Stream Restoration Construction

Greg Jennings, PhD, PE
President, Jennings Environmental PLLC
Professor Emeritus, NC State University
greg@jenningsenv.com

Grassy Creek, Spruce Pine, NC

River Course 401
Stream Restoration Workshop
NC State University

Jennings Environmental

NC STATE UNIVERSITY
Department of Biological and Agricultural Engineering

Stream Impairments

- Straightening & dredging
- Floodplain filling
- Watershed manipulation
- Sedimentation & stormwater
- Pollution discharges
- Utilities & culverts
- Buffer removal

What is Stream Restoration?

Adjusting physical, chemical, and biological conditions to set the stream ecosystem on a trajectory toward improved ecological functions and services

Grassy Creek, Spruce Pine, NC

Stream Ecosystem

- Channel
- Floodplain
- Water
- Sediment
- Nutrients
- Habitats
- Animals
- Plants

Outcomes of Restoration

- Water quality & habitats
- Natural flow regimes
- Recreation & aesthetics
- Public enthusiasm

Stream Restoration Components

- Channel & Floodplain Adjustments (Fluvial Geomorphology)
- In-stream Structures (grade control, bank protection, habitat)
- Vegetation: Bio-engineering & Riparian Buffers
- Targeted Solutions: AOP, Daylighting, Livestock, Stormwater

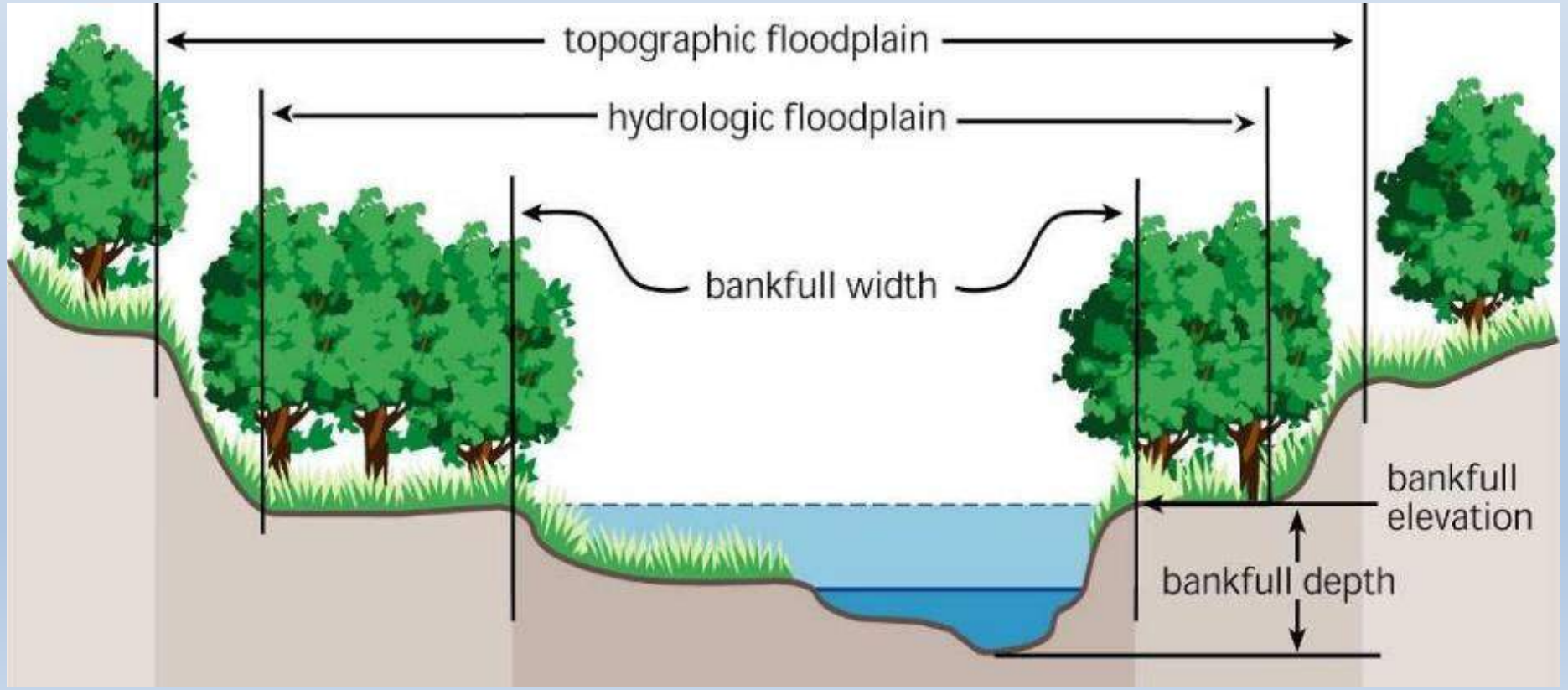
Fluvial Geomorphology:

Study of the form and function of streams and how they are shaped by flowing water

- Bankfull channel dimension, pattern, profile
- Floodplain connection
- Sediment transport
- Departure from equilibrium

Bankfull Channel Stage

"corresponds to the discharge at which channel maintenance is the most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work results in the average morphologic characteristics" *(Dunne and Leopold,1978)*



Stream Corridor Restoration: Principles, Processes, and Practices. 1998. Federal Interagency Stream Restoration Working Group.

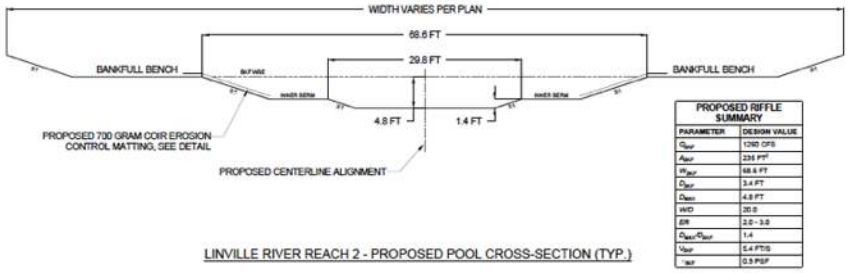
Reference Streams:

- Floodplain connection
- Vegetation
- Bedform diversity
- Freely-formed pattern

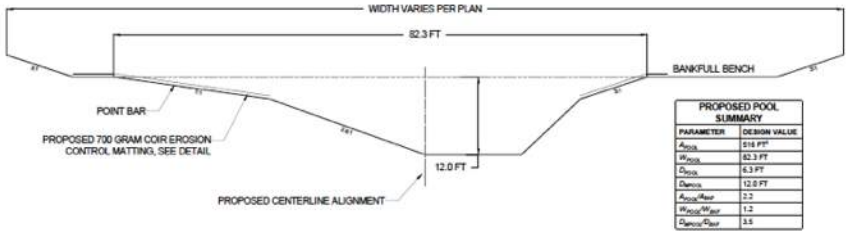
Similar climate, geology, soils, hydrology, sediment supply, vegetation

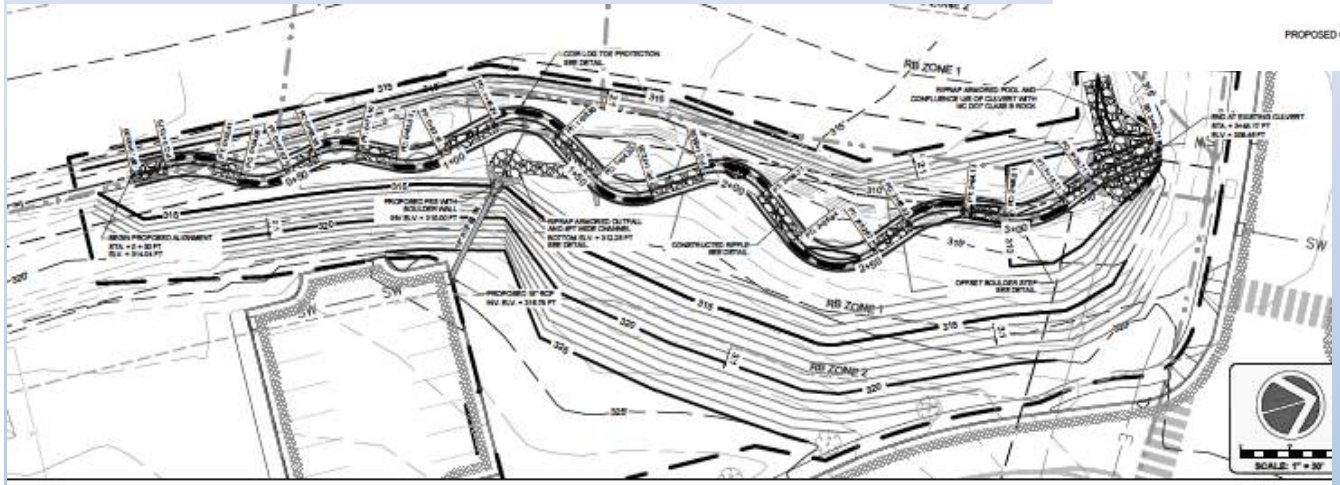
Design Plans Based on:

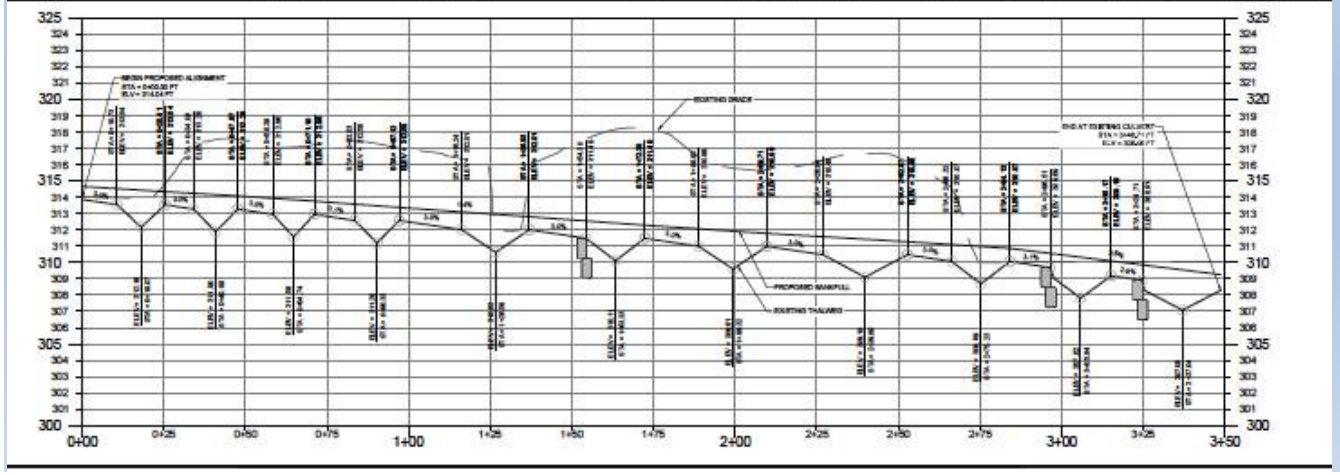
- Hydrology & Hydraulics
- Constraints
- Reference Geomorphology



LINVILLE RIVER REACH 2 - PROPOSED POOL CROSS-SECTION (TYP.)



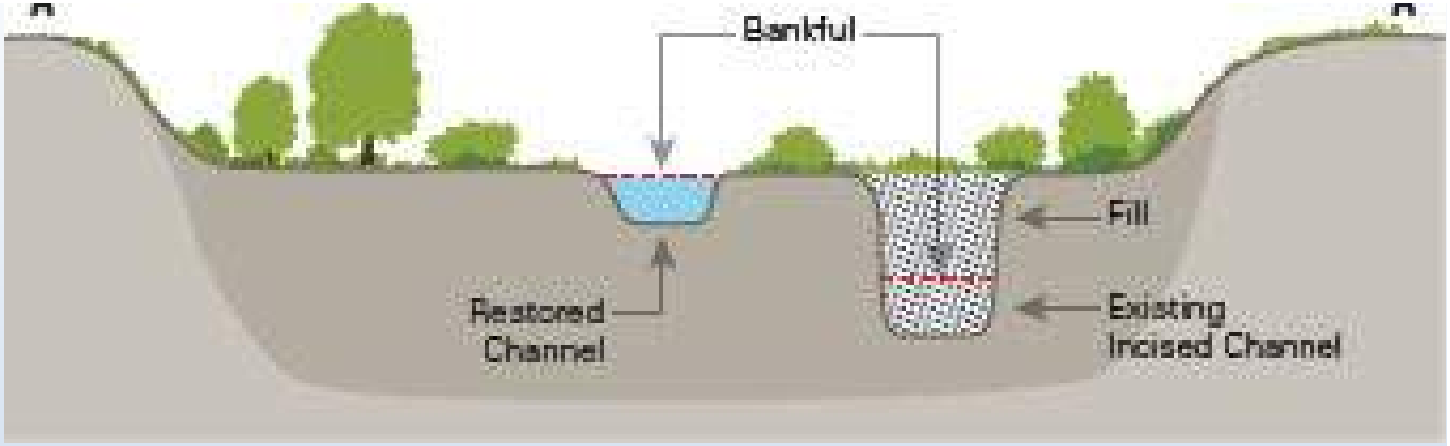




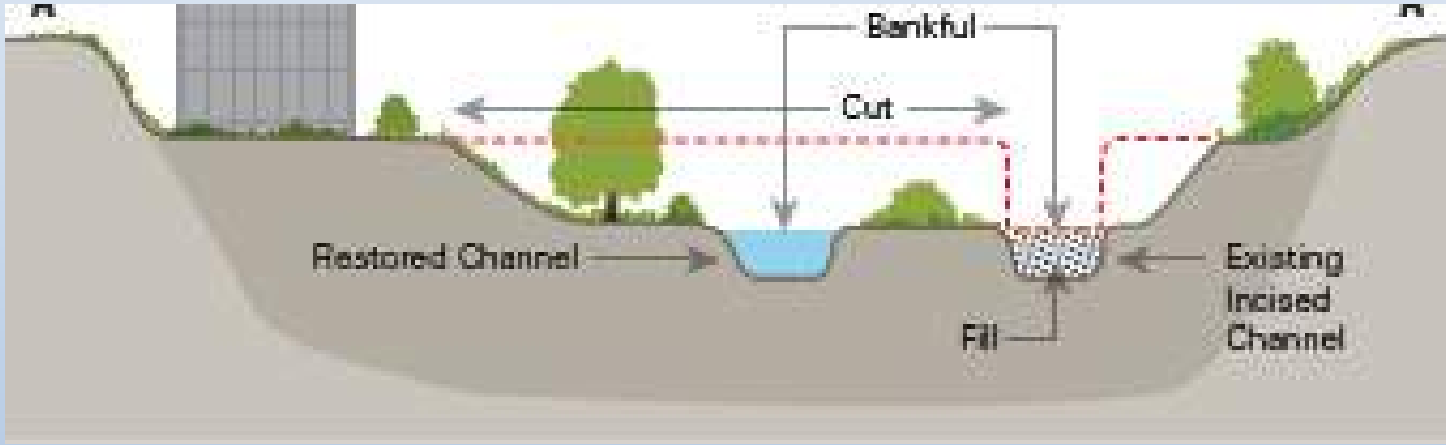
- Dimension
- Pattern
- Profile

Floodplain Connection

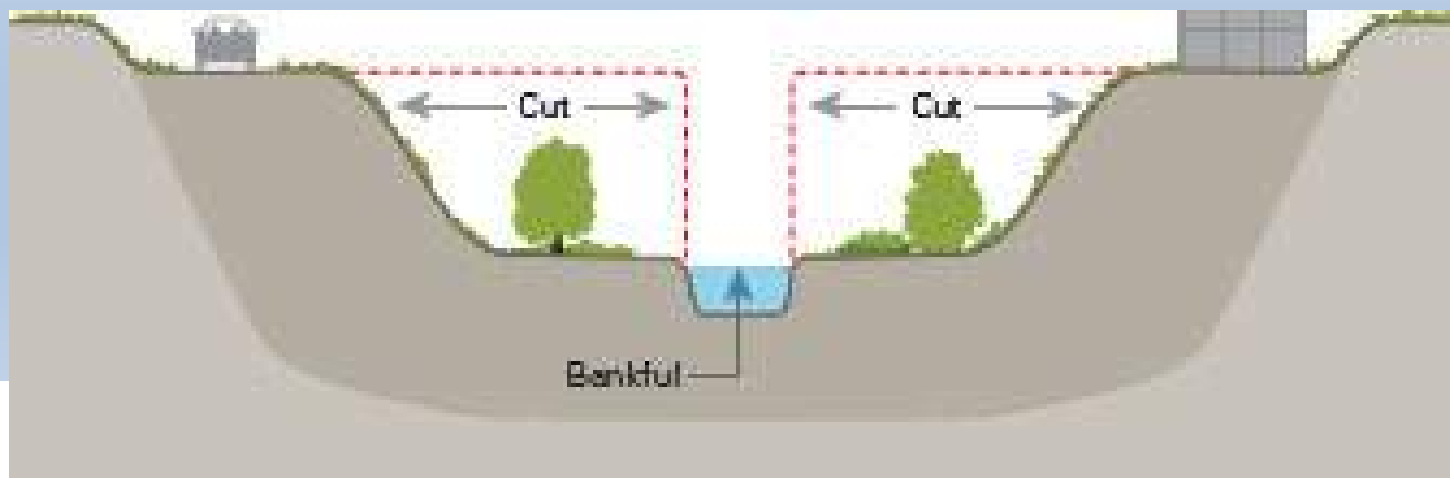
Priority 1



Priority 2



Priority 3



Harman, W., R. Starr. 2011. Natural Channel Design Review Checklist. US Fish and Wildlife Service, Chesapeake Bay Field Office, Annapolis, MD and US Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Wetlands Division. Washington, D.C. EPA 843-B-12-005

