MONITORING YEAR 2 ANNUAL REPORT

Final

CROOKED CREEK #2 RESTORATION PROJECT

Union County, NC
DEQ Contract D09126S
DMS Project Number 94687

Data Collection Period: April – November 2017
Draft Submission Date: November 30, 2017
Final Submission Date: December 20, 2017

PREPARED FOR:

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EXECUTIVE SUMMARY

Wildlands Engineering, Inc. (Wildlands) completed a design bid build project at the Crooked Creek #2 Mitigation Site (Site) for the North Carolina Division of Mitigation Services (DMS) to restore and enhance 6,147 linear feet (LF) of perennial streams, enhance 1.0 acre of existing wetlands, restore and create 10.5 acres of wetlands, and restore and enhance 70,936 square feet (SF) of riparian buffer in Union County, NC. The Site is expected to generate 3,489.6 stream mitigation units (SMUs), 8.4 wetland mitigation units (WMUs), and 1.24 buffer mitigation units (BMU) for the Goose Creek watershed (Table 1). The Site is located off NC Highway 218 in the northern portion of Union County, NC in the Yadkin Pee-Dee River Basin; eight-digit Cataloging Unit (CU) 03040105 and the 14-digit Hydrologic Unit Code (HUC) 03040105040010 (Figure 1). The project streams consist of two unnamed tributaries (UT) to Crooked Creek, UT1 and UT2, and two reaches of the Crooked Creek mainstem (Reach A and Reach B) (Figure 2). Crooked Creek flows into the Rocky River 4 miles northeast of the site near Love Mill Road at the Stanly County line. The adjacent land to the streams and wetlands is primarily maintained for agricultural and residential uses.

The Site is within a Targeted Local Watershed (TLW) in the Lower Yadkin Pee-Dee River Basin Restoration Priority Plan (RBRP) (NCEEP, 2009). The Site is also located within the Goose Creek and Crooked Creek Local Watershed Plan (LWP). The final watershed management plan (WMP) for Goose Creek and Crooked Creek was completed in July 2012 (NCEEP, 2012). The stressors to watershed function identified in the WMP were sediment pollution and increases in peak stream flows resulting in impairments to aquatic habitat and aquatic life. Stream enhancement and restoration were identified as the best management opportunities to offset these impacts. Other stressors identified included nonpoint source runoff, degraded terrestrial habitat, and disconnected floodplains. Wetland enhancement and restoration was also identified as a best management opportunity to offset impacts related to these stressors. The wetland portion of the project was identified as a specific priority in the Project Atlas that accompanies the 2012 WMP.

The project goals established in the mitigation plan (Wildlands, 2013) were completed with careful consideration of goals and objectives that were described in the RBRP and to address stressors identified in the LWP. The following project goals established include:

- Improve wetland hydrologic connectivity;
- Decrease sediment input into stream;
- Create appropriate terrestrial habitat;
- Decrease water temperature and increase dissolved oxygen concentrations; and
- Decrease nutrient and adverse chemical levels.

The Site construction and as-built survey was completed in 2015. Planting and baseline monitoring activities occurred in January and February 2016. Monitoring Year 2 (MY2) assessments were completed between April and September 2017, to assess the conditions of the site. The average stem density for the Site is 283 stems per acre and is therefore not on track to meet the interim Year 3 requirement of 320 stems per acres. Cross-section dimensions appear stable and functioning as designed. Hydrologic success criteria were achieved in three of the 10 groundwater monitoring gages, and at least one bankfull event occurred on all monitored reaches.

CROOKED CREEK #2 RESTORATION PROJECT
Monitoring Year 2 Annual Report

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Section 1: PROJECT OVERVIEW

The Crooked Creek #2 Mitigation Site (Site) is located in the Yadkin Pee-Dee River Basin; eight-digit Cataloging Unit (CU) 03040105 and the 14-digit Hydrologic Unit Code (HUC) 03040105040010 (Figure 1). The Site is located off NC Highway 218 in the northern portion of Union County, NC (Figure 1). Located in the Carolina Slate Belt of the Piedmont Physiographic Province (USGS, 1998), the project watershed includes primarily agricultural forested and developed land. The drainage area for the project site is 24,619 acres.

The project streams consist of Crooked Creek and two UTs to Crooked Creek; UT1 and UT2. Stream restoration consists of UT1 and Stream Enhancement consist of UT2 and Crooked Creek.

The Site is within a Targeted Local Watershed (TLW) in the Lower Yadkin Pee-Dee River Basin Restoration Priority Plan (RBRP) (NCEEP, 2009). The Site is also located within the Goose Creek and Crooked Creek Local Watershed Plan (LWP). The final watershed management plan (WMP) for Goose Creek and Crooked Creek was completed in July 2012 (NCEEP, 2012). The stressors to watershed function identified in the WMP were sediment pollution and increases in peak stream flows resulting in impairments to aquatic habitat and aquatic life. Stream enhancement and restoration were identified as the best management opportunities to offset these impacts. Other stressors identified included nonpoint source runoff, degraded terrestrial habitat, and disconnected floodplains. Wetland enhancement and restoration was also identified as a best management opportunity to offset impacts related to these stressors. The wetland portion of the project was identified as a specific priority in the Project Atlas that accompanies the 2012 WMP.

Prior to construction activities, the streams on the Site had been channelized and the adjacent floodplain wetland areas had been cleared and ditched to provide drainage for surrounding pasture. These land use activities resulted in bank instability due to erosion and livestock access, lack of riparian buffer, and altered hydrology. Stream Incision, lateral erosion, and widening also resulted in degraded aquatic and benthic habitat, reduction in quality and acreage of riparian wetlands, and lowered dissolved oxygen levels in the stream. Table 4 in Appendix 1 and Table 6 in Appendix 2 present the post-restoration conditions in more detail.

1.1 Project Goals and Objectives

This mitigation site is intended to provide numerous ecological benefits within the Yadkin Pee-Dee River Basin. While many of these benefits are limited to the Crooked Creek project area, others, such as pollutant removal, reduced sediment loading, and improved aquatic and terrestrial habitat, have farther-reaching effects. Expected improvements to water quality and ecological processes are outlined below as project goals and objectives.

The project goals established in the mitigation plan (Wildlands, 2013) were completed with careful consideration of goals and objectives that were described in the RBRP and to address stressors identified in the LWP. The following project goals established include:

- Improve wetland hydrologic connectivity;
- Decrease sediment input into stream;
- Create appropriate terrestrial habitat;
- Decrease water temperature and increase dissolved oxygen concentrations; and
- Decrease nutrient and adverse chemical levels.

The project objectives have been defined as follows:

- Construct stream channels that will remain relatively stable over time and adequately transport their sediment loads without significant erosion or aggradation;
- Construct stream channels that maintain riffles with coarse bed material and pools with finer bed material;
- Provide aquatic and benthic habitat diversity in the form of pools, riffles, woody debris, and in-stream structures;
- Add riffle features and structures and riparian vegetation to decrease water temperatures and increased dissolved oxygen to improve water quality;
- Construct stream reaches so that floodplains and wetlands are frequently flooded to provide energy dissipation, detain and treat flood flows, and create a more natural hydrologic regime;
- Construct fencing to keep livestock out of the streams;
- Raise local groundwater table through raising stream beds and plugging agricultural drainage features;
- Perform minor grading in wetland areas as necessary to promote wetland hydrology; and Plant native tree species to establish appropriate wetland and floodplain communities and retain existing, native trees where possible.

1.2 Monitoring Year 2 Data Assessment

Annual monitoring was conducted between April and October 2017 to assess the condition of the project. The stream restoration success criteria for the Site follows the approved success criteria presented in the Crooked Creek #2 Project Mitigation Plan (Wildlands, 2013).

1.2.1 Vegetation Assessment

Planted woody vegetation is being monitored in accordance with the guidelines and procedures developed by the Carolina Vegetation Survey-EEP Level 2 Protocol (Lee et al., 2008). A total of 12 vegetation plots were established during the baseline monitoring within the project easement areas. All of the plots were installed using a standard 10 meter by 10 meter plot. The final vegetative success criteria will be the survival of 210 planted stems per acre in the riparian corridor along restored and enhanced reaches at the end of the seven year monitoring period (MY7). The interim measure of vegetative success for the Site will be the survival of at least 320 planted stems per acre at the end of year three of the monitoring period (MY3) and at least 260 stems per acre at the end of the fifth year of monitoring (MY5). Planted vegetation must average 10 feet in height in each plot at the end of the seventh year of monitoring. If this performance standard is met by MY5 and stem density is trending towards success (i.e., no less than 260 five year old stems/acre), monitoring of vegetation on the Site may be terminated provided written approval is provided by the United States Army Corps of Engineers in consultation with the NC Interagency Review Team.

The MY2 vegetative survey was completed in August 2017, resulting in an average stem density of 283 stems per acre. Only 4 of the 12 vegetation plots meet the interim requirement of 320 stems/acre. The planted stem mortality was approximately 46% from the baseline density recorded in February 2016 at MY0 of 526 stems/acre. There is an average of 7 stems per plot as compared to 13 stems per plot in MY0. The average stem height is 4.2 feet which is 35% increase from MY1. The suffocation due to surrounding herbaceous material continues to impact the planted stems. In addition, vine strangulation is affecting the stem growth in several plots. Please refer to Appendix 2 for vegetation plot photographs and the vegetation condition assessment table and Appendix 3 for vegetation data tables.

1.2.2 Vegetation Areas of Concern

An herbicide treatment was applied along the fence line around photo point 33. However, the invasive vine species, such as Chinese lantern, Japanese honeysuckle and morning glory, continue to impact the stem growth within the site. Several invasive species were noted throughout the site and include Chinese lantern (*Physalis spp.*), Chinaberry (*Melia* azedarach), Chinese privet (*Ligustrum sinense*), Japanese honeysuckle (*Lonicera japonica*), Johnson grass (*Sorghum halepense*), and morning glory (*Ipomoea sp.*). The native invasive cattail (*Typha latifolia*) has colonized into Vegetation Plot 5, which may impact planted woody stem survival, along with the dense herbaceous coverage of rice cutgrass (*Leersia oryzoides*). Invasive maintenance will need to continue to enable the planted stems to grow within the site.

Most of the floodplain still contains dense, native herbaceous cover that is suffocating the planted stems and out competing for water and sunlight. Several of the oak species exhibited mildew due to lack of air circulation. The treated areas of Chinese privet on Crooked Creek Reach A and Reach B have re-sprouted and are showing increasing dominance. Refer to Appendix 2 for the vegetation condition assessment table, Integrated Current Condition Plan View (CCPV), and reference photographs.

1.2.3 Stream Assessment

MY2 Morphological surveys were conducted in April 2017. Results indicate that the channel dimensions are stable and functioning as designed. In general, the cross-sections on UT1 show little to no change in the bankfull area, maximum depth ratio, or width-to-depth ratio compared to baseline. Surveyed riffle cross-sections fell within the parameters defined for channels of the appropriate Rosgen stream type (Rosgen, 1996). Due to drier conditions, the stream, especially the riffles, are inundated with vegetation. In general, the restoration reaches show little to no changes with substrate materials. The particle size distribution for MY2 riffle cross-section 4 are similar or slightly larger than the as-built conditions, however pebble count data for riffle cross-section 2 continues to reflect increased deposition of fine sediment. This area will be watched in future monitoring years for embeddedness. Refer to Appendix 2 for the visual stability assessment table, CCPV map, and reference photographs. Refer to Appendix 4 for the morphological summary data and plots.

1.2.4 Stream Areas of Concern

Dense herbaceous ground cover has entered the UT1 streambed which hinders the movement of sediment during bankfull events. The streambed is difficult to locate due to this herbaceous coverage, especially when the stream is dry.

1.2.5 Hydrology Assessment

At least one bankfull event occurred on all reaches during the MY2 data collection. This event was recorded on the UT1 stream gage that was installed late April, along with crest gages and visual indicators for UT2 and Crooked Creek. Two bankfull flow events must be documented on the restoration reaches within the seven-year monitoring period and the two bankfull events must occur in separate years. There was a bankfull event recorded during MY1 and MY2; therefore, the performance criteria has been met in MY2. The stream gage indicates there were 22 consecutive days of stream flow; however, the stream gage was not installed until late April; therefore, missing the rainfall during the winter months. Refer to Appendix 5 for hydrologic data and graphs.

1.2.6 Wetland Assessment

Ten groundwater monitoring gages (GWG 1-10) were installed during the baseline monitoring so that the data collected will provide an indication of groundwater levels throughout the wetland areas. The

target performance criteria for wetland hydrology success consists of groundwater surface within 12 inches of the ground surface for 17 consecutive days (7.5 percent) of the defined 227 day growing season for Union County (March 23 through November 4) under typical precipitation conditions. Only three of the ten gages (GWG 6, GWG 7 and GWG 8) met the performance criteria for MY2. GWG 6 met criteria for 75 consecutive days (33.2%), GWG 7 recorded 47 consecutive days (20.8%) and GWG 8 recorded 31 consecutive days (13.7%). Although the remaining gages did not meet criteria, they do reflect improvement between MY1 and MY2. According to onsite rain gage data and climate data from a nearby USGS station, the site received less than typical amount of rain during January through March 2017. It is anticipated that these wetland areas will continue to recharge and meet hydrologic success criteria in the upcoming monitoring years as precipitation normalizes. Refer to Appendix 5 for the groundwater hydrology data and plots.

1.2.7 Wetland Areas of Concern

The headcut located in the Wetland Creation Zone B area, between GWG 8 and vegetation plot 7, has increased in size. On August 29, 2017, the headcut measured approximately 1.7 feet deep, 2 feet wide, and 7 feet long, before entering the Wetland Enhancement Zone B. The tall herbaceous material covered the scoured area and was not visible; therefore, surrounding vegetation was cleared and made easier to locate for repair purposes. The placement of coir logs is suggested to re-direct the water flow around the headcut.

1.3 Monitoring Year 2 Summary

The restored streams within the Site appear stable and functioning as designed. The average stem density (283 stems per acre) for the Site is currently not on track to meeting the MY7 success criteria; therefore, the Site will receive supplemental planting with 1-gallon or larger containerized trees in January 2018 in response to not meeting success criteria. In addition, the Site will be treated site wide for invasives in 2018 in response to persistent invasives which have recolonized the Site. Three of the 10 groundwater gages met the performance criteria in MY2. The bankfull performance criteria has been met in MY2; however, continuous flow has not been shown in UT1. UT1 contains vegetation over-growth and the concern that the jurisdictional nature of this restoration tributary remains to be determined.

Summary information and data related to the performance of various project and monitoring elements can be found in the tables and figures in the report appendices. Narrative background and supporting information formerly found in these reports can be found in the Mitigation Plan documents available on DMS's website. All raw data supporting the tables and figures in the appendices are available from DMS upon request.

Section 2: METHODOLOGY

Geomorphic data were collected following the standards outlined in The Stream Channel Reference Site: An Illustrated Guide to Field Techniques (Harrelson et al., 1994) and in the Stream Restoration: A Natural Channel Design Handbook (Doll et al., 2003). All Integrated Current Condition Mapping was recorded using a Trimble handheld GPS with sub-meter accuracy and processed using Pathfinder and ArcGIS. Crest gages and pressure transducers were installed in surveyed riffle cross-sections during annual site visits. Hydrologic monitoring instrument installation and monitoring methods are in accordance with the United States Army Corps of Engineers (USACE, 2003) standards. Vegetation monitoring protocols followed the Carolina Vegetation Survey-EEP Level 2 Protocol (Lee et al., 2008).

Section 3: REFERENCES

Doll, B.A., Grabow, G.L., Hall, K.A., Halley, J., Harman, W.A., Jennings, G.D., and Wise, D.E. 2003. Stream Restoration A Natural Channel Design Handbook.

Harrelson, Cheryl C; Rawlins, C.L.; Potyondy, John P. 1994. *Stream Channel Reference Sites: An Illustrated Guide to Field Technique.* Gen. Tech. Rep. RM-245. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 61 p.

