunities. A paved path, popular with both residents and visitors, parallels Boulder Creek throughout the city. Outside city limits, historic gravel mining operations shifted and straightened sections of the creek and left numerous former mining pits as shallow ponds or wetlands within the creek's floodplain. The creek's native open canopy cottonwood/willow riparian community has been replaced in many locations by non-native species including crack willow, Russian olive, and reed canarygrass.

Despite the disturbance, Boulder Creek, especially reaches immediately outside of the city limits, remains a refuge for some native species. Immediately east of the city limit, surveys conducted by the Colorado Division of Parks and Wildlife (CPW) have shown the creek supports a diverse sport and native fish community. Native creek chub, longnose dace, longnose sucker, plains topminnow and white sucker have been found in this section of the creek, as well as a variety of non-native sport fish. Native birds, including great blue heron and riparian dependent songbirds, frequent the creek's riparian and floodplain areas. Further away from the city, bald eagles successfully nest on protected riparian lands.

In recent years, the City of Boulder has been working with various partners to restore Boulder Creek and its floodplain, focusing on areas near the eastern city limits. The City recently completed a fish passage structure at a utility line buried under Boulder Creek immediately upstream of 55th Street. Also immediately upstream of 55th Street, the City of Boulder completed the restoration of a former gravel mining pit that was infested with Eurasian water milfoil. The former gravel pit was returned to meandering creek channel (Goose Creek) with adjacent riverine wetlands and cottonwood riparian habitat. Between 55th Street and Valmont Road, the City of Boulder, along with Wildland Restoration Volunteers, is actively restoring a small cottonwood gallery adjacent to Boulder Creek. This restoration work has included removal of non-native trees, shrubs, and herbaceous plants as well as native planting and seeding. The City is doing similar non-native removal work west of 55th Street as well. Immediately downstream of Valmont, the Colorado Department of Transportation (CDOT) is restoring approximately 20 acres of highly disturbed floodplain. This work has included the removal of previously dumped material and restoration of wetland, riparian, and prairie habitat.

The September 2013 flood event had a significant impact on Boulder Creek, particularly in the area immediately east of the city limits. In the Green Ditch Diversion Rehabilitation and Fish Passage project area (Figure 1), the flood altered Boulder Creek's path. During the flood, the Short Milne Pond, a former gravel pond, situated immediately south of Boulder Creek, breached its northeast corner, spilling sediment into Boulder Creek (Figure 2). This sediment plugged Boulder Creek forcing water in the creek to breach the creek's northern (left) bank diverting all its flow into a wetland (also a former gravel pit) to the north of the creek. While this change in creek path did not directly impact human infrastructure, it left the Green Ditch Company without the ability to divert its adjudicated water as Boulder Creek no longer flowed past the Green Ditch diversion point.

In 2014, the Green Ditch Company constructed a temporary berm across the breached left bank of Boulder Creek, directing creek water back into its pre-flood channel (Photo 1). This temporary repair provided time for the Green Ditch Company and the City of Boulder, who owns the property immediately upstream of the Green Ditch headgate, to develop a restoration plan to restore the Green Ditch Company's ability to divert water while protecting and enhancing the ecological values of city-owned property.

Photo 1. Temporary berm being constructed across the Boulder Creek breach to redirect the creek back into its pre-flood channel.

Prior to the September 2013 flood event, the Green Ditch Company and City of Boulder had been exploring opportunities to enable fish passage at the Green Ditch diversion point. The Green Ditch diversion structure included a diversion dam spanning the entire width of Boulder Creek creating an impediment to fish passage. Additionally, the ditch company's headgate was located off-line. This meant that, at times, the ditch company would sweep the creek and return any unwanted or out of priority water to the creek approximately 600 feet downstream of the point of diversion[1]. During low flow, this mode of operation dewatered 600 feet of Boulder Creek, further fragmenting aquatic habitat. Both the Green Ditch

[1] The CWCB holds an instream flow water right (1-90CW193) on Boulder Creek through this reach. This is one of the first ISF acquisitions, where the City of Boulder donated valuable senior water rights to the CWCB to maintain instream flows in Boulder Creek.

Company and City of Boulder were exploring options to address these issues while still ensuring the Company received its adjudicated water.

Following the 2013 flood, the Green Ditch Company and the City of Boulder commissioned several engineering studies to examine alternatives that addressed both the pre-existing fish passage issues and new issues created by the flood. Any alternative needed to satisfy the initial project objectives which were:

1. Restore the Green Ditch Company's ability to divert water
2. Repair and upgrade the Green Ditch diversion structure to provide fish passage
3. Restore the Boulder Creek channel to increase its stability (i.e the ability in the present climate to transport streamflows and sediment, over time, in such a manner that the channel maintains its dimension, pattern, and profile without either aggrading or degrading" Rosgen 2011). The restoration would focus on returning the creek to reference conditions and incorporating aquatic habitat features to support native and sport fish.
4. Restore the riparian and wetland habitat adjacent to the creek channel. The restoration would allow for overbank flooding where feasible.

The initial engineering study served as a basis for the design of the temporary repair work completed in 2014 (see above) to ensure water reached the Green Ditch headgate. A subsequent study examined the feasibility of using natural channel design to achieve all the project objectives listed above. Results from this initial feasibility study indicated the use of natural channel design may be possible. Consequently, the City of Boulder and Green Ditch Company moved forward with a more detailed feasibility and design study.

The project stakeholders, which included the CWCB, U.S. Fish and Wildlife Service, and CPW as well as the Green Ditch Company and City of Boulder, hoped that by achieving Objective 3 they would nearly eliminate the potential for future creek breaches. This would ensure the Green Ditch Company access to its Boulder Creek water and prevent the need for future costly repairs. A third, more detailed engineering feasibility and design study revealed that while it is possible to create a design to fully achieve Objective 3, such a project would face significant legal, regulatory, and financial challenges. Specifically, such a project would require:

1. Moving the existing Green Ditch diversion point roughly one-half mile upstream of its existing location
2. Injuring an existing instream water right (this would be mitigated)
3. Constructing a new ditch under a busy county road
4. Relocating a 24-inch water main
5. Obtaining an Individual Permit from the U.S. Army Corps of Engineers and a Conditional Letter of Map Revision (CLOMR) from the Federal Emergency Management Agency, as well as numerous other state and local permits

Faced with these challenges, the stakeholders scaled back the objectives to pursue a project that would fully achieve Objectives 1-2 while maximizing the creek's stability (Objective 3) and ecological value (Objective 4) to the extent feasible.

While the Green Ditch Diversion Rehabilitation and Fish Passage project is a single project, it complements other work described above that the City of Boulder and its partners have completed or are currently working on to address the historic degradation of the creek and its floodplain/riparian corridor. The Green Ditch project will also complement the post-flood creek restoration recently completed immediately upstream of 61st Street. The Boulder Creek Confluence project, which was completed with funding from the CWCB, also addressed impacts due to the September 2013 flood event. The City, along with its partner, The Boulder Flycasters (Trout Unlimited chapter), are embarking on a habitat improvement project along Boulder Creek just upstream of the Boulder Creek Confluence project in 2018. Collectively, these projects will result in habitat (instream, riparian, riverine wetland, and floodplain) restoration, improved fish passage, and utility protection along several miles of Boulder Creek.

Background

The overall goal of the Green Ditch Diversion Rehabilitation and Fish Passage project is to address flood damage while improving the ecological function and value of Boulder Creek and its riparian corridor within the project site. Stakeholders believed they would achieve this goal if they met the following four objectives:

1. Restore the Green Ditch Company's ability to divert water from Boulder Creek
2. Repair and upgrade the Green Ditch diversion structure to provide fish passage
3. Restore the Boulder Creek channel to increase its stability (i.e ability in the present climate to transport streamflows and sediment, over time, in such a manner that the channel maintains its dimension, pattern, and profile without either aggrading or degrading" Rosgen 2011). The restoration will focus on returning the creek to reference conditions and incorporating aquatic habitat features to support native and sport fish.
4. Restore the riparian and wetland habitat adjacent to the new creek channel. The restoration should allow for overbank flooding where feasible.

Through various feasibility studies project stakeholders recognized they only had current resources to fully address objectives 1 and 2. The project was designed to maximize progress toward objectives 3 and 4.

A competitive bid process was held to attract the most qualified design-build team to build a project that would achieve the project objectives outlined above. Based on an agreement with the Green Ditch Company, the City of Boulder's Open Space and Mountain Parks Department (OSMP) oversaw the administration of the bid and contract for the project. OSMP hired the team of 5 Smooth Stones Restoration (5SSR) and North State Environmental (NSE) to complete the design and construct the project.

The 5SSR/NSE team used data collected as part of the various feasibility studies and a variety of tools to inform the restoration design. This work included identification of an on-site reference point. The team used a section of Boulder Creek located immediately upstream of 61st Street. This section of Boulder Creek suggested the creek should have the following:

Width to Depth Ratio: 20
Bankfull Width: 52 ft
Cross-Sectional Area: 133 ft^2
Bankfull Discharge: 528 cfs

Pattern and profile of the reference section of Boulder Creek were measured to help inform the design pattern and profile. 5SSR/NSE further developed the design parameters by analyzing existing gage data and completing a topographic survey and geomorphic assessment of the project reach. The resulting design dimensions, pattern and profile are summarized on the construction plans, particularly in Sheets 3-6 (plan and profile) and 7-10 (dimensions) (Appendix 1).

Because ensuring fish passage was one of the objectives stakeholders hoped to fully satisfy, the design was also informed by work completed by GEI Consultants fisheries biologist, Ashley Ficke. Ficke documented existing habitat conditions, described the limiting factors to resident fish, and provided recommendations to both ensure fish passage at the diversion point and improve habitat throughout the project reach (Appendix 2). 5SSR/NSE incorporated these recommendations, as feasible, in the design.

Methods

For the most part, the restoration was constructed according to the final plan set (Appendix 1 and 2). These plans can be used in the future to implement a similar project in the same way. Notable changes to the plan set included:

1. The combination rock/wood j-hook at Sta. 1+04 was made entirely of rock.
2. Addition of wood toe along the right bank from Sta. 5+00 to 7+00 and from Sta. 8+29 to 10+39. Although modeling completed by 5SSR indicated that these bends were slight enough not to require stabilization, the wood toe provides an extra level of protection against erosion. The wood toe also increased amount of large wood in the creek following recommendations by Ficke to improve fish habitat.
3. Addition of a wood vane in front of the rock cross vane serving as the diversion structure. This vane helps to direct flow to the center of the diversion cross vane. It also adds large wood to the creek following recommendations by Ficke to improve fish habitat.
4. A rock j-hook was installed at roughly Sta. 19+50. During high flow, some minor bank erosion was observed along the left bank between Sta. 20+50 and 21+50. To address this issue, 5SSR/NSE returned to the project site following high flows and adjusted the angles on the constructed riffle vanes and installed the rock j-hook. Both corrective actions were taken to push the creek's thalweg away from the bank.

Quality control was provided throughout the course of construction. 5SSR provided regular construction oversight to ensure construction proceeded according to design and to make field adjustments as needed. During construction of the cross vane that served as the diversion structure, Bill Rice, the Mountain Prairie Region Fish Passage Coordinator for the USFWS National Fish Passage Program, visited the site and suggested field adjustments to improve fish passage and prevent fish entrainment in the ditch. An engineer from Olsson Associates also inspected the cross vane diversion structure to ensure the structure would enable the Green Ditch Company to divert its adjudicated water. Ashley Ficke inspected the project site to ensure grades were low enough and changes in water height were small enough to allow native fish to navigate the steepest section of the project reach. A stream restoration specialist contracted by the CWCB inspected the project site as well. Lastly, an OSMP project manager was at the project site daily. These combined efforts ensured OSMP and other project stakeholders, including the CWCB, received a high-quality product.

The Green Ditch Company and OSMP focused CWCB funding toward the construction phase of the project. Overall the construction phase cost $429,000 (Table 1). The CWCB funding covered nearly two thirds (64%) of the labor associated with the construction phase. This was a significant contribution and helped bring the project to fruition.

Table 1. Costs associated with the construction phase of the project. CWCB funding was focused on supporting the construction phase of the project.

Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Mobilization	1	LS	$ 40,000.00	$ 40,000.00
Temporary Construction Access Road	1	LS	$ 10,000.00	$ 10,000.00
Upstream Grading Cut	17350	YD^3	$ 4.50	$ 78,075.00
Upstream Grading Fill	17350	YD^3	$ 4.50	$ 78,075.00
Downstream Grading Cut	1550	YD^3	$ 4.50	$ 6,975.00
Downstream Grading Fill	1550	YD^3	$ 4.50	$ 6,975.00
Clearing and Grubbing (As Directed)	1.82	AC	$ 4,000.00	$ 7,280.00
Wood Toe Habitat Structures	360	LF	$ 50.00	$ 18,000.00
Log J-Hook with Rootwad	2	Each	$ 9,375.00	$ 18,750.00
Log Boulder Constructed Boulder Riffle	2	Each	$ 25,000.00	$ 50,000.00
Rock Cross-Vane "A" Vane	1	Each	$ 18,750.00	$ 18,750.00
Diversion Return/Augmentation Station	1	Each	$ 35,000.00	$ 35,000.00
Boulder Toe on overflow	60	TN	$ 125.00	$ 7,500.00
Seeding	6.8	AC	$ 1,000.00	$ 6,800.00
			Construction	$382,180.00
			Materials provided by City of Boulder	$46,820.00
			Total Construction	**$429,000.00**

Results

The project resulted in significant ecological and geomorphological improvements to Boulder Creek and its floodplain/riparian corridor while also providing the Green Ditch Company with their adjudicated water. These improvements included:

1. Delivery of water to the Green Ditch while eliminating fish passage barriers
2. Improved channel stability
3. Improved habitat diversity and complexity
4. Improved riparian and floodplain habitat

Each of these improvements is described in more detail below.

Delivery of water to the Green Ditch while eliminating fish passage barriers

Achieving the project's primary objective of delivering the Green Ditch Company its Boulder Creek water and establishing fish passage involved three main steps. First, the contractors installed a new headgate at the ditch's point of diversion (Photo 2). The ditch company's original headgate was located off-line. At times, the ditch company would sweep the creek and return any unwanted or out of priority water to the creek approximately 600 feet downstream of the point of diversion. During low flows, this mode of operation dewatered 600 feet of Boulder Creek, fragmenting fish habitat. Installation of the new head gate at the point of diversion and removal of the return flow channel (i.e. the wasteway) eliminated this dewatering.

Photo 2. New Green Ditch headgate.

After installing a new headgate, the creek bed below the existing diversion dam was raised to eliminate the immediate drop in grade below the diversion dam (Photo 3). To protect the new creek bed as this section of the creek has the steepest grade, this work included the installation of two constructed riffles reinforced with boulder vanes set flush with the new grade of the creek (Photo 4). Based on consultation with Ficke, the creek's new grade was designed to eliminate any drops greater than approximately 0.3-0.4 feet to accommodate passage of most age classes of Boulder Creek fish (Photos 5 and 6).

Photo 3. Raised creek bed. View looking downstream from the existing low head diversion dam.

Photo 4. Boulder vanes being installed in the constructed riffles immediately downstream of the existing low head diversion dam. View looking upstream from end of project reach.

Photo 5. Constructed riffle at low flow. View looking upstream from end of project reach.

Photo 6. Constructed riffle at low flow. View looking downstream from diversion point.

The final fish passage work included installation of a rock “A” cross vane to divert the Green Ditch Company’s adjudicated water (Photo 7). As seen in the photos, the cross vane incorporated the existing low head dam. With guidance from Bill Rice, the Mountain Prairie Region Fish Passage Coordinator for the USFWS National Fish Passage Program, the cross vane included a small opening in the vane near the new headgate to provide an escape path for fish in danger of being entrained in the Green Ditch (Photo 8). Photos 9 and 10 show the completed cross vane and raised stream bed below the cross vane under higher flow.

Photo 7. Constructing the rock “A” cross vane that will allow diversion. Note existing low head diversion dam around which the cross vane is being built. View looking right bank to left bank.

Photo 8. Fish "escape path" in the rock cross vane adjacent to the new headgate.

Photo 9. Rock cross vane under high flow (approximately 500 cfs). View facing downstream.


Photo 10. Rock cross vane and raised creek bed. View facing upstream.

Improved channel stability

Prior to the project, the project reach was best classified as an entrenched F4 stream type. The upstream half of the project reach had been straightened and moved several times while the site was mined for gravel in the latter half of the last century. This section of the creek was overwidth and lacked sinuosity. The project included re-routing the upstream portion of the project reach and reshaping the remaining portion of the creek above the diversion to the appropriate dimension, pattern, and profile (Photos 11 and 12) for a creek of its type, setting, and approximate discharge.

Photo 11. New channel prior to water flowing in it. Inner berm and gently sloping banks to bankfull are clearly visible on the river right bank. View facing upstream.

Photo 12. Sinuosity is returned to the channel. View facing upstream.

Improved habitat diversity and complexity

Prior to the project, the project reach lacked diversity and complexity. The reach consisted largely of wide shallow riffles and runs; pools were absent or severely impaired. The Ficke technical memo points to the lack of diversity in the project reach as one of the most limiting factors to the fish community. The project addressed this issue by re-establishing riffle pool sequences in the portion of the reach upstream of the diversion. Habitat at the meander pools was further improved by using wood toe structures at each of the meanders (Photos 13 and 14). Immediately downstream of the diversion, cover boulders were installed to provide fish refuge as they moved upstream in the long riffle below the diversion (Photo 15).

Photo 13. Installing base of wood toe structure.

Photo 14. Installing soil encapsulated lifts with live willow and cottonwood branches on top of wood toe structure.

Photo 15. Habitat boulders below the new point of diversion. View facing downstream.

Improved riparian and floodplain habitat

Two other factors that the Ficke technical memo mentions as highly limiting factors to the project reach's fishery are the reach's lack of connection to its floodplain and the prevalence of invasive species in the riparian zone. The project took steps to address both of these issues. Total channel shaping and floodplain grading resulted in the movement of approximately 35,000 cubic yards of material (17,500 cubic yards of cut and 17,500 cubic yards of fill). Much of the floodplain grading involved lowering the floodplain grade to re-connect the project reach with its floodplain (Photo 16). The expanded floodplain was most obvious on the left bank of the upstream portion of the reach (Photo 17). Prior to the project, the left bank was hugged by a levee separating the creek from a former gravel mining pit. The project also included the installation of over 4,000 live willow stakes (Photos 17 and 18) and 3,000 native riparian shrubs. To further enhance the soil lifts over the wood toe structures, willow and cottonwood cuttings were placed between the lifts (Photo 19). Finally, all disturbed areas were seeded with native seed mixes.

Photo 16. Lowering of left floodplain. View facing east from 61st Street.

Photo 17. New floodplain along creek. Note levee in background of the photo on the left bank. Prior to the project, the levee bordered the creek's left edge. Floodplain grading and relocation of the creek has expanded the floodplain. View facing downstream.

Photo 18. Same willow stakes as shown in Photo 17 later in 2017. Red arrows point to the same tree in both photos.

Photo 19. Willow and cottonwood cuttings sprouting in the soil lifts above a wood toe structure. View facing upstream.

Table 2 quantifies the improvements made to the creek resulting from the project.

Table 2: Improvements resulting from project

Item Description	Quantity	Unit
Woody Debris Toe Protection Structure	360	feet
Boulder J-Hook	2	each
Log J-Hook	1	each
Boulder Constructed Riffle	2	each
Boulder Habitat Units	3	each
Erosion Control Blanket	6,000	sq feet
Upland Seeding	2.5	acre
Riparian Seeding	4	acre
Streambank Seeding	1.25	acre
Willow Staking	4,000	each
Riparian Shrubs	3,500	each
Cottonwood Poles	80	each
Willow and Cottonwood Cuttings	5,000	each

Conclusions and Discussion

Long term monitoring will be needed to determine whether the project meets its goals and objectives. However, before and after restoration pictures below (Photos 20-33) suggest the project is on the correct trajectory for success. (*Red arrow points to the same location in each before and after restoration pair of photos*.)

Photo 20. Prior to restoration, the temporary riprap berm provides poor habitat. Creek dimensions created an entrenched channel. View facing downstream September 7, 2016.

Photo 21. Following restoration wood toe replaces riprap and creek channel dimensions more closely approximate reference conditions. View facing downstream August 17, 2017.

Photo 22. Second view of temporary riprap and entrenched channel. View facing upstream September 7, 2016.

Photo 23. Following restoration wood toe replaces riprap and creek channel dimensions more closely approximate reference conditions. View facing upstream August 17, 2017.

Photo 24. Prior to restoration riprap on left bank provides poor habitat and extensive cover of non-native vegetation (reed canary grass and crack willow). View facing upstream September 7, 2016.

Photo 25. Following restoration wood toe replaces riprap (left bank), creek channel dimensions more closely approximate reference conditions, and riparian corridor seeded and planted with native vegetation. View facing upstream August 17, 2017.

Photo 26. Prior to restoration steep cut banks on both banks (left bank most visible). View facing downstream September 7, 2016.

Photo 27. Following restoration banks reshaped and seeded and planted with native vegetation. View facing downstream August 17, 2017.

Photo 28. Prior to restoration creek was actively eroding the right bank to the right of the large crack willow. If left unaddressed, the creek would split flows here. Temporary berm also visible on the left bank immediately below the red arrow. View facing downstream September 7, 2016.

Photo 29. Creek restored to a more stable plan view and dimension. Wood toe visible where temporary berm was located. View facing downstream August 17, 2017.

Photo 30. Close up of temporary riprap berm. View facing upstream September 7, 2016.

Photo 31. Close up of wood toe and realigned plan form of restored creek. View facing upstream August 17, 2017.

Photo 32. Typical view of reach straightened during historic gravel mining operations. Note cut left bank. This reach was abandoned during restoration. View facing upstream September 7, 2016.

Photo 33. Re-aligned reach constructed with a more stable plan view and dimension. Wood toe visible at bend in background. View facing upstream August 17, 2017.

Long term monitoring of the project will include monitoring of:

1. the riparian/floodplain vegetation to ensure the establishment of a native riparian community,
2. the creek's geomorphological attributes at established cross sections to ensure the creek is neither aggrading or degrading and properly transporting sediment, and
3. the creek's biological community with a focus on the fish community.

OSMP will work with Colorado Parks and Wildlife on monitoring any changes in the fish community. Monitoring of the creek's macroinvertebrate community is also possible in the future as the City's Utilities Department (Stormwater Quality Section) has long term macroinvertebrate monitoring stations near and within the project area.

Some future work in the area will be informed by the long-term monitoring results. However, OSMP is currently planning site management, including weed management and supplemental seedings and plantings, for 2018.

The primary "lesson learned" was the need to account for the fact that many flood restoration projects were occurring simultaneously. This created bottlenecks in permitting as some regulatory agencies had insufficient staff to support the influx in permit applications and a shortage in common materials. OSMP tried to overcome bottlenecks by submitting permit applications early and working closely with the regulatory agencies prior to application submittal to ensure efficient processing.

OSMP took a variety of approaches to address the shortage of materials by using existing resources and collaborated with other City departments and sister agencies. OSMP used pine logs harvested as part of the department's forest mitigation work in the wood toe structures. OSMP also collaborated with the City's Urban Forestry department to obtain ash logs that Urban Forestry was removing from within the city due to damage from the emerald ash borer. OSMP girdled and herbicided crack willows on-site a year prior to the project. This was done so that OSMP could experiment with using crack willow root wads. In the past, OSMP has not used crack willows in creek restoration due to crack willow's potential for sprouting and regrowth. This project will provide OSMP (and other agencies) with information on whether girdling and herbicide are sufficient treatment prior to complete submergence in the wood toe structure to prevent regrowth. OSMP also salvaged any native materials already on site. This included over 1000 two to three-year-old cottonwood saplings that had established on the alluvium deposited in the gravel pits at the creek breaches. Crews were able to loosen the alluvium around the cottonwood saplings and then pull the entire sapling, root included, out of the ground. These "bare root" cottonwoods were planted directly into the restored ground and used as live branches between the soil encapsulated lifts. OSMP used hand collected seed to address shortages in seed quantities. Lastly, OSMP worked closely with other sister agencies, especially Boulder County Parks and Open Space, to share plant materials. All these efforts helped the project team overcome shortages in available materials.

Actual Expense Budget

Table 3 compares the budget proposed in the grant application with the actual budget. The contracting team of 5 Smooth Stones and North State Environmental made every effort to ensure the project was completed within budget and likely provided several cost breaks to ensure a high-quality project. OSMP provided the contracting team with additional in-kind services including having our department's restoration crew on-site to assist with construction of soil lifts that were placed on the wood toe structures. While this increased OSMP's in-kind commitment, it allowed the contracting team to focus on earthwork related tasks that OSMP's restoration crew were unable to do.

Table 3. Proposed budget compared to actual budget

Task	CWCB Funds	Proposed Other Funding Cash	Actual Other Funding Cash	Proposed Other Funding In-Kind	Actual Other Funding In-Kind	Actual Total
Project Management	$0	$58,000	$58,000	$0	$10,400[1]	$68,400
Data Collection and Mgmt	$0	$26,000	$26,000	$0	Included in above	$26,000
Conceptual Design	$0	$33,000	$33,000	$0	Included in above	$33,000
Stakeholder Engagement	$0	$5,000	$5,000	$0	Included in above	$5,000
Final Design	$0	$22,000	$22,000	$0	Included in above	$22,000
Permitting	$0	$49,000	$49,000	$0	Included in above	$49,000
Construction	$245,000	$137,180[2]	$137,180	$46,820[3]	$69,200[1]	$451,380
As-built Survey	$0	$8,000	$8,000	$0	$0	$8,000
TOTALS	**$245,000**	**$338,180**	**$338,180**	**$46,820**	**$79,600**	**$662,780**

[1]Figure is estimated
[2]Figure includes cash contribution of $263,180 from the City of Boulder and $75,000 from the USFWS in the form of a grant for fish passage construction.
[3]Figure includes boulders and logs for creek habitat structures.

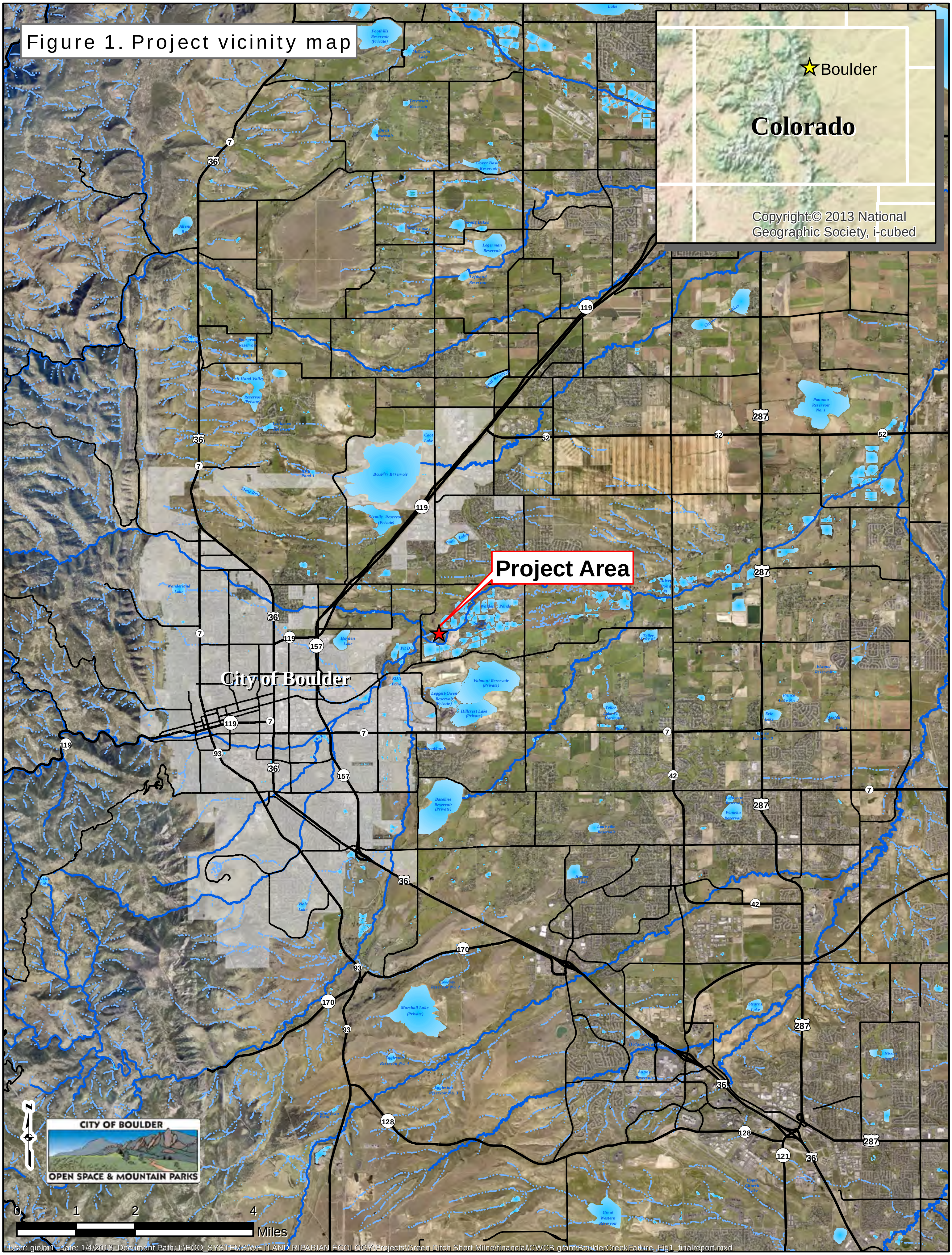
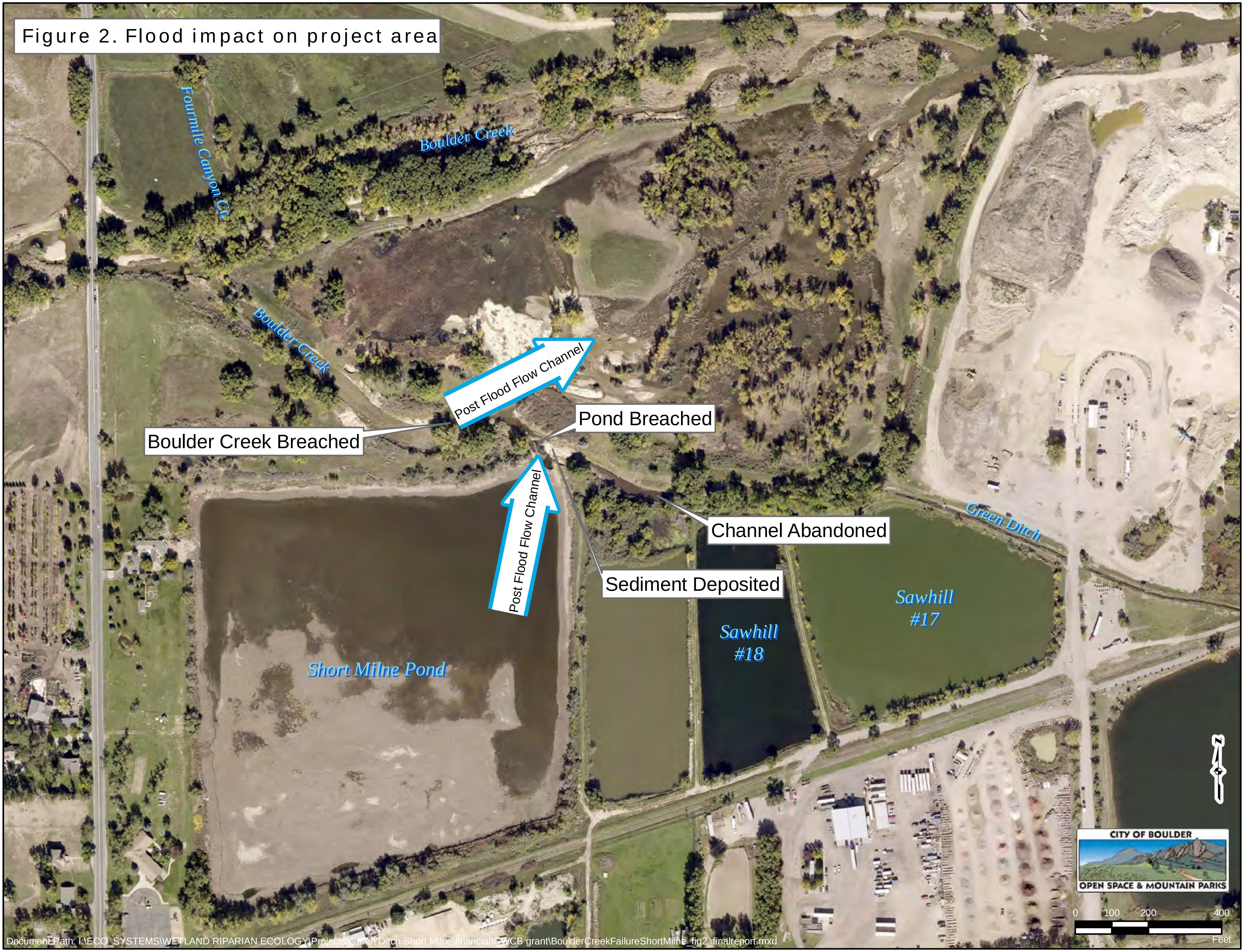