Purlear Creek Restoration, Wilkes County, NC

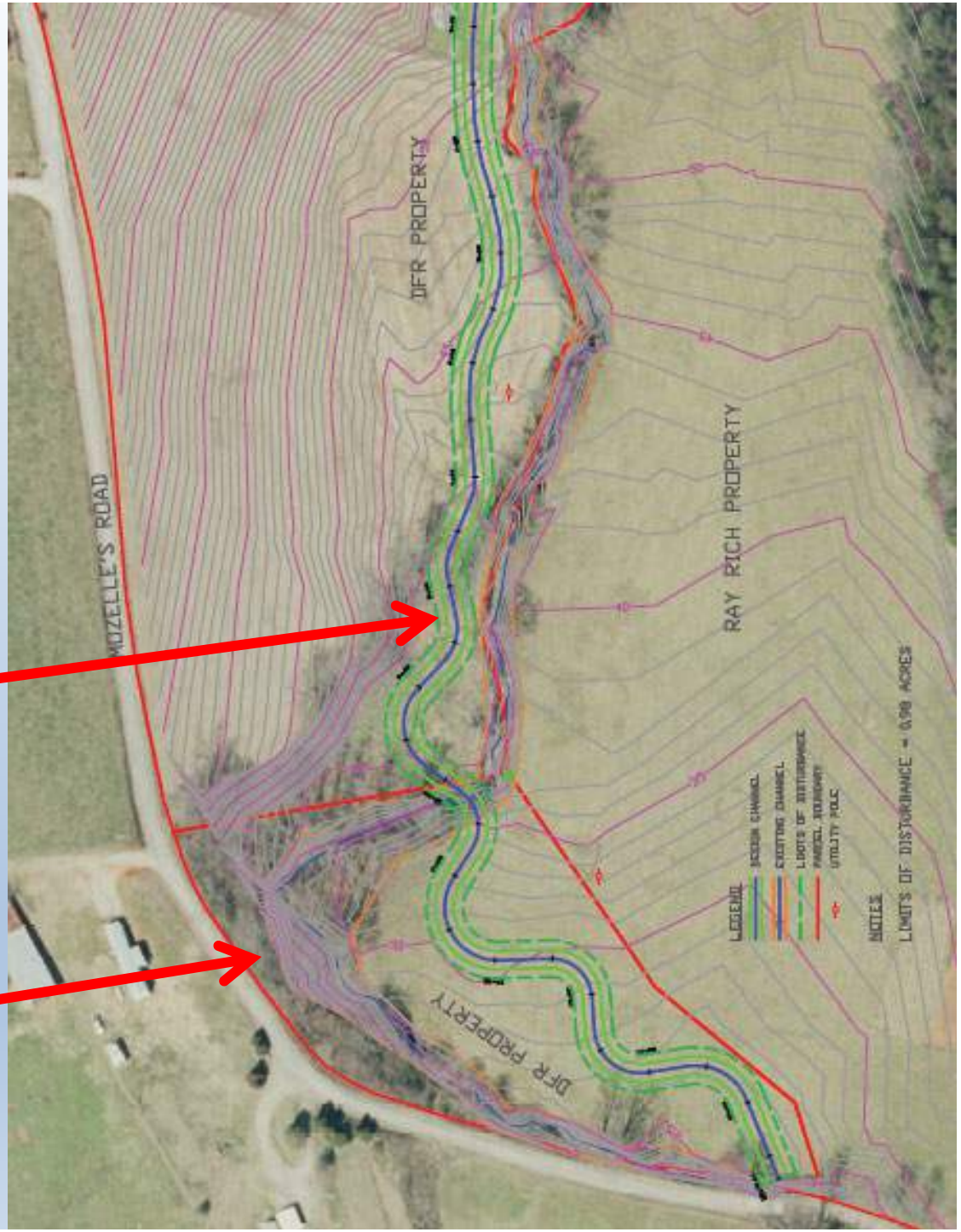
- Priority 1 & 2 floodplain connection
- 3300 ft channel realignment
- In-stream log habitat structures
- Native riparian vegetation
- Brook trout re-introduction

Priority 1 & 2 Floodplain Connection:

Realign channel to follow valley thalweg

New channel

Old channel
(600 ft in road ditch)



Priority 1
Floodplain Connection & Channel Realignment

2009

2011

Purlear Creek

2016

- Floodplain connection
- Dimension
- Pattern
- Profile
- Vegetation

Shawneehaw Creek, Avery County, NC

- Priority 1 Floodplain Connection (ER = 4)
- Realign 800 ft channel (4% valley slope, K = 1.05)
- In-stream rock and log habitat structures with cobble riffles

`

2018

Cobble Riffles &Boulder Steps, 2018 (7 years later)

UT Crabtree Creek, MAFC, Morrisville, NC

- Urban headwater stream in Neuse River Basin
- Drainage Area = 0.2 square miles
- Priority 2 Floodplain Connection (ER = 2 to 3)

Construction: *June - August, 2018*

Construction:
June - August, 2018

Planting: *December, 2018*

Rocky Branch: NCSU Campus

- Urban stream in Neuse River Basin
- Drainage Area = 1 square mile
- Priority 2 Floodplain Connection (ER = 2 to 3)
- Construction in 2006

NCSU Rocky Branch Downstream at Pullen Road

2009

2012

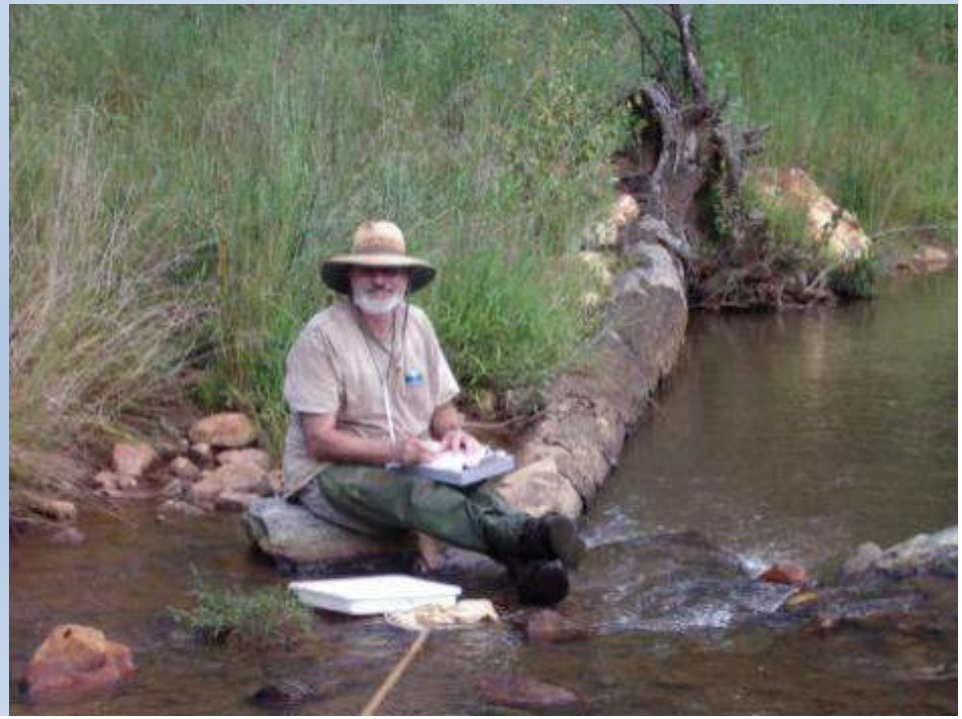
Boone Creek Daylighting: Priority 3 Project Constructed 2015

2013 Google Earth Image showing parking lot & buildings

Boone Creek: 2016 one year after construction

In-stream Structures (Rocks & Logs)

- Grade control
- Near-bank shear stress reduction
- Sediment transport
- Habitat Enhancement

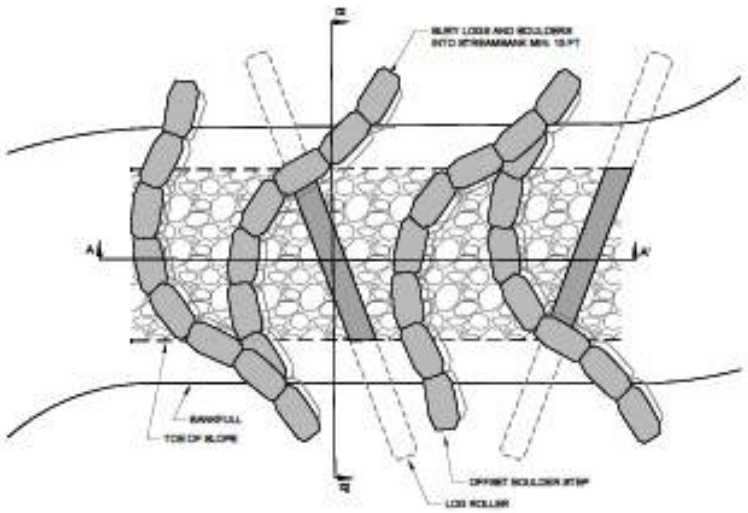


Successful Structures

- Properly designed and located
- Low profile
- Constructed to withstand stress
- Excellent vegetation

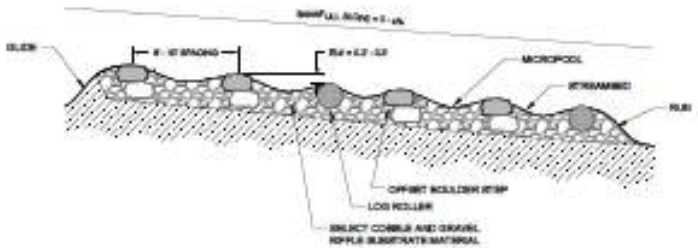
Constructed Riffle: Rocks and Logs

Constructed Riffle or Cascade



CASCADE WITH BOULDER STEPS AND LOGS NOT TO SCALE

DETAILED PLAN



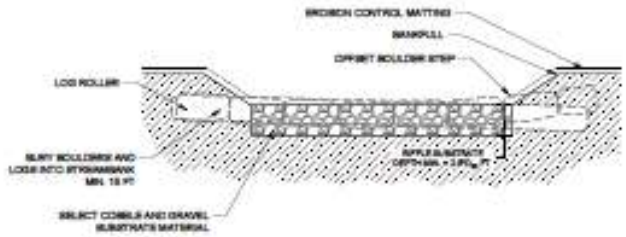
CASCADE WITH BOULDER STEPS AND LOGS NOT TO SCALE

DETAILED CROSS-SECTION A - A'

CASCADE WITH BOULDER STEPS AND LOGS

NOTES

1. THE CASCADE STRUCTURE WITH OFFSET BOULDER STEPS AND LOG ROLLERS IS A STREAM AND RIVER RESTORATION DESIGN FEATURE THAT INCORPORATES COARSE MATERIAL SUBSTRATE MATERIAL, BOULDERS AND LARGE WOOD (LOGS) IN THE CHANNEL BOTTOM THAT WILL NOT BE MOBILIZED UNDER DEFINED FLOW CONDITIONS. REPLACING (OR ADDING TO) THE NATIVE CHANNEL BED MATERIAL WITH LARGER DIAMETER ROCK AND LARGE WOOD CREATES A RIFFLE THAT FUNCTIONS AS A RIGID GRADE CONTROL AND HABITAT FEATURE. LARGER ROCK MATERIAL AND WOOD ENHANCES FLOW DIVERSITY AND TURBULENCE UNDER BASE FLOW CONDITIONS, WHICH PROMOTES AQUATIC HABITAT, NUTRIENT PROCESSING AND RE-AERATION OF STREAM FLOW BENEFITING WATER QUALITY. THE D_{35}, D_{50}, D_{84} OR D_{100} PARTICLES OF THE CONSTRUCTED MAY BE DESIGNED TO RESIST τ_{bkf} WHILE ALLOWING SMALLER SUBSTRATE PARTICLES TO BE MOBILIZED AND REPLACED BY UPSTREAM SEDIMENT SEDIMENT SUPPLY. THIS STRUCTURE MAY BE USED IN RIFFLES WITH STEEPER SLOPES AS A GRADE CONTROL.
2. ALL SELECT RIFFLE MATERIAL SHALL BE QUARRIED STONE UNLESS NATIVE MATERIAL OF SIMILAR SIZE IS AVAILABLE ONSITE AND MEETS THE CONSTRUCTED RIFFLE SIZE SPECIFICATIONS. THE ENGINEER MUST APPROVE THE USE OF ALL ONSITE NATIVE MATERIAL.
3. THE GRAVEL AND COBBLE SUBSTRATE USED FOR THIS DESIGN FEATURE SHOULD BE PREFERENTIALLY HARVESTED FROM THE EXISTING CHANNEL AND OTHER DESIGNATED MINING AREAS ONSITE.
4. SORTING AND SIEVING OF THE HARVESTED RIFFLE SUBSTRATE IS INCIDENTAL TO THE CONSTRUCTION OF THIS STRUCTURE.
5. LOGS SHALL HAVE MINIMUM DIAMETER OF 2.0 FT. LOGS SHALL HAVE A MINIMUM LENGTH OF W_{BKF} + 30 FEET.
6. ALL LOGS SHALL BE RELATIVELY STRAIGHT AND LIMBS AND BRANCHES SHALL BE TRIMMED FLUSH.
7. FOR INSTALLATION, THE CONTRACTOR SHALL OVER EXCAVATE THE LENGTH OF THE CASCADE, INSTALL 700 GRAM COIR FIBER EROSION CONTROL MATTING, KEY MATTING INTO THE RIFFLE TRENCH AND BACKFILL WITH THE SPECIFIED SELECT RIFFLE MATERIAL TO THE ELEVATIONS SHOWN ON THE PROPOSED PROFILE.
8. CONSTRUCTED RIFFLE MATERIAL SHALL EXTEND A MINIMUM OF 15 FT U/S OF THE P.T. INTO THE GLIDE AND D/S TO THE P.C.
9. P.T. AND P.C. STATIONS AND ELEVATIONS ARE INCLUDED IN THE PROPOSED PLAN AND PROFILE SHEETS. SET RIFFLE INVERTS AT ELEVATION SHOWN ON THE PLAN AND PROFILE SHEETS. NO ELEVATIONS OF THE CONSTRUCTED RIFFLE WITH LOG ROLLERS MAY VARY FROM THE PLAN SHEETS WITHOUT DIRECTION FROM THE ENGINEER.
10. THE VERTICAL SLOPE OF EACH LOG AND BOULDER ARM SHALL NOT EXCEED 2% 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, AND THE VERTICAL DROP OVER THE LOG AND LOG DIAMETER.
11. THE MAXIMUM DISTANCE BETWEEN LOG AND BOULDER SHALL BE 8 - 10 FT. MAXIMUM ELEVATION DROP BETWEEN LOGS SHALL BE 0.2 - 0.3 FT OF THE LOG DIAMETER.
12. SELECT RIFFLE MATERIAL SHALL BE USED AS BACKFILL MATERIAL AROUND THE STRUCTURE.
13. SECURE ALL GEOTEXTILE FABRIC ON TOP OF FOOTER LOG USING 3 IN 10D GALVANIZED COMMON NAIL ON 12 IN SPACING ALONG LOG. NAIL NON-WOVEN GEOTEXTILE TO EDGE OF HEADER LOG AND BACKFILL.
14. SELECT RIFFLE MATERIAL DEPTH SHALL BE AT LEAST 2.5 TIMES THE D_{84} (MM) SPECIFIED BY THE ENGINEER.
15. SELECT RIFFLE MATERIAL WILL BE PLACED AT A UNIFORM THICKNESS.
16. THE SELECT RIFFLE MATERIAL WILL BE PLACED SUCH THAT, IN CROSS-SECTION, ITS LOWEST ELEVATION OCCURS IN THE CENTER OF THE CHANNEL AS PER THE DETAIL.
17. SELECT RIFFLE MATERIAL SHALL BE COMPACTED USING TRACK EQUIPMENT OR AN EXCAVATOR BUCKET SUCH THAT FUTURE SETTLEMENT OF THE MATERIAL IS KEPT TO A MINIMUM.
18. 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.
19. 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.