Lee, Michael T., Peet, Robert K., Steven D., Wentworth, Thomas R. 2008. CVS-EEP Protocol for Recording Vegetation Version 4.2. Retrieved from: http://cvs.bio.unc.edu/protocol/cvs-eep-protocol-v4.2-lev1-2.pdf

North Carolina Ecosystem Enhancement Program (NCEEP), 2009. Lower Yadkin Pee-Dee River Basin Restoration Priorities. Retrieved from: http://deq.nc.gov/document/yadkin-pee-dee-rbrp-2009-final

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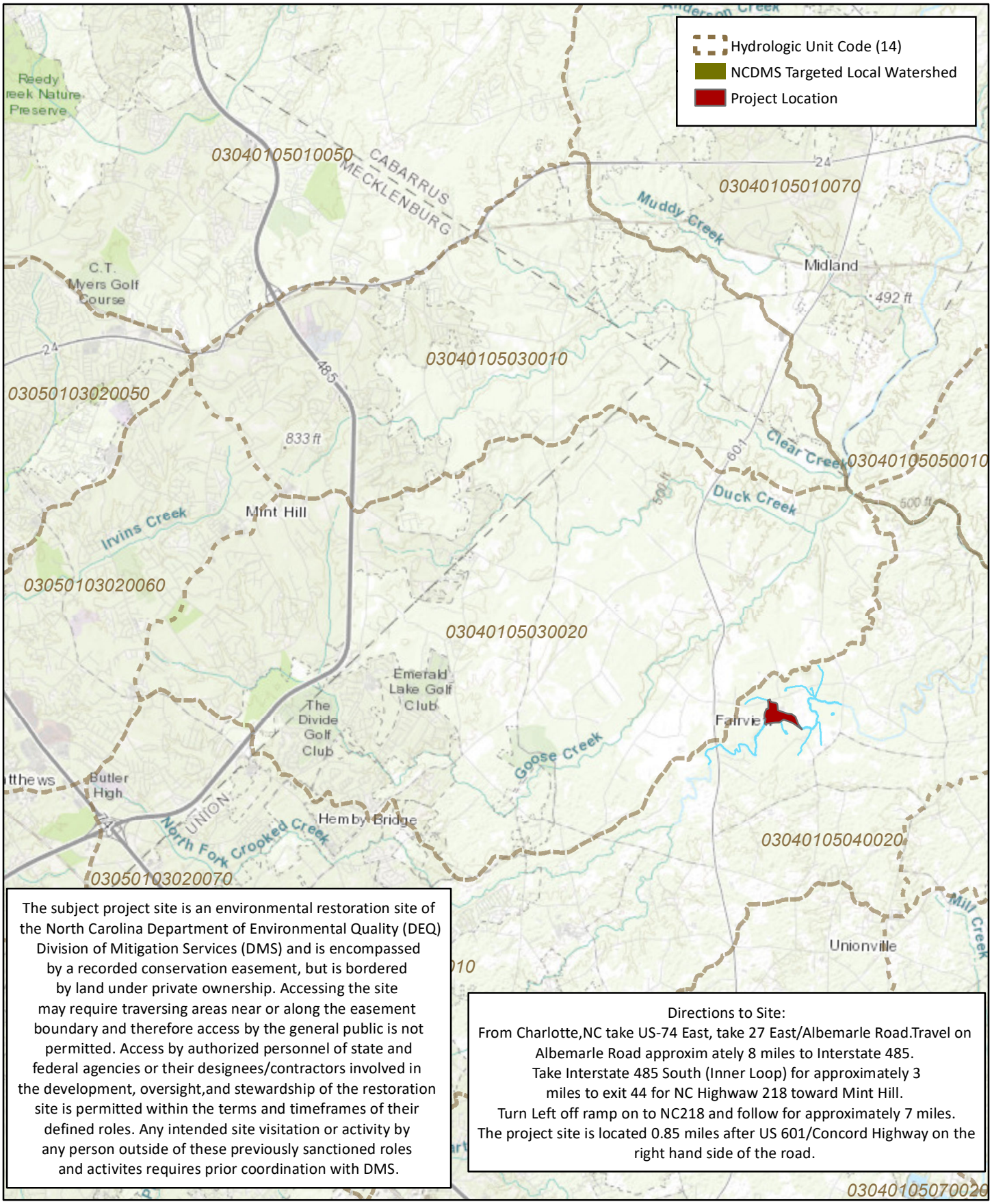
United States Army Corps of Engineers (USACE), 2003. Stream Mitigation Guidelines. USACE, NCDENR-DWQ, USEPA, NCWRC.

United States Geological Survey (USGS), 1998. North Carolina Geology. Retrieved from: http://www.geology.enr.state.nc.us/usgs/coastalp.htm

United States Geological Survey (USGS), 2016. Real Time Water Data for North Carolina. Retrieved from: http://nc.water.usgs.gov/realtime/real_time_yadkin_peedee.html

Wildlands Engineering, Inc. (2013). Crooked Creek #2 Restoration Project Final Mitigation Plan. NCEEP, Raleigh, NC.

APPENDIX 1. General Tables and Figures



The subject project site is an environmental restoration site of the North Carolina Department of Environmental Quality (DEQ) Division of Mitigation Services (DMS) and is encompassed by a recorded conservation easement, but is bordered by land under private ownership. Accessing the site may require traversing areas near or along the easement boundary and therefore access by the general public is not permitted. Access by authorized personnel of state and federal agencies or their designees/contractors involved in the development, oversight,and stewardship of the restoration site is permitted within the terms and timeframes of their defined roles. Any intended site visitation or activity by any person outside of these previously sanctioned roles and activites requires prior coordination with DMS.

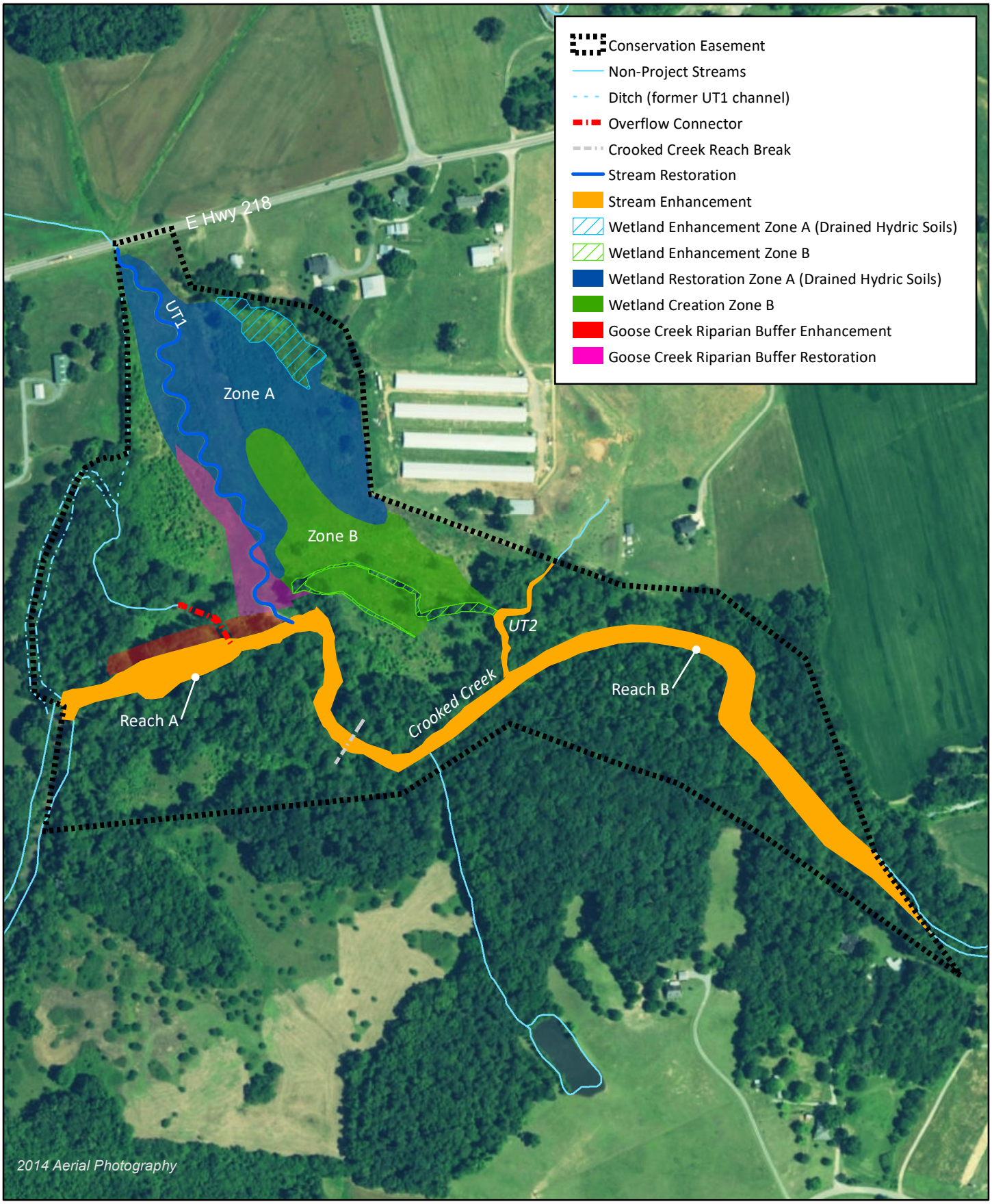
Directions to Site:
From Charlotte,NC take US-74 East, take 27 East/Albemarle Road.Travel on Albemarle Road approxim ately 8 miles to Interstate 485.
Take Interstate 485 South (Inner Loop) for approximately 3 miles to exit 44 for NC Highwaw 218 toward Mint Hill.
Turn Left off ramp on to NC218 and follow for approximately 7 miles.
The project site is located 0.85 miles after US 601/Concord Highway on the right hand side of the road.

WILDLANDS ENGINEERING

0 0.5 1 Mile

N

Figure 1 Project Vicinity Map
Crooked Creek #2 Restoration Project
DMS Project No. 94687
Monitoring Year 2 - 2017
Union County, NC



WILDLANDS ENGINEERING

0 200 400 Feet

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Figure 2 Project Component/Asset Map
Crooked Creek #2 Restoration Project
DMS Project No. 94687
Monitoring Year 2 - 2017
Union County, NC

Table 1. Project Components and Mitigation Credits
Crooked Creek #2 Restoration Project Site
DMS Project No. 94687
Monitoring Year 2 - 2017

Mitigation Credits									
	Stream		Riparian Wetland		Non-Riparian Wetland		Buffer (sqft)	Nitrogen Nutrient	Phosphorous Nutrient Offset
Type	R	RE	R	RE	R	RE			
Totals	3,489.6	N/A	7.9	0.5	N/A	N/A	54,135.33	N/A	

Project Components							
Reach ID	As-Built Stationing/ Location	Existing Footage/ Acreage	Approach	Restoration or Restoration Equivalent	Restoration Footage/ Acreage	Mitigation Ratio	Credits (SMU/ WMU)
STREAMS							
Crooked Creek Reach A	200+00-228+29	1,555 LF	N/A	Enhancement II	1,555	2.5:1	622.0
Crooked Creek Reach B		2,404 LF	N/A	Enhancement II	2,404	2.5:1	961.6
UT1	100+00-117+18	1,762 LF	P1	Restoration	1,718	1:1	1,718.0
UT2	300+00-305+60	470 LF	N/A	Enhancement II	470	2.5:1	188.0
WETLANDS							
Zone A (Drained Hydric Soils)	N/A	0.7 AC		Enhancement	0.7	2:1	0.35
Zone A (Drained Hydric Soils)	N/A	N/A		Restoration	6.6	1:1	6.6
Zone B	N/A	0.3 AC		Enhancement	0.3	2:1	0.15
Zone B	N/A	N/A		Creation	3.9	3:1	1.3
BUFFER							
Goose Creek Buffer	N/A	25,201 sqft		Enhancement	25,201 sqft	3:1	8,400.33 sqft
Goose Creek Buffer	N/A	N/A		Restoration	45,735 sqft	1:1	45,735 sqft

Component Summation						
Restoration Level	Stream (LF)	Riparian Wetland (acres)		Non-Riparian (acres)	Buffer (square feet)	Upland (acres)
		Riverine	Non-Riverine			
Restoration	1,718	6.6			45,735	
Enhancement		1.0			25,201	
Enhancement I						
Enhancement II	4,429					
Creation		3.9				

Table 2. Project Activity and Reporting History
Crooked Creek #2 Restoration Project Site
DMS Project No. 94687
Monitoring Year 2 - 2017

Activity or Report		Data Collection Complete	Completion or Scheduled Delivery
Mitigation Plan		June 2011	August 2013
Final Design - Construction Plans		August 2011	April 2014
Construction		January 2015 - April 2015	January 2015 - April 2015
Temporary S&E mix applied to entire project area[1]		January 2015 - March 2015	January 2015 - March 2015
Permanent seed mix applied to reach/segments		January 2015 - March 2015	January 2015 - March 2015
Bare root and live stake plantings for reach/segments		January 2016	January 2016
Baseline Monitoring Document (Year 0)		January - February 2016	May 2016
Year 1 Monitoring	Stream Survey	August 2016	November 2016
	Vegetation Survey	September 2016	
Year 2 Monitoring	Stream Survey	April 2017	November 2017
	Vegetation Survey	August 2017	
Year 3 Monitoring	Stream Survey	2018	November 2018
	Vegetation Survey	2018	
Year 4 Monitoring	Stream Survey	2019	November 2019
	Vegetation Survey	2019	
Year 5 Monitoring	Stream Survey	2020	November 2020
	Vegetation Survey	2020	
Year 6 Monitoring	Stream Survey	2021	November 2021
	Vegetation Survey	2021	
Year 7 Monitoring	Stream Survey	2022	November 2022
	Vegetation Survey	2022	

[1]Seed and mulch is added as each section of construction is completed.

Table 3. Project Contact Table
Crooked Creek #2 Restoration Project Site
DMS Project No. 94687
Monitoring Year 2 - 2017

Designer Aaron Early, PE, CFM	**Wildlands Engineering, Inc.** 1430 South Mint Street, Suite 104 Charlotte, NC 28203 704.332.7754
Construction Contractor	**North State Environmental, Inc.** 2889 Lowery Street Winston Salem, NC 27101
Planting Contractor	**Keller Environmental** 7921 Haymarket Lane Raleigh, NC 27615
Seeding Contractor	**North State Environmental, Inc.** 2889 Lowery Street Winston Salem, NC 27101
Seed Mix Sources	**Green Resource, LLC**
Nursery Stock Suppliers **Bare Roots** **Live Stakes**	**Dykes & Son Nursery** 825 Maude Etter Rd. McMinnville, TN 37110
Monitoring Performers	**Wildlands Engineering, Inc.**
Monitoring, POC	Kirsten Gimbert 704.332.7754, ext. 110

Table 4. Project Information and Attributes
Crooked Creek #2 Restoration Project Site
DMS Project No. 94687
Monitoring Year 2 - 2017

Project Information	
Project Name	Crooked Creek #2 Restoration Project
County	Union County
Project Area (acres)	54.94
Project Coordinates (latitude and longitude)	34° 58' 54.78"N, 080° 31' 25.79"W

Project Watershed Summary Information	
Physiographic Province	Carolina Slate Belt of the Piedmont Physiographic Province
River Basin	Yadkin
USGS Hydrologic Unit 8-digit	03040105
USGS Hydrologic Unit 14-digit	03040105040010
DWR Sub-basin	03-07-12
Project Drainiage Area (acres)	24,619
Project Drainage Area Percentage of Impervious Area	28%
CGIA Land Use Classification	Agriculture 38%, Forested 29%, Developed 28%, Wetlands 3%, and Herbaceous Upland 2%

Reach Summary Information					
Parameters	**Crooked Creek Reach A**	**Crooked Creek Reach B**	**UT1**	**UT2**	
Length of reach (linear feet) - Post-Restoration	1,555	2,404	1,718	195	275
Drainage area (acres)	24,619		153	51	
NCDWR stream identification score	52		34.5	24.5	38
NCDWR Water Quality Classification	C				
Morphological Desription (stream type)	P	P	P	I	P
Evolutionary trend (Simon's Model) - Pre- Restoration	N/A	N/A	Stage III	Stage IV	
Underlying mapped soils	Chewacala silt loam 0-2% slopes (ChA)	Chewacala silt loam 0-2% slopes (ChA)	Chewacala silt loam 0-2% slopes (ChA)	Badin channery silt loam 8-15% slopes (BaC)	
Drainage class	Somewhat poorly drained	Somewhat poorly drained	Somewhat poorly drained	Well drained	
Soil hydric status	Type B (inclusions)	Type B (inclusions)	Type B (inclusions)	N/A	
Slope	0.0022		0.0047	0.0050	
FEMA classification	Zone AE	Zone AE	no regulated floodplain	no regulated floodplain	
Native vegetation community	Piedmont Bottomland forest				
Percent composition exotic invasive vegetation -Post-Restoration	5%	5%	60%	5%	

Regulatory Considerations			
Regulation	**Applicable?**	**Resolved?**	**Supporting Documentation**
Waters of the United States - Section 404	X	X	USACE Nationwide Permit No.27 and DWQ 401 Water Quality Certification No. 3885. Action ID # 2011-02201
Waters of the United States - Section 401	X	X	
Division of Land Quality (Erosion and Sediment Control)	X	X	NPDES Construction Stormwater General Permit NCG010000
Endangered Species Act	X	X	Crooked Creek #2 Mitigation Plan; Wildlands determined "no effect" on Union County listed endangered species. June 21, 2011 email correspondence from USFWS indicating no listed species occur on site.
Historic Preservation Act	X	X	No historic resources were found to be impacted (letter from SHPO dated 6/23/2011).
Coastal Zone Management Act (CZMA)/Coastal Area Management Act (CAMA)	N/A	N/A	N/A
FEMA Floodplain Compliance	X	X	Crooked Creek is a mapped Zone AE floodplain with defined base flood elevations. Base flood elevations have been defined and the floodway has been delineated; (FEMA Zone AE, FIRM panel 5540).
Essential Fisheries Habitat	N/A	N/A	N/A

Table 5. Monitoring Component Summary
Crooked Creek #2 Restoration Project Site
DMS Project No. 94687
Monitoring Year 2 - 2017

Parameter	Monitoring Feature	Quantity / Length by Reach					Frequency
		Crooked Creek Reach A	Crooked Creek Reach B	UT1	UT2	Wetlands	
Dimension	Riffle Cross-Section	N/A	N/A	2	N/A	N/A	Annual
	Pool Cross-Section	N/A	N/A	2	N/A	N/A	
Pattern	Pattern	N/A	N/A	N/A	N/A	N/A	N/A
Profile	Longitudinal Profile	N/A	N/A	N/A	N/A	N/A	Year 0
Substrate	Reach Wide (RW)/ Riffle 100 Pebble Count (RF)	N/A	N/A	1 RW / 2 RF	N/A	N/A	Annual
Hydrology	Crest Gage	1		1	1	N/A	Quarterly
Hydrology	Groundwater Gages	N/A	N/A	N/A	N/A	10	Quarterly
Vegetation	Vegetation Plots	12					Annual
Visual Assessment	All Streams	Y	Y	Y	Y	Y	Semi-Annual
Exotic and nuisance vegetation							Semi-Annual
Project Boundary							Semi-Annual
Reference Photos	Photo Points	34					Annual