Figure 1. Project vicinity map

Figure 2. Flood impact on project area

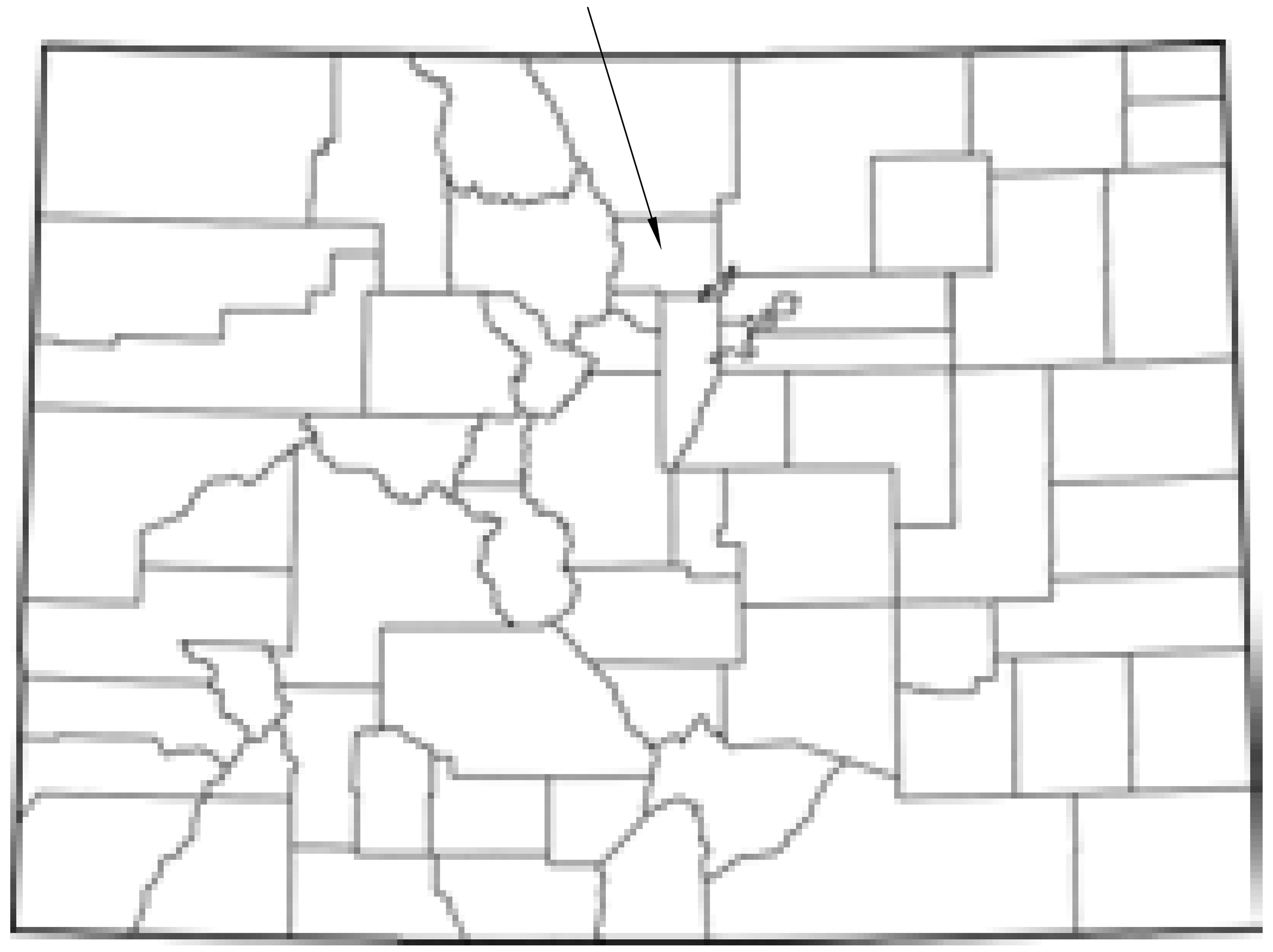


Appendix 1.

Construction Plan Set

Green Ditch Diversion Rehabilitation and Fish Passage:

WSRF Grant – CTGGI 2017-1569



98% DESIGN PLANS

BOULDER CREEK RESTORATION DESIGN

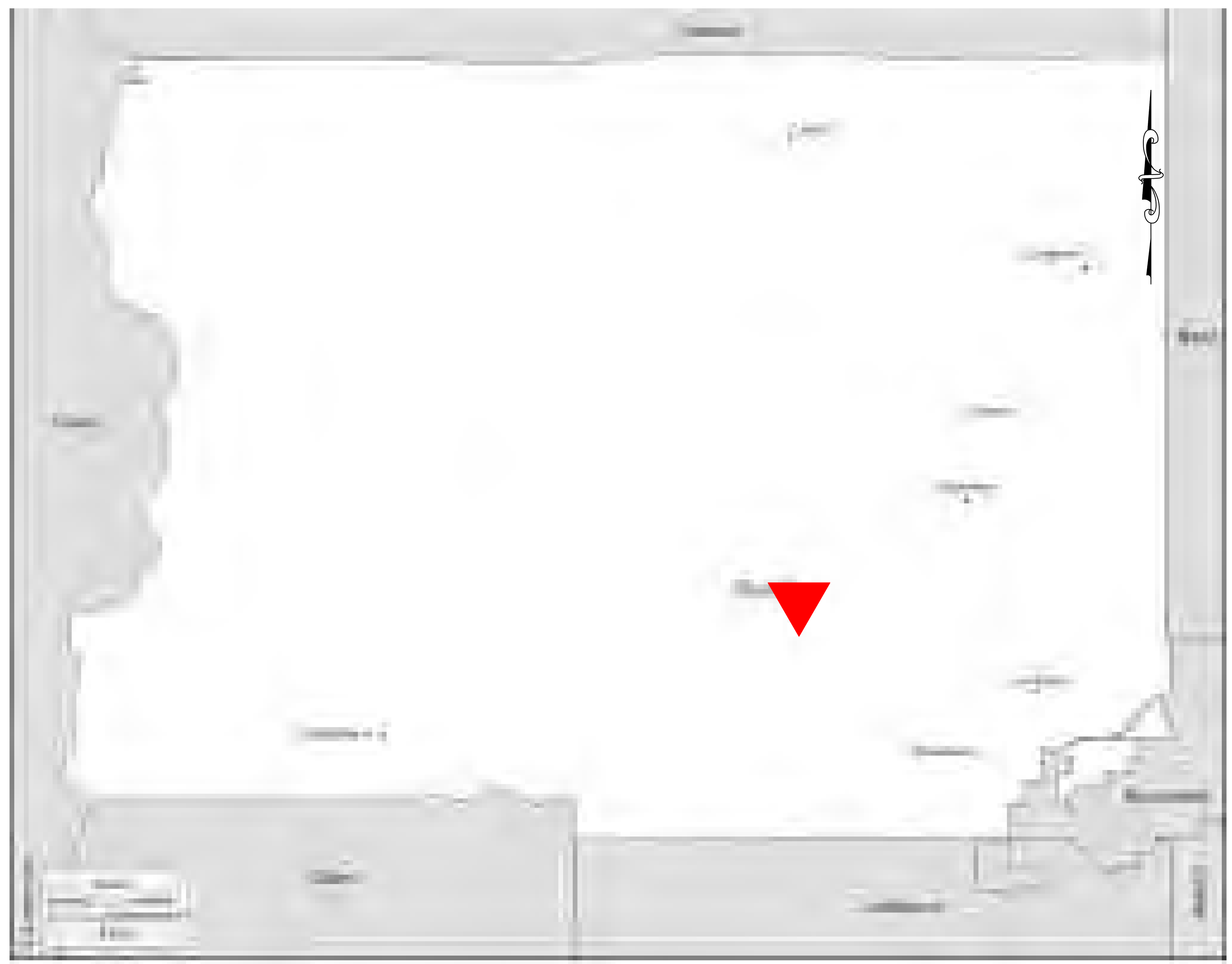
PLANS PREPARED BY:

North State ENVIRONMENTAL

754 MOUNT MAHOGANY
LIVERMORE COLORADO
www.nsenv.com

Boulder Creek Project Site
Lat: 40°02'13.63"N
Long: 105°12'32.96"W

SHEET NUMBER AND DESCRIPTION



VICINITY MAP
NOT TO SCALE

BOULDER CREEK RESTORATION 98% SUBMITTAL

REV	DESCRIPTION	DATE	APPROVED
1	30% Concept Re-Design	7/01/16	DTW/DAB
2	60% Concept Re-Design	10/18/16	DTW/DAB
3	98% DESIGN	02/23/17	DTW/DAB

REVISIONS

DATE 3/9/2017

SHEET 0

SCALE 1" = 40'

DRAWING NO.

DRAWN BY:

CHECKED BY:

APPROVED BY:

North State Environmental
754 Mount Mahogany, Suite B
Livermore, CO 80536

PROJECT: 98% Design
North State Environmental / 5SSR

CLIENT: Boulder Creek Restoration
Boulder County, Colorado
98% Design

Boulder Creek02232017_98%.dwg

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GENERAL CONSTRUCTION NOTES

1. THE WORK ON THIS PROJECT SHALL ADHERE TO THE FOLLOWING SPECIFICATIONS, STANDARDS AND/OR REGULATIONS:
2. THIS PROJECT IS LOCATED WITHIN A FEMA 100-YEAR FLOODPLAIN BUT WILL RESULT IN A NO-RISE.
3. INSTREAM STRUCTURES SHALL BE INSTALLED AS THE CHANNEL IS BEING CONSTRUCTED AND NOT POST CONSTRUCTION. FILTER FABRIC INSTALLED AS PART OF THE INSTREAM STRUCTURE SHALL BE A NONWOVEN GEOTEXTILE UNLESS OTHERWISE SPECIFIED IN STRUCTURE DETAILS OR SPECIFICATIONS.
4. WHERE PRACTICABLE, EXISTING TREES AND VEGETATION SHOULD BE LEFT IN PLACE TO FACILITATE NATURAL REGENERATION AND SOIL STABILIZATION WHEN AT THE CORRECT ELEVATION.
5. DEFINITIONS:
   A. BANKFULL ELEVATION IS THE POINT OF INCIPIENT FLOODING IN AN ALLUVIAL CHANNEL. THIS ELEVATION IS THE REFERENCE FOR DEPTHS ON OR ALONG THE CHANNEL PROFILE AND STRUCTURES DESCRIBED IN THESE SHEETS.
   B. THE BANKFULL BENCH IS A CONSTRUCTED FLOODPLAIN ADJACENT TO THE CHANNEL. THE BANKFULL BENCH IS CONSTRUCTED AT THE BANKFULL ELEVATION.
   C. THE THALWEG IS THE LOWEST PORTION OF THE CHANNEL.
   D. THE VANE LENGTH IS THE STRAIGHT LINE DISTANCE BETWEEN THE VANE ARM AND A LINE TANGENT TO THE STREAMBANK AT THE POINT WHERE THE VANE ARM INTERSECTS THE STREAMBANK.
   E. THE VANE ANGLE IS THE ANGLE BETWEEN THE VANE ARM AND A LINE TANGENT TO THE STREAMBANK AT THE POINT WHERE THE VANE ARM INTERSECTS THE STREAMBANK.
   F. SOD MATS ARE GRASS AND WILLOW TRANSPLANTS THAT STILL CONTAIN ROOTING DEPTH. APPROXIMATELY 9-12IN OF DEPTH WILL BE NEEDED WHEN HARVESTING THE SOD MATS.
6. NORTH STATE ENVIRONMENTAL (NSE) WILL STAKE OUT THE PROPOSED STREAM CENTERLINE FOR REVIEW BY THE ENGINEER BEFORE INITIATING EXCAVATION. DEPENDING ON ENCOUNTERED CONDITIONS SOME SHIFTING OF THE STREAM CHANNEL MAY BE NECESSARY. ANY COST ASSOCIATED WITH CHANGING STRUCTURE LOCATIONS OR ALIGNMENT SHALL BE CONSIDERED INCIDENTAL TO CONSTRUCTION. STAKING MAY BE OMITTED FOR PORTIONS OF THE STREAM WHEN SURVEY-GRADE GPS IS USED TO CONSTRUCT THE CHANNEL. IF GPS IS USED IN LIEU OF STAKING THE CHANNEL IN THE FIELD, NSE ASSUMES ALL RESPONSIBILITY FOR THE STREAM BEING CONSTRUCTED AS DESIGNED, INCLUDING ANY ISSUES RELATED TO PROJECTIONS, BASE POINTS OR CONVERSION OF DIGITAL TERRAIN MODELS.
7. PRIOR TO CLEARING AND GRUBBING, NSE SHALL MARK THE LIMITS OF CLEARING NEAR TREES FOR VERIFICATION OF INTENT BY THE ENGINEER. SOME MINOR ADJUSTMENT OF CHANNEL ALIGNMENT MAY BE REQUIRED TO PRESERVE TREES OR MINIMIZE IMPACT TO TREES.
8. ANY HARVESTING OF WILLOWS AND SOD FROM ONSITE MUST BE APPROVED BY THE ENGINEER.
9. NSE SHALL MINIMIZE, TO THE MAXIMUM EXTENT POSSIBLE, IMPACTS TO THE ADJACENT TREES. CONSTRUCTION EQUIPMENT TRACKS AND PATHWAYS SHALL BE GRADED AND RECONTOURED AFTER CONSTRUCTION TO PREVENT RILL AND GULLY EROSION.
10. THE PROPOSED GRADING IS SHOWN ON THESE PLAN SHEETS. NSE MAY EXTEND THE LIMITS OF DISTURBANCE ONLY WITH THE APPROVAL OF THE ENGINEER.
11. NSE SHALL USE AN EXCAVATOR WITH A HYDRAULIC THUMB TO INSTALL INSTREAM STRUCTURES.
12. CHANNEL RELOCATION WORK SHALL BE COMPLETED AND STABILIZED PRIOR TO ALLOWING FLOW TO ENTER INTO THE NEWLY CONSTRUCTED STREAM CHANNEL. NSE SHALL NOT OPEN UP MORE THAN 200 FEET OF CHANNEL WITHOUT EROSION CONTROL BLANKET IN PLACE OR BY APPROVAL OF THE ENGINEER.
13. THE PROPOSED STREAM CHANNEL SHALL BE CONSTRUCTED BY FIRST GRADING THE FLOODPLAIN ADJACENT TO THE CHANNEL TO THE ELEVATION INDICATED ON THESE PLANS. THIS MAY BE DONE AS GENERAL EXCAVATION. THE PROPOSED STREAM CHANNEL SHALL THEN BE EXCAVATED TO THE PROPER DEPTHS INDICATED ON THE PROFILE AND PROPOSED CONTOURS. THIS SHALL BE DONE AS SPECIALIZED EXCAVATION AND IS TYPICALLY ACCOMPLISHED WITH A TRACK EXCAVATOR. THE PROFILES AND CONTOURS SHOWN PROVIDE WIDTHS AND SLOPES FOR AID IN CONSTRUCTING THE CHANNEL TO THE APPROPRIATE DIMENSIONS. THE THALWEG CAN FIRST BE EXCAVATED TO THE POINT INDICATED ON THE PROFILE. EXCAVATION AND FINE GRADING OF THE CROSS SECTIONS SHALL THEN BE PERFORMED AS SHOWN ON THE TYPICAL CROSS SECTIONS AND PROPOSED CONTOURS.
14. IF THE EXISTING GROUND IS LESS THAN 0.2 FEET HIGHER THAN THE PROPOSED BANKFULL ELEVATION, IT IS NOT NECESSARY TO EXCAVATE MATERIAL TO THE PROPOSED ELEVATION SHOWN ON THE PROFILE.
15. THE SURFACE OF ALL INSTREAM STRUCTURES SHALL BE FINISHED TO A SMOOTH LINE IN ACCORDANCE WITH THE LINES, GRADES, AND CROSS SECTIONS OR ELEVATIONS SHOWN ON THE DRAWINGS. THE DEGREE OF FINISH FOR THE VANE SLOPES AND INVERT ELEVATIONS SHALL BE WITHIN 0.1 VERTICAL FEET OF THE GRADES AND ELEVATIONS INDICATED. ALL GAPS OR VOIDS BETWEEN THE ROCKS SHALL BE PLUGGED WITH SMALL GRAVEL TO FORM A TIGHT-FITTING SEAL.
16. NSE SPECIFICATIONS FOR BANKFULL CHANNEL DIMENSIONS OR CROSS SECTIONS WILL BE HELD TO THE DIMENSIONS SHOWN ON THE TYPICAL CROSS SECTIONS. ELEVATIONS SHALL BE CONSTRUCTED WITHIN 0.1 VERTICAL FEET; WIDTHS AND MEAN DEPTHS MUST FALL WITHIN THE RANGES SHOWN IN THE DRAWINGS.
17. THE CONSTRUCTED STREAM CHANNEL SHALL BE STABILIZED AS SOON AS POSSIBLE BY SEEDING IN ACCORDANCE WITH THE PLOT SCHEDULE, ADDING STRAW MULCH TO BARE SOIL, AND BY INSTALLING EROSION CONTROL BLANKET FROM THE INNER BERM TO BEYOND THE TOP OF THE BANKFULL CHANNEL. SEE EROSION CONTROL BLANKET DETAIL. PRIOR TO INSTALLING BLANKET, PREPARE THE BED BY LOOSENING THE SOIL 3 TO 6 INCHES, APPLY SEED AND THEN STRAW MULCH. SEED SHALL BE BROADCAST EVENLY OVER THE AREA USING A BROADCAST SPREADER PRIOR TO COVERING WITH THE EROSION CONTROL BLANKET. THE BLANKET SHALL BE ROLLED OUT IN THE DIRECTION OF THE ANTICIPATED RUN-OFF FLOW. INSTALL BLANKET IN ACCORDANCE WITH DETAIL SHOWN HEREIN. REWORKING OF AREAS THAT DO NOT ESTABLISH VEGETATION OR BECOME UNSTABLE SHALL BE NECESSARY IF THE EROSION CONTROL BLANKET SEPARATES FROM THE SOIL. GEOCOIR / DEKOWE 700 OR APPROVED EQUAL SHALL BE USED FOR THE EROSION CONTROL BLANKET. SEEDING OF THE BANKFULL BENCH SHALL BE IN ACCORDANCE WITH THE PLANTING TABLE. REFER TO EROSION CONTROL BLANKET DETAIL FOR PLACEMENT OF EROSION CONTROL BLANKET.
18. IF THE TIMING OF PROJECT IS SUCH THAT RIPARIAN SEED MIX CANNOT BE PLACED IN THE SPRING, THEN NSE SHALL SEED WITH TEMPORARY COVER ACCORDING TO THE EROSION AND SEDIMENT PLAN OR APPROVED BY THE ENGINEER UNTIL RIPARIAN MIX CAN BE SEEDED IN THE FALL.
19. THE HARVESTING AND INSTALLATION OF LIVE STAKES SHALL BE PERFORMED ONLY DURING THE DORMANT SEASON TYPICALLY BETWEEN DECEMBER 1 AND FEBRUARY 15. NSE SHALL NOTIFY ENGINEER 7 DAYS PRIOR TO HARVESTING TO REVIEW AND APPROVE ALL HARVESTING SITES. UPON APPROVAL BY ENGINEER, NSE SHALL BE RESPONSIBLE FOR HARVESTING AND TRANSPORTING THE LIVE STAKE CUTTINGS TO THE JOB SITE.
20. LIVE STAKES SHALL BE INSTALLED ALONG THE OUTSIDE MEANDER BEND AND ALONG RIFFLES WHERE INDICATED ON THE DRAWINGS AND DETAILS. LIVE STAKES SHALL BE INSTALLED INTO THE EROSION CONTROL BLANKET IN ADDITION TO THE DEAD STAKES.
21. EXCESS SPOIL MATERIAL MAY BE SPREAD AND GRADED ONSITE OR IN THE ONSITE PIT AS APPROVED BY THE ENGINEER.
22. TOPSOIL SHALL BE REMOVED FROM EXCAVATION AND SPOIL AREAS PRIOR TO CUT OR FILL AND RE-APPLIED TO AREAS AFTER ROUGH GRADING IS COMPLETE. SIX INCHES OF TOPSOIL SHALL BE PLACED ON DISTURBED AREAS TO MEET GRADE.
23. SPOIL AREAS SHALL BE SEEDED WITH TEMPORARY VEGETATION WITHIN 7 DAYS FOLLOWING GRADING.
24. THE PLACEMENT OF MULCH SHALL OCCUR A MAXIMUM 48 HOURS AFTER SEEDING. MULCH WILL BE SPREAD TO COVER THE INSTALLED AREAS AT A MINIMUM RATE OF 1.5 TONS PER ACRE. MULCH SHALL BE KEPT OUT OF THE CROWNS OF SHRUBS AND GROUND COVER.
25. IF SOFT SOILS ARE ENCOUNTERED WHEN RECONSTRUCTING STREAM BANKS, RESTORE BANK WITH SOD MAT COVERING ALONG RIFFLES AND WOOD TOE SOD MAT ALONG BENDS.
26. NSE WILL CALL FOR UTILITY MARKING AT LEAST 48 HOURS PRIOR TO START OF CONSTRUCTION. IT MAY BE NECESSARY FOR NSE TO CONTACT THE COUNTY CLERK TO DETERMINE WHAT UTILITY COMPANIES HAVE FACILITIES IN THE PROJECT AREA. THE LOCATIONS OF THE UTILITIES SHOWN ON THESE DRAWINGS ARE APPROXIMATE ONLY AND MAY NOT BE ACCURATE. LOCATING UTILITIES IS THE SOLE RESPONSIBILITY OF NSE. THE ENGINEER AND PROJECT OWNER WILL NOT BE RESPONSIBLE FOR ANY DAMAGES TO UTILITIES.
27. NSE WILL UTILIZE NATIVE MATERIAL FROM THE SITE WHERE AVAILABLE AND ALLOWED BY THE ENGINEER. NATIVE MATERIAL THAT CAN BE FOUND ON SITE INCLUDE TREES THAT CAN PROVIDE LIVE STAKES AND TREES THAT CAN BE USED FOR LOG STRUCTURES AND WOOD DEBRIS.
28. AFTER CONSTRUCTION, THE ACCESS ROADS LEADING TO THE PROJECT SITE SHALL BE RESTORED TO AS GOOD OR BETTER CONDITION THAN BEFORE CONSTRUCTION.
29. FOOTER DEPTH ON ALL STRUCTURES REQUIRING FOOTERS SHALL BE AT LEAST 6 TIMES GREATER THAN THE DROP BETWEEN THE STRUCTURE AND THE FOOTERED STRUCTURE DIRECTLY UPSTREAM OR APPROVED BY THE ONSITE ENGINEER.

EROSION/SEDIMENTATION CONTROL NOTES

1. ALL CONTROL MEASURES SHALL BE CHECKED, AND REPAIRED AS NECESSARY, MONTHLY IN DRY PERIODS, AND WITHIN 24 HOURS AFTER ANY RAINFALL AT THE SITE OF .75 INCHES OR GREATER WITHIN A 24 HOUR PERIOD. DAILY CHECKING AND, IF NECESSARY, REPAIRING SHALL BE DONE DURING PROLONGED RAINFALLS. THE PERMITTEE SHALL MAINTAIN WRITTEN RECORDS OF SUCH CHECKS AND REPAIRS ON-SITE AT ALL TIMES, AND RECORDS SHALL BE SUBJECT TO INSPECTION AT ANY REASONABLE TIME.
2. THE CONSTRUCTION ENTRANCE SHALL BE MAINTAINED AS REQUIRED TO PREVENT SILT/SEDIMENT FROM LEAVING THE SITE. THIS INCLUDES BUT IS NOT LIMITED TO WASH DOWN OF THE CONSTRUCTION ENTRANCE, INSTALLING AND UTILIZING A VEHICLE WASH DOWN AREA, INSTALLING ADDITIONAL STONE, ETC.
3. ANY AND ALL SILT/SEDIMENTATION SHALL BE FREQUENTLY REMOVED FROM THE SILT FENCE, DITCHES, CHECK DAMS AND RETENTION AREAS. AT THE END OF CONSTRUCTION, THESE AREAS SHALL BE COMPLETELY FREE OF SILT/SEDIMENTATION AND SHALL BE STABILIZED AS STATED IN THE PLANS AND SPECIFICATIONS.
4. ALL BMPS SHALL BE DESIGNED AND INSTALLED IN ACCORDANCE WITH THE EROSION CONTROL AND STORMWATER QUALITY FIELD GUIDE, LOCAL STANDARDS FOR EROSION AND SEDIMENT CONTROL AND THE PLANS AND SPECIFICATIONS. IF CONFLICTS ARISE BETWEEN THESE REQUIREMENTS, THE MORE STRINGENT SHALL APPLY.
5. BMPS SHOWN ALONG THE PERIMETER OF THE DISTURBED AREAS SHALL BE INSTALLED PRIOR TO DISTURBANCE ACTIVITY. OTHER BMPS SHALL BE INSTALLED AS SOON AS CONSTRUCTION SEQUENCES ALLOW.
6. TEMPORARY DIVERSION OF RUNOFF/RUNON WATER SHALL BE INSTALLED AS NEEDED TO FACILITATE CONSTRUCTION OR AS DIRECTED ON-SITE BY THE ENGINEER.
7. ALL DISTURBED AREAS SHALL BE PERMANENTLY STABILIZED IMMEDIATELY AFTER THE COMPLETION OF THE GRADING OPERATION. AREAS REQUIRING COCONUT COIR MATTING SHALL BE SEEDED AND MULCHED FOR STABILIZATION PRIOR TO THE INSTALLATION OF THE MATTING.
8. TEMPORARY STABILIZATION OF DISTURBED AREAS MUST BE INITIATED IMMEDIATELY WHENEVER WORK TOWARD PROJECT COMPLETION AND FINAL STABILIZATION OF ANY PORTION OF THE SITE HAS TEMPORARILY CEASED AND WILL NOT RESUME FOR A PERIOD EXCEEDING THIRTEEN (13) CALENDAR DAYS. THOSE AREAS SHALL BE SEEDED AND MULCHED IN ACCORDANCE WITH THE PLANS AND SPECIFICATIONS.
9. NECESSARY MEASURES SHALL BE TAKEN TO PRODUCE AND MAINTAIN AN ACCEPTABLE STAND OF GRASS. SAID MEASURES TO INCLUDE (BUT NOT LIMITED TO) WATERING, RE-SEEDING, REGRADING ERODED AREAS, RE-FERTILIZING, ETC.
10. NSE IS RESPONSIBLE FOR KEEPING MUD AND DEBRIS OFF CITY/STATE STREETS AND ROW. CLEANUP IS REQUIRED DAILY.
11. ALL HAZARDOUS SUBSTANCES USED FOR THIS PROJECT (PAINT, OIL, GREASE, AND OTHER PETROLEUM PRODUCTS) SHALL BE STORED IN ACCORDANCE WITH SPCC REGULATIONS. THESE SUBSTANCES SHALL BE STORED AWAY FROM DRAINS AND DITCHES IN WATERTIGHT CONTAINERS. DISPOSAL OF THESE SUBSTANCES SHALL BE IN ACCORDANCE WITH ADEM REGULATIONS. DAILY INSPECTIONS SHALL BE PERFORMED FOR LEAK DETECTION. IF LEAKS OCCUR, APPROPRIATE ACTION SHALL BE TAKEN TO CONTAIN AND REMEDIATE THE SPILL. ADEQUATE TRASH CONTAINERS SHALL BE KEPT ON SITE FOR THE DISPOSAL OF CONSTRUCTION MATERIALS WASTE. NECESSARY MEASURES SHALL BE TAKEN TO PREVENT ANY TRASH OR OTHER POLLUTANTS FROM ENTERING "WATERS OF THE UNITED STATES."
12. ALL TEMPORARY MEASURES SHALL BE REMOVED ONCE ACCEPTABLE PERMANENT STABILIZATION IS ACHIEVED. THE ENGINEER SHALL DETERMINE IF THE PERMANENT STABILIZATION IS ACCEPTABLE.