CASCADE WITH BOULDER STEPS AND LOGS NOT TO SCALE

DETAILED CROSS-SECTION B - B'

Constructed Riffle: Rocks and Logs

Vanes *(Boulder or Log)*

- Oriented upstream at 20-30 degrees from bank tangent
- Sloping up from channel invert at 3-5 % arm toward bank
- May control grade using J-hook (< 0.5 ft drop)
- May need footers, sills, geotextile to avoid piping/washout

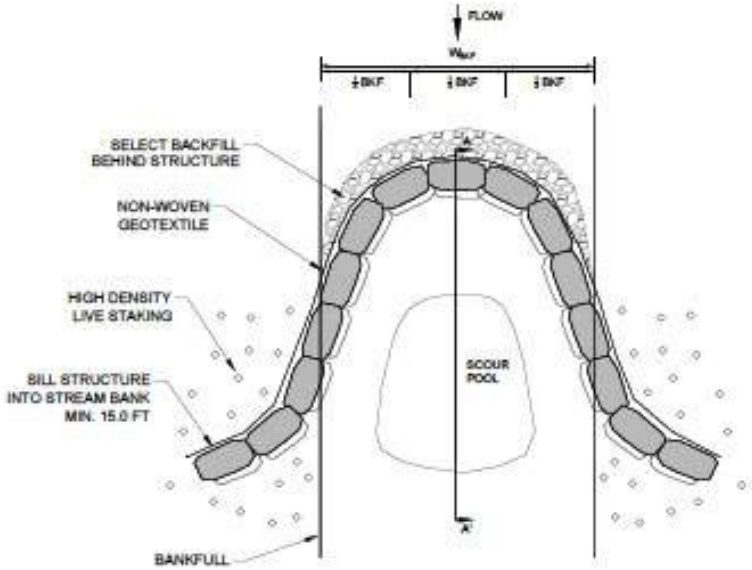
Vanes

- Single-arm
- J-hook
- Cross-vane

20-30 degrees

3-5 % arm slopes

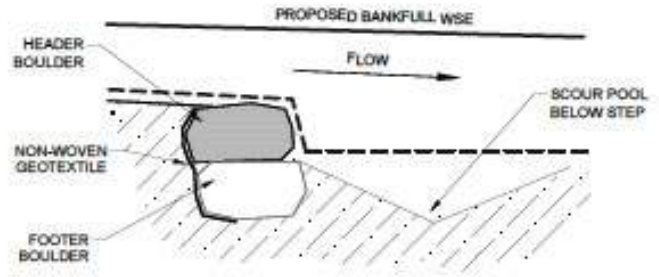
Cross Vanes for flow direction & grade control



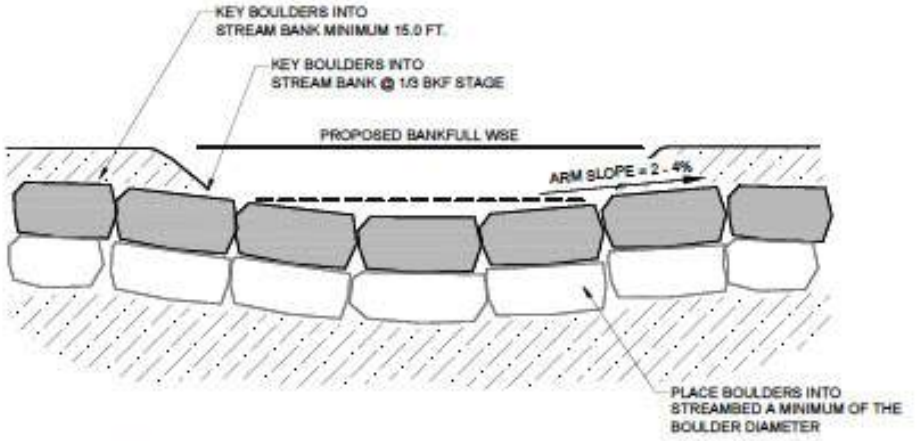
BOULDER CROSS-VANE
DETAILED PLAN
NOT TO SCALE

BOULDER CROSS-VANE
NOTES

1. THE BOULDER CROSS-VANE IS A DESIGN FEATURE USED TO CONTROL GRADE IN HIGH IN GRADIENT REACHES OR AT CRITICAL JUNCTURES OF THE PROPOSED CHANNEL. THE CROSS-VANE IS ALSO USED TO PROVIDE ENERGY DISSIPATION, REDUCE NEAR BANK STRESS (NBS), AND CREATE A DIVERSITY OF AQUATIC HABITAT THROUGH SCOUR OF THE STREAM BED. THE CROSS-VANE IS COMPOSED OF A BOULDER SILL, WHICH IS A ROW OF BOULDERS SET AT AN ELEVATION PROVIDED IN THE PROPOSED PROFILE THAT SPANS PERPENDICULAR TO AND SLIGHTLY ARCED ACROSS THE CHANNEL. THE BOULDER SILL EXTENDS APPROXIMATELY 1/3 OF THE CHANNEL WIDTH IN THE CENTER OF THE CHANNEL. FROM THE EXTENTS OF THE SILL BOULDERS, TWO VANE ARMS EXTEND UP AND TOWARDS THE STREAM BANK, EVENTUALLY KEYING INTO THE BANK AT AN ELEVATION HIGHER THAN THE SILL BOULDERS.
2. ALL BOULDERS USED FOR THE OFFSET BOULDER STEP SHALL BE STRUCTURAL STONE, CUBICAL OR RECTANGULAR IN SHAPE. THE ENGINEER MUST APPROVE THE USE OF BOULDERS THAT MAY BE AVAILABLE ONSITE.
3. DIMENSIONS AND SLOPES OF STRUCTURES DESCRIBED IN THE DETAIL MAY BE ADJUSTED BY DESIGN ENGINEER TO FIT CONDITIONS ONSITE.
4. CONTRACTOR WILL BE REQUIRED TO FIT BOULDERS TOGETHER TIGHTLY.
5. GAPS BETWEEN BOULDERS SHALL BE MINIMIZED BY FITTING BOULDERS TOGETHER AND PLUGGING WITH NC DOT CLASS A AND SELECT MATERIAL OR CHINKING STONE APPROVED BY DESIGN ENGINEER, AND LINING WITH FILTER FABRIC.
6. THERE SHALL BE NO DROP GREATER THAN 0.5 FT OVER A SINGLE STEP. BOULDERS SHALL BE 3 FT X 4 FT X 2 FT +/- 0.5 FT.
7. NON-WOVEN GEOTEXTILE 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.



BOULDER CROSS-VANE
SECTION A - A'
NOT TO SCALE



BOULDER CROSS-VANE
CROSS-SECTION
NOT TO SCALE

Boulder Cross Vanes: *Grade Control & Habitat*

Rocky Branch Cross Vanes: 2015 (9 years after)

Ability Access Fishing Deck: North Toe River

Offset Boulder Cross Vane at a Bridge

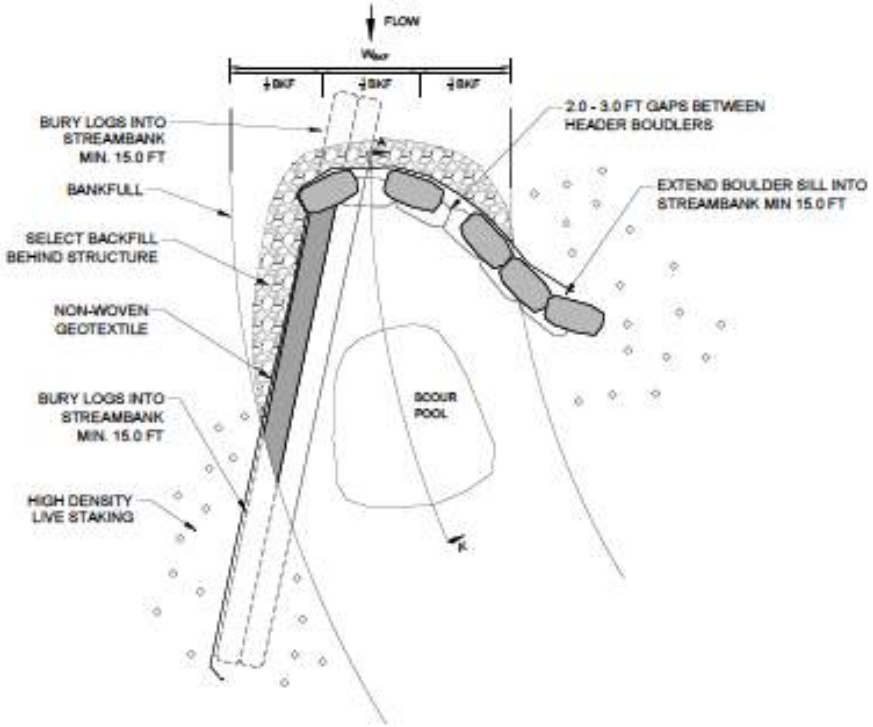
Boulder Cross Vane with Logs Integrated into Footer

Boulder Vane: *Ivy Creek*

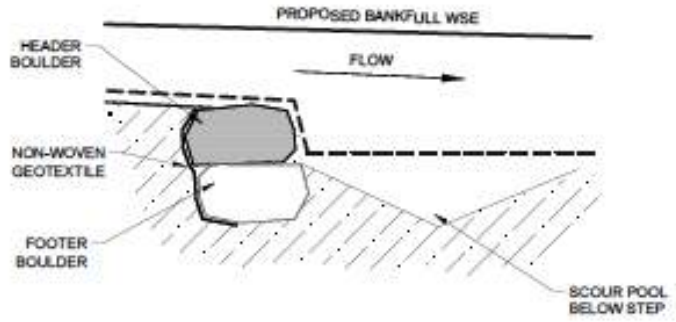
Boulder J-Hook Vane: *Scour Pool*

Chinking Gaps to Prevent Piping

Log J-hook Vane for flow direction & habitat



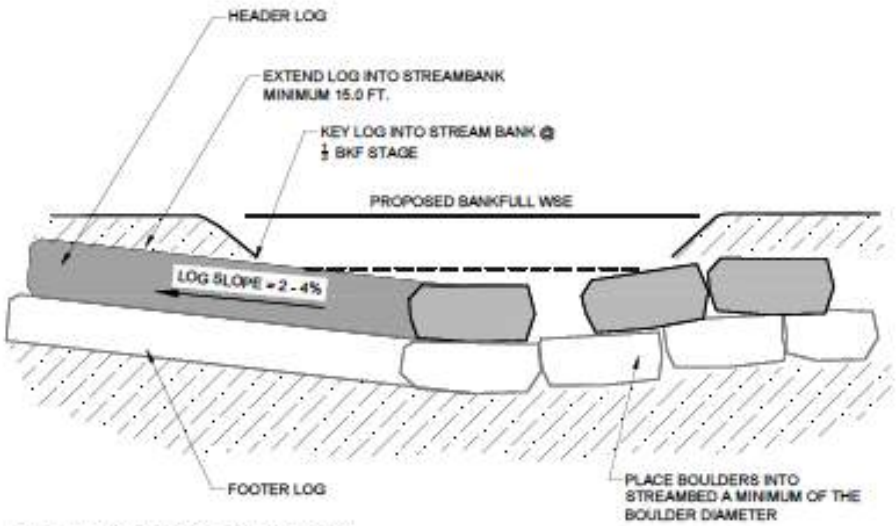
LOG J-HOOK WITH BOULDERS
DETAILED PLAN
NOT TO SCALE



LOG J-HOOK WITH BOULDERS
SECTION A - A'
NOT TO SCALE

LOG J-HOOK WITH BOULDERS
NOTES

1. THE LOG J-HOOK WITH BOULDERS IS A DESIGN FEATURE USED TO PROVIDE ENERGY DISSIPATION, FLOW DIRECTION CONTROL AND TO REDUCE NEAR BANK STRESS. THIS STRUCTURE WILL ALSO ENCOURAGE POOL MAINTENANCE AND CREATE A DIVERSITY OF AQUATIC HABITAT THROUGH SCOUR OF THE RIVER BED. THE LOG J-HOOK WITH BOULDERS IS COMPOSED OF A BOULDER SILL, WHICH IS A ROW OF BOULDERS SET AT AN ELEVATION PROVIDED IN THE PROPOSED PROFILE THAT SPANS PERPENDICULAR TO AND SLIGHTLY ARCED ACROSS THE CHANNEL. THE BOULDER SILL EXTENDS EXTENDS FROM A LOG VANE ARM INTO THE OPPOSITE STREAMBANK. THE LOG VANE ARM EXTENDS UP AND TOWARDS THE OUTSIDE STREAM BANK, EVENTUALLY KEYING INTO THE BANK AT AN ELEVATION HIGHER THAN THE SILL BOULDERS.
2. ALL BOULDERS USED FOR THE BOULDER SILL SHALL BE STRUCTURAL STONE, CUBICAL OR RECTANGULAR IN SHAPE. BOULDERS AVAILABLE ONSITE MAY BE USED IF APPROVED BY THE ENGINEER.
3. DIMENSIONS AND SLOPES OF STRUCTURES DESCRIBED IN THE DETAIL MAY BE ADJUSTED BY DESIGN ENGINEER TO FIT CONDITIONS ONSITE.
4. CONTRACTOR WILL BE REQUIRED TO FIT LOGS AND BOULDERS TOGETHER TIGHTLY. ALL LOGS AND BOULDERS SHALL BE INSTALLED WITH FOOTERS.
5. HEADER BOULDERS SHALL HAVE 2.0 FT - 3.0 FT GAPS BETWEEN EACH BOULDER TO MAINTAIN SEDIMENT TRANSPORT FUNCTIONS AND FISH PASSAGE.
6. GAPS BETWEEN LOGS AND FOOTER BOULDERS SHALL BE MINIMIZED BY FITTING BOULDERS TOGETHER AND PLUGGING WITH NC DOT CLASS A, WOODY DEBRIS AND SELECT MATERIAL OR CHINKING STONE APPROVED BY DESIGN ENGINEER, AND LINING WITH FILTER FABRIC.
7. THE LOG VANE SHALL EXTEND INTO THE OUTSIDE STREAMBANK AND STREAMBED A MINIMUM OF 15.0 FT ON EACH END.
8. THE BOULDER SILL SHALL EXTEND A MINIMUM OF 15.0 FT INTO THE INSIDE STREAM BANK.
9. BOULDERS SHALL BE 3.0 FT X 4.0 FT X 2.0 FT +/- 0.5 FT. MINIMUM LOG DIAMETER IS 2.0 FT.
10. NON-WOVEN GEOTEXTILE SHALL BE PLACED ON THE UPSTREAM SIDE OF THE STRUCTURE TO PREVENT WASHOUT OF SEDIMENT THROUGH FOOTER 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.



LOG J-HOOK WITH BOULDERS
CROSS-SECTION
NOT TO SCALE

J-Hook Log Vane

STATION 2+00 meander bend streambank protection and scour pool maintenance

Before

After

Log J-Hook Vane: Flow direction, bank protection, habitat

Arm slope = 1.2 / 30 = 4%; Arm angle = 25 degrees

Storm Flow: Flow direction + Bank protection

Toe Wood Revetment

- streambank protection
- habitat enhancement

November, 2015

August, 2016

How Do We Reduce Risk in Stream Restoration?

1. **Boundary Conditions:** ***Soil Strengthening***
   - Earth (soil, rock)
   - Artificial supplements (concrete, plastic, fiber)
   - Vegetation (bio-engineering)
2. **Forcing Functions:** ***Hydraulic Force Reductions***
   - Watershed hydrology (retention, LID)
   - Shear stress (depth, slope): ***FLOODPLAIN***
   - Sediment supply (stream power)

Reducing Risk: *Boundary Conditions*

Soil Strengthening:

- Wood Toe Revetment,
- Matting
- Vegetation

Reducing Risk: *Forcing Functions*

Hydraulic Force Reductions:

- Watershed hydrology (retention, LID)
- Shear stress (depth, slope): ***FLOODPLAIN***
- Sediment supply (stream power)

When in Doubt, Spread it Out!