APPENDIX 2. Visual Assessment Data

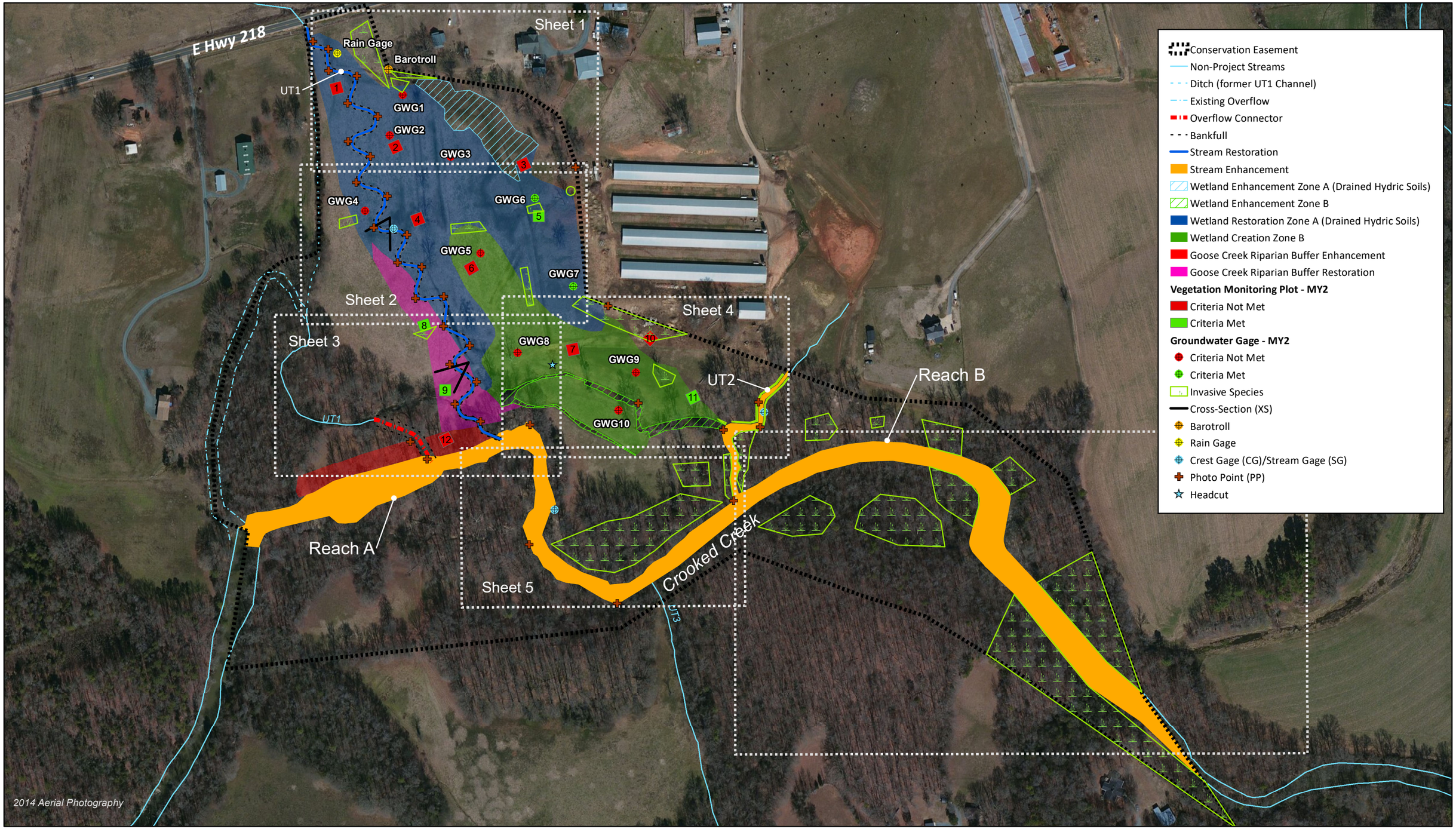
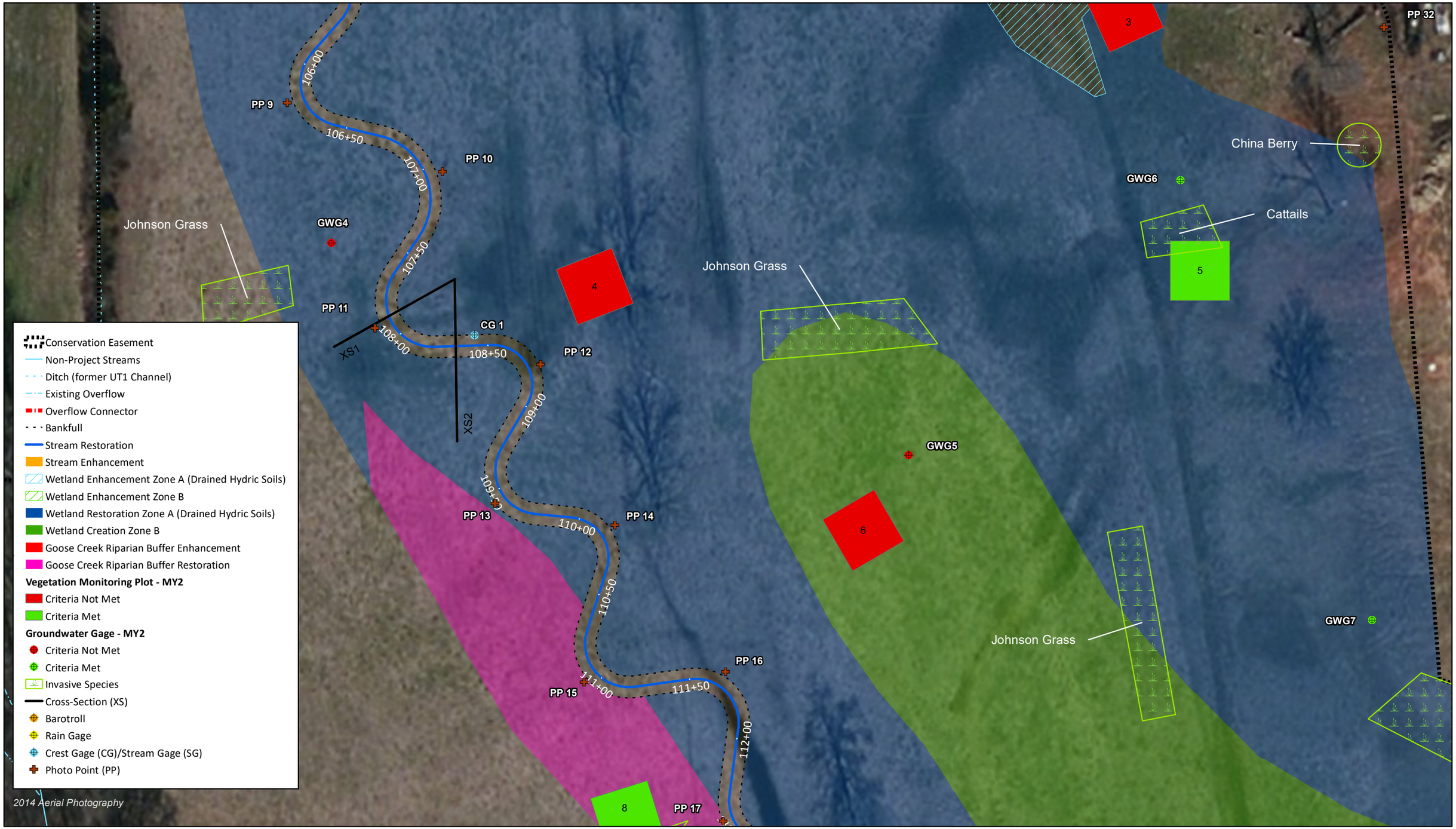


Figure 3.0 Integrated Current Condition Plan View
Crooked Creek #2 Restoration Project
DMS Project No. 94687
Monitoring Year 2 - 2017
Union County, NC

0 25 50 100 Feet

N

Figure 3.1 Integrated Current Condition Plan View (Sheet 1)
Crooked Creek #2 Restoration Project
DMS Project No. 94687
Monitoring Year 2 - 2017
Union County, NC

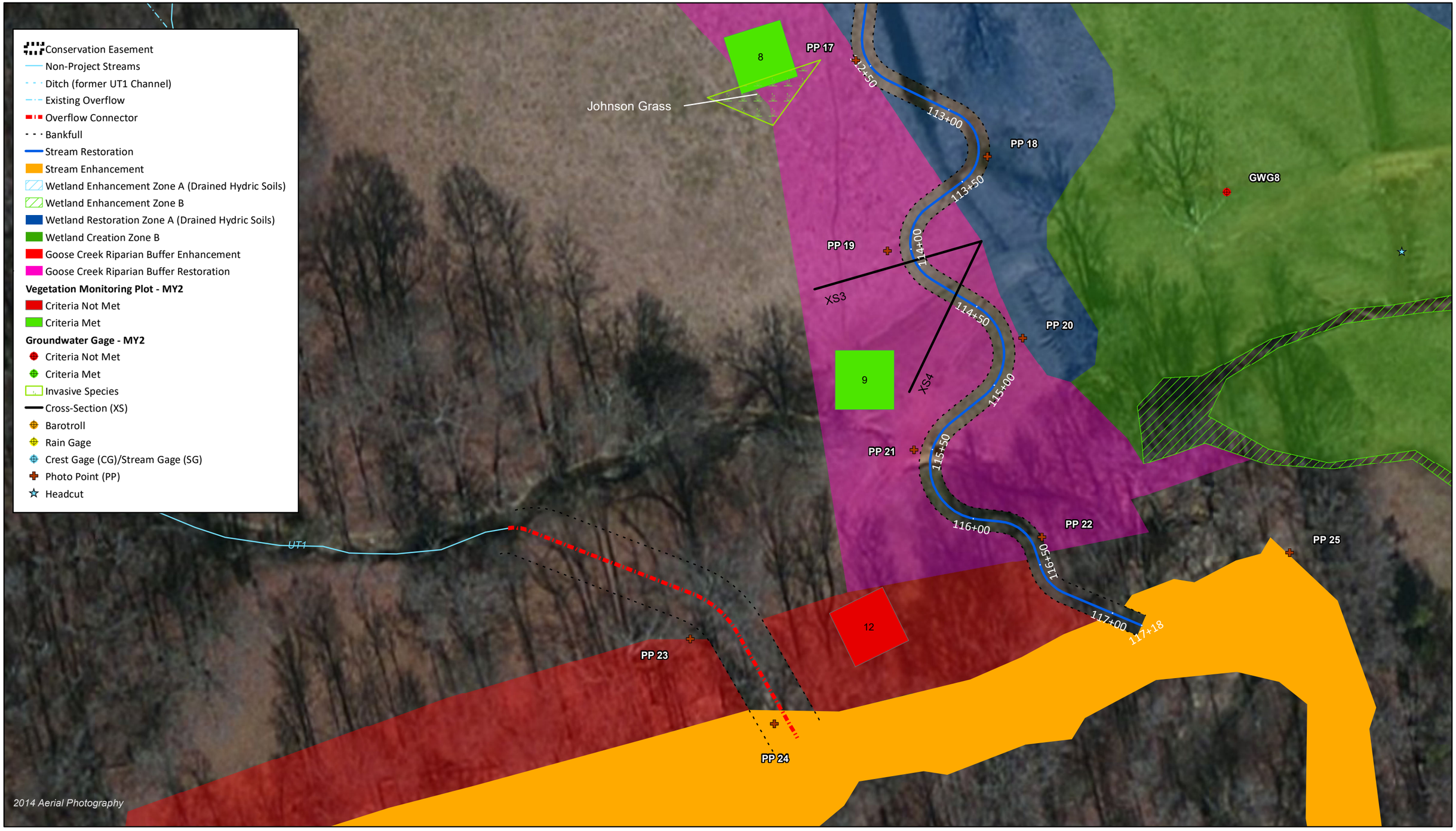


WILDLANDS ENGINEERING

0 25 50 100 Feet

N

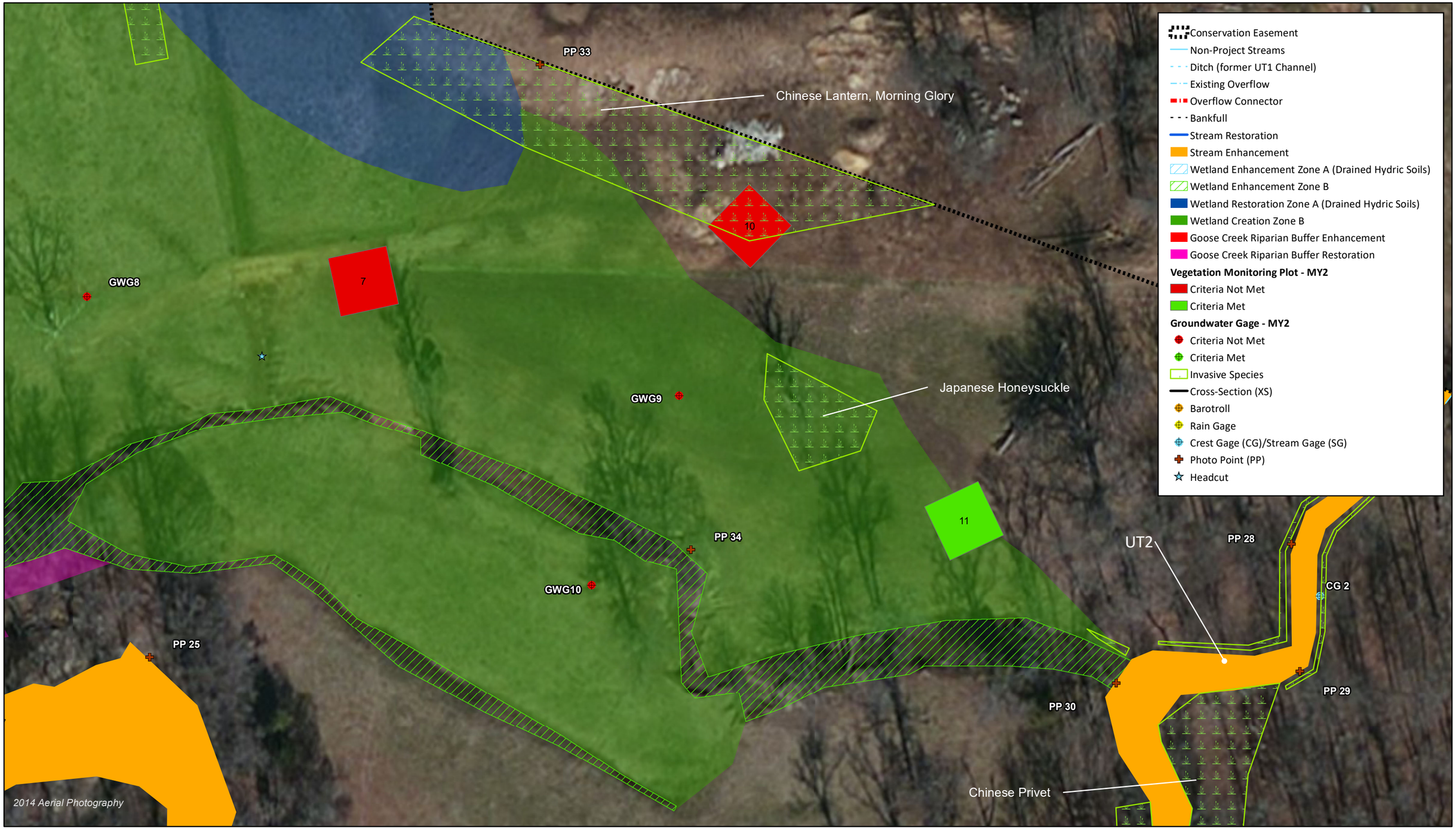
Figure 3.2 Integrated Current Condition Plan View (Sheet 2)
Crooked Creek #2 Restoration Project
DMS Project No. 94687
Monitoring Year 2 - 2017
Union County, NC



0 25 50 100 Feet

N

Figure 3.3 Integrated Current Condition Plan View (Sheet 3)
Crooked Creek #2 Restoration Project
DMS Project No. 94687
Monitoring Year 2 - 2017
Union County, NC



WILDLANDS ENGINEERING

0 25 50 100 Feet

N

Figure 3.4 Integrated Current Condition Plan View (Sheet 4)
Crooked Creek #2 Restoration Project
DMS Project No. 94687
Monitoring Year 2 - 2017
Union County, NC

Figure 3.5 Integrated Current Condition Plan View (Sheet 5)
Crooked Creek #2 Restoration Project
DMS Project No. 94687
Monitoring Year 2 - 2017
Union County, NC

WILDLANDS ENGINEERING

0 25 50 100 Feet

N

Figure 3.6 Integrated Current Condition Plan View (Sheet 6)
Crooked Creek #2 Restoration Project
DMS Project No. 94687
Monitoring Year 2 - 2017
Union County, NC

Table 6. Visual Stream Morphology Stability Assessment Table
Crooked Creek #2 Restoration Project
DMS Project No. 94687
Monitoring Year 2 - 2017

UT1 (1,718 LF)

Major Channel Category	Channel Sub-Category	Metric	Number Stable, Performing as Intended	Total Number in As-Built	Number of Unstable Segments	Amount of Unstable Footage	% Stable, Performing as Intended	Number with Stabilizing Woody Vegetation	Footage with Stabilizing Woody Vegetation	Adjust % for Stabilizing Woody Vegetation
1. Bed	1. Vertical Stability (Riffle and Run units)	Aggradation			0	0	100%			
		Degradation			0	0	100%			
	2. Riffle Condition	Texture/Substrate	16	16			100%			
	3. Meander Pool Condition	Depth Sufficient	20	20			100%			
		Length Appropriate	20	20			100%			
	4. Thalweg Position	Thalweg centering at upstream of meander bend (Run)	20	20			100%			
		Thalweg centering at downstream of meander bend (Glide)	20	20			100%			
2. Bank	1. Scoured/Eroded	Bank lacking vegetative cover resulting simply from poor growth and/or scour and erosion			0	0	100%	n/a	n/a	n/a
	2. Undercut	Banks undercut/overhanging to the extent that mass wasting appears likely. Does NOT include undercuts that are modest, appear sustainable and are providing habitat			0	0	100%	n/a	n/a	n/a
	3. Mass Wasting	Bank slumping, calving, or collapse			0	0	100%	n/a	n/a	n/a
				Totals	0	0	100%	n/a	n/a	n/a
3. Engineered Structures[1]	1. Overall Integrity	Structures physically intact with no dislodged boulders or logs.	9	9			100%			
	2. Grade Control	Grade control structures exhibiting maintenance of grade across the sill	4	4			100%			
	2a. Piping	Structures lacking any substantial flow underneath sills or arms.	4	4			100%			
	3. Bank Protection	Bank erosion within the structures extent of influence does not exceed 15%.	9	9			100%			
	4. Habitat	Pool forming structures maintaining ~Max Pool Depth : Bankfull Depth ≥ 1.6 Rootwads/logs providing some cover at baseflow.	20	20			100%			

[1]Excludes constructed riffles since they are evaluated in section 1.