SPECIAL NOTES

1. THE ELEVATIONS SHOWN HEREIN ARE BASED ON NSE TEAM GPS SURVEY THAT ENCOMPASSES THE EXISTING GROUND SURFACE FROM WHICH ALL COMPUTATIONS FOR CUT/FILL ARE BASED. SLIGHT DISCREPANCIES BETWEEN THE EXISTING GROUND DIGITAL SURFACE AND FIELD CONDITIONS CAN RESULT IN SIGNIFICANT VARIATIONS IN TOTAL EXCAVATED QUANTITIES. THUS, QUANTITIES OF MATERIAL EXCAVATED SHOULD BE COMPARED TO THOSE SHOWN ON THE DRAWINGS TO MANAGE THE MOVEMENT OF MATERIAL ACROSS THE SITE.

TOPOGRAPHIC INFORMATION:

EXISTING GROUND SURFACES ARE BASED ON A SURVEY COMPLETED IN SEPTEMBER OF 2016. THE USE OF GPS SURVEY EQUIPMENT WAS USED TO COLLECT THE DATA WITHIN A TOLERANCE OF 1 VERTICAL AND 0.06 HORIZONTAL. THE DATA WAS NOT COLLECTED BY A PLS. BENCHMARKS WERE SET THROUGHOUT THE SITE AND CAN BE PROVIDED AT ANY TIME. CHANGES IN EXISTING SURFACES SHALL BE INCIDENTAL AND AT RISK BY NSE. THE ENGINEER MAKES NO WARRANTY FOR THE ACCURACY OF ANY SURVEY INFORMATION SHOWN IN THESE DRAWINGS. IF DISCREPANCIES EXIST BETWEEN THE THREE DIMENSIONAL DIGITAL SURFACE AND THE ACTUAL GROUND SURFACE, SIGNIFICANT VARIATIONS IN THE EXCAVATIONS QUANTITIES CAN BE EXPECTED, WHICH COULD AFFECT HANDLING AND PHASING CONSIDERATIONS FOR THE PROJECT. THE ENGINEER ACCEPTS NO RESPONSIBILITY FOR CHANGES TO EXCAVATION QUANTITIES THAT CHANGE AS A RESULT OF ANY DISCREPANCIES BETWEEN THE DIGITAL SURFACE AND EXISTING GROUND.

SPECIAL GRADING NOTE:

THE AGREED UPON INTENT OF THIS GRADING PLAN IS TO MAINTAIN A "LIVE" SURFACE SO THAT ANY CHANGES THAT ARISE DURING CONSTRUCTION CAN BE QUICKLY ENCOMPASSED INTO THE THREE-DIMENSIONAL SURFACE GENERATED DURING THIS DESIGN PROCESS. AS SUCH, FINE TUNING OF THE SURFACE THAT WOULD ELIMINATE THE APPEARANCE OF JAGGED CONTOUR LINES WHERE SLIGHT VARIATIONS BETWEEN THE EXISTING AND PROPOSED SURFACES WAS NOT COMPLETED.

REVISIONS

REV	DESCRIPTION	DATE	APPROVED
1	30% Concept Re-Design	7/01/16	DTW/DAB
2	60% Concept Re-Design	10/18/16	DTW/DAB
3	98% DESIGN	02/23/17	DTW/DAB

DATE: 3/9/2017
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SHEET: 1

North State Environmental
754 Mount Mahogany, Suite B
Livermore, CO 80536

PROJECT: Boulder County OSMP
North State Environmental / 5SSR

CLIENT: Boulder Creek Restoration
Boulder County, Colorado
98% Design

Item Description	Estimated Quantity	Unit
Mobilization	1	LS
Temporary Construction Access Road	1	LS
Upstream Grading Cut and Transplants	17350	CU YD
Upstream Grading Fill Haul Distance and Berm (20-100ft)	17350	CU YD
Downstream Grading Cut and Transplants	1550	CU YD
Downstream Grading Fill Haul Distance (20-50ft)	1550	CU YD
Clearing and Grubbing (As Directed)	1.82	Acres
Optional - Installation of Wood Toe Habitat Structures with existing stockpiled wood	360	LF
Optional-STA 1+01 - Log J-Hook with Rootwad @ 75TNS/structure Boulders availble and stockpiled or	1	Each
Log J-Hook with Rootwad @ 75TNS/structure Boulders availble and stockpiled onsite	1	Each
Log Boulder Constructed Boulder Riffle @200TNS/structure Boulders availble and stockpiled onsite	2	Each
Rock Cross-Vane "A" Vane @ 160TNS/structure Boulders availble and stockpiled onsite	1	Each
Boulder and Concrete Diversion Return/Augmentation Station	1	Each
Optional - Boulder Toe on overflow	60	TN
Temporary/Permanent Seeding with Staw	6.8	Acres

REVEGETATION PLANTING PLAN

ZONE: Riparian Bench

SPECIES NAME	LIFE FORM*	COMMON NAME	CONTAINER TYPE	% IN PALETTE	ECO TYPE AVAILABLE?
CONTAINERS					
Alnus incana var tenuifolia	NS	thinleaf alder	15 CI	5	YES
Betula occidentalis var rivularis	NS	western riverbirch	15 CI	10	YES
Coralys cornuta	NS	american hazelnut	15 CI	5	YES
Glyceria grandis	NPG-L	American mannagrass	10 CI	5	YES
Paddus virginiana	NS	chokecherry	40 CI	10	YES
Panicum virgatum	NPG-L	switchgrass	10 CI	5	NO
			SUBTOTAL:	40	
CUTTINGS					
Salix irrorata	NS	bluestem willow	CUTTINGS	3	
Populus angustifoliia	NT	narrowleaf cottonwood	CUTTINGS	5	
Populus deltoides	NT	plains cottonwood	CUTTINGS	2	
Populus x acuminata	NT	lanceleaf cottonwood	CUTTINGS	15	
Salix amygdaoides	NT	peachleaf willow	CUTTINGS	5	YES
Salix exigua	NS	coyote willow	CUTTINGS	10	
Salix lucida var caudata	NS	shining willow	CUTTINGS	10	
Salix bebbiana	NS	coyote willow	CUTTINGS	5	
Salix monticola	NS	shining willow	CUTTINGS	5	
			SUBTOTAL:	60	
			TOTAL:	100	

ZONES: Revegetation Islands; Riparian Transition

SPECIES NAME	LIFE FORM*	COMMON NAME	CONTAINER TYPE	% IN PALETTE	ECO TYPE AVAILABLE?
CONTAINERS					
Coralys cornuta	NS	american hazelnut	40 CI	10	YES
Mondarda fistulosa	NPF	beebalm	10 CI	5	YES
Paddus virginiana	NS	chokecherry	40 CI	20	YES
Populus angustifolia	NT	narrowleaf cottonwood	40 CI	20	YES
Prunus americana	NS	American plum	40 CI	10	NO
Ribes cereum	NS	wax currant	40 CI	20	YES
Rosa woodsii	NS	Wood's rose	40 CI	10	NO
Salix amygdaoides	NT	peachleaf willow	1 GALLON	5	YES
			TOTAL:	100	

ZONES: Cuttings (Willow / Cottonwood); Vegetated Cobble Bar

SPECIES NAME	LIFE FORM*	COMMON NAME	CONTAINER TYPE	% IN PALETTE	ECO TYPE AVAILABLE?
CUTTINGS					
Salix irrorata	NS	bluestem willow	CUTTINGS	5	
Populus angustifoliia	NT	narrowleaf cottonwood	CUTTINGS	8	
Populus deltoides	NT	plains cottonwood	CUTTINGS	3	
Populus x acuminata	NT	lanceleaf cottonwood	CUTTINGS	25	
Salix amygdaoides	NT	peachleaf willow	CUTTINGS	8	YES
Salix exigua	NS	coyote willow	CUTTINGS	17	
Salix lucida var caudata	NS	shining willow	CUTTINGS	17	
Salix bebbiana	NS	coyote willow	CUTTINGS	8	
Salix monticola	NS	shining willow	CUTTINGS	8	
			TOTAL:	100	

* NP=Native Perennial; NA=Native Annual; G=Grass; G-L=Grass-Like; S=shrub; T=Tree; F=Forb.

REVISIONS

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2	60% Concept Re-Design	10/18/16	DTW/DAB
3	98% DESIGN	02/23/17	DTW/DAB

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DRAWING NO.

SHEET: 2

North State Environmental
754 Mount Mahogany, Suite B
Livermore, CO 80536

PROJECT: Boulder County OSMP
North State Environmental / 5SSR

CLIENT: Boulder Creek Restoration
Boulder County, Colorado
98% Design

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2	60% Concept Re-Design	10/18/16	DTW/DAB
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DATE: 2/23/2017

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North State Environmental
754 Mount Mahogany, Suite B
Livermore, CO 80536

PROJECT: Boulder County OSMP
North State Environmental / 5SSR

CLIENT: Boulder Creek Restoration
Boulder County, Colorado
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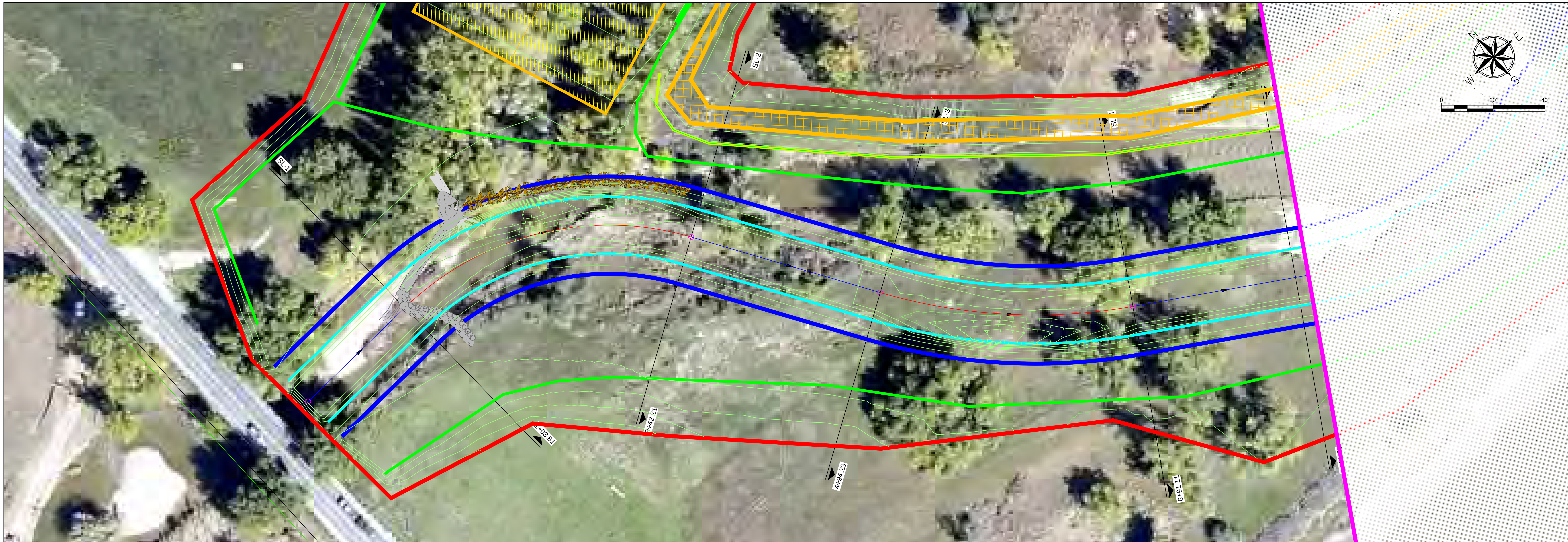

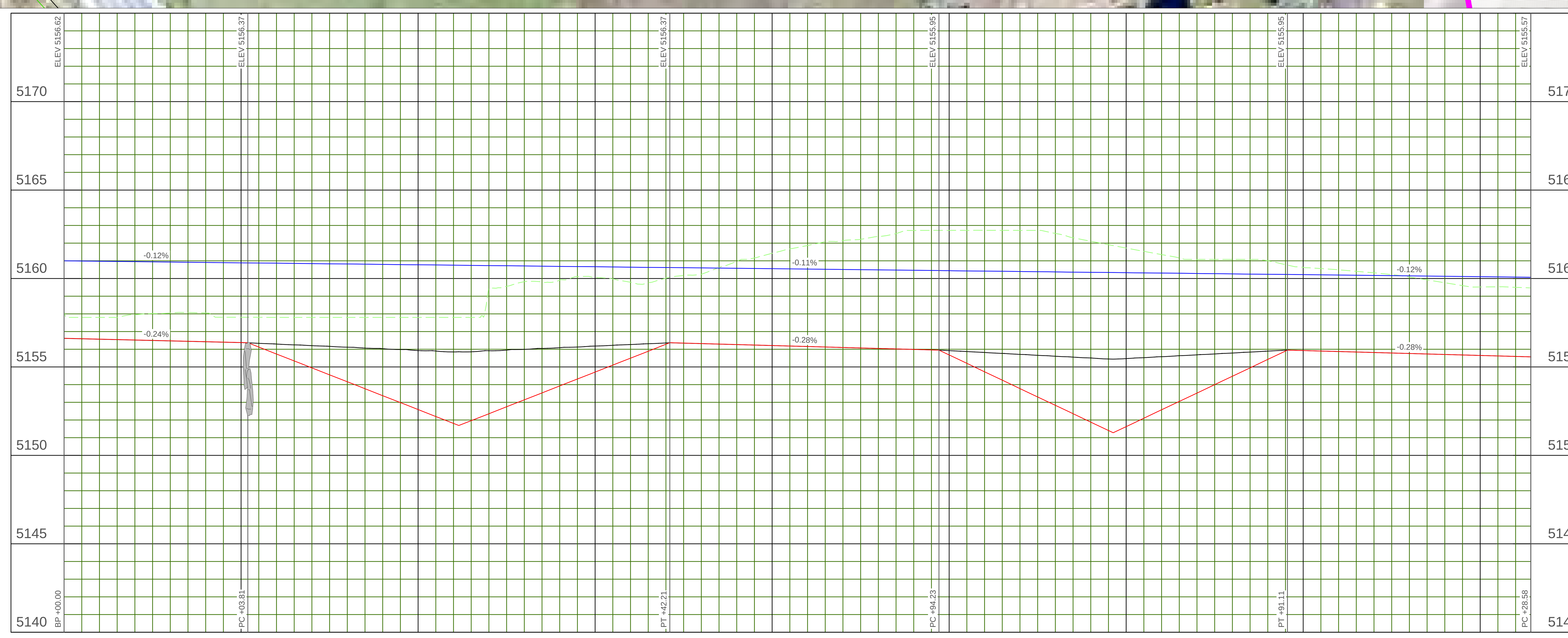

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754 Mount Mahogany, Suite B
Livermore, CO 80536

PROJECT: Boulder County OSMP
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Boulder County, Colorado
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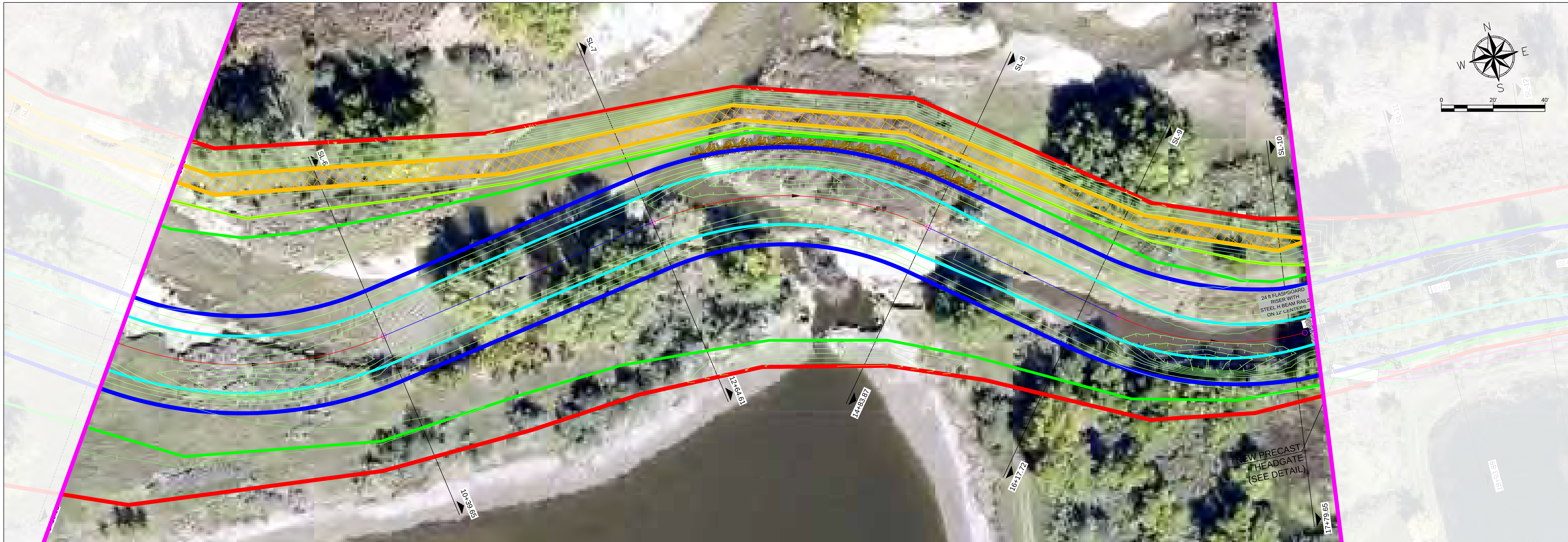

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754 Mount Mahogany, Suite B
Livermore, CO 80536

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CLIENT: Boulder Creek Restoration
Boulder County, Colorado
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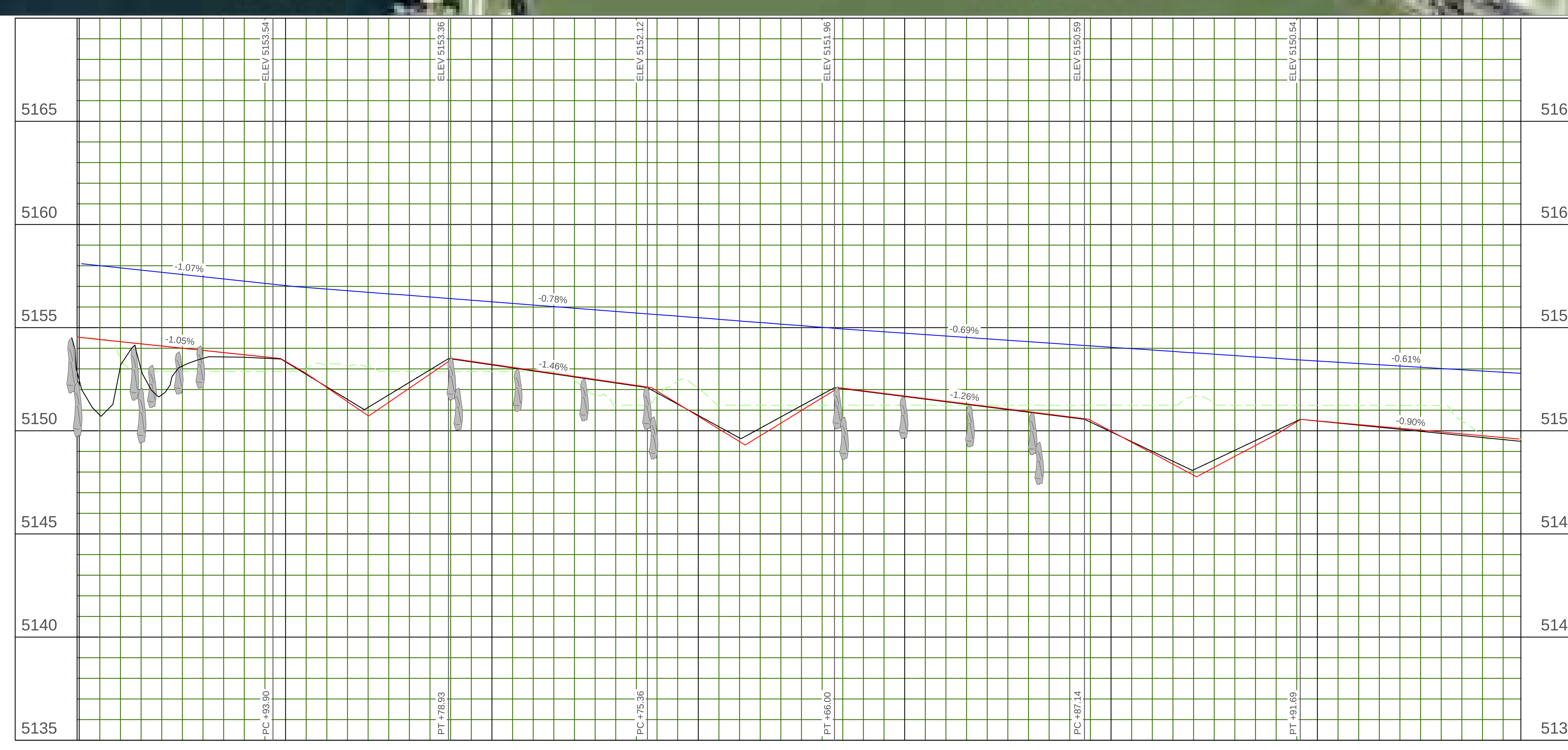

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2	60% Concept Re-Design	10/18/16	DTW/DAB
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NorthState ENVIRONMENTAL
North State Environmental
754 Mount Mohogany, Suite B
Livermore, CO 80536

PROJECT: Boulder County OSMP
North State Environmental / 5SSR

CLIENT: Boulder Creek Restoration
Boulder County, Colorado
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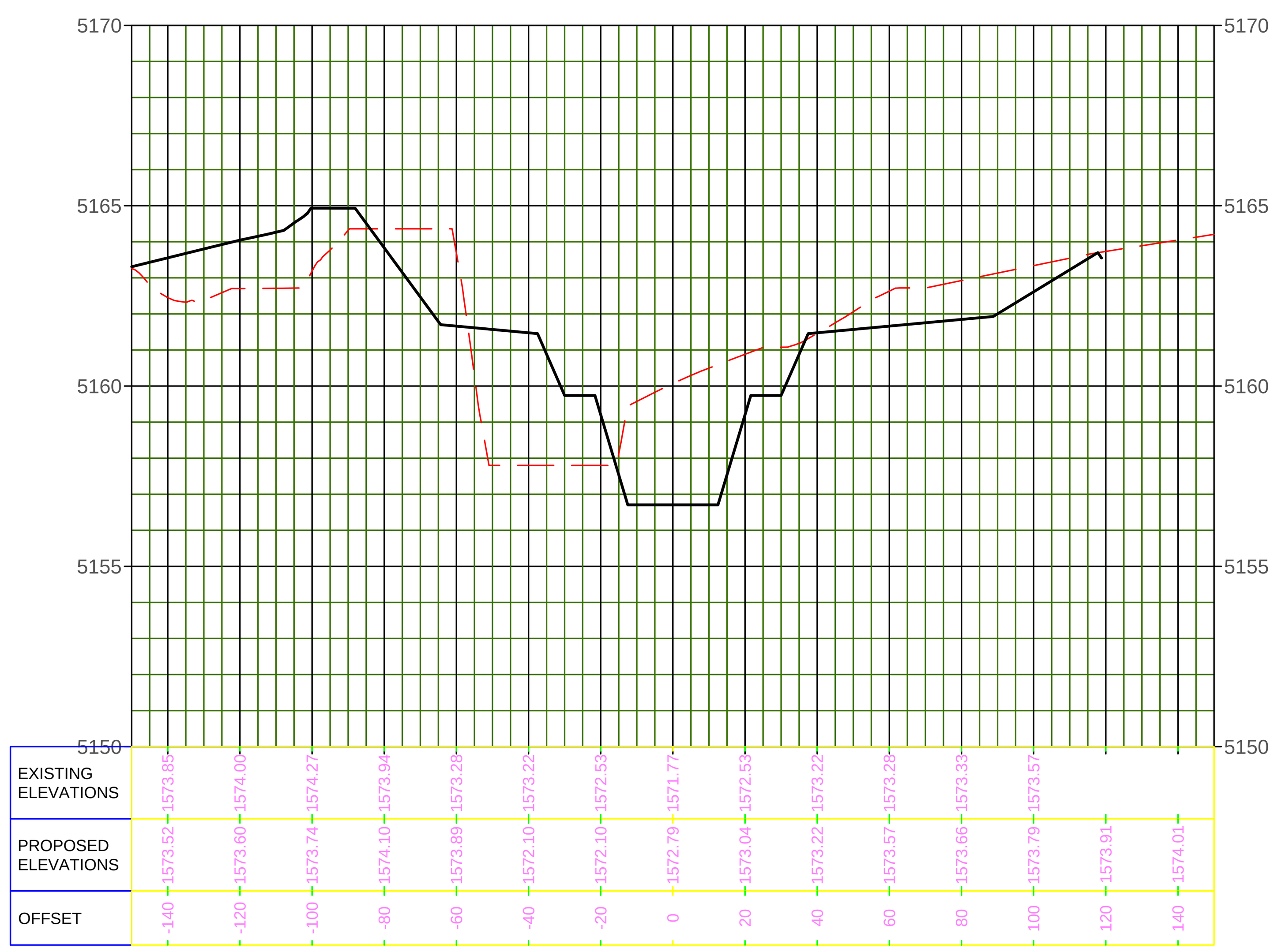

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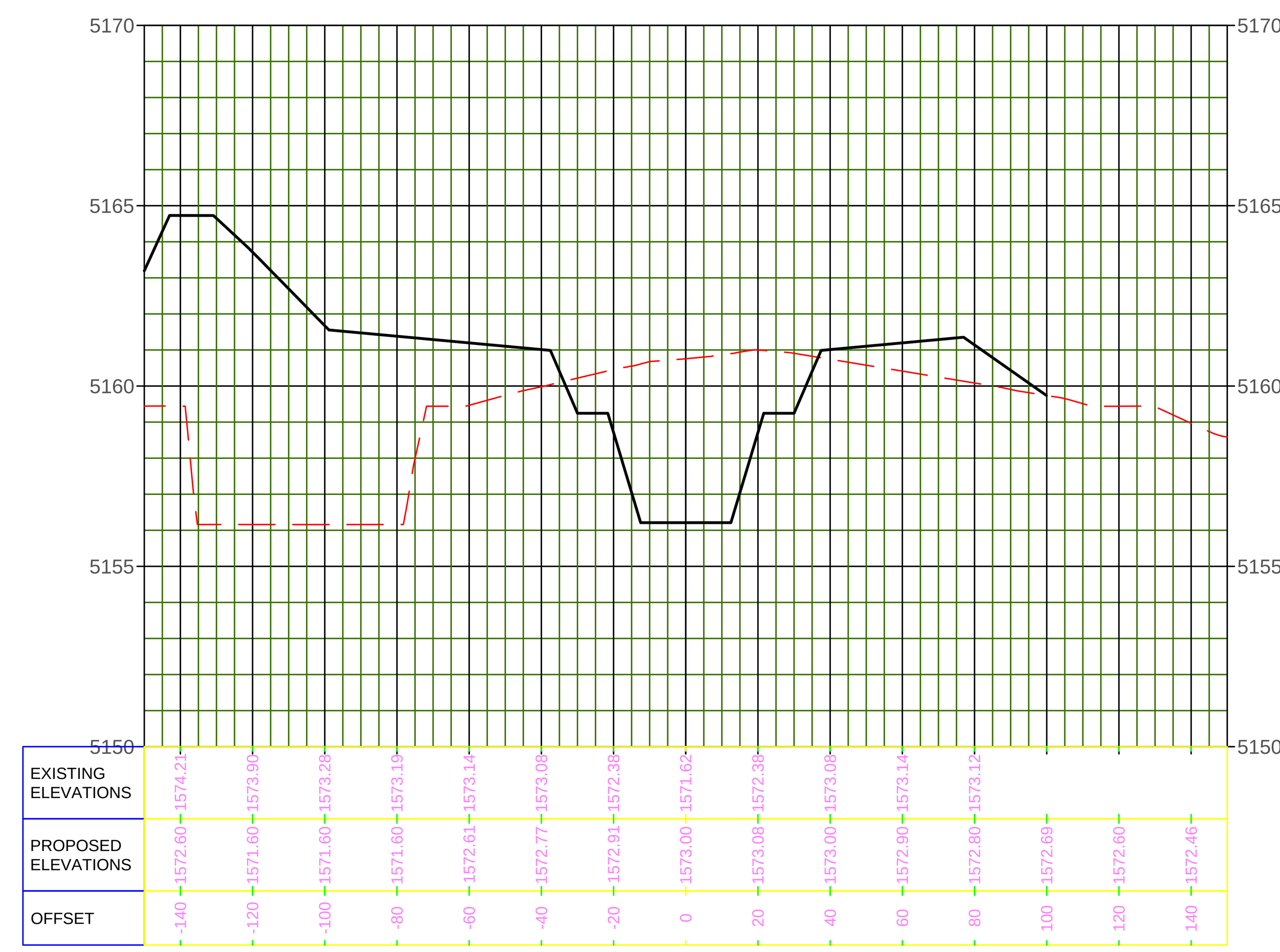