Environmental Permits

1. US Army Corps of Engineers (Clean Water Act Section 404)
2. NC Division of Water Resources (Clean Water Act Section 401)

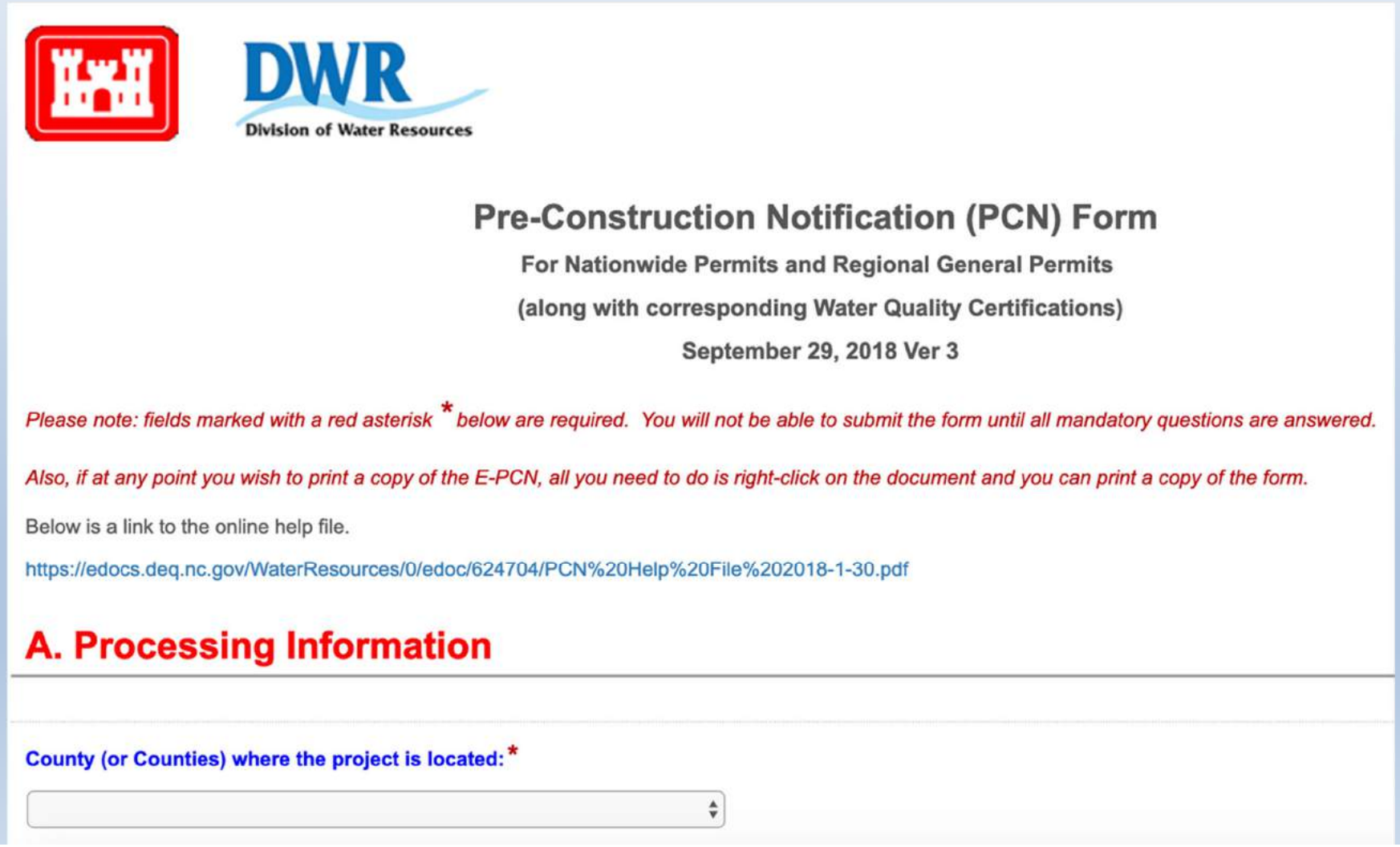
Scale of impacts to wetlands[1], waters[1], and streams[2]	Fee Schedule
Major[3] water quality applications: Greater than or equal to one acre of wetlands/ waters AND/OR greater than or equal to 150 feet of streams (intermittent or perennial)	$570.00
Minor[3] water quality applications: Less than one acre of wetlands/waters AND less than 150 feet of streams (intermittent or perennial)	$240.00

Check should be made payable to "N.C. Division of Water Resources"

Environmental Permits

401/404 Pre-Construction Notification (PCN)

https://edocs.deq.nc.gov/Forms/Pre-Construction_Notification_Form



DWR
Division of Water Resources

Pre-Construction Notification (PCN) Form

For Nationwide Permits and Regional General Permits

(along with corresponding Water Quality Certifications)

September 29, 2018 Ver 3

*Please note: fields marked with a red asterisk * below are required. You will not be able to submit the form until all mandatory questions are answered.*

Also, if at any point you wish to print a copy of the E-PCN, all you need to do is right-click on the document and you can print a copy of the form.

Below is a link to the online help file.

https://edocs.deq.nc.gov/WaterResources/0/edoc/624704/PCN%20Help%20File%202018-1-30.pdf

A. Processing Information

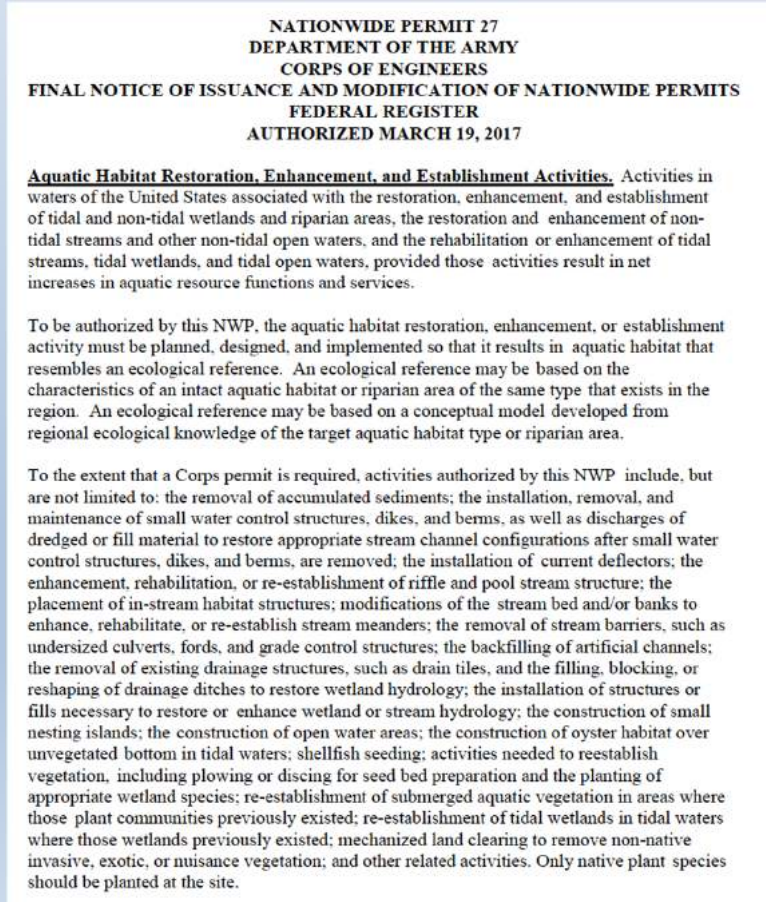
County (or Counties) where the project is located: *

Environmental Permits

USACE Nationwide Permit 27 for Aquatic Habitat Restoration

http://saw-reg.usace.army.mil/NWP2017/2017NWP27.pdf

- Reference-based habitat restoration
- Natural stream morphology
- In-stream habitat logs & rocks
- Native plants



NATIONWIDE PERMIT 27
DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
FINAL NOTICE OF ISSUANCE AND MODIFICATION OF NATIONWIDE PERMITS
FEDERAL REGISTER
AUTHORIZED MARCH 19, 2017

Aquatic Habitat Restoration, Enhancement, and Establishment Activities. Activities in waters of the United States associated with the restoration, enhancement, and establishment of tidal and non-tidal wetlands and riparian areas, the restoration and enhancement of non-tidal streams and other non-tidal open waters, and the rehabilitation or enhancement of tidal streams, tidal wetlands, and tidal open waters, provided those activities result in net increases in aquatic resource functions and services.

To be authorized by this NWP, the aquatic habitat restoration, enhancement, or establishment activity must be planned, designed, and implemented so that it results in aquatic habitat that resembles an ecological reference. An ecological reference may be based on the characteristics of an intact aquatic habitat or riparian area of the same type that exists in the region. An ecological reference may be based on a conceptual model developed from regional ecological knowledge of the target aquatic habitat type or riparian area.

To the extent that a Corps permit is required, activities authorized by this NWP include, but are not limited to: the removal of accumulated sediments; the installation, removal, and maintenance of small water control structures, dikes, and berms, as well as discharges of dredged or fill material to restore appropriate stream channel configurations after small water control structures, dikes, and berms, are removed; the installation of current deflectors; the enhancement, rehabilitation, or re-establishment of riffle and pool stream structure; the placement of in-stream habitat structures; modifications of the stream bed and/or banks to enhance, rehabilitate, or re-establish stream meanders; the removal of stream barriers, such as undersized culverts, fords, and grade control structures; the backfilling of artificial channels; the removal of existing drainage structures, such as drain tiles, and the filling, blocking, or reshaping of drainage ditches to restore wetland hydrology; the installation of structures or fills necessary to restore or enhance wetland or stream hydrology; the construction of small nesting islands; the construction of open water areas; the construction of oyster habitat over unvegetated bottom in tidal waters; shellfish seeding; activities needed to reestablish vegetation, including plowing or discing for seed bed preparation and the planting of appropriate wetland species; re-establishment of submerged aquatic vegetation in areas where those plant communities previously existed; re-establishment of tidal wetlands in tidal waters where those wetlands previously existed; mechanized land clearing to remove non-native invasive, exotic, or nuisance vegetation; and other related activities. Only native plant species should be planted at the site.

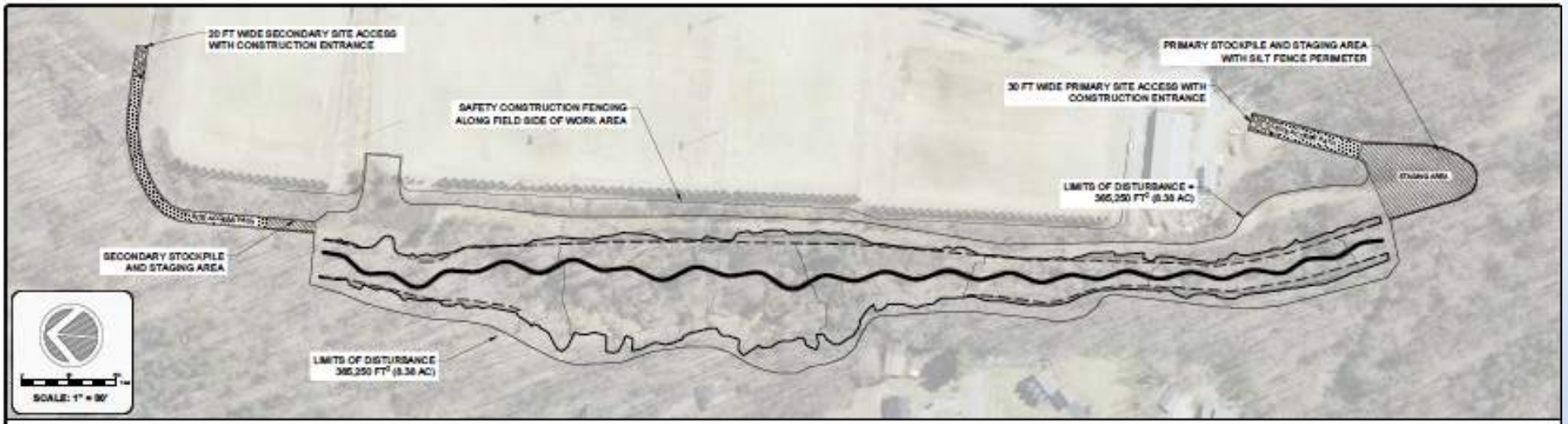
Construction of Stream Restoration Projects

1. Site Preparation
2. Grading
3. Site Stabilization

Best Construction Practices

- Track equipment
- Spill management plan
- Staged construction phases to limit exposure

Erosion & Sediment Control Plan



CONSTRUCTION SCHEDULE

A. OBTAIN EROSION AND SEDIMENTATION PLAN APPROVAL AND ALL OTHER APPLICABLE PERMITS.
B. NOTIFY INSPECTOR FROM WINSTON SALEM REGIONAL OFFICE OF DEQ PRIOR TO DISTURBANCE.
C. POST CERTIFICATE OF APPROVAL FOR LAND DISTURBANCE AT SITE.
D. INSTALL RAIN GAUGE AND PERFORM INSPECTION FORMS AS DESCRIBED ABOVE.
E. FLAG THE WORK LIMITS AND STAKE OUT THE EXTENTS AND ELEVATIONS OF THE PROJECT.
F. LOCATE ALL UNDERGROUND UTILITIES WITHIN THE WORKSITE.
G. HOLD PRE-CONSTRUCTION MEETING PRIOR TO STARTING CONSTRUCTION.
H. INSTALL CONSTRUCTION ENTRANCES, CONSTRUCTION / SAFETY FENCE AND SILT FENCE PER THE ATTACHED PLAN SHEETS AND DETAILS.
I. INSPECT EROSION AND SEDIMENTATION CONTROL PRACTICES DAILY AND AFTER SIGNIFICANT RAINFALL EVENTS. MAKE NEEDED REPAIRS IMMEDIATELY.
J. STOCKPILE MATERIALS FOR STREAM WORK (R-5, BOULDERS, LOGS, WOODY DEBRIS) OUTSIDE OF THE RIPARIAN ZONE (AT LEAST 30 FEET FROM THE TOP OF BANK).
K. TO THE EXTENT PRACTICABLE, WORK STRATEGY FROM UPSTREAM TO DOWNSTREAM THROUGHOUT THE PROJECT REACHES. CONTRACTOR SHALL LIMIT STREAMBANK DISTURBANCE TO AREA THAT CAN BE COMPLETED AND STABILIZED DURING ONE DAY OF WORK. DURING EACH STAGE OF DISTURBANCE, FOLLOW THE FOLLOWING STEPS:
   - AS NEEDED TO IMPLEMENT BANK GRADING, REMOVE VEGETATION. DO NOT REMOVE HEALTHY, NATIVE VEGETATION FROM AREAS WHERE NO GRADING OR STRUCTURE INSTALLATION WILL OCCUR. STOCKPILE VEGETATION FOR REPLANTING, AS APPROPRIATE.
   - AS SHOWN ON PLANS, REGRADE CHANNEL. ENSURE CONSTRUCTED SLOPES ARE GRADED AT A 3:1 SLOPE OR FLATTER, UNLESS DIRECTED OTHERWISE BY THE ENGINEER. WHEN POSSIBLE, PERFORM WORK FROM STREAMBANKS IN ORDER TO MINIMIZE TIME SPENT WORKING IN THE CHANNEL.
   - INSTALL IN-STREAM STRUCTURES, RIFFLE/POOL FEATURES, AND STREAMBANK PROTECTION PER THE PLANS. WHEN POSSIBLE, PERFORM WORK FROM STREAMBANKS IN ORDER TO MINIMIZE TIME SPENT WORKING IN THE CHANNEL.
   - INSTALL COIR STREAMBANK MATTING, TEMPORARY AND PERMANENT SEEDING AND MULCHING ON ALL DISTURBED SURFACES ON THE STREAMBANK UP TO THE TOP OF BANK.
L. ANY AREA DISTURBED WITHIN 30 FEET FROM THE TOP OF THE STREAM BANK SHALL BE PROVIDED WITH TEMPORARY GROUND COVER SPECIFIED IN THE VEGETATION PLAN WITHIN 10 CALENDAR DAYS, UNLESS SUPERSEDED BY THE CONDITIONS OF GENERAL STORMWATER PERMIT NCG-010000.
M. ONCE SITE IS STABILIZED, REMOVE AND DISPOSE OF ALL NON-BIODEGRADABLE EROSION CONTROL DEVICES.
N. NOTIFY INSPECTOR FROM WINSTON SALEM REGIONAL OFFICE OF DEQ AFTER STABILIZATION.
O. WHEN APPROPRIATE, INSTALL PERMANENT VEGETATION PER PLANTING PLANS.

BASIC PLAN

DURING PROJECT IMPLEMENTATION, IMPACT/CONSERVATION MEASURES WILL BE IMPLEMENTED TO MINIMIZE SEDIMENTATION INTO THE BENSON CREEK AND OTHER SURFACE WATERS DOWNSTREAM. THE DESIGN ATTEMPTS TO MINIMIZE SEDIMENTATION AND OTHER POTENTIALLY NEGATIVE IMPACTS THROUGH THE FOLLOWING PRACTICES:

- THE CONTRACTOR WILL BE REQUIRED TO STAGE AND STORE EQUIPMENT AND MATERIALS IN THE DESIGNATED AREAS SHOWN ON THE APPROVED ISAAC PLAN.
- EQUIPMENT WILL BE WELL MAINTAINED, CLEANED PRIOR TO MOBILIZATION, AND CHECKED DAILY FOR LEAKS OF PETROLEUM PRODUCTS.
- FUELING WILL BE PERFORMED IN A CONTAINED AREA OUTSIDE OF THE RIPARIAN ZONE.
- THE CONTRACTOR WILL BE REQUIRED TO STAGE WORK SUCH THAT DISTURBED AREAS WILL BE STABILIZED IN PHASES WITH MIRRING, MULCH AND BIODEGRADABLE (COIR) EROSION CONTROL MATTING (WHERE APPROPRIATE).
- ALL TIMBER, UTILITIES AND OTHER SITE FEATURES WILL BE PROTECTED UNLESS MARKED FOR REMOVAL OR RELOCATION.
- ALL WORK ADJACENT TO STREAM/WETTING WILL BE CONDUCTED IN A DRY WORK AREA TO THE EXTENT POSSIBLE.
- APPROPRIATELY SIZED EQUIPMENT WILL BE UTILIZED TO PREVENT EXCESSIVE COMPACTING AND MINIMIZE CLEARING.

SITE ACCESS AND STAGING

SITE ACCESS WILL BE VIA EXISTING HARDWOOD GRAVEL ROADS ON THE IVEY BROWN SPORTS COMPLEX, AS SHOWN ON THE APPROVED ISAAC PLAN. TWO STAGING AREAS FOR EQUIPMENT AND MATERIALS WILL BE CREATED. ONE STAGING AREA WILL BE LOCATED NEAR THE UPSTREAM END OF THE PROJECT. THE OTHER WILL BE NEAR THE DOWNSTREAM END. STANDARD CONSTRUCTION ENTRANCE(S) WILL BE INSTALLED AT EACH ACCESS POINT. SILT FENCE WILL BE INSTALLED ALONG THE STREAM SIDE OF EACH STAGING AREA.

SILT FENCE

PRIOR TO ANY SOIL DISTURBANCE, SILT FENCE WILL BE INSTALLED ON THE SITE AS INDICATED ON APPROVED ISAAC PLAN AND THE DETAIL. SILT FENCE WILL BE LOCATED ALONG DOWN SLOPE SIDE OF THE STAGING AND ACCESS AREAS. SILT FENCE MUST ALSO BE PLACED ALONG ANY OTHER TEMPORARY STOCKPILE AREAS DURING EXCAVATION AND GRADING ACTIVITIES. AT THE END OF THE PROJECT, WHEN ALL DISTURBED AREAS HAVE BEEN STABILIZED, ALL SILT FENCE WILL BE REMOVED. MATERIAL SPECIFICATIONS, INSTALLATION PROCEDURES, AND MAINTENANCE SHALL CONFORM TO SECTION 6.62 OF THE NORTH CAROLINA SEDIMENT CONTROL PLANNING AND DESIGN MANUAL, INCLUDING THE CONSTRUCTION DETAIL.