Table 7. Vegetation Condition Assessment Table

Crooked Creek #2 Restoration Site

DMS Project No. 94687

Monitoring Year 2 - 2017

Planted Acreage **15.0**

Vegetation Category	Definitions	Mapping Threshold	Number of Polygons	Combined Acreage[1]	% of Planted Acreage
Bare Areas	Very limited cover of both woody and herbaceous material	0.1 ac	0	0.0	0%
Low Stem Density Areas[1]	Woody stem densities clearly below target levels based on MY3, 4, 5, or 7 stem count criteria.	0.1 ac	17	0.41	2.7%
		Total	**17**	**0.41**	**2.7%**
Areas of Poor Growth Rates or Vigor[1]	Areas with woody stems of a size class that are obviously small given the monitoring year.	0.25	17	0.41	2.7%
		Cumulative Total	**17**	**0.4**	**2.7%[3]**

Easement Acreage **54.9**

Vegetation Category	Definitions	Mapping Threshold	Number of Polygons	Combined Acreage[2]	% of Easement Acreage
Invasive Areas of Concern[2]	Areas or points (if too small to render as polygons at map scale).	1000 SF	27	6.3	11%
Easement Encroachment Areas	Areas or points (if too small to render as polygons at map scale).	none	0	0	0%

[1]Acreage calculated from annual vegetation monitoring plots and plant warranty inspection plots.

[2]Acreage of each polygon modified by estimated percent cover of invasive population

[3]Low Stem Density Areas are the same as Areas of Poor Growth Rate

Vegetation Photographs

Vegetation Plot 1 – (08/28/2017)

Vegetation Plot 2 – (08/28/2017)

Vegetation Plot 3 – (08/29/2017)

Vegetation Plot 4 – (08/28/2017)

Vegetation Plot 5 – (08/29/2017)

Vegetation Plot 6 – (08/28/2017)

Vegetation Plot 7 – (08/29/2017)

Vegetation Plot 8 – (08/28/2017)

Vegetation Plot 9 – (08/28/2017)

Vegetation Plot 10 – (08/29/2017)

Vegetation Plot 11 – (08/29/2017)

Vegetation Plot 12 – (08/28/2017)

Stream Photographs

	
Photo Point 1 – UT1 looking upstream (06/28/2017)	**Photo Point 1** – UT1 looking downstream (06/28/2017)
	
Photo Point 2 – UT1 looking upstream (06/28/2017)	**Photo Point 2** – UT1 looking downstream (06/28/2017)
	
Photo Point 3 – UT1 looking upstream (06/28/2017)	**Photo Point 3** – UT1 looking downstream (06/28/2017)

	
Photo Point 4 – UT1 looking upstream (06/28/2017)	**Photo Point 4** – UT1 looking downstream (06/28/2017)
	
Photo Point 5 – UT1 looking upstream (06/28/2017)	**Photo Point 5** – UT1 looking downstream (06/28/2017)
	
Photo Point 6 – UT1 looking upstream (06/28/2017)	**Photo Point 6** – UT1 looking downstream (06/28/2017)

	
Photo Point 7 – UT1 looking upstream (06/28/2017)	**Photo Point 7** – UT1 looking downstream (06/28/2017)
	
Photo Point 8 – UT1 looking upstream (06/28/2017)	**Photo Point 8** – UT1 looking downstream (06/28/2017)
	
Photo Point 9 – UT1 looking upstream (06/28/2017)	**Photo Point 9** – UT1 looking downstream (06/28/2017)

	
Photo Point 10 – UT1 looking upstream (06/28/2017)	**Photo Point 10** – UT1 looking downstream (06/28/2017)
	
Photo Point 11 – UT1 looking upstream (06/28/2017)	**Photo Point 11** – UT1 looking downstream (06/28/2017)
	
Photo Point 12 – UT1 looking upstream (06/28/2017)	**Photo Point 12** – UT1 looking downstream (06/28/2017)

	
Photo Point 13 – UT1 looking upstream (06/28/2017)	**Photo Point 13** – UT1 looking downstream (06/28/2017)
	
Photo Point 14 – UT1 looking upstream (06/28/2017)	**Photo Point 14** – UT1 looking downstream (06/28/2017)
	
Photo Point 15 – UT1 looking upstream (06/28/2017)	**Photo Point 15** – UT1 looking downstream (06/28/2017)

	
Photo Point 16 – UT1 looking upstream (06/28/2017)	**Photo Point 16** – UT1 looking downstream (06/28/2017)
	
Photo Point 17 – UT1 looking upstream (06/28/2017)	**Photo Point 17** – UT1 looking downstream (06/28/2017)
	
Photo Point 18 – UT1 looking upstream (06/28/2017)	**Photo Point 18** – UT1 looking downstream (06/28/2017)

	
Photo Point 19 – UT1 looking upstream (06/28/2017)	**Photo Point 19** – UT1 looking downstream (06/28/2017)
	
Photo Point 20 – UT1 looking upstream (06/28/2017)	**Photo Point 20** – UT1 looking downstream (06/28/2017)
	
Photo Point 21 – UT1 looking upstream (06/28/2017)	**Photo Point 21** – UT1 looking downstream (06/28/2017)

	
Photo Point 22 – UT1 looking upstream (06/28/2017)	**Photo Point 22** – UT1 looking downstream (06/28/2017)
	
Photo Point 23 – UT1 looking upstream (06/28/2017)	**Photo Point 23** – UT1 looking downstream (06/28/2017)
	
Photo Point 24 – Crooked Creek looking upstream (06/28/2017)	**Photo Point 24** – Crooked Creek looking downstream (06/28/2017)

	
Photo Point 25 – Crooked Creek looking upstream (06/28/2017)	**Photo Point 25** – Crooked Creek looking downstream (06/28/2017)
	
Photo Point 26 – Crooked Creek looking upstream (06/28/2017)	**Photo Point 26** – Crooked Creek looking downstream (06/28/2017)
	
Photo Point 27 – Crooked Creek looking upstream (06/28/2017)	**Photo Point 27** – Crooked Creek looking downstream (06/28/2017)

Photo Point 28 – UT2 looking upstream (06/28/2017)

Photo Point 28 – UT2 looking downstream (06/28/2017)

Photo Point 29 – UT2 looking upstream (06/28/2017)

Photo Point 29 – UT2 looking downstream (06/28/2017)

Photo Point 30 – UT2 looking downstream to UT2 (06/28/2017)

Photo Point 31 – UT2 looking upstream Crooked Creek

Photo Point 31 – UT2 looking downstream (06/28/2017)

Photo Point 31 – UT2 looking upstream UT2 (06/28/2017)

Wetland Photographs

	
Photo Point 30 –Wetland CC outlet facing W (06/28/2017)	**Photo Point 30** –Wetland CC outlet facing E (06/28/2017)
	
Photo Point 32 –Wetland AA facing W (06/28/2017)	**Photo Point 32** – Wetland Zone A facing S(06/28/2017)
	
Photo Point 33 – Wetland Zone A & B facing W (06/28/2017)	**Photo Point 33** - Wetland B facing S (06/28/2017)

	
Photo Point 34 –Wetland CC facing NW (06/28/2017)	**Photo Point 34** –Wetland CC facing S (06/28/2017)

APPENDIX 3. Vegetation Plot Data

Table 8. Vegetation Plot Criteria Attainment

Crooked Creek #2 Restoration Project Site
DMS Project No. 94687
Monitoring Year 2 - 2017

Plot	MY2 Success Criteria Met (Y/N)	Tract Mean
1	N	33%
2	N	
3	N	
4	N	
5	Y	
6	N	
7	N	
8	Y	
9	Y	
10	N	
11	Y	
12	N	

Table 9. CVS Vegetation Plot Metadata
Crooked Creek #2 Restoration Project
DMS Project No. 94687
Monitoring Year 2 - 2017

Report Prepared By	Ruby Davis
Date Prepared	8/31/2017 10:54
Database Name	cvs-eep-entrytool-v2.5.0 Crooked Creek MY2.mdb
Database Location	Q:\ActiveProjects\005-02156 Crooked Creek Monitoring\Monitoring\Monitoring Year 2\Vegetation Assessment
Computer Name	RUBY
File Size	74317824
DESCRIPTION OF WORKSHEETS IN THIS DOCUMENT----------	
Metadata	Description of database file, the report worksheets, and a summary of project(s) and project data.
Project planted	Each project is listed with its PLANTED stems per acre, for each year. This excludes live stakes.
Project Total Stems	Each project is listed with its TOTAL stems per acre, for each year. This includes live stakes, all planted stems, and all natural/volunteer stems.
Plots	List of plots surveyed with location and summary data (live stems, dead stems, missing, etc.).
Vigor	Frequency distribution of vigor classes for stems for all plots.
Vigor by Spp	Frequency distribution of vigor classes listed by species.
Damage	List of most frequent damage classes with number of occurrences and percent of total stems impacted by each.
Damage by Spp	Damage values tallied by type for each species.
Damage by Plot	Damage values tallied by type for each plot.
Planted Stems by Plot and Spp	A matrix of the count of PLANTED living stems of each species for each plot; dead and missing stems are excluded.
ALL Stems by Plot and spp	A matrix of the count of total living stems of each species (planted and natural volunteers combined) for each plot; dead and missing stems are excluded.
PROJECT SUMMARY----------	
Project Code	94687
Project Name	Crooked Creek #2 Restoration Project
Description	Crooked Creek #2 Restoration Project
Required Plots (calculated)	12
Sampled Plots	12

Table 10. Planted and Total Stem Counts
Crooked Creek #2 Restoration Project
DMS Project No. 94687
Monitoring Year 2 - 2017

			Current Plot Data (MY2 2017)																							
			94687-WEI-0001			94687-WEI-0002			94687-WEI-0003			94687-WEI-0004			94687-WEI-0005			94687-WEI-0006			94687-WEI-0007			94687-WEI-0008		
Scientific Name	**Common Name**	**Species Type**	**PnoLS**	**P-all**	**T**	**PnoLS**	**P-all**	**T**	**PnoLS**	**P-all**	**T**	**PnoLS**	**P-all**	**T**	**PnoLS**	**P-all**	**T**	**PnoLS**	**P-all**	**T**	**PnoLS**	**P-all**	**T**	**PnoLS**	**P-all**	**T**
Acer negundo	Box elder	Tree			2																		2			6
Acer rubrum	Red maple	Tree										1	1	1										3	3	3
Betula nigra	River birch	Tree				1	1	1										3	3	3				1	1	1
Carpinus caroliniana	Ironwood	Shrub Tree																								
Celtis laevigata	Southern Hackberry, Sugarberr	Shrub Tree																								
Cornus florida	Flowering dogwood	Shrub Tree																								
Diospyros virginiana	American persimmon	Tree																						4	4	4
Fraxinus pennsylvanica	Green ash	Tree			4						8			1									6			
Juglans nigra	Black walnut	Tree																								
Liquidambar styraciflua	Sweet gum	Tree			1																		4			
Liriodendron tulipifera	Tulip poplar	Tree																								
Nyssa sylvatica	Black Gum	Tree																			1	1	1			
Platanus occidentalis	Sycamore	Tree	5	5	5	3	3	3										2	2	33				2	2	2
Quercus sp.	Oak	Shrub Tree																1	1	1						
Quercus lyrata	Overcup oak	Tree				2	2	2																		
Quercus nigra	Water oak	Tree																			3	3	3	1	1	1
Quercus phellos	Willow oak	Tree				1	1	1													3	3	3			
Taxodium distichum	Bald-cypress	Tree							3	3	3				9	9	9									
Ulmus alata	Winged elm	Tree																					5			
Ulmus americana	American elm	Tree																								
		Stem count	5	5	12	7	7	7	3	3	11	1	1	2	9	9	9	6	6	37	7	7	24	11	11	17
		size (ares)	1			1			1			1			1			1			1			1		
		size (ACRES)	0.02			0.02			0.02			0.02			0.02			0.02			0.02			0.02		
		Species count	1	1	4	4	4	4	1	1	2	1	1	2	1	1	1	3	3	3	3	3	7	5	5	6
		Stems per ACRE	202	202	486	283	283	283	121	121	445	40	40	81	364	364	364	243	243	1497	283	283	971	445	445	688

Color for Density

Exceeds requirements by 10%
Exceeds requirements, but by less than 10%
Fails to meet requirements, by less than 10%
Fails to meet requirements by more than 10%

PnoLS: Number of planted stems excluding live stakes
P-all: Number of planted stems including live stakes
T: Total stems

Table 10. Planted and Total Stem Counts
Crooked Creek #2 Restoration Project
DMS Project No. 94687
Monitoring Year 2 - 2017

			Current Plot Data (MY2 2017)												Annual Means								
			94687-WEI-0009			94687-WEI-0010			94687-WEI-0011			94687-WEI-0012			MY2 (2017)			MY1 (2016)			MY0 (2016)		
Scientific Name	**Common Name**	**Species Type**	**PnoLS**	**P-all**	**T**	**PnoLS**	**P-all**	**T**	**PnoLS**	**P-all**	**T**	**PnoLS**	**P-all**	**T**	**PnoLS**	**P-all**	**T**	**PnoLS**	**P-all**	**T**	**PnoLS**	**P-all**	**T**
Acer negundo	Box elder	Tree			4			2			4			23			43			18			17
Acer rubrum	Red maple	Tree	7	7	7										11	11	11	13	13	13	14	14	14
Betula nigra	River birch	Tree				2	2	2	5	5	5			2	12	12	14	14	14	15	18	18	18
Carpinus caroliniana	Ironwood	Shrub Tree																					2
Celtis laevigata	Southern Hackberry, Sugarberr	Shrub Tree			1									3			4			1			
Cornus florida	Flowering dogwood	Shrub Tree										2	2	2	2	2	2	2	2	2	6	6	6
Diospyros virginiana	American persimmon	Tree	3	3	3										7	7	7	10	10	13	27	27	27
Fraxinus pennsylvanica	Green ash	Tree			1			4			1						25			26			45
Juglans nigra	Black walnut	Tree												4			4						1
Liquidambar styraciflua	Sweet gum	Tree									1			1			7			7			4
Liriodendron tulipifera	Tulip poplar	Tree												1			1			1			2
Nyssa sylvatica	Black Gum	Tree										1	1	1	2	2	2	3	3	3	7	7	7
Platanus occidentalis	Sycamore	Tree			1										12	12	44	13	13	26	15	15	16
Quercus sp.	Oak	Shrub Tree													1	1	1	16	16	16	53	53	53
Quercus lyrata	Overcup oak	Tree	1	1	1	1	1	1	3	3	3	2	2	2	9	9	9	7	7	7			
Quercus nigra	Water oak	Tree							6	6	6	1	1	1	11	11	11	2	2	2			
Quercus phellos	Willow oak	Tree	1	1	1										5	5	5	2	2	2			
Taxodium distichum	Bald-cypress	Tree													12	12	12	13	13	13	16	16	16
Ulmus alata	Winged elm	Tree															5						1
Ulmus americana	American elm	Tree																		7			
		Stem count	12	12	19	3	3	9	14	14	20	6	6	40	84	84	207	95	95	172	156	156	229
		size (ares)	1			1			1			1			12			12			12		
		size (ACRES)	0.02			0.02			0.02			0.02			0.30			0.30			0.30		
		Species count	4	4	8	2	2	4	3	3	6	4	4	10	11	11	18	11	11	17	8	8	15
		Stems per ACRE	486	486	769	121	121	364	567	567	809	243	243	1619	283	283	698	320	320	580	526	526	772

Color for Density

Exceeds requirements by 10%
Exceeds requirements, but by less than 10%
Fails to meet requirements, by less than 10%
Fails to meet requirements by more than 10%

PnoLS: Number of planted stems excluding live stakes
P-all: Number of planted stems including live stakes
T: Total stems

APPENDIX 4. Morphological Summary Data and Plots

Table 11. Baseline Stream Data Summary
Crooked Creek #2 Restoration Project
DMS Project No. 94687
Monitoring Year 2 - 2017