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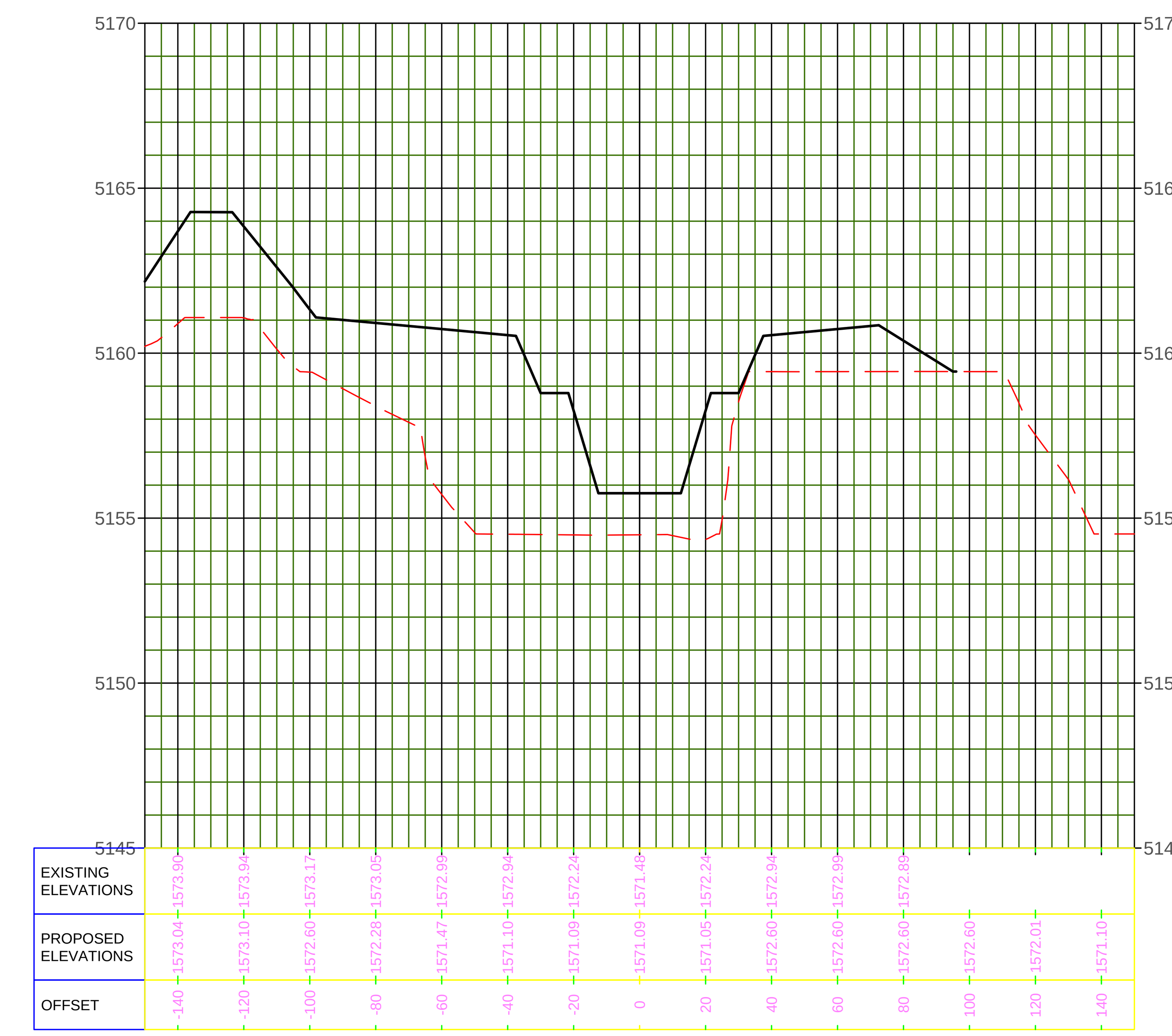

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4+94.23

8+18.51

DESIGN PROFILE

EXISTING PROFILE

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2

3/9/2017 9:44:48 AM

REVISIONS

REV	DESCRIPTION	DATE	APPROVED
1	30% Concept Re-Design	7/01/16	DTW/DAB
2	60% Concept Re-Design	10/18/16	DTW/DAB
3	98% DESIGN	02/23/17	DTW/DAB

DRAWN BY: | DATE 3/9/2017

CHECKED BY: | DATE

APPROVED BY: | DATE

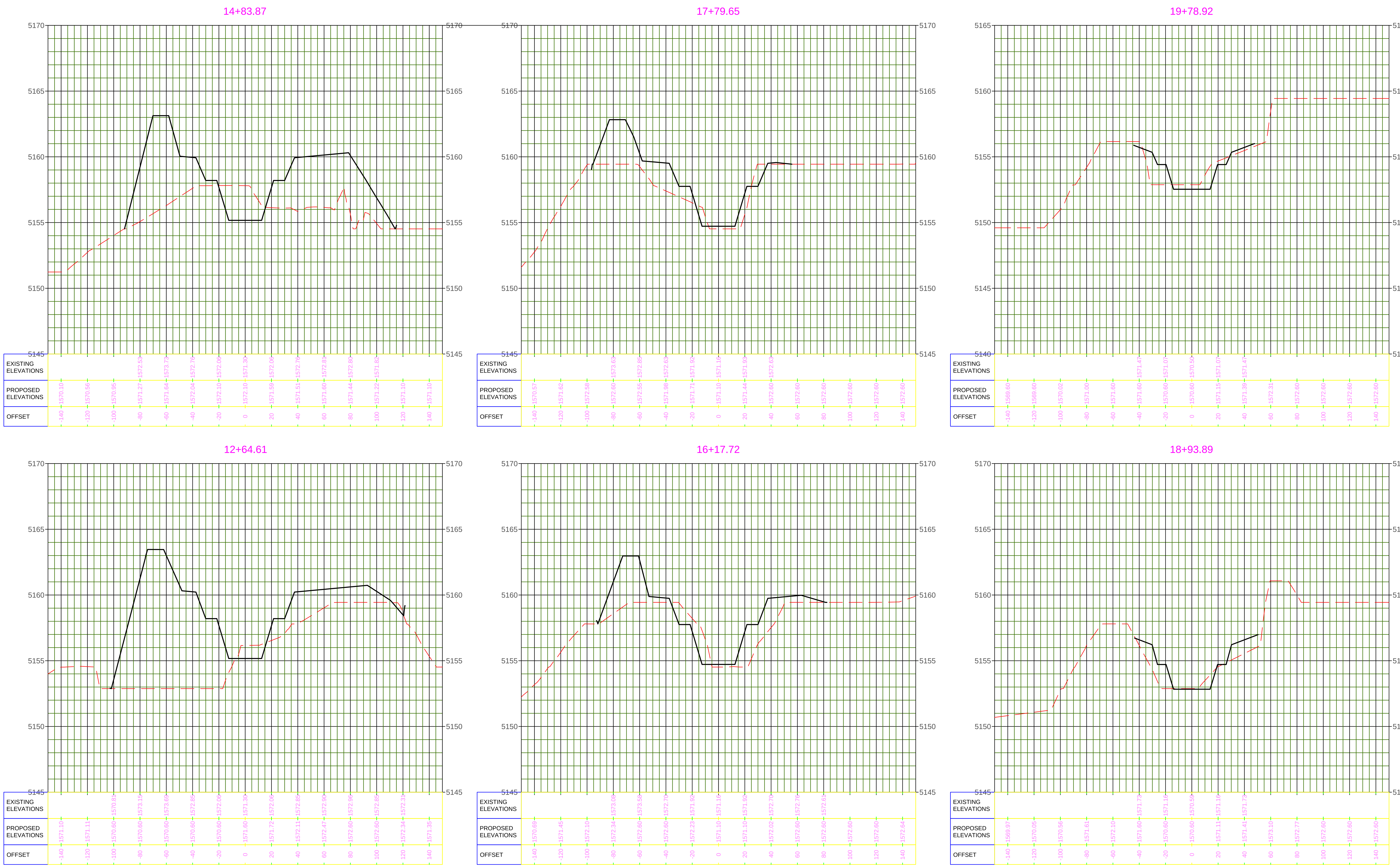
SCALE 1" = 40' | DRAWING NO. | SHEET 7

NorthState ENVIRONMENTAL

North State Environmental
754 Mount Mahogany, Suite B
Livermore, CO 80536

PROJECT: Boulder County OSMP
North State Environmental / 5SSR

CLIENT: Boulder Creek Restoration
Boulder County, Colorado
98% Design



DESIGN PROFILE

EXISTING PROFILE

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2	60% Concept Re-Design	10/18/16	DTW/DAB
3	98% DESIGN	02/23/17	DTW/DAB

REVISIONS

DRAWN BY: DATE 3/9/2017

CHECKED BY: DATE

APPROVED BY: DATE

SCALE 1" = 40'

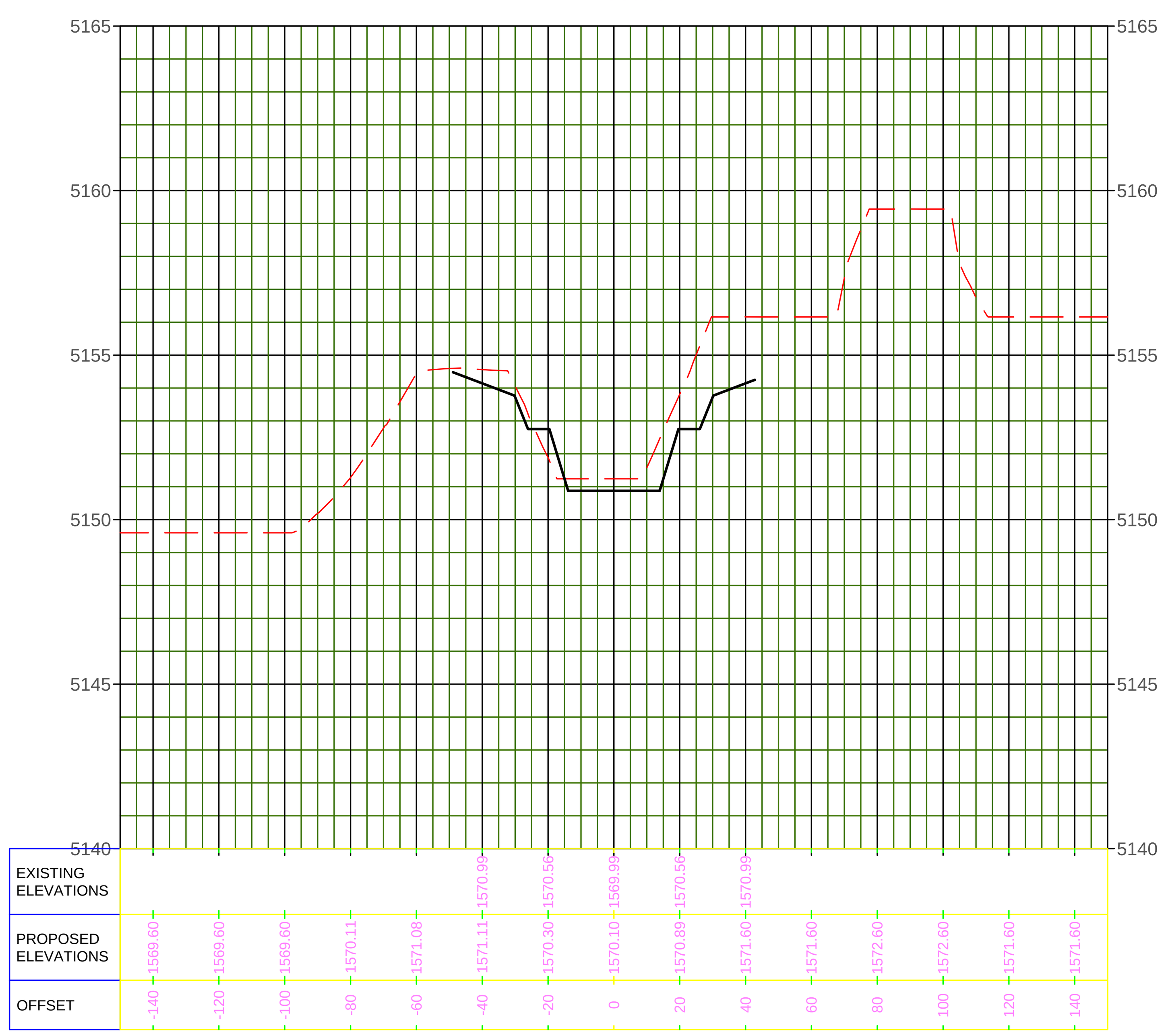
DRAWING NO.

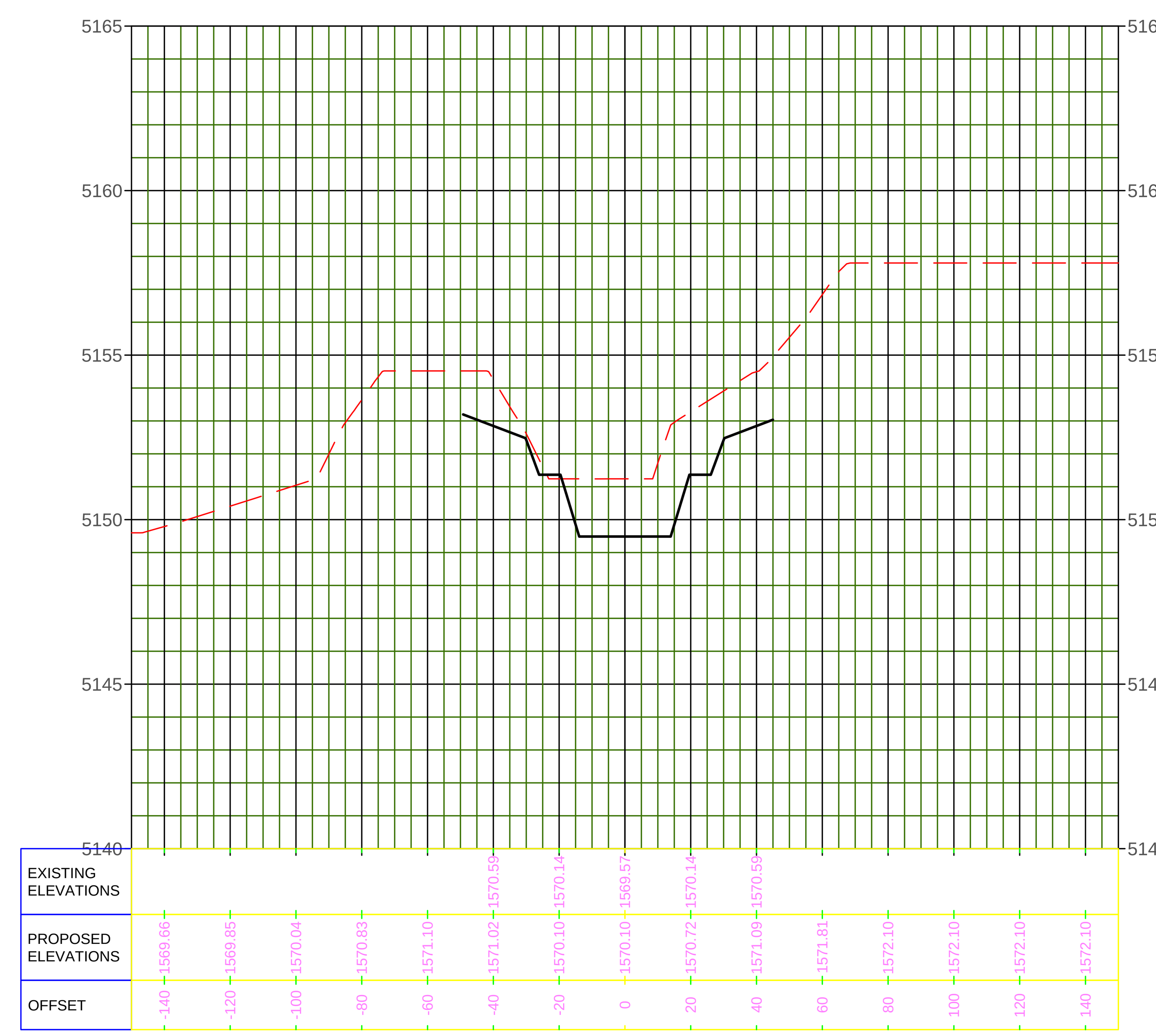
SHEET 8

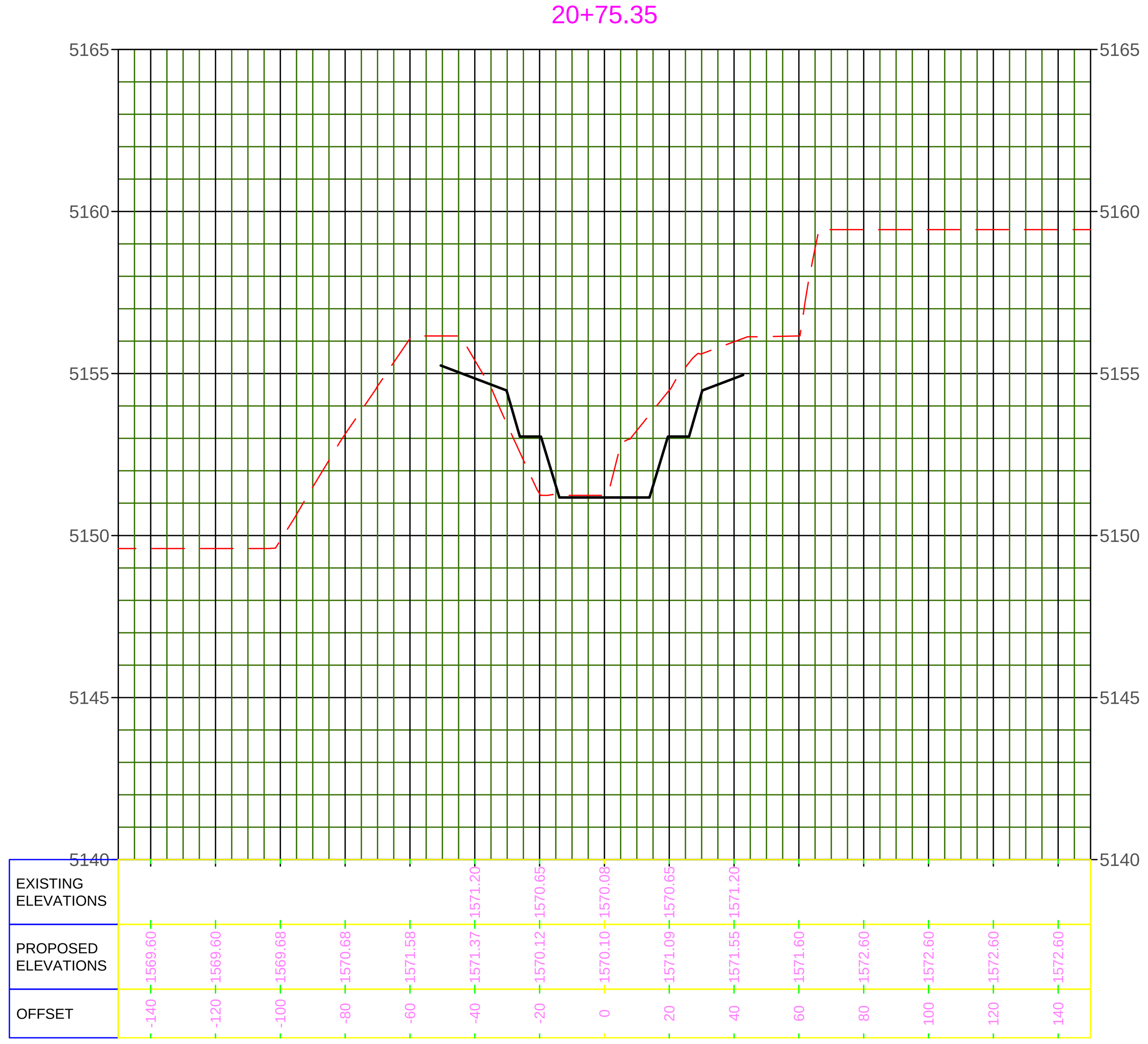
North State Environmental
754 Mount Mohogany, Suite B
Livermore, CO 80536

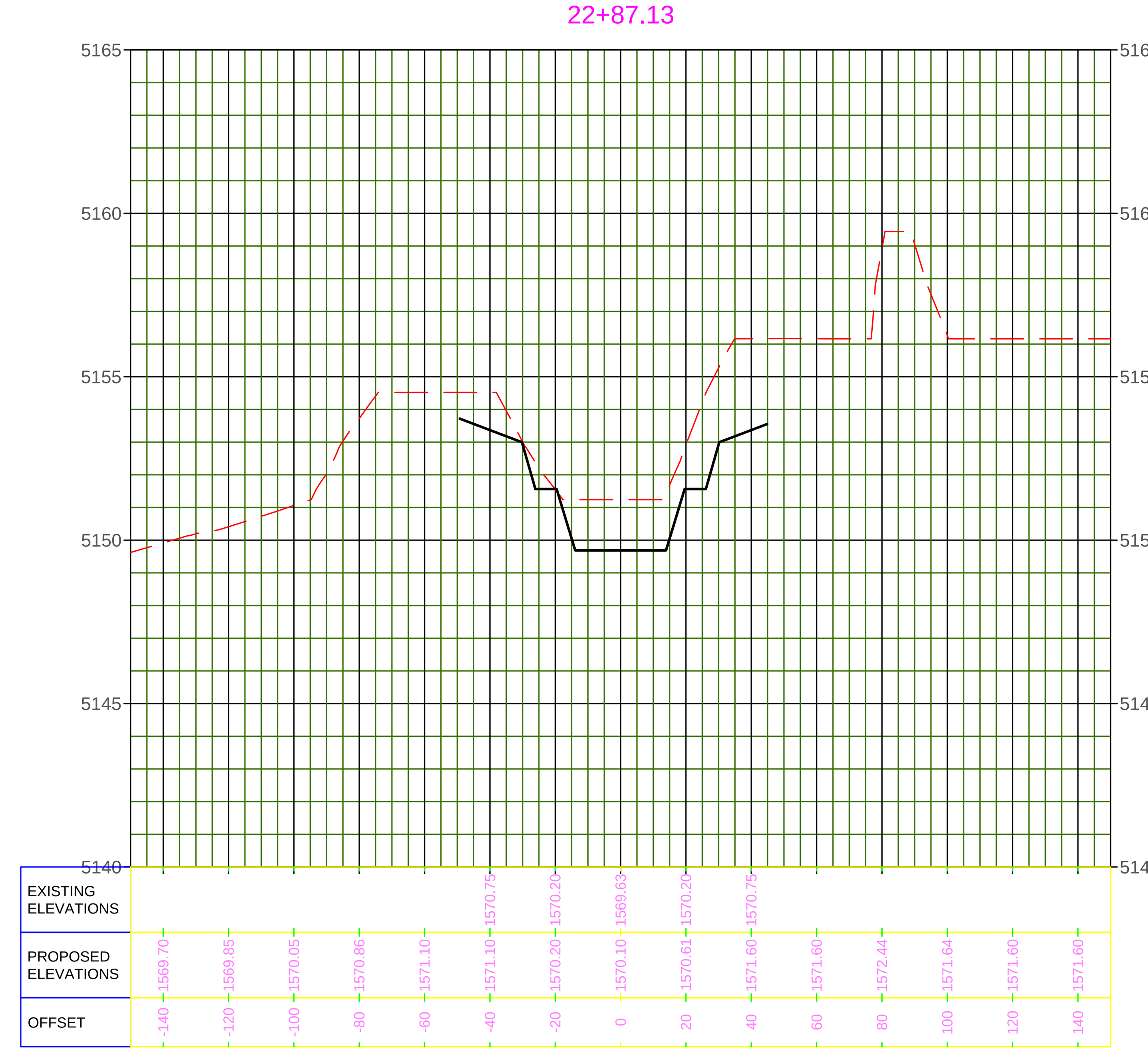
PROJECT: Boulder County OSMP
North State Environmental / 5SSR

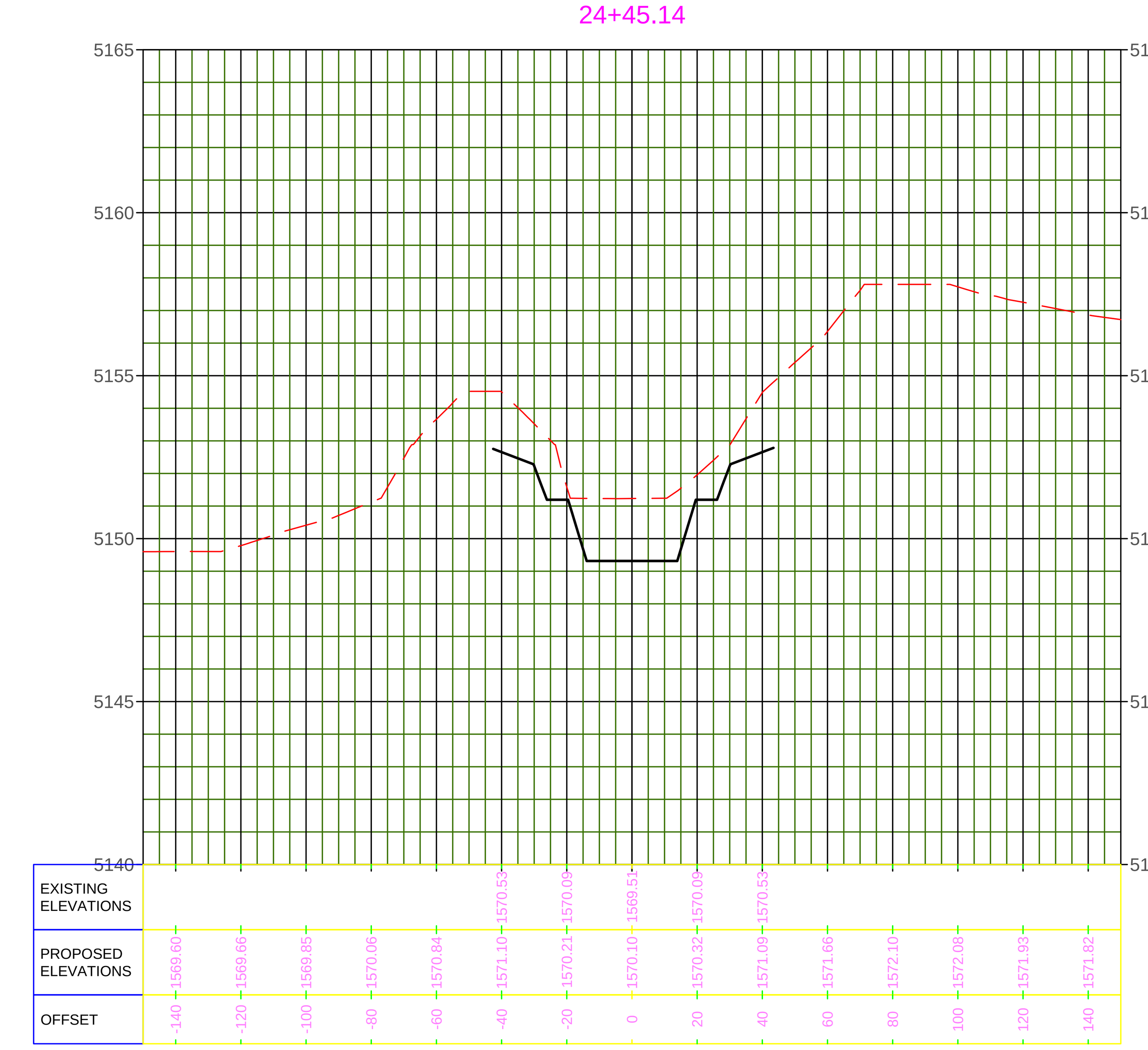
CLIENT: Boulder Creek Restoration
Boulder County, Colorado
98% Design











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EXISTING PROFILE

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3	98% DESIGN	02/23/17	DTW/DAB

REVISIONS

DATE 3/9/2017

DRAWN BY:

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SCALE 1" = 40'

DRAWING NO.