PUMP AROUND OPERATIONS

A TEMPORARY PUMP AROUND SYSTEM SHALL BE INSTALLED IF WORK IS TO TAKE PLACE WITHIN THE CHANNEL, AND ACTIVE BASE FLOW IS OBSERVED. LITTLE BASE FLOW HAS BEEN OBSERVED TO DATE. NO WORK SHALL OCCUR IN THE CHANNEL DURING STORM FLOWS. THE PUMP SHALL BE ADEQUATELY SIZED TO HANDLE CURRENT FLOW CONDITIONS IN THE CHANNEL.

STREAMBANK MATTING

NORTH AMERICAN GREEN C125BN (OR EQUIVALENT) MATTING WILL BE USED ALONG NEWLY GRADED STREAM BANK SECTIONS. MATTING WILL NOT CONTAIN SYNTHETIC (PLASTIC) MATERIALS. MATTING WILL BE INSTALLED BEGINNING AT THE TOP OF STREAMBANK TO THE BANKFULL STAGE AND WILL EXTEND ABOVE THE BANKFULL STAGE BY A MINIMUM OF THREE FEET. THE UPPER EDGE OF MATTING WILL BE TRENCHED IN AND STAKED AS SPECIFIED IN THE PLANS. A COMBINATION OF 12-INCH AND 18-INCH WOODEN STAKES WILL BE USED TO SECURE THE MATTING IN PLACE.

DUST CONTROL

EXPOSED SOILS OR LEVEL SURFACES WILL BE KEPT MOIST DURING DRY CONDITIONS TO MINIMIZE THE POTENTIAL FOR WIND EROSION AND DUST ACCUMULATION.

STORMWATER

THE INTENT OF THE RESTORATION PROJECT WILL NOT CREATE ADDITIONAL POINT SOURCES OF STORMWATER. THE INTENT OF THE PROJECT IS TO IMPROVE OVERALL WATER QUALITY IN BENSON CREEK AND DOWNSTREAM SURFACE WATERS BY STABILIZING ERODING STREAMBANKS, PROVIDING FLOODPLAIN STORAGE, AND PROMOTING APPROPRIATE RIPARIAN VEGETATION. ALL CONSTRUCTION ACTIVITIES WILL CONFORM TO NORTH CAROLINA GENERAL STORMWATER PERMIT NCG-010000.

SPECIFICALLY:

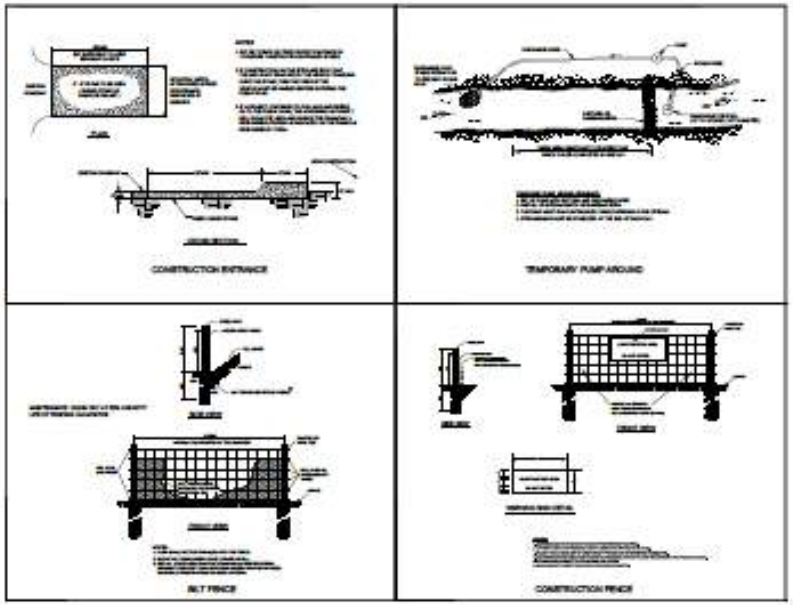
- ADE, STABILIZATION SHALL BE ACHIEVED ON ANY AREA OF A SITE WHERE LAND-DISTURBING ACTIVITIES HAVE TEMPORARILY OR PERMANENTLY CEASED ACCORDING TO THE FOLLOWING SCHEDULE: 1) ALL PERIMETER DIKES, BANKS, DITCHES, PERIMETER SLOPES AND ALL SLOPES STEEPER THAN 3 HORIZONTAL TO 1 VERTICAL SHALL BE PROVIDED TEMPORARY OR PERMANENT STABILIZATION WITH GROUND COVER AS SOON AS PRACTICABLE BUT IN ANY EVENT WITHIN 7 CALENDAR DAYS FROM THE LAST LAND-DISTURBING ACTIVITY.
- ALL OTHER DISTURBED AREAS SHALL BE PROVIDED TEMPORARY OR PERMANENT STABILIZATION WITH GROUND COVER AS SOON AS PRACTICABLE BUT IN ANY EVENT WITHIN 14 CALENDAR DAYS FROM THE LAST LAND-DISTURBING ACTIVITY.

ALL INSPECTION AND REPORTING WILL CONFORM TO NORTH CAROLINA GENERAL STORMWATER PERMIT NCG-010000. SPECIFICALLY, MINIMUM SELF INSPECTION AND REPORTING REQUIREMENTS ARE AS FOLLOWS:

A. A RAIN GAUGE SHALL BE MAINTAINED IN GOOD WORKING ORDER ON THE SITE.
B. A WRITTEN RECORD OF THE DAILY RAINFALL AMOUNTS SHALL BE RETAINED AND ALL RECORDS SHALL BE MADE AVAILABLE TO DEQ OR AUTHORIZED AGENT UPON REQUEST. IF NO DAILY RAIN GAUGE OBSERVATIONS ARE MADE DURING WEEKEND OR HOLIDAY PERIODS, AND NO INDIVIDUAL DAY RAINFALL INFORMATION IS AVAILABLE, THE CUMULATIVE RAIN MEASUREMENT FOR THOSE UNATTENDED DAYS WILL DETERMINE IF A SITE INSPECTION IS WARRANTED. (NOTE: IF NO RAINFALL OCCURRED, THE PERMITTEE MUST RECORD "ZERO".)
C. EROSION AND SEDIMENTATION CONTROL MEASURES SHALL BE INSPECTED TO ENSURE THAT THEY ARE OPERATING CORRECTLY. INSPECTION RECORDS MUST BE MAINTAINED FOR EACH INSPECTION EVENT AND FOR EACH MEASURE. AT A MINIMUM, INSPECTION OF MEASURES MUST OCCUR AT THE FREQUENCY INDICATED IN ALL EROSION AND SEDIMENTATION CONTROL MEASURES MUST BE INSPECTED BY, OR UNDER THE DIRECTION OF THE PERMITTEE AT LEAST ONCE EVERY SEVEN CALENDAR DAYS, AND IS ALL EROSION AND SEDIMENT CONTROL MEASURES MUST BE INSPECTED BY OR UNDER THE DIRECTION OF THE PERMITTEE WITHIN 24 HOURS AFTER ANY STORM EVENT OF GREATER THAN 0.50 INCHES OF RAIN PER 24 HOUR PERIOD (INSPECTIONS ARE ONLY REQUIRED TO BE MADE DURING NORMAL BUSINESS HOURS. WHEN ADVERSE WEATHER CONDITIONS WOULD CAUSE THE SAFETY OF THE INSPECTION PERSONNEL TO BE IN JEOPARDY, THE INSPECTION CAN BE DELAYED UNTIL IT IS DEEMED SAFE TO PERFORM THESE DUTIES (TAKE WHEN INSPECTIONS WERE DELAYED BECAUSE OF SAFETY ISSUES SHOULD BE NOTED IN THE INSPECTION RECORDS.) IF THE INSPECTION CANNOT BE DONE ON THAT DAY, IT MUST BE COMPLETED ON THE FOLLOWING BUSINESS DAY.
D. TWENTY-FOUR HOUR REPORTING FOR VISIBLE SEDIMENT DEPOSITION: 1) THE PERMITTEE SHALL REPORT TO THE DIVISION OF WATER QUALITY CENTRAL OFFICE OR THE APPROPRIATE REGIONAL OFFICE ANY VISIBLE SEDIMENT BEING DEPOSITED IN ANY STREAM OR WETLAND OR ANY NONCOMPLIANCE WHICH MAY ENDANGER HEALTH OR THE ENVIRONMENT. ANY INFORMATION SHALL BE PROVIDED ORALLY OR ELECTRONICALLY WITHIN 24 HOURS FROM THE TIME THE PERMITTEE BECAME AWARE OF THE CIRCUMSTANCES. 2) A WRITTEN SUBMISSION SHALL BE PROVIDED TO THE APPROPRIATE REGIONAL OFFICE OF THE DIVISION OF WATER QUALITY WITHIN 5 DAYS OF THE TIME THE PERMITTEE BECOMES AWARE OF THE CIRCUMSTANCES. THE WRITTEN SUBMISSION SHALL CONTAIN A DESCRIPTION OF THE SEDIMENT DEPOSITION AND ACTIONS TAKEN TO ADDRESS THE CAUSE OF THE DEPOSITION. THE DIVISION OF WATER QUALITY STAFF MAY WAIVE THE REQUIREMENT FOR A WRITTEN REPORT ON A CASE-BY-CASE BASIS.
F. RECORDS OF INSPECTIONS MADE DURING THE PREVIOUS 30 DAYS SHALL REMAIN ON THE SITE AND AVAILABLE FOR AGENCY INSPECTIONS AT ALL TIMES DURING NORMAL WORKING HOURS. UNLESS ANOTHER DIVISION OF WATER QUALITY PROVIDED A SITE-SPECIFIC EXEMPTION BASED ON UNIQUE SITE CONDITIONS THAT MAKE THIS REQUIREMENT NOT PRACTICAL, OLDER RECORDS MUST BE MAINTAINED FOR A PERIOD OF THREE YEARS AFTER PROJECT COMPLETION AND MADE AVAILABLE UPON REQUEST. THE RECORDS MUST PROVIDE THE DETAILS OF EACH INSPECTION INCLUDING OBSERVATIONS, AND ACTIONS TAKEN IN ACCORDANCE WITH THIS PERMIT. THE PERMITTEE SHALL RECORD THE REQUIRED RAINFALL AND MONITORING OBSERVATIONS ON THE INSPECTION RECORD FORM PROVIDED BY THE DIVISION OR A SIMILAR INSPECTION FORM THAT IS INCLUSIVE OF ALL OF THE ELEMENTS CONTAINED IN THE DIVISION'S FORM. USE OF ELECTRONICALLY AVAILABLE RECORDS IN LIEU OF THE REQUIRED PAPER COPIES FOR INSPECTION WILL BE ALLOWED IF SHOWN TO PROVIDE EQUAL ACCESS AND UTILITY AS THE HARD COPY RECORDS. INSPECTION RECORDS MUST INCLUDE: 1) A NARRATIVE STATING THE FOLLOWING: 1) IDENTIFICATION OF THE CONTROL MEASURES INSPECTED, 2) DATE AND TIME OF THE INSPECTION, 3) NAME OF THE PERSON PERFORMING THE INSPECTION, 4) INDICATION WHETHER THE MEASURES WERE OPERATING PROPERLY, 5) DESCRIPTION OF MAINTENANCE NEEDS FOR THE MEASURE, 6) CORRECTIVE ACTIONS TAKEN (DATE OF ACTIONS TAKEN, AS WELL AS THE DATE AND MAGNITUDE OF RAINFALL EVENTS), 7) VISIBLE SEDIMENTATION FOUND OUTSIDE THE SITE LIMITS. INSPECTION RECORDS MUST INCLUDE: 1) AN EXPLANATION AS TO THE ACTIONS TAKEN TO CONTROL FUTURE SEDIMENT, 2) CONSTRUCTION SEQUENCE SHALL BE REVISED TO ADDRESS SEDIMENT THAT WAS LEFT THE SITE LIMITS AND 3) THE DATE OF ACTIONS TAKEN. 8) VISIBLE SEDIMENTATION FOUND IN STREAMS OR WETLANDS ALL INSPECTIONS SHOULD INCLUDE EVALUATION OF STREAMS OR WETLANDS ONSITE OR OFFSITE (WHERE ACCESSIBLE) TO DETERMINE IF VISIBLE SEDIMENTATION HAS OCCURRED.

MAINTENANCE OF BASIC MEASURES

ALL EROSION CONTROL AND SEDIMENTATION MEASURES WILL BE INSPECTED DAILY AND AFTER SIGNIFICANT RAIN EVENTS BY THE ON SITE ENGINEER OR THE CONTRACTOR. THE CONTRACTOR WILL ASSURE THAT ALL INSTALLATIONS ARE FUNCTIONING PROPERLY AT THE END OF EACH WORK DAY. INSPECTION REQUIREMENTS, AS DEFINED IN THE STORMWATER SECTION, WILL BE FOLLOWED. ONCE THE SITE IS STABILIZED, ALL NON-BIODEGRADABLE EROSION CONTROL MEASURES WILL BE REMOVED AND PROPERLY DISPOSED OF BY THE CONTRACTOR.



1. Site Preparation

- Construction entrance
- Silt fence
- Staging & stockpile
- Temporary crossings
- Stream flow diversion

Silt Fence

- Metal Posts 8 feet apart
- Reinforcing wire backing (14 ga. w/ 6-inch mesh)
- Bury fence at least 8 inches deep

Staging and Stockpile

Stockpile Area

Silt fence & seeding

Temporary Stream Crossing

- Rock ford
- Culvert
- Portable log mat

Pump Around: Match pump to 2 x base flow

Check dam to retain base flow

Quiet pump in residential area

Special Stilling Basin: Filter Bag

2. Grading

1. Stage project to limit exposed areas
2. Use temporary ground cover
3. Use track equipment if possible
4. Keep stormwater runoff away from site

Clearing & Grubbing
Followed by Survey Stakeout

Organized Staging Areas

Laser Level for Grade Check

3. Site Stabilization

- Temporary ground cover (mulch & matting)
- Permanent ground cover (vegetation)
- Prepare for rain!

Temporary Erosion Control

- Soil prep, seed, straw
- Biodegradable matting (coir, 700g)
- Wood stakes

Straw Mulch: 75% cover (2 tons/acre)

Matting

- Biodegradable (coir, jute, excelsior, straw)
- Seed and straw UNDER matting
- Keep matting relaxed
- Stakes: wood or biodegradable plastic

Erosion Control Blankets

Straw Single Synthetic Net

Straw Double Synthetic Net

Straw Double Jute Net

Coir / Straw Double Jute Net

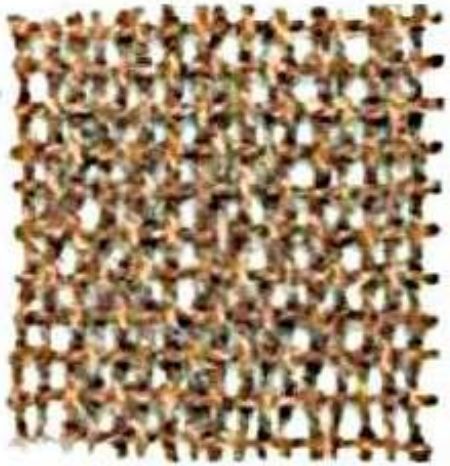
Coir / Straw Double Synthetic Net

Coir Double Jute Net

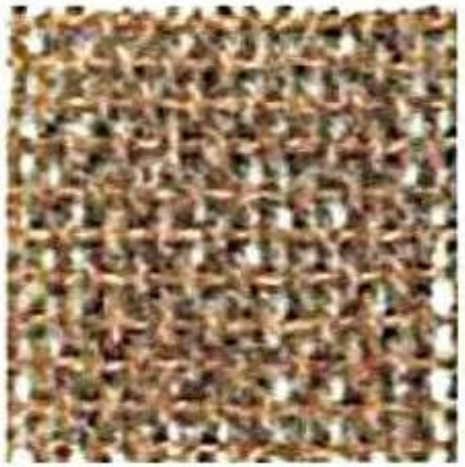
Coir Double Synthetic Net

Heavy Duty Excelsior Double Net

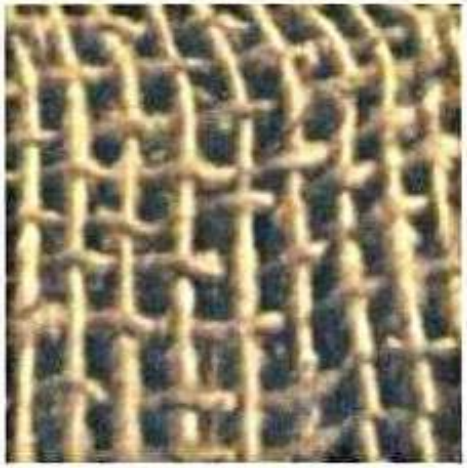
Erosion Control Mats



Woven Bristle Coir Mat 70



Woven Bristle Coir Mat 90



Spun Jute Yarn Mat

Heavy Coir Woven Mesh Mat 60

No Plastic!