UT1

		Pre-Restoration Condition				Reference Reach Data				Design		As-Built/Baseline	
Parameter	**Gage**	**UT1 Reach 1**		**UT1 Reach 2**		**UT to Lyle Creek**		**Spencer Creek 1**		**UT1**		**UT1**	
		Min	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Dimension and Substrate - Shallow													
Bankfull Width (ft)		17.7		10.9		7.0	8.6	8.7		12.0		11.7	12.6
Floodprone Width (ft)		500		539		45	49	229		44+		200+	
Bankfull Mean Depth		0.5		0.7		0.5		1.2		0.7		0.6	
Bankfull Max Depth		1.3		1.0		1.0	1.1	1.9		1.0		1.1	
Bankfull Cross-sectional Area (ft^2)	N/A	8.6		7.8		3.5	4.1	10.6		8.7		7.3	7.5
Width/Depth Ratio		36.4		15.3		14.9	18.3	7.3		16.6		18.9	21.1
Entrenchment Ratio		28.2		49.3		5.7	6.4	26.3		2.2+		2.2+	
Bank Height Ratio		1.4		2.9		0.6	0.9	1.0		1.0		1.0	
D50 (mm)		3.1		---								0.3	35.9
Riffle Length (ft)						---		---		---		12	50
Riffle Slope (ft/ft)		*		*		0.0055	0.0597	0.0100	0.0670	0.0045	0.0080	0.0004	0.0193
Pool Length (ft)	N/A					---		---		---		17.8	65.4
Pool Max Depth (ft)		0.76	1.27	0.76	1.27	1.3		2.5		1.5	2.1	1.1	3.0
Pool Spacing (ft)		20	74	20	74	15	28	13	47	42	84	36	99
Pool Volume (ft^3)													
Pattern													
Channel Beltwidth (ft)		---		115	543	21		24	52	30	72	30	72
Radius of Curvature (ft)		61.2	170.6	61.2	170.6	19	32	5	22	22	48	22	48
Rc:Bankfull Width (ft/ft)	N/A	3.5	9.6	3.5	9.6	2.7	3.7	0.6	2.5	1.8	4.0	1.8	4.0
Meander Length (ft)		---		163	400	39	44	54	196	72	132	102	135
Meander Width Ratio		---		10.5	49.7	2.4	3	2.8	6.0	2.5	6.0	2.5	6.0
Substrate, Bed and Transport Parameters													
Ri%/Ru%/P%/G%/S%													
SC%/Sa%/G%/C%/B%/Be%													
d16/d35/d50/d84/d95/d100	N/A	-/-/3.1/8.6/11.0/16.0		---		-/0.1/0.2/0.5/4.0/8.0		0.1/3.0/8.8/77/180/-				SC/SC/0.1/19/90/256	
Reach Shear Stress (Competency) lb/ft^2		---		---						0.012		0.11	0.12
Max part size (mm) mobilized at bankfull													
Stream Power (Capacity) W/m^2													
Additional Reach Parameters													
Drainage Area (SM)		0.24		N/A		0.25		0.50		0.24		0.24	
Watershed Impervious Cover Estimate (%)		<1%		<1%		---		---		<1%		<1%	
Rosgen Classification		N/A[1]		N/A[1]		C5/6		E4/C4		C4		C4	
Bankfull Velocity (fps)		3.5		4.1		4.7		---		3.4		2.2	
Bankfull Discharge (cfs)		30		N/A[2]		18		---		30		16	
Q-NFF regression (2-yr)		50		N/A[2]									
Q-USGS extrapolation (1.2-yr)	N/A	17	40	N/A[2]									
Q-Mannings		24		N/A[2]									
Valley Length (ft)		---		---		---		---		1,353		1,353	
Channel Thalweg Length (ft)		1,789				---		---		1,718		1,718	
Sinuosity		1.0		1.5		1.1		1.1		1.3		1.3	
Water Surface Slope ($ft/ft)^2$		0.0071		0.0034		0.004		0.0132		0.0032		0.0034	
Bankfull Slope (ft/ft)		0.0066		0.0058		0.009		0.0139		0.0041		0.0036	

SC: Silt/Clay <0.062 mm diameter particles
(---): Data was not provided
N/A: Not Applicable
N/A[1]: The rosgen classification system is for natural streams. These channels have been heavily manipulated by man and therefore the Rosgen classification system is not applicable
N/A[2]: Donstream of the confluence with overflow channel, hydraulic regime not applied
*: Channel was dry during survey, slope was calculated using channel thalweg

Table 12. Morphology and Hydraulic Summary (Dimensional Parameters - Cross-Section)

Crooked Creek #2 Restoration Project

DMS Project No. 94687

Monitoring Year 2 - 2017

	Cross-Section 1, UT1 (Pool)						Cross-Section 2, UT1 (Riffle)						Cross-Section 3, UT1 (Pool)						Cross-Section 4, UT1 (Riffle)					
Dimension and Substrate	**Base**	**MY1**	**MY2**	**MY3**	**MY4**	**MY5**	**Base**	**MY1**	**MY2**	**MY3**	**MY4**	**MY5**	**Base**	**MY1**	**MY2**	**MY3**	**MY4**	**MY5**	**Base**	**MY1**	**MY2**	**MY3**	**MY4**	**MY5**
based on fixed bankfull elevation	541.8	541.9	541.8				542.1	542.0	542.1				539.7	539.7	539.7				539.8	539.8	539.8			
Bankfull Width (ft)	13.3	12.7	13.6				11.7	11.1	11.4				12.6	12.3	12.2				12.6	11.9	12.0			
Floodprone Width (ft)	---	---	---				200+	200+	200+				---	---	---				200+	200+	200+			
Bankfull Mean Depth (ft)	0.7	0.7	0.6				0.6	0.5	0.6				1.0	0.9	1.0				0.6	0.7	0.6			
Bankfull Max Depth (ft)	1.5	1.4	1.4				1.1	0.9	1.0				2.4	2.2	2.1				1.1	1.0	1.2			
Bankfull Cross-Sectional Area (ft^2)	8.7	8.5	8.3				7.3	5.9	6.5				12.6	11.4	12.3				7.5	7.8	7.6			
Bankfull Width/Depth Ratio	20.4	18.9	22.4				18.9	20.8	20.1				12.7	13.4	12.1				21.1	18.0	18.9			
Bankfull Entrenchment Ratio	---	---	---				2.2+	2.2+	2.2+				---	---	---				2.2+	2.2+	2.2+			
Bankfull Bank Height Ratio	---	---	---				1.0	1.0	1.0				---	---	---				1.0	1.0	1.0			

Table 13. Monitoring Data - Stream Reach Data Summary
Crooked Creek #2 Restoration Project
DMS Project No. 94687
Monitoring Year 2 - 2017

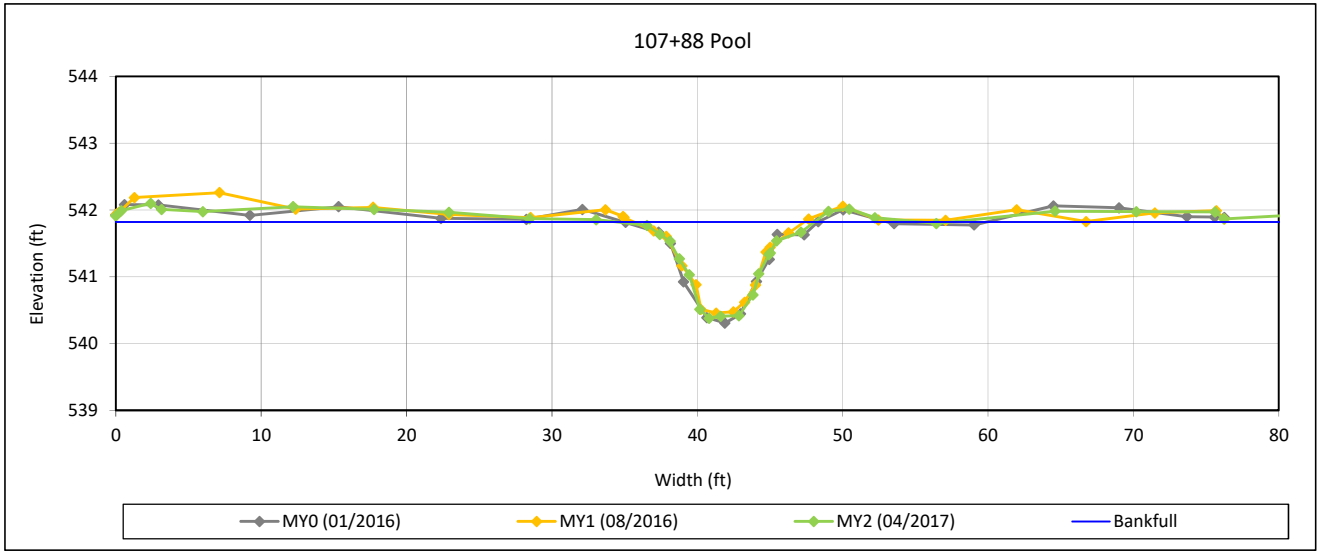
UT1

Parameter	As-Built/Baseline		MY-1		MY-2		MY-3		MY-4		MY-5	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Dimension and Substrate - Riffle												
Bankfull Width (ft)	11.7	12.6	11.1	11.9	11.4	12.0						
Floodprone Width (ft)	200+		200+		200+							
Bankfull Mean Depth	0.6		0.5	0.7	0.6							
Bankfull Max Depth	1.1		0.9	1.0	1.0	1.2						
Bankfull Cross-sectional Area (ft^2)	7.3	7.5	5.9	7.8	6.5	7.6						
Width/Depth Ratio	18.9	21.1	18.0	20.8	18.9	20.1						
Entrenchment Ratio	2.2+		2.2+		2.2+							
Bank Height Ratio	1.0		1.0		2.0							
D50 (mm)	0.3	35.9	SC	65.6	SC	66.2						
Profile												
Riffle Length (ft)	12	50										
Riffle Slope (ft/ft)	0.0004	0.0193										
Pool Length (ft)	18	65										
Pool Max Depth (ft)	1.1	3.0										
Pool Spacing (ft)	36	99										
Pool Volume (ft^3)												
Pattern												
Channel Beltwidth (ft)	30	72										
Radius of Curvature (ft)	22	48										
Rc:Bankfull Width (ft/ft)	1.8	4.0										
Meander Wave Length (ft)	102	135										
Meander Width Ratio	2.5	6.0										
Additional Reach Parameters												
Rosgen Classification	C4											
Channel Thalweg Length (ft)	1,718											
Sinuosity (ft)	1.3											
Water Surface Slope (ft/ft)	0.0034											
Bankfull Slope (ft/ft)	0.004											
Ri%/Ru%/P%/G%/S%												
SC%/Sa%/G%/C%/B%/Be%												
d16/d35/d50/d84/d95/d100	SC/SC/0.1/19/90/256											
% of Reach with Eroding Banks												

Cross Section Plots

Crooked Creek #2 Stream and Wetland Mitigation Site
DMS Project No. 94687
Monitoring Year 2 - 2017

Cross Section 1-UT1



Bankfull Dimensions

8.3	x-section area (ft.sq.)
13.6	width (ft)
0.6	mean depth (ft)
1.4	max depth (ft)
14.1	wetted perimeter (ft)
0.6	hydraulic radius (ft)
22.4	width-depth ratio

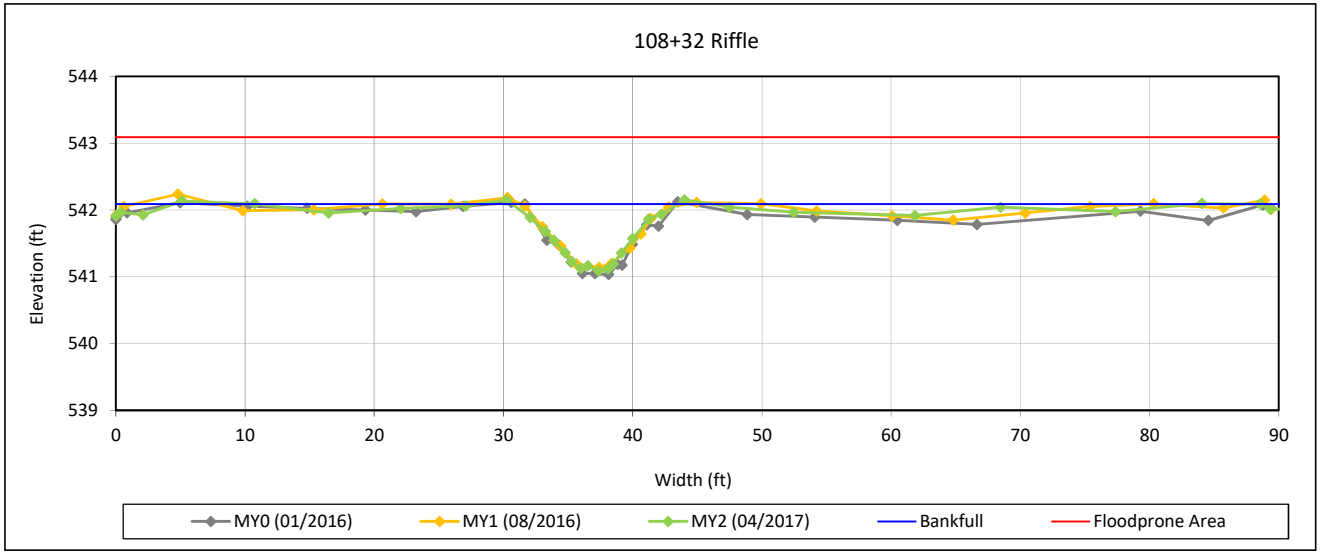
Survey Date: 4/2017
Field Crew: Wildlands Engineering

View Downstream

Cross Section Plots

Crooked Creek #2 Stream and Wetland Mitigation Site
DMS Project No. 94687
Monitoring Year 2 - 2017

Cross Section 2-UT1



Bankfull Dimensions

6.5	x-section area (ft.sq.)
11.4	width (ft)
0.6	mean depth (ft)
1.0	max depth (ft)
11.6	wetted perimeter (ft)
0.6	hydraulic radius (ft)
20.1	width-depth ratio
150.0	W flood prone area (ft)
13.1	entrenchment ratio
1.0	low bank height ratio

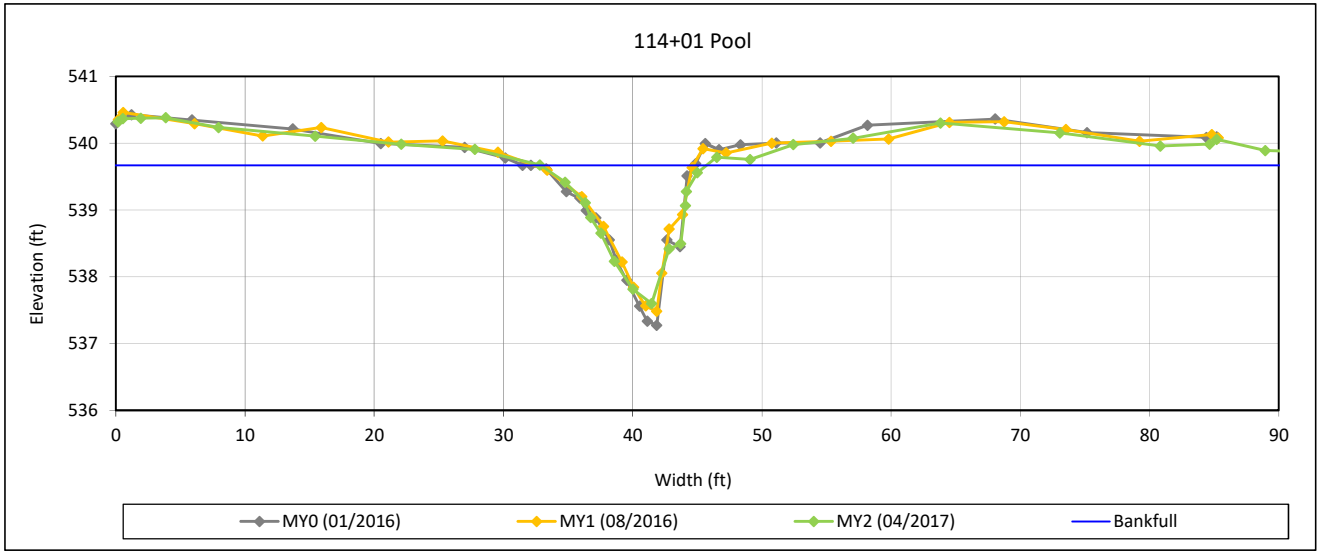
Survey Date: 04/2017
Field Crew: Wildlands Engineering

View Downstream

Cross Section Plots

Crooked Creek #2 Stream and Wetland Mitigation Site
DMS Project No. 94687
Monitoring Year 2 - 2017

Cross Section 3-UT1



Bankfull Dimensions

12.3	x-section area (ft.sq.)
12.2	width (ft)
1.0	mean depth (ft)
2.1	max depth (ft)
13.2	wetted perimeter (ft)
0.9	hydraulic radius (ft)
12.1	width-depth ratio

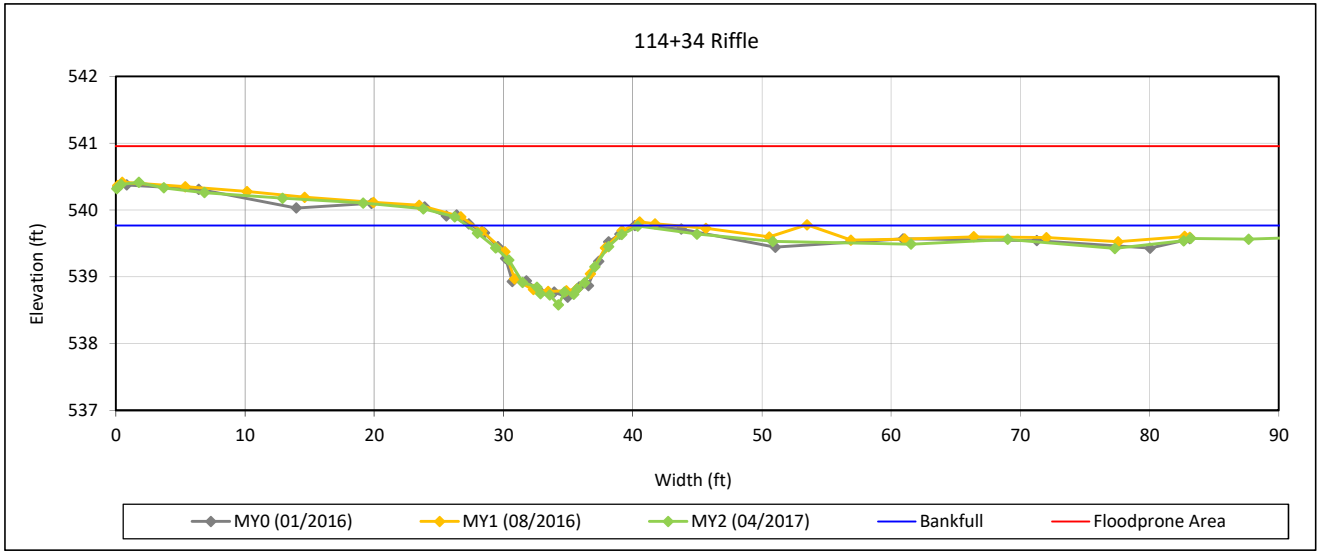
Survey Date: 04/2017
Field Crew: Wildlands Engineering

View Downstream

Cross Section Plots

Crooked Creek #2 Stream and Wetland Mitigation Site
DMS Project No. 94687
Monitoring Year 2 - 2017