SHEET 9

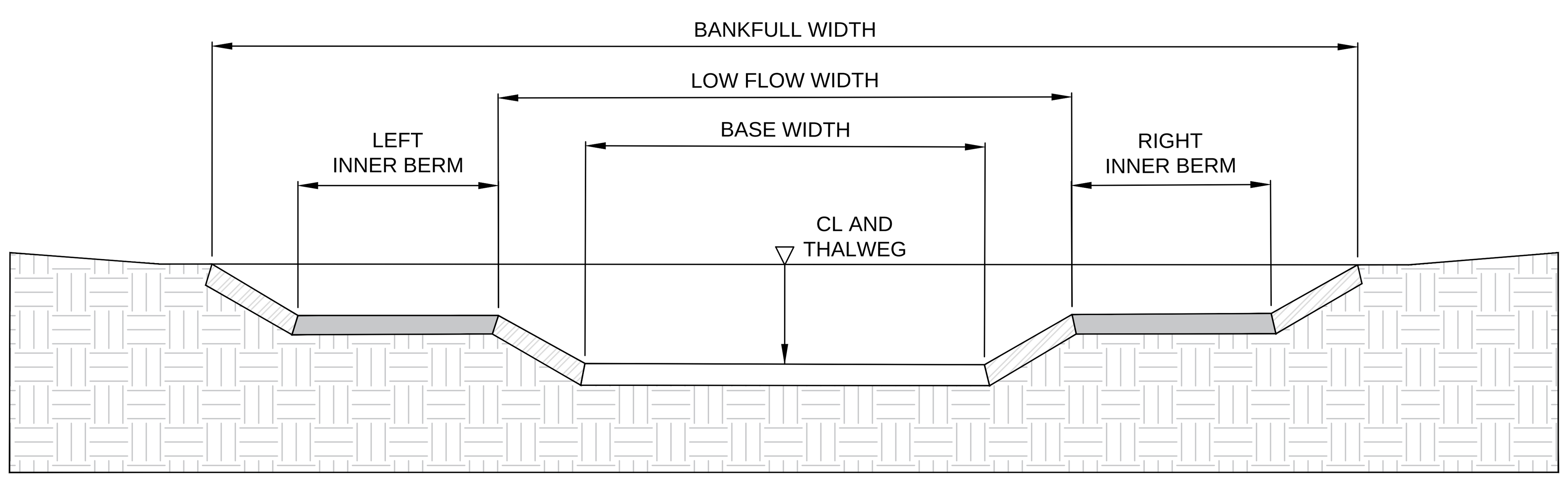
NorthState ENVIRONMENTAL

North State Environmental
754 Mount Mohogany, Suite B
Livermore, CO 80536

PROJECT: Boulder County OSMP
North State Environmental / 5SSR

CLIENT: Boulder Creek Restoration
Boulder County, Colorado
98% Design

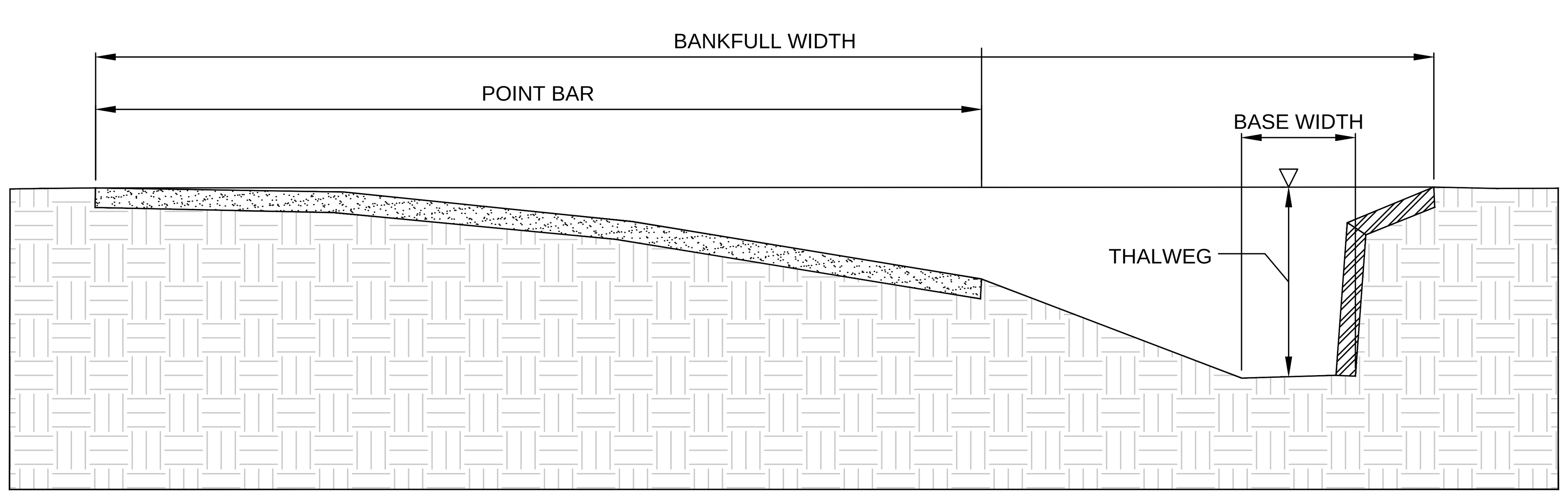
DOWNSTREAM REACH TYPICAL CROSS-SECTIONS
STA 0+00 TO 17+98



TYPICAL RIFFLE

NTS

DESIGN PARAMETERS	SIZE (FT)
BANKFULL AREA	205 SQ. FT.
BANKFULL WIDTH	70
MAX DEPTH	4.3
BASE WIDTH	28
LOW FLOW DEPTH	2.6
LOW FLOW WIDTH	43

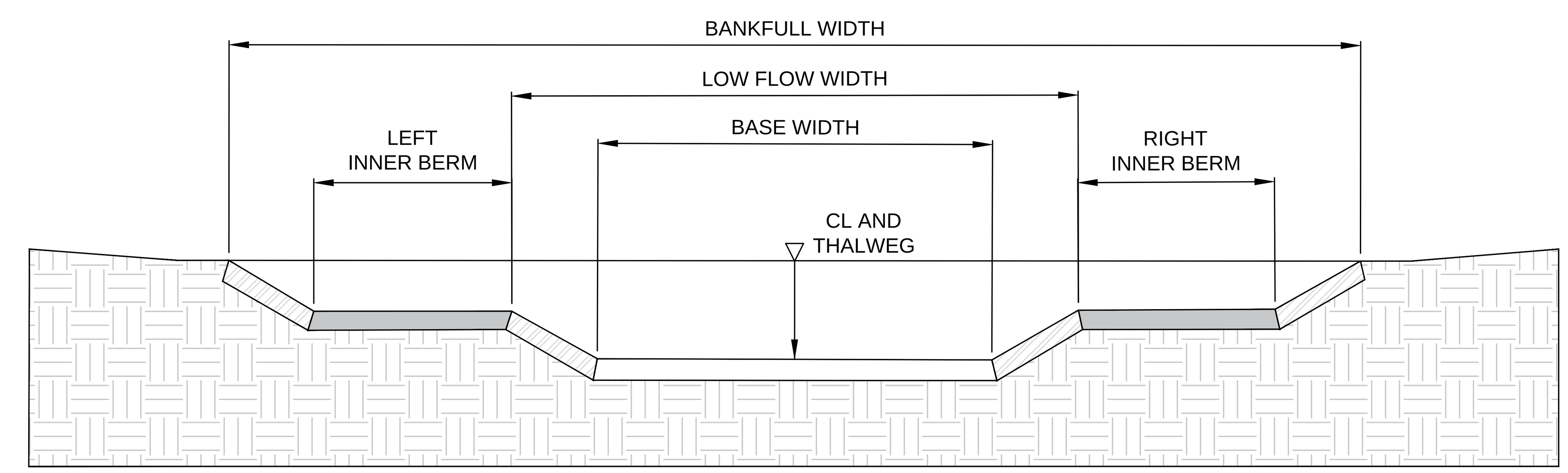


TYPICAL POOL MAX

NTS

DESIGN PARAMETERS	SIZE (FT)
BANKFULL WIDTH	77
MAX DEPTH	9.0
BASE WIDTH	8.5

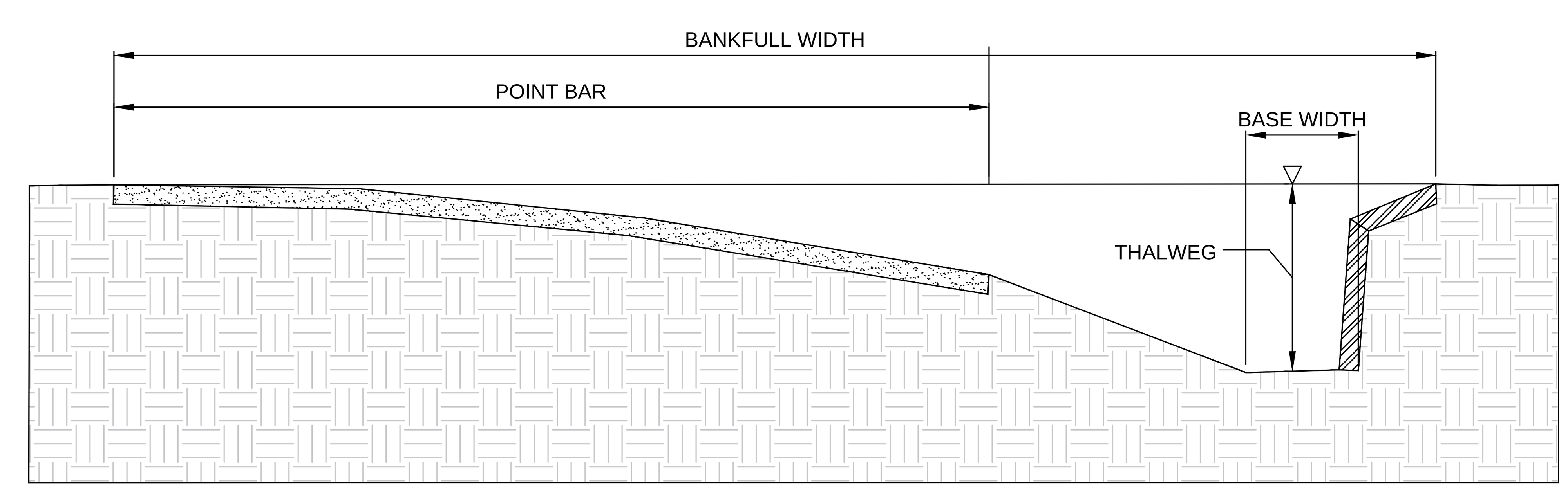
DOWNSTREAM REACH TYPICAL CROSS-SECTIONS
STA 17+98 TO 24+99



TYPICAL RIFFLE

NTS

DESIGN PARAMETERS	SIZE (FT)
BANKFULL AREA	150 SQ. FT.
BANKFULL WIDTH	70
MAX DEPTH	3.2
BASE WIDTH	25
LOW FLOW DEPTH	2.2
LOW FLOW WIDTH	38



TYPICAL POOL MAX

NTS

DESIGN PARAMETERS	SIZE (FT)
BANKFULL WIDTH	77
MAX DEPTH	6.0
BASE WIDTH	19

REVISIONS

REV	DESCRIPTION	DATE	APPROVED
1	30% Concept Re-Design	7/01/16	DTW/DAB
2	60% Concept Re-Design	10/18/16	DTW/DAB
3	98% DESIGN	02/23/17	DTW/DAB

DATE: 3/9/2017
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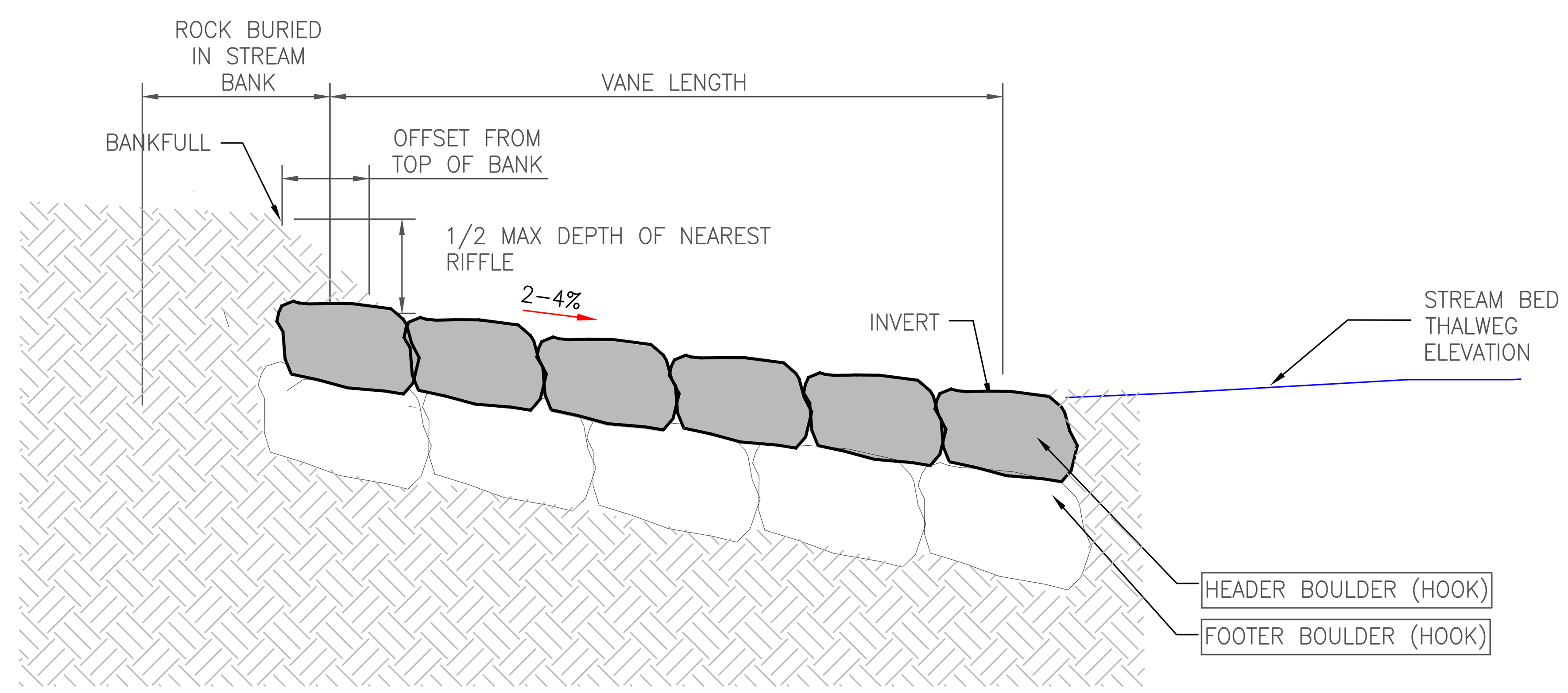
APPROVED BY:
SCALE 1" = 40'
DRAWING NO.
SHEET 10

NorthState ENVIRONMENTAL
North State Environmental
754 Mount Mohogany, Suite B
Livermore, CO 80536

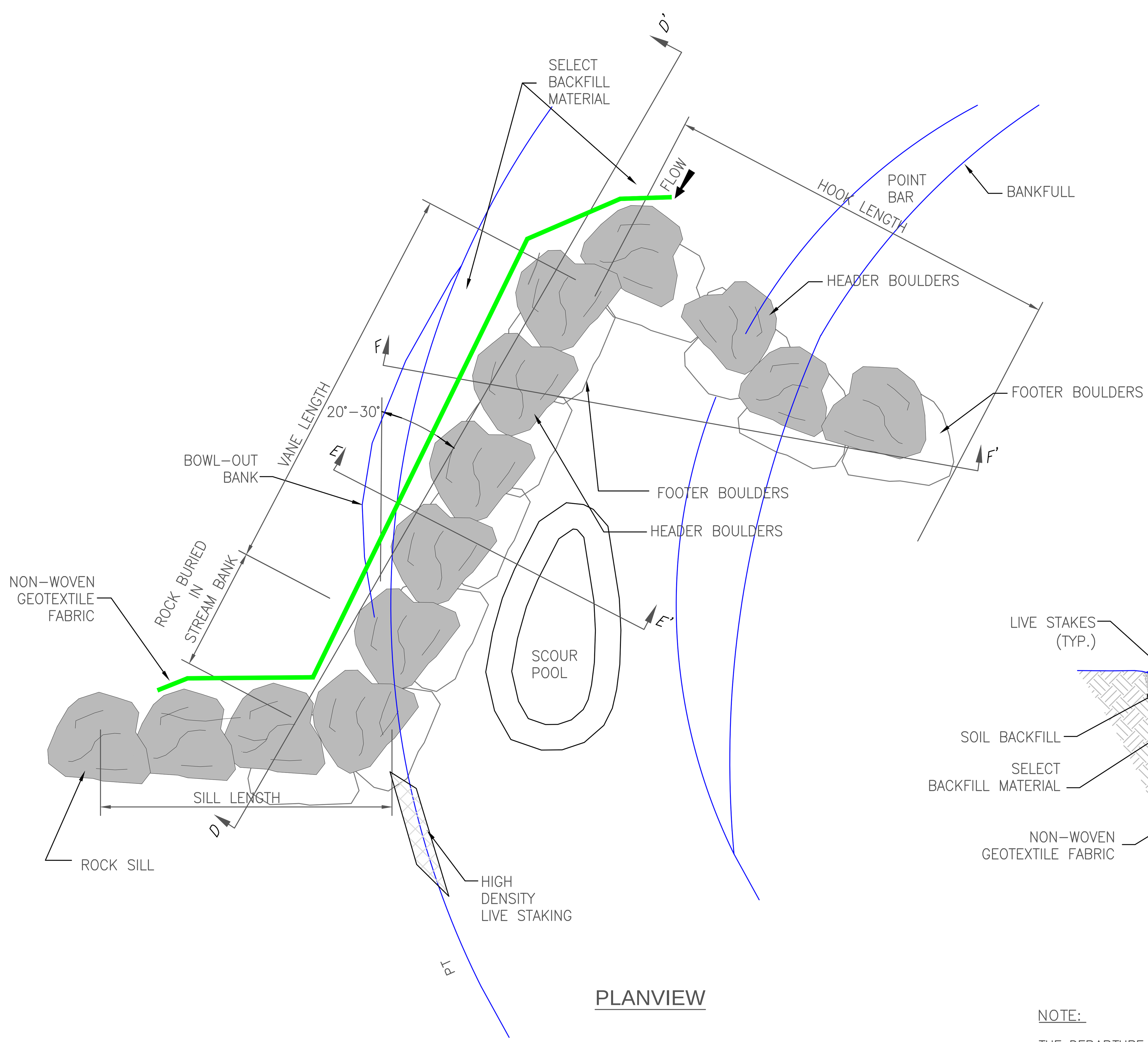
PROJECT: Boulder County OSMP
North State Environmental / 5SSR
CLIENT: Boulder Creek Restoration
Boulder County, Colorado
98% Design

PLAN-SYMBOL



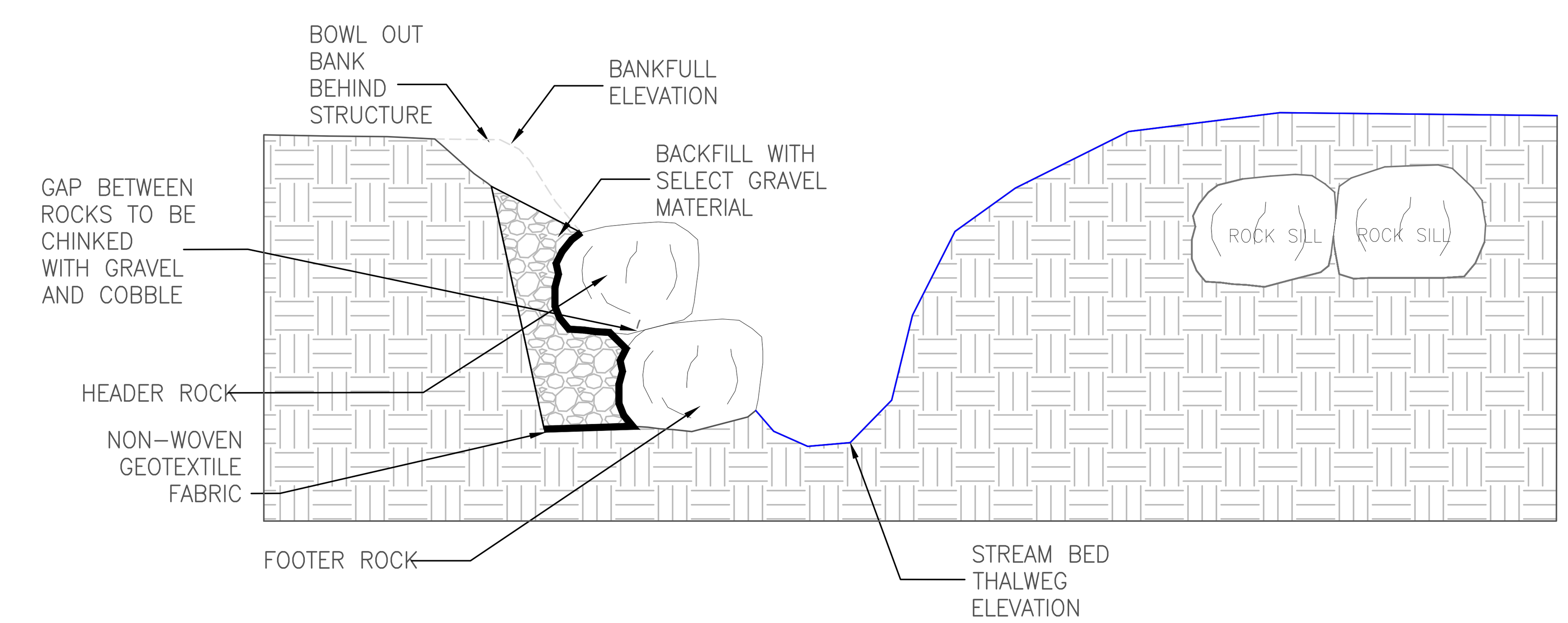
SECTION D-D'

EXAMPLE PHOTO

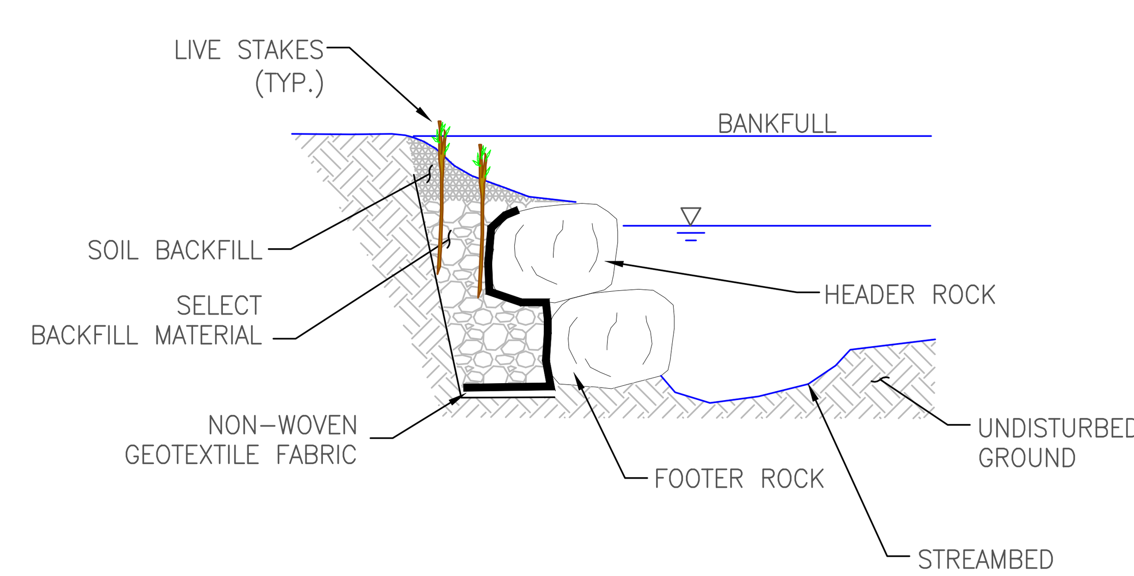


PLANVIEW

DETAIL - ROCK J-HOOK
NOT TO SCALE



SECTION F-F'



SECTION E-E'

NOTE:

THE DEPARTURE ANGLE SHOWN ABOVE IS DEPICTED IN SUCH A WAY TO EMPHASIZE DETAIL. ACTUAL DEPARTURE ANGLE AND STRUCTURE LOCATION SHALL BE AS SHOWN ON THE PLAN AND PROFILE SHEETS AND WILL BE PROVIDED TO THE CONTRACTOR AS A 2004 FORMAT DWG FILE AND LN3 FILE.

NOTES:

1. BOULDERS FOR THE CONSTRUCTED RIFFLE MUST BE A MINIMUM OF 1-2 TN BOULDER WITH A MIN. DIAMETER OF 2-3FT.
2. FOOTER BOULDERS ARE BOULDERS PLACED TO PROVIDE A FOUNDATION AND SCOUR PROTECTION FOR THE HEADER BOULDERS.
3. HEADER BOULDERS SHALL BE UNDERLAIN BY FOOTER BOULDERS UNLESS OTHERWISE DIRECTED BY THE ENGINEER.
4. HEADER BOULDERS ARE THE TOP MOST BOULDER USED IN EACH STRUCTURE. ALL HEADER BULDERS CAN BE SEEN PARTIALLY PROTRUDING FROM THE WATER SURFACE DURING EXTREMELY LOW FLOWS.
5. HEADER BOULDERS SHALL BE OFFSET SLIGHTLY DOWNSTREAM OF THE FOOTING BOULDERS WHERE SCOUR POOLS ARE ANTICIPATED TO FORM AS SHOWN IN THE DETAIL.
6. SILL BOULDERS SHALL BE PLACED PERPENDICULAR TO THE BANKFULL FLOW DIRECTION.
7. THE FOOTER BOULDERS SHALL EXTEND FROM THE SILL BOULDER TO THE END OF THE HEADER BOULDER TOWARD THE BANK.
8. HOOK BOULDERS SHALL EXTEND FROM THE HEADER BOULDER TO BEYOND BANKFULL WIDTH.
9. SET INVERTS AT ELEVATION SHOWN ON THE PLAN AND PROFILE SHEETS. INVERTS AND ELEVATIONS WILL BE PROVIDED TO THE CONTRACTOR AS A 2004 FORMAT DWG FILE. NO ELEVATIONS OF THE BOULDER DROPS STRUCTURE MAY VARY FROM THE PLAN LOCATIONS WITHOUT DIRECTIONS FROM THE ENGINEER.
10. HEADER BOULDER SHALL TIE INTO THE STREAM BANK AT A MINIMUM ELEVATION OF 1/4 DMAX (MEASURED AT THE NEXT DOWNSTREAM RIFFLE) BELOW BANKFULL ELEVATION AND A MINIMUM ELEVATION OF 1/2 DMAX (MEASURED AT THE NEXT DOWNSTREAM RIFFLE) BELOW BANKFULL ELEVATION UNLESS OTHERWISE DIRECTED BY THE ENGINEER.
11. ALL GAPS/VOIDS LARGER THAN 1 INCH BETWEEN THE HEADER AND FOOTING BOULDERS SHALL BE CHINKED WITH GRAVEL AND COBBLES.
12. ON THE UPSTREAM SIDE OF THE BOULDERS NON-WOVEN GEOTEXTILE FABRIC SHALL BE PLACED AS SHOWN IN THE GEOTEXTILE PLACEMENT AND SELECT BACKFILL DETAIL FOR THE ENTIRE LENGTH OF THE BOULDER HOOK.
13. BACKFILL STRUCTURE WITH SELECT BACKFILL MATERIAL AS SHOWN AND DEFINED IN THE GEOTEXTILE PLACEMENT AND SELECT BACKFILL DETAIL.
14. SELECT BACKFILL AND SOIL BACKFILL MATERIAL SHALL BE COMPACTED SUCH THAT FUTURE SETTLEMENT OF THE MATERIAL IS KEPT TO A MINIMUM.
15. THE SURFACE OF THIS STRUCTURE 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 0.1 FT OF THE GRADES AND ELEVATIONS INDICATED.
16. RE-DRESSING OF CHANNEL AND BANKFULL BENCH/FLOODPLAIN WILL LIKELY BE REQUIRED FOLLOWING INSTALLATION OF IN-STREAM STRUCTURES AND SHALL BE CONSIDERED INCIDENTAL TO CONSTRUCTION.
17. SEE THE PLANTING TABLE FOR DETAILS ON HIGH DENSITY LIVE STAKING.
18. NO LIVE STAKES SHALL BE INSTALLED ON THE UPSTREAM SIDE OF THE VANE AT OR BELOW THE TIE-IN ELEVATION OF THE HEADER LOG WITH THE STREAM BANK UNLESS OTHERWISE DIRECTED BY THE ENGINEER.
19. FOOTER DEPTH ON ALL STRUCTURES REQUIRING FOOTERS SHALL BE 6 TIMES GREATER THAN THE DROP BETWEEN THE STRUCTURE AND THE FOOTERED STRUCTURE DIRECTLY UPSTREAM.

REVISIONS

REV	DESCRIPTION	DATE	APPROVED
1	30% Concept Re-Design	7/01/16	DTW/DAB
2	60% Concept Re-Design	10/18/16	DTW/DAB
3	98% DESIGN	02/23/17	DTW/DAB

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APPROVED BY: | DATE:
SCALE: 1" = 40' | DRAWING NO. | SHEET: 11

North State Environmental
754 Mount Mahogany, Suite B
Livermore, CO 80536

PROJECT: Boulder County OSMP
North State Environmental / 5SSR

CLIENT: Boulder Creek Restoration
Boulder County, Colorado
98% Design

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2

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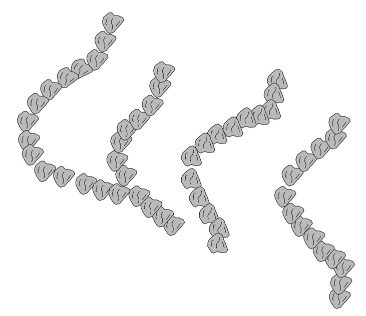
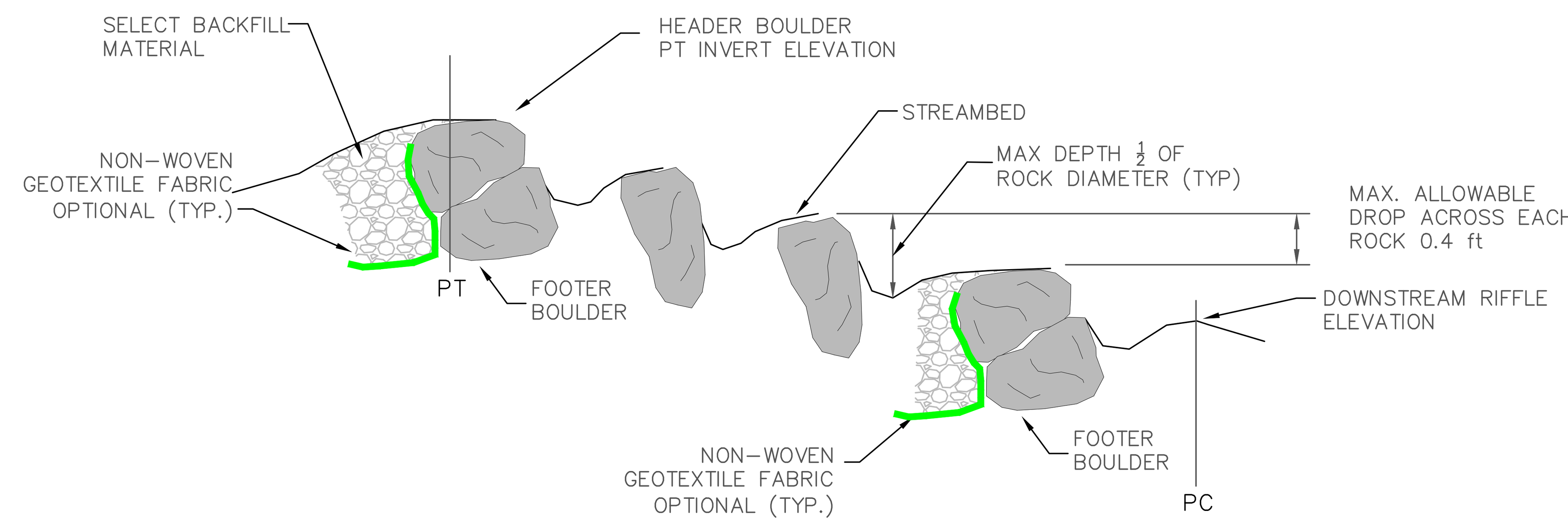
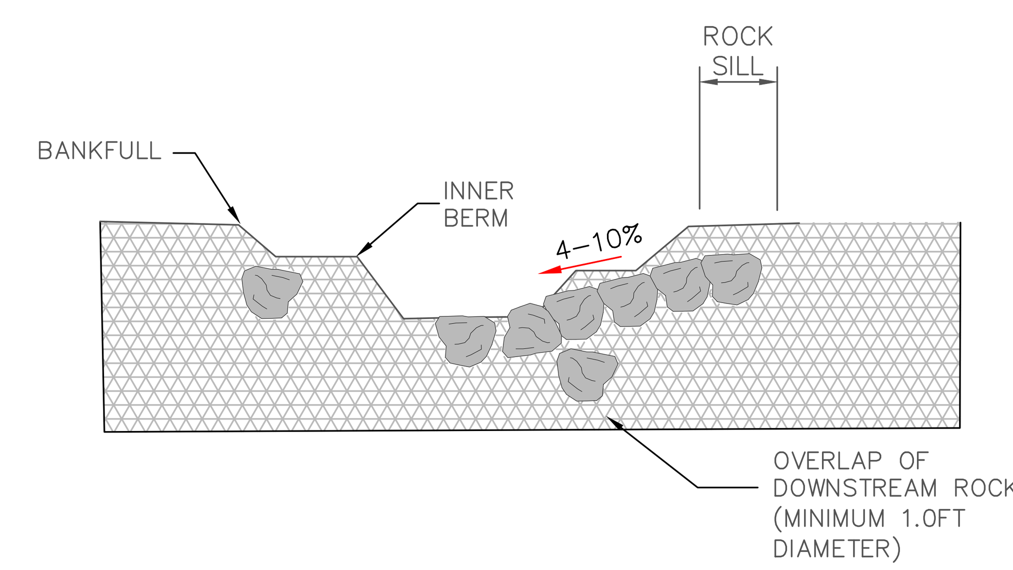