Each Day:

Seed, straw, matting

Temporary Erosion Control Matting (coir 700g)

Seed and straw under

November, 2015

January, 2016

Large stakes at toe of slope

Successful Ecosystem Restoration

- Achieve ecological objectives
- Self-sustaining ecosystem
- Model for future projects
- Build public enthusiasm

Rocky Branch, NC State University

Thank you,
Greg Jennings
greg@jenningsenv.com

Jennings Environmental

NC STATE UNIVERSITY
Department of Biological and Agricultural Engineering

Beeson Creek Restoration
Ivey Redmon Sports Complex, Kernersville, NC

Greg Jennings, PhD, PE
Jennings Environmental PLLC
NC State University
greg@jenningsenv.com

Thanks to Wendi Hartup, Darrell Westmoreland, Brandon Spaugh, Riley Lecka, Corben Brewer, Jonathan Hinkle, Jason Zink, David Penrose

Jennings Environmental

North State Environmental

Project Partners

Town of Kernersville, NC

NC Clean Water Management Trust Fund

NC State University

NC Cooperative Extension Service

NC Division of Water Resources

US Army Corps of Engineers

Penrose Environmental

LDSI

North State Environmental

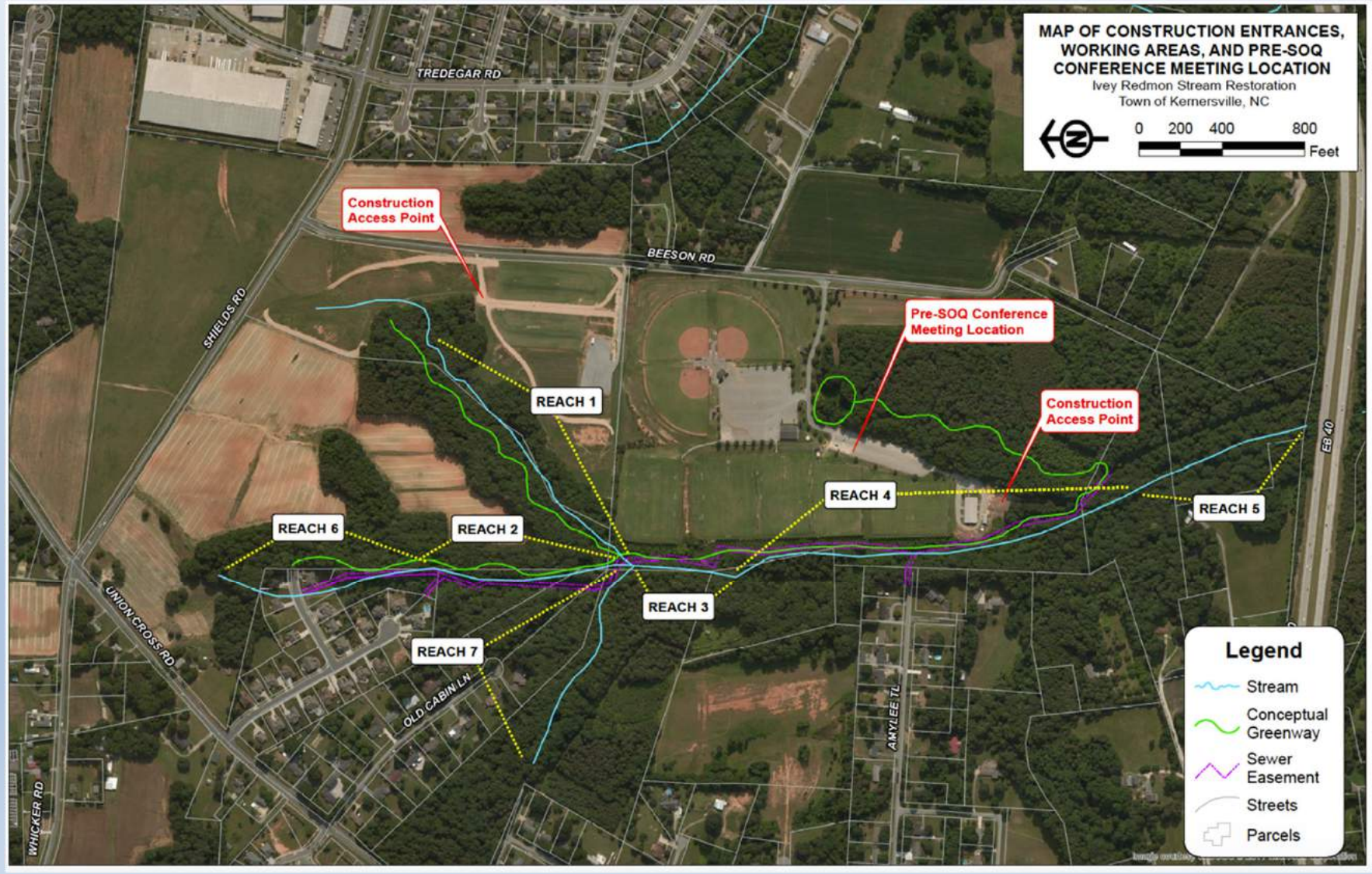
Jennings Environmental

Stream Problems

1. Streambank erosion
2. Poor riparian buffer
3. Incised, headcutting channel with poor habitat
4. Stormwater runoff

Feasibility Study: 2016

7 Stream Reaches totaling 8,000 feet



Beeson Creek Watershed, Kernersville, NC: 2002

Beeson Creek Watershed, Kernersville, NC: 2018

Stream Reach 4

- 1,950 feet located mostly on Town property
- 0.33 square mile drainage area (42% developed)
- Channel incision 6 to 10 feet
- Available space for Priority 1 Floodplain Connection
- Grant from NC Clean Water Management Trust Fund

Project Objectives

1. Improve water quality by reducing sediment
2. Improve aquatic and terrestrial habitats
3. Provide educational and recreational opportunities

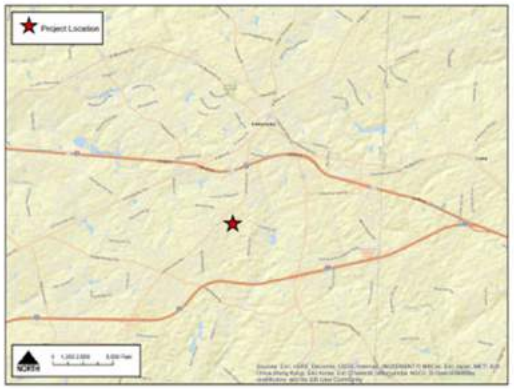
Stream Restoration Design Plan

BEESON CREEK REACH 4: IVEY REDMON SPORTS COMPLEX STREAM RESTORATION

KERNERSVILLE - FORSYTH COUNTY, NORTH CAROLINA

PROJECT DIRECTORY	
OWNER	TOWN OF KERNERSVILLE
	Wendi Hartup Stormwater Manager 336.564.1613 whartup@toknc.com
ENGINEER	JENNINGS ENVIRONMENTAL PLLC
	Greg Jennings, PhD, PE President 919.600.4790 greg@jenningsenv.com
CONSTRUCTION	NORTH STATE ENVIRONMENTAL
	Brandon Spaugh Project Manager, Business Development 336.793.8997 b.spaugh@nsenv.com

VICINITY MAP



SHEET INDEX	
COVER SHEET	1.0
PROJECT SPECIFICATION, MATERIALS, QUANTITIES	2.0
PROJECT OVERVIEW	3.0
EROSION AND SEDIMENT (E&SC) CONTROL	4.0
STREAM RESTORATION: CHANNEL CROSS-SECTIONS	5.0
STREAM RESTORATION: PLAN AND PROFILE	6.0
STREAM RESTORATION: GRADING SECTIONS	7.0
STREAM RESTORATION: DETAILS	8.0
STABILIZATION AND RE-VETATION PLAN	9.0

80% DESIGN

-

FEBRUARY 19, 2019

Jennings Environmental
7 SAMUEL ASHE DRIVE
ASHEVILLE, NC 28805
919.600.4790

REACH 4: BEESON CREEK AT IVEY REDMON SPORTS CMPLX.
FORSYTH COUNTY - NORTH CAROLINA

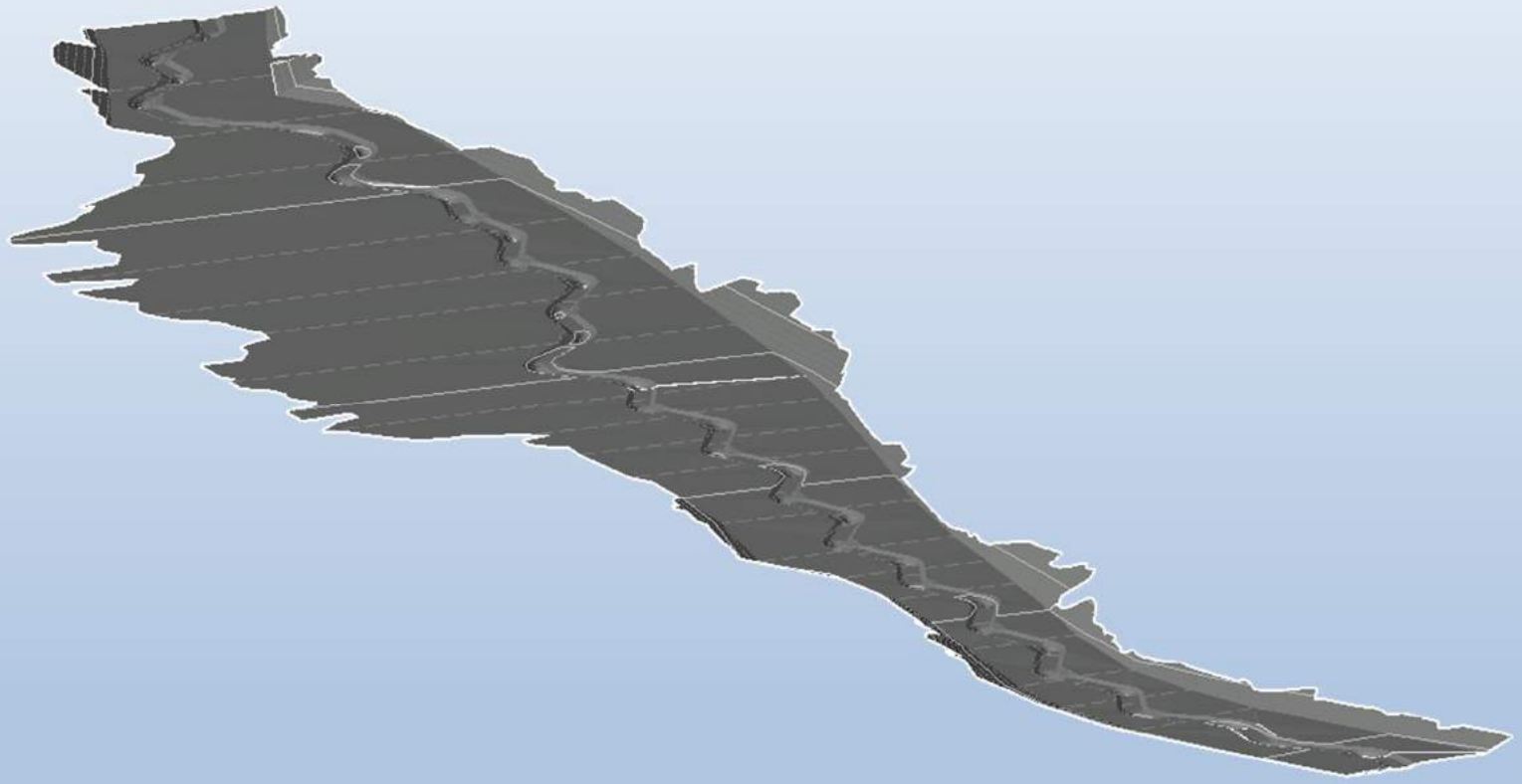
COVER SHEET

80% DESIGN

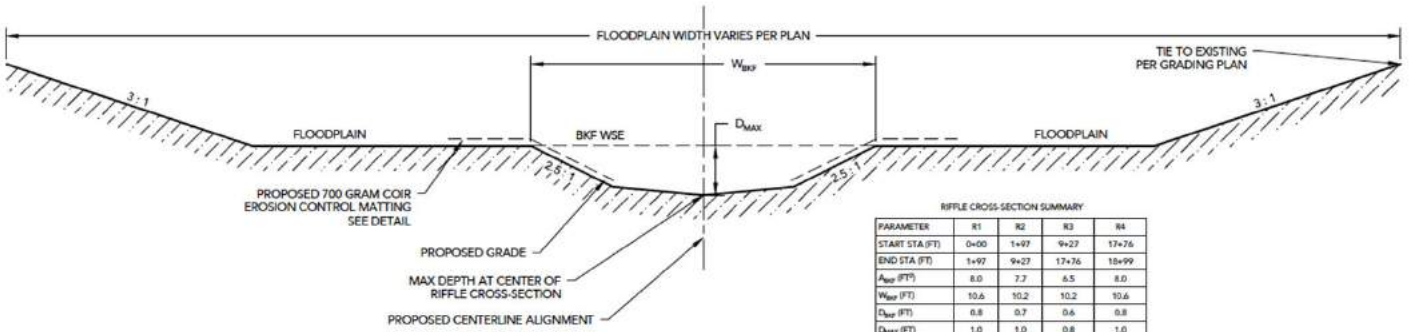
REVISIONS:
30%: 4/25/2018
60%: 6/15/2018
DATE: 2/19/2019
PLOT SIZE: 24" x 36"
AS NOTED
H.D.: NAD83 (NCSP)
V.D.: NAVD88
JE PID: 3302
PO#: 6577305

1.1

Stream Restoration Design Plan



Stream Restoration Design Plan

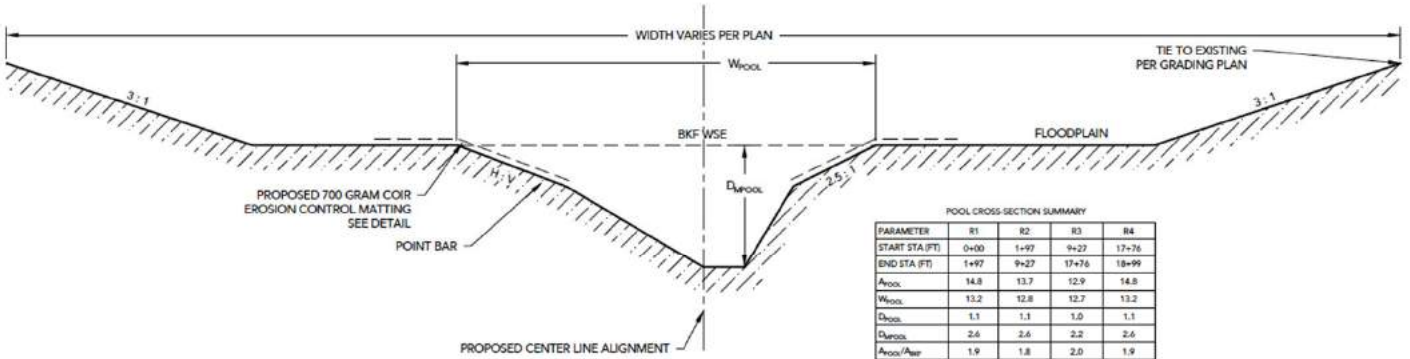


RIFFLE CROSS-SECTION SUMMARY

PARAMETER	R1	R2	R3	R4
START STA (FT)	0+00	1+97	9+27	17+76
END STA (FT)	1+97	9+27	17+76	18+99
A_{BKF} (FT^2)	8.0	7.7	6.5	8.0
W_{BKF} (FT)	10.6	10.2	10.2	10.6
D_{BKF} (FT)	0.8	0.7	0.6	0.8
D_{MAX} (FT)	1.0	1.0	0.8	1.0
W/D (FT)	14.0	13.9	16.0	14.0
D_{MAX}/D_{BKF}	1.3	1.3	1.2	1.3
S_e (FT/FT)	0.008	0.011	0.016	0.013

BEESON CREEK
RIFFLE CROSS-SECTION

NOT TO SCALE



POOL CROSS-SECTION SUMMARY

PARAMETER	R1	R2	R3	R4
START STA (FT)	0+00	1+97	9+27	17+76
END STA (FT)	1+97	9+27	17+76	18+99
A_{POOL}	14.8	13.7	12.9	14.8
W_{POOL}	13.2	12.8	12.7	13.2
D_{POOL}	1.1	1.1	1.0	1.1
D_{MPOOL}	2.6	2.6	2.2	2.6
A_{POOL}/A_{BKF}	1.9	1.8	2.0	1.9
W_{POOL}/W_{BKF}	1.3	1.3	1.2	1.2
D_{MPOOL}/D_{BKF}	3.5	3.5	3.5	3.5