Cross Section 4-UT1



Bankfull Dimensions

7.6	x-section area (ft.sq.)
12.0	width (ft)
0.6	mean depth (ft)
1.2	max depth (ft)
12.3	wetted perimeter (ft)
0.6	hydraulic radius (ft)
18.9	width-depth ratio
150.0	W flood prone area (ft)
12.5	entrenchment ratio
1.0	low bank height ratio

Survey Date: 04/2017
Field Crew: Wildlands Engineering

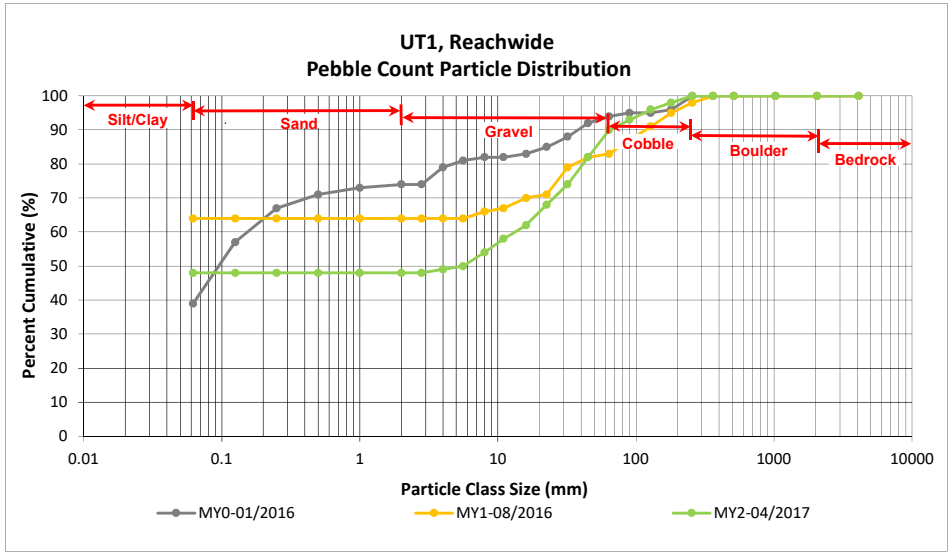
View Downstream

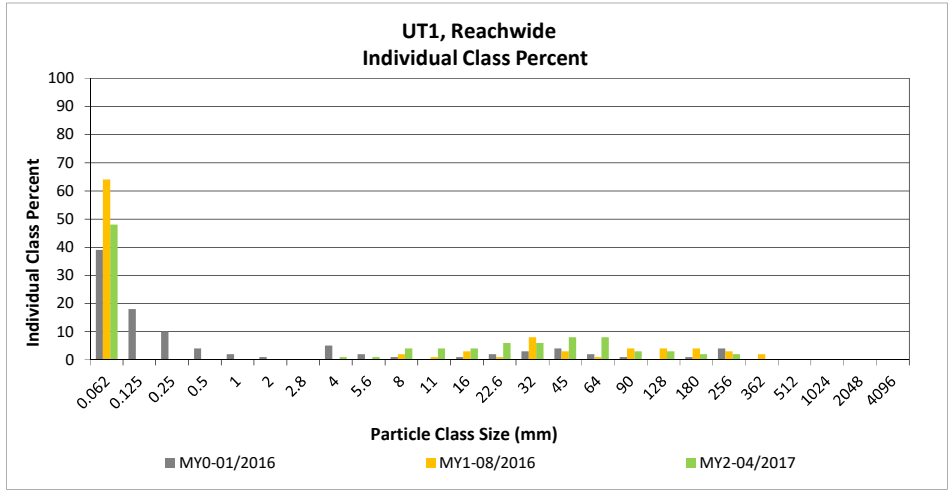
Reachwide and Cross-Section Pebble Count Plots

Crooked Creek #2 Stream and Wetland Mitigation Site
DMS Project No. 94687
Monitoring Year 2 - 2017
UT1, Reachwide

Particle Class		Diameter (mm)		Particle Count			Reach Summary	
		min	max	Riffle	Pool	Total	Class Percentage	Percent Cumulative
SILT/CLAY	Silt/Clay	0.000	0.062	8	40	48	48	48
SAND	Very fine	0.062	0.125					48
	Fine	0.125	0.250					48
	Medium	0.25	0.50					48
	Coarse	0.5	1.0					48
	Very Coarse	1.0	2.0					48
GRAVEL	Very Fine	2.0	2.8					48
	Very Fine	2.8	4.0	1		1	1	49
	Fine	4.0	5.6	1		1	1	50
	Fine	5.6	8.0	3	1	4	4	54
	Medium	8.0	11.0	2	2	4	4	58
	Medium	11.0	16.0	2	2	4	4	62
	Coarse	16.0	22.6	4	2	6	6	68
	Coarse	22.6	32	3	3	6	6	74
	Very Coarse	32	45	8		8	8	82
	Very Coarse	45	64	8		8	8	90
COBBLE	Small	64	90	3		3	3	93
	Small	90	128	3		3	3	96
	Large	128	180	2		2	2	98
	Large	180	256	2		2	2	100
BOULDER	Small	256	362					100
	Small	362	512					100
	Medium	512	1024					100
	Large/Very Large	1024	2048					100
BEDROCK	Bedrock	2048	>2048					100
			Total	**50**	**50**	**100**	**100**	**100**

Reachwide	
Channel materials (mm)	
D_{16} =	Silt/Clay
D_{35} =	Silt/Clay
D_{50} =	5.6
D_{84} =	49.1
D_{95} =	113.8
D_{100} =	256.0



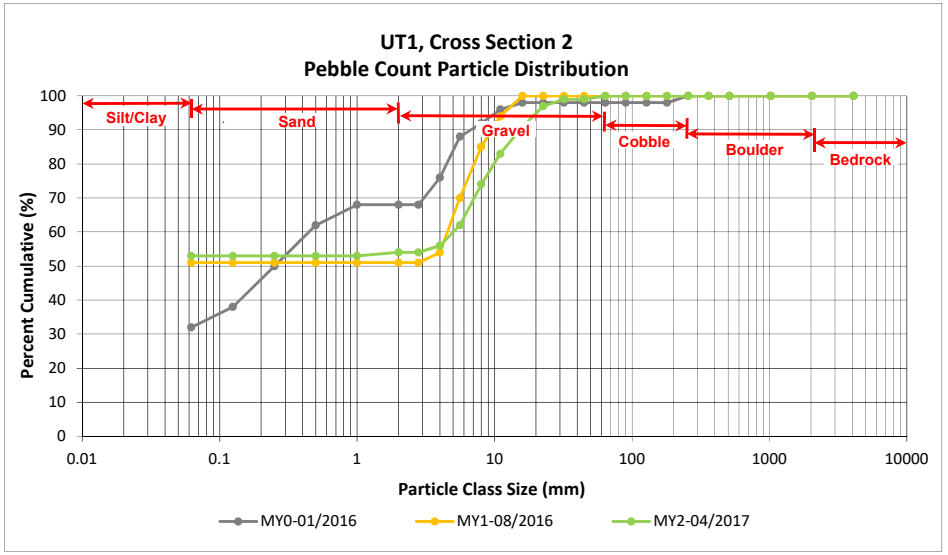


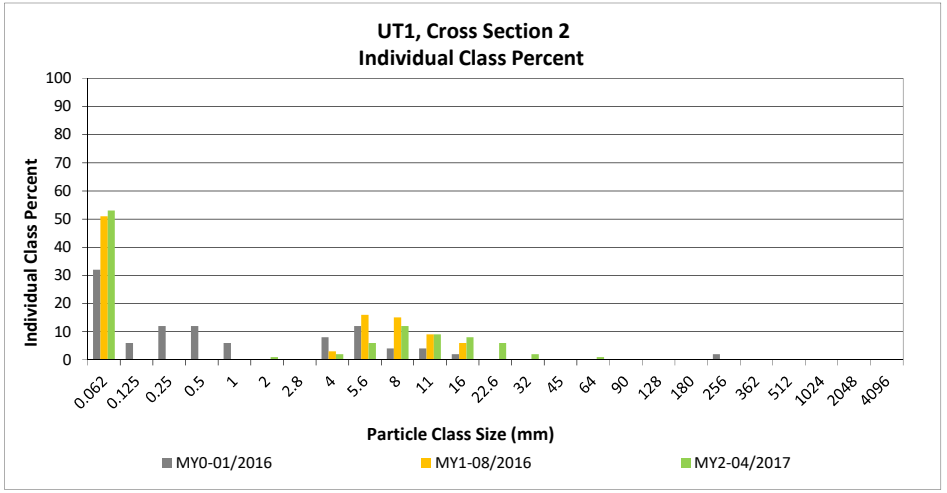
Reachwide and Cross-Section Pebble Count Plots

Crooked Creek #2 Stream and Wetland Mitigation Site
DMS Project No. 94687
Monitoring Year 2 - 2017
UT1, Cross Section 2

Particle Class		Diameter (mm)		Riffle 100-Count	Summary	
		min	max		Class Percentage	Percent Cumulative
SILT/CLAY	Silt/Clay	0.000	0.062	53	53	53
SAND	Very fine	0.062	0.125			53
	Fine	0.125	0.250			53
	Medium	0.25	0.50			53
	Coarse	0.5	1.0			53
	Very Coarse	1.0	2.0	1	1	54
GRAVEL	Very Fine	2.0	2.8			54
	Very Fine	2.8	4.0	2	2	56
	Fine	4.0	5.6	6	6	62
	Fine	5.6	8.0	12	12	74
	Medium	8.0	11.0	9	9	83
	Medium	11.0	16.0	8	8	91
	Coarse	16.0	22.6	6	6	97
	Coarse	22.6	32	2	2	99
	Very Coarse	32	45			99
	Very Coarse	45	64	1	1	100
COBBLE	Small	64	90			100
	Small	90	128			100
	Large	128	180			100
	Large	180	256			100
BOULDER	Small	256	362			100
	Small	362	512			100
	Medium	512	1024			100
	Large/Very Large	1024	2048			100
BEDROCK	Bedrock	2048	>2048			100
			Total	**100**	**100**	**100**

Cross Section 2	
Channel materials (mm)	
D_{16} =	Silt/Clay
D_{35} =	Silt/Clay
D_{50} =	Silt/Clay
D_{84} =	11.5
D_{95} =	20.1
D_{100} =	64.0



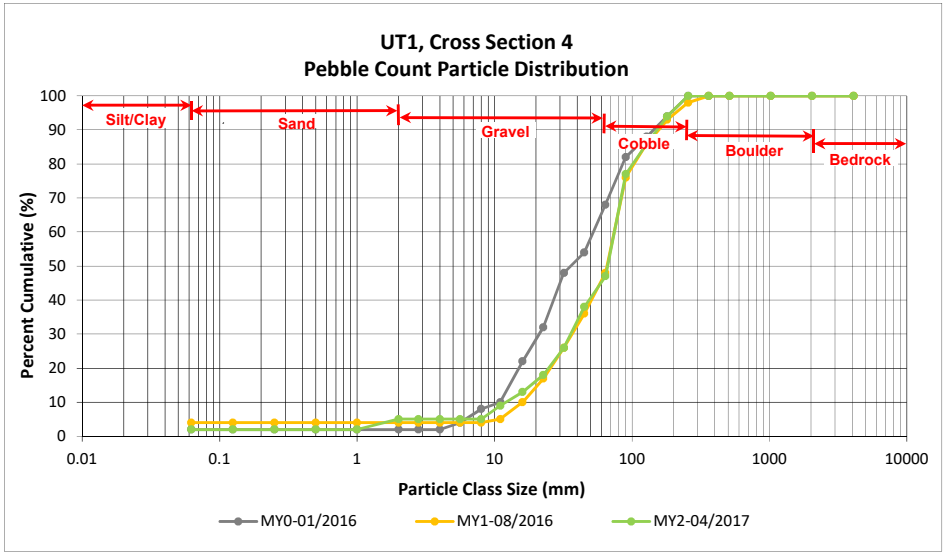


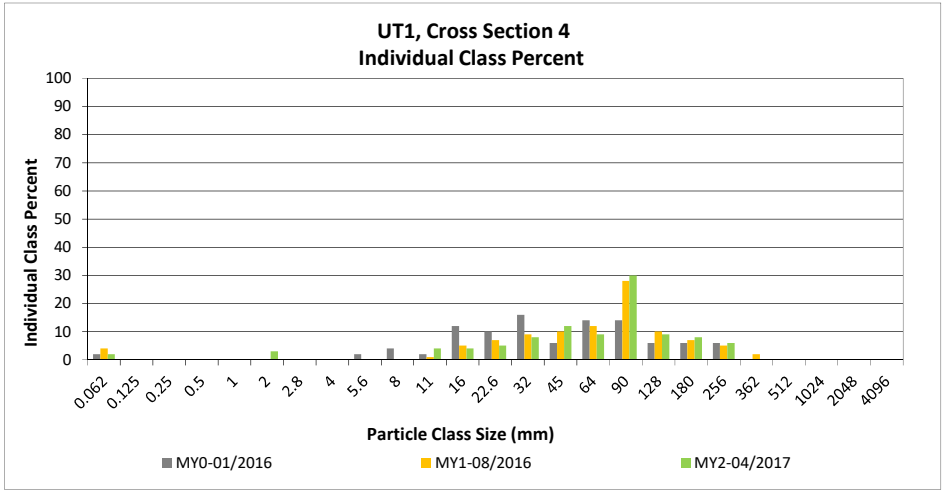
Reachwide and Cross-Section Pebble Count Plots

Crooked Creek #2 Stream and Wetland Mitigation Site
DMS Project No. 94687
Monitoring Year 2 - 2017
UT1, Cross Section 4

Particle Class		Diameter (mm)		Riffle 100-Count	Summary	
		min	max		Class Percentage	Percent Cumulative
SILT/CLAY	Silt/Clay	0.000	0.062	2	2	2
SAND	Very fine	0.062	0.125			2
	Fine	0.125	0.250			2
	Medium	0.25	0.50			2
	Coarse	0.5	1.0			2
	Very Coarse	1.0	2.0	3	3	5
GRAVEL	Very Fine	2.0	2.8			5
	Very Fine	2.8	4.0			5
	Fine	4.0	5.6			5
	Fine	5.6	8.0			5
	Medium	8.0	11.0	4	4	9
	Medium	11.0	16.0	4	4	13
	Coarse	16.0	22.6	5	5	18
	Coarse	22.6	32	8	8	26
	Very Coarse	32	45	12	12	38
	Very Coarse	45	64	9	9	47
COBBLE	Small	64	90	30	30	77
	Small	90	128	9	9	86
	Large	128	180	8	8	94
	Large	180	256	6	6	100
BOULDER	Small	256	362			100
	Small	362	512			100
	Medium	512	1024			100
	Large/Very Large	1024	2048			100
BEDROCK	Bedrock	2048	>2048			100
			Total	**100**	**100**	**100**

Cross Section 4	
Channel materials (mm)	
D_{16} =	19.68
D_{35} =	41.32
D_{50} =	66.2
D_{84} =	118.4
D_{95} =	190.9
D_{100} =	256.0





APPENDIX 5. Hydrology Summary Data and Plots

Table 14. Verification of Bankfull Events

Crooked Creek #2 Restoration Project
DMS Project No. 94687
Monitoring Year 2 - 2017

UT1, UT2, Crooked Creek

Reach	MY of Occurrence	Date of Data Collection	Date of Occurrence	Method
UT1	1	8/18/2016	7/11/2016	Crest
	N/A	11/9/2016	N/A	
	2	6/28/2017	6/20/2017	Crest/Stream
UT2	1	8/18/2016	7/11/2016	Crest
	1	11/9/2016	10/8/2016	
	2	6/28/2017	6/20/2017	Crest/Stream
Crooked Creek	1	8/18/2016	7/11/2016	Crest
	1	11/9/2016	10/8/2016	
	2	6/28/2017	6/20/2017	Crest/Stream

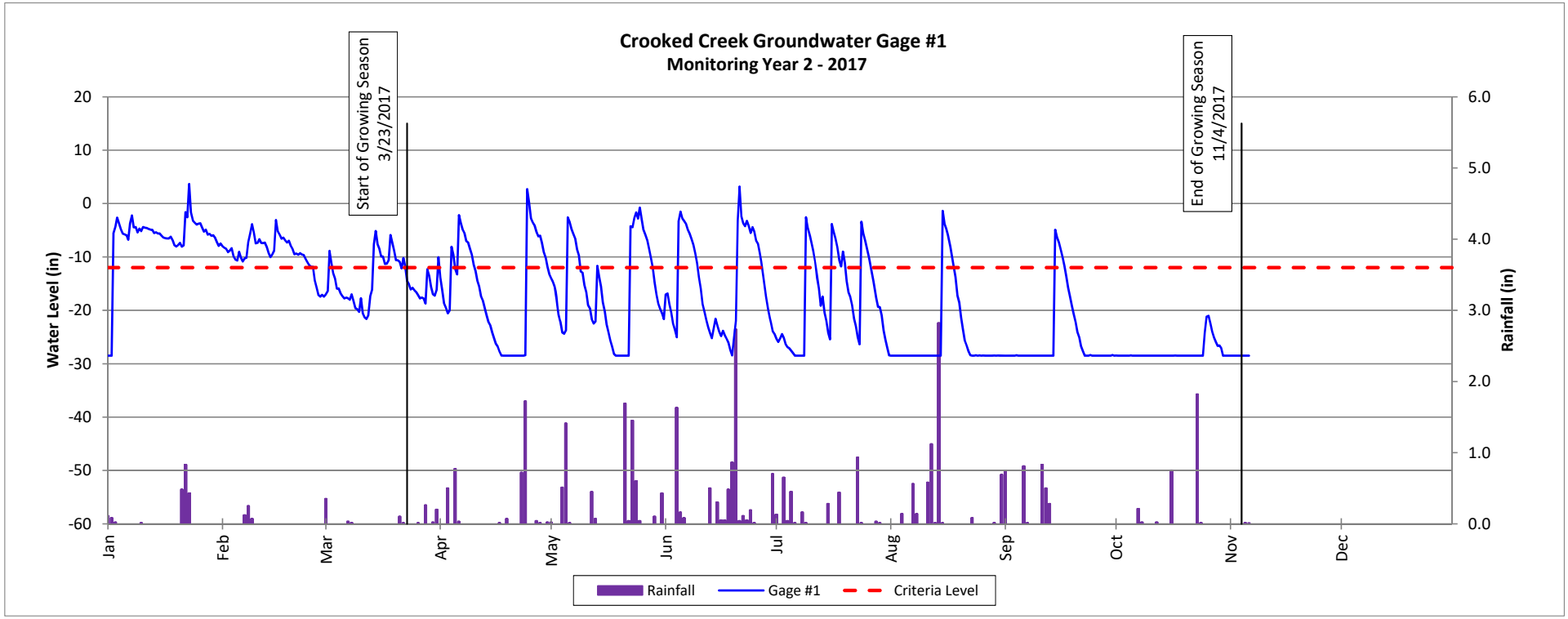
Table 15. Wetland Gage Attainment Summary