PLAN–SYMBOL

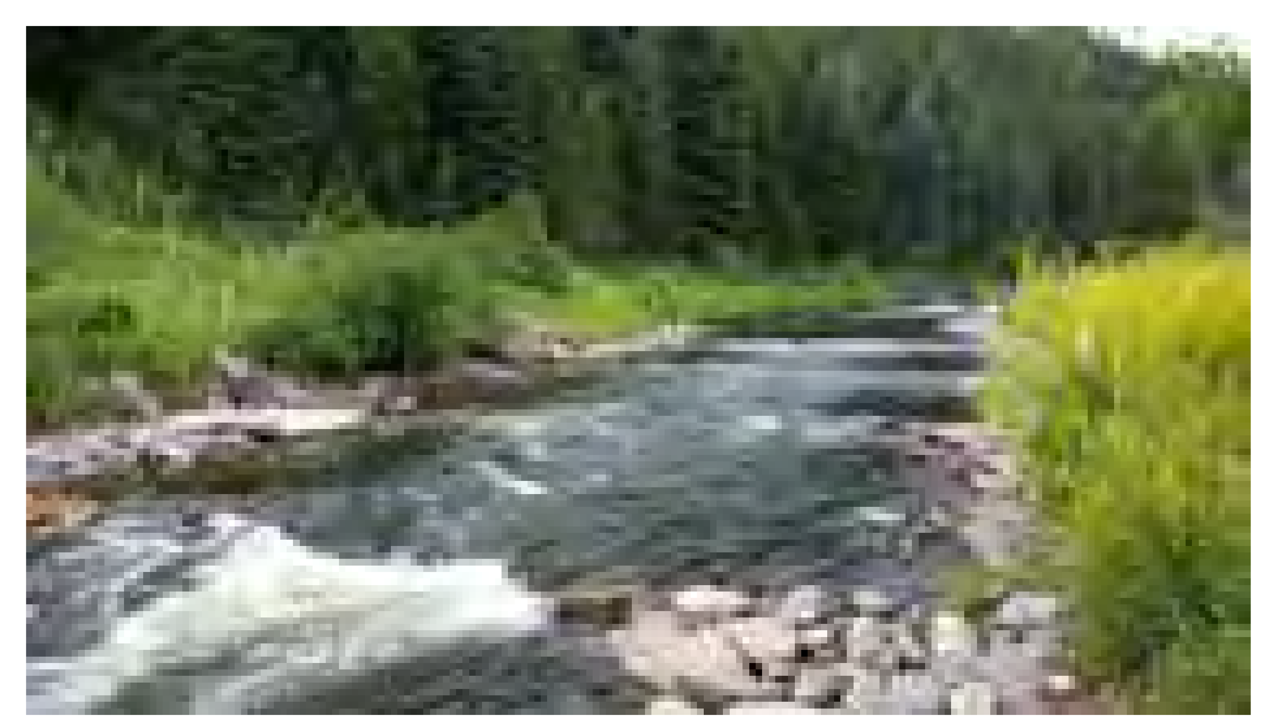


SECTION G–G'

PLANVIEW



SECTION H–H'



EXAMPLE PHOTO

DETAIL – CONSTRUCTED BOULDER RIFFLE
NOT TO SCALE

NOTES:

1. BOULDERS FOR THE CONSTRUCTED RIFFLE MUST BE A MIN. OF 1–2TN BOULDER WITH A MIN. DIAMETER OF 2–3FT.
2. THE UPSTREAM AND DOWNSTREAM HEADER BOULDERS SHALL BE UNDERLAIN BY FOOTER BOULDERS UNLESS OTHERWISE DIRECTED BY THE ENGINEER.
3. HEADER BOULDERS ARE THE TOP MOST BOULDERS USED IN EACH STRUCTURE. HEADER BOULDERS FOR THIS STRUCTURE ARE ONLY VISIBLE BETWEEN THE INNER BERMS.
4. HEADER BOULDERS SHALL BE OFFSET SLIGHTLY UPSTREAM OF THE FOOTER BOULDERS. FOOTER BOULDERS SHALL BE INSTALLED BEFORE THE HEADER BOULDERS.
5. SET INVERTS AT ELEVATION SHOWN ON PLAN AND PROFILE SHEETS. INVERTS AND ELEVATIONS WILL BE PROVIDED TO THE CONTRACTOR AS A 2014 FORMAT DWG FILE. NO ELEVATIONS OF THE CONSTRUCTED RIFFLE ARMS MAY VARY FROM THE PLAN LOCATIONS WITHOUT DIRECTION FROM THE ENGINEER.
6. THE DROP IN ELEVATION ACROSS THE STRUCTURE SHALL NOT EXCEED 0.5FT UNLESS OTHERWISE DIRECTED BY THE ENGINEER.
7. MINI–VANES WILL BE SPACED IN THE RIFFLE AS A FUNCTION OF THE RIFFLE LENGTH.
8. THE MOST UPSTREAM RIFFLE MINI–VANE ARM SHALL BE PLACED SUCH THAT THE BANK TIE–IN IS ON THE SAME SIDE AS THE NEXT UPSTREAM OUTSIDE BEND IN ORDER TO SERVE AS A VANE AND HELP DIRECT STREAM FLOW AWAY FROM THE PREVIOUS OUTSIDE BEND. LOCATION OF ALL RIFFLE VANE ARMS ARE SHOWN ON THE PLAN AND PROFILE SHEETS.
9. THE MOST DOWNSTREAM MINI–VANE ARM SHALL BE PLACED SUCH THAT THE HIGH POINT IS ON THE SAME SIDE AS THE NEXT DOWNSTREAM OUTSIDE BEND IN ORDER TO HELP DIRECT STREAM FLOW FROM THE NEXT OUTSIDE BEND.
10. THE VERTICAL SLOPE OF EACH MINI–VANE ARM SHALL NOT EXCEED 10% UNLESS OTHERWISE DIRECTED BY THE ENGINEER. THE SLOPES WILL BE DICTATED BY THE WIDTH–TO–DEPTH RATIO OF THE REACH, TYPICAL RIFFLE INNER BERM CHANNEL, VERTICAL DROP OVER THE LOG, AND LOG DIAMETER.
11. ALL GAPS/VOIDS LARGER THAN 2IN BETWEEN THE HEADER AND FOOTER BOULDERS SHALL BE HAND CHINKED WITH COBBLE AND GRAVEL ON THE UPSTREAM SIDE PRIOR TO PLACEMENT OF THE GEOTEXTILE. ALL CHINKING SHALL BE APPROVED BY THE ENGINEER BEFORE THE MINI–VANES ARE BACKFILLED.
12. THE UPSTREAM SIDE OF THE FIRST AND LAST MINI–VANE ARM REQUIRE A LAYER OF NON–WOVEN GEOTEXTILE FABRIC THAT SHALL BE PLACED AS SHOWN IN THE GEOTEXTILE PLACEMENT DETAIL THE ENTIRE LENGTH OF THE MINI–VANE.
13. BACKFILL VANES WITH SELECT BACKFILL MATERIAL AS SHOWN AND DEFINED IN THE CONSTRUCTED RIFFLE DETAIL.
14. SELECT BACKFILL AND SOIL BACKFILL MATERIAL SHALL BE COMPACTED SUCH THAT FUTURE SETTLEMENT OF THE MATERIAL IS KEPT TO A MINIMUM.
15. THE SURFACE OF THIS STRUCTURE 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 0.1FT OF THE GRADES AND ELEVATIONS INDICATED, PROVIDED ANY HEIGHT DOES NOT EXCEED MAX. ALLOWABLE DROP OF 0.5FT FOR THIS STRUCTURE.
16. RE–DRESSING OF CHANNEL AND BANKFULL BENCH/FLOODPLAIN WILL LIKELY BE REQUIRED FOLLOWING INSTALLATION OF IN–STREAM STRUCTURES AND SHALL BE CONSIDERED INCIDENTAL TO CONSTRUCTION.
17. FOOTER DEPTH ON ALL STRUCTURES REQUIRING FOOTERS SHALL BE 6 TIMES GREATER THAN THE DROP BETWEEN THE STRUCTURE AND THE FOOTERED STRUCTURE DIRECTLY UPSTREAM.
18. THE DEPARTURE ANGLE SHOWN ABOVE IS DEPICTED IN SUCH A WAY TO EMPHASIZE DETAIL. ACTUAL DEPARTURE ANGLE SHALL BE AS SHOWN ON THE PLAN AND PROFILE SHEETS AND WILL BE PROVIDED TO THE CONTRACTOR AS A 2014 FORMAT DWG FILE AND LN3 FILE.

REVISIONS

REV	DESCRIPTION	DATE	APPROVED
1	30% Concept Re–Design	7/01/16	DTW/DAB
2	60% Concept Re–Design	10/18/16	DTW/DAB
3	98% DESIGN	02/23/17	DTW/DAB

DATE: 3/9/2017
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CHECKED BY: DATE:
APPROVED BY: DATE:
SCALE: 1" = 40'
DRAWING NO.:
SHEET: 12

North State Environmental
754 Mount Mahogany, Suite B
Livermore, CO 80536

PROJECT: Boulder County OSMP
North State Environmental / 5SSR

CLIENT: Boulder Creek Restoration
Boulder County, Colorado
98% Design

Boulder Creek02232017_98%.dwg
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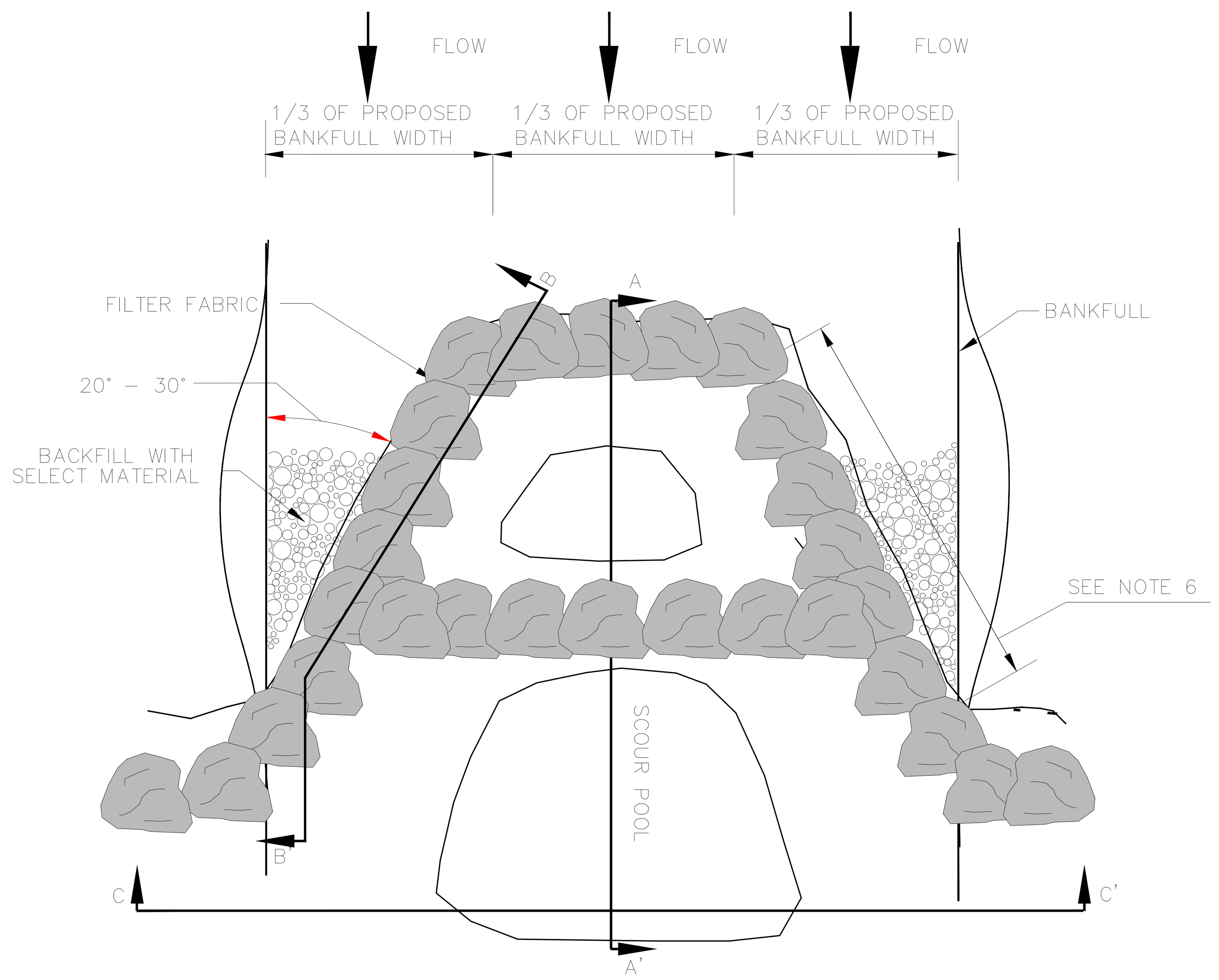
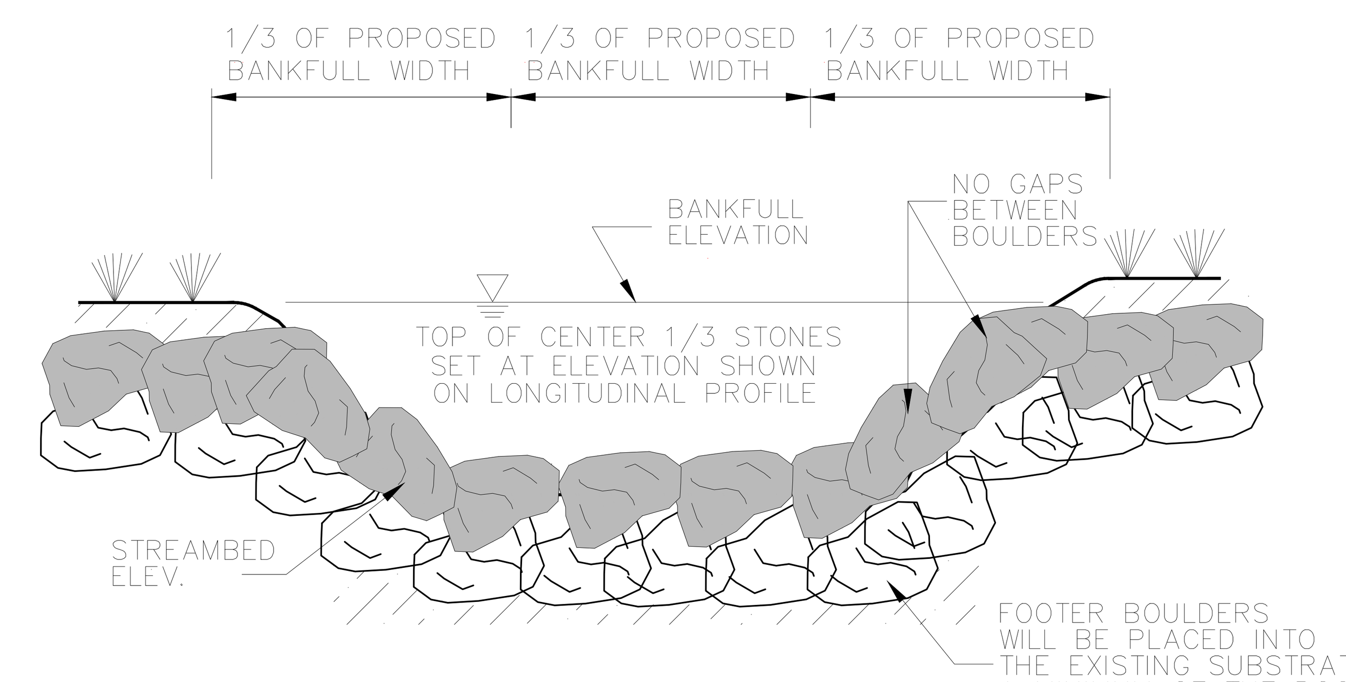
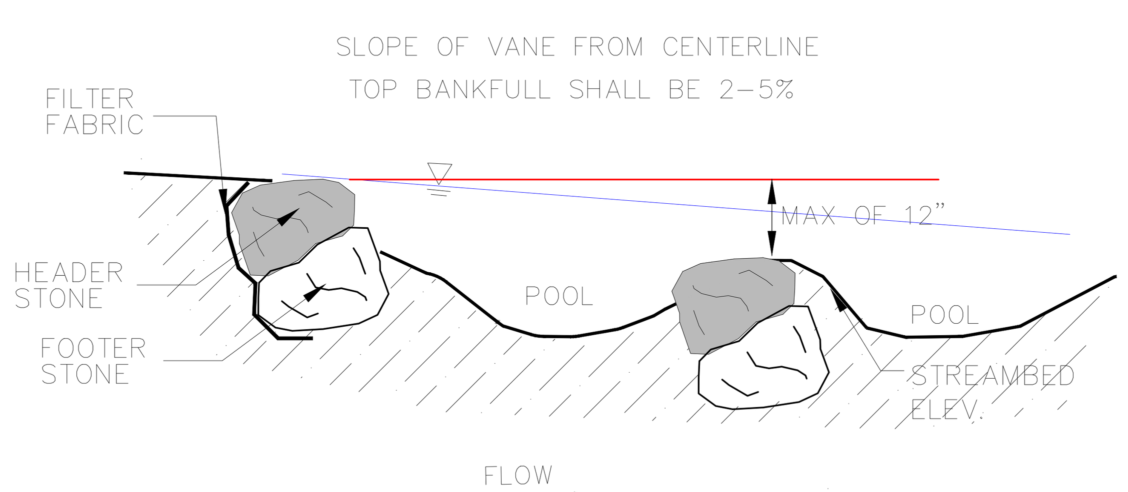


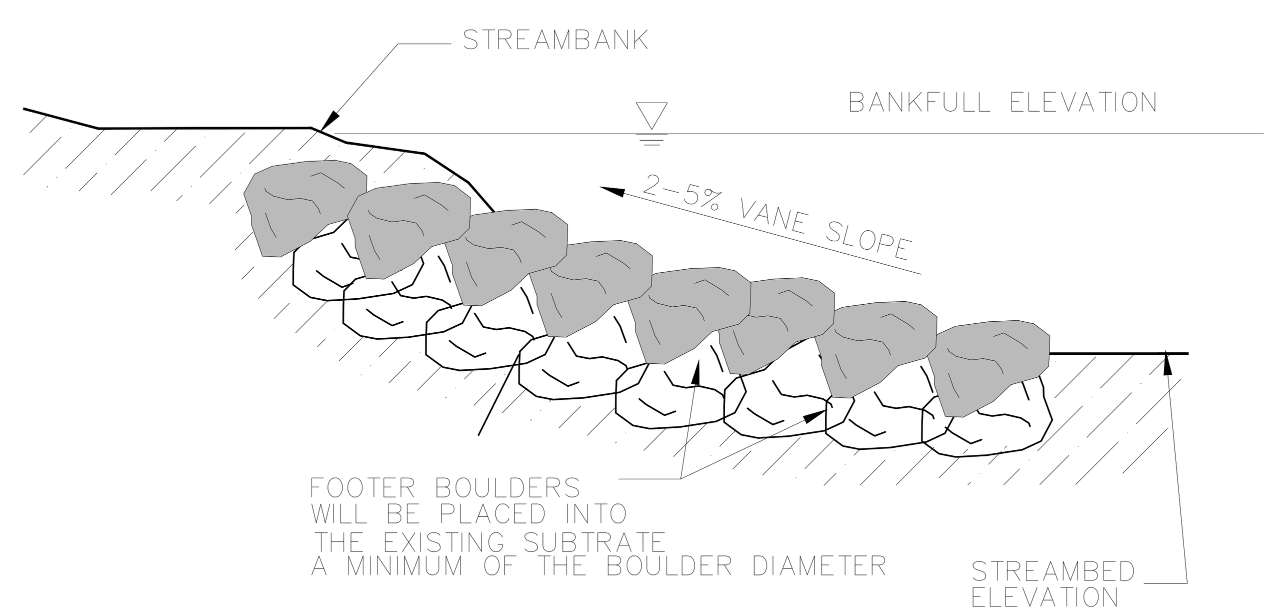


SECTION C–C'

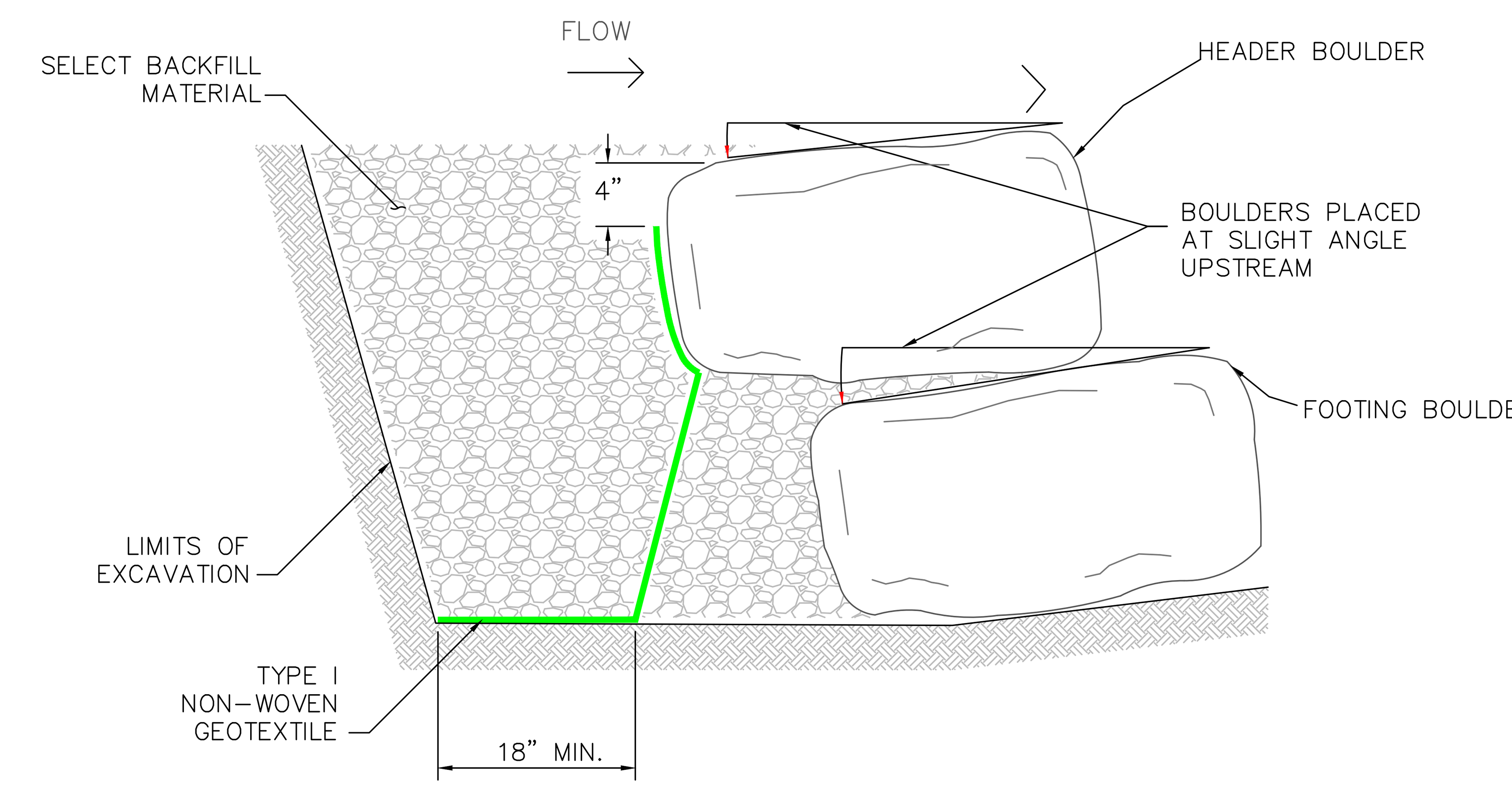
EXAMPLE PHOTO



SECTION A–A'



SECTION B–B'



GEOTEXTILE PLACEMENT

NOTES:

1. ALL STONES ARE TO BE STRUCTURE STONE.
2. GAPS BETWEEN BOULDERS SHALL BE MINIMIZED BY FITTING BOULDERS TOGETHER AND PLUGGING WITH STRUCTURE STONE CLASS A AND SELECT MATERIAL OR CHINKING STONE APPROVED BY THE ENGINEER, AND LINING WITH FILTER FABRIC.
3. DIMENSIONS AND SLOPES MAY BE ADJUSTED TO FIT BY THE ENGINEER.
4. NSE WILL FIT BOULDERS TIGHTLY.
5. FOOTER BOULDERS AND VANE BOULDERS SHALL BE 1–2 TONS MINIMUM AND NATIVE STONE OR SHOT ROCK, CUBICAL OR RECTANGULAR IN NATURE.
6. SLOPE OF VANE FROM CENTERLINE TO THE TOP OF THE VANE ARM SHALL BE 2–5%.
7. THERE SHALL BE NO DROP GREATER THAN 6".
8. THE ELEVATION OF EACH GRADE CONTROL STRUCTURE SHOULD BE EQUAL TO OR GREATER THAN THE ELEVATION OF THE TOP OF THE FOOTER ROCKS DIRECTLY UPSTREAM.
9. FILTER FABRIC SHALL BE PLACED ON THE UPSTREAM SIDE OF THE STRUCTURE TO PREVENT WASHOUT OF SEDIMENT THROUGH BOULDER GAPS. FILTER FABRIC SHALL EXTEND FROM THE BOTTOM OF THE FOOTER BOULDER TO THE FINISHED GRADE ELEVATION AND SHALL BE PLACED THE ENTIRE LENGTH OF THE STRUCTURE.
10. FOOTER DEPTH ON ALL STRUCTURES REQUIRING FOOTERS SHALL BE 6 TIMES GREATER THAN THE DROP BETWEEN THE STRUCTURE AND THE FOOTERED STRUCTURE DIRECTLY UPSTREAM.