BEESON CREEK
POOL CROSS-SECTION

NOT TO SCALE

Jennings Environmental
7 SAMUEL ASHE DRIVE
ASHEVILLE, NC 28805
919.200.4790

REACH 4: BEESON CREEK AT IVEY REDMON SPORTS CMPLX.
FORSYTH COUNTY - NORTH CAROLINA

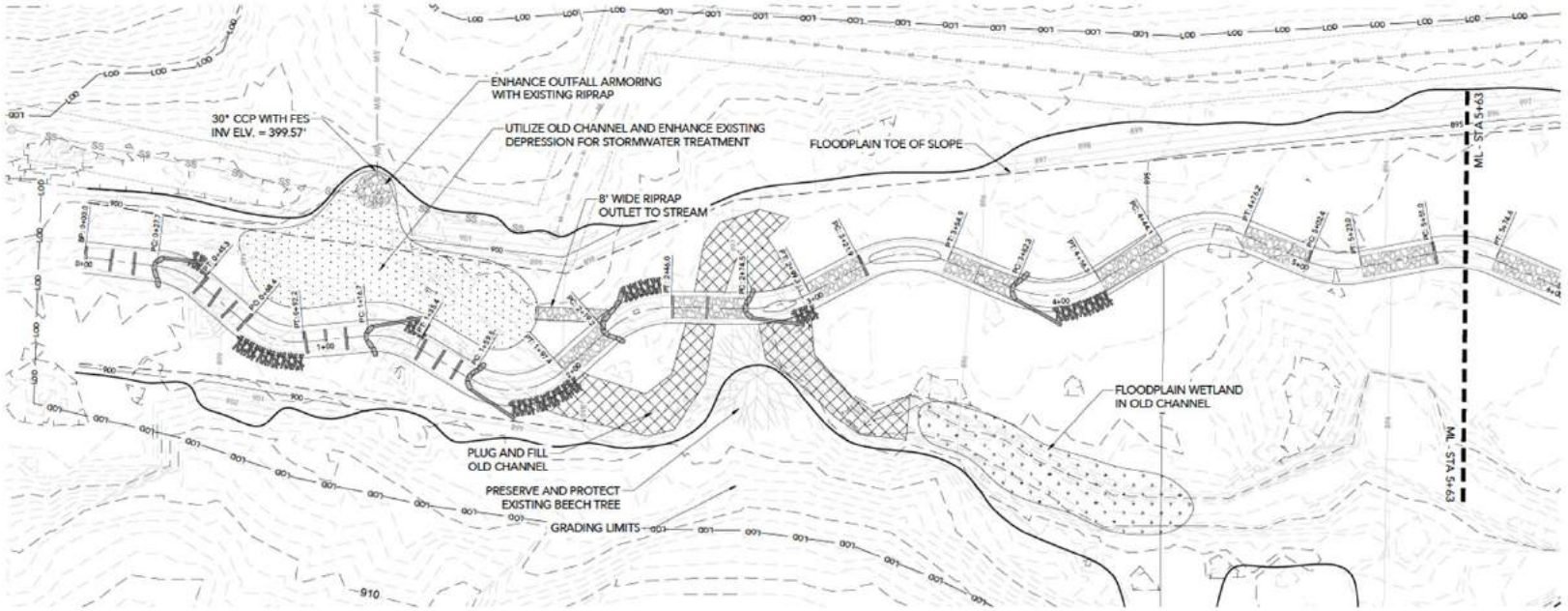
STREAM RESTORATION: CHANNEL CROSS-SECTIONS

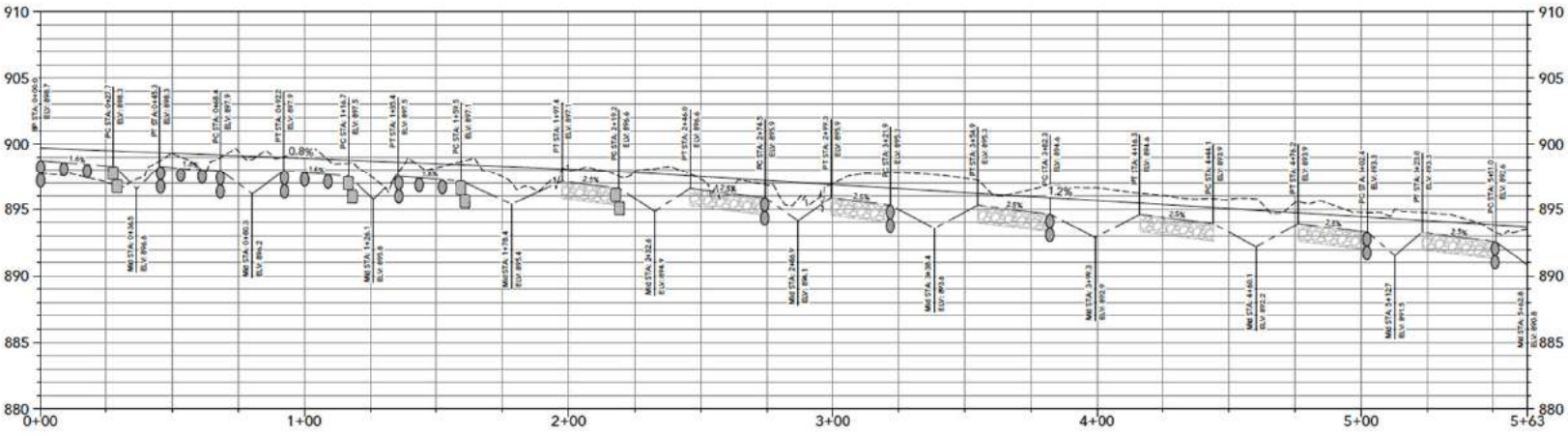
80% DESIGN

REVISIONS:
30%: 4/25/2018
60%: 6/15/2018
DATE: 2/19/2019
PLOT SIZE: 24" x 36"
SCALE: 1" = 10'
H.D.: NAD83 (NCSP)
V.D.: NAVD88
JE PID: 3302
POR: 6577305

5.1

Stream Restoration Design Plan





Jennings Environmental
7 SAMUEL ASHE DRIVE
ASHEVILLE, NC 28805
919.630.4790

REACH 4: BEESON CREEK AT IVEY REDMON SPORTS CMPLX.
FORSYTH COUNTY - NORTH CAROLINA

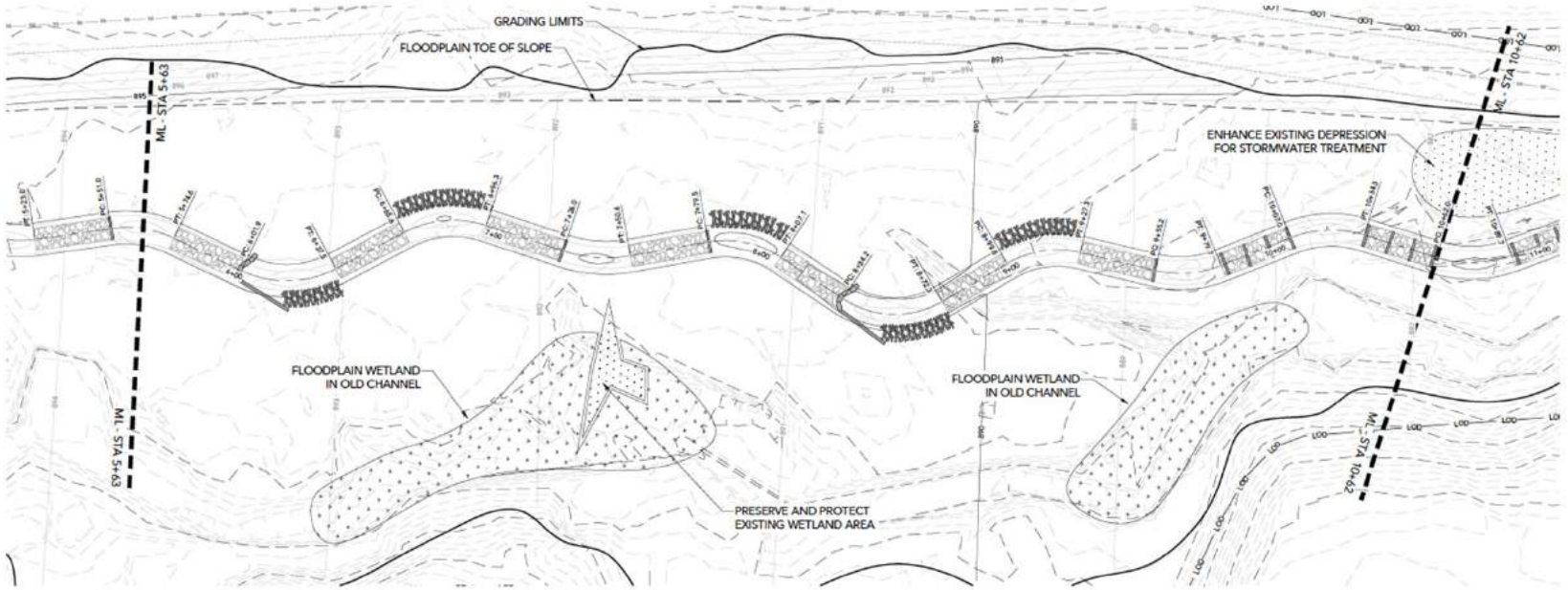
STREAM RESTORATION: PLAN AND PROFILE STA 0+00 TO 5+63

80% DESIGN

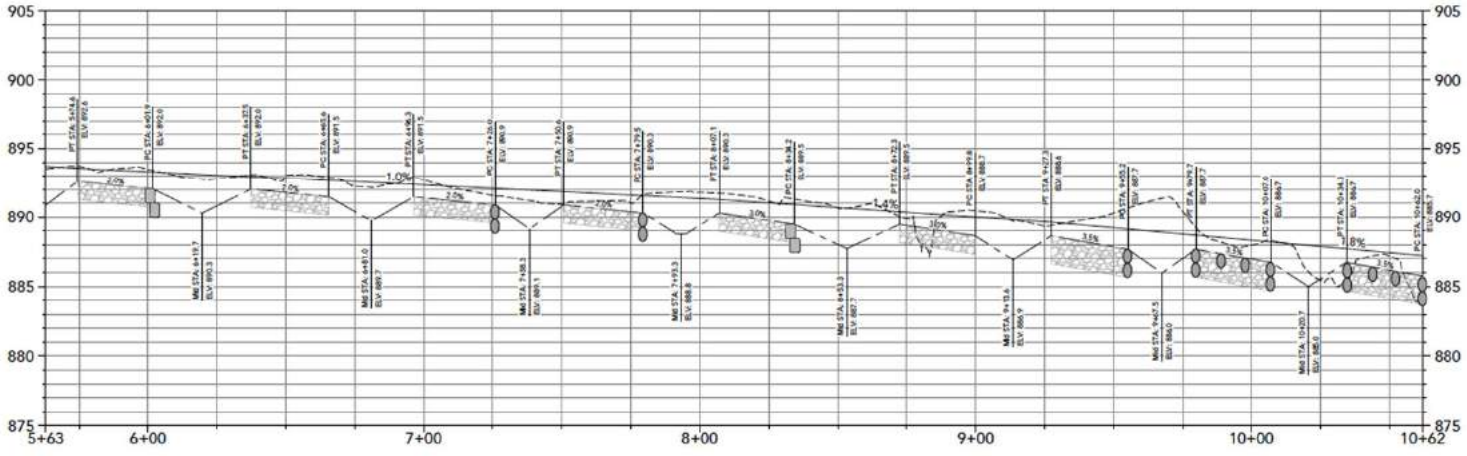
REVISIONS:
30%: 4/25/2018
60%: 6/15/2018
DATE: 2/19/2019
PLOT SIZE: 24" x 36"
SCALE: 1" = 20'
H.D.: NAD83 (NCSP)
V.D.: NAVD88
JE PID: 3302
PO#: 6577305

6.1

Stream Restoration Design Plan



SCALE: 1" = 20'



Jennings Environmental
7 SAMUEL ASHE DRIVE
ASHEVILLE, NC 28805
919.600.4790

REACH 4: BEESON CREEK AT IVEY REDMON SPORTS CMPLX.
FORSYTH COUNTY - NORTH CAROLINA

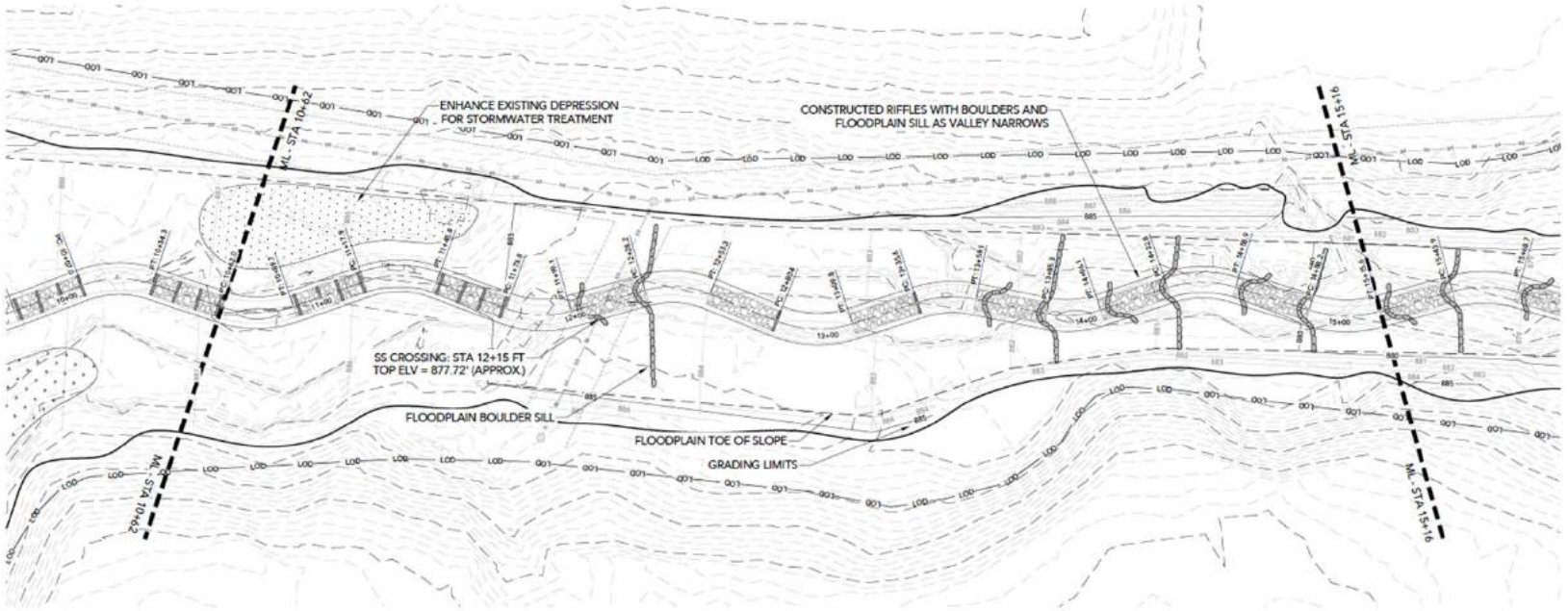
STREAM RESTORATION: PLAN AND PROFILE STA 5+63 TO 10+62

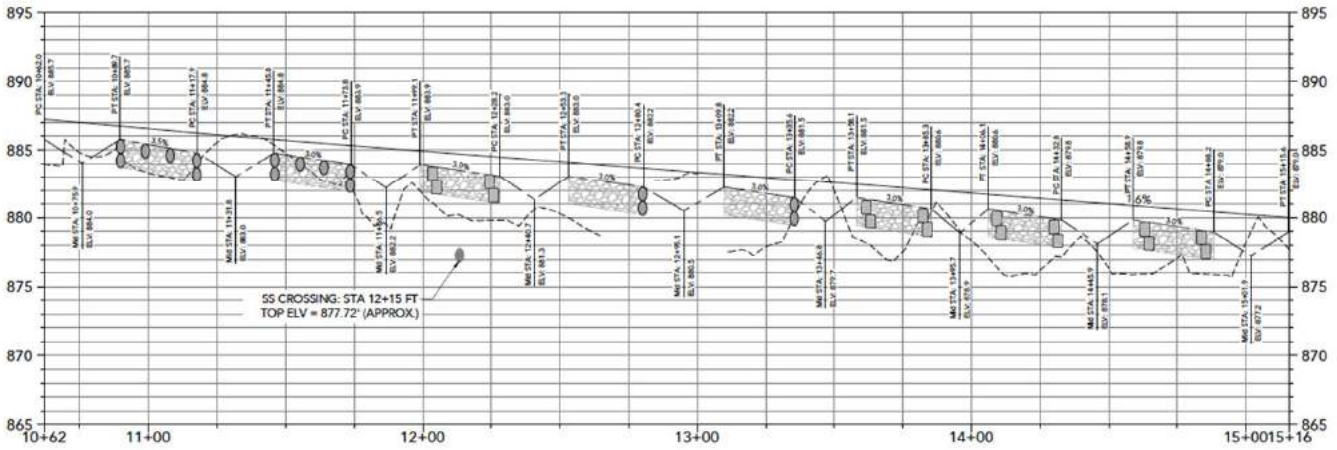
80% DESIGN

REVISIONS:
30%: 4/25/2018
60%: 6/15/2018
DATE: 2/19/2019
PLOT SIZE: 24" x 36"
SCALE: 1" = 20'
H.D.: NAD83 (NCSP)
V.D.: NAVD88
JE PID: 3302
PO#: 6577305

6.2

Stream Restoration Design Plan





Jennings Environmental
7 SAMUEL ASHE DRIVE
ASHEVILLE, NC 28805
919.600.4790

REACH 4: BEESON CREEK AT IVEY REDMON SPORTS CMPLX.
FORSYTH COUNTY - NORTH CAROLINA

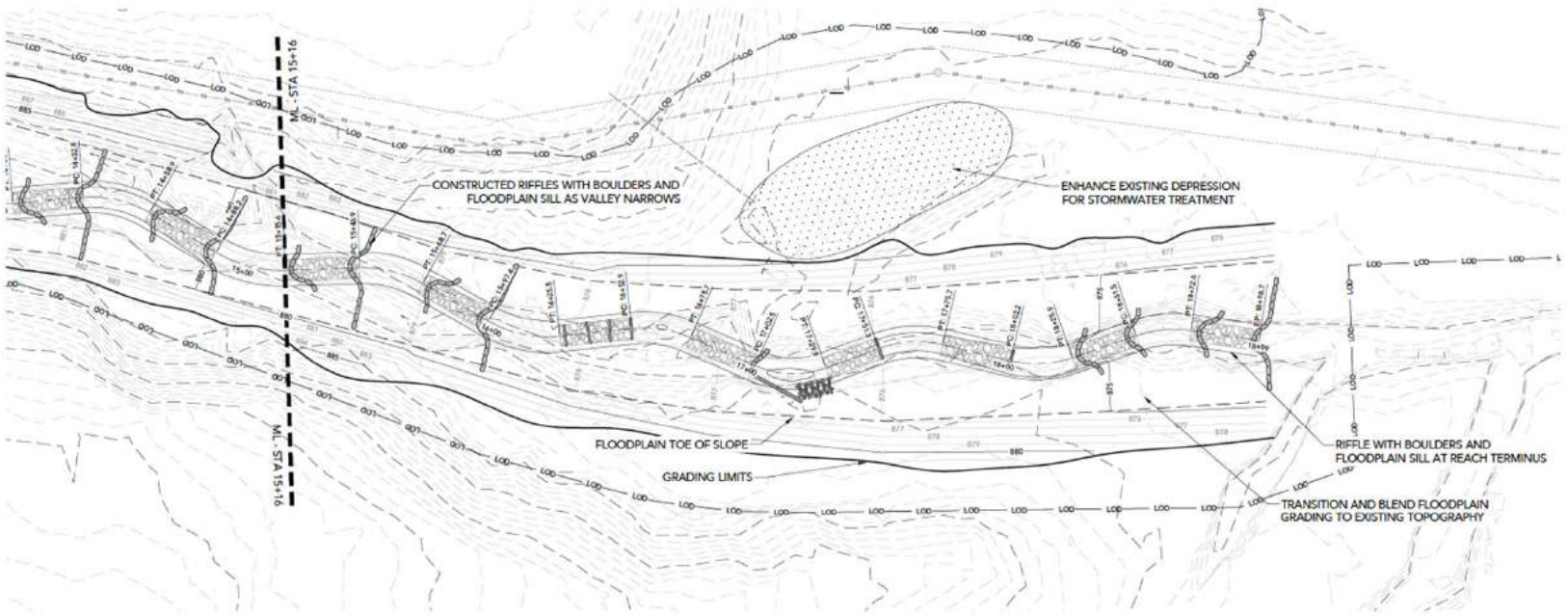
STREAM RESTORATION: PLAN AND PROFILE STA 10+62 TO 15+16

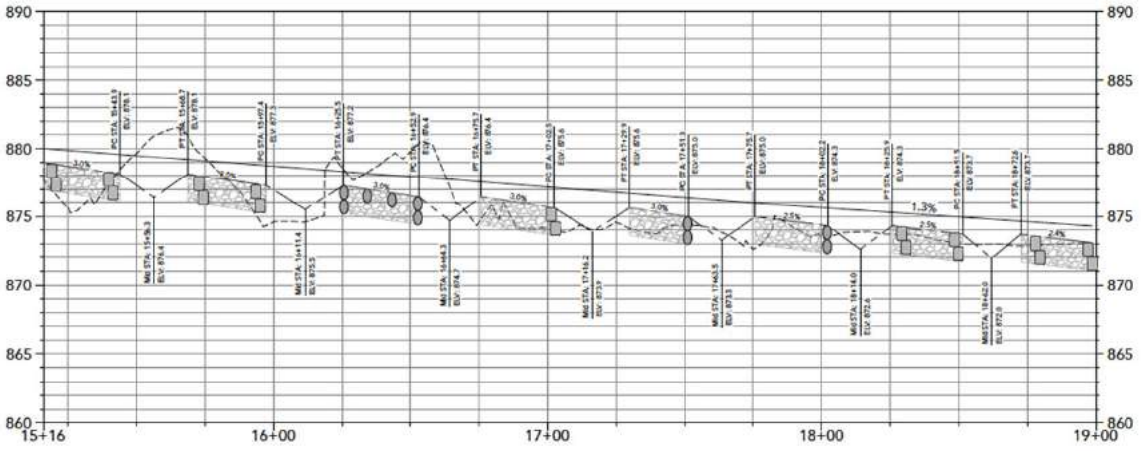
80% DESIGN

REVISIONS:
30%: 4/25/2018
60%: 6/15/2018
DATE: 2/19/2019
PLOT SIZE: 24" x 36"
SCALE: 1" = 20'
H.D.: NAD83 (NCSP)
V.D.: NAVD88
JE PID: 5302
PO#: 6577305

6.3

Stream Restoration Design Plan





Jennings Environmental
7 SAMUEL ASHE DRIVE
ASHEVILLE, NC 28805
919.800.4790

REACH 4: BEESON CREEK AT IVEY REDMON SPORTS CMPLX.
FORSYTH COUNTY - NORTH CAROLINA

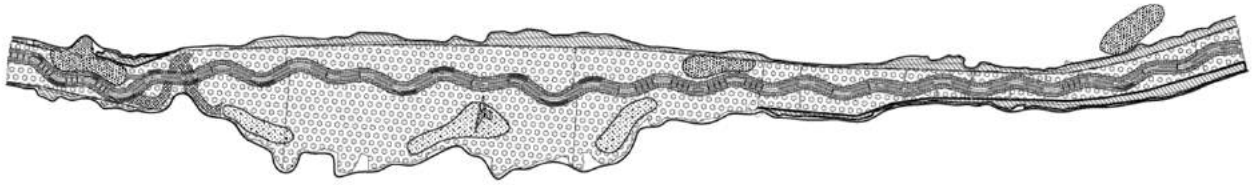
STREAM RESTORATION: PLAN AND PROFILE STA 15+16 TO 18+99

80% DESIGN

REVISIONS:
30%: 4/25/2018
60%: 6/15/2018
DATE: 2/19/2019
PLOT SIZE: 24" x 36"
SCALE: 1" = 20'
H.D.: NAD83 (NCSP)
V.D.: NAVD88
JE PID: 3302
POP: 6577305

6.4

Stream Restoration Design Plan



SCALE: 1" = 80'

ZONE 1 - STREAMBANK - 23,000 FT²

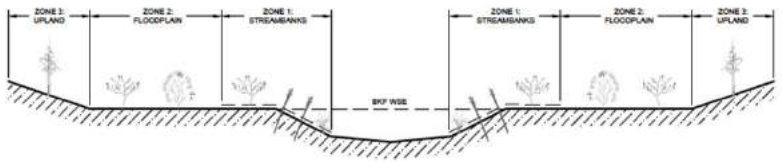
ZONE 2 - FLOODPLAIN - 130,000 FT²

ZONE 3 - UPLAND - 22,000 FT²

ZONE 4 - STORMWATER TREATMENT - 9,700 FT²

ZONE 5 - FLOODPLAIN WETLAND - 17,000 FT²

ZONE 1: STREAMBANK			
GENUS SPECIES	CULTIVAR/COMMON	TYPE	QTY
CORNUS AMOMUM	SILKY DOGWOOD	LIVE STAKE	
SALIX SERICEA	SILKY WILLOW	LIVE STAKE	
PHYSOCARPUS OPULIFOLIUS	NINEBARK	LIVE STAKE	
ALNUS SERRULATA	TAG ALDER	BARE ROOT	24
ILEX MYRTICOLLATA	MYRTLEBERRY	BARE ROOT	38
ITEA VIRGINICA	SWEETSPIRE	BARE ROOT	28
LYONIA LUCIDA	FETTERBUSH	RBCP	40
VACCINIUM CORYMBOSUM	HIGHBUSH BLUEBERRY		5
VIBURNUM NUDUM	WINTERTHUR	4"	28
XANTHORHIZA SIMPLICISSIMA	YELLOWROOT	BARE ROOT	28
BETULA NIGRA	RIVERBIRCH	BARE ROOT	15
NYSSA AQUATICA	WATER TUPELO	4"	24
TAXODIUM DISTICHUM	BALD CYPRESS	BARE ROOT	15
ZONE 2: FLOODPLAIN			
GENUS SPECIES	CULTIVAR/COMMON	TYPE	QTY
LINDERA BENZOIN	SPICEBUSH	BARE ROOT	103
AMELANCHIER CANADENSIS	SHADBLOW SERVICEBERRY	BARE ROOT	100
CARPINUS CAROLINIANA	HORNBEAM	BARE ROOT	100
CATALPA SPECIOSA	CATALPA	BARE 2'-3'	100
DIOSPYROS VIRGINIANA	PERSIMMON	BARE ROOT	100
FRANKLINIA ALATAMAHA	FRANKLIN TREE	PLUG	50
HALESIA CAROLINA	CAROLINA SILVERBELL	BARE 1/0'	100
ILEX MYRTICOLLATA	MAGICAL BERRY	PLUG	50
ILEX MYRTICOLLATA	SOUTHERN GENTLEMAN	LPMDC	40
ILEX OPACA	HOLLY	BARE ROOT	100
MAGNOLIA VIRGINIANA	SWEETBAY MAGNOLIA	BARE ROOT	100
PLATANUS OCCIDENTALIS	AMERICAN SYCAMORE	BARE ROOT	100
QUERCUS LYRATA	OVERCUP OAK	BARE ROOT	100
QUERCUS PAGODAEFOLIA	CHERRYBARK OAK	BARE 2'-3'	100



ZONE 3: UPLANDS			
GENUS SPECIES	CULTIVAR/COMMON	TYPE	QTY
AESCULUS PAVIA	RED BUCKEYE	BARE ROOT	14
CARYA TOMENTOSA	MOCKERNUT HICKORY	BARE ROOT	14
CHIONANTHUS VIRGINICUS	FRINGETREE	BARE ROOT	14
CLADRASTIS KENTUKEA	AMERICAN YELLOWWOOD	BARE 1'-2'	38
CORNUS FLORIDA	FLOWERING DOGWOOD	BARE ROOT	14
GYMNOCLADUS DIOICA	KENTUCKY COFFEE TREE	BARE 12-18'	19
HAMAMELIS VIRGINIANA	WITCH HAZEL	BARE ROOT	14
JUNIPERUS VIRGINIANA	EASTERN RED CEDAR	BARE ROOT	14
NYSSA SYLVATICA	BLACK GUM	BARE ROOT	5
QUERCUS VIRGINIANA	LIVE OAK	BARE ROOT	5
QUERCUS RUBRA	RED OAK	BARE ROOT	12
OXYDENDRUM ARBOREUM	SOURWOOD	BARE ROOT	14
PRUNUS CAROLINIANA	CHERRY LAUREL	4"	39
QUERCUS SHUMARDII	SHUMARD OAK	BARE ROOT	14
SASSAFRAS ALBIDUM	SASSAFRAS TREE	BARE ROOT	14
TILIA AMERICANA	LINDEN	1 GALLON	5
ZONE 4 & 5: STORMWATER TREATMENT & FLOODPLAIN WETLANDS			
GENUS SPECIES	CULTIVAR/COMMON	TYPE	QTY
IRIS VIRGINICA	VIRGINIA IRIS	PLUG	1,219
JUNCUS EFFUSUS	COMMON RUSH	PLUG	1,218
PONTEDERIA CORDATA	PICKEREL WEED	PLUG	1,218
HELIANTHUS ANGUSTIFOLIUT	SWAMP SUNFLOWER	PLUG	1,220
TEMPORARY SEEDING AND SOIL FIEL			
GENUS SPECIES	CULTIVAR/COMMON	RATE	QTY
SECALE CEREALE	RYE GRAIN		
-	10-10-10 FERTILIZER		
-	GROUND AG. LIMESTONE		
-	WHEAT STRAW MULCH		
PERMANENT SEEDING			
GENUS SPECIES	CULTIVAR/COMMON	RATE	QTY
CHAMAECRISTA FASCICULATA	PARTRIDGE PEA		
JUNCUS EFFUSUS	JUNCUS		
ECHINACEA PURPUREA	PURPLE CONEFLOWER		
IRIS VIRGINICA	SOUTHERN BLUE FLAG		
RUDBECKIA FULGIDA	ORANGE CONEFLOWER		
SCHIZACHYRIUM SCOPARIUM	LITTLE BLUESTEM		
FESTUCA OVINA	SHEEP'S FESCUE		
FESTUCA RUBRA	RED FESCUE		
COREOPSIS LANCEOLATA	LANCE LEAF TICKSEED		
ELYMUS HYSTRIX	BOTTLEBRUSH GRASS		

GENERAL RE-VEGETATION PLAN NOTES

1. SOIL PREPARATION ELEMENTS, TEMPORARY AND PERMANENT SEED AND GROUND COVER SHALL BE SPREAD OVER ALL AREAS WITHIN THE LOD THAT ARE DISTURBED DURING CONSTRUCTION.
2. LIVE STAKES, BARE ROOT STOCK AND CONTAINERIZED PLANTS SHALL BE LOCATED WHERE SHOWN ON PLAN.
3. ADJUSTMENTS TO THE VEGETATION PLAN SHALL BE MADE ONLY IF APPROVED BY THE TOWN OR ENGINEER.

BARE ROOTS

4. ALLOW BARE ROOTS TO SOAK IN WATER AN HOUR OR TWO BEFORE PLANTING. DO NOT SOAK THE ROOTS FOR MORE THAN 24 HOURS.
5. DIG A PLANTING PIT THAT IS THREE (3) TIMES WIDER THAN THE TREE'S CURRENT ROOT SYSTEM. SPREAD OUT ROOTS TO ENCOURAGE OUTWARD GROWTH.
6. KEEP THE TREE VERTICAL IN THE PLANTING PIT (PERPENDICULAR TO THE GROUND) SO THAT IT GROWS STRAIGHT.
7. REFILL THE PIT WITH NATIVE SOIL (WHAT WAS REMOVED AT DIGGING TIME), AND ANY OTHER SOIL AMENDMENTS.
8. GENTLY TAMP OUT ANY AIR POCKETS FROM THE SOIL ONCE THE PLANTING HOLE IS FILLED.

LIVE STAKES

9. LIVE STAKES MUST BE DORMANT WHEN CUT. KEEP LIVE STAKES MOIST UNTIL PLANTING. THE STAKE SHOULD BE PREPARED WITH THE BUDS POINTED UP, AND THE BOTTOM SHOULD BE CUT AT AN ANGLE FOR EASY INSERTION INTO THE GROUND.
10. LIVE STAKES SHOULD BE PLACED WITH ¾ TO ⅞ OF THE LENGTH OF THE STAKE BELOW GROUND AND ANGLED DOWNSTREAM. ENSURE THE BASE OF THE LIVE STAKE WILL REACH THE WATER TABLE.
11. AN IRON BAR CAN BE USED TO MAKE A PILOT HOLE TO PREVENT BARK FROM BEING DAMAGED DURING INSTALLATION.
12. INSERT LIVE STAKES POINTED END FIRST INTO THE STREAMBANK.

CONTAINER STOCK

13. STOCK SHALL HAVE BEEN GROWN IN A CONTAINER LONG ENOUGH FOR THE ROOT SYSTEM TO HAVE DEVELOPED SUFFICIENTLY TO HOLD ITS SOIL TOGETHER ONCE REMOVED FROM THE CONTAINER.
14. CONTAINER PLANTS WILL NEED TO BE WATERED REGULARLY AND PLACED IN SHADY CONDITIONS UNTIL PLANTING OCCURS. CREATE PLANTING AREA FOR EACH PLANT AND EXCAVATE PIT.
15. THE DIAMETER OF THE PLANTING PITS FOR EACH PLANT SHOULD BE AT LEAST THREE TIMES THE DIAMETER OF THE ROOT MASS. SCARIFY THE PLANTING PIT PRIOR TO EACH PLANT INSTALLATION.
16. SET PLANTS UPRIGHT IN THE CENTER OF THE PIT. THE BOTTOM OF THE ROOT MASS SHOULD BE RESTING ON UNDISTURBED SOIL.
17. PLACE BACKFILL AROUND BASE AND SIDES OF ROOT MASS, AND WORK EACH LAYER TO SETTLE BACKFILL AND TO ELIMINATE VOIDS AND AIR POCKETS. WHEN PIT IS APPROXIMATELY ½ FULL, WATER THOROUGHLY BEFORE PLACING REMAINDER OF THE BACKFILL. WATER AGAIN AFTER PLACING FINAL LAYER OF BACKFILL.

Jennings Environmental
7 SAMUEL ASHE DRIVE
ASHEVILLE, NC 28805
919.600.4790

REACH 4: BEESON CREEK AT IVEY REDMON SPORTS CMPLX.
FORSYTH COUNTY - NORTH CAROLINA

STABILIZATION AND REVEGETATION PLAN

80% DESIGN

REVISIONS:
30%: 4/25/2018
60%: 6/15/2018
DATE: 2/19/2019
PLOT SIZE: 24" x 36"
SCALE: 1" = 80'
H.D.: NAD83 (NCSP)
V.D.: NAVD88
JE PID: 3302
POI#: 6577305

Implementation: March-April, 2019

- Realign 1,950 ft channel and connect to floodplain
- In-stream habitat structures
- Native riparian vegetation