Crooked Creek #2 Restoration Project
DMS Project No. 964687
Monitoring Year 2 - 2017

Summary of Groundwater Gage Results for Monitoring Years 1 through 7					
Gage	Success Criteria Achieved/Max Consecutive Days During Growing Season				
	Year 1 (2016)	Year 2 (2017)	Year 3 (2018)	Year 4 (2019)	Year 5 (2020)
1	No/0 Days (0%)	No/7 Days (3%)			
2	No/2 Days (0.9%)	No/8 Days (4%)			
3	No/1 Days (0.4%)	No/9 Days (4%)			
4	No/0 Days (0%)	No/6 Days (3%)			
5	No/1 Days (0.4%)	No/7 Days (3%)			
6	Yes/26 Days (11.5%)	Yes/75 Days (33%)			
7	yes/18 Days (8%)	Yes/47 Days (21%)			
8	No/14 Days (6.2%)	Yes/31 Days (14%)			
9	No/1 Days (0.4%)	No/7 Days (3%)			
10	No/2 Days (0.9%)	No/11 Days (5%)			

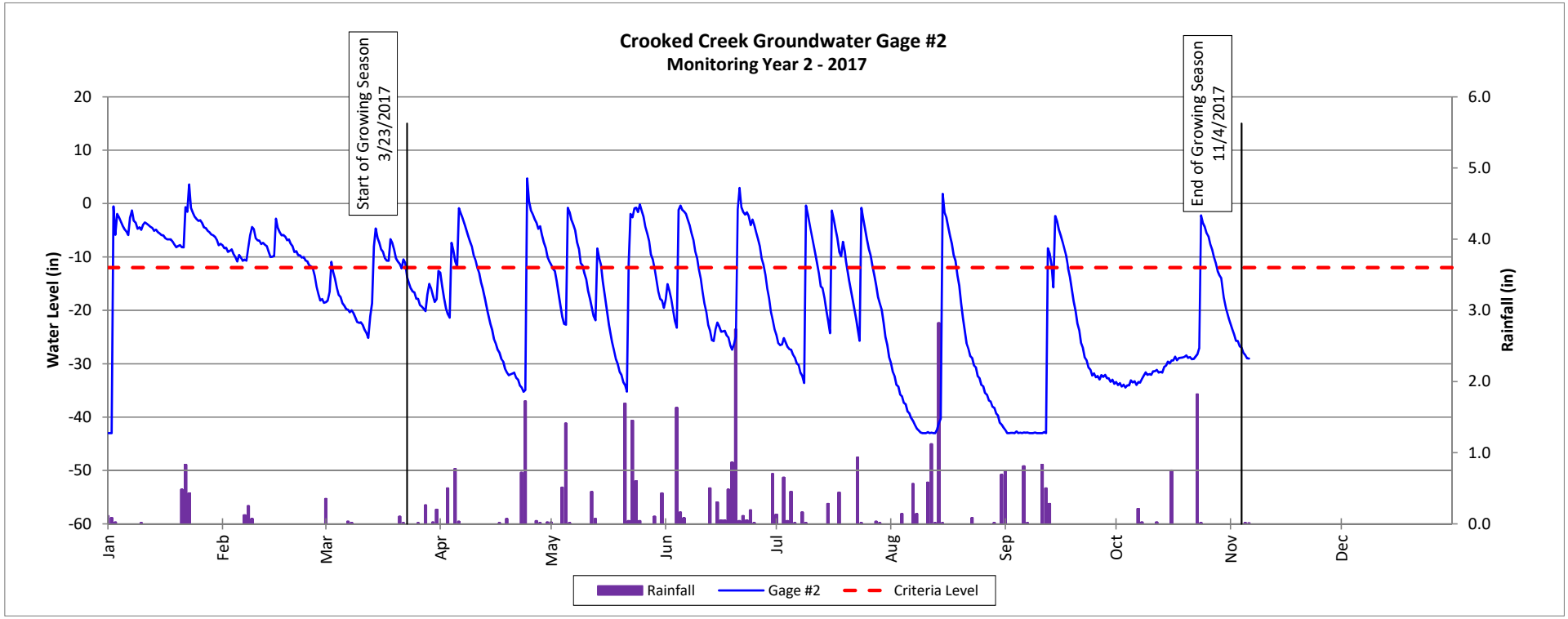
Groundwater Gage Plots

Crooked Creek #2 Restoration Project
DMS Project No. 94687
Monitoring Year 2 - 2017
Wetland Restoration



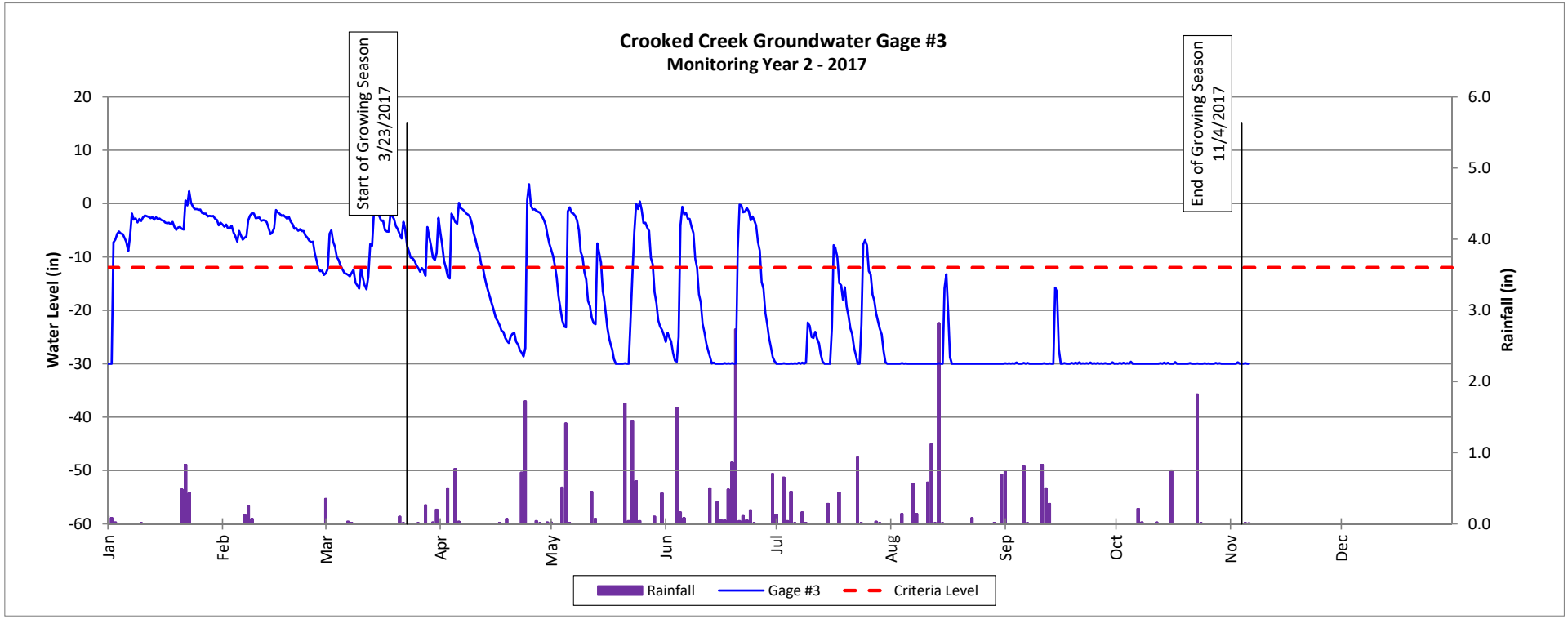
Groundwater Gage Plots

Crooked Creek #2 Restoration Project
DMS Project No. 94687
Monitoring Year 2 - 2017
Wetland Restoration



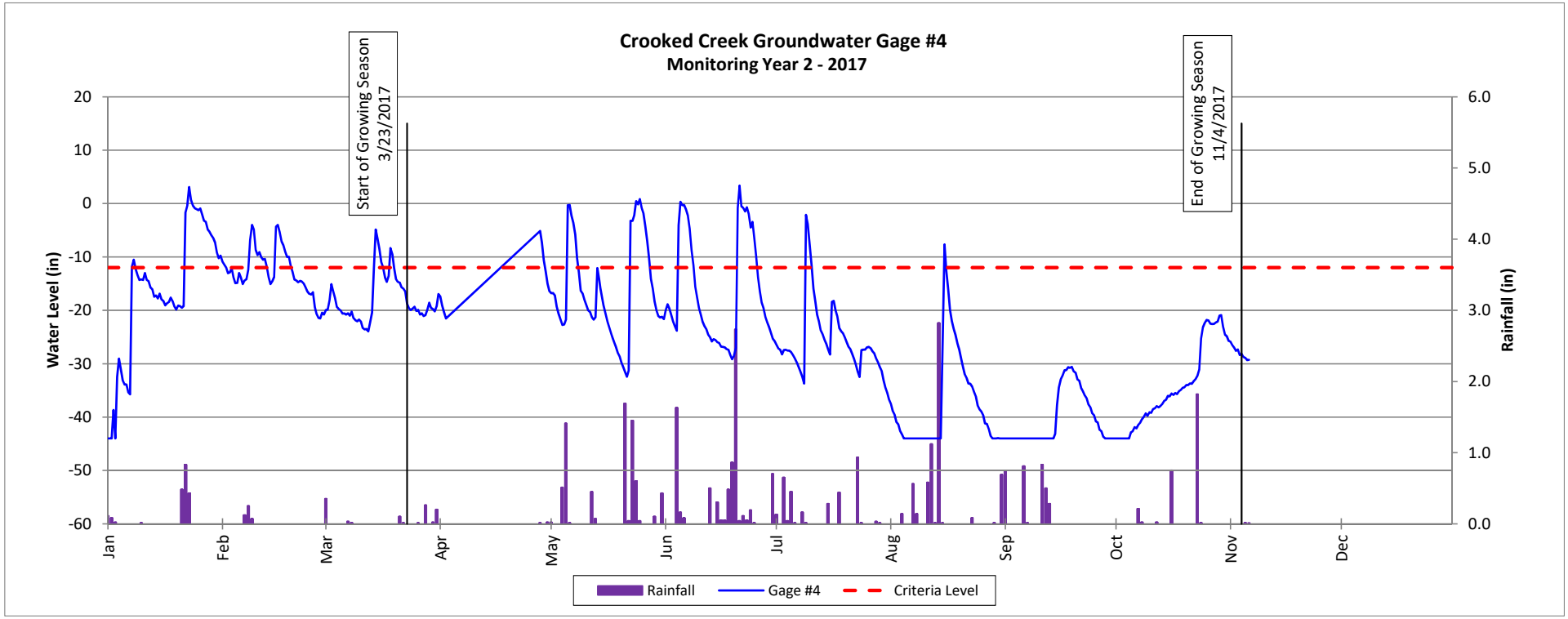
Groundwater Gage Plots

Crooked Creek #2 Restoration Project
DMS Project No. 94687
Monitoring Year 2 - 2017
Wetland Restoration



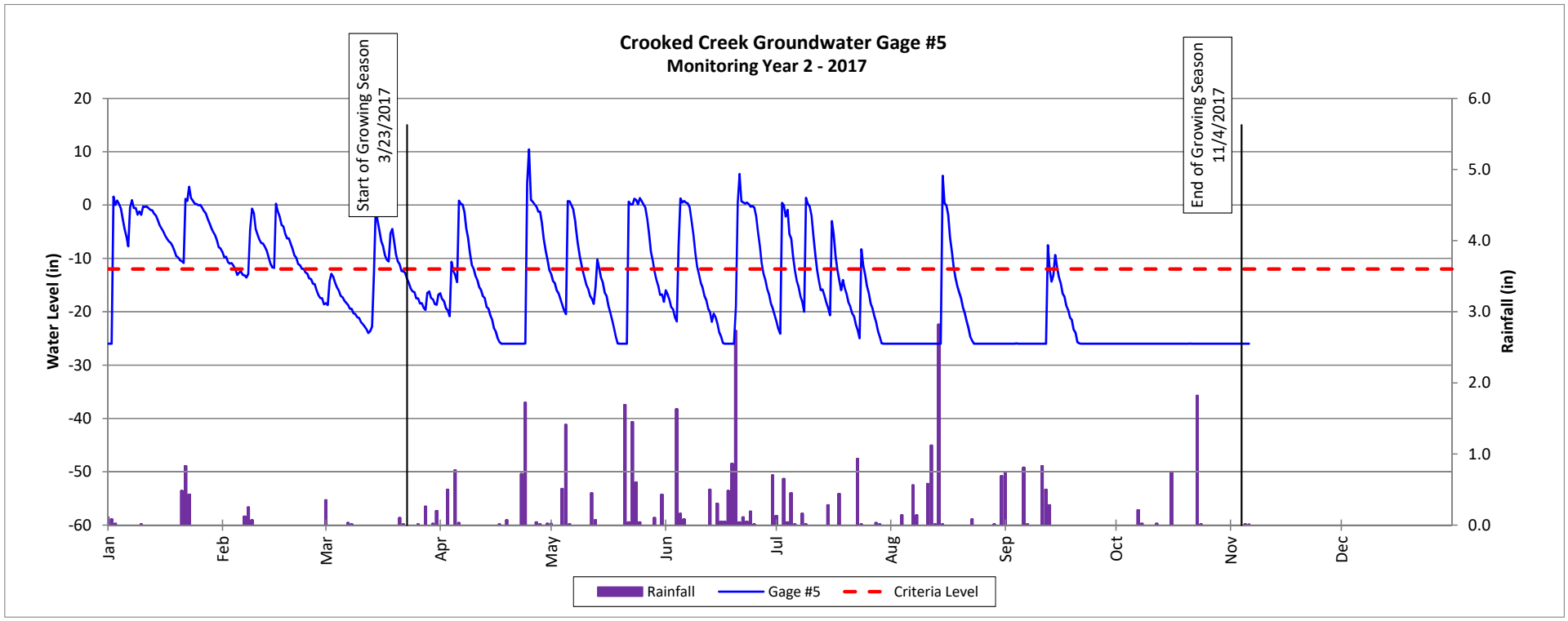
Groundwater Gage Plots

Crooked Creek #2 Restoration Project
DMS Project No. 94687
Monitoring Year 2 - 2017
Wetland Restoration



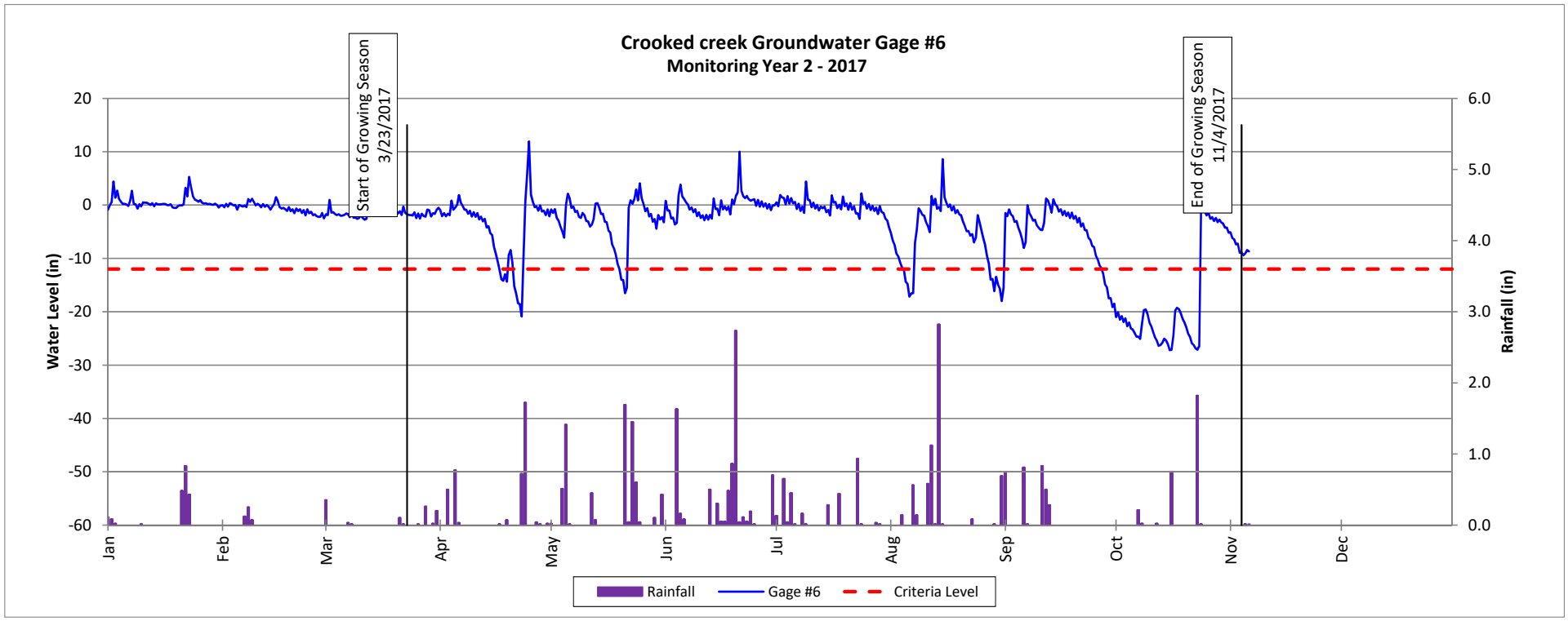
Groundwater Gage Plots

Crooked Creek #2 Restoration Project
DMS Project No. 94687
Monitoring Year 2 - 2017
Wetland Restoration