DETAIL – ROCK CROSS VANE

NOT TO SCALE

REV	DESCRIPTION	DATE	APPROVED
1	30% Concept Re-Design	7/01/16	DTW/DAB
2	60% Concept Re-Design	10/18/16	DTW/DAB
3	98% DESIGN	02/23/17	DTW/DAB

DATE: 3/9/2017

SHEET: 13

SCALE: 1" = 40'

DRAWN BY:
CHECKED BY:
APPROVED BY:
DRAWING NO.:

North State Environmental

North State Environmental
754 Mount Mahogany, Suite B
Livermore, CO 80536

PROJECT: Boulder County OSMP
North State Environmental / 5SSR

CLIENT: Boulder Creek Restoration
Boulder County, Colorado
98% Design

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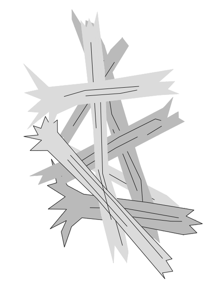
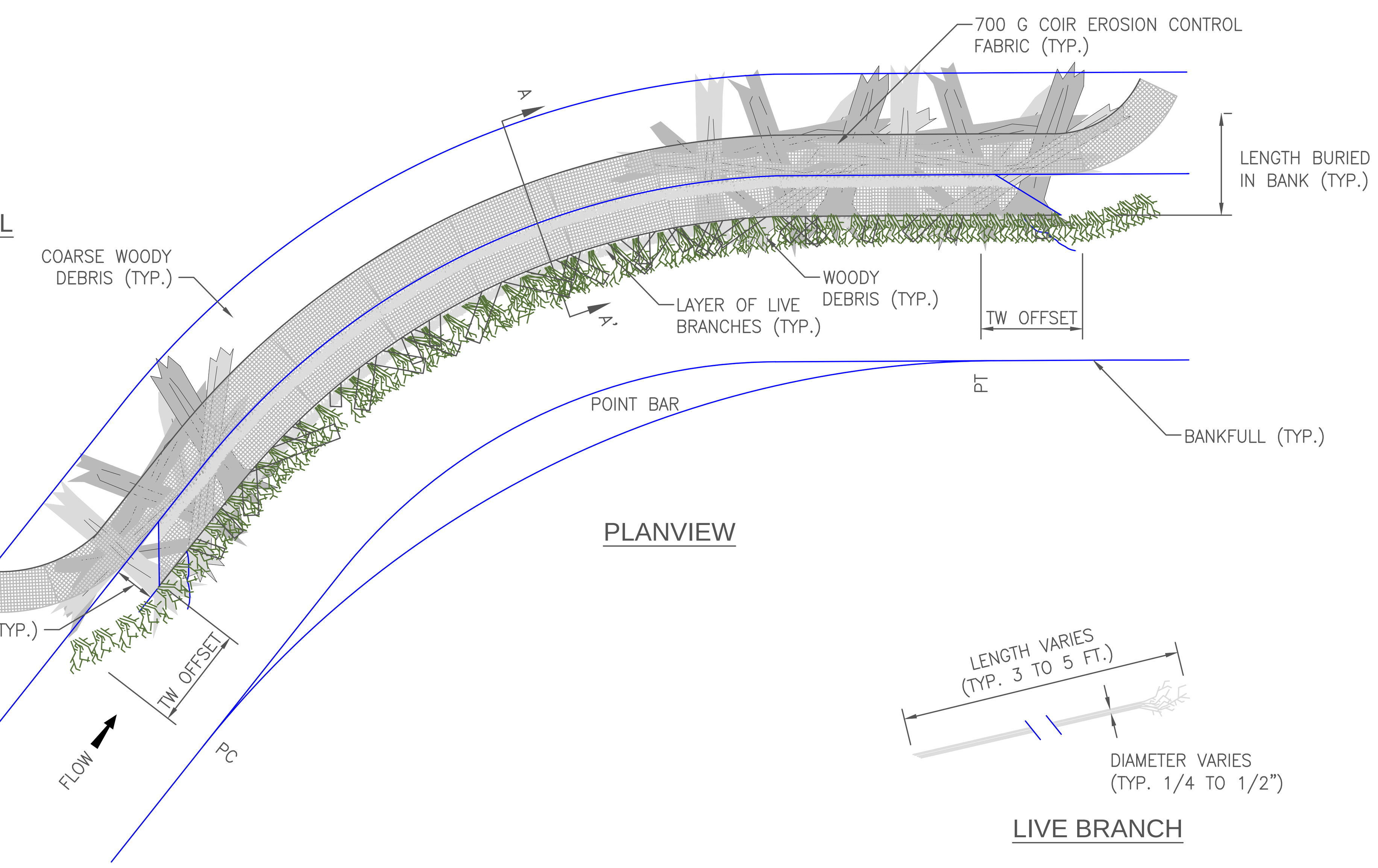
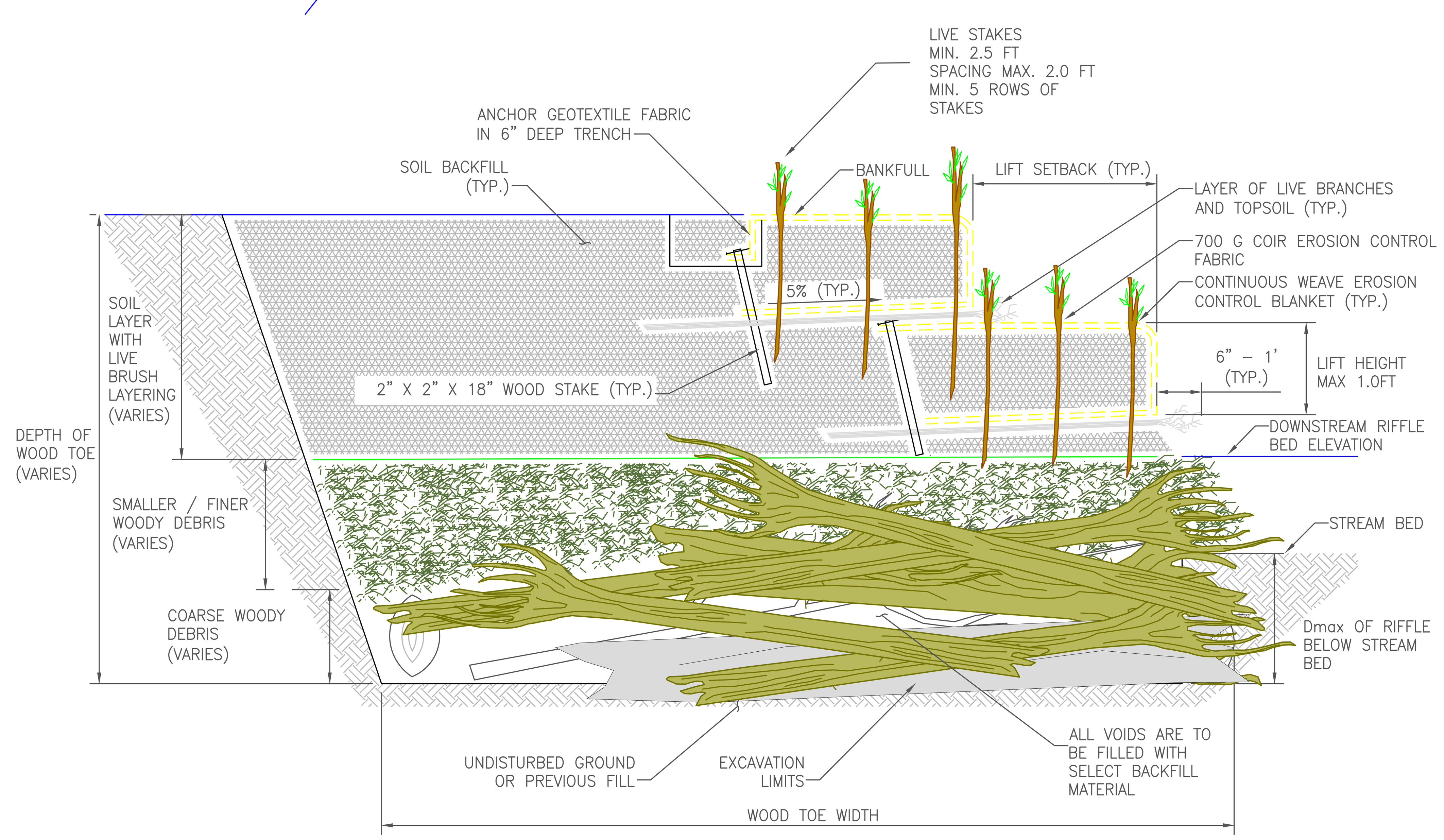




PLANVIEW

LIVE BRANCH



SECTION A-A'

DETAIL - WOOD TOE
NOT TO SCALE

NOTES:

1. COARSE WOODY DEBRIS SHALL CONSIST OF LOGS, ROOTWADS, AND LARGE BRANCHES NOT SUITABLE FOR CONSTRUCTION OF LOG STRUCTURES. ALL MATERIALS ARE TO BE APPROVED BY THE ENGINEER.
2. COARSE WOODY DEBRIS SHALL BE CONSTRUCTED WITH THE LARGEST MATERIAL PLACED FIRST. NO LOGS SHALL BE PLACED PARALLEL TO THE FLOW OF WATER, UNLESS DIRECTED BY THE ENGINEER. LOGS SHALL BE PLACED IN A CROSSING PATTERN OR WEAVE SUCH THAT EACH LOG IS ANCHORED BY ANOTHER LOG.
3. SMALL/FINE WOODY DEBRIS SHALL CONSIST OF MEDIUM TO SMALL LIMBS, BRANCHES, BUSHES, AND/OR LOGS. INVASIVE SPECIES SHALL NOT BE USED.
4. SMALL/FINE WOODY DEBRIS SHALL BE PLACED ABOVE THE COARSE WOODY DEBRIS WITH THE LARGEST MATERIAL BEING PLACED FIRST AND THE SMALLEST MATERIAL PLACED LAST.
5. ALL WOODY DEBRIS SHALL BE COMPACTED WITH THE EXCAVATOR BUCKET IN ORDER TO REDUCE THE PRESENCE OF VOIDS IN THE SMALL/FINE WOODY DEBRIS LAYER.
6. THE HORIZONTAL LOCATIONS OF ALL WOODY DEBRIS ARE LOCATED ON THE PLAN AND PROFILE SHEETS AND WILL BE PROVIDED TO THE CONTRACTOR AS A 2004 FORMAT DWG FILE. NO LOCATIONS OF WOODY DEBRIS SHALL VARY FROM THE PLAN LOCATIONS WITHOUT DIRECTION FROM THE ENGINEER.
7. GRAVEL LEVELING BASE SHALL BE INSTALLED ABOVE THE HIGHEST ELEVATION OF THE WOODY DEBRIS BEFORE THE SOIL LIFTS ARE INSTALLED.
8. THE SOIL BACKFILL USED FOR LIFTS AND TOPSOIL USED FOR LAYERING WITH THE LIVE BRANCHES SHALL BE FREE OF ANY LARGE ROOTS OR WOODY DEBRIS AND SHALL GENERALLY BE FREE FROM ANY GRAVEL OR COBBLE MATERIAL.
9. SOIL BACKFILL SHALL BE COMPACTED SUCH THAT FUTURE SETTLING WILL BE KEPT TO A MINIMUM; YET, NOT SUCH THAT THE UNDERLYING BRUSH IS DISPLACED OR DAMAGED.
10. THE TOP OF THE BACKFILL FOR THE FIRST LIFT SHALL BE SLOPED AT APPROXIMATELY 5% AWAY FROM THE STREAM.
11. PLACE A LAYER OF TOPSOIL AND LIVE BRANCHES ON TOP OF EACH SOIL LIFT SUCH THAT APPROXIMATELY 6 INCHES TO 1 FOOT OF EACH LIVE BRANCH WILL BE EXPOSED AND THE REMAINDER (2' TO 4') OF EACH LIVE BRANCH WILL BE COVERED BY THE NEXT SOIL LIFT.
12. LIVE BRANCHES SHALL BE OF THE SPECIES SPECIFIED FOR LIVE STAKES OR APPROVED BY THE ENGINEER AND SHALL EXCLUDE INVASIVE SPECIES.
13. PLACE A LAYER OF 6.5 FEET WIDE GEOCOIR DEKOWE 700 EROSION CONTROL BLANKET, OR EQUIVALENT, ON TOP OF THE TOPSOIL AND LIVE BRANCHES SUCH THAT 2.5 FEET OF THE BLANKET WILL BE BURIED BELOW THE NEXT SOIL LIFT. ALLOW THE REMAINING 4.0 FEET OF BLANKET TO HANG OVER THE PRECEDING SOIL LIFT OR COIR FIBER LOGS.
14. PLACE A LAYER OF 6.5 FEET WIDE NON-WOVEN COIR MATTING OVER THE EROSION CONTROL BLANKET TO THE SAME LIMITS.
15. SOIL CAN BE COMPACTED BY STACKING A PIECE OF 2 X 6 SAWN LUMBER EDGEWAYS UP TO THE LIFT HEIGHT SPECIFIED IN THE STRUCTURE TABLE AND SECURING WITH WOODEN STAKES TO PROVIDE A RIGID BACKSTOP FOR COMPACTING SOIL LIFT.
16. PLACE SOIL BACKFILL UP TO THE LIFT HEIGHT SPECIFIED OF NO GREATER THAN 1.0 FT BEING CAREFUL NOT TO PUSH/PULL OR TEAR THE FABRIC PREVIOUSLY PLACED.
17. THE TOP OF THE SOIL BACKFILL SHALL BE FLAT WITHIN THE LIFT SETBACK DISTANCE SPECIFIED IN THE STRUCTURE TABLE. BEYOND THE LIFT SETBACK DISTANCE, THE SOIL BACKFILL SHALL BE SLOPED AT AN APPROXIMATE 5% SLOPE AWAY FROM THE STREAM.
18. TOP DRESS THE SOIL LIFT WITH TOPSOIL FROM THE FACE OF THE SOIL LIFT BACK INTO THE FLOODPLAIN AT LEAST 4FT.
19. REMOVE THE SAWN LUMBER AND WOODEN STAKES FROM THE FACE OF THE SOIL LIFT AND WRAP THE FACE AND TOP OF THE SOIL LIFT USING THE WOVEN AND NON-WOVEN COIR MATTING HANGING OVER THE PREVIOUS LIFT/COIR FIBER LOGS.
20. THE EROSION CONTROL FABRIC SHALL BE PULLED AS TIGHT AS POSSIBLE WITHOUT TEARING OR EXCESSIVELY DISTORTING THE FABRIC.
21. SECURE THE EROSION CONTROL AND NON-WOVEN MATTING IN PLACE BY STAKING THE END OF THE EROSION CONTROL FABRIC WITH WOODEN STAKES ON 1.5-FOOT CENTERS.
22. BEGIN CONSTRUCTION OF THE NEXT SOIL LIFT BY REPEATING THE PREVIOUS NOTES STARTING WITH NOTE 11.
23. THE OVERALL SLOPE CREATED BY THE LIVE BRUSH LAYERING SHALL MATCH THE PROPOSED CROSS SECTION SHAPE FOR THE OUTER BANK OF THE THE TYPICAL POOL CROSS-SECTION FOR EACH REACH.
24. THE COIR BLANKETS AND GEOTEXTILE FABRIC USED FOR THE UPPER MOST SOIL LIFT WILL BE SECURED WITHIN A 6 INCH DEEP TRENCH AS SHOWN IN DETAIL.
25. THE SURFACE OF THIS STRUCTURE 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 ELEVATIONS SHALL BE WITHIN 0.1 FT OF THE GRADES AND ELEVATIONS INDICATED OR APPROVED BY THE ENGINEER.
26. RE-DRESSING OF CHANNEL AND BANKFULL BENCH/FLOODPLAIN WILL LIKELY BE REQUIRED FOLLOWING INSTALLATION OF IN-STREAM STRUCTURES AND SHALL BE CONSIDERED INCIDENTAL TO CONSTRUCTION.
27. THE LOWER BANK STABILIZATION IS CRITICAL TO THE DESIGN INTENT OF THIS PROJECT. VARIANCE FROM WOOD TOE BANK STABILIZATION WILL ONLY BE CONSIDERED IF THE WOOD IS NOT AVAILABLE ONSITE.

REVISIONS

REV	DESCRIPTION	DATE	APPROVED
1	30% Concept Re-Design	7/01/16	DTW/DAB
2	60% Concept Re-Design	10/18/16	DTW/DAB
3	98% DESIGN	02/23/17	DTW/DAB

DRAWN BY: DATE 3/9/2017
CHECKED BY: DATE
APPROVED BY: DATE
SCALE 1" = 40' DRAWING NO. SHEET 14

NorthState ENVIRONMENTAL
North State Environmental
754 Mount Mahogany, Suite B
Livermore, CO 80536

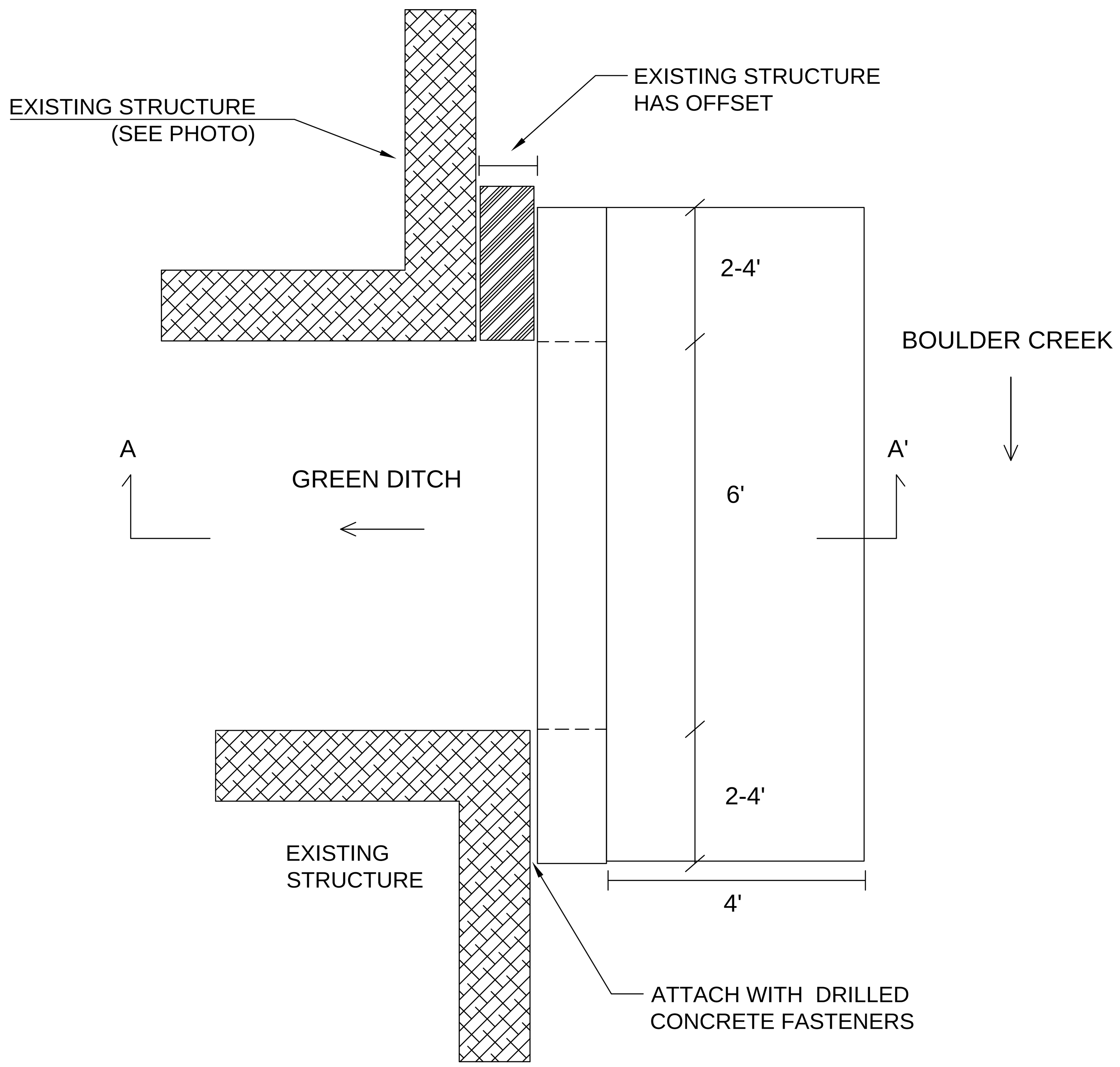
PROJECT: Boulder County OSMP
North State Environmental / 5SSR

CLIENT: Boulder Creek Restoration
Boulder County, Colorado
98% Design

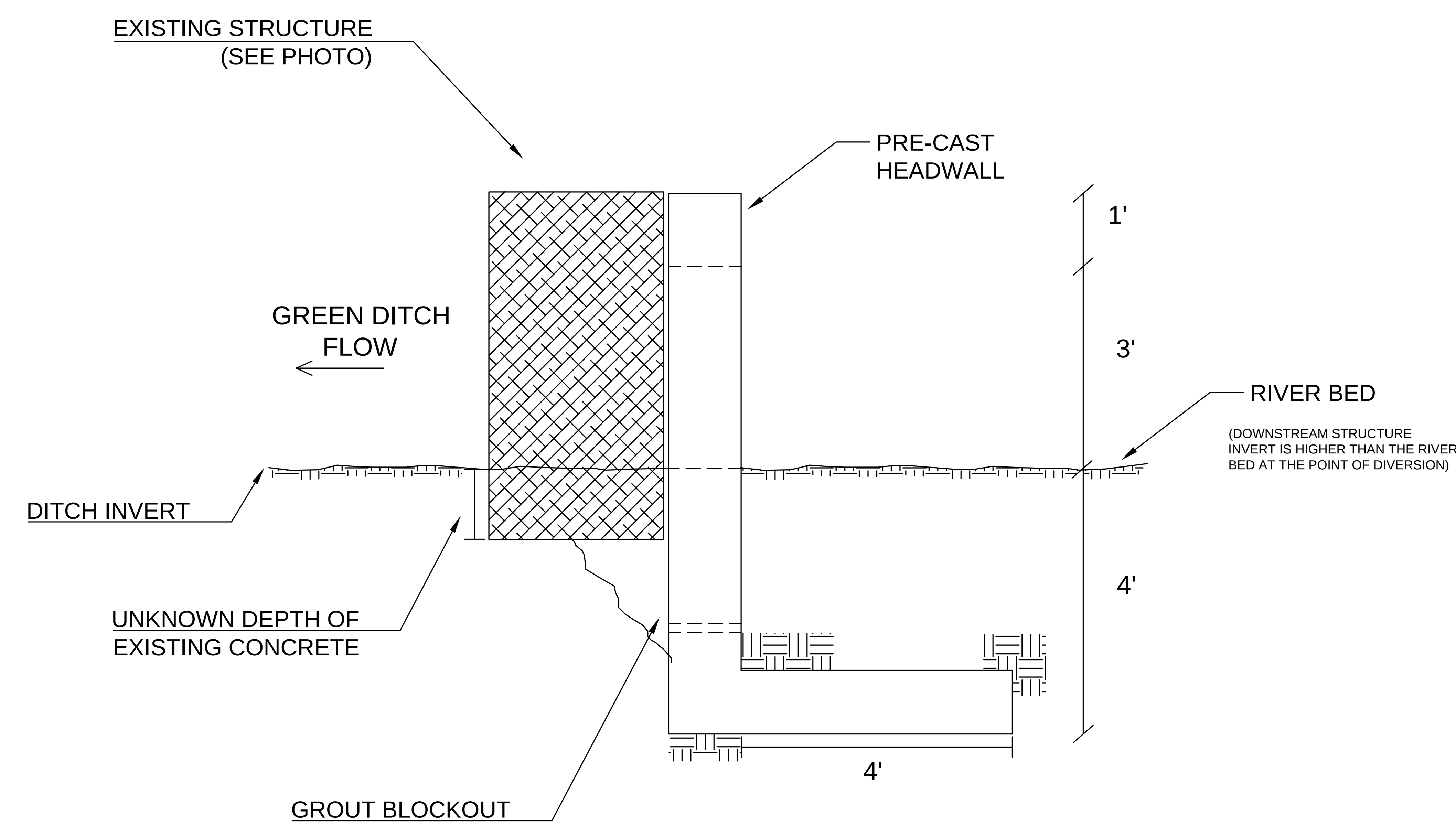
Boulder Creek02232017_98%.dwg

2

3/9/2017 9:45:58 AM



PLAN



SECTION A-A'

THE PRE-CASTER SAID HE WOULD MAKE THE STRUCTURE 12' LONG
WITH THE 6' WIDE BY 3' TALL OPENING FOR THE SLIDE GATE.

REBAR STUBS REQUIRED THAT CAN BE USED TO CAST TO THE
EXISTING STRUCTURE

PRE-CAST HEAD GATE STRUCTURE WITH SLIDE GATE
NOT TO SCALE

Boulder Creek02232017_98%.dwg

2

3/9/2017 9:46:08 AM

REV	DESCRIPTION	DATE	APPROVED
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2	60% Concept Re-Design	10/18/16	DTW/DAB
3	98% DESIGN	02/23/17	DTW/DAB

REVISIONS

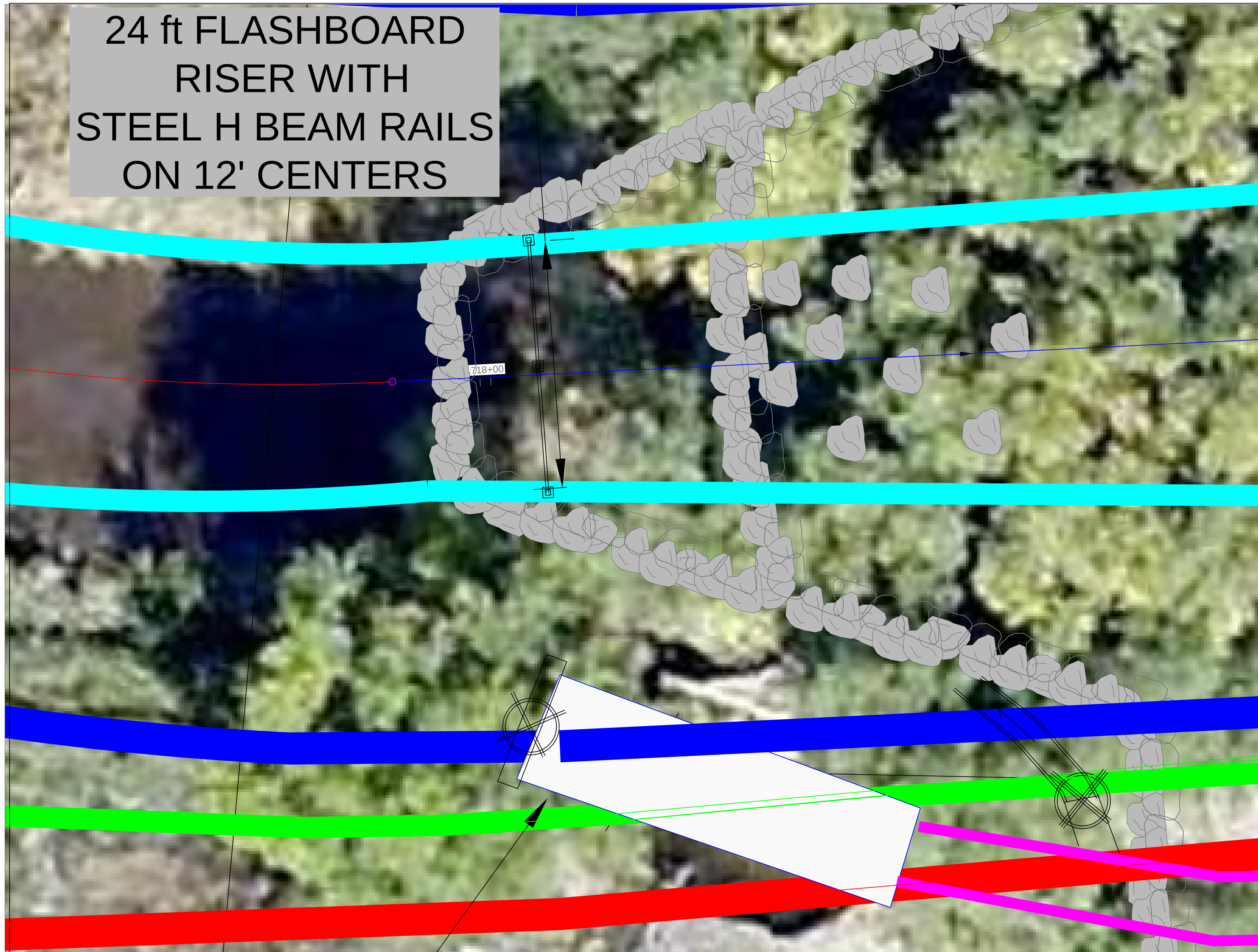
DRAWN BY: DATE 3/9/2017
CHECKED BY: DATE
APPROVED BY: DATE
SCALE 1" = 40'
DRAWING NO.
SHEET 15

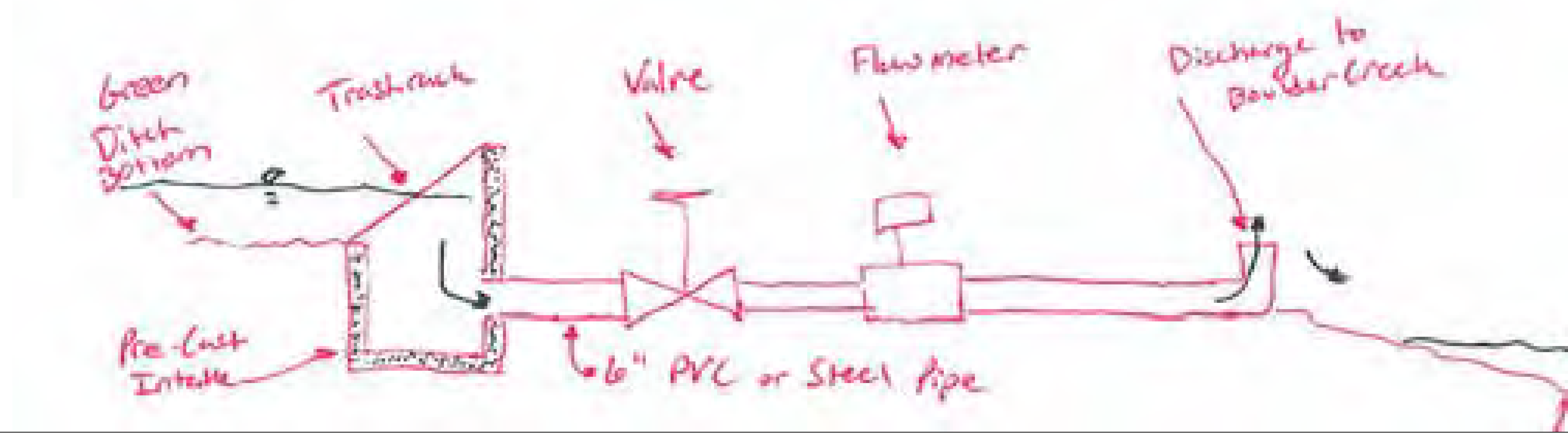
North State ENVIRONMENTAL

North State Environmental
754 Mount Mahogany, Suite B
Livermore, CO 80536

PROJECT: Boulder County OSMP
North State Environmental / 5SSR

CLIENT: Boulder Creek Restoration
Boulder County, Colorado
98% Design





AUGMENTATION STATION
NOT TO SCALE

REV	DESCRIPTION	DATE	APPROVED
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2	60% Concept Re-Design	10/18/16	DTW/DAB
3	98% DESIGN	02/23/17	DTW/DAB

DRAWN BY: DATE 3/9/2017
CHECKED BY: DATE
APPROVED BY: DATE
SCALE 1" = 40' DRAWING NO. SHEET 16

North State Environmental
North State Environmental
754 Mount Mahogany, Suite B
Livermore, CO 80536

PROJECT: Boulder County OSMP
North State Environmental / 5SSR
CLIENT: Boulder Creek Restoration
Boulder County, Colorado
98% Design

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Appendix 2

Technical Memo: Fishery Data Analysis and Reporting
Green Ditch Diversion Rehabilitation and Fish Passage:
WSRF Grant – CTGGI 2017-1569

Geotechnical
Environmental
Water Resources
Ecological

GEI Consultants

Technical Memorandum

Fishery Data Analysis and Reporting: Boulder Creek Restoration and Relocation Project, Short Milne Property

This technical memo fulfills the requirements of the fishery data analysis and reporting portion of task order # 212205173, as executed under the Master Services Agreement between GEI Consultants, Inc. (GEI) and Stantec, Inc. The scope of work submitted to Stantec for this project included a site visit, a set of semi-quantitative habitat surveys, data analysis, and resulting recommendations for fish passage design and habitat restoration for native and resident Boulder Creek fishes. These recommendations are primarily qualitative but have been developed for incorporation into engineering designs.

1.0 Introduction

1.1 Boulder Creek

Boulder Creek is located in the South Platte Drainage and flows through Boulder, Colorado. Downstream of Boulder, the stream runs northeast to flow into the St. Vrain River downstream of Longmont, Colorado. Boulder Creek is characterized by a snowmelt-dominated hydrograph, with monthly average flows less than 45 cfs from October through March and monthly average flows ranging from 172 to 268 cfs from May through July. From 1987 through 2013, mean annual flows ranged from 43 to 198 cfs (USGS gage 06730200, Boulder Creek @ North 75th St.).

Boulder Creek and its riparian corridor have been impacted by historic gravel mining along much of their length, including the Project site. Numerous abandoned mining pits exist within the floodplain; some have been backfilled and others exist as shallow ponds. These mining operations resulted in a southward shift and a widening and straightening of Boulder Creek within the Project site. Prior to September 2013, Boulder Creek within the Project site exhibited a relatively low gradient with areas of major sediment deposition. The stream was channelized by a berm constructed along its northern bank during mining operations, and it was higher in elevation than the mined lands to its north. In addition to these unstable geomorphic conditions, non-native plant species including crack willow (*Salix fragilis*), Russian olive (*Elaeagnus angustifolia*), and reed canary grass (*Phalaris arundinacea*) dominate the riparian and floodplain vegetation at the Project site. In September 2013, major flooding occurred across the Colorado Front Range, and peak flows approached 5,000 cfs in Boulder Creek. The 2013 flood resulted in extensive property damage and major modifications to channel morphology on streams throughout the Front Range, including Boulder Creek.