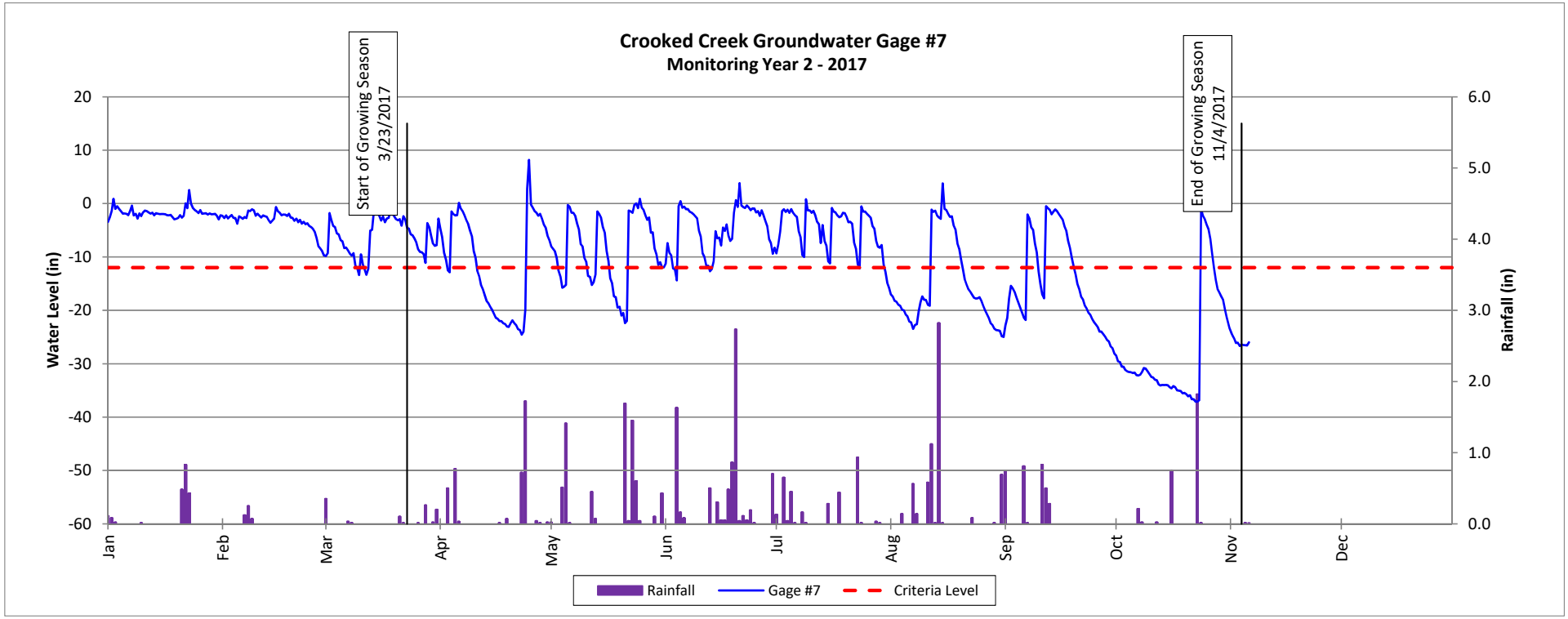
Groundwater Gage Plots

Crooked Creek #2 Restoration Project
DMS Project No. 94687
Monitoring Year 2 - 2017
Wetland Restoration



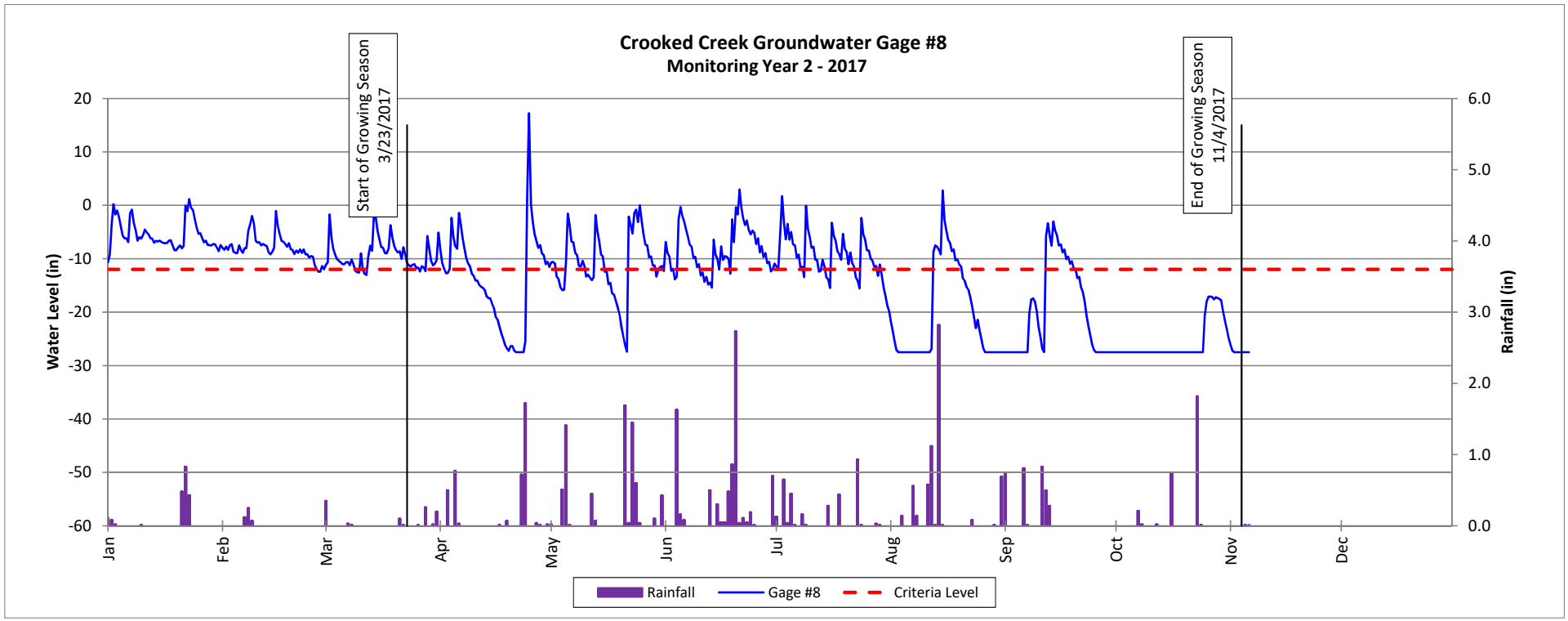
Groundwater Gage Plots

Crooked Creek #2 Restoration Project
DMS Project No. 94687
Monitoring Year 2 - 2017
Wetland Restoration



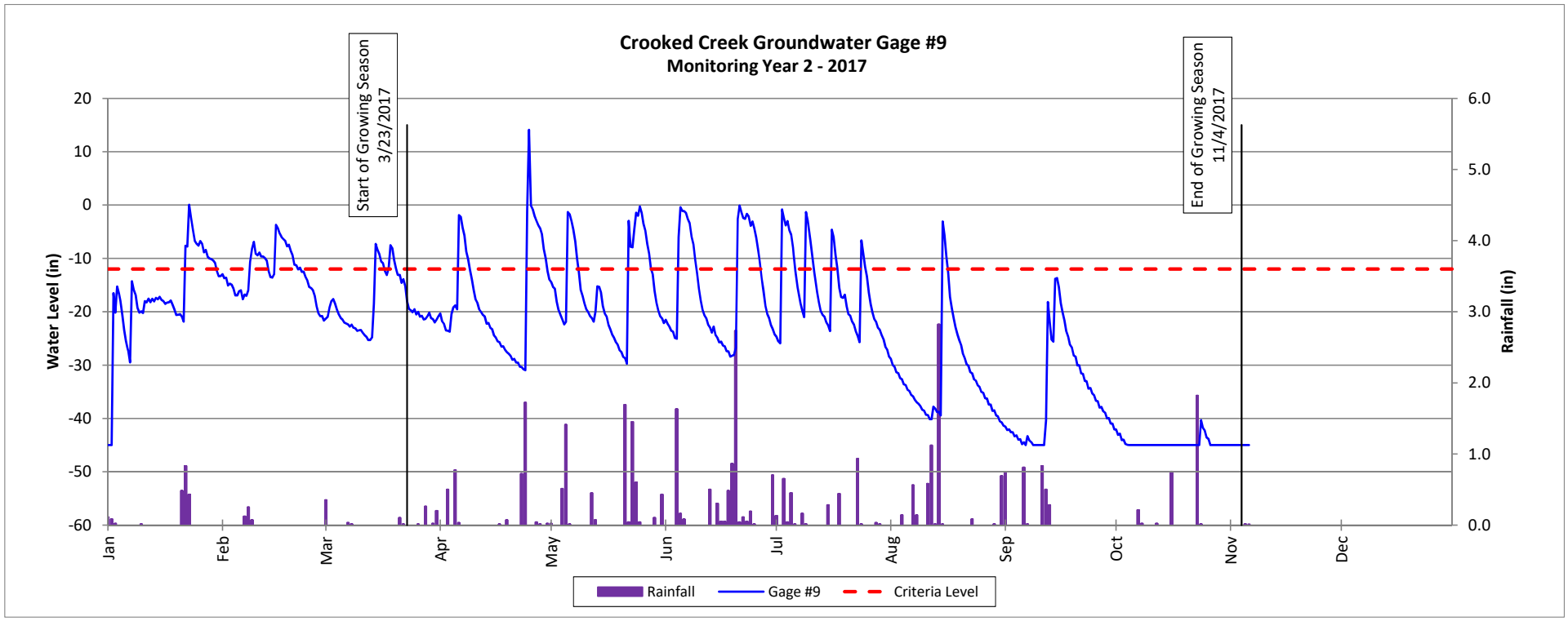
Groundwater Gage Plots

Crooked Creek #2 Restoration Project
DMS Project No. 94687
Monitoring Year 2 - 2017
Wetland Restoration



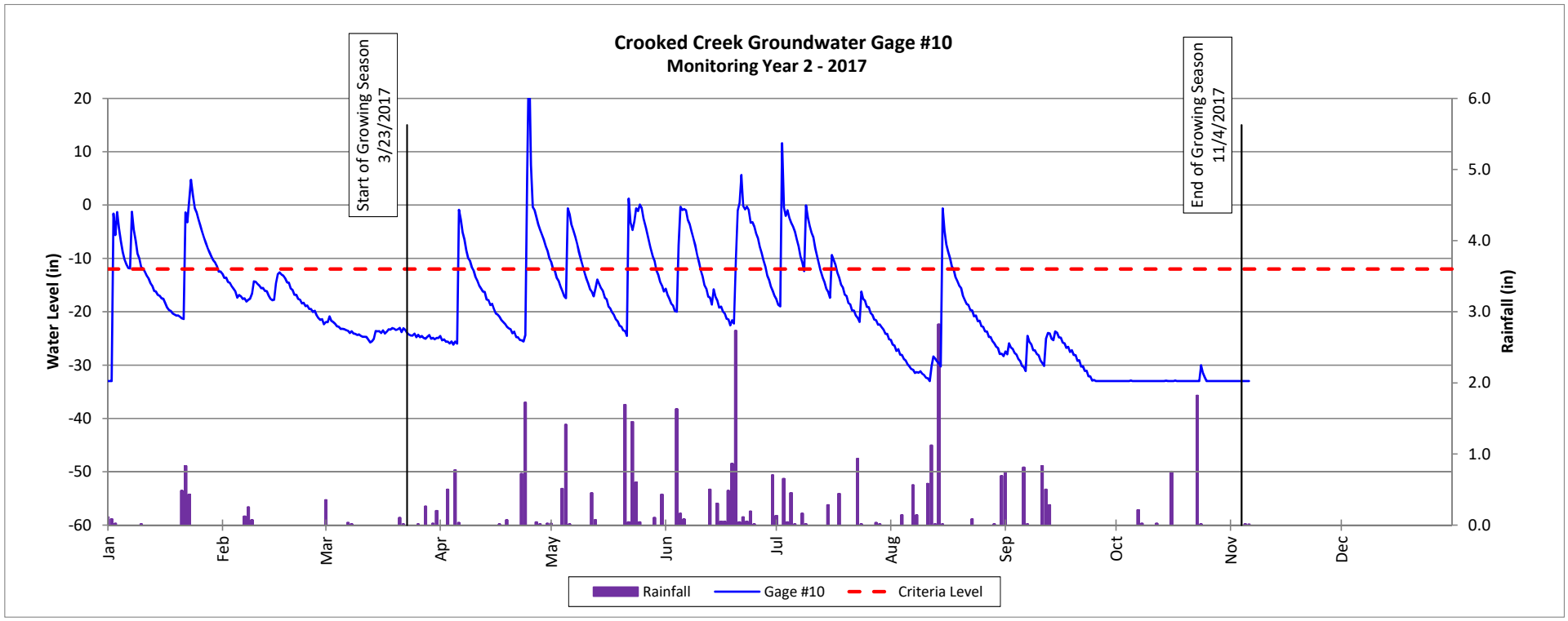
Groundwater Gage Plots

Crooked Creek #2 Restoration Project
DMS Project No. 94687
Monitoring Year 2 - 2017
Wetland Restoration



Groundwater Gage Plots

Crooked Creek #2 Restoration Project
DMS Project No. 94687
Monitoring Year 2 - 2017
Wetland Restoration

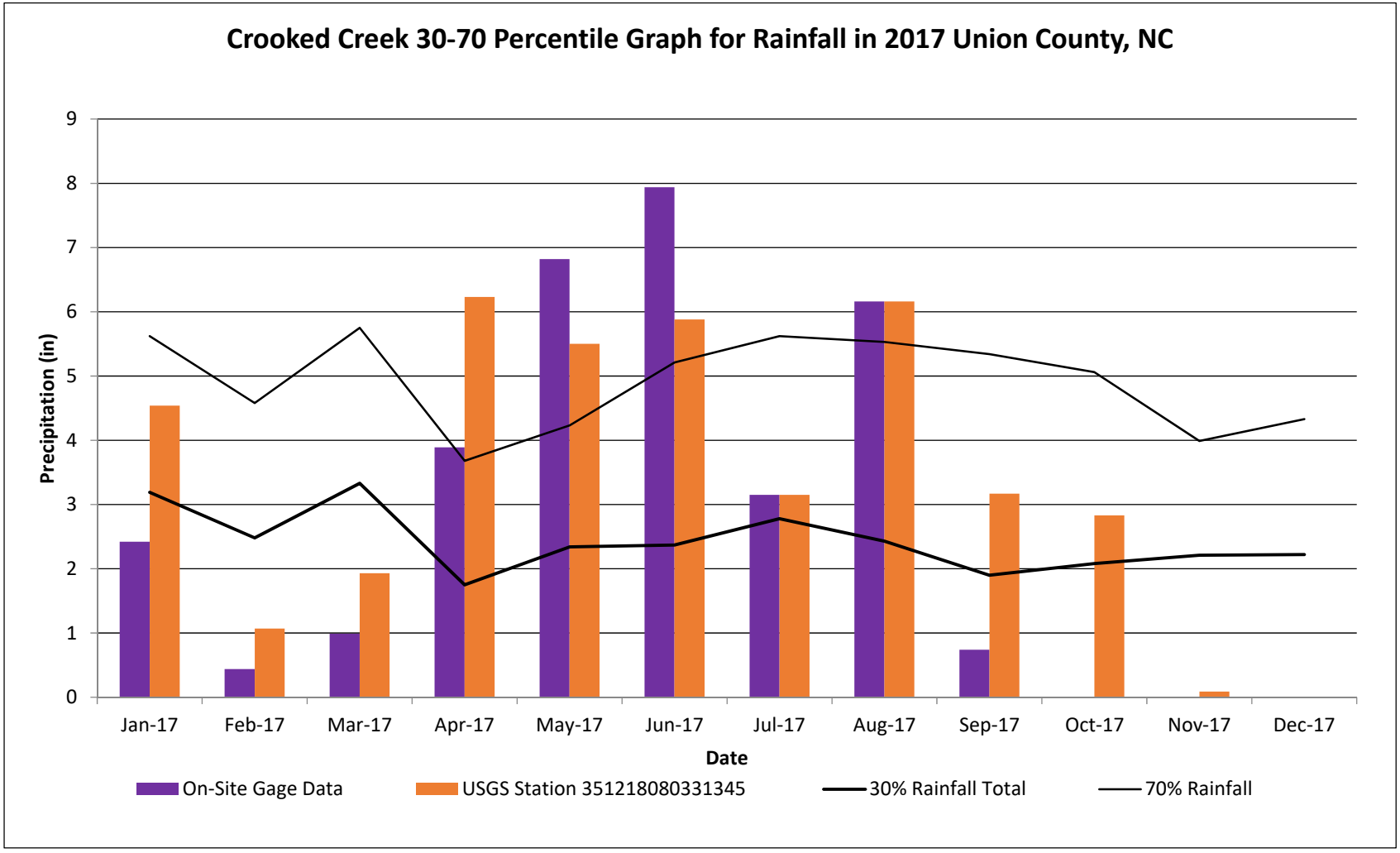


Monthly Rainfall Data

Crooked Creek #2 Restoration Project

DMS Project No. 94687

Monitoring Year 2 - 2017



[1] 30th and 70th percentile rainfall data generated from WETS Table: Monroe, NC5771 (1971-2000). (USDA Field Office Climate Data, 2016)

[2] On Site rain Gauge (HOBO) installed on 2/5/2016