10:45
2:30

The Project site is located downstream (east) of 61st St. and includes approximately 4,000 linear feet of Boulder Creek and its adjacent floodplain (Figure 1). Because of the floods, Boulder Creek is currently split into three separate channels within the Project site. The main, southern channel flows southeast from 61st Street to the Green Ditch diversion and then northeast. The Green Ditch diversion spans the full width of the creek and acts as a barrier to fish passage. The northern channel was previously an artificial extension of Fourmile Canyon Creek created during mining operations. When the main channel of Boulder Creek avulsed during the 2013 flood, this northern channel captured a portion of Boulder Creek flows. This northern channel is still active. Boulder Creek also avulsed and flowed through this northern channel during high flows in 2011. The breach that allowed water to flow into the northern channel was repaired, but the berm failed again in 2013. A center channel was also created during the main channel avulsion in 2013, but it is largely abandoned and characterized by intermittent flow.

Figure 1: Aerial view of the Project site on Boulder Creek. The site begins east of 61st Street (north-south oriented, center left) and is split into three channels. The southern channel is located close to several gravel pit ponds.

The City of Boulder retained North State Environmental and Stantec Consulting Inc. (Stantec) to restore this portion of Boulder Creek. Stantec retained GEI Consultants, Inc. to conduct a fish habitat survey, and to develop fish habitat and fish passage design criteria as input to the restoration engineering design. The fishery objectives for this restoration project are habitat improvement and bi-directional fish passage across the water diversion for native and desirable resident fish species in Boulder Creek.

1.2 Transition Zone Streams and Fisheries

Transition zones in streams are unique in that they contain characteristics of both montane and plains streams. These tend to be single-thread systems but can contain slow-water habitats such as sloughs, backwaters, and side channels (Fausch and Bestgen 1997). Transition zones contain a unique fish assemblage. In addition to supporting coldwater and warmwater fishes, these streams also harbor glacial relict fishes, such as common shiner and Iowa darter, which are restricted to the transition zone (Fausch and Bestgen 1997). These species require a combination of water temperature and physical habitat that do not occur in the mountains or on the plains.

Because coldwater, warmwater, and glacial relict species all utilize transition zones, these systems can be the most species-rich assemblages in the State of Colorado. However, the large urban corridor along Colorado's Front Range has resulted in extensive modification to most transition zone streams, Boulder Creek included. Anthropogenic changes include altered hydrographs, habitat, and water quality (e.g., Bestgen and Kondratieff 1996; Strange et al. 1999; GEI 2013; Rees 2013). As a result, species richness has declined rapidly in many of Colorado's transition zones. This project offers the opportunity to restore some of the historic elements of a transition zone stream that will benefit native species and desirable introduced species (i.e., trout) and limit habitat for undesirable non-native species.

2.0 Methods

2.1 Habitat Surveys

A site visit was conducted on September 18, 2014. The site was walked in its entirety, and existing conditions were noted and photographed.

A formal habitat survey was conducted at three sites on Boulder Creek that were representative of existing conditions: an upstream reference upstream of 61st St, the southern (i.e., original) channel downstream of the Green Ditch diversion, and the northern avulsion of the channel downstream of 61st St. The upstream reference site was chosen because it is subject to the same large-scale ecological stressors as the sites immediately downstream, such as altered water quality and altered flow regime, but is more geomorphically stable than the split channels downstream of 61st St. The upstream reference site provides a template for stable channel design within the constraints of existing watershed-wide disturbances that will not be altered by the restoration project. GEI's habitat survey methods are based on protocols developed by the U.S. Forest Service (Overton 1997) and modified for use in small Colorado streams. The modified surveys use the same basic methods as the R1/R4 inventory, but characteristics that are not relevant to small Colorado streams were not measured. Habitat units (riffles, runs, glides, and pools) were identified and measured individually. Pools were subclassified by formative structures (meanders, large woody debris, or boulders), and riffles were subclassified by gradient (low, high). Cascades, step pools, and high gradient riffles, which are characteristic habitat units in steeper streams, were not present within the Project site. Length, wetted width, bank width, average and maximum depth, substrate type, percentages of undercut and eroding banks, and the type of bank vegetation were measured within each habitat unit. Information such as the percentage of area taken up by each habitat unit type (e.g., pools, riffles, runs, etc.), the average depth of the habitat unit types, and the total number of habitat units were calculated from the information collected in these surveys and used to describe existing conditions before rehabilitation.

A Rapid Bioassessment Protocol (RBP) habitat survey (Barbour et al. 1999) was also conducted at each site. This qualitative assessment method provides additional information about site conditions not covered in the modified R1/R4 protocol, such as riparian vegetative community health and measures of pool complexity. This protocol requires visual assessment of 10 categories, each of which is scored on a scale of 0 to 20, with higher scores indicating better condition. The scores for each category are summed for a given site and rated as "optimal" (total score 160 – 200), "suboptimal" (total score 110 – 159), "marginal" (total score 60 – 109), or "poor" (total score ≤ 59).

The data collected from the habitat surveys described above were used to identify limiting factors to the native and desirable introduced fishes in the restoration reach of Boulder Creek.

2.2 Fisheries Data for Habitat and Fish Passage Recommendations

Existing fish and macroinvertebrate data were available through Colorado Parks and Wildlife and Timberline Aquatics, Inc., respectively. These data were reviewed to document existing conditions in the fish and macroinvertebrate assemblages and to ensure that stream restoration and diversion designs were suitable for the resident and native species in Boulder Creek. The basic habitat preferences of resident fishes were obtained from Page and Burr (2011) and described. Recommendations for incorporating certain habitat features into the restoration design were based on these preferences. Habitat requirements were also described for sensitive native species not currently present in the restoration reach (i.e., common shiner, plains topminnow). Information is provided for these species because they were historically present in this drainage, and because creating habitat features that are compatible with their needs creates the potential for future reintroduction.

Recommendations for the diversion structure design are based on swimming performances of the target species in Boulder Creek. The swimming performances of native species (sustained and burst speeds) were compiled whether or not they are extant in the reach, in the event that there is interest in reintroducing these species into the restored reach. Swimming abilities of these native fishes have been researched but have not been published at this time. However, swimming performance data were collected using a peer-reviewed published methodology that involves using a constant acceleration test in a laboratory to measure performance (Leavy and Bonner 2009). Swimming ability was measured with Loligo Model 32 or Loligo Model 90 swim tunnels (Loligo Systems, Tjele, Denmark). In a constant acceleration test, the water velocity is increased at a constant rate over time, and fish swim until exhaustion. This allows the measurement of an aerobic or sustained swimming speed and an anaerobic or sprint swimming speed for each individual fish. A minimum of 25 individuals of each species was tested, and median swimming speeds are presented in this report.

Recommendations for diversion design velocities, slope, and placement of roughness elements is based on the swimming data described above, a literature review involving field tests of rock ramps, and hydraulic data collected from a study at the Colorado State University Engineering Research Center.

3.0 Results

3.1 Habitat Analyses

Extensive urban and agricultural land use has affected all of Boulder Creek, and some of the large-scale effects of this land use are evident at all three surveyed reaches. However, pronounced differences also exist between them.

3.1.1 Upstream Reference

The Upstream Reference site contained a mix of habitat units: glides, riffles, runs, and pools formed by lateral scour, scour under large woody debris, and scour over boulders. It contained the highest number of habitat units and the highest number of habitat unit types of the three sites (Table 1). The Upstream Reference site is comprised of 55% pool habitat and has a pool spacing that is fairly typical of pool-riffle sequence streams (5 – 7 stream widths, Montgomery and Buffington 1997). The pool-to-riffle ratio and pool spacing in the Upstream Reference site provides adequate holding water for large-bodied fishes and adequate riffle habitat for macroinvertebrates and riffle-dwelling fishes such as longnose dace. Surface fines were also low throughout the site, with no habitat unit containing more than 30% coverage. Although this site contained habitat units with significant amounts of erosion, average bank erosion throughout the site was relatively low at 23%. Undercut bank was generally absent. Average site width was 11.0 m, and average depth was 0.5 m. Maximum depths in pool habitats regularly exceeded 1.0 m.

Table 1: Summary habitat characteristics for the three surveyed sites on Boulder Creek, 9/18/2014.

Habitat Attribute	Upstream Reference	South Channel	North Avulsion
No. of Habitat Units	9	6	8
No. of Habitat Unit Types	6	3	5
% Pool area	55	0	86
% Surface Fines	12 (5 – 30)	7 (2 – 15)	35 (5 – 90)
% Undercut	2.5	< 1	< 1
% Eroding Bank	23	2.5	17
Average site width (m)	11	7	8
Average site depth (m)	0.5	0.25	0.35

The Upstream Reference site received a rating of "suboptimal" under RBP criteria, but it had the highest score of all three sites (Table 2). This site is incised and disconnected from the floodplain, and the left bank (looking downstream) is channelized by a concrete sewer conduit. The suboptimal score at this site resulted mostly from disconnection from the floodplain, channelization by the sewer pipe, and a limited amount of instream cover (such as snags and woody debris). However, the vegetative community is relatively healthy, with a mix of willows, sedges, and trees providing bank stability and overhead cover.

The Upstream Reference site is currently receiving water directly from a breached gravel pit pond. Although the reference reach is outside of the project site, this pond is almost certainly a source of undesirable non-native fishes such as western mosquitofish and largemouth bass to Boulder Creek.

3.1.1.1 Limiting Factors

The primary limiting factors in the Upstream Reference site are disconnection from the floodplain, low habitat complexity, and the connection with the gravel pit pond outlet. Stream incision has resulted in the disconnection of the main channel and the floodplain, which deprives fish of important temporary spawning and foraging habitats during spring runoff. Disconnection of the main channel and the floodplain also limits the exchange of materials between the terrestrial and aquatic environment, a process that increases the productivity of both environments. Although the Upstream Reference site contains much deeper pools than the two downstream sites, these pools have limited complexity. Increased structural complexity, which could be achieved with addition of large woody debris and creation of undercut banks, would increase the habitat quality in the reach and provide refuge for fishes during low and high flows. The gravel pit pond outlet at the upstream end of the reference reach also provides a source of non-native predatory fishes that prey upon or compete with with native species. Habitat quality in the Restoration site would be improved if the pond did not drain into the stream.

3.1.2 Southern Channel

The Southern Channel site possesses relatively homogenous habitat with fewer habitat units ($n = 6$) and fewer unit types ($n = 3$) than the Upstream Reference site (Table 1). Although riffle habitat is extensive and provides cover for macroinvertebrates and habitat for fishes such as longnose dace, pools are absent, so there is no holding water for large-bodied species such as trout and suckers. The Southern Channel contains a high proportion of clean substrate, with no habitat unit containing more than 15% surface coverage by fines and a near-absence of eroding banks, but undercut banks were absent. Average site width was lower than at the Upstream Reference site, indicating flow reduction and possible sediment deprivation from the upstream diversion. Average site depth was 50% lower than at the Upstream Reference site, and maximum habitat unit depths never exceeded more than 0.5 m.

The Southern Channel is incised and disconnected from the floodplain. Although the banks have good vegetative coverage, most of the vegetation is non-native, invasive reed canarygrass. The Southern Channel received a "suboptimal" RPB rating (Table 2), mostly due to lack of pools, extensive vegetative coverage by an invasive plant, and an overly straight channel. Upstream of the habitat survey site, the Southern Channel is located near three gravel pit ponds, all of which likely harbor many non-native predatory fishes.

Table 2: Rapid Bioassessment Protocol (RBP) habitat scores and ratings for the three surveyed sites in Boulder Creek, 9/18/2014.

Habitat Attribute	Site		
	Upstream Reference	**Southern Channel**	**Northern Avulsion**
Epifaunal substrate/available cover	12	8	10
Pool substrate characterization	16	11	12
Pool variability	16	1	12
Sediment deposition	16	17	8
Channel flow status	18	19	6
Channel alteration	12	16	16
Channel sinuosity	14	8	12
Bank stability (L/R)	5/6	9/8	3/3
Vegetative protection (L/R)	6/8	5/5	4/2
Riparian zone width (L/R)	5/6	6/6	7/7
Total Score	140	119	102
Quality Rating	Suboptimal	Suboptimal	Marginal

The diversion on the Southern Channel upstream of the surveyed site creates an extensive backwater effect that results in a large proportion of slackwater habitat. This creates conditions that favor non-native species and do not benefit native fishes or macroinvertebrates that are adapted to flowing water.

3.1.2.1 Limiting Factors

Habitat quality in the Southern Channel is most limited by disconnection from the floodplain, low habitat heterogeneity and lack of pools, and the prevalence of an invasive plant in the riparian zone. The disconnection from the floodplain limits habitat quality for the same reasons discussed above in the limiting factors section for the Upstream Reference site. However, the habitat quality in the Southern Channel is lower than that at the Upstream Reference site due to additional constraints. Pools are absent in the Southern Channel, and most of the habitat consists of wide, shallow riffles and runs. This provides habitat for macroinvertebrates and small, riffle-dwelling fish species, but there is no available habitat in this site for fish that prefer deep water, such as creek chub, suckers, and trout. Overhead cover is also absent from this reach. This is exacerbated by the predominance of reed canary grass, which provides good bank stability but effectively prevents establishment of other plant species. Therefore, reed canary grass prevents any future benefits a more heterogeneous plant community could provide, such as large woody debris input, input of terrestrial insects, and vegetative shading.

The southern channel outside of the surveyed habitat site also contains significant limiting factors to habitat quality. First, the southern channel within the Project area is fragmented by the Green Ditch diversion. Fragmentation threatens many riverine fishes (see Section 3.3 for further detail). The southern channel of Boulder Creek also flows past several gravel pit ponds, and a backwater effect from the diversion creates extensive areas of sluggish flow.

The ponds may be hydrologically connected to the stream and could provide a source of undesirable non-native fishes that would benefit from the slow water velocities in the channel.

3.1.3 Northern Avulsion

This site contains a variety of habitat units (n = 8) and a similar number of habitat unit types (n = 5) as the Upstream Reference site. The Northern Avulsion contained riffles, runs, lateral scour pools, and a plunge pool caused by a headcut. The proportion of pool habitat at this site is much higher than at the Upstream Reference site (86%). This high percentage of pool habitat provides good holding water for larger-bodied transition zone fishes (trout, suckers, creek chub), but the low proportion of riffles likely limits site productivity through decreased macroinvertebrate habitat. The site is characterized by multiple thread channels with areas of mass aggradation that are highly unstable. Bank erosion is generally low throughout the unit, but undercut banks are absent. Clean gravel or cobble substrate in the Northern Avulsion is the lowest of the three sites, with substrate in some pools consisting of nearly 100% fine sediment. This site has an average width of 8 m and an average depth of 0.35 m. Maximum depths were 0.75 m or less in all units except one lateral scour pool.

The vegetative community consists of a mix of trees (e.g., crack willow and cottonwood), grasses, and coyote willow, but bare areas such as denuded or eroding banks and new point bars are very common at this site. The Northern Avulsion received a "marginal" RBP rating (Table 2), primarily due to poor instream cover, siltation in pools, and bank instability, all of which are to be expected in a channel avulsion after a large flood.

3.1.3.1 Limiting Factors

The primary limiting factors to habitat quality in the Northern Avulsion are a low proportion of riffle habitat, limited pool depths, fragmentation, high channel instability, and sedimentation. Although this site contains many pools, they are smaller than those at the Upstream Reference site (due to lower flows) and more structurally simple. These pools provide habitat for pool-dwelling fishes but probably cannot support the same density or species richness as the pools in the Upstream Reference site. The low proportion of riffles would limit habitat for riffle-dwelling fishes and for macroinvertebrates. This in turn would reduce food availability for insectivorous fishes. Although the Northern Avulsion is still connected to its floodplain in part of the surveyed reach, it is incised in others. This intermittent incision has led to several headcuts that fragment the reach. The reach is further fragmented by a grade control structure that spans the width of the channel and contains a pronounced vertical drop (see Section 3.3 for further details). Multiple headcuts within this reach indicate that it is vertically as well as horizontally unstable. This pronounced channel instability has led to habitat quality and structure that change unpredictably over time and to high proportions of fine sediment. Fine sediment is detrimental to habitat quality because many macroinvertebrates and some fishes live in the spaces between large-grained sediment (gravel and cobble) and because many transition zone fishes require clean gravel or cobble for spawning.

3.1.4 Summary: Limiting Factors to Fish Habitat

Boulder Creek is disconnected from its floodplain throughout the Project site. Restoring floodplain access will provide temporary spawning and foraging habitats for native fishes and increase system productivity by allowing the exchange of materials between terrestrial and aquatic habitats.

Like many urban streams, Boulder Creek is fragmented. However, multiple projects within the drainage have been designed to reverse this. Removing instream barriers provides fish with a means to cope with seasonal or sudden changes in physicochemical conditions that are typical in the transition zone. For example, although creation of large, complex pools may provide a thermal refuge for trout during summer, providing these coldwater fish with the opportunity to move upstream to cooler water increases their habitat quality on a larger scale and returns a historic ecological process to the stream.

Boulder Creek lacks deep pools throughout much of the Project site. Although shallow habitats are not uncommon or necessarily detrimental in transition zones, the southern channel within the Project site contains an unusual predominance of these habitats, and their width-to-depth ratio is unusually wide. In other portions, pools are predominant, and riffles are rare. This limits habitat for some fishes and for macroinvertebrate species and thus reduces food availability. Providing a mix of habitats, including pools of varying depth and complexity, riffles, runs, and glides, throughout the Project site will greatly increase habitat quality within the Project Site.

The presence of extensive slackwater conditions upstream of the Green Ditch diversion and the close proximity of many gravel pit ponds provide habitat for undesirable non-native fishes and a source of these fishes, respectively. Returning the stream to a more natural, historic form will reduce habitat availability for these species, and modifying the gravel pit ponds and/or moving the stream channel away from them will reduce introduction of these species into Boulder Creek.

Restoring the riparian community by removing reed canary grass and introducing other, native species would also increase habitat quality. The benefits of a varied riparian plant community include vegetative shading, and input of terrestrial insects and woody debris into the stream.

3.2 Fish and Macroinvertebrate Assemblages

The Boulder Creek fish assemblage in the restoration reach consists of 13 species: five native and eight non-native (Table 3). Sensitive species with special listing status in the State of Colorado, such as plains topminnow and common shiner, are currently absent from the restoration reach.

Boulder Creek historically supported central stoneroller, northern redbelly dace, plains killifish, and plains topminnow (CPW 2014) which have been extirpated from many of Colorado's transition zone streams because of extensive habitat modifications such as removal of large woody debris and disconnection from the floodplain (e.g., Meneks et al. 2003; GEI 2013). Common shiners were collected downstream near 75th St. in 2006 (CPW 2014). These individuals probably migrated into Boulder Creek from the St. Vrain River, which supports this species. Plains topminnow are present downstream of the restoration site. Studies and analyses of macroinvertebrate data indicate that macroinvertebrate communities in Boulder Creek are also negatively affected by large-scale anthropogenic stressors typical of urban streams (e.g., nutrient enrichment, Rees 2013).

Table 3: Fish presence[1] and habitat preferences[2] of species present at the project site.

Fish Species	Native?	Habitat Preference
Black crappie	N	Slackwater
Bluegill	N	Slackwater
Creek chub	Y	Pools, small to medium streams
Longnose sucker	Y	Pools and runs in streams
Largemouth bass	N	Slackwater
Longnose dace	Y	Riffles in streams
Brown trout	N	Pools, medium to large streams
Pumpkinseed	N	Slackwater
Rainbow trout	N	Pools, medium to large streams
Green sunfish	Y	Slackwater, but found in stream channel
Western mosquitofish[3]	N	Slackwater
White sucker	Y	Pools and runs in streams
Yellow perch	N	Slackwater

1. Fisheries data obtained from Colorado Parks and Wildlife.
2. Habitat preferences are from Page and Burr (2011).
3. Western mosquitofish were observed in the restoration reach during the 9/18/2014 field survey.

Many of the non-native fishes (including western mosquitofish) in the restoration reach prefer slackwater habitats in streams and lentic habitats such as ponds or lakes (Table 3). Whereas these non-native species largely rely on slackwater habitats year-round, native transition zone fishes can use temporarily inundated habitats (floodplains, side channels) for foraging and spawning in spring (reviewed in GEI 2013). The non-native fishes in Boulder Creek negatively affect the native species through predation and competition. For example, western mosquitofish prey upon early life stages of small fishes (e.g., Meffe 1985) and can outcompete adult plains topminnow (Haas 2005). Largemouth bass are aggressive predators with a diet that contains a high proportion of fish (Pflieger 1997). These non-native fishes have a competitive advantage over native species because human modifications such as the creation of gravel pit ponds, water diversion, and construction of instream structures such as grade control structures and diversion dams all decrease water velocities and create slackwater conditions. Colorado historically contained very few lakes and thus most of its native fish assemblage is not adapted to these conditions.

3.3 Diversion Design and Fish Passage

Fragmentation, also referred to as the artificial severing of stream connectivity, is pervasive (Jackson et al. 2001; Dynesius and Nilsson 1994) and has been implicated in the decline of fish populations worldwide; thereby threatening many North American fishes (reviewed in Ficke et al. 2011). Fragmentation is of particular concern in transition zones, because they are dynamic environments, and their resident fishes must move in response to large seasonal changes in conditions such as flow and temperature. Many native transition zone fishes are tolerant to changes in water quality and hydrograph that come with urban and agricultural land use but cannot tolerate fragmentation and/or channelization. Fishways have traditionally been used to restore connectivity to stream systems, and a growing body of knowledge about swimming abilities of transition zone fishes makes it possible to design instream structures using these swimming abilities as engineering design criteria to ensure passage.

Based on the visual assessment of the Green Ditch diversion, it is probably not impeding upstream or downstream passage of trout at all times of the year. Instead, it probably creates a seasonal barrier to movement, most likely during low flows. However, the diversion dam likely impedes passage of suckers throughout the year and creates a near-total barrier to movement of small-bodied resident fishes. A redesigned diversion could allow bi-directional passage of the resident fishes in the Project site. The northern avulsion currently contains multiple vertical drops at headcuts and one permanent weir-type structure. The vertical drops and the weir would not be navigable for small-bodied transition zone species and would likely reduce (but not prevent) movement of trout and suckers as well. The proposed method for reversing fragmentation in the Restoration site involves redesigning the diversion structure and reshaping and/or moving the channel to eliminate headcutting. The redesigned diversion will consist of a cross-vein weir that spans the width of the stream.

The ability of a fish to negotiate a potential obstacle depends on whether it can maintain a sufficient ground speed to move between velocity refuges without becoming exhausted (Peake et al. 1997). Like other animals, fish can use different gaits to meet the challenges of their environment (Webb 1998). For example, the maximum aerobic speeds presented below (Table 4) can be maintained for long periods of time, and thus, the cross-vein weir will not need added velocity refuges if water velocities are not to exceed 0.4 – 0.5 m/s (1.3 to 1.6 fps). However, if velocities are designed to be 0.7 m/s (2.3 fps) or greater, velocity refuges such as cobbles must be provided to enable passage. The swimming performances summarized below are primarily for small-bodied species. Swimming performance data for adult trout and large adult suckers were omitted because although notable exceptions exist, larger fishes are almost always faster than smaller ones (e.g., Aedo et al. 2009, Table 4). Therefore, design criteria that accommodate the abilities of smaller fishes will also work for larger fishes. Vertical drops should be avoided, because many transition zone fishes cannot jump, and those that can are small enough to make inclusion of vertical drops in the diversion structure impractical (Ficke et al. 2011; Prenosil 2014). Putting gaps between the boulders that form the cross-vein weir will allow small fishes to move past the structure, provided that water velocities between the boulders do not exceed their sprinting abilities. The maximum fishway water velocities below are provided with the assumption that the fastest water velocities encountered by a small fish will occur between the boulders used to construct the cross-vane. Maximum allowable velocities are given for the spaces between 2-ft diameter boulders and 3-ft diameter boulders.

The diversion also has the potential to entrain a large number of fishes. Although entrainment studies on Colorado fishes are rare, anecdotal evidence suggests that diversions can result in a substantial loss to the fish assemblage. The number of fish lost through entrainment into the Green Ditch diversion is not known, and studies of entrainment rates of fish in western streams have produced conflicting results. For example, a study on a Wyoming stream found that entrainment rates at three diversions ranged from 1.2 to 7.1%, while annual natural mortality was over 40% (Carlson and Rahel 2007). On the other hand, a study of a diversion on a Montana stream showed that the number of fish entrained at the surveyed diversions exceeded the number that moved downstream past them (Bahn 2007). Although the number of fish lost depends on stream flows and migration rates and timing (Bahn 2007; Carlson and Rahel 2007), the design of the diversion also probably has a large influence on entrainment rates.

Table 4: Swimming performance summary of native species found in the vicinity of the Green Ditch diversion. Natives that were historically present were also included. Note differences in lengths of tested fishes. Maximum allowable velocities depend on distance traveled and are given for distances of 2 and 3 ft (see text for details).

Species	Average length (in)	Maximum Aerobic Speed (ft/s)	Maximum Sprinting Speed (ft/s)	Maximum fishway velocity (ft/s)	Maximum drop height	Other specifications
Longnose sucker	9.4	2.3[a]	n/a	3.5/3.3	n/a	Avoid large pools downstream of structure
White sucker	3.0	1.5	83	2.3/2.1	n/a	
Creek chub	2.8	1.7	88	2.5/2.3	n/a	
Common shiner	2.3	n/a	67[b]	1.8/1.6	0.3[b]	
Longnose dace	2.8	1.4	78	2.2/2.0	0	
Northern redbelly dace	2.2	1.3	72	2.0/1.8	n/a	
Plains killifish	2.3	1.6	102	2.9/2.7	0.2[c]	
Plains topminnow	2.2	1.1	84	2.4/2.2	0.1[c]	
Green sunfish	3.0	1.3	79	2.2/2.0	0.4[c]	

[a] From Underwood et al. 2014

[b] From Ficke et al. 2011.

[c] From Prenosil 2014.

4.0 Recommendations

4.1 Habitat

Because the Upstream Reference offers the best habitat of the three sites, its features (i.e., pool depths, pool-riffle spacing, etc.) should be used for design, but adding features that provided more habitat complexity and bank stability than was observed in the Upstream Reference site would remove the additional limiting factors of low pool complexity and lack of undercut banks. The loss of habitat represented by abandoning or modifying the Southern Channel or the Northern Avulsion is minimal, because of low habitat diversity and quality in the Southern Channel and because of high instability in the Northern Avulsion. Therefore, alignment choices are not restricted by the necessity of retaining habitat features in either the Southern Channel or the Northern Avulsion.

Large wood should be used to create habitat structures, because historically, boulders were not the major habitat-forming structures in transition zone streams. Wood provides better habitat complexity than boulders, and it creates additional habitat for macroinvertebrates. Common shiners prefer systems with woody debris and overhanging riparian vegetation (Zuellig et al. 2007), so use of wood in the restoration could create potential habitat for this declining species.

Reconnecting the stream to the floodplain would be beneficial since many transition zone fishes, including common shiner (Meneks et al. 2003) are intolerant of channelization or disconnection from the floodplain (reviewed in GEI 2013).

Reduction in year-round slackwater habitats would also be beneficial because many of the undesirable non-native species in Boulder Creek require slackwater habitats that are present year-round. This does not conflict with the previous recommendation, because floodplain habitats such as side channels and backwaters are still beneficial to transition zone fishes if they are only available spring runoff. Small transition zone fishes use temporarily inundated habitats for spawning and foraging (Scheurer et al. 2003; Falke et al. 2010) and will thus benefit from habitats that are only available at high flows, whereas the non-native species would not benefit as much. Seasonal flooding also increases stream productivity by increasing the input of allochthonous (i.e., external) materials that fuel the food web (i.e., Bowen et al. 2003).

Providing sufficient water velocity that will periodically flush fine sediment from gravel and cobble substrate is important because most transition zone fishes are short-lived (Fausch and Bestgen 1997), and because some require clean (i.e., unembedded) substrate for spawning. Flushing of fines should occur at least every 2 – 3 years.

The Southern Channel passes by three large gravel pit ponds that likely provide habitat for non-native fishes to Boulder Creek. Increasing the distance between the channel and these gravel pit ponds would reduce the probability of hydrologic connectivity and the probability of a surface water connection when pond overflow occurs. This would remove a source of undesirable non-native fish.

The marsh located between the Southern Channel and the Northern Avulsion is a source population for invasive western mosquitofish as observed during the site visit. The feasibility of temporarily draining or eliminating this habitat could be explored to reduce mosquitofish habitat. If this ponded area were isolated from the stream, drained, and left dry for the winter, it could become potential habitat for plains topminnow instead of the source of an invasive species.

Riparian restoration could include the removal of reed canary grass and replacement with a more heterogeneous native plant community. This would provide future benefits to the stream such as vegetative shading, input of allochthonous material (including insects), and input of woody debris, an important habitat attribute in transition zones.

4.2 Diversion Design and Fish Passage

The proposed cross-vein weir should be designed with the velocity criteria provided above, and vertical drops should be avoided. GEI plans to work with Stantec during the design process to ensure that the target species can move past the new diversion structure. The velocities at the cross-vein weir will change with stream flows, so it will be necessary to ensure that this structure allows fish passage at multiple flows. Some fish do exhibit predictable spawning migrations, but recent movement data from South Boulder Creek suggest pulsed movements of trout and suckers throughout the year, not just during their spawning seasons.

If the cross-vein weir is long (i.e., in the upstream-downstream direction), the slope of the structure should be 5% or less if at all possible. A recent review of the few available field studies of instream structures such as rock ramps indicated that slopes over 5% reduce the efficacy of a structure to pass a variety of species.

The use of more, smaller roughness elements increases rock ramp utility for small fishes. A recent study at the Engineering Research Center at Colorado State University showed that spacing cobbles approximately one diameter apart reduced energy dissipation factor and median rock ramp velocity more than twice as much as cobbles that were two diameters apart. If velocities in the cross-vein weir are expected to exceed the sprinting ability of the small-bodied native fishes in Boulder Creek, smaller, more closely spaced velocity refuges can be used to reduce velocities.

The current Green Ditch diversion is likely entraining fishes. A fish screen at the headgate would prevent losses of fish from this portion of Boulder Creek. Alternatively, designing the cross-vein weir with spaces between the rocks and creating habitat conditions near the headgate that are not attractive to native fishes (i.e., shallow water with no overhead cover) would also reduce losses. Designing velocities at the headgate that are less than 34 cm/s (1.12 ft/s), the lowest known aerobic swimming ability in the native fish assemblage (Table 4), could also reduce entrainment rates.

The excess water return at the diversion likely exacerbates entrainment rates since it is passable to some upstream-migrating fish that may subsequently move down the ditch. The possibility of removing this structure was mentioned during the site visit. Removal of this return would also likely reduce movement of fish into the ditch.